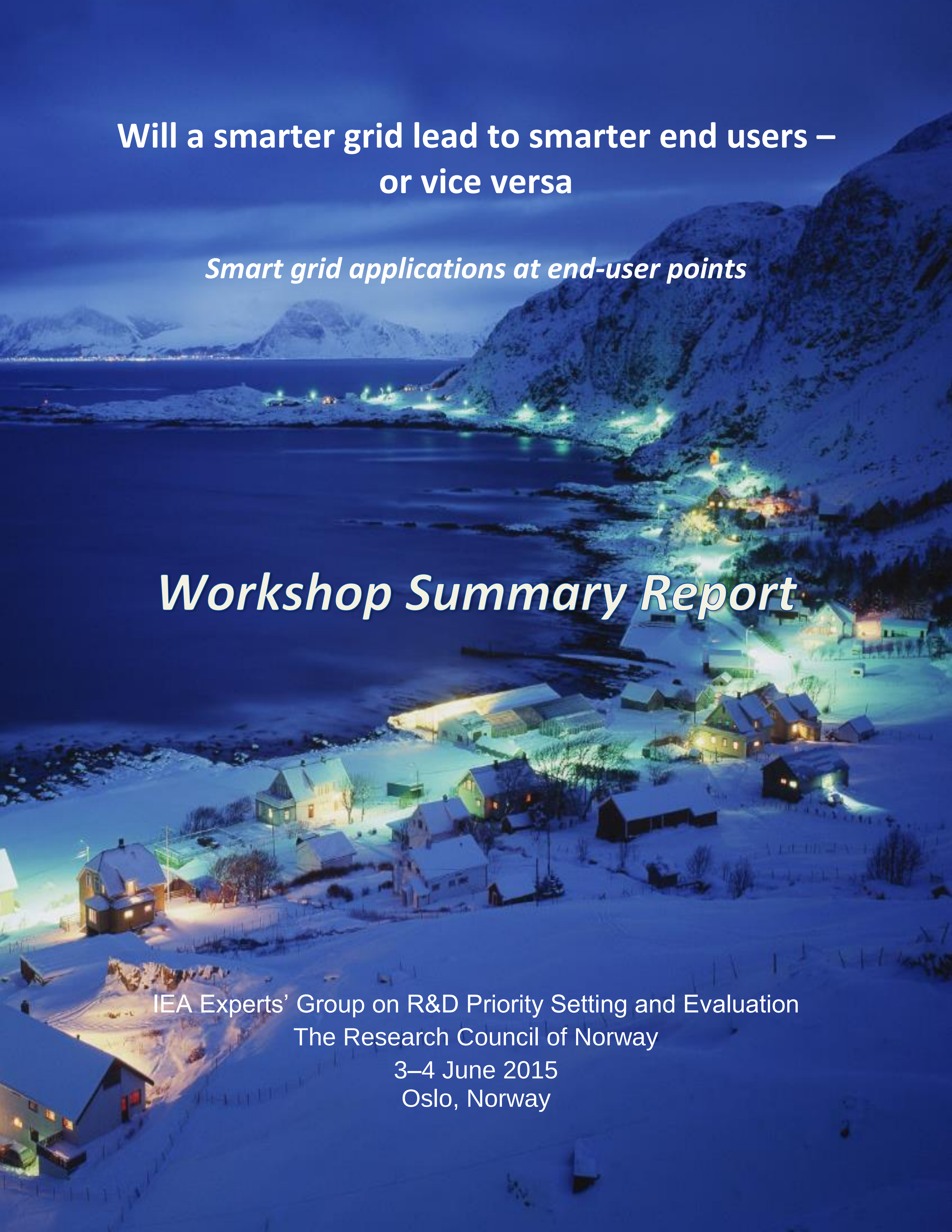

Will a smarter grid lead to smarter end users – or vice versa

Smart grid applications at end-user points

Workshop Summary Report

IEA Experts' Group on R&D Priority Setting and Evaluation
The Research Council of Norway
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International Energy Agency

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its mandate is two-fold: to promote energy security among its member countries through collective responses to physical disruptions in oil supply and to advise member countries on sound energy policy.

The IEA carries out a comprehensive program of energy cooperation among 28 advanced economies[1], each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency aims to:

- Secure member countries' access to reliable and ample supplies of all forms of energy—in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context, particularly in terms of reducing greenhouse gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organizations, and other stakeholders.

IEA Experts' Group on R&D Priority Setting and Evaluation

Research, development, and deployment of innovative technologies is crucial to meeting future energy challenges. The capacity of countries to apply sound tools in developing effective national research and development (R&D) strategies and programs is becoming increasingly important. The Experts' Group on R&D Priority Setting and Evaluation (EGRD) was established by the IEA Committee on Energy Research and Technology (CERT) to promote development and refinement of analytical approaches to energy technology analysis, R&D priority setting, and assessment of benefits from R&D activities.

Senior experts engaged in national and international R&D efforts collaborate on topical issues through international workshops, information exchange, networking, and outreach. Nineteen countries and the European Commission participate in the current program of work. Results provide a global perspective on national R&D efforts that aim to support the CERT and feed into the IEA Secretariat's analysis.

For further information about EGRD activities, see http://www.iea.org/aboutus/standinggroupsandcommittees/cert/egrd/.

To view the agenda and the presentations for this workshop, see https://www.iea.org/workshops/egrd-will-a-smarter-grid-lead-to-smarter-end-users---or-vice-versa.html.

[1] Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States; the European Commission also participates in the work of the IEA.

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EXECUTIVE SUMMARY

The International Energy Agency (IEA) Experts' Group on R&D Priority Setting and Evaluation (EGRD) convened a workshop titled *Will a smarter grid lead to smarter end users – or vice versa* to examine the potential benefits of smart grids for end-users and society at large, with the goal of identifying novel approaches and critical aspects for realising this potential as well as core R&D needs. The Research Council of Norway hosted the workshop, which took place 3-4 June 2015 in Oslo, Norway. A total of 45 participants included EGRD national experts; government representatives; research, development and demonstration (RD&D) decision makers; strategic planners; and program managers from industry. Speakers presented examples of end user-applications, consumer segmentation and engagement schemes, and a range of business models to illustrate emerging international best practices.

Several trends are driving grid modernization and can speed the transition to next-generation energy delivery (see Figure ES-1). These trends include adoption of low-carbon and market liberalisation policies, growing customer interest in autonomy, and the new possibilities presented by the information and communications technology (ICT) sector. Technology challenges are being resolved rapidly. For example, while the increasing share of renewables has created some problems due to fluctuations in wind and solar, data from the European Union show that in 2014, renewables share in member states grew to over 50% without causing any operational difficulties.

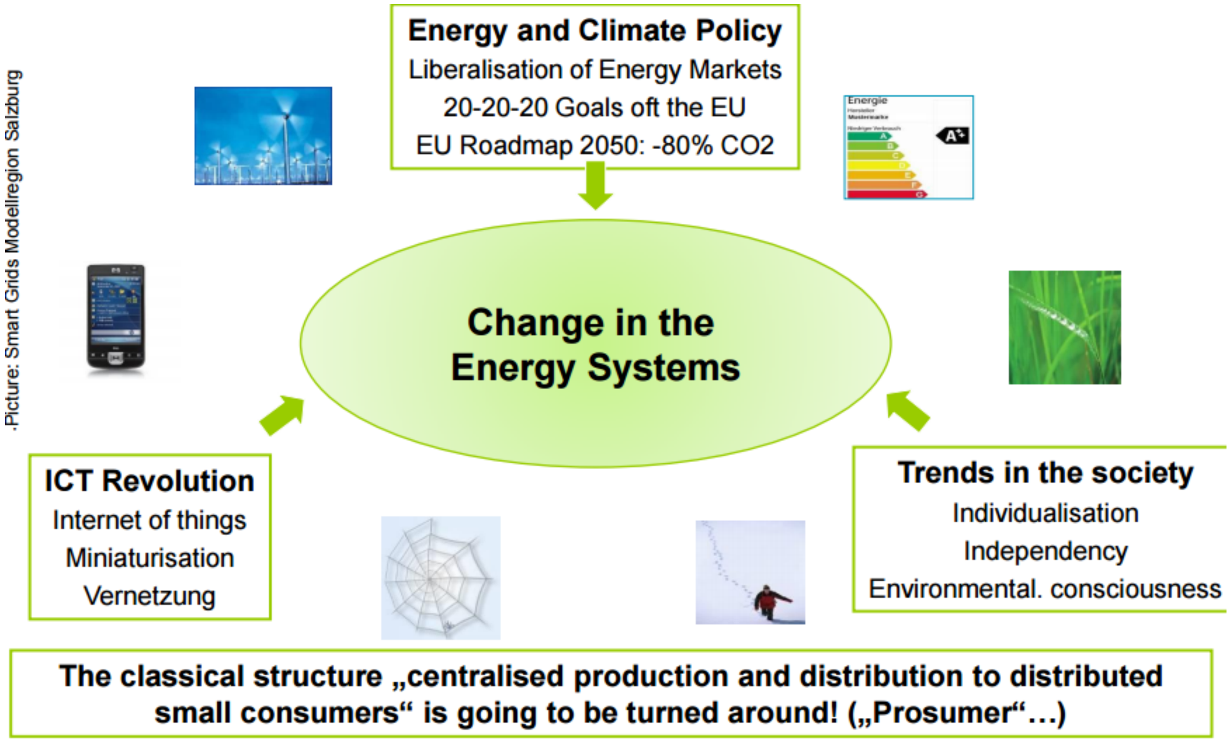


Figure ES-1. Drivers of change in modern energy systems.

Simultaneously, however, are slow-to-change practices that are holding back progress. Non-technical challenges include regulations and incentives based on traditional electricity grids and customers who are resistant to change.

In this workshop, participants examined best practices, advanced technological developments, and challenges surrounding end-user adoption of new technologies. The primary focus was developments in ICT and how smart grids and customer-facing technologies can help and encourage end users to understand, control, and modify their energy consumption patterns. The group discussed projects that have studied whether new technology influences human behavior and how to encourage consumer adoption and behavior modification.

End-User Benefits and Consumer Engagement

Many countries are in the midst of massive smart meter rollouts, which presents opportunities for a wide range of benefits, such as customer empowerment through energy usage information. Several smart grid projects have indicated that smart meters must be paired with customer-facing products and/or services so that customers can become full participants in realizing smart grid benefits. These products/services would be more impactful if they are made available to all customers. If only the most interested customers avail themselves of these services, energy savings will be limited—not only because of fewer participants but also because benefits have already been captured by those customers who are already interested in energy efficiency (i.e., these customers are the first adopters and would have already explored and implemented solutions).

Motivated customers are the exception rather than the rule. Few customers perceive energy itself as a product; instead, it is the means to an end—transport, heating, washing, cooking, entertainment. As a result, it is left largely up to decision-makers in these sectors to determine how smart technologies can benefit consumers and society. Services that combine customer-focused benefits with energy efficiency will best optimize the smart grid's potential. Companies that build energy efficiency technology directly into products without involving the consumer in complex decision making will be more successful than products that rely on motivated users.

Similarly, consumers surprise economists by not always focusing on cost savings or the most cost-efficient choices. Incentives based solely on economic benefits often have limited long-term effects on consumer behavior. Customers often make quality-based rational judgments ("qualculations"), and their decisions can be heavily influenced by moral, social, and political issues.

Customer confidence in the proven performance and longevity of new technologies is also important. Earlier products—especially those focused on energy efficiency—have had disappointing performance and quickly disappeared from the market. In addition, experts have presented issues with products that were marketed as environmentally friendly but have not been fully evaluated in terms of their lifecycles. Customers are reluctant to invest in technology if they are uncertain as to how well it will perform or how long it will remain relevant. Customers also need confidence in after-markets, knowing that suppliers will provide repairs, warrantees, and other follow-up.

Although there is reason to further motivate customers to adopt new technologies and behaviors, workshop participants discussed the experiences from several long-term demonstration projects and noted that significant change has already taken place. Some of these shifts are customer-based. For example, customers are often willing to pay a little extra for "green" energy, and they will consider energy efficiency when shopping for new appliances or homes. Changes may be gradual and go unnoticed in the middle of a transformation, but comparing present-day technologies and associated behaviors with those of ten years ago leaves no doubt that new technologies (including smart grid and smart technologies) are transforming electricity delivery at all levels. How energy is generated, delivered, purchased, and used are all in flux.

New Business Models and Opportunities

Understanding customer perspectives is helpful when considering new business opportunities and business models. There are several examples of new, "smart" energy efficient products and services that focus on consumer benefits. For example, the Norwegian energy company Lyse has combined energy delivery and ICT to provide new services for smart homes, safety and security, and communications (see Figure ES-2).

Figure ES-2. Functionality potentially enabled through Lyse Energi's home energy control system.

Experiences from the telecom sector shows that new business models can lower the barriers for investing in new technology. If the customer can buy a service instead of having to invest in technology and expensive equipment, much of the risk stays with the suppliers. Such models could open markets much more quickly than models that require each customer to investigate all options and risks before investing. An example in the United States shows a new business model that encourages adoption of renewable energy: some companies install their own solar panels on rooftops and rent the rooftop space from the customer. In this case, both the technological and the financial risk stay with the professional partner. New business models are also needed to encourage storage adoption and flexibility. Although big coalitions of companies have demonstrated a willingness to invest in smart grids in many countries, it still is unclear which stakeholders should pay—and how much they are willing to pay—for flexibility and grid safety.

Consumers wants and needs, and the relative importance of these, will vary from region to region and within consumer groups. Business models will need to adjust to each market in order to succeed. In one project, three different consumer groups were identified: older people who were most interested in cost savings, younger people who were most interested in the technology, and environmentalists who were most interested in the impact related to climate change.

Another important motivation is consumers' wish to be self-sufficient or independent. This drive can pave the way for wide-scale adoption of distributed energy resources, solar cells paired with electric vehicle charging, and other combinations. Business models should also consider—and leverage, when possible—the creative potential of the end user.

Similarly, different sectors have varying service needs and capabilities that merit investigation. For example, the transport sector combines with energy delivery systems to create new opportunities—and new challenges. Studies of electric vehicles and power systems provide an interesting integrated approach. For example, electric vehicle systems may add significantly to peak load while also providing new possibilities for storage.

New payment models can also be used to benefit both the company and the customer. Time-based electricity rates can encourage customers to reduce energy usage during peak usage periods, for example. One project is experimenting with a flat rate for connection to the grid with restrictions on energy usage. In most such new models, there is a role for aggregators in the system.

Standards and Regulations

Interoperability presents a major challenge to smart grid application. Codes and standards are needed to establish open networks and support wide-scale, cost-effective smart grid implementation. Universal standards will also lower barriers for competitors to enter the marketplace. Particular challenges are faced by projects implementing direct current, both at high and low voltage. Governments and standards organizations can play an important role in developing such standards.

Similarly, effective smart grid implementation would benefit from regulations and policies that encourage all players to adopt next-generation systems and techniques. Incentives throughout the lifecycle should be considered. For example, in the buildings sector, those who design and construct buildings do not ultimately pay the electricity bills for those structures, making energy efficiency less important than other aspects in the planning process. Good standards and certifying regimes can help ensure that both smart grid application and implementation is prioritized.

Conclusion

While global resources are appropriately focused on smart grids as a solution to many challenges presented by aging electricity delivery infrastructure, it is important to bear in mind that "smart grid" is not a single solution but rather a portfolio of tools, techniques, and technologies. A broad range of factors—from technical to societal—must work hand in hand to optimise smart grid implementation and benefits. The various aspects are interwoven, mandating a holistic approach to achieving the optimal results from advanced systems.

Customer participation is essential to a successful new energy economy; the importance of the customer's role in this larger picture cannot be overemphasized. Consumers participate in reducing demand, adopt technologies and techniques that result in energy efficiency, and enable flexibility—key to a successful next-generation system—through demand response, storage, and distributed generation.

Many consumers are ready to invest in new technologies and participate in new business models, but the stage must be set. New behaviours cannot be expected without new contexts. The energy economy is undergoing a transformation that opens the door wide for new products—and, indeed, demands that energy providers master new technologies and provide new business models and services to survive in the new era.

A supportive policy portfolio is also essential in establishing the contexts and incentives that drive innovation. And continued international and multidisciplinary cooperation is an important factor in successful smart grid implementation.

BACKGROUND

Challenges in Realising the Benefits of a Smarter Grid

Rapid evolution in the character of electricity supply and demand requires increasingly strategic approaches. Energy providers are challenged by incorporating higher proportions of intermittent sources, balancing supply and demand, and providing reliable cost-efficient electricity services to end users. Effectively implemented, smart grids can address many electricity delivery challenges by integrating a range of advanced technologies to monitor and manage electricity transport from all generation sources and meet the varying electricity demands of all end users. Smart grid technologies are an essential enabler to achieving the global community's shared goals for energy security, economic development, and avoiding the worst consequences of climate change. However, the exact role of the electricity consumer in the uptake of smart grids and, more broadly, the evolution of the power sector is still emerging.

Substantial challenges are caused by changing electricity demands. In many developed economies, electricity demand is flat or declining, causing stress on traditional utility business models. In many developing economies, electricity demand is rapidly increasing, causing a number of technical, regulatory, and economic challenges. The demand for higher power *quality* is increasing around the world as more sensitive electronic appliances and equipment are added to the grid. The shift to electricity in end-use sectors such as home heating (via electric heat and combined heat and power [CHP]) and transportation (via electric vehicles), if not managed effectively, could drive up both base load and peak demand, stressing existing infrastructure. In markets with flat electricity tariffs, changes in peak demand could also strain the financial sustainability of electric systems since the added investment costs to meet the peak may not be adequately recovered by additional revenue from annual demand. In urban settings, space constraints complicate efforts to expand or upgrade network capacity to ensure adequacy, and implementation can be detrimental to busy urban centers (e.g., tearing up roads to bury power lines). Unlike most other low-carbon energy technologies, smart grid technologies must be deployed in both new power systems and existing power grids, which in some cases are well over 40 years old. In many cases, these technologies must be installed in systems that are fully operational and whose disruption would entail interrupting power delivery to end users.

These challenges do not detract from the significant potential benefits from developing and deploying smart grids. However, challenges go beyond the technical; there are also a number of policy, market, and behavioral hurdles that need to be overcome for smart grids to deliver the promised benefits.

For example, technological approaches to smart grids should consider the electricity consumer's vital role in full realization of benefits. Exactly what part the consumer will play in power sector evolution is not yet clear, but what is clear is that consumers must perceive and understand the smart grid's value, whether in terms of solutions that meet their energy needs, cost savings on electricity services, and/or perceived societal benefits. If customers do not see the value, they will resist smart grid implementation.

Smart equipment deployment involves funding—often a significant outlay—and utilities typically rely on ratepayer recovery mechanisms to finance such deployment. Public utility commission approval is usually required for these rate cases, with changes in utility rates being obviously more palatable under favorable economic conditions. Similarly, intelligent endpoint applications for the smart grid (demand response, energy efficiency, distributed renewables and storage, etc.) require some sort of investment (time, attention, technology, etc.) from the commercial, industrial, and residential consumer. Such investments are made more willingly during periods of prosperity and with clear benefits for the end user.

The consumer's role is becoming increasingly important and complex, and many businesses are questioning a singular focus on ratepayer recovery mechanisms to finance smart grids and a simplistic division of consumers into basic commercial, industrial, and residential categories. For the transition to truly smart and clean power systems, a more sophisticated understanding is needed across the following areas to align investment risks with the receipt of benefits:

- **Business and operating models** that take advantage of widespread sensors and controls and dynamic two-way communications with end users. Though quite new within electricity markets, such models have a long tradition in other industries, e.g., information and communications technologies (ICT) and e-commerce. New models are needed that will give clearer incentives and responsibilities to the different actors and open up opportunities for new financing paths.
- **Regulatory and standards frameworks** (and related planning processes) that take into account how smart grids integrate technologies and operational concepts from different sectors. The potential benefit streams from leveraging solutions across sectors that are not captured under current frameworks. On the other hand, wide-scale integration may open the door to more expensive, proprietary solutions. It is uncertain whether open-source innovation will play a driving role or if big industrial companies try to control the developments.
- **End-user behavior**. Improved consumer understanding is critical to realizing the potential benefits of intelligent end-point applications of smart grids. Smart ICT integration will influence end users' lifestyles, workplaces and procedures, educational approaches and formats, and modes of transport.
- **Consumer engagement and empowerment** as a core function of electric service providers. Companies must treat customers as a utility asset, not a liability, and develop a deep understanding of customer demographics and interests within market segments that are far more granular than simply commercial, industrial, and residential. Other industries, such as consumer electronics or retail, have a much more nuanced understanding of their customers than does the electricity sector.
- **Risks and vulnerabilities** introduced by smart grids, primarily in the realm of cyber security, through increased dependency on ICT. Smart grid's advantages and benefits to consumers, and to society more broadly, will ultimately result in wide-scale deployment; thus, it is imperative that industry be able to manage information security and privacy effectively.

