ISSN 2345-0282 ONLINE
DOI: http://dx.doi.org/10.9770/jesi.2014.2.2

ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES

2(2)

2014

ENTREPRENEURSHIP AND SUSTAINABILITY CENTER
University of Essex
ESSEX BUSINESS SCHOOL
THE UNIVERSITY OF SALFORD
VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS
HP-MOS Health Psychology Management Organisation Services
RISEBA
REDINN Rete Europea Dell'Innovazione
PLB Asociacija Pasaulio lietuvių bendruomenės
AVADA
EUROPE for business

http://jssidoi.org/jesi/aims-and-scope-of-research

Dear readers,

It's my pleasure to introduce the regular issue of the peer-reviewed scientific journal devoted to a wide range of sustainability facets. Energy security nowadays has become an object of international concern, cause and consequence of clashes of diverse character starting with direct and public ones and finishing with hidden and sophisticated controversies.

During those turbulent times, concern of stable and sustainable future is natural. It embraces widening circles of stakeholders, including households, entrepreneurs, society, military forces, and governments. Despite that each interested party has got its specific activities and aims, there is one universal and uniting aim: to continue building our future, preserve economic viability and secure environment.

I truly believe that engagement in solving contemporary problems, especially the ones related to behavioral patterns of entrepreneurial behavior in a field of energy use, switching priorities towards renewable sources of energy, incorporating innovations and smart solutions into our daily lives, would facilitate the formation of new living styles, which would lead us to more sustainable and secure future.

With best regards,

Colonel Gintaras Bagdonas
Director
NATO ENERGY SECURITY CENTRE OF EXCELLENCE
Šilo g. 5A, LT-10322 Vilnius, Lithuania
Phone: +370 5 2032380
Gintaras.Bagdonas@enseccoe.org
www.enseccoe.org

ENTREPRENEURSHIP AND SUSTAINABILITY CENTER
University of Essex
ESSEX BUSINESS SCHOOL
International Centre for Entrepreneurship Research

ISSN 2345-0282 (online) http://jssidoi.org/jesi/aims-and-scope-of-research/

Volume 2 Number 2 December 2014

ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES

2014
2(2)

Guest Editor-in-Chief
Prof. **Robert Sylvain**

The *Entrepreneurship and Sustainability Issues* ISSN 2345-0282 (online) is a peer-reviewed journal, which publishes original research papers and case studies. It is international journal published cooperating with universities, social companies, consultancies and associations indicated on the cover of the journal. It is published quarterly.

Areas of research include, but are not limited to, the following:

- **Conceptual Approaches towards Entrepreneurship**
- **Entrepreneurship and Sustainable Development**
- **Globalization Processes Sustainable Development**
- **Innovations and Technological Development for Entrepreneurship and Sustainability**
- **Transition Issues and Sustainable Development**
- **Entrepreneurship and Environmental Sustainability**
- **Economic Growth and Entrepreneurship**
- **Economics and Management of Sustainable Organizations and Industries**
- **Intercultural Communication for Security and Sustainability**
- **Sustainable Development of Sector Economics**
- **Sustainable Finance and Investment and Entrepreneurship**
- **Strategic Management for Sustainability**
- **Case Studies on Entrepreneurship and Sustainable Development**
- **Sustainable cities and entrepreneurship**
- **Organizational studies**
- **Social cohesion and social innovation**
- **Public policy, economic security for sustainable entrepreneurship**
- **Business models and strategic management for sustainable futures**
- **Social responsibility and sustainable development**
- **Psychology and entrepreneurship**
- **Intuitions about contemporary phenomena in business and society**
- **Social inclusion and entrepreneurship**
- **Social inclusion and sustainable development of societies**
- **Life-long learning and sustainable development**
- **Life-long learning and entrepreneurship**
- **Women and entrepreneurship**
- **Creative industries and entrepreneurship**
- **Case studies**

All papers published in the *Entrepreneurship and Sustainability Issues* are indexed/abstracted by:

- ECONIS of the ZBW – Leibniz Information Centre for Economics http://www.zbw.eu/EconBiz
- RePEc http://repec.org/EconBiz
- Ulrich's Periodicals Directory
  Serials Solutions http://www.serialssolutions.com/
  a ProQuest business http://www.proquest.co.uk/en-UK/
- Crossref
- Google Scholar
- The European Library http://www.theeuropeanlibrary.org
- Database Lituanistika http://www.lituanistikadb.lt
- Index Copernicus International

Editorial correspondence including manuscripts and submissions
Prof. dr. Manuela Tvaronavičienė
Tel.: +37068783944
E-mail: manuela@post.omnitel.net; manuela.tvaronaviciene@vgtu.lt

ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES
ISSN 2345-0282 (online) http://jssidoi.org/jesi/aims-and-scope-of-research/

Publisher: ENTREPRENEURSHIP AND SUSTAINABILITY CENTER http://jssidoi.org/esc/home

CONTENTS Volume 2 Number 2 December 2014

ENTREPRENEURSHIP AND SUSTAINABILITY CENTER
University of Essex
International Centre for Entrepreneurship Research
ESSEX BUSINESS SCHOOL

ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES
ISSN 2345-0282 (online) http://jssidoi.org/jesi/aims-and-scope-of-research/

TOOLS TO SUPPORT SUSTAINABLE ENTREPRENEURSHIP IN ENERGY POSITIVE NEIGHBOURHOODS

Mia Ala-Juusela[1], Michael Short[2], Uzi Shvadron[3]

[1]VTT Technical Research Centre of Finland, Espoo;
[2]Teesside University, UK;
[3]IBM Haifa research, Israel

E-mails: [1]mia.ala-juusela@vtt.fi; [2]mshort@tees.ac.uk; [3]SHVADRON@il.ibm.com

Received 6 September 2014; accepted 28 October 2014

Abstract. In an Energy Positive Neighbourhood (EPN) the annual energy demand is lower than annual energy supply from local renewable energy sources. Short-term imbalances in energy supply and demand are corrected with national energy supplies. In this paper the early stages of the development - the specifications - of the tools for intelligent management of energy positive neighbourhoods are presented. These tools include an energy management tool for real-time management of the energy flows, user interfaces that support energy efficient behavior of the users in the neighbourhood and an urban planning decision support tool. The specifications and tools are the result of European co-operation, and are designed so that they can easily be adopted in different European countries with minimum changes[1].

Keywords: sustainable development, sustainable entrepreneurship, business model, Energy positive neighbourhood, energy management, user interfaces

Reference to this paper should be made as follows: Ala-Juusela, M.; Short, M.; Shvadron, U. 2014. Tools to support sustainable entrepreneurship in energy positive neighbourhoods, *Entrepreneurship and Sustainability Issues* 2(2): 49–59.
DOI: http://dx.doi.org/10.9770/jesi.2014.2.2(1)

JEL Classifications: M10, Q4

1. Introduction

Direction towards sustainable development requires incorporation of renewable energy production and use into economic routine of organizations and households. Alas, this aim is hard to implement to numerous conflicts of economic interests at macro and micro level (Garškaitė-Milvydienė 2012, 2014; Tvaronavičienė 2012; Tvaronavičienė, Grybaitė 2012; Balkienė 2013; Miškinis *et al.* 2013; Mačiulis, Tvaronavičienė 2013; Vosylius *et al.* 2013; Baublys *et al.* 2014; Matyasik 2014; Tvaronavičienė 2014; Vasiliūnaitė 2014). Sustainable entrepreneurship in renewable energy sector well-articulated business model (Caurkubule, Rubanovskis 2014; Figurska 2014; Raudeliūnienė *et al.* 2014; Tarabkova 2014; Peker *et al.* 2014; Tvaronavičienė *et al.* 2014). In an Energy Positive Neighbourhood (EPN) the annual energy demand is lower than energy supply from local renewable energy sources. Short-term imbalances in energy supply and demand are corrected with national energy supplies. The aim is to provide a functional, healthy, user friendly environment with as low energy demand and little environmental impact as possible. (Ala-Juusela *et al*. 2014) The IDEAS project aims to develop and validate technologies and business models required for the cost effective and incremental rollout of EPNs. The tools for intelligent management of energy positive neighbourhoods include an energy management tool for real-time

[1] This work is part of the "IDEAS - Intelligent NeighbourhooD Energy Allocation & Supervision" project that is funded under the EC's FP7 framework initiative FP7-2012-NMP-ENV-ENERGY-ICT-EeB. Project partners are acknowledged.

optimization of the energy balance, user interfaces that support energy efficient behavior of the users in the neighbourhood and an urban planning decision support tool. The technologies and business models developed in IDEAS will underpin the incremental rollout of EPNs at principally two specially selected demonstration sites: part of a University campus in Bordeaux (IUT), France and a newly built residential area (Omenatarha) in Porvoo, Finland. An analysis of the user requirements for stakeholders in an Energy Positive Neighbourhood was conducted in beginning of the project, and the development of the tools and user interfaces are based on this analysis (described by Huovila *et al.* 2013). They are also the starting point for the business model development. The primary intended user of the tools developed in the IDEAS project is a new type of actor, the energy positive neighbourhood service provider (EPNSP, described in Crosbie *et al.* 2014). Currently this actor does not exist as such, but is represented in the project by an energy company and a facility manager at the respective demonstration sites, both of which could be the central actor in the business model. In the business model, some key activities are supported by the control and optimisation tools and user interfaces, as well as the decision support tool for urban planning. The neighbourhood energy management tool will enable intelligent energy trading and operation of equipment and buildings along with local energy generation and storage. The user interfaces will use mixed reality technologies to provide intuitive environments that engage casual users and in doing so improve their energy literacy and energy consuming behaviours. The decision support urban planning tool will inform the future development plans for neighbourhood energy infrastructures. It will be used to illustrate how the progress towards energy positive neighbourhoods achieved at the demonstration sites can be further advanced. In addition, in the IDEAS project, appropriate business models for the demonstration cases will be developed, as well as investigating how different utility industry structures and property markets impact on the viability of those business models in different EU countries will be identified. These business models are out of scope for this paper, and the interested reader is referred to Crosbie *et al.* (2014), where an in-depth analysis of the elements of the business models is provided. In this paper the early stages of the development - the specifications - of the tools for intelligent management of energy positive neighbourhoods are presented. This is one of the first attempts to balance the energy demand and supply on a neighbourhood level in real time, simultaneously regarding more than one type of energy variable. Innovative ways to involve the users in this activity are developed. Decision support is needed to ensure that the infrastructure of the neighbourhood supports energy positivity: the low local demand connected with possibility for local renewable production. The tools and user interfaces will interact through an Energy Positive Neighbourhood control center (Figure 1).

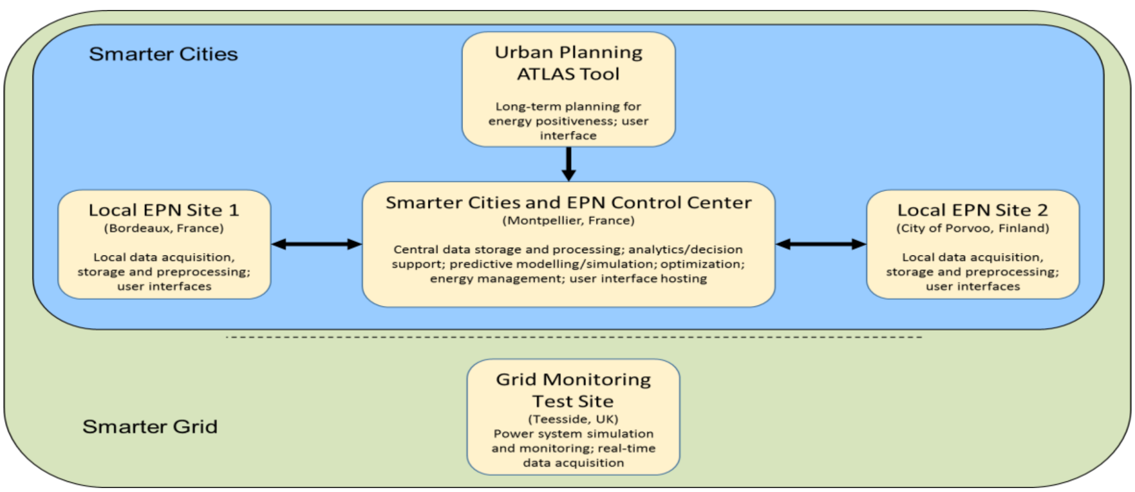

Fig.1. High-level overview of demonstration sites, IT tools and functionalities in the IDEAS project

Source: Crosbie *et al*. (2014)

2. Underlying use cases and business models
2.1. Functional use cases for the IDEAS project

The development of the specifications started with the definition of use cases. A total of 9 functional uses cases have been identified for the IDEAS project, based on the user requirements capture in earlier stages of the project

(Huovila *et al.* 2013). These use cases are listed in Table 1 below2. The use cases were defined in a parallel task for the business model development, which is why the actors appearing in the titles differ slightly from the actors defined in the BMs. The central actor in the business model is an energy positive neighbourhood service provider (EPNSP).

Table 1. List of identified (functional) use-cases in the IDEAS project

ID	Title	Description
1	Home Energy Management (Finnish demo site)	This use case describes how to inform home residents about fine grain energy consumption in order to help them meet Energy Positive Neighbourhoods (EPN) energy supply objectives
3	City Planner Acquires Decision Support for Energy Aspects in Urban Planning (Finnish demo site)	This use case describes how the user of AtLas tool (a city planner in first place) compares the long term effect of two planning strategies regarding energy flows on the greenhouse gas emissions, costs and energy balance
4	Public Energy Awareness Interface for residential users	This use case aims to engage residents of Omenatarha (Finnish demo site) into the Energy Positive Neighbourhood's goals through awareness feedback of the energy consumption of their (Energy Positive) Neighbourhood
5	Decision Support for Energy Trading for Energy Service Companies (ESCOs) and Supply/Demand Regulation within EPNs (Finnish demo site)	This use case describes how to carry out (i) prediction of future electrical energy consumption and supply within an EPN and (ii) optimization of available resources such that operational costs and/or CO2 emissions can be minimized subject to the balancing of supply with demand
6	User Interface for Energy Service Companies (ESCOs) (Finnish demo site)	Visualising the decision support information for energy trading and configuration of the optimizer
7	Facility Manager Acquires Decision Support on Renovation Investments' Effect on Energy Balance of the Neighbourhood (French demo site)	This use case describes how the user of the AtLas tool (a facility manger in first place) compares the long term effect of two renovation investment options on the greenhouse gas emissions, costs and energy balance
8	Decision Support for Supply/Demand Regulation within EPNs (French demo site)	This use case describes how to carry out (i) prediction of future electrical energy consumption by the neighbourhood (IUT buildings) and PV supply potential within the area (IUT campus area) and (ii) optimization of available resources such that operational costs and/or CO_2 emissions can be minimized through arbitrage and storage, subject to the balancing of supply with demand
9	Educational 3D Virtual Space (French demo site)	This use case describes shared 3D virtual space for demonstrating EPN concepts to interested visitors (IUT students and others). The idea is to provide remote visitors with a venue to learn about the IDEAS project, via an immersive rich collaborative environments without the need to actually visit the project pilot site
10	Awareness Tools Dedicated to Energy Manager and Occupants of the Site (French demo site)	An interface to better understand how the site consumes energy, electricity, gas, water to increase occupant awareness about energy and waste, and to visualise the output of the optimization

Source: Huovila *et al.* 2013

2.2. Business models

Two versions of the Energy Positive Neighbourhood Service Provider (EPNSP) business models were created in the project (Crosbie *et al.* 2014): "To realise an EPN it will be necessary to encourage a new type of service provider that offers tailored services which engage whole communities in Demand Side Management (DSM), Supply Side Management (SSM), energy trading, investment in renewable energy production and energy storage

[2] Please note that use case #2 does not appear in this list as it was merged with use case #4; the numbers have been left as-is for traceability and documentation purposes.

and careful consideration of future design options for the urban environment. We have called this new type of service provider an Energy Positive Neighbourhood Service Provider (EPNSP)." The EPNSP business concept developed in the context of the Finnish pilot site involves "an energy company that generates, supplies and distributes electricity and heat from renewable resources in a predominantly residential neighbourhood. The area also includes small commercial customers such as shops and small offices etc. The energy company has a contract to sell electricity and heat with most of the occupants in the Neighbourhood, supplies Demand Side Management (DSM) services to those customers and operates in partnership with the local authority. … The critical role of the local authority is encouraging investment in the efficient buildings required for an EPN by the occupants' of the neighbourhood and encouraging the occupants of the neighbourhood to connect to the district heating system" (Crosbie *et al.* 2014).

The EPNSP business concept developed in the French context involves "an energy service company that installs, maintains and runs renewable energy production for a public or private organisation that owns a group of buildings in the same geographical location and is responsible for the energy costs associated with running those buildings. The company also supplies consultancy services to help their customers select the most energy efficient building renovation and energy infrastructure investments and implement and implements building renovations as part of an Integrated Energy Contract (IEC)" (Crosbie *et al*. 2014). The neighbourhood energy management tool will support the business models in Demand Side Management (DSM), Supply Side Management (SSM) and optimization of energy trading and arbitrage activities in the presence of variable energy market prices. The user interfaces will support the business models in the DSM by informing the customers of when the local renewable supply is available and of expected imbalances in supply and demand, engaging them in the operation of the EPN, and by giving them support in reducing the overall demand. The decision support urban planning tool will support the business models in comparing economic and environmental effects of different future scenarios regarding the urban development and redevelopment and the renewable energy options on the area.

3. Real-time energy management

3.1. ICT infrastructure

Achieving EPNs will require co-ordinated and optimised demand side management (DSM) and supply side management (SSM) to reduce and shift peak energy demands and smooth out the inevitable production variability of renewable energy. To facilitate this, a supporting ICT infrastructure that provides a wide variety of interconnectivity options for measurement, control and user interface equipment (e.g. smart meters, synchrophasors, weather measurement stations, grid inverters, building automation controllers, energy trading applications, etc.) is needed. The ICT infrastructure envisions a smarter grid, to enable the buying and selling of energy between prosumers connected via a local grid infrastructure. This grid infrastructure is smart - in that it not only allows for the physical transfer of energy - but also supports ICTs that enable information related to energy supply/demand availability and pricing to be exchanged, along with real-time information related to the health and status of the power flows. The ICT architecture specified in course of the IDEAS project covers three separate domains: (i) the local generation and distribution management domain, (ii) the customer domain and (iii) the web services domain. Relevant standards are leveraged to provide a path towards common data semantics and protocols that may be used across these domains within the context of an EPN. The communications infrastructure required to support smart-grid applications (the so-called 'utility intranet') has not yet been fully developed, but current indications are that it is likely to be based upon IP addressing – to facilitate open interconnectivity – and differentiated services (diffserv) concepts – to support prioritization of traffic flows between real-time, soft real-time and non-real-time classes. This utility intranet is likely to act as the backbone network bridging together local network installations (e.g. control centres, switching- and sub-stations, large generators, microgrids, data concentrators).

The ICT architecture developed for the IDEAS project covers energy management and control systems at the neighbourhood (microgrid) scale. Building upon the proposals for a larger smart grid ICT infrastructure outlined above, it extends the current state-of-the-art by integrating IEEE Audio-Video-Bridging (AVB) technology to enable reliable real-time and soft real-time data transfers of energy control and management related information over a microgrid Ethernet-over-fibre network. The infrastructure also allows for non-real-time (best-effort) traffic to be carried over the network using standard UCP/IP and TCP/IP over fibre, copper or wireless (WiFi) links, thus allowing services such as smart energy meter reading/aggregation and also information presentation for the main system users using standard protocol stacks. Although not the main focus of the current paper, the interested reader is referred to Short and Dawood (2014a, b) for further details of the low-level real-time aspects of the ICT infrastructure.

The IBM© Intelligent Operations Centre (IOC), with its associated analytics, data warehousing and optimization software, acts as a central platform for the development of the microgrid central control station and data repository. In IDEAS, the IOC is not only the data repository for most data (city and sites data, energy management and urban planning software), but also provides a strong analytics, optimisation and decision support system capability. It provides a host platform for user interfaces, enables stakeholder and partner notifications (via SMS/email and web services), and provides reporting capabilities that can be leveraged by all project partners and used by all end users. With respect to the higher-level, IP-based aspects of the IT infrastructure, please refer to the Figure 2 below. In order to realise and manage the remote interface capabilities required for the demonstrations, the IOC Representational State Transfer (REST) Application Programming Interface (API) will be employed. The REST API may be implemented using a standard HTTP connection via TCP/IP.

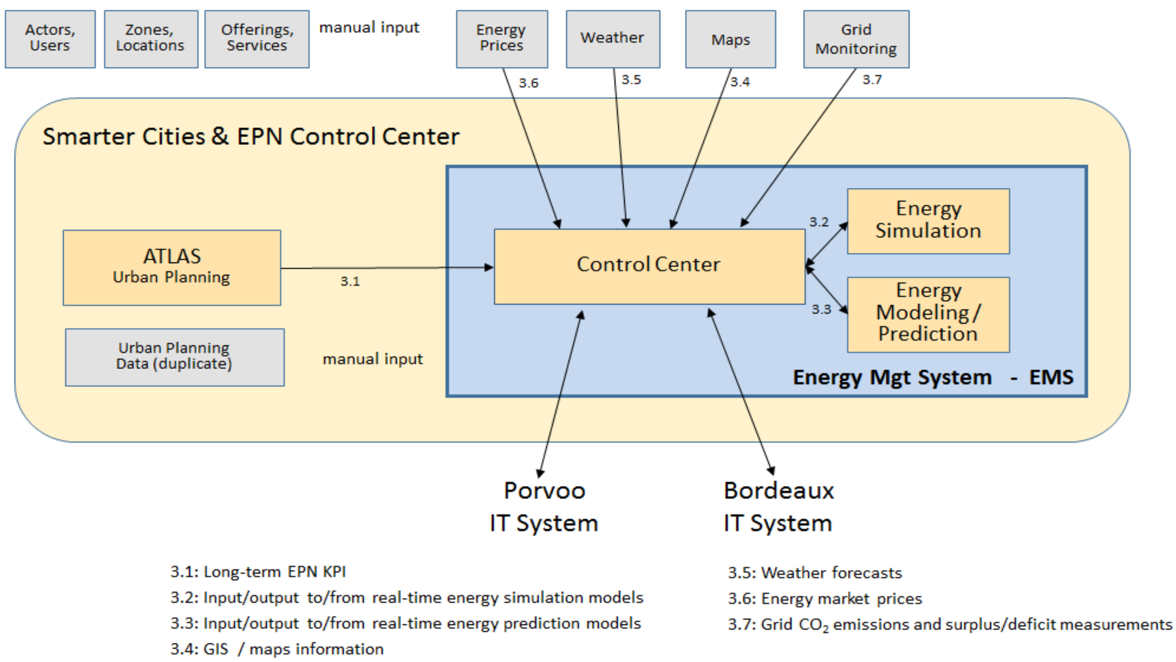

Fig.2. Overview of main IT interfaces

Source: Short and Dawood (2014a, b)

3.2. Optimisation and support tool

Again at a generic level, the optimisation and decision support tool provides several main types of operational functionality: (i) adaptive prediction of future energy supply and demand potential, (ii) access to current market conditions and predictions of future market conditions (e.g. energy prices), (iii) receding horizon optimisation to balance supply and demand given the market conditions and (iv) additional decision support and dynamic pricing incentives to prosumers and utilities within the EPN.

In terms of building management services and systems such as HVAC, the application of model-based predictive control and optimisation schemes is now known to be beneficial in terms of energy reduction and efficiency improvement potential in both residential and commercial buildings. An enabling step before the application of such schemes is the ability to quickly produce reliable predictions of short-term energy demands. In IDEAS, a novel self-calibrating adaptive demand predictor was specified and is being developed and prototyped. This predictor requires no apriori calibration, and produces predictions of hourly heat and electricity load demands with a mean absolute prediction error (MAPE) increasing from ≈ 1% for a one-hour ahead prediction to ≈ 5% for a 24 hour ahead prediction when applied to representative electricity demand data, and increasing from ≈ 2% for a one-hour ahead prediction to ≈ 10% for a 24 hour ahead prediction when applied to representative heating demand data. Further details of the prediction model specifications may be found in Short *et al.* (2013). These predictions are repeated at hourly intervals and once obtained, a novel optimisation scheme - based upon the minimization of a linear (weighted) function of economic and CO2 emissions subject to constraints upon energy storage and generation/availability capacity – can be solved. This finds the optimal plan for balancing supply with predicted demand over a short future horizon of 24 hrs. Overall the scheme extends the current state-of-the-art by adapting automatically to changes in the environment through the adaptive prediction models, taking uncertainty into account through the use of a receding horizon and the incorporation of historical prediction errors when adapting the optimization horizon weights, and finally the co-optimization of both heat and electricity within a common framework. An overview of the generic concept is shown in Figure 3 below.

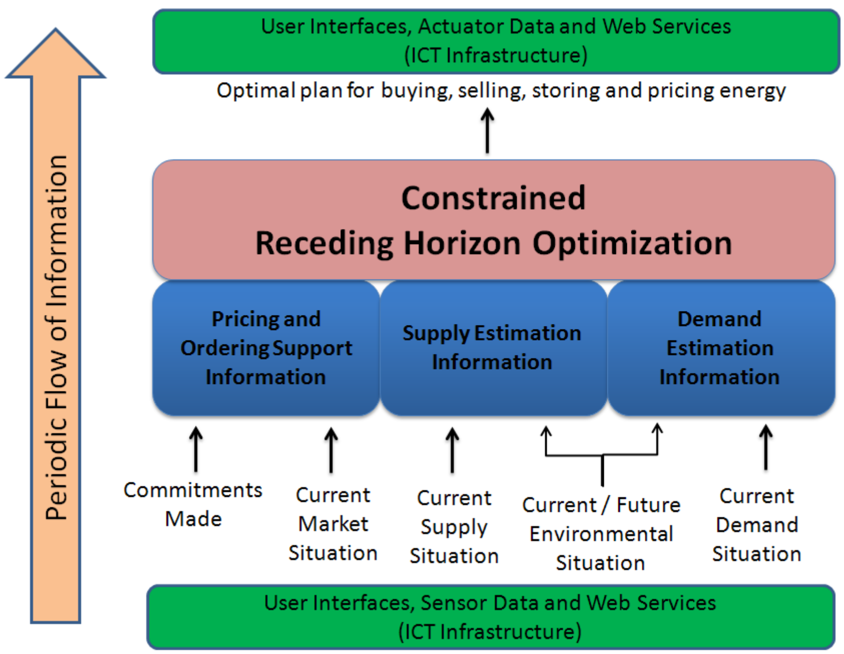

Fig.3. Prediction and Optimization architecture for EPNs

Source: Short *et al.* (2013)

4. User interfaces

The other set of specifications created in the IDEAS project concern the user interfaces. They will be used to create prototype systems to be demonstrated in the two demonstration sites. As such the user interfaces described cover all the aspects of how users in both IDEAS pilot sites can act and what they will experience as a result of those actions. A special user interface is defined for visiting the project in the virtual world site, which will be deployed as part of the French pilot.

4.1 Home energy application

Residents in an EPN need to be aware of their local neighbourhood energy production/consumption so that they can contribute to meeting collective neighbourhood energy positive consumption and production goals. They will not necessarily want to partake in micro energy trading deals, but may be willing to shift their patterns of usage in some cases if they are informed in simple terms that there is an excess or deficit of energy (Shvadron *et al.* 2013).

The research done in the IDEAS project moves beyond the state of the art in energy feedback technologies by using real-time augmented reality technology on hand-held see-through video to give alerts, interact with users and allow them to visualise real-time energy usage of various energy consumption appliances in the home. The user interfaces developed as part of the IDEAS project will inform home residents about fine grain energy consumption of the home appliances and home in general to help them meet Energy Positive Neighbourhood (EPN) energy supply objectives.

To enable this, a user interface has been specified with which the residents of the Finnish demo neighbourhood in Porvoo will be notified by the neighbourhood Energy Management System (EMS) about potential actions that could be taken to reduce peak energy demand and shift energy demand to periods when renewable energy is available. The notifications will be in simple terms and will provide easy to follow actions. A number of appliances or energy consuming devices will be 'tagged' in the home of each resident. An application that runs on a handheld device will show the resident the saving potential of these home appliances and the potential actions that one can take. This Energy Awareness Application (EAA) will make the resident aware of current and historical energy consumption for each appliance. The provided interface is going to be natural even for novice users. The above features will be enabled by installing at home a Home Energy Application (HEA) that will be fed by a smart energy metering system (Shvadron *et al*. 2013).

To realize the above, a special real-time computer vision environment has been created. It runs novel method for object recognition specially designed for the target appliances at home. This method also enables the augmentation of 2D and 3D graphical objects on the hand held display and provides a natural and clear view of real time information without a need to go through menus or access websites. The information includes notifications on the status of current energy availability that is provided by the central energy management system. The augmentation also provides suggestions of what should be done by the resident per appliance based on the current notification (Figure 4). This novel approach will be tested during the demonstration period.

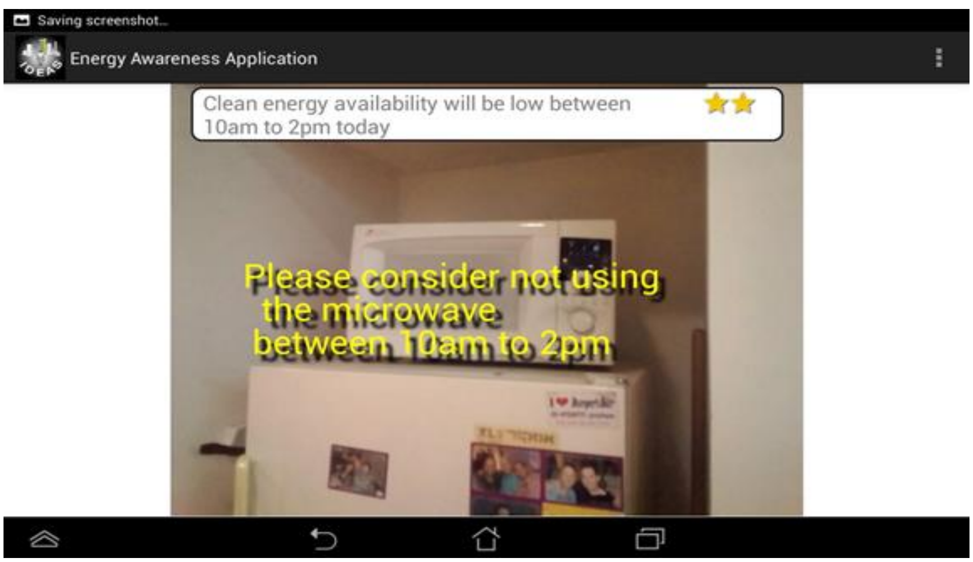

Fig.4. Example of the display of the Energy Awareness Application

4.2. 3D virtual space

Social interaction within and between communities has a large effect on peoples' behaviour and the uptake and use of technologies and therefore the impact of new technologies on energy demand. The IDEAS project has moved beyond the current state of the art in this area by developing a user interface which is based on mixed reality technology that share publicly accessible 3D virtual space, representing a replica of the IUT demonstration site in Bordeaux, France (Figure 5). The 3D virtual site that has been developed is based on the OpenSim technology. It enables remote users to access the IUT site from anywhere in the world, to be hosted by a local (virtual) person (avatar), and to learn about energy consumption and production options in the site without actually visiting it. The developed system will be connected to the IDEAS energy management system and will show real time energy data of the actual site in the virtual site, such a capability is novel. It will also show simulated energy production data as provided by the EMS.

