European Network of
Transmission System Operators
for Electricity

RESEARCH AND DEVELOPMENT PLAN

EUROPEAN GRID TOWARDS 2020 CHALLENGES AND BEYOND

23 MARCH 2010

FIRST EDITION

FOREWORD

This document is the first edition of the *European Network of Transmission System Operators for Electricity (ENTSO-E) Research and Development (R&D) plan*. It is required by the Third Energy Package, both in Directive EC/72/09 and in Regulation 714/09, which underlines 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 TSOs and DSOs, the consolidated ENTSO-E R&D Plan serves Transmission System Operators' (TSO) needs and contributes to the process launched by the European Commission for a Strategic Energy Technology (SET) plan in order to initiate dialogue between European TSOs, European Regulatory Authorities, 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 Strategic Energy Technology plan of the European Union. ENTSO-E will ensure the cross-functional coordination over all TSO research subjects. ENTSO-E will define and monitor a portfolio of TSOs' R&D innovation projects covering system design and technology, optimization and assets, system operation, market facilitation and system technology. ENTSO-E may need to engage both in promoting common R&D actions and projects among TSOs and also in direct participation in pan-European R&D initiatives, if appropriate.

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 leads 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 established a Working Group for Research and Development (WG R&D), which will take on the cross-functional role of coordination within ENTSO-E of the R&D portfolio in all matters in relation to the TSOs' business: system operation, electricity markets operation, transmission grid development, asset implementation and management.

The ENTSO-E R&D plan also underlines the need to define the interaction between TSOs and Distribution System Operators (DSOs) when smart grids solutions will grow from microgrids to large supergrids solutions or intelligent grids.

Given the enormous investments in transmission and generation infrastructure needed over the coming decade to replace aging assets and to integrate renewable resources, innovation and R&D should contribute to choosing the most efficient investments that support system development, operations and market goals. Information Communication Technology (ICT) progress will keep opening up new, cost-effective opportunities for improved market integration while maintaining reliability. The future-oriented concepts of smart grids and of a potential European supergrid exemplify this. 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.

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 – which are to begin in 2010 and 2011, include the following:

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

The specific R&D products will likely extend from advanced tools for designing future energy scenarios:

- tools for pan-European network behavior monitoring for better transmission adequacy assessments,
- tools for better surveys of pan-European markets,
- new tools for market modeling, taking into account the rapidly increasing penetration of renewable energy sources,
- complementary tools for facilitating the specific market integration of these renewable energy sources,
- planning tools dedicated to taking into account active demand.

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

It is the intention of ENTSO-E to update this plan every two years. The basis of this document has been adopted from the work performed by a group of European TSOs (Amprion, Elia, REE, RTE, TenneT TSO, transpower, 50Hertz Transmission GmbH), which published the first draft as their contribution to the European Electricity Grid Initiative (EEGI), which focuses on the development of the smart electricity system, including storage, and on the creation of a European framework to implement a research program for the European transmission network.

ENTSO-E appreciates the outstanding commitment shown by this group of TSOs, giving ENTSO-E WG R&D the opportunity to use their first draft as a platform for this first edition of the ENTSO-E R&D plan. ENTSO-E would also like to acknowledge members of WG R&D as well as other experts from 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 version of the ENTSO-E R&D Plan is an updated version which takes into account stakeholders' comments addressed to ENTSO-E during the public consultation of the ENTSO-E R&D Plan that has been launched in January 2010.

ABSTRACT

The transmission grid is a key facilitator for the European low-carbon energy future. The 2008 IEA World Energy Outlook predicts €135 billion being allocated to pan-European transmission over 2007-2030 in a 'business as usual' scenario in order to cover electricity consumption growth, replacement of aging infrastructures and a strengthened integration of national electricity systems. This amount of investment will also help to take up a large share of fluctuating renewable electricity, mainly from wind and solar energy sources. But renewable electricity may often be produced at times and in places where there are no local needs to be met: it must then be transported at high voltages over long distances and redistributed where consumption needs arise or where large-scale storage facilities (dams and/or water reservoirs) stand. European TSOs notice the need to speed up R&D activities in the use of super grids, off-shore grids, long HVAC cables, HVDC technology and the perspectives of using smart grids as future tools to meet the challenges of integrating large amounts of renewable electricity. In addition, the average distance between the generation and the consumption of electricity will increase within the next few years. A dramatic increase and fast changes in the power flow in several regions of the power system have to be managed by 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 new technology, its implementation must take into account pan-European optimization objectives, addressing both the technological and economic dimension.

ENTSO-E is now proposing an R&D plan in order to keep the costs of accessing the transmission grid under control, with major direct economic impact for the users of the pan-European grid. The R&D activities listed in the ENTSO-E plan cover research, development, demonstration and deployment aspects. The 7th Framework Program funded by the European Commission gives the following definition, also adopted in the ENTSO-E R&D plan:

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

ENTSO-E is committed to covering four targets:

- 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 to connect off-shore generation or solar facilities from the Sahara desert in Africa to the European transmission grids. Which is the most effective?

- To **understand and properly value the impact and potential benefits** brought to the electricity system by the deployment of **state-of-the-art transmission or power technology,** in support of the chosen grid architecture. European manufacturers, who are world leaders in their sector, have already developed several advanced transmission technology such as high power semiconductor devices, Wide Area

Measurement/Monitoring Systems (WAMS), power flow controlling devices or High Voltage Direct Current (HVDC) lines. Full scale demonstrations must be performed to value the real system benefits of such technology, with the first results expected by 2015.

- To **design and validate novel monitoring and control methodologies** of the pan-European electrical system in order **to meet today's and tomorrow's reliability** and security of supply challenges: How to cope safely with storms closing wind turbines or clouds passing by solar power plants without affecting system stability? How to introduce large-scale demand response approaches to withstand peak consumption periods? How could smart grids applications in super grids support the need to balance and stabilize the transmission grid?

- To **develop shared electricity market simulators** able to analyze options for market designs and rules, and identify the ones that are most beneficial to both the energy system and consumers. For instance, weather conditions around some large European airports impact air traffic control in all of Central Europe because of congestion. The same happens to electricity transportation. Who should solve the congestion? Who should pay for the revenue losses incurred by solving congestion? Can renewable electricity take part in the spot market? Electricity market simulators will make it possible to provide regulators and governments with recommendations as early as 2015.

In order to be effective, the proposed R&D work, which copes with European and regional issues, must simultaneously address questions related to system architecture, power technology, system control and market design. Moreover, it must be coordinated at the European level, since the success of the R&D work depends on a full understanding of the pan-European transmission system, without neglecting individual TSO's system responsibilities in their control areas (which is a local issue).

The full-scale demonstrations of the state-of-the-art transmission/power technology and off-shore grid solutions should also be coordinated at European level. This will allow for a drastic reduction in demonstration costs and will reinforce the TSOs' bargaining power when negotiating the future procurement of the validated technology with manufacturers. This is why the implementation of the proposed R&D plan requires a new structural collaboration among European TSOs that goes beyond what is already performed within several EU-supported research projects, such as the European Wind Integration Study (EWIS), which uses results from detailed network and market models of the European transmission system for scenarios representing immediate and longer-term needs as well as, where possible and appropriate, common European solutions to wind integration challenges. The implementation of the R&D plan also requires well-defined cooperation and interaction with the DSOs in order to get the full benefit of the smart grids initiatives. These collaborative approaches allow for accelerated innovation and to make the best use of TSOs' scarce internal resources to manage innovation projects, with a view to delivering research and demonstration results on time, starting in 2013. This collaboration requires:

- A dedicated TSOs framework to coordinate the R&D plan that is open to the participation of DSOs, generation companies and other stakeholders when relevant.

- Covering 100 per cent of the TSOs' expenses (around €560 million over ten years, split into €270 million for research and €290 million for demonstrations), since the expected benefits for European electricity customers, which go far beyond the mere TSOs' concerns;

- Advising the European Commission on dedicated calls for tenders to award contracts to perform the R&D work for the proposed functional projects composing the 2010-2018 R&D plan;

- The implementation of the resulting R&D projects by accredited research partners, which may also include experts from TSOs and/or technology manufacturers;

- An Open Access policy for innovation results, with intellectual property rights (IPR) rules decided on a per project basis to favor their exploitation by European players;

- Fair treatment of all interested parties, where the participation of a stakeholder is recommended by a dedicated Stakeholder Advisory Board (SAB), including electricity producers, distribution system operators, electricity retailers, end customers, representatives from the other SET plan Industrial Initiatives, and the European Technology Platforms. Thanks to this SAB, the above energy players will take part in the R&D plan definition and evaluation even though they are not directly involved in the research and demonstration projects.

- A program management structure that also captures the added value of the functional projects for Europe using KPIs (key performance indicators), related to the European energy policy goals.

Provided that the proposed innovation R&D plan starts by early 2010, Europe will be able to deploy a power transmission system at reasonable capital costs without sacrificing reliability, while coping with the challenging generation mix required to achieve a low carbon future. This affordable and clever network is based on:

- Optimal choices in architecture, implemented progressively between 2015 and 2020;

- Reliable state-of-the-art transmission and power technology, with measured benefits starting 2015;

- The implementation of improved monitoring and control tools and procedures, both for today's and tomorrow's grids;

- Novel market designs validated through intensive market simulations.

Last but not least, transmission systems operators will be able to identify the need for new functions and technology. This will allow manufacturers initiating research and development programs to provide solutions beyond 2020, in time to meet future power transmission requirements at the pan-European level.

Further refinements in the program's organization and stakeholders' participation are needed, taking into account:

- The costs of packaging each project's output into tools usable by any TSO belonging to ENTSO-E,
- Future interactions with DSOs and manufacturers, which will detail some of the present projects,
- Smart grids have an impact on TSO operation, e.g. ancillary services, and consequently TSOs and DSOs need close cooperation on their interface.
- The implementation of the Third Energy Package by each of the Member States.

This release of the ENTSO-E R&D plan does not address the issues related to funding and the management of the program. The following basic principles can be used to summarize these issues:

- The European objectives for 2020 require extra efforts when compared to existing R&D activities in the Member States and at EC level;
- A significant part of these efforts should be focused on grids;
- The R&D extra effort focusing on transmission system must be led by TSOs;
- The R&D results will be shared by all ENTSO-E TSOs, even if some are not directly participating in the projects;
- The efforts of TSOs, as regulated players of the electricity supply industry, must be recognized via a unique scheme, which covers 100 per cent of the costs (to give them visibility over the next ten years);

Taking into consideration the last two points, the organizational framework and management rules to manage the ENTSO-E R&D plan go beyond the current ones used in the 7th Framework Program, which have initiated some joint collaborative research and demonstration projects.

The ENTSO-E R&D plan is broken down into base work streams, which are still high-level projects. Some initial sub-projects are also defined yet and some others will be defined on a yearly basis to implement the work streams. Those new sub-projects are not described or even mentioned in this document. Many sub-projects could be defined, but the objective of the first release of the ENTSO-E R&D plan is to define the major R&D activities.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

ACER	Agency for Cooperation of Energy Regulators
CEER	Council of European Energy Regulators
DSO(s)	Distribution System Operator(s)
EER(s)	European Energy Regulator(s)
EII	European Industrial Initiative
GenCo(s)	Generation Company(-ies)
HVAC	High Voltage Alternate Current
HVDC	High Voltage Direct Current
ICT	Information Communication Technology
IEA	International Energy Agency
IPR	Intellectual Property Rights
KPI(s)	Key Performance Indicator(s)
NRA(s)	National Regulatory Authority(-ies)
R&D	Research & Development
RES	Renewable Energy Sources
subgrid	Sub-transmission grid (medium voltage grid)
TSO(s)	Transmission System Operator(s)
WAMS	Wide Area Measurement/Monitoring Systems

1 EUROPE'S ENERGY CHALLENGES BY 2020 AND BEYOND

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

- ✓ 20 per cent reduction of GHG emissions (compared to 1990 levels)
- ✓ 20 per cent to be renewable energy sources in EU Member States' energy mix (6.5 per cent today)
- ✓ 20 per cent reduction in primary energy used (saving 13 per cent when compared to 2006 levels)

This is in compliance with the three pillars of EU energy policy (i.e. security of supply, sustainability and market efficiency).

As a first consequence, 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 adopted in April 2009. The national overall targets for the share of energy from renewable sources in gross final consumption of energy in 2020 are shown on the following chart (Figure 1.1).

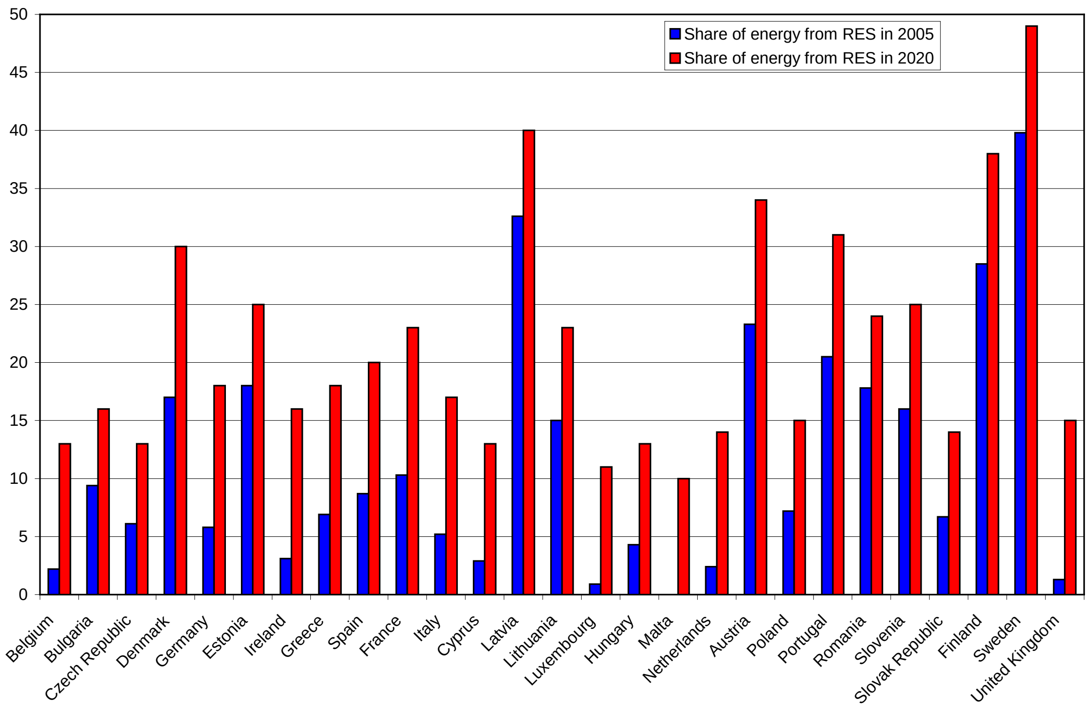


FIGURE 1.1 NATIONAL OVERALL TARGETS FOR THE SHARE OF ENERGY FROM RENEWABLE SOURCES IN GROSS FINAL CONSUMPTION OF ENERGY IN 2020

Parallel to this, the Third Energy Package, adopted by the European Parliament in April 2009 pushes Member States and regulators and transmission & distribution operators to launch innovation programs with appropriate incentivizing schemes, much 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)*

- **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 timeframe 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, Annex 1, cl 2)

The deployment of smart houses, smart metering and coherent local energy systems with electrical vehicles, electricity storage, cooling systems or micro combined heat and power, together with demand response, are all expected to be connected and combined with new information architecture and computer systems. However, it is mainly an obligation for the DSO to orchestrate the dissemination of these new means in an effort to allow substantial amounts of sustainable energy in the form of local RES production to be installed in the local grid.

All local Smart technology will only be a benefit and matter of concern for the TSO if they can offer ancillary services and balance the regional subgrid clusters to help system operation. These initiatives are dedicated to utilizing distributed generation and demand responses as thousands of small units aggregated in a virtual power plant to be a future controllable resource for the TSOs.

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

These **system challenges** induce new **network challenges** for the pan-European Transmission Network. Hence, each TSO in the European Union will have to evolve progressively from a ‘business as usual approach’ to a proactive approach in order to avoid becoming the bottleneck of the future European electricity system:

- **Renewable electricity sources**, such as wind energy or photovoltaic solar energy, deliver electricity where and when resources are available; but energy might not be needed at the same time and in the same location. Power might then be transported at a time and to locations where this was not originally foreseen, leading to congestion. Moreover, fluctuating power sources can impact network stability margins. Hence, each TSO must face planning and operation challenges not addressed so far. The increased penetration of non-dispatchable generation resources increases uncertainty in the pan-European grid. The so-called loop power flows experienced in the European network push TSOs to operate with larger safety margins.
- **The design and operations of networks must account for new constraints.** The Third Energy Package sets energy targets, but does not address the issue of the installed capacities: **energy and power will both matter.** The actual generation pattern of a power plant is only a fraction of its potential production since power plants are sometimes unavailable. Yet, 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 renewable energy sources and long-term line operation, the grid measures have to be designed in a sustainable way. There is high sensitivity to environmental issues related to overhead structures, which makes it difficult to build overhead lines. This new unavoidable constraint requires innovation from network operators to develop new grid solutions (e.g. new design for overhead lines, AC and DC underground cables) and improved network operations (making the power flows follow new routes to avoid congestion).
- **Part of the electricity demand will become flexible enough**, thus allowing network operators to use it to optimise their own operations in connection with new storage options: this raises new opportunities, such as the use of detailed consumption data coming from metering to curtail consumption via appropriate incentives. But this also has an impact on the old way of sizing networks (based on consumption forecasts), since load can then be controllable.
- Last but not least, the further development of the European energy market and the related cross-border power exchanges contribute to rising uncertainty and related congestion problems at borders, thus potentially **stressing 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 the former design of electrical systems: 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 above-mentioned Third Energy Package.

2 THE TSOS' VISION FOR THE PAN-EUROPEAN TRANSMISSION SYSTEM

European TSOs share a common vision to face the above-mentioned challenges. The common vision is to become and remain the focal point for all European technical, market and policy issues related to TSOs, interfacing with the power system users, EU institutions, regulators and national governments. ENTSO-E's work products contribute to security of supply, a seamless pan-European electricity market, secure integration of renewable resources and a reliable future-oriented grid, adequate to energy policy goals.

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

- Security – it pursues coordinated, reliable and secure operations of the electricity transmission network.
- Adequacy – it promotes the development of the interconnected European grid and investments for a sustainable power system.
- Market – it 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 – it facilitates secure integration of new generation sources, particularly growing amounts of renewable energy and thus the achievement of the EU's greenhouse gases reduction goals.

ENTSO-E actions to achieve this vision are, among others:

- Joint activities of manufacturers and TSOs will facilitate the implementation of new technology at optimized costs. Universities and research centers 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 successfully entered into application;
- Increasing use of ICT will not only contribute to secure operations, but also to European network design flexibility for the European transmission network. ENTSO-E will have provided well-founded contributions to the debate on a supergrid and on smart grids to transform those visionary discussions into realistic options;
- Cooperation with DSOs (especially with regard to smart grids) and manufacturers (especially with regard to possible supergrid technology) will lead to R&D results that open up a new large potential of demand response as the future basis for sufficient balancing resources in face of ever increasing volatile renewable generation.

2.1 BACKGROUND TO THE VISION

The Reference Scenario of the *International Energy Agency 2008 Energy Outlook* describes a world 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 needs to change 'business as usual' approaches can be quantified and shows that **European electricity players** would have to invest far more than €1.000 billion over the next twenty years to cover electricity consumption growth, replacement of aging infrastructures and a more efficient use of electrical energy.

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

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

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 research, development and demonstrations**. The 550 Policy Scenario requires **in total $4.2 trillion more investments worldwide between 2010 and 2030 than the Reference Scenario does**. Most of this goes towards deploying and improving 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 the global world energy related investments by sector in the IEA 550 Policy Scenario relative to the Reference Scenario is shown in the IEA 2008 report.

Yet, in the IEA carbon-restrained 550 Scenario, the investment needs identified worldwide in transmission and distribution are about 20 per cent lower in global terms than in the Reference Scenario, because they are **assumed to be directly linked to the amount of electricity generated**. This assumption would be valid if the generation mix was constant and there were 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 efficiency technology** will also require a massive investment in grid technology. Without these extra investments, the 550 Scenario **cannot be met.**

As a matter of fact, as shown in the qualitative diagram below (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 of capital expenditures (CAPEX) and operational expenditures (OPEX) of transmission networks.

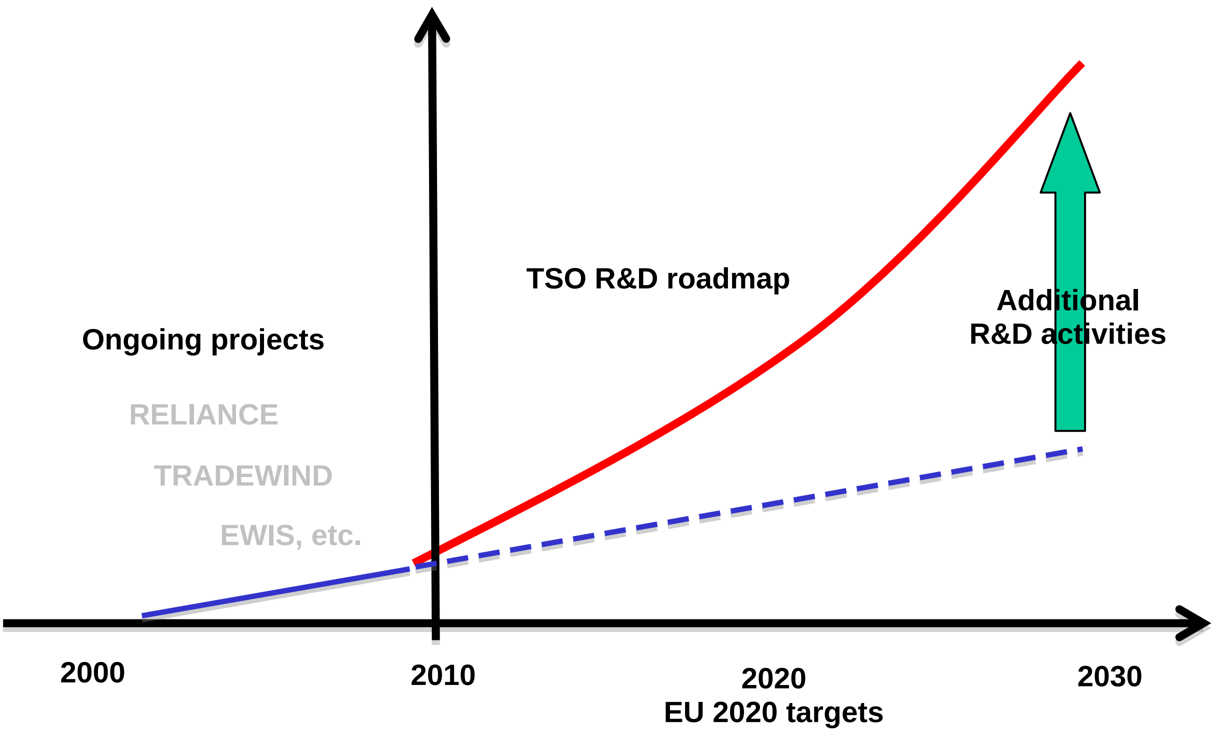


FIGURE 2.1 BUSINESS NEEDS DUE TO RENEWABLES INTEGRATION

These R&D efforts, which include not only research and development but also demonstration efforts, must add to the ongoing research activities. An excerpt of these activities (started in 2006) is given in Annex 3. Indeed, an increase in R&D efforts will be essential in order both to reach 2020 targets and to ensure high reliability of the pan-European transmission system.

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

2.2 MAKING THE VISION HAPPEN

2.2.1 THE REQUIRED STEP CHANGES FOR TSOS

Many European TSOs are already involved in EU-funded projects, which help prepare for the above future changes (see Annex 3). However, based on the knowledge gained so far, **several step changes are still required** within the pan-European transmission network to make the above vision happen on a very large scale.

2.2.1.1 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. To balance this, TSOs must rely on the reserves available on the market to keep consistency with the unbundling between the transmission and the 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 within downgraded conditions (in terms of voltage and frequency) in order to avoid major blackouts. Hence, new knowledge is needed to prepare:

- Transmission investments against peak power production/consumption (what is the European optimum?).
- The integration of new large-scale and decentralized storage technology.
- New market design options in order to allow variable generation participating in intra-day markets (what is the new European optimum?).
- The ways and means to upgrade existing planning methodologies in order to incentivize local production at a European level.
- The harmonization of grid codes: behavior of the distributed generation in downgraded conditions, 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 damp inter-area oscillations, which is not generally the case for renewables.

2.2.1.2 DEVELOPING NETWORK ARCHITECTURE WITH NEW TRANSMISSION SOLUTIONS AS A COMPLEMENT TO CLASSIC OVERHEAD LINES

With the help of manufacturers, two major options must be investigated:

a) On-shore network architecture:
   - o New design of overhead lines, with a higher degree of environmental compatibility and social acceptance.
   - o HVAC overhead lines combined with underground cable sections.
   - o Long-distance HVAC underground cables having an impact on reactive compensation; will these cables contribute to an increased reliability as compared to today's experience, will the role of protection systems be modified with an impact on the resulting power quality (over voltage, harmonics, etc.)?.
   - o On-shore HVDC lines, operated parallel to existing AC overhead lines.

b) Off-shore network architecture to connect off-shore generation to the mainland grid and to allow cheap interconnections between distant areas. A new project at the Kriegers Flak location in the Baltic Sea between Denmark (Energinet.dk) and Germany (50Hertz Transmission GmbH) will connect the three off-shore wind farms at a newly developed Multiterminal probably with off-shore HVDC back-to-back technology. The project has been granted €150 million by the European Commission Recovery Plan.

