Societal Embedding of Innovations Related to Renewable Energies and Energy Saving

Juurruttaminen uusiutuvien energioiden käytön ja energiansäästön edistämisessä

Erja Väyrynen, Sirkku Kivisaari, Raimo Lovio
VTT Technology Studies
VTT Teknologian tutkimus

Abstract

This project assesses the possibilities of constructing a market for climate-friendly energy technologies by applying the process of 'societal embedding of innovations'. The term refers to an interactive learning process amongst three groups of key actors: producers, users and societal actors. Their co-operation shapes the innovation to fit the needs of the market and contributes to creation of conditions in which the innovation can be adopted.

The project consists of two case studies representing both promotion of energy saving and renewable energy sources: (1) Shaping of the ESCO energy service concept in the municipal sector and (2) Increasing the use of wood pellets in single-family houses The results of the first case demonstrate that the approach of societal embedding has evidently contributed to the adoption of the ESCO concept in municipalities. As an outcome of interaction between the key actors, a reviewed model for municipal ESCO activities was prepared. The experiences in the second case manifest that, given the relatively early stage of development on the market, societal embedding would have benefited from a longer time period. The useful results in this case study include identification of barriers for diffusion and description of the needs for further development.

The overall results of the project indicate that a more profound understanding of the demands made on the product by its environment has been achieved. The findings of the case studies also highlight the need for allocating a sufficient time span for societal embedding as well as for adjusting the process according to the situation on the market.

As a conclusion the project indicates that societal embedding may promote the implementation of climate-friendly energy technologies in at least three ways. *Firstly,* the process mobilises key actors to co-operation. This generates interactive learning on the problem and its solving. Market construction is forged ahead by mutual adaptation of the innovation and its environment. *Secondly,* this approach offers a tool to examine the societal quality of the innovation, a question related vitally to climate change. *Thirdly,* by producing new knowledge of the needs on the market, this approach supports the societal actors in choosing different instruments to induce the intended transition.

Tiivistelmä

Hankkeen tavoitteena on tuottaa tietoa siitä, miten kasvihuonekaasuja vähentävien energiateknologioiden markkinoita voidaan rakentaa ns. juurruttamisen keinoin. Juurruttamisella tarkoitetaan vuorovaikutteista oppimisprosessia, johon osallistuu teknologian tuottajia, käyttäjiä sekä yhteiskunnallisia toimijoita. Osapuolten yhteistyöllä teknologista ratkaisua muovataan sopivammaksi markkinoiden tarpeeseen. Hanke on toteutettu kahtena tapaustutkimuksena.

Ensimmäisessä tapauksessa on tutkittu energiansäästöinvestointeihin liittyvän ESCO-toiminta-

mallin juurruttamista kuntasektorille. Juurruttamislähestymistavan voidaan todeta edistäneen ESCO-konseptin käyttöönottoa. Tapauksen osapuolet laativat lisäksi KuntaESCO-toimintamallin selkeyttämään ESCO-hankkeen etenemisen kriittisiä vaiheita.

Toisessa tapauksessa on pyritty juurruttamisen keinoin tukemaan puupellettien käyttöä pientalojen tulisijoissa etenkin lisälämmönlähteenä. Markkinoiden kehitysvaihe oli hankkeen käynnistyessä vielä varhainen ja käytettävissä oleva aika tähän nähden lyhyt. Juurruttaminen tuotti kuitenkin hyödyllisiä tuloksia mm. käyttöönoton esteiden tunnistamisessa ja kehittämistarpeiden kuvaamisessa.

Tapaustutkimukset ovat osoittaneet, että juurruttamisprosessi on sovitettava kuhunkin markkinavaiheeseen ja sille on varattava riittävästi aikaa. Tällöin voidaan luoda toimintaympäristölle mahdollisuus parantaa valmiuttaan käyttöönottoon, ja markkinat ehtivät reagoida tähän muutokseen.

Juurruttaminen voi edistää ilmastomyötäisten innovaatioiden käyttöönottoa vähintään kolmella tavalla. *Ensinnäkin* juurruttaminen saattaa avaintoimijat vuorovaikutukseen keskenään. Prosessissa tapahtuva yhteinen oppiminen auttaa osapuolia ylittämään havaittuja esteitä ja löytämään yhteisesti hyväksyttyjä kehittämisperiaatteita. Markkinat alkavat rakentua, kun sekä innovaatio että sen ympäristö sopeutuvat toinen toisiinsa. *Toiseksi* juurruttamisprosessi nostaa esille ilmastomuutoksen yhteydessä keskeisen yhteiskunnallisen laadun käsitteen ja tarjoaa välineen sen monipuoliseen tarkasteluun. *Kolmanneksi* juurruttamisen yhteydessä syntyvä tieto hyödyttää yhteiskunnallisia toimijoita myös muiden tarvittavien ohjauskeinojen valinnassa.

1 Introduction

Strengthening the status of energy saving and increasing the use of renewable energy sources are significant means of reducing greenhouse gas emissions. Despite the obvious benefits, the market has not yet adopted these procedures on as large a scale as one might have hoped. It can be stated that there are both visible and invisible barriers on the market impeding the implementation and commercialisation of these technologies.

As a part of the Climtech technology programme, the aim of the JUMENE project is to assess the possibilities of constructing a market for climate-friendly energy technologies and to explore prospects for enhancing the operating conditions of Finnish energy technology businesses. More specifically, the project focuses on identifying the *key actors*, setting conditions for the development and for the diffusion of new technologies, and examines their *needs, visions and expectations* in regard to the implementation of these technologies. Another issue studied is the possibility of building *interactive strategies* between the key actors in order to develop both the technologies and the market.

The method chosen to explore these questions is called *'Societal Embedding of Innovations'*. This approach has been inspired by and is closely related to the studies of *'Strategic Niche Management'* (Kemp et al. 1998), and it has been developed further at VTT Technology Studies (Kivisaari et al. 1999).

Societal embedding of innovations can be characterised as an interactive learning process amongst three groups of key actors: producers, users and societal actors. The innovation is shaped in co-operation to fit the needs of the market. The approach also aims at creating conditions in which the innovation can be adopted by its environment. This approach is most suitable in promoting innovations that are designed to meet societal needs. The Kyoto Protocol, the National Climate Strategy and the National Energy Conservation Programme are examples of commitments reflecting societal needs and necessitating measures in the sphere of energy sector.

The project consists of two case studies representing both the promotion of energy saving and renewable energy sources: (1) JUMESCO: Shaping of ESCO energy service concept in the municipal sector, and (2) JUMPE: Increasing the use of wood pellets in single-family houses. In terms of methodology, the project represents action research.

Besides analysing the intervention processes, researchers have also supported problem solving and network building by acting as convenors, catalysts and facilitators.

The second chapter of this article focuses on the description of the process of societal embedding. It also refers to recent research dealing with transition to sustainability, and considers the role of societal embedding in this transition. In the third chapter we present the results of the project and continue with discussion in chapter 4. Our conclusions and recommendations are found in chapter 5.

This article is based on the JUMENE project report by Väyrynen et al. (2002). The project has been carried out by VTT Technical Research Centre of Finland, in co-operation with Helsinki School of Economics and Business Administration, and Motiva, an impartial service organisation implementing the government's decisions on energy conservation and promotion of renewable energy sources.

2 Societal embedding of innovations

The objective of societal embedding of innovations is to promote the commercialisation of innovations that on the one hand yield a business profit and on the other hand support sustainable development. The process contributes to creating conditions in which these innovations can be adopted and, at the same time, it assists in adapting the innovation to the demands made by its environment. This approach can be characterised as a mutual adjustment of an innovation and the needs of the market, i.e. the impact goes in both directions (Kivisaari 1999).

2.1 Societal embedding as a learning process

The notion of societal embedding is built on the idea of innovation as a recursive process; the different stages (idea generation, development, testing and implementation) do not follow one another

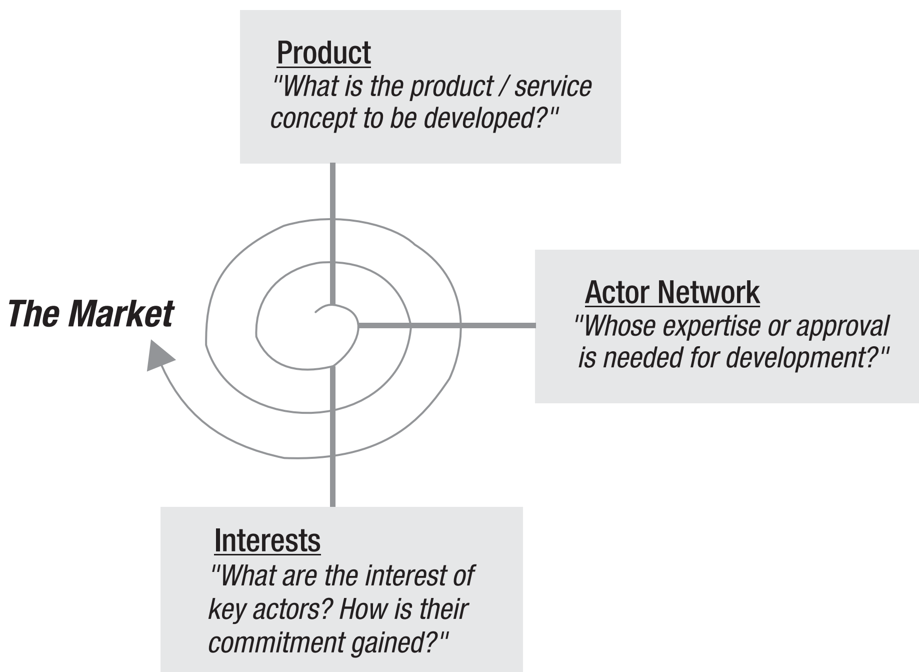

Figure 1. The process of societal embedding as an interactive learning loop (Kivisaari 2001).

in linear fashion. Instead, the stages overlap each other. The possible problems of implementation are built into the product in the course of the development process. The final product reflects the developers' values and ideas - and also aspects that they were not aware of. So in order to secure acceptance on the market, the expertise of users, various interest groups and regulators also needs to be integrated into the development process.

