



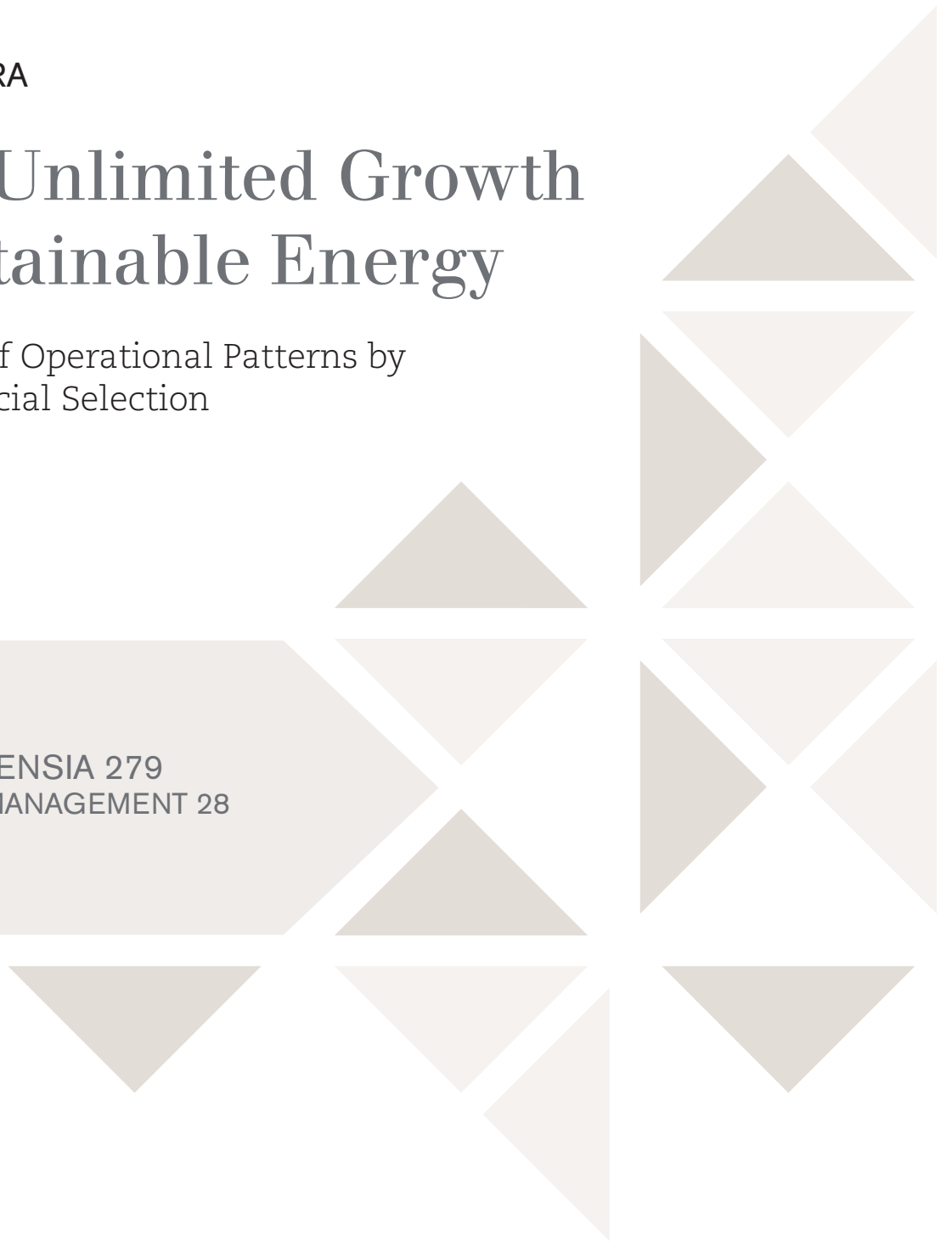
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From Unlimited Growth to Sustainable Energy

The Origin of Operational Patterns by
Means of Social Selection

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INDUSTRIAL MANAGEMENT 28



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*'Every time I open my mouth
there will be a revolution –
or a new project'*

*To my nearest ones
Jakob, Tomas and Maria, my soul mates*

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	Sivumäärä 204	Kieli Englanti
	Julkaisun nimike Rajattomasta kasvusta kestävään energiahuoltoon – Toiminnallisten mallien synty sosiaalisen valinnan tuloksena	
Tiivistelmä Tämä väitöskirja perustuu neljään vertaisarvioituun artikkeliin, jotka yhdessä muodostavat yhtenäisen pitkittäisen tutkimus- ja tiedonluomisprosessin. Sen kulmakiviä ovat käsitteellinen integraatio ja dialektinen päättely. Työssä keskeistä on ”zoomaus” makrotason ajattelusta – filosofiasta ja maailmankuvasta – kohti pienempiä yksityiskohtia. Tavoitteena on ensin ymmärtää ja sitten syventää tietoa tutkimuksen kautta, hakea ratkaisuja selkeästi esitettyihin käytännön ongelmiin, sekä lopulta viedä tulokset käytännön toteutukseen. Työn looginen rakenne on seuraava: Maailman ympäristön tila heikentynyt siinä määrin, että koko ihmiskunta on vaarassa. Tähän liittyviä kysymyksiä on työssä käsitelty ja analysoitu laajasti. Muutos kohti kestävä kehityksen periaatteiden noudattamista on pitkäkestoinen sosiaalinen prosessi, ja sen ominaispiirteiden ja dialektiikan ymmärtäminen on elintärkeää. Työssä esitellään ja analysoidaan tekijän kehittämää kolmitasomallia sosiaalisesta evoluutiosta. Muutos kestäväan kehitykseen edellyttää käytännön toimia – todelliset teot ovat välttämättömiä – mutta ennen muuta se edellyttää tieteellisen osaamisen kehittämistä. Tätä näkökulmaa on käsitelty lyhyesti. Energian tuotanto on ollut perinteisesti yksi tärkeimpiä tekijöitä ihmiskunnan ympäristövaikutusten aiheuttajana. Tästä syystä energiasektorin muutosprosessi ja potentiaalinen uudistuminen ovat keskeisessä asemassa koko ihmiskunnan kannalta. Suurin osa väitöskirjan empiirisestä aineistosta koskee energiasektoria ja sen potentiaalista muutosta kohti kestäväan energiahuollon periaatetta.		
Asiasanat Kestävä energiahuolto, kestävä kehitys, RES, uusiutuvat energianlähteet, energiaomavaraisuus, Malthus ja Boserup, sosiaalinen muutos		

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Abstract This doctoral thesis is based on four peer reviewed articles, which together make a coherent longitudinal research and knowledge creating process, with conceptual integration and dialectical reasoning as its corner stones. The thesis is based on zooming in from large scale thinking – philosophy and worldview – towards smaller scale issues, first in order to understand, then to deepen knowledge through research, then to search for solutions for clearly explicated problems, and finally to implement the findings in practice. The logical framework is as follows: The state of the global environment is approaching a point where the whole of humankind is in danger. These issues are widely discussed and analysed. The change towards more sustainable development will be a long societal process, and it will be essential to understand the characteristics and dialectics of the process. The author presents and analyses his three layer model of societal evolution. The change of making humankind more sustainable creates practical needs – real actions will be necessary – but above all, it creates a need to develop scientific understanding, which is briefly discussed. The production of energy has traditionally been one of the core issues concerning the effect humankind has on the environment, and in the process of change, the potential reform of the energy sector will be in a key position. The main part of the thesis' empirical material concerns the energy sector and its potential shift towards the principle of sustainable energy.		
Keywords Sustainable energy, Sustainable development, RES, Renewable energy sources, Energy self-sufficiency, Malthus and Boserup, Societal change		

PREFACE

“All in all it's just another brick in the wall.”
Roger Waters, Pink Floyd, 1979

Tradition always consists of innumerable single actions accomplished over a long period of time. As the famous Finnish film director Aki Kaurismäki expressed it, it is like building a wall, film by film, brick by brick. You can however only see the tradition when the big picture, the wall, can be outlined and understood – still, the bricks must be relevant, in place and fit into the wholeness. This is, in essence, how science and its traditions are also constructed.

In this doctoral thesis the dialectics between the details and the wholeness is the intellectual core. The ideas, thinking and world view in the background, and even the single articles included in the dissertation, have grown and matured over decades, creating the basis for this nearly life-long journey. This also means that this particular selection of articles accompanied by the summarizing article is more than just a doctoral thesis. Although I have been able to address it in academic format quite recently, this study represents the tradition I have been working with over my whole career thus far, starting from my early student life in the mid-1970s, through to environmental activism since the 1970s to environmental administration, private environmental business, and finally, my present position at the University of Vaasa.

My “scientific wall” is about to take its form, I have placed a number of bricks, but the wall is by no means finished. I hope this thesis makes the big picture understandable. I also hope that I, together with my colleagues, can continue the tradition towards a more sustainable world. This tradition will never cease.

There are a number of people without whom my thesis would never have been possible and to whom I owe the greatest possible thanks: Josu Takala, my supervisor and friend from the mid-1970s, who encouraged and guided me through the academic routines, the constructive pre-examiners Donald Huisinck and Imre Fertő, my colleague and co-author Timo Hyttinen, and the other co-authors Hanna Kuittinen, Lindsay Knuckey, Lisa Goodall and László Dinya. Special thanks go to Merja Kokko for most of the graphics, Tarja Salo for preparing the layout and the University of Vaasa for financial support.

Many people have inspired and stimulated me during my journey, for instance Hannu Katajamäki, Matti Inkinen, Juha Tolonen, Rainer Rajakallio, all my colleagues at the University of Vaasa, and particularly my most active present part-

X

ner Erkki Hiltunen. I especially wish to mention my former and present bosses, Jouko Havunen and Jukka Peltoniemi: thank you for your support, encouragement, trust and the opportunity you gave me. There are also many other people who deserve my gratitude – of all of them I just mention my doctors Anders Almqvist and Anders Wahlin – thank you for keeping me alive. Finally, I thank my sons Jakob and Tomas, and my wife Maria. I pay tribute to your tolerance and support, I love you unconditionally.

In Vaasa, May 2013

Pekka Peura

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1 INTRODUCTION

1.1 Title, Logical Framework and Objectives

This thesis is an evolutionary account of social change in general and reform in the energy sector in particular. As the title reflects, any large-scale reform, here represented by the energy sector, is fundamentally a societal process. Firstly, the thesis aims at understanding the need for global changes and how they relate to the energy sector. Secondly, it aims to understand and outline the fundamentals and dynamics of societal changes in general. Thirdly, the thesis aims to research and attain empirical evidence of the on-going and anticipated changes in the energy sector. Fourthly, it aims to promote such changes, which have been proven to be useful or necessary, from strategy formation to practical implementation programmes.

The comprehension of environmental damage caused by human activities and the subsequent need for changes in humankind's operational patterns originate from the thesis author's academic studies in hydrobiology, ecology and environmental sciences starting from the mid-1970s. The idea of societal change as an evolutionary process has its roots in academic studies in philosophy and sociology in the late 1970s. These ideas have matured during my professional career in environmental administration (1982–1987), then in pioneering environmental entrepreneurship, and simultaneously, as an environmental activist, for instance, as the chairman of the regional board and a member of the national board of the Finnish Association for Nature Conservation in the 1980s. Regular readings from different branches of science to the present day have reinforced my world view.

My career at the University of Vaasa brought me to academia, energy research and development issues, and importantly in the context of doctoral studies, to industrial management. The recent progress in the energy sector was a logical continuation of my preceding ideas on both mitigating environmental impacts and understanding social change: production of energy has been one of the core issues when it comes to the humankind's environmental impacts, and it should be possible to explain the dynamic of the energy sector as an evolutionary process corresponding to any other social change. From this perspective, this doctoral thesis forms a longitudinal process, which integrates the author's studies, readings, thinking and world view with the preceding professional career and recent empirical research in the energy sector.

The scope and *logical framework* of the thesis is as follows:

- The state of the global environment is approaching a point where the whole of humankind is in danger.
Article II discusses humankind's limits of existence and the dialectics of the human – nature relationship. The discussion takes a macro theoretical and multidisciplinary perspective.
- The change towards more sustainable development will be a long societal process, and it will be essential to understand the characteristics and dialectics of the process.
The three layer (3L) model of societal change was presented and discussed in Article I and further developed in Article II.
- The change of making humankind more sustainable creates practical needs – real actions will be necessary – but above all, it creates a need to develop scientific understanding.
Article II discusses the need for new kinds of philosophy and cross-scientific theories giving rise to new syntheses, adopting a horizontal, multidisciplinary and integrative approach.
- The production of energy has traditionally been one of the core issues concerning the effect humankind has on the environment, and in the process of change, the potential reform of the energy sector will, therefore, hold a key position.
Article II discusses and analyses the way the already established renewal of the energy sector corresponds to the 3L model, and the diverse potentials of the anticipated further progress.
Article III shows by empirical material and a global review that the physical prerequisites for a comprehensive deployment of sustainable energy (SE) already exist.
Article IV presents an example of how the slowly progressing change in the energy sector towards SE can be boosted by a strategic and comprehensive practical procedure.

The framework can be positioned in the 'big picture' (Fig. 1) as part of the dynamic interaction between society and environment as follows:

- Human activities, such as energy production (Society; lower half) have an effect on ecosystems (Environment; upper half), in different scales and habitats. The effect can be measured as discharge (arrow from 'Society' to 'Environment'). The impacts of human activities can be seen in the state of the environment, usage and sustainability of resources, and the well-being and growth of the population. Examples of these impacts include acidification and climate change.
These questions have been addressed in Article II theoretically and by reviewing literature - the other Articles have also touched upon them.

- The impacts are reflected in society through observations and direct effects (health, state of the environment; arrow from ‘Environment’ to ‘Society’), with harmful effects calling for change. Cognition and societal change for removing a nuisance is a long and complicated process, where the development of social norms precedes practical responses. This process has been addressed in Article I by creating an evolutionary scenario for empirical testing – further developed in Article II.
- Closing the circle, the environmental impacts may change as a result of the anticipated change to the new and potentially sustainable behaviour of humankind, here represented by reforming the energy sector. These issues have been addressed in all Articles (I–IV).

When understood as a temporally developing system, this circle makes a spiral, and it corresponds to the concept of social self-reflection (Beck *et al.*, 1994). Energy production is part of the system representing a significant share of the interface between the environment and society, and it is where the rules of the game are formed as a societal process.

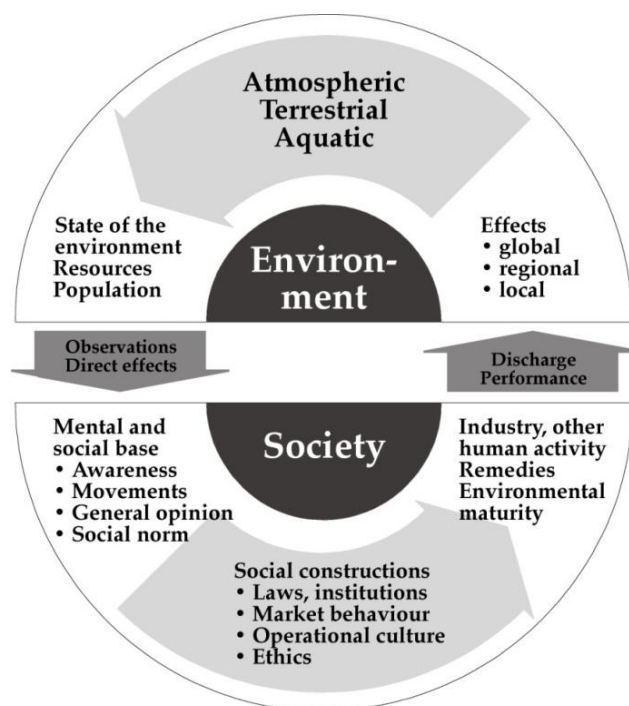


Figure 1. Dynamics between the environment and society (Articles II and III).

The humankind–nature relationship has been poorly understood as a whole system and there has been lack of cohesion between different theories, each explaining only some parts of the system. Moreover, most science until the last decades of 1900s took a totally different perspective on the subject of creating maximal material conditions for living. This tradition has resulted in deterioration of the global environment and an explosive growth of the global population.

Based on the logical framework, the main objectives of this dissertation are as follows:

- **Objective 1:**
To understand and add knowledge about humankind's limits of existence, and to structure the consequences.
- **Objective 2:**
To understand and add knowledge about the needs and the fundamental mechanisms, features and dynamics of societal changes and cultural evolution.
- **Objective 3:**
To analyse and structure the development in environmental issues in general, and the reforming energy sector in particular.
- **Objective 4:**
To test empirically the potential of sustainable energy and to understand and add knowledge about its future impacts in a wider societal context.
- **Objective 5:**
To understand and add knowledge about how intentional, conscious change can be promoted and implemented at the regional level in the energy sector.

1.2 Philosophical Starting Points

1.2.1 *Ontology: materialism and evolution*

“We have one great advantage over historians: we have agreed theories both of chemistry and of the mechanism of evolutionary change.”
Maynard Smith and Szathmáry 2002

The philosophy behind this dissertation is derived from the theory of materialism, according to which everything that exists is matter or energy, and all things are composed of material. Materialism is one of the two grand themes in the history of philosophy, and it contrasts with the other, idealism, which presupposes spirit or mind, or the objects of mind, to be primary and essentially separate from material. In materialism, non-material or spiritual phenomena like consciousness, knowledge and feelings are explained as characteristic of material organized in a certain way. In human beings, these phenomena are based on physical abilities and characteristics, without presupposing an independent abstract ideal entity or other spiritual reality (e.g., Niiniluoto 1985; Määttänen 1998).

The mechanisms and dynamics of the changes and development of different organizations, and even consciousness, cognition and thinking can be understood by the theory of evolution. Evolution is a vital part of the materialistic view in this thesis, underlining the differences of regularities and details at each level of evolution, and thus being neither reductionist nor deterministic.

There is a plethora of writings, handbooks, websites, etc., about evolution theory (e.g., Laihonon *et al.* 1986; Gould 1991; Ridley 1997; Mayr 2001; Hall and Hallgrímsson 2008; Björklund 2009; Hanski *et al.* 2009; Ylikoski and Kokkonen 2009). The most well-known and the first evolution theory to be introduced was that by Charles Darwin (1859/1979), his idea of biological evolution. At a general level it can be defined as the change in the inherited characteristics of biological populations across successive generations. Evolutionary processes give rise to diversity at every level of biological organization, including species, individual organisms and molecules such as DNA and proteins (see also the popularized encyclopaedia Wikipedia 2012).

For evolution to happen there must be **variation** between individuals or units, and there must be **selection** so that the fittest ones survive, recreate and bring their **genetic information** to the next generation. The fundamental parts of the synthetic theory of evolution are the Darwinian theory of evolution and the Mendelian theory of heredity (Ridley 1997). On one hand, variation, selection and heredity are the unconditional preconditions for evolution, but, on the other, for discarding the theory one should be able to show that none of these preconditions have ever happened (Björklund 2009).

In the process of evolution a number of major transitions have affected the way in which the genetic information is transmitted between generations. Maynard Smith and Szathmáry (2002) list the following phases:

The origin of chromosomes: from replicating molecules to independent replicators and nucleic acid molecules (RNA and DNA).

The origin of eukaryotes: from free-living prokaryotes (e.g., mitochondria and chloroplasts) to host cells.

The origin of sex: from asexual clones to sexual populations.

The origin of multicellular organisms: from single-celled protists to sexual populations and solitary individuals.

The origin of social groups: from individuals to human societies and, for example, language.

One feature is common to most of the transitions: entities that are capable of independent replication before the transition can replicate only as part of a larger whole after it. The idea of levels of organization, and hence levels of selection, is central for the transitions (Maynard Smith and Szathmáry 2002). Friedrich Engels had already noticed these levels and defined them as ‘dialectical leaps’ as early as the 1880s (Engels 1971). Biological evolution essentially happens at the level of populations, although the single separate changes and variation can be seen in individuals (e.g., Ylikoski and Kokkonen 2009).

This is also essential for understanding that evolution is a cross-cutting feature at all levels of reality. There has been physical and chemical evolution (e.g., Maynard Smith and Szathmáry 2000), and evolution in all the levels of the major transitions. One of the most important presuppositions in this thesis is that human beings are a product of the evolution. This is generally accepted in the scientific literature of evolution (e.g., Ylikoski and Kokkonen 2009). Moreover, there is no reason to suppose that evolution stopped when human beings attained their present biological and mental abilities, and it would be peculiar if the mental and social characteristics of human beings would not be rooted in the evolution (e.g., Sintonen 2009).

Evolution has no aims, no progressive direction and it is not intentional, it is a reaction to (changed) environmental selection pressures. In this sense evolution is blind and coincidental, without ‘thoughts’ about benefits in the future (Gould 1991; Björklund 2009). Evolution is the gradual improvement of characteristics as a reaction to actual current circumstances, and when the environment and selection pressures change, characteristics will also change (Ylikoski and Kokkonen 2009).

According to these principles the human mind has also evolved, resulting in the abilities to produce societal life and cultures. Today, the generally accepted conception is that social life with its numerous relationships has been the synergic factor accelerating the growth of human brains and intellect (see the comprehensive review by Ylikoski and Kokkonen 2009; also Leakey and Lewin 1993). It is also widely agreed that the main abilities which enabled cultures to develop evolved some 100,000 years ago. This means that the Stone Age circumstances are important in analysing and understanding the origins of these abilities. It is, however, important to note that the Stone Age is by no means the ‘original’ environment for human cultural abilities, as evolution is continuous and bears the weight of the whole preceding inheritance (Ylikoski and Kokkonen 2009).

There have been many deviating opinions and arguments about how evolution theory can be applied in analysing the development of human culture (Ylikoski and Kokkonen 2009). The famous overshoots of sociobiology and other views when applied directly to biological evolution in human societies even justified aggression, wars, racism and sexual discrimination, and polarized the discussion in 1970s and 1980s, and the combination ‘evolution–culture’ became academically dangerous, even a forbidden theme. However, the “... *misunderstanding and misinterpretation*” (Ylikoski and Kokkonen 2009) are about to be overcome and the lately value of the evolution theory has been re-discovered.

There is expanding understanding of the evolutionary mechanisms employed in the development of cultures as being **analogously** similar to those at the other levels of evolution, or as David Hull (2001) reasons convincingly, they are exactly the same. This also creates justification for the use the concept of *cultural evolution*. Its main features are as follows:

Social learning and continuation:

One of the most important cultural abilities is learning and transmitting the culture itself, first in the evolution from parents and later horizontally, comprehensively and reliably from the society – the tradition far exceeds the abilities of separate individuals, and it creates the essential element of continuation of the culture.

External memories:

The ability of storing knowledge and other cultural achievements in external memories, first based on writing and later on other visuographic innovations, enabled the theoretic culture and learning, even ancillary function for collective societal thinking.

Scale

Size and networks of populations became critical factors in cultural evolution. Small populations produce only little innovations, but networks enable accelerating diffusion of new knowledge from a larger society. Culture will be gradually more ‘detached’ from biological fitness along with the process when transmission of cultural products becomes more horizontal.

Cumulativeness:

Material, cognitive and intellectual culture accumulates in successive additions based on the abilities and features listed above, and gradually they as a wholeness have accelerated the process, they have made culture the evolutionary stable strategy (Maynard Smith 1974) and a new transitional level of human evolution.

Biological (or molecular) evolution is not in focus in this dissertation, and its vast tradition will not be further discussed here. However, it must be touched upon when discussing the evolution of the human mind, societies and culture, because it, as the preceding phase, makes the basic developmental environment for cultur-

al evolution. The whole process of evolution is like a pile of transparencies pasted on top of each other; the former levels (i.e., molecular and biological) can still be seen underneath the top sheet (cultural). This metaphor implies that molecular and biological features still have their impacts somewhere in the background, but also that culture and the societal sphere is reasonably independent and brings its own regularities.

1.2.2 *Epistemology: dialectics and conceptual integration*

According to realistic ontology the reality exists outside and independent of conscious subjects or observers. The fundamental epistemological problems have concerned the relationship between the subject and the target of knowledge (Niiniluoto 1985). The empiricist view emphasizes the importance of sensory perception, while in the rationalistic view human intellect, understanding or intuition are the sources of knowledge (Niiniluoto 1985).

In the evolutionary view observations and cognition about the reality evolve according to what is important for each species – survival, avoidance of enemies, finding food, mating, and, especially for human beings, society and culture. Senses have developed for observing primarily these aspects in the environment, but Immanuel Kant (1724–1804) noticed that there are no pure observations, and in all experience-based information there is a conceptual element (Niiniluoto 1985). This means that the human mind and intellect have a strong impact on any knowledge, and they have co-evolved with the senses. For human beings, reality is socially constructed.

This implies that empiricism and rationalism are in a dialectical relationship with each other, like different sides of the same phenomenon ('coin'). This also affects which kind of knowledge living organisms in general, and human beings in particular, can attain concerning the reality. Only a smaller part of the reality can be reached by human sensory perception, but scientific theories, empirical testing, and logical reasoning – i.e., the human intellect – can attain knowledge concerning the reality 'behind' the direct perception (Niiniluoto 1985): "*Atom, molecule etc. cannot be observed by a microscope, but only by thought*" (Engels 1971).

This fits in with realistic materialism, which is essentially dialectical. The basic thought in dialectics is that reality comprises a holistic, integrated and dynamic process, which is under continuous movement and evolution. Dialectical logical reasoning strives to find the general regularities that reality and, for instance, thinking follow, and it has also been called 'the logic of change' (Niiniluoto 1985). Dialectics is about transition of quantity into a new quality, unity and

struggle of contradictions, where thesis and antithesis will produce a synthesis, and negation of negations (things undergo development and become their own contradiction; Engels 1971; Arbnor and Bjerke 2009).

This is reflected in thinking, theory formation and also the research process in this thesis, so that deduction and induction are in a dialectical relationship with each other, instead of a static distinction between deduction (from pre-existing theory or general law to a specific case) and induction (from observations to general law). It might be difficult to define how 'stable' and unquestionable the prior theoretical knowledge is, the existing presumptions may have to be adjusted, and it is impossible to say which one has come first, the hen or the egg. Therefore, in some phases induction is primary while in others deduction is primary, and together they produce the synthesis. This corresponds neatly with the review by Kovács and Spens (2005) concerning *abductive reasoning*, where the central features are:

- Aims to understand something in a new way, from the perspective of a new conceptual framework: new insight about existing phenomena;
- Theory matching, systematic combining, learning loop: "back and forth" between theory and empirical study;
- Intuitive leap, instead of following strict logical procedure;
- Creativity to break out of the limitations of deduction and induction;
- Importance of unexpected observations, even anomaly against an established theory.

Although evolution is an 'all embracing' theory, "*... the thought of a total theory capable of answering simultaneously to all questions concerning all phenomena and reality is an impossible dream based on conceptual misunderstanding*" (Ylikoski and Kokkonen 2009). Evolution theory is not an attempt to go in this direction, but still it touches upon all branches of science: ultimately they all study and create understanding concerning the same reality, the main characteristics of which are evolutionary. This leads to conceptual integration, which is central in the theory formation in this dissertation.

Conceptual integration "*... only requires that the postulates of different branches of science are compatible in a meaningful way to each other*" (Ylikoski and Kokkonen 2009). Instead of violating, reducing or simplifying the independent genuine achievements of the different branches of science, conceptual integration explains and merges the background presuppositions into larger intellectual entities. It can integrate the originally different and separate explanations into chains, creating an important philosophical level of managing and understanding the ever growing amount of knowledge, and structuring it into a meaningful wholeness (e.g., Ylikoski and Kokkonen 2009). Application of conceptual integration in this dissertation has been illustrated in Figure 2.

Conceptual integration and dialectical logical reasoning correspond to heuristics, which is innovative problem solving, learning and discovery, creative thought and constructing of scientific theories (Frigg and Hartmann, 2006). *“Creative thought in science is ... not a mechanical collection of facts and induction of theories, but a complex process involving intuition, bias, and insight from other fields”* (Gould, 1991). This is also what the constructive research approach (Kasanen *et al.* 1991, 1993) and creation of knowledge (Arbnor and Bjerke 2009) require.

The more theoretic Articles I and II touch upon all branches of science in Figure 2, but especially those in the upper half, while technical and economic, along with social understanding, are central in Articles III and IV. Law as scientific theory plays a smaller role, but it is important to understand and be aware of the regulation of changing circumstances, which is the case in Articles III and IV, and to some extent in Article II.

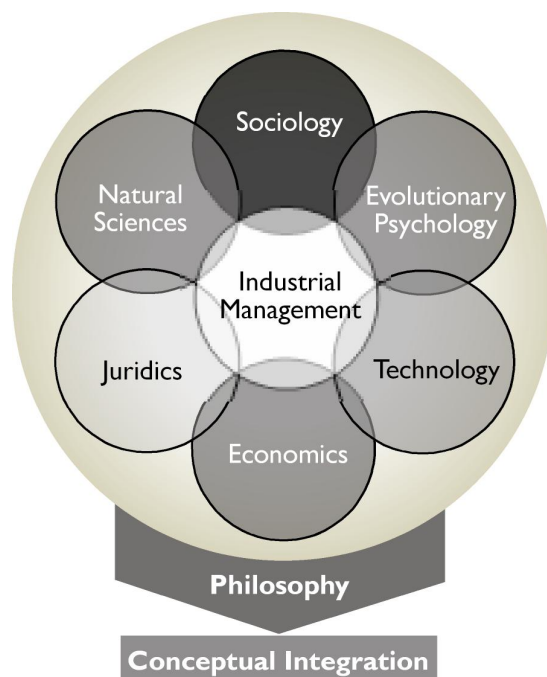


Figure 2. Scientific theories and conceptual integration employed in the dissertation.

1.3 Approach

The view of this thesis is holistic: although single and separate actors always process certain actions or operations, they must still be understood as parts of a wider context. No individual or enterprise is able to live outside of societal constructions. Enterprises, for instance, are open systems (e.g., Daft 1983; Tersine 1985)

in the world of constant societal change and pressure. Therefore, their behaviour, while simultaneously capable of being innovative, also follows some general rules and patterns, and their degree of independence and freedom is relative. This constellation is fundamental from the enterprises', or from any organizations' or societal actors', point of view when they make their conscious strategic and operational choices. This also creates fundamentals for the evolutionary development of enterprises and organizations as a whole and as parts of the society.

The constructive approach is a research procedure for producing constructions. Constructive research is a type of applied studies, which are by their philosophical nature technical norms. One example of the constructive approach particularly mentioned is, by chance, that “*if we wish to keep the Earth as a place which is fit to live in, the pollution must be restricted immediately*” (Niiniluoto 1985), which corresponds exactly to the logical framework of this dissertation. Therefore, the constructive approach is intentional, characterized by the aim of producing new knowledge, applications or results (Kasanen *et al.* 1991, 1993), which can also be applied to this thesis.

Constructive research (Kasanen *et al.* 1991, 1993):

- produces innovative and theoretically justified solutions to explicit and practically relevant problems;
- solve practical problems in scientific contexts, from practical (pragmatic) relevance to practical functioning, from theory connection to theoretic contribution;
- tend to create new reality;
- produces results that can be shown to be applicable in a wider context.

Even in philosophy constructive research has been used to construct the world step by step from supposedly basic elements (Kasanen *et al.* 1991, 1993). It is intentional and includes all interests of knowledge (Habermas 1968): the technical interest emphasizes the ability to manage reality, the hermeneutical interest is a fundamental process for perceiving the human reality, while the emancipatory interest is to free people from false ideology. While Habermas connected the interest to certain branches of science, constructivism integrates them all (Kasanen *et al.* 1991, 1993) into a coherent dialectical approach, where also the theoretical interest could be added (Niiniluoto 1985).

It is important that the constructive approach makes generalizations based on comprehensive and deep understanding. “*The innovation phase is the core element of a successful constructive study ... often heuristic by nature; stricter theoretical justification and testing of the solution typically come afterwards ... after*

designing a working [managerial] construction, we may begin to consider what are the more general features which are revealed by the creation of a new reality” (Kasanen *et al.* 1993). This corresponds to abductive reasoning and conceptual integration, both central in this dissertation.

Therefore, the approach in this dissertation as a whole clearly comes under the umbrella of the constructivism in the typology given by Kasanen *et al.* (1991, 1993). The separate Articles (I–IV), however, can also be positioned as independent papers in the same typology, as illustrated in Fig. 3. Article I comprises conceptual integration in creating the evolutionary three layer (3L) model, being mostly descriptive and theoretic, and with some evidence from the literature. Article II also includes the 3L model, and it reviews theories concerning the human-kind’s limits of existence and sustainable energy, thus having elements of the decision-oriented approach. It refers to literature as its empirical evidence. The approach in Article III is purely constructive, while Article IV falls into the category of action-oriented research, with the RESGen procedure described and its implementation as its empirical material.

In terms of the definitions by Arbnor and Bjerke (2009), this dissertation has features mainly compatible with the actor (understanding reality, which is socially constructed) and system (explaining or understanding reality as systemic) views.

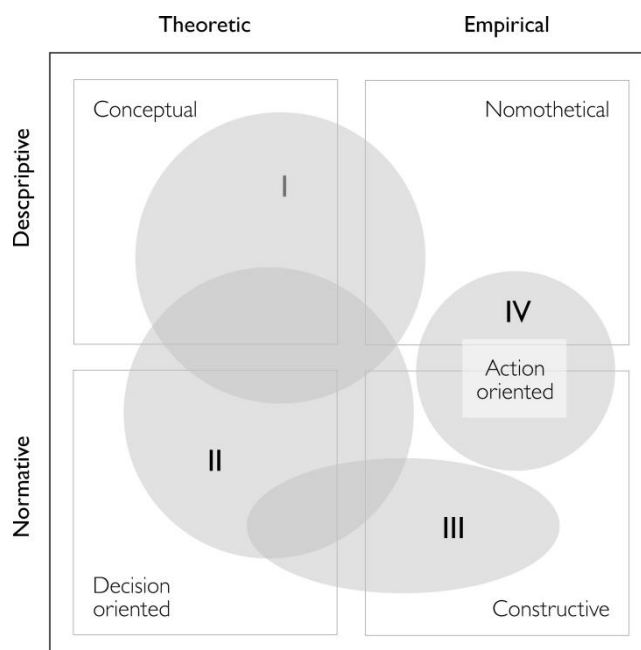


Figure 3. Approach of the four Articles (I–IV) in the dissertation according to the typology suggested by Kasanen *et al.* (1991; 1993).

1.4 Research Process

In addition, in terms of the research process (Fig. 4), the phases of constructive research listed by Kasanen *et al.* (1991, 1993) correspond to the logical framework and the main ideas in this dissertation:

1. Find a practically relevant problem, which also has research potential.
2. Obtain a certain general and comprehensive understanding of the topic.
3. Innovate, i.e., construct a solution.
4. Demonstrate that the solution works.
5. Show the theoretical connections and the research contribution of the solution concept.
6. Examine the scope of applicability of the solution (pragmatic or practical relevance).

The research process of this dissertation (Fig. 5) had already begun in the 1990s, when the three layer (3L) model for understanding societal changes was outlined. It was typically a result of conceptual integration through a dialectical heuristics exercise. It combined a number of prior scientific theories, which were the essential presumptions for the abductive process of creating the 3L model. It became an evolutionary scenario of cultural evolution for further empirical testing. In Article I the empirical evidence was a compilation of literature and previous personal experience from environmentalism and its diffusion in a societal context.

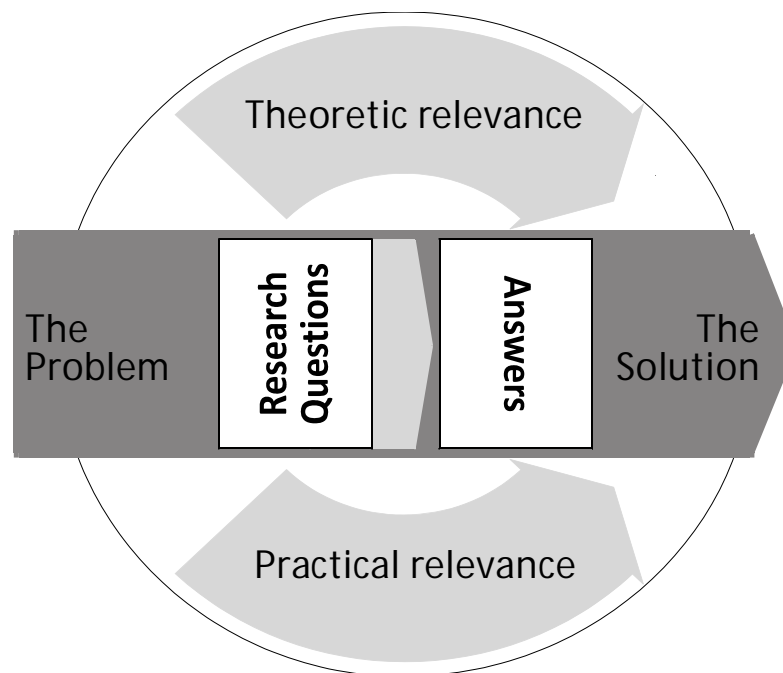


Figure 4. The research process from problem to solution, with reference to theoretic and practical relevance.

The presumptions have been reinforced in Article II, and they will be discussed further in this dissertation. The main drivers for the anticipated societal change towards sustainable development, both theoretic and practical, have been explicated in Article II, although the idea, theories, literature and much of the experience became familiar to the author in the 1990s when preparing Article I. This reflects the innovative nature of the ‘knowledge creation process’ (Arbnor and Bjerke 2009) where the theoretic views are accompanied by a long practical experience from voluntary nature conservation activism to eight years of professional environmental administration and 14 years of pioneering environmental business, and the last ten years in academia.

Article II also outlines the energy sector as an example of a more comprehensive change and launches its reform in a wider societal context, and it defines sustainable energy (SE) as one of the main concepts in this reform.

Articles III and IV are directly focused on the renewal of the energy sector. Article III studied the potential and economy of the anticipated reform, summarizing five different studies carried out at the Levón Institute of the University of Vaasa. Logically, Article IV reports the main findings from implementing the comprehensive regional SE strategy, which follows the RESGen procedure developed in the RESGen project by an international team.

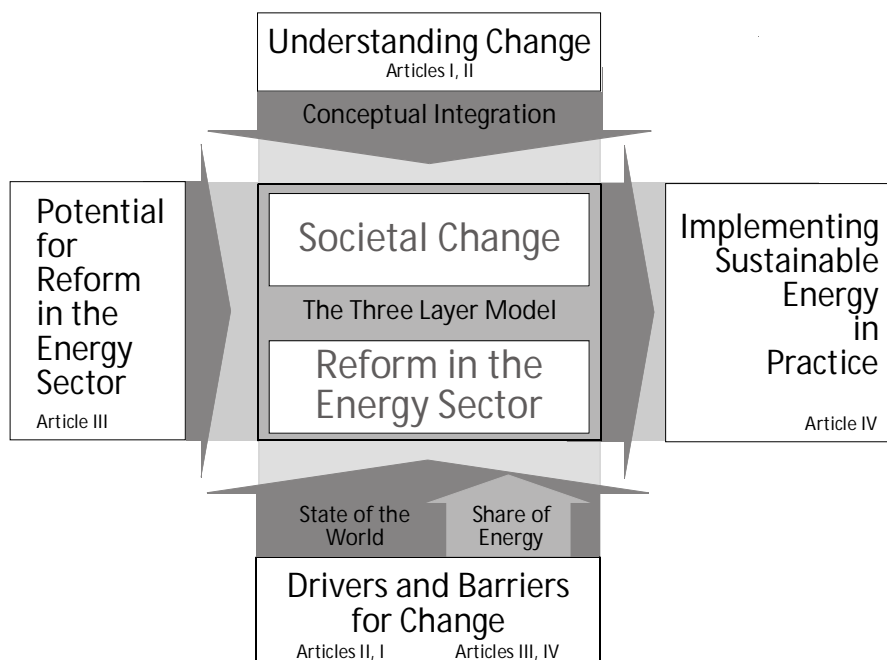


Figure 5. The research process and Articles I–IV of the dissertation.

In the course of the last nine years the tradition, strategy and programmes of SE research at the University of Vaasa have been crystallized in the research agenda of the Energy Chain (Fig. 6), introduced and launched by the author together with the Dean and two Professors at the technical faculty, University of Vaasa. The 'Energy Chain' is a logical construction, starting from renewable energy sources (RES), RES-based fuels and production of energy (from separate methods using different RES to hybrid solutions of integrated use of RES), towards delivery and formation of potentially independent micro and smart grid entities, energy markets and environmental, social and economic impacts.

It is also important to realize that the chain consists of a vast number of actors, actions and phenomena, which all must be understood as such and as parts of the whole system, and also in the societal context. The idea of reform makes it even more complicated, emphasizing the need for a comprehensive understanding and a helicopter or satellite view of the phenomena. The agenda is an on-going and accelerating process, from which this dissertation is one result.

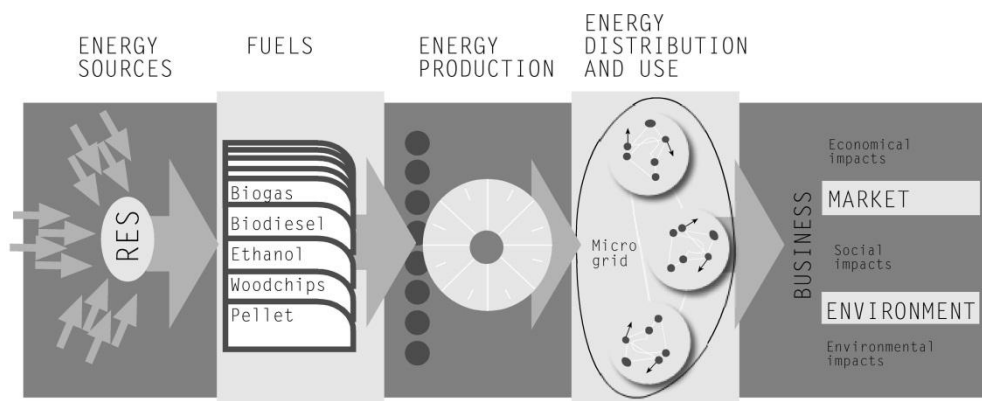


Figure 6. Energy Chain as the longitudinal research agenda.

2 SUMMARIZING THE ARTICLES AND FINDINGS

2.1 The Articles in Brief

A summary of the information contained in the articles included in this dissertation has been collated in Tables 1 and 2. All publications have gone through the scientific blind peer review process. Article I was presented at a conference and published in the conference proceedings, which was reviewed. All the other articles have been published in international, well-known journals.

Table 1. Summarizing information of the four thesis articles: title, publication context, authors and their contribution.

Article	Publication I	Publication II	Publication III	Publication IV
Title	From Ideology to Company Practice – The Origin of Operational Patterns through Social Selection	From Malthus to Sustainable Energy – Theoretical orientations to reform in the energy sector	The potential and economics of bio-energy in Finland	Implementing Sustainable Energy – The RESGen Procedure
Publication context	Refereed papers presented at the 8 th International Conference on Productivity & Quality Research, June 14-14 1999, Vaasa, Finland	Renewable and Sustainable Energy Reviews	Journal of Cleaner Production	International Journal of Sustainable Economy
Author	Pekka Peura	Pekka Peura	Pekka Peura	Pekka Peura (Corresponding)
Co-authors			Timo Hyttinen	Hanna Kuittinen Lindsay Knuckey Lisa Goodall László Dinya
Contribution	Designed and written by the thesis author Material concerning occupational safety management (OSM) collected and analysed by the project team; analysis of how OSM fits into the model by the thesis author	Designed and written by the thesis author	Joint effort by the two authors. Research design, the core idea and writing by the thesis author. The second author: contribution to data collection and other parts of the article.	The core idea, design, coordination, collection of data and writing by the thesis author. The other authors: contribution to national sections, commenting on the other parts of the article.

Articles I and II have been designed and written by the thesis author alone, and they illustrate the background theory for understanding the societal change in general and the environmental issues and the energy sector in particular. Article II also reviews the theoretic views of humankind's limits of existence, and reformulates the definition of the concept of sustainable energy. These articles aim to answer research objectives 1–3.

Table 2. The thesis articles' purposes and aims, conceptual focus and relation to the thesis' logical framework.

Article	Publication I	Publication II	Publication III	Publication IV
Purpose and Aims	To outline a macro level theory for understanding the process from emerging new ideas to operational patterns To filter and structure environmental issues through this theory	To consider macro level theories for understanding the urge for reform and societal change in general, and within the energy sector To consider the energy sector in a wider context and as a potential part of this reform	To study empirically regional energy self-sufficiency potential of bioenergy To study empirically economy of smaller scale energy production units, based on pilot biogas plants	To increase knowledge on how sustainable energy can be boosted at a regional level To develop comprehensive implementation of sustainable energy regionally involving all of the main stakeholders
Conceptual Focus (Fig. 3)	Conceptual integration through dialectical heuristic	Theoretic analysis and review	Constructive research	Action-oriented research
Relation to the thesis' logical framework and research objectives	Basic theory (3L) for understanding the process of societal change; Objective 1 Review of the societal change in environmental issues	Theoretic review of the driving forces affecting the state of the world; Objective 2 Alignment of the development in the energy sector with the above; Objective 3	Shows empirically the potential for the anticipated change in one of the most important sector; Objective 4	Shows the scientific, strategic and practical basics for implementing the societal change of reforming the energy sector regionally; Objective 5
Novelty	New metatheoretic model for understanding cultural evolution	Comprehensive understanding from global drivers to the reforming energy sector in practice Malthus-Boserup dichotomy redefined New definition of sustainable energy	New empirically proven information for Finland The dichotomy vision of the reforming energy sector	New procedure for implementing sustainable energy with a potential for a more widespread use
Findings	Changes in environmental issues following the 3L model	The urge for a global change, the need for a new kind of understanding	RES potential allows energy self-sufficiency, RES-based solutions which are economically feasible	Procedural and comprehensive (systemic) approach and tools vital and useful in practical implementation

In articles III and IV, the thesis author has been the main designer, writer and coordinator. Article III summarizes five studies and several years of development of the theoretic landscape and empirical data in the energy sector, all carried out at the Levón Institute of the University of Vaasa. It produced new information for Finland but also reviewed the development internationally, and it outlined the dichotomy vision for the future development of the energy sector. Article III aims to contribute to the research objective 4.

Article IV is an example of how the ideas developed earlier can be implemented in practice. This was done in the RESGen (RES Generation – From Research Infrastructure to Sustainable Energy and Reduction of CO₂ Emissions) EU Regions of Knowledge project together with nine partners from four EU member states, where a strategic and practical procedure for implementing sustainable energy was developed and tested. In Article IV, the other authors represent the partnership from Basque Country, Spain, Cornwall, UK, and Northern Hungary. This article was designed to contribute to the research objective 5.

The four articles included in this dissertation follow the logical framework (chapter 1.1) and they are intended to form a logical and coherent whole. The starting point has been the societal change that will be necessary for responding to the negative changes in the state of the world's environment. The thesis illustrates an evolutionary scenario of the change, and it also reviews the main urgent needs arising from the environmental concerns. In analysing the potential and other basics, as well as the strategic and practical implementation of the change, it focuses on the energy sector, which is one of the core issues in how humankind affects its environment.

2.2 Towards Limits of Existence?

Contribution to:

Research Objective 1

“To understand and add knowledge about humankind’s limits of existence, and to structure the consequences.”

Main references:

Article II

“Only the greatest stupidity can contemplate this with indifference. The Finn lives in the forest, and of the forest, and – like the old woman in the mythical tale – in a fervour of stupidity and greed, kills the chicken that lays him golden eggs.”¹
Edmund von Berg, 1859 (Berg 1988)

The above citation tells of what the German forest expert Edmund von Berg observed and thought of the Finnish forests during his travels in the mid-1850s. It opens views that integrate the ways nature and natural resources have been used earlier in the history, on the first hand, and in the present time, on the other. Firstly, the observations and subsequent understanding reveal that the state of the environment and its utilization potential are seriously threatened. Secondly, nature and resources are seen as targets for utilization with an economic base. Thirdly, the hen allegory includes a comprehension of the idea of sustainable use of resources.

The fourth point of emphasis rising from Berg’s citation is that the pattern of human activities during his time looked the same as it does today: there is a mechanism according to which humankind repeats its history without taking care of the consequences. It is clear that nature and the environment in mid-1800s could not have been as polluted and overexploited on a larger scale than they are today. However, there were local and regional disasters (e.g., Worster 1988; Ponting 1992; Crosby 1996; Bowler 1997; McNeill 2001) even in the peripheral parts of the globe, or usually it was particularly there, and already in the 1800s the manner of resource exploitation could be characterized as displaying a lack of care about environmental impacts or sustainability. Although more than 150 years has passed since Berg’s writing, the situation looks identical to the present time.

It is clear that humankind is approaching its limits of existence. Already in the mid-1970s it was clear to us young biologists that pollution, acidification and the early signs of climate change were outcomes of an unsustainable way of living. Nowadays this all has been proven by a vast compilation of observations, research results and even modelling, and it is reinforced by a comprehensive tradition of literature. Some of them are reviewed in Article II and touched upon in

¹ Translated from Finnish by Emilia Aaltonen

Article I. Especially after the harmful impacts were directed towards the health and well-being of human beings, it has been to a large extent accepted that the problems are real and that the main cause is human activity.

Following the vast tradition of research, monitoring and observations since the 1960s, it was only when the first alarming signals of climate change appeared that changes happened in the political sphere. Pollution, discharge and population growth are only one part of the problem, being the most visible and easy to understand and measure. Depletion of the sustenance base, poverty and other more subtle economic disturbances are among the impacts that are more difficult to assess and judge as being caused by environmental deterioration alone.

Despite some scepticism (Lomborg 2001) and errors in research details (IPCC, 2011), the big picture is the same: deterioration of the environment will be a threat to the survival of the whole of humankind. We live in a risk society (e.g., Beck 1990), where one accident can deteriorate the living conditions of a whole continent, and where countless small risks make an ungovernable entity. Other cross-cutting global features are overpopulation and overexploitation of resources, all intertwined to create an unsustainable way of living and resulting in an unbearable future for humankind. This was the conclusion drawn from the review and theoretic analysis made in Article II, the main findings of which are shortly summarized in the following section.

2.2.1 Population dynamics and carrying capacity

One of the main factors behind environmental deterioration is population growth. World population exceeded 7 billion sometime between October 31th 2011 (PRB 2011; UN 2011; UNEP GEAS 2011; UNDESA 2011; USCB 2012) and March 2012 (Worldometers 2012). Population growth has been accelerating in history until the early 1970s when it reached its all-time peak of 2.1% per year. The world population has grown 8-fold since 1800, quadrupled since 1900 and it will be three times as much as it was in 1950 in a couple of years. Although the growth rate has declined to 1.16% in 2005-2010 (UN 2012), the world population increases by some 75–80 million people every year (UNEP GEAS 2011; UNDESA 2012; Fig. 7).

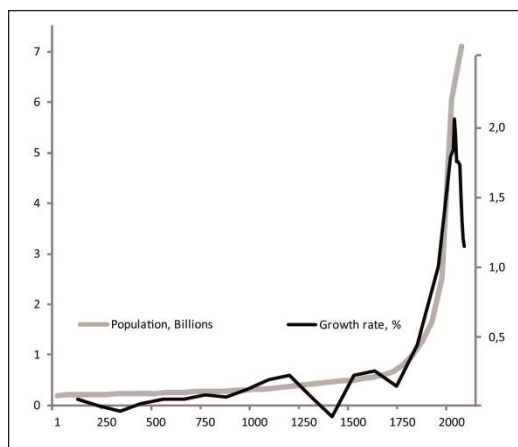


Figure 7. World population and population growth rate in 0–2010 (Kremer 1993; UNDESA 2012).