The Workshop

The IEA's Experts Group on R&D Priority Setting and Evaluation (EGRD) held a workshop on 3-4 June 2015 in Oslo, Norway, hosted by the Research Council of Norway. The workshop focused on the potential benefits of smart grids for end users and society at large, with the goal of identifying novel approaches and critical aspects for realizing this potential as well as core R&D needs on this topic and similar areas that need attention. Achieving the vision of grid modernization between now and 2050 will require collaboration of governments, research organizations, industry, the financial sector, consumer advocates, international organizations, and other power sector stakeholders.

Forty-five workshop participants represented various actors, sectors, and regions and included EGRD national experts; research, development and demonstration (RD&D) decision makers; strategic planners; and program managers from industry concerned with intelligent end use and distributed energy technologies related to electrical grids.

The participating experts addressed the following questions:

- End-user and societal benefits: What are the most clear and/or most important benefits of smart grids for end users? For society?
- Business models: Who will pay for reducing risk and vulnerability? Will those parties also realize the benefits?
- Regulation and standards: Who will drive the transition to smart grids: governments, regulators, utilities, vendors, consumers, new enterprises, or someone else?
- Consumer engagement and end-user behavior: What do electricity service providers need to understand about end users? How can end users be empowered to become more effective participants in the power system?
- Innovation: Is there a tipping point for smart grid innovations? What possible breakthroughs or “game changers” are expected in smart grid technology, policy, regulation, standards, or economics? How we can accelerate their development?

Report Structure

This report summarizes the workshop findings: identifying challenges concerning smart grids and end users, highlighting several examples of pilot projects and recent research on consumer behaviour, and identifying priorities and gaps in current programs for RD&D planners. Following this background section, the report follows the agenda from the workshop, with four session chapters:

- Session 0 – Introduction
- Session 1 – Benefits of Smart-Grid/ICT End-Use Innovations
- Session 3 – Insights into End-Use Behaviour
- Session 4 – Technology/Software Solutions and R&D Priorities
- Session 5 – Policy, Markets, Government Interventions

Note that Session 2, Barriers to Realising Benefits, included only one presentation and is not included in this summary report.

Appendices to the report provide a list of acronyms, speakers, workshop agenda, and photos taken at the workshop.

SESSION SUMMARIES

1. Introduction

1.1 IEA Smart Grid Technology Roadmap, ISGAN Review of Flexibility, and Energy Technology Perspectives 2014

(link to presentation slides not available)

Michael Hübner, the Ministry for Transport, Innovation and Technology, Austria

The *Renewable Energy Medium-Term Market Report 2014* includes a market analysis and forecast to 2020. From 2013 to 2020, renewable electricity is projected to scale up by 45% (see Figure 1), driven partly by the economical attractiveness of self-consumed PV electricity in several markets. Scaled-up PV usage limits potential household demand. This trend necessitates both regulatory adjustments and new business models for “prosumers.”

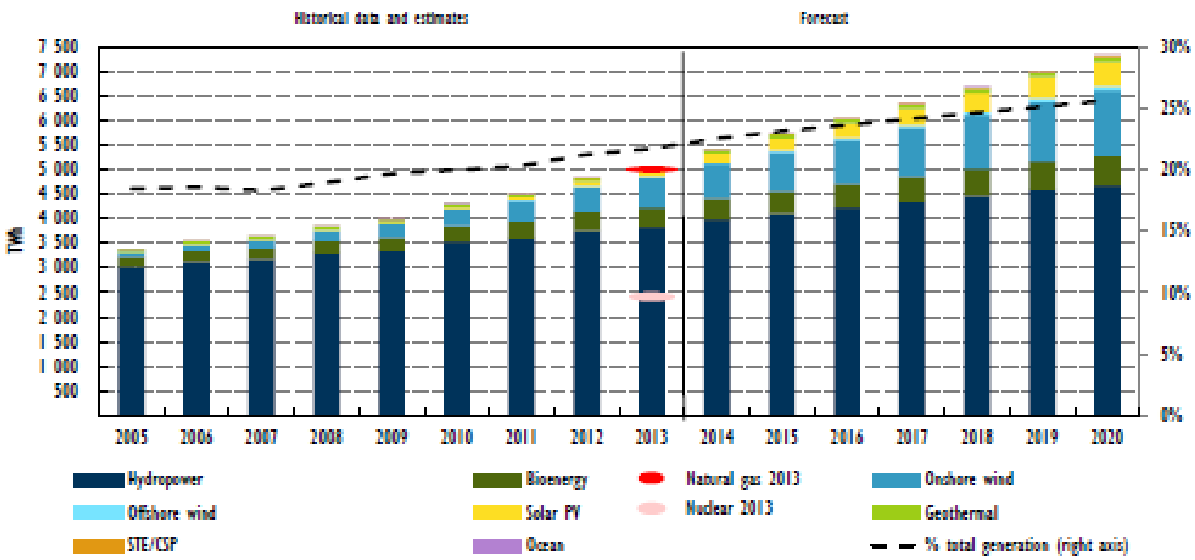


Figure 1. Projected global renewable electricity production indicating scale-up of 45% from 2013 to 2020.

The *Africa Energy Outlook* notes that Africa’s total power generation capacity is 90 GW, 75% of which is based on coal, oil, and gas. However, this emphasis on fossil fuels is expected to change substantially in the years to come. Projected capacity by 2040 is 380 GW, and renewables will account for almost half of the growth (see Figure 2). Different African regions will have different paths to power, depending on resource availability. The *Outlook* predicts that nearly one billion people will have access to electricity in sub-Saharan Africa in 2040, but 530 million people in rural areas will remain without power in 2040.

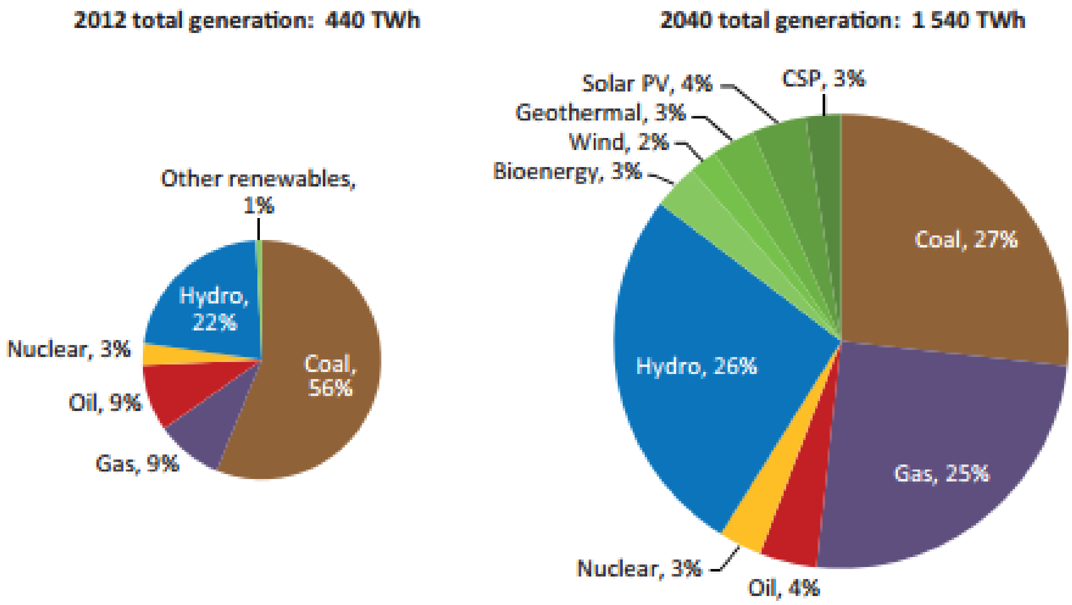


Figure 2. Electricity generation by fuel in sub-Saharan Africa in the New Policies Scenario, 2012 and 2040 – power generation capacity quadruples and becomes more diverse.

Additional relevant reports include the following:

- IEA's *Technology Roadmap: Smart Grids*
- ISGAN's *Smarter & Stronger Power Transmission: Review of feasible technologies for enhanced capacity and flexibility*
- IEA's *Energy Technology Perspectives 2014*

There are three planned IEA publications and one upcoming event:

- *How2Guide for Smart Grids in Distribution Networks: Roadmap Development and Implementation*, a guidance on developing roadmaps for smart distribution grids, with a focus on smart cities and a request for ISGAN involvement (not yet published at time of workshop)
- An energy technology perspectives document on smart cities, including all IEA work on smart grids and cities in one document, with a focus on economics and technology of decentralized versus centralized energy system development for OECD as well as non-OECD countries (planned for launch in May 2016)
- A hydrogen-to-grid (H2G) analysis
- "Technology Track," an IEA event during the Asia Clean Energy Forum, June 15–19, Manilla

1.2 Energi21: Norway's National RD&D Strategy for Renewable and Climate-Friendly New Stationary Energy Technology

Lene Mostue, energi21, Norway

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/2.LeneMostueEnergy21.pdf

The Norwegian RD&D strategy for renewable energy and climate-friendly new stationary energy technology (Energi21) is led by the Norwegian Ministry of Petroleum and Energy and performed by an independent advisory board appointed by the minister (See Figure 3). The main function of the Energi21 initiative is to provide strategic input and recommendations to the authorities on RD&D activities that target development of climate-friendly, stationary energy technology.

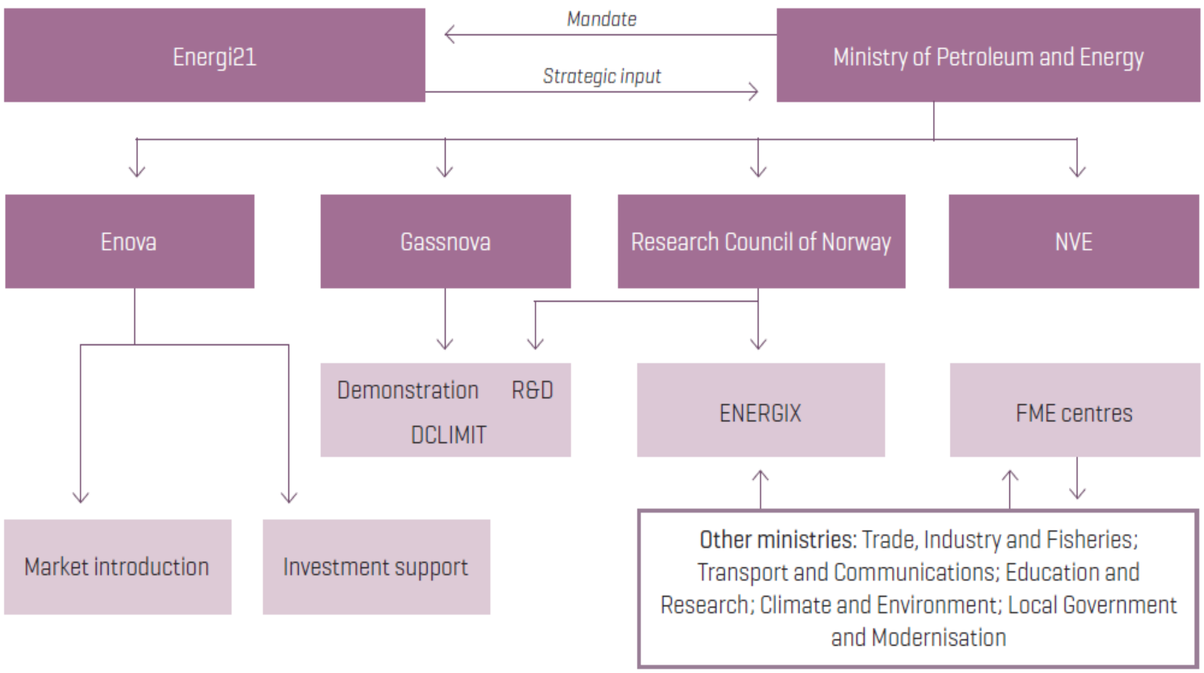


Figure 3. Energy research under the Ministry of Petroleum and Energy.

The Energi21 process, which started in 2007, is considered an important factor in the large increase in public financing of energy research R&D from 2009 to 2011. A national strategy with consensus recommendations made it easier for all the involved ministries to support the increase.

The current strategy for 2014 is documented in two parts:

- Part 1 – Priority focus areas and implementation measures for the strategy
- Part 2 – Background, analysis, and assessments

The strategies are based on collaborative work with broad input from a range of stakeholders from the business sector, academia, and the relevant authorities. The vision for the strategy is "a climate-friendly energy nation—and an international supplier of energy, power, technology and knowledge." The Ministry has laid out a mandate that includes three strategic objectives:

- Increased value creation from natural energy resources and utilization of energy
- Energy system restructuring through efficient use of energy and increased flexibility in energy systems
- Competitive energy industry through access to knowledge

The drivers for the strategy are:

- Climate change
- Security of energy supply
- Industry ambitions
- Gaining positions in international markets
- Leveraging competitive advantages within:
    - Natural energy resources
    - Technology and expertise base
    - Industrial experience
- Flow of competences between industries

The strategic analysis recommends strong funding growth and concentrated efforts targeting RD&D in six key areas (see Figure 4). Electric vehicles are not included, as the Energi21 mandate is limited to stationary energy. However, the strategy does take into account how the electrification of the transport sector will affect the power system in terms of power requirements (charging stations), frequency stability, and general supply.

Strategic implementation includes R&D funding through innovation and the value chain, international cooperation, testing and demonstration, and competence-building through recruitment.

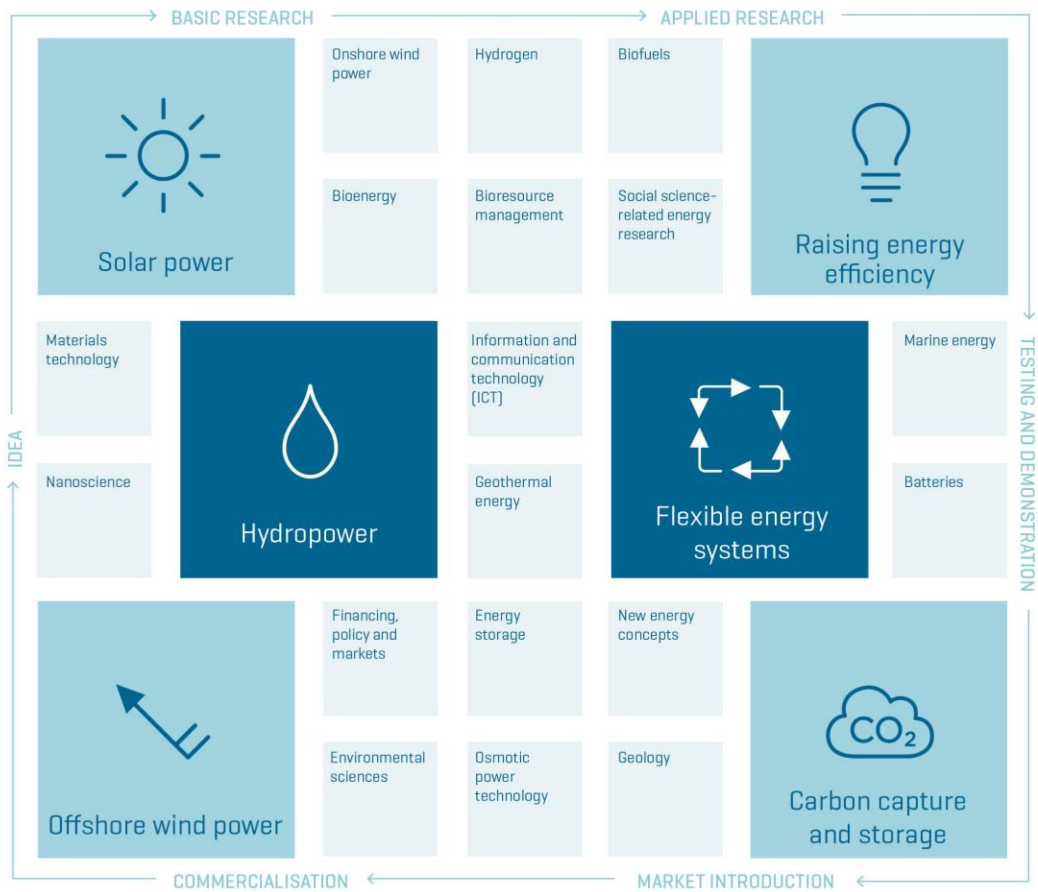


Figure 4. Six key Energi21 RD&D areas.

Hydropower. Norwegian hydropower, the historic starting point of Norway's industrialization, represents 50% of the total storage capacity in Europe.

Flexible energy systems. This area must be furthered to balance production and consumption. Electric vehicles, demand side management (DSM), and battery storage influence system operation. The influx of these new technologies entails new solutions, markets, and innovations.

Solar power. Solar power is one of the fastest-growing renewable energy technologies and is starting to play an increasingly meaningful role in energy supply around the world, including in emerging economies. Norway has industries and knowledge in this field, especially within the silicon material side of the supply chain for crystalline silicon solar cells, as well as a strong cluster of businesses and academic and research institutes.

Offshore wind power. The market for offshore wind power is growing, and Norway can leverage competence and services from the oil and gas industry.

Energy efficiency. Energy efficiency has a large potential and is an important part of the solution both within the building sector and industry.

Carbon capture and storage (CCS). CCS is necessary if the potential of natural gas is to be exploited. Norway has a competitive advantage with the storage capacity on the Norwegian continental shelf.

1.3 Moving Towards the Smart Grid: The Norwegian Case

Grete Håkonsen Coldevin, The Norwegian Smartgrid Center

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/2a.GreteColdevinNorwegianSmartgridcentreMovingtowardsthesmartgrid.pdf

In 2010, Energi21 recommended establishing the Norwegian Smartgrid Centre (NSGC, http://smartgrids.no/). NSGC comprises 48 stakeholders and a steering committee that sets priorities. Consumers are not yet directly involved in NSGC, but their participation has been recommended.

Norwegian power consumption averages 16,000 kWh/year per household for 2.8 million households (approximately 45 TWh/year), and flexible capacity on the demand side represents 3,000 MW from industry and 1,700 MW in the households. On the production side, the dominant hydroelectric power, with a mix of running river and magazine plants, provides a flexible capacity of approximately 31 GW. Thanks to policy incentives, use of electric vehicles is growing quickly, with over 50,000 on the road. Two electric buses are now being tested in Stavanger. Two-way meters (advanced metering systems, or AMS) are now being rolled out, with the aim of reaching all households by end-2019. Roughly 1.3 million households have high-speed broadband Internet connections, and 0.8 million have fiber-to-home installed. Norway is thus establishing the platform for “smart homes” (AMS + gateway + broadband).

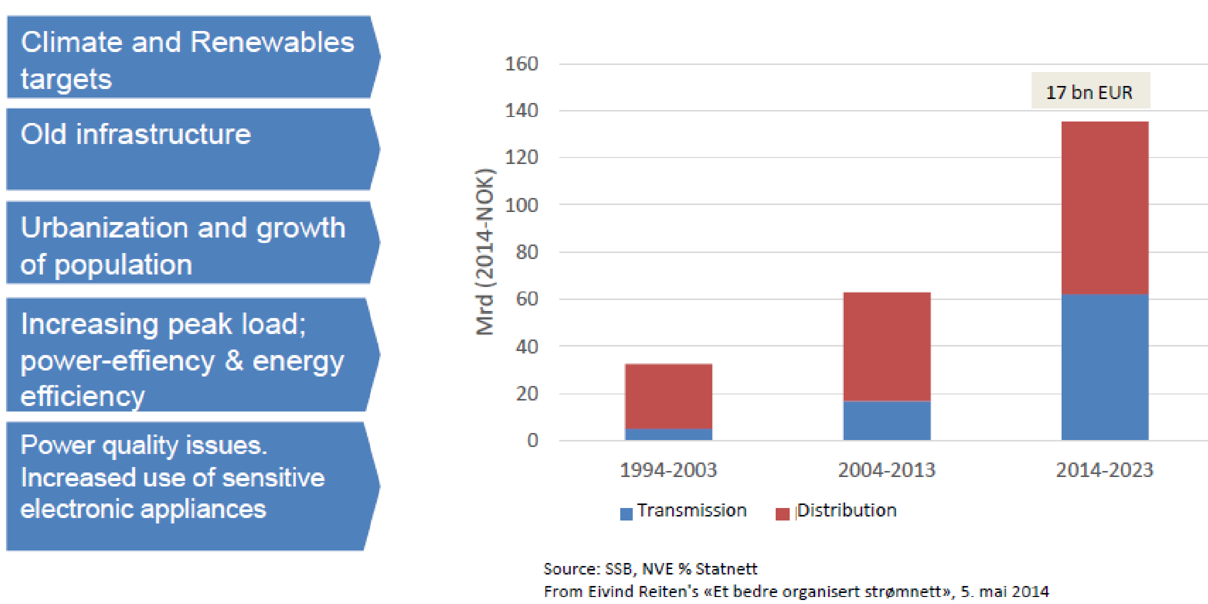


Figure 5. Norway's investments in distribution and transmission systems.

The existing power system has already incorporated smart technologies (communications and automation) at the production and transmission levels. However, AMS has not been implemented, and distribution systems are typically not yet “smart.” Distribution grids are weak in many places, with severe voltage quality problems; a significant portion are 230 V, in contrast with the 400 V systems in most of Europe. Upgrades for the period 2014–2023 are estimated to require €17 billion.

