Thule Institute - NorTech Oulu

SMARCTIC
Roadmap to a Smart Arctic Specialization

WP4 Report: Natural resources management and economics

Smart Energy Grids

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Contents

Forewords

Finland new strategy for the Arctic region has been introduced in a recent publication commissioned from the Office of the Prime Minister [1]. The produced document, underlying the Country's interest as active player in shaping the development of the region, outlines the four pillars supporting the new policy strategy: *Finland as an Arctic Country, its Arctic expertise, Sustainable Development and environmental considerations, International cooperations.*

Although the definition of the Arctic region may differ among experts and scholars of different fields and disciplines, we operate under the paradigm that Finland, in its entirety, is an Arctic Country. More specifically, Finland's identity as a member of the Arctic community has been defined by its environmental, climatic and socio-cultural background. Finland is an Arctic expert, able to provide top level knowledge and know-how to monitor and manage the major transitions currently undergoing in the Arctic region. Furthermore, the aim is to responsibly commercially exploit such expertise to support a sustainable use of the natural resources in recognition of the particular conditions imposed by the Arctic climate and environment. In this framework, Finland's aim is to set an example as an expert in research and technology, reinforcing its position in the Arctic community and to promote stability and internal cooperation in a time and age characterized by rapidly growing political and commercial interest toward the Arctic.

In this context, the SMARCTIC project aims at formulating a future vision and a roadmap toward the further development of the Arctic expertise. Funded by Tekes, the Finnish funding agency for technology and innovation, the SMARCTIC project primary goal is to evaluate how the principles of sustainable development and human well-being shall be realized in future natural resource exploitation projects and when taking advantage of new transportation routes. In order to respond to this concern, the project examines the main research questions and, at the same time, evaluates the capacity for industrial assessing new business potential.

The project is based on an innovative combination of high-level expertise, through which we can evaluate interdisciplinary interfaces, which in turn can lead to new innovations. The implementation of the project is based on thematic areas, or work packages (WPs), carried out in cross- and multi-disciplinary working groups:

WP 1: The Arctic context. The aim is to identify the level of knowledge of the Arctic, the level of Finnish organizations Arctic expertise and the potential added value of Finland's key technology areas of competence.

WP 2: Environmental informatics and mobile technology. The aim is to identify the future development of wireless communication environment, human measurement and data transmission. Based on this analysis, personalized and interactive services supporting human well-being and sustainable development will be analyzed. The vision is to support the development wireless communication and smart metering methods to maintain Arctic capability.

WP 3: Smart logistics, infra and living environment. The aim is to look at the impact of new traffic openings and intensified use of natural resources on traffic flows, urban structures and infrastructure, as well as to identify and list those related to new business opportunities and the development of services. Key priorities are accessibility, sustainability and growth. The vision is to support the development of a vibrant community in the North, with sufficient logistics secured for people and companies, accessible services, as well as ecologically, socially and economically sustainable environment.

WP4: Natural resources management and economics. The aim is to identify and list synergistic solutions to the sustainable use of Arctic resources to support and identify related innovations and business opportunities. The vision is to support the the development of an Arctic IT-enhanced eco-industrial system.

WP5: People in the North. The aim is to characterize and list measurement and information systems related to the monitoring of well-being of Arctic residents, and those moving to the Arctic in search of work; furthermore, to identify related services and new business development opportunities. The vision is to identify health indicators (to be monitored in real-time) and factors affecting welfare and safety of individuals and community. Data on welfare are to be collected into databases that allow comprehensive assessment and enable influencing factors at an early stage.

WP 6: Roadmap to an Arctic expertise. The aim is to develop roadmaps for selected Arctic regions and, based on them, produce a vision for formulating strategic openings.

WP 7: Strategic opening and business potential. This work package evaluates suitable business models and ecosystems for the Arctic and analyzes them through a scenario process to be linked with the roadmaps. The assessment of business opportunities is to be linked to enablers and substance work packages in order to result in integrated scenarios.

This document is to be included in the framework of the analysis of Natural Resources management and economics (WP4). The key idea behind this work is to present

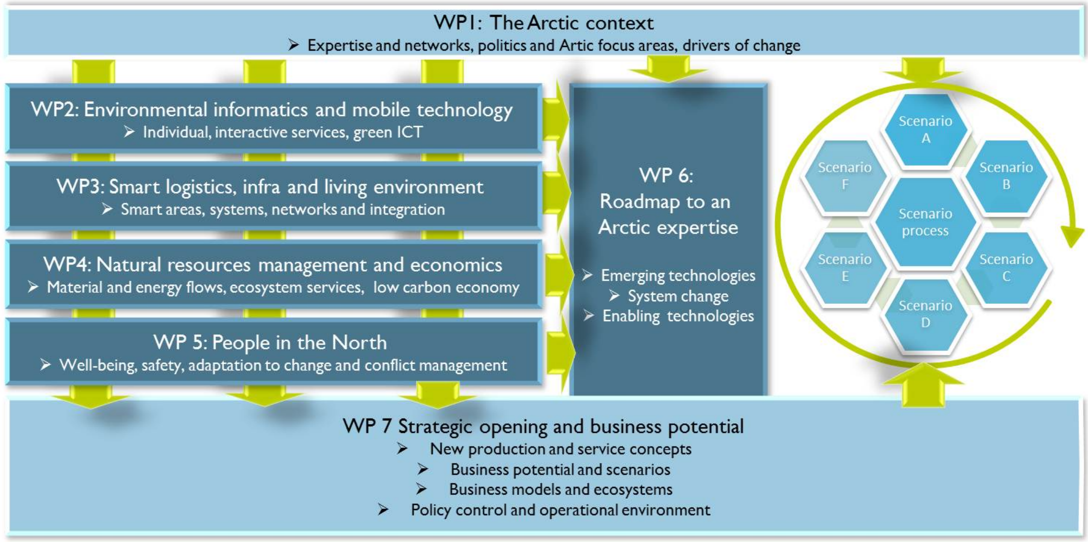

Figure 1: Schematic representation of the SMARCTIC project WPs and their respective role within the roadmap building strategy

a policy framework supporting a responsible and controlled exploitation of the Arctic resources, taking into account economic, social, cultural and environmental impacts. The EU underlines that all business activities must maintain a balance between environmental protection and the sustainable use of natural resources. The aim of this work package is to figure out how the exploitation of natural resources is realized taking into account environmental and economic sustainability as well as human wellbeing.

The vision for the future is a synergetic material flow, smart grid based energy solutions and optimization of data transfer services.

List of Abbreviations

AMI	Advanced Metering Infrastructure
ASP	Ancillary Services Provider
CS	Customer Side system
DER	Distributed Energy Resource
DG	Distributed Generation
DMS	Distribution Management System
DLR	Dynamic Line Rating
DSO	Distribution System Operator
ED	European Directive
EEGI	European Electricity Grid Initiative
EMS	Energy Management System
ESCO	Energy Service Company
ESD	European Energy Service Directive
EU13	Member States that joined the European Union on 1 May 2004, i.e. Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia, or on 1 January 2007, i.e. Bulgaria and Romania, or on 1 July 2013, i.e. Croatia.
EU15	Member States of the European Union prior to the accession of ten countries on 1 May 2004, i.e. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.
EU28	Member States that joined the European Union
ERP	Enterprise Resource Planning
EV	Electric Vehicle
FACT	Flexible AC transmission
GHG	Greenhouse Gas
GIS	Geographic Information System

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G2V	Grid-to-Vehicle
HEV	Hybrid Electric Vehicle
HTS	High Temperature Superconductor
HVDC	High Voltage DC
ICT	Information and Communication Technology
OPS	Outage Management System
PHEV	Plug in Hybrid Electric Vehicle
RES	Renewable Energy Source
SCADA	Supervisory Control And Data Acquisition
SG	Smart Grid, Smart Energy Grid
SEN	Smart Energy Network
SLE	Smart Living Environment
SM	Smart Meter
SME	Small- and Medium-size Enterprise
SMS	Smart Metering System
SMI	Smart Metering Infrastructure
TSO	Transmission System Operator
TSP	Telecommunication Service Provider
VPP	Virtual Power Plant
V2G	Vehicle-to-Grid
WAMS	Wide-Area Monitoring System
WAAPCA	Wide-Area Adaptive Protection, Control and Automation
WASA	Wide-Area Situation Awareness
WEEE	Electronic and Electric Equipment Waste
WMS	Workforce Management System
WP	Work Package

Chapter 1

Introduction

The global challenges, which rose at the turn of 21^{st} century, brought, among others, an unquestionable call for a new thinking of the energy distribution platform. Future trends for global energy consumption, increasing energy costs and environmental issues [2, 3], are pushing for an increasing use of renewable energy sources, smaller power plant and distributed generation (DG), improved efficiency and reduced environmental impact. In this framework, the future development of the European energy network, a major player in the green house gases (GHGs) emissions [2, 3], will have to be re-thought and re-shaped taking into account new needs and technological breakthroughs as well as the new economical environment. This leads toward numerous technical and non-technical challenges such as the assurance of reliable and cost-effective energy supply, as well as a more effective energy network management system that would facilitate an extensive and effective use of renewable energy sources (RESs) and their integration in an envisioned energy network based on DG.

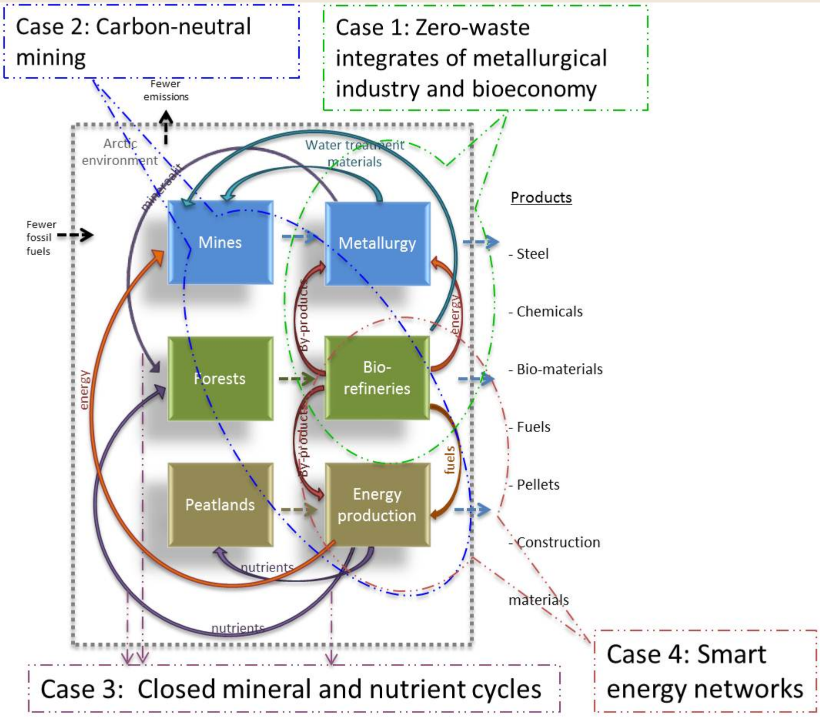


Figure 1.1: Synergic flow of material, defined by the complex interaction between material energy and information flows.

Smart energy grids are a solution that can provide a valuable answer to these needs. The expression smart energy grid, or smart grid, (SG) indicates a power grid that allows suppliers and consumers to have a two ways communication monitoring in real time the grid condition (i.e., the electricity production, consumption and distribution). This model of energy network allows for a more dynamic system control, making it possible to respond more efficiently to changes in the grid conditions. Furthermore, it allows consumers to acquire a central role in the energy system value chain: supported by the technological development of the last few decades, especially in the field of Information and Communication Technologies (ICTs), consumers are given the possibility to choose and be directly engaged.

The motivation behind studying the development of smart energy grids can be explained in terms of what a smart grids are expected to do. Using real time monitoring together with smart control system capable to evaluate and improve its performances, the envisioned smart grid based system can anticipate and mitigate power peaks and power quality problems. At the same time, it allows for a more prominent position on the market of those renewable energy resources characterized by a discontinuous and irregular power generation (i.e., wind power). The transition from a highly centralized energy network to a decentralized one is a transition that aims at rethinking the energy industry business model: from growth through quantity to growth through quality.

A transition such as the one mentioned above implies a more interactive and participatory role of the consumer. Due to a real-time two ways communication, consumers are then able to effectively gain through a more efficient energy usage and the possibility to directly interact with the energy market. Furthermore, by enabling distributed power generation, it is possible to effectively initiate a process of democratization through participation of the energy market.

The considerations presented in this document were carried under the SMARCTIC project; more specifically within the thematic area focussing on material resources management and economics. Our work developed around three key concepts:

A synergic flow of material: based on the same idea of an industrial ecological park, we considered materials, resources and energy transfers over large distances and among different actors. Four pre-selected case studies were taken into consideration: (1) Zero-waste integrates of metallurgical industry and bioeconomy; (2) Bioeconomy and closed nutrient cycles; (3) Carbon-neutral mining and (4) Smart energy networks (Figure 1.1).

Smart Energy Networks (SEN): described as an evolution of the smart grid concept, SEN refers to an information-based distributed systems based on a multilayered and multidimensional interaction of different energy carriers and different energy vectors. The synergies of multiple form of energy (and their network flows) allow for a more comprehensive theoretical framework upon which we could base our analyses (Figure 1.2).