Population growth or decline is the result of a gap between the birth rate and the death rate. It varies along with the population's endogenous dynamics, called the demographic transition, idealized paths of which are portrayed in Fig. 8. Because death rates typically decrease before birth rates begin to decline, the population tends to grow rapidly during the early transition (e.g., Livi-Bacci 1999; Caldwell 2006; Cincotta *et al.* 2003; UNEP GEAS, 2011). All countries are going through this process or have passed through it. Individually, fertility and mortality transitions have taken from 50 to 150 years to complete and some developing countries are passing through these transitions very rapidly, much faster than European or North American countries did (Cincotta *et al.* 2003). Overall, the world population has grown explosively, but the recent decline in the global population growth rate may be the first step towards stabilization.

Population growth is always intertwined with the carrying capacity of the environment, not only of each region but also globally. The dialectics of the human-kind–nature relationship work in two directions. Carrying capacity makes the sustenance base and sets the limits of existence, but humankind itself affects carrying capacity. In addition to the number of people, the volume of humankind's activities and technical possibilities of exploiting the resources are also expanding, and simultaneously the carrying capacity of the environment is declining (Hugo 2011; Berck *et al.* 2012; Alcott 2012).

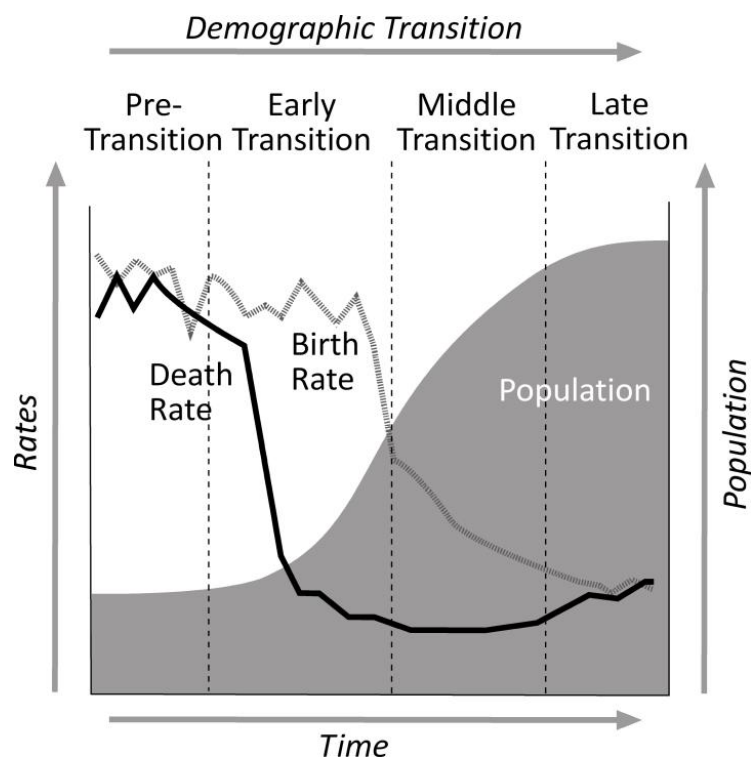


Figure 8. Schematic illustration of the demographic transition model (source: Cincotta *et al.* 2003; Population Action International).

The basic demographic formula $I=PAT$ implies that the critical factors affecting the impact (I) that human societies have on the environment are population (P), its level of affluence (A) and its technology as efficiency (T). They all are factors that depend on the demographic characteristics of the area, which may change over time. The main point of emphasis, however, is that population size remains a relevant factor when it comes to environmental sustainability, although the other factors may include conscious operations towards sustainability (Alcott 2012).

Schematic alternatives of the relationship between population and carrying capacity are illustrated in Fig. 9. A number of world models have tried to analyse this relationship (e.g., Meadows *et al.* 1972 and 1992; Cohen 1996; Seidl and Tisdell 1999; Kelly and Kolstad 2001; Ghirlanda *et al.* 2010), but its quantification is problematic and the range of the estimates is vast. Decisions related to social carrying capacity are normative and social ones, the concept is far from being universally consistent (Seidl and Tisdell 1999), and it is hardly conceivable that all humans could have exactly the same living conditions (e.g., Neurath, 1994; Cohen 1996).

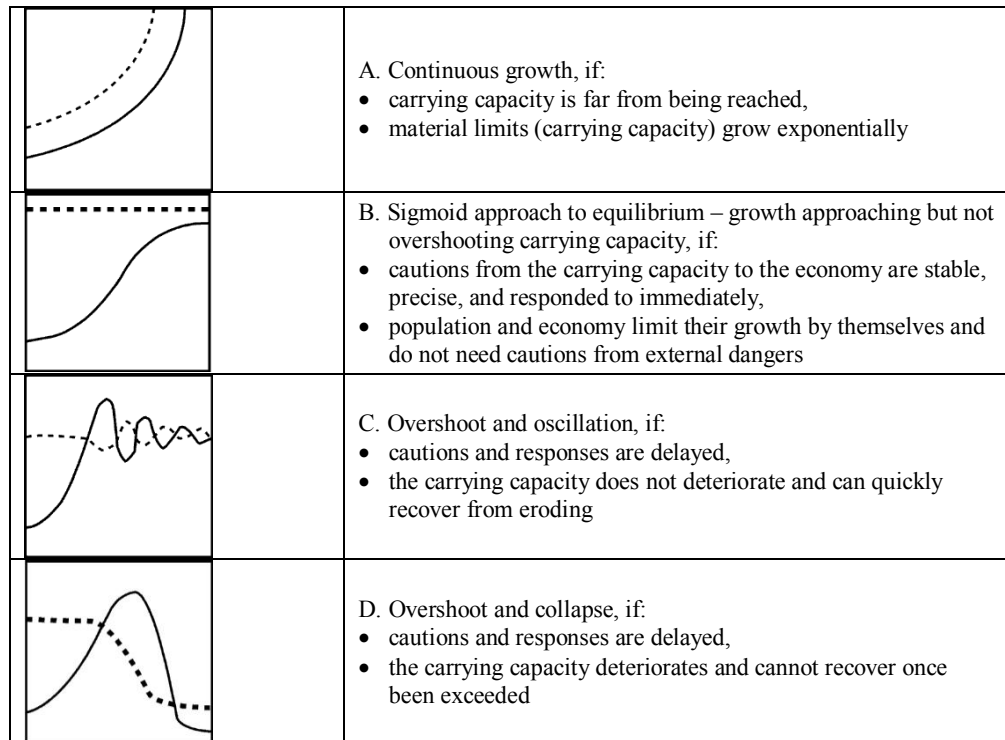


Figure 9. Schematic alternatives of population development (dotted line = carrying capacity, solid line = population and economy; source: Meadows *et al.* 1992).

As a cross-cutting feature, it is widely accepted that the carrying capacity of the environment sets the limits for population (Hugo, 2011). However, there is no agreement on the exact numbers of how many people the Earth can support sustainably. In line with the present growth rate, the world population will double in ca. 70 years, meaning some 15 billion people on the Earth in around 2080. According to some estimates, the limits of sustainable living may already have been exceeded (Seidl and Tisdell 1999), and today all global statistics and world models (e.g.; Meadows *et al.* 1972 and 1992; Cohen 1996; Seidl and Tisdell 1999; Kelly and Kolstad, 2001; Ghirlanda *et al.* 2010; Kapitza 1996; Dolgonosov and Naidenov 2006) show an explosive growth of human environmental impacts. Notwithstanding, it seems clear that urgent actions will be necessary. Because the human carrying capacity of the Earth is constrained by the facts of nature, human choices are not entirely free (Cohen 1996; Hall and Day 2009; Ghirlanda *et al.* 2010; Berck *et al.* 2012).

2.2.2 *Malthus, Boserup and their opposing views*

The humankind–nature relationship has been widely discussed in world literature since 1700s. The basic theoretical views can be crystallized in the seemingly opposing views originally presented by the British political economist Reverend Thomas Robert Malthus (1766–1834; Malthus 1985; Winch 1987) and the Danish sociologist Ester Boserup (1910–1999; Boserup 1993) as follows:

- According to the Malthusian view...
the power of population growth is indefinitely greater than the power of the Earth to produce subsistence. Human beings, as any biological organisms, tend to procreate more offspring than the environment can support. Other biological organisms are checked by natural systems, but for humankind this power is still to be equated either by conscious intentional ‘preventive checks’ for decreasing fertility, or by ‘positive checks’ increasing mortality (e.g., wars, pestilence, famine). Malthus spoke for the preventive checks, but he saw that without them the positive checks would be unavoidable.
- According to the Boserupian view...
agrarian population growth is compensated by migration to new areas, and technological change is itself spurred by increases in the population. She showed by her empirical material that differences in agrarian techniques and social structures could be explained by differences in population density. She concluded that pressure caused by population growth might be the main stimulus to agrarian change.

Due to the importance of the contributions of Malthus and Boserup to demographic theory, their works have been widely cited and referred to in scientific literature. Their ideas are often presented in opposition to each other in relation to topics ranging from population growth and carrying capacity to societal development. A brief review and analysis about the vast area of application and volume of literature related to the Malthus–Boserup dichotomy based on some selected influential references is given in Article II.

Malthus with his ‘Essay on Population’ (first published in 1798; Malthus 1985) was the first to bring the ideas of population growth together in a coherent demographic theoretical system. His writings have “...generated more misunderstanding and personal vilification than any comparable figure in the history of social and political thought” (Winch 1987). However, most of the literature reviewed in Article II seems to support either explicitly or implicitly the Malthusian view.

Analysed as single separate theories, the main conflict between Malthus and Boserup relates to scale. The limit of carrying capacity has not, until now, been reached globally, and natural resources have seemed inexhaustible. There has

always been a possibility to develop according to Boserup's understanding. If one area has been exploited or emptied from resources, there have always been other areas available. The 'Waterloo' of Boserup's model is the situation where migration to new areas is impossible, and all replacing resources have already been utilized. In fact, Boserup's theory is a model of no limits, it represents the purely technological optimistic view, and it is valid only for single separate regions surrounded by unlimited resources and the possibility of migration and substitutions.

Despite the apparent differences, a number of authors (for references: Article II) have pointed out that rather than representing contrasting views, Malthus' thesis and Boserup's theory in fact complement each other. This has resulted in a new formulation of the Malthus–Boserup dichotomy (Article II):

On the whole Malthus and Boserup explain the same entity, only on a different scale and from different perspectives. The Malthusian perspective is a holistic one, where conscious endogenous self-reflections carried out by humans can be interpreted as 'preventive checks'. Whilst the technical improvements suggested by Boserup are necessary preconditions for achieving a sustainable civilization, over the long-term and within a global perspective they are by no means sufficient alone.

The main conclusion drawn from this analysis is that there is massive support for the Malthusian view, according to which material preconditions set the limits of existence. These limits have been extended by the discovery of large fossil reserves, giving human beings the impression that there are no limits at all (Hall and Day 2009). Another important notion concerns the complexity of the interrelationships between population, its mobility and demographic transition, and environmental and societal change: "*long-term sustainability depends on solving major societal problems*" (Tainter 2011). Especially importantly in the context of this dissertation, energy supply is considered of vital importance, as all other supplying systems depend on a secure operation of the energy supply (Smalley 2005; Dinya 2009).

2.2.3 *Robbery – the human pattern*

History is full of examples of how formerly productive places and regions have been exhausted, permanently deteriorated and then abandoned, and the population has moved to reside in other places (e.g., Worster 1988; Ponting 1992; Crosby 1996; Livi-Bacci 1999; McNeill 2001). Simply following the demographic formula $I=PAT$ (e.g., Alcott 2009), the quantity of population and the level of its activities, technical capabilities and means of production have been able to exceed

the carrying capacity in all these cases. It is logical to think that in terms of the observed demographics all societies would always have acted according to the same pattern whenever it was possible – or, for any given society, only these prerequisites would define whether or not it is capable of deteriorating its environment. According to this, the ideal of a life in harmony with nature is only an illusion as the possibilities for fulfilling the ‘internal insight for progress’ are temporally and spatially insufficient.

Environmental sociology has provided this analysis with the suitable concept of *robbery* (‘raubwirtschaft’ in German, introduced by Ernst Friedrich in 1904, summarized by Massa 1994, 1999 and 2009). Robbery is defined as overexploitation of resources and carelessness towards the environment, as well as not taking care of our offspring or securing future availability of resources for them (Massa 1994, 1999, 2009). In environmental sociology the roots of robbery have been explored within Malthus, Boserup and a number of other theories.

- Ecological colonialism (Massa 1994, 1999, 2009; Worster 1988; Ponting 1992; Crosby 1996; Livi-Bacci 1999; McNeill 2001) is the observed historical way of behaviour in exploiting resources.
Resources have been exploited and resource pools have been emptied one after the other without any concern for the impacts. It has always been possible to move to other pools. This has been the established pattern especially in peripheral regions, as it has been successful where political pressure and control has been the least.
- The staples thesis (originally by Harold Innis; ref. Massa 1994) is the way that even peripheral resources have been integrated into the international markets.
These areas are connected to the world economy through staple products and centres, and peripheries act as resource pools for the wider economies. This, by means of commerce, exchange and logistics, has enabled the maintenance and continued welfare of populations far larger than the resources and carrying capacity in single separate regions would have sustained.
- The social incapability of ecological communication (Luhmann 2004; Massa 1994) illustrates the difficulty of integrating societal interests and its consequences.
In modern differentiated societies, different sub-systems are struggling against each other without means of communication. The aim for a common good does not belong to any of the sub-sectors’ codes. Lack of communication has resulted in a situation where all systems are trying to fulfil their own needs, as also stated in the iterated prisoner’s dilemma (e.g., Axelrod 1984).

Article II added to this the evolutionary approach. In a constant conflict between the common and individual needs, and without communication, it is the personal needs, which take over. Survival, improvement of fitness and maximization of well-being have been the main strategies in the early evolution of human beings, resulting in a pattern, according to which individuals have striven for the maximal utilization of their environment. This has most probably been one of the main advantages in human and social evolution. It sounds only logical that this has formed the mental sphere of humankind and the social norms of communities throughout history – this ‘undercurrent at both the individual and community level of the collective mind has resulted in an established pattern throughout the whole of humankind. This suggests that the deeper essence of robbery ultimately lies in the evolution of human beings. This pattern, driven by the ‘internal evolutionary pressure’, has continued in spite of high living standards and other achievements.

Until recently, as long as there have still been unoccupied places, it has been possible to function according to the Boserupian view, relying on technical development and migration, and with fossil resources giving the illusion of no limits on growth. But today, the ‘hand of man’ touches every part of the globe, and raw-material reserves and the sustenance base have proved limited, including all thinkable fossil resources (Jefferson 2008). Edmund von Berg, Malthus and a number of their contemporaries had the foresight to understand how this ‘progress’ will result – but “*Malthus could not have foreseen ... through petroleum*” (Hall and Day 2009).

Growth without limits is impossible in a finite world, and humankind is approaching the limits – no one can tell exactly when the limits will be met, but there is a growing understanding that it will be quite soon, perhaps in a couple of generations. Therefore, the main challenge of humankind is to free itself from the evolutionary pressure and the pattern of robbery, make new conscious choices, create new evolutionary stable strategies as well as societal rules, and launch a new praxis that makes the world sustainable.

2.3 Towards Intellectual and Practical Paradigm Shift – Matching Social Evolution

Contribution to:

Research Objective 2

“To understand and add knowledge about the needs and the fundamental mechanisms, features and dynamics of societal changes and cultural evolution.”

Main reference:

Articles I and II

2.3.1 *Calls for paradigm shifts*

“In these days of specialization there are too few people who have such a deep understanding.”
Richard P. Feynman 1999

The worst scenario for humankind is that population growth continues to follow alternative D in Fig. 9. This would result in an overshoot of carrying capacity, deterioration of the sustenance base, and dramatically lower future carrying capacity. The population after the collapse would be much smaller than today or what today’s carrying capacity would support. All indicators today imply that population growth and humankind’s environmental impacts are increasing explosively, in fact faster than exponential or logistic curves would predict. It is clear that along with the approaching limits, comprehensive changes will be unavoidable. Humankind can do them consciously and collectively in order to avoid drifting towards pure Malthusian ‘positive checks’ like ‘famine, pestilence, wars, misery and vice’.

The situation calls for changes in two spheres:

- New kinds of philosophies, syntheses and scientific knowledge will be necessary for understanding the dynamics of the humankind–nature and resources relationship.
- Ultimately, the change must result in a new praxis in how population size can be stabilized and humankind’s environmental impacts can be mitigated to match the sustenance base sustainably. It will require a new ‘social contract’ (e.g., Lubchenko 1998) and long-term societal processing.

Articles I and II took short tours exploring the main features of the anticipated and required new knowledge. The urged for change will be in any case a multi-branch exercise and an orientation for the future. This means that no single branch of science can understand, outline or solve the whole problem alone. For instance, the following aspects are vital in reforming the energy sector:

- Technology is necessary for any new solutions, including the whole value chain.
- The whole field must also be understood and managed economically, any reform will have economic consequences, and all solutions must be economically justified, not only in terms of business but also regionally.
- Social acceptance in a wider perspective, at the level of general opinion, but also concerning single separate projects, is necessary: sustainable and comprehensive changes are not possible without social acceptance.
- Involvement of industries and all relevant stakeholders along the whole value chains of new energy solutions is imperative, from citizens to politicians, from clients to financiers, from end users to technology developers, for instance.
- Regulations, laws and other general rules of the game must be reformed to support new solutions, or conversely, old regulations must be interpreted in a new way.
- Comprehensive reforms must also be anchored in the political sphere. They must be integrated into the national and regional strategies, through which they are put into practice. They will have an impact on regional economies, employment, rural vitality and environmental matters, to name some of the most important spheres.

The main point the list reveals is that the reform consists of a comprehensive process of change, where a cross-sector and multi-scientific knowledge, comprehension and other capabilities are necessary (Buttel and Taylor 1992; Massa 1994, 1999 and 2009; Metzger and Zare 1999; An and López-Carr 2012; Fouquet and Pearson 2012). This kind of paradigm shift in science is a social change in itself, but it can be a change agent in a more comprehensive societal reforming process towards a more sustainable world and, in the context of this dissertation, sustainable energy.

The last 100 years demonstrate the difficulty of this kind of philosophy. The history of science reflects the ‘evolutionary bias’, according to which the core focus in sciences has been on developing material living conditions and maximizing the ways of exploiting nature and resources. We have a history of winners and (over)exploitation, which until recently has been seen as a great achievement (Massa 1994, 1995; Ponting 1992; Worster 1988; Buttel and Taylor 1992; Bowler 1997). In general science has been geared towards detailed knowledge, and from philosophy towards specialized disciplines, with explosively expanded the volume of information. This has created strong barriers, which isolate the generally accepted ‘real’ science from the ‘discriminated grey zones’ between disciplines. The integrative approach has met with the academic dilemma of the grey peripheries between vertically isolated disciplines (e.g., Metzger and Zare 1999).

Environmental sociology prepared the ground for a horizontal approach and anticipated it to show the way to the next paradigm shift in science. More recently there have been signs of a more general acceptance to include all branches of science in this horizontal, multidisciplinary and integrative programme (e.g., Buttel 1986 and 1987; Hahn and Simonis 1991; Dickens 1992; Spaargaren and Mol 1992; Laska 1993; Catton 1994; Redcliff and Benton 1994; Massa 1994, 1998 and 2009; Kuhn 1996; Hannigan 1997; Metzger and Zare 1999; Goldman and Schurman 2000; Giri 2002). “*Whatever name we use, this new paradigm treats human and natural systems in an integrative manner*” (An and López-Carr 2012).

This development will be a long process, and it will employ both the academic community and practical actors. This dissertation has tried to contribute to the programme from its part by employing conceptual integration and dialectical heuristics, which play the main role in the next section.

2.3.2 *Understanding Societal Change – The Three Layer (3L) model*

“Every reform was once a private opinion.”
Ralph Waldo Emerson, 1841

My comprehension of the fundamental nature of societal changes was based on studies and later readings in philosophy, sociology and biology, and a combination of thinking around a number theories and ideas from other branches of science. The heuristic emergence of the three layer model (3L) happened when we, together with my entrepreneur colleague, argued about why our great business ideas were not successful, or progressed too slowly. Although these theoretic considerations were not spurring our business, they resulted in the 3L model.

The main argument my colleague presented was that individuals are subordinate to the society and incapable of introducing comprehensive changes, which might be true, I agreed, in seemingly static and stagnated situations. The argument forced us to consider the dynamic nature and dialectics of the relationship between the individual and society. It really seems impossible to change the current system, especially by individuals, but still, history has shown that all habits have been renewed one after the other. All eras in history have had social norms, structures and practices of their own. They are collective manifestations of each society, while at the same time they consist of activities and values of countless individuals, organizations and other ‘units’ of society. The key point here is the emergence of change and its mechanisms, or in terms of dialectics: How does one detail gradually become prevailing in the whole?

The fundamental thesis with regards to the dynamics of societal change is the *dialectics between details or parts and the whole*, as between the individual and society, or the idea and the norm. Although single and separate actors always process certain actions or operations, they must still be understood as parts of a wider context. There is neither an individual person nor a conscious person-like creature called the society, who dictates the rules, but societies have tended to move towards collective thinking and self-organization. Further to this, there must be someone who takes the initiative for changes – logically there is no one other than the individual who can do this!

The 3L model is based on the notion that for societal changes to happen, there must be fundamental reforms at all levels of a society. Before practical tools, operational patterns and praxis in general can evolve, motivation, motives and social constructions must be in place. This will all be impaired without a shift in the mental sphere, general opinion and social norms. That is why the theory consists of three successive and interactive but conceptually distinct layers (Fig. 10), which all have their own evolution and dynamics:

Social base

The social base develops in a mechanism where single separate ideas, subject to social selection, become more generally accepted, form the general consciousness and opinions, and finally social norms, which control society as unwritten laws. For a *certain* given thought, change might never take place, and it may vanish or be left within a marginal minority, which is the case for the majority of new thoughts. But *some* thoughts which are generated in society give rise to anomalies against the prevailing norm and are accepted, thereby encouraging new supporting observations and ideas, and causing an accumulation of anomalies. Gradually, the *single* deviating observations and thoughts overcome the old norm, and finally a new *societal* pattern is established.

Therefore, single observations of defects, deviating and nonconformist ideas, and anomalies against the prevailing norm, must get support from other people and become more common. The supporters may form groups, coalitions and movements ready to fight for the idea, and some single ideas may attain the position as general opinion and social norm, which controls the behaviour of the majority of the society as an unwritten law.

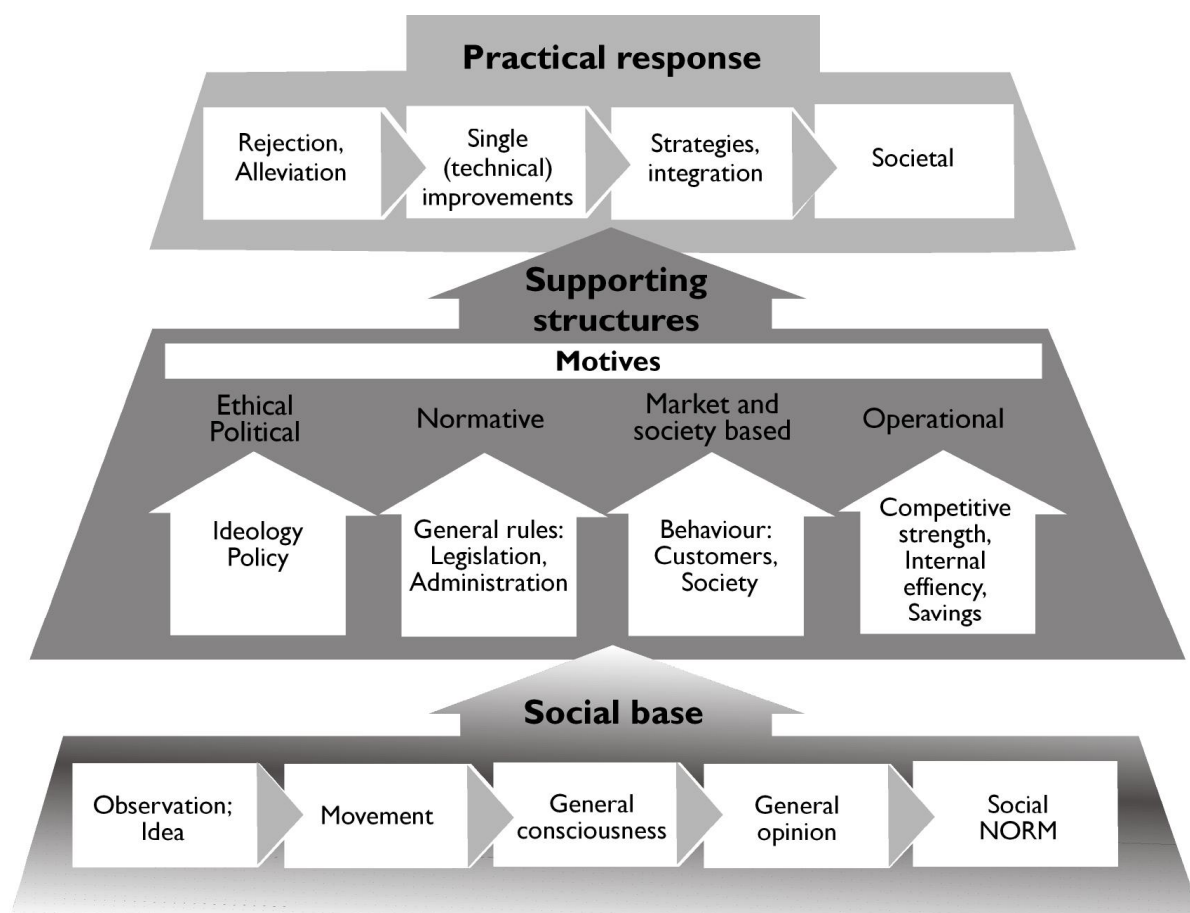


Figure 10. The structure of societal change: the three layer model (3L). First presented in Article I, further developed in Article II.

Supporting structures

The norm or mental base of society is impaired without a corresponding practice – general rules and other supporting structures are necessary in order to prepare motives for bringing the established idea and norm into practice equally for all actors. The development of supporting structures is classified according to their motives:

– *Ethical and political motive:*

A total philosophy, world view or a way of thinking is established in society, and the first step towards their institutionalization is through political interest groups and policies. This is the only slight adjustment in Article II compared with Article I, where the ethical world view was considered more as an individual motive.

– *Normative motive:*

Legislation and other regulations establish new general rules, administration is readjusted to new conditions, and follow-up and research are reoriented.

– *Market-based motive:*

customer behaviour changes, demands from clients become stronger.

– *Societal motive:*

Because of the new social pressure and behaviour of other people, the new way of thinking becomes more attractive, which is reflected in market and other behaviour.

– *Operational motive:*

Internal efficiency, quality, productivity and competitive strength in terms of the new way of thinking takes over in enterprises;
adjustment of one's own activities to the new way of thinking.

Practical responses

The change in praxis has its own evolution, starting from avoidance and separate technical improvements, and developing into strategies and integrative practices. Operational patterns are the final implication of the development of the social change. There is a time lag between the mental base and practical responses, because development of general rules and other supporting structures are necessary for putting the norm into practice. The first reactions to new ideas are usually denial or understatement of the phenomenon or its impacts, and avoidance of disadvantages as they become obvious. After the establishment of the first laws, a new practice is no longer voluntary. Social order and motivation for progress are encouraged through other supporting structures. The phases of this process are classified as follows:

- Rejection and alleviation: denial of the problems, avoidance, dilution.
- Single separate technologies and improvements for the management of the symptoms.
- Strategy, integration and synergy: search for efficiency and competitive strength.
- Societal patterns: adaptive changes at the societal level and structural changes

Further to this, the 3L theory suggests the following in terms of social evolution:

Variation

Change always comes from a variety of ideas, generated by individuals and inspired either by innovations or nuisances, defects or other inconveniences of the prevailing system. Norms, the social base and mental development are primary factors in the beginning of change and in terms of the dynamics of change. Deviating or nonconformist ideas always emerge in the social context under actual prevailing norms, structures and practices.

Selection

The continuous conflict between new and prevailing thoughts is solved in the *social selection* process, which determines the extent to which new ideas become generally accepted. Some ideas become accepted by other people, and they gradually become approved of, accumulating in the whole society and encouraging new ones. These finally force the old paradigm to give way to the new one. However, the great majority of ideas never overcome the old ones.

‘Heredity’

The new winning thoughts will be ‘stored’ in the societal memory and they accumulate as more people and organizations support them. They are reflected in a change of rules and other supporting structures such as legislation, institutions, market behaviour and operational patterns in enterprises and other organizations. All general operational patterns and practices have developed through a long process, which ensures that they are socially accepted and follow the existing norms.

2.4 From Environmentalism to Reforming the Energy Sector

Contribution to:

Research Objective 3

“To analyse and structure the development in environmental issues in general and the reforming energy sector in particular.”

Main reference:

Environmental issues: Article I, updating notions in Article II;
energy sector issues: Articles II, III and IV.

2.4.1 *Evolving environmentalism*

Environmentalism became a popular and global discourse in the 1960s, and the basic claims of modern environmentalism were presented half a century ago. The ideology of natural parks and nature conservation has had a long history since the latter half of the 1800s. The real wakeup calls were, however, the classical works by Rachel Carson (*Silent Spring*, 1962) and Barry Commoner (*Science and Survival*, 1966; *The Closing Circle*, 1971), accompanied by a number of famous writings by, for instance, the ecologists Garret Hardin (*The Tragedy of the Commons*, 1968) and Paul Ehrlich (*The Population Bomb*, 1968), David Pimentel, Howard Odum, John Steinhart, George Woodwell, Kenneth Boulding and Herman Daly, to name a few American authors (Hall and Day 2009). The main ideas were crystallized in *The Limits to Growth* (Meadows *et al.* 1972).

These texts were followed by writings, debates and discourses about industrialization, pollution and even “doomsday prophecies”. Strong waves of environmentalism swept over societies across the world, and the idea of pollution prevention and nature protection became more generally accepted. The success of the environment theme resulted in new societal demands and reactions, for instance the establishment of the official environmental protection administration, and the ideology of sustainable development. Writings and discussions about the scarcity of resources and sustenance base, and the survival of humankind decreased, even disappeared, sometime in the early 1990s, as new large oil reserves continued to be found.

There have been different views and opinions at different times, depending on the specifics of each situation. New oil reserves pushed the problems aside, however, lately the issue has become topical again: “*the world today faces enormous problems related to population and resources*” (Hall and Day 2009), and “... *the world is facing so many challenges that a paradigm shift is needed, and this will inevitably include a development towards a sustainable biobased economy*” (Östergård *et al.* 2010), which is “... *a great challenge for sustainability at the planetary scale*” (Seto and Satterthwaite 2010).

Environmental management is a practical implication of this process and many approaches and tools have been introduced. These have been supported by a strong general opinion, which has developed into a social norm, forcing enterprises to join the process. However, there is no complete model for preserving the Earth, although the idea of sustainable development with its interpretations provides some guidelines (e.g., Johnston *et al.* 2007). Still, around the year 2000, the praxis consisted of single separate methods like scattered pieces of a puzzle with no picture of the whole puzzle available. Until now, the approaches and tools for measuring and monitoring (Mayer 2008), selection, design, application (Robért *et al.* 2002) and assessment (Ness *et al.* 2007) of sustainability have attained strategic and practical relevancy.

The development of environmentalism has been a long societal process, and it is clearly connected to damage in the environment and developments in society, as illustrated in Fig. 1. The environmental theme with ever strengthening norms and other consequences has swept over the whole society. The history of environmental movements is described in some chronologies of early environmentalists (e.g., Primack 1993), some orientations to environmental history (e.g., Worster 1988; Ponting 1992; Massa 1994; Crosby 1996; Bowler 1997; Livi-Bacci 1999; McNeill 2001) and some more structured analyses by environmental sociologists (reviewed by Buttel 1987; Buttel and Taylor 1992; Hannigan 1997).

In the course of its over a hundred-year history, environmental protection has developed from an issue promoted by single separate thinkers to general environmental consciousness, and from the ideology of national parks towards sustainable development and the ecological modernization (e.g., Mol and Sonnenfeld 2000) of society. There has been a shift from the protection of areas towards an active environmental policy, and a shift from ideology towards a new practice (e.g., McCormick 1991; Article I). This process has been briefly analysed in terms of the 3L model in the following:

Social Base

Development of the social base is a necessary prerequisite for any larger societal change, and for evolving environmentalism the most important phases are as follows:

- Single thinkers, mainly (natural) scientists, and writings as a reaction to the observed impacts and threats of industrialization; the second half of the 1800s.
- A loose movement of environmentalists, mainly scientists concentrated in civilization centres, and the ideology of national parks; until the 1940s.
- Expanding of the contents: cultural (aesthetic, scientific and ethical resources) and social (recreation, health; for people) protection of nature; mid-1900s (e.g., Hustich 1937; Kalliola 1968).
- Radicalization and pollution problems: environmental protection, polarization of opinions, expanding in volume and achievement of social significance; since the 1960s.
- Establishment of a new public opinion, environmental policy and social norm (e.g., Uusitalo 1986; Buttel 1987; Tulokas 1990; Brechin and Kemp-ton 1994), environmental conflicts; from the late 1980s to the present.

There has been continuous conflict between the developing and the old norms. The main reasons for conflicts are misunderstanding and lack of trust, deviating (mainly economic) interests, as all changes mean redistribution of gain and loss (Lafferty and Meadowcroft 1996), and different values (Sairinen 1994). The equilibrium has been continuously changing, as the new norm has become stronger, and many fundamental societal changes have taken place. This has also meant that the environmental movement has become less necessary, and there has been less environmental activism in the form of local conflicts now than in the late 1980s (Sairinen 1994): there is no need to fight for what already has been achieved! But correspondingly, new cases of pollution, for instance, have immediately resulted in the emergence of new activist groups and environmental conflicts. This is an implication of the fact that the social base of environmentalism has become stable.

Supporting Structures

The development of supporting structures of environmentalism can be characterized as an accelerating progress from the first Nature Protection Acts at the beginning of the 1900s toward institutionalization and international integration of environmental protection, new customer and societal behaviour, and environmental ethics. Enterprises did not play their part in this development until the 1990s, but environmental protection is probably the most significant factor that

has changed the prerequisites of private companies since the 1990s. In the following, this process has been described based on motives classified in the 3L theory:

- Normative motive
Over the last 30–40 years the normative base of environmental protection has expanded enormously: there is a comprehensive compilation of legislation and international agreements, which in the EU are harmonized in Member States. In addition, voluntary activities have their own regulations. State and municipal administration, and expert and follow-up organizations have been established. There is a shift from voluntary to official environmental protection and institutionalization.
- Market and society-based motive
The logic of economy and competitive strength through markets, general opinion and common practice encourage and even force enterprises to develop their environmental codes beyond the level required by legislation. Environmental management is becoming a central criterion when assessing the value and the responsibilities of enterprises. The social pressure and politics also affect individuals.
- Operational motive
Search for internal efficiency and the most advantageous way of operation is reflected both at the individual and company level. Direct reduction of costs, avoidance of risks and motivation of personnel belong to company objectives.
- Ethical and political motive
Ethics is an implication of a total world view or philosophy and it affects behaviour. Companies, on their part, have an economic dilemma: an investment, for instance, may be an ‘irrational choice’ if it results in heavy costs and a weakened competitive strength. Institutionalization of ethics takes place in the sphere of political and interest groups.

The first laws established general rules just for companies and their own production (Fig. 11). Over time, the norms and other motives for the development of environmental motives have expanded their application area towards the ends of companies’ production chain, in a way, outside the company itself. Simultaneously, the motives have been accepted and established more deeply in business ideas inside the companies. The motives are moving from the core towards the circle of the left hemisphere in Fig. 11.

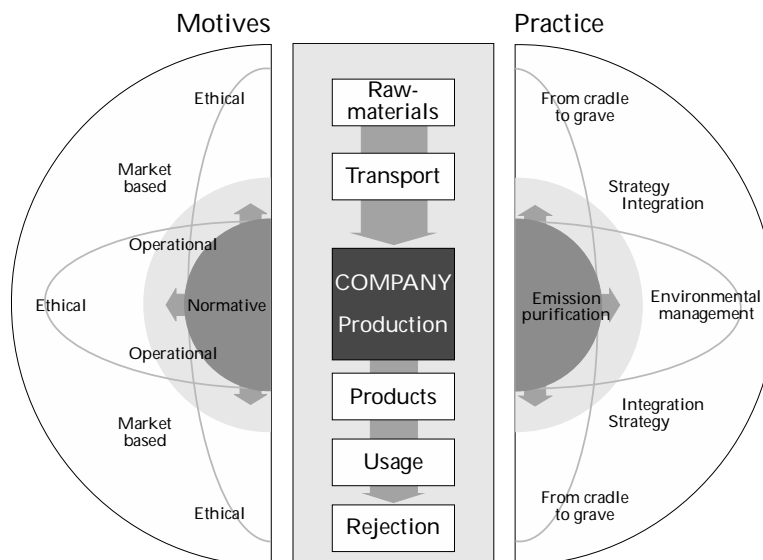


Figure 11. Environmental motives and practices in a production chain.

Practical Responses

The development of practices in environmental protection has been similar to that of motives (Fig. 11, right). After accepting that the problem exists, it started from pollution prevention measures for the core companies. Today, they are about to be replaced by new strategies, including, for instance, environmental impact assessment, environmental audit, accounting and statement, the life cycle approach and environmental management systems. Although voluntary, these new strategies are in the process of developing into organized systems. Environmental protection is becoming inseparable from the administration, activities and image of an enterprise.

The development of environmental protection practices (Hahn and Simonis 1991; Sairinen 1994) has identical phases with the typology suggested in the 3L theory (Fig. 10):

1. Avoidance, alleviation: *the 'high chimney' phase*
The principle was to distribute pollutants evenly to a larger area, by elevating the emitting chimney or prolonging the sewage pipe. Although it has been clear for a long time that "*dilution is no solution to pollution*", these answers to environmental problems are still in use (e.g., Hahn and Simonis 1991).
2. Single separate techniques: *the 'end of pipe' technology*
The second answer was "*technical treatment after the fact*" (Hahn and Simonis 1991). The aim was to meet the legal requirements for pollution pre-

vention by purification devices for exhaust fumes and sewage, waste incineration, controlled dumps, storages for nuclear waste, etc. These devices were typically separate from the organization of the enterprise; they usually created an extra liability for the economy of the enterprise. Moreover, they cannot really solve the problems but only shift them regionally. Until today, this has constituted a standard answer by enterprises to environmental protection issues (Hahn and Simonis 1991).

3. Strategies and synergies: *technical prevention* (Hahn and Simonis 1991), *preventive environmental policy* (Simonis 1989; Sairinen 1994)
This level aims at minimizing the use of raw materials and energy, and production of waste and emissions by utilizing technology and planning. This approach demands establishing cycles or partially integrated systems. Environmental policy deals with larger units and creates strategies. Changes of legislation and strengthening of other motives in environmental protection have given rise to environmental strategies and methods: today these techniques and approaches are spreading quickly.
4. Societal patterns: *preventive techniques and concepts with socio-ecological principles* (Hahn and Simonis 1991), *ecological modernization* (Spaargaren and Mol 1992; Sairinen 1994) and *structural changes* (e.g., Jokinen 1995)
“A real solution to the environmental crisis is possible only when the social and cultural dimensions (...) are incorporated” (Hahn and Simonis 1991). This would mean ecological restructuring of processes of production and consumption (Spaargaren and Mol 1992). Reaching this phase requires major changes in the society and culture (Sairinen 1994; Jokinen 1995).

2.4.2 Towards Sustainable Energy? – Drivers and Barriers

Sustainable Energy (SE) has become one of the key concepts in reforming the energy sector in the EU and worldwide. As the production of energy has caused major impacts on the environment, “renewable energy is one of the most efficient ways to achieve sustainable development” (Goldemberg 2007), and “one of the main tasks in this century (...) will be to manage a transition process towards a sustainable energy system” (Haas *et al.* 2008).

SE directly descends from the concept of sustainable development, with its more than 300 definitions within environmental management (e.g., IUCN 1980; WCED 1987; Markandya *et al.* 2002; Johnston *et al.*, 2007, Chichilnisky 2011). There is also a plethora of definitions of SE in recent literature, which was reviewed in Article II. Based on the review, the SE concept was redefined to include the following contents (Article II):

- 1 **RUE** (Rational Use of Energy; saving, efficiency)
- 2 **RES** (Renewable Energy Sources)

3 Integration of RUE and RES

4 Sustainability management

There are a number of technologies for **RUE** and **RES** that can be implemented separately or in combination. The **integration** of RUE and RES is the key in creating complete solutions. With different combinations of technologies and regional RES it is possible to outline solutions with different degrees of energy self-sufficiency. The use of RES depends on the carrying capacity and cannot be increased limitlessly, and sustainability management is necessary to avoid adverse impacts and careless use of RES. There is always a danger that SE projects become a new field of ecological colonialism where the pattern of robbery will take over. A number of examples have already been reported, where maximal economic gain and carelessness towards the environment have been applied in order to produce RES in the name of sustainability (Blarke 2008; Moriarty and Honnery 2009).

Today, there are a number of positive drivers for SE. However, the diffusion of SE has been slow and there are also many barriers. It is easy to find economic motivation for energy saving and efficiency (RUE). Over the last two decades there has been increasing awareness and aspirations to see more widespread use of renewable energy sources (RES). The main reasons for this have included the following:

- The RES potential
Empirical material from Europe (e.g., Evrendilek and Ertekin 2003; Ragwitz *et al.* 2005; Lewandowski *et al.* 2006; Božičević Vrhovčak *et al.* 2006; Schneider *et al.* 2007; van Dam *et al.* 2007; Verbruggen *et al.* 2010; Article III) and globally (e.g., Smeets and Faaij 2007; Resch *et al.* 2008; de Vries *et al.* 2009; Ladanai and Vinterbäck 2009; Seiffert *et al.* 2009; Ceciliano 2010; Jacobson and Delucchi 2009 and 2011) demonstrates that there is realistic and easily mobilized potential for RES to enable energy self-sufficiency and to satisfy today's energy demand, even globally.
- The economy of RES technologies
The business case for RES, including investments (Article III; Masini and Menichetti 2012) and benefits beyond business profitability, can be significant. The **regional added value** (monetary aspects, reduction of costs, increase of purchasing power, new employment, tax income, social, ecological and ethical aspects, improved vitality) would be remarkable if all the money which currently flows out remained within the region (Hillebrand *et al.* 2006; Lehr *et al.* 2008; Moreno and López 2008; Thornley *et al.* 2008; Blanco and Rodrigues 2009; Hoffmann 2009; del Río and Burguillo 2009; Openshaw 2010; Sastresa *et al.* 2010; Dalton and Lewis 2011; Masini and Menichetti 2012).

- General perception and policies
Positive general perception and social acceptance of RES since the early 1980s (Wüstenhagen *et al.* 2007), policies and other support frameworks (REN21, 2011a) have lifted RES to the top of the international political agenda (REN21, 2011b), and institutionalization of SE is occurring globally (Article II).
- Technical evolution
Technical evolution is still in its early development phase, but new solutions are emerging and are being installed on a constant basis. According to a recent historical diffusion analysis (Lund P.D. 2010), however, RES technologies have a high overall diffusion potential to cover up to 60% of all produced energy by 2050.

Despite the strong signs of progress, the expansion of RES has been slow and far less than, for instance, the increase of world coal production (Jefferson, 2008). There are a number of reasons for this:

- Institutional opposition
The prevailing large actors tend to prevent any development that is not in support of their own business (Lund H. 2010). This also means that RES-based solutions are, in effect, fighting against existing energy utilities and structures.
- Diffusion of RES-based technologies
The diffusion of SE towards RES-based energy self-sufficiency, and the establishment of larger scale RES-based energy management systems, means in many cases a total change from fossil fuels to the use of new raw materials. This innovation requires not only new technologies but also innovative institutional frames (e.g., Unruh 2000 and 2002; Jacobsson and Johnsson 2000; Bergek 2010; Wolsink 2000, 2007, 2012a). The shift towards these structures, which are different from the prevailing centralized system, will be a long-term process. As is the case for the diffusion of any innovation, institutional lock-ins preventing acceptance of new innovations by key actors have to be ‘unlocked’.
SE and its technical solutions are in the early phases of diffusion. However, the concurrence always takes place in real time markets, where the opponents are at the opposite end of their diffusion. This means that they are competing against technologies with many years of operation and technical evolution, where investments have been repaid, supportive social structures are in place and where all the benefits of mass production and pre-established value chains exist.
- The process
Change itself towards SE will be a long evolutionary process at local, regional, national and international levels. The process will need to involve the majority of people and there will be a huge number of decision-makers, from individual citizens, families, farmers and businesses, to the public sector. This process will need to involve those who consume and produce en-

ergy, those who manufacture the technical solutions, those who deliver the raw materials and those who create the general preconditions for the whole movement. The success of this process depends primarily on how the different levels engage, what is approved and by crucial stakeholders (Wüstenhagen *et al.* 2007).

The conclusion drawn is that physical prerequisites for SE exist. A shift towards SE and away from fossil fuels will presumably be on the global agenda in the near future (Article II). A strong will exists among the majority of stakeholders to see this agenda move forwards, however, there are institutional and other barriers preventing progress and slowing the process.

2.5 From Research to Reality

2.5.1 *The potential and economics of bioenergy in Finland*

Contribution to:

Research Objective 4

“To test empirically the potential of sustainable energy and to understand and add knowledge about its future impacts in a wider societal context.”

Main reference:

Article III

Article III summarizes the results from five studies carried out at the Levón Institute (University of Vaasa) in the period 2003–2008. The scope of the studies was to explore the degree of energy self-sufficiency that could be achieved by the use of bioenergy, and the economic feasibility, implications and benefits of distributed renewable energy production. The underlying hypothesis when introducing the first project in 2003 was that the potential of RES is large enough to enable energy self-sufficiency in Finnish rural areas. There was also a pre-established thought that the distributed production of energy was already feasible. These considerations were formulated into research questions 1 and 2, which were deepened in the discussion in Article III through questions 3, 4 and 5:

1. What is the volume, energy content and regional self-sufficiency potential of bioenergy in the study areas?
2. What are the prerequisites for the economic feasibility of small-scale biogas plants?
3. What is the energy self-sufficiency potential of bioenergy and RES from a wider perspective, in Finland and globally?
4. What is the spatial distribution of RES and self-sufficiency potential in Finland?

5. What are the economic prerequisites and operational concepts of distributed energy production units?

These studies started an expanding and still on-going research and development programme concentrating on RES-based production of energy. The main objective of the programme is to create an improved understanding of the whole energy sector as a regional system, surrounded and interlinked with a number of phenomena. This type of ‘helicopter’ or ‘satellite perspective’ from above is the only way, we believe, to see the dimensions as a whole, and to understand the dynamics of the phenomena, including the processes of social structuring and future perspectives. From the start as one single project and undertaken by the two authors of Article III the programme has grown to comprise more than 25 researchers and a turnover of over €2 million annually.

Study areas and methods

The bioenergy potential has been studied in the following four areas and studies (Fig. 12):

- Study I: National research in 15 municipalities and their sub-areas in rural Finland
- Study II: County of Ostrobothnia, consisting of 18 municipalities
- Study III: County of South Ostrobothnia, consisting of five regions
- Study IV: Region of Suupohja in the County of South Ostrobothnia (5 municipalities), as part of the ASPIRE project (Intelligent Energy Europe; EU).

Study V researched the economy of 11 case biogas plants, all in South Ostrobothnia. The study areas represent together almost 10% (nearly 510 000 inhabitants) of the Finnish population, and approximately 15% (44 700 km²) of the national land area. The study areas constitute a large sample of Finland and are especially representative of rural regions.

Electricity demand figures were mainly attained from official statistics as follows: from municipalities, Adato Energia (2003) and for small areas collected from network companies in Study I; from Energy Industry (2006) in Studies II and IV. Direct figures for heat demand were not available, and they were estimated by multiplication of building areas and average heat demand according to statistics; building areas were based on Statistics Finland (Study I: 2003; Studies II and IV: 2005). All figures for Study III were attained from Ruralia (2008), who used identical methods.



Figure 12. Study areas of the national Study I (left) and regional Studies II–IV (right).

RES-related research was not mainframe science in 2003, and much effort was devoted to developing a relevant methodology for the research. RES supplies include a number of different sources (e.g., Doukas *et al.* 2007; IPCC-WGIII 2007; Verbruggen *et al.* 2010), for instance, continuing or repetitive currents of energy such as solar, wind, geothermal and other ground source-based energy, hydro-power, tide and waves, energy from waste and bioenergy. The empirical material collected in Article III concentrated on combustible and digestible materials of bioenergy and waste for the following reasons: these materials exist in the study areas, there are industries refining some of them, there is the infrastructure for utilizing them (e.g., in forestry), their energy content can reliably be measured, and there is practically no social resistance to taking advantage of them. In Studies I–IV and Article III these different materials were defined as the bioenergy potential for the studied areas. Their energy content was calculated according to the following methods:

Manure:

Number of domestic animals (different species and sub-groups; municipal officers, Ministry of Agriculture and Forestry), multiplication by specific manure production per animal group;

Fur animal dung:

Number of animals by municipality, multiplication by specific dung production;

Sludge:

Municipal statistics, West Finland Environment Office;

Biomass from cultivation grounds:

Reed canary grass crop (tons/ha) potential from fallowed areas;

Straw and other cultivation residues:

Multiplication by specific harvest and energy content figures for cultivated species and areas by municipality;

Wood:

Logging residues only; Regional Forestry Centres;

Municipal biowaste:

Multiplication by 70 (Study I; scattered population) and 72 kg/a per person (Studies II–IV); population: municipalities.

All quantities were transformed into energy content units by multiplication with generally available and used specific values (e.g., Turunen 1999; Alakangas 2000; Uusi-Penttilä 2004; Finbio 2005; Doukas *et al.* 2007). This compilation of bioenergy metrics, based on official statistics and relevant specific figures with geographical features, corresponds to the harmonization proposed for the EU (Doukas *et al.* 2007) and used in recent scientific literature (for references: Article III).

The economic evaluation of RES-based energy production was based on calculations by an investment model, which was elaborated and validated in Study V. The model was built on capital budgeting models, which are crucial in supporting capital expenditure decision-making in RES projects. The economic viability of the 11 case biogas plants was calculated by general cash flow-based investment criteria, including net present value (NPV), internal rate of return (IRR) and both undiscounted and discounted payback period. The model has been described in more detail by Järvinen and Laitinen (2007).

Results

The bioenergy potential was compared with energy demand figures by small areas in Study I and by municipality and region in the other studies. The dominant feature was that the overall bioenergy potential far exceeds the energy demand in rural areas. In the most peripheral areas the potential is manifold, and in the ‘rural heartland’ it is large in relation to energy demand. In urban adjacent rural areas the potential and demand are almost equal, with the exception of areas where there are industries, which make the demand larger than the potential. Study I identified also the following features:

- Forest residues are the dominant bioenergy fraction in sparsely populated areas, where typical agricultural materials are also important (e.g., straw, manure).
- A mixture of RES materials (straw, green cultivated materials, manure) from agriculture is characteristic for rural heartlands.
- A mixture of several materials dominates also bioenergy potential in urban adjacent rural areas.
- Nationally, wood from forestry dominates the bioenergy potential in eastern and northern Finland, but in the south and west the bioenergy potential consists of a mixture of mainly agricultural materials.

Results for the Counties of Ostrobothnia and South Ostrobothnia have been summarized in Table 3 and for Suupohja Region in Fig. 13.

There is a remarkable bioenergy potential in both counties. The overall potential is ca. 2.7 TWh/a in Ostrobothnia corresponding 63% of the total energy demand of 4.3 TWh/a. A large share of the demand comes from the forest industry, which is included in the figures of Pietarsaari and Kaskinen. Forestry is mainly self-supporting in its energy management, and the majority of its raw material comes from outside the specific region. For this reason their demand figures should be omitted in analysing the energy self-sufficiency potential. Without Pietarsaari and Kaskinen bioenergy corresponds almost 100% to the total demand (Table 3). In purely rural areas (also Vaasa omitted) the bioenergy potential is about 1.5 times as large as the demand for energy. In South Ostrobothnia the potential is 4.6 TWh/a, which makes 150% compared with the total demand for electricity and heat (3044 TWh/a).

