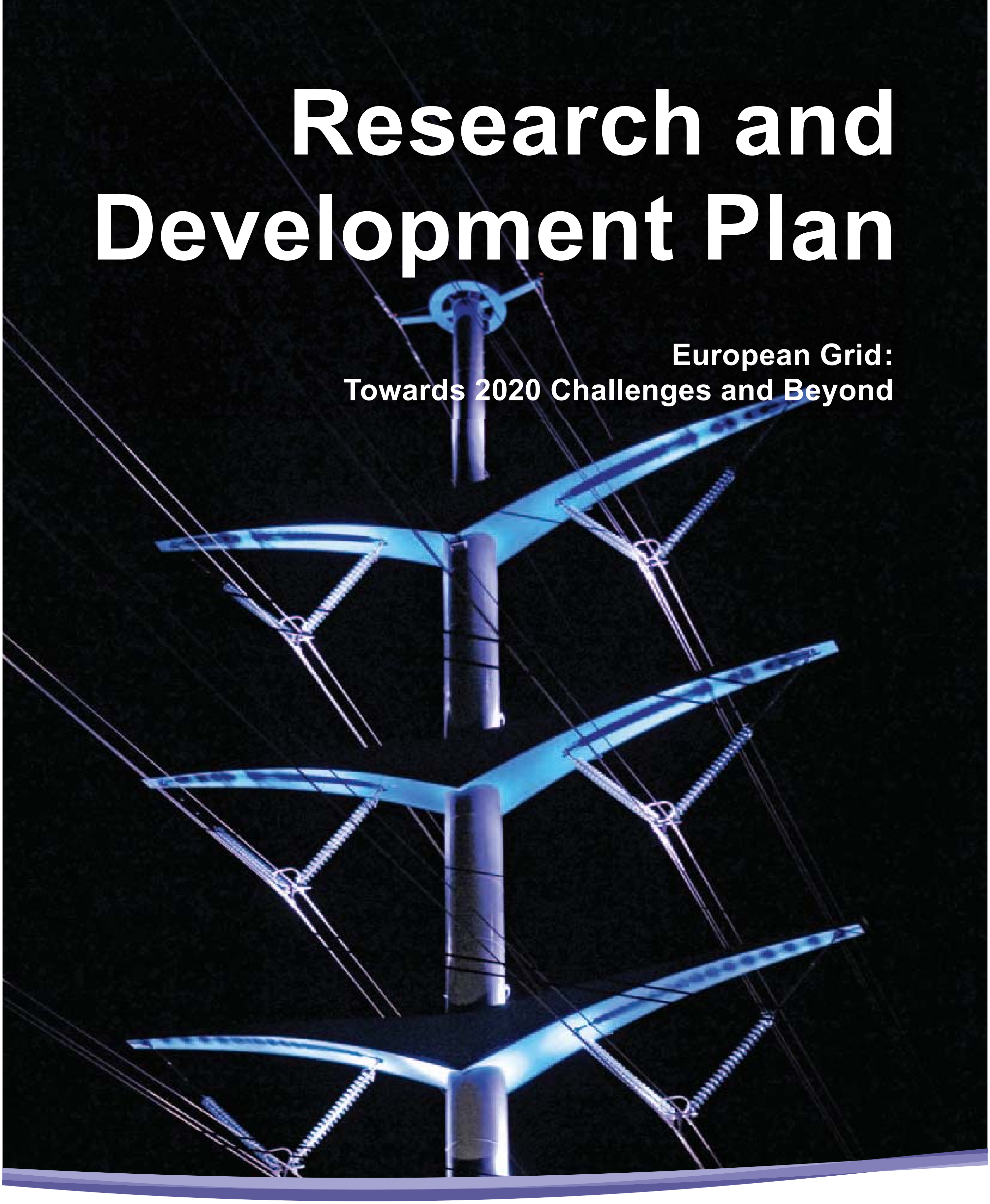
Research and Development Plan



European Grid: Towards 2020 Challenges and Beyond

European Network of
Transmission System Operators
for Electricity

entsoe

Research and Development Plan

European Grid:
Towards 2020 Challenges and Beyond

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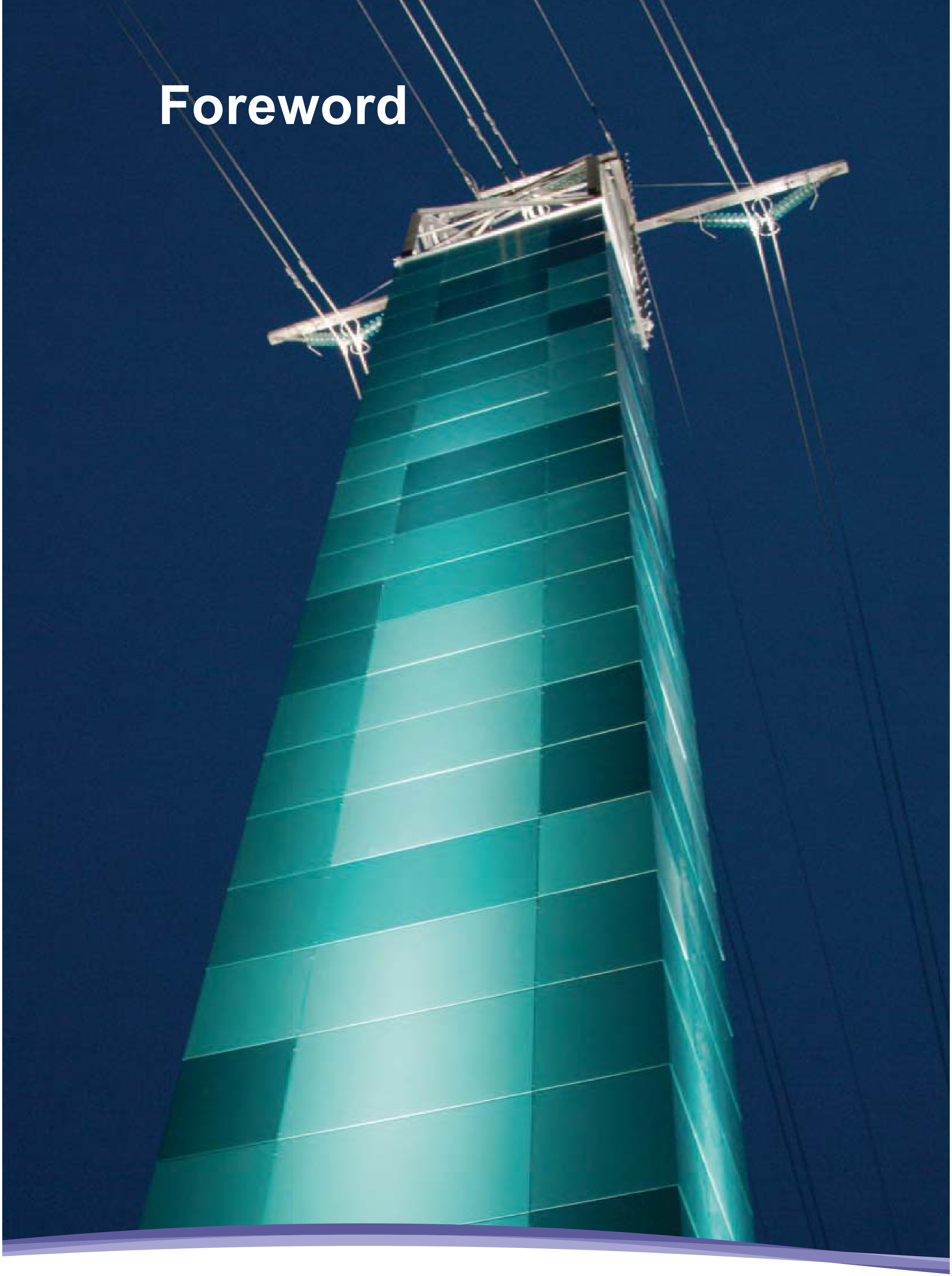
Foreword



This document is an updated version of the first edition of the European Network of Transmission System Operators for Electricity (ENTSO-E) Research and Development (R&D) Plan, which was issued in March 2010. It is required by the Third Energy Package, both in Directive EC/72/09 and in Regulation 714/09, which underline that ENTSO-E shall adopt a research plan for common network operation, by means of an R&D plan included in the annual work program.

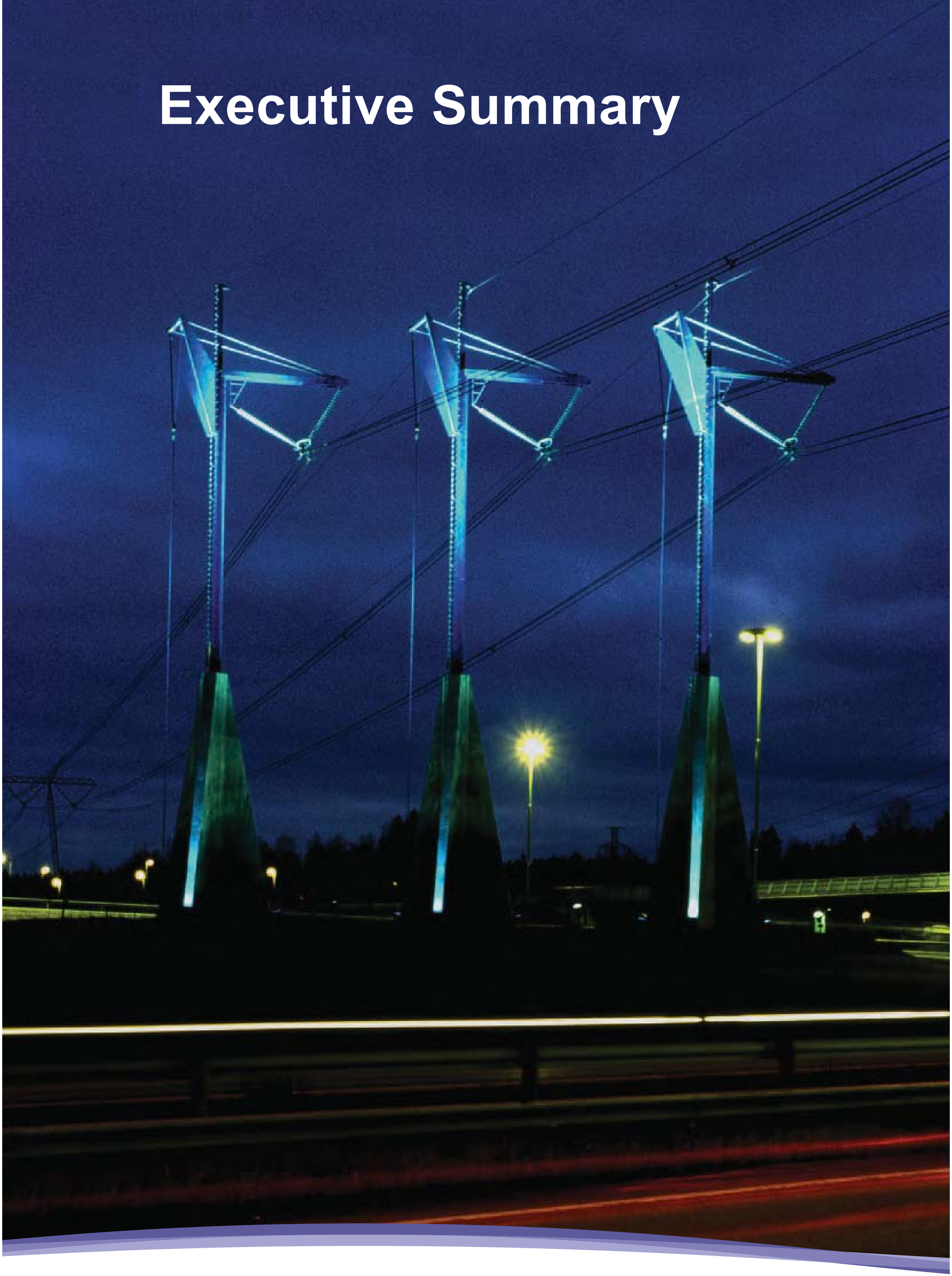
In the context of the European Electricity Grid Initiative (EEGI) as a common platform for transmission system operators (TSOs) and distribution system operators (DSOs), the consolidated ENTSO-E R&D Plan serves the needs of TSOs and contributes to the process launched by the European Commission to create a Strategic Energy Technology (SET) Plan in order to initiate a dialogue between European TSOs, European regulatory authorities, European Union (EU) Member States and the European Commission. This R&D Plan defines priority research fields as a basis for ENTSO-E's active participation in line with the SET Plan of the EU.

The ENTSO-E R&D Plan takes into account the vision of the ENTSO-E TSOs to meet the challenges imposed on the electricity community by EU energy policy targets for 2020 and beyond. The TSOs' vision has led to research, development and demonstration projects, which have specific benefit targets in line with EU energy policy targets. ENTSO-E TSOs have recognized the importance of research and development across the whole range of ENTSO-E's activities and have established an Research and Development Committee (RDC), which will take on the cross-functional role of coordinator within ENTSO-E of the R&D portfolio in all matters relating to the TSOs' business: system operation; electricity markets operation; transmission grid development; asset implementation and asset management; and information communication technology (ICT)-based issues.

ENTSO-E would like to acknowledge members of the Research and Development Committee and its working groups as well as other experts from the ENTSO-E TSOs who were involved in the process. Without their input into discussions, this R&D Plan could not have represented the full range of challenges and could not have been completed on time.

This updated version takes into account stakeholders' comments which were addressed to the transmission part of the EEGI Roadmap consultation process which was carried out at the beginning of 2011. It also includes some important updates on functional project and operational project levels by providing the most recent information on the mapping of the ongoing operational projects to functional projects. A significant effort was made to reformat the plan in order to achieve better consistency with the EEGI Roadmap and Implementation Plan published in May 2010, as well as to provide the reader with concise and condensed information to ensure correct understanding of the topics addressed in the ENTSO-E R&D Plan.

Executive Summary



The transmission grid is a key facilitator for Europe's low-carbon energy future. The 2008 International Energy Agency (IEA) World Energy Outlook predicted that €135 billion would be allocated to pan-European transmission over 2007 – 2030 in a "business as usual" scenario in order to cover the growth in electricity consumption, the replacement of aging infrastructures and to strengthen the integration of national electricity systems. This amount of investment will also help to make use of a large share of fluctuating renewable electricity, mainly from wind and solar energy sources.

European TSOs have noticed the need to speed up R&D activities in the use of electricity highways, offshore grids, long HVAC cables, HVDC technology and the use of smart grids as future tools to meet the challenges of integrating large amounts of renewable electricity. A dramatic increase and rapid changes in the power flow in several regions of the power system have to be managed using enhanced tools in terms of the latest technology in hardware and software. Although the resulting reinforcement of electricity networks can be ensured by a combination of existing and emerging technology, its implementation must take into account pan-European optimization objectives, addressing both the technological and economic dimensions. R&D coordinated by TSOs and by ENTSO-E should contribute to a realistic discussion of these concepts, in preparation for well-founded and well-tested implementations.

ENTSO-E publishes an R&D plan in order to facilitate future operation of the European grids; significant challenges for grids are facilitating integration of massive amounts of RES and developing technology solutions which are cost effective. Working together, TSOs will develop and experiment with new solutions that can be replicated all over Europe. The R&D activities listed in the ENTSO-E Plan cover R&D, demonstration and deployment aspects. The 7th Framework Program funded by the European Commission gives the following definition of R&D activities, which is also adopted in the ENTSO-E R&D Plan

Research and technological development activities means activities directly aimed at creating new knowledge, emerging technology, and products, including scientific coordination. Demonstration activities means activities designed to prove the viability of emerging technology that offer a potential economic advantage, but which cannot be commercialized directly (e.g. testing of products such as prototypes).

ENTSO-E ensures the cross-functional coordination of all TSO research subjects. Priority research fields, which are included in the R&D Plan and subsequently in R&D projects managed by ENTSO-E members (and therefore monitored by ENTSO-E), include the following:

- New architecture and planning tools for the pan-European network,
- new tools to prove the efficiency of technology aimed at increasing both the flexibility and the security of the operation of transmission systems and
- new tools based on simulation techniques that will give rise to new market design options.

Specific R&D products will probably extend from advanced tools for designing future energy scenarios, including:

- new tools for monitoring pan-European network behaviour for better transmission adequacy assessments,
- new tools for better surveys of pan-European markets,
- new tools for market modelling, taking into account the rapidly increasing penetration of RES,
- complementary tools for facilitating the specific market integration of these RES and
- new planning tools dedicated to taking into account active demand.

Further refinements relating to the launch of the R&D Plan and stakeholder participation are needed, taking into account, on the one hand, interaction with other TSOs, DSOs and manufacturers, and on the other, the implementation of the Third Energy Package by EU Member States.

In order to be effective, the proposed R&D work, which addresses European and regional issues, must simultaneously address questions relating to system architecture, power technology, system control and market design. Moreover, it must be coordinated at the European level. Full-scale demonstrations of the state-of-the-art power technology and offshore grid solutions should also be coordinated at the European level. This will allow a reduction in demonstration costs and will reinforce the TSOs' bargaining power when negotiating the future procurement of the validated technology with manufacturers. Last but not least, TSOs will be able to identify the need for emerging functions and technology. This will allow manufacturers initiating R&D programs to provide solutions which will reach beyond 2020, in time to meet future power transmission requirements at the pan-European level.

The release of the ENTSO-E R&D Plan does not address in detail the issues relating to funding and the management of the R&D Plan. The organizational framework and management rules for the ENTSO-E R&D Plan go beyond the current ones used in the 7th Framework Program, which has initiated some joint collaborative research and demonstration projects. ENTSO-E have recently published a position paper entitled "A new regulatory framework for TSO R&D in ENTSO-E countries"[1] with the general objective of defining the main criteria to be developed at the European level in order to guarantee an appropriate, homogeneous and coherent regulatory framework for R&D activities, capable of promoting and incentivising the vital R&D activities by TSOs.

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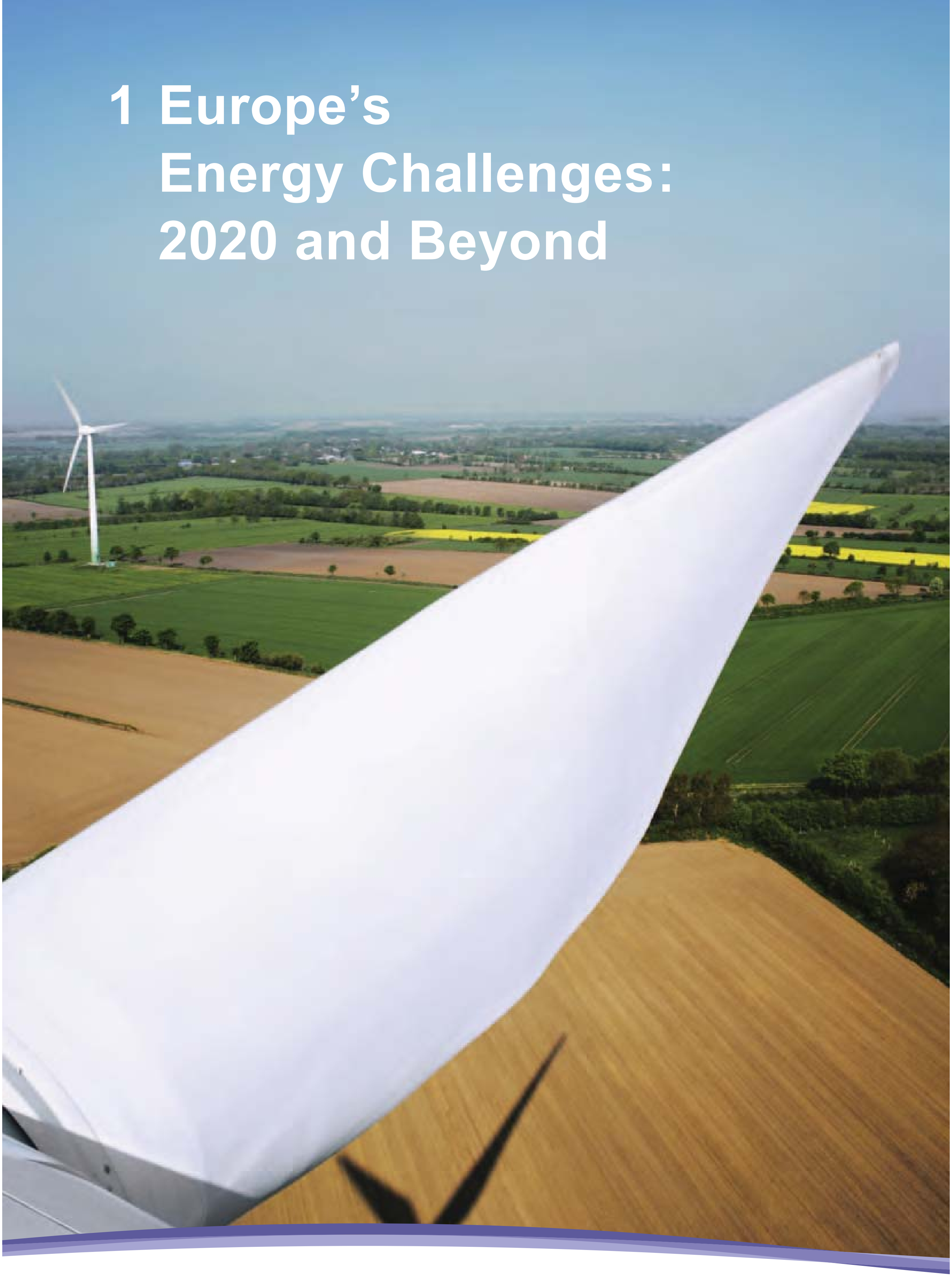
[1] The position paper and the summary are published on the ENTSO-E website. The links are as follows:
- Position paper: www.entsoe.eu/fileadmin/user_upload/_library/position_papers/110701_ENTSO-E_PP_on_Regulatory_Framework_for_RD_vFINAL.pdf
- Summary: www.entsoe.eu/fileadmin/user_upload/_library/position_papers/Summary_of_R_and_D_regulatory_framework_position_paper_18_07_11.pdf

The ENTSO-E R&D Plan is broken down into five clusters, which represent the five high-level topics covered by the R&D Plan. All five clusters are broken down into functional projects, which are high-level projects that may result in various operational projects. Some initial sub-projects have already been defined and others will be defined on a yearly basis in order to implement the functional projects. These new sub-projects are not described or even mentioned in this document. The ongoing R&D projects, the results of which are linked to the functional projects, are described in Appendix 2.

1 Europe's Energy Challenges: 2020 and Beyond



The 2007 EC Integrated Energy and Climate Change Package led all EU Member States to share an initial set of ambitious targets for 2020, namely:

- 20 % reduction of GHG emissions,
- 20 % of the EU Member States' energy mix to come from RES and
- 20 % reduction in primary energy used.

These targets are in compliance with the three pillars of the EU energy policy.

One of the first consequences of this package, a very detailed set of national targets for renewable energy use, is defined in Directive 2009/28/EC on the Promotion of the Use of Renewable Energy Sources, which was adopted in April 2009. The national overall targets for the share of the gross final consumption of energy to come from RES in 2020 are shown on the following chart (Figure 1).

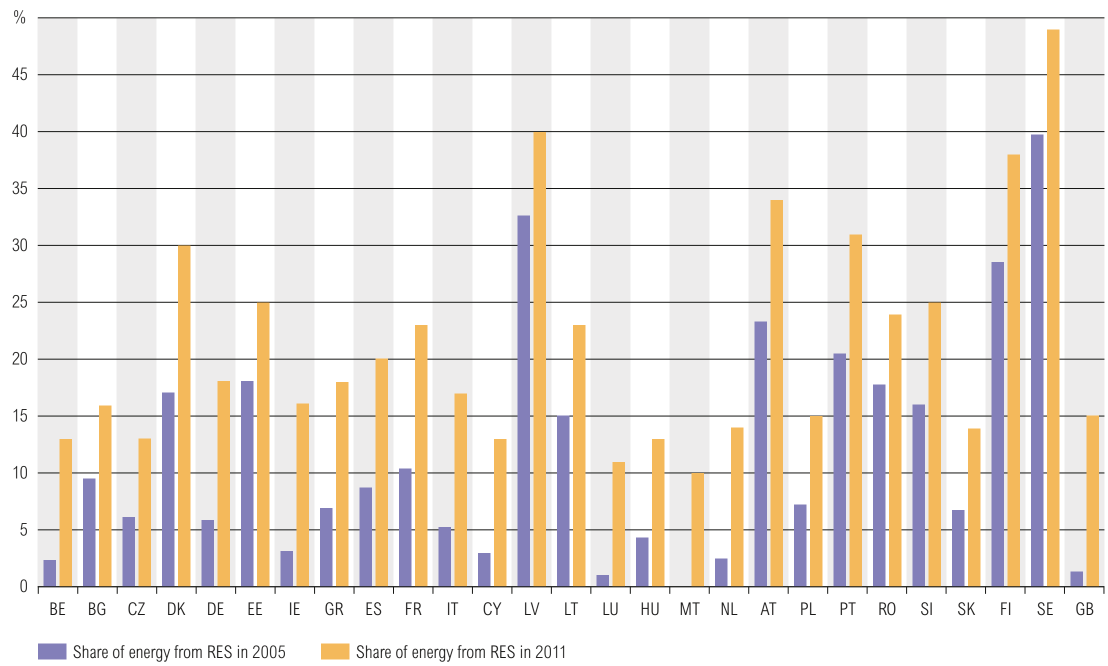


Figure 1:
National overall targets for the share of energy

Parallel to this, the Third Energy Package, adopted by the European Parliament in April 2009, requires Member States, regulators, TSOs and DSOs to launch innovation programs with appropriate incentive schemes, reaching far beyond 2020, more specifically:

- **In the regulation applicable to transmission operators:**
  - "ENTSO-E shall adopt common network operation tools to ensure co-ordination of network operation in normal and emergency conditions, including a common incidents classification scale, and **research plans**." (Regulation (EC) 714/2009, art 8.3.a)
  - "The annual work program shall contain a list and description of the network codes to be prepared, a plan on coordination of operation of the network, and **research and development activities**, to be realized in that year, and an indicative calendar." (Regulation (EC) 714/2009, art 8.5)

- **In the regulation applicable to transmission and distribution:**
  - "In fixing or approving the **tariffs** or methodologies and the balancing services, the regulatory authorities shall ensure that transmission and distribution system operators are granted **appropriate incentive**, over both the short and long term, to increase efficiencies, foster market integration and security of supply and support the related research activities." (Directive 2009/72/EC, art 37.8)

- **Regarding the future role of intelligent metering for electricity:**
  - "Member States should encourage the modernization of distribution networks, e.g. through the introduction of **smart grids**, which should be built in a way that encourages decentralized generation and energy efficiency." (Directive 2009/72/EC, (27))
  - "In order to promote energy efficiency, Member States, or when the Member State has so provided, the regulatory authority shall strongly recommend that electricity undertakings optimise the use of electricity, for example by providing energy management services, developing innovative pricing formulas or introducing **intelligent metering systems** or smart grids where appropriate." (Directive 2009/72/EC, art. 3.11)
  - "Member States shall ensure the implementation of **intelligent metering systems** that shall assist the active participation of consumers in the electricity supply market. The implementation of those metering systems may be subject to an economic assessment of all the long-term costs and benefits to the market and the individual consumer or which form of intelligent metering is economically reasonable and cost-effective and which time frame is feasible for their distribution."
  - "Where roll-out of smart meters is assessed positively, at least 80 % of consumers shall be equipped with intelligent metering systems by 2020." (Directive 2009/72/EC, Appendix 1)

The deployment of smart houses, smart metering and coherent local energy systems with electric vehicles, electricity storage, cooling systems or micro-combined heat and power, together with demand response, are all expected to form an interface using a complex ICT architecture called the smart grid (see 2.2.2.1). All local "smart" technology will also be a great benefit and matter for concern for the TSO if they can offer ancillary services and balance the regional areas in order to aid system operation. These initiatives are dedicated to the utilization of distributed generation and demand responses as thousands of small units aggregated in a virtual power plant will be a controllable resource for the TSOs in the future.

Both routes chosen by the European Council in 2007, i.e. more energy generation from RES and decentralized generation, and better informed and more energy-efficient clients, set key challenges for the electrical system as a whole, with a subsequent need to re-engineer the electricity networks, which, in turn, will require massive investments over the next 20 years.

These **system challenges** induce **new network** challenges for the pan-European transmission network. Hence, each TSO in Europe will have to evolve progressively from a "business as usual approach" to a proactive approach in order to avoid a bottleneck effect in the future European electricity system:

– **RES**, such as wind energy or photovoltaic solar energy, deliver electricity where and when resources are available, but energy may not always be needed at the same time and in the same location. Power may then need to be transported at an unforeseen time and to an unforeseen location, leading to congestion. Moreover, fluctuating power and the resulting power ramps can affect network stability margins. Hence, each TSO must face challenges in system planning and system operation which have yet been not addressed. The increased penetration of non-dispatchable generation resources has increased the level of uncertainty in the pan-European grid.

– **The design and operation of networks must take into account new constraints.** The Third Energy Package set energy targets, but does not address the issue of installed capacities: **energy and power will both matter**. The actual generation pattern of a power plant is only a fraction of its potential production level, as power plants are sometimes unavailable. However, most renewable energy power plants experience even smaller capacity factors, due to the intermittent character of their resources. Thus, transmission lines might be constructed and left under-utilized for the expected year of commissioning, but bearing in mind the continuous increase of RES and long-term line operation, grid measures have to be designed in a sustainable way. There is a high level of sensitivity to environmental issues relating to overhead structures, which makes it difficult to build overhead lines. This new and unavoidable constraint requires network operators to be innovative in order to develop new grid solutions (e.g. new designs for overhead lines, AC and DC underground cables) and improved network operations (making power flows follow new routes in order to avoid congestion).

- **Part of the electricity demand will become flexible enough** for network operators to use it to optimise their own operations in connection with new storage options: this will create new opportunities, from the use of detailed consumption data from metering to the curtailment of consumption via appropriate incentives.
  However, this will also have an impact on the traditional way of measuring networks (based on consumption forecasts), as load will therefore be controllable.

- Last but not least, the further development of the European energy market and the related cross-border power exchanges will contribute to rising uncertainty and the related congestion problems at borders, thus potentially **putting a strain on the transmission network**.

Overall, these inevitable evolutions will also require the adaptation of existing regulatory regimes. Most of the market rules in operation since 1 July 2007 are still based on an earlier design of electrical systems, in which centralized generation delivers power through transmission and distribution lines with network charges calculated according to this split. This will require the evolution of the regulatory frameworks, in line with the orientations proposed in the aforementioned Third Energy Package.

2 The TSOs' Vision for the Pan-European Transmission System

European TSOs share a common vision as regards facing the aforementioned challenges. This common vision involves becoming and remaining the focal point for all European technical, market and policy issues relating to TSOs and interfacing with power system users, EU institutions, regulators and national governments. ENTSO-E's work products contribute to the security of supply, a seamless pan-European electricity market, the secure integration of renewable resources and a reliable future-oriented grid, which is appropriate for meeting energy policy goals.

This ENTSO-E vision aims to facilitate several important aspects of European energy policy:

- **Security**
  the vision pursues coordinated, reliable and secure operations of the electricity transmission network.
- **Adequacy**
  the vision promotes the development of the interconnected European grid and investments for a sustainable power system.
- **Market**
  the vision offers a platform for the market by proposing and implementing standardized market integration and transparency frameworks that facilitate competitive and truly integrated continental-scale wholesale and retail markets.
- **Sustainability**
  the vision facilitates the secure integration of new-generation energy sources, and particularly the growing amounts of renewable energy and thus the achievement of the EU's GHG reduction goals.