Information nodes: Built as an expansion of the more generally familiar data hub concept, information nodes represent, in the context of SG based systems (or

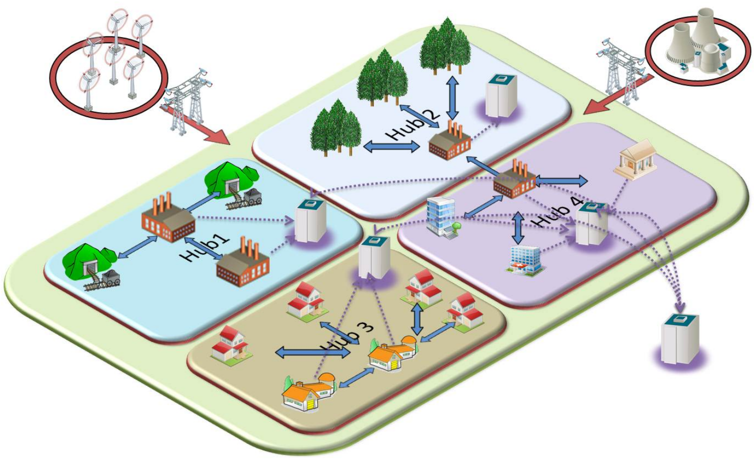


Figure 1.2: Schematic representation of the visioned smart energy network systems and their multilayered structure.

more generally in the context of SEN based systems), a piece of infrastructure as fundamental as power generation systems. Although their functions may vary according to the envisioned information flow model supporting the energy system, they represent key elements of the energy network monitoring, data analysis and information extraction (Figure 1.3).

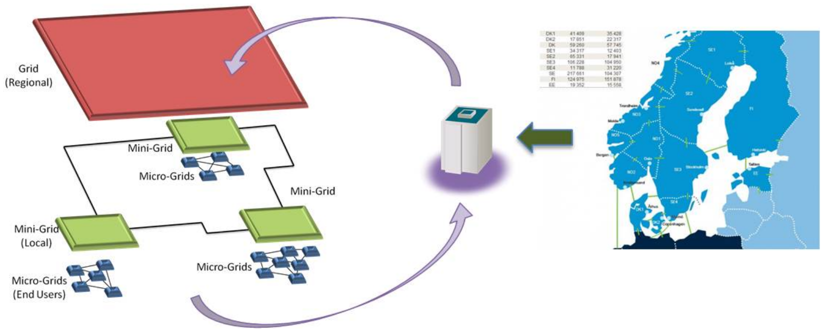


Figure 1.3: The role of the information nodes in the envisioned smart energy system is a key one, providing real time data to support and facilitate a correct, efficient and resilient function of the network

Given the working function of WP4, the vision introduced in this document focusses on the development of the energy infrastructure in Northern Finland, for the next 20 years. On the other hand it should be kept in mind that the mentioned aim for a decarbonized society [4] calls for a vision for the development of our energy future spanning almost 40 years (Figure 1.4). The next 10 years are expected to focus on the integration of distributed energy resources (DERs) and renewable energy systems (RESs) into the existing system. This work, though, is expected to be propaedeutic for what is to be achieved in the following 10 years, when the full potential of Smart Grid

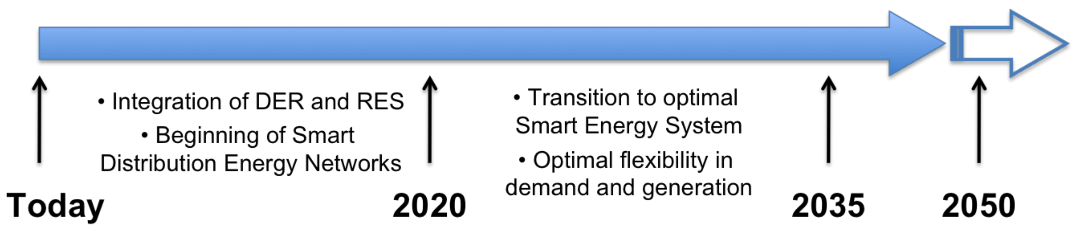


Figure 1.4: The decarbonization plans for our future energy system from the European prospective [4] calls for an 80% reduction of GHGs emission by 2050 (from 1990 levels) and a significant increase in energy production from RES. This goals come with serious challenges to maintain high quality level of power supply and security. Figure based on [4].

Technology is to be exploited. A vision for a sustainable energy system by 2050 implies the filling of a quality gap in the answers we can provide to a number of open issues such as the development of SEN to support a sustainable use of available resources and the development of a set of usable sustainability indicators to support us on the path to the goal.

Chapter 2

Development of the energy system

During the years, the evolution of the energy network has been characterized by a number of transformations reflecting the social, economic, technological and political reality of the time. In this context, it is perhaps appropriate to adopt the interpretation offered by some experts, which describes the evolution of the energy system over time in terms of industrial revolutions [5]. Although presented mainly in socio-economic terms, this approach fits particularly well our analysis for two reasons: the crucial role of ICT systems and the fact that talking about evolution of energy networks from the first industrial revolution implicitly serves our intention to present the case of SGs in relation with SENs. The future development and deployment of a SGs based system is also a result of this evolution, and understanding how we got where we are today can help us to understand and select the criteria that should guide our future choices.

The basic idea for this theoretical framework is that industrial revolutions occur when new energy regimes meet communication revolutions enabling them to become operational. In this context, the first industrial revolution was fuelled by coal and steam power supported by printing technology; the mecchanization of many production systems and the birth of modern industry was enabled by large production and dissemination of information supported by modern printing technology. The second industrial revolution, based on oil and centralized electricity production, underwent a similar process, supported this time by the fast developing high-speed communication technologies such as the telegraph, the telephone and, in more recent times, radio and TV. Today, we find ourselves on the verge of a third industrial revolution, where the availability of distributed – renewable – energy systems require the enabling support of the modern ICT systems.

2.1 The development of the power grid

The modern power system is the result of a century long development based on an over a highly centralized model [6]. From the beginning, the structure of the power system has been built following a rather straightforward scheme (Figure 2.1): with a relatively small number of large production centers delivering power to consumers through the transmission and distribution networks.

The advantage of this model lays in its simplicity: large power producing units made efficient and run by a relatively small amount of specialized personnel, with transmission and distribution networks designed for a unidirectional flow and scaled to fit the consumers loads.

With the liberalization of the energy market in Europe at the end of the 90s, the previously integrated service companies in charge of energy production, transmission and

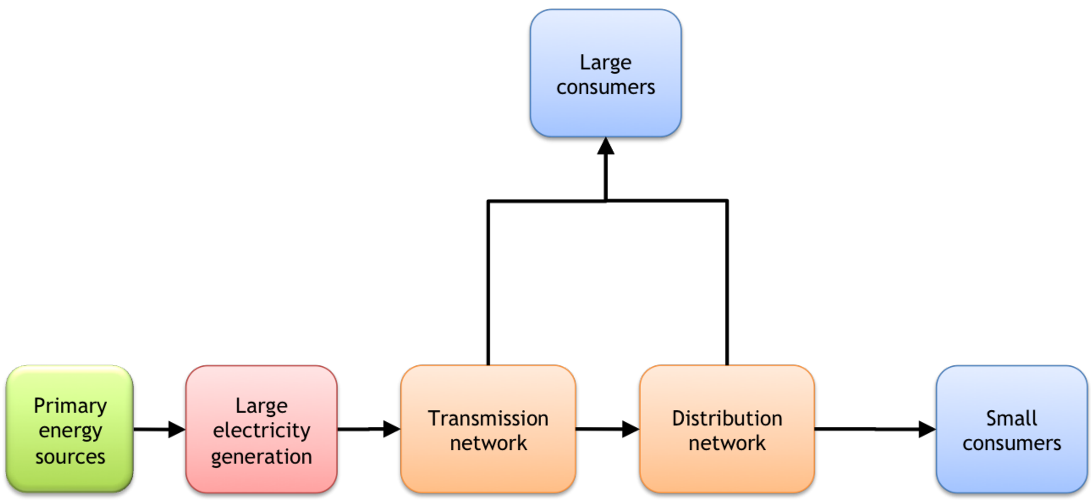


Figure 2.1: Schematic representation of the power supply system before liberalization. Figures based on [6].

supply, were required to unbundle. This brought a significant change in the structure of the power supply system (Figure 2.2) with a separation between the management of the physical transmission and distribution networks from the corresponding supply markets (wholesale and retail respectively).

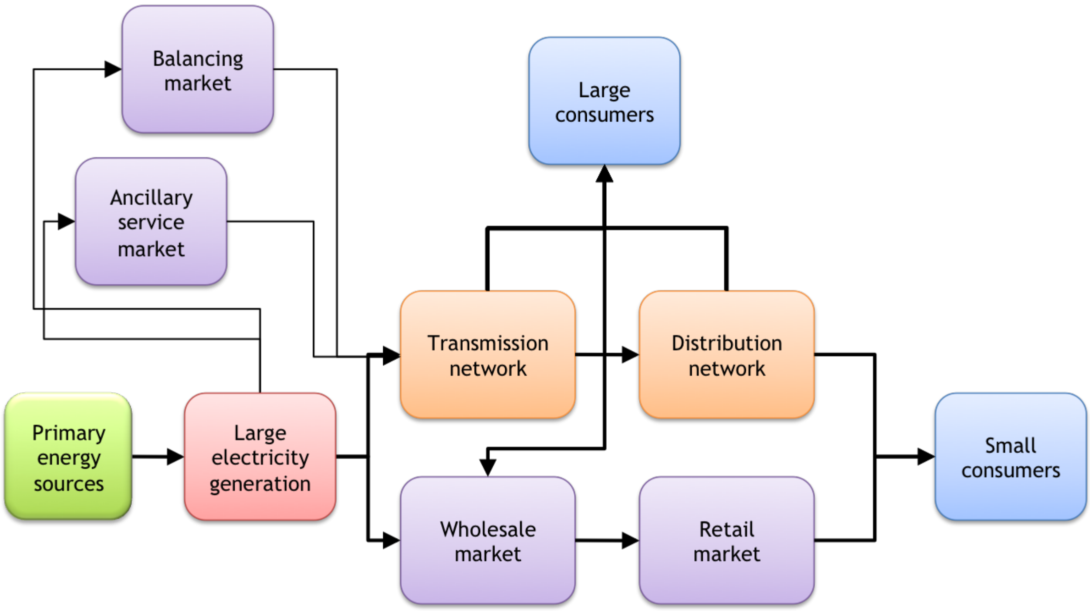


Figure 2.2: Schematic representation of the power supply system after liberalization. Figures based on [6].

The new system opened the possibility for the development of two more markets: the balancing and the ancillary services markets. In a now more complex system with a growing number of interacting players, it became increasingly important for transmission system operators (TSOs) to be able to purchase surplus power in order to maintain a balanced network, now more exposed than before to unbalances between supply and demand. On the ancillary service markets other power quality services were made available, such as reactive power, voltage control, etc.

In a liberalized market, the growing DG sector was prevalently playing a passive role, motivated primarily by special consume interests, important production capabilities or particular logistic conditions (e.g. long distance connections to the common grid), the distributed generation has been insofar substantially an appendage of the distribution network without any real sizable interaction with the rest of the supply system. In more recent years, the combined effects of liberalization of the energy market on one side and the support for renewable energy solutions on the other produced new opportunities for participating in different market sectors.

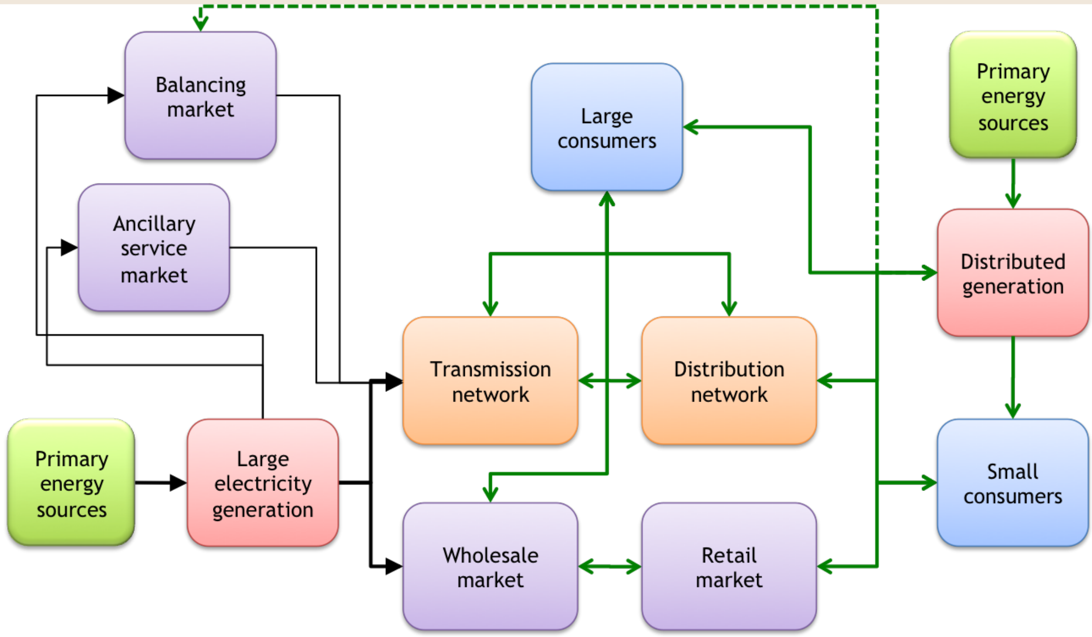


Figure 2.3: Schematic representation of the power supply system in a liberalized market with the integration of DG based on RESs. Figures based on [6].

2.2 What's Next?

2.2.1 Smart Grids

The market liberalization brought further modifications to the power supply system structure. Small scale distributed power generators, by tapping into previously unused RES, are now able to directly deliver power to consumers or to operate via electricity markets (Figure 2.3).

Depending on the considered system architecture, small- and medium- size renewable and distributed energy systems are now able to deliver to consumers or to operate via common market. At the distribution level, this implies the possibility for end-users to access a new bi-directional energy network. Especially considering desirable scenarios of an important deployment of DESs in the next 20 years, a similar transformation should occur at the transmission level.

