European Network of
Transmission System Operators
for Electricity

STUDY ROADMAP
towards
MODULAR DEVELOPMENT PLAN on pan-European ELECTRICITY HIGHWAYS SYSTEM 2050

Way to 2050 PAN-EUROPEAN POWER SYSTEM

JULY 2011

FINAL DOCUMENT FOR PUBLICATION

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GLOSSARY

ACER	Agency for the Cooperation of Electricity Regulators
AMM	Automated Meter Management
AMR	Automated Meter Reading
CAES	Compressed Air Energy System
CBA	Cost Benefit Analysis
CCS	Carbon Capture and Storage
CSP	Concentrated Solar Power
DR	Demand Response
DSO	Distribution System Operator
DSR	Demand Side Response
ECMWF	European Centre for Medium Range Weather Forecasts
ENTSO-E	European Network of Transmission System Operators for Electricity
EC	European Commission
ECF	European Climate Foundation
EHS	Electricity Highways System
EU	European Union
EUETS	European Union Emissions Trading Scheme
EU-NA	European Union and North Africa
EREC	European Renewable Energy Council
EV	Electric Vehicle
GenCo	Generation Company
GDP	Gross Domestic Product
H&C	Heating and Cooling
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
ICT	Information and Communications Technology
IEM	Internal Energy Market
IRENA	International Renewable Energy Agency
MoDPEHS	Modular Development Plan on pan-European Electricity Highways System 2050
NA	North Africa
NASA	National Aeronautics and Space Administration
NCAR	National Centre for Atmospheric Research
NCEP	National Centre for Environmental Protection
NEP	New Energy Policy
NREAP	National Renewables Energy Action Plan
NSOGI	North Seas Countries Offshore Grid Initiative
PV	Photovoltaics
RES	Renewable Energy Sources
SET Plan	Strategic Energy Technology Plan
SOAF	System Outlook & Adequacy Forecast
TSO	Transmission System Operator
TYNDP	Ten Year Network Development Plan
VSC	Voltage Source Converter

MANAGEMENT SUMMARY

In response to society's desire towards a sustainable, reliable and cost-efficient energy supply system, EU Energy Policy has set ambitious goals for 2050. Consequently, the Treaty of Lisbon clearly highlights the objectives of European Policy on energy:

- Ensure the functioning of the energy market;
- Ensure security of energy supply in the Union;
- Promote energy efficiency and energy saving and the development of new and renewable forms of energy; and
- Promote the interconnection of energy networks.

The 41 TSOs members of ENTSO-E are responsible for system security and system development in their control areas. Considering the overall importance of the development of a pan-European electricity highway system for the integration of renewable energy sources, of further market integration and to maintain the security of electricity supply, ENTSO-E prepared in cooperation with DG Energy and in line with the Commission's Communication "Energy infrastructure priorities for 2020 and beyond" (17 November 2010), this corresponding study project. Besides involvement of ENTSO-E members, this three-year study programme shall be realized with broad involvement and direct participation of external stakeholders.

The preparation of the Study Roadmap was done by following these three steps:

1. Issue identification and analysis for developing the work programme;
2. A critical review of methodologies used in analysing the issues identified; and
3. The development of a recommended work programme for the development of the MoDPEHS.

The Work Programme consists of nine interrelating Work Packages:

WP 1 on Boundary Conditions develops the general idea of an Electricity Highways system and will set the necessary limitations for all issues which must be covered by the programme and describes therefore the overall basis for the study programme.
Person months estimated needed for realization: ****Consortium-internal number*** ***

WP 2 on Scenarios elaborates plausible power system scenarios and defines a multi-dimensional scenario room for the main factors towards an Electricity Highways System taking into account the scenario limitations as set in WP 1.

Person months estimated needed for realization: ****Consortium-internal number*****

WP 3 on Technology Assessment will evaluate expected breakthrough transmission technology within the limitations as set in WP1 but must also focus on overall future technology developments in the whole energy supply chain which are most likely from today's point of view. Special focus needs to be taken on standardized solutions.
Person months estimated needed for realization: ****Consortium-internal number*****

WP 4 on Implementation and Operation considers the issue of planning and operational requirements, permission aspects including issue of environmental impact and lack of acceptance
Person months estimated needed for realization: ****Consortium-internal number*****

WP 5 on Electricity Highways System Governance looks at the relevant, legal, regulatory, financing, market requirements including the ownership issues which have to be clarified as precondition for any investment decisions.
Person months estimated needed for realization: ****Consortium-internal number*****

WP 6 on Socio-Economic Profitability covers all aspects of costs and benefit assessment but also addresses the non-monetary added values given by Electricity Highways system realization and will assure a comprehensive overall risk.
Person months estimated needed for realization: ****Consortium-internal number*****

WP 7 on Stakeholder Involvement will take care of close interaction with all relevant stakeholders considering the complexity and importance of Electricity Highways issue.

WP 8 on Modular Development Plan on pan-European Electricity Highways System will deliver the first issue of MoDPEHS by end 2014 comprising the results from all previous work packages and will therefore also take a central and coordinating role within the whole programme structure.

Finally, **WP 9 on Dissemination** is in charge of proactive disclosure of the MoDPEHS aiming highest possible transparency.

Person months estimated needed for realization of WP 7/8/9: ****Consortium-internal number*****

The estimation of resources needed for the whole Study Programme is ****Consortium-internal number***** person months. Thereof ****Consortium-internal number***** are TSO-specific expertise. As the active involvement and commitment of European TSO's is

important for ensuring the success of the project, TSOs should take over approx. 50% of all needed efforts. In addition to the TSO-specific work, TSOs should also take over the overall coordination and the Work Package management. This together will increase TSOs involvement to ****Consortium-internal number**** person months.

The Consortium will need active participation of TSOs, Energy Economics / Law Partners, Policy / Regulatory partners, Generation Companies / RES partners, DSOs / Smart Grid partners, R&D performers with respective expertise, Manufacturers, Consumers, NGOs, Communication Partners and Legal Partners.

All of these Consortium members need to be competent and experienced in their area, objective and multidisciplinary in their work and available and committed to the MoDPEHS project. The Consortium as a whole should cover a large number of European countries.
As a matter of efficiency and time, within this Study Roadmap not every aspect must be analysed from very first beginning. Any relevant inputs from other study projects (esp. relevant FP7 projects) will be assessed and taken into account. All major neighbouring and influencing activities within the Electricity Highways topic are shown in the figure below on the Electricity Highways environment.

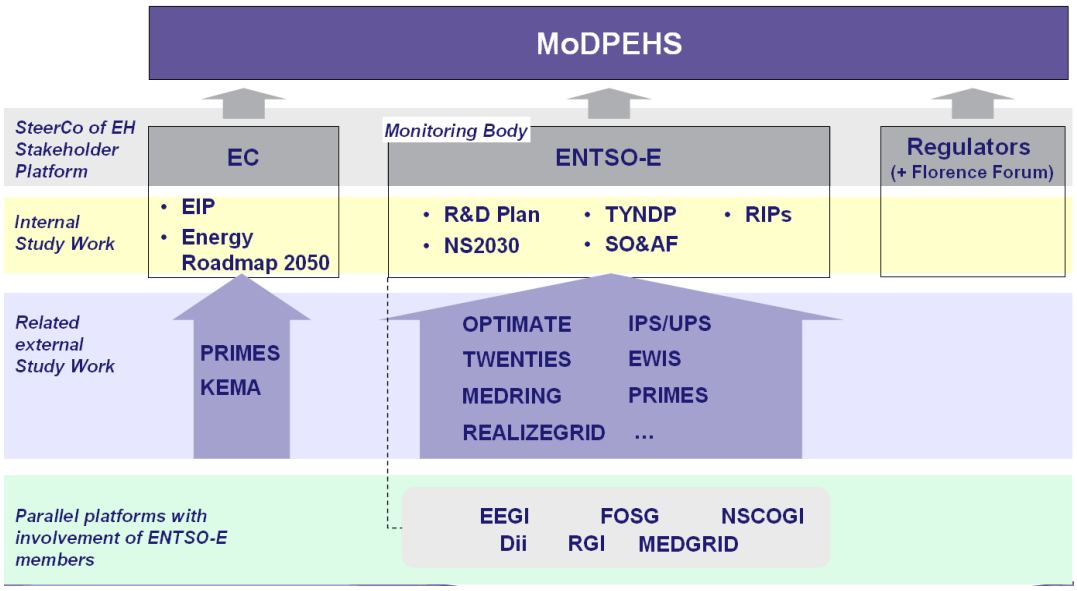

Figure 1: Electricity Highways Environment in Europe

Effective control and monitoring measures in the programme structure of the overall study programme ensure efficient working procedures of the complex and interrelating Work Packages. The programme will be organized along the Work Package and underlying Work

Stream structure, managed and controlled by the Steering Committee. A General Assembly as overarching committee will integrate important stakeholder involvement via the Advisory Board and therefore make sure, that the results will be widely accepted. The Monitoring Body will ensure the important overall TSO view on the project. Different bodies within ENTSO-E will be actively involved in the monitoring: System Development Committee, Research and Development Committee, System Operation Committee and Market Committee.

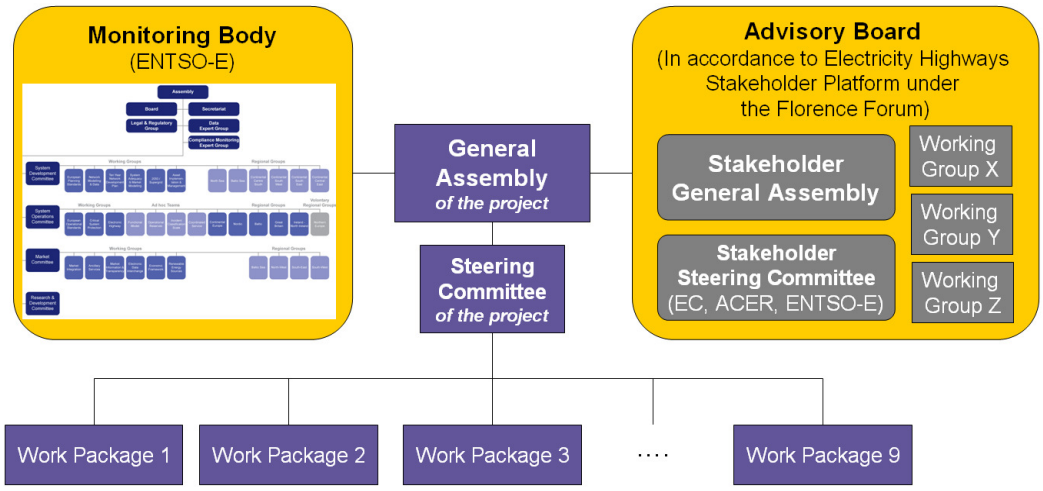

Figure 2: Electricity Highways Stakeholder Platform organisation

The success of the realisation of an Electricity Highways concept depends to a large extent on the acceptance of the new infrastructure, changes in market rules, policy reforms and any recommended revisions in market related law by all affected stakeholders. Stakeholder involvement therefore will be crucial to the success of the programme.

In December 2010 the Florence Forum supported the DG Energy proposal to set up a dedicated "Electricity Highways Platform" led by the European Commission in cooperation with ENTSO-E and the Regulators and with the involvement of all relevant stakeholders (see proposed participant groups below). This Stakeholder Platform will play an important role as Advisory Group. A wider stakeholder group will be invited to participate in workshops, debating fora and conferences. Finally everyone interested in the MoDPEHS work can participate in the public consultation.

The study roadmap was prepared as basis for later proposal for EU grants (FP7) including a successful **Public Consultation** (with Workshop on 10th May 2011 in Brussels) as well as presentation at **20th Florence Forum** on 23rd May 2011. The suitable call will be published by the **European Commission** (Directorate-General for Research and Innovation and Directorate-General for Energy) on 20th July 2011: ENERGY.2012.7.2.1: Planning for

European Electricity Highways to ensure the reliable delivery of renewable electricity and pan-European market integration.

