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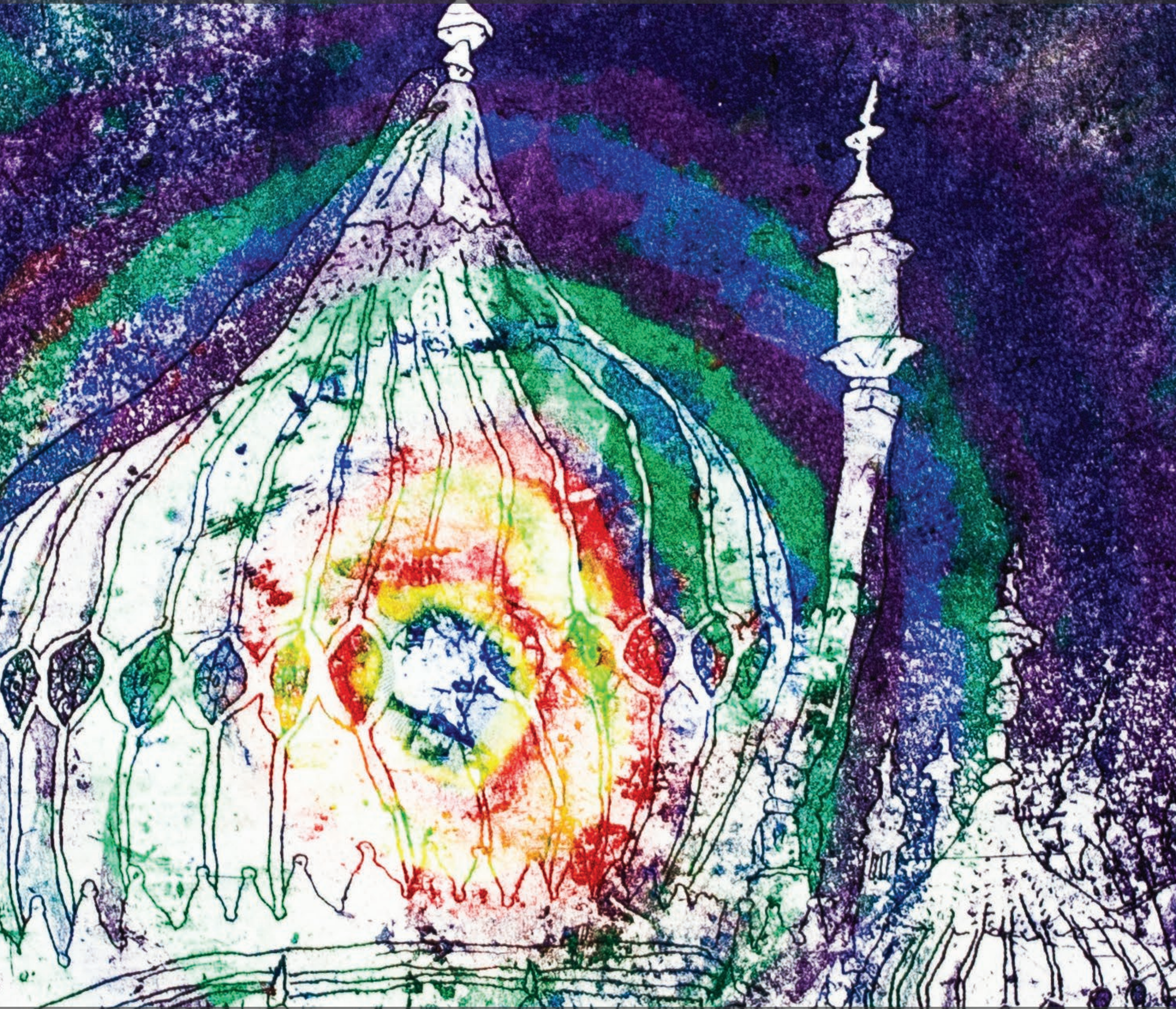

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# *Theoretical Underpins of Lean Construction for Environmental Sustainability in the Built Environment of Developing Economies*

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**Abstract**
One of the key global concerns for sustainability is to achieve environmental sustainability. According to earlier studies achieving environmental sustainability is attainable mainly through sustainable activities in the built environment, particularly in developing economies where not much has been achieved. Thus, this study robustly reviews the theoretical discourse that underpins Lean Construction. The potentials Lean Construction (LC) has towards advancing and for achieving environmental sustainability are highlighted and presented in this study. This is particularly important for the developing countries where construction activities contribute greatly to their development and economic growth. More so that, earlier studies have shown that the construction industry has the capacity to proffer solutions for environmental sustainability where rightly guided. Furthermore, LC has been noted to be advancement and a sustainable strategy over the traditional unsustainable construction processes and practices of the built environment. Additionally, LC has been acknowledged to manage and guide the processes of building designs, construction and practices, in order to add value and reduce waste in construction activities. The study also suggests areas of future research involving the formulation of a framework to guide design and construction activities for sustainable development.

Keywords: built environment, lean construction, sustainability

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## Introduction

One of the key global concerns for sustainability is to achieve environmental sustainability. This is because researchers have noted that developmental activities within the built environment has contributed significantly to climate change, environmental pollution and natural resource depletion (IPCC, 2007; Atkinson 2008; Surenran and Sekar, 2010; WRI 2016). Thus, the construction industry poses a major challenge to achieving sustainability in the built environment (IPCC, 2007; Wenger, 2012; WRI, 2016). Yet, the solutions lays with the professions within the built environment to practice their profession sustainably (Akadiri et al., 2012; Jagger et al, 2013) and for the advancement of research in this regard is encouraged (WRI, 2016). It has also been observed that i the developing economies and particularly in the Sub-Saharan African (SSA) economies, research towards the promotion of environmental sustainability seem to be limited (Laryea, 2011; Allu, 2014). Additionally, Research has also shown that the application of sustainability concepts is questionable in SSA due to constrained knowledge and capacity of built environment stakeholders (Ebohon et al, 2013; Emuze et al., 2013). This gap needs to be closed. This is because the knowledge and capacity of practitioners within the construction sector is very important (Idoma and Mohammad, 2013).

Elsewhere research has advanced in the construction sector, which is the most active activity in the built environment towards lean principles and strategies for construction deliverables. Hence, the aim of this review is to highlight the importance of lean construction towards the promotion of environmental sustainability within the developing economies of the Sub-Saharan African region.

## Lean construction

The construction sector deliverables are mainly the products of the processes from design and construction. As such, in this study construction sector is viewed as the activities of pre-design, design and the construction products which forms the built environment. Furthermore, in this study Learn construction is viewed as sequential activities from project initiation through all applicable processes that leads to the assembling of infrastructures within the built environment using the techniques of lean applications.

Lean construction (LC) principles and techniques involve the entire processes and stakeholders in the construction industry and is also seen as the supplement to the traditional construction management (Abdelhamid, 2007). LC aims at managing and improving design and construction processes in favour of value creation and waste elimination (Koeskela et al., 2003, Abdelhamid et al., 2008; Issa, 2013; Jamil and Fathi 2016). Despite these potentials of LC, the developing economies and particularly the Sub-Saharan countries have been noted to also have their limitations in research and the capacity to apply new innovations (Allu, 2014; Ebohon et al, 2013; Emuze et al., 2013).

However, Leimeister (2010) has early argued that given the strategic pathway, Africans have the potential to carry out what is needful for the actualization of a sustainable built environment. From the attributes of LC presented in the preceding paragraph has presented the opportunity to actualized and promote a sustainably built for the built environment professionals in the SSA economies

**Lean Construction and environmental sustainability**

Lean Construction (LC) has the potential to move the construction industry forward sustainably. This has been acknowledged by Marhani et al. (2012). The study conducted by Issa (2013) concluded that LC approaches and techniques can be adopted and applied by developing economies to improve construction activities. Furthermore, LC involves the entire processes and stakeholders in the construction industry and is also seen as the supplement to the traditional construction management (Abdelhamid, 2007). LC aims at managing and improving design and construction processes in favour of value creation and waste elimination (Koeskela et al., 2003, Abdelhamid et al., 2008; Isa et al., 2015). LC is generally geared towards improving the productivity of the construction industry in addition to improving capacity of the industry's practitioners to apply their knowledge (Ballard and Howell, 1998, 2003; Azziz and Hafez, 2013; Issa, 2013).

According to Biton and Howell (2013) the discussions on LC have been on-going for the last two decades mostly in the western countries, however, they argued that it has been largely been theoretical and recommended that researchers advance these discussions by exploring and refining the subject of LC. Pursuing this argument would certainly ensure that, processes and framework for regional peculiarities would be formulated to ensure applicable sustainable strategies are adopted.

This then suggest that the application of LC approaches and techniques can be a subject of continuous development training for practitioners within environmental professions in order to build their understanding, knowledge and capacity to apply the approaches and techniques of LC in the built environment processes and professional practices. Thus, promoting environmental sustainability through the applications of LC in the production of infrastructures within the built environment.

**Conclusion and recommendation**

The continuous increasing concern for environmental sustainability has been rested on the ability of the practices within the built environment to act sustainably. Lean Construction has been identified as tools to be used to advance environmental sustainability by the built environment professions. The potentials of LC has been noted to include; value added construction deliverables, reduced construction waste and the promotion of sustainable environmental practices. Regional frameworks formulation has also been suggested in order to address specific peculiarities and applications.

Despite this theoretical discourse contributions to knowledge, it limitations is noted in the generalization of the Sub-Saharan countries as the reference for the developing economies. Consequently, the study recommends future studies to examine specific context with other methodologies.

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# *Optimization of Electrical Generation Cost Using Diferential Evolutionary Algorithm for Large Four Regions Electrical Grid*

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**Abstract**
In this paper, a techno-economic assessment of electrical generation cost optimization for four region large electrical grid is presented. This optimization was attained by using the Differential Evolutionary Algorithm (DEA). The study is the first of its kind as none of the previous studies were conducted in the context of a real fuel value and system constraints. In each of the four large grid regions there is generation fleet with different technology and large load center. The four regions are connected via transmission lines with power flow constraints. The performance of the DEA in optimizing the generation cost is benchmarked with a business as usual (BAU) case. The problem was articulated as a constrained nonlinear problem. The constraints were all real values reflecting the system equipment and component limitations and operation constraints. The results obtained from the research show the efficiency and prospects of the proposed research in optimizing the generation cost. Also addressed in this study is annual cost avoidance from optimization of the study objectives.

Keywords: Differential Evolutionary Algorithm (DEA), generation cost, fuel value, millions of standard cubical feet of gas (MMscf).

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## Introduction

Electrical generation technology and fuel mix have a large impact on the cost of electricity generation. In this study the Kingdom of Saudi Arabia (KSA)'s electrical grid was modelled as four regions each with its own generation fleet. The effect of availing more gas as part of the fuel mix and introducing more efficient technology in one of the four regions on the generation cost was demonstrated compared to the base case scenario. A Differential Evolutionary Algorithm (DEA) was implemented to identify optimal generation cost given the aforementioned parameters.

## Problem Formulation

The problem formulation consists of two parts: the development of the objective functions and the identification of the system electrical constrains to be met; equality and inequality constrains.

## Problem Objective Function

The objective to be achieved is the minimization of electricity generation cost $J_1$ of the generation fleet. This objective function can be expressed in terms of the four region electricity generation cost as follows:

$$J_1 = \text{Minimize (Generation- Value Cost)} = Min \sum_{i=1}^{nl} [\boldsymbol{P}_i^{\mathbf{ER}} + \boldsymbol{P}_i^{\mathbf{CR}} + \boldsymbol{P}_i^{\mathbf{WR}} + \boldsymbol{P}_i^{\mathbf{SR}}] \quad (1)$$

Where nl is the number of generation units in each region, ER, CE, WR and SR are the four generation regions in the KSA electrical grid.

A. Problem Equality and Inequality Constrains

The system constrains are divided into two categories: equality constrains and inequality constrains [1][2]. Details are as follows:

A.1 Equality Constrains

These constrains represent the power load flow equations. The balance between the active power injected PGi, the active power demand PDi and the active power loss Pli at any bus i is equal to zero. The same balance applies for the reactive power QGi, QDi, and Qli. These balances are presented as follows:

$$\text{PGi- PDi - Pli} = 0 \quad (2)$$

$$\text{QGi- QDi - Qli} = 0 \quad (3)$$

The above equations can be detailed as follows:

$$\text{PGi- PDi-}V_i \sum_{j=1}^{NB} \boldsymbol{V_j} \, [\, G_{ij} cos(\delta_i\text{-}\delta_j) + B_{ij} \sin(\delta_i\text{-}\delta_j)] = 0 \quad (4)$$

$$QGi - QDi\text{-}V_i \sum_{j=1}^{NB} \boldsymbol{V_j} \left[ G_{ij} sin\left(\delta_i\text{-}\delta_j\right)\text{-}B_{ij} \cos\left(\delta_i\text{-}\delta_j\right)\right] = 0 \qquad (5)$$

where i = 1, 2, …, NB; NB is the number of buses; PG and QG are the generator real and reactive power, respectively; PD and QD are the load real and reactive power, respectively; Gij and Bij are the conductance and susceptance between bus i and bus j, respectively.

A.2 Inequality Constrains
These constrains represent the system operating constrains posted in Table 1 and they are as follows:

a. The transformers taps.
b. The load buses voltages VL.
c.
Combining the objective function and these constrains, the problem can be mathematically formulated as a nonlinear constrained single objective optimization problem as follows:

Minimize $J_1$
Subject to:

$$g(x,u) = 0 \qquad (6)$$
$$|h(x,u)| \leq 0 \qquad (7)$$

Where:

x: is the vector of dependent variables consisting of load bus voltage VL and generator reactive power outputs QG. As a result, x can be expressed as

$$x^T = [V_{L1}..V_{LNL}, Q_{Gi}\dots Q_{GNG}] \qquad (6)$$

u: is the vector of control variables consisting of generator voltages VG and transformer tap settings T. As a result, u can be expressed as

$$u^T = [V_{G1}..V_{GNL}, T_1\dots T_{NT}] \qquad (8)$$

g: are the equality constrains.
h: are the inequality constrains.

TABLE 1
SYSTEM INEQUALITY CONSTRAINS

| Description | Lower Limit | Upper Limit |
|---|---|---|
| Generator Unit Terminal Voltage | 90% | 105% |
| All Load Buses Voltage | 90% | 105% |
| Main Transformer Taps | +16 (+10% ) | -16 (-10%) |
| Generators Step-up Transformer Taps | +8 (+10% ) | -8 (-10%) |

**Differential Evolution Algorithm (DEA) Implementation**

The implementation of the DEA technique can be summarized in the following steps [3]-[5]:

1. Generate initial populations of chromosomes; each chromosome consists of genes and each of these genes represents either transformer tap settings, the generation units MW outputs, or the generators voltages values.

2. Assign fitness to each chromosomes, as follows:
   a. Use the Newton-Raphson method to calculate the generation cost for each population.
   b. Identify if the voltage constrains are satisfied.
   c. Assign fitness values to the populations that meet all constrains; the population best power generation fuel cost value ($J_1$).

3. Identify the best population with its associated chromosomes that has the best objective function value and store it.

4. Apply mutations using the DE/rand/1 mutation technique [4]. Vi (t) - the mutated vector, is created for each population member Xi (t) set by randomly selecting three individuals' $x_{r1}$, $x_{r2}$ and $x_{r3}$ values and not corresponding to the current individual $x_i$. Then, a scalar number F is used to scale the difference between any two of the selected individuals. The resultant difference is added to the third selected individual. The mutation process can be written as:

$$V_{i,j}(t) = x_{r1,j}(t) + F * [x_{r2,j}(t) - x_{r3,j}(t)] \qquad (9)$$

   The value of F is usually selected between 0.4 and 1.0. In this study, F was set to be 0.5 (50%). In [14], scaling mutation based on the frequency of successful mutations is applied.

5. Perform the binomial crossover, which can be expressed as follows:

$$u_{i,j}(t) = \begin{cases} v_{i,j}(t) \ if \ rand \ (0,1) < CR \\ x_{i,j}\ (t) \qquad\qquad\qquad else \end{cases} \qquad (10)$$

   CR is the crossover control parameter, and it is usually set within the range [0, 1]. The child $u_{i,j}$ (t) will compete with its parent $x_{i,j}$ (t). CR is set equal to 0.9 (90%) in this study.

6. Perform the selection procedure as described below:

$$x_i(t+1) = u_i(t) \quad \text{condition} \quad f(u_i(t)) \leq f(x_i(t)) \qquad (11)$$

$$x_i(t+1) = x_i(t) \quad \text{condition} \quad f(x_i(t)) \leq f(u_i(t)) \qquad (12)$$

Where $f(\ )$ is the objective function to be minimized.

7. Looping back for the terminating criteria. If the criteria are not fulfilled, then generate new offspring population and begin again.

8. If the termination criteria are met, identify the best population with its associated chromosomes, in terms of minimum real power loss. The DEA evolution process is shown in Figure 1.

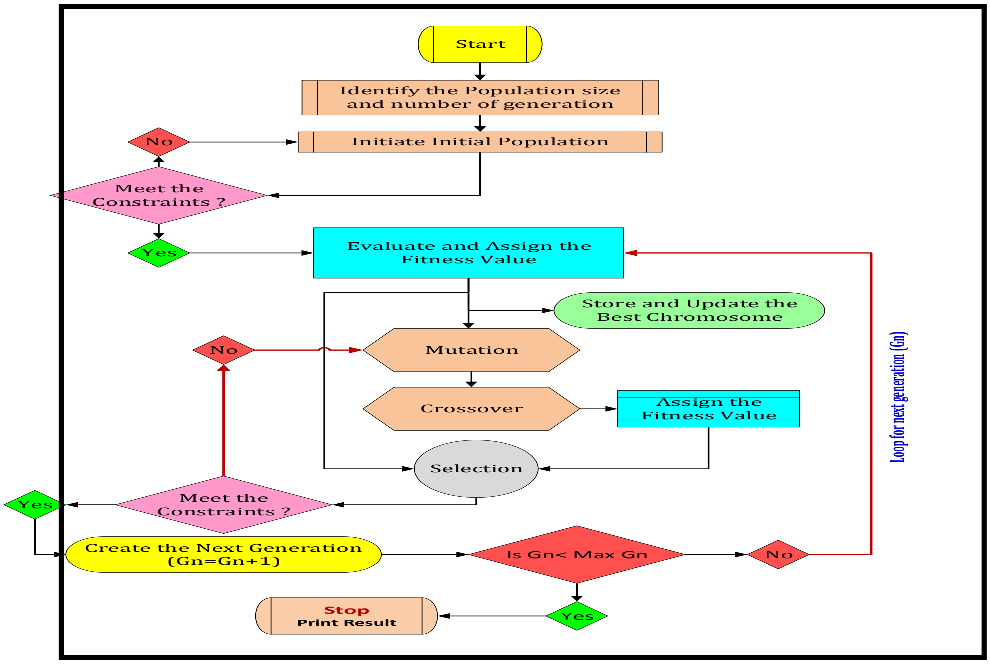


Figure. 1: DEA in single-objective mode evolutionary process chart

## Conclusion

The base case scenario (base) is benchmarked against the optimized case scenario (Case-1). In the base case scenario the generation fleet has different technologies and base case fuel mix. In the optimal case, the fleet technologies mix was kept with no change except the introduction of combined cycle (CC) generation at the southern area. Also, more gas were made available, diesel consumption was pushed to zero and Arab Light crude (ALC) fuel was minimized. Figure 2 demonstrates the evolution of the objective function ($J_1$: total generation cost) to its optimal value. As shown, the objective function converged to its optimal value ($272,187) at the 21$^{st}$ generation.

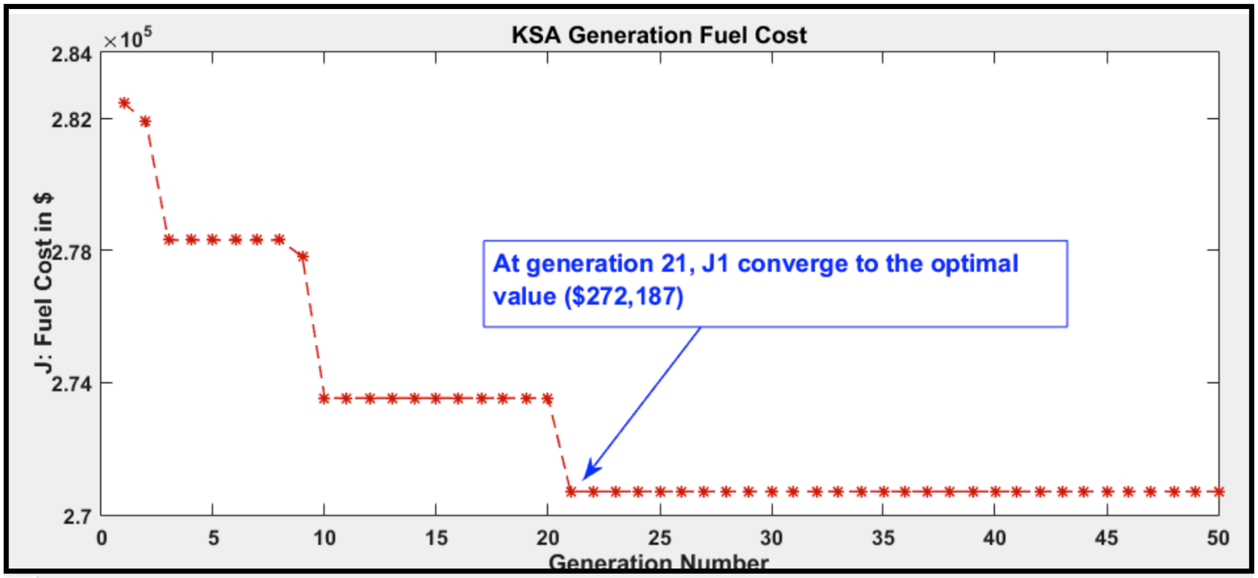


Figure. 2: Evolution of the objective function ($J_1$) value over 50 generations

The MW distribution among the generation fleet for both scenarios is shown in Figure 3. As you can see, the desalination (DES) and the heat and power plant (CHP) fuel were kept the same for both scenarios as they did not only produce electricity.

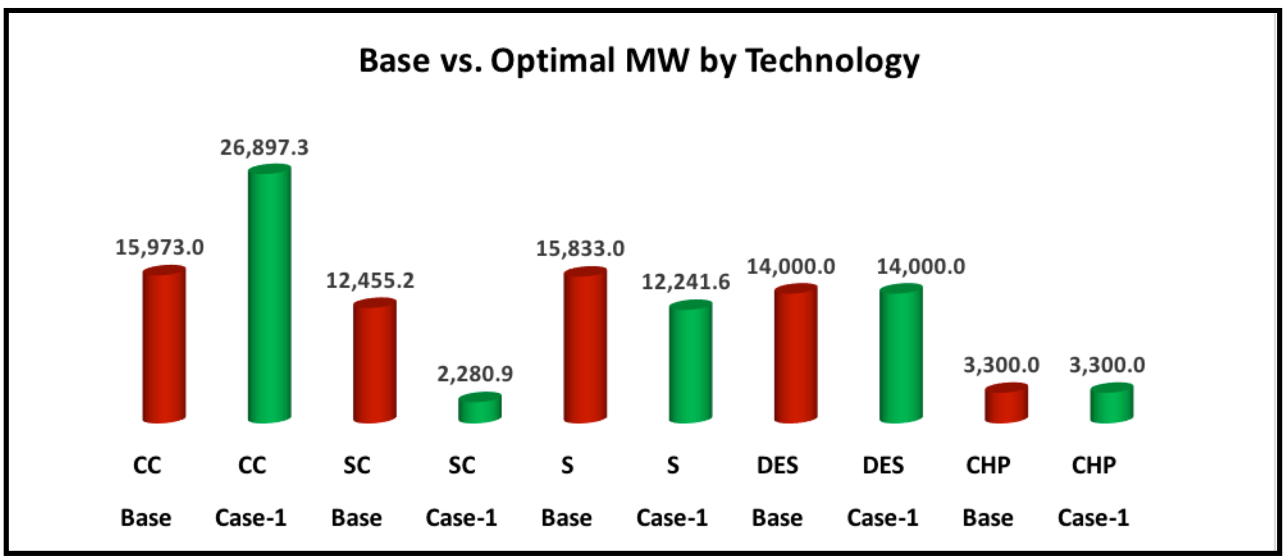


Figure. 3: Base case vs. optimized case senario generation MW distribution

Figure 4 shows the generation cost by technology for the two scenarios. The DES plant fuel consumption was assumed zero for both scenarios and the CHP was kept the same as stated earlier.

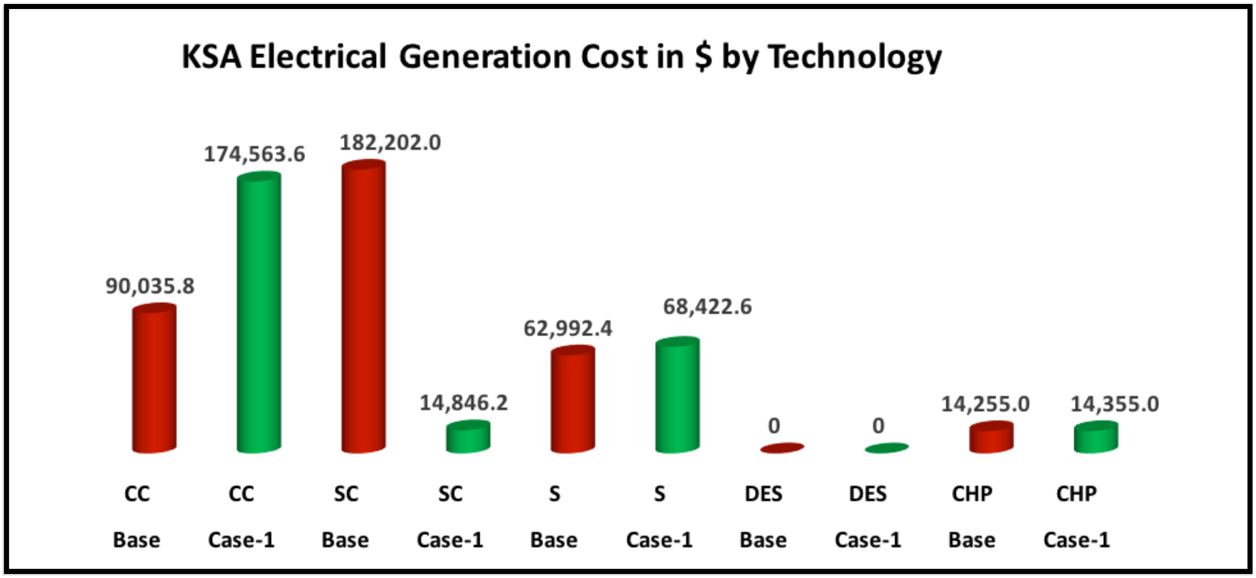


Figure. 4: Base case vs. optimized case senario generation fuel distribution

The total reduction in the generation cost comparing the base case to the optimal case is -22% as shown in Figure 5. The generation cost is reduced from 7.79 $/MWh to 6.1 $/MWh.

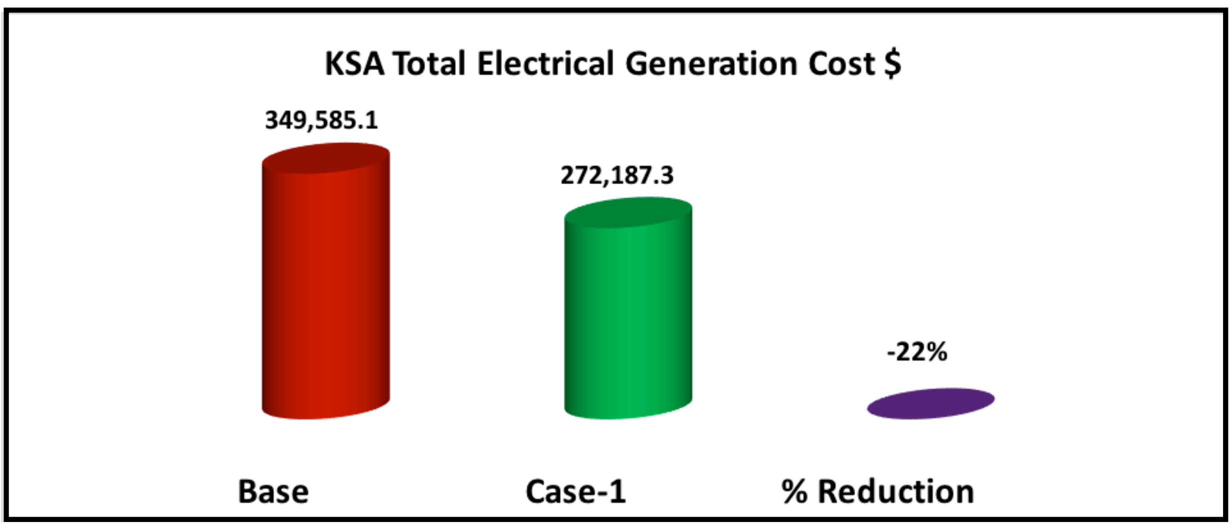


Figure. 5: Base case vs. optimized case senario total generation cost

The base case benchmarked to the optimal case scenario fuel mix is shown in Figure 6. The diesel consumption was reduce to zero in the optimal case scenario as it is the most expensive fuel among the fuel mix. Also, the Arab Light crude (ALC), which is the second highest fuel with regard to cost among the fuel mix was reduced by 91%.

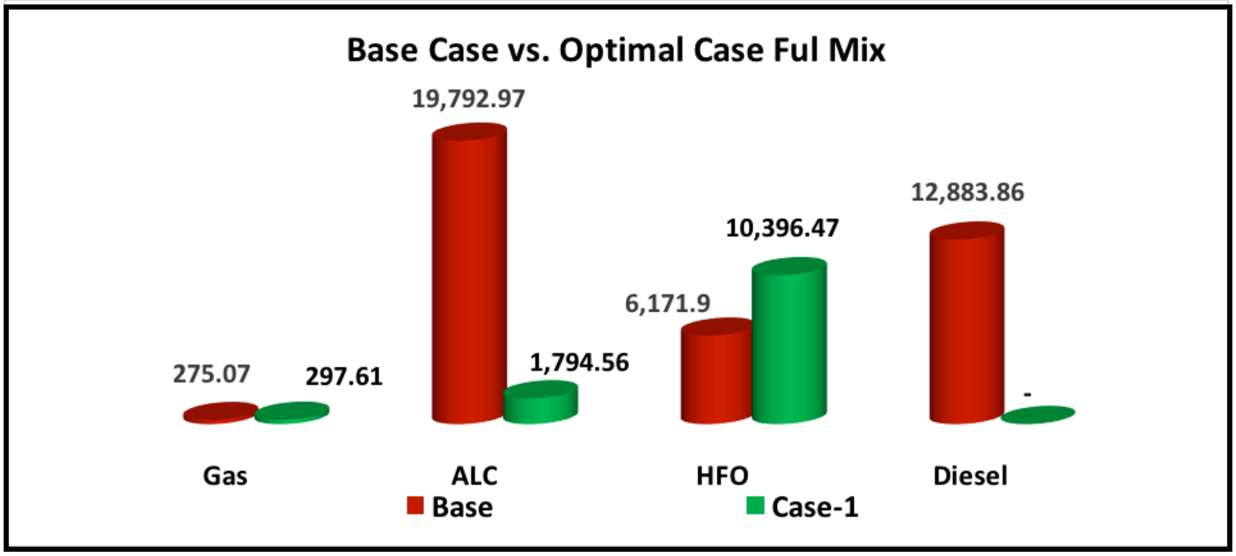


Figure. 6: Base case vs. optimized case senario fuel mix

**Acknowledgement**

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# *A Review of System Dynamics Applications in Sustainable Urban Transportation*

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**Abstract**
Towards the end of 20th century, ever-increasing pressures for the need of sustainable development have re-shaped our way of thinking in which sustainability is now widely accepted as a top priority. Most of the economic and social activities are provided via transportation. Thus, it is of great importance to achieve sustainable transportation for sustainable development, especially from the point of energy and carbon dioxide emission reduction. However, transportation systems are complex and involve social, economic and environmental aspects which call for employing a holistic approach rather than conventional methods. System dynamics (SD) is such a holistic methodology for studying and managing complex systems in order to make integrated assessments and policy decisions. While its conception and early applications have been mainly related to industrial applications (frequently referred to "industrial dynamics"), it has also been used recently for the analysis of transportation systems. The aim of this study is to explore the feasibility of SD for transportation-related energy consumption, CO2 emissions, health impacts and economics by conducting a critical literature review of SD applications in the urban transportation field. Through the end of paper, implications and results of the review are shared as conclusion in addition to further research areas in the field.

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## Introduction

Our current road-based transportation system which is mainly dependent on automobile use causes a wide range of formidable problems. These include traffic congestion, air pollution, noise, accidents and related fatalities, depletion of non-renewable resources and inaccessibility of amenities and services. To illustrate this, more than one-quarter of total U.S. greenhouse gas emissions come from the transportation sector and light vehicles are responsible for 59% of transportation energy use (C2ES, 2012). Due to the accidents on roads, approximately one million people dies apart from millions of injuries (WHO, 2010). These are just a few examples to illustrate detrimental effects of transportation on sustainable development especially due to automobile use. Therefore, the current transportation system especially in urban areas may be considered as unsustainable from various viewpoints. Furthermore, transport demand, however, increases as economic growth increases (European Comission, 2012) which will make the situation even worse in the years to come. To counter this challenge of moving towards sustainable transportation, much more effort is needed. To direct investments and efforts into the right places and achieve livable and sustainable urban areas, understanding dynamics of transportation and making projections under different scenarios for upcoming years is of vital importance (Birol, 2014).

System dynamics (SD), originally called industrial dynamics, was developed by Jay Forrester from MIT in the late 1950s (Forrester, 1958). It is a methodology for studying and managing complex feedback systems to make integrated assessments and policy decisions (Saeed, 1994). Since many systems such as structure of a corporation, an urban area, or economic processes are complex, making it difficult to understand and control. In this sense, SD seeks, firstly, to identify the underlying structure of a system to gain insight into patterns of how a system behaves, then to focus on interactions of the system's components into each other to understand the roles each component plays rather than concentrating on specific events, and lastly, to try contributing designing process of policies which seek to eliminate unwanted patterns of behavior through modifying the underlying structure of a system (Kirkwood, 1998). Although its early applications were mainly limited to industrial management, it has been applied to various fields by time, including government policy (Forrester, Mass, & Ryan, 1976), healthcare (Homer & Hirsch, 2006; Lane, Monefeldt, & Rosenhead, 2000; Royston & Dost, 1999), the automobile industry (Hayter, 1997; Kumar & Yamaoka, 2007), electrical power industry (Ford, 1997), urban studies (Duran-Encalada & Paucar-Caceres, 2009; Dyson & Chang, 2005; Forrester, 1970; Han, Hayashi, Cao, & Imura, 2009). Furthermore, Abbas and Bell (1994) showed that it is also applicable to transportation field due to various advantages in transportation field in comparison with traditional transport modeling.

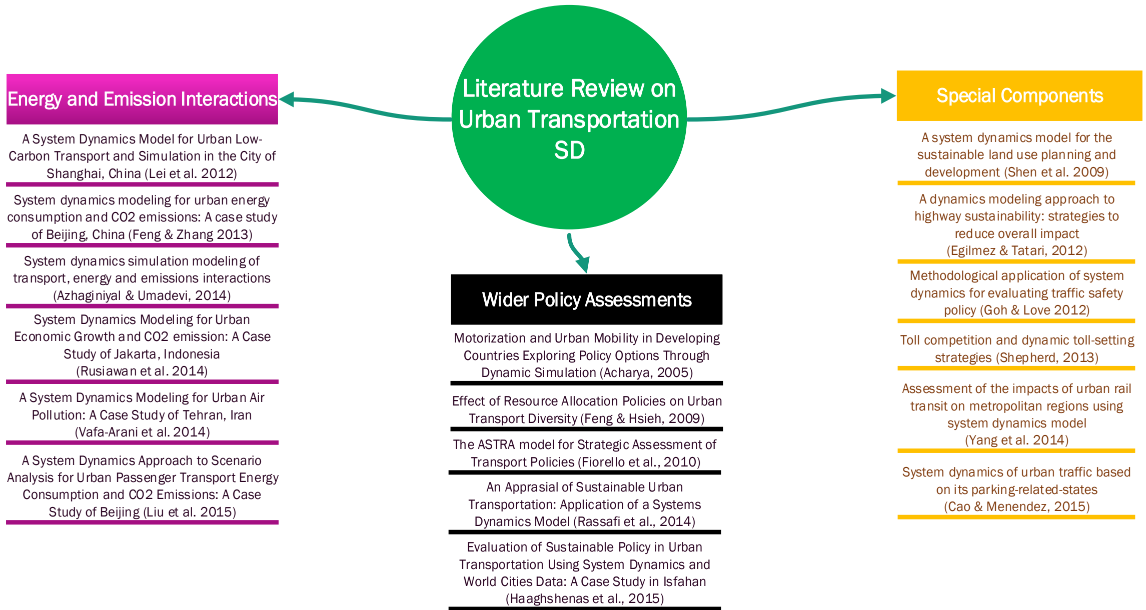


*Figure 1: Selected SD articles on the components of urban transportation within the scope of this paper*

After Abbas and Bell (1994) particularly suggested SD as a well-suited approached to strategic policy analysis and as a support tool for decision making processes, noteworthy applications of SD into transportation field have since evolved. Thus, we have identified SD as an appropriate approach to investigate and study transportation status and its future expectations in urban areas. Our review focuses on the applicability of SD in the field of sustainable urban transportation and indicates that SD is applied in numerous components of sustainable urban transportation including wider-policy assessments studies, studies focusing on interaction between transportation, emissions and energy consumption, and studies focusing on special components of urban transportation (see Figure 1).

**Wider-policy assessments studies**

Transportation in urban areas manifests a multidimensional problem in which one may approach them from different angles on a small scale with few dimensions or on a large scale with many dimensions. In this direction, various different policies and interventions have been developed over time. Acharya (2005) proposed an SD model in particular for developing countries to experiment three scenario options including road investment, early rapid transit investment, and late rapid transit investment against business as usual scenario. The model tests the effects of these options on congestion, modal share and attractiveness of public transportation, motorization and urban sprawl. Simulation results revealed that introduction of off-road rapid transit is important not only to improve modal share and attractiveness of public transport but also to mitigate traffic congestion. However, it is also revealed that too late development of rapid transit may bring about limited impact.

In a similar fashion to Acharya's study (2005), Feng and Hsieh (2009) proposes a hybrid model integrating SD, cognitive maps and a sensitivity model to tackle problems related to transportation investment. In particular, they try to answer the questions when to invest and how to allocate resources over time. Taipei case is used to empirically illustrate the approach to enhance the managerial implications in the city. The study reveals that an increase in private vehicle trips reduces transport diversity which causes an increase in emissions, energy consumption, and accidents. Therefore, policies which control the growth of car use are the most effective for meeting the needs of stakeholders. However, the system is shown to be insensitive to tuning policy implementation delays due to managerial choices of resource allocation.

In parallel with above studies, Fiorello et al. (2010) demonstrates an overview of the ASTRA model which have been developed to investigate strategic policy scenarios at the European level. These include scenarios concerning energy scarcity, high oil prices, and technological investments in the transport sector and application of these measures included in the European transport policy. This model links transport demand, economy, vehicle fleet and environmental effects. Thus, it enables integration of multidimensional assessment of alternative scenarios. Additionally, the authors provide advantages of using ASTRA for transport modeling and illustrate their points by providing an example project's results (iTREN-2030 European project).

With the increase in concern over sustainable development, two different studies were published which take interaction one step further to include all of the three pillars of sustainability. Rassafi et al. (2014) proposes a new comprehensive model to evaluate sustainable urban transportation. The model includes economic, environmental, social, and urban transportation variables. They validated the model by using actual data for years 1994 to 2009 of Masshad, Iran. Then, a simulation model was run from 2009 to 2044. Effects of two policies "Increasing average car occupancy", and "increasing salvage rate of vehicles" were analyzed. It is revealed that increasing salvage rate of vehicles had superior effects on minimizing the annual fuel consumption in Masshad. As a result, the authors claimed that the proposed approach has the capability to find the optimal strategy for sustainable urban transportation. Haghshenas et al. (2015) developed an SD model on world cities data to analyze sustainable transportation dynamics for Isfahan, Iran, to evaluate different transportation development scenarios. Trip generation, modal share, transportation supply and equilibrium between supply and demand are taken as key modules of SD model. Nine different indicators were selected and assigned into environmental, economic and social key categories which are considered as key outputs of the model. For Isfahan, the model results revealed that urban transportation policymakers should develop policies pertinent to non-motorized transit network development after monitoring future scenarios. The authors also claim that the model could be applied to other cities as well in policy development and evaluation to identify the best sustainable policies.

**Studies related to interaction between transportation, emissions and energy consumption**

Currently transportation systems mainly run on fossil fuels. This is important from two aspects: (1) it increases pressure on non-renewable energy resources and (2) causes air pollution more importantly $CO_2$ emissions which result in various problems including climate change. To this end, Azhaginiyal and Umadevi (2014) focus on the interaction between transport, energy and emissions. They developed a new SD model to analyze the existing transport supply and demand in Chennai, India by using data inventory on energy requirement and emissions from transport sector to determine the energy requirement and emissions caused from transport sector in the year 2026. Results of the study reveal that personalized modes contributes to about 80% of trips and about 300% increase in fuel demand for 'business as usual scenario'. However, results indicate that the scenario of augmenting public transport and simultaneously restricting growth of personalized vehicles showed a substantial decrease in energy consumption (nearly 65%) and nearly 50% reduction in emissions from personalized travel modes. Similarly, Lei et al. (2012) studied dynamic relationship between society, economy, motor vehicles, transport infrastructure, city traffic management level and urban transportation carbon emissions through building an urban low-carbon transport system. For the case of Shanghai, China, the results indicate that rapid increase of private cars is an important driving factor of carbon emission and thus strengthening urban transport demand management and improving urban transport structure is essential for building urban low-carbon transport.

From a wider perspective, Vafa-Arani et al. (2014) propose a model in order to estimate behavior parameters affecting air pollution in Tehran, Iran, by taking into account urban transportation and air polluting industries. They run the proposed model under several scenarios for testing various policies including road construction, technology improvement in fuel and automotive industries, traffic control plans, and development of public transportation. As a result, the study indicates that technological improvement in the fuel and automotive industries and development of public transportation infrastructures are more effective policies in order to mitigate air pollution. Likewise, Feng et al. (2013) developed an SD model in order to capture energy consumption and $CO_2$ emissions trends for Beijing over the years 2005-2030. According to the results, it is expected that the service sector will gradually replace the industrial dominant status in energy consumption as the largest energy consuming sector, followed by industrial and transport sector.

Rusiawan et al. (2015) studied relations between $CO_2$ emission and economic growth in Jakarta, Indonesia, from SD perspective. They tested three different scenarios (namely, business as usual, development of green open space, and increasing share of renewable energy) during the period of 2009-2029 by taking into account economic growth and its effects on population, transportation, energy consumption etc. As a result, they propose a role model of sustainable urban development policy for Jakarta.

More recently, Liu et al. (2015) built a new SD model for Beijing urban passenger transport carbon model which includes economy, population, transport, energy consumption, and $CO_2$ emission subsystems for testing a variety of policy options. These individual policies are the technical progress (TP), priority to the development of public transport (PDPT), travel demand management (TDM), administrative rules and regulations management (ARM). According to the results, the optimal implementation sequence of each individual policy is provided. However, it is also indicated that the effect of comprehensive policy (CP) which is a policy scenario integrating all of PDPT, TDM, TP, and ARM scenarios was better than any of the individual policies pursued separately.

**Studies related to special components of urban transportation**

Elements of mobility and access management for urban transportation are nicely summarized by Meyer (1997) (see Figure 2). There are various studies which particularly focus on these specifics elements. Shen et al. (2009) focused on sustainable land use and urban development in Hong Kong and found that compact high-density scenarios in terms of land use are more sustainable with investment in rail based transport over car infrastructure. Egilmez and Tatari (2012) aimed to reduce $CO_2$ emission associated to US highway system sustainability problem to meet the Liberman and Warnet Climate Act's targets by 2050. They tested three potential strategies (fuel efficiency, public transportation, and electric vehicle usage) for policy making and indicate via their results that hybrid implementation of individual policies is crucial on the success of policy making. In similar fashion, Yang et al. (2014) analyze impacts of urban rail transit system on metropolitan regions from the aspects of urban traffic, economy, society and environment by building an SD model. They carried out a case study of Guangzhou, China to verify their model. As a result, they claim that their SD is a feasible and effective approach for simulating complex traffic system and government decision-making processes.

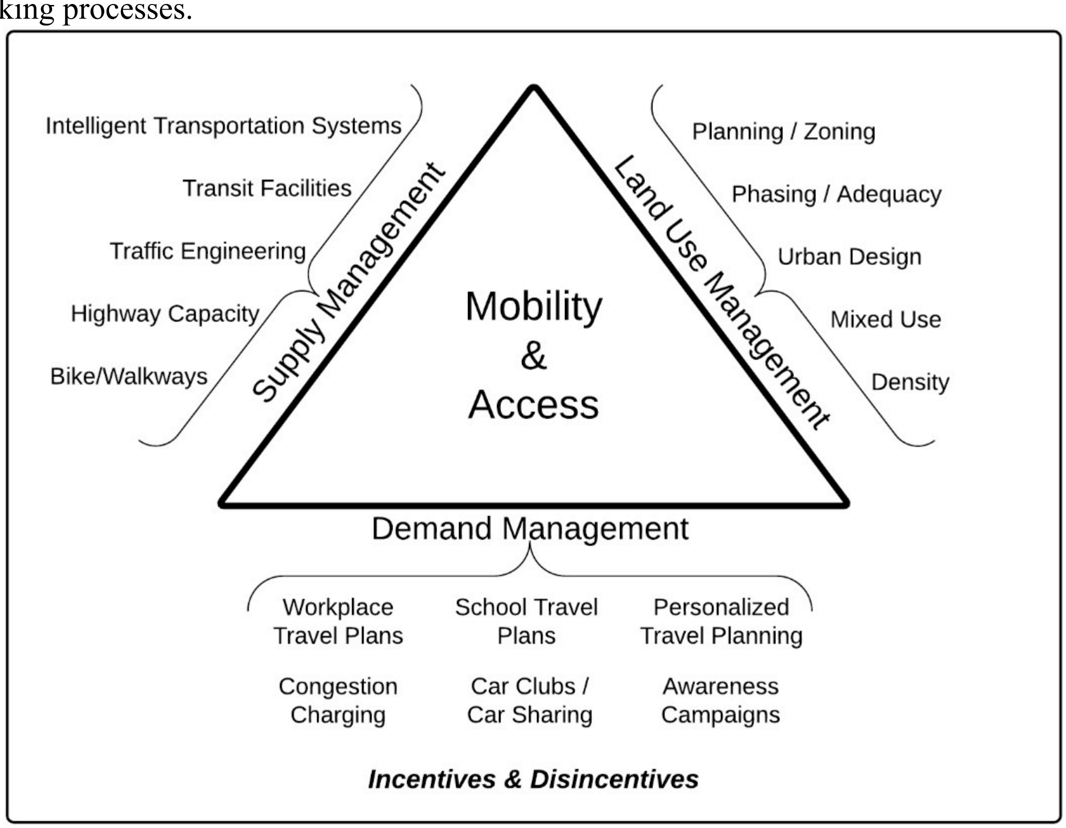


*Figure 2: Elements of Mobility and Access Management (reproduced from* (Meyer, 1997)*)*

In more detail, Goh and Love (2012) propose two models to demonstrate how SD approach can facilitate and encourage macro and meso level analysis of traffic safety policy and suggested that SD is the most appropriate for formulating macro level policy. Cao and Menendez (2015) propose a model which shows dynamics of urban traffic based on its parking related states and can be used efficiently to evaluate urban traffic and parking systems macroscopically. Overall, they conclude that their proposed model is useful to study multiple strategies and scenarios for traffic operations and control, transportation planning, land use planning, or parking management. Shephered (2013) used SD approach to model both user's route choice and demand response to changes in generalized cost and model the toll operators' decision rules or toll-update strategies. The results indicate that solutions depend upon the frequency of decisions or changes in toll level, and errors are related to the disequilibrium which are present as users respond to changes in toll levels.

**Conclusion**

To conclude, SD has been using diversely in transportation field to evaluate different policy options, address possible intervention policies and help decision makers. It has been implemented to make wider policy assessments such as investments strategies aiming when to and how to invest. Besides that, it has been used to determine dynamic relationship between transport, emissions and energy consumption in urban areas. More specifically, there are studies which employ SD for modeling special components of urban transportation such as highway sustainability, and traffic safety. In particular, each study uses one urban area to test their developed SD models in order to provide its efficient use.

Some recent studies imply the way for further research areas. Shepherd (2013) addresses the gap for lacking comparison studies between cities. Feng (2013) indicates the importance of different sensitivity analysis at the micro levels to make results more robust and reliable. Liu et al. (2015) reveals their studies' further direction into that universally use of their developed model needs to be further studied to take into account of each city's own characteristics and development stage. In relation to these, Egilmez and Tatari (2012) addresses sustainability footprint generation and involvement of society's sustainability awareness to be considered as future work. Besides that, there isn't one particular study available which focuses on cities from resource-rich counties based on our review. Therefore, the next research questions in this fields have to address urban transportation policies based on comparisons of different cities in terms of energy consumption, $CO_2$ emissions, economy and society. The cities should be selected in the way of differentiating resource-rich countries and resource-poor countries, developed cities and developing cities, and cities with all sizes. This includes taking into consideration of cities own characteristics, sustainability metrics and different sensitivity analysis.

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# *Optimisation of the Size and Cost of Heliostats in a Concentrating Solar Thermal Power Tower Plant*

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**Abstract**
Concentrating solar thermal (CST) power tower (PT) is one of the most promising renewable technologies for large-scale electricity production, however the main limitation of PT systems is their significantly larger levelised cost of electricity (LCOE) relative to base load energy systems. One opportunity to lower the LCOE is to reduce the capital cost of heliostats through optimisation of the size and position of heliostat mirrors to withstand maximum wind loads during high-wind conditions when aligned parallel to the ground in the stow position. Wind tunnel experiments were carried out to measure the forces on thin flat plates of various sizes at a range of heights in a simulated part-depth atmospheric boundary layer (ABL). Calculated peak wind load coefficients on the stowed heliostat showed an inverse proportionality with the chord length of the heliostat mirror, which suggests that the coefficients could be optimised by increasing the size of the heliostat mirror relative to the sizes of the relevant eddies approaching the heliostat. The peak lift coefficient and peak hinge moment coefficient on the stowed heliostat could be reduced by as much as 23% by lowering the elevation axis height of the heliostat mirror by 30% in the simulated ABL. A significant linear increase of the peak wind load coefficients occurred at longitudinal turbulence intensities greater than 10% in the simulated ABL. Hence, the critical scaling parameters of the heliostat should be carefully considered depending on the turbulence characteristics of the site.

Keywords: heliostat, stow position, turbulence, atmospheric boundary layer

## Introduction

Current energy systems, based primarily on the combustion of fossil fuels, are unsustainable in the long term, so that a transition to an environmentally-sustainable energy system with the integration of renewable energy sources is necessary (Hernández-Moro & Martínez-Duart, 2012). Concentrating solar thermal (CST) is one of the most promising renewable technologies capable of large scale electricity production (Hinkley et al., 2013). A CST system operates by focusing direct solar radiation to obtain higher energy densities and thus an improved Carnot efficiency at higher temperatures. Heat collected in the receiver is typically used to heat a working fluid to generate supercritical steam that drives a turbine for electricity generation (IRENA, 2015); although a wide range of alternative power cycles is under development including Brayton and $CO_2$ power cycles. Parabolic trough systems are the most commercially-deployed CST technology, however power tower (PT) systems have been identified as an emerging concept that can operate at higher concentration ratios and higher working fluid temperatures than parabolic troughs, thus allowing for higher power cycle efficiency (IEA-ETSAP & IRENA, 2013). Although the intermittency of solar irradiation is a practical limitation of CST systems, PT plants can be deployed with thermal energy storage or as a hybrid system with existing fossil fuel power plants for a base-line power supply (Hinkley et al., 2013; Kolb, Ho, Mancini, & Gary, 2011).

The main limitation of PT systems is their significantly larger levelised cost of electricity (LCOE), in the range of 0.15-0.19 USD/kWh in 2015 (IRENA, 2015), compared to base-load energy systems such as fossil fuel power plants in the range of 0.06-0.13 USD/kWh in 2011 (IRENA, 2013). To reduce the LCOE of PT systems there is a need to lower the capital cost of a PT plant, of which the largest cost is the heliostat field, with an estimated contribution of between 40% and 50% (Coventry & Pye, 2014; Hinkley et al., 2013; IRENA, 2015; Kolb et al., 2007). Government-funded initiatives that support the research and development of CST systems to make them competitive with base-load energy rates include the SunShot Initiative by the Department of Energy (DOE) in the USA, with a goal LCOE of 0.06 USD/kWh by 2020 (Kolb et al., 2011), and the Australian Solar Thermal Research Initiative (ASTRI) targeting a LCOE of 0.12 AUD/kWh by 2020. Currently, the total installed cost of a 150 MW PT plant is 5700 USD/kW. Figure 1 shows that the total cost of PT plants is projected to be reduced by 37% to 3600 USD/kW by 2025, compared with a projected 33% reduction in parabolic troughs (IRENA, 2015). The largest reduction of 24% in the cost of the solar field is expected to be achieved through the optimisation of the structural design of heliostats to wind loading. Hence, the aim of this paper is to optimise the size and cost of heliostats to withstand the maximum wind loads during high-wind conditions in the stow position.

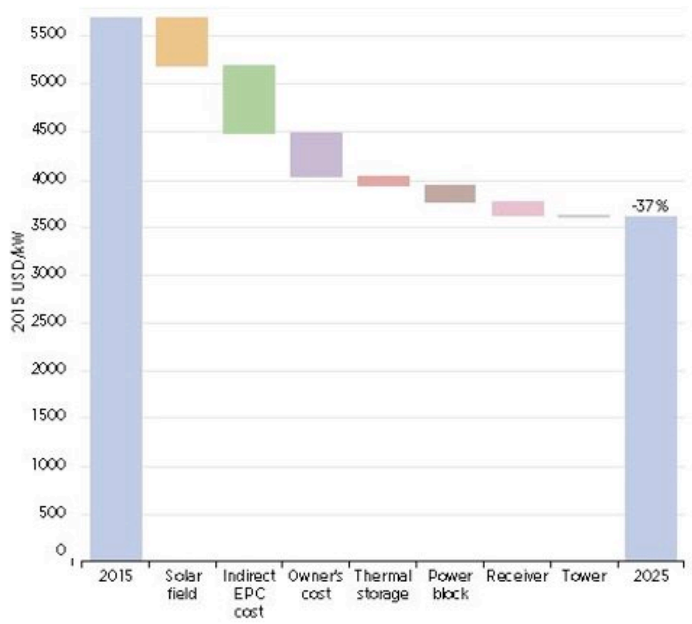


Figure 1: Projected reduction in capital cost (USD/kW) of a 150 MW PT plant from 2015 to 2025 (IRENA, 2015).

Kolb et al. (2007) concluded that the optimum heliostat size for a molten-salt PT plant is between 50 $m^2$ and 150 $m^2$, however there is no consensus on the optimal size of a heliostat mirror. This is because the optimum heliostat size is dependent on many factors associated with the production volume and manufacturing processes, ease of access to the electricity network in the region and the terrain type and wind conditions at the site. Therefore, further understanding of the relationships between the heliostat cost and the wind loading on heliostats needs to be developed. One opportunity to lower the heliostat cost is through optimisation of the size and position of heliostat mirrors to withstand maximum wind loads during high-wind conditions. Heliostats are aligned parallel to the ground in the stow position during periods of high wind speeds to minimise the frontal area and the large drag forces that the heliostat are exposed to in operating positions, however stowed heliostats must withstand maximum lift forces and hinge moments due to the effects of vortex structures embedded within the turbulence in the atmospheric boundary layer. The motor drives, support structure and mirror must all withstand any forces and moments, applied to the heliostat from the wind. These wind-sensitive structural components account for up to 80% of the heliostat capital cost according to research by Kolb et al. (2011). A cost analysis of quasi-static wind loads on individual heliostat components by Emes, Arjomandi, and Nathan (2015) found that the sensitivity of the total heliostat cost to the stow design wind speed increased by 34% for an increase in mean wind speed from 10 m/s to 15 m/s. Following the linear cost-load proportionality developed by McMaster Carr, a 40% reduction in the peak hinge moment on the elevation drive of a conventional heliostat can lead to a 24% saving in the representative gear reducer cost (Lovegrove & Stein, 2012). Hence, this paper investigates the effect of the critical scaling parameters of the heliostat on the peak wind loads in stow position.

## Methodology

Experimental measurements were taken in a closed-return wind tunnel at the University of Adelaide. Figure 2 shows the test section of the tunnel with a development length of 17 m and a cross-section expanding to 3 m × 3 m to allow for a pressure gradient resulting from growth of the boundary layer. The tunnel can be operated at speeds of up to 20 m/s with a low level of turbulence intensity, ranging between 1% and 3%. Accurate representation of a part-depth ABL in the wind tunnel is required to replicate similar turbulence properties that heliostats are exposed to in the lower surface layer of the ABL, including a logarithmic mean velocity profile. It is generally accepted that the most effective wind tunnel simulation of the ABL is obtained when a flow passes over a rough surface producing a natural-growth boundary layer (De Bortoli, Natalini, Paluch, & Natalini, 2002). The most commonly-used passive devices include spires to generate turbulent mixing through separation of flow around their edges, fence barriers to increase the height of the boundary layer and floor roughness to develop the velocity deficit near the ground (Cook, 1978; Counihan, 1973). Two different triangular spire designs and timber roughness blocks are shown in Table 1. These dimensions were derived following a theoretical design method outlined by Irwin (1981) such that the height $h$, base width $b$ and depth $d$ of the spires could be determined based on the desired power law profile with exponent $\alpha$ of 0.2 and boundary layer thickness $\delta$ of 1.2 m. Velocity measurements for the two configurations of spire and roughness in Table 1 were taken at different heights using a multi-hole pressure probe and a traverse. The operating conditions of the tunnel were a freestream velocity $U_\infty$ = 11 m/s and Reynolds number $Re_\infty = U_\infty \delta / \nu$ = $8.8 \times 10^5$.

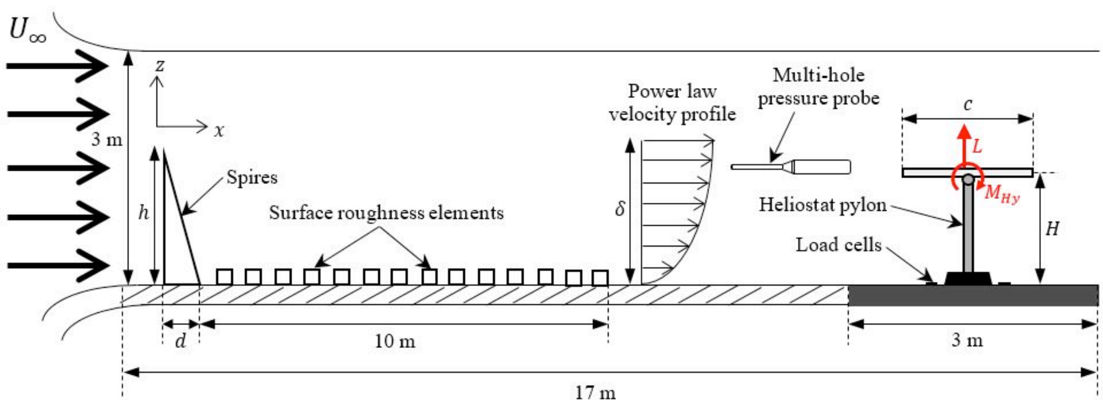


Figure 2: Schematic of the experimental setup for generation of the ABL in the wind tunnel and force measurements on the heliostat model.

Table 1: Dimensions and characteristics of spires and roughness elements

| Configuration | Spire height $h$ (m) | Spire base width $b$ (m) | Spire depth $d$ (m) | Roughness width $R_b$ (m) | Roughness height $R_h$ (m) |
|---|---|---|---|---|---|
| SR1 | 1.3 | 0.155 | 0.34 | 0.09 | 0.045 |
| SR2 | 1.4 | 0.2 | 0.74 | 0.09 | 0.045 |

Figure 3(a) and (b) show the mean velocity and turbulence intensity profiles, respectively, of the two spire and roughness configurations in Table 1. The mean velocity profiles generated by SR1 are within a maximum error of ±5% of a power law ($\alpha = 0.18$) velocity profile. The turbulence intensities generated by SR1 are within ±2% of ESDU 85020 (1985) data for a neutral ABL with a mean wind speed of 10 m/s at a 10 m height, surface roughness height $z_0 = 0.002$ m and boundary layer thickness $\delta = 350$ m. In contrast, the mean velocity profile generated by SR2 is close to linear in the part-depth simulated ABL and generated turbulence intensities above 10%. Hence, the two spire and roughness configurations, SR1 and SR2, can be used to investigate the effect of turbulence intensity on the peak wind loads on the heliostat mirror that was stowed at a range of heights ($0.3 < z/\delta < 0.5$) indicated by the shaded region in Figure 3.

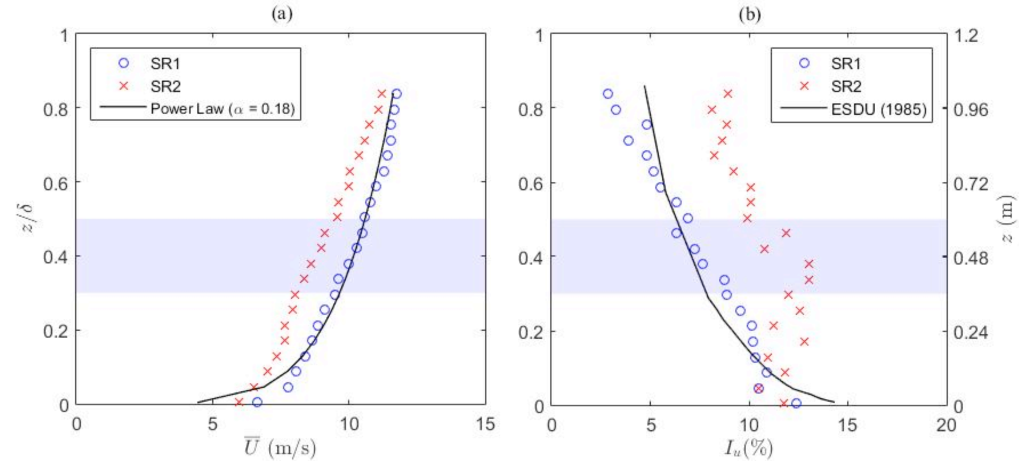


Figure 3: (a) Mean velocity profiles of the two spire configurations compared with the power law profile of a low-roughness terrain; (b) Longitudinal turbulence intensity profiles compared with the ESDU (1985) profile of a low-roughness terrain. The shaded area indicates the heights at which the heliostat mirror was stowed.

Force measurements on the model heliostat were taken using four three-axis load cells, mounted on a rotary turntable in Figure 2. Each load cell has a capacity of 500 N with a sampling frequency of 1 kHz in all three axes and an accuracy of ±0.5% of full scale. The heliostat was modelled as a thin flat plate in the absence of a support structure. A series of six square aluminium plates with 3 mm thickness and chord length ($c$) ranging from 300 mm to 800 mm were manufactured and mounted on a common pylon with a telescopic design to allow the elevation axis height $H$ of the plate to vary between 0.35 m and 0.6 m. The peak lift force on the plate ($L$ in Figure 2) was determined from the difference between the measured lift forces on the heliostat (plate mounted to pylon) and those on the heliostat pylon in the absence of a mounted plate. The peak hinge moments on the plate ($M_{Hy}$ in Figure 2) were calculated from the product of the peak lift force on the plate and the longitudinal distance from the centre of pressure to the centre of the plate. The peak lift coefficient and peak hinge moment coefficients on the plate were calculated following Peterka and Derickson (1992) as:

$$c_L = \frac{L}{1/2\rho\bar{U}^2 A} \quad (1)$$

$$c_{M_{Hy}} = \frac{M_{Hy}}{1/2\rho\bar{U}^2 Ac} \quad (2)$$

Here $\rho$ (kg/m$^3$) is the density of air, $\bar{U}$ (m/s) is the mean wind speed at the heliostat elevation axis height $H$, $A = c^2$ (m$^2$) is the heliostat mirror area and $c$ is the heliostat chord length.

**Results**

Figure 4 shows the effect of the heliostat chord length on the peak wind load coefficients on a heliostat in stow position exposed to SR1 and SR2. The peak lift coefficients for SR2 in Figure 4(a) and the peak hinge moment coefficients in Figure 4(b) are approximately double those for SR1. Both the peak lift and peak hinge moment coefficients increase by approximately double as the chord length is halved from 0.8 m to 0.4 m. This indicates that there is an inverse proportionality between the wind load coefficients and the chord length of the heliostat mirror.

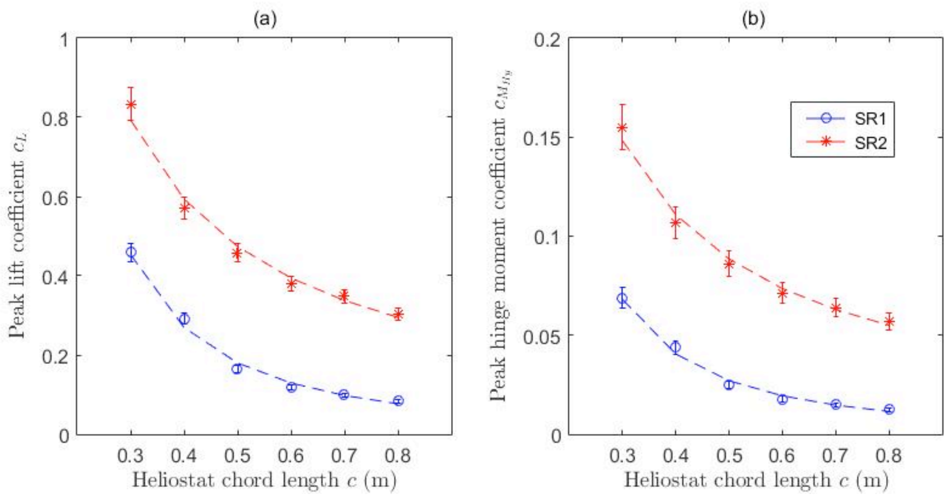


Figure 4: Effect of the heliostat chord length for SR1 and SR2 on (a) peak lift coefficient; (b) peak hinge moment coefficient on a stowed heliostat.

Figure 5 shows the effect of the elevation axis height on the peak wind load coefficients on stowed heliostats of two different chord lengths exposed to SR1. Both the peak lift coefficients in Figure 5(a) and the peak hinge moment coefficients in Figure 5(b) increase linearly with the elevation axis height of the heliostat. Hence, the peak wind load coefficients can be reduced by 21% and 23% for chord lengths of 0.5 m and 0.8 m, respectively, by lowering the elevation axis height of the heliostat by 30%.

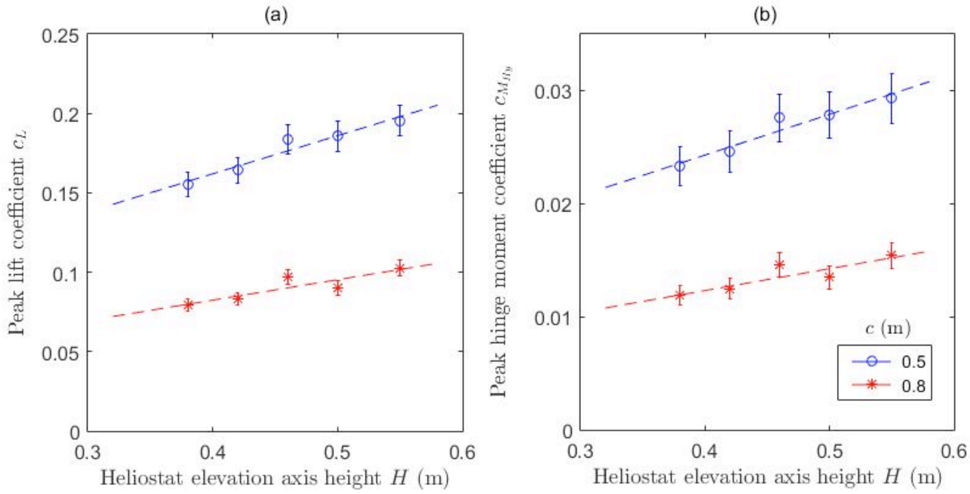


Figure 5: Effect of the heliostat elevation axis height for SR1 on (a) peak lift coefficient; (b) peak hinge moment coefficient on a stowed heliostat.

Figure 6 shows the effect of the outer diameter and thickness of the heliostat pylon for a heliostat mirror with chord length of 0.8 m stowed at different elevation axis heights and exposed to SR1. Both the peak lift coefficient (Figure 6(a)) and the peak hinge moment coefficient (Figure 6(b)) can be reduced by approximately 10% by increasing the outer diameter of the pylon from 33 mm to 42 mm and increasing the thickness of the pylon from 5 mm to 6 mm.

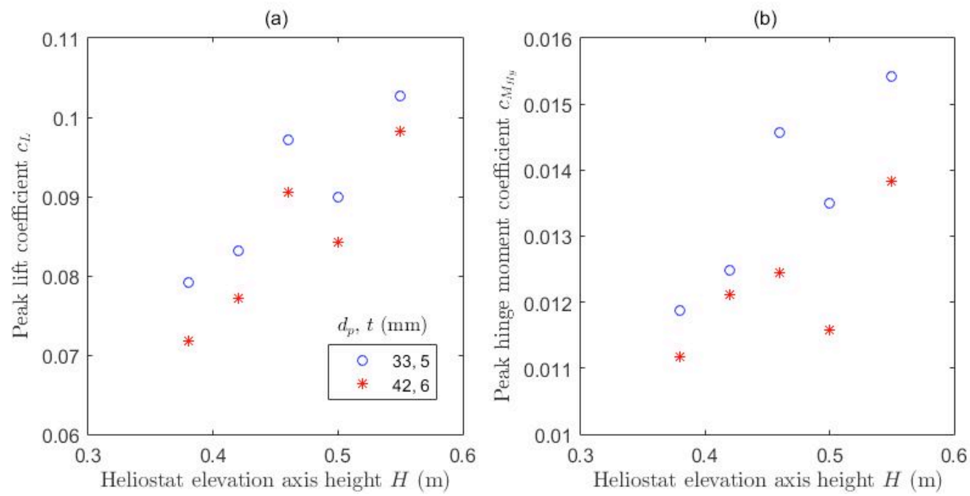


Figure 6: Effect of the heliostat pylon diameter on (a) peak lift coefficient; (b) peak hinge moment coefficient on a stowed heliostat with a chord length of 0.8 m.

Figure 7 shows the effect of longitudinal turbulence intensity on the peak wind load coefficients for comparison with the coefficients reported by Pfahl et al. (2015) at a turbulence intensity of 13%. At a similar turbulence intensity of 12.5%, the peak lift coefficient (Figure 7(a)) and peak hinge moment coefficient (Figure 7(b)) on the heliostat with chord length of 0.5 m in the current study were 13% and 23% lower, respectively than those measured by Pfahl et al. (2015). The pronounced linear increase of the peak wind load coefficients on stowed heliostats at turbulence intensities larger than 10% in the current study is in agreement with a similar finding by Peterka, Tan, Cermak, and Bienkiewicz (1989) for the peak drag and lift coefficients on heliostats in operating positions.

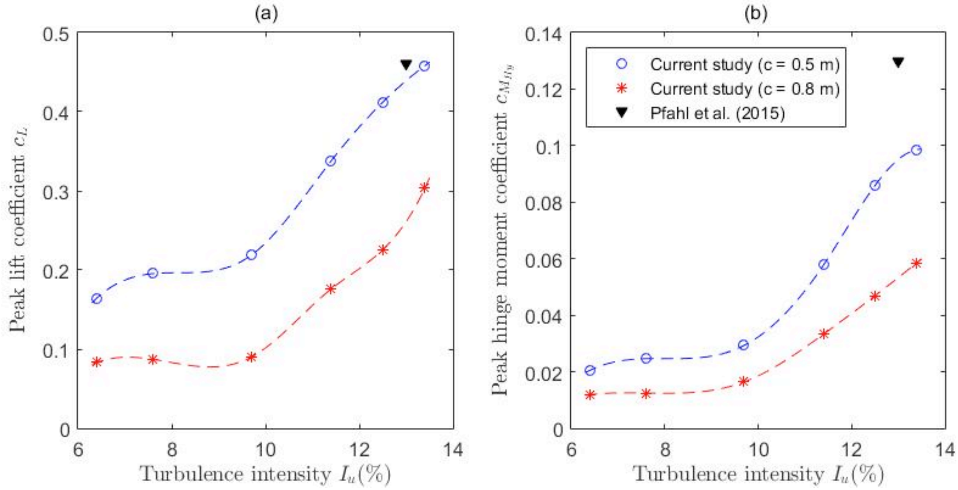


Figure 7: Effect of longitudinal turbulence intensity on (a) peak lift coefficient; (b) peak hinge moment coefficient on a stowed heliostat.