The implications on the required system development at the infrastructural level are of primary importance. A network designed for a radial structured unidirectional power flow has to be converted in a networked bi-directional flow structure. The very role of the network and, consequently, of all the players operating in it, is expected to change. The network will not only distribute power, but will also need to provide access among the connected parties. As the role of DG is expected to grow and develop, so it is reasonable to expect from its role on the markets, including eventually the balancing

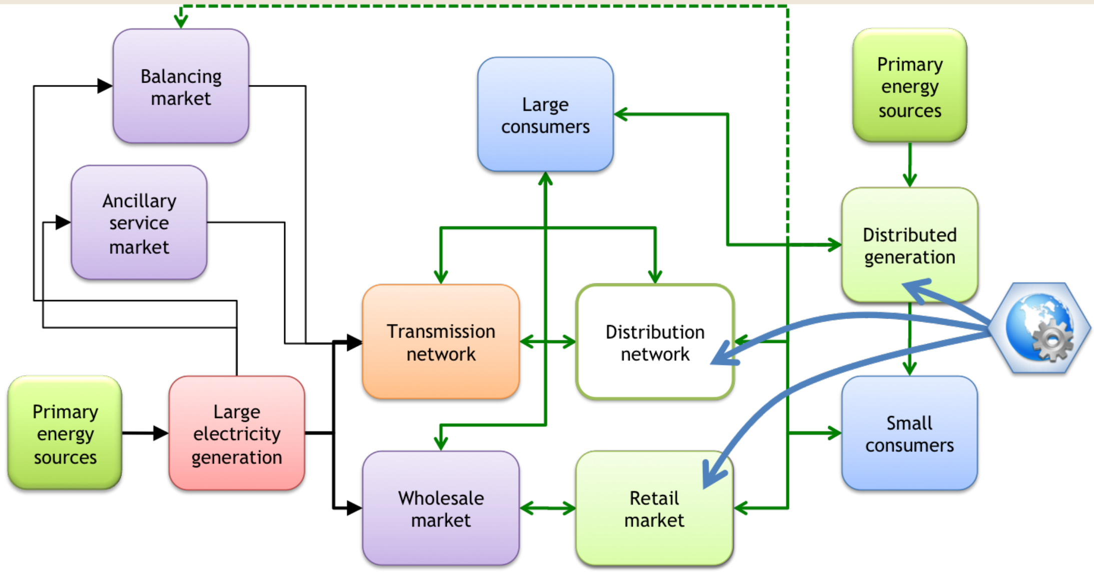
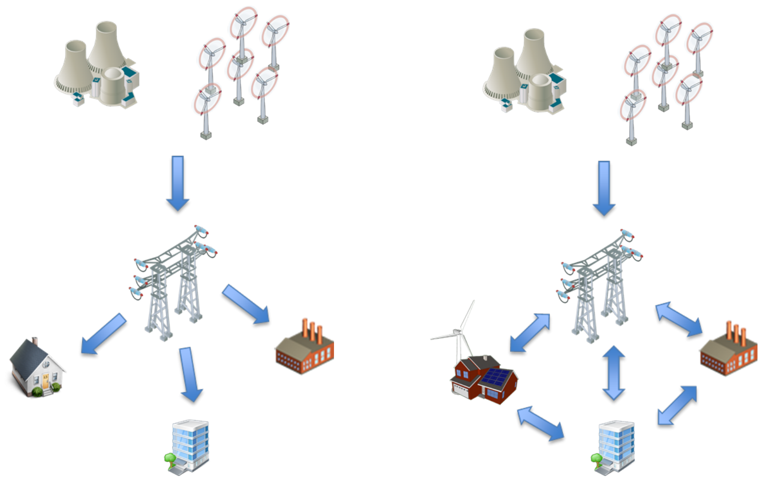


Figure 2.4: Schematic representation of the role of energy services within a distributed (smart) energy system. Figures based on [6].

and the ancillary service markets. This last stage of the evolution of the power grid has not reached maturity yet. It is within the framework of this last evolutionary step of the power grid that the smart energy grid based system envisioned in this work is to be developed.



(a) Centralized energy system

(b) Decentralized energy system

Figure 2.5: Schematic representation of the decentralization concept at the base of the smart energy grid development paradigm

2.2.2 Smart Grids vs. Smart Energy Networks

As mentioned earlier, there is currently no accepted definition of Smart Grids. An argument can be made that, in many respects, this also reflects a lack of generally accepted understanding of what SGs should be, do or achieve. Any discussion on SGs, though, includes the commonly accepted premise that they represent the on going evolution of the power network driven by our ever more pressing needs for a more efficient, environmentally performing and sustainable energy system.

In recent years, the quest for energy efficiency and environmental performance has led to extending the boundaries of SGs and a broader concept of energy network has emerged [7, 8]. The expression Smart Energy Network (SEN) indicates a concept intended to go beyond the SG idea, where multiple energy carrier and their synergies can be considered. SENs are therefore defined by broader boundaries and they can be expected to provide a better systemic tool for the development of a more sustainable energy regime.

At the same time, analyses concerning the sustainability of SEN focus primarily on the environmental performance, and, more specifically, on the reduction of greenhouse gases (GHGs) emissions based on an increased use of RES and improved efficiency supported ICT applications. On the other hand, in terms of assessing the sustainability of SENs, attention is usually limited to environmental considerations only (such as CO_2 emissions and the share of renewables), often ignoring entirely the economic and social dimensions of sustainability.

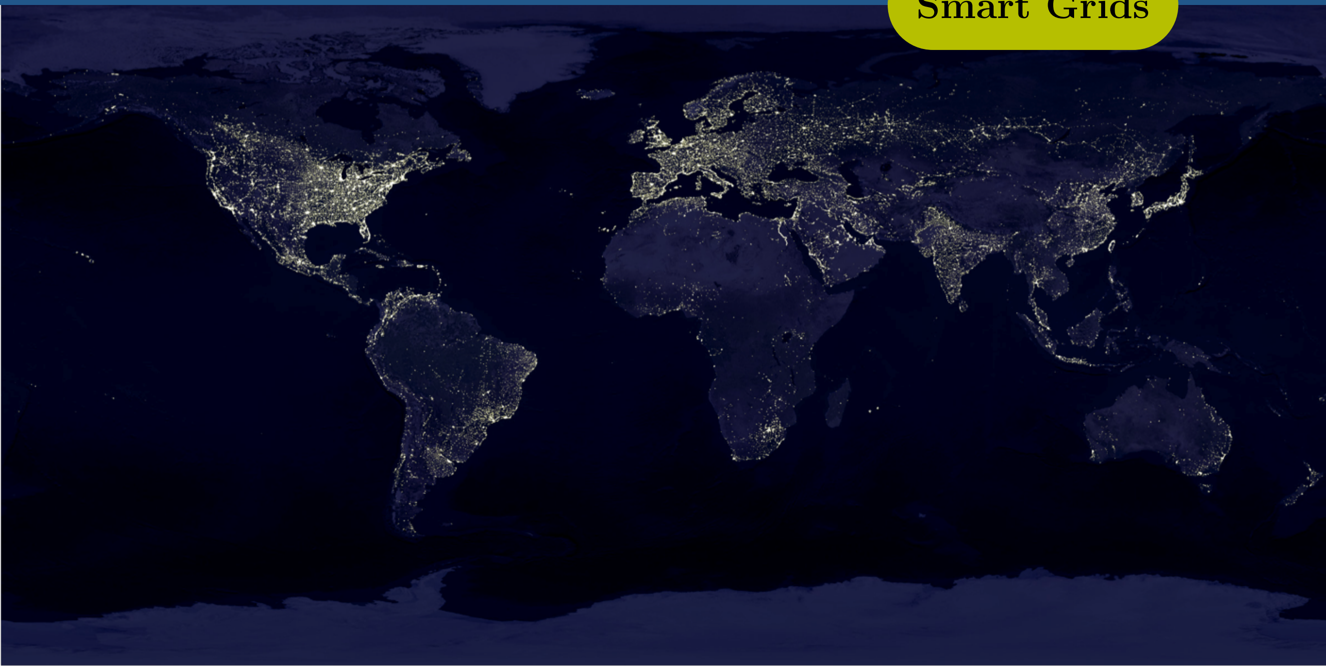
It is therefore paramount that, for what concern the future development of SGs, we take into consideration two key elements:

- the concept of SG is in itself intrinsically inadequate for a proper sustainability evaluation as it represent a far too limited portion and, therefore, an incomplete representation of the energy system;
- the economic driver of the future energy regime will have to oversee a transition from an energy based system to an energy service based system.

Based on these considerations it is therefore important to consider the development of SGs (or SENs) within a broader, multilayered and cross-disciplinary frame of reference. It is thus essential to consider our energy future based on a comprehensive analytical approach such as promoted SMARCTIC project.

Chapter 3

Smart Grids



This chapter, together with chapter 4, will briefly describe the strategic elements of the smart grid, its key components, their description both in general terms and in relation to each other.

As it is our intention to discuss SG future development in (northern) Finland within the European envisioned energy regime, it is reasonable to accept the EU definition: "*A smart grid is an electricity network that can cost efficiently integrate the behavior and actions of all users connected to it – generators, consumers and those who do both – in order to ensure an economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety*" [9, 10].

In this chapter we will adopt this definition and its two implications: SG as an evolution of the power network and the key role ICTs are required to play. We presented already what we believe to be the limitations of this definition introducing issues to consider in the development of our energy network (section 2.2.2); it is perhaps important to present a working idea of what we mean by SG, its components and the broad range of stakeholders involved in its making.

3.1 Short overview of Smart Grids

In figure 3.1 we reported a schematic representation of the envisioned system. A portion of the power generated by the conventional plants will be displaced by distributed generation, with a prominent role of RES. End-users will play a more active role, with the possibility to produce, at least to some extent, their own energy and contributing to the to the overall management of the network by sharing and/or storing energy according to their possibilities and convenience. The interaction between single users and

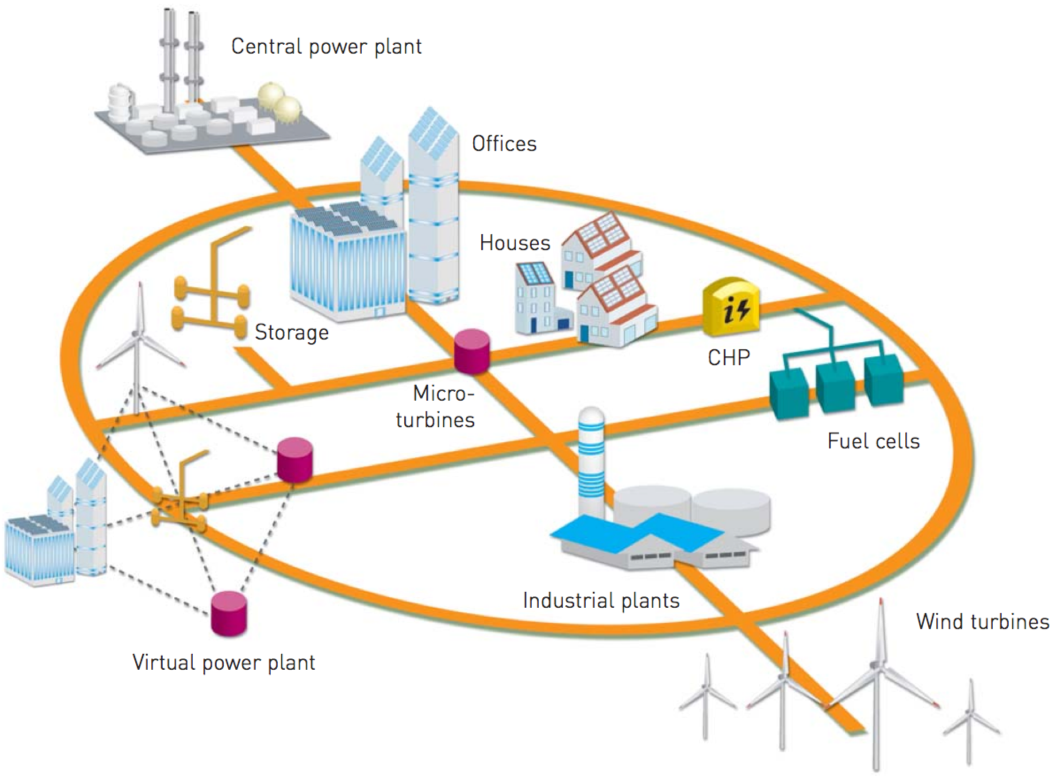


Figure 3.1: Schematic representation of a number of components (and their interaction) of the future smarter energy system. Figure reproduced from [11].

the network occurs through smarter metering systems (SMSs), which enable users and providers to access a larger and more comprehensive set of information, an essential element of improving energy efficiency and network flexibility. Virtual power plants (VPP) are a valid example of possibilities smarter systems can give rise to, where combined control of distributed physical elements can be coordinated to produce benefits such as peak load management.

A more comprehensive (and not exhaustive) list of characteristics of SGs are reported in the table below [12].

Table 3.1: Characteristics of Smart Grids as reported in [12].

Characteristics	Description
Enables informed participation by customers.	Consumers help balancing supply and demand, ensuring reliability by modifying the way they use and purchase electricity. These modifications come as a result of consumers having choices that motivate different purchasing patterns and behavior. These choices involve new technologies, new information about their electricity use, and new forms of electricity pricing and incentives.
Accommodates all generation and storage options.	A smart grid accommodates not only large, centralized power plants, but also the growing array of customer-sited distributed energy resources. Integration of these resources including renewables, small-scale combined heat and power, and energy storage will increase rapidly all along the value chain, from suppliers to marketers to customers.
Enables new products, services and markets.	Correctly designed and operated markets efficiently create an opportunity for consumers to choose among competing services. Some of the independent grid variables that must be explicitly managed are energy, capacity, location, time, rate of change and quality. Markets can play a major role in the management of these variables. Regulators, owners/operators and consumers need the flexibility to modify the rules of business to suit operating and market conditions.