The actions which ENTSO-E plans to take in order to achieve this vision are, among others:

- Joint activities between manufacturers and TSOs will facilitate the implementation of emerging technology at optimised costs. Universities and research centres will have concentrated additional expertise in response to systematic TSO R&D funding. The first results from consolidated TSO R&D will have been systematically evaluated and tested in ENTSO-E, and will have been applied successfully.
- Increasing use of ICT will not only contribute to secure operations, but also to the flexibility of the European network design for the European transmission network. ENTSO-E will have provided well-founded contributions to the debate on electricity highways and on smart grids in order to transform those visionary discussions into realistic options.
- Cooperation with DSOs and manufacturers will lead to R&D results that will open up the significant potential of demand response as the future basis for a sufficient balance of resources in the face of the ever-increasing volume of volatile renewable generation.

2.1 Background to the Vision

The Reference Scenario of the IEA 2008 Energy Outlook describes the world's energy future based on **established trends and policies**, without **new initiatives by governments on energy security or climate change**. It provides a **baseline** against which the need to change the current "business as usual" approach can be quantified and which shows that **European electricity players** would have to invest far more than one trillion euro over the next 20 years to cover the growth in electricity consumption, the replacement of aging infrastructures and to ensure more efficient usage of electrical energy.

The same IEA 2008 report then considers two climate policy scenarios that deal with the long-term stabilization of the GHG concentration per million of CO_2 equivalent:

- The 550 Policy Scenario (which equates to an increase in global temperature of approximately 3°C and involves a plateau in GHG emissions by 2020 and a reduction in overall demand of 9 %, mainly as a result of efficiency gains).
- The 450 Policy Scenario (which equates to a rise in global temperature of around 2°C).

It should be borne in mind that the currently established goal of limiting global mean temperature increases to 2°C would be much more demanding. Shifting this goal to 3°C is, of course, in no way a slight change, as critical tipping points could be crossed which would launch devastating consequences and even start positive feedback loops toward totally uncontrollable scenarios. The least that can be said is that whatever investment would be avoided that could have kept the global temperature shift at a lower level would have to be multiplied several times for the adaptation measures which would be demanded by this new climate pattern.

In order to reach either of these targets, hundreds of millions of households and businesses around the world would have to change the way they use energy, thus requiring innovative policies, appropriate regulatory frameworks, the rapid development of a global carbon market and increased **investment in energy R&D and demonstrations**. The 550 Policy Scenario would require **a total of $ 4.2 trillion more in investment worldwide between 2010 and 2030 than the Reference Scenario**. Most of this goes toward the deployment and improvement of existing technology in the **power generation sector**, where more low-carbon generating capacity is needed, and on the demand side in **energy efficiency** investments in transport, buildings and industry. The change in global energy-related investments by sector in the IEA 550 Policy Scenario relative to the Reference Scenario is shown in the IEA 2008 report.

However, in the IEA carbon-restrained 550 Scenario, the required investment which is identified worldwide in transmission and distribution is around 20 % lower in global terms than in the Reference Scenario, because the investment level is assumed to be linked directly to the amount of electricity generated. This assumption would be valid if the generation mix was constant and there was no need for any grid investment to enable energy efficiency and demand response. In reality, the large-scale integration of new renewable sources and the support of demand side energy-efficient technology will also require a massive investment in grid technology. Without these extra investments, the 550 Scenario cannot be realized.

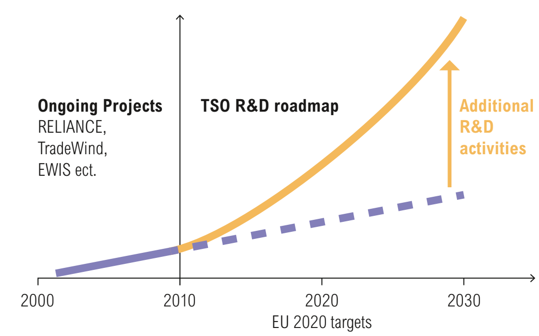


Figure 2.1:
Business needs due

As shown in the qualitative diagram (Figure 2.1), renewable integration forces TSOs to re-engineer their networks, above and beyond a "business as usual" approach: the pan-European transmission network operators must therefore integrate further R&D efforts, implement them via coordinated approaches within ENTSO-E, and at the same time aim to minimize the increase in the capital expenditures (CAPEX) and operational expenditures (OPEX) of transmission networks.

These R&D efforts, which include not only R&D but also demonstration efforts, must add to previous and ongoing research activities. An example of these activities (started in 2006) is given in Appendix 2 and 3. Indeed, an increase in R&D efforts will be essential in order both to reach 2020 targets and to provide an adequate level of security of supply of the pan-European transmission system.

There is an additional need for close cooperation between the European TSOs, DSOs and Generating Companies (GenCos) to ensure the optimal development and management of a coherent electricity grid in Europe.

2.2 Making the Vision Happen

2.2.1 Smart Grids: Vision, Definition and the Importance of the Concept for TSO R&D

Smart grids are central to ENTSO-E's vision of the future of the European electricity system. Smart grids are often thought to affect distribution more than transmission, but in fact one of the major potential benefits of smart grids cannot be achieved without the involvement of TSOs: the reaction of loads to price signals following RES fluctuations, and the difficulty of building up new lines or, in other words, enabling demand response to bid into Europe-wide intraday and balancing markets. The Europe-wide integration of these markets is to be completed in 2014 through ENTSO-E network codes and will involve the strong involvement of TSOs (in intraday market operations, together with power exchanges) or possibly even sole management by TSOs (balancing markets). Among the many kinds of benefits which it is hoped that smart grids will bring, enabling demand response is a major one.

According to the European standardization mandate[1] from the Commission to CENELEC, based on the EC Task Force Smart Grids[2], a smart grid is defined as an electricity network that can integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in a manner that is cost-effective in order to ensure a economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety.

The six high-level services defined by Smart Grids Task Force are listed below, together with their relevance to the security of supply and TSO tasks:

1. Enabling the network to integrate users with new requirements (in particular, fluctuating RES, which are directly relevant to TSOs and the security of supply),
2. enhancing efficiency in day-to-day grid operation (primarily for distribution grids which do not yet use sensors and controls as pervasively as the transmission grids),
3. ensuring network security, system control and the quality of supply (using more sensors and controls in distribution including real-time data exchange with the respective TSO, but also by enabling demand

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1) The Standardization Mandate to European Standardization Organizations (ESOs) to support European Smart Grid deployment (M490) is published here: www.ec.europa.eu/energy/gas_electricity/smartgrids/doc/2011_03_01_mandate_m490_en.pdf

2) Documents relating to the EC TF on smart grids can be found here: www.ec.europa.eu/energy/gas_electricity/smartgrids/taskforce_en.htm

response to bid into TSO-administered markets, thereby helping to balance fluctuating RES, which is crucial for the security of supply),

4. enabling better planning of future network investment (this benefit relates mostly to improved distribution through better data, but for both distribution and transmission, data from smart grids lay the foundation for planning efficient grids which can accommodate massive RES),

5. improving market functioning and customer service (demand response but also distributed generation bidding into Europe-wide intraday and balancing markets, which is crucial for balancing and the security of supply) and

6. enabling and encouraging stronger and more direct involvement of consumers in their energy usage and management (which is directly tied to demand response).

The smart grids concept means not only the deployment of new technologies, but also the optimal design and operation of electrical grids including new means of generation, new HV facilities to enhance grid flexibility, active demand and new usage of electricity in line with European and national energy policies. From the point of view of the TSOs, the integration of new components and interoperability are the key challenges. The planning, operating and marketing tools used by the TSOs also need to be smarter, and developing these tools is an important part of the EEGI and the ENTSO-E R&D Plan. All choices must be consistent in order to ensure global security of supply, the quality of electricity, minimal costs for society etc.

Power systems are becoming increasingly complex. Some traditional solutions which are applied in transmission systems could be adopted in distribution systems as well.

Smart grids are not specified by amount and location of distributed generation, but instead provide opportunities for intelligent management and the integration of energy sources into the power system.

Smart grids are power systems which sustain the energy supply while using all of the available resources in such a way that the benefit for society can be maximized. Hence, it may be that the minimization of transmission losses will not be the top priority. In the transmission grid, the term "self-healing technologies" should be approached with some caution. It must be understood as "increased use of intelligent autonomous subsystems," so as to deliver a highly reliable service to consumers

Smart grids are not restricted to electricity and ICT infrastructures, but also encompass market and regulatory systems and planning and operational practices designed to deliver services to the end-user that will help him or her to control his or her bills and which will offer incentives, making optimal use of the entire electricity infrastructure, including generation, transmission and distribution.

2.2.2 The Required Step Changes for TSOs

Many European TSOs are already involved in EU-funded projects, which will help them to prepare for the aforementioned changes (see Appendix 3). However, based on the knowledge gained thus far, **several step changes are still required** within the pan-European transmission network in order to realize this vision on a very large scale.

2.2.2.1 Supporting the development of variable generation

In accordance with European legislation, the role of TSOs is to facilitate grid connection while meeting pan-European system security requirements. In order to achieve this balance, TSOs must rely on the reserves available on the market to maintain consistency in unbundling between the transmission and generation sectors. This means that the more intermittent the resources, the more they will be involved in providing system services. Moreover, they will be required to provide power under downgraded conditions (in terms of voltage and frequency) in order to avoid major blackouts. Hence, new knowledge about optimum solutions for Europe is needed in order to prepare:

- transmission investments against peak power production/consumption,
- the integration of new large-scale and decentralized storage technologies,
- new market design options which will allow variable generation to participate in intra-day markets,
- the ways and means to upgrade existing planning methodologies in order to incentivise local production at the European level and
- the harmonization of grid codes: behaviour of the distributed generation under downgraded conditions; and provision of ancillary services and recommendations to ensure global system stability, e.g. classical generation has internal stabilization loops that contribute to system stability and dampen inter-area oscillations, which is not generally the case for renewables.

2.2.2.2 Developing network architecture with new transmission solutions as a complement to conventional solutions

With the help of manufacturers, two major directions should be investigated:

- On-shore network architecture
  - New design of overhead lines, with a higher degree of environmental compatibility and social acceptability
  - HVAC overhead lines combined with underground cable sections
  - Long-distance HVAC underground cables which have an impact on reactive compensation
  - On-shore HVDC lines, operated in parallel to existing AC overhead lines
  - Interoperability of equipment across technologies and vendors

- Offshore network architecture designed to connect offshore generation to the mainland grid and to allow inexpensive interconnections between distant areas
  - New capabilities of long-distance AC submarine cables
  - New multi-terminal HVDC network, high-capacity cables, DC breakers, submarine DC switchgear, substations etc.
  - Cost-effective submarine solutions and developments
  - Assessment of new functionalities and parameter settings of HVDC (submarine) network, as breaking capabilities should be faster and performed by power electronics only
  - Security constraints and grid codes for the operation of a possible future offshore meshed grid to ensure reliability
  - Interoperability of equipment across technologies and vendors

While improving the performance of the hybrid network (a HVDC network embedded in an AC network), security constraints, construction processes and environmental conditions should be taken into account.

2.2.2.3 Increasing the flexibility of the existing pan-European transmission network

Increasing the flexibility of the transmission network will lead to enhanced controllability and increased power transfer capability. Five complementary routes must be jointly examined at the European level in order to increase the reliability and flexibility of the pan-European transmission network. They will coexist within a hierarchical organization, from simple processes to highly sophisticated tools:

- **Pan-European grid security initiatives and cross-border regional coordination centres include:**
  - Increasing the observability of the system,
  - operating closer to limits, in particular regarding the interconnections between Member States and
  - preventing the likelihood of severe propagations of local single faults to neighbouring networks.

  Coordination is becoming absolutely necessary, as shown by the birth of regional centres, e.g.
  - Transmission System Operator Security Cooperation (TSC, www.tso-security-cooperation.eu),
  - CORESO (www.coreso.eu),
  - the Security Service Center (SSC, www.securityservicecenter.eu) etc.

- **Increased observability so that the network can be exploited closer to its stability limits:**
  The main issue is that of grasping the dynamics of the system, as transitions from one stable state to another may induce uncontrollable instabilities. This requires more accurate models and sensing capabilities (with sampling rates, synchronization and accuracy in line with the observable transient behaviours used to understand the physics and real-time modelling tools so that these behaviours can be anticipated).

- **Increased network controllability:**
  The current daily operations of transmission systems no longer allow the adoption of classical preventive security standards all year round.
  The system cannot always survive single faults without post-fault actions. Increasingly, corrective (post-fault) actions are being defined to ensure the security of the system, which means that the operating time during which the system requires corrective action in order to be secure is increasing. Thus, more and more Special Protection Schemes (SPS) are being deployed in order to implement such corrective actions automatically.
  Devices such as phase shifter transformers (sometimes an interim solution because grid measures are not ready on time) and static VAR compensators (SVC), are located within the system to increase its controllability, making the system increasingly complex to control. Interoperability is needed between FACTS devices (such as TCSC, STATCOM, SSSC and UPFC) from different vendors. These devices are useful for faster, more efficient and more flexible control of network parameters,

such as active and reactive power flows, nodal voltage magnitudes and angle difference. Moreover, the impact of these technologies must be measured against new transmission lines, active demand management and new generation capacity.

– **Real-time, optimal, ICT-based control of the transmission systems:**
  Today, preventive measures are used as a rule to optimise transmission networks. This is due to reduced observability and controllability. However, with improvements in observability and controllability, a new optimal control could be implemented, which would further increase the system's complexity.

2.2.2.4 Taking full advantage of demand management at the system level

As is the case for distribution networks, knowledge of the demand for power will help to keep the entire pan-European system under control. Moreover, smart demand management may help the system to better manage peak conditions. Demand must be looked upon like generation: part of the demand flexibility can be used to offer adjustment capabilities to TSOs. Market mechanisms ought to be designed, for instance, through the aggregation of renewable generation and loads, where this type of service is remunerated by TSOs. This in turn will affect:

– Today's planning methodologies, which consider consumption patterns as an input to asset optimization studies. This will no longer be the case if part of the load becomes controllable.

– Current operating practices, in which TSOs assume that the power of the load is an uncontrollable exogenous stochastic variable.

2.2.2.5 Performing large-scale experiments on a European scale in support of the above step changes, with a view to maximizing benefits for European society while minimizing validation costs

TSOs are national, interconnected players. Thus far, innovation has been technology-driven, based on the proposals of manufacturers rather than market demand. While unbundling introduced uncertainty, newly regulated players did not feel incentivised to invest in innovation. The knowledge gaps outlined above must be bridged. TSOs must, therefore, connect with each other and address experimental programs with clear specifications in mind, based on their common needs. This approach is new, and requires dedicated workforce to perform at short notice.

2.2.3 The Mission of the Integrated R&D Projects to be Performed by TSOs at the Pan-European Level

In order to be effective, the R&D work on architecture, system control and market design must be performed in an integrated manner at the European level. Indeed, it is critically dependent upon the full knowledge of the pan-European transmission system. Demonstrations of state-of-the-art transmission and power technology should also be coordinated at the European level. When demonstrations are carried out jointly, this will drastically reduce the demonstration costs and will reinforce the bargaining power of transmission operators when negotiating the future procurement of the validated technology.

The mission to be achieved with the help of the R&D results can be summed up in five areas:

- To identify the most suitable **innovative transmission grid architecture** needed to cope effectively with the 2020 low carbon electricity generation mix and power flows over the whole of Europe. There are several technical alternatives for connecting offshore generation or solar facilities to the European transmission grids, but it is not clear which is the most economically efficient. In this context, methods for financially assessing and supporting transmission projects of pan-European importance need to be developed by TSOs.
- To **understand and properly value** the impact and potential benefits brought to the electricity system by the deployment of **state-of-the-art transmission/power technology and offshore solutions**, in support of the chosen architecture: European manufacturers, who are world leaders in their sector, have already developed several advanced transmission or power technologies (for instance, high power semiconductor devices, WAMS, flow control devices or HVDC lines). Full-scale demonstrations must be performed in order to evaluate the real system benefits of these technologies, with the first results expected by 2015.
- To **design and validate novel monitoring and control methodologies** (ICT-based) of the pan-European electrical system in order **to meet today's and tomorrow's reliability targets**.
  - How can we cope safely with wind gusts or clouds passing over solar power plants without affecting system stability?
  - How can we introduce large-scale demand response approaches to withstand peak consumption periods?
  - How can we utilize the benefits of smart grid applications in the subgrid for services to the transmission grid?
- To **develop shared electricity market simulators** which are able to analyse options for market designs and rules, and to identify those that are most beneficial to both the energy system and consumers. For instance, weather conditions around some large European airports can have an impact on air traffic control across all of Central Europe

because of congestion. The same happens for electricity transport.
   - Who should resolve this congestion?
   - Who should pay for the losses incurred in resolving congestion?
   - Can renewable electricity play a part in the spot market?

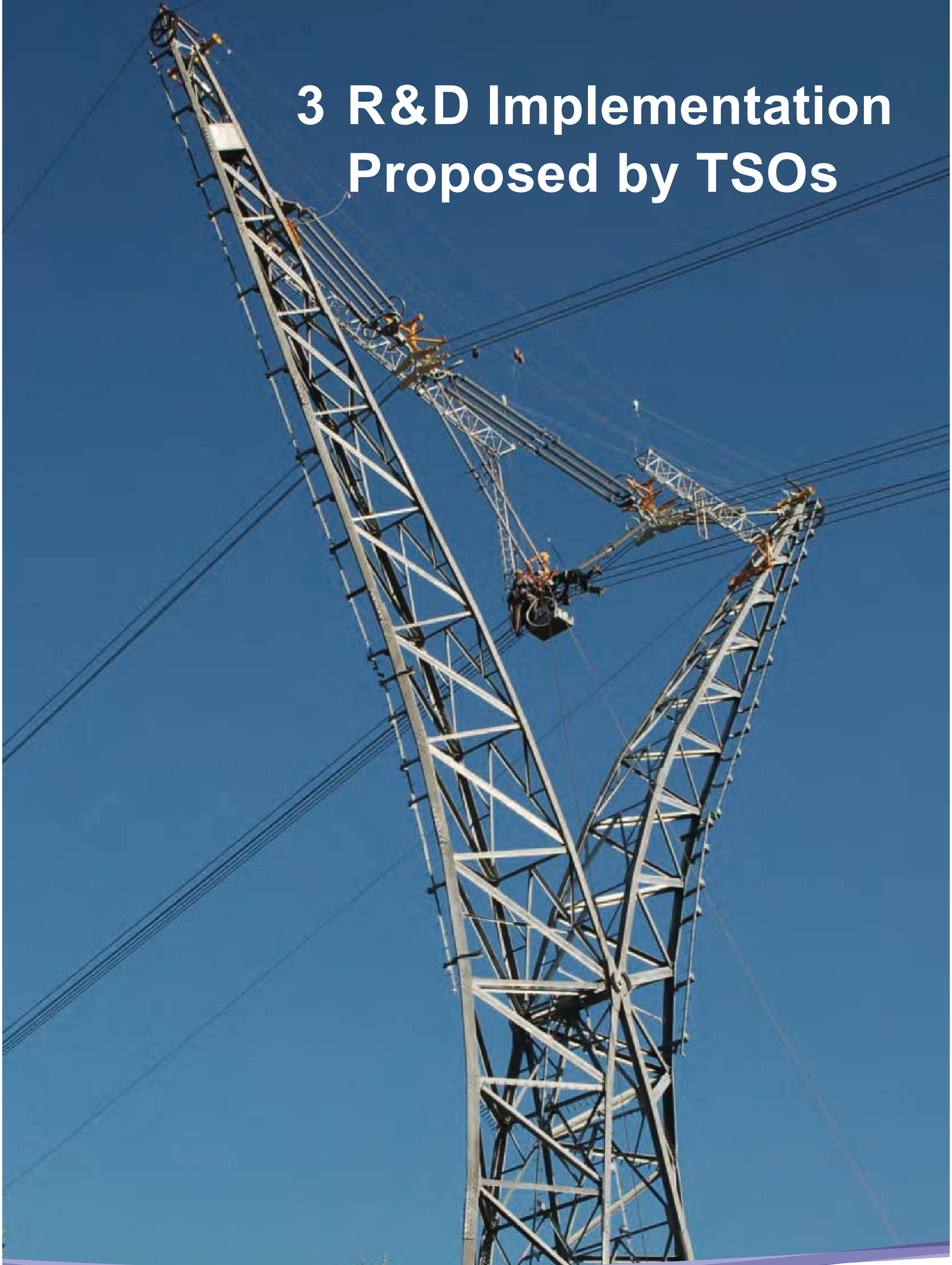
   These simulators will make it possible to provide regulators and governments with recommendations as early as 2015.

- To **reinforce the cooperation between TSOs and DSOs** in order to facilitate the deployment of distributed energy resources (DER) like smart grids, electric vehicles etc. For instance, in order to benefit fully from the flexibility caused by DER, communication and coordination for decision-making is mandatory. In addition, the concerns of TSOs differ slightly from those of DSOs. Therefore, joint efforts are needed to design tools and mechanisms that can leverage mutual benefits.

Provided that the ENTSO-E R&D Plan is followed, Europe will be able to deploy a power transmission system at a reasonable capital cost without sacrificing the security of supply, while coping with the challenging generation mix required to achieve a low carbon future. This affordable and intelligent network is based on:
- optimal choices regarding the architecture, implemented progressively between 2015 and 2020,
- reliable state-of-the-art transmission/power technology, with measured benefits starting in 2015,
- the implementation of improved monitoring and control tools and procedures, for the grids of today and tomorrow and
- novel market designs validated through intensive market simulations.

Last but not least, transmission operators will be able to identify needs for new functions and technology. This will allow manufacturers to initiate R&D programs to provide solutions which will reach beyond 2020, in line with future power transmission requirements at the pan-European level. In this context, a roadmap study for MoDPEHS (Modular Development Plan on Pan-European Electricity Highways System 2050) was elaborated by ENTSO-E and its members in response to the Energy Infrastructure Package blueprint published by the EC in November 2010. This is the first time that a full planning approach will be followed by ENTSO-E for looking beyond the next decade, i.e. the scope of the Ten-Year Network Development Plan (TYNDP).

3 R&D Implementation Proposed by TSOs



3.1 The Pan-European Transmission Network Concept to Support R&D Activities

The electricity superstructure, also called the electricity highway, in and around Europe is becoming one of the main topics of investigation. Up to now, most proposals have shown little regard for system reliability through the secure operations of such grid. This superstructure remains a vision today, which must be converted into practicable concepts. Such super-grids will have to be operated at the level of security of supply required by all stakeholders. Moreover, these super-grids must not have a negative impact on the existing electricity grids. Security functions are, therefore, of critical importance when designing any electricity superstructure, and they will have a significant impact on the resulting network topology.

As presented in Chapter 2, regional coordination centres have recently been created in parallel to these prospective studies. This shows that issues relating to cross-border influences are increasing and are being addressed adequately through voluntary and dedicated coordination activities.

In bringing together extra R&D efforts, the European TSOs aim to develop the knowledge and tools that are required to support the further development of the pan-European transmission grid.

An overview of the clusters, functional projects and current priorities is shown in Table 3.1 (next page).

<table>
<tr><th rowspan="2">Cluster</th><th rowspan="2">Functional project</th><th colspan="11">Year</th><th rowspan="2">Costs (M€)</th></tr>
<tr><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th></tr>
<tr><td rowspan="3">C1</td><td>T1</td><td></td><td></td><td colspan="4">Toolbox for new network architecture assessment</td><td></td><td></td><td></td><td></td><td></td><td>19</td></tr>
<tr><td>T2</td><td colspan="5">Tools to analyse pan-European expansion options</td><td></td><td></td><td></td><td></td><td></td><td></td><td>21</td></tr>
<tr><td>T14</td><td colspan="9">Environmental impact and social acceptance of transmission facilities</td><td></td><td></td><td>50</td></tr>
<tr><td rowspan="3">C2</td><td>T3</td><td colspan="9">Demonstration of power technologies for more network flexibility</td><td></td><td></td><td>80</td></tr>
<tr><td>T4</td><td></td><td></td><td colspan="7">Demonstration of power technologies for novel network architecture</td><td></td><td></td><td>120</td></tr>
<tr><td>T5</td><td colspan="9">Demonstration of renewable integration</td><td></td><td></td><td>130</td></tr>
<tr><td rowspan="4">C3</td><td>T6</td><td colspan="8">Innovative tools for pan-European network observability</td><td></td><td></td><td></td><td>12</td></tr>
<tr><td>T7</td><td></td><td colspan="6">Innovative tools for coordinated operations with stability margin evaluation</td><td></td><td></td><td></td><td></td><td>24</td></tr>
<tr><td>T8</td><td></td><td></td><td></td><td colspan="5">Improved training tools to ensure better coordination at the regional & pan-European levels</td><td></td><td></td><td></td><td>25</td></tr>
<tr><td>T9</td><td></td><td colspan="8">Innovative tools and approaches for pan-European network reliability assessment</td><td></td><td></td><td>14</td></tr>
<tr><td rowspan="4">C4</td><td>T10</td><td></td><td></td><td colspan="5">Advanced tools for pan-European balancing markets</td><td></td><td></td><td></td><td></td><td>18</td></tr>
<tr><td>T11</td><td></td><td></td><td colspan="7">Advanced tools for capacity allocation and congestion management</td><td></td><td></td><td>21</td></tr>
<tr><td>T12</td><td colspan="5">Tools for renewable market integration</td><td></td><td></td><td></td><td></td><td></td><td></td><td>14</td></tr>
<tr><td>T13</td><td colspan="9">Tools for the integration of active demand into electrical system operations</td><td></td><td></td><td>12</td></tr>
<tr><td rowspan="5">C5</td><td>TD1</td><td></td><td colspan="8">Increased observability of the electrical system for network management and control</td><td></td><td></td><td>45</td></tr>
<tr><td>TD2</td><td></td><td></td><td colspan="7">The integration of demand side management into TSO operations</td><td></td><td></td><td>70</td></tr>
<tr><td>TD3</td><td></td><td colspan="8">Ancillary services provided by DSOs</td><td></td><td></td><td>50</td></tr>
<tr><td>TD4</td><td></td><td colspan="8">Improved defence and restoration plans</td><td></td><td></td><td>45</td></tr>
<tr><td>TD5</td><td></td><td colspan="8">Joint taskforce on IT system protocols and standards</td><td></td><td></td><td>20</td></tr>
<tr><td colspan="2">**Functional projects**</td><td colspan="11">**Functional projects with high priority**</td><td>**790**</td></tr>
</table>

Table 3.1:
Functional projects and their order of priority

3.2 Five Innovation Clusters to Better Capture European Added-value

TSOs rely on three intertwined levers to develop the pan-European transmission grid effectively, with a view to achieving the decarbonisation of electricity production:

- **Re-engineering assets**
  that have a long lifespan and the technical evolution of which by manufacturers is usually slow.
  Asset improvement takes time and will have a significant impact at the European level from a medium- to long-term perspective. Improved planning tools are needed to develop and assess innovative grid architecture and emerging power technologies which will provide enhanced functionalities like flexibility. The additional freedom will enable operators to cope with renewable generation and demand side management.

- **Daily process improvements**
  that combine the use of innovative power technology and new control procedures, in order to cope with generation and load volatility within the right stability margins.
  These improvements can deliver results more quickly, due to the recent developments in ICT. However, the need to improve assets and the need to improve operations must be addressed simultaneously, as innovative technologies that do not fit into today's network architecture will become effective in upgraded architectures (for instance, a deep sea backbone in the North of Europe and the increased use of active distribution networks, which involve two concepts: first, the network provides connectivity between points of power supply and demand, and second, the network interacts with the consumer).

- **Proposing new market rules to regulatory bodies.**
  Such rules will affect both the regulated part of the network and the free market. For instance, finding new ways of integrating more renewable electricity into spot markets may speed up the decarbonisation of Europe more efficiently than today's implemented feed-in tariffs.

The five research and innovation clusters that will contribute to keeping both the system capital and operational costs and the security of supply at affordable levels are summarized in the table below. Although they are highly intertwined, these five clusters correspond to the main core activities of each TSO (Table 3.2).

Cluster	Topics	Scope of the innovation cluster
1	Pan-European grid architecture	Novel approaches to developing a pan-European grid and emerging technology for pan-European offshore grids
2	Power technology	Affordable technology to make the transmission system more intelligent and flexible
3	Network management and control	Critical building blocks to operate the interconnected transmission system in real time and reliably
4	Market rules	Market simulation techniques to develop a single European electricity market
5	Enhanced link between transmission and distribution	Utilization of smart grid applications for services in order to balance the system

Table 3.2:
Research and innovation clusters

3.3 Selection of Topics, Performance of R&D Activities and Integration of the Resulting Knowledge

As shown in Figure 3.3, the process of selecting the activity topics for each of the clusters comprised four steps:

1. Setting the **concepts underlying the proposed research plan** in the cluster of interest and listing the prerequisites to innovation tasks,
2. examining capacity issues that would hamper new knowledge **development and dissemination** and providing ways and means to overcome these barriers,
3. examining innovation management issues that could **prevent new knowledge from being developed** and proposing steering actions for the portfolio management tasks and
4. examining non-technical barriers that could ultimately **prevent the use of new knowledge** and designing a set of integration projects to control the packaging of the new knowledge for its future availability within ENTSO-E.

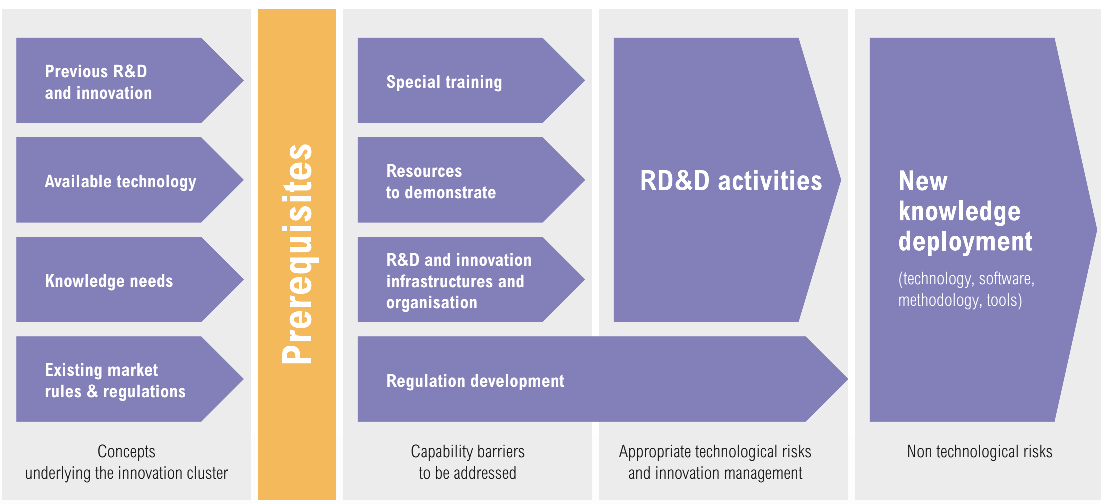


Figure 3.3:
Selection process of activity topics

3.4 Implementation and Sharing of Results

This section includes basic guidelines on the funding, implementation and management of the plan, and on sharing the results of the projects in the R&D Plan. It is the intention of ENTSO-E to update this plan every year, as defined in the Third Energy Package by the EU, in order to take into account the evolution of different technologies, the general framework and the achievements within the R&D Plan.

An adequate level of coordination between the ENTSO-E R&D Plan and other European industrial initiatives (EIIs) has been in evidence since ENTSO-E became a member of the EEGI. The EEGI guarantees close cooperation and coordination with the relevant stakeholders. Due to the central role of the grid as the integrator of different generation technologies and the TSOs' responsibility for the system security, R&D interaction with other industrial initiatives is crucial.

ENTSO-E itself has established the Working Group Monitoring and Knowledge Sharing (WG MKS) under the Research and Development Committee in order to contribute actively to the dissemination of the results and to the sharing of the generated knowledge.