The process includes continuous dialogue and negotiation between multiple actors. It can be described as an interactive learning loop in which both the development target and the participating network of actors undergo continuous change. The spiral in Figure 1 represents the time from idea generation to diffusion of the innovation. During this development path three fundamental questions arise:

1. What are the desired characteristics of the product or service under development?
2. Whose expertise or approval is needed for development and diffusion?
3. What are the interests of key actors to participate in the development work?

During the process these questions are reconsidered repeatedly. As a result, a more thorough understanding of the development target is achieved, new challenges emerge regarding the composition of the development network and new commitments to co-operation need to be ensured.

Working methods

The process of societal embedding can be divided in three main tasks:

1. Identifying the key actors setting conditions to the development and diffusion of the innovation.
2. Describing the needs, interests and visions of key actors
3. Finding common ground for action in development of the innovation.

The key actors are identified and their needs, interests, and visions are described by *thematic interviews* of a number of specialists in different positions and roles. For building a more organised picture of the market, potential key actors are categorised into three groups on the basis of their *primary interest* in technology development and diffusion. Potential key actors can be found in three different domains: we can distinguish between producers, users and societal actors (Figure 2).

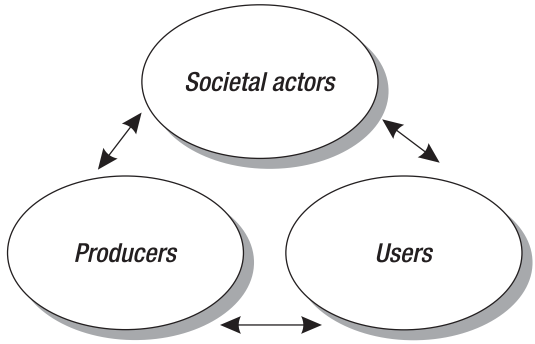

Figure 2. Key actors in societal embedding.

The actors referred to as *producers* are business organisations, which seek to financially profit from their businesses. Another interest they often share is their pursuit of technical progressiveness. The actors referred to as *users* share an interest in the usefulness, usability and price-quality ratio of the product. The group of *societal actors* consists of public authorities involved in setting general guidelines and of various interest groups, including the media, exerting influence on technology diffusion. The main interest of these societal actors can vary from technical infrastructure to employment policy and from export activities to external costs of greenhouse gas emissions. All these domains cover a variety of actors depending on the product.

The various expectations and needs are discussed in *'multi-voiced' seminars or organised dialogues* where key actors representing different types of expertise and roles are invited. The target of these seminars is to support the interaction between producers, users and societal actors and to discover common ground for action.

2.2 Transition management and societal embedding

Societal embedding focuses on enhancing commercialisation of innovations that yield financial profit and contribute to sustainable development. However, the process can be placed into a wider context by asking whether this approach can promote and speed up sustainable development in wider society. This question links the study with recent literature on transition management (Kemp et al. 1998, Weber and Dorda 1999, Kemp and Rotmans 2002).

Transition refers to fundamental changes in society or societal subsystems. It has been claimed that certain kinds of network management strategies aiming at diffusion of sustainable innovations may promote transition. Having been proposed as such a strategy, 'Strategic niche management' introduces sustainable innovations in a probe and learn kind of manner. It pays special attention to the building up of support networks, to changes required in the institutional framework and to facilitating social and technological learning processes in experimenting with innovations. Societal embedding is based on similar ideas. Both approaches aim at fostering development and diffusion of sustainable concepts by promoting interaction and dialogue between different actor groups.

Although this kind of network management strategies have been viewed as necessary components of transition, not all cases of strategic niche management or societal embedding act as stepping stones for transition. When assessing successfulness from the point of view of transition, attention should be paid to the quality of learning and institutional embedding. (Hoogma et al. 2001, 2002)

Network management is often presented as the most advanced way of steering complex change processes and it has recently gained popularity in governance. However, it is clear that network management alone is not effective means for advancing transition towards sustainability. It needs to be supported by active use of other instruments, such as regulation and economic incentives (see Kivisaari et al. 2002, Hoogma et al. 2002).

3 Case studies

3.1 Background

In the *JUMESCO case* we examine the possibilities of implementing the ESCO service concept in Finnish municipalities. ESCO concept is based on the idea that ESCOs (Energy Service Companies) offer their customers the service of taking responsibility for the implementation of energy saving investments by financing, designing and installing the equipment, and gain their returns by taking a share of the energy costs saved.

The significance of this case arises from the fact that municipalities are major possessors of building stock and consequently, major consumers of heating energy and electricity. Provided the municipalities would start to apply the ESCO concept, the volume of the energy saving market would expand considerably.

The *JUMPE case* aims at increasing the use of wood pellets in single-family houses. This relates to a more comprehensive objective of promoting wood based energy, as expressed in the Action Plan for Renewable Energy Sources. It has been estimated that up to 80% of Finnish single-family houses could use wood heating at least as a supplement. The under-utilisation of fireplaces is often due to difficulties in acquiring suitable firewood, particularly in urban areas.

Wood pellets are made from waste sawdust and compressed under high pressure with no glues or other additives. Wood pellets offer a novel way of using fireplace as a secondary heating unit even in houses with electric heating as primary system. Wood pellets may be used in specially designed pellet stoves standing alone or inserted into existing fireplaces. Wood pellets can also be burned in a wood stove or masonry fireplace by means of a pellet basket. As a hypothesis of this case study, we suppose that, with an increasing number of households installing a pellet stove or adding a pellet basket to their fireplace, the peak loads in electricity consumption during the winter season would decline.

3.2 Results of the case studies

JUMESCO Case

The JUMESCO case related to shaping of the ESCO concept to meet the needs of Finnish municipalities. Based on Motiva's know-how and contacts, three municipalities, three ESCO-businesses and three financing institutions were identified as potential partners for experimentation. The target was that the three "local groups" would agree on concrete local piloting sites for ESCO experimentation and the JUMENE project would support the network construction and learning processes and further develop the ESCO concept.

The societal embedding process was carried out according to the tasks described earlier (2.1). The major barriers for implementation were identified and actions were taken to find ways to remove or attenuate them. One of the most difficult issues concerning regulations turned out to be the legislation that necessitates the use of competitive bidding in public procurement. In a project of ESCO nature, municipalities are in need of well thought-out criteria for comparing the total value of different tenders. A more diversified set of appropriate criteria, than economic efficiency, was proposed. Other questions raising concern were financing and guarantees for the investment, allocation of government subsidies and municipal decision making in outsourcing.

During the 9-month project, the local partners were working on finding appropriate pilot sites. Researchers facilitated the work of the tripartite local groups by identifying and decreasing barriers. Towards the end of the project, one of the pilot sites advanced considerably. One city and one ESCO company entered into agreement, and the energy saving investment of the pilot case was granted a 20% subsidy by the Ministry of Trade and Industry.

The results of the JUMESCO case demonstrate that the approach of societal embedding has evidently contributed to the adoption of the ESCO concept in municipalities. As an outcome of interaction between the key actors, a reviewed model for ESCO activities was prepared, with expert assistance from the Association of Finnish Local and Regional Authorities and with the selected local groups, to make the concept better fit the needs of municipalities.

JUMPE Case

The experiences in the JUMPE case were in some degree different. The relatively early stage of development on the market would have required a longer time period for the process of societal embedding. The progress in the case has been slowed mainly by two factors. The process has revealed considerably more divergent interests among the actor groups than anticipated. At the same time, it has become evident that the expectations of certain key actors have been so weekly articulated that the possibilities to market construction in practice have remained remote.

However, the benefits of the approach should not be underestimated. The useful results in this case study include identification of obstacles on the market and description of the needs for further development. One of the needs expressed with emphasis has been the need for special research comparing the combustion of wood pellets and its emissions with the corresponding results of conventional firewood. Smaller enterprises also considered testing of their pellet equipment in independent test laboratories so expensive that they could not afford it. Their claim to subsidised testing may be justified by their own R&D needs, but in addition, by consumers' interest in the results. The lack of objective test results has turned out to be one of the obstacles for the increase in demand of pellet equipment.

Successfulness of the case studies

When assessing the success of the process of societal embedding, we have to pay attention to collective learning and to evolution of deeper understanding of the problem and its possible solutions. As a tool we can apply the criteria Hoogma (et al. 2001) has suggested (see 2.2). The aspects he brings forth are the *quality of learning* and *institutional embedding*. Learning is in turn divided in single-loop learning and double-loop learning.

Table 1. Evaluation of the success of societal embedding in the two case studies.