Fig.5. A screen capture from the 3D virtual space

The idea is to provide remote visitors with a virtual venue to learn about the IDEAS project, an immersive rich collaborative environment without the need to actually visit the project pilot site. A unique aspect of the virtual environment is the incorporation of energy production and storage elements into the neighbourhood representation that do not exist in the real sites, and to show how these are integrated into the intelligent management and trading mechanisms developed as part of the project (Shvadron *et al.* 2013). The 3D virtual site includes also the ability of IUT students to enhance the 3D IUT virtual world with new features and virtual information. This will enable the students to be more involved in the project and give them a chance to add extensions as they see fit to meet new requirements and project capabilities (Shvadron *et al.* 2013). The 3D virtual space will include models of the equipment that is actually installed in IUT for the IDEAS project. In addition, it may include additional equipment that was not actually installed due to budget restrictions. These may be equipment for energy production, energy storage – where their characteristics and simulation data will be provided by the IDEAS energy management system (Shvadron *et al.* 2013). The implementation of the 3D virtual site will contribute to efforts to move towards an energy positive neighbourhood at the IUT by enabling anyone to be easily engaged in these efforts. Therefore this interface will enable the concepts of the IDEAS project to be disseminated to many communities and individuals who are interested in energy positive neighbourhoods around the world.

4.3. Energy awareness screens

Public screen displays have been designed as part of the project. After a state of the art study on the techniques to improve user engagement through awareness interfaces, these interfaces have been designed to improve Finnish stakeholders' engagement on the Finnish pilot site. The main justifications are that residents on the demo site want to be aware of their local neighbourhood energy production/consumption state so that they can contribute their share towards meeting the collective neighbourhood energy positive consumption and production goals. Awareness information will be displayed on three public screens in the nursery school and one at the public info point of the city in order to draw residents' attention. These tactile screens will be located near the entrances of the nursery school in order to allow people to interact with them and to find detailed information. Access will be provided through a web interface both for viewing energy status in the site as well as interaction based on the occupants role. The same display will also be available from any computer so occupants will be able to access the information from home too.

This Energy Awareness interface will make the residents aware of current and historical energy consumption for their neighbourhood. This screen will help the IDEAS project and the City of Porvoo to promote EPN to residents. Wide screen interfaces are based on web technologies and are fed with data provided by the EMS. Based on the previous research for the Finnish pilot site and in order to have coherent interfaces, the wide screens for the French pilot site are based on the same design and structure as the one for the Finnish pilot site. Awareness information will be displayed on 5 screens on the campus in order to draw students and teachers' attention. As it's not possible to use tactile screens, interfaces are going to rotate regularly.

The information will be originally created in English, but will also be presented in local languages on the demo sites (French for IUT site, Finnish and Swedish for the Porvoo site).

5. Long term energy planning

This section presents the specifications for a decision support urban planning tool to estimate the economic and environmental effects (e.g. ROI period and CO2-ekv emissions) on different renewable energy supply options and future building developments and redevelopments. The tool evaluates and gives guidance on the possibilities to meet local energy demand with local renewable supply. In addition to supporting the decision making related to the planning of neighbourhood energy networks, the energy positivity indicators produced by the decision support tool will be shown to the users of the neighbourhoods on the public screens mentioned above. To support the development of EPNs an urban planning decision support tool, called AtLas, is under development as part of the IDEAS project. The name of the tool is derived from the Finnish term, Aluetason energia-positiivisuuslaskuri, which roughly translates into energy positivity calculator for neighbourhoods. As part of the later stages of the research the AtLas tool will be tested at the two demonstration sites of the IDEAS project: part of a University campus in Bordeaux (IUT), France and a newly built residential area in Porvoo, Finland (Ala-Juusela *et al*. 2014). The AtLas tool is a decision support planning tool for use by local planning authorities, energy companies and facilities managers or other EPNSP like actors to support their decision making related to the planning of energy networks for a site or district. The key functionality of the tool is to enable different planning solutions and their long term impact to be quickly and easily compared (Ala-Juusela *et al.* 2014). The tool will enable the user of the tool (e.g. the Energy Positive Neighbourhood Service Provider, EPNSP) to compare different planning options with regard to the costs and ROI, but also the other aspects contributing to the value proposition, like energy balance and CO2 emissions of the area. This tool moves beyond the current state of the art as it is more simple to use than currently available tools, it has the ability to function with limited input data and perform calculations over different time periods (i.e. 10 year 20 years and so on). These key requirements and the lack of tools available to meet these requirements were identified as part of the business and community requirements analysis in earlier stages of the project.

The development of the specifications began by defining two use cases for the tool. One in which the user of the AtLas tool (a city planner) compares the long term effect of two planning strategies regarding energy flows on the greenhouse gas emissions, costs and energy balance. The other, in which the user of the AtLas tool (a facility manger) compares the long term effect of two renovation investment options on the greenhouse gas emissions, costs and energy balance (Ala-Juusela *et al.* 2014). These users represent the central actor of the EPNSP business model at the demonstration sites. The development of the use cases was informed by input from city officials, area planners, energy producers, and energy distributors and facilities managers. As such, the tool's envisaged users played a central role in the definition of the future tool's functionality. A review of existing tools used by city planners and facilities managers to support their decision making was also undertaken to inform the specifications by identifying the shortcomings and benefits of existing tools from the user's perspective. Furthermore initial pilot versions of the Atlas tool were demonstrated to users in parallel with the development of the specifications to ensure that the users' requirements are built into the specifications. The major shortcomings that were addressed in the development of the tool include issues with complexity of the existing tools, the required high level of energy and building related knowledge, the lack of site level tools, the transparency of the processes and the lack of time and economic perspective of the existing tools (Ala-Juusela *et al*. 2014). In addition to supporting the decision making related to the planning of neighbourhood energy networks, the energy positivity indicators produced with the Atlas tool will be shown to the general public at the demonstration sites on the public screens described above. The energy positivity indicators and their calculation are described in more detail by Ala-Juusela *et al.* (2014).

Conclusions

ICT tools can support the incremental rollout of EPNs and the key partners of innovative business models to realise this in many different ways. The tools being developed in IDEAS support the key activities of the related business model by enabling the near real time matching of energy demand and supply, engaging the users and public in large to the concept of EPNs and by enabling the comparison of different possible future scenarios for urban renewable deployment.

The specifications and tools are the result of European co-operation, and are designed so that they can easily be adopted in different European countries with minimum changes.

This paper has described the early stages of the tools development in the IDEAS project. Prototypes of these tools have now been developed - based on the specifications presented in this paper - for deployment in the later phases of the research. Currently the project is moving to a demonstration phase, where the tools and user interfaces (as well as elements of the business models) will be tested by real users at the two demonstration sites. Future works by the authors will report the findings of these tests, and evaluate the relative merits and drawbacks of the proposed solutions.

References

Ala-Juusela, M.; Hradil, P.; Jantunen, J.; Kontio, M.-R.; Ståhlberg, M.; Rosqvist, J.; Rouhiainen, J. and Brassier, P. 2014. Specifications for the urban planning decision support tool. Deliverable 3.4 of IDEAS project.

Balkienė, K. 2013. Sustainable innovativeness: issues and public policy, *Journal of Security and Sustainability Issues* 3(2): 53–76. DOI: http://dx.doi.org/10.9770/jssi.2013.3.2(5)

Baublys, J.; Miškinis, V.; Konstantinavičiūtė, I.; Lekavičius V. 2014. Aspirations for sustainability and global energy development trends, *Journal of Security and Sustainability Issues* 3(4): 17–26. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(2)

Caurkubule, Ž.; Rubanovskis, A. 2014. Sustainable entrepreneurship through motivation: case of Latvian companies, *Entrepreneurship and Sustainability Issues* 2(1): 43–48. DOI: http://dx.doi.org/10.9770/jesi.2.1(6)

Crosbie, T.; Ye, J.; Short, M.; Thibault, E.; Rosqvist, J.; Brassier, P. and Huovila, A. 2014. Specific business models for demo cases. Deliverable 2.2 of IDEAS project.

Figurska, I. 2014. Sustainable entrepreneurship: localization, acquiring and use of knowledge sources in competitive organization, *Entrepreneurship and Sustainability Issues* 1(4): 210–222. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(3)

Garškaitė-Milvydienė, K. 2014. Anti-crisis management of enterprises and possibilities of overcoming their critical condition, *Journal of Entrepreneurship and Sustainability Issues* 1(4): 187–203. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(1)

Garškaitė-Milvydienė, K.2012. Diagnostics of bankruptcy threat to enterprises, *Journal of Security and Sustainability Issues* 1(3): 197–203. DOI: http://dx.doi.org/10.9770/jssi/2012.1.3(5)

Huovila, A.; Jantunen, J.; Ala-Juusela, M.; Sepponen, M.; Tuominen, T.; Thibault, E.; Decorme, R.; Brassier, P.; Rouhiainen, J.; Tuomi, L.; Varis, A.; Ståhlberg, M.; Gras, D. 2013. Business & community requirements analysis. Deliverable D2.1 of IDEAS project

Mačiulis, A.; Tvaronavičienė, M. 2013. Secure and sustainable development: Lithuania's new role in taking the Presidency of the EU, *Journal of Security and Sustainability Issues* 3(2): 5–13. DOI: http://dx.doi.org/10.9770/jssi.2013.3.2(1)

Matyasik, M. 2014. Secure sustainable development: impact of social media on political and social crises, *Journal of Security and Sustainability Issues* 4(1): 5–16. DOI: http://dx.doi.org/10.9770/jssi.2014.4.1(1)

Miškinis, V.; Baublys, J.; Lekavičius, V.;Morkvėnas, A. 2013. New Changes in Lithuanian Energy Sector, *Journal of Security andSustainability Issues* 2(3): 15–28. DOI: http://dx.doi.org/10.9770/jssi.2013.2.3(2)

Peker, S.; Tvaronavičienė, M.; Aktan, B. 2014. Sustainable risk management: fuzzy approach to volatility and application on FTSE 100 index, *Entrepreneurship and Sustainabillity Issues* 2(1): 30–36. DOI: http://dx.doi.org/10.9770/jesi.2014.2.1(4)

Raudeliūnienė, J.; Tvaronavičienė, M.; Dzemyda, I. 2014. Towards economic security and sustainability: key success factors of sustainable entrepreneurship in conditions of global economy, *Journal of Security and Sustainability Issues* 3(4): 71–79. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(7)

Short, M.; Dawood, M. 2014a. Networking Infrastructures for Micro Grids Part I: Review and Proposal. To appear in: Proceedings of the International Conference on Green Technology and Sustainable Development 2014 (GTSD'14), Ho Chi Minh City, Vietnam, October 2014.

Short, M.; Dawood, M. 2014b. Networking Infrastructures for Micro Grids Part II: Prototype Architecture and Initial Testing. To appear in: Proceedings of the International Conference on Green Technology and Sustainable Development 2014 (GTSD'14), Ho Chi Minh City, Vietnam, October 2014.

Short, M.; Dawood, M.; Shvadron, U.; Ye, J.; Gras, D.; Ala-Juusela, M. 2013. Specifications for the neighbourhood energy management tool. Deliverable D3.2 of IDEAS project, November 2013.

Shvadron, U.; Short, M.; Gras, D.; Thibault, E.; Brassier, P.; Rosqvist, J.; Ala-Juusela, M. 2013. Specifications for the user interfaces. Deliverable D3.3 of IDEAS project.

Tarabkova, L. 2014. Model of motivating linked-up with education, *Entrepreneurship and Sustainability Issues* 2(1): 12–18. DOI: http://dx.doi.org/10.9770/jesi.2014.2.1(2)

Tvaronavičienė, M. 2012. Contemporary perceptions of energy security: policy implications, *Journal of Security and Sustainability Issues* 1(4): 235–247. DOI: http://dx.doi.org/10.9770/jssi.2012.1.4(1)

Tvaronavičienė, M. 2014. If industrial sector development is sustainable: Lithuania compared to the EU, *Entrepreneurship and Sustainability Issues* 1(3):134–142. DOI: http://dx.doi.org/10.9770/jesi.2014.1.3(2)

Tvaronavičienė, M.; Grybaitė, V. 2012. Sustainable development and performance of institutions: approaches towards measurement, *Journal of Security and Sustainability Issues* 1(3): 167–175. DOI: http://dx.doi.org/10.9770/jssi/2012.1.3(2)

Tvaronavičienė, M.; Šimelytė, A., Lace, N. 2014. Sustainable development facets: exporting industrial sectors from inside, *Journal of Security and Sustainability Issues* 3(4): 37–44. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(4)

Vasiliūnaitė, R. 2014. Sustainable development: methodological approaches toward issues, *Journal of Security and Sustainability Issues* 3(3): 69–75. DOI: http://dx.doi.org/10.9770/jssi.2014.3.3(6)

Vosylius, E.; Rakutis, V.; Tvaronavičienė, M. 2013. Economic growth, sustainable development and energy security interrelation, *Journal of Security and Sustainability Issues* 2(3): 5–14. DOI: http://dx.doi.org/10.9770/jssi.2013.2.3(1)

International Centre for Entrepreneurship Research

ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES
ISSN 2345-0282 (online) http://jssidoi.org/jesi/aims-and-scope-of-research/

SUSTAINABLE ENERGY ENTREPRENEURSHIP THROUGH ARCHITECTURAL DESIGN: A KEY POINT CONTROLLED METHOD[3]

Romy Guruz[1], Raimar Scherer[2]

Technische Universität, Dresden, Germany

E-mails: [1]Romy.Guruz@TU-Dresden.de; [2]Raimar.Scherer@TU-Dresden.de

Received 20 September 2014; accepted 26 October 2014

Abstract. The biggest opportunity to influence the relationship between energy goals and architectural design is during the early planning phases of a building project. It is commonly known that unilateral elaborate design decisions can have substantial negative influence on the economic and the environmental performance of a building. Great opportunities are seen in the early design phase, where only general conditions and basic constraints are predetermined by the client and the participating planners. Building requirements contain numerous explicit and implicit requests, which can in a next step be defined as verifiable design checkpoints. These Key Points will allow designers to easily structure the design process in individual evaluable parts and will thus help them to concentrate on high-level strategic decision making tasks. Against this background, the central question that motivates this paper is: how can we aggregate building requirements to be able to formalize the data as basis for the definition of Key Points? To answer this question, a closer look at building requirements of different participating planners and their individual decision making is taken. The Key Point driven design process is expected to lead to greater efficiency in the planning procedure to final design results of higher quality. At the same time, it will provide an opportunity of weighing up many more alternatives than currently possible.

Keywords: sustainable energy entrepreneurship, Key performance indicators (KPIs); building requirements; decision making; process pattern; key design points

Reference to this paper should be made as follows: Guruz, R.; Scherer, R. 2014. Sustainable energy entrepreneurship through architectural design: a key point controlled method, *Entrepreneurship and Sustainability Issues* 2(2): 60–73.
DOI: http://dx.doi.org/10.9770/jesi.2014.2.2(2)

JEL Classifications: O180

1. Introduction

Sustainable energy entrepreneurship from both, supply and demand sides, i.e. from side of architects designing energy-efficient buildings, and from side of entrepreneurs, who develop other activities in those buildings, significantly depends on approach, which has been used for buildings design (Laužikas, Mokšeckienė 2013; Vosylius *et al.* 2013; Bileišis 2014, Dzemyda, Raudeliūnienė 2014; Korsakienė, Tvaronavičienė 2014; Litvaj, Poniščiaková 2014; Raudeliūnienė *et al.* 2014; Tvaronavičienė 2014; Tvaronavičienė *et al.* 2014; Vasiliūnaitė 2014; Scherer, Schapke 2011).

[3] This paper reveals the ongoing PhD thesis of the first author under the supervision of the second one. The research presented in this paper was enabled by the financial support of the European Commission to the eeEmbedded project under Grant Agreement #609349. This support, as well as the support of the project partners, is gratefully acknowledged.

The presented in the paper tackles this issue by introducing eeEmbedded system, which will comprehend a Key Point-controlled holistic design methodology, and evolve an integrated information management framework for designing energy-efficient buildings and their optimal energetic embedding in the neighbourhood of surrounding buildings and energy systems. Building Information Model (BIM) will thereby be complemented by a newly developed Energy System Information Model (ESIM) based on the principles of the BIM-IFC (ISO 16739) standard and subsuming existing proprietary energy system models, and an extended Building Automation and Control System (BACS) model integrated with BIM, following the suggestions collaboratively elaborated in the FP7 projects HESMOS (09/2010-12/2013), SEEDS (09/2011-08/2014) and ISES (12/2011-11/2014).

Existing information representation gaps will be filled and the BIM methodology will be extended to an energy-enhanced embedded BIM methodology (eeeBIM). The domain models BIM, ESIM, BACS (see Figure 1) will provide: (a) the eeeBIM information framework for a holistic architecture and energy design of buildings embedded in the energetic neighbourhood, and (b) the baseline of the information collaboration between the involved different specialists, namely building designers, construction engineers, facility managers, energy designers, fluid dynamic engineers, control engineers, etc. The design of the energy system and of the energy-efficient behaviour of buildings that are optimally embedded in their energetic surroundings has a broad interdisciplinary scope. It requires intensive collaborative work of many different discipline experts and special management capabilities to manage and control the complex, evolving design process.

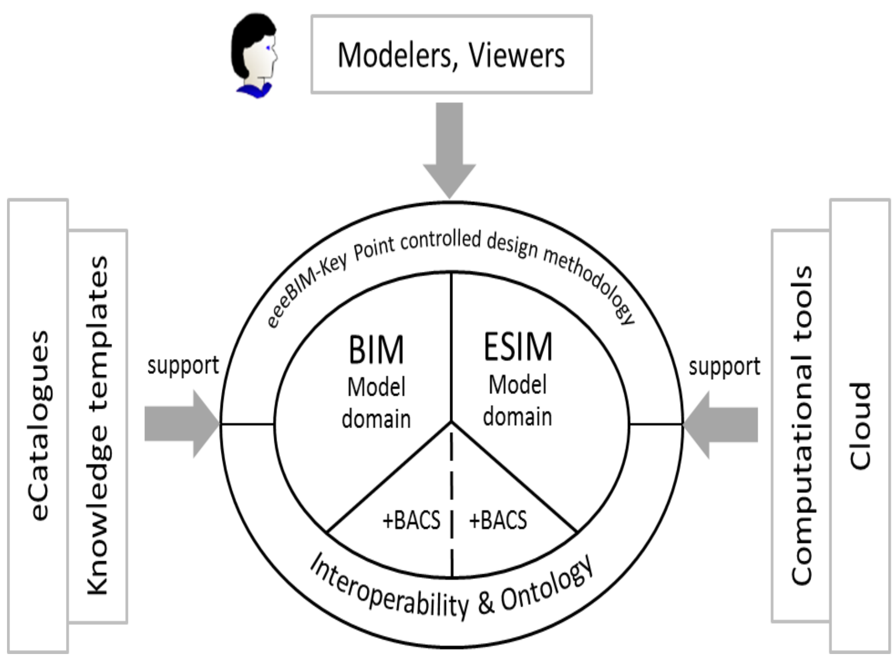

Fig.1. eeEmbedded System - Concept of the Collaborative Holistic Design Lab, embracing the 3 domains BIM, ESIM and BACS

To guide the multi-disciplinary design process and to focus on reaching the optimum value for the client as fast as possible, first a vision of a Key Point controlled design methodology has to be developed, which allows constant control and monitoring of the complex design process.

The main objective of this research is the examination of building requirements for the achievement of a consistent Key Point definition. For the purposes of this development, the term Key Points will be taken to mean verifiable design checkpoints. This term refers to Key Performance Indicators (KPIs), which are simple numeric metrics of energy usage or observed building characteristics that can be associated with better or worse energy performance. Similar to KPIs in other business organizations these KPIs are intended to yield the best information for the minimizing costs and analysis time. This enables the planners to better understand the impact of their design choices and moreover provides them a simple framework to reference when defining requirements for energy monitoring equipment and analysis for their new (or existing) building project (Harris and Higgins 2012).

The central question then becomes: if KPIs are integrated in the design process to check energy performance by means of simulation tools, are there any further "Key" requirements which can be used in defining design checkpoints and design process milestones? And which requirements do they have to fulfil that makes them capable of being checked? The vision of our new design methodology necessitates a net of verifiable design checkpoints, which are based on building requirements and during the different design phases used as milestones which are defined as Key Points.

In the first part of the paper, we discuss the basis interdependencies of the Key Points between building requirements, domain models and the scopes of action to get an overview of the components of the preferred new design process. These are reported in more detail in the third section about process pattern.

In the second part, we suggest a stepwise aggregation of building requirements to derive the Key Points. The more requirements and principles are defined in the front-end, the simpler it will be to fix target values in the stage of the definition of Key Points. Therefore, the Key Points are hierarchically categorized:

Key Design Requirements (KDRs)
Represent the mandatory building requirements and usually have a limited value.

Key Design Parameters (KDPs):
Represent the plan values, which are to be introduced by the domains after their domain related tasks.

Key Performance Indicators (KPIs):
Represent the simulation results after comparing and ranking.

Decision Values (DVs):
Represent the preferences of the decision-makers related to the project goals. This allows prioritising KPIs by means of a weighting factor.

In the third part, the results will be examined for recurrent pattern to facilitate general automation of the different process steps in each design phase. We reduce the diversity process to three generic process patterns unfailingly applicable to our method. We introduce a 3-step control and monitoring system, which is combined with the newly developed requirements aggregation structure. We show how the governing KDIs, KPIs and DVs can be applied to a variety of tasks within their patterns.

Finally, we present an example of how to express the Key Points in terms of KDRs, KPIs and DVs regarding the different domains with a use case. These initially identified KDRs, KPIs and DVs form a basis for the integration and synthesis to a coherent overall design method.

2. Basis interdependencies of the Key Points

The key point controlled design methodology will prepare the existing simulations and analyses tools for an integrated holistic design system and will combine them to an interoperability design framework serving the complex multi-information model and multi-physics demands. The purpose of the methodology is to guide through the numerous design options and help choosing the best ones in the shortest time possible (Guruz *et al.* 2012; Eastman *et al.* 2011).

Basis of each design decision are the predetermined building requirements. After formalization of the Key Points, as target elements for the following analyses, conclusions can be drawn with regard to domain models and the related elements and the inputs for the analyses can be prepared. As shown in Figure 1, upon completion of the design cycle, the analysis step of the decision cycle, the results are validated against the building requirements. In addition to the consequences for the domain models, the quality of the results should be evaluated here as well. The challenge is to develop an IT and BIM based combination of evaluation for the next design steps. To achieve the envisaged functionality, methods are being developed to formalize and resolve each single step in a pattern.

The design processes have been analysed to identify the different decision making as basis for the development of the 3 step design method. In a first step the tasks have been divided in the different cycles, with regard to various process conditions:

1. Design cycle: this includes the architecture domain, the energy system domain, the Heating, Ventilation and Air Conditioning (HVAC) domain, the Building Automation and Control System (BACS) domain and the (Facility Management) FM domain.
2. Simulation (Analysis) cycle: this includes the simulation domain, the Life Cycle Assessment (LCA) domain and the Life Cycle Costing (LCC) domain.

3. Decision cycle: The developer/owner/or one of the experts above (in most cases the architect) decides if the concept developed by the project team is worth implementing.

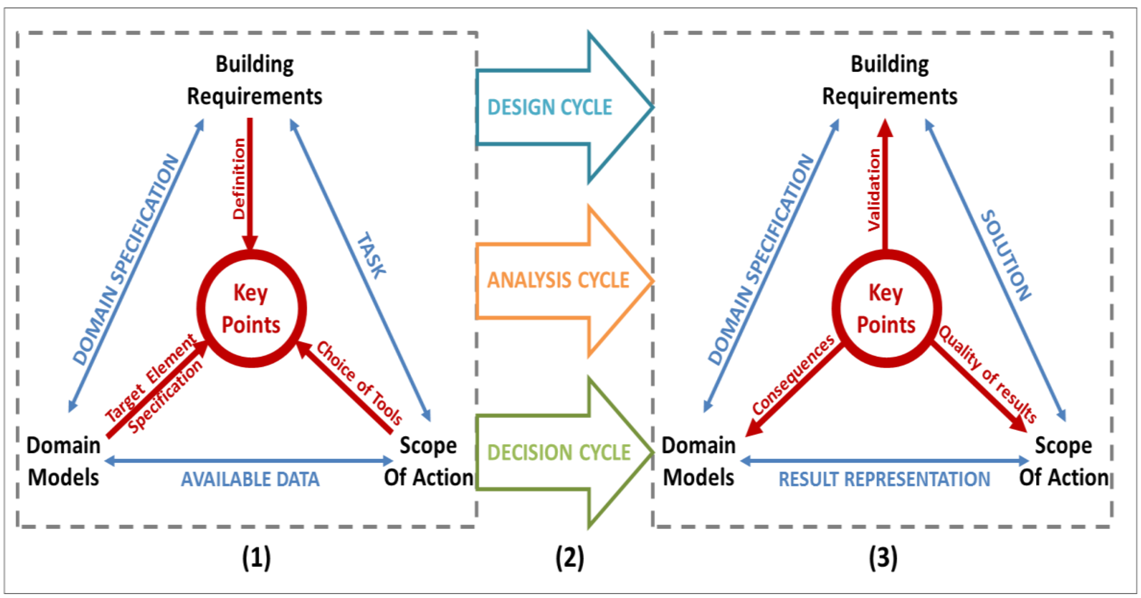

Fig.2. General interdependencies between Key Points, building requirements, domain models and variable scope of actions in (1) Definition (2) trough tasks and in (3) Validation

As shown in Figure 2 in the left part (1), the Key points were defined from building requirements depending to the related task. The middle part (2) and the right part (3) are strongly related to each other: three different task cycles are supported: **Design Cycle:** the design variants and alternatives are verified. **Simulation/Analysis Cycle:** the building performance alternatives are compared and/ or ranked. **Decision Cycle:** the final alternatives are weighted evaluated.

3. Building Requirements as Basis for Key Point Evolution

Regardless of the complexity of the methods we use to make our decisions, the basis of each of them are the predetermined requirements. They are the basis of each project and define its characteristics. Consequently, the stepwise refinement of requirements with the possibility to verify results at predefined Key Points would result in a continuous monitored planning process.

3.1. General Steps towards Identification of Requirements

Primary, the description of building requirements in the first step varies depending on the client, the type and the size of the project. In addition, country specific factors, laws and regulations determine the valences of the individual requirements. During the requirements specification process the regulatory requirements, the environmental requirements and the client desires as well as the site requirements are translated into building and design requirements. After defining the main concepts of a building in cooperation with the client, in the second step the initial conceptual design is worked out by the different domain experts. They are determining subject-related bases in the required project scope, depth and quality.

At third step of these considerations is to clarify, which kind of requirements, information and knowledge is needed within our patterns to support a task related decision making. We generally expect that the domain experts are going to translate the various requirements into (their) design requirements, which are the basis for common domain related tasks. Lastly, in the fourth step, the alignment of the worked out building requirements, a consistent check is needed. Eventually, after completing a planning phase, this step is repeated and stepwise refined.

3.2. Building Requirements Aggregation to Key Points

To enable structured definition and formalization of Key Points via rules and/or algorithmic constituents, first the building requirements have to be appropriately categorized. Figure 3 shows the overall concept for a key point controlled design methodology based on hierarchically structured dynamic evolving decision points, expressed in aggregated requirements. The pyramid shows the generic structure of requirements aggregation related to 4 main tasks in design. The requirements level on the bottom of the figure 3 starts the progress.

1. **Aggregation:**

Based on the client, regulatory, site requirements (etc.) and all involved design partners, the key requirements need to be translated, developed and reported in a structured way. The results of this process, in which each participating design partner is involved, are described as *Key Design Requirements* (KDRs), shown in the right side of the figure. To verify compliance with the design objectives and specifications the requirements should be translated to Key Design Requirements (KDRs). As part of this process step, the KDRs are also finally checked and matched within the participating domains.

2. **Aggregation:**

The KDRs guide the design, by inclusion (build it this way) or exclusion (don't build it this way), and are used for ruling out different design options. In the domain task level, where all domains start their iterating working cycles, the KDR are used as target values for verification of the alternatives, for tracking the design process.
KDRs represent the mandatory requirements and usually have a limited value.
The plan values, which are to be introduced by the domains after this working step, are expressed in Key Design Parameters (KDPs).

3. **Aggregation:**

The third aggregation takes place during the simulation and analysis tasks. The KDPs are uses for comparing and ranking the simulation results, which are defined as Key Performance Indicators (KPIs). To compare the design variants and alternatives regarding their sustainable performance, relevant KPIs have to be introduced. For elaborated comparisons, the simulation, Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) experts develop based on the requirements their KDPs to evaluate the performance in their field of expertise. With KPIs alone it is possible to make a statement on how well a design alternative or option performs regarding a specific goal. With the KPIs structured according to the ecological (final energy and emissions), socio-cultural (thermal comfort and air quality) and economic (investment and operational costs) target-quality, different alternatives can be compared to identify the one with the best cost-quality ratio. KPIs offer the possibility to quantify the performance of measurable indicators as well as of qualitative indicators. They are defined relative deviations from before-hand agreed KDRs.

4. Aggregation:

The last aggregation is in higher decision making. For weighted evaluation the KPIs have to be aggregated to Decision Values (DVs). The preferences of the decision-makers vary, so they need the possibility to prioritise KPI with a weighting factor. The DVs comprise the weighted ecological (final energy, primary energy, etc.), socio-cultural (temperature over-/underruns, etc.) and economic (investment, maintenance and energy costs) KPI regarding their priority for the project.