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Table 3.1 – *Continued from previous page*

Characteristics	Description
Provides the power quality for the range of needs.	Not all commercial enterprises, and certainly not all residential customers, need the same quality of power. A smart grid supplies varying grades (and prices) of power. The cost of premium power-quality features can be included in the electrical service contract. Advanced control methods monitor essential components, enabling rapid diagnosis and solutions to events that impact power quality, such as lightning, switching surges, line faults and harmonic sources.
Optimizes asset utilization and operating efficiency.	A smart grid applies the latest technologies to optimize the use of its assets. For example, optimized capacity can be attainable with dynamic ratings, which allows assets to be used at greater loads by continuously sensing and rating their capacities. Maintenance efficiency can be optimized with condition-based maintenance, which signals the need for equipment maintenance at precisely the right time. System-control devices can be adjusted to reduce losses and eliminate congestion. Operating efficiency increases when selecting the least-cost energy-delivery system available through these types of system-control devices.
Provides resiliency to disturbances, attacks and natural disasters.	Resiliency refers to the ability of a system to react to unexpected events by isolating problematic elements while the rest of the system is restored to normal operation. These self-healing actions result in reduced interruption of service to consumers and help service providers better manage the delivery infrastructure.

3.2 Key elements

In general terms, we can simplify and reduce the number of key elements defining the development of smart grids in 4 focus areas: generation, transmission and distribution, storage and smart living environment. Sometimes referred to using different terminology and in different contexts, these four elements represent, in most cases, the four pillars upon which the planned smartening of the power grid relies upon.

3.2.1 Power generation

We are moving toward a distributed world, were disperse networks are going to increasingly become the founding mechanism for innovation and development. Thanks to the convergence of a number of contributing factors, this (r)evolution includes the role of distributed energy production, as the need for grater share of renewable and greener production systems is able to benefit from the remarkable technological development of the last decades. Furthermore, distributed energy generation systems are more likely to efficiently tap in the locally available renewable resources: opposite to the non-renewable resources, generally characterized by large centralized stocks and limited by its size, renewable resources are generally distributed and limited by the flow we can access; it is therefore rather intuitive that renewable sources and distributed systems are, in some respects, different faces of the same energy system (r)evolution. A smart grid system is expected to efficiently combine centralized and distributed energy production systems in a synergic mode: forecasting, monitoring, managing and quickly responding and adapting to an exponentially far more complex energy production system, subject to irregular production, decision making and increasingly larger number of active network users. The complexity of the system and the proper coordination of different elements of the network rely greatly on different and effective information flows. The role of ICT in supporting the network is fundamental.

3.2.2 Transmission and Distribution

Concerning the role of transmission and distribution systems within a SG, they are expected to play an important part in managing reserve power and outweigh imbalances. Also in this case, ICT will play a critical role, even though a distinction should be made between transmission and distribution networks. At the transmission level, these systems are already in place and technology development consists mainly in improving the system. Major changes, on the other hand, are expected at the distribution level. Beside deployment of smart meters, considered in most cases a mature technology and in phase of deployment – although with often remarkable differences among countries (Figure 3.2) – [13] important infrastructure and modus operandi changes are expect at the bottom (end-users) level.

Power and information delivery systems need to be adopted and renewed as the distribution networks are not, in most cases, conceived to be bi-directional.

3.2.3 Energy Storage

Reserve (stored) power can play a double role. On one hand it can be used to outweigh voltage imbalances, therefore providing an important contribution in terms of *power quality*. On the other hand it can be used for managing peak loads, therefore

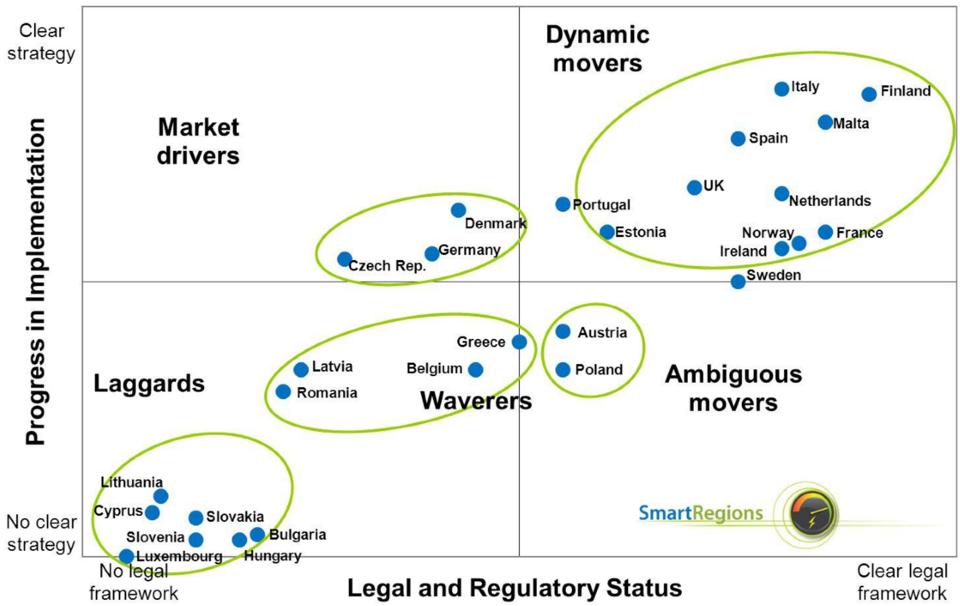


Figure 3.2: Graphical overview of the development and implementation of smart metering systems status in the EU countries and Norway. Figure reproduced from [13].

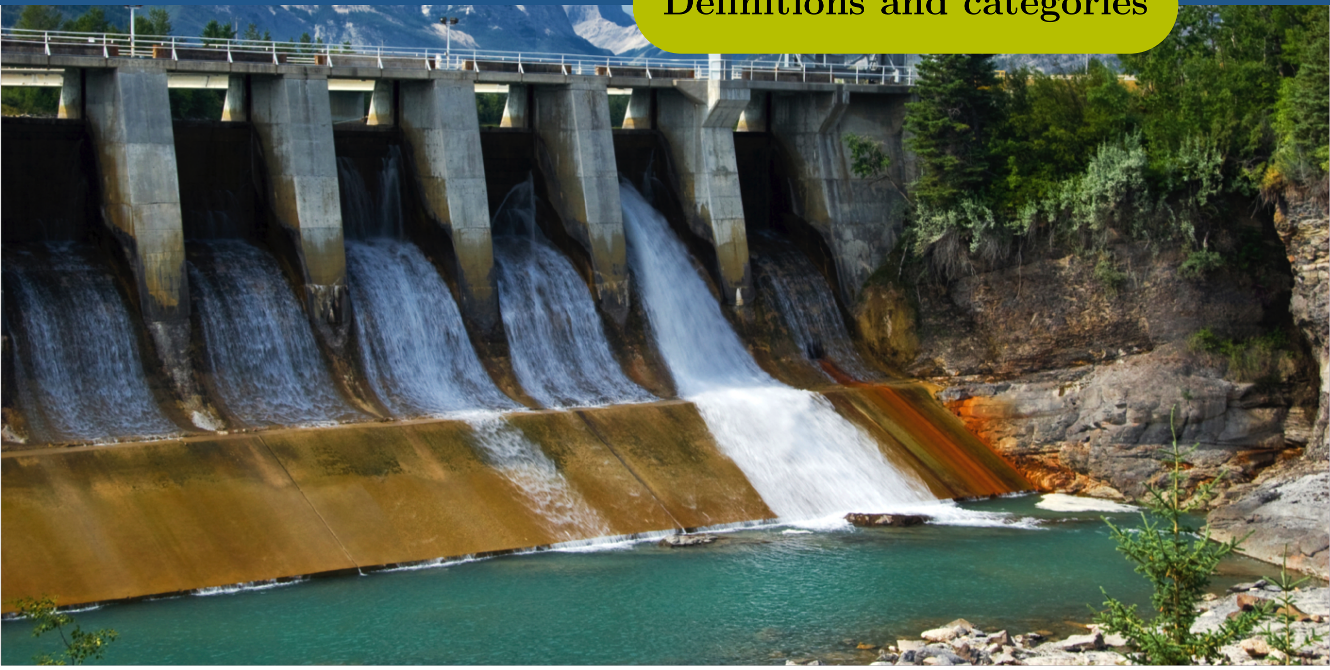
providing a contribution in terms of *power quantity*. Within this framework, electric vehicles (plug-in, hybrid, plug-in hybrid) are expected to play a special role. Enabling a two way communication between vehicles and grid, the systems is able to access a potential source of stored energy. Also in this context the role of ICTs are going to be fundamentally important. Based on an efficient bi-directional flow of information, both users and administrators are to be able to optimize their energy utilization profile.

3.2.4 Smart Living Environment

Indicating by smart living environment (SLE) the houses and buildings where the generated power is utilized, they represent the bottom line of the energy value chain. The expression *living environment* in this context it is meant to be more comprehensive than houses and buildings, as it tends to include all the devices and services that make up the actual living environment. Interfacing with the network through the advance metering systems, SLEs are expected to interact and support end-users in responding to the overall network and environmental conditions. Forecasting energy production and consumption, managing storage (e.g. recharging electric vehicles) and helping users to efficiently and effectively redistribute their energy consumption, SLEs rely on *ad hoc* ICT solutions. Beside monitoring, therefore providing users with detailed information on their energy consumption profile, ICTs are expected to develop a smooth transition from smart metering systems to SLEs though a number of information based services.

Chapter 4

Definitions and categories



In the previous chapter we provided a short overview of what a SG system is expected to be. In this chapter we intend to provide a list of stakeholders involved in the new system. Based, again, on the European vision [14], the aim is to provide an overview of the new role many currently operating parties will have to play, and a – probably incomplete – overview of of the new parties that will fill the new niches in the next generation energy system.

The last section of this chapter is dedicated to different project categories identified based on the work carried on across Europe. Although they do not represent an exhaustive list, they can provide the readers with a basic overview of the field of study and research dedicated to development of SGs.

4.1 Stakeholders

Consumers

Traditionally associated to the consumption of energy products, they represent the end element of the chain. A consumer becomes therefore associated to the consumption of energy products and services, the end-user of the electricity. Consumers are persons, households, SMEs and industries. Within the new smart system paradigm consumers will require a (new?) set of (mobile?) interfaces for real time information exchange and a security of supply (in quantitative and qualitative terms).

Prosumers

Traditionally associated to the production of small-scale owned electricity generation, a prosumer is a consumer with additional self-provided (owned) electricity generation and/or storage. Usage of self produced electricity generation is motivated by high private energy consumption and/or expenses, comfort and SME businesses supported by their logistic and economic framework conditions (e.g.. significant production of energy rich waste, etc.). The rise of role of prosumers and their ever more significant role within the development of a smart energy system call for a number of considerations:

- Is the transition from consumer to prosumer efficient and/or effective?
- How can a consumer be incentivized to become a prosumer?
- Should a consumer be incentivized or motivated in the first place? At what cost, speed, rate, mode?

Electric Appliances Users

Traditionally included in the energy consumer category they represent the subcategory of users in direct communication with the power grid through the usage of their appliances. The use of electrical appliances is expected to increase and to be more closely interfaced with the grid. Questions associated to this stakeholders category relates to the overall role of the user response in the definition of the (smartness of the) system:

- Is the users' cooperation to be sought?
- Or rather other (more passive) form of involvement such as the implicit openness regarding private data and information?

Electric Vehicles Users

Electric vehicles users include users operating vehicles including a range of technologies: electric vehicle (EV), hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV). This group of users is identifiable and describable by a specialized mobility requirement and it represents a specific set of currently largely untapped potential concerning energy storage. Open questions concerning the developing role of this energy users' group include privacy and infrastructure related issues:

- Similar to the previous case, the data and information requirement for the system functioning are potentially very intrusive. Where and how do we strike a balance of system efficiency vs. privacy?
- Standards regarding charging, communication, billing and a number of other technological sector are still to be defined and implemented and any delay is likely to increase the further costs of a technology currently undergoing a significant expansion.

Generators

This category includes large scale centralized power generator as well as RES. The development of smart power systems, as mentioned earlier, implies the integration of ICT and energy technology. The definition of centralized power generation, therefore, should be adapted to fit the new framework paradigm. This leaves unanswered an – deceivingly – simple group of questions:

- What do we mean by centralized? What's the role of centralization of control and/or information vs. the physical distribution across the territory? Is a (physically) distributed generation managed by a centralized data management system to be still considered decentralized?

Distributed Generators

Mirroring the previously mentioned category, this group of stakeholders includes small and medium scale – usually renewable – power generators. In this category we include generation for third parties and own consumption. Based on the considerations mentioned in the previous category, we are here also concerned with the same questions: what do we mean by decentralized? What's the role of centralization of control and/or information vs. the physical distribution across the territory?

Storage Providers

This group of stakeholders includes providers of storage products and services. Within the primary objectives of a smart grids they represent primary subjects dedicated to the power load shifting. Their role can therefore represents benefits as well as a risk for a massive third party managed storage on the market. Storage providers are to be considered a subgroup of the ancillary services providers mentioned later.

Ancillary Services Providers (ASP)

This group of stakeholders provides a number of support services for the correct function of the grid (Figure 4.3). Provided services include power balancing, voltage profile support, frequency and time, black start, etc. It is reasonable to expect a growing role of ASP in the future SG structure. As the number and the intensity of power exchanges are to increase significantly, so is the need for a set of network balancing and stabilizing services.