## Conclusions

The effect of the critical scaling parameters of a heliostat on the peak lift coefficient and peak hinge moment coefficient on a stowed heliostat was investigated using force measurements on different-sized plates at a range of elevation axis heights. Peak wind load coefficients showed an inverse proportionality with the chord length of the heliostat mirror, so that a halving of the mirror chord length resulted in a doubling of the coefficients. This suggests that the coefficients can be optimised by increasing the size of the heliostat mirror relative to the sizes of the relevant eddies approaching the heliostat. The peak lift coefficient and peak hinge moment coefficient on the stowed heliostat could be reduced by 21% and 23%, respectively, by lowering the elevation axis height of the heliostat mirror by 30% in the simulated ABL. In comparison, the peak wind load coefficients were reduced by less than 10% with an increase in the outer diameter and thickness of the heliostat pylon. A significant linear increase of the peak wind load coefficients occurred at longitudinal turbulence intensities greater than 10% in the simulated ABL. Hence, the peak wind loads on stowed heliostats during high-wind conditions in the ABL are highly sensitive to the critical scaling parameters of the heliostat and should be carefully considered depending on the turbulence characteristics of the site. Optimisation of the ultimate design wind loads can lead to cost reductions in the manufacturing of heliostats from lower strength and lighter materials.

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# *On-site Production of Electricity and Hydrogen for the Energy Needs of Rural Areas*

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**Abstract**
In both developed and developing countries, energy supply in rural areas is needed in an economical and environmentally sustainable way. On the one hand, extensions of the power grid are often inadequate due to their high cost and impact on the landscape. On the other hand, diesel generator sets have high greenhouse gas emissions and other undesirable environmental impacts. As a result, on-site renewable energy generation becomes the best option. The two main types of energy required are electricity for stationary uses and diesel for mobility. Therefore, the European project LIFE REWIND proposes the implementation of off-grid renewable energy systems, producing both electricity and hydrogen. A prototype has been designed and installed in a vineyard, to carry out the validation in a real case. It includes three photovoltaic sets: one is on the terrain, another is floating on an irrigation pond and the last one is on a solar tracker. The electrical system is configured as a micro-grid, with the same characteristics of the utility grid. The electricity is supplied to a wastewater treatment plant, a drip irrigation system and other uses like air conditioning and lighting. Moreover, with the surplus energy, an electrolyser produces hydrogen by electrolysis of water. An off-road vehicle with a fuel cell feeds on that hydrogen and carries people around the vineyard. In conclusion, electricity and hydrogen are produced from renewable resources on the farm itself. In addition, it is expected to obtain positive effects on the rural economy and employment.

Keywords: renewable energy, photovoltaic, hydrogen, irrigation, fuel cell, $CO_2$ emissions.

## Introduction

Combustion of fossil fuels to produce energy is the major source of $CO_2$ emissions and the main cause of the greenhouse effect (EEA, 2016). To avoid this, it is necessary to drastically reduce the use of coal, oil and natural gas, replacing them with renewable energy sources. On the one hand, developed countries must make changes and investments to replace the sources of the large amount of energy they consume. Two difficulties they have for this are the high energy intensity of their economy and the resistance to change of some sectors involved (Yaqoot, Diwan, & Kandpal, 2016). On the other hand, developing countries still have the challenge of bringing energy to their entire population, even in remote areas (External, Of, & Union, 2014). In this case, a weak public power grid and large transport distances are costly obstacles. There are many studies proposing the use of renewable energy systems for the supply of electricity in developing areas (Hao, Li, Cao, & Ma, 2016). The proposed technical solutions are mainly stand-alone generation or micro grids, avoiding the need to expand the public electrical grid. By contrast, in developed countries, the electricity supply in rural areas is expected to be done with extensions of the grid. Only when the cost is very high, another solution is taken into account. However, in both developing and developed countries, an energy supply with low environmental and landscape impacts is needed in natural or rural areas. Another issue which is often addressed differently in developed or developing countries is the effect of the solution adopted on the local population. Regarding developing countries, several approaches (Bhattacharyya, 2012) consider imperative not only that the concerned rural communities accept the proposed solutions, but also their involvement in the maintenance work. In contrast, in developed countries, no one shows an interest in the effect on the local population of how energy is supplied. As a result, the opinion of the affected population is not taken into account and even the opportunity to create local employment is lost. To summarize, despite the differences, in both developed and developing countries, the way of supply of electricity in rural and natural areas may be chosen with a focus not only technical but also environmental and socioeconomic.

A very important demand for energy in rural areas, with its related $CO_2$ emissions, comes from agricultural activities (Lal, 2004)(Schneider & Smith, 2009). Usually, electricity is obtained from the grid or is produced on site by diesel generator sets. Its replacement by renewable energy could minimize the environmental impacts. As for the agricultural machinery, it is also necessary to reduce its $CO_2$ emissions, derived from diesel combustion (Moreda, Muñoz-García, & Barreiro, 2016). In addition, if on-site generation is incorporated in rural areas, it is possible to obtain a positive socioeconomic impact in the areas involved (Goel & Supriya, 2015).

## The LIFE REWIND project

The full name of the European project LIFE REWIND is "Profitable small scale renewable energy systems in agrifood industry and rural areas: demonstration in the wine sector". This project has carried out a holistic approach to energy supply in rural areas. Although their focus has been the energy needs of agricultural activities, especially vine-growing (Carroquino, Dufo-López, & Bernal-Agustín, 2015), very similar techniques can be applied to power supply in any remote area. Furthermore, vine growing and wine making are among the activities most sensitive to climate change (Mozell & Thach, 2014). The challenge is to produce energy where it is needed, where the power grid does not reach, safely and at a reasonable cost. In the absence of the electricity grid, energy production must be well adapted to demand. If more energy is produced than necessary, it will be wasted. In addition, if production is not simultaneous with consumption, it will need to be stored. Consequently, a good characterization of the energy demand is necessary to find the optimum size of the generation system, including the batteries. Thus, the first step is to obtain information on demand and other factors to take into account. Table 1 shows the data groups and the sources where they were obtained.

Table 1 Data collection (energy and resource)

| Data sources | Data sets |
|---|---|
| Electricity bills | Historical electricity consumption |
| | Electricity prices |
| | Seasonality of the demand |
| Fuel delivery notes and user annotations | Historical fuel consumption |
| | Maintenance costs |
| Market prices | Installation investment cost |
| Interviews and Surveys | Demand side manageability |
| | Needs and criteria of operation |
| | Attitude about sustainability |
| On site measurements | Powers and consumptions |
| Photovoltaic Geographic Information Systems | Solar resource |
| Bibliographic databases | Wind resource |
| On-site measurement campaigns | Solar resource |
| | Wind resource |
| | Temperatures |

Both objective and subjective data, including the attitude towards environmental sustainability, have been obtained in the Spanish wine sector. One of the objectives is to know the difficulties and motivations that affect the incorporation of renewable energy. The methodology used for the surveys has been carried out in three stages. A first exploratory phase, through semi-structured and directed interviews that were used as tests of the questionnaire or pre-test. A second stage in which the final questionnaire has been developed and the type of sampling has been designed. And a third phase that has been dedicated to the statistical analysis of the data provided by the survey to draw conclusions and to be able to make the right decisions. In order to simplify the sampling procedure to the maximum extent while preserving the representativeness of the sample, it was decided to use a simple random sampling and, subsequently, a stratification by administrative region. A detailed explanation of the methodology used in the surveys, as well as the results, will be the subject of a specific publication.

Regarding renewable resources, the European online Photovoltaic Geographic Information System (PVGIS) has been used to quantify the geographical distribution of solar resources in different areas studied. In five case studies, including that for the location of prototypes, two-year measurement campaigns have been carried out for the on-site measurement of renewable resources. Each measuring station incorporates wind sensors (two anemometers and a wind vane), a solar irradiation sensor (pyranometer), a data-logger, an autonomous power system with solar panel and a data transmitter. The dataset obtained allows the characterization of the solar and wind resources in the studied areas, mainly southern Europe.

Once the data on available renewable resources and energy demand have been characterized, several kinds of facilities have been identified, corresponding to winery, pumping for irrigation and, in addition, farms and other agricultural activities. All of them have been studied to a greater or lesser degree. Obviously, the case where the prototype was installed was analysed in depth.

One of the actions carried out by the project is the design and assembly of a prototype that supplies renewable energy produced on-site for a vineyard and a winery. The prototype has a dual role in the project. On the one hand, it is a demonstration facility and prepared to be visited and shown to stakeholders. On the other hand, the data obtained from its operation will allow us to carry out a thorough technical and economic study. The design of the renewable generation system has been performed by heuristic methods. For this purpose the iHOGA program was used, which is a software tool based on genetic algorithms (Bernal-Agustín & Dufo-López, 2009). Firstly, sets of simulations and optimizations have been performed, in search of the best configuration and size, both from an economic and emission reduction point of view. Secondly, the prototype has been designed and installed. Thirdly, it is being used for the validation in a real case. Finally, throughout a year of operation, various technical and economic parameters are being measured for further analysis.

Figure 1 Floating photovoltaic set and solar tracker photovoltaic set

The chosen generation technology has been photovoltaic, for having an annual profile compatible with the energy demand of the irrigation and winery. The prototype includes 43.2 kWp of photovoltaic panels, distributed in three sets. The first one is mounted on a fixed structure on the terrain, which is the simplest solution. Its fixation on the ground has been made using prefabricated blocks of concrete, which can be placed and removed without environmental impact in the place. The second set (Figure 1) is floating on an irrigation pond. This innovative solution saves the use of land, its preparation and the placement of the fence (Sahu, Yadav, & Sudhakar, 2016).

The floating system has been specifically designed for use in irrigation ponds, adapting to its frequent filling and emptying. The last set is mounted on a solar tracker (Figure 1). As it is permanently oriented towards the sun, this solution offers a greater production of energy. Figure 2 shows the production of the set on the fixed structure and Figure 3 of the set on the solar tracker, for the same day. On the one hand, this variety of mounting systems allows visitors to see different options. On the other hand, it allows for the collection of data that will be used for technical and scientific comparatives.

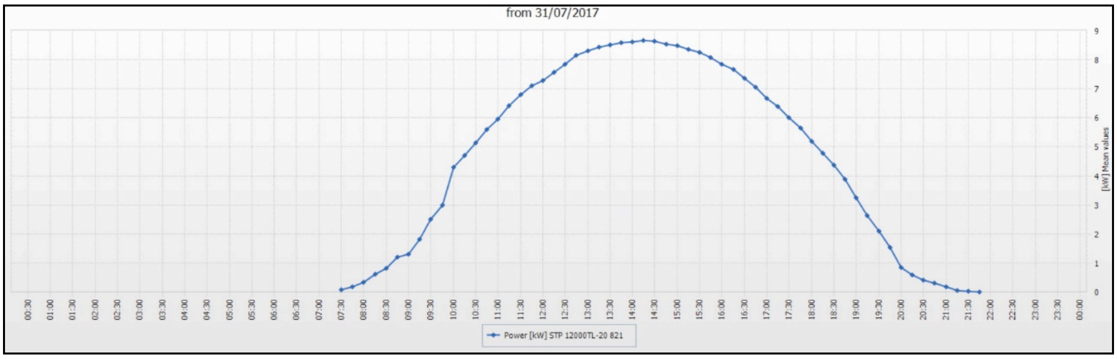


Figure 2 Production of the photovoltaic set on the fixed structure, on 07/31/2017

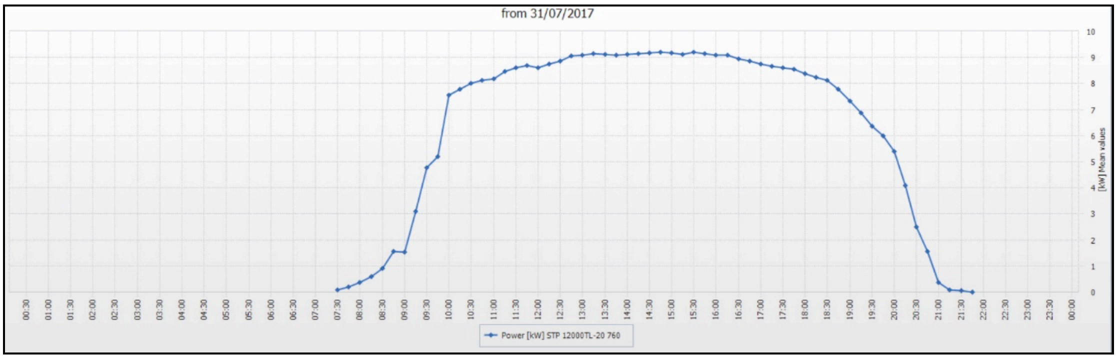


Figure 3 Production of the photovoltaic set on the solar tracker, on 07/31/2017

Regarding the stand alone electrical system, a three-phase AC 400 V 50 Hz bus has been chosen, produced by three inverters that manage a set of batteries of 48 V 2,680 Ah C10. The energy produced by the three photovoltaic fields is injected into the AC bus via three three-phase solar inverters. Thus, the electrical system is configured as a micro-grid, with the same characteristics of the public electrical grid. The electricity is supplied to the wastewater treatment plant of the winery, a drip irrigation pumping system and other uses like air conditioning and lighting. It is remarkable to note that the wastewater from the winery, after its treatment, is used for irrigation. Furthermore, with the surplus energy, an electrolyser produces hydrogen by electrolysis of water, which is then compressed to 200 bar and stored (Figure 4). An electric off-road vehicle has been adapted, by incorporating a fuel cell system and carries people around the vineyard (Figure 5). Thus, the vehicle feeds on hydrogen produced in the vineyard itself. The whole process is 100% clean and operates without emissions.

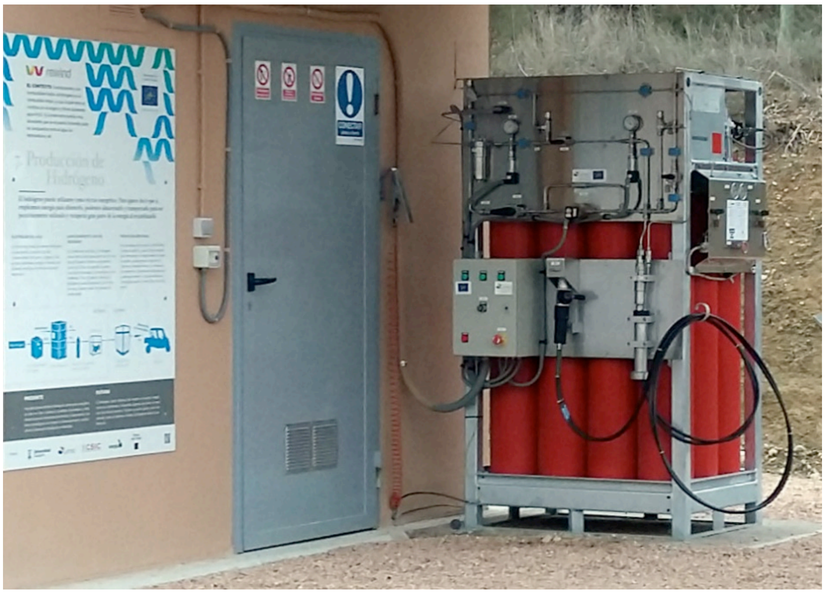

Figure 4 Hydrogen refuelling station


Figure 5 All-wheel drive fuel cell vehicle

The management of the system can be done from the location itself or through the internet, with a computer, tablet or mobile phone. There are also two high-definition IP cameras, one of them motorized, which allow the visit and inspection of the system remotely, for purposes of demonstration, control and security. In addition, the controller collects data from inverters and sensors and sends them to an external server via the internet. Since the mobile internet coverage in the location is practically zero, a point-to-point link has been installed to connect to the net of the winery itself.
The technical room is thermally insulated and air-conditioned by means of a heat pump also supplied by the system's own renewable energy. This, in addition to making visits more comfortable in summer and winter, will prolong the life of the batteries and the electronics. As an additional safety measure, when temperatures are very low, heating resistors prevent the freezing of the water destined to the production of hydrogen.

As for the loads, the motors of the pumps of greater power have been equipped with frequency inverters and the smaller ones with progressive starters. Each device has been determined how critical it is and its degree of manageability. Thus, some are automatically managed by the system and others are operated by the user, either manually or by daily or weekly programing. The controller includes hardware and software developed specifically in the project.

Table 2 Data collection to analyse socioeconomic impact

<table>
<tr><th colspan="3">Group</th></tr>
<tr><td rowspan="4">People</td><td colspan="2">Inhabitants of the region</td></tr>
<tr><td colspan="2">Visitors</td></tr>
<tr><td colspan="2">Workers of the region</td></tr>
<tr><td colspan="2">Consumers of the company’s products</td></tr>
<tr><td rowspan="4">Business</td><td rowspan="2">Customers</td><td>Wineries in the region</td></tr>
<tr><td>Other companies in the region</td></tr>
<tr><td rowspan="2">Suppliers</td><td>Services: hotels, restaurants, shops…</td></tr>
<tr><td>Supplies for renewable energy systems</td></tr>
<tr><td rowspan="4">Institutions</td><td>Public</td><td>Municipal, provincial and regional administration</td></tr>
<tr><td>Private</td><td>Consumer and business associations</td></tr>
<tr><td rowspan="2">Scientific community</td><td>Schools, colleges and universities</td></tr>
<tr><td>Research centres</td></tr>
</table>

To complete the study, the local socioeconomic impact caused by the implementation of the proposed renewable energy systems has been evaluated. Among the different methods available, the contingent valuation method, which is directly evaluated through surveys, has been chosen (UNDP – Seemin Qayum, 2012). Table 2 shows the identified interest groups, which should be consulted.

**Conclusion**

The LIFE REWIND project fights against climate change in the rural environment, both by mitigation and adaptation. As mitigation, it reduces $CO_2$ emissions related to energy consumption in agricultural activities and industries. As adaptation to climate variations, it allows the production of clean energy for irrigation in isolated or remote locations. Furthermore, noise, spills and other environmental impacts of diesel are avoided, as well as the impact on the landscape of the electricity grid in natural areas. The approach to a specific sector (the wine industry) allows for the establishment of common characteristics and to facilitate the replication of the proposed solutions.

Regarding the prototype, the energy generated during a year of operation has been of 70,545.60 kWh, which has obtained a saving of 47.9 tons of $CO_2$. It is probably the first time that hydrogen is produced from electricity generated on-site by a stand-alone renewable energy system, to be used for mobility on the farm itself. Although this part of the prototype is not yet economically profitable, it opens the door to the transition of the agricultural machinery leaving the diesel and becoming electric, with fuel cells or with batteries. All this has been achieved by producing the energy on-site, from renewable resources and in the farm itself.

There are several innovations introduced by the LIFE REWIND project. One of them is the support for floating photovoltaic panels in irrigation ponds. There were other floating supports, but their characteristics were not suitable for use in this kind of ponds because of its frequent filling and emptying. The floating system developed for the project can occupy practically all the surface of the pond if necessary and it adapts perfectly to the differences of level by the filling and emptying of the pond. In addition, the inclination of the panels is intended for the irrigation season. The project studies the thermal effects that can increase the performance of the panels, as well as the reduction of the water loss of the pond by evapotranspiration.

Having studied the case of vineyards in Spain and in the rest of southern Europe, the REWIND project has demonstrated the technical and economic feasibility of off-grid photovoltaic generation systems, avoiding the diesel generation sets and the extensions of the electrical grid. The project has find an optimum sizing procedure, incorporating advanced methods such as genetic algorithms. In order to facilitate replication in every specific case, two user-friendly software tools have been developed for future distribution. Another result is a positive impact on rural society and economy. In a vineyard and for off-grid systems, photovoltaic, whether on its own or in a hybrid combination with a small proportion of diesel, is the most appropriate generation technology. In these cases, the sizing and the management of the system are critical in order to avoid a very high cost or a high probability of failure in demand coverage. The resulting energy costs are lower than those of diesel generation, and often than those of the extensions of the electricity grid. This makes photovoltaic energy the most cost-effective and reliable alternative. For the wineries, which are usually grid-connected, photovoltaic self-consumption is the technically ideal solution to incorporate renewable energy. In this case, the size of the generator is not critical. In general, the need for a relatively high initial investment is a difficulty for the implementation of renewable generation systems.

In a stand-alone renewable energy system, maximum profitability can be achieved by installing the optimum combination of photovoltaic power, storage and in some cases hybrid generation. In order to find the optimal design, it is essential to carry out the characterization of the energy demand. A high degree of communication with the user is also important, from the design phase to the start-up and subsequent maintenance. Installations carried out without these guarantees are at risk of providing inadequate service to users or completely failing. When supplying energy to pumps or other electric motors, a problem that usually arises is derived from the strong starting current of the motors, which can be solved with the use of variable frequency drivers or, at least, of motor soft starter. Much more difficult to solve are electromagnetic interferences and harmonics, which require highly qualified technicians.

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# *The Influence of Skycourt as Part of Combined Ventilation Strategy in High-Rise Office Buildings*

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Official Conference Proceedings

**Abstract**
Skycourts are recognised nowadays as essential transitional, movement and social interaction spaces in high-rise and mid-rise buildings. The paper reports on analytical research into the energy saving promising associated with the modification of air movement strategy in skycourt zones. Heating and cooling in office buildings use a high percentage of the overall energy consumption. Nevertheless, ventilation is addressed vastly according to cooling loads without considering its actual influence. The study aims to investigate the skycourt as a ventilated buffer space in high-rise office buildings and explore its impact on reducing energy demand for heating and cooling. Using a theoretical reference model of an office building, energy and CFD simulations are carried out over two modes; an air conditioning skycourt and a ventilated, unheated and uncooled skycourt. Results are compared with respect to energy reduction besides thermal comfort. Three spatial configurations of skycourt are investigated to define the optimal prototype of the skycourt in temperate climate exemplified by London. Overall, the simulation results highlight that the incorporation of skycourt as a ventilated buffer zone reduces the annual heating and cooling demand remarkably. Furthermore, the comparison between the skycourt prototypes shows a variation in the energy performance of the building and the thermal conditions inside the skycourt.

Keywords: Skycourt, Ventilation, Coupling Simulation, Thermal Comfort, Energy Efficiency

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## Introduction

A skycourt is defined as an integrated space in a high-rise building that offers a diversity of functions. This facilitates significant social, environmental and economic benefits, and improves the overall performance of the building. Skycourts help to create a sense of community in high-rise buildings where there is normally a lack of engagement between occupants. They perform as places for transitional, movement and social interaction. Furthermore, skycourts can enhance passive features and support heating and cooling strategies. Consequently, they can have a significant impact on reducing energy consumption and improving health, wellbeing and productivity. Also, they can provide climate responsive approaches to design, facilitate the holistic sustainable design and improve the performance of high-rise and mid-rise buildings (Pomeroy, 2014; Yeang, 1999).

The skycourt concept is initiated from re-adapting the traditional/vernacular elements in low-rise buildings, such as the courtyards and atriums (Figure 1). These spaces show significant potential in dealing with climate, culture and context. Therefore, skycourts in high-rise buildings could provide a contemporary alternative to courtyards or atria due to their potential to allow natural light to penetrate deeper into the interior of high-rise buildings and promote natural ventilation while avoiding unwanted solar gain. Other possible advantages of occupants' social networking and on more prestigious that build economic benefits. These have made skycourt to become a primary zone in these buildings.

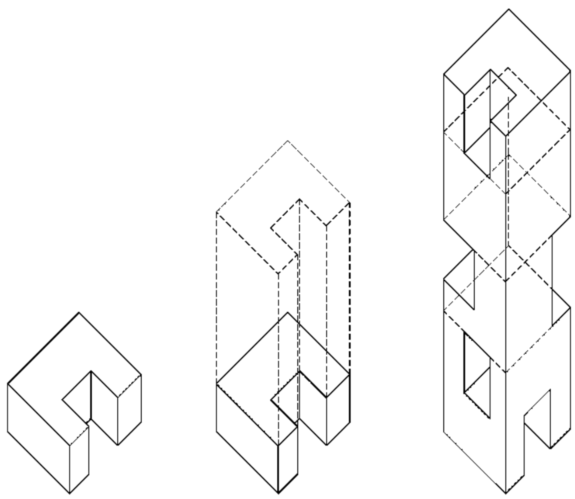


Figure 1: Transformation from courtyard at low-rise to skycourt at mid-rise and high-rise buildings.

A skycourt may be located within the high-rise building at the lower part (sky-entrance), the top of the building (sky-roof), or between the middle floors (sky-court). These void spaces are two or more floors height linked with the surrounding indoor and outdoor areas by open or enclosed walls. The spatial configuration or form geometry of skycourt can be classified into infill space, stepped terrace space, interstitial space, hollowed-out space, corner space, chimney and roof space (Pomeroy, 2014) (Figure 2). The hollowed-out prototype, the corner prototype and the sided prototype are the common spatial configurations in high-rise office buildings (Alnusairat, Hou, & Jones, 2017).

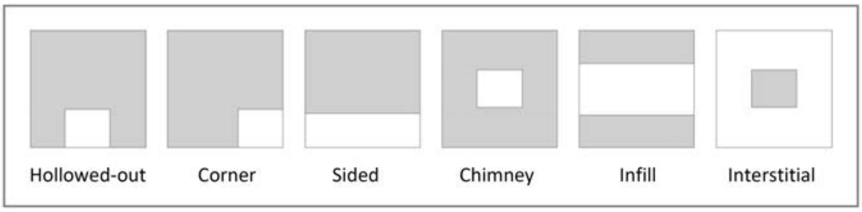



Figure 2: Spatial configurations of skycourt in high-rise buildings.

In UK, office and retail buildings' sector accounts for almost half the total of energy consumption, due to the extensive use of air conditioning systems (Pérez-Lombard, Ortiz, & Pout, 2008). Significantly, heating, cooling and ventilation in high-rise buildings consume nearly 40 percent of the total energy consumption (Al-Kodmany, 2015). Therefore, it is crucial to look for solutions to minimise the energy consumption and at the same time to enhance the quality of the built environment. Attention recently has focused on the effect of skycourt phenomena on the ventilation performance of high-rise buildings (Etheridge & Ford, 2008; Pomeroy, 2012; Taib, Abdullah, Ali, Fadzil, & Yeok, 2014). Skycourts could be integrated into the buildings and act as features for air supply, air exhaust and air circulation in the buildings and they are combined with other design elements to maximise the efficiency of airflow (Wood & Salib, 2013). However, studies addressing the impact of skucourt by its own on the total performance of the building are limited.

The paper aims to investigate the influence of skycourt as part of the ventilation strategy in office buildings. Ventilation is relatively the process of airflow to maintain a satisfactory environment within a building or an enclosed space, by controlling the temperature, humidity and providing good air quality (Moghaddam, Amindeldar, & Besharatizadeh, 2011). It can support cooling and improve heat exchange mechanism (CIBSE, 2001). This study suggests ventilation strategies to mediate the thermal conditions in skycourts based on the fresh air required for the adjacent offices. Convective heat transfer of air occures inside the volume of skycourt because of the variation in air temperature and height (Figure 3), and this air motion could induce significant thermal comfort cooling.

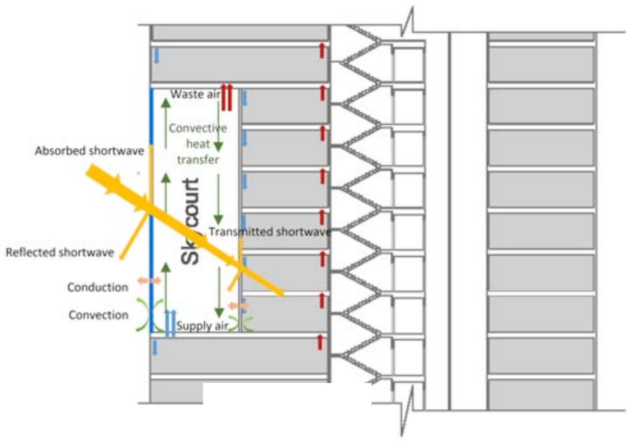



Figure 3: Heat transfer and airflow mechanisms in skycourt and adjacent offices.

In the study, three spatial configurations of skycourt are modelled using energy simulation and CFD. The models are examined under three proposed ventilation strategies: isolated ventilation, combined-exhaust ventilation and combined-supply ventilation. The strategies are evaluated regarding two criterions: the heating and cooling energy consumption for the building and the thermal conditions inside the skycourt. The following sections describe the process of the study.

## Methodology

The study uses a coupling simulation approach in which two models are integrated: Building Energy Simulation (BES) and Computational Fluid Dynamics (CFD). This method can produce equivalent information for the energy consumption and the indoor thermal conditions for buildings. Also, it can predict more accurate, detailed and quick results compared to separate simulations (Barbason & Reiter, 2014; Wang & Wong, 2008; Z. Zhai, Chen, Haves, & Klems, 2002; Z. J. Zhai & Chen, 2005). BES provides the thermal and energy analysis for the building on an hourly basis for the whole year. This includes mean (average) air temperature, heating, cooling, ventilation, solar gain, fabric and incidental loads. However, this type of simulation assumes the air is well-mixed. Therefore, it is unable to provide detailed predictions of the spaces' indoor air properties such as the distribution of air velocity and temperature. CFD can predict the full spatial distribution of air velocity, air temperature and air quality for both the natural and mechanical ventilation. However, it requires thermal and flows boundary conditions that are obtained from the BES.

In the study, the coupling approach uses the interior surface temperatures that are obtained from BES to set up the CFD model which, then predicts the air temperature and air velocity at the internal of the skycourt. This significance is essential for the assessment of thermal comfort (Figure 4).

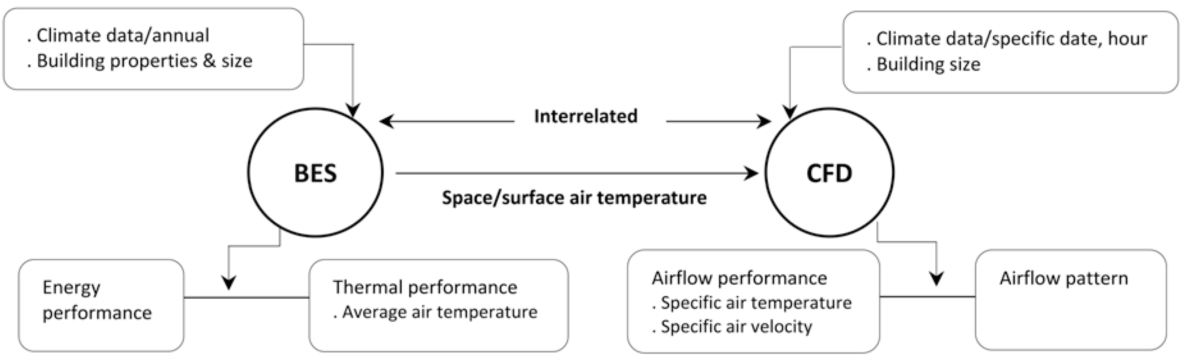



Figure 4: BES and CFD coupling models.

HTB2 and WinAir are coupled in this study. HTB2 software (version 10) is used to inform the thermal performance and energy efficiency, while WinAir (version 4) is adopted as a CFD simulation to inform the ventilation performance inside the skycourt. These two softwares were developed by the Welsh School of Architecture (WSA) at Cardiff University. HTB2 numerical model can predict the indoor thermal performance and estimate the energy demands for buildings during both design stage and occupancy period (Lewis & Alexander, 1990). It is recommended due to its high validity; it has undergone a series of extensive testing: the IEA Annex 1 (Oscar Faber and Partners, 1980), IEA Task 12 (Lomas, Eppel, Martin, & Bloomfield, 1994) and IEA BESTEST (Neymark, Judkoff, Alexander, Strachan, & Wijsman, 2011). Further, it has been validated under ASHREA standards (Alexander & Jenkins, 2015). Also, HTB2 has flexibility and ease of modification (Xing, Bagdanavicius, Lannon, Pirouti, & Bassett, 2012). WinAir can predict airflow patterns, indoor air velocities, indoor air temperature distribution and air flow rates in the skycourt. Thermal conditions for WinAir simulations are established from previously calculated values using the HTB2 including internal surfaces temperatures, heat gain and loss and constant air supply to modify the internal environment of the skycourt. Then, the resulted temperature from the CFD simulation was compared with the average skycourt temperature from the BES to find the predicted temperature difference. The temperature difference was small (approximately 1°C). That little difference is usually accepted for ventilation cases to continue the simulation for the next time step (Wang and Wong 2008). Therefore, one-step data exchange was adopted in the study.

## Coupling Simulation

A theoretical reference model was developed based on design guidelines for high-rise office buildings in London (British Council for Offices (BCO), 2014). To reduce the time required for each simulation run, the models were simplified to an eight-storey, since six-storeys is the most common height of skycourt in the research context. This study focuses on three representative configurations. These configurations function as buffer zones that intermediate between the inside air conditioning offices and the outside. This could be connected to the outdoors by one edge prototype (A) , two edges prototype (B) and three edges prototype (C) as illustrated in Figure 5.

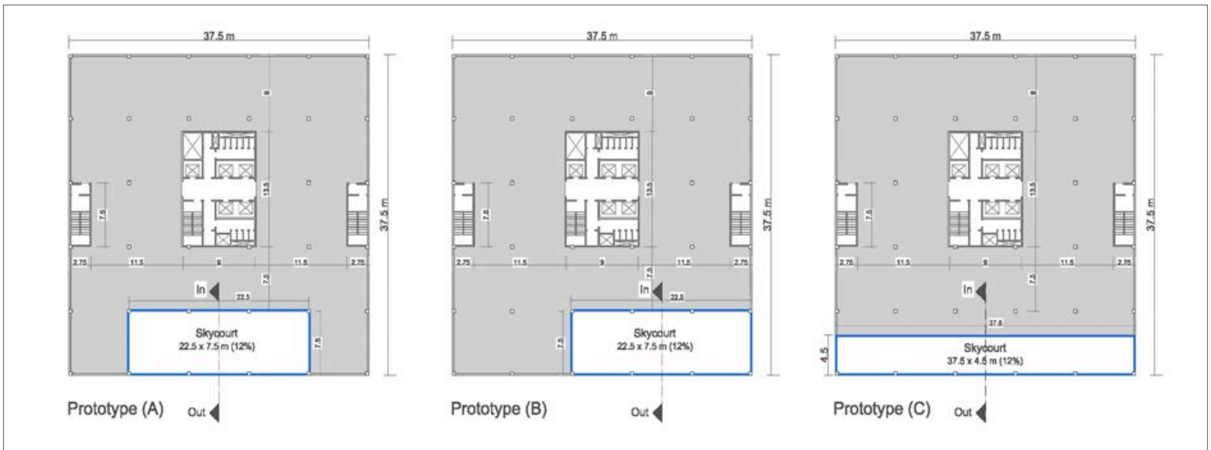



Figure 5: Spatial configurations of skycourt floor plans considered in the study: prototype (A), prototype (B) and prototype (C).

All energy simulation is carried out for one year period using the climate data of London. However, CFD simulation is carried out on three specific times, these are the following: the hottest external air temperature in summer (28.3 °C on 30th June at 14.00), the coldest external temperature in winter (-5.0 °C on 7th December at 9.00) and the typical temperature in mid-tseasons (13.2 °C on 19th April at 9.00) (Figure 6). The main criterions to assess the study's hypothesis are:

(1) the annual energy demand of heating and cooling (Kwh/$m^2$ .year) for the building and the annual energy reduction percentage.

(2) the occupants' thermal comfort: indoor air temperature (° C) and average air speed (m/s) at the occupied area of the skycourt (1.6m height above the floor level ).

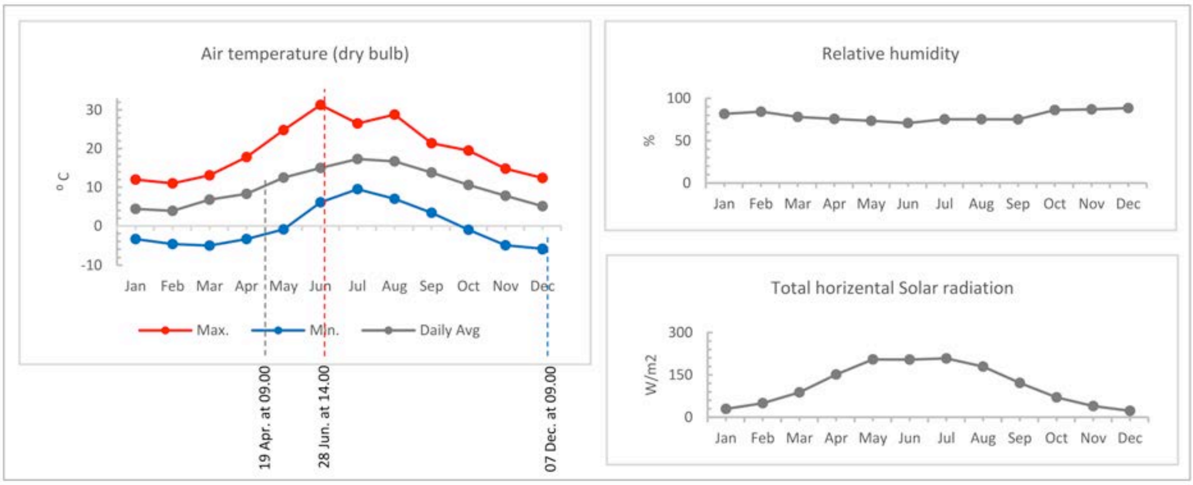



Figure 6. Weather data applied in the study.

All cases are simulated under same numerical settings and boundary conditions. South has assumed a standard orientation for the main facade. The minimum ventilation rate to maintain an accepted air-quality is determined based on the number of occupants, and taking into consideration the building envelope airtightness (infiltration) at the perimeter of the building. The heating set point is 18°C, and the cooling set point is 25°C. Single set point controls are used for cooling in the offices, while air handling unit controls heating. Table 1 illustrates the main numerical settings and assumptions for the simulation process.

Table 1: Summary of numerical settings of the study.

| | | | |
|---|---|---|---|
| **Workplace density:** | | **Ventilation setting:** | |
| NIA per workspace | 12 m² /person | Infiltration rate | 3.5 $m^3/(m^2.hr)$ at 50 Pa |
| | | Air supply rate | 10 L/s per person |
| **Internal heat gain*:** | | Heating set point | 18°C |
| People | 12 $w/m^2$ | Cooling set point | 25°C |
| Equipment | 15 $w/m^2$ | Operating time | 08:00-18:00 |
| Lighting | 12 $w/m^2$ | | |
| | | **Total simulation time:** | |
| **Fabric parameter U-value:** | | Energy building simulation | All over the year |
| Windows U-value | 1.53($W/m^2$.C) | CFD simulation | 3 peak hours (hottest, coldest, typical) |
| Window to Wall ratio | 70% | | |
| Wall U-value | 0.23($W/m^2$.C) | | |
| Floor U-value | 0.20($W/m^2$.C) | **Thermal comfort:** | |
| | | Air temperature-Winter | 20°C ± 2°C |
| | | Air temperature - summer | 24°C ± 2°C |

*Occupancy profile: the building occupied five days a week, based on the following schedule, for offices 09:00-13:00 occupied 100%, 13:00-14:00 occupied 70%, 14:00-18:00 occupied 100%. For Skycourt 09:00-18:00 occupied 100%

**Proposed Ventilation Strategies**

Three ventilation strategies to mediate the thermal conditions of the skycourt are investigated, an isolated ventilation strategy and two combined ventilation strategies between the skycourt and the adjacent offices based on the required fresh air for the adjacent offices. Therefore, the skycourt in the combined strategies does not consume energy for heating either cooling. The follwing describes the prposed ventilation strategies:

I. The isolated ventilation strategy: both spaces, the skycourt and the adjacent offices of skycourt are mechanically ventilated, cooled and heated seperately as shown in Figure 7. These models are considered the base cases, as this ventilation strategy represents the common way to cool and heat skycourt in practice. The air change rate for each office floor is 3.1 ac/h and for the skycourt is 0.167 ac/h at 18 °C.

II. The combined-exhaust ventilation strategy that relies on the maximum airflow volume rate exhausted from the adjacent offices to the skycourt. The inlet air volume rate for the skycourt is 5.58$m^3$/s with air change rate 5.76 ac/h (Figure 8).

III. The combined-supply ventilation strategy. In this strategy, air flows in opposite direction: all supply air enters through skycourt zone then into the adjacent offices and all air exhausts through the offices' zone. The inlet air volume rate for the skycourt is 5.58m$^3$/s with air change rate 5.76 ac/h (Figure 9).

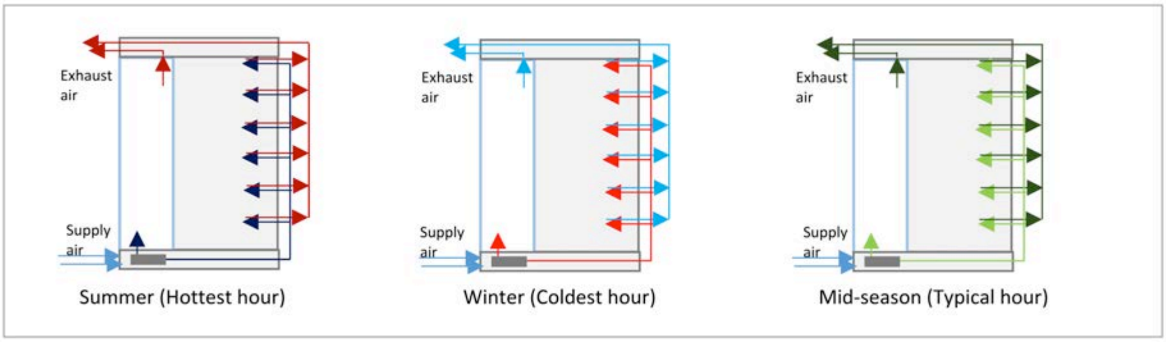



Figure 7: Ventilation strategy (I) in the base model: isolated mechanical ventilation.

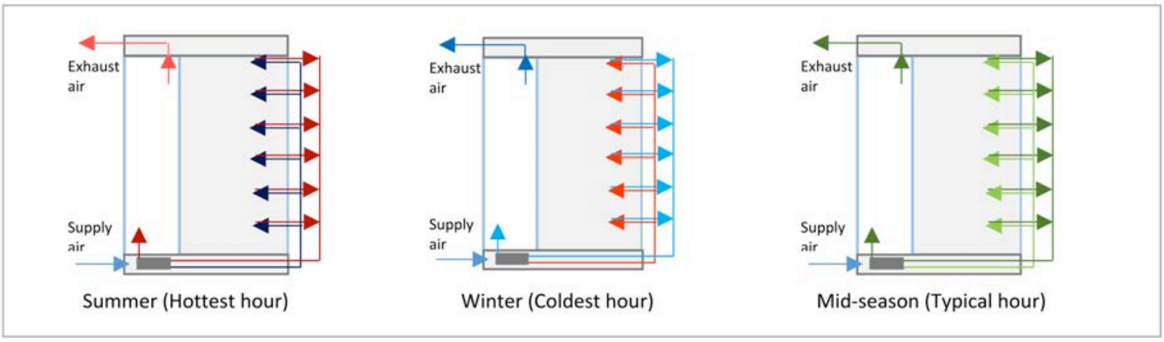



Figure 8: Ventilation strategy (II): combined-exhaust ventilation; skycourt is cooled, warmed and ventilated by the exhaust air from the office spaces.

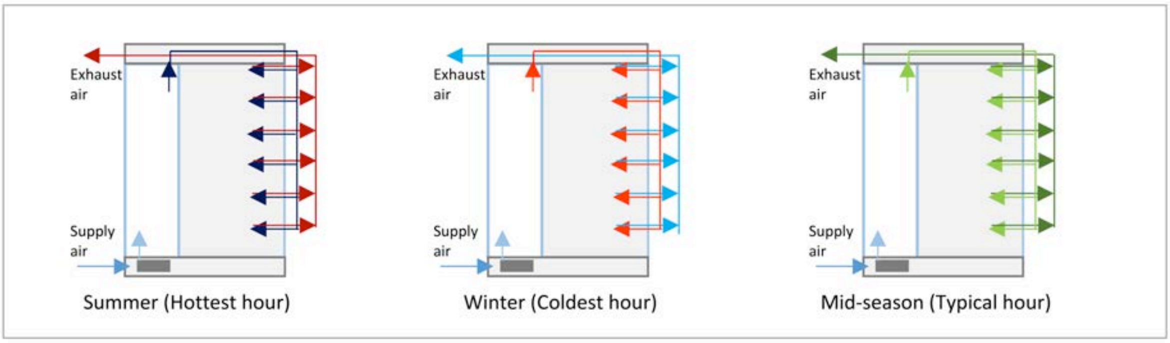



Figure 9: Ventilation strategy (III): combined-supply ventilation; skycourt is cooled, warmed and ventilated by the supplying air to the offices.

**Results and Discussion**

The energy demand for heating and cooling of the building and the thermal comfort conditions at the occupancy level of the skycourt are taken as criteria of comparison. Thus to define the optimum ventilation strategy.

## Energy performance comparison

Figure 10 and Figure 11 illustrate the energy efficiency comparison for the different cases. It is apparent that the annual energy demand for heating and cooling of the (II) and (III) ventilation strategies is less than half of the demand in case of strategy (I). However, it is evident that there is a significant difference between the three prototypes in the case of ventilation strategy (I). While, strategies (II) and (III) have similar energy demand and this due to the assumption that skycourt is a ventilated, unheated and uncooled space and heating and cooling for the buildings depend on the office spaces only.

Skycourt (A) building consumes the least heating and cooling loads in case of strategy (I), while the building that integrates skycourt (C) uses the highest amount of cooling and heating loads. This is because skycourt (C) gets high solar gain from three external facades and this requires high-energy demand to cool the skycourt. The three prototypes (A), (B) and (C) accounted the following energy demand respectively, under ventilation strategy (I): 220 Kwh/m$^2$.yr, 245 Kwh/m$^2$.yr and 329 Kwh/m$^2$.yr. The energy demand when conducting ventilation strategy (II) recorded the following values: 91.9 Kwh/m$^2$.yr for prototype (A), 91.5 Kwh/m$^2$.yr for prototype (B) and 90.0 Kwh/m$^2$.yr for prototype (C). Results obtained from strategy (III) recorded the following: 110.0 Kwh/m$^2$.yr for prototype (A), 98.9 Kwh/m$^2$.yr for prototype (B) and 100.6 Kwh/m$^2$.yr for prototype (C).

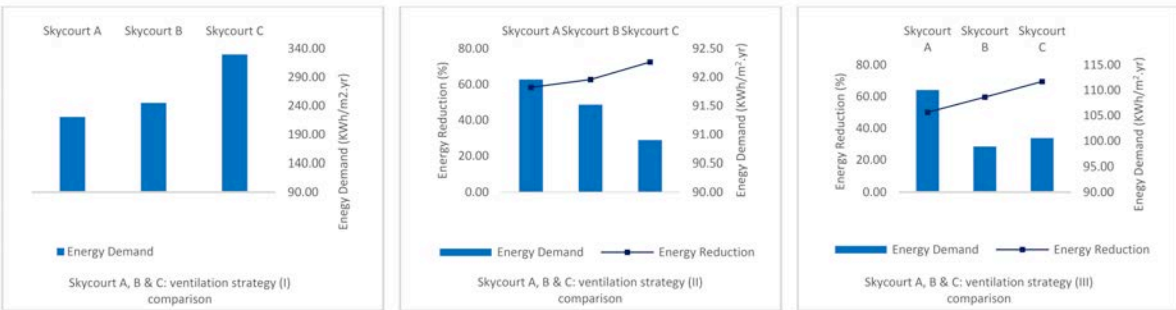
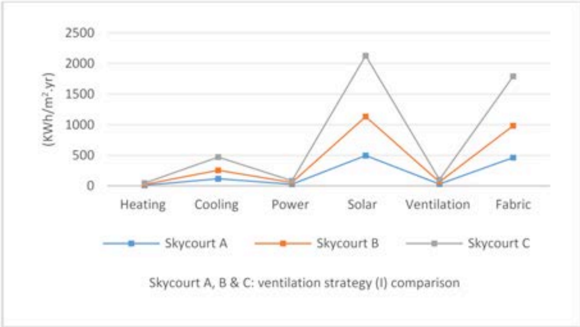
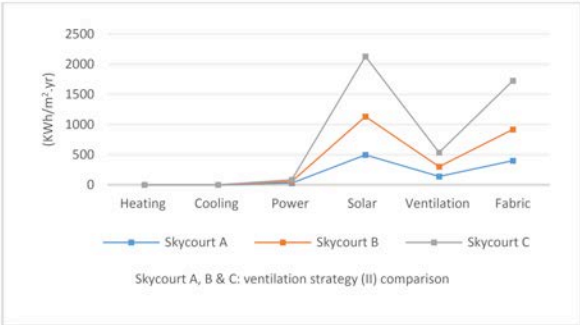



Figure 10 : Annual heating and cooling demand comparison for skycourts (A), (B) and (C): ventilation strategies (I), (II) and (III).

Comparing this data shows that the strategy (II) can reduce the annual total heating and cooling for skycourts (A), (B) and (C) by 58.3%, 62.7% and 72.4%, respectively. Whereas, strategy (III) obtain less energy reduction percentages. It accounts the following savings: 50.0% for skycourt (A), 59.7% for skycourt (B) and 69.5% for skycourt (C).

Taken together, the results indicate the effectiveness of strategy (II) -the combined exhaust ventilation strategy- to reduce the annual energy demand of heating and cooling for the building.



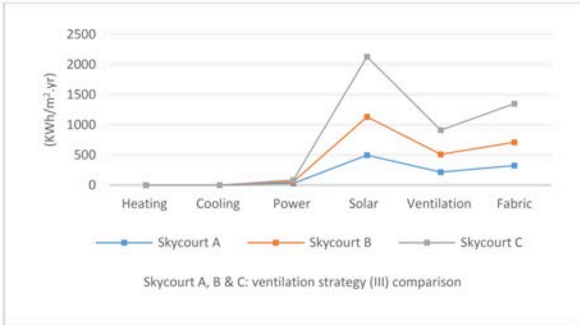




Figure 11: Annual heating, cooling, solar, fabric, ventilation and power loads comparison for skycourts (A), (B) and (C): ventilation strategies (I), (II) and (III).

**Thermal performance comparison**

Figures 12, 13 and 14 illustrate the CFD temperature and airspeed distributions inside the skycourt prototypes under the proposed ventilation strategies at three hours conditions, the highest, the coldest and the mid-degree of the external air temperature. Cross-section location is shown in Figure 5. The comfort criteria recommended by the British Council for Offices (BCO) guide (2014) is adapted to verify the thermal conditions at the occupancy level of the skycourt; air temperature ranges in summer 24°C ± 2°C, in winter 20°C ± 2°C and airspeed ranges between 0.1m/s and 0.2m/s (British Council for Offices (BCO), 2014). It is apparent that under ventilation strategy (I), the mean air temperature was very high and airspeed was very low and quite constant at the occupied area of the three skycourts in summer. In winter, airspeed was much higher and this air movement causes low temperature at the occupied level. The simulation records the following air temperature and airspeed at the occupied level for skycourt (A), (B) and (C) respectively: 33.8 °C and 0.031m/s, 34.7°C and 0.034m/s, 37.2°C and 0.039m/s in the hottest summer hour. Whereas results in the coldest winter hour were 11.6°C and 0.336m/s, 9.4°C and 0.35m/s , 8.8°C and 0.31m/s. Therefore, the results indicate the ineffectiveness of strategy (I) to produce thermal comfort conditions at the occupied area of the skycourt, as the supply air rate is considered small and might not be efficient due to the height of the skycourt.

Results for strategies (II) and (III) indicate better thermal conditions in the skycourts. The air temperature and airspeed were similar to the comfort conditions in the different seasons significantly under strategy (II). Strategy (III) records higher temperature in summer and lower temperature in winter.

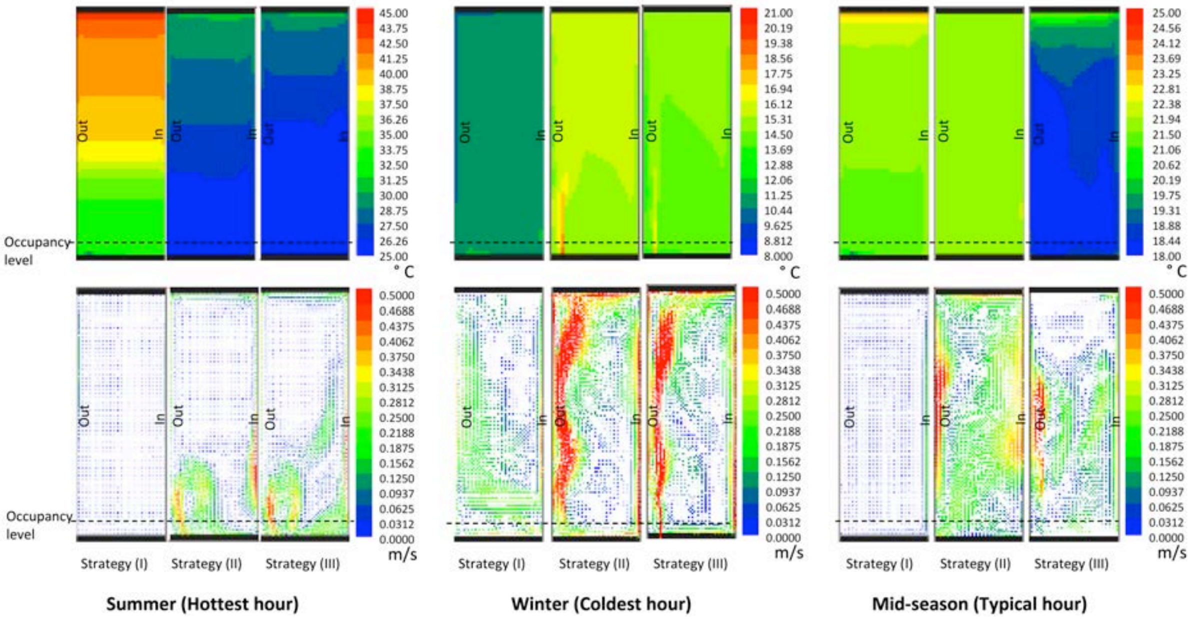



Figure 12. Thermal conditions in skycourt (A) comparison at the hottest hour in summer, the coldest hour in winter and typical hour in mid-season: ventilation strategies (I), (II) and (III).

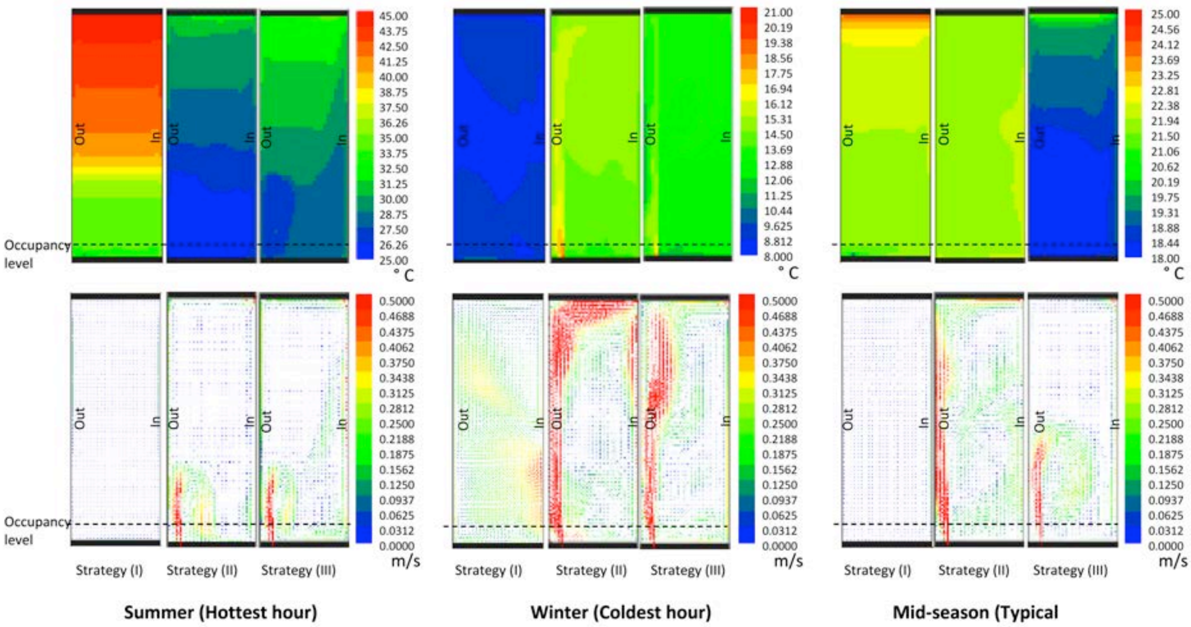



Figure 13. Thermal conditions in skycourt (B) comparison at the hottest hour in summer, the coldest hour in winter and typical hour in mid-season: ventilation strategies (I), (II) and (III).

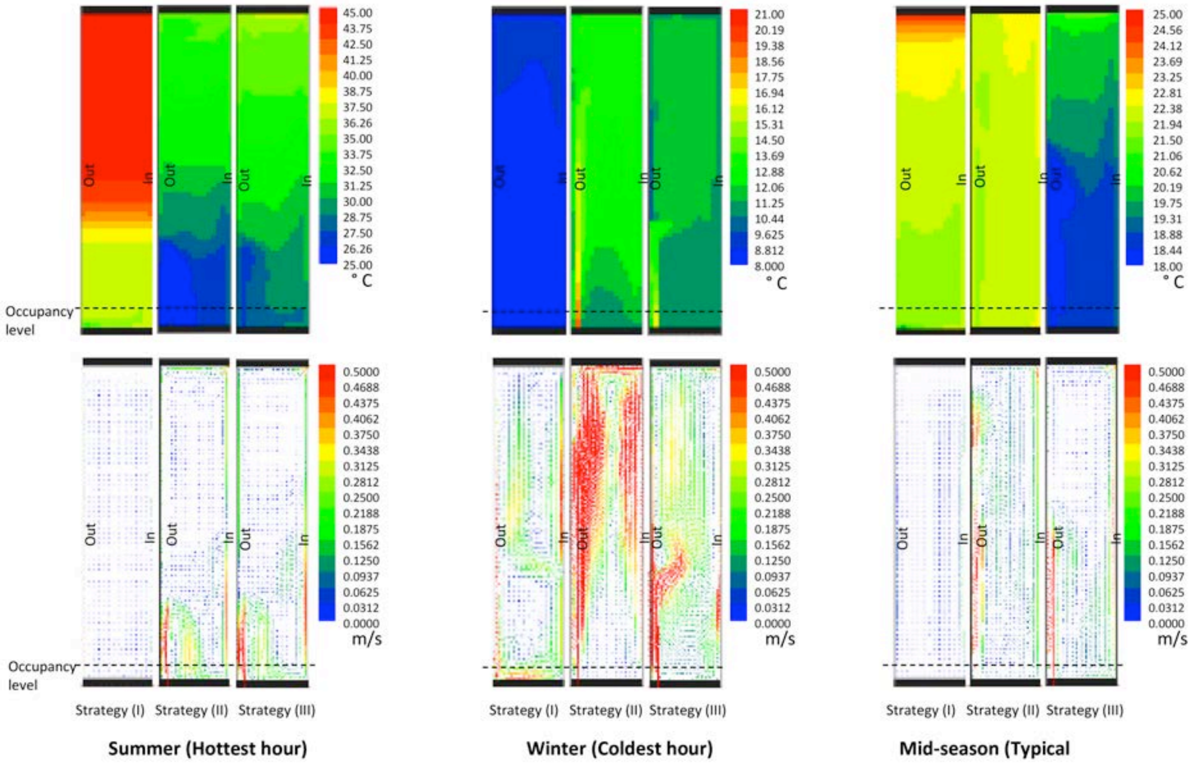



Figure 14. Thermal conditions in skycourt (C) comparison at the hottest hour in summer, the coldest hour in winter and typical hour in mid-season: ventilation strategies (I), (II) and (III).

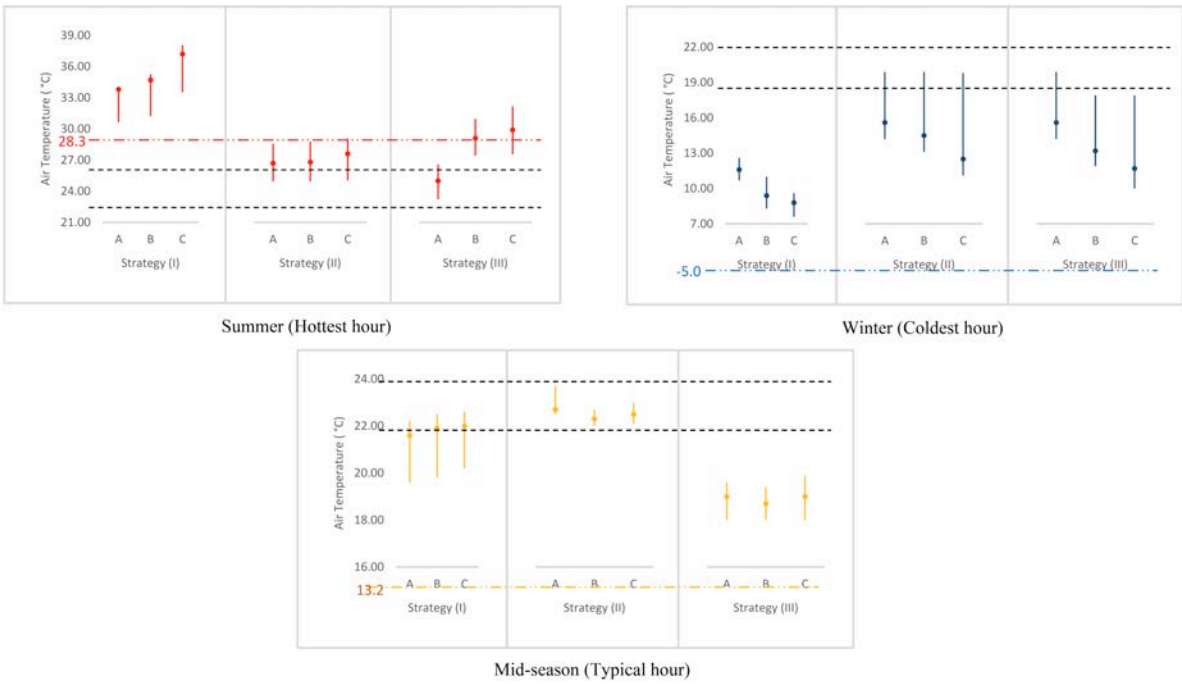



Figure 15. Air temperature comparison at occupancy level in skycourt (A), (B) and (C) (dotted-lines show comfort air temperature ranges, dots show mean air temperature): ventilation strategies (I), (II) and (III).

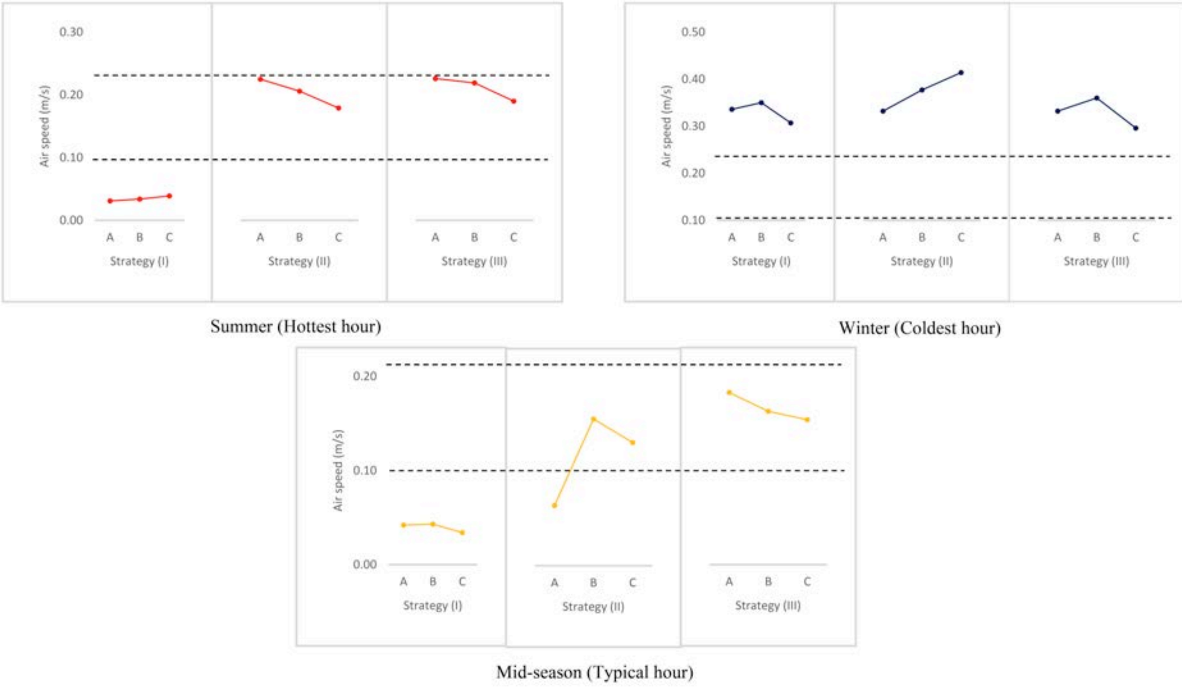



Figure 16. Airspeed comparison at occupancy level in skycourts (A), (B) and (C) (dotted-lines show comfort airspped ranges): ventilation strategies (I), (II) and (III).

Under strategy (II), the thermal conditions for skycourt (A) is about 26.4°C with 0.2m/s average airspeed in the summer hour. In the coldest hour, the air temperature ranges between 14.2°C and 20.0°C. However, airspeed is considered high and reaches up to 0.4m/s. For skycourt (B), the temperature records 26.8°C with 0.2m/s in the hottest hour and fgrom 13.1°C to 20.0°C with 0.38m/s in the coldest hour. In skycourt (C), the hottest hour records 27.6 °C with 0.18m/s and at the coldest hour, the temperature ranges between 11.1°C and 20.0°C with 0.414m/s.

However, when the results obtained from strategy (II) are comparable to those obtained from strategy (I) there is a reduction in air temperature of about 7°C to 9°C degrees in summer case and an increase in air temperature of about 4°C to 5°C degrees in winter. While, correlatining the thermal conditions between strategy (II) and strategy (III) shows that the previous method produces less air temperature range that is closer to thermal comfort levels in summer case. However, the winter comparison shows similar average air temperature in the different skycourt prototypes, yet, it is slightly lower in strategy (II).

The simulation at a normal hour in spring accounts the following results for the skycourt prototypes at the occupied area. Firstly, air temperature ranges between 20°C and 22.5°C with 0.04m/s average airspeed under strategy (I). Secondly, average air temperature under strategy (II) accounts around 22.3°C with 0.15m/s. Strategy (III) produces 19.0°C with 0.16m/s. The results, therefore, indicate the influence of strategy (II) in transitional seasons to provide thermal comfort conditions.

As can be seen from the analysis of data, strategy (II) - the combined exhaust ventilation strategy - indicates significant effectiveness to produce thermal comfort conditions at the occupied area of skycourt prototypes.

Air temperature and average air speed in the skycourts were related to the outdoor air temperature, solar gain, airflow volume rate and air inlet temperature. The thermal comparison between the skycourt prototypes shows that skycourt (A) - the hollowed-out - performs the optimal prototype under the proposed ventilation strategies. It is colder in summer and warmer in winter. This is due to less solar gain as it exposed to external conditions by one sided only, this is followed by skycourt (B), which is exposed to outside weather by two sides and finally, skycourt (C) with three outer sides.

## Conclusion

The paper has suggested that the skycourt, like a ventilated buffer zone in office buildings, has potential to produce significant heating and cooling savings and provides thermal comfort for occupants. Three ventilation modes have been investigated: the first considers the skycourt as an air conditioning space and the second and third consider it as a ventilated space that does not consume energy for heating nor cooling. The annual heating and cooling energy demand is employed to assess the energy performance of the cases. Whereas, the thermal performance is investigated at the occupied area of the skycourt. Three spatial prototypes of skycourt were examined.

The following conclusions can be drawn from the present study:

1) The different spatial prototypes of skycourt when perform as part of combined ventilation strategy in high-rise office buildings can achieve more than 50% heating and cooling reduction for the building. Furthermore, the results indicate the effectiveness of this strategy to produce thermal comfort conditions at the occupied area of the skycourt prototypes.

2) A combined ventilation strategy that depends on the maximum airflow volume rate exhausted from the adjacent offices to the skycourt has a significant effect on cooling the skycourt space and reducing the energy demand compared to the strategy that is based on the air flows with opposite direction.

3) The energy influence of the three skycourt prototypes under the combined-exhaust ventilation strategy shows a variation in the energy savings. Greater external façade areas requires greater cooling demand under the isolated ventilation strategy (air conditioning skycourt), therefore, greater energy reduction when applying the combine-exhaust ventilation strategy. However, less external facade areas provides better thermal performance. Therefore, the hollowed-out skycourt (A) is considered the optimal thermal comfort prototype under the proposed ventilation strategies in the different seasons.

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# *Creating Livable Public Spaces*

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**Abstract**

The city and its public spaces should provide the desired setting for everyday urban life. The development of the city should foster the continuation of daily living for all social classes. Cities have continuously been losing its legacy embodied in its urban spaces and urban life, due to the lack of appreciation of the social part of sustainability in design and decision making. This research is a descriptive research that aims to retrieve the legacy of the city by understanding the logic of place-making, and generating various strategies that help in creating healthy, productive, and enjoyable spaces. First, it defines the types of public spaces; second, it explains the meaning of place-making; then, it analyses some case studies in the western and European countries, and finally, it provides practical strategies that help in creating livable spaces. This paper confirms that creating livable public spaces that suit all users is a critical issue when shaping the future of the sustainable cities.

Keywords: Public spaces, Livable spaces, Livable cities, Place-making.

## Introduction

The Urban design is the art of creating public spaces; it draws together the many strands of place-making, environmental responsibility, social equity and economic viability. It is about creating a vision for an area and the deploying of the skills and resources to realise that vision (Lang 2005).

Public spaces are the common ground where people come as friends, neighbours, and citizens to meet, talk, sit, relax, and read. Places where people share together parks, streets, sidewalks, squares, markets, waterfronts, beaches, museums, gardens, and all primary sites for human action. Public spaces should support activities and provide opportunities for social interaction, cultural, enrichment and recreation. Accordingly, when designing the public spaces, urban designers should study the physical aspects as well as the social aspects to create livable places.

The MIT report highlights that "the relationship of places and their communities is not linear, but cyclical, and mutually influential. Places grow out of the needs and actions of their formational communities, and in turn, shape the way these communities behave and grow." (Places 2017). Accordingly, spaces become places after people act on them and those places are loved and owned by the people. These spaces are serving as self-motivating places to encourage communications and create a stage for public life. Thus, the livable places are spaces that promote human contact and social activities, safe areas, welcoming, accommodating for all users, visually attractive, encourage community involvement, reflect the local culture or history, and have unique or special characters. In addition, public spaces have an essential effect on the human well-being. These spaces are strengthening the social identity and humanising the urban environment by promoting life outside the buildings. They also bring economic benefits by drawing the customers for the nearby businesses, by making an attractive city to live, work and play.

Livable spaces are places that attract all strata and classes (rich and poor, educated and uneducated), suit all ages (children, youth, and elders), and encourage various activities. The livable spaces are affordable to all people, easily accessible and connected to the surrounding neighbourhoods. They are open to all, regardless of ethnic origin, age, or gender. They present a democratic forum for citizens and society. They provide meeting places and foster social ties. Livable spaces shape the cultural identity of an area, and provide a place for local communities.

On the other hand, lifeless public spaces are spaces without activities, and without identity. Each lifeless place is a missed opportunity to challenge and delight or to inspire the people with a passion for the place. These spaces are spaces with Globalized Identity, without soul and character; therefore, they do not tell us a particular story and do not become part of our memory. Lifeless spaces are a missed opportunity to challenge and delight, and to inspire people with a passion for place that they might carry back to their own neighborhoods (Lang 2005). At the lifeless spaces, people who live and work in a given area are left without a place to interact in an informal, pleasant environment, and the people who pass through lose the possibility to experience the unique sense of place (Places 2017).

## The types of public spaces

As cities worldwide grow, the role of parks is changing. Public spaces and parks are no longer seen as beautiful areas for a picnic, but rather as a necessary system within the city's overall fabric. Therefore, livable, sustainable cities must balance density with public space for the health of their inhabitants, their environments, and their prosperity (Silver 2017). The main types of public spaces are:

1- **Open squares**: an open square is a public space commonly found in the heart of a traditional town used for community gatherings. Gardens, sitting areas, children play areas are some elements of the public spaces. Other names are the civic centre; Market square, urban square, square, and plaza. Most town squares are hardscape suitable for open markets, music concert, political rallies, and other events. Squares are usually enclosed by small shops and stores, similar to al Hashemite square in Amman/Jordan (Figure 1). At the square centre, there is often a fountain, monument, or statue.

Figure 1: Al Hashemite square in Amman/Jordan

2- Enclosed or covered space: means inside the building or structure to which the public can access, including retail shops, indoor shopping malls (Figure 2), restaurants, bars, places of entertainment, casinos and billiard halls. Designated smoking rooms are also part of the enclosed spaces. Providing for court games, children's play, and sitting out area.

