Smart Grid in Norway: Status and Outlook

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Introduction

The Smart Grid is a term coined to give a name to a wide range of solutions for the electricity grids of the future. Experience is already showing that each country and even regions are responding to the driving forces by developing their own versions of Smart Grids, depending on the national/regional characteristics of energy systems, communication systems, geography, topography, industrial and societal contexts. Consequently, some issues might well be common on a global scale and will find solutions through international development and cooperation while others instead will need tailored solutions to fit the national/regional context.

In Norway, the smart grid priorities are partly driven by the regulator (e.g. the requirement in Norway to implement smart meters by 2019-01-01), and partly by new technologies and challenges such as distributed generation (e.g. small hydro, PV), adoption of electrical vehicles, new challenging electric devices such as induction stoves, fiber-to-home communication, smart phones etc. Given these peculiarities, Norway can in some areas import Smart grid solutions and knowledge from international cooperation while in others it will need to develop tailored solutions to fulfill its own needs. At the same time, some nationally developed solutions, technologies and software might have potential for the international market. In support to this emerging vast potential for development in the Smart Grid sector, Norway has given priority to this topic through dedicated R&D-D programs by the Research Council of Norway (RCN), The Energy Efficiency Agency (Enova), academia and industry. This has resulted in a set of joint multisector initiatives to face the challenges brought along with the smart grid.

This article will present Smart Grid initiatives at different levels in an attempt to portrait the Norwegian approach to Smart Grid development and expose it to a discussion: The Norwegian Smart Grid Center; the National Smart Grid Laboratory; FME CINELDI – a long term centre for environment-friendly energy research; actions taken by the Power Industry in Norway (“living labs”, demonstration or pilot projects) in the “Demo Norway” framework; strategic positioning of R&D priorities from the Research Council of Norway; overview of ongoing short term R&D projects.

National smart grid context

Smart grids development will be different in different parts of the world depending on national or regional energy system characteristics and challenges. In Norway historically inexpensive hydro power has been the main energy source for electricity generation. Thus, today 98- 99% of the total electricity generation in Norway is hydro power based. Due to this fact, it is not on the Norwegian smart grid agenda to convert fossils based electricity generation to renewable generation. But as

Norway is committed to fulfill the so-called European Renewables Directive, 67% of the total energy use in Norway should be based on renewable energy by 2020, which requires an increase in renewable electricity generation which should be used to substitute the use of fossils based energy in industry (on-shore and off-shore) and in transport. Incentive schemes in terms of a common green certificate market with Sweden thus motivates for more renewable electricity generation which in part will be based on intermittent energy sources like wind, PV and small hydro power plants without any reservoir capacity. The Norwegian power system and electricity use has several characteristics different from most countries giving specific challenges and opportunities within the Smart Grid context:

- Large part of electricity in the domestic sector used for space and water heating offers much flexibility for demand response and demand side management schemes.
- Large availability of hydropower plants with reservoirs which are fast and easy to control. These offer lowcost balancing services. (Most new production is small scale distributed generation without storage.)
- Quickly growing use of purely battery based electric vehicles due to very good incentives (tax exempt, free parking, free use of toll roads and bus lanes etc.)
- Significant part of the LV distribution system is of type 230 Volt IT system (230 V line voltage) different from the 400 Volt line voltage systems in most of Europe.
- Weak grids with approx. 40% of the supply terminals weaker than the standardized EMC reference impedance give more severe voltage quality problems when connecting EVs, PVs etc. than many countries
- Well-developed broadband communication to homes and increased use of fiber-to-home communication provided by power utilities.
- Well-developed electricity markets. There are multinational markets with significant volumes for dayahead, intra-day and balancing with participation of producers and consumers.

In total, Norway's power system and markets are well positioned for a future smarter and more renewable power and energy system, but some barriers such as weak grids in parts of the LV system needs to find their cost efficient and smart solutions.