With KPIs alone it is possible to make a statement on how well a design alternative or option performs regarding a specific goal. To evaluate the results from different domains and priories, the results have to be weighted in the direction of the project goal. This methodology with an appropriate precision is needed for the controlled multi-disciplinary design. Variants or alternatives with the best score are selected as the basis for the next development stage.

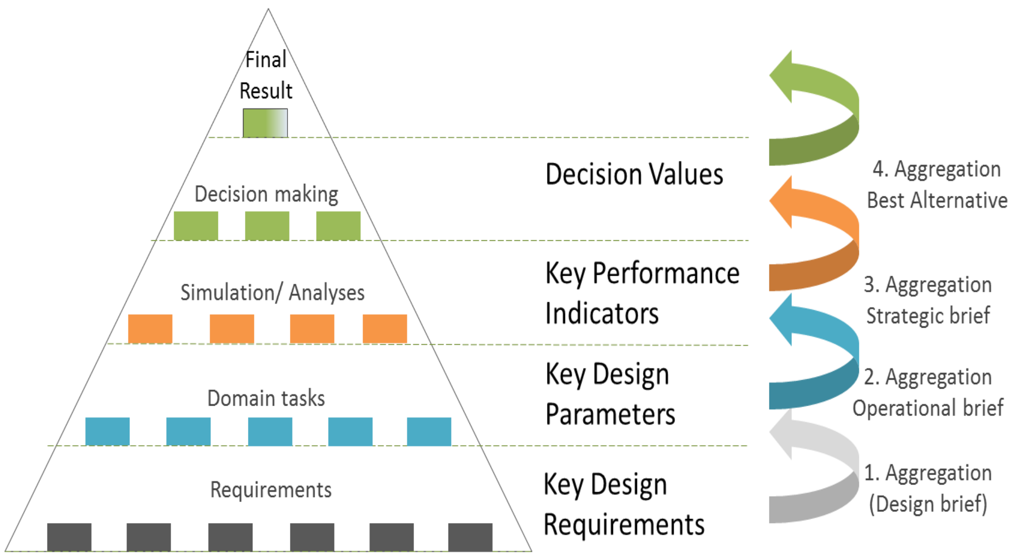

Fig.3. Step wise requirements aggregation

3.3. Building Requirements to Key Points

The design goals for the suggested Key Points should be developed in a structured briefing process top down starting from requirements to the technical brief, and then operational brief, and summarised in the strategic brief as shown in Figure 4.

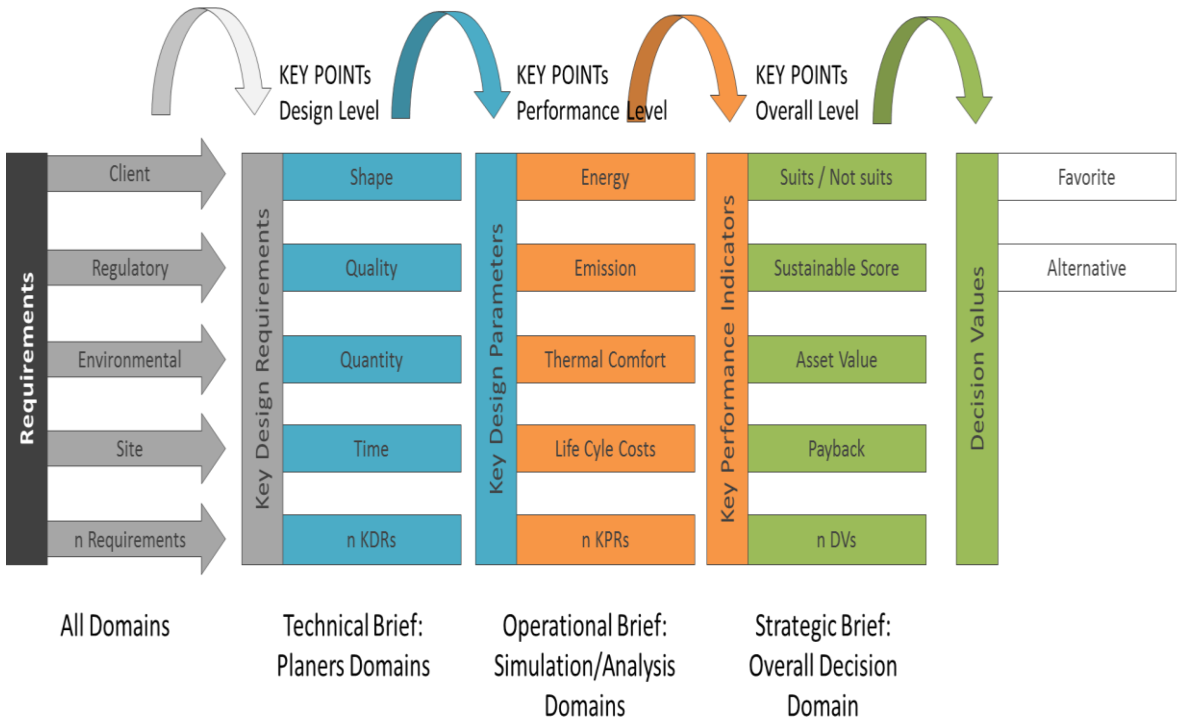

Fig.4. Schema briefing process based on KDRs, KDPs, KPIs and DVs

In the technical brief, Key Design Requirements (KDR) need to be developed based on the client, regulatory, site and design partner requirements in a structured way.

Their Key Points are in the design level, and are described as Verification Points and it will be checked:

- *Have we made what we were trying to make?*
- *Does the building/ energy system conform to the specifications?*

Key Design Parameters – qualitative and quantitative aspects of the design - are used to verify (model-based) that the design is created to fulfil the requirements.

In the operational brief, Key Design Parameters are derived from the regulatory, site and environmental requirements and also from former results. The KDPs describe the level of performance in solution independent terms that must be reached to achieve the clients' project goal.

Their Key Points are in the performance level, and are described as Validation Point and it will be checked:

- *Are we trying to make the right thing?*
- *Is the product specified to the user's actual needs?*

Key Performance Indicators – performance measurements - are processed from the stochastic simulations and analysis and validate against target-performance.

In the strategic brief, Key Performance Indicators are established and weighted very carefully based on the project goal to judge the impact of design solutions considered and to protect what is most important during the decision making process.

Their Key Points are in the performance level, and are described as Decision Points; the choice is made based on the values and preferences of the decision maker.

The Decision Value - ratio of function (comfort, flexibility, energy savings, fewer emissions, aesthetics etc.) per life cycle costs - is processed by weighting results of different domains regarding the preferences and is then used for the final decision.

3.4. Criteria for using building requirements

In general, three types of requirements can be distinguished:
a) Requirements that are difficult to formalize (because they describe, e.g. an impression like "relations of different views"),
b) Requirements that allow drawing direct conclusions, such as space use, furniture concept etc., and
c) Requirements that can be formalized as facts (values, value ranges, rules, fixed algorithms). This has influence on the scope of the potential key points in respect of the verifiability (Figure 5).

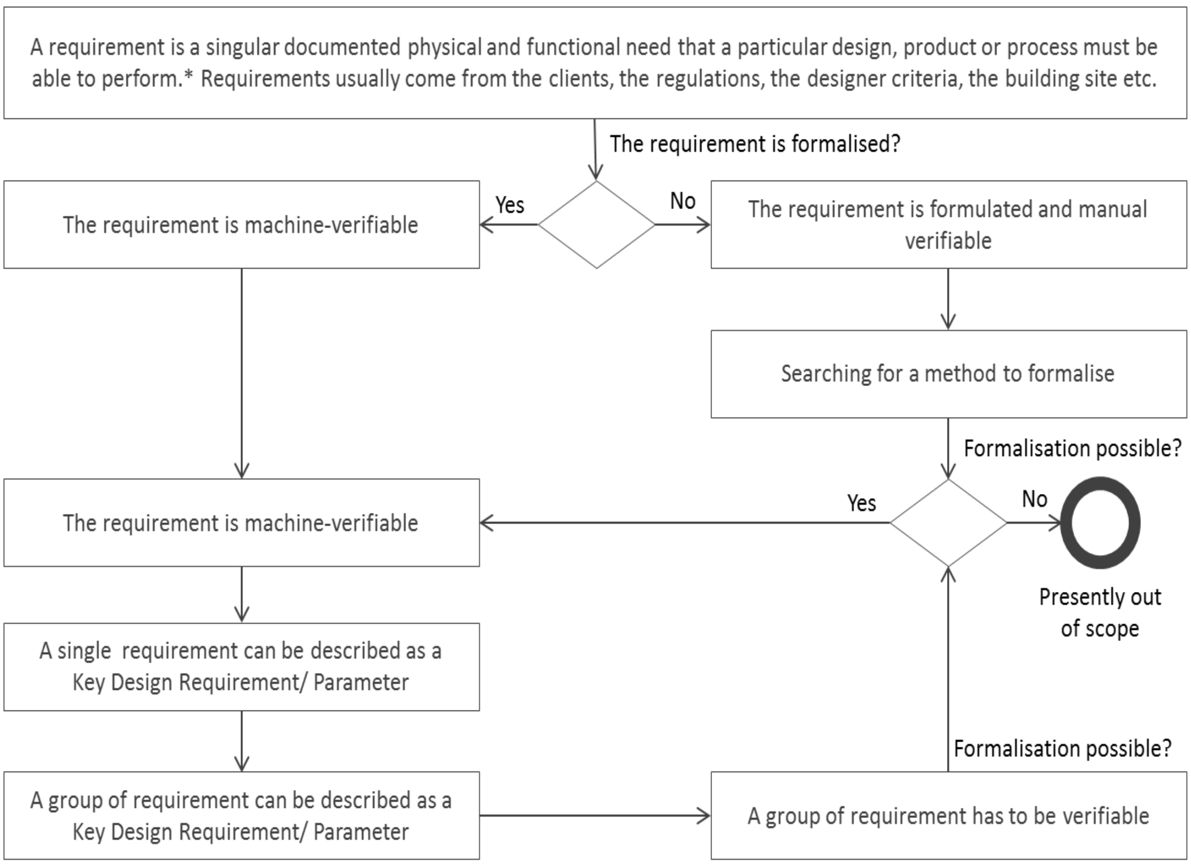

Fig.5. Basis requirements test within the design level

4. Key Points in generic Design Pattern

Based on the worked out use cases for the *ee*Embedded system and with regard to various process conditions, the different domains are divided in 3 levels with different ways of decision making:
1. Experts' Level: includes the architecture, the energy system, the HVAC domain, the BACS domain and the FM domain:

Verification: Discarding design options by reducing those to the ones which meet the domain related KDRs.
2. Simulation and Analysis Level: includes the simulation domain, where experts perform the required simulations to optimise the design concepts; the LCA domain, where LCA consultants estimate the lifetime

environmental impact and the LCC domain, for estimating the whole life cycle costs of the building and its systems.

Domain-related decision making: Comparing and/or ranking of simulation/ analysis results with assistance of KPIs.

3. Decision-making Level: The developer/owner/ or one of the experts above (in most cases the architect) decides if the concept developed by the project team is worth implementing.

Overall decision making: Prioritisation of decision criteria with goal oriented DVs (e.g. using hierarchies of domain experts' perspectives).

As a result of this classification, we precisely examined these levels to reduce complexity by inference and derivation of complex tasks and decision-making in a generic process. For each of the above levels, a pattern could be created with special attentions to our overall objective: i.e. to support the different decision-making.

The three elaborated patterns can be described as follows:

I. Input conditions: aggregated requirements and additional requirements, as well as models by other domains and results of former iterations. These conditions are split in mandatory and optional sets;
II. Process starting point;
III. The individual process task (usually initiated by requirements) produces results;
IV. Results (different Alternatives);
V. KEY POINT: decision-making within the pattern related to evaluation of the results;
VI. Process end point;
VII. Output conditions: also separated in mandatory and optional sets- typically results, transferred as domain model, as well as further requirements (depended on aggregation level).

Therefore, each design phase can be described with the 3 patterns: Domain task pattern, simulation/computation pattern and the decision making pattern. In front of the different methods and strategies existing in the decision theory, it is necessary to further define the characteristics and restrictions of the decision challenge.

4.1. Pattern 1: Design verification with Key Design Requirements

Every domain expert should be able to set up the specific requirements in a structured way and refine them throughout the design process. To verify compliance with the design objectives and specifications the requirements should be translated to KDRs. KDRs are requirements´ measures which are used for tracking the design process. KDRs represent the mandatory requirements and usually have a limited value (Figure 6).

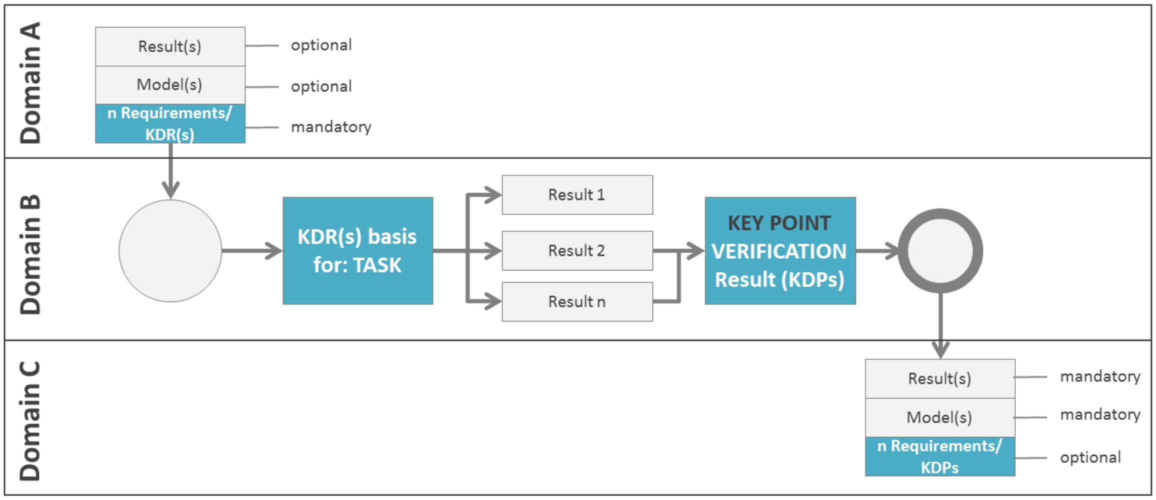

Fig.6. Fully described "Pattern 1" including KDR decision making as BPM

Verification: Discarding design options by reducing those to the ones which meet the domain related KDRs.

I.	Input conditions:	*Mandatory:* ***n requirement(s) expressed in KDRs***
		Optional: ***Former domain results / models***
III.	Process task:	***Task*** *related to KDR(s)*
V.	Key Point:	***Verification results*** *(alternatives);*
		If the result constitutes a required target (value) for simulation/ analyses, then it's a mandatory output for the following key point.
VII.	Output conditions:	*Mandatory:* ***Domain results/ model(s)***
		Optional: ***Alternatives; Further requirements (KDPs)***

4.2. Pattern 2: Performance optimization - Key Performance Indicators

This pattern supports the optimisation of the performance of building developments based on Key Design Parameters (KDPs) (Figure 7). With the result KPIs structured according to the ecological (final energy and emissions), socio-cultural (thermal comfort and air quality) and economic (investment and operational costs) quality different alternatives can be compared to identify the one with the best cost-quality ratio. KPIs offer the possibility to quantify the performance of measurable indicators as well as of qualitative indicators. They are defined relative deviations from beforehand agreed target value (Schreyer *et al.* 2010).
Domain-related decision making: Comparing and/or ranking of simulation/ analysis results with assistance of KPIs.

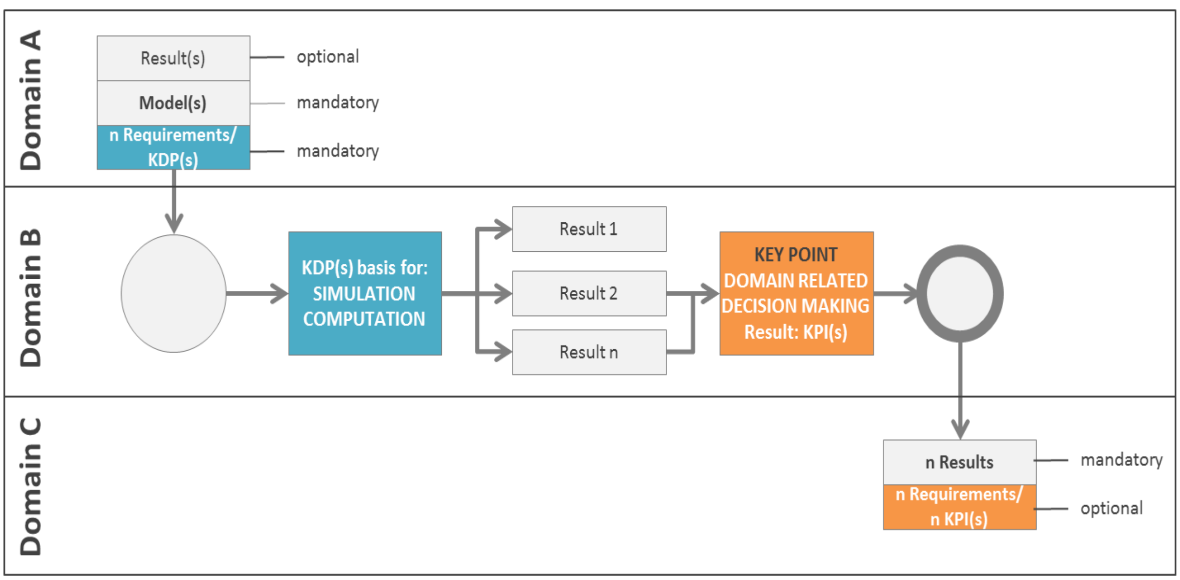

Fig.7. Fully described "Pattern 2" including KPI decision making as BPM

I.	Input conditions:	*Mandatory:* ***n requirement(s) expressed in KDPs***
		Optional: ***Former domain results / models***
III.	Process task:	***Simulation/ Analysis*** *related to KDP(s)*
V.	Key Point:	***Comparing results via KPIs*** *(alternatives);*
		If the result constitutes a required target (value) for overall decision making, then it's a mandatory output for the following key point.
VII.	Output conditions:	*Mandatory:* ***Domain results/ model(s)***
		Optional: ***Alternatives; Further requirements (KPIs)***

4.3. Pattern 3: Prioritisation and decision making with Decision Values (DV)

DV comprise the weighted ecological (final energy, primary energy, GWP etc.), socio-cultural (temperature over-/under-runs, PMV/PPD etc.) and economic (investment, maintenance and energy costs) KPI regarding their priority for the project. With KPIs alone it is possible to make a statement how well a design alternative or option performs regarding a specific goal (Schreyer *et al.* 2010). To evaluate the results from different domains and priories, the results have to be weighed in the direction of the project goal. This methodology with an appropriate precision is needed for the controlled multi-disciplinary design (Figure 8).

Overall decision making: Prioritisation of decision criteria with goal oriented DVs (e.g. using hierarchies of domain experts' perspectives).

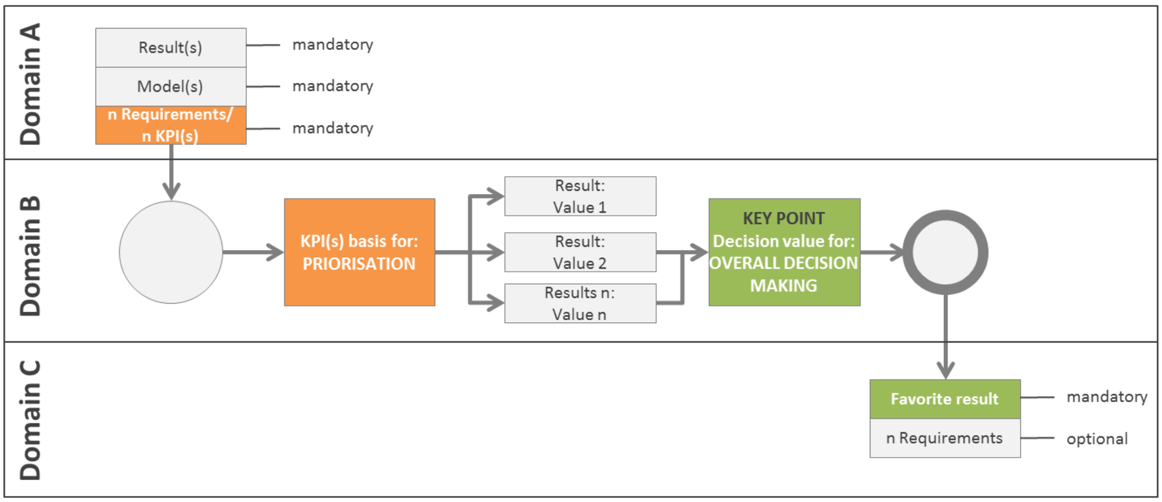

Fig.8. Fully described "Pattern 3" including DV decision making as BPM

I.	Input conditions:	*Mandatory:* ***n requirement(s) expressed in KPIs, Domain results and Model(s)***
III.	Process task:	***Prioritisation*** *related to KPI(s)*
V.	Key Point:	***Overall decision making via DVs*** *(alternatives);*
VII.	Output conditions:	*Mandatory:* ***favourite result*** *Optional:* ***n requirements.***

5. Example for preliminary urban design

The following example was worked out in context of the EU project eeEmbedded in collaboration end users (Geißler *et al*. 2014). The represented use case "Urban design" has the aim of designing the most optimal energetic embedding in the neighbourhood which comprises the definition of the building envelope geometry and the district energy system, as well as its colour-coded Key Points (Figure 9).

To express the Key Points of the design process in terms of KDRs, KPIs and DVs regarding the different domains for the Urban Design Phase, *ee*E examples are given in the Table 1. These initially identified KDRs, KPIs and DVs form a basis for the integration and synthesis to a coherent overall design method.

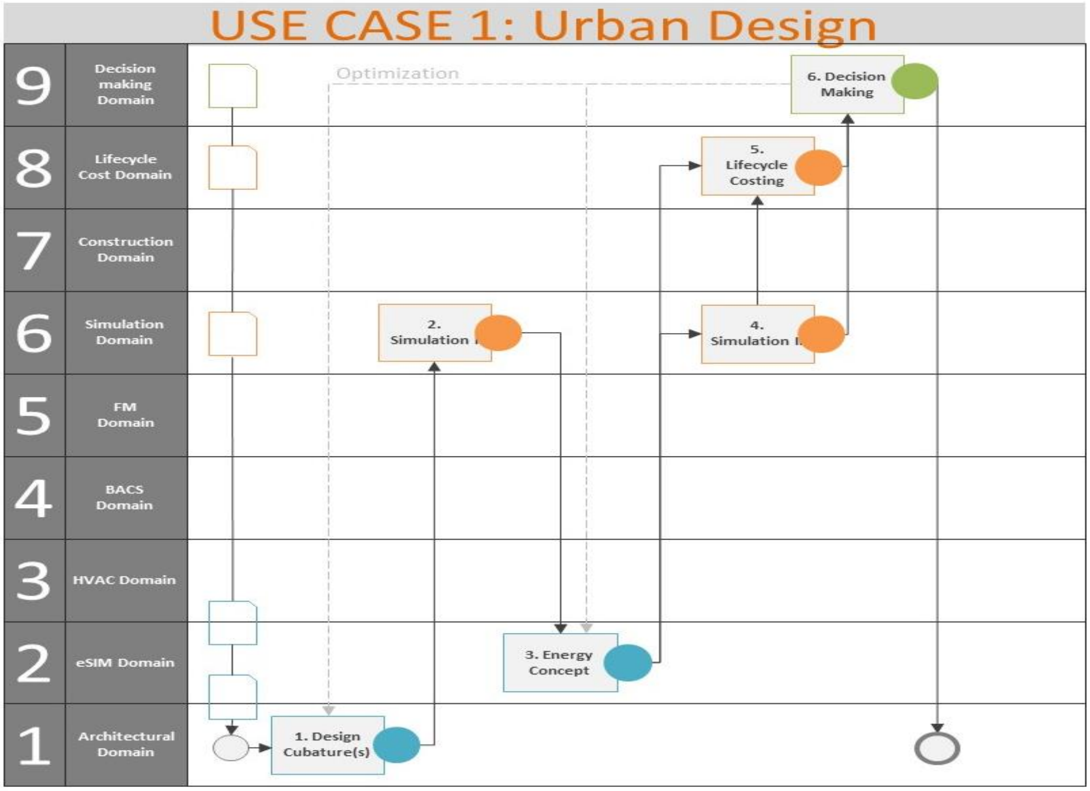

Fig.9. Simplified representation of the use case with color-coded Key Points

Table 1. eeEmbedded: KDR/KPI/DV examples for Urban Design

Use Case 1: Urban Design		
Domain	**Type**	***ee*Embedded examples**
1 Architectural	**KDR**	• **Site use** ○ Density Gross Floor Area/Site Area [%] ○ Landscaping vegetation/build area [%] ○ Functional relations of building types [-] • **Building shape** ○ Compactness A/V [m^{-1}] ○ Form l/w/h [m] ○ Size of the zone [m^2, m^3] • **Orientation** ○ Building orientation N/S; E/W [°] ○ Orientation of the main rooms N/S; E/W [°] • **Building shell** ○ Facade open / close [%] ○ Insulation standard [W/(m^2*K)] ○ Roof slope [°] / Roof area [m^2]
6 Simulation	**KPI**	• **Cooling and heating demand - net energy [kWh/a, kWh/(m^2 x a)]** ○ Solar gains [W/m^2] ○ Heat losses / cooling losses [kWh/(m^2xa] ○ Peak loads [kW; kW/m2] • **Comfort Conditions** ○ Physiological Equivalent Temperature [°C] ○ Air flow rate [m^3/h] ○ Shading / Daylight [% , unit/h]
2 Energy System	**KDR**	• **Renewable energy** ○ On-site renewables (ground, solar, wind, biomass) [%] ○ District heating and cooling [%] ○ Waste heat [%]

Use Case 1: Urban Design		
Domain	**Type**	***ee*Embedded examples**
		• **Demand profiles** ○ Schedule energy demand [h] ○ Energy demand [kWh/a] ○ Peak loads [kW/a] • **System operating requirements** ○ Temperature of working fluids [Tin,max, Tout,max, Tin,min, Tout,min] ○ Pressure restrictions (p, Δp) • **Space restrictions** ○ Technical rooms [m2] ○ Distribution systems [horizontal / vertical]
6 Simulation	**KPI**	• **Energy consumption [kWh/a, kWh/(m^2 x a), Top/a, Top/(m^2 x a)]** ○ Overall efficiency [%] ○ Percentage of thermal energy demand covered [%]
8 Life Cycle Costing	**KPI**	• **Life Cycle Costs [€]** ○ Investment costs [€] ○ Operation costs [€] ○ Maintenance costs [€] • **Payback [a]**
9 Decision-making	**DV**	• **Principle decision [suits / do not suit]** • **Sustainable score [medal]** ○ Ecological quality [points/total points of category] ○ Socio-cultural quality [points/total points of category] ○ Economical quality [points/total points of category] • **Asset value [€]**

Conclusions and further work

In this paper a new concept for a holistic design methodology was presented based on hierarchically structured dynamic evolving Key Points, expressed in aggregated requirements: KDRs, Key Design requirements for ruling out options for domain related tasks, KPIs, Key performance indicators for performance evaluation and optimization, and finally DVs, Decision Values for prioritisation and decision making. This design method is proposed to guide and monitor the progress of the multi-disciplinary, multi-model and multi-physics design process. The holistic design methodology approach has been chosen to optimize the design path and design process as well as increase coordinated decision-making.

In a next step, building requirements will be classified, and represented, in a taxonomy structure. In parallel, Key Design Requirements, Key Requirement Parameters as well as Key Performance Indicators will be examined in taxonomies to find multi combinations regarding to the building requirements.

The proposed approach is currently under development and is also being extended from the results of the European FP7 projects HESMOS (2010-2013) and ISES (2011-2014) in the direction of a multi-model energy enhanced BIM framework (eeBIM). The outlined concept for a holistic design methodology will be intensively further investigated, elaborated and validated in the frames of the eeEmbedded project. The requirements and specifications of the new design methodology and the new (ICT) combined virtual design office for teamwork collaboration and the virtual design lab for energy analysis and simulation will be developed are current under development. The development of the supporting information and communication technology (ICT) methods, namely the collaborative holistic design lab and office will start in autumn 2014. Development and implementation of this new building design methodology would have significant implication for sustainable energy entrepreneurship, which is significant driving force of sustainable development process.

References

Bileišis, M. 2014. Public Sector Control as a Factor in Entrepreneurial Policy: the Case of Lithuania, *Entrepreneurship and Sustainability Issues* 1(3): 151–161. DOI: http://dx.doi.org/10.9770/jesi.2014.1.3(4)

Korsakienė, R.; Tvaronavičienė, M. 2014. Processes of economic development: case of Lithuanian real estate sector, *Entrepreneurship and Sustainability Issues* 1(3): 162–172. DOI: http://dx.doi.org/10.9770/jesi.2014.1.3(5)

Dzemyda, I.; Raudeliūnienė, J. 2014. Sustainable youth entrepreneurship in conditions of global economy toward energy security, *Entrepreneurship and Sustainability Issues* 1(4): 247–256. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(7)

Eastman, C.; Teicholz, P.; Sacks, R.; Liston, K. 2011. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors.* John Wiley & Sons. 2nd edition.

eeEmbedded [online], http://www.eeEmbedded.eu.

eeEmbedded 2013-17, EU FP7 Project No. 609349.

Geißler, M.C.; Guruz, R.; van Woudenberg, W. 2014; eeEmbedded Deliverable D1.1: Vision and requirements for a KPI-based holistic multi-disciplinary design, © eeEmbedded Consortium, Brussels.

Guruz, R.; Katranuschkov, P.; Scherer, R.J.; Kaiser, J.; Grunewald, J.; Hensel, B.; Kabitzsch, K.; Liebich, T. 2012. Ontological Specification for the Model Integration in ICT Building Energy Systems, to be published in: Proceedings of the 9th European Conference on Process and Product Modelling, 25-27.07.2012, Reykjavik, Iceland.

Harris, D.; Higgins, C. 2012. Key Performance Indicators and Analysis for Commercial Buildings with System Level Data, New Buildings Institute. Available on the Internet: <http://newbuildings.org/kpi>.