The results show significant regional differences, especially in Ostrobothnia, where the largest population centres and energy intensive industries clearly differ from the rural areas, while South Ostrobothnia is mainly rural. Suupohja is an excellent example of what is typical for rural areas. Bioenergy potential is approximately double compared with the total energy demand. In the bigger centres it is proportionally smaller, and in more peripheral municipalities it is three, even four times bigger than demand (Fig. 13).

Investments in the 11 case biogas plants ranged from €250000–€13.7 million in size, and the size was from farm scale (two cases) to nine pig farms (one case), small (two cases) and large (four cases) industry, and treatment of organic waste from 14 and sludge from 22 municipalities (two cases). In all cases the revenues exceed the expenses, except for the case of nine pig farms; also in this case the expenses without capital costs remain smaller than the revenues. The price for produced energy was mainly 36–63 €/MWh, with the exception of an extremely

high price in one of the municipal cases. In six cases NPV was positive, the discounted payback time was 7.5–13 years, and the IRR was 6–13%. These cases fulfil the normally used criteria (Järvinen and Laitinen 2007) for a positive decision for an investment. In all the other cases the investment should be rejected, according to the criteria.

Table 3. Energy demand (heat and electricity), bioenergy potential (GWh/a) and energy self-sufficiency potential (%) in the County of Ostrobothnia (upper), and bioenergy potential (GWh/a) in the County of South Ostrobothnia (lower).

Ostrobothnia	Energy Demand	Bioenergy				%
		Wood	Straw	Other	Total	
Pietarsaari Region	1593	373	200	167	740	46
Without Pietarsaari	515	361	197	143	701	136
Vaasa Region	1669	414	320	161	895	54
Without Vaasa	526	386	310	151	847	161
Kyrönmaa Region	254	143	276	79	498	196
Coastal Suupohja	806	293	213	87	593	74
Without Kaskinen	421	292	213	87	592	141
TOTAL Ostrobothnia	4322	1223	1009	494	2726	63
TOTAL without Kaskinen and Pietarsaari	2859	1210	1006	470	2686	94
TOTAL without Kaskinen Vaasa, and Pietarsaari	1716	1182	996	460	2638	154

South Ostrobothnia	* Fields	** Biogas	Wood	*** Other	TOTAL
Seinäjoki Region	620	232	485	73	1410
Härämämaa Region	365	107	241	22	735
Suupohja Region	297	126	567	21	1011
Järvisetu Region	169	64	377	13	623
Kuusiokunnat Region	179	80	549	19	827
TOTAL	1630	609	2219	147	4605

* Straw and rape seed residues

** Manure and reed canary grass potential from fallowed grounds

*** Industrial and municipal combustible and fermentable waste and sludge

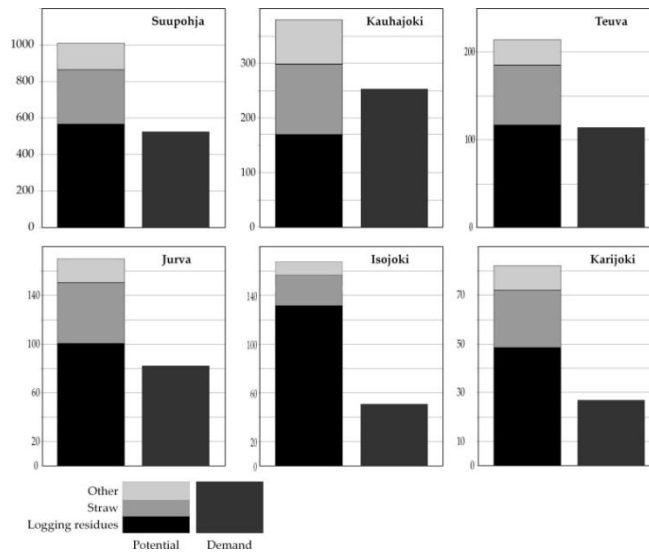


Figure 13. RES potential and energy demand (in GWh/a) in the five municipalities of the Suupohja Region in South Ostrobothnia.

For those cases with no or less profitability the preconditions for business profitability were studied using even stricter criteria (discounted payback time less than eight years, IRR at least 12%). The most important means for improving the feasibility for new biogas plants would be to decrease the investment and capital costs. A reduction of investment by 17–47% (corresponding normal investment subsidies) would make most of the cases profitable. Another alternative would be increased income. This would require some combination of the following means: (1) improved efficiency for savings or more gas production or both; (2) higher price for biogas; (3) more sources of income integrated as parts of the total profitability and intelligent planning of the operational concept (Fig. 14). It is important to notice that all cases have income already in the first year of operation even without these improvements, which is the real basis for a sustainable economy.

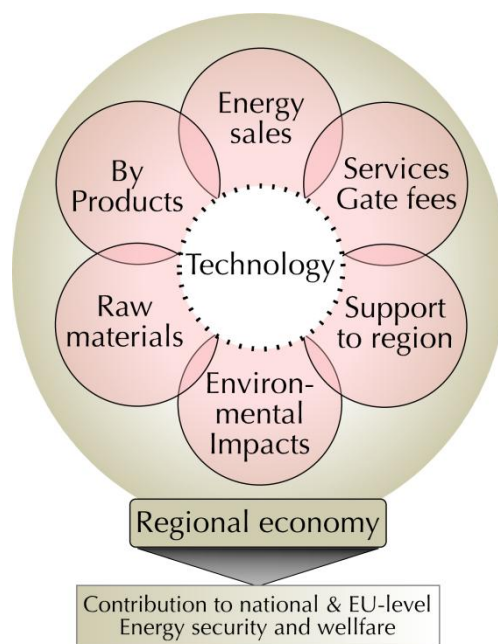


Figure 14. Operational concept and sources of income in distributed energy production.

The RES potential in Article III was estimated to reach the ‘market potential’ as defined by Verbruggen *et al.* (2010) for bioenergy. All the materials calculated in our studies are available immediately for any use depending on the infrastructure, including energy production under prevailing market conditions by present technology. It is however important to remember that the potential figures represent primary energy, while the demand implies figures for produced and used energy. As the bioenergy materials were calculated based on specific values in energy production, where the maximal efficiencies are normally 85–90%, then there is a loss of some 10–15% of the energy content.

But the other side of the coin is that the studies omitted large supplies of materials and areas utilized for other purposes, i.e., mass wood (usually ‘reserved’ for wood industry), cultivation grounds (food production), and smaller scale harvesting of wood. Therefore, the real bioenergy potential is significantly larger than indicated in Article III. Even more importantly, if the total RES potential, when solar, wind and ground source energy are included, it would be practically inexhaustible in relation to today’s demand. For instance, in 2008 the planned wind parks alone in Ostrobothnia would produce 3.4–6.5 TWh/a electricity (with 30% effective hours). This implies that all these areas could easily be self-sufficient in their energy management, even if traffic fuels (ca. one quarter of the total national energy demand) are included in the demand.

In Finland, the share of renewable materials was 14% in electricity generation (74.5 TWh, net import omitted) and 12.3% in the total production (87.4 TWh) in 2008. The share of hydro and wind power was approximately one fifth of power generation in Finland. According to this, the share of RES is about one third in the Finnish electricity production. In heating the share is not known exactly because of deficiencies in statistics. In Ostrobothnia, some 36% of all electricity was produced by RES in 2008, but it is difficult to define the RES share in the end use of electricity as power stations are connected to the national grid. Nearly 20% of heat production was RES-based in Ostrobothnia in 2008 (in district heating and heating by electricity 36%; peat non-renewable). This makes an overall degree of *renewable energy self-sufficiency* of about 30% in Ostrobothnia.

Summarizing, the main finding of Article III was that the bioenergy potential in the study areas, and also more widely in Finland, is tremendous, and the total RES potential exceeds overall energy demand. This is supported by similar results elsewhere from Europe and globally. The economics of small-scale power generation units, here represented by biogas plants, is already feasible, despite the technology being at an early developmental phase. The results give rise to an anticipation of more RES-based energy generation in Ostrobothnia, Finland and even globally. This development may result in, as we think, structural changes across the whole energy sector.

This reasoning resulted in the **dichotomy** vision (division into two parts), introduced in Article III. According to the vision, in a time frame of 10–30 years, and instead of purely fossil fuels and centralized structures, there will emerge a new distributed strategy using RES from each region and from the very vicinity where they are used in energy production. As RES potential is abundant and economy of energy production units is feasible, with a large potential for decent business and regional impacts in most cases, this development might even be unavoidable. In the context of the energy sector, the dichotomy would mean the coexistence of the following two parts:

- The centralized system, which prevails and uses mainly fossil fuels today, but which can also adopt RES.
- The new RES-based distributed system, at least outside energy intensive industry and the largest population centres.

So far however there is no scientific research or direct evidence supporting the vision, and it will be one of the future research challenges for researchers in this area.

2.5.2 *Implementing sustainable energy*

Contribution to:

Research Objective 5

“To understand and add knowledge about how intentional conscious change can be promoted and implemented at regional level in the energy sector.”

Main reference:

Article IV

Article IV completes the logical framework of the thesis, and it closes the circle from the limits of existence to practical responding, and from theory to implementation, which without a doubt will cause new theoretic problems and practical responses in the future. The article aims to increase knowledge and find best practices on how sustainable energy (SE) can be boosted and implemented at a regional level. It presents the main results from the RESGen (*RES Generation – From Research Infrastructure to Sustainable Energy and Reduction of CO₂ Emissions*; EU Regions of Knowledge) project and introduces the RESGen procedure developed within the project, which aims to support regionally comprehensive implementation of SE involving all of the main regional stakeholders.

The RESGen partnership consisted of nine partners, representing the three main regional stakeholder groups (industry, administration, R&D bodies; ‘triple helix’), from four regions and EU Member States (the RESGen project details: www.resgen.eu), and they carried out the project in the period 2009–2012. The RESGen procedure was applied in the following four case studies: Ostrobothnia Finland, Basque Country, Spain, Cornwall, UK, and Northern Hungary, which all have existing energy clusters or other previous activities in developing SE. One of the main purposes was to create regional commitment and stakeholder involvement by professionally high level procedures.

Method – The RESGen procedure

The underlying idea was to promote SE by developing a replicable common approach and methodology, here named as the RESGen procedure. In the project it resulted in four regional Roadmaps for the future implementation of SE. The Roadmaps are clearly defined practical project programmes based on regional strategies, for which stakeholder commitment is crucial. Fig. 15 illustrates an overview of the procedure. It starts with development of regional strategies based on regional characteristics and today’s priorities, and continues with development of Vision and Roadmaps to 2020. The regions will then be responsible for the implementation in the future after the project.

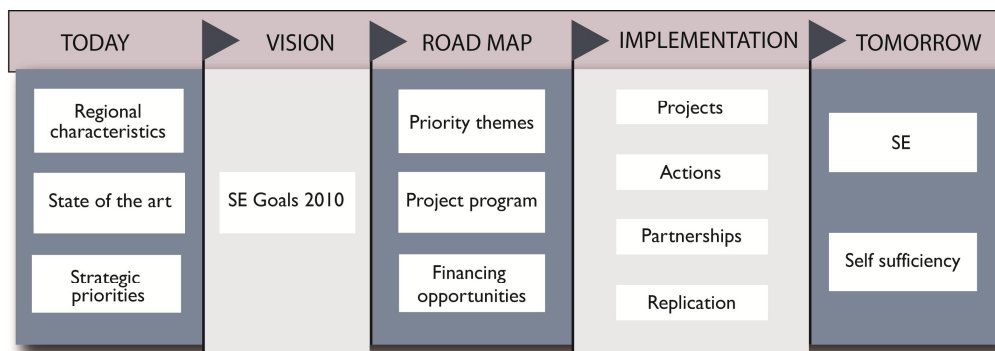


Figure 15. Overview of the RESGen procedure.

For defining the strategic priorities and SE goals, each region collected information about their regional characteristics, including SE state of play (energy overview, situation and perspectives; workshops, interviews, analyses), SE policies and SE-related R&D demand and supply (including, e.g., company base, R&D employees, turnover, expenditures, international presence, fields of SE activity, funding). The data was further elaborated in regional SWOT analyses (Porter 1990; modified by Dinya 2011). Information attained through questionnaires and workshops was organized into a SWOT matrix, which enabled the definition of strategic steps by combining strengths (S), weaknesses (W), opportunities (O) and threats (T) as follows: ‘SO’: exploiting opportunities, based on strengths; ‘WO’: eliminating weaknesses, exploiting opportunities; ‘ST’: avoiding threats, based on strengths; and ‘WT’: avoiding threats, eliminating weaknesses.

In Finland and Hungary the matrix was used in the following way: each collectively defined S, W, O and T was placed into the matrix where every cell was a combination of S-O, S-T, W-O or W-T. The SWOT panels gave scores to each cell according to how important they considered each combination (e.g., S1-O1, S1-O2...W1-T1, W1-T2, etc.) on a scale of 0-5 (0= no relevance, 1= very little relevance...5= very important). The collective opinion was the sum of all scores and those combinations that received the biggest scores were considered the most important ones.

In the Vision and Roadmap procedure regional panels outlined the most likely future scenarios for the Vision and defined the priority themes and project ideas. They were further developed by emails, discussions and a series of regional workshops. The Delphi method (Linstone and Turoff 2002) was recommended, but the regions were free to use any relevant method to attain a collectively defined Roadmap. In the final workshop the results were discussed and the partici-

pants could comment on the earlier results. The proposed themes and project ideas were emailed to all panel participants for scoring (including instructions and Excel templates ready to be filled in). The overall scores were considered as the regional collective opinion, and the regional priorities and projects were defined according to these results. This organization resulted in the ‘fishbone’ structure, which represented the Roadmap for each region (Fig. 16). In the fishbone structure, the themes are the four blocks, the priority areas the fish bones and the separate projects the actions.

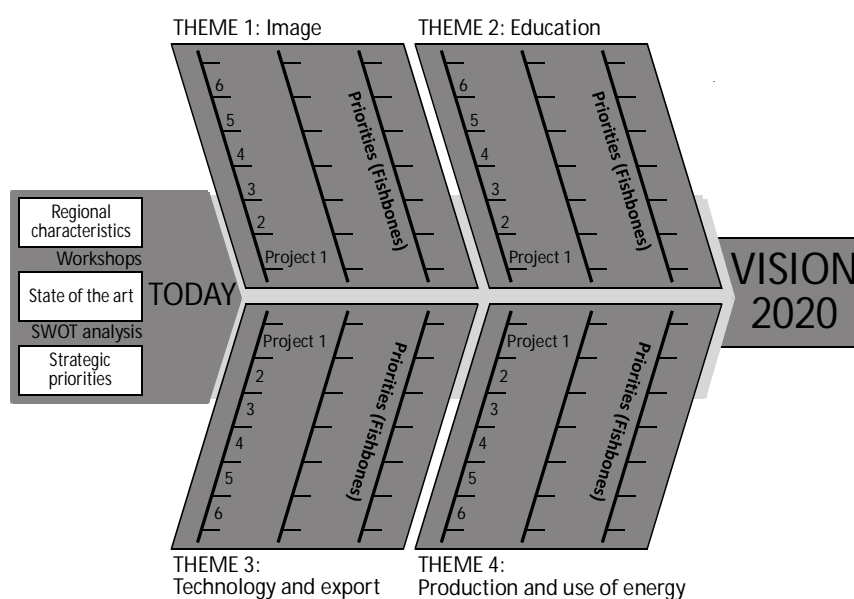


Figure 16. Regional roadmap using the fishbone structure. The themes shown: case Ostrobothnia.

Results – Four regional Roadmaps

In **Ostrobothnia**, the most important feature in developing SE is that the RES potential is much larger than the current energy demand. Today the RES self-sufficiency is about 30%. The energy cluster in Vaasa, the centre of Ostrobothnia, is the largest in Scandinavia comprising some 120 companies and 10,000 employees in its supply chain, total net sales of ca. €7 billion, and share of export 70%. Over 800 employees work in R&D, and more than half of them work with SE. The cluster also consists of regional authorities and R&D partners, including the University of Vaasa.

The final SWOT list of Ostrobothnia is shown in Table 4, and Fig. 17 gives the results from the scoring. The dominating field is ‘SO’ strategies reflecting optimism related to the RES industry. The main weaknesses include that the region may lag behind in terms of technical development, poorly developed infrastructures and value chains, and strategic conservatism against RES solutions (visible and especially non-visible barriers when today’s dominating actors protect their own business interests).

Table 4. The SWOT list of Ostrobothnia.

STRENGTHS	WEAKNESSES
S1 Plenty of RES, RES potential significant S2 Nationally the best wind power potential S3 “Region of New Energy”; positive attitude, common approach toward RES generation among stakeholders S4 Open mind and low threshold for technical innovations S5 Strong energy industry and technical innovations S6 Cumulative development knowhow S7 Global activity and ability to internationalize by the local industries S8 Significant share of the RES-focused companies are local or regional S9 Tradition of entrepreneurship S10 Recognized status among experts in the energy sector nationally S11 Excellent location geographically (e.g., logistics, fuel deliveries) S12 Own university in the region	W1 The need for systemic change, with the objective of integration of centralized and decentralized systems W2 Monumental need for development W3 Poorly developed infrastructure and value chains for RES-based production (incl. logistics and regulations) W4 Strategic conservatism: large traditional actors trying to prevent new actors penetrating the markets W5 Hesitation in decisions by enterprises W6 Poor marketing: the big audience don’t recognise “Energy Capital” or “Region of New Energy” W7 Dependence on fossil fuels, massive need for investments to RES-based production (also O) W8 All RES are not competitive or realistic in Ostrobothnia (wave, some solar, floating wind) W9 Low subsidies for investments nationally W10 Slow reacting capacity by innovation systems by demand W11 Weak national political lobbying
OPPORTUNITIES	THREATS
O1 Relative advantages and new specialization (e.g., manufacturing of fuel cells to Vaasa) Q2 The initiator’s advantage in totally new markets O3 Global growth of RES-based energy markets O4 Demand for systemic expertise and ability for management of large entities O5 Released R&D capacity caused by leakage of expertise from Ostrobothnia abroad (e.g., China) O6 Establishing of Scandinavian enterprises to Finland via Ostrobothnia O7 Opportunity to international energy consultancy	T1 Receding of the ownership and decision-making away from Ostrobothnia T2 Transfer of Ostrobothnian expertise elsewhere T3 Continuous vortex for developing novel solutions T4 Competition in RES markets, nationally T5 RES markets will not grow as soon as forecasted T6 Unsteady political trends T7 Global recession will not support the markets T8 Mysticism in the energy-related discourse (no full logic, one sided approaches)

	S	S	S	S	S	S	S	S	S	S	S	S	W	W	W	W	W	W	W	W	W	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10
O 1	20	21	20	29	27	22	23	21	16	15	13	23	24	15	14	21	13	7	22	9	11	17
O 2	21	11	14	23	23	16	25	18	18	14	7	17	18	13	15	22	15	8	15	7	7	17
O 3	22	17	16	21	31	22	32	20	15	12	14	14	21	15	15	15	12	12	14	13	11	16
O 4	13	11	25	15	22	26	30	16	12	16	5	26	30	20	27	22	16	8	17	15	12	15
O 5	7	21	16	21	19	18	15	6	7	10	6	16	14	10	9	10	13	7	14	7	11	16
O 6	9	15	6	9	8	9	12	3	8	11	21	17	2	2	8	10	6	9	10	3	14	9
O 7	10	10	13	16	27	27	28	10	10	21	8	23	21	14	7	8	8	13	10	7	7	9
T 1	9	5	13	8	24	16	22	20	5	6	4	11	13	7	13	16	15	7	8	6	16	18
T 2	6	9	11	11	19	21	27	19	10	16	6	15	16	11	16	20	20	12	8	7	17	22
T 3	8	9	9	15	12	17	12	13	11	14	5	13	21	14	15	10	17	5	10	9	14	19
T 4	20	19	18	12	14	15	10	14	13	12	9	14	20	11	19	22	16	22	12	9	21	19
T 5	15	14	16	17	16	10	17	13	12	6	6	7	14	12	13	14	8	6	13	7	17	18
T 6	12	20	12	12	11	9	9	8	8	12	3	15	20	14	21	12	12	16	16	8	20	11
T 7	11	10	11	11	17	11	14	11	12	5	7	6	8	6	7	11	6	7	7	10	9	9
T 8	10	16	15	9	6	4	6	2	5	9	4	8	22	9	9	9	11	12	19	9	10	6

No or very little relevance
 Little relevance
 Important
 Very important

Figure 17. The scoring results of the SWOT analysis in Ostrobothnia.

The main threats were listed as follows: (1) industries might move their strategic functions outside of the region; (2) decisions concerning their business environment are made outside the region; (3) RES industry depends on political support; (4) and structural barriers (e.g., the ownership and monopolistic control of the delivery network are guaranteed to energy utilities by law). The weak political position of the region on the national political scene poses a threat to the continuation of the present favourable trend. This picture is reinforced in the ‘WT’ quadrant, where the scores were low, reflecting optimism in Ostrobothnia.

The procedure resulted in the ambitious Vision 2020 aiming at “*a significant increase in SE self-sufficiency through regionally available RES, and well-being and development of the energy industry by improving its business environment*”.

The panel identified the following four themes and number of projects for the Ostrobothnian Roadmap, illustrated in Fig. 16:

- Production and use of RES (33 projects)
Significant potential for SE self-sufficiency
- Technology and export (14 projects)
The RES industry as the driving force, its business environment important
- Education (14 projects)
Constant need for qualified workers, education vital
- Image (13 projects)
‘The Region of New Energy’ and its industry

The other partner regions elaborated Roadmaps of their own, and they went through a similar procedure to Ostrobothnia with some slight modifications for a better match with the cultural features and priorities in each region. In these Roadmaps and regional procedures the role of the author lay in being the scientific advisor of the RESGen project, including coordinating, commenting and guiding the partners in partnership meetings. The same applies for writing the information in Article IV, where the role was to give instructions and to harmonize the final versions as much as possible. The other regional parts are briefly reviewed in the following.

In **Basque Country** (Spain) the RESGen project contributed to the regional technological and industrial strategy called EnergiBasque (approved by the Basque Government 2011), which is a part of the regional energy strategy called 3E2020 and provides input to the regional Science, Technology & Innovation Plan. The energy sector is one of the cornerstones of Basque industry with more than 350 companies and 24,000 employees, and importance for the regional economy. This meant an extensive stakeholder involvement and commitment in the RESGen procedure. The strategy is oriented towards achieving an ambitious vision: “*to turn the Basque Country into an international knowledge pole and a reference for industrial development in the energy industry*”.

The procedure resulted in the Basque Roadmap comprising the following strategic areas: Wind energy (4 projects); Smart grids (6); Energy storage (3); Wave energy (4); Electrification of transport (4); Energy services (1); and Exploration of unconventional gas. The estimated budget of the Roadmap is €1 316 M (2011–2015). The majority of the funds (73%) are expected from the business sector, followed by funds from regional administration (17%) and the remaining 10% from the national administration and the EU.

In **Cornwall** (UK) the priority areas were identified to further Cornwall’s ambitions towards a low carbon economy. These include RES Technologies, Energy Infrastructure, Future Proofing and Energy & Resource Efficiency. The prioritization process has involved extensive stakeholder engagement and has been closely aligned with the development of the Green Cornwall Strategy and Cornwall Council’s prioritization processes. At a strategic level, the Roadmap aims to move the low carbon agenda forward. The result of this process was a detailed overview of both existing and future priority projects, and three common areas of activity were agreed as a focus for future development: Marine Energy; Deep Geothermal; and Smart Grids.

The **Hungarian** Regional Strategic Committee with extensive stakeholder involvement outlined the RES strategy with the most important actions as follows:

1. Developing integrated local systems based on the bioenergy potential and pilot systems.
2. Introducing zero-emission technologies into the exploitation of coal reserves and subsidizing the co-firing of biomass with coal.
3. Serving the increasing innovation and education needs through the regional bioenergy knowledge centre and involving solar energy.
4. Intensive dissemination of successful RES-projects to drive innovation and RES investment, and to exchange the culture and attitude of energy consuming and to establish the social basics of SE management.
5. Providing knowledge services for RES projects outside the region based on developing regional RES innovation capacity especially in bioenergy and distributed energy systems.
6. Establishing RUE programmes using the knowledge services of regional innovation centres.
7. Implementing consultation programmes to involve the public sector (local governments, hospitals, schools, etc.) in SE management.
8. Elaborating innovative solutions for the private, public and NGO sectors to help them in starting successful RES projects.

Practical experiences from implementing the RESGen procedure were very positive. The method was applied differently in each region, implying the vital flexibility of the method and various needs of the regions. As expected, commitment, social acceptance and trust among stakeholders is vital for a successful implementation of SE. Quite unexpectedly, a number of previously unknown facts were revealed, which was important for understanding the complexity and systemic nature of SE. It can also reveal institutional opposition and make the barriers to SE and bottlenecks visible. The quantitative SWOT procedure proved difficult in some cases, but it produced a lot of valuable information. The fishbone structure was found easy to use and understand.

The decision-making process worked well according to the analysis based on the project valuation in Ostrobothnia: the valuers agreed as to the best projects, but there were differences with the least scored projects (Fig. 18). The results by different stakeholder groups were somewhat similar, but the number of valuers per group remained quite low (for authorities $n=3$; industry $n=8$; R&D $n=5$).

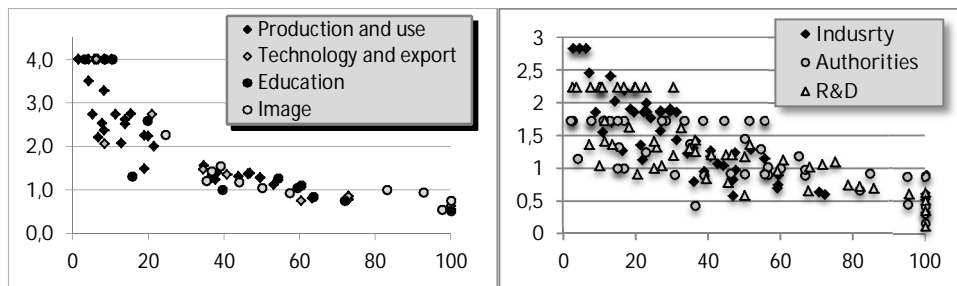


Figure 18. The relationship of the scores (highest average=100) and the deviation of scores (standard deviation divided by average) in the Ostrobothnian valuation of projects, in different themes (n=16; left) and by different stakeholders (right).

There is a call for general ‘rules of the game’ in order to reduce the uncertainty within the business environment for SE. Conscious development through comprehensive regional strategies and programmes will be vital so that single separate actors can join the process, instead of the need for creating the prerequisites by themselves. The RESGen procedure provided a systematic tool for this, and according to the experiences, it may be appropriate for a more widespread use. The existence of this kind of tool may also encourage the development and implementation of SE more generally.

3 DISCUSSION

3.1 Research Process

This doctoral thesis has resulted from a long and longitudinal research process. It crystallizes the whole professional career of the thesis' author – from academic studies in biology and ecology, sociology and philosophy since the 1970s, voluntary environmental activism through the 1980s and 1990s, environmental administration in the 1980s and environmental business in the 1990s, to academic work since 2002 within industrial management and the energy sector. It has been a knowledge-creating process (Arbnor and Bjerke 2009), where conceptual integration (Fig. 2) and dialectical reasoning have been the cornerstones.

In a process like this it is impossible to define exactly where the research itself begins. The prior research development resulted in a maturing of the author's world view into a holistic multi-scientific philosophy, based on both reflections (observations and scientific evidence concerning the state of the world's environment) and active participation (environmental activism, administration and business) in the evolving research target. This contributed to macro-level reasoning and theory formation, which were crystallized in Article I in 1999. It was however first the university career that enabled dissertation scale academic work. The fast evolution and comprehensive changes in the energy sector provided an excellent case where the preceding work could be integrated into a coherent research process, from macro-level theories to micro-level problematic and practical implementation.

This dissertation falls under 'constructive research' in the typology suggested by Kasanen *et al.* (1991, 1993). Among the main characteristics of constructive research are that it is intentional and it searches for solutions for certain explicated problems. That is the case in this thesis as well. The approach had two kinds of impacts on the research process. Firstly, it enabled and motivated the logical framework and the integrated method of 'zooming' from large-scale thinking – philosophy and world view – towards smaller scale issues, first in order to understand, then to deepen knowledge through research, and finally implement the findings in practice, according to a genuine constructive research process.

Secondly, this was the reason why it was logical rather to formulate research 'objectives' than set and aim at answering research 'questions'. As, for instance, the literature research in Article II implies, it would not be possible to answer meaningfully the question "*What are the limits of existence?*" However, the question

“*Are there limits?*” could easily be answered “*Yes*”. But because no one can quantify the limits exactly, it is more motivating to set an objective to ‘add knowledge’ about the limits and, even more importantly, about the reasoning concerning the limits.

In constructive research there is always a danger of confusion between intentions based on values, on the first hand, and scientific evidence, on the other. This refers directly to the dialectical relationship between the social construction of what are the generally or personally accepted values and what can be scientifically proven. It is clear that research results in general affect values and are important in deducing moral and political judgements. In this research, the logical framework and its ‘intentional search’ for large-scale changes is solidly based on and deduced from a long scientific tradition. The thesis also strives to contribute to the research objectives by scientific reasoning, where all results go through the same critical analysis, including those not supporting the pre-established hypotheses, and where the empirical postulates cannot be judged by moral or ideological conviction.

3.2 Research Objective 1

To understand and add knowledge about humankind’s limits of existence, and to structure the consequences.

The starting points in designing the thesis’ logical framework have been the deterioration of the world’s environment and the approaching limits of humankind’s existence. A comprehensive review of environmental problems from the pollution of water bodies, air and ground, to the observed severe consequences like eutrophication and even hygienic deterioration of water bodies since the 1960s, acidification of waters and forests in the 1980s, and climate change in the 2000s is, however, beyond the scope of this thesis. The reason for this is that these problems have been well-known since the 1970s and even earlier, they have been well documented elsewhere and there has been a wide consensus within the scientific community: these problems are real and they are caused by human activities.

Pollution and eutrophication problems caused in water bodies were reasonably easy to observe and identify, they were accepted early on and also actions to remedy them since the 1980s have been efficient. However, the situation concerning other larger scale problems has been different, and it has taken an astonishingly long time for them to be generally accepted. Global phenomena like acidification, climate change and global warming, and, even to a larger extent, the limits of existence and growth, are problematic for research. For them there are no border-

lines between states or even continents, and there are a number of phenomena affecting them. By single, smaller scale studies alone it is not possible to achieve comprehensive results and draw competent conclusions concerning the phenomena, the problems they cause or introduce solutions for solving the problems. It is only possible to outline the big picture through extensive global research programmes.

Within the scientific community, like the Intergovernmental Panel for Climate Change (IPCC), the consensus has been achieved, but still, there are deviating opinions – with two typical features. The first case is that single, separate scientists have presented them. Often they have revealed some mistakes in the research details – typically they have resulted in due responses by the scientific community and corrections of the mistakes, for instance, by the IPCC (e.g., IPCC 2011), but this has not affected the big picture concerning the phenomenon itself. Some personal sceptical opinions (e.g., Lomborg 2001) have attained a lot of publicity, but later they have been shown to be based on misunderstanding.

The second case is that they have been elaborated and spread purposely and consciously in order to mislead “... *the world in vehement denial of these dangers*” and to protect business and in more general terms, to avoid any intervention towards individual freedom (Oreskes and Conway 2010). Oreskes and Conway (2010) revealed these ‘Merchants of Doubt’ and “... *how a loose-knit group of high-level scientists, with extensive political connections, ran effective campaigns to mislead the public and deny well-established scientific knowledge over four decades (...) addressing tobacco, acid rain, the ozone hole, global warming, and DDT (...) showing how the ideology of free market fundamentalism, aided by a too-compliant media, has skewed public understanding (...)*” (Oreskes and Conway 2010). Their impudent tactic has been to “... *discredit the science, disseminate false information, spread confusion, and promote doubt*”, by which they contributed to the strategy of delay with the aim of gaining more time for industries to operate without restrictions. “*The only hope against the truth is doubt!*” (Oreskes and Conway 2010).

It is clear that this reasoning has been based on political and value judgements, and not scientific ones. They have been systematically promoted by “... *a handful of politically conservative scientists with strong ties to particularly industries (...) fiercely anti-communist (...) and with access to power*” (Oreskes and Conway 2010). This challenge has resulted in ‘deliberate obfuscation’ of the issues (Oreskes and Conway 2010), and it is well known, for instance, that the USA has not joined the Kyoto Protocol with the motivation that climate change ‘may not be caused by human activity’.

Resembling features can also be found in discourses concerning the limits of humankind's existence. The basic views can be crystallized in the bipolar dichotomy originally presented by Thomas Malthus (Malthus 1985; Winch 1987) and Ester Boserup (1993). According to Malthus, the power of population growth is greater than the power of the Earth to produce subsistence, and these powers will be equated either by conscious intentional 'preventive checks' for decreasing fertility, or by 'positive checks' increasing mortality. Boserup argued that agrarian population growth is compensated by migration to new areas, and technological change is itself spurred by increases in the population.

The Boserupian views are analogous with technology optimism and the logic of limitless resources. These views, like "*it has been shown that Malthus was wrong*" and "*population bomb defused*" (some reviewed by Alcott 2012), undermine the existence of limits to growth, and they find their support from the fact that still more than 200 years after Malthus' 'forecast' the end of the world has not come. They can only be understood historically: until recently, as long as there still have been unoccupied places, it has been possible to function according to the Boserupian view, and with fossil resources giving the illusion of no limits of growth (Hall and Day 2009). But today the 'hand of man' touches every part of the globe, and raw-material reserves and the sustenance base have proved limited, including all thinkable fossil resources (Jefferson² 2008).

A great majority of the scientific community agrees that there are limits, despite the fact that they cannot be defined exactly, thus supporting the Malthusian view. Many authors even write that these limits have already been exceeded, human beings' ecological footprint is continuously increasing and it exceeded the natural carrying capacity already by the 1970s and reached an ecological overshoot, resulting in an ever-growing sustainability gap, loss of ecosystems, reduction in natural buffers for self-purification abilities, and tremendous costs, according to some estimates exceeding 14 trillion Euros and a 7% loss in global GDP by 2050 (Article II; EC 2008; GFN 2010; Seto and Satterthwaite 2010; Weijermars 2011). However, the analysis in Article II showed that the Boserupian technological reforms are necessary for achieving sustainability, but in the long-term and within a global perspective, alone they are insufficient.

The impact of human societies on the environment is a sum of a number of factors, as the demographic formula $I=PAT$ (e.g., Alcott 2012) implies, and as Arti-

² Michael Jefferson is former chief economist and director of oil supply and trading of Shell and deputy secretary-general of the World Energy Council

cle II widely discusses. In addition to the number of people, the volume of humankind's activities and technical possibilities of exploiting the resources are expanding, and simultaneously the carrying capacity of the environment is declining (Hugo 2011; Berck *et al.* 2012; Alcott 2012). Ecological colonialism, robbery and total lack of care about the environment have been the established operational patterns with economic and political interests as the most important driving forces. Article II argues that ultimately their origins can be traced back to human evolution. Survival, improvement of fitness and maximization of well-being have been the main strategies in the early evolution of human beings and influential factors in forming the human mentality. In a constant conflict between the common good and individual needs they are the personal preferences that take over, resulting in a pattern, according to which individuals have striven for maximal utilization of their environment.

The whole reasoning from the views presented by Malthus to the modern demographics and scientific evidence about climate change and other environmental deterioration leave us with the only possible conclusions: infinite growth in a finite world is not possible, the limits of existence are really approaching and humankind is in danger. No more time should be spent arguing whether or not these problems are real, but instead all efforts should be devoted to solving the problems in practice. Just like in any therapy, the first step is to confess the problem, and then launch the remedying programmes. There is a severe and scientifically-based call for a collective global programme for sustainable development. The human being as a species must free itself from its primitive evolutionary instinct of maximal material needs and create a new, strong societal sustainability strategy (4S) to its ESS (evolutionary stable strategy; cf. Maynard Smith 1974).

3.3 Research Objective 2

To understand and add knowledge about the needs and the fundamental mechanisms, features and dynamics of societal changes and cultural evolution.

While the preceding section discussed the needs for change, the three layer (3L) macro-level model is used to explain the fundamental mechanisms, features and dynamics of these changes. The model was introduced by the author in 1999 (Article I), and it was further developed and discussed in Article II. 3L is an evolutionary scenario and hypothesis, which is based on conceptual integration of several separate, independent scientific theories. Each theory has its own role and function as parts of the whole model, and they have been used as presumptions explaining certain sections of 3L. It is however important that they complement and reinforce each other and the model, and that they are compatible in this con-

text. 3L is fundamentally and strongly an evolutionary model, and it has been inspired by the following theories and approaches:

Paradigm shift and conceptual evolution

The paradigm shift is based on the theory of scientific revolutions and structural changes (Kuhn 1996). This theory has been further explored and improved (Hull 1988, 2001) by introducing the ideas of ‘conceptual evolution’ and ‘social selection’ (Ylikoski and Kokkonen 2009). This is completely analogous with the Social base in 3L, where the underlying thought is that all intellectual constructions follow the same process of conceptual evolution through social selection.

Iterated prisoner’s dilemma

The prisoner’s dilemma is an example of game theory, where a person’s success is based upon the choices of others. It shows why two individuals might not cooperate, even if it appears that it would be in their best interest to do so. It becomes ‘iterated’ when the situation is repeated and solutions become strategic choices. “*What is best for each person individually leads to mutual defection, whereas everyone would have been better off with mutual cooperation*” (Axelrod 1984). In terms of what is best for society, it is essential to break out of the dilemma.

In 3L the general rules and the supporting structures for bringing the ideas and norms into practical realization are of great importance. They are motives on the one hand, and incentives and sanctions on the other. Their purpose is to ensure that all actors have equal preconditions for the aspired actions, according to the new norms and ideas, which have been adopted by the social base of the society. They also reveal the reason for the social lag (Massa 1994): it is possible to put an idea into practice at the general societal level only after it has gone through the selection process.

Diffusion of innovations

The diffusion of innovations is the theoretical model for explaining how novel technical solutions spread across societies, as summarized by Rogers (1985). Although it mainly explains technical innovations, it is clear that the preceding phases, suggested by 3L, are necessary for a successful diffusion.

Ecological modernization

Ecological modernization means, as defined by environmental sociologists, structural changes in production and consumption, social and cultural maturing and the emergence of new patterns at the societal level, on top of and prior to merely technical reforms. In practice it means leverage to a collective level above separate actors (e.g., Massa 1994; Mol and Sonnenfeld 2000).

Self-reflection of society

The self-reflection of the society is the feedback system of how societies and ultimately the whole of humankind can collectively correct its actions and praxis whenever it reflects harmful impacts (Beck *et al.* 1994). This corresponds with the interaction of society and the environment as illustrated in Fig. 1, and the actions inside society according to the 3L model.

Cultural evolution

Cultural evolution is the main point of emphasis of the whole 3L model. There is a wide variety of literature about cultural evolution. The debate explores, for instance, whether the diffusion of thought takes place through replication of the so-called memes, as proposed by, e.g., Dawkins (1976), Blackmore (2000a,b,c) and a number of other authors (e.g., Mardsen 1998), or through a more complicated process of cognition and comprehension (e.g., Aunger 2000; Kuper 2000; Plotkin 2000; Sperber 2000). But opposing opinions are also strongly supported and promoted, often by evolutionary psychologists (e.g., Dunbar *et al.* 2003). Some of the discussion has been summarized by Sperber (1998), Aunger (2000), Dunbar *et al.* (2003) and Knight *et al.* (2003), while Ylikoski and Kokkonen (2009) provide a comprehensive review, unfortunately only in Finnish. Although 3L as such does not take sides with either of these views, the remaining unifying feature however is that they are all evolutionary.

As a macro-level theory, 3L simplifies the dynamics and omits for instance the numerous feedback loops that are natural for any societal systems. However, some 15 years after the invention, I still support it steadily, and, as a matter of fact, all subsequent readings and doings have reinforced my claim: at a general level the 3L model catches something fundamental about cultural evolution, and it can be seriously tested as an evolutionary scenario of social development.

There have been several attempts since evolution theory was presented to apply ecology and biological evolution to explain societal phenomena. Sociology and ecology had a close relationship in the late 1800s, as evolution theory and ecological thinking had a significant influence on the development of the classical theories of sociology (Durkheim, Marx, Weber). Sociological theories were also partly counteractions to evolutionist views. Since then, and until recently, these disciplines have led their histories apart from one another. The evolving environmentalism has however been reflected in the theoretic development, as well as in political and public discourse, and in this brought these disciplines again closer to one another, and additionally, of late the importance of evolution theory has been re-discovered.

After 100 years of isolation and specialization, the 'reunion' has been characterized by confrontations between ecologists and sociologists, anthropocentric and ecological views. It was a general feature that the fundamental characteristics of evolution have (intuitively or by lack of knowledge of evolution) been neglected or misinterpreted when applying the ecological or evolutionary concepts to broader contexts. Manifestations of this have included, for instance, the societal views of sociobiology, started by Wilson (1975), and subsequent popular, even 'vulgar', public debate and direct interpretations like justification of wars, aggres-

sions and racism based on biological evolution. Socio-evolutionist, deterministic, neo-Darwinist and reductionist views of society have been criticized and rejected correctly. This polarization was the reason why cultural evolution was academically risky for a long time, especially during the last quarter of the 1900s.

In the 2000s, however, the literature has expanded, and there is a widening agreement about the importance of understanding evolution theory. An excellent and comprehensive review concerning how evolution theory has been used in explaining the development of the human mind and societies was written by philosophers Ylikoski and Kokkonen (2009). Unfortunately, it is the only review found, and even more unfortunately it is available only in Finnish. Among the main postulates are that (Ylikoski and Kokkonen 2009):

- Culture itself is a product from biological evolution;
- Culture is a selection environment for genetic evolution;
- Culture shapes the development of individuals;
- Psychological (i.e., also biological) capabilities are a selection environment for culture.

Summarizing, there is no reason to suppose that evolution would have stopped when human beings attained their present biological and mental abilities, and the same kinds of mechanisms can be found in the development of culture. A comprehensive review of this literature is however beyond the scope of this doctoral thesis.

3.4 Research Objective 3

To analyse and structure the development in environmental issues in general and the reforming energy sector in particular.

The analysis concerning the development of environmental issues as a social movement and process dates back to the latter half of the 1990s. It was a part of Article I, but updating notions have been introduced in Article II. This is the part of the thesis where the influence of the author's original academic education in environmental sciences, career within environmental administration, voluntary movement and entrepreneurship in environmental business is the largest. These experiences and deep interest have given a good viewpoint on the evolving environmentalism, which even in the late 1970s and up to the 1990s was continuously fighting its way to a more general acceptance and especially towards everyday routines in the private sector.

In the course of its over a hundred-year history, environmental protection has developed from an issue promoted by single separate thinkers to general environmental consciousness, and from the ideology of national parks towards sustainable development and ecological modernization (e.g., Mol and Sonnenfeld 2000) of society. There has been a shift from the protection of areas towards an active environmental policy and a shift from ideology towards a new practice (e.g., McCormick 1991; Articles I and II). In terms of 3L, this evolution can be summarized as follows: the social base of societies has evolved to include environmentalism and sustainable development as integral and central parts of their social norms affecting everyday life. Presently, supporting structures and motives like ideologies, policies, regulations and institutions, market behaviour and operational patterns are widely supporting sustainable development. Practical responses have evolved from denial and institutional opposition towards new technologies and technical evolution, new strategic thinking and new societal patterns.

According to the literature reviewed and research for this thesis, it seems clear that similar phases can also be identified in the evolution of the energy sector towards SE. In the following, this evolution is briefly analysed with reflections on the 3L model.

Social acceptance is one of the most important preconditions for diffusion of any new innovation, and for a more widespread implementation of SE technologies this has been generally noticed. *“They first need to gain the respect, understanding, and consent of citizens at large by achieving positive results”* (Jefferson 2008). The special issue of the journal *Energy Policy* (issue 5, volume 35) summarized some of the most influential literature and writers, and it structured ‘social acceptance’ in its introduction (Wüstenhagen *et al.* 2007) using a triangular approach:

Socio-political acceptance

of technologies and policies, by the public, key stakeholders and policy makers;

Community acceptance

to specific siting decisions of RES projects by local stakeholders, residents and local authorities;

Market acceptance

or the process of market adoption of an innovation by consumers and investors.

In comparison with the 3L model, socio-political acceptance includes the ‘social base’, including formation of general opinion, but also parts of the ‘supporting structures’, because policy formation is already a step towards institutionalization

of collective thought. In 3L, the whole social base belongs to the socio-political acceptance. Wüstenhagen *et al.* (2007) also name 'public acceptance' and 'general public support', which are partly synonymous with the social base in 3L. 'Social acceptance' however also includes community and market acceptance, which in turn are weighed in connection with concrete RES projects or plans, and therefore they differ from the general opinion. In terms of 3L, they belong to customer and market behaviour, and are important motives for putting the plans into practice. Thus, 'social acceptance' includes elements from both 'social base' and the 'supporting structures' of 3L.

Today, social acceptance as a whole (Wüstenhagen *et al.* 2007) develops in the interface between general opinion and supporting structures, such as the feedback system, and through customer behaviour in concrete projects. This dichotomy can sometimes be seen in opposition to proposals for new developments, which the majority considers beneficial. Similar dichotomies have often crystallized even in one person's opinions and attitudes, although typically individual motivation is different from group attitudes (van der Horst 2007). Often only a small but loud minority gets the most publicity, giving an impression that the opposition is larger than it really is. However "*there is hardly anything in life that is universally supported*" (Wolsink 2007). It is especially important to "*... recognize that the belief in the NIMBY theory (...) must be abandoned*" and that "*in all renewable energy acceptance cases at all levels there is only one common factor, trust*" (Wolsink 2012b).

This suggests that there are dialectics between general opinion and practical acceptance that are actually inside 'socio-political acceptance'. According to this, the acceptance moves from the social sphere towards market behaviour as the development moves along the diffusion curve (Rogers, 1995). It has also been observed that social acceptance forms a U-curve temporally – the initial high support decreases to its lowest point shortly before implementation of the actual innovation, and rises again when people get used to it. This also means that there should be a clear distinction between general level and site-specific acceptance. Institutionalization of values is essential for a successful implementation (Wolsink 2007). "*Social acceptance of RES means acceptance among all relevant actors in society—indeed much broader and conceptually fully distinguished from mere public acceptance*" (Wolsink 2012b). This is exactly what 3L is based on in the dialectics of the social sphere and supporting structures.

"Several indicators demonstrate that public acceptance for renewable energy technologies and policies is high in many countries" and has been since the early 1980s (Wüstenhagen *et al.* 2007), and that SE is among the top priorities of Euro-

peans (Eurobarometer 2011). This shows that the social base of SE, as suggested by 3L, was successfully passed a long time ago. However, “the implementation processes of renewable energy require ‘strong’ ecological modernization”, where the key approaches are, for instance, open democratic decision-making, participation and involvement, and incorporation of multiple views and ecological concerns (Wolsink 2007). This requirement for societal structuring is also at the core of 3L, where supporting structures and motives precede and are necessary for successful practical responses.

The development has enabled policies and other motives to emerge and grow. Energy, and RES in particular, has moved to the top of the international political agenda (REN21 2011a,b), which clearly means that the institutionalization of sustainable energy is an on-going process globally. The development of industrial applications and products, new business, and integration with the mainstream energy sector of SE is in its early phase. Industries who manufacture the technologies are emerging in the markets, starting with an early generation of technologies, and actually fighting against the prevailing structures instead of mutual synergy. Single, separate technologies are evolving continuously, but the systemic level of creating larger entities, for instance independent micro grid regions, are only in their infancy. The level of acceptance of SE as a societal strategic and operational pattern still remains to be seen in the future.

The evolution of the energy sector in terms of 3L can be summarized as follows:

Social base

The idea of SE has pierced the society, with the exception of institutional opposition by the prevailing structures protecting their own business or some other interests;

Supporting structures

Institutionalization of SE is an on-going societal structuring process, including international, national and especially regional policies, market acceptance and promotion of SE-based industries; regulations are developing, but still there are barriers and structural hindrances for SE and support for fossil energy-based solutions;

Practical response

Technical evolution is proceeding, mainly for separate solutions for RES-based production of energy, but regional (100% RES-based) systems are just emerging in the scientific literature and practical testing.

3.5 Research Objective 4

To test empirically the potential of sustainable energy and to understand and add knowledge about its future impacts in a wider societal context.

Sustainable energy (SE) has become one of the key concepts in reforming the energy sector in the EU and worldwide. SE includes integrating RUE (rational use of energy; energy saving and efficiency) and RES (renewable energy sources) technologies for regional energy self-sufficiency. Usually this means the introduction of distributed strategies and solutions, which utilize regionally available RES from bioenergy to other forms of RES, like wind, solar and ground source energies, although it is possible that also larger scale centralized energy production units deploy RES. After reviewing a number of definitions, Article II redefined SE to include *sustainability management* in order to avoid new ecological colonialism in the name of SE.

The most important precondition for SE to become more common is the potential of renewable energy – without RES it is impossible to implement SE, but it is also necessary to make it economically feasible. The main reference in this thesis concerning RES potential and its economy is Article III, which collated four studies of RES and one study on the economy of smaller scale production units, represented by biogas plants. The main observations were the following:

- The bioenergy potential in the two Counties of Ostrobothnia and 15 study areas in Finland far exceeds the total energy demand. Taking the whole RES, including wind, solar, ground source energies and other bioenergy sources (not included in the calculations in Article III), the RES potential in Finland is tremendous. Although the calculations in primary energy were compared with produced and used secondary energy, the big picture is the same: a number of materials were omitted from calculations, as their use at present might be problematic because of other interests, like food production or forestry competing for them.
- The economics of small and medium-sized RES energy production units are feasible, as analysed based on biogas plants. Most cases were profitable using strict economic investment criteria, and all but one would have been profitable with a reasonable investment subsidy. All cases had positive economy without capital costs.

These observations concerning RES potential have been supported by a plethora of literature globally (e.g., Evrendilek and Ertekin 2003; Ragwitz *et al.* 2005; Lewandowski *et al.* 2006; Božičević Vrhovčak *et al.* 2006; Schneider *et al.* 2007; van Dam *et al.* 2007; Smeets and Faaij 2007; Resch *et al.* 2008; de Vries *et al.* 2009; Ladanai and Vinterbäck 2009; Seiffert *et al.* 2009; Ceciliano 2010; Verbruggen *et al.* 2010; Jacobson and Delucchi 2009 and 2011). A general feature is

that the total RES potential exceeds all present energy demand. It is clear however that bioenergy supplies are also finite and there are limits to their sustainable use (Running 2012).

It is important that the benefits beyond business profitability can be significant. The money presently flowing along wires and with tankers to oil producing countries, for instance, would have significant benefits if it stayed 'at home' and contributed to the regional added value (monetary aspects, reduced costs, increased purchasing power, new employment, tax income, social, ecological and ethical aspects). *"Each € not spent on imported fossil fuels, and instead spent on a regional bioenergy project can have a multiple effect"* (Hoffmann 2009). RES also generates more jobs than conventional energy (Hillebrand *et al.* 2006; Lehr *et al.* 2008; Moreno and López 2008; Thornley *et al.* 2008; Blanco and Rodrigues 2009; Hoffmann 2009; del Río and Burguillo 2009; Openshaw 2010; Sastresa *et al.* 2010; Dalton and Lewis 2011; Masini and Menichetti 2012).

Empirical evidence shows convincingly that the material preconditions and main elements of a feasible economy for SE exist globally. The other justifying arguments for intentional promotion of SE have included the following:

- Depletion of fossil energy supplies (e.g., Jefferson 2008; Hall and Day 2009) and the need for new replacing sources of energy;
- Highly positive environmental impacts, including a substantial decrease in, and in some cases even total avoidance of, CO₂ and other greenhouse gas emissions, based on which RES is an integral part of IPCC (IPCC 2012);
- Strategic and national economic benefits from creating improved energy self-sufficiency, independence and security;
- New opportunities in the development of technology and the manufacturing industry;
- The liberation of energy markets enabling smaller scale units to operate in a new way.