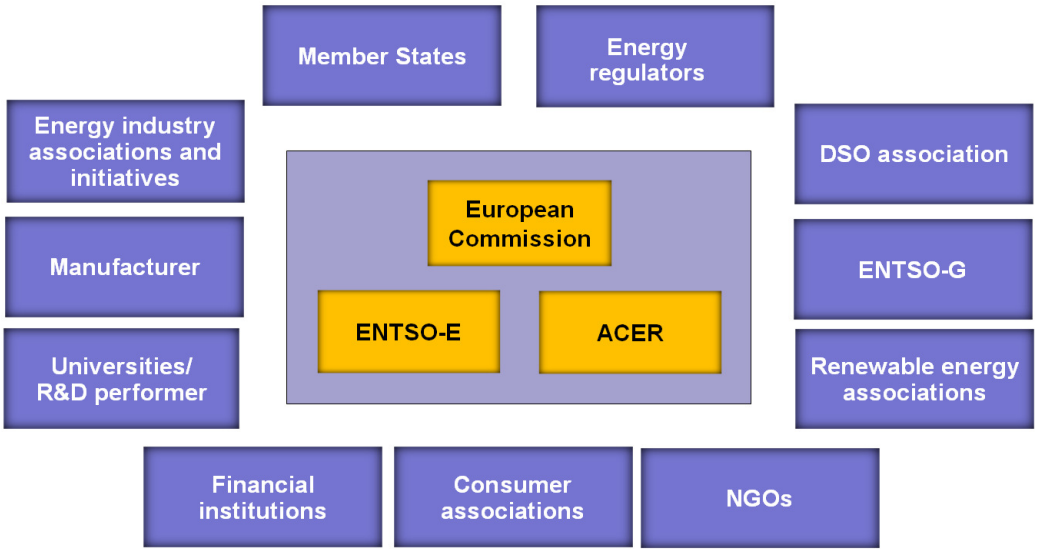

Figure 3: Relevant players for the Electricity Highways Stakeholder Platform

The project consortium will be established as soon as possible after publication of this call. In order to achieve the first version of the MoDPEHS by the end of 2014 the first Work Package on Boundary Conditions will be split into a pre-project of the study consortium which must be realized before the EC funded part will start and into a regular, EC funded WP 1 part for remaining activities (further validation/detailing/completion of the achievements of the pre-project). The scheduled start of the EC funded part of the project is in late March 2012 – depending on the outcome of the FP7 application.

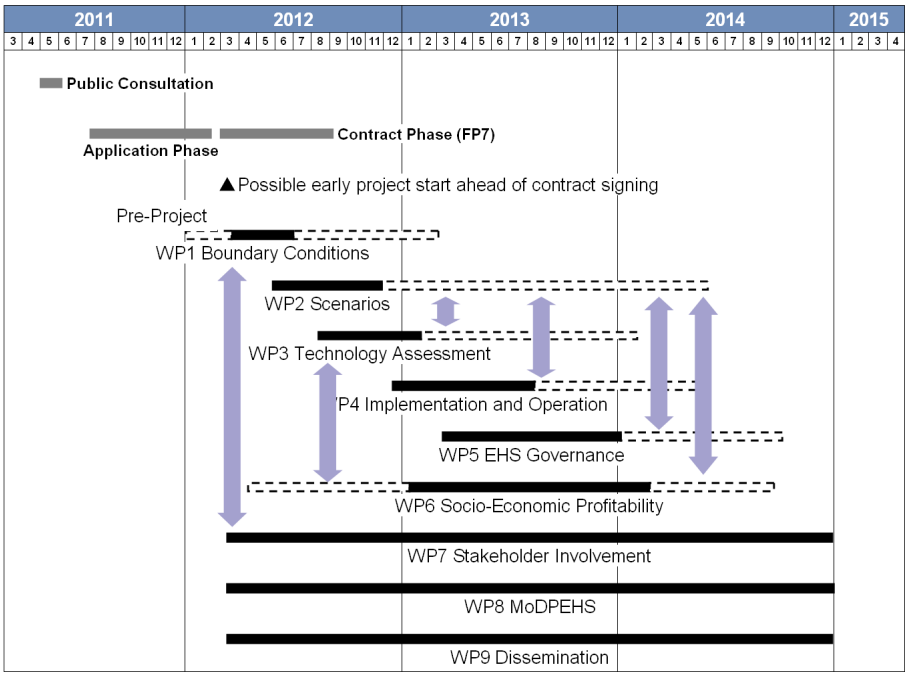

Figure 4: Schematic programme

Background

Combating Climate Change is a major priority for Europe. The European Commission has clearly stated that it is planning to maintain the momentum of global efforts to tackle climate change.

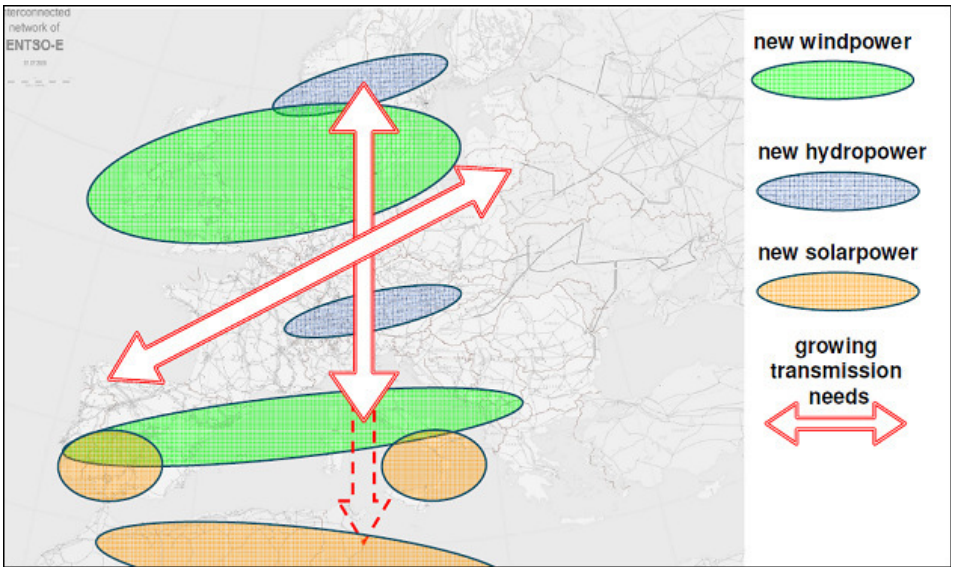

Figure 5: Main drivers for a pan-European Electricity Highways System

EU energy security policy faces significant challenges, as we move towards a pan–European network, all aggravated by the wide diversity of energy systems among EU members. It is historically proven that energy security policies are set to protect 'business as usual' trends, mainly defined as 'adequate supplies at affordable prices'. In view of the fundamental transformation needed to deliver a sustainable Europe by the middle of the 21st century, fundamental structural changes are required; and as investments in the energy sector are of a long-term nature, the decisions taken today will have a major impact on the energy system of tomorrow.

As one of the main stakeholders in this regard, ENTSO-E is an association of transmission network operators with the mission to support the shift to a low carbon economy by developing a vision of advanced European electricity infrastructure requirements through realization of a 'Study Roadmap' towards a functional pan-European power system. Its presence and influence is aimed at defining the key ingredients, specialist support and funding requirements necessary to deliver the capability (interconnection and connectivity) to

support a sustainable, secure low carbon future (with consequent economic benefits) on a European wide scale. Already in the first ENTSO-E Work Program the topic of supergrid was identified as an issue of importance: "… ENTSO-E will engage in shaping a pragmatic approach towards the offshore and onshore 'Super Grid' concept". In the context of the conclusions of the Bucharest Energy Efficiency Forum 2009 and following the 1st European Electricity Grid Reliability Conference (European Parliament on 8 January 2009) ENTSO-E established a dedicated working group to set up and coordinate comprehensive and sustainable ENTSO-E Electricity Highways concepts (covering the grid development beyond the TYNDP) and perform consultations with the EC and other stakeholders.

In response to society's desire towards a sustainable, reliable and cost-efficient energy supply system, EU Energy Policy sets ambitious goals for 2050. Consequently, the recently ratified Treaty of Lisbon clearly highlights the objectives of European Policy on energy,

- Ensure the functioning of the energy market;
- Ensure security of energy supply in the Union;
- Promote energy efficiency and energy saving and the development of new and renewable forms of energy; and
- Promote the interconnection of energy networks.

Main objectives for the European Transmission System Operators under the ENTSO-E umbrella are in this regard the integration of renewable energy sources and the support of the Internal Electricity Market's establishment while maintaining a secure and reliable supply of electricity. In this context and in response to the blueprint on Energy Infrastructure Package as published by the EC in November 2010, ENTSO-E has coordinated the development of a Study Roadmap towards Modular Development Plan on pan-European Electricity Highways System (MoDPEHS) with special focus on infrastructure related issues as an overall guideline for the conceptual way to 2050 pan-European power system.

Figure below shows how the MoDPEHS activities are embedded in the overall European discussion on Electricity Highways establishment. The MoDPEHS study programme will be accompanied by a dedicated Electricity Highways Stakeholder Platform under the scope of Florence Forum and to be chaired by EC in cooperation with ENTSO-E and the Regulators (see also chapter 4.2.1).

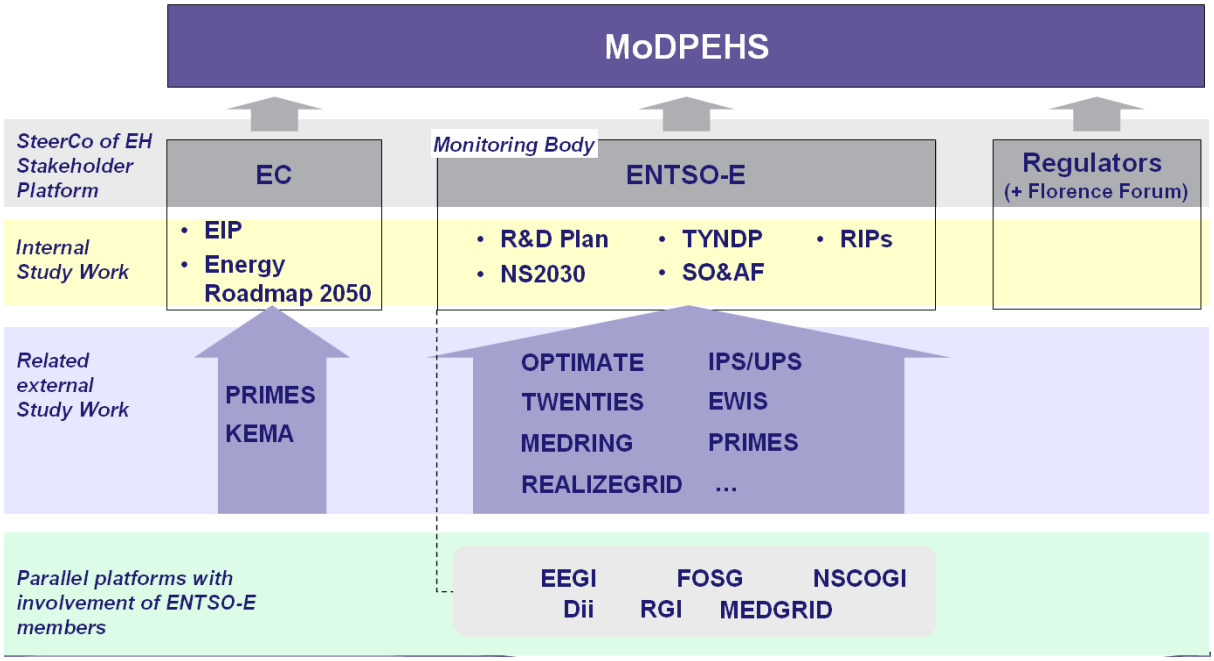

Figure 6: Electricity Highways Environment in Europe

In the absence of a cohesive planning framework, Europe's energy system is confronted with a number of challenges and uncertainties: highly volatile upward trending fossil fuel prices, resulting economic challenges, geopolitical risks related to import dependency, and the harmful environmental consequences of fossil fuel based energy generation. However, what remains certain, is that if the trend witnessed over the past few decades continues, climate change will have a more and more unpredictable consequential impact, energy import dependency will rise, and fossil fuels will become scarcer and concentrated around fewer and fewer countries around the world.

Today's energy decisions will start to shape Europe's supply system for at least the next 50 years, thereby determining the future level of greenhouse gas emissions, fossil fuel dependency and the competitiveness of European economies.

Europe must prepare the ground for a 100% (or thereabouts) decarbonized energy future, there is no time to lose. In this context, for instance a 100% RES based electricity system (i.e. no nuclear or CCS share) could describe a kind of maximum scenario which must clearly be part of the Study Roadmap. Main question in this regard is of course how to solve the RES generation fluctuation (see figure below) respectively how to transform the yesterday's "generation follows load" into a tomorrow's "load follows generation" principle.