Laužikas, M.;Mokšeckienė. 2013. The role of creativity in sustainable business, *Entrepreneurship and Sustainability Issues* 1(1): 10–22. DOI: http://dx.doi.org/10.9770/jesi.2013.1(2)

Litvaj, I.; Poniščiaková, O. 2014.Entrepreneurship and quality management, *Entrepreneurship and Sustainability Issues* 1(4): 204–209. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(2)

Raudeliūnienė, J.; Tvaronavičienė, M.; Dzemyda, I. 2014. Towards economic security and sustainability: key success factors of sustainable entrepreneurship in conditions of global economy, *Journal of Security and Sustainability Issues* 3(4): 71–79. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(7)

Scherer, R.J.; Schapke, S.-E. 2011. A Distributed Multi-Model-Based Management Information System for Simulation and Decision-Making on construction projects, *Advanced Engineering Informatics* 25(4): 582–599.

Schreyer, M.; Bögl, M.; Benning, P. 2010. A Smart Decision Making Framework for Building Information Models, InPro Public Report of Deliverable iewD10, January 2010, Dortmund.

Tvaronavičienė, M. 2014. If industrial sector development is sustainable: Lithuania compared to the EU, *Entrepreneurship and Sustainability Issues* 1(3):134–142. DOI: http://dx.doi.org/10.9770/jesi.2014.1.3(2)

Tvaronavičienė, M.; Šimelytė, A., Lace, N. 2014. Sustainable development facets: exporting industrial sectors from inside, *Journal of Security and Sustainability Issues* 3(4): 37–44. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(4)

Vasiliūnaitė, R. 2014. Sustainable development: methodological approaches toward issues, *Journal of Security and Sustainability Issues* 3(3): 69–75. DOI: http://dx.doi.org/10.9770/jssi.2014.3.3(6)

Vosylius, E.; Rakutis, V.; Tvaronavičienė, M. 2013. Economic growth, sustainable development and energy security interrelation, *Journal of Security and Sustainability Issues* 2(3): 5–14. DOI: http://dx.doi.org/10.9770/jssi.2013.2.3(1)

Romy GURUZ, Graduate Student, Technische Universität Dresden, Civil Engineering, Germany.

Prof. Dr. Ing. Raimar Joseph SCHERER, Head of the Institute for Construction Informatics Department of Civil Engineering TU Dresden, Germany.

International Centre for
Entrepreneurship Research

ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES
ISSN 2345-0282 (online) http://jssidoi.org/jesi/aims-and-scope-of-research/

SUSTAINABLE DISTRICT DEVELOPMENT: A CASE OF THERMOECONOMIC OPTIMIZATION OF AN ENERGY HUB

Alessandra Cuneo[1], Mario L. Ferrari[2], Alberto Traverso[3], Aristide F. Massardo[4]

[1,2,3,4] University of Genoa
DIME – Thermo-chemical Power Group (TPG) Via Montallegro,1
16145 Genova, Italy

E-mail: alessandra.cuneo@edu.unige.it

Received 10 September 2014; accepted 20 November 2014

Abstract. Sustainable distric development requires innovative energy use solutions. The aim of this paper is to illustrate the operation of a real energy hub that can satisfy both thermal and electrical demands of a generic user. In particular, a specific case study developed around the smart grid of the University Campus of Savona (Italy), which just completed in 2014, is analysed. The grid includes different cogenerative prime movers and a storage system to manage the thermal load demand. Through a time-dependent thermo-economic hierarchical approach developed by the Authors, the work aims at optimizing the management strategy of the different prime movers to satisfy the energy demand, taking into proper account both the energetic and economic aspects. The analysis was carried out considering two different layouts, with and without a conventional stratified thermal storage, to evaluate the impact of this component in the management of the district.

Keywords: sustainable development, energy, smart grid, cogeneration, thermoeconomic optimization, thermal storage

Reference to this paper should be made as follows: Cuneo, A.; Ferrari, M.L.; Traverso, A.; Massardo, A.F. 2014. Sustainable district development: a case of thermoeconomic optimization of an energy hub, *Entrepreneurship and Sustainability Issues* 2(2): 74–85.
DOI: http://dx.doi.org/10.9770/jesi.2014.2.2(3)

JEL Classifications: R11, 04, 031, M1, Q4

Nomenclature
P power [kW]
C Cost [€]
c Specific cost [€/kWh]
E Electricity flow [kWh]
F Fuel consumption [kg]
Q Heat flow [kWh]
<u>Subscripts</u>
el electrical
th thermal
var variable
virt virtual
acq acquired
<u>Acronyms</u>
mgt MicroGasTurbine
ice InternalCombustionEngine

1. Introduction

According to the strategy for Climate Action, implemented by the European Commission in 2008, the Member States will reduce their collective greenhouse gas emissions by at least 20% and boost the share of renewable energy to 20% of total consumption by 2020 (UNEP 2012). In addition, the European Union has set an indicative objective to reduce its primary energy consumption by 20% compared with the projected 2020 energy consumption (EC, The "20-20-20" targets 2010). Issues related to implementation of targets set are widely discussed in scientific literature (Stańczyk 2011; Białoskórski 2012; Lankauskienė, Tvaronavičienė 2012; Balkienė 2013; Miškinis *et al.* 2013; Vosylius *et al.* 2013; Dzemyda, Raudeliūnienė 2014; Tvaronavičienė 2014; Korsakienė, Tvaronavičienė 2014; Laužikas, Mokšeckienė 2013; Baublys *et al.* 2014; Tvaronavičienė *et al.* 2014; Vasiliūnaitė 2014).

Sustainable districts' development oriented to set targets requres innovative solutions in energy sector. We believe, that in this context a primary role is played by the Distributed Generation (DG), which refers to the electrical and thermal generation located near to the place of use, exploiting available renewable sources. One of the best way to exploit the emerging potential of DG is to take a system approach which views generation and associated loads as a whole concept called "microgrid". The major benefits can be divided into two categories: economic and operational (El-khattam 2004). From an economic point of view, distributed generation provides power support when load increases during peak demand periods, thus reducing interruption that may lead to system outages. It also reduces the risk of investment, due to the flexibility of its capacity and installation placement. Distributed generation cuts operational costs when installed close to the customer load because it avoids upgrading or setting up a new transmission and distribution network, thereby providing a cost saving. From the operational point of view, distributed generation warranties the reliability and stability of supply and reduces power losses.

These main aspects increase the interest of researchers on distributed polygeneration grids at both industrial and academic levels. Specifically, the Thermochemical Power Group (TPG) of the University of Genoa is involved in a four years European Collaborative project called E-HUB (Energy-HUB for residential and commercial districts and transport). An E-hub is similar to an energy station in which some different forms of energy are used in order to satisfy the energy demand of the district. Both consumers and suppliers of energy should be connected to this E-hub by means of bi-directional energy grids (low and/or high temperature heat grid, cold grid for cooling, electrical grid, gas grid). The main aim of the hub is to distribute the energy in the smart way over the consumers. The "smartness" is also in the management system, where control strategies aiming at the optimization of technical, economic and environmental issues are typically implemented.

Under such conditions storing energy will become beneficial, because those who can store energy can generate flexibility and make use of market opportunities. An important difference between electrical and thermal energy is that heat can be stored more easily and efficiently. So, thermal storage will be one of the first candidates to support smart grids. Heat pumps, CHPs and other devices convert electrical power into heat or vice versa and can do this when the market conditions are best (Ferrari *et al.* 2014).

Aim of this paper is to study the best management of the energy hub installed in Savona Campus with studying in particular the better operational strategy of the e-hub if a thermal storage is installed. So the same simulation was carried out considering with or without this component.

2. E-hub description

The facilities installed are based on different technologies with the aim to produce both electrical and thermal energy: the poly-generation smart grid analyzed here is based on the one installed at the TPG laboratory of the University of Genoa (Ferrari *et al.* 2012).
T
he test rig considered in this work (Fig.1) is based on the following technology (both electrical and thermal energy):

- a 100 kW_{el} recuperated micro gas turbine (T100 PHS Series): nominal electrical efficiency of 30% and thermal efficiency of 47%;

- 20 kW_{el} internal combustion engine (TANDEM T20-A): nominal electrical efficiency of 29% and thermal efficiency of 68%;
- 5000 l storage tank.

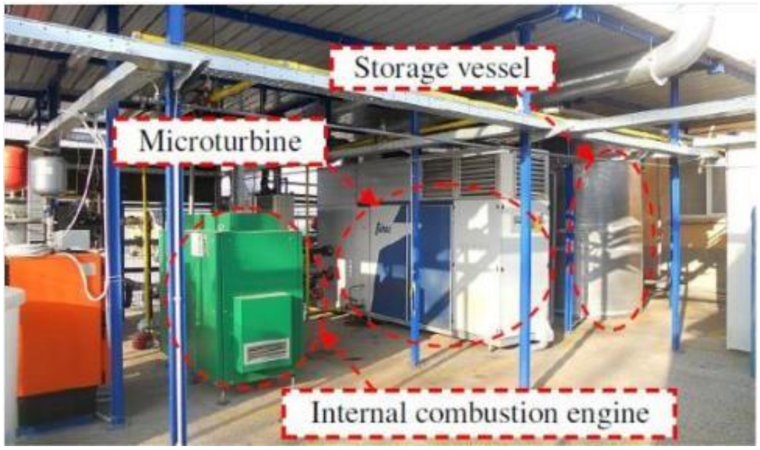

Fig.1. Test rig

Since the test rig is real installed in a University Campus and from the next winter it will contribute to satisfy the load demand of the Campus, the aim of this paper is to find the best operational strategy of the prime movers taking into account only the variable cost and not the economic parameters (like NPV or PBP) because there is no investment for the machine.

3. ECoMP description

ECoMP (Economic Cogeneration Modular Program) is an original software developed by the Thermochemical Power Group (TPG), at the University of Genoa, aiming at thermo-economic time-dependent analyses and optimization of energy systems, including off-design conditions (Rivarolo *et al.* 2013). Recently, a standard component interface (NeWECoMP) has been added to the software, allowing for the implementation of the most complex plant lay-outs with a user-friendly interface.

ECoMP is characterized by a modular approach and a standard component interface. It maintains the flexibility and the extendibility of the library components (46 modules are available at the moment), allowing users to add new components without modifying the core of the software (Yokoyama and Oseb 2012). Each component is described by three subroutines, which define mass and energy flows, off-design performance curves, variable and capital costs. Thanks to its modular approach, ECoMP allows to analyze various plant solutions, searching for the optimal dimensioning and/or for the best strategy of management from the thermo-economic point of view.

The Figure 2 shows how, given as an input the economic environment and the electrical and thermal loads, taking into account the connection to the power grid, the desired plant optimisation is obtained.

The choice of the design conditions and optimal management is carried out by pursuing a very clear goal: minimize the total cost calculated over the considered period. For the definition of the total cost, two items must be considered:

- Fixed cost
- Variable cost

The first considers the capital cost of each component and it is a function of size, the second one takes into account the consumption of energy and fuel and depends on the chosen operational strategy.

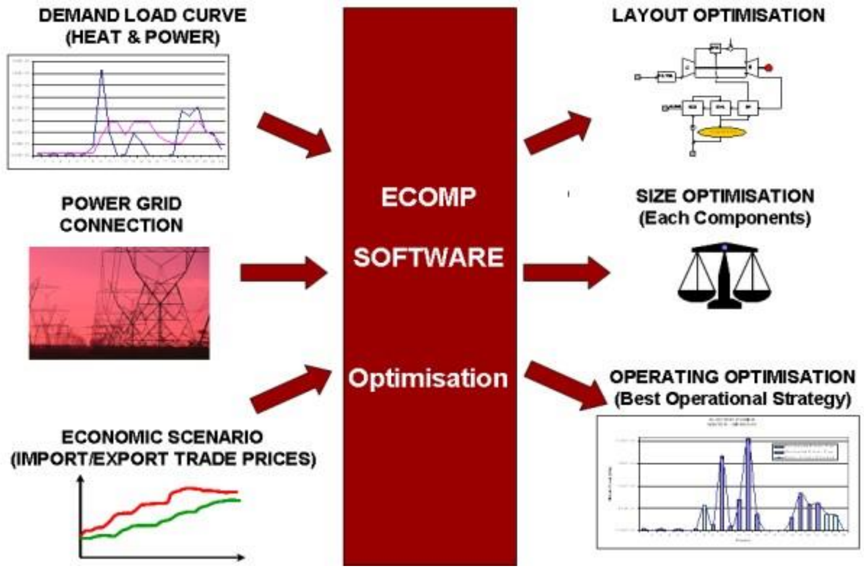

Fig.2. General structure of ECoMP

First of all, the software loads the input data, which are stored in specific matrices and report information about ambient temperature, user electrical demand, user thermal demand, etc.. Secondly, it calculates the component fixed costs, using internal cost functions. Finally, it calculates the variable costs basing on the decided operational strategy and the prime movers off-design performance curves. The revenues, obtained from the sale of electrical or thermal energy to the network, are considered as negative costs and then lower the objective function to be minimized. The input file of requested energy must be completed in a timely manner, and it contents information about the operation/non operation days. The operating days are divided into a number of periods: one of the most important features of ECoMP is the possibility of performing analysis for whatever number of periods, depending on the plant under analysis; moreover, it is possible to choose the number of seconds which a single period is made of.

ECoMP software uses built-in cost equations, which evaluate the capital cost of the single components of the plant based on installed power (gas turbines, internal combustion engines, boilers, fuel cells, solar panels, etc.) or volume (thermal storage), or other relevant parameters. The cost functions for different modules were developed and updated thanks to the contribution of industrial partners over the last few years, from literature data and from commercial offers collected during the Energy-Hub construction (Turbec SpA... 2012; asJagen, SpA..2013).

In order to improve the reliability of the simulation results, the off-design curves of the prime movers installed in the plant have been implemented in the software. These curves have been extracted from experimental tests. The curves refer to the internal combustion engine TANDEM T20, as well as to the micro gas turbines Turbec T100. The curves are plotted as a function of the electrical power, taking into account three different indicators: thermal power produced by the mover (black line), electrical efficiency (blue line) and fuel consumption (red line). All the values are compared to the nominal ones, as shown in Figure 3 (Ferrari 2014).

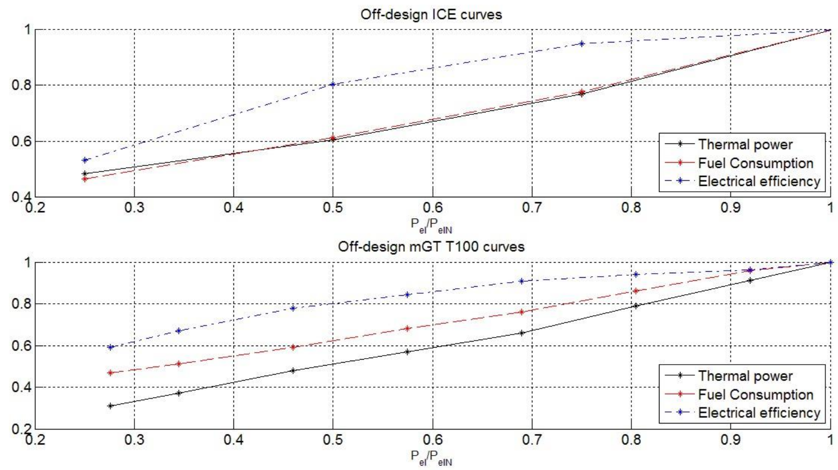

Fig.3. Performance curves for prime movers

Two different optimization levels can be investigated by ECoMP: a low and a high level. At the low level, the size of the components is considered fixed (therefore, capital costs are fixed) and the software employs a genetic algorithm in order to determine the best operational strategy. The choice of the use of a genetic algorithm to solve this kind of problem and the advantages/disadvantaged respect to other technique/programme is well described in (Carroll 1996).
In this case, the software aims to minimize the objective function (Eq. 1), which represents the hourly (or less) variable costs, as follows:

$$C_{\text{var}} = F_i \cdot \sum_{i=1}^{N} c_{fuel,i} + c_{el} \cdot E_{acq} + c_{virt} \cdot \left(F_{virt} + E_{virt} + Q^{*}_{virt}\right) \quad (1)$$

Variable costs are made up of the following terms: (i) fuel consumption costs, (ii) electrical energy costs, and (iii) ‘‘virtual costs’’. The electrical energy costs term represents the product of the electrical energy purchased from the external grid and the specific cost of electricity: when the electricity produced by the plant is not sufficient to satisfy the electrical load, which is one of the problem constraints, electricity is purchased from the external grid. It is important to underline that “virtual flows” represent energy exchanges between the plant and the external environment, necessary to satisfy the optimization constraints (i.e. load demands). Since these amounts of energy cannot be produced by the plant, penalty costs are associated with virtual flows. Since the term c_{virt} assumes a high value (two orders of magnitude higher than the other specific cost terms), the optimization process is forced to find an operational strategy which minimizes virtual flows.

The results of the optimisation process and some additional input data are passed to the economic subroutine for the investment analysis, which is carried out considering a variety of economic scenario parameters (e.g.: construction time, inflation, escalation rates, plant life, financial interests, etc.).

4. Main inputs for the thermo-economic analysis

As mentioned before, a large number of inputs, most of them related to the site where the plant is installed, must be considered in the thermo-economic optimization approach. This section details the main plant data considered for the analysis. The simulation was carried out for three hours considering five minutes as time step.

a) Electricity and thermal load curves: they represent the main optimization problem constraint. The software receives the time dependent electrical/thermal load demands as input, which must be satisfied in each period of the year using electricity produced by the generators or by purchasing electricity from the National grid.
For this study Fig. 4 and 5 represent the thermal and electrical demand considered.

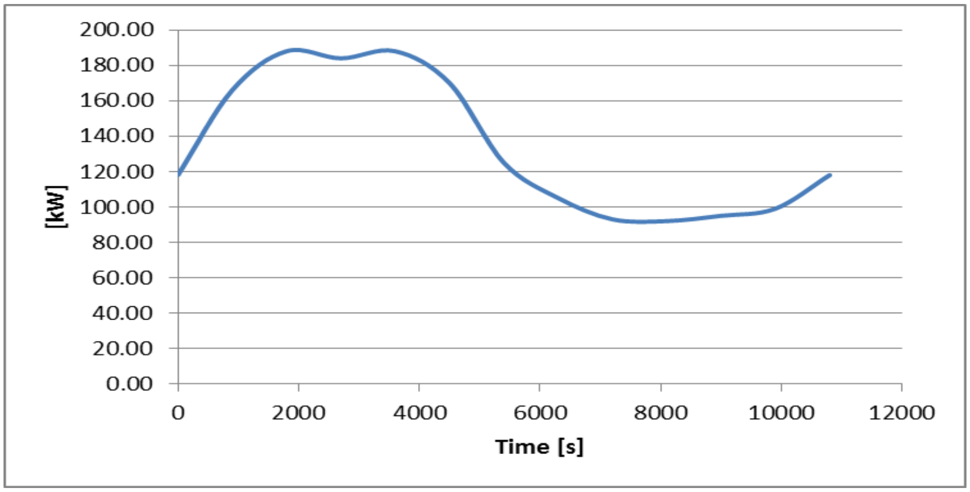

Fig.4. Thermal demand profile

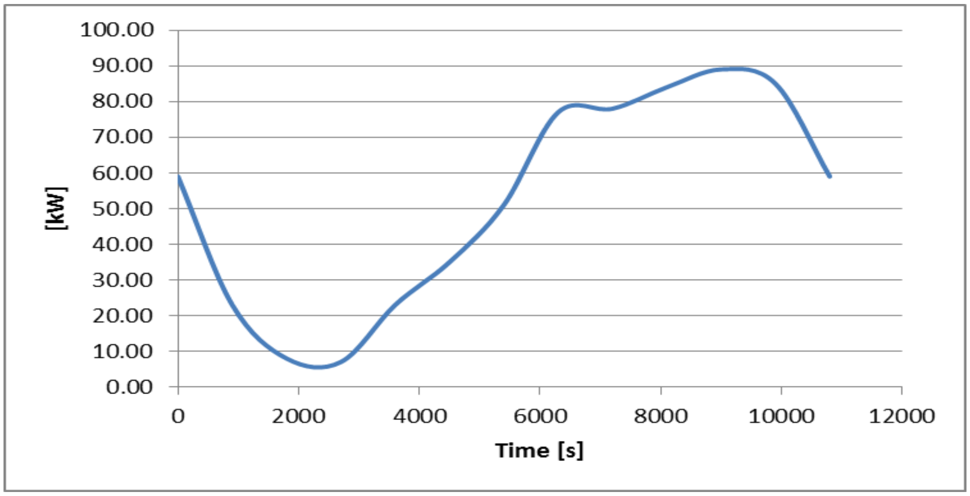

Fig.5. Electrical demand profile

It is important to underline that electrical and thermal demand are conflicting. This creates a problem for the management of the plant, especially in the first case without the thermal storage, since there is no flexibility in the thermal demand.

b) Operating costs: they have been evaluated starting from statistic data available from Eurostat (Cassa Depositi e Prestiti 2013; Market Analysis 2014). Italian case study has been taken into consideration and global values are summarized in Table 1.

Table 1. Energy cost

Electricity cost [€/kWh]	0.2
Electricity price [€/kWh]	0.1
Thermal energy [€/kWh]	0.1
Gas [€/kg]	0.25

It has to be said the distinction between Electricity cost and Electricity price is due to different value in terms of money associated to energy bought from the grid or sold back to. Value of thermal energy has been evaluated by considering a 90% efficiency boiler.

5. Simulation and results

WITHOUT STORAGE

The first test simulated with ECoMP was without a thermal storage; in this way the system is forced to satisfy the heat demand in a timely manner, without exception.

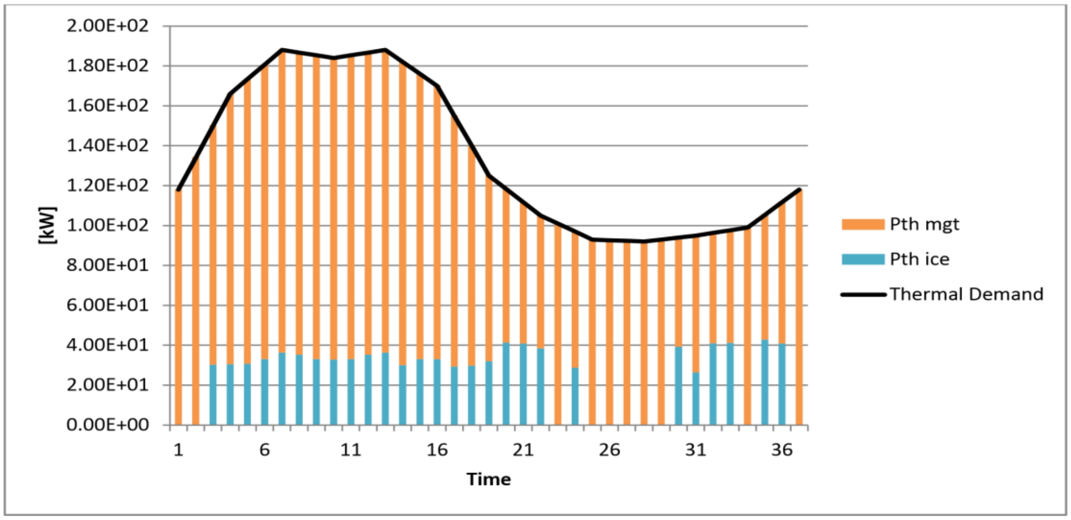

Fig.6. Thermal generation/consumption without thermal storage

Figure 7 shows the results for electricity production/consumption. It can be immediately seen how the request (black curve) and production (orange and blue line) have different trends and are not related each other. This behaviour is due to the constraints regarding the heat commodity imposed during the test (i.e. no thermal demand flexibility). The plant is, in fact, in the position of having to meet a given heat load without having the possibility to store thermal energy; electricity production, on the other hand, has the ability to interact with the grid network.

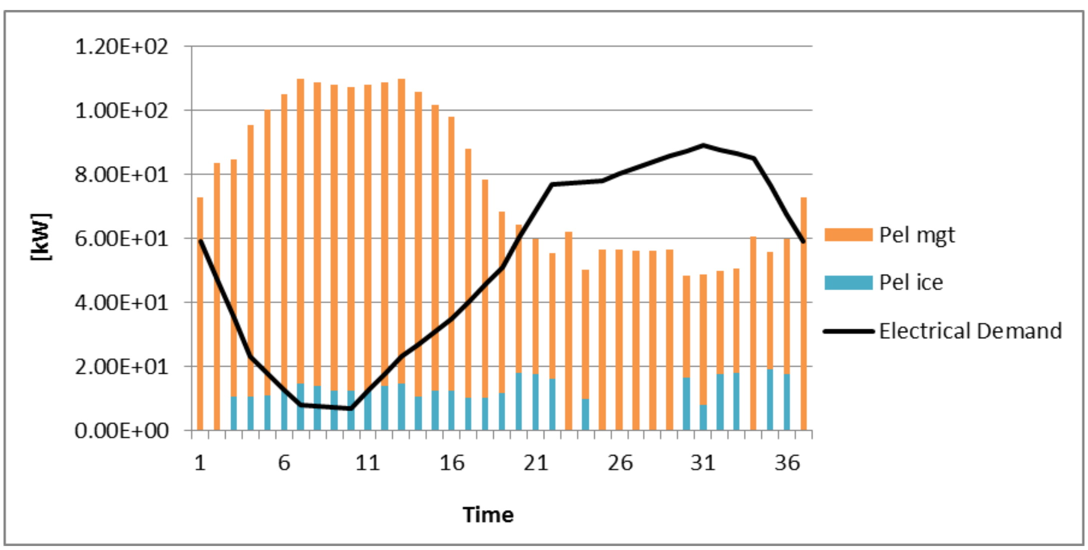

Fig.7. Electrical generation/consumption without thermal storage

Analysing the power levels of CHP (Combined Heat and Power) generators, it can be observed that the production of the microturbine is always higher than the internal combustion engine; this is due both to the choice made by the control system (i.e. ECoMP optimiser) and the different size of the two machines. Secondly, the microturbine is maintained almost constantly close to the nominal working point, while most of the adjustments are assigned to the internal combustion engine. Table 2 summarizes the energetic parameters of the plant.

Table 2. Energetic Results

Electricity Consumed [kWh]	1.92E+03
Electricity Production [kWh]	2.86E+03
Electricity sold to the grid [kWh]	1.35E+03
Electricity bought from the grid [kWh]	4.06E+02
Fuel Consumption [kg]	7.81E+01

WITH STORAGE

The second analysis was performed including the use of thermal storage. In this case, the system can exploit one additional degree of freedom, thanks to the flexibility on the thermal demand/load; the model, in fact, is no longer required to meet the heat demand in a timely manner, without exception, but it can depart from that request within the limits of the storage.

Analyzing the curves of the request and production it can be seen that the two curves have nearly the same trends for quite all the time; this behaviour does not differ from that recorded in the previous simulation without storage. During the peak of the thermal demand, where the electrical load is very low, the storage help to satisfy the request keeping off the internal combustion engine and at the maximum power the micro-gas turbine.

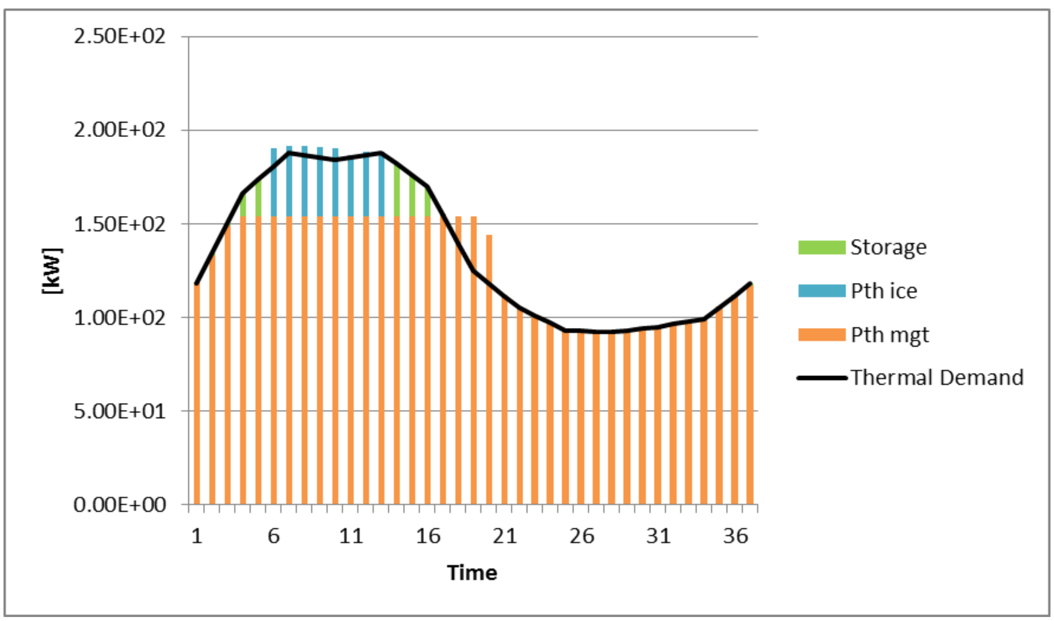

Fig. 8. Thermal generation/consumption with thermal storage

In Figure 9 it is possible to see how the request and the production have different trends, as the thermal demand dominates, despite the additional flexibility introduced by the thermal storage. The flow of energy exchanged with the grid network indicates intense exchanges where the production deviates from the demand. This condition occurs in two periods during the simulation, in particular:

• At the beginning, when production definitely overmatches, this configuration is characterized by a large sale of electricity (it reaches a maximum power of almost 100 kW)
• Subsequently, since the storage is almost fill, the thermal demand is covered exactly by the mGT taking switch off the ICE. This configuration is clearly biased in favour of an underproduction compensated by a large purchase of electricity (indicated by the purple curve). Also in this case the network balances the mismatch, providing a maximum power of about 39 kW.

