INTECH
open science | open minds

OPEN ACCESS
ARTICLE

International Journal of Engineering Business Management

Commercializing Emerging Renewable Energy: A Case Study

Regular Paper

Matti Lehtovaara[1,*], Matti Karvonen[1], Jussi Tuunanen[2], Olli Pyrhönen[2] and Tuomo Kässi[1]

1 Lappeenranta University of Technology, Department of Industrial Management, Lappeenranta, Finland
2 Lappeenranta University of Technology, Department of Electrical Engineering, Lappeenranta, Finland
* Corresponding author E-mail: matti.lehtovaara@lut.fi

Received 12 September 2012; Accepted 26 October 2012

DOI: 10.5772/54707

Abstract A broad scientific consensus exists that the global climate is changing. The Earth's surface temperature could rise significantly over the next few decades, leading to us witnessing an entirely new and unknown planet. Improved energy efficiency, decreasing use of fossil fuels and wide diffusion of various renewable energy sources are among the focal measures to limit global warming to a sustainable level. The objective of this study is to analyse how renewable energy, such as wind power and bioenergy, could be efficiently commercialized. The evaluation is based on a case study and expert analyses exploiting lateral and parallel thinking methods, and group decision support systems tools. The results reveal that some of the generated ideas are ready for implementation to commercialize renewable energy, whereas others still require technical and commercial development, and improvements before maturity.

Keywords Commercialization, Wind Power, Bioenergy, Renewable Energy, Climate Change

1. Introduction

The demand for renewable energy (RE), the threat of global warming and climate change, and the question of how to make the long transition to an economy based on fossil-fuel alternatives are concerns for all societies [1]. The United Kingdom, for example, will have to generate about 40% of the required electricity from renewable sources by 2020, in order to comply with the legally binding European Union targets [2]. There is a wide scientific consensus that the Earth's climate is changing and this phenomenon has become a worldwide concern. The global surface temperature has increased by about 1°C during the last century and the temperature will most likely increase further during the next hundred years. However, the temperature increase could be potentially limited to about two degrees provided that the carbon dioxide (CO_2) equivalent concentration in the atmosphere can be limited to 450 parts per million (ppm) [3]. The world's primary energy use is predicted to increase during the next decades, reaching a total energy consumption of about 50% higher in 2050 than today. The key drivers behind the development are the increase in population and expected gross domestic production (GDP) increase [4]. If mankind does nothing to prevent the global temperature increase and continues to consume energy and fossil fuels in a "business as usual" manner, [5] foresees a 130% rise in CO_2 emissions by 2050. Such an increase in emissions could raise the global average temperature by 6°C or more, resulting in significant impacts on all aspects of life and irreversible changes in the environment.

In spite of the huge challenges that the mankind faces, the climate change issue can be solved in such a manner that global warming can be limited perhaps to two or three degrees, especially before the "tipping point" when the warming phenomenon itself may accelerate the warming. There are enormous resources of wind energy globally to be harnessed into energy production and biomass utilization can also be increased significantly. The overall energy efficiency could be improved, e.g., by using smart grids, novel energy storage systems and electric vehicles. Technological solutions exist for solving many of the problems and sustainable solutions can most certainly be invented for the rest. The biggest hindrances preventing development seem to be human behaviour and the desire to increase personal prosperity. In general, the reluctance of politicians to support the diffusion of renewable energy by consistent, long-term policy increases the challenge [3, 6].

Environmental concerns and the predicted global increase in energy demand are the key drivers behind the growing wind energy markets. A more significant part of the gigantic global wind resources could well be harnessed to supply the increasing demand of energy [7]. Also decentralized, biofuelled combined heat and power production (CHP) could offer a qualified, sustainable solution for the growing energy demand in many regions. It is appropriate to implement novel technologies utilizing forest biomasses above all in the regions that possess sufficient natural resources enabling their sustainable exploitation [8].

In this paper we use the case study approach to study how renewable energy (wind power and biomass) could be efficiently commercialized. Expert group assessments exploiting Edward de Bono's [9] lateral thinking models and group decision support systems (GDSS) tools were carried out in order to answer the research question: *"How to get wind and biomass electricity commercialized in the Nordic countries by 2030?"* This paper focuses on the key concepts behind the development of renewable wind and biomass technologies and emphasizes the acceleration of the commercialization of these technologies. The research reveals that the de Bono methods and GDSS provide powerful tools for facilitating idea generation and innovative thinking in expert organizations. Among the generated ideas, four were selected for more in-depth analysis: modular mass production units, electric grid investment support, electric cars as energy storage and home energy control systems. The results indicate that many issues in commercializing renewable energy are already quite ready for implementation, whereas others still require technology and system level development especially and predictable long-term government subsidies.

2. Wind power and bioenergy

Hydro power, solar- and geothermal energy, wind power and bioenergy can be regarded as renewable energy. Hydro power has been exploited for a long time and its further harnessing is challenging in many countries. The other renewable technologies have varying maturity and all of them have significant diffusion potential globally. In this research renewable energy generation is limited to wind energy and distributed small-scale CHP-production using bioenergy.