3.4.1 Funding

A long-term perspective on funding is mandatory in order to mobilize sufficient external players and internal TSO staff. The proposed program requires long-term commitment from the TSOs, as they will have to recruit or train the required staff so that they can perform the extra R&D tasks. One hundred per cent of the TSOs' total costs (extra R&D activities above the running expenses of "business as usual") must be covered.

Financial resources could be obtained through the swift implementation of the Third Energy Package, which would provide a solution for each of the Member States involved. However, nobody can afford to wait until its full implementation in each state to start working on supplementary R&D tasks. Hence, a concerted approach is necessary for Europe as a whole to enable all TSOs to execute the mandatory R&D work. The development and introduction of improved R&D funding must be sped up in the coming months in order to meet the ambitious challenges of tomorrow's pan-European electricity transmission system and to attract research players from academia, manufacturing and other candidates to join the R&D action plan.

ENTSO-E published a position paper entitled "A new regulatory framework for TSO R&D in ENTSO-E countries"[1)] with the general objective of defining the main criteria to be developed at the European level in order to guarantee an appropriate, homogeneous and coherent regulatory framework for R&D activities, which is capable of promoting and incentivising the vital R&D activities by to be performed by TSOs.

3.4.2 Governance and Organization

The following principles will be applied:

- Research is collaborative and open to other relevant market players, stakeholders etc. However, leadership and management responsibilities will be taken on by the TSOs involved.
- The sub-projects within the functional projects and clusters will use high-level key performance indicators (KPIs) to measure the EU value added by each of the work streams and the five clusters working simultaneously.

Roles and responsibilities:

- ENTSO-E is committed to publishing a long-term R&D Plan, based on consultation with internal and external stakeholders. The R&D Plan is periodically reviewed and updated. The first edition of the R&D Plan was reviewed by internal and external stakeholders. For this updated version of the R&D Plan (1st edition), an external stakeholder consultation is not envisaged. The design of the stakeholder consultation process will be an issue for the GRID+ project that is funded by the EC. Taking into account the results of the GRID+ project, ENTSO-E will commence the development of the second edition of the R&D Plan in 2012, taking into account input from internal and external stakeholders;
- The EC is committed to issuing calls for proposals relating to this R&D Plan, in order to execute the functional projects that are part of the R&D Plan.
- ENTSO-E facilitates, through the RDC, the process of bringing together partners for the projects addressed by the calls in such a way that TSOs, GenCos, manufacturers, research institutes etc. form consortia and submit proposals for R&D activities to the EC.

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1) The position paper and the summary are published on the ENTSO-E website. The links are:
- Position paper: www.entsoe.eu/fileadmin/user_upload/_library/position_papers/110701_ENTSO-E_PP_on_Regulatory_Framework_for_RD_vFINAL.pdf
- Summary: www.entsoe.eu/fileadmin/user_upload/_library/position_papers/Summary_of_R_and_D_regulatory_framework_position_paper_18_07_11.pdf

– ENTSO-E could be directly involved in an R&D project as a partner, if needed.

– The EC evaluates the proposals sent in response to the calls and awards grant agreements for performing the work.

– The awarded consortia are responsible for contractual commitments, the execution of the project and for reporting on their progress to the EC.

– ENTSO-E monitors the R&D Plan through predefined high-level KPIs, as part of the R&D Plan management.

– ENTSO-E facilitates the dissemination of results based on the packaging and the publications prepared within the framework of the R&D projects. For this purpose, the WG MKS has been established.

As regards the role of ENTSO-E, the ENTSO-E bodies involved are the RDC as the central platform for R&D issues, but also the System Development Committee (SDC), the System Operations Committee (SOC), the Market Committee (MC) and the Assembly. The consultation and approval procedures, as laid down in the Articles of Association and Internal Regulations of ENTSO-E, will be followed.

Collaboration with the EC

The role of ENTSO-E is to facilitate the launch of the SET Plan activities, based on regular collaboration between the EC and the European TSOs: this is in full compliance with (EC) Regulation No 714/2009, as Article 8 §3 states that "the ENTSO for Electricity shall adopt: common network operation tools to ensure coordination of network operation in normal and emergency conditions, including a common incidents classification scale, and research plans."

Set of processes for governing the ENTSO-E R&D Plan

The basic processes used to govern the plan that are going to be assumed by ENTSO-E, in close cooperation with the relevant stakeholders, are:
– designing and approving the ENTSO-E R&D Plan,
– supporting the EC during the launch of calls for proposals,
– monitoring the R&D Plan as a whole and
– disseminating the results among the stakeholder community and facilitating the scaling up and implementation of results by the entire ENTSO-E community.

The table below shows the description of the "Design and approval of the ENTSO-E R&D Plan" process, displayed for the updated first edition.

Responsible body	Tasks / actions / responsibilities
RDC	Asks the WG R&D Plan to draft a preliminary version of the R&D Plan
	In parallel, asks the other committees for their input to ensure a holistic approach taking into account all areas of expertise, i.e. from the system development, system operation and market points of view
WG R&D Plan	Drafts the preliminary version of the R&D Plan in close cooperation with the SDC, the SOC and the MC
	Submits the preliminary version to the RDC
RDC	Reviews the draft
	Asks the WG R&D Plan for a new version of the R&D Plan, considering the input from the RDC
WG R&D Plan	Drafts the R&D Plan (updated 1st edition) and submits it to the RDC
	Internal consultation with the SDC, the SOC and the MC
	Submits the final version to the RDC
RDC	Approves the R&D Plan (updated 1st edition) and submits it to the Assembly
Assembly	Approves the ENTSO-E R&D Plan 1st edition (updated for 2011)

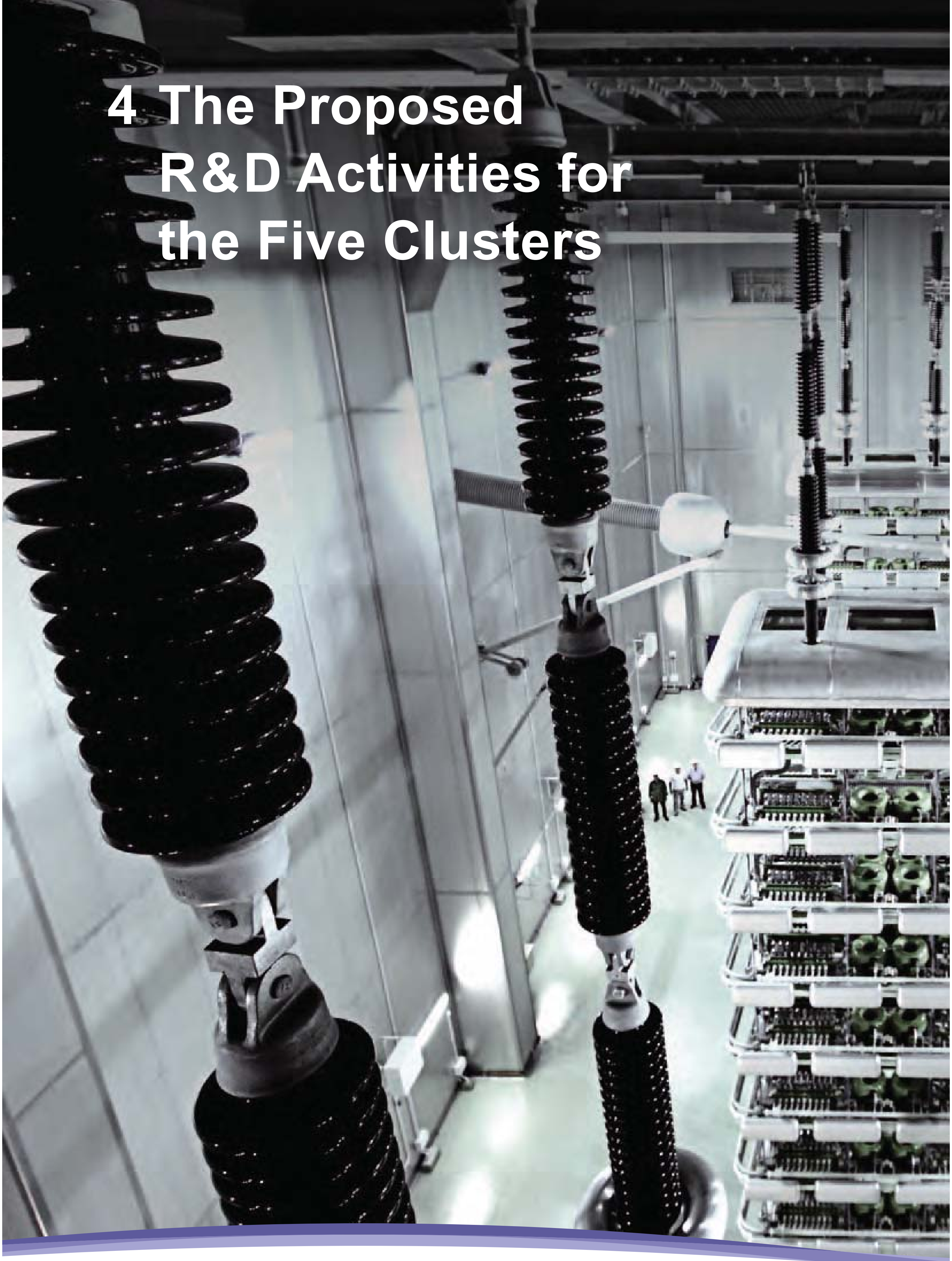
Table 3.3:
Design and approval process of the ENTSO-E R&D Plan

3.4.3 Result Exploitation

ENTSO-E leads the packaging and dissemination of the new knowledge and technologies developed by the TSO initiative. The following guidelines may be applied:

- The sharing of results is focused on sharing foreground information, new knowledge and expertise gained during the project's development. All intellectual property rights (IPR; including but not limited to industrial property rights) to the foreground information are owned by the TSOs participating in the project in accordance with the relevant agreements.
- Project results owned by the TSOs are shared within ENTSO-E: TSOs specify, package and validate the project results which are made accessible via ENTSO-E.
- TSOs share (disseminate and facilitate access to) all foreground information, new knowledge and expertise gained during the project's development within ENTSO-E.
- TSOs will grant access to new software developments at a reasonable cost, not including commercial profits for the TSO owner of this software within ENTSO-E.
- TSOs will grant access to new testing facilities at a reasonable cost, not including commercial profits for the TSO owner of these facilities within ENTSO-E.
- New devices, prototypes or demonstration facilities are owned by the TSOs participating in the project in accordance with the relevant agreements.
- Access rights will be granted through ENTSO-E to the TSO's background information which is needed to use the generated foreground information in accordance with the relevant agreements.
- TSOs commit themselves to do their best to grant ENTSO-E members access through ENTSO-E to the project results and background information needed for the use of such results, owned by other partners on the same conditions as the TSOs participating in the project.
- TSOs manage the integration of the knowledge within ENTSO-E; as soon as possible, ENTSO-E will ensure the cross-functional coordination of the R&D portfolio in all subjects relating to the TSOs' business.

4 The Proposed R&D Activities for the Five Clusters



4.1 Cluster 1: Pan-European Grid Architecture

4.1.1 Background

Transmission networks are long-life assets (beyond 50 years), the specifications, construction and maintenance of which are driven by the following issues at the European level:

- Cross-border electricity transport, which must face geographical barriers (e.g. the Pyrenees and the Alps for connections between Spain, Italy and France) and environmental and socio-economic constraints,
- market liberalization, which has induced steady growth in the erratic behaviour of cross-border exchanges, with consequences for network loading, network interactions and system vulnerability, pushing toward the optimal usage of existing assets or increasing the stress on interconnected networks,
- no integrated planning in the power supply sector due to unbundling between generators and transmission operators,
- the need for long-term coordination of investments due not only to new operational constraints (see above), but also due to budget and regulatory constraints, which require more negotiating power to beat down the price of equipment and
- the need for pan-European regulatory solutions to finance transmission projects which will have a pan-European impact, in terms of interconnections as well as the relevant internal lines. The integration of RES into the system will lead to both additional investments and innovative solutions in network architecture.

4.1.2 Knowledge Produced

Therefore, knowledge is required at the European level by the TSO community in order to ease (harmonize) system planning and asset management over the next 50 years. Previous energy development programs chose energy vectors (oil, gas, electricity) during the first stage of planning. Next, they developed transportation infrastructures with no apparent constraints. This approach is no longer valid, as power transportation can be constrained by:

- environmental issues,
- geo-political issues and
- public opposition

Future energy scenarios will have to account for transmission first, which in turn requires a permanent think-tank which is capable of using new techno-economic models to design the optimal transport architecture, based on several potential energy sources including RES.

4.1.3 The Knowledge Portfolio

The expected impact of the cluster's activities in 2020 implies that a set of validated network architectures will have been proposed by 2015, possibly using the technology which will be demonstrated within this R&D framework, and making sure that the network costs (investments and operations beyond 2020) can be kept under control, even though massive renewables are to be deployed in Europe. Hence, this cluster has three main activities, described below:

- Scenario building,
- modelling tools and software solutions for asset planning studies at the European level and
- architecture for pan-European options: migration studies.

4.1.3.1 Scenario building

The purpose of this topic is to define generation and consumption scenarios for the years 2030/2050. These scenarios rely on the use of existing models and software tools dedicated to this type of pure energy simulation. The network is not taken into account at this stage, or it is assumed that it will not impose any constraints. However, the locations of the expected new generating plants must be given (alternative locations may of course be considered). Different consumption growth scenarios must be considered in line with the current European energy policy. The impact of storage and demand response on load profile and peak demand are to be analysed by such simulation techniques.

The output is a reference report on possible future generation and consumption scenarios, with the possibility of replaying alternative scenarios, if needed. A simulation toolbox (yet to be industrialized at this stage of the project) is then made available, permitting the sharing of views with all electricity sector players (regulators, Member States, GenCos etc.).

Scenario building in a broader sense, taking into account grid development, market issues and cross-border issues, is being addressed in the MoDPEHS. The purpose of this upcoming high-level project is to develop a strategic plan that will provide a vision for how a pan-European power system built around the electricity highways concept could develop sequentially in the period leading up to 2050.

4.1.3.2 Modelling tools and software solutions for asset planning studies at the European level

The purpose of this activity is to define how to model the various parameters which will be considered in the network development studies below and to implement them using a dedicated software tool that can be used for pan-European planning studies. A planning study tool must cope with:

– New issues such as emerging technology modelling, specifications in planning studies and tools (HVDC, FACTS etc.). The assessment of emerging technology will be carried out in MoDPEHS and therefore can easily be used in the modelling process.

– The impact of electricity storage technology, such as electrical vehicles or new large-scale storage options. Storage technologies will also be assessed in MoDPEHS.

– Agreements on operating rules to be considered (security).

– Agreements on what the "good" criteria for an "adapted network" are, i.e. the purpose of the transmission grid.

– Innovative approaches to improving public acceptance of transmission facilities.

4.1.3.3 Architecture for pan-European options: Migration studies

Once scenarios have been defined and the appropriate methods and tools have been validated, detailed studies can be launched (as they were for the offshore grid, electricity highway and Mediterranean ring proposals). The work must focus on the future network architecture, while emerging technology will be addressed by Cluster 2. Such studies should provide possible grid architectures associated with the different scenarios. The important boundary conditions are:

– the level of reliability of TSOs must not be reduced and

– the planning process must include financial issues to be handled in regulatory schemes such as welfare distribution after investment, project cost distribution etc. in order to stimulate and advance the discussion on innovative and progressive projects with the involved authorities.

Another key issue is to show how it would be possible to reach even more ambitious targets (e.g. 2050 targets), starting in 2010. This is the so-called "migration problem," which addresses the fact that decisions made today will affect the 2030/2050 grid. Migration studies will ensure that the chosen reinforcements are still compliant with the "Grid of the Future" vision.

4.2 Cluster 2: Power Technology for a More Flexible, Observable and Controllable Pan-European Transmission Grid

4.2.1 Background

In Europe, a new framework for electricity markets has been established since the 1996 IEM Directive: on the one hand, each TSO is responsible for the operations of its electrical system, transporting energy from central generation units down to the DSO lower voltage network. On the other hand, national systems are interconnected (as in the synchronous areas of Nordic or Continental Europe) in a way that goes far beyond the initial specifications. From this point onwards, operators began to rely on power units that are beyond the boundaries of their responsibility, which means that power exchanges are increasing continuously.

As the construction of additional power lines is facing major obstacles, the operational margins of networks are reducing, which is causing each TSO to reconsider:

- optimization (adaptation) of operating procedures,
- new skills for the operators, which will require new training concepts and
- the implementation of emerging technology that would ease operations.

The first two items are addressed in Cluster 3. The third item will be addressed in part in MoDPEHS, as this project contains a work package with the purpose of assessing emerging technologies. The purpose of Cluster 2 is to address the affordability of components of emerging technologies that can significantly improve the operations of the interconnected transmission systems, thereby reducing the extra costs that arise from the management of the variability of generation and volatility of load which are linked to renewables and demand management.

Manufacturers have developed their own technologies that they feel will be needed by network operators. Below are mentioned the most prominent in terms of publications and advertisements:

- WAMS typically comprise a series of phasor measurement units (PMUs), which are monitoring devices that collect continuous data on power flow in a central control room using the global positioning system (GPS) for time synchronization. The manner of processing the measured quantities, i.e. magnitudes and phase angles, allows critical nodes in a power system to be monitored dynamically.

- At a later stage, once the impact of WAMS has been demonstrated, technology for monitoring the system (WMS), controlling the system (WACS) and protecting the system (WAPS) will also be of interest.
- FACTS facilitate the control of power flows while also serving as voltage regulators that can improve overall system stability.
- The combination of WACS and FACTS opens the door for active damping control or enhanced SPS.
- Super conducting current limiters can be used systematically to reduce the fault levels and thus the costs of other components in the network, based on their varying electrical resistance (several orders of magnitude over voltages from 10 kV to 100 kV).
- Super conducting cables, GIL, HTC, switches and other devices.
- Phase-shifting transformers, i.e. a specialized type of transformer which is typically used to control active power flow between two points in electrical power systems.
- Underground smart cables allow smart exploitation using "dynamic thermal current rating" approaches with an impact on the predictive maintenance of networks-
- Electricity storage technology-
- Smart metering, as a prerequisite for efficient demand side management approaches.

These technologies have their own learning curves and innovation cycles: transmission operators may therefore argue about their investment costs, reliability, expected lifetime and the appropriateness of their behaviour when the system experiences a fault. However, provided that their performance can be predicted using appropriate simulation tools, system studies must be performed to validate their performance impact, and to specify real-life tests that would lead to final product specifications and product implementation plans, as well as new network management rules. The entire process requires new knowledge before it can reach commercial application, which involves strong couplings between network owners/operators and manufacturers. This research should provide indisputable responses to questions raised by TSOs when emerging technologies are proposed by manufacturers.

Another important point is to evaluate the smart grid initiatives by DSOs and their possible utilization for supporting the transmission grid with regulation and ancillary services provided by the subgrid.

4.2.2 Knowledge Produced

There are commonalities between each of the technological topics covered in Cluster 2:

- How to value their impact in order to measure their added value for the electrical system as a whole,
- how to locate the technology in the system optimally,
- how to ensure inter-technology coordination within the network and
- how to integrate the technology within the grid.

It is therefore assumed that each piece of technology which is addressed at the European level must follow the same path in terms of innovative field validation at the European level. Once the functional needs to be fulfilled by the technology (not identical for each TSO) have been defined, four innovative deployment steps are followed:

1. Valuation of the use of each of the functions by the network operators (the increase in revenue or loss),
2. optimal location within the pan-European network,
3. optimal coordination with the pan-European network and
4. optimal integration within the existing grid.

Other issues to be faced in order to make the technology work are tackled in other clusters:

- How to integrate the technology within the system architecture (existing and future) (Cluster 1),
- how to integrate the technology within the system operations (see the activities in Cluster 3) and
- how to control the technology (see the activities in Cluster 3).

4.2.3 The Knowledge Portfolio

The expected impact of the Cluster 2 activities by 2020 is to make it possible to evaluate the benefits for the network of each of the studied technologies and to quantify these benefits with demonstration experiments that are deemed sufficient to start national deployment.

Cluster 2 has one activity per studied technology and one activity which is devoted to the deployment of network-connected tests. This latter activity is considered, for example, within the response to the Call Energy 2009.7.1.1, which relates to the optimization of the electricity grid with large-scale renewables and storage. Storage may refer to the direct storage of electricity or indirect storage in the system, the improved management of existing pump stations etc. Existing wind production forecasting tools and power planning tools shall be used together with existing grid management tools to ensure optimal integration with the grid connection, and with its needs and limits, taking into account the optimal use of high voltage lines.

4.3 Cluster 3: Network Management and Control

4.3.1 Background

This cluster addresses stable and disturbed operations of the electrical system in the presence of increased volatility due to massive variable generation (wind and solar farms), distributed energy resources (DER) and increased demand side management technologies. Variable generation is indeed an atypical product in electricity markets and conventional system operations. These issues have already been addressed by two European R&D projects (EWIS and TradeWind), the outcomes of which are recommendations and requirements designed to cope with intermittent generation capacity issues. However, neither R&D project seems to fully address novel market designs, which integrate the expected progress on coordination issues relating to flow-based market coupling.

The pan-European transmission system is confronted with several issues:

1. The new market rules are led by unbundling, and therefore push the operation of the electrical system to its limits, as energy companies are now optimising their portfolio of assets without much regard for transmission constraints. Operating close to the limits comes from the "optimal" use of assets. The definition of security limits becomes critical, together with the assessment of the distance to these limits.

2. The difficulty of building new overhead lines due to issues of public acceptance of new interconnection lines and the cost of alternative solutions.

3. The massive integration of renewable generation into the system reduces the predictability of the sources (location and power in-feeds) and consequently the predictability of flows. Moreover, TSOs have poor observability of these power in-feeds and limited control over them in some control blocks. Overall, the best locations for wind farms will be mostly along the coast and offshore, and the best location for photovoltaic farms is in Southern Europe. Since load centres are not necessarily located near the site of generation, dedicated transmission networks are required, and they will have to cope with the variability of the flows. Demand-side management (including smart grids, EVs etc.) can be seen as an opportunity to compensate for this unpredictability. In order to avoid missing this opportunity, TSOs are required to play a leading role in the field and should be very demanding in the results required from RD&D activities, which should support the establishment of an appropriate demand response architecture and an adequate system services market.

TSOs will therefore have to rethink the architecture of the system, e.g. long distance HVAC underground cables may be installed, with a need for large reactive compensators, HVDC underground cables may be deployed in parallel with the AC grid, including smart controls for the AC/DC converters, and later HVDC grids will be created, first to connect offshore wind farms efficiently and then to offer cost-effective interconnections between distant areas. TSOs will have to improve existing systems, adding more and more special devices, such as PSTs (phase shifting transformers), SVCs, advanced controls (e.g. FACTS), protection schemes and storage, and will have to use demand response in order to increase system flexibility. Such enhanced control of the system will substantially change operating practices.

4.3.2 Produced Knowledge

The complexity of the system will continue to increase. The definition of security limits will become increasingly critical, as well as the assessment of the distance to these limits. These increasingly rapid changes in flows resulting from faster and faster changes in generation and consumption patterns will affect not only the operation of the system but also the dynamics of the system. On the one hand, operators will need enhanced decision-helping tools to keep the security of supply at today's level. On the other hand, dynamic simulations will have to be further developed and data will have to be gathered and validated in order to assess the right level of reserves needed and to maintain the stability of the system.

Beyond this, the complexity of the system is increasing and a more robust and accurate assessment of the security limits is needed. This means that some of the standard approximations, methods and tools used to assess security must be reviewed.

TSOs today try to improve their state estimators by describing, using their real-time IT systems (SCADA), larger and larger parts of neighbouring networks. Alternative solutions exist, such as hierarchical state estimators. Nevertheless, there should be a stronger focus on data exchanges and the robustness of these solutions.

In order to balance the system, TSOs will need to use all available means, including the distributed resources available through virtual power plants and smart grid solutions.

For the days ahead and intraday security assessments, TSOs will have to build base cases in order to assess security, running complex "what if…" analyses. Existing methods are mostly deterministic and based on forecasting the load and the generation in each bus of the network and then on a power flow with a contingency analysis. The generation forecast is typically done using a model based on theoretical costs and merit order. However, in more and more active intra-day electrical markets, the objective of producers is not necessarily to minimize their operating costs, but rather to maximize their benefits by playing on the short-term market. The generation schedules of all of the power plants in Europe are becoming increasingly difficult to predict a day in advance. Moreover, wind power in-feeds are difficult to forecast, and due to the massive integration of wind power in Europe, other classical means of generation are needed in order to balance the system. Each individual method of generation becomes more variable. Improved methodologies require the use of advanced optimization methods to build realistic base cases and probabilistic approaches.

Finally, a security assessment cannot neglect the dynamic behaviour of the system. When operating the system as close as possible to its limits, unstable dynamic phenomena can appear after a contingency, before any static overload issues appear (which is more "easily" manageable). In static security assessment, power flow simulations give an impression of the stabilized post-contingency state, as the security assessment is performed on this state. The underlying assumption is that a stable trajectory exists between the initial state and the stabilized post-contingency state, meaning that all neglected dynamics are stable. This assumption is becoming less and less valid. A robust security assessment must check the validity of this assumption. Time domain simulations are needed to assess security, with the following features:

– "Quality"
  (a time domain simulation method which simulates
  the system accurately)

– "Performance"
  (a time simulation obtained as quickly as possible)

– "Modelling flexibility"
  (taking into account technology such as PSTs, SVCs and HVDCs)

4.3.3 The Knowledge Portfolio

Cluster 3 has four main classes of activities:

1. The development of new simulation techniques which help to move the pan-European network closer to its limits in a rapidly changing context,

2. the development of training methodologies for operators that will deal with European issues,

3. the development of interfaces and decision-making tools to support operators in appraising the network status and making decisions in real time and

4. the development of methodologies to improve, by design, the flexibility of the system.

4.4 Cluster 4: Market Rules

4.4.1 Background

The unbundling and the liberalization of the electricity markets in Europe have underlined/highlighted the specific nature of the electricity markets: working rules and the resulting efficiency are very much constrained by the technical performances of networks, both at the transmission and distribution level. Thus, market facilitation involves a multidisciplinary approach to research activities, whereby network operators, manufacturers and economists must interact closely in order to address five types of issue:

1. Large-scale market simulation tools
   involving renewables and demand-side response
2. Cross-border interaction,
   including new options for congestion management
3. Designing new markets for balancing and ancillary services
   at the European level (opportunities and benefits)
4. Coordination between TSOs and DSOs –
   network construction and evolution
5. Energy-efficient networks
   involving the optimal use of DER, demand-side management
   and electricity storage.

It must be remembered that over previous years, two types of coordination activities are being launched in EU Member States:

1- Enhancing the operational security of the grids and the reliability of power supplies in Europe through increased coordination in daily operations.

2. Regional Group North West Europe Day Ahead
   Market Coupling Project:
   - Single price coupling – enduring solutions,
   - single price coupling with coordinated matching across the combined North West Europe region and
   - extendable to all Europe, facilitating the IEM, Central Western European, Nordic and Great Britain regions from the outset.

4.4.2 The Knowledge Produced

Regulatory challenges

As a consequence of the future DER, demand-side approaches and electricity storage, there are several regulatory challenges to be faced:

- Will large amounts of DER increase the operational costs of networks?
- Can existing networks value the extra benefits that could be gained from DER operations (proximity to consumption sites, allowing the use of heat when using combined cycles or taking advantage of carbon-free sources)?
- Therefore, what is the real value of electricity from such integrated DER units?
- Can DER users reap a fair reward from reducing their carbon emissions?
- What are the new rules needed to account for connection charges in a system facing massive DER expansion?
- How can innovation projects and/or studies help regulatory authorities to identify the benefits/costs of transmission and distribution?
- How will storage systems be considered from a regulatory point of view?
- What are the incentive schemes to be put in place to reach the expected level of technical expansion?

Responding to the questions above requires a full revisit of the entire electrical system, with networks which vary in terms of age and working conditions from one Member State to another.

Below are listed three of the key issues that must be tackled with the help of TSOs:

1. **Care must be taken with investments, operating principles and regulations which favour approaches leading to more active "local management" and "demand response".**
2. **Care must be taken with the "service quality" and "value added to the system" when setting transmission and distribution tariffs and incentive schemes.**
3. **Care must be taken with emerging "value added services" at the distribution and transmission levels.**

Dynamic market simulation tools

One of the prerequisites for understanding new market dynamics at a pan-European level is to model their dynamic interactions, taking into account the physical constraints introduced by transmission networks. The single European electricity market means that transmission system design and performance have a direct impact on price formation. Such a tool, with several design options, should cover the following needs of end-users:

- Modelling the strategic behaviour of market participants in order to produce information to feed the TSOs' decision making process,
- understanding the impact of investment decisions on market efficiency,
- understanding the role of forward contracting in addition to spot market bidding,
- proposing market mechanisms to ensure a capacity reserve at a pan-European level and
- proposing new options for congestion management at a pan-European level.

The other issue which is mainly addressed by the Optimate project deals with a more efficient interfacing of physical network models with market operation models. Such interfacing techniques should be further developed and tested, and should also integrate capacity calculation, prediction and allocation in all of the relevant operations of power exchanges. This should involve existing methodologies such as flow-based market coupling, which is recognized as one of the most promising design approaches for fostering enhanced regional coordination in Europe.

Different techniques exist, like flow-based and available transfer capacity approaches, which can be used for day-ahead market coupling. The first reveals the limiting branches that physically limit cross-border exchanges, i.e. spot market convergence, be it located on a border or within a country. The latter is considered as an acceptable method in less meshed networks, such as the Nordic power system.

European opportunities for balancing and system services

The development of renewables and demand-side integration in Europe will create significant challenges for balancing control, including the management of reserves. In restructured electricity markets, the trend is toward the decoupling of the operational aspect of balancing control and the market settlement aspect of managing deviations in generation and consumption. Therefore, balancing can be seen to address two tasks almost independently:

1. Maintaining the frequency within predefined limits and
2. online management of network congestion arising from erratic deviation.

The implementation of these solutions requires new transmission capacity, flexibility in power flow control and new tools for market and network analysis.

Risk assessment of the pan-European electricity market

Regardless of the capacity calculation method and the allocation approach used, the electricity market has to use risk assessment methods in order to control the economic costs derived from countertrading-measures. The transmission reliability margin (TRM), which is a security margin, copes with uncertainties in computed transfer capacity values.

TSOs shall take into account the following uncertainties when assessing the reliability margin:

- Unintended deviation of physical flows as a result of the activation of the automatic load-frequency control and primary reserve activation and balancing activities due to normal and continuous demand-generation imbalances.
- Inaccuracies of data and measurements and modelling errors.
- Uncertainties in the scenario(s) considered for the capacity calculations, such as aggregated load and generation forecast and localization, network topology, expected exchange schedules and physical flows. These uncertainties shall be taken into account either in the reliability margin or in the base case.
- Emergency exchanges (mutual assistance among TSOs) to cope with unexpected unbalanced situations in real time which are affected by the risk of heavy consequences for the system (e.g. load shedding).

The impact of transactions outside of the assessed/controlled area shall be taken into account.

A focus on specific components of the TRM is needed while addressing the following issues:

- Methodology and approaches for defining the TRM,
- evaluation of the value of the TRM while maximizing the net transfer capacity (NTC), taking into account the risk of secure power system operation and
- assessment of the effectiveness of the electricity market: how can one quantify the cost of re-dispatching and countertrading actions and compare it to the increased social welfare resulting from the opening up of the electricity market?

Pan-European market for ancillary services

In order to provide the right service to customers, an important aspect of the TSOs' business is system adequacy, i.e. the ability to balance the system. This is required in order to serve the load under any circumstances, and also in the event of unplanned outage at the power plant, which is the purpose of most ancillary services. Moreover, ancillary services are also needed to compensate for the uncertainties which are inherent in wind and solar generation, which implies a need for a larger volume of ancillary services as RES grow. Ancillary services which are delivered by dispatchable load through aggregators may contribute to a balanced system in the future, even considering the challenges of the increase in RES production. Due to the volatility of RES production, there is also a need for significant new storage capacities to be built in order to balance the system every minute of the year. Nowadays, the most capable storage facilities are pump storage power plants. For the future, new alternatives like compressed air storage or storage provided by electrical cars might play a role in this context.