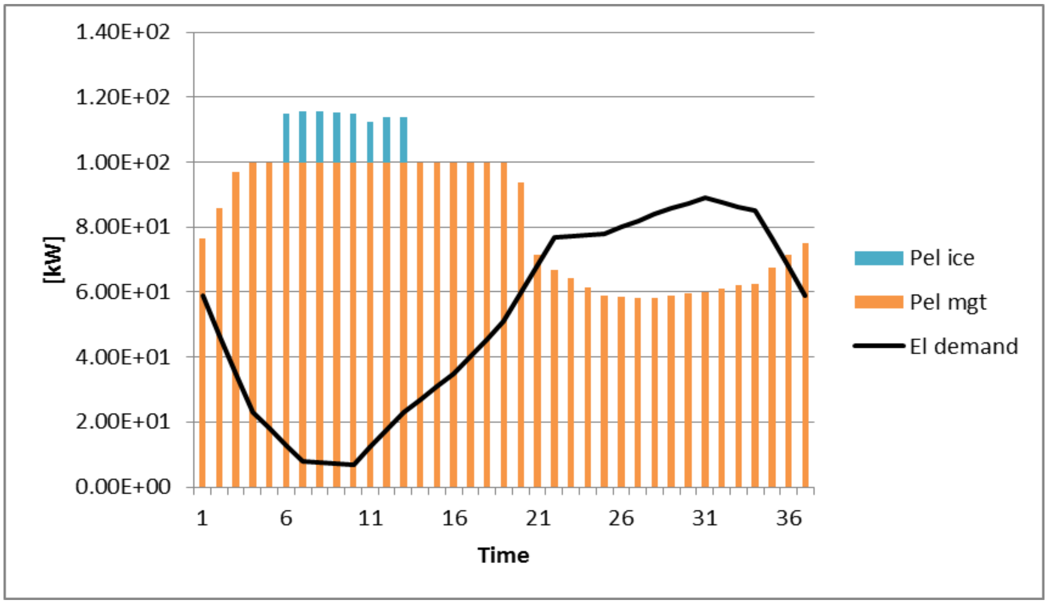

Fig.9. Electrical generation/consumption with thermal storage

Table 3 summarized the energetic parameters of the plant.

Table 3. Energetic Results

Electricity Consumed [kWh]	1.92E+03
Electricity Production [kWh]	3.14E+03
Electricity sold to the grid [kWh]	1.52E+03
Electricity bought from the grid [kWh]	2.96E+02
Fuel Consumption [kg]	7.30E+01

It is possible to notice that the use of a thermal storage in the management of a smart grid brings an improvement in the energetic consumption of the plant. In fact, with respect to the solution without a thermal storage, the electricity produced by the prime movers is higher, this caused a reduction of the electricity bought from the grid and an increase of revenues from the electricity sold to the grid (Figure 10).

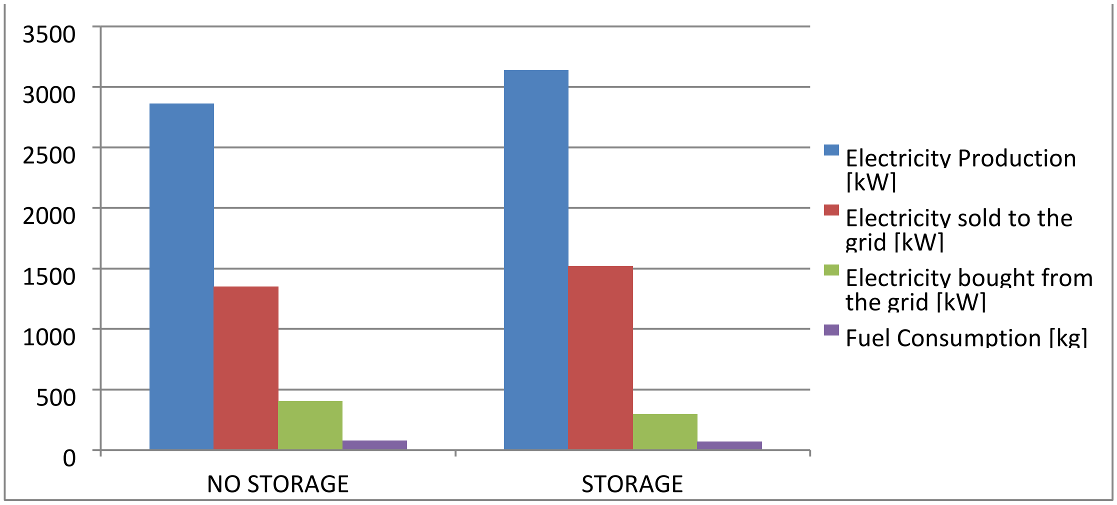

Fig.10. Energetic Comparison

Based on the operating cost in Table 4, it is possible to evaluate the variable cost for both configuration evaluating the economic improvement if the thermal storage.

Table 4. Economic results

	Without thermal storage	**With thermal storage**
Revenues [€]	633.70	650
Costs [€]	81.20	78.73
Profit [€]	522.5	571.97

Considering how the machine work in both case (Figure 11), the use of thermal storage have an important impact in the management of the mGT because it works for a longer time in nominal condition, with an important reduction of the time in off design. This is very significant since when the mGT operates outside of its nominal conditions, average efficiency decreases and the impact of maintenance costs on the energy produced increases. On the other hand, the ICE, in the configuration with thermal storage, never works in nominal condition and it is switch off for a longer time.

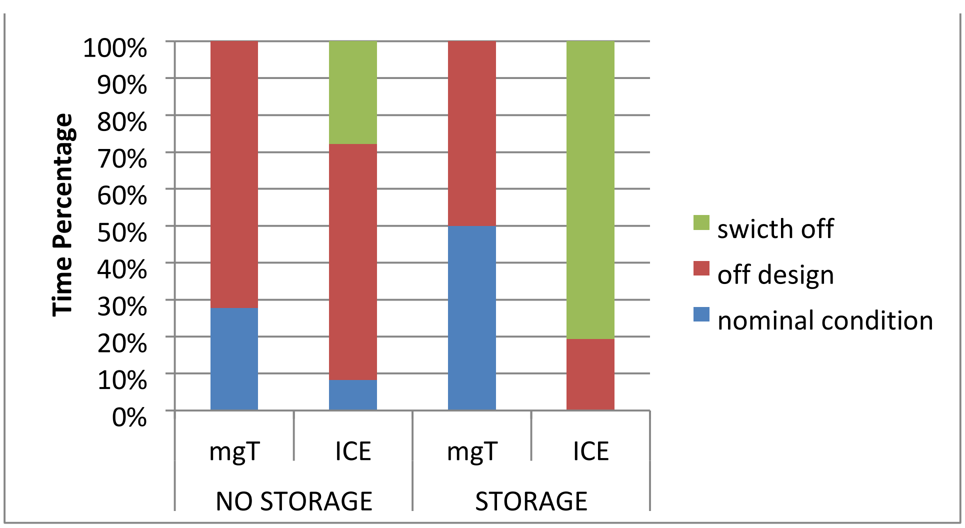

Fig.11. Comparison of time percentage of the prime movers with and without thermal storage

Conclusions

In this paper the Energy Hub installed in the Savona Campus of the University of Genoa, Italy, to satisfy the thermal and electrical demands was analysed via a thermo-economic approach, employing the software ECoMP. In particular the impact of thermal storage was investigated. From the results, it can be inferred that the thermal storage has a considerable impact in the system behaviour. The use of a thermal storage to management better the thermal demand, have an improvement not only in the energetic results but also in the economic one with a reduction of about 4% in the variable costs. So, it can be concluded that a relatively simple device, as a conventional water stratified thermal storage, can have a significant positive impact on system performance, provided that proper control algorithms are employed. Implementation of suggeted innovative solution contributes to sutainable development of district and facilitates meating goals set by the EU.

Reference

asJagen, SpA, Tandem Technical Description, ST_Ver. 3a_13, 2013.

Balkienė, K. 2013. Sustainable innovativeness: issues and public policy, *Journal of Security and Sustainability Issues* 3(2): 53–76. DOI: http://dx.doi.org/10.9770/jssi.2013.3.2(5)

Baublys, J.; Miškinis, V.; Konstantinavičiūtė, I.; Lekavičius, V. 2014. Aspirations for sustainability and global energy development trends, *Journal of Security and Sustainability Issues* 3(4): 17–26. DOI:http://dx.doi.org/10.9770/jssi.2014.3.4(2)

Białoskórski, R. 2012. Cyberthreats in the security environment of the 21st century: attempt of the conceptual analysis, *Journal of Security and Sustainability Issues* 1(4): 249–260. DOI: http://dx.doi.org/10.9770/jssi.2012.1.4(2)

Carroll, D.L. 1996. Chemical Laser Modelling with Genetic Algorithms, *AIAA Journal* 34: 338–346.

Cassa Depositi e Prestiti – Studio di Settore [Market Analysis] "Il Mercato del Gas Naturale in Italia: lo sviluppo delle infrastrutture nel contesto europeo" – Italy, March 2013.

Dzemyda, I.; Raudeliūnienė, J. 2014. Sustainable youth entrepreneurship in conditions of global economy toward energy security, *Entrepreneurship and Sustainability Issues* 1(4): 247–256. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(7)

EC.The "20-20-20" targets. 2010. Available at <http://ec.europa.eu/clima/policies/package/index_en.htm>.

El-khattam, W. 2004. Distributed Generation Technologies, definitions and benefits, *Electric Power Systems Research* 71: 109–121.

Energy-HUB for residential and commercial districts and transport. Available online: <http://www.e-hub.org/> [Accessed 10 July 2014]

Ferrari, M.L.; Pascenti, M.; Sorce, A.; Traverso, A.; Massardo, A.F. 2014. Real-time tool for management of smart polygeneration grids including thermal energy storage, *Applied Energy* 30: 670–678. DOI:10.1016/j.apenergy.2014.02.025 (article in press)

Ferrari, M.L.; Pascenti, M.; Traverso, A.; Rivarolo, M. 2012, Smart Polygeneration Grid: a New Experimental Facility, ASME Paper GT2012-68585, ASME Turbo Expo 2012, Copenhagen, Denmark.

Ferrari, M.L.; Traverso, A.; Pascenti, M.; Massardo, A.F. 2014. Plant management tools tested with a small-scale distributed generation laboratory, *Energy Conversion and Management* 78: 105–113.

Yokoyama, R.; Oseb, S. 2012. Optimization of energy supply systems in consideration of hierarchical relationship between design and operation, *Proceedings of 25th International Conference on Efficiency, Cost, Optimization and Simulation of Energy Conversion Systems and Processes*, Perugia (Italy), 26-29 June 2012.

Korsakienė, R.; Tvaronavičienė, M. 2014. Processes of economic development: case of Lithuanian real estate sector, *Entrepreneurship and Sustainability Issues* 1(3): 162–172. DOI:http://dx.doi.org/10.9770/jesi.2014.1.3(5)

Lankauskienė, T.; Tvaronavičienė, M. 2012. Security and sustainable development approaches and dimensions inn the globalization context, *Journal of Security and Sustainability Issues* 1(4): 287–297. DOI: http://dx.doi.org/10.9770/jssi.2012.1.4(5)

Lažikas, M.; Mokšeckienė, R. 2013. The role of creativity in sustainable business, *Entrepreneurship and Sustainability Issues* 1(1): 10–22. DOI: http://dx.doi.org/10.9770/jesi.2013.1(2)

Miškinis, V.; Baublys, J.; Lekavičius, V.;Morkvėnas, A. 2013. New Changes in Lithuanian Energy Sector, *Journal of Security andSustainability Issues* 2(3): 15–28. DOI: http://dx.doi.org/10.9770/jssi.2013.2.3(2)

Rivarolo, M.; Greco, A.; Massardo, A.F. 2013. Thermo-economic optimization of the impact of renewable generators on poly-generation smart grids including hot thermal storage, *Energy Conversion and Management* 65: 75–83.

Stańczyk, J. 2011. European security and sustainability issues in the context of current international environment, *Journal of Security and Sustainability Issues* 1(2): 81–90. DOI: http://dx.doi.org/10.9770/jssi.2011.1.2(1)

Turbec SpA, D14127-02 Descrizione Tecnica Ver.2, 2012

Tvaronavičienė, M. 2012. Contemporary perceptions of energy security: policy implications, *Journal of Security and Sustainability Issues* 1(4): 235–247. DOI: http://dx.doi.org/10.9770/jssi.2012.1.4(1

Tvaronavičienė, M. 2014. If industrial sector development is sustainable: Lithuania compared to the EU, *Entrepreneurship and Sustainability Issues* 1(3):134–142. DOI: http://dx.doi.org/10.9770/jesi.2014.1.3(2)

Tvaronavičienė, M.; Šimelytė, A., Lace, N. 2014. Sustainable development facets: exporting industrial sectors from inside, *Journal of Security and Sustainability Issues* 3(4): 37–44. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(4)

UNEP 2012. The Emissions Gap Report 2012. United Nations Environment Programme (UNEP), Nairobi.

Vasiliūnaitė, R. 2014. Sustainable development: methodological approaches toward issues, *Journal of Security and Sustainability Issues* 3(3): 69–75. DOI: http://dx.doi.org/10.9770/jssi.2014.3.3(6)

Vosylius, E.; Rakutis, V.; Tvaronavičienė, M. 2013. Economic growth, sustainable development and energy security interrelation, *Journal ofSecurity and Sustainability Issues* 2(3): 5–14. DOI: http://dx.doi.org/10.9770/jssi.2013.2.3(1)

Alessandra CUNEO (Ph.d student). Alessandra Cuneo was born in Genoa in 1989. She obtained her Master Degree in Environmental Engineering: Sustainable Development and Risk Management at University of Genoa in 2015. She started to work at TPG with a scholarship in 2013 and she carried out research about distribution generation, smart poly-generation grid and renewable energy collaborating in the E-HUB project. She started her PhD in 2014 with a research project about design under uncertainty and its application to different energy systems.

Mario L.FERRARI (Researcher). Mario Luigi Ferrari was born in Novi Ligure (AL) in 1978. He obtained his Degree in Mechanical Engineering with honours at the University of Genoa in 2003. He obtained the Ph.D. in Mechanical Engineering at the University of Genoa in 2006. He has worked as an Associate Researcher in the Dipartimento di Macchine, Sistemi Energetici e Trasporti of the University of Genoa, and as a Researcher at Rolls-Royce Fuel Cell Systems Ltd, under the Marie-Curie program. At the moment he is a permanent Researcher in the Dipartimento di Ingegneria meccanica, energetica, gestionale e dei trasporti, where he is studying the transient behaviour of SOFC hybrid cycles and the optimization of smart grids based on both fossil fuel and renewable energy systems (the TPG laboratory of Savona).

Alberto TRAVERSO (Associate professor). Alberto Traverso is Associate Professor of Energy Systems for Mechanical Engineering. He obtained the Ph.D. in 2004 with the thesis "TRANSEO: A New Simulation Tool for the Transient Analysis of Innovative Energy Systems". His main field of expertise is the time-dependent analysis of energy systems, including fuel cell hybrid cycles. He is also responsible of WTEMP software development for thermoeconomic analysis of innovative energy systems. He is part of the steering committee at TPG for the Rolls-Royce Fuel Cell Systems Ltd UTC.

Aristide F. MASSARDO (Professor). Aristide Massardo obtained his Degree in Mechanical Engineering with honours at the University of Genoa, Italy, in 1978. After several years working for international companies in the field of energy and power plants in 1984 he entered the University of Genoa as a researcher. Now he is Full Professor of Energy Systems at the Department of Mechanical Engineering). Prof. Massardo established the Thermochemical Power Group at DIMSET in 1998, and he is at the moment the University of Genoa co-ordinator for several international projects. He was also responsible for administering many grants from Italian Space Agency, National Research Council of Italy, MURST, ENEL, and other private companies. He is now the Dean of the Polytechnic School of Engineering and Architecture.

International Centre for
Entrepreneurship Research

ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES
ISSN 2345-0282 (online) http://jssidoi.org/jesi/aims-and-scope-of-research/

SUSTAINABLE ENTREPRENEURSHIP VIA ENERGY SAVING: ENERGY HARVESTER EXPLOITING SEEBECK EFFECT IN TRADITIONAL DOMESTIC BOILER

Stefano Barberis[1], Lorenzo Di Fresco[2], Vincenzo Alessandro Santamaria[3], Alberto Traverso[4]

[1,2,4]University of Genoa, *Department of Mechanical Engineering,*
Via Montallegro,1, 16145 Genova, Italy
[3]TechCom Srl, Via Argonne 5r, 16146 Genova, Italy

E-mails: [1]Stefano.barberis@edu.unige.it; [2]lorenzo.difresco@unige.it; [3]Vincenzo.alessandro.santamaria@gmail.com;
[3]Alberto.traverso@unige.it

Received 20 September 2014; accepted 10 November 2014

Abstract. In this paper, energy saving solutions are being elaborated, i.e. A system to harvest waste heat and convert it into electrical energy is presented; such a system is based on thermoelectric generators (teg) modules exploiting the seebeck effect. A technical and economic feasibility study of the system is presented, the most convenient applications of thermal energy residuals recovery in residential environment (detached house, condos, isolated off-the grid house) are evaluated according to the electrical supply of typical domestic low consumption devices (i.e. Led lighting); the total yearly production of thermoelectric generator is considered in different techno-economic scenarios.[4]

Keywords: sustainable entrepreneurships, energy saving, Seebeck effect

Reference to this paper should be made as follows: Barberis, S.; Di Fresco, L.; Santamaria, V.A.; Traverso, A. 2014. Sustainable entrepreneurship via energy saving: energy harvester exploiting seebeck effect in traditional domestic boiler, *Entrepreneurship and Sustainability Issues* 2(2): 86–97.
DOI: http://dx.doi.org/10.9770/jesi.2014.2.2(4)

JEL Classifications: R11, 04, 031, M1, Q4

1. Introduction

Sustainable entrepreneurship in business and household domain requires innovative energy solutions (Tvaronavičienė 2012; Balkienė 2013; Laužikas, Mokšeckienė 2013; Mačiulis, Tvaronavičienė 2013; Vosylius *et al.* 2013; Raudeliūnienė *et al.* 2014; Baublys *et al.* 2014; Caurkubule, Rubanovskis 2014; Garškaitė-Milvydienė 2014; Litvaj, Poniščiaková 2014; Kaminskienė *et al.* 2014; Prause 2014; Rakauskienė 2014; Tvaronavičienė *et al.* 2014; Tvaronavičienė 2014; Vasiliūnaitė 2014). Thermoelectric conversion may be defined as the result of a process by which heat and temperature gradient can be converted into electricity through the use of a thermo-electric generator (TEG) exploiting the Seebeck effect. Thanks to this effect a thermal gradient formed between two dissimilar conductors produces a voltage (Seebeck 1825).

[4] The authors want to acknowledge Francesco Roncallo, graduated student at University of Genoa, for his contribution to this research activity.

This effect can be used for energy saving, as exploited by energy harvester devices recovering waste heat or exploiting the natural thermal gradients available in the environment to produce electricity. At the heart of the thermoelectric effect is the fact that a temperature gradient in a conducting material results in heat flow; this results in the diffusion of charge carriers. The flow of charge carriers between the hot and cold regions in turn creates a voltage difference. In 1834, Jean Charles Athanase Peltier discovered that running an electric current through the junction of two dissimilar conductors, depending on the direction of the current, could cause it to act as a heater or cooler. The heat absorbed or produced is proportional to the current, and the proportionality constant is known as the Peltier coefficient. Today, due to the knowledge of the Seebeck and Peltier effects, thermoelectric materials can be used as heaters, coolers and generators (TEGs) (Bell 2008). Ideal thermoelectric materials have a high Seebeck coefficient (the most important coefficient to evaluate TEG potential as it correlates thermal gradient with the produced voltage), high electrical conductivity, and low thermal conductivity (Nolas *et al.* 2001).

Low thermal conductivity is necessary to maintain a high thermal gradient at the junction. Standard thermoelectric modules manufactured today consist of P- and N-doped bismuth-telluride semiconductors sandwiched between two metallized ceramic plates. The ceramic plates add rigidity and electrical insulation to the system. The semiconductors are connected electrically in series and thermally in parallel. Thermoelectric conversion is nowadays strongly exploited in electronics and computer industry, using micro-TEG generator in order to make wireless sensor and similar devices totally power self sustained (Harb 2011; Vuller *et al.* 2009). One of the most common applications is the use of thermoelectric generators on gas pipelines providing electricity to the remote sensors monitoring the conduits, but they can be applied in a variety of applications (Murugavel 2008).

Thermoelectric generators are ideally used for small applications where other heat recovery system like ORC turbine or Stirling engines, which are bulkier, would not be possible, thermoelectric generators are more reliable and have a smaller chance of breaking over time and use. Spacecraft are a typical example of an application where maintenance is next to impossible after launch. TEGs are also used as remote and off-grid power generators for isolated sites (Nuwayhid *et al.* 2003). They are the most reliable power generator in such situations as they do not have moving parts (thus virtually maintenance free), work day and night, perform under all weather conditions, and can work without battery backup.

Cars and other ICE vehicles produce waste heat (in the exhaust and in the cooling agents) (Wang *et al.* 2013; Chien-Chou Weng and Mei-Jiau Huang 2013). Harvesting that heat energy, using a thermoelectric generator, can increase the fuel efficiency of the car. Waste heat is freely available in many other circumstances, such as in industrial processes and in heating (wood stoves, outdoor boilers, cooking, oil and gas fields, pipelines, and remote communication towers) (Champier *et al.* 2011; Champier *et al.* 2010; Bianchini *et al.* 2014).

Again, the waste heat can be reused to generate electricity. Since TEGs suffer from low electrical conversion efficiency, they are suitable for energy harvesting applications rather than large size electrical generation. In this paper an innovative TEG device based on commercial low cost Peltier cells and called qb_HOT is presented; this generator is able to exploit thermal gradient between the air environment and the flue chimney of traditional gas boiler or biomass stove suitable for heat generation in detached houses and condos as well as in alpine huts, mountain dew or off-the-grid isolated houses. The potential of this generator is evaluated in different scenarios and studying its production related to different possible consumption profiles and application.

NOMENCLATURE

ΔT	Thermal Gradient
DC	Direct Current
DHW	Domestic Hot Water
PV	Photovoltaic
TE	Thermo – Electric
TEG	Thermo – Electric Generator

Subscripts

c	cold
h	hot
t	thermal
teg	Thermo – Electric Generator

2. qb_HOT: an innovative low cost TEG

In a TE module, an electric voltage is generated between two semiconductors exposed to a temperature difference. Typical TE modules (also named Seebeck or Peltier cells) are composed by a set of semiconductor components formed from two different materials. As shown in Figures 1 and 2, these components are connected thermally in parallel and electrically in series.

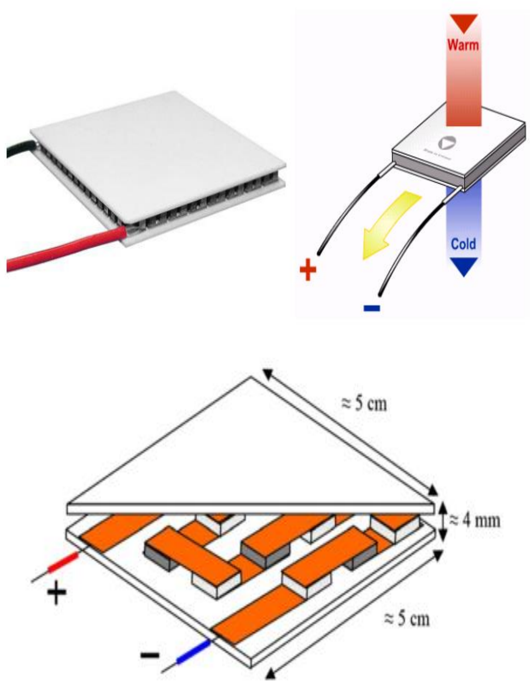

Fig.1. Structure and typical sizes of a Seebeck Cell (under) and its functioning principle (above)

Source: Seebeck (1825)

Two ceramic plates are stuck on each side for electrical insulation. Semiconductors are divided, depending on the material they are made of, into P-type and N-type components (Figure 2).

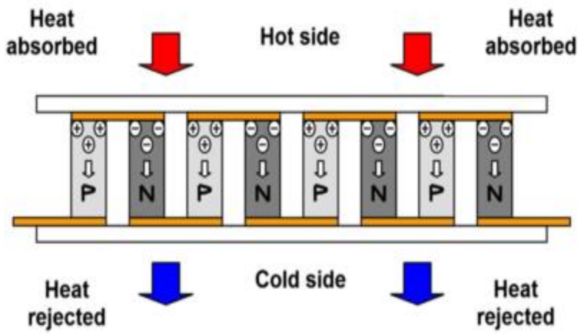

Fig.2. Working Scheme of a Seebeck Cell

Source: Seebeck (1825)

When heat flows through the cell, the N-type components are loaded negatively (excess of electrons) and P-type components are loaded positively (default electron), resulting in the formation of an electric flow. Materials wide available on the market at a reasonable price with thermoelectric properties suitable for ambient temperature applications are Bismuth Tellurid (Bi_2Te_3) and Bismuth Tin (BiSn).

2.1. qb_HOT Concept: Design Parameters

For this research, we designed and built a TEG (see Figure 3) based on low cost material: four Bi_2Te_3 modules for thermoelectric cooling applications from Thermonamic Co. Ltd. are used coupled to a classical heat sink for computer application, a conductive patch on the hot side in order to optimize the heat recovery towards the cell.

The specifications of the modules are reported here below (Thermo-electric module generator – TEP 1-1264-15 Technical Data Sheet):

- Part Number: TEP 1-1264-15
- Size: 4 mm x 4 mm x 3.3 mm
- Life Expectancy: 200000 hours

Looking at the performances they are linked to the Hot Face temperature of the cell:

Table 1. Operating Performances

Hot Side Temperature (˚C)	300
Cold Side Temperature (˚C)	30
Open Circuit Voltage (V)	9.4
Matched Load Resistance (ohms)	2.8
Matched load output voltage (V)	4.7
Matched load output current (A)	1.56
Matched load output power (W)	7.3
Heat flow across the module(W)	≈ 152
Heat flow density(W cm^{-2})	≈ 9.5
AC Resistance(ohms) Measured under 27 ˚C at 1000Hz	1.3 ~ 1.8

Source: Thermonamic Co. (2014)

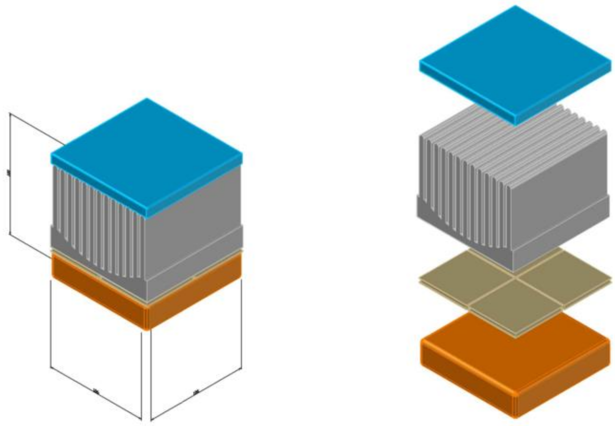

Fig.3. qb_HOT Structure

Source: Thermonamic Co. (2014)

It is worthy to underline that the maximum load output power of these cells is about 7-8 W, even if it depends on the available thermal gradient, as it can be seen in fig. 4. In our test conditions, the cell was able to produce 1-2 W of electrical power.

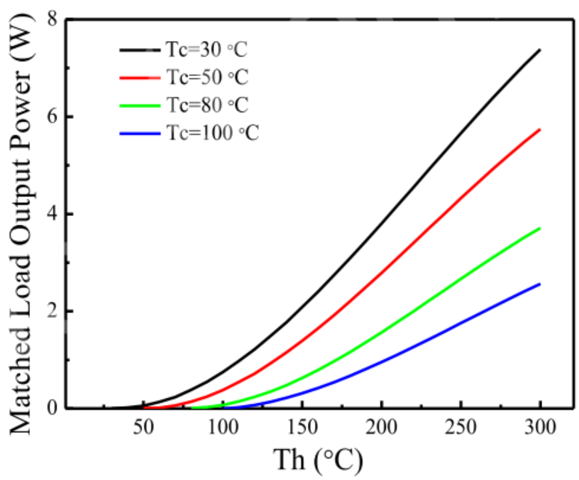

Fig.4. Performance Curves

Source: Thermonamic Co. (2014)

2.2. qb_HOT possible configurations

One of the most innovative features of qb_HOT is its compact and modular size that allows its use for different purposes with no limitations for mobility.

a) qb_HOT portable charger

In its basis configuration, qb_HOT includes, as reported in Figure 3: an energy harvester for outdoor dockings application, making possible to produce power wherever a thermal gradient or waste heat are present.
This device has a maximum power of 10 W and, coupling it with a USB plug, it will be able to charge different electronic devices with low voltage electric supply (i.e. mobile phone, smartphone, mp3 player…) just exploiting a thermal gradient available all around the user. This kind of configuration could be also integrated with a little PV cell (Figure 5 – left), in order to increase the power production of the charger or with a little solar mirror

concentrator (Figure 5 – right) in order to increase the thermal gradient exploitable by the thermoelectric cell and improve the power potential of the TEG.

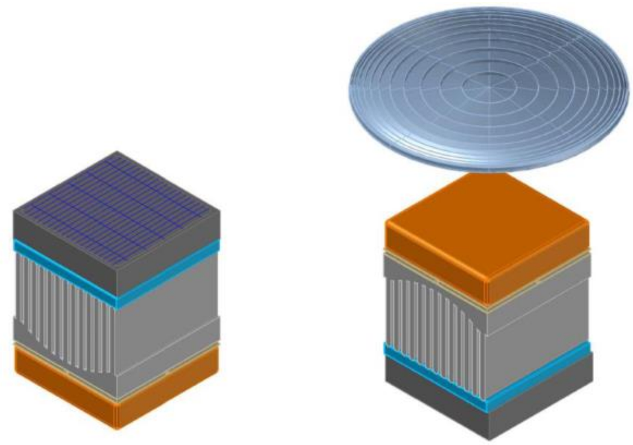

Fig.5. qb_HOT Mobile Charger Possible Integration

Source: Thermonamic Co. (2014)

b) belt_HOT

In order to exploit waste heat from the flue gas chimney of a boiler fed by any fuel (biomass, pellet, oil, gas…), a group of qb_HOT TEGs can be organized like in fig.6, putting them all around a belt capable to integrate from 15 to 150 TEG modules according to the diameter of the chimney. This kind of configuration extends the power potentiality to 20 – 250 W for each belt and it is worthy to underline that it's possible to install a certain number of belt_HOT on a single chimney according to its length.