2.1 Wind power

The world's wind resources are tremendous: it has been estimated that utilizing only one fifth of the economically viable global inland wind resources for power generation would have exceeded the world's electricity consumption in the year 2000 seven times over [7]. Studies by the European Environment Agency (EEA) also claim that the technical potential of offshore wind in Europe is six to seven times greater than the predicted electricity demand in Europe in 2020 [10].

The most common design of a modern wind turbine is the horizontal axis wind turbine (HAWT) with the rotation axis parallel to the ground. The major components of a HAWT include a rotor (containing a hub and typically two or three blades), a nacelle (including a generator, the main frame, a drive train containing rotating parts, such as the main shaft and possibly a gearbox and control and electrical systems) and a tower and foundation. During the past decades the nominal power of wind turbines has grown notably and today the biggest operational turbines are 6 to 7 MW in size. Wind turbines with a power rating of 10 MW and beyond are under design [11].

The global installed cumulative wind power capacity was about 240 GW in 2011, consisting mostly of onshore installations. The cumulative market is predicted to reach 1000 GW by 2021. The biggest cumulative markets in 2011 were China and the USA, followed by Germany and Spain. The biggest wind turbine manufacturer in 2011 was Danish Vestas with sales of almost six billion euros. Among the top ten turbine manufacturers were four Chinese firms that had grown rapidly, as had the Chinese market [12].

2.2 Bioenergy

Biomass accounts for approximately 10% of the total primary energy consumed globally, and for 80% of renewable energy. However, not all of this is used in a sustainable manner [13]. In this paper, electricity production by bioenergy is limited to distributed (small-scale) combined heat and power production (CHP) that uses biomasses, such as woodchips from logging residue. The technologies for commercial small-scale CHP production are mostly based on combustion technologies. A biofuelled CHP-plant consists of a boiler, firing unit, turbine, biofuel storage and conveyor, as well as automation [14]. The principle of combined heat and power production has been known for a long time, and since the beginning of the 20th century a number of units have been in operation. However, commercial small-scale CHP technologies are still under development today. CHP contains the following essential elements: simultaneous heat and electricity production, high efficiency performance and proximity of the energy production unit to the customers [15].

Potential customers for small-scale bio-CHP technology using forest biomasses include farms, greenhouses, small and medium size enterprises (SMEs), real estate outside urban areas and district heating plants. These may operate fairly independently or cooperate actively e.g., in joint forest biomass harvesting, transportation and refining to wood chips. Further, they may also collaborate with various service providers, such as maintenance firms and plant and component manufacturers [16].

3. Methods and results

3.1 Innovation methods

The research was conducted with a case study strategy, where Edward de Bono's Lateral Thinking Ideation Model was utilized along with GDSS tools and methods.

[17] describes a case study as a research strategy that typically combines diverse data collection methods, such as interviews, questionnaires, observations and archives. [18] states that a case study investigates a contemporary phenomenon in the real world context. According to [19], a case study is an exploration of a bounded system that can be described in terms of time and place, through detailed, in-depth data collection, involving multiple and rich sources of information. [20] emphasizes the importance of selecting a typical sample in a case study and an extraordinary sample only if it could reveal unique and valuable characteristics to the research.

The de Bono model is divided into two phases: (a) idea generation only and (b) selection, development, refinement and combination of ideas (Figure 1). The idea generation phase requires individual idea generation, whereas the latter parts, preliminary idea selection and idea development, refinement and combination, are executed in collaboration with all the participants. An idea is defined as a specific way of doing something that can be implemented in concrete. A concept above the idea, on the other hand, is a more general approach that cannot be implemented alone as such [9].

The benefits of group work include the following: groups are better than individuals at understanding problems, catching errors and balancing risks. Group work may stimulate the participants and a group is more knowledgeable than individuals. Computer-aided GDSS has been carried out since the middle of the 1980s and typically a computerized decision support system speeds up the process, increases productivity and provides technical and quality support. Collaborative computing technology enables a group to work either at the same time in the same or a different place, or at a different time in the same or different place, utilizing not only computers with sophisticated software, but also whiteboards, smart boards, E-mails, V-mails, multimedia and video-, audio- and computer conferencing. The benefits of GDSS include the following: parallel and simultaneous work enables the participants to simultaneously learn and discuss, anonymous working hinders connecting the ideas, comments, and votes among persons, individuals cannot dominate the discussion and the software memory records all information [21, 22].

In this research, the objective was to answer the research question: *"How to get wind and biomass electricity commercialized in the Nordic countries by 2030?"* Altogether 17 international energy experts from a university and various companies contributed to the research in different phases. In the first phase, a group of 11 experts including two professors and two doctors of technology generated ideas to respond to the objective. After the first individual ideas, a concept was determined, after which new potential ideas within the concept were identified. The idea generation then continued by using the objective/idea/concept – triangle and finally the ideas and concepts were placed on a concept fan by using self-adhesive notes.