Telecommunications Services Providers (TSP)

Traditionally identified with the state companies providing the telephone services, they represent a sector which has undergone a dramatic liberalization and restructuring throughout the past few decades, changing the market structure and role. In charge of communication services they are expected to play an important role related to the mobile interface infrastructure. Open questions related to their role are the same mentioned before. They are in charge of a sector which is vital for SGs' correct operation. On the other hand they are in a privileged position to access a large, and potentially intrusive, set of data and information while in charge of the energy *nervous system*:

- How and where to set the balance between privacy and efficiency?
- Is such a balance to be sought in the first place?
- Is the limited number of players in the telecommunication system representing a *de facto* limitation in the effective democratization of the new energy paradigm?

ICT Equipment and System Providers

Traditionally identified as an extension of the telecommunication service providers, ICT is expected to play a crucial role at multiple levels. Communication, monitoring, safety, etc. As an extension of the TSPs, they are, in our view, subject to the same questions concerning their future role in the SG development.

Energy Retailers

They are in charge of the final step of delivery the electricity from generation. Energy retailers sell energy and other (related) services to consumers. They are expected to develop more consumer oriented programs, products and offers. The open questions related to energy retailers are therefore focussing primarily to their future role.

Aggregators

Brooking energy for a group or groups of prosumers, it is the body in charge of combining different loads (and supplies) with the goal of minimizing the costs for the represented parties (the clients). Their expected role is to be considered pure business oriented and primarily focussing on the flattening of the energy consumption profile. The open question concernig their role is to be considered directly connected to the previous questions concerning aggregators and energy retailers: what happen if we move on large scale including a significant number of prosumers in the system?

Energy Services Company (ESCOs)

Expected to provide a broad range of services including design and implementation of energy efficiency dedicated projects, power generation, supply, etc. Their role in the future data management and information extraction process is to be defined.

Data Processing Services Providers
In charge of data processing services following consumer privacy. They provides the knowhow for the information extrapolation based on large users' data set.

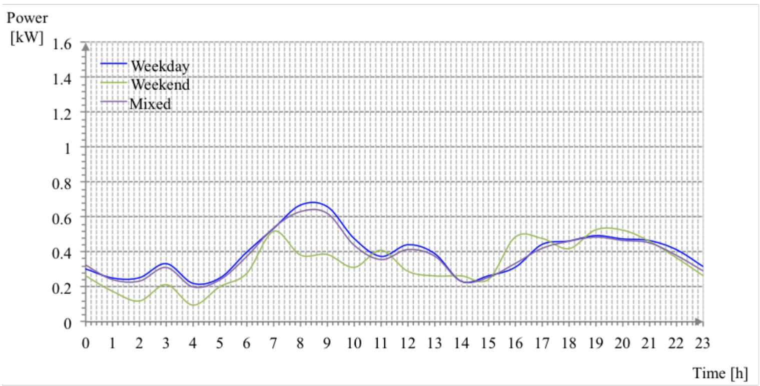


Figure 4.1: Data management and information extraction is likely to represent the core of the future energy market system functioning.

Energy Equipment and System Manufacturers
Sale of electro-technology system products and services. They include all the devices and technologies required for data collection, feedback and real time information (re-)distribution (including mobile devices), electronics to support distributed energy production systems and the necessary interface technology, etc.

Distributed System Operators (DSOs) Provision of secure, efficient and sustainable operation of electricity distribution systems (Figure 4.3). Legal obligation of high quality. Secure planning, operation and maintenance of the distribution grids.

Transmission System Operators (TSOs) Provision of secure, efficient and sustainable operation of electricity transmission systems (Figure 4.3). Legal obligation of high quality. Secure planning, operation and maintenance of the transmission grids.

Wholesale Electricity Market Traders Provision of market based prices for products and services by liquid electricity markets.

Policy Makers and Regulators Set up of natural monopoly requirements for highly effective electricity markets.

Electricity Markets Operators Operators of market places for energy and other energy products and services.

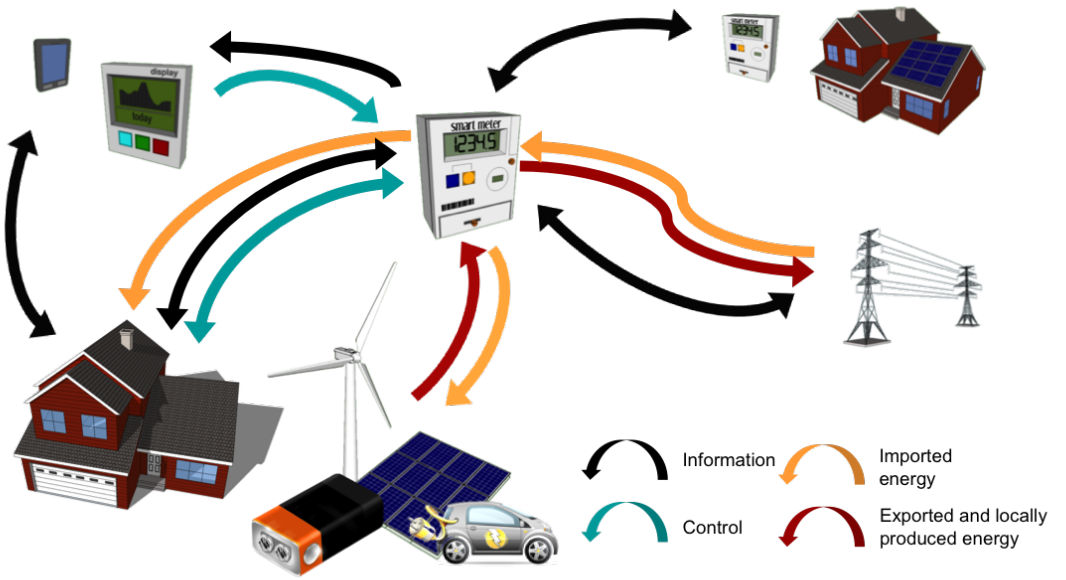


Figure 4.2: Schematic and simplified representation of the potentially complex energy and information exchange from the ends-users prospective.

4.2 Project categories

Smart grids R&D projects currently span over a broad range of disciplines and topics. A process aiming at obtaining a proper overview of the current state of the art risks, therefore, to be too dispersive. In order to systematically describe the status quo of SGs development in the Arctic, it is, therefore, useful to point out a number of key issues grouped in specific field of interest, which can be singled out and whose role, within the large scale system development, can be clearly identified. These fields have been described in the recently published European Commission report [15], where smart grids projects have been grouped in a number of closely related categories. The decision was made, for practical purposes, to follow the same approach throughout this document. This should help the interested parties to better consider all the aspects the development of SG research projects in the arctic might include and offer. The mentioned document includes 6 project categories:

Smart Network Management Projects focussed primarily on improving the operational flexibility of the electricity network. Typically themes focus on grid monitoring and control, mainly at medium and low voltage levels.

Integration of Large Scale RESs Integration of large RES mainly at the transmission level: i.e. planning and control for market integration and tools for production forecast.

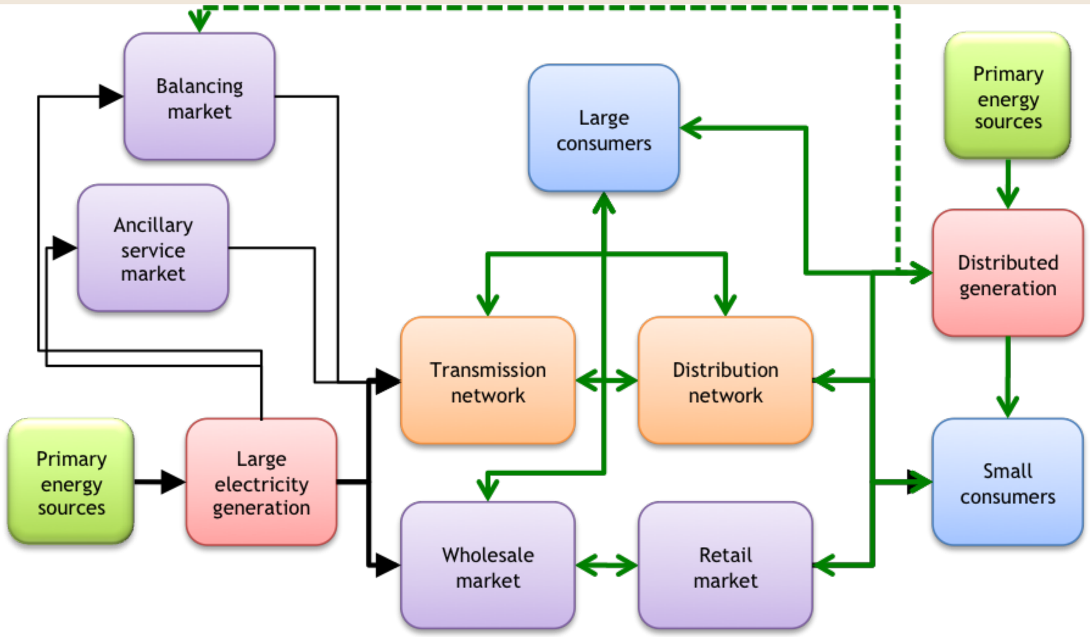


Figure 4.3: schematic representation of the market dynamics including the prominent role of (smart and) distributed energy system

Integration of DERs Projects aiming at the integration of DER, assuring the overall system reliability and security. This includes the development of new control schemes, new hardware/software solutions and the integration (but not the development) of storage technology.

Aggregation (Demand Response, VPP) This category includes implementation of aggregation mechanisms (i.e. virtual power plants) to aggregate the supply and demand flexibilities of decentralized resources.

Smart Customer and Smart Home Implementation and testing of smart appliances and home automation within new tariff schemes. Consumers participation is usually required as the aim is to analyze consumer behavior and increase consumer awareness and involvement.

Electric Vehicles and V2G applications Integration of electric vehicles (EVs) and Plug-in Hybrid Vehicles (PHEV) in the electricity network. In this area of research, projects ultimately aim at answering questions such as the following: how could EVs be smartly coordinated with the production of local DERs to reduce the peak load on the power grid? How can we achieve maximum benefit from the charging and discharging of EVs in future electricity networks? Is the smart integration of EVs feasible in technical and economic terms?

Although in this work our interest is primarily focussed on R&D areas in relation to the Arctic, it is to be taken into consideration that SG projects assessments within an European framework is also categorized as R&D, demonstration or deployment.

A R&D project can include three types of activities - basic research, applied research and experimental development - and it is defined as a *creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications* [16]; demonstration projects are designed to test the performance of a technology in different operational environments [17]; deployment projects refer to the deployment of a technology as a default solution within a specific area or region.

A separated sub-set of projects is dedicated to smart-meter and smart metering. The reason behind this choice is that smart metering represent the areas where most of the advancements have been made and most of the technology is at the deployment stage and it represents a significant discrepancy with all the other field of work within the SG related research.

Chapter 5

Discussion

Based on the previously introduced considerations, in this chapter we intend to discuss the evolution the power network is expected to undergo in the near future. This is to be understood as an opportunities for Finland and its main players in the scientific and technology communities to play a relevant role in the rapidly evolving energy regime.

It is to be noticed that despite the expression *Smart Grid* is today well known, accepted and understood (at least at some high conceptual level), it is also a misapprehension of the reality. The use of the word *smart* indeed presumes the general understanding or at least some form of definition of what *smart* is to indicate. It is, in other words, a target, a goal. It should therefore be more logic and correct referring to *smarter grid* or *smartening grid*, underlining in this way the vast and complex evolutionary character of the transformation we are currently witnessing (Figure 5.1).

In this framework it is then more important than ever to take part in this process, as we find ourselves in a unique – space and time – position, not only to be part of the

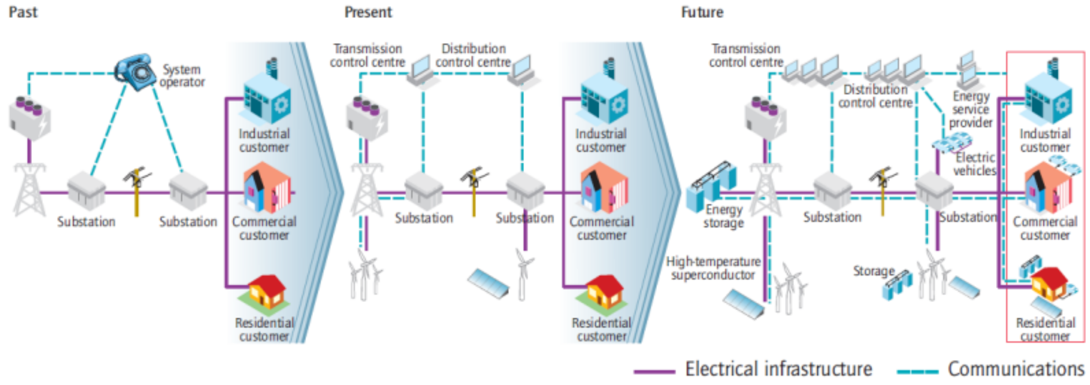


Figure 5.1: Schematic representation of the evolutionary character of smartening process of the power grid. Figure reproduced from [12].

future, but to shape it.

This chapter includes a short description of what we believe to be the untapped potential and the foreseen challenges on the path for the development of SGs in the North. The last sections focus on the work our team has done to actively contribute, including some considerations regarding current topics related to the development of the energy industry.

5.1 Untapped potential

5.1.1 Deployment of RES

As mentioned earlier, an important advantage provided by the development of SGs is the possibility to improve the effectiveness of RESs. Often characterized by variable generation, an important limitation in the economics of their deployment is usually their unstable and unreliable energy production. The development of Smart Technologies can provide an important contribution in terms of predictability, real-time detailed monitoring and flexibility of the grid, allowing for a more economically significant development in an energy sector largely untapped in northern Finland (Figures 5.2 and 5.3).

