Smart Grid implementation to reduce peak loads in industrial areas: A business approach.

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Introduction

Currently, the most energy used in the world comes from fossil fuel sources such as oil, coal and gas. The use of fossil fuels has negative environmental consequences, such as global warming. Scarcity of these resources is a growing problem, and increases the costs for energy, which demands are ever growing. Moreover, gaining these fossil fuels have been a cause for conflicts in history. Taking this in mind, a transition towards sustainable energy from renewable sources is a necessary and responsible step. Most countries have ambitious targets on clean energy. The European Union targets with its 20/20/20 goals for 20% reduction of CO_2, 20% more energy efficiency and 20% renewable energy in 2020 (European Commission, 2012). The Intergovernmental Panel on Climate Change (IPCC, 2012) states a CO_2 reduction of 80-95% compared to levels of 1990 is required for developed countries in 2050.

The implementation of clean energy also requires improvements in the energy infrastructure: development of smart grids is essential for the success of clean energy. A smart grid allows energy flows in two directions and is capable of matching the supply and demand of energy. The randomness, intermittent, and the unbalanced nature of renewable energy require such a smart grid (Peng et al, 2011). Moreover, smart grids contribute to a more efficient electricity infrastructure.

Industrial areas consume vast amounts of energy for their production activities, which take place at the established companies. In 2004, industrial customers consumed 41,4% of electricity globally (IEA, 2006). Industrial energy customers are confronted with the rising prices of energy. In order to be competitive in the global market, companies should take measures to reduce their energy costs. When companies are able to purchase energy at times of the day that it is cheaper, they can have great benefits. Therefore, smart grids in industrial areas seem to have a great potential.

Embedment in literature

Smart grids are a popular theme in scientific literature. Technological developments and ICT components on smart grids are investigated in numerous papers. Many studies have investigated the possibilities of demand management on household levels. Also a number of pilot projects have been initiated in Europe. On the implementation of smart grids in industrial areas is very little literature. Braithwaith and Hansen (2011) acknowledge this gap in literature. They mention a project in California where commercial and industrial customers are faced with dynamic electricity prices and demand responses. Furthermore, they have investigated the impact of critical peak pricing (peaks which occur a few times per year), however, the fraction of customers who can respond to critical peak pricing is relatively low and users are more likely to participate in demand response programs.

In the study of CE Delft (2012) it is stated that the daily peak in commercial and industrial activities can be reduced by deploying smart grids with 15% (bandwidth between 3-25%) by shifting activities in time of the day. The critical peak power (CPP) can be reduced with 30% (bandwidth between 23-45%). Furthermore, they acknowledge that industrial activities have far more potential to shift activities in time and that the industry is more responsive to price incentives, compared to household energy users.

Projects that implement smart grids in industrial premises are hard to find. However, a good example is the e-harbours program, which focuses on energy use of businesses. “The challenge is to create a more sustainable energy model in harbour regions on the basis of innovative intelligent energy networks” according to e-harbours (2012). Interesting developments are proposed in harbours of Antwerp and Hamburg.

Borenstein et al (2002) investigate peak load reduction of commercial and residential buildings. The project in California, USA, aims to reduce peak loads caused by air-condition on sunny days. Simulations are made for a peak reduction program. They investigate costs of curtailment per kWh in a peak reduction program of $50 million. They agree that dynamic pricing is best applicable to large industrial and commercial energy users.

Cooling capacity seems a good example of flexible energy demand applications. Hovgaard et al (2012) have studied the energy use of refrigerators in supermarkets. Their model predictive control method indicated that cost savings of up to 70% could be achieved.

Literature on industrial energy use and the potential for saving energy and renewable energy is scarce, compared to the available literature on the build environment. Ang (1995) has done much research on industrial energy use. He applied diverse methods to analyse industrial energy demand, and has compared numerous studies on this topic. The literature on flexible energy demand in industrial use is rarely available. Clearly, more research on flexible demand is desirable.

Research framework

Problem analysis and research questions

The problem in this research is:

The industry is confronted with a growing energy demand and rising energy costs, combined with the transition to sustainable energy production, the constant availability of affordable energy is threatened!