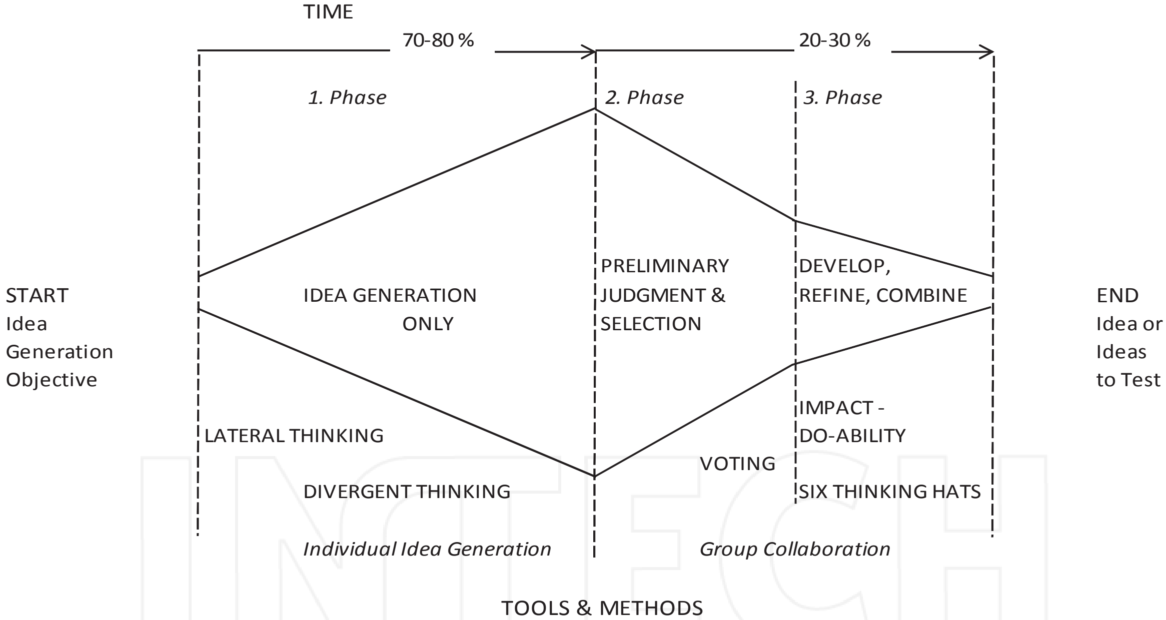

Figure 1. Lateral thinking ideation model, adapted from de Bono (2012)

In the second phase, a preliminary judgment and selection of the concepts and ideas was executed by five experts, including two doctors of technology. Low-impact, impractical and overlapping ideas and concepts were removed and the concepts and ideas were grouped in a PESTEL – framework (Political, Economical, Social, Technological, Environmental and Legal). In the third phase, the ideas were assessed by a group of 8 experts, including one professor and five doctors and conducted in a group decision support systems (GDSS) laboratory using [23] software. The ideas that got the highest scores (each participant used the scale 10 to 1; 10 being the highest and one the lowest value) in an impact–doability matrix were discussed, and of the top five ideas in each PESTEL category, four were then selected for in-depth analysis. Each of the four ideas were then analysed by using de Bono's Six Thinking Hats framework. The parallel team thinking framework consists of Six Thinking Hats that are jointly performed within time limits set in advance, typically in the following order:

- White Hat – Information and data: facts and missing information about the subject
- Yellow Hat – Why it may work: objective values and benefits
- Black Hat – Why it may not work: objective dangers and problems
- Green Hat – Creative thinking: possibilities and alternatives to reinforce yellow hat values and overcome black hat problems
- Red Hat – Feelings and intuition: emotions without reasoning or justification
- Blue Hat – Managing the thinking: the facilitator of the parallel team thinking session

The facilitator (Blue Hat) managed the sessions and discussions, concluded and also participated in the teamwork like the other panellists. In the beginning of each four idea analysis set, one or two experts gave a short briefing about the issue before the White Hat session.

3.2 Empirical findings compared to earlier research

In the second phase of the research, the original list of 42 concepts and 15 sub-concepts in the first phase were combined to 12 concepts. Of the original 161 ideas 63 were selected for the GDSS session. In the third phase the four ideas, which were evaluated to contribute significantly to renewable energy commercialization, were further assessed by using de Bono's Six Thinking Hats framework. In the second phase, many ideas turned out to be a combination of different PESTEL categories, which resulted in regrouping the original framework into political and legal, social and environmental, and techno-economic categories. Purely economical and technological categories remained as well. By definition, a concept has a general approach and cannot be implemented on its own. The results supported the theory well. The refined concepts and examples of ideas are presented in Table 1.