All off-shore wind farms in operation today are connected to the on-shore power system through HVAC transmission cables. Due to the high capacitance of shielded power cables, the length of such AC cables for practical use is limited by the charge current of the cable. The length of undersea AC cables is, therefore, limited: this can be overcome by using HVDC cables. HVDC technology can be used to transport electricity over long distances or to interconnect different power systems whose grid frequencies are not synchronized. In the North Sea, HVDC technology will be used to connect the off-shore wind farms in the German Bight to the German on-shore transmission grid. The cost of an HVDC transmission system depends on parameters like the power capacity to be transmitted, the voltage levels, the network architecture – including the security constraints – the construction process and environmental conditions. HVDC networks require static inverters at both the sending and receiving stations. They are expensive and have limited overload capacity. HVDC cable systems become cost-effective for transmission distances above 100 km. The first HVDC connection for off-shore wind energy connects the wind farm Bard Off-shore 1 in the German Bight to the German transmission system. The length of this connection is 203 km of which 75 km are on-shore underground and 128 km at the North Sea. Most other North Sea wind farms in the German Bight will be clustered at HVDC converter stations at sea and then connected to shore via HVDC VSC as well.

So far, data available from the literature has not been used to assess the impact of security constraints on the investment and operations of meshed HVDC networks. The European Commission has granted €165 million to support the building of the first stepping stones to the North Sea off-shore grid. A possible first stepping stones is going to be the COBRA cable from Holland (TenneT TSO) to Denmark (Energinet.dk).

The resulting HVDC off-shore meshed grid should be as reliable as the current mainland AC meshed system: faulty parts of the grid have to be detected and taken out through circuit breaking actions. In a DC grid, the current rises very fast in case of short circuits to ground, if no specific measures are taken. This means that a DC breaker has to break much faster than an AC breaker. So far, the only breaker that can fulfill this requirement is a semiconductor breaker. It is basically the same device as the valves that are used in the converters. These valves can break the current in less than one microsecond. The drawbacks with semiconductor breakers are mainly that losses are a bit high and the cost is also high compared to ordinary AC breakers.

Overall, HVDC appears to be the appropriate technology to interconnect off-shore generation technologies and to link them with the AC mainland grid. The operation of HVDC infrastructures has to be ensured by TSOs, which requires a specific grid code, a systemic approach of their reliability when connected to the mainland AC grid and proper solutions to licensing issues. Moreover, all effects of connecting such large amounts of power in-feed to single points on the operation of the pan-European system (e.g. primary reserves) must be investigated.

2.2.1.3 INCREASING THE FLEXIBILITY OF THE EXISTING PAN-EUROPEAN TRANSMISSION NETWORK

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

- **Pan-European grid security initiatives such as the TSC project** by eleven TSOs (VERBUND APG, CEPS, EnBW TNG, transpower, PSE Operator, Amprion, swissgrid, TenneT TSO, TIWAG Netz, 50Hertz Transmission GmbH, VKW-Netz).

- **Cross-border regional coordination centers:** operating closer to the limits, in particular on interconnections between Member States, increase the likelihood of severe propagations of local single faults to neighboring networks. Coordination is becoming a must as shown by the birth of regional centers between Germany (EnBW TNG) and Switzerland (swissgrid) (CESOC), France and Belgium

(CORESO), Spain and Portugal and the Netherlands and Germany (TenneT TSO and Amprion)

- **Increased network observability for exploitation closer to its stability limits:** the main issue is to grasp the dynamics of the system, since transitions from one stable state to the other may induce uncontrollable instabilities. This requires more accurate models and sensing (with sampling rates, synchronization, and accuracy in line with the transient behaviors to be observed in order to understand the physics, and real-time modeling tools to enable anticipating them).

- **Increased network controllability**: the present daily operations of transmission systems no longer allow the adoption of classical preventive security standards over the whole year. The system cannot always survive all single faults without post-fault actions. More and more corrective actions (post-fault) are defined to ensure the security of the system, which means that the operation time during which the system requires corrective actions to be secure is increasing. Thus, more and more Special Protection Schemes (SPS) are deployed 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 more and more complex to control. FACTS devices (such as TCSC, STATCON, SSSC, UPFC) can be very useful for a more efficient, fast and flexible control of network parameters, such as active and reactive power flows, nodal voltage magnitudes and angles difference. Moreover, the impact of these technologies must be measured against new transmission lines, active demand management and new generation capacity.

- **Real-time optimal control of the transmission systems:** today, preventive measures are the rules 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, yet further increasing the system's complexity. It is to better deal with this increased complexity that advanced regional coordination is being implemented: the real-time control of the pan-European network may one day look like what is already operational on combat airplanes. These airplanes are designed to be unstable and are too complex to be controlled by a pilot. The pilot acts on a model of a virtual classical airplane and the automatic control system manages the transition from this virtual airplane to the real one, allowing in particular for fast, transparent adaptations to severe disturbances (self-healing).

2.2.1.4 TAKING FULL ADVANTAGE OF DEMAND MANAGEMENT AT SYSTEM LEVEL

As is the case for distribution networks, the knowledge of the power demand will help to keep the whole 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 aggregation of renewable generation and loads, where this type of service is remunerated by TSOs. This in turn will impact:

- 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, where TSOs make the assumption that the power of load is an uncontrollable exogenous stochastic variable.

2.2.1.5 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 CONTAINING VALIDATION COSTS

TSOs are national, interconnected players. So 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 incentives to invest in innovation. The above knowledge gaps have to be bridged. TSOs must, therefore, link with each other and address experimental programs with clear specifications in mind, based on their common needs. This approach is new, and requires dedicated work forces performing at short notice.

2.2.2 THE MISSION OF THE INTEGRATED R&D PROJECTS TO BE PERFORMED BY TSOS AT 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 European level. Indeed, it critically depends on the full knowledge of the pan-European transmission system. The demonstration for state-of-the-art transmission and power technology should also be coordinated at European level. When the demonstration is done jointly it 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 four 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 to connect offshore generation or solar facilities from the Sahara desert in Africa to the European transmission grids. 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 off-shore solutions**, in support of the chosen architecture: European manufacturers, who are world leaders in their sector, have already developed several advanced transmission or power technology (for instance, high power semiconductor devices, WAMS, flow control devices or HVDC lines). Yet, full-scale demonstrations must be performed to value the real system benefits of these technologies, with the first results expected by 2015.

- **To design and validate novel monitoring and control methodologies** of the pan-European electrical system in order **to meet today's and tomorrow's reliability targets**: How to cope safely with wind gusts or clouds passing over solar power plants without affecting system stability? How to introduce large-scale demand response approaches to withstand peak consumption periods? How to utilize the benefit of smart grid applications in the subgrid for services to the transmission grid.

- **To develop shared electricity market simulators** able to analyze options for market designs and rules, and identify the ones that are most beneficial to both the energy system and consumers. For instance, weather conditions around some large European airport impact air traffic control in the whole of Central Europe because of congestion. The same happens for electricity transport. Who should solve the congestion? Who should pay for the losses incurred by solving congestion? Can renewable electricity take part in the spot market? These simulators will make it possible to provide regulators and governments with recommendations as early as 2015.

Provided that the proposed innovation R&D plan starts by early 2010, Europe will be able to deploy a power transmission system at reasonable capital costs without sacrificing on reliability, while coping with the challenging generation mix required to achieve a low carbon future. This affordable and clever network is based on:

- Optimal choices on the architecture, implemented progressively between 2015 and 2020.

- Reliable state-of-the-art transmission/power technology, with measured benefits starting 2015.

- The implementation of improved monitoring and control tools and procedures, both for today's and tomorrow's grids.

- 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 initiating research and development programs to provide solutions beyond 2020, in time with future power transmission requirements at the pan-European level.

3 R&D IMPLEMENTATION PROPOSED BY TSOs

3.1 THE PAN-EUROPEAN TRANSMISSION NETWORK CONCEPT TO SUPPORT R&D ACTIVITIES

The concept of an electricity superstructure in and around Europe is becoming one of the main topics of the investigations. Since secure operations of such grids are usually neglected, the resulting network architecture is still a vision, which has to be converted into practicable concepts. Such supergrids will have to be operated under the same security constraints as existing mainland grids, being required to have no negative impact on them, whatever the operating conditions. Security functions are, therefore, of critical importance when designing any electricity superstructure, and they will strongly impact the resulting network topology.

As presented in Chapter 2, regional coordination centers have been created recently, parallel to these prospective studies. This shows that cross-border issues are addressed through voluntary and dedicated coordination activities, each of them having specific issues to deal with because of their past history as national TSOs with their own unbundling history. In the Baltic Sea the Kriegers Flak project represents a unique cooperative project between Denmark (Energinet.dk) and Germany (50Hertz Transmission GmbH) with the connection of three off-shore wind farms at a newly developed Multiterminal with off-shore HVDC back-to-back technology.

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

3.2 FOUR INNOVATION CLUSTERS TO BETTER CAPTURE THE EUROPEAN ADDED-VALUE

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

- **<u>Re-engineering their assets</u>, which have a long life-time and evolve only slowly**. Asset improvement will take time, having a significant impact at European level only beyond 2020, even if launched by 2015. Moreover, improved planning tools are needed to study scenarios involving innovative grid architecture, and new power technology that can reveal interesting functionalities with more freedom to cope with renewable generation and demand side management.
- **<u>Improving on their daily processes</u>, which must combine the use of innovative power technology and control procedures, in order to find appropriate stability margins to cope with generation and load volatility**. Here improvements can be seen more quickly, due to the recent developments in information and telecommunication technology. Yet, improving assets and

operations must be addressed simultaneously, since innovative technology that do not fit into today's network architecture might become relevant within upgraded architectural choices (for instance, a deep sea backbone in the North of Europe, the increased use of active distribution networks, which involve two concepts: firstly, the network provides connectivity between points of power supply and demand, and secondly, the network interacts with the consumer).

- **<u>Proposing new market rules to regulatory bodies</u>**: such rules can impact 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 avoid socializing the costs of implemented feed-in tariffs.

The four research and innovation clusters which 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. These four clusters reflect the typical cycle of activities of any TSO, which in turn will involve different responsibilities within any given TSO to specify the R&D work, and implement the resulting knowledge and methodologies to address European issues (Table 3.1).

TABLE 3.1 RESEARCH AND INNOVATION CLUSTERS

Cluster	Topics	Scope of the innovation cluster
1	Pan-European grid architecture	Novel approaches to develop a pan-European grid and new technology for pan-European off-shore grids
2	Power technology	Affordable technology to make the transmission system more clever, and flexible utilization of smart grids applications in the subgrid for services and to balance the transmission grid.
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.

3.3 SELECTING TOPICS, PERFORMING THE R&D ACTIVITIES AND INTEGRATING THE PRODUCED KNOWLEDGE

As shown in the diagram below (Figure 3.1), the process of selecting the activity topics for each of the clusters has followed four steps:

Step A: Setting the **concepts underlying the proposed research plan** in the cluster of interest, and listing the prerequisites, which must be accounted for before starting the innovation tasks.
Step B: Examining capacity issues that would hamper new knowledge **production and dissemination**, and providing ways and means to overcome such barriers.
Step C: Examining innovation management issues that could prevent **new knowledge from being produced**, and proposing steering actions for the portfolio management tasks.

Step D: Examining non-technical barriers that could ultimately **block the use of new knowledge**, and designing a set of integration projects that will be in charge of packaging the new knowledge for its future availability within ENTSO-E.

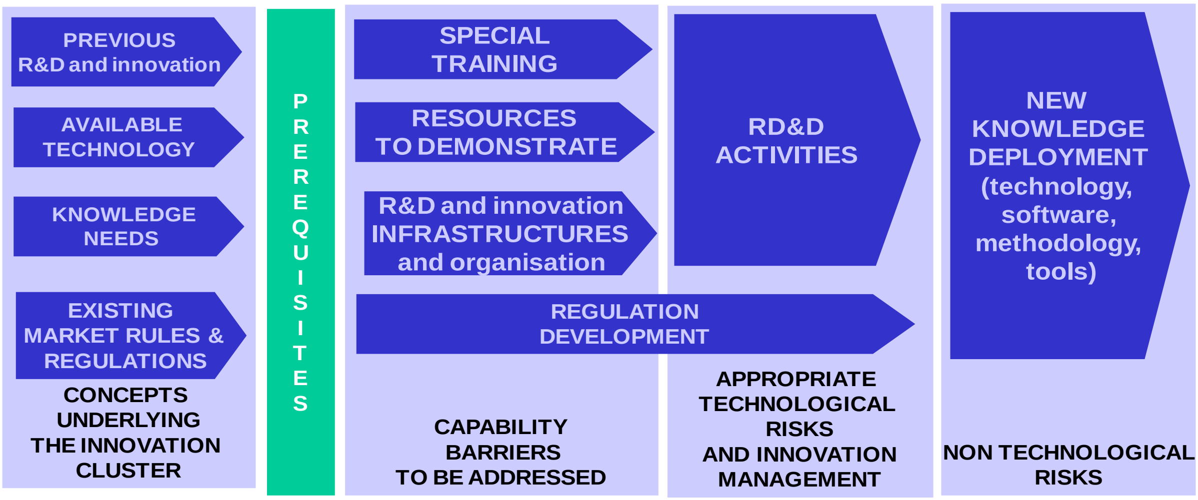


FIGURE 3.1 SELECTION PROCESS OF ACTIVITY TOPICS

These four steps are detailed hereafter.

Step A: Concepts underlying the proposed research plan

In Step A, the following issues are addressed parallel to each other:

- What are the ongoing R&D activities at European level (and sometimes at Member States level), which can produce new knowledge useful to the cluster?
- Which tools and/or new experimental knowledge can be made available to reach the cluster target?
- Which existing market rules and regulatory frameworks can support the new knowledge implementation?
- What is the new knowledge needed to reach the overarching cluster target? The new knowledge very often combines simulation techniques or experimental data, prior to the delivery of operational knowledge with technology, market and regulation contents.

This analysis allows defining the cluster activities with the added value required to address pan-European network issues.

Step B: Capacity issues that can hamper new knowledge delivery

In each of the knowledge blocks (i.e. the elementary R&D activities of each cluster), the following issues have been addressed:

- **Is the existing knowledge packaged enough to be readily used?** This applies to the ongoing research projects at European level. Links with the project coordinators and the consortium will be required to check the status of intellectual property rights and practicalities to use the new knowledge generated as early as 2010.

- **Are there specific needs for shared infrastructures, which will be used for demonstration, validation or use of the new knowledge?** Clearly, Cluster 2 will most probably require new demonstration sites in order to validate cross-border issues involved in the deployment of novel network management technology. Similarly, Cluster 4 will deliver market simulation techniques, the use of which would be optimized through the sharing of a common IT platform using internet techniques linking the tool developers and the TSO end-users.

- **What are the resources needed to perform the R&D tasks and package the new knowledge for pan-European use?** A set of cross-cutting integration projects with a high percentage of direct TSO contribution has been defined:

    - TSOs specify, package and validate the new knowledge which will be made accessible via ENTSO-E: this work will be performed through ENTSO-E, the TSO contributing with their own personnel in order to secure the future use of the produced knowledge.
    - The produced knowledge encompasses methodologies, software-based toolboxes or experimental results coming from small- to large-scale experiments
    - TSOs choose appropriate teams to outsource a fair share of the core R&D innovation tasks at pan-European level: these tasks are sometimes located in several clusters.

The diagram below (Figure 3.2) illustrates the interaction between the integration projects and R&D cluster activities, which will ensure that a packaged knowledge for pan-European use through ENTSO-E will be delivered; this interaction will also specify R&D projects aimed at producing the required knowledge through outsourcing.

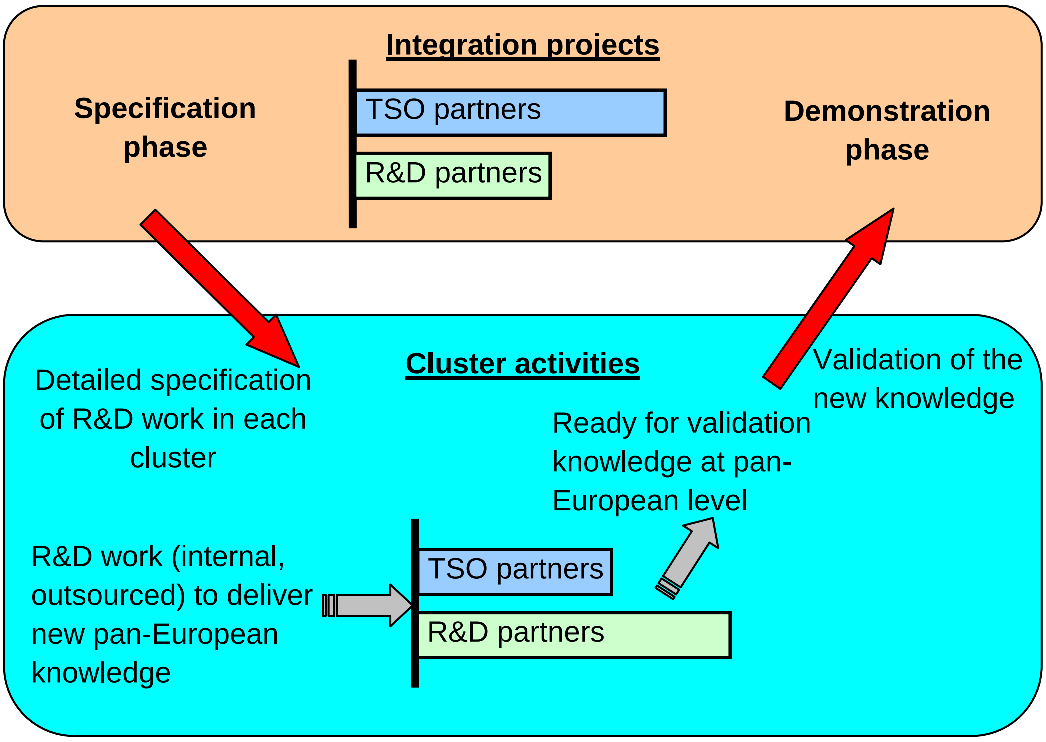


FIGURE 3.2 INTERACTION BETWEEN THE INTEGRATION PROJECTS AND THE R&D CLUSTER ACTIVITIES

- **What is the impact of the new knowledge produced on market rules or regulatory regimes?** Let us take one example: storage technology can help network managers cope with the variability of renewable-based electricity, also giving arbitrage functionalities to generators to sell power when market prices are the most favorable. New knowledge gained on market design and regulations should, therefore, have an impact on future market rules or regulatory regimes: constant links with regulatory bodies (ERGEG, ACER) will provide packaged recommendations for their further investigation.

Step C: Are there innovation management issues that prevent collaborative research from delivering the promised new knowledge?

TSOs will have to outsource a significant share of the innovation tasks to external players as outlined below, if they want to meet the deadlines to produce the required tools and knowledge. There are several risks attached to this outsourcing:

- Competence risks, where the chosen teams are not able to deliver in a timely manner.
- Technical risks, where the topics addressed are so complex that there are budget overruns and/or delays in providing the new knowledge.
- Risks of non deployment at a pan-European level: the delivered knowledge at cluster level will be validated and packaged in such a way that any participating TSO can handle the transfer and/or use in its daily operations.

Moreover, each of the clusters will have its own R&D difficulties; this will require sizing the project ambitions to the actual R&D team available, with subsequent project granularity issues. Dedicated steering actions have been designed, the role of which is:

- To manage the above risks for each cluster with a tuning specific to experimental activities or software development.
- To manage the knowledge integration with ENTSO-E.

Step D: Are there any non-technical barriers that prevent the deployment of the produced knowledge?

TSOs are already used to working within bilateral organizations or within international agreements. The issue here is to perform sufficient validation tasks within the integration projects, showing the usefulness of the novel results, before having each of them implement it into real operations.

These innovation costs, which cover knowledge packaging, have yet to be evaluated on an ad-hoc basis. For Clusters 2 and 3, which are the most risky in terms of budget and regulatory issues, it is indeed foreseen that some large-scale experiments will require dedicated management in a similar way to what is implemented in the TWENTIES project as shown below (Figure 3.3): the packaging of new knowledge includes validation of scaling up rules and the replication potential (whereas the budgeted cluster activities – see below – correspond to the dedicated task force on one or several technology experiments).

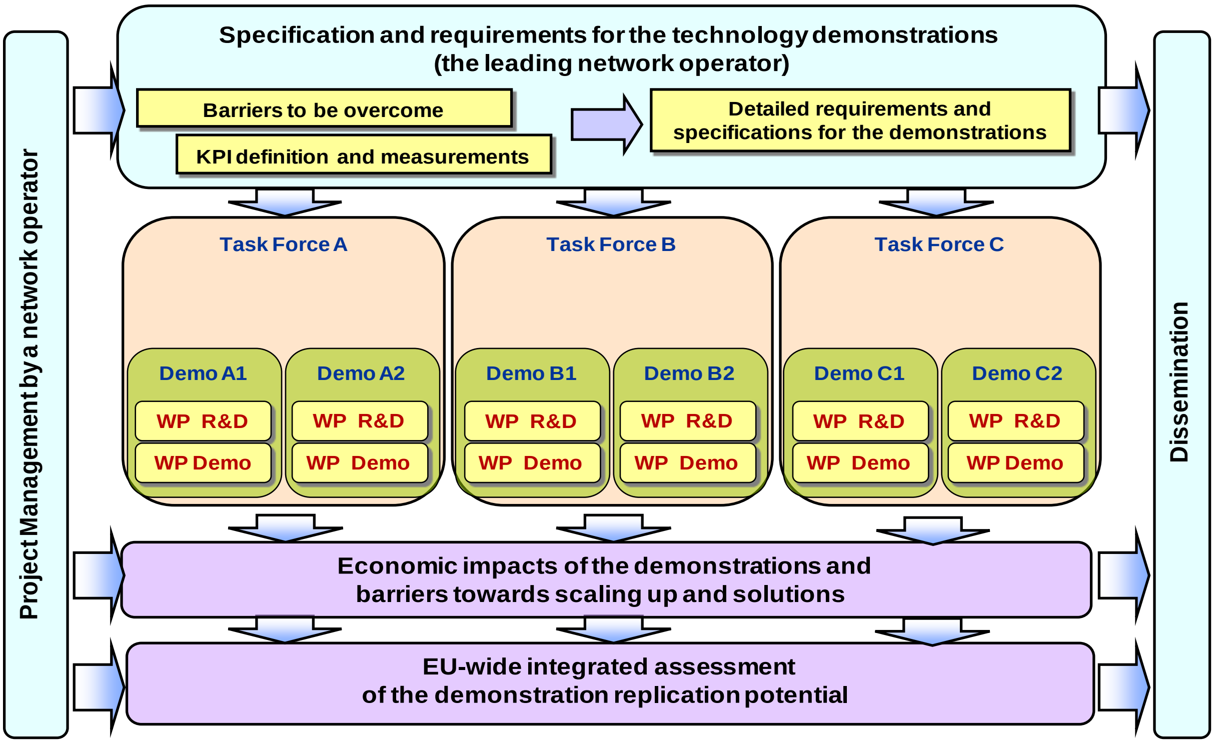


FIGURE 3.3 TWENTIES PROJECT APPROACH

3.4 IMPLEMENTATION AND SHARING OF THE RESULTS

This section includes basic guidelines on plan funding, implementation and management, 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 two years in order to consider the evolution of the different technology, the general framework, and the achievements within the R&D plan.

An adequate level of coordination between the ENTSO-E R&D Plan as part of the European Electricity Grid Initiative and other European Industrial Initiatives should be implemented in the framework of the SET Plan, given the relevance of the interaction the EEGI has due to the central role of the grid as integrator of different generation technologies and responsible for the system security

3.4.1 FUNDING

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

The financial resources could be obtained through the swift implementation of the Third Energy Package, which brings 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. This is why a concerted approach is needed in the months to come to reach an agreement on funding issues and in order to attract research players in academia, manufacturers and other candidates to join the R&D action plan.

3.4.2 GOVERNANCE AND ORGANIZATION

The following principles will be applied:

- Research is collaborative, opened to other relevant market players, stakeholders, etc. However, leadership and management responsibilities should be taken on by the involved TSOs.
- The sub-projects within the base work streams and clusters could use high level KPIs to measure the EU added value brought in by each of the work streams and the four clusters working simultaneously.

Roles and responsibilities:

- ENTSO-E is committed to draft a long term R&D Plan, based on consultation of internal and external stakeholders. The R&D Plan must be periodically reviewed and updated.
- The European Commission (EC) is committed to issue Calls for Proposals related to this R&D Plan, in order to execute the work streams (named functional projects in the EEGI document) that are part of the R&D Plan.
- ENTSO-E facilitates the process of bringing together partners for the projects addressed by the Calls, making it therefore, possible that TSOs, generation companies, manufacturers, research institutes, etc. join to form a consortia and submit proposals of R&D activities to the EC.
- 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 to perform the work.
- Awarded consortia are responsible for contractual commitments, executing the project and reporting on their progress to the EC.
- ENTSO-E implements monitoring of 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 in the frame of the R&D projects.