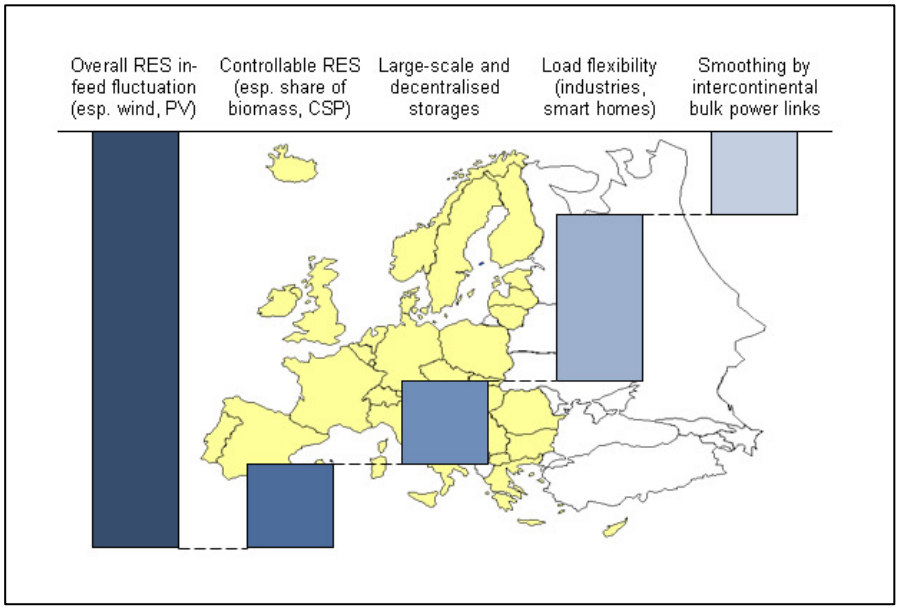

Figure 7: Example for coping the in-feed fluctuations in case of a 100% RES based European electricity system

This project seeks to develop a strategic plan that will provide a vision for how a pan-European power system built around the Electricity Highways concept could develop sequentially over a time horizon to 2050. The Study Roadmap will identify the necessary programme of work that will need to be undertaken to produce a Modular Development Plan on pan-European Electricity Highways System (MoDPEHS) for 2050 covering all of the relevant issues required to produce and develop a credible long-term strategic plan.

CONTEXT AND METHODOLOGY

This Study Roadmap is aimed to identify the necessary programme of work that will need to be undertaken to produce an Electricity Highways roadmap to 2050. The programme of work has to be comprehensive and cover all of the relevant issues that will need to be considered to produce a credible long-term strategic plan to 2050 – The Modular Development Plan on Electricity Highways System – (MoDPEHS). In close cooperation with the relevant stakeholders and especially ENTSO-E and taking into account a stepwise respectively modular approach, the overall objective of MoDPEHS must be analyzing and justifying the future bulk power transmission needs and - as ultimate deliverable – proposing concrete implementation, operation and governance solutions for the needed grid investments throughout Europe and to relevant neighboring areas. Consequently, besides the fact that the main focus is on Electricity Highways System, in the interest of efficiency and feasibility **the whole energy supply chain** including all relevant technical/technological, economical/financial and political/sociopolitical issues must be considered.

As a matter of efficiency and time, within this Study Roadmap not every aspect must be analysed from very first beginning. Any relevant inputs from other study projects (esp. relevant FP7 projects) will be assessed and taken into account, given that there is access to those reports and results.

During the preparation phase of this Study Roadmap, the technological issues that surround the development of a pan-European power system were fully explored. It was similarly important to consider the regulatory questions that arise from the technical solutions especially with respect to financial security and funding. To be fully comprehensive, the socio-political issues that are associated with the development of new infrastructure were also assessed. Overall the programme of work was elaborated to provide a package of work that enabled the respective teams to comprehensively address the planning, financing, construction, extension, integration and operation of future Electricity Highways that are relevant to, and aligned with, the existing power system across Europe.

The preparation of the Study Roadmap was done by following these three steps:

4. Issue identification and analysis for developing the work programme;
5. A critical review of methodologies used in analysing the issues identified; and
6. The development of a recommended work programme for the development of the MoDPEHS.

In this regard a full range of issues that are relevant to ENTSO-E's development of the Study Roadmap programme have been identified. These were categorised as either *Technical/technological, Economical/financial or Political/sociopolitical* in nature, and prioritised with respect to their respective contribution towards the MoDPEHS. The outputs from this are shown in the tables below:

Table 1: List of issues

Technical/technological	
Transmission System Operation	• Reserves and system balancing • System monitoring, controlling and protection • Potential advantages, savings and challenges associated with regional system operation requiring increased interactions between multiple TSO organisations; • Collaboration, co-ordination and joint planning requirements for regional system operation and regional investment; • Potential implications for System Operation as a result of Electricity Highways System developments; • Scope for harmonisation of rules and guidelines across multiple TSOs; • Approaches for managing and mitigating transmission congestion and constraints.
Generation & storage	• Generation technologies to be integrated; • Regional dispersion of generation sources and overall generation mix; • Technical characteristics of new generation and storage sources; • Impact of RES variability/intermittency; • Volatility of RES output and mitigation options through regional interconnection; • Extent of RES output curtailment and scope for optimisation • Generation adequacy assessments and regional guidelines for generation capacity margins; • Availability, cost, efficiency and potential role of electrical storage; • Technical characteristics and associated economics of energy storage.
Technology/ Network development & analysis	• Power flow analysis and capacity implications for future grids including; Electricity Highways System requirements; • National Electricity Highways System architectures, e.g. potential locations of nodes; • Future requirements for offshore networks and interconnectors; • Evaluation of planning frameworks for transmission and associated national standards; • Technology selection and choices for transmission infrastructure; • Timing and lead times for network investment; • Feasibility of implied build rates for transmission infrastructure ; • Identification of priority investments and projects;

Demand Growth	• Forecast asset utilisation for new transmission infrastructure; • Impact on Security of Supply; • Impact on Internal Electricity Market; • Impact of transmission investment on RES integration; • Optimisation of capital expenditure. Interactions with asset replacement cycles. • Opportunities and effectiveness of upgrades/reinforcements of existing infrastructure. • Pan-European and regional demand forecasts - review of different forecasts and methodologies. • Comparison of different demand growth scenarios. • Regional variations of seasonal and intraday load profiles with associated capacity implications resulting from changes in electricity usage. • Impact of extreme loading conditions, e.g. cold winters/hot summers • Extent of Demand Response available to TSOs. • Consistency with Smart Grid initiatives and relevant technologies

Economical/financial	
Investment frameworks and network charging	• Availability of capital to fund future investments • Treatment and cost assessment of network congestion • Scope for and regulatory treatment of 'anticipatory' or 'strategic' investments ahead of need, i.e. generation presence. • Incentivisation of innovation to encourage efficient network investment. • Payment and reward mechanisms for TSOs.

Political/sociopolitical	
Policy and regulation	• Regulatory frameworks and approval mechanisms for major transmission expenditure in different Member States and scope for harmonisation. • Future Fuel Switching: Penetration rates of EVs and heat pumps etc. • Identification of key future capacity 'bottlenecks' • Identification of low or no regret investment projects. • Merits of different transmission network charging arrangements, e.g. nodal approaches, cost reflectivity, socialisation, long-run marginal pricing. • Options for future transmission tariff structures • Impact on Internal Energy Market and market requirements • Addressing divergences between the parties incurring the costs of transmission network expansion and the parties deriving benefits.
Socio-political considerations	• Social acceptance of transmission capacity expansion • Public awareness and attitudes regarding requirements for transmission infrastructure,particularly new lines of route. • Options for streamlining planning frameworks, public enquiries and permitting arrangements for new transmission infrastructure • Impact on transit countries of interregional electricity flows. Cost recovery mechanisms for regional interconnection • European States self-sufficiency regarding electricity supplies and reliance on other European States for energy provision. • Impact on cost of delivered electricity, i.e. affordability of power system investments.

A set of criteria, presented in the following table, were then used to filter an initial long-list of topics and issues for inclusion in possible work packages for the Study Roadmap development process.

Table 2: Screening criteria

Criteria for inclusion in package	Criteria for exclusion from package
Directly relevant to the Study Roadmap process, having an expected material impact on the costs of or how a European Electricity Highways System would be planned, financed, extended, constructed or operated	The development of the issue has no material impact on the costs of or how a European Electricity Highways System would be planned, financed, extended, constructed or operated
Issue may not be directly relevant, to the ENTSO-E Study Roadmap process, however there is currently a lack of information available and therefore may need to be incorporated to the Study Roadmap e.g. because of inconsistent assumptions or results presentation	Issue is being studied extensively by others and the results as presented could be used without modification to support the ENTSO-E Study Roadmap process

This initial assessment and filtering of issues led to nine discreet priority groups that were subsequently used to inform the preparation of the Study Roadmap towards Modular Development Plan on pan-European Electricity Highways System (MoDPEHS).

1. The idea of an Electricity Highways System and associated boundary conditions
2. Plausible future power system scenarios for the European energy sector;
3. What supply chain or technological breakthroughs will influence an Electricity Highways System?;
4. Practical issues associated with the implementation and operation of Electricity Highways System infrastructure;
5. Electricity Highways governance - esp. legal, regulatory, financing, market and ownership issues;
6. Sustainable but cost efficient solutions - costs/benefits/values/risks assessment
7. Interaction with all relevant stakeholders;
8. Compilation phase and final concept report
9. Dissemination of Electricity Highways System concept findings

In the next step the three most comprehensive and relevant 2050 studies were selected put of a set of twenty-one most relevant existing studies (see Table below). These were critically and comprehensively reviewed according to their methodologies. The detailed assessment

of methodologies of these existing studies describes valuable external input for elaboration of the Study Roadmap.

Table 3: Already existing 2050 studies

- **European Climate Foundation**: Roadmap 2050 - A Practical Guide to a Prosperous, Low-carbon Europe. Technical, economic and policy analysis (2010)
- **PWC**: 100% Renewable Electricity – A Roadmap to 2050 for Europe and North Africa
- **Energy Research Centre of The Netherlands**: A zero-carbon European power system in 2050: Proposals for a policy package (2010)
- Energy Research Centre of The Netherlands: Climate, Energy Security and Innovation (2008)
- Energy Research Centre of The Netherlands: A sustainable energy system in 2050: Promise or possibility? (2007)
- **European Climate Forum**: The Supersmart Grid (2007)
- **European Commission**: Strategic Research Agenda for Europe's Electricity Networks of the Future (2007)
- **International Energy Agency**: Prospects for Large-Scale Energy Storage in Decarbonised Power Grids (2007)
- **Shell** energy scenarios to 2050 (2008)
- "Scenarios for electricity supply in the future" – "Cost-optimal variation for the electricity supply in Europe and its neighbors from renewable energy sources"; **Czisch**
- Market based analysis of Interconnections between Nordic, Baltic and Poland Areas in 2025 (2010)
- **Tradewinds**; KEMA Contributor
- **Dena study** - Planning of the grid integration of wind energy in Germany onshore and offshore up to the year 2020
- **UK Energy Networks Strategy Group**: A Vision for 2020 (2009)
- Re-thinking 2050 – A 100% Renewable Energy Vision for the European Union; European Renewable Energy Council **(EREC)**
- **National Grid:** Fundamental Review of National Electricity Transmission System Security and Quality of Supply Standards (2010)
- **European Wind Integration Study** (2010)
- **UK Energy Networks Strategy Group:** A Smart Grid Vision (2009)
- **ERMInE:** Electricity Research Road Map in Europe (also called Coordinated Action within the 6th Framework Program of the European Commission)
- **Airtricity:** European Offshore Supergrid Proposal - Vision and Executive Summary
- **UK Energy Networks Strategy Group:** A Smart Grid Routemap (2009) DESERTEC

Table 4: Assessment of study methodologies

Subject	**PWC:** 100% Renewable Electricity – A Roadmap to 2050 for Europe and North Africa[1]	**Czisch:** Scenarios for electricity supply in the future – Cost-optimal variation for the electricity supply in Europe and its neighbours from renewable energy sources[2]	**EREC**: Re-thinking 2050 – A 100% Renewable Energy Vision for the European Union[3]
Electricity Highways System Governance	****	**	**
Policy & Legal Framework	****	**	**
Planning Arrangements	***	**	*
Power System Scenarios	*	****	**
Technology & Design	**	**	**
Technical Application	*	****	***
Implementation Issues	**	**	**
Infrastructure Delivery	**	***	**
Market Modeling	*	****	**
Economic Development	*	****	***
Concept of Electricity Highways System	**	****	***
Practical Application	*	***	***

Finally, taken into account the identified relevant issues to be considered and the impulses on methodologies from assessment of existing studies, six key Work Packages (Study Definition Documents) were identified as task related delivery units with significant cross dependencies throughout the development of the MoDPEHS. They relate directly to the priority groups mentioned. They are:

1 http://uk.sitestat.com/pwc/uk/s?ukws.eng_publications.pdf.sustainability.the_climate_principles_progress_review&ns_type=pdf&ns_url=http://www.pwc.co.uk/pdf/100_percent_renewable_electricity.pdf

2 https://kobra.bibliothek.uni-kassel.de/bitstream/urn:nbn:de:hebis:34-200604119596/1/DissVersion0502.pdf

3 http://www.rethinking2050.eu/fileadmin/documents/ReThinking2050_full_version_final.pdf

1. Boundary Conditions
2. Scenarios
3. Technology Assessment
4. Implementation and Operation Issues
5. Electricity Highways System Governance
6. Socio-Economic Profitability

To differentiate specialist programme requirements, remaining Work Packages 7, 8 and 9 are designated as Programme Management activities units that will be critical to the smooth running of the programme (supporting stakeholder involvement and communications throughout) and the final collation and delivery of the MoDPEHS by the end of 2014. They are:

7. Stakeholder Involvement (Stakeholder interaction, consultation etc)
8. The Modular Development Plan on pan-European Electricity Highways System (MoDPEHS) (Programme management and project collation)
9. Dissemination (Dissemination of findings, outputs and related information)

1 PROGRAMME GOVERNANCE

The programme structure of the overall study programme towards MoDPEHS needs to ensure efficient working procedures of the highly complex and interrelating Work Packages with effective control and monitoring measures. The programme will be organized along the Work Package and underlying Work Stream structure, managed and controlled by the Steering Committee. A General Assembly as overarching committee will integrate important stakeholder involvement via the Advisory Board and therefore make sure, that the results will be widely accepted. In chapter 4.2 the stakeholder involvement within the programme is described in detail. The Monitoring Body will ensure the important overall TSO view on the project. Different bodies within ENTSO-E will be actively involved in the monitoring: System Development Committee, Research and Development Committee, System Operation Committee and Market Committee.