The outsourcing of ancillary services beyond the country's frontiers needs to be addressed, as follows:

- What are the different kinds of response that are needed to maintain system stability?
- What blend of sources and service quality (e.g. response time: it is obvious that one cannot accurately measure the response time of a collection of EVs) is needed in order to deliver each kind of response?
- What volume of ancillary services is needed for each blend?
- How can one stimulate competition by offering ancillary services?
- Transparent procedures must be established to be able to measure whether or not it is worthwhile, from a social welfare point of view (for each particular case), to reserve cross border capacity for power reserve and/or balancing purposes.

In addition, it is very important to introduce incentive schemes in order to encourage RES units to change their role in the future from ancillary service users to ancillary service providers. Adequate research from both technical (the potential of different RES units to provide ancillary services) and regulatory points of view is necessary.

Market mechanisms

The approach chosen for integrating the pan-European markets should ideally lead to a decrease in the volatility of prices through efficient use of the available means across Europe. Price spikes also indicate the need for affordable peak units; current signals to investors regarding the need for peak units are becoming less and less easy to translate into investment decisions. System adequacy will becoming increasingly difficult to manage, as the operating hours of peak units will decrease in favour of "cheap" energy provided by RES.

A focus on specific markets is needed in order to address the following issues:

- How is it possible to stimulate investors to build power plants with fewer running hours?
- What kind of capacity payments mechanism (the same incentives across Europe, or zonal incentives based on system adequacy and stability requirements, even if the price of electricity is the same across Europe) is suitable, considering the target model for the European electricity market?
  In other words, it is necessary to carry out research to determine whether or not harmonized long-term capacity payments are useful for warranting sufficient conventional generation adequacy in the long term, taking into account the introduction of massive amounts of RES generation. The final goal is to incentivise flexible generation (both current and future), e.g. an open cycle operating mode capable of combining cycle units and the ability to regulate pump storage units (on both generating and pumping modes).
- How is it possible to deal with controllable devices (PSTs, HVDC links, FACTS etc.) from the mid- and long-term market perspectives?

Pan-European business model

Since the deregulation of the electricity sector, the business model of the industry has changed progressively. TSOs, DSOs, regulators, power producers, retailers, suppliers, traders, industrial consumers and wind and solar production developers are playing important roles in delivering an efficient electricity market. However, the electricity industry may still change radically. New actors are surfacing, such as ICT companies that can use the Internet to develop and implement new mechanisms that could even be used "off the radar."

Revisiting the business model of the industry as a whole will help to define regulations, incentives and other mechanisms that aim to decarbonise Europe while ensuring a reliable and efficient supply of electricity. The following questions must be addressed:

- What is the value/welfare created?
- What value/welfare will be created in the future?
- Who is creating value? How and why? Who is destroying value? How and why?
- What are the different models for who should create what part of the value in the future?
- What is the status of competition in the industry?
- What value could be created through further consolidation? Per role?
- What target model would Europe need in order to face climate and economic challenges? What are the barriers? What are the realistic steps to reach this target model within a reasonable time frame?

Improved coordination between TSOs, DSOs and GenCos

The advent of massive DER systems coupled with real-time pricing contracts, implemented in demand-side management contracts at the consumer level, will introduce more volatility in both the production and consumption of electricity. Several solutions are being researched and developed at the pan-European level, including aggregation, virtual power plants and so on. This will have an impact on new connection rules, new market designs and new responsibilities between TSOs and DSOs.

Due to the prospective impact of the increase in demand on control power, comprehensive tools for managing ancillary services are required. Modern tools and procedures for GenCos' prequalification and permanent monitoring of the quality of the corresponding services must be developed.

4.4.3 The Knowledge Portfolio

This cluster studies the ways and means to facilitate interactions between the European electricity markets and the pan-European transmission system, with the aim of reaching a more efficient market through the optimization of the energy mix at the pan-European level while maintaining reliable operations, i.e. the security of supply. New market designs must be analysed in order to ensure that they can cope with not only the variability of renewable energy generation, but also with demand-side management and storage.

A hierarchical view of the issues to be addressed is given in figure 4.4.3.

This R&D program should be able to cope with most of the interactions between all of the items in the table above. A realistic R&D program requires tasks to be split into different projects focusing on one specific issue, taking into account some of the critical interactions.

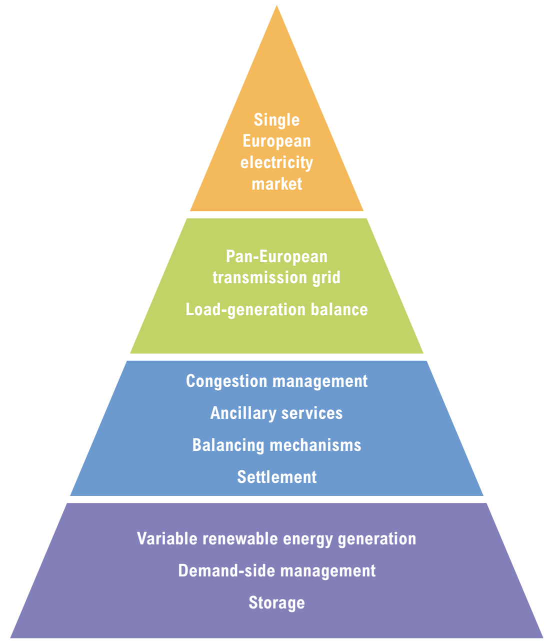


Figure 4.4.3:
Hierarchical view

Moreover, simulation tools are needed to demonstrate the benefit of each new "market design" option. Six classes of activities have been defined in order to generate manageable R&D activities:

- **C4.1**
  European electricity market and European transmission network
  New methods for capacity allocation at the European level are required, generating signals to encourage the optimal location of generation and/or network development, but also taking into account new network technology (HVDC etc.) and its environmental impact.

- **C4.2**
  European electricity market and European load-generation balance
  The optimization of the European energy mix must be pursued, including short-term balancing mechanisms and possibly centralized storage facilities. Signals have to be developed in order to encourage portfolio managers to minimize their imbalance.

- **C4.3**
  European electricity market and variable renewable energy generation
  This is the objective of the Optimate project (an Open Platform to Test Integration in New Market Designs of massive intermittent energy sources dispersed over several regional power markets).

- **C4.4**
  European electricity market and DSM/decentralized storage

- **C4.5**
  European electricity market and ancillary services

- **C4.6**
  Generic tools and methodologies to simulate market behaviours

Based on the results of the Optimate project, this study proposes the development of a simulation platform that will host the majority of the simulation tools developed within Clusters 1, 3 and 4.

4.5 Cluster 5: Joint TSO/DSO R&D Activities

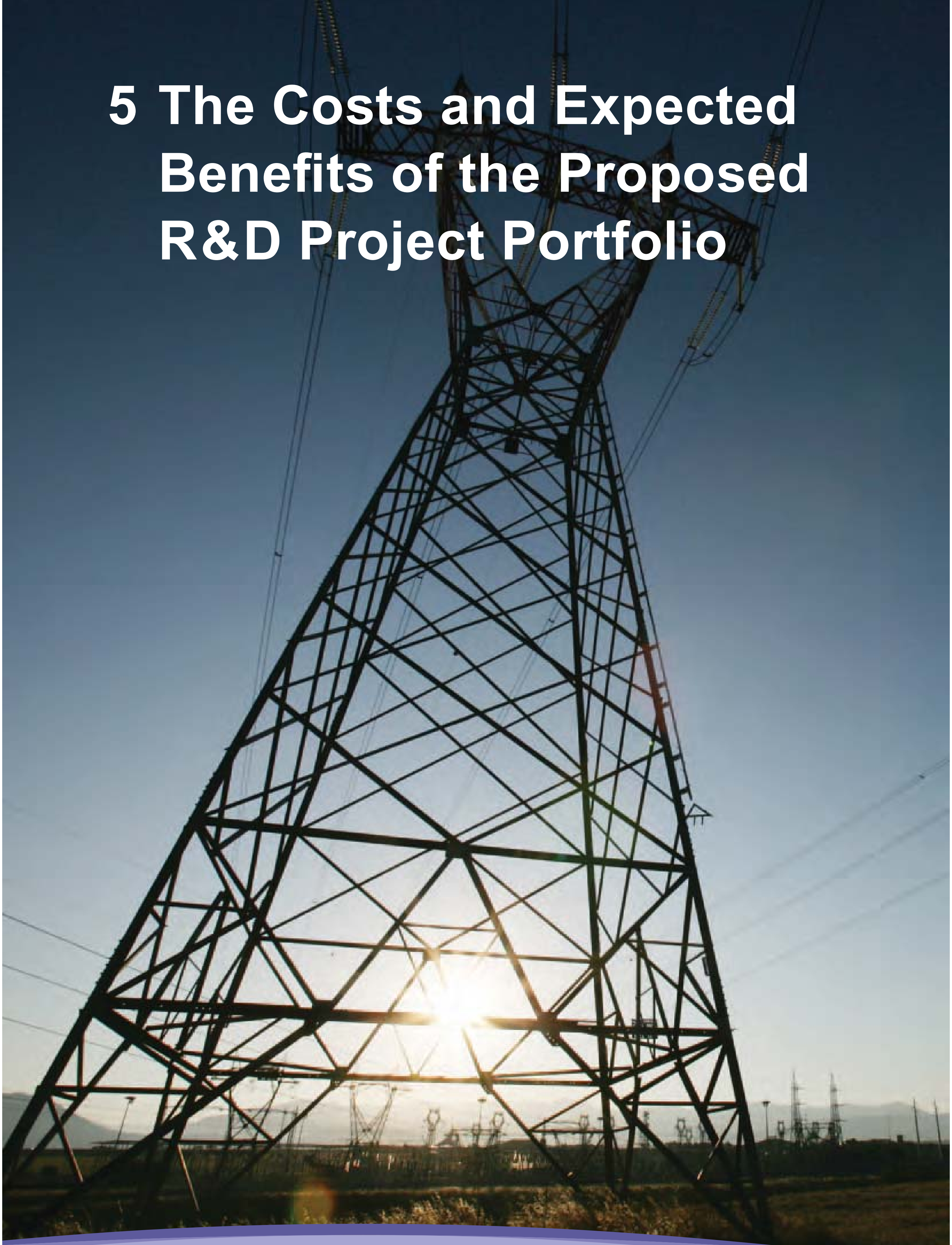
This section emphasizes the functional projects that the TSOs and DSOs have in common. The following relies on the EEGI Roadmap 2010 – 2018 and Detailed Implementation Plan 2010 – 2012 and the Cooperation Agreement between ENTSO-E and EDSO-SG. An updated version of this part will be published in 2012 with the update of the EEGI Roadmap.

Transmission and distribution networks increasingly need to coordinate their operations and to exchange data in real time for this purpose. The work is divided into the following functional projects:

- Tools for improved system observability and network interaction (DSO driven),
- integration of demand-side management into TSO operations,
- DSOs as system service providers (DSO driven),
- improved defence and restoration plan (TSO driven) and
- taskforce on data exchange between regulated and free market players (DSO driven).

Additional information on the description of functional projects is provided in Appendix 1.

5 The Costs and Expected Benefits of the Proposed R&D Project Portfolio



5.1 Costs of the Five Clusters

The table below summarizes the predicted costs per cluster activity, including management and dissemination at the pan-European level (Table 5.1). The costs indicated in the table are based on the information available in the EEGI Roadmap.

		Cost in million €	
Cluster	**Scope of the activity**	**Total R&D cost**	**TSO share**
1	Architecture and planning for the pan-European grid	90.0	33.0
2	Demonstration of technology to make the transmission system more flexible, intelligent and secure	330.0	100.0 – 120.0
3	Operational tools to make the pan-European system more secure	75.0	25.0
4	New market design options based on simulation techniques	65.0	19.5
5	Joint TSO/DSO R&D activities	230.0	*
	Total:	790.0	177.5 – 197.5
	Research:	360.0	85.5 – 90.5
	Demonstration:	430.0	92 – 107.0

* It is expected that the TSO share will be approximately 15 %, but this estimate is not defined in the EEGI Roadmap. Information will be provided in the next version of the ENTSO-E R&D Plan

Table 5.1:
Costs per cluster activity

Clusters 1, 3 and 4 include mainly research activities. Cluster 2 covers demonstration activities including associated research, for which the retained ratio (research/total costs) is that which is advised by DG TREN for demonstration activities (i.e. 20 %). Cluster 5 covers joint TSO/DSO activities.

Several remarks must be made at this stage in the program definition:

– The integration project costs cover the R&D cluster costs. The packaging costs of implementing the results for any TSO belonging to ENTSO-E have not yet been evaluated.

– Proposals on new R&D sub-projects within the different functional projects started early in 2010.

5.2 Expected Global Benefits

The table below further summarizes the expected high-level impact of the proposed innovation activities of the five R&D clusters (Table 5.2).

<table>
<tr><th>R&D cluster</th><th>Scope of the R&D topics</th><th>Output delivered by 2020 with the tools and knowledge produced</th></tr>
<tr><td>1</td><td>Innovative architecture and planning approaches for the pan-European grid</td><td>– Secure network architecture to integrate renewable generation (offshore & on-shore)
– Pan-European planning methodologies able to account for active demand</td></tr>
<tr><td>2</td><td>Demonstrations of technology to make the transmission system more flexible</td><td rowspan="2">– Power technology able to increase transmission capacity while limiting overhead lines, with related cost and benefit analysis
– More accurate assessment of security limits of the pan-European system
– Real-time assessment of security margins thanks to robust simulators</td></tr>
<tr><td>3</td><td>Novel operations to make the pan-European system more secure</td></tr>
<tr><td>4</td><td>New market design options based on simulation techniques</td><td>– Proposals of more efficient market rules to regulatory bodies</td></tr>
<tr><td>5</td><td>Activities to coordinate transmission and distribution networks</td><td>– Improved defence and restoration plans, IT system protocol and standards
– Integration of demand-side management in TSO operations
– Increased observability of the electric system for network management and control</td></tr>
</table>

Table 5.2:
Impact of the proposed innovation activities

Overall, the increase in renewables and consumers' energy-conscious behaviours as a reaction to real-time energy price signals will lead to **increased volatility** in electricity generation and consumption, potentially **stressing the networks**, at both the transmission and distribution levels. As a consequence, the expected improvement in the carbon footprint of the European electricity system may be more costly than expected, **due to unresolved network problems**.

Both transmission and distribution networks contribute up to more than 50 % of the cost of electricity delivered to end-users. Hence, potential trouble with the networks will inevitably increase European electricity system costs. It is therefore of paramount importance to introduce **increased innovation** in order to minimize, and possibly annihilate/eliminate, such cost increases, while reducing the overall carbon footprint of the European electrical system.

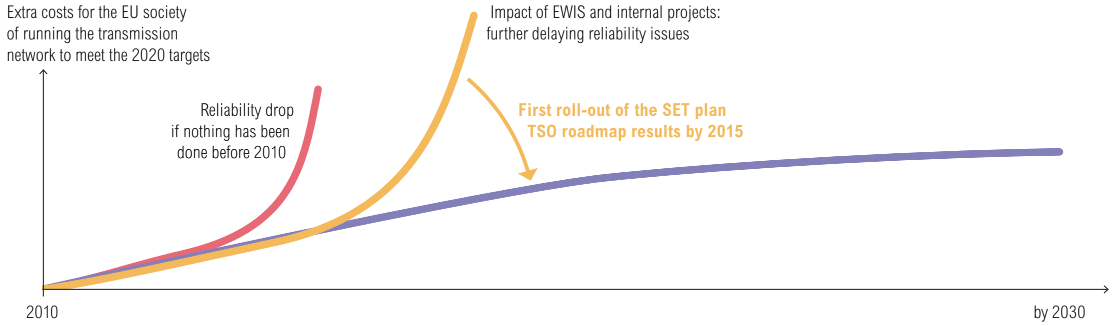


Figure 5.2:
Implementation plan to meet the 2020 targets

Figure 5.2 illustrates the actions that will be implemented in order to progressively meet 2020 targets:

- The results of projects such as EWIS, TradeWind and other national projects are aiming to make it possible to reach 2015 while limiting the impact of any major reliability risk for the pan-European transmission system.
- However, if no further action is taken now, then due to the increased share of renewables, network management will become more and more difficult, thus increasing the probability of major European reliability failures and the related social costs (billions of Euros of GDP lost per day) before 2020.
- By rolling out the results of the present program by 2015, it is expected that the extra costs of reengineering and running the new network will be contained.

Overall, the contribution of TSOs to the EEGI for the period 2010 – 2018 will cost over € 0.5 billion worth of extra R&D investments. This R&D investment primarily aims to:

- decrease future transmission investment uncertainty and
- help to prepare smart investments for all electricity players
(more than € 1,600 billion for 2007 – 2030, as revealed table 5.3, taken from the IEA 2008 analysis).

Baseline scenario (business as usual)		**Europe 2006**	**Europe 2030**
Electricity consumption (TWh)		3,022	3,980
Prodution capacity (GW)		834	1,133
CO_2 emissions (Mt) (power generation only)		1,422	1,513
Investments (billion Euro) 2007 – 2030	**Total**		**1,614**
	Generation		1,075
	Transmission		134
	Distribution		405

Table 5.3:
Investments for all electricity players

More specifically, the aim of implementing the R&D output jointly within ENTSO-E is to:

- Reduce the extra network expenditures (CAPEX and OPEX) in order to meet electricity decarbonisation targets.
- Prepare for the integration of offshore generation technologies by 2015, with wind possibly involved in spot markets and system services.
- Keep the pan-European system security margins at acceptable levels, through:
  - Clever network architecture and operations and
  - cross-border coordinated operations
    with shared network management tools.
- Take advantage of demand response via smart distribution grids.
- Be fully compliant with the Third Energy Package, including the role of smart metering.

5.3 Benefits Per Project

- The projects have their own intrinsic benefits, which are briefly described in the appendices within an initial functional description.
- KPIs for each cluster (which are yet to be defined) will help to monitor the contribution of each project to the European added value of the cluster. When the desired KPI is reached, this means that the probability of reaching the EU policy goals is high. If not, this means that either the policy must be redesigned, or incentives must be found to reach the desired KPI value.

5.4 Industrial Benefits: Reinforcing the Standardization of Power Technology

The large-scale projects outlined above have direct benefits for ongoing standardization activities, in favour of the European power manufacturing industry:

– Overall communication standards and protocols for a seamless exchange of data, such as IEC 61850.

– Coordination at the international, IEC and CENELEC levels, when dealing with DER integration into electrical networks. The IEC decided to establish a Strategic Group on Smart Grids in order to coordinate the standardization work between the committees and parties involved.

– Work on common requirements and DER grid connection procedures. Connection standards are covered by EN 50438 or similar solutions in the USA, with IEEE 1547 presenting common requirements. The new European power quality standard EN 50160 should take into account the wider penetration of DER units.

Transmission operators will then be in a position to progressively identify needs for emerging functions and technology for their networks in a more coordinated fashion. This will allow manufacturers to initiate R&D programs in order to provide solutions which will stretch beyond 2015, in line with future distribution requirements. Moreover, work on demonstrations with generation equipment, smart building developers or electrical vehicles will lead to a European showroom that will demonstrate the types of electrical system which will be able in the future to integrate such a variety of technology seamlessly, effectively and efficiently.

6 Appendices

6.1 Appendix 1: Functional Project Descriptions

The table below summarizes the functional projects that have been proposed in order to address the issues affecting TSOs. In addition to the impact on TSOs, the table also provides the predicted impact on DSOs, manufacturers, GenCos etc.

		DSO		Manufacturer		GenCos		Other
Functional Projects		Partner	Impact	Partner	Impact	Partner	Impact	Partner
T1	A toolbox allowing new network architecture assessment in the pan-European transmission system	×	Medium	✓	Medium	×	Low	✓
T2	Advanced tools to analyse pan-European network expansion options according to energy scenarios for Europe	✓	Medium	✓	Medium	✓	High	✓
T3	Demonstration of power technology for increased network flexibility	×	Medium	✓	High	×	Low	✓
T4	Demonstration of power technology for novel network architecture	✓	High	✓	High	×	Low	✓
T5	Demonstration of renewable integration	✓	High	✓	Medium	✓	Medium	
T6	Innovative tools for pan-European network observability	×	Medium	✓	Medium	×	Low	✓
T7	Innovative tools for coordinated operations with stability margin evaluation	×	Low	✓	Medium	×	Low	✓
T8	Improved training tools to ensure better coordination at the regional and pan-European levels	✓	Medium	✓	Low	×	Low	✓
T9	Innovative tools and approaches for pan-European network reliability assessment	×	Medium	×	Low	×	Low	✓
T10	Advanced tools for pan-European balancing markets	✓	Medium	✓	Medium	×	Low	✓
T11	Advanced tools for capacity allocation and congestion management	×	Low	×	Low	×	Medium	✓
T12	Tools for renewable market integration	✓	Medium	×	Low	✓	High	✓
T13	Tools for the integration of active demand in electrical system operations	✓	High	✓	Medium	✓	High	✓
T14	Environmental impact and social acceptance of transmission facilities	✓	Medium	✓	Medium	✓	Low	✓
TD1	Increased observability of the electrical system for network management and control	✓	High	✓	High	×	Low	✓
TD2	Integration of demand-side management into TSO operations	✓	High	✓	High	×	Low	✓
TD3	Ancillary services provided by DSOs	✓	High	✓	High	✓	Medium	✓
TD4	Improved defence and restoration plan	✓	High	✓	Medium	×	Low	✓
TD5	Joint taskforce on IT system protocols and standards	✓	High	✓	High	✓	High	✓

High impact   Medium impact   Low impact

6.1.1 Functional Projects – Cluster 1

Functional project		Before 2011	2011	2012	2013	2014	2015
T1	A toolbox for new network architecture assessment	Twenties					
		Almacena					
T2	Tools to analyse pan-European network expansion options						
T14	Innovative approaches to improve the public acceptance of overhead lines						

Relevant ongoing projects
Identified sub-projects

T1 A toolbox allowing new network architecture assessment in the pan-European transmission system

Contents/scope: The purpose of this toolbox is to facilitate architecture simulations at the EU level which are capable of comparing several designs based on various technical and economic criteria, taking into account emerging technologies such as HVDC, GIS, FACTS etc. A cost-benefit analysis would be performed for transmission assets (including interconnections). The simulation toolbox will introduce security constraints which may severely constrain the new architectural design.

Specific tasks:
- Gathering information from the TSOs and defining the input data requirements and data interfaces (to or from cost-benefit simulators, power flow tools etc.),
- developing new algorithms for static simulation without exchanging data through the decentralization of the various subsystems' simulation engines and
- validating specific cost-benefit modules for coordinated use in architectural design and validation: flow control power devices, HVDC technology.

The effect of one flow control device can be countered by another, meaning that the net effect is nil. Cost-benefit tools are therefore needed in order to implement and use the power flow control devices efficiently. Similarly, a harmonized toolbox is needed in order to assess the cost of HV lines for society.

Expected impact: This is a cost-benefit analysis tool for optimizing grid development at the pan-European level. This tool comprises databases on technology and would identify the most cost-effective technology for implementation in standard or new architecture, the added value evaluation of HVDC or FACTs, the optimization of the location and new regulatory constraints which would favour the cross-border operation of networks with such devices

The security assessment can provide constraints or indications for designing a proper grid code which is in line with the security expectations of the novel architecture. In addition, technical needs could be derived from the results obtained by the tool.

Additional information: This project will build on available results from other projects.

Partners involved:
- TSOs (providing data, network topology, long-term planning scenarios, analyzing results)
- Research providers (surveying technology capabilities, developing algorithms, gathering data needed for algorithms, testing the developed tool)
- Technology providers -manufacturers (developing the calculation engine, adapting data formats, etc.)

Project duration: 2012 – 2015

T2 Advanced tools to analyse pan-European network expansion options according to energy scenarios for Europe

Contents/scope: TSOs will develop a toolbox for analyzing pan-European grid expansion scenarios in conjunction with the post-2020 targets, which reflect the need for Europe's electricity supply to be carbon-free by 2050 in order to further integrate renewable and conventional generation, use power flow control devices, address the role of active demand (controllable loads) and take into account energy storage, with optima that are researched at the EU level and no longer at the national level. These tools are complementary to architectural design tools and will build on results from the MoDPEHS project scenarios.

The scenario analysis tool should be able to answer the following questions:
- Up to what point is the existing transmission system able to integrate large amounts of intermittent and disperse generation, and from what level will dedicated transmission investments become necessary?
- What kind of technology is most suited to this purpose?
- How can we improve on previous planning and reliability tools and methods to feature transmission systems with growing amounts of wind-based generation?
- What kind of storage market mechanism could better address the intermittent nature of wind?

The objectives of this task are to investigate how this new load flexibility will be taken into consideration by the new planning tool when planning the expansion of the transmission network.

The simulation toolbox which is to be developed for new technology services (e.g. storage) will make possible to analyse their long-term or integral costs.

Expected impact:
- Optimization in planning and network development at the EU level:
  Coordinated planning tools are available for key investments and will take into account models of network investment in future competitive electricity markets.
- Optimization of network reliability:
  Each investment in a network will influence the reliability of the power supply at the local, regional and national levels.

Additional information:

Technology involved: Typical optimization tools.

Partners involved:
- TSOs
- DSOs
- Research providers
- Electricity producers and retailers

Project duration: 2010–2014

T14 Environmental impact and social acceptance of transmission facilities

Contents/scope: The objective of this project is to continue to improve the relationship between transmission facilities and the natural and social environment in which they should be deployed. The expected results are:
– the production of a European guide to the construction of overhead power lines by a group of leading experts in environmental and acceptance issues after a broad consultation process and
– physical protection of the infrastructures against a variety of potential dangers (natural catastrophes, terrorism, hackers, robbery, vandalism etc.) in order to ensure suitable levels of system reliability and security of supply.

Some of the most relevant deliverables will be new models of bird savers which will be able to reduce bird collisions, as well as durable, inexpensive, innovative methodologies used to install bird saver devices, possible alternatives to SF6 as a high-voltage insulator, biological laboratory research studies on the possible health effects of power frequency electromagnetic fields, software tools to calculate the level of EMF generated by high-power frequency infrastructures, new methodologies and software to evaluate the exposure of the public and workers in order to ensure compliance with exposure standards, new design features to minimize the generation of audible noise, passive acoustic barriers designed to reduce audible noise near to the source or where the public may be affected, active ways to eliminate the noise etc.

Expected impact: This is expected to affect the social acceptance, the environment and the critical infrastructure protection.

The expected benefits are as follows:
– An improved relationship between TSOs and final customers,
– valuable feedback and signals from the "outside world",
– a clear increase in public acceptance, occurring first in the selected grid areas,
– enabling TSOs to contribute significantly to achieving the European objectives for 2020 and beyond,
– rapid repair of damaged installations,
– rapid recovery of the demand/supply balance and
– protection against cyber-attacks.

Additional information:

Technology involved:
– High-voltage insulation
– Biological laboratory research
– Computational techniques
– Equipment design
– Acoustic barriers
– Noise elimination
– Mobile emergency installations
– Firewalls against cyber-hackers

Partners involved:
– TSOs
– Power equipment manufacturers
– Research providers

Project duration: 2010 – 2018

6.1.2 Functional Projects – Cluster 2

<table>
<tr><th colspan="2">Functional project</th><th>Before 2011</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td rowspan="3">T3</td><td rowspan="3">Demonstration of power technologies for increased network flexibility</td><td colspan="6">Substation 61850</td></tr>
<tr><td></td><td colspan="4">SUMO</td><td></td></tr>
<tr><td colspan="3">Early Warning Systems</td><td></td><td></td><td></td></tr>
<tr><td>T4</td><td>Demonstration of power technologies for novel architecture</td><td colspan="5">220 kV SSSC device</td><td></td></tr>
<tr><td rowspan="3">T5</td><td rowspan="3">Demonstration of renewable integration</td><td>EWIS</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Twenties</td><td></td><td></td></tr>
<tr><td colspan="5">220 kV SSSC device</td><td></td></tr>
</table>

Relevant ongoing projects   Identified sub-projects

T3 Demonstration of power technology for increased network flexibility

Contents/scope: The use of power electronics, high-temperature cables and other technologies to increase the transmission capacity and flexibility of the pan-European network.

The demonstration of emerging technology which is able to increase the transmission capacity of the existing grid and emerging technology which is able to control the current flow in order to increase the flexibility of the existing grid.

Increasing transmission capacity: The advent of a pan-European electricity market with a free flow of energy across multiple borders has led to the need for increased transmission capacities at interconnections between control areas. The transmission capacity of existing lines can be increased through several different methods.

The present demonstration projects must show the degree to which thermal capacity could be increased at the cross-border level through the implementation of different approaches. This project will provide a joint analysis of all possible technical solutions within the domain of application. Cost-benefit analyses of different case studies will be performed.

Increased flexibility: The advent of a pan-European electricity market with a free flow of energy across multiple borders has led to an increased interest in power flow control devices.

Expected impact:
- Validated methodologies to upgrade the existing grid,
- increased capacity at a reduced cost and with a reduced environmental impact,
- short-term relief for some network pinch points and
- new technology to control power flow and tools to position it.

Additional information:

Technology involved:
- Equipment and methodologies to monitor conductor temperature
- High-temperature cables and equipment
- FACTS and PSTs

Partners involved:
- TSOs
- Manufacturers
- Research institutes

Project duration: 2010–2018

T4 Demonstration of power technology for novel network architecture

Contents/scope: The scope of this project includes the impact of power electronics on architectural choices (the validation of offshore and on-shore options), which are quantified based on full-scale demonstrations including the security aspects of meshed network management, as well as the demonstration of new grid technologies like HVDC, superconductivity and any other promising technology for keeping up with the needs and expectations of the European electrical system in the next few decades.

Technology is demonstrated in large-scale experiments to address pan-European problems such as:
- providing a reliable and stable backbone for European internal electricity markets,
- the interconnections in the system can be increased, e.g. with selective reinforcements or by creating an ultra-high voltage transmission system (a so-called supergrid) or a DC backbone,
- an increase in power fluctuations in feeds from RES is possible with the help of increased power flow steering at the transmission (bulk power) level and
- regional interconnection and local distribution (e.g. including mini- and micro-grids) can be reconsidered (power flow, control and protection).

These studies should help to determine the best structure, by keeping the actual voltage levels at 380–220 kV/150 kV and through selective reinforcement at bottlenecks, by introducing a new AC voltage level of 750 kV, by introducing selected HVDC links, by creating a DC grid and by making greater use of the underlying 380 kV network in separated sub-networks.

Superconducting cables are able to transport much more power with very low (or no) losses, with the disadvantage that the installation must be kept at a very low temperature, usually with liquid nitrogen. This technology seems valid to reinforce the power supply to big cities, big generators or consumers. In addition, there will be an increasing number of high-voltage applications based on superconductivity, like fault current limiters.

Expected impact: The experimental data gathered during experiments will feed into planning models, operational strategies and market simulators in order to validate network expansion and network flexibility costs within different pan-European scenarios.

Additional information:

Technology involved:
- HVDC technology
- Superconducting cables and equipment (like fault current limiters)

Partners involved:
- TSOs
- Manufacturers
- Research institutes

Project duration: 2012–2018

T5 Demonstration of renewable integration

Contents/scope:

- The validation of the contribution of renewables to the power system (voltage and frequency control, balancing using VPP concepts).
- The resolution of the security aspects of offshore HVDC meshed networks (circuit breakers, multi-terminal control systems).
- Monitoring and controlling the network in order to avoid large-scale intra-zone oscillations.
- The validatation of integration scenarios in which the network is more user-friendly in order to welcome variable renewable energy generation. The generation technology can become smarter in order to contribute to system services and enter electricity markets and future network architecture is validated from both power and reliability standpoints.