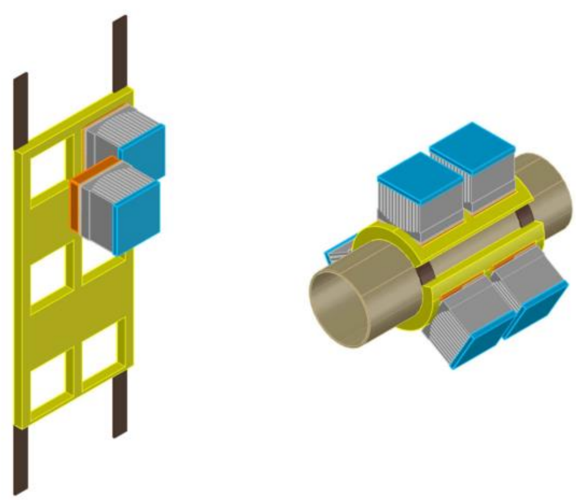

Fig.6. belt_HOT Energy Harverster for Flue Gas Chimney

Source: Thermonamic Co. (2014)

3. Qb_Hot possible exploitation

Three different belt_HOT application scenarios were analyzed:

- detached house with traditional 20 kW_t natural gas domestic boiler;

- condo heated by a 500 kW_t natural gas boiler;
- alpine hut with a 50 kW_t wood biomass boiler.

In all these scenarios the potential power producibility of the TEG is evaluated as well as the related thermal consumption, according to the different purposes of each scenario and using the correlation described by Hsu *et al.* 2011, which introduces a relationship with the measured Thot and Tcold and the effective ΔT across the TE cell.

$$\Delta T_{teg} = 0.8742\ (T_h - T_c)\ (1)$$

The presence of a boost high efficiency DC-DC ultralow voltage step-up converter and power manager is taken into account according to its typical conversion efficiency of 85-90% (OnSemi Conductor 2014; Champier *et al.* 2011).

Hence, a total correction factor of the power producibility can be evaluated approximately at 75% to correct the estimated values considered from the TE cell technical data sheet (Thermonamic Co. 2014).

3.1. Detached house

In a single family detached house, heat and domestic hot water (DHW) are provided by a traditional non-condensing 20 kW_t gas natural boiler. These kind of boilers evacuate flue gas from their chimney (typical diameter 10 cm) at a temperature of about 100-120°C, so a thermal gradient of 80-100°C can be exploited in winter season by the belt_HOT TEG.

Two different options are analyzed: in the first one the power produced by the belt_HOT is used to feed the auxiliary systems of the boiler (circulating pumps, led lighting, fan in the chimney etc…), making the boiler able to work without being connected to the house electrical distribution grid. In the second one, the electricity produced by thermoelectric generator is used to supply power to a plug in docking station. Such docking station could be installed in the kitchen, and used to recharge typical house electrical devices, which don't require high voltage supply: vacuum cleaner, smartphone, battery charger, cordless phone, etc. It can be also used to feed garden LED lighting for security purposes during the night. Basing on chimney geometry, it is supposed to use a belt_HOT realized coupling three rows of TEG with 7 cell per row.

3.1.1. Autonomous Boiler

According to the Italian technical normative UNI 10348, the electrical power required by the auxiliary systems of a boiler of such this size can be evaluated in about 90 – 150 W (Italian Technical Normative… 1993) and the boiler has an operating period supposed in 2000 hours/year, related to a classical intermediate Italian climatic zone (Table 2) (Italian Governmental Decree… 1993).

Basing on such power request and on the exploitable thermal gradient (80-100°C – Figure 4), it is supposed to install 6 belt_HOTs all along the evacuating piping: one just at the beginning of the pipe (where it is connected with the boiler), four in the central area and the last one at the chimney.

Table 2. belt_HOT application to make energy autonomous a boiler in a detached house

belt_HOT configuration	6 belt made by 21 TEG cells
Total Pmax installed	1 kW
Power Output with ΔT = 80°C	100-150 W
Total Year Energy Saving	200 kWh – 40 €

Source: Italian Technical Normative…(1993)

Such configuration, coupled with a battery to harness the overproduction, guarantees a continuous production of 100 W in these operating condition with a Pmax estimated in about 140 W. The power required by the auxiliaries during the operating time (2/3 of the total amount is required by the hot water circulating pump) is guaranteed as it is simultaneously produced by belt_HOT.

3.1.2 Docking Station and LED lightning

The power produced by the four belt_HOTs installed as described in the previous paragraph can be also used to feed a docking station for smart charging application. This docking station is made by 4-6 plugs-in which little size house appliances and electrical devices and battery charger can be connected. Thanks to a user-friendly interface (red/yellow/green LED light) and to a smart energy management system that is able to find the best strategy to satisfy all the requests, this docking station is able to show to the user when the power produced by the TEG is inviting to connect devices to be charged. Thanks to this device, the power produced by the belt_HOT could be easily exploited directly at home during the day and, thanks to a battery to store the whole day overproduction, it can be also used in the night to feed up to 10-12 LED lights, typically installed in the garden for security purposes. So TEG power is directly consumed at house avoiding as much as possible distribution losses, even if the power request is not as constant as in 3.1.1 option.

3.2. Condo

In this scenario a eight floors building is considered. In this building there are 30-40 flats, whose heating and DHW requests are satisfied by a centralized 500 kW_t gas natural boiler. In this scenario, boiler installation needs to be carefully considered. If it is installed on the top of the building, the exhaust piping is quite similar to the §3.1 scenario, even if a larger diameter (e.g. 60 cm) can be considered. If the boiler is installed in a special room in the basement of the building, a longer piping system can be considered, in order to exploit the exhaust waste heat. In this scenario the power produced by the belt_HOT TEGs aims to satisfy the lighting of the condo common spaces (hall, stairway, entrance, lobbies…). This power consumption can be estimated in 1 kW using 20 compact neon fluorescent lamps (CFL), 50 – 60 W each one, or in 500 W using 20 LED tube lamps, 25-30 W each one.

Basing on chimney geometry, it is supposed to use a belt_HOT realized coupling three rows of TEG with 40 cell per row. As in the previous scenario, the boiler has an operating period supposed in 2000 hours/year, related to a classical intermediate Italian climatic zone (Table 3) (Italian Governmental Decree… 1993). Looking at the power request and at the exploitable thermal gradient (80-100°C – fig.4), it is supposed to install 10 belt_HOT all along the evacuating piping in the presence of CFLs or 5 belt_HOT TEGs in the presence of LEDs. Such configuration, coupled with a battery to harness the overproduction, guarantees a continuous production of 500 W and 1 kW in these operating conditions with a P_{max} supposed of about 600 W or 1,2 kW. This application produce an energy saving of about 1000-2000 kWh and a cost saving of 200-400 €/year.

Table 3. belt_HOT application coupled to high efficiency lighting in a condo (CFL lamp – LED lamps)

belt_HOT configuration	5-10 belt made by 120 TEG cells
Total Pmax installed	4,2 – 8,4 kW
Power Output with ΔT = 80°C	600 W -1,2 kW
Total Year Energy Saving	1000 - 2000 kWh – 200 - 400 €

Source: Italian Governmental Decree… (1993)

3.3. Alpine Hut

In an isolated alpine hut, biomass stoves are used for cooking and heating purposes. These kind of boilers evacuate flue gas from their chimney (typical diameter 20 cm) at a temperature of about 200°C, so a thermal gradient of

170-180°C can be exploited, even if the operating hours of these systems are significantly lower. Thanks to these higher values, the producibility of each TE cell approximately doubles (Thermonamic Co. 2014). In such situation, a battery to harness overproduction is necessary, extending the potential use of the electricity produced by TEGs as the operating hour period is related to the presence of guests in the hut.

Table 4. belt_HOT application coupled to biomass boiler in an alpine hut

belt_HOT configuration	4 belt made by 36 TEG cells
Total Pmax installed	1 kW
Power Output with ΔT = 180°C	200-250 W

Source: Champier *et al.* (2010)

Installing 4 belt_HOT TEGs composed by three rows of 12 cells per row, a production of 200 W can be estimated with a P_{max} supposed of about 250W, in accordance to the experimental results of Champier *et al.* 2010 (Table 4). The electricity produced by TEGs can be used directly by the guest to charge their electronic devices (and making possible to make an autonomous on-demand recharging station in the shelter) or to feed some LED lights installed in the hut.

This power production can also easily integrate the contribution from other renewable generators typically installed in this kind of resort, like PV panels or micro-wind generator.

Conclusions

This study describes a preliminary design of a low-cost thermoelectric generator, evaluating the power producibility and the energy saving that can be achieved in three different scenarios. For a simple and cheap application, commercially available modules have been tested and the performance of TE modules have been evaluated according to technical data sheet and previous research models and experiments. The main features of TEGs evaluated in this research are as follows, confirming other previous research results about TEGs' techno-economical feasibility (Patyk 2013).

- The TEG is a heat recovery generator: it doesn't need any extra energy from the thermal source even if it converts only a small part of the heat flux into electrical energy (efficiency between 0,6 % to 3%)
- The TEG can be easily incorporated in the structure of the heat source, i.e. the exhaust piping and the fluegas chimney in our research
- The generator produces whenever the boiler is on night and day and without weather implications, guaranteeing a continuous and autonomous production as the maintenance is very light
- Designing the TEG, a strong attention has to be considered to evaluate and manage the heat dissipation at the cold side of the TE cell studying heat sink and exchange in order to maintain T_c and ΔT_{TEG} as much stable as possible.
- It is worthy to underline that, unfortunately, to produce a certain amount of power TEGs work with significant thermal gradient (70-100°C), so this technology can't be coupled, for example, with more efficient heating system like condensing boiler which have an exhausts temperature of 40 – 65°C with a reduced exploitable thermal gradient.

The cost price has been briefly estimated as follows:
- The price of the Step Up Boost DC-DC Converter is 6€ for one sample and drops to 1-2 € for more than 1000 samples
- The price of one TE module is 10-15 € and it decreases to 5€ for 1000 samples. However the price of Peltier TE cooling modules of the same size produced in large quantities starts at 6-8 € for one piece and decreases to 1 € for 1000 pieces. As the production of Peltier modules uses the same materials and the same technology except for welding on the hot side (exploiting the same reverse effect) except for welding on the hot side it could be possible to use these cell with a little bit lower performances.

- The price of the heat sink and the thermal patch can be evaluated in 1-2 € as this kind of components are typically used for electronic and computer purposes.

The total price of our qb_HOT TEG can be estimated around 50 €, with a cost per Watt around 8-12,5 €/W (depending on the exploitable thermal gradient). This initial cost is estimated to decrease towards 20 € per sample and 4 €/W, when a relatively small production line is started. Our study shows that the exhausts of traditional gas boilers can be exploited also for feeding high efficient devices like Smart Docking Station or LED lighting, making cogenerative all the thermal generators thanks to the TEG energy harvesting capability. Initially, it is envisaged that qb_HOT TEG would be assembled and tailored to the application, while, in a second stage, also the TEG cells could be locally manufactured and improved.

Future work will consist in testing the proposed TEG concepts on the field, coupling them to exhaust pipes and testing their performance also in presence of reduced thermal gradients, which are very frequent in everyday life.

References

Balkienė, K. 2013. Sustainable innovativeness: issues and public policy, *Journal of Security and Sustainability Issues* 3(2): 53–76. DOI: http://dx.doi.org/10.9770/jssi.2013.3.2(5)

Baublys, J.; Miškinis, V.; Konstantinavičiūtė, I.; Lekavičius, V. 2014. Aspirations for sustainability and global energy development trends, *Journal of Security and Sustainability Issues* 3(4): 17–26. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(2)

Bell, L.E. 2008. Cooling, heating, generating power and recovering waste heat with thermoelectric systems, *Science* 321:1457–61.

Bianchini, A.; Pellegrini, M.; Saccani, C. 2014. Thermoelectric cells cogeneration from biomass power plant, *Energy Procedia* 45: 268–277.

Caurkubule, Ž.; Rubanovskis, A. 2014. Sustainable entrepreneurship through motivation: case of Latvian companies, *Entrepreneurship and Sustainability Issues* 2(1): 43–48. DOI: http://dx.doi.org/10.9770/jesi.2.1(6)

Champier, D.; Bédécarrats, J.P.; Kousksou, T.; Rivaletto, M.; Strub, F.; Pignolet, P. 2011. Study of a TE (thermoelectric) generator incorporated in a multifunction wood stove, *Energy* 36: 1518–1526.

Champier, D.; J.P.Bédécarrats, M.Rivaletto, F.Strub. 2010. Thermoelectric power generation from biomass cook stoves, *Energy* 35: 935–942.

Chien-Chou Weng, Mei-Jiau Huang. 2013. A simulation study of automotive waste heat recovery using a thermoelectric power generator, *International Journal of Thermal Sciences* 71: 302–309

Comitato Termotecnico Italiano – CTI - Italian Technical Normative UNI 10348: 1993 – "Riscaldamento degli edifici. Rendimenti dei sistemi di riscaldamento. Metodo di calcolo."

Garškaitė-Milvydienė, K. 2014. Anti-crisis management of enterprises and possibilities of overcoming their critical condition, *Journal of Entrepreneurship and Sustainability Issues* 1(4): 187–203. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(1)

Harb, A. 2011. Energy harvesting: State-of-the-art, *Renewable Energy* 36: 2641–2654.

Hsu *et al.* 2011. An effective Seebeck coefficient obtained by experimental results of a thermoelectric generator module, *Applied Energy* 88(12): 5173–5179.

Italian Governmental Decree. D.P.R. 26 agosto 1993 n.412 - "Regolamento recante norme per la progettazione, l'installazione e la manutenzione degli impianti termici degli edifici, ai fini del contenimento dei consumi di energia, in attuazione dell'art. 4, comma 4 della legge 9 gennaio 1991, n.10"

Kaminskienė, N.; Žalėnienė, I.; Tvaronavičienė, A. 2014. Bringing sustainability into dispute resolution processes, *Journal of Security and Sustainability Issues* 4(1): 69–77. DOI: http://dx.doi.org/10.9770/jssi.2014.4.1(6)

Laužikas, M.; Mokšeckienė. 2013. The role of creativity in sustainable business, *Entrepreneurship and Sustainability Issues* 1(1): 10–22. http://dx.doi.org/10.9770/jesi.2013.1(2)

Litvaj, I.; Poniščiaková, O. 2014.Entrepreneurship and quality management, *Entrepreneurship and Sustainability Issues* 1(4): 204–209. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(2)

Mačiulis, A.; Tvaronavičienė, M. 2013. Secure and sustainable development: Lithuania's new role in taking the Presidency of the EU, *Journal of Security and Sustainability Issues* 3(2): 5–13. DOI: http://dx.doi.org/10.9770/jssi.2013.3.2(1)

Miškinis, V.; Baublys, J.; Lekavičius, V.; Morkvėnas, A. 2013. New Changes in Lithuanian Energy Sector, *Journal of Security andSustainability Issues* 2(3): 15–28. DOI: http://dx.doi.org/10.9770/jssi.2013.2.3(2)

Murugavel, Raju. 2008. Energy harvesting, White Paper, Texas Instruments, November.

Nolas, G.S.; Sharp, J.; Goldsmid, H.J. 2001. *Thermoelectrics: basic principles and new materials developments.* New York: Springer. 2001

Nuwayhid, R.Y.; Rowe, D.M.; Min, G. 2003. Low cost stove-top thermoelectric generator for regions with unreliable electricity supply, *Renewable Energy* 28: 205–222.

OnSemi Conductor Ltd. 2014. NCP1406, NCV1406 25 V/25 mA PFM Step-Up DC-DC Converter Technical Sheet. Available online: < http://www.onsemi.com/> [Accessed 03 September 2014]

Patyk, A.2013. Thermoelectric generators for efficiency improvement of power generation by motor generators – Environmental and economic perspectives, *Applied Energy* 102: 1448–1457.

Peltier, J.C.A. 1834. Nouvelles expériences sur la caloricité des courants électrique [New experiments on the heat effects of electric currents], *Annales de Chimie et de Physique* 56: 371–386.

Prause, G. 2014. A holistic concept for the sustainable evaluation of company shares, *Entrepreneurship and Sustainability Issues* 2(1): 37–42. DOI: http://dx.doi.org/10.9770/jesi.2014.2.1(5)

Rakauskienė, O. G. 2014. Long term changes in the quality of life of Lithuanian population: 20 years in the market economy, *Journal of Security and Sustainability Issues* 4(1): 41–58. DOI: http://dx.doi.org/10.9770/jssi.2014.4.1(4)

Raudeliūnienė, J.; Tvaronavičienė, M.; Dzemyda, I. 2014.Towards economic security and sustainability: key success factors of sustainable entrepreneurship in conditions of global economy, *Journal of Security and Sustainability Issues* 3(4): 71–79. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(7)

Seebeck, T. J. 1825. Magnetische Polarisation der Metalle und Erze durch Temperatur-Differenz [Magnetic polarization of metals and minerals by temperature differences)] Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin [Treatises of the Royal Academy of Sciences in Berlin], 265–373.

Thermonamic Co. Ltd. 2014. Thermo-electric module generator – TEP 1-1264-15 Technical Data Sheet. Available online: <http://www.thermonamic.com/>. [Accessed 02 September 2014]

Tvaronavičienė, M. 2012. Contemporary perceptions of energy security: policy implications, *Journal of Security and Sustainability Issues* 1(4): 235–247. DOI: http://dx.doi.org/10.9770/jssi.2012.1.4(1)

Tvaronavičienė, M. 2014. If industrial sector development is sustainable: Lithuania compared to the EU, *Entrepreneurship and Sustainability Issues* 1(3):134–142. DOI: http://dx.doi.org/10.9770/jesi.2014.1.3(2)

Tvaronavičienė, M.; Šimelytė, A., Lace, N. 2014. Sustainable development facets: exporting industrial sectors from inside, *Journal of Security and Sustainability Issues* 3(4): 37–44. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(4)

Vasiliūnaitė, R. 2014. Sustainable development: methodological approaches toward issues, *Journal of Security and Sustainability Issues* 3(3): 69–75. DOI: http://dx.doi.org/10.9770/jssi.2014.3.3(6)

Vosylius, E.; Rakutis, V.; Tvaronavičienė, M. 2013. Economic growth, sustainable development and energy security interrelation, *Journal ofSecurity and Sustainability Issues* 2(3): 5–14.DOI: http://dx.doi.org/10.9770/jssi.2013.2.3(1)

Vuller, R.J.M.; Van Schaijk, R.; Doms, I.; Van Hoof, C.; Mertens, R. 2009. Micropower energy harvesting, *Solid-State Electronics* 53: 684–693.

Wang, Y.; Dai, C.; Wang, S. 2013. Theoretical analysis of a thermoelectric generator using exhaust gas of vehicles as heat source, *Applied Energy* 112: 1171–1180.

Stefano BARBERIS was born in Genoa in 1988. He obtained his Master Degree in Mechanical Engineering at University of Genoa in2012 with the Thesis “Thermoeconomic Analysis and Optimization of Innovative Concentrating Solar Power Plants”. He joined TPG as PhD student in 2013.

Lorenzo DI FRESCO, born in Genoa in 1975, obtained the Degree in Mechanical Engineering at the University of Genoa in 2002. He worked in the Industry as Manufacturing Engineer dealing with production efficiency and quality management issues being beside a ISO 9001:2000 quality management system assessor. He joined the TPG in 2008: his activity focused on the thermoeconomic analysis of renewable energy systems, and on the study of energy buildings certification standards development: he is a qualified energy assessor accredited by Liguria region. He obtained his Ph. D. on the Seaspoon, an innovative Ocean Energy device for distributed microgeneration.

Vincenzo Alessandro SANTAMARIA was born in Genoa in 1985. He obtained his Master Degree in Informatics Engineering at University of Genoa in 2012 with the Thesis “Techniques of variables selection for sensor diagnostic: application to a micro gas turbine-based test rig”. He joined TPG (Thermochemical Power Group) of the University of Genoa in 2012 as temporary research fellow. He carries out research about the control and monitoring system of Seaspoon, an innovative Ocean Energy device for distributed microgeneration.Now he works with TechCom, an innovative informatics Italian start-up.

Alberto TRAVERSO is Associate Professor of Energy Systems for Mechanical Engineering. He obtained the Ph.D. in 2004 with the thesis “TRANSEO: A New Simulation Tool for the Transient Analysis of Innovative Energy Systems". His main field of expertise is the time-dependent analysis of energy systems, including fuel cell hybrid cycles. He is also responsible of WTEMP software development for thermoeconomic analysis of innovative energy systems. He is part of the steering committee at TPG for the Rolls-Royce Fuel Cell Systems Ltd UTC.

International Centre for Entrepreneurship Research

ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES
ISSN 2345-0282 (online) http://jssidoi.org/jesi/aims-and-scope-of-research/

ACCOUNTING PRODUCTIVITY IN THE SECTORS OF ECONOMY: METHODOLOGICAL ASPECTS

Toma Lankauskienė

Vilnius Gediminas Technical University
Sauletekio al. 11, LT–10223 Vilnius, Lithuania

E-mail: toma.lankauskiene@gmail.com

Received 10 July 2014; accepted 20 August 2014

Abstract. Level of productivity is vital for each country striving develop sustainably. It appears that accounting of productivity requires additional attention of scientists. This paper is focused on the methods allowing to evaluate productivity in economy sectors. Scrutinized scientific literature proposes the following possible perceptions of productivity increase: as labour move from low to high productivity sectors, the process contributes to aggregate country's productivity growth, and causes further productivity increase in more productive sectors. After critical scientific literature review, conclusions about contemporary productivity methods and are being be provided.

Keywords: economic sectors' performance, productivity, aggregate productivity, economic growth, sustainable development.

Reference to this paper should be made as follows: Lankauskienė, T. 2014. Accounting productivity in the sectors of economy: methodological aspects, *Entrepreneurship and Sustainability Issues* 2(2): 98–106.
DOI: http://dx.doi.org/10.9770/jesi.2014.2.2(5)

JEL Classifications: O40, O47

1. Introduction

Sustainable development of countries and their economies' sectors is driven by array of factors (Mačiulis, Tvaronavičienė 2013; Baublys *et al.* 2014; Balitskiy *et al.* 2014; Caurkubule, Rubanovskis 2014; Dzemyda, Raudeliūnienė 2014; Fuschi, Tvaronavičienė 2014; Kaminskienė *et al.* 2014; Raudeliūnienė *et al.* 2014; Scaringelli 2014; Tarabkova 2014; Tvaronavičienė 2014; Tvaronavičienė *et al* 2014; Vasiliūnaitė 2014). Productivity is vitally import as driving force of sustainable development, which in own turn is affected by various factors (Mathur *et al.* 2013; Bonetto *et al.* 2014; Demir *et al.* 2014; Figurska 2014; Garškaitė-Milvydienė, 2014; Ruza *et al.* 2014; Tvaronavičienė 2014, Wahl 2014). Researches, related to relevant economy structure and economic growth, generally named as structural economics, are in foreign rather common in scientific literature of development economics. This research area in Lithuania is relatively young and currently is intensively developing (e.g. Lankauskienė, Tvaronavičienė 2013; Lankauskienė, Tvaronavičienė 2014). In this paper attention is being focused to productivity measurement and accounting methods. This paper aims to systemize and group the methods evaluating productivity, which can reveal more precise picture of productivity in separately taken economy sectors.

2. Economy sectors' performance in structure of economy

2.1. Determinants of economy sectors' performance

Based on the reform agenda agreed upon in Lisbon, enterprise and industrial policies require a detailed understanding of the competitive process at the level of individual industries and sectors (Peneder 2009; Figurska 2014; Tvaronavičienė 2014).Within this context, the current study on sectorial growth drivers aims to identify the major determinants, patterns and trends in European competitiveness from a distinctly sectorial perspective. The first part of this study investigated European sectorial competitiveness, assessing the relative strengths and weaknesses of European industries with respect to the various dimensions of performance, such as the growth of value added, employment, labour and multifactor productivity, profitability, international trade, and foreign direct investments (Peneder 2009; Tvaronavičienė 2014). Hereinafter, an investigation of the major determinants or 'drivers' of sectorial growth will be provided.

Sectorial performance is driven by a myriad of distinct sources. At present, no single, comprehensive theory exists which can explain the role of these elements within a jointly integrated economic model. However, many of them are the subject matter of different strands of economic research. Accordingly, this model is organized according to six groups of related factors: macroeconomic conditions, demand side factors, inputs to production, R & D and innovation, market structure, and finally openness and barriers to trade (Peneder 2009). Figure 1 illustrates the six major dimensions of sectorial performance. First, macroeconomic conditions affect sectorial performance by defining the environment within which companies and industries operate.

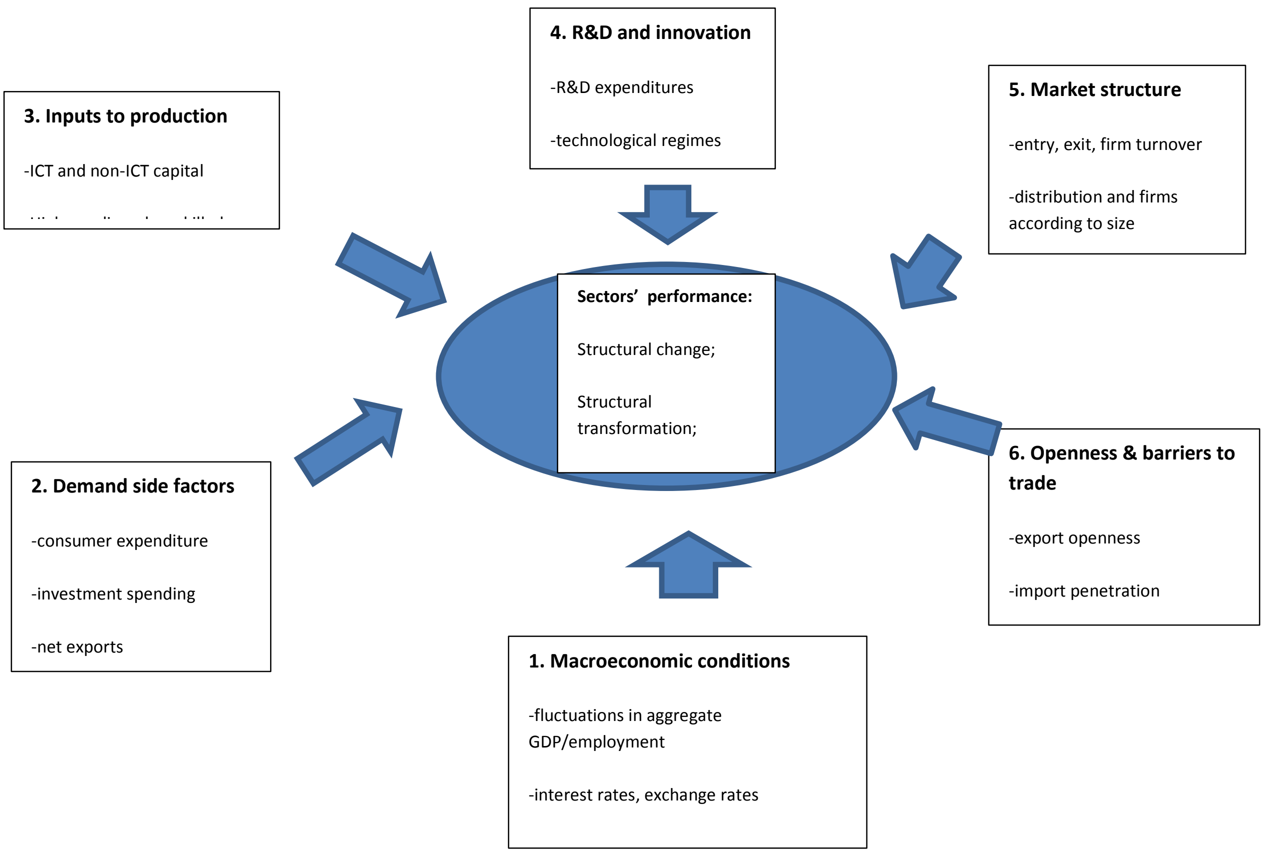

Fig 1. Stylized model of selected sectorial performance drivers

Source: complemented by author referring Peneder, M. 2009. Sectorial growth drivers and competitiveness in the European Union. European Commission, Enterprise and industry, European communities, 1-542 p.

2.2. Possible economy sectors' performance variations

Economic growth can not be perceived without role of economic sectors, as economies are comprised of them. The following economic sectors' performance peculiarities in the structure of economy could be distinguished: structural change, structural transformation, structural growth, and structural development. It is important to mention that structural change and transformation are quite similar expressions, as well as structural growth and development (Lankauskienė, Tvaronavičiene 2013). Economic sectors' performance in the structure of economy most commonly is being defined as structural changes by foreign scientists (Lankauskienė, Tvaronavičienė 2013; Figurska 2014). Structural change is the central insight of development economics. Economic growth reflects in economic sectors' performance and entails structural change. Structural change, narrowly defined as the reallocation of labour across economy sectors, featured in the early literature on economic development by Kuznets (1966). As labour and the other resources move from traditional into modern economic activities, overall productivity rises and income expand. The nature and speed with which structural transformation takes place is considered one of the key factors that differentiate successful countries from unsuccessful ones. Therefore, the new structural economists argue that economy structures should be the starting point for comparative economic analysis and the design of appropriate policies. For the process of sustainable development elabouration, it is especially important for economy sectors to perform in a sustainable manner (Lankauskienė, Tvaronavičienė 2013; Litvaj, Poniščiaková 2014; Tvaronavičienė 2014). Economic sectors' sustainable performance manner is associated as a target at the development of knowledge based and innovation susceptible sectors, but not with exploiting non renewable natural resources (Tvaronavičienė, Lankauskienė 2013). Economic growth encompasses the growth of value added, created by economic sectors and their branches performance. Moreover, economy structure has to operate through all the possible capabilities of sustainability**.**

3. Productivity phenomenon evaluation methods in the structure of economy

Productivity most generally is perceived as a measure of output or value added per labour input (hour worked). But due to the economy sectors' performance, in the structure of economy this phenomenon gains more forms. Hereinafter different methods accounting productivity will be provided.