5.1.2 Electrification of transport

It is estimated that by 2050, the transportation sector will represent approximately 10% of the total electricity consumption thanks to the increasing deployment of electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV). Within the framework of increased power consumption/generation fluctuation mentioned before, the electrification of a significant share of the transport system is likely to increase peak demand and present further challenges in terms of energy supply. Smart grids technology has

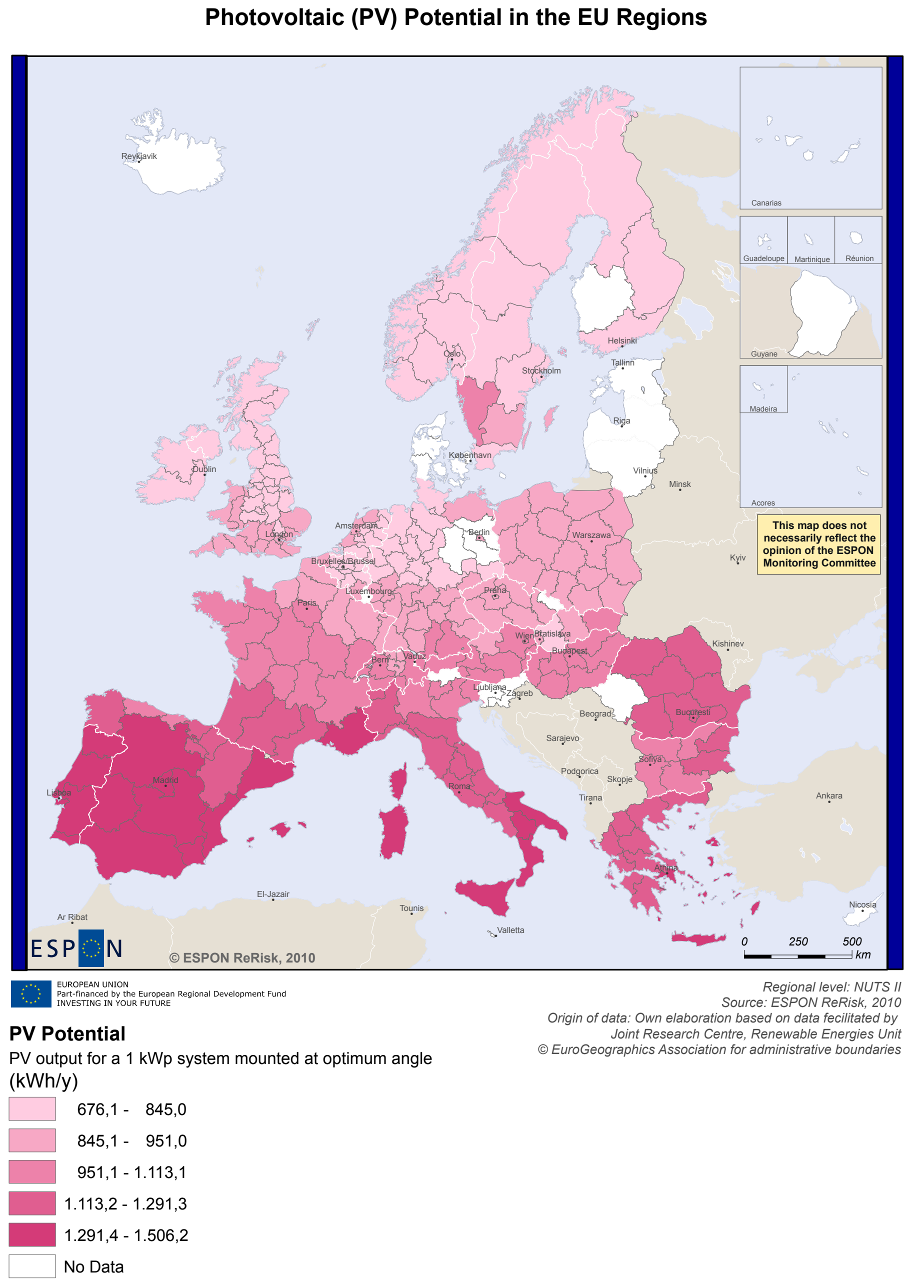


Figure 5.2: PV power potential in Europe; figure reproduced from [18].

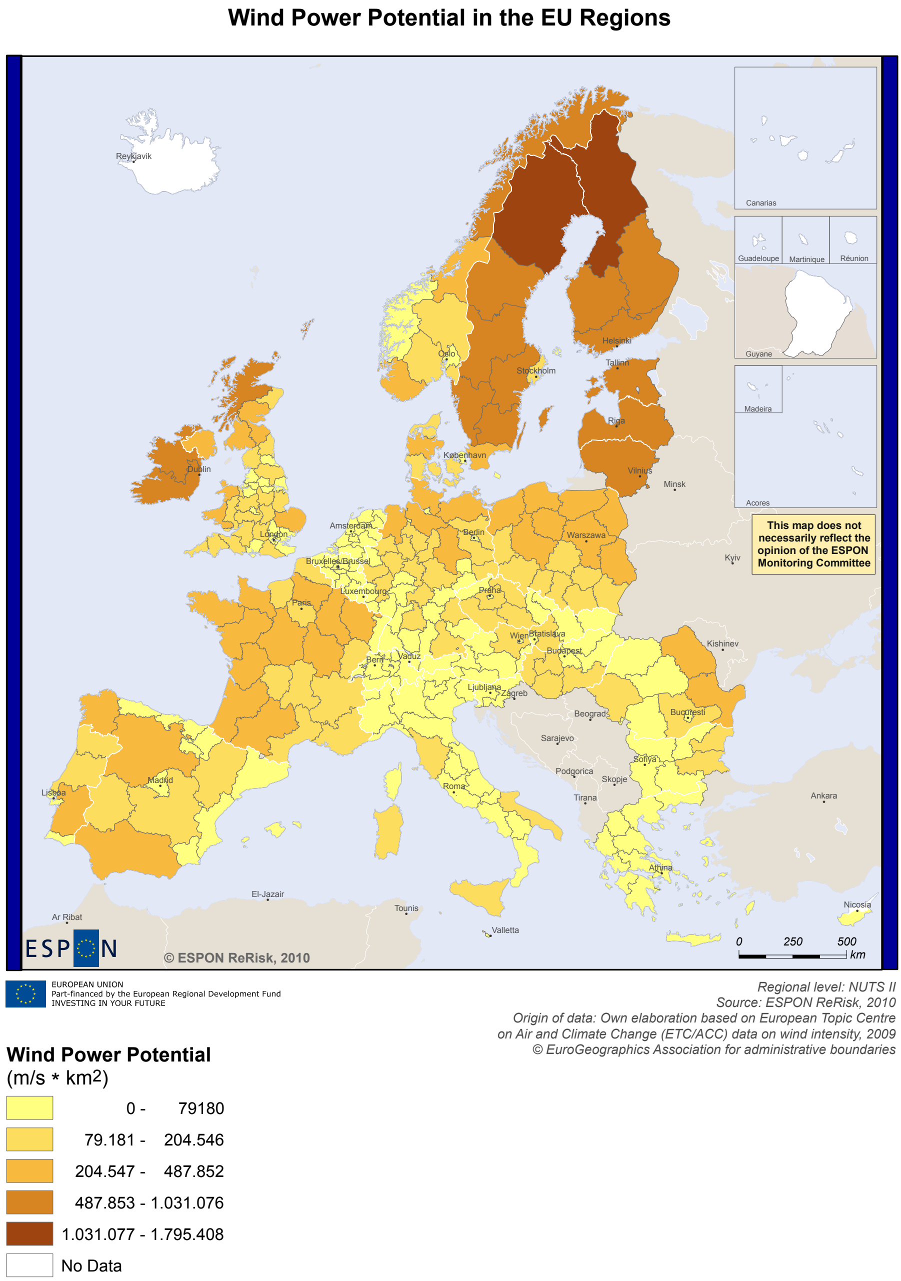


Figure 5.3: Wind power potential in Europe; figure reproduced from [18].

the potential to enable more strategic charging schemes, redistributing energy demand and allowing (mobile) storage capacity on the grid (Figure 5.4). The potential in terms of economic development and opportunities is imposing. A number of services and infrastructure development for the global support of the transport electrification industry rely on ICT and telecommunication technology, sectors of strategic importance for the North and for Finland as whole.

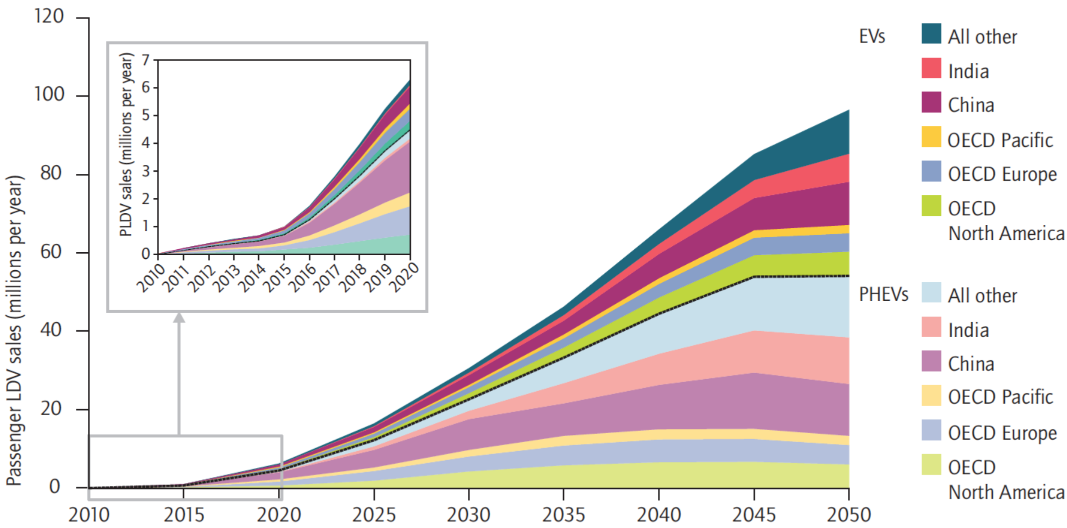


Figure 5.4: Deployment of electric vehicles and plug-in hybrid electric vehicles; figure reproduced from [12].

5.1.3 Electric system development

The aging infrastructure requires major investment for maintenance, improvement and adaptation to the needs of the 21st century. On one hand the necessary investments are supported by the development of smart technologies and the consequence optimization of the existing infrastructure in terms of economic performance; on the other hand, the development of smart technologies can be considered in itself infrastructure development. Within the new paradigm, where the energy grid is described by the synergic integration of the power and information networks, the development of strategic data management and information extraction applications, services and processes can be seen as major contribution for the renewal and expansion of the existing power system. It is, indeed, in this framework where Nordic territories and Finland can play a major role. Given the Finnish logistic and environmental limitations, it is unlikely that a significant contribution on the future global energy market could be provided in terms of mere production volumes. Nevertheless, a key role can be played in terms of ICT supported energy services. Here is were Finland, and the Northern territories in particular, can play a significant role. Furthermore it is possible to provide services on global scale in relation to redistribution of energy demand, lowering of peak of demand, optimization of energy consumption, improvement of energy system reliability and flexibility, system level security, network resilience. A list of smart grid technologies for the development of smart grids is reported in the figure 5.5 and table 5.1 [12]; they include:

Wide-area monitoring and control
Real-time monitoring and control of system performance across large geographic areas. These technologies aim at the optimization of the system components as well as the overall performance optimization.

Information and Communication Technology (ICT) integration
Data and information communication infrastructure supporting real-time monitoring operations as well as communications among all stakeholders.

Renewable and distributed generation integration
Integration of RES including large, medium and small scale systems at the transmission, distribution and residential level, respectively. These technologies include distributed storage systems and their potential to decouple energy produc-

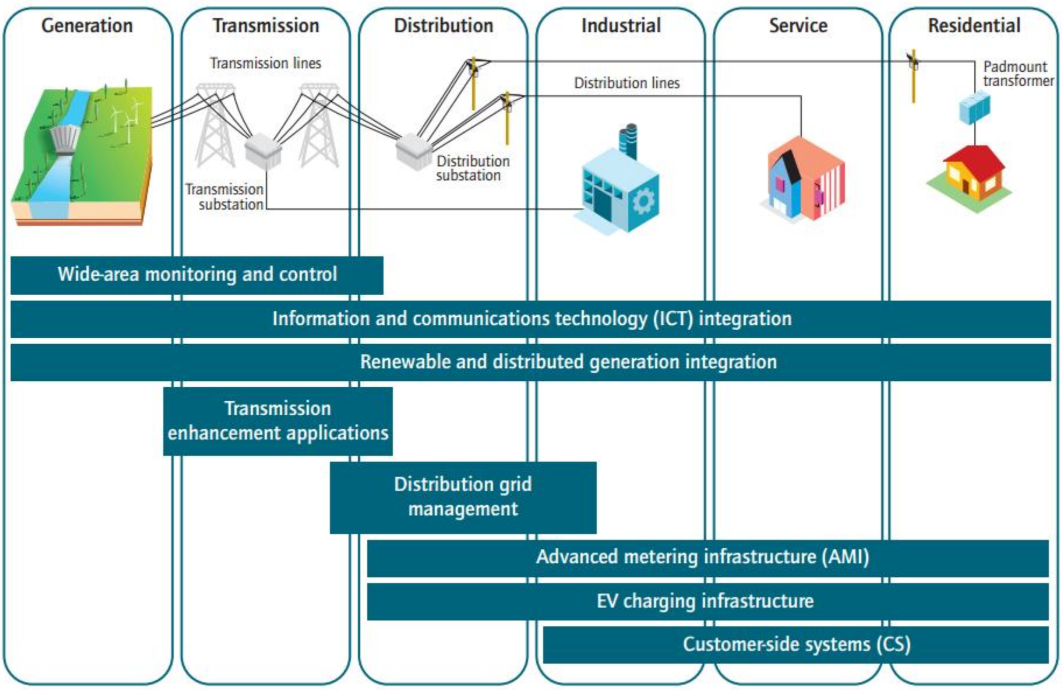


Figure 5.5: Technology areas encompassed by the development of smart grids; see text and table 5.1. Figure reproduced from [12].

tion and delivery.