	Concepts	Examples of ideas
Political & Legal	Ways to get subsidies and financing	Supporting grid investments suitable for decentralized energy. Lighter permit procedure by removing extra phases.
	Ways to create a price for CO2 emissions	Developing CO_2 accounting.
Economic	Ways to support small-scale generation	Building local grids.
	Ways to cut down the prices of power plants	Finding modular mass production units. Developing novel construction material.
	Ways to increase renewable energy supply	Establishing cooperatives for energy production.
Social & Environmental	Ways to increase environmental consciousness	Teaching students from childhood for how to consume energy. Supporting people to save energy, penalties for over-consumers.
	Ways to get buyers for renewable products	Introducing CO_2 criteria for public procurement.
Technological	Ways to create new technology	Developing concepts with many renewable energy technologies working together. Creating a home energy control system. Renewable energy stored as liquid fuel.
	Ways to develop renewable plants as more powerful	Testing and piloting environment.
	Ways to develop renewable plants as more powerful	Finding novel materials for power plants.
Techno-economic	Ways to improve the electricity grid	Installing smart meters to follow energy consumption. Easier grid access for small-scale production.
	Ways to improve the energy storage system	Electric cars as energy storage for renewable energy.

Table 1. Refined concepts and examples of ideas

3.2.1 Overall voting results

In the GDSS session, the top ideas were related mostly to economic, political and legal, techno-economic and technological factors. In the economic factors ways to cut down the prices of power plants, such as modular mass production units, had their importance assessed by the panellists. In political and legal factors, ways of getting subsidies and financing encompassed many important ideas, including grid investments suitable for decentralized energy. In the techno-economic and technological factors the ideas were related to ways of improving energy storage systems e.g. using electric vehicles as stores and ways of creating new technology e.g., home energy control systems were evaluated as the most important factors for commercializing renewable energy. Next, an overview and a summary of the focal research results of the selected four ideas for more in-depth analysis are presented.

3.2.2 Six Thinking Hats 1: Finding modular mass production units

Product architecture becomes modular when the interfaces of functional components are designed to allow component variations and the interface specifications are standardized [24]. [25] adds that modular design enables the addition of new functions to modular units at different system levels. Modularity can also be split up into six different types: component-sharing, component-swapping, cut-to-fit, mix, bus and sectional modularity. Component-sharing modularity enables the use of common components in different products. In component-swapping modularity different modules can be alternatively selected for standard products and in cut-to-fit modularity the modules have unique dimensions, such as length, width or height. Mixed modularity appears when a combination of the modules can be selected for standard products. Bus modularity refers to the ability to add one or more modules to an existing base, such as track lighting. Finally, sectional modularity appears when standard modules can be arranged in a unique pattern like Lego bricks [26, 27].

Modular design has several admitted benefits. [28, 29] claim that modularity is a prerequisite for ensuring firms' competitive advantage. The benefits of modularity include increased economies of scale, increased product variety, reduced time to market, cost savings in inventory and shorter product life cycle. It is also noted that modular design decreases product complexity, enables mass customization and accelerates product innovation cost efficiently [28; 30]. Modularity also contains disadvantages: the modular approach

Finding modular mass production units	
White Hat Information and data	Modularization varies, being more widely used in mature than evolving businesses. Many bioenergy firms are SMEs and have inadequate resources for modularization. Modularity increases the reliability and functionality of products and improves firms' profitability. It may increase development costs and hinder innovation. The car industry is an adequate benchmark for modularity.
Yellow Hat Objective values and benefits	Modularity improves the reliability, functionality and possibility of the variation and mass customization of products and systems. It enables serial production and improved use of business networks. It reduces production costs by increasing the market penetration of RE and is crucial in international business. Due to better the competitiveness, subsidies are no longer as critical as previously.
Black Hat Objective dangers and problems	Integrated solutions sometimes just offer a better fit than modularity. SMEs are not willing/capable to invest into modular design. Modularity may kill innovativeness and firms may drop behind in development and lose their market position. Modularity fits mature industries better than evolving businesses and it may lead to overdesign of products.
Green Hat Creative thinking: possibilities and alternatives	When an industry matures, its dominant design is formed and modular designs become more general. Modular and integrated solutions could be used in parallel in order to offer the best solution. Manufacturers have to develop their production to fit the CE-criterion in the future and this could increase the shift to modular design. A global renewable modular directory board needs to be established. Best practices can be learned from other industries.
Red Hat Feelings and intuition	Modularity is essential in the commercialization of RE.

Table 2. Results of Six Thinking Hats 1

may create unplanned additional fixed costs [31], lead to overdesign with increased variable costs [32], or modular design may lead to similar products due to constantly used common modules [33]. However, it can be concluded that in most cases the benefits of modular design overcome the potential disadvantages.