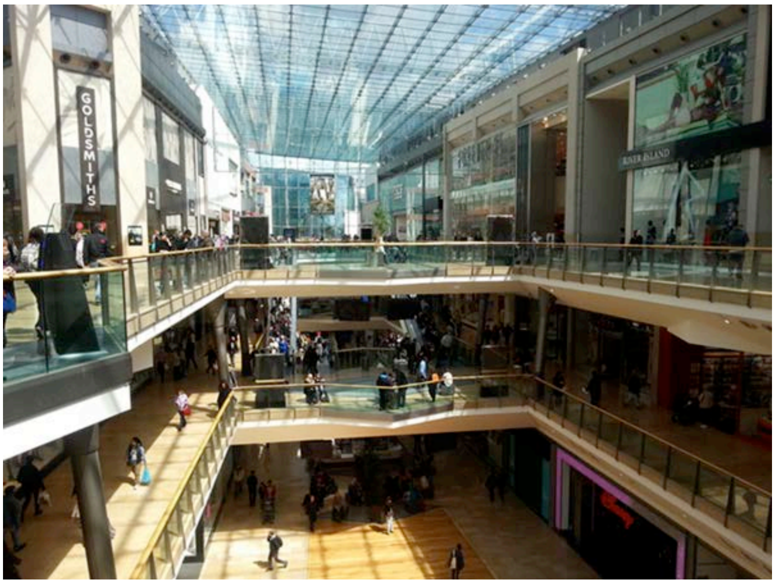

Figure 2: Shopping malls are example for an enclosed space

3- Pockets park, and green spaces: pockets are small areas of open space that accommodate natural surfaces and shaded areas for play and passive recreation that sometimes have seating and playing equipment (Policy 2017) (Figure 3).


Figure 3: Informal pocket parks in Amman/Jordan.

4- District parks are large areas of open spaces that provide a landscape setting with a mixture of natural features accommodating a broad range of activities including outdoor spans facilities and playing fields. These parks include playgrounds, walking paths, decorative landscaping, and unique features such as riding trails (Figure 4).

Figure 4: District parks with playing areas

5- Boulevard and linear open space: it is wide, multi-lane arterial thoroughfare, divided with a median down the centre, and with roadways along each side designed as slow travel and parking lanes and for bicycle and pedestrian usage. They are often characterised by attractive areas which are not completely accessible to the public but contribute to the enjoyment of the space (Policy 2017), such as the Abdali Boulevard in Jordan (Figure 5).


Figure 5: Abdali Boulevard in Amman/Jordan

**The logic of place-making**

To create livable spaces in the city, architect and planners should apply the art of place-making. In place-making, the best experts in the field are the people who live, work, and play in a place. One of the primary principles of the place-making is people attracting people (Community 2017). A management plan that comprehends and develops ways of keeping the public spaces protected and livable should be elaborated by the city council to guarantee that people will come back and revisit the place. The council should manage, maintain, the space to increase its quality and to give the people a feeling of comfort and safety (Harvard 2017).

Place-making is the practice of designing, creating and programming public spaces around the needs and desires of the community of users. The research asserts that the place-making process provides many benefits for community empowerment as it does for creating public spaces themselves (Places 2017). As a result, the connection between people, professionals, and the places they share is strengthening, and space will be converted to a place that a person never wants to leave.

The place-making approach developed in response to the progressive trends of the 19th and 20th centuries when the public spaces were designed by industrialisation, auto-centered planning and urban regeneration projects. The term came into use by the landscape architect, architects, and urban planners in the 1970s to describe the process of creating open spaces that attract people. The landscape often plays an essential role in the design process, supported by other disciplines that involved in designing the built environment. Throughout the 1960s, the top-down planning eliminated the community voices during all design stages; consequently, broke the bond between communities and public places (Places 2017). As a result, writers like Jane Jacobs and William Whyte offered ground breaking ideas about creating cities for people, not just for vehicles and shopping malls. Both of them emphasised essential elements for creating a social life in public spaces (Community 2017; Places 2017). At that time, urban planners were razing finely-grained neighbourhoods and constructing lifeless housing developments and parking lots, surrounded by endless grey ribbons of the expressway. Streets and squares known as places for commerce and social interaction were lost, and the cities, decades later, are still struggling to recover (Places 2017).

Recent research reveals that in the half-century since that movement started, the making of a place has become as necessary as the place itself. Throughout the public participation, residents are shaping public spaces, contacting each other, forging relationships, building social capital and engaging with different people, institutions and organisations. Places in the Making report highlights that the importance of people in establishing the place is a crucial aspect that is always forgotten by experts and planners (Places 2017).

The place-making approach based on a belief that it is not enough to merely plan and elaborate design ideas and elements to revitalise a public space. A public involvement to process that responds to space is one of the most important factors in designing a successful open space. Place-making is how people collectively shape their public realm to maximise their shared value. Furthermore, place-making involves the planning, design, management and programming of public spaces. It facilitates creative patterns of activities and connections (cultural, economic, social, and ecological) that define a place and support ongoing evolution. Consequently, the success of a particular public space is not solely in the hands of the designers; it also relies on people adopting, using and managing the space.

## Case studies

This section discusses two case studies one of them is an unsuccessful open space that can be considered as a lifeless space in Los Angeles, and the other is a successful open space that can be recognised as a livable space in London. The analyses of these case studies highlight the major characteristics that define the public spaces.

### 1 Unsuccessful example: Pershing Square, Los Angeles, California, USA.

Pershing Square -Figure 6- has a long history dating back to 1866. It has gone through many redesigns by various architects, landscape architects and gardeners: Fred Eaton's (in the 1890s), John Parkinson's (1911), Frank Shearer's (1928), Stiles Clements' (1950), and finally, Ricardo Legoretta and Laurie Olinin in 1994 (Lang 2005).

Figure 6: Pershing Square, Los Angeles, California, USA.

In 1994, the city decided to reclaim the park from young drug users by redeveloping the site with $US14.5 million. The implemented design by Ricardo Legoretta and Laurie Olin aims to create a *zócalo*, the heart of many Mexican cities. The designers used an orange grove at the centre of the square as a reminder of the importance of orange cultivation in Los Angeles County (Lang 2005). The square contains a sculpted court with a fountain, a 'Mayan' style amphitheatre, seats in which representations of Los Angeles embedded and traditional arts represented (Hinkle 1999).

Despite these various components and the enormous amount of money that was spent on design and construction, the park is still a lifeless place. Jon Lang (2005) states that it is hard to see the connection among the design elements; moreover, the location of the underground garage is a continuing concern; constructing a plaza above the surrounding ground level weakens the accessibility to the park. Furthermore, the neighbouring services do not encourage people to be the square users. Only poor and homeless are there, as the benches in Pershing Square provide a place for them to gather and sleep.

## 2 Successful example: Trafalgar Square in London, England.

Since the 13th century, London's Trafalgar Square (Figure 7) has been used for gatherings and political demonstrations, and campaigns against climate change. The streets surrounding the square were dominated by vehicles for decades. In the mid of the 1990s, the town added new pedestrian-only areas to its centre to convert it into a pedestrian-friendly zone (McCarren 1999).

The square becomes a hub of tourism surrounded by the major attractions for people, and the people themselves become a major attraction for each other. In addition to the public benches, the edge of the central fountain is used for seating. The redesigned square is regarded as great artistic successes that enhance the quality of the public realm. This transformation changed the behaviour of both drivers and pedestrians thus enhance the logic of livable spaces.

Figure 7: Trafalgar Square in London, England

## Conclusion

This research describes the meaning of public spaces and highlights the main strategies that should be implemented to convert the lifeless spaces into livable ones. The main strategy is that people attract people, which means that the architect should design spaces that encourage people to come and initiate various activities all around the years, these attractive spaces should be safe, accessible, and affordable for all. The mentioned case studies of the Pershing Square in Los Angeles and the Trafalgar Square in London are just examples to presents the way public space can transform the lives of residents towards negative or positive ends.

In the 21st century, under the power of capitalism and where urbanisation is extremely increased, it becomes difficult to focus on the human needs and create spaces with Soul. Cities are struggling to create livable spaces that fulfil the locals' needs and respect their desires, spaces that inspired people, suits their needs, and that they simply find stunning.

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# *Electrochemical Treatment of Oily Wastewater using Three Dimensional Steel Wire Electrodes*

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**Abstract**
Electrochemical technologies have been successfully applied for the removal of heavy metals, dyes, organics and oils from wastewater. In the present study, wastewater containing cutting oils was treated by applying electric field using stainless steel wire bed electrodes. The steel wires were 0.3 mm in diameter and 1 cm in length. In addition, three different polyurethane materials have been tested for the separation of steel wire electrodes in the coalescer cell. The experiments were performed under constant potential and the applied voltages were 5, 10 and 15 V. As the potential difference between the electrodes increases, the current passing through electrocoalescer cell increases. This improves electrolysis reaction rates at the stainless steel wire electrode surfaces. Then the transport of oil droplets to the water surface by gas bubbles is accelerated. In the experiments, the highest removal efficiency was 85% and obtained at 15 V. The experiments were also performed by varying the steel wire bed lengths. The studied bed lengths were 9 cm, 18 cm and 27 cm. Even though, higher oil yields were obtained at 27 cm bed length, similar oil yields were also obtained at 18 cm bed length, especially after 60 min, with less energy consumption. Therefore, the optimum electrode bed length was concluded to be 18 cm. The results also show that the electrical conductivity and porosity of the intermediate material are important parameters in the evaluation of oil removal efficiency.

Keywords: Electrocoalescer, steel wire electrodes, oily wastewater, electrochemical treatment

## Introduction

Electrochemical technologies have made great progress in wastewater treatment recent years due to its high efficiency, environmental friendly and versatility (Chen, 2004; Zhang et al., 2012). The major electrochemical methods for the treatment of wastewater are electrocoagulation, electroflotation and electrooxidation. There are many successful applications of electrocoagulation process for the removal of dyes (Merzouk et al., 2009), metals (Hu et al., 2014), oils (Genc & Bakirci, 2015), and organics (Sakka et al., 2015) from wastewaters. In addition, electric field assisted coalescence is found to be one of the most efficient methods for the dehumidification of oil emulsions (Luo et al., 2016).

Coalescers are commonly used for the separation of unstable emulsions and are basically improved filtration processes using a medium which accelerate the coalescence of dispersed droplets (Sokolovic et al., 2010). In order to improve oil removal efficiency, polymeric materials, woven and non-woven fabrics, sponges and foams, carbon derived materials, metals, various particles and powders were tested as bed mediums in coalescers (Hu et al., 2017). During the treatment of oily wastewater, oil droplets move towards the bed medium, more and more oil droplets are accumulated on the surface with time. Then larger droplets form as a results of coalescing and these droplets can be separated easily by gravity settlers. The separation capacity can be improved by applying electric field (Kakhki et al., 2016). Dispersed oil droplets are reoriented in emulsion as a result of changes in the distribution of droplets surface charges in the presence of electric field. Therefore, emulsion becomes unstabilized and oil droplets coalescences are promoted.

## Wastewater Characteristic

The synthetic oily wastewaters were produced from bor oil (Petrol Ofisi). It is one of the commonly used oils in metal cutting industry in Turkey. It is paraffin based mineral oil and contains surfactants and other chemicals such as biocides, lubricating agents, pressure additives, anti-foam agents and corrosion inhibitors. The synthetic wastewater samples which were used as in the experiments were prepared by adding bor oil to tap water (2%). Then the mixture was stirred mechanically (Heidolph R2R 2020) at a stirring speed of 2000 rpm for 30 minutes. The initial pH, conductivity, turbidity and COD of the wastewaters were measured before the experiments.
The characteristics of the synthetic wastewater used in the study were presented in Table 1.

Table 1: The characteristics of synthetic wastewaters

| Parameters | Value |
|---|---|
| pH | 7-8,5 |
| Conductivity (μS/cm) | 350-500 |
| Color | White |
| Turbidity (NTU) | 10500-13500 |
| COD (mg/l) | 50000-60000 |
| Density (g/cm$^3$) | 0.983 |

## Experimental Set-up

The electrocoalescer cell was made of plexiglass and its dimension were 35 cm in length, 17 cm in width and 9.5 cm (Figure 1). The electrocoalescer cell was horizontally divided into two sections in order to form electrode beds. The electrode beds were packed by stainless steel wires which were in 1cm length and the top bed was the anode electrode. The electrode beds were separated by placing a porous polymer material which was made of polyurethane in the middle. The potential gradients at anode and cathode electrodes were supplied by using a DC power supply (18 V, 10 A) and water flow rate was adjusted by a peristaltic pump (Masterflex). In all experiments, the electrodes were only used once and they were submerged into water.

The electrochemical experiments were performed at batch operating mode and were carried out by recirculating the effluent to the inlet. At the start of each experiment, the electrocoalescer cell was first filled by newly prepared wastewater and then the inlet and effluent flow rates were adjusted by keeping the water height in the cell at a constant level. After the adjustment of water flow rates, the potential difference was applied to the electrodes. In this study, the oil removal efficiencies were evaluated in terms of turbidity because a strong linear correlation was observed in between turbidity and oil percentage of wastewater. The evaluated regression coefficient was very close to 1 ($R^2$= 0.9976). 10 mL of water samples were taken from the effluent at every 5 min in order to evaluate turbidity variations with time. The turbidities of samples were measured by using Aqualytic AL450T-IR after dilution of the water samples 20 times. Three samples were prepared for the same operating conditions and the arithmetic average of these readings was used in the evaluation of removal efficiency.

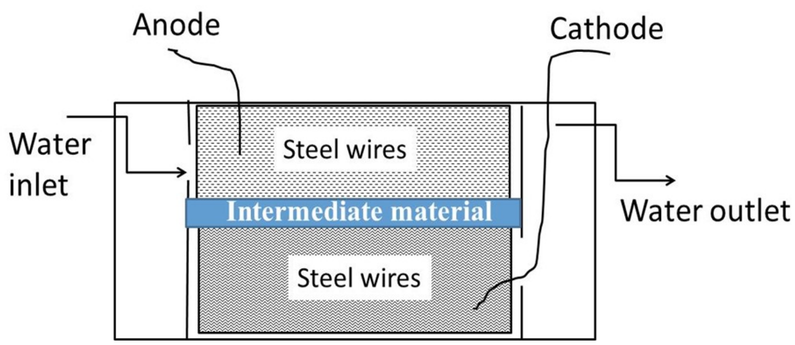


Figure 1: Electrocoalescer cell

## The Effects of Operating Parameters on Removal Efficiency

### a) The Potential Difference Applied to the Electrodes

The potential difference of 5 V, 10 V and 15 V was applied to the stainless steel wire bed anode and cathode electrodes in the electrocoalescer experiments. The evaluated turbidity removal efficiencies were shown in Figure 2. Also, when the potential difference is not applied on the electrodes, the turbidity removal percentages were presented in the same graph. These results clearly show that the oil droplets are not adsorbed on the steel wires or the intermediate material, which was a material made of polyurethane. In addition, as the potential difference applied to the electrodes is increased, an increase in removal efficiency is observed. When 15 V potential difference was created between the electrodes, the highest oil removal efficiency was around 85%. On the other hand, the attained removal efficiency was stayed around 30% when the applied potential difference was 5 V. When the potential difference between the electrodes was 10 V, 85% removal efficiency was only achieved after 180 minutes. When the applied potential difference is increased, the rate of gas bubbles formed on the electrode surfaces is also increasing as a result of electrolysis of water. The oil droplets are carried to the surface by gas bubbles. It has also been observed that the oil droplets moved toward the steel wire electrodes located in the anode zone and attached on the surface. Then larger oil droplets were generated on the steel wires as a result of coalescence of droplets.

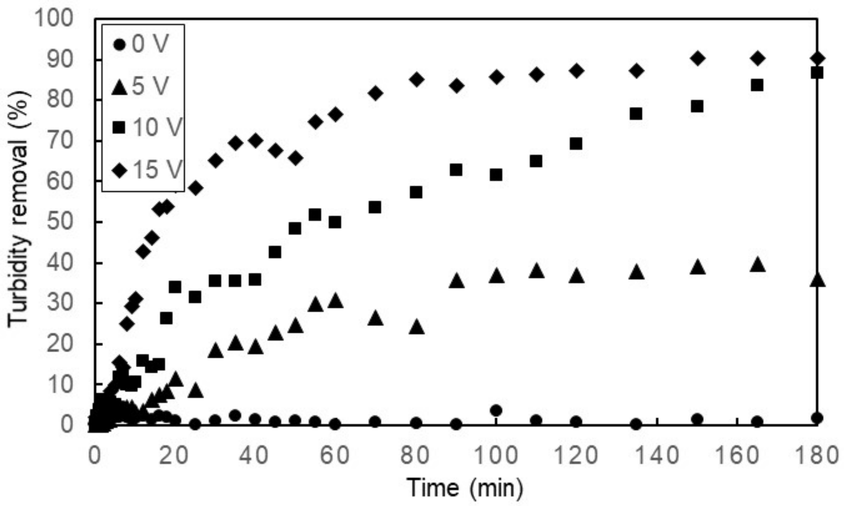


Figure 2: Turbidity removals depending on the potential difference applied to the electrodes

**b) The Bed Length of Stainless Steel Wire Electrodes**

In this study, the bed length of stainless steel wires (L) was changed by keeping the bed height and porosity constant. 15 V potential difference was applied during the experiments. Figure 3 shows the variations in turbidity removal efficiency with time for three different bed lengths (L= 9 cm, 18 cm and 27 cm). The currents passing through the cells were also depicted in the same figure. At the beginning, the highest removal efficiencies were attained at L = 27 cm, while the oil yields at L = 18 cm and L = 27 cm were almost coincide after 60 min.

As the bed length of stainless steel wires increases, the current passing through the medium should also increase under constant applied potential difference to the electrodes. The highest currents passing through the cell was at L= 27 cm. Since the energy consumed is equal to the potential difference multiplied by the current, the energy consumption was the highest at L= 27 cm. For this reason, the optimum bed length can only be obtained by evaluating both yield and energy consumption.

**c) Properties of Intermediate Materials**

Three polyurethane materials (A, B, and C) were located between the anode and cathode stainless steel wire electrode beds in the electrocoalescer experiments in order to analyze the effect of intermediate material on removal efficiency. The material A and B were in the form of fabric whereas the material C was in the form of sponge. Moreover, their porosities were different: the porosity of material A was the highest while the porosity of material C was the lowest. The removal efficiencies and corresponding currents passing through the electrocoalescer cell were shown in Figure 4. The use of material A results in higher removal efficiencies and higher currents. According Faraday law, the formation of gases at the electrodes is the highest for the material A. The results show that the electrical conductivity of the material C is very low and, therefore, electrolysis reaction rates at the steel wire electrodes are very low. This causes almost no oil removal, i.e., the turbidity removal efficiencies were almost stayed constant around 8%.

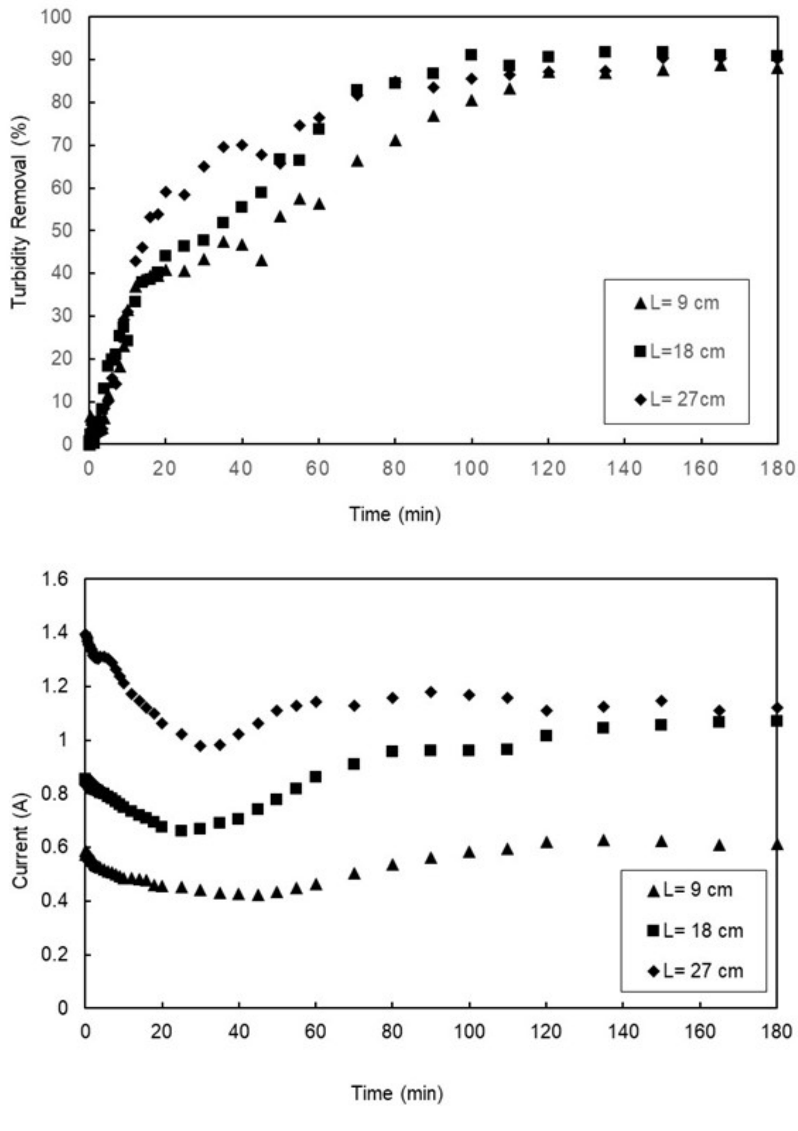


Figure 3: Removal efficiencies and current variations depending on bed length

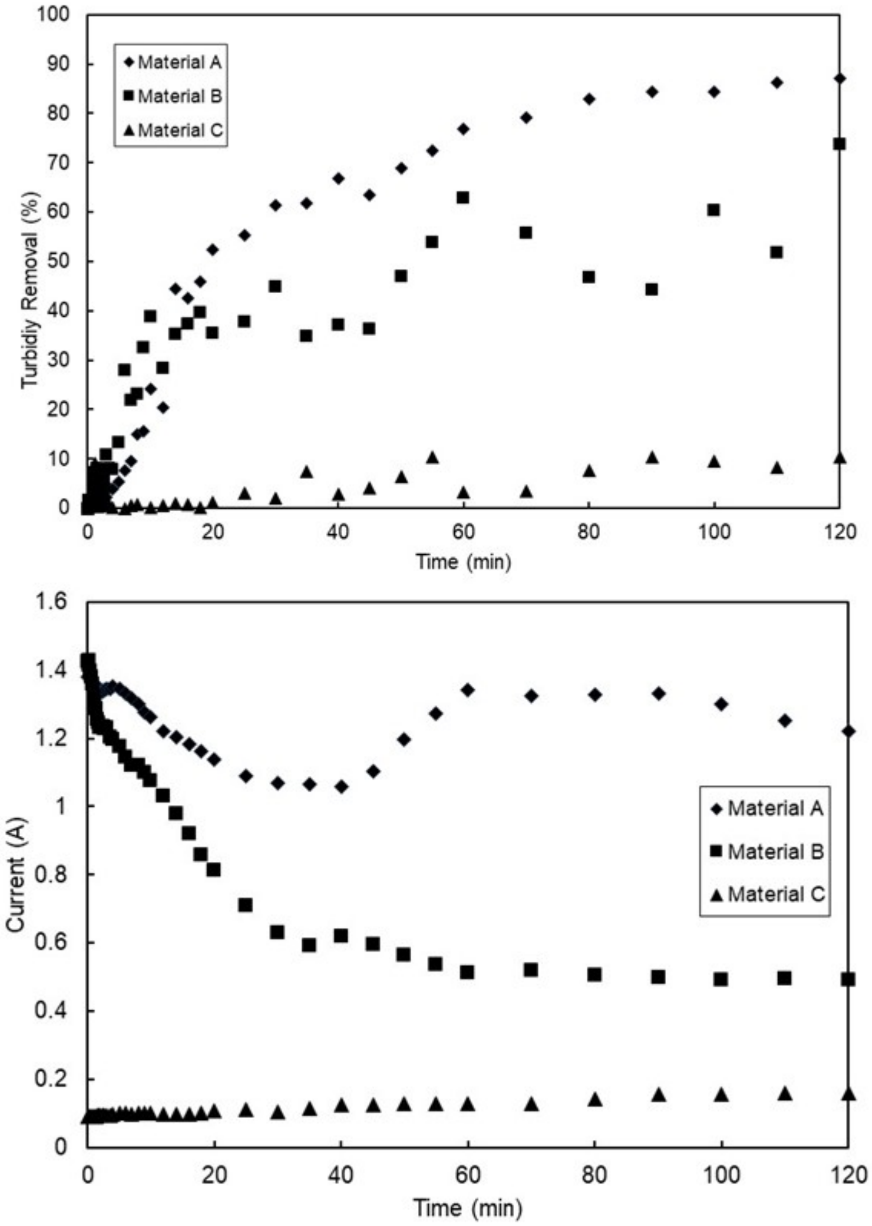


Figure 4: Removal efficiencies and current variations depending on intermediate material

## Conclusions

Based on the experiments performed by using oily wastewaters, the following conclusions are drawn:

- 85% oil removal efficiency was obtained by applying 15 V potential difference to the stainless steel wire bed electrodes.
- The optimum bed length was found to 18 cm depending on the evaluations of removal efficiency and power consumption.
- The removal efficiency was strongly affected by the porosity and conductivity of polyurethane materials used in the separation of the stainless steel wire electrode beds.

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# *Eco-Innovations: Kick-Starting the Circular Economy*

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**Abstract:**
The generation of goods and services depends on the use of natural resources and generates discards throughout the productive process. The current economic model based on overproduction and overconsumption caused global warming and the growing depletion of natural resources. Deteriorating living conditions on the planet made discussions on sustainability and environment become an urgent issue. Among other actions from different agents, this context requires companies to adopt radical innovative ways of producing. Reviewing industrial practices is now a crucial element to disclose the areas where the innovative efforts must focus. Circular economy emerges as an alternative to the current linear approach, in which resources are used and discarded as if the planet had unlimited capacity to provide new sources of resources and absorb pollution. It is a way of (re)organising economic activities through a "resource-production-resource-regeneration" feedback vector. The concept may lead to a new circular production system where there is minimal waste, since all discards would potentially serve as input for a new productive cycle. The challenge of circular economy is to develop an innovative approach to overcome the current trade-off between our model of incessant economic growth and the environmental crisis. In this context, could eco-innovations contribute to build this approach? How could the implementation of eco-innovative practices by firms change the current linear approach? The present study aims to shed light to this discussion through a literature review analysing the generation of eco-innovations to stimulate the circular economy.

Keywords: eco-innovation; circular economy; sustainability; environment; ecological crisis.

## 1. Introduction

Human activities have vastly caused negative impacts on the environment on all scales. In the last decades, disturbing evidence has shown that both developing and developed industrial countries are critically deteriorating the ecological system that underpins all life on Earth (WWF, 2016; UNEP 2010). The current mode of production and consumption has generated an ecological crisis with devastating consequences to the planet and human societies, such as global warming, depletion of natural resources and declining biodiversity (Issberner & Léna, 2016; Latouche, 2012; Léna, 2012; UNEP, 2011, 2012). As the human population is drastically increasing, the circumstances are becoming even more critical and challenging. The UN Department of Economic and Social Affairs has just published its "World Population Prospects: The 2017 Revision" in June, estimating a population growth to 8.6 billion in 2030 and to 9.8 billion in 2050.

Coupled with the world population growth, more three billion middle-class consumers are expected to enter the global market by 2030 (World Economic Forum, 2014). This rise will generate an unparalleled demand for goods and services and for a finite supply of natural resources if the population keeps the same consumption patterns. The UN Sustainable Developmental Goals anticipate that the equivalent of almost three planets will be required to sustain the current lifestyles of the linear 'take-make-dispose' economy. According to Léna (2012), while the limits for the physical expansion of the economic system and the degradation generated were not noticeable, however there were crises, the belief that the system would provide what is needed for the growing consumption remained unshaken. This notion also hides an assumption that the planet has an endless capacity of recovering from its natural losses (Motta, Prado & Issberner, 2015). However, obvious signs of depletion of a large amount of natural resources, which may destabilise the operation of the current production system, started to raise distrust and suspicion on the current model (Wagner, Sullivan, & Sznopek, 2002). Despite the difficult scenario, the enthusiasm for changes is not commonplace, a good perspective is the Paris Agreement on climate change with its promises of radical transformation in technologies, investments and modes of consumption.

In the meantime, several studies have been questioning the current predominantly linear economic system (Andersen, 2007; Bonciu 2014; Greyson 2007; Lieder & Rachid 2016; Preston, 2012) based on extraction-production-consumption-discard/waste. This process prioritises economic objectives, with little or no regard for the environmental or social impacts generated at each stage. The natural resources depletion – but also its impacts in the prices volatility across the global economy – shed light to the need for a new economic model. In this context, circular economy has strengthened, as a concept but also as a practice. In search for improving their resources performance, many businesses tried to reuse products or their components and recover the material, energy or inputs used in their production processes (World Economic Forum, 2014). In doing so, they tried to change to an industrial model that decouples revenues from material input. In this sense, a circular economy is understood as an industrial system that is restorative or regenerative by intention and design (World Economic Forum, 2014). It is a proposal whose basic concepts were presented by Boulding (1966) and received theoretical contributions of industrial ecology. The circular economy aims to maximise the sustainable use of natural resources seeking to minimise waste and organise economic activities considering a continuous process of refeeding (resource-production-regenerative resources). The concept may lead to a new production system where there is minimal waste, since all discards would potentially serve as input for a new productive cycle.

This new production system needs an innovative approach. However, technological innovations cannot always address ecological problems. As stated by Veiga and Issberner (2010, p. 114), “the innovations, particularly the technological ones, are part of the solution. But they have also been part of the ecological problem”, as innovation has been oriented to competiveness achievement, not towards environmental issues for a long time (Prado & Issberner, 2016). In the last decade, though, private sector has been required to invest in technologies that can improve aspects such as energy and water use, reduction of emissions, management of natural resources and waste, among others (Freeman, Harrison, Wicks, Parmar, & de Colle, 2010; Zollo, Cennamo, & Neumann, 2013). This investment allows firms to reduce costs and enter into new markets for ecological products and services. On the other hand, firms have increased their commitment level towards environmental sustainability as a way to contribute to their short- and long-term value. (MIT, 2011; McKinsey, 2011). In doing so, these firms have been developing eco-innovations - innovations aiming to minimise the negative impacts on the environment and to reduce the use of natural resources.

It is necessary to understand the process of generation and adoption of eco-innovations for a sustainable life on the planet in a broader perspective. It is a crucial condition to face the ecological crisis. Reviewing industrial practices becomes an essential element to reveal the areas where eco-innovative effort should focus. The challenge of circular economy is then to develop an innovative approach to overcome the current trade-off between our model of economic development and the environmental crisis. In this context, could eco-innovations contribute to build this approach? How could the implementation of eco-innovative practices by firms change the current linear approach? The present study aims to shed light to this discussion through a literature review analysing the generation of eco-innovations to stimulate the circular economy.

## 2. Circular economy

In recent years the concept of circular economy has received increasing attention worldwide, but its origins are far from the last century. It has originated from various schools of thought and theories that challenge the prevailing economic system based on overconsumption leading to the finiteness of natural resources (Rizos, Tuokko, & Behrens, 2017). The ideals and foundations underlying circular economy had already been put forward, but its first formal use as a concept was made by Pearce and Turner (1990).

Various disciplines, authors and reports collaborated and influenced the construction of the circular economy as a concept. The industrial ecology brings the notion that the natural ecosystem and man-made industrial system operate in a similar way and are characterised by flows of materials, energy and information (Erkman, 1997; Ehrenfeld, 2007; Garner & Keoleian, 1995; Rizos et al., 2017). The cradle-to-cradle design demonstrates the need to maintain and even enhance the value, quality and productivity of material resources in order to have a net positive environmental effect

(Braungart, McDonough & Bollinger, 2006; Ankrah, Manu & Booth, 2015; Mcdonough & Braungart, 2002; Rizos et al., 2017). The blue economy introduces the idea that innovation is a fundamental lever in guiding businesses towards a transformation of practices influenced by the design and functions of natural ecosystems (Pauli, 2010; Rizos et al., 2017). Besides, there are also the 'limits to growth' proposed by the Club of Rome in the 1970s; the 'spaceship earth' metaphor presented by Barbara Ward and Kenneth Boulding also in the 1970s; and the steady state proposal by the eco-economist Herman Daly at the end of the 1970s.

Aiming to maximise resource efficiency, the circular economy represents an alternative to the current linear 'take-make-use-dispose economic' model. The central theme of the new concept is the valuation of materials within a closed-looped system, which involves other subjects such as: eco-innovation, eco-efficiency, eco-design, cleaner production, life cycle management, reverse logistics, and cleaner energy among others.

The concept of circular economy organises economic activities through a feedback vector (resource-production-regeneration of resources) and seeks to maximise the sustainable use of natural resources, eliminating waste. It can be understood as an alternative to the current and predominant system, where resources are used for a purpose and then discarded (linear economy). From a circular economy perspective, there is 'virtually' no concept of waste, as everything would be used as an input for a new productive cycle. This view is inspired by biological cycles, emphasising the importance of optimising the use of natural resources in a system over time (Di Maio & Rem 2015; Ellen Macarthur Foundation, 2013a and b; World Economic Forum, 2014).

Due to different subjects it addresses, the circular economy is a multidisciplinary field with the purpose of fostering a shift towards a more sustainable society. It relies on three fundamental principles: (1) preserving and enhancing natural capital by controlling finite stocks and balancing renewable resource flows; (2) optimising resource yields by circulating products, components, and materials at the highest utility and value at all times within technical and biological cycles; and (3) fostering system effectiveness by revealing and designing out negative externalities (Ellen Macarthur Foundation, 2013a).

According to Rizos et al. (2017), the main processes of a circular economy involve: 1) use of less primary resources throughout recycling, efficient use of resources and utilisation of renewable energy sources; 2) maintenance of the highest value of materials and products throughout product life extension and refurbishment, remanufacturing and re-use of products and components; 3) change of utilisation patterns throughout product as service, sharing models and shift in consumption patterns.

The shift toward a circular economy will require radical changes in the current mode of production and consumption, so that both producers and consumers as well as all stakeholders in the value chain will have a significant role to play (Mendoza, Sharmina, Gallego‐Schmid, Heyes & Azapagic, 2017). Effective implementation requires a systemic change involving innovative transformational technologies such as non-technological innovations. Together with the application of circular economy concepts, they can radically reshape the process across the life cycle of products and drive fundamental changes across entire value chains that are not restricted to specific sectors or materials (Bicket et al., 2014; Acsinte & Verbeek, 2015; Accenture, 2014; Rizos et al., 2017; Ghisellini, Cialani & Ulgiati, 2016; Mendoza et al., 2017; Ellen MacArthur Foundation, 2013a).

## 3. Eco-innovative Approach

Environmental impacts and biodiversity losses caused by the traditional linear production model have gained visibility in economic and political discussions at a global level. In this context, the role played by innovation and technology are questioned as they have been driven towards competitiveness with little or no regard to the negative effects on the environment. For many years, innovation has been oriented to economic growth, productivity improvements and add value to products or services. However, the ecological crisis demands innovations, which are part of the solution, not of the problem. An eco-innovative approach emerges as a response to the need of changing current practices of 'business as usual'. Compared to traditional innovation, eco-innovation highlights environmental aspects, alongside economic aspects.

Fussler and James (1996) were possibly pioneers in the proposal of ecological innovation as a concept in Driving *Eco-Innovation*, a book that designates eco-innovations as "new products and processes, which provide customer and business value but significantly decrease environmental impact." Following the same idea, many authors have widened the scope of investigation, providing alternative definitions and posing new queries. Eco-innovation has a distinct characteristic compared to Schumpeterian terms[1], as it emphasises the reduction of environmental burdens (Prado & Issberner, 2016). In this sense, Kemp and Pearson (2008) proposed a definition for eco-innovation in an EU funded research project called "Measuring Eco-Innovation" (MEI)[2]. Based on the Oslo Manual (2005)[3], the authors describe eco-innovations as:

> "the production, assimilation or exploitation of a product, production process, service or management or business method that is new to the organization (developing or adopting it) and which results, throughout its life cycle, in reductions in environmental risks, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives " (Kemp & Pearson, 2008, p. 7).

Besides environmental gains, Kemp and Pearson (2008) highlight that an environmental improvement achievement is not sufficient. A satisfactory outcome is the one that considers the whole product lifecycle and the supply chain in the analysis,

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[1] Schumpeter, J. A. (1934, 1980). The theory of economic development. Oxford University Press: London.

[2] MEI is a project for DG Research of the European Commission, carried out in collaboration with Eurostat, the European Environment Agency (EEA) and the Joint Research Centre (JRC) of the European Commission. It offers a conceptual clarification of eco-innovation (developing a typology) and discusses possible indicators, leading to proposals for eco-innovation measurement.

[3] The Oslo Manual (OECD 2005) defines innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practice" (where implementation means realisation for use).

including all the stages from raw material extraction to the product final destination (Hellström, 2007). The life cycle analysis provides a wide perspective in production process, showing that a firm considered environmental friendly, due to a good performance at a certain point in the sequence, ends up showing a negligible result if the whole life cycle is considered in the analysis (Kemp & Pearson, 2008). Adding to environmental impacts reduction, some more recent definitions of eco-innovations have included the reduction of the use of natural resources and the discharge of unsafe substances throughout the whole life cycle (Eco-innovation Observatory, 2012).

These definitions help to expand the more usual focus on the end of life to the whole life cycle bringing up concepts such as sharing, leasing and remanufacturing to generate possibilities of new business models. Like other types of innovations though, eco-innovations may also happen when different materials are combined; along production processes; when new products are created or when new attributes are proposed to an existing product or service. They can also occur with the discovery of new raw materials, or when new markets or market niches are created as well as with the extension of the lifetime of a product (Motta et al., 2015). Despite the changes in definitions, it is important to bear in mind that the motivations for the development and adoption of these category of innovations may not be necessarily environmental. It is rather common that they are good for the business, having the environmental benefits as a kind of positive aftermath.

The Paris Agreement are expected to promote the development of this type of innovation. At least, that is what the sustainable development goals (SDG), especially Goal 12 - Ensure sustainable consumption and production patterns - promises to tackle. Additionally, digitisation, artificial intelligence, robotisation and so on, opened up some promising technological avenues for eco-innovation to progress.

## 4. Eco-innovation as a means to kick-start Circular Economy

Even in a positive scenario where political and economic forces support transitioning to circular economy, there remains the challenge of building a knowledge base, capable of promoting the necessary eco-innovations. What we have today is a knowledge base for innovation focused on an outmoded model, which means that we will need to create new knowledge and build bridges to connect already developed knowledge to the new requirements of the circular economy. The European Union has already made some progress towards the circular economy. New technologies, design concepts, services, and innovative forms of co-operation are being developed for this purpose. But too many gaps still remain to be bridged.

The transition to the circular economy depends on catalysing investments and innovations, giving rise to more eco-efficient modes of production. In fact, a fully-fledged circular economy will require radical and systemic eco-innovations to transform linear patterns of production and consumption. Such patterns have evolved over the past two centuries, creating regimes of overuse and waste of natural resources. Multiple approaches apply to reducing the use of resources in the economy, and increase resource efficiency and circularity, in the circular economy.

According to Eco-Innovation Observatory (2016), circular economy involves eco-innovations from two very different fields, which can be termed 'hardware' and 'software' of circular economy. In this model, technologies and technical infrastructures that would turn waste into resources again – hardware – and skills, expertise, and business models, that would turn these transformation processes into business opportunities – software (Eco-Innovation Observatory, 2014).

The 3 R's approach is most widely known: reduce, reuse, and recycle (Wu, Shi, Xia & Zhu, 2014; Yang, Zu & Xu, 2014). The 3 R's weakness lies on the fact that it focusses mainly on waste management; taking into account the fact that the waste has already been generated, new concepts have become necessary, to attain economic requirements. In this sense, the 6 R's approach is more adequate to meet the principles of circular economy. The 6 R's activities are: waste prevention (Reduce); sharing/leasing (Reuse); turn waste in new materials (Recycle), turn discharged products into new materials or products (Recover), turn materials recovered from the previous life-cycle in new materials (Redesign), turn already used products in new products restoring then to the original state (Remanufacture) (Jawahir & Bradley, 2016). Those activities are new for the industry, they have to be identified, deciphered, specified, designed, tested etc., until ready for running in a production process. All these steps are nothing else than a process of innovation. This is a challenge for the transition to a resource-efficient circular economy like the schumpeterian process of 'creative destruction'. To achieve both the 3 R's and the 6 R's, a major effort in eco-innovation will be paramount.

Regulatory and consumer pressures play a role in the transition to a circular economy. The transition involves changes in institutions, meaning, social, ethical, and environmental values, which do not come spontaneously. Those changes will have an impact on traditional institutions that support traditional business, but will also generate opportunities to be captured through innovations, been more precise, through eco-innovations. Those pressures have the power to trigger the process, persuading firms to change their way of producing, packaging, delivering products, and discarding waste. Appropriate policy instruments may contribute to the spread of innovation culture, helping stakeholders to meet the multiple objectives of circular economy, related to environmental, economic, societal/managerial, and topological (Winans, Kendal & Deng, 2016). Such factors reinforce the need of eco-innovation development and diffusion (Horbach, Rammer, & Rennings 2012; Kemp, 2008; Motta, 2013; Jaffe & Palmer, 1997).

The instruments to promote eco-innovations for the circular economy are in the beginning of its existence. If favourable environment opened up for circular economy, the measures adopted will be: the development of new practices based on sharing, reusing, repairing, as well as remanufacturing. In addition, at national level a number of measures could be taken, such as:

• Regulatory instruments, such as regulations on recycling, producer responsibilities, eco-design, mandatory targets, codes, standards, and certification for products; Economic instruments, including fiscal and financial incentives, direct funding, and public procurement;
• Research, development and deployment support measures, such as grants for R&D and piloting activities, R&D infrastructure, innovation vouchers, supporting innovation incubation, and R&D personnel;

• Information, education and networking support measures, for example, advising, training, offering direct support in activities to SMEs, customers, technology adopters, promotion of networking, providing information, and supporting public private partnerships, and
• Voluntary measures, such as performance labels and guarantees for products and services, or voluntary agreements and commitments.

Certainly the transition to a circular economy will not be easy. There is a myriad of obstacles intervening such as falling commodity prices, insufficient investment, lack of skills and expertise, limited acceptance of alternative models of consumption and business, and lack of political coherence. These have to be addressed in a comprehensive way by favourable framework conditions (e.g. embracing regulation, institutional settings, targets, instruments, curricula, infrastructures, networks, key actors, etc.).

## 5. Conclusions

This paper starts addressing the circular economy in order to contribute to the advancement and improvement of its theoretical approach. A brief literature review shows that innovation play a key role in the transition to circular economy. Our contribution in this paper is to reinforce the role of innovation, but emphasising its environmental aspect, which means highlighting the eco-innovations.

Circular economy brings a powerful logic to reshape the design of products, production processes, and disposal, in order to meet the requirements of reducing natural resources use, greenhouse gases emission, and environmental pollution. Mainly focusing in three goals: reduction, reuse and recycle, this approach has been influencing the innovation policy of many countries.

It is expected that this paper can provide sufficient elements for understanding the interrelations between eco-innovations and circular economy. It is also expected that future case studies could be developed to further contribute to this field of analysis, as well as motivate practical applications of eco-innovations in a circular economy model.

A final remark to this paper is that we do believe that eco-innovations are crucial to sustainability transition. But a lot more is necessary to reduce greenhouse gas emissions, particularly phasing out subsidies to energy production through fossil fuels and massive adoption of renewable energy sources. The transition will not come about in an automatic and natural way, but will require a better and widespread understanding of the risk of continuing on the same path of indefinite economic growth. Civil-society pressure is necessary for political and market action to pave the way from the contemporary growth society to a future flourishing society.

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# *Effect of Aloe Vera Gel on Quality and Shelf Life of Mango (Mangifera indica L.) Fruits cv. Nam Dok Mai and Technology Dissemination*

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**Abstract**

This study was designed to assess the suitable concentration of natural coating materials, namely, *Aloe vera* gel to control antracnose of mango *(Mangifera indica* L.*)* fruits cv. Nam Dok Mai taken from Bangkla, Chachoengsao Province. The experiment was to evaluate the benefits of this technology. It was found that coating with 20% *Aloe vera* gel gave the longest shelf life with good quality at 12 days at a storage temperature of 25 °C and 75±5 % relative humidity as well as slowing down the weight loss, firmness and changed in chemical compositioned such as titratable acidity (TA) and total soluble solids (TSS) significantly compared to control and other treatment ($p \leq 0.05$). The use of the *Aloe vera* gel coatings did not alter the quality of the fruit when ripe.

Technology dissemination to mango growers of Chachoengsao Co-orperatory Community was performed by using the training created by the researcher. The results of the pre-test and after training post-test showed that farmers increased their knowledge, skills, awareness and attitudes in the use of *Aloe vera* gel for prolonging shelf life of mango fruits.

Keywords: *Aloe vera* gel, shelf life, Nam Dok Mai, technology dissemination.

## Introduction

Mango (*Mangifera indica* L.) is a tropical fruit that has economic importance in Thailand and can be grown in all regions of the country. Mango is mainly for domestic consumption and the rest is exported. The export volume and value of mangoes from Thailand increased respectively from 2016 at 33,347 tons (1,223 million baht) (Office of Agricultural Economics, 2017). The important exporting markets are Japan, Europe and America. Because of nutritional and sensory qualities, mangoes become favorite fruit for foreigners with exported varieties such as Nam Dok Mai, Tongdum, Nung Glang Wan, Koh Rong and Rad but the major problems of mango fruits during storage and export are weight loss, ripening during logistic, and formation of brown spot resulting in value decreased. Therefore, identifying the suitable coating compositions is a key role to extend the shelf life and reduce post-harvest deterioration which required efficient and safe methods of fruit coating. (Pongsotom et al, 2007). This research aimed to reduce the loss of productivity, give added value, extend the shelf life and propagate the information that will help the farmers to select the appropriate coating.

## Material and methods

### *Aloe vera* gel

Leaves of *Aloe vera* harvested from local farms, Bangkla, Chachoengsao Province, Thailand. only the fully extended mature leaves were harvested, then stored in plastic papers and transported to the laboratory within same day.

### Preparing mango fruits

Mango (*Mangifera indica* L.) fruits 115 days old after flowering in March 2011 weight 300-350 g, which were selected from Bangkla, Chachoengsao Province. All of them were disease-free, no wounds on the skin and nature at the same stage selected by using water floating and putting in 2% brine. The fruits then were washed and air dried.

### Coating method

Coating materials were prepared and used immediately. The mango fruits were dipped in the different coating *Aloe vera* gel for 30 s, air dried and weighed afterward. Then serial numbers were written on each of the mango fruits and stored under specified temperature.

### Methodology

This study is a Completely Randomized Design (CRD) as follows.
Experiment 1 : To determine the type and concentration of the appropriate coating solutions. The mango fruits were divided into five groups. They were treated with uncoated (control) (A1), solvent (water) (A2), 10% *Aloe vera* gel (A3), 20% *Aloe vera* gel (A4) and 40% *Aloe vera* gel (A5). Each condition was tested using three mango fruits. Then the storage experiment was carried out at 25 $^{o}$C (relative humidity.

75 ± 5%). The mango fruits were inspected every 2 days for a total of six times or 12 days.

Experiment 2 : *Aloe vera* based edible coating technology was disseminated to mango growers of Chachoengsao Co-orperatory Community (101 farmers and exporters), and was performed by using the training created by the researcher. A selection of participants for the training was performed by using purposive sampling.

In the workshop, the researcher constructed a test of knowledge, understanding, skills, awareness and attitudes in the following order:

1. Studied from books, journals and research papers related to the use of natural coatings in order to guide the creation of research questionnaires.
2. The data was collected from 20 multiple-choice questionnaires to measure their knowledge, skills, awareness and attitudes towards using Aloe vera gel coatings.
3. The questionnaire was completed. Five experts were provided to give suggestions for improvement, and considered the content, as well as the correctness of the language used.
4. The test to correct the defect was taken.
5. The test was applied to 50 mango growers in Chachoengsao Province. The test scores were analyzed to determine the difficulty, and the discriminative power of the test.
6. Chose a test with a difficulty value of 0.20 - 0.80 and a positive discriminative power and covered the test content of 10, and calculated the reliability of the test. Using the KR21 formula of Kuder-Richardson, the reliability of 0.91, which was a highly reliable test, should be used to measure the knowledge, skills, awareness and attitudes of the farmers and exporters.

**Qualitative analysis**

Experiment 1 : Disease and shelf life were analysed by determining the number of mango fruits affected with anthracnose by browning score with could be seen on mango skin. Browning score greater than 30% was considered expired storage. Weight loss, firmness, titratable acidity (TA), total soluble solid (TSS) were observed to assessed the overall acceptance by 8 trained testers. A nine point hedonic scale was accepted in this experiment (Peacock et al., 1986) as follows.
Overall acceptance (score)

1 = dislike extremely
2 = dislike very much
3 = dislike moderately
4 = dislike slightly
5 = like no dislike
6 = like slightly
7 = like moderately
8 = likes (like very much)
9 = like most (like extremely)

Sampling three mango fruits was done in each trial. Peeled mango, then sliced the mango on the cheeks on both sides, then sliced the transverse cut of the mango into 3 pieces and place in a white plate for each tester tasting 3 pieces per treatment by the tasting every process.

Percentage and analysis of variance were calculated by considering the differences in all experiment aspects. When the difference was statistically significant at the confidence level of 95 percent, Duncan's New Multiple Range Test was used. In experiment 2, the average of pre- and post-test scores was analyzed by using a t - test.

**Results and discussion**

Experiment 1 : Appropriate type and concentration of the coating solutions
The disease, and shelf life of mango fruits in all series of experiments showed that the brown spot was found in mango fruits coated with A4 later than the other groups with 12 days shelf life (Table 1), indicating that the coating was a slow ripening agent as the unripe fruits were more disease resistance compared to the ripe fruits. (Kumpoun et.al., 2005). This might be due to the antibacterial activity of *Aloe vera* gel (Chien et.al., 2007). The possible explanation may be that too low concentration was not enough for antibacterial activity and too high a concentration could inhibit anaerobic respiration thus increase susceptibility to the disease. Moreover, the coating limits the exchange of $O_2$ and increase $CO_2$, consequently slowing down the metabolism by inhibition of ethylene (Hagenmaier, 2005), resulting in a delay of mangoes ripening destruction of mango fruits by pathogens and making the shelf life longer (Boonyakiat et al., 2007; Worrell et al., 2002; Bai et al., 2003).

**Table 1** Percentage of disease affected mango fruits cv. "Nam Dok Mai" when coated with different *Aloe vara* gel concentrations and then stored at 25 $^{o}$C (relative humidity 75 ± 5%).

| Treatment | % Disease day 12 |
|---|---|
| A1 | 70 |
| A2 | 70 |
| A3 | 60 |
| A4 | 30 |
| A5 | 50 |

Weight loss of mango fruits in all treatments were time dependently increased (Figure 1a). Mango fruits coated with A4 was found to lose weight less than the others, the A4 group that showed the minimal weight loss only 5.14% on day 6 of storage while compared to the control group ($p \leq 0.05$) (Table 2). Transpiration of mango fruits depended on the specific properties of coating materials which the replace natural wax and closed the opening pores. The limitation of gases diffusion resulted in a decreased respiratory rate and decreased mango weight loss (Dang et al., 2004; Han et al., 2004). Weight loss is directly related to the concentration of the coating materials; low concentration gave less transpiration and gas exchange whereas the high concentration will limit gas exchange and decrease the tissue $O_2$ supply (Hagenmaier, 2005) resulting changes in the smell and flavor of the mango fruits.

The firmness of mango fruits in all treatments decreased throughout the shelf life (Figure 1b). Mango fruits coated with A4 were found to decelerate this process significantly compared to the control ($p \leq 0.05$) with a firmness of 15.95 kg/cm$^2$ for A4 on day 6 of storage (Table 2). The firmness of the fruits naturally decreased gradually when they ripened because pectin causes tight bonds in raw fruits changed to a smaller size and more water soluble resulting in loos of cell adhesion. The firmness was decreased when coated because of a limitation $O_2$ diffusion resulting in a decrease in ethylene (Hagenmaier, 2005). Since $O_2$ is involved in the process ethylene production and through activating enzymes is involved in cell wall degradation of the fruit resulting in soft tissue (Blankenship and Dole, 2003). This makes the coating beneficial in decelerating firmness loss (Ju and Curry, 2000).

Titratable acidity (TA), and total soluble solids (TSS) of mango fruits in every series of experiments tended to vary inversely. While the amount of TA in all mango fruits was decreased, the TSS in the fruits increased through the harvest period (Figure 1c and d). This means that when the storage period of mango fruits was longer, ripe mangoes tasted sweeter but less sour. Mango fruits coated with A4 was the best groups that could prevent the decline of TA and increase TSS, especially mango fruits coated with A4 on day 6 of storage with maximum amount of TA at 1.20 % but the lowest amount of TSS at 21.65% which were significantly different compared to the control and other treatments ($p \leq 0.05$) (Table 2). This implied that the coating could delay the amount in the TA and TSS in the fruit because the coating maintains a state of adaptation resulting in an increase of $CO_2$ which inhibits activity of ethylene thus delay ripening, and slow changes in the amount of TA in the vacuole. Most of the acids found in the fruit were citric acid and malic acid (Bai et al., 2003; Nabigol and Asghari, 2013). Moreover, coating could delay the decomposition of starch into sugar (glucose, fructose and sucrose), which was the majority composition of TSS (Chien et al., 2007). This is consistent with the report of Luengwilai et al., 2007 that an increase in the amount of TSS in ripe fruit had a direct relationship with the decomposition of starch.

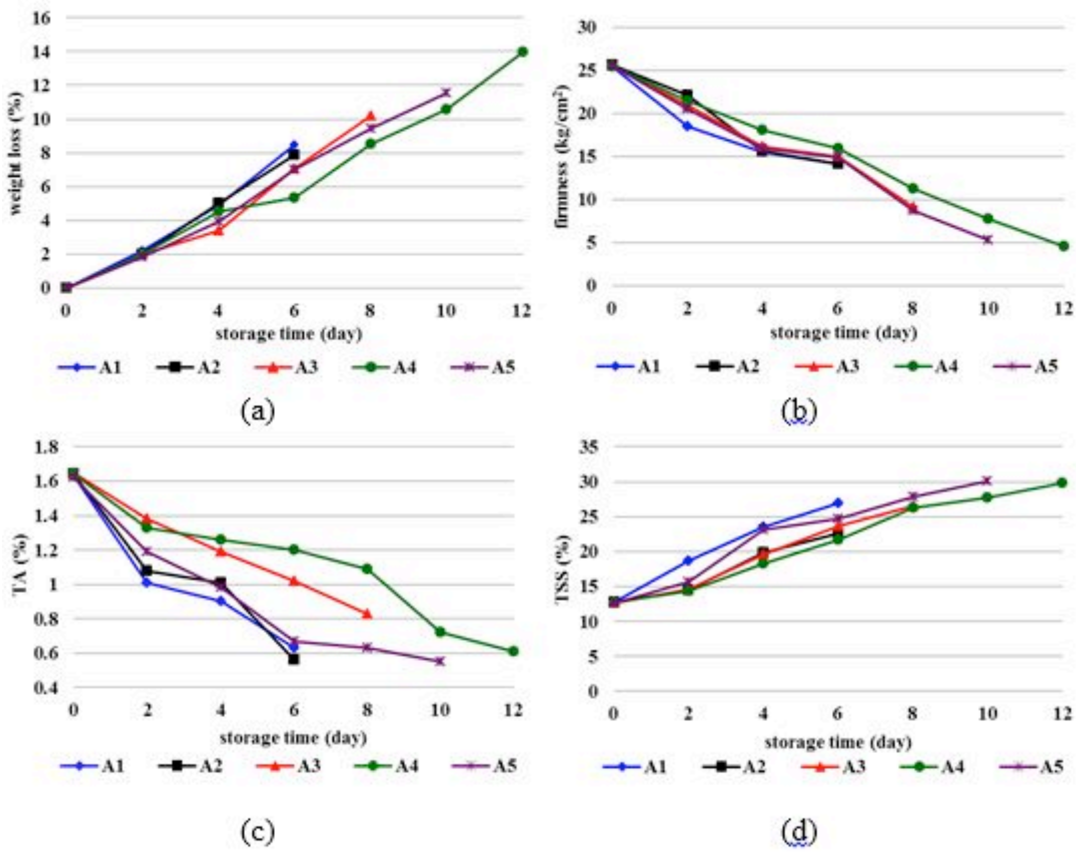


**Figure 1 :** Weight loss (a), firmness (b), TA (c) and TSS (d) of 'Nam Dok Mai' when coated with the different *Aloe vera* gel concentrations and then stored at 25 °C (relative humidity 75±5 %).

**Table 2** Weight loss, firmness, TA and TSS of mango fruits cv. 'Nam Dok Mai' when coated with different *Aloe vera* gel concentrations and then stored at 25 °C (relative humidity 75 ± 5%).

| Treatment | Weight loss (%) | Firmness ($kg/cm^2$) | TA (%) | TSS (%) |
|---|---|---|---|---|
| | Day 6 | Day 6 | Day 6 | Day 6 |
| A1 | $8.46 \pm 0.94^{a}$ | $14.15 \pm 0.27^{c}$ | $0.63 \pm 0.16^{c}$ | $26.95 \pm 0.53^{a}$ |
| A2 | $7.89 \pm 0.96^{a}$ | $14.17 \pm 0.33^{c}$ | $0.56 \pm 0.14^{c}$ | $22.55 \pm 0.68^{c}$ |
| A3 | $7.04 \pm 0.95^{a}$ | $15.03 \pm 0.82^{b}$ | $1.02 \pm 0.17^{ab}$ | $23.69 \pm 0.59^{b}$ |
| A4 | $5.14 \pm 0.93^{b}$ | $15.95 \pm 0.51^{a}$ | $1.20 \pm 0.25^{a}$ | $21.65 \pm 0.62^{c}$ |
| A5 | $6.97 \pm 0.94^{a}$ | $14.83 \pm 0.31^{bc}$ | $0.67 \pm 0.14^{c}$ | $24.74 \pm 0.50^{b}$ |

Numbers followed by a letter in the column represents the statistical significance of the mean comparison according to Duncan's New Multiple Range Test ($p \leq 0.05$).

Overall acceptance score of mango fruits in all treatments showed an increasing tendency along with the shelf life and decreased again when mango fruits came to deterioration stage. Mango fruits coated with A4 were effective in helping to maintain the best quality, especially mangoes coated with A4 on day 6 of storage. Overall the acceptance score did not significantly differ from the control group ($p > 0.05$) (Table 3). We found that on the 10th of storage, mango fruits coated with A4 had the overall acceptance score at 7.68 (Table 3). The concentration of the coating materials also affects the quality of the fruit (Boonyakiat et.al., 2007)., with a low concentration of materials or too thin a coating allowing transpiration and more $O_2$ exchange while a high concentration or too thick a coating causing materials to waste due to a lack of $O_2$ thus causes an accumulation of acetaldehyde and ethanol by anaerobic respiration causing a fermented smell and taste disorders (Hussain et al., 2004). This was not acceptable to the taste which consistent with the report of that the factors that affect the inclination of consumers to mango fruits was the texture (Kaswija et al., 2006).

**Table 3** The overall acceptance score of mango fruits cv. 'Nam Dok Mai' when coated with *Aloe vera* gel concentrations and then stored at 25 $^oC$ (relative humidity 75 ± 5%).

| Overall acceptance (score) | | |
|---|---|---|
| **Treatment** | **Day6** | **Day10** |
| A1 | $8.08\pm1.05^a$ | ND |
| A2 | $5.83\pm1.14^b$ | ND |
| A3 | $4.55\pm0.98^b$ | ND |
| A4 | $7.90\pm0.88^a$ | $7.68\pm1.04$ |
| A5 | $5.45\pm0.92^b$ | $6.09\pm0.96$ |

Numbers followed by a letter in the column represents the statistical significance of the mean comparison according to Duncan's New Multiple Range Test ($p\leq0.05$).

**Experiment 2 :** Results of the coating technology propagation.

The analysis of the achievement, knowledge, skills, awareness and attitudes before and after training created by the researcher showed that the after training score was higher than the pre-test score. When analyzed by using a t-test we found that the post-test score was significantly higher than pre-test score ($p\leq0.05$) (Table 4). This indicated that training helps farmers and exporters to improve knowledge skills and attitudes. We delivered what we found to farmers and exporters by reading, lecture and practice and learn from scenario and real situations and discussion. The participants cooperated in the implementation of activities as well as pleasure in learning as shown in figure 2: a) chemistry majored students received registration, b) Mr.Sakda Kuntipalo introduced researchers, lecturers and students majoring in chemistry to farmers and exporters, c)researchers discussed the use of *aloe vera* gel coatings to inhibit anthracnose in mango fruits cv. Nam Dok Mai, d) farmers and exporters listened to the research report intentionally, e) farmers and exporters divided the experimental groups using *aloe vera* gel coatings mango fruits cv. Nam Dok Mai, f) researchers farmers and exporters together discussed the results of the experiment, g) paid food together, and h) farmers and exporters responded to the questionnaire with the researchers and students helped and advised. The training budget was not much and did not take much time. Moreover, the trainees could use the knowledge immediately after training (Watanawong, 2004; Vella, 2002). In addition, the training manuals helped farmers and exporters to aware of the problems after the harvests, skills in the use of natural coating, attitudes and enthusiasm to cooperate in solving and preventing problems, being confident in using natural coating to reduce the yield loss. This will lead to an increase in value and prolong the storage life of mangoes.

**Table 4** Comparison of the achievement, cognitive skills, awareness and attitudes before and after training.

| Training interval | n | $\bar{X}$ | S.D. | t – test | p – value |
|---|---|---|---|---|---|
| Before training | 101 | 4.04 | 0.73 | 54.94* | 0.001 |
| After training | 101 | 7.99 | 0.46 | | |

* mean the significant difference ($p \leq 0.05$).


**Figure 2 :** The participants cooperated in the implementation of activities as well as having pleasure to learn.

## Conclusions

Coating Nam Dok Mai mangoes with different concentrations and temperature storage at 25 $^{o}$C (relative humidity 75 ± 5%) indicated that *Aloe vera* gel 20 % could slow down the disease and prolong shelf life for the 12 days, delayed weight loss, firmness and changed in chemical compositioned such as titratable acidity (TA) and total soluble solids (TSS) significantly compared to the uncoated (control) and other treatments ($p \leq 0.05$). The overall acceptance score was not different from the control ($p > 0.05$) and the use of *Aloe vera* gel coatings had no negative impacts on the quality of the mango fruits when ripe.

The propagation of technology to farmers and exporters created by testing before and after training showed that farmers and exporters developed knowledge, skills, awareness and attitudes in the use of *Aloe vera* gel coatings significantly ($p \leq 0.05$).

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# *A Community Market as Economic Foundation of Logistics Process Starting Point: A Case Study of Community Market at Chachoengsao Municipal Stadium, Muang District, Chachoengsao Province, Thailand*

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**Abstract**
A community market is the unique resource of economic rotation in the local community and is still well-accepted by the consumers among the growth of very big and highly competitive department stores. The study of the community market at Chachoengsao Municipality Stadium was conducted. The objectives of this study were 1) to study the context of the community market held in the area of Chachoengsao Municipal Stadium, 2) to study the levels of money spent on merchandise circulating through the community market, 3) to prepare a database regarding the market's direct effects on the community's economy, and 4) to study factors influencing the market's strengthening of the community. The research instruments were interviews with entrepreneurs/merchants and government officers. The data of income from merchandising was collected from the records of the Market Committee. The research subjects were 203 merchants at the community market in the area of Chachoengsao Municipal Stadium. The merchants consisted of permanent merchants and the agriculturalists selling organic agricultural products. The income from merchandising was 50 million baht per year; 40 million baht from permanent merchants of Community Enterprise Market, and 10 million baht from agriculturalists selling agricultural products. The selling point to make this community market very popular is the location in the community, convenient transportation, close to government offices, hospitals, and educational institutes. In addition, due to the good logistics, the consumers are satisfied with the fresh food and the price is reasonable, compared with the good quality.

Keyword: Community-Market/ Flee/Flea Market, Economic Foundation, Community Economics, Logistics.

## Introduction

The present researcher has studied a community market held in the area of Chachoengsao Municipal Stadium, which is located close to government offices, a hospital, educational institutes, shopping centers, and residences. As it is easy to access, many people go there to buy products, even though it is a traditional local open air market and not as comfortable and luxurious as a modern market or department store. Merchants bring their products from their own communities, in a total of 11 districts, to sell at the market. Typically, the products are laid on the ground or sold from temporary stalls, are packed back up when the market fair is over, and then the market place is cleared and transformed into an open area again, as usual. Within this community market, there are two discrete component markets, including the Community Enterprise Market, which has operated for more than 20 years, and the agricultural market, which started merchandising in December, 2014. These two component markets sell different kinds of products: the Community Enterprise Market sells a variety of consumer products, while the agricultural market consists of agriculturalist merchants selling their own chemical-free products, such as fresh fruits and vegetables, as well as premium agricultural products. According to provincial policy, this market is monitored and supervised by the Provincial Administration Office, the Provincial Agricultural Extension Office, and the Provincial Public Health Office. Public health officers will randomly check the quality of these agricultural products. If chemical residues are found on their products twice, offending merchants will not be allowed to sell in this community market again. In fact, even before selling their agricultural products, merchants should submit them to the Provincial Public Health Office for checking. If they are found to be uncontaminated, they can then be sold at the market. All agriculturists selling in this market are selected by the Provincial Administration Office, and are given the logo “Chachoengsao High Safety Product” to certify that they sell high quality agricultural products. However, these standards are not emphasized for the consumer products in the Community Enterprise Market. Merchandise is available at the market fair three days per week, on Tuesdays, Fridays, and Sundays, from 5 a.m. to 11 a.m. Both component markets have their own committees that are responsible for management. The term of service for the Community Enterprise Market Committee is two years, whereas it is only one year for the agricultural market committee. New elections are held when their respective members’ terms end.

## Materials and Methods

The qualitative research used in this study was field work, which had four objectives: 1) to study the context of the community market held in the area of Chachoengsao Municipal Stadium, 2) to study the levels of money spent on merchandise circulating through the community market, 3) to prepare a database regarding the market's direct effects on the community’s economy, and 4) to study factors influencing the market's strengthening of the community. The research subjects were officials of government agencies concerned with the promotion and care of the community market held in the area of Chachoengsao Municipal Stadium and entrepreneurs/merchants from the two component markets: the Community Enterprise Market and the agricultural market, both held in the area of Chachoengsao Municipal Stadium. The research sample was comprised of 10 officials from concerned government agencies, 149 merchants from the Community Enterprise Market, and 54 merchants from the agricultural market.

This field research was conducted according to the methodology of qualitative research, which emphasizes research flexibility. It is believed that the data found during research results in part from the interaction between researchers and their studied phenomenon, as well as the researchers' recollections of their experiences, both past and present. Beginning with data collection using the Holistic Approach, a researcher is the key instrument used to collect data without bias and to realize the importance of informants' opinions and perspectives (Chai Podhisita, 2011). The data collection was planned to be accomplished in several periods to help in understanding the system and process of merchandising in both markets. A device for recording needed to be prepared in advance: a mobile phone was used for taking photos and voice recordings, as well as field work notes. During non-participatory observation, the researcher acted as an outsider who frequently went to buy products at both markets, in order to become familiar to the merchants. The researcher collected data, took field work notes, recorded the amounts of merchants, committee members of both markets, officials, and other people. Also recorded were observations of the products and atmosphere of this market place. During data collection, the researcher analyzed the data without consideration of process separation. In order to examine data reliability, the researcher interviewed merchants and compared this data with that which was recorded in the Products Selling Record, Rental Fee Collecting Record, and Expenses for Market Management Record reports. As for the statistics used for data analysis, descriptive statistics were used for analyzing the context of the community market, as well as income from selling products. Content analysis was used for analyzing data from the interviews, and literature review of the research and related documents was also implemented.

## Results

The following are observations regarding the context of the community market held in the area of Chachoengsao Community Stadium: the market fair was available three days per week, on Tuesdays, Fridays, and Sundays, from 5 a.m. to 11 a.m. There were two discrete component markets, with 203 merchants in the Community Enterprise Market (73.40%), and 54 merchants in the agricultural market (26.60%). The aggregate group of merchants from both markets included females (70.44%), and males (29.56%). The largest percentage of the merchants graduates of primary schools (44.03%), compared with those from high schools (33.96%) and those who graduated with a bachelor's degree or higher (22.01%). The distinguishing feature of the agricultural market was that it sold chemical-free products, which were randomly checked for chemical residues by concerned government agencies including the Provincial Public Health Office. At the agricultural market, the products which were sold the most were fresh fruits and hydroponic vegetables (46.30%), organic rice (11.11%), and the combination of raw and ripe mangoes as well as coconuts (7.41%), respectively. In terms of the levels of money spent on merchandise circulating through both markets, the overall grand total of sales was about 50 million baht. The total of sales for the Community Enterprise Market was higher than the total of sales for the agricultural market. At the Community Enterprise Market, the average monthly total of sales was about 3.33 million baht, and the overall total of sales for the year was about 40 million baht. At the agricultural market, the average monthly total of sales was about 900,000 baht, and the overall total of sales for the year was about 10 million baht. This result was accounted from the starting point of the logistic process, in that products from their sources had the ability to be distributed to consumers rapidly. In addition, the products were fresh, good quality, and had a quality assurance mark. This resulted in satisfied consumers, and consequently, the community in each district was able to profit from sales of the merchandise. In terms of preparing a database regarding the market's direct effects on the community's economy, a database was created from lists of the names of 203 merchants from the two markets: 149 merchants from the Community Enterprise Market, and 54 merchants from the agricultural market, which identifies each merchant's address, contact number, sex, age, level of education, and type of products sold. Regarding factors influencing the market's strengthening of the community, there were six factors: 1) people in the community should have jobs, income, and good health, 2) merchants should be patient, enthusiastic, and adaptable to provide a variety of competitive products for customers' satisfaction, 3) products sold should be fresh, clean, good quality, and kept to the community standards, and 4) merchants should be honest and friendly salespeople.

## Discussion

The products sold in this community market are essentially very fresh. The merchants had stated that fruits and vegetables were required to be picked in the evenings and cleaned to be ready for selling the following mornings. This degree of garden fresh produce is rarely found in department stores or general markets. In addition, in this community market, consumers are allowed to negotiate lower prices acceptable to both parties. As the merchants do not need to contact a middleman, they are able to reduce a price and give you more for free. In this market, family growers come to sell the products themselves; therefore, laborers are not needed. Furthermore, the elderly are given opportunities to make Thai desserts, which are products of time-consuming processes and seldom found in general markets. By involvement of the elderly, people can witness their value as they live their lives in meaningful ways, and, consequently, the next generation can also absorb Thai culture. The existence of this market is supported by the concerned government agencies' provision of the open-air market fair location. Their objectives in doing this are to give product makers the chance to meet customers while eliminating contact with middle-men. In addition to the quality of products, the products also come from a variety of localities in each season and are carefully selected in each district. This is also part of the charm of this place that we hardly ever find in department stores or general markets, and is consistent with Robinson (2000), who stated that a market fair becomes a cultural place which is able to express a community's identity, as well as the responsiveness between the society and the economy. Compared to activities of people in the conventional economic system, which is connected in every society, the behaviors found in a traditional market are derived from the local culture (Naruphon Duangwiset, 2008). Additionally, a market fair is also an inventive place for tourism and consumption (Rainab Sriaremhad, 2012), which conforms to Somrak Chaisingkananon's research (2006), which found that the activity of exchange has existed along with human society for a long time because humans cannot produce all things independently. The things normally exchanged are items concerning their basic necessities. A market is not only a place for exchanging products or services, but also has social, cultural, and economic meanings, which cannot be separated from each other. It is also a place of life, for the social interaction of people in various interesting patterns. If no one participated in its activities, a market would be just an empty space. Therefore, a community market is a place to create a cyclical economy, in a market fair that influences the larger economy of a concerned community, and should be considered as a starting point of the logistic process.

## Conclusion

In the future, the markets' products may be distributed to a wider area, from the local level on up to the provincial level, the national level, and even the international level. An information center should be created for sharing the data of production volume along with the amount of customers' demand, in order to assist distribution of products in large quantities to expected areas. In this way, it would be truly beneficial for agriculturalists and the community enterprise. However, the cost of transportation would also need to be considered. According to the sufficiency economy, merchandising in localities should be done to reduce the cost of transportation, but if there are surplus products, these could be distributed to other areas for sales. Therefore, the shelf-life of products should be prolonged, and better food-packaging should be developed to maintain the quality of products during delivery. In addition, information technology should be implemented to spread news thoroughly and rapidly to each market at the provincial level. Consequently, there are various fields to be developed, including agriculturalists' education, productivity, transportation for distribution, production, marketing, etc. Agriculturalists should follow innovative news. For example, presently, a freshpack, which is called Active Pak$^{TM}$, has been invented, by the Inno-freshpack research team, National Science and Technology Development Agency (NSTDA), and instructors at Kasetsart University, to prolong the shelf-life and maintain the nutrients of fresh products for customer satisfaction (Active Pak$^{TM}$, 2016, pp. 50-51).