The concrete mandate of the different project bodies for taking decisions on main study assumptions and selection of boundary conditions and approval of scenarios and final reports will be clarified in the Consortium Agreement which must be agreed between all consortium partners before the start of the project.

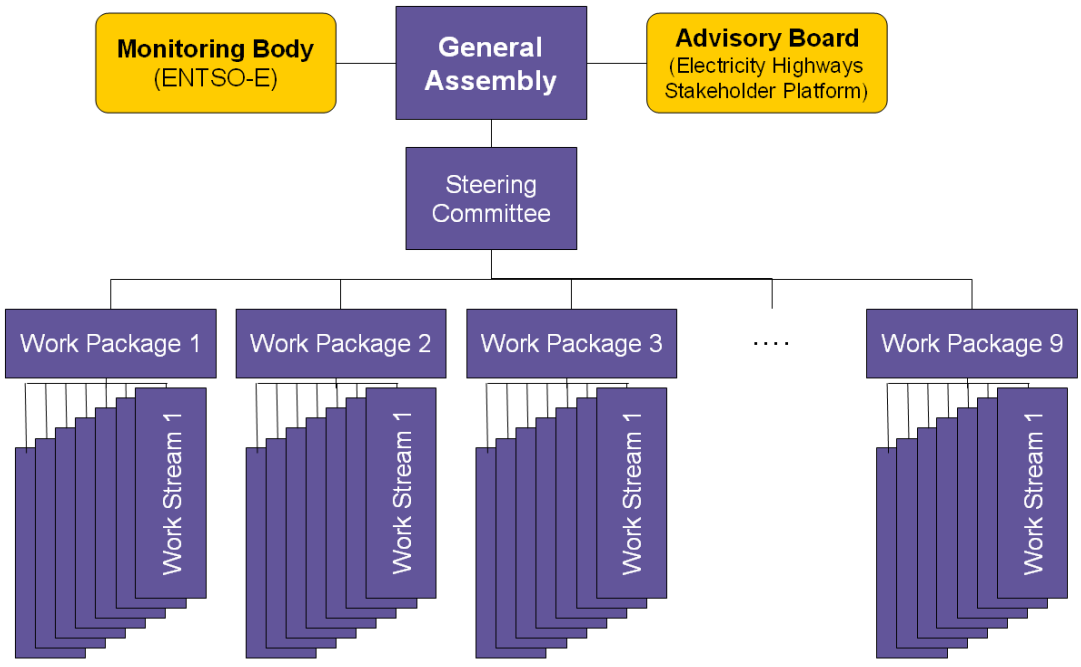

Figure 8: Governance structure

Following characteristics should be fulfilled by the Consortium partners in order to ensure the needed expertise to deliver the promised outputs in defined time, price and quality.

General characteristics of the Consortium partners

1. Leading companies/associations/partners in their respective fields, ensuring competence and reliability.
2. Companies/associations/partners with proven track record of successfully completed multilateral study projects and/or local expertise. A mix of these competences is important in the overall Consortium composition.
3. Experienced companies/associations regarding the use or development or integration of RES or de-carbonized electricity production.
4. Objectivity
5. Multidisciplinarity
6. Availability and commitment to a definite amount of participation in sense of personnel / person months.

Criteria to ensure equilibrium in the Consortium

1. It is desirable that a large number of European countries are represented in the Consortium. Given the size of the project, it should be avoided to have two or more partners of the same country, unless clear added value is found.
2. All European areas or regions (North-South, East-West, Central countries-peripheral countries…) must be represented in the Consortium in a balanced manner.

Experience

It is necessary that experienced people with outstanding competence in the area belong to and even have a leading role in the project.

2 PROGRAMME AND DEPENDENCIES

The following diagram shows how all of the Work Packages interrelate to achieve the ultimate deliverable: the MoDPEHS. In association with this a detailed Deliverables Matrix and a project plan providing indicative timelines and milestones is included in chapter 5 of this report.

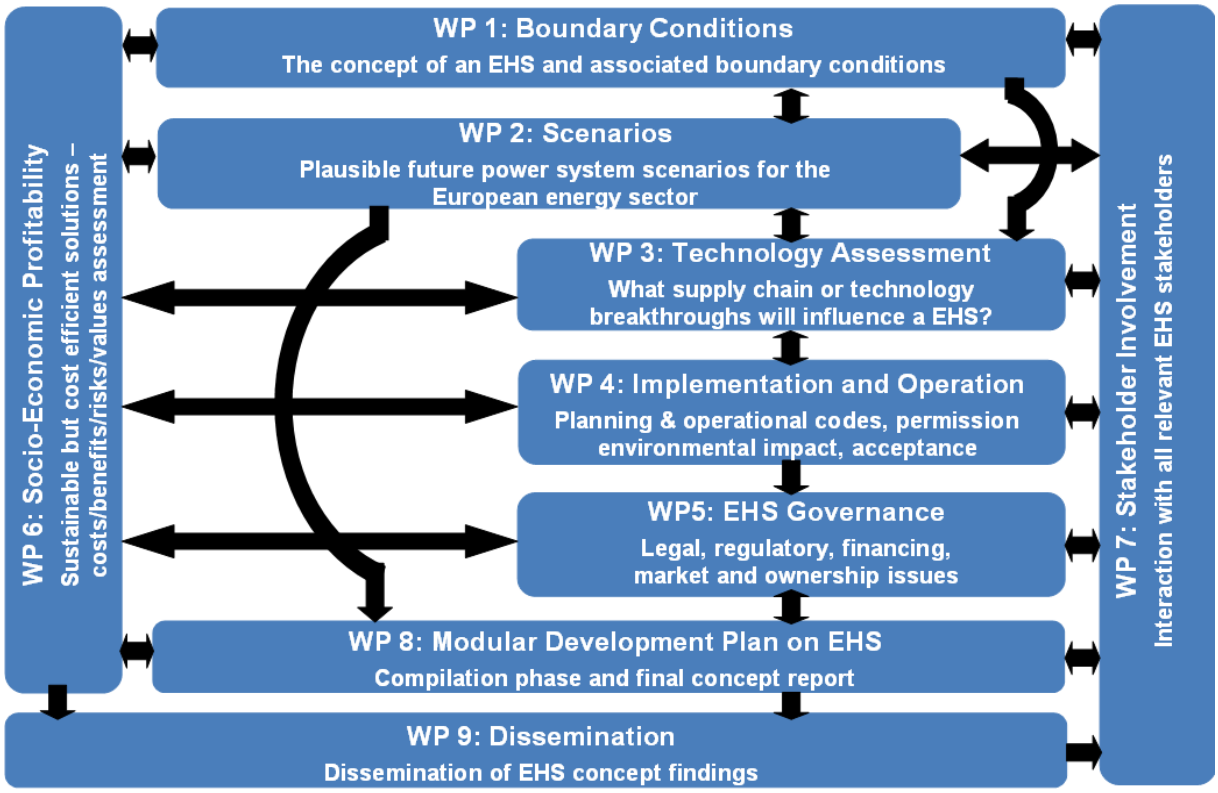

Figure 9: Programme structure

WP 1 on Boundary Conditions develops the general idea of an Electricity Highways system and will set the necessary limitations for all issues which must be covered by the programme and describes therefore the overall basis for the study programme.

WP 2 on Scenarios elaborates plausible power system scenarios and defines a multi-dimensional scenario room for the main factors towards an Electricity Highways System taking into account the scenario limitations as set in WP 1.

WP 3 on Technology Assessment will evaluate expected breakthrough transmission technology within the limitations as set in WP1 but must also focus on overall future technology developments in the whole energy supply chain which are most likely from today's point of view. Special focus needs to be taken on standardized solutions.

WP 4 on Implementation and Operation considers the issue of planning and operational requirements, permission aspects including issue of environmental impact and lack of acceptance

WP 5 on Electricity Highways System Governance looks at the relevant, legal, regulatory, financing, market requirements including the ownership issues which have to be clarified as precondition for any investment decisions.

WP 6 on Socio-Economic Profitability covers all aspects of costs and benefit assessment but also addresses the non-monetary added values given by Electricity Highways system realization and will assure a comprehensive overall risk.

WP 7 on Stakeholder Involvement will take care of close interaction with all relevant stakeholders considering the complexity and importance of Electricity Highways issue.

WP 8 on Modular Development Plan on pan-European Electricity Highways System will deliver the first issue of MoDPEHS by end 2014 comprising the results from all previous work packages and will therefore also take a central and coordinating role within the whole programme structure.

Finally, **WP 9 on Dissemination** is in charge of proactive disclosure of the MoDPEHS aiming highest possible transparency.

3 WORK PACKAGES

3.1 Work Package 1: Boundary Conditions - Investigation into the Idea of an Electricity Highways System and Associated Boundary Conditions

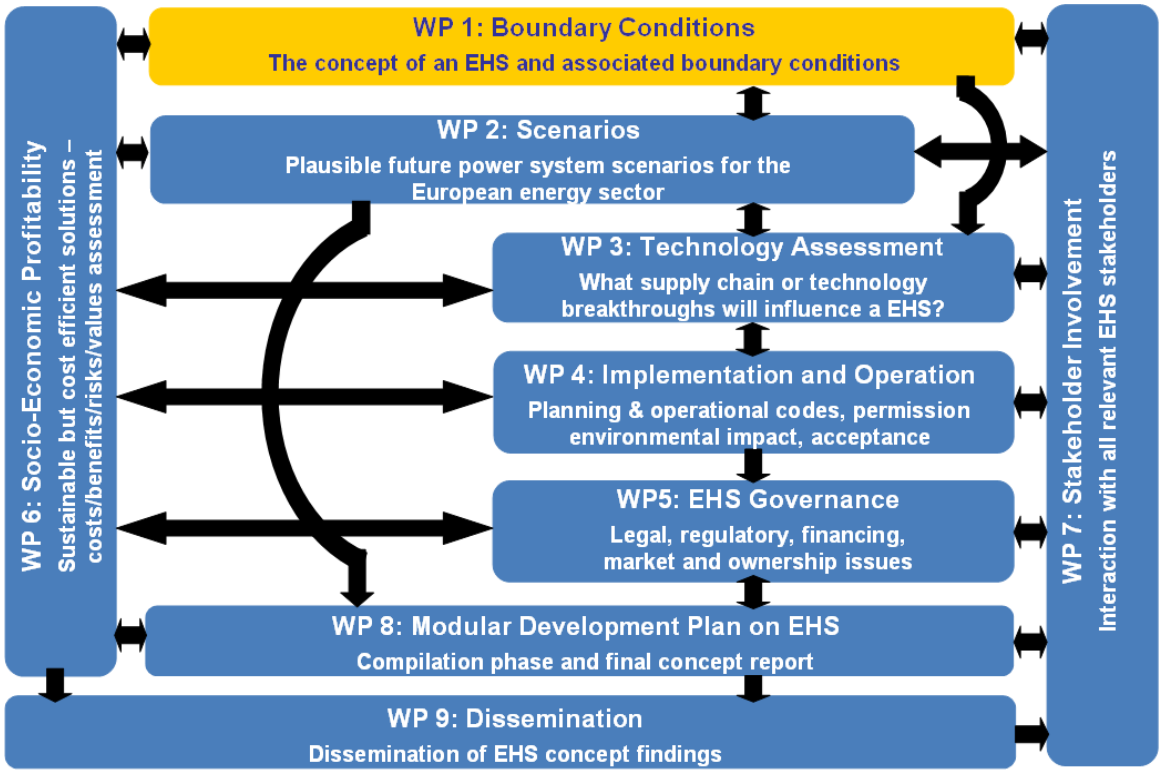

Figure 10: Placement of WP1 within programme structure

3.1.1 Introduction

When considering what defines Electricity Highways of the future and what sets the framework for their development a great many issues need to be considered. Are they defined by their embedded technology i.e. their 'smartness', or are they, more directly, defined by the way existing assets (and asset enhancements) are operated and managed? Or on another level, is it more about new system infrastructure (overlay) provided specifically to serve the changing dynamics of traditional demand growth coupled with a new mix of generation technologies designed to meet medium and long term emissions reduction targets? Or is it a combination of both?