	Criteria of success	JUMESCO	JUMPE
Quality of learning	1. Single-loop -learning	good	moderate
	2. Double-loop -learning	fairly good	low
Institutional embedding	3. Are complementary technologies and infrastructures developed?	moderately	in some degree
	4. Are credible and widely shared expectations produced about what might be feasible?	to some extent	to low extent
	5. How broad is the array of actors aligned in support of the new concept?	broad	fairly broad

According to Hoogma, learning should not be limited to conventional *single-loop* learning but it should include also *double-loop* learning. This means that conceptions about technology, user demand and regulations are not only tested, but also questioned and explored. As to institutional embedding, three crucial aspects are identified. The first aspect is to consider whether complementary technologies and needed infrastructures are developed. The second aspect relates to widely shared, credible and specific expectations about what might be feasible. And the third question relates to considering how widely different actors – users, producers and societal actors – are aligned in support of the new mode of operation.

Table 1 gives a simplified description of the success of the case studies according to these criteria. The distinction between the two cases is evident; the JUMESCO case fulfils all the criteria to a higher degree compared to the JUMPE case. A special characteristic of JUMESCO is the occurrence of double-loop learning (crit. 2), enabled partially by the successive multi-voiced seminars. In the course of the process, target setting, modes of action and roles of key actors have been questioned and reassessed. This has also contributed to the broad support of the new concept given by the network of actors (crit. 5).

One of the positive features in JUMPE case is the activeness of the participants to discuss the barriers and the ways of surmounting them. As a consequence, the commitment of actors to further development is considered to be fairly broad (crit. 5). The weakest point in JUMPE is obviously the failure in achieving widely shared expectations about feasible targets (crit. 4.) The key actors seem to be in a certain kind of wait condition, not willing to move over-hastily. Thus, the situation would be favourable for a continuation of societal embedding.

4 Discussion

The quality of an innovation is far from being an unambiguous concept. Besides technological progressiveness, the product needs to be useful and well integrated in the context of use and allowable according to regulations. When an innovation is designed to meet societal needs, e.g. controlling climate change and reducing emissions, we have a reason for highlighting the *'societal quality'* of the innovation. This term refers to co-operative efforts to secure the societal benefits and implications of the innovation.

Realising the multi-dimensional societal quality of a product is beyond the capabilities of the producer alone. It calls for a continuous dialogue and co-op-

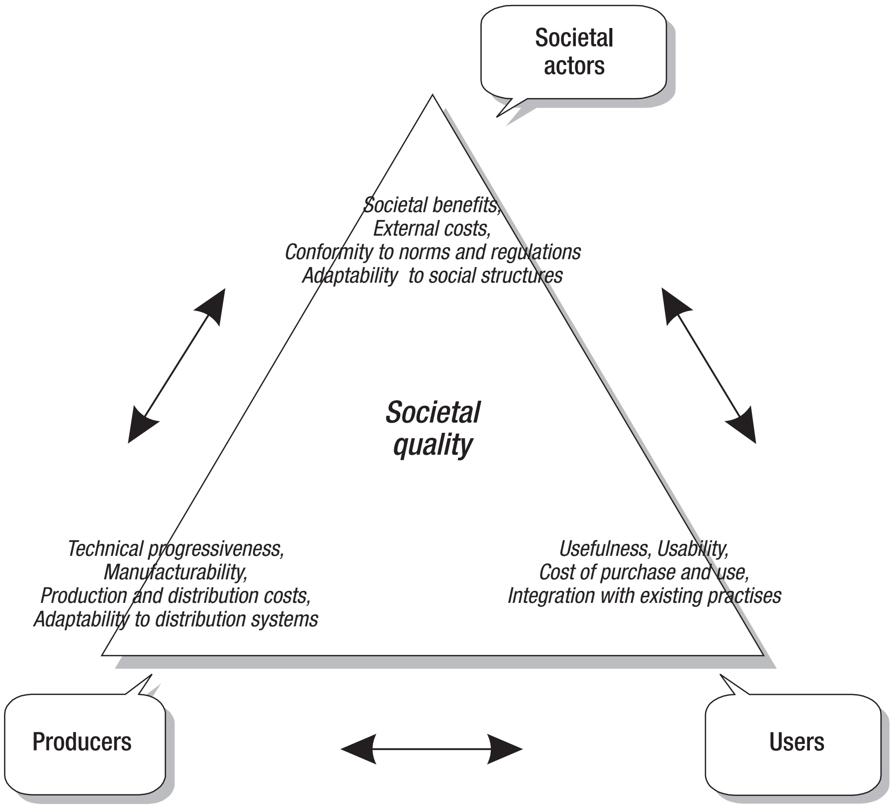

Figure 3. Dimensions of societal quality with critical actors contributing to success (Kivisaari and Lovio 2000).

eration between a number of external actors. Orchestrating parallel interaction with users, producers and the wider society, including media and regulators, is needed. The three dimensions of societal quality are presented in Figure 3.with the critical actors contributing to the success of the innovation.

If we apply this triangular model to innovations aimed at reducing GHG emissions, we perceive that the technical progressiveness of the product or its adaptability to infrastructure are not sufficient elements in market construction. Besides these, several other questions should be solved: Who will be responsible for external costs ensuing from the use of the product? How will the product be integrated with existing practices of the users? What are the prerequisites for its wider acceptance by the public?

The case studies of this project may also be assessed referring to this frame. In the JUMESCO case all key actors have participated in the discussion with their own preferences and concerns, and most of the questions have reached a practicable solution. Meanwhile, the JUMPE case leaves several questions unanswered, particularly from the user perspective. For example, the conceptions of the usefulness of pellet equipment are so far apart that, given the limited time available, the possibility of making progress evades. These results are convergent with the earlier evaluation in chapter 3.

Pursuing commercial success and societal quality are by no means in conflict with each other. Instead, societal quality is a necessary precondition for commercial success. Societal embedding offers a tool to examine, in close interaction between the different actor groups, the various dimensions of quality and contributes to achieving a combination of these features.

5 Conclusions

The overall results of the project indicate that a more profound understanding of the demands made on the product by its environment has been achieved. The findings of the case studies also highlight the need for allocating a sufficient time span for the process of societal embedding as well as for adjusting the process according to the situation on the market. The market requires time for adapting to the change.

Processes aiming at commercialisation of radical innovations are typically long lasting due to the numerous changes they require in their environment. This also explains why societal embedding focuses on market construction by influencing extensively on the environment of the innovation. When sufficient time is provided for the process, the ground for co-operation is smoothened and the different actor groups are better prepared for the implementation and commercialisation.

The heterogeneous composition of the actor groups calls for special attention to communication, solving conflicts and maintaining momentum during the process. Therefore the project has brought out the demand for an impartial consultant managing the process of societal embedding. Consequently, research and R&D programs should include a parallel, specially funded project for societal embedding managed by the consultant.

As a conclusion the project indicates that societal embedding of innovations may promote the implementation of climate-friendly energy technologies in at least three ways. *Firstly,* the process mobilises key actors to co-operation where different expectations and interests are articulated and awareness of the needs is increased. This generates interactive learning on the problem and its solving. Market construction is forged ahead by mutual adaptation of the innovation and its environment. *Secondly,* this approach offers a tool to examine the societal quality of the innovation, a question vitally related to climate change. Realising the various dimensions of societal quality calls for a continuous dialogue between a number of actors, provided by societal embedding. *Thirdly,* by producing new knowledge of the needs on the market, this approach supports the societal actors in choosing different instruments to induce the intended transition to sustainability.

Publications and reports made under the project

Kivisaari, S., Lovio, R., Väyrynen, E., Saranummi, N. 2002. Public Private Partnership in Influencing Transitions. Comparing Public Interventions for Health Care and Energy Sector Transitions. Paper for workshop on Transition to Sustainability through System Innovations. Enchede 4-6.7.2002.

Lovio, R., Kivisaari, S., Väyrynen, E. 2002. Uuden teknologian kaupallistamisen ja käyttöönoton edistäminen. [*Commercialisation and implementation of new technology. (In Finnish)*] In the Final Report of the Climtech- Technology and climate change programme. (to be published)

Väyrynen, E., Kivisaari, S., Lovio, R. 2002. Juurruttaminen uusiutuvien energioiden käytön ja energiansäästön edistämisessä – JUMENE. [*Societal Embedding of Innovations Related to Renewable Energies and Energy Conservation. (In Finnish, with English abstract)*]. VTT Research Notes. (to be published)

References

Hoogma, R., Kemp, R., Schot, J., Truffer, B. 2002. Experimenting for Sustainable Transport, the Approach of Strategic Niche Management. Spon Press. London and New York. 212 p. ISBN 0-415-27117-7.

Hoogma R., Weber M., Elzen B. 2001. Integrated Long-term Strategies to Induce Regime Shifts to Sustainability. Paper presented in the conference "Towards Environmental Innovation Systems". 7-29 September 2001. Eibsee, Germany. 25 p.

Kemp, R., Rotmans, J. 2002. Managing the transition to sustainable mobility. Paper for workshop on Transition to Sustainability through System Innovations. Enchede 4-6.7.2002. 29 p.

Kemp, R., Schot, J., Hoogma, R. 1998. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. Technology Analysis & Strategic Management 10 (2): pp. 175-195.