Power quality issues are also relevant to peak load, which is increasing with the use of sensitive electronic appliances. Without any load-dependent grid tariffs (within the main fuse capacity), households tend to use equipment that draws high power loads, such as induction ovens, instant water heaters, and fast chargers for electric vehicles. Between 2000 and 2013, the power load increased 15%, while energy consumption increased only 4%.

The NSGC was established to address Norway’s grid challenges. The Centre has three roles:

- Setting priorities and organizing coordination and mobilization activities related to the European Commission’s Horizon 2020 Programme and the Norwegian Centres for Environment-friendly Energy Research (FME)
- Disseminating information and results from demonstration projects
- Trendspotting and technology monitoring

These activities include coordinating several demonstration projects (see Figure 6). Ongoing projects include:

- “Pilot North,” focusing on transmission management (Statnett)
- “Demo Steinkjer,” focusing on implementation of 4,500 two-way meters (NTE, or Nord-Trøndelag Elektrisitetsverk AS)
- “Smart-Grid Hvaler,” focusing on implementation of 8000 two-way meters and distributed solar power (PV) (FEAS, or Fredrikstad Energi AS)
- “Skarpnes-project,” consisting of 40 plus-energy households with geothermal heat-pumps and building integrated PV (Agder Energi)

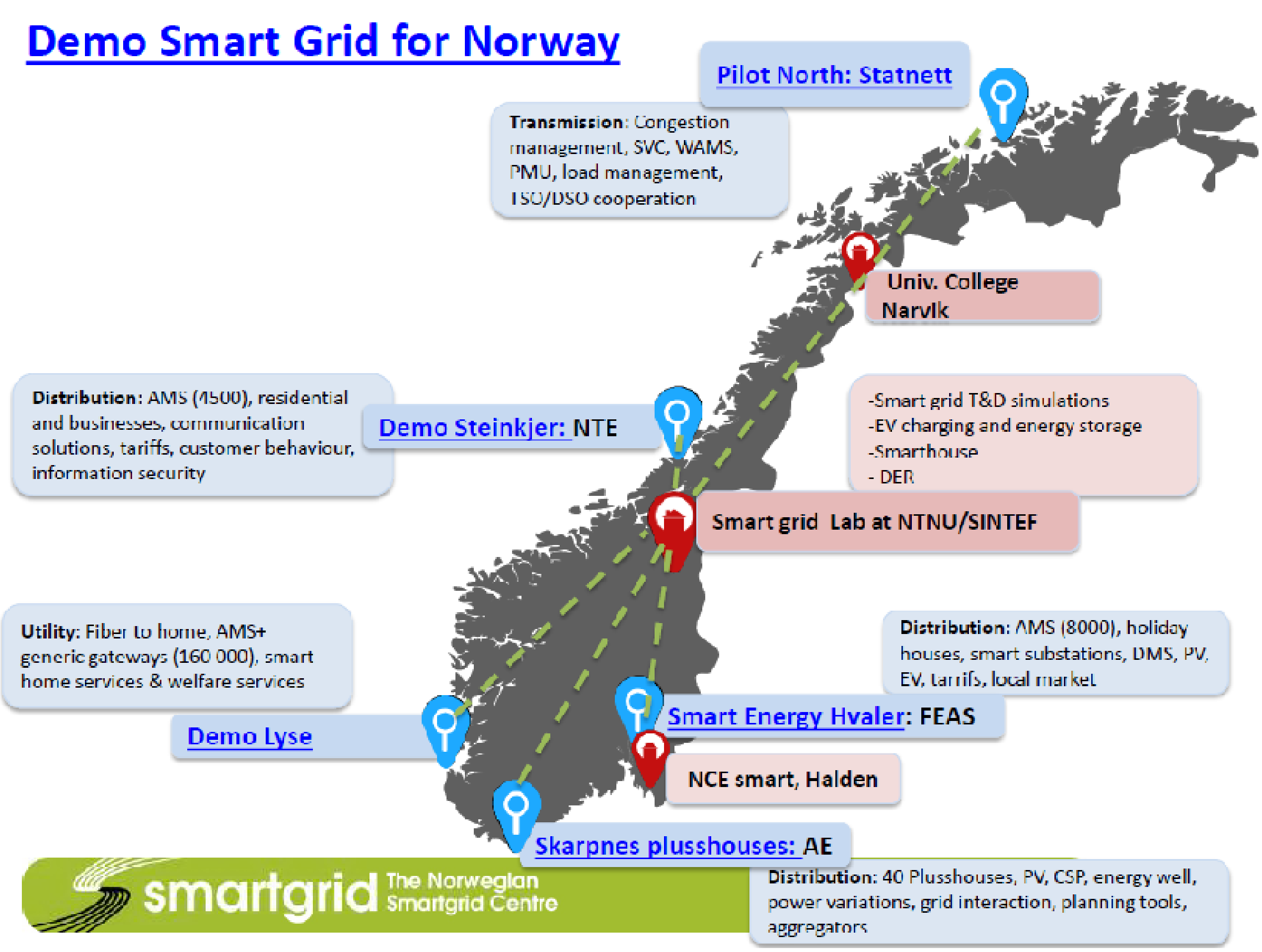


Figure 6. Ongoing smart grid demonstrations in Norway.

Regarding a possible conflict of interest between energy efficiency and the power system, load shifting at the consumer level may strengthen the security of supply, which is a key point for utilities.

2. Benefits of Smart Grid/Information and Communications Technology End-Use Innovations

Session Chair: Rob Kool, Netherlands Enterprise Agency (RVO.nl)

This session focused on the possible benefits and opportunities that smart grids can enable for the end users, illustrated by examples from different sectors. Topics included services and products that can become available to end users and the types of companies most likely to be on the front lines of development. Questions addressed in this session include the following:

- What benefits and opportunities will be the first to be realized, and what sectors or end users might be expected to be front runners?
- Are there significant differences among customer classes (e.g., between commercial buildings and residential buildings)?
- Who will pay and for what? What kind of business and financing models will enable more rapid changes?
- Is it possible to imagine a “tipping point” of smart grid technology?

2.1 Residential Demand Response

Henrik Bindner, Technical University of Denmark

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/3.HenrikBindner.pdf

iPower is a strategic platform to consolidate university and industry innovation and research activities. iPower has 26 partners and a five-year budget (2011–2016) of €16 million. The company aims to develop intelligent control of decentralized power consumption. iPower is working to address the power system challenges presented by more solar and wind power, including balancing power generation with consumption at all times.

The introduction of electric vehicles and a general trend towards more electrification in combination with energy efficiency lead to increasing variation in demand and higher peak loads. The power system is becoming increasingly market-based, with a need for separation of responsibilities and formal interaction between producers, system operators, parties responsible for balance, and consumers. This process should result in better transparency and competition. However, it is not yet clear how end users benefit. For example, to the end user, an electric vehicle represents only a tool for transport. The market must be designed to engage the end user and make electric vehicles available as a system asset in the form of storage capacity.

Technical solutions exist to address, at least in part, the challenges for the power system, e.g., DSM, heat storage, and batteries—but the business case must be established. Intelligent control of end use with power reduction and load shifting has great potential to make flexibility available for distribution and transmission system operators (DSOs and TSOs), and these technologies and techniques will contribute to safe operation and security of supply. However, the costs of smart grid solutions must be evaluated and compared with those of conventional grid reinforcements. Furthermore, realizing smart grid's potential—in a manner that is both effective and cost-effective—requires internationally agreed-upon standards for communication.

Ongoing work at iPower includes producing the right tools to manage millions of flexible consumption units, as well as uncovering ways to run the distribution grid with flexible power generation. In-practice testing is evaluating ways to identify user needs and incorporate flexible consumer units. Specific ongoing activities cover the following areas:

- Testing different user interfaces on real consumers
- Aggregating end-user data and control for clusters of several end users
- Evaluating demand response from industrial loads such as supermarkets and cooling of office buildings
- Implementing voltage control using active and reactive power via local controllers and an overlying supervisory controller for PV, electric vehicles, and "smart house" communications
- Developing a DSO market for flexible services: http://ipower-test2.droppages.com/Publications/WP%203-8%20report.pdf
- Testing the FLECH (FLExibility ClearingHouse) concept of interaction between DSOs and aggregators with DSO services such as load management and voltage control (see Figure 7 and Figure 8): http://ipower-test2.droppages.com/Publications/FLECH%20Market%20Regulations.pdf
- Validating delivery of control services: http://ipower-test2.droppages.com/Publications/FLECH_analysis.pdf

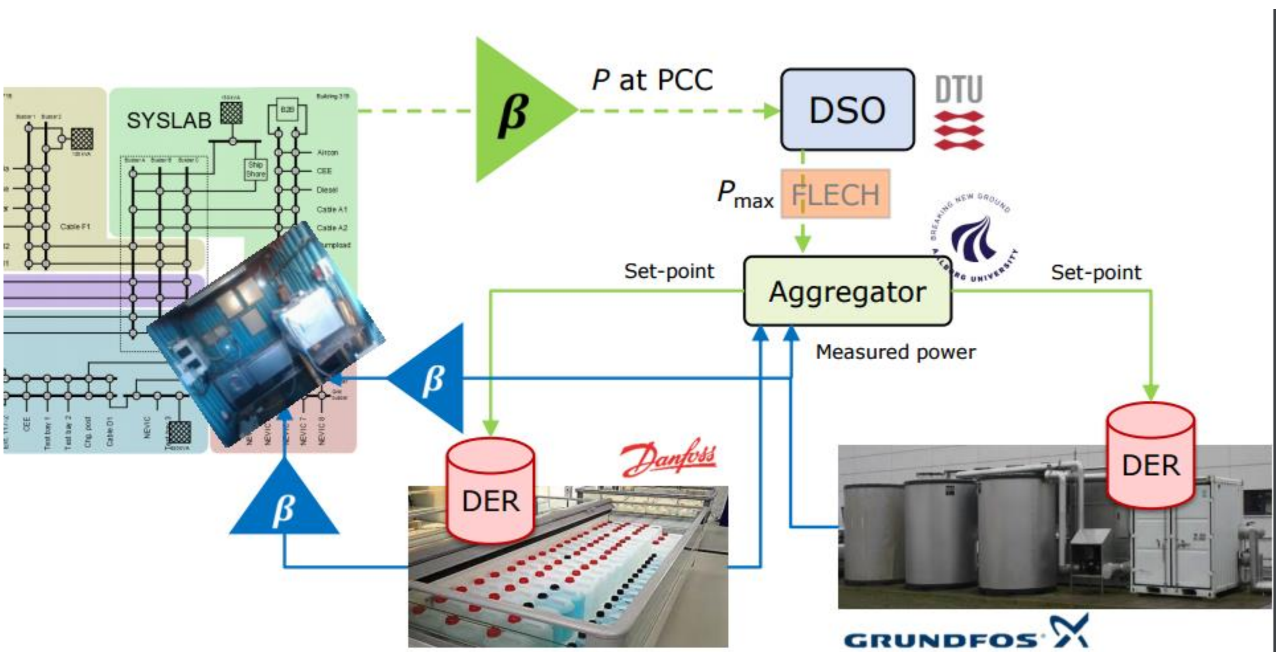


Figure 7. iPower's FLECH concept.

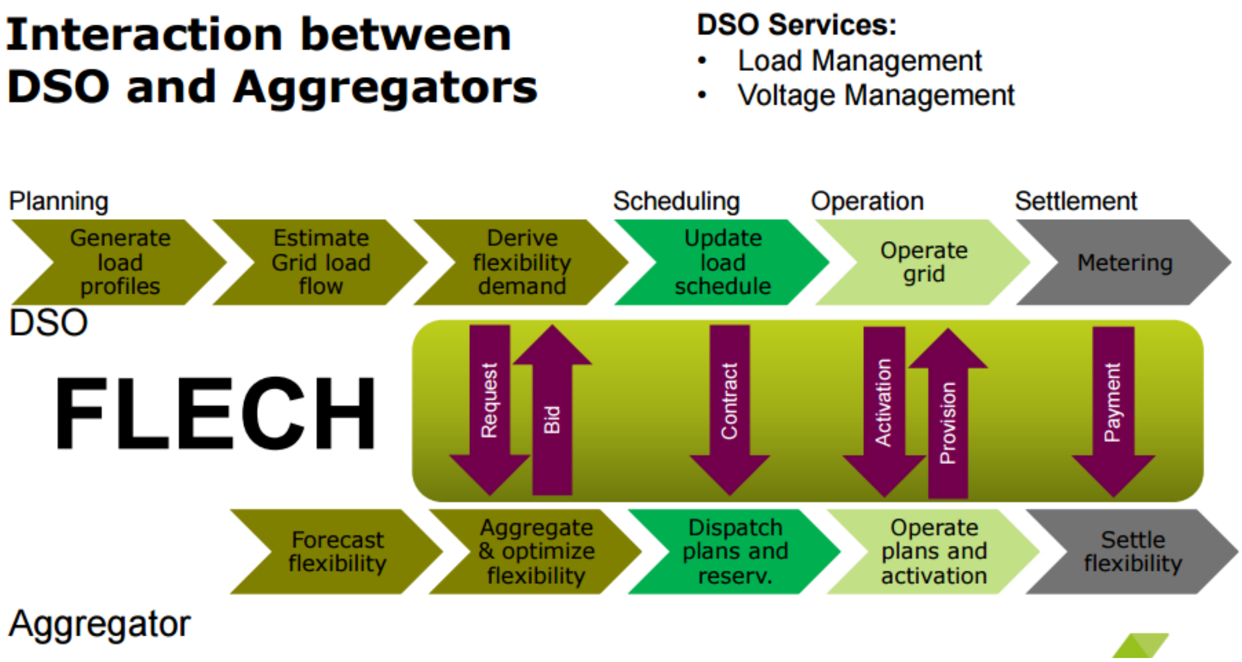


Figure 8. Interaction between DSO and aggregators in FLECH concept.

2.2 Smart Grid Gives New Business Opportunities and End-User Services

Dagfinn Wåge, Lyse Energi AS, Norway

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/4.DagfinnWage_Lyse_Smartgrid.pdf

Lyse Energi is a hydropower-based utility that now defines itself as a multi-utility supplying energy in various forms (e.g., electricity, natural gas, and district heating), as well as infrastructure and telecommunications services. The business is changing, and revenues from the telecom and energy divisions are now the same. The telecom services use fiber infrastructure and consist of interactive television and Internet services to 400,000 homes, and the existing installation capacity connects around 40,000 new customers each year. The company has chosen a business model based on innovation to expand from "service provider" to "ecosystems." Hardware is an important part of this strategy, which combines disruptive innovation (with practical demonstration testing) and open innovation.

Lyse Group's relevant projects include a welfare technology services project, generic smart gateway installations, and smart home control via the smart gateways. These projects are discussed below.

The welfare project is focused not on technology but on social innovation, specifically, developing services for the elderly to enable them to live at home longer. This proof-of-concept project ran from 2011 to 2013 and combined smart home technologies and alarm services. Different user interfaces were developed, and the tests showed the importance of keeping the interfaces simple. Users with simple switches for Day/Night and Home/Away had no difficulty with the controls. Energy was saved through lower temperature settings at night, and appliances and lights were turned off as a safety precaution when residents were not at home.

For the smart gateway project, gateways were installed in 160,000 homes, together with traditional one-way (“dumb”) energy meters (see Figure 9). The smart gateway provides real-time measurement data for the system operator, who can aggregate and analyze the data and act proactively. The result is shorter outage durations, which reduces maintenance costs.

Smart home control via the smart gateway incorporates both remote control of devices for load shifting and local controls for cost-optimal operation of, for example, heating systems. The gateway provides two-way communication with potential to support a range of other functions, e.g., welfare and care services such as alarms with live camera monitoring, remote monitoring and remote control of door locks and windows, and control of appliances (see Figure 10).

Figure 9. Lyse Energi's smart generic gateway.

Figure 10. Functionality potentially enabled through Lyse Energi's smart gateway.

Recently completed Lyse Energi telecommunications projects include development of VideoForAll, a user-friendly videoconference/telepresence system with unique usability.

Utilities are facing new competitors and new business models. Future DSOs will look different and have different business opportunities. Eurelectric recently published a report, *Utilities: Powerhouses of Innovation*, that provides three recommendations for innovation in this changing industry: master new technology, get close to customers, and develop new business models and services. With new business players arriving, utilities must be proactive and begin making changes.

2.3 Integration of Electric Transportation with Smart Grids

Kari Mäki, VTT Technical Research Centre of Finland, Finland

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/5.KariMaki.pdf

VTT is a non-profit organization for applied research that operates under the mandate of the Ministry of Employment and the Economy. The Centre's strategic research portfolio includes low-carbon energy solutions, bioeconomy transformation, solutions for a clean environment (e.g., substitute materials and lifecycle design), digital systems (e.g., the Internet of Things), resource-efficient production systems, and solutions for health and well-being.

One recent area of research has been electric transport systems and, specifically, electric buses, or eBuses. Buses operate with fixed routes and time schedules, which allows for optimal design of zero-emission transport systems with high utilization. VTT is examining this potential using integrated research capabilities for electric vehicle R&D and smart grid research environments that enable studies of integration between vehicles, batteries, and the grid. Studying transport and power systems together provides an interesting integrated approach.

VTT has developed an analysis and optimization model that considers the total cost of eBus ownership. The model was employed as a case study in Espoo, Finland's second-largest city. The study conducted a sensitivity analysis to compare the effects of driving distance on costs for different vehicle types (see Figure 11). As electric vehicles have different plug types, charging rates, and communications technologies, the charger can be an important interface. For the Espoo case study, different concepts of charging were analyzed based on when and where charging was needed, time to charge, and the type of connection to the electric grid. The main options are fast-charging at every bus stop versus charging at a central charging facility. These options must be weighed against battery size, network connection, and charging loads. The case study examined consumption for a 20-kilometer bus route, charging for eight minutes after each trip using a 250 kW fast charger. The eBus consumed 1 kWh/kilometer in summer and 1.5 kWh/kilometer in winter.

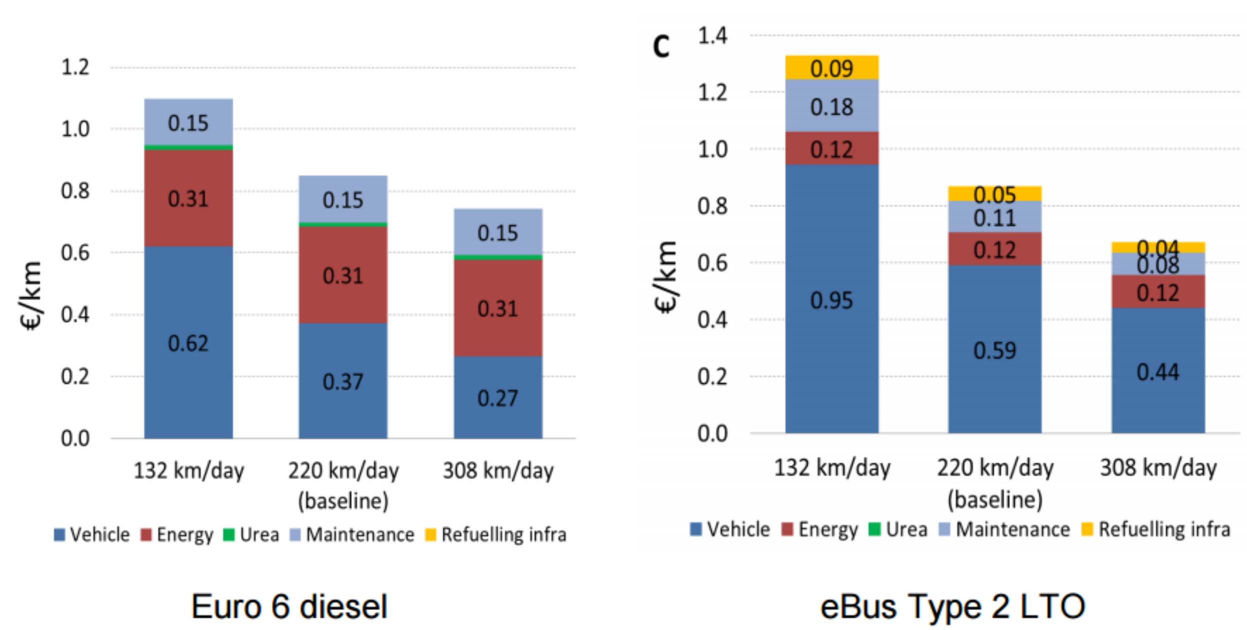


Figure 11. Bus fleets' sensitivity to daily mileage, as seen in the Espoo case study.

There are notable differences between traditional and more flexible cooperation approaches for electric mobility integration in smart grids. The "grid as a service channel" approach is robust, with the interface ordered and dimensioned according to peak power. The cooperative approaches avoid peak power and control charging power according to network status. Network regulation plays an important role in managing charger interfaces.

The impact of electric vehicles on the grid is not crucial on the system level but could present challenges locally. Different eBus options affect electricity distribution reliability and quality in different ways, and flexible approaches to management could benefit from opportunities that electric vehicles present. Key opportunities include “storage on wheels” and its implications for demand response (see Figure 12), bus depots with overnight slow charging, and utilizing battery capacity for vehicle-to-grid (V2G) operation, which is possible with eBuses in the overnight depot scenario. The possible services a charging operator could offer show potential for new business models.