The industrial consumers are depending on the availability of energy in order to fulfil their primary processes. Often, established companies where formed on the idea that energy is cheap and widely available. However, costs of energy are rising for decades, due to the higher demand and the depletion of resources. The ambitions to make a transition towards renewable sources, such as solar and wind power can cause unbalances in the electricity grid, due to the random and intermitting character of these energy sources. The central question in this research is: **"How can smart grids contribute to the continues availability of clean an affordable energy on industrial areas?"**

An important feature of smart grids is demand management; this can be used to match the intermittent supply of renewable energy and to reduce peaks in the demand of energy. To investigate this subject, some research questions are developed:

> *What are the costs and benefits of a smart grid in industrial parks, compared to a normal power grid?*
>
> *What is an optimal combination of companies; to create a local closed energy balance in a smart grid?*
>
> *Which companies or activities are flexible in energy demand and can be used to match the supply of energy in order to reduce peak loads?*
>
> *What business opportunities can be found to develop such a smart grid?*
>
> *Can a smart energy infrastructure attract businesses to settle on an industrial plot?*
>
> *How can industrial energy consumers benefit from deploying a smart grid on their premises?*

The research questions are relevant for municipalities, companies and the business opportunities to develop a local smart grid.

Research objectives and limitations

Purpose of this study is to investigate the feasibility to implement smart grids in industrial parks or harbours. To investigate these research questions a case study will be preformed on an industrial park development. The municipality of Zaanstad and developer Haventerrein Westzaan are developing the sustainable industrial park 'HoogTij'. In this collaboration the municipality owns 20% of the land, Haventerrein Westzaan owns the other 80%. The aim is to create a smart energy infrastructure; a heat/cold network is developed and there are ambitions to create a smart grid. Currently the land issuing is far behind schedule; only 13 companies are settled at HoogTij and use a small fraction of the 130ha available land. Zaanstad sees opportunities to attract companies with the smart energy infrastructure that is planned for HoogTij. Therefore they need to know which companies can consolidate each other to form a better collective.

In this research, the focus will be on finding a theoretical combination of companies, which are selected on their electricity use profile. In this situation, the costs and benefits of a smart grid can be investigated on an integral manner.

Methodological justification

To be able to answer the research questions, literature study is required on smart grids and industrial energy use. Because gaps are expected in literature, some expert interviews will be required. In order to have an idea of how smart grids can be implemented in practice, it is required to look at a real life situation, and thus make a case study. The energy needs and the production of energy are varying over time, and have a probabilistic component; a simulation model needs to be used. By making simulations, the impact of flexible demand of certain companies can be investigated in order to find an optimal combination.

Research approach

Research method

The first step in this research will be a desk study on the literature on smart grids and industrial energy use. Once a general understanding of these topics is made, the next step will be to apply this in a case study. Based on the characteristics of HoogTij, the influence of applying a smart grid will be investigated. An important step in this will be the development of a simulation model. To achieve a closed energy balance, and to be able to determine a good combination of companies, a multi-agent simulation model shall be made. This model can simulate the production and consumption of energy and can be use to evaluate peak reduction measures for companies which apply a demand management programme.

A Multi-Agent System (MAS) shall be made for this study. MAS is a relatively new modelling technique in the scientific world. Due to the increasingly complex world, with all its interdependencies, traditional modelling techniques are often not able to cope with these problems. MAS have the possibility to model individual preferences or behaviours. The 'agents' in the model are most important features. Agents are an independent component, which have the capability of making individual decisions. Agent's behaviour can range from primitive reactive decision rules to complex adaptive intelligence (Macal, 2005).

Several scenarios for the development of HoogTij can be analysed in the MAS model. The goal is to achieve a closed energy balance for the area, to investigate the costs and benefits and to find business opportunities for the smart grid development. From this, conclusions and recommendations can be made. These recommendations are aimed on municipalities, policy makers and developers of industrial areas. Optionally, the developers of HoogTij can choose to implement the proposed smart grid in the project. In figure 1, a scheme of the research approach is displayed.