## Acknowledgement

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# *The Design and Development Application for Learning an ASEAN Language on Social Media*

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**Abstract**
This paper proposes a new method for learning a mutually accepted ASEAN language on social media for Thai students under the Association of Southeast Asian Nations or ASEAN Declaration for ASEAN Community (ASEAN Political and Security Community – APSC, ASEAN Economic Community – AEC, ASEAN Socio - Cultural Community – ASCC). This paper addresses the design and development of an application for learning a mutually accepted ASEAN language on social media by creating an ASEAN Link application with evaluation of satisfaction and achievement of learning goals. A sample of 100 participants from Rajabhat Rajanagarindra University was selected by purposive sampling. The experiment was conducted in the second semester of 2016, 4 days per week, one hour per day. The test was conducted on a social network, and implemented in the classroom. The comparison between the students learning by traditional methods and learning by an ASEAN Link application was conducted and it was found that the students who learned by an ASEAN Link application achieved much more positive results.

Keywords: ASEAN Link, social media, application, language, design and development

## Introduction

In 2016, Thailand entered the ASEAN Community. It has 10 States — Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. 1 observer, Papua, New Guinea. The ASEAN Declaration states that the aims and purposes of the Association are: (1) To accelerate the economic growth, social progress and cultural development in the region through joint endeavors in the spirit of equality and partnership in order to strengthen the foundation for a prosperous and peaceful community of Southeast Asian nations, and (2) To promote regional peace and stability through abiding respect for justice and the rule of law in the relationship among countries in the region and adherence to the principles of the United Nations Charter. In 1995, the ASEAN Heads of State and Government reaffirmed that, "Cooperative peace and shared prosperity shall be the fundamental goals of ASEAN."

The mutually accepted language of the ASEAN community is English. At present, the Thai people have a disadvantage in terms of language, specifically English. As well as the national language of neighboring countries. When entering the ASEAN Economic Community, there may be problems communicating in matters of trade with member countries. At this point, it is considered to be a weakness of the Thai people who must plan, and be encouraged, to develop skills using English and neighboring languages to effectively communicate with member countries of the ASEAN Community.

Therefore, in order to promote the support of learning the mutually accepted ASEAN language for Thai students, the researchers designed and developed the application of an ASEAN Link by using interactive communication via a smartphone in the sticker style that is used as a greeting in everyday life. It is audio visual, and expresses the mood of communication of the cartoon character format.

Statistical studies of digital communications in Thailand reveals that 68.05 million individuals out of the total population have a mobile connection. 82.78 % are using a social media application. On Facebook, up to 32% and LINE, up to 29%. As a result, the researchers designed and developed the application for learning a mutually accepted ASEAN language via social media. They selected the Cambodian language as a pilot project for ASEAN Learning.

This research is a pilot project for learning a mutually accepted ASEAN language from stickers. It consists of 3 languages: Thai, English and Cambodian. It is hoped that learning the language from the ASEAN Link application will enable students to learn the Cambodian and English language in an enjoyable manner, and to use it in everyday life.

## Objective

1. Design and development of an application for learning a mutually accepted ASEAN language
2. Comparison of achievement testing between the learners who study by the traditional model and the proposed model.
3. Evaluate the efficacy and satisfaction of the ASEAN Link application.

## ASEAN Link Application

ASEAN Link Application concept:

**a) ASEAN's official language:**

English is the official language of the ASEAN community. A result, the people in the ASEAN community must learn English language skills for effective communication. This paper focusses on a Thai-English-Cambodian model of language combinations. The concept of an ASEAN Link application is shown in figure 1.

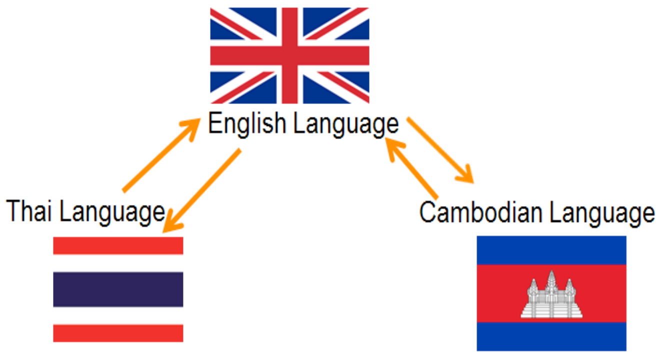


Figure 1: Translation of Thai Language and Cambodian Language

**b) Sticker ASEAN Link:**

The component of a sticker from the ASEAN Link consists of 4 parts: A National flag, a word from the English language, a pronunciation, and a cartoon from the ASEAN Link of each country. The detail of sticker from the ASEAN Link is shown in figure 2.

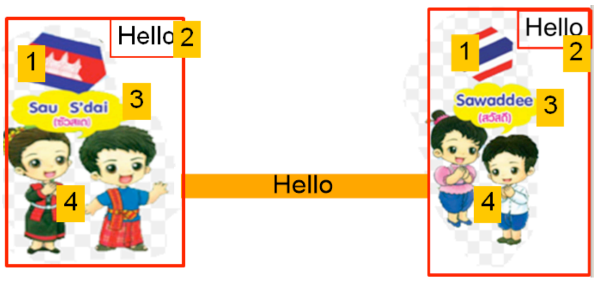


Figure 2: Components of a sticker from the ASEAN Link

**c) Logo of Application ASEAN Link:**

Figure 3 shows the details of logo of application in an ASEAN Link.

1) ASEAN Link Logo symbol is ten stalks of golden rice referring to the ties of the countries in the region. The ten Southeast Asian countries together in fellowship is shown by the solidarity of the red circle. The white and blue represents the union of the letters in the word "ASEAN". The blue beneath the image represents a commitment to work together for peace, unity, stability and progress of the ASEAN

member countries. All colors shown in the label of ASEAN are important in the flag.

ASEAN member countries.
Blue stands for peace and stability.
Red stands for courage and progress.
White stands for innocence.
Yellow stands for prosperity.

2) The text "Link" refers to the communication amongst the ASEAN population.
3) The "Chat" icon signifies that the ASEAN population can interact through the Link application.
4) The "Green Border" signifies that all of the ASEAN member states are prosperous.

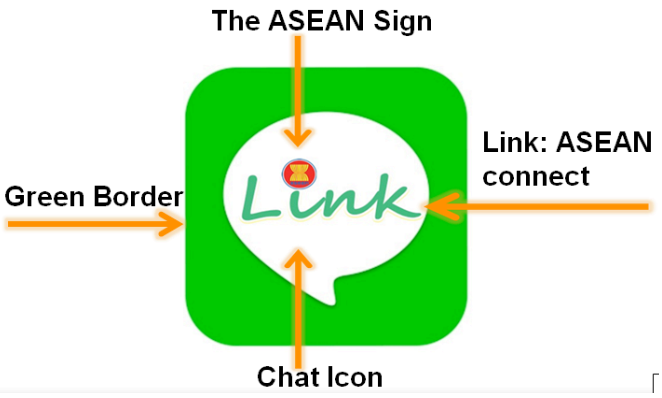


Figure 3: Logo of the ASEAN Link Application

**d) Screen of the ASEAN Link Application:**

The design of the ASEAN Link Application shows the screen on a smartphone. To the left is a start application link, and the right shows the chat screen.

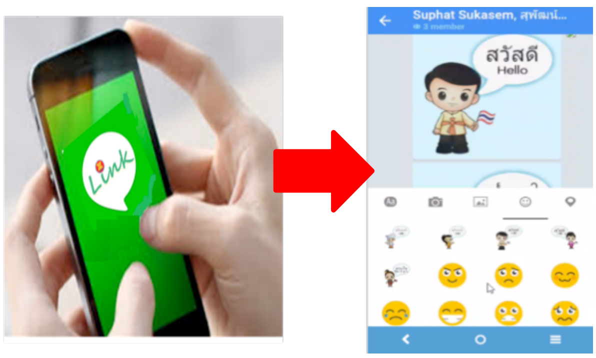


Figure 4: Screen of the ASEAN Link Application

**Architecture of the ASEAN Link Application**

The proposed model of the ASEAN Lin Application consists of three parts for communication and exchanging messages such as, sender, receiver, and a transmission channel. The architecture of this is client/server (figure 5), and has two parts: hardware and software. Requirements are shown below.

1. **Hardware Requirement:**
   Client: Android Operating System mobile phone version 5.0 or above
2. **Software Requirement:**
   Apache HTTP Server: HTTP Server for Web Application Deployment (PHP)
   PHP: Programming Language for Web Application
   Google Firebase for server-side storage Ionic Framework with Android
   SDK for Mobile Application Development

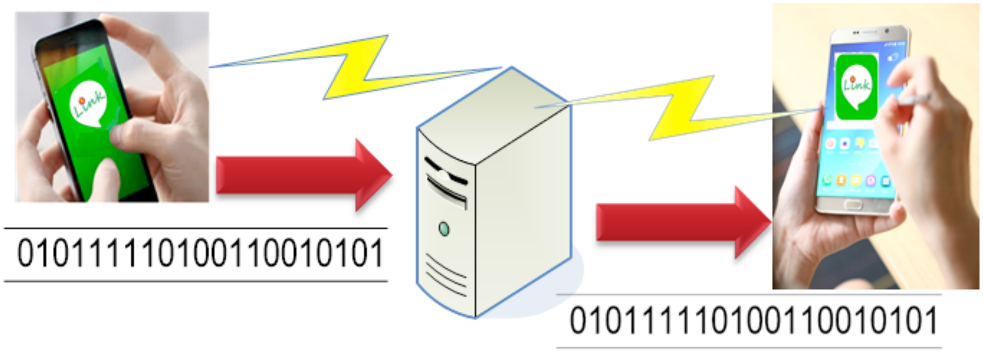


Figure 5: Architecture of the ASEAN Link Application

**Experiments**

The details of this experiment :

**a) Experimental concept:**

Figure 6 shows the experimental concept of this proposal. We start at the pre- test phase of the experimental group and add the control group, then input the treatment, ie: the mutually accepted ASEAN language, (learned traditionally) for the control group, and the ASEAN Link Application for the experimental group. Finally, a post-test both of groups.

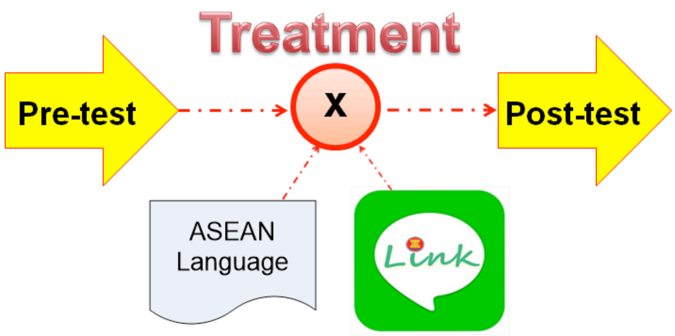


Figure 6: Concept of the experiment

**b) Experimental Diagram:**

The diagram of the experiment is divided into two groups. Group A is a new method of learning which is achieved by application of the ASEAN Link, combined with testing and evaluation of the application. Group B is a traditional learning system which is achieved by documenting the mutually accepted ASEAN language, and testing before learning. This concept is shown in figure 7.

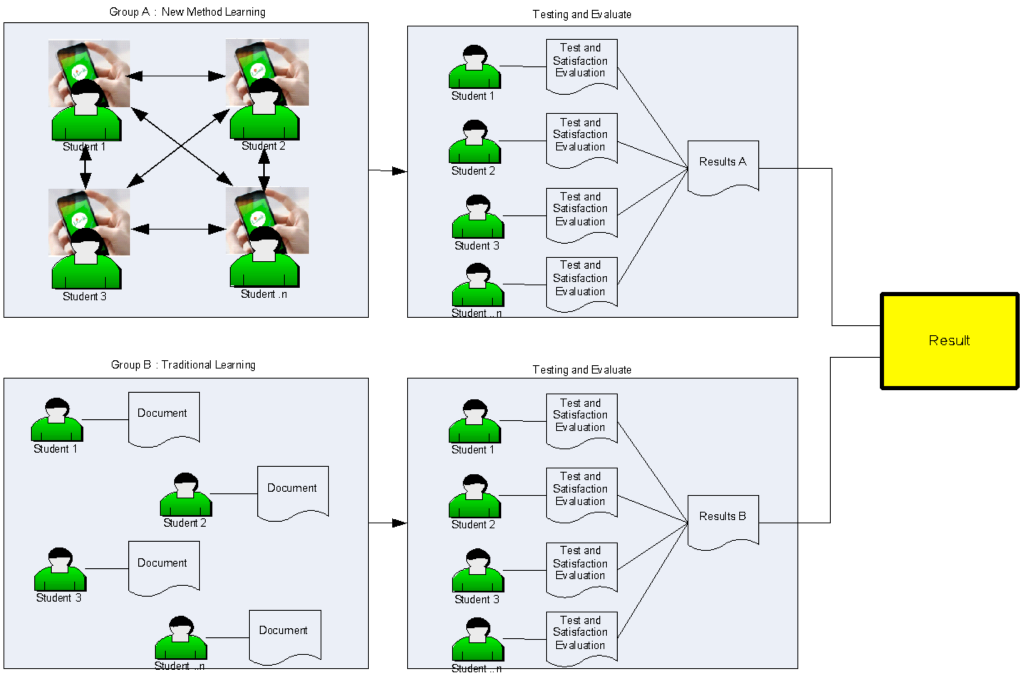


Figure 7: Diagram of the experiment

**c) Steps of the experiment:**

1. Dividing the students into two groups, fifty participants per group, consisting of a control group and an experimental group. The students were comprised of members of the first year of Rajabhat Rajanagarindra University.
2. Pre-test the ASEAN language (Thai-English-Cambodian) both of groups.
3. The control group learns the ASEAN language, (Thai-English-Cambodian) by the traditional method, and the experimental group learns the ASEAN language via the ASEAN Link Application. The experiment was conducted in the second semester of 2016, 4 days per week, and one hour per day. Finally, a post-test of both groups.
4. Evaluate the achievement tests.
5. Evaluate the satisfaction of the proposed methods.

**d) Method and measures:**

The method of evaluating the achievement tests using the statistic values below. The flow of calculations of this process in the experiment are shown in figure 8.

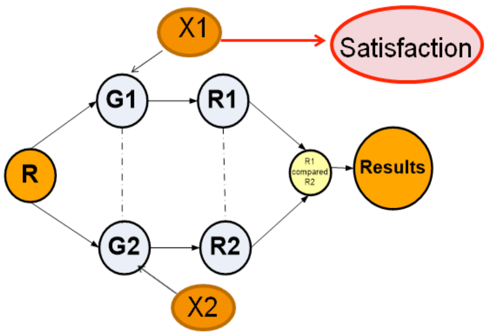


Figure 8: Flow of the experiment

## 1. Notation:

*R* = Average of achievement tests of the experimental group and control group before the experiment.
*X1*= Previous achievement tests of the experimental group.
*G1* = Average of achievement tests of the experimental group after the experiment.
*X2* = Previous achievement tests of the control group.
*G2* = Average of achievement tests of the control group after the experiment.
*R1* = Adding the percentages of the achievement tests of the experimental group after the experiment.
*R2* = Adding the percentages of achievement tests of the control group after the experiment.
*Results* = The difference of achievement tests of the experimental group and the control group after the experiment.
*n1* = The number of participants in the experimental group.
*n2* = The number of participants in the control group.

## 2. Formula:

$$R = \frac{\sum_1^{n1} x1 + \sum_1^{n2} x2}{(n1+n2)} \quad \text{.........................................(1)}$$

$$G1 = \frac{\sum_1^{n1} x1}{(n1)} \quad \text{.................................................(2)}$$

$$G2 = \frac{\sum_1^{n2} x2}{(n2)} \quad \text{.................................................(3)}$$

$$R1 = \frac{(G1-R)x100}{(n1)} \quad \text{.........................................(4)}$$

$$R2 = \frac{(G2-R)x100}{(n2)} \quad \text{.........................................(5)}$$

$$Results = R1 - R2 \quad \text{....................................(6)}$$

**3. Measure:**

Measure of user satisfaction on a 5-point scale as in the table below:

| Extremely Satisfied | Satisfied | Neutral | Dissatisfied | Extremely Dissatisfied |
|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 |

## Results

The results of this experiment were divided into two parts: the achievement test of experimental group in comparison with the control group, and the experimental group satisfaction in the ASEAN Link Application .

### The achievement test of experimental group comparison with control group

The difference between the results of the achievement tests of the experimental group and control group after the experiment equals 36.58%**.** The details are in Table 1.

The average of previous achievement tests of the experimental group and the control group equals *R* =40.25%. The achievement tests of the experimental group equals *x1*=59.75%, The achievement tests of the control group equals *x2*=45.00%. The average of achievement tests of the experimental group after the experiment equals *G1*=19.50%, Average of achievement tests of the control group after the experiment equals *G2*=4.75%. Adding the percentages of achievement tests of the experimental group after the experiment equals *R1*=48.45%. Adding the percentages of achievement tests of the control group after the experiment equals *R2*=11.87%.

**Table1.** The results of the achievement test

| *R* | *X1* | *X2* | *G1* | *G2* | *R1* | *R2* |
|---|---|---|---|---|---|---|
| 40.25% | 59.75% | 45.00% | 19.50% | 4.75% | 48.45% | 11.87% |

From Table 1. Statistics revealed that the achievement tests of the experimental group after the experiment obtained better results the than the control group. So, by extension, the ASEAN Link Application is shown to support the ASEAN language learning module, (Cambodian language).

### The satisfaction in Application ASEAN Link of the experimental group

The results of survey of the experimental group who were using the ASEAN Link Application revealed that six items which provided satisfaction consist of ease of use, ease of installation, the features of the application, the abilities of the application, the suitability for support in learning the mutually accepted ASEAN language, and overall satisfaction. The details show in Table 2.

**Table2**. The results of survey of the user satisfaction in ASEAN Link Application

| No | Item | Mean | Description |
|---|---|---|---|
| 1 | Ease of use | 4.50 | Satisfied |
| 2 | Ease of installation | 4.60 | Satisfied |
| 3 | The features of the application | 4.00 | Satisfied |
| 4 | The abilities of the application | 4.10 | Satisfied |
| 5 | The look and feel of the application | 3.10 | Neutral |
| 6 | The ability to collaborate | 3.05 | Neutral |
| 7 | The security of the application | 2.50 | Dissatisfied |
| 8 | The suitability for support in learning a mutually accepted ASEAN language | 4.40 | Satisfied |
| 9 | Overall satisfaction | 4.45 | Satisfied |

## Discussion and Conclusions

The result of the achievement tests revealed that the student who learns by the ASEAN Link Application on social media obtains the greater achievement than the traditional method. Also, the overall satisfaction in the ASEAN Link Application is very high. However, this paper focusses on the Cambodian language, which is only a segment of the ASEAN language base. In the future the author will be expand the ASEAN stickers of neighboring country's languages.

## Acknowledgement

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# *CFD Simulation of Natural Ventilation in Urban Buildings Due to Wind Effect*

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**Abstract**
Previous studies regarding natural ventilation in buildings were mostly limited to isolated buildings. Considering an urban context, this study investigates the wind-induced single-sided natural ventilation in buildings near a long street canyon under a perpendicular wind direction using CFD method. Four aspect ratios (AR) of the street canyon, from 1.0, 2.0, 4.0 to 6.0, are investigated to examine the influence of street configuration. Ventilation rate of rooms in buildings is analyzed. AR influences ventilation rate and its distribution among rooms along height of buildings. The percentage decrease of ventilation rate of buildings reaches 67% when AR of a street canyon is increased from 1.0 to 6.0. The findings of this study are intended to increase the understanding of natural ventilation performance in urban buildings.

Keywords: Natural ventilation, urban environment, street canyon, aspect ratio, CFD simulation

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## Introduction

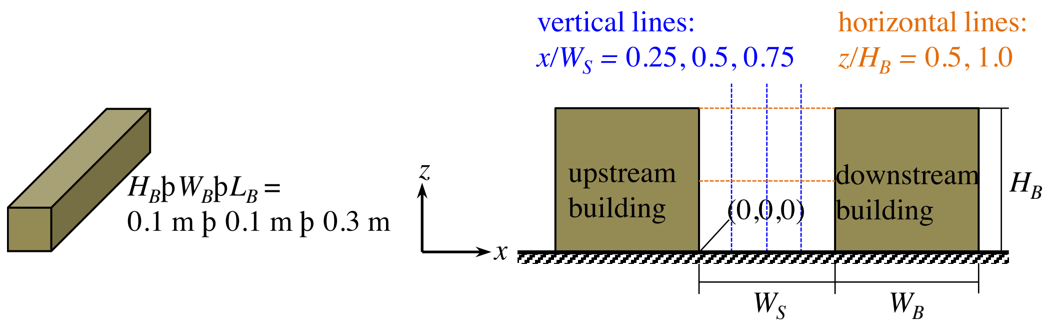
Given that few buildings in urban areas can be regarded as isolated buildings, the urban microclimate would directly influence the natural ventilation in buildings (Ai and Mak, 2015). Review of on-site measurements of wind speeds inside and outside (mostly above) street canyons by Ai and Mak (2015) suggests that, depending on AR, the ratio of wind speed inside a canyon to that outside the canyon ranges mostly between 10% and 30%. In addition, wind direction in vicinity of a building near a street canyon is dominated by the along canyon flow combined with upward and downward movements, while the normal-to-facade flows are very weak. The decreased wind speeds and substantially changed flow patterns inside street canyons would influence (mostly lower) wind-induced pressure difference for natural ventilation in buildings, which thus highlight the importance of taking into account urban context in natural ventilation studies.

A few studies examined the natural ventilation performance in buildings when considering the influence of surrounding buildings, which show that the wind speed near building facades could be lowered by up to 86.8% (Gao and Lee, 2012) and the natural ventilation performance in urban buildings could drop by up to 83% (Georgakis and Santamouris, 2006) when compared to isolated buildings. These findings are, however, case dependent and again may not be applicable to a different situation.

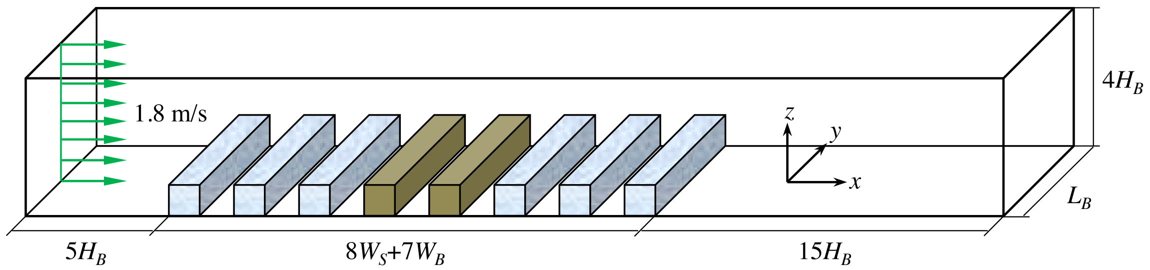
In general, current understanding of natural ventilation in urban buildings is far from sufficient, and there is still a strong need to provide a systematical investigation using a general urban geometry. From both street configuration perspective, the objective of this study is to investigate the wind-induced single-sided natural ventilation in urban buildings. A long street canyon flanked by two buildings is considered, while four AR values are investigated, including 1.0, 2.0, 4.0 and 6.0, which all correspond to the skimming flow regime (Oke, 1987; Ai and Mak, 2015). Ventilation performance of rooms is evaluated using air change rate per hour (ACH). CFD simulations are conducted and steady-state results are obtained by solving the Reynolds-Averaged Navier-Stokes (RANS) equations using the Renormalization group (RNG) $k-\varepsilon$turbulence model.

## CFD simulations: model validation

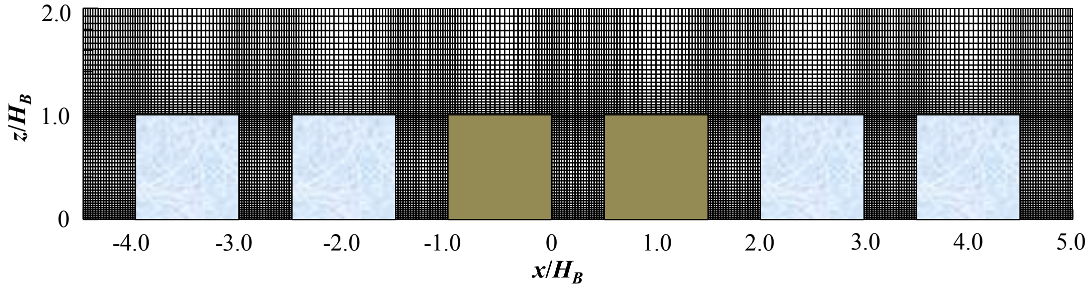
Li et al. (2008) conducted a water tunnel ($L_T \times W_T \times H_T$: 10 m × 0.3 m × 0.5 m) experiment to measure the flow field inside a street canyon. The street canyon of AR ($H_B/W_s$) equal to 1.0 was investigated, which was formed by eight identical building models ($L_B \times W_B \times H_B$: 0.3 m × 0.1 m × 0.1 m). The water flow approaches the street canyons in a perpendicular direction (Figure 1 (b)). The height of the buildings and the width of the street canyon was equal to 0.1 m. The depth of water in the experiment was fixed at 0.4 m. The Reynolds number based on the reference water speed ($U_{ref}$) in freestream at $z = 0.3$ m and the building height was 12,000, implying that $U_{ref}$ was equal to 1.8 m/s. Velocity components in the streamwise and vertical directions along three vertical lines and two horizontal lines on the vertical centerplane ($y = 0$) of the target street canyon (see Figure 1 (a)) were measured.




(a) building model and the vertical centerplane ($y = 0$) of the target street canyon model




(b) computational domain




(c) mesh information on part of vertical centerplane (AR = 2)

**Figure 1:** The street canyon model, computational domain and mesh information.

The building model and street canyon model used in CFD simulations are the same with those in the experiments (see Figure 1 (a) and (b)). Computational domain and its dimensions (see Figure 1 (b)) are selected based on the existing best practice guidelines for CFD simulation of urban aerodynamics (Franke et al., 2007; Tominaga et al., 2008), except that the height and lateral length of the domain follow those in the experiments. The whole computational domain is constructed using structured hexahedral cells (see Figure 1 (c)). After a grid sensitivity test, a grid with 3,168,000 cells in total is used. Same with the experiments, a uniform wind speed at 1.8 m/s is defined at the inlet of the computational domain. A turbulent intensity of 5% and a turbulent length scale of 0.35 m are imposed for the inflow. At the domain outlet, pressure outlet with zero static pressure is specified. Zero normal velocity and zero normal gradients of all variables are defined at the lateral sides and the top of the domain. The domain ground and the building surfaces are imposed as non-slip walls.

ANSYS Fluent 13.0.0 (Fluent, 2010) is employed to conduct the CFD simulations. A steady-state two-equation RANS model, namely RNG $k-\varepsilon$ model (Yakhot and Orszag, 1986), is used to predict the flow and turbulence fields. RNG $k-\varepsilon$ model is selected due to its good performance in predicting flow in and around buildings (Ai et al., 2013). A two-layer model (Wolfshtein, 1969) and standard wall functions are combined to treat the near-wall regions. SIMPLEC algorithm is used for coupling pressure and momentum equations. The second-order schemes are used to discrete the convection and diffusion terms. Convergence is achieved when all scaled residuals are less than $10^{-5}$ and the average wind speeds at important locations within the street canyon are stable for over 50 iterations.

Figure 2 shows the velocity component in $x$ direction along some vertical and horizontal lines on the vertical centerplane of the targe street canyon. In general, the CFD predictions show a good agreement with the experimental data. Overall, the CFD method used in this study including the turbulence model selected (namely, RNG $k-\varepsilon$ model) can predict acceptably the flow field in the street canyon, which justifies the use of it in the rest of this paper.

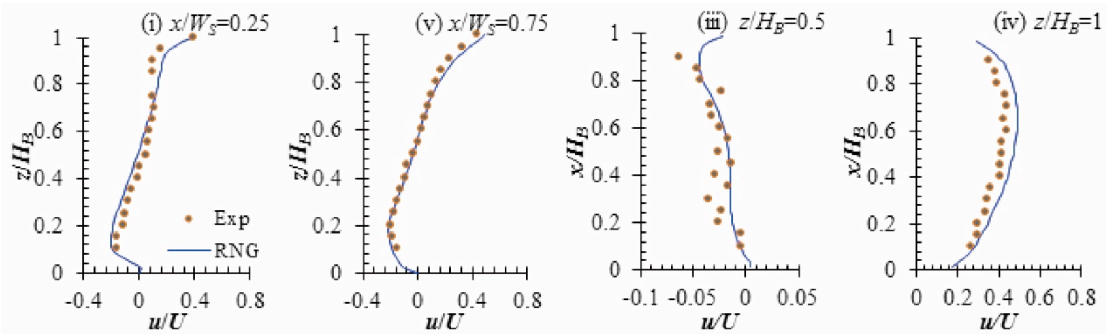



**Figure 2:** Velocity components in $x$ and $z$ directions along two vertical and two horizontal lines on the vertical centerplane of the target street canyon.

**CFD simulations: geometry and computational settings**

A street canyon model formed by two parallel slab-like buildings is investigated in this study (see Figure 3 (a)). Four aspect ratios ($H/B$), namely 1.0, 2.0, 4.0 and 6.0, are considered. The height of buildings ($H$) remains constant, while the width of the street canyon ($B$) is varied to form different AR values. The street canyon is included into a T-shape computational domain (see Figure 3 (b)). This T-shape computational domain configuration and its dimensions are selected, because many previous studies employed such a T-shape computational domain to investigate the atmospheric flow and related processes in a street canyon (Ai and Mak, 2016).

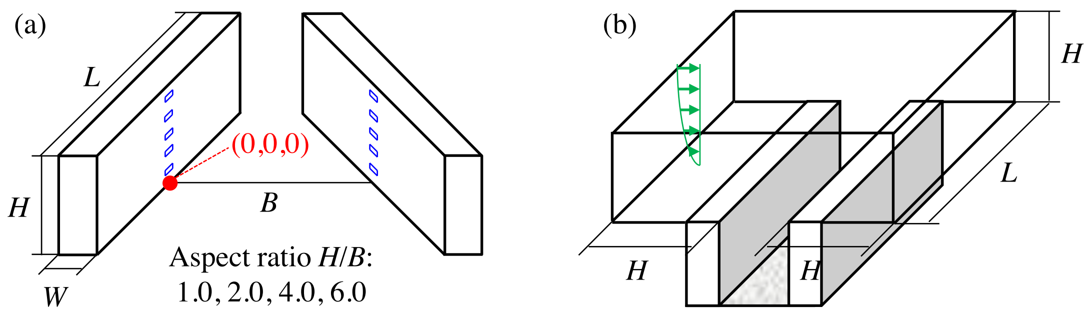



**Figure 3:** Street canyon model (a) and computational domain (b).

The dimensions of each building are 55.2 m × 29.7 m × 6.2 m ($L \times H \times W$). Considering that the dimensions of a single room are 2.4 m × 2.7 m × 3.1 m ($L_R \times H_R \times W_R$), the building models contain 23 × 11 rooms on both windward and leeward sides (see Figure 4). Five rooms on the second, fourth, sixth, eighth and tenth floors, respectively, at the horizontal centres of the leeward facade of the upstream building and the windward facade of the downstream building are investigated (see Figure 3 (a) and Figure 4). The dimensions of the openings are 1.2 m × 0.8 m ($H_O \times W_O$). Depending on the building facade and floor where a room is located, the rooms are named (see Figure 4 (a)).

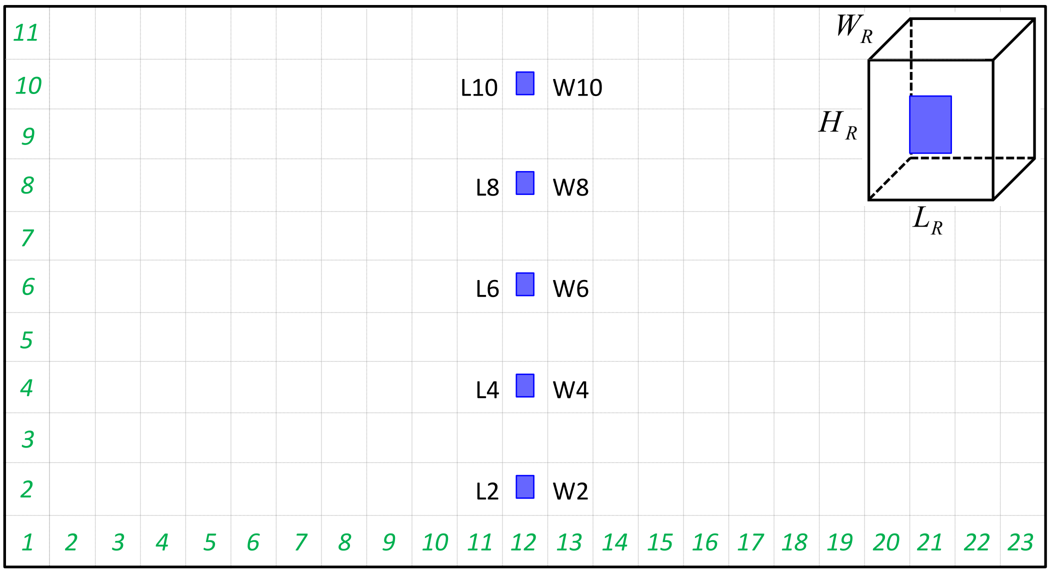



**Figure 4:** Details of building models of the street canyon; the ‘L’ and ‘W’ indicate the leeward facade of the upstream building and windward facade of the downstream building, respectively.

The street canyon is simulated as a 1:15 reduced-scale model, considering that a small model can save computational cost (Ai and Mak, 2014b). The $R_e$ number based on the wind speed and building height in the present study is around 2.4 × $10^5$, which is sufficiently high to allow an independence of $R_e$ number (Snyder, 1981). In this study, hexahedral cells are used to construct the whole computational domain for all cases. As a result of grid sensitivity test, the number of cells used eventually for the four cases are summarized in Table 1.

**Table 1:** A summary of the number of cells used for the four cases.

| AR | 1.0 | 2.0 | 4.0 | 6.0 |
|---|---|---|---|---|
| No. of cells | 6,637,568 | 5,813,248 | 4,988,928 | 4,164,608 |

A logarithmic law velocity profile is defined at the domain inlet. The aerodynamic roughness height $z_0 = 0.001$ m, the reference velocity ($U_{ref}$) at the height of $Z_{ref} = 2m$, $H$ are $U_{ref}$ = 4.2 m/s and $Z_{ref}$ = 59.4 m, the friction velocity of atmospheric flow above the building tops ($u^*$) is 0.17 m/s. The streamwise turbulence intensity $I_u$ is defined as 15% above the building top, while the hydraulic diameter is 38.6 m. The other boundary conditions, solver settings and convergence criteria are the same with those used in the validation study.

**CFD simulations: results and analysis**

The integral method is employed to calculate the mean ventilation rate ($Q_{mean}$), which integrates the mean velocities on an opening that are extracted from a time-averaged flow field generated by the steady RANS simulations. The ACH value can be then obtained by: $ACH = Q_{mean}/V_{room}$, in which $V_{room}$ is the volume of a room.

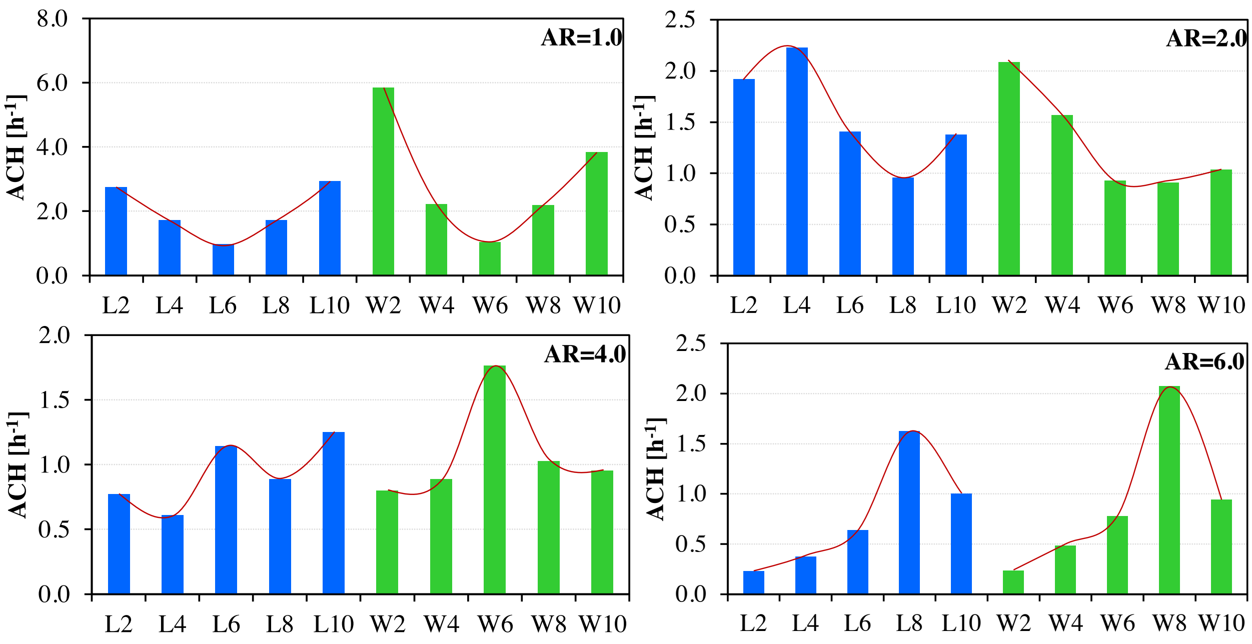



**Figure 5:** ACH values of rooms in buildings near the street canyon under different aspect ratios.

Figure 5 presents the ACH values of rooms at both leeward and windward sides of the street canyon under different aspect ratios. It is obvious that the ACH values along height are not uniformly distributed. For AR = 1.0, the rooms located on the lowest floor and the top most floor show the best ventilation performance. This distribution of ACH values is similar with that observed on an isolated building (Ai et al., 2013). The locations of the rooms that have the best ventilation performance shift with the increase of aspect ratio. The reason for the distributions of ACH values along height can be obtained from the analysis of the flow patterns inside street canyons (see Figure 6).

For AR = 1.0, a large and strong vortex is formed inside the street canyon. Rooms located at the lower and top parts of the street canyon would have the highest possibility to experience normal-to-facade near-wall flows, which contribute mostly to the indoor and outdoor flow exchange. Although it is a fact that along-facade flows still contribute to indoor ventilation due to their turbulent effects (Ai and Mak, 2014a), for the case with perpendicular wind direction studied in this paper, the normal-to-facade flows should be the main contributor of the indoor ventilation. When AR = 2.0, two vortices are formed and they interact at the lower part of the street canyon, which produces opportunities for nearby rooms to have higher ventilation rates (see Figure 5: AR = 2.0). Similar reasons can be found for the cases of AR = 4.0 and AR = 6.0. However, when AR = 6.0, the skimming flow above the street canyon cannot penetrate deeply into the lower part of the street canyon, which results in the very low ventilation rates for the rooms located at the lower part of the street canyon. These distributions of ACH values along height under different aspect ratios are important findings, which reveal the locations where the best and the worst ventilation could occur.

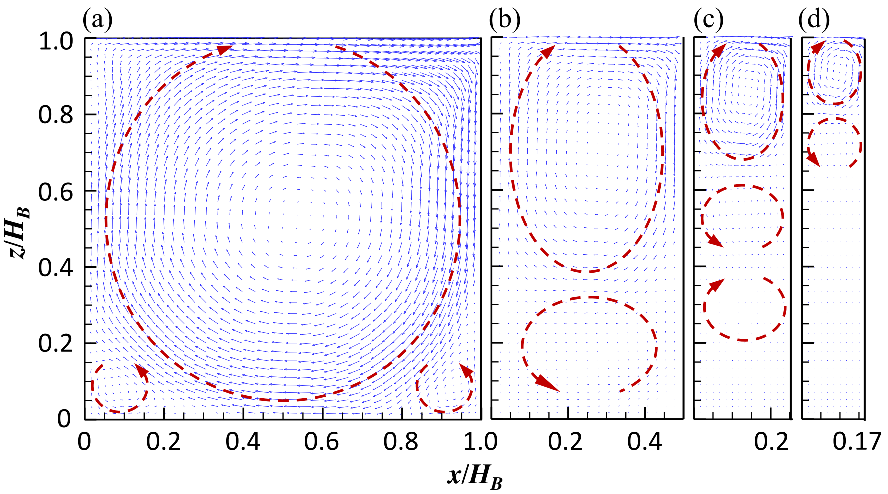



**Figure 6:** Flow vectors on the vertical centerplane of the street canyon under different aspect ratios: (a) AR = 1.0, (b) AR = 2.0, (c) AR = 4.0 and (d) AR = 6.0.

Figure 7 shows the average ACH values of rooms for different aspect ratios. ACH values on both the leeward and windward sides decrease with the increase of aspect ratio. Taking the case of AR = 1.0 as the base case, the percentage decreases of ACH of other cases with a higher AR are calculated. In general, a large decrease of ACH is observed when the aspect ratio is increased. However, such a decrease becomes slow gradually. Obviously, it is more difficult for the atmospheric flow above a street canyon to penetrate deeply into the inside of a deeper street canyon (namely, with a higher aspect ratio). The findings in this section suggest that on one hand describing the major surroundings in detail is important when assessing natural ventilation performance in buildings and on the other hand the aspect ratio of a street canyon is an important factor influencing the building natural ventilation.

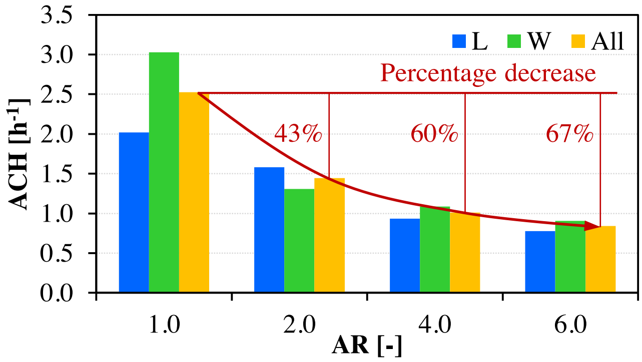



**Figure 7:** Average ACH values of all rooms at leeward facade (L), windward facade (W) and both facades (All), where the percentage decreases of ACH in comparison to the case of AR = 1.0 are also presented.

## Conclusions

Considering four aspect ratios, this study investigates natural ventilation in buildings near a street canyon. Since the atmospheric flow above a street canyon is more difficult to penetrate deeply into a deeper street canyon, ventilation performance of buildings is decreased with the increase of aspect ratio of a street canyon. Compared to the case of AR = 1.0, the percentage decrease of ACH values are, on average, 43%, 60% and 67% for the cases of AR = 2.0, 4.0 and 6.0, respectively. Influenced by flow pattern inside a street canyon, ACH values of rooms along height of a building are not uniformly distributed. Such a distribution varies significantly with the change of aspect ratio. These findings (namely, ACH values and their distributions) suggest that aspect ratio is an important parameter that should be considered when designing natural ventilation of urban buildings.

## Acknowledgement

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# *From Junk Bonds to Green Bonds - Do Sustainability Ratings Matter?*

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**Abstract**
The market for green bonds has been growing rapidly in recent years globally, thereby making them one of the most promising financial instruments to support environmental sustainability. For traditional corporate or sovereign bonds, rating agencies have been key actors to reduce information asymmetry to facilitate the development of debt markets. External reviews, certifications, second or third party opinions and in particular sustainability ratings can play a similar role to verify the sustainable feature of green bonds, which in turn can inform credit analysis and impact investment decisions. However, while there is no uniform definition for green bonds yet, common criteria and methodology for sustainability ratings is also lacking. The paper analyses the theoretical economic functions of sustainability ratings for green bonds and the current international approaches and practices for them. It concludes that there might be much room for improvement for such sustainability ratings and that increased market competition among rating providers might be a key condition of the possible future development of these ratings.

Keywords: environmental sustainability, green bonds, climate bonds, ratings

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## 1. Introduction

A green bond is "*any type of bond instrument where the proceeds will be exclusively applied to finance or re-finance in part or in full new and/or existing eligible Green Projects (...) and which are aligned with the four core components of the GBP*" (ICMA 2017, p. 2.). Several aspects of their rapidly increasing market have been discussed in papers and market commentaries published in recent years. Many of them deal with the evolution of this new asset class and the challenges to establish the necessary definitions and standards for them (see for instance World Bank 2015; OECD 2016). Other pieces of research focus on more specific issues like their investor base (see for instance Bank of America Merrill Lynch 2014) or pricing characteristics (see for instance Östlund 2015; Prag&Andersson 2015). Nonetheless, very few papers have discussed the role of external reviews so far, and even less have focused on sustainability ratings of green bonds.

Ehlers & Packer (2016, p. 4-5.) discusses the many different instruments that have emerged to certify "greenness", including second opinions and green ratings, and highlights that these certification schemes differ across a number of important dimensions. Importantly, the authors consider that a limitation of green bond second opinions is that they do not mandate monitoring and verification on an ongoing basis. However, for investors it would be highly useful to have green bond certifications refreshed periodically. While theoretically index providers can serve this function by excluding bonds that no longer comply with some pre-determined criteria, the authors argue that ratings from major agencies might also be helpful in this regard.

ICMA et. al. (2016, p. 24-25.) discusses the current practices of green bond ratings in some details. Among the advantages, the paper highlights the potential to integrate such ratings with credit rating services so as to help expand the labelling and certification of green bonds into the much broader and deeper mainstream debt capital markets. By that way green bond issuers could benefit from rating agencies' credibility in the mainstream financial markets. At the same time, the paper points out some challenges as well, for instance independence (conflict of interest) issues and the needed specialized expertise. The paper recommends that rating methodologies should reflect that a green bond cannot get a high green bond rating based on good management of proceeds and reporting processes alone if the bond is not funding sound green projects, and that green credentials of the bond should be evaluated against more detailed definitions of green than the high level categories proposed by the GBP.

## 2. External reviews and ratings

External reviews play an important role in the green bond market. The most widely accepted framework for green bonds, the International Capital Market Association's Green Bond Principles (GBP) recommend that - among other things - an issuer's process for project evaluation and selection and the issuer's management of proceeds be supplemented by an external review. These external reviews can serve as an input into the formulation of the Green Bond Process and also to confirm the alignment of the bonds with the key features of the GBP. The Principles contain a non-exclusive list of four potential types of external reviews: consultant reviews, verifications, certifications and ratings. These ratings are separate from an issuer's ESG rating as they typically apply to individual securities or Green Bond frameworks. (ICMA 2017).

In this paper, I use the term sustainability ratings for green bonds meaning a qualitative or quantitative approach by which certain grades are provided to the securities which express the extent they are efficiently and effectively contributing to environmental sustainability. Such ratings should be clearly differentiated from credit ratings, which reflect the credit quality of a bond.

Whereas the GBP contain only broad and high level principles, the so called Climate Bond Standards (CBS) constitute a more robust and effective certification system for climate bonds. Since climate bonds are a subset of green bonds, they have to comply with the GBP and also meet additional requirements as set out in the CBS. Accordingly, issuers seeking a Climate Bond Certification have to meet certain pre-issuance requirements which include engaging a verifier to assess the readiness of the issuer and the proposed bond to conform to the standards. Similarly, the post-issuance requirements of the CBS require assurance from a verifier that the issuer and the bond comply with the relevant requirements of the CBS (Climate Bond Initiative 2017).

Sustainability ratings for green bonds do not have a strong role in these frameworks. The current internationally used standards for green bonds only put an emphasis on second party or assurance opinions to provide an independent confirmation for investors about the compliance with the standards. While this is logical and understandable, it can be argued that such opinions have a somewhat limited efficiency from an environmental policy perspective. As explained in details in Gyura (2017), it can be argued that simple yes or no-type opinions are inferior to sustainability ratings.

Most importantly, external opinions without a rating do not allow comparability between different green bonds and therefore do not support true competition among issuers. Neither does their binary nature provide much incentive for the issuers to pursue environmental excellence and to compete with their own previously issued bonds. In the universe where bonds are either green or not green, the superiority of a bond that more efficiently finances projects with higher environmental benefits will not be recognized. What is more, opportunistic issuers may even feel tempted to engage in a race to the bottom, whereby they target a green label with the least environmental efforts (and therefore least costs).

## 3. Analysis of sustainability rating methodologies

Many companies and NGOs provide ESG (environmental, social and governance) sustainability ratings for companies. Sustainability ratings for green bonds are much less common. Based on Gyura (2017), I analyze three major rating methodologies in the following section based on their global presence and coverage for bonds.

Not surprisingly, the most important players of the credit rating industry have also established their green bond assessment business, and some of them also offer rating-like services. Credit rating agencies explicitly declare that these assessments are not to be confused with credit ratings, and that they are provided as so called Other Permissible Service under the applicable regulation.

Moody's has launched its Green Bond Assessment service in 2016. Its approach is principally qualitative and it focuses on five factors, all of which stem from the Green Bond Principles. These factors are: Organization; Use of Proceeds; Disclosure on the Use of Proceeds; Management of Proceeds; and Ongoing Reporting and Disclosure. A composite grade is constructed out of these factors, which formulates the basis for the overall assessment ranging from GB1 (Excellent) to GB5 (Poor). A bond with a GB5 rating is still a green bond in Moody's opinion, but this indicates a poor approach to "manage, administer, allocate proceeds to and report on environmental projects financed with proceeds derived from green bond offerings" and poor prospects for achieving the "stated environmental objectives". In contrast, a GB1 rating reflects an excellent approach and prospect in the same dimensions (Moody's (2016, p. 2).

Another major rating agency, S&P has chosen a largely different approach. The agency's Green Evaluation is more of a numerical and quantitative nature. While S&P provides a second opinion on the alignment with the GBP, it also assigns a so called "relative green impact score" on green bonds. This relative green impact score is based on scores for three dimensions: transparency, governance and mitigation (environmental impact) or adaptation (resilience level). These are ultimately combined to produce a so called final Green Evaluation, which is on a scale between 0 and 100. This final rating is driven mainly by the environmental dimension. Transparency and governance cannot improve the final Green Evaluation, but they can have a neutral or negative effect on that (S&P Global Market Intelligence 2017).

Within transparency, three factors are scored: the quality of disclosure, reporting, and management of bond proceeds. The governance score evaluates the measures taken to measure and manage the environmental impact of the proceeds of the bond, while the mitigation score expresses the environmental impact of the use of proceeds over the life of the assets, considering several variables (S&P Global Market Intelligence 2017).

Besides the aforementioned large credit rating agencies, other organizations also issue rating-like assessments. CICERO, a Nordic NGO that has been issuing second opinions on green bonds for several years, has applied the so called Shades of Green methodology since March 2015. Strictly speaking, these are not ratings: the three shades of green are used to classify CICERO's second opinions. However, they do perform the functions of ratings as they differentiate between green and greener bonds and allow comparison of different green bonds. The shades reflect an overall, qualitative assessment of how well the issuers' green bond framework supports the transition to a low-carbon and climate-resilient society. By the means of the Shades of Green methodology, the climate and environmental ambitions of the projects supported by the green bond and the robustness of the governance structure of the green bond framework are assessed.

The three shades (light, medium and dark) correspond to an increasing level of supporting a low carbon and climate-resilient or otherwise environment friendly future. The best rating is dark green which is reserved for projects that today already apply the low carbon and climate-resilient solutions of the future. The Shades of Green approach is applied for each of the project types in the framework, and then an overall shading for the green bond is given (CICERO 2016, Gyura 2017). The differences and similarities of these rating frameworks can be summarized in Table 1.

*Table 1: Comparison of rating methodologies*
*Source: Gyura (2017).*

| | **Moody's** | **S&P** | **Cicero** |
|---|---|---|---|
| Nature of rating | Qualitative | Mainly quantitative | Qualitative |
| What is rated? | (i) Organization;<br>(ii) Use of Proceeds;<br>(iii) Disclosure on the Use of Proceeds;<br>(iv) Management of Proceeds;<br>(v) Ongoing Reporting and Disclosure | Transparency, governance and mitigation or adaptation | How well the bond supports transition to a low-carbon and climate-resilient society |
| Rating grades | GB1 (Excellent) to GB5 (Poor) | The final Green Evaluation is on a scale between 0 to 100, which is divided into 5 grades ranging from E1 (highest) to E5 (lowest) | Light, medium, dark green |

## 4. Analysis of current ratings

Moody's has published altogether 16 Green Bond Assessments since the launch of this service until June 2017. The issuers had a mixed background such as municipalities, banks and companies. Interestingly, all issues received top (GB1) rating out of the five possible grades (Moody's s.a.). While theoretically it is completely possible that all issues were excellent to "manage, administer, allocate assets to and report on environmental projects financed by proceeds from green bond", it can be argued that it is certainly somewhat unusual that all assessed securities got the best rating.

S&P has only started its Green Evaluation services in April 2017 and therefore could only issue 6 assessments since May 2017. There is slightly more variability here in the final ratings. Again, almost all issues received top grade (E1) with only one issue getting the second best (E2). However, S&P's methodology allows some variability

within the grades. For the E1 graded issues the overall scores ranged from 77 to 92 (S&P s.a.).
Cicero has issued more Shades of Green opinions. Altogether 28 opinions were published until June 2017 (CICERO s.a.). The majority of green bonds got the best (dark green) rating, although the weighted share of medium green rated bonds is higher (2nd Table).

*Table 2: CICERO's Shades of Green Ratings Distribution (2015 to June 2017)*
*Source: Author's calculations based on data available at CICERO (s.a.) and issuers' websites*

| | Number | Share | Weighted share |
|---|---|---|---|
| Dark Green | 16 | 57% | 40,7% |
| Medium Green | 11 | 39% | 58,6% |
| Light Green | 1 | 4% | 0,0% |

This indicates that medium green bonds issues were on average larger than those of dark green ones, as also shown on Chart 1 below.

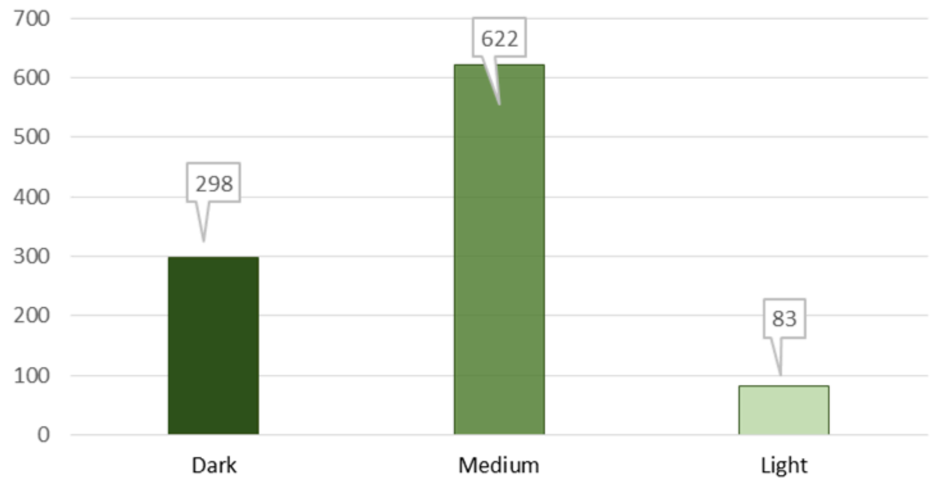


*Chart 1: Average issue size (2015 to June 2017, USD million)*
*Source: Author's calculations based on data available at CICERO (s.a.) and issuers' websites*

## 5. Discussion

As explained in Section 2, there are strong arguments for increasing the importance of sustainability ratings for green bonds. Obviously, it would be equally important to avoid excessive reliance on ratings as well, a failure seen with external credit ratings for (non green) securitized assets in the subprime financial crisis of 2007-2009. The green bond standards themselves do not promote sustainability ratings any more than simple second opinions, and it would be probably unwise to change the standards or to issue regulations so that such ratings gain importance in a non-organical (non-market based) way. (It is worth mentioning here that in financial regulation regulatory driven reliance on external credit ratings is being drastically reduced.) As a result, it is probably the quality of sustainability ratings that could potentially increase their importance.

Quality in turn might be fostered by increasing competition between agencies providing sustainability ratings. It could be argued that issuers (who currently pay for these services) would order sustainability ratings if the latter was an important benchmark for green investors, something that might be a key element of their investment decisions. In this case the more credible, reliable and informative ratings might provide a competitive edge for green bond issuers using the best rating agencies' services.

But how to decide which rating is the "best", i.e. the most credible, reliable and informative (at a given price, obviously)? A precondition for that the market's selection forces can work is that rating agencies methodology is as transparent as possible. Credit rating agencies put a lot of emphasis on making their rating approach transparent (in fact, they are also legally forced to do so). The current sustainability rating methodologies as published are fairly short and concise compared to credit rating methodologies, even if accounted for being less sophisticated and less complex.

Once that – based on the methodology - investors can understand more thoroughly what factors and how are being rated for a given green bond, it becomes theoretically possible to compare rating (given at a point in time) and reality. For credit ratings, rating performance is easy to capture since assets' credit quality changes throughout the lifetime of bonds or loans. Credit rating agencies periodically and also on an ad-hoc basis issue rating reviews which can track such changes. Obviously, such subsequent ratings to some extent also allow to back test how thorough the initial rating assessment was. (Here an important question is to assess whether subsequent rating changes were driven by foreseeable or unpredictable factors.) By analogy, during the lifetime of a green bond, a subsequent rating might be used to rate – for instance - the extent the green bond framework was adhered to or the projects actually financed by the bonds.

Of course, these are much more difficult to observe externally than the credit quality of a bond, so subsequent sustainability ratings would have to be relying to a large extent on the impact reporting of the issuer. Still, with time it would become possible to back test the accuracy of the initial ratings, and thus for investors to identify the most reliable sustainability rating providers. However, there have been very few (if any) such subsequent ratings so far, which is of course explainable also by the fact that the ratings themselves were only recently issued.

Another effective way to foster competition between sustainability rating providers (complementary to the previously mentioned one) would be if the same green bond issues were rated by multiple agencies. Again this is quite common with credit ratings, but very rare with sustainability ratings. Multiple ratings not only allow the investor to apply the four-eyes principle, but also to assess which rating proves to be the most precise during the lifetime of the green bond. Unsolicited ratings might play a role here, although due to cost reasons it looks unlikely that such ratings would be issued in the short or middle term future.

In Section 4 I showed that currently top sustainability ratings are quite common. This may be because of several reasons. It is possible that only issuers of the greenest bonds hired rating agencies (a kind of a positive selection bias), or – alternatively – it may be a sign of a grading scheme in which it is fairly easy to receive top ratings. In either case a potential way to incentivize environmental excellence would be to set the "bar" higher time by time, so that bonds need to become even "greener" to get the best rating. While this might raise some comparability challenges in time series, green technologies (and in fact even the green bond standards) are evolving fast, meaning that the greenest investment today might be the least green tomorrow.

Lastly, it would also be important to let the watchers be watched by someone else, so that sustainability raters are exposed to even stronger market discipline. Researchers – be they market analysts or academics – might play a useful role in empirically testing sustainability ratings. However, today the conditions are to a large extent missing for this. There are still quite few green bonds outstanding and very few have sustainability ratings, not to mention multiple ratings for the same green bonds. Time series are also quite short for obvious reasons, and subsequent ratings (rating reviews) are virtually non-existent, too, making rating migrations unobservable. While green bond standards recommend (or in some cases, require) impact reporting, the impact reports published so far do not seem to be a proper basis for rating back testing, for several reasons, but in particular because of non-comparable, non-standardized and often on-audited contents.

## Conclusion

As a young and fast-growing asset class, green bonds need to establish and maintain credibility in the eyes of investors. External reviews are one the most important pillars for that. Out of the many types of external reviews for green bonds, sustainability ratings seem to be the most informative and most capable to spur competition in greenness among issuers. However, today very few agencies provide such ratings and very few green bonds are rated from a sustainability point of view. In this paper I have argued that sustainability rating should not be promoted via regulation but rather by the superior quality of them compared to simple yes-or-no-type second opinions.

For that purpose in turn, a stronger competition between rating providers seems to be needed, which might be fostered by increased transparency in rating methodology and the issuance of subsequent ratings and multiple ratings for the same green bonds to make rating accuracies' assessment possible. Here researchers may also have an important role to empirically study sustainability ratings, although the conditions for detailed empirical studies are largely missing today.

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# *Energy Efficiency in the Residential Sector: Identification of Promising Policy Instruments and Private Initiatives among Selected European Countries*

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**Abstract**
Improving residential energy efficiency is widely recognized as one of the best strategies for reducing energy demand, combating climate change and increasing security of energy supply. However, progress has been slow to date due to a number of market and behavioural barriers that have not been adequately addressed by energy efficiency policies and programmes. This study is based on updated findings of the European Futures for Energy Efficiency Project that responds to the EU Horizon 2020 Work Programme 2014-15 theme ‘Secure, clean and efficient energy’. This article draws on five case studies from selected European countries - Finland, Italy, Hungary, Spain, and the UK - and evaluates recent energy efficiency developments in terms of indicators, private initiatives, and policy measures in the residential sector. Our analysis shows that the UK government has implemented a better range of policies, coupled with initiatives from the private sector, aimed at improving energy efficiency. However, its existing conditions appear to be more problematic than the other countries. On the other hand, the lack of effective and targeted policies in Finland resulted in increased energy consumption, while in Hungary, Spain and Italy some interesting initiatives, especially in terms of financial and fiscal incentives, have been found.

Keywords: energy efficiency policy, residential sector, European Union, NEEAPs, ESCOs

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## Introduction

Energy efficiency is widely considered as the most cost effective way to enhance security of energy supply, and to reduce emissions of greenhouse gases. In fact, the cheapest energy, the cleanest energy, the most secure energy is the energy that is not consumed at all (EC 2016a). Furthermore, energy efficiency improvements might have the potential to support economic growth and social development, to improve occupant health and well-being, and to enhance competitiveness and investment opportunities (IEA 2014a).

In the last years, the European Commission has acknowledged these benefits in a series of directives and long-term strategy documents - such as the Energy Performance of Buildings Directive 2010/31/EU, the Energy Efficiency Directive 2012/27/EU, the Energy Roadmap 2050, etc. - by establishing a set of measures for improving the existing policy framework of measures and promoting energy efficiency within EU. In addition, the new 30% binding energy efficiency target for 2030 recently proposed by the European Commission in the Winter package (EC 2016a) put the level of ambition of European energy efficiency policies into sharp focus. These regulations and policy documents have been mainly designed to meet the EU climate policy goals, i.e. an 80% reduction of CO2 emissions by 2050, but they are still not in line with the commitments under the Paris climate treaty which would require more efforts, so for the future stricter rather than relaxed regulations can be expected.

The residential sector is responsible for one of the largest share of energy consumption presenting the highest cost-efficient potential for mitigation, and it is consequently vital to meeting the EU objectives toward a low-carbon economy and energy system. Nevertheless, the move towards energy efficiency is happening too slowly and there continues to be a degree of inertia on a national level. Recent years' experience has shown that there are considerable barriers to full uptake of economically effective and technically feasible energy savings opportunities across the EU (EC 2016b).

In compliance with the Energy end-use efficiency and energy services Directive 2006/32/EC (ESD) and Energy Efficiency Directive 2012/27/EU (EED), Member States are required to translate the energy savings objectives into domestic and effective measures in their National Energy Efficiency Action Plans (NEEAPs). But there exists a wide disparity in terms of content, level of detail in describing, and the level of ambition about the energy efficiency instruments in place and planned for the next years between Member States. At the same time, the energy share of residential sector strongly varies among countries due to different energy infrastructure, climate conditions, energy resource availability, income, economic structure (IEA 2014b), dwelling characteristics, energy culture (Stephenson et al. 2010), household behaviour (Lopes et al. 2012; Frederiks et al. 2015), and other country-specific conditions.

Therefore, the type of policy instrument suitable for driving energy efficiency depends on many country and sector specifics, and the circumstances determine which policy instruments are more appropriate than others, depending e.g. on market and behavioural barriers, and target groups. However, the achievable impact of energy efficiency policies

depends more on the design of the instrument and the way in which it is implemented than on the type of instrument itself (Phylipsen 2010).
Although policy maker have a major role to play in impacting energy consumption in the residential sector, there are many other players that can stimulate energy efficiency improvements:

- Energy Service Companies (ESCOs), under an Energy Performance Contracting (EPC) arrangement, implement an energy efficiency project and use the stream of income from the cost savings to repay the costs of the project;
- Energy utilities provide advice and assistance to energy consumers, technology development, on-bill financing, etc.;
- Non-Governmental Organisations (NGOs) promote energy efficiency through an active participation of citizens and provide input to policies;
- National or regional banks develop specific packages for households to support energy efficiency improvements, renewable energy and broader green investments.

A comprehensive review of all energy efficiency policies and private initiatives in the residential sector of the European Union is beyond the scope of this paper, but several instruments seem particularly relevant to understanding the recent trends of energy efficiency, especially in terms of country-specific actions. This paper provides some overarching European data and insights, but mainly concentrates on five case countries - Finland, Hungary, Italy, Spain and the United Kingdom - by evaluating recent residential energy efficiency policies and private initiatives complementing public activities.

In order to make a robust assessment and provide an accurate picture of the European Union and the countries under investigation, we first build disaggregated indicators of energy efficiency suggested by the International Energy Agency (IEA 2014b; IEA 2014c). By doing so, we provide a strong basis for policy making evaluation and development of effective energy efficiency strategies. Then, we assess the residential energy efficiency policies in force, identifying best practice, instrument-specific success factors, and policy gaps. Moreover, we analyse the role of the private sector in stimulating the investments in energy efficiency and complementing European and national public policies. We conclude by discussing whether the policy instruments and private measures targeting energy efficiency in the residential sector are sufficient to contribute to reductions in energy use. In addition, we formulate policy recommendations in order to strengthen the existing policy packages.

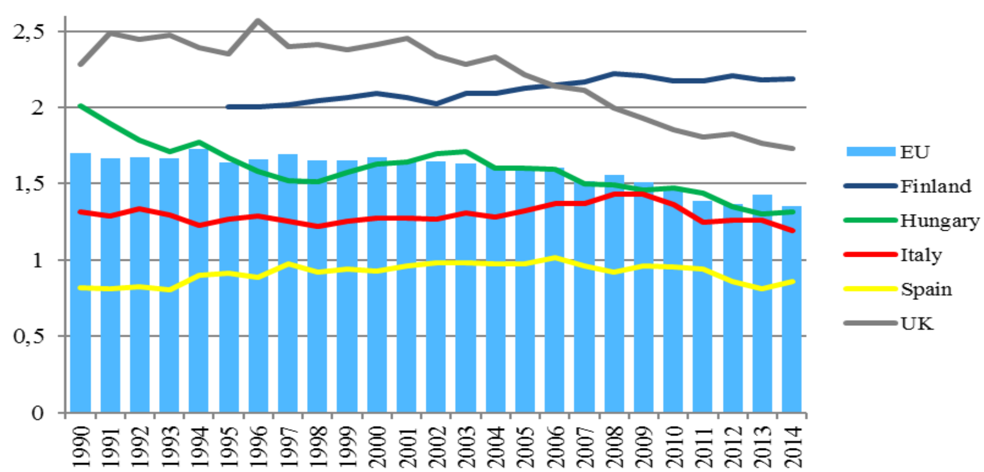
Most of the literature focuses on the analysis of the energy efficiency policies by the type of instrument (regulatory, economic, informational, etc.) without considering (i) the way they are implemented, (ii) synergies among policies, and (iii) the underlying determinants driving the design of a specific policy. In addition, to the best of the authors' knowledge, the role of the private sector across multiple actors in supporting the national government to stimulate energy efficiency investment in the residential sector has not been previously analysed.

## The EU residential energy sector

The residential sector accounted for about a quarter of the total final energy consumption in Europe in 2013. This is only a global average of the European Union, and there exists a wide disparity of the share of the residential energy sector among countries due to climate condition, resource availability, energy infrastructure, economic structure and other country-specific conditions. For example, among the countries under investigation, in Spain the residential sector represented only 18.3% of the total energy consumption in 2013, while in Hungary and UK it was 32.5% and 30.6%, respectively; in Finland it represented 19.9%, while in Italy it was 25.3% (Odyssee database 2017).

At EU level the space heating consumption holds the largest portion of households energy use representing 68% in 2013, followed by the electricity consumption for electrical appliances and lighting (14%), water heating (13%) and cooking (5%). A similar composition of the energy consumption by end-use is found in Finland, Hungary, Italy, UK, but not in Spain where the portion of space heating is lower and electricity consumption is higher than the other European countries, respectively.

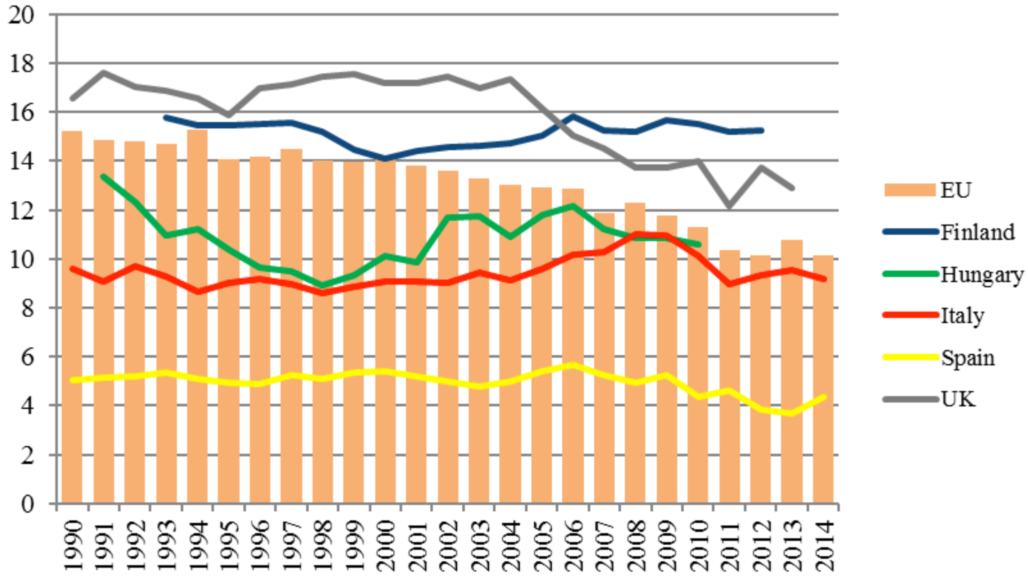
For each end-use, we selected the indicators of energy efficiency suggested by the International Energy Agency (IEA 2014b; IEA 2014c), namely the final residential energy consumption per stock of dwelling permanently occupied (at normal climate[1], figure 1), the final residential space heating consumption per floor area 1990-2014 (at normal climate, figure 2), and the final water heating, cooking, electrical appliances and lighting consumption per stock of dwelling permanently occupied (figure 3).




Source: Authors' elaboration based on Odyssee database (2017)

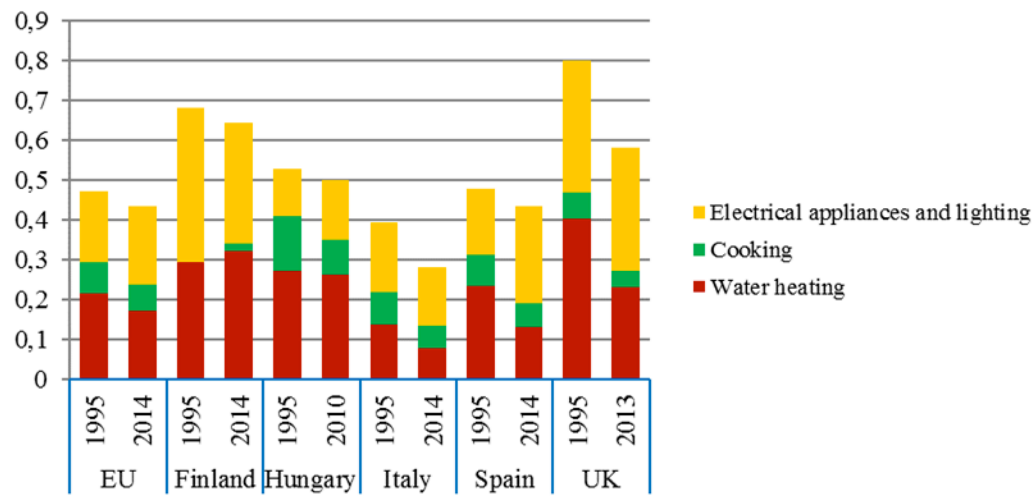
**Figure 1. Final residential energy consumption per stock of dwelling permanently occupied 1990-2014 (at normal climate) for the European Union and selected countries (toe/dwellings)**

[1] 'Normal climate' or 'climate correction' is an adjustment to space heating and cooling energy consumption to normalise the consumption pattern over time by removing the impact of year-to-year temperature variations (IEA 2014b; IEA 2014c).