Increased demand for electricity and security of supply is a very powerful driver of major power sector change in Europe and worldwide. Currently, for example, about 50% of

Europe's energy demand is met with imported fuels and there are projections that this could increase to 70% in the coming decades[4]. Economic development and increasing use of electricity-consuming devices will increase future demand for electricity. Alongside demand and security of supply issues, climate change also poses a global threat. Substantial and fairly rapid decarbonisation of electricity generation will have to take place if the world is to have any chance of staying within the 2 degree centigrade goal for limiting the effects of global warming.

This Study Roadmap and especially this WP must consider these and other challenges facing the region's current power systems and examine whether such a vision of Europe, and possibly in combination with other countries such as North Africa and / or neighbouring Asian countries, can support a 2050 vision in developing an integrated power grid with an evolving mix of electricity generation driven predominantly by renewable sources by 2050.

The vision requires coordinated progress on many fronts – finance, technology, research and development (R&D), the development of adequate supply chains, change in the generation mix and in evolving grid capability throughout Europe. It is therefore vital that (through this Work Package) we are able to agree a set of operating / design boundaries that adequately defines the pan-European Electricity Highways vision and sets a detailed framework for the work that needs to be undertaken in order to develop a unified approach to the considerable task in hand.

This must combine the active involvement of National Energy Regulators and ACER who are responsible for developing common standards and approaches for cross-border cooperation; Policy Makers responsible for reforming existing market arrangements and building on existing EU policy directives to achieve firm and binding targets for Member States for 2030 – 2050 to inform the strategic planning process; the European Network of Transmission System Operators for Electricity (ENTSO-E) in their key role of promoting the reliable operation and optimal management of the European transmission system; and other key market participants responsible for regional distribution, supply and delivery of future generation assets and associated infrastructure.

The questions to be answered in this WP show that the vision of a pan-European Electricity Highways System is today still very unclear. But in order to achieve the **first version of the MoDPEHS by the end of 2014** it is important

- from the study programme range point of view to limit the scale of every of these dimensions (e.g. definition of minimum and maximum share of RES generation in the

[4] Re-thinking 2050 – A 100% Renewable Energy Vision for the European Union

system). These limitations or boundary conditions are the overall goals of this Work Package.

- from programme organization point of view to split this first WP into a **pre-project of the study consortium** which must be realized before the EC funded part will start and into a **regular, EC funded WP 1 part** for remaining activities (further validation/detailing/completion of the achievements of the pre-project).

The modular approach includes a verification of the Boundary Conditions with every new module or new version of the Plan – adapting real-world developments and reducing insecurity with passing time.
The subsequent Work Package 2 (Scenario Analysis) will pick up the boundary conditions. Every defined scenario will consist of a set of parameter-values within the WP1 defined boundary conditions of every dimension.

Whilst the Boundary Conditions Work Package does not depend on input from other Work Packages, its outputs will inform the framework for the remainder of the programme. This part of the programme (as the lead element) is therefore critically important in terms of its content, its interaction and its timing.
Although there is no direct dependency on other WP's outputs, it might be necessary to review the defined Boundary Conditions depending on results of WP2 (Scenarios), WP 6 (Socio-Economic Profitability) and WP 7 (Stakeholder Involvement). This iterative mode will ensure consistency throughout the programme.

3.1.2 Rationale for Inclusion in ENTSO-E Study Roadmap Package

This investigation (the programme) and the associated Boundary Conditions that define it represent the first Work Package in an overall sequence of nine Work Packages designed by the collective members of ENTSO-E. The purpose is to define, scope and articulate the very significant process of delivering a meaningful and practical Study Roadmap towards a Modular Development Plan on pan-European Electricity Highways System (MoDPEHS) that has the capability and intelligence (smartness) to serve the needs and objectives of the European energy policy over the period leading to and beyond 2050.

A significant number of independent studies have been carried out to underscore the importance of planning for a system that can better manage the changing mix of generation technologies being deployed (and increasingly being deployed over time) in response to decarbonisation directives. A number of these studies have been considered when structuring this programme. And whilst their content (and to some extent their influence) has

been useful in informing the process, ENTSO-E is keen to point out that none of the studies reviewed to date are sufficiently well informed in their own right to be used as directional indicators for the industry.

Some have useful content but none, in ENTSO-E's opinion, have the 'rounded' perspective that is only informed by industry experience and / or participation. Therefore it is justified to develop an independent approach to the subject so that plans and strategies are specifically structured to meet collective aims and objectives of all key stakeholders. Furthermore no study or respected informed body has yet developed (in sufficient detail) a set of design requirements that justify the levels of investment and political / policy intervention necessary to stimulate the collective change process and reforms required to deliver the step change that is required.

ENTSO-E are viewing this as a long term project that will deliver its findings through a range of different participating specialist partners working with the transmission system operators so that all system dimensions, definition criteria and operating requirements are considered in detail before the crucial next steps of infrastructure modification / execution are finally committed and funded.

3.1.3 Project Objectives

The objective of Work Package 1 is to define the overall boundary conditions of the future European power system (technical/technological, economical/financial, political/sociopolitical factors that will have the greatest impact) as guideline for all other Work Packages. The analysis will be designed to extract levels of detail not yet, in ENTSO-E's opinion, clearly defined in any other study relating to pan-European grid definition and/or infrastructure delivery.

A set of boundary conditions (rules of engagement) will be established as a key imperative of this Work Package. The outputs, in this regard, will be structured to inform all participants of the opportunities but also necessary limitations that are required to bring about a successful transition from today's infrastructure arrangements to the next generation of infrastructure (supporting uni directional inter regional and cross boundary electricity transmission) needed to serve the EU Member States and those states with IEM affiliation adequately (efficiently, reliably and economically) over the next forty years leading to 2050.

In bringing this about, an in-depth analysis of the overall energy sector is needed. And it is important that the industry and policy makers have a clear understanding of the level of intervention that this is likely to demand so that all parties are positioned to positively input to

the process (regional growth expectation in renewable generation, demand characteristics, regulatory harmonisation, policy changes, network unbundling etc.) and timely delivery (ahead of need or in line with growth prospects) is possible over the stated planning time horizon.

Input data for the definition of the Boundary Conditions might for instance be:

- The ENTSO-E TYNDP,
- Studies carried out in the framework of NSOGI,
- Raw data that will be used to elaborate the scenarios and that will not be provided by TSOs (demand and generation scenarios),
- Results from other FP7 projects.
- etc.

This Work Package is a highly complex (and pivotal) piece of work. It requires close attention to detail by informed participants who are intimately familiar with the operation of transmission systems and sub distribution networks throughout the EU Member States and those states with IEM affiliation. The participants will also need to draw on information and data pertaining to regional asset planning frameworks. This will be supported through stakeholder workshops, discussion fora and executive meetings arranged and supported by supporting Work Packages and through ENTSO-E member companies.

3.1.4 Project Scope

As stated in the project objectives section, this highly complex Work Package requires particular focus on specific subject areas that will be pivotal. Importantly by dealing with many, as yet, unanswered questions, this Work Package will act as a starting point. It will not answer but define the boundary conditions (set up corner stones in the wide field of possibilities) for a large number of questions as important basis for the other Work Packages.

Technical boundary conditions to be defined / key drivers to be identified for following questions in preparation for subsequent Work Packages:

- To which extent could the existing networks, with some adaptation (no real change), provide the infrastructure requirements needed over the future (2050) time horizon i.e. will it cope?
- Would it be adequate to assume that the existing networks could be sufficiently reinforced to cope with new load growth and renewable generation in feeds, with particular focus on network transition points and inter country network boundaries?

- What are plausible technical transmission solutions which can provide from today's perspective a pan-European Electricity Highways System incorporating high power flows and low system loss capabilities?
- What form will the 'Highways' take? Are they defined by their technology, how are they geographically meshed or more by the way the assets are operated?
- How smart does it have to be?
    - What level of new or embedded smartness is required to make it happen efficiently, reliably and economically?
- Could it include energy transformation and transport (e.g. hydrogen)?
- What influence will storage capacity have on the 'Highways' dimension?
- To which extent could special planning restrictions (i.e. no overhead lines) influence the technological developments?

Economical/financial boundary conditions to be defined / key drivers to be identified for following questions in preparation for subsequent Work Packages:

- What are the energy market and overall economic conditions that are assumed for the future upon which the case for change and network development is based?
    - How will tomorrow's economical pathways in Europe drive future demand, and in what areas and regions of the market?
    - What is the basis of the forecast and where is the data derived and what assumptions are considered to be reasonable and credible?
- What economic changes would have most dramatic impact on the need case for Electricity Highways and what is the out turn probability of such changes taking place over the planning time horizon?
- Strong growth in GDP, for example, might lead to lower demand flexibility and this in turn might significantly effect generation mix, asset availability / flexibility and operating regimes?
- The general economic conditions that prevail and the expectation of realistic economic variance that should be factored into the debate over reasonable and realistic timescales?
- How attractive is the idea of an Electricity Highways System to existing TSOs?
    - What benefits over and above business as usual will it deliver?
    - Will it solve known and anticipated issues
    - Will it lead to new service revenues and commercial opportunities?
- Which changes in the energy market structure might be needed to ensure successful implementation of an Electricity Highways System?
- Which broad scenarios are relevant for the probable connection with the North-African electrical systems?

- To which extent will market frictions could appear due to the limited manufacturer capacities (e.g. cable productions) or resources effiency/availability issues (e.g. use of copper)?

Political/sociopolitical boundary conditions to be defined / key drivers to be identified for following questions in preparation for subsequent Work Packages:

- What existing policies must (barriers to super grid) be changed / modified if the benefits case for the Electricity Highways System is to be supported? What current policies should be sustained?
    - Separation of transmission from other services?
    - Back up generation arrangements and impact?
    - Regulation at national level or 'Super Regulator'
    - What policies would have the most dramatic impact on the need case for a move towards the Electricity Highways System vision?
    - EU tackling the renewable targets as individual Member States vs. collaboratively as a unified body
    - European incentive programmes (and demand flexibility options)
    - Energy efficiency initiatives
    - Increased renewable subsidies to drive 100% renewable vision
- Who will carry the investment costs and who will benefit from the Electricity Highway System: the mechanism and structure of cost and benefit sharing?
- Which changes are required to licences and operating codes to support system unification and regional / cross border alignment (separation of network services, asset management, benefits / cost sharing, operating rules)?
- To what extent will European countries be expected (or incentivised) to participate?
    - Structure of responsibility?
    - Operating regimes?
    - Mandated participation?
- What would be the objectives, responsibilities and obligations of the operator(s) and what would be their place in the hierarchy of system operation (locally, regionally, Europe wide)?
- How will sharing of resources (storage and reserve), variability (RES and loads, generation, demand, storage) be managed / facilitated on a pan-European basis?
- Political perception - as a facilitator of climate goals?
- Political perception - as a facilitator of market goals?
- What environmental concerns will influence the grid development, and what kind of environmental constrains is relevant?

- What major changes in existing European environmental framework are necessary and achievable?

Further boundary conditions to be defined / key drivers to be identified for following questions:

- What requirements are needed for organisation and governance linking to policy, system management and implementation?
- Will the needed level of reliability be the same, lower or higher than today? Do the current reliability standards have to be reviewed?
- Could its operator(s) procure transmission services from asset owners?
- The proportion of variable generation sources that should be considered in the analysis and the location (and growth prospects) of such resources?
- The extent to which it is reasonable and valid to consider connection to and imports / exports with countries within / outside Europe and the issues that may ensue as a result?

It is important to note that developing a future system is not only about the possibility of an overlay grid. It is also about the extent to which the whole (existing and emerging) electricity system must be considered in scoping the most efficient concept (generation, transmission, distribution, storage technologies, demand flexibility, smart grid functionalities).

As the purpose of this Work Package is to clearly define the idea of Electricity Highways System and outline the Boundary Conditions that define the dimension of the required infrastructures as reference points for interfacing Work Packages, a key output must be a full appraisal of all of the options available and a summary position on what resulting factors and conditions will make the Electricity Highways concept more, or less likely to be a feature of future pan-European network design.