Kivisaari, S. 1999. Managing Societal Embedding of Innovations: The Case of Health Care. Article in Schienstock G. & Kuusi O. (eds.), Transformation towards a Learning Economy – The Challenge for the Finnish Innovation System. Hakapaino. Helsinki. Sitra Series no. 213/1999, pp. 292-302. ISBN 951-563-358-3.

Kivisaari, S. 2001. Kokemuksia vuorovaikutuksesta kehittämistyössä; juurruttaminen kokeiluna. [*Experiences from interaction in development work. Societal embedding of innovations as experiment. (In Finnish)*]. VTT Technical Research Centre of Finland, Group for Technology Studies. Espoo. Working Papers 58/01. 54 p. + app. 16 p.

Kivisaari, S., Kortelainen, S., Saranummi, N. 1999. Innovaatioiden juurruttaminen terveydenhuollon markkinoilla. [*Societal embedding of innovations in health care. (In Finnish, with English Summary)*] The National Technology Agency, Tekes. Helsinki. Reports of the Digital Media 7/99. 44p + app. 25p. ISBN 952-9621-59-0.

Kivisaari, S., Lovio, R. 2000. Tuottajan, käyttäjän ja yhteiskunnan vuorovaikutus teknologian muutoksen suuntaajana. [*Interaction between producers, users and society in the steering of technological change (In Finnish)*]. In Tarmo Lemola (ed). Näkökulmia teknologiaan [*Perspectives on technology*]. Gaudeamus. Helsinki, pp. 218 - 238. ISBN 951-662-810-9.

Weber, M., Dorda, A. 1999. Strategic Niche Management: a Tool for the Market Introduction of New Transport Concept and Technologies. The IPTS Report 31: 20-28.

Financing of the Commercialisation of Climate-Friendly Energy Technology

Ilmastomyönteisen energiateknologian kaupallistamisen rahoitus

Matti Pulkkinen, Ville Lehtinen
LTT-Tutkimus Oy, Helsinki, Finland

Abstract

This research concentrated on the financing of the commercialisation of climate-friendly energy technology from the viewpoint of business enterprises, investors and public financing. According to the research findings, the financing does not seem to be a substantial problem to the development of climate-friendly energy technology. Capital investment in the industry has increased and, in addition to domestic investors, international investors as well have taken interest in the Finnish environment technology. Business enterprises are also quite satisfied with public financing. Although the general view is positive, there is room for improvement in business enterprises, investors as well as in the public sector.

Lyhennelmä

Tutkimuksessa keskityttiin ilmastomyönteisen energiateknologian kaupallistamisen rahoitukseen alan yritysten, sijoittajien ja julkisten rahoittajien näkökulmasta. Tutkimuksen havaintojen mukaan rahoituksen saatavuus ei näyttäisi olevan ilmastomyönteisen energiateknologian kehittämiselle suuri ongelma. Pääomasijoitukset alalle ovat kasvaneet ja kotimaisten sijoittajien lisäksi kansainväliset sijoittajat ovat kiinnostuneet suomalaisesta ympäristöteknologiasta. Lisäksi yritykset pitävät julkisia rahoituspalveluita melko hyvinä. Vaikka yleiskuva on myönteinen, kehittämisen varaakin löytyy niin yritysten, sijoittajien kuin julkisen sektorinkin toiminnassa.

1 Introduction

Extensive ratification of international climatic treaties will create a globally increasing demand for climate-friendly technology. The growing market gives new expansion possibilities to Finnish enterprises. Finland is already a significant agent in some areas of energy technology.

In the last ten years the Finnish economy has become increasingly driven by financial market, where financiers and investors play an important role. In Finland, the growth of climate-friendly energy industry will partly depend on the ability of the industry to get an increasing share of the capital investment resources. This in turn depends on whether the expected yield is attractive enough for the investors. Efficient public financing continues to be an important factor, especially in the initial phases of young business enterprises.

The research project sought answers especially to the following questions:

1. What are the present financing opportunities for small and medium-sized enterprises concentrating on climate-friendly energy technology, and what kinds of business and financing plans do these enterprises have for the next few years?
2. As an investment object, how do investors view energy technology, are they willing to increase investments in Finnish energy technology, and if they are, on what conditions?
3. In the area of energy technology, how has capital investment business developed in Finland as opposed to the rest of Europe?
4. What kind of possibilities do the different actors in Finland (Tekes, the National Technology Agency, Ministry of Trade and Industry, Motiva, Finnvera etc.) offer presently, and how could these be developed further?

2 Technology / Methods

The data of this research was gathered with several different methods. The state of innovation and financial environment of energy technology in Finland and abroad was examined by using earlier researches and literary sources.

The basic method for the interviews was a theme interview technique, which was used to gather data in a structured though flexible manner, according to interview situations. The interview round consisted of two parts: the interviews of authorities on commercialisation of energy technology and on financing, and the interviews of the key personnel in the case enterprises.

Fifteen case enterprises were selected from small and medium-sized climate-friendly enterprises that manufacture energy production or operation technology, or other enterprises that advance climate-friendly energy technology (maximum 250 employees). One criterion for selection was that about half of the enterprises should have risk financing. Existing balance sheets and the relevant information gathered from the interviews were used to draw up a financial statement analysis concerning the growth, profitability and financial status of the enterprises. When the management was interviewed, the main topic was the financing of the enterprise.

In addition to the interviews conducted in the case enterprises, the position of climate-friendly energy technology in the financial market was analysed by getting acquainted with capital investors' and business angels' views of the industry and its future. This analysis was made with a questionnaire that was given to the member companies of the Finnish Venture Capital Association and to the members of business angel network maintained by Sitra (the target group consisted of approximately 110 interviewees).

3 Summary of results

3.1 Enterprises' yield on capital high – renewable energy technology enterprises have biggest growth expectations

The turnover of enterprises analysed (15) varied between fourteen thousand euros and thirty-two million euros. On the average, the turnover of the analysed enterprises has increased by nine per cent a year in the last five years, and net earnings have increased even more. Overall, the financial structure is satisfactory. Capital invested in 1997 in the enterprises in the ratio of their turnovers would have resulted in approximately forty-four per cent annual yield on the portfolio. The high yield depends on many factors, but the most important ones are the comparatively good economic and operational continuity of the selected enterprises, as well as the gain from the spread of the investments.

Although the general view of the enterprises is comparatively good, it should be said that the analysed areas and their respective enterprises varied significantly from each other. Some enterprises had not even begun the commercialisation of their product and their profitability was very poor.

The biggest growth expectations of the case enterprises were in the ones that dealt with renewable energy technology (biomass excluded). These enterprises expected their turnovers to grow from the present two-and-a-half million euros to a hundred million euros in the year 2005. The actualisation of the growth predictions of the wind power technology enterprises depends on their growth in the global market. On the other hand, the growth of the sales of earth heat pumps depends on the domestic demand, although the export prospects to e.g. Russia are quite good.

Approximately half of the case enterprises had one or several capital investors as a shareholder. So far only domestic capital investors are shareholders of these enterprises, but about a third of them have been approached by a foreign capital investment enterprise. All the interviewed small and medium-sized enterprises did not have growth objectives. In these cases the financing was not seen as a problem, and in general these enterprises were not interested in risk financing. The majority of the enterprises had applied and received bank loans.

3.2 Interest of capital investors is growing – political risks slow down investments

Many of the investors thought that enterprises developing energy technology do not have enough knowledge of the possibilities offered by capital investors. The capital investors have been contacted mainly by other renewable energy technology enterprises. There were also many of these enterprises among the candidates for investments. So far, however, only one of the interviewees had made an investment in these enterprises. The enterprises that offer software and expert services have also been quite active. In the area of building materials, several inquiries have been made but they have resulted only in few investments. The inquiries from the enterprises that utilise biomass seem to have resulted in investments in several cases.

The studied enterprises have not had as much contact with business angels as with capital investors. At the moment, very few business angels consider investments in the energy technology, and of the interviewees only one had made an investment in the field.

In general, the capital investors were more optimistic than business angels about the internationalisation of the climate-friendly energy technology. The capital investors thought that there is good potential for internationalisation in biomass and other renewable energy production, as well as in software and expert services. The long experience and tradition in Finland, as well as the wealth of raw materials, were seen as strengths of biomass. The faith in the internationalisation of building materials was the weakest. Reasons for this were the regionality of the industry as well as the hard competition in the field.

The investors thought that global emission trade and the ratification of the Kyoto treaty would significantly hasten the innovations and investments in the energy industry. It was also thought that the liberation and competition in the energy market would hasten innovations. Several of the interviewees thought that the introduction of new environmental technology had too many political risks.

3.3 Enterprises satisfied with public financing services – investors more critical

In Finland, climate-friendly energy technology is financed e.g. by Ministry of Trade and Industry (energy aid), Employment and Economic Development Centres (internationalisation aids etc.), Tekes (research and development aids and loans), and Finnvera (environment loans and backings).

The interviewed (15) enterprises had extensive experience of the public sectors' sources of financing. Tekes had financed research and development in almost all of the enterprises either with aids or with loans. In addition, many enterprises had received financing or backing from Finnvera as well as backing from the employment and economic centres. So far, the share of international financing has not been significant. Only one of the enterprises had financing from the European Union.