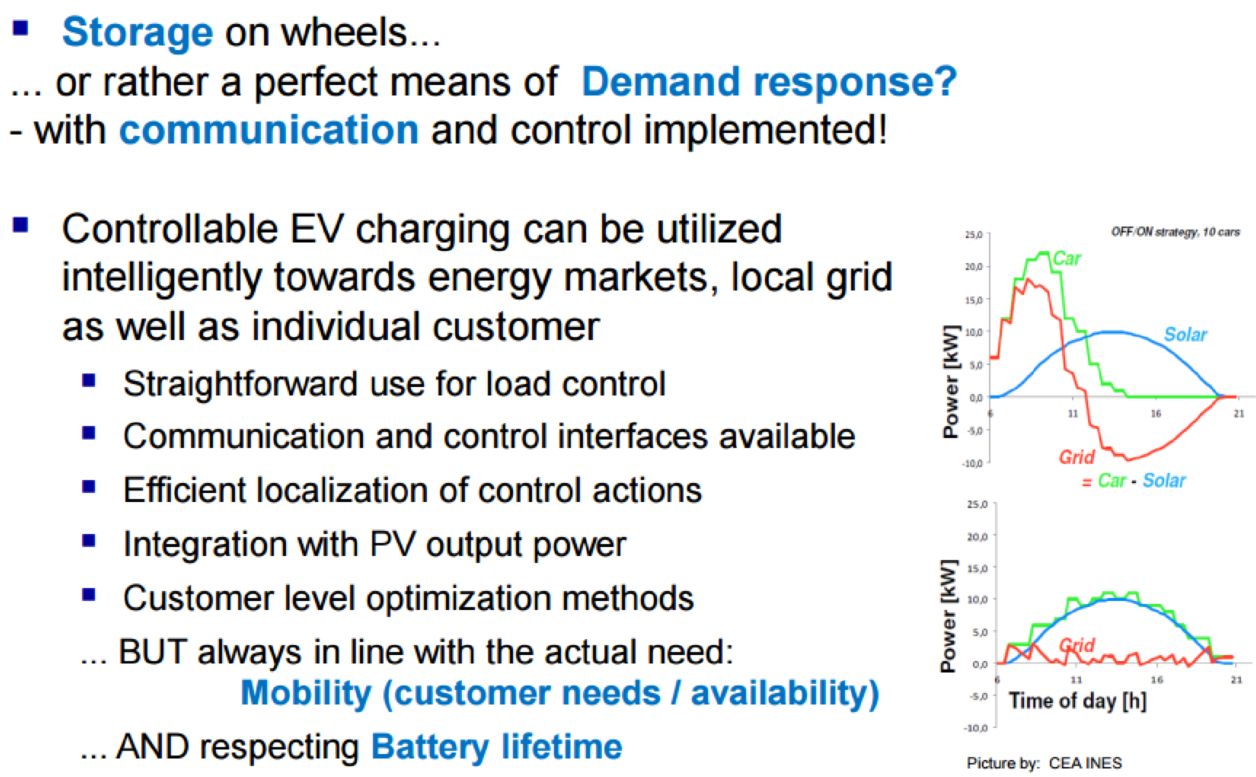


Figure 12. An opportunity presented through electric mobility integration in smart grids.

Feeding back to the grid is already technically possible. Communication protocols needed for two-way charging/discharging are already in place. Consumers would accept V2G provided that the user can control the settings and that it is of economic benefit to the vehicle owner. Can manufacturers, on the other hand, are generally averse to V2G, which presents additional challenges such as the constraints of battery lifetimes.

2.4 ISGAN: A Cooperative Programme on Smart Grids

Michael Hübner, Ministry for Transport, Innovation and Technology, Austria

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/6.MichaelH%C3%BCbner_ISGANacooperativepersepectiveonsmartgrids.pdf

An initiative of the Clean Energy Ministerial, ISGAN creates a mechanism for multilateral collaboration—with 25 participating countries—to advance the development and deployment of smarter electric grid technologies, practices, and systems. Different geographical regions of the world face different challenges and opportunities related to smart grid implementation. For example, U.S. power markets are mainly regulated, and grid reliability and security are priorities, while Europe has deregulated markets with high competition and a focus on challenges related to distributed production and integration of electric vehicles. China has a growing demand for power and is facing integration of large quantities of renewable energy, while other Asian countries struggle with critical peak loads and operate microgrids in rural areas. In several regions, energy theft and losses add to problems related to growing consumption.

What most regions share, however, is extensive change to power systems, and decision makers would benefit from taking action to stay appraised of sector transformation. ISGAN's role is to identify and clarify challenges and share information. ISGAN technical cooperation identifies core transmission and distribution system needs and supports joint evaluation of emerging smart grid concepts through a network of test bed and research facilities. The network collects and shares best practices and lessons learned, informing peer-to-peer exchange and contributing to the wider application of smart grid solutions. A best practice database and a virtual training academy are under construction. The idea is to share best practices and perform courses on specific topics.

ISGAN has published international casebooks on advanced metering infrastructure and DSM. The ISGAN DSM casebook is an example, which was developed as part of the Grid4EU program and explains how DSM is bringing flexibility into the electric system. The publication disseminates results from top-notch demonstrators, promotes modernization of state regulations, and expands worldwide exchange of knowledge to ease development of smart grid technologies.

To date, ISGAN has analyzed and documented 98 projects in 17 countries.

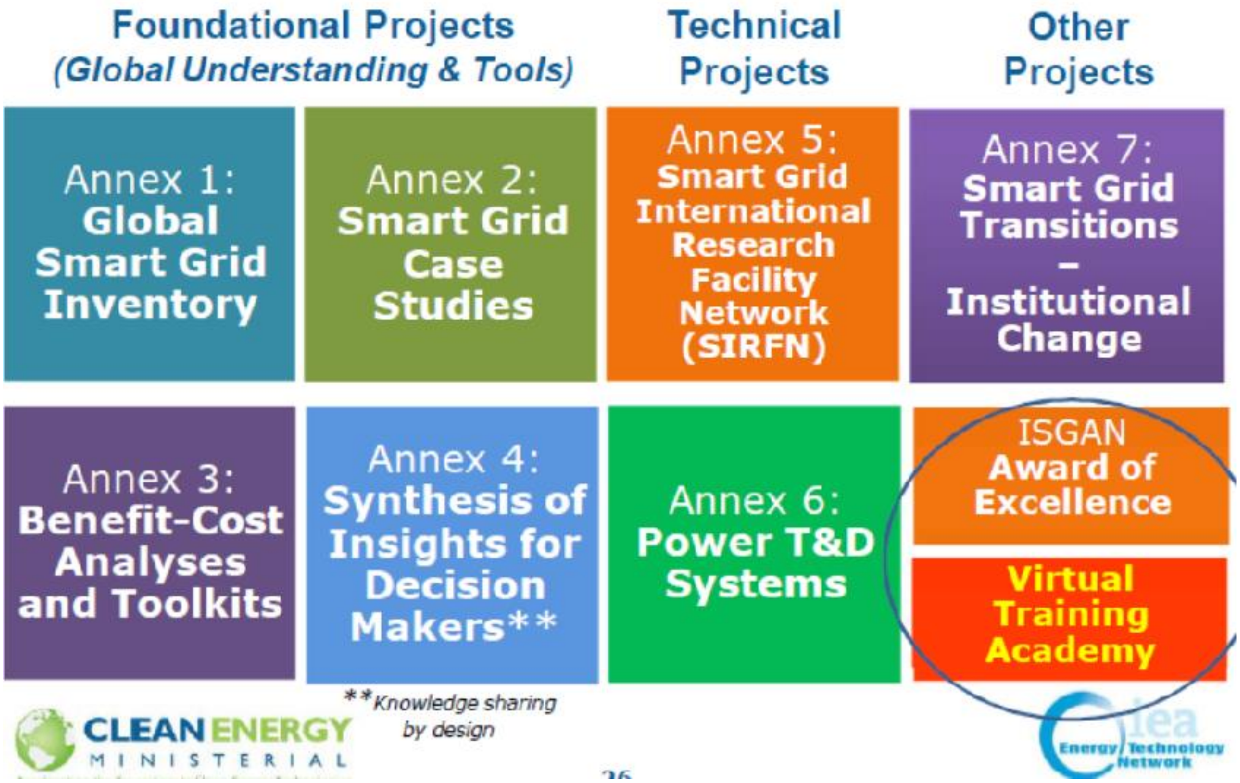


Figure 13. The scope of ISGAN smart grid work.

Challenges related to the implications of integrating renewable energy are related to system reliability and the optimized integration on different network levels, while the economic implications are related to sustainable business and market models that enable leveraging grid investments and extracting maximum value from investments in renewables. Obtaining the necessary flexibility in the electricity networks is a key issue. There are a number of technical options in supply management, demand management, storage integration, and network control, and their characteristics differ substantially. For example, large bulk storage realized through power-to-gas is quite different from stationary lithium-based home battery storage with respect to:

- Reaction time to voltage and frequency changes
- Power delivery and energy storage capacity
- Duration of the load shift
- Geographical location and level of the power grid

Economic aspects also vary between these alternatives:

- Cost efficiency from an overall perspective
- Ownership and stakeholders in the related business models
- Requirements for market design

Key findings from 12 case studies indicate that marketed technologies have reached different levels of maturity, and different approaches and methodologies applied vary from case to case. The boundary conditions and scale also vary. Therefore, careful documentation of assumptions and the use of standardized terminology are necessary. There are three main approaches to DSM, and countries may have approaches that combine methods:

- The feedback system, based on informing customers about system constraints
- The price-based approach, which relies on customer responses to price signals
- The system capacity-based approach, which relies on system forecasts

The casebook provides recommendations for equipment providers, system operators and customers. Equipment providers are encouraged to engage customers by allowing them to test the products.

Outstanding questions about end-user benefits that affect the business models include:

- Who pays and covers the economic risks?
- Will the economic potential of smart grid be attractive enough to drive the transition?
- Does a tipping point for smart grid innovations exist?
- What can create breakthroughs and game-change?

Some key trends are worth attention in this respect (see Figure 14). Energy and climate policy has led to liberalisation of the energy markets and increased focus on renewables. Parallel social trends include individualisation and independence, with consumers becoming "prosumers." These needs are met and accelerated by an ICT revolution; new products and technologies are implemented and adopted quickly. These trends combine to foster the transition from centralized to distributed power production and to decentralized and flexible industrial production, enabled by new technologies such as cooperative, intelligent machines and 3D-printing.

When we discuss end-user innovation strategies, it is important to retain focus on the consumer. People are different and behave differently according to their socio-cultural contexts. Customers' motives and priorities vary. Some consumers react only to financial incentives, while others are driven by a wish to be "green," regardless of the economics. Many look for ways to fight climate change and are ready to contribute by investing in PV, DSM, and storage. Some of these consumers are restricted by laws, regulations, circumstances, etc. (e.g., ownership and metering structures in blocks of flats). For

some people, the drive for self-sufficiency and independence—through self-supply, for example—can be strong motivators. These customers are ready to invest privately in renewable technologies. There is also movement in the field of new innovative "participation business models," such as cooperatives and crowd-funding, that allow everyone to take part.

For sustainable development, it will be important that people take ownership of the energy transition. It is therefore important to determine how to engage and encourage these motivated people. The "self-consumption optimization paradigm" must be transformed from a focus on the individual to a means of supporting the electrical power system. These forces and potential investments can be utilized to realize smart grids—the question is how. New technical and organizational concepts are needed to enable active citizens to take part in powering not only smart homes but also smart communities, cities, and regions.

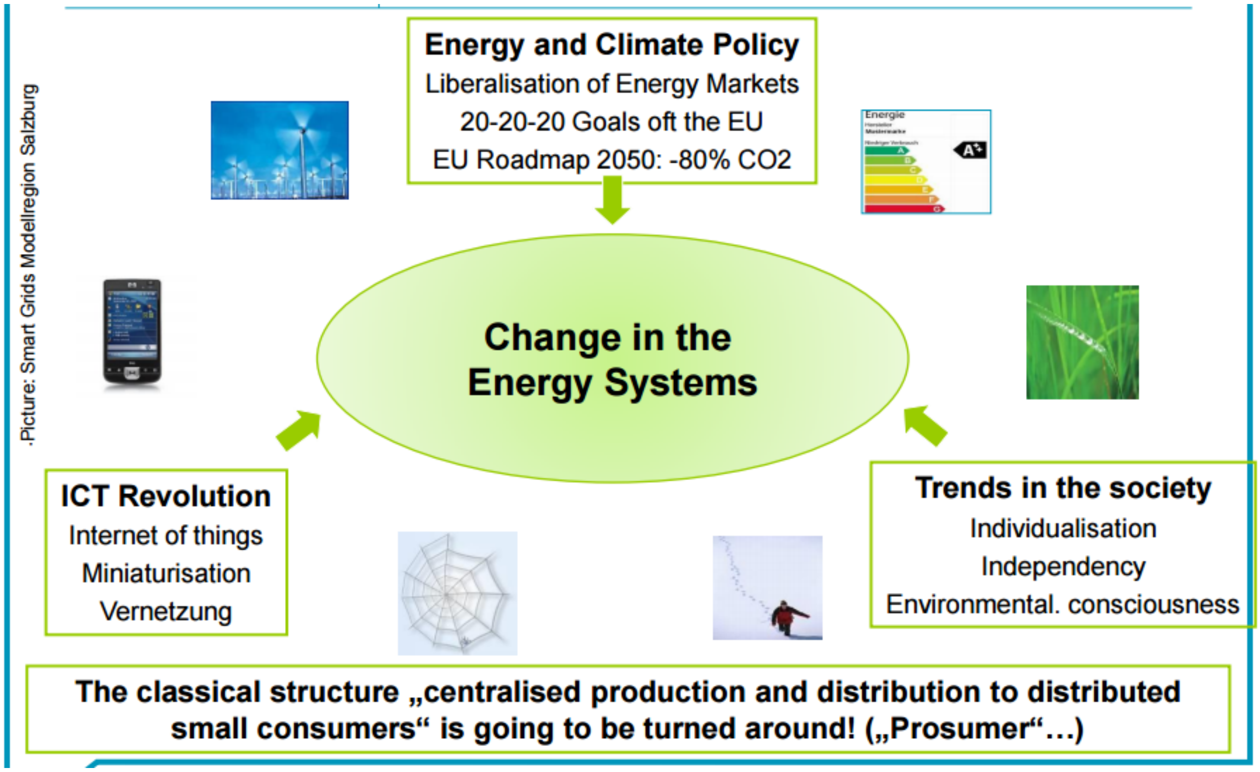


Figure 14. Drivers for change in energy systems.

3. Insights into End-Use Behavior

Session Chair: Birgit Hernes, The Research Council of Norway

The third session focused on understanding end-user behavior, which is crucial to realizing the potential of smart technologies. Lessons learned and knowledge gained from resent research and case studies on end-user behavior can be instructive to R&D and policy priorities. This session addressed:

- How important is consumer confidence to ensuring successful implementation of the smart grid?
- What should consumers know about electricity? What if they do not care to know that?
- To realize the potential of the smart grid, will it be necessary for consumers to change behavior?
- What are the experiences in this sector or others on how people do or do not change behavior with available technology?
- Are there differences in behavior between private and professional end users, and what does that mean?

3.1 IEA DSM: Closing the Loop

Rob Kool, Netherlands Enterprise Agency, RVO (Rob Kool presented on behalf of Sylvia Breukers)

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/7.RobKool_DSMClosingtheloop.pdf

The DSM Energy Technology Initiative is an IEA implementing agreement whose topic is the demand side of energy use. Both the technology side and the financial/social elements are studied, as an integrated approach is needed to achieve a sustainable society. The initiative includes a study on human behavior. Researchers have tried to identify which actions work and which do not. A main goal is to identify useful models for end-user behavior. Work also includes case studies of existing projects from participating and interested countries and workshop discussions on human behavior related to the need for change. The results have been compiled for dissemination to policymakers and other stakeholders.

The study has determined that if only individual behavior is targeted, a permanent lasting change towards sustainable development is not likely to succeed. Incentives for energy efficiency generally do not create lasting change. The study evaluated a number of retrofitting energy efficiency programs, which were designed well, and many homes were insulated during those campaigns. The retrofitting market shows potential for growth, but program participants had often decided to retrofit before the incentives were provided. Participants used the subsidy to retrofit more comprehensively. After the programs, there were no follow-up initiatives or noticeable changes in behavior. These kinds of retrofitting programs are not focused on changing user patterns and seem unlikely to change the building sector or market in the long run.

To obtain sustainable changes, programs should focus more on the social aspects, i.e., not just what customers buy but what customers do. Lessons from the programs include:

- Take the end-user perspective
- Change lifestyles, not lightbulbs. Information and options to take actions have more effect than single-topic campaigns
- Make end users aware of benefits
- Use a toolbox of interventions instead of a single action
- Seek real change rather than kilowatt-hour targets
- Benchmark, measure, and model when designing a program. Know what model or theory supports your intervention, acknowledging that the model is useful but never perfect
- Learn from the unwilling, only they can tell you why something does not work

The study determined that about 30% of energy demand is locked in a “behavioral wedge” resulting from the fact that people are not only thinking and behaving economically. An overly technocratic approach within campaigns pairs with limited transfer of best practices and is a lack of meaningful monitoring and evaluation. The resulting “wedge” affects technology uptake, use and maintenance, purchasing investment, habits and routine, and social acceptability. The full report of these efforts can be found on the IEA website and includes campaigns, models, and results.

The study has moved on to a new task and is working on a new value-driven business model. The short-term aim is a better understanding of what works and why to achieve the long-term aim of more effective market uptake of DSM energy services for small and medium enterprises and communities. So far, researchers have collected 250 propositions from participating countries and examined 69 different business models. Early findings show that the energy efficiency market has limited types of business models that fail to leverage the end user’s creative potential. Most business models are built solely within the company. These models usually describe the energy efficiency market in terms of technological, financial, or legal possibilities and rarely address consumer behavior.

3.2 Smart Consumer, Smart Customer, Smart Citizen

Ludwig Karg, B.A.U.M. Consult GmbH, Germany

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/8.LudwigKarg.pdf

Smart Consumer, Smart Customer, Smart Citizen (S3C), is a European Union-funded project comprising several partner projects with psychological and sociological viewpoints. From that angle, S3C has identified some important characteristics of power markets that may influence strategies and market approaches to developing smart grid markets.

Conservative stakeholders within the energy value chain see the end user as an asset, a consumer, or (collectively) as the demand side, with associated risk that sales could decline if the end user switches suppliers or invests in energy efficiency or renewable energy. Some less conservative stakeholders talk about DSM services to smart consumers. These approaches lack complexity; end users are people, all of whom have different behaviors and needs. To explain his point, refer to Maslow’s “pyramid of needs” (see Figure 15). The bottom and broad base of this pyramid comprises physiological basic needs, such as food and comfortable temperature. Next comes security, followed by social relations and sharing. The top of the pyramid includes self-realization and intellectual creativity. An “inverted pyramid” guideline for developing "people-centered" products is presented in Figure 15. The approach focuses broadly on community-building and health and security on top, with commodities and prosumer management in the middle, and energy consulting and finally energy itself in the narrow bottom.

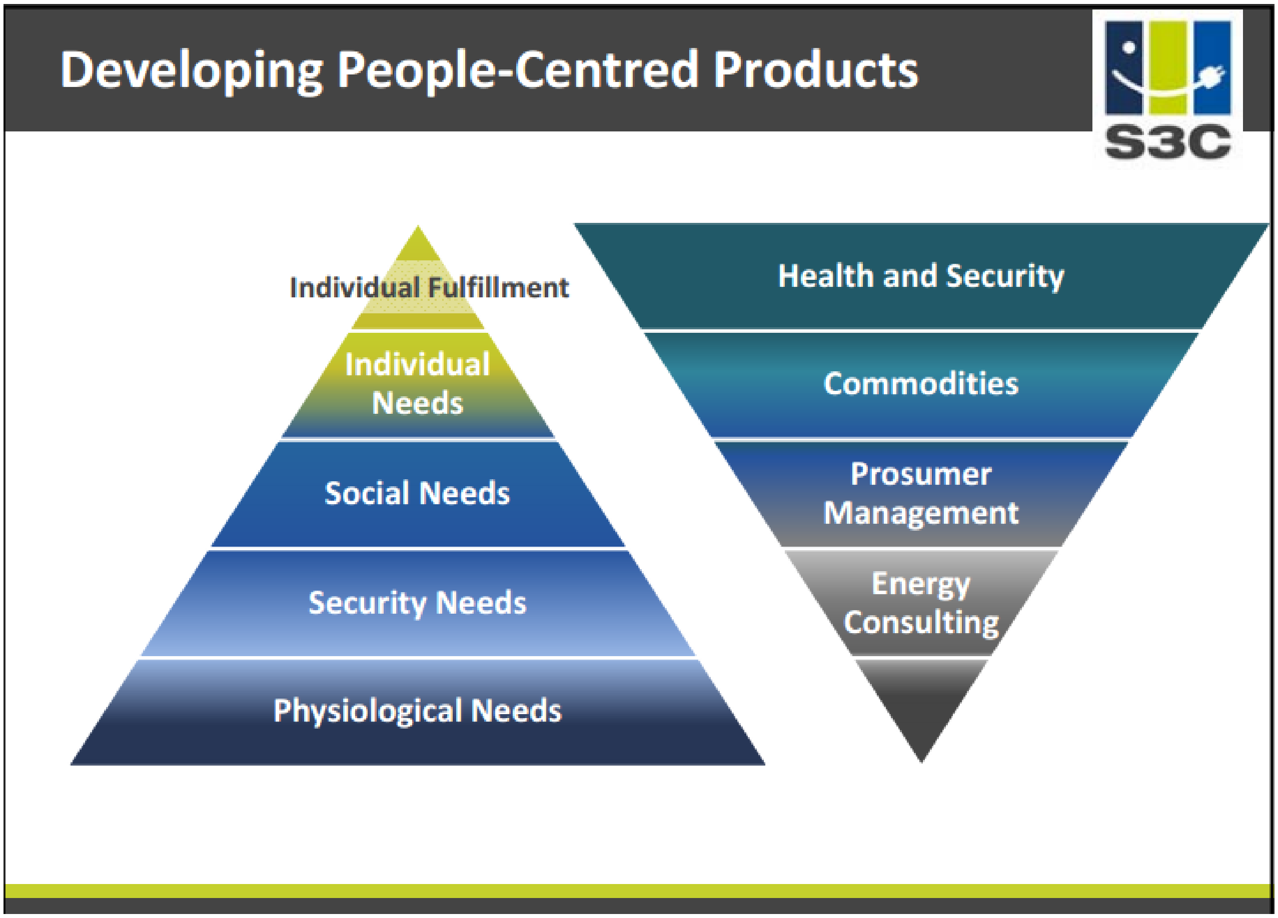


Figure 15. Maslow's pyramid of needs (left) and S3C's inverted pyrmand for product development (right).