As far as the role of ENTSO-E is concerned, the main involved ENTSO-E bodies are the Working Group Research and Development (WG R&D), the System Development Committee (SDC) and the Assembly, and to a lower extent, the System Operations Committee (SOC) and the Market Committee (MC). 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 a regular collaboration between the EC and the European TSOs: this is in full compliance with

Regulation (EC) No 714/2009, where at Article 8 §3 it is stated 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 to govern the ENTSO-E R&D Plan:

The basic processes to govern the Plan that are going to be assumed by ENTSO-E, in close cooperation with relevant stakeholders, are:

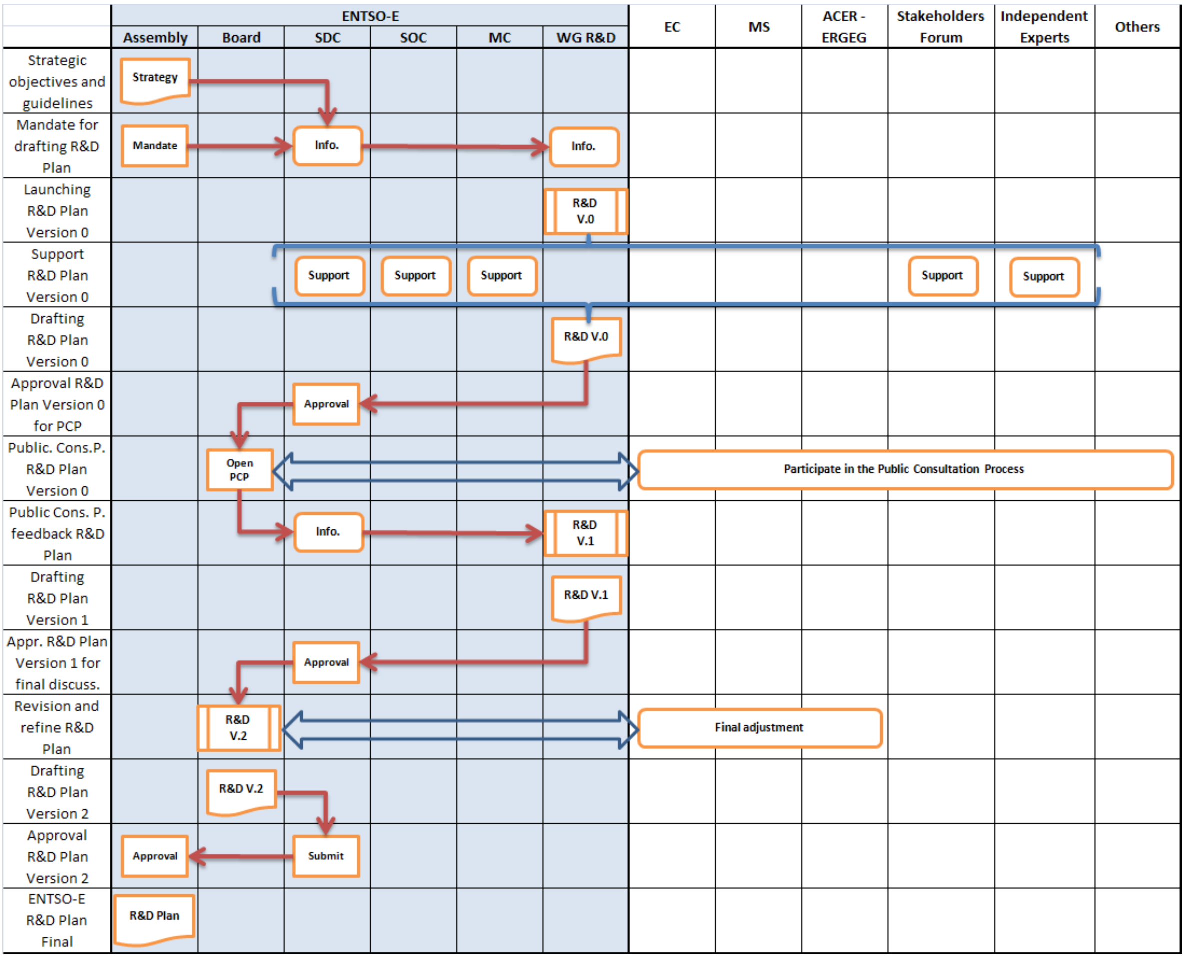
- Design and approval of the ENTSO-E R&D Plan,
- Support the EC during the launching of Calls for Proposals,
- Monitor the R&D Plan as a whole,
- Disseminate the results among the technical stakeholder community and facilitate the scaling up and implementation of results by the whole ENTSO-E community.

The table and flowchart below show the detailed description of the "*Design and approval of the ENTSO-E R&D Plan*" process. Detailed descriptions of other processes in the list, also involving the EC and other stakeholders participating in R&D activities, are currently being defined and should be approved in the following months.

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

Responsible body	Tasks/Actions/Responsibilities
Assembly	• Establishes the strategic objectives and relevant guidelines • Mandates the System Development Committee to draft the ENTSO-E R&D Plan for the next years;
SDC	• Asks the WG R&D to draft a preliminary version of the R&D Plan
WG R&D	• Drafts the preliminary version of the R&D Plan in close cooperation with: o SDC, SOC and MC, o Stakeholders (e.g. Smartgrids Forum, DG Energy TF SmartGrids), o Network of experts (formed by independent and internationally acknowledged experts). • Submits the preliminary version to the SDC
SDC	• Approves the R&D Plan (V.0) and asks the Board to launch a public consultation process
Board	• Launches the public consultation process • Informs the SDC about the public consultation process results
SDC	• Asks the WG R&D for a new version (V.1) of the R&D Plan, considering the inputs from the public consultation process
WG R&D	• Drafts the R&D Plan (V.1) and submits it to the SDC
SDC	• Approves the R&D Plan (V.1) and demands the Board for refine the R&D Plan in consultation with most relevant institutions at EU level

Board	• Reviews and refines the R&D Plan in consultation with: o EC representatives o Member States representatives (under EC coordination) o ACER (or ERGEG) • Sends the updated version (V.2) to the SDC.
SDC	• Validates the R&D Plan (V.2) and submits it to the Assembly
Assembly	• Approves the ENTSO-E R&D Plan for the next years • Mandates to the Board to arrange with EC the issuing of Call for Proposals (CfP) in accordance with the FP7 rules and the approved R&D Plan



3.4.3 RESULT EXPLOITATION

ENTSO-E would be the most appropriate place to package and disseminate the new knowledge produced by the TSO initiative. The following guidelines may be applied:

- Sharing results is focused on sharing foreground information, new knowledge and expertise gained during the project's development.All intellectual property rights (including but not limited to industrial property rights) on the foreground information are owned by the TSOs participating in the project in accordance with the relevant agreements.

- Project results owned by the TSOs will be shared within ENTSO-E: TSOs will specify, package and validate the project results which will be made accessible via ENTSO-E.
- TSOs will 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 demo 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 needed to use the generated foreground information in accordance with the relevant agreements.
- TSOs commit themselves to do their best to grant ENTSO-E access through ENTSO-E in to the project results and background information needed for the use of such project results, owned by other partners on the same conditions as the TSOs participating in the project.
- TSOs will manage the knowledge integration within ENTSO-E; As soon as feasible, ENTSO-E will ensure the cross-functional coordination of R&D portfolio in all subject in relation with TSOs' business

4 THE PROPOSED R&D ACTIVITIES FOR THE FOUR CLUSTERS

4.1 CLUSTER 1: PAN-EUROPEAN GRID ARCHITECTURE

4.1.1 BACKGROUND

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

- Cross-border electricity transport, which must face geographical barriers (e.g. the Pyrenees and Alps for connections between Spain, Italy and France), environmental and socio-economic constraints.
- Market liberalization, which has induced steady growth in cross-border exchanges behaving erratically, with consequences for network loading, network interactions and system vulnerability, pushing towards 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 negotiation power to beat down prices for equipment.
- The need for pan-European regulatory solutions to finance transmission projects of pan-European impact, in interconnectors as well as relevant internal lines. The interconnection of renewable energy sources (RES) in the system, which leads to both additional investments and innovative solutions in network architecture.

4.1.2 PRODUCED KNOWLEDGE

Knowledge is, therefore, needed at European level by the TSO community, to ease (harmonize) system planning and asset management over the next fifty years. Past energy development programs first chose the energy vectors (oil, gas, electricity). Next, they developed transport infrastructures with no apparent constraints. This approach is no longer valid, since power transport can be constrained by:

- Public opposition
- Environmental issues
- Geo-political issues

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

4.1.3 THE KNOWLEDGE PORTFOLIO

The expected impact of the cluster's activities in 2020 implies to propose by 2015 a set of validated network architecture, possibly using the technology to be demonstrated in Cluster 2 activities, and making sure that the network costs (investments and operations beyond 2020) can be kept under control, even though massive renewables are deployed in Europe. Hence, Cluster 1 has three main activities, described below:

- Scenario building.
- Modeling tools and software solutions for asset planning studies at European level.
- 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 by the years 2030/2050. These scenarios may rely on the use of existing models/software tools dedicated to this type of pure energy simulation. The network is not taken into account at this stage or it is supposed/assumed not to be constraining. 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. Impact of storage/demand response on load profile/peak demand are to be analyzed 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 regulators/Member States/generation companies.

4.1.3.2 MODELING TOOLS AND SOFTWARE SOLUTIONS FOR ASSET PLANNING STUDIES AT EUROPEAN LEVEL

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

- New issues such as new technology modeling, specifications in planning studies and tools (HVDC, FACTS, etc.).
- Impact of electricity storage technology, such as electrical vehicles or new large-scale storage options.
- Agreements on operating rules to be considered (security).
- Agreements on what the 'good' criteria for 'an adapted network' are, meaning 'what is the purpose of the transmission grid?'

- Innovative approaches to improve the 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 (like for the off-shore grid, super grid or Medring proposals). The work must focus on future network architecture, while new technology will be addressed by Cluster 2. Such studies should provide possible grid architecture(s) associated with the different scenarios. The important boundary conditions are:

- Reliability levels of TSOs must not be reduced.
- 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 bring forward the discussion on innovative and progressive projects with the involved authorities.

Another key issue is to show how to reach possibly more ambitious targets (e.g. 2050 targets) starting by 2010. This is the so-called 'migration problem', i.e. addressing the fact that decisions made today will impact the 2030/2050 grid. Migration studies will ensure that the decided 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 set up since the 1996 IEM Directive: on the one hand, each TSO is responsible for the electrical system operations, transporting energy from central generation units down to the DSO lower voltage network. On the other hand, the national systems are interconnected (for instance as in the synchronous areas of Nordic or Continental Europe), in a way that goes far beyond the initial specifications. From now on, operators rely on power units that are beyond the boundaries of their responsibility, which causes continuous increases in terms of power exchanges.

Since the construction of additional power lines is facing major obstacles, the operational margins of network operations are reducing, which leads each TSO to reconsider:

- Optimization (adaptation) of the operation procedures.
- New skills for the operators, needing new training concepts.
- The implementation of new technology that would ease operations.

The first two items are addressed in Cluster 3. The purpose of Cluster 2 is to address the affordability of new technology components that can significantly improve the operations of the interconnected transmission systems, thus reducing the extra costs that will come from the management of the variability of generation and volatility of load linked to renewables and demand management.

Manufacturers have developed their own technologies that they feel will be needed by network operators. Let us mention the most prominent ones in terms of publications and advertisements:

- WAMS (Wide Area Monitoring Systems): they typically comprise a series of Phasor Measurement Units (PMUs), which are monitoring devices that collect data on power flow continuously, in a central control room, using the Global Positioning System (GPS) for time synchronization. The processing of the measured quantities, i.e. magnitudes and phase angles, allows for a dynamic monitoring of critical nodes in a power system.
- At a later stage, once WAMS have demonstratively shown their impact, technology for monitoring the system (WMS), for controlling the system (WACS), and for protecting the system (WAPS) will also be of interest.
- FACTS (Flexible Alternating Current Transmission Systems): allow for 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 Special Protection Schemes.
- Super conducting current limiters: can be systematically used 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 going 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 typically used to control active power flow in electrical power systems between two points.
- Underground smart cables: they allow smart exploitation using ‘Dynamic Thermal Current Rating’ approaches with 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 be then arguing about their investment costs, their reliability, their expected lifetime, and their appropriate behavior under faulty system working conditions. 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 whole process requires new knowledge before reaching commercial application, which involves strong couplings between network owners/operators and manufacturers. This research should provide indisputable responses to questions raised by TSOs when new technologies are proposed by manufacturers.

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

4.2.2 PRODUCED KNOWLEDGE

There are commonalities for each of the above technological topics as covered in Cluster 2:

- How to value their impact in order to measure their added value for the whole electrical system.
- How to locate the technology in the system optimally.
- How to ensure inter-technology coordination within the network.
- How to integrate the technology within the grid.
- It is therefore assumed that each technology addressed at a European level must follow the same path in terms of innovative field validation at 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 needed:
    - Valuation of the use of each of the functions by the network operators (how much more revenue or losses);
    - Optimal location within the pan-European network (where?);
    - Optimal coordination with the pan-European network;
    - 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's architecture (existing and future). (Cluster 1).
- How to integrate the technology within system operations. (See activities of Cluster 3).
- How to control the technology. (See activities of 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 technology 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 devoted to the deployment of network-connected tests. This last activity is covered within the response to the Call Energy 2009.7.1.1, related to the optimization of the electricity grid with large-scale renewables and storage. Storage may be direct storage of electricity or indirect storage in the system, 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 the best integration with grid connection, and with its needs and limits, taking into account the best use of high voltage lines. The deployment of network-connected tests is also covered by the TWENTIES proposal, where six TSOs have collaborate with generation companies and manufacturers for the first time in a large-scale integrated demonstration proposal.

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 dispersed generation (wind and solar farms), distributed energy resources (DER) and increased demand side management approaches. variabvle generation is indeed an atypical product in energy markets and conventional system operation. These issues are addressed by two European R&D projects (EWIS and TRADEWIND), whose aims are to propose **recommendations and requirements** in order 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 related to flow-based market coupling.

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

- Firstly, the new market rules led by the unbundling, which push the operation of the electrical system to its limits since generators are now maximizing their revenue under transmission constraints. Indeed, TSOs define the security limits of the system provided once these are understood and agreed by the other stakeholders. 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.

- Secondly, the difficulty of building new overhead lines, because of citizens' opposition to new interconnection lines and the costs of alternative solutions.

- Thirdly, the massive integration of renewable generation in the system reduces the predictability of the sources (location and power in-feeds) and consequently the predictability of the flows. Moreover, TSOs have poor observability of these power in-feeds and they have limited control over them in some control blocks. Overall, the best locations for wind farms will be mostly along the coasts and off-shore, and for photovoltaic farms in southern Europe. Since the load centers are not necessarily located near generation, dedicated transmission networks are required, and they will have to cope with the variability of the flows.

TSOs will thus have to adjust the architecture of the system, e.g. long distance HVAC underground cables will be installed, with the need for large reactive compensators, HVDC underground cables will be deployed in parallel with the AC grid, including smart controls of the AC/DC converters, and later HVDC grids will be created, first to efficiently connect off-shore wind farms and then to offer cheap interconnections between distant areas. TSOs will have to improve existing systems, adding more and more special devices, such as PSTs

(Phase shifting Transformers) or SVCs and advanced controls (e.g. FACTS) or protection schemes, and will have to use demand response to better control the system, which will modify current operating practices.

4.3.2 PRODUCED KNOWLEDGE

The complexity of the system will continue to increase. The definition of security limits becomes more and more critical, as well as the assessment of the distance to these limits. The PEGASE project focuses on these issues to provide new tools to assess the security of the pan-European electrical network by:

- Implementing realistic descriptions of the system for different time-frames (real-time, intra-day, day ahead, etc.).
- Assessing the security of the system by running time domain simulations.

As previously mentioned, the complexity is increasing and a more robust and accurate assessment of the security limits is needed. This means that some of the standard approximations generally made in methods and tools to assess the security must be reviewed.

Some TSOs still have a poor description of their neighboring systems, especially when estimating the state of the system in real time. In the past, this description was accurate enough because the variability of external systems was very low. It was thus possible to define time invariant equivalent models, which gave an acceptable assessment of system security. TSOs today try to improve their state estimator by describing, in their real-time IT systems (SCADA) larger and larger parts of neighboring networks. The TSOs in the ENTSO-E RG Central East have started to tackle this issue with the RAAS system (Real-time Awareness System in Central Eastern Europe formed in 2007 by the eight TSOs: VERBUND APG, CEPS, ELES, MAVIR ZRt., SEPS, transpower, PSE Operator, 50Hertz Transmission GmbH), giving information on the state of the networks in the region in real time. Alternative solutions (for instance using hierarchical state estimator concepts) should also focus on further needs for data exchanges and robustness. This leads to the fact that the regulation and balancing of the transmission grid will need to utilize the potential distributed resources in the subgrid and activated by smart grids applications.

For day ahead and intraday security assessments, TSOs have to build base cases to assess the security, running a ‘What if’ analysis. Existing methods are based first on the forecast of load and generation in each bus of the network and then running a power flow model with a contingency analysis. The generation forecast is generally done using a very poor model based on theoretical costs and merit order. Yet, with more and more active intra-day electrical markets, the objective of producers is not necessarily to minimize their operating cost, but rather to maximize their benefits playing on the short-term market. The generation schedules of all the power plants in Europe are more and more difficult to predict a day ahead. Moreover, wind power in-feeds are difficult to forecast and with a massive integration of wind power in Europe, other classical generation means have to balance the system. Each individual generation becomes de facto more variable. Improved methodologies require the use of advanced optimization methods to build realistic base cases.

Last, a security assessment cannot neglect the dynamic behavior of the system. When operating the system closest to its limits, unstable dynamic phenomena can appear after a contingency, before any static overload issue appears (more 'easily' manageable). In static security assessment, power flow simulations gave the stabilized post-contingency state, the security assessment being 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 less and less valid. A robust security assessment must check the validity of this assumption. Time domain simulations are needed to assess the 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).
- 'Modeling flexibility' (taking into account technology such as PSTs, SVCs, HVDCs).

4.3.3 THE KNOWLEDGE PORTFOLIO

Cluster 3 has four main classes of activities:

- The development of new simulation techniques contributing to increasing the robustness of the pan-European network.
- The development of training methodologies for operators that will deal with European issues.
- The development of interfaces to help operators appraise network status in real time.
- The development of methodologies to improve, by design, the robustness of a 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 transmission and distribution level. Thus, market facilitation involves a multidisciplinary approach to research activities, where network operators, manufacturers and economists have to interact closely in order to address five types of issues:

- Large-scale market simulation tools involving renewables and Demand Side Response.
- Cross-border interaction, including new options for congestion management.
- Designing new markets for balancing and ancillary services at European level (opportunities and benefits).

- Coordination between TSOs and DSOs: network construction and evolution.
- Energy efficient networks involving the optimal use of distributed energy resources, demand side management and storage of electricity.

It must be remembered that past years have seen two types of coordination activities being launched in EU Member States:

- Enhancing the operational security of the grids and the reliability of power supplies in Europe through increased coordination in daily operations:
    - TSO grid security cooperation such as the TSC initiative by 11 TSOs: VERBUND APG, CEPS, EnBW TNG, transpower, PSE Operator, Amprion, swissgrid, TenneT TSO, TIWAG Netz, 50Hertz Transmission GmbH and VKW-Netz.
    - Regional coordination centers such as:
        - CORESO (Elia, RTE, National Grid);
        - Amprion – TenneT TSO;
        - MIBEL: REN and REE (Single electricity market for Portugal and Spain);
        - CESOC: swissgrid – EnBW TNG.
    - Real-time Awareness Systems such as RAAS in Central Eastern Europe by the eight Central Eastern European TSOs (VERBUND APG, CEPS, ELES, MAVIR, SEPS, transpower, PSE Operator, 50Hertz Transmission GmbH) introduced in 2007.
- The Pentalateral Energy forum:
    - It deals with market coupling and security of supply in the Central Western European region;
    - Five Member States with their eight TSOs: Belgium, France, Germany, Luxemburg, the Netherlands;
    - Objectives:
        - Flow-based market coupling implemented by the end of 2010
        - Improved regional system adequacy forecast (2008)
        - Common assessment of incidents affecting system reliability (2008)
        - Regional transmission capacity plan by 2009
- The Central Eastern European (VERBUND APG, CEPS, ELES, MAVIR, SEPS, transpower, PSE Operator, 50Hertz Transmission GmbH) flow-based explicit capacity allocation process starting in 2010.

4.4.2 THE PRODUCED KNOWLEDGE

Regulatory challenges

As a consequence of the future distributed energy resources (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 (since close to consumption sites, allowing the use of heat when using combined cycles or taking advantage of carbon-free sources)?
- What is then the real value of electricity from such integrated DER units?
- Can DER users reap a fair reward from reducing 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 benefits/costs on transmission and distribution?
- How will storage systems be considered from the regulatory point of view?
- What are the incentive mechanisms to be put in place to reach the expected technical expansion?

Responding to the above questions requires a full revisit of the whole electrical system, with networks whose age and working conditions differ from one Member State to another.

Let us mention three of the key issues that must be tackled with the help of TSOs:

- **Care must be taken with investments, operation principles and regulations favoring approaches leading to more active 'local management' and 'demand response'.**
- **Care must be taken with the 'service quality' and 'value added to the system' when setting transmission and distribution tariffs and incentive schemes.**
- **Care must be taken with emerging 'value added services' at the distribution and transmission level.**

<u>Dynamic market simulation tools</u>

One of the prerequisites to understanding the new markets 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 end-users' needs:

- Modeling the strategic behavior of TSOs, including their role as managers of marketplaces.
- Understanding the impact of investment decisions of market efficiency.
- Understanding the role of forward contracting besides spot market bidding.
- Proposing market mechanisms to ensure a capacity reserve at a pan-European level.
- Proposing new options for congestion management at a pan-European level.

The other issue, mainly addressed by the OPTIMATE project, deals with a more efficient interfacing of the physical network models with the market operation models. Such interfacing techniques should be further developed and tested, also integrating capacity calculation, prediction and allocation in all 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 to fostering enhanced regional coordination in Europe.

A flow-based model allows for day-ahead market coupling in order to reveal what the limiting branches are that physically limit cross-border exchanges, i.e. spot market convergence, be it located on a border or within a country. Hence, the clearing process is the most efficient for allocating day-ahead cross-border capacities.

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 towards decoupling the operational parts of balancing control and the market settlement part of managing deviations in generation and consumption. Therefore, balancing can be seen to address two tasks almost independently:

- Maintaining frequency within predefined limits.
- Online management of network congestion arising from erratic deviations.

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

Improved coordination between TSOs, DSOs and Generation companies

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

Due to the prospective increase in demand on control power, comprehensive tools for managing the ancillary services are required. Modern tools and procedures for GenCos' prequalification, and permanent monitoring of the quality of the corresponding services have to 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 to reach a more efficient market trough the optimization of the energy mix at a pan-European level, while keeping operations reliable i.e. the Security of Supply. New market designs must be analyzed to cope not only with variable renewable energy generation, but also with demand side management and storage.

A hierarchical view of the issues to be addressed is given below (Figure 4.1):

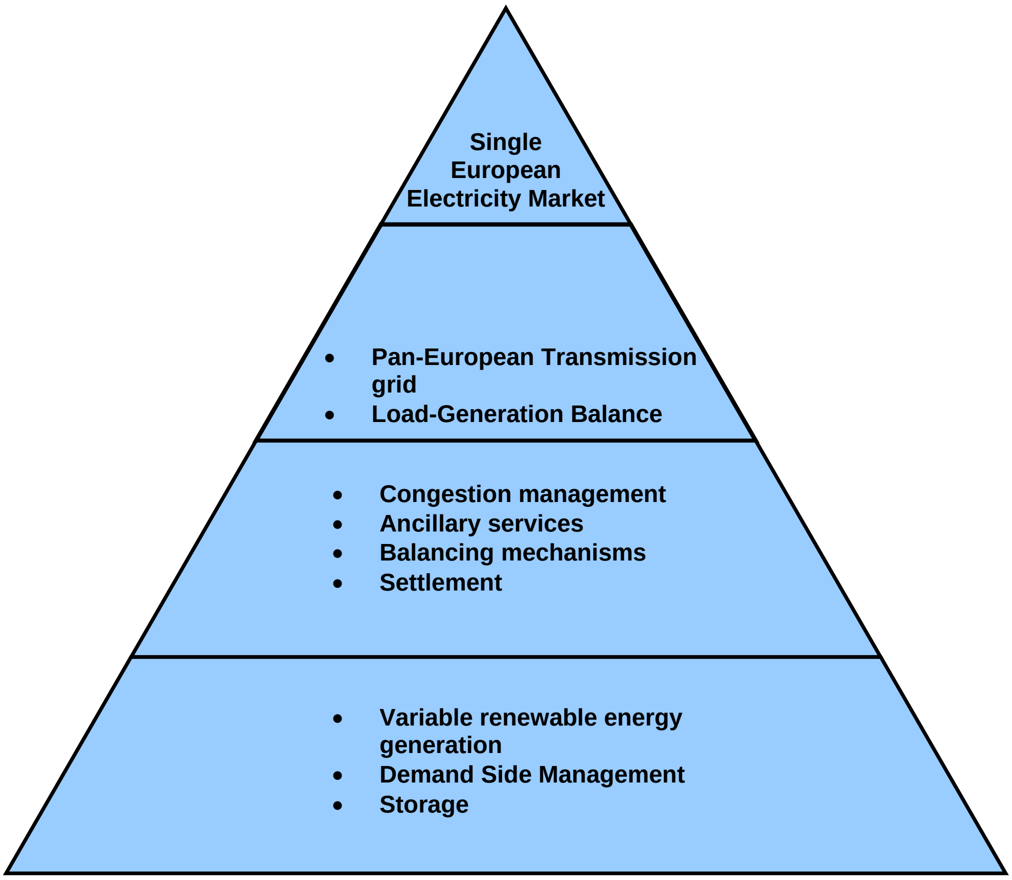


FIGURE 4.1 HIERARCHICAL VIEW OF THE ISSUES

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

Moreover, simulation tools are needed to demonstrate the benefit of each resulting new ‘Market Design’ option. Six classes of activities have been defined in order to end up with manageable R&D activities:

- **C4.1: European Electricity Market and European Transmission Network:** The European Transmission Network is not a copper plate. New methods for capacity allocation at the European level are required, generating signals to encourage optimal location of generation and/or network development, but also taking into account new network technology (HVDC, etc.) and environmental impact.

- **C4.2: European Electricity Market and European Load-Generation Balance:** Optimization must be pursued for the European energy mix, including short-term balancing mechanisms and possibly centralized storage facilities. Signals have to be developed 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 in 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 Behaviors**

Based on the results of the OPTIMATE project, it is proposed to develop a simulation platform that will host the majority of the simulation tools developed within Clusters 1, 3 and 4.

4.5 BASE WORK STREAMS

The table below (Table 4.1) summarizes the base work streams that are proposed to address the TSOs' issues over the period 2010-2018 in line with the new directives. The ENTSO-E R&D plan will be adapted every two years to take into account the results of the ongoing projects, new technological developments and changes in the framework conditions.

Base work streams are functional projects focused to address a more specific objective than the ones defined at Cluster level. Work streams deal with a more homogeneous set of technologies and their results are of the interest of different clusters although normally their impact on one of them dominates over the impact on the other ones, as it is showed in the table below.