The agents in the Finnish innovation chain, Tekes, Finnvera and the employment and economic centres, got mainly positive comments from the interviewed enterprises. It is possible that the selection criteria for the enterprises had something to do with this. In general, the interviewed enterprises thought that it was not a problem to get public financing for their projects. It was also thought that there had been a lot of improvement in the public innovation system. Finnvera has become more market oriented and, according to the enterprises, they work more efficiently and swiftly. In principle, the employment and economic centres got positive feedback from their active attitude, but they are still in formative stages and there is a lot of room for development. The research and development aid and loan from Tekes got mostly positive comments. Although the general view is positive, the interviews showed several possibilities for development.

The investors were more critical than the enterprises about the energy technology's public financing system. Among other things, the investors thought that the public agents should take greater risks in the financing of energy technology. The public sector's cautious risk taking shows e.g. in the fact that capital investors and business angels do not have enough good investment objects in energy and environment technology. This statement is supported in part by the observation that all but one of the researched enterprises had received Tekes financing, but many of them did not have any significant expansion plans. From this it can be deduced that these enterprises have low research and development risks and little potential for commercialisation.

All in all, an effective relationship between public and private financing is becoming increasingly important. Capital investment activities aimed at developing business ventures has grown enormously in our country while the public financial instruments have largely remained stagnant. One can ask, if the possible changes in the public financing will enhance the part of private financing in the industry, or if these changes add to the risks and in turn raise the costs of investments. An interesting question in itself is, whether private and public financing influence each other in the current situation. According to the interviews in the energy technology enterprises, this relationship is not very clear-cut. Some of the interviewees thought that public and private financing do not have any influence on each other, while others thought that getting public financing helps in getting better terms on capital financing. Perhaps surprisingly, many of the interviewees thought that getting private financing helps significantly in getting public financing.

3.4 Strong growth in investments to the energy sector in Europe in 2001

In recent years, capital financing has grown rapidly in Finland. In 2001, the total sum of capital investments was 340 million euros. There were altogether 449 investment decisions that concerned 294 enterprises. In 2001, there were three investments to the energy industry that were worth approximately four million euros.

In Europe, Great Britain is the leading country in capital investments, In Finland, Sweden, Belgium and the Netherlands there are more capital investments in high technology than on the average in the EU. In Austria, Greece and Portugal only few capital investments are made in high technology.

The investments in the energy industry by the European Venture Capital Association represent approximately one per cent of all their investments. Between 1996 and 2001, the investments in the energy industry increased by eighty-five per cent, with the same pace as investments altogether. In 2001, the member organisations of EVCA made altogether 10 672 investments, of which 120 had some connection to energy technology.

In 2001, the proportion of investments in the energy industry in Europe rose from 0.7 per cent to 2.8 per cent. In Finland, energy industry's share of all capital investments was about 1%. However, these figures are not comparable, because EVCA does not separate investments in environment friendly energy technology from investments e.g. in power companies. EVCA's examination of Europe covers the whole energy industry, and the powerful growth in investments might be explained by the privatisation of energy companies and the adjoining investments, increased investments in the energy technology and especially increased investments in the climate-friendly energy technology.

4 Discussion

The initial assignment was significantly larger than the actual conducted research. According to the assignment, in addition to the commercialisation of the climate-friendly energy technology the research should have covered the promotion of the introduction of this technology. The research should also have covered an international comparison of the commercialisation and introduction of this technology. However, at a very early stage the management group of the research decided to concentrate on the financing aspect.

In evaluating the results of the research, it should be taken into consideration that although the interviewed enterprises represent a wide range of small and medium-sized climate-friendly energy technology enterprises, their financial position is possibly better than that of an average enterprise in the industry. The problem with a systematic comparison between different lines of business is that the researched enterprises work on several lines of business.

When examining the experiences and attitudes of capital investors, it should be remembered that the return percentage of the questionnaires was not very high, so that the results and interpretations are not conclusive. It is probable that the questionnaires were answered more readily by those agents who have already invested in the energy industry's enterprises or who considered making those investments. In this case the answers may give an overly positive picture of the views of capital investors.

5 Conclusions

One of the starting points of this research was the suspicion that lack of financing was slowing down the commercialisation of climate-friendly energy technology. According to the findings of the research, financing does not seem to present a major problem in developing climate-friendly energy technology. Capital investments in the industry have increased, and in addition to domestic investors, also international investors have taken interest in Finnish environment technology. Additionally, the enterprises were quite satisfied with the public financing services.

Although the general view is positive, there is room for development in all sectors. The financing of demonstration targets is still a substantial problem, and at least points for examination can be found in the activities of the enterprises, investors as well as the public sector. One of these points is whether the Tekes aid should be given at an earlier stage, because financing is more expensive to the small and middle-sized enterprises than to the government and Tekes. In connection to the demonstrations, there should be a research project that would produce marketing material. Tekes could also take into consideration if the demonstrations could be viewed more as research and development than commercialisation. Some kind of risk insurance for the financing product should be developed and used in projects that have great technological risks. Most of the OECD countries have replaced direct support to enterprises' research and development by tax reliefs. In Finland, there should also be consideration and analysis of the effectiveness of tax reliefs and direct aids in commercialisation of climate-friendly energy technology, as well as in other targets. In addition, there should be a systematical comparison between the private and public financing of climate-friendly energy technology e.g. in EU countries, so that the right perspective could be acquired.

Publications and reports made under the project

Pulkkinen, M., Lehtinen, V. 2002. Ilmastomyönteisen energiateknologian kaupallistamisen rahoitus. [*The Financing of the Commercialisation of Climate-Friendly Energy Technology (in Finnish).*] LTT Tutkimus Oy, 2002.

Markets of New Energy Technologies
Uusien energiateknologioiden markkinat

Suvi Monni, Sampo Soimakallio,
Mikael Ohlström, Ilkka Savolainen
VTT Processes, Espoo, Finland
VTT Prosessit, Espoo

Abstract

Some 85% of the global energy need is covered by using fossil fuels. The demand of energy, particularly need of electricity, is increasing, but emissions of carbon dioxide should be halved to fulfil the ultimate objective of the UNFCCC: the stabilisation of the greenhouse gas concentrations in the atmosphere. Therefore, the structure of energy production as well as energy use are under pressure for a significant change, resulting in increased demand of new green energy technology.

Currently, global annual energy investments are just over 1% of gross world product. Tightened requirements for reduction in greenhouse gas emissions may result in the growth of this contribution close to 2%.

Large investments are needed to cover the growth of electricity demand. Globally, need of additional electricity generation capacity is assessed to be 600–1500 GW from 2000 to 2020, corresponding to average annual investments of 90–180 billion (10^9) US$. In addition, by taking all the plant retirements into account, total annual investments may be over 200 billion US$.

In the European Union, new plant requirements to cover increasing electricity needs are approximately 300 GW between 2000 and 2020. Decommissioning of power plants will, however, double this demand, corresponding to average annual investments of 15–22 billion €.

In Finland, the demand for new electricity capacity is assessed to be 5.5–7.5 GW in 2020. Roughly half of the capacity demand substitutes plant retirements. Cumulative investments associated with electricity production are estimated to be around 25 billion € between 2000 and 2020, including also the capital expanditure of electricity transmission.

The increase in electricity demand, as well as markets of energy technologies, depend on several factors, resulting in significant differencies between estimated investments. Especially, this is the case when considering investments in renewables, which are strongly dependent on international agreements, capital grants and on other policy measures as well as on technological development.

Tiivistelmä

Maailmassa käytettävästä energiasta n. 85 % tuotetaan fossiilisilla polttoaineilla. Energian kysyntä ja erityisesti sähköntarve kasvaa, mutta samalla fossiilisten polttoaineiden käytöstä syntyvät hiilidioksidipäästöt olisi vähennettävä alle puoleen nykyisistä ilmastonmuutoksen hillitsemiseksi. Tämä aiheuttaa merkittäviä paineita maailman energiantuotantorakenteen ja käytön muuttamiselle. Ekologiselle ja taloudelliselle energiatekniikalle on siis odotettavissa kasvava maailmanlaajuinen kysyntä.

Tällä hetkellä energiainvestoinnit ovat hieman yli prosentin maailman kokonaisbruttokansantuotteesta. Osuus saattaa lähivuosikymmeninä nousta lähelle kahta prosenttia kasvihuonekaasupäästöjen rajoittamisvelvoitteista johtuen.

Lisääntyvän sähköntarpeen tyydyttämiseen tarvittavat investoinnit ovat suuria. Maailmanlaajuisesti uutta sähköntuotantokapasiteettia tarvitaan arviolta 600–1500 GW vuosien 2000 ja 2020 välillä. Keskimääräisinä vuosittaisina investointikustannuksina tämä tarkoittaa 90–180 miljardia USA:n dollaria. Lisäksi käytöstä poistuvan kapasiteetin korvaaminen saattaa nostaa kokonaisinvestoinnit jopa yli 200 miljardiin dollariin.

EU:ssa lisääntyvän sähköntarpeen tyydyttämiseen tarvittavan uuden kapasiteetin määrä on arviolta n. 300 GW vuosien 1995 ja 2020 välillä. Suljettavat voimalaitokset nostavat investointitarpeen kuitenkin noin 600 GW:iin vastaavana ajanjaksona, mikä vastaa keskimääräisinä vuosittaisina pääomakustannuksina n. 15–22 miljardia euroa.