Source: Authors' elaboration based on Odyssee database (2017)

**Figure 2. Final residential space heating consumption per floor area 1990-2014 (at normal climate) for the European Union and selected countries (Kgoe/m2)**




Source: Authors' elaboration based on Odyssee database (2017)

**Figure 3. Final water heating, cooking, electrical appliances and lighting consumption per stock of dwelling permanently occupied in 1995 and 2014 for the European Union and selected countries (toe/dwellings)**

While these detailed indicators do not fully explain what is driving the changes in observed energy consumption, they provide indications about recent trends, and combined with implemented European and national policy and private instruments aimed at reducing energy consumption and CO2 emissions, they can provide some guidance on the efficiency improvements achieved in the residential sector.

**Promising policy instruments**

**Improving the energy performance standards of new and existing buildings**

Buildings standards ensure that the desirable energy performance of e.g. building components and (especially) heating equipment is achieved even when its purchaser does not show interest in obtaining more efficient products due to either credit constraints or lack of incentives (IEA 2011).

Reviews of the literature on energy efficiency policy shows that instruments such as energy efficiency standards have been one of the main drivers of innovation (Noailly 2012), and the preferred policy option in the European Union to address barriers to energy efficiency (Bleischwitz et al. 2009).

The 2010 recast Directive on Energy Performance of Buildings (recast EPBD) is the main legislative instrument affecting energy use and efficiency in the building sector in the EU. In a recent study commissioned by the DG Energy, the ICF Consulting Group analysed the national frameworks and systems put in place by Member States to help deliver and achieve compliance in relation to requirements of the Energy Performance of Buildings Directive (EPBD) concerning minimum energy performance and energy performance certificates (EC 2015b). Among the countries under investigation, Italy received an higher score in terms of compliance rate with the application of MEP requirements and production and use of EPCs placing fifth in the EU Member States' ranking, followed by the UK (seventh position), Finland (tenth position), Spain (thirteenth position), and Hungary (fifteenth position). Most of the Member States reported a high compliance rate for MEP requirements. Spain and Hungary failed to comply with the production of EPCs in rented buildings, while Italy and the UK have not produced EPCs for public buildings.

**Financial facilities to encourage private capital investments**

Financial incentives can take many forms – grants, subsidies, soft loan, etc. – and are commonly used to encourage energy efficiency improvements by lowering inhibitive up-front costs faced by households. According to the EED (preamble (52) and article 12 (2a)), Member States should make use, promote and facilitate innovative financing mechanisms that reduce the risks of energy efficiency projects and allow for cost-effective renovations among households.

In Hungary, the main financial instrument managed by the central government to promote investments aimed at furthering energy efficiency in households is a grant scheme called the 'Warmth of the Home Programme'. The Warmth of the Home Programme was launched in September 2014 and consisted of five sub-programmes providing co-financing up to a maximum of 40% or 50% of the total expenses incurred

by the households. Due to overwhelming interest on the part of households, the sub-programme funds have been sourced out fully after announcement, either within hours, or after a few days the latest (Slezák et al. 2015).
In Spain, the Royal Decree 233/2013 of 5 April 2013 of the Ministry of Development approved the State Housing Plan aimed at promoting the energy renovation of residential buildings. Measures eligible for subsidy include: improving the thermal envelope of buildings to reduce energy demand for heating and cooling; installing heating, cooling, domestic hot water and ventilation systems and common building facilities such as lifts and lighting. Up to 35% or 50% of the eligible costs of the action, with a maximum of up to €11,000 euros per house or 100 m2 of the premises useful surface could be claimed.

**Fiscal incentives that indirectly reduce the cost of investments**

Fiscal incentives for the energy efficiency in buildings include several measures to lower the taxes paid by consumers and are one of the instruments that can be used by Member States to promote and facilitate efficient use of energy among domestic costumers (EED, article 12 (2a)). In particular, measures include tax deductions on retrofitting investments and equipment, tax credits, tax reductions and rebates, accelerated depreciation allowances, tax or customs duty exemptions. They are widely used across the European Member States but not to the extent of financial instruments as grants. From a government perspective, fiscal incentives impact revenues, while grants require outlay of the public budget. Fiscal incentives are difficult to limit to a certain amount of revenue forgone and the amounts may only come to light at the end of the fiscal year, while costs for grants may be easier to track and control as they have a certain budget limit (Hilke and Ryan 2012). However, one advantage of fiscal incentives over grants, is that they are more likely to encourage greater scale of projects as they are usually granted over a longer time period and do not have a limited budget attached (Dyer et al. 2011).

Fiscal incentives have been traditionally common in Italy and Finland. Tax deductions for the energy upgrading of buildings were introduced in Italy by the Budget Law 2007 and are still in force. They consist of reductions of IRPEF (personal income tax) and IRES (corporate income tax) in respect of actions to improve the energy efficiency of existing buildings.

A tax deduction for the labour costs incurred in replacing, upgrading and repairing the heating and electricity systems of residential houses has been available in Finland since 2000. The maximum amount of household deduction varied according to the year it has been claimed. The house owner bears the first €100 of the labour costs and the deduction is available for the taxation of both spouses.

**Promotion of small-scale renewable energy production systems**

Most government policies start from the assumption that renewable energy and energy efficiency investments go hand in hand by creating a virtuous circle: one enhances the other. With greater energy efficiency, the total demand for energy drops, meaning that the same amount of renewable energy covers a larger share of demand. At the same time, renewable energy technologies enhance efficiency, creating a symbiotic relationship (IRENA 2015). In addition, many applications of renewable energy, in particular renewable heating technologies, are more effective in an energy efficient home. Thus, the Italian and the UK governments implemented policies to promote the generation of renewable thermal energy in buildings as a way of contributing to the national energy efficiency target.

The Thermal Account, introduced by the Ministerial Decree of 28 December 2012 'Renewable Energy for Heating & Cooling Supporting Scheme', is the first nationwide and the youngest direct incentive scheme in Italy for projects of energy efficiency improvements and the generation of small-scale renewable thermal energy in buildings.

In order to support the deployment of renewable and low-carbon heating technologies in the residential sector, the UK government launched on 9 April 2014 the Domestic Renewable Heat Incentive (Domestic RHI). This scheme helps to bridge the gap between the cost of renewable heating systems and the conventional alternatives and it is open to home owners, private landlords, social landlords and self-builders.

**Measures addressing vulnerable consumers and fuel poverty**

The EED article 7 (7a) allows Member States to include requirements with social aims in their Energy Efficiency Obligation Schemes, as for example to prioritize households in energy poverty or social housing (EC 2012). However, most of the Member States have not translated this requirement into national legislation, if not through one-off measures.

The United Kingdom is one of the few EU Member States where this problem is both recognized and systematically addressed by means of household support policies and energy efficiency investments (Bouzarovski 2014). The Energy Companies Obligation (ECO), which started in 2013, is a government scheme for Great Britain that placed legal obligations on larger energy companies to deliver energy efficiency measures to domestic premises–targeted at low-income and vulnerable households, and homes in low income areas.

**Measures addressing the landlord-tenant problem**

According to the article 19 of the EED, Member States should take appropriate measures to overcome misaligned incentives between landlords and tenants. The landlord-tenant problem occurs when landlords have little incentive to invest in the energy efficiency of their properties, given that it is the tenant who benefits from lower energy bills (Allcott and Greenstone 2012). As a consequence, rental properties tend to be less energy efficient than owner occupied houses.

This split incentive between owners and renters is one of the greatest barriers hindering the development of sustainable renovation of residential buildings in Europe, but it has hardly been an objective of policy-making. In 2015, on average in the European Union, 69.5% of the dwellings were owner-occupied (own it outright and mortgagors), while the remaining were privately or social rented. Significant differences exist among Member States: for example, in Hungary 86.3% of the dwellings, while in UK only 63.5%, were owner occupied in 2015. In particular, the private rented sector has been growing in recent years in UK, and is at its highest level since the early 1990s. In 2014-15, 19% (4,3 million) of households were renting privately, while 17% (3,9 million) of households lived in the social rented sector (EHS 2014-2015).

**Increasing consumer information and promoting behavioural change**

Consumers need relevant information and motivation for taking action, and to be able to make informed decisions and choices towards energy efficiency measures. While information is not sufficient to generate motivation or change behaviour, it is nonetheless a necessary (but not sufficient) condition for action.

With the aim of guiding consumers to be more concerned of energy efficiency in their purchasing decisions, governments and energy agencies have introduced in the last years a number of different mechanisms, ranging from energy labels and energy performance certificates to pure publication of information in brochures and mass media campaigns via internet or TV, respectively. Their effectiveness vary depending on the objective pursued, the obstacles present, and the way they are integrated with measures addressing routines, social norms and values, etc., and of course the technical feasibility.
The shift in consumer behaviour towards energy conservation measures can be also supported by the installation of smart meters and more accurate billing information (articles 9, 10 and 11 of the EED). By providing real time feedback, smart meters allow consumers to take control of the energy bill, and to become more aware of their actual energy consumption. The early actor of the smart meters roll out has been Italy (completed in 2011), followed by Finland and UK; in Spain the complete roll out of the smart meters is expected to be by the end of 2018, while in Hungary pilot projects are still on-going.

**Private initiatives**

Beyond public programs and policy instruments, energy efficiency improvements in the residential sector are supported by the private sector in a variety of ways:

- Initiating and implementing concrete actions, e.g. through providing loans, investment and implementing demonstration programs, alternative solutions to low-energy buildings;
- Organizing awareness raising and information exchange programs;
- Providing input to policies, analysing policies and initiating discussion.

Mobilising investments and actions from the private sector is therefore essential to complement public activities and to contribute meeting the energy efficiency and climate change goals. What motivates the private sector is the possibility for profit. Shareholders tend to request maximal dividends (institutional shareholders all the more), and reject ‘climate motivated’ actions. It is politics which must make sure that the environmentally necessary is also the economically desirable – that is the justification for economic instruments and should be our yardstick for their efficacy.

**Energy service companies (ESCOs)**

The ESCO can be a natural or legal person that delivers energy services and/or other energy efficiency improvement measures in a user's facility or premises - such as project finance, engineering, project management, equipment maintenance, monitoring and evaluation - and accepts some degree of financial risk in so doing (EC 2006). Despite the large economic energy saving potential, the ESCO market in the residential sector is much less developed compared to the industry, tertiary and public sectors in the European Union, as indicated in a recent JRC ESCO report (Bertoldi et al. 2014). Irrek et al. (2013) have traced the barriers preventing a large scale application of the ESCO concept in the residential sector on several sources: (i) the particularly high transaction costs for ESCOs relative to the small amount of energy costs and thus potential cost savings per single energy efficiency service supplied; (ii) the decision making processes existing in multi-apartment buildings, where typically at least one half of the apartment owners must agree on the energy efficiency investment; (iii) the perception of the ESCO as not a trustworthy organisation and the fear of households to become too much dependent on the ESCO, especially if the contract also includes the supply of energy; (iv) the difficulties for residential customers to understand the ESCO model and the EPC financing and contract and lack of information on the availability of ESCO services. The number of ESCOs, their market size and the type of services provided varies a lot among Member States. In Italy (that ranks second in terms of number of ESCOs in Europe after Germany) there were about 50-100 ESCOs in 2013, with a market size of €500 million.

**Energy providers**

The principal driver of the energy providers to deliver energy saving activities is induced by regulatory mechanisms created by the 'Energy Efficiency Obligation Scheme' (EEOS, article 7, EED) which calls on each Member State to ensure that energy providers achieve new savings each year from 1 January 2014 to 31 December 2020 of 1.5% of the annual energy sales to final customers of all energy distributors.

In the transposition of the EEOS into national law, the government of Finland decided to adopt the 'alternative approach', meaning that it opted to take other policy measures such as energy or CO2 taxes, financing schemes and fiscal incentives, voluntary agreements, etc., in order to achieve an equivalent energy saving target, while Hungary, Italy, Spain and the UK adopted a combination of both EEOS and alternative measures (Bertoldi et al. 2015).

Even though in almost all jurisdictions we find energy providers active in some form of demand-side management or other types of programmes, this energy efficiency activity seems to be only a window dressing or driven by legal requirements. On the other hand, in some cases energy suppliers seem to be genuinely attempting to develop and implement new business models that incorporate energy efficiency, driven by a non-traditional profit motive and a belief that it is the right thing to do (Fawkes 2016).

## Conclusion and implications for energy policy

This study builds on the EU Horizon 2020 project 'European Futures for Energy Efficiency' and provides unique insights from a large set of different perspectives bringing out ground-breaking elements for the European residential energy sector.

In this article we evaluated recent energy efficiency developments in terms of indicators, private initiatives and policies implemented in the residential sector over the last years in Finland, Hungary, Italy, Spain and the UK. Since it is not possible to show a causal relation between energy efficiency trends and differences on the basis of indicators alone, an assessment of implemented policies combined with private measures targeting energy efficiency in the residential sector can further improve the understanding of the country-specific conditions and actions. With the development of this framework that takes into account multiple actors and both quantitative and qualitative criteria in the evaluation process, we aim at contributing to a comprehensive and comparable analysis among case studies.

When compared to what has been done in the last years in Finland, Spain, Italy, and Hungary, the UK government seems to have implemented a better balanced set of energy efficiency policies targeted at the residential sector, with the participation of diverse private actors. In fact, a holistic policy package with a medium-term framework addressing many aspects of energy efficiency in the residential sector is also partially supported by a developed ESCO market and legal obligations placed on energy suppliers to deliver domestic energy efficiency programmes. But the UK residential energy sector appears to be more problematic than other countries. In particular, the prevalence of older dwellings in the national stock built to lower standards of energy efficiency combined with a high share of the private rented sector in the housing market leaves larger untapped potential for improvements than the other countries under investigation. In addition, a confusing number of only slightly different policy measures specifically address the same target (e.g. vulnerable consumers, energy poverty); increased flexibility, combined with a long-term perspective and continuous funding could help to optimise their impact.

It is currently unclear how Brexit will impact future energy efficiency policies in the UK. On the one hand, it is unlikely to change the orientation towards the Government's greenhouse gas target codified in the 2008 Climate Change Act. Consequently, the importance of energy efficiency improvements in the residential sector will prevail, as reducing household emissions is an important mean contributing to meeting the national emission reduction targets. On the other hand, after Brexit the UK will not be obliged to transpose the EU Winter Package into national legislation, in particular not the extension for the period 2021-2030 in article 7 of the proposed new Energy Efficiency Directive. This means that progress will slow unless a strong national energy efficiency strategy replaces the EU legislation as a driver of efficiency improvements.

With regard to Finland, improvements of energy efficiency in the residential sector seem not to be a priority for policymakers. Considering that Finland has one of the highest energy consumption per capita and space heating demand per dwelling in Europe, this result is quite surprising. Beyond a general tax reduction for any household services, no real economic incentives have been provided to stimulate energy efficiency investments in the last years. Also, issues like fuel poverty and the landlord-tenant problem have not been taken into account in the national energy efficiency strategy, and the private sector remains a marginal player. As a result, Finland is the only country that did not decrease its residential energy consumption per stock of dwelling permanently occupied within the period 1995-2014. However, the lack of political commitment in this regard can partially be explained by the policy makers' focus on the energy-intensive industries representing almost half of the energy consumed in the national energy sector.

Also in Spain the residential energy sector seems not to be at the top of the political agenda, while a major attention has been given to the transport sector representing about 40% of the energy consumption. But as opposed to Finland and the UK, in Spain the residential energy sector is one of the most efficient in Europe, mainly because of the modern building stock and the low level of space heating demand. In addition, with the State Housing Plan 2013-2016 and the PAREER-CRECE Programme, both the national and local governments have recently allocated a significant share of the budget for energy efficiency and saving projects in residential buildings.

Similarly, with the Warmth of the Home Programme, the Hungarian government provided financial incentives to households ranging from the replacement of inefficient appliances or obsolete facade doors and windows, to complex energetic refurbishment of blocks of flats. The success of this policy measure has been witnessed by the rapid end of funds allocated (the other side of the coin is that the program was underfunded as compared to demand). Also, in order to increase energy awareness, large-scale educational programmes targeted to specific groups, have been provided by both the government (ECARAP) and the energy providers E.ON and ELMÜ-ÉMÁSZ.

With regard to Italy, we have found some interesting policy initiatives, especially in terms of fiscal incentives and promotion of small-scale renewable energy sources that have kept the energy demand per dwelling stable. However, these measures have not been developed into a comprehensive policy package addressing all the aspects of the residential energy sector. The tax deduction scheme (implemented for the first time in 2007 and still in force) has proven to be very effective in attracting more investments than what it actually cost in terms of foregone fiscal revenue. In addition, the Thermal Account that entered into force for the first time in 2012 has provided substantial incentives for renewable energy and energy efficiency investments. Subsidies covering part of the expenses for renovation will be available until 2021. Benefits from these policy measures are also exploited by the ESCO market that has grown rapidly in the last years, becoming one of the largest in Europe.

Overall, an optimal policy strategy aiming at improving energy efficiency in the residential sector should seek to impact different barriers and target segments through a holistic approach pursuing multiple goals coherently, mutually supporting each other. Our study has provided some evidence on this. We could also confirm that an energy efficiency policy package is likely to be more effective if it is maintained over the long-term, while remaining flexible. In this latter regard, the Integrated National Energy and Climate Plans (EC 2016c) that will replace the National Energy Efficiency Action Plans (NEEAPs) and the National Renewable Energy Action Plans (NREAPs) and that will cover the ten-year period 2021-2030, will stimulate Member States to think up new energy efficiency policies with a longer perspective.

A long-term policy horizon could empower the confidence in the private sector that there is money to be made through efficiency. But getting private investments in energy efficiency in the residential sector is challenging. The cliché "the cheapest energy, the cleanest energy, the most secure energy is the energy that is not used at all" commonly used to highlight the advantages of energy efficiency, actually points its greatest weakness from a business point of view: there is, or appear to be, nothing to sell, and thus no profit (Fawkes 2016). Energy providers cannot easily decouple utility profits from energy volumes and ESCOs cannot benefit from economy of scale by selling energy efficiency solution to households.

Nevertheless, large reductions in household energy use are unlikely to be achieved from interventions designed to retrofit buildings alone. Studies on household energy use have found a large degree of variability in energy consumption across identical houses: this means that when it comes to energy consumption the role of the occupant behaviour can be as important as building physics (Santin et al. 2009). Also, the inclusion of sufficiency principles into the design of policy measures with a focus on what is really needed for a good quality of life could strengthen motivations for changing behaviours and contribute to reducing energy consumption. This does not undermine the importance of investments in efficiency solutions, but emphasizes energy saving and energy sufficiency measures as complementary approaches to energy efficiency which reduce the rebound effects and partially change the way we think of reductions in energy use from 'using less energy to provide the same service' to 'living well on less'.

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# *Analysis and Improvement of the Management of Stocks in 'Vasco da Gama' Frigates - A Practical Study*

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**Abstract**
Vessels, as an autonomous system, require the provision of maintenance needs, and transport the spare parts necessary to meet those needs. The existence of stocks and the type of lots on board are intertwined with the type of mission assigned, and according to the duration of the mission, often the ship cannot be supplied by land. For this reason, the normal time in the supply chain requires stocks, since in the Portuguese Navy, and in particularly on ships during its voyages, it is not possible to implement the 'Just-in-Time' system, which limits the time factor. Thus, in order to guarantee the autonomy of the missions with the supply cycle available, board batches to 'Vasco da Gama' frigate's engines, allow the ship's systems to be permanently operational. This study includes, in a first phase, an estimate of the maintenance needs of the main propulsion engines of the 'Vasco da Gama' Class Frigates using the arithmetic mean method and the least squares method. This is followed by an approach to stock management using the ABC analysis to determine which spare parts require more detailed control. Finally, the optimum quantity of spare parts per board batch, to be used for autonomous navigation missions up to a maximum of one year, is determined. The aim of this study is to reduce maintenance costs by calculating the optimal size of on-board batches, and also to improve sustainability by reducing the impact on the environment by not overloading the vessels with too many spare parts.

Keywords: Maintenance needs; stocks management; Portuguese navy; on-board batches; costs reduction.

## Introduction

In 1976 the Portuguese War Navy entered a new stage of its history, turning to the North Atlantic and to the participation in NATO missions. The adoption of this new course soon made evident the need to re-equip the Navy with surface ships.

A proposal for the construction of three MEKO 200 frigates was then made by a German consortium, which included special support from the German government. Finally, on July 25, 1986, a contract was signed between the Portuguese state and the German consortium for the construction of the three frigates.

In terms of logistics, Vasco da Gama class frigates have significant capabilities. Spare parts are available for 365 days, and these parts are stored in 23 warehouses throughout the ship. There are also several workshops equipped with machines and tools, and a documentation and database center with computer support that helps the exchange of information on board.

Maintenance on board the ships is one of the basic functions of the Portuguese Navy's logistics system, and its main objective is to ensure levels of availability of equipment and systems that are compatible with the established operational usage programs. After the entry of equipment and materials and during their usage, it is aimed to maximize their operational availability and minimize their maintenance costs. Hence, the maintenance of the first step relates to maintenance work involving the replacement of materials, and the replacement of spare parts that are damaged, or in the end of their life cycle, including adjustments or refinements within the technical services of the ship itself.

The present work addresses the thematic of management of stocks, with the research focused on the definition of board lots, in the context of the maintenance of the main propulsion engines of the "Vasco da Gama" class frigates. The frigate-type ship in which this study is based will be the NRP “Corte-Real” that participated in the NATO mission "Noble Mariner", which corresponds to the reference time period used to calculate the optimal quantity of a board lot.

We intend to determine the optimal quantity of a board lot in the context of the maintenance of the main propulsion engines, which guarantee the operation during a maximum time of 12 months of autonomous navigation (365 days), with the objective of ensuring the existence on board of a stock of equipment, materials and accessories essential to the proper and efficient maintenance of the engines during the participation in NATO missions with a maximum duration of one year.

This will be the basis to develop this study, addressing issues that arise at the operational subsystem level and at the management of indispensable material resources. We seek the equilibrium between divergent forces that tend to increase the stock and the cost of holding that stock. It is also intended to define an economic board lot (the optimal quantity of spare parts to be carried on board each mission), and to determine which of these spare parts require more thorough control in order to minimize the total cost of storage.

## Literature review and research questions

### Logistics Mission

Logistics and the supply chain are not new ideas. Throughout the development history of global economies, the principles governing the efficiency of flows of materials and information following logistical requirements have changed over time (Bloomberg, LeMay & Hanna, 2002).

As a management philosophy, supply chain management makes a system approach to show the supply chain as a whole. All organizations contribute to the individual performance of chain members as well as to the global chain (Cooper, Douglas & Janus, 1997). According to Christopher (2005), the goals of logistics management are to plan and coordinate all the activities of an organization that are necessary to achieve the desired levels of performance and quality, at the lowest possible cost. Adam and Foster (2000) argue that the extent of logistics goes from material management to the delivery of the final result.

Ballou (2004) defines logistics as the process that strategically manages the needs, movement and storage of materials, and the information about its flow through the organization, so that current and future performance are maximized by increasing the efficiency/cost ratio of processes and orders. In their new concept, for Bai and Zhong (2008) logistics encompasses purchasing, stock management, and the physical distribution itself, and each activity in the chain must contribute to the common goal with a constant improvement (Handfield & Nichols Jr., 2002).

For the case under study, the relevant logistic activities are forecasting, planning maintenance needs, managing warehouses, handling materials, planning distribution, and the processing of orders.

### Stock Management

According to Chopra and Meindl (2016), logistics are concerned with the stock as a whole, and more than 50% of an organization's assets are normally invested in stocks. Thus, organizations' policy regarding inventory levels and their locations will have a considerable impact on the size of the stocks (Gonçalves, 2006).

Logistics also has functions of monitoring, managing and implementing operational strategies that allow the minimization of stock levels. Effective and efficient stock management is essential in the operation of any organization, with stocks being created by storing materials along the logistics channel. The cost of having these stocks can represent 20% to 40% of their value, and thus the management of stock levels makes economic sense (Bassin, 1990).

### Significant Costs of Stock Management

Lalonde and Masters (1999) and Russell and Taylor III (2011) argue that there are three important cost classes in determining inventory policies: the costs of purchasing spare parts, the costs of having spare parts and the stockout costs of spare parts.

Purchasing costs are costs associated with the purchase of goods to replace on-board inventory, and those that are mostly taken into account when deciding order quantities or maintenance planning within the 1$^{st}$ level. These costs may vary according to the quantities ordered and the type of organization (Ptak & Smith, 2011).

Ownership costs result from the storage, maintenance and possession of spare parts in a given time interval, and, usually, costs are directly proportional to the quantity stored (Goldsby & Martichenko, 2005). These costs are divided into 4 classes:

• Space costs (costs and fees charged for the use of the volume within the storage building (Shang, Tadikamalla, Kirsch & Brown, 2008));

• Capital costs (refer to the value of the cost of money invested and assigned to the inventory (Slack, Brandon-Jones & Johnston, 2013));

• Inventory service costs (include insurance and fees, and depend on the quantity in stock (Silver, Pyke & Peterson, 1998), which represent a low percentage of the total costs of stock management (Simchi-Levi, Kaminsky & Simchi- Levi, 2004));

• Inventory risk costs (costs related to material deterioration, theft, damage, or obsolescence (Coyle, Langley Jr., Novack & Gibson, 2017)).

**Forecasting Concept**

According to Van Horne and Wachowicz Jr. (2009), forecasts are visions about the future. Predictions about sunrise and sunset can be made without great error, but this is not the scenario concerning forecasts of the main engines maintenance needs of the "Vasco da Gama" class frigates.

The conditions surrounding organizations change over time, and therefore forecasts generate errors. Mentzer and Moon (2005), describe forecasts as a future projection for the expected maintenance needs, knowing a set of conditions of the current environment, and according to Zermati (2000) the maintenance planning process should not be confused with the process of forecasting maintenance needs.

Chopra and Meindl (2016) summarize the characteristics of forecasts:

1- Forecasts are always wrong, and as such, errors must be expected;

2- Long-term forecasts are usually less accurate than short-term forecasts;

3- Aggregate forecasts are usually more accurate than disaggregated forecasts;

4- The greater the distortions of information in the supply chain, the higher the errors in forecasts.

Therefore, a forecast that is as close as possible to the reality will be decisive to accomplish a correct maintenance planning of the operational systems of the ship.

## Forecasting Methods of Maintenance Needs

In choosing the method to be used, we first have to choose whether we opt for quantitative or qualitative methods. In this study, quantitative methods were chosen, as they provide the information required for the development of the project. Also, the choice of method should be based on the data and time interval available to analyze the forecast of maintenance needs, as well as to adapt to the organization's expectations (accuracy, margin of error, cost of the method). According to Slack et al. (2013), the first question is to know the time period to be analyzed, and also Roldão and Ribeiro (2014) mention that the choice of method is based on the following points:

1- Possibility of collecting data that satisfy the input requirements;

2- Intended rigor;

3- Applicability of each of the methods;

4- Cost of the method.

Courtois, Pillet and Martin-Bonnefous (2007), still add the following points:

5- The time available to make the forecast;

6 – Availability of historical data on the considered articles or family of articles.

There are several quantitative methods to be used in study this, which can be grouped into two categories: Time Series Models and Associative Models (Heizer, Render & Munson, 2017) or Causal Models (Jacobs & Chase, 2014; Slack et al., 2013).

These authors assert that time-series models attempt to predict the future based on past data, and that associative or causal models incorporate all variables or factors that may influence the quantity being predicted.

This study will be based on the methods with lower implementation costs and that are adequate to the data available in the Portuguese Navy, as well as to the time period of the project (the arithmetic averages method and the least squares method).

## ABC analysis

According to Grosfeld-Nir, Ronen and Kozlovsky (2007), the ABC Analysis (also known as Pareto rule) consists of three steps: Classification, Differentiation, and Affectation of resources. The ABC analysis indicates that approximately 20% of the total number of spare parts in storage correspond to approximately 80% of the value invested in stocks (Figure 1).

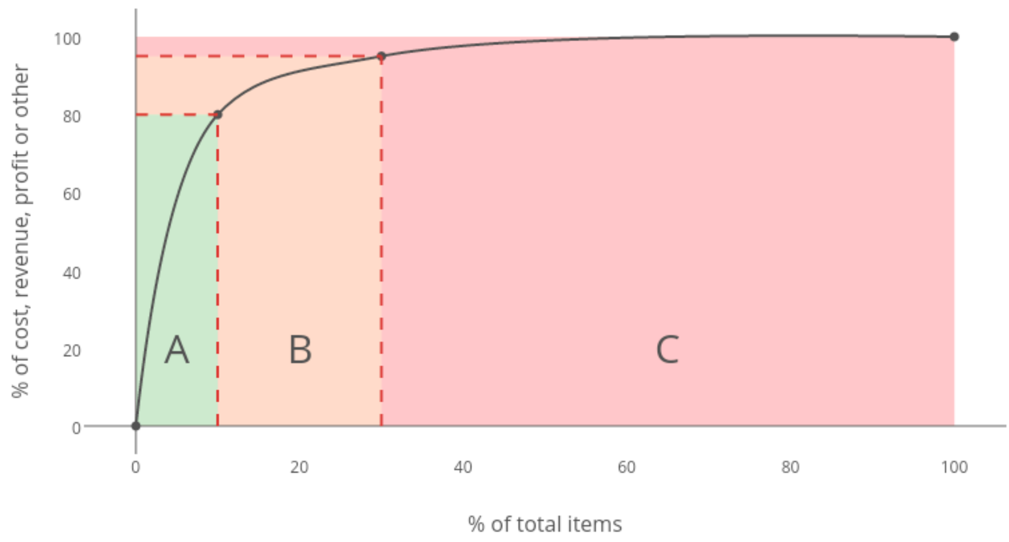



Figure 1: ABC analysis curve
Source: ABC Analysis – The Ultimate Guide to Inventory Classification, (2017)

Reis (2008) mention that if the majority of management resources (material, human, and time) are concentrated in those spare parts, results are much more relevant than they would be if such resources were dispersed equally or indiscriminately by all articles.

Heizer et al. (2017) classify classes A, B and C as follows: Class A, containing the items representing between 70% and 80% of the financial value and 15% of the total inventory; Class B containing 30% of the inventory and representing 15% to 25% of the financial value; Class C containing 55% of the total inventory and only representing 5% of the financial value of the total inventory.

Reis (2008) also states that another advantage of using the ABC Analysis is to allow the detection of non-moving articles (articles in the base of class C), which can be taken from the global stock as their storage increase the costs.

**Research questions**

In order to the Portuguese Navy know the performance of its operational units, in particular of the system that drives the mobility of each of its frigates (main propulsion engines), it is imperative to forecast the maintenance needs for one, or more, short, medium, or long-term malfunctions. Therefore, this study aims essentially to answer two research questions:

• What is the optimal composition of a board lot to be transported in each autonomous navigation mission for a maximum period of 12 months, in the context of the maintenance of the main propulsion engines of the "Vasco da Gama" class frigates?

• What are the most important spare parts that ensure the effectiveness and efficiency of on-board maintenance of "Vasco da Gama" Class Frigates?

## Methodology

For this study the forecasts of extreme relevance are the short and medium term forecasts, since these are the ones that allow to elaborate the 1st level maintenance planning, and allow on board management of stocks.

The forecasting of malfunction maintenance needs of the main propulsion engines of the "Vasco da Gama" class frigates is based on the NRP "Corte-Real" failure history for the period from Year X to Year X + 1 (for Confidentiality reasons it is not allowed to identify the actual dates). The historical data on the consumption of spares, and on malfunctions referring to this period, support the forecasting of maintenance needs.

Two methods were used to calculate the forecasts: the arithmetic mean method, and the least squares method. Based on historical data for Year X and Year X+1 (Table 1), the following forecasts were calculated.

Table 1: Number of faults on main propulsion engines for Year X and Year X+1
Source: Authors

| Months | Year X | Year X+1 |
|---|---|---|
| | Number of faults | |
| Jan | 1 | 3 |
| Feb | 3 | 2 |
| Mar | 7 | 5 |
| Apr | 9 | 8 |
| May | 5 | 6 |
| Jun | 1 | 2 |
| Jul | 2 | 2 |
| Ago | 3 | 3 |
| Set | 1 | 2 |
| Oct | 8 | 9 |
| Nov | 7 | 7 |
| Dec | 6 | 10 |
| Total | 53 | 59 |
| Average | 4 | 5 |

The final formula for the trend line is determined by the following formula:

$$x - x_1 = \frac{x_2 - x_1}{t_2 - t_1}\,(t - t_1)$$

Where:

x - Number of malfunctions to be determined;

x1 - Monthly average of malfunctions verified in time period 1;

x2 - Monthly average of malfunctions verified in time period 2;

t1 - Date corresponding to half of time period 1;

t2 - Date corresponding to half of time period 2;

t - Month corresponding to the number of malfunctions to be determined.

By determining the trend line, we can determine the demand forecast for the period we want.

The number of failures divided into 2 periods for Year X is now determined (Table 2).

Table 2: Number of faults in main propulsion engines divided into 2 periods for Year X+1
Source: Authors

| Number of faults | | | |
|---|---|---|---|
| **Period 1** | **t1** | **Period 2** | **t2** |
| 1 | 3 | 7 | 2 |
| 2 | 2 | 8 | 3 |
| 3 | 5 | 9 | 2 |
| 4 | 8 | 10 | 9 |
| 5 | 6 | 11 | 7 |
| 6 | 2 | 12 | 10 |
| **Total** | 26 | | 33 |
| **Average** | 4 | | 6 |

From Table 2, the following values are obtained:

$$x1=4; x2=6;$$

$$t1=3; t2=9.$$

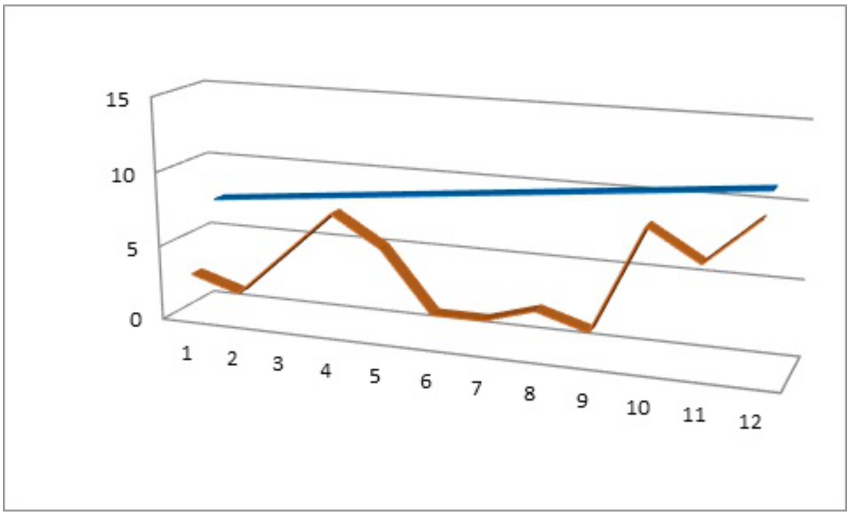
And the demand forecast for Year X + 2 is then (Table 3):

Table 3: Prediction of the number of faults in main propulsion engines for Year X+2 (Arithmetic Mean Method)
Source: Authors

| Year X+1 | Faults | Year X+2 | Prediction |
|---|---|---|---|
| 1 | 3 | 13 | 7 |
| 2 | 2 | 14 | 8 |
| 3 | 5 | 15 | 8 |
| 4 | 8 | 16 | 8 |
| 5 | 6 | 17 | 9 |
| 6 | 2 | 18 | 9 |
| 7 | 2 | 19 | 9 |
| 8 | 3 | 20 | 10 |
| 9 | 2 | 21 | 10 |
| 10 | 9 | 22 | 10 |
| 11 | 7 | 23 | 11 |
| 12 | 10 | 24 | 11 |
| **Total** | 59 | | 110 |

It is, therefore, possible to determine the following trend line (Figure 2):

$$x - 4 = \frac{6-4}{9-3}(t-3) \Leftrightarrow x = \frac{t}{3} + 3$$




**Year X+1; Year X+2**

Figure 2: Trend line (Arithmetic Mean Method)
Source: Authors

By analyzing the trend line in Figure 2, it can be seen that the method predicts an increasing trend during Year X+2, which is explained by the degradation of the auxiliary systems of the ship as the number of hours of operation increases.
By analyzing the values referring to the Year X+1 it is verified that there is the need for seasonal maintenance of malfunctions, with 2 peaks, which are directly related to the adverse weather and navigation conditions during the respective periods.

**Least Squares Method**

The final formula for the trend line is determined by the following formula:

$$x = a + bt, \ \ where \ \ a = \bar{x} - b.\bar{t}\,, \ \ and \ \ b = \frac{\sum(t\,.x) - \bar{x}.\sum t}{\sum t^2 - \bar{t}\,.\sum t}$$

Where:

x - Number of malfunctions to be determined;

t - Month corresponding to the number of malfunctions to be determined.

Determination of the trend line for the number of malfunctions in the main propulsion engines, based on Table 1.

Calculation of a: a = 5-0.47*7 = 1.71

Calculation of b: b = (439-5*78)/(650-7*78) = 0.47

The trend line will be given by:

$$x = a + bt \Leftrightarrow x = 1.71 + 0.47t$$

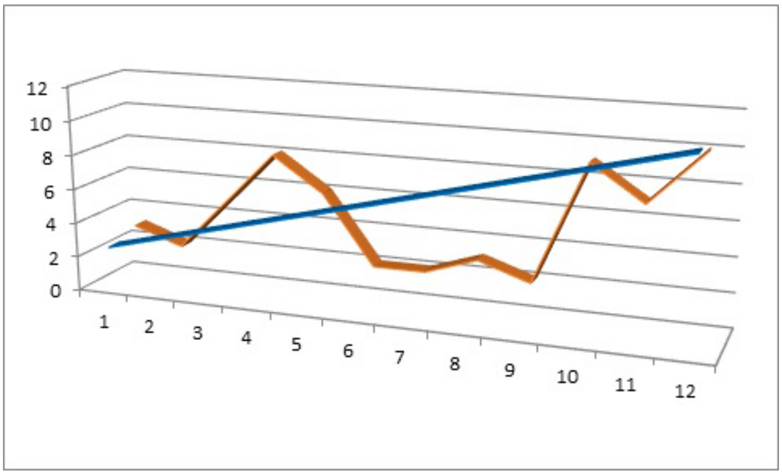
And the demand forecast for Year X+2 is presented in Table 4:

Table 4: Prediction of the number of faults in main propulsion engines for Year X+2 (Least Squares Method)
Source: Authors

| | Number of faults in main propulsion engines | | | | |
|---|---|---|---|---|---|
| | Months *(t)* | Faults *(x)* | $t^*x$ | $t^2$ | Prediction |
| | 1 | 3 | 3 | 1 | 2,45 |
| | 2 | 2 | 4 | 4 | 3,19 |
| | 3 | 5 | 15 | 9 | 3,93 |
| | 4 | 8 | 32 | 16 | 4,67 |
| | 5 | 6 | 30 | 25 | 5,41 |
| | 6 | 2 | 12 | 36 | 6,15 |
| | 7 | 2 | 14 | 49 | 6,89 |
| | 8 | 3 | 24 | 64 | 7,63 |
| | 9 | 2 | 18 | 81 | 8,37 |
| | 10 | 9 | 90 | 100 | 9,11 |
| | 11 | 7 | 77 | 121 | 9,85 |
| | 12 | 10 | 120 | 144 | 10,59 |
| Total | 78 | 59 | 439 | 650 | 78,24 |
| Average | 7 | 5 | 37 | | |

It is, therefore, possible to determine the following trend line (Figure 3):

Figure 3: Trend line (Least Squares Method)
Source: Authors




**Year X+1; Year X+2**

Analyzing the trend line in Figure 3, and comparing both methods, it can be concluded that the method of the least squares results in a forecast that is closer to reality.

For this specific study, which analyzes the history of malfunctions in the main propulsion engines of the NRP "Corte-Real", the arithmetical mean method tends to make forecasts "above" the expected number of failures in the propulsion systems of the ship during the navigation hours of Year X+2.

**Results analysis and discussion**

Currently the increasing need to reduce costs, makes it necessary to save in all areas. Since stocks of materials are one of organizations' assets with the greatest weight in treasury, it is imperative to determine the best way to keep the stocks at their minimum cost without running out of stock on board.

It is therefore imperative to know the quantity of spare parts to be ordered annually in order to determine the optimal composition of a board lot, with the objective to provide the stocks of Vasco da Gama class frigates at the lowest possible cost, aiming effective and efficient maintenance of the main propulsion engines.

In order to better understand the spare parts in stock and to determine which are most important, or those that require a more detailed management by the command of each frigate, we will use ABC Analysis, which tells us that about 20% of the total number of articles correspond to approximately to 80% of the financial value invested by the organization.

In Table 5 we will define which spare parts are directly allocated to maintenance operations of the main propulsion engines of NRP "Corte-Real".

Table 5: List of spare parts under analysis
Source: Authors

| Article | System | Designation | Value of Total Consumption (Euros) | Total Consumption (units) | Unit Cost (Euros) |
|---|---|---|---|---|---|
| 1 | | Bloco armado completo | 224,28 | 84 | 2,67 |
| 2 | | Camisa Gola Sup.2ªRect Saia STD | 2.307,44 | 4 | 576,86 |
| 3 | | Aros para camisas com rect. no assentamento 6,5mm | 2.753,52 | 4 | 688,38 |
| 4 | | Aros para camisas com rect. no assentamento 7mm | 31,44 | 2 | 15,72 |
| 5 | | Cadeira Interior STD | 72,96 | 1 | 72,96 |
| 6 | | Prisioneiros de aperto das cadeiras | 24.635,15 | 5 | 4927,03 |
| 7 | | Porca de aperto das cadeiras | 45.728,72 | 17 | 2682,92 |
| 8 | | Braço de articulação com rotulas nos extremos | 1.218,10 | 10 | 121,81 |
| 9 | | Ponta com rotula | 18.218,56 | 1.065 | 17,11 |
| 10 | | Veio de Manivelas completo | 1.610,96 | 4 | 402,74 |
| 11 | | Capas de Apoio Ext.2ªRect - Int.STD | 1.492,80 | 2 | 746,40 |
| 12 | | Casquilho de apoio Ext.STD - Int.1ªRect. | 3,21 | 1 | 3,21 |
| 13 | | Amortecedor de vibrações (VIBRATION DAMPER) | 252,18 | 32 | 7,88 |
| 14 | | Embolo completo | 586,81 | 12 | 48,90 |
| 15 | | Tirante completo | 3.484,57 | 36 | 96,76 |
| 16 | | Cabeça completa | 3.923,45 | 5 | 784,69 |
| 17 | | Casquilhos dos balanceiros | 48.688,30 | 48 | 1014,34 |
| 18 | | Veios dos balanceiros | 244,81 | 1 | 244,81 |
| 19 | | Veio de excentricos (esquerdo) | 1.351,16 | 1 | 1351,16 |
| 20 | | Amortecedor de vibrações (DAMPER) | 24.771,72 | 19 | 1303,77 |
| 21 | | Regulador de velocidades (completo) | 5.323,65 | 12 | 443,64 |
| 22 | | Turbo ZR 170 (Completa) | 56.698,61 | 61 | 929,49 |
| 23 | | Injector (completo) | 54,96 | 2 | 27,48 |
| 24 | | Bomba Injectora (completa) | 98,28 | 2 | 49,14 |
| 25 | | Bomba elevatória de combustivel (completa) | 43,52 | 2 | 21,76 |
| 26 | | Caixa de válvulas | 88,52 | 2 | 44,26 |
| 27 | | Bomba de água Doce (completa) | 904,44 | 12 | 75,37 |
| 28 | | Bomba de água Salgada (completa) | 1.387,68 | 12 | 115,64 |
| 29 | | Arrefecedor de água doce (completo) | 706,08 | 4 | 176,52 |
| 30 | | Válvula termoestática (completa) | 180,92 | 4 | 45,23 |
| 31 | | Bomba de reposição nivel óleo, acoplada ao veio de ressaltos (completa) | 842,16 | 4 | 210,54 |
| 32 | | Electrobomba de óleo de prélubrificação (completa) | 1.254,45 | 5 | 250,89 |
| 33 | | Bomba de oleo principal (completa) | 197,22 | 2 | 98,61 |
| 34 | | Filtro de oleo lado esquerdo (completo) | 64,88 | 4 | 16,22 |
| 35 | | Cardan Voith Tripod (completo) | 2 | 2 | 1,00 |
| 36 | | Acoplamento Geislinger (completo) | 0,01 | 1 | 0,01 |
| 37 | | Acoplamento TEK (completo) | 26,5 | 2 | |

Based on Table 5, we can do the ABC Analysis (Table 6), and draw the ABC Analysis curve (Figure 4).

Table 6: ABC analysis
Source: Authors

| Article | Value of Article | Number of Exits | Total (€) | Accumulated Value (€) | Accumulated Articles | Class |
|---|---|---|---|---|---|---|
| 22 | € 929,49 | 61 | € 56 698,89 | € 56 698,89 | 22,74% | A |
| 17 | € 1 014,34 | 48 | € 48 688,32 | € 105 387,21 | 42,26% | A |
| 7 | € 2 682,92 | 17 | € 45 609,64 | € 150 996,85 | 60,55% | A |
| 20 | € 1 303,77 | 19 | € 24 771,63 | € 175 768,48 | 70,49% | A |
| 6 | € 4 927,03 | 5 | € 24 635,15 | € 200 403,63 | 80,37% | A |
| 9 | € 17,11 | 1065 | € 18 222,15 | € 218 625,78 | 87,68% | A |
| 21 | € 443,64 | 12 | € 5 323,68 | € 223 949,46 | 89,81% | B |
| 16 | € 784,69 | 5 | € 3 923,45 | € 227 872,91 | 91,38% | B |
| 15 | € 96,76 | 36 | € 3 483,36 | € 231 356,27 | 92,78% | B |
| 3 | € 688,38 | 4 | € 2 753,52 | € 234 109,79 | 93,89% | B |
| 2 | € 576,86 | 4 | € 2 307,44 | € 236 417,23 | 94,81% | B |
| 10 | € 402,74 | 4 | € 1 610,96 | € 238 028,19 | 95,46% | B |
| 11 | € 746,40 | 2 | € 1 492,80 | € 239 520,99 | 96,06% | B |
| 28 | € 115,64 | 12 | € 1 387,68 | € 240 908,67 | 96,61% | B |
| 19 | € 1 351,16 | 1 | € 1 351,16 | € 242 259,83 | 97,15% | B |
| 32 | € 250,89 | 5 | € 1 254,45 | € 243 514,28 | 97,66% | B |
| 8 | € 121,81 | 10 | € 1 218,10 | € 244 732,38 | 98,15% | C |
| 27 | € 75,37 | 12 | € 904,44 | € 245 636,82 | 98,51% | C |
| 31 | € 210,54 | 4 | € 842,16 | € 246 478,98 | 98,85% | C |
| 29 | € 176,52 | 4 | € 706,08 | € 247 185,06 | 99,13% | C |
| 14 | € 48,90 | 12 | € 586,80 | € 247 771,86 | 99,36% | C |
| 13 | € 7,88 | 32 | € 252,16 | € 248 024,02 | 99,47% | C |
| 18 | € 244,81 | 1 | € 244,81 | € 248 268,83 | 99,56% | C |
| 1 | € 2,67 | 84 | € 224,28 | € 248 493,11 | 99,65% | C |
| 33 | € 98,61 | 2 | € 197,22 | € 248 690,33 | 99,73% | C |
| 30 | € 45,23 | 4 | € 180,92 | € 248 871,25 | 99,80% | C |
| 24 | € 49,14 | 2 | € 98,28 | € 248 969,53 | 99,84% | C |
| 26 | € 44,26 | 2 | € 88,52 | € 249 058,05 | 99,88% | C |
| 5 | € 72,96 | 1 | € 72,96 | € 249 131,01 | 99,91% | C |
| 34 | € 16,22 | 4 | € 64,88 | € 249 195,89 | 99,94% | C |
| 23 | € 27,48 | 2 | € 54,96 | € 249 250,85 | 99,96% | C |
| 25 | € 21,76 | 2 | € 43,52 | € 249 294,37 | 99,97% | C |
| 4 | € 15,72 | 2 | € 31,44 | € 249 325,81 | 99,99% | C |
| 37 | € 13,25 | 2 | € 26,50 | € 249 352,31 | 100,00% | C |
| 12 | € 3,21 | 1 | € 3,21 | € 249 355,52 | 100,00% | C |
| 35 | € 1,00 | 2 | € 2,00 | € 249 357,52 | 100,00% | C |
| 36 | € 0,01 | 1 | € 0,01 | € 249 357,53 | 100,00% | C |

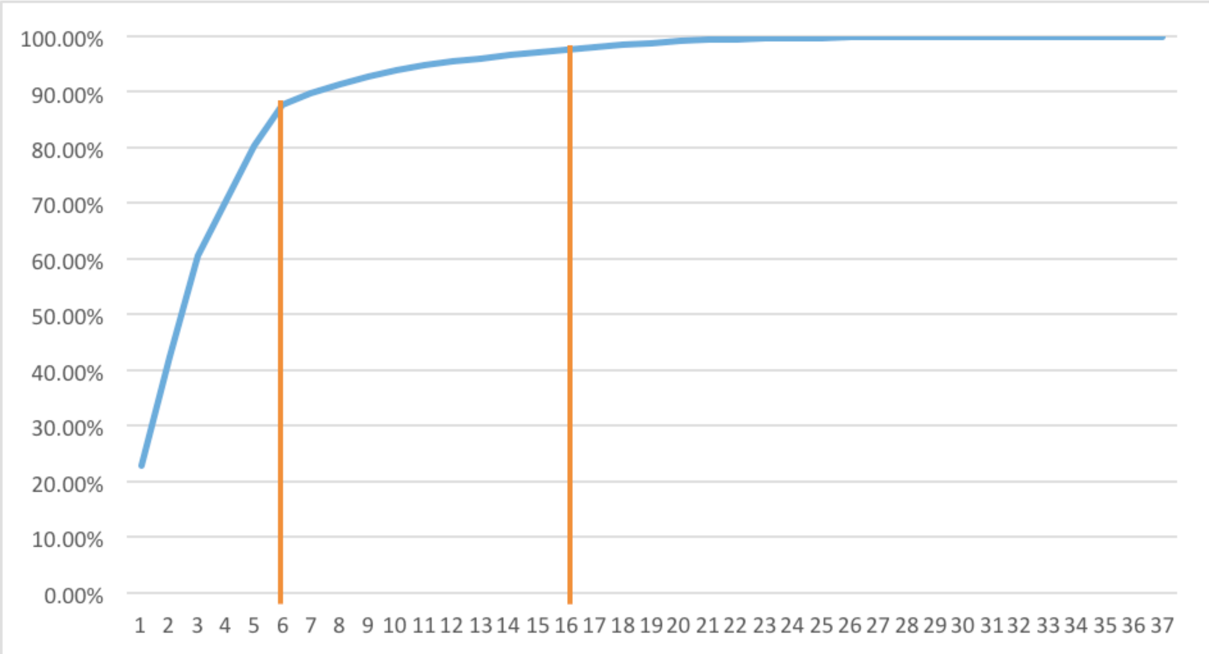



Figure 4: ABC analysis curve
Source: Authors

As we are in the presence of a small amount of spare parts (37), the values for the division are approximations, still fulfilling the objectives of this study, since this analysis intends to define the classes of the spare parts.

Class A and some class B spare parts are the most important, and those requiring more detailed management by the command of each of the "Vasco da Gama" class frigates. It is in these spare parts that the management should focus, giving more attention to their control.

**Total Cost of Inventory and Onboard Economic Lot**

Following Heizer et al. (2017), the Total Cost of Inventory (TCI), is the sum of product costs (C1), setup (order) costs (C2) and holding (carrying) costs (C3).

$$TCI = C1 + C2 + C3$$

Purchasing costs include all the costs related to the purchase process of a spare part (requisitions, human resources, computer equipment, etc.), and its calculation formula is as follows:

$$C1 = D \times p$$

(D) is the number of spare parts purchased for use in missions with a maximum duration of one year, and (p) the unit price.

The setup (order) cost (C2), includes the cost of making an order (S) (sum of the direct and indirect costs of completing the order). To determine (C2) we multiply (S) by the annual number of orders, which is obtained by dividing the annual consumption of spare parts (D) by the economic lot onboard (EL).

$$C2 = S \times (D/EL)$$

The holding (carrying) cost (C3) involves the overall carrying cost (I), which includes all the costs of storing the spare parts inside the ship's warehouses, such as warehousing costs, and the interest on the fixed assets used in spare parts.

$$C3 = I \times (EL/2) \times p$$

The Economic Lot on Board (EL) is calculated using the following formula:

$$\mathbf{EL} = \sqrt{\frac{\mathbf{2DS}}{\mathbf{Ip}}}$$

Based on the previous formulas, and considering the overall carrying cost of 1%, and an order cost (S) equivalent to 7% of the unit price of the spare part (these values are defined by the Portuguese Navy), the Economic Lot on Board (EL) and the Total Cost of Inventory (TCI) were calculated for each item (Table 7).

Table 7: Total Cost of Inventory (TCI) and Economic Lot on Board (EL)
Source: Authors

| Article | Value of Article (p) | Number of Exits | C1 | S | C2 | C3 | TCI | EL |
|---|---|---|---|---|---|---|---|---|
| 22 | € 929,49 | 61 | € 56 698,89 | € 65,06 | € 132,30 | € 139,42 | € 56 970,61 | 30 |
| 17 | € 1 014,34 | 48 | € 48 688,32 | € 71,00 | € 131,08 | € 131,86 | € 48 951,27 | 26 |
| 7 | € 2 682,92 | 17 | € 45 609,64 | € 187,80 | € 199,54 | € 214,63 | € 46 023,82 | 16 |
| 20 | € 1 303,77 | 19 | € 24 771,63 | € 91,26 | € 102,00 | € 110,82 | € 24 984,45 | 17 |
| 6 | € 4 927,03 | 5 | € 24 635,15 | € 344,89 | € 191,61 | € 221,72 | € 25 048,47 | 9 |
| 9 | € 17,11 | 1065 | € 18 222,15 | € 1,20 | € 10,37 | € 10,52 | € 18 243,04 | 123 |
| 21 | € 443,64 | 12 | € 5 323,68 | € 31,05 | € 28,67 | € 28,84 | € 5 381,18 | 13 |
| 16 | € 784,69 | 5 | € 3 923,45 | € 54,93 | € 30,52 | € 35,31 | € 3 989,28 | 9 |
| 15 | € 96,76 | 36 | € 3 483,36 | € 6,77 | € 10,60 | € 11,13 | € 3 505,09 | 23 |
| 3 | € 688,38 | 4 | € 2 753,52 | € 48,19 | € 24,09 | € 27,54 | € 2 805,15 | 8 |
| 2 | € 576,86 | 4 | € 2 307,44 | € 40,38 | € 20,19 | € 23,07 | € 2 350,70 | 8 |
| 10 | € 402,74 | 4 | € 1 610,96 | € 28,19 | € 14,10 | € 16,11 | € 1 641,17 | 8 |
| 11 | € 746,40 | 2 | € 1 492,80 | € 52,25 | € 17,42 | € 22,39 | € 1 532,61 | 6 |
| 28 | € 115,64 | 12 | € 1 387,68 | € 8,09 | € 7,47 | € 7,52 | € 1 402,67 | 13 |
| 19 | € 1 351,16 | 1 | € 1 351,16 | € 94,58 | € 23,65 | € 27,02 | € 1 401,83 | 4 |
| 32 | € 250,89 | 5 | € 1 254,45 | € 17,56 | € 9,76 | € 11,29 | € 1 275,50 | 9 |
| 8 | € 121,81 | 10 | € 1 218,10 | € 8,53 | € 7,11 | € 7,31 | € 1 232,51 | 12 |
| 27 | € 75,37 | 12 | € 904,44 | € 5,28 | € 4,87 | € 4,90 | € 914,21 | 13 |
| 31 | € 210,54 | 4 | € 842,16 | € 14,74 | € 7,37 | € 8,42 | € 857,95 | 8 |
| 29 | € 176,52 | 4 | € 706,08 | € 12,36 | € 6,18 | € 7,06 | € 719,32 | 8 |
| 14 | € 48,90 | 12 | € 586,80 | € 3,42 | € 3,16 | € 3,18 | € 593,14 | 13 |
| 13 | € 7,88 | 32 | € 252,16 | € 0,55 | € 0,80 | € 0,87 | € 253,83 | 22 |
| 18 | € 244,81 | 1 | € 244,81 | € 17,14 | € 4,28 | € 4,90 | € 253,99 | 4 |
| 1 | € 2,67 | 84 | € 224,28 | € 0,19 | € 0,45 | € 0,47 | € 225,20 | 35 |
| 33 | € 98,61 | 2 | € 197,22 | € 6,90 | € 2,30 | € 2,96 | € 202,48 | 6 |
| 30 | € 45,23 | 4 | € 180,92 | € 3,17 | € 1,58 | € 1,81 | € 184,31 | 8 |
| 24 | € 49,14 | 2 | € 98,28 | € 3,44 | € 1,15 | € 1,47 | € 100,90 | 6 |
| 26 | € 44,26 | 2 | € 88,52 | € 3,10 | € 1,03 | € 1,33 | € 90,88 | 6 |
| 5 | € 72,96 | 1 | € 72,96 | € 5,11 | € 1,28 | € 1,46 | € 75,70 | 4 |
| 34 | € 16,22 | 4 | € 64,88 | € 1,14 | € 0,57 | € 0,65 | € 66,10 | 8 |
| 23 | € 27,48 | 2 | € 54,96 | € 1,92 | € 0,64 | € 0,82 | € 56,43 | 6 |
| 25 | € 21,76 | 2 | € 43,52 | € 1,52 | € 0,51 | € 0,65 | € 44,68 | 6 |
| 4 | € 15,72 | 2 | € 31,44 | € 1,10 | € 0,37 | € 0,47 | € 32,28 | 6 |
| 37 | € 13,25 | 2 | € 26,50 | € 0,93 | € 0,31 | € 0,40 | € 27,21 | 6 |
| 12 | € 3,21 | 1 | € 3,21 | € 0,22 | € 0,06 | € 0,06 | € 3,33 | 4 |
| 35 | € 1,00 | 2 | € 2,00 | € 0,07 | € 0,02 | € 0,03 | € 2,05 | 6 |
| 36 | € 0,01 | 1 | € 0,01 | € 0,00 | € 0,00 | € 0,00 | € 0,01 | 4 |

## Conclusions and recommendations

Despite the recognized usefulness and importance of the study carried out concerning the implementation of a more precise methodology for management of stocks, and the definition of the onboard lots of the "Vasco da Gama" class frigates, due to bureaucratic reasons it was not possible to implement this methodology.

Therefore, the conclusion is restricted to the analysis made and the information obtained, being limited to a policy suggestion aiming the improvement of the stock management practiced on board the "Vasco da Gama" class frigates of the Portuguese Navy.

Concerning the first research question, the optimal board lot, to be carried in each autonomous navigation mission for a maximum period of 12 months, was defined for the maintenance of the main propulsion engines of the "Vasco da Gama" class frigates.

Each board lot consists of the number of units of each spare part, indicated in Table 7 (Total Cost of Inventory (TCI) and Economic Lot on Board (EL), column ‘EL’.

For the management of stocks, the focal point of the whole process ends up being the logistics of placing the spare parts on board the ships, but because this is assigned to entities subcontracted by the Portuguese Navy, the Navy can only define which spare parts are the most important to ensure the effectiveness and efficiency of onboard maintenance of the "Vasco da Gama" Class Frigates.

To do so, and addressing the second research question, an ABC analysis (Table 6 - ABC analysis) was performed, defining 3 classes of articles, and concluded that class A spare parts are indeed the most important. However, some spare parts of Class B are also important, and the control of the remaining spares should not, obviously, be neglected.

A number of proposals to improve the stock management on board the "Vasco da Gama" class frigates in the context of the maintenance of their main propulsion engines are now presented.

In the future, it would be possible to define the critical values for each spare part under analysis, which could provide data to make spares’ control even more effective and efficient, thus defining the Safety Stock, The Minimum Stock and the Maximum Stock.

Concerning the physical space of the frigate warehouses, some simple changes, that would certainly improve the management of stocks, could be made. For example, the space inside the warehouses should be resized by changing the different shelves. There are shelves with little space to store larger materials, and more shelves should be created, with greater space and visible dividers that differentiate the different articles and materials in stock.

Since stocks in the Portuguese Navy are responsible for a large part of the capital allocation, a good stock management will optimize the use of capital and reduce the costs associated with stocks, presented in Table 7.

A suggestion for future studies will be the reproduction of this study in other classes of ships in the Portuguese Navy, in order to also determine the possibilities of improving the stock management in those ships.

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# *The Needs of Sustainability Solid Waste Management in Perhentian Island, Terengganu*

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**Abstract**
Malaysia is blessed with many idyllic tropical islands favoured by many an ecotourist. Perhentian Island, located in the South China Sea at the northeastern corner of Peninsular Malaysia, has been one of the favorites whose tourism activities have increased considerably. The recent annual tourist arrival for the island is about sixty thousands, compared to a local population of only one thousand three hundreds residing in the only village on the island. Located about 21 km offshore, the 15 km island has seen its number of resorts grow from five (~100 rooms) in 1985 to more than forty now (~1200 rooms ).With growth comes the problem of managing the solid waste generated by the island's tourism industry. The large amount of wastes produced by tourist is a difficult problem for small islands particularly since it is typically generated over a short period, thereby often overloading existing disposal and treatment facilities. Onsite burying of solid waste that was practiced during its early days of tourism business is no longer suitable and sustainable due to land scarcity. The current practice of hauling the waste to be landfilled on the mainland 21 km away is viewed by many to be uneconomical and is putting unwanted stress on the fast-shrinking landfill space. The local authority administering the island is now looking for a better way of managing this waste. Therefore, protection of the environment from pollution is extremely important in small island, since aside from other reasons that are common to all countries, two important industries, tourism and fisheries, depend on a pristine environment. This paper overview the current waste management plans of Perhentian Island in Malaysia and the problems that are being encountered, both by local municipal and chalet owners and its effectiveness. The purposes of this study is to investigate the collection system and handling of solid waste in Perhentian Island. The study outline strategy laid out to improve the current waste management plan such as focusing and going back to composting and recycling method which is seen as more economical and environmental friendly.

Keywords: Sustainability, waste management, island resort, recycling, composting, collection system

## Introduction

Increasing population and tremendous urbanization growth and other factors influence directly the municipal solid waste generation in Malaysia. In 2002, population living in the local authority areas in Peninsular Malaysia generated about 17,000 tonnes of solid waste daily according to the Ministry of Housing and Local Government (2003). The same ministry also estimated an average generation of 0.85 kg/cap/day. According to the ministry again about 76 % of this waste were collected but only a meager 1-2 % were recycled while the remainder were taken to disposal sites. In its effort to change the current unsustainable practice of solid waste management, the ministry has identified the need for more research on strategic plans for solid waste management, solid waste composition and characteristics, recycling, composting, refuse-derived fuel, etc. Sustainable solid waste management is among the key principles to guide the ministry's strategic plan on solid waste management. Through sustainable solid waste management the ministry is targeting to change the waste hierarchy of 95 % landfill/5 % recovery to <65 % landfill/15 %intermediate processing/>20 % recycling by the year 2020. Most of the current and past studies on solid waste management in Malaysia concentrate on municipal areas whose solid waste are commonly categorized into residential, commercial, institutional and industrial wastes(MHLG,2003).

The disposal of solid waste on island resort is a particularly critical problem. Limited land area makes the option of landfill unsustainable in the long term and other options of collection and disposal, such as incineration have so far proved to be economically unfeasible. Solid waste is produced in a much larger volume by tourist resorts than local inhabited islands.

Not that many studies have been done on sustainable management of solid waste generated on island resorts. (M.Rafee et.al 2007). Those studies that were done focused more on one specific treatment of waste such as thermal treatment or incineration. There are several factors that make management of wastes from island resorts an interesting case to study. Firstly, is the limited land available on the island itself which puts a strong case for a sustainable integrated waste management. Secondly is the peculiarity of the waste which a high proportion of it comes from the resorts' restaurants/kitchens whose limited number make them easy to manage. Third is the probability that the level of awareness on sustainable waste practice is high among the tourists holiday at the resorts. On the basis of these factors, a study was carried out to investigate the possibility of implementing a better and more sustainable solid waste management program on the resort island of Pulau Perhentian in Terengganu.

### Solid waste management in Malaysia

One of the most dramatic examples of the environmental policy paradox may be found in the area of solid waste management. (Hostovsky, 2006). For example, for many years municipalities in Malaysia still faced problem to find a suitable site for new landfill and yet policy makers have been slow to act. The problem and its solution have been well known to policy makers for decades. However, the best long term solutions to municipal waste problems are expensive, while short term solutions seem to be cheap. Policy makers in some areas are being forced to take what they consider drastic measures that they might not otherwise be willing to consider.

Solid waste management is also considered as major environmental problems in small islands in Malaysia.

The major problems in waste management in small islands are: (B. Stephen and D.C Barry. 1995)

a) Pollution of groundwater, surface water and marine environment from land based sources such as solid wastes, and domestic sewage: they carry risk to human health and can degrade habitats such as coral reefs and tourist attractions such as beaches. Consequently, small islands will outbreaks of diseases and the destruction of fisheries, which can cause major adverse economic impacts.

b) Lack of solid waste disposal facilities and sites: gullies and the marine environment are still used as disposal sites by some small islands because of the shortage of land and inadequate capacity to collect garbage for centralized disposal.

c) Lack of facilities for storage and management of hazardous wastes.

d) Ineffective regulations: some small islands have spent a considerable amount of time and financial resources on developing regulations; However regulations have not been very effective in many cases because of inadequate institutional and human resource capacities to enforce them.

Solid waste management in Malaysia also has a number of implementation problems, including low collection coverage, irregular collection services, inadequate equipment used for waste collection, crude open dumping, institutional deficiencies, inadequate legal provisions and resource constraints. These problems are caused by complex factor, which mitigate against the development of an effective national policy of a solid waste management (SWM) system

**Perhentian Island: Background and Tourism**

Pulau Perhentian or Perhentian Island is located in the South China Sea some 21km northeast of Kuala Besut in the State of Terengganu (Figure 1). The name Pulau Perhentian is commonly used to refer to a group of islands in the vicinity made up of two major islands -Perhentian Besar and Perhentian Kechil and several small islands surrounding these major islands. The islands can be reached by boat either from Kuala Besut in Terengganu or Tok Bali in Kelantan which is closer by 6 km. A boat trip to the islands can take between 30-45 minutes depending on the sea condition. The land area of this group of islands is about 1500 hectares. The most important economic activity on the islands is tourism. Tourists go to Perhentian Island for a variety of reasons including the beach, snorkeling, scuba diving, fishing, etc. Tourist season begins in March until late October when the South China Sea is calmer. Due to their popularity, the islands have seen the number of resorts grow from five (~100 rooms) in 1985 to more than forty now (~1000 rooms). The recent annual tourist arrival or the island is about sixty thousands, compared to a local population of only 1300 residing in the only village on the island, Kampung Pasir Hantu on Perhentian Kechil (Majlis Daerah Besut,2006)


Figure 1: Perhentian Islands

## Current Solid Waste Management on Perhentian Island

Pulau Perhentian is under the administration of Majlis Daerah Besut (MDB). As such, all matters pertaining to solid waste management on the islands are under the administration of MDB. Onsite burying of solid waste that was practiced during early days of tourism business is no longer suitable and sustainable due to land scarcity. At present, solid wastes from the island generated by the resorts are still managed in a conventional way. This conventional practice which requires hauling the waste to be landfilled on the mainland 21 km away is viewed by many to be uneconomical and is putting unwanted stress on the fast-shrinking landfill space. The process involves three parties/actors, i.e. the resort operators, a waste collection contractor appointed by MDB and MDB (Figure 2)

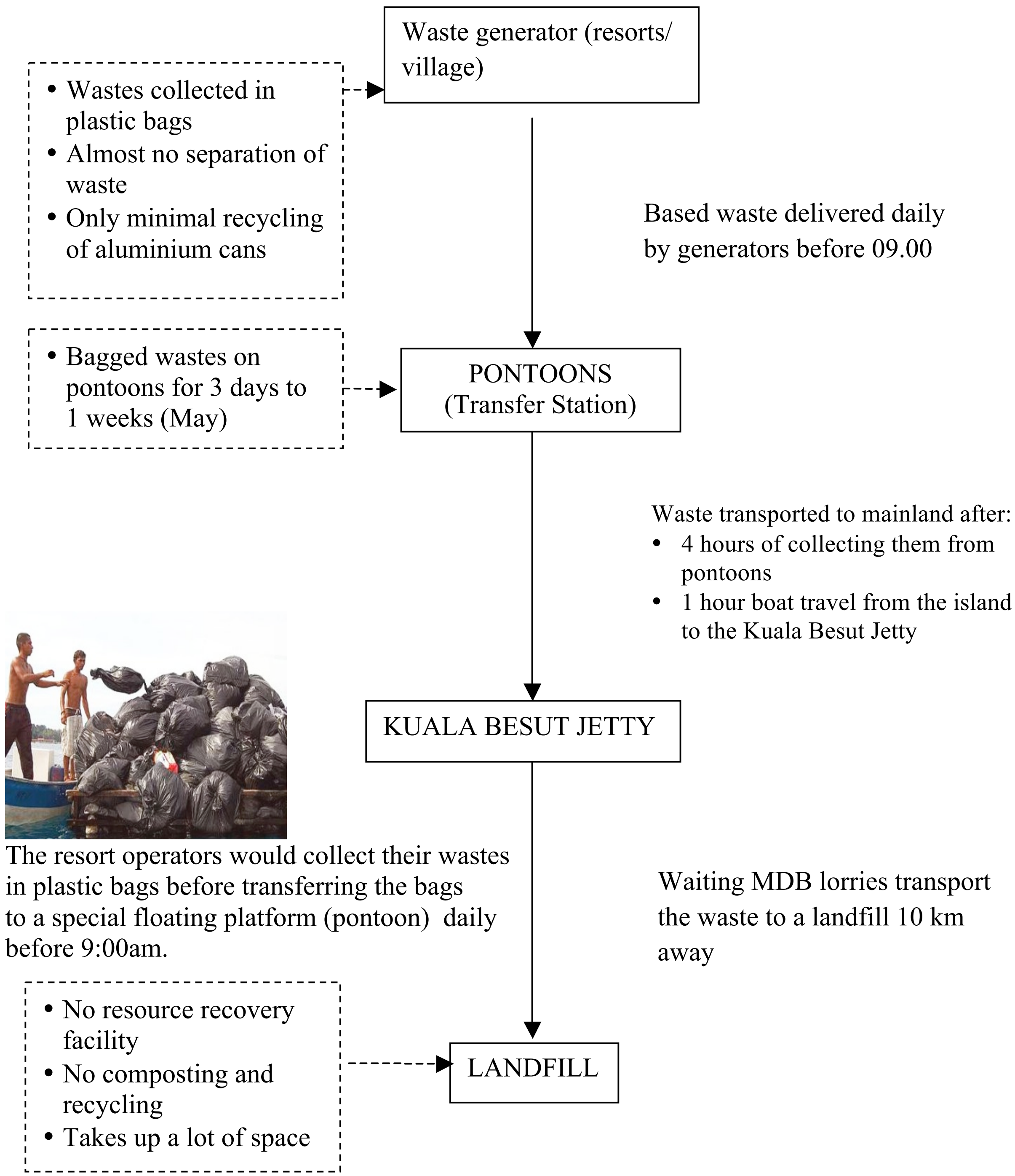


**Figure 2: Current Solid waste Management on the Perhentian island**

**Source: developed for this study from fieldwork conducted in 2015**

A quick survey on the operators revealed that most of the operators did not recycle anything except for 20 % of them who recycled some aluminum cans. The pontoon acts as a transfer station for these bags of wastes before they are collected for transportation to a landfill on the mainland in Kuala Besut . The appointed solid waste contractor (transporter) would then use a big boat to make his round around the islands collecting the bagged wastes from the pontoons and then transporting them to Kuala Besut jetty on the mainland. Though appointed by MDB, the solid waste contractor is paid directly by the resort operators. The collecting fees paid vary according to number of resort rooms and they range from less than <RM 100 to more than >RM 600 ringgits per year. Depending on the weather and some other reasons, these bags of wastes could be sitting on the pontoons for three days to one week before getting transferred to the landfill. Also depending on the weather, the contractor may take up to four hours collecting wastes from these pontoons and then another hour to travel from the islands to the Kuala Besut jetty. From the jetty the wastes would be then be loaded to the waiting MDB lorries for disposal at a landfill operated by MDB.

The trash collection service is only operated during peak season, usually around mid-February to mid- September; it cannot operate during monsoon season or bad weather as the waves are to high. The trash generated during the off-season is considerably less due to the limited number of tourist on the islands, but what is generated is usually burned. The difficulty comes when the service stop operating, but tourist are still arriving or workers are still on the islands. In these situations some resorts will ferry their trash back to the mainland, others bury or burn it behind their resorts. At the start of the 2008 season there were numerous examples of partly buried and partly burned trash piles at many of the resorts. Even during peak season when trash is routinely collected, a number of the kitchen areas on resorts would burn their waste materials and several staff living quarters would burn trash rather than dispose of it in trash cans.