3.1. Aggregate productivity growth accounting method

What is the impact of structural change on productivity growth? In response to this question many authors use an empirical methodology designed to analyse such issues, often called 'shift-share analysis'. It has been used frequently by among others economic geographers, economic historians, industrial economists and trade analysts. Essentially, it is a purely descriptive technique that attempts to decompose the change of an aggregate into a structural component, reflecting changes in the composition of the aggregate, and changes within the individual units that make up the aggregate. As such it is closely related to analysis of variance. There are many versions of this methodology, the main difference being the choice of base year or 'weights': initial year, final year, some kind of 'average', linked, etc., and each version usually has its critics as well as defenders (Hurber, Mayerhofer 2006; Maroto-Sanchez, Cuadrado-Roura 2009; Jalava 2006; Van Ark, Hann 1997; Vries *et al.* 2011). The reason for this state of affairs is the well known result in index number theory that if, say, initial or final year weights are applied throughout in decomposition, a residual will occur necessarily. So what many versions of this methodology do is to try to reduce this residual as much as possible (Tanuwidjaja, Thangavelu 2007). Authors examine the effects of recent structural changes on the growth of labour productivity. The traditional assumption of the growth accounting literature is that structural change is an important source of growth and overall productivity improvements. The standard hypothesis assumes a surplus of labour in some (less productive) parts of the economy (such as agriculture), thus shifts towards higher productivity sectors (industry) are beneficial for aggregate productivity growth. Even within industry, shifts towards more productive branches should boost aggregate productivity. On the other hand, structural change may have a negative impact on aggregate productivity growth if labour shifts to industries with slower productivity growth. The 'structural bonus and burden' hypotheses were examined by the example of Asian economies by Timmer and Szirmai (2000), a large sample of OECD and developing countries (Fagerberg 2000), and more recently by Peneder and DG Employment for the USA, Japan and EU Member States (Peneder 2009). The overall developments regarding output, employment and productivity described above mask substantial structural changes within economies and their individual sectors. Structural changes reflect inter alia different speeds of restructuring and resulting efficiency gains or losses at branch level. The impact of structural change on aggregate productivity growth in is evaluated by the frequently applied shift-share analysis in analogy with Timmer and Szirmai (2000), Fagerberg (2000), Peneder (2003) and others. The shift-share analysis provides a convenient tool for investigating how aggregate growth is linked to differential growth of labour productivity at the sectorial level and to the reallocation of labour between industries. It is particularly useful for the analysis of productivity developments in countries where data limitations prevent us from using more sophisticated econometric approaches (Havlik 2005).

Using the same notation as presented in Peneder (2003), authors decompose the aggregate growth of labour productivity into three separate effects:

$$growth(LP_T) = \frac{LP_{T,fy} - LP_{T,by}}{LP_{T,by}} =$$

$$\frac{\overbrace{\sum_{i=1}^{n} LP_{i,by} \cdot (S_{i,fy} - S_{i,by})}^{I: static.shift.effect} + \overbrace{\sum_{i=1}^{n} (LP_{i,fy} - LP_{i,by}) \cdot (S_{i,fy} - S_{i,by})}^{II: dynamic.shift.effect} + \overbrace{\sum_{i=1}^{n} (LP_{i,fy} - LP_{i,by}) \cdot S_{i,by}}^{III: within.growth.effect}}{LP_{T,by}} \quad (1)$$

First, the structural component is calculated as the sum of relative changes in the allocation of labour across industries between the final year and the base year, weighted by the value of the sector's labour productivity in the base year. This component is called the static shift effect. It is positive/negative if industries with high levels of productivity (and usually also high capital intensity) attract more/less labour resources and hence increase/decrease their share of total employment. The standard structural bonus hypothesis of industrial growth postulates a positive relationship between structural change and economic growth as economies are upgrading from low- to higher-productivity industries. The structural bonus hypothesis thus corresponds to an expected positive contribution of the static shift effect to aggregate growth of labour productivity (Havlik 2005).
The structural bonus hypothesis:

$$\sum_{i=1}^{n} LP_{i,by} (S_{i,fy} - S_{i,by}) > 0 \quad (2)$$

Second, dynamic shift effects are captured by the sum of interactions of changes in employment shares and changes in labour productivity of individual sectors/industries. If industries increase both labour productivity and their share of total employment, the combined effect is a positive contribution to overall productivity growth. In other words, the interaction term becomes larger, the more labour resources move toward industries with fast productivity growth. The interaction effect is, however, negative if industries with fast growing labour productivity cannot maintain their shares in total employment. Thus, the interaction term can be used to evaluate Baumol's hypothesis of a structural burden of labour reallocation which predicts that employment shares shift away from progressive industries towards those with lower growth of labour productivity (Baumol 1967; Havlik 2005).

We would expect to confirm the validity of the structural burden hypothesis in the NMS due to the above-sketched shifts from industry to services (with lower productivity levels) at the macro level, and due to shifts from heavy (and capital-intensive) to light industries within manufacturing, respectively (Havlik 2005).

The structural burden hypothesis:

$$\sum_{i=1}^{n}(LP_{i,fy} - LP_{i,by})(S_{i,fy} - S_{i,by}) < 0 \qquad (3)$$

Third, the 'within-growth' effect corresponds to growth in aggregate labour productivity under the assumption that no structural shifts in labour have ever taken place and each industry (sector) has maintained the same share in total employment as in the base year. Authors, however, recall that the frequently observed near equivalence of the within-growth effect and aggregate productivity growth cannot be used as evidence against differential growth between industries. Even in case all positive and negative structural effects net out, much variation in productivity growth can be present at the more detailed level of activities (Havlik 2005).

3.2. Accelerations and decelerations in aggregate productivity growth evaluation method

Recent studies of economic growth have moved from explaining average trends in long-term growth to study growth accelerations and decelerations, because of the great instability in growth rates within countries. Authors argue that the standard shift-share analysis is inadequate to measure the contribution of sectors to accelerations in productivity. Very few countries have experienced consistently high growth rates over long periods. Rather, the more typical pattern is that countries experience phases of growth, stagnation, or decline of varying length. A study of these separate periods seems more revealing for a study of the determinants of growth than a long-period average (Pritchett 2000). This raises the natural question which sectors in the economy contribute most to accelerations and decelerations in growth. For example, Jones and Olken (2008) suggest that employment reallocation to more productive sectors lies behind accelerations and decelerations of growth in many developing countries. Because of missing sectorial data, they are unable to test this hypothesis. Authors provide empirical evidence on the significance of various sectors in generating aggregate productivity growth by introducing a novel shift-share analysis and by applying this method to a new sectorial database for 19 countries in Asia and Latin America, spanning the period from 1950 to 2005. Each sector can contribute to aggregate growth in two ways: by productivity growth within the sector (the within-effect) and by expanding its share in aggregate inputs (the between- or shift-effect). To measure these contributions authors modify a standard tool in an economic historians' tool-box: the shift-share analysis introduced by Fabricant (1942). The shift-share analysis is used in many studies to measure the contribution of structural change to aggregate growth. For example, it features prominently in the discussion about the extent of Britain's decline relative to Germany and the US since the end of the nineteenth century (Broadberry 1998). Unfortunately, the interpretation of results from the traditional shift-share method is not straightforward (Timmer, Vries 2008; Timmer, Vries 2007).

Authors propose two modifications to the traditional shift-share analysis, which make its results more useful. First, the standard method does not allow for disequilibria in factor markets in which average productivity differs from marginal productivity. Especially in early stages of development, the agricultural sector is characterized by wide-spread disguised unemployment (Broadberry 1998). Authors use estimates of the shadow price of labour to measure this wedge and adjust the shift share method accordingly. This adjustment increases the measured importance of structural change to growth. Second, the traditional method does not properly account for differences in productivity levels between sectors. For example, the expansion of a low-productive sector such as government services would show up as being positive for aggregate growth. Authors account for differences in productivity levels between sectors and derive more meaningful measures of the contribution of particular sectors to aggregate productivity growth. Authors find that resource reallocation is not the main driver of accelerations and decelerations in aggregate economic growth. Productivity improvements within sectors, in particular within manufacturing and market services, appear to be much more important for growth in Asia and Latin America since the 1950s (Timmer, Vries 2008; Timmer, Vries 2007).

Since long, the importance of sectorial development patterns for economic growth has been recognized. Changes in the sectorial composition of production and employment and their interaction with the pattern of productivity growth feature prominently. Technological change typically takes place at the level of industries and induces differential patterns of sectorial productivity growth. At the same time, changes in domestic demand and international trade patterns drive a process of structural transformation in which labour, capital and intermediate inputs are continuously relocated between firms, sectors and countries (Kuznets 1966; Chenery *et al.* 1986; Harberger 1998). One of the best documented patterns of structural change is the shift of labour and capital from production of primary goods to manufacturing and services. Another finding is that the level and growth rate of labour productivity in agriculture is considerably lower than in the rest of the economy (at least at low levels of income), reflecting differences in the nature of the production function, in investment opportunities and in the rate of technical change (Syrquin 1984; Crafts 1984). Together these findings suggest a potentially important, albeit temporary, role for resource allocation from lower to higher productive activities to boost aggregate productivity growth. This potential growth bonus was already identified in classical dual economy models such as Lewis (1954) and Fei and Ranis (1964). These models presumed that in early stages of development, agricultural labourers shift to the industrial sector without any reduction in total agricultural output. The existence of this source of inefficiency can be explained by the immobility of agricultural labour vis-a-vis the industrial sector caused by the discrepancy between private costs, approximated by the average product in agriculture, and social costs. Differences in the potential for structural change have featured prominently in explanations of differential growth within European countries in the post-World War II period (Temin 2002).

However, the quantification of its importance has been hampered by a clear methodology to measure the effect of structural change on aggregate productivity growth. The standard method to measure this is the shift-share decomposition originating from Fabricant (1942). This method is part of the standard tool kit of economic historians and used in many studies. One major problem of the traditional shift share method is the assumption that productivity growth within each sector is not affected by structural change. Clearly productivity growth rates are affected since, for example, productivity growth in agriculture is largely possible due to the employment reallocation to manufacturing and services. For example, labour productivity in South Korean agriculture increased 5% annually during the period 1963–2005. It is not likely that this high growth rate could have been sustained when in 2005 still 63% of the population was working in agriculture, as in 1963. Broadberry (1998) argued that the shift-share analysis should be modified by assuming that the marginal productivity of workers leaving shrinking sectors is equal to zero. Although this adjustment overestimated the effect of sectorial expansions (Booth 2003), authors propose an extension and improvement of the traditional shift-share analysis in a similar direction without overstating sectorial employment reallocation.

Authors suggest the following modified shift-share analysis:

$$P^T - P^O = \sum_{i \in K,J} (P_i^T - P_i^O) * S_i^- + \sum_{i \in K} (S_i^T - S_i^O) * (P^- - P^-_J) \qquad (4)$$

Where: P being labour productivity, S i sectorial employment shares in the i-th sector (1,…,10), T indicating the end of a period, 0 the beginning of a period, and a bar indicating period average.
The first term on the right hand side measures the contribution of within-sector productivity growth (intra effect). The second term on the right hand side measures the contribution of sectorial reallocation of employment to aggregate productivity growth (shift effect).

With average labour productivity in shrinking sectors

$$P^-_J = \frac{\sum_{i \in J} (S_i^T - S_i^O) * P_i^-}{\sum_{i \in J} (S_i^T - S_i^O)} \qquad (5)$$

J the set of shrinking sectors, K the set of shrinking sectors.

The modified shift-share analysis decomposes growth in GDP per worker into improvements within industries and improvements due to the reallocation of labour across industries. In the decomposition, authors account for surplus labour. Furthermore, expanding sectors only contribute to productivity growth if their productivity level is higher than the economy's average (Timmer, Vries 2007, 2008).

Conclusions

Productivity usually is perceived as a measure of output or value added per labour input (hour worked).

Analysis of relevant scientific literature in this research area let to reveal much more productivity measurement options. From one point of view it can be related to labour movement from low productivity to high productivity sectors and in such a manner contributing to aggregate country's productivity growth. And from another point of view productivity increase can be associated within sectors to capital accumulation, technological change, innovation, etc.

In the structure of economy, due to economic sectors' performance, productivity phenomenon can be accounted by different shift-share (decomposition) methods: aggregate productivity accounting method encompassing structural bonus, structural burden and within growth hypothesis; accelerations and decelerations in aggregate productivity growth evaluation method. Each of listed methods could be used *ad hoc* depending on the purpose of carried research. Hence, proper evaluating of productivity could provide possibilities of economy restructuring, which, in its turn would facilitate sustainable development and long-term competitiveness increase.

References

Balitskiy, S.; Bilan, Y.; Strielkowski, W. 2014. Energy security and economic growth in the European Union, *Journal of Security and Sustainability Issues* 4(2): 123–130. DOI: http://dx.doi.org/10.9770/jssi.2014.4.2(2)

Baublys J.; Miškinis V.; Konstantinavičiūtė I.; Lekavičius V. 2014. Aspirations for sustainability and global energy development trends, *Journal of Security and Sustainability Issues* 3(4): 17–26. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(2)

Baumol, W.J. 1967. Macroeconomics of unbalanced growth: the anatomy of urban crisis, *The American Economic review* 57: 415–426.

Bonetto, P.; Hoffmann, B.; Prause, G. 2014. Rise and fall of the Lyon silk cluster: a case study about entrepreneurial sustainability, *Entrepreneurship and Sustainability Issues* 2(1): 1–11. DOI: http://dx.doi.org/10.9770/jesi.2014.2(1)

Booth, A. 2003. The Broadberry–Crafts view and evidence: a reply, *Econ Hist Rev* 56:736–742.

Broadberry, SN.1998. How did USA and Germany overtake Britain?: a sectorial analysis of comparative productivity levels, 1870-1990, *Econ His* 58: 375–407.

Caurkubule, Ž.; Rubanovskis, A. 2014. Shadow economy as a obstacle to sustainable Economic development, *Journal of Security and Sustainability Issues* 4(2): 175–186. DOI: http://dx.doi.org/10.9770/jssi.2014.4.2(6)

Chenery, H.; Robinson, S.; Syrquin, M. 1986. Industrialization and growth: a comparative study. Oxford University press: New York.

Crafts, NFR. 1984. Patterns of development in nineteenth century Europe, *Oxfor Economics Papers* 36: 438–458.

Demir, E.; Marco Lau, Chi.K.; Bilgin, M.H. 2014. The impact of 2008 financial crisis on firm's productivity: evidence from Latvia, Lithuania and Romania, *Journal of Security and Sustainability issues* 3(4): 27–35. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(3)

Denison, EF. 1967. Why growth rates differ. Washington DC: Brookings.

Dzemyda, I.; Raudeliūnienė, J. 2014. Sustainable youth entrepreneurship in conditions of global economy toward energy security, *Entrepreneurship and Sustainability Issues* 1(4): 247–256. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(7)

Fabricant, S. 1942. Employment in manufacturing: New York.

Fagerber, J. 2000. Technological progress, structural change and productivity growth: a comparative study, *Structural change and economic dynamics* 11(4): 393–412.

Fei, JCH; Ranis, G. 1964. Development of the labour surplus economy. Irwin: Homewood.

Fuschi, D.L.; Tvaronavičienė M. 2014. Sustainable development, Big Data and supervisory control: service quality in banking sector, *Journal of Security and Sustainability Issues* 3(3): 5–14. DOI: http://dx.doi.org/10.9770/jssi.2014.3.3(1)

Garškaitė-Milvydienė, K. 2014. Anti-crisis management of enterprises and possibilities of overcoming their critical condition, *Journal of Entrepreneurship and Sustainability Issues* 1(4): 187–203. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(1)

Harbeger, A.1998. A vision of the growth process, *American Economic Revision* 88:1–32.

Havlik, P. 2005. Structural change, productivity and employment in the new EU member states, the Vienna institute for international economic studies, Wiiw research reports 313. Available on the Internet< http://www.ekof.bg.ac.rs/nastava/savremni_priv_sistemi/dec2006/structural%20change%20,peter%20tr.pdf>.

Hurber, P.; Mayerhofer, P. 2006. Structural Change in the CENTROPE Region, Workshops proceedings of on workshops, No 9. Available on the Internet <www.oenb.at/.../Workshops/2006/Workshop-No.../ws_09_tcm16-42773.p... >.

Jalava, J. 2006. Production, primary, secondary and tertiary: Finnish growth and structural change, 1860-2004, *Pellervo Economic Research Institute Working Papers* 80: 27. ISBN 952-5594- 06-8 (PAP), ISBN 952-5594-07-6 (PDF), ISSN 1455-4623.

Jones, B.F.; Olken, B.A. 2008. The anatomy of start- stop growth. Rev Econ Stat.

Kaminskienė, N.; Žalėnienė, I.; Tvaronavičienė, A. 2014. Bringing sustainability into dispute resolution processes, *Journal of Security and Sustainability Issues* 4(1): 69–77. DOI: http://dx.doi.org/10.9770/jssi.2014.4.1(6)

Kuznets, S. 1966. Modern economic growth: rate, structure and spread. Yale university press: London.

Lankauskienė, T.; Tvaronavičienė, M. 2012. Production factors and structural changes in economy sectors: genesis of theoretical approaches. ISI Conference proceedings “Contemporary issues in business, management and education”, Vilnius, Lithuania. ISSN 2029-7963/ISBN 978-609-457-323-1. DOI:10.3846/cibme.2012.20

Lankauskienė, T.; Tvaronavičienė, M. 2013. Economic sector performance and growth: contemporary approaches in the sustainable development context, *Intellectual economics* 3(7): 355–374.

Lankauskienė, T.; Tvaronavičienė, M. 2014. Economy structure, productivity and economic growth: towards methodological perspective, 8th International Scientific Conference “Business and Management 2014” May 15–16, 2014, Vilnius, Lithuania, ISSN print 2029-4441/ ISSN online 2029-929X, ISBN print 978-609-457-652-2/ ISBN online 978-609-457-651-5. DOI: 10.3846/bm.2014.064

Lewis, W.A. 1954. Economic development with unlimited supplies of labor, *Manchester Sch Econ Soc Stud* 22: 139–191.

Litvaj, I.; Poniščiaková, O. 2014. Entrepreneurship and quality management, *Entrepreneurship and Sustainability Issues* 1(4): 204–209. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(2)

Figurska, I. 2014.Sustainable entrepreneurship: localization, acquiring and use of knowledge sources in competitive organization, *Entrepreneurship and Sustainability Issues* 1(4): 210–222. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(3)

Mačiulis, A.; Tvaronavičienė, M. 2013. Secure and sustainable development: Lithuania’s new role in taking the Presidency of the EU, *Journal of Security and Sustainability Issues* 3(2): 5–13. DOI: http://dx.doi.org/10.9770/jssi.2013.3.2(1)

Maddison, A. 1987. Growth and slowdown in advanced capitalist economies: techniques of quantitative assessment, *Journal of Economics Lit* 25: 649–698.

Maroto-Sanchez, A.; Cuadrado-Roura, J.R. 2009. Is growth of services an obstacle to productivity growth? A comparative analysis, *Structural Change and Economic Dynamics* 20: 254–265.

Mathur, A.K; Roy, S.; Mitra, J. 2013. Toward sustainable development of economic sub-sectors: case of Indian sericulture, *Journal of Security and Sustainability Issues* 3(2): 15–30. DOI: http://dx.doi.org/10.9770/jssi.2013.3.2(2)

Peneder, M. 2003. Industrial structure and aggregate growth, *Structural change and economic dynamics* 14: 427–448.

Peneder, M. 2009. Sectoral growth drivers and competitiveness in the European Union. European Commission, Enterprise and industry, European communities, 1–542.

Pritchett, L. 2000. Understanding patterns of economic growth: searching for hills among plateaus, mountains and plains, *World bank Econ Rev* 14: 221–250.

Pritchett, L. 2000. Understanding patterns of economic growth: searching for hills among plateaus, mountains and plains, *World bank Econ Rev* 14: 221–250.

Raudeliūnienė, J.; Tvaronavičienė, M.; Dzemyda, I. 2014. Towards economic security and sustainability: key success factors of sustainable entrepreneurship in conditions of global economy, *Journal of Security and Sustainability Issues* 3(4): 71–79. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(7)

Ruza, O.; Lavrinenko, O.; Zelcs, R. 2014. Sustainable development of real estate market: impact of the micro and meso level factors, *Journal of Security and Sustainability Issues* 3(4): 45–60. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(5)

Scaringelli, M.A. 2014. Are the foreign controlled firms more environmentally sustainable than domestically controlled ones?, *Journal of Security and Sustainability Issues* 4(2): 131–146. DOI: http://dx.doi.org/10.9770/jssi.2014.4.2(3)

Syrquin, M. 1984. Resource allocation and productivity growth, in Syrquin, M.; Taylor, L.; Westphal, LE. (Eds.). *Economic structure and performance.* Essays in honour of Hollis B. Chenery. Academic Press: Orlando.

Tanuwidjaja, E.; Thangavelu, S. 2007. Structural Change and Productivity Growth in the Japanese Manufacturing Industry, *Global economic review* 36(4): 385–405.

Tarabkova, L. 2014. Model of motivating linked-up with education, Entrepreneurship and Sustainability Issues 2(1): 12–18. DOI: http://dx.doi.org/10.9770/jesi.2014.2.1(2)

Temin, P. 2002. The golden age of European growth reconsidered, *Eur Rev Econ Hist* 6:3–22.

Timmer, M. P.; Szirmai, A. 2000. Productivity growth in Asian manufacturing: the structural bonus hypothesis examined, *Structural change and economic dynamics* 11: 371–392.

Timmer, M.P.; Vries, G.J. 2007. A Cross-country Database for Sectoral Employment and Productivity in Asia and Latin America, 1950-2005.

Timmer, M.P.; Vries, G.J. 2008. Structural change and growth accelerations in Asia and Latin America: a new sectoral data set, Cliometrica. DOI 10.1007/s11698-008-0029-5.

Tvaronavičienė, M. 2014. If industrial sector development is sustainable: Lithuania compared to the EU, *Entrepreneurship and Sustainability Issues* 1(3): 134–142. DOI: http://dx.doi.org/10.9770/jesi.2014.1.3(2)

Tvaronavičienė, M.; Šimelytė, A., Lace, N. 2014. Sustainable development facets: exporting industrial sectors from inside, *Journal of Security and Sustainability Issues* 3(4): 37–44. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(4)

Van Ark, B.; Hann, J. 1997. The Delta- Model revisited: recent trends in the structural performance of the Dutch Economy, Research memorandum GD-38, Groginen growth and development centre.

Vasiliūnaitė, R. 2014. Sustainable development: methodological approaches toward issues, *Journal of Security and Sustainability Issues* 3(3): 69–75. DOI: http://dx.doi.org/10.9770/jssi.2014.3.3(6)

Vries, G.J.; Erumban, A.A; Timmer, M.P; Voskoboynikov, I; Wu, H. X. 2011. Deconstructing the BRICs: Structural Transformation and Aggregate Productivity Growth, Research memorandum GD-121, Groginen growth and development centre, University of Groginen.

Wahl, M. 2014. Sustainable Entrepreneurship: The Wolf ButterBack Case, *Entrepreneurship and Sustainability Issues* 1(4): 223–229. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(4)

Toma LANKAUSKIENĖ is PhD in Economics at Vilnius Gediminas Technical University, Faculty of Business Management, Department of Economics and Management of Enterprises. Scientific research area: structural economics, development economics, sustainable development.

ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES
ISSN 2345-0282 (online) http://jssidoi.org/jesi/aims-and-scope-of-research/

SUSTAINABLE ENTREPRENEURSHIP THROUGH ENERGY STEWARDSHIP: ROLE OF VALUES AND BEHAVIORAL PATTERNS

Jurgita Raudeliūnienė[1], Manuela Tvaronavičienė[2], Ignas Dzemyda[3], Mohamad Sepehri[4]

[1,2,3] Vilnius Gediminas Technical University, Saulėtekio av. 11, LT- 10223, Vilnius, Lithuania
[4]Jacksonville University, 2800 University Boulevard North, Jacksonville, FL 3221, USA

E-mails: [1]jurgita.raudeliuniene@vgtu.lt; [2]manuela.tvaronaviciene@vgtu.lt; [3]ignas.dzemyda@vgtu.lt, [4]msephr@ju.edu

Received 15 October 2014; accepted 21 November 2014

Abstract. In conditions of globalization, due the transformation of the information society to the knowledge society, changing technological and social circumstances, change not only the needs of consumers, but also can be observed structural changes in the management structure, economics and management science disciplines. Especially actual for business practitioners and researchers discourse becomes sustainable entrepreneurship through energy stewardship concept, which is associated with the ability to discover new opportunities for creation of economic and social value for consumers and the organization, country, region and the world. Under such circumstances it is important to identify the key factors of sustainable entrepreneurial through energy stewardship, because it is becoming one of the cornerstones of strategy of Europe in order to become the most competitive economy in the world. Scientists investigating the concept of sustainable entrepreneurship through energy stewardship and its components expose to the problem, which is more integrated approach that reflects the reality. The goal of article is to present the concept of sustainable entrepreneurship through energy stewardship and identify key success factors for sustainable entrepreneurship through energy stewardship in the global economy.

Keywords: sustainable entrepreneurship, energy stewardship, behavioral patterns, global economy, values

Reference to this paper should be made as follows: Raudeliūnienė, J.; Tvaronavičienė, M.; Dzemyda, I.; Sepehri, M. 2014. Sustainable entrepreneurship through energy stewardship: role of values and behavioral patterns, *Entrepreneurship and Sustainability Issues* 2(2): 107–117.
DOI: http://dx.doi.org/10.9770/jesi.2014.2.2(6)

JEL Classifications: M10, Q01, Q43, F64

1. Introduction

Structural economic changes has led to a stage of sustainable development, where major economic success factors appeared to be entrepreneurship (Laužikas, Mokšeckienė 2013; Moskvina 2013; Bonetto *et al.* 2014), knowledge (Figurska 2014; Tvaronavičienė *et al.* 2014), application of technology (Išoraitė 2014), innovations and energy stewardship (Kaminskienė *et al.* 2014; Tvaronavičienė 2014; Tvaronavičienė *et al.* 2014; Vasiliūnaitė 2014). As globalization increasingly influences business competitiveness through energy stewardship and operational area, organization faces problems not only of the ability to adapt to global economic trends, as well as issues of technology transfer and application, but also how to change consumer behaviour aspects. In order to achieve sustainable entrepreneurship through energy efficiency enhancing, we need to rely on such factors as new culture, values and behavioural patterns. It is important to focus on cultural change and acceptable behavioral patterns for finding more efficient ways of energy use. In this context sustainable entrepreneurship transforms into a key factor of efficient energy resources use through instilling new approaches towards energy consumption. The concept of sustainability entrepreneurship is a relatively new concept in scientific literature. The concept is developed aiming to relate sustainable development and entrepreneurship literature (Hall *et al*. 2010; Vasiliūnaitė 2014). In this theoretical perspective sustainable entrepreneurship could be defined as a synthesis of conventional and social entrepreneurship. Sustainable entrepreneurship could be defined as the process of identifying and starting a new business venture, organizing and managing needed resources, thinking both risks and revenues related with the venture, while considering of how, by whom, and with what economic, psychological, social, and environmental consequences, the opportunities are discovered, created, and exploited to bring future goods and services into existence (Dzemyda, Raudeliūnienė 2014).

Sustainable entrepreneurship is a concept related to ability to find new opportunities, ability to realise and create economic, ecological and social value, take into account contemporary sustainability and security issues, especially related to energy security (Lankauskienė, Tvaronavičienė 2012; Tvaronavičienė 2012; Miškinis *et al.* 2013; Vosylius *et al*. 2013; Baublys *et al.* 2014; Balitskiy *et al.* 2014; Garškaitė-Milvydienė 2014; Matyasik 2014; Scaringelli 2014; Vasiliūnaitė 2014). A key factor of successful development of the country or region is becoming knowledge and innovation based on sustainable entrepreneurship through energy stewardship. It is important to present new ways how to create sustainable entrepreneurship through energy efficiency that is directly related with operational efficiency, cultural aspects, and economic efficiency and environment sustainability.

The goal of article is to present the concept of sustainable entrepreneurship through energy stewardship and identify key success factors for sustainable entrepreneurship through energy stewardship in the global economy.

2. Sustainable entrepreneurship through energy stewardship

The discussion about sustainable development arose from the account of vast ecological, economic and social problems: most of these problems resulted from the proliferation of the current system of production and consumption from local to the global scale (Zabel 2005; Vasiliūnaitė 2014). In order to describe the concept of sustainable entrepreneurship through energy stewardship at the beginning is necessary to define the concept of entrepreneurship, which is dealt with in different scientific fields: economics, psychology, management, education science.

Throne-Holst, Strandbakken, Eivind (2008) based on former studies, six potential barriers for radical consumer changes were identified: physical and structural barriers; political barriers; cultural-normative barriers; economic barriers; information barriers; and individual-psychological barriers. The following three are considered as those with the highest explanatory value:

- cultural (realising optimal adjustments between work- and family life, hobbies and interest, and in addition an extensive social life is viewed positively; the degree of freedom is also limited by other cultural norms: in the sense that the range of options for energy savings are constrained by behavioural norms and rules in different settings);
- economic (there are economic barriers to investments in new energy systems, and this is confirmed by the recent public debate on this matter);
- information (the consumers not only need information on what and how to save energy, but also help in identifying when they should make their investments).

According Bunse *et al*. (2011), there are three main drivers that forces industries to put in efforts to increase energy efficiency: the increase of energy prices, the introduction of new environmental regulations, and consumers purchasing behaviour (Bunse *et al.* 2011). According to Hussaini, Majid (2014), energy use have revealed three major issues that are associated with energy efficiency as: architectural (design) issue, appliances/services (technology) efficiency issue, and the human (behavioural) issue. Nonetheless, there is a fundamental assumption that the technology-based improvement on energy efficiency is significantly influenced by human social behaviour in the utilization of the energy. According Authors, the human dimension to energy analysis is influenced by the level of education, awareness and social status of the individual users of the energy (Hussaini, Majid 2014).

Entrepreneurship is percieved today as a cultural and economic phenomenon. Entrepreneurship could be understood as activities of creation of new businesses that produce new products and services, and thereby ensure public needs, such as to create new jobs and contribute to the overall economic stimulus and developement of community life quality. Entrepreneurship is very important for economic development, believing that people in developing countries have a lot of potential to create, develop and manage their own businesses, thereby contributing to a variety of social problems such as sustainable regional development, solving problems of unemployment in general, the involvement in solving issues of povety.

From the social and economic perspectives of the business, entrepreneursip is understood as the ability to achieve results in organization. In psychological sciences entrepreneurship is regarded as an individual personal characteristics, traits, abilities in acting organization's success. From the science of management pint of view entrepreneurship is interpreted as an element of strategic management, seeking to link aims of organization and personal intentions. Of education positions enterpreneurship is examined through entrepreneurship education and innovation development perspective.

Vinig and de Kluijver (2007) refer to the conditions of modern entrepreneurship to be considered in light of the growing importance and influence of the phenomenon of globalization. Therefore, the authors perceive entrepreneurship as a three-dimensional interface, including the ability to discover new opportunities; the ability to deploy and use existing resources to exploit discovered opportunities; participation in a global society and preparation for global competition. L. Galloway (2009) argues that the concept of entrepreneurship can fully understood just in case it will explore how the relationship between personality characteristics and personal knowledge and practical skills with a whole based on appropriate attitudes and learning.