The Boundary Conditions Work Package forms part of an integrated assembly of analysis comprising nine Work Packages, and hence the partners or consortia working in this area of the Study Roadmap will be expected to interface effectively and responsibly with the participants (and their outputs) from other key Work Packages as a matter of priority. The Boundary Conditions participants therefore, despite being the first to deliver, are likely to be called upon to re-engage at various points in the programme cycle.

3.1.5 Project Deliverables

The key deliverable for this Work Package is a precise summary of the boundary conditions that should prevail as reference points for developing the 2050 infrastructure project itself and for developing subsequent project related sub set initiatives. This should be informed

and supported by answering the questions shown in the Project Scope section above and thereby giving the following summary information:

- **Boundary Conditions Report** (key deliverable): definition of all dimensions, that have been analysed, description of the approach/selection criteria and a detailed description of the chosen boundary conditions.
- **Study review**
- **Infrastructure policy review:** A detailed review of energy / infrastructure policy relating to the realisation of Electricity Highways over the mid and long term;
    - National specifics
    - Regulatory harmonisation
    - Governance and funding
    - Incentivisation of participants
    - Public funding implications
- An **appraisal of the economic factors** impacting on pan-European 'grid' development over the 2050 time horizon;
- **Assessment of effects on EU Member States and those states with IEM affiliation:** A high level appraisal of the effect that an implementation of a EHS will have on state utilities i.e. mechanism for cost and benefit sharing resulting from the needed usage of state infrastructure; some will be more seriously affected (resourcing, economic, project risk etc) than others - who are likely to be the winners and who might be the losers. To which degree will this limit the EHS vision?
- **Industry Code Review:** A detailed summary of the changes that will be required to licences and operating codes to support system unification and regional / cross border alignment (separation of network services, asset management, benefits / cost sharing, operating rules);
- A detailed **vision statement** of what is required to realise the 2050 infrastructure vision clearly stating the key areas of focus and how they affect the responsibilities of existing system owners and operators; and
- What **infrastructure configurations** are ruled in and what are ruled out. For example are inter-country infrastructure options a realistic prospect.

3.1.6 Resource plan

The following matrix shows human resources needed to grasp all relevant issues of Work Package 1 (Boundary Conditions). This needed expertise will be covered – apart from the required TSO involvement – also by other consortium partners as shown in the table below.. The estimated person-months need to be updated when the Project Consortium is set up.

Table 5: WP1 Resources[5]

Specialists / Workstreams	TSOs	Energy Economics / Law Partners*	Policy / Regulatory Partners*	GenCos and RES Partners*	DSOs/Smart Grid Partners*	Manufacturer	Person-months per workstream
WP1 Management	*** CONFIDENTIAL *** ESTIMATED NUMBER AND DISTRIBUTION OF PERSON-MONTHS IS KEPT CONFIDENTIAL BEFORE CONSORTIUM ESTABLISHMENT						
Boundary Conditions Report (key deliverable)							
Study review							
Infrastructure policy review							
Industry code review							
Appraisal of key economic factors							
Vision statement of 2050 infrastructure							
Assessment of effects on Member States							
Implications on infrastructure configurations							
Person-months exclud. WP1 Management							

*includes respective R&D performers

[5] See chapter 3.1.1: WP 1 will be divided into a pre-project of the study consortium which must be realized before the EC funded part will start and into a regular, EC funded WP 1 part.

3.2 Work Package 2: Plausible Future Power System Scenarios for the European Energy Sector

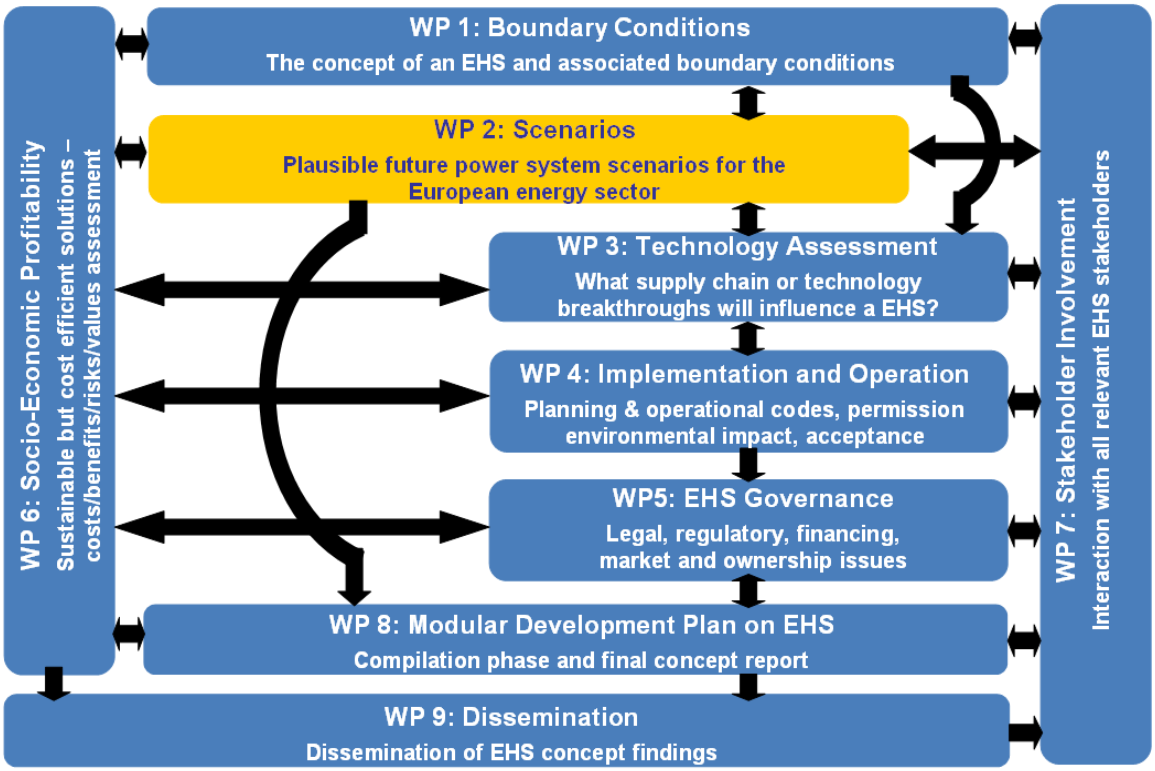

Figure 11: Placement of WP2 within programme structure

3.2.1 Introduction

A key requirement in the development of the MoDPEHS is the development of a number of market and infrastructure scenarios that will serve as reference points (future vision) for the development of the Study Roadmap process. In driving this Work Package forward close attention will be given to the outputs of Work Package 1 (Boundary Conditions) so that the emerging scenarios are consistent with the agreed Boundary Conditions outcomes.

To develop credible representative 2050 and intermediate (for the years 2030, 2035, 2040 and 2045) scenarios it will be important to consider the input of other key issue areas (notably Work Packages 3, 4 & 6) on technology applications, fuel mix, generation mix, storage potential, and demand response potential to understand the range of costs associated with 'real' operation and how this might affect planning decisions moving forward. A number of very well informed papers have been published on the subject of a unified European electricity system with shared resources and embedded technologies and the

content of these should be considered when building the scenario options for consideration. Special acceptance will be paid to the forthcoming EC Energy Roadmap 2050 which is expected before the end of 2011 and will be an important reference as it should provide realistic (i.e. technically and economically plausible) development scenarios. However, whilst a number of Electricity Highways System studies are available besides latest official EC energy view to inform the general development of the 'scenarios' Work Package (thought process) it is vitally important that an independent approach to the assembly of suitable market, infrastructure and socio-economic scenarios is maintained. In this way the important corner stones (the agreed scenarios) of the MoDPEHS will be prepared and delivered with the aim of commissioning the first European Electricity Highways by 2020.

This Scenarios Work Package has a dependency on WP 1 (Boundary Conditions) and needs to consider the early outputs from the Boundary Conditions section when preparing the supporting analysis for scenario development. The outputs of this Work Package are critical to informing other elements of the programme, especially WP 3 (Technology Assessment), WP 6 (Socio-Economic Profitability), WP 7 (Stakeholder Involvement) and WP 8 (MoDPEHS).
Although there is no direct dependency on other WPs outputs than WP 1, it might be necessary to review the defined Scenarios depending on results of, WP 3 (Technology Assessment), WP 4 (Implementation and Operation), WP 6 (Socio-Economic Profitability) and WP 7 (Stakeholder Involvement). This iterative mode will ensure consistency throughout the programme.

3.2.2 Rationale for Inclusion in ENTSO-E Study Roadmap Package

As with all highly complex projects and situations, determining the optimum way forward requires careful planning and consultation. Importantly the overall outcome (the Modular Development Plan on Electricity Highways System) must be built on firm foundation which requires the definition of clear principles for scenario building. As a result the information and data sets that are used to construct the Electricity Highways scenarios need to be shared, agreed and robustly tested by stakeholders, and agreed for inclusion as the basis of further analysis, by the programme Steering Committee.

The inclusion of Work Package 2 in the project is therefore a prerequisite for the aim of MoDPEHS.

3.2.3 Project Objectives

In context of required modular approach, essentially the objective is to develop a set of long term scenarios (2030, 2035, 2040, 2045, 2050) that serve as sensible reference points upon which all other activities and actions will be based. Starting point will be the scenarios taken into account by ENTSO-E for elaboration of TYNDP. To develop the Work Package will call upon partners and / or consortia to investigate and examine the question, what are the credible and secure scenarios for all relevant power system factors for next decades to 2050 that represent the possible futures? More in detail: In considering the above outcomes attention must be directed towards supply uncertainties and regional variations. Out turn sensitivities will therefore need to be constructed to aid understanding in extreme supply / demand circumstances i.e. low wind conditions, climatic uncertainties etc.

The extent to which demand will be affected by decarbonisation measures (demand response (DR) and energy efficiency) will also be critically important inputs; as will the longer term effect on demand from fuel shifting driven by significant changes in customer behaviour patterns. Some key characteristics to be considered when developing the analysis will be:

- The impact associated with the fuel shift driven by the mid to long term take up of electric vehicles;
- The effect of the shift from fossil fuel systems in buildings to, among others, heat pump technologies;
- The long term effect of concentrated energy efficiency and decarbonisation programmes;
- The possible impact of incentivised DR and load shifting initiatives; and
- The management and impact of integrated electricity storage systems on future infrastructure scenarios

From a supply / production perspective informed assumptions will be required for review, examination and agreement by the advisory group. The assumptions must be founded on reliable market / stakeholder data and must be reasoned in terms of the possible split of applied generation technologies.

In addition clear assumptions and supporting analysis are required regarding:

- What fuel mix would provide the required European wide system security from fuel shocks, including geopolitical risks and terrorist attack;
- What level of electricity import reliance would be acceptable;
- What level of primary fuel import reliance would be acceptable;
- What is the generation adequacy, with the politically accepted fuel mix and future expectations of RES etc;

- When considering the Electricity Highways of the future, can the generation mix be analysed EU/Europe wide, or will self sufficiency remain strong within national / regional objectives?
- Which market principles must be taken into account and which are not likely to be relevant for a future Electricity Highways System?

These are searching questions that require very careful consideration, consultation and iteration. In developing this piece of work it will also be important to take account of the broader objectives of European energy markets in terms of security of supply, decarbonisation and energy competition. Partners must therefore be able to demonstrate capability and deep specialist knowledge in all related areas and operating disciplines.

Input data for the definition of scenarios might for instance be:

- TYNDP,
- Studies carried out in the framework of NSOGI,
- Raw data that will be used to elaborate the scenarios and that will not be provided by TSOs (demand and generation scenarios),
- Results from other FP7 projects.
- etc.