The Norwegian Smartgrid Centre

The Norwegian Smartgrid Centre (NSGC) was established in 2010 on the basis of a recommendation of the Norwegian Ministry of Petroleum and Energy in its national strategy process for defining future Energy R&D in Norway.

NSGC is a strategic partnership, organized as a membership organization, where the purpose is to coordinate and promote smart grid R&I initiatives, education, and exchange of information between the members of the NSGC.

The NSGC also promotes international initiatives on Smart Grid by being a member of GSGF (2012), by acting at the Executive Committee of ISGAN (2016), and holding a position as Co-Chair at the EU National Stakeholders Coordination Group under the Energy Platform on Smart Energy Networks for the Energy Transition (**ETIP-SNET, 2016**).

Founded in: 2010
No. of Members: 46
Target Audience: Industry, Research Institutes, Education, Government
Top competencies: Advanced Metering Infrastructure | Demand Response | Private & Industrial Prosumers |
Storage | Market Integration | Grid Intelligence | Distribution Network Solutions | Island Power System | E-Mobility
Our main goals: Bring SG stakeholders together| Promote SG concept | Facilitate transition to roll-out | Develop roadmaps| Promote technology & innovation Cooperation
Interests for international cooperation:
Demand Response & Prosumers | Big Data |
Smart Cities | Island Power Systems | Storage

"Demo Norway" for Smart Grids

One of the main achievements of the NSGC so far is the establishment of **Demo Norway for Smart Grids**, a national Smart Grid demonstration and laboratory platform. The main purpose of Demo Norway is to support development, testing and verification Smart Grid technologies, services and use cases both in real life and laboratory environment. Demo Norway comprises presently eight real power system demo sites with more than 10.000 network customers with Smart meters connected as well as the brand new National Smart Grid Laboratory – see the figure below:

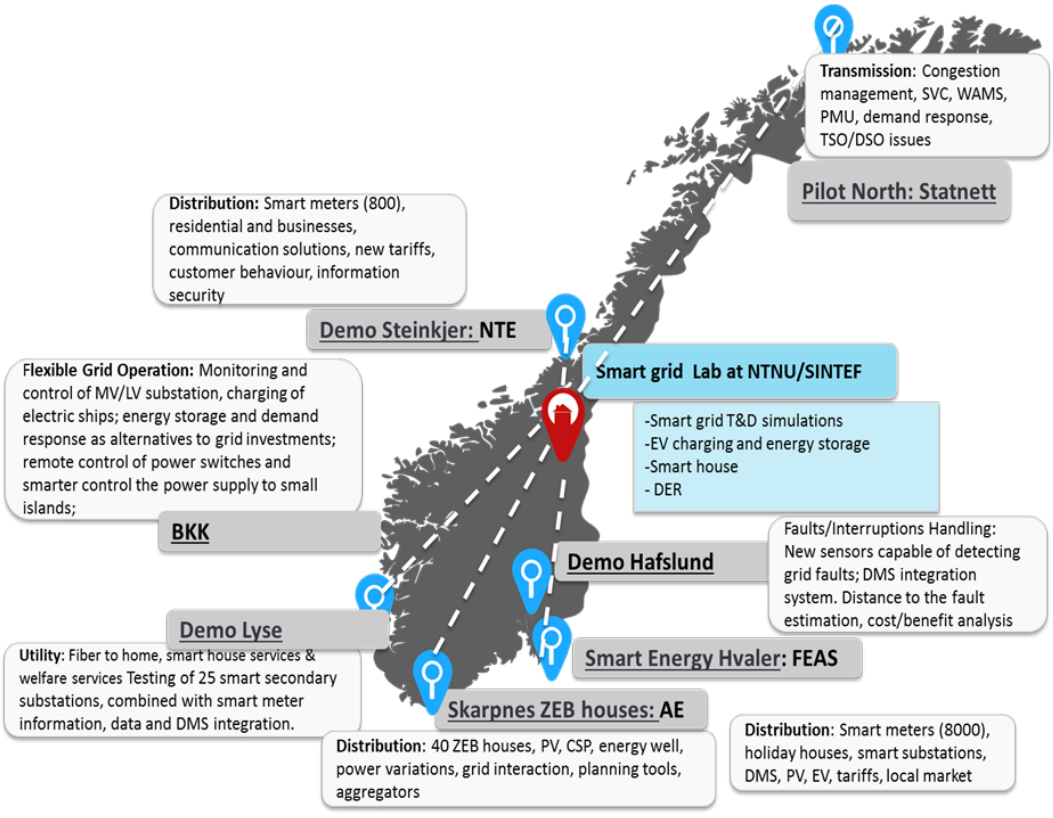

Figure 1 Demo Norway for Smart Grids

The demos are generally operated by regional DSOs except for *Pilot North*, which is operated by the Norwegian TSO: Statnett. The focus areas for the different pilots are indicated in the map (figure 1).

Key words describing selected ongoing demonstration projects:

- **Demo Smart Energy Hvaler:** Consists of 6800 customers in an island community. The demo focuses on developing and testing enhanced network utilisation, end user flexibility, residential PV and storage solutions, prosumers, local energy market solutions.

- **Demo Steinkjer:** Energy companies, vendors, researchers, customers and governmental bodies can test smart meters, communication, system services, and other products on 800 end users consisting of ordinary households, commercial companies and industry. Flexibility of end users, value added services for DSOs, dynamic tariffs schemes, and feedback solutions to customers of Smart Meter Data are particularly in focus.

- **Demo Lyse Customer Services & Demo Smart City Grid:** Testing of new energy services for residential customers. Gateway rollout to >150,000 customers as a new service platform. Testing of 25 smart secondary substations, combined with smart meter information, data processing and integration into a new DMS.

- **Demo Hafslund Grid Faults and Interruptions Handeling:** Installation of sensors capable of detecting grid faults; information about grid faults from sensors connected to the control system. Combination with various measurements in the grid for calculation of the distance to the fault location. A new methodology for calculation of costs and benefits.

- **Demo BKK Flexible Grid Operation:** Monitoring equipment and control of MV/LV substation where special loads are connected, e.g. charging stations for EV, prosumers, tram, charging of electric ferry/ships; evaluation of energy storage as an alternative to grid investments; remote control of power switches and smarter control the power supply to small islands; DR as an alternative to grid investments (industry customers).

- **TSO Pilot North Norway:** Load management and smart system operation on the basis of the monitoring and control of 200 load objects. Executed in cooperation with local DSOs.

Furthermore, together with 18 other national or regional innovation - and technology platforms in Europe the NSGC has mapped its smart grid activities in order to make it easier identify areas of common strengths and cooperation:

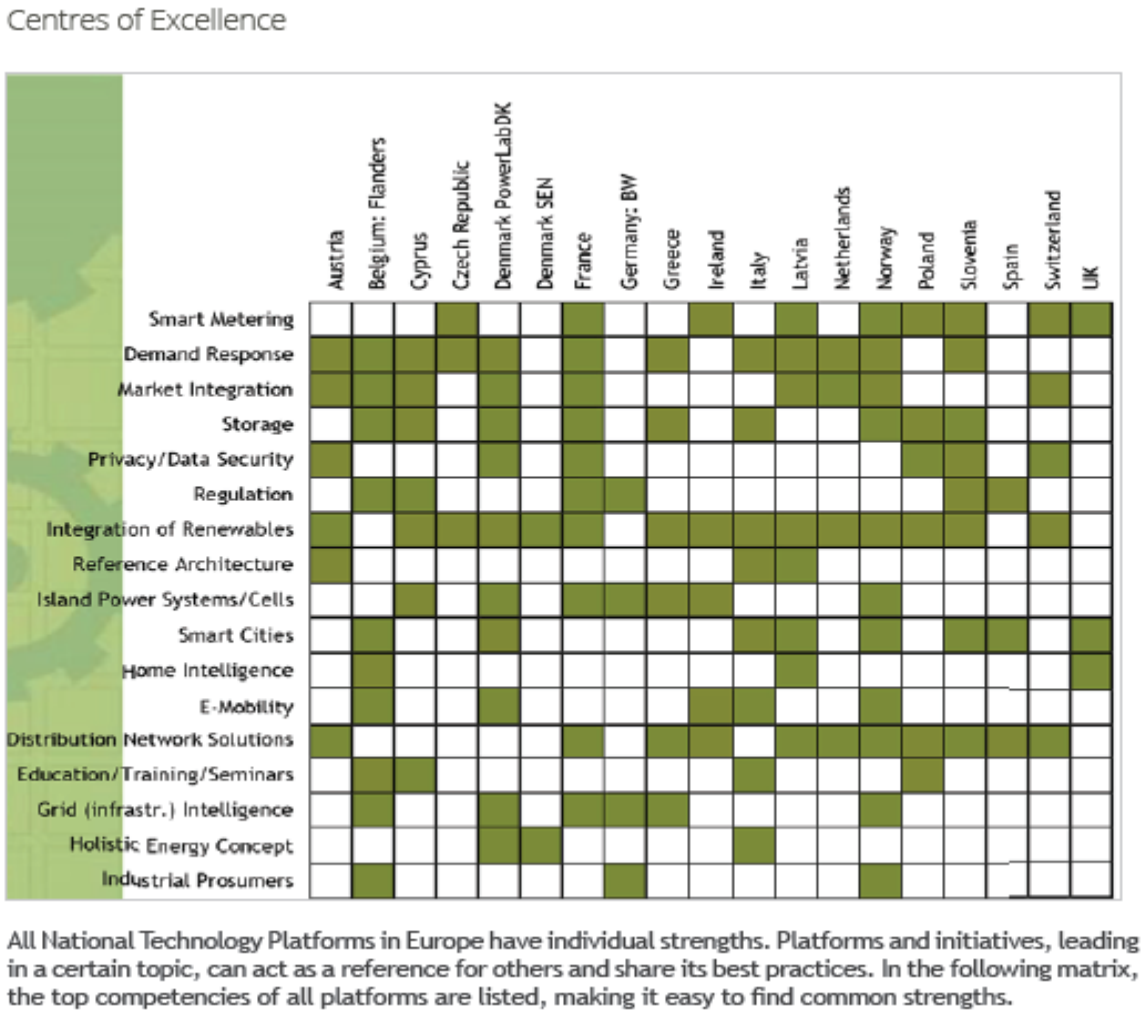

Figure 2 Mapping of Demo Norway for Smart Grids in comparison to other technology platforms in Europe.

See the document **National and Regional Smart Grids initiatives in Europe**" - **Cooperation opportunities among Europe's active platforms** (May 2016, 2nd Ed.) on the website http://www.smartgrids.eu/ETP_Documents

Experience from the "living labs" in Demo Norway

The experience from the living labs under the Demo Norway for Smartgrids umbrella, has proven to be very useful for ongoing full-scale rollout of Smart Meters in Norway, which should be completed by January 1st 2019. The learnings range from practical issues concerning smart meter installation and communication to investigations on how to utilize customer flexibility for smart operations of transmission and distribution systems.

The National Smart Grid Laboratory

Immature and high-risk use cases and technologies are best first studied and tested in laboratories while the more mature use cases and use cases which include the behaviour or human response of customers need to be tested in real power systems with real customers. In 2016 the Norwegian National Smart Grid Laboratory at NTNU and SINTEF Energy research was formally opened. A specific feature of the laboratory is the opportunity to integrate real-time simulations and physical power system assets (power hardware-in-the-loop) with ratings up to 200 kVA, 400 V AC or 700 V DC. The set-up is very flexible allowing a range of use cases to be tested ranging from smart homes/micro grids to AC or multi-terminal DC transmission systems. The figure below shows the laboratory concept.