Suomessa uuden sähköntuotantokapasiteetin tarpeen on arvioitu olevan noin 5,5–7,5 GW vuonna 2020. Karkeasti arvioituna noin puolet tästä määrästä korvaa käytöstä poistuvia voimalaitoksia. Sähköntuotantolaitoksiin ja sähkönjakeluun liittyvät kumulatiiviset investoinnit vuosien 2000 ja 2020 välillä ovat arviolta noin 25 miljardia euroa.

Sähköntarpeen kasvu ja eri teknologioiden markkinat riippuvat monista eri tekijöistä, ja siten myös arviot tarvittavista investoinneista vaihtelevat runsaasti eri tutkimusten välillä. Erityisen suurta vaihtelu on tarkasteltaessa investointeja uusiutuviin energianlähteisiin, sillä ne ovat voimakkaasti riippuvaisia mm. teknologian kehityksestä, kansainvälisistä sopimuksista, investointituista ja muista ohjauskeinoista.

1 Introduction

The use of fossil fuels, including coal, oil and natural gas, represents some 85% of the global energy production. The demand of energy is increasing particularly in developing countries, but also in the industrialised world, in concomitance with a target to reduce carbon dioxide emissions to a harmless level in order to mitigate climate change. According to IPCC (2001) this means that global CO_2 emissions should be more than halved. Therefore, strong emission cuts in industrial countries should be implemented within the next few decades. Significant changes in the energy production and in the usage are required to achieve the challenging target.

Rising to the challenge takes decades due to relatively slow energy system regeneration. Operating time of investments in power plants, industrial, buildings or in infrastructures typically varies from 20 to 50 years, with an annual substitution rate of some 3–4% (Savolainen et al. 2000). Currently, global annual energy investments are just over 1% of gross world product. According to Nakicenovic et al. (1998), this share may increase to near 2%, due to emission reduction requirements.

The demand for new green energy technology is projected to increase significantly world-wide, resulting in a generation of remarkable business possibilities for relevant enterprises. The extent of adoption of new energy technologies is, however, limited by different types of factors. First of all, there are scientific or theoretical maximum potentialities, which do not necessarily remain at a constant level, e.g. in a case of biomass. In addition, the amount of energy that could be produced is restricted by technological and economic aspects. The maximum adoption potential, named as market potential, is finally generated by demand and supply, policies of government as well as by acceptance of consumers.

The scope of this work was to study the investments needed for new energy technologies over the next few decades. Capital expenditure was only calculated for capacity of electric power production, due to lack of data. In addition, investments associated with electric transmission and utilisation were not taken into account. Instead, decrease of further investments due to technological development was assessed. Investments were examined by energy sources from global, European Union and from national point of view, and are expressed as currency and as power unit, and represented cumulatively. Costs are expressed in US dollars (2000) or in euros (2000).

2 Methods

The study was carried out by using literature review and existing energy scenarios. Results of projects made under the Climtech programme were also exploited. Two different types of approach were used in the analysis. The first one concerned investments associated with the whole energy system, whereas in the second one, individual energy technologies covering wind power, solar energy, bioenergy as well as combined heat and power production (CHP) were studied. Connection between examined energy technology and energy system was assessed only roughly, if at all, in the latter type of approach.

Energy scenarios are typically based on projections of population growth and economic expansion. Assumptions concerning development of specific consumptions associated with different types of economic sectors are also generally included in the scenarios. Gross world product is assessed to be three to five-fold compared with the current level by 2050, due to projected population and economic growth (Nakicenovic et al. 1998). This means that energy demand will necessarily increase, regardless of continuous slow development of energy efficiency. However, administrative controlling, e.g. by means of energy and environmental taxes or with emission trading, could accelerate this development due to environmental protection matters.

In addition to above mentioned basic parameters, the scenarios typically contain many other assumptions resulting in divergence of progression. In fact, there could be as much different types of scenarios as assumptions. In the analysis of investments associated with the whole energy system, two types of scenarios were taken into consideration. One represents progression like business as usual (BAU), whereas another describes more ecological development (ECO) with assumptions of energy saving.

3 Results

3.1 Global review

3.1.1 Total investments

Global primary energy and electricity demand were estimated by using existing scenarios, IIASA/WEC (1998), IEA (2000) and EIA (2001), representing global energy production and use. World primary energy need was close to 400 EJ/a, and electricity production some 12 000 TWh/a, in the year 1990. Electricity demand will increase some 75% from 1990 to 2020, and become three-fold by 2050, in the case of BAU-scenario. The respective growth is approximately 43% and 91%, in the case of ECO-scenario. Proportion of electricity from primary energy will increase roughly equally in both scenarios through the examined period. Thus, the growth of primary energy consumption is slower.

The contribution of world electricity production is projected to decrease in OECD region by 2050. Furthermore, a shade decrease is also estimated for reforming economies (REFs), whereas remarkable growth is assessed for developing countries by 2050, due to relatively rapid growth of population and of economics.

Global average full-load hours for electricity production was approximately 4 300 h/a in 1998, based on published statistics (EIA 1999). The demand of additional electricity production capacity was calculated using average full-load hours for each individual energy source. The need of new capacity to meet the increasing demand of electricity varies between 600 GW (ECO) and 1 500 GW (BAU) from 2000 by 2020. Respective numbers are 1 000 GW (ECO) – 2 400 GW (BAU) by 2030, and 2 700 GW (ECO) – 4 400 GW (BAU) by 2050. It should be noted that substitution of capacity that will be decomissioned was not totally included in these numbers, resulting in significant underestimating of demand of new capacity. Currently, approximately 3–4% of existing capacity is substituted annually, corresponding to some 90–130 GW.

Cumulative investments in additional electricity production capacity vary between 1 800 billion US$ (ECO) and 3 600 billion US$ (BAU) from 2000 by 2020. Respective number is roughly 2 800 (ECO) – 5 300 (BAU) billion US$ by 2030, and 6 000 (ECO) – 9 600 (BAU) billion US$ by 2050.

If cumulative investments of additional electricity generation capacity were divided equally for each year, the annual investments would represent 90–180 billion US$ on the average between 2000 and 2020. By taking all the plant retirements into account, total annual investments may be over 200 billion US$.

In the case of BAU scenario, two thirds of investments result from coal, nuclear power and natural gas plants between 2000 and 2020. Approaching the year of 2050, the share of nuclear power will increase, corresponding to just under half of the total, whereas the contribution of coal goes down to negligible level. The other half of the investments will result roughly from renewables (e.g. wind power) and from waste between 2030 and 2050.

In the case of ECO scenario, natural gas, nuclear power and hydro power cover some 15% each of the total investments between 2000 and 2020. Contribution of renewables and wastes is roughly 40% over the same period, but will increase to near 90% between 2030–2050. It should be noted that energy saving assumed in ECO scenario will possibly require remarkable investments in usage technologies, which are not considered in this study.

Most of the investments will be implemented in developing countries. Furthermore, taking also the short of infrastructure for electricity distribution and supply into account, the contribution of total investments will be even higher.

3.1.2 Investements in renewables

Estimates of global investments in renewable energy were based on several publications (e.g. IEA 1999, NCPV 2001, Clini and Moody-Stuart 2001, BTM 2001, IPCC 2001).

Current investments in solar energy technology are at a relatively low level, corresponding around 3 billion US$ annually. Despite, the sector is growing rapidly. Assessments of global cumulative investments in solar electricity vary between 30 to 85 billion US$ by 2010, and between 180 and 850 billion US$ by 2020, respectively. The estimates published in several studies represent that investments in solar heat are projected to be higher than in solar electricity, at least on a short view.

Investments in wind power are also rapidly increasing worldwide, especially in Europe. Therefore, many evaluations concerning installed capacity in 2010 done at the end of 1990s have already become obsolete, due to the extremely rapid growth of wind power market in the recent years. However, future investments in wind energy strongly depend on policies and measures, and naturally also on development of technologies and costs. Thus, the assessments have quite a large variation. The estimated global cumulative investments in wind power are 100–900 billion US$ by 2010, and 200–1300 billion US$ by 2020.

Estimates of biomass use as primary energy in the forthcoming decades are available, but the investments are difficult to assess based on these. The investment costs depend strongly on the processes and technologies used. Biomass can also be used to produce heat, electricity, both (CHP) or e.g. to process traffic fuels. In addition, biomass may substitute fossil fuels without large investments, or it can be combusted together with fossil fuels. The estimates on investments in electricity produced by using biomass vary between 20 and 240 billion US$ by 2020.

Combined heat and power production (CHP) has a significant potential, because in many areas heat and power are still produced separately, even though CHP might be a more economical and ecological alternative. The share of combined heat and power production of global electricity production was 6% in the year 2000. This share is projected to grow to 10–30% by 2010. The future of CHP market depends strongly on ratification of Kyoto Protocol, and particularly on emission trading (Brown 2001, ENS 1999).

3.2 Consideration of the European Union

3.2.1 Total investments

Estimates on development of primary energy and electricity demand in the EU were based on *European Union Energy Outlook 2020* (EC 1999), where a kind of BAU scenario has been described. No type of ECO scenario concerning the EU was found in any study. Thus, only BAU scenario was considered.

The primary energy need of the EU was approximately 55 EJ/a in 1990. It is projected to increase to 65 EJ/a by 2010, and to near 68 EJ/a by 2020 (EC

1999). At the same time, the share of the EU from global primary energy need will decrease from around 15% in 1990 to 11–12% in 2020. Electricity production was some 2 200 TWh/a in the EU in 1990. It is assessed to grow to 3 000 TWh/a by 2010, and roughly 500 TWh/a per decade by 2030 (EC 1999). By comparing these numbers with global electricity production estimates based on constructed BAU scenario, the proportion of the EU will decrease from approximately 18% to near 15% during above mentioned period.