The process for integrating already existing ENTSO-E scenarios and those in progress can be seen in following figure:

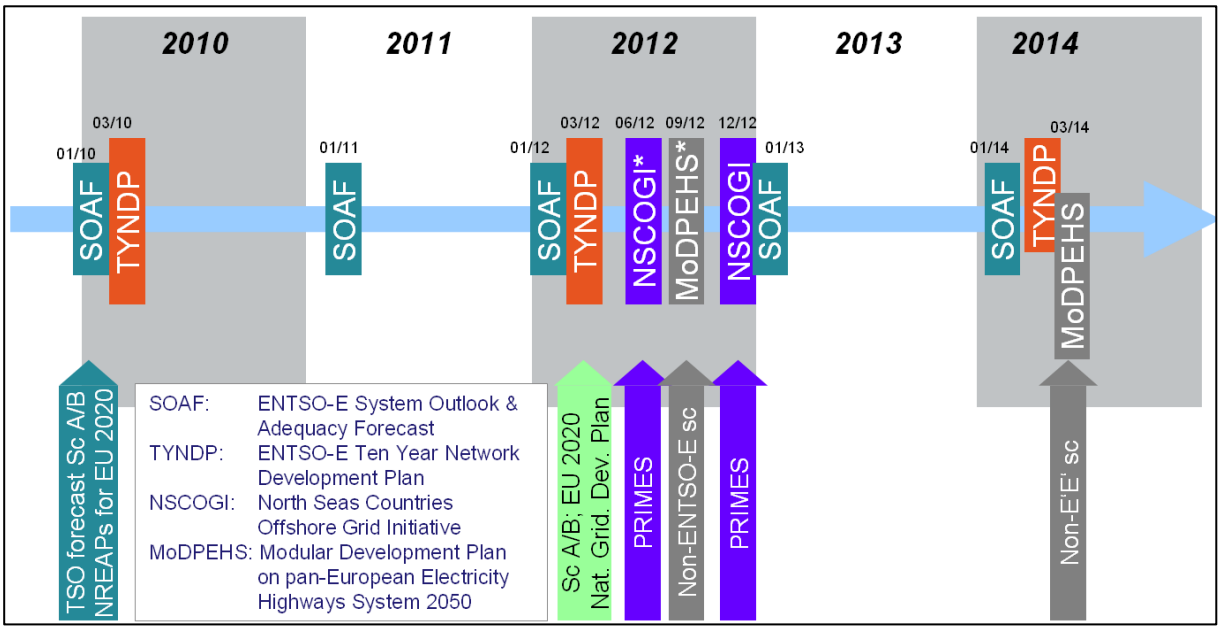

Figure 12: Integration process of scenarios towards MoDPEHS

3.2.4 Project Scope

Work Package 2 incorporates a wide ranging brief and requires specialist input regarding national progress and aspirations in relation to the development of the modular plan. All dimensions of the electricity system must be taken into account in developing the analysis that eventually supports the assembly of the final scenario options. In addition, this project has also to cover the external dimension of EU energy policy regarding – among others – options for inter-continental connections as to the synchronous system in Eastern neighborhood or to North Africa.

In the context of the Study Roadmap this must include credible and secure long term scenarios for time horizons 2030, 2035, 2040, 2045 and 2050 associated with:

- Installed capacity of generation units;
- Generation mix and respective gradients;
- RES infeed based on weather simulations
- Demand assumptions (including demand flexibility);
- Regional spread;
- Im-/export incl. interconnectivity;
- System flexibility incl. storages scenarios;
- Possible production technologies and their manufacturing, environmental and resources constraints;;
- Energy market implications based on market simulations;
- Infrastructure and general grid architecture options based on network analyses;
- Political framework; and
- Relative economic impacts.

The market studies will be elaborated in close cooperation with the respective ENTSO-E bodies for all Working Scenarios and time horizons aiming the justification of expected future transmission needs between countries and defined zones.

Based on these market simulation results network analyses will be carried out in close cooperation with respective ENTSO-E bodies. Thus, likely grid architecture options as further scenario dimension will be identified. Thereby appropriate grid planning criteria (and for implications regarding expected grid operation conditions also appropriate real-time grid operation criteria) have to be taken into account. Since this analyses must be done based on simplified assumptions e.g. for future generation parameters, the analyses will include concrete load flow calculations but cannot cover concrete studies on dynamic stability. Based on dynamic characteristics of future generation and transmission devices, consideration of

aspects of dynamic stability will be done within Work Package 3 based on simplified generic approach. The stability results of Work Package 3 will then iteratively be integrated and reviewed in Work Package 2

The resulting scenarios will describe a multi-dimensional scenario room for the power system out of which a limited number of scenario vectors (working scenarios) will be selected. The final working scenarios adopted as reference points for inclusion, will have a close fit with the Boundary Conditions developed in Work Package 1. Thus, consistency and continuity throughout the project will be ensured.

It will be ensured that both bottom-up and top-down scenario approaches are considered and used to reach a best synthesis option. In this sense, at least the following scenarios shall be included, based on iterative approach with WP 6 on Socio-Economic Profitability and especially on dedicated costs-benefits analyses:

1. Generation scenarios based on the national RES plans until 2050 with the minimum cost transmission system needed for that generation. The generation plans to be used will preferably be the plans approved by the governments (such as the national renewable energy action plans for 2020) or the plans that each EU Member State or state with IEM affiliation sets as objective or estimates for itself.
2. Generation and transmission scenarios resulting from a pan-European total cost (generation- and transmission-) optimization.
3. Generation scenarios in which a given percentage of the total European demand is imported from North African and Middle Eastern countries (e.g. Desertec concept).

In addition a common counterfactual (or business as usual) scenario from which all other business cases can be referenced for cost benefit purposes has to be elaborated.

This Work Package is project critical to all other Work Packages in the Study Roadmap process. In this regard the cost benefit work associated with Work Package 6 is particularly reliant on the scenario outputs from this Work Package.

3.2.5 Project Deliverables

The Work Package is required to deliver a set of long term recommendations for scenarios including data files related to key application areas as follows:

- Generation incl. RES penetration;

- Fuel mix;
- Technology mix;
- Demand deployment and demand response;
- Storage deployment;
- Energy efficiency development;
- Infrastructure and general grid architecture;
- Market and overall economic impacts; and
- Geopolitical and socio-political impacts

Deliverables of Work Package 2 (Scenarios) are:

- **Working Scenario Report:** Overall summarizing report on all steps taken towards a reasonable set of scenarios as basis for the MoDPEHS and as item for intermediate dissemination and as input for the TYNDP reports.
- **Study Review:** The initial deliverable will be a study review, the assessment of possible inputs from other study projects dealing with the scenario issue, especially any relevant FP7 projects already realized or still ongoing (certain access provided).
- **Assessment of demand evaluation:** Definition of possible future demand scenarios in line with the defined Boundary Conditions.
- **Decarbonisation, demand response, storage deployment and energy efficiency impacts:** Definition of possible and plausible scenarios of the development of demand side management, deployment of large-scale and decentralized storages and energy efficiency potentials.
- **Technology pre-assessment:** First assumptions regarding the technology pathway in order to limit the scenarios; further analyses and update to follow in an iterative approach with WP3 (Technology Assessment).
- **Secure generation assessment:** Elaboration of different credible and secure long term load and generation scenarios associated with:
    - Installed capacity of generation units
    - Generation mix and respective gradients
    - Demand assumptions
    - Regional spread
    - Im-/export incl. interconnectivity
    - System flexibility incl. storages scenarios
    - Etc
- **Market simulation, network considerations and infrastructure assessment** for all time horizons and defined Working Scenarios.

- **Economic impact assessment:** Credible and secure long term scenarios associated with relative economic impacts, e.g. the monetary aspect as further dimension of the multi-dimensional scenario room. Scenarios to be covered:
    - generation costs,
    - infrastructure costs, including costs in distribution grids for DSM
    - scenarios for national tariffs for electricity and
    - impact on gross national product (GNP)

  …as important impulses for overall economy. An iterative approach between the Work Packages is needed.
- **Scenarios construction:** Definition of a set of "Working Scenarios" out of the complex multi-dimensional scenario room.

From the above, the partners in close co-operation with the Electricity Highways Stakeholder Platform as project advisory group, will be required to construct potential composite 'Working Scenarios' that are judged to be representative of realistic future views of the European system leading to 2050 and that are described in the Working Scenario Report.

3.2.6 Resources

The following matrix shows human resources needed to grasp all relevant issues of Work Package 2 (Scenarios). This needed expertise will be covered - apart from the required TSO involvement – also by other consortium partners as shown in the table below. The estimated person-months need to be updated when the Project Consortium is set up.

Table 6: WP2 Resources

Specialists / Workstreams	TSOs	Energy Economics / Law Partners*	Policy / Regulatory Partners*	DSOs/Smart Grid Partners*	Manufacturer	GenCos and RES Partners*	Consumers	NGOs	Person-months per workstream
WP2 Management	*** CONFIDENTIAL *** ESTIMATED NUMBER AND DISTRIBUTION OF PERSON-MONTHS IS KEPT CONFIDENTIAL BEFORE CONSORTIUM ESTABLISHMENT								
Working Scenarios Report (key deliverable)									
Study review									
Assessment of demand evolution									
Decarbonisation, demand response storage deployment and energy efficiency impacts									
Technology pre-assessment									
Secure generation assessment									
Market simulation, network analyses and infrastructure assessment									
Economic impact assessment									
Scenarios construction									
Person-months exclud. WP2 Management									

*includes respective R&D performers

3.3 Work Package 3: Technology Assessment – What Supply chain or Technology Breakthroughs will Influence the Electricity Highways Vision

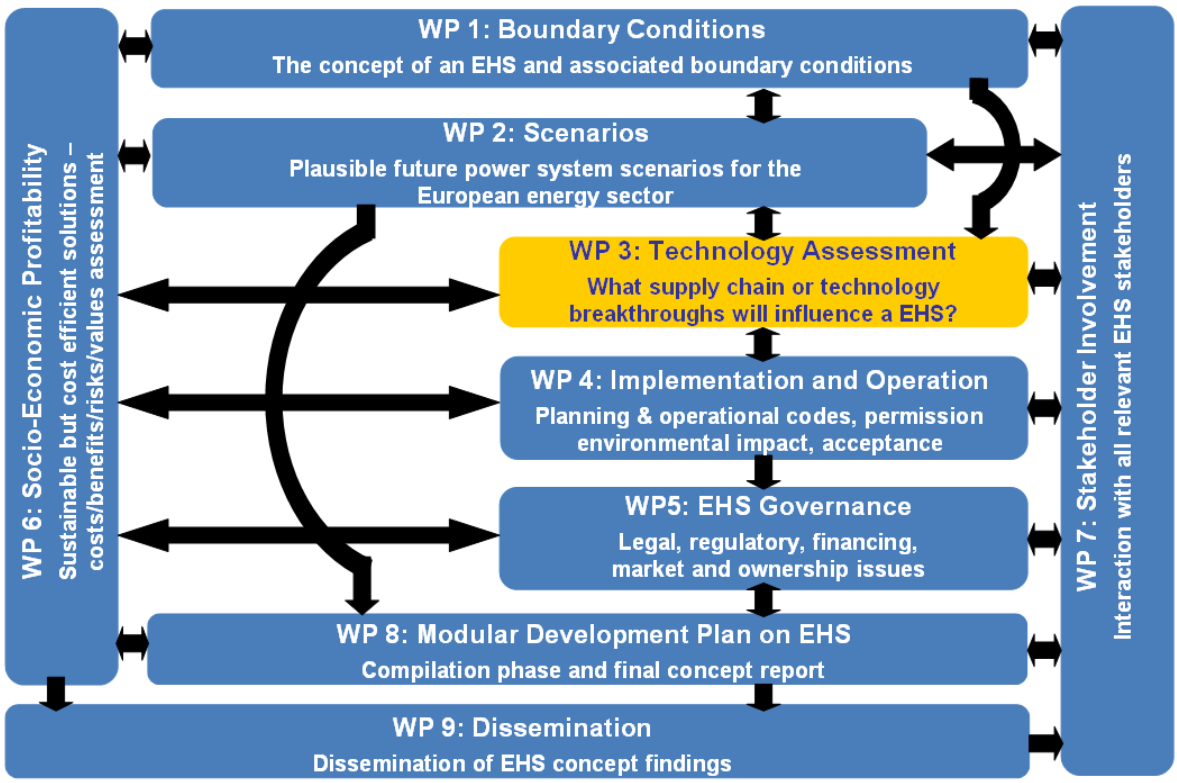

Figure 13: Placement of WP3 within programme structure

3.3.1 Introduction

A key enabler in the realisation of the 2050 vision will be the inclusion of advanced network technologies and systems that allow TSOs and utilities in the future to develop the tools and systems required to effect reliable and efficient network operation. Technology companies are increasingly rising to this challenge. Consumers are encouraged to engage in the process of change through the application of smart metering and smart energy systems and pricing policies that will drive active participation.

Power grids are evolving from one-way legacy power systems into two-way carriers of traditional grid to customer generation combined with increasing volumes of distributed generation from renewable energy projects. These evolving networks will increasingly require

embedded supporting technologies. Systems to enable efficient moment to moment operation. and management of the vast quantities of data that will become a feature in the active management and efficient operation of the new grid.

The transition from one-way power dispatched to consumers gives opportunities for consumers to deliver power back into the grid. This creates challenges crossing utility, internet, security and regulatory worlds. However, it also creates opportunities for technology providers who are able to come up with solutions that address key operational areas of concern. In this regard much of what drives this will be technologies that exist today (or variants of these).