TABLE 4.1 SUMMARY OF PROJECTS

Nº	Title Expected step changes with implementation starting by 2015 Foreseen impact by Cluster (high/medium)
1	**A tool box allowing new network architecture assessment in the pan-European transmission system**
	Several new technologies are going to emerge in the coming decade that will impact architectural choices of the pan-European transmission grid (HVDC, Gas Insulated Lines, FACTS, etc.). Assembling these technologies will lead to new architecture options which have to be studied both from cost and operation standpoints (including their secure operations). The purpose of this toolbox is to allow architecture simulations able to compare several designs based on technical and economical criteria.
	Cluster 1: high; Cluster 2: medium
2	**Advanced tools for analyzing the pan-European network expansion options according to energy scenarios for Europe (i.e. expansion optima that must be searched to maximize European welfare)**
	TSOs share a toolbox to analyze pan-European grid expansion scenarios in accordance with the post-2020 targets in order to: • further integrate renewable and conventional generation, • use power flow control devices, • address the role of active demand (controllable loads), • take into account energy storage, with optima that are searched at EU level and no longer at national level. These tools are complementary to architecture design tools.

	Cluster 1: high; Cluster 2: medium
3	**Demonstrations of power technology for increased network flexibility** The use of power electronics, smart cables and new grid architecture is validated to progressively meet future EU renewable integration targets at affordable costs. Cluster 1: medium; Cluster 2: high
4	**Demonstrations of power technology for novel network architecture** The impact of power electronics on architectural choices (off-shore and on-shore options are validated) are quantified based on full-scale demonstrations Cluster 1: medium; Cluster 2: high
5	**Demonstrations for renewable integration (TWENTIES and beyond in cooperation with the EEI on renewables)** • Renewables contributions to the power system are validated (voltage and frequency control, balancing using VPP concepts) • off-shore HVDC meshed networks can be optimized, including the corresponding grid codes The network is monitored and controlled to avoid large-scale intra-zone oscillations Cluster 1: medium; Cluster 2: high
6	**Innovative tools for pan-European network observability** • Sensors and simulation tools are validated to offer regional coordination centers the real-time status of neighboring zones which allow for better observability • European standards are specified in line with the ongoing NIST approach in the USA to facilitate coordinated observation between neighboring zones Cluster 2: medium; Cluster 3: high; Cluster 4: medium
7	**Innovative tools for coordinated operations with stability margin evaluation** • Starting with the output of the PEGASE project, this project aims to develop a simulation toolbox able to understand how the harmonization of operation procedures and coordination between TSOs will allow the pan-European transmission system operators to: o face new generation and transmission uncertainties coming in particular from renewable expansion (requires gains in observability of the overall system) o require more control to improve the commandability of the overall system. • Their prototype simulation toolbox will allow design policies for operations involving the harmonization of existing rules and increased coordination. Cluster 3: high
8	**Improved training tools to ensure better coordination at regional and pan-European level as well as optimising operator-system interactions** • Network simulation tools are used to train operators of national dispatch and regional coordination centers. Operators are able to better interpret stability margin evaluations and the status of neighbor systems. Cluster 1: medium; Cluster 2: medium; Cluster 3: high
9	**Innovative tools and approaches for the pan-European network reliability assessment** Tools and rules to make current security criteria for the new pan-European system architecture evolve without losing present-day reliability levels. Cluster 1: medium; Cluster 2: medium; Cluster 3: high
10	**New tools for pan-European balancing markets** Network-constrained market simulation tools which provide recommendations

	about pan-European markets for balancing and system services, including the contribution of renewables, which go beyond existing national rules for balancing.
	Cluster 1: medium; Cluster 4: high
11	**Advanced tools for congestion management**
	• Network constrained market simulation tools provide recommendations about specific network management and market rules to manage congestion within the pan-European grids without impacting system reliability • Flow based market coupling
	Cluster 2: medium; Cluster 4: high
12	**Tools for renewable Market integration**
	Network constrained market simulation tools provide recommendations on specific rules to integrate renewables in power, balancing and system services, for instance via aggregation schemes.
	Cluster 2: medium; Cluster 4: high
13	**Tools to study market integration of active demand**
	• Specifications of a pan-European system for demand side management based on experimentally validated business models and business cases • Specifications for standards in telecommunication infrastructures and a governance model to make these standards evolve within a world-based approach (the NIST ongoing work)
	Cluster 1: medium; Cluster 2: medium; Cluster 4: high
14	**Environmental impact and social acceptance of transmission facilities**
	To continue improving the relationship between the transmission facilities and the natural and social environment where they should be implemented in order to gain social acceptance, to reduce the environmental impact and to be able to translate public opinion, the actual impact of the transmission facilities in these fields in order to be able to develop the high power infrastructures needed to achieve the goals of the electricity sector.
	Cluster 1: high; Cluster 2: medium;

These projects specify, integrate and package the knowledge produced in the Clusters for use by ENTSO-E players, once the resulting toolboxes have been validated.

4.6 ONGOING R&D PROJECTS

The ongoing R&D projects, whose results will be integrated in the base work streams, are described in Annex 1.

5 THE COSTS AND EXPECTED BENEFITS OF THE PROPOSED R&D PROJECT PORTFOLIO

5.1 COSTS OF THE FOUR CLUSTERS

The table below summarizes the tentative costs per cluster activity, including management and dissemination at a pan-European level (Table 5.1).

TABLE 5.1 COSTS PER CLUSTER ACTIVITY

Cost in million €			
Cluster	**Scope of the activity**	**Total R&D costs**	**TSO share**
1	Architecture and planning for the pan-European grid	70	33
2	Demonstration of technology to make the transmission system more flexible, intelligent and secure	350	100-120
3	Operational tools to make the pan-European system more secure	75	25
4	New market design options based on simulation techniques	65	19.5
	TOTAL:	**560**	**177.5-197.5**
	Research:	**270**	**85.5-90.5**
	Demonstration:	**290**	**92-107**

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 the one advised by DG TREN for demonstration activities (i.e. 20 per cent). The ratio for the TWENTIES proposal is close to 35 per cent.

Several remarks must be made at this stage of program definition:

- The integration project costs cover the R&D cluster costs. The packaging costs to implement the results for any TSO belonging to ENTSO-E have not yet been evaluated.
- Proposals on new R&D sub-projects within the different base work streams will start early 2010 in order to have the project consortia ready to start on January 2011.

5.2 EXPECTED GLOBAL BENEFITS

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

TABLE 5.2 IMPACT OF THE PROPOSED INNOVATION ACTIVITIES

R&D Cluster	Scope of the R&D topics	Output delivered by 2020 with the produced tools and knowledge
1	Innovative architecture and planning approaches for the pan-European grid	• Secure network architecture to integrate renewable generation (off-shore & on-shore) • Pan-European planning methodologies able to account for active demand
2	Demonstrations of technology to make the transmission system more flexible	• 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
3	Novel operations to make the pan-European system more secure	
4	New market design options based on simulation techniques	• Proposals of more efficient market rules to regulatory bodies

Overall, more renewables and more energy conscious behaviors of consumers reacting to real-time energy price signals will lead to **increased volatility** in electricity generation and consumption**,** hence potentially **stressing the networks** both at transmission and distribution levels. As a consequence, the expected improvement of the carbon footprint of the European electricity system can be more costly than foreseen, **due to unsolved network problems.**

Both transmission and distribution networks contribute up to more than 50 per cent 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.

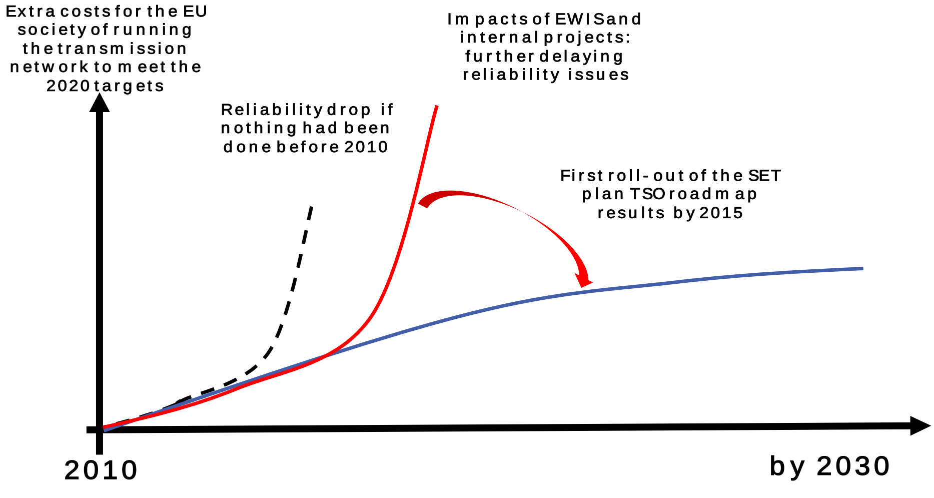


FIGURE 5.1 IMPLEMENTATION PLAN TO MEET THE 2020 TARGETS

The above diagram (Figure 5.1) illustrates what will be implemented to progressively meet 2020 targets:

- The results of projects such as EWIS, TRADEWIND and other national projects make it possible to reach 2015 while limiting the impact of any major reliability risk for the pan-European transmission system.
- However, if nothing more is done 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 TSO contribution to the European Industrial Initiative (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.
- Help prepare smart investments for all the electricity players (more than €1600 billion for 2007-2030 as revealed in the table below taken from the IEA 2008 analysis) (Table 5.3).

TABLE 5.3 INVESTMENTS FOR ALL ELECTRICITY PLAYERS

Baseline scenario (business as usual)	Europe 2006	Europe 2030
Electricity consumption (TWh)	3,022	3,980
Production Capacity (GW)	834	1,133
CO2 emissions (Mt) (power generation only)	1,422	1,513
Investments (billion Euro) 2007-2030	**1,614**	
Generation		**1075**
Transmission		**134**
Distribution		**405**

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

- Reduce the extra network expenditures (CAPEX and OPEX) to meet the electricity decarbonization targets.
- Be ready for off-shore generation technologies integration by 2015, with wind possibly involved in spot markets and system services.
- Keep the pan-European system security margins at acceptable levels:
  - Clever network architecture and operations;
  - 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 annexes within a first functional description.
- KPIs (key performance indicators) for each cluster (yet to be defined) will help monitor the contribution of each project to the European added value of the cluster,. When the desired KPI is reached, it means that the probability of reaching the EU policy goals is high. If it is not, it means that either policy must be redesigned, or incentives must be found to reach the desired KPI value.

5.4 INDUSTRIAL BENEFITS: REINFORCING EUROPEAN LEADERSHIP IN POWER TECHNOLOGY

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

- Overall communication standards and protocols for a seamless exchange of data, within the continuation of the TC 57 work on interoperability and worldwide marketing of the developed standard series. Within IEC TC57, several parts are already addressed, including IEC 61968, IEC 61850-7-420, IEC 61970, IEC TS 62351. Interoperability between these protocols needs to be further developed, with some parts already being dealt with in IEC 61850 and IEC 61970.
- Coordination at international level, at the IEC and CENELEC levels, when dealing with DER integration into electrical networks. IEC decided to establish a Strategic Group on Smart Grids in order to coordinate the standardization work between the involved committees and parties..
- 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 present common requirements. The new European power quality standard EN 50160 should take into account a wider penetration of DER units.

Transmission operators will then be in a position to progressively identify needs for new functions and technology for their network in a more coordinated fashion. This will allow manufacturers initiating research and development programs to provide solutions beyond 2015, in time with future distribution requirements. Moreover, working on demonstrations with generation equipment, smart building developers or electrical vehicles will lead to a European showroom that demonstrates what type of electrical system is able in the future to seamlessly integrate such a variety of technology effectively and efficiently.

6 ANNEX 1: BASE WORK STREAMS DESCRIPTIONS

The table below summarizes the base work streams that are proposed to address the TSOs' issues. It also provides an expectation of the impact on TSOs, DSOs, manufacturers, GenCo, etc.

Work streams	TSO		DSO		Manufacturer		GenCo		Other
	Partner	Impact	Partner	Impact	Partner	Impact	Partner	Impact	Partner
6.1. A toolbox allowing new network architecture assessment in the pan-European transmission system	Yes	High	No	Medium	Yes	Medium	No	Low	Yes
6.2. Advanced tools to analyze the pan-European network expansion options according to energy scenarios for Europe	Yes	High	Yes	Medium	Yes	Medium	Yes	High	Yes
6.3. Demonstration of power technology for more network flexibility	Yes	High	No	Medium	Yes	High	No	Low	Yes
6.4. Demonstrations of power technology for novel network architecture	Yes	High	Yes	High	Yes	High	No	Low	Yes
6.5. Demonstrations for renewable integration	Yes	High	Yes	High	Yes	Medium	Yes	Mediu m	No
6.6. Innovative tools for pan-European network observability	Yes	High	No	Medium	Yes	High	No	Low	Yes
6.7. Innovative tools for coordinated operations with stability margin evaluation	Yes	High	No	Low	Yes	Medium	No	Low	Yes
6.8. Improved training tools to ensure better coordination at the regional and pan-European level	Yes	High	Yes	Medium	Yes	Low	No	Low	Yes
6.9. Innovative tools and approaches for the pan-European network reliability assessment	Yes	High	No	Medium	No	Low	No	Low	Yes
6.10. Advanced tools for pan-European balancing markets	Yes	High	Yes	Medium	Yes	Medium	No	Low	Yes
6.11. Advanced tools for congestion management	Yes	High	No	Low	No	Low	No	Mediu m	Yes
6.12. Tools for renewable market integration	Yes	Mediu m	Yes	Medium	No	Low	Yes	High	Yes
6.13. Tools for the integration of active demand in electrical system operations	Yes	High	Yes	High	Yes	Medium	Yes	High	Yes
6.14. Environmental impact and social acceptance of transmission facilities	Yes	High	Yes	Medium	Yes	Medium	Yes	Low	Yes

The table below (Table 6.1) indicates the expected timeline over the program duration (2010 to 2018), assuming the TWENTIES project starts in early 2010.

The table also indicates the contribution to each of the base work streams of other ongoing R&D projects (see Annex 3) not part of this R&D Plan.

TABLE 6.1 INDICATIVE TIMELINE OF PROPOSED AND ONGOING PROJECT

<table>
<tr><th colspan="10">Year</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></tr>
<tr><td></td><td></td><td colspan="4">Tool box for new network architecture assessment</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">INTEGRINET</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">S.I.TR.E.N.</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Tools to analyze the pan European expansion options</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Almacena Project</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">REALISEGRID</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="9">Demonstrations on power technologies for a more network flexibility</td><td></td></tr>
<tr><td colspan="3">220 kV SSSC for power flow control</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="7">Demonstrations on power technologies for a novel network arquitectures</td><td></td></tr>
<tr><td colspan="6">COBRA</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="9">Demonstrations for renewable integration</td><td></td></tr>
<tr><td colspan="3">TWENTIES Project</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">KriegersFlak</td><td></td><td></td><td></td></tr>
<tr><td colspan="3">SAFEWIND</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">SUSPLAN</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">ANEMOS.PLUS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>IS-P.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="8">Innovative tools for a pan European network observabiliy</td><td></td><td></td></tr>
<tr><td colspan="6">Sub-station 61850</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">PEGASE</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="6">Innovative tools for coordinated operations with stability margin evaluation</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="5">Training tools for improved coordination</td><td></td><td></td></tr>
<tr><td></td><td colspan="8">Tools for pan European network reliability assessment</td><td></td></tr>
<tr><td></td><td></td><td colspan="5">Advanced tools for pan European balancing markets</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="6">Advanced tools for congestion management</td><td></td><td></td></tr>
<tr><td colspan="6">Tools for renewable market integration</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">OPTIMATE Project</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="9">Tools for market integration of active demand</td><td></td></tr>
<tr><td colspan="5">EcoGrid Europe</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">ADDRESS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="9">Environmental impact and social acceptance of transmission facilities</td><td></td></tr>
<tr><td colspan="4">Social acceptance of overhead lines</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2010</td><td>2011</td><td>2012</td><td>2013</td><td>2014</td><td>2015</td><td>2016</td><td>2017</td><td>2018</td><td>2019</td></tr>
</table>

Base workstream
Already identified sub-projects
Other relevant on-going projects

6.1 A TOOLBOX ALLOWING NEW NETWORK ARCHITECTURE ASSESSMENT IN THE PAN-EUROPEAN TRANSMISSION SYSTEM

Project abstract:	Start date: **2012**	End date: **2015**

Several new technologies are going to emerge in the coming decade that will impact architectural choices of the pan-European transmission grid (HVDC, Gas Insulated Lines, FACTS, etc.). Assembling these technologies will lead to new architecture options which have to be studied both from cost and operation standpoints (including their secure operations). The purpose of this toolbox is to make possible architecture simulations capable of comparing several designs based on technical and economical criteria.

Project objectives:

The project aims to expand the results of the REALISEGRID project, which will, by the end 2011, be proposing a cost benefit analysis for transmission assets (including interconnections).
The expansion will use the results of the activities of Cluster 1 and the experimental results of Clusters 2 and 3 if of any relevance for assessing costs and benefits of the demonstrated technology. The simulation tool box will introduce security constraints which may severely constrain the new architectural design.

Project description:

The present research work integrates the various clustered research work by:

- Gathering of complete and common 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 subsystem's simulation engines: it is then assumed that virtual network integration leads to partitioning of the whole system into subsystems adequately linked together.
- Complementing the REALISEGRID tool with the building blocks that can assess the widest possible range of architecture.
- Insert modules generated by activities in Cluster 1.

Specific cost/benefit modules will be validated for coordinated use in architecture design and validation. This is, for instance, the case for costs and benefits of flow control power devices. Introducing the pan-European electricity market to free exchanges of energy across multiple borders has led to an increased interest in power flow control devices. With these technological developments, both the number of different flow control devices as well as the range of their control flexibility has also increased. However, the principles of the interactions in meshed networks remain unchanged. This means that the effect of one flow-control device can be countered by another one so that the net effect is nil. In the extreme case this could lead to massive investments in flow control technology with almost no impact on European power flows due to the uncoordinated use of these devices.
Cost benefit tools are therefore needed to implement and use the power flow control devices efficiently. This toolbox allows the coordinated assessment of new locations for flow control devices: instead of putting the devices on cross-border lines of different TSOs independently, putting them at a number of carefully and multilaterally chosen locations can become optimal. Such a toolbox makes it possible to answer questions like:

- What would the breakdown of investment costs be? Who should be responsible for their operation?
- Provided that flow control devices are operated in a coordinated way, what will the underlying management principle(s) be? (Reliability? Congestion management?)
- What are the other objectives of centralized control? (The maximization of network security, the minimization of the costs of network losses, the maximization of transmission capacity).

Similarly, **a harmonized toolbox is needed to assess the HV line costs to society.** There are no methodologies to address the environmental impact of the HV lines transporting electricity and its cost

to society. People accept the HV lines of train systems or the bridges generated by highway expansion, but refuse the development of new high voltage lines, on grounds that are often more emotional than rational (NIMBY effect). The purpose of the toolbox, using a common definition of sustainability in grid development is: • The implementation of a common methodology for the SEA (Strategic Environmental Assessment) of a development plan, taking into account the strong interaction with other plans and policies (energy policy, generation program, etc.). • The use of common indicators to measure the impact on the environment of the grid installations. • The use of a common methodology to measure sustainability in transmission grid development. • Harmonized and accepted methodologies to measure the visual impact of overhead lines and substations. • Harmonized and accepted methodologies to measure the impact of noise (transformers, overhead lines).
Expected deliverables, benefits and impact:

A cost benefit analysis tool making sense at a pan-European level with databases on technology, taking up the REALISEGRID output and available to address issues such as:
• Identifying the most cost-effective technology implementation in standard or new architecture (for instance HVDC lines).
• Added value evaluation of HVDC or FACTs project due to their ability to perform power flow control.
• Optimization of the location of such technology with regard to pan-European grid operation (strengthening of the network with FACT or phase shifter installation).
• New regulatory constraints to favor cross-border operation of the network having such devices.
• Improved control algorithms needed for power oscillation damping, control and load flow optimization etc.
These studies can develop specifications for innovative technology in line with implementation constraints:
• To reduce the acoustic noise generated by high voltage equipment.
• To reduce the EMF values generated by high voltage equipment, which meet the limit requirements.
• To reinforce social acceptance of overhead lines which share the following features:
  o Reducing the disparity between social acceptability and transmission business all over Europe.
  o Generic enough to give the European manufacturers clues and technology-based solutions for increasing public acceptance for transmission equipment all over Europe.
The security assessment can give constraints or indications to design a proper grid code in line with the security expectations of the novel architecture.

Technology involved:
• Cost benefit analysis • Static power flow simulations • Security assessment of a given network architecture
Involved partners:
• TSOs • Research providers • Manufacturers

6.2 ADVANCED TOOLS TO ANALYZE THE PAN-EUROPEAN NETWORK EXPANSION OPTIONS ACCORDING TO ENERGY SCENARIOS FOR EUROPE

Project abstract:	Start date: **2010**	End date: **2014**

TSOs share a toolbox for analyzing pan-European grid expansion scenarios in conjunction with the post-2020 targets reflecting 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 energy storage into account,

with optima that are researched at EU level and no longer at national level. These tools are complementary to architecture design tools.

.

Project objectives:

Directive 2003/54/EC aims for a pan-European market with a free flow of goods and services. The creation of the fully competitive internal electricity market (IEM) is dependent on the European network. Massive investments in high voltage transmission grids are needed in order to alleviate the existing bottlenecks by increasing interconnectivity of the Member States, thus allowing for a more significant presence of import/export in each domestic electricity market.

TSOs need to justify all investments to their regulatory authority. However, regulators focus on national issues, and are thus less interested in common European benefits. In this national vs. European view, the following issues need to be addressed:

- It is worth considering allowing investments outside of one's control zone, i.e. under a form of merchant investments. This would be especially interesting for investments benefiting a specific country but located outside of its control zone. However, a significant level of cooperation between the involved TSOs would be needed in order to settle the legal and operational issues (i.e. participation in revenues from transmission tariffs). R&D in this case should be focused on rules allowing the integration of merchant investments in the grid (i.e. financial compensation schemes).
- Going even further, it might be opportune to look at a single grid and no longer at control zones that behave like islands. There is a need for coordinated investment planning and funding, especially at a multinational level. R&D in clusters will address transparent and non-discriminatory procedures for determining priority investments and funding schemes.

The purpose of the present project is to integrate Cluster 1, 2 and 4 research activities into a set of tools which allow TSOs to respond to European energy scenarios which will be constrained by:

- Variable renewable energy generation.
- The capacity to control power flows.
- The role of active demand in planning future investments.
- The role of energy storage (electricity and possibly other means)

Project description:

Electrical system optimization with **intermittent generation sources.**

The planning of transmission investments with large-scale fluctuating/intermittent wind generation could impact the adequacy and security needs of transmission systems at the short- and long-term planning stages. The wind generation will change and perhaps increase the fluctuating power flows on the European transmission grids. The scenario analysis tool should be able to answer the following questions:

- Intrinsic change (due to balancing) and larger dispersion of the power flow induced on the European transmission system. Up to what point is the existing transmission system adequate, and from what level will dedicated transmission investments become necessary?
- Will new transmission investments require ‘classical’ AC technology or dedicated technology such as FACTS or DC transmission technology?
- How to improve on classical/former planning and reliability tools and methods to feature transmission systems with a growing wind based generation?
- What could a storage market mechanism look like to better address the wind’s intermittent nature?

Market simulation tools as developed in Cluster 4 are expected to be linked with planning tools.

Electrical system optimization with active demand

Transmission networks have traditionally been designed on the basis of projections on the future evolution of the load. These projections usually assume that the load is not price-sensitive. This assumption will no longer be held acceptable in the future. A larger proportion of the load may become price-sensitive and may be shifted to periods of lower prices. The objectives of this task are to investigate how this new flexibility in the load will be taken into consideration by the new planning tool when planning the expansion of the transmission network.

The impact of electricity storage

Electricity storage will be a key element for system service that can be defined by four main functionalities, irrespective of the candidate storage technology:

- *The discharge **time** during which it can be delivered (which is technology-dependent): short-, medium- and long-term storage.*
    a. **Short-term storage** is storage that maintains energy reserves at a level sufficient to provide rated power for between a few seconds and a minute. The two basic applications are uninterruptible power supplies (UPS) and power system stabilization.
    b. **Medium-term storage** is storage that maintains energy reserves sufficient to provide rated power for between a few seconds and a few hours. Applications include renewable energy management, customer energy management, area control/frequency regulation, and rapid reserve.
    c. **Long-term storage** is able to hold energy for times ranging from a few hours to sometimes weeks and months. This is typically bulk energy storage and is generally used to take advantage of the energy price difference between peak and off-peak periods.
- *The **cost** at which it can be delivered (which is technology-dependent).*
- *The **price** at which it can be purchased (which is system-dependent based on the services performed and the local electricity market features).*
- *The **regulatory environment** within which it operates; and which can in the long run be improved to better value storage capabilities.*

The simulation toolbox to be developed for storage services valuation must cope **with the stochastic nature of electricity production by renewables, the stochastic behavior of electricity distribution networks and the stochastic nature of electricity consumption.**

The key questions to be answered by the toolbox are:

- ***How does investment in storage compare to other investments?***
- ***How do storage services impact the compromise between affordable, secure, and clean electricity?***
- ***Which regulatory framework makes electricity markets more efficient at using storage services?***

This toolbox will make it possible to analyze the long-run or integral costs of electricity storage, i.e. the operational and capital costs, in comparison with alternatives that have the same function for the electricity system.

Expected deliverables, benefits and impact:

Coordinated planning tools are available for key investments, taking into account:

- Models of network investment in future competitive electricity markets:

- o A better understanding of how to incorporate long-term price signals and the non-convexities typical of transmission investments in models.
- o A comparison, by modeling the outcomes reached by different institutional structures of TSOs with regard to investment (TRANSCO, merchant lines, etc.).
- o An analysis of the possible applications of models of optimal investments (either cross-border or with a cross-border impact) for the specific institutional setting of the European market.
- o Market design solutions integrated with an institutional and legal framework, which should focus on the harmonization of rules and procedures for investments.

- Relations between network investments (development and replacement) and the reliability of the system: each investment in a network will influence the reliability of the power supply at the local, regional and national level. Having a good database of each network component, it is possible to compute reliability indices at each node of the system.
- European transmission planning model: a sustainable and cost-effective development of the European power system is likely to require different transmission expansion solutions than what is optimal for purely national objectives.