TSOs and end-users are challenged by renewables from the point of view of system security as well as economic interests. With increasing wind gradients, the necessary reserves to maintain system stability will increase. This will cause a need for high system margins on power reserves and standby production. With higher margins on reserves, wind integration will lead to increased costs for balancing services, which will ultimately mean increased costs for security and also for end-users.

It is possible to mobilize local assets and to co-optimise them with central production operations in order to balance wind gradients. However, it must be shown at full scale that:

- A market-integrated solution that combines demand and generation signals is possible,
- a clear assessment of the cost structure of mobilizing local assets and of the benefits to all stakeholders involved is required before scaling up and replicating the solution and
- the control of wind or solar farms helps to provide more stability from a systems perspective, even though it causes reduced exploitation of wind/solar power.

Expected impact:

- Effective rules for the management of variable power production in liberalized energy and power markets where renewable can be balanced cost-effectively over longer periods of time by optimizing across the value chain over central and local assets and
- control procedures for system security and ancillary services, not only by central power plants but also by wind farms (offshore and on-shore) and local assets (distributed generators and loads).

Additional information:

Technology involved:

- IT solutions to integration that are secure and scalable
- Power electronics
- HVDC technology

Partners involved:

- TSOs
- DSOs
- GenCos
- Manufacturers

Project duration: 2010 – 2018

6.1.3 Functional Projects – Cluster 3

<table>
<tr><th colspan="2">Functional project</th><th>Before 2011</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td rowspan="5">T6</td><td rowspan="5">Tools for pan-European network observability</td><td colspan="2">The Cell Controller Project</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Smart Grids and Energy Markets (SGEM)</td><td></td></tr>
<tr><td colspan="3">PEGASE</td><td></td><td></td><td></td></tr>
<tr><td colspan="3">SafeWind</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Twenties</td><td></td><td></td></tr>
<tr><td rowspan="6">T7</td><td rowspan="6">Tools for coordinated operations with stability margin evaluation</td><td colspan="5">Smart Grids and Energy Markets (SGEM)</td><td></td></tr>
<tr><td colspan="3">PEGASE</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="4">After</td><td></td></tr>
<tr><td colspan="4">Twenties</td><td></td><td></td></tr>
<tr><td></td><td colspan="5">Umbrella (proposal submitted to EC) *(identified sub-project)*</td></tr>
<tr><td></td><td colspan="5">iTesla (proposal submitted to EC) *(identified sub-project)*</td></tr>
<tr><td rowspan="2">T8</td><td rowspan="2">Improved training tools for improved coordination</td><td colspan="5">Smart Grids and Energy Markets (SGEM)</td><td></td></tr>
<tr><td colspan="3">PEGASE</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">T9</td><td rowspan="3">Tools for pan-European network reliability assessment</td><td></td><td colspan="4">After</td><td></td></tr>
<tr><td colspan="4">Twenties</td><td></td><td></td></tr>
<tr><td>EWIS</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Relevant ongoing projects Identified sub-projects

T6 Innovative tools for pan-European network observability

Motivation: The monitoring, control and protection systems which are implemented today in transmission system applications have intrinsic limitations, and there is currently no pan-European observability of the interconnected system. Offline simulation methods or static remote measurements with very low flexibility to account for the stressed operating conditions of transmission systems are used to tune controllers. Protection systems detect faults, but do not allow the accurate location of the fault nor identify the equipment's parameters.

Contents/scope: Sensors (like PMUs) and simulation tools are able and validated to offer regional coordination centres the real-time status of their neighbouring zones, thereby facilitating better observability.
The following objectives should be pursued:

- To assess and validate the performances of local sensors and data processing facilities (with sensor manufacturers) against the requirements of state estimation and dynamic simulation,
- To develop local state models with the right level of intelligence at the substation level (with power technology manufacturers aiming toward a standardized approach throughout Europe, i.e. IEC 61850) and to use this valuable information with state estimators and dynamic simulation,
- To broaden observability and improve accuracy (both steady state and dynamic accuracy) through adequate modelling (including not only modelling protection schemes and other automatisms to some extent, but also by merging transmission and distribution models) to enable the real-time detection of instabilities, prevent over-passing the limits, review defence and restoration plans etc. and
- to standardize overall communication, the sensing infrastructure (in line with the NIST approach in the USA) and data exchange.

This project should integrate results from the experiments in Cluster 2 and Cluster 3 and from past projects.

Expected impact: To enable the accurate monitoring of the system in order to facilitate a high share of RES while maintaining the same level of reliability.

Additional information:

Technology involved: PMUs open up new possibilities in power system control and protection design, including the implementation of model-based (or model predictive) and/or adaptive controllers that previously have not been feasible or sufficiently useful.

Partners involved:

- TSOs
- Manufacturers (of sensors and power technology)
- European standardization bodies
- Telecommunications technology and service providers
- Research providers

Project duration: 2010 – 2017

T7 Innovative tools for coordinated operations with stability margin evaluation

Motivation: The increasing share of RES is affecting system operations by increasing the volatility of flows in the grid. This results in higher levels of complexity in anticipating and managing congestion and operating the grid in a reliable way. In addition, dynamic aspects must be examined as close to real time as possible and planned on a daily basis. During the last decade, the system moved from a very well-planned and almost certain operation to a volatile operation faced with many uncertainties. Today, operators know the weak points of their systems and make decisions based on their experience. Increasingly rapid changes complicate the learning process, and guidance is needed to make the right decisions quickly. Identifying the worst-case situation has become extremely complicated. Hence, preparing to operate is becoming more complicated than ever.

Contents/scope: New tools are needed in order to facilitate the harmonization and coordination of operational procedures among TSOs in order to deliver electricity according to the level of quality customers require.
The objective of this project is to integrate the output of activities in Cluster 3 into a single toolbox that will address this complex optimization problem. It will allow the pan-European transmission system operators:
- To assess the effectiveness of control actions to deliver the right level of reliability while facing generation, consumption, distribution and transmission uncertainties, resulting in particular from the large-scale deployment of RES and the integration of markets,
- to conceptualize optimization challenge as seen by operators and to test optimal solutions in order to deal with the transit maximization problem,
- to implement stochastic approaches to critical optimization variables (larger dispersions around the deterministic values obtained from the current steady state simulation tools) in order to cope adequately with uncertainties,
- to facilitate the converging of policies for operational planning and to support the harmonization of operating rules at the ENTSO-E level,
- to propose data exchange procedures in order to simulate the system adequately, to identify the critical contingencies and to assess residual risk, taking into account effectiveness and the availability of control actions and automatic protection schemes while identifying the action paths which should be implemented and
- to develop new approaches to the establishment of coordinated defence plans.

Expected impact: This project will enable the system to be operated in a coordinated and reliable way through the use of new tools, methods and knowledge, thereby supporting a European reliability doctrine which allows systems to operate under narrower stability margins.

It will also enable the creation of coordinated defence plans based on a new set of principles and methods which take uncertainty into consideration.

Additional information:

Technology involved: The ideal formulation of the problem of translating functional objectives is either the mixed logical dynamical framework (MLD), for transforming the most logical expressions into equivalent forms using discrete variables, or the equilibrium constraints (MPEC) formulation and solvers for handling, simultaneously and robustly, continuous and discrete variables (large-size mixed integer linear problems (MILP) or complementary constraints (MPEC)).

Partners involved:
- TSOs
- Research providers
- Commercial solutions providers.

Project duration: 2011 – 2016

T8 Improved training tools to ensure better coordination at the regional and pan-European levels

Motivation: Operators need to be trained to face the increasingly rapid changes that are occurring in their transmission systems. On the one hand, they must be trained more frequently. On the other hand, today's tools have not been designed to simulate uncertainties, automatic control actions and the dynamics of the system. Moreover, they are not suited to managing a broader scope and to organizing coordinated training, i.e. where people from different TSOs are trained to interact with each other, as an increasing level of coordination is required.

Contents/scope: Simulator/training facilities must evolve to cope with modelling the increasing complexity of operations in the presence of a large amount of RES. At the pan-European level, the design of future common training centres must make it possible:

- To simulate in real time the entire interconnected European power system for training purposes,
- to train dispatchers to reproduce and understand large-scale incidents,
- to provide training, but also certification, to operators on a validated European power system model and improve the emergency condition procedures,
- to make the dispatching training simulation facility available to other operators, such as power plant operators and distribution network operators, in order to improve grid/plant and grid/distribution network interfaces and
- to develop and test common procedures for emergency scenarios.

The training facility will be developed and tested at a prototype level with dispatchers: it will involve novel man-machine interfaces in which the state of neighbouring systems is displayed using new visualization techniques and interactions with other operators are either simulated or real.

Expected impact:

- To enable the training of operators by specifying the training simulator of the future, including the validation of critical algorithms and
- to enable experimentation on what the training of the future should be and who should be involved in order to learn and test the benefits of coordination mechanisms in stable and critical situations.

Additional information:

Technology involved:

- IT systems for training and simulations
- Software tools already developed (e.g. PEGASE)

Partners involved:

- TSOs
- IT providers
- Training centres
- Manufacturers
- Research providers

Project duration: 2013–2017

T9 Innovative tools and approaches for pan-European network reliability assessment

Motivation: The operation of today's electrical grid is complex because of the large share of RES that has already been integrated. Tomorrow's operations will be even more complicated. In addition to operation, planning activities play a crucial role in providing a reliable system. The longer the horizon, the greater the uncertainty. Hence, system planning has become one of the most challenging tasks for TSOs.
Current security criteria were developed decades ago, under far more certain conditions.

The integration of new technologies, e.g. PSTs and HVDC connections, have considerably changed the way in which the system is operated. Future technologies such as FACTS, smart grids etc. will further affect the operation not only of the owner's grid but also of all neighbouring grids. Today's criteria do not properly address these aspects.

Contents/scope: New principles designed to deliver the right level of reliability when managing the new pan-European system architecture must evolve without jeopardizing present-day reliability levels. The current N-1 preventive security principles must be reviewed, from long-term planning to operation.

This research project aims to develop new principles covering all time horizons:
- To evaluate the current performance of the (N-1) preventive security principles,
- to evaluate the required level of reliability from the customer's perspective,
- to identify the possible options for replacing (or complementing) the current principles,
- to define the additional information to be exchanged and the additional coordination needed to support the deployment,
- to provide an appropriate approach to risk based on probabilistic network analyses which takes into account correlation and
- to develop indicators for planners and operators to help them to make decisions.

The outcome will be the basis for new European principles, which allow for evolutions of system design and operations based on new observability and control means while taking advantage of the benefits of all new technologies.

Expected impact: To enable changes to the N-1 dogma used in Europe while developing good planning practices and good operating practices.

Additional information:

Technology involved: Simulation and optimization tools and cost-benefit methodologies adapted to the pan-European system for both design and operations.

Partners involved:
- TSOs
- Research providers

Project duration: 2011 – 2018

6.1.4 Functional Projects – Cluster 4

<table>
<tr><th colspan="2">Functional project</th><th>Before 2011</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td>T10</td><td>Advanced tools for pan-European balancing markets</td><td colspan="3">Optimate</td><td></td><td></td><td></td></tr>
<tr><td>T11</td><td>Advanced tools for capacity allocation and congestion management</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">T12</td><td rowspan="3">Tools for renewable market integration</td><td></td><td colspan="4">EcoGrid EU</td><td></td></tr>
<tr><td colspan="2">Belgium East Loop</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Optimate</td><td></td><td></td><td></td></tr>
<tr><td>T13</td><td>Tools for the integration of active demand in electrical system operations</td><td></td><td colspan="4">EcoGrid EU</td><td></td></tr>
</table>

Relevant ongoing projects | Identified sub-projects

T10 Advanced tools for pan-European balancing markets

Contents/scope: This project covers market simulation tools for constrained networks that provide recommendations about pan-European markets for balancing and system services, including the contribution of RES, which go beyond the existing national rules for balancing.

The goal of the project is to develop a toolbox which is able to address:
- the improvement/coordination means for balancing control and management beyond existing national boundaries (the optimal use of the system, high penetration of renewable energy generation) and
- the detailed analysis of various balancing market designs in support of a balancing market at the pan-European level;

Present targets for the integration of RES, and in particular wind and solar energy, will create significant challenges for balancing the control and management of power and energy reserves within existing national systems. Balancing control can be seen to be made up of two fairly independent tasks: maintaining frequency within defined limits and the online management of network congestion arising from unplanned deviations.

The main challenges that remain to be resolved is how to manage congestion and deviations from planned operations that will result from such a solution and how to split the costs among market participants. This requires new transmission capacity, flexibility in power flow control and new tools for market and network analysis.

The project will develop of toolbox which is capable of:
- analyzing the need to balance control in the future European power system and to assess and develop balancing control markets and automatic control schemes,
- developing simulation tools for secondary control analysis,
- designing market mechanisms for incentivising both the maximization of the provision of ancillary services (including aggregated RES, CHP etc.) and the reduction of the use of ancillary services, with the aim of harmonizing the requirements for the provider license and the supervision, control and recording of the provided service,
- designing and developing mechanisms and platforms for cross-border balancing services and related cross-border power reserve services, moving toward a possible future development of regional/pan-regional markets and
- performing case studies to analyse the economic and technical impact of a common European solution for balancing control, based on the results of technology demonstrations.

The toolbox must demonstrate its ability to evaluate the economic properties of different arrangements in case studies and the available options in terms of market design.

Expected impact:
- To develop the framework and technology necessary to implement a real-time market for balancing services.
- The options for balancing services at the pan-European level can be studied and assessed.

Additional information:

Technology involved: Optimization techniques and market simulation tools constrained by transmission issues (Optimate).

Partners involved:
- TSOs
- DSOs
- IT providers
- Research providers

Project duration: 2012–2016

T11 Advanced tools for capacity allocation and congestion management

Contents/scope: The purpose of this toolbox is to develop network-constrained market simulation tools to provide recommendations about specific network management and market rules in order to manage congestion within the pan-European grids without affecting system reliability.

Project objectives:
- To understand the interactions between system operations and capacity allocation methods at the regional level,
- to model strategies in view of improved congestion management and to analyse the possibility of more efficient options, if any exist, for the pan-European electricity market,
- to expand flow-based market coupling in areas with interdependent flows, based on successful experience,
- to develop an algorithm for computing possible extra capacities available near to real time, with respect to security criteria and without the need for countertrading issues,
- to perform risk-benefit analysis and
- to develop an interface with the Congestion Management Module (CMM).

The successful implementation of the flow-based market coupling approach should be applied in order to address congestion management, balancing markets and capacity reserve markets in those areas and regions with interdependent flows leading to a set of coherent interactive tools, which are able to address all of these complex issues at once.

The present project is composed of several steps, integrating the various elementary research results generated by the activities in Cluster 4:
- At a theoretical level, to compare the currently available tools and results developed at the national level involving power systems engineering, operations research and economics,
- to validate that the flow-based market coupling approach can be applied across a wide region with interdependent flows, coexisting with ATC market coupling approaches in other adjacent regions without interdependent flows,
- to introduce simulation options that can take into account the interactions between the various regulatory framework and;
- to introduce data on transmission and generation that are vital in order to achieve meaningful results.

Expected impact:
- A toolbox for studying the expansion of well-accepted approaches and which is able to compare options in new allocation methods,
- proposals for the implementation of the most promising approaches, by providing quantitative answers to the complex issues of balancing, congestion and capacity markets (including the implementation of flow-based market coupling in regions with interdependent flows),
- location-based pricing approaches and
- new tools for real-time pan-European congestion management.

Additional information:

Technology involved:
- Simulation techniques
- Flow-based market coupling

Partners involved:
- TSOs
- Research performers

Project duration: 2012 – 2018

T12 Tools for renewable market integration

Contents/scope: Network-constrained market simulation tools provide recommendations on specific rules to integrate renewables in power, balancing and system services, for instance via aggregation schemes.

The project will use the results from Cluster 4 as well as the experimental results which will be delivered from other proposed projects.

In addition to the integration of the power market, as studied in Optimate, there are two basic issues to consider regarding wind and solar power integration: active power control by wind farms and solar power generators, and reactive power control.

The results will be analysed within the Twenties project, with the tools and data that have already been implemented in the EWIS and TradeWind projects.

Project objectives:
- To design market mechanisms for controlling RES production (under regional/local constraints or in an electric system imbalance),
- RES as active providers of ancillary services and balancing energy,
- to design market mechanisms for incentivising the flexibility of current and future (for instance, long-term flexible generation capacity auctions) conventional production units (cogeneration included) and
- the design and development of market mechanisms for active demand-side management (DSM) in the operation of the electrical system.

A toolbox which will probably rely on the building blocks of Optimate is therefore required in order to study the detailed impact of scalable and replicable solutions for renewable integration using not only power markets but also system services.

Expected impact: The development of a simulation toolbox which will make it possible to quantify the economic impact of several renewable integration routes from large-scale experiments in order to test the market integration of renewable generation, taking into account the results of the Twenties project.

Additional information:

Technology involved:
- Simulation tools

Partners involved:
- TSOs
- Research partners
- Generators
- DSOs
- Power exchanges.

Project duration: 2010–2014

T13 Tools for the integration of active demand in electrical system operations

Contents/scope:

– The specification of a pan-European system for demand-side management based on experimentally validated business models and business cases.

– The specification of standards in telecommunication infrastructures and a governance model to help these standards evolve within a world-based approach (the ongoing work of NIST).

– To perform large-scale experiments involving metered customers that show the costs and benefits of demand-side management approaches at the pan-European level.

– To develop a set of standards for data exchange at the pan-European level.

This project will use the results of the activities carried out in Cluster 4, with an emphasis on the allocation of network charges to end-users.

Expected impact:

– Business models in support of virtual power plants at the DSO level (see the Twenties experiments to be performed in Denmark),

– cost-benefit analysis for each market player and business case,

– the specification of services provided by the load,

– ICT system architecture to allow for such virtual power plant approaches,

– telecommunications protocols,

– the specification of equipment and devices in the load site and

– forecasting tools, load activation and control and management tools.

Additional information:

Technology involved:

– Metering
– Telecommunications
– Software tools for forecasting
– Control and management algorithms
– Monitoring

Partners involved:

– TSOs
– Electricity retailers
– ESCOs
– Power utilities
– Metering industry
– Automation and control systems industry
– Telecommunications providers
– Research centres
– Universities and technology
– Regulatory authorities
– DSOs

Project duration: 2010 – 2018

6.1.5 Functional Projects – Cluster 5

<table>
<tr><th colspan="2">Functional project</th><th colspan="2">Before 2011</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th></tr>
<tr><td rowspan="2">TD1</td><td rowspan="2">Increased observability of the electrical system for network management and control</td><td rowspan="14">Concept for management of future electrical systems</td><td></td><td colspan="4">EcoGrid EU</td></tr>
<tr><td colspan="2">The Cell Controller Project</td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">TD2</td><td rowspan="5">The integration of demand-side management into TSO operations</td><td>EVCOM</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="4">EcoGrid EU</td></tr>
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<tr><td rowspan="4">TD3</td><td rowspan="4">Ancillary services provided by DSOs</td><td></td><td colspan="4">EcoGrid EU</td></tr>
<tr><td colspan="3">From wind power to heat pumps</td><td></td><td></td></tr>
<tr><td colspan="2">The Cell Controller Project</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Belgium East Loop</td><td></td><td></td><td></td></tr>
<tr><td>TD4</td><td>Improved defense and restoration plan</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">TD5</td><td rowspan="2">Tools for the integration of active demand in electrical system operations</td><td>EVCOM</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">From wind power to heat pumps</td><td></td><td></td></tr>
</table>

Relevant ongoing projects   Identified sub-projects

TD1 Increased observability of the electrical system for network management and control

Contents/scope: This functional project is a DSO-driven project and covers the following areas:
- Load and generation modelling based on data aggregation allowing for the clear division of responsibility between TSOs, DSOs, generators, retailers and customers,
- forecast engine integration to allow more accurate production and load analysis and
- the feasibility of new DER connection requirements which allow for the deployment of DER control centres, responding to both TSO and DSO constraints.

Expected impact: Tools exist in every network operator, but they need to interact on the basis of data streams that are coherent at all voltage levels and between operations. The challenge is to aggregate dynamic data in order to model the load and the distributed generation for different horizons (encompassing real-time operations (short term) and network planning (long term)). This project should trigger several other activities on observability.

Forecasting engines are required to provide conditions for reliable reserve requirements in a timely and secure way. Forecasting conditions should provide forecasted values and uncertainty curves which will serve as a basis for the detection of potential operational risks in the hours ahead, for instance, for wind production, turbine stall due to high wind conditions or strong production variation. The presence of low levels of generation at the DSO level will also require DSOs to manage the generation of PV, wind or CHP units at the cell level. The accuracy of forecast tools still needs to be increased so that DSOs will be able to manage power and energy at the cell level.

The principles of DER connection (“connect and forget”) should evolve as new connection requirements are written so that the impact of DER on the network is minimized: some level of control over DER will be required, which may lead DER control centres to monitor, forecast and operate DER according to the needs of DSOs and TSOs. This would therefore provide power flow control, load management and islanding capabilities.

Project duration: 2011–2018

TD2 The integration of demand-side management into TSO operations

Contents/scope: This functional project is a TSO-driven project and covers the operational implementation of active demand.

Expected impact: Specifications for demonstrating the potential benefits of load control, such as peak shaving and energy savings, when they involve end customers on a large scale, must be drawn up before assessing their impact on TSO planning and operations.

New technologies such as smart meters and energy boxes must be included to add value to the traditional demand response proposition in order to raise awareness about consumption patterns and to foster active customer participation in the energy market. These demonstration specifications will cover:
- the data needed by TSOs for the pan-European planning tool,
- TSO operations designed to achieve a reduction in peak demand (10–15%) through active customer participation,
- the requirement to planning tools in case using metering data and
- models to describe customer behaviour and segmentation.

Project duration: 2012–2018

TD3 Ancillary services provided by DSOs

Contents/scope: This functional project is a DSO-driven project and covers the following areas:

- The legal, contractual and regulatory aspects of ancillary services provided by distributed generation and/or loads, allowing for more aggregated business models and
- the technical issues and novel solutions for voltage and reactive power management within TSO/DSO interfaces (and the impact on future ancillary services with a high level of DER penetration).

Expected impact: Distribution companies used to contribute to ancillary services on transmission systems in a very simple way, through reactive compensation on the MV side of the HV/MV transformer, load tripping schemes to limit the drop in frequency in the event of a loss of generation etc. The evolution of the electricity sector and the birth of new players like aggregators will affect the roles of the TSOs and distribution network operators: specific attention is to be paid by TSOs and DSOs, taking into account legal, contractual and market aspects.

The advent of distributed generation (DG) in distribution networks will bring about a more active contribution from DSOs, with issues like active and reactive power reserves, voltage and frequency control and network restoration. The evolution of electric power systems and electricity markets will also promote the contribution of loads to ancillary service provision and ancillary service markets. The aggregation of (even small) commercial and domestic loads may also appear with new schemes to replace load tripping. The many different ways of implementing the provision of ancillary services by loads and their impact on transmission networks must be studied by DSOs and TSOs: distributed generation and RES may have a very limited capability to provide ancillary services with the highly variable and unpredictable nature of DER exerting even more constraints on such services. The contribution of loads which provide more flexibility may therefore be a way toward novel solutions for DSOs.

Project duration: 2011 – 2018

TD4 Improved defence and restoration plans

Contents/scope: This functional project is a TSO-driven project and covers the following areas:

- simulation tools allowing for the detection of weak points in reconnection scenarios involving DER units and
- regulatory and technical challenges to implement restoration plans at the pan-European level.

Expected impact: There are no existing common and binding procedures for managing RES behaviour (wind farms in particular) during emergency situations throughout Europe, and RES suppliers have a lack of responsibility toward the grid. Moreover, distribution networks could participate in defence plans using domestic intelligent electrical appliances. Smart appliances are electrical devices (televisions, air conditioners) that can sense any changes in network frequency and respond accordingly. In the event of frequency drops, domestic (and possibly industrial) intelligent appliances could reduce their consumption or even switch off one by one according to the order of priority set by the user. Defence plans could take advantage of these appliances using selective load shedding instead of disconnecting an entire part of the network. Research is needed in order to develop a collective strategy for the Member States to implement into their national legislation a harmonized emergency strategy in connection with RES and DER management during emergency situations. It requires simulation tools which are able to detect the weak points in the pan-European system and to propose a European doctrine in line with acceptable reconnection scenarios. This work will specify the tools for further development, one of which is a common TSO/DSO training tool which is used to simulate critical network and balance situations in the context of the electricity system as a whole.

Regulatory and technical issues as well as social and economic aspects must be considered when designing a restoration plan at the pan-European level. Although several recommendations and requirements have been proposed in the operational handbook of UCTE, it appears that the full recovery of the European system may take a long time.

A joint TSO/DSO approach is needed to cover all of the issues before a new doctrine is developed:

- Simulation tools to assess the risk of a breakdown during reconnection,
- black start capability of wind turbine generators,
- the impact of micro-grids and islanding capabilities and
- training for operators in the evolution of national regulatory schemes in order to foster coordination.

Project duration: 2011 – 2018

TD5 Joint taskforce on IT system protocols and standards

Contents/scope: This functional project is a DSO-driven project and covers the following areas:

- Data exchange protocols for smart grid applications,
- semantic models for metering, demand response and electrical transportation data exchanges and
- information models for European smart grids.

Smarter networks will use real-time, two-way communication technologies to allow users to connect directly with power suppliers. They require:

- A framework for interoperability:
  The taskforce will have the responsibility for coordinating the development of a framework that includes protocols and model standards for information management in order to achieve the interoperability of smart grid devices and systems.
- A high-level architecture for the smart grid, including a conceptual model with architectural principles.
- A consensus on the critical standards and standard development activities needed.

The main challenge is to continue to connect with ongoing activities on matters of standardization in Europe and worldwide at the TSO and DSO levels while designing a European data management environment which will minimize the CAPEX and OPEX of such IT systems in the future, in which huge data flows on consumption will originate from smart meters.

Expected impact: Based on a conceptual model for developing interacting transmission and distribution grids and its implementation with architectural principles defined to enable the networks to support new technologies and new business models, data exchange protocols will be proposed which will reinforce interoperability constraints at the European level.

It is expected that the largest possible spectrum for applications, including an automated metering infrastructure (AMI), demand response (DR), plug-in electric vehicles (PEV), wide area situation awareness, distributed generation (DG) and energy storage and market communications will be dealt with at the EU level to ensure interoperability at all levels. The project aims to develop a common semantic model (covering at least advanced metering, demand response and electric transportation), so that network operators (including the various industry players) will coordinate activities and catalyze the adoption of a unified semantic model for these applications.

Security requirements for smart European networks must take into account business interactions and the physical processes of delivering electricity, including interferences or the disruption of business communications as well as the disruption of the delivery of electricity. Identity and authorization requirements, privacy and appropriate access are of paramount importance for shaping the final information model to be specified through joint work by TSOs and DSOs.

Project duration: 2011 – 2018

6.2 Appendix 2: Ongoing R&D Projects on Pan-European Transmission Issues

R&D is essential for the future of the pan-European electricity system (please refer to the main document for further information). In order to meet these challenges, European TSOs have developed this common R&D Plan, incorporating five clusters and several functional projects within these clusters. This appendix gives an overview of **R&D activities** (called R&D projects) which have already been launched and hence which are contributing to the identified functional projects. The focus of Appendix 2 is **ongoing** activities. Please find below more information regarding the individual activities. In order to meet the goals of this R&D Plan, many additional activities will have to be launched in the future. The launch of individual R&D activities depends heavily on the financial support of European and national (Member States) R&D funding mechanisms.

		TSO		DSO		Manufacturer		GenCo		Other
	Project	Partner	Impact	Partner	Impact	Partner	Impact	Partner	Impact	Partner
6.2.1	Optimate	5	High	0	Low	0	Medium	0	Medium	7
6.2.2	Twenties	6	High	0	Low	3	Low	2	Medium	2
6.2.3	EcoGrid EU	3	Medium	3	High	4	High	1	High	4
6.2.4	Substation 61850	✓	High	✓	Medium	✓	Medium	✓	Low	✓
6.2.5	Almacena	✓	High	×	Low	✓	Medium	×	Low	✓
6.2.6	220 kV SSSC device for power flow control	×	High	×	Medium	✓	Low	×	Low	✓
6.2.7	S.I.TR.E.N.	✓	Medium	×	Medium	✓	Medium	×	Low	✓
6.2.8	INTEGRINET	✓	Medium	×	Medium	✓	Medium	×	Low	✓
6.2.9	SafeWind	4	High	1	Low	0	Low	2	Medium	17
6.2.10	PEGASE	8	High	0	Low	0	High	0	High	12
6.2.11	ADDRESS	0	Medium	4	High	5	High	2	Medium	12
6.2.12	Kriegers Flak	3	High	0	Low	2	High	0	High	3
6.2.13	COBRA	2	High	0	Low	2	Medium	0	High	3
6.2.14	SUMO	1	High		Low		Low		Low	
6.2.15	Early warning systems	1	High	0	Medium	0	Medium		Low	2
6.2.16	The Cell Controller Project	1	Medium	1	High	2	Medium	✓	Medium	3
6.2.17	Smart grids and energy markets	1	High	✓	Medium	✓	Medium	✓	High	✓
6.2.18	Umbrella	9	High	0	Low	0	Low	0	Low	6
6.2.19	iTesla	6	High	✓	High	0	Low	0	Low	✓
6.2.20	After	3	High	✓	High	✓	Medium	0	Low	✓
6.2.21	Belgium East Loop	1	High	1	High	0	Low	0	Low	0
6.2.22	From wind power to heat pumps	1	Medium	✓	High	✓	High	0	Low	✓
6.2.23	Concept for management of future electricity systems	1	High	✓	High	0	Medium	0	Medium	✓

High impact Medium impact Low impact

6.2.1 Optimate

Functional projects: T10, T12

Project duration: September 2009 – August 2012

Project website: www.optimate-platform.eu

Partners involved:
- TSOs:
  ELIA (BE), EnBW (DE), REE (ES), RTE (FR), 50Hertz Transmission GmbH (DE)
- Others:
  ARMINES (FR), K.U. Leuven (BE), DTU-RISOE (DK), University of Madrid-Comillas (ES), University of Manchester (GB), SEAES University of Paris (FR), TECHNOFI

Abstract: An open simulation platform to share new market design approaches based on the coupling of physical network models with market simulation models at the pan-European level.

Objectives: This project aims to:
- develop an open simulation platform which is able to mimic existing and future intra-day and balancing markets involving classical and intermittent generation and
- demonstrate that this platform can help TSOs to compare new market rules and tools which are capable of integrating massive intermittent generation into electricity markets, while maintaining the security of the European power system.

Description: Five TSOs, together with seven RTD performers, have proposed a three-year research and demonstration project to compare the pros and cons of new market designs aimed toward the integration of massive intermittent energy sources dispersed over several regional power markets.

Under the technical coordination of RTE, they will implement a novel network/system/market modelling approach to provide the consortium with an open simulation platform which is able to exhibit the comparative benefits of several market design options. Such options may originate either from any of the four studied markets or from partners that have already worked for the UK or Danish electrical systems. Market participants and TSOs are players in this type of simulation: each area is represented by aggregated realistic data over one year and system security rules are fulfilled at all times. The demonstration tasks require data with appropriate non-disclosure agreements, in order to address the market behaviour of fully rational players first, and then the impact of non-optimal behaviours using agent modelling. The results will be compared (and possibly ranked) before being packaged and presented to the TSO community and regulatory authorities for analysis of the platform's potential and the trustworthiness of the simulation results. This demonstration will be complemented by intensive dissemination activities among the TSO community within the EU27 and beyond, with dedicated training to accompany the adoption of the simulation platform.

An exploitation agreement has been proposed in order to further improve and expand the platform within the pan-European TSO community, beyond the end of this project.