Entrepreneurship is defined by characteristics of a person, values, skills, attitudes provisions own business building intentions in the context of activating, distinguishing between the internal and external determinants of entrepreneurship. Internal determinans are related with individual entrepreneurship curriculum, educational intervention aimed to influence individual entrepreneurial internal factors (attributes values, skills, perceptions, and behavior). External determinant are understood as other then personal entrepreneurial factors (social, economic, political, legal) acts personal point of view of intrapreneurship within an institutional framework for entrepreneurship education. These few examples of the entrepreneurial concept definitions show that different authors emphasize different aspects of entrepreneurship. With the rapid emergence of scholarly thinking and analysis about entrepreneurship has come a multiplicity of approaches, emanating from different academic traditions, that has resulted in an academic field that is complex and heterogeneous with respect to approaches, methodologies and even the understanding about what exactly constitutes entrepreneurship (Audretsch 2012).

Sustainablility entrepreneurship is more complex issue. Sustainablity entrepreneurship can be understood as enterpreneurs activities that meet the needs of the present without compromising the ability of future generations to meet their own needs. The strong relationshis between entrepreneurship and sustainable development exist in research literature literature. There are used such concepts as environmentally orientated entrepreneurship; social entrepreneurship (entrepreneurship that aims to provide innovative solutions to unsolved social problems); institutional entrepreneurship (contributing to change regulatory, societal and market institutions), responsible entrepreneurship (a term coined which joining economic, technological, environmental factors is or must be responsible to society, enhancing the business positive contribution to society whilst minimizing negative impacts on people and the environment) (Kardos 2012).

The concept of sustainable entrepreneurship (or sustainability entrepreneurship) can be defined by differently. Sustainable entrepreneurship is an area within the larger concept of sustainable development (Parra 2013). Sustainable entrepreneurship can be understood as the examination of how, by whom, and with what economic, psychological, social, and environmental consequences the opportunities are discovered, created, and exploited to bring future goods and services into existence (Cohen and Winn 2007, p. 35). From the process scope, it is the process of discovering, evaluating, and exploiting the economic opportunities present in market failures which detract from sustainability, including those that are environmentally relevant (Dean and McMullen 2007, p. 58). As well sustainable entrepreneurship is defined as the teleological process aimed at the achievement of sustainable development by discovering, evaluating and exploiting opportunities and creating values that produce economic prosperity, social cohesion and environmental protection (Katsikis and Kyrgidou 2008, p. 2).

According to Lans *et al.* (2014), the concept of sustainable entrepreneurship has gained importance over recent years. The relationship between entrepreneurship and sustainable development has been dealt with through various schools of thought, often resulting in the launching of new types of entrepreneurs, such as the ecopreneur and the social entrepreneur. The concept of 'sustainable entrepreneurship' has been coined more recently as an overarching way of looking at the contribution of entrepreneurial endeavours to social, ecological and economic aspects: or, in other words, sustainable development (Lans *et al.* 2014). Santiago (2013) represents, that even if the concept of sustainability entrepreneurship is unknown to the entrepreneurs, yet, they engaged in sustainable business practices, meant to improve living conditions of marginalized groups. However, while they have actually helped communities to take better control of their livelihood, they have not yet consciously imbibed the element of futurity (Santiago 2013).

Sustainable entrepreneurship is much related with energy stewardship. Sustainable entrepreneurship is much related with strategy based on conscious use of energy, as well as using renewable energy sources. This makes a lot of chalanges. Because renewable energy sources are stochastic and geographically diffuse, their ability to match demand is determined by adoption of one of two approaches: the utilisation of a capture area greater than that occupied by the community to be supplied; or the reduction of the community's energy demands to a level commensurate with the locally-available renewable resources (Omer 2012).

The potential energy savings is one of the most important determinant of sustainable business. This could be achieved by basing sustainable entrepreneurship on renewable energy technologies and green energy. The key factors to reducing and controlling CO2, which is the major contributor to global warming, are the use of alternative approaches to energy generation and the exploration of how these alternatives are used today and may be used in the future as green energy sources (Omer 2012). This aspect is much related with energy relations and energy consumtion quantifications that opens new ways of the energy security and sustainable competition. This is potentially of considerable interest given that energy security is a widespread concern, particularly among highly energy dependent and vulnerable countries, and in view of the current context of growing competition for resources, characterised by increasing energy demand and the exhaustion of fossil fuels (Munoz-Delgado 2011). Thus, according Ozolina, Roša (2013) research results, is a lack of information regarding costumers' role and impact on energy efficiency in general.

Bonzo (2008) points out, the most important role of energy policy is its contribution towards achieving sustainability in the social, economic and environmental dimensions of development. In order to achieve energy sustainablility, it is important that authorities elaborate a long-term energy plan that envisages a sustainable development path (Fellows 2006). At some stage, we need to move from the relativism of improvement to the absolutism of sustainability assurance, if only, to the best that our knowledge allows – only such a stance is really a culture of sustainability (Fellows 2006).

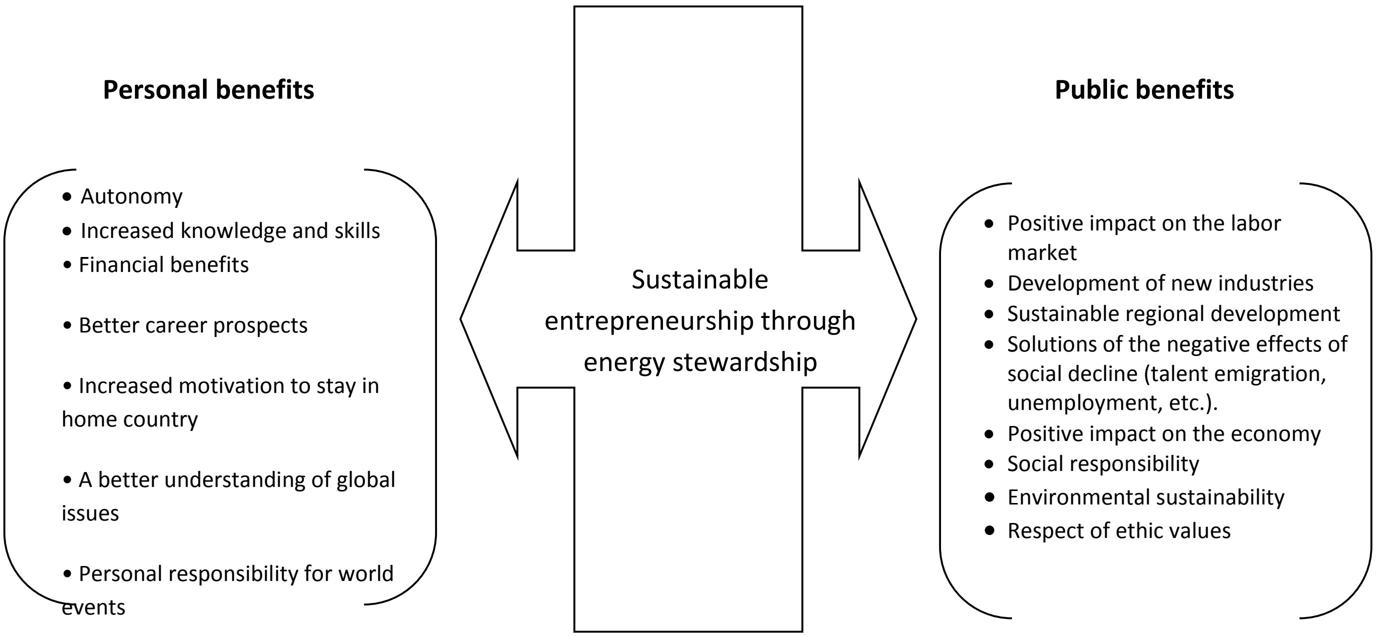

Fig. 1. Sustainable Entrepreneurship through Energy Stewardship

An analysis conducted by Martinez (2010) indicated that economic and technical factors have played an important role in the energy efficiency performance because increases in economic growth and technology improvements increase the industrial sector's ability to improve energy efficiency. Abdelhamid *et al.* (2011) shows that this new technology represents in theory a solution for environmental problems and could also be economically competitive with conventional energies if wisely exploited.

In sum, the promotion of sustainable entrepreneurship has a positive impact on both the individual level and the social level, as well as for energy security. One of the most important ways to achieve sustainable entrepreneurship is through energy stewardship. The concept of sustainable entrepreneurship through energy security is presented in Figure 1.

In conclusion, sustainable entrepreneurship ithrough energy security is very much affected by changed needs and behavior of consumers. We can identify shift from need of cheap goods and services of mass production to niche products and services delivered on sustainable way. By reached good life quality consumers start to consider options to consume less, but better quality products and services, produced on conscious way. This makes the social change of values of consumers. Sustainability of the product is as much important as other more material aspects, such as durability and functionality of products. Sustainable entrepreneurship could be implementend in societies, taking into account not only benefits that they get from the product, but as well as other more sophisticated values, related with public benefits in the terms of socio-economic, environmental, respect of ethical values (like fair trade supply chain, animal rights, support of local production). By this change of consumption entrepreneurs are encouraged to balance their personal benefits with public benefits, and to orientate their entrepreneur activities to more sustainable way.

3. Key success factors of sustainable entrepreneurship: role of values and behaviour patterns

Changes in consumtion in conditions of globalization has significant impacts on sustainable entrepreneurship - the rapid development of technology, hyper-competition, constant change, information surplus, more sophisticated concumer behavour, etc. This socio-economic change provides both new opportunities and new challenges.

Under these conditions sustainable entrepreneurship through energy stewardship becomes a very important determinant for local economies to response global chalanges. Because of this it is a very important to identify key success factors of sustainable entrepreneurship.

Key success factors of sustainable entrepreneurship is in much part related with culture or organization. Seemingly, at present, that requires a cultural shift from immediate self-interest perspectives which are commonplace; as such, institutions are likely to be forced to act as catalytic instruments (as in safety) to initiate change through pluralist mechanisms of various levels of formality and appeal (Fellows 2006). Interpretation of what represents entrepreneurship is likely to vary cross-nationally according to the distinctive patterning of social values and norms of behaviour rooted in the host culture (Omar and Davison 2001). Culture represents a complex and largely ethereal phenomenon, compounded by its multiple representation within such elements as: different levels (national, regional, business, individual); layers of society (gender, age, social class, occupation, family, religion); and varying context of life (individual, group, community) (Morrison 2006). If it is a culture, it espouses our values and shapes our behaviour such that sustainability is the norm, rather than the exception (Fellows 2006).

Zabel (2005) was suggested a model of human behaviour for sustainability, which try to establish new structures to enhance sustainable behaviour on the individual level. These efforts aim at constructing a network of interaction among institutions and individuals that commit to the general ideas of sustainable development and the advancement of sustainable patterns of individual and collective behaviour. This network may provide a chance to have some bearing on individual behaviour through cultural and situational influences. Adequate framework conditions at the local, regional, national and international level are necessary to change values and individual behaviour. According Zabel (2005) the establishment of a sustainability-oriented interaction network will only succeed if the relevant social and individual actors contribute. Fields of action are: legal regulation, education, infrastructure, and support for cultural activities, nature conservation, public participation and deliberation, prevention of risks, open access to information and others (Zabel 2005).

According Ozolina, Roša (2013) research results, there are at least three elements that can influence energy efficiency progress in manufacturing companies: energy prices, environmental regulations, consumers. The major difference is that the consumers' behaviour cannot be regulated directly by state policy. The opposite way is through environmental regulations. The state can be the initiator to develop new regulations in order to promote energy efficiency in companies. A smaller impact of the state can be seen in the regulation of energy prices, but still the energy prices depend on the market conditions, general state policies and strategies. It is very hard to influence consumers because there are different factors that are taken into account before choosing the products. Also, the factors related to environmental issues are less important.

For changing customers behavioral aspects, Hussaini, Majid (2014) suggesting to use a social scheme of balanced framework like the "TIME" model: targeting (this is to recognize the consumption pattern; and the diversity within the community in terms of people and their actions); informing/engaging (effort should be geared towards helping people and communities to develop the capacity to be mindful of their energy use through a "people-centered-initiative"; the public are encouraged to participate actively or passively in saving energy through the application of their knowledge to given situations); motivating (there is the need to motivate people using financial and non-financial mechanisms to turn intentions into behaviour through goals, norms, networks, commitments, etc.; this can be accomplished through financial incentives; use of demonstration projects to illustrate energy saving criterion); empowering/enabling (there should be concerted effort to remove financial and structural barriers; and to provide better choice sets, and creating supportive communities through policies and legislation, etc) (Hussaini, Majid 2014).

Laestidus (2003) represents, that the one of key success factor of eco-efficient business is a situation in the value chain where all actors involved show materials data for each stage that follows the product as an aggregated information package along the value. Laestidus (2003) concludes, the efficiency of becoming eco-efficient would be much more cost efficient if looking at total costs for an entire value chain, but is probably immensely difficult to implement if not supported by international legislation or at least an unofficial standard for materials declaration (perhaps followed by an international standard). Fellows (2006) concludes, that unfortunatelly, unless the green approach is adopted universally and very rapidly, via continuous improvement in respect of the operation of the various "environmental protection standards", it may well prove to be the case that the sustainability sought by adherents to the Brundtland principles (economic growth, environmental protection, social equality) is unattainable.

Another factor important for sustainabile entrepreneurship is promotion of this kind of business. Informing entrepreneurs of the value of sustainability entrepreneurship, may lead to more for-profit enterprises to consider the effects of their business practices on the future of marginalized group and the environment (Santiago 2013). Vinig and de Kluijver (2007) state that entrepreneurship is influenced by different aspects of globalization. The authors distinguish three main forms of globalization that affect entrepreneurship:

1. economic globalization - many companies and organizations, and business ideas coming out in several countries; is created and developed in international relations global business;
2. political globalization - is being developed by international standards and national policy, is influenced by global events. All of this has an impact on the business sector, youth entrepreneurship;
3. social globalization - which gets more opportunities, including young people, to exchange ideas and information with people all over the world, to communicate with people in different countries. This particularly facilitates information technology, various youth exchange programs and etc.

This indicates that social entrepreneurship is influenced by the conditions of globalization processes. These conditions create additional opportunities for people from developing countries, makes circumstances to gain global importance in everyday business conditions. This empowers people to act independently of increased competition. In this aspect sustainable entrepreneurship is much related with energy security as sustainability values have positive impact for energy efficiency over wide geographical areas.

Key success factors of sustainable entrepreneurship is consisted by four dimensions - sustainability, that practically could be implemented by wise use of natural resources, territorial approach of business, local business running, sustainability-driven understanding in all business processes; niche strategy; entrepreneurship and sustainable development competences (such as systems-thinking competence, embracing diversity and inter-disciplinarity, foresight-thinking competence, normative competence, action competence, interpersonal competence, strategic management); ability to resist market pressure by value based business management and marketing (Raudeliūnienė *et al.* 2014). The key ingredient of these success factors is motivation of entrepreneur that could be increased by various political measures aiming to rise initiative of people to run existing or start new business ventures in more sustainable way (Raudeliūnienė *et. al*. 2014).

Howevew, the final consumer has the exclusive right to define what constitutes value in a product or service (Macharia *et al.* 2013). Rokeach (1973) defined value as an enduring belief that a specific mode of conduct or endstate of existence is personally or socially preferable to an opposite mode of conduct or end-state of existence. Combining values with demographic information can provide a better understanding of targeted consumers, and marketing programs based on this understanding can enhance the effectiveness of retail management (Erdem *et al.* 1999).

Macharia *et al.* (2013) researched, a consumer-focused approach to performance improvement in supply chains can lead to more satisfied consumers and improved returns to growers and retailers under increasing pressures of globalization and urbanization. The researchers identified, that Ethics Crusaders form the largest segment. The universal value profile for this segment can be summarized as: a large segment of consumers, with high preference for customer service and average preference for product quality, who mostly buy fresh vegetables from street vendors and are mainly youthful with high education but low to medium income (Macharia *et al.* 2013).

Another example of research of values and behavour patterns is research done by Peattie et al. (2009) on climate change on a social and commercial marketing communication. Researches finds, that effective communication on climate change which is capable of motivating changes in consumer behaviour (rather than simply raising awareness further) will depend upon: the relevance of climate change to consumers' lives and the relationship to their consumption behaviours being made clear; targeting strategies which take account of differences amongst key consumer segments; and developing a message which motivates rather than overwhelms consumers whilst avoiding any perceptions of "greenwashing".

The most important factors that need to be triggered in order to promote social entrepreneurship are: access to working capital; access and use of the latest technology and equipment; new product development and allowing people to try out their ideas in practice by creating value added. Thus, the greatest importance to the promotion of sustainable entrepreneurship is a practical help to people with conscious point of view and set of values, as well as want and need to start entrepreneur activities. It is necessary to promote the importance of social entrepreneurship by various means, such as entrepreneurial skills development programs, business consultancy, mentorship, local, national and international support networks. But, the most important aspect is to promote change of values of society and consumtion behaviour, to make background and education on conscious consumtion, to create a need for consuming products and services that made in sustainable way, by sustainable entrepreneurship, by people aiming sustainability.

Conclusions

Sustainable entrepreneurship is a set of conscious decisions leading success of small and medium enterprises in a very complex competitive environment. Sustainable entrepreneurship could be defined as the process of identifying and starting a new business venture, organizing and managing needed resources, thinking both risks and revenues related with the venture, while considering of how, by whom, and with what economic, psychological, social, and environmental consequences the opportunities are discovered, created, and exploited to bring future goods and services into existence. Sustainablity entrepreneurship can be understood as enterpreneurs activities that meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable entrepreneurship is related with energy stewardship, because conscious use of energy as well as using renewable energy sources can lead to competitive success in changing global environment.

Development of sustainable entrepreneurship is very much connected to change of consumption behaviour. Key success factors of sustainable entrepreneurship is related on values and consumtion patterns. The shift from needs of cheap goods and services of mass production to niche products and services based on social and environmental responsibility is a key success factor of sustainable entrepreneurship. By change of consumption needs entrepreneurs are encouraged to balance their personal benefits in terms of revenues and profits with public benefits in terms of sustainability, and to orientate their entrepreneur activities considering social-economic and environmental aspects, as well as energy stewardship. Also it is needed to promote change of values of society and consumtion behaviour, to make cirsumstances conscious consumtion, to create a need to consume products and services resulted by sustainable entrepreneurship.

References

Abdelhamid, L.; Bahmed, L.; Benoudjit, A. 2012. Impact of renewable energies – environmental and economic aspects: Case of an Algerian company, *Management of Environmental Quality: An International Journal* 23 (1): 6–22. DOI: 10.1108/14777831211191566.

Audretsch, D. 2012. Entrepreneurship research, *Management Decision* 50 (5): 755–764.

Balitskiy, S.; Bilan, Y.; Strielkowski, W. 2014. Energy security and economic growth in the European Union, *Journal of Security and Sustainability Issues* 4(2): 123–130. DOI: http://dx.doi.org/10.9770/jssi.2014.4.2(2)

Baublys, J.; Miškinis, V.; Konstantinavičiūtė, I.; Lekavičius, V. 2014. Aspirations for sustainability and global energy development trends, *Journal of Security and Sustainability Issues* 3(4): 17–26. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(2)

Bonetto, P.; Hoffmann, B.; Prause, G. 2014. Rise and fall of the Lyon silk cluster: a case study about entrepreneurial sustainability, *Entrepreneurship and Sustainability Issues* 2(1): 1–11. DOI: http://dx.doi.org/10.9770/jesi.2014.2(1)

Bozo, M. G. 2008. Energy policies in Latin America and the Caribbean and the evolution of sustainability, *International Journal of Energy Sector Management* 2 (1): 8–35.

Bunse, K.; Vodicka, M.; Schonsleben, P.; Brulhart, M.; Ernst, F.O. 2011. Integrating energy efficiency performance in production management – gap analysis between industrial needs and scientific literature, *Journal of Clean Production* 19 (6-7): 667–679.

Cohen, B.; Winn, M. 2007. Market imperfections, opportunity and sustainable entrepreneurship, *Journal of Business Venturing* 22: 29–49.

Dean, T.; McMullen, J. 2007. Toward a theory of sustainable entrepreneurship: Reducing environmental degradation through entrepreneurial action, *Journal of Business Venturing* 22: 50–76.

Dzemyda, I.; Raudeliūnienė, J. 2014. Sustainable youth entrepreneurship in conditions of global economy toward energy security, *Entrepreneurship and Sustainability Issues* 1(4): 247–256. DOI: 10.9770/jesi.2014.1.4(7)

Erdem, O.; Oumlil, A. B.; Tuncalp, S. 1999. Consumer values and the importance of store attributes, *International Journal of Retail & Distribution Management* 27 (4): 137–144. DOI: 10.1108/09590559910268435

Fellows, R. 2006. Sustainability: a matter of energy? *Property Management* 24(2): 116–131. DOI: 10.1108/02637470610658005.

Figurska, I. 2014. Sustainable entrepreneurship: localization, acquiring and use of knowledge sources in competitive organization, *Entrepreneurship and Sustainability Issues* 1(4): 210–222. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(3)

Galloway, L. 2009. *Diversity in entrepreneurship: the role of women and ethnic minorities. Enterpreneurship and small firms.* Deakins, D. & Freel, M. (Eds.) 5th edition.

Garškaitė-Milvydienė, K. 2014. Anti-crisis management of enterprises and possibilities of overcoming their critical condition, *Journal of Entrepreneurship and Sustainability Issues* 1(4): 187–203. DOI: http://dx.doi.org/10.9770/jesi.2014.1.4(1)

Hall, J.; Daneke, G.; Lenox, M. 2010. Sustainable development and entrepreneurship: Past contributions and future directions, *Journal of Business Venturing* 25(5): 439–44.

Hussaini, I. U.; Majid, N. H. A. 2014. Human behaviour in household energy use and the implications of energy efficiency delivery, *International Journal of Energy Sector Management* 8(2): 230–239. DOI: 10.1108/IJESM-10-2013-0005

Išoraitė, M. 2014. ICT and entrepreneurship: social network marketing, *Entrepreneurship and Sustainability Issues* 2(1): 19–29. DOI: http://dx.doi.org/10.9770/jesi.2014.2.1(3)

Kaminskienė, N.; Žalėnienė, I.; Tvaronavičienė, A. 2014. Bringing sustainability into dispute resolution processes, *Journal of Security and Sustainability Issues* 4(1): 69–77. DOI: http://dx.doi.org/10.9770/jssi.2014.4.1(6)

Kardos, M. 2012. The Relationship between Entrepreneurship, Innovation and Sustainable Development. Research on European Union Countries. *Procedia Economics and Finance*: Vol. 3 (January 2012): 1030–1035. DOI: 10.1016/s2212-5671(12)00269-9

Katsikis, I.; Kyrgidou, L. 2008. The Concept of Sustainable Entrepreneurship: a Conceptual Framework and Empirical Analysis, *Academy of Management Proceedings* 1–6.

Laestadius, P. C. S. 2003. The efficiency of becoming eco-efficient, *Management of Environmental Quality, An International Journal* 14 (2): 221–241.

Lankauskienė, T.; Tvaronavičienė, M. 2012. Security and sustainable development approaches and dimensions inn the globalization context, *Journal of Security and Sustainability Issues* 1(4): 287–297. DOI: http://dx.doi.org/10.9770/jssi.2012.1.4(5)

Lans, T; Blok, V.; Wesselink, R. 2014. Learning apart and together: towards an integrated competence framework for sustainable entrepreneurship in higher education, *Journal of Cleaner Production* 62: 37–47.

Laužikas, M.; Mokšeckienė, R. 2013. The role of creativity in sustainable business, *Entrepreneurship and Sustainability Issues* 1(1): 10–22. DOI: http://dx.doi.org/10.9770/jesi.2013.1(2)

Macharia J.; Collins R.; Sun T. 2013. Value-based consumer segmentation: the key to sustainable agri-food chains, *British Food Journal* 115 (9): 1313–1328. DOI: 10.1108/BFJ-09-2011-0215

Martínez, C. I. P. 2010. Analysis of energy efficiency development in the German and Colombian food industries, *International Journal of Energy Sector Management* 4 (1): 113–13. DOI: 10.1108/17506221011033125

Matyasik, M. 2014. Secure sustainable development: impact of social media on political and social crises, *Journal of Security and Sustainability Issues* 4(1): 5–16. DOI: http://dx.doi.org/10.9770/jssi.2014.4.1(1)

Miškinis, V.; Baublys, J.; Lekavičius, V.; Morkvėnas, A. 2013. New Changes in Lithuanian Energy Sector, *Journal of Security andSustainability Issues* 2(3): 15–28. DOI: http://dx.doi.org/10.9770/jssi.2013.2.3(2)

Morrison, A. 2006. A contextualisation of entrepreneurship, *International Journal of Entrepreneurial Behaviour & Research* 12(4): 192–209.

Moskvina, J. 2013. Social enterprises as a tool of social and economic policy, *Entrepreneurship and Sustainability Issues* 1(1): 45–54. DOI: http://dx.doi.org/10.9770/jesi.2013.1.1(5)

Muñoz-Delgado, J. 2011. Affinity and rivalry: energy relations of the EU, *International Journal of Energy Sector Management* 5(1): 11–38.

Omar, A.; Davidson, M. 2001. Women in management: a comparative cross-cultural overview, *Cross Cultural Management* 8: 35–67.

Omer, A. M, 2012. Clean energies development in built environment, *World Journal of Science, Technology and Sustainable Development* 9(1): 45–63.

Ozolina, L.; Roša, M. 2013. The consumer's role in energy efficiency promotion in Latvian manufacturing industry, *Management of Environmental Quality: An International Journal* 24(3): 330–340. DOI: 10.1108/14777831311322640

Parra, S. 2013. Exploring the Incorporation of Values for Sustainable Entrepreneurship Teaching/Learning, *Journal of Technilogy Management & Innovation* 8(1): 11–20.

Peattie, K.; Peattie, S.; Ponting, C. 2009. Climate change: a social and commercial marketing communications challenge, *EuroMed Journal of Business* 4(3): 270–286.

Raudeliūnienė, J.; Tvaronavičienė, M.; Dzemyda, I. 2014. Towards economic security and sustainability: key success factors of sustainable entrepreneurship in conditions of global economy, *Journal of Security and Sustainability Issues* 3(4): 71–79. DOI: 10.9770/jssi.2014.3.4(7).

Rokeach, M. 1973. *The Nature of Human Values.* The Free Press, New York, NY.

Santiago, A. 2013. On the road to sustainability entrepreneurship: Filipino case, *World Journal of Entrepreneurship, Management and Sustainable Development* 9(4): 255–271.

Scaringelli, M.A. 2014. Are the foreign controlled firms more environmentally sustainable than domestically controlled ones? *Journal of Security and Sustainability Issues* 4(2): 131–146 DOI: http://dx.doi.org/10.9770/jssi.2014.4.2(3)

Throne-Holst, H.; Strandbakken, P.; Eivind, S. 2008. Identification of households' barriers to energy saving solutions, *Management of Environmental Quality: An International Journal* 19(1): 54–66. DOI: 10.1108/14777830810840363

Tvaronavičienė, M. 2012. Contemporary perceptions of energy security: policy implications, *Journal of Security and Sustainability Issues* 1(4): 235–47. DOI: http://dx.doi.org/10.9770/jssi.2012.1.4(1)

Tvaronavičienė, M. 2014. If industrial sector development is sustainable: Lithuania compared to the EU, *Entrepreneurship and Sustainability Issues* 1(3): 134–142. DOI: http://dx.doi.org/10.9770/jesi.2014.1.3(2)

Tvaronavičienė, M.; Šimelytė, A., Lace, N. 2014. Sustainable development facets: exporting industrial sectors from inside, *Journal of Security and Sustainability Issues* 3(4): 37–44. DOI: http://dx.doi.org/10.9770/jssi.2014.3.4(4)

Vasiliūnaitė, R. 2014. Sustainable development: methodological approaches toward issues, *Journal of Security and Sustainability Issues* 3(3): 69–75. DOI: http://dx.doi.org/10.9770/jssi.2014.3.3(6)

Vinig, T.; Kluijver, J. 2007. *Does Globalization Impact Entrepreneurship? Comparative Study of Country Level Indicators.* Netherlands: University of Amsterdam.

Vosylius, E.; Rakutis, V.; Tvaronavičienė, M. 2013. Economic growth, sustainable development and energy security interrelation, *Journal of Security and Sustainability Issues* 2(3): 5–14. DOI: http://dx.doi.org/10.9770/jssi.2013.2.3(1)

Zabel, H. U. 2005. A model of human behaviour for sustainability, *International Journal of Social Economics* 32(8): 717–734. DOI: 10.1108/03068290510608228.

Jurgita RAUDELIŪNIENĖ. Assoc. Prof. Dr. of social sciences at the Faculty of Business Management, Vilnius Gediminas Technical University; member of editorial boards of peer-reviewed international scientific journals, member of scientific projects. The author and co-author of more than 30 scientific papers. Research interests: knowledge management, formation and evaluation of competitive strategic decisions, sustainable development.

Manuela TVARONAVIČIENĖ - Dr., full professor at Vilnius Gediminas Technical University, Business Management Faculty and full professor at The General Jonas Žemaitis Military Academy of Lithuania; member of editorial boards of peer-reviewed international scientific journals, expert of the Research Council of Lithuania, head and member of scientific projects. She is alumnus of IESE Business School; raised qualifications at Harvard Business School (USA) and Cambridge University, Judge School (UK). She is author of more than 60 papers. Research interests: economic growth, sustainable development, innovations, investments, energy security, entrepreneurship.

Ignas DZEMYDA. Assoc. prof. dr. of social sciences at the Faculty of Business Management of Vilnius Gediminas TechnicalUuniversity. The author carries out research in the fields of sustainable entrepreneurship, international management and the EU regional integration. He has published number of scientific research articles on various issues of management and economy. Research interests: strategic management, regional development, higher education, export development, innovations, new public management, sustainable entrepreneurship.

Mohamad SEPEHRI (Dr. Mo) is the Associate Dean and Director of the Graduate Business Programs (MBA, EMBA, MSOL, and DBA) and professor of Strategic International Management at Davis College of Business, Jacksonville University. He has a unique combination of academic and business experience, with extensive background in strategic management/leadership and broad experience in international and global business operations. Dr. Sepehri has Triple-Ph.D. in Management, Higher Education Administration, and Comparative Political Economy from Indiana University, Bloomington. Dr. Sepehri has been listed in the Harvard Business Who's Who as a distinguished scholar in international business. He was inducted as AIBSE Fellow in 2014. Dr. Sepehri has over 35 years of experience in strategic planning and global competitive market analysis. He is a consultant and research analyst to business corporations.