Technology involved:
Typical optimization tools
Involved partners:
TSOs, DSOs, research providers, electricity producers and retailers

6.3 DEMONSTRATIONS OF POWER TECHNOLOGY FOR MORE NETWORK FLEXIBILITY

Project abstract:	Start date: **2010**	End date: **2018**

The use of power electronics, high temperature cables and other technology to increase the transmission capacity and flexibility of the pan-European network.

Project objectives:

Demonstration of new technology able to increase the transmission capacity of the existing grid; and new technology able to control the current flow in order to increase the flexibility of the existing grid.
Beyond the TWENTIES project, this project will integrate results from any of the activities in Clusters 2, 3 and 4 for the economic impact assessment.

Project description:

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. They include, for instance:

- Monitoring conductor temperature: today in most of the European countries no monitoring is done. A worst-case scenario is used to derive one value of the thermal capacity of lines and it has been used over years. The effort necessary for a complete monitoring of conductor temperatures of lines is high and the actual resulting capacity values are not known in advance. Therefore alternatives have to be taken into account. One alternative is the usage of seasonal values for the thermal capacity of lines. This is already done in some European countries. A different approach is the consideration of weather forecasts or the development of dedicated sensors with their communication systems. A power line sensor may provide direct measurements of sag through the use of laser technology, direct measurements of the transmission line temperature by use of a temperature sensor, direct measurements of the ambient temperature through the use of a temperature sensor, direct measurement of the vegetation and the conditions on the overhead line through the use of video.
- Increased voltage on existing transmission lines: there is a need to find methods that avoid requiring a complete rebuilding of the line. The important issue is to find the optimum level of component replacement and required reinforcements to achieve the required reliability of the higher system voltage. It is also important to keep the right-of-way unchanged, hence the insulation level is important. This solution is hopefully very cost-efficient, estimated at 50 per cent of the cost of a new line.
- Use of high-temperature wires. Those wires can be operated at up to 150ºC or even higher and their transmission capacity is much higher than that of conventional conductors. These wires have approximately the same weight and size as conventional conductors, so they can replace them without the need to change or reinforce the towers, allowing for higher transmission capacity in a short time.

The present demonstration projects must show how much the thermal capacity could be increased at cross-border level through the implementation of different approaches. The project will provide a joint analysis of all possible technical solutions within the domain of application. Cost-benefits analysis of different study cases will be performed.

Increasing flexibility

Also, 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. Technological developments have increased both the options, in terms of possible control devices, and the range of their control flexibility, for example by using FACTS (Flexible AC Transmission System), able to regulate the amount of current flow through a power line by changing its impedance. However, the principles of the interactions in meshed networks remain unchanged. This means that the effects of one flow control device can be countered by another one so that the net effect is nil. In extreme cases, this could lead to massive investment in flow control technology with almost no impact on the European power flows due to uncoordinated use of these devices.

Therefore research is needed to find the best way to use the power flow devices within the pan-European transmission network. The issues to be tackled in conjunction with work performed on architecture in the other projects:

- Coordinated location studies for flow control devices? Rather than putting the devices on cross-border lines of different TSOs independently, a more effective impact can be achieved by putting them at a number of carefully and multilaterally chosen locations.
- What is the breakdown of investment costs amongst TSOs in doing so?
- Who must be responsible for their operation?
- What are the basic rules for coordinated operations? (Maximization of ATC? Reliability? Congestion management?).
- What are the other objectives of centralized control? (The maximization of network security, the minimization of the costs of network losses, the maximization of the transmission capacity).

The demonstration work will include the following tasks (coupling cost/benefit analysis and experiments when possible, based on already existing technology):

- How to identify the most cost-effective implementation project and how to compute the added value of HVDC or FACTS projects due to their ability to perform power flow control?
- How to optimize their location with regard to pan-European grid operation? (To optimize strengthening of the network with FACT, or phase shifter installation).
- What type of new regulatory constraints must be envisaged to favor a cross-border operation of the network having such devices?
- What type of improved control algorithms are needed for power oscillation damping, control and load flow optimization?
- What type of cost/benefit analyses makes sense at a pan-European level to support the efficient implementation and uses of such devices?

Expected deliverables, benefits and impact:

- Validated methodologies to upgrade existing grid.
- Increased capacity at reduced cost and reduced environmental impact.
- Short-term relief for some network pinch points.
- New technology to control power flow and tools to position it.

Technology involved:

- Equipment and methodologies to monitor conductor temperature.
- High temperature cables and equipment.
- FACTS (Flexible Alternating Current Transmission Systems).
- Phase shifting transformers.

Involved partners:

TSOs, manufacturers, research institutes

6.4 DEMONSTRATIONS OF POWER TECHNOLOGY FOR NOVEL NETWORK ARCHITECTURE

Project abstract:	Start date: **2012**	End date: **2018**

The impact of power electronics on architectural choices (off-shore and on-shore options are validated) are quantified based on full-scale demonstrations including the security aspects of meshed network management.

Project objectives:

Demonstration of new grid technology like HVDC, superconductivity and any other promising technology to keep up with the needs and expectations of the European electrical system in the next few decades.
Beyond the TWENTIES project, this project will integrate results from any of the activities in Clusters 1, 2 and 4 for the economic impact assessment.

Project description:

Technology is demonstrated in large-scale experiments to address pan-European-size problems like:

1. Providing a reliable and stable backbone for European internal electricity markets.
2. The interconnections of the system can be increased, e.g. with selective reinforcements or by creating an ultra-high voltage transmission system (so-called supergrid) or DC backbone.
3. More fluctuating power in feeds from renewable sources is possible with the help of increased power flow steering at the transmission (bulk power) level.
4. The regional interconnection and local distribution (e.g. including mini and micro grids) can be reconsidered (power flow, control and protection).

The studies should help determine the best structure: keeping the actual voltage levels 380 kV – 220 kV/150 kV and reinforcing selectively at the bottlenecks, introducing a new AC voltage level of 750 kV, introducing selected HVDC-links, creating a DC grid and operating the underlying 380 kV-network more in separated sub-networks. Such studies could then take into account several assumptions such as:

- Evolution of the generation parks, of market needs.
- The possibilities of grid extension (environmental issues, etc.).
- The introduction of more FACTS and the optimal use of them.

Also, superconducting cables are able to transport much more power with very low (or no) losses, having the disadvantage of keeping the installation 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. Also, there will be an increasing number of high-voltage applications based on superconductivity, like fault current limiters.
Similar large-scale experiments will be needed following the TWENTIES project results in order to address:

- Off-shore secure operations (the role of HVDC technology).
- Network operations with massive wind power flows controlled either via hydro storage or via power flow controllers managed at a pan-European level.

The Dutch and Danish initiative to develop a power link between both countries is remarkable. The purpose of the link, entitled COBRA Cable, is to allow for the integration of more renewable energy (RES) into the Dutch and Danish power systems and to increase security of supply. The power link will also help to intensify competition in the north-western European power markets. The COBRA cable will examine the possibility of being the first stepping stone for a North Sea off-shore grid for the pan-European interconnection of multiple off-shore wind parks.

Expected deliverables, benefits and impact:
The experimental data gathered during experiments nourish: • Planning models • Operational strategies • Market simulators To validate network expansion and network flexibility costs **within different pan-European scenarios.**
Technology involved:
• HVDC technology. • Superconducting cables and equipment (like fault current limiters).
Involved partners:
• TSOs • DSOs • Manufacturers • Research institutes

6.5 DEMONSTRATIONS FOR RENEWABLE INTEGRATION

Project abstract:	Start date: **2010**	End date: **2018**

- Renewables' contribution to the power system is validated (voltage and frequency control, balancing using VPP concepts).
- The security aspects of off-shore HVDC meshed networks are solved (circuit breakers, multi-terminal control systems).
- The network is monitored and controlled to avoid large-scale intra-zone oscillations.

Project objectives:

To validate integration scenarios where:

- The network is more user-friendly to welcome variable renewable energy generation.
- The generation technology can become smarter to contribute to system services and enter electricity markets.
- Future network architecture are validated both from power and reliability standpoints

Beyond the TWENTIES project, this project will integrate results from any of the activities in Clusters 2 and 4 for the economic impact assessment.

Project description:

TSOs and end-users are challenged by renewables from a system security as well as from an economical perspective. With increasing wind gradients, the necessary reserves to maintain system stability will increase. This causes a need for high system margins on power reserves and standby production. With higher margins on reserves, the wind integration has increased costs for balancing services, which ultimately means increased costs for security and also for the end-users. Moreover, the wind is a challenge for utilities investing in wind farms and integrating wind electricity production into the markets. Increasing wind gradients causes unexpected imbalances in production, which directly relates to loss of earnings for the utility.

Demonstrations are needed (beyond TWENTIES) to address large-scale renewable energy integration through an optimization across the value chain – from the power generation at the off-shore and on-shore wind farms and large PV farms, to regulating the central power production, and the mobilization and management of distributed generators and consumptions units (hereafter referred to as 'local assets') including the transmission system operator network and operation. Demonstrations must show that variable power can be balanced effectively and cost-efficiently using a co-optimized management of central production, distributed energy resources integrated into existing markets, and contributing to the demand side management.

A first demonstration is proposed in TWENTIES in Denmark with wind production and central assets from DONG Energy's portfolio (5620 MW CHPs, 431 MW wind, and by end 2009 additional 209 MW at Horns Rev 2 – the world's largest off-shore wind farm to date). The demonstration will integrate into the SPOT/Intraday markets and the TSO regulating services in the price areas of Denmark in the west and east.

The main assumption of such demonstrations is to lever results from the fact that the existing distribution grid is sized for peak load: most of the time, there are no congestion issues. Further large-scale experiments might be needed to take into account congestion at distribution level.

Thus, mobilizing local assets and co-optimizing them with the operation of central production to balance wind gradients is possible. 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 of all the

stakeholders involved is required before scaling up and replication.

- The control of wind or solar farms helps provide more stability from a system perspective, even though it causes a reduced exploitation of the wind/solar power.

An outstanding experience in the field of off-shore integration is being carried out in the Kriegers Flak project which is focused on building the world's first off-shore grid – combining grid connection of off-shore wind farms with interconnection between different countries and electricity markets. Additionally, the Kriegers Flak project is proposing to use the cable as extra interconnection capacity among the three countries, in the case the cable capacity is not fully used by the wind power production.

Expected deliverables, benefits and impact:

- Effective management rules 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.
- Control procedures for system security and ancillary services not only by central power plants but also by wind farms (off-shore and on-shore) and local assets (distributed generators and loads).

Technology involved:

- IT solution to perform this integration that is secure and scalable (see the DONG proposal in the TWENTIES experiments).
- Power electronics
- HVDC technology

Involved partners:

- TSOs
- DSOs
- Generator companies
- Manufacturers

6.6 INNOVATIVE TOOLS FOR PAN-EUROPEAN NETWORK OBSERVABILITY

Project abstract:	Start date: **2010**	End date: **2017**

Sensors and simulation tools are validated to offer regional coordination centers the real-time status of neighboring zones which allow for better observability
European standards are specified in line with the ongoing NIST approach in the USA to facilitate the coordinated observation between neighboring zones

Project objectives:

- To improve the state estimation involving local sensors and data processing (with sensor manufacturers).
- To develop local state models with the right level of intelligence at substation level (with power technology manufacturers aiming at a standardized approach throughout Europe).
- To improve both on steady state and dynamic observability.
- To standardize the overall communication and sensing infrastructure (in line with the NIST approach in the USA).

This project will use the PEGASE project results and will integrate results from Cluster 2 and Cluster 3 experiments.

Project description:

The monitoring, control and protection systems implemented today in transmission system applications reach intrinsic limitations. There is no global observability at the overall interconnected system. Controllers tuning uses off-line simulation methods or static remote measurements with very low flexibility to account for the stressed operating conditions of transmission systems. Protection systems allow for the detection of faults but do not make it possible to accurately locate the fault or identify the equipment's parameters. Synchronized by GPS (or Galileo) PMU-based systems appear to be a promising way to push these limitations forward. Thanks to accurate time stamping and fast telecommunication systems it becomes possible to compare far away voltage phasors. The use of Phasor Measurement Units (PMUs) opens up new possibilities in power system control and protection design, including implementation of model based (or model predictive) and/or adaptive controllers that had not been feasible or sufficiently useful before.

The integration project will deal with four major issues for observability of the pan-European grid:

- The state estimation involving local sensors and data processing (with sensor manufacturers).
- The development of local state models with the right level of intelligence at substation level (with power technology manufacturers aiming for a standardized approach throughout Europe).
- Steady state and dynamic observability.
- Standardization of the overall communication infrastructure (in line with the NIST approach in the USA).

1. State estimation with guaranteed performances

GPS-synchronized equipment (PMUs) in general have higher precision equipment when compared to typical SCADA systems. Conceptually, PMU data are time tagged with accuracy of better than 1 microsecond and magnitude accuracy that is better than 0.1 per cent. This potential performance is not achieved in an actual field installation due to errors from instrumentation channels and system imbalances. Presently, PMU data precision from substation installed devices is practically unknown. On the other hand, specific applications of PMU data require specific accuracy of data. Applications vary from simple system monitoring to wide area protection and control, to voltage instability prediction. Each application may have different accuracy requirements. For example for simple system monitoring in a steady state highly accurate data may not be critical, while for transient instability prediction high precision may be critical. To address data precision requirements for a variety of applications, it is necessary to quantify the accuracy of the collected PMU data. A new approach to improving data accuracy via estimation methods is needed.

2. Local state models at substation

Manufacturers have their own approach, which must be progressively standardized to allow for inter-zone observability. The PEGASE project will show how to deal with static phenomena and consequences on simulation tools. TWENTIES will address the sensors and simulation tools to address the inter-zone oscillations.
Enough knowledge will be gathered to impose on manufacturers and interoperable approaches. This relates to IEC 61850, which models all the equipment and functions in the substation. If those models could be brought back to the control centre, then this same powerful information model would be used for SCADA and other applications, thus minimizing translations and expensive data maintenance activities that sometimes lead to insecure/non-secure and/or unsafe situations.

3. Steady state and dynamic observability:
   - Steady state applications: wide area monitoring systems making it possible, for instance, to calculate power exchanges between areas, reduced equivalent system, detection of a mismatch between estimated topology and outcome of state estimation algorithms.
   - Dynamic applications:
     - Real-time detection of instabilities (small signal, transient, voltage, frequency, etc.) increasing the robustness of the assessment of the dynamic state of the system and the efficiency of the visualization in the control centers.
     - Supply of real-time data to enable fast and accurate determination of security margins closed loop control of actuators based on new generation algorithms that use the extended observability of the system provided by the PMU.
     - Complementation of classical SCADA functions with ultra-fast SCADA functions.
     - Management of system security in case of loss of the PMU's telecommunication.
     - Revisiting the four defense plan components (voltage collapse, frequency collapse, loss of synchronism and cascading tripping), load shedding and emergency control actions being based on centralized or virtually centralized point algorithms.
     - Unit protection system: equipment characteristics, accurate monitoring of the fault location for further equipment inspection, etc.

- Towards a standardized European approach.

- There is a need for requirements and standards ready to fill the Gaps Related to Wide Area Situational Awareness. The NIST document recently put out in the USA is illustrative of the urgent need for a similar approach in Europe; among the issues of relevance to TSOs, one may mention:
  - Interoperable messaging standards for the IEC 61970 (CIM): The CIM for transmission (IEC 61970) does not specify formats or messaging methods for exchanging CIM information, thereby requiring much implementation to develop its own formats and messaging requirements.
  - IEC 61850 standard between substations: some protective relaying and certain other functions require communication between substations but still rely on legacy, or proprietary protocols. Since IEC 61850 is used within substations, the same protocol could be used between substations.
  - Calibration rules for PMUs: standard rules for calibration and updating measurement devices, common tolerances, depending on application.
  - Exchanging both transmission and distribution power system models: it becomes increasingly critical for transmission and distribution operations to have clear and accurate information about each other’s status and situations. They will need to be

able to exchange their respective T&D power system models, including the merging of relevant databases for interconnected power systems. The recent NIST report on the *Smart Grid Interoperability Standards Roadmap* by Don Von Dollen (published in June 2009) shows an exhaustive list of proposals. Simulation tool prototypes that allow for local state model implementation and observability at dispatch level.
Expected deliverables, benefits and impact:
• Accuracy requirements of PMU and related telecommunication systems for the various envisaged applications. • Requirement at the simulation tool level to develop PMU based solutions.
Technology involved
• The use of Phasor Measurement Units (PMUs) opens up new possibilities in power system control and protection design, including implementation of model-based (or model predictive) and/or adaptive controllers that had not been feasible or sufficiently useful before.
Involved partners
• TSOs • Manufacturers (sensors and power technology) • European standardizing bodies • Telecommunication technology and service providers • Research providers

6.7 INNOVATIVE TOOLS FOR COORDINATED OPERATIONS WITH STABILITY MARGIN EVALUATION

Project abstract:	Start date: **2011**	End date: **2016**

Starting with the output of the PEGASE project, this project aims to develop a simulation toolbox able to understand how the harmonization of operation procedures and coordination between TSOs will allow the pan-European transmission system operators to:

- Face new generation and transmission uncertainties, coming in particular from renewable expansion (requires gains in the observability of the overall system).
- Require more control to improve the commandability of the overall system.

Their prototype simulation toolbox will allow for design policies for operations involving the harmonization of existing rules and increased coordination.

Project objectives:

The basic principle underlying network operations is that, due to growing uncertainties in system operations, decisions regarding system operations are taken by operators at the latest time possible. Uncertainties are brought in by:

- The growing contribution of renewables.
- The power market uncertainties.
- The behavior of customers.

Today operators know the weak points of the system they operate. Hence they make optimal decisions:

- With regard to power transits.
- Using corrective actions based on a worst case scenario.
- Implementing preventive actions if, and only if, there are not enough corrective actions to ensure system reliability.

The objective of the project is to integrate the output of activities in Cluster 3 into a single toolbox that will address this complex optimization problem with the recommendations coming from the PEGASE project.

The project has five major objectives, needing the active participation of TSOs.

O1: To conceptualize the optimization challenge as seen by operators daily into a single well-posed question that can be addressed by newly available optimization packages.

O2: To test optimizer solutions in order to deal with the above transit maximization problem.

O3: To develop the toolbox based on a stochastic approach of the critical optimization variables (larger dispersions around the deterministic values obtained from the current steady state simulation tools).

O4: To perform joint tests with the TSOs using their existing operational rules.

O5: To propose converging policies for operational planning tools that will support operational rule harmonization at ENTSO-E level.

Overall, an adequate formulation of the building of anticipated states for operational planning and to test the feasibility of solving such problems using available solvers will be reached. The construction of anticipated states will take into account the new context in which more and more corrective actions are used to ensure security and many significant injections are difficult to predict due to the presence of renewables. Discrete variables (taps of PST or ULTC), switching of reactive compensators and the status of breakers will be dealt with as discrete variables in the optimization process to implement the most common corrective actions accurately. Major decisions, such as the starting/stopping of generating units, implementation of preventive or corrective actions, will be modeled using discrete variables.

Project description:

Generally, anticipated states of the system are built using an optimal power flow (OPF). The problem is formulated as a minimization of generating costs under balance and network constraints. Only the base case is considered, no outage of generations or lines are taken into account. The voltage set-points, transformer taps (including PST) and status of reactive compensators are sometimes also optimized by adding other components in the objective function of the minimization problem. For controllable generations, the optimization problem generally considers only the upper and lower boundaries on the active power. It doesn't have the flexibility to start or to stop a unit. Some heuristics are sometimes added to solve this problem but these usually provide only a very suboptimal solution. As far as we know, if these start/stop decisions are to be taken into account, the most advanced solution is to solve a preliminary problem using a DC approximation of the network equations. The problem then becomes linear and the start/stop decisions can be modeled as discrete variables. A mixed integer linear programming (MILP) optimization engine can then be used. Moreover, with this approximation, it is relatively easy to add post-contingency states to the formulation of the problem.

The higher-level interactions between the various European transmission systems forces the TSOs to change the way they ensure reliability and security of the grid today, with an emphasis on the progressive generalization of corrective security instead of preventive security. This research work will deal with modeling, at a pan-European level, of :

- Data exchanges required to achieve a realistic description of contingencies.
- Filtering of contingencies, which should be analyzed in real-time to assess the robustness of the system (today the simulations are limited normally to (n-1) contingencies of network elements or generation units).
- Methods to identify and assess severe contingencies will be proposed through the analysis of the probability of occurrence and a risk analysis of the consequences.
- The detailed system analysis is then performed in order to address the most severe contingencies (bus bar faults, multiple circuit overhead line losses, loss of all distributed generation in one area, etc.).
- The examination of the consequences of such contingencies on the system.
- The definition of the type of contingencies that should be examined and which should be excluded on the basis of a probability analysis of occurrence and risk analysis.
- Methods to propose automatic mitigation measures following severe contingencies.

Next, expected operations of the system nearer to its limits increase the need for protective security, especially the coordination of the defense plans. Although it appears that some requirements and standards have been introduced in the *Operation Handbook* of the former UCTE association, there are major threats of spreading system disturbances across borders and formally agreed common procedures to deal with such events are missing. This research work aims also to provide:

- A toolbox to define the weak points of the pan-European network's operating procedures.
- A European doctrine that goes above and beyond the existing doctrine in each cooperating Member State, and is able to limit the extent and impact of major system disturbances, especially against cascading tripping which can affect very large portions of interconnected transmission systems.

In case of a major blackout in the network, most of the transmission system operators are supposed to restart their networks on their own. Before the separately operated networks can be reconnected, complex simulations have to be performed. A significant number of these simulations can be performed in advance. With these simulations, critical connection points can be determined. Using dynamic analysis, the different control systems of the power plants can be evaluated. If simulations show a relevant risk of a breakdown during reconnection, measures to lower this risk can then be identified, and subsequent reduced time for restoration of energy supply can be obtained.

Although several recommendations and requirements have been proposed in the *Operational Handbook* of the UCTE, it appears that the full recovery of the European system may take long.

The research work is composed of several items:

- Define the amount and type of national system data that need to be shared to implement such approaches.
- Develop simulation tools able to detect weak points of reconnection scenarios.
- Develop methodologies to optimize reconnection scenarios.
- Develop ad-hoc training tools for operators based on the above results.

Expected deliverables, benefits and impact:

- Knowledge and methods to support the development of a European security doctrine to allow system operations under narrower stability margins.
- Defense actions and a set of principles and methods to achieve the coordination of defense plans and black starts at pan-European level.

Technology involved:

- The ideal formulation of the problem translating the functional objectives is either the mixed logical dynamical framework (MLD) to transform the most logical expressions into equivalent forms using discrete variables or the Equilibrium Constraints (MPEC) formulation.
- Solvers for handling, simultaneously and in a robust manner, continuous and discrete variables (large size mixed integer linear problems (MILP), or complementary constraints (MPEC)).

Involved partners:

- TSOs
- Research providers
- Commercial solver providers

6.8 IMPROVED TRAINING TOOLS TO ENSURE BETTER COORDINATION AT REGIONAL AND PAN-EUROPEAN LEVEL

Project abstract:	Start date: **2013**	End date: **2017**

- Network simulation tools are used to train operators of national dispatch and regional coordination centers.
- Operators are able to better interpret stability margin evaluations and the status of neighboring systems.

Project objectives:

To develop a common training centre using a pan-European transmission network simulator able to train dispatching operators in coordination for real-time operations.

- Overall, this project integrates the results of activities performed in Cluster 3. It will also integrate at a later stage the results of restoration strategy activity, if implemented in the training tools.

Project description:

Among existing training facilities, the DUtrain PowerSystemHandler (a subsidiary of KEMA) is a facility located in Germany dedicated to simulating power system operations. Its technological design is based on almost a decade of experience in operator training (a SCADA system, models for the technical equipment, power system simulation software). The SCADA system comprises operational user interfaces and process data handling. The telemetric line interface is used for the connection of, and the data exchange with, the models for the technical equipment such as switching and protection devices, automatic tap changers, generation units, load performance, etc. The power system simulator calculates the physical performance of the entire power system, represented by the actual topology retrieved from the SCADA system and the physical parameters of its equipment (e.g., line and transformer impedances, generation capability, load trajectories).

This type of simulator/training facility must evolve with several options possible, induced by the future pan-European system evolutions.

First, an increased number of hardware and software techniques will be used to improve on the flexibility and the controllability of the transmission system. As a result, and thanks to the increasing automation embedded in the power system, the operation of the system will be brought closer to its physical limits than today.

Secondly, in case of contingencies, interactions between operators and the various control systems become critical. The training of the system operators at a pan-European level becomes even more critical. This is why a common European training facility operated by the TSOs is of importance. This simulator is not a specific control system like simulators in control centers, but trains operators at gaining fundamental knowledge on the operation of disturbed interconnected systems in general.

Overall, such a training centre will deliver pre-defined levels of new knowledge to address pan-European power system issues. Since dispatching training simulation is now a mature technology where transient, mid- and long-term phenomena can be simulated in real time for training purposes, it can be extended for testing purposes such as the design and optimization of restoration procedures, etc.

Today, facilities are able to:

- Represent any power system control hierarchical organization comprising several control centers parallel to each other.
- Split grid control and generation control, each of them being represented in specifically customized control centers.
- Simulate 'normal' and 'abnormal' operational conditions up to system restoration after full blackouts.
- Implement scenario management at dispatch level.

The design specifications of the future common training centre must make it possible, at a pan-

European level, to:

- Simulate in real time the whole interconnected European power system for training purposes.
- Train dispatching operators to reproduce and understand large-scale incidents.
- Provide training, but also certification, to operators on a validated European power system model and improve the emergency condition procedures.
- Make the dispatching training simulation facility available to other operators such as the power plant operators and the distribution network operators to improve grid/plant and grid/distribution network interfaces.
- Develop and test common procedures to face emergency scenarios.

- The specification study performed will examine the pros and cons of several possible architecture:
  - A centralized training centre within one single location.
  - Distributed training systems where the simulation engines/computers are decentralized and coordinated through a common hub which host the simulation software tools.
  - A 'flight simulator' type training tool where a full dispatch room is made available to trainees reproducing adjacent control areas.
- The training facility will be developed and tested at a prototype level with dispatching operators: it will involve novel man-machine interfaces where the state of neighboring systems is displayed using new visualization techniques.

Expected deliverables, benefits and impact:

1. The specifications of the training simulator, including the validation of the critical algorithms.
2. A prototype simulator.
3. A first set of training assignments to test the benefits of coordination mechanisms in stable and critical situations.