The trash is collected offshore on floating pontoons which prevents the concentration of pests around the trash and also removes an unsightly and unpleasant problem from the islands. Smalls boats will leave a resort loaded with trash to deposit on the pontoons and return empty, leading a number of tourists to believe the trash is dumped at sea. There are a number of problems identified by many islands residents with these trash pontoons. One of the key problems was the lack of schedules for the service collection.

Additionally, some of the trash barges are in poor state of repair and sections may be falling apart which means that the bags may fall from the platform and end up in the water. There were several examples of black bags being found washed-up on the beach which had receipts or paperwork linking them to particular resorts. The platforms are also not collected as regularly as needed, leading to some being piled higher than sensible for the particular platform. Many islands residents suggested that the trash pontoons needed improving and told stories of trash falling from pontoons and being washed into coral reefs or onto beaches. When asked about the trash falling from the pontoons, many western participants blamed the local workers. Another described how some of the workers had thrown the bags on and missed, but had not attempted to retrieve them. Around many of the resorts there is no frequent collection of trash from outside guest quarters or staff quarters.

Looking at the current practice of solid waste management described above, there is no doubt that there are some weaknesses and potentials. Considering the fact that most of the wastes are kitchen wastes from the resorts, there is a very high chance that a good percentage of the wastes are organic wastes that can be composted (Table 1). Source-separation of these wastes would not be much of a problem due to their minimal number of generators. Leaving these wastes in black plastic bags out in the open does not go well with the image of the islands as a tourist destination. When left too long in the hot sun the wastes can produce an offensive fetid smell, especially down wind. To make things worst, the plastic bags are not secured on the pontoons subjecting them to the rough sea during bad weather. Having to transport the wastes to the mainland for disposal is also not sustainable. It requires a lot of fuel to drive the big boat for almost five hours each trip in order to collect the waste bags from all the pontoons around the islands and then transport them to the mainland. Better ways of managing these wastes should therefore be explored and one possibility is through encouraging composting and recycling.

**Table 1: Composition of the solid waste in Perhentian island**

| **Waste Category** | **Average Weight (kg/day)** | **Average Weight (%)** |
|---|---|---|
| Organic Waste (food wastes) | 858.75 | 71.73 |
| Paper | 69.14 | 5.77 |
| Timber | 18.64 | 1.56 |
| Cans | 96.52 | 8.06 |
| Plastics (Bottles/bags) | 60.65 | 5.07 |
| Glass | 32.08 | 2.68 |
| Yard Wastes | 62.45 | 5.13 |

Source, .Rafee, M.( 2007).

**A Need for Waste Management Plan in Perhentian island**

The Perhentian Island faces challenges in their sustainable development effort, the same as those encountered by other small islands in Malaysia. The National Conservation Strategy has recognized that the principle of sustainable tourism must include the conservation and sustainability of natural, social and cultural resources and reduction in waste to avoid restoration cost (Economic Planning Unit, 1993). The Commonwealth Secretariat, (2000), identified the following characteristic of small islands that post special development challenges. These are their remoteness and isolation, openness and vulnerability to global markets susceptibility to natural disasters and environmental change, poverty, limited capacity in public and private sectors.

The projected population growth in the Perhentian Island is expected to increase the generation of municipal waste arising. The historic level of growth in tourism is not the main reason; instead focus is on the upgrading existing capacity. However, seasonal fluctuations in tourist levels are likely to have associated waste management implications in term of collection, transportation, treatment and capacity.

For environmental sustainability solid waste management needs to work towards the following objectives; (OECD 2000)

a) The generation of waste, both by consumers as producers, should be minimised. At the production site, waste minimisation can be achieved through a new organization of production process, which makes use of clean technology and use less packaging materials. At the consumption site, waste generation can be reduced by awareness-raising campaigns on the environmental impacts of waste and on recycling and re-use. Attention should be paid to the waste generation behaviour of the target group. For example, upper and middle income households import a lot of products and therefore the amount and kind of waste is different e.g: more plastic and packaging materials, than waste produced by low income groups. Poor people produce less waste since they often re-use or sell valuable materials and the main of their part consists of organic materials.

b) Re-use and recycling should be maximised. This includes recognising and making use of the informal sector and micro-enterprise that are already involved in collecting and selling recyclable materials.
c) The remaining waste should be disposed in a controlled manner in order to stay within the absorption capacity of local and global sinks. For developing countries the best method regarding technical and financial means, is disposal at landfills (Chris 2000). However, the ultimate goal is to reduce waste generation and optimise recycling in such a way that waste becomes a closed-cycled system, preventing loss of raw material, energy and nutrients.

Others argue that interpretations of sustainable waste management systems should be expanded include participation for all stakeholders (Petts, 2000; OECD, 2002) and in particular between localities. The Rio Declaration on Sustainable Development (UNCED, 1992) defined sustainable waste management as the application of the integrated life cycle management concept in waste management. This was later elaborated by the United Nations (2005) as;
"Environmentally sound waste management must go beyond the mere safe disposal or recovery of wastes that are generated and seek to address the root cause of the problem by attempting to change unsustainable patterns of production and consumption".
In effect, the declaration suggests an approach to waste management that incorporates environmental, social and economic perspectives into environmental policy, planning and practice. However, it is only recently that waste management policies, plan and programmes have begun to consider all of these different stands of sustainability.

The concept of sustainable development, as set out in the Bruntland Report (1987) report of the World Commission on Environment and Development) is that development should be carried out in a manner, which will not prejudice the ability of future generations to meet their own needs. This is extended to include the concept that we should not leave a legacy of problems to be resolved by future generations (for examples, land, air and water which is polluted or poorly restored) and the scarce resources should be conserved. Such an approach is particularly appropriate in dealing with waste. Therefore, the approach of the planning authorities in dealing with waste for Perhentian Island is that waste handling, treatment and disposal should be dealt with in an environmentally acceptable manner minimising the long-term impact of waste. Therefore, the research revealed a number of recommendations of waste management plan for Perhentian Island :

1) The planning should proposed for new waste management facilities in accordance with the principles of sustainable development and the following waste management hierarchy:

    i) Reduction
    ii) Re-use and recycling including composting
    iii) Recovery, including energy from waste
    iv) Final dispose

2) Disseminate appropriate information and education about waste issues throughout society. This information needs to be developed by sources that are respected by all waste management actors for it to be effective.

3) The local authorities should support public, private and voluntary sector initiatives to reuse, recovery, recycle waste in accordance. Public awareness of waste management in Perhentian Island is low. A public education and awareness rising programme needs to be developed in support of the establishment of any future recovery and recycling schemes. This should highlight the extent of the problem and highlight the benefits of minimising, separating and recycling wastes.

4) All civil society organizations, all spheres of government and all individuals should come together to implement the overall principle of sustainability.

**Conclusion**

The environment problems of small islands are related to issues that pertain to the sustainable use of natural recourses and the environmentally sound management of wastes. The unique social, economic and environmental characteristics of small island, such as limited availability of land space and the lack of human and financial resources, reduce the choice of appropriate options for sound management of waste. Furthermore, tourists produce large amounts of wastes, especially during the peak tourism period, compounding the difficulty of small island authorities to manage waste with their limited capacities. One person or organization needs to be given overall responsibility for implementing the plan and reporting to government on progress in achieving the objectives. Procedures for coordinating the activities of different agencies need to be set out. Budgets for the various actions needs to be established and approval sought. Therefore, the authorities need to develop local strategies and capabilities for the implementation of sustainable waste management within the context of sustainable development. In most cases, the resulting municipal strategy will be a mix of private and public sector activities.

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# *Towards Sustainable Buildings Production Through the Lens of Lean Construction Perspectives*

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**Abstract**
The study proposes the application of the principles of lean construction to the processes that would lead to the production sustainable buildings. This is aimed at promoting sustainability in the built environment, because buildings form the greater per cent of the built environment. Sustainable buildings are the products of sustainable processes of design and construction, while lean construction manages and adds value to the processes of construction from the conceptions to the delivery of the construction deliverables – buildings. The study's discourse presents the concepts of lean applications and the novelty it provides to the construction of buildings sustainably. This theoretical discourse suggests that lean applications to construction activities has threefold positive impact on the construction sector. Firstly, it guides the design conception of buildings. Secondly, it controls the deliverable processes of their construction and thirdly, it improves and allows for the production of sustainable buildings as against those from the conventional construction processes. These in the overall ensure the production of sustainable buildings and promote environmental sustainability. Furthermore, the study recommends amongst others a deliberate reorientation of the construction sector practitioners and encourages the installations of mechanisms that would ensure the implementation and application of lean principles into the processes leading to the production of sustainable buildings.

Keywords: buildings, built environment, lean principles, construction, sustainability

## Introduction

The construction sector forms a significant part of the built environment and construction projects are ever increasing globally. According to Newswire Report (2016) the industry has a forecast growth rate of 5.5% and its major drivers are the continuous growth rate of urbanization and population (Govindan et al., 2016). As much as this sector has the largest market (Newswire Report, 2016; Market Research Hub, 2017), is also a huge employer of labour and drives the economy of many countries (Wibowo, 2012; Allu, 2014). This is because the demand for housing and other infrastructures is high (Govindan et al., 2016). The sector is also hugely responsible for environmental waste and pollutions (Atkinson 2008; Dixon; 2010; Wenger, 2012; WRI, 2016). So much so that many agencies, government (Sarhan and Fox, 2013) and researchers (Govindan et al., 2016; Jamil and Fathi, 2016) expressed concern for new construction project to comply with processes that are sustainable in order to minimise waste and promote environmental sustainability (Jamil and Fathi, 2016). Additionally, there is also the global challenge for curb poor construction performance and delivery (Sawhney et al., 2014). These challenges propelled the construction sector to look for possible strategies that would address both the construction waste and promote environmental sustainability.

In order to address these challenges for the construction sector, the lean perspectives to construction has been adopted in some countries. In the construction arena the lean perspective is seen processes that improves production quality and add value to project delivery (Forbes and Ahmed, 2011; Banawi, 2013). Additionally, LC also promotes sustainability within the built environment sector with consciousness for the future (Banawi, 2013; Bawani and Bilec, 2014; Ogunbiyi et al., 2014).

This study's focus is therefore, to presents the theoretical underpins of the applications of lean construction, in order to further raise the awareness and knowledge of construction professionals. This is aimed at repositioning and reorienting the construction practitioners towards the applicable options of engaging with lean approach to construction practices. The applications are discussed as the potentials of LC in relation to firstly; the pre and design phase, secondly, during the construction processes and lastly, how the two phases ensure that the construction projects or buildings are improved upon sustainably.

## Lean Construction Potentials

The term 'Lean construction' has its origin from the International Group for Lean Construction in 1993 (Gleeson et al., 2007). According to Biton and Howell (2013) Lean Construction (LC) has been around for a long enough period to move beyond theory to actions. Yet, its applications are still new to many countries (Sarhan et al., 2017). LC also has been acknowledged to be a supplementary process from the traditional construction management, that reduces waste, manage and improves the processes of design and construction productivity sustainably (Abdelhamid, 2007; Azziz and Hafez, 2013, Issa, 2013). The lean thinking and its principles drive the lean applications for any production process to be effective. These principles are; customer based value identification, generation of value streams through delivery value, removal of waste through improved processes, creation of system-pull-production and pursuits for perfections in all processes (Kumar et al., 2013). Thus, enhancing the application of lean principles into the processes of design and construction becomes a continuous flows at all levels or phases of production. It is therefore, necessary to understand how the lean principles in construction can impact positively on the design and construction productivity sustainably, through the application of lean principles into design and construction.

**Lean thinking (Perspectives) in Design and Construction**

The act of constructing a building starts with the design phase and consequently, when the design thinking is well thought-out then the construction process would follow suit. Lean Construction also starts with lean thinking towards designing and the planning of cost effective the production processes (Pinch, 2005; Aziz and Hafez, 2013). As such, optimising the design processes with the principles of lean would subsequently be expected to also gear up processes of production of buildings through construction.

Most of the environmental waste and depilation of raw materials from the natural environment is ascribed to the activities of the construction sector. Researcher have also opined that the production activities in construction of buildings are still; wasteful, poor performance and time consuming (Issa, 2013). Whilst other researchers argued that this situation is likely because the adoption of lean thinking to construction is still transitional (Viana et al., 2012; Sarhan and Fox, 2012), cultural barriers and because of poor perceptions and implementation of the lean perspectives by practitioners (Biton and Howell, 2013; Kannan et al., 2016). In furtherance to these discourse, the need for the integration of lean principles to design and construction are always being sought. Researchers have suggested that the use of necessary tools are required to support the implementation of lean construction for the design and construction (Sarhan et al., 2017). These tools are collated from the different studies and are presented in Table 1 in relation to design and construction phases.

**Table 1. Tools that support lean construction implementation**
**Source: Author's arrangement, 2017**

<table>
<tr><th>s/n</th><th>Design Phase</th><th>Construction Phase</th></tr>
<tr><td>1</td><td>Understanding client's brief</td><td>Understanding clients value for project deliverables</td></tr>
<tr><td>2</td><td>Computer aided design</td><td>Computerised systems planning</td></tr>
<tr><td>3</td><td>Target value design</td><td>Target planned schedules</td></tr>
<tr><td>4</td><td>Sustainable approaches to design process</td><td>Preferences for prefabricated materials to reduce waste</td></tr>
<tr><td>5</td><td>Environmental consciousness to design specifications</td><td>Environmental consciousness to construction activities</td></tr>
<tr><td></td><td>Value adding design features</td><td>Value adding activity schedules</td></tr>
<tr><td>6</td><td colspan="2">Continuous refresher and improvement development and training</td></tr>
<tr><td>7</td><td colspan="2">Daily meetings and appraisals</td></tr>
<tr><td>8</td><td colspan="2">Preventive and routine maintenance options</td></tr>
<tr><td>9</td><td colspan="2">Concurrent engineering options</td></tr>
<tr><td>10</td><td colspan="2">Health and safety measures</td></tr>
</table>

As discussed, the prerequisite for engaging with lean construction is lean thinking. However, it goes beyond the reorientation of practitioners to 'think lean for sustainability' but to also adopt and use the necessary available resource and tools in this regards in order to produce sustainable buildings. According to the study conducted by Sarhan et al. (2017) the use and implementation of lean construction is the tool required for the construction industry to improve its; productivity, quality, customer satisfaction, relationships and to minimise waste. Thus validating an earlier study by Arayici et al. (2011) who opined that, the overall engagement practitioners with lean approaches to design and construction led to improved productivity and capacity building amongst its practitioners.

## Conclusion

The construction industry has been continuously faced with poor performance, environmental waste management challenges, in the face of global concern for environmental sustainability. The ability to re-orientate the built environmental practitioners to; think lean, adopt and apply lean techniques and principles would promote effective construction productivity. Secondly, the processes of design and construction are guided to have a systematic sequential flow in its deliverable purpose. Thirdly, buildings produced from the processes of lean construction are going to be sustainable buildings. Finally, since the operations of lean construction are sustainable, in the overall, the adaptations and implementation of lean construction promotes environmental sustainability. Further research is proposed to develop a framework that integrates sustainable lean construction processes into construction practices to validate the theoretical methodologies.

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# *The Journey on Sustainable Energy and Environmental Preservation for Improving Community's Welfare: the Ideas from Pesanggaran Power Generation, Bali - Indonesia*

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**Abstract**
Energy efficiency and environmental sustainability are now the highest priority for Pesanggaran Power Generation, Bali – Indonesia. Considering the energy demand has increased exponentially along with environmental degradation, both local and global impact, Pesanggaran Power Generation commit certain efforts to minimize waste disposal from electricity main process, supporting process, and domestic activity. This paper mainly discuss about the journey on implementing the efforts, consist of several aspects: (a) Environmental Management System ; (b) Energy Efficiency ; (c) Hazardous Waste Management ; (d) Solid Waste Management; (e) Emission Reduction; (f) Water Efficiency; (g) Reduction on Wastewater Load; (h) Endemic-Biodiversity Protection; and (i) Community Empowerment. Several ideas intended to improve the local community's welfare by conducting environmental issues and economic as a value added to it. Bali itself has its own uniqueness, due to the usage on resources mostly taking into account the cultural, the heritage, and the complexity of endemic-biodiversity. As the very-fast-growing activity on tourism required energy demand, Pesanggaran Power Generation as one of the biggest companies on electricity generation has to support the demand. The journey on this paper starts from people of Pesanggaran Power Generation together with all local community so it will have mutual-integrated-sustainability for the future.

Keywords: Environmental Sustainability, Energy Demand, Pesanggaran Power Generation, Community's Welfare

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## Introduction

Electricity and its mutual to environmental sustainability are the priority of business for Indonesia Power Corporation. PT Indonesia Power Generation Unit (Unit Pembangkitan - UP) of Bali, though it is one of generation unit that using non-renewable primary energy source to generate electricity in Bali Island through Java-Madura-Bali (JaMaLi) interconnection grid system. PT Indonesia Power UP Bali, generates three units of power plant, consist of Pesanggaran Diesel-Gas Power Plant in Denpasar City, Gilimanuk Gas-Turbine Power Plant in Jembrana District, and Pemaron Gas-Turbine Power Plant in Singaraja District [Dewi P., *et al*., 2015].

Pesanggaran Power Generation situated in Denpasar, Bali Province, Indonesia, as depicted in Figure 1. It operates 4 Unit of Gas-Turbine (installed capacity of 125.45 MW) and 12 Unit of Diesel-Gas Turbine (installed capacity of 200 MW). Currently, several primary energies are used in Pesanggaran Power Generation, such as Natural Gas, High Speed Diesel (HSD), and/or Marine Fuel Oil (MFO).

Figure 1: Overview of Pesanggaran Power Generation, Bali Province, Indonesia. It operates by PT Indonesia Power UP Bali, a subsidiary of State Electricity Company (PT Perusahaan Listrik Negara – PLN Persero), with main core business in operation and maintenance of power plant [Subawa P., 2016].

This paper presents the journey of Pesanggaran Power Generation on environmental preservation along with sustainable electricity generation, which emphasizes to their social responsibility on surrounding Bali community. The journey begins with innovation idea from People of Pesanggaran that has been reflected on achievements of appreciation in Environmental Compliance (EC) and Corporate Social Responsibility (CSR) as discussed below. It is also brings Balinese cultural and the heritage, and the importance on generating electricity for supporting tourism activity in Bali Island.

**Achievement on Environmental Preservation and Community Development**

For the last decade, Pesanggaran Power Generation has been contributed to support governmental goals on conserving the nature, mainly in topics of environmental sustainability and community development. There are some appreciations achieved by Pesanggaran Power Generation [Sumanta, I.M., *et al*. 2017], which are:

- Green PROPER (Period of 2016) – Awarded by Indonesian Minister of Environment and Forestry
- Platinum Indonesian CSR Awards (Period of 2014) – Coastal Community Development in Seahorse Conservation
- Indonesian Green Awards (Period of 2014) – Developing Community's Welfare Throughout Coral Reefs Conservation
- Green PROPER (Period of 2013) – Awarded by Indonesian Minister of Environment, latest becoming Indonesian Minister of Environment and Forestry
- Platinum CSR Best Practice for MDG's (Period of 2012) – Women Empowerment in Koperasi Bangkung Sari
- Platinum Indonesian CSR Awards (Period of 2011) – Coastal Development "Blue is New Green" in Jembrana and Buleleng District, Bali Province

This paper discussed about comprehensive environmental compliance assessment, taking into account energy management and community development [Edgar S., & Adisa A., 2014], which in Indonesia known as PROPER (Program Penilaian Peringkat Kinerja Perusahaan dalam Pengelolaan Lingkungan Hidup). PROPER is a mandatory instrument to measure compliance and beyond compliance effort for industries in many sectors in terms of implementation of 3P Conception (People, Planet, and Profit). It is assessed and awarded by Indonesian Ministry of Environment and Forestry every one year period. PROPER has effectively drive industries to improve their concern on sustainability of business and the environment, as Pesanggaran Power Generation successfully transformed the society not only as regulatory comply but also innovate beyond the regulation.

**Overview of Environmental Compliance Assessment and Beyond (PROPER) in Indonesia**

Regulatory Framework

As mentioned previously, that Indonesian Government has endorsed national environmental conservation in many sectors (industrial and non-industrial). The government drive industries to contribute in environmental compliance and beyond which commonly known as PROPER (Program Penilaian Peringkat Kinerja Perusahaan dalam Pengelolaan Lingkungan Hidup). It is currently regulated under Indonesian Minister of Environment Regulation No. 03/ 2014 within more than ten years period implementation of transforming industries to green paradigm [Ministry of Environment and Forestry, 2014]. PROPER, it has also many improvements in regulatory enforcement, field assessment and evaluation, *etc*.
PROPER will be awarded to industries, whose invited or voluntarily participated, after sequential assessment criteria have been fulfilled. Pesanggaran Power Generation believe that PROPER is an effective instrument to measure the whole

system of industrial activity, as main and supporting process, and also the way industries manage social impact, through Corporate Social Responsibility (CSR).

*Assessment Sequence*

According to PROPER current system of rules, there are some steps for assessing criteria as described in this part.

- Preparation; the very first step, consists of periodical data collection, lesson learned of the best practice from previous PROPER result, and program inventory in on going year activity.
- Compliance Assessment; step where each participant should report their data and supporting evidence. There are some of environmental aspects in this sequence, for energy sector (as Pesanggaran Power Generation is one of it) such as water and air pollution control including ambience monitoring, hazardous waste management, environmental permitting (EIA, sub-EIA, etc.), and also company profile with total numbers of employee and production capacity. This step delivers the results of percentage which divided into Comply (**Blue Ranking**), Barely Comply (**Red Ranking**), and Totally No Comply (**Black Ranking**).
- Beyond Compliance Assessment; the candidates of this step were chosen by considering the results of compliance percentage. Only participants that bringing "100% Compliance" have a chance to propose their beyond compliance document. There are several aspects assessed: the Summary of Environmental Performances with absolute-proven calculation and innovative action, Environmental Management System, Energy Efficiency, Hazardous Waste Management, Solid Waste Management, Emission Reduction, Water Efficiency and Effort on Reducing Wastewater Load, Biodiversity Protection, and also Community Development (a CSR non-charity implementation). Results on this sequence categorized as 25% bottom percentile (back in **Blue Ranking**), between 25% to 75% percentile (**Green Ranking**), and 25% highest percentile (promoted to the **Gold Assessment** – latest known as **Gold Candidate**).
- Gold Assessment; the last but the hardest step to follow. Only the top 25% per sector can be promoted. There is also consideration of environmental consistency as in PROPER required at least twice Green Ranking in-a-row of periodical assessment. The chosen candidates will present their Not-Business-as-Usual (NBaU) and innovative way of thinking, and if necessary, there will be field verification to make sure the adequacy of the NBaU program. This step delivers **Gold Ranking** and **Green Ranking** (if does not meet **Gold Standard** of the ongoing year).

*Environmental Goals*

The society of Pesanggaran Power Generation believes that **Gold Ranking** is the furthest goals for every industry, with many deserving efforts to imply. Pesanggaran Power Generation has just started their journey in beyond compliance area, the certain goals is to optimize resource conservation and utilization as much as possible for better environment and sustainable electricity in Bali Island.

## Best Practice Results and Discussions

PROPER drives many industries to promote environmental conservation, for instance introduce new technology or approach to reduce fossil fuel usage. Therefore, the combination between waste utilization and community involvement are perfect match to promote green paradigm. There are some aspects that assessed under PROPER regulation, every single of them is an optional but mandatory to fulfill progressively. The best practices of Pesanggaran Power Generation for each aspect are discussed below.

Environmental Management System

PT Indonesia Power UP Bali has been certified with International Organization for Standardization - ISO 14001: 2015 (Environmental Management System). UP Bali conducted EMS as fundamental reference on environmental planning to implementation (as for PDCA cycle; Planning-Doing-Checking-Action), and continuous improvement [Rakayana, I.M., & Dewi, A., 2017]. Certified EMS fundamentally is a basic management system as a function of guidance to manage environmental aspects. It is reflected in overall environmental aspects, which aim to manage the impact to the environment as a cause of power generation activities.

EMS is the key role to maintain the activities in Pesanggaran Power Generation, also as guidance awareness on environmental potential harm. Situation and activities is well documented under EMS implementation and monitoring, as depicted in Figure 2.


Figure 2. Effect on EMS Implementation: (left) symbol of potential harm to environment provided in certain location; (right) operational activity in Control Room – all evidences are well documented and controlled by person in charge. It is also communicated both top-down and bottom-up system.

In order to measure the effectiveness of EMS implementation, periodical audit (internal and external) also conducted. Each environmental aspect represents the importance of EMS as guidance to manage environmental impact, not only in physical environment, but also in every point of environment that covered under Environmental Impact Assessment (EIA) document.

Energy Efficiency: Mini-Scale LNG Facility

Pesanggaran Mini-Scale LNG Facility is the first Mini-Scale LNG Terminal in Indonesia, that initiated by PT Indonesia Power UP Bali since year of 2016. The objectives of this program are to reduce fuel oil consumption and to increase energy efficiency from main process. There is also indirect positive impact by implementing this program, such as to reduce emission released to the atmosphere and liquid hazardous waste generation. Mini-Scale LNG Facility illustrated in Figure 3.


Figure 3. Illustration on Mini-Scale LNG Facility that has been built and initiated by PT Indonesia Power UP Bali, introduced as energy efficiency innovative effort for Pesanggaran Power Generation.

The first three months implementation of Mini-Scale LNG, this program has effectively increased energy efficiency about 1,142.83 MWh [Wiadnyana, K.N., *et al*, 2017].

Hazardous Waste Management: Re-Design Waste Gate Coupling

Pesanggaran Diesel-Gas Turbine Power Plant of 200 MW (Wartsila 18V50DF) is motor-combustion power plant that consists of 12 units within each installed capacity of 17 MW. As per June of 2016, Pesanggaran Diesel-Gas Turbine Power Plant has operated with natural gas fuel consumption of 32,000 MMBTU per day [Sofwat, S., 2017]. This situation enforced Pesanggaran Power Generation to compel and maintain the reliability of power generation using natural gas as primary energy.

Waste-Gate Valve is one of main equipment in Diesel-Gas Turbine Power Plant that controlled the rotation of Turbocharger in order to maintain stability of Air-Fuel Ratio of combustion. Any interference on Waste-Gate Valve could decrease absorption on natural gas fuel realization. That situation significantly reduce the potential power generation due to time consuming on amelioration of Waste-Gate Valve within at least required 6 hours/unit of down time. When this condition happen to power operation, disadvantage could occur neither in financial aspects nor in increasing liquid hazardous waste generation due to engine operational mode will automatically switch from Gas Mode to Diesel Mode.

According to that condition, the engineer collaborates to conduct Re-Design of Waste-Gate Valve to minimize or even to eliminate the operational failure. Rigid coupling modification design is illustrated in Figure 4, while the situations on program activities are depicted in Figure 5.

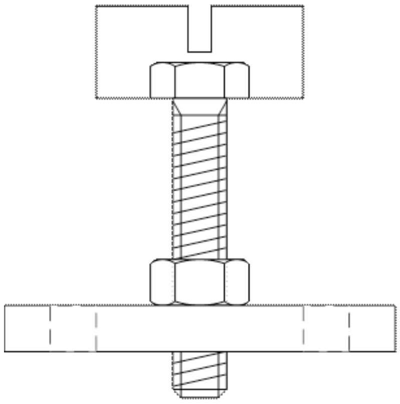

Figure 4. Rigid-Coupling Modification Design

Figure 5. Activity of Re-Design Waste-Gate Valve: (left) Dismantling the Waste-Gate Valve in PLTDG 10 Pesanggaran; (right) Assesmbly the Re-Designed Waste-Gate Valve in PLTDG 10 Pesanggaran.

As in integrated environmental perspective, this program aims to minimize operational failure within gas mode. That is also preventing the liquid hazardous waste disposal 2,630 liter/disruption/engine.

Solid Waste Management: The Bank of Solid Waste

As mentioned previously that Pesanggaran Power Generation generates electricity within environmental concern and surrounding community involvement. Domestic activity in Pesanggaran Office however has consequence on solid waste generation. In order to be able to prevent the solid waste disposal to the environment, we initiate integrated solid waste management program that adopted banking system conception. It is known as Pesanggaran Bank of Waste that has a main purpose to assist local community, in the same time, improving their earnings and knowledge about practical municipal solid waste management. Program activity is shown in Figure 6.

Figure 6. Bank of Waste Activity: (left) Waste Collection; (right) Waste Weight Measurement.

As per May of 2017, at least 431 kg inorganic solid waste has been managed in Pesanggaran Bank of Waste [Sukarma, I.M., et al, 2017]. It is monitored and evaluated periodically (weekly, monthly, and also quarterly per year).

Emission Reduction: Methane Gas Utilization

As part of integrated emission reduction to improve community's welfare, Society of Pesanggaran contribute to reduce anthropogenic global warming potential from landfill waste activity [Thomas G., & Edgar H., 2014]. We utilize Methane Gas from Landfill Waste "TPA Suwung" Pesanggaran to eliminate the use of Liquefied

Petroleum Gas (LPG-Household Gas Consumed). Schematic process is shown in Figure 7.


Figure 7. Schematic process of Methane Gas Utilization from TPA Suwung for Household Application [Mahendrayana, I.G.N., *et al*, 2017]

The aim of this program is to optimize renewable energy utilization from Bali Waste Landfill where organic waste is dominant compared to inorganic waste. The potential is much higher than other regions in Indonesia since Bali has high organic waste from cultural and religious activity of Balinese. Program has been initiated in year of 2017 within stage one development of 10-burner methane-gas stove. It is calculated that the program potentially reduce 453,600 ton $CO_2$ per year.

Water Efficiency: Reverse Osmosis Reject Water Utilization for Demineralized Water

Power generation operation does require certain amount of water, for main and supporting process, and domestic activity. As water resource plays important role on business operation, it is highly recommended to manage the use of water wisely. Water efficiency program that conducted in this paper came from reverse osmosis reject water, which utilized for demineralized water. The utilization taking into account pipeline modification, as depicted in Figure 8.


Figure 8. Pipeline Modification for Reverse Osmosis Reject Water Utilization

This program has been started since year of 2016, which effectively reduce groundwater consumption [Ponidi, *et al*, 2017] as shown in Figure 9.

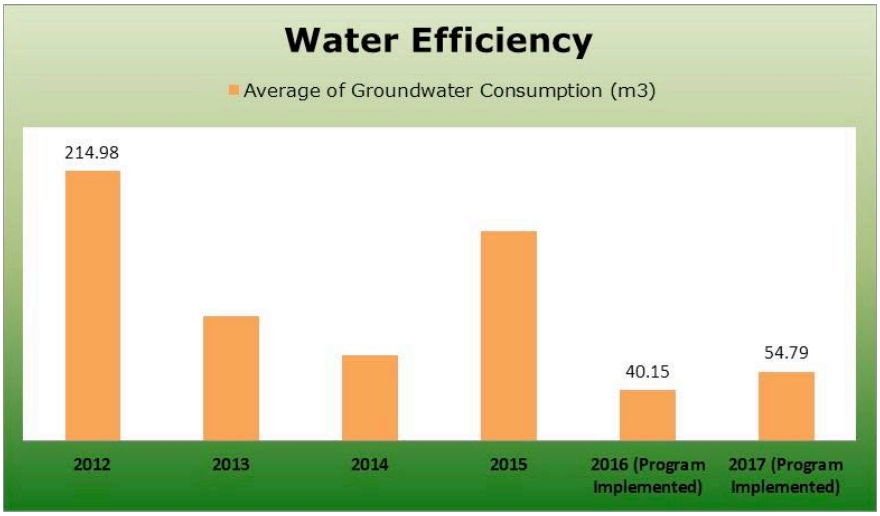


Figure 9. Profile of Groundwater Consumption: before (2012-2015) and after Program Implementation (2016 – present).

Figure 9 shows the effectiveness of water efficiency program that reflected on amount of groundwater consumption. It can be seen that after program has been implemented, groundwater consumption reduced significantly compared to previous year of operation. However, the amount of water consumption for power generation activities also depending upon actual number of power plant unit operates.

Reduction on Wastewater Load: the Integration of Water Efficiency

The water efficiency program discussed above also has indirect impact to the amount of wastewater load to the stream environment. Calculated wastewater load disposed to the stream is depicted in Figure 10.

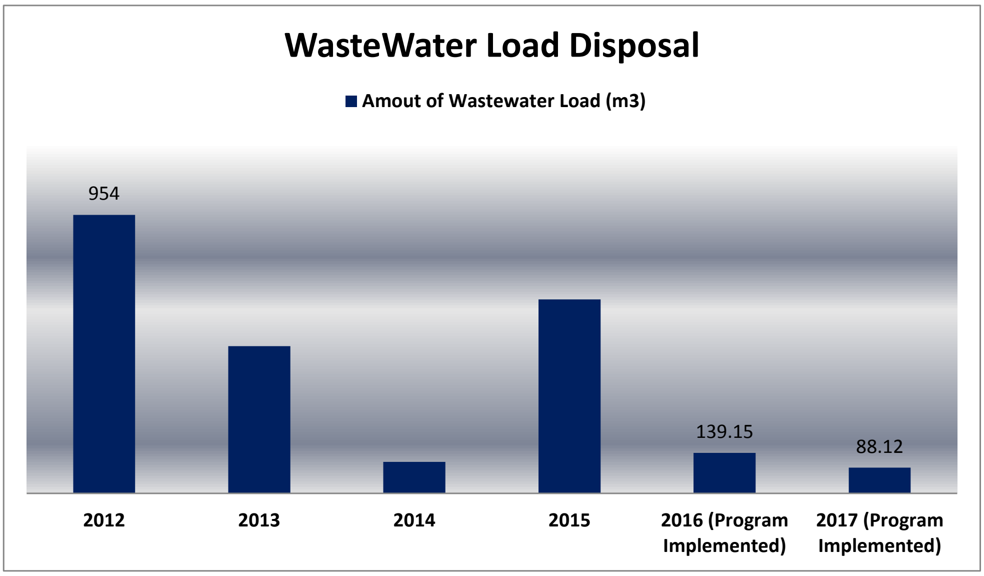


Figure 10. Calculated Wastewater Load Disposal to the Environment

The first year of implementation in 2016 has been effectively reduced wastewater load approximately 79% in comparison with previous year before implementation. Monitoring and evaluation has also played important role to measure the periodical effectiveness of the program [Ponidi, *et al*, 2017].

Endemic-Biodiversity Protection (I): Sea-Turtle Conservation

In addition to focusing on waste utilization as consequences of power generation activity, Pesanggaran Power Generation also taking action to preserve number of natural biodiversity in Bali. It is also contribute to support government and surrounding community as part of tourism development. There are two programs discussed in this paper, which consists of marine biodiversity (I) and land biodiversity (II).

For marine biodiversity preservation, Society of Pesanggaran collaborated with Bali Sea-Turtle Conservation Troop (Kelompok Konservasi Penyu Bali). It is located in Saba Village, Blahbatuh, Gianyar District, Bali Province. The program also supported under Center of Natural Resource Conservation of Bali (Balai Besar Konservasi Sumber Daya Alam) - Indonesian Ministry of Environment and Forestry. Monitoring activity also conducted by local university [Mirela, S., 2014] in order to contribute knowledge development of endemic biodiversity in Bali. Several activities are depicted in Figure 11 – Figure 12.

Figure 11. (Left) Cultivation of Sea-Turtle Eggs; (Right) Hatchling Sea-Turtle that Ready to Release to the Sea


Figure 12. (Left) Overseas student visit to Bali-Sea Turtle Saba Village; (Right) Representation of Pesanggaran Society in Preparation of Sea-Turtle Release

As a result of collaborative action in 2017, at least 200 Hatchling-Sea Turtles (*Lepidochelys olivaceae*) has been released to the sea [Sukerena, I.W., *et al*, 2017]. We believe that the program will continue and even improved the number of biodiversity index of Sea-Turtle.

Endemic-Biodiversity Protection (II): Balinese White-Ox Conservation

For land biodiversity conservation, we conducted biodiversity based on Balinese cultural and religious point of view. It is White-Ox Conservation (Lembu Putih) that initiated in year of 2017, in collaboration with White-Ox Taro Foundation (Yayasan

Lembu Putih Taro) – see Figure 13. This program is stil under planning and field visitation of Pesanggaran Team.

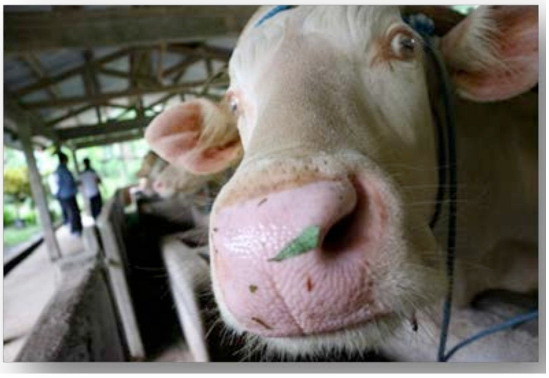


Figure 13. (Left) Appearance of White-Ox in Taro Village; (Right) Monitoring Board of White-Ox Population

There is uniqueness of Balinese White-Ox, where it used for rituals and ceremonies activity [Sukerena, I.W., *et al*, 2017]. This animal is much respected and sacred mainly for Balinese due to it is the ride of Lord Siwa, the symbol of mother of the earth, and the complimentary animal as the witness of certain ceremony. After ceremony is over, Balinese White-Ox is given many offerings and foods, and then this holy White-Ox is taken back to the Forest in Taro Village.

<u>Community Empowerment: Organic Farming Development in Subak Kedua Rice Clusters</u>

Pesanggaran Power Generation has been awarded in many criteria of integrated Corporate Social Responsibility (CSR). They have value added to CSR implementation, which is not only focus on charity, but also even more focus in community empowerment [Gusti, K.S., 2012]. This paper discussed the new-launched community development program based on recommendation of social mapping study.

Pesanggaran Power Generation empowered women [Rita, V., et.al., 2014] as an icon to drive food security in organic farming. It is situated in Subak Kedua Rice Clusters – see Figure 14, with main purposes to introduce new-paradigm of farmer-based-entrepreneurship development [Sumanta, I.M., et al, 2016]. The program also aims to support governmental goals to improve community's welfare.

Figure 14. Subak Kedua Rice Clusters: Organic Farming Women Empowerment Program

Subak Kedua Rice Clusters development initiated since year of 2016, and under ongoing implementation in year of 2017. Monitoring and evaluation will be reported in other publication by considering particular parameter, such as time scheduling, benefit recipients, feedback from the community, etc.

## Conclusions and Recommendations

We conclude that program conducted by Society of Pesanggaran, cannot applied effectively without collaboration and teamwork among certain actors. Program that under planning or even has been implemented require monitoring and evaluation procedures as covered by Environmental Management System manuals.

We also recommend to the industry to collaborate with government, higher education, and local community to campaign for environmental preservation. These all are the key to establish surrounding environment.

## Acknowledgement

We would like to thanks to overall persons in charge of each aspects, for their remarkable effort from planning to implementation of each program. We also deliver our gratitude for surrounding community in Pesanggaran Power Generation implementation program. Overall program will not be able to complete without support from government, expert from universities, etc. We hope that those programs

could inspire any other industries to develop environmental conservation campaign to reduce negative impact from industrial activities.

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# *Socio-Energy-Environmental Management in West Bali: a Case Study of Gilimanuk Gas-Turbine Power Plant, Indonesia*

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**Abstract**
This paper mainly presents about Environmental Management, taking into account energy and societal aspects, of Gilimanuk Gas-Turbine Power Plant (GTPP), West Bali – Indonesia. Currently Gilimanuk GTPP is a stand-by unit for electricity back-up in Java – Madura – Bali (JaMaLi) interconnection grid system. Over the last couple years, Gilimanuk GTPP is not in full operation condition, which has been challenged to maintain environmental aspects of Gilimanuk GTPP as a beyond compliance initiatives without focusing on profit. Furthermore, Gilimanuk GTPP still needs some natural resources, such as produced water, primary energy (high speed diesel), and for domestic activity. As for the consequences of resource utilization, the impact on the environment is a must to be reduced. This paper proposes several programs to maintain environmental preservation particularly in West Bali. The objectives of this paper are to share 3 (three) fundamental efforts on resource conservation: (1) technical innovation for energy efficiency and emission reduction; (2) waste minimization for water resource and wastewater management, including hazardous and non-hazardous waste responsibility; and (3) sustainable biodiversity conservation surrounding community development area. Some items have been implemented, monitored and evaluated periodically, while other programs are still in the design and planning which will be implemented in mid to late 2017.

Keywords: Environmental Management, Gilimanuk Gas-Turbine Power Plant, Resource Conservation.

## Introduction

Electricity, as part of energy security, is now the most vital demand for both domestic and industrial activity. Prolific energy sources in Indonesia also drive many power generation companies to accomplish electricity demand by considering the most viable primary energy to be used. According to that situation, Gilimanuk Gas-Turbine Power Plant (GTPP), one of power plant unit operated by PT Indonesia Power UP Bali, is currently stand-by unit for power generation back-up. It is due to the electricity demand already fulfilled by other power plants in Jawa-Madura-Bali (JaMaLi) interconnection grid system.

However, stand-by unit doesn't mean there is no activity in Gilimanuk GTPP. In fact, it is still require natural resource for temporary start operation (produced water, primary energy – represents as high speed diesel, etc.) and also for domestic activity in office building. This situation has challenged People of Gilimanuk GTPP, to manage environmental impact without focus in creating any profit since its current operational condition. We believe that even a very small amount of natural resource utilization, the effect to surrounding environment is unavoidable. In this paper we present the effort from People of Gilimanuk GTPP in order to conduct environmental management, by taking into account energy and societal aspect [Edgar, S., & Adisa, A., 2014].

Gilimanuk GTPP located in West Bali, Jembrana District, Bali Province, Indonesia (see Figure 1). It has been operated since 1997 within total installed capacity of 133.8 MW [Dewi P., *et al*., 2015]. Primary energy used in Gilimanuk GTPP is High Speed Diesel (HSD).

Figure 1. Appearance of Gilimanuk Gas-Turbine Power Plant in West Bali [Purwakanta, I.N., 2017]

Effort on environmental management in Gilimanuk GTPP has achieved appreciation from Indonesian Minister of Environment and Forestry as Green PROPER 2016. This achievement was the first environmental accomplishment for People of GTPP. It is also becoming a motivation to maintain the way they manage environmental impact and the surrounding community.

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- Gold Assessment; the last but the hardest step to follow. Only the top 25% per sector can be promoted. There is also consideration of environmental consistency as in PROPER required at least twice Green Ranking in-a-row of periodical assessment. The chosen candidates will present their Not-Business-as-Usual (NBaU) and innovative way of thinking, and if necessary, there will be field verification to make sure the adequacy of the NBaU program. This step delivers **Gold Ranking** and **Green Ranking** (if does not meet **Gold Standard** of the ongoing year).

*Environmental Goals*

People of Gilimanuk GTPP, as part of PT Indonesia Power UP Bali, presume that **Gold Ranking** is the very furthest goals for every industry, with many deserving efforts to imply. Gilimanuk GTPP has just started their journey in beyond compliance area, the certain goals is to minimize environmental impact to the environment. We also focus on exploring potential innovation about energy-environment-social management mainly in Gilimanuk area, West Bali, Indonesia.

## Best Practice and Discussion

PROPER drives many industries to actively encourage environmental conservation, to drive innovation in waste utilization and resource optimization. Collaboration between stakeholders (higher education, local community, local to regional government, etc.) and company is other key role towards excellent environmental management. There are some aspects that assessed under PROPER regulation, every single of them is suggested to fulfill progressively. The best practices of each environmental compliance aspect are discussed below.

<u>Environmental Competencies</u>

People of Gilimanuk GTPP commonly have background of study in mechanical and electrical engineering. Only a few of them have background and basic knowledge in managing environment. As the complement of their competencies, the human resource division provides every person in charge an informal education, either in training or certification of specific environmental aspects.

There is also discussion forum about current progress of environmental management program, including energy efficiency and community development [Dewi, P., *et al.*, 2017]. Discussion forum are depicted in Figure 2.

Figure 2. Environmental Discussion Forum for People of Gilimanuk GTPP

Providing certain environmental competencies is also a part of strategic planning on environmental compliance and beyond. There are several training and certification, such as:

- Training and Certification on ISO 14001: 2015 (Environmental Management System)
- Training and Certification of Manager of Energy
- Training and Certification of Auditor of Energy
- Training and Certification of Air Pollution Control Management
- Training and Certification of Water and Wastewater Management
- Training of Hazardous Waste Management
- Training of Municipal and Industrial Solid Waste Management
- Training of Biodiversity Protection
- Training of Basic on Implementing Community Development

In order to maintain adequacy and effectiveness, overall aspects were mapped by human resources department by considering passion of each person in charge. Training and/ or certification also updated at least every 2 years period.

Energy Efficiency: Motion Detection System (Passive Infra-Red and Oto-Switch Lamp

As Gilimanuk GTPP is under stand-by condition, the use of energy consumption for main and supporting process is very modest. This situation left no chance on implementing previous energy efficiency program, such as VIGV (Variable Inlet Guide Vane) and TAT (Temperature after Turbine). Those two programs have been successfully implemented before Gilimanuk GTPP becoming stand-by. So that energy efficiency program maintained until nowadays is from domestic activity.

In this paper, we presents energy efficiency program, which is motion detection system using Passive Infra-Red and Oto-Switch Lamp (see Figure 3).


Figure 3. One of Motion Detection System in Gilimanuk GTPP

This program is located in several points such as Office Building, Demineralization Plant, *etc*. with an objective to use electricity wisely. Motion Detection System has been started since year of 2012 with approximate total energy saving until May 2017 is about 2.43 MWh [Jun, F.S., 2017]. Other program in energy efficiency will be evaluated later examine power generation status in Gilimanuk GTPP.

Integrated Effort on Hazardous Waste Management

There are currently three main programs in hazardous waste management, such as:

- Reduction on Hazardous Liquid Waste (See Figure 4)

  This program is focusing on the reduction of hazardous waste in liquid form and also to avoid its disposal to the environment. The fuel waste generates from combustion drainage, leaching fuel filters, and residual product from combusting process. Meanwhile lubricant waste generates from First Line Maintenance (FLM) activity. As per May of 2017, there is only one activity on maintenance, with amount of liquid waste reduction about 2,000 liter [Francisco, S., & Darmawan, I.N., 2017].

Figure 4. Recycle on Hazardous Liquid Waste for Internal Reuse

Other advantage shows in financial perspective, where lubricant and fuel can be used as a recycled product. It has been calculated that the program effectively reduce fuel and lubricant consumption about 11,478,000 IDR.

- Substitution of Mercury Lamp to Light Emitting Diode (LED) Lamp

This program can be considered as the longest common practice on industries in Indonesia, mainly in power generation sector. It is aim to substitute the use of Mercury Lamp into Light Emitting Diode (LED) Lamp. Environmental advantage based on this program is the reduction on hazardous waste generation (Mercury Lamp). At least, it shows an effort as part of integrated hazardous waste management as depicted in Figure 5.


Figure 5. Substitution of Mercury Lamp to LED in Office Building

This program mainly implemented in office building of Gilimanuk GTPP, and monitored the effectiveness periodically by specific person in charge.

- Reduction on Dust Cloth Waste (See Figure 6)

  Dust cloths are used to protect workers from hazardous material contamination, which is part of safety procedure. As a consequence, there will always dust cloths waste generates from each maintenance activity. People of Gilimanuk GTPP, as mentioned previously works in operation and maintenance area, reduce dust cloths waste disposal within behavior based safety and environment. They accentuate carefulness and awareness around working area, so that contaminated dust cloths can be reduced. The used-dust cloths that still properly usable, is then re-using in the next maintenance activity.

Figure 6. Activity on Reduction of Dust Cloth Waste

The three program at least capable to reduce hazardous waste disposal for the last five year, as depicted in Figure 7.


Figure 7. Ratio of 3R Hazardous Waste Implementation

Figure 7 shows that the effort on implementing hazardous waste management with 3R basic conception (Reduce, Reuse, Recycle). At least it is capable to increase the 3R ratio to 86.05% as per 2016.

Solid Waste Management: Plastic Waste to Handicrafts

This program was firstly implemented in the beginning of 2017, with an objective to improve community skills in processing plastic waste. Located near area of Gilimanuk GTPP, we also empower local community that in the same time promoting environmental campaign in reducing plastic waste. The community icon of this program is empowering local women in manage the processing to marketing of the handicrafts product (handicrafts product see Figure 8).

Figure 8. Handicrafts Product Made from Plastic Waste

Program has successfully implemented for the first semester of 2017 [Ryan, T.P., & Wijaya, I.W., 2017], as depicted in Figure 9.


Figure 9. Amount of Plastic Waste Processed into Handicrafts

As shown in Figure 9., amount of plastic waste mostly increases depending upon number of waste that viable to be used as handicraft raw material. The most concern about waste management is not amount of waste that can be processed, as long as the waste generation reducible from the source.

Emission Reduction: Re-Design of Ignition Torch to Minimize Start Failure

One of original innovation from People of Gilimanuk GTPP in action of emission reduction is Re-Designing Ignition Torch in order to minimize failure on start operation. Apparently operational problem starting since start-stop pattern on power operation has been effectively applied. The root-cause of start failure is due to disruption on ignition torch, which is in Gilimanuk GTPP the old-type of ignition torch has obsoleted spare part. Moreover, whorl-shaped of ignition connector require time-consuming overhaul. So it is considered as chronic operational problem that require re-design.

This program aims to improve reliability of power operation by replacing isolator ceramic within thicker and bigger diameter. Specification of isolator is porcelain with approximate dielectric strength 6 kV/mm. The changing on ignitor isolator ceramic is from 2.5 mm to 5 mm within dielectric strength from 15 kV to 30 kV [Wahyu, D.N., *et al*., 2016]. The objective is to increase life time of it as depicted in Figure 10.

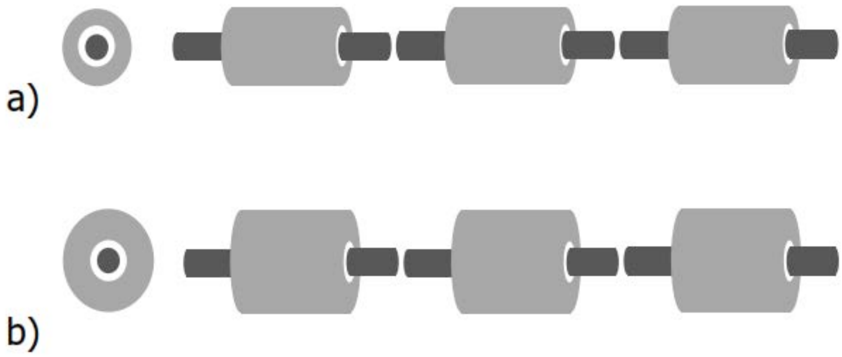


Figure 10. Ignitor Isolator Ceramic: (a) before ; (b) after innovation

Based on calculated emission reduction potential, this program possibe to reduce 5.4 ton $CO_2$-eq per year per start operation, as shown in Table 1.

Table 1. Emission Reduction Potential from Re-Designing Ignition Torch in Gilimanuk GTPP

| Year | Amount of Start (Unit/ year) | $CO_2$ Reduction per Start (ton $CO_2$-eq/year) | Total Emission Reduction | Remark |
|---|---|---|---|---|
| 2013 | 216 | 5.4 | 1166.4 | Fully Operated |
| 2014 | 182 | 5.4 | 982.8 | Peak Load |
| 2015 | 9 | 5.4 | 48.6 | Standby |
| 2016 | 0 | 5.4 | 0 | Standby |
| 2017 | 3 | 5.4 | 16.2 | Standby |
| Total | | | 2,214.00 | ton $CO_2$-eq/year |

Based on Table 1., total emission reduction on various operational condition in Gilimanuk GTPP as per year of 2017 is about 2,214.00 ton $CO_2$-eq per year [Wahyu, D.N., 2017]. it is very additional where power generation is not in operation condition, but has effort to reduce emission released to the atmosphere. This program also monitored periodically, mainly every start-up.

Water Efficiency: Reverse Osmosis Reject Water Utilization for Demineralized Water

This program aims to utilized reject water as substitution for raw water, which is clean water treatment processed from local water company – Perusahaan Daerah Air Minum (PDAM) Gilimanuk. The utilization is using Reverse Osmosis unit as the process briefly shown in Figure 11.

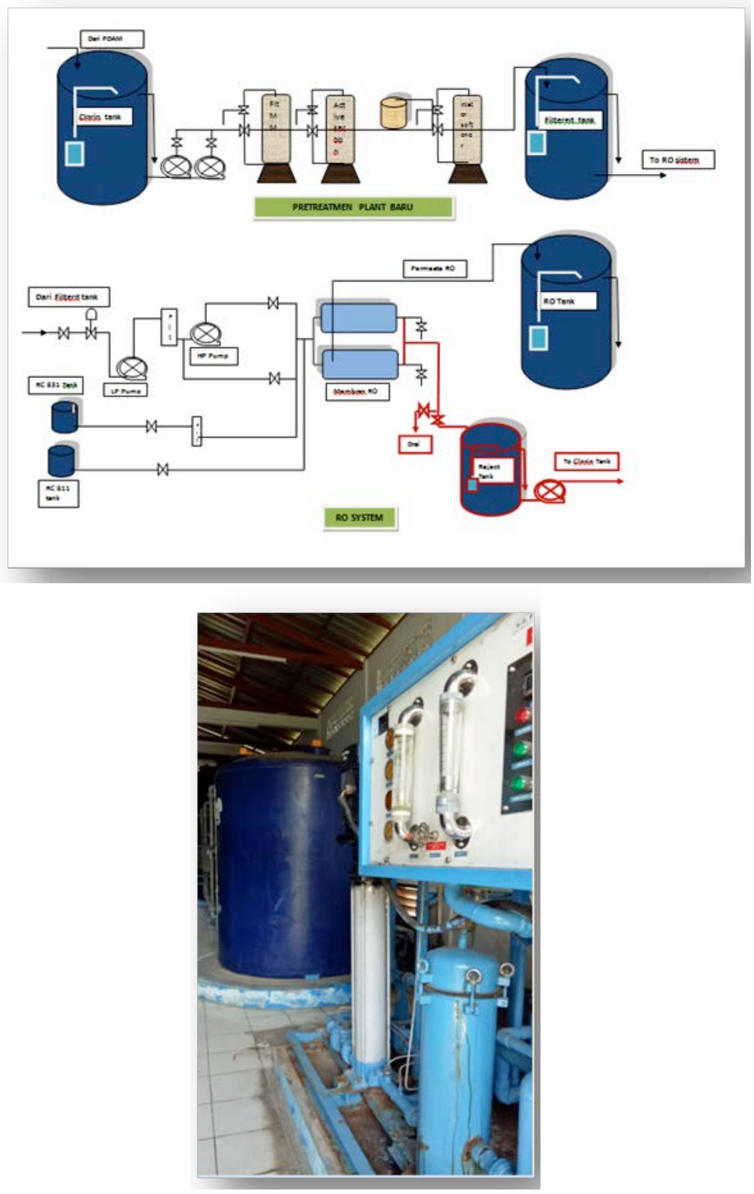


Figure 11. Process Flow Diagram of Reverse Osmosis Reject Water Utilization

Reject water utilization for demineralized water is a program towards water conservacy due to start-stop operation condition. Water efficiency measured and calculated as an positive impact in Gilimanuk GTPP is then depicted in Figure 12.

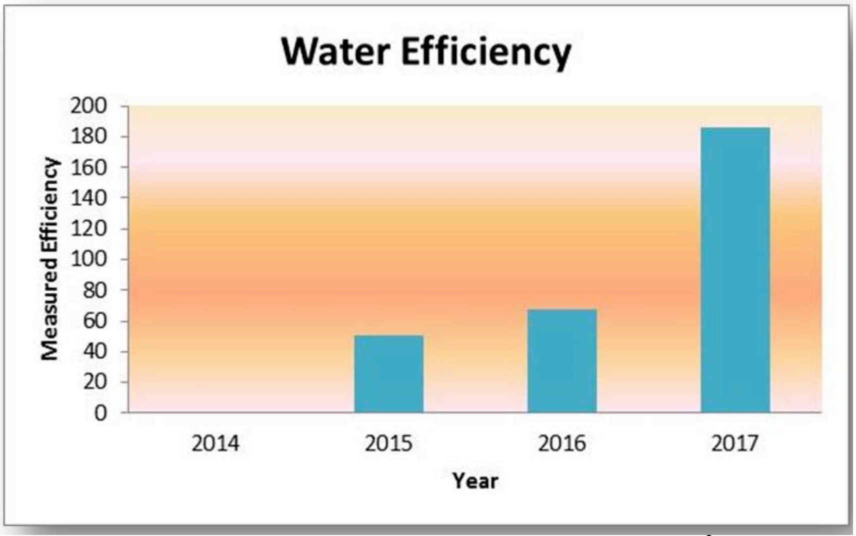


Figure 12. Water Efficiency (in cubic meter-m$^3$)

Figure 12 shows the effectiveness on this program based on water measurement. As per March of 2017, the water efficiency of this program has increased more than 275 percent in comparison with previous year of implementation [Pasek., I.W.M., & Swartana, I.N., 2017].

<u>Reduction on Wastewater Load: Wastewater Garden Land Application</u>

People of Gilimanuk GTPP show their concern in reducing wastewater load disposal to the environment by utilizing treated wastewater into land application. Wastewater garden land application also aims to reduce the use of groundwater or processed clean water. Other advantage on applying this program is shown in Figure 13. The essential-organic content in treated wastewater is better than processed clean water for improving fecundity of the plants.

Figure 13. Appearance on Wastewater Garden Application

Treated wastewater content on several parameters since implementation of this program is depicted in Figure 14.

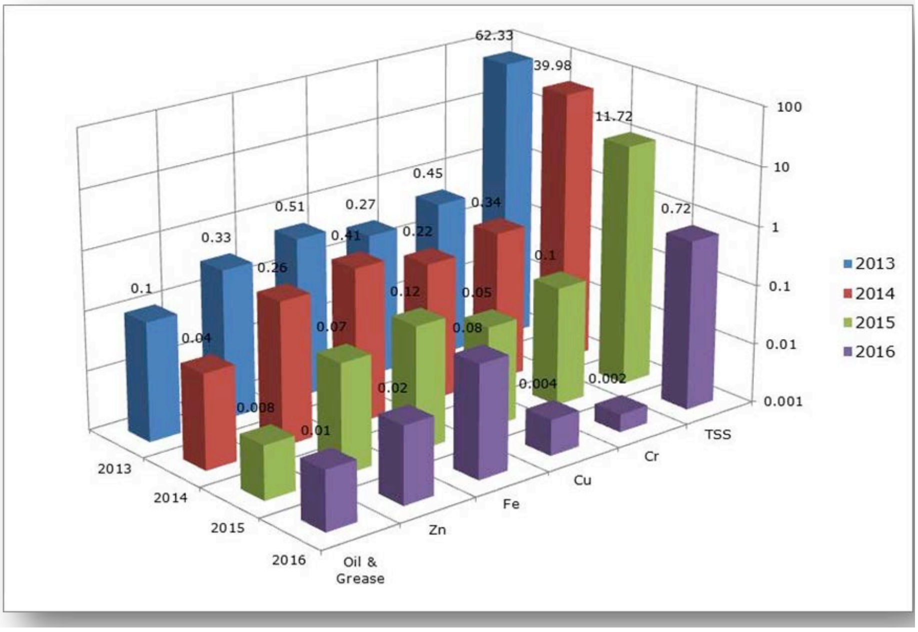


Figure 14. Treated Wastewater Content in Gilimanuk GTPP for Land Application [Dewi, P., *et al*., 2017]

Figure 14 shows the fluctuation on treated wastewater content that used in land application during four year of implementation. It is clearly shown that content of each parameter decreased year by year. The impact on plant fertility are not discussed in this paper and planned to be monitored furtherly.

Endemic-Biodiversity Protection: Lovebird Conservation

Lovebird or *Agapornis* birds has number of species variety, with also vary conservation status (from Stable, Least Concern, Vulnerable, to Near Threatened). This situation is becoming one of concern in Gilimanuk area due to the power plant location adjoined with National Parks of West Bali (Taman Nasional Bali Barat-TNBB). So that, the person in charges taking action on various lovebird conservation to increase the status of lovebird population. For at least two and half year of implementation, this program has progressively increases the proliferation of lovebird as depicted in Figure 15.

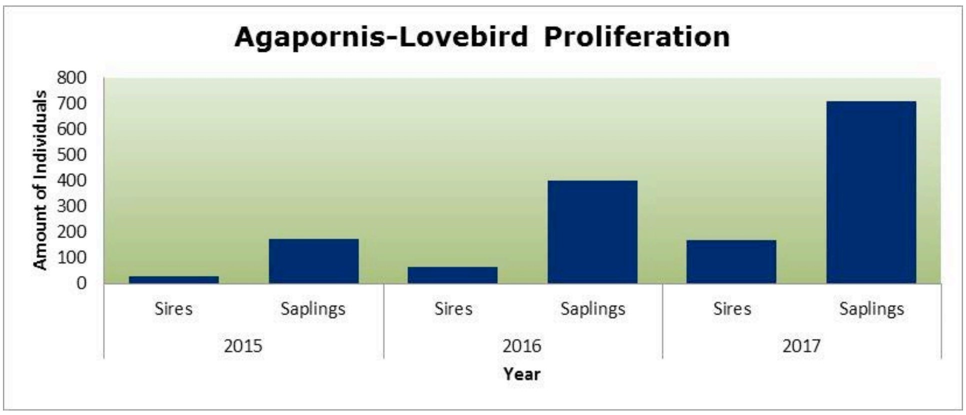


Figure 15. Lovebird Proliferation in Gilimanuk Conservatory Area

Figure 15 shows population trend on Lovebird conservation during the last three years of initiatives. It is known that the population has been increased both Sires and Saplings [Rizal, I.K.M., *et al*., 2017], and also increasing the color and uniqueness variety of Lovebird as depicted in Figure 16.

Figure 16. Variety of Lovebird Population

This program has been successfully increased number of population and variation of *Agapornis* birds in West Bali. The other advantage also shows in social perspective, due to this program is integrated with local community empowerment.

<u>Community Empowerment: Integration to the Environmental Endeavor</u>

As an integrated effort in environmental management within surrounding local community, Gilimanuk GTPP has been implemented some program taking into account CSR perspective. This paper discussed two environmental based community empowerment program that initiated by People of Gilimanuk.

- Plastic Waste to Handicrafts

  The objective of this program is to utilized used-plastic waste by enhancing women as agent of change. The empowerment of local women as an icon believes to effectively transform waste into something valuable. As per year of 2017, craftswomen empowered in this program have been increased up to 9 persons from only 2 persons in the beginning. Gilimanuk GTPP facilitates the craftswomen informal education, such as workshop and training on related activity. It is then depicted in Figure 17.


Figure 17. Activity on Waste Crafting using Sewing Machine and Manual

As the community development officers monitored and evaluated the program, it has been increasing average income up to 47% in comparison with regional standard [Airlangga., *et al*., 2017]. We believe this program is effective way to connect people with environment by realizing the important of waste, not to be wasted but to be processed.

- Lovebird Conservation

As already stated this program has begun with initiatives to preserve biodiversity surrounding West Bali Area. Not only implemented in biodiversity concept, Lovebird conservation also broadening community involvement. This program started with one breeder, and for the recent three years period it has been expanded to ten breeders. It is very significant as reflected in growing population number depicted in Figure 15 above. The uniqueness of Lovebird also became a magnet to attracting tourism in West Bali, as depicted in Figure 18.

Figure 18. Tourism Visitation in Lovebird Conservatory Area

As number of breeders growing significantly along with tourist visitation [Abdul, R.A.R., *et al*., 2013], the interest of nourishing the birds also positively drives the tourist to purchase. This program has successfully increased current average income amount 2,600,000 IDR per month per breeder.

## Conclusions and Recommendations

This paper concludes that environmental management in power plant industry also taking into account energy and societal aspect. People of Gilimanuk wish overall environmental management program can be improved within or without considering operational condition. We believe that the effectiveness of environmental sustainability represents in the way we conserve natural resources and manage its impact in many aspects. We wish that out effort inspired other industries to conserve the environment because sustainable environment start here.

## Acknowledgement

We wish to express our gratitude to surrounding community in Gilimanuk, Jembrana District - West of Bali. We comprehend that overall environmental management effort initiated in Gilimanuk GTPP are nothing without their genuine involvement. We also thank to local government in Jembrana District for their support on our initiatives. This paper will also not going to be published without support from top management of PT Indonesia Power Generation Unit of Bali. Their vision to develop sustainable electricity generation towards becoming World Class Service Company has endorsed every single part of corporation to transform into environmental paradigm.

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# *Effects of CSR Performance and Disclosure on Institutional Ownership*

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**Abstract**

This study investigates correlations and lead-lag relationships between Corporate Social Responsibility (CSR) and the institutional ownership base of North American and European utility companies. The utility sector belongs to the best CSR performing sectors according to CSR scores and is generally seen as fairly "environmentally sensitive". Two samples of 105 and 87 mid- to large-cap utility companies and a panel data regression are used to examine each of the CSR dimensions (environmental, social and governance) between 2011 and 2015. Additionally, a lead-lag analysis establishes causality between the variables. The study finds that while more socially responsible utility companies exhibit greater long-term institutional ownership (LIO), higher corporate governance disclosure and performance is accompanied by less long-term and greater short-term institutional ownership. The lead-lag analysis entirely supports a causal effect of CSR performance on LIO and a causal effect of LIO on CSR disclosure. The latter finding indicates that it is rather the long-term institutional investor influencing the CSR disclosure than the other way around. As for the short-term horizon, the lead-lag analysis shows a causal effect of CSR performance and disclosure on the short-term institutional ownership base of sample firms. This study contributes to scientific literature by using a recent data set, looking at both the performance and disclosure dimension of CSR. Furthermore, most prior studies have only looked at simple correlations, neglecting the causality issue. This study establishes causality between the variables with a lead-lag analysis.

Keywords: Corporate Social Responsibility (CSR); institutional ownership; CSR disclosure; CSR performance; lead-lag analysis; value relevance; utility companies

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## 1. Introduction

With the emergence of sustainability and responsibility issues in the 20th century, the term Corporate Social Responsibility (CSR) has quickly become a buzzword, uttered by everyone and intrinsically valued by (almost) no one. However, with global companies encroaching upon entire biospheres, destroying the livelihood of local communities and along the way possessing cash savings three to four times larger than the gross domestic product (GDP) of numerous countries, the discourse about CSR has even climbed to whole new heights with the beginning of the 21st century.

Slowly but finally, the environmental, social and governmental activities of companies (and their failures and frauds!) all over the world, are starting to gain their appropriate attention. Cases like the disastrous contamination of the Rio Doce in Brazil in 2015, wreaking havoc on the entire biosphere, making the survival of any biological organism around it impossible, show that companies do often – if not regularly – have substantive influence on the (social) environment surrounding them.

With companies constantly growing to global enterprises, this phenomenon gets even more severe for society. Recent studies like Heflin and Wallace (2017) show that negative shareholder wealth effects of oil spills are smaller for companies with more environmental disclosure. Not only institutional investors may be able to exert pressure on companies' CSR but a positive CSR may also attract long-term oriented investors looking for smooth and stable returns. The management of multinational companies slowly starts to realize that the concept of CSR does not know any boundaries and should have entered the corporate universe already a long time ago.

Therefore, this study investigates the effects of Corporate Social Responsibility (CSR) on the institutional ownership base of North American and European utility companies, applying a lead-lag analysis to establish causality between the variables. In doing so, the authors contend that *ceteris paribus*, higher CSR performing and disclosing companies should have a higher and more stable long-term institutional ownership base (i.e. attract long-term equity capital).

Accordingly, this hypothesized relationship is disputed along the two CSR dimensions, performance and disclosure, and based on several sub-hypotheses. Hence, the authors use two recent samples of 105 and 87 mid- to large-cap utility companies and a panel data regression, to examine the two CSR dimensions for the period of 2011 to 2015. Further providing sufficient robustness of results, the authors also include the short-term institutional ownership base as benchmark. A lead-lag analysis tests the correlations for causality.

The authors decided to investigate the North American and European utility sector due to two central reasons. Firstly, the utility sector is generally perceived as "environmentally sensitive" and secondly, utility companies belong to the best performing companies in terms of CSR – according to CSR performance scores.

## 2. Background Theory and Literature

### Corporate Social Responsibility (CSR)

This study consistently follows the definition of CSR by van Marrewijk (2003), according to which Corporate Sustainability (CS) and Corporate Social Responsibility (CSR) are precisely "two sides of [the same] coin". This implicates that the term CSR also includes the sustainability (environmental) and governance and not only the social dimension.

This notion also finds its expression in the term ESG (**E**nvironmental, **S**ocial and **G**overnance). ESG describes the three relevant input factors to measure the CSR performance and disclosure[1] of companies. In this study, CSR and ESG are used as synonyms.

Besides, several studies exist dealing with sub-categories of CSR reporting mostly with regard to emissions reporting (e.g. Comyns, 2016; Depoers, Jeanjean, & Jérôme, 2016; Matsumura, Prakash, & Vera-Muñoz, 2014) or social disclosure (e.g. Anderson & Frankle, 1980; Cormier & Gordon, 2001; Patten, 1991; Qiu, Shaukat, & Tharyan, 2016; Richardson & Welker, 2001).

### Principal-Agent-Theory (PAT) and CSR Engagement

Since this investigation focuses on institutional ownership, the Principal-Agent-Theory (PAT) plays a major role in understanding the possible relationship between a company's CSR and an investor's investment behavior. In general, the PAT assumes that regarding their informational level, investors are in entirely different (asymmetric) positions compared to management because they delegate the responsibility of daily business conduct. This *information asymmetry* and the two implications *adverse selection* and *moral hazard* were already research topic of many studies (Akerlof, 1970; Baber, Janakiraman, & Kang, 1996; Baiman, 1982, 1990; Bushman & Indjejikian, 1993; Clinch, 1991; Ely, 1991; Sloan, 1993; Watts & Zimmerman, 1986 as cited in Berthelot, Cormier, & Magnan, 2003).

The PAT seems to stand between investors and the company, and since institutions belong to the largest, most committed and seemingly ever-expanding group of investors, they are of substantial value to the enterprise as a whole. Research by Grossman (1981) and Milgrom (1981) suggests that companies (should) have incentives to disclose information beyond financial statements voluntarily. Other studies examine whether a companies' management tends to withhold (potentially detrimental) information regarding a company's CSR performance (e.g. Barth, McNichols, & Wilson, 1997; Bewley & Li, 2000; Dye, 1985; Li, Richardson, & Thornton, 1997; Verrecchia, 1983). In fact, they find several reasons why management is withholding information (e.g. sanction risk, proprietary costs, external group uncertainty). Hence, they argue in line with the PAT and its consequences.

[1] Whenever the authors write only "CSR", they address both dimensions, performance and disclosure. If the authors address only one dimension, they state either "CSR performance or CSR disclosure". CSR performance concerns the actual CSR activities. CSR disclosure comprises the extent of disclosure about those CSR activities.

Even though some recent studies find evidence that CSR-conscious companies suffer less from the implications of the PAT (e.g. Gao, Lisic, & Zhang, 2014; Graham, Harvey, & Rajgopal, 2005), the case for voluntary disclosure may not seem to be so strong by now.

**Signaling and Legitimacy Theory as an Explanation for CSR**

Even though management may be incentivized not to disclose certain CSR related information, companies apparently voluntarily report about their CSR activities. This study focuses on the two most important explanations for the disclosure of and engagement in CSR: *signaling* and *legitimacy* theory. *Signaling* is also commonly known as an approach to solving the various issues arising with the PAT. *Legitimacy* theory is of particular importance, as the environmentally sensitive business of utility companies seems to be under special observation by investors, politicians and the media.

Many studies are supporting *signaling* theory, according to which companies with a good CSR performance try to *signal* to their investors their superior CSR and financial performance (e.g. Blacconiere & Patten, 1994; Clarkson, Fang, Li, & Richardson, 2013; Cormier & Magnan, 1999; Healy & Palepu, 2001[2]; Mahoney, Thorne, Cecil, & LaGore, 2013; Skinner, 1994; Su, Peng, Tan, & Cheung, 2016; Verrecchia, 1983). Different studies show evidence that CSR performance is strongly associated with disclosure (i.e. the better the performance, the more the company signals to investors) (e.g. Clarkson, Li, Richardson, & Vasvari, 2008; Herbohn, Walker, & Loo, 2014; Iatridis, 2013).

Assuming that signaling theory holds, utility companies – according to CSR performance scores, belonging to the best CSR performing industries – are first to report their CSR activities, signaling superior performance to investors. Accordingly, signaling theory does already make a strong case for explaining the reporting of CSR activities in the utility industry.

*Legitimacy* theory refers to the social position in which each company operates and to the legitimizing nature of disclosure, thereby aiming at the prevention of sanctions by society or government (Berthelot, Cormier, & Magnan, 2003). Several studies exist, adopting *legitimacy* theory to explain voluntary CSR disclosure activity. Older studies did not find any consistent pattern in companies legitimizing their businesses by CSR reporting (e.g. Guthrie & Parker, 1989; Hogner, 1982; Wilmshurst & Frost, 2000). In contrast, others could verify that companies and its management are in fact inclined to legitimize their operational business in their CSR reporting decisions (e.g. Buhr, 1998; Deegan & Rankin, 1996; Deegan, Rankin, & Tobin, 2002; Gray, Kouhy, & Lavers, 1995; O'Donovan, 2002; O'Dwyer, 2002; Patten, 1991; Savage, Cataldo, & Rowlands, 2000).