Expected deliverables, benefits and impact: The joint involvement of TSOs that already interact in day to day operations should lead, in the coming years, to:
- a better common understanding of the pros and cons of existing market designs based on quantitative analysis,
- the joint exploration of novel market designs with a view to facing the pan-European transmission network issues which will be addressed in the next 10 years,
- the progressive dissemination and adoption of the simulation platform by other TSOs based on demonstrative results on the market integration of massive renewable-based electricity production and
- a more formal link with regulatory bodies when addressing pan-European electricity market issues over the next 10 years.

Project costs: Project costs: € 4.2 million
Project funding: € 2.6 million

6.2.2 Twenties

Functional projects:	T1, T5, T6, T7, T9	**Project duration:**	January 2010 – December 2012

Project website: www.twenties-project.eu/node/1

Partners involved:

- TSOs:
  Elia (BE), Energinet.dk (DK), RTE (FR), 50Hertz Transmission GmbH (DE), Tennet TSO (NL), REE (ES)
- Others:
  DONG (DK), IBR (ES), RISO (DK), EDF (FR), AREVA (UK), ITT (ES), Fraunhofer IWES (DE), SINTEF (NO), GAMESA (ES), SIEMENS (ES), EWEA (BE), CORESO (BE), ABB (ES), INESC-PORTO (P), UCD (EI), ERSE (ENEA – Ricerca sul Sistema Elettrico) (IT), STRATHCLYDE (UK), ULG (BE), KUL (BE), ULB (BE)

Abstract: The Twenties collaborative RD&D project addresses the ENERGY 2009.7.1.1 call for the optimization of the electricity grid with large-scale renewables and storage.

It aims to demonstrate by early 2014 through real-life, large-scale demonstrations the benefits and impact of several critical types of technology required to improve the pan-European transmission network, thereby giving Europe the ability to respond to the increasing share of renewables in its energy mix by 2020 and beyond, while maintaining its present level of performance reliability.

Objectives:

- To show that active and reactive power control can be performed reliably with the help of aggregated wind farms, thus allowing **secondary frequency control and voltage/reactive control in the system**,
- to show on a large scale that **aggregating wind production with flexible loads** within appropriate regulatory schemes leads to a more secure and efficient electricity system with **high scalability** potential,
- to provide the critical building blocks for DC grid control/protection strategies and DC breakers based on full-scale demonstrations which will make it possible to guarantee the security of future HVDC multi-terminal grids,
- to demonstrate that the adequate coordination mechanisms between offshore wind farms and hydro-power capacity which are available in Norway through an existing HVDC link provide a viable way to control securely the power balance during offshore storm passages,
- to demonstrate that adequate coordination mechanisms between dynamic line rating, power flow control devices and WAMS increase the flexibility of the electrical system within affordable capital and operational costs,
- to demonstrate that alternative operation parameters provided by dynamic line rating and FACTS technology, applied on a regional basis, do increase flexibility, security and the capability of the network to evacuate more wind,
- to assess the impact, barriers and solutions needed to scale up the demonstration results,
- to assess the benefits of replicating the obtained results throughout the entire pan-European interconnected transmission system and
- to disseminate the results obtained widely enough for an early take-up of sales and replication rules by stakeholders.

Description:	A group of six TSOs with two GenCos and five manufacturers and research organizations proposed six demonstration projects to remove, in three years, several barriers which prevent the electrical system from welcoming more wind electricity, and wind electricity from contributing more to the electrical system. The full-scale demonstrations aim to provide the benefits of novel technologies (most of them available from manufacturers), coupled with innovative system management approaches. The contribution of wind energy to the system will show that aggregated wind farms can provide system services (voltage and frequency control) in Spain. The aggregation of wind farms with flexible generation and loads will be demonstrated in Denmark using a scalable IT platform developed by a generator. The process of increasing the flexibility of transmission networks will be tested in Belgium (existing sensors and coordinated power flow control devices avoiding possible large-scale instabilities induced by wind farms in the CWE region) and in Spain (dynamic wind power evacuation capacity using real-time computations based on short-term generation forecasts and the use of a mobile overload line controller). Offshore wind farms are addressed from a security viewpoint. Secure HVDC meshed networks will be validated in France using simulations and full-scale experiments with two different types of HVDC circuit breaker technology. Offshore wind farm shut-downs under stormy conditions will be demonstrated in Denmark using the world's largest offshore wind farm with balancing power provided by Norway's hydro capacities through a HVDC link.
Expected deliverables, benefits and impact:	The experimental results will be integrated into European impact analyses to show the scalability of the solutions: routes for replication will be provided with benefits for the pan-European transmission network and the European electricity market as soon as 2014, in line with the SET Plan objectives.
Project costs:	EU FP7 application is currently in the contract negotiation stage. Approximate project costs: € 58 million Estimated EC contribution: € 31 million

6.2.3 EcoGrid EU

Functional projects: T12, T13, TD1, TD2, TD3

Project duration: Jan. 2011 – Late 2014 (if approved)

Project website: www.eu-ecogrid.net

Partners involved:
- TSOs:
  Energinet.dk (DK), Elia (BE)
- DSOs:
  Østkraft (DK), Eandis (BE), EDP (PT)
- Other:
  IBM (CH, DK, NL), Siemens (DE, DK, CH), DTU-CET (DK), Sintef (NO), EnCT (DE), AIT (AT), Tecnalia (ES), ECN (NL), Landis&Gyr (DK), TUT (ES)

Abstract: The project description is being prepared and will be applied for in FP7-EN-2010-2/7.1-1. The drivers in this project are the full-scale deployment and operation of all smart grid facilities in a real grid on the island of Bornholm in Denmark.

Objectives: The EcoGrid EU project aims to develop and demonstrate a full-scale, generally applicable concept for a smart electricity distribution network with a high level of penetration of RES and active user participation based on real-time price signals enabling small and medium-size DER to contribute actively to system balancing and enabling the optimised operation and control of the distribution grid. The integration of more than 50 % of RES into the power system – stemming mainly from fluctuations in RES production, like wind power and PV – requires participation from all distributed resources and demand response ("prosumers").

Description: The project will be based on a single full-scale demonstration of a complete distribution system covering the Bornholm distribution grid, which is part of the Nordel interconnected system.

The Bornholm system has a very high degree of penetration of a variety of low-carbon energy resources, including wind power (30 MW), CHP units (37 MW), Biogas units (2 MW), PV units (1 MW growing to 5 MW) (under implementation), active demand (28,000 consumers – 55 MW peak load and 239 MWh annual energy demand) and electrical vehicles (under roll-out).

This enables the demonstration of several scenarios of future power system configurations based on RES, which are representative of future European distribution systems, especially those featuring high levels of wind power.

The EcoGrid EU smart grid solution is going to be integrated into the subgrid (under 150 kV) and dissemination performed by the DSO. However, the benefit for the TSO is that if the subgrid is capable of delivering multiple ancillary services and balancing the grid with substantial local production from many small RES, then there is potentially a large benefit for the TSO.

Expected deliverables, benefits and impact: The benefits and impact of the EcoGrid EU project are, in short:
- a potential new market model based on real-time pricing and active demand response,
- a high degree of end-user involvement with automatic technology to balance fluctuations in local RES production, like wind power and solar energy,
- new market actors helping to balance the grid; a full-scale power lab for R&D in smart grid applications, for the benefit of all of Europe,
- the development and deployment of new ICT technology and
- a valuable contribution to achieving the EU 20-20-20 goals, through the demonstration of a grid with more than 50 % RES.

Project costs: Project costs: € 21 million
Approximate funding: € 10.5 million.

6.2.4 Substation 61850

Functional projects: T3 **Project duration:** November 2009 – December 2015

Partners involved: REE (ES)

The main idea of the project is to encourage the technology industry to participate in the development of this emerging technology. Therefore, the project will be open to the participation of all of the technological partners involved.

Collaboration is predicted with all of the main REE providers:
- Equipment,
- tools,
- tests,
- telecommunications and
- homologation labs.

Abstract: This project is oriented toward the introduction of the IEC 61850 standard into a substation.

This project is expected to develop new equipment based on the standard and to implement it fully in a real substation. This project implies the first step toward a digital substation: a smart grid at the substation level.

The acceptance of the IEC 61850 standard in the substation will result in a cultural change and will have a huge impact on engineering, construction and substation maintenance, fostering the efficiency of all of these processes.

Objectives: To use the IEC 61850 standard as a means to improving the design, maintenance and operation of the substation automation systems.

The final goal of the project is to install a complete IEC 61850 system in the field.

Description: The project is organized in two stages. The first one started in November 2009 and will last until 2011, and the second one will finish in 2015.

The first activity to be carried out is the feasibility study (technical and economic) of the deployment of the complete IEC 61850 (substation bus and process bus), involving:
- the definition of a normalized substation solution based on IEC 61850 in order to be able to deploy it systematically;
- to achieve interoperability between different control and protection equipment in a substation,
- to design and define homogeneous solutions which are not dependent on provider technology (for engineering, maintenance etc.) and
- improving system security and increasing current redundancy levels.

Expected deliverables, benefits and impact:
- 61850 mock-ups and prototypes of:
  - protection and control devices,
  - current and voltage transformers and
  - disconnectors and circuit breakers, advance protection and control.
- Test tools
- A digital substation

Milestones: **Stage I**

- Agreements with providers for the testing and development of new 61850 equipment
- Building a complete mock-up in the laboratory in order to test the infrastructure and interoperability of the 61850 as a whole
- Defining a test procedure based on the CIGRE 401 Brochure (REE – Pioner. No previous experiences known)
- Test the complete 61850 substation solution installed in the laboratory
- Technical and economic feasibility study of the complete IEC 61850 solution

Stage II

- Field installation
- Process bus test
- Test & validation of the entire solution
- Conclusions

Technology involved: The first stage will be devoted to the telecontrol part or substation bus. The following aspects will be considered:

- 61850 protection and control,
- embroidery frame,
- test tools
- device interoperability,
- mock-up and
- telecommunications.

In the second stage, the process bus will be considered:

- Current and voltage transformers,
- switches and breakers and
- advance protection and control.

Project costs: This project has an overall approximated budget of € 4.2 million.

6.2.5 Almacena

Functional projects: T1

Project duration: November 2009 – December 2012

Partners involved: REE (ES)

In addition to REE, this project needs the contributions of:

- power electronics providers/developers,
- telecommunications providers/developers,
- battery providers and
- R&D centres.

Abstract: The demonstration of an electrochemical storage system in a TSO network for system operations.

Objectives:

- The demonstration of an electrochemical battery – installation in the field (in a transmission substation) of a 1 MW storage device,
- to assess the potential benefits of using electrochemical storage systems to provide system stability services to the TSO and
- to investigate the minimum requirements for extending the use of these devices to other possible services in the mid-term, like demand-side management or pick-saving.

Description:	Currently, energy storage systems seem to be a promising technology for power systems. However, up to now, most experiences have been oriented toward providing services at a distribution or generation level and not at a transmission and system operational level. The objective of this project is to examine the existing energy storage technology and to study its technical and economic feasibility for system applications in network flexibility and system stability. The project is organized into five blocks: – Definition: application definition, technology selection, location selection, functional specification of the battery control system, budget specification etc. – Bidding – Installation – Tests – Conclusions Other potentially interesting uses will also be investigated.
Expected deliverables, benefits and impact:	Expected deliverables, benefits and impact: – Real technology feasibility analysis (at least these kinds of technology will be considered: NaS, Redox Vanadium and Ion-Lithium) – Specification of the expected battery behaviour for the selected application – Specification for control system – Installed battery prototype – Regulatory proposals
Milestones:	**Activity** **H1** Requirements specification – Done **H3** Equipment installation **H4** Conclusions
Technology involved:	– Grid flexibility – New network management and control
Project costs:	This project has an overall estimated budget of €4,000,000.

6.2.6 ESP-LIDER: 220 kV SSSC Device for Power Flow Control

Functional projects: T4, T5

Project duration: July 2009 – December 2012

Partners involved:
- REE (ES)
- Industrial partners:
  Ingeteam Technology and Incoesa Trafos
- Technological partners:
  Universidad de Comillas and Universidad de Mondragón

Abstract: In the project described in this form, it is foreseen that a FACTS will be used to prevent overload situations in the 220 kV transmission grid.

At present, during some specific generation-demand scenarios, the system operator needs to reduce the meshing of the network in order to resolve certain overloads or to curtail wind production. The former causes a reduction in the safety margin of the network, whereas the latter results in economic damage to the wind producers.

By incorporating a FACTS into one of the affected 220 kV lines, it is envisaged that the number of this kind of undesirable operation will be significantly reduced.

Objectives: Nowadays, electrical power producers in Spain are enjoying a high degree of freedom in choosing suitable sites for the installation of new generation plants. This, along with the inherent uncertainty associated with the amount and location of electricity demand, causes power flows through transmission lines to vary a great deal relatively quickly. Consequently, increased demand is placed upon the transmission network to adapt to these rapidly changing conditions.

Traditionally, the transmission network has been able to evolve along with the needs of the time by either incorporating new assets (lines, substations, transformers etc.) or by upgrading existing ones (change of voltage levels, tightening of cables etc.). However, due to the high environmental and social impact that some of these measures may have, the commissioning of new installations can experience significant delays or may not even be feasible. Moreover, RES usually make poor use of the network, with a low number of hours at peak-power operation, and its geographical dispersion forces changing flow depending on the location of the primary energy source. Therefore, situations in which some of the lines are operated at their peak load, while others are lightly loaded, could easily arise, depending on the generation and load profiles at the time.

Consequently, equipment that can dynamically control the power flow through certain lines, either by limiting or boosting the transmitted power, could be very advantageous for avoiding potential overload scenarios.

Description: This project will use an SSSC to prevent overload situations.

The SSSC operates by injecting voltage which is controlled for amplitude and phase in series with the distribution network. This voltage, which is 90º out of phase with the line current, will have the effect of either decreasing or increasing the power flow when the current is leading or lagging, respectively. The SSSC in this application was initially conceived to reduce the power flow in order to avoid overload situations. This will result in the diversion of the remaining excess power to alternative parallel lines that are less heavily loaded.

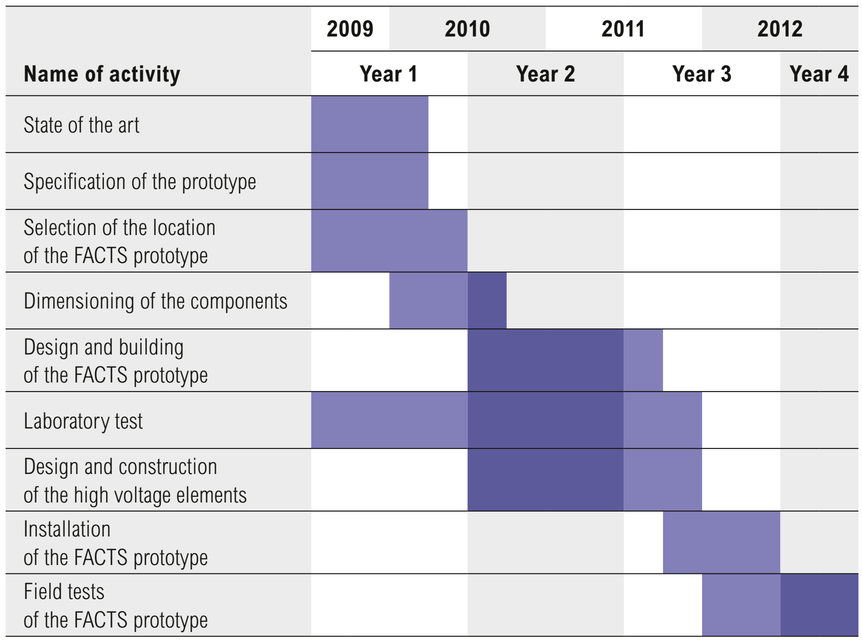
Although the power rating of an SSSC is just a fraction of that which is flowing through the network, it is comparatively large (a few tenths of MVar). The SSSC is connected in series with the distribution network through the primary windings of a coupling transformer, whereby its secondary windings are fed by a power electronic converter. This voltage sourced converter (VSC) converts the DC voltage stored in a capacitor bank, or DC bus, into AC voltage, which is variable in phase and magnitude. This is achieved through the combination of several inverter modules, based on the existing Ingeteam MV700 range, connected either in series or in parallel in order to obtain the required power. They are implemented using state-of-the-art Integrated Gate-Commutated Thyristor (IGCT) semiconductor technology.

These high power/medium voltage devices, which belong to the thyristor family, have an optimised gate with an integrated driver, making it possible to switch frequencies within the range of 500 Hz.

The initial studies consider the use of two different modulation strategies to obtain the converter output voltage: pulse width modulation (PWM) and synchronous full-wave multi-pulse modulation. The former obtains a very fast output response, whereas the latter reduces the semiconductor loss. The fault currents in the transmission network are usually very high; around 50 times higher than the rated value of the line. Therefore, it becomes mandatory to provide the secondary windings of the coupling transformer with a short circuit path or bypass, in order to protect the VSC converter. The bypass is implemented in this application using a combination of thyristor semiconductor devices.

In the first two years, its main characteristics have been performed and the requirements imposed by the system operator. This project will also explain the design of the SSSC, including the VSC and the bypass. This will be supported by simulation results that will validate the design, both in normal and faulty conditions. This work will also focus on the impact that the SSSC has on the high-voltage transmission network, both in terms of high-voltage equipment, protection system requirements and in system operation.

During the following two years, the demonstration prototype will be installed in the grid.



Expected deliverables, benefits and impact:
- Document of specifications and requirements
- Simulation results
- Prototype installation
- Field test results

Technology involved:
- Cluster 2: Power technology for a more flexible, observable and controllable pan-European transmission grid
- Cluster 3: Network management and control

Project costs: € 10 million

6.2.7 S.I.TR.E.N.

Functional projects: T1 **Project duration:** 2012 – 2015

Partners involved: TERNA, ITALCERTIFER (subsidiary of the Italian Railways Company), Salerno University, Rome University, University of Sannio

Abstract: **S.I.TR.E.N** – Pianificazione e gestione di Sistemi Integrati di Trasmissione Elettrica Nazionale (The Planning and Operation of National Integrated Transmission Grids) – is a project which aims to develop new planning criteria for the integration of the national transmission grid with the national railway electrical infrastructure, providing, if necessary, innovative technical solutions to overcome critical issues relating to O&M, the quality of supply and EMF phenomena.

The project is carried out in close cooperation with Terna, the Italian TSO, ITALCERTIFER, the engineering branch of the Italian Railways Company, and several universities which specialise mainly in EMF analyses and grid stability issues.

Objectives: To evaluate possible developments of the national transmission network through a better integration and synergy between the Terna grid and the Italian railway network.

Description:

- Analysis of Terna and the railway-integrated electrical network:
  - Description of the network (e.g. line extension and number of substations, control, command and protection systems) and of the related users (e.g. load diagrams),
  - evaluation of the use and maintenance of electrical infrastructures with specific regard to the unavailability rate of the lines and
  - adequacy and static security analysis (N-1 criterion) on the expected planned network, with the aim of finding the critical conditions and establishing the necessary reinforcements.
- Analysis of the nodal disturbances, reduction systems, probable metrics and field measure certification:
  - Evaluation of technical problems at the interface between the national transmission network and the electric railway network, relating mainly to electromagnetic effects,
  - research on techniques and technology capable of reducing the effects of the aforementioned problems and the implementation of related measurement methods and
  - introduction of appropriate methodologies to detect, analyse and measure grid disturbances.
- Control strategies and related technology:
  - Specification of methodological, operational and technological measures for integrating the various available transmission systems with distributed generation systems and
  - achievement of improved overall exploitation of the transmission capacity of each network and more effective dispatching of DER.

Expected deliverables, benefits and impact: Comparison of the solutions conceived for the planning and operation of the system developments and evaluation of the related benefits.

The technological solutions found will be compared according to the following criteria:
- Effectiveness of the technology,
- costs relating to implementation, operation and maintenance and
- benefits brought about in the operation of the transmission systems.

Project costs: € 2 million

6.2.8 INTEGRINET

Functional projects: T1

Project duration: 2011 – 2014

Partners involved: TERNA, ITALCERTIFER (subsidiary of the Italian Railways Company), Salerno University, Rome University, University of Sannio

Abstract: This project provides innovative technical solutions for the attainment of underground cable line projects which are compatible with road and motorway infrastructures. This innovative project is based on the integration of two infrastructures. Therefore, all of the companies involved will provide specific experience relating to their own field of competence:
- TERNA: electrical TSO
- CIE: design company in the energy service sector
- MUSINET: motorway infrastructure engineering company
- UNIPD: scientific research

Objectives:
- Research into emerging technologies for laying underground cables located along roads or motorways
- Finding solutions to problems relating to compatibility between the two infrastructures (electricity and road).

Description: Activities to be carried out and the resources involved:
- State-of-the-art assessment of the integration of cable lines with road and motorway infrastructures.
- Feasibility criteria for integration, based on geometrical compatibility, and specification of types and modalities of cable installation.
- Current practices in cable transportation and the necessary developments for integrating power and motorway infrastructures in a synergic way.
- Evaluation of possible thermo-mechanical problems due to interactions between motorway infrastructures and the power cable system.
- Development of specific tests to evaluate the suitability of the cable to be laid along motorways.
- Analysis of transmission line thermal behaviour and line compatibility with ventilation systems installed in tunnel.
- Assessment of external effects relating to a possible phase-screen failure for AC and DC current.
- Assessment of electromagnetic interference and electromagnetic compatibility with existing technological systems in the motorway.
- Maintenance:
  state-of-the-art monitoring systems and the identification of strategies to obtain optimal maintenance and maximize the coordination between the motorway operator and the electric line operator.
- Analysis of compatibility with complementary technological services.

Expected deliverables, benefits and impact: Expected benefits for users of the national electrical system:
- Facilitating the construction of new lines allows power systems to benefit from the elimination of congestion in the power system and from the consequent possibility of more efficient energy flows in the grid.
- In the case of interconnections between different countries, the increase in total transfer capacity (TTC) gained allows better exploitation of eventual price differentials between the two systems, contributing also to the development of a more efficient and integrated internal energy market.
- The project results are finalized to find technical solutions regarding practical applicability, to be used for both preliminary and detailed designs of electrical infrastructures in synergy with road and motorway infrastructures. Therefore, the practical implementation of these concepts will ensure a more efficient evaluation of feasibility study results and increased efficiency in project management, due to the expected savings both in terms of cost and time.

Project costs: € 4 million

6.2.9 SafeWind

Functional projects: T6

Project duration: September 2009 – August 2012

Project website: www.safewind.eu

Partners involved:
- TSOs:
  RTE (FR), Energinet.dk (DK), EirGrid (IE), SONI (GB)
- Other:
  ARMINES (FR), cener (ES), DTU-IMM (DK), DTU-RISOE (DK), ForWind (DE), energy & meteo (DE), overspeed (DE), ECMWF (EU), EDF (FR), CSIRO (AT), University Oxford (GB), University Computens Madrid (ES), University Carlos Madrid (ES), DEI (GR), Meteo France (FR), teri (India), University Athens (GR)

Abstract: Multi-scale data assimilation, advanced wind modelling and forecasting with the emphasis on extreme weather situations for secure large-scale wind power integration.

The aim of SafeWind is to substantially improve wind power predictability in challenging or extreme situations. In addition, wind predictability is considered to be system parameter which is linked to the resource assessment phase, during which the aim is to make optimal decisions for the installation of a new wind farm.

Objectives: The project addresses the following scientific and technical objectives:
- Definition and identification of extreme events,
- large-scale vision of wind power forecasting through the development of an adequate information management infrastructure,
- alerting and data assimilation techniques for improved short-term wind power predictability,
- optimised ensemble forecast systems applied to wind power prediction,
- novel methods for wind power forecasting and extreme conditions,
- wind resource assessment vs. predictability,
- assessment of benefits from new measuring technology for better estimation of external conditions, resource assessment and forecasting and
- demonstration of operational benefits.

Description: The integration of wind generation into power systems is affected by uncertainties in the forecasting of the expected power output. Misjudging meteorological conditions or large forecasting errors (phase errors, near cut-off speeds etc.) can be very costly for infrastructures (i.e. the effect of unexpected loads on turbines) and can reduce the value of wind energy for end-users. The state-of-the-art in wind power forecasting has focused thus far on the "usual" operating conditions rather than on extreme events. Thus, the current wind forecasting technology presents several strong bottlenecks.

End-users are demanding dedicated approaches to reduce large prediction errors or predict extreme conditions on a local scale (gusts, shears) up to a European scale, as extreme conditions and forecast errors may be propagated.

Expected deliverables, benefits and impact: This project will develop:
- new forecasting methods for wind generation focusing on uncertainty and challenging situations/extreme conditions,
- models for "alarming" (providing information on the level of predictability in the (very) short term) and
- models for "warning" (providing information on the level of predictability in the medium-term (e.g. next day)).

Project costs: EU FP Energy, 7th. FWP
Project costs: € 5.58 million
Project funding: € 3.99 million

6.2.10 PEGASE (Pan-European Grid Advanced Simulation and State Estimation)

Functional projects: T6, T7, T8

Project duration: July 2008 – June 2012

Project website: www.fp7-pegase.eu

Partners involved:
- TSOs:
  RTE (FR), REE (ES), Lietuvos Energija (LT), Transelectrica (RO), REN (PT), SO UPS (RU), HEP (HR), TEIAS (TR)
- Other: TRACTEBEL (BE), DELING DOO (BA), DIGITEO (FR), CRSA-ECP (FR), AICIA (ES), FGH (DE), University of Liege (BE), University of Duisburg (DE), University of Manchester (GB), University Eindhoven (NL), Rigs University (LT), TY Energosetproject (RU), NUCLEO (ES)

Abstract: PEGASE deals with the high- and extra-high-voltage transmission and sub-transmission networks in Europe (designated hereafter as “European transmission network” or ETN). This system has been built progressively by interconnecting the national transmission grids with the main purpose of sharing the reserve generation capacity required to deal with generator outages.

Objectives: The overall objectives of the PEGASE project are to:
- define the most appropriate state estimation, optimization and simulation frameworks, their performances and the requested data flows,
- relieve the technical barriers that prevent European-wide real-time state estimation and offline and online simulations from being run,
- develop methodologies for building and validating static and dynamic models (including RES, power electronics etc.) and
- study the architecture of a pan-European real-time state estimation, simulation and training framework.

Description: PEGASE is a four-year-long project dealing with the high- and extra-high-voltage transmission and sub-transmission networks in Europe (designated ETN) and implemented by a consortium composed of 20 partners including TSOs, expert companies and leading research centres in power system analysis and applied mathematics. Its overall objectives are to define the most appropriate state estimation, optimization and simulation frameworks and their performance and dataflow requirements in order to achieve an integrated security analysis and control of the ETN.

The heart of the PEGASE project will involve advanced algorithms, software prototypes and demonstrations of the feasibility of real-time state estimation, multi-purpose constrained optimization and time domain simulation of very large models representative of the ETN, taking into account its operation by multiple TSOs. The ambitions of this R&D project are:
- to relieve all knowledge barriers in order to provide all TSOs with a synchronous display of the state of the ETN, in very close to real time (typically each five to 10 seconds) and
- to develop OPF programs which determine realistic system operating points that include TSO operating rules but also optimal preventive or corrective actions, typically for real-time congestion management.

Expected deliverables, benefits and impact: The heart of the PEGASE project involves devising advanced algorithms, building software prototypes and demonstrating the feasibility of:
- real-time state estimation,
- multi-purpose constrained optimization and
- detailed time simulation of a very large model representative of the ETN, taking into account its operation by multiple TSOs.

Project costs: EU FP7 Energy – 7th FWP
Project cost: € 13.59 million
Project funding: € 8.62 million

6.2.11 ADDRESS

Functional projects: T13

Project duration: June 2008 – May 2012

Project website: addressfp7.org

Partners involved: UPC (ES), Responsiveload (UK), ZIV Medida (ES), EDF (FR), ENEL (IT), Iberdrola (ES), US (IT), VITO (BE), VTT (FI), UM (UK), Philips (NL), Vattenfall (SE), ABB (CH), Ericsson (ES), Landis (FR), Concentec (DE), Alcatel-Lucent (IT), ENEL (RO), Electrolux (BE), EDF (UK), Current (CH), Labein (ES), UC (IT), KEMA (NL)

Abstract: Active distribution networks with full integration of demand and DER.

Reaching the objectives and exploiting the results of the ADDRESS project can help the European smart grids technology platform vision to become a reality: a network that is flexible, reliable, accessible and economic. ADDRESS will add value to each of the areas of this vision in the following way:
– It will add flexibility,
– it will add reliability,
– it will add accessibility and
– it will add economy.

Objectives: ADDRESS aims to study, develop and validate solutions in order to enable active demand and exploit its benefits.

In order to enable active demand, ADDRESS intends to:
– develop technical solutions at both the consumer's premises and the power system level and
– identify possible barriers preventing the development of active demand and develop recommendations and solutions to remove these barriers, taking into account economic, regulatory, societal and cultural aspects.

To exploit the benefits of active demand, ADDRESS will:
– identify the potential benefits for the different power system participants,
– develop appropriate markets and contractual mechanisms to manage the new scenarios and
– study and propose accompanying measures in order to deal with societal, cultural and behavioural aspects.

Description: ADDRESS will research, develop and deploy technology and processes in order to increase the usage of distributed generation and RES, thereby engaging in a new relationship between customers, generators and network operators. ADDRESS aims to develop new innovative architectures to enable active distribution networks to balance, in real time, power generation and demand, thereby allowing network operators, consumers, retailers and stakeholders to benefit from the increased flexibility of the entire system.
The innovative use of communication, automation and household technology will be combined with new trading mechanisms and algorithms, thereby providing active distribution networks with low-cost and reliable solutions.

Customers will be encouraged to participate actively, enabling them to change their consumption habits, to adopt smarter usage patterns of energy and to save money. A cost-benefit analysis of different solutions will be developed: the most promising will be tested in three sites with different geographic, demographic and generation characteristics. The consortium has a distinguished membership of large, medium and small enterprises with international experience.

Expected deliverables, benefits and impact: The target is to enable active demand in the context of the smart grids of the future, or, in other words, the active participation of small and commercial consumers in power system markets and in the provision of services to the different power system participants.

Project costs: Project costs: € 15.72 million
Funding: € 9 million

6.2.12 Kriegers Flak (Offshore Grid in the Baltic Sea with Two Offshore Wind Farms)

Functional projects: T5

Project duration: February 2010 – December 2016

Project website: www.energinet.dk

Partners involved: This feasibility study is a joint project carried out by three TSOs, and is relevant to Kriegers Flak: 50Hertz Transmission GmbH (DE), Svenska Kraftnät (SE) and Energinet.dk (DK).
The feasibility study was finalized in February 2010.

In January 2010, Svenska Kraftnät withdrew from this project, as their internal assessments showed that they did not expect offshore wind farms to be constructed at the Swedish part of Kriegers Flak in the foreseeable future. 50Hertz Transmission and Energinet.dk decided to continue the project.

Abstract: Kriegers Flak is a unique opportunity to build the world's first offshore grid, combining the grid connections between offshore wind farms with the interconnections between different countries and electricity markets. The additional market benefit of the Kriegers Flak project is that it can use the cable between the two countries as extra interconnector capacity in the many hours of the year when there is not a full load from the wind parks.

Objectives: The aim of this feasibility study is to assess whether there is potential in a combined offshore grid solution compared to separate, national solutions. This comparison is made under the assumption that several wind farms will be erected at Kriegers Flak in the Baltic Sea. The key questions are:
- Is it technically possible?
- Is it economically viable?
- What are the environmental issues?
- Is it practicable within the current legal, market and regulatory situation?

Description: The Kriegers Flak area in the Baltic Sea is well-suited for offshore wind farms. Spread out over the German, Swedish and Danish parts of Kriegers Flak, there is the potential for up to 1,600 MW of installed wind turbine capacity. The revised project with only Danish and German participation foresees approximately 900 MW of installed capacity. It is important that this large amount of wind energy is connected to the on-shore grids in the best way possible.