In order to ensure and hasten the diffusion of the products and systems related to renewable energy generation, the products should be commercially and technically attractive. The economic issue (mean 7.13, STD 1.81) achieved the 19th rank among the assessed ideas. Modular product design is most commonly used by bigger firms in mature industries. It tends to increase customer satisfaction and the firms' competitive advantage, when properly implemented. However, modularity may also hinder innovativeness, lead to overdesign and produce unforeseen expenses. All in all, modularity was assessed as necessary in commercializing renewable energy in the long run (Table 2).

3.2.3 Six Thinking Hats 2: Supporting grid investments suitable for decentralized energy

Efficient transmission and distribution of electricity is crucial to the future of the world. However, the current electric power transmission and distribution systems need to be upgraded urgently in many countries. Smart grids offer the opportunity to improve the efficiency, reliability and flexibility of electrical systems. They are used to integrate renewable energy sources and reduce transmission and distribution losses [34, 35]. However, smart grids have R&D requirements and environmental and energy efficiency issues have resulted in many governments supporting smart grid investments in particular, in order to solve environmental and energy challenges [36]. In the USA, for example, the state and federal level politicians and state officials encourage local demonstration and also wider adoption of new technologies. Legislation for significant public (federal ARRA funds) and private investments into smart grid demonstrations have been established. However, more profound energy policy analyses and tools are required in order to support the required future grid investments efficiently [37].

Decentralized electricity generation creates challenges for electricity transmission, distribution and storage. The issue defined in the political and legal category was ranked 5th (mean 7.88, STD 1.89). The fluctuating distributed energy generation and consumption may require investments in electricity grid reinforcement that could be significant. However, before the electricity storage issues are mature enough, the necessary investments may have to be carried out in order to support the diffusion of renewable energy. Since different countries and electricity distribution operators (DSOs) have various practices, the legislation and practices should be harmonized (Table 3).

Supporting (government) grid investments suitable for decentralized energy	
White Hat Information and data	Countries have various practices in supporting grid investments and electricity distribution operators (DSOs) also have ones of their own. DSOs need investment support from government/higher distribution charges. It was unclear whether any government supports grid investments. Powerful networks have already been built in countries like Finland. The lack of subsidies for small-scale renewable energy (RE) raised concerns.
Yellow Hat Objective values and benefits	This idea would probably work, because the social acceptability of RE for consumers and politicians has improved. If grid investments become easier, RE investments will be more common. If the government supports grid investments, DSOs have incentives to connect RE into the network. EU energy efficiency commitments have set targets that motivate grid investments.
Black Hat Objective dangers and problems	The financial crisis of the EU has diminished the support for new investments and can slow down technology R&D. Government support is too expensive, especially with wrongly determined/directed subsidies. DSOs do not have incentives to improve grid investments. Network investments e.g., for offshore wind, are remarkable. The present electricity price is too low.
Green Hat Creative thinking: possibilities and alternatives	As a part of energy efficiency, residential customers could produce their own electricity to avoid network investments. Locating RE should create criteria for network planning. Big energy companies should tolerate small-scale production as pioneers in the changing operational environment. Optimized electricity use could help avoid network reinforcements. The best solutions should be learnt from other industries. The RE grid connection should be congruent with all DSOs. Strict legislation for electricity markets is needed.
Red Hat Feelings and intuition	Supporting grid investments was considered a good idea.

Table 3. Results of Six Thinking Hats 2

3.2.4 Six Thinking Hats 3: Electric cars as energy storage for renewable energy

The energy efficiency of the electric grid can be improved and the load peaks during peak hours can be cut by utilizing energy storages and electric vehicles (EVs) with smart vehicle-to-grid (V2G) characteristics provide a qualified solution to meet this target. Large adoption of EVs with improved battery technology will eventually decrease the prices of energy storage systems, and cut the distribution fees of electricity end users. On the other hand, if smart grid development is neglected, huge investments will be needed to reinforce the aging electricity grid infrastructure [34]. Investments in the smart grid are especially important when increasing renewable energy, such as wind or solar power, in the energy generation portfolio, as these intermittent renewable resources are not fully predictable and have a tendency to fluctuate [36, 38]. Wide utilization of EVs as decentralized energy resources will efficiently cut the grid peak loads, but the implementation of the system still requires remarkable technological development, especially in control systems [34].

The increasing volume of distributed and intermittent renewable energy requires storage to be able to balance demand and supply. The techno-economic idea (mean 7.88, STD 1.46) received the 6th rank overall. The use of electric vehicles (EVs) as energy storage is an encouraging future issue. The diffusion of EVs has to increase significantly and battery technologies, charging and smart grid issues have to be developed before this idea can be widely commercialized (Table 4).