More specifically, as Berthelot, Cormier and Magnan (2003) point out, several studies confirm that voluntary CSR disclosure increases with membership in environmentally

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[2] Healy and Palepu (2001) further outline single voluntary disclosure (signaling) motives such as "capital markets transactions hypothesis", "corporate control contest hypothesis", "stock compensation hypothesis", "litigation cost hypothesis", "management talent signaling hypothesis", and "proprietary cost hypothesis" (pp. 420–424).

sensitive industries (e.g. Barth et al., 1997; Bewley & Li, 2000; Cormier & Gordon, 2001; Neu, Warsame, & Pedwell, 1998; Patten, 1991), the risk of environmental accidents (e.g. Walden & Schwartz, 1997), raising concerns of lobby groups (e.g. Deegan & Gordon, 1996) and the exposure to media (e.g. Bewley & Li, 2000; Brown & Deegan, 1998; Li et al., 1997; Neu et al., 1998). These findings are crucial, since this study investigates the utility industry, it seems likely that all of the before mentioned CSR disclosure drivers are making a strong case for *legitimacy* theory as an explanation for CSR reporting in this industry.

Naturally, the utility sector is an environmentally sensitive industry. The risk of environmental disasters is business immanent (one has just to think of nuclear power plants). Non-governmental organizations (NGO) are frequently raising questions about the CSR performance of utility companies, and in case there is a critical incident, the media are on the spot immediately. Additionally, Villiers and van Staden (2011) prove the hypothesis that a higher environmental exposure fosters the disclosure of CSR activities. Going even a step further, Cormier and Magnan (2015) and Aerts and Cormier (2009) empirically witness an impact of a company's CSR disclosure on its legitimacy. In a nutshell, *legitimacy* theory (besides *signaling* theory) does indeed offer compelling explanations for the engagement in and reporting of CSR activities by companies in the utility sector.

**Institutional Investment and CSR**

Several studies point to an increasing role of institutional investors, not only due to institutional investors' increasing stakes and influence but simply due to massive amounts of equity assets they are responsible for (e.g. Binay, 2005; Denis & McConnell, 2003; Li & Lu, 2016). Institutional investors are large and remarkably professional such as pension funds, hedge funds or insurers[3].

Institutional investors not only differ from other investors concerning their size but also when it comes to their demand behavior for stocks. Institutional investors invest in stocks which are large, more liquid and have had a relatively low (past-year) return (Gompers & Metrick, 2001). Besides, institutional investors' demand for stocks is more stable than that of other investor types (ibd.). While institutional investors may be homogenous in some ways (e.g. investing in large stocks) and to some degree (i.e. the ones more than others), they also show fundamental differences in their investment behavior, particularly as for their investment horizon (Yan & Zhang, 2009). The authors deal with the operationalization of an investor's investment horizon in a later stage of the paper.

**Characteristics of the North American and European Utility Sector**

The focus on the utility sector is based on the relative outperformance of the utility sector in terms of CSR performance (cf. Figure 1), which makes this particular industry especially interesting to investigate (recall *signaling* and *legitimacy* theory). Apparently, utility companies already seem to exert themselves for being compliant with CSR expectations and standards, probably intensified by their business

[3] By now, the *Vanguard Group Inc.* and *BlackRock Institutional Trust Company* – two of the largest professional investment companies – have already 4.0 and 5.1 trillion(!) equity assets under management (AUM), respectively.

immanent risk and exposure in an environmentally sensitive industry. Studies like Barth et al. (1997) further support that relation by stating that companies in the regulated utility industry may have fewer costs for disclosure, can pass on environmental costs to consumers on a regulatory basis and thus, have more incentives to disclose about CSR.

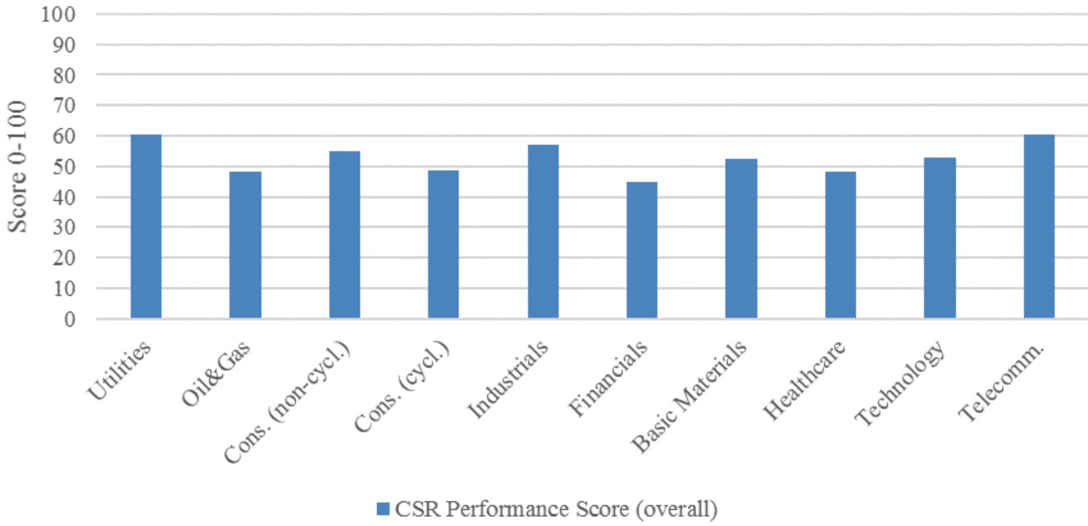


Figure 1: Industry Average CSR Performance
Note: averages of all companies (worldwide), covered by *ASSET4 Thomson Reuters*, in the respective industry, measured by a score of 0–100. Data Source: ESG *ASSET4 Thomson Reuters* database; own illustration.

**Literature Review and Research Gap**

There has been little but highly relevant research in the past, examining the relationship between CSR and institutional ownership. The presumably first study in this area by Graves and Waddock (1994) hypothesized that institutional holdings increase with stronger CSR performance. Results indicate that the number of institutional investors and the institutional holdings per investor increase with higher CSR performance, but with the former relationship being statistically significant and the latter statistically insignificant (ibd.). Graves and Waddock conclude that improving CSR performance does not invoke a penalty on institutional ownership at least.

Furthermore, Cox and Wicks (2011) and Cox, Brammer, and Millington (2004) substantiate this finding by incorporating the investment horizon and – in addition to CSR – market liquidity and portfolio theory as factors of institutional interest. Cox and Wicks exhibit that for most transient (= short-term) institutional investors market liquidity is the most and CSR the least important determinant of share demand, while for long-term institutional investors share demand is stronger influenced by CSR than market liquidity (ibd.). This finding assigns CSR an important role concerning its effects on institutional investment behavior, even though Cox and Wicks make no differentiation between the performance and disclosure dimension of CSR in their study.

Other studies support the evidence of an institutional ownership enhancing effect of CSR (e.g. Bistrova et al., 2014; Cormier & Magnan, 2015; Dhaliwal et al., 2012; Diamond & Verrecchia, 1991; Johnson & Greening, 1999; Li & Lu, 2016; Nielsen & Noergaard, 2011). Healy, Hutton, and Palepu (1999) explicitly examine the disclosure dimension of CSR and find that higher disclosure ratings come along with increases in institutional ownership. Chen and Gavious (2015) find recent evidence that only marginal and *not* long-term institutional investors do value CSR. Chen and Gavious explain their twofold result by moral sentiment of the former investor group and the exposure of corporate misbehavior through a superior informational level by the latter.

Studies like that of Graves and Waddock (1994) and Healy et al. (1999) have serious measurement problems since at the time when the studies were conducted, there haven't been adequate (technical) resources and data available to measure CSR performance and institutional ownership appropriately. Hence, this study closes the gap by using an operationalization approach for institutional ownership, which has been proved successful in previous studies but in other contexts.

Besides, Cox et al. (2004) and Cox and Wicks (2011) only look at extremely short periods of CSR (1 or 2 years) and its effects on institutional interest and exclusively for a sample in the *United Kingdom*. Chen and Gavious (2015) also very specifically use an *Israeli* sample and a unique CSR ranking system only applicable for *Israel*[4].

Almost all studies either look at one dimension of CSR (performance or disclosure) or make no real differentiation between the two. For those reasons, results of prior studies are moderately robust, somehow outdated, certainly locally limited and therefore, only partially satisfying. Finally, research dealing with CSR, institutional ownership, and the highly relevant utility sector is scarce.

## 3. Empiricism

### Hypotheses

In order to close the research gap and to add further evidence regarding the relation between CSR and institutional ownership, this study applies several hypotheses. The hypotheses of this thesis are consistent with those of previous studies (e.g. Girerd-Potin et al., 2014; Graves & Waddock, 1994; Johnson & Greening, 1999; W. Li & Lu, 2016; Serafeim, 2015). To test whether CSR has an influence on the *long-term* institutional ownership (LIO), the authors deploy the following null and alternative hypotheses H1 and H2[5]:

[4] The non-profit organization called "Maala" (Hebrew for "virtue") was founded in *Israel* in 1998 and yearly issues a "Maala Ranking of Corporate Social Responsibility", on which the study of Chen and Gavious is based on.

[5] Each hypothesis is applied to all CSR characteristics (environmental, social, and governance) separately. Thus, each CSR characteristic is investigated separately.

*$H1_0$: There is **no significant correlation** between CSR disclosure and the LIO base at all; i.e. significant partial correlation coefficients $\alpha_i = 0$*

*$H1_a$: CSR disclosure **significantly correlates** with the LIO base; i.e. significant partial correlation coefficients $\alpha_i > 0$ or $\alpha_i < 0$*

*$H2_0$: There is **no significant correlation** between CSR performance and the LIO base at all; i.e. significant partial correlation coefficients $\alpha_i = 0$*

*$H2_a$: CSR performance **significantly correlates** with the LIO base; i.e. significant partial correlation coefficients $\alpha_i > 0$ or $\alpha_i < 0$*

To further support H1 and H2, hypotheses H3 and H4 examine the relationship between the companies' CSR and short-term institutional ownership (SIO) base, thereby serving as benchmark, since according to theoretical expectations and if the null hypotheses are rejected, the relation should be opposite to the alternative hypotheses of H1 and H2:

*$H3_0$: There is **no significant correlation** between CSR disclosure and the SIO base at all; i.e. significant partial correlation coefficients $\alpha_i = 0$*

*$H3_a$: CSR disclosure **significantly correlates** with the SIO base; i.e. significant partial correlation coefficients $\alpha_i > 0$ or $\alpha_i < 0$*

*$H4_0$: There is **no significant correlation** between CSR performance and the SIO base at all; i.e. significant partial correlation coefficients $\alpha_i = 0$*

*$H4_a$: CSR performance **significantly correlates** with the SIO base; i.e. significant partial correlation coefficients $\alpha_i > 0$ or $\alpha_i < 0$*

All hypotheses are tested on the 95% confidence level throughout the whole study. The subsequent lead-lag analysis tries to establish causality between the variables but is not part of the hypothesis test.

## Data and Sample

The authors collect data from different sources. First of all, *Thomson One* (also known as *Thomson Financial*) provides all the ownership data for all companies for the years 2011 to 2015. Ownership holdings data is aggregated on a yearly basis to correspond to the companies' ESG data.

In accordance with Bushee (1998), Gompers and Metrick (2001), Yan and Zhang (2009), and Li and Lu (2016) this study consistently follows the *US* classification of institutional investors, whereby only institutions investing at least \$100 million in equity qualify as so-called qualified institutional investors (QII)[6]. Even though this study does not exclusively focus on *US* securities, it uses the classification of QIIs for *European* investors uniformly. The respective investor universe only includes QIIs. The total institutional ownership universe consists of 3'657 and 3'729 QIIs for the disclosure and performance dimension, respectively.

The required data regarding ESG Performance comes from *Thomson Reuters ASSET4* database, which offers comprehensive data concerning the environmental, social and, governance activities of a company, expressed by a score ranging from 0 to 100.[7] ESG performance data is available for about 6'000+ global companies and reaches back until 2011, which is also the time constraint of this investigation. *Datastream* also provides data regarding dividend yield, price-earnings ratios, firm size (total assets) and market-to-book ratios of sample firms.

As the disclosure dimension of this study is concerned, *Bloomberg* database offers corporate ESG meta-data since 2009. The *Bloomberg* ESG disclosure scores are calculated with data of the companies' own verified ESG metrics, publicly disclosed via their corporate sustainability and integrated reports and range from 0 to 100. At the time of origination of this paper, the *Bloomberg* screening universe included about 11'000 global companies in more than 100 countries[8].

One should definitely bear in mind that the disclosure score does not, in any sense, represent the quality of disclosure – like is the disclosed information really relevant or is it even true what the company is reporting – but the amount or extent to which the company is disclosing information regarding its environmental, social and governance activities. Besides, the authors obtained end-of-year financial and market data – like average of daily equity traded value, shares outstanding, return on assets, leverage ratio, annualized beta and sales growth ratio – for the period 2011 to 2015 from *Bloomberg*.

After excluding those observations with insufficient data and applying the screening criteria (*Europe and North America*; >1bn market capitalization; utility sector), the final sample for the disclosure and the performance dimension is 105 and 87 companies, respectively.

## Operationalization

In order to determine the investment horizon of institutional investors for the period 2011 to 2015 and in accordance with a method used by Gaspar, Massa and Matos (2005), Yan and Zhang (2009) and a more recent study by W. Li and Lu (2016)[9], this

[6] This classification is based on the *United States Securities and Exchange Commission* (SEC) rule No. 13-F. More information about the filing process can be obtained from: https://www.sec.gov/answers/form13f.htm

[7] The score consists of about 118 ESG criteria – like CO2 Equivalents Emission, Waste Total, Management Training or Compensation Policy.

[8] According to *Bloomberg* the ESG score is "[a] measure of the amount of ESG data a company has reported for the latest fiscal year. The number of data points disclosed is presented as a percentage of total possible disclosure across the ESG fields available on Bloomberg, with a higher value representing fuller disclosure". The information can be accessed via *Bloomberg* Terminal.

[9] The method is adjusted by the authors to fit the used data format. The single adjustments are minor and therefore not stated in detail.

investigation classifies each QII $k$, based on their portfolio turnover in the respective year $t$, into either short- or long-term. In a first step, each QII *k's* churn rate (for all 3'657 and 3'729 QIIs for the disclosure and performance dimension, respectively), $CR_{k,j}$, is calculated for each quarter $j$ as follows:

$$CR_{k,j} = \frac{\left| VAL\_Chg_{k,j} \right|}{\frac{VAL_{k,j} + VAL_{k,j-1}}{2}}$$

The variables $VAL\_Chg_{k,j}$, $VAL_{k,j}$ and $VAL_{k,j-1}$ are defined as the change in holdings value (calculated as the *change in shares held times adjusted month-end US dollar price of filing date*) and holdings value of QII $k$ at the end of quarter $j$ and $j-1$, respectively. Due to missing data for the holdings value of the 4th quarter of 2010, the authors adjust the formula in this case by replacing the two quarterly average ($VAL_{k,t}$ + $VAL_{k,t-1}$)/2 with the factor 1/(1+$VAL_{k,t}$). With this adjustment, the authors account for an otherwise occurring design error for investors selling most of or all their stakes in the 1st quarter of 2011. In a second step, the authors calculate each QII *k's* average churn rate, $ACR_{k,t}$, for each year $t$ by taking the average of investor *k's* four quarterly churn rates ($CR_{k,j}$) (Yan & Zhang, 2009):

$$ACR_{k,t} = \frac{1}{4}\sum_{j=1}^{4} CR_{k,j}$$

After calculating the average churn rate for each year $t$ and investor $k$, the overall average churn rate ($OACR_k$) is calculated for each investor $k$ for the whole investigation period of 2011 to 2015:

$$OACR_k = \frac{1}{5}\sum_{t=1}^{5} ACR_{k,t}$$

Institutional investors with an *OACR* ranked in the *top* tertile of the distribution are classified as short-term; institutional investors with an OACR ranked in the *bottom* tertile of the distribution are classified as long-term (Yan & Zhang, 2009)[10]. Finally, the regression variables short-term (long-term) institutional ownership (called SIO ratio and LIO ratio in the following) are calculated for each stock as "the ratio between the number of shares held by short-term (long-term) institutional investors and the total number of shares outstanding" (ibd.).

**Control Variables**

Since previous literature states several determinants for institutional ownership, the relationship between CSR and institutional ownership of *European* and *North American* utility companies needs to be controlled by numerous control variables. First of all, according to Hessel and Norman (1992) profitability and debt ratios determine demand for shares by institutional investors. Therefore and according to

[10] The sample's strongest short-term and long-term investors do have an *OACR* of 5.089544 and 0.000004. Hence, there are great differences between the investors' investment horizons.

Graves and Waddock (1994) and Li and Lu (2016), the *return on assets* (ROA) is used to control for profitability effects on institutional ownership.

Furthermore, the firm's leverage, measured by *debt ratio* (LEV), is deployed to account for firm risk and creditor power (Johnson & Greening, 1999). M*arket-to-book ratio* (MKTB) and *price-earnings ratio* (PE) control for future (earnings) growth opportunities (W. Li & Lu, 2016). *Sales growth ratio* (SGR) proxies for intangible assets (Porter & van der Linde, 1995). Since according to prior research, institutional investors prefer large stocks, this study also controls for *firm size* (SIZE), defined as the natural logarithm of end-of-year total assets (Gompers & Metrick, 2001; Graves & Waddock, 1994; W. Li & Lu, 2016; Yan & Zhang, 2009).

Finally, prior studies find that nonbank institutions consider prudence in their investment decisions (e.g. Del Guercio, 1996) and thus, this study includes the dividend yield (DY) to account for prudence (Cox & Wicks, 2011; Gompers & Metrick, 2001). SIZE is calculated as the natural logarithm to reduce the impact of extreme values and heteroscedasticity in the data (Cox et al., 2004; Gompers & Metrick, 2001; W. Li & Lu, 2016).

**Regression Results**

Table 1 shows results of the multiple panel data regression models which are run on the disclosure dimension and sample (H1 and H3). As the LIO base is concerned, the authors can reject the null hypothesis ($H1_0$) for the social characteristic of CSR disclosure, as the correlation coefficient is significantly different from zero after controlling for multiple firm characteristics. The average social disclosure score across the 105 cross-sectional regressions significantly *positively correlates* with LIO. Thus, for the social disclosure characteristic, $H1_a$ is approved.

**Table 1: CSR Disclosure and Institutional Ownership - Cross-Sectional Regressions: Correlation Matrix**

Notes: p-values in parentheses; * $p<0.05$, ** $p<0.01$, *** $p<0.001$. This table summarizes the results of the cross-sectional time-series GLS regressions of environmental-, social-, and governance disclosure on the long- and short-term institutional ownership base. Estimates are calculated as generalized least squares (GLS) with panel-specific autoregressive correlations *within* the panels, some degree of heteroscedasticity in the data and *no* autocorrelation *between* the panels.

| | **Dependent Variables** | |
|---|---|---|
| | (1) | (2) |
| **Independent Variables** | LIO ratio | SIO ratio |
| ENVD | -0.026 | -0.026*** |
| | (0.221) | (0.000) |
| SOCD | 0.047** | -0.025*** |
| | (0.007) | (0.000) |
| GOVD | -0.066** | 0.038*** |
| | (0.002) | (0.000) |
| **Control Variables** | | |
| ROA | -0.040 | -0.042*** |
| | (0.507) | (0.002) |
| LEV | -0.309*** | 0.041*** |
| | (0.000) | (0.000) |
| SGR | 0.007 | -0.004 |
| | (0.464) | (0.151) |
| SIZE | 0.031*** | -0.002*** |
| | (0.000) | (0.000) |
| MKTB | 0.002 | 0.004*** |
| | (0.255) | (0.000) |
| DY | -0.192 | -0.037** |
| | (0.107) | (0.010) |
| PE | 0.002 | 0.006*** |
| | (0.896) | (0.002) |
| Constant | 0.164*** | 0.0115 |
| | (0.000) | (0.208) |
| N | 524 | 524 |
| Wald $Chi^2$ Statistic | 281.81 | 895.04 |
| Prob > $Chi^2$ | 0.00 | 0.00 |

Higher social disclosure scores seem to be accompanied by a higher LIO base, indicating that disclosing about, for instance, employee safety, diversity or product responsibility attracts long-term institutional investors in utility companies. This result is in line with Healy et al. (1999) finding that better CSR disclosure leads to higher institutional ownership. However, the authors cannot reject $H1_0$ for the environmental characteristic

In addition, $H1_0$ can be rejected for the governance characteristic of CSR disclosure, as the correlation coefficient is significantly different from zero. This finding indicates that a more extensive governance disclosure goes along with a *lower* LIO base. This result is contrary to theory, which rather suggests that higher governance disclosure should reduce information asymmetry and thereby rather foster LIO. It becomes even more interesting by looking at the results of the second multivariate panel data regression (2), which is testing *H3*. The correlation coefficient between governance disclosure and SIO, in this case, is significantly positive (rejecting $H3_0$, accepting $H3_a$).

The results of both long- and short-term correlation coefficients for the governance metric are in line with the findings of Chen and Gavious (2015), suggesting that long-term institutional investors do *not* value governance disclosure, while short-term institutional investors do value it. However, the major part of prior literature would still rather suggest the opposite direction of correlation.

Table 2 presents the results of the multiple panel data regressions for the performance dimension and sample (H2 and H4). As is already the case in the disclosure dimension, the null hypothesis $H2_0$ cannot be rejected for the environmental performance characteristic (regression (1)). A possible explanation could be that CSR performance and disclosure are already quite high in the utility sector so that further environmental disclosure or performance is not of notably importance to investors. In contrary, results offer compelling evidence for a significant positive relation between social performance and LIO and a significant negative relation between governance performance and LIO.

## Table 2: CSR Performance and Institutional Ownership - Cross-Sectional Regressions: Correlation Matrix

Notes: p-values in parentheses; * $p<0.05$, ** $p<0.01$, *** $p<0.001$. This table summarizes the results of the cross-sectional time-series GLS regressions of environmental-, social-, and governance performance on the long- and short-term institutional ownership base. Estimates are calculated as generalized least squares (GLS) with panel-specific autoregressive correlations *within* the panels, some degree of heteroscedasticity in the data and *no* autocorrelation *between* the panels.

| | Dependent Variables | |
|---|---|---|
| | (1) | (2) |
| **Independent Variables** | LIO ratio | SIO ratio |
| ENVP | 0.004 | -0.005 |
| | (0.823) | (0.333) |
| SOCP | 0.117*** | -0.001 |
| | (0.000) | (0.915) |
| GOVP | -0.108*** | 0.038*** |
| | (0.000) | (0.000) |
| **Control Variables** | | |
| ROA | 0.164* | -0.022 |
| | (0.038) | (0.219) |
| LEV | -0.113** | 0.045*** |
| | (0.002) | (0.000) |
| SGR | -0.000 | -0.002 |
| | (0.978) | (0.506) |
| SIZE | 0.02*** | -0.004*** |
| | (0.000) | (0.000) |
| MKTB | 0.001 | 0.002** |
| | (0.597) | (0.002) |
| DY | -0.241* | -0.016 |
| | (0.021) | (0.393) |
| PE | 0.014 | 0.003 |
| | (0.178) | (0.291) |
| Constant | 0.217** | 0.058*** |
| | (0.002) | (0.000) |
| N | 435 | 435 |
| Wald $Chi^2$ Statistic | 225.48 | 286.94 |
| Prob > $Chi^2$ | 0.00 | 0.00 |

The correlation coefficients are comparably high (>0.1) and significant at the confidence level of this study. Hence, the authors reject the null hypothesis $H2_0$ for the social and governance characteristics (accepting $H2_a$). In particular, the negative relation between governance performance and LIO is interesting, as it corresponds to the finding for the disclosure dimension.

Apparently, long-term institutional investors in the utility sector do neither positively value governance disclosure nor performance. While this finding is in line with the implications of Endrikat (2016) and Krüger (2015), it clearly deviates from Bistrova et al. (2014). Probably this anomaly is also explained by the sensitivity of the utility sector to CSR issues.

As the highly significant positive relation between social performance and LIO indicates, long-term institutional investors do indeed value social efforts like employee safety, training and development, product responsibility or the like, by increasing their stakes. At least up to the social characteristic of CSR performance, this finding complements the results of Graves and Waddock (1994) that higher CSR performance not only leads to a greater number of institutional investors but that institutional investors also increase their stakes with higher social performance.

Furthermore, this finding is in line with Johnson and Greening (1999) who find that investments of pension funds (supposed to be rather long- than short-term investors) increase with the people (= social) characteristic of CSR performance, while investments by rather short-term investors (like hedge funds and investment banks) do not. The result of a significantly positive relation between social performance and LIO is also perfectly supported by Cox et al. (2004), finding that CSR performance, in general, is positively correlated with LIO.

For the second multiple panel data regression (2), results show again a positive and significant correlation between governance performance and SIO. The null hypothesis $H4_0$ can only be rejected for the governance performance characteristic (accepting $H4_a$), while results offer no evidence to reject $H4_0$ for the environmental and social performance characteristics.

Apparently, short-term institutional investors positively value governance performance but the correlation coefficient is rather weak. Long-term institutional investors might fear that companies with a good corporate governance performance and disclosure might not possess enough persistence in the long-term (e.g. if governments seize additional regulatory measures).

However, merely looking at correlations does not provide any evidence regarding a possible causal relationship between the variables. With this in mind, the authors try to establish causality between the independent and dependent variables by a *lead-lag* analysis in the following.

**Lead-Lag Analysis**

While results in previous chapters show a significant and distinct relationship between certain CSR dimensions and institutional ownership, it would be a foregone conclusion that, for instance, CSR activities influence the institutional ownership base (even though, *legitimacy* and *signaling* theory suggest). It could also be the case that companies with an already strong LIO base are being forced to disclose more CSR information and to perform better in terms of CSR (e.g. due to high monitoring power and influence of large institutional investors). Put differently, a large LIO base could well influence a company's CSR activities and not the other way around.

In order to establish causality between CSR and institutional ownership, this study applies a *lead-lag* analysis in accordance to Serafeim (2015). Therefore, one-year and two-year changes in all variables are calculated. Subsequently, lagged values for the changes in all three ESG metrics (ENV, SOC, and GOV) and the changes in the two dependent variables, LIO ratio and SIO ratio, are calculated for both samples. The authors choose to calculate one-year and two-year changes to account for a reasonable lagged effect and still include sufficient observations.

Overall evidence of the lead-lag analysis rather speaks for long-term institutional investors *influencing* the CSR disclosure of utility companies and not the other way around (i.e. lagged changes in LIO lead lagged changes in CSR disclosure) (Table 3). Contrary to the authors' expectations, it is rather the long-term institutional investor having the power to influence CSR disclosure decisions of companies. According to lead-lag results, this is not the case for short-term institutional investors. Short-term institutional investors rather react to changes in CSR disclosure than influencing the very same.

Findings do not point to such a causal relationship for the performance dimension of CSR (Table 4). Numbers clearly indicate that it is rather the CSR performance *influencing* the long-term institutional investor than the other way around (i.e. lagged changes in CSR performance lead lagged changes in LIO). Overall, results point to an (no) *influencing role* of long-term (short-term) institutional investors as the CSR disclosure is concerned, but to an *influencing role* of CSR performance as the long- and short-term institutional investors are concerned.

## Table 3: Lead-Lag Analysis - Disclosure Dimension

Note: p-values in parentheses; * p<0.05, ** p<0.01, *** p<0.001. OLS regressions with robust and clustered standard errors at the firm level. Estimates of independent variables in bold are statistically significant at least on a 10% significance level. The dependent variable is either change in LIO ratio or SIO ratio, calculated as either a 1-year or 2-year change. All remaining variables are calculated as changes. The first, third, fifth and seventh regressions use changes for all variables over one year. The second, fourth, sixth and eighth regressions use changes for all variables over two years. For the first four regressions, change in ENVD, SOCD and GOVD (= ESG disclosure metrics) is calculated on a 1-year, and 2-year lagged basis, while change in LIO ratio and SIO ratio is calculated on a non-lagged basis. For the last four regressions, change in the ESG disclosure metrics is calculated on a non-lagged basis, while change in LIO ratio and SIO ratio is calculated on a 1-year and 2-year lagged basis. Estimates are rounded to 3 decimals.

| | Differences lagged ESG disclosure metrics | | | | Differences lagged LIO and SIO ratio | | | |
|---|---|---|---|---|---|---|---|---|
| | LIO ratio | | SIO ratio | | LIO ratio | | SIO ratio | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| **Independent Variables** | 1-year | 2-year | 1-year | 2-year | 1-year | 2-year | 1-year | 2-year |
| **ENVD** | 0.077 | -0.054 | 0.004 | 0.043* | -0.041 | -0.166* | -0.015 | 0.037 |
| | (0.093) | (0.541) | (0.808) | (0.038) | (0.486) | (0.034) | (0.369) | (0.184) |
| **SOCD** | -0.090 | 0.082 | 0.003 | 0.043 | 0.079 | 0.099 | 0.013 | 0.028 |
| | (0.091) | (0.355) | (0.827) | (0.081) | (0.257) | (0.266) | (0.619) | (0.414) |
| **GOVD** | 0.037 | -0.034 | -0.010 | -0.077* | -0.024 | 0.260* | 0.008 | -0.076 |
| | (0.375) | (0.718) | (0.478) | (0.016) | (0.695) | (0.041) | (0.703) | (0.055) |
| **Control Variables** | | | | | | | | |
| ADETV | 0.025*** | -0.021 | 0.008*** | 0.003 | 0.007** | 0.037* | 0.004** | 0.005 |
| | (0.000) | (0.081) | (0.000) | (0.553) | (0.002) | (0.013) | (0.001) | (0.317) |
| ROA | 0.028 | -0.088 | -0.038 | 0.045 | 0.080 | 0.305 | 0.086* | 0.143 |
| | (0.728) | (0.528) | (0.303) | (0.321) | (0.449) | (0.253) | (0.010) | (0.152) |
| LEV | -0.246 | -0.473* | -0.054 | 0.041 | 0.312 | 0.670 | 0.191** | 0.300* |
| | (0.177) | (0.049) | (0.357) | (0.316) | (0.221) | (0.076) | (0.004) | (0.025) |
| BETA | -0.006 | -0.042 | 0.004 | 0.023 | -0.007 | -0.024 | -0.015 | 0.022 |
| | (0.751) | (0.402) | (0.533) | (0.274) | (0.703) | (0.683) | (0.082) | (0.296) |
| SGR | 0.017 | 0.002 | -0.012 | -0.033** | -0.007 | 0.048 | 0.004 | -0.006 |
| | (0.321) | (0.965) | (0.214) | (0.002) | (0.699) | (0.258) | (0.733) | (0.736) |
| SIZE | 0.001 | 0.085 | 0.002 | -0.002 | 0.118* | 0.068 | 0.007 | -0.002 |
| | (0.977) | (0.111) | (0.917) | (0.833) | (0.015) | (0.179) | (0.723) | (0.891) |
| MKTB | 0.002 | 0.007 | 0.002 | -0.001 | 0.002 | -0.012 | 0.001 | 0.000 |
| | (0.208) | (0.176) | (0.115) | (0.607) | (0.465) | (0.111) | (0.611) | (0.996) |
| DY | 0.340* | 0.485 | 0.044 | 0.031 | 0.032 | 0.460 | -0.041 | -0.132 |
| | (0.020) | (0.080) | (0.387) | (0.665) | (0.835) | (0.108) | (0.497) | (0.162) |
| PE | 0.033 | 0.055 | -0.006 | 0.002 | 0.004 | 0.003 | -0.008 | -0.001 |
| | (0.156) | (0.231) | (0.532) | (0.867) | (0.813) | (0.946) | (0.458) | (0.974) |
| Constant | 0.01** | 0.009 | 0.004** | 0.009*** | 0.004 | 0.008 | 0.002 | -0.002 |
| | (0.004) | (0.168) | (0.003) | (0.000) | (0.188) | (0.443) | (0.149) | (0.373) |
| N | 315 | 105 | 315 | 105 | 315 | 105 | 315 | 105 |
| adj. R-squared | 23.1% | 7.8% | 16.0% | 10.3% | 10.7% | 26.2% | 9.7% | 21.8% |

## Table 4: Lead-Lag Analysis - Performance Dimension

Note: p-values in parentheses; * p<0.05, ** p<0.01, *** p<0.001. OLS regressions with robust and clustered standard errors at the firm level. Estimates of independent variables in bold are statistically significant at least on a 10% significance level. The dependent variable is either change in LIO ratio or SIO ratio, calculated as either a 1-year or 2-year change. All remaining variables are calculated as changes. The first, third, fifth and seventh regressions use changes for all variables over one year. The second, fourth, sixth and eighth regressions use changes for all variables over two years. For the first four regressions, change in ENVP, SOCP and GOVP (= ESG performance metrics) is calculated on a 1-year, and 2-year lagged basis, while change in LIO ratio and SIO ratio is calculated on a non-lagged basis. For the last four regressions, change in the ESG performance metrics is calculated on a non-lagged basis, while change in LIO ratio and SIO ratio is calculated on a 1-year and 2-year lagged basis. Estimates are rounded to 3 decimals.

| | **Differences lagged ESG performance metrics** | | | | **Differences lagged LIO and SIO ratio** | | | |
|---|---|---|---|---|---|---|---|---|
| | **LIO ratio** | | **SIO ratio** | | **LIO ratio** | | **SIO ratio** | |
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** |
| **Independent Variables** | **1-year** | **2-year** | **1-year** | **2-year** | **1-year** | **2-year** | **1-year** | **2-year** |
| **ENVP** | -0.0393 | **0.174** | 0.0323 | 0.0339 | 0.0963 | 0.0208 | 0.0437 | -0.0511 |
| | (0.606) | **(0.058)** | (0.220) | (0.420) | (0.137) | (0.880) | (0.102) | (0.101) |
| **SOCP** | -0.063 | **-0.265** | -0.009 | -0.009 | -0.023 | 0.088 | -0.021 | 0.050 |
| | (0.529) | **(0.077)** | (0.615) | (0.672) | (0.561) | (0.394) | (0.293) | (0.110) |
| **GOVP** | **0.135*** | 0.396 | **-0.043** | **-0.064*** | -0.052 | 0.016 | -0.002 | -0.007 |
| | **(0.043)** | (0.191) | **(0.098)** | **(0.033)** | (0.268) | (0.775) | (0.862) | (0.539) |
| **Control Variables** | | | | | | | | |
| ADETV | 0.023*** | -0.059* | 0.011*** | 0.009 | 0.012 | 0.017 | 0.000 | 0.012* |
| | (0.000) | (0.040) | (0.000) | (0.174) | (0.134) | (0.437) | (0.916) | (0.032) |
| ROA | 0.226 | 0.103 | 0.226 | 0.021 | 0.165 | 0.558* | -0.413 | 0.110 |
| | (0.285) | (0.695) | (0.388) | (0.691) | (0.406) | (0.013) | (0.392) | (0.110) |
| LEV | 0.020 | -0.141 | -0.049 | -0.087 | 0.412 | 0.903** | 0.209 | 0.368*** |
| | (0.941) | (0.710) | (0.583) | (0.178) | (0.159) | (0.002) | (0.074) | (0.001) |
| BETA | -0.011 | -0.160 | -0.002 | 0.035 | -0.047 | 0.103 | -0.011 | 0.020 |
| | (0.599) | (0.173) | (0.856) | (0.218) | (0.347) | (0.191) | (0.306) | (0.408) |
| SGR | 0.020 | 0.019 | -0.011 | -0.020 | -0.005 | 0.034 | 0.004 | 0.006 |
| | (0.510) | (0.807) | (0.316) | (0.202) | (0.806) | (0.633) | (0.840) | (0.703) |
| SIZE | -0.070 | -0.003 | 0.011 | -0.007 | 0.071 | 0.079* | 0.017 | 0.015 |
| | (0.404) | (0.972) | (0.509) | (0.201) | (0.098) | (0.048) | (0.335) | (0.081) |
| MKTB | -0.002 | 0.009 | 0.001 | 0.001 | 0.000 | -0.014 | 0.002 | -0.001 |
| | (0.489) | (0.290) | (0.694) | (0.872) | (0.935) | (0.130) | (0.403) | (0.762) |
| DY | 0.224 | 0.090 | -0.039 | -0.014 | 0.136 | 0.469 | 0.147 | -0.049 |
| | (0.286) | (0.876) | (0.587) | (0.892) | (0.538) | (0.390) | (0.376) | (0.635) |
| PE | 0.010 | 0.008 | -0.002 | -0.016 | 0.017 | 0.053 | 0.002 | 0.009 |
| | (0.555) | (0.899) | (0.903) | (0.421) | (0.289) | (0.213) | (0.932) | (0.683) |
| Constant | 0.015*** | 0.034* | 0.001 | 0.007* | 0.015** | 0.030 | 0.002 | 0.003 |
| | (0.000) | (0.020) | (0.849) | (0.018) | (0.001) | (0.097) | (0.088) | (0.480) |
| N | 261 | 87 | 261 | 87 | 261 | 87 | 261 | 87 |
| adj. R-squared | 10.4% | 11.6% | 4.0% | 4.8% | 4.2% | 21.8% | 4.1% | 39.7% |

## Conclusions

This study investigates the relation between CSR and institutional ownership and arrives at interesting and to some extent surprising answers. Based on *signaling* and *legitimacy* theory, the authors contend that *ceteris paribus*, higher CSR performing and disclosing companies should have a higher and more stable long-term institutional ownership base (i.e. attracting long-term equity capital). By using two samples of 105 and 87 large-cap utility companies, the authors find that more socially responsible companies exhibit greater long-term institutional ownership and that higher corporate governance disclosure *and* performance goes along with *less* long-term and *greater* short-term institutional ownership.

The lead-lag analysis shows that it is rather the long-term institutional investor influencing CSR disclosure decisions of companies than the other way around. While this study does not posit this direction of causality, it is well known in other contexts of institutional ownership (e.g. financial disclosure). However, the *lead-lag* analysis suggests that social and governance performance indeed rather *causally influences* long-term institutional ownership than the other way around. A possible explanation is that investors may rather be able to influence the disclosure of CSR activities than the engagement in such activities itself.

Social performance apparently seems to raise the investment attractiveness for long-term institutional investors, seeking for smooth and stable income stocks. The negative relation between governance performance and LIO may be justified by the fear of long-term investors that companies might not possess enough persistence in the future (e.g. if governments seize stricter regulatory measures), while short-term investors will divest in the short-run anyway. Findings of this study furthermore suggest that large and powerful institutional investors are able to influence CSR disclosure decisions of utility companies[11].

After all, this study contributes to literature by closing the research gap of rather weak measurement methods (e.g. Graves & Waddock, 1994; Healy et al., 1999), extremely short investigation periods (e.g. Cox et al., 2004; Cox & Wicks, 2011), the negligence of the institutional ownership stakes (e.g. Graves & Waddock, 1994) and most importantly, the lack of addressing the causality issue.

However, results of this study may come with several limitations. Firstly, this study looks at the performance and disclosure dimension separately. This separation may have some advantages but also the disadvantage that interdependency is neglected. Secondly, general (financial) disclosure metrics are not included, although, they could explain some of the variation in the results. Thirdly, the CSR disclosure metric of *Bloomberg* does only address the extent and *not* the quality of disclosure. Finally, the utility sector in different countries is partially affected by diverging regulatory rules which impede comparability (Cormier & Gordon, 2001, p. 607). However, since this study does not investigate profitability or purely financial issues, the different rules – mostly regarding financial topics – should not represent such a significant limitation.

[11] This direction of causality is commonly known with regards to financial disclosure and institutional ownership.

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# *Gross Domestic Production (GDP) and Gases Emissions: Are the G7 Rich Countries Contributing to Air Damage?*

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**Abstract**
This paper addresses an important issue: Are increasing levels of gross domestic production related to increasing levels of environmental damage? It aims to analyze this growth-environmental relation focusing on the G7 countries' economic and environmental performances. Theories on growth-cum-environment, sustainable development and the environmental Kuznets' curve hypothesis are presented to support the empirical study. Statistical correlation is the method used and data source is The World Bank (2016). Results show that production levels are negatively related to gases emissions of four types of gases. Exceptions are USA and Japan whose GDP's growths are paired with increasing levels of $CO_2$ and total greenhouses emissions. Germany, UK and France seem to be fulfilling the environmental Kuznets' curve with decreasing gases emissions pairing intense growth.

Keywords: GDP and Environmental Performances; Gases Emissions; Air Damage. G7 Rich Countries.

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## Introduction

Economic growth has been a subject of great importance since the first contributions of leading economists, such as Adam Smith's "The Wealth of Nations", published in England in 1776. Throughout the years many other important authors have developed works focusing on production growth, but only in the forties and fifties of the 20th century more elaborated papers on this theme appeared, e.g., the contributions of Domar (1946) and Solow (1956 and 1957). Domar (1946), for instance, emphasized the role of industrial investments in physical capital to prompt production growth, while Solow (1956 and 1957) focused on both the role of technological advances to foster production growth and the way total factor productivity is measured to assure that production growth is obtained via technological progress.

Despite the importance of these seminal contributions on production growth in the forties and fifties, the first works of the modern theories of endogenous growth were published during the 1980s and 1990s, such as Romer (1986) and Lucas (1988) who highlighted the relevance of human capital, education and knowledge to prompt development, and Grossman and Helpman (1990 ; 1991) who brought and treated trade as an important source of endogenous production growth.

A huge change on the prospects of traditional and modern growth theories has occurred since the late eighties, under the influence of the Brundtland Commission (1987), mapping a new direction to target the environment as a key variable to be considered in any attempt of a country to develop. Accordingly, current theories of economic growth have embodied environmental variables into their specifications in a way to analyze the implications to rapid production growth when the environment is taken into account. Important contributions, e.g., Geldrop and Withagen (2000), Palmada (2003), Islan (2005), Charles (2005), Comolli (2006), Bretschger and Smulders (2006), Auty (2007), and Voinov and Farley (2007), have used analytical frames jointly treating production and environmental variables under a single theoretical approach. Daly (2008) contribution on ecological economics and sustainable development is a conceptual work elaborated with no relation to growth-development models, but with important implications to sustainable development strategies. Najam, Runnalls, and Halle (2007) offered propositions for environmental safety under the globalized production processes in course worldwide.

It is obvious that the upgrade of production growth theories to include the environment has had important implications to academic and political issues, as well as to sustainable development policy design and implementation. Thus, sustainable development policy supported by the theoretical contributions presented in section 1 will be discussed. Nations have to be aware of not repeating the mistakes of some today's advanced countries that damaged the environment in their earlier phases of rapid production growth.

Due to the current need for outstanding production performance and sustainable environmental standards, an important question is: Is augmenting Gross Domestic Production (GDP) related to increasing air damage, measured by emissions of pollutant gases? We analyze this issue by evidencing aggregate production performance and standards of gases emissions of the G7 rich countries in the last four decades (1970 - 2012).

In section 1 the relevant theories on production-cum-environment, the concept of sustainable development and the environmental Kuznets' hypothesis are presented to give support to the analysis. In section 2 Graphical analysis and statistical correlation are introduced and arguments on their use appropriateness are elaborated. Section 3 reports the empirical evidence: statistical correlation analysis is applied to evidence the strength of the relationship between GDP paths and trajectories of gases emissions. In general, the evidence shows a significant and negative correlation between GDP and gases emissions for the G7 rich countries, exceptions being USA, Canada and Japan. Production augmentation in USA and Japan are paired with increasing levels of $CO_2$ and total greenhouses gases, and Canada's GDP increases are correlated to increasing levels of $CO_2$, methane and total greenhouses gases emissions. Three Europeans countries (Germany, UK and France) performed very well both on production and gases emissions standards, seeming to be under the environmental Kuznets' hypothesis, pairing GDP growth with decreasing levels of gases emissions.

## 1. Theories on Production Growth with Environment and Sustainable Development

This section presents a set of growth-cum-environment models trying to bridge production and the environment. Following, the Brundtland Commission Report (1987) is referred as a crucial publication that has pioneered and institutionalized the concept of sustainable development. The important environmental Kuznets' U-inverted curve relating advanced stages of development and decreasing environmental damage is presented to end the theoretical section.

### 1.1. Production-Cum-Environment

Two classes of environmentally-based production growth models are presented: production growth using finite and depletable natural resources; and output growth with pollution as waste generation. The first type of pioneering production-environmental model comes from Anderson (1972), who explores the implications to production growth from explicitly accounting for depletion of a nonreproducible natural resource, such as a fossil fuel reserve. Stiglitz (1974) used a similar construction to model production growth in the presence of exhaustible natural resources. More recently, Amigues, Favard, Gaudet, and Moreaux (1998) and Palmada (2003) formalized optimal allocations of different natural resources, such as air, water and forests, during production phases.

A second class of models was pioneered by Forster (1973 and 1980) who brought an important feature not considered in standard growth models. He presented an optimal physical capital accumulation model taking into account the possibility of waste generation (pollution). Other recent models of pollution generation under optimal environmentally-based output growth are Lyon and Lee (2003); Chakravorty, Moreaux and Tidball (2006); and Chakravorty, Magné, and Moreaux (2006).

In the two classes of pioneering production-cum-environment models mentioned to above the authors follow the standard procedure of considering a one-sector economy, such as in Bretschger and Smulders (2006) analysis of optimal uses of nonrenewable resources, or in Farzin and Akao (2006) and Voinov and Farley (2007) who included renewable natural capital into an output growth model in an one-sector economy.

The most important feature of the pioneer Anderson's (1972) model is that when the nonreproducible stock of natural resources is considered, the main result shows a tendency to postpone capital accumulation and spend time on production growth paths where capital is used less intensively than in models of unconstrained natural resource uses. Therefore, the basic prediction coming from this production growth model accounting for depletable natural resource uses points to a general slowdown trend of production growth. This is so because the environmental constraint poses a limiting restriction on the use of depletable resources, which leads to a reduced rate of physical capital accumulation, driving production downwards. It is optimal to slow down the country's capital accumulation (decreasing production) when depletable natural resources are considered.

Recent contributions have shown this result in different contexts. Comolli (2006) by investigating the relation between natural and physical capital during specific production phases concludes that production growth has to slow down as facing the natural capital constraint; and Farzin and Akao (2006) by studying the optimal exhaustion of a nonrenewable resource under different production settings reach the same result.

Following the other pioneering production-cum-environment model, Forster (1973, p. 544) states that "It is naive to think that no wastes are produced and fairly obvious that the free disposal assumption of the neoclassical growth model is not satisfied in the real world". The most relevant prediction coming from this environmentally-sounded production model points out that when pollution is accounted for, the production process tends to a lower physical capital accumulation than when pollution control is not considered, the same prediction coming from the analysis of the depletable natural resource model by Anderson (1972).

These predictions show us that, theoretically, when we consider production-cum-environment models, the growth-environmental damage relation is explicit, a relevant aspect to guide the empirical exercise in section 3, where the economic (GDP) and environmental (gases emissions) performances of the G7 rich countries are analyzed.

### 1.2. The Concept of Sustainable Development and Sustainability Issues

As stated by Sena (2009, p. 214), "the well known fact that today's economy activities are imposing a heavy burden on the earth's capacity has led to an increasing interest in sustainable development and related issues. It has been emphasized that economic growth depletes the current stock of natural resources and damages the environment and that there are clearly economic limits to rapid growth".

Despite the classical pro-technology optimistic arguments, which pose that technical progress is what is needed to eliminate all constraints on production growth, the approaching exhaustion of many natural resources is a reality. Even in the mining sector, an economic activity that is alleged to be free of its finite mineral resources exhaustion, i. e., where, according to Mudd (2013), the classical pro-technology optimistic arguments are supposed to be applied, is now facing trouble, since evidence on decreasing ore grades, increasing mine waste rock and deeper and larger mines are easy to find.

Current discussions on those issues and attempts to design sound socioeconomic and environmental policy to improve welfare of populations worldwide have had, as a supporting frame, the pioneer definition of sustainable development coming from the Brundtland Commission Report (1987, p. 43): "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Holmberg and Samdbrook (1992) emphasized that the Brundtland Commission gave geopolitical significance to the sustainable development concept.

Many other definitions have followed, all including economical, social, political, institutional and environmental issues to assure that future generations must have not less than we have today. As taking into account the economic, social and environmental pillars, Environment Canada (2006, p. 2) states that "The integration of environmental sustainability with economic competitiveness and productivity and social equity lies at the core of sustainable development [...] It is an approach that seeks to ensure that in meeting our current needs, we do not jeopardize the ability of future generations to meet their needs."

Daly (2002, p. 1) defines sustainable development as "dependable on the maintenance of physical throughput over generations […] Natural capital is to be kept intact. The future will be at least well off as the present in terms of its access to biophysical resources and services supplied by the ecosystem." Gamage and Boyle (2008) offer a review of the concept of sustainable development, including important aspects of consumerism, materialism, and psychological and entrepreneurial aspects, while analyzing the concept in terms of its theoretical advances.

Back to the main focus, and remembering the predictions from the production-cum-environment theoretical models – when constrained by natural resources uses production has to slow down – we ask: is there an inverse relation between production and gases emissions as we consider GDP paths and trajectories of emissions in the G7 rich countries? Are the leader countries in economic (GDP) performance also the leaders in contributing to air degradation? Empirical evidence in section 3 shows the performances of the G7 rich countries on these matters and tries to answer these questions.

### 1.3. The Environmental Kuznets' Curve Hypothesis

Kuznets (1955) originally proposes to study the relation between economic growth (augmentation of production-income) and inequality (income distribution). Kuznets (1955, p. 1) opens his seminal paper posing that "The central theme of this paper is the character and causes of long-term changes in the personal distribution of income. Does inequality in the distribution of income increase or decrease in the course of a country's economic growth?" Sarigiannidou and Polivos (2015) offer an interesting modern version of the original Kuznets' hypothesis, as connecting production growth and income distribution.

In relation to environmental economics, authors have used Kuznets inverted-U relation to study how the environment has been damaged over the different stages of economic growth. Dinda (2004, p. 432), making use of the environmental Kuznets' curve hypothesis, poses that "[…] environmental quality deteriorates in early stage of economic development/growth and improves in later stage as an economy develops." Stern (2003) referring to the origin of the apparent environmental Kuznets's curve effect affirms that independent of specific phases a country experiences, impacts on the environment will occur depending on the interplay of time and scale effects. For developing and emerging countries experiencing rapid growth, scale effects dominate and pollution increases, while in rich countries facing slower growth paths, time spent in reducing pollution may overcome scale effects.

Considering the empirical record on recent studies about the environmental Kuznets' curve hypothesis, Lau, Choog e Eng (2014), in the context of foreign direct investments and trade, investigate carbon emissions in Malaysia. They found that there is evidence supporting Kuznets' hypothesis. Kennedy and Hutchinson (2014), in a cross-country analysis, study the relationship between pollutant emissions and income growth and conclude that there is a pollutant-spillover effect as income increases. Al-Mulali, Saboori and Ozturk (2015) found a positive relationship between environmental degradation (pollution) and capital accumulation in Vietnam. Katz (2015), on the other hand, finds that the relation between income growth and freshwater uses, as a natural resource, does not match the environmental Kuznets' curve.

As the empirical record shows, there are no unambiguous results concerning the relationship between production growth and environmental damage. As posted by Katz (2015) empirical results are dependent on choice of datasets and statistical techniques.

Combining the main arguments on the environmental Kuznets' curve hypothesis with those of the production-cum-environment models presented before, i.e., that production growth has to be reduce if constraints on natural capital uses are imposed, we can say that even in advanced stages of development, environmental damage could happen if production is free to increase. Thus, in the empirical section these issues will be taken into account in the context of the G7 rich countries economic (production) and environmental (gases emissions) performances in the last four decades (1970-2012).

## 2. Methods: Cross-Country Graphical Analysis and Statistical Correlation

A graphical presentation of GDP paths (in levels) opens the empirical section 3. We aim to show graphically whether or not increasing production is paired with increasing emissions of four gases: $CO_2$, methane, nitrous oxide and other greenhouses. Following this analysis, statistical correlation is introduced as a measurement technique used to check if two variables are correlated. For example, consider the variables 'individual disposable income' and 'consumption'. It is expected that the values of these two variables increase or decrease together, i. e., they are related in a way that a positive (negative) change in one variable is paired with a positive (negative) change in the other variable. In this case, we say that 'disposable income' and 'consumption' of an individual are positively correlated. On the other hand, if income-consumption is related to production that to be obtained damages the environment, then 'production' and 'stock of fresh/clean environment' are said to be negatively correlated. Then we say that when 'production' increases, natural capital decreases and vice-versa.

According to Choudhury (2009), correlation analysis is about a relationship between variables and gives us two relevant types of information: i) whether the relationship is positive, null or negative; and ii) if the magnitude of the relationship is weak, moderate or strong. Statistical correlation cannot give us information about cause-effect among variables nor can be applied to variables presenting non-linear trajectories.

If endogeneity (loop causation) between two variables is present, statistical correlation has an advantage as compared to cause-effect methods, such as regression analysis. For instance, increasing figures on Foreign Direct Investments (FDI) may cause increasing levels of Gross Domestic Production (GDP) in a certain country. Also, increasing levels of GDP in such a country may cause increasing FDI inflows, characterizing a sort of loop causation. In such cases, it is convenient to use correlation analysis because it is not possible to isolate dependent and independent variables. Correlation could appropriately be applied just to track the paths of the two variables without taking causalities into account.

Let $Y_1, Y_2, \ldots, Y_n$ and $X_1, X_2, \ldots, X_n$ be values of two quantifiable variables, with i = 1, 2, …, n a sample of n observations. Three types of correlation between $Y_i$ and $X_i$ can be derived from the reduced variables $V_i$ and $U_i$, the standardized values of original variables $Y_i$ and $X_i$, respectively. If $\sum [V_i.U_i] > 0$, correlation between $Y_i$ and $X_i$ is positive; if $\sum [V_i.U_i] = 0$, null; and if $\sum [V_i.U_i] < 0$, correlation between $Y_i$ and $X_i$ is negative. There is a forth type of correlation called spurious - even with an eventual strong positive correlation, e. g., between a variable ‘number of street lights’ and variable ‘number of born female babies’, both annually measured, it makes no sense to study this relationship (even if it is possible that the two series coincidently present a high positive correlation), so it is called ‘spurious’. Theory, as relating key-variables in an appropriated and expected way, is the best devise to avoid us using spurious correlation.

The correlation coefficient ‘r’ is the operator for calculating correlation between two variables. It is obtained dividing $\sum [V_i.U_i]$ by (n – 1). This has to be so since $\sum [V_i.U_i]$ increases as the sample size ‘n’ increases. Plugging the reduced-standardized variables $V_i$ and $U_i$ given above into ‘r’, after some algebraic rearranging we get $r = \sum(x_i.y_i) / (\sum x_i^2.\sum y_i^2)^{1/2}$, where $x_i$ and $y_i$ are the deviations of the $x_i$ and $y_i$ values in relation the their means. The values of the correlation coefficient ‘r’ range from -1 to +1, including zero which is the value for null correlation. The -1 value holds for perfect negative correlation and +1 for perfect positive correlation. For a clear treatment of the applicability of the coefficient of correlation, see Bobko (2001).

We can discuss on the ranges for values of ‘r’ that correspond to different degrees of strength of the relationship between two variables. According to Choudhury (2009), there is no agreement among scholars on the choice of the interval limits for ‘r’. We will consider in the empirical section three closed intervals of the values for r: i) strong strength, with $r = [\pm 0.7 ; \pm 1]$; ii) moderate strength, with $r = [\pm 0.5 ; \pm 0.69]$; and iii) weak strength, with $r = [< \pm 0.5]$.

## 3. G7 Rich Countries: Empirical Evidence on Production and Gases Emissions

The G7 (Group of Seven) includes the 7 most industrialized countries in the planet: United States, Japan, Germany, United Kingdom, Canada, France, and Italy. They cooperate on economic issues, including the real side (production, investment, budget etc) and the monetary side (inflation, interest rate, exchange rate etc). The G7 rich countries are a subset of the 34 OECD countries.

We start the empirical section clarifying some issues. First, the aggregate production (GDP) is treated here as a variable intentionally chosen to depict a country' production performance. It is an *ex-anti* given indicator that we take without searching for causes to explain successes or failures in production outcomes. The main purpose here is to check the strength of the relationship between production paths and the trajectories of the selected gases emissions, both over the same period of time. We selected data from the World Bank (2016) on GDP, $CO_2$, methane, nitrous oxide and total greenhouses gases emissions for a 1970-2012 time series. The behavior of GDP paths and trajectories of these gases emissions will be analyzed to investigate whether or not there is a positive relation between GDP production and emissions over the specified period of time.

A brief account of the consequences to the environment from the emissions of harmful gases is needed in order to justify the selection of the indicators. The consequences of $CO_2$ emissions to the environment are the following: i) rise of sea level leading to "densely settled coastal plains to become uninhabitable …, which would result from melting of the ice caps …; ii) rise of global warming impacting negatively on agriculture, that could have major effects on agricultural productivity; iii) reduction of the ozone layer, since warming would result in increase high cloud cover in winter, giving chemical reactions a platform in the atmosphere, which could result in depletion of the ozone layer; iv) increased extreme weather, changing the climate systems of the earth, meaning there would be more droughts and floods, and more frequent and stronger storms …; v) depletion of ecosystem causing the range of plants and animals to change, with the net effect of most organisms moving towards the North and South Poles." (http://www.carboncalculator.co.uk/effects.php).

Methane emissions contribute to "Earth's greenhouse effects and to warm the atmosphere. Methane is the second most damaging greenhouse gas produced by human activity after carbon dioxide. While methane is a more potent greenhouse gas than $CO_2$, there is over 200 times more $CO_2$ in the atmosphere. Hence the amount of warming methane contributes is 28% of the warming $CO_2$ contributes." (http://www.skepticalscience.com/print.php?r=84).

According to Benton-Short (2014, p. 323), "Globally, about 80 per cent of total nitrogen oxide emissions come from human activities. Nitrous oxide molecules stay in the atmosphere for an average of 120 years before being removed by a sink or destroyed through chemical reactions. The impact of 1 pound of $N_2O$ on warming the atmosphere is over 300 times that of 1 pound of carbon dioxide." "Changes in the atmospheric concentration of $N_2O$ have evoked considerable concern because of its role in regulating stratospheric ozone levels, contributing to the atmospheric greenhouse phenomenon and participating in the acid-rain formation process. The global concentration of $N_2O$ in the atmosphere has been rising since the start of the

Industrial Revolution …"
(http://www.sciencedirect.com/science/article/pii/030626199390018K).

"The consequences of greenhouses gas emissions to the air and the environment are to warm the Earth's surface and the lower atmosphere... Human activities, primarily the burning of fossil fuels and deforestation, have intensified the greenhouse effect, causing global warming… The main effect of increases in atmospheric greenhouse gas concentrations is global warming. Increases in the different greenhouse gases have other effects apart from global warming including ocean acidification, smog pollution, ozone depletion, and plant growth reduction." (http://whatsyourimpact.org/effects-increased-greenhouse-gas-levels).

3.1. Pairing GDP Paths and Trajectories of Gases Emissions

We start analyzing the absolute GDP graphs for the G7 rich countries from 1970 to 2015. The data set was taken from The World Bank (2016), The Development Indicators. In Figure 1a we see that GDP levels are growing fast in USA for the whole period (from US$1 billion in 1970 to US$18 billion in 2015) and in Japan and Germany at slower paces (both from around US$0.2 billion in 1970 to around US$4 billion in 2015). On average, these three countries are the best GDP performers among the G7 economies in the investigated decades. Even during the hard years of the world financial crisis (2008-2009), the USA and Germany had just a slight downward change in their GDP levels. Japan's GDP slowdown starts a little after the crisis, in 2012.

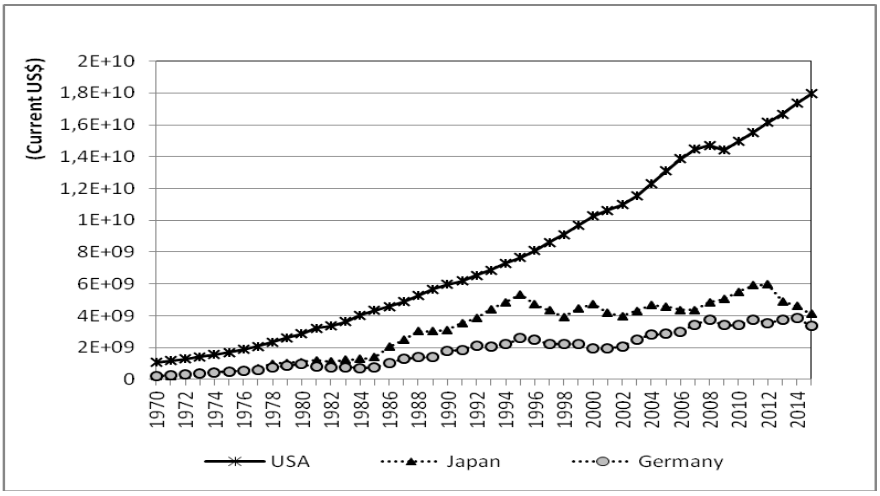

Figure 1a: GDP Levels of the Top 3 G7 Rich Countries - 1970-2015

Comparing the slopes of the tendency line of the three countries, the USA is by far the leader in speeding up its GDP levels over time. Japan and Germany's long run GDP trends are similar, with that of Japan steeper than Germany's.

Figure 1b shows that UK, France, Italy and Canada present GDP graphs growing fast but at lower levels as compared to the top three G7 rich countries in Figure 1a (UK from around US$100 million in 1970 to US$2.8 billion in 2015; and France from around US$100 million to US$2.4 billion). All four countries experienced more intensively the negative effects of the financial crisis by 2008-2009. Italy and Canada grow at the lowest paces among the G7 countries; the slopes of their trend lines are less steep than those of UK and France, as seen in Figure 1b.

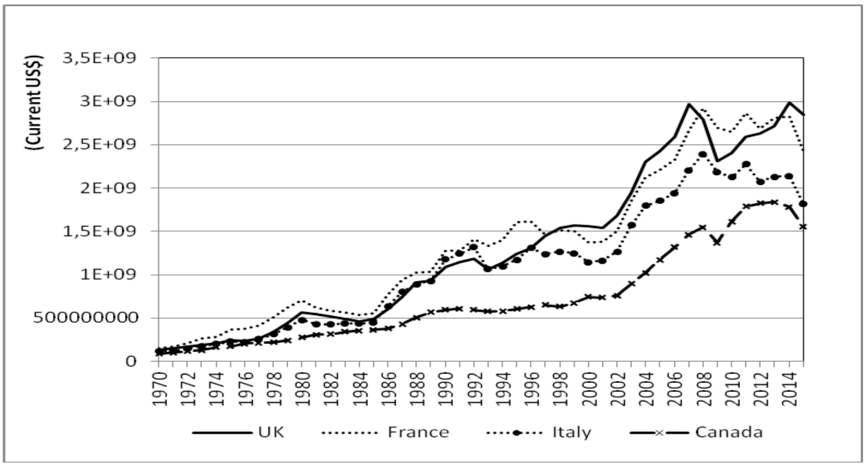


Figure 1b: GDP Levels of the Other Four G7 Rich Countries - 1970-2015

Overall, the GDP levels are increasing in all G7 countries for the whole 1970-2015 period, mainly in the 2000s when the slopes of the tendency lines are steeper. The top seven richest countries in the world did so well in speeding up aggregate production.

3.1.1. $CO_2$ Emissions

To pair the outstanding production performances of the G7 rich countries with their $CO_2$ emissions, Figure 2a shows that the top 3 performers in GDP levels were exactly the same countries leaders in $CO_2$ level emissions: USA, Japan and Germany are the leaders in $CO_2$ emissions as they are GDP performers. USA is by far both the champion in GDP (Figure 1a) and in emitting $CO_2$ gas to the atmosphere, with levels in between around 4.3 million and 5.1 million of tons in the 1970-2013.

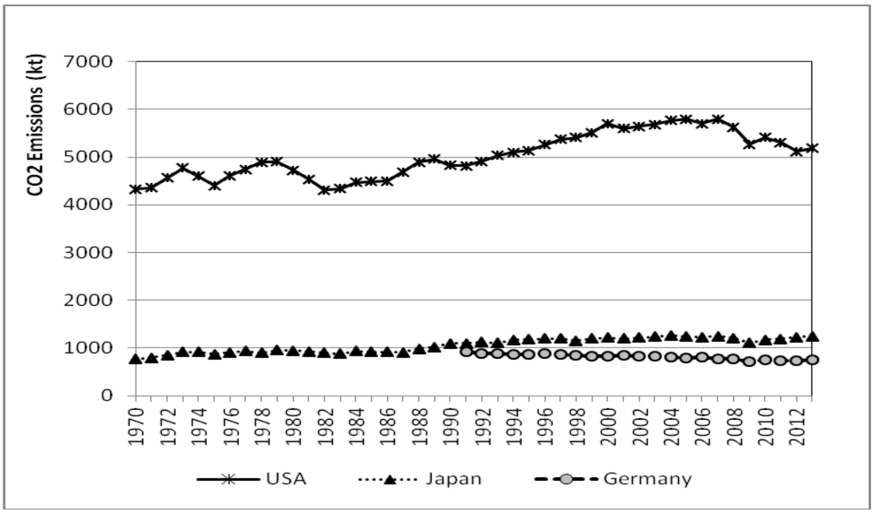


Figure 2a: CO2 Emissions – USA, Japan and Germany / 1970-2013

Japan and Germany performed as mid $CO_2$ emissors; Japan oscillating a little above and Germany slightly below 1 million tons of emissions (data for Germany emissions are only from 1991 to 2013). Note that Germany is the only, among the three, to present a long run downward trend of its $CO_2$ emissions.

Figure 2b shows that UK emitted around 0.66 million tons of $CO_2$ in 1970, decreasing its emissions to 0.47 million in 2013. France followed the same trend, at a lower level, decreasing its $CO_2$ emissions from 0.44 million in 1970 to 0.34 million tons in 2013.

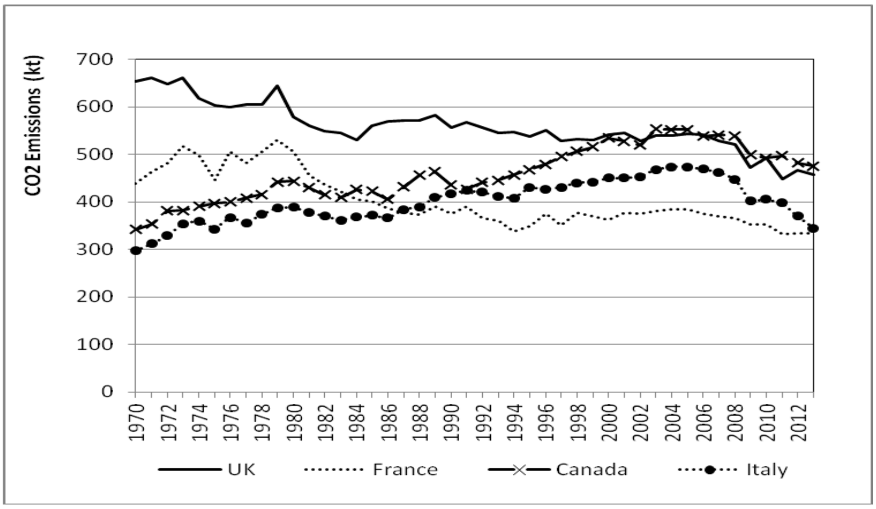


Figure 2b: CO2 Emissions – UK, France, Canada and Italy / 1970-2013

On the other hand, Canada and Italy show increasing long run trends in their $CO_2$ emissions, mainly from 1970 to 2004, reversing them only by the mid-2000s. It is worth to note that three European countries – Germany (Figure 2a), UK and France (Figure 2b) – had long run decreasing trajectories of $CO_2$ emissions over 1970-2013.

3.1.2. Methane Emissions

Figure 3a shows that the top 3 performers in GDP levels were also the same countries leaders in methane level emissions: USA, Japan and Germany were leaders in methane emissions as they were as GDP performers.

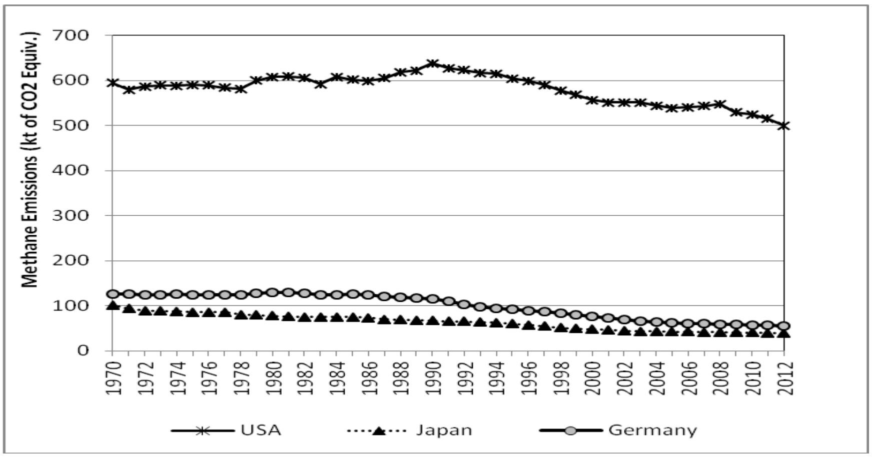


Figure 3a: Methane Emissions – USA, Japan and Germany / 1970-2012

The USA again are both the champion in GDP growth (Figure 1a) and in emitting methane gas, with levels in between 0.5 million and 0.6 million of tons of $CO_2$ equivalent in the 1970-2012 period. Japan and Germany performed as mid methane emissors; Japan oscillating a little below and Germany slightly above 100 thousand tons of methane emissions from 1970 to 1990 and around 50 thousand tons afterwards. Note that all the 3 top performers in GDP (Figure 1a) present a long run downward trend of its methane emissions, an evidence hopefully leading to reducing levels of emissions of this gas in the future.

Figure 3b shows that UK emitted around 120 thousand of methane tons of $CO_2$ equivalents in 1970, decreasing its emissions to 60 thousand tons by 2012. France followed a constant trend, emissions oscillating around the order of 80 thousand of methane tons of $CO_2$ equivalent over the whole period; and Italy showed a similar constant long run trend, but with methane emissions oscillating at a lower level, around 40 thousand tons.

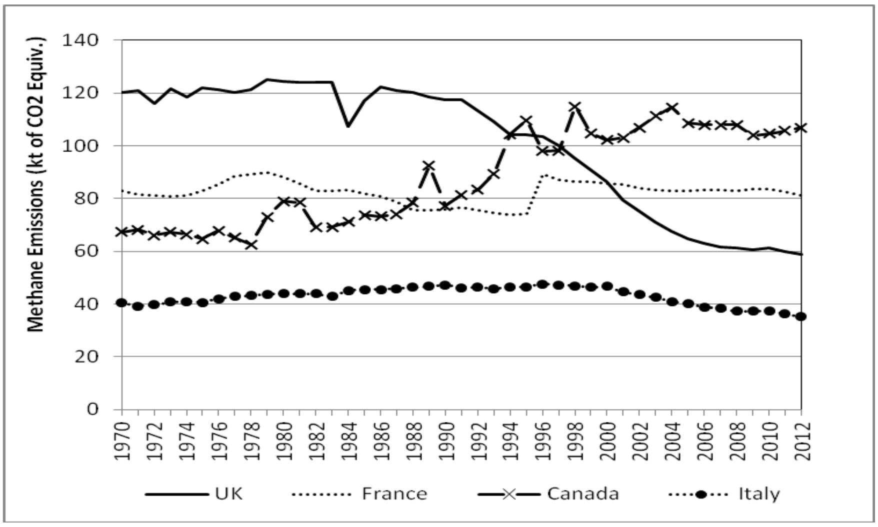


Figure 3b: Methane Emissions – UK, France, Canada and Italy / 1970-2012

Canada is the only country having an increasing long run trend, starting its methane emissions at a level around 70 and ending with 110 thousand tons of $CO_2$ equivalent in 2012. It is worth to note that UK shows a sharp long run decrease in its methane emissions over 1970-2012.

3.1.3. Nitrous Oxide Emissions

Figure 4a shows that USA levels of nitrous oxide emissions are huge, compared to Japan and Germany's. From 1970 to 1997-98, USA and Japan, the top 2 GDP performers, increased their emissions of nitrous oxide into the atmosphere; and Germany presented a more or less constant trend. But, starting in the late 1990s, all three reduced their nitrous oxide gas emissions.