Transmission enhancement applications
Set of technologies aiming at improving the efficiency and overall performance of existing and innovative infrastructures. Considered technologies include:

- Flexible AC transmission systems (FACTSs) for the optimization of AC transmission system performance;
- High-voltage DC (HVDC) technologies for high-performance long distance connection with large scale solar and wind farms;
- Dynamic line rating (DLR), sensor based system for real-time monitoring of network capabilities, optimizing system utilization and avoiding overloads;
- High-temperature superconductors (HTSs) for long-distance high-performance transmission systems (The technology reediness level is currently debated).

Distribution grid management
Set of technologies focussing on distribution and substation monitoring. They hold the potential for detailed real-time information on system performance, allowing for system operation optimization and improvement of network resilience.

Advanced metering infrastructure (AMI)
Set of technologies enabling two-way communications between end-users and utilities. A broad range of services that rely on AMI technologies for an applications spanning from energy pricing and billing to the detailed monitoring (end-user level) system performance.

EV charging infrastructure
Set of technologies supporting V2G and G2V operations, including envisioned large-scale charging installations providing a broader range of ancillary services such as energy storage capacity.

Customer side system (CS)
Set of technologies supporting end-users in energy management operations, (smart) appliances utilizations, improved energy efficiency and support the overall end-user-to-smart-grid interface experience.

As mentioned earlier, an important field of developing technologies relates to consumer behavior, automation supported behavioral modification, customer education and choice making based on ICT based services. This field of technology development is primarily related with what we previously mentioned as smart living environment and it is likely to be a major area of technological development as well as an area of expertise where Finland has a major possibilities to excel thanks to its high level of general education and service oriented economy.

Table 5.1: Smart grid technologies. Table from a partial reproduction of the original on [12]; see text and table 5.5.

Technology area	Systems and softwares
Wide-area monitoring and control	Supervisory control and data acquisition (SCADA), wide-area monitoring systems (WAMS), wide-area adaptive protection, control and automation (WAAPCA), wide-area situational awareness (WASA).
Information and communication technology integration	Enterprise resource planning (ERP) software, customer information system.
Renewable and distributed generation integration	Energy management system (EMS), distribution management system (DMS), SCADA, geographic information system (GIS).
Transmission enhancement	Network stability analysis, automatic recovery systems.
Distribution grid management	Geographic information system (GIS), distribution management system (DMS), outage management system (OMS), workforce management system (WMS).
Advanced metering infrastructure	Meter data management system (MDMS).

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Table 5.1 – *Continued from previous page*

Characteristics	Description
Electric vehicle charging infrastructure	Energy billing, smart grid-to-vehicle charging (G2V) and discharging vehicle-to-grid (V2G) methodologies).
Customer-side system	Energy dashboards, energy management systems, energy applications for smart phones and tables.

5.2 Expected challenges

As we approach the goals set for the year 2020, it is time to explore, analyze and develop long-term plans for the creation of a high-quality, economically affordable and sustainable electricity system. As we expect the smartening of the power grid to play a primary role in this endeavor, from an EU stand point we begin to set different milestones and deadlines for the timeframe definition of our roadmap. We believe that the development of a Smart Arctic environment should look at this timeframe as the opportunity to synchronize and exploit its potential.

As mentioned earlier, the 2020 deadlines refers to the EU climate and energy strategy, including 20% reduction in GHGs emissions (from 1990 levels), 20% energy production from renewable resources and 20% improvement in energy efficiency. As we approach these deadlines with justified confidence concerning the overall EU community performance, it is important to look beyond. Within the EU, the 2035 deadline has been proposed. In this 15 years timeline, we expect to deploy and set in motion a number of technologies and support systems for more ambitious targets set for the year 2050 (Figure 5.6). If the work till the year 2020 is expected to focus on the integration

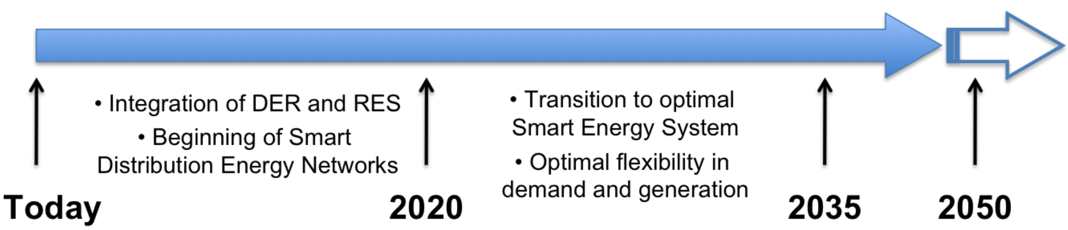

Figure 5.6: Schematics of the proposed smartening grid process timeline; figure based on [4].

of DER, RES and the deployment of the first components for the development of a smarter infrastructure, the 2020-2035 period is expected to focus on the optimization of the newly developed (and greener) energy mix. Within this framework, it is possible to set the objectives for the following 15 years period (2035-2050) based on the expected progresses planned for 2035:

- 80% reduction in GHGs emissions by 2050
- 41 % reduction in energy demand (compared to the 2005-2006 peaks)
- limited increase (15%–16% from 2020 levels) in energy (and related services) expediter for SMEs
- At least 53% of RES gross final energy consumption
- New legislative framework aiming at:
  - Supporting significant deployment of large-, medium- and small-scale RESs.
  - Supporting the integration of distributed and centralized energy production systems
  - Supporting market integration and economy of scale for RESs and energy services

The discussion for the development of an adequate regulatory framework supporting different sectors and components of a smart grid based energy regime goes beyond the scope of our report. Consequently, although a topic of interests and with many connections and repercussions on our work, we will focus our attention on more technical issues.

There are three main fields where the core challenges for moving toward an intelligent electricity system by 2035 can be grouped: Electro-Technologies, ICT, Compatibility.

Electro-Technologies

- Interventions are required to improve system controllability and flexibility supporting security and quality of supply. Furthermore, developing and deploying flexible electricity consumption technologies is necessary to improve system adaptability in time and space:
  - time: power usage balancing, peak shifting, flattening of local consumption profile;
  - space: geographic aggregation of power users and their profile for combined optimization of system performance (environmental, security, economic, etc.);

- development of storage components and control technologies for the management of irregular renewable energy production. It is to be underlined that energy storage, especially within the context of the northern territories, should not be limited to power but should consider thermal energy as well;
- development of meshed HVDC network infrastructure to support and secure long distance transmission with RES located in more remote areas (i.e., wind in costal areas and solar in southern areas, etc.);
- research and development is required in the field of improved and critical materials for grid components. The network performance relies on the availability of a number of strategic resources whose availability needs to be considered and analyzed within the prospective of an economy of scale. Recommended field of work include:
  - Management and recycling of Electronic and Electric Equipment Waste (WEEE);
  - Analysis of large scale material flows for critical materials within the context of SG development.

ICT

- Development of better monitoring and metering technologies. This includes a broad range of technologies, spanning from sensors to distributed computing platforms. Data and information are expected to play a key role in the development of centralized and distributed systems.
- Development of control systems allowing for a large scale synergic iteration of centralized and distributed systems.
- Development and deployment of predictive models and algorithms supporting the correct functioning of the grid
- Development of software architectures allowing, supporting and improving and-users-to-smart-grid real time communication.

Compatibility

- Development of initiatives assuring a smooth transition from the "deployment" phase (till 2020) to the "smartening" phase (till 2035). This, in Finland, and in the norther territories, implies close contacts with the European Electricity Grid Initiative (EEGI).

5.3 Final considerations

Our team has been active in pursuing the development of some of the above mentioned research topics. Within the context of our areas of expertise, as NorTech Oulu and Thule, we proposed a number of research activities in direct continuity with some key ideas mentioned before. Furthermore, through the SMARCTIC research activity we supported the publication of international conference papers in the fields of critical material flow analysis [19] and the sustainability of smart energy networks [20].

The submitted project proposals general descriptions have been included in the appendices[1]. The first two projects, submitted within the Academy of Finland Arctic Research Programme, relate to critical material flow analysis and the modeling of data management, information extraction and flows within the context of SG development. The third submitted project proposal has been submitted by a consortium including a broad range of range disciplines; the proposed project focuses on the development of Smart Arctic Communities which includes, for what concerns our direct contribution, the development of sustainable smart technologies.

The second section of the appendix chapter includes a number of Finnish (or Finland related) projects focussing on the above mentioned R&D topics. The produced list is not to be considered exhaustive; it is extracted from [15] and it includes projects of a significant European dimension.

5.4 Addendum

In this closing section we report three key elements for the consideration of our partners and colleagues summarizing the finding of different WPs and shaping the Finnish future energy roadmap. These thought are not to be considered complete analyses but rather open questions often overlooked or considered in separated discussion forums. They included issues are:

- the Finnish organization within the NordPool Spot market system;
- the role of nuclear power;
- the (apparent) dichotomy between system performance vs. personal (cyber-) space.

If the first two considered topics are characteristic for the Finnish socio-economic environment and represent limitations and/or opportunities on the roadmap for a smart arctic development strategy; the last one is to be understood as an opportunity where the quantitative large and qualitative profound Finnish expertise in the field of ICT can find a second renaissance.

5.4.1 Multiple price areas

One element to take into consideration for future smart grid development in (northern) Finland, is the possibility to divide the Country in multiple energy price areas. In practical terms this would correspond in dividing Finland in multiple bidding areas within the NordPool Spot market system. Finland is currently the only large Country

[1] **Note**: the publicly distributed version of this document does not include the mentioned appendices with the described project proposals.

within the market to be counted as one single bidding area. This is primarily related to the fact that bidding areas are determined by limitations and bottlenecks that do not allow for sufficient power flow to support a single bidding area price. On the other hand the development of a SG based energy system does call for an efficient and sustainable use of locally available resources and for reducing power losses due to long transmission. This means that energy should, in principle, be produced locally and used locally. Our projects proposals, insofar, have been based on this principles, trying to develop a system architecture based on some 3 key targets:

- a sustainable use of locally available resources;
- minimization of power losses due to transmission and distribution;
- flattening of the overall power load at the local (end-user) and general (network) level by implementing a controlled cooperation among users and networks at multiple levels.

Within this context, the creation of a separated (northern) Finnish bidding area could potentially open up new interests and investments in the Northern territories. Furthermore, it has been rightfully suggested that best smart grid development should consider solutions not limited by national borders; as neighbour Sweden and Norway have already developed their own Northern bidding areas, the creation of a Finnish one would add into the possible coordinated development of the Arctic territories also from the SG point of view. This possibility, on the other hand, calls for serious planning and scenario building. In particular the development of a number of small scale energy production system should be considered and their contribution/impact properly evaluated, especially from the economic (not only financial) point of view.

5.4.2 The role of nuclear power

Proportionally, there is no other Country in the world that is investing in nuclear power like Finland is currently doing. The situation is even more peculiar when we take in consideration that Finland does not have a nuclear industry (no uranium extraction, processing and enrichment industry, no power plant construction knowhow). The targets of our discussion does not include a detailed discussions on the opportunity of on Nuclear power production in Finland, but this is a factor that cannot be ignored and that calls for three considerations:

Investments. It should be taken in consideration if (and we suggest it does not) Finland has the actual – economic and intellectual – resources for investing at the same time in SG and nuclear power.

Strategy and logistics. Nuclear power production represents the nemesis of any smart energy grid based on distributed and renewable energy production: the highly centralized massive amount of power generated is likely to offset the short and medium term development of these technologies in a way that still remain to be understood.

Socio-political. The near future development of the nuclear technology in a globalized market (Finland does not have an independent nuclear industry) is likely to indirectly affect the economic aspirations of the northern territories.

5.4.3 System performance vs. personal (cyber-)space

This is an issue often underestimated. The shifting of end-users private spaces (homes and buildings) into interactive elements of the energy network, and the merging of the concept of smart houses with the far more comprehensive and including concept of smart living environment, open the door for serious concerns in respects to a potentially extremely intrusive technology. Rather often, with the idea of access and control required for an efficient system functioning – in principle, the more I know, down to the single user, the more *easily* I can manage the network – issues related to data acquisition and information extraction have been, if not ignored, surprisingly overlooked. Even if privacy was not a point of concern, and it is, taking in consideration these issues can provide, potentially, important benefits for the development of SGs. First of all, generally speaking, confidence and trust might be a characteristics of Finnish users, but it is by no means to be considered a universal factor; any intention to develop a valuable SG industry on the international market requires the development of a system architecture that would consider the protection of end-user private (cyber-) space without compromising the system performance. A second element to consider, closely connected to the first, is that to some extend, SG development and performance depend on the interaction between single users and the network operators. Lack of confidence, distrust or limited interaction result (directly or indirectly) i to a poorer SG performance. It is therefore important to present to the use a system developed not on the basis of the system performance but also on the user centered requirements such as privacy, security and respect of private (cyber-) space.

Chapter 6

Conclusion

In this work we aimed at producing a short essay regarding some of the key issues we believe will characterise the future development of smart energy grids in the Arctic region.

As concluding remarks, we intend to introduce a list of strategic sectors where, we believe, Finland can play an important role based on a number of factors: existing experience and expertise, pre-existing necessity of infrastructure renewal, logistic and climatic conditions, etc. This list aims also at suggesting the interested readers potential strategic field of R&D that could provide important contributions for the future socio-economic development of the Country and an opportunity to gain a globally recognised elite role for the development of a sustainable economy.