Increasing renewables generation is causing dramatically increased volatility on the demand side. Renewable power therefore is likely to test grid operations as never before. These circumstances create the need for new technical solutions to track events and manage the resulting power flows, alongside traditional generation methods, in real time. Additionally, cross-border power flows and cross continental power transfer arrangements become increasingly obvious besides the need for large-scale and decentralised storages. The sources of electricity are expected to be a broad mix of i.e. On- and Offshore Wind, CSV, Photo Voltaic Systems, Hydro storage and traditional fossil fuel (CCS) and nuclear generation. In this context, the need for technology intervention and ever more sophisticated control systems is obvious.

This technology based Work Package aims to deliver greater visibility and insight into what is currently available. Which technologies are in use and what is in development and likely to be available within a maximum 10 -20 year time horizon. Technologies will need to be embedded until 2030 if they are likely to be influential in operation and management of an enduring electricity system with a 2050 time horizon.
Many leading academics and industry commentators advocate that a 100% renewable energy future for Europe is practically possible, environmentally necessary and economically viable. Making this happen, however, will be a huge cross industry and cross boundary challenge for policy makers, regulators, TSOs and other utilities. The objective in commissioning this investigation / assessment is to:

1. Collect more evidence and details regarding 'smart' enabling technologies to understand how they might influence the design and development of a unified European 'Electricity Highways System'
2. Apply the outputs from this Work Package to the outputs received from other key Work Packages in the process;
3. Understand the respective actions (and timings of actions) that need to be assigned to take the process forward within an agreed working framework; and
4. Finally allow the project partners and stakeholders as ENTSO-E to gain traction with regard to the development of a detailed Modular Development Plan on pan-European Electricity Highways System (MoDPEHS);

3.3.2 Rationale for Inclusion in ENTSO-E Study Roadmap Package

The inclusion of technologies must be fully justified and supported by detailed analysis in order that the project partners and stakeholders as ENTSO-E are able to systematically judge the level of added value in terms of costs, performance, risk and efficiency that can be attained by inclusion in forward network plans. By doing so, a full range of priorities and issues associated with the development of the pan-European power system can be assembled. The overall power system consists of the generation, demand, storages, network and associated technologies. It is considered important that the project consortium has a robust analysis of the technologies that will be mature both in terms of those that will connect to the grid and those that will form and control the grid.

The intention for this Work Package is to provide an understanding of constraints and opportunities regarding the grid technologies that are likely to be available for use in the 2050 time horizon and in the intermediate horizons. Without such analysis, there is a risk that the range of scenarios proposed for assessment could be too broad in practice. Therefore these scenarios would be unrealistic due to technological factors, supply chain issues or other constraints which would otherwise not be revealed.

This Work Package will provide analysis to help to define technology boundaries within which scenarios can be defined.

This WP 3 (Technology Assessment) highly depends on the results of WP 1 (Boundary Conditions) and WP 2 (Scenarios). If Work Package 3 takes place sequentially behind Work Packages 1 (Boundary Conditions) and 2 (Scenarios) the outputs can be picked up and included without unnecessary determent to the progress of the project. Work

Packages 4 (Implementation and Operation), 6 (Socio-Economic Profitability) and 7 (Stakeholder Involvement) are however dependant on the outputs of the Technology Assessment section.
Although there is no direct dependency on the following WPs, it might be necessary to review the technology assessment depending on results of WP 4 (Implementation and Operation), WP 6 (Socio-Economic Profitability) and WP 7 (Stakeholder Involvement). This iterative mode will ensure consistency throughout the programme.

3.3.3 Project Objectives

The objective of this part of the Study Roadmap is to seek detailed technology and capability forecasts of the existing and emergent technologies. The goal is to know what will be available to form and influence grid development from the present day to 2050, with special attention to the intermediate time horizons 2030, 2035, 2040 and 2045. Deliverables from this Work Package will provide critical insights to improve ENTSO-E's understanding of the following issues:

- Emergent transmission technologies that could enable the more efficient and widespread operation of future networks;
- Generation technologies that will begin to influence and reshape the way power flows are managed
- Control systems that are critical to the development and acceptance of increasing numbers of renewable schemes and its volatility in line with long term European targets and forecasts;
- Viable large scale but also decentralized storage technologies that will contribute to low carbon energy networks of the future and in so doing justify incorporation into future roadmaps and plans;
- Demand response initiatives; where innovative methods are being developed and deployed, results obtained and the form and nature of how these will evolve in future including the development of smart buildings and smart city incorporation.

The project consortium seeks to understand in detail the range of technologies likely to influence infrastructure design over the next 10 to 20 years; as it will be these technologies and devices that will influence network capability and derived benefits through to 2050. In association with this the project consortium and stakeholders as ENTSO-E requires an informed forecast of the nature and level of innovation support that will be required to accelerate the delivery of emerging technologies.

The key drivers for technological developments are the delivery of a low carbon electricity sector (and associated environmental targets), ongoing concerns regarding security of supply and network reliability, power network innovation to improve quality standards.

3.3.4 Project Scope

The scope of this Work Package covers the key technologies that will be essential to the effective and efficient development of European Electricity Highways (including information and communication technologies (ICT) and electronic enabling devices). The focus of this work should be on technology groups which are not likely to be widely deployed within the next years, but will mature over the envisaged time horizon to support incorporation into the design and evolution of intelligent networks of the future. The Study Roadmap should forward looking out to 2050, through a modular approach, i.e. step to step, starting, with particular emphasis on identifying the innovation potential up to 2030.

The purpose of this Study Roadmap is to describe and quantify the relevant innovation opportunities that are (and will become) available, and to consider and describe how these might be incorporated into specific programme proposals. The Study Roadmap should also look at existing support measures to assess gaps and opportunities, and it should test and evaluate the effectiveness of existing policy measures and the ability of those policies to deliver the technology requirements. This technology breakthrough assessment will form part of an integrated package of analysis, and hence the team working in this Work Package will be expected to interface effectively with the outputs from other key priority groups.

The scope of the project must include the following assessment analysis:

1. Firstly, as well as assisting the realisation of a European Highways vision and its attendant smart grid and bulk power characteristics, the technologies must be assessed for their contribution towards the economic achievement of ever challenging carbon abatement targets. When considering this area key questions should be addressed including for example; is the technology practically viable (if not immediately, then what would change this) and what is it's deployment potential of the technology over the period considered;
2. Furthermore, having satisfied the criteria in 1, it will be important to understand whether certain technologies have significant value creation potential, and how each scores in this area, in relation to the others. This requires careful assessment of market size and potential (home markets and internationally), existing manufacturing capability and the scope for economic value creation.

3. As next item, a perspective is required on policy definition in relation to the uptake of the technology. What existing barriers can be identified? How must these barriers change to effectively facilitate the enablement of an emerging pan-European vision over the next 10 – 20 years. Additionally, what EU support would be appropriate and what mechanisms should be developed to encourage these to happen.
4. As further step, potential scenarios will be identified most suited to the deployment, followed by identification of potential barriers to deployment;
5. For the pan-European Electricity Highways System including connections to neighboring systems, the dynamic aspects as especially the issue of inter-area oscillations or e.g. stability aspects of mainly converter infeeded electricity system (low inertia) are of high importance. Due to the long-term character of considerations and taking into account expected implementation of breakthrough technologies, the dynamic stability issues must be analyzed black-box wise i.e. based on generic “green field models” but must consider as far as possible dynamic characteristics of future generation and transmission devices;
6. Finally, recommendation regarding scope and locations for the next stage of technology development and demonstration will be elaborated.

It should be emphasised that this is the initial stage of a process of identifying and prioritising innovation opportunities relevant to the development of a pan-European transmission network that has the inbuilt 'intelligence' (smartness) and flexibility to harness / maximise low carbon generation output and in so doing attract broader EU support.

This phase of the work will need to be comprehensive and contain clarity regarding each technology area i.e. it will not be sufficient to discuss high level aspirations without defining the specific technology that will be used to enable it. Hence, activity in this phase should draw upon existing information and experience (both publicly available and proprietary to the bidder), relevant advancements in the area of research and development and the practical knowledge of the bidder in terms of applied technology and its ability to deliver tangible benefits.

Technologies that could significantly influence pan-European power system development to 2050 could include:

- Transmission technologies
  - State of the art HVAC infrastructure developments,
  - Alternative HVAC technologies different from 50 Hz
  - HVDC: Voltage Source Converter including multi-terminal HVDC (VSC) and Line Commutated Converters

- Cable, both sub sea and underground in terms of capacity, cost and reliability (Extra High Voltage, too)
- Overhead line technologies, incl. aspects of upgrading of existing routes as well as combined HVAC/HVDC routes
- Gas insulated lines
- Voltage options and selection
- Reactive compensation
- System stabilisers
- Superconductivity
- Offshore substations
- System level protection and control
- Operational control

- Generation technologies
  - Photo Voltaic
  - Concentrate Solar Power
  - Wind, onshore and offshore
  - Geothermal
  - Hydro with or without storage

  - Fossil fuel generation with or without CCS
  - Nuclear power, (in particular fusion nuclear)
  - Biomass and bio fuels
  - Various forms of distributed and micro generation
  - Wave power generation
  - Tide power
  - Hydrogen fuel cells

- Storage technologies
  - Storage, e.g. types, cost, efficiency, power vs. energy
    - Hydro with reservoirs and pumping storage
    - Battery
    - Large scale and distributed
    - CAES (Compressed air energy system)
    - Hydrogen
    - Molten salt as heat storage for Concentrated Solar Power plants

- Demand side technologies initiatives that may lead to more efficient and flexible loads in area of industry, households and public sector

The majority of power system technologies have long asset lives. Consequently, their replacement rate is low. Therefore this technological review should highlight those technologies that will mature to commercial deployment within a reasonable timeframe to enable wide ranging deployment, e.g., using above mentioned modular approach, within 10 years or other period as demonstrated as appropriate for each technology.

The project should therefore exclude technologies that are not likely to be widely deployed by 2050.

Each of the technology groups would need to be assessed against a predefined set of Technology Assessment Selection Criteria. If possible this assessment should be based on quantitative values. The output of this assessment should be a score per technology, leading into an unambiguous ranking.

Possible Technology Assessment Selection Criteria:

1. Transmission capacity, losses and distance
2. Technological readiness and maturity (i.e. reliability, availability) or R&D needs and expected learning curve
3. Flexibility (handling volatility to safeguard security of supply)
4. System impact on currently installed technology
5. Key uncertainties (risk evaluation)
6. Public acceptance
7. Environmental impact
8. Cost forecast
9. Supply chain and standardization

3.3.5 Project Deliverables

The initial deliverable will be a **study review**, the assessment of possible inputs from other study projects dealing with the technology issue, especially any relevant FP7 projects already realized or still ongoing (certain access provided).

Required project deliverables for this Work Package include:

- **Technology Assessment Report** (key deliverable)

- **Summary of performance characteristics** and risk evaluation for each technology;
- **Assess cost impact:** anticipated unit costs for each technology development
- **Assess technology innovation:** a timeline for emerging technologies that would specify those that are considered most likely to be deployable in the time to 2050 such that they could have a significant influence on capability, design, etc of the pan-European power system
- **Assess possible constraints:** a view on the possible constraints and standardization issues on current and emerging technologies to recognise the ability that the development of the power system is hindered/finite
- **Valuation – winners/losers:** identification of most likely technological 'winners' and low risk options for consideration within the scenario development for establishing how the pan-European power system might be required to develop and the technologies that would support the development.
- **Supply chain technology and related dynamic system stability aspects:** Identification of the control and performance coordination and dynamic system stability related issues between the overlay network and the areal/national/regional network as well as the generation environment considering the different combinations of technologies that can be or will be applied in connection of different scenarios (with reference to WP2)

3.3.6 Resources

The following matrix shows human resources needed to grasp all relevant issues of Work Package 3 (Technology Assessment). This needed expertise will be covered - apart from the required TSO involvement – also by other consortium partners as shown in the table below. The estimated person-months need to be updated when the Project Consortium is set up.

Table 7: WP3 Resources

Specialists / Workstreams	TSOs	Energy Economics / Law Partners*	GenCos and RES Partners*	DSOs/Smart Grid Partners*	Manufacturer	Person-months per workstream
WP3 Management	*** CONFIDENTIAL *** ESTIMATED NUMBER AND DISTRIBUTION OF PERSON-MONTHS IS KEPT CONFIDENTIAL BEFORE CONSORTIUM ESTABLISHMENT					
Technology Assessment Report (key deliverable)						
Study review						
Summary of performance characteristics						
Assess technology innovation						
Assess possible constraints						
Assess cost impact						
Valuation – winners/losers						
Supply chain technology and related dynamic system stability aspects						
Person-months exclud. WP3 Management						

*includes respective R&D performers

3.4 Work Package 4: Implementation and Operation: Planning & operational codes, permission, environmental impact, acceptance