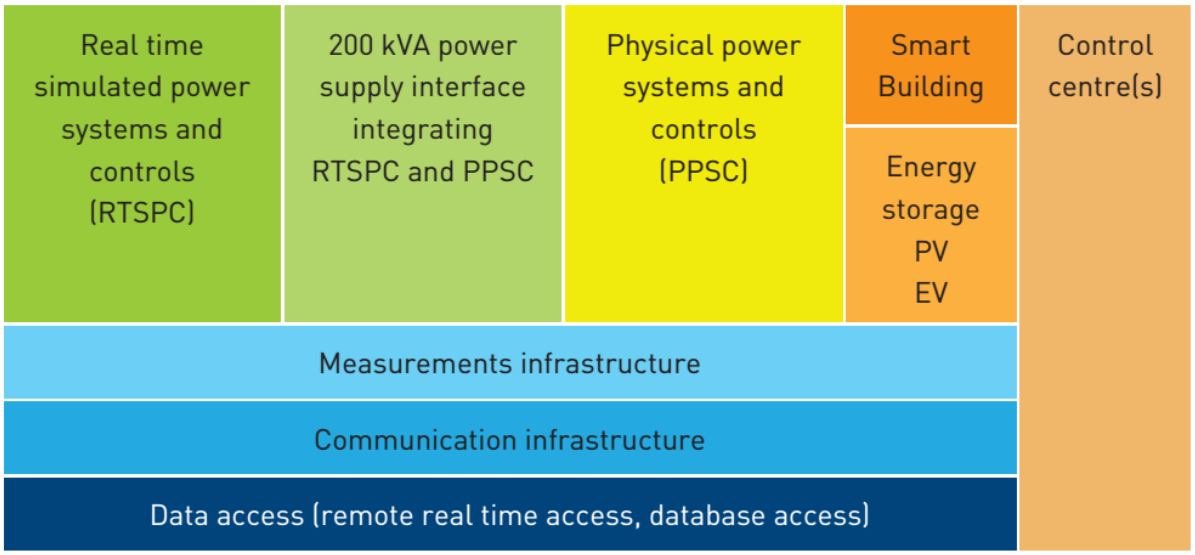

Figure 3 The National Smart Grid laboratory concept at NTNU and SINTEF

FME CINELDI: A newly established 8-yrs research centre

CINELDI is one of the new Centres for Environmentally-Friendly Energy Research in Norway. The objective is to enable a cost-efficient realisation of the future flexible and robust electricity distribution grid. The centre is headed by SINTEF Energy Research in cooperation with NTNU: https://www.sintef.no/cineldi

FME CINELDI has a budget of about NOK 360 million (about 40 MEuro) and will last for 8 years. 16MEuro of the total funding is public funding from the Research Council of Norway, the rest of the funding is from industry partners and strategic funding from the research insitututions. CINELDI targets innovation on the system level of the cyber-physical distribution system of 2030-2040. The main topics of research are smart grid development, asset management and operation, interaction between the distribution system operators and the transmission system operator, microgrids and utilization of flexible resources in the system. Altogether, this will provide input to smart grid scenarios and transition strategies for the Norwegian distribution system.

This centre is a unique opportunity to build up a national team for the long-term research needed to digitalize the distribution system, where multi-disciplinary research teams mainly at SINTEF and NTNU work together with leading grid companies (DSOs), the system operator (TSO) and leading technology providers. There are 29 partners in CINELDI altogether, including the energy regulator, electricity authority and the communications authority, as well as partners for knowledge transfer and innovation. CINELDI will also collaborate with international research institutes in Europe, the USA and Japan, to strengthen our competences. It is the ambition that CINELDI will become a European reference project. The Norwegian SmartGrid laboratory is a unique and important resource for the research in CINELDI as well as "living labs" at the grid companies where pilot projects will be running.