In developed societies, people tend to spend time and money in accordance with the inverted pyramid, in which energy demands represent the smallest bottom part. Energy delivery should work, and it should be cheap and easy. People tend to be more willing to spend money and time to be social, to communicate, and to share information. A significant portion of our budget is spent on self-realization and personal safety—the top of the pyramid. Based on expenditures, the energy business players' "old school" perception of people is highly inaccurate. For example, flexibility is not a human need; flexibility is of interest only to system operators.

Many people are also driven by a wish to be self-sufficient or independent. When combined with access to capital, this drive affects our energy technology choices. The old expression "My home is my castle" may soon be rewritten: "My home is my energy system." New products such as PV-plus-battery-storage are key enabling technologies in this evolution. When combined with our willingness to engage socially and share information and services, the human wish for independence makes it interesting to take part in new cooperatives and networks related to energy products and services. Car sharing, PV plants financed as cooperatives, and crowd-funding of new ideas are examples of this trend. In Germany, there have been early attempts to extend energy cooperatives to include grid operation.

People are responding well to new business models such as the "energy cloud" that reuses old electric vehicle batteries. Other new business models are emerging:

- The "chalk board" business, in which customers pay voluntarily for services that should, in principle, be free. Satisfied customers want the business to continue, making income directly related to quality of the service.
- Flat rate, in which production and energy costs are practically zero. There is a fixed grid cost and customer support fee, resulting in a fixed flat rate with limitations on the maximum electricity wattage. This business model is similar to that used by many Internet service providers. One advantage of flat rate is that meters, and meter data, are no longer needed.
- Mobile device apps, such as those offering services to visualize energy consumption.
- "Energy-on-the-go," which meets the needs of travelers who need to charge laptops and electric vehicles in multiple locations—and have costs charged to their own energy bills.

There is unexploited potential for business apps and unexplored potential for new business models. More information is available at http://www.smartgrid-engagement-toolkit.eu/list-of-all-guidelines-and-tools/. This site provides practical guidelines and tools for utilities, energy agencies, and city developers.

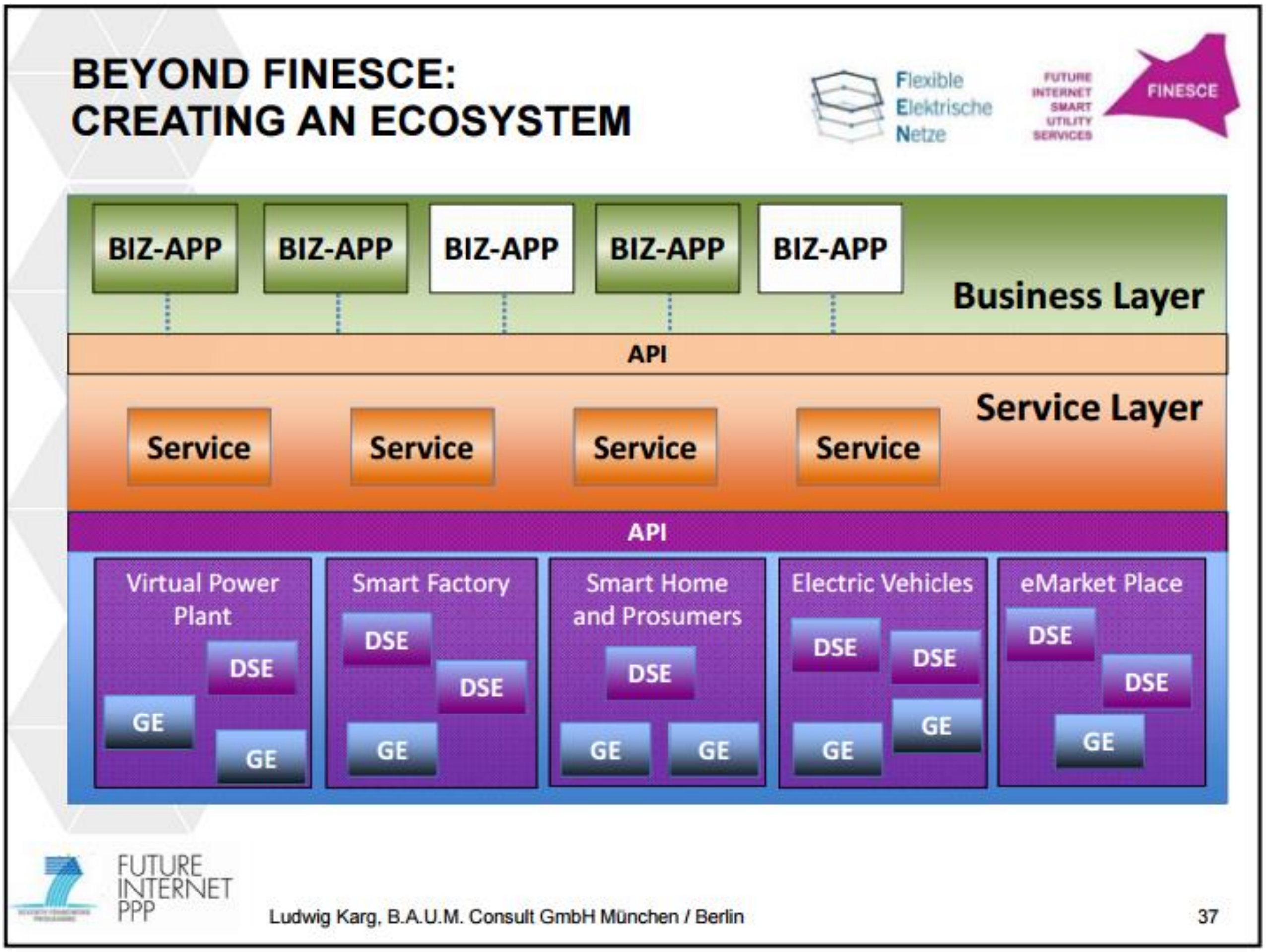


Figure 16. A new persepctive on electricity services that opens the door to new business models.

3.3 Demo Gotland

Monica Löf, Vattenfall AB, Sweden

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/9.MonicaLoewDemoGotland.pdf

Vattenfall's demonstration project on the island Gotland represents an interesting model of future Sweden, as the island has only one grid operator and the primary energy sources will be renewables. The Gotland project goal is redevelopment of an existing distribution network into a smart grid. The upgraded system is needed to address the challenges associated with an increased proportion of renewable electricity generation. The project consists of three main areas of activities: integrating wind power; demonstrating modern technology's potential to increase reliability, efficiency, and power quality in rural networks with large amounts of installed renewable generation; and promoting active customer participation with the aim of displacing 10% of the grid load. The presentation focused on the third area: customer participation.

The project is addressing several unknowns, such as to what extent the customer will adopt and use new technology, how active different customers are in various locations, whether remote control will be necessary to achieve peak load targets, and whether any changes in customer behavior will be sufficient and sustainable. The project will determine whether technology and/or pricing models have a considerable and lasting impact on consumption, energy cost, and peak loads.

The project split customers into two groups, one with and one without remote steering technologies. The 200 remotely steered customers were offered time-of-use tariffs, a special price model with a reduction related to wind power, and remote-controlled heating systems and hot water heaters. The 50 customers without remote steering were offered regular spot pricing or optional time-of-use tariffs, daily price signals and next-day forecasts (through the product Energy Watch), smartplugs, and temperature control (without a remote feature).

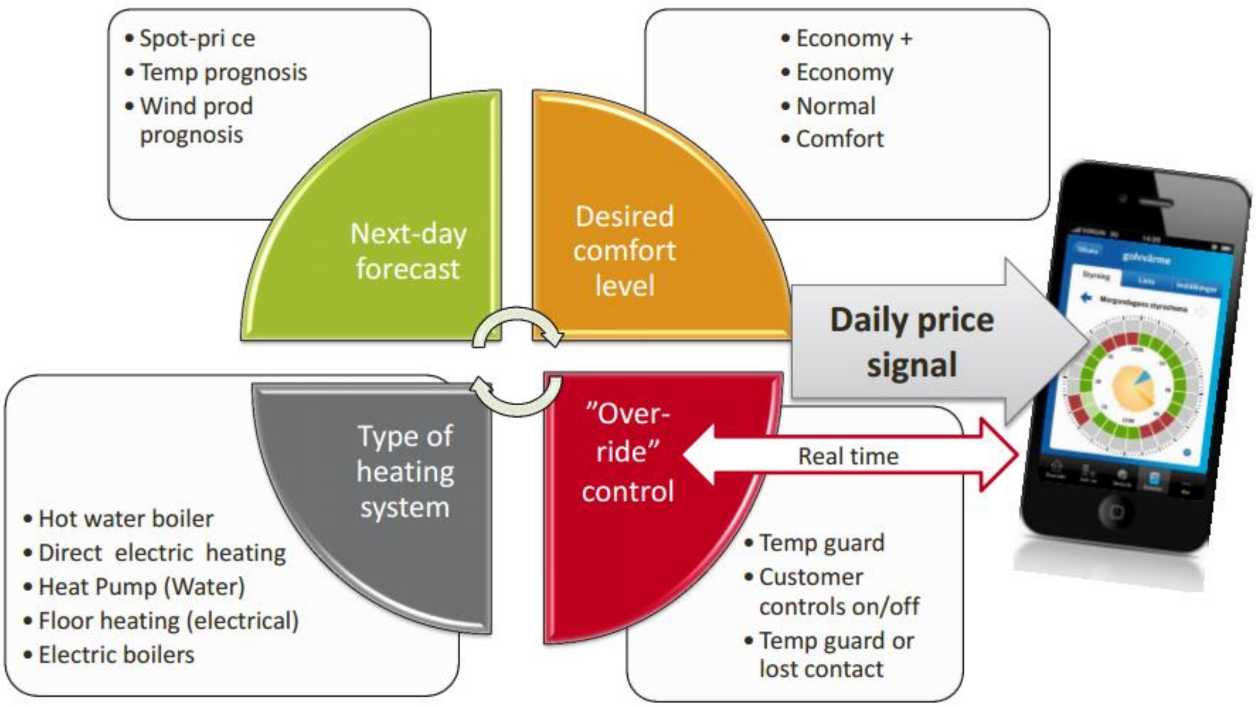


Figure 17. Gotland project control system configuration.

Preliminary results from the project's first year are available, and the first analyses are focused on load shift, control activity, customer behavior and attitudes, and economic benefits. Customers can be placed into three categories: those most interested in cost savings, those most interested in the technology, and those most interested in the environmental benefits.

From the system operator's point of view, a typical day starts with a morning peak around 09:00, with a second peak around 11:00. The consumption curve during peak hours shows that approximately 10% load shift is achieved (see Figure 18). Both manual and automatic households showed behavior changes, but customers without remote steering have higher consciousness about their energy use than the remotely steered group.

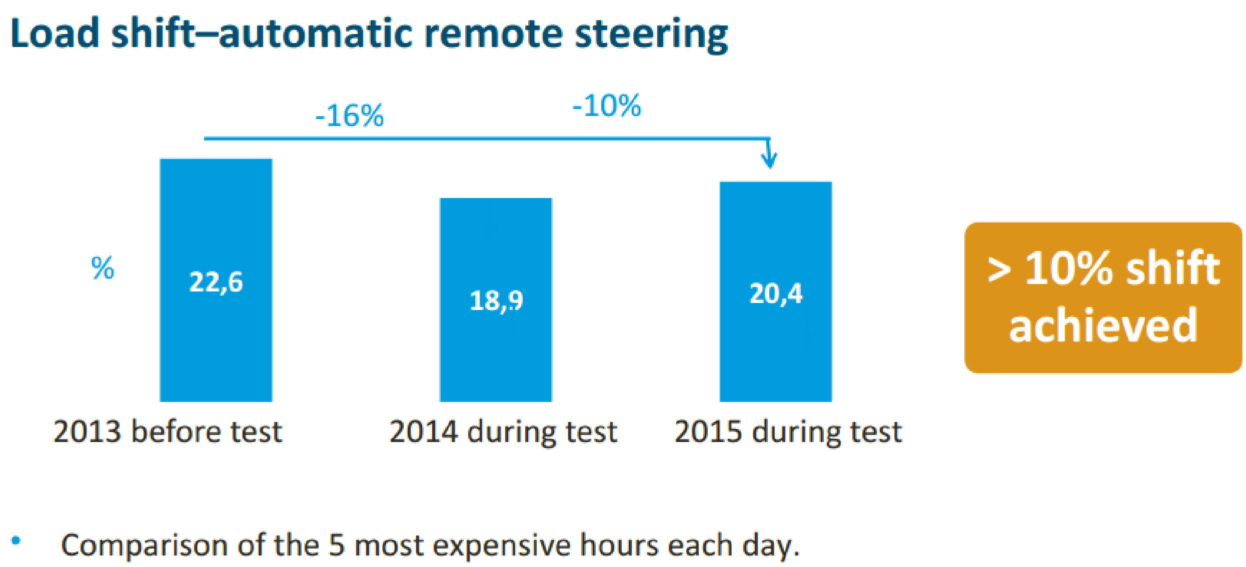


Figure 18. Consumption during peak hours in Gotland project.

The project analyzed customers' responses to price signals to determine the degree of customer engagement. Of the customers with automatic controls, around 70% have made changes to the settings. About half the customers have experienced reduced energy costs, and the majority are satisfied and would recommend the solution to their friends.

More information about the project is available at www.smartgridgotland.com.

3.4 Market, Money and Morals

Åsne Lund Godbolt, SINTEF, Norway

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/10.%C3%85sneGodboltLundMarket.pdf

Two underlying factors should be considered for understanding Norwegian energy consumers from a sociological point of view: the Norwegian power market was deregulated in 1990, and power production consists of 98% hydropower. These facts influence the views of both political stakeholders and individual citizens.

A study consisting of interviews, surveys, document analyses, and re-analyses of existing data (see Figure 19) show that the political expectation is that consumers see electricity as a commodity, are economical by nature, and use common calculation practices; therefore, consumers will respond predictably to economic incentives. On the other hand, customers see electricity as a public good and do quality-based rational judgments ("qualculations"); customer choices are heavily influenced by moral, social, and political issues.

Data material

- Focus group interviews with consumers: 9 interviews, 44 participants (2009)
- Expert interviews: 15 interviews with economists, policymakers (2009)
- Survey: 1500 respondents (2009)
- Document analysis: white papers, parliamentary debates, legal documents (1970 – 2006)
- Re-analysis of existing data: survey of 1050 persons (1991), 34 in-depth-interviews with 60 persons (1992-1995), 10 focus groups with 62 participants (2006-2009)

Figure 19. Data sources for Dr. Godbolt's study.

The study also considered whether the threat of global warming has changed the Norwegian energy culture. The general thinking is that consumers should do what they can but that the government needs to take responsible action on behalf of the country. Although consumers are concerned about climate change, people still put their own convenience and comfort first—but now that act is accompanied by guilt. This moral aspect is driving the public towards energy efficiency investments. In this way, consumers can save energy through efficiency to compensate for other consumption.

There is a mismatch between the perceptions of policymakers and consumers that results in ineffectiveness of energy efficiency policies. People are concerned about their energy consumption in light of climate change, but they wonder why there are so few incentives for saving energy. Smart grid solutions may appeal to "qualculating" customers. Concerned customers may want to contribute by becoming politically engagement as smart grid proponents.

The study is available at http://ntnu.diva-portal.org/smash/get/diva2:764799/FULLTEXT01.pdf. The abstract is at http://brage.bibsys.no/xmlui/handle/11250/244236.

3.5 Touch Points and Practices in the Smart Grid

Cecilia Katzeff, Interactive Institute Swedish ICT, Sweden

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/11.CecilieKatzeff.pdf

Interactive Institute Swedish ICT is a research institute founded in 1998 with 60 employees in 9 studios geographically spread around in Sweden. The Energy Design studio carried out several relevant projects. The studio is a research group at Interactive Institute Swedish ICT specializing in research on energy use, ICT design, and behavioral science.

One project involved the group's participation in the Swedish governmental inquiry on smart grids. In December 2014, the government released the final report and national action plan for smart grid development in Sweden from 2015 to 2030 (*Planera för effekt*). The Institute categorized research on touch points between people and smart grid as follows: flexible behavior (utility side), micro-generation of electricity, automated homes, dynamic pricing and how prices are communicated, and visualization and feedback of energy use.

Design plays a vital role between the smart grid and people, requiring knowledge, feedback, and aesthetics—as well as playfulness. For effective engagement, an invisible product as electricity must be made visible. The Institute has done testing with games such as "Powerhouse for Kids," "Power Agent," and "Power Explorer" to target young people. More generic user participation has been tested using smart phone technology as an enabler. The Institute has developed new innovative products to encourage consciousness about energy use (see Figure 20). For example, the Power Aware Cord emits light when power is flowing, the Energy Aware Clock shows the household's daily power consumption, and the Flower Lamp opens or closes depending on energy use. Test results differ, but in general, access to these products changes people's behavior in two to three weeks. The right design should also achieve sustainable change; the effectiveness of the Energy Aware Clock, for example, has not yet diminished.

Figure 20. Innovative products that enhance energy usage awareness.

Further work is now organized under a new project, Future Alley – Sustainable Lifestyles with Smart Grids, which runs from 2014 to 2017. This is a field study of lifestyles—eating, sleeping, socializing, working, etc.—that will increase knowledge about households' use of smart grid equipment in retrofitted rental apartments (rather than in new residential areas). The challenge is how to involve the households in the study. The project is being performed by the Swedish Energy Agency in partnership with a building company, an energy company, and a smart grid technology developer.

4. Technology/Software Solutions and Research and Development Priorities

Session Chair: Robert Marlay, U.S. Department of Energy

Session 4 focused on the kinds of enabling technologies that would be important for overcoming key challenges to smart grid implementation and the R&D necessary to implement those solutions. The following questions were considered:

- What kinds of enabling technologies are most important from an end-user perspective?
- What priorities should government have in their R&D investments?
- What is the "killer app" for smart grids? How do we realize that potential?
- Is technology driving business models for smart grids, or do good business ideas drive grid innovation?

4.1 The Netherlands Experience

Nicole Kerkhof, the Netherlands Enterprise Agency (RVO.nl), Netherlands

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/13.NicoleKerkhof_TheNetherlandsexperience.pdf

Dutch funding schemes for smart grids and connections to European Union programs provides a case study for smart grid implementation, especially as it pertains to consumer behavior and user approach. Studies of related projects were done by the Task Force on Smart Grid in 2011; twelve pilot projects that took place over four years are of particular interest. The projects involved multiple sectors, including academia and the public and private sectors, and received 40% cost share in subsidies. These efforts focused on aspects such as legislation, standards, new products, consumer behavior, and visualization.

These efforts focused on how consumers can be engaged—and how to keep them engaged. Results indicated the importance of involving customers early—education and information are extremely important—and focusing on the goal rather than the technique/technology. Consumer involvement has more staying power if dedicated customers become smart grid "ambassadors." The studies also found that the best results come with having only one intermediator (contact person) per project.

Three examples from the twelve pilot projects include:

- PowerMatcher, an open-source platform for matching supply and demand: https://www.tno.nl/powermatcher/
- Your Own Energy Moment, involving automated control including price prognosis http://jouwenergiemoment.nl/
- Products and services on Texel island, where people wish to develop a self-sufficient society http://www.texelenergie.nl/

Information about the opportunity to participated and results from the pilot projects were shared using mass media.