Electric cars as energy storage for renewable energy	
White Hat Information and data	The required network investments and technology cause concern. The systems could work in the private sector and in cities, where electric vehicles (EV) can operate. Plug-in and battery technologies have developed rapidly and China is a leading country in developing EVs. The number of EVs and the battery technology may set some limitations.
Yellow Hat Objective values and benefits	A number of EVs are already in use and more will come onto the markets. The batteries of EVs could work as stores for renewable energy. The system could provide new business opportunities and models. Finland could be a pioneer in R&D due to their car-heating infrastructure. The stores can level out consumption and production peaks and secure electricity supply during blackouts. Smart charging and a smart grid environment will improve the development of EVs and storages.
Black Hat Objective dangers and problems	The EVs and the whole system are still too expensive. The number of EVs is far too small at the moment and the volume will not increase enough by 2030. The initiatives for buying an EV are not enticing. There are still many uncertainties and safety problems. The storage capacity of cars is too small compared with the capacity of wind turbines. The batteries incur environmental problems and are not developing fast enough. The charging of EVs is too slow.
Green Hat Creative thinking: possibilities and alternatives	The panellists suggested tax incentives and more charging points for EVs, in addition to exchange batteries at service stations. Public transportation should be a pacesetter and the national transport associations could promote EVs. Different kinds of hybrid and electric vehicles are needed. The size of cars could provide possibilities. Smart grid development is an extremely important issue.
Red Hat Feelings and intuition	A positive idea, but the topic is not yet current. Many issues should be solved before using EVs as energy storages. The smart grid environment will create a basis for this.

Table 4. Results of Six Thinking Hats 3

3.2.5 Six Thinking Hats 4: Creating home energy control systems

A smart grid utilizes information and communication technologies (ICT) in two-way communication between customers and power companies, in order to optimize energy distribution and consumption. Intelligent home energy control systems, or smart meters, measure power consumption, communicate with smart home appliances and are capable of optimizing energy consumption and variable electricity tariffs [36, 38, 39]. The European Union (EU), for example, has introduced directives binding the member states to implementing instruments and systems to measure energy consumption and efficiency. Smart home energy control systems are offered to the market at an increasing pace. However, many devices are still under field testing and further development is needed before the systems can fully contribute to environmental and energy efficiency issues. The most important driver for consumers to implement smart home energy control systems are financial benefits in terms of variable electricity tariffs based on demand and grid conditions. The biggest hindrances are related to consumers' limited willingness to change their routines and behaviour in order to optimize energy use [38].

Home energy control systems increase consumers' overall knowledge about energy issues, encourage them to save energy and most probably increase their use of renewable energy. The technological idea received the 3rd rank, with an average value of 8.63 and STD 1.30 in the assessment. Versatile home energy control systems are already commercial and their implementation does not require any special resources. The systems are still expensive and may be technologically vulnerable, but mass-production and large-scale implementation will eventually increase their reliability and usability and lower the prices. Detailed results are illustrated in Table 5.

All in all, the results supported the findings of earlier research rather well. Among the ideas, modular product design, EVs as energy storage and home energy control systems had the closest fit with the previous research.

Creating home energy control systems	
White Hat Information and data	The systems are already commercial, Germany being one of the leading countries. The implementation does not require extensive resources or skills. The system can, for example, guide room temperatures, limit the use of domestic appliances, be connected to alarm systems, or electricity price. Grid load data could be included in the parameters.
Yellow Hat Objective values and benefits	The systems increase consumers' overall knowledge and interest in energy issues, which could increase the use of renewable energy. The systems impact on consumers' behaviour and motivate consumers to save and use energy efficiently and thus to save money.
Black Hat Objective dangers and problems	The systems and appliances are still far too expensive, complicated and technologically vulnerable. The diffusion of the new concept will be very slow. Consumers are afraid of any control upon their behaviour and malfunctioning of the system. They are also concerned about the potential rise of energy prices due to electricity optimization.
Green Hat Creative thinking: possibilities and alternatives	Subsidies to consumers' investments could increase the diffusion of the systems, along with marketing emphasizing energy saving issues. Combining with other devices may interest customers. Mass-production and large-scale implementation will eventually lower the prices and ensure technology reliability. Legally binding implementation of the systems will lead to comprehensive market penetration.
Red Hat Feelings and intuition	The systems are ready for piloting. The prices are likely to come down and the systems will sooner or later become general.

Table 5. Results of Six Thinking Hats 4

4. Conclusions

Global climate change and the finiteness of current primary energy resources have increased the importance of more sustainable energy sources. This study has focused on ideas and concepts of *"How to get wind and biomass electricity commercialized in the Nordic countries by 2030?"* In spite of the complex and many-sided nature of topic, the Lateral and Parallel Thinking methods proved to be very useful toolkits. The Lateral Thinking methods facilitated the contribution of diverse experts who would probably normally not collaborate, promoted interdisciplinary and multidisciplinary and produced potentially more radical ideas. With the Lateral Thinking method the participants generated over 160 ideas and almost 50 concepts. The focus stayed on the same issue and also new ideas arose. The Parallel Thinking methods, with the help of key experts, were used to develop the selected ideas further. Finally, all information, benefits, cautions and possibilities related to the idea could be recognized. The Group Decision Support System (GDSS) supported the panel assessment sessions well. The main results were the final concept fan and the GDSS results. The key results can be further augmented and utilized in potential future research.