Technology involved:

4. IT systems for training and simulations.
5. Software tools developed in line with the ongoing PEGASE project.

Involved partners:

- TSOs
- IT providers
- Training centers
- Manufacturers
- Research providers

6.9 INNOVATIVE TOOLS AND APPROACHES FOR THE PAN-EUROPEAN NETWORK RELIABILITY ASSESSMENT

Project abstract:	Start date: **2011**	End date: **2018**

Tools and rules to make current security criteria for the new pan-European system architecture evolve without jeopardizing present-day reliability levels.

Project objectives:

Evaluate the options to improve the actual N-1 preventive security doctrine **at the design and operations stage** of the pan-European transmission network.

This project will involve Cluster 1 tools, Cluster 2 experiments, Cluster 3 tools and techniques, and possibly Cluster 4 (economic impact assessment tools) to perform a cost/benefit analysis of the new reliability doctrine at a European level.

Project description:

Today, the most important principle of transmission network planning and operation is to guarantee (n-1)-preventive security as a strict constraint. According to the increasing uncertainties linked to the variable renewable energy generation sources, the pan-European electricity market and the communities' opposition to new transmission infrastructures, meeting this constraint is getting more and more difficult. There is a need to re-evaluate the constraint of (n-1)-security: Can this (n-1)-criterion be improved by other regulatory constraints for reliability performances?

The research project aims to answer the following questions:

- Under which circumstances and to what extent can the loss of the (n-1)-preventive security be tolerated?
- What are the possible options to replace (or complement) the (n-1)-criterion?
- What is the additional information to be exchanged to support the replacement of the (n-1) criterion? (For instance clustering of forecasts).
- What are the new methodologies in support of probabilistic network analysis?
- What are the new probabilistic indicators for risk of an outage to be implemented?
- What are the techniques to quantify the impact of such changes?
- What are the resulting options in terms of security criteria at the pan-European level?

The resulting answers will be the basis for a new European doctrine, which allows evolutions of system design and operations based on new observability and control means.

This work is dealing with a change of the n-1 dogma set in Europe. The impact of this work will be planning and operations with tools that can be used in project 7 (both forecast and real-time operations).

Expected deliverables, benefits and impact:

A cost/benefit approach able to compare design and operation options that can improve the current (n-1) criterion

Adoption of the new doctrine at a European level, showing the pros and cons of accepting the lack of observability and/or control.

Technology involved:

Simulation and optimization tools, cost/benefit methodologies adapted to the pan-European system for both design and operations.

Involved partners:

TSOs, research providers

6.10 ADVANCED TOOLS FOR PAN-EUROPEAN BALANCING MARKETS

Project abstract:	Start date: 2012	End date: 2016

Market simulation tools for constrained networks that provide recommendations about pan-European markets for balancing and system services, including the contribution of renewables, which go beyond existing national rules for balancing.

Project objectives:

To develop a toolbox able to address:

- The improvement/coordination means for balancing control and management beyond existing national boundaries (optimal use of the system, high penetration of renewable energy generation).
- The detailed analysis of various market designs in support of a balancing market at a pan-European level.

The project will integrate results from activities performed in Cluster 4 including extended simulation tools.

Project description:

Present targets for the integration of renewable energy sources, in particular wind energy, will create significant challenges for balancing control and management of reserves within existing national systems. Balancing control has traditionally been the responsibility of regional or national system operators maintaining balanced operation within well defined geographical and network areas. The control problem is typically based on monitoring of the 'area control errors' (ACE) derived from deviations in system frequency and planned power exchanges to neighboring areas. The ACE is then controlled to a minimum, partly through automatic generation control schemes involving larger generators and partly through the manual set-point control of dedicated generators. In the restructured electricity markets the trend is towards decoupling the operational part of balancing control and the market settlement part of managing deviations in generation and consumption. Balancing control can be seen to be made up of two quite independent tasks:

- Maintaining frequency within defined limits.
- On-line management of network congestion arising from unplanned deviations.

When system frequency drops in the European interconnection due to the loss of generation in the south of Europe, this can be balanced by increased generation or load shedding in Germany. It can even be balanced by trading on the Nordic Balancing Power Market providing there is available capacity on the HVDC links between the two synchronous areas. It is thus technically feasible to create one common European market for frequency control that may result in a more optimal utilization of reserve capacity than there is today.

The main challenge that remains to be solved is how to manage congestion and deviations from planned operations that will result from such a solution. This requires new transmission capacity, flexibility in power flow control and new tools for market and network analysis.

The project will develop of toolbox capable of:

- Analyzing balancing control needs in the future European power system and assessments and developments of balancing control markets and automatic control schemes.
- Developing simulation tools for secondary control analysis.
- Performing case studies analyzing the economic and technical impact of a common European solution for balancing control, based on the results of technology demonstrations.

The provision of balancing services is a key element of electricity markets: it has, indeed, a direct impact on market prices and on the reliability of the system. Two main routes can be studied with the help of the toolbox, on the basis of typical case studies:

1. Stimulate market players to remain close to their commitments and reduce the need for balancing services to be delivered by TSOs. The method is supported by penalties imposed on operators when they do not meet the contracted forward positions. The main issue is then the effectiveness of the required tools for verifying that commitments are fulfilled.

2. As in the currently adopted position in the US East Coast system, consider balancing as an energy market in line with the day ahead and other forward markets. Basically market players are then supposed to pay the real-time price of electricity rather than a fee, since this cannot provide the appropriate incentives. The main mentioned limitations of this approach reside in the narrowness of the market and its vulnerability to market power.

The toolbox must show its abilities in case studies for evaluating the economic properties of different arrangements and the offered options in terms of market design. Such an analysis is made more complex than for national markets because of the existing market mechanisms: the various European implemented balancing mechanisms are disparate, especially in terms of gates closures between the various control areas. This slows down the harmonization of the various control area organizations into one single control area organization (or coordinated organization displaying virtually unique features). A comprehensive cost/benefit analysis must be carried out to support that assumption.

Expected deliverables, benefits and impact:

- Developing the framework and technology necessary to implement a real-time balancing market for AGC services.
- Options for balancing services at a pan-European level can be studied and assessed before implementation.
- New tools for real-time pan-European congestion management in the absence of control area balancing.

Technology involved:

1. Optimization techniques.
2. Market simulation tools constrained by transmission issues (OPTIMATE).

Involved partners:

- TSOs
- DSOs
- IT providers
- Research providers

6.11 ADVANCED TOOLS FOR CONGESTION MANAGEMENT

Project abstract:	Start date: **2012**	End date: **2018**

- Network-constrained market simulation tools provide recommendations about specific network management and market rules to manage congestion within the pan-European grids without impacting system reliability.
- Flow-based market coupling

Project objectives:

- To understand the interactions between system operations and capacity allocation methods at the regional level.
- To model TSOs' strategies (currently TSOs' operations choices are not modeled) in view of improved congestion management; and to analyze the possibility of more efficient options, if any, for the pan-European electricity market.
- To expand flow-based market coupling based on the successful experience.

The project will integrate results from the activities performed in Cluster 4.

Project description:

Congestion management is one of the main concerns. It has an impact on the level of electricity prices and it should be a key instrument for determining investments in generation and transmission. Today, each area has its own clearing rules and its own allocation techniques. The challenges are therefore to study and implement new options that would increase overall electricity market efficiency and reduce congestion costs significantly.

On the other hand, a reliable and secure operation of the power system requires the availability of capacity reserves and the possibility to use them under stressed situations that may involve congestions. Proper electricity market design must provide incentives to generators to provide adequate capacity reserves. The objective then is to find mechanism(s) to adequately remunerate such investments. Theoretical approaches state that the prices of the capacity reserves should be derived from the economical value brought by the additional reliability provided by the capacity reserves. The underlying question is the need for dedicated market mechanisms to ensure electrical system adequacy/security. In economical terms, the reliability becomes a public good: the market cannot set the price alone.

The successful implementation of flow-based market coupling approach should be extended to address congestion management, balancing markets and capacity reserve markets within a joint unified approach all over Europe leading to a set of coherent interacting tools able to address all these complex issues at once.
The present project is composed of several steps, integrating the various elementary research results generated by Cluster 4 activity:

- At a theoretical level, compare the currently available tools and results developed at a/the national level involving power systems engineering, operation research and economics.
- Validate that the flow-based market coupling approach can be extended with a similar simplified description of interacting zones all over Europe.
- Introduce simulation options that can take into account the interactions between the various regulatory frameworks.
- Introduce data on transmission and generation that are vital in order to reach meaningful results.
- Envisage locational pricing that includes any congestion costs arising from the need to dispatch lower flows in order to meet reliability and transmission constraints.

Expected deliverables, benefits and impact:

- A toolbox to study the expansion of well-accepted approaches (flow-based market coupling) and able to compare options in new allocation methods.

• Simulations of the proposed options to compare their overall efficiency. • Proposals for the implementation of the most promising approaches, by bringing quantitative answers to the complex issues of balancing, congestion and capacity markets (including the generalization of flow-based market coupling). • Locational pricing approaches.
Technology involved:
• Simulation techniques. • Flow-based market coupling.
Involved partners:
• TSOs • Research performers

6.12 TOOLS FOR RENEWABLE MARKET INTEGRATION

Project abstract:	Start date: **2010**	End date: **2014**

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

Project objectives:

To extend the OPTIMATE results to balancing and system service markets, to take into account the TWENTIES experimental results, where with the aggregation of wind farms to provide system services, to validate a set of simulation tools that can be used for scaling up and replication of the results all over Europe, and to propose complementary experimental demonstrations which will be needed to validate the most promising options for the European market.
The project will use the results from Cluster 4 as well as the experimental results to be performed as per other proposed projects.

Project description:

Beyond the integration of the power market as studied in OPTIMATE, there are two basic issues when considering wind power integration:
1. Active power control by wind farms, with the objective being to perform secondary frequency control for the system: the main challenge for the implementation of an active power control is to set the operating point of a wind farm in such a way that the aggregation of wind farms has the capability to decrease or increase the resulting active power provided to the power system when 'secondary frequency control' is requested.
2. Reactive power control, with the objective being to stabilize voltage in a region or zone: aggregated wind farms can be considered like any conventional power plant for voltage regulation purposes, within the technical limits of the tested turbines for providing reactive power. The critical challenge is to set the reference values for the reactive compensation to be provided by individual wind farms in order to reach optimal voltage stability in an area or a zone of the transmission system.
These issues will be experimentally tested in TWENTIES. The results will be analyzed within the TWENTIES project with the tools and data that have already been implemented in the EWIS and TRADEWIND projects. Such tools have intrinsic limitations when the coupling of national energy systems implementing some or all of the TWENTIES demonstrations are at stake:

- What is the positive and negative impact for the interconnected power markets when the secondary frequency control or voltage stabilization is implemented in several regions at once?
- What are the optimal combinations of TWENTIES recommendations that maximize European welfare through dedicated scenarios for secondary frequency control or voltage stabilization?
- What are the combinations of solutions that will negatively impact European welfare, in spite of making sense at the regional and national level?

A toolbox relying most probably on the OPTIMATE building blocks is therefore required to study the detailed impact of scalable and replicable solutions for renewable integration using not only power markets but also system services.

Expected deliverables, benefits and impact:

A simulation toolbox making it possible to quantify the economic impact of several renewable integration routes coming from large-scale experiments to test market integration of renewable generation, taking into account the results of the TWENTIES project.

Technology involved:

Simulation tools.

Involved partners:

TSOs; Research partners, generators, DSOs, Power Exchanges

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

Project abstract:	Start date: **H2 2010**	End date: **2018**

- Specifications of a pan-European system for demand side management based on experimentally validated business models and business cases.
- Specifications for standards in telecommunication infrastructures and a governance model to make these standards evolve within a world-based approach (the NIST ongoing work).

Project objectives:

- To perform large-scale experiments involving metered customers that show the costs and benefits of demand side management approaches at a pan-European level.
- To develop a set of standards for data exchange at a pan-European level.

The project will use the results form activity carried in Cluster 4 with an emphasis on network charges allocation to end-users.

Project description:

Today, power systems face challenges that can be addressed by active demand. They include:

- Continuous increases in distributed generation units connected to the grid, both at transmission and distribution levels. Conventional load management practices applied to centralized generation are no longer suitable for properly managing such resources.
- The high temporal variability of generation using renewable energy sources, both from wind and solar sources.
- Faster increases in peak-load values than in energy demand, which stresses grid requirements, leading to a higher number of hours of wasted transmission capacity. Being able to move load from peak to off-peak hours becomes a must for an optimized grid development.

This situation requires new tools that allow both TSOs and DSOs to address the above challenges in an efficient and safe way. These tools should encompass:

- Improved network observability: any action helping the participation of distributed energy resources in system operations, particularly demand, requires that the TSO have an aggregated visibility of such resources.
- Forecasting: improving forecasting accuracy is a must when integrating non-manageable energy resources. Similarly, load participation in system services requires new tools for accurately forecasting load behavior of different end-user groupings.
- Load activation and management tools: efficient load management integration into system operations requires the specification of system services that can be provided to the TSOs, as well as the necessary tools to implement such services, at both end-user and TSO sites. The specification must include time response, available capacity, relationships among market players (end-users, ESCOs, DSOs, TSOs), regulatory frameworks, etc.
- The new types of relationships between retailers and consumers where signals can be sent to adapt consumption to real electricity prices

The resulting grid, allowing for active demand, will become a key strategic infrastructure needed for consumers, utilities, service providers, operators and Europe. Technology deployments will be driven by legislative and regulatory policies, making operational efficiencies, creating customer value. However, implementations in fragmented efforts with little or no stakeholder coordination or agreed-upon standards will result in extra costs and inefficiency. Early adopters may be faced with ‘sunk costs’ or serious integration and interoperability issues.

A governance process for standards at European level is therefore required, which prioritizes the development of standards and adoption based on consensus and value, publishes deliberations and standard selection criteria early and often for free-of-charge public web access to ensure the process is open, unbiased, and fully documented. Due to the very fast implementation of a similar approach in the

USA described in the report to NIST on the *Smart Grid Interoperability Standards Roadmap* (published on 7 June 2009), it is recommended that a similar approach be taken in the EU in early 2010 parallel to the large-scale experiments foreseen within the TWENTIES project where all the concerned stakeholders are involved.

Expected deliverables, benefits and impact:

- Business models in support of Virtual Power Plants at DSO level (see TWENTIES experiments to be performed in Denmark).
- Cost/benefit analysis for each market player and business cases.
- Specifications of services provided by the load.
- ITC system architecture to allow for such VPP approaches.
- Telecommunication protocols.
- Specifications of equipment and devices in the load site.
- Forecasting tools, load activation, control and management tools.
- Regulatory recommendations.

Technology involved:

- Metering: metering technology is a key enabler for the implementation of demand management at system level.
- Telecommunications: load management means making use of extremely distributed resources. It requires suitable telecommunication schemes that ensure the proper management of large amounts of data within stringent response time requirements.
- Software: forecasting, control and management algorithms, monitoring.
- Automation: Automatic data management and decision systems allow for suitable demand management approaches to be implemented by additional system service providers within the real-time TSO requirements.
- The technology development should be complemented by guarantees of inter-operability and the use of open systems for ensuring the compatibility of different equipment manufacturers.

Involved partners:

- TSOs
- Electricity retailers, ESCOs
- Power utilities
- Metering industry
- Automation and control system industry
- Telecommunication providers
- Research centers, universities and technology companies specialized in algorithm development, modeling, simulation studies, …
- Regulatory authorities
- DSOs

6.14 ENVIRONMENTAL IMPACT AND SOCIAL ACCEPTANCE OF TRANSMISSION FACILITIES

Project abstract:	Start date: 2010	End date: 2018

The public in general, the media, the NGOs, and most other social organizations are usually against the development of new high voltage infrastructures, especially new overhead power lines and substations, arguing that there are environmental and social negative effects derived from these facilities. This strong opposition is delaying and even stopping the planned development of the transmission grid.

It is absolutely necessary to gain social acceptance, to reduce the environmental impact and to be able to explain to the public what the real impact of the transmission facilities in these fields is, in order to be able to develop the high power infrastructures needed to achieve the goals of the electricity sector: massive integration of renewable energy, security of supply, the internal electricity market.

Project objectives:

The main objectives are to continue to improve the relationship between the transmission facilities and the natural and social environment where they should be deployed, in the following:

Environmental issues:

- Bird collision. To reduce or prevent bird collision against the earth wires.
- SF6 management. To find a replacement for SF6 gas in the high power equipment.
- Exposure to electromagnetic fields. To study the possible health effects of the exposure to power frequency electromagnetic fields generated by the high power infrastructures and ensure compliance with the exposure standards both for the public and for the workers.
- Audible noise. To reduce the audible noise generated by the high power infrastructures

On the social issues:

- Social acceptance. The objective would be to gain social acceptance. This could be achieved with a European guide to the construction of overhead power lines done by a group of leading experts in environmental and acceptance issues after a broad consultation process.
- Physical protection of the infrastructures. The infrastructures must be protected against a variety of potential dangers (natural catastrophes, terrorism, hackers, robbery, vandalism …) in order to ensure suitable system reliability and security of supply.

Project description:

The main environmental issues to be covered by the project are:

Bird collision. One of the most important environmental effects of the existing aerial power lines is the risk of bird collision against the earth wires. At present it is common practice to install specific devices on the earth wires that enable birds to see it at a distance far enough to be able to change their flight path and skip it. This device is called 'birdsaver'. The birdsavers must:

- Be useful for the kind of birds present in the surroundings.
- Be durable, in order to be installed for many years without losing their visual properties and without the risk of falling.
- Be as cheap as possible.
- Easy and cheap to install.

SF6. SF6 gas is used as an insulator in the high voltage equipment. This gas has an enormous greenhouse effect, so there is strong political and social pressure to stop using it. Some new gases or even a vacuum have been proposed to substitute the SF6 in high voltage equipment, but nowadays there are no good technical and economical alternatives so a serious effort must be made at the level of basic scientific research.

Electromagnetic fields. The possible health effects of the exposure to power frequency have been object of a crude social and scientific debate over the last few decades. Nowadays, the scientific consensus is that power electromagnetic fields do not have long-term effects (sickness); and that the only known effects are short-term effects that cease when the exposure ceases (like shocks), due to exposure above the recommended level. In this field it is necessary to:

- Advance our understanding of the biological interaction of this kind of electromagnetic field with cells and tissues, in order to determine if there could be any possible harm.
- Develop software to calculate the levels of power frequency electromagnetic fields generated by the high power lines and substations, based on the geometry, the amount of electrical current transmitted, the voltage, the weather conditions, etc.
- Establish accepted methodology to determine the value of the current density (parameter on which the exposure standards are based) inside the body due to exposure to high power electromagnetic fields.
- Develop software to evaluate whether the power frequency electromagnetic field that someone is exposed to at a certain point could exceed the limit value of the current density imposed by international standards.

Audible noise. The level of audible noise generated by high power lines and substations provokes most of the complaints of the public against existing infrastructures and the planning of new ones. This noise is due mainly to the corona effect because of the ionization of the air where the voltage gradient is very high, and also the magnetostrictive noise produced in the nucleus of the transformers because of the magnetic induction, plus the noise due to the ventilation. There are several research areas in this field:

- New materials, designs, geometry, etc. to reduce the corona effect on the surface of the high voltage equipment.
- Transformer designs to reduce audible noise due to magnetic induction.
- Better design of transformer ventilation.
- Passive methods to reduce the noise generated, for example by using acoustical barriers.
- Active methods to reduce the noise generated, for example, by using speakers to create a sound wave shifted 180º from the original noise so the two waves cancel each other out.

On the social side:

Social acceptance. The next steps would be:

- Nomination of a team of leading experts for construction, electrical engineering, permission procedures (lawyers), psychology, design, environment and landscaping.
- Investigation into existing extra-high voltage OHL types (tower configurations, cable types, footing types and parameters) and assessment of their environmental effect (electromagnetic fields, noise, visibility, etc.).
- Development of new and improved OHL types with fewer environmental effects.
- Public consultation process to have feedback on the proposals.
- Evaluation of the consultation process results of the public consultation and adaptation of the new OHL types in order to improve their environmental performance.
- Publication of European guidelines for the construction of new OHL based on all the information.

Physical protection of the infrastructures. There are several research areas:

- Evaluation of the possible threats to the transmission grid and their possible impact on the installations and society.
- Risk assessment and emergency plans for a combined attrack on different public services infrastructures
- Measures to prevent non-desired entrance into substations (fences, radars, etc.) to prevent robberies, terrorism and vandalism.
- Emergency pylons and substation equipment (for example mobile transformers) to substitute the affected installations in order to recover the demand supply in the affected areas in the minimum possible time.
- Emergency coordinated plans to repair damaged installations.
- Firewalls to prevent hacker attacks.

Expected deliverables, benefits and impact:

Regarding the **environmental issues,** some of the most relevant deliverables are going to be new models of birdsavers able to reduce the bird collision, durable and non-expensive, innovative methodologies to install the birdsaver devices, possible alternatives for SF6 as a high voltage insulator, biological laboratory research studies on the possible health effects of the 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 the workers in order to ensure compliance with exposure standards, new design features to minimize the generation of audible noise, passive acoustical barriers to reduce the audible noise near the source or where the public can be affected, active ways to eliminate the noise, etc.
The main benefits should be:

- Reduction of the number of bird collisions.
- Reduction of greenhouse gas emissions.
- Compliance with international exposure standards.
- Reduction of audible noise in areas where people live or work.

With regard to the **social acceptance and physical protection** of infrastructures, new and improved OHL designs, commonly adopted guidelines for the construction of new OHL, risk assessment of the possible threats to the transmission grid and their possible impact on the installations and society, emergency installations (power lines and substations), emergency plans to repair the damaged installations, etc. can be highlighted as the main deliverables

The expected benefits are:

- Improved relationship between TSOs and final customers (trust in TSOs). Valuable feedback and impulses from the 'outside world'. Clear increase in public acceptance, first in the selected grid areas. Enabling TSOs to significantly contribute to the European objectives for 2020 and beyond.
- Fast repair of damaged installations. Fast recovery of the demand supply. Protection against cyber-attacks.

Technology involved:

Environmental issues:

- High voltage insulation.
- Biological laboratory research.
- Computational techniques to calculate the level of EMF generated by high power frequency infrastructures and to evaluate the exposure of the public and the workers in order to ensure compliance with exposure standards.
- Equipment design.
- Acoustical barriers.
- Noise elimination.

Social acceptance and physical protection of infrastructures:

- Besides all aspects of OHL technology,, all social acceptance-related research and development areas are covered.
- Mobile emergency installations.
- Firewalls against cyber-hackers.

Involved partners:

- TSOs
- Power equipment manufacturers
- Research providers

7 ANNEX 2: R&D PROJECTS ON THE PAN-EUROPEAN TRANSMISSION ISSUES FOR THE COMING THREE YEARS

Project	TSO		DSO		Manufacturer		GenCo		Other
	Partner	Impact	Partner	Impact	Partner	Impact	Partner	Impact	Partner
7.1. OPTIMATE	5	High	0	Low	0	Medium	0	Medium	7
7.2. TWENTIES	6	High	0	Low	3	Low	2	Medium	2
7.3. EcoGrid EU	3	Medium	3	High	4	High	1	High	4
7.4. Substation 61850	Yes	High	Yes	Medium	Yes	Medium	Yes	Low	Yes
7.5. Almacena	Yes	High	No	Low	Yes	Medium	No	Low	Yes
7.6. 220 kV SSSC device for power flow control	No	High	No	Medium	Yes	Low	No	Low	Yes
7.7. Acceptance of overhead lines	Yes	High	No	High	Yes	Low	No	Low	Yes
7.8. S.I.TR.E.N.	Yes	Medium	No	Medium	Yes	Medium	No	Low	Yes
7.9. INTEGRINET	Yes	Medium	No	Medium	Yes	Medium	No	Low	Yes

7.1 OPTIMATE

Workstream: 12	September 2009 - August 2012
Project web:	

Involved partners:

TSOs: ELIA (BE), EnBW (DE), REE (ES), RTE (FR) and 50Hertz Transmission GmbH (DE).
Other: ARMINES (FR) , K.U.Leuven (BE), DTU-RISOE (DK), Uni. of Madrid-Comillas (ES), Uni. of Manchester (GB), SEAES -University of Paris (FR) and 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 a pan-European level.

Objectives:

The project aims to: develop an open simulation platform able to mimic existing and future intra-day and balancing markets involving classical and intermittent generation. Demonstrate that the above platform can help TSOs compare new market rules and tools capable of integrating massive intermittent generation into electricity markets, while keeping the European power system secure.

Description:

Five TSOs together with seven RTD performers propose a three- year research and demonstration project to compare the pros and cons of new market designs aimed at the integration of massive intermittent energy sources dispersed in several regional power markets. Under the technical coordination of RTE, they will implement a novel network/system/market modeling approach to provide the consortium with an open simulation platform 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 behavior of fully rational players first, and next the impact of non-optimal behaviors using agent modeling. Results will be compared (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 towards the TSO community within EU27 and beyond, with dedicated training to accompany the take-up of the simulation platform. An exploitation agreement is proposed 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 to be addressed in the next ten 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. A more formal link with regulatory bodies when addressing pan-European electricity market issues over the next ten years.

Project costs:

Project cost: €4.2 million - Project funding: €2.6 million

7.2 TWENTIES

Workstream: 5	January 2010 - December 2012 (if approved)
Project web:	

Involved partners: TSOs: Elia (BE), Energinet.dk (DK), RTE (FR), 50Hertz Transmission GmbH (DE), Tennet TSO (NL) and 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 research, development and demonstration (RD&D) project addresses the ENERGY 2009.7.1.1 call (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, thus giving Europe the ability to respond to the increasing share of renewables in its energy mix by 2020 and beyond, while keeping its present level of performance reliability.