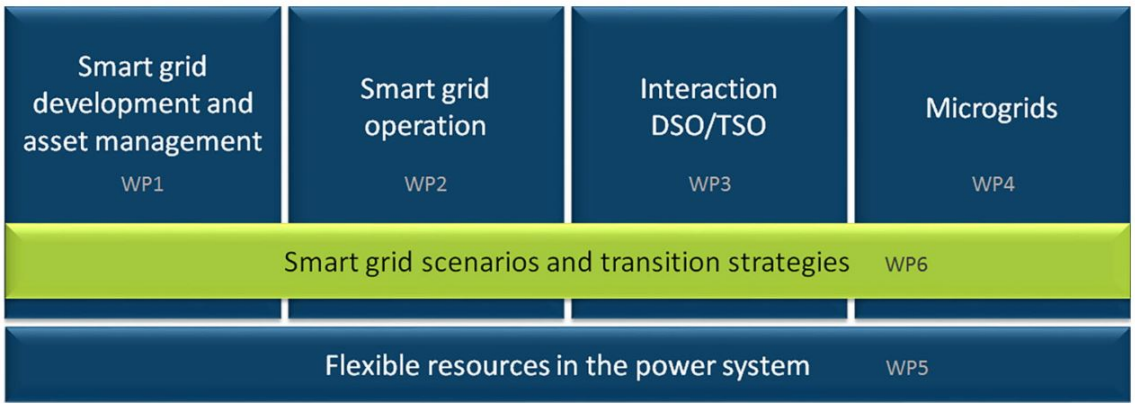

Figure 4 The National Smart Grid laboratory concept

What achievements do we foresee from the research in CINELDI?

The DSOs will realise an intelligent grid that is robust, flexible and cost-effective. The TSO will get access to flexible resources from grid customers and the DSO. The Technology providers have developed new products and services and strengthened their competitiveness. The grid customer being a producer, a consumer or prosumer, has gotten the value of their flexible resources realised.

The main objective of CINELDI, is to enable a cost-efficient realisation of the future flexible and robust electricity distribution systems including TSO/DSO interactions. This will pave the ground for increased distributed generation from renewable sources, electrification of transport, and more efficient energy use. To develop a credible set of Smart Grid visions and scenarios is a key element, which will provide a basis for fostering new ideas and innovations. To develop guidelines and recommendations for the transition to the flexible, robust, and cost-efficient electricity distribution system of 2030 – 2040 is an important goal for CINELDI.

Smart grid outlook Norway 2017

As mentioned, the roll-out of smart meters keeps the DSOs quite busy these days and the smart metering infrastructure will be an important element in the next generation power system. But, there is not a clear view or road map describing the Norwegian Smart Grid version 2030-2040. There are so many options and the rapid technology development e.g. the IoT development, will bring almost infinite ways of combining stakeholders (old, new), technologies and systems in the construction of next generation power systems/energy systems - and their integration with smart city concepts (which at this stage are even more fuzzy than the smart grids). The Norwegian Smartgrid Centre has for worked for new instruments to support the strategy work needed to create a more clear vision and transition strategy for the future development.

During 2016 a new initiative were launched which will become fully operational in 2017**: Forum for the future power networks in Norway**

The Forum for the future power networks is operated by the Norwegian energy regulator NVE on a mandate from the Ministry of Petroleum and Energy. The scope is to develop a vision for the development of future power grids with respect to more efficient operation, utilization and development. Especially to evaluate the implications of the future smart grid for various stakeholders and the needs for the development of the regulatory framework.