The assessed four ideas were seen as important phenomena in commercializing renewable energy in the Nordic countries during the next two decades. However, some issues are more ready to market, whereas others still need time, development and subsidies before implementation. Home energy control systems, electric grid investments and modular product design were seen as quite ready for implementation, whereas the idea of electric cars as energy storage is not yet current according to the panellists. All in all, the extensive diffusion of renewable energy calls for customer benefits in terms of lower cost and high numbers of reliable devices and systems and lower cost of energy. Consistent government support is also required for the next few decades.

The research contributed a significant number of ideas and concepts for commercializing renewable energy. Although there exist incentives, such as increasing market demand, environmental concerns and new business opportunities, many issues are still early on in their lifecycle technologically and on the system level, requiring subsidies, for example, before technology maturity, learning curve effects and scale-of-economics enable the economical viability of the products and systems. The results contribute to previous research, especially ideas such as home energy control systems, EVs as energy storage and modular product design support earlier findings. The research methods used were solid and highly educated and experienced specialists were selected as panellists in order to ensure the validity and reliability of the research.

Overall, this qualitative case study revealed the usefulness of the innovation methods used. However, a systematic and wider comparison of other emerging renewable technologies and historical cases would probably provide a more solid ground to draw conclusions of the methodology and commercialization opportunities of the ideas. The concepts and also some of the ideas were more general than concrete and after all, some of the potentially most radical ideas were not revealed. In addition, the members of the expert panel in the process were chosen on an informal basis. Regardless of the careful choosing of the panellists, there is always a possibility of bias in the selection and contribution of the respondents.

5. Acknowledgements

The authors are grateful to associate professor, D. Sc. (Tech) Kalle Elfvengren and researcher Juha Kortelainen for data collection and preliminary analysis and to the distinguished experts who contributed to the research.

6. References

[1] Smil, V. (2010) Energy Transitions – History, Requirements, Prospects. Santa Barbara: Praeger publishing. 178 p.

[2] Hammons, T., J. (2011) Tidal Power in the UK and Worldwide to Reduce Greenhouse Gas Emissions. International Journal of Engineering Business Management. Vol. 3, No 2, pp 16-28.

[3] Lynas, M. (2008) Six Degrees. Our Future on a Hotter Planet. Washington, D.C: National Geographic. 335 p.

[4] Weijermars, R., Taylor, P., Bahn, O., Das, S., R. & Wei, Y-M. (2012) Review of models and actors in energy mix optimization – can leader visions and decisions align with optimum model strategies for our future energy systems? Energy Strategy Reviews. Issue 1, pp 5-18.

[5] IEA (2008) [Retrieved August 2012] Available from <http://www.greenfacts.org/en/energy-technologies/>.

[6] Gore, A. (2009) Our Choice. A Plan to Solve the Climate Crisis. New York: Melcher Media. 414 p.

[7] Global Wind Energy Council (GWEC) (2008) Global Wind Energy Outlook 2008. [Retrieved August 2012]. Available from <http://www.gwec.net/fileadmin/images/Logos/Corporate/GWEO_A4_2008_lowres.pdf>.

[8] Tekes. (2009). Growing Power. Bioenergy Solutions from Finland. Research reports. 43 p. [retrieved August, 2012]. Available from: <http://www.tekes.fi/fi/community/Etusivu/307/Haku/383?tf_query=growing+power>.

[9] de Bono, E. (2012) The de Bono Group. [Retrieved May 2012]. Available from <http://www.debonogroup.com/parallel_thinking.php.>

[10] The European Wind Energy Association (EWEA) (2009) Oceans of opportunity – Harnessing Europe's largest domestic energy resource. [Retrieved August 2012]. Available from <http://www.ewea.org/fileadmin/ewea_documents/documents/publications/reports/Offshore_Report_2009.pdf>.

[11] Manwell, J., F., McGovan, J., G. & Rogers, A., L. (2010) Wind Energy Explained – Theory, Design and Application. Second edition. Chichester: John Wiley & Sons. 689 p.

[12] BTM Consult ApS. (2012). International Wind Energy Development – World Market Update 2011. [Retrieved August 2012]. Available from<http://www.btm.dk/reports/world+market+update+2011>, commercial report.

[13] IEA (2012) Technology Roadmap: Bioenergy for Heat and Power 2012. [Retrieved August 2012]. Available from <http://www.globalbioenergy.org/bioenergyinfo/background/detail/en/news/147073/icode/>.

[14] Kara, M., Hirvonen, R., Mattila, L., Viinikainen, S. & Tuhkanen, S. (2003) Energy Visions 2030 for Finland. VTT Energy. Helsinki: Edita. 237 p.

[15] Pehnt, M., Cames, M., Fischer, C., Praetorius, B., Schneider, L., Schumacher, K. & Voss, J.-P.(2006) Micro cogeneration – Towards Decentralized Energy Systems. E-book. 346 p.