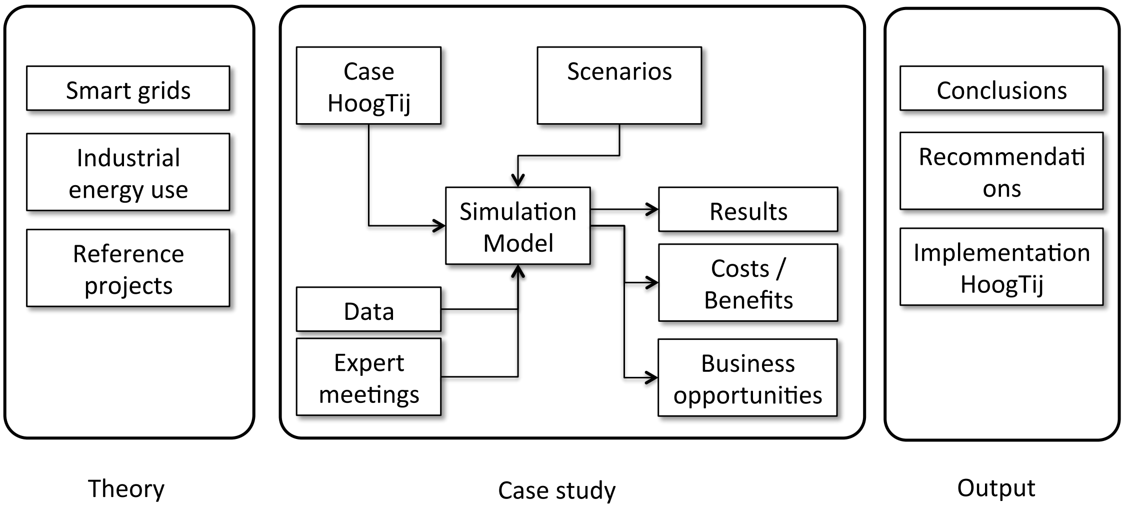

Figure 1 Graphical representation of research methodology

Planning

In figure 2 a global planning is made for the research project.

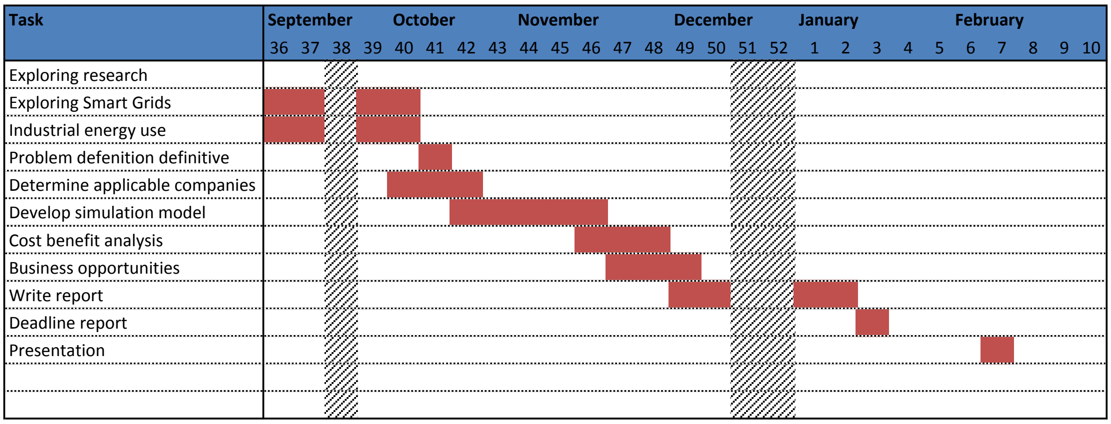

Figure 2 planning of the research project.

Scientific and social relevance

Relevance TU/e

Energy use is an important subject of research in the Eindhoven University of technology. Research on sustainable energy at the TU/e belongs to the top of the world. A number of faculties are interested in renewable energy. The Master track Construction Management & Engineering has special interest in the transition towards sustainable energy use, and has the focus on the implementation in the urban environment. Industrial (re)-development is a subject that is considered well within the course. More knowledge on this subject is therefore desirable. The Sustainable Energy Technology master programme has a multidisciplinary approach on sustainable energy. Smart grids are one of the research topics, as well as sustainable energy in the build environment. Industrial applications of smart grids can be a complement to the knowledge developed at the TU/e.

Relevance for businesses and public institutes

Businesses have seen energy prices rising for decades. In a globalising world it is important to stay competitive and to reduce cost where possible. Demand management can be a good way to reduce costs for energy intensive companies. Grid operators will be interested in these developments, investments in more capacity could be postponed and the grid can be made more reliable. Energy producers can achieve greater efficiency and operate more profitable. For the province of Brabant, this research and case study can be an important example of how smart industrial areas can be developed. The conclusions of the research can be helpful to develop sustainable and competitive industrial areas in Brabant.

Furthermore, demand management is crucial for widespread implementation of clean energy technologies. Of course, this is relevant for both businesses and society.

Expected results

An important result of this study will be the multi-agent simulation model. This should be able to model electricity use and local (sustainable) production. The model should be a tool to find an optimal mix of production of energy, and energy consumers.

In this study, a MAS simulation model shall be developed in Netlogo. Netlogo is a programming language based Logo, which has many similarities with Java. Netlogo models consist of Turtles (agents), which follow rules to move over Patches (environment). By measuring the movements and behaviour of the turtles, simulation can be made and data can be exported to process further.

The MAS model shall consist of three blocks (see figure 3); Production, consumption and balance. The energy production shall be modelled as the renewable energy sources on the site. The generated wind and solar power can be modelled based on climate data. The consumption of companies can be modelled based on energy profiles which companies have. Once production and consumption are known, the energy balance can be modelled. The simulation can predict at what times energy need to be imported or exported, or perhaps storage of energy is attractive.