The three TSOs initiated this feasibility study in order to investigate the possibility of connecting future wind farms at Kriegers Flak through an international offshore grid connecting Germany, Sweden and Denmark. An offshore grid has never been built, but it would serve three purposes:
- It would bring renewable energy to European consumers,
- it would strengthen the energy markets for a large amount of RES and
- it would increase the security of supply by providing the necessary transmission capacity.

The European benefit from the project lies in the valuable solutions which will offer all other European countries a fast track to expected and upcoming similar projects.

The challenge is that the three geographical areas are not synchronous power systems: there are three different supporting schemes for RES and three different market areas (Denmark East and Germany). There are also two marketplaces involved: Nord Pool Spot and EEX.

The Kriegers Flak project is prioritized to obtain funding from the EU Commission Recovery Plan. In the Recovery Plan, 150 M€ has been allocated to the Kriegers Flak project. With only German and Danish participation, the expected funds to be allocated are expected to be approximately 125 M€.

Expected deliverables, benefits and impact:	The benefits and impact of the Kriegers Flak project are, in short: – the world's first offshore grid connection between two countries and two offshore wind farms, – better market integration of a large amount of electricity from offshore wind farms, – better North-South interconnector capacity between the two countries, – the development of novel technologies for offshore HVDC and back-to-back systems and – the project is prepared to include Swedish offshore wind farms and an interconnection to Sweden if they, at a later stage, should wish to take part in the Kriegers Flak project.
Project costs:	The project budget covers the additional costs by establishing a grid instead of establishing separate connections to the individual countries, and is estimated to be around 250 M€. The establishment of the wind farm is not included. EU-funding app.: 125 M€.

6.2.13 COBRA (a Stepping Stone in the North Sea Offshore Grid)

Functional projects:	T4 — **Project duration:** November 2009 – December 2015
Project website:	www.energinet.dk
Partners involved:	– TSOs: TenneT TSO (NL), Energinet.dk (DK) – Others: Technology suppliers
Abstract:	The Dutch and Danish TSOs TenneT and Energinet.dk are carrying out a feasibility study in order to assess a power link between Denmark and the Netherlands. The purpose of the link, entitled the COBRA cable, is to allow the integration of more RES into the Dutch and Danish power systems and to increase the security of supply. This power link will also help to intensify competition on the North-Western European power markets. The COBRA cable will examine the possibility of becoming the first stepping stone for a North Sea offshore grid for pan-European interconnections between multiple offshore wind parks.
Objectives:	The aim to provide a power link between Denmark and the Netherlands is in line with the EU's ambitions for a stronger and more interconnected European electricity transmission grid and will contribute to the development of a more international, sustainable power market, which is a main priority in European energy policy.
Description:	The new COBRA cable would also be in line with the EU's stated ambition of creating more interconnections between the various European countries. The COBRA cable would help to strengthen the links that already exist between the Scandinavian countries and the rest of Europe, thus contributing to the integration of the European electricity market. This cable would also contribute to the development of a sustainable international energy landscape, which is a key priority of European energy policy. The COBRA cable has prioritized funding from the EU Commission Recovery Plan. In the Recovery Plan, € 165 million are allocated to North Sea offshore grid projects.
Expected deliverables, benefits and impact:	The COBRA cable will be built from the Netherlands to Denmark (West). The benefits and impact of the cable are, in short: – A new North-South interconnector capacity in Europe, – better integration of more RES in the European grid, – better market development between the NordPool and APX and – a potential first stepping stone toward a North Sea offshore grid.

Project costs:	Estimated project costs: € 450 million (this budget covers the development and construction costs of the power link). The EU funding is according to budget, and will hopefully be € 86.5 million.

6.2.14 SUMO

Functional projects:	T3 **Project duration:** September 2011 – December 2014
Partners involved:	– TSOs: Elektro-Slovenija (SL) – Others: Faculty of Electrical Engineering at the University of Ljubljana, Milan Vidmar Electric Power Research Institute
Abstract:	Dynamic thermal ratings will be incorporated into the SCADA/EMS environment. Network analyses will use near real-time system capabilities. The calculation of element ratings will use ambient parameters from relevant geographical areas.
Objectives:	Given the fact that the overhead line thermal limits not only change seasonally, but even on a minute-by-minute basis, ELES believes that through accurate determination of these thermal ratings, a higher degree of operational security can be reached, thereby preventing unforeseen overloads and avoiding unnecessary preventive measures. The basic goal of the SUMO project is to integrate overhead line dynamic thermal rating (DTR) into the Slovenian transmission system.
Description:	One of the key areas of smart grids is the dynamic evaluation of transmission lines' capacity (DTR), which allows the optimum utilization of transmission capacity. The purpose of the SUMO project is to establish a system for determining the operational performance limits of transmission lines on the basis of real-time measurements and short-term forecasts, which will allow: – Increased utilization of transmission lines, while ensuring that the prescribed safety limits of transmission lines will not be violated and that the phase conductor temperature will not exceed the permissible limit of 80° C. – Increased operator awareness within the national control centre (NCC) about the critical lines in the system which would be overloaded in the event that the worst element in the system trips. The project is divided into a study and the implementation. The study is intended to analyse different ways of determining DTR (both real-time DTR and short-term forecast DTR) and how to use the results in real-time system operations in the most effective way. The implementation will, based on the results of cost-benefit analysis, implement DTR on relevant overhead lines and the central system into the national control centre.
Expected deliverables, benefits and impact:	– Increased awareness regarding real-time potential remaining capacity of overhead lines and – increased operational security through better awareness of both real-time and forecasted system state.
Project costs:	€ 2 million

6.2.15 Early Warning Systems (PMU/WAMS)

Functional projects: T3

Project duration: 2006–2012

Partners involved:
- TSOs: Energinet.dk (DK)
- Others: CET DTU (DK), University of Kassel (D)

Objectives: The purpose is to develop systems that can monitor the state of the overall power system and alert system operators and other protection systems about forthcoming critical situations in the power system.

Description: Most of the large power system collapses in the past 20 years have been sneaking voltage collapses which could only be discovered through subsequent failure analyses.

However, PMU and WAMS have since been developed. PMU technology provides unprecedented opportunities to monitor the actual state of the power system in real time.

Energinet.dk (a TSO) has thus far undertaken a number of Ph.D. projects in order to illustrate the issue and to develop algorithms to identify forthcoming voltage collapses.

Efforts are being spent on R&D in advanced PMU applications for the development of a SCADA-based early warning system for predicting system instability.

Project costs: Budget: 100 % Energinet.dk
Funding: 0 DKK (€ 0)

6.2.16 The Cell Controller Project

Functional projects: T6, TD1, TD2, TD3

Project duration: 2004–2011

Project website: www.energinet.dk/EN/FORSKNING/Energinet-dks-forskning-og-udvikling/Celleprojektet-intelligent-mobilisering-af-distribueret-elproduktion/Sider/default.aspx

Partners involved:
- TSOs: Energinet.dk (DK)
- Others:
  SydEnergi (DK), Spirae Inc, (USA), Energynautics GmbH (D), Kalki Tech (India), Tjaereborg Industri (DK), PonPower (DK)

Description: The project has been designed to help to adapt the Danish power system to future requirements by increasing the extent of system control and monitoring to ensure the balance between power generation and consumption remains stable.

Energinet.dk (a TSO) uses long-term, holistic planning to expand the power system. Generally speaking, this means that the security of supply, a well-functioning market, economic efficiency, the environment and sustainability are considered during the planning stage.

The security of supply is vital to Energinet.dk to be able to fulfil its social mission as the entity holding the overall responsibility for the Danish power system. The consumers must always have power readily available. Energinet.dk must therefore design its power system to support the needs of society, now and in the future. The Cell Project is a very important part of this task.

Project costs: Budget: 100 million DKK (€ 13.4 million) from Energinet.dk
Funding: 0 DKK (€ 0)

6.2.17 Smart Grids and Energy Markets (SGEM)

Functional projects: T6, T7, T8

Project duration: 2009 – 2014

Project website: www.cleen.fi/en/program_overviews/sgem_smart_grids_and_energy_markets

Partners involved:

- TSOs: Fingrid Oy (FI)
- Others:
  Cleen Oy (FI), ABB Oy (FI), Aidon Oy (FI), Alstom Grid Oy (FI), Elektrobit Wireless Communications Oy (FI), Empower Oy (FI), Emtele Oy (FI), Fortum Sähkönsiirto Oy (FI), Helen Sähköverkko Oy (FI), Nokia Siemens Networks Oy (FI), Oy Cybersoft Ab (FI), Suur-Savon Sähkö Oy (FI), Tekla Oyj (FI), Telia Sonera Finland Oyj (FI), The Switch Engineering Oy (FI), There Corporation Oy (FI), Vantaan Energia Sähköverkot Oy (FI), Vattenfall Verkko Oy (FI), Viola Systems Oy (FI), Aalto University (TKK) (FI), Lappeenranta University of Technology (FI), MIKES (FI), Tampere University of Technology (FI), University of Eastern Finland (FI), University of Oulu (FI), University of Vaasa (FI), VTT (FI)

Abstract: The aim of the SGEM research consortium is to develop international smart grid solutions that can be demonstrated in a real environment, utilizing the Finnish R&D and innovation infrastructure. At the same time, the benefits of an interactive international research environment will result in the accumulation of the knowledge of world-leading ICT and smart grid providers. The Finnish government has recognized the co-operational research model of CLEEN.

Objectives:

- Smart grid architectures and distribution infrastructure
- Intelligent management and operation
- Active resources
- Market integration and new business models

Description: The general objectives of the research program are:

- to create an innovative foundation for new solutions, products and services to enable the implementation of the smart grid vision,
- to demonstrate solutions in a real environment and
- to cultivate the accumulation of competence in the research and business environment in order to secure long-term competitiveness.

International research cooperation is a prerequisite to achieving these objectives.

Project costs: € 7.2 million

6.2.18 Umbrella

Functional projects: T7

Project duration: 2011 – 2015

Partners involved:

- TSOs:
  TenneT TSO GmbH (D), Amprion GmbH (D), ČEPS, a.s. (CZ), Elektro-Slovenija, d.o.o (SI), EnBW Transportnetze AG (D), PSE Operator S.A. (PL), swissgrid ag (CH), TenneT TSO B.V. (NL), Austrian Power Grid AG (A)
- Others:
  Delft University of Technology (NL), ETH Zurich (CH), Graz University of Technology (A), RWTH Aachen (D), University Duisburg-Essen (D), FGH e.V. (D)

Objectives:

- To develop a dedicated innovative toolbox to support a coordinated decentralized grid security approach for TSOs,
- to demonstrate the enhancement of existing and current procedures by the utilization of the developed toolbox and
- to provide a scientifically sound basis to support common TSO decisions.

Description:

The growing share of electricity generated by intermittent RES, as well as the increase in market-based cross-border flows and the related physical flows, are leading to rising uncertainties in transmission network operation.

In the synchronous area of mainland central Europe, due to large installations of RES such as wind and photovoltaic sources, the difference between actual physical flows and market exchanges can be substantial. Remedial actions were identified by previous smart grid studies within the 6th European framework program in operational risk assessment, flow control and operational flexibility measures for this area. At the same time, an efficient and sustainable electricity system requires efficient usage of existing and future transmission capacities in order to provide the maximum number of transportation possibilities. New interconnections and devices for load flow control will be integrated into future transmission networks and will offer new operational options.

Further developments of coordinated grid security tools constitute one of the major challenges which TSOs will face in the future. The methods to be applied have to take into account all technological measures used to enhance the flexibility of power system operations.

The zonal structure of the European energy market, along with the legal responsibilities of TSOs for different system areas, will continue to set increasingly complex requirements to the system operators concerning the quality and accuracy of cooperation.

The proposed UMBRELLA research and demonstration project is designed to cope with these challenging issues and boundary conditions. The toolbox to be developed will enable TSOs to ensure secure grid operations in future electricity networks with a high level of penetration of intermittent renewables. It will enable TSOs to act in a coordinated European target system where regional strategies converge to ensure the best possible use of the European electricity infrastructure.

6.2.19 iTesla (Innovative Tools for Electrical System Security Within Large Areas)

Functional projects: T7

Project duration: Preliminary 2011–2015

Partners involved:
- TSOs:
  RTE (FR), Elia (BE), REE (ES), REN (PT), STATNETT (NO), HTSO (GR), NGC (UK)
- Others:
  CORESO (BE), AIA (ES), ARTELYS (FR), BULL (FR), PEPITE (BE), QUINARY (IT), Imperial (UK), I NESC Porto (PT), KTH (SE), KUL (BE), RSE (IT), RISOE (DK), TECHNOFI (FR), TRACTEBEL (BE)

Objectives: The iTesla project addresses technical and scientific challenges in order to ensure the smoothoperation of the grid.

Description: The main goal is to develop and validate an open interoperable toolbox which is able to support future operations of the pan-European electricity transmission network, thus favouring increased coordination and harmonization of operating procedures among transmission network operators.

In order to do so, a flexible risk-based approach is adopted, in order to better tackle the increasing amount of uncertainty and to make best use of the opportunities for corrective action enabled by new power electronic devices and demand response. It will help system operators to appraise more effectively their network security limits, using a given set of reliability criteria. Flexibility will allow them to adapt to evolving reliability criteria and system conditions, like those which could emerge from other R&D projects and/or from future regulatory considerations carried out in parallel with this project. This flexibility also covers the urgent need to assess and recalibrate the role of defence and restoration plans as a part of a novel overall reliability strategy at the pan-European level.

The security assessment methodology covers system-wide dynamic phenomena based on validated modelling techniques of system-wide dynamic behaviour, in order to ensure an accurate and reproducible approach to security assessment. They will be designed to be adaptable in a flexible way to future control devices and to incorporate new knowledge about the system's dynamic behaviour. These dynamic models can also be used for the assessment of defence and restoration plans. Overall, risk-based approaches will make daily system operations smarter, helping, for instance, to:
- maximize system capacity while meeting security standards,
- support the coordinated development of pan-European network stability and security strategies to allow robust system operations under narrower stability/security margins,
- propose corrective actions and strategies which are able to limit the extent and impact of critical system disturbances at the pan-European level,
- clarify the role of defence and restoration plans in pan-European security and
- ensure increased coherence between each of the national defence plans when facing major pan-European disturbances.

The final product will be an IT platform which will favour the access of TSO users in order to address single, regional or pan-European network simulations of their own systems, coordinated regional systems or the entire pan-European system, provided that adequate system data are made available at the national, regional or pan-European level. The toolbox developed will therefore be open, with the interfaces between the toolbox and the modules clearly specified. These specifications will be made public.

6.2.20 AFTER (A Framework for Electrical Power Systems Vulnerability Identification, Defence and Restoration)

Functional projects: T7, T9

Project duration: 2011 – 2014

Partners involved:
- TSOs:
  ELIA (BE), TERNA (IT), ČEPS, a.s. (CZ)
- Others:
  RSE (IT), ENEA (IT), SINTEF-EN (NO), SINTEF ICT (NO), Genoa University (IT), University College Dublin (IR), City University London (UK), ALSTOM Power (FR), SIEMENS (DE), JRC (BE)

Objectives:
- To define and develop the architecture of a framework for risk and vulnerability assessment for integrated power and ICT systems,
- to develop methodologies for dealing with risk and vulnerability in integrated power and ICT systems,
- to develop tools and techniques for dealing with risk and vulnerability in integrated power and ICT systems and
- to develop the concepts and techniques for physical security.

Description: AFTER addresses vulnerability evaluation and contingency planning for energy grids and energy plants, taking into account the ICT systems used in protection and control. The main problems which are addressed concern high-impact, widespread, multiple contingencies and cascading.

6.2.21 Belgium East Loop Active Network Management

Functional projects: T12, TD3

Project duration: 2010 – 2011

Partners involved:
- TSOs: Elia (BE)
- Others: Ores (BE)

Abstract: This project aims to design an active network solution based on power system analysis. It will define principles of access for generators to perform a curtailment assessment that will help to estimate the frequency with which limits are challenged. This will lead to the generator modulation necessary in order to keep power flows within limits. This project will provide guidelines for the deployment of the active network solution, as well as estimated costs.

Description: This project addresses the issue of active network management on a 70 kV loop in order to enhance the capacity of intermittent generation that can be accommodated securely during the period preceding network reinforcement (which is expected to take years). The additional intermittent generation accommodated is required to accept curtailment under certain operational conditions as a counterpart to their acceptance by the TSO under the control of the regulating authorities. This project is composed of three steps:

1. Regulation issues:
   Welfare analysis is used to assess the extent to which it is beneficial for the community to accept additional curtailable intermittent generation, taking into account the associated network reinforcement costs.
2. Technological and equipment issues:
   The need of the TSO/DSO/Generator for telecommunications, information and control devices.
3. Contractual framework between the stakeholders,
   including the question of compensation for curtailment.

This project has been launched using Belgian funding and the first step is well underway. An extension of the tool which was initially designed which can accommodate probabilistic issues is under consideration.

6.2.22 From Wind Power to Heat Pumps

Functional projects: TD2, TD3, TD5 **Project duration:** 2009 – 2011

Project website: www.energinet.dk/EN/FORSKNING/Energinet-dks-forskning-og-udvikling/Sider/Fra-vindkraft-til-varmepumper.aspx

Partners involved:
- TSOs: Energinet.dk (DK)
- Others: Danish Energy Authority (DK), Center for Energy Savings (DK)

Objectives: To ensure that the communication platform and the control unit are developed in order to realize the socioeconomic potential of heat pumps, using an open standard and architecture so that the heat pump, electricity traders and the power system can communicate.

Description: This groundbreaking project is the only one of its kind in the world, and the idea is to control 300 intelligent heat pumps as if they were one big energy storage facility, capable of storing electricity as heat. The house owners will therefore be involved in developing the intelligent power system of the future, using wind power to replace fossil fuel for heating purposes. By introducing heat pumps, the house owners will make an active contribution to the integration of more renewable energy in Denmark.

Electricity cannot be stored. Electricity must be used as it is generated as the technology for storing electricity is not currently available. The generation of increasing amounts of wind power is therefore a challenge to the power system because the energy is, so to speak, blowing in the wind. By connecting 300 heat pumps, it is possible to create a large energy store where electricity can be stored as heat. When winds are strong, the generation of green electricity exceeds consumption, and the electricity can be stored by the heat pumps in the form of heat. In calm weather, when all of the electricity generated is needed, the heat pumps stop producing heat, and the houses are heated by the stored heat.

Project costs: 100 % of funding is provided by Energinet.dk / Funding: 0 DKK (€ 0)

6.2.23 Concept for Management of Future Electricity Systems

Functional projects: TD1, TD2, TD3, TD4, TD5 **Project duration:** 2009 – 2011

Partners involved:
- TSOs: Energinet.dk (DK)
- Others: Danish Energy Association (DK), a number of Danish DSOs (DK)

Objectives: To develop and describe a concept for the necessary and sufficient management of the future power system in 2025. The concept description should be at a level that will allow it to be subsequently broken down into specific projects and an early-stage phased rollout.

Description: Based on the total power system challenges towards 2025, the project entitled "Concept for the management of power systems", in brief, draws on a Danish plan for how the Danish power system must be controlled until 2025. This includes interdisciplinary collaboration and a consensus on principles, both within Energinet.dk (a TSO) and among external Danish electricity suppliers, Danish power producers, industry and politicians. International development must also be followed in order to ensure that standards and products are prepared for the future power system. In this context, the project should also be coordinated with Danish energy R&D.

Project costs: 100 % of funding is provided by Energinet.dk / Funding: 0 DKK (€ 0)

6.3 Appendix 3: Past EU-supported R&D Projects on Pan-European Transmission Issues

European TSOs have been aware of the importance of R&D for some time. While Appendix 2 has shown which R&D activities are planned for the future or which have already commenced, the goal of Appendix 3 is to give an overview of R&D projects in the past. The projects described below are several examples of EU-supported R&D projects that have been executed. The selected examples had a substantial impact on more than one TSO. The short descriptions of the individual R&D activities are based on information which is available to the public.

	Project	TSO		DSO		Manufacturer		GenCo		Other
		Partner	Impact	Partner	Impact	Partner	Impact	Partner	Impact	Partner
6.3.1	EWIS	15	High	0	Low	0	Low	0	Medium	7
6.3.2	TradeWind	15	High	0	High	0	Medium	0	High	9
6.3.3	Reliance	8	High	1	Low	0	Medium	1	Low	8
6.3.4	WindGrid	2	High	2	Low	2	Low	1	High	3
6.3.5	IS Power	3	Low	1	High	1	Low	0	Medium	1
6.3.6	SUPWIND	2	High	0	High	0	Low	0	High	5
6.3.7	FENIX	2	High	2	High	7	Low	1	Medium	7
6.3.8	DESIRE	0	Medium	0	High	1	Medium	0	Low	9
6.3.9	Offshore Grid Study – The Irish Vision	1	High	0	Low	1	High	0	Medium	0
6.3.10	Investigating the Impact of HVdc Schemes in the Irish Transmission Network	3	High	0	Medium	1	Medium	0	Low	0
6.3.11	TEPCO study	2	High	0	Low	1	Medium	0	Low	0
6.3.12	ICOEUR	3	High	0	Low	2	Medium	0	Medium	15
6.3.13	REALISEGRID	4	High	0	Low	4	Medium	0	Medium	16
6.3.14	SUSPLAN	6	High	0	Medium	0	Low	10	High	14
6.3.15	ANEMOS.plus	4	High	2	High	0	Medium	3	High	12
6.3.16	EVCOM	1	Medium	1	High	1	High	0	Low	✓

High impact Medium impact Low impact

6.3.1 EWIS (The European Wind Integration Study)

Project duration:	June 2007 – October 2009 **Project website:** www.wind-integration.eu
Partners involved:	Stakeholder-oriented project performed by 15 TSOs: VERBUND APG (AT), CEPS (CZ), Elia (BE), Energinet.dk (DK), Amprion (DE), 50Hertz Transmission GmbH (DE), EirGrid (IE), HTSO (GR), National Grid (GB), PSE Operator (PL), REE (ES), REN (PT), RTE (FR), TenneT TSO (NL), transpower (DE)
Abstract:	Initiated by TSO associations in 2005, after the German DENA study. Up to 2007, this project was funded by TSOs. From 2007 – 2009, DG TREN funded 100 % of the costs.
Objectives:	– To investigate all of the relevant network issues arising from wind integration, – to produce quantified options to accommodate wind (reliability, quality of power supply, integration costs) between 2008 and 2015 and – to put forward recommendations for manufacturers, network operation and development, markets and regulations, reaching up to 2015.
Description:	EWIS is an initiative which was established by the associations of European TSOs in collaboration with the European Commission. It aims to work with all of the relevant stakeholders, and especially representatives of wind generation developers. This study will use results from detailed network and market models of the European transmission system (including all four synchronous areas: mainland Europe, the Nordic countries, Great Britain and Ireland) for scenarios representing immediate and more long-term needs. The recommendations will be aimed at developing, where possible and appropriate, common European solutions to wind integration challenges. Given the particular statistical characteristics of wind generation, this study will seek arrangements that will make best use of the pan-European transmission network in order to deliver the benefits of wind generation across Europe.
Expected deliverables, benefits and impact:	The scope of this work covers all of the detailed technical, operational, market and regulatory aspects relating to the integration of wind power in Europe on a large scale between now and 2015. Alternative generation developments that will achieve 2020 targets will be assessed, taking into account the estimates which have already been developed by the TradeWind project. This approach will provide the best fit to ensure that the EWIS results and findings address all aspects of network integration needed to achieve Europe's 2020 renewable energy targets. A draft interim report about the approaches and methodologies used in the study, together with preliminary findings that will serve to focus the ongoing work for all stakeholders, was presented in spring 2008. After receiving positive feedback from the stakeholders, the report was presented to the European Commission in July 2008.
Project costs:	– Up to 2007, funded by TSOs – From 2007 – 2009, funded by DG TREN (100 % of the costs) – Project cost: € 4.04 million – Project funding: € 4.04 million.

6.3.2 TradeWind (Wind Power Integration and Exchange in the Trans-European Power Markets)

Project duration: November 2006 – February 2009 **Project website:** www.trade-wind.eu

Partners involved: EWEA (BE), SINTEF (NO), DTU-RISØ (DK), 3E NV (BE), KEMA (NL), VTT (FI), GARRAD HASSAN (GB), Tractebel Engineering (BE), DENA (DE)

Cooperation agreement with EWIS, i.e. 15 TSOs.

Abstract: The TradeWind project is the first EU-level study to explore the benefits of a European grid with better interconnections and an improved power market design on the integration of large amounts of wind power. Coordinated by EWEA (the European Wind Energy Association) and funded by the IEE, TradeWind has a cooperation agreement with EWIS, i.e. 15 TSOs.

Objectives:

- To examine issues raised by large-scale, cross-border wind power transmission and market design at the European level.
- To examine the need for transmission upgrades on-shore and offshore (42 on-shore interconnections, saving € 1,500 million/year in total system operating costs, justifying investments of € 20 billion).
- R&D efforts in meshed HVDC technology needed to enable network expansion in the North Sea.

Description: TradeWind was a European project funded under the EU's IEE Program. The project addressed one of the most challenging issues facing wind energy: its maximal and reliable integration into the trans-European power markets. Recent studies have shown that a large contribution from wind energy to European power generation is technically and economically feasible in the same order of magnitude as individual contributions from conventional technology, with a high degree of system security and modest additional costs. Wind power penetration is not constrained by technical problems with wind power technology, but by regulatory, institutional and market barriers.

TradeWind aimed to facilitate the dismantling of barriers to the large-scale integration of wind energy into European power systems, on the transnational and European levels, and to formulate recommendations for policy development, market rules and interconnector allocation methods to support the integration of wind power.

The scoped area was the EU-25, and included the synchronous zones. The study was built on the results of national and supra-national wind integration studies and answered the questions that these studies had raised. The supply of Europe's islands was also addressed.

TradeWind was implemented by a consortium led by the EWEA. It was composed of leading European specialists in wind power integration, power systems and power market analysis.

Expected deliverables, benefits and impact: The final report is available from the website:
www.trade-wind.eu/fileadmin/documents/publications/Final_Report.pdf

Project costs: Funded under the EU's IEE Program.

Project cost: € 1.748 million
Project funding: 50 %.

6.3.3 Reliance

Project duration: 2005 – September 2007

Project website: www.ca-reliance.org

Partners involved:

– Elia (BE), ELES (SI), Energinet.dk (DK), ČEPS (CZ), REE (ES), Statnett (NO), Terna (IT), TenneT TSO (NL)

– Other:
EDF (FR), FEEM (IT), FGH (DE), ISET (DE), K.U.Leuven (BE), Sintef (NO), Technofi (FR), Terna (IT), University Manchester (GB)

Abstract:

Reliance (Coordination Perspectives of the European Transmission Network Research Activities to Optimise the Reliability of Power Supply, Using a Systemic Approach, involving Growing Distributed Generation and Renewable Energy Markets) is a coordination action of the European transmission network's research activities. The project is funded by the European Commission's Sixth Research and Technological Development Framework Program. It addresses:

– the implementation of a European electricity market,

– wider network problems due to energy supply diversification,

– the need to improve the existing power system research capacities and

– the need to expand the exchange of information and collaboration between European electricity network operators.

Objectives:

– To identify the challenges which will be faced by the pan-European network up to 2030,

– to design a research roadmap reaching up to 2030,

– to propose a framework for the European Power System Research Organization,

– to address European electricity transmission challenges,

– to involve all power system stakeholders,

– to provide a European focal point for research into electricity transmission and

– to create funding and organizational schemes for performing R&D tasks.

Description:

A group of eight European TSOs, one power producer, one DSO and several research centres, on the initiative of Tractebel Engineering (SUEZ), gathered in order to share their common understanding of the need to resume research and technology development (RTD) on power system issues in Europe. They agree on a common analysis, which can be summarized as follows:

The liberalization of the power market through Europe has led to power exchanges that were not foreseen at the time of the design of the European transmission networks.

Capturing wind energy on a large scale as part of the diversification of supply, as has already been implemented, and its subsequent enormous development, as has already been decided, will lead to major risks, including a power imbalance and unpredictable load flows.

The expected growth of distributed generation in line with the Kyoto protocol guidelines will affect the development of the European transmission network as well as the control and stability of the entire system.

Expected deliverables, benefits and impact:

The final report is available from the website:
www.ca-reliance.org/download/download_index.htm

Project costs:

– The coordination action was funded by EC DG Research (2005 – 2007)
– Reliance Coordination Action over two years
– Project costs: € 2.2 million

6.3.4 WindGrid (Wind on the Grid)

Project duration: December 2006 – December 2009

Partners involved:
- TSOs: REE (ES), REN (PT).
- Other:
  Enercon (DE), ISET (DE), Windenergie (CZ), Iberdrola (ES), Deloitte (ES), Korona (SI), Gamesa (DK)

Abstract: WindGrid, an initiative supported by the EU Commission and DG TREN, is a project which focused on the preparation of the European electricity network for the large-scale integration of wind farms through the design, development and validation of new tools and devices for planning, control and operation in a competitive market.

Objectives: To support the preparation of the European electricity network for the large-scale integration of wind farms through the design, development and validation of new tools and devices for planning, control and operation in a competitive market. Results were produced at the by end of 2009.

Description: Europe's energy supply system is heavily dependent on fossil fuels imported from third-party countries. The energy consumption of the members of the EU is expected to grow during the coming years at a reasonable pace, leading to a higher dependence on imported fossil fuel as well as a rise in the volume of CO_2 emissions.

In order to alleviate the EU's dependence on external sources of energy supply, achieve CO_2 reduction commitments and improve the quality of life both within the EU and globally, the EU has adopted several policies and a strategic approach in order to encourage the use of renewables, setting a target of 12 % of the market share for this technology in the total primary energy consumption for 2010. In addressing these objectives, wind farms appear to constitute efficient technology. The recent developments in this area, making wind farms commercially competitive, have resulted in a high number of wind farms, which are increasing in individual size from year to year, connected to the European high voltage transmission networks. As a result of this process, the penetration of wind generation into the European electricity systems is increasing to such levels that some problems associated with the reliability of electricity supply have started to appear.

Expected deliverables, benefits and impact: In order to achieve these goals, four scientific and technological (S&T) objectives have been established:

- the design, development and demonstration of an efficient wind farm energy management system (a wind farm cluster management system),
- the design, development and demonstration of security tools to integrate large-scale wind farms into high-voltage electricity networks,
- the demonstration of the economic attractiveness of the electricity supply system with a significant penetration of wind power and the development of regulatory market designs/ conditions for the integration of the future network and
- practical tests and assessments of the aforementioned objectives by leading European TSOs and wind farm operators

Project costs: EU-funded project under FP6 – Sustainable Energy Systems

Project cost: € 4.27 million
Project funding: € 1.69 million.