In this work we identified 9 strategic technology sectors whose characteristics are summarised in figure 6.1. Each technology has been described in terms of business potential and time span. Business potential does not necessarily indicate direct financial returns or benefits but rather the economic scale and volume of the considered endeavour. Consistently, the associated time scale implies the time-frame required to reach a self sustaining working regime.

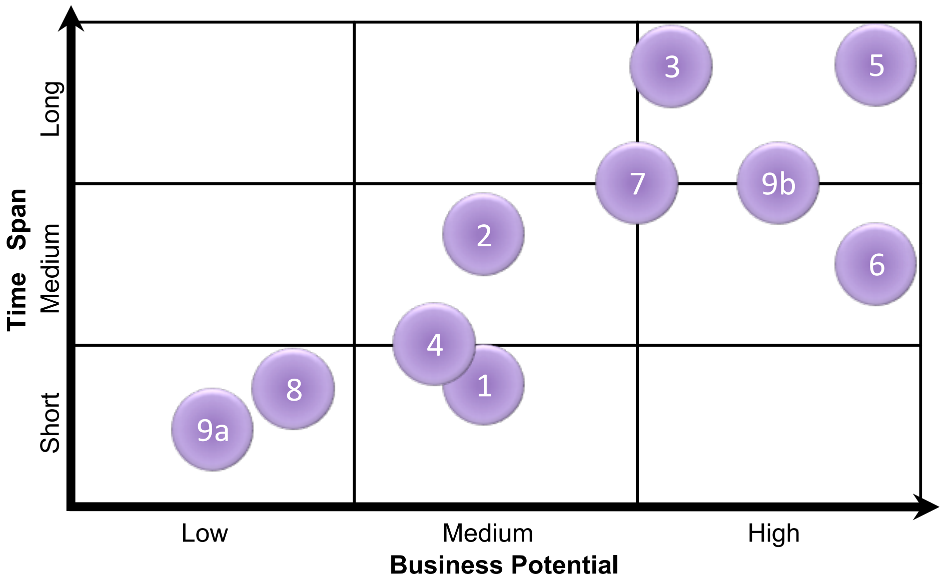

Figure 6.1: Characterization of the identified strategic business opportunities in terms of business potential and time span (see text for further details).

Recommended strategic openings

1 - Smart metering infrastructure

As described in the previous chapters, the smart metering infrastructure is a fundamentally important working element of the future energy system. Finland, with its long experience and expertise in the ICT industry, has a precious opportunity to revitalise a strategic sector if its economy. This is a sector of significant economic potential and an important starting point as it is considered a field technologically mature, requiring resources primarily for full development and deployment.

2 - Electric Vehicles

Electric vehicles (including EV, HEV, PHEV) have bee insofar considered an interesting R&D sector but, we believe, underestimated in terms of economic development when it comes to the deployment in the Arctic and, more generally, Nordic regions. The need for the decarbonization of the economy and the development of a sustainable logistics through, also, the electrification of transportation, requires a more profound and holistic analysis of the contribution electric vehicles can produce. Furthermore, any development of electric transportation in the Arctic requires the development of a significant infrastructure (recharging points, recharging stations, closed/covered parking places, car sharing hot spots, etc.) that alone can significantly benefit different sectors of the Finnish economy.

3 - Wind

Wind power potential in Finland is largely underestimated (Figure 5.3). On the other hand we believe that Finnish logistical and climatic conditions will, in the beginning, privilege larger and more centralised power productions and, on a longer term, smaller and distributed systems. Primary obstacles are regulatory in nature. The need for the development of an infrastructure able to efficiently and affectively integrate their potential into the energy system also requires significant work.

4 - Solar

Solar power potential in Finland is also largely underestimated (Figure 5.2). Suffering from the same limitations as wind power, solar energy technologies are also suffering from common (and mistaken) understanding that *the North is dark* and, consequently, there is little or no solar energy potential. Solar, on the other hand, has the advantage of being more readily available and technically fit for smaller scale solutions, more likely, therefore, to provide significant economic results on a shorter time-frame.

5 - Heavy transport

This sector is to be considered, in many respects, the complementary element of the EV sector previously mentioned. Large scale transportations include, for example, electric busses as well a trains and trams. The Northern territories, as they are expected to become the theatre of an important share of the future economic development, is also in need for (smart technology supported-) heavy transportation infrastructure. The potential benefit in economic terms are expected to be very high, as the actual investments in terms of time and resources.

6 - ICT - SG services to customers

The strategic role of this sector cannot be underestimated. ICT based SG dedicated services are likely to represent a significant share of the future energy business as well as one of its strategically important element. Energy billing, power quality support services, real time energy prices, energy data acquisition and management, information extraction, etc. These services have a pivotal role in the functioning of the smart grid based systems, and they provide a business potential whose scale is by no means limited to or by the local physical infrastructure. Based on the significant scale of importance and experience Finland has in the ICT sector, time wise, the economic benefits of this strategic sector are likely to emerge within a shorter time span.

7 - Energy/Market

This strategic sector focusses primarily on the development of local and regional market tools and systems. The possibility to provide local real-time energy market solutions and a range of energy services including technical support, assistance and maintenance, it is not only very important, but it represents, to some extent, the *on the field* projection of the energy market concept defining the previously mentioned ICT-SG services.

8 - Smart House

The development and deployment of smart technologies for domestic solutions is, together with the smart metering infrastructure, one of the most technologically mature sectors. Requiring primarily a coordinated effort for an efficient and effective deployment and integration within the building industry, this is a sector likely to reach a self sustaining economic regime within a short time span but, at the same time, expected to provide a large return in terms of economic development. An often underestimated beneficial contribution of this strategic area, on the other hand, is the potential improvement of the interaction with the general public. We mentioned earlier how the SG development relies (and it is to some extent defined by) a qualitatively and quantitatively significantly increased interaction with the energy end-users. The development of these technologies is, in many respects, a significant step in this direction, increasing public awareness, knowledge and participation.

9 - Small-Scale biomass burners

Small-scale biomass burners represent a set of technologies which can significantly improve the sustainability of the energy sector, especially in a Country like Finland where the availability of important biomass resources is matched by the need of efficiency relying on energy cogeneration based solutions. Within this categories we could identify two subcategories:

9a - Small-Scale biomass burners for home use

Small-Scale biomass burners for home use are solutions particularly indicated for rural areas or situations where logistics relying on centralised stems are more costly and less efficient. Capable to rely on relatively *all included* technical solutions, they are technologies relatively easily deployed, requiring a relatively small time-frame for providing a direct contribution onto the energy system.

9b - Small-Scale biomass burners for power grid

Small-Scale biomass burners for power grid are solution more indicated to be developed in synergy with a number of other services and integrating solutions such as ancillary services, power storage, etc. Time wise this systems require a larger investment while, at the same time, are likely to provide a more comprehensive and dimensionally more important economic benefit.

Bibliography

[1] Office of the Prime Minister (2013), *Finland's Strategy for the Arctic Region 2013. Government resolution on 23 August 2013*, Prime Minister's Office Publications 16/2013, ISBN (PDF) 978-952-287-062-9.
(http://www.ecn.nl/docs/library/report/2004/c04011.pdf)

[2] International Energy Agency (2009), *World energy outlook. Report, OECD/IEA*.
(http://www.iea.org/textbase/nppdf/free/2009/weo2009.pdf)

[3] U.S. Energy Information Administration (2010), *International energy outlook 2013*.
(http://www.eia.gov/oiaf/ieo/index.html)

[4] SmartGrids - European Technology Platform (2012), *SmartGrids SRA 2035 - Strategic Research Agenda Update of the SmartGrids SRA 2007 for the Needs by the year 2035*.
(http://www.smartgrids.eu/documents/sra2035.pdf)

[5] Rifkin J. (2011), *The Third Industrial Revolution.*, Palgrave Macmillan, New York.
(http://www.ecn.nl/docs/library/report/2004/c04011.pdf)

[6] Donkelaar M. and Scheepers M.J.J. (2004), *Dispower – a socio-economic analysis of the technical solutions and practices for the integration of distributed generation.*. Energy research Centre of the Netherlands (ECN).
(http://www.ecn.nl/docs/library/report/2004/c04011.pdf)

[7] Chai D. S. (2012), *Simulation of cogeneration within the concept of smart energy networks*, M.A.Sc. thesis, University of Waterloo, Mechanical Engineering, 2012.

[8] Chai D. S., Wen J. Z. and Nathwani J. (2013), *Simulation of cogeneration within the concept of smart energy networks*, Energy. Convers. Manage., vol. 75, 2013, pp. 453-465.

[9] ERGEG (2010) Position paper on smart grids – An ERGEG Conclusions Paper. European Regulators Group on for Electricity and Gas, Brussels.

[10] *European SmartGrids Technology Platform: Strategic deployment document – final version* – Strategic Deployment Document for Europe Electricity Network of the Future.

[11] European Commission (2006) European Technology Platform Smart Grids – Vision, Strategy for Europes Electricity Networks of the Future. European Commission, Luxembourg.

[12] International Energy Agency (2011), *Technology Roadmap, Smart Grids.* (http://www.iea.org/publications/freepublications/publication/smartgrids_roadmap.pdf)

[13] *European Smart Metering Landscape Report 2012 – update May 2013*, SmartRegions Deliverable 2.1, Intelligent Energy Europe. (http://www.smartregions.net/)

[14] *SmartGrids SRA 2035 Strategic Research Agenda. Update of the SmartGrids SRA 2007 for the needs by the year 2035*, European Technology Platform SmartGrids. (http://www.smartgrids.eu/documents/sra2035.pdf)

[15] Giordano V., Meletiou A., Covrig C. F., Mengolini A., Ardelean M., Fulli G., Sánchez Jiménez M., Filiou C. (2013), *Smart grid projects in Europe: Lessons learned and current developments*, JRC Scientific and Policy Reports, European Union, pp. 140.
ISBN 978-92-79-28603-2 (pdf), ISBN 978-92-79-28604-9 (pdf), ISSN 1831-9424 (online), ISSN 1918-5593 (print), doi: 10.2790/82707 (online)

[16] OECD, Organization for Economic Cooperation and Development (2002), *Frascati Manual 2002: Proposed standard practice for surveys on research and experimental development*, OECD Publications, Paris, pp 254. (ISBN 92-64-19903-9).

[17] Brown J., Hendry C. (2009), *Public demonstration projects and field trials: Accelerating commercialisation of sustainable technology in solar photovoltaics*, Energy Policy, Vol. 37, pp. 2560-2573.

[18] ESPON (2013), *ReRisk - Regions at Risk of Energy Poverty.* (http://www.espon.eu/export/sites/default/Documents/Projects/AppliedResearch/ReRISK/ReRiskfinalreport.pdf)

[19] Pongrácz E. (2014), *Critical Minerals: Recycling Vs. Dissipative losses – The case of Indium*, Proceedings of SUM 2014, Bergamo, Italy. (http://urbanmining.it/search-app/pdf/123.pdf)

[20] Caló A., Louis J.-N., Pongrácz E. (2014), *Concerning the Sustainability of Smart Grids*, Proceedings of ENERGY 2014, Chamonix, France. (http://www.thinkmind.org/download.php?articleid=energy_2014_4_20_30042)

[21] European Commission (2007) Directorate-General for Research. Strategic Research Agenda for Europes Electricity Networks of the Future.

[22] European Commission (2007) An Energy Policy for Europe. Communication from the Commission to the European Council and the European Parliament.

[23] European Commission (2011) Joint Research Centre Institute for Energy. Smart Grid Projects in Europe: Lessons Learned and Current Developments. Joint Research Centre Reference Report.

[24] European Commission (2011) Smart Grids: From Innovation to Deployment. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions.

[25] Giordano V. and Bossart S., Assessing Smart Grid Benefits and Impacts: EU and U.S. Initiatives, European Commission, EUR 25522 EN, Nov. 2012.

[26] European Commission (2012), Communication form the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "Energy roadmap 2050" COM(2011) 885/2.

[27] Finngrid Oyj. (2012), *Finngrid 2012 Annual Report*, Lönnberg Painot Oy (2013), Helsinki, pp. 156.

[28] Finngrid Oyj. (2012), *Finngrid Grid Service 2012-2015.* (http://www.fingrid.fi/en/customers/grid service/Pages/default.aspx)

[29] Finngrid Oyj. (2012), *New Electricity Market Act changes the rules of the game.* (http://www.fingrid.fi/en/news/announcements/Pages/default.aspx)

[30] Eduskunta (2013), *HE 20/2013 vp.* (http://www.eduskunta.fi/valtiopaivaasiat/he+20/2013)

[31] European Union (2013), *ESPON 2013 – Wind Power and Photovoltaic Potential.* (http://www.espon.eu/main/Menu_Publications/Menu_MapsOfTheMonth/map1101.html)

[32] European Union (2013), *ReRisk – Regions at Risk of Energy Poverty.* (http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/rerisk.html)

[33] Römer B, Reichhart P, Kranz J and Picot A (2012), The role of smart metering and decentralized electricity storage for smart grids: The importance of positive externalities. Energy Policy, November 2012, pp. 486–495

SMARCTIC

To secure a sustainable growth in the Arctic, it is essential that the Arctic's resources are exploited in a controlled manner, taking into account economic, social, cultural and environmental impacts. In this framework, the EU underlines that all business activities must maintain the balance between environmental protection and the sustainable use of natural resources.

The aim of this work was to provide a set of thoughts and recommendations for the development of a sustainable, efficient and economically valuable development for the energy sector in the Arctic. The included vision is a future based on a synergetic material flow, supported, for what concern the energy sector, by smart grid based solutions and optimization of data transfer services.
In this work we expanded the smart grid concept, developing our considerations on the more comprehensive concept of *"Smart energy network"* or SEN. The expression Smart energy network refers to an information-based distributed energy systems, allowing two-way interaction between producers and consumers.

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