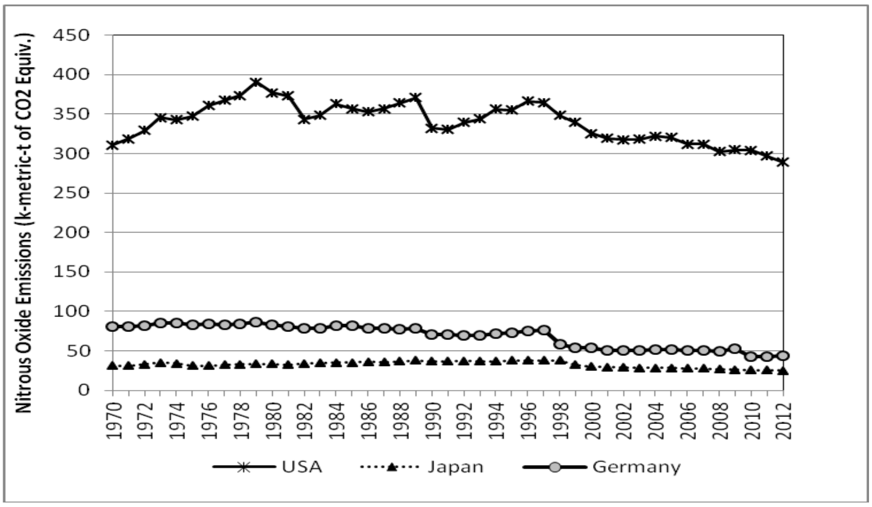


Figure 4a: Nitrous Oxide Emissions – USA, Japan and Germany / 1970-2012

The USA levels of emissions ranged in between around 290 and 370 thousand metric tons of $CO_2$ equivalents from 1997 to 2012. Germany, at higher levels, paired Japan's downward trend during the 2000s, Japan emitting around 48 thousand metric tons and Germany 50 thousand metric tons of $CO_2$ equivalents of nitrous oxide.

Figure 4b shows that France and UK present similar downward trends, France emitting around 65 thousand nitrous oxide metric tons of $CO_2$ equivalents in 1970, decreasing its emissions to 37 thousand metric tons by 2012. UK emissions are cut in half, decreasing from 50 thousand nitrous oxide metric tons of $CO_2$ equivalent in 1970 to 25 thousand metric tons in 2012. These two countries, following the top 3 GDP performers (USA, Japan and Germany in Figure 1a), rank high as outstanding GDP performers (Figure 1b). Despite their decreasing trends, they score relatively high in terms of levels of nitrous oxide emissions until the mid-1990s.

Italy showed also a long run decreasing trend, with nitrous oxide emissions ranging from 30 to 20 thousand of metric tons. Canada presented a sharp increasing trend until the mid-1990s, from 30 thousand in 1970 to 70 thousand of nitrous oxide metric tons of $CO_2$ equivalent in 1995, reversing its emissions since then. By the late 1990s until 2012, all countries in Figure 4b experienced a strong downward tendency at their levels of nitrous oxide emissions, a trend hopefully leading to reducing this gas in the future.

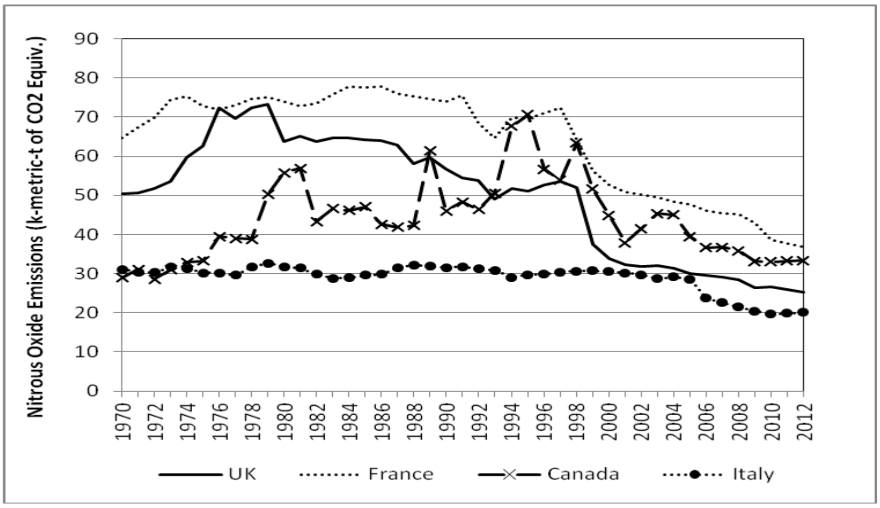


Figure 4b: Nitrous Oxide Emissions – UK, France, Canada and Italy / 1970-2012

Summing up, evidence in Figures 4a and 4b shows that the leader countries in GDP performances are also the leaders in nitrous oxide emissions. But, in the long run considering the whole period, the trajectories of nitrous oxide emissions in all G7 countries present decreasing trends, again a sound result presumably leading to reduced levels of nitrous oxide emissions in the future.

3.1.4. Total Greenhouses Emissions

As in the evidence showed for $CO_2$, methane and nitrous oxide emissions, Figure 5a shows that the top 3 GDP performers are also the leaders in level emissions of the total greenhouses gas.

USA, Japan and Germany are top in emitting total greenhouses gases (HFC, PFC and SF6) into the atmosphere. USA is by far the champion, with a very high level and an increasing trend of emissions over the four decades. Their levels of total greenhouse gas emissions increase from around 5.4 million to around 6.2 million tons of $CO_2$ equivalents in the investigated period.

Japan and Germany, as mid-emissors of total greenhouse gases, present similar trends, with Germany leading emissions around 1 million until 1990, and Japan taking the lead from then on. It is worth to note that Germany is the only, among the three top other greenhouses emissors, evidencing a steady long run downward tendency in its emissions of other greenhouses gases into the air from 1970 to 2012.

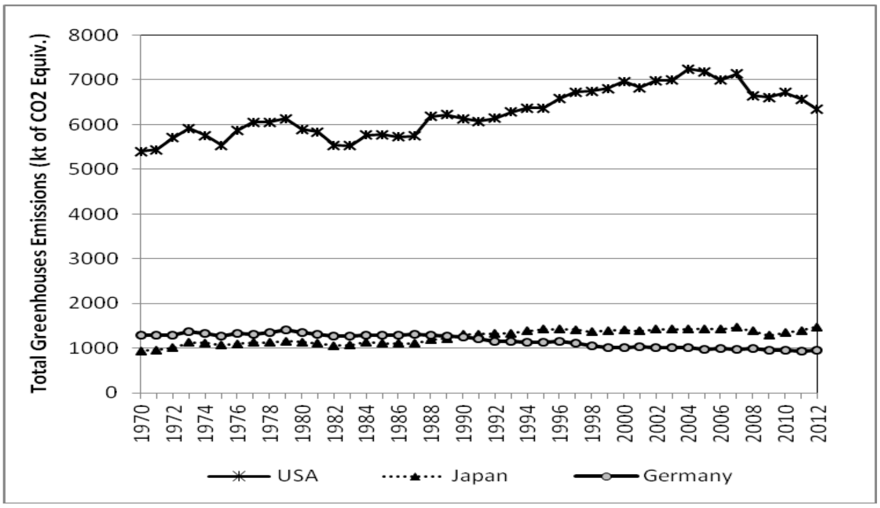


Figure 5a: Total Greenhouses Emissions – USA, Japan and Germany / 1970-2012

Figure 5b shows very similar evidence on the trends of total greenhouses emissions when compared to the emissions of nitrous oxide gas (Figure 4b). Except for Italy's increasing long run trend, both UK and France present downward long run tendency lines - UK emitting around 8.5 million total greenhouses tons of $CO_2$ equivalents in 1970, decreasing its emissions to 6 million tons by 2012. France emissions are cut from 6 million to 5 million of total greenhouses tons of $CO_2$ equivalents over 1970-2012. Otherwise, Canada and Italy present upward trends, with Canada showing a steeper slope of its long run tendency line.

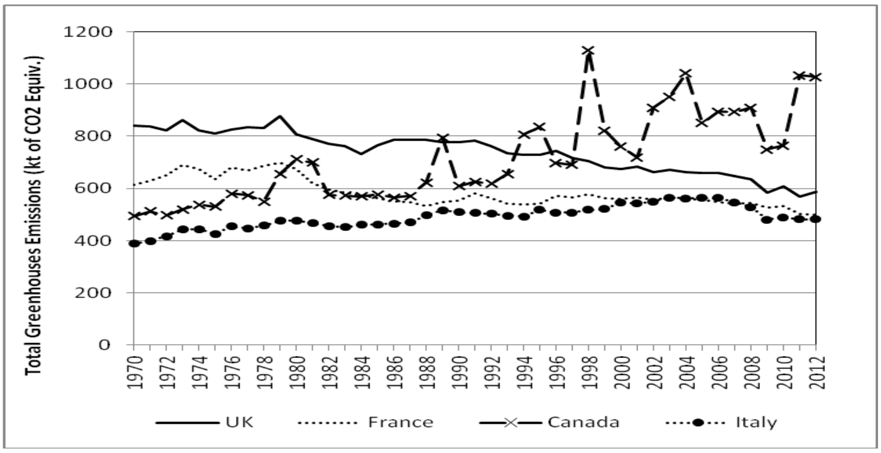


Figure 5b: Total Greenhouses Emissions – UK, France, Canada and Italy / 1970-2012

To sum up, evidence in Figures 5a and 5b show that USA, Japan and Germany, the leader in GDP performances, are also leaders in levels of total greenhouse gas emissions. Looking at the long run trends, a problematic environmental concern for today and into the future is that the trajectories of HFC, PFC and SF6 gases emissions, mainly in USA, Japan, Canada and Italy, presented increasing trends, a risk to the current air conditions.

3.1.5. A Word on GDP and Gases Emission Levels

In terms of GDP and emissions of the four air pollutant gases (in levels), Table 1 shows that the rankings of the top three GDP performers – USA, Japan and Germany

– are exactly the same as those of the leading emissors of $CO_2$ and total greenhouses. In Table 1, calculated annual averages for the period from 1970 to 2012 evidence that USA are by far the champions in contributing to accumulated levels of emissions of all four gases. Its high average level of production (US$7.8 billion) is tied to its high levels of emissions of $CO_2$, (5 million tons), total greenhouses gases (6.2 million tons), methane (581 thousand tons of $CO_2$ equivalent) and nitrous oxide (340 thousand metric tons of CO2 equivalent). These numbers compared to those of the countries ranked 2nd and 3rd places in GDP performance and gas emissions average levels – Japan and Germany – are huge. Thus, in terms of average levels of pollutant gas emissions, we prize USA with the 'red light' award. Japan is ranked 2nd as a GDP performer (annual average of US$3.1 billion) and also 2nd in $CO_2$ (around 1.1 million tons) and total greenhouses (around 1.2 million tons) emissions.

**Table 1: GDP (billion US$) and Gases Emissions (million tons) Level Averages – 1970-2012**

| **G7** | **GDP** | **$CO_2$** | **Total Greenhouses** |
|---|---|---|---|
| USA | 7,82 | 5,02 | 6,27 |
| Japan | 3,08 | 1,06 | 1,26 |
| Germany | 1,87 | 0,82 | 1,17 |
| **G7** | **Methane** | | |
| USA | 0,581 | | |
| UK | 0,101 | | |
| Germany | 0,992 | | |
| **G7** | **Nitrous Oxide** | | |
| USA | 0,340 | | |
| Germany | 0,072 | | |
| France | 0,063 | | |

Source: Word Bank (2016). Elaborated by the authors.

To conclude, we say that in terms of average levels, countries with high GDP figures, mainly the USA, are also the countries that present the highest levels of gas emissions in the four decades investigated, contributing thus for the accumulation of Earth's air damage. An alert: USA and Japan have to keep their eyes opened to fight against level emissions of $CO_2$ and total greenhouses (HFC, PFC and SF6) gases emissions.

3.2. Correlation Analysis: G7 Rich Countries' GDP Versus Gases Emissions

To evaluate the strength of relationship between production paths and the trajectories of the four gases emissions, Table 2 shows the relevant coefficients of correlations. All of them are statistically significant at the 5% level, except the GDP x Methane correlation for France and GDP x Nitrous Oxide correlation for Canada.

**Table 2: Correlations between GDP and Gases Emissions of the G7 Rich Countries - 1970-2012**

| | GDP x CO2 | GDP x Methane | GDP x Nitrous Oxide | GDP x Total Greenhouses |
|---|---|---|---|---|
| * USA | 0,83 | -0,76 | -0,70 | 0,84 |
| * Japan | 0,93 | -0,93 | -0,29 | 0,93 |
| ** Germany | -0,86 | -0,94 | -0,89 | -0,91 |
| * UK | -0,81 | -0,95 | -0,88 | -0,93 |
| * France | -0,76 | -0,05 [i] | -0,85 | -0,74 |
| * Canada | 0,73 | 0,79 | -0,16 [i] | 0,76 |
| * Italy | 0,66 | -0,34 | -0,75 | 0,73 |

Source: Elaborated by the authors (2016). All coefficients significant at 5%. [I] Insignificant at 5%. * 1970-2013 for GDP x $CO_2$. ** 1991-2013 for GDP x $CO_2$.

The evidence in Table 2 shows that the magnitudes of correlations of GDP x $CO_2$ are strong in all G7 countries, except in Italy that presents a moderate correlation [$| r | = 0.66 < 0.7$]. We prize the three Europeans, Germany, UK and France with a 'green light' – strong negative GDP x $CO_2$ correlations [$| r | \geq 0.76$], meaning that there exist a significant inverse relation between GDP paths and $CO_2$ emissions in these countries. 'Red lights' winners USA, Japan and Canada present strong positive GDP x $CO_2$ correlations [$| r | \geq 0.73$], meaning that increased $CO_2$ emissions are paired with increasing levels of aggregate production.

Regarding GDP x Methane and GDP x Nitrous Oxide correlations, Table 2 shows a dominance of negative signals, evidence that for these two gases there is lesser concern in terms of expecting increasing emissions. Only Canada presented a strong positive GDP x Methane correlation [$| r | = 0.79$], winning a 'red light' for its methane emissions.

Increasing GDP levels are strongly related to decreasing levels of methane emissions in Japan, USA, Germany and UK, the top four G7 countries leaders as GDP performers. The same holds for the GDP x Nitrous Oxide correlation figures, except for Japan with a significant but weak negative correlation [$| r | = 0.29$] and Canada with an insignificant coefficient [$| r | = 0.16$].

From Table 2, evidence on correlation coefficients involving total greenhouses gas emissions is a concern: 'red lights' to USA, Japan, Canada and Italy, all with correlations coefficients $r \geq 0.73$. Increasing paces of rapid production are very strong and positively related to increasing levels of HFC, PFC and SF6 gases emissions. Note that the three Europeans, Germany, UK and France, showed consistently strong and negative correlations [$| r | \geq 0.74$]. Again, all three countries are winners of 'green light' prizes.

Considering the three Europeans 'green light' winners, a relevant issue to be brought in the analysis is if these countries have been already facing high stages of economic development since the 1970s, and thus, the environmental Kuznets' curve hypothesis is under way – as higher stages of economic growth/development are being attained, environmental damage is prompted to reduce. As we know, Germany, UK and France have attained an economic stage of maturity since the mid-1950s, differently from Japan and Canada, for example, where higher stages of economic prosperity is a more recent phenomenon. This is an important issue to be discussed, but it is out of the scope of the present study.

To answer the question posed in the title of the paper (Are the G7 Rich Countries Contributing to Air Damage?) we use the empirical evidence presented to argue that in terms of levels, countries with high GDP figures are also the countries that presented the highest levels of gases emissions in the four decades investigated. This is evidence that the G7 rich countries are contributing to the accumulating levels of air damage via emissions of pollutant gases.

But, in terms of relational tendencies, i.e., using correlation analysis, increasing paths of GDP levels over time in the G7 rich countries are significantly related to decreasing levels of methane and nitrous oxide emissions. The villain are $CO_2$ and total greenhouses gases emissions – USA, Japan, Canada and Italy presented strong and positive correlations on GDP x $CO_2$ and GDP x Total Greenhouses over the long run of the four decades investigated. Alleviating evidence comes from the three Europeans: Germany, UK and France have been experiencing production growth and, at the same time, facing decreasing levels of all four gases emissions.

## Conclusion

Taking into account the current need for nations adhering to environmental standards, a relevant issue is investigated: are augmenting levels of Gross Domestic Production (GDP) tied to increasing levels of air damage? This paper aims to analyze this production-environmental relation focusing on the G7 rich countries' economic (production) and environmental (gases emissions) performances in the four decade 1970-2012 period.

Graphical and statistical correlation analyses are the methods used to evidence that the relationships between GDP paths and trajectories of gases emission are, in general, significant, negative and strong. The source of the data set used is World Bank (2016), The Development Indicators. Results show that increasing GDP levels in the G7 countries are negatively related to methane and nitrous oxide gases emissions. Otherwise, the USA, Japan, Canada and Italy's DGP growth paths are paired with increasing levels of both $CO_2$ and total greenhouses gases emissions - they are winners of the 'red light' prizes, a concern to be taken into account if air safety is a priority.

To answer the question posed in the title of the paper, empirical evidence shows that, in terms of levels, countries with high GDP figures are also countries that present the highest levels of gases emissions in the four decades investigated, contributing thus to Earth's air damage. An alert: in terms of levels, USA and Japan have to keep their eyes opened to fight against emissions of $CO_2$ and total greenhouses (HFC, PFC and SF6) gases.

But, in terms of tendencies, correlation analysis brings a set of sound evidences: increasing trajectories for GDP levels over time in three European countries –

Germany, UK and France – were significantly related to decreasing levels of $CO_2$, methane, nitrous oxide and total greenhouses emissions. Another alert is needed: in terms of trends, USA, Japan, Canada and Italy have to keep their eyes opened to fight against $CO_2$ and total greenhouses (HFC, PFC and SF6) gases emissions.

Considering the three Europeans ‘green light’ winners, a relevant issue is if these countries have been already facing high stages of economic development since the 1970s, and thus, the environmental Kuznets’ curve hypothesis is under way – for a country, as higher stages of economic growth/development are being attained, environmental damage is prompted to reduce. As we know, Germany, UK and France have attained economic stages of maturity since the mid-1950s, differently from Japan and Canada, for example, where higher attainment of high stages of economic prosperity are a more recent phenomenon. This is an important issue to be discussed in a future work; it is out of the scope of the present study.

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# *Investigating the Energy Performance of Buildings with a 3D City Model and Thermal Simulation: Results from the Urban Transition Lab*

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**Abstract**
Reduction in consumption of non-renewable energy resources at the local level (e.g. district or neighbourhood) is one of the effective manners to support sustainable development. To achieve this goal, engagement of citizens and other actors in the early stage of research is important. In this regard, the "Urban Transition Lab 131" (R131), which acts as a platform to identify problems and to set goals for sustainable development, was established to engage both the citizens of Karlsruhe through participatory processes and the researchers from the Karlsruhe Institute of Technology (KIT). Within the framework of R131, the energy performance of buildings and thermal simulations were carried out in Oststadt, a district of the city of Karlsruhe. At first, 3D city models were used to perform a morphology and exploratory cluster analyses. Secondly, the heating energy demand of the residential buildings were simulated at different spatial and temporal resolutions. Thirdly, as a proof of concept, three scenarios for the reduction of non-renewable energy consumption in a multi-family building were analysed. The data was collected from multiple sources, e.g. field surveys, interviews with landlords and local utility companies as well as expert and literature reviews. Finally, the results were communicated with the citizens through a formal workshop. This integrated research and the results from this project can help the citizens and local policy makers to identify different options for sustainable energy concepts. Furthermore, the findings can also contribute to the sustainable energy policy agenda in the short and long term, across different districts, cities and regions.

Keywords: 3D city model, Clustering, Building heating demand, Energy concept, Sustainability.

## 1. Introduction

The way we organize our life in the cities is a crucial determinant of the success of sustainable development. Against this background, the Karlsruhe Institute of Technology (KIT) establishes "Urban Transition Lab 131" (R131), which acted as a research platform to identify problems and to set goals for sustainable development. It integrated science, innovation, and urban development into a transdisciplinary process, where the scientists of KIT work together with committed citizens and local stakeholders. This participatory process addressed the district level, which was especially suited to test sustainable development projects. Therefore, the main concern of the R131 was to merge research, practice and education.

The societal objective of the R131 was to draft a sustainable development plan of the district Oststadt in Karlsruhe. In this regard, a science venue named Future Space for Sustainability and Science, was established in the district (Oststadt) of Karlsruhe for personal interaction, exchange of ideas, and sharing of knowledge through events, regular meetings of various groups, seminars and exhibitions related to the current projects. The research on Energy Concept was carried out in the R131, along with three transdisciplinary research activities, e.g. Mobility, Social Issues and the Urban Space, Sustainable Consumption. They were accomplished through participatory project planning and were designed as transdisciplinary "real experiments" or "sustainability experiments" (Parodi et al., 2016). Figure 1 gives a structural overview of the R131.

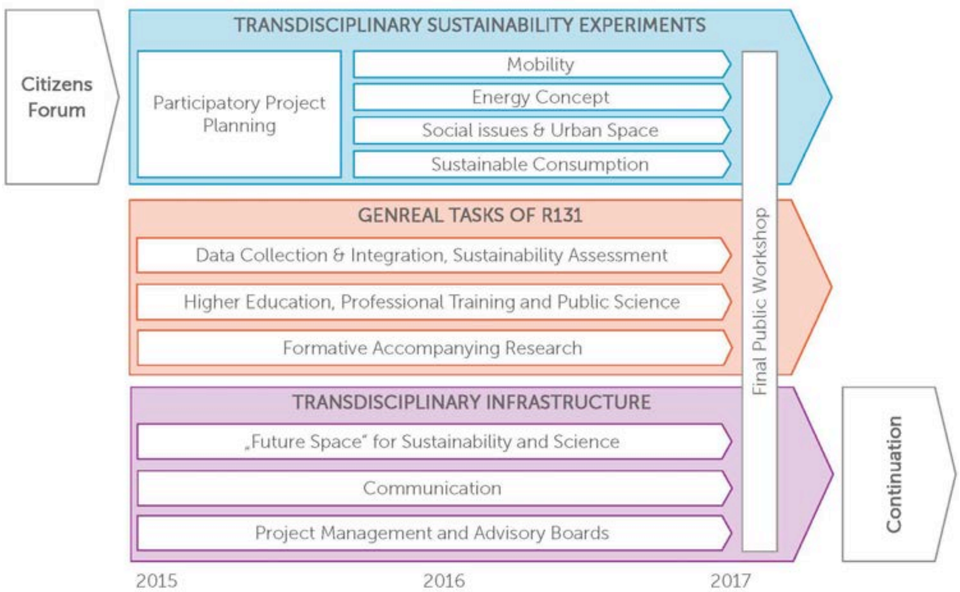


**Figure 1: Transdisciplinary sustainable activities within the "Urban Transition Lab 131" (R131).**
**Source: (ITAS, 2015).**

One of the effective manners to support sustainable development is the reduction in consumption of non-renewable energy resources at the local level (e.g. district or neighbourhood). This paper discusses the research activities and results performed in the Energy Concept project. Various aspects, such as energy efficiency, reduction of greenhouse gas emissions, optimisation of energy supply, etc. play significant role in the sustainable energy concepts. Such concepts can be achieved through integrated analyses of existing conditions, e.g. the energy performance of the buildings, spatial and temporal patterns of energy demand as well as energy saving potentials scenarios in the future. The technical solutions can be assessed by statistical analyses and dynamic simulation. Afterwards, the results can be shared with the residents and local stakeholders for better understanding of the short and long-term consequences of energy planning (concepts) and their further implications. The local policy makers and utility companies can decide different options for energy planning and develop alternative scenarios at a district level – by engaging the citizens in the process.

## 2. Description of the study area and required data

### *2.1 Study area*

The research was carried out in the district Oststadt of the city of Karlsruhe. Karlsruhe consists of 27 districts in an area of around 173 km², with a population of around 308,000 (StatistischesBundesamt, 2016). The total area of Oststadt is around 5.19 km² with a population of 23,000 (StadtKarlsruhe, 2017b). It is characterised by a mixed land use having different residential, commercial and small industries. The district boasts of numerous cultural monuments and technology parks (Figure 2).

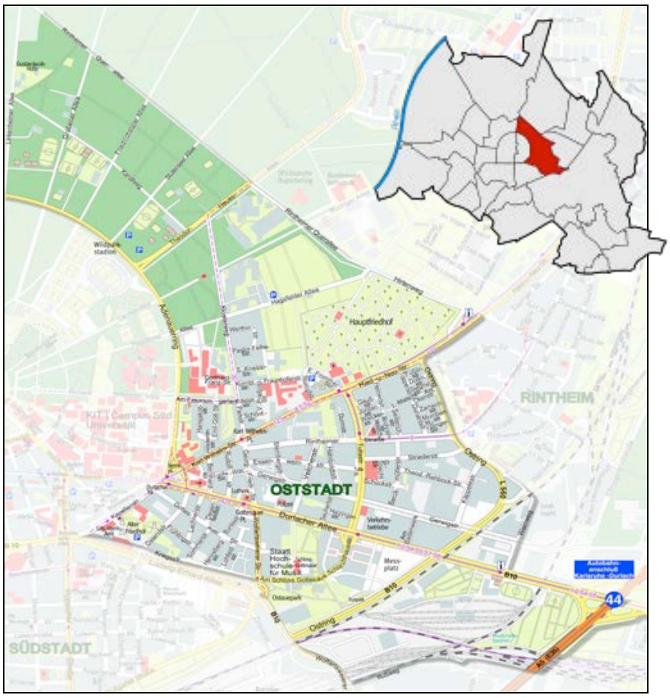


**Figure 2: Description of the study area (left: land use map of district Oststadt, top right: boundary of city Karlsruhe and its 27 districts, Oststadt is marked in red). Source: (StadtKarlsruhe, 2017b).**

The statistical analyses reveal that about 80% of all apartments in Oststadt are situated in multi-family houses (MFH) and the buildings with 7 – 12 apartments have the largest share (43%) (Figure 3). Around 80% of all residential buildings were built before 1970. In terms of energy consumption, heating (57%) and domestic hot water

(25%) are most dominant. These diverse land use and existence of old buildings make the district attractive to study energy concepts.

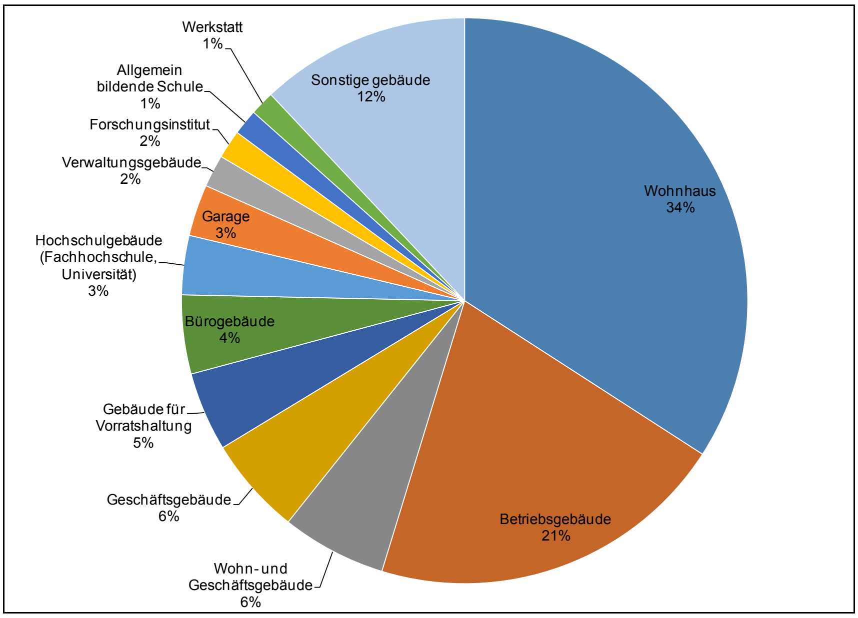


**Figure 3: Share of different building types in the district Oststadt. Source: Data Collection Group of the Urban Transition Lab.**

### *2.2 Description of data*

Several spatial (2D and 3D) and non-spatial datasets were required for this study. They were collected from multiple sources, e.g. field surveys, interviews with property owners and local utility companies as well as expert and literature reviews (Table 1).

**Table 1: Description of data required in this study.**

| Category | Content/description | Source |
|---|---|---|
| Spatial data | 3D city model: LoD2 data in CityGML format | (StadtKarlsruhe, 2017a) |
| | OSM data: building locations, footprints, tags | (OpenStreetMap, 2017) |
| Building attribute | German census survey: total # buildings, frequency per age class and building type | (ZENSUS2011, 2014) |
| | Market research data: building type, building age, # flats, # commercial units, etc. | (INFAS, 2011) |
| | Student survey: building geometry (footprint, height, roof, basement & attic types), size & material of construction elements | Urban Transition Lab |
| Building typology | EU project TABULA (Typology Approach for Building Stock Energy Assessment) | (IWU, 2015) |
| Weather data | Solar radiation and temperature profiles | (EuropeanCommission, 2016), (NASA, 2016) |

## 3. Research approach

The energy performance of buildings and thermal simulations were carried out in a holistic manner by incorporating transdisciplinary research of several institutes of the KIT. The building typology in Oststadt was identified with primary and secondary data collected by the R131. They were required to calculate the building energy demand and to perform 3D building morphology and explorative cluster analysis for identifying homogenous groups of buildings. The energy demand of the residential buildings were simulated and mapped at the different spatial and temporal resolutions. Afterwards, as a proof of concept, three scenarios for the reduction of non-renewable energy consumption in a multi-family building were performed. Finally, the outcome of the research were communicated with the citizens through a formal workshop.

The methodological approach of this research can be divided into four main parts (Figure 4): (1) 3D morphology and cluster analyses (2) Mapping of energy demand (3) Simulation of energy concepts and (4) Citizens' participation. The approaches and their interrelationships are explained in the following chapters.

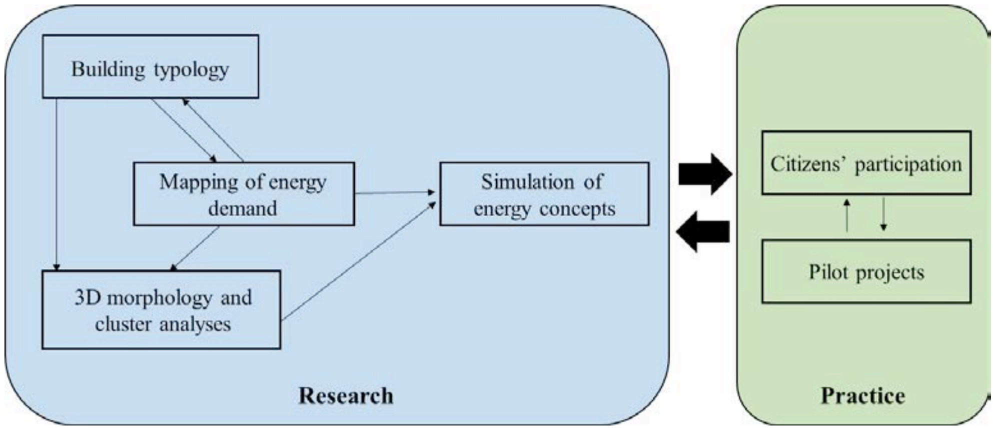


**Figure 4: Methodological overview of the energy concept topic. Source: Own depiction.**

## 4. Analysis of 3D building morphology and clustering

The 3D building morphology and cluster analyses were preceded by the exploratory evaluation of different spatial and non-spatial data with different methods and tools. An overview of different geometric and statistical analyses involved in this part of research is given in Figure 5.

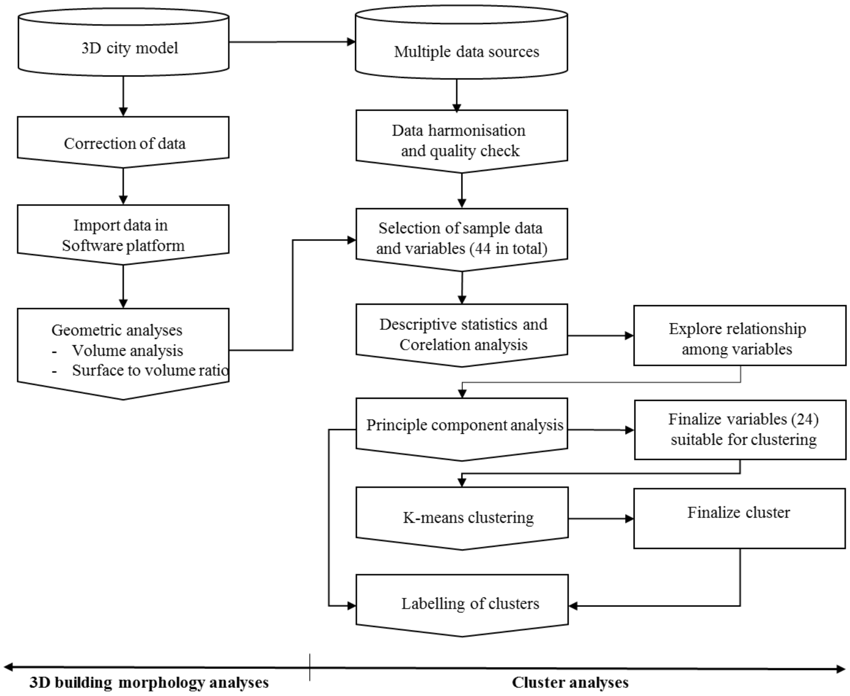


**Figure 5: Methodological overview of geometric and statistical analysis. Source: Own depiction.**

### *4.1 3D building morphology analyses*

### 3D city model

Virtual 3D city models are used in various areas of urban and spatial planning such as, sustainability, energy and environment (Biljecki, Stoter, Ledoux, Zlatanova, & Çöltekin, 2015). The energy performance of buildings can be derived from semantic 3D city models (which contains building geometries) and other building attributes (e.g. type, age). CityGML is a widely used standard for displaying 3D city models at different levels of detail (LoDs) (Figure 6).

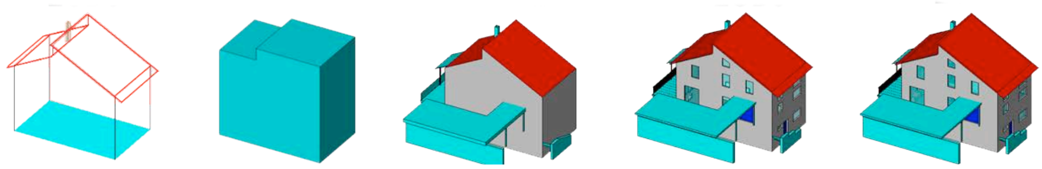

**Figure 6: CityGML level of Details (LoDs). From left to right, LoD0 to LoD4. Source*:* (OGC, 2012).**

The 3D city model in the CityGML LoD2 (with roof structure) format of the Oststadt was rectified to analyse building (heated) volume and the ratio of the outer wall surface and the building volume (A/V ratio). The data was imported in the open source software PostgreSQL, which is dedicated to the analysis of 3D data and calculation of energy simulation (Murshed, Picard, & Koch, 2017).

## Morphology analyses

The (heated) volume of buildings, which is a sum of a storey volume and a roof volume (if heated), was calculated from the CityGML data using a python script developed at EIFER. The python script is based on PostGIS functions and the Python library PyHull[1]. The results were validated with the volume of buildings calculated by the tool Voluminator developed at the TU München[2]. The building volume can be used to estimate the useable area of buildings (Figure 7).

Next, the surface area of the building envelope was calculated using another python scripts developed at EIFER to study the compactness of the buildings. The ratio of building envelope area and heated volume (A/V ratio) gives a general indication of the efficiency of the buildings. High A/V ratio indicates more heat losses or gains, in comparison to a building with a low A/V ratio (assuming everything else is constant), which indicates more energy efficient buildings (Figure 8). Around 30% of the buildings are characterised by the A/V ratio between 0.4 and 0.6 (higher energy efficiency) and 24% indicate the ratio between 0.7 and 0.9.

Furthermore, the volume and A/V ratio give indications on the energy consumption of the buildings and therefore, were used as important variables in the cluster analyses.


**Figure 7: Calculation of building volume based on 3D city models. Source: Own depiction.**

[1] http://pythonhosted.org/pyhull/
[2] https://github.com/SteuerHorst/Voluminator


**Figure 8: Calculation of building surface area to volume ratio. Source: Own depiction.**

*4.2 Cluster analysis*

**Data from multiple sources**

Multiple data sets were combined to analyse the building stock of the study area (Figure 9 and Table 1). The building footprints, gathered from the Open Street Map, contain 2,352 buildings. Out of them, only 1,346 buildings contained data from the market research (INFAS, 2011), 1,143 buildings contained data originating from the student survey and 861 buildings contained results of the heating energy demand performed in Chapter 5. Therefore, in order to ensure maximum number of variables to be considered in statistical data investigation, only 861 buildings were used in cluster analyses (Figure 9).

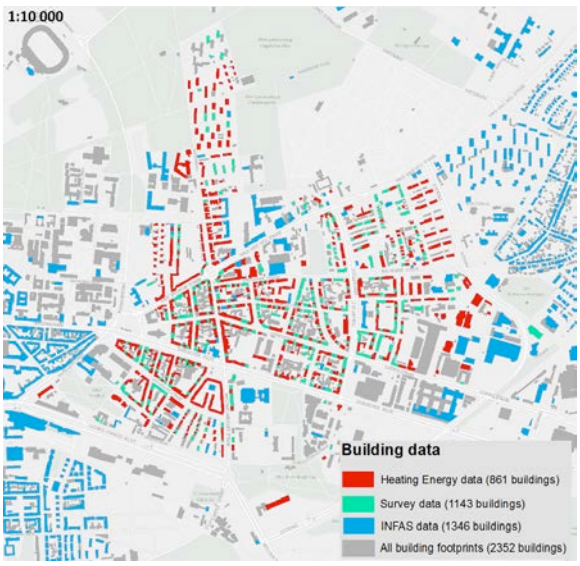


**Figure 9: Overview of the data coverage of the different data sets used in the cluster analysis.**
**Source: Own depiction.**

## Methodology

Multiple statistical methods were applied to analyse this data set (Figure 5). In a first step, descriptive statistics and correlation analysis were used to obtain an overview of the data and to explore the relationship among the 44 variables of these data sets. Correlation analysis indicates a high positive correlation between the number of living units within a building and the volume of the building - a high cullis height or if a flat roof is present (> 0.65) and at the same time shows high negative correlations with the presence of a basement (> -0.4) or the presence of a heated attic (> -0.5). In the Oststadt, most buildings with a high number of living units built in the 1970s are tall and equipped with a flat roof while the traditional style house built in the 19th century are very common in this district and usually occupy a smaller number of housing units and are usually equipped with a pitched roof type.

Furthermore, the correlations of volumetric building variables such as building volume and roof type volume revealed high correlation values (>0.9) and buildings parameters such as building height showed high correlation values with for example building surface area (> 0.9). This indicated that there might redundant variables in the data set. In order to check for redundancy in the data set and to reduce the dimensionality of the data set, **Principle Component Analysis (PCA)** was used to only select relevant variables that will be suitable for clustering. After PCA analysis, the data set was reduced from originally 44 variables to 24 variables.

In order to analyse the data set in an unbiased manner without any presumption of possible outcomes, an unsupervised clustering approach, e.g. K-Means clustering was chosen as it delivered better clustering results than hierarchical clustering that was also tested on this data set. To avoid random cluster generation in the k-Means clustering process, multiple clustering iterations were implemented (Everitt, Landau, & Leese, 2001). In order to select an appropriate number of clusters, statistical cluster validation using the Sum-of-Squares index, the Davies-Bouldin index and the Silhouette index was implemented and 9 clusters have been identified as the optimal clustering solution (Hothorn & Everitt, 2014), (Rousseeuw, 1987), (Davies & Bouldin, 1979). PCA was then used again, not this time to reduce the dimensionality of the data set but to label the clusters by using the highest and lowest loadings of the first three principal components. Figure 10 shows the 9-cluster solutions and cluster labels identified by k-Means and PCA of the study area.

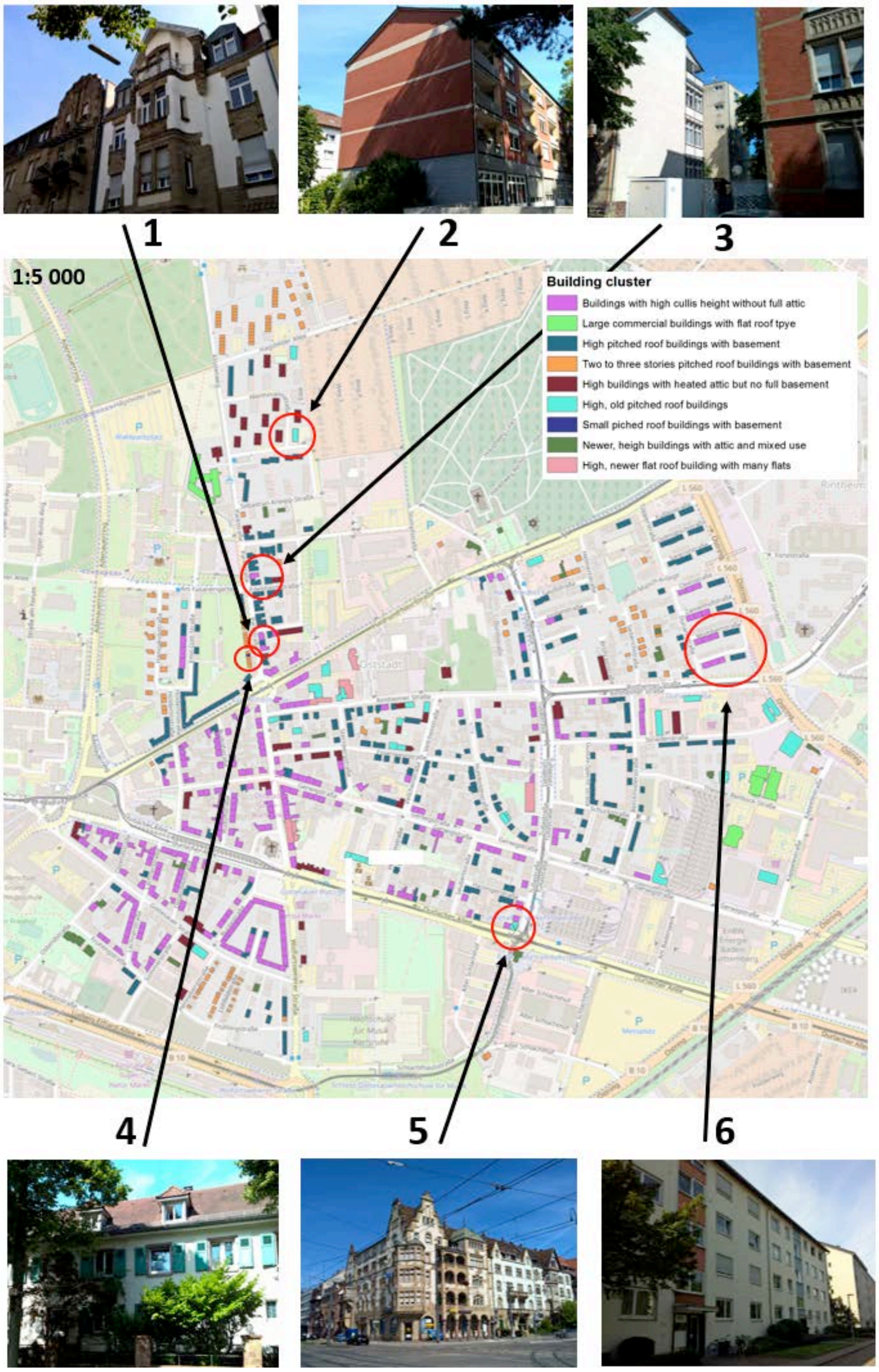


**Figure 10: Clustering results of the district Oststadt and the validation of the results.**
**Source: Own depiction.**

## Discussion of results

From the Figure 10, it can be observed that the pink clusters shows the largest share that includes buildings with high cullis height without a full attic present, followed by the second largest cluster (dark blue-green) that shows buildings with a high pitched roof and a basement present. Furthermore, some outliers within the homogenous grouping of the large clusters (e.g. Figure 10, 1-6) are present. These outliers required further analysis, therefore, they were visually inspected during a field visit in the district. For example, Figure 10 (1) represents a single building with a full attic surrounded by buildings with a different roof type structure. Figure 10 (2) shows a building that has a commercial unit on the ground floor - surround by buildings with residential units. Figure 10 (3) shows an outlier building with a flat roof in a neighborhood with pitched roof buildings. Figure 10 (5) shows a building with a different and higher attic structure than the surrounding buildings, and the cluster differentiation in Figure 10 (6) is due to the different number of floors of the building. Overall, k-Mean clustering returned meaningful clusters that could be validated by visual inspection of the clusters during a field trip in the city quarter.

The cluster analyses give an indication of buildings of homogenous nature where possible energy concepts can be realized. They also provide an indication of efficiency classification for helping the policy makers for strategic orientation. Furthermore, results may be included in the representation of, e.g. heating cost mapping for the tenants (“Heizspiegel").

## 5. Mapping of heat energy demand

### Methodology

The methodology was based on the creation of a custom tailored building typology, which was then used to calculate the daily heat demand for each building type. These heat demand profiles were then applied to each building in the district and scaled according to the size of each building. Figure 11 provides an overview of the employed methodology and data.

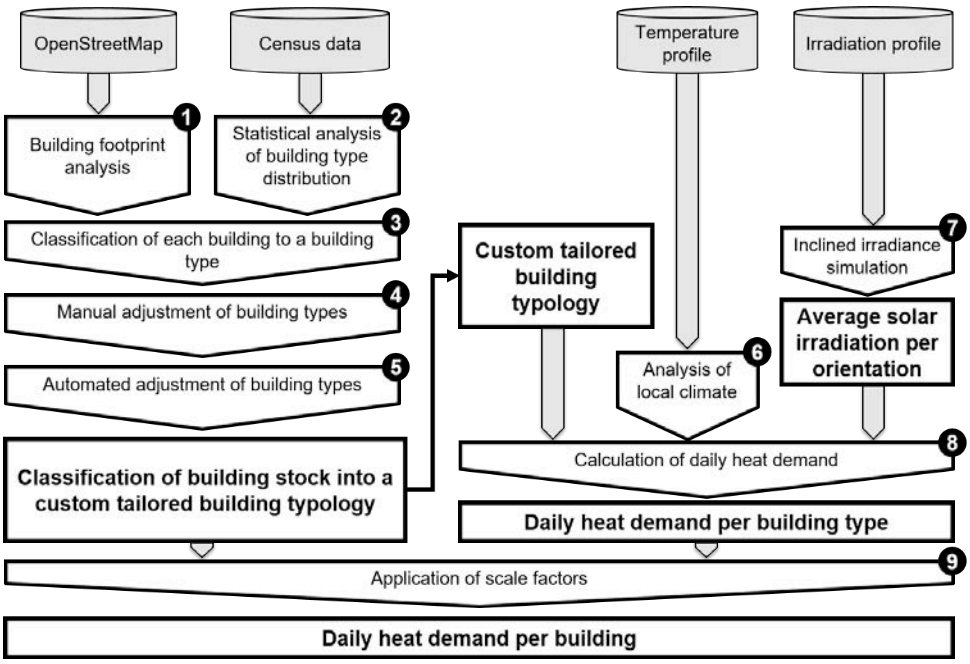


**Figure 11: Flow chart of the approach for determining and mapping the heat demand for residential buildings). Source: Own depiction.**

The method involves the following steps:

1. Building footprint analysis

Building footprints were obtained from the OpenStreetMap database (OpenStreetMap, 2017). For each of the 3,891 buildings in the Oststadt, the size and centre location of the footprint area was calculated.

2. Statistical analysis of building type distribution

Statistical building data from the German census survey (ZENSUS2011, 2014) was retrieved and mapped to the area of interest. This data contains information on the distribution of the 1,198 residential buildings over 10 age and 10 building size classes for each cell within a 1 km-raster in the Oststadt (Figure 12). These numbers were then combined and aggregated to correspond to the TABULA building typology classes (see 12 age and 4 building size classes in (IWU, 2015)).


**Figure 12: Analysis of the Census grid data. The color of each grid cell represents the total number of residential buildings, from blue (10%-quantile) to red (90%-quantile).**
**Source: Own depiction with data from OpenStreetMap and the German census survey.**

3. Classification of each building to a building type

Using the exact centre locations, each building was geographically mapped to one of the census data grid cells. It was then classified as belonging to one of the TABULA building types that were present in this grid cell, using for each building the type that had the closest floorplate size. This was done for all buildings that had been provided by OSM. Since the census data contains only residential buildings while the OSM data contains all building types, some buildings were left unclassified. These buildings usually had sizes that were uncommon for residential buildings (e.g. garden sheds, garages, factories, office buildings, etc.) and were subsequently classified as non-residential. As the project focuses on the residential building stock, non-residential buildings were not further analysed.

4. Manual adjustment of building types

The TABULA building types are meant to represent the national building stock. The local building stock, however, can deviate from the national one in a number of aspects. For this reason, a student seminar was conducted within this project to carry out site and building surveys in the district Oststadt. Based on the observations from the students, 86 parameters in the national building typology were adjusted in order to better reflect the local building stock. Additionally, building types that were present in the national building typology but not in the district had been removed.

5. Automated adjustment of building types

In addition to the manual adjustment of the building typology, an automated adjustment was conducted in order to correctly represent the typical building sizes in the district. Since the buildings were grouped to the building types based on their sizes in the first place, these adjustments were usually not very large. As a result of the first five steps, each building is classified into a new custom-tailored building typology that can then be used to calculate actual heat demands.

6. Analysis of local climate

Through an analysis of publicly available temperature profile data (NASA, 2016), the heating degree-days and average temperatures for each day in a year were calculated.

7. Inclined irradiance simulation

Global horizontal irradiation data (EuropeanCommission, 2016) was retrieved for the location of interest and through a calculation of the sun's position over the course of the year, the irradiation received by inclined surfaces (e.g. the window areas of the building) can be calculated, using the methods described in (Mainzer, Killinger, McKenna, & Fichtner, 2017).

8. Calculation of daily heat demand

With the customized building typology and the temperature and irradiation data, the heat demand can be calculated for each building type. This was done by applying the seasonal method according to EN ISO 13790, on the basis of a one-zone model (DIN, 2008). It considered the heat losses from transmission through the building envelope and from ventilation as well as the internal and solar heat gains. This calculation was conducted for each day in a year and can thus provided detailed results (Figure 14).

9. Application of scale factors

The heat demand per building type was then combined with the classified building stock to determine the heat demand for each single building. This was done simply by scaling the heat demand for the respective building type up/down for each building, depending on the actual building size compared to the building types' average building size.

## Results and discussion

With the described method, the specific yearly heat demand for all building types from the customized typology was obtained and compared to the standard building typology. This way, the impact of the specifics of the local building stock as well as of the local climate were analysed (Figure 13). For example, it can be seen that terraced house buildings from the age class 1860-1918 in the district have a substantially lower heat demand than the national average of buildings from the same age and size class, partly due to the warmer-than-average climate and partly due to the observation that retrofit measures are quite common for this building type in the Oststadt.

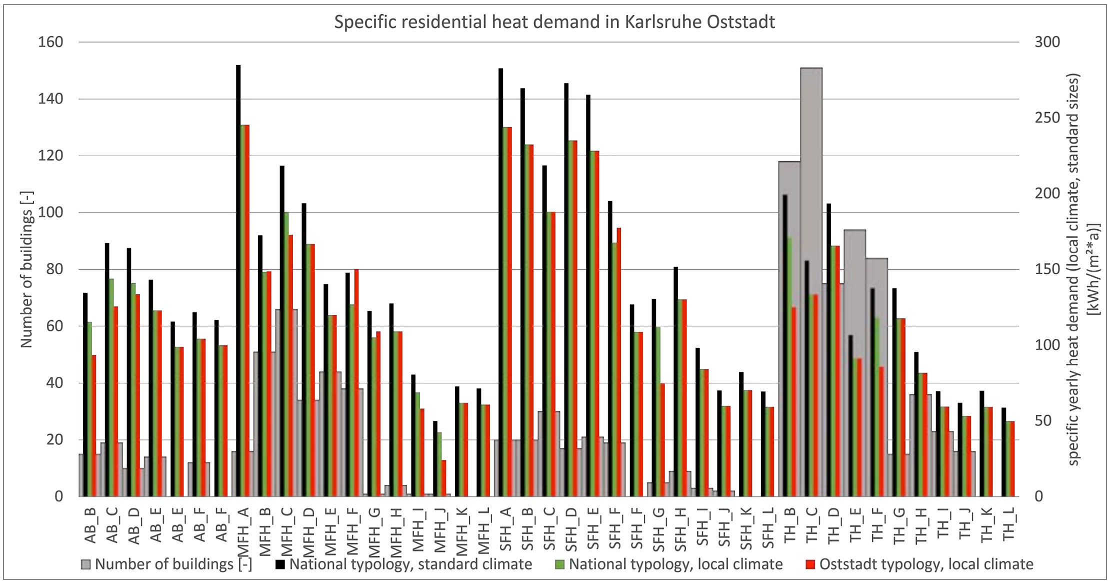


**Figure 13: Results for the specific yearly heat demand of buildings from the national and customized typology. Source: Own depiction.**

The heat demand profiles with a high (daily) temporal resolution was also calculated by aggregating the (scaled) heat demands for all buildings in the district for each day over the course of a year (Figure 14). These profiles allow for the identification of periods with maximum heat demand and the contribution of the different building types. This could help, e.g. with dimensioning heat networks, calculating the feasibility and profitability of seasonal storage options and other considerations. Therefore, it can help developing an optimized energy supply concept in the Oststadt.

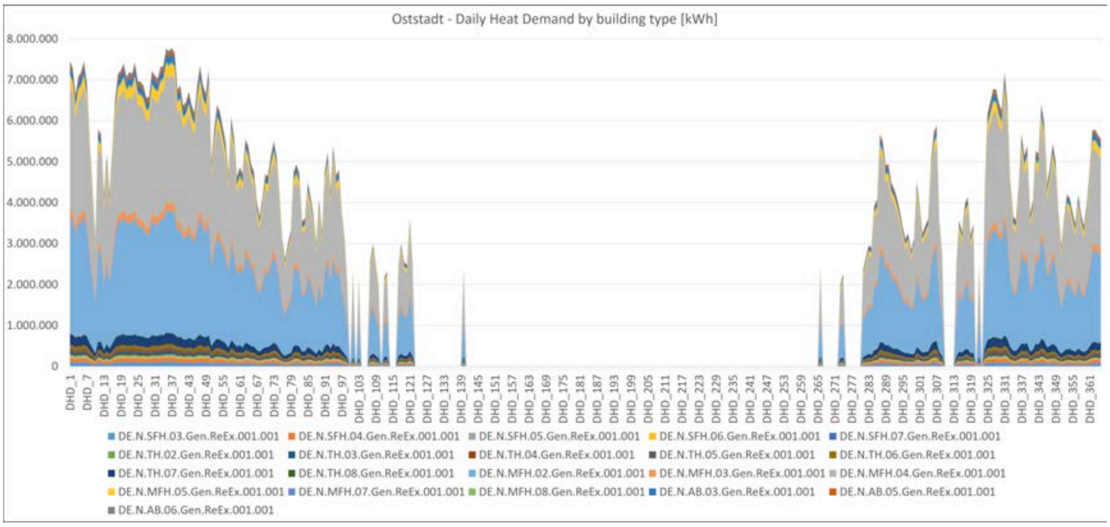


**Figure 14: Residential heat demand profiles over the course of a year. Colours represent different building types. Source: Own depiction.**

Additionally, the high geographical resolution of the results allowed the creation of detailed heat demand maps (Figure 15). Since each (residential) building in the district is assigned its own heat demand profile, the spatial information could be used to derive optimization potentials, e.g. through connecting areas of high energy demand with areas which could provide waste heat, e.g. from industrial processes. The results can also serve to develop efficient energy supply concept.

**Figure 15: Resulting heat demand map. Each building is colored according to its calculated specific yearly heat demand, which depends on type and size. Gray buildings was classified as non-residential. Source: Own depiction with image data from Bing Maps.**

## 6. Simulation of energy concepts

### Approach

Most of the residential buildings in Oststadt are multifamily houses. Therefore, the simulation of energy concepts was performed in one of the clustered multifamily buildings (built before 1950), that was identified in 3D morphology and cluster analysis. This building consists of 15 apartments (having three apartments in each of the 5 floor) with a total living area of around 1,218 m² and window to wall ratio 20%. The simulation of energy concept was performed in TRNSYS software, considering assumptions on building insulation options (thickness), cost, and efficiency of heating systems.

For example, the U-value of the building constructions (wall, roof, floor, window) with and without adding insulation (IWU, 2015) and corresponding 16 cases were simulated to identify the optimum case (Table 2 and Table 3 in Appendix). The assumptions for calculating the energy consumption of the multifamily house used in the simulation and associated energy cost and $CO_2$-emissions factor for electricity and gas are shown in Table 4 and Table 5, respectively. The type of heating system affects significantly on the $CO_2$-emissions and the overall annual cost. Therefore, three types of heating systems (electrical resistance heater, gas boiler and air to water heat pump - having efficiency of 3, 1, and 0.9, respectively) were considered in this study.

### Energy concepts

Three energy concept scenarios were investigated for the reduction of non-renewable energy consumption.

1. Optimize insulation standard: by adding insulation to the construction of the building
2. Effect of changing the heating system: by increasing the efficiency of the system with cost reduction
3. Effect of adding PV panels to the building: by increasing the share of renewable energy resources

1. Optimize insulation standard

Economic and environment effects of the building insulation with different heating systems (gas boiler, heat pump, or electrical resistance heater) were simulated and analyzed. The economic effect was calculated after (BKI, 2015). Figure 16 represents the reduction in $CO_2$-emissions and cost savings in a case of using gas boiler or air to water heat pump or electrical resistance heater (ERH) with different thickness of insulation. Case 11 (12 cm of insulation to the wall and roof, 8 cm to the floor and change the windows) leads to reduction of the $CO_2$-emissions by 30 % with a heat pump, 48 % with ERH and 34 % with a gas boiler. The cost was reduced by 13.8 % with a heat pump, 39 % with ERH and 15 % with a gas boiler compared to the reference case.

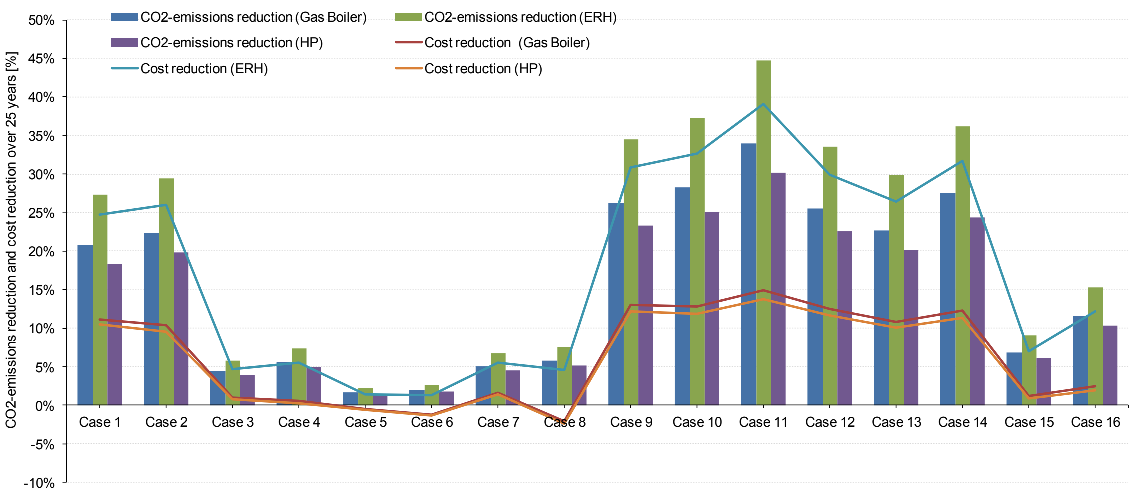


**Figure 16: $CO_2$-emissions saving and cost saving of different cases compared to the reference case, using Gas boiler or air to water Heat pump or ERH as a main heat source. Source: Own depiction.**

2. Effect of changing the heating system

It was assumed that the main heating system is ERH and that the installation cost of the ERH is zero Euro as it was an existing system. The economic and environment effects of changing heating system, e.g. using air to water heat pump or gas boiler instead of ERH were calculated. Figure 17 shows the installation and operation costs of different heating systems. The calculations were based on the annuity method in VDI 2067 and the assumptions on the economic factors, such as an inflation rate, an interest rate as well as a cost of the different components of the heating systems. The findings show that the installation cost of air to water heat pump was higher than gas boiler, and the operation cost of the gas boiler and air to water heat pump were significantly lower than electrical resistance heater. The operation cost includes the heating demand and household electrical demand.

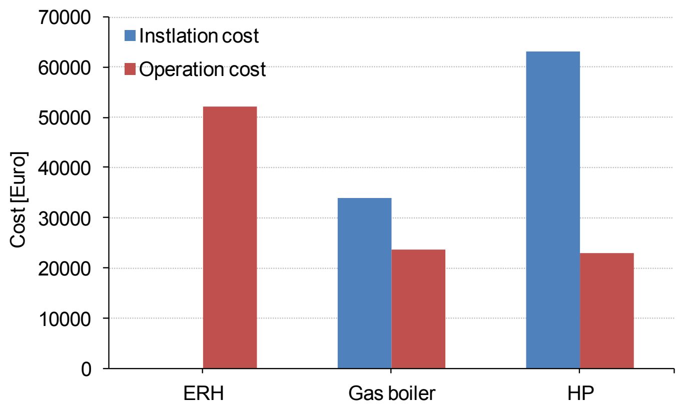


**Figure 17: Installation cost and operation cost of different heating systems. Source: Own depiction.**

Finally, the total annual cost over 20 years and $CO_2$-emissions of different heating systems was calculated (Figure 18). The economic heating system is gas boiler, which can reduce the overall cost by 54.6 % per year compared to the ERH. However, the lowest $CO_2$-emissions can be achieved by using the air to water heat pump, which reduces the $CO_2$- emissions by 51% compared to the ERH.

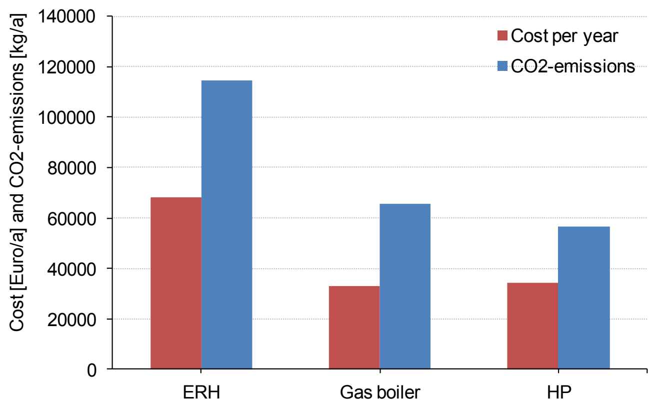


**Figure 18: $CO_2$-emissions and overall cost per year for different heating systems. Source: Own depiction.**

3. Effect of adding PV panels to the building

The PV panels can be installed on building roofs with an average area of around 148 m². It was assumed that 21 kWp PV panels, with an inclination angel 40° could generate about 20,683 kWh energy per year. Figure 19 depicts the monthly electrical energy generated by PV panels and household electricity demand for 15 apartments. This electrical energy from photovoltaic could cover 46% of the household electrical assuming 45,000 kWh with an average annual consumption of 3,000 kWh per apartment. In this case, there is no energy surplus from the PV system, even in summer. The share of the electrical energy from PV would increase to 69% of the annual electricity demand per household, assuming an annual electricity demand of 2,000 kWh per apartment.

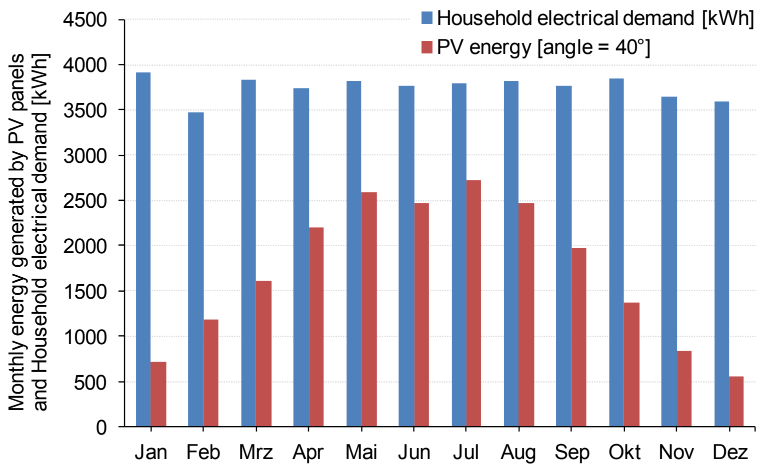


**Figure 19: Monthly energy generated by PV panels and household electricity demand.**
**Source: Own depiction.**

The cost calculation shows that PV panels (with a life time of 20 years) may reduce the annual cost to 5,750 € for a building, which represent 19% of the reduction compared to the same building without PV panels (in case of using air to water heat pump as a main heat source). The annual $CO_2$-emission reduction amounts to 12,761 kg which represents 22.5 % of the reduction compared to the same building without PV panels in case of using air to water heat pump as a main heat source. Figure 20 illustrates the cost and $CO_2$-emissions in case of the building insulation (see case 11 in Table 3) and 21 kWp of PV modules.

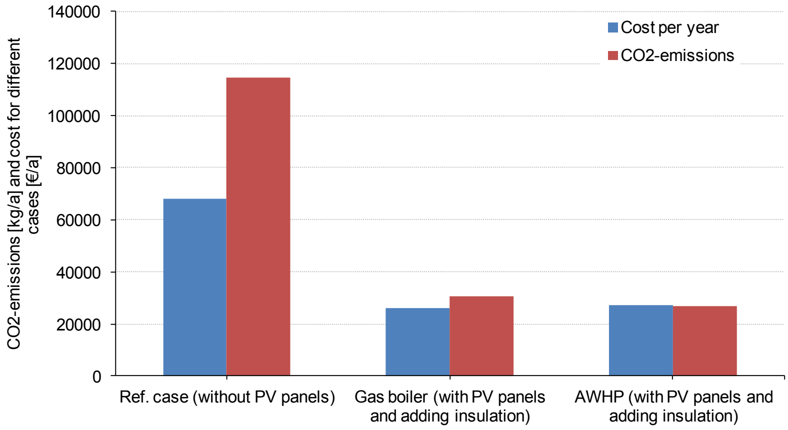


**Figure 20: Cost per year and $CO_2$-emissions for different cases compared to the Ref. case (using ERH without adding insulation and PV panels). Source: Own depiction.**

Due to the reduction of the heating demand by using building insulation, and reducing the electrical energy needs, $CO_2$-emissions and annual cost might be reduced by 77 % and 60 %, respectively, compared to the reference case (electrical resistance heater without building insulation and PV panels).

## 7. Citizens' participation

One of the objectives of the R131 was to increase the engagement of citizens and other relevant actors in the projects. Several participatory approaches, depending on the objective and overall scope, were tested in the different sub-projects of the R131 (Meyer-Soylu, Parodi, Trenks, & Seebacher, 2016). The citizens and local stakeholders in Oststadt had the opportunity to participate in the above described energy concept study. In this regard, a formal workshop was organized.

During the workshop, several posters depicting the main methods and results concerning the 3D morphology and cluster analyses, mapping of heat energy demand and the scenarios for energy concept were presented. Generally, the citizens were interested in the results as they could identify the overall potential of implementation of an energy concept in their buildings. However, they were more enthusiastic in concrete implication of energy concepts.

Several issues were revealed during the workshop:

- Multi-family houses often contain multiple owners who need more support regarding decisions on energy topics. The property owners and tenants need to be brought together to agree on how the cost regarding renovation, changing heating systems, etc. be shared. The question of **financing energy concept** to the individual group interested in renovation seemed most important.

- More investigation on **economic feasibility of the energy concept** need to be studied by the experts and scientists. The ideas can then be shared with the citizens concerned.
- In preparing energy concept, the **local authorities**[3] who give advice on energy issues, (e.g., electricity check, heating check) need to be consulted.
- There is an inherent need of improvement of **institutional support**. In this regard, stronger regulatory measures might help in implementing the concepts.
- **Education and awareness development** on energy saving potentials early in the childhood (kindergarten) need to be introduced.
- Some of the residential buildings in the district also contain **old shops** (with single glazing), which need to be integrated into the concept.

## 8. Conclusion

This research focuses on a holistic approach for studying the energy performance of the buildings by exploratory data analyses and thermal simulations. The cluster analyses, mapping of spatial and temporal patterns of energy demand as well as simulation of different energy scenarios may help the citizens and local policy makers to identify different options for reducing non-renewable energy consumption. Such findings may also contribute to the sustainable energy policy agenda in the short and long term, in other districts, cities and regions.

Due to lack of complete sets of variables in the spatial and non-spatial data, many residential and commercial buildings could not be considered in the cluster analysis. Future research should focus on the collection of a complete set of variables of all the buildings. The cluster analysis algorithm should be further improved to optimize the clusters, e.g. by classifying the outliers exist in some clusters.

The proposed method for energy demand calculation employs building typologies, so that a small number of building types can be modelled explicitly, each representing a larger number of buildings in the district. A potential drawback of using building typologies is that the real buildings might actually differ in some aspects from the standardized and nationally invariant building types. In this study, this is (at least partially) mitigated by adjusting the employed typologies through the application of observations from the local building stock. In future research, the calculation of electricity and cooling demand could be performed in order to incorporate them into the energy concept scenarios.

This study considered three energy concepts. Future research could focus on the investigation of other energy supply concepts, e.g. use of industrial waste heat or geothermal energy, planning of district heating network, possibility of achieving zero energy non-residential buildings (e.g. education buildings), reduce energy demand in the factories, etc. Moreover, the techno-economic assumptions related to the concepts can be improved. Such energy concepts can also be simulated in some other potential clusters.

[3] E.g. Karlsruhe Energie- und Klimaschutzagentur gGmbH (KEK).

This research included a number of proven technologies that can reduce the use of non-renewable energy and thus greenhouse gas emissions for heating purposes. The exchange with citizens pointed towards issues of financing mechanisms and communication strategies. This leads to conclude that available technologies and applied solutions still are not put into practice to the full extent. Since the project does not include a structured analysis of these aspects, the organizational framework of energy concepts or efficiency measures is clearly identified as an important field for future research.

**Acknowledgement**

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## Appendix

**Table 2: U-value of the building constructions with and without adding insulation (IWU, 2015).**

| Construction of the building | U-value W/(m$^2$K) |
|---|---|
| Wall | |
| Before 1950 | 1.7 |
| Add 12 cm of insulation | 0.25 |
| Add 24 cm of insulation | 0.13 |
| Roof | |
| Before 1950 | 1.4 |
| Add 12 cm of insulation | 0.41 |
| Add 30 cm of insulation | 0.14 |
| Floor | |
| Before 1950 | 0.77 |
| Add 8 cm of insulation | 0.28 |
| Add 12 cm of insulation | 0.21 |
| Window | |
| Before 1950 | 2.8 |
| Windows with double glazing | 1.3 |
| Windows with triple glazing | 0.8 |

**Table 3: Simulated cases (U-value of the constructions after adding insulation).**

| Case study | U-value of Wall [W/(m²K] | U-value of Roof [W/(m²K] | U-value of Floor [W/(m²K] | U-value of Window [W/(m²K] | Heating demand [kWh/m²] |
|---|---|---|---|---|---|
| Ref. case | 1.7 | 1.4 | 0.77 | 2.8 | 85 |
| Case 1 | 0.25 | 1.4 | 0.77 | 2.8 | 43 |
| Case 2 | 0.13 | 1.4 | 0.77 | 2.8 | 40 |
| Case 3 | 1.7 | 0.41 | 0.77 | 2.8 | 76 |
| Case 4 | 1.7 | 0.14 | 0.77 | 2.8 | 74 |
| Case 5 | 1.7 | 1.4 | 0.28 | 2.8 | 81.5 |
| Case 6 | 1.7 | 1.4 | 0.21 | 2.8 | 80.9 |
| Case 7 | 1.7 | 1.4 | 0.77 | 1.3 | 74.6 |
| Case 8 | 1.7 | 1.4 | 0.77 | 0.8 | 73.2 |
| Case 9 | 0.25 | 0.41 | 0.77 | 2.8 | 32.1 |
| Case 10 | 0.25 | 0.41 | 0.28 | 2.8 | 28 |
| Case 11 | 0.25 | 0.41 | 0.28 | 1.3 | 16.5 |
| Case 12 | 0.25 | 1.4 | 0.77 | 1.3 | 33.6 |
| Case 13 | 0.25 | 1.4 | 0.28 | 2.8 | 39.3 |
| Case 14 | 0.25 | 1.4 | 0.28 | 1.3 | 29.5 |
| Case 15 | 1.7 | 1.4 | 0.28 | 1.3 | 71.1 |
| Case 16 | 1.7 | 0.41 | 0.28 | 1.3 | 61.5 |

**Table 4: the main assumptions for calculating the energy demand of multifamily house.**

| | |
|---|---|
| Household electrical demand [kWh/a per apartment] | 3000 |
| DHW demand [kWh/a per apartment] | 2500 |
| Heat Gain [W/m²] | 3 |
| Ventilation [1/h] | 0.5 |
| The building has only three external wall | N,S and E |
| Infiltration [1/h] | |
| Before 1950 | 0.3 |
| Add insulation to (wall or roof or floor) or change the window | 0.2 |
| Add insulation to (wall, roof, floor and change the window | 0.1 |

**Table 5 Energy cost and $CO_2$-emissions factor.**

| Energy cost | Value [€] |
|---|---|
| Electricity | 0.22[4], 0.28 |
| Gas | 0.07 |
| $CO_2$-emissions Factor | |
| Electricity [kg/kWh] | 0.617 |
| Gas [kg/kWh] | 0.241 |

[4] Special tariff for heat pump.

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