[16] Kokkonen, K., Lehtovaara, M., Rousku, P. & Kässi, T. (2011) Networking of biomass heating enterprises – a two-dimensional approach. XX11 ISPIM Conference – Sustainability in Innovation: Innovation Management Challenges. June 12-15 2011. Hamburg. Germany.

[17] Eisenhardt, K. (1989) Building theories from case study research. Academy of Management review, Vol. 14, No 4, pp 532-550.

[18] Yin, R.K. (2009) Case Study Research. Design and Methods. 4th edition. USA: SAGE Publications

[19] Creswell, J., W. (2007) Qualitative Inquiry & research design. Choosing Among Five approaches. 2nd edition. USA: SAGE Publications. 395 p.

[20] Olkkonen, T. (1993) Johdatus teollisuustalouden tutkimustyöhön. 2nd edition. Helsinki: TKK Offset. 143 p.

[21] Turban, E. & Aronson, J., E. (2001) Decision Support Systems and Intelligent Systems. New Jersey: Prentice Hall. 867 p.

[22] Torkkeli, M. (2002) Technology Selection and Group Decision Support Systems: Case studies on supporting strategic technology selection processes. Dissertation. Lappeenranta: Digipaino. 121 p.

[23] GroupSystems (2012) [Retrieved May 2012]. Available from <http://www.groupsystems.com/>, commercial software.

[24] Sanchez, R. & Collins, R., P. (2001) Competing-and Learning- in Modular Markets. Long Range Planning, 34, pp 645-667.

[25] Vekteris, V. & Moksin, V. (2010) The modular principle of design of adaptive film lubrication bearings. Mechanika. –Kaunas: Technologija, Nr 4(84), pp 53-57.

[26] Ulrich, K. & Tung, K. (1991) Fundamentals of product modularity. Proceedings of the 1991 ASME Winter Annual Meeting Symposium on Design and Manufacturing Integration. November 1991, Atlanta. USA, pp 73-79.
[27] Duray, R., Ward, P., T., Milligan, G., W. & Berry, W., L. (2000) Approaches to mass customization: configurations and empirical validation. Journal of Operations Management, 18, pp 605-625.
[28] Jacobs, M., Vickery, S., K. & Droge, C. (2007) The effects of product modularity on competitive performance. International Journal of Operations & Production Management, Vol. 27 No 10, pp 1046-1068.
[29] Worren, N., Moore, K. & Cardona, P. (2002) Modularity, Strategic Flexibility, and Firm Performance: A Study of the Home Appliance Industry. Strategic Management Journal. 23, pp 1123-1140.
[30] Jose, A. & Tollenaere, M. (2005) Modular and platform methods for product family design: literature analysis. Journal of Intelligent Manufacturing, 16, pp 371-390.
[31] Sako, M. (2003) Modularity and Outsourcing: The Nature of Co-Evolution of Product Architecture and Organisation Architecture in the Global Automotive Industry. Onzieme Rencontre Internationale Du Gerpisa Eleventh Gerpisa International Colloquim. 11-13 June 2003. Paris. France, pp 1-18.
[32] Gershenson, J., K., Prasad, G., J. & Zhang, Y. (2003) Product modularity: definitions and benefits. Journal of Engineering design, 14:3, pp 295-313.
[33] Schilling, M., A. (2003) Commentary: toward a general modular systems theory, In: Garud, R., Kumaraswamy, A. and Langlois, R., N. (Eds), Managing in the Modular Age, Malden, MA: Blackwell Publishers Ltd. 417 p.
[34] Lassila, J., Haakana, J., Tikka, V. & Partanen, J. (2011) Methodology to Analyse the Economic Effects of Electric Cars as Energy Storages. IEEE Transactions on Smart Grid. Accepted August 30, 2011. Paper no. TSG-00112-2011.
[35] Grimes, H.D., Payumo, J.G. & Fatland, A. (2012) Managing Clean Technology Research, Development, and Commercialization: Success Stories and Lessons Learned from Washington State University, Proceedings of PICMET, pp. 327-339.
[36] Byun, J., Hong, I., Kang, B. & Park, S. (2011) A Smart Energy Distribution and Management System for Renewable Energy Distribution and Context-aware Services based on User Patterns and Load Forecasting. IEEE Transactions on Consumer Electronics, Vol. 57, No 2, May 2011. pp 436-444.
[37] Imhoff, C. (2011) Grid 2050. Shaping system transformation. Public Utilities Fortnightly. 149, 8, pp 28-35.
[38] Paetz, A-G., Dutschke, E. & Fichtner, W. (2012) Smart Homes as a Means to Sustainable Energy Consumption: A Study of Consumer Perceptions. J Consum Policy. 35: pp 23-41.
[39] Lai, Y-X., Rodrigues, J., J., P., C., Huang, Y-M., Wang, H-G. & Lai, C-F. (2012) An Intercommunication Home Energy Management System with Appliance Recognition in Home Network. Mobile Netw. Appl. 17: pp 132-142.