According to EC (1999), energy supply in the European union is dominated by fossil fuels over the time period examined. Despite increasing adoption of renewables, the share of them in energy supply shall remain at a relatively low level, and achieve appr. 6% by 2020. The use of electricity is projected to increase roughly 1.7% annually over the period. The proportion of wind power in electricity production is assessed to grow from 0.1% in 1999 to just over 4% by 2030.

According to EC (1999), approximately 300 GW of new power production capacity is needed in the European union to cover the increase of electricity demand between 1995 and 2020. If plant retirements are also taken into account, the EU will require close to 600 GW of new capacity in the same period. Respective numbers between 2020 and 2030 are some 110 GW and near 400 GW. The use of combined heat and power production is becoming more general. Even a third of the power plant investments may be associated with CHP between 1995 and 2020 as well as 2020–2030.

The investment costs were evaluated by using basic assessments published in *Backround Study for the Finnish Climate Change Action Plan* (MTI 1/2001), as well as estimates represented by Nakicenovic (1998). Cumulative investments in electricity production capacity corresponding to the analysed scenario were assessed to be roughly 380–570 billion € from 1995 by 2020. Assuming that these investments are divided equally between years, the annual investments would be roughly 15–22 billion €.

3.2.2 Investments in renewables

In the European Union, the use of renewable energy is promoted by action plans and directives. A target of 12% for the contribution of renewable sources of the electricity production until 2010 was set in the White Paper "Energy for the future: renewable sources of Energy" (EC 1997), against 6% in 1996. Commission has also set a directive on the promotion of electricity from renewable energy sources in the internal electricity market.

In the EU, investments in solar electricity are estimated to be 6–9 billion € by 2010. Solar heat market is evaluated to be broader also in the EU, corresponding to investments of some 5–40 billion € until 2010 (ATLAS 1999, Solpros 2001a). Roughly half of the globally installed solar electricity capacity has been installed in developing countries. They are projected to be a significant market area for European solar electricity industry also in the future, especially in the case of off-grid applications (ATLAS 1997).

Europe is globally the most remarkable market area of wind energy. Nearly all of the European wind energy capacity is installed in the EU countries, and 90% of world's wind turbine manufacturers are European. Cumulative investments are estimated to be as high as 70 billion € in the EU by 2010. Investments of even 190 billion € could be achieved by 2020 (EC 1997, BTM 2001, IEA 2001).

The investments in combined heat and power in the European Union were estimated using four scenarios from *European Cogeneration Study* (Whiteley et al. 2001) and a scenario from *European Union Energy Outlook 2020* (EC 1999). In addition, *White Book on renewable energy* (EC 1997) was also used in the case of biomass-CHP. Investments in CHP depend strongly on market prices of the fuels used, especially of natural gas, which is the most important CHP fuel at the moment and also in the near future. Possible deregulation of European gas and electricity market, as well as policies and measures, will also have a significant impact on the investments in CHP. Under favourable circumstances, cumulative investments in CHP in total may rise up to 100 billion € by 2010, and up to 190 billion € by 2020, respectively. In that case, investments in biomass-CHP may rise up to 60 billion € by 2010, and close to 70 billion by 2020.

3.3 National review

3.3.1 Total investments

Estimates on the development of primary energy and electricity demand in Finland were based on scenarios of the Climtech programme. Three types of scenarios were taken into consideration. BAU scenario represents circumstances where emission cuts to fulfil the requirements of the Kyoto Protocol are not implemented. In addition, the fifth nuclear power plant will not be constructed in the BAU scenario. On the contrary, preceding assumptions are fulfilled in two ECO scenarios concerned in this study. These represent conventional (CONV) and optimistic (OPT) technological development.

In Finland, primary energy consumption was some 1.1 EJ/a in 1990, and close to 1.4 in 2000. The increase of energy consumption has not been as high as the economic growth of recent years. According to BAU, CONV, and OPT scenarios, the energy demand is assessed to rise to 1.5 EJ/a by 2010, and it is estimated to vary from just below 1.5 to approximately 1.6 EJ/a in 2030, depending on the scenario.

Absolute consumption of electricity has been growing steadily in Finland. Total annual electricity consumption was just over 60 TWh in 1990, against close to 80 TWh in 2000. The consumption of electricity is estimated to grow to 89–92 TWh/a by 2010, and to be 102–107 TWh/a by 2030.

Relatively large investments are needed to cover the increasing demand of electricity. Besides, the present power and heat plants will have to be replaced gradually. In many cases the present plants are being used as far as it is economically and environmentally reasonable, so the decomissioning schedules are not well known. The present electricity production capacity in Finland is approximately 17 GW nominal power. The demand of new electricity capacity is assessed to be 2–3 GW by 2010, 5.5–7.5 GW by 2020 and 10–14 GW by 2030 (Kara et al. 2001). Roughly half of the capacity demand substitutes plant retirements.

Total energy investments in Finland were approximately 660 million € in 2000. The share of energy investments were around a percent of GDP in 1990s, and it is projected to remain at the same level during the considered time period.

Cumulative energy investments are estimated to be roughly 17 billion € within BAU scenario during the first decade of 21st century. These costs are assessed to be 10% higher in both ECO scenarios, resulting mainly from investments in nuclear power plant. Respective cumulative investments are projected to be 21–22 billion € during the following two decades within all examined scenarios. Roughly two thirds of total energy investments are associated with the costs of electricity production. It should be noted that capital expenditure associated with electric transmission is included in this share.

3.3.2 Investments in renewables

The estimates on investments in renewable energy in Finland are mainly based on estimates made in Climtech projects and also on some other publications (Vartiainen et al. 2002, Solpros 2001b, Helynen et al. 1999). Like in many other countries, the investments in renewable energy in Finland strongly depend on policies and measures, on taxation and investment grants. Assessments of cumulative investments in solar energy technology vary between 30 and 590 million € by 2010, and between 30 and 720 million € by 2020. Respectively, investments in wind energy were estimated to be 110–590 million € by 2010 and 360–2240 million € by 2020. Value of investments in biomass-CHP was estimated to be some 2–5 billion € by 2010.

4 Export of Finnish energy technology

Export of Finnish energy technology increased significantly in the past decade (Figure 1). Value of energy technology export was approximately 0.8 billion € in 1990, against 3.2 billion € in 2000, corresponding to 6.5% of the whole Finnish export. Approximately a quarter of energy technology exported in 2000 was so called sustainable technol-

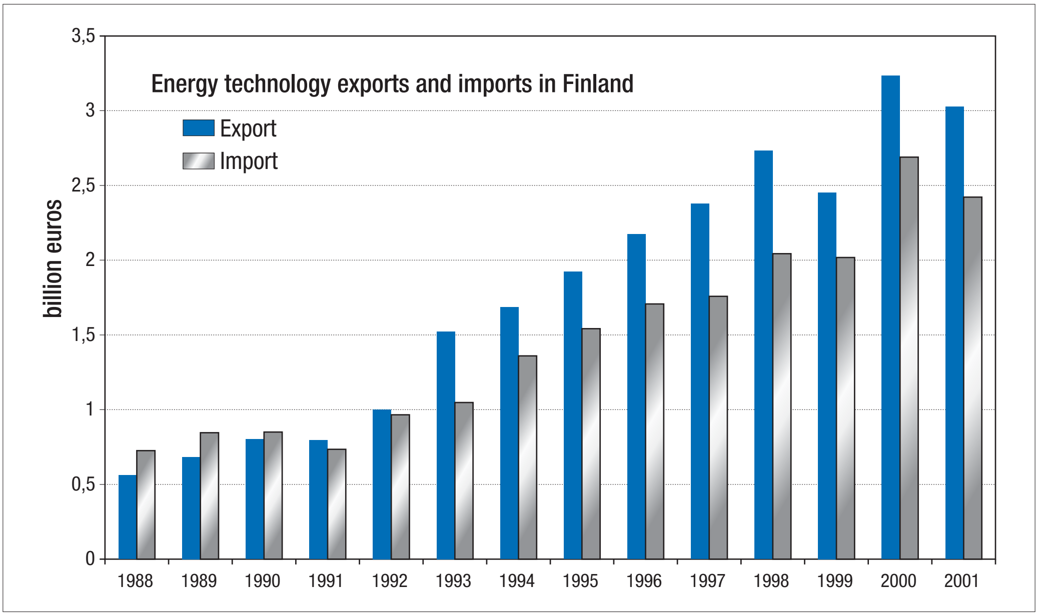

Figure 1. Export and import of Finnish energy technology between 1988 and 2001 (Hernesniemi 2002).

ogy. Currently, Finland is one of the most in energy technology spesialised country in the world.

Advanced combustion technology and associated component manufacturing is one of the strong aspects of Finnish energy technology. In addition, manufacturing of wind power plant components have continuously become more important in export markets. Start-up of Finnish wind power plant manufacturing, penetrating roughly a share of 10% from the global market by 2010, has also been settled as an objective. Annual export of Finnish wind power technology could in that case be at least 2 billion €. The current export of Finnish solar power products is approximately 8 million €. According to *National Action Plan for Solar Energy* (Solpros 2001b), export of 115 million € by 2010 has been settled as a target.

The total annual export of Finnish renewable energy technologies is assessed to be from 1 to 6 billion € in 2010. The potential could be even larger, when also other sustainable energy technologies, such as frequency converters providing more efficiency, would be taken into account.

5 Conclusions

The growth of electricity demand appears to be inevitable during the next few decades, regardless of continuous but slow development of energy efficiency. Therefore, large investments are needed world-wide to cover the growth of electricity demand. Globally, annual investments of additional electricity generation capacity was assessed to be on the average 90–180 billion US$ between 2000 and 2020. Contribution of the European Union is roughly 10% of projected global investments. Furthermore, average annual investments in additional electricity production capacity in Finland are under 1 billion € between 2000 and 2020, corresponding to some 5% in maximum of respective invesments in the EU.

Significant differencies between examinations exist, due to numerous assumptions and uncertainties associated with assessments. Particularly, this is the case when considering investments in renewables, which arise from strong dependence on policies and measures as well as on developments of technologies and costs.

In Finland, export of energy technologies has increased significantly in the past years. Furthermore, the demand for ecological and economic technologies is projected to grow, resulting in emerging markets. This may considerably benefit Finnish enterprises involved in energy technology.

Publications and reports made under the project

Monni, S., Soimakallio, S., Ohlström, M. 2002. Arvioita energiateknologian markkinoista lähivuosikymmeninä. [*Estimates on Markets of Energy Technologies During the Next Few Decades. (In Finnish)*]. VTT Processes, Project report PRO4/Tnnn/02. Espoo, 2002. 69 p. (to be published).

References

Atlas, 1997. www-sites of ATLAS project involved in 4th Framework Programme for Research and Technological Development (RTD) of the European Commission. http://europa.eu.int/comm/energy_transport/atlas/

Brown, M., 2001. The Global Market Opportunity – and How it can be Achieved. 2nd International CHP Symposium, Amsterdam. 10 May 2001.

BTM 2001. International Wind Energy Development. World Market Update 2000. Forecast 2001-2005. BTM Consult ApS, 65 s, Ringköbing 2001.

Clini, C., Moody-Stuart, M., 2001. Renewable Energy: Development that Lasts. 2001 G8 Renewable Energy Task Force Chairmen's report.

EC 1997. Notification of the European Commission. COM(97) 599 of 26.11.1997. Energy for the Future: Renewable Sources of Energy – White Paper for a Community Strategy and Action Plan.

EC 1999. European Union Energy Outlook to 2020. European Commission. Serie: Energy in Europe, Special issue. November 1999. 217 p.

EIA 1999. International Energy Annual 1999. www-pages. Table 6.3 and 6.4. Referred in autumn 2001. http://www.eia.doe.gov/emeu/iea/elec.html.

EIA 2001. International Energy Outlook 2001. www-pages. Referred in July 2001. http://www.eia.doe.gov/oiaf/ieo.

ENS 1999. Cogeneration Online for Global Power Surge. www-pages. Environment News Service. http://www.ens-news.com

Helynen, S., Holttinen, H., Lund, P., Sipilä, K., Wolff, J., 1999. Uusiutuvien energialähteiden edistämisohjelman taustaraportti. [*Backround report for the Action Plan for Renewable Energy Sources. (In Finnish)*]. Ministry of Trade and Industry, Studies and reports 24/1999. Edita ltd, 1999. 112 p.

Hernesniemi, H. 2002. Stats of Finnish Energy Technology Export. Private communication 20.2.2002.

IEA 1999. The Evolving Renewable Energy Market.

IEA 2000. World Energy Outlook. Highlights. OECD/IEA, 2000. 92 p.

IEA 2001. The potential of wind energy to reduce CO2 emissions. Report Number PH3/24.

IIASA/WEC 1998. IIASA/WEC Global Energy Perspectives. www-pages. Referred in July 2001. http://www.iiasa.ac.at/Research/ECS/docs book_st/wecintro.html.

IPCC 2001. Climate Change 2001: Mitigation. Contribution of Working Group III to the Third assessment Report of the Intergovernmental Panel on Climate Change. [Metz, B., Davidson, O., Swart, R., Jiahua, P. (eds.).]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 752 pp.

Kara, M., Hirvonen, R., Mattila, L., Viinikainen, S., Tuhkanen, S., Lind, I. (eds.) 2001. Energy Visions 2030 for Finland. VTT Energy. Edita Plc, Helsinki 2001.

MTI 1/2001. Teknologia ja kasvihuonekaasupäästöjen rajoittaminen – Taustatyö kansallista ilmasto-ohjelmaa varten. [*Technology and Mitigation of Greenhouse Gas Emissions – Backround Study for the Finnish Climate Change Action Plan. (In Finnish)*]. Ministry of Trade and Industry, Publications 1/2001. Edita ltd, 2001. 198 p.

Nakicenovic, N., Grübler, A., McDonald, A. 1998. Global Energy Perspectives. Cambridge University Press. 299 p.

NCPV 2001. Investing PV is Good, Sound Business. *Solar Electricity, the power of choice*. National Renewable Energy Laboratory, National Center for Photovoltaics, USA.

Savolainen, I., Tuhkanen, S., Ohlström, M., Pipatti, R., Pingoud, K., Johansson, A. 2000. Teknologia ja ilmastonmuutos – Lähtökohtia Climtech-ohjelmalle. [*Technology and Climate Change – Starting point for the Climtech technology programme. (In Finnish)*]. Tekes, Helsinki. 65 p. Technology Review: 85/2000. Available also at: http://www.vtt.fi/ene/Climtech/Suomi/julkaisut.html.

Solpros 2001a. Aurinkoenergian teknologia- ja markkinakatsaus. [*Technology and Market Review of Solar Energy. (In Finnish)*]. Tekes project 594/480/00.

Solpros 2001b. Kansallinen aurinkoenergian toimenpideohjelma. [*National Action Plan for Solar Energy. (In Finnish)*]. Road-map for Solar Energy Technology and Markets in Finland. Tekes-project 594/480/00.

Vartiainen, E., Luoma, P., Hiltunen, J., Vanhanen, J. 2002. Hajautettu energiantuotanto: teknologia, polttoaineet, markkinat ja CO_2-päästöt. [*Distributed Energy Production: Technology, fuels, markets and CO_2 emissions. (In Finnish)*]. Gaia Group Plc. Edita Plc, Helsinki 2002.

Whiteley, M., Minett, S., Hinnells, M., Rajkiewicz, A., Alakangas, E., Kolin, S. 2001. The Future of CHP in the European Market – The European Cogeneration Study. Final publishable report. XVII/4.1031/P/99-169.

Tekes' Technology Programme Reports

14/2002	Technology and Climate Change. CLIMTECH 1999–2002. 258 p. Sampo Soimakallio, Ilkka Savolainen (eds.)
13/2002	Avautuneet sähkömarkkinat ja jätteiden energiakäyttö – lainsäädännöllä synnytettyinä markkinoina. TESLA- ja Jätteiden energiakäyttö -teknologiaohjelmien arviointiraportti. 62 s. Mervi Rajahonka, Lasse Kivikko, Mikko Valtakari, Matti Pulkkinen
12/2002	Information Technology and Electric Power Systems, TESLA Technology Programme 1998–2002. Final Report. 80 p.
11/2002	Informaatiotekniikka sähkönjakelussa, TESLA-teknologiaohjelma 1998–2002. Loppuraportti 102 s.
10/2002	Kilpailukykyä yritysten toimintatapoja kehittämällä – GPB-, ProBuild- ja Laatu-ohjelmien arviointi. Arviointiraportti 44 s. Mikko Valtakari ja Mervi Rajahonka
9/2002	Energiateknologiayritykset liiketoimintaympäristön murroksessa. Materiaalit energiatekniikan palveluksessa, KESTO-teknologiaohjelma 1997–2001. Arviointiraportti. 31 s. Lasse Kivikko
8/2002	Materials for Energy Technology, KESTO Technology Programme 1997–2001. Final Report. 128 p.
7/2002	Materiaalit energiatekniikan palveluksessa, KESTO-teknologiaohjelma 1997–2001. Loppuraportti. 128 s.
6/2002	Water Services 1997–2001. Evaluation and Final Report. 132 p.
5/2002	Pigmentit paperin raaka-aineena 1998–2001. Loppuraportti. 87 s.
4/2002	Global Project Business, Kansainvälinen liiketoiminta 1998–2001. Loppuraportti.
3/2002	ETX – Electronics for the Information Society 1997–2001. Final Report. 387 p.
2/2002	Evaluation of Finnish R&D Programmes in the Field of Electronics and Telecommunications (ETX, TLX and Telectronics I) Evaluation Report. 95 p.
1/2002	TLX Telecommunications – Creating a Global Village 1997–2001. Final Report. 200 p.
14/2001	Laatu verkostotaloudessa -teknologiaohjelma 1998–2001. Loppuraportti.
13/2001	Vesihuolto 1997–2001. Loppuraportti. 94 s.
12/2001	Pro Muovi -teknologiaohjelma 1998–2001. Loppuraportti. 74 s.
11/2001	Space Technology Programmes 1995–2000. Evaluation Report. 36 p.
10/2001	Competitive Reliability 1995–2000. Evaluation Report. 2001, 42 p.
9/2001	Transport Chain Development Programme KETJU 1998–2000. Final Report.

Subscriptions: www.tekes.fi/english/publications