These R&D pilot projects are steps toward developing large-scale implementation programs and engaging large sector players within the smart grid arena (see Figure 21). Large-scale involvement is taking place through Green Deal, an agreement that involves enterprises, social organizations, and local authorities across five cities and includes involvement of the Ministry of Economic Affairs. The Ministry helps with bottlenecks such as regulation and partner engagement, and participants share information on energy, climate, water, raw materials, mobility, bio-based economy, building, and food, as well as legal issues related to smart grids. The project aims to realize low-carbon energy solutions for 100,000 buildings in the five participating cities. A successful outcome will attract investors in innovative technologies and consumer-oriented services.

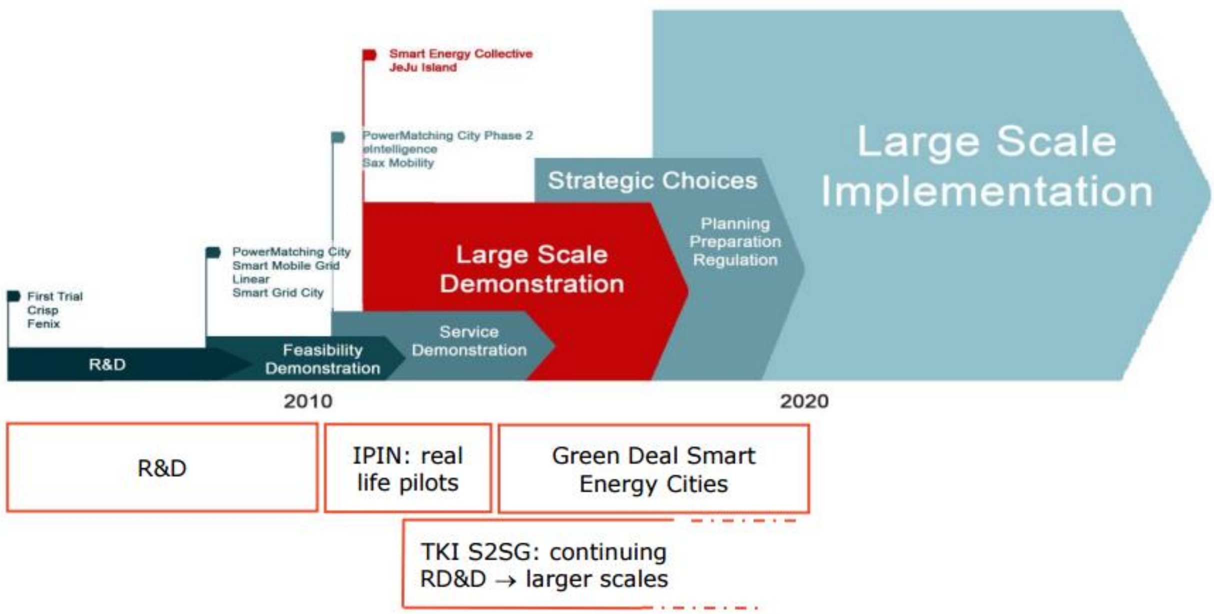


Figure 21. Moving from R&D to large-scale implementation.

4.2 ChargeFlex: Management of Charging of Electric Vehicles

Stig Ødegaard Ottosen, Norwegian University of Science and Technology/E-smart, Norway

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/14.StigOttesen.pdf

eSmart systems has three full-time researchers focused on two megatrends: changing power systems (electric vehicles, distributed energy resources, and storage) and ICT (communications and cloud storage of big data). eSmart products are based on a software platform for grid operators enabling management of two-way energy meter data (from AMS) and electric vehicles.

Thanks to very strong incentives over several years, Norway now has more than 50,000 electric vehicles. These incentives include no import tax, no value-added tax, free passage on toll roads, free parking (often with free charging), and access to bus lanes. In early 2015, 23% of all new cars sold in Norway were battery electric vehicles or plug-in hybrids. This high number of electric vehicles presents some challenges related to distribution grid power loads as a result of user behavior: users often charge their cars in late afternoon, simultaneously with the use of electric cooking stoves in Norwegian kitchens (see Figure 22). Most traditional distribution grids are not designed for such high simultaneous loads. The identified solutions are to invest in new grid capacity at different levels, utilize DSM with storage, or control the electric vehicle charging process. If charging is coordinated, the existing electric distribution grid can handle five times the current number of cars. Without this kind of coordination, grid operators may soon be forced to restrict vehicle charging in some areas.

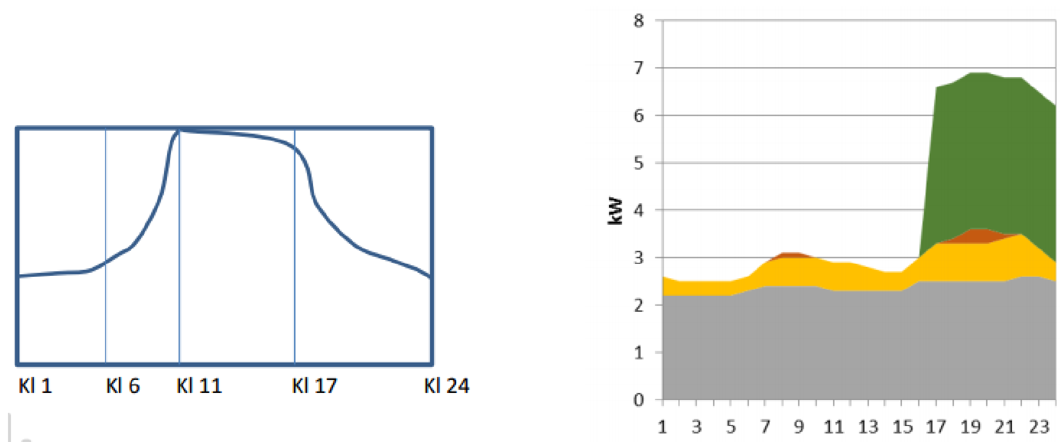


Figure 22. Increased peak load in total electricity system due to high penetration of electric vehicles.

ChargeFlex is a three-year project with a budget of 12 million Norwegian Krone (NOK) with the goal of increasing grid capacity for vehicle charging through smart control. Researchers are working on handling big data uncertainty and dynamics related to human behavior resulting in peak loads.

A decision model is being developed to support the operational phase to keep the load within given limits. Three existing charging stations will be used in the pilot project. The stations consist of 14 charging points with a fuse capacity restricting the maximum power obtained from the grid. Different decision models for operation are being developed, and two different management strategies will be tested: a rule-based strategy and an optimization-based strategy. The former is simple and easy to implement, while the latter is more complex and requires more information. For comparison, two additional strategies will be analyzed: a “no-control” strategy will provide a baseline, and a full information strategy—i.e., the optimization-based strategy assuming perfect foresight—to serve as an upper benchmark. Input data for the model will come from real-life charging sequences and have a time resolution of 15 minutes.

The projects aims to determine the best management strategy for charging effectively, the lowest-cost strategy, and the capacity needed to meet all charging demand.

Preliminary results show little variation between the strategies, although optimization outperforms the rule-based strategy for charging effectively. The rule-based strategy uses half the grid capacity of baseline (no control), and the optimization strategy reduces the load even more. The researchers quantify each management strategy's value by estimating the cost of battery storage that could deliver equivalent power and energy. The value of the optimization-based strategy equals the cost of a storage system that delivers 33.5 kW and 70 kWh.

The model results can be used for dimensioning charging stations within the limits of the trafo capacity available, although V2G is not yet possible in the charging stations.

4.3 EcoGrid EU – A Prototype for European Smart Grids: Experience with Energy Management Systems and Customers

Maja Felicia Bendtsen, Østkraft, Denmark

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/15.MajaBendtsen_EcoGrid2015.pdf

The European Union smart grid demonstration project, EcoGrid EU, which is co-funded by the Seventh Framework Programme (FP7), involves 16 European partners and has a total 2011–2015 budget of €20.5 million. The project focuses on power flexibility in households, examining which loads are significant and should be shifted.

Often, running the washing machine at night is a suggested strategy for peak load reduction. However, the project team considered daily loads related to different household appliances, noting that the washing machine draws only 1.5 kW of power and consumes only about 1 kWh/wash, which for all practical purposes has no impact on the system or the household's economy. What really draws power and represents a large portion of the annual consumption are electric heating, heat pumps, and electric vehicles.

The EcoGrid project focuses on households on the island of Bornholm, one third of which have been engaged in the project. The four residential groups received smart grid technologies and services as follows:

- Reference (350) – no new equipment
- Manual control (500) – smart meters, daily price prognosis, high price level warnings
- IBM control (650) – smart meters, home automation systems, two-way data exchange
- Siemens control (450) – smart meters, home automation systems, one-way data exchange

Twenty businesses also participated and received smart meters and energy management systems.

Figure 23 depicts an overview of the EcoGrid project. The project implements overall control of the "EcoGrid Market" using technologies that facilitate data exchange with the participants' local control equipment. Price signals are communicated to the overlying control systems, which translate this information into on/off control signals that are communicated to the households. Appliance loads are regulated only if it is possible to measure the response (in terms of, for example, temperature or consumption). The project energy management systems can regulate only load on/off; appliances that are not compatible with this type of regulation, such as air conditioners, are not regulated. The heat pumps can be turned off—but not on—in response to the appliance temperature settings. The regulation is implemented at the fuse box level, limiting the control according to dedicated wiring for heating.

The project has experienced several challenges, including Internet connection problems, lack of standardized communication, and temperature sensor failures. Also, many consumers are willing to accept only a certain level of temperature modification in the home, ultimately readjusting the settings for comfort. Interoperability was also a challenge, which could be partially resolved through using a generic energy management system. System down time was another issue, and the project is seeking ways to resolve it.

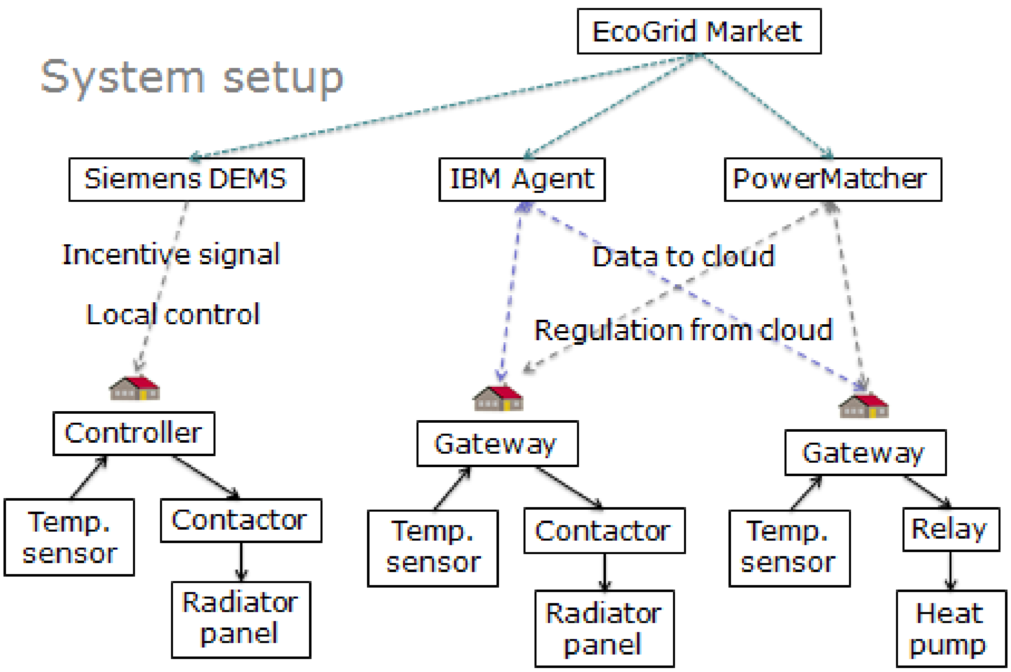


Figure 23. The EcoGrid system setup.

4.4 EMPower Local Electricity Retail Markets

Dieter Hirdes, NCE Smart Energy Markets, Norway

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/20.DieterHirdes_EMPOWERLocalelectricityretailmarkets.pdf

EMPower is a three-year Horizon 2020 project with a total budget of €6.12 million, including €4.43 million in European Union funding. Three pilot projects at Hvaler, Lübben, and Malta (see Figure 24) are part of the EMPower project, which involves a range of partners, including universities and smart grid companies. The project aims to develop new local electricity retail markets that enable prosumers to buy and sell locally produced electricity to neighbors. One targeted result is to alleviate the burden on the central and regional grids and balance local distribution grids.

Figure 24. EMPower pilot project locations.

A new local market is needed in the face of a changing energy economy, with distributed production and storage key factors in the power sector's revolution. In energy efficient houses with active prosumers, 80% of the energy will be produced locally and only 20% delivered from the regional grid, which will serve as a reserve. This development will have large impacts on DSOs, policy and business models, regulation, and security of supply. DSOs will have to adapt to survive. The reshaped power market will entail new roles and rules that will involve prosumers, aggregators, energy service companies, and new business models. One example is the recent launch of Tesla's stationary batteries for end users, which might be a game-changer designed to optimize self-sufficiency through solar power generation.

Although a new local market model is clearly needed, its development faces challenges and barriers. Existing energy companies will resist local markets as an alternative strategy to adaption. National regulations can delay decentralization of energy markets. Not all consumers fully understand the benefits of becoming prosumers. Privacy of prosumer data needs to be secured against misuse. Finally, standards are needed to enable interoperability and free competition among suppliers.

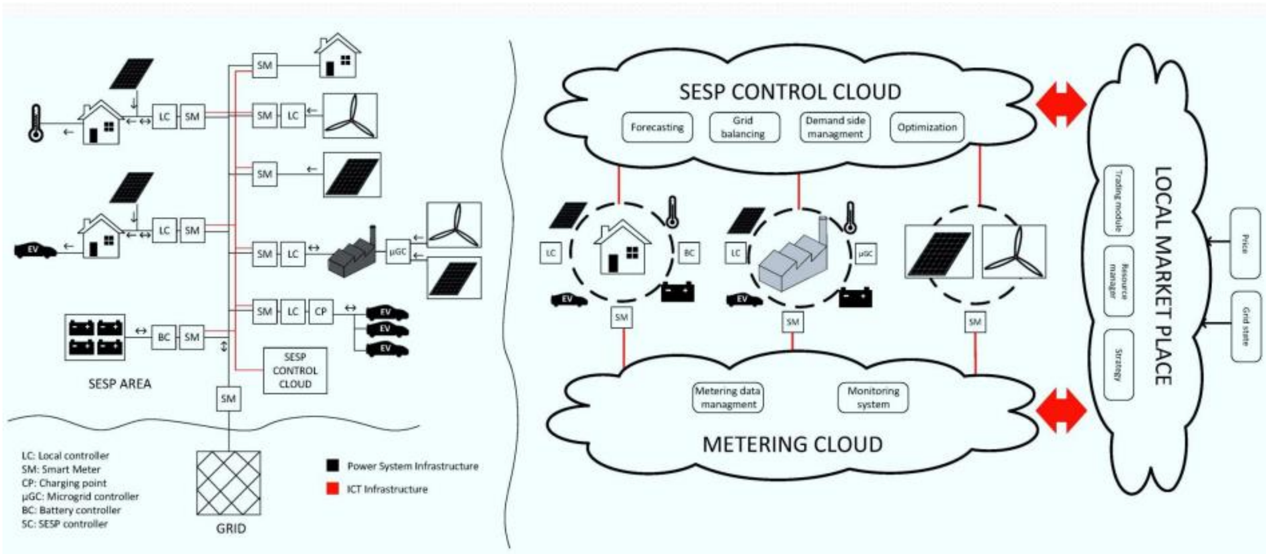


Figure 25. EMPower's new local market model.

5. Policy, Markets, Government Interventions

Session 5 covered the importance of regulatory framework conditions in terms of new business opportunities, business models, and research needs. The following questions were areas of focus:

- How important is the regulatory framework to achieving benefits from the smart grid? Does it need to be changed, and if so, what sort of change is needed?
- Which is better: national or common frameworks? Which is feasible?
- Is there a need for more incentives for the industry? For the end users?
- The combination of power systems and ICT opens up new business opportunities, likely cutting across sectors. How do we exploit these opportunities?

5.1 Policy, Market and Government Interventions: European Electricity Grid Initiative

Henrik Dam, Directorate-General for Energy, European Commission

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/16.HenrikDam_EUEuropeanElectricityGridInitiative.pdf

The European Electricity Grid Initiative (EEGI) of the European Commission focuses on policy, market, and government interventions in power markets. European energy policy balances three primary drivers: sustainability, security of supply, and competitiveness. The correct balance must be obtained to set the stage for utilisation of renewable energy resources, energy efficiency, diversified supply, competitive markets, and smart infrastructures. Power grids need to change in order to achieve these objectives and, ultimately the European Union's climate goals: 20% renewable energy in 2020 with up to 35% renewable electricity and a single market for electricity matched with security of supply. The European Energy Roadmap has amplified the vision for 2050 and includes energy efficiency, a strong increase in renewable electricity, and an increased role for electricity in final consumption and energy delivery.

Developing renewable electricity faces multiple challenges. A large portion of renewable electricity is generated far from the point of consumption, which increases the needed grid capacity. Strong regional grids and support for local generation are both needed to meet future power demand and security of supply. The variable nature of renewable energy requires flexibility in generation with active demand control, interconnections, and storage. The smart supporting technologies are digital and translate into "big data"—data from millions of supply points as generation becomes more distributed. Perhaps one of the greatest barriers is energy monopolists' unwillingness to change.

The EEGI program is linked to the European Strategic Energy Technology, or "SET," plan towards a low-carbon future, which established objectives for 2020: 20% carbon dioxide emissions reduction, 20% share of renewable energy, and 20% improvement in energy efficiency. EEGI focuses on energy technologies that will have market impact in this timeframe: wind, solar, bioenergy, nuclear, fuel cells and hydrogen, carbon capture and storage, electricity grids, and smart cities and communities. The EEGI roadmap covers all levels of the power system from generation to end-customer (see Figure 26), as well as technologies in different development stages with respect to market readiness. EEGI-supported activities support a range of activities, including financial schemes, knowledge platforms, research agendas and plans, roadmaps and R&D implementation plans, and strategic mapping of international projects on storage and smart grids.

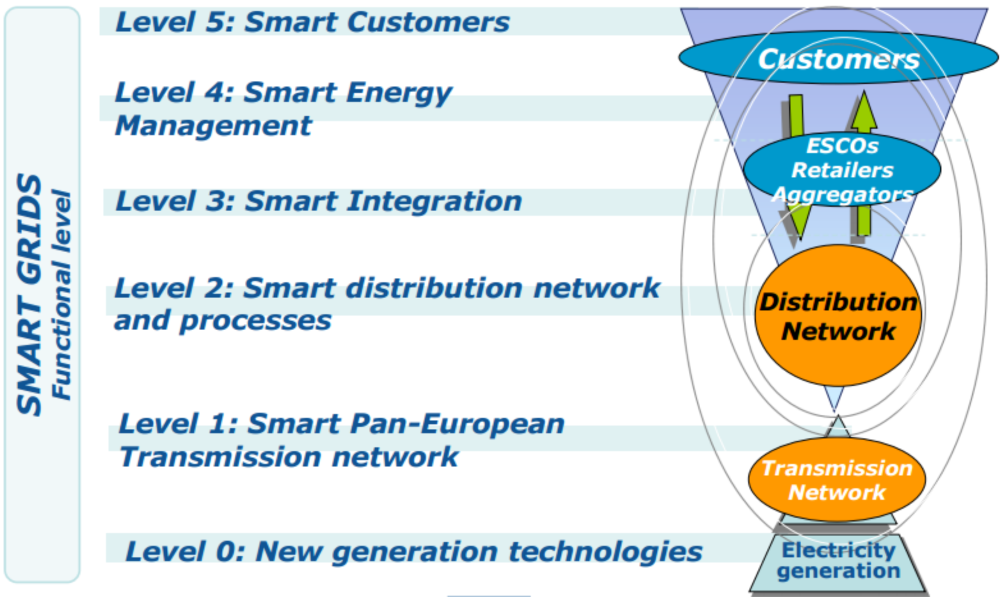


Figure 26. Levels addressed in the EEGI roadmap.

In terms of the perspective beyond 2020, there are several new challenges related to bridging research and innovation with energy policy and optimal use of financial resources. EEGI is planning next steps that include a robust reporting system and a new coordination structure to monitor Initiative impacts. The follow-up will focus on achievements in three main areas: energy efficiency, an efficient and flexible system, and market uptake. EEGI must also incorporate new competencies covering non-technological barriers. Key issues include cost competitiveness and performance, system integration, supply-chains, non-technological aspects and social issues.

Objectives have been established for 2030: 40% carbon dioxide emissions reduction, 27% share of renewable energy, and 27% improvement in energy efficiency. The strategy to reach these goals spans five dimensions (see Figure 27), and EEGI has defined 15 concrete actions and identified 43 associated initiatives. The overall R&D goal is to obtain global leadership in low-carbon technologies. Most European Union member states have identified electrical grids as a top R&D priority.

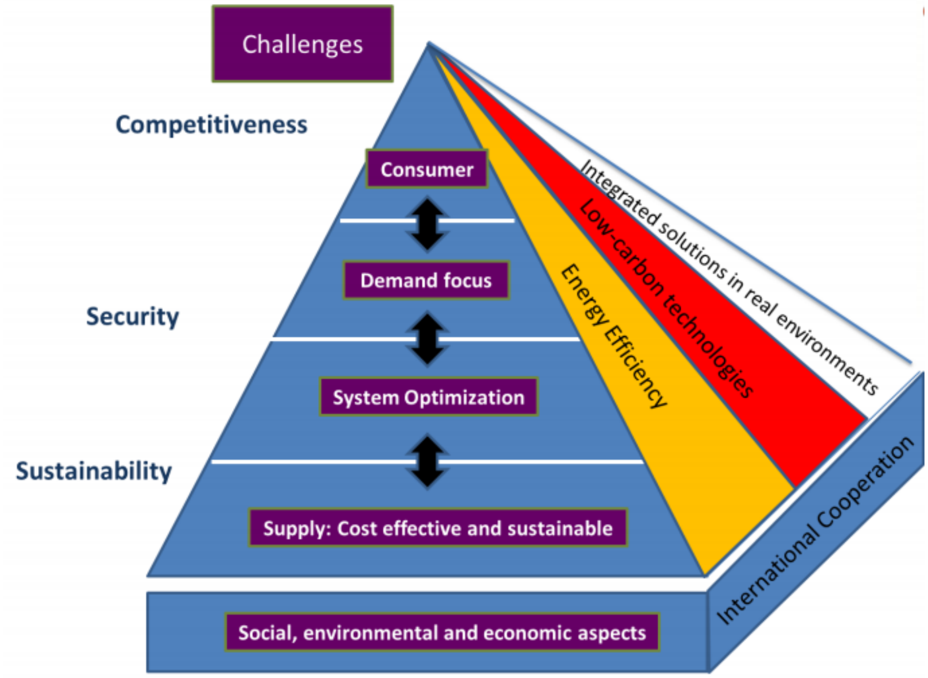


Figure 27. Holistic approach to energy systems.

5.2 Intelligent Energy through Flexibility across Energy Systems and Activating Flexibility in Buildings

Helle Juhler-Verdoner, the Danish Intelligent Energy Alliance, Denmark

- Link to presentation slides:
  https://www.iea.org/media/workshops/2015/egrdjune/17.HelleJuhlerVerdoner.pdf

The Danish Intelligent Energy Alliance, established in 2012, aims to make Denmark the internationally leading smart energy hub by uniting essential stakeholders. Intelligent energy requires integration of all energy systems and utilizes the potential for flexibility on the demand side (see Figure 28).

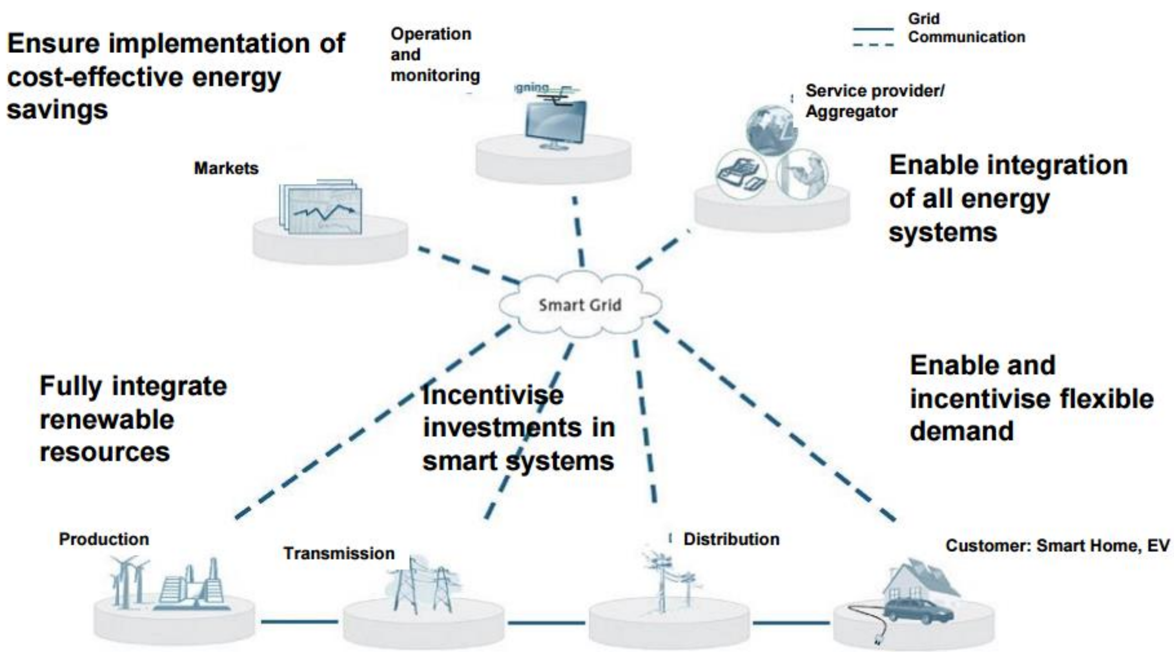


Figure 28. The Alliance's key messages: requirements for intelligent energy.

Drivers for the transition to intelligent energy include the Danish government's "green" targets, which are based on phasing in renewable energy and phasing out fossil fuels. The green targets are 50% electricity from wind power and 40% carbon dioxide emissions reduction by end-2020, phase-out of coal in power plants and fossil oil for heating by end-2030, 100% renewable energy for electricity and heating by end-2035, 100% renewable energy in all sectors by end-2050, and 30% reduction in energy consumption by end-2050. Also worth attention: 50% of the total electricity price is tax.

One policy incentive is not in line with a pressing need: flexibility. Energy efficiency and energy flexibility both play central roles in a smart energy system and must work hand-in-hand. The current policy of not taxing biomass has driven a conversion to decentralized biomass, which does not achieve the required end.

Wind power represents an increasing percentage of the base load capacity in the Danish power system, which presents some challenges for grid operation (see Figure 29). The Danish system has interconnections to the Norwegian hydroelectric system, with high buffer capacity, which contributes to Denmark's high security of supply. Nonetheless, green targets require implementation of flexible DSM and energy efficiency, which must be stimulated through a new market model. Accelerating development of smarter and stronger grids is also important, as they are needed for both integration of intermittent energy resources and improved energy efficiency, so smart grid investments must be incentivized through changes to existing DSO regulations and establishment of a business case.

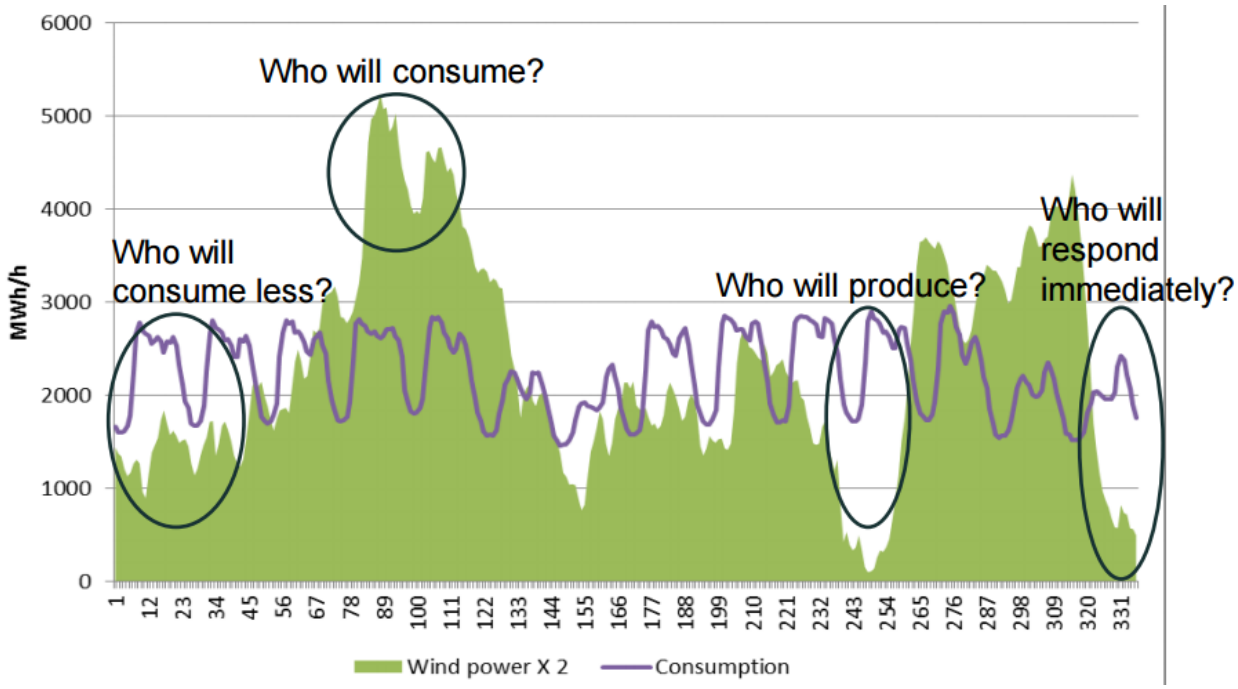


Figure 29. Questions posed by the "new normal" resulting from increased wind power.

Change in Denmark is underway. The country has a national smart grid roadmap and a national forum. Smart meter rollouts are on track, with over two million accumulated installations. Once the supportive technologies are fully rolled out, hourly metering and pricing data can support variable pricing, which will reward energy efficiency and energy flexibility, such as through DSM with consumption decoupling.

Furthermore, the Danish TSO recently completed Market Model 2.0, a study of the electricity market of the future. This analysis shows that decoupling has a conservative technical potential of 840 MW of power capacity. To realize this potential, barriers to demand response must be removed. Such barriers include lack of knowledge about the power market and lack of awareness about the opportunity to reduce energy cost by decoupling in accordance with day-ahead and intra-day hourly prices.

The government has issued a new tariff model to be implemented by all Danish DSOs by April 2016. Private residences will receive incentives for demand response, encouraging flexibility and helping to ease existing barriers to demand response.

Other changes are required. For example, the volume requirement (size of bids) for participation in the tertiary market must be reduced from the present-day 10 MW to 1 MW. The duration of decoupling of power should be flexible down to one hour, and contractual commitment should also be open for different forward time periods, such as 6–12 months ahead in a new capacity market and secondary reserve market.

With the new market model and supporting technologies in place, buildings can contribute with distributed production, storage, and decoupling, thus filling an important role of the flexible power system. The next step will be establishing a more general platform for smart energy by extending the scope to include heat, gas, water, waste-water, waste, and transportation. It will be important to investigate barriers and solutions across sectors and large-scale commercial potential across sectors.

5.3 Smart Community Demonstrations – Experiences in Japan

Atsushi Kurosawa, Institute of Applied Energy, Japan

- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/18.AtsushiKurosawa.pdf

The "smart community" is a new community utilizing advanced ICT with participation of citizens, involving smart transportation, homes, office building and factories, and enabling introduction of distributed renewable energy sources (see Figure 30). These concepts are being developed and demonstrated as part of the mitigation technology testbed.

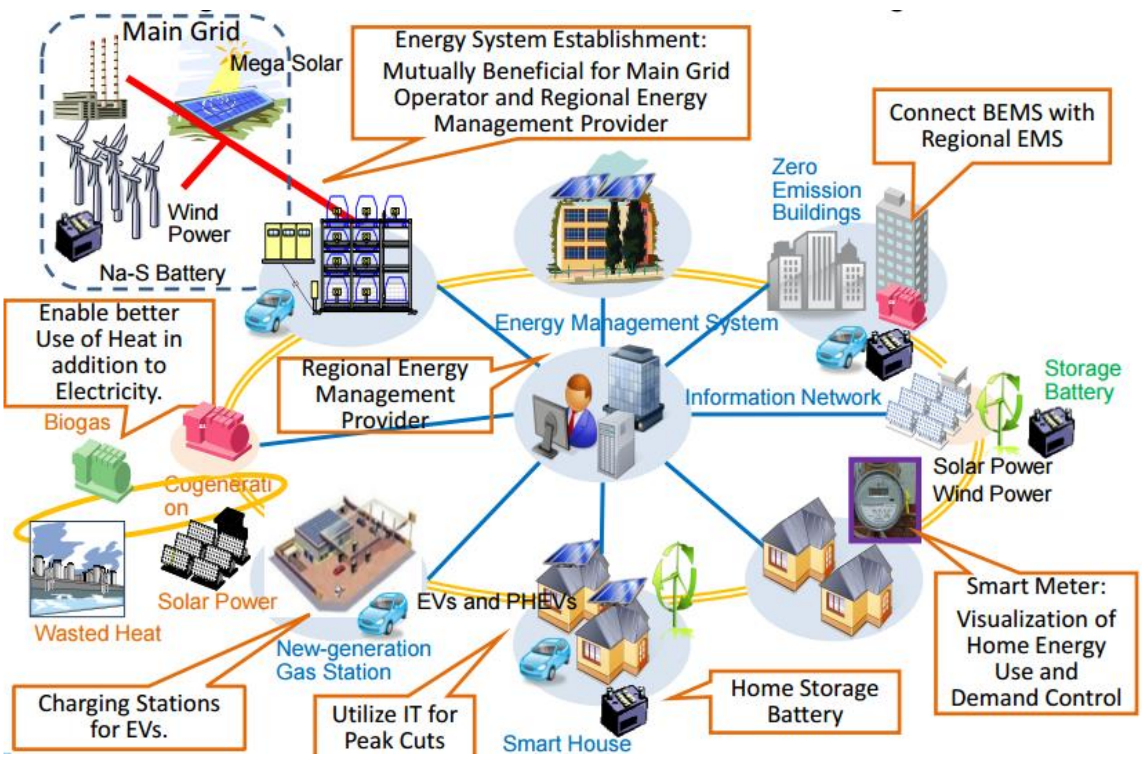


Figure 30. The smart community concept under development in Japan.

In the wake of accident at the Fukushima Daiichi nuclear power plants, smart technologies and techniques have received increased attention—including the need for demand response. Distributed renewable energy, and PV in particular, drive the need to shift peak loads. Several initiatives have been established to solve these challenges, including energy management demonstration projects and large social system demonstrations. The projects were organized through the Japan Smart Community Alliance, which has 282 members from industry, academia, local governments, and non-profit organizations. More information is available online: https://www.smart-japan.org/english/index.html and www.nepc.or.jp.

In Yokohama, energy management has been implemented in three areas of the city, and large-scale testing of demand response is under way. In fiscal year 2013, 1,200 households participated in testing, and a maximum peak demand reduction rate of 15.2% was achieved.

Toyota City is also testing demand response with a focus on households and next-generation vehicles; testing includes heat pumps, stationary batteries and fuel cells for households, and a range of chargeable vehicle types. A 2012 demand response demonstration achieved 18.7% carbon dioxide emissions reduction.

In Kansai Science City (Keihanna), 600–700 households are participating in a project focusing on household demand response and electric vehicle charging. The tariff structure has a daily rebate scheme for off-peak hours—time of use—and peak hours during summer and winter—a critical peak pricing power tariff. Keihanna is also conducting experiments with 14 households using home energy management systems and PV. These efforts have achieved up to 51% reduction in carbon dioxide emissions and 62% reduction in park demand (see Figure 31).

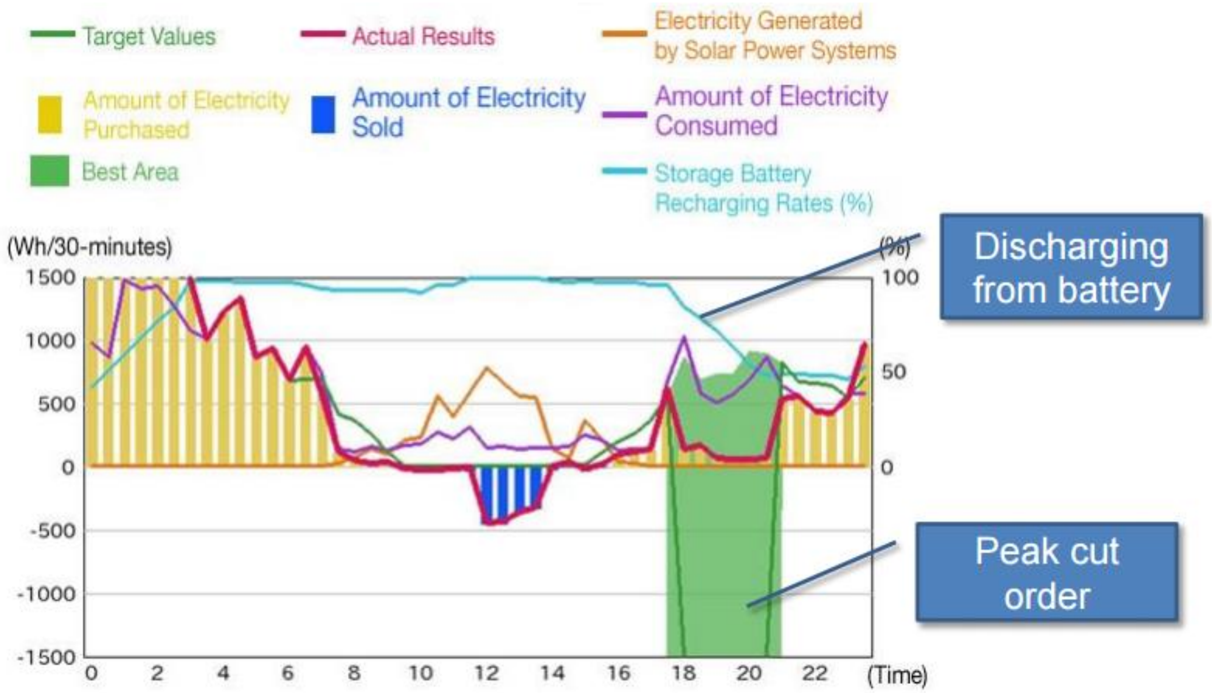


Figure 31. Results of energy management and solar PV experiments in Keihanna.

Kitakyushu is demonstrating micro-combined heat and power systems for 230 houses and 50 businesses. The project also involves demand response through time-of-use and critical peak pricing tariffs. In addition, the City is investigating the use of hydrogen, including a hydrogen filling station for operation of fuel cell vehicles and short-range pipeline delivery for stationary fuel cells in buildings.

The projects have revealed challenges related to engaging and maintaining stakeholder interest, which to a large degree is connected to a viable business model, viable pricing structures, and tariff incentives. The economic payback is important but should not outweigh valuation of carbon dioxide emissions reductions. Institutional or market design also presents challenges related to tariff structures, aggregation, and trading in the power market. Several of the projects both electric and non-electric energy (e.g., gas and hydrogen) and other utility services such as water supply.

5.4 DC Smart Grids with More Benefits

Pepijn van Willigenburg, The Hague University of Applied Sciences, Netherlands

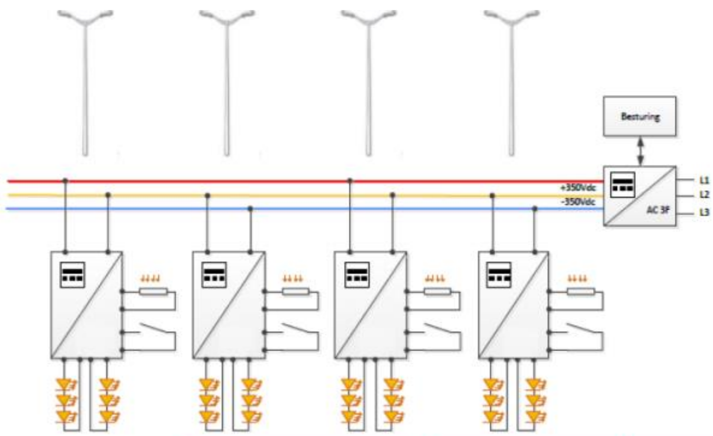
- Link to presentation slides: https://www.iea.org/media/workshops/2015/egrdjune/19.Pepijnvanwilligenburg.pdf

The question of whether direct current (DC) could replace alternating current (AC) in future distribution grids has been raised and discussed within academic educational institutions in partnership with industrial stakeholders. When electricity was discovered and harnessed in the late 1800s, Edison focused on DC, while Tesla and Westinghouse developed AC. Ultimately, AC was implemented in large-scale grids because AC with transformers offered low-cost distribution.

However, DC has a range of advantages in distribution grids and end use, such as avoided losses due to AC–DC conversion, lower material use (especially for iron and copper), power line communications at no added cost, and a longer lifetime due to avoided dependence of capacitors. These benefits translate into lower capital and operating expenses. In addition, the USB (Universal Serial Bus) communications contact can serve as a standardized plug. The USB-C bidirectional standard plug can deliver 100 W of power.

High-voltage DC (HVDC) over 1500 V can be used for long-distance point-to-point transmission once multipoint connections are fully developed. High voltage is needed to reduce the cable-dimensions and prevent losses ($P_{loss} = I^2R$). Higher voltages allow for lower currents (I in the formula) and thus lower losses (P_{loss}). Low-voltage DC (LVDC) (ideally 350 V in-house) can power household LEDs (light-emitting diodes), high-pressure sodium (HPS) lighting, and electronic devices. Electric vehicles and batteries can also use DC. DC can also be used in transmission lines.

Implementing DC faces many challenges, as the AC system has already been implemented around the globe. The business case for the switch must be established through targeted implementation, such as LED–DC public lighting (see Figure 32). Currently, for example, a greenhouse with 30 kW power demand has been equipped with a DC lighting system, and RVO.nl has approved a project proposal for funding to extend the greenhouse system to 1.5 MW; the proposal awaits approval from the Dutch minister of economic affairs.



	AC system	DC system	Savings
Copper cables	100%	39%	61%
LED driver + conversion	100% (AC-DC)	95% (DC-DC)	5%

Figure 32. LED-DC public lighting system (350 V) to establish the business case for DC.

Visible successes can pave the way for increased DC usage and create a market pull that would justify volume production of the necessary system components. In countries that currently have limited or no electricity delivery systems, governments could “leapfrog” AC implementation and move forward with DC, just as they began telephone service with cellular systems.

For new DC systems, privacy can be secured by building proactive measures and integrating technical principles into the design (see Figure 33). The principles are part of the proposed European Union Data Protection Regulation.

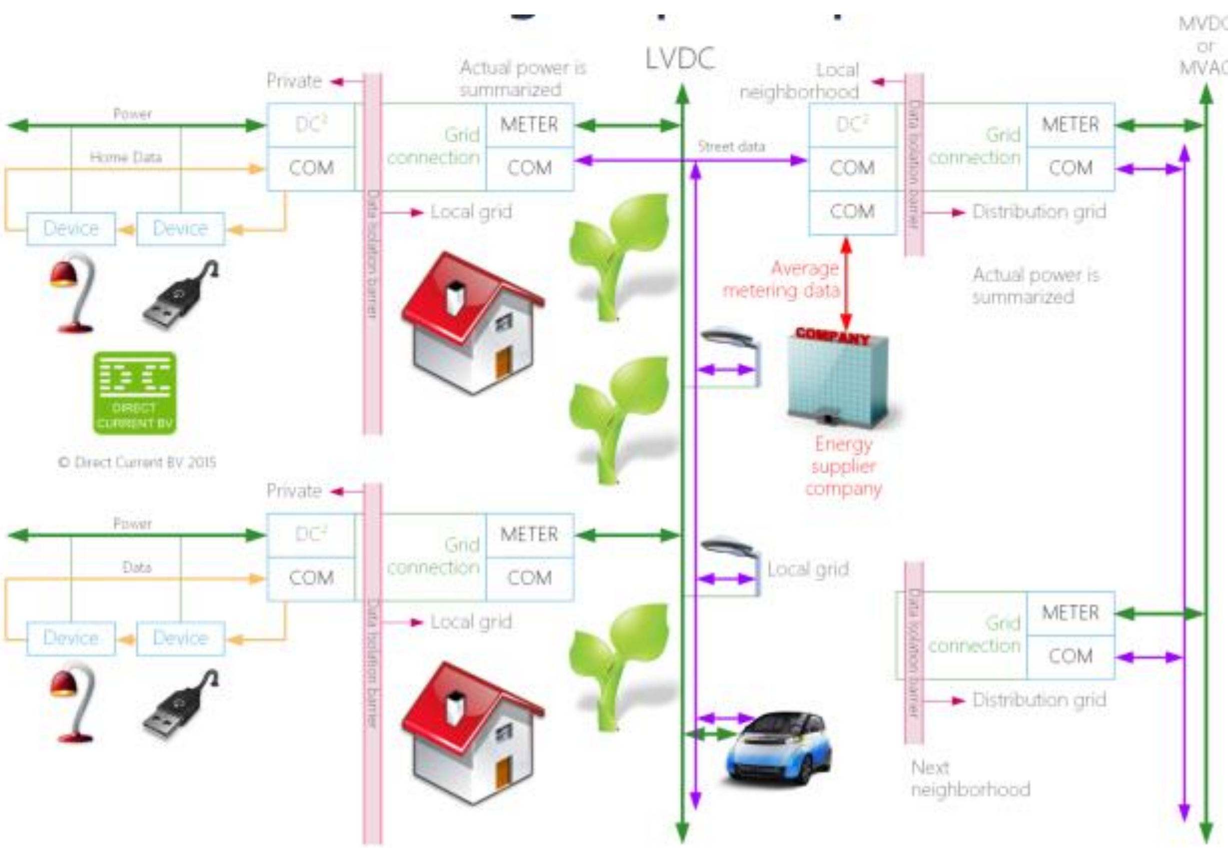


Figure 33. DC distribution grid principles to secure privacy.

More information can be found online: http://www.directcurrent.eu/en/vision, http://www.dcfoundation.org/foundation/objectives, and http://www.citytec.nl/.

CONCLUSION

Multiple factors are speeding the transition to next-generation electricity delivery systems. Many of these are related to energy security and climate change, such as increasing deployment of renewable energy and other low-carbon technologies and improved resilience to extreme weather events. System upgrades are necessary to meet changing consumption levels and needs for higher-quality power. As next-generation technologies are deployed, consumers are becoming interested in smart devices and the benefits they enable, and there is growing consumer interest in the autonomy attained through distributed energy resources.

Through collaboration, significant change has already taken place. Many governments and companies have invested in AMS and other smart grid implementation to meet the energy needs of 21st century society. There is a strong willingness to participate in identifying, developing, and implementing solutions across geographical and sector boundaries. A complementary drive to gain competitive advantages—become leading experts in what is clearly the energy future and stake out claims in the marketplace—also drives results. The resulting technical deployments have already enabled significant consumer and societal benefits.

Yet any list of drivers or solutions or benefits oversimplifies a complex picture. While global resources are appropriately focused on smart grids as a solution to many challenges presented by aging electricity delivery infrastructure, it is important to bear in mind that “smart grid” is not a single solution but rather a portfolio of tools, techniques, and technologies. A broad range of factors—from the technical to societal—must work hand in hand to achieve optimal smart grid implementation and benefits. The various aspects are interwoven, mandating a holistic approach to achieving the optimal results from advanced systems.

The importance of the individual customer’s role in this larger picture cannot be overemphasized. Key to a successful new energy economy is customer participation. Consumers must participate in peak demand programs if the peak is to be lowered. Consumers must adopt energy efficiency technologies if their homes and businesses are to become more energy efficient. Gathering and presenting energy usage information to customers serves no purpose if those customers do not act on that information.

In addition, consumers play an increasingly important technical role in next-generation systems. For example, adding renewable energy sources to the grid can result in instability due to generation fluctuation. Customers can become important assets through various avenues such as demand response, energy storage, and distributed energy generation. Flexibility is key to a successful next-generation system—and customers are key to flexibility.

Many consumers are ready to invest in new technologies, as is evident through the growing popularity of rooftop PV. And many are ready for new business models, such as crowd funding.

But the stage must be set. New behaviors cannot be expected without new contexts. The energy economy is undergoing a transformation that opens the door wide for new products—and, indeed, demands that energy providers master new technologies and provide new business models and services to survive in the new era. Putting forth new concepts successfully entails a good understanding of the target audience, and the customer “picture” is a complicated one, with highly variable responses to new technologies and wide-ranging motivations for adoption.

A supportive policy portfolio is also key in establishing the contexts and incentives that drive innovation. Grid modernization can be put into three categories: continuous evolution of established systems, the ICT revolution or “Internet of energy,” and a radical movement toward distributed energy resources and microgrids. Each of these presents potential business models and customer-based options—as well as policy needs. For example, the evolution of the existing system requires policies that incentivize TSOs and DSOs to test and deploy new technologies, the ICT revolution must encourage more cross-sector innovation, and the microgrid movement focuses on energy access and enabling prosumers.

The EGRD workshop reviewed several projects and programs that are making significant contributions to next-generation electricity delivery. What these successes share is the involvement of multiple organizations and disciplines, commanding a breadth and depth of expertise and resources that generate valid, concrete results. Regional and local governments, regulators, TSOs, DSOs, equipment manufacturers, utilities, academia, and consumers—all must be represented in viable holistic solutions. Continued international and multidisciplinary cooperation is an important factor in successful implementation.

APPENDICES

Appendix A. Acronyms

CHP	Combined Heat and Power
DC	Direct Current
DSM	Demand Side Management
DSO	Distribution System Operator
EEGI	European Electricity Grid Initiative
EGRD	Experts' Group on R&D Priority Setting and Evaluation
EU	European Union
FLECH	Flexibility Clearinghouse
FME	Centres for Environment-friendly Energy Research
FP7	Seventh Framework Programme (European Union)
H2G	Hydrogen-to-Grid
HPS	High-Pressure Sodium
HVDC	High-Voltage Direct Current
ICT	Information and Communications Technology
IEA	International Energy Agency
ISGAN	International Smart Grid Action Network
kW	Kilowatt(s)
kWh	Kilowatt-Hour(s)
LED	Light-Emitting Diode
LVDC	Low-Voltage Direct Current
MW	Megawatt(s)
NOK	Norwegian Krone
NSGC	Norwegian Smartgrid Centre
PV	Photovoltaic(s)
R&D	Research and Development
RD&D	Research, Development and Demonstration
RVO.nl	Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland)
SC3	Smart Consumer, Smart Customer, Smart Citizen
SET	Strategic Energy Technology
TSO	Transmission System Operator
TWh	Terawatt-Hour(s)
USB	Universal Serial Bus
V	Volt(s)
V2G	Vehicle-to-Grid
W	Watt(s)

Appendix B. Speakers

Name	Institution	Country	Presentation
Henrik Bindner	Technical University of Denmark	Denmark	Session 1
Hanne Christensen	Danish Energy Agency	Denmark	
Henrik Dam	DG Energy		Session 5
Ömer Faruk GÜMRÜKÇÜ	Ministry of Energy and natural resources	Turkey	
Maja Felicia Bendtsen	Østkraft	Denmark	Session 4
Åsne Godbolt Lund	Sintef	Norway	Session 3
Herbert Greisberger	Energy and Environment Agency of Lower Austria (ENU)	Austria	Session 2
Lars Gulbrand	Ministry of the Environment and Energy	Sweden	
Grete Håkonsen Coldevin	The Norwegian Smartgrid Center	Norway	Session 0
Birgit Hernes	The Research Council of Norway	Norway	Session 0 and 3
Dieter Hirdes	Smart Innovation Østfold	Norway	Session 4
Øystein Holm	Multiconsult	Norway	
Birte Holst Jørgensen	Technical University of Denmark (DTU)	Denmark	Session 5
Michael Hübner	Ministry for Transport, Innovation and Technology	Austria	Session 1
Tone Ibenholt	The Research Council of Norway	Norway	
Astri Irene Fotland	eSmart Systems	Norway	
Muhiddin İzgi	Ministry of Energy and natural resources	Turkey	
Helle Juhler-Verdoner	Danish Energy Association	Denmark	Session 5
Ludvig Karg	B.A.U.M. Consult GmbH	Germany	Session 3
Cecilia Katzeff	Interactive Institute Swedish ICT (TII)	Sweden	Session 3
Nicole Kerkhof	Netherlands Enterprise Agency (RVO)	The Netherlands	Session 4
Rob Kool	Netherlands Enterprise Agency (RVO)	The Netherlands	Session 0 and 3
Atsushi Kurosawa	The Institute of Applied Energy	Japan	Session 5
Monica Löf	Vattenfall	Sweden	Session 3
Kari Mäki	VTT	Finland	Session 1
Robert Marlay	Department of Energy (DOE)	USA	Session 4
Juan Martinez	Ministerio de Industria, Energía y Turismo	Spain	
Lene Mostue	Energi 21	Norway	Session 0
Stig Ødegaard Ottesen	NTNU, eSmart Systems	Norway	Session 4
Thor Øivind Jensen	University of Bergen	Norway	
Estathios Peteves	DG Energy		Session 5
Johannes Tambornino	JFZ Jülich	Germany	
Heidi Tuiskula	Smart Innovation Østfold	Norway	
Fridtjof Unander	The Research Council of Norway	Norway	Session 0
Pepijn van Willigenburg	De Haagse Hogeschool	The Netherlands	Session 5
Dagfinn Wåge	Lyse Group	Norway	Session 1

Appendix C. Agenda

Day 1, Wednesday 3 June

Session 0: 9:00-10:30 Introduction

This session provides background and context for the Workshop. It reminds participants of the purposed, interactive nature of presentations, dialogue and social interactions, and the expected outcomes, and post-meeting activities and communications.

<table>
<tr><th colspan="4">Introduction</th></tr>
<tr><td colspan="4">Chair: Rob Kool</td></tr>
<tr><td>08:30</td><td colspan="3">Registration</td></tr>
<tr><td rowspan="6">9.00
- 10:30</td><td colspan="2">Welcome</td><td>Fridtjof Unander,
The Research Council of Norway</td></tr>
<tr><td colspan="2">Previous work of the group, Rationale of the workshop</td><td>Rob Kool, Chair EGRD,
Netherlands Enterprise Agency</td></tr>
<tr><td colspan="2">Practical information</td><td>Birgit Hernes, The Research Council of Norway</td></tr>
<tr><td>1</td><td>IEA’s Smart Grids Technology Roadmap, ISGAN's Review of feasible technologies for enhanced capacity and flexibility and the IEA's ETP 2014</td><td>Luis Munuera,
Energy Demand Technology Unit, IEA</td></tr>
<tr><td>2</td><td>Norway: Energy21, Strategy for energy research</td><td>Lene Mostue,
Energy21, Norway</td></tr>
<tr><td>3</td><td>Mowing towards the Smart Grid: The Norwegian case Experiences and actions taken by industry, academic and research sectors.</td><td>Grete Håkonsen Coldevin,
The Norwegian Smartgrid Center</td></tr>
<tr><td>10:30</td><td colspan="3">Coffee break</td></tr>
</table>

Session 1: 11:00-14:15 (including lunch)
Benefits of Smart-Grid/ICT End-Use Innovations

This session will focus on the possible benefits and opportunities that smart grids can enable for the end-users, illustrated by examples from different sectors. What kind of services and what kind of products can become available to end-users, and what kind of companies are most likely to be in the front of the development?

Questions to be addressed:

- *What benefits and opportunities will be the first to be realized, and what sectors or end-users might be expected to be front-runners?*
- *Are there significant differences among customer classes (e.g., between commercial buildings and residential buildings)?*

- *Who will pay and for what? What kind of business and financing models will enable more rapid changes?*
- *Is it possible to imagine a "tipping point" of smart grid technology?*

1. Benefits of Smart-Grid/ICT End-Use Innovations			
Chair: Rob Kool			
11:00	4	Residential Demand Response – an iPower view on how it can contribute to a smart grid	Henrik Bindner, Technical University of Denmark
11:30	5	Smart grid gives new business opportunities and end-user services	Dagfinn Wåge, Lyse Group, Norway
12:00	6	Integration of electric transportation with smart grids	Kari Mäki, VTT, Finland
12:30		Lunch	
13:30	7	ISGAN – Comprehensive/Integrated View	Michael Hübner, Ministry for transport, innovation and technology, Austria
14:00	Discussion		

Session 2: 14:15-15:45 Barriers to Realizing Benefits

If this is so smart, why doesn't it implement itself?

The session will focus on various kinds of barriers connected to implementation and use of Smart Grid systems. And give examples on how they barriers can be overcome.

Questions to be addressed:

- *Who will pay for system flexibility and resilience – do we need new business models?*
- *What kind of barriers do today's regulatory frameworks represent?*
- *What should utilities know about their consumers? Is a electricity end-user a system asset or a liability?*
- *Who will lead the smart grids transition? Will the development be led by existing utilities and enterprises or will new organizations form?*
- *What is most important, technology, business models, standards, or policy-regulatory frameworks?*

2. Barriers to Realizing Benefits			
Chair: Herbert Greisberger			
14:15		World café: Barriers and how they can be overcome	
15:00		Summing up and discussion	
15:30		Break	

Session 3: 16:00-18:30 Insights into End-Use Behavior

And what about smart users? Understanding the end-users behavior is crucial to realize the potential of smart ICT. The session will discuss end-users behavior with respect to Smart Grid applications and focus on lessons learned from case studies and knowledge from recent research and studies on end-users behavior.

Questions to be addressed:

- *How important is consumer confidence to ensure a successful implementation of the smart grid?*
- *What should consumers know about electricity? What if they do not care to know that?*
- *To realize the potential of the smart grid, will it be necessary for consumers to change behavior? What are the experiences in this sector or others on how people do or do not change behavior with available technology?*
- *Are there differences in behavior between private and professional end-users, and what does that mean?*

3. Insights into End-Use Behavior			
Chair: Birgit Hernes			
16:00	8	Presentation from DSM "Closing the Loop"	Sylvia Breukers, Duneworks, The Netherlands
16:30	9	Smart Consumer, Smart Customer, Smart Citizens	Ludwig Karg, B.A.U.M. Group, Germany
17:00	10	Demo Gotland,	Monica Löef, Vattenfall AB, Sweden
17:30	Break		
17:45	11	Market, money and morals. Understandings of Norwegian energy consumers	Åsne Godbolt Lund, Sintef, Norway
18:15	12	Touchpoints and practices in the smart grid,	Cecilia Katzeff, Interactive Institute Swedish ICT, Sweden
18:45	Discussion, close day 1		
19:00	Group Dinner – at The Research Council of Norway		
21:00	Boat trip on the Oslo fjord with transport to Oslo city center and Sandvika (optional)		

Day 2, Thursday 4 June

Day 2 of the workshop will focus on different solutions for implementing the smart grid and applications that can give benefits to end-users, businesses and the society at large. The day will be divided into two sessions; the first one will concentrate on technology and the second one on business models and framework conditions.

Session 4: 09:00-11:45 Technology/Software Solutions and R&D Priorities

The session will look the need for technology and software development that will be necessary. What should be the priorities for government support to R&D be, and what kind of enabling technologies will be important?

Questions to be addressed:

- *What kind of enabling technologies are most important, from an end-user perspective?*
- *What kind of priorities should government have in their R&D investments?*
- *What is the "killer app" for smart grids? How do we realize that potential?*
- *Is technology driving business models for smart grids? Or do good business ideas drive grid innovation?*

4. Technology/Software Solutions and R&D Priorities			
Chair: Bob Marlay			
09:00	13	ISGAN's "Spotlight on Demand Side Management": lessons learned in in developing and deploying technologies,	(speaker to be confirmed)
09:30	14	The Netherlands experiences	Nicole Kerkhof - RVO, The Netherlands
10:00		Coffee break	
10:30	15	Charge flex, management of loading of electric vehicles	Stig Ødegaard Ottesen, NTNU/E-smart, Norway
11:00	16	Ecogrid2015 – Experience with energy management systems and customers	Maja Felicia Bendtsen, Østkraft, Denmark
11:30	Discussion		
12:00	Lunch		

Session 5: 13:00-15:15 Policy, Markets, Government Interventions

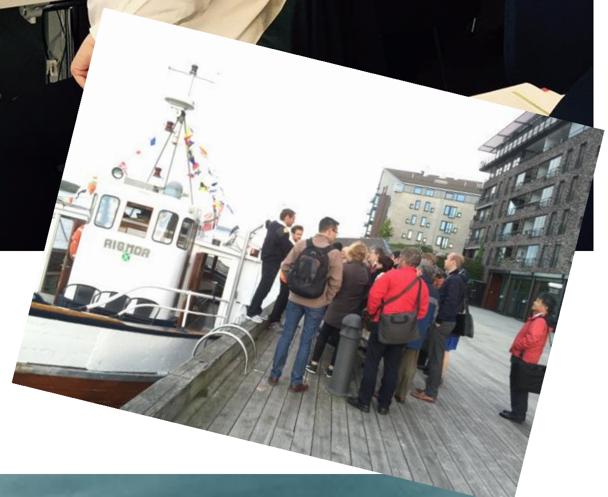
The session will discuss the importance of regulatory framework conditions, business opportunities and the need of new business models. The section will also focus on the research needs in this area.

Questions to be addressed:

- *How important is regulatory framework to achieve benefits from the smart grid? Does it need to be changed and if so, what sort of change is needed?*
- *Which is better: national versus common frameworks? Which is feasible?*
- *Is there a need for more incentives for the industry, for the end-users?*
- *The combination of power systems and ICT opens up new business opportunities, likely cutting across sectors. How do we exploit these opportunities?*

5. Policy, Markets, Government Interventions			
Chair: Estathios Peteves			
13:00	17	EUs smart grid initiative	Henrik Dam – DG Energy
13:30	18	Intelligent Energy through flexibility across energy systems and activating flexibility in buildings	Helle Juhler-Verdoner, The Danish Intelligent Energy Alliance
14:00	19	Smart community demonstrations - experiences in Japan	Atsushi Kurosawa, The Institute of Applied Energy, Japan
14:30	20	Do we really need to change to make the most of the benefits of DC?	Pepijn van Willigenburg, De Haagse Hogeschool, The Netherlands
15:00		Discussion	
Summing Up			
Chair: Birte Holst Jørgensen,			
15:15		Discussion & Round-the-Table; Takeaways from the workshop Closing Remarks Follow-Up Actions (Reports, Communications, Briefs to CERT)	
16:00		End of workshop	

Appendix D. Photos from the Workshop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