6.3.5 IS Power (dealing with isolated power systems)

Project duration:	October 2007 – April 2010 **Project website:** www.ispower.eu
Partners involved:	– TSOs: REE (ES), EEM (PT), Cyprus TSO (CY) – Others: Deloitte (ES), Acosslimit (Malta), Iberdrola (ES)
Abstract:	IS Power is an EU-funded project under FP6 – Sustainable Energy Systems. This project deals with isolated power systems; that is, those systems which are not interconnected with other neighbouring systems by tie-lines and thus restricted to using their own resources for the maintenance of synchronous operations.
Objectives:	IS Power aims to develop technical and regulatory frameworks in order to improve the performance of power systems (guaranteed reliability and supply) and to ease the integration of renewable energies and other distributed forms of generation in isolated areas (insular systems). The results were produced in mid-2010.
Description:	Insular isolated territories have difficulty in terms of their natural resources and biodiversity with the expansion of power grids and the installation of new capacities for conventional electrical generation. Geographical singularities strongly influence the management of insular power systems. Technical, economic and operative difficulties occur in interconnecting these power systems with continental systems. The aim of IS Power is therefore to study the sustainable development of insular systems' economies which require the efficient use of the natural resources which are available in these territories and their efficient integration and management in their electricity grid. Based on cooperation and knowledge sharing, this project proposes to develop technical and regulatory frameworks with which to improve the performance of these energy systems (through guaranteed reliability and supply) and to ease the integration of renewable energies and other distributed forms of generation.
Expected deliverables, benefits and impact:	The IS Power Dissemination Plan pursues the following objectives: – To communicate to other S&T communities the results of the analyses performed in the project. Some of these results will be based on scenarios and assumptions provided by these third parties. – To prepare recommendations regarding improvements to the management of electricity grids placed in isolated electrical systems with the expectation of having to accommodate large-scale penetration of RES for the following institutions: the European Commission, European energy industry players, energy authorities and standardization bodies.
Project costs:	EU-funded project under FP6 – Sustainable Energy Systems Project cost: € 3.1 million Project funding: € 1.67 million

6.3.6 SUPWIND (Decision Support for Large-Scale Integration of Wind Power)

Project duration: October 2006 – September 2009 **Project website:** www.supwind.risoe.dk

Partners involved:

- TSOs: HTSO (GR), Energinet.dk (DK)
- Other: University Duisburg (DE), DTU-RISOE (DK), University Vienna (AT), IER (DE), iRM (AT)

Abstract: SUPWIND is a research project supported by the European Commission under the Sixth Framework Program. SUPWIND addresses these strategic objectives:

- Grid issues:
  The management of electricity grids linked to large-scale decentralized wind power generation
- Large-scale RES integration

Objectives: The project has the following objectives:

- To demonstrate the applicability of decision-making support tools based on stochastic analysis and programming for the operational management of grids and power plants,
- to demonstrate the applicability of strategic analysis tools for decision-making support for long-term grid management and
- a detailed analysis of improved coordination mechanisms between grid operators, power plant operators, power exchanges etc.

Description: A new issue in the planning and operation of electricity systems is gaining importance with the increase in the installed capacity of wind power, namely the handling of fluctuations in electricity production. Recent projects such as WILMAR have developed optimization models that endogenously include the information contained in wind power production forecasting in order to support the making of decisions that are more robust in the face of fluctuations in wind power production. In the GreenNet/GreenNet-EU27 project, a tool for endogenously determining optimal investment strategies in grids with large-scale wind integration has been developed.

Building on the tools developed and experiences gained in these projects, the SUPWIND project will demonstrate the applicability of optimization models that support TSOs and other relevant actors in both the day-to-day operation of the power system and long-term investment planning in transmission lines and production assets.

Expected deliverables, benefits and impact: This project helped to secure the operation of the European electricity supply system and to develop it further in view of a sustainable energy future.

Through the development and application of detailed simulation and optimization models, this project makes it possible to identify system configurations and operation modes which best fulfil the concurrent and partly conflicting objectives of sustainable electricity systems: the security of supply, economic efficiency and environmental friendliness.

It thereby focuses on the large-scale integration of wind energy, which is expected to contribute substantially to the reduction of CO_2 and other emissions but at the same time raises new challenges for guaranteeing the security of supply, given the large-scale fluctuations involved.

Project costs: Project cost: € 1.86 million
Project funding: € 1.17 million

6.3.7 FENIX (Flexible Electricity Network to Integrate the Expected “Energy Revolution”)

Project duration: October 2005 – September 2009 **Project website:** www.fenix-project.org

Partners involved:

– TSOs:
REE (ES), National Grid (UK)

– Other:
Iberdrola (ES), Areva T&D EME (FR), Ecro (RO), EDF (FR, UK), ECN (NL), Labein (ES), Gamesa (ES), IDEA (FR), ILC (UK), ILC(UK), ISET (DE), Korona (SL), Poyry (UK), ScalAgent (FR), Siemens PSE (AT), Manchester (UK), VUA (NL), ZIV (ES)

Abstract: Over the past decade, the EU has been deploying significant amounts of DER1 of various technology in response to the climate change challenge and the need to enhance fuel diversity. However, conventional large-scale power plants remain the primary source of control of the electricity system, assuring the integrity and security of its operation. In order to address this problem, DER must take over the responsibility from large conventional power plants and provide the flexibility and control necessary in order to support secure system operation.

Objectives: The objective of FENIX is to boost DER by maximizing their contribution to the electrical power system, through aggregation into large-scale virtual power plants (LSVPP) and decentralized management.

Description: This project is divided into three phases:

– Analysis of the contribution of DER to the electrical system, assessed in two future scenarios (Northern and Southern) with realistic DER penetration.

– The development of a layered communication and control solution validated for a comprehensive set of network use case studies, including normal and abnormal operation, as well as recommendations to adapt international power standards. We envision a threefold R&D effort:
  – The key component is the LSVPP, which is an aggregation of DER, taking into account the actual location of individual DER in the network. LSVPPs will have the flexibility and control to provide different services to the energy and ancillary service markets.
  – The bottom level is the local solution at the individual DER themselves, which are responsible for managing the unit in connection with the LSVPP.
  – Finally the higher level, which consists of a new generation of EMS and DMS tools to be developed and placed with the TSO and the DSO respectively, with the new ability to manage LSVPP capacities for network operation, and the markets that will put a value on these capacities.

– Validation through two large field deployments, one focused on domestic CHP aggregation, and the second aggregating large DER in LSVPPs (wind farms, industrial cogeneration), integrated with global network management and markets.

In order to achieve these multi-disciplinary objectives, the FENIX consortium incorporates:

– research centres and universities with high levels of involvement in previous and current EU projects in this area (CRISP, DISPOWER, MICROGRIDS, EUDEEP),

– transmission and distribution utilities, which today hold the responsibility for the networks where DER are being integrated,

– equipment and ICT manufacturers with a strong presence in the energy sector,

– DER owners who bring their business vision to the project and finally

– the organizations responsible for regulation, standardization etc., which will be managed in the project through a Stakeholders Advisory Group, which is absolutely necessary for the future effective widespread exploitation of the project results.

Expected deliverables, benefits and impact:	Within the FENIX project, we can encounter the challenge of DER integration. The aim of FENIX was to conceptualize, design and demonstrate the technical architecture and commercial and regulatory framework for the virtual power plant-based large-scale aggregation of DER.
Project costs:	Project costs: € 14.76 million Funding: € 7.8 million

6.3.8 DESIRE

Project duration:	June 2005 – May 2007 **Project website:** www.project-desire.org
Partners involved:	AAU (DK), EMD (DK), PE (DK), UoB (UK), ISET (DE), UniK (DE), EMD-DE (DE), Labein (ES), WUT (PL), TUT (EE)
Abstract:	DESIRE is the dissemination strategy on electricity balancing for the large-scale integration of renewable energy. The European electricity market is facing upcoming problems. The proportion of renewable electricity is rising in Europe, while local electricity systems are unable to absorb the excess capacity, meaning that we are unable to use the renewable electricity which is being produced. Interconnectors of electricity are blocked up by the need to transport excess supplies across EU borders. At the same time, the competitiveness of the European electricity market is constrained.
Objectives:	– To promote the integration of fluctuating RES into local and regional electricity systems, – to balance wind power in the European electricity system through the use of CHP and – to disseminate the knowledge created to market actors in Europe.
Description:	– **Demonstration of techniques** The DESIRE project develops methods and disseminates practices for the integration of renewable electricity. CHP can work with wind power to produce a balanced and more predictable supply of electricity. When excessive wind power production takes place, the CHP unit decreases its production and relies on its heat store to satisfy the heat demand. When wind production is low, the CHP plant operates in order to build up heat stores and make up for the lack of electricity produced using wind power. In the project, these balancing techniques are demonstrated at case study plants in Denmark, Germany and the UK, and supplemented by studies in Spain, Poland and Estonia. The demonstrations are used to further improve the guidelines on co-generation, which will be disseminated to market actors in Europe. – **Identification of barriers and solutions** In some European countries, CHP is a well-known and widely used technology. In others, CHP has not yet been integrated into the electricity supply. A general integration of CHP and wind power at the European level is expected to be achieved only by active public regulation. Consequently, possible barriers within the participating countries are identified as part of the project and suggestions to overcome these barriers are presented. – **Meeting national and European standards** DESIRE draws on the experiences of the countries involved in the project and promotes the integration of CHP and wind power into the European electricity supply. On the basis of the knowledge created, it will be possible to integrate balancing techniques on different scales into all European countries. The project will have an impact on the European electricity supply as a whole and will contribute to help to meet both national and European standards for the deployment of renewable energy and CHP. Through a further development and implementation of this technology, it will be possible to implement the EU Directives concerning the internal electricity market, the promotion of co-generation and the promotion of electricity produced through renewable sources.

Expected deliverables, benefits and impact:	– The DESIRE project has demonstrated how local CHP plants can help to achieve a balance between supply and demand in a system with fluctuating wind power production. These plants are equipped with a CHP capacity equal to the maximum heat demand in the winter and thermal stores equal to the heat demand of a summer weekend. The relevant software and other tools have been used in case studies in Denmark, Germany and the UK. – In six regions in Denmark, Germany, the UK, Poland, Spain and Estonia, models of the electricity supply have been made and the magnitude of CHP regulation systems has been evaluated against other relevant measures, including the expansion of interconnectors. – The barriers have been investigated both at the EU level as well as at the national level in the six participating countries.
Project costs:	Project costs: € 2.32 million Funding: € 1.2 million

6.3.9 Offshore Grid Study

Project duration: June 2009 – March 2010 **Project website:** www.eirgrid.com

Partners involved:
- TSOs: EirGrid (IE)
- Others: ERSE (ENEA – Recerca sul Sistema Elettrico) (IT)

Abstract: The Irish Vision.
Offshore grids are attracting more interest as another opportunity to develop renewable resources.
As a consequence of the great number of connection requests, and due to the large amount expected over relatively wide areas, TSOs are developing the concept of an offshore network which is capable of fulfilling these requests, in order to increase reliability and to optimise investment costs for infrastructure.
In this framework, EirGrid is undertaking an internal study focusing on the Irish Sea context.

Objectives: The overall objectives of the Offshore Grid Study are:

- To find a potential offshore grid structure, the most suitable technology and whether there are any synergies between on-shore and offshore grids and
- to evaluate whether, to what extent and in which market context the interconnection strategy could create further opportunities for the All-Ireland Transmission System (AITS) for wind resource exploitation.

Description: For the Offshore Grid Study, an expansion planning methodology has been proposed which is implemented using a software tool named ESPAUT developed by ERSE (ENEA - Ricerca sul Sistema Elettrico).

The Offshore Grid Study is divided into two parts:

- The first part considers offshore generation from the Irish perspective with the offshore grid transferring power to the AITS.
- The second part deals with the impact of interconnection. Basically, the off-shore grid is seen not only in terms of the connection of the wind but as a support for the energy transfer between the AITS and its neighbouring countries. This synergy may result in further optimization, as the offshore infrastructure may have spare capacity for many hours of the year.

Different sensitivity analyses are performed in order to explore the impact on the expansion of the amount of wind offshore, the number of offshore locations and the effect of the installation of smart devices.

Finally, a "business as usual" case is studied as a technical/economic comparison with the alternatives which have been examined.

Expected deliverables, benefits and impact:

- To define possible general design parameters to help the decision-making process at the planning stage of offshore grids,
- to help to formulate a comprehensive EirGrid position in a future regulatory framework for the offshore grid,
- to identify suitable technology for offshore grid deployment and
- to investigate new planning methodology approaches.

Project costs: Costs are shared between EirGrid and ERSE.

6.3.10 TransGrid HVdc

Project duration: October 2008 – November 2009 **Project website:** www.eirgrid.com

Partners involved:

- TSOs: EirGrid (IE), SONI (NI), NIE (NI)
- Others: TransGrid Solutions (Canada)

Abstract: This study investigated the Impact of HVdc schemes in the Irish transmission network. The TransGrid HVdc study was commissioned to investigate the impact of HVdc schemes in the Irish network and to compare these HVdc schemes to equivalent AC solutions for various scenarios.

Objectives: The overall objectives of the TransGrid HVdc project are to:

- perform an investigation into various HVdc schemes and the impact they would have on the operation, performance and security of the transmission system of Ireland and
- to identify the nature of the available schemes, their impact upon AC systems, how and under what circumstances they might be applied to the Irish transmission system and how these schemes perform in comparison with each other and with equivalent AC schemes.

Description: EirGrid/NIE/SONI are currently faced with the challenge of expanding and modifying the meshed Irish AC network in order to accommodate the increasing demand for electricity, for the connection of large amounts of renewable generation and to facilitate greater cross-border power transfers between Northern Ireland and the Republic of Ireland while still maintaining the security of supply. As part of a solution to this challenge, EirGrid/NIE/SONI are investigating the feasibility or otherwise of using HVdc schemes to develop the transmission system of the Republic of Ireland and Northern Ireland.

Four scenarios were investigated in the TransGrid HVdc study:
- Northwest wind,
- a North-South interconnector,
- drawing power out of the Cork Region and
- system expansion in Northern Ireland.

Steady state contingency analysis, short circuit analysis, transient stability analysis, harmonic frequency scans and subsynchronous resonance (SSR) screenings were performed in order to derive a basis for comparison of the technical performance of the AC and HVdc transmission solutions.

The investigation qualitatively compared VSC HVdc, line-commutated converter (LCC) HVdc and equivalent AC solutions for a number of transmission development scenarios. Schemes were compared exclusively in terms of their relative impact on transmission system performance, security and flexibility rather than on aspects such as cost or environmental impact.

Expected deliverables, benefits and impact:

- To help to formulate a comprehensive EirGrid position in presenting the North-South project and other future projects to the Irish authorities,
- to define possible general design parameters to help the decision-making process at the planning stage for possible HVdc projects,
- to define a study methodology for future detailed HVdc planning studies and
- to identify rules to be introduced to the EirGrid Transmission Planning Criteria.

6.3.11 TEPCO study

Project duration: November 2008 – September 2009 **Project website:** www.eirgrid.com

Partners involved:
- TSOs: EirGrid (IE); Northern Ireland Electricity (NIE)
- Others: TEPCO (Japan)

Abstract: An assessment of the technical issues relating to significant amounts of EHV underground cable in the AITS.

This study deals with the evaluation of the impact of large amounts of underground cables on the AITS. Steady state and electromagnetic transient (EMT) phenomena have been examined on potential HV projects taken from the Grid Development Strategy (GRID25). A thorough investigation has been devoted to the North-South interconnector project.

Objectives: The overall objectives of the TEPCO study are:

- to investigate issues relating to the introduction of a large amount of underground cable systems into the AITS and
- to identify potential risks and possible countermeasures.

Description: The TEPCO study is divided into three parts.

The first part explores the application of an underground cable system (UGCS) in the AITS, by choosing the most critical scenarios according to the GRID25 plan. In order to build a worst-case scenario, all new proposed reinforcements are modeled as underground cables. Scenarios at different voltage levels are analysed, as well as phenomena such as EMT, black start capability and voltage stability.

The second and third parts focus specifically on the North-South interconnector. In particular, the second part examines the fully undergrounded option, whereas the third considers a partially undergrounded solution.

The results show that for EHV, a steady state solution can always be found for any length of cable.

Temporary over voltages (TOVs) represent a major risk to the system that cannot be mitigated without preventing several operational actions. This is due to resonance phenomena as a consequence of a combination of large capacitance (long cable) and a weak system (high impedance).

Switching and transient over voltages can be mitigated following traditional insulation coordination practice.

Moreover, large amounts of cables may influence some emergency actions, i.e. black start capability, as a consequence of the large charging current of the circuit which requires a review of the black start generator's reactive performances.

Expected deliverables, benefits and impact:
- To help to formulate a comprehensive EirGrid position in presenting the North-South project to the Irish authorities,
- to define possible general design parameters to help the decision-making process at the planning stage for underground projects and
- to identify rules to be introduced into the EirGrid Transmission Planning Criteria.

Project costs: The costs will be shared between NIE and EirGrid.

6.3.12 ICOEUR (Intelligent Coordination of Operation and Emergency Control of EU and Russian Power Grids)

Project duration: January 2009 – December 2011 **Project website:** www.icoeur.eu

Partners involved:
– TSOs: Eles (Slovenia), TEIAS (Turkey), Terna (IT)
– Others: Research centres, universities, suppliers of technology

Abstract: The possible future interconnection between the European and Russian electricity transmission systems requires the elaboration of methods for monitoring, controlling and protecting large-scale systems and especially for providing support for their interconnections. The development and prototypical implementation of these new methods and tools is the major goal of the ICOEUR project. New technologies like WAMS, control and protection technologies as well as advanced network controllers (FACTS) and HVDC systems will be considered.

The ICOEUR concept envisions an optimal technical interconnection of the EU and Russian electricity transmission networks which will create the ideal conditions for the secure and stable operation of the common as well as isolated power systems and which will realize "highways" for energy exchange between both energy markets. The security of the operation is ensured by innovative control and monitoring systems, which include innovative monitoring and controlling tools, intelligent controlling devices and ingenious protection functionality. The ICOEUR concept realizes the secure interconnection of both networks while retaining the autonomy of all of the participants, taking into account their individual technical and regulatory requirements.

Objectives: The ICOEUR project addresses the topic of ENERGY.2008.7.2.1:
"Innovative operational and monitoring tools for large power systems"
within the call FP7-ENERGY-2008-RUSSIA, FP7 Cooperation Work Program: Theme 5 Energy.

The ambitious vision of the ICOEUR project is the definition of the core requirements for a large-scale interconnection of the EU and Russian networks and their optimal realization, in other words:

– Optimization of the use of installed capacities,
– reliability improvements, thereby reducing the economic cost of power outages,
– sharing reserve capacities and reducing the level of reserves required,
– providing mutual support for the interconnected systems in case of emergency,
– facilitating the large-scale integration of renewable energies due to higher flexibility of the interstate network operations and
– improved control of system frequency to minimize major disturbances.

Description: ICOEUR is based on the following five Work Packages (WPs):
– WP1 – Specification of requirements for large-scale network interconnections
– WP2 – Technology for large-scale network interconnections
– WP3 – Control and monitoring of large-scale interconnections
– WP4 – Protection functions for large-scale interconnections
– WP5 – Quality assurance, dissemination and exploitation

Expected deliverables, benefits and impact:

- The most important contribution of the ICOEUR project consists of the new criteria, methodologies and tools that show clearly and quantitatively to political, regulatory and infrastructural decision-makers.
- The envisioned ICOEUR goals can be achieved only in close cooperation with experts with extensive knowledge of the EU and Russian power systems, as well as manufacturers and network operators. The ICOEUR consortium involves leading experts in all of these domains and guarantees efficient collaboration and the knowledge required for testing the methodologies developed. The joint development of innovative monitoring, simulation and control concepts, tools and equipment through the diverse and international ICOEUR consortium and the implementation of prototypes will promote their adoption.

Project costs: Estimated costs: € 4.885 million
EU funding: € 2.00 million.

6.3.13 REALISEGRID

Functional Project: T2

Project duration: September 2008 – February 2011

Project website: realisegrid.erse-web.it

Partners involved: The project is coordinated by ERSE (ENEA – Ricerca sul Sistema Elettrico) (IT), formerly CESI RICERCA

- TSOs:
  TenneT TSO (NL), Verbund APG (AT), Terna (IT), RTE (FR)
- Other:
  TECHNOFI (FR), Politecnico di Torino (IT), JRC (BE), Observatoire Méditerranéen de l'Energie (FR), Vienna University (AT), University Delft (NL), University Dortmund (DE), R&D Center for Power Engineering (RUS), PRYSMIAN (IT), KANLO (FR), riecado (AT), University Dresden (DE), Univerza v Ljubljani (SI), ASATREM (IT), University Manchester (GB)

Abstract: REALISEGRID comprises Research, Methodologies and Technologies for the Effective Development of pan-European Key Grid Infrastructures, and aims to support the achievement of a reliable, competitive and sustainable electricity supply.

The mission of REALISEGRID, a new project co-funded by the EU within the Seventh Framework Program, is to develop a set of criteria, metrics, methods and tools to assess how the transmission infrastructure should be optimally developed in order to support the achievement of a reliable, competitive and sustainable electricity supply in the EU.

Objectives: The ultimate objective of REALISEGRID is to develop a set of criteria, metrics, methods and tools to assess how the transmission infrastructure should be optimally developed in order to support the achievement of a reliable, competitive and sustainable electricity supply in the EU.

Description: The European electricity system is facing major challenges to the implementation of a strategy for a reliable, competitive and sustainable electricity supply. The development and the renewal of the transmission infrastructure are central and recognized issues in this strategy.

The transmission system is a complex and highly interconnected infrastructure that offers a wide range of benefits, such as improved reliability, the promotion of competitive electricity markets and economic growth, support for the development of new generation resources and for the exploitation of renewable resources. Within this context, the objective of REALISEGRID is to develop a set of criteria, metrics, methods and tools (hereinafter called a framework) to assess how the transmission infrastructure should be optimally developed in order to support the achievement of a reliable, competitive and sustainable electricity supply in the EU.

Expected deliverables, benefits and impact: The expected output of the project is fourfold:

- The implementation of the framework to assess the benefits provided by the development of the transmission infrastructure for the pan-European power system,
- the preparation of a roadmap for the incorporation of new transmission technology into electricity networks,
- the analysis of the impact of different scenarios on future electricity exchanges among European countries and
- testing and application of the framework for the cost-benefit analysis of specific transmission projects.

Project costs: EU FP7 Energy, 7th FWP

Project cost: € 4.21 million
Project funding: € 2.73 million

6.3.14 SUSPLAN (Planning for Sustainability)

Functional Project: T5

Project duration: September 2008 – August 2011

Project website: www.susplan.eu

Partners involved:

- Partners:
  UHI Millennium Institute (GB), CnES (GB), ECN (NL), Fraunhofer-ISI (DE), MVV (DE), Dena (DE), UP Comillas (ES), ERSE (ENEA – Recerca sul Sistema Elettrico) (IT), EEG (AT), Verbund-AHP (AT), SINTEF (NO), EC BREC IEO (PL), ENERO (RO), Statkraft Western Balkans (RS), BSREC (BG), nPower (GB), GTS (NL), E.ON Ruhrgas (DE), EWE Netz (DE), GSE (IT), Statkraft (NO), Pomorskie (PL), Sofia EDC (BG)
- TSOs involved in the Advisory Board:
  REE (ES), Amprion (DE), 50Hertz Transmission GmbH (DE), Statnett (NO), EnBW TNG (DE), Terna (IT)

Abstract: SUSPLAN is a project which was initiated in 2008 under the EU's 7th Framework Program, and which is sponsored by the DG TREN. SUSPLAN seeks to raise awareness of and solutions for the coming environmental and energy challenges facing the European Community.

Objectives: Over three years, SUSPLAN will focus on developing strategies, recommendations and benchmarks for the integration of RES by 2030 – 2050 within a pan-European context. Against this background, SUSPLAN has adopted a multi-dimensional approach, assembling legislative, policy, business, economic, environmental and energy professionals together with a view to addressing the following objectives:

- To develop grid-based integrated RES scenarios for the national, regional and European levels,
- to compare results from each scenario in order to identify the optimal path for RES integration, taking account of security issues and economic competitiveness,
- to establish the institutional capacity and knowledge base on which subsequent SUSPLAN findings or recommendations can be implemented and
- to publish SUSPLAN work for decision-makers and related professionals on the national and European levels via workshops, reports and online resources.

Description:	The overall impact of SUSPLAN is a contribution to the work on the substantially increased share of RES in Europe at an acceptable level of cost, thereby increasing the security of supply and the competitiveness of the RES industry. The results will ease pan-European harmonization and lead to a more integrated European energy market. The main objective is to develop guidelines for more efficient integration of RES into future infrastructures and to provide support for decision-makers at the regional as well as the pan-European level. The guidelines shall consist of strategies, recommendations, criteria and benchmarks for political, infrastructural and network decision-makers and power distributors with a timescale of 2030–2050.
Expected deliverables, benefits and impact:	– Future scenarios for electricity, heating and gas infrastructure will be assessed simultaneously. – The timeframe for SUSPLAN scenarios and analyses extends into a broader period until 2050. – SUSPLAN will continue to evaluate the relationship between national, regional and other influences across Europe on RES integration.
Project costs:	EU FP7 Energy – 7th FWP Project cost: €4.79 million Project funding: €3.42 million.

6.3.15 ANEMOS.plus (Advanced Tools for the Management of Electricity Grids with Large-Scale Wind Generation)

Functional Project:	T5	**Project duration:**	January 2008–June 2011
Project website:	www.anemos-plus.eu		
Partners involved:	– TSOs: EirGrid (IE), SONI (UK), REE (ES), REN (PT) – Other: Enfor (DK), Vattenfall (SE), DONG (DK), ACCIONA (ES), EWE (DE), NTUA (GR), UAG (FR), PPC (GR), NUI (IE), INESC Porto (PT), CENER-CIEMAT (ES), EMS (DE), Overspeed (DE), DTU (DK), DTU Riso (DK), EDF (FR), UCM (ES)		
Abstract:	Nowadays, wind power has an increasing share in the electricity generation mix in several European countries. Due to the variable nature of wind, the large-scale integration of wind power causes several difficulties in the management of a power system. Often, a high level of reserves is allocated to account for wind power variability, thus reducing the benefits of the use of wind energy. Today, it is widely recognized by end-users such as TSOs, utilities and others that forecasts of the power output of wind farms up to 48 hours ahead contribute to more secure and economical power system operations.		
Objectives:	This research, which is related to short-term wind power forecasting within the framework of ANEMOS.plus, aims to enhance state-of-the art prediction systems with new functionalities such as probabilistic forecasting. At a second stage, new operational tools for managing wind generation and for trading in electricity markets are proposed.		

Description: The ANEMOS.plus project is aimed toward the optimal management of electricity grids which are linked to large-scale wind power generation. For this purpose, the project develops new intelligent management tools for addressing the variability of wind power. The emphasis is given to the integration of wind power forecasts and the related uncertainty in power system key management functions. This project demonstrates the applicability of such tools at an operational level, both for managing wind penetration and for trading wind generation in electricity markets.

In the first stage, wind forecasting tools will be enhanced with new functionalities such as probabilistic forecasting. In the second stage, new operational tools for managing wind generation and for trading in electricity markets will be developed. The project will then focus on demonstrations of issues which have been identified as the key challenges for the large-scale integration of wind power into the electricity supply, including:

- The reliable provision of advanced wind power forecasts through alterna¬tive technology and on different scales, ranging from a single wind farm to the regional/national scale. The focus will be on:
  - the accuracy of forecasts provided by different modelling approaches,
  - the online estimation of the uncertainty of forecasts and
  - the ergonomics of the prediction tools.

- Optimal integration of wind energy into power systems and electricity markets.
  This project will aim to demonstrate the benefits of the use of advanced tools for the:
  - allocation of balancing power and the definition of reserves for TSOs,
  - optimal scheduling of power systems with high levels of wind penetration,
  - bottleneck management in large power systems as well as local grids,
  - the management of storage associated with wind energy and
  - the trading of wind power in electricity markets using advanced strategies.

Expected deliverables, benefits and impact: The tools will be demonstrated at two levels: the wind power prediction tools are brought into everyday practice, and their results used for decision-making purposes in a highly integrated approach, welding together the worlds of fluctuating wind power and traditional energy systems. The use and integration of the needs and knowledge of end-users like operators and traders are key parts of this project.

Project costs: Project costs: €5.65 million
Funding: €2.6 million.

6.3.16 EVCOM

Functional Project:	TD2, TD5 — **Project duration:** 2008 – 2010
Partners involved:	– TSOs: Energinet.dk (DK) – Others: Danish Energy Association (DK), DONG Energy (DK), Eurisco (DK)
Objectives:	The primary purpose is to establish a concept for electric vehicles and their communication with the power system. This concept has been disseminated to standardization work and to the relevant stakeholders. The supply of input to a work with a roadmap for the infrastructure for electric vehicles is also included.
Description:	The project includes the following deliveries: – Definition of the technical/economic charging concept in relation to international work on standardization and Danish conditions, – definition of the information exchange between EVs, charge stands and the power system, – internal discussion, vote and dissemination of the concept via Energinet.dk, – external discussion, vote and dissemination of the concept, – provision of technical input to the interdepartmental working group in order to draft a roadmap for the infrastructure of EVs and – national and international standardization work (S-454, JWG V2G CIPT1-PT5 and S-454).
Project costs:	100 % provided by Energinet.dk Funding: 0 DKK (€ 0)

6.4 Appendix 4: ENTSO-E Response to Comments Submitted through EEGI Public Consultation

Many valuable comments were received during the EEGI public consultation. The comments can be summarized as follows:

- An integral approach, considering not only the electricity networks but also the gas and heat networks and the impact of their development on the smart grid (micro. CHP), should be applied.
- Local balancing vs. the local electricity trade should be considered.
- Active customer participation: new services for customers are needed, as well as the creation of new players in the market. New projects in these areas should be created.
- It is necessary to include smaller and new players in order to develop and test specific technologies.
- A pan-European tool for designing and planning that considers energy planning, the investments model, the grid infrastructure, the seasonal variation in supply and demand and the geographical and technology detail of the systems should be included in Cluster 1, Functional Project 2.
- Future tariff schemes as well as producers that benefit from the smart grid development should recompense grid investors.
- Regarding Cluster 1:
It has been suggested that there is a need for common and mandatory grid planning principles. A new topic of research has been suggested: the approach taken to planning for the operational security of supply requires further research.
- There is a need for an adequate planning stage in order to achieve sufficient network flexibility. Another important issue is to ensure the flexible development of the distribution grid toward its new tasks, involving the integration of the decentralised generation at various percentages. This flexibility shall be considered from the very beginning of all activities.
- A proposal to develop interactions between the electricity TSO and the gas TSO has been considered outside of the scope of this work, but might be complex and necessary with the arrival of RSE and the need to move toward more flexible generation using gas (CCGT).
- Regulators need to promote standards while also allowing utilities and market participants to innovate with these standards.

– Network operators should lead the demonstration activities.
– The analysis of the Framework Program program shows a fragmentation and lack of coordination between projects.
– Complete KPIs with details of the social and environmental impact are missing.

ENTSO-E took into account the aforementioned comments to the greatest possible extent. The updated version of the ENTSO-E R&D Plan aims to slightly update the plan in order to resolve some of these issues. The new edition of the R&D Plan is expected at the end of 2012.

Abbreviations

ACER	Agency for Cooperation of Energy Regulators
CEER	Council of European Energy Regulators
DER	Distributed energy resources
DSO(s)	Distribution system operator(s)
EDSO-SG	European Distribution System Operators for Smart Grids
EER(s)	European energy regulator(s)
EII	European Industrial Initiative
EEGI	European Electricity Grid Initiative
ENTSO-E	European Network of Transmission System Operators for Electricity
FACTS	Flexible alternating current transmission systems
GenCo(s)	Generation company(-ies)
GIL	Gas insulated line
GIS	Gas insulated switchgear
HVAC	High voltage alternate current
HVDC	High voltage direct current
HTC	High temperature conductors
ICT	Information communication technology
IEA	International Energy Agency
IPR	Intellectual property rights
KPI(s)	Key performance indicator(s)
MoDPEHS	Modular Development Plan on Pan-European Electricity Highways System 2050
NRA(s)	National regulatory authority(-ies)
PMU	Phasor measurement unit
R&D	Research & development
RES	Renewable energy sources
SSSC	Static synchronous series compensator
STATCOM	Static synchronous compensator
Subgrid	Sub-transmission grid (medium voltage grid)
TCSC	Thyristor controlled series capacitor
TSO(s)	Transmission system operator(s)
UPFC	Unified power flow controller
WAMS	Wide area measurement/monitoring systems

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Images of shortlisted pylons from this year's UK Pylon Design Competition, managed by Department for Energy and Climate Change (DECC), Royal Institute of British Architects (RIBA) and National Grid Electricity Transmission plc (p. 66 above, below left),
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