Data sources

To be able to build a successful model, reliable data is required. Energy load profiles of various companies will be acquired from the network operator Alliander. Additionally data from literature studies and the e-harbours projects can be used. Data of sustainable energy production can be found in literature, or can be used from former graduation projects, for instance from the studies of Cyrrille Pennavaire and Cathelijne Broersen. Also metrological data is required, which can be found at the metrological institute KNMI.

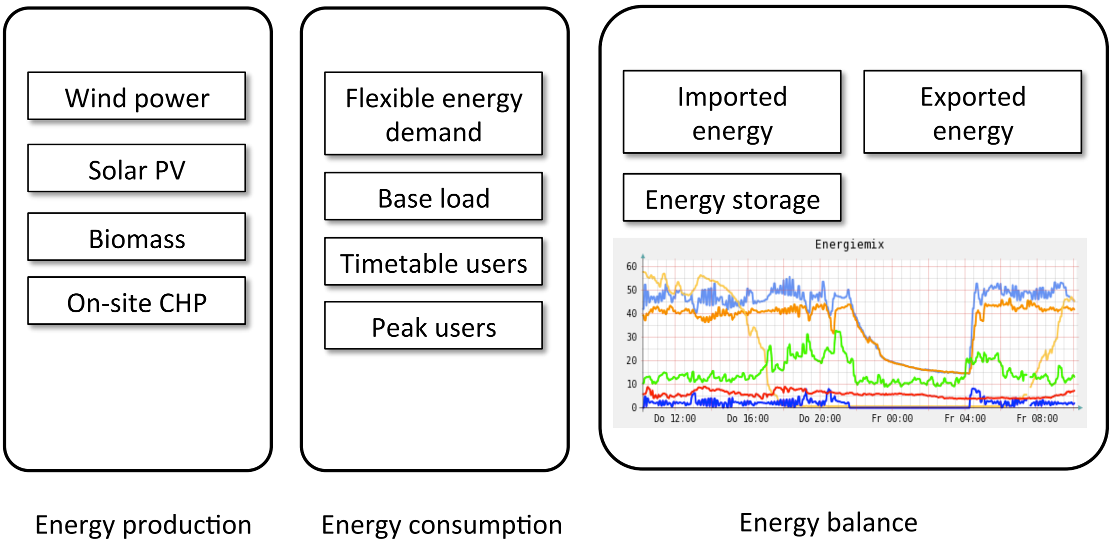

Figure 3 building blocks of Multi-agent simulation model

Outline final report

1. Introduction
    a. Problem analysis
    b. Research questions
    c. Case description HoogTij
2. Research methodology
3. Smart grids in industrial context
4. Simulation model
5. Cost benefit analysis
6. Implementation of smart grid on HoogTij
7. Business model industrial smart grid
8. Conclusions
9. Discussion
10. Acknowledgements

    References

    Appendices

References

Used literature

- Ang, B.W. 1995. Decomposition methodology in industrial energy demand analysis. Energy vol 20, no 11.
- Borenstein, S. Jaske, M. Rosenfeld, A. 2002. Dynamic pricing advanced metering, and demand response in electricity markets. University of California Energy Institute.
- Braithwait, S.D. Hansen, D.G. 2011. How Large Commercial and Industrial Customers Respond to Dynamic Pricing - The California Experience. In: Fereidoon P. Sioshansi. 2011. Smart Grid. Academic Press. Chapter 12.
- CE Delft, KEMA. 2012. Maatschappelijke kosten en baten van intelligente netten. CE Delft.
- e-harbours. 2012. The objectives of e-harbours. [Online] available at: < http://eharbours.eu/about> [accessed on June 27, 2012].
- European Commission. 2012. [Online] available at: <http://ec.europa.eu/clima/policies/package/index_en.htm> [accessed on July 1, 2012].
- IEA (International Energy Agency). 2006. Key world energy statistics. IEA, Paris.
- IPCC. 2012. [Online] available at: <http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml#.T_BXd465ZD0> [accessed on July 1, 2012].
- Macal, C.M. North M.J. (2005). Tutorial on agent - based modelling and simulation.
- Peng, li. Gao-Shi Yan. 2011. Clean Energy Grid-Connected Technology Based on Smart Grid. Elsevier.

Relevant literature

- Karnouskos, S. de Hollanda, T.N. Simulation of a Smart Grid City with Software Agents.

Expertise

- Alliander (Network operator)
- e-harbours (European smart grid pilots)
- Frits Wattjes (TU/e, researcher on smart grids)
- Frits Verheij (KEMA, director smart energy)
- Robert Gordon University (partner in e-harbours)