Objectives:

1. 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.**
2. 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 having **high scalability** potential.
3. To provide the critical building blocks of 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.
4. To demonstrate that adequate coordination mechanisms between off-shore wind farms and hydro power capacity available in Norway through an existing HVDC link bring viable solutions to securely control the power balance during off-shore storm passages.
5. To demonstrate that adequate coordination mechanisms between dynamic line rating, power flow controlling devices and wide area monitoring systems (WAMS) bring more flexibility to the electrical system within affordable capital and operational costs.
6. To demonstrate that alternative operation parameters provided by dynamic line rating and FACTS technology applied on a regional basis do bring flexibility, do enhance security and do expand the capability of the network to evacuate more wind.
7. To assess the impact, barriers and solutions needed to scale up the demonstration results.
8. To assess the benefits of replicating the obtained results throughout the entire pan-European interconnected transmission system.
9. To disseminate the obtained results widely enough for an early take-up of sales and replication rules by the stakeholders.

Description:

A group of six TSOs with two generator companies, five manufacturers and research organizations, propose 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 technology (most of them available from manufacturers) coupled with innovative system management approaches. The contribution of wind energy to the system will show how 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. 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). Off-shore wind farms are addressed from a security viewpoint. Secure HVDC meshed networks will be validated in France using simulations and full-scale experiments of two different types of HVDC circuit breaker technology. Off-shore wind farm shut-downs under stormy conditions will be demonstrated in Denmark using the world's largest off-shore wind farm with balancing power provided by the Norwegian 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 in Contract negotiation stage. Approximate project costs €58 million. Estimatec EC contribution: €31 million.

7.3 ECOGRIDEU

Workstream: 13	January 2011 - Late 2014 (if approved)
Project web:	http://www.eu-ecogrid.net/

Involved partners:

TSOs: Energinet.dk (DK), and two more TSOs will be invited.
DSOs: Østkraft (DK), VKW-Netz and two more DSO will be invited).
Other: IBM Zurich (CH), Siemens (DE), DTU-CET (DK), Sintef (NO), MDT Analyses (NO), VITO (BE), EnCT (DE), AIT (AT), Areva (FR) and Alstom Power (FR) are invited.

Abstract:

The project description is being prepared and will be applied for in FP7-EN- 2010-2/7.1-1. Drivers in the project are: full-scale deployment and operation of all smart grids 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 high penetration of renewable energy sources and active user participation based on real-time price signals enabling small and medium-size distributed energy resources to contribute actively to system balancing and enabling optimized operation and control of the distribution grid. The integration of more than 50 per cent RES in the power system – mainly coming from fluctuation 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 very high 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 renewable energy sources, which are representative of future European distribution systems, especially with high level of wind power.
The EcoGrid EU smart grids solution is going to be integrated in 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 EcoGrid Europe project's benefits and impact are, in short: a possible new market model based on real-time prizing and active demand response. High degree of end-user involvement of automatic technology to balance local RES production from fluctuating 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 grids applications, for the benefit of all of Europe. Development and deployment of new ICT technology. Valuable contribution to achieving the EU 20-20-20 goals, when demonstrating a grid with more than 50 per cent RES.

Project costs:

EU FP7 call March 2010 call will be applied for funding.
Project costs: €22 million – possible project funding €12-14 million.

7.4 SUBSTATION 61850

Workstream: 6	Start date: Nov 2009	End date: Dec 2015

Project abstract:

This project is oriented towards introducing the IEC 61850 standard into a substation.
Within this project it is expected to develop new equipment based on the standard and to fully implement it on a real substation. This project implies the first step towards a digital substation: smart grid at a substation level.
The acceptance of the IEC61850 standard in the substation results in a cultural change and has a huge impact on the engineering, construction and substation maintenance, fostering the efficiency of all these processes.

Project objectives:

Use the standard IEC61850 as a means to improve the design, maintenance and operation of the substation automation systems.
The final goal of the project is to install a complete IEC61850 system in the field.

Project description:

The project is organized in two stages. The first one starting in November 2009 and lasting until 2011 and the second one finishing in 2015.
The first activity to be done is the feasibility study (technical and economical) of the deployment of the complete IEC61850 (substation bus and process bus).

- Definition of a normalized substation solution based on IEC61850 in order to be able to deploy it systematically.
- To achieve interoperability between different control and protection equipment in a substation.
- Design and definition of homogeneous solutions not dependent on provider technology (for engineering, maintenance, etc.)
- Improve system security, increasing current redundancy levels.

Expected deliverables, benefits and impact:

- 61850 mock-ups and prototypes of:
  - Protection and control devices.
  - Current and voltage transformers.
  - Disconnectors and circuit breakers, advance protection and control.
- Test tools,
- Digital Substation

Milestones:

Stage I	Description	Date
H1	Substation Bus	Jan 2010
H2	SCI 61850 – Phase I	Sep 2010
H3	Technical and economical feasibility study of the complete solution of IEC61850 (substation bus and process bus).	Sep 2011
Stage II	Description	Date
H1	Agreements with providers for the development of new equipment.	Jan 2012
H2	Process bus.	Sept 2012
H3	Software and equipment development.	Dec 2013
H4	Software and equipment approval.	Dec 2014
H12	Conclusions.	Jun 2015

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, advance protection and control.
Involved partners:
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 the involved technological partners. It is expected to collaborate with all main REE providers: equipment, tools, test, telecommunication, homologation labs.
Project costs:
The project has an overall approximated budget of €4,2 million.

7.5 ALMACENA

Workstream: 2	Start date: Nov 2009	End date: June 2011

Project abstract:

Demonstration of an electrochemical storage system in a TSO network for the system operation.

Project objectives:

- Demonstration of an electrochemical battery → Installation in the field (in a transmission substation) of 1 MW storage device.
- Assess the potential benefits of using electrochemical storage systems to provide system stability services to the TSO.
- 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.

Project description:

Currently, energy storage systems seem to be promising technology for power systems. However up until now most of the experiences have been oriented towards providing services at a distribution or generation level and not at a transmission and system operation level. The objective of this project is to examine the existing energy storage technology, to study its technical and economical feasibility for system applications in network flexibility and system stability.

The project is organized into five blocks:

- Definition: application definition, technology selection, selection of the location, 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:

- Real technology feasibility analysis (at least these kinds of technology will be considered: NaS, Redox Vanadium, Ion-Lithium).
- Specification of the expected battery behavior for the selected application.
- Spec. for control system.
- Installed battery prototype.
- Regulatory proposals.

Milestones:

	Activity	Date
H1	Requirement specification	Mar 2010
H2	Battery purchase order	Jun 2010
H3	Equipment installation	Mar 2011
H4	Conclusions	Dec 2011

Technology involved:

Grid flexibility.

New network management and control.

Involved partners:

Besides REE, the project needs the contribution of:

Power electronics providers/developers

Telecommunication providers/developers

Battery providers

R&D centers

Project costs:

The project has an overall estimated budget of €4,000,000

7.6 REEDES2025: 220 kV SSSC DEVICE FOR POWER FLOW CONTROL

Workstream: 3	Start date: July 2009	End date: December 2012

Project abstract:

In the project described in this form it is foreseen to use a FACTS 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 to solve certain overloads or to curtail wind production . The first one causes a reduction of the safety margin of the network, whereas the latter results in economic damage to the wind producers.
By incorporating a FACTS in one of the affected 220 kV lines, it is envisaged that the number of these kinds of non-desired operations will be significantly reduced.

Project 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 the electricity demand, causes power flows through transmission lines to vary very much 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, renewable energy generation sources usually make poor use of the network, with a low number of hours at peak-power operation, and its geographical dispersion forces changing flows depending on the location of the primary energy source. Therefore, situations in which some of the lines are operated at their peak load, while some 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.

Project description:

In the project described in this paper it is foreseen to use a static synchronous series compensator (SSSC) to prevent overload situations.

The SSSC operates by injecting voltage controlled in 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 that current is leading or lagging, respectively. The SSSC in this application has been 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 loaded.

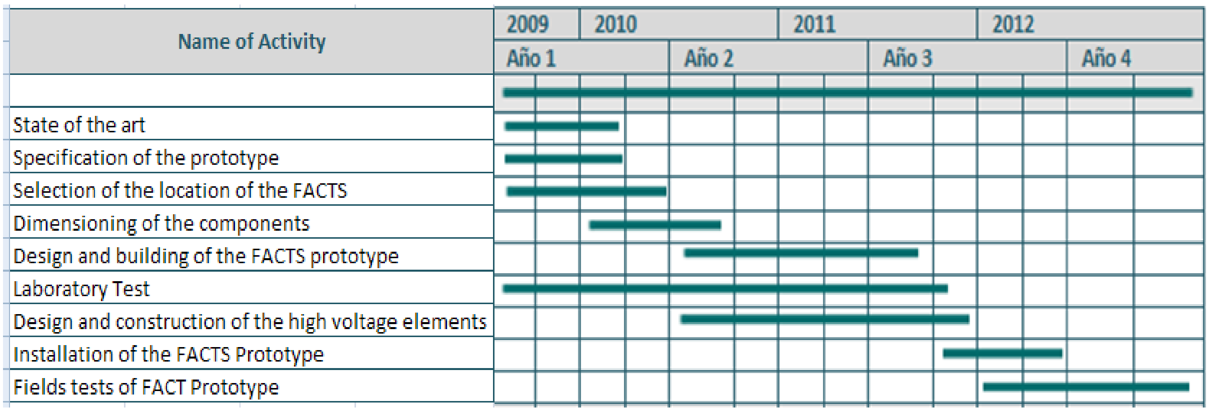
Although the power rating of a SSSC is just a fraction of that flowing through the network, it is comparatively large, of a few tens of MVAR. The SSSC is connected in series with the distribution network through the primary windings of a coupling transformer, whereby its secondary windings are fed by a power electronic converter. That converter is of the voltage sourced converter (VSC) type, converting the dc-voltage stored in a capacitor bank, or dc-bus, into ac voltage, variable in phase and magnitude. It is achieved through the combination of several inverter modules, based on the existing Ingeteam MV700 range, connected in either series or parallel to obtain the required power. They are implemented using state-of-the-art IGCT (Integrated Gate Commutated Thyristor) semiconductor technology. These high power-medium voltage devices, which belong to the thyristor family, have an optimized gate with an integrated driver, making it possible to switch frequencies in the range of 500

Hz.

The initial studies consider the use of two different modulation strategies to obtain the converter output voltage: PWM (Pulse Width Modulation) 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, about fifty 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 by-pass, to protect the VSC converter. The by-pass is implemented in this application by using a combination of thyristor semiconductor devices.

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

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



Expected deliverables, benefits and impact:

- Document of specifications and requirements.
- Simulation results.
- Prototype installed.
- 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.

Involved partners:

Industrial Partners: Ingeteam T&D and Ingeteam Technology.
Technological Partners: Universidad Politécnica de Madrid, Universidad de Mondragón.

Project costs:

€10 million

7.7 ACCEPTANCE OF OVERHEAD LINES

Workstream: 14	Start date: 2010	End date: 2013

Project abstract: the step changes addressed

In order to meet the European objectives for the integration of renewable energy sources' (RES), contribution to the internal electricity market (IEM) and the maintenance the security of electricity supply (SoS), a significant increase in social acceptance for the construction/erection of overhead lines (OHL) is needed. Leading experts in OHL, environmental and acceptance issues and design will compose a European guideline for the erection of future OHL based on an overall consultation process.

Project objectives:

Considering the ongoing RES and especially massive wind power development in parts of Europe, but also the TSO obligation to ensure the grid access needed by classic market participants, and considering the respective European-wide trading challenges, it must be emphasized that due to a local/regional lack of adequate demand the energy has to be transmitted through a very limited number of transmission lines over increasing distances.

Nevertheless, the completion of the required grid measures turns out to be more and more difficult due to an increasing lack of social acceptance, i.e. by affected people, NGOs and local politicians. Thus the duration of the completion of transmission grid extension measures increases from a few years to more than a decade. Some of the urgently needed grid measures are even threatened with being stopped altogether. Besides the problem that new OHL projects are not acceptable especially from the point of view of many affected property owners, the identification and construction process itself is not sufficiently transparent for the 'outside world'. But to fulfill the EU and national climate protection targets, and also for free grid access and free cross-border trading, while maintaining an appropriate level of security of electricity supply, a massive but efficient grid extension mostly by OHL is unavoidable. This challenge is the motivation for this project.

Project description:

<u>Phase 0:</u> Nomination of team of leading experts for

- Construction
- Electrical engineering
- Permission procedures (lawyers)
- Psychology
- Design
- Environment
- Landscaping

<u>Phase 1:</u> Investigation of existing extra-high voltage OHL types

- Investigation of existing tower configurations and parameters, OHL cable types and parameters, footing types and parameters.
- Assessment of the electromagnetic fields and environmental factors.
- Assessment of the visibility (also painting effects).
- Assessment of investment and maintenance costs and other maintenance characteristics.
- Categorization of landscapes and experiences concerning acceptance.
- SWOT analysis/value benefit analysis with special focus on the potential for smooth building of the OHL

<u>Phase 2:</u> Development of new/improved OHL types

- Development of new/improved OHL types based on the *OHL Assessment Catalogue.*
- Documentation of the technical OHL and electromagnetic field parameters and environmental factors comparable to Phase 1 and also compliance with binding standards regarding (if necessary) proposals for adaptations of these standards.
- Estimate of the investment and maintenance costs and other maintenance characteristics.

• Visualization of dependence of the landscape categories defined in Phase 1. • SWOT analysis/value benefit analysis with special focus on the potential for smooth building of the OHL. Phase 3: Public consultation process • Development of an efficient consultation strategy and suitable documents. • Selection of three OHL projects with low degree of acceptance. • Modeling of transportable scaled-down prototype models of the new/improved OHL types including landscapes for visualization purposes. • Public consultation process in selected grid areas with existing/expected strong acceptance problems (e.g. through questionnaires, public presentations and discussions of the scaled-down prototype models, newspaper campaigns etc.) Phase 4: Adaptation of the developed OHL types • Evaluation of the feedback results from the public consultation. • Adaptation of the developed new/improved OHL types according to the consultation results and finalizing draft *OHL Assessment Catalogue Annex.* Phase 5: Study report • Providing an OHL study report as a (European) guideline for the building of future OHLs under consideration in the *OHL Assessment Catalogue* including an annex considering an assessment of technical, economical, legal and regulation aspects and the public consultation results. Updating the visualization documents for further public consultation activities.
Expected deliverables, benefits and impact:
Deliverables: • *OHL Assessment Catalogue.* • Different new/improved OHL types to OHL *Assessment Catalogue Annex.* • OHL 2020 study report as a European guideline for the construction of future OHLs. Benefits and Impact: • Improved relationship between TSOs and final customers (trust in TSOs). • Valuable feedback and ideas from the ‘outside world’ • Clear increase in public acceptance, firstly in the selected grid areas. • Enabling TSOs to significantly contribute to the European objectives for 2020 and beyond.
Technology involved:
Besides all aspects of OHL technology, all social acceptance-related research and development areas are covered.
Involved partners:
TSOs, engineering companies, OHL manufacturers, universities and other leading consultants, Renewables Grid Initiative (RGI) (so far with the NGOs WWF and Germanwatch), other NGOs.
Project costs:
€2.5 million (first estimate)

7.8 S.I.TR.E.N.

Workstream: 1	Start date: 2010	End date: 2013

Involved partners:

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 **S**istemi **I**ntegrati di **TR**asmissione **E**lettrica **N**azionale* (Planning and Operation of National Integrated Transmission Grids") is a project aiming at developing 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 related to O&M, Quality of Supply and EMF phenomena. The project is carried out in close cooperation by Terna, the Italian TSO, ITALCERTIFER, the engineering branch of the Italian Railways Company, and some universities, mainly specialised in EMF analyses and grid stability issues.

Objectives:

Evaluate possible developments of the National Transmission Network (RTN) through a better integration and synergy between Terna grid and the Italian railway network.

Description:

A)Analysis of the 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.
- Adequacy and static security analysis (N-1 criterion) on the expected planned network, which aims at finding the critical conditions and establishing the necessary reinforcements.

B)Analysis of the nodal disturbances, evaluation of the reduction systems, probable metrics and field measures certification:

- Evaluation of technical problems at the interface between the RTN and the electric railway network, mainly related to electromagnetic effects.
- Research on techniques and technology capable of reducing the effects of the above mentioned problems and implementation of related measurement methods.
- Introduction of appropriate methodologies to detect, analyse and measure grid disturbances.

C)Control strategies and related technology:

- Specification of methodological, operational and technological measures for integrating the various available transmission systems with Distributed Generation systems.
- Achievement of improved overall exploitation of the transmission capacity of each network and a more effective dispatching of DER.

Expected deliverables, benefits and impacts:

Comparison of the solutions conceived for planning and operation of the system developments system and evaluation of the related benefits:

The technological solutions found will be compared according to the following criteria:

- Technology effectiveness;
- Costs related to the implementation, operation and maintenance;
- Benefits brought about in the operation of the transmission systems.

Project costs:

Project cost: 2 million €

7.9 INTEGRINET

Workstream: 1	Start date: 2010	End date: 2013

Involved partners:

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

Abstract:

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

Objectives:

•Research in new technologies for laying underground cables located along roads or motorways

•Finding solutions for problems related to compatibility between the two infrastructures (electricity and road).

Description:

Activities to be carried-out and resources involved:

•State of the art assessment on integration of cable lines and road and motorway infrastructures.

•Feasibility criteria on integration, based on geometrical compatibility, and specification of types and modalities of cable installation.

•Current practices in cable transportation and necessary developments for integrating in a synergic way power and motorway infrastructures.

•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 of line compatibility with ventilation systems installed in tunnel.

•Assessment of external effects related 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 of monitoring systems and identification of strategies to obtain optimal maintenance and maximizing the coordination between the motorway operator and the electric line operator.

•Analysis of the compatibility with complementary technological services.

Expected deliverables, benefits and impacts:

Expected benefits for users of the National Electrical System:

•Facilitating the construction of new lines allows power system to get benefits from the elimination of congestions on the power system and from the following possibility of more efficient energy flows on the grid.

•In the case of interconnections between different countries, the gained increase of Total Transfer Capacity (TTC) 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.

Project results are finalized to find technical solutions of practical applicability, to be used both for preliminary and detailed design 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 the expected savings both in terms of cost and time.

Project costs:

Project cost: 4 million €

8 ANNEX 3: PAST OR ONGOING EU-SUPPORTED R&D PROJECTS ON PAN-EUROPEAN TRANSMISSION ISSUES

This is a list of examples on past or ongoing EU-supported R&D projects. The list also contains some projects that are ongoing and about to start in 2010 or 2011. Only projects with a substantial impact on more than one TSO are present. The list is a snapshot from late 2009. Therefore, there may be projects that are not on the list. Additional projects could be presented in the next edition.

The following is a description of the projects. The short description is mainly based on the information about the projects that is available from their websites. If there should be inaccurate information it will be corrected in next edition.

Project	TSO		DSO		Manufacturer		GenCo		Other
	Partner	Impact	Partner	Impact	Partner	Impact	Partner	Impact	Partner
8.1. EWIS	15	High	0	Low	0	Low	0	Medium	0
8.2. TradeWind	15	High	0	Low	0	Medium	0	High	9
8.3. RELIANCE	8	High	1	High	0	Medium	1	Low	8
8.4. WindGrid	2	High	2	Low	2	Low	1	High	3
8.5. iS-POWER	3	Low	1	High	1	Low	0	Medium	1
8.6. SafeWind	4	High	1	Low	0	Low	2	Medium	17
8.7. REALISEGRID	4	High	0	Low	0	Medium	0	Medium	16
8.8. SUSPLAN	6	High	0	Medium	0	Low	10	High	14
8.9. SUPWIND	2	High	0	High	0	Low	0	High	5
8.10. PEGASE	8	High	0	Low	0	High	0	High	12
8.11. FENIX	2	High	2	High	7	Low	1	Medium	7
8.12. Anemos.Plus	4	High	2	High	0	Medium	3	High	12
8.13. DESIRE	0	Medium	0	High	1	Medium	0	Low	9
8.14. ADDRESS	0	Medium	4	High	5	High	2	Medium	12
8.15. OFFSHORE GRID STUDY - The Irish Vision	1	High	0	Low	1	High	0	Medium	0
8.16. Investigating the Impact of HVdc Schemes in the Irish Transmission Network	3	High	0	Medium	1	Medium	0	Low	0
8.17. TEPCO study	2	High	0	Low	1	Medium	0	Low	0
8.18. Kriegers Flak	3	High	0	Low	2	High	0	High	3
8.19. COBRA	2	High	0	Low	2	Medium	0	High	3
8.20. ICOEUR	3	High	0	Low	2	Medium	0	Medium	15

8.1 EWIS (The European Wind Integration Study)

Project time:	June 2007 - October 2009:
Project web:	http://www.wind-integration.eu/

Involved partners:

Stakeholder-oriented project performed by fifteen 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) and transpower (DE).

Abstract:

Initiated by TSO associations in 2005, after the German DENA study. Up to 2007 funded by TSOs. 2007-2009 funded by DG-TREN 100 per cent of the costs.

Objectives:

- Investigating all relevant network issues arising from wind integration.
- Producing quantified options to accommodate wind (reliability, quality of power supply, integration costs) between 2008 and 2015.
- Recommendations for manufacturers, network operation and development, market and regulations up to 2015.

Description:

The European Wind Integration Study (EWIS) is an initiative established by the TSO associations of the European transmission system operators in collaboration with the European Commission. It aims to work with all the relevant stakeholders, especially representatives of wind generation developers.

The study will use results from detailed network and market models of the European transmission system (including all four synchronous areas like mainland Europe, the Nordic countries, Great Britain and Ireland) for scenarios representing immediate and longer-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, the study will be seeking arrangements that will make the best use of the pan-European transmission network to deliver the benefits of wind generation across Europe.

Expected deliverables, benefits and impact:

The scope of work covers all the detailed technical, operational, market and regulatory aspects related to the integration of wind power in Europe on a large scale between now and 2015. Alternative generation development that will achieve 2020 targets will be assessed considering the estimates already developed by the TradeWind project. This approach will fit the best to ensure that EWIS results and findings address all network integration aspects needed to achieve Europe's 2020 renewable energy targets. A draft interim report about the approaches and methodologies being taken 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 (EC) in July 2008.

Project costs:

- Up to 2007, funded by TSOs.
- 2007-2009, funded by DG-TREN (100 per cent of the costs).
- Project cost: €4.04 million – Project funding: €4.04 million

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

Project time:	Nov 2006 - Feb 2009
Project web:	http://www.trade-wind.eu/

Involved partners:

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. fifteen TSOs.

Abstract:

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

Objectives:

- Issues raised by large-scale, cross-border wind power transmission and market design at European level.
- Need for transmission upgrades on-shore and off-shore (forty-two on-shore interconnections saving in total system operation costs €1,500 million/year, justifying investments in the order 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 Intelligent Energy-Europe Program. The project addressed one of the most challenging issues facing wind energy: its maximal and reliable integration in 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 form 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 was aimed at facilitating the dismantling of barriers to the large-scale integration of wind energy in European power systems, on transnational and European levels, and to formulate recommendations for policy development, market rules and interconnector allocation methods to support wind power integration.

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 gave answers to questions these had raised. The supply of Europe’s islands was also addressed.

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

Expected deliverables, benefits and impact:

Final report is available from website. http://www.trade-wind.eu/fileadmin/documents/publications/Final_Report.pdf

Project costs:

Funded under the EU’s Intelligent Energy-Europe Program.
Project cost: € 1.748 million – Project funding (50 per cent)

8.3 RELIANCE

Project time:	2005 - September 2007
Project web:	http://www.ca-reliance.org/

Involved partners:

Elia (BE), ELES (SI), Energinet.dk (DK), CEPS (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) and Uni.Manchester (GB).

Abstract:

RELIANCE (CooRdination perspectives of the European transmission network research activities to optimize the reLIAbility of power supply, usiNg a systemiC approach, involving growing distributed generation and renewable energy markEts).

RELIANCE is a Coordination Action of the European transmission network research activities. The project is funded by the European Commission Sixth Research and Technological Development Framework Programme. Background

- Implementation of a European electricity market.
- Wider network problems due to energy supply diversification.
- Need to shape up the existing power system research capacities.
- Need to expand the exchange of information and collaboration between European electricity network operators.

Objectives:

Identify the challenges to be faced by the pan-European network up to 2030. Design a research roadmap to 2030. Propose a framework for a/the European Power System Research Organization. Address European electricity transmission challenges. Involve all power system stakeholders. European focal point for research in electricity transmission. Funding and organizational schemes to perform the R&D tasks.

Description:

A group of eight European Transmission System Operators (TSOs), one power producer, one Distribution System Operator (DSO) and several Research Centers, at the initiative of Tractebel Engineering (SUEZ) have gathered and shared a common understanding on the needs to resume Research and Technology Development (RTD) on power system issues in Europe. They agree on a common analysis summarized as follows:

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

The capture of wind energy on a large scale as part of the supply diversification, as it is already implemented and its huge further development, as already decided, lead to major risks: power imbalance and unpredictable load flows.

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

Expected deliverables, benefits and impact:

Final report is available from website: http://www.ca-reliance.org/download/download_index.htm

Project costs:

Coordination action funded by EC DG Research (2005-2007). Reliance Coordination Action over two years. Project cost: €2.2 million

8.4 WINDGRID (WIND ON THE GRID)

Project time:	December 2006 - December 2009
Project web:	http://www.windgrid.eu/

Involved partners:

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

Abstract:

Wind on the Grid, an initiative supported by EU Commission-DGTREN, is a project 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 its 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 its planning, control and operation in a competitive market. Results by end 2009.

Description:

Wind on the Grid is a project 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 its planning, control and operation in a competitive market. Europe's energy supply system is heavily dependent of fossil fuels imported from third party countries. The energy consumption of the members of the European Union is expected to grow during the next years at a reasonable pace, leading to a higher dependence on imported fossil fuel as well as a rise in the volume of CO2 emissions.

In order to alleviate the European Union's dependence on external sources of energy supply, achieve CO2 reduction commitments and improve quality of life both within the European Union and globally, the European Union has adopted several policies and a strategic approach to encourage the use of renewables, setting a target of 12 per cent of market share for this technology in total primary energy consumption for 2010. In addressing these objectives, the use of wind farms appears to be efficient technology. The recent developments in this technology, making it commercially competitive, have resulted in the high number of wind farms, increasing 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 in 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: design, development and demonstration of an efficient wind farm energy management system: wind farm cluster management system. Design, development and demonstration of security tools to integrate large-scale wind farms into high-voltage electricity networks. Demonstration of the economic attractiveness of the electricity supply system with a significant penetration of wind power, and development of regulatory market designs/conditions for the integration of the future network . Practical test and assessment of the above-mentioned 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

8.5 IS-POWER (THE PROJECT DEALS WITH ISOLATED POWER SYSTEMS)

Project time:	October 2007 - April 2010
Project web:	http://www.ispower.eu/

Involved partners:

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. The project deals with isolated power systems; that is, those systems not interconnected with other neighboring systems by tie-lines and thus restricted to using their own resources for the maintenance of synchronous operation.