Overview national research priorities and publicly funded R&D projects in Norway

A	***Key country research priorities within Smart Grids field (research council of Norway)***
	Smart operation and planning in DSOs and TSOs Microgrids and next generation of power electronics Digitalization of the power system (utilizing smart assets, data architecture and management, data analytics, data security, open source) Electricity market design and regulation enabling distributed energy resources (Active customers/prosumers; Storage; Distributed renewable production) The smart and flexible electricity system within a larger energy system transition

B	***Research Framework***			
B1	**Government or public funded agencies supporting the Smart Grids research** (Top 5 Agencies)			
	Agency Name	***Existing activities***	***Potential future activities***	***Agency Web***

1	Norwegian Research Council Strategic Program and FME Scheme	ENERGIX-program FME Centers ERA-NET Smartgrids +	New calls every year	www.rcn.no; www.energix.no
2	Enova	Demonstration of Customer Oriented Feedback solutions based on Smart Meter Data	Energy system demonstration program	www.enova.no
3	SkatteFUNN R&D tax incentive scheme	All branches of industry and all types of companies can apply for support from the SkatteFUNN Tax Incentive Scheme. To be eligible, the company must seek to develop a new or improved product, service or production process through a dedicated R&D project. The incentive is a tax credit and comes in the form of a possible deduction from a company's payable corporate tax	Innovation and commercialization	http://www.skattefunn.no
4	Regulator's R&D-D funding	The Regulator (NVE) runs a program for R&D-D where 0.3 per cent of the grid company's income base is included as an addition to the companies' annual income framework. The purpose of the scheme is to stimulate research and development that can contribute to more efficient operation and development of the grid.	Funding scheme	https://www.nve.no/elmarkedstilsynet-marked-og-monopol/okonomisk-regulering-av-nettselskap/finansiering-av-fou/
5				

B2	**Industries supporting Smart Grids research** (Top 5 industries; there are more than these active)			
	Industry Name	***Existing activities***	***Potential future activities***	***Industry Web link***
1	ABB	Smart monitoring and control	SCADA, secondary sub stations	www.abb.no
2	Eltek	Local storage; micro grids	Power conversion	http://www.eltek.com/
3	Powel	DMS, Big data handling	Big data analytics	www.powel.no
4	eSmart	Prosumer support and energy use	Big data analytics	https://www.esmartsystems.com/
5	Embriq	ICT for smart grids	Digitalization	https://www.embriq.no/energi/

B3	**Utilities supporting the Smart Grids research** (Top 5 Utilities; there are more than these active)			
	Utility Name	***Existing activities***	***Potential future activities***	***Utility Web link***

1	Statnett (TSO)	Smart monitoring and control	Same	http://www.statnett.no/
2	Agder Energi	Prosumers, zero emission buildings	Smart monitoring and control	
3	Hafslund	Smart monitoring and control, big data analytics	Smart monitoring and control	
4	BKK	Self healing, storage, grid flexibility	Smart monitoring and control	
5	Lyse	Future energy services, local markets, smart city grid	Smart monitoring and control, new services	https://english.lyse.no/?lang=en_GB
B4	**Other entities supporting the Smart Grids research** (Top 3 entities)			
	Entity Name	***Existing activities***	***Potential future activities***	***Web link***
1	National Smart Grid Centre	National technology platform for smart grids		www.smartgrids.no
2	NCE Smart energy market	Industry cluster for future energy market solutions		www.ncesmart.no
3	Smart grids services cluster	Industry cluster on SME's for smart grid solutions		http://smartgridservices.no/
C	***Research cooperation activities on Smart Grids in Norway***			
C1	**Main finished relevant projects on Smart Grids** (Top 5 projects with public funding)			
	Project Name	***Focus***	***Main partners, partner type (e.g. research institution, TSO, DSO, industry) and partner nation***	***web link***
1	DeVID	Demonstration and verification of smart power converters for smart applications	DSO, RI	http://www.sintef.no/Projectweb/DeVID/
2	Next generation control center	Principles for smart SCADA-systems	RI, DSO	
3	Enabling Smart Grids	Power converters for smart grids	Industry, RI	
4	Spesnet	Voltage quality in smart distribution	DSO, RI	
5	Flexelterm	Flexible use of electricity and heat	DSO, RI	
C2	**Main ongoing relevant projects on Smart Grids** (Top 10 projects with public funding, from the Research council of Norway or ENOVA)			
	Project Name	***Focus***	***Main partners, partner type (e.g. research institution, TSO, DSO, industry) and partner nation***	***Direct contact and web link***
1	FME CINELDI	The future intelligent electricity distribution.	29 partners. DSOs, TSO, Authorities	www.sintef.no/cineldi