This has given rise to the vision of dichotomy in the energy sector, introduced in Article III. Summarizing, dichotomy in the energy sector means division into two parallel systems, (1) the prevailing centralized and (2) the new anticipated distributed structure. With the RES supplies abundantly available and the feasible economy it is natural that new RES-based power generation units will be initiated and established, which to an ever-growing extent already happens. The next step in this evolution is to develop and establish regional systems based on RES from the regions themselves and to organize them into independent entities, for instance according to the concept of micro grids. 100% RES systems have already been studied, initiated and planned in a number of places (Lund 2007; Lund and Mathiesen 2009; Lund *et al.* 2011; Mathiesen *et al.* 2011; Connolly *et al.* 2011;

Ćosić *et al.* 2012; Deng *et al.* 2012). In a timeframe of 10–30 years these kinds of single, separate changes will increase in number so that the evolution will result in larger scale structural changes, according to the vision.

There are also other positive signals for a more widespread SE, like the general perception, social acceptance (e.g., Wüstenhagen *et al.* 2007) and development of related policies (REN 2011a and b), the evolution and diffusion of perspectives of technology – according to a recent analysis the share of RES in energy production could grow to cover 60% of all energy by 2050 (Lund P.D. 2010). All this implies that the development towards dichotomy of the energy sector might even be unavoidable. Despite the positive signs, there still are barriers for the diffusion of SE, including the following, corresponding to the 3L layers:

- Institutional opposition: the prevailing large actors tend to prevent any development not supporting their own business (Lund H. 2010; Choice awareness theory), implying that RES-based solutions are fighting against existing energy structures.
- Diffusion of RES-based technologies: the diffusion of SE and the establishment of larger RES-based systems means a change from fossil fuels to the use of new raw materials requiring not only new technologies but also innovative institutional frames (Unruh 2000 and 2002; Jacobsson and Johnsson 2000; Bergek 2010; Wolsink 2000; 2007; 2012a; Lezczynska 2011). The shift towards these structures, different from the prevailing centralized system, will be a long-term diffusion process which requires at least the following:
 1. The innovation must be accepted by key social actors.
 2. The process must be ‘structured’ so that laws, regulations and other institutions support them, or at the very least do not oppose them.
 3. Innovations must evolve technically.
- Slow technical evolution: RES solutions are in the early phases of diffusion, but concurrence always takes place in real time markets, where the opponents are at the opposite end of their diffusion. This means that they are competing against technologies with many years of operation and technical evolution, where investments have been repaid, supportive social structures are in place and where all the benefits of mass production and established value chains exist. The development has mainly been focused on separate technologies and small units, where the integration of technical and economical optimization with regional economies and infrastructures has been defective. Motivation in R&D has also been defective, as the connection to larger meaningful entities has been insufficient.

The process of change towards SE will be a long evolutionary process, which will need to involve the majority of people, from individual citizens, families, farmers and businesses, to the public sector. The success of this process depends primarily on how the different levels engage and which crucial stakeholders approve it

(Wüstenhagen *et al.* 2007). Logically, the next step in this evolution is to create conscious programmes for intentional promotion of SE.

3.6 Research Objective 5

To understand and add knowledge about how intentional conscious change can be promoted and implemented at regional level in the energy sector.

Although “... *sustainability in a fundamental sense is connected to the survival of our species*” (Chichilnisky 2012), it is important to develop SE in line with all other ‘normal’ business criteria, such as economics, operations, quality and sustainability. SE is however not normal business and cannot be understood merely as economic transactions and ‘business as usual’. “... *unsustainable practices have become a problem (...) because we are using world resources to the limit*”, but the constraints involved by sustainability criteria “... *do not exist in neoclassical decision criteria*”, and “... *we need new economic foundations that update classical economic thinking*” (Chichilnisky 2012). Simultaneously, it is essential that any new power plant or project is economically feasible. All operations take place in real time markets and concurrence cannot be avoided.

The construction of the energy infrastructure has typically been subsidised by public funding and public bodies. Privatization of power plants and networks (originally publicly built or subsidised) has still not led to free markets based on equal competition, which would be a precondition for classical economic decisions to be made “...*without a ‘constraint’ for sustainability*” (Chichilnisky 2011). The development of the energy infrastructure is still led by political decisions, and general rules of the game define what is or can be profitable in the energy sector. Today most regulations still support the prevailing actors and systems, and there are a number of structural barriers for newcomers trying to introduce sustainable energy to the market. For instance, in 2011 subsidies to fossil fuels were \$523 bn globally, but only \$83 bn to renewable energy (IEA 2012).

Therefore, decisions to support the development of SE are essentially strategic ones, and they are directed towards creating a stable business environment.

The RESGen project was an attempt in this direction. It was an example of how SE can be boosted and implemented at a regional level. The main approach for this has been through the development of comprehensive regional strategies, which integrate all the main stakeholders (authorities, industry, R&D bodies; ‘triple helix’) into regional programmes, so that the development is rooted in the regions. The project introduced the RESGen procedure developed within the pro-

ject, which aims to support regional implementation of SE. It comprised the following phases:

- Development of regional strategies based on the regional characteristics (regional SE, capacities and capabilities) and today's priorities;
- Development of Vision and Roadmaps to 2020.

All regions followed the procedure, and the project resulted in four regional Roadmaps, one for each region. The Roadmaps were clearly defined project programmes for future implementation after the project. The regions had their own priorities based on regional characteristics, which caused natural differences in the details of the procedure. Stakeholder involvement was very high in all regions, and all main stakeholder groups, including regional authorities (municipalities, regional councils), R&D bodies and industries, were represented in the Roadmap work. In practice the procedure worked well, and together with the involvement it created an excellent base for commitment and implementation of the Roadmaps.

The innovation of the RESGen procedure was two-fold. It integrated new approaches and methods with previously well-known tools (e.g., SWOT) into an easily applicable system, and it was applied in a novel branch in order to develop a bottom-up strategy and implementation of SE. Systematic management is essential because the SE reform is a comprehensive social process involving all stakeholders. The procedure provided regional stakeholders with a 'platform' for structured discussion and ensured commitment. The project reinforced that public awareness, attitudes and trust, stakeholder commitment and functioning of the decision-making system are vital for successful implementation of SE. The procedure revealed positive facts that usually are not known or expected, but it also revealed institutional opposition and negative attitudes against SE, thus making the barriers and bottlenecks visible.

There is clearly a call for 'rules of the game', in order to reduce uncertainty in the business environment for SE. The RESGen procedure provided a systematic tool enabling unified development for all regions. The experiences suggest that the procedure could be appropriate for a more widespread use: a unifying and integrating factor or actor can bring together stakeholders, which all have positive attitudes towards SE but none of them could act alone or organize the regional procedure. Thus, the RESGen, or some corresponding procedure can assist in initiating and launching integrative programmes for implementing strategically important issues, like SE. The existence of this kind of tool may encourage regional programmes and thus promote the implementation of SE.

3.7 Implications for Future Research

Logical framework and research objective 1

The logical framework was reinforced by the thesis reasoning. The anticipated potential crisis, without remedying actions, can be a turning point for the whole of humankind. It requires comprehensive changes and self-reflection of the society, according to Fig. 1. In order to construct a solid base for the changes, there must be both a new kind of knowledge and a new kind of praxis. This will be a comprehensive global challenge and it will be vital to develop:

- New philosophy of survival,
based on multi-scientific evolutionary understanding and integration of the relevant phenomena;
- New strategy for survival,
based on development of sustainable praxis, including sustainable energy.

The main research challenges arising from this logic concern the societal changes and their dynamic, and the interfaces of how societies affect the environment and how environmental issues are reflected back to the society. As part of this, it is also essential to outline the ways and impacts of putting the ideas into practice. These all are global challenges that can be responded to by comprehensive programmes where scientific communities, authorities, politicians and practitioners are involved. As suggested by the 3L model, someone must take the initiative, but among the core success factors will be a high level coordination of the process and integrated implementation of the praxis.

The other more detailed and smaller scale implications for future research arising from this dissertation are listed below in brief.

Research objective 2

The three layer model (3L)

3L is an evolutionary scenario for understanding the mechanisms, features and dynamics of societal changes. It has however not been tested scientifically except for the evidence and discussion in this thesis. 3L should be exposed to a full scale scientific testing, before it can be called a 'theory'. This testing should follow the principles of conceptual integration (the pre-existing other scientific theories, including those not mentioned here), dialectical reasoning, multi-scientific horizontal programmes discussed in this thesis.

3L, critical incidents and the energy sector

The energy sector is experiencing a fundamental change, which is a social process. This provides an excellent new process that can give new insight

towards the 3L model – it can be tested in terms of the reform in the energy sector, and what kind of role the critical incidents play in this process.

Research objectives 3, 4 and 5

Dichotomy of the energy sector

The vision of dichotomy anticipates structural changes within the energy sector as a result of accelerating implementation of RES-based technical solutions and regional systems. According to the vision, there will emerge a new distributed structure to form the other part of the dichotomy besides the prevailing centralized system. This reform would have significant impacts especially on the societal role and welfare of rural areas, but also there would be large national and regional effects. This vision has not been tested empirically. In order to test the vision and form it into a theory, including more detailed contents, a research programme should be launched.

Diffusion of SE

Detailed knowledge concerning the diffusion of SE technologies and systems according to the problems defined in the diffusion of innovation literature would reveal the fundamental characteristics of the processes, especially in comparison with the normal diffusion processes. Thus, research on the diffusion of SE would be highly beneficial and a natural part of the ‘new survival strategy’.

Technical evolution

It is clear that the implementation of SE requires relevant and applicable tools, namely functioning technologies. They can only be developed by creating long-term R&D programmes for assisting enterprises in their product development. Technology development and specifications are by themselves however not enough: it will be necessary to create preconditions for understanding (and also for stabilizing) the business environment, and development of the whole value and supply chains, including raw materials and fuel production for RES-based energy production, for instance.

Systemic development

The main part of the technical evolution has concerned single, separate RES-based technologies. The real significance for SE comes however first when there are meaningful entities for application and implementation. This implies that there will be a fundamental call for a systemic level of expertise – this will only be achieved via conscious intentional research programmes and knowledge creation processes, which besides technical details also include approaches for business, regulation and social acceptance.

Regional added value

The concept of regional added value has only recently been defined, and there is reasonably little research concerning the values beyond pure business values. It would however be essential to understand the total value of SE for regions, for instance, it would probably be among the main motives and stimulators for creating regional implementation programmes, contributing importantly to the ‘new survival strategy’ from a regional perspective. The first phase in this would be a comprehensive research programme.

4 CONCLUSIONS

“... we by no means rule over nature like a conqueror over a foreign people, like someone standing outside nature – but that we, with flesh, blood, and brain, belong to nature, and exist in its midst, and that all our mastery of it consists in the fact that we have the advantage over all other beings of being able to know and correctly apply its laws.”
Friedrich Engels 1971

This dissertation is the result of a long and longitudinal research and knowledge creating process, with conceptual integration and dialectical reasoning as its cornerstones. The logical framework has been designed according to a genuine constructivist approach: it is based on zooming from large-scale thinking – philosophy and world view – towards smaller scale issues, first in order to understand, then to deepen knowledge through research, and finally implement the findings in practice. It searches for solutions to clearly explicated problems, which makes the context for the research and avoiding gathering loose or disconnected pieces of knowledge.

The logical framework was reinforced by the thesis, and the main conclusions relating to the five research objectives were the following:

Research objective 1

To understand and add knowledge about humankind’s limits of existence, and to structure the consequences.

The whole reasoning from the views presented by Malthus to the modern demographics and scientific evidence about climate change and other environmental deterioration leave us with the only possible conclusions: infinite growth in a finite world is not possible, the limits of existence are really approaching and humankind is in danger. No more time should be spent on arguing whether or not these problems are real, but instead devote all efforts to solving the problems in practice. There is a severe and scientifically based call for a collective global programme for sustainable development.

Research objective 2

To understand and add knowledge about the needs and the fundamental mechanisms, features and dynamics of societal changes and cultural evolution.

The three layer (3L) model is an evolutionary scenario and hypothesis which is based on conceptual integration of several separate, independent scientific theories, all reinforcing and complementing each other. Each theory has its own role and function as parts of the whole model, and they have been used as presumptions explaining certain sections of 3L. Being a macro-level theory, 3L simplifies the dynamics and omits for instance the numerous feedback loops that are natural

for any societal systems. This thesis finds empirical evidence to support the model from the evolution of environmentalism and the energy sector. Some 15 years after the invention, the thesis' author steadily supports it, with the claim that at a general level 3L catches something fundamental about cultural evolution, and it can be seriously tested as an evolutionary scenario of social evolution.

Research objective 3

To analyse and structure the development in environmental issues in general and the reforming energy sector in particular.

In the course of its over a hundred-year history, environmental protection has developed from an issue promoted by single, separate thinkers to general environmental consciousness, and from the ideology of national parks towards sustainable development and ecological modernization of society. There has been a shift from the protection of areas towards an active environmental policy, and a shift from ideology towards a new practice. In terms of 3L, this evolution can be summarized as follows: the social base of societies has evolved to include environmentalism and sustainable development as integral parts of their social norms. Presently, supporting structures and motives like ideologies, policies, regulations and institutions, market behaviour and operational patterns are widely supporting sustainable development. Practical responses have evolved from denial and institutional opposition towards new technologies and technical evolution, new strategic thinking and new societal patterns.

It seems clear that similar phases can be identified in the evolution of the energy sector towards SE. This evolution in terms of 3L can be summarized as follows:

Social base

The idea of SE has pierced the society, with the exception of institutional opposition by the prevailing structures protecting their own business or some other interests;

Supporting structures

Institutionalization of SE is an on-going societal structuring process, including international, national and especially regional policies, market acceptance and promotion of SE-based industries; regulations are developing, but still there are barriers and structural hindrances for SE and support for fossil energy-based solutions;

Practical response

Technical evolution is proceeding, mainly for separate solutions for RES-based production of energy, but regional (100% RES-based) systems are just emerging in the scientific literature and practical testing.

Research objective 4

To test empirically the potential of sustainable energy and to understand and add knowledge about its future impacts in a wider societal context.

Empirical evidence shows convincingly that the material preconditions and main elements of a feasible economy for SE exist globally. This has given rise to the vision of dichotomy of the energy sector. Summarizing, dichotomy in the energy sector means division into two parallel systems, (1) the prevailing centralized and (2) the new anticipated distributed structure. In a timeframe of 10–30 years, these kinds of single, separate changes will increase in number so that the evolution will result in larger scale structural changes, according to the vision. This vision needs to be further tested by empirical research.

The process of change towards sustainable energy will be a long evolutionary process which will need to involve the majority of people, from individual citizens, families, farmers and businesses, to the public sector. The success of this process depends primarily on how the different levels engage and which crucial stakeholders approve it.

Research objective 5

To understand and add knowledge about how intentional conscious change can be promoted and implemented at regional level in the energy sector.

It is important to develop SE in line with all ‘normal’ business criteria, such as economics, operations, quality and sustainability. SE is however not normal business and cannot be understood merely as economic transactions and ‘business as usual’. It has typically been subsidised by public funding and public bodies, there are no free markets based on equal competition, which would be a precondition for classical economic decisions. Therefore, decisions to support the development of SE are essentially strategic ones, and they are directed towards creating a stable business environment.

The RESGen project was an example on how SE can be boosted and implemented at a regional level through comprehensive regional strategies, which integrate all the main stakeholders. The project reinforced that public awareness, attitudes and trust, stakeholder commitment and functioning of the decision-making system are vital for the successful implementation of SE. The procedure revealed positive facts that usually are not known or expected, but it also revealed institutional opposition and negative attitudes against SE, thus making the barriers and bottlenecks visible. There is clearly a call for ‘rules of the game’, in order to reduce uncertainty in the business environment for SE.

The RESGen procedure provided a systematic tool enabling unified development for all regions. The RESGen, or some corresponding procedure can assist in initiating and launching integrative programmes for implementing strategically important issues, like SE: a unifying and integrating actor can bring together stakeholders, which all have positive attitudes towards SE but none of them could organize the regional procedure alone. The existence of this kind of tool may encourage regional programmes and thus promote the implementation of SE.

The world will undoubtedly face comprehensive changes in the near future, requiring self-reflection of the society, according to Fig. 1. This can be a turning point for the whole of humankind, but in order to construct a solid base for the changes, there must be both a new kind of knowledge and a new kind of praxis. This will be a comprehensive global challenge and it will be vital to develop:

- New philosophy of survival,
based on multi-scientific evolutionary understanding and integration of the relevant phenomena;
- New strategy for survival,
based on development of sustainable praxis, including sustainable energy.

These all are global challenges that can be responded to by comprehensive programmes where scientific communities, authorities, politicians and practitioners are involved. Summarizing, the human being as a species must free itself from its evolutionary instinct of maximal material needs and create a new 4S (strong societal sustainability strategy) to its ESS (evolutionary stable strategy). Knowledge and cultural evolution “... *is actually the only driving force to the development of civilization*” (Dolgonosov and Naidenov 2010).

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ARTICLE I

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FROM IDEOLOGY TO COMPANY PRACTICE
– THE ORIGIN OF OPERATIONAL PATTERNS
THROUGH SOCIAL SELECTION

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ABSTRACT

This paper describes a macro level theory for understanding the process from emerging new ideas to operational patterns. It filters and structures through this theory environmental and occupational safety management (EM; OSM) and their integration, which contribute to productivity and quality, but lack an overall theoretical background.

The theory distincts three processes: **Social base** develops in a mechanism where single separate ideas, subject to social selection, become more generally accepted, form the general opinion, and finally social norms, which control society as unwritten laws. **Supporting structures** prepare motives for bringing the idea to practice. Legislation and regulations cause obligatory *normative* motives, changed customer behaviour gives rise to *market based*, social pressure to *societal*, and efficiency and quality thinking to *operational* voluntary motives. A total philosophy may develop into an *ethical* motive. **Practical responses** start from avoidance, alleviation and separate technical improvements and develop strategies. Macroeconomic models at the level of society are future aspirants.

The first two processes have reached their final stages in both EM and OSM. The future trend will most likely be a search for integration and synergy between sectoral strategies and operations within companies. According to the theory, integration at regional and society's level will follow this trend.

1 INTRODUCTION

This paper is an outcome of the project “Environmental and Occupational Safety Management” financed by The Finnish Work Environment Fund, Employment and Economic Development Centre of Ostrobothnia, and ESF (EU). The starting point was to introduce the justifying theoretic arguments for integrating EM and OSM. In the background there is the well-known and widely accepted fact that the new practice of EM in enterprises has developed without a general scientific framework (e.g. Linnanen 1998). The integration seems practically reasonable and has also been suggested earlier (e.g. Dennis 1997), but it has no theoretic base, either.

The main purposes of this article are to:

- outline a macro level theory for understanding the process from emerging new ideas to operational patterns and practice
- filter and structure through this theory EM and OSM and their integration, which contribute to productivity and quality, but still lack an overall theoretical background
- to prepare the most likely future scenario.

The approach in this article is *horizontal, multidisciplinary and integrative*: new kinds of philosophy and cross-scientific theories giving rise to new syntheses are necessary for the following justifications:

- The specific issues – EM and OSM – can not be properly understood without being aware of the evolution of their themes through the whole century. They are late practical implications in long social processes, and they deal with a wide spectrum of expertise, e.g. technology, economy, strategy, and motivation of personnel of private companies, to name but a few.
- The world will face comprehensive changes in the nearest future: Deterioration of the environment will be a threat to survival of the whole mankind. Environmental damages and overexploitation of natural resources have intensively been observed and often modelled specially since the 1960's. The state of the world can now reliably be documented even through official statistics (e.g. Brown 1991–1998, Brown *et al.* 1993, Meadows *et al.* 1993). This has also been accepted by business leaders (e.g. Schmidheiny 1992). We live in a risk society (e.g. Beck 1990), where one accident can deteriorate a whole continent, and where countless small risks make an ungovernable entity.
- A new social contract for science will be necessary “*to move toward a more sustainable biosphere*” (Lubchenko 1998). It will also be a challenge for democracy in general (Lafferty and Meadowcroft 1996a) and e.g. the European integration process (Lieberink *et al.* 1993). Unfortunately there is no complete model for preserving the earth, although the idea of sustainable development with its interpretations provides guidelines (Schmidheiny 1992).

So far, none of the disciplines or science as a whole has been able to produce neither a structured analysis nor a satisfactory picture of the “man – nature (resources)” relationship. We have a history of winners and (over) exploitation which, until recently, has been counted as a great achievement, as resources have been considered unlimited (cf. Buttel and Taylor 1992, Ponting 1992, Massa 1994, 1998, Bowler 1997). It is also striking, that it is the newly emerged practice of EM that has created the need for a new kind of knowledge – it has not been planned or predicted by science.

This can be understood in the light of the history of science: The direction in science has been from general towards detailed knowledge and specialisation, and from philosophy towards specialised disciplines and even new branches of science. The volume of ever more detailed information has expanded explosively. This has created strong barriers, which isolate the generally accepted “real” science from the “discriminated grey zones” between disciplines. The integrative approach has met with the academic dilemma of the grey peripheries between vertically isolated disciplines. Researchers who move across disciplinary fences put their careers at risk (Metzger and Zare 1999).

Environmental science has traditionally been governed by natural sciences (e.g. Massa 1994, Bowler 1997), which is clearly insufficient for today’s needs. Environmental sociology (e.g. Buttel 1986 and 1987, Laska 1993, Catton 1994, Massa 1994, Redclift and Benton 1994, Hannigan 1997) prepared the ground for the *second environmental science*, introduced in early 1990’s mainly by sociologists (e.g. Massa 1994, 1998). This horizontal approach has been anticipated to show the way to the next paradigm shift or revolution in science (Massa 1994). Presently, there are signs of a more general acceptance of this approach. Instead of merely adding sociology along with natural sciences, all branches of science should be included in this horizontal, multidisciplinary and integrative program (see also Hahn and Simonis 1991).

2. THEORY

2.1 Structure and Dynamics: The Three Layer Model (3L)

The theory consists of three successive and interactive layers (Figure 1), which have their own evolution and dynamics:

- 1 **Social base** develops in a mechanism where single separate ideas, subject to social selection, become more generally accepted, then form the general consciousness and opinion, and finally social norms, which control society as unwritten laws.
- 2 **Supporting structures** prepare motives for bringing the idea to practice. Legislation and other regulations cause an obligatory normative motive, changed customer behaviour gives rise to market based, social pressure of the environment to societal, and efficiency and quality thinking to operational voluntary motives. A total philosophy may develop to an ethical motive.
- 3 **Practical responses** start from avoidance and separate technical improvements and develop into strategies and integrative practices.

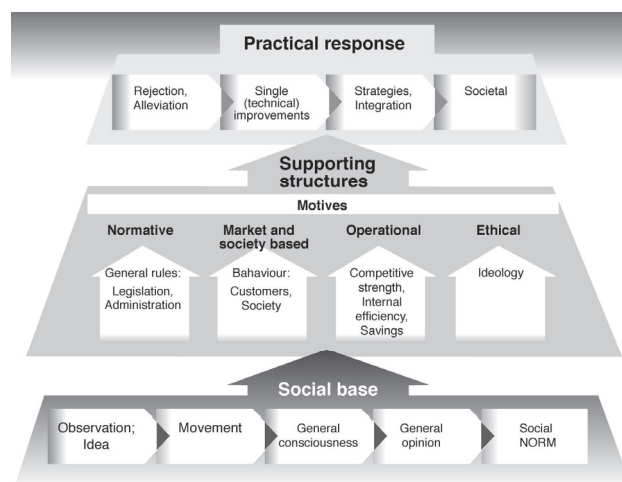


Figure 1. Structure of the 3L theory. (Graphics: Gunilla Ahlholm).

The fundamental thesis of the dynamics in the 3L theory is *dialectics between details or parts and the whole* like individual and society, or idea and norm. All eras in the history have had norms, structures and practices of their own. It always seems impossible to change the current prevailing system, especially by individuals. But still, history has shown that all these layers have been replaced one after another. The key question here is: How does the change emerge, and what is its mechanism? Or in terms of dialectics: How does one detail gradually become prevailing in the whole?

The 3L theory suggests that:

- norms, the social base and mental development make the primary factor in the start and dynamics of change,
- the change always starts from a variety of ideas, generated by individuals and inspired by nuisances, defects or other inconveniences of the prevailing system,
- deviating or nonconformist ideas always emerge in the social context under actual prevailing norms, structures and practices, and the great majority of ideas never overcome the old ones,
- the continuous conflict between new and prevailing thoughts is solved in the *social selection* process, which will show how well and generally accepted the new ideas become,
- the generally accepted anomalies accumulate, encourage new ones and finally force the old paradigm to give way to a new one,
- the new winning thoughts are reflected in a change of rules and other supporting structures,
- all general operational patterns and practices have developed in a long process, which ensures that they are socially accepted and follow the norms.

According to this, history would be a continuous chain of waves or cycles, which follow the 3L mechanism. All prevailing systems at their times have inspired deviating thoughts which gradually have disproved, discredited and finally replaced the current ideas, and given rise to renewed structures and practices, and progress.

2.2 Social Base:

Sociality is a specific feature of man. An individual grows up as a human being only as a part of a community. Life in the community is controlled by social norms, which make the rules for behaviour of single individuals. The social control tends to eliminate deviating behaviour. However, there are no societal collectives, which like living organisms consciously would decide and dictate the rules for its members. The prevailing practices in communities and social trends and laws are a collective manifestation of behaviour of individuals (e.g. Kangas 1994).

In a stagnant situation, individuals seem to be submissive in the community, and for them it would seem impossible to consciously change the prevailing system in the society. But still, norms are continuously changing, although the thought of an independent creative activity of the community is logically impossible. Therefore, individuals in their insights produce the seeds for all newness. There is a dynamic process of the dialectics between individuals and society.

In the society, a great variety of unconformist thoughts are generated, giving rise to anomalies against the prevailing norm. The main part of these differences will be excluded under the societal pressure. For a *certain* given thought a change may never come true; it may vanish or be left in a marginal minority. But *some* of them will be accepted. This process will encourage new supporting observations and ideas, and cause an accumulation of anomalies.

Gradually, the *single* deviating observations and thoughts will overcome the old norm, and finally a new *societal* pattern will be established (cf. the structure of scientific revolutions; Kuhn 1994).

This process of **social selection** is directed towards a variability of single thoughts and ideas generated by individuals, and the selection pressure is societal. Its main phases are:

- single observations of defects, deviating and unconformist ideas and anomalies against the prevailing norm,
- observations and the ideas become more common,
- the first phase of societal activity: formation of groups, coalitions and movements ready to fight for the idea,
- formation and strengthening of general opinion,
- confirmation of the social norm: an unwritten law, which controls the behaviour of the whole society.

There is a continuous conflict between new ideas and the prevailing norm, as change always will be a redistribution of gain and loss (cf. Lafferty and Meadowcroft 1996b). The selection pressure and the controlling strength of the norm depends on in which phase this cycle is. A newly established and strong norm will be effective in excluding deviations. At the other end there is a state without norms at all, when the “rational choice” (e.g. Uusitalo 1986, Kangas 1994) would be a maximisation of individual gain.

In the modern society of “supernetworks” norms are about to be nearly global, and one individual would experience it hopeless to attain changes (Massa 1995). On the other hand, here the awareness of new thoughts can spread quickly. In the society of insecure truths also the behaviour of small groups may turn to fashion (cf. Massa 1995).

2.3 Supporting Structures

The norm or mental base of society is impaired without a corresponding practice. History has shown that generally accepted ideas have found their practices. However, the rational choices made by individuals do not self evidently follow the norm or what would be good for the society. General rules and other supporting structures are necessary to prepare the ground for putting the norm into practice.

The development of supporting structures is classified according to their motives:

- Normative motive:
Legislation and other regulations establish new general rules, administration will be readjusted to new conditions, and follow-up and research will be reoriented
- Market based motive (for enterprises):
Customer behaviour changes, demands from clients become stronger
- Societal motive (individuals):
Because of the new social pressure and behaviour of other people, the new thinking becomes more attractive
- Operational motive:
Internal effectivity, quality, productivity and competitive strength in terms of the new thinking will take over in enterprises;
Adjustment of own activities to the new thinking
- Ethical motive:
A total philosophy or a way of thinking will be established in the society

Legislation and other regulations make the only obligatory motive. However, signals from markets normally have a strong impact on enterprises, and for instance direct demands in subcontractor chains or from clients are usually practically obligatory. The societal pressure tends to eliminate differences, which may be difficult to maintain without proper motivations or justifications. Operational effectivity, for instance by avoiding waste and structural loss, is a normal objective for both enterprises and private persons.

2.4 Practical Responses

Operational patterns are the final implication of development of the social base. There is a time lag between the mental development and practical responses, because general rules and other supporting structures are needed. The first reactions to new ideas are usually denial or understatement of the phenomenon or its impacts, and avoidance of disadvantages as they become obvious.

After the establishment of the first laws a new practice is no more voluntary. Through the other structures there is a social order and a motivation for progress. Typical features in the course of development are unpolicitation (cf. Jokinen 1995) and weakened interest movements, as the norms, laws and practices are more generally accepted. The voluntary development of more effective practical ways of realising the new idea will make fighting for them unnecessary.

Phases of the progress are classified as follows:

- rejection and alleviation: denial of the problems, avoidance, dilution
- single separate technologies and improvements for management of the symptoms
- strategy, integration and synergy: search for effectivity and competitive strength
- societal patterns: adaptive changes at the level of society, and structural changes

3 TESTING 3L: HOW DOES THE THEORY MATCH?

3.1 Environmental Management

Social Base

In the course of its over hundred-year history, environmental protection has developed from single separate thinkers to environmental consciousness and from the ideology of national parks towards sustainable development and ecological modernisation of society. There has been a shift from protection of areas towards an active environmental policy and a shift from ideology towards a new practice.

Environmental management is a recent practical implication of this process. Here, the development of social base is a necessary prerequisite, and the most important phases of it are the following:

- Single thinkers, mainly (natural) scientists, and writings as a reaction to the observed impacts and threats of industrialisation; the second half of 1800's
- A loose movement of environmentalists, mainly scientists concentrated in civilisation centres, and the ideology of national parks; until 1940's
- Expanding of the contents: cultural (aesthetic, scientific and ethical resources) and

social (recreation, health; for people) protection of nature; mid 1900's (e.g. Hustich 1937, Kalliola 1968)

- Radicalisation and pollution problems: environmental protection, polarisation of opinions, expanding in volume and achievement of social significance; from 1960's until now
- Establishment of a new public opinion, environmental policy and social norm (e.g. Uusitalo 1986, Buttel 1987, Tulokas 1990, Brechin and Kempton 1994), environmental conflicts; from late 1980's until now

This has been a long process, and it is clearly connected to damages in the environment and developments in society. Today, the theme environment with ever strengthening norms and other consequences is about to sweep over the whole society. History of environmental movements is described in some chronologies of early environmentalists (e.g. Primack 1993), some orientations to environmental history (e.g. Ponting 1992, Massa 1994, Bowler 1997) and some more structured analysis by environmental sociologists (e.g. reviewed by Buttel 1987, Buttel and Taylor 1992, Hannigan 1997). Today, environmental concern is a global phenomenon. It belongs to the most important values among *citizens* with similar patterns both in wealthier and poorer countries and regardless of whether the environmental problems are in-country or global (Brechin and Kempton 1994). Still, there are differences between *countries* (cf. Buttel and Taylor 1992), e.g. many poorer countries have not ratified the Earth Summit agreements.

There has been a continuous conflict between the new developing norms and the old ones. The main reasons (according to sociological analysis, reviewed by Sairinen 1994) for conflicts are:

- misunderstanding and lack of trust, which are matters of knowledge
- deviating (mainly economical) interests, as all changes mean redistribution of gain and loss (also Lafferty and Meadowcroft 1996b)
- different values, which are affected by knowledge and interests

The equilibrium has been continuously changing: the new environmental norm has become stronger, and many fundamental societal changes have taken place. Achievements – supporting structures and practical implications – have made the traditional environmental movement even less necessary. Indeed, there is less environmental activism in the form of local conflicts now than in late 1980's. This has sometimes been misinterpreted as a neoliberalist and conservative feature in the environmental movement (Rannikko 1994): there is no need to fight for what you already have achieved! More likely, it is one implication of the fact that the social base of environmentalism has become stable.

Supporting Structures

The development of supporting structures of environmentalism can be characterised as an accelerating progress from the first Nature Protection Acts in the beginning of this century toward institutionalisation and international integration of environmental protection, new customer and societal behaviour, and environmental ethics. Enterprises have not had their part in this development until recent years, but environmental protection is probably the most significant factor, which has changed the operational prerequisites of private companies during the 1990's.

In the following, this process has been described based on motives classified in the 3L theory:

- Normative motive
During the last 20-30 years the normative base of environmental protection has expanded enormously: There is a comprehensive compilation of legislation and international agreements, which in the EU are harmonised in Member States. Also voluntary activities have their own regulations. Also, the state and municipal administrations, and expert and follow-up organisations have been established. There is a shift from voluntary to official environmental protection and institutionalisation.
- Market and society based motive
The logic of economy and competitive strength through markets, general opinion and common practice encourage and even force enterprises to develop their environmental standards beyond the level required by legislation. Environmental management is becoming a central criterion when assessing the value and the responsibilities of enterprises. The social pressure and politics affect individuals, as well.
- Operational motive
Search for internal effectivity and the most advantageous way of operation is reflected both at individuals' and companies' level. Direct reduction of costs, avoidance of risks, motivation of personnel etc. belong to the objectives of environmental management in companies.
- Ethical motive
Ethics is usually an implication of a total world view or philosophy and it affects at least the behaviour of individuals. Companies, on their part, have an economic dilemma: an investment, for instance, may be an "irrational choice", if it results heavy costs and a weakened competitive strength.

A company, as the core of its production chain, is the starting point for the development of environmental motives (Figure 2). The first laws established general rules just for companies. Along with time, norms and the other motives have expanded their application area toward the ends of the production and consumption chain. Simultaneously, the motives have been accepted and established more deeply in business ideas inside the companies. The motives are moving from the core toward the circle of the left hemisphere in Figure 2.

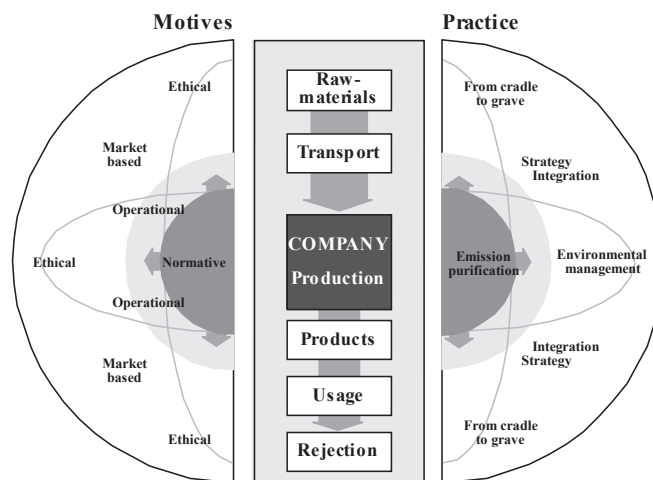


Figure 2. Environmental motives and practices in a production chain.

Practical Responses

The practical development of environmental protection has been similar to that of motives (Figure 2). It started, after accepting that the problem exists, from pollution prevention measures for the “core” company. Today, they are about to be replaced by new strategies, and several new approaches have been introduced. Environmental impact assessment, environmental audit, accounting and statement, life cycle approach and environmental management systems are new concepts, the contents of which have not yet been fully established. Although voluntary, these new strategies are in the process of developing into organised systems, and methods for their standardisation are under development. Environmental protection is becoming inseparable from the administration, activities, and the image of enterprises.

The development of environmental protection practices (here modified after Hahn and Simonis 1991 and Sairinen 1994) has identical phases with the classification suggested in the 3L theory (Figure 1):

1 Avoidance, alleviation: *The “high chimney” phase*

The principle was to distribute pollutants evenly to a larger area, by elevating the emitting chimney or prolonging the sewage pipe. Although it has been clear for a long time that “dilution is no solution to pollution” these answers to environmental problems are still in use (e.g. Hahn and Simonis 1991).

2 Single separate techniques: *The “end of pipe” technology*

The second answer was “technical treatment after the fact” (Hahn and Simonis 1991). The aim was to meet the legal requirements for pollution prevention by purification devices for exhaust fumes and sewage, waste incineration, controlled dumps, storages for nuclear waste etc. These devices were typically separate from the organisation of the enterprise; they usually created an extra liability for the economy of the enterprise. Moreover, they cannot really solve the problems but only shift them regionally. Until today, this has represented standard answers to environmental protection of enterprises (cf. Hahn and Simonis 1991).

3. Strategies and synergies: *Technical prevention* (Hahn and Simonis 1991), *Preventive environmental policy* (Simonis 1989, Sairinen 1994)

The third level of development aims at minimising the use of raw materials and energy, and production of waste and emissions by utilising technology and planning. This approach demands establishing cycles or partially integrated systems. Environmental policy deals with larger units and creates strategies. Changes of legislation, the pressure for change as well as the strengthening of other motives in environmental protection have given rise to great turmoil in environmental strategies and methods: These techniques and approaches are spreading quickly today.

4 Societal patterns: *Preventive techniques and concepts with socio-ecological principles* (Hahn and Simonis 1991), *Ecological modernisation* (Spaargaren and Mol 1992, Sairinen 1994) and *structural changes* (e.g. Jokinen 1995)

“A real solution to the environmental crisis is possible only when the social and cultural dimensions (...) are incorporated” (Hahn and Simonis 1991). It would mean ecological restructuring of processes of production and consumption (Spaargaren and Mol 1992). Reaching this phase requires major changes in the society and culture (cf. Sairinen 1994, Jokinen 1995).

Today, the process culminates in EM of enterprises in two ways. First, EM as an *independent* operation is developing rapidly. New handbooks have been published (e.g. Winter 1992,

Hutchinson and Hutchinson 1997), and scientific and practical literature is expanding (reviewed e.g. by Linnanen 1998). However, there is still lack of structure and cohesion. The development has, so far, been based on several but various and separate methods. There are two standard procedures, EMAS (Eco Management and Audit Scheme) and ISO 14001 but only very few really useful tools. This is problematic for especially smaller enterprises, which are having difficulties, as they only can utilise tools developed by others. Second, EM is becoming an *integral part* of competitive advantage and business strategy of enterprises (e.g. Newman and Hanna 1996, Linnanen 1998, Pun *et al.* 1998). Changes in the philosophies of production economics have resulted along with quality thinking several documented systems, which without integration make an ungovernable whole. Integration is the next on-going step: *“To sustain competitiveness, firms need to strategically plan and integrate EM concerns into their business operations and performance. The total quality environmental management (TQEM) philosophy merges the total quality concepts with EM. It can integrate the adoption of green manufacturing to attain continuous quality improvement”* (Pun *et al.* 1998).

“Health and safety” and “avoidance of injuries and damages” are among the factors and criteria of green manufacturing and TQEM adoption as well as the TQEM implementation model (Pun *et al.* 1998). Also the total quality management approach in general includes occupational safety management (e.g. Dennis 1997, Mattila 1997, Linnanen 1998, Pekkola 1998, Kekäle 1998), which therefore belongs to the industrial integration process.

3.2 Occupational Safety management

Social Base

Up to the end of the 1940s, society’s concern for health risks usually focused on those factors that could decrease the risk of infectious diseases. This was appropriate since these were the greatest hazards. However, beginning in the late 1940s, after having eliminated many of the truly serious threats to health, our attention began to be diverted to other, lower risks and the management of these. Occupational safety has developed in parallel with the industrial development and has in many countries become a natural part of most activities in the society. As in environmental protection, the trend has been to shift from personal protection of the employees towards better work places, inherently safer designs, and a better safety culture.

OSM has developed from the insight that there usually are several underlying reasons for occupational accidents or ill-health. The recognition that a good safety management and a positive safety culture are important in order to minimise lost working hours has grown out of a social base characterised by the following phases:

- Single studies establishing causal links between adverse health effects and hazardous activities: During the 16th to 18th centuries, the basis for our current approach to health risk assessment became established. For instance, the study by Agricola [1556] linked adverse health effects to various mining and metallurgical practices, and the study by Sir Percival Pott [1775] indicated that juvenile chimney sweeps were especially susceptible to scrotal cancer. Despite these studies, progress toward establishing causal links between adverse health effects and different types of hazardous activities seems to have been exceedingly slow (Covello and Mumpower 1985).
- Accident investigation and learning from experience: The first known technical report

of an explosion that was based on the use of scientific methods is by Count Morozzo di Bianzé [1786]. His report is not only the first investigation of a work accident, but also the first suggestion of safety standards. In the 20th century, accident investigations and engineering standards are two of the cornerstones in accident prevention.

- Scientific programmes: During the early years of the 20th century, it became clear that the industrial revolution had been responsible for introducing health and safety hazards that were adversely affecting a large number of workers. Dozens of scientific papers appeared in the literature, which discussed various unique diseases observed in numerous workplaces.
- Organised occupational health and safety activities: Beginning in the 1930s the need to protect humans from the adverse effect of chemicals in the workplace and the environment became a commonly recognised goal in Europe and the United States. The systematic management of occupational health and safety was developed in the beginning of the 20th century. For instance, the Safety First-movement developed amongst the employers in the United States and Europe. However, the Safety First movement did not seem to resolve the basic problem of the labour in industry. The labour unions took an active role in, for instance, introduction of laws against child labour, forbidding juveniles and women to work in unhealthy professions, and in organising summer holidays for everybody.
- Technical development: As a result of the strong technological development, many occupational health and safety problems could be solved by technological means. Automation was introduced and the production systems became increasingly complex. During this process many traditional work opportunities were lost. This development has put increasing demands on the remaining workforce. This can today be noticed, for instance, as stress symptoms and psychosocial problems.
- Management of occupational safety issues: The responsibility of the employer to manage the different risks of his activities in a holistic way developed. Many problems have now been managed and have become the norm in many parts of the world, some battles are, however, still ongoing. For instance, the use of child labour is clearly condemned in the western world, but still western companies buy goods manufactured by children in small firms in the developing countries. Also, changes in the society have created new occupational safety and security problems especially in the growing service sector.

Analogous conflicts as in the environmental field are valid for occupational safety problems, too. The fight for occupational safety improvements has diminished, as has the environmental activism. Again, this is probably one implication of the fact that the social base of occupational safety has become more stable than before.

Supporting Structures

The development of supporting structures for occupational health and safety has mainly been characterised by the role played by laws and regulations. But also standards covering everything from equipment design to safety management have been developed. Exposure values for chemicals have been agreed. Risk analysis and assessment techniques have been established. Accidents have been investigated in order to identify the need for improvement. Finally, the private sector has found that a well motivated work force is an import asset and a prerequisite to achieve a competitive advantage. Here, the process has been shortly

described based on the motives given by the 3L theory:

- Normative motive
In Finland, for instance, the period prior to 1923, occupational health and safety was generally of the enlightenment type with the goal of informing both employers and employees about the first Finnish labour protection act [1889]. The safety inspectorate was the main information provider. The next period (1923–1945) was a period of new occupational health and safety regulations. The last period (1989–) has been characterised by the many EU Directives that have been implemented into Finnish law.
- Market and society based motive
Insurance companies started educational programmes directed towards accident prevention – in Finland in the 1920s. This stage was the beginning of both technical and educational accident prevention. Increasing competition in the markets has shown that accidents have an adverse effect on the business, not only are they expensive, but lost market shares and a destroyed image are difficult to regain.
- Operational motive
In the beginning of the 20th century the major industrial companies recognised the positive connection between occupational safety and productivity, but it took several decades before this connection became generally accepted. The operational motive led to a strive towards undisturbed production by informing and educating the labour force and by the introduction of more reliable equipment and techniques.
- Ethical motive
It will be the task of future research to establish if ethical motives are currently increasing or decreasing in importance. Today, globalisation involving “faceless” company owners seems to decrease the understanding of local needs. The demand for ever increasing profits seems to have left the well-being of the workforce in its shade. Also, activities not allowed in some countries due to the associated occupational health and safety problems are transferred to countries where the activity is still allowed. This can be seen as unethical behaviour.

Practical Responses

The practical development of occupational safety has been analogous to that of environmental protection. Again it started from labour protection for the “core” company (Figure 2). Today many companies tend to buy their raw-materials from reliable and well-established sources, they use engineering firms that are aware of applicable regulations, norms, and standards, they train the employees of sub-contractors working on their site and the customers buying their products, etc. The four phases suggested in the 3L theory (Figure 1) can be identified in the occupational safety field, too:

- 1 Avoidance, alleviation: *The phase of adopting man to the workplace*
Here the occupational health and safety problems were minimised not by changing the working conditions but by choosing the most suitable group of people to carry out the tasks needed. For instance, women and children were selected for certain jobs, men for others. There was also the belief that some persons are more accident prone than others and that this was the reason why they were injured at work (and not the working conditions).
- 2 Single separate techniques: *The phase of protecting the labour*
The principle was mostly reactive: After an unsafe act had occurred, training was provided in order to prevent the same accident to recur, and if unsafe conditions had been identified,

technical improvements were implemented for each problem in turn.

3 Strategies and synergies: *The safety management phase*

The prevailing system in industry is based on safety management. Occupational health and safety organisations have been introduced in most workplaces in order to promote a participatory approach in OSM. The launching of the concept of "organisational accident" (Reason 1990) has been of crucial importance for the development of safety management systems in companies. In the development of an organisational accident, the story starts with the organisational factors: strategic decisions, generic organisational processes – allocating resources, planning, communicating, managing etc. The consequences of these activities are the local workplace factors – control rooms, human-machine interfaces, training, manning, and the like. These local conditions may shape or provoke individual or team unsafe acts leading to accidents. Employers have seen the advantages of managing the latent conditions in a holistic way. The demands from quality assurance, environmental protection, financial risk management, and occupational health and safety, etc. have influenced this development. In Europe, the management of safety have shorter traditions than in the USA. In fact, phrases describing "an internal control of safety" were introduced as late as in the 1980's, starting in Norway and Sweden.

4 Societal patterns: *The safety culture phase*

The most progressive companies are currently moving towards a safety culture phase. The effects of the work force on the safety level have often been underestimated. However, factors like risk taking, skill level, training, motivation and commitment to the safety policy of the company significantly influences the safety level reached. It has therefore been recognised that OSM, i.e. to establish safety targets and means to reach these, is not enough to achieve a safe workplace. The opinions and attitudes of the employees are of major importance as they to a great extent dictate how well people adopt the targets set and the ways to achieve these. Skilful leadership can alter the behaviour of people in order to achieve a good safety culture in the workplace. The focus of occupational health and safety has shifted from the implementation of the control of technical details in a direction that takes social norms, individual preferences, and voluntary actions into consideration.

3.3 From Evolution to Modernity – or Beyond?

The basic axiom of 3L is the *evolution theory*, according to which, for instance, man is a product of a long gradual development process. Evolution consists of successive phases or levels, each of which is a prerequisite for and actuates the next one. Still, every level of evolution has *new emerging characteristics* typical only for it. That is why the qualitative steps from level to level are impossible to explain by reductionist views (e.g. Laihonon *et al.* 1986). The process as a whole resembles a pile of transparencies, where the upper pages can not exist without the underlying ones: all pages have their own (emerging) figures, but all the earlier phases are reflected and can be seen as parts of the whole.

The driving force and the motor of progress in evolution is the mechanism of *selection*. Communities always generate a considerable variability, which provides material for the selection. Certain parts of the variability will be excluded by enemies and hostility of the environment, or favoured or excluded by the community itself. The equilibrium will be collective manifestations, which can be seen as species, or, for instance, according to 3L, operational patterns.

The 3L theory suggests that:

- the development of human societies is in line with evolution theory and makes the level of *cultural evolution* (cf. Laihonen *et al.* 1986),
- the fundamental procedure unifying the different levels of evolution is the *selection mechanism*,
- in cultural evolution the selection pressure is *societal* (instead of natural selection in biological evolution).

There have been several attempts to apply the concepts of ecology and evolution into explaining societal phenomena since evolution theory was presented, starting from Herbert Spencer (1820-1903; reviewed e.g. by Buttell 1996, Gronow 1997). Actually, sociology and ecology had a close relationship in the late 1800's: The newly presented evolution theory and strong ecological thinking had a significant influence on the development of the classical theories of sociology (Durkheim, Marx, Weber). On the other hand, sociological theories were partly counteractions to evolutionist views (e.g. Spaargaren and Mol 1992). Since then, and mainly until recently, these disciplines have had their histories apart from each other.

The formation of the social base of environmental protection has brought these disciplines near to each other again. The importance of environmentalism has been reflected in the theoretic development as well as in political and public discourse. Manifestations of this have been for instance:

- the societal views of socio-biology, started by Wilson (1975), and subsequent mainly popular, even "vulgar", public debate (reviewed by Laihonen *et al.* 1986),
- the gradually expanded traditions of human ecology and environmental sociology (e.g. Buttell 1986 and 1987, Spaargaren and Mol 1992, Catton 1994, Massa 1994),
- the new environmental economics (Raumolin 1995).

After a hundred years of isolation and specialisation, the "reunion" has been characterised by confrontations between ecologists and sociologists, anthropocentric and ecological views, and self-sufficiency and dependency of man on the sustenance base. Socio-evolutionist, deterministic, neodarwinist and reductionist views of society have been criticised and rejected correctly. However, it is a general feature that the fundamental characteristics of evolution, described above, have (intuitively or in lack of proper knowledge of evolution) been neglected or misinterpreted when applying the ecological or evolutionary concepts to broader contexts. Therefore, their critics are not valid for the 3L theory, either.

Today, environmental aspects are about to be integrated into the modern sociological theories of industrial and reflexive modernisation (Spaargaren and Mol 1992, Massa 1995, Beck *et al.* 1996). "*Ecological modernisation seems to be the general concept that describes this growing consensus*", it is "*An ecosocial restructuring of the technosphere, (...) an ecological switch of the industrialization process into a direction that takes into account maintaining the sustenance base, (...) overcoming the environmental crisis without leaving the path of modernisation*" (Spaargaren and Mol 1992). Also production philosophies and practices are integrating environmental aspects (e.g. Newman and Hanna 1996, Pun *et al.* 1998).

But the question is, if only technical reforms will be enough! The quantity of people, volume of activity, and technical possibilities of exploiting the resources are expanding, while the carrying capacity of the environment is declining. The hand of man touches every part of the globe, and raw-material reserves and the sustenance base have proved

limited. All global statistics (e.g. Brown 1991-1998, Brown *et al.* 1993) and calculations (e.g. Meadows *et al.* 1993) show an explosive growth of human impacts. They resemble the classical curves of animal populations introduced to islands, where they have no competition. If the curves are bravely followed, they show a rapid collapse of the population. It will be a test of humanity for man to avoid this collapse.

4 CONCLUSIONS

The 3L theory introduces a new synthesising framework for understanding the dynamics and development of operational patterns in society. It is an orientation among countless phenomena and details towards the deep essence on a macro level. Therefore, it creates a unifying cross-scientific theory of a mechanism, which is analogous to all phases of development. Instead of being an oversimplification or “a conceptual hybrid” (cf. Spaargaren and Mol 1992), 3L suggests a hierarchy of theories: Overall frameworks enable the understanding of large entities and systems, like a wide angle lens views a whole scenery. All the details can be seen logically in their places, and they can be zoomed, even microscoped correspondingly by micro level theories. The necessity of this kind of new philosophy arises from two main justifications:

- practical needs to preserve the earth and the sustenance base of society,
- scientific needs to understand the information produced by isolated and specialised disciplines of science.

According to the 3L theory the development of human societies, *cultural evolution*, is in line with evolution theory, the unifying mechanism being the social selection. The fundamental characteristics of evolution have been neglected or misinterpreted when applying the evolutionary concepts to broader contexts. Therefore, their critics are not valid for the 3L theory. Today environmental aspects are about to be integrated into the modern sociological theories as well as production economics.

At the macro level, 3L creates an overall understanding which allows environmental and occupational safety management to be logically structured. EM is a milestone on the way from environmental concern in the 1800's to ecological modernisation in the 2000's. OSM, in turn, is a narrow practical “slice” of improving working conditions, for instance supporting the tradition of labour movement. The present practical strategy of entrepreneurship culture and organising working arrangements is to integrate EM and OSM into quality management. Processes of the social base and supporting structures have reached their final stages in both EM and OSM, but the practical development is still unfinished. The future trend is most likely to be a search for integration and synergy between sectoral strategies and operations within companies. Integration at regional and society level will follow this trend, according to the theory.

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ARTICLE II

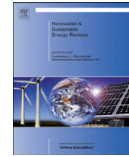
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From Malthus to sustainable energy—Theoretical orientations to reforming the energy sector

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ABSTRACT

The main purpose of this article is to consider macro level theories for understanding the urge for reform as well as the process of societal change both in general terms, and more specifically within the energy sector. The aim is also to consider the energy sector in a wider context and analyse its recent development as a potential part of this reform. The scope and logical framework of this article is the following: The state of the global environment is approaching a point where the whole of humankind is in danger. The article reviews and discusses humankind's limits of existence and dialectics of the human–nature relationship by contrasting Malthusian and Boserupian theoretical views. This creates both practical and scientific needs. The long societal process of change is discussed according to the three-layer (3L) model of societal change.

The production of energy has traditionally been one of the core issues concerning the effect humankind has on the environment, and with regards to potential change related to it, reforming the energy sector is in a key position. This article reviews and discusses the way the already established renewal of the energy sector corresponds to the 3L model, and the diverse potentials of the anticipated further progress.

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1. Introduction

"Man must stop pollution and conserve his resources, not merely to enhance existence but to save the race from

intolerable deterioration and possible extinction." New York Times editorial, the day after the first Earth Day 1970.

Environmentalism became a popular and global discourse already in the 1960s, and the basic ideas and claims of modern environmentalism were presented half a century ago. The ideology of natural parks and nature conservation already had a long history back then, dating back to the latter half of the 1800s. The

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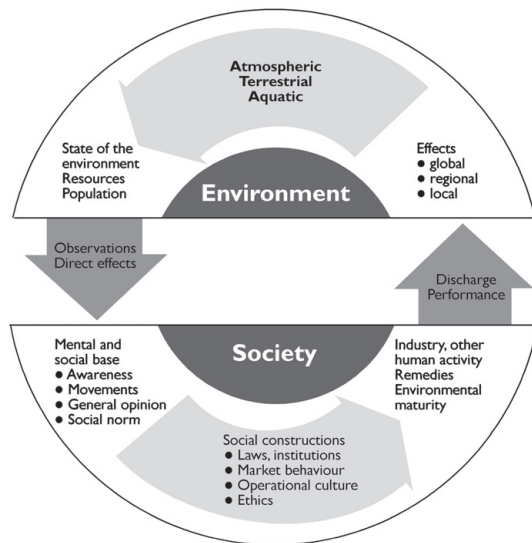


Fig. 1. Dynamics between the environment and society.

real wakeup calls were, however, the classical works by Rachel Carson (*Silent Spring*, 1962) and Barry Commoner (*Science and Survival*, 1966; *The Closing Circle*, 1971), accompanied by a number of famous writings by, for instance, the ecologists Garret Hardin (*The Tragedy of the Commons*, 1968) and Paul Ehrlich (*The Population Bomb*, 1968), David Pimentel, Howard Odum, John Steinhart, George Woodwell, Kenneth Boulding and Herman Daly to name a few American authors [1]. The main ideas were crystallised in *The Limits to Growth* [2].

These texts were followed by writings, debates and discourses about industrialisation, pollution and even “doomsday prophecies”. In the course of its over a hundred-year history, environmental protection has developed from an issue promoted by single separate thinkers to general environmental consciousness and from the ideology of national parks towards sustainable development and the ecological modernisation e.g., [3] of society. There has been a shift from the protection of areas towards an active environmental policy and a shift from ideology towards a new practice e.g., [4,5].

Strong waves of environmentalism swept over societies across the world, and the idea of pollution prevention and nature protection became more generally accepted. The success of the environment theme resulted in new societal demands and reactions, for instance the establishment of the official environmental protection administration, and the ideology of sustainable development.

Environmental damage and overexploitation of natural resources have been observed, modelled and documented intensively, including in official statistics since the early days of environmentalism e.g., [6–13]. In present day discourse, the main problems are crystallised in the problematic of climate change [14], preceded by discussions and concerns that concentrated on pollution problems mainly from the 1960s and acidification from the 1980s [15]. However, all these are details within a more comprehensive whole of a general unsustainable way of living of human beings.

Writings and discussions about the scarcity of resources and sustenance base, and the survival of humankind decreased, even disappeared, sometime in the early 1990s, as new large oil reserves continued to be found. There have been different views and opinions at different times, depending on the specifics of each situation. New oil reserves moved the problems aside. However, lately the issue has become topical again: “*The world today faces enormous problems related to population and resources*” [1], and “... the world is facing so many challenges that a paradigm shift is needed, and this will inevitably include a development towards a sustainable biobased economy” [16], which is “... a great challenge for sustainability at the planetary scale” [17].

Despite some scepticism e.g., [18] and a number of errors in research details [19] the big picture and conclusions have not changed [20]: Deterioration of the environment will be a threat to survival of the whole of humankind. We live in a risk society e.g., [21], where one accident can deteriorate the living conditions of a whole continent, and where countless small risks make an ungovernable entity. Human beings’ ecological footprint is continuously increasing; it exceeded the natural carrying capacity already in the 1970s and reached an ecological overshoot of 44% in 2006, resulting in an ever-growing sustainability gap [13,22]. The loss of ecosystems also means a reduction in natural buffers for e.g., self-purification abilities [13], and the cost has been estimated to exceed 14 trillion Euros and a 7% loss in global GDP in 2050 [13,23]. To a large extent, it has been accepted that (1) the problems are real, and that (2) the main cause is human activity.

This means that the world will undoubtedly face comprehensive changes in the near future, and these changes will be so large that according to a number of authors a new social contract, involving both science and praxis, will be necessary – as stated by the Science already before the Millennium – “to move toward a more sustainable biosphere” [24]. It will also be a challenge for democracy in general [25] and for instance the European integration process [26].

Many approaches and practical tools have already been introduced. These have been supported by a strong general opinion, which has developed into a social norm, forcing enterprises to join the process. However, there is no complete model for preserving the earth, although the idea of sustainable development with its interpretations provides some guidelines e.g., [27]. Still around the year 2000 the praxis consisted of single separate methods resembling pieces mixed up in confusion without a vision of the whole puzzle. Until today, the approaches and tools for measuring and monitoring [28], selection, design, application [29] and assessment [30] of sustainability have clearly attained strategic and practical relevancy.

Traditionally energy production has been one of the core issues concerning the effect humankind has on the environment. This is also why “*climate policy is principally, but not exclusively, energy policy*” [31]. In the “big picture” it is part of the dynamic interaction between society and the environment, as illustrated in Fig. 1 [32]:

- human activities, such as energy production (Society; lower half) have an effect on ecosystems (Environment; upper half), on different scales and in different habitats. The effect can be measured as discharge (arrow from “Society” to “Environment”);
- the impacts can be seen in the state of the environment, usage and sustainability of resources, well-being and growth of the population. Examples of these impacts include acidification and climate change;
- the impacts are reflected in society through observations and direct effects (health, state of the environment; arrow from

Table 1

World population (millions) since 1800.
Sources: [9,37–39].

Year	Population
1800	900
1860	1200
1900	1625
1950	2500
1987	5000
1999	6000
2011	7000

“Environment” to “Society”), with harmful effects calling for change;

- societal change geared towards removing the problem is a long and complicated process, where the development of social norms precedes practical responses.

When understood as a temporally developing system, this spiral corresponds to the concept of social self-reflection, introduced by modern sociology [33]. Energy production is part of a system representing a significant share of the interface between the environment and society and it is where the rules of the game are dictated as a societal process.

The main purposes of this article are:

- to consider macro level theories for understanding the urge for reforms and the necessary responses to the processes of societal change;
- to consider sustainable energy in a wider context and analyse its recent development as a potential part of this reform.

The scope and logical framework of this article is the following:

- The state of the global environment is approaching a point where the whole of humankind is in danger. In Section 2 this article reviews and discusses humankind’s limits of existence and dialectics of the human–nature relationship. The discussion takes a macro theoretical and multidisciplinary perspective.
- This creates practical needs – real actions will be necessary – but above all, it creates a need to develop scientific understanding. Section 3 in this article discusses the need for new kinds of philosophy and cross-scientific theories giving rise to new syntheses. Also, in this article the approach is horizontal, multidisciplinary and integrative.
- Change will be a long societal process, and it will be essential to understand the characteristics and dialectics of the process. In Section 4 this article presents and discusses the three-layer model (3L; presented earlier by the author [5]) of societal change.
- The production of energy has traditionally been one of the core issues concerning the effect humankind has on the environment, and in the process of change, the potential reform of the energy sector will, therefore, be in a key position. This article reviews and discusses (Section 5) the way the already established renewal of the energy sector corresponds to the 3L model, and the diverse potentials of the anticipated further progress.

2. From unlimited growth to sustainable development?

“Finite resources imply that population must eventually stabilise. Our only choice is to control it consciously, humanely

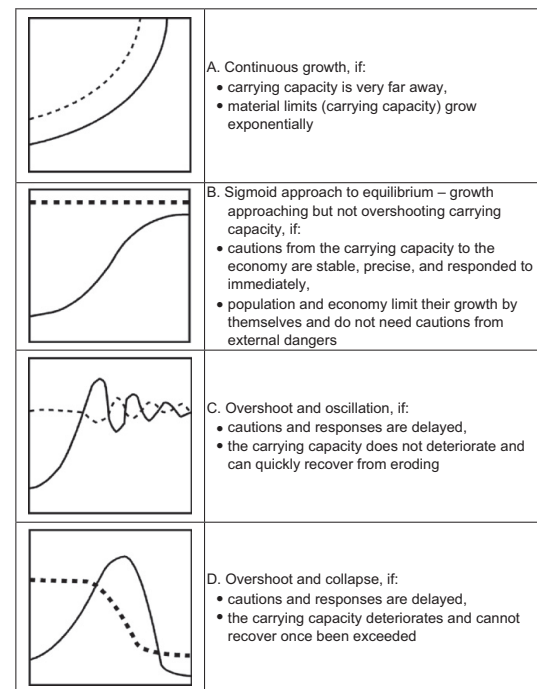


Fig. 2. Schematic alternatives of population development (dotted line=carrying capacity, solid line=population and economy; source: [8]).

and democratically or to wait for real limits to do it for us.”
—Blake Alcott, 2012 [34].

2.1. Population growth and carrying capacity

The deterioration of the environment has only now begun to be accepted as a real threat to humankind globally. Despite the vast tradition of research, monitoring and observations since the 1960s, it was only when the first alarming signals of climate change appeared that changes happened in the political sphere. Pollution, discharge and population growth are only one part of the problem, being the most visible and easy to understand and measure. Depletion of the sustenance base, poverty and other more subtle economic disturbances are among the impacts that are more difficult to assess and judge as being caused by environmental deterioration alone.

However, it is important to realise that one of the main factors behind it is population growth. For example computational exploration of integrated assessment models reveals an almost one-to-one correspondence between population and productivity growth assumptions, the degree of climate change, and the optimal response to climate change. Continued growth greatly increases the severity of climate change. Fortunately this also means that reductions in the growth rate of the population can be effective in controlling climate change [35].

Population growth has been accelerating in history until the early 1970s (Table 1), but today also a smaller growth percentage means about 90 million new people every year e.g., [36]. Population growth rates

- never exceeded 0.5% per year until 1750
- never exceeded 1% per year until 1930
- never fell below 1.5% in 1950–1995
- reached their all-time peak of 2.1% per year around 1965–1970, being far higher in certain regions (e.g., developing countries in Africa and Asia; [9,36])
- have decreased in 2000s to their present level of below 1.2% per year [37].

A widely used concept in demography is the **doubling time** of population. Its estimate is 69.3 divided by the relative change (percent; rounded to the nearest 0.1 year; exact: $\ln 2 / \ln(1 + \text{growth percent})$). According to this an increase of only 1% per year means that the population doubles in ca. 70 years. It sounds like a paradox that if the annual global population growth rate was only 0.0007%, the population would be about 6 trillion in 10000 years. If the populations continued to grow in each major region of the world at the rate observed in 1995, then the population would increase more than 130-fold in 160 years, to about nearly 700 billion in 2150 (examples by [9]).

The human population growth curve has always, but in recent times in particular, been much steeper than exponential or logistic growth curves. In some areas growth has been slow, but in others explosive. The growth has been very fast during the last decades especially in developing countries [9]. Between 1990 and 2010 the world population has increased by 30%, most rapidly in Nigeria (62.4%), and Pakistan (55.2%). In comparison with these figures, however, the 2000s have been encouraging, as the growth rates have declined considerably, the figure now being below 1.2% per year globally [37,39].

It is an axiom of ecological economics that resource depletion and environmental pollution depend on the size of the population, and on the amount of goods and services each member consumes, modified by the technological efficiency of production [34]. The basic demographic formula $I = PAT$ implies that there are certain critical factors that affect the impact (I) that human societies have on the environment. The population (P), its level of affluence (A) and the technology as efficiency (T) are factors that depend on the demographic characteristics of the area, which may change over time. The main point of emphasis, however, is that population size remains a relevant factor when it comes to environmental sustainability, although and as the formula enables, the other factors may include conscious operations towards sustainability (cf. [34]).

The significance of population growth is always intertwined with carrying capacity, not only of each region but also globally. Schematic alternatives of the relationship of population growth or its fluctuations and carrying capacity are illustrated in Fig. 2. It is widely accepted that the carrying capacity of the environment sets the limits for population growth [40]. Its quantification is problematic, however, as the human carrying capacity is “*the estimated maximum number of people who can live ... long, healthy, self-fulfilling lives*” [40]. The concept is far from being universally consistent, as no exact limits can be set, and decisions related to social carrying capacity are normative and social ones [41].

A number of world models have tried to analyse this relationship e.g., [2,8,9]. Cohen [9] reviewed more than 65 estimates of the global human carrying capacity, the earliest from 1679, and the latest from 1995. The estimates vary from less than one billion to more than 1000 billion. A considerable part of the computations “... are based only on the capacity of the earth to feed mankind, with no consideration of any other problems and questions after raw materials industrialization and pollution” [42], being therefore estimates of how many people can live off the earth, not on the earth.

Most estimates suggest that the maximum supportable human population could go up to 10–15 billion, while the highest estimates would “allow” as many as 10 or even 100 times more. Strikingly the estimates are increasing, despite modern demographics, along with newer models. Still, the most frequent estimates place the limit between 4–8 and 8–16 billion, more than half of the estimates between 4 and 16 billion, half of the estimates below 12 billion and three quarters below 30 billion [9]. On the other hand, as Smail has suggested more recently, “*these limits may already have been reached (or soon will be)*” [46].

According to all models analysed by Ghirlanda et al. [53]) “a population capable of maintaining a large amount of culture, including a powerful technology, runs a high risk of being unsustainable”. Estimations require more than a demographic arithmetic: it is hardly conceivable that all humans could have exactly the same living conditions, for example, equal nutrition. The question is about human choices that are yet to be made by this and the future generations. Because the human carrying capacity of the earth is constrained by the facts of nature, for instance, human choices are not entirely free and may have consequences that are not fully predictable [9,44,45,53].

As well as the number of people, also the volume of human-kind’s activities and technical possibilities of exploiting the resources are expanding. Simultaneously the carrying capacity of the environment is declining [45,40,34]. Today, all global statistics and world models e.g., [8,9,47,48] show an explosive growth of human impacts. They resemble the classical curves of animal populations introduced to desert islands, where they have no competition (D. in Fig. 2). If the curves are allowed to run their course, after the early success, they will show an overrun and a rapid collapse of the population because of the exhaustion of the sustenance base and carrying capacity.

2.2. Malthus and Boserup—The opposing theories

This problematic is analysed in the following section using two influential themes in macro-demographic theory [9]:

- 1 the **Malthusian** one: the population equilibrates with resources mediated to some level by technology and a conventional standard of living. Thomas Robert Malthus (1766–1834) was a political economist whose writings, especially the “*Essay on Population*” (first published in 1798 [49]), have “...generated more misunderstanding and personal vilification than any comparable figure in the history of social and political thought.” [50]
- 2 the **Boserupian** one: (1) agrarian population growth is compensated by migration to new areas, and (2) technological change is itself spurred by increases in the population.

Ester Boserup (1910–1999) was a Danish economist and sociologist, whose writings about the interrelationships between economic, demographic, and technical change e.g., [51] have had a major impact over the last quarter century on the evolution of thought in anthropology, demography, economics, and sociology.

Malthus was the first to bring all the ideas of population growth problems together in some kind of coherent theoretical system [9,50]. Human beings’ innate biological urge to procreate is stronger than their ability to provide the necessary food for the ever-increasing numbers of their offspring. This is true for any natural biological organisms, which are checked by natural systems, including nutrition and enemies. Human beings have a tendency to multiply their numbers faster than they can increase their food supply, too. The populations will or must be checked somehow from time to time—whether it is by famine, war,

Table 2
Malthus and Boserup in selected literature reviewed (edited by the author).

Source	Contents	Remarks
[54]	General: – material preconditions are primary for the well-being of human societies	Identical to Malthus
[56,55]	Unified growth model: – the economy evolves through a demographic transition resulting in reduced population growth and sustained income growth; – the Malthusian regime vanishes endogenously in the long run, reinforcing the importance (conscious or unconscious) human activities (culture)	Malthusian and Boserupian theories coexist
[43]	Models reviewed: – all models agree that a population capable of maintaining a large amount of culture runs a high risk of being unsustainable; – a variety of steady states are possible, Malthusian checks employed	Supports Malthus
[45]	Model; Lotka-Volterra application: –the course of the environment and population displays oscillations that do not lead to extinction—it still would lead to a significantly decreased quantity of population	Supports Malthus
[44]	Historical: – any factor that causes large resource depletion may lead to a general crises; – material preconditions are primary for the well-being of human societies	Supports Malthus
[57,58]	Historical: – a population may respond to a harsh environment by increasing yield via improved agricultural methods; – a society can only improve welfare by either increasing mortality or decreasing fertility”	Identical to Malthus; Boserupian theory coexists
[59]	Historical: – any technical improvement can only relieve misery for a while, for as long as misery is the only check on population, the improvement will enable population to grow– resulting in more people in misery; – no simple solutions are evident ... One must work at being sustainable	Identical to Malthus
[60,61]	Global; pre-historian data (1–1500 CE): – resource surpluses beyond the maintenance of subsistence consumption were channelled primarily into population growth; – societies characterised by higher land productivity and an earlier onset of agriculture had a higher density	Supports Malthus; dispels a non-Malthusian theory
[62]	8 European countries (1960–1998) – an increase in real output per capita: higher fertility – positive employment shocks: deterioration of fertility	Supports Malthus
[63]	Central Africa: – “... reduce the pace of deforestation ... caused by an agrarian system ... growing population densities” referring directly to the Malthusian dynamics; – propose the Boserupian theory for conscious actions, which “also has its limits and beyond these limits, Malthus will be right again”	Malthusian and Boserupian theories coexist
[64]	Côte d'Ivoire: – innovation has been largely able to compensate for the repercussion of increasing population pressure, which again seems to be unleashed after a critical population density is attained	Malthusian and Boserupian theories coexist
[65]	93 countries, 1975–1996: – population growth: increasing CO ₂ emissions worldwide; – the impact more than proportional (increase 1% in population, 1.42% in emissions)	Supports Malthus
[47]	Environmental: –technical evolution a necessary precondition but not sufficient alone, for achieving sustainability	Supports both Malthus and Boserup
[40]	Environmental: – carrying capacity can be redefined upward; – still there are limits, they just can be adjusted	Malthusian and Boserupian theories coexist
[46]	General: – indeed finite limits to global human numbers; – still time to choose whether this dramatic decrease will be under conscious control or essentially chaotic	Identical to Malthus
[66,67]	General: – the expansion of human activities causes decline in biodiversity, ecosystem resilience and buffering capacity, thus narrowing the scope of human adaptations – abrupt and irreversible ecosystem changes may lead to drastic drop in population	Support Malthus
[47,48]	General, cultural evolution: –not the reproduction rate but the collective experience of knowledge, habits and culture determine the population growth rate	Malthusian and Boserupian theories coexist
[34]	General; comprehensive review: –lower population growth can only help to alleviate poverty – regardless of one's estimate of future population size or carrying capacity	Supports Malthus; reviews also opposing views

pestilence, or voluntary “human methods”, is up to human beings to choose, according to Malthus.

Malthus’ principle of population [49,50] is shortly summarised below (Malthus’ moral restraint and other findings, many of which have been subject to a vast variety of debate, writings and critique ever since, are excluded here):

- Three propositions:
 - population cannot increase without the means of subsistence;
 - population invariably increases when the means of subsistence are available;
 - the superior power of population growth cannot be checked without producing misery or vice.
- The power of population growth is indefinitely greater than the power of the earth to produce subsistence:
 - the geometric power of population increase;
 - the arithmetic power of improvements in food production (neither of which were meant to be taken with mathematical precision, but rather as reasonable suppositions).
- The two unequal powers must be equated somehow: the preventive and positive checks are at work keeping the population down to subsistence;
 - preventive checks: means of voluntary restraint on birth rates (abortion, infanticide, prostitution and other ‘unnatural’ attempts to accommodate the constant passion between sexes);
 - positive checks: higher mortality rates and lower life expectancy (war, pestilence, and famine).
- Malthus proposed and believed in human beings’ capacity for reason and foresight to act as a preventive check, meaning a controlled future instead of an ungovernable and chaotic world with active positive checks.

Malthus observed that in the nature plants and animals produce far more offspring than can survive, and that human beings too are capable of overproducing if left unchecked. He concluded that unless family size was regulated, human misery produced by famine would become a global epidemic and eventually consume humanity. Malthus’ view that poverty and famine were natural outcomes of population growth and food supply was not popular among social reformers who believed that with proper social structures, all ills of humanity could be eradicated.

Although Malthus thought famine and poverty were natural outcomes, the ultimate reason for those outcomes was divine institution. He believed that such natural outcomes were God’s way of preventing human beings from being lazy. Both Darwin and Wallace independently arrived at similar theories of Natural Selection after reading Malthus. Unlike Malthus, however, they framed the principle in purely natural terms both in outcome and in ultimate reason. By doing so, they extended Malthus’ logic further than Malthus himself could ever take it. They realised that producing more offspring than can survive establishes a competitive environment among siblings, and that the variation among siblings would produce some individuals with a slightly greater chance of survival. This, in turn, is in complete analogy with the evolution of any species [52].

Malthus’ key expressions to underline are ‘capacity’ and ‘when unchecked’. He claimed that the power of multiplication has never fully been exercised or realised. On the contrary, he insisted that “... in no state that we have yet known, has the power of population been left to exert itself with perfect freedom”. In other words, he realised the power and the mechanism that could be changed by human beings: “... the sums of the various checks must be sufficient to neutralise the power of increase. (...) By promoting

(...) moral restraint we can reduce the sum of vice and misery which would otherwise be the necessary consequence of the operation of the principle of population” [49]. In a way, there is an equilibrium, the parts of which are changeable and replaceable. This gives human beings the opportunity to control their own future by replacing vice, famine, war and pestilence with planned human actions.

Ester Boserup presented “The Conditions of Agricultural Growth” in 1965 [53]. It heralded a breakthrough in the theory of agricultural development. Since then, it has also come to represent a more general technological optimistic view of world development, which is in contrast to Malthus’ thoughts. Whereas ‘development’ had previously been seen as the transformation of traditional communities by the introduction or imposition of new technologies, Boserup argued that changes and improvements occur from within agricultural communities, and that improvements are governed not only by outside interference, but also by those communities themselves. She concluded that technical, economic and social changes are unlikely to take place unless the community concerned is exposed to the pressure of population growth.

In sharp contrast to widely accepted earlier ideas, she showed how population growth might be the main stimulus to agrarian change. She identified successive stages of agriculture, characterised by differences in techniques of cultivation and social structure, and showed how they can be explained by differences in population density [53]. As a matter of fact, also Malthus was of the opinion that without the pressure of population upon subsistence, human beings would never have left the savage state, and if the pressure could be permanently abated, humans would sink back into a state of torpor and lose all the advantages of civilisation [50].

2.3. Malthus versus Boserup briefly reviewed and analysed

Due to the importance of the contributions of Malthus and Boserup to demographic theory, their works have been widely cited and referred to in scientific literature. Their ideas are often presented in opposition to each other in relation to topics ranging from population growth and carrying capacity to societal development. Due to the vastness of the area of application and volume of literature related to the Malthus–Boserup dichotomy, an exhausting review is beyond the scope and possibilities of this paper. In the following section, however, a brief review and analysis is given, based on some selected influential references. Some of the main contents have been collected into Table 2.

A dominant view has been that material well-being is of primary importance for human societies, and that social disturbances (including e.g., revolutions, economical chaos, famine, war, emigrations) have commonly emerged in connection with food scarcity caused, for instance, by climate and environmental change, overpopulation, overconsumption and bio-productivity fluctuations [44,54,45,59,65,61]. This is backed up by observations and empirical data regarding population growth and its relation with environmental deterioration and declining carrying capacity and sustenance base [40,34,46,65,62,56,61,66,67,41]. This is in line with the Malthusian view, according to which material preconditions set the limits of existence. These limits have been extended by the discovery of massive fossil reserves, giving human beings the impression that there are no limits at all [1].

Nobel Prize winner Richard Smalley (chemistry, 1996) reinforces this view in his ranking system of human needs (Fig. 3, [54], also [68]). Especially in the context of this paper, energy supply is considered of vital importance, as all other supplying systems depend on a secure operation of the energy supply. For example, poverty means limited or complete denial of access to

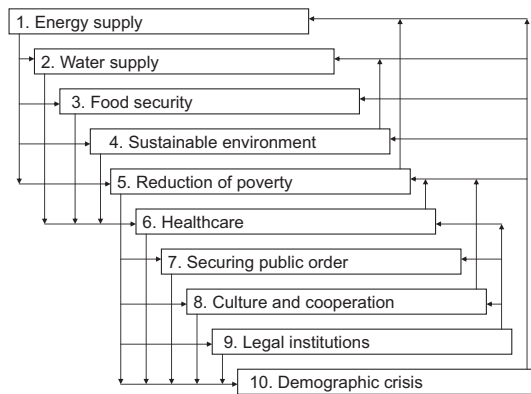


Fig. 3. The complex system of human preferences and global challenges ([68] according to [54]).

different supplies, and fighting against poverty in an isolated manner, in other words separating it from other priorities, would be ineffective in the long term due to unresolved energy, water, food, and environmental problems. Therefore, reforming the energy sector is a highly important challenge to be faced in the immediate future, and analogously it should be treated as a comprehensive societal process.

Another general notion concerns the complex interrelationships between population, its mobility and demographic transition, and environmental and societal change [40]: “*long-term sustainability depends on solving major societal problems*” [59]. This also refers to the possibility for conscious human choices and actions, even cultural evolution: The key might be “*collective experience (...) and culture*” [48] and development of information, which “*... obeys its own evolutionary laws (...) in successive stages*” [47]. The aspiration for technical reforms and more comprehensive societal development towards sustainability can easily be interpreted being in support to both Boserup and Malthus.

Alcot [34] reviews some views in opposition to those of Malthus, many of which, he reveals, are based on false interpretations or political motives (e.g., “no state-imposed population control”, “no population lobby”, “food availability and environmental scarcity no problems”, “the population bomb defused”). Neumayer [69], on the other hand, did not find empirical support for the neo-Malthusian view that fertility is kept in check by scarcities. The explaining factor may be the extent to which Malthus has been interpreted literally, e.g., “scarcity limits fertility” is not the same as to say “scarcity limits population”. Malthus’ postulation was that scarcity increases mortality via famine, war and pestilence, which would make Neumayer’s reasoning logical.

Analysed as single separate theories, the main conflict between Malthus and Boserup relates to scale, which can be described with the help of the dilemma of ‘vertical’ and ‘horizontal’ carrying capacity:

- the vertical carrying capacity, at a local or regional level, has been improved by means of e.g., the green revolution;
- the horizontal carrying capacity, at a larger scale, ultimately globally, has been utilised to substitute deficiencies on a smaller scale.

The limit of the environment’s carrying capacity has not, until now, been reached on a global level, and natural resources have

therefore seemed inexhaustible. There has always been a possibility to develop according to Boserup’s meaning. If one area or region has been exploited or emptied from resources and a sustenance base, there have always been other areas available. The “waterloo” of Boserup’s model is the situation where migration to new areas is impossible, and all replacing resources have already been utilised. In fact, Boserup’s theory is a model of no limits and it is valid only for single separate regions surrounded by unlimited resources and the possibility of migration and substitutions.

The global carrying capacity cannot be exceeded. When no further use of natural resources is possible, and when technical reforms will no longer be sufficient, and when substitutions through migrations or import are impossible, the limits will be met at a global scale. Here, the Malthusian thesis proves valid. Another question is when, at which point in time, will these material and technical limits be met? All speculative models indicate that it might take a couple of generations, but in any case it will be an extremely short time on a geological scale.

Despite the apparent differences, a number of authors, also cited in Table 2, have pointed out that rather than representing contrasting views, Malthus’ thesis and Boserup’s theory in fact complement each other. This has led to a new formulation of the Malthus–Boserup dichotomy: On the whole they explain the same thing, only on a different scale and from different points of view. The Malthusian perspective is a holistic one, in which all conscious endogenous self-reflections carried out by humans can be interpreted as “preventive checks”. On the other hand, while the technical improvements suggested by Boserup are necessary preconditions for achieving a sustainable civilisation, in the long term and within a global perspective they are by no means sufficient alone.

All positive changes boosting sustainability are not “conscious”, as they may also be the result of the population’s structural internal constraints, as, for example, the demographic transition towards both lower mortality and fertility [62]. Therefore, it is essential in the future to be aware of all the relevant aspects of the population dynamics. Or as Dolgonosov and Naidenov [47] wisely point out, the “demographic imperative” must be completed by an “informational imperative”, as knowledge and cultural evolution “... is actually the only driving force to the development of civilization” [47].

2.4. Robbery—The human pattern?

Theoretically and in order to escape from this trap it is not enough only to observe and analyse the end result of the process, but it is crucial to be aware of the pattern behind the behaviour. Environmental sociologists introduced the concept of *robbery* (started by Friedrich 1904, summarised by Massa [51,55]) to describe human activity in relation to natural resources throughout history. As defined by Massa [51], the economy of robbery is based on the overexploitation and carelessness of resources and the environment as well as not taking care of offspring or securing future availability of resources.

In environmental sociology the roots of robbery have been explored, in addition to texts by Malthus and Boserup, within the following theories, to mention a few [51]:

- the staples thesis (originally by Harold Innis, ref. [51]). The economic development and industrialisation of the peripheries (Canada in Innis’ writings) within the World economy has been based on exporting natural resources from the peripheries. These areas are connected to the world economy through staples products and centres—in other words peripheries act as resource pools for the wider economies. The search

for and exploitation of these staples led to the creation of institutions that defined the political culture of the nation and its regions. Innis argues that different staples led to the emergence of regional economies (and societies) within Canada.

- Ecological colonialism e.g., [51,71]. Resources have been exploited and resource pools have been emptied one after the other without any concern for the end results in those areas. It has always been possible for the exploiters to move to other pools. According to history this kind of ecological colonialism has been the established pattern in peripheral regions. It has been especially successful where political pressure and control has been the least.
- Societal incapability of ecological communication (originally by Niklas Luhmann, ref. [51]). The modern and differentiated society is seen as a fighting arena where the different sectors within societal sub-systems are struggling against each other without means of communication. The aim for a common good does not belong to any of the sub-sectors' codes. Lack of communication has resulted in a situation where everyone is trying to fulfil his or her own needs (as also stated in the iterated prisoner's dilemma, e.g., [72]).

The above analysis has explored the definition and criteria for robbery by looking at the end result: Human activity becomes robbery only when the exploitation of the environment exceeds a certain limit of quality and quantity, characteristic of robbery. This could be expressed simply as the intensity of the use of resources, as also the $I=PAT$ formula implies [34]. From this point of view, there are three main factors to be controlled:

- population and the level of its activity;
- technical capability and means of production;
- carrying capacity of the environment.

This means that whether the intensity of resource utilisation achieves the level of robbery depends on these "parameters", and for any given society only these prerequisites would define whether it is capable of robbery or not. It is logical to think that in terms of the above three parameters all societies would always act according to the robbery thesis whenever it was possible, leading inevitably to the conclusion that there must be a **pattern** which always produces the **end result** when it is possible. According to this thesis, the ideal of a life in harmony with nature is only an illusion as the possibilities for fulfilling the "internal insight for progress" are temporally and spatially insufficient.

There is a constant conflict between the common and individual needs, and without communication it is the personal needs, which take over. The same situation is also central in the evolutionary approach: It is clear that survival, improvement of fitness and maximisation of well-being have been the main strategies even in the early evolution of human beings. This has resulted in a pattern, according to which individuals – and without communication of individuals also communities – have striven for the maximal utilisation of their environment. It has most probably been one of the main advantages in human and social evolution. It sounds only logical that this has formed the mental sphere of humankind and the social norms of communities throughout history.

Nature and its resources have always been the source of livelihood for people, and this has also shaped human beings' relationship with their environment. It is understandable that this "bottom stream" in both individuals' and communities' collective mind has resulted in an established pattern at a societal level and within the whole of humankind. This suggests that the deeper essence of robbery ultimately lies in the evolutionary heritage of

human beings. Throughout history technical devices for the (maximal) exploitation of resources have been developed. This pattern, driven by the "internal evolutionary pressure", has continued in spite of high living standards and other achievements – resulting in the overexploitation of resources and environmental damage. "...during the course of human evolution, natural selection has given rise to certain core elements defining human psyche" [73].

From this point of view, the main challenge of humankind is to free itself from this pressure, make new conscious choices, create new evolutionary and stable strategies as well as societal rules, and launch a new praxis that makes the world sustainable.

2.5. Conclusions

History is full of examples of how formerly productive places and regions have been exhausted, permanently deteriorated and then abandoned, and the population has moved to reside in other places [74]. This has been possible as long as there have still been unoccupied places. But today the "hand of humankind" touches every part of the globe, and raw-material reserves and the sustenance base have proved limited.

The discovery of large oil reserves at the end of the 1900s had a significant effect on discussions and theoretical views. As Hall and Day [1] expressed, "... it seemed that technical innovations and resource substitutions, driven by market incentives, have and would continue to solve the long-term issues", and the limits were "... seen as invalid". It was also agreed that "Malthus's premise has not held between 1800 and the present". But Hall and Day also concluded that "... our exponential escalation in energy use (...) is the principal reason that we have generated a food supply that grows exponentially as the human population" and that "... since Malthus's time we have avoided wholesale famine for most of the Earth's people because of fossil fuel use"[1].

It was mainly the new oil reserves that created the illusion of limitlessness and technology optimism. The expansion of the world economies has nearly always increased parallel to an increase in the use of fossil energy, and when that energy has been withdrawn, the economies have shrunk accordingly. "Malthus could not have foreseen (...) through petroleum" [1]. Although many have considered the limits-to-growth model as a failure, Hall and Day "... are not aware of any model made by economists that is as accurate over such a long time span"[1].

These conclusions leave us with the fact that growth without limits is impossible in a finite world. "What is certain is that there are limits (...). This general statement is in complete accord with Malthus' view" [9].

There is neither a general agreement upon what the factors are that set the limits, nor is there a common shared opinion of the interactions between the factors. Especially the world models created by the Club of Rome have brought the idea of limits into the discussion and incorporated it into general knowledge: according to a very simple demography, it is clear that whatever the limits are, they will be reached quite shortly, maybe even in a couple of centuries [9,42].

The future of the Earth and of humankind is in the hands of human beings. All the choices **can** be made, on the one hand, and **must** be made, on the other, by humankind itself. This is also what Thomas Robert Malthus originally suggested, already over 200 years ago. Hence, there is a fundamental test of humanity for people: Which kind of praxis are people ready to accept to limit population growth and environmental deterioration, to avoid overshoot and collapse, and to consciously choose among alternatives other than D in Fig. 2.

3. Towards a multidisciplinary scientific understanding?

“In these days of specialization there are too few people who have such a deep understanding”—Feynman [75]

The urged change will in any case be a multi-task and a multi-branch exercise and an orientation for the future. This means that no single branch of science can understand, outline or solve the whole problem alone. For instance the reforms the energy sector must carry out are commonly seen to be primarily technical, and while technology is necessary for new energy solutions, the whole field must also be understood and managed economically.

Moreover, change is not possible without social acceptance in a wider perspective, at the level of general opinion. For example, in order to introduce a new single separate power generation unit, its acceptance by the local population is necessary. On top of this, change should involve industries and a number of stakeholders along the whole value chains of the new energy solutions. Among the prerequisites for the new solutions are new regulations, laws and other general rules of the game, or conversely, old solutions must be interpreted in a new way.

Still, this is not enough. Comprehensive reforms must be anchored in the political sphere as well. They must be integrated into the national and regional strategies, through which they are put into practice and managed. They have an impact on regional economies, employment, rural vitality, and environmental matters, to name some of the most important spheres. But the main point the list reveals is that reform consists of a comprehensive process of change, where a cross sector and multi-scientific know how, expertise, comprehension and other capabilities are necessary. Hence, multidisciplinary is of particular importance in the energy sector [70–72,76,77].

The last 100 years of history have demonstrated the difficulty of this kind of philosophical orientation. So far, no disciplines or science as a whole has been able to produce neither a structured analysis nor a satisfactory picture of the “human–nature (resources)” relationship. We have a history of winners and (over)exploitation which, until recently, has been seen as a great achievement, as resources have been considered unlimited cf. [51,74,78–81].

This can be understood in the light of the history of science: In general science has been geared towards detailed knowledge, and from philosophy towards specialised disciplines and new branches of science. The amount of detailed information in science has expanded explosively. This has created strong barriers, which isolate the generally accepted “real” science from the “discriminated grey zones” between disciplines. The integrative approach has met with the academic dilemma of the grey peripheries between vertically isolated disciplines e.g., [82].

Environmental science, for instance, has traditionally been governed by natural sciences e.g., [51,81], which is insufficient for today’s needs. Environmental sociology e.g., [51,82–88] prepared the ground for the *second environmental science*, introduced in the early 1990s by sociologists [51,78]. It has been anticipated that this horizontal approach will show the way to the next paradigm shift or revolution in science [51,89]; cf. [90]. Later there have been signs of a more general acceptance of this approach. Instead of merely adding sociology to natural sciences, all branches of science should be included in this horizontal, multidisciplinary and integrative program also [94].

Today, the progress of environmentalism culminates in practical measures of enterprises. Development is rapid, and environmental protection has become a part of the competitive advantage of enterprises. However, there are several severe problems. Changes of legislation, the pressure for change in the near future as well as the strengthening of various other motives

in environmental protection have given rise to great turmoil in environmental strategies and methods. Especially SMEs are having difficulties as, for example, investments in environmental management are large in proportion to their size, and they can only utilise tools developed by others, which they can use but which will not demand too much capacity. Also, a commitment to environmental protection is a risk since there are no generally accepted methods.

But the most serious defect is that there is a lack of structure in the field and its theoretical basis is defective—lack of cohesion is typical for the development of this rapidly expanding field, which has been based on several different and separate methods.

There is clearly a need for a new synthesis and philosophy, which is able to integrate the expertise of traditional natural sciences with, for instance, technology and process control, legislation, economy, strategies and management, organisation development, and social operations [95]. It is clear that the combination of research, education and practical work will be necessary in the near future. The necessity of this new philosophy arises from two main justifications:

- practical needs for preserving the sustenance base of society
- scientific needs for understanding the information produced by isolated specialised disciplines within science.

In comparison with the traditional vertically highly detailed and specialised branches of science, this cross scientific approach combines several branches and theories into a horizontal multidisciplinary and integrative program.

Today, environmental aspects are about to be integrated into sociological theories of industrial and reflexive modernisation. “Ecological modernisation seems to be the general concept that describes this growing consensus”, it is “... an ecosocial restructuring of the technosphere, (...) an ecological switch of the industrialization process into a direction that takes into account maintaining the sustenance base, (...) overcoming the environmental crisis without leaving the path of modernisation” [96]. Also production philosophies and practices are integrating environmental aspects. “Whatever name we use, this new paradigm treats human and natural systems in an integrative manner” [76].

This development will be a long process, and it will employ both the academic community and practical actors. Because of the academic tradition there is no generally accepted theoretical framework for the approach. Although scientific development is a slow process, practical solutions are needed all the time.

4. Understanding the change

“Every reform was once a private opinion”—Ralph Waldo Emerson 1841.

All eras in history have had norms, structures and practices of their own. They are collective manifestations of society, while at the same time they consist of activities and values of often countless individuals and organisations. There are no individual people who dictate the rules, and societies have tended to move towards a kind of collective thinking and self-organisation. It seems impossible to change the current system, especially through individuals. But still, history has shown that often all habits have been renewed one after the other. The key point here is the emergence of change and its mechanisms, or in terms of dialectics: How does one detail gradually become prevailing in the whole?

The fundamental thesis with regards to the dynamics of societal change is the *dialectics between details or parts and the whole*, as between the individual and society, or the idea and the

norm. Although certain actions or operations are always processed by single and separate actors, they must still be understood as parts of a wider context. No individual or enterprise is able to live outside of societal constructions. Enterprises are open systems [97,98] in a world of constant societal change and pressure. Therefore, their behaviour, while simultaneously capable of being innovative, also follows some general rules and patterns, and their degree of independence and freedom is relative. This constellation is fundamental from the enterprises' point of view when they make conscious strategic and operational choices. It is also fundamental for the evolutionary development of enterprises and organisations as a whole and as parts of society.

The Three Layer (3L) macro level model for understanding societal change has been presented earlier by the author [5], and it is briefly summarised in the following. The 3 L-theory suggests that:

- norms, the social base and mental development are primary factors in the beginning and in terms of the dynamics of change. They are the mental environment that the new emerging ideas will face.
- Change always comes from a variety of ideas, generated by individuals and inspired either by innovations or nuisances, defects or other inconveniences of the prevailing system.
- Deviating or nonconformist ideas always emerge in the social context under actual prevailing norms, structures and practices, and the great majority of ideas never overcome the old ones.
- The continuous conflict between new and prevailing thoughts is solved in the *social selection* process, which determines the extent to which new ideas become generally accepted.
- Some ideas are accepted by other people and groups, and they gradually become approved of, accumulating in the whole society and encouraging new ones. These finally force the old paradigm to give way to the new one.
- The new winning thoughts are reflected in a change of rules and of other supporting structures, such as legislation, institutions, market behaviour, and operational patterns in enterprises and other organisations.
- All general operational patterns and practices have developed through a long process, which ensures that they are socially accepted and follow the existing norms.

Summarising, the change consists of three successive and interactive layers (Fig. 4), which have their own evolution and dynamics:

1 Social base

The social base develops in a mechanism where single separate ideas, subject to social selection, become more generally accepted, then form the general consciousness and opinions, and finally social norms, which control society as unwritten laws. For a *certain* given thought change might never take place, and it may vanish or be left within a marginal minority. Actually the main part of new thoughts is excluded due to societal pressure. But *some* thoughts generated in society, giving rise to anomalies against the prevailing norm, are eventually accepted, encourage new supporting observations and ideas, and cause an accumulation of anomalies. Gradually, the *single* deviating observations and thoughts overcome the old norm, and finally a new *societal* pattern is established. The main phases are [5]:

- single observations of defects, deviating and nonconformist ideas and anomalies against the prevailing norm emerge.
- The new ideas become more common.
- The first phase of societal activity: formation of groups, coalitions and movements ready to fight for the idea emerge.

- Formation and strengthening of general opinion occur.
- Confirmation of the social norm: an unwritten law, which controls the behaviour of the majority of the society.

2 Supporting structures

The supporting structures prepare motives for bringing the idea into practice. Legislation and other regulations cause an obligatory normative motive. Changed customer behaviour gives rise to market based motives, and pressure from the environment produces the societal motive. Efficiency and quality thinking prepare the ground for operational voluntary motives and a complete philosophy may develop into an ethical motive. The norm or mental base of society is impaired without a corresponding practice—general rules and other supporting structures are necessary in order to prepare the ground for putting the norm into practice. The development of supporting structures is classified according to their motives [5]:

- ethical and political motive: a total philosophy, world view or a way of thinking is established in society, which is often institutionalised through political interest groups and policies.
- Normative motive: legislation and other regulations establish new general rules, administration is readjusted to new conditions, and follow-up and research are reoriented.
- Market based motive: customer behaviour changes, demands from clients become stronger.
- Societal motive (individuals): because of the new social pressure and behaviour of other people, the new way of thinking becomes more attractive.
- Operational motive: internal efficiency, quality, productivity and competitive strength in terms of the new way of thinking takes over in the enterprises; adjustment of one's own activities to the new way of thinking

3 Practical responses

The practical responses start from avoidance and separate technical improvements and develop into strategies and integrative practices. Operational patterns are the final implication of the development of the social change. Because of the need for general rules and other supporting structures there is a time lag between the mental base and practical responses. The first reactions to new ideas are usually denial or understatement of the phenomenon or its impacts, and avoidance of disadvantages as they become obvious. After the establishment of the first laws a new practice is no longer voluntary. Social order and motivation for progress are encouraged through other supporting structures. Phases of this process are classified as follows [5]:

- rejection and alleviation: denial of the problems, avoidance, dilution.
- Single separate technologies and improvements for the management of the symptoms.
- Strategy, integration and synergy: search for efficiency and competitive strength.
- Societal patterns: adaptive changes at the societal level, and structural changes.

The 3L is fundamentally and strongly an evolutionary model and it has been inspired by the following theories and approaches:

Paradigm shift and conceptual evolution

The paradigm shift is based on the theory of scientific revolutions and structural changes, as first crystallised by Thomas Kuhn [90]. This theory has been further explored and improved by David Hull [91,92] who introduced the idea of conceptual evolution (see also [93]). This is completely analogous with the dynamics of the Social base in the 3L

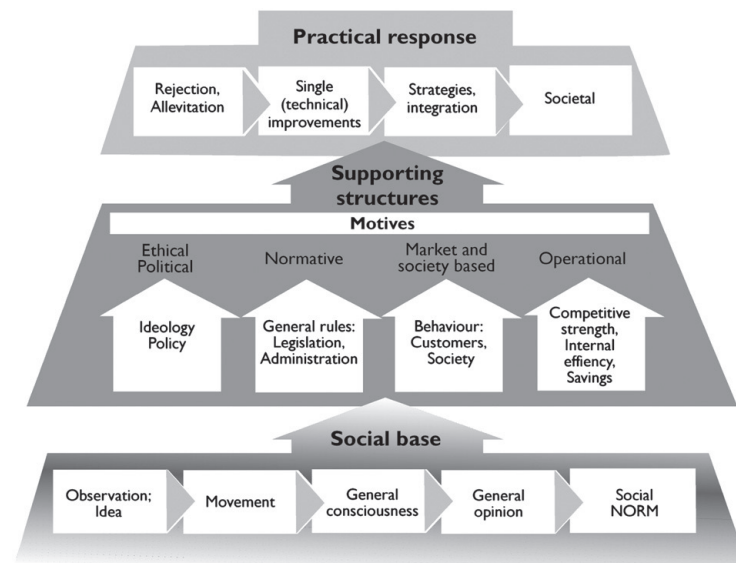


Fig. 4. The structure of social change: The Three Layer model (3L; [5]).

model, where the underlying thought is that as well as scientific paradigms also other intellectual constructions are subject to the same process of conceptual evolution.

Iterated prisoner's dilemma

The prisoner's dilemma is an example of the game theory, which is a mathematical method for analysing calculated circumstances, where a person's success is based upon the choices of others. It shows why two individuals might not cooperate, even if it appears that it is in their best interest to do so. It becomes "iterated" when the situation is repeated and solutions become strategic choices related to how the other person acts. "What is best for each person individually leads to mutual defection, whereas everyone would have been better off with mutual cooperation" [72]. In terms of what is best for society it is essential to break out of the dilemma. In 3L the general rules and hence the supporting structures for bringing the ideas and norms into practical realisation are of high importance. They are motives on the one hand, and incentives and sanctions on the other. Their purpose is to ensure that all actors have the same prerequisites for the aspired actions, according to the new norms and ideas, which have newly been adopted by the Social base of the society. They also reveal the reason for the social lag e.g., [51]: it is possible to put an idea into practice at the general societal level only after it has gone through the selection process.

Ecological modernization

Ecological modernisation means, as defined by environmental sociologists, structural changes in production and consumption, social and cultural maturing and the emergence of new patterns at the societal level, on top of and prior to merely technical reforms. In practice it means leverage to a collective level above separate actors e.g., [3,51]. Ecological modernisation has been the basis for structuring the Practical response of 3L. Even technical evolution can be structured according to these categories from a strategic point of view.

Self reflection of society

The self reflection of the society is the feedback system of how societies and ultimately the whole of humankind can

collectively correct its actions and praxis whenever it reflects nuisances and harmful impacts [33]. This corresponds with the interaction of society and the environment as illustrated in Fig. 1 and the actions inside society according to the 3L model.

Diffusion of innovations

The diffusion of innovations is the theoretical model for explaining how novel technical solutions spread across societies, as summarised by Rogers [99]. Although it mainly explains technical innovations, it is clear that the preceding phases, suggested by 3L, are necessary for a successful diffusion.

Cultural evolution

Cultural evolution is the main point of emphasis of the whole 3L model, which hopefully adds value to the discussion about cultural evolution. There is a wide variety of literature about cultural evolution with different opinions concerning the details. The debate explores, for instance, whether the diffusion of thought takes place through replication of the so-called memes (as proposed by e.g., Dawkins, Blackmore and a number of other authors [100–103]) or through a more complicated process of cognition and comprehension e.g., [104–107]. Memetics became a widely exercised program and even the Journal of Memetics was established. But opposing opinions are also strongly supported and promoted, often by evolutionary psychologists e.g., [108]. Some of the discussion has been summarised in [73,104,108,109], while [93] provides a comprehensive review, unfortunately only in Finnish. 3L as such does not take sides with either of these views, the unifying feature remaining that they are all evolutionary.

5. Towards sustainable energy

"Renewable energy is one of the most efficient ways to achieve sustainable development" [110], and "One of the main tasks in this century (...) will be to manage a transition process towards a sustainable energy system" [111]. Sustainable Energy (SE) has

become one of the key concepts in reforming the energy sector in the EU and worldwide. Among key questions are the following:

- Is SE possible, in terms of energy parameters and technology, environmental impacts, social acceptance and economics?
- Is SE enough (for preserving the earth)?
- What will be the process towards SE?

5.1. Sustainable energy reviewed, defined and analysed

Sustainable Energy is a direct descendant of the idea of sustainable development, with regards to its different interpretations and emphases e.g., [112–115], as well as its origins and evolution, in how they are linked with energy systems [116]. There are more than three hundred definitions of sustainable development within the domain of environmental management, but in many of them the original starting point of protecting the environment and taking other aspects into account has been replaced by other kinds of priorities [115]. From the point of view of this paper the original priority of preserving the earth is highly important.

Table 3
Some definitions of sustainable energy reviewed (edited by the author).

Source	Main contents of the definition
[117]	<ul style="list-style-type: none"> – RES key component of sustainable development – supply in the long term available at reasonable cost, without negative societal impacts – increased energy efficiency
[118]	–support human development over the long term in all its social, economic and environmental dimensions
[119]	<ul style="list-style-type: none"> – satisfying essential human needs for both this and future generations – sparing non-renewable energy sources, and replacing non-renewable energy sources with renewable sources – ecological impacts within the carrying capacity of natural systems
[120]	<ul style="list-style-type: none"> – does not exceed the environment's capacity to absorb the effects – does not unnecessarily consume resources in ways that ensure rapid depletion
[121]	–the harnessing of energy resources for human use in a manner that supports lasting development (Encyclopedia of Energy)
[122]	<ul style="list-style-type: none"> – reduce environmental impacts, are socially acceptable and economically competitive – renewable energy, distributed energy systems, natural gas, demand-side energy efficiency
[123]	–a living harmony between the equitable availability of energy services to all people and the preservation of the earth for future generations
[124,125,126]	–“20–20–20” rule; 20% RES, 20% improved energy efficiency, 20% decreased green house gas emissions by 2020
[127]	–no single definition (...) a wide range of interpretations (...) lack of a common framework
[128]	–energy savings on the demand side, efficiency improvements in energy production, and replacement of fossil fuels by RES
[129]	<ul style="list-style-type: none"> – climate crisis solutions – the two pillar definition (RES and RUE alone) falsified
[130]	–efficient use of both diversified replenishable and nonreplenishable energy resources while severely limiting the ecological footprint
[131]	<ul style="list-style-type: none"> – balance of energy production and consumption – no, minimal, or negative impact on the environment but gives the opportunity for a country to employ its social and economic activities
[132]	–maintaining the capability to provide non-declining energy services in time
[133]	<ul style="list-style-type: none"> – meets the needs of the present without compromising the ability of future generations to meet their needs – all renewable energy sources and usually (...) energy efficiency
[134]	<ul style="list-style-type: none"> – meets the needs of the present without compromising the ability of future generations to meet theirs – replenishable within a human lifetime and causes no long-term damage to the environment – all renewable energy; fossil fuels are not
[135]	<ul style="list-style-type: none"> – can be produced without using resources that are not able to be renewed – renewable energy
[136]	–minimal negative impacts on human health and the healthy functioning of vital ecological systems
[137]	<ul style="list-style-type: none"> – energy generation, efficiency & conservation, energy independence – enable to become a significant portion of energy generation long term, can reach and get below power parity by 2020 or earlier, compared to traditional fossil fuels – low to zero or even a negative carbon footprint, no significant side effects to earth's resources – boosts long term economy and job opportunities

There is a plethora of definitions of SE in recent scientific literature and other sources; some typical ones have been collected into Table 3. Many authors simply refer to the original definition by the Brundtland Commission or give some corresponding phrases on a general level. There are also definitions, which take into account the efficient use of non-renewable resources with the aim to create energy security for “as long as possible”. Some offer no explicit definition in one sentence, but instead they list relevant aspects, while others find no single definition at all and are characterized by the lack of a common framework. However, there is an almost overall agreement that all forms of renewable energy belong to the concept of SE. Another cross cutting feature of SE, either explicitly or implicitly, is energy efficiency.

Taking the literature review into account the fundamental contents of the Sustainable Energy Concept are defined in this article as follows. Further, the concept has been visualised in Fig. 5.

- 1 **Rational Use of Energy (RUE)**—energy efficiency and saving
- 2 **Renewable Energy Sources (RES)**—materials and other sources (biomass, wood, hydro, solar, geo, wind etc.)

3 Integration of RUE and RES
4 Sustainability management

There are a number of technologies for both RUE and utilising RES, which can all be implemented alone as separate solutions or designed to be used as a combination. However, the **integration** of RUE and RES technologies (some examples of which are indicated in Fig. 4) will be the key to the creation of complete solutions. With different combinations of the available RUE and RES technologies and regional RES energy it is possible to outline alternative solutions with different degrees of energy self-sufficiency. This concept can be applied to any target, whether it is a region or a separate building, and anything between these two extremes. It is then up to the decision making system to choose the alternative which has the best possible outcome from a number of perspectives.

Fig. 5 illustrates how the SE concept can be composed in practice. The starting point is implementing RUE technologies. Then, the energy which cannot be saved or upgraded and is needed is produced by RES. RES, in turn, can consist of a number of raw materials or other sources, which are formed or can be collected from the same region where it is used. These sources

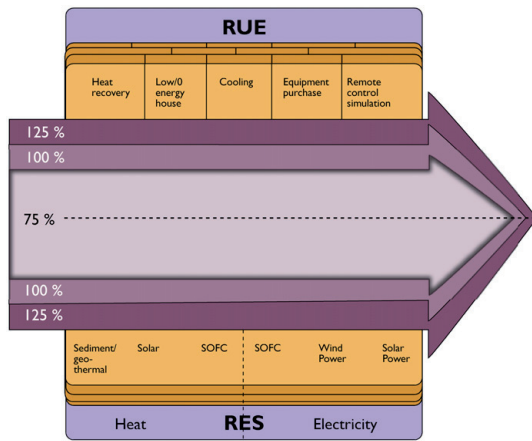


Fig. 5. Integration of RUE (rational use of energy) and RES (renewable energy sources).

can be utilised using several technical solutions. The use of RES from the local region refers strongly to the distributed energy strategy. In principle it is possible that also large centralised energy production units adopt RES for their raw material production. This, however, is a question of technical and economical optimisation.

It is also essential to establish management systems for implementing sustainable energy strategies and separate projects. There is always a danger that these projects become a new field of ecological colonialism where the old pattern of robbery (cf. Section 2) will take over. A number of examples have already been reported e.g., [129,138], where maximal economic gain and carelessness of the environment have been applied for producing renewable energy in the name of sustainability. A potential concept for operationalizing and monitoring sustainability management by combining performance (impacts) and organisation (actions) is presented in Fig. 6 (modified after [139]).

This formation of SE is in full agreement with the early definition by Dincer [117], according to which RES have much less environmental impacts (presupposing proper sustainability management) and cannot be depleted, unlike fossil fuels that indeed are finite. The analysis above also supports Dincer's conclusion that the use of RES favours power system decentralisation and locally applicable solutions.

As well as providing a definition it is essential to analyse whether SE is possible or realistic in practice. This can be assessed by looking at the relationship of SE and the global use of primary energy. The first unavoidable question relates to the total amount of energy consumption, and the second to the amount and the way in which RES are used.

World primary energy use in 2009 was 12150 Mtoe (ca. 140 PW h) of which 13.5% was RES; correspondingly the consumption was 8353 Mtoe (ca. 100 PW h) and the share of RES was 16.2% [140]. According to a recent review [138] the main global scenarios regarding the use of energy all suggest that there will be sufficient availability of fossil fuels in the future. For instance, the newest scenario by the International Energy Agency suggests that the global primary energy demand will increase by 35% from 2010 to 2035, with China and India accounting for 50% of the growth. RES will grow the most, but also the use of fossil fuels will increase [141].

However, Moriarty and Honnery [138] conclude very convincingly that the "... future energy consumption will be significantly lower than the present level" and "only large reductions in global primary energy use (...) can meet the (...) problems that future

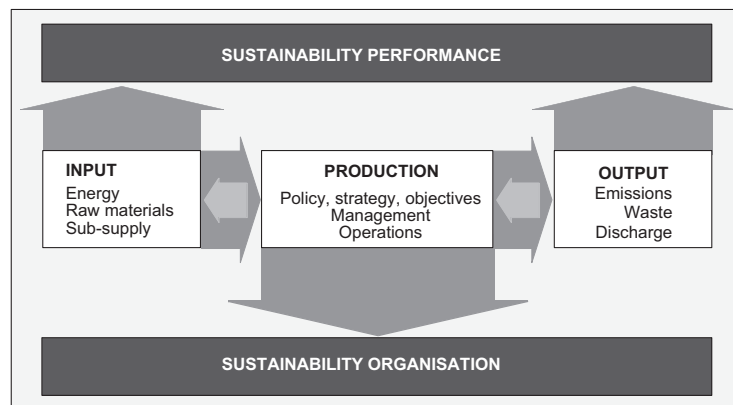


Fig. 6. Production flow chart re-structured into sustainability organisation and performance.

energy use will face" [138]. Recent statistics estimate that both conventional and non-conventional oil reserves will meet the projected world demand only for some 50 years and gas reserves correspondingly for 80 years [142]. These figures are in full agreement with the theoretical analysis presented in this article. It also underlines the importance of future energy efficiency and saving.

There are also suspicions that the "Future use of RE is (...) highly uncertain, for a variety of reasons" [138]. The main arguments relate to the economics and realism in the potential diffusion of RES technologies, and the sensitivity of RES to adverse environmental impacts (also [129]). According to the economic arguments [129,138] it seems impossible to deploy enough RE globally to move towards sustainable energy on a large scale. The analysis is to be taken seriously, though as such it is not valid for the future economics of RE technologies for the following reasons:

The analysis only looks at the costs of today's technologies—which are in an early developmental phase, with no mass production, poorly developed value chains, and with the whole prevailing structure including opposing businesses and regulations against them e.g., [32]. Further, it does not differentiate between the structural options of energy generation, namely centralised and distributed systems, which might have a significant impact on the economics of energy solutions. According to a recent analysis even just normal investments in RES technologies have performed exceptionally well [143], the main risks being changing policies, regulations and other general rules.

Also the benefits beyond the normal business profitability can be significant. "Each € not spent on imported fossil fuels, and instead spent on a regional bioenergy project can have a multiple effect" [144]. This **regional added value** is the sum of all values being produced in RES projects, including monetary aspects, reduction of costs, increase of purchasing power, new created employment, higher tax income, and social, ecological and ethical aspects. For instance, in Rhineland-Palatinate (Germany) the saving potential created by compensating fossil fuels with available short-term renewable potentials is ca. 400M€ [144]. One of the repeatedly up-coming and generally accepted points is that RES generate more jobs than conventional energy. For instance per installed megawatt RES gives 1.7–14.7 times more jobs than natural gas, and four times more than coal [145].

Adverse environmental impacts include, for instance, a potential depletion of ecological carrying capacity and a diminishing RES potential, large land requirements, increased species extinction, large scale pollution [129,138], and that "widely deployed, RE can act to undermine ecosystem services" [138]. They are all realistic threats but not as such caused by default. It is always a question of how things will be put into practice—and it is for this end that the concept of sustainability management has been included in the definition of SE.

Empirical material from Finland and reviewed international observations [32,146] show a surprisingly high potential of the exclusive use bioenergy even when materials that are not used for other purposes are included (for classifications of RES potential: [32,147]). Considering the whole potential of all RES, for instance wind and solar power and a more efficient use of bioenergy, the main observations suggest that today's energy demand could be satisfied by RES. Up to 100% renewable energy systems with substantial climate mitigation potential have already been studied and planned e.g., [128,148–152]. However, it is clear that the use of these resources also depends on the carrying capacity and cannot be increased limitlessly.

In conclusion, indeed there is a social demand for a more wide spread use of SE, both in terms of efficiency and energy saving, as well as for the use of especially locally or regionally produced RES. With reference to the analysis of Boserupian ideas, presented

earlier in this article, technology can develop in order to take advantage of the existing potential of RES, and replace the use of fossil fuels within the limits of the carrying capacity, without undermining the ecosystem services. By contrast, in Malthusian terms, the use of energy cannot increase without depleting the sustenance base of the whole of humankind.

5.2. Diffusion of sustainable energy

The diffusion of SE towards RES based energy self-sufficiency and distributed strategy will be a long evolutionary process at the local, regional and national as well as at the international levels. In rural regions it will stimulate employment, welfare and the regional economy. It offers rural regions a totally new societal role: besides food production, the countryside can also be a source of energy. This process of change will necessarily involve most people, and there will be a huge number of decision-makers involved, from single citizens, families, farmers and enterprises, to the public sector. The process also involves those who need energy, those who produce it, those who manufacture the technical solutions, those who deliver the raw materials, and those who create the general preconditions for the whole movement of decentralised energy production [32,155].

In most places the establishment of larger scale RES based energy management systems will lead to at least some practical changes, and in many cases, a complete change from the use of fossil fuels to the use of new raw materials. This innovation requires not only new technologies, but particularly new innovative institutional frames [156–160,163,161]. The shift towards these kinds of structures, which are very different from the prevailing centralised system, will in all cases be a long-term process. Similarly to the process of acceptance and diffusion of new innovations in general, institutional lock-ins, which are reproduced by key actors, and that prevent the acceptance of new innovations, have to be 'unlocked'. For this to happen, key social actors must accept the innovation. The process must be "structured" so that laws, regulations and other institutions (social structures) support them, or at the very least do not oppose them in the first phase. New innovations must go through a technical evolution to become more developed, efficient and common solutions.

The analysis of this process below follows the structure of the Three Layer model (3L; Section 4). The special issue of the journal *Energy Policy* (issue 5, vol. 35) structured *social acceptance* in its introduction [155] as a triangle approach:

- socio-political acceptance** of technologies and policies, by the public, key stakeholders and policy makers;
- community acceptance** to specific siting decisions of RES projects by local stakeholders, residents and local authorities;
- market acceptance** or the process of market adoption of an innovation by consumers and investors.

In comparison with the Three Layer model (3L; Section 4), socio-political acceptance includes the Social base, consisting of the formation of general opinion, but also parts of the Supporting structures, because policy formation is already a step towards institutionalisation of collective thought. In 3L, the whole Social base belongs to the socio-political acceptance. Wüstenhagen et al. [155] also refers to "public acceptance" and "general public support", which are partly synonymous with the Social base in 3L. Therefore, "social acceptance" is something more developed and comes close to community and market acceptance. The latter ones, in turn, are weighed in connection with concrete RES projects or plans, and therefore they differ from the general level of opinion. In terms of 3L they belong to customer and market

behaviour, thus being important motives for putting the plans into practice.

Based on the innovation diffusion literature [99] it is known that along with the rising diffusion curve, capabilities and general knowledge about the given innovations improve—both as a precondition and as a result of the development. Today, the social acceptance as a whole, as structured by Wüstenhagen et al. [155] is developed both in the interface between the general opinion and supporting structures, such as the feedback system, and through customer behaviour in concrete projects.

This dichotomy can sometimes be seen in opposition to proposals for new developments, although in principle the majority of the population considers the activity as beneficial. Similar dichotomies have often been crystallised even in one person's opinions and attitudes, although typically individual motivation is different from group attitudes [162]. Often only a small but loud minority gets the most publicity, giving an impression that the opposition is larger than it really is. We must remember “there is hardly anything in life that is universally supported” [163]. Especially it is important to “... recognize that the belief in the NIMBY theory (...) must be abandoned” and that “In all renewable energy acceptance cases at all levels there is only one common factor, trust” [164].

This suggests that there are dialectics between the general level of opinion and practical acceptance that are actually inside “socio-political acceptance”. According to this, the acceptance moves from the social sphere towards market behaviour as the development moves along the diffusion curve. It has also been observed that social acceptance forms a U-curve temporally—the initial high support decreases to its lowest point shortly before the implementation of the actual innovation, and rises again when people get more used to the project [163]. This underlines the importance of demonstrating successful examples, as “They first need to gain the respect, understanding, and consent of citizens at large by achieving positive results” [142].

This also means that there should be a clear distinction between the general level of acceptance and site-specific acceptance. Also Wolsink [163] notes the importance of the institutionalisation of values for a successful implementation. “Social acceptance of RES means acceptance among all relevant actors in society—indeed much broader and conceptually fully distinguished from mere public acceptance” [164]. This is exactly what 3L is based on in the dialectics of the social sphere and supporting structures.

Social acceptance has most commonly been discussed in the context of large RES projects, but micro-generation technologies require a different approach as homeowners and local stakeholders become a part of the energy supply infrastructure, and their acceptance can be expressed in attitudes, behaviour and most importantly investments [165]. It is also a question of how the planning and implementation processes have been realised. There has most commonly been a tendency towards top-down planning, which does not take the local population into account. As Wolsink notes “the implementation processes of renewable energy require ‘strong’ ecological modernisation”, where the key approaches are, for instance, open democratic decision-making, participation and involvement, and incorporation of multiple views and ecological concerns [163].

For Europeans renewable energy is the second most important issue in energy production (average 27%) ranging from Denmark's 53% and Sweden's 51% to 12% in Lithuania and 13% in Czech Republic. The fourth most important issue is energy efficiency (2011), thus underlining the importance of SE. The other top priorities, stability of prices (29%) and especially security of energy supply (20%) [166], are also partly intertwined with SE. As Wüstenhagen et al. [155] have reviewed, “Several indicators

demonstrate that public acceptance for renewable energy technologies and policies is high in many countries” and has been already in the early 1980s. This suggests that the social base of SE, as suggested by 3L, has been successfully passed a long time ago.

The development has enabled policies and other motives to emerge and grow. Europeans seem to be in favour of the EU coordination of energy policies (60%) above national measures, and also of solidarity between Member States in the event of supply difficulties (79%) [166]. “The number of countries with some type of policy target and/or support policy related to renewable energy more than doubled (...) from an estimated 55 in early 2005 to 118 by early 2011” [167]. Energy, and RES in particular, has moved to the top of the international political agenda [168], which clearly means that the institutionalisation of sustainable energy is an on-going process globally.

According to a recent review [142], until lately, the expansion of RES in practice has been very slow, being far less than, for instance, the increase of world coal production. “China alone increased its coal output in 2005 and 2006 by more than three times (...) the equivalent rise of world renewable output since 1990”, and global projections for coal output were even more striking [142]. Subsidies have also been smaller for RES than for any conventional fossil production. For instance in the USA nuclear energy production has the largest proportion of tax breaks (76%), coal has 12%, while RES has only 3%. In 2004 the World Bank gave out a total of US\$12 billion for energy projects, of which only US\$1.7 billion went into RES projects [142].

The development of industrial applications and products, new business, and integration with the mainstream energy sector of the Sustainable Energy Concept is in its very early phase. Industries who manufacture the technologies are only just about to emerge in the markets, starting with an early generation of technologies, and actually fighting against the prevailing structures instead of mutual synergy. Energy utilities do not really rely on these newcomers, as they logically strive for a maximal economic gain. Still, the RES solutions must always meet the concurrence in real time markets, where the opponents are at the opposite end of their diffusion—meaning that technologies with decades of operation and technical evolution, investments paid back a long time ago, and the social structures supporting them, all have the benefits of mass production and developed value chains etc.

In 2010, however, renewable power increased by 15.5%, biofuels by 14%, solar capacity by 73% and wind capacity by 24.6% [169]. This is a fundamental increase compared to development in earlier years and it gives very positive signals for the future.

Despite some pessimistic views [129,138] there are some indications that by 2050 the projected savings and implementation of RES technologies can realistically result in the creation of a 100% RES system in Denmark [148–150], Ireland [151], Macedonia [152], Croatia, Portugal, New Zealand, Australia, and some towns and islands in various other countries (review and original references in [152]), or a transition to a fully sustainable global energy system [170], with all energy being produced by wind, water and solar power globally [153,154]. This development has a number of significant positive impacts, for instance in the regional and national economics, energy security and independence, reduction of greenhouse gas emission (to only 10.2% from the 2000 levels) and health costs, improved employment with new jobs, and a remarkable commercial potential. Reductions in the value chain of fossil fuels will, of course, be inevitable [148–150].

A recent historical analysis of the diffusion of coal, oil, gas and nuclear technologies showed that under favourable conditions a massive penetration of these few energy technologies has led to

market dominance [171]. For RES technologies, despite their low market shares of all energy, their expansion until now fits this historical pattern. Further, their already strong spatial diffusion worldwide could indicate a high overall potential if the growth conditions remain good. Using the average observed growth rates of the prevailing energy sources in the past, the share of RES would grow from its present 19% to 60% in 2050, representing a 27% drop in the baseline CO₂ emissions [171].

The physical prerequisites for this kind of renewal of the energy sector exist, but the question is whether there is political will and courage to boost new SE. Diffusion of these technologies depends on a number of factors, but single and separate units are emerging all the time. Along with time they will become more common and form meaningful entities. In a time frame of 20–30 years, the development may result in structural changes across the whole energy sector, as already anticipated by Peura and Hyttinen [32] in their **dichotomy** vision: There will be a division of the energy sector into two strategically different spheres—one centralised, the other distributed, which in the future will form the structure of implementation of integrated sustainable energy.

6. Conclusions

No species has ever been able to multiply without limit. There are two biological checks (...)—a high mortality and a low fertility. (...) Man can choose which of these checks shall be applied....

—Harold F. Dorn, in [9].

... even with extremely large limits on human population size, the amount of time remaining (...) is not extremely long. Within the next 150 years or so, and possibly much sooner than that, a drastic (...) decline in the global population growth rate will be inevitable (...) only by some combination of fewer births and more deaths. Hardly anybody favors more deaths.

—Joel E. Cohen [9].

The above citations neatly summarise the urgent need for global change. This need has a firm theoretical basis, and it is the only valid conclusion that can be drawn from the abundant compilation of data and observations. The state of the world of course, ultimately only reflects the impact of practical actions for breaking out from the evolutionary pattern of robbery, including for instance population regulation, pollution prevention and a sustainable use of resources. There is a call for a new kind of scientific understanding. Technical reforms alone will not be enough; the anticipated renewal will most likely lead to a comprehensive societal change.

Energy plays an important role just on the edge of the interface between society and the environment, having significant economical, societal as well as environmental impacts. Gradually environmentalism and sustainability have been introduced into the conduct codes along with the traditional business thinking. In the energy sector, this ecological modernisation means a shift towards sustainable energy.

Changes in the organisational culture and the response to environmental issues can be outlined in evolutionary phases as described in the Three Layer (3L) model. This development is a social phenomenon, which is in line with cultural evolution. This is a collective manifestation of the behaviour of single actors. It can clearly be seen as an accelerating process where measures of sustainable energy are in the process of being integrated into international, national and regional policies, business strategies, and personal values. The institutionalisation of the process is the

most important prerequisite for a successful implementation of sustainable energy in practice.

The establishment of sustainable energy systems on a larger scale will, in most places, require at least some practical changes, and, in many cases, a total change from fossil fuels to new raw materials and new technical solutions. The emergence of such new structures, which differ a great deal from the prevailing centralised system and also from implementing just separate RES projects, will, in all cases, be a long-term process. The process resembles the acceptance and diffusion of any new innovations which always have to overcome several thresholds or obstacles:

1. They have to attain the social acceptance and general approval. The analysis here suggests that this phase has been successfully passed.
2. They must be “structured” and institutionalised in such a way that laws, regulations and other social structures support them or do not oppose them; the evidence reviewed in this study shows that the policy level and market behaviour are in many cases, positive, but national regulations and structural opposition by a number of large energy utilities are still delaying the development.
3. They have to go through technical evolution to more advanced solutions. Technologies are still in an early developmental phase and system approaches have become more common only recently.

Even 100% RES systems are technically and physically possible, and there is a social demand for a more wide spread use of sustainable energy. In Boserupian terms, technology can develop towards taking advantage of the existing potential of RES and replacing the use of fossil fuels within the limits of their carrying capacity without undermining the ecosystem services. But in Malthusian terms, the use of energy cannot increase without depleting the sustenance base of the whole of humankind.

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ARTICLE III

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The potential and economics of bioenergy in Finland

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ABSTRACT

This article summarises the results from four studies on the potential of bioenergy, and one study on the economic feasibility of distributed renewable energy production, in Ostrobothnia, Finland. The scope of the studies was to explore the degree of energy self-sufficiency that could be achieved, and the economic implications and benefits.

The results suggest that a great majority of rural areas have the potential for being self-sufficient in their energy production through bioenergy alone, but other renewable energy sources (RES), including for example wind and solar power, will make an even greater contribution in the future. This applies to areas especially outside the largest population centres and most energy intensive industries. Indeed, in peripheral regions the renewable energy potential far exceeds the energy demand, and the spatial coverage of energy self-sufficiency is huge. Other European and global studies also show tremendous RES potential.

The economics of small scale power generation units, here represented by biogas plants, are already feasible, despite the technology still being at an early developmental phase. Diffusion of these technologies depends on a number of factors, but single and separate units are emerging all the time. The adoption of RES based energy management systems will however be a long social process.

The results give rise to an expectation for more RES based energy generation in Ostrobothnia and Finland and even in Europe and globally. In a time frame of 20–30 years, this development may result in structural changes across the whole energy sector. This comprehensive movement can only be understood and supported by multi- and cross-scientific approaches, and it will in future be a challenge for forthcoming research.

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1. Introduction

Renewable Energy Sources (RES) have emerged into everyday and more serious discussions, policies, science, and technology development during the last two decades, especially during the 2000s. Historically the roots can be found in environmental discourse and the “big picture” is that energy production has been at the core of how mankind has affected the environment. There is thus a dynamic interaction between society and the environment, as illustrated in Fig. 1:

- Human activities, such as energy production (Society; lower half) affect ecosystems (Environment; upper half), in different scales and habitats. The effect can be measured as discharge (arrow from “Society” to “Environment”);

- The impacts can be seen in the state of the environment, usage and sustainability of resources, well-being and growth of the population. Examples of these impacts include acidification and climate change;
- The impacts are reflected in society through observations and direct effects (health, state of the environment; arrow from “Environment” to “Society”), with harmful effects calling for change;
- Societal change for removing the nuisance is a long and complicated process, where the development of social norms precedes practical responses.

When understood as a temporally developing system, this spiral corresponds to the concept of social self reflection, introduced by modern sociology (Beck et al., 1994). Energy production is a part of the system representing a significant share of the interface between the environment and society and, hence, environmental impacts have traditionally originated from energy production, while the rules of the game are dictated as a societal process.

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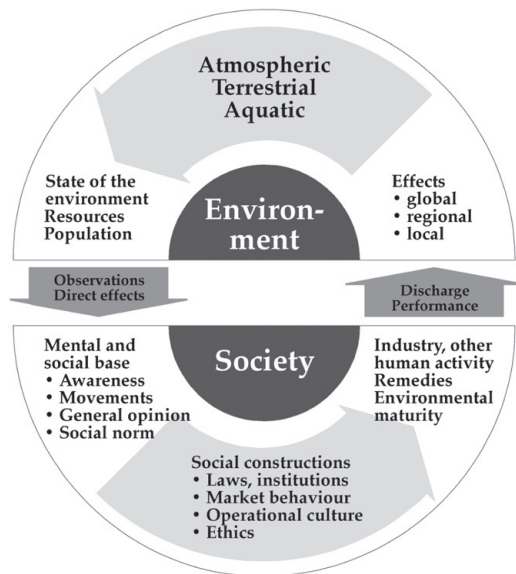


Fig. 1. Dynamics between the environment and society (Peura, 2007a).

Environmental damage and overexploitation of natural resources have been intensively observed, modelled and documented through official statistics for many years (e.g. Brown, 1991–2009; Meadows et al., 1992; Brown et al., 1993–2002; Cohen, 1996; Stanner and Bourdeau, 1995; Cole and Masini, 2001; Colombo, 2001). Despite the vast quantity of research and monitoring carried out since the 1960s, it was the first alarming signals of climate change that alerted the political sphere. Pollution, discharge and population growth only represent part of the problem, being the most visible and easiest to understand and measure. Depletion of resources, poverty and other more subtle economic disturbances are among those impacts that are more difficult to assess and judge (e.g. Meadows et al., 1992; Cohen, 1996).

We live in a risk society, where one accident can deteriorate a whole continent, and where countless small risks make an ungovernable entity. Already in the 1990s it was clear that the world would face comprehensive changes in the future. A new social contract for science has been seen necessary “to move toward a more sustainable biosphere” (Lubchenko, 1998).

These examples illustrate that the development of RES based energy production systems will be a comprehensive societal process. This gives rise to a need for synthesis and philosophy which are able to integrate the expertise of natural sciences, technology, legislation, economics, strategies, organisational development and management, and sociology (cf. e.g. Giri, 2002). In comparison with the traditional vertically detailed and specialised branches of science, this *cross-scientific approach combines several branches and their theories into a horizontal multidisciplinary and integrative program*. This has been preceded by environmental sociology (e.g. Buttel, 1986, 1987; Hahn and Simonis, 1991; Buttel and Taylor, 1992; Laska, 1993; Catton, 1994; Redclift and Benton, 1994; Bowler, 1997; Hannigan, 1997; Metzger and Zare, 1999). As many authors have suggested, this may even predict a wider scientific paradigm shift (e.g. Goldman and Schurman, 2000; Kuhn, 1996).

It is interesting, even striking, that the demands for more sustainable energy production have originated from outside of the

prevailing energy production establishment. The discourse has long been characterised by polarisation and dialectics neatly crystallised by the following citations (Verbruggen et al., 2010), one playing down the significance of RES, the other seeing its future options:

- “Until recently it was a widely held belief, or conventional wisdom, that RE [Renewable Energy] can make only a marginal contribution to future energy supplies”
- “Substituting renewable energy supplies for non-sustainable energy sources is considered to be one of the major mitigation options” for climate change

Gradually, the idea of a more common RES based energy production has been established into EU and national policies. Some examples have been gathered in Appendix 1. It has, therefore, become a part of “official thinking”, and national programmes have been initiated and launched. The situation has been described for instance at the EU level (Lauber, 2005), in different member states (Reiche and Bechberger, 2005; Reiche, 2005), and in Finland (Vehmas and Luukkanen, 2005); other European and global literature is cited in the Discussion section of this article.

RES is also now an integral part of the IPCC (International Panel for Climate Change, IPCC-WGIII, 2001, 2007). It has even been argued that Europe must strive for 100% renewable electricity by 2050 in order to keep the mean global temperature increase below 2 °C. Technically this could for example be achieved by combining area wide and decentralised power generation according to the SuperSmart Grid approach (Battaglini et al., 2009). The solution in practice should also be “...de-centralised generation of renewable energy combined with improvements in energy efficiency throughout all of our societies”, remembering that RES are also finite resources (Klemeš and Huising, 2008). In this process, economic and environmental sustainability may be a success factor for growth in an era of increasing scarcity of fossil fuels (D’Alessandro et al., 2010). “The global warming related CO₂ emissions, coupled with steeply rising prices and the recent global financial institutional melt-down are causing massive societal concerns and give rise to increasing demand for ways to improve societal and individual energy efficiency and for ways to shift increasingly to alternative, low of non-carbon based systems” (Dovi et al., 2009).

Yet in practice the diffusion of RES based energy production has been slow in Finland. Technological development has mainly been based on small separate units and understanding of the whole energy sector as a regional phenomenon, with economic, social and environmental interconnections, has been insufficient.

The first logical step in this developmental phase has been to evaluate the potential of RES in general and its different components. This step has been widely taken across Europe and globally, and there is today an extensive literature from global as well as national perspectives; some of this literature is discussed later in this article.

Levón Institute at the University of Vaasa, and a member of Vaasa Energy Institute, has initiated and performed a research program concentrating on RES based production of energy. The main objective of the program has been to create an improved understanding of the whole energy sector as a regional system, surrounded and interconnected with a number of phenomena. This type of “helicopter perspective” from above is the only way, we believe, to see the dimensions and form as a whole, and to understand the dynamics of the phenomena.

This article summarises the results from four studies carried out since June 2003 on the energy content of bioenergy and the potential energy self-sufficiency of rural areas. We have also finished one research project concerning the economics of biogas plants, here representing the technical solutions for RES based production of energy.

- *Study I*: National research in 15 municipalities and their sub-areas in rural Finland (Fig. 2; Hyttinen, 2005)
- *Study II*: County of Ostrobothnia, consisting of 18 municipalities (Fig. 2; Unpublished, 2006)
- *Study III*: County of South Ostrobothnia, consisting of five regions (Fig. 2; Unpublished, 2007)
- *Study IV*: Region of Suupohja in the County of South Ostrobothnia (Fig. 2; Unpublished material from the ASPIRE project)

The main regional characteristics of the study areas are shown in Table 1. They represent together nearly 510,000 inhabitants, almost 10% of the Finnish population, and a total area of 44,700 km², which is approximately 15% of the national land area. Primary production is more common in these rural areas than in the country overall, but regional variation is also significant. The study areas provide a large sample of Finland and are especially representative of the country's regions.

2.2. Potential of renewable energy sources (RES)

2.2.1. Energy demand and RES potential metrics

Energy demand figures were mainly collected from or calculated according to published statistics and interviews. The methods used are listed in Table 2.

Energy demand consists of the use of electricity and heating energy, but traffic fuels are not included. Electricity use data has been taken from official statistics, which are metered and reported by energy utilities. These figures represent total actual use of electricity in a given area, and they have been published and are controllable at Adato Energia (2003), Energy Industry (2006); ("Municipalities according to consumption") and the website www.energia.fi.

The use of heating energy includes all buildings and has been calculated by multiplying the area of a building with the estimated average consumption per square meter (141 kWh/m²). These figures have been taken from the official statistics, published in Statistics Finland (2002, 2004); ("Building by heating fuel").

From industries the energy demand figures include all use of electricity, but the process heat demand is not known.

There are several definitions of RE supplies in the literature, most adequately summarised by Verbruggen et al. (2010) and Doukas et al. (2007). The supplies consist of several types of sources "... obtained from the continuing or repetitive currents of energy occurring in the natural environment and includes non-carbon technologies such as solar energy, hydropower, wind, tide and waves and geothermal heat, as well as carbon-neutral technologies such as biomass" (IPCC-WGIII, 2007). These have been described in more detail e.g. by Verbruggen et al. (2010).

The studies discussed in this article have concentrated on combustible and digestible materials (bioenergy) for the following reasons: these materials are natural existing resources in the study

areas, there are industries refining some of them already for other purposes, there is infrastructure that can be utilised (e.g. forestry), their energy content can reliably be measured, and there is practically no social resistance against them. In addition these sources include a number of different renewable materials which altogether make the bioenergy potential, meaning the energy content of renewable materials, in a given area.

Renewable energy also includes wind, solar and hydro power and geoenergy. There are however no reliable statistics for these sources which could be compared with or presented in the same way as bioenergy potential, and as such these forms of RES have been excluded from the calculations. Because they are in principle inexhaustible, especially in small areas, they have been included in some regional analyses and discussion, not as a "total regional potential" but as examples of "how many wind turbines would cover a certain energy demand" etc. Other RES have not been considered because they are either not available in Finland or the technology still is underdeveloped for wider utilisation.

The energy content figures of each RES material were calculated or collected separately. The methods for attaining quantities of RES materials are shown in Table 3.

In the national *Study I* the research targets were villages or sub-regions of municipalities. Because most of the statistics have been organised by municipalities, the material in *Study I* was mainly collected by personal contacts in the areas. Ten villages were visited and the interviews were made face-to-face, and in the remaining five areas the contacts were made via phone and email. The people contacted belong to the following categories: municipal officers (technical directors, environmental, rural and business managers), personnel of the regional energy utilities and some development organisations and enterprises.

For *Study II*, in the County of Ostrobothnia, the quantities of animal fat and sludge from the potato industry were obtained directly from businesses, and the combustible fractions of industrial waste were provided by the West Finland Environment Office. Biogas potential was calculated based on the share of total and volatile solids (TS; VS) and material specific gas production (Turunen, 1999; Uusi-Penttilä, 2004). All quantities were then transformed into energy content units by multiplication with generally available and used specific values (Uusi-Penttilä, 2004; Alakangas, 2000; Finbio, 2005).

The compilation of bioenergy metrics in this article corresponds neatly to the harmonisation carried out by Doukas et al. (2007) and the categories used here. Also in the literature the corresponding methods of using official statistics as a starting point, multiplication with specific values, and taking geographical characteristics into account, seem to be typical, for instance for the potential of global field biomass (Hakala et al., 2009), global bioenergy (Fischer and Schrattenholzer, 2001; Smeets et al., 2007), or global sustainable biomass energy (Ladanai and Vinterbäck, 2009; Ceciliano, 2010), global bioenergy from forestry (Smeets and Faaij, 2007), RES globally

Table 2
Summary of the methods for attaining energy demand figures.

	Study I	Studies II and IV	Study III
Electricity demand	Municipalities: demand 2001; Adato Energia (2003) Small areas: collected from network companies	Energy Industry (2006); Electricity demand statistics from 2004	Ruralia (2008)
Heat demand	Statistics Finland (2002), Buildings 2002 Calculation based on building areas and average heat demand according to statistics	Statistics Finland (2004): Buildings 31.12.2004 Calculation based on building areas and average heat demand according to statistics	Ruralia (2008)

Table 3
Summary of the methods for attaining RES material quantities.

	Study I	Study II	Study III	Study IV
Manure	Number of domestic animals: Municipal officers Multiplication by specific quantity by species	Number of domestic animals by municipality and species: MAF ^a 2005 Multiplication by specific quantity by species	Number of domestic animals by municipality and species: MAF ^a 2005 Multiplication by specific quantity by species	Number of domestic animals by municipality and species: MAF ^a 2005 Multiplication by specific quantity by species
Dung from fur animals		Number animals by municipality: The Finnish Fur Breeders' Association 2006 Multiplication by specific quantity West Finland Environment Office		
Sludge	Municipal statistics		Municipal statistics and waste management companies	Municipal statistics and waste management companies
Biomass from fields	Reed canary grass crop tons/ha Multiplication by fallowed areas; municipal statistics	Reed canary grass crop tons/ha Multiplication by fallowed areas; statistics by MAF 2005	Reed canary grass crop tons/ha Multiplication by fallowed areas; TE Centre of South Ostrobothnia Forestry Centre of South Ostrobothnia	Reed canary grass crop tons/ha Multiplication by fallowed areas; statistics by TE Centre of South Ostrobothnia Forestry Centre of South Ostrobothnia
Wood	Logging residues (Ranta, 2004; Tolonen, 2000)			
Straw and other residues of cultivation		Cultivation areas by municipality and species: MAF ^a 2005	Cultivation areas by municipality and species 2005: TE Centre of South Ostrobothnia	Cultivation areas by municipality and species 2005: TE Centre of South Ostrobothnia
Municipal bio waste	Population: municipalities Multiplication by 70 kg/a per person	Population: municipalities Multiplication by 40% of 180 kg/a per person	Population: municipalities Multiplication by 40% of 180 kg/a per person	Population: municipalities Multiplication by 40% of 180 kg/a per person

^a MAF = Ministry of Agriculture and Forestry.

(Resch et al., 2008), bioresources of a rural village (Khanbalkar et al., 2008) or in separate farms (Lampinen and Jokinen, 2006), biomass in Central and Eastern European Countries (van Dam et al., 2007) and in Czech Republic (Lewandowski et al., 2006), RES in Turkey (Evrendilek and Ertekin, 2003) and Croatia (Bozicevic Vrhovcak et al., 2006), or biomethane in Chile (Seiffert et al., 2009). In Argentina land use and cover maps have been used together with geographical indicators (Belmonte et al., 2009).

In a number of articles scenarios (taking forecasted climate change, population growth, economic situations etc. into account) have been used for the estimation of RES potentials. These scenarios as such have a lot of uncertainties and this approach has not been used in this article.

Summarising, the methods used in our studies are based on the same principles as in the mainframe of literature.

2.2.2. Classification of RES potential

The renewable energy literature provides several definitions for the categorisation of RES potential. These classifications are important to understand because the utilisation of RE supplies and feasibility of different technological solutions are changing over time. They depend, to name but a few factors, on technology and value chains, social acceptance, legislation, and economics, each of which are also changing continuously. Some classifications summarised by Verbruggen et al. (2010) and others have been collected in Table 4.

The overview by Verbruggen et al. (2010) shows that the notion of RES potentials is an unsettled concept, where many authors have their own poorly explained definitions (Verbruggen et al., 2010), and the differences between these and IPCC definitions are significant (IPCC-WGIII, 2001, 2007). For this reason these classifications have been given here only as examples, and detailed explanations are provided in the respective references (Table 4).

Verbruggen et al. have also proposed a unified taxonomy of RES potentials with an emphasis on policy-driven aspects. This classification is shadowed in Table 4 and illustrated in Fig. 3. The categories are shortly summarised below (citations and for more details cf. Verbruggen et al., 2010):

Market potential

"The amount of RE output expected to occur under forecast market conditions that are shaped by private economic agents and are regulated by public authorities".

Economic potential

"The amount of RE output projected when all – social and private – costs and benefits related to that output are included".

Table 4
Classification of RES potential in selected literature.

Fischer and Schrattenholzer (2001)	RET D (2006)	Stangeland (2007)
Theoretical Technical Economic	Theoretical Technical Current use	Theoretical Technical Realistic Realisable
Doukas et al. (2007)	de Vries et al. (2007)	Resch et al. (2008)
Theoretical Technical Realisable	Geographical Technical Economic	Theoretical Technical Realisable Mid-term
Hoogwijk and Graus (2008)	Krewitt et al. (2008)	Verbruggen et al. (2010)
Theoretical Geographical Technical Economic Market	Theoretical Technical Economic Deployment Demand	Technical Sustainable development Economic Market

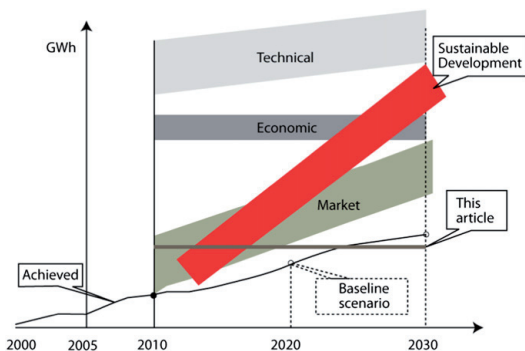


Fig. 3. Classification of RES potential, redrawn after Verbruggen et al. (2010); y-axis = energy content, schematic. Bioenergy potential in this study = solid line.

Sustainable development potential

"The amount of RE output that would be obtained when all four sustainability dimensions [...] are taken into account in an integrated manner" ("Cultural" besides the three traditional pillars of sustainability).

Technical potential

"The amount of RE output obtainable by full implementation of demonstrated and likely to develop technologies or practices".

The RES potential calculated in this article has been estimated to reach the "market potential" described by Verbruggen et al. (2010) (Fig. 3), but only for bioenergy. This potential has been drawn in Fig. 3 schematically as the solid line. Therefore the real potential is much larger. All the materials calculated in our studies are already available, and could be taken into any use depending on the available infrastructure. We have also omitted large supplies of materials, crops and areas presently utilised for other purposes, for instance mass wood used by the wood industry, cultivation grounds used for food production etc. This means that the RES potential identified in this article could easily be utilised for production of energy even in the prevailing market conditions and present technology. It also means that in the future the Finnish bioenergy potential, but even more importantly the total RES potential, might be significantly larger than indicated here.

2.3. Economy of RES based energy production

The economic evaluation of RES based energy production is based on the results of the project "Business in distributed generation of energy" reported by Peura (2007b), Study V). The project resulted in an investment model for analysing the economics of distributed and renewable energy production. The model was verified for 11 biogas plants, but it was assumed that it can easily be adjusted to be valid in any kind of distributed and renewable energy production system, analogously. The model has been described in detail by (Järvinen et al., 2007; Järvinen and Laitinen, 2007).

The investment model was built on capital budgeting models, which are crucial in supporting capital expenditure decision-making in projects of RES based energy generation. Cooper et al. (2002) show in their review article of empirical studies on capital budgeting methods that the discounted cash flow techniques are the most popular methods for assessing projects, especially the internal rate of return. They also found that many firms still use the payback method as a backup or secondary approach. Biezma and San Cristobal (2006) and Cooper et al. (2002) found in combined

heat and power (CHP) unit project evaluations that virtually the only criteria that have been used were net present value, internal rate of return, and payback period.

In our investment model, economic viability was calculated by general cash flow-based investment criteria, including Net Present Value (NPV), Internal Rate of Return (IRR) and both undiscounted and discounted Payback Period (PP). A short description of the model (modified after Järvinen and Laitinen, 2007) is given in Appendix 2.

The 11 pilot cases (for titles, see Table 7) have been briefly described and classified below:

Independent production units

I Industry 1

Raw materials industrial waste (large slaughter house), manure and dung from agriculture; farmers transport their materials, no gate fees for farmers; the industry uses all biogas

II Industry 2

As in I but farmers pay gate fees; the plant pays for transportation

III Industry 3

As I but biogas (left after own use) is used as traffic fuel

IV 9 farms

Produces traffic fuel from manure and dung from the 9 owner farms

Energy production unit integrated with a production company

V Industry

Owned by the large industry, produces biogas as a part of the waste management system of the industry

VI 1 farm

Owned by 1 farm; produces biogas for the farm from the farm's pig manure and cut reed canary grass

VII 1 farm

Owned by 1 farm; dry fermentation of broiler dung, biogas used by the farm

VIII SME 1

Owned by the SME; raw materials from the SME (tannery), waste from potato industry, waste water treatment sludge and manure from agriculture; biogas is used for heat and steam production for the SME

IX SME 2

As in VIII but biogas is used as CHP (combined heat and power generation)

Municipal production units

X municipal 1

Owned by a municipal company; produces biogas from sludge from a number of municipal waste water treatment plants and some municipal organic waste; biogas is used for the company's electricity and heat demands and the surplus energy is sold externally

XI municipal 2

As in X but biogas is refined and sold as traffic fuel; heat and electricity is bought externally

3. Results from regional studies

3.1. Potential of bioenergy

3.1.1. Bioenergy potential in 15 rural areas in Finland

The main results from the national Study I (Hyttinen, 2005) in 15 rural areas in Finland have been summarised in Figs. 4–7. The dominant feature is that the overall bioenergy potential far exceeds

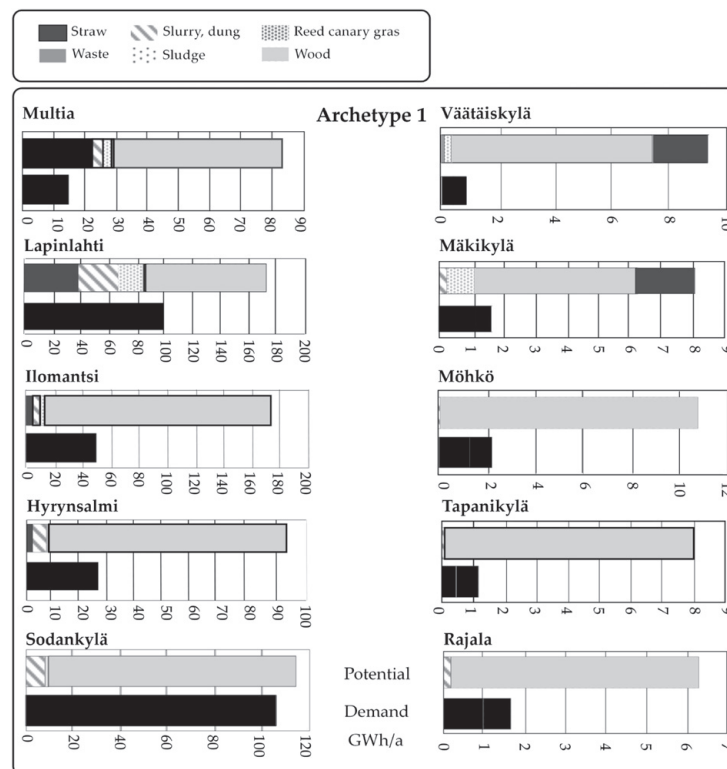


Fig. 4. Bioenergy potential (upper bar) and energy demand (lower) in five Finnish municipalities (left) and small areas inside each municipality, respectively (right; Study I, source: Hyttinen, 2005).

the energy demand in rural areas, especially in the most peripheral areas (Fig. 4) where the potential is manifold compared with the demand. Also in the so called 'rural heartland' the potential is large in relation to energy demand (Fig. 5). In the urban adjacent rural areas the potential and demand are almost equal, or the demand is larger than the potential (Fig. 6). In the rural heartlands or more peripheral sparsely populated areas there may be industries which result in a large energy demand (Fig. 6).

Bioenergy potential consists of several fractions, and the study found the following features:

- In the sparsely populated areas forestry residues represent the clearly dominant fraction, accompanied with some smaller amounts of other typical materials from agriculture (e.g. straw, manure; Fig. 4)
- In the rural heartlands the strong agriculture can be seen in the mixture of RES materials, cultivation being reflected in the large share of straw and the potential of other green materials, here indicated as reed canary grass, and domestic animal husbandry reflecting in manure (Fig. 5)
- Mixture of several materials is the dominant feature of RES potential also in the urban adjacent rural areas (Fig. 6)
- Nationally, the eastern and northern regions have the most wood based bioenergy potential, while in the southern and western rural areas the bioenergy potential consists of a mixture of materials mainly from agriculture

The results suggest that most of rural Finland could be self-sufficing in its energy management. As this potential has never been researched properly, the material of the study (Hyttinen, 2005) was arranged as a continuum starting from the most peripheral areas to the larger municipal centres. The results shown in Fig. 7 provide an indication and a rough idea of the potential rural energy self-sufficiency.

3.1.2. Bioenergy potential in the County of Ostrobothnia

The bioenergy potential in the County of Ostrobothnia was calculated by region and municipality, and the figures were compared with energy demand from the same areas, respectively. The results have been summarised in Table 5.

The study shows a remarkable bioenergy potential in the County, especially in rural parts. The overall potential is ca. 2.7 TWh/a, while the whole energy demand is 4.3 TWh/a. This means an overall potential self-sufficiency of 63 percent. The study shows however large regional differences. The most important characteristic is that the large centres of population and energy intensive industries clearly differ from the remaining rural areas, which cover most of the County of Ostrobothnia.

Vaasa and Pietarsaari Regions are almost equal in their energy demand. They are both characterised by the fact that energy demand is very concentrated, with the central municipality representing 2/3 of the total demand. In Vaasa, Pietarsaari and Kaskinen there are energy intensive industries, and in Vaasa a population

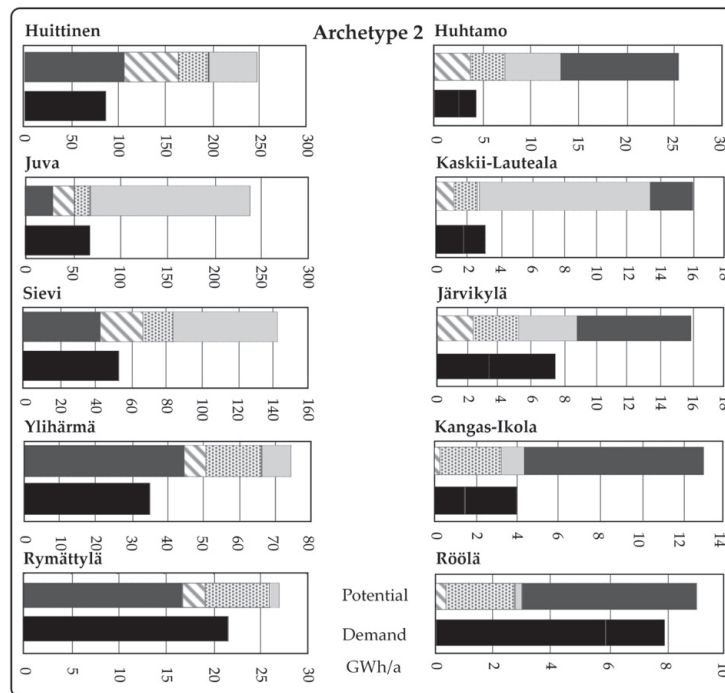


Fig. 5. Bioenergy potential (upper bar) and energy demand (lower) in five Finnish municipalities (left) and small areas inside each municipality, respectively (right; legend in Fig. 4; Study I, source: Hyttinen, 2005).

of nearly 60,000. If these centres of high energy demand are omitted, the overall potential energy self-sufficiency of the County is 154 percent. This means that the whole rural countryside outside Vaasa, Pietarsaari and Kaskinen produces biomass and other materials which are not in currently utilised, and the energy content of which far exceeds the energy demand in the same area. The same characteristic can be seen in the Regions too: without the large population centres and energy intensive industry the rural areas have the potential to become plus 100 percent energy self sufficient.

3.1.3. Other studies on bioenergy potential

Another regional study was performed in the neighbouring County of South Ostrobothnia as a part of the energy self-sufficiency strategy work carried out by Ruralia Institute (Fig. 1; (Unpublished, 2007)). The figures were studied more precisely in the municipalities of Suupohja region (Fig. 1) inside the County of South Ostrobothnia, as a part of the IEE (Intelligent Energy Europe) project ASPIRE (Unpublished material from the ASPIRE project). The results have been summarised in Table 6 and Fig. 8.

Electricity and heating energy demand in 2005 in South Ostrobothnia was 1833 GWh/a and 1211 GWh/a, respectively (Unpublished, 2007). The total bioenergy potential is ca. 150% compared with the total energy demand, which is nearly equal to the figure from the neighbouring County without energy intensive industry and large population centres. Summarising the results in Tables 5 and 6, the total energy demand and bioenergy potential in these two neighbouring counties are almost equal.

The great majority of the bioenergy potential consists of harvesting residues from the cultivation of crops (straw and rape seed

and logging (including stubs). Other organic materials from farms and municipal and industrial waste only constitute some 15 percent of the whole bioenergy potential. It is worth mentioning that should biogas treatment become more popular, the harvesting techniques of crops may change as it would also be possible to digest the residues.

Suupohja is an excellent sample of what is typical in the rural areas. Bioenergy potential is approximately double compared with the total energy demand. In the bigger centres it is proportionally smaller, and in more peripheral municipalities it is three, even four times bigger than the demand.

3.2. Economics of bioenergy generation

The basic results from Study V (Peura et al., 2007) have been collated in Tables 7 and 8.

In cases I–III and V some results are confidential, because the calculations were made for a large industry. Investments in the 11 studied cases varied from €250,000 to €13.7 million. The smallest plants were of farm scale (VI and VII). The largest biogas plant (cases X and XI) was planned for the treatment of organic waste from 14 and sludge from 22 municipalities. In addition to these, there was one case for nine pig farms (IV) and two alternative concepts for a smaller industry (VIII and IX).

In all cases the revenues exceed the expenses, except for case IV (Table 7; 9 pig farms), where the capital costs raise the total expenses; also in this case the expenses without capital costs remain smaller than the revenues (Table 8). The price for the produced energy was mainly 36–63 €/MWh, with the exception of an extremely high price in case X. In six plants the net present value

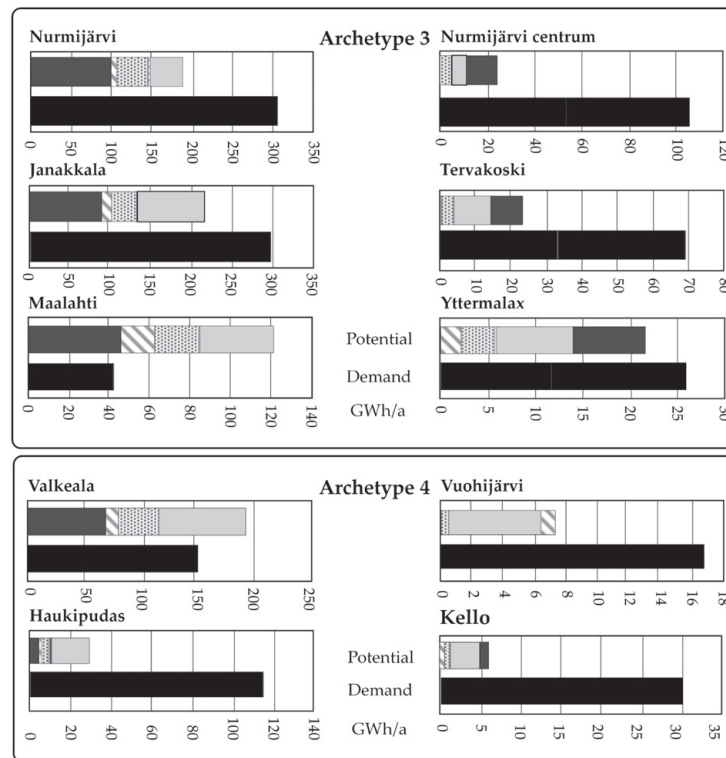


Fig. 6. Bioenergy potential (upper bar) and energy demand (lower) in five Finnish municipalities (left) and small areas inside each municipality, respectively (right; legend in Fig. 4; Study I, source: Hyttinen, 2005).

is positive, and the discounted payback time is between 7.5 and 13 years. The internal rent rate in these cases is 6–13 percent. These cases fulfil the normally used criteria (Järvinen et al., 2007; Järvinen and Laitinen, 2007) for a positive decision for an investment.

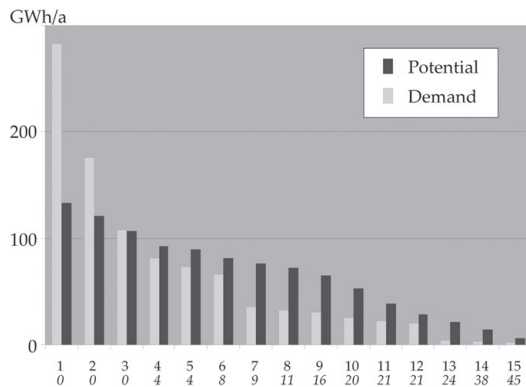


Fig. 7. Cumulative bioenergy potential and energy demand in 15 Finnish rural areas from peripheral (right) to central areas (left; areas 1–15, distance from the municipal centre below in km; Study I, source: Hyttinen, 2005).

According to the criteria, in all the other cases the investment should be rejected.

For those cases with no or less profitability we wanted to find the main factors to achieve profitability and the practical actions that should be taken. For this the preconditions for business profitability were studied using even stricter criteria than above. This was done to avoid being overoptimistic and to prevent any criticism of too eagerly promoting these cases. The main criteria was to achieve a discounted payback time smaller than eight years, and another one to attain an internal rent rate of at least 12% (Table 8).

The most important means for improving the feasibility for new biogas plants would be to decrease the investment and capital costs. A reduction of investment by 17–47 percent would make most of the cases profitable by these strict criteria. Another alternative for a better profitability would be an increase in income. This, in turn, would require some combination of the following means:

- (1) Improved internal efficiency bringing savings or more gas production or both
- (2) A higher price for the sold biogas, which however is highly dependent on the markets and prices of other alternative sources of energy
- (3) More sources of income, which would call for more intelligent planning of the operational concept of the biogas plant

Table 5

Energy demand (heat and electricity), RES potential (in GWh/a) and energy self-sufficiency potential (%) in the municipalities of the County of Ostrobothnia (*Study II*; Unpublished, 2006).

	Energy demand	RES			%	
		Wood	Straw	Other	Total	
<i>Pietarsaari region</i>						
Luoto	42	20	1	2	23	55
Pietarsaari	1078	12	3	24	39	4
Kruunupyy	159	96	48	33	177	111
Pedersöre	164	130	69	44	243	148
Uusikaarlepyy	150	115	79	64	258	173
Total	1593	373	200	167	740	46
Total without Pietarsaari	515	361	197	143	701	136
<i>Vaasa region</i>						
Oravainen	46	33	36	20	89	195
Vöyri	67	73	80	33	186	276
Maksamaa	16	29	4	3	36	225
Mustasaari	248	138	120	50	308	124
Vaasa	1143	28	10	10	48	4
Maalahti	91	75	60	33	168	184
Korsnäs	58	38	10	12	60	104
Total	1669	414	320	161	895	54
Total without Vaasa	526	386	310	151	847	161
<i>Kyrönmaa region</i>						
Isokyrö	73	40	111	34	185	254
Vähäkyrö	66	23	70	22	115	174
Laihia	115	80	95	23	198	172
Total	254	143	276	79	498	196
<i>Coastal Suupohja</i>						
Kaskinen	385	1			1	0
Kristiinankaupunki	144	129	44	23	196	136
Närpiö	277	163	169	64	396	143
Total	806	293	213	87	593	74
Total without Kaskinen	421	292	213	87	592	141
Total Ostrobothnia	4322	1223	1009	494	2726	63
Total without Kaskinen, Vaasa, and Pietarsaari	1716	1182	996	460	2638	154

Table 8 shows these means as two alternative preconditions, which do not have to be applied simultaneously. It is important to notice that all cases have income already in the first year of operation even without these improvements, which is the real basis for a sustainable economy of the plants.

4. Discussion

4.1. Observations

The main observations from the research described here are the following:

- The RES (bioenergy) potential in the two Counties of Ostrobothnia far exceeds the total energy demand, and according to this and the other results it could be expected that the potential in Finland is tremendous (research question 1);
- The economics of small and medium sized RES energy production units are already feasible (research question 2).

Study I provided a rough idea of the potential energy self-sufficiency in rural areas (Figs. 4–7). The study areas were not from the same region however, and when placed in a line from periphery to the centre would only represent one sector around the centre. A better understanding was therefore attained from *studies II* and *III*

Table 6

RES potential (GWh/a) in the municipalities and Regions of South Ostrobothnia (Fields: straw and rape seed residues; Biogas: manure and reed canary grass potential from fallowed grounds; Wood: logging residues; Other: industrial and municipal combustible and fermentable waste and sludge; *Study III*, Unpublished, 2007).

	Fields	Biogas	Wood	Other	Total
<i>Seinäjoki region</i>					
Ilmajoki	155	60	91		
Jalasjärvi	127	58	131		
Kurikka	88	37	77		
Nurmo	45	17	50		
Seinäjoki	78	28	65		
Ylistaro	127	32	71		
Total	620	232	485	73	1410
<i>Härnänmaa region</i>					
Alahärmä	73	23	59		
Kauhava	91	23	70		
Lapua	153	50	112		
Ylihärmä	48	11			
Total	365	107	241	22	735
<i>Suupohja region</i>					
Isojoki	26	8	131		
Jurva	50	16	101		
Karjajoki	24	8	48		
Kauhajoki	129	70	170		
Teuva	68	24	117		
Total	297	126	567	21	1011
<i>Järviseuutu region</i>					
Alajärvi	52	15	106		
Evijärvi	23	10	99		
Kortesjärvi	38	28	42		
Lappajärvi	32	6	94		
Vimpeli	24	5	36		
Total	169	64	377	13	623
<i>Kuusikunnat region</i>					
Alavus	75	24	108		
Kuortane	41	19	76		
Lehtimäki	10	5	66		
Soini	13	16	67		
Töysä	22	9	71		
Ahtäri	18	7	160		
Total	179	80	549	19	827
Total	1630	609	2219	147	4605

covering two counties: Bioenergy potential far exceeds energy demand in large rural areas, here represented by the Counties of Ostrobothnia and South Ostrobothnia.

Very similar results from these two counties have also been attained by another study (Simola and Kola, 2010), and parallel results have been published elsewhere in Europe (van Dam et al., 2007; Lewandowski et al., 2006; Evrendilek and Ertekin, 2003; Bozicevic Vrhovcak et al., 2006; Ragwitz et al., 2005; Schneider et al., 2007) and even globally (Ladanai and Vinterbäck, 2009; Ceciliano, 2010; Smeets and Faaij, 2007; Resch et al., 2008; de Vries et al., 2007). The results from other European studies are even more encouraging for the use of RES. For instance in most Central and Eastern European countries the production potentials merely by biomass are larger than the current energy use (van Dam et al., 2007) and in many cases, such as the Czech Republic, biomass could also be exported as biofuels to other EU-countries (Lewandowski et al., 2006). In Turkey the already projected development could cover 90% of the total future energy supply (Evrendilek and Ertekin, 2003). In Croatia the current RES-E share is

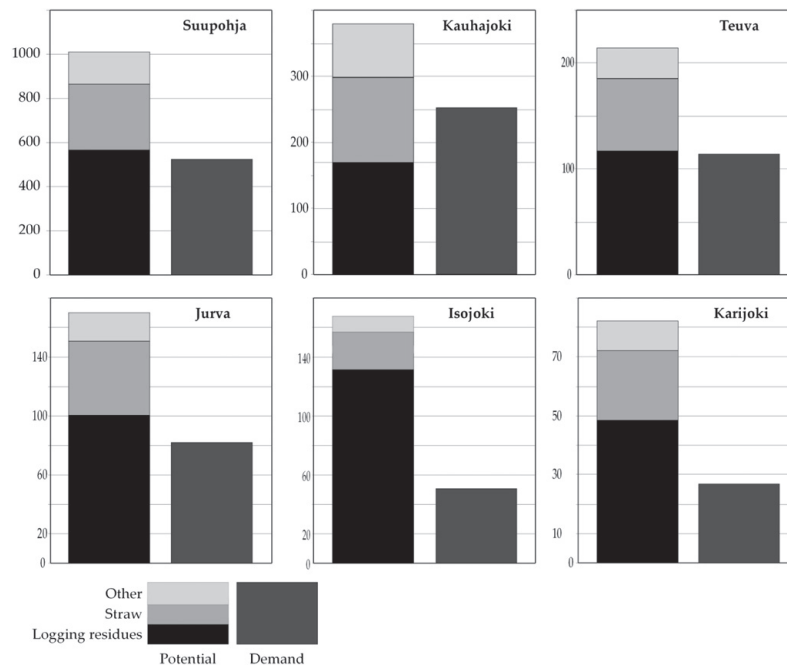


Fig. 8. Bioenergy potential and energy demand (in GWh/a) in five municipalities of Suupohja Region in South Ostrobothnia (Study IV, source: Unpublished material from the ASPIRE project).

already some 50% with a potential for a total coverage in the future (Bozicevic Vrhovcak et al., 2006; Schneider et al., 2007). In Chile some 84% of the natural gas consumption in the year 2015 could be substituted by biomethane (Seiffert et al., 2009).

Globally the technical potential of RES is 16 times higher than the current demand, but at present RES only cover some 13.1% (Resch et al., 2008). The achievable mid-term (to 2020) potential coverage in electricity has been estimated at some 40%, while in the long-term perspective RES-E could provide all global power needs (Resch et al., 2008). Theoretically, future electricity demand can amply be met by wind, solar and biomass based sources in most regions by 2050 below 10 snt kWh⁻¹ (de Vries et al., 2007). The world's bioenergy potential alone seems to be large enough to meet the global energy demand in 2050 (Ladanai and Vinterbäck, 2009; Ceciliano, 2010). Forests can become a major source of bioenergy without endangering the supply of industrial roundwood and without further deforestation (Smeets and Faaij, 2007) (research question 3).

In general, the total energy demand (which has been compared with RE potential) has been poorly defined in the literature cited. Some publications implicitly cover all forms of energy, e.g. including traffic fuels in their own references or referencing "total primary energy" (e.g. Ladanai and Vinterbäck, 2009). A number of articles handle only some sources of energy, for instance RES-E (Resch et al., 2008; Bozicevic Vrhovcak et al., 2006; de Vries et al., 2007; Schneider et al., 2007), wood fuels (Smeets and Faaij, 2007), biomethane (Seiffert et al., 2009) etc. However, a general feature is that the total RES potential seems to exceed all energy demand. In Finland the share of traffic fuels in the total primary energy is about one quarter. The material in this article suggests that the total RES potential would easily cover traffic fuels as well.

In our research areas only bioenergy would also cover energy for transport. Production of biofuels for transport on a larger scale would require strategic prioritisation of bioenergy for this purpose.

The quality of bioenergy and its regional distribution in Finland is clear, and this combined with the available quantities have given rise to the archetypes for RES based production of energy (Fig. 9; based on data in Figs. 4–6). The more peripheral areas in municipalities and also nationally (archetype 1) are the main sources of forestry residues and wood energy, while the rural heartlands (archetype 2) produce large quantities of a number of different RES materials. In these areas RES potential exceeds energy demand.

Industries will always represent a peak of energy demand (archetype 4; Fig. 9), and population centres, including the urban adjacent rural areas (archetype 3), also have a high energy demand, usually exceeding the bioenergy potential. Their energy demand could, however, potentially be covered by the RES materials from the neighbouring rural areas (archetypes 1 and 2). Here, the high energy demand and good logistical options combined with versatile and abundant RES materials provide an excellent ground for new feasible technical solutions of RES based production of energy. There are probably also areas or situations where RES materials will not be enough to satisfy energy demand, as illustrated by Fig. 9.

There are also regional differences in the exploitability of wind and solar power in Finland. Solar energy potential is largest in the south of Finland, while the best wind energy potential is available off-shore, in coastal areas and fells in Lapland (The Finnish Wind Atlas web site, 2009). As they are practically inexhaustible, they could be utilised all over the country, and would make an important addition to the RES potential (research question 4).

The results of the economic feasibility of the studied biogas plants give rise to the following comments:

Table 7
Economy of 11 biogas plants (I–XI; Study V, source: (Peura, 2007b; Peura et al., 2007)).

	Investment expenses revenues, 1000 €	Net present value, 1000 €	Internal rent rate, %	Discounted payback time, a	Energy price, €/MWh
I: Industry 1	7000	-2794	-4	>15	58.8
a					
II: Industry 2	7000	-1767	-1	>15	62.1
a					
III: Industry 3	7100	4365	13	7.5	
a					
IV: 9 farms	3000	-2236	-29	>15	
441					
246					
V: Industry 4	a	-2489	-3	>15	63.0
a					
VI: 1 farm	250	14	6	13.0	26.8
17.3					
20.3					
VII: 1 farm	755	-9	5	14.8	56.3
50					
54					
VIII: SME 1	5000	696	9	11.4	35.9
965					
1066					
IX: SME 2	5500	630	8	12.0	42.0
1004					
1102					
X: Municipal 1	11,912	1126	8	12.5	1334
2020					
2196					
XI: Municipal 2	13,712	4603	12	9.2	
2588					
3103					

^a Confidential.

- A payback period of 15 years is quite short in the energy sector, where many investments are discounted in tens of years;
- With reasonable public support most of the cases were profitable according to even tighter criteria (payback time 8 years, internal rent rate 12%);
- All cases embrace values other than pure business profitability, including impacts of regional employment and economy.

Although business profitability and market based diffusion of RES based production of energy will be the ultimate objective, the other aspects should be taken into account especially in the early phases of diffusion. For instance public support for the new

solutions would be justified for many reasons: The replacement of fossil fuels and development of regional self-sufficiency have a number of strategic benefits even at national level. It is also important to note that the prevailing energy structures have been constructed with the help of public support, as the public interest has always been important in energy management (Jylhä, 2006). Thus, privatisation and market based characteristics do not seem sustainable justifications for totally ignoring the public interest.

Table 8
Preconditions for profitability (discounted payback time < 8 years, internal rent rate 12%; either reduction of investment or increase in income) and income in the first year of operation in eight biogas plants (Peura, 2007b; Peura et al., 2007).

	Reduction of investment		Increase in income, 1000 €	Income year 1, 1000 €
	1000 €	%		
I: Industry 1	3300	47	710	180
II: Industry 2	2800	40	600	252
III: Industry 3	3200	45	650	200
IV: 9 farms	2100	70	390	3
VI: 1 farm	90	36	11	14
VII: 1 farm	324	43	40	38
VIII: SME 1	850	17	200	350
IX: SME 2	1100	20	220	369

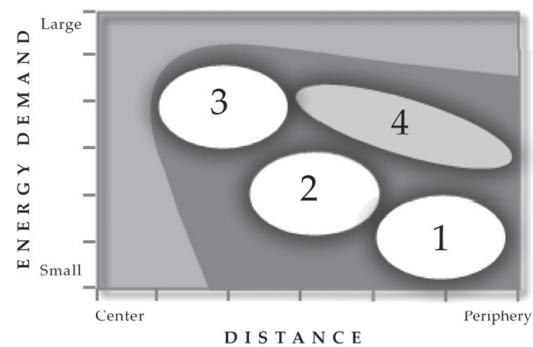


Fig. 9. Archetypes of bioenergy potential in rural Finland (based on Figs. 4–6; Study I, source: Hyttinen, 2005; Peura et al., 2007).

In single separate RES based energy production units it is necessary to outline and in practice tailor the operational concept so that it consists of and involves a number of actors and stakeholders (Fig. 10).

This concept is based on the integration of several factors. Its constituents vary in different cases; it may offer for instance waste treatment services or products such as nutrient concentrates, it can provide job opportunities in producing raw materials, and it can support farmers with their treatment of manure. It also stimulates the regional economy by circulating money and employment inside the region, instead of sending it outside. Regional economics will be the motivation for the public sector to support, and potentially invest in, these new solutions (research question 5).

4.1.1. Potential energy self-sufficiency in Finland

The total consumption or end use of electricity in Finland in 2008 was 87 TWh. The demand for heating in 2006 was approximately 60 TWh, of which 10.6 TWh was produced by electricity. The sale of traffic fuels in the whole country was 43.6 TWh (in 2005; gasoline 49%, diesel 51%). The production of electricity was slightly smaller than the demand, being 82.2 TWh in 2006; with the remaining electricity being imported.

The share of national electricity demand in the Region of Ostrobothnia in 2008 was only about 4%. However the variation between different years has been quite big. For instance in 2006 the demand was 2.75 TWh, while in 2008 it was already 3.55 TWh. Industries consumed slightly more than half the total both here and in the whole country. In Ostrobothnia the private sector demand, including agriculture, was nearly one third of the total consumption, while in Finland it was about one quarter.

In 2008 the production of electricity in Ostrobothnia was about 1 TWh more than the demand. The region has the potential to produce more than twice its own demand, e.g. in 2006 it produced 7.3% (6 TWh) of the electricity produced in the whole of Finland. A substantial share of power generation is only for producing electricity without taking advantage from the heat that is produced, and cooling water is mainly directed to the sea. There are, however, CHP units with district heating or industrial heating systems, where the electricity production corresponds to one quarter of the whole electricity production in Ostrobothnia. The nationally important hydro power is not at all significant in Ostrobothnia with the exception of a couple of power stations. There is no nuclear power generation in the region (Table 9).

In Ostrobothnia the heating demand of buildings was nearly 2 TWh in 2004. The coastal and southern part of Ostrobothnia is a concentration of greenhouses, which use some 700 GWh/a of heating energy. Greenhouses mainly produce their heating energy by oil (85%) and partly by wood and peat (15%). Taking this into account, nearly 50% of all the heat is still produced by oil. The share of district heating is little more than one fifth. From this roughly 40% is produced by coal. In 2008, some 1.5 TWh or 3.4% of the national traffic of fuels were sold in Ostrobothnia.

The sources including RES are well documented in Finnish electricity generation, and the main figures can be seen in Table 9. CHP units and conventional separate power generation also use domestic RE materials, like wood based materials and other biomasses and waste. There the use of biomass was 9.71 TWh and waste 0.71 TWh in 2008, while the remaining part was produced by fossil fuels (8.56 TWh coal, 0.38 TWh oil, 10.99 TWh natural gas, 4.89 TWh peat). Therefore, the share of RE materials was about 14% of electricity production (74.5 TWh in 2008, net import omitted) and 12.3% of the total production (87.4 TWh). The share of hydro and wind power corresponded to approximately one fifth of the Finnish power generation. According to this, the share of RES in the

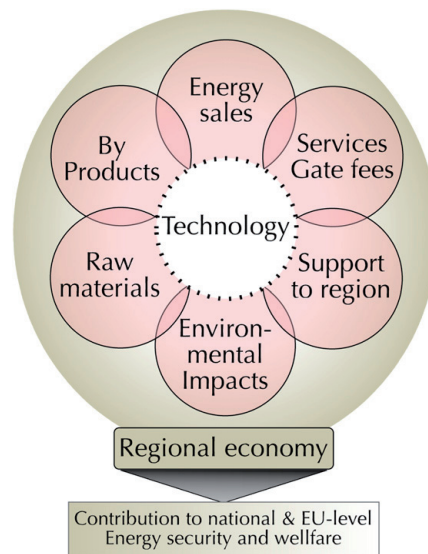


Fig. 10. Operational concept in distributed energy production (Hyttinen, 2005; Peura et al., 2007).

Finnish electricity production is about one third, which already is quite high.

The proportion of hydro power in Ostrobothnia is very low, being only 1.3% of the total electricity production. Wind power is still nearly negligible both in the whole country and in Ostrobothnia, although there are large and quickly growing wind generation industries in Vaasa. However, in CHP generation the share of RE materials is significant in Ostrobothnia. For instance the fuel consumption (primary energy; 2007) for producing some 5 TWh electricity in the five largest power plants was as high as 18.8 TWh, whereas coal makes 7.8 TWh and 42%, and bark, black liquor and other wood based materials and peat 10 TWh and 53%. The share of peat is 1.

Summarising, some 36% of all electricity is produced by RES in Ostrobothnia. However, it is quite difficult to estimate the amount and share of RES based energy in the end use of electricity in Ostrobothnia, mainly because the power stations are connected to the national grid.

From the present heat production in Ostrobothnia nearly 20% is RES based, taking into account that in district heating and heating with electricity the share of biofuels is about 36%, and peat has been considered as a fossil fuel.

Some 40% of the electricity in Ostrobothnia is produced by imported and fossil fuels, like coal and oil. Moreover, from all the domestic raw materials peat makes about 14%, which is a non-renewable resource. This means that the degree of *renewable energy self-sufficiency* (the share of domestic and regional RES) in power generation in 2008 in Ostrobothnia was 36%. Correspondingly, the self-sufficiency in heating is about 20%.

This makes an overall degree of renewable energy self-sufficiency of about 30% in Ostrobothnia.

In 2008 the total energy demand was much higher and the yearly variations seem to be quite large. Moreover, the RES energy content of certain materials does not take into account efficiencies in the energy production phase. However, the real potential would

Table 9
The demand and production of electricity and heating in Finland and the County of Ostrobothnia.

<i>Electricity</i>							
Demand	Private	Industry	Service	Loss	Total		
Finland	22.1 25.3%	44.3 50.7%	17.6 20.1%	3.4 3.9%	87.4		
Ostrobothnia	1.01 28.6%	2.06 58.4%	0.46 13.0%	3.53			
Production	Hydro power	Wind	Nuclear	CHP	Separate ^a	Net import	Total
Finland	16.9 19.3% 22.7%	0.26 0.3% 0.3%	22.1 25.3% 29.6%	26.5 30.3% 35.6%	8.8 10.1% 11.8%	12.8 14.6%	87.4 b
Ostrobothnia	0.10 2.2%	0.01 0.2%	1.50 32.8%		2.96 64.8%	4.57	
<i>Heating</i>							
Production	District heating	Oil	Electricity	Wood Peat	Geothermal & other	Total	
Finland	29.4 49.4%	8.0 13.5%	10.6 17.7%	7.0 11.8%	4.5 7.6%	59.5	
Ostrobothnia	0.57 21.5%	*1.25 47.2%	0.39 14.7%	**0.31 11.7%	0.13 4.9%	***2.65	

Electricity: in 2008; TWh/a, upper and share, %, lower. Heating: Finland in 2006 and Ostrobothnia in 2004; TWh/a, upper and share, %, lower. Includes heating energy for green houses: * 0.60 TWh; ** 0.10 TWh; *** 0.70 TWh.

^a Separate power generation without heat utilisation.

^b Percentage from the domestic production (net import omitted).

be much higher if wind or solar power or the energy reserves of the water bodies and the ground were taken into account. Also the omitted cultivation grounds and wood mass presently used by the forest and paper industry might provide important RE supplies in the future. For instance only the presently planned wind parks in Ostrobothnia would produce 3.4–6.5 TWh/a electricity (effective hours: 30%). Thus it is not possible to give exact figures for the potential degree of renewable energy self-sufficiency.

Still it is clear that the large potential of bioenergy reported here is significant, and accompanied with the other RES potential (not researched here) the total RES potential would even be inexhaustible. This will give Ostrobothnia a great opportunity to become totally energy self-sufficing in the very near future. As Ostrobothnia is a representative sample of Finland, the same can be applied to the whole country.

In order to fulfil the EU targets by 2020 (European Parliament resolution of 25, 2007) it would only be necessary to raise the share of RES in energy production by less than 10% of the total energy demand. In Finland this would mean less than 10 TWh/a electricity and 6 TWh/a heating energy and in Ostrobothnia some 0.5 TWh/a and 0.3 TWh/a, respectively. In Ostrobothnia only some 27% of the unused and easily available bioenergy potential would be needed in order to achieve this target.

4.1.2. The process

The establishment of RES based energy management systems at a larger scale will in most places mean at least some practical changes, and in many cases, a total change from fossil fuels to new raw materials and new technical solutions. The emergence of this kind of new structures, much different from the prevailing centralised system, will in all cases be a long-term process. The process of the acceptance and diffusion of any new innovations always have to overcome several thresholds or obstacles (cf. Peura, 1999; Rogers, 1995):

1. They have to surpass the social acceptance – they must attain a general approval as well nationally as locally;

2. They must be “structured” so that laws, regulations and other social structures support them, or in the first phase, do not oppose them;
3. They have to go through technical evolution from less to more developed, efficient and common solutions.

Distributed energy production and its technical solutions are clearly in the early phases of diffusion. On the other hand, the concurrence always takes place in real time markets, where the opponents are at the opposite end of their diffusion – meaning technologies with decades of operation and technical evolution, investments paid back for a long time ago, social structures supporting them, have all the benefits of mass production and developed value chains etc.

This situation is schematically described in Fig. 11. Distributed energy technologies can be located to the left and down part of the diffusion curve (cf. Rogers, 1995), while the conventional prevailing technologies are right to the opposite side of their curve. As Fig. 11 shows, there are a number of capabilities which have to be developed before the diffusion of distributed technologies will proceed (cf. Leonard, 1988). This also refers to the change process in the social sphere (Peura, 1999).

This change process will necessarily involve most people, and there will be a huge number of decision-makers, from single citizens, families, farmers and enterprises, to the public sector. The process also involves those who need energy, those who produce it, those who manufacture the technical solutions, and those who deliver the raw materials, as those who create the general preconditions for the whole movement to decentralised energy production.

Understanding the whole energy sector, markets and the social context as the operational environment for the new solutions will be of critical importance in the future. It is clear that building capacity, commitment and raising awareness generally and among stakeholders locally, regionally and nationwide will be necessary.

Summarising, the establishment of RES based energy self-sufficiency and distributed strategy will be a long evolutionary

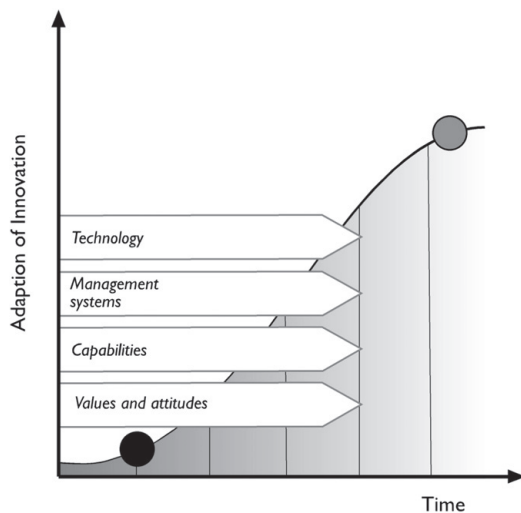


Fig. 11. Diffusion of innovations (Rogers, 1995) and the role of capabilities (Leonard, 1988) in the diffusion process of distributed generation of energy.

process at local, regional and national as well as international levels. In rural regions it will stimulate employment, welfare and the regional economy. It offers rural regions a totally new societal role: besides food production, the countryside would also be a source of energy. Its duration and comprehensiveness depends on whether it will merely be market driven, supported by the government, adopted by energy companies, or a combination of all these factors.

According to the results in this article, the physical prerequisites for this kind of renewal of the energy sector are highly realistic. In terms of national strategy and economic and environmental reasons it should especially be an aspiration in the very near future.

4.1.3. Towards a vision?

"A **dichotomy** is any splitting of a whole into exactly two non-overlapping parts" (Wikipedia, 2008)

The results from the studies presented in this article allow us to anticipate a more common RE based energy production in the near future. This, in a time frame of 10–30 years, may result in structural changes, maybe even renewal of the whole energy sector. Instead of purely fossil fuels and centralised structures, there will emerge a new distributed strategy using renewable energy sources. As there are diverse RE materials abundantly available, and the economy can be developed even for a good business in some cases and for decent regional impacts in most cases, this development might even be unavoidable.

When one RES based production unit is possible, demonstrated and in operation, the next one will be encouraged immediately – more units will be initiated and established. Along with this process, factors of internal efficiency and the whole value chain in RES based production of energy will improve, technical solutions will evolve and prices will decrease, accompanied by more supportive regulations and policy towards the new solutions. When separate production units become sufficiently widespread, perhaps during the next 10–30 years, the outcome makes a structure different from the situation today.

The most likely starting places for this development are twofold:

- (1) Farms, households and municipal regional plants adopt RE materials into their heat production, accompanied with investments in new technology or smaller changes enabling the change of fuel. Most farm and household cases like this would be typically the archetypes 1 and 2, while the regional units would mainly represent archetype 3 (Fig. 9);
- (2) New regional RES based CHP units, perhaps with an option for also producing road fuel, will be established in "hot spots", representing the archetype 4 (Fig. 9). In these places at least the following value producing aspects can be integrated: Energy infrastructure and well maintained utility grid usually exists; RES is available in large amounts and a variety of materials and side products from other local industries can potentially be utilised; industries make a concentration of energy consumption.

This kind of hot spots in the middle of the RES pool would be the dispersion centres for the new structure. This scenario of dispersion would actually correspond to the process according to which the whole energy production and delivery originated in Finland – energy production was started by industries which then started to serve the surroundings. This way the coverage of the new structure may become more widespread. When the sphere of influence of two and finally several dispersion centres meet, the area together will represent an integrated zone. This, as the theory suggests, will be the new emerging structure, partly instead of but mainly beside the prevailing centralised system of energy production.

In the context of the energy sector this dichotomy would mean the following two parts:

- The prevailing centralised structure, mainly using fossil fuels today;
- The anticipated new structure outside large population centres and energy intensive industry, such as wood processing and metal industries.

There are very little really negative factors in a more comprehensive use of RES in the production of energy. These negative factors could include for instance the pressure for more efficient harvesting of forests and resistance to the transformation of productive agricultural land to energy production, and these are both now issues for serious social and political discussion in Finland. It is also clear that the technology is not yet fully developed and still has many shortcomings and deficiencies, and the efficiency from many perspectives (e.g. performance by economic, energy, and environmental parameters) may be poor. Many people are also concerned that increasing the integration of RES might require too much and continuous public support. However, it is necessary to remember that the prevailing energy infrastructure has always been constructed by public support, and the public interest has traditionally been central in developing energy management in Finland (e.g. Jylhä, 2006).

Overall, for instance the emissions will decrease both when looking at the direct discharge (end-of-pipe) and especially when considering the whole life cycle and compared with the corresponding methods of producing (fossil) energy today. As a matter of fact, this as a part of the battle against climate change is one of the main arguments for a more comprehensive use of RES.

The main hindrance will be the process itself – there are many phases and thresholds to surpass, and it will be the social evolution process that will show whether or not the vision will be achieved. The adoption curves for deploying and implementing

RES based technologies for the production of energy are rising steeply, but there are no scientific publications to confirm this quantitatively. There are many factors defending and promoting the development towards the vision, but there are also many factors and actors trying to prevent it. For instance in the prevailing energy markets it might be difficult to compete with proven solutions and all the regulations and rules that support them, and maybe some utilities would even prefer that newcomers are excluded from the markets.

However, there is no scientific research or evidence that would directly support this vision. Therefore, it remains a future research theme, at least for our research team.

5. Conclusions

The main finding of this article is that bioenergy potential in the Ostrobothnian Counties, and also more widely in Finland is tremendous and available energy resources exceed overall energy demand. In Ostrobothnia there is great potential to work towards regional energy self-sufficiency, and in order to fulfil the EU's 2020 targets less than one third of available bioenergy resources would need to be mobilised. Ostrobothnia is a representative sample of the whole country and Finland would have the same opportunity. This is supported by similar results elsewhere from Europe and even globally, and the potential practical implications are extensive.

The economics of small scale power generation units, here represented by biogas plants, are already feasible, despite the technology being at an early developmental phase. Diffusion of these technologies depends on a number of factors, but single and separate units are emerging all the time. Along with time they are about to become more common. However, at a larger scale, the adoption of RES based energy management systems will be a long social process.

The results give rise to an expectation for more RES based energy generation in Ostrobothnia and Finland, and even in Europe and globally. In a time frame of 20–30 years, the development may result in structural changes across the whole energy sector. This comprehensive movement can only be understood and supported by multi- and cross-scientific approaches, and it will in future be a challenge for forthcoming research.

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Appendix 1. Summary table of European and Finnish policies on RES

	Objectives
<i>EU policy/activity</i>	
2020 Vision: saving our energy. DG Energy and Transport, 2007	To achieve a certain CO ₂ reductions in 2020.
Directive on the Energy Performance of Buildings – 2002/91/EC	To achieve ambitious increases in the energy performance of public, commercial and private buildings in all Member States.
Proposed Directive on the Promotion of Energy End-Use Efficiency & Energy Services Directive COM(2003)0739	To improve end-use energy efficiency at Member State level, development of the market for energy services, to promote the market both for energy services and for energy efficiency measures in general in major energy end-use sectors. Public sector to lead by example.
Green Paper on Energy Efficiency COM(2005)265	To improve energy efficiency at all levels of European society – EU, national, regional and local.
Green Paper on Security of Energy Supply COM(2000)769	To generate debate concerning a longer-term EU strategy to reduce reliance on external sources of energy supplies.
Directive on the promotion biofuels or other renewable fuels for transport – 2003/30/EC	To promote the use of biofuels or other renewable fuels to replace diesel or petrol for transport purposes in each Member State.
Directive on the promotion of electricity produced from RES in the internal electricity market – 2001/77/EC	To promote an increase in the contribution of RES to electricity production in the internal market for electricity; national targets to be set at Member State level.
White Paper on Renewable Energy Sources – COM(97)599	To set out an action plan for increasing the exploitation of RES within the EU, to maximise opportunities for job creation and regional development within the community.
Biomass Action Plan – COM(2005)628	To increase the use of energy from forestry, agriculture and waste materials in order to reduce dependence on external sources of energy supply, cut greenhouse gas emissions and safeguard jobs in rural areas.
Sustainable Energy Europe Campaign	To promote the concept of a 'Sustainable Energy Europe', projects and partnerships that are actively informing and educating EU citizens on the importance of RES
<i>Finnish policy/activity</i>	
National Climate and Energy Strategy 2001. (Accompanied by the Background surveys) Directions for Energy and Climate Policy in the nearest future – the National strategy for implementing the Kyoto protocol (Report to the parliament given by the government 24.11.2005)	– Decrease CO ₂ emissions – Promote RES and RUE – Maintain flexibility of energy management
West Finland Environmental Strategy 2000. (West Finland Environment District, three county councils, other regional authorities) Updated 2006	– Energy self-sufficiency – Promoting RES and RUE in Ostrobothnia especially bioenergy.
Regional Plan of the County of Ostrobothnia.	Energy self-sufficiency 100% or more, based on RUE & RES and distributed generation, primarily by bioenergy. To develop own manufacturing capacity of technology

Appendix 2. Description of the investment models

The model was developed and implemented in a spreadsheet program framework, *Microsoft Excel*, using formulas and *Visual Basic* macros. The core of the model consisted of three main sheets: 1) current costs sheet, 2) energy sheet and 3) investment calculation sheets. The model also includes separate sheets for the results, sensitivity analysis, evaluation of the economic forecasts of the investment unit, and raw material data.

The *current costs sheet* is only applicable when examining energy generation in conjunction with a manufacturing firm. Thus, current waste treatment and transport costs as well as cost of outside energy (which are removed if the firm applies own energy generation) are technically considered as revenues (decrease in costs) in the calculation. Prerequisites for adopting this class point of view are typically the following: 1) the firm produces lot of waste which can be used as a raw material in a biogas production, 2) current waste treatment and transport costs are high, and 3) the firm has big electricity and/or a heat need. In the sheet, all current material treatment and transport costs are given as inputs for the model. The costs are allocated to each material type by their yearly generated amounts (default). Weight-based allocation is considered as a sufficient approximation by the management of the case firms. Finally, the desired material types for generation are selected and their proportion of total costs is calculated. In this sheet, information of the current energy sources, prices and yearly consumption data are given to calculate the benchmark price of the replacement energy.

The first part of the *energy calculation sheet* makes it possible to perform a rough analysis of the regional material energy potential and its sources if the material amounts are available. In the second part, the theoretical biogas potential of the selected materials is estimated. The calculation is based on the proportions of total solids, volatile solids and methane production potential of the materials. The amount of available energy potential is calculated using the overall amount of biogas and its methane content.

The produced biogas is then converted to the user-desired energy form with different efficiency multipliers. The possibilities are heat or combined heat and power production, vehicle fuel and other use. The own energy need of the plant can be either subtracted from the own production or it can be bought from the outside. The residual energy is called free energy, which can be sold. This energy is always case-specifically valued in the model. If the vehicle fuel form is selected, then the model calculates the amount of the regular vehicle fuel equivalent litres.

The *investment calculation sheet* consists of input data of all revenues and costs, which are related to investment. The actual investment calculations are prepared using the conventional discounted cash flow technique. Typical cash flows for such an investment are initial investment, government's investment grant and all regular yearly based operating costs and revenues. For the discounting procedure, the model uses a weighted average cost of the capital (WACC; generally used in practical capital budgeting). The model assumes that typically both debt and equity are needed. In addition, only positive income taxes are taken into account in the cash flow projection. Thus, all negative taxes, tax refunds, are excluded from the analysis.

The cash flow concepts used in the model are *traditional* (cash flows are calculated on an accrual basis). The net cash flow is defined as cash receipts (earnings) minus cash payments (costs and taxes) over a given period of time. The model calculates the net cash flow before and after the income taxes. For calculating the investment criteria (NPV, IRR and PP) the traditional cash flow after taxes is used, if the tax rate is applied. All investment grants are handled as a deduction of the initial investment (net investment concept).

The *results sheet* reports the general investment criteria (NPV, IRR and PP), and price of the generated energy in several alternative

ways. The production cost of energy (heat and electricity, per MWh) is reported. The energy price calculated with only operating costs and investment depreciation is also presented. Also the break-even energy selling price per produced MWh is reported (energy cost price), including all operating costs and revenues (without energy selling revenues). In municipality owned power generation, the model calculates the processing cost of raw materials per incoming material ton. This result can be for example used for fixing gate fees for incoming materials.

When calculating the energy price of the own energy generation, the model takes into account all the costs and revenues which are related to the new generation form. In this way a comparable energy price is obtained to the current and distributed generation alternatives. The energy costs are calculated separately for both alternatives for every planning year using discounted prices. However, the depreciations of the investment expenditure are not discounted because they are computational (book) expenses.

The *sensitivity analysis sheet* examines the sensitivity of the results for the investment criteria and energy price calculation, to certain input data parameters. This analysis is based on a *ceteris paribus* principle limited to a change in one individual parameter value at a time. In the model, the effect of a change in the following parameters can be simulated: cost of equity capital, net investment, variable costs, fixed costs, and revenues.

In the *economic forecast sheet*, the economic development of the biogas plant can be estimated with a separate tool (a financial model). With the help of this tool, the forecasts of the income statements and balance sheets for the future years are obtained. In this analysis, the depreciations of different fixed assets categories can be calculated for different depreciation times as required by the Accounting Act. Furthermore, this sheet includes a specific financing calculation procedure which helps the user to estimate the effect of investments on the financing need and enables planning of the annual amortisation level of the liabilities.

The *raw materials data sheet* includes the parameters that describe the total solids, volatile solids and methane production potential of each waste material. These raw material data are used by the energy calculation sheet. There are built-in parameters in all to 35 material fractions which are adjustable by the user of the model. In addition, the user can also add new raw materials to the database in the sheet.

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ARTICLE IV

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Implementing sustainable energy – four case studies

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Abstract: This article aims to increase knowledge and find the best practices on how sustainable energy (SE) can be boosted and implemented at a regional level. It presents the main results from the RESGen (RES Generation – from research infrastructure to SE and reduction of CO₂ emissions) project and the procedure developed within the project, which aims to support regionally comprehensive implementation of SE involving all the main stakeholders. Physical prerequisites to support the transition of the energy sector towards SE exist. The RES potential is vast, the economics, especially regional impacts, are feasible, general perceptions are positive, technologies are evolving and the majority of stakeholders support this agenda. There are however barriers slowing the process. The RESGen procedure provides a structured and strategic approach for the shift towards SE.

Keywords: sustainable energy; RES; renewable energy sources; energy self-sufficiency; regional implementation process; RESGen.

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1 Introduction

This article aims to increase knowledge and find the best practices on how sustainable energy (SE) can be boosted and implemented at a regional level. The main approach for this has been through developing comprehensive regional strategies, which integrate all the main stakeholders (authorities, industry, and R&D bodies) into regionally rooted programmes. This paper presents the main results from the RESGen (RES Generation – from research infrastructure to SE and reduction of CO₂ emissions; EU Regions of Knowledge; 2010–2012) project within which a documented 'RESGen procedure' was prepared and used.

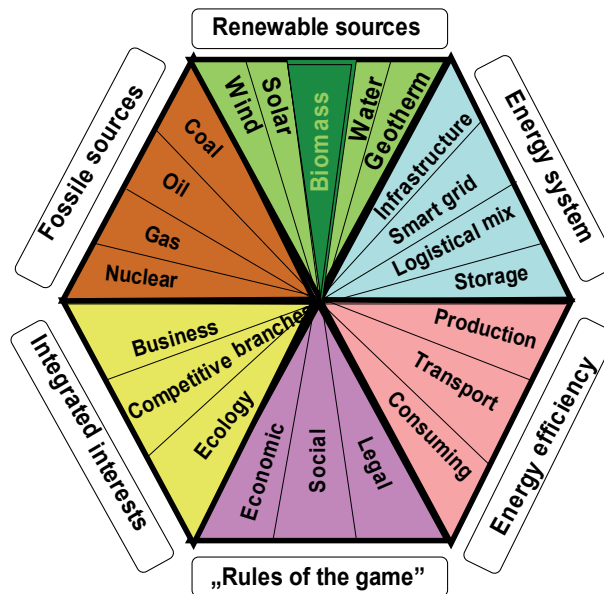
SE was recently reviewed and defined as follows (Peura, 2013):

- 1 rational use of energy (RUE; saving, efficiency)
- 2 renewable energy sources (RES)
- 3 integration of RUE and RES
- 4 sustainability management.

SE descends from the idea of sustainable development, which has several different interpretations, including more than 300 definitions within environmental management (WCED, 1987; Johnston et al., 2007; Chichilnisky, 2011). SE interlinks with all the other aspects of sustainability, which depend on the secure operation of energy supplies. Comprehensive understanding is necessary in developing SE (Figure 1).

There are a number of technologies for RUE and RES, the integration of which is the key to creating complete alternative solutions with different degrees of regional energy self-sufficiency. SE management is necessary to avoid adverse impacts and careless use of RES in the name of SE (Peura, 2013). In developing the RESGen procedure this approach has been applied regionally.

Figure 1 The concept of SE management (see online version for colours)



Source: Dinya (2009)

The main objectives and research problems in this paper were:

- To construct a documented procedure for assisting implementation of SE regionally.
- To test and analyse the procedure in three regions, questioning:
 - 1 Can the procedure help create commitment and trust among stakeholders?
 - 2 Is the procedure helpful in implementation of SE?
 - 3 Is the procedure suitable for a more widespread use?

The need for SE is based on the following reasoning:

- Deterioration of the environment is a threat to the whole of human kind and caused by discharge and overconsumption of natural resources. Human kind's ecological footprint reached an overshoot of 44% in 2006, resulting in an ever-growing sustainability gap and causing reductions in natural buffers for self-purification abilities (Weijermars, 2011). The cost for remedies has been estimated to exceed 14 trillion Euros and a 7% loss in global GDP in 2050 (EC, 2008). It has been widely accepted that the problems are real and caused by human activity.

- Energy production has been one of the core issues concerning human kind's environmental impacts, whilst also having significant economical and societal impacts. That's why "*climate policy is principally...energy policy*" (Huberty and Zysman, 2010). All thinkable fossil energy sources are becoming scarce and more expensive (Smalley, 2005; Jefferson, 2008; Hall and Day, 2009), and the transition to SE will be among the most important components in comprehensive global change (Peura, 2013).

There is a vast literature about human kind's environmental impacts, population dynamics, limits of existence and natural resources (Peura, 2013). Summarising, the world will face comprehensive changes and the transition towards SE can be an integral part of them. "*... sustainability in a fundamental sense is connected to the survival of our species*" (Chichilnisky, 2011). It is important to develop SE in line with 'normal' business criteria. SE is however not normal business and cannot be understood merely as economic transactions and 'business as usual' based on the following reasoning:

The construction of energy infrastructure has been subsidised by public funding. It has become more of a commercial activity following the privatisation of power plants and networks (originally publicly subsidised). However privatisation has not led to free markets based on equal competition, which would be a precondition for classical economic decisions "*...without a 'constraint' for sustainability*" (Chichilnisky, 2011). The development of energy infrastructure is still led by political decisions and the general rules define what can be profitable in the energy sector. Today, most regulations still support the prevailing actors, and there are a number of structural barriers for any newcomers trying to introduce SE to the market. For instance, in 2011 subsidies to fossil fuels were \$523 bn globally, but only \$83 bn to RES (IEA, 2012).

Energy safety and self-sufficiency have national strategic implications, and there are important regional impacts. The money presently flowing to oil producing countries, for instance, would have significant benefits if it stayed 'at home'. Therefore, decisions to support the development of SE are essentially strategic ones, and they are directed towards creating a stable business environment.

It is essential however that any new power plant is feasible. All operations take place in real time markets and concurrence cannot be avoided. "*... unsustainable practices have become a problem (...) because we are using world resources to the limit*", but the constraints involved by sustainability criteria "*... do not exist in neoclassical decision criteria*" (Chichilnisky, 2011). Therefore, "*we need new economic foundations that update classical economic thinking*" (Chichilnisky, 2011).

Also, this reasoning is reinforced by a vast scientific literature (Peura, 2013), the reviewing of which is beyond the scope here. As this article aims at promoting SE and its business environment, the requirement for normal feasibility of every action still remains.

Today, there are a number of positive drivers for SE. However, the diffusion of SE has been slow and there are many barriers. To make the dynamics understandable, the main drivers and barriers have been briefly reviewed in Chapter 2.

2 Drivers of and barriers to SE

Over the last two decades there has also been increasing awareness and aspirations to see more widespread use of RES. The main reasons for this have included the following:

- *The RES potential:* Empirical material from Europe and globally demonstrates that there is realistic and easily mobilised potential for RES to enable energy self-sufficiency. Even 100% RES systems have been planned in practice (Peura and Hyttinen, 2011; Peura, 2013).
- *The economy of RES technologies:* The business case for RES solutions is often already feasible (Peura and Hyttinen, 2011) and investments in RES technologies have performed well (Masini and Menichetti, 2012). The benefits beyond business profitability can be significant. This regional added value (Hoffmann, 2009; monetary aspects, reduced costs, increased purchasing power, new employment, tax income, social, ecological and ethical aspects, improved vitality) would be remarkable. RES also generates more jobs than conventional energy (review and references: Peura and Hyttinen, 2011; Peura, 2013).
- *General perception and policies:* Development of a positive perception has prepared the ground for social acceptance of SE, which has been high since early 1980s (Wüstenhagen et al., 2007). Policies and other support frameworks were established in 118 countries by early 2011 (REN21, 2011). RES has moved to the top of the international political agenda, the institutionalisation of SE is occurring globally, and SE has become the key concept in reforming the energy sector.
- *Technical evolution:* Technical evolution is in early development phase, but new solutions are being developed on constantly. The strong spatial diffusion of RES technologies worldwide, despite their low market share, indicates a high overall potential for further diffusion to cover 60% of produced energy in 2050 (Lund, 2010b).

Despite strong signs of progress, the expansion of SE has been far less than, for instance, the increase of world coal production (Jefferson, 2008). There are a number of reasons for this:

- *Institutional opposition:* The prevailing large actors tend to prevent any development that does not support their own business (Lund, 2010a). This also means that RES-based solutions are fighting against existing energy structures.
- *Diffusion of RES-based technologies:* SE and RES-based systems require often a total change from fossil fuels to new raw materials. The shift towards these structures, different from the prevailing system, will be a long-term process. Technology and innovative institutional frames (Leszczynska, 2011; Wolsink, 2012; Peura, 2013) are necessary. As is the case of any innovation, institutional lock-ins preventing acceptance by key actors must be ‘unlocked’:
 - 1 key social actors must accept the innovation
 - 2 the process must be ‘structured’ so that laws, regulations and other institutions support them, or do not oppose them
 - 3 innovations must evolve technically.

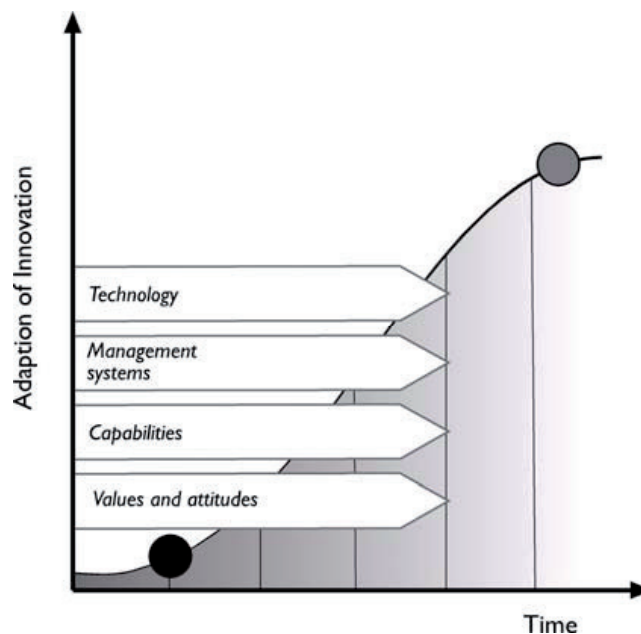
RES solutions are in early phase of diffusion, but concurrence takes place in real time markets, where the opponents are at the opposite end of diffusion. Thus, they are competing against technologies with many years of technical evolution, where investments have been repaid, supportive social structures are in place and the

benefits of mass production and established value chains exist. As illustrated in Figure 2, RES technologies can be located to the left and lower down the diffusion curve, whilst the prevailing technologies are to the right and higher up the curve.

- *The process:* Change towards SE will be a long evolutionary process, which needs to involve the majority of people. There will be a huge number of decision-makers, from individual citizens, families, farmers and businesses, to the public sector. Its success depends primarily on how the crucial stakeholders approve it (Wüstenhagen et al., 2007).

The conclusion drawn is that physical prerequisites for SE exist. A shift towards SE and away from fossil fuels will presumably be on the global agenda in the near future. The majority of stakeholders wish to see this agenda move forwards, but there are barriers slowing the process. Also, the role of economics is problematic: market penetration and competition against powerful prevailing structures is difficult, but along with the diffusion, the prerequisites and feasibility of SE are expected to improve. Conscious strategies and programmes can boost this development, which has been the focus in constructing the RESGen procedure.

Figure 2 Diffusion of innovation and capabilities, RES technology: bottom left, conventional technology: top right



Source: Rogers (1995)

3 Methodology and case studies

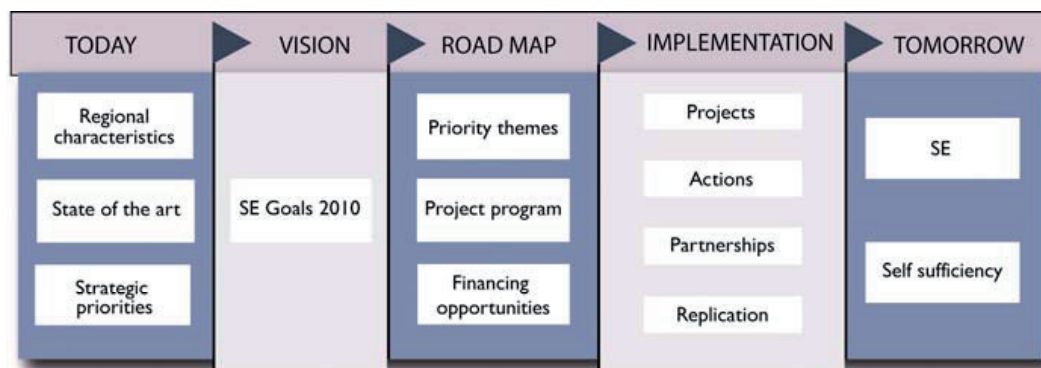
3.1 Methodology

The underlying idea was to boost SE by developing a replicable common approach and methodology, the RESGen procedure. In the project it resulted in four regional roadmaps

for implementing SE. The roadmaps were clearly defined practical project programmes based on regional strategies, for which stakeholder commitment is crucial. Figure 3 illustrates an overview of the procedure and its phases:

- development of regional strategies based on the regional characteristics (regional SE, capacities and capabilities) and priorities
- development vision and roadmaps 2020.

Figure 3 Overview of the RESGen procedure (see online version for colours)



Regional characteristics formed the starting point, i.e., the current energy mix and future perspectives of SE. The analysis aimed to identify alignment and complementarity between the regional SE RTD supply, demand and policies. Each region collected information as follows:

- SE – state of play
 - a current energy overview
 - b situation and perspectives: workshops, interviews, analyses.
- SE policies
- directories of SE RTD demand and supply, basic regional information (2008)
 - a companies' R&D: employees, turnover, expenditures, international presence, main fields of activities, funding sources.

The data was further elaborated in regional SWOT analyses for defining the regional priorities. Information attained through questionnaires and workshops was organised into a matrix (Figure 4), which enabled the definition of strategic steps:

- 'SO': Exploiting opportunities, based on strengths.
- 'WO': Eliminating weaknesses, exploiting opportunities.
- 'ST': avoiding threats, based on strengths.
- 'WT': Avoiding threats, eliminating weaknesses.

Figure 4 The SWOT matrix (see online version for colours)

		Present (inside)	S (+)		W (-)	
		Future (outside)	<ul style="list-style-type: none"> •RES •Non-RES •Supply chain •Rules •Value chain •Efficiency 	<ul style="list-style-type: none"> •I-Input •I-Output •I-Competition •I-Service 	<ul style="list-style-type: none"> •RES •Non-RES •Supply chain •Rules •Value chain •Efficiency 	<ul style="list-style-type: none"> •I-Input •I-Output •I-Competition •I-Service
O (+)	<ul style="list-style-type: none"> •RES •Non-RES •Supply chain •Rules •Value chain •Efficiency 	SO		WO		
	<ul style="list-style-type: none"> •I-Input •I-Output •I-Competition •I-Service 					
T (-)	<ul style="list-style-type: none"> •RES •Non-RES •Supply chain •Rules •Value chain •Efficiency 	ST		WT		
	<ul style="list-style-type: none"> •I-Input •I-Output •I-Competition •I-Service 					

Source: Dinya (2011)

In Finland and Hungary the matrix was used as follows: Each S, W, O and T was collectively defined and given numbers (S1, S2...T1, T2, etc.), which were placed into the matrix. Every cell was a combination of S-O, S-T, W-O or W-T. The SWOT panel participants gave scores to each cell according to how important they considered each combination (S1-O1, S1-O2 ... W1-T1, W1-T2, etc.) on a scale of 0 to 5 (0 = no relevance, 1 = very little relevance ... 5 = very important). The collective opinion was the sum of all scores and those combinations that received the biggest scores were considered the most important ones. In Basque Country and Cornwall the procedure was simplified to better meet their strategy processes.

Then, the regions defined their Vision 2020 and roadmap. Regional panels outlined the most likely future scenarios for the Vision, defined the priority themes and project ideas; these were further developed by e-mails and discussions. A series of regional workshops were organised to guide the regions. The Delphi method (Linstone and Turoff, 2002) was recommended, but the regions could use any relevant method to attain a collectively defined roadmap. The project partners produced short descriptions of all project ideas. All materials were delivered to the panels. In the final workshop the results were discussed and the participants could comment on the earlier results.

Each participant received an e-mail including the proposed themes and project ideas for scoring, instructions and Excel templates to be filled in. The overall scores were considered as the regional collective opinion. This organisation resulted in the ‘fishbone’ structure, which was the roadmap for each region. In the fishbone (Figure 5) the themes are the four blocks, the priority areas the fish bones and the separate projects the actions.

3.2 Case studies

The RESGen partnership consisted of nine partners, representing the three main regional stakeholder groups (industry, administration, R&D bodies), from four regions and EU member states (for details: <http://www.resgen.eu>). The RESGen procedure was applied in four case studies, Ostrobothnia Finland, Basque Country Spain, Cornwall UK and Northern Hungary. Information about the regions and the RESGen procedure is collated in Table 1.

Table 1 The RESGen case studies

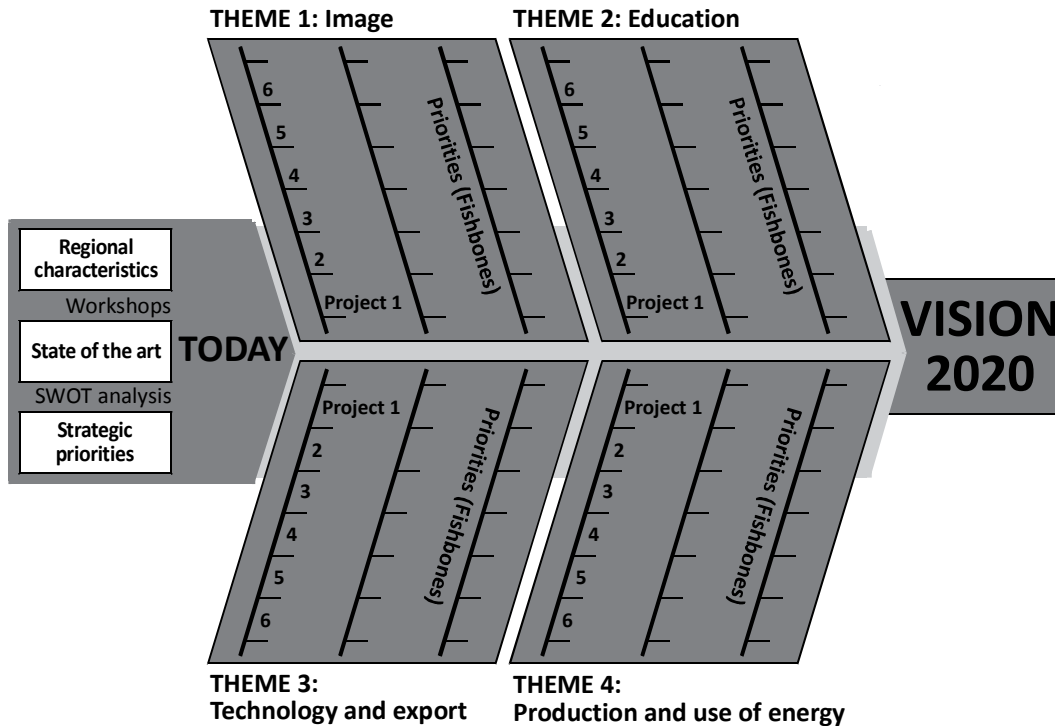
	<i>Ostrobothnia Finland</i>	<i>Basque Country Spain</i>	<i>Cornwall UK</i>	<i>Northern Hungary</i>
Population	180,000	2,100,000	531,000	1,280,000
Cluster	Vaasa	Bilbao	N/A	Gyöngyös
Companies	120	> 350		> 50
Employees	10,000	24,000		3,500
RSC*				
Participants	20	6	8	16
Meetings	5	5	5	4
SWOT analysis				
Participants	12	20	18	33
Workshops	3	4	1	2
Other				
LFA**	20			16
Roadmap themes				
Participants	70	25	35	21
Workshops	2	7	2	1
Project scoring/selection				
Participants	40	15	6	16
Workshops	2	3	1	1
E-mail-responses	16			34

Notes: *RSC = regional strategic committee

**LFA = logical framework analysis.

Stakeholder involvement was extensive, which implies a good regional commitment. The data is not statistically representative, but involving key persons from key stakeholders ensures that the results represent the regions and their SE sectors.

Figure 5 The regional roadmap as the fishbone structure, presents the final priority themes and projects



Note: The themes shown are from Ostrobothnia.

4 Applying the RESGen procedure – experience from four countries

4.1 Ostrobothnia, Finland

The most important feature in Ostrobothnia is that the RES potential exceeds the energy demand, and bioenergy alone could potentially cover current energy needs. Ostrobothnia produces more electricity than it consumes, 40% of which is produced by imported fossil fuels and 14% by (non-renewable) peat. Hence, the degree of *SE self-sufficiency* (the share of regional RES) in 2008 was 36% in power generation, 20% in heat production and 30% overall (Peura and Hyttinen, 2011).

The Ostrobothnian SWOT list is in Appendix, and Figure 6 gives the results from the scoring. The dominating field is the 'SO'-strategies, reflecting optimism linked to the RES-industry. The main weakness is the risk that Ostrobothnia may lag behind and be unable to pursue the technical development. RES solutions may be impeded by the strategic conservatism of the dominating actors protecting their own business by visible, but mostly non-visible, entry barriers. Poorly developed infrastructure and value chains are also seen as weaknesses.

The main threats are the volatile international market situation and that the large industries might locate their strategic functions outside of the region. Primarily the actors are from within Ostrobothnia, but decisions made outside the region can have significant impacts. Moreover, the development of the RES-industry depends on political support.

For instance legislation guarantees the ownership and monopolistic control of the delivery network to energy utilities. The weak political position of the region on the national political scene poses a threat to the continuation of the present favourable trend. This picture is reinforced in the ‘WT’ quadrant, where the scores were low.

The procedure resulted in the vision aimed at a significant increase in SE self-sufficiency through regionally available RES, and well-being and development of the energy industry by improving its business environment.

The panel identified the following four themes and number of projects for the roadmap:

- Production and use of RES (33 projects)
Significant potential for SE self-sufficiency.
- Technology and export (14 projects)
The RES-industry as the driving-force, and its business environment.
- Education (14 projects)
Constant need for qualified workers, education vital.
- Image (13 projects)
‘The Region of New Energy’ and its industry.

Figure 6 The scoring results of the Ostrobothnian SWOT analysis (see online version for colours)

	S	S	S	S	S	S	S	S	S	S	S	S	W	W	W	W	W	W	W	W	W	W
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10
O 1	20	21	20	29	27	22	23	21	16	15	13	23	24	15	14	21	13	7	22	9	11	17
O 2	21	11	14	23	23	16	25	18	18	14	7	17	18	13	15	22	15	8	15	7	7	17
O 3	22	17	16	21	31	22	32	20	15	12	14	14	21	15	15	15	12	12	14	13	11	16
O 4	13	11	25	15	22	26	30	16	12	16	5	26	30	20	27	22	16	8	17	15	12	15
O 5	7	21	16	21	19	18	15	6	7	10	6	16	14	10	9	10	13	7	14	7	11	16
O 6	9	15	6	9	8	9	12	3	8	11	21	17	2	2	8	10	6	9	10	3	14	9
O 7	10	10	13	16	27	27	28	10	10	21	8	23	21	14	7	8	8	13	10	7	7	9
T 1	9	5	13	8	24	16	22	20	5	6	4	11	13	7	13	16	15	7	8	6	16	18
T 2	6	9	11	11	19	21	27	19	10	16	6	15	16	11	16	20	20	12	8	7	17	22
T 3	8	9	9	15	12	17	12	13	11	14	5	13	21	14	15	10	17	5	10	9	14	19
T 4	20	19	18	12	14	15	10	14	13	12	9	14	20	11	19	22	16	22	12	9	21	19
T 5	15	14	16	17	16	10	17	13	12	6	6	7	14	12	13	14	8	6	13	7	17	18
T 6	12	20	12	12	11	9	9	8	8	12	3	15	20	14	21	12	12	16	16	8	20	11
T 7	11	10	11	11	17	11	14	11	12	5	7	6	8	6	7	11	6	7	7	10	9	9
T 8	10	16	15	9	6	4	6	2	5	9	4	8	22	9	9	9	11	12	19	9	10	6

No or very little relevance
 Little relevance
 Important
 Very important

4.2 Basque Country, Spain

The project contributed to the definition of the regional technological and industrial strategy EnergiBasque, which was approved by the Basque Government in December 2011. EnergiBasque forms part of the regional energy strategy (3E2020) and provides

input to the regional Science, Technology & Innovation Plan (PCTI 2015) by delivering the key development areas of the energy sector. The 3E2020 has the objectives of increasing energy efficiency in all sectors, increasing the use of RES, consolidation of energy infrastructure and promotion of eight key areas of R&D, which form the basis of EnergiBasque.

The strategy process was a collective effort of the Basque partners with a number of stakeholder meetings. The process was led by the Basque Regional Government (Department of Industry), together with the Basque Energy Board (Ente Vasco de la Energía).

The energy sector is one of the cornerstones of Basque industry, and its development is important for the regional economy. The energy related RTD has a long trajectory and it has reached global excellence in certain fields. The SWOT-analysis showed that future opportunities of the sector lie around new emerging technologies such as wave, off-shore wind, photovoltaic, geothermal and electric vehicles. Taking into account the regional profile, the export of technological know-how in renewables was considered a future avenue. The major threat for growth is the global economic downturn and lower investment levels in SE RTD.

EnergiBasque seeks to consolidate the existing competitive network of science and technology companies and agents within the energy industry. The strategy is oriented towards achieving an ambitious vision: *“To turn the Basque Country into an international knowledge pole and a reference for industrial development in the energy industry”*.

The priority RTD areas were pre-selected based on their contribution to the energy strategy focus and compared with the criteria of existing and potential market appeal and the capacities of the region. The areas with the highest scores were selected as priority RTD lines of EnergiBasque (Figure 7). These areas were classified into three ‘orbits’ (Figure 8), depending on the current size of the market (x-axis), technological positioning of Basque Country (y-axis) and the R&D investment level (orbit size) of each technological area. Each orbit was further detailed as a general objective (GO) of EnergiBasque.

The first general objective (GO1) applies to RTD areas, which are already strong and have relatively large market potential. These areas are smart grids (SG), wind energy (WIND) and solar thermoelectric energy (STE). The objective is to consolidate the driver companies in the Basque Country as leaders within their particular areas and thus create a driver effect throughout the value chain focusing on products of high added value. The second general objective (GO2) is directed towards the RTD areas of STE, energy storage (STORAGE), wave energy (WAVE) and electromobility (ELM). The objective is to develop business activities in these emerging fields in which the existing technology base of the Basque Country already provides a strong starting point. The third general objective (GO3) aims to generate new energy-related markets and opportunities to be harnessed by the Basque business sector, like WAVE, ELM, management of energy services (MES) and unconventional gas exploration (UGE).

Figure 9 shows the Basque Country roadmap with eight strategic areas and the corresponding projects and technological development lines. The strategic areas and projects have been set along the roadmap based on current regional capacities. Thus, the priority areas of SG and WIND, for example, are already important strategic areas, whereas energy services or electrification of transport are currently at the preliminary stage of development, but are expected to have higher importance in the future.

Figure 7 The priority RTD areas in the Basque Country according to the EnergiBasque strategy (see online version for colours)

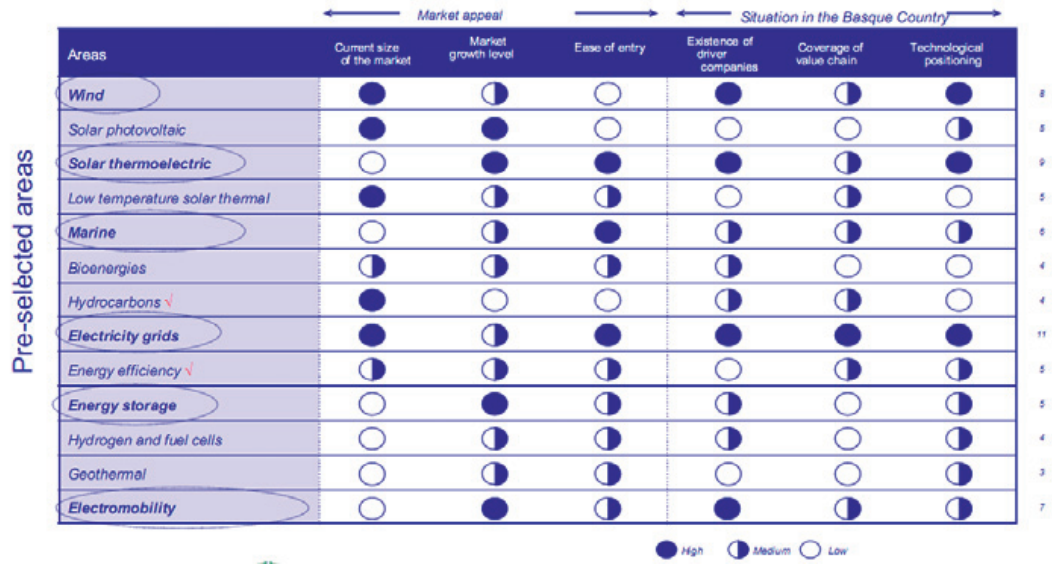


Figure 8 Classification of the selected priority areas in the Basque Country (see online version for colours)

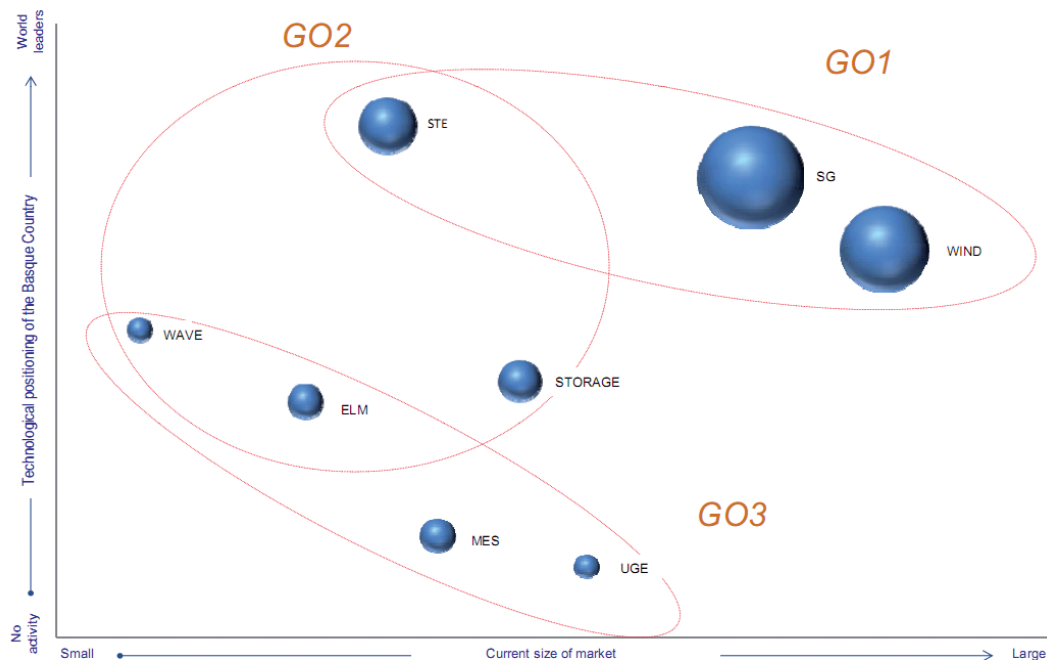
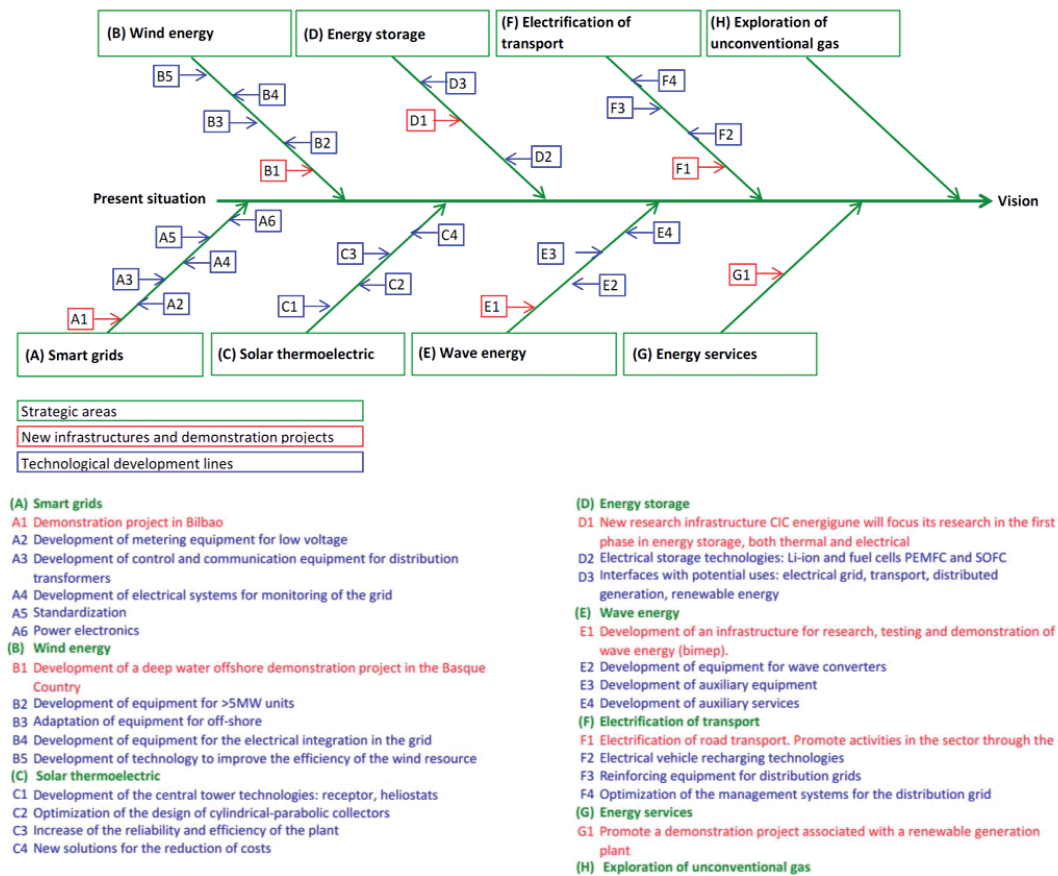


Figure 9 The RESGen roadmap of the Basque Country (see online version for colours)

4.3 Cornwall, UK

The economic opportunities of SE in Cornwall had particular emphasis on developing the marine energy sector and large infrastructure investment. RESGen was significant in supporting a coordinated approach between the business, research and public sectors that will need to work closely together to realise Cornwall's RES potential.

The SWOT analysis identified a number of important factors related to Cornwall's RES capabilities and capacity. Cornwall should be in a strong position as a result of the large available RES, which include wind, wave, geothermal and solar. The Combined Universities in Cornwall provide a strong research focus. Cornwall also benefits from a strong industrial heritage, skilled local workforce and both public and political support for RES-generation. However, only a small percentage of Cornwall's energy is currently produced by renewables.

Several weaknesses were identified, including the lack of market and demand for RES, limited grid capacity, a lack of strategic leadership and joined up approach amongst the public sector. In addition, the small size of businesses in Cornwall and low levels of manufacturing lead to a lack of capacity, which affects market leverage and investment opportunities.

There are a large number of future opportunities to expand RES innovation capacity. Cornwall has a strong academic sector and good links with local businesses. There are several large projects already in development, such as the Wave Hub, the Environment and Sustainability Institute and the development of solar parks. There is potential for job creation and skills development and the region could gain a first mover advantage allowing expertise to be sold both nationally and globally.

The most significant threats are economic uncertainty and changing priorities within the UK Government. Additional threats are posed through investment in unsuitable technologies, public opposition to RES developments and competition from large companies. Cornwall could become a leader in RES-generation, but needs to capitalise heavily on the strengths and opportunities presented to the region whilst effectively mitigating weaknesses and threats.

In preparing the roadmap, Cornwall Development Company worked with local stakeholders to define the vision, identify areas where Cornwall can make significant steps towards a low carbon economy and set out delivery options and actions in order to achieve maximum benefit from these opportunities. At a strategic level, the roadmap aims to move the low carbon agenda forward and provide the evidence base for identifying future priorities and the necessary resources for efficient delivery.

Priority areas for RTD were identified to further Cornwall's ambitions towards a low carbon economy. These include RES Technologies, Energy Infrastructure, Future Proofing and Energy & Resource Efficiency. The prioritisation process involved extensive stakeholder engagement and was closely aligned with the development of the Green Cornwall Strategy and Cornwall Council's (CC) prioritisation processes.

The result of this process was a detailed overview of both existing and future priority projects, and the following vision: *“To develop a confident, resilient Cornwall that is a leader in innovative business and low carbon technologies”*. Overall there are four common areas of activity that were agreed as a focus for future development:

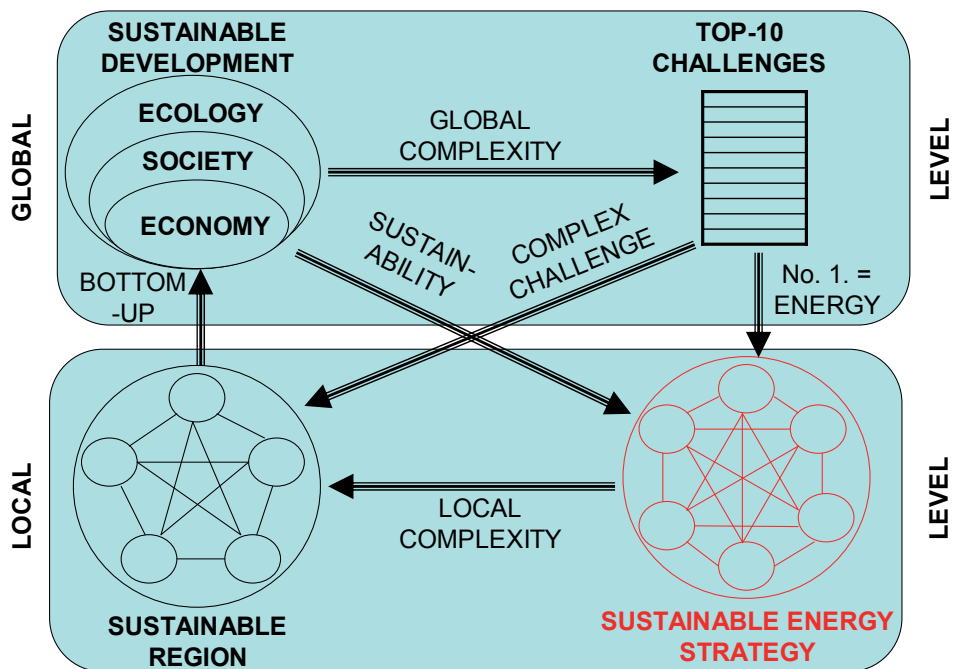
- RES technologies, 13 projects
- energy infrastructure, three projects
- future proofing, two projects
- energy and resource efficiency, five projects.

The roadmap was developed in close alignment with CC and supported their developing strategic thinking on SE and low carbon agenda. This was seen necessary to ensure that the prioritised actions and themes identified have political support, as well as the support of representatives from across the wider public, private and research sectors in Cornwall. The roadmap has already had some successes with some of the identified issues already being taken forward. For instance, CC has produced the Green Cornwall Strategy with clear objectives and targets. CC has also outlined priority areas for investment, which provides local businesses with confidence in SE developments. Through these activities Cornwall is now in a clearer position to drive the low carbon agenda forward.

4.4 Northern Hungary

In Northern Hungary the starting point was the complex system of global sustainability challenges, which was applied at the regional level (Figure 10). Selected actors (forming the Regional Strategic Committee; RSC) tested this model in Northern Hungary. The RSC had an open geographical, sector-wise and functional representation of the regional stakeholders.

Figure 10 The SE region model applied in Northern Hungary (see online version for colours)



Source: Dinya (2011)

The RSC elaborated the regional SWOT matrix and provided the regional energy (Figure 11) and RES-innovation profiles (Figure 12). Based on these the present situation and the future potential of the energy sector and RES related innovation capacity in Northern Hungary were defined (Figures 13 and 14). The work resulted in the following vision: *“The Northern Hungarian region will work towards energy independence by achieving the highest possible RES-ratio and effectiveness of energy production and consumption by 2020”*.

The RSC outlined the regional RES-strategy with the most important actions as follows:

- 1 developing integrated local systems based on the bioenergy potential and pilot systems
- 2 introducing zero-emission technologies into the exploitation of coal reserves and subsidizing the co-firing of biomass with coal

- 3 serving the increasing innovation and education needs through the regional bioenergy knowledge centre and involving solar energy
- 4 intensive dissemination of successful RES-projects to drive innovation and RES-investment and to exchange the culture and attitude of energy consuming and to establish the social basics of SE management
- 5 providing knowledge services for RES-projects outside the region based on developing regional RES-innovation capacity especially in bioenergy and distributed energy systems
- 6 establishing RUE programmes using the knowledge services of regional innovation centres
- 7 implementing consultation programmes to involve the public sector (local governments, hospitals, schools, etc.) in SE management
- 8 elaborating innovative solutions for the private, public and NGO-sectors to help them in starting successful RES-projects.

Figure 11 The regional energy profile of Northern Hungary (see online version for colours)

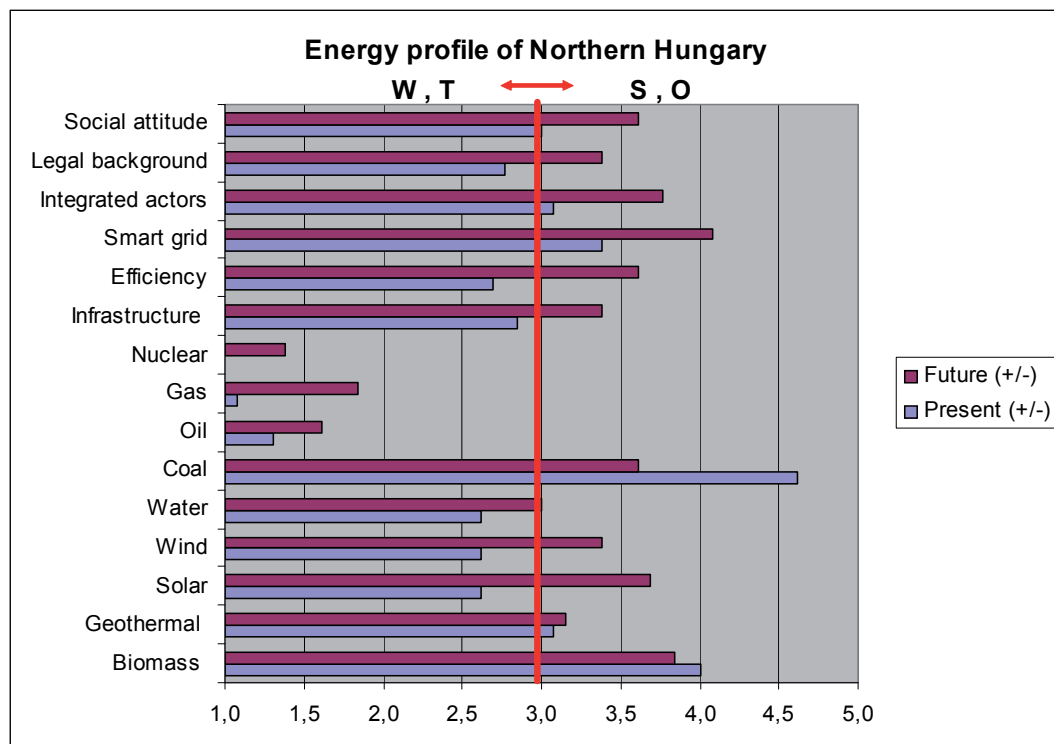


Figure 12 The regional RES-innovation profile of Northern Hungary (see online version for colours)

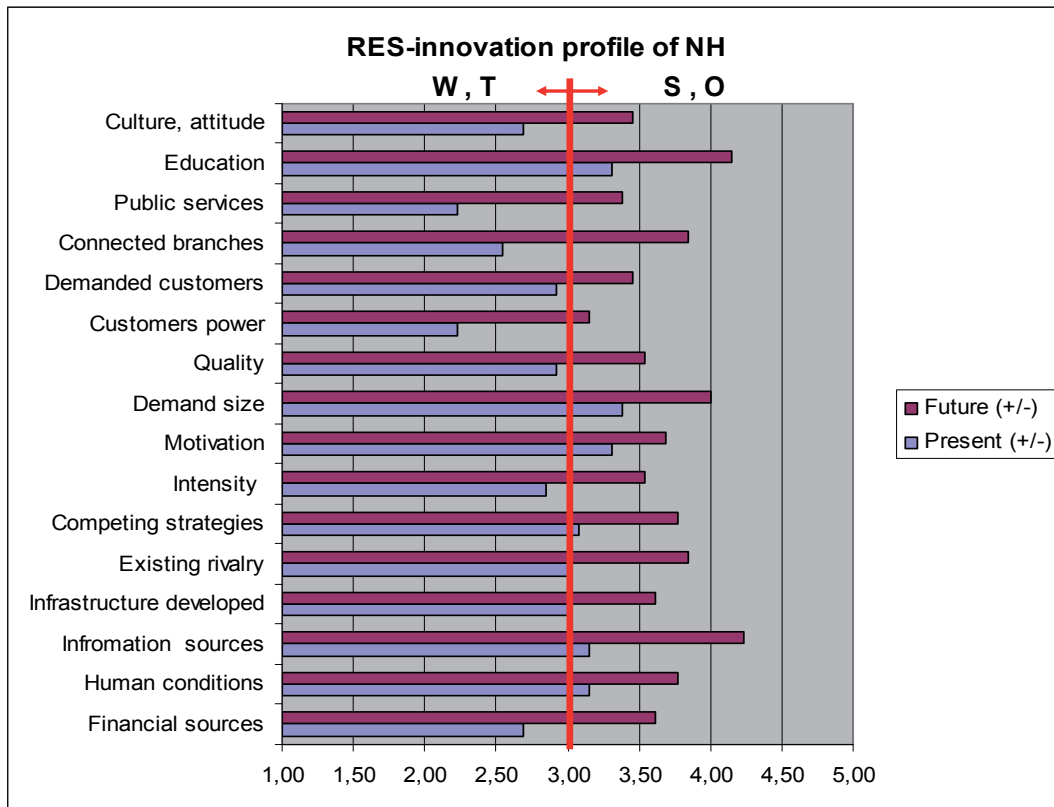


Figure 13 The present and future potential of the energy sector in Northern Hungary (see online version for colours)

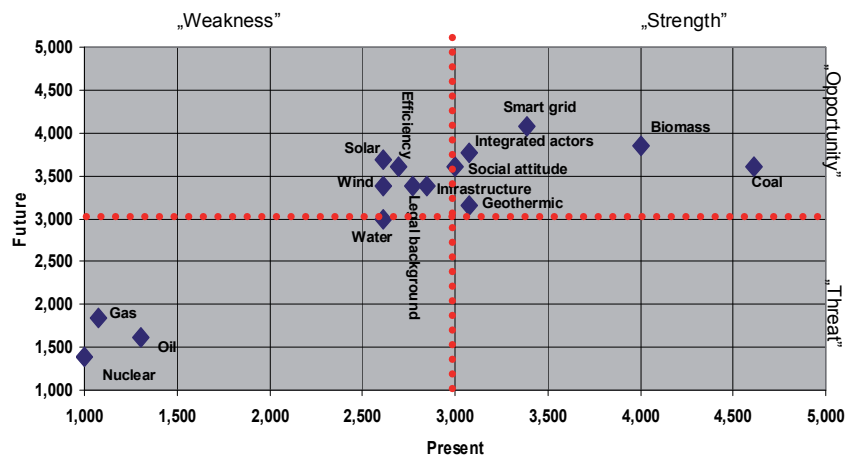
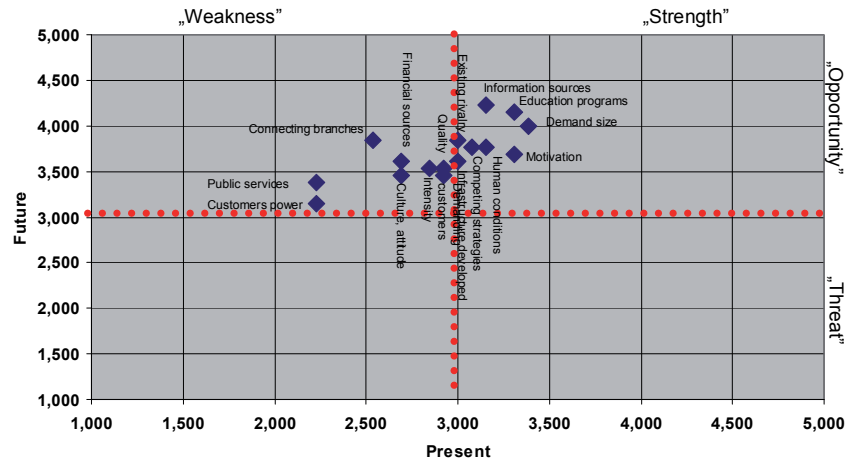


Figure 14 The present and future potential of innovation capacity in Northern Hungary (see online version for colours)**Table 2** The RESGen case results

	<i>Ostrobothnia Finland</i>	<i>Basque country Spain</i>	<i>Cornwall UK</i>	<i>Northern Hungary</i>
Stakeholder bodies				
Involved	3	3	3	8
Authorities	3	4	5	5
R&D	10	5	11	6
Industries				
SWOT	Quantitative	Qualitative	Qualitative	Quantitative
Vision	<ul style="list-style-type: none"> • Towards SE self-sufficiency • Regional RES • Promoting energy industry 	<ul style="list-style-type: none"> • SE knowledge pole • Development of energy industry 	<ul style="list-style-type: none"> • Leader in innovative business and low carbon technologies 	<ul style="list-style-type: none"> • Sustainable development • RES-ratio highest possible • Regional energy independency
Roadmap themes				
Regional systems	1		2	1
Technology development	1	8	2	2
Education, dissemination	2			5
Roadmap budget € millions	85.8	ca. 1,300	Not	Not
Private funding %	22	73	Defined	Defined
Public regional %	26	17		
National and EU %	52	10		

4.5 *Summary of the results*

Results from the case studies are collated in Table 2. The main features included the following:

- All regions followed the RESGen procedure and had their own priorities based on regional characteristics, which caused differences in details of the procedure.
- Stakeholder involvement was high, and all main actors were represented in the roadmaps. This created excellent commitment and base for implementing the roadmaps.
- In Ostrobothnia and Northern Hungary the roadmap focus was establishment of regional systems and creating regional energy self-sufficiency. Regional systems and infrastructures were important also in Cornwall, whilst in Basque Country the main themes concentrated on technology development.
- Ostrobothnia and Basque Country defined tentative budgets for their roadmaps, where the focus areas are reflected: regional development is more based on public funding and committing stakeholders by dissemination activities and education (Ostrobothnia), while technology development requires more funding from the private companies (Basque Country).

5 **Discussion and conclusions**

The innovation of the RESGen procedure was two-fold. It integrated new approaches and methods with well-known tools (SWOT) into an easily applicable system, and it was applied in a novel branch for a bottom-up strategy and implementation of SE. Systematic management is essential, as the anticipated SE reform is a social process involving all stakeholders. The procedure provided regional stakeholders with a 'platform' for structured discussion and commitment. This contributed to the fact that the project was nominated among success stories in EU projects in 2012. It also contributed to the '3S' (Smart Specialization Strategies; Foray et al., 2009; EC, 2010) definition to include SE.

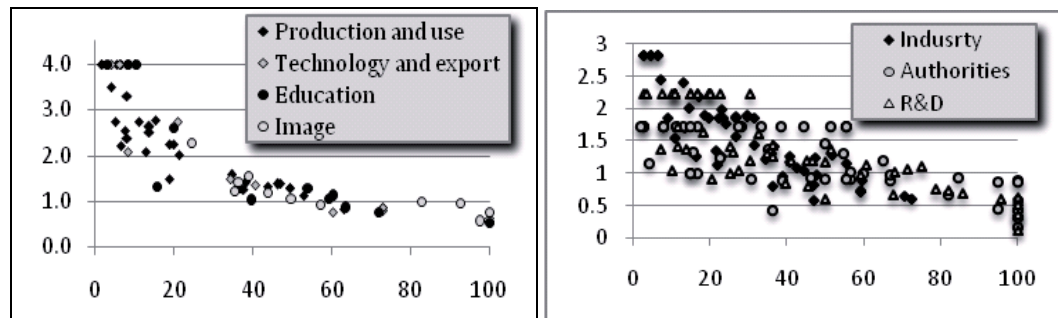
5.1 *Practical experiences*

The method was applied differently in each region, demonstrating various needs of the regions and flexibility of the method. The main observation was that the procedure worked well and that the regional process was easy to structure. It proved visual, easy to use and update, in many points quantitative and well structured. The other observations were:

- *Commitment:* Commitment of the regional stakeholders (municipalities, companies, industries, citizens) is necessary for successful implementation of SE. This is in line with earlier experience, according to which social acceptance and trust among key stakeholders is vital (Wüstenhagen et al., 2007; Wolsink, 2012).

- *Regional characteristics:* The RES potentials were high, supporting earlier observations. Understanding of the economic potential varied hugely at the regional level. A number of unknown facts, totally new for the stakeholders and especially municipalities, were revealed. This activated and motivated the regional stakeholders and became one of the change agents (Rogers, 1995).
- *SWOT analysis:* The SWOT procedure proved difficult in some cases, despite detailed instructions. In most cases, where the valuation was prepared by workshops, the results were good. This implies that the presentation image should be improved. The procedure gave a lot of valuable information, including new aspects that were not predicted.
- *The fishbone:* The fishbone structure was found easy to use and understand, both for the project organisation and the participants.
- *Decision making:* The decision making process worked well. It was analysed based on the project valuation in Ostrobothnia by comparing the average scores with the deviation of opinions. The results (Figure 15) imply that the valuers were in general agreement as to the best projects, especially according to the different themes (opinions deviated only slightly in the best scored projects), but there were more differences with the least scored projects. The shape of the plot area indicated a good decision making process (e.g., Lintala and Takala, 2008). The analysis by different stakeholder groups was somewhat similar, but the number of valuers per group remained low (for authorities $n = 3$; industry $n = 8$; R&D $n = 5$).

Figure 15 The relationship of the scores (highest average = 100) and the deviation of scores (standard deviation divided by average) in the Ostrobothnian valuation of projects, in different themes ($n = 16$; left) and by different stakeholders (right)



5.2 Abating barriers for SE

The RESGen procedure identified a number of barriers for developing SE. Some of them can be actively abated, but some of them are out of reach of regional actors. The most difficult barriers are the invisible but existing institutional opposition to SE and slow diffusion of SE. These dilemmas can only be solved during a long-term social process, which involves all key stakeholders. Conscious development through comprehensive regional strategies and structured programmes will be important. All four roadmaps addressed the abatement of the barriers.

- *Uncertainty of SE development:* Changing policy and regulatory frameworks have resulted in an unstable business environment. Its stabilisation is vital for SE industries, including public RTD support and wider policy context. There is a call for establishment of general ‘rules of the game’.
- *Technology and economy:* Technical advancements and bringing RES supply and demand to maturity are crucial for the SE sector’s ability to compete in real-time markets. Sustainable business cannot be developed-based merely on subsidies: it must be profitable in the long run. The critical phase will be the establishment of larger scale systems, and in this the public support is necessary, remembering that the prevailing energy systems have been created by public support (Peura and Hyttinen, 2011).
- *Value chains and RTD:* While some technologies are already cost-competitive, significant cost reductions are necessary through market development and RTD. This is only possible by developing whole value and supply chains (Rogers, 1995), networks (Winkler, 2010) and strategic alliances (Higginson and Vredenburg, 2010) and for single technical solutions it is important to get support from larger SE systems. This is why continuity of public RTD-funding is a crucial factor for the development of the industry.
- *Lack of qualified workers:* Lack of engineers specialising in RES technologies is a real growth barrier for enterprises. Adequate support mechanisms to establish and develop programmes training young professionals as well as life-long-learning for senior experts would help to overcome the barrier.

5.3 *The role of regions*

Transition to SE must be implemented locally, but European regions are heterogeneous – there must be flexibility and specialised strategies combining the unique resources and capabilities of the regions. SE policies should focus on local and regional implementation. This approach is central in the RESGen procedure.

‘Smart specialisation’ will be important for the next European Cohesion Fund period 2014–2020. The RESGen procedure supported this development in the participating regions by setting a vision based on their strengths, making a detailed implementation plan, and by taking advantage of the complementarities between the regions and the roadmaps with the presupposition of flexibility.

Communication with and involvement of the stakeholders facilitates the development and enables the commitment for implementation. The roadmap was a good example of wide involvement of regional stakeholders and different perspectives. It also proved that this kind of procedure is possible, and the decision making process works well.

Regional SE RTD-policies are subject to several different horizontal policy areas and coordination of different policy levels (local – European). The first refers to policy-mix and the latter to multi-level governance. Regional policy makers should ensure a robust policy-mix to support SE by aligning energy, environmental and industrial policies. The regional SE policies are implemented in coordination with other levels of governance and often depend on objectives set elsewhere (national or European level). Thus, efficient communication among the different policy levels is necessary. The RESGen procedure provides a structured approach for this.

5.4 Conclusions

This article introduces the RESGen procedure for implementing SE regionally, and it was tested in four regions. The main conclusions are the following:

- The procedure worked well, with some requirements to improve user-friendliness. The method was applied differently in each region, demonstrating flexibility of the method.
- Public awareness, attitudes and trust, stakeholder commitment and functioning of the decision-making system are vital for successful implementation of SE.
- Regional stakeholders were motivated to develop their own strategy, aiming at SE.
- The procedure can reveal facts that are not known or expected. It may also reveal institutional opposition and negative attitudes against SE, thus making the barriers and bottlenecks visible. These and the new strategic tool enable realistic development.
- There is a call for ‘rules of the game’, in order to reduce uncertainty of the business environment for SE. Conscious development through comprehensive regional strategies and structured programmes will be important. The RESGen procedure is an attempt towards SE development integrating local and regional implementation, national and international policies, smart specialisation and general progress.

The RESGen procedure provided a systematic tool enabling unified development for all regions. The experiences suggest that the procedure could be fit for a more widespread use. The existence of this kind of tools encourages regional programmes and thus promotes the implementation of SE.

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Appendix

The SWOT list of Ostrobothnia

<i>Strengths</i>		<i>Weaknesses</i>	
S1	Plenty of RES, RES potential significant	W1	The need for systemic change, with the objective of integration of centralised and decentralised systems
S2	Nationally the best wind power potential	W2	Monumental need for development
S3	‘Region of new energy’; positive attitude, common approach toward RES generation among stakeholders	W3	Poorly developed infrastructure and value chains for RES based production (incl. logistics and regulations)
S4	Open mind and low threshold for technical innovations	W4	Strategic conservatism: large traditional actors trying to prevent new actors to penetrate to the markets
S5	Strong energy industry and technical innovations	W5	Hesitation in decisions by enterprises
S6	Cumulative development knowhow	W6	Poor marketing: the big audience do not recognise ‘Energy capital’ or ‘Region of new energy’
S7	Global activity and ability to internationalise by the local industries	W7	Dependence on fossil fuels, massive need for investments to RES-based production (also O)
S8	Significant share of the RES-focussed companies are local or regional	W8	All RES are not competitive or realistic in Ostrobothnia (wave, some solar, and floating wind)
S9	Tradition of entrepreneurship	W9	Low subsidies for investments nationally
S10	Recognised status among experts in the energy sector nationally	W10	Slow reacting capacity by innovation systems by demand
S11	Excellent location geographically (e.g., logistics, fuel deliveries)	W11	Weak national political lobbying
S12	Own university in the region		

The SWOT list of Ostrobothnia (continued)

<i>Opportunities</i>		<i>Threats</i>	
O1	Relative advantages and new specialisation (e.g., manufacturing of fuel cells to Vaasa)	T1	Receding of the ownership and decision making away from Ostrobothnia
O2	The initiator's advantage in totally new markets	T2	Transfer of Ostrobothnian expertise elsewhere
O3	Global growth of RES based energy markets	T3	Continuous vortex for developing novel solutions
O4	Demand for systemic expertise and ability for management of large entities	T4	Competition in RES markets, nationally
O5	Released R&D capacity caused by leakage of expertise from Ostrobothnia abroad (e.g., China)	T5	RES markets will not grow as soon as forecasted
O6	Establishing of Scandinavian enterprises to Finland via Ostrobothnia	T6	Unsteady political trends
O7	Opportunity to international energy consultancy	T7	Global recession will not support the markets
		T8	Mysticism in the energy related discourse (no full logic, and one sided approaches)