Objectives:

IS-Power aims to develop technical and regulatory frameworks to improve the performance of power systems (reliability and supply guarantee) and to make the integration of renewable energies and other distributed generation in isolated areas (insular systems) easier.. Results by mid 2010.

Description:

Insular isolated territories have difficulties in terms of their natural resources and biodiversity, with the expansion of power grids and the installation of new capacity for conventional electrical generation. Geographical singularities strongly influence insular power systems' management. Technical, economic and operative difficulties to interconnect these power systems with continental systems are found when managing insular power systems.
The aim of IS Power is hence targeted at the study of the sustainable development of the insular systems' economies required the efficient use of natural resources available in these territories and efficient integration and management in their electricity grid. Based on cooperation and knowledge sharing, this project proposes to develop technical and regulatory frameworks to improve the performance of these energy systems (reliability and supply guarantee) and to make the integration of renewable energies and other distributed generation easier.

Expected deliverables, benefits and impact:

IS-POWER Dissemination Plan pursues the following objectives:

- Communicate to other technical and scientific 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.
- Prepare recommendations regarding improvements to the management of electricity grids placed in isolated electrical systems with the expectation of having to accommodate large-penetrations of RES for the following institutions: European Commission, European energy industry players, energy authorities, standardization bodies.

Project costs:

EU-funded project under FP6 – Sustainable Energy Systems
Project cost: € 3.1 million – project funding: €1.67 million

8.6 SAFEWIND

Project time:	September 2008 - August 2012
Project web:	http://www.safewind.eu/

Involved partners:

TSOs: RTE (FR), Energinet.dk (DK), EirGrid (IE) and 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), Uni. Oxford (GB), Uni. Computens Madrid (ES), Uni. Carlos Madrid (ES), DEI (GR), Meteo France (FR), teri (India) and Uni. Athens (GR).

Abstract:

Multi-scale data assimilation, advanced wind modeling and forecasting with emphasis on extreme weather situations for a secure large-scale wind power integration.
The aim of SafeWind is to substantially improve wind power predictability in these challenging or extreme situations. Going beyond this, wind predictability is considered a system parameter linked to the resource assessment phase, where 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
- optimized ensemble forecast systems applied to wind power prediction.
- Novel methods for wind power forecasting and extremes.
- Wind resource assessment vs. predictability.
- Assessment of benefits from new measuring technology for better estimation of external conditions, resource assessment and forecasting.
- Demonstration of operational benefits.

Description:

The integration of wind generation into power systems is affected by uncertainties in the forecasting of expected power output. Misjudging meteorological conditions or large forecasting errors (phase errors, near cut-off speeds etc), are very costly for infrastructures (i.e. unexpected loads on turbines) and reduce the value of wind energy for end-users. The state of the art in wind power forecasting focused so far on the 'usual' operating conditions rather than on extreme events. Thus, the current wind forecasting technology presents several strong bottlenecks. End-users urge for dedicated approaches to reduce large prediction errors or predict extremes on a local scale (gusts, shears) up to a European scale as extremes and forecast errors may be propagated.

Expected deliverables, benefits and impact:

The project will develop: new forecasting methods for wind generation focusing on uncertainty and challenging situations/extremes. Models for 'alarming': providing information for the level of predictability in the (very) short term. Models for 'warning': providing information for the level of predictability in the medium-term (next day(s)).

Project costs:

EU FP Energy, 7th. FWP

Project cost: €5.58 million – Project funding: €3.99 million.

8.7 REALISEGRID

Project time:	September 2008 - February 2011
Project web:	http://realisegrid.erse-web.it/

Involved partners:

The project is coordinated by ERSE (ENEA - Ricerca sul Sistema Elettrico) (IT), former CESI RICERCA
TSOs: TenneT TSO (NL), Verbund APG (AT), Terna (IT) and RTE (FR)
Other: TECHNOFI (FR), Politecnico di Torino (IT), JRC (BE), Observatoire Méditerranéen de l'Energie (FR), Vienna Uni. (AT), Uni. Delft (NL), Uni. Dortmund (DE), R&D Center for Power Engineering (RUS), PRYSMIAN (IT), KANLO (FR), riecado (AT), Uni. Dresden (DE), Univerza v Ljubljani (SI), ASATREM (IT), Uni. Manchester (GB).

Abstract:

REALISEGRID - REseArch, methodoLogies and technologieS for the effective development of pan-European key GRID infrastructures to support the achievement of a reliable, competitive and sustainable electricity supply.

The mission of REALISEGRID, a new project co-funded by the European Union (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 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 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 implement 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.

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

Expected deliverables, benefits and impact:

The expected output of the project is fourfold: implementation of the framework to assess the benefits provided by transmission infrastructure development to the pan-European power system. Preparation of a roadmap for the incorporation of new transmission technology in the electricity networks. Analysis of impact of different scenarios on future electricity exchanges among European countries. 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

8.8 SUSPLAN (PLANNING FOR SUSTAINABILITY)

Project time:	September 2008 - August 2011
Project web:	http://www.susplan.eu/

Involved partners:

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) and Sofia EDC (BG).
TSOs involved in the Advisory Board: REE (ES), Amprion (DE), 50Hertz Transmission GmbH (DE), Statnett (NO), EnBW TNG (DE) and Terna (IT)

Abstract:

SUSPLAN is a project initiated in 2008 under the European Union's 7th Framework Program, and is sponsored by the Directorate General Transport and Energy (DG-TREN). SUSPLAN seeks to bring awareness to 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 renewable energy sources (RES) by 2030-2050 within a Europe-wide context. Against this background, SUSPLAN has a multi-dimensional approach by assembling legislative, policy, business, economic, environmental, and energy professionals together with a view towards addressing the following objectives:

- Develop grid-based renewable energy sources integrated scenarios for national, regional and European levels.
- Compare results from each scenario to identify the optimal path for RES integration, in consideration of security issues and economic competitiveness.
- Establish the institutional capacity and knowledge based on which the subsequent SUSPLAN findings or recommendations are implemented.
- Publish SUSPLAN work for decision-makers and related professionals on national and European levels via workshops, reports, and online resources.

Description:

The overall impact of SUSPLAN is contribution to a substantially increased share of renewable energy sources (RES) in Europe at an acceptable level of cost, thereby increasing security of supply and 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 as a support for decision-makers at regional as well as pan-European level. The guidelines shall consist of strategies, recommendations, criteria and benchmarks for political, infrastructure and network decision-makers and power distributors with a time perspective 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 evaluates the relationship between national, regional and other influences across Europe on renewable energy sources integration.

Project costs:

EU FP7 Energy - 7th FWP

Project cost: €4.79 million – Project funding: €3.42 million

8.9 SUPWIND (Decision Support for Large-scale Integration of Wind Power)

Project time:	October 2006 - September 2009
Project web:	http://supwind.risoe.dk/

Involved partners:

TSOs: HTSO (GR) and Energinet.dk (DK)
Other: Uni. Duisburg (DE), DTU-RISOE (DK), Uni. Vienna (AT), IER (DE) and 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 – Management of electricity grids linked to large-scale decentralized wind power generation. Large-scale integration of renewable energy supplies.

Objectives:

The project has the following objectives: Demonstrate the applicability of decision support tools based on stochastic analysis and programming for operational management of grids and power plants.
Demonstrate the applicability of strategic analysis tools for decision support for long-term management of grids. 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 of installed capacity of wind power, namely the handling of fluctuating electricity production. Recent projects such as WILMAR have developed optimization models that endogenously include the information contained in wind power production forecasting to make decisions that are more robust towards the fluctuations in the 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 transmission system operators (TSOs) and other relevant actors in both the day to day operation of the power system and the long-term planning of investment in transmission lines and production assets.

Expected deliverables, benefits and impact:

The project contributes to securing the operation of the European electricity supply system and to developing it further in view of a sustainable energy future. Through the development of detailed simulation and optimization models and their application, the project makes it possible to identify system configurations and operation modes which best fulfill the concurrent and partly conflicting objectives for sustainable electricity systems: 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.

Project costs:

Project completed. EU support from FP6.
Project cost: €1.86 million – Project funding: €1.17 million

8.10 PEGASE (PAN-EUROPEAN GRID ADVANCED SIMULATION AND STATE ESTIMATION)

Project time:	July 2008 - June 2012
Project web:	http://fp7-pegase.eu/

Involved partners:

TSOs: RTE (FR), REE (ES), Lietuvos Energija (LT), Transelectrica (RO), REN (PT), SO UPS(RUS), HEP (HR) and TEIAS (TU). Other: TRACTEBEL (BE), DELING DOO (BA), DIGITEO (FR), CRSA-ECP (FR), AICIA (ES), FGH DE), Uni. Of Liege (FR), Uni. Of Dusiburg (DE), Uni. Of Manchester (GB), Uni. Eindhoven (NL) Rigs Uni. (LT) TY, Energosetproject (RUS) and ELIOP (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 progressively built by interconnecting the national transmission grids for 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 off-line and on-line simulations to be run. Develop methodologies for building and validating static and dynamic models (including renewable energy sources, power electronics, etc.). Study the architecture of a pan-European real-time state estimation, simulation and training.

Description:

PEGASE is a four-year 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 twenty partners including TSOs, expert companies and leading research centers in power system analysis and applied mathematics. Its overall objectives are to define the most appropriate state estimation, optimization and simulation frameworks, their performance and dataflow requirements to achieve an integrated security analysis and control of the ETN.

The heart of the PEGASE project will involve advanced algorithmic, build prototypes of software and demonstrate the feasibility of real-time state estimation (SE), multi-purpose constrained optimization (OPF) and time domain simulation of very large models representative of the ETN, taking into account its operation by multiple TSOs. project R&D ambitions: the first ambition is to relieve all knowledge barriers to provide all TSOs with a synchronous display of the state of the ETN, very close to real time (typically each five to ten seconds). The second ambition is to develop OPF programs determining 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 prototype software and demonstrating the feasibility of: real-time state estimation. Multi-purpose constrained optimization. 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.

8.11 FENIX (FLEXIBLE ELECTRICITY NETWORK TO INTEGRATE THE EXPECTED 'ENERGY REVOLUTION')

Project time:	October 2005 - September 2009
Project web:	http://www.fenix-project.org

Involved partners:

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:

In the last decade, the EU has been deploying significant amounts of DER[1] 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, DERs must take over responsibilities from large conventional power plants and provide the flexibility and controllability necessary to support secure system operation.

Objectives:

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

Description:

The project is divided into three phases:

- Analysis of the DER contribution to the electrical system, assessed in two future scenarios (Northern and Southern) with realistic DER penetration.
- Development of a layered communication and control solution validated for a comprehensive set of network use cases1, including normal and abnormal operation, as well as recommendations to adapt international power standards. We envision a threefold R&D effort:
  - o The key component is the Large-scale Virtual Power Plant (LSVPP) which is an aggregation of DER, taking into account the actual location of individual DERs in the network. LSVPPs will have flexibility and controllability to provide different services to energy and ancillary services markets.
  - o The bottom level is the local solution at the individual DER themselves, responsible for managing the unit in connection with the LSVPP.
  - o And finally the higher level, which consists of a new generation of EMS and DMS tools to be developed, placed respectively with the TSO and the DSO, 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.

To achieve these multi-disciplinary objectives, the FENIX consortium incorporates: research centers and universities with high involvement in previous and current EU projects in this area (CRISP, DISPOWER, MICROGRIDS, EUDEEP); transmission and distribution utilities, which today hold the responsibility of the networks where DER are being integrated; equipment and ICT manufacturers with a large presence in the energy sector; DER owners who bring their business vision to the project, and finally organizations responsible for regulation, standardization, etc., that 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 meet the challenge of Distributed Energy Resources (DER) integration.
The aim of FENIX was to conceptualize, design and demonstrate the
technical architecture and commercial and regulatory framework for Virtual Power Plant-based large-scale aggregation of DER.

Project costs:

€14.76 million, funding €7.8 million

8.12 ANEMOS.PLUS (ADVANCED TOOLS FOR THE MANAGEMENT OF ELECTRICITY GRIDS WITH LARGE-SCALE WIND GENERATION)

Project time:	January 2008 - June 2011
Project web:	http://www.anemos-plus.eu/index.php

Involved partners:

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 Transmission System Operators, Utilities and others that forecasts of the power output of wind farms up to forty-eight hours ahead contribute to a secure and economical power system operation.

Objectives:

The research work, related to short-term wind power forecasting in the frame 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 at the optimal management of electricity grids linked to large-scale wind power generation. For this purpose, the project develops new intelligent management tools for addressing the variability of wind power. Emphasis is given to the integration of wind power forecasts and related uncertainty in power system key management functions. The project demonstrates the applicability of such tools at an operational level both for managing wind penetration and for trading wind generation in electricity markets.

At a first stage the wind forecasting tools will be enhanced with new functionalities such as probabilistic forecasting. At a 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 identified as the key challenges for large-scale integration of wind power into the electricity supply, including:

1. Reliable provision of advanced wind power forecasts through alternative 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 modeling approaches.
- The on-line estimation of uncertainty in the forecasts.
- The ergonomics of the prediction tools.

2. Optimal integration of wind energy into power systems and electricity markets. The project will aim to demonstrate the benefits of the use of advanced tools for the:

- Allocation of balancing power and definition of reserves for TSOs.
- Optimal scheduling of power systems with high wind penetration.
- Bottleneck management in large power systems as well as local grids.
- Management of storage associated with wind energy.
- 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 using their results for decision-making, and 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:

€5.65 million, funding €2.6 million

8.13 DESIRE

Project time:	June 2005 - May 2007
Project web:	http://project-desire.org

Involved partners:

AAU (DK), EMD (DK), PE (DK), UoB (UK), ISET (DE), UniK (DE), EMD-DE (DE), Labein (ES), WUT (PL), TUT (EE)

Abstract:

Dissemination strategy on electricity balancing for the large-scale integration of renewable energy. The European electricity market is facing upcoming problems. Proportions of renewable electricity rise in Europe, while local electricity systems are unable to absorb the excess capacity. This means that we are unable to use the renewable electricity 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 renewable energy supplies into local and regional electricity systems.
- To balance wind power in the European electricity system through the use of combined heat and power (CHP).
- 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. Combined heat and power (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 on 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 for a further improvement of 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 built, it will be possible to integrate balancing techniques on different scales in all European countries. The project will have an impact on the European electricity supply as a whole and will contribute to the meeting of 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 productions. 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:

€2.32 million, funding €1.2 million

8.14 ADDRESS

Project time:	June 2008 - May 2012
Project web:	http://www.addressfp7.org

Involved partners:

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 distributed energy resources.

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. Let's see how ADDRESS will ADD value to each of the vision issues:

- To add FLEXIBILITY
- To add RELIABILITY
- To add ACCESSIBILITY
- To add ECONOMY

Objectives:

ADDRESS wants to study, develop and validate solutions to enable active demand and exploit its benefits.

To enable active demand ADDRESS intends to:

- Develop technical solutions both at the consumers' premises and the power system level.
- Identify the possible barriers against active demand development and develop recommendations and solutions to remove these barriers considering 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.
- Study and propose accompanying measures to deal with societal, cultural and behavioral aspects.

Description:

ADDRESS will research, develop and deploy technology and processes to increase usage of distributed generation and renewable energy resources thereby engaging in a new relationship between customers, generators and network operators. ***ADDRESS*** aims to develop new innovative architecture for Active Distribution Networks (ADN) able to balance, in real time, power generation and demand, allowing network operators, consumers, retailers and stakeholders to benefit from the increased flexibility of the entire system. Innovative use of communications, automation and household technology will be combined with new trading mechanisms and algorithms providing ADN with low-cost and reliable solutions.

Customers will be encouraged to participate actively, enabling them to change their consumption habits, adopting a smarter use of energy and saving money. A cost/benefit analysis of different solutions will be developed: the most promising will be tested in three sites with different geographical, 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 the 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:

€15.72 million, funding: €9 million

8.15 OFFSHORE GRID STUDY

Project time:	June 2009 - March 2010
Project web:	http://www.eirgrid.com

Involved partners:

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 a great number of connection requests, due to the large amount expected in relatively wide areas, TSOs are developing a concept of an offshore network capable of fulfilling these requests, in order to increase reliability and to optimize 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:

The potential offshore grid structure, the most suitable technology and if there are synergies between on-shore and off-shore grids.

To evaluate if, to what extent, and in which market context, interconnection strategy could create further opportunities for the All Ireland Transmission System for wind resource exploitation.

Description:

For the Offshore Grid Study an expansion planning methodology has been proposed which is implemented in 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 off-shore grid transferring power to the All Ireland Transmission System (AITS).

The second part deals with interconnection impact. Basically, the off-shore grid is seen not only in terms of the connection of the wind but as a support of energy transfer between the AITS and neighboring countries. Indeed this synergy may result in a further optimization as the off-shore infrastructure may have spare capacity for many hours of the year.

Different sensitivity analyses in order to explore the impact on the expansion result of: the amount of wind off-shore, the number of locations off-shore, the effect of the installation of 'Smart Devices'

Finally a 'business as usual case' is studied as a technical/economical comparison with the examined alternatives.

Expected deliverables, benefits and impact:

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

Project costs:

Cost sharing between Eirgrid and ERSE.

8.16 TRANSGRID HVDC

Project time:	October 2008 - November 2009
Project web:	http://www.eirgrid.com

Involved partners:
TSOs: EirGrid (IE), SONI (NI),NIE (NI).
Others: TransGrid Solutions (Canada).

Abstract:
Investigating 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.

To identify the nature of the available schemes, how they 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 security of supply. As part of a solution to the 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, North-West wind, 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) screening were performed to derive a basis for comparison of the technical performance of the AC and HVdc transmission solutions.

The investigation qualitatively compares Voltage Source Converter (VSC) HVdc, Line-Commutated Converter (LCC) HVdc and equivalent AC solutions for a number of transmission development scenarios. Schemes are compared exclusively in terms of their relative impact on transmission system performance, security and flexibility rather than on aspects such as cost or the environment.

Expected deliverables, benefits and impact:
To help formulate a comprehensive Eirgrid position in presenting the N-S 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.

To identify rules to be introduced to the EirGrid Transmission Planning Criteria.

Project costs:

8.17 TEPCO STUDY

Project time:	November 2008 - September 2009
Project web:	http://www.eirgrid.com

Involved partners:

TSOs: EirGrid (IE)
Northern Ireland Electricity (NIE)
Others: TEPCO (Japan)

Abstract:

Assessment of the Technical Issues relating to Significant Amounts of EHV Underground Cable in the All-Island Electricity Transmission System.

The study deals with the evaluation of the impact of large amounts of underground cables into the All-Island Transmission System (AITS). Steady state and electromagnetic transient (EMT) phenomena have been examined on potential high voltage (HV) projects taken from the *Grid Development Strategy* (GRID**25**). A thorough investigation has been devoted to the North-South Interconnector project.

Objectives:

The overall objectives of the TEPCO study are:
To investigate issues related to the introduction of a large amount of underground cable systems in the AITS.
To identify potential risks and possible countermeasures

Description:

The TEPCO study is divided into three parts.

The first part explores the Underground Cable System (UGCS) application in AITS, by choosing the most critical scenarios according to the GRID**25** plan. In order to build a worst-case scenario, all new proposed reinforcements are modeled as underground cables. Scenarios at different voltage levels are analyzed, as well as phenomena such as EMT, black-start capability and voltage stability.

The second and third part 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.

Results shows that for EHV, a steady state solution can always be found for any length of cable.

Temporary over voltages (TOVs) represent a major risk for the system that cannot be mitigated without preventing several operation 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 action, 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 reactive performances.

Expected deliverables, benefits and impact:

To help formulate a comprehensive Eirgrid position in presenting the N-S project to the Irish authorities.
To define possible general design parameters to help the decision-making process at the planning stage for underground projects.
To identify rules to be introduced to the *EirGrid Transmission Planning Criteria*.

Project costs:

Shared between NIE and Eirgrid.

8.18 KRIEGERSFLAK (OFFSHORE GRID IN THE BALTIC SEA - WITH TWO OFF-SHORE WIND FARMS)

Project time:	July 2009 (EU Application)/February 2010 (Grant Contract) - December 2016 (project realization)
Project web:	http://energinet.dk

Involved partners:

The feasibility study is a joint project carried by 3 TSOs - relevant to Kriegers Flak: 50Hertz Transmis-sion GmbH (DE), SVENSKA KRAFTNÄT (SE) and Energinet.dk (DK). The feasibility study was final-ised in February 2010.

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

Abstract:

Kriegers Flak is a unique opportunity to build the world's first Offshore Grid - combining grid connection of offshore wind farms with interconnection between different countries and electricity markets. The additional market benefit of the Kriegers Flak project is to use the cable between the two countries an extra interconnector capacity in the many hours of the year where there is not 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 as 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 a potential for up to 1,600 MW installed wind turbine capacity. The revised project with only Danish and German participation foresees capac-ity of approximately 900 MW installed capacity. It is important that this large amount of wind energy is connected to the onshore
grids in the best way possible.
The three TSO's initiated this feasibility study 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 build, but it would serve three purposes:
• Bring renewable energy to the European consumers
• Strengthen the energy markets for large amount of renewable energy (RES)
• Increase the security of supply by providing needed transmission capacity.
The European benefit from the project is going to be valuable solutions offering all other European a Fast Track for expected and coming similar projects.
The challenge is that the three geographical areas are not synchronous power systems, there are three different supporting schemes for RES and there are three different market areas (,Denmark East and Germany). And there are involved two marketplaces, Nord Pool Spot and EEX.
The Kriegers Flak project is prioritized to obtain funding from the EU Commission Recovery Plan. In the Recovery Plan there is allocated 150 M€ to the Kriegers Flak project. With only German and Dan-ish participation the expected funds to be allocated is expected to be approximately 125 M€.

Expected deliverables, benefits and impact:

The benefit and impacts from the Kriegers Flak project are in short;

The world's first Offshore Grid connection two countries, two offshore wind farms. Better market integration of large amount of electricity from offshore wind farms. Better interconnector capacity North-South between the two countries. Development of novel technologies for offshore HVDC and back-to-back systems. The project is prepared to include Swedish off shore wind farms and an inter-connection to Sweden if they, at a later stage should wish to take part of the Kriegers Flak project.
Project costs: Project budget covers the additional costs by establishing a grid compared to establishing separate connections to the individual countries and is estimated to be around 250 M€. Establishment of the wind farm is not included. EU-funding app. 125 M €.

8.19 COBRA (Stepping stone in the North Sea Off-shore Grid)

Project time:	November 2009 - December 2015
Project web:	http://energinet.dk

Involved partners:

TSOs: TenneT TSO (NL) and Energinet.dk (DK).
Others: Suppliers of technology.

Abstract:

The Dutch and Danish TSOs TenneT and Energinet.dk, have decided to develop a power link between Denmark and the Netherlands. The purpose of the link, entitled COBRA Cable, is to allow for the integration of more renewable energy (RES) into the Dutch and Danish power systems and to increase security of supply. The power link will also help to intensify competition on the north-western European power markets.

The COBRA cable will examine the possibilities of being the first stepping stone for a North Sea off-shore grid for pan-European interconnection of multiple off-shore wind parks.

Objectives:

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 different European countries. The COBRA cable would help 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, a key priority of European energy policy.
The COBRA cables prioritized to obtain funding from the EU Commission Recovery Plan. In the recovery plan €165 million are allocated to North Sea off-shore grid projects.

Expected deliverables, benefits and impact:

The COBRA cable will be built from the Netherlands to Denmark (Vest).
The benefit and impact 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.
- Possible first stepping stone for a North Sea off-shore grid.

Project costs:

Estimate of €450 million (the budget covers development and construction costs for the power link).
EU funding according to budget and hopefully €86.5 million.

8.20 ICOEUR (INTELLIGENT COORDINATION OF OPERATION AND EMERGENCY CONTROL OF EU AND RUSSIAN POWER GRIDS)

Project time:	01/01/2009 – 31/12/2011
Project web:	http://www.icoeur.eu

Involved partners:

TSOs: Eles (Slovenia), TEIAS (Turkey) and Terna (IT)
Others: Research centres, universities, suppliers of technology.

Abstract:

The possible future interconnection between the European and Russian electricity transmission systems requires elaborating methods for monitoring, control and protection of large scale systems and especially for the support of their interconnections. The development and prototypically implementation of these new methods and tools is the major goal of the ICOEUR project. New technologies like Wide Area Monitoring, Control and Protection as well as advanced network controllers (FACTS) and HVDC systems will be considered.
The ICOEUR concept envisions an optimal technical interconnection of EU and Russian electricity transmission networks which allow best circumstances for secure and stable operation of the common as well as of isolated power systems and realises sure “highways” for energy exchange between both energy markets. The secure operation is ensured by innovative control and monitoring systems, which includes innovative monitoring and control tools, intelligent control devices and ingenious protection functionality. The ICOEUR concept realises the secure interconnection of both networks while retaining autonomies of all the participants with consideration of their individual technical and regulatory requirements.

Objectives:

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

The ambitious vision of the ICOEUR project is the definition of the core requirements for a large-scale interconnection of EU and Russian networks and their optimal realisation, i.e:

- Optimization of the use of installed capacities
- Reliability improvements 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 large scale integration of renewable energies due to higher flexibility of the interstate network operations
- Improved control of system frequency to minimise major disturbances

Description:

ICOEUR is based on the following 5 Work Packages:

- WP1 - Specification of requirements for large scale network interconnections
- WP2 - Technology for the large scale network interconnection
- WP3 - Control and monitoring of large scale interconnection
- WP4 - Protection functions for large scale interconnection
- WP5 - Quality assurance, dissemination and exploitation

Expected deliverables, benefits and impact:

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

Project costs:

Estimate of €4,885 million, EU funding of € 2,00 million.