2	Samba	Smarter Asset management with big data	TSO, R&D Institutions, Industry	
3	FlexNet	Flexibility in the future smarter distribution grid	DSOs, R&D Institutions	
4	Smart energy use based on smart metering	7-demonstration projects on feedback solutions based on smart metering	R&D institutions, DSO, TSO	
5	Control Centre Platform for Synchrophasor and PMU	Control Centre Platform for Synchrophasor and PMU Applications, Integration and Data Exchange	TSO, University,	
6	ProSmart	Power system protection in a smartgrid perspective –	University, TSO, DSO, Industry	
7	Flexmod	Modelling Flexible Resources in Smart Distribution Grid	University, TSO, DSO, Industry	
8	The future DSO	Organizing for innovation and reaping the benefits of new technology for the future DSO.	DSO, R&D institutions.	
9	SmartGuide	(ERA-NET project) Defining Planning and Operation Guidelines for European Smart Distribution Systems	Belgium, Germany, Norway (DSO, Rresearch insitute), Portugal, England	
10	IoTSec - Security in IoT for Smart Grids	promote the development of a safe and secure Internet-of-Things (IoT)-enabled smart power grid infrastructure.	Universities, DSOs, Industry	
C3	**Main foreseen <u>future</u> relevant projects on Smart Grids** (Top 5 projects that got funded from 2017)			
	Project Name	***Focus***	***Main partners, partner type (e.g. research institution, TSO, DSO, industry) and partner nation***	***web link***
1	E-REGIO	Smart community energy markets	RI, DSO, Netherlands, Sweden	
2	PowerShaper	Realizing cost efficient energy storage for power efficiency in buildings through bi-directional power electronics.	Industry, University	
3	Integer	Integration of storage in the distribution grid	DSO, R&D Institutions, Industry	
4	Energytics	Test and verification of big data analytics based on smart meter data	DSOs, R&D Institutions	

5	Smart Community Neighborhood	Smart Community Neighborhood - driven by energy informatics	R&D institutions, DSO, TSO	

D	***Research infrastructures***		
D1	**Main relevant universities working on Smart Grids** (Top 5 universities)		
	University name	***Area of Research***	***Web link***
1	NTNU	Smart grids	www.ntnu.no
2	Univ. of Stavanger	Energy informatics	www.uis.no
3	Univ. of Tromsø	Microgrids	www.uit.no
4	Høgskolen i Østfold	Information security in IoT	www.hio.no
5	Univ. of Oslo	Information security in IoT	www.uio.no
D2	**Main research institutions/laboratories working on Smart Grids** (Top 5 institutions)		
	Institution and laboratories name	***Area of Research***	***Web link***
1	SINTEF ICT	ICT in the energy sector	http://www.sintef.no/
2	Sintef Energy	Energy systems	http://www.sintef.no/
3	National Smart Grid Laboratory at NTNU and SINTEF	Smart electricity systems	
4	IRIS	Energy use	
5			
D3	**Other entities (e.g. Industries) working on Smart Grids**		
	Entity name	***Area of Research***	***Web link***
1	The Norwegian Smart Grid Centre – Multi-Industry and multi stakeholder collaboration	Umbrella for the whole smart grid R&I field in Norway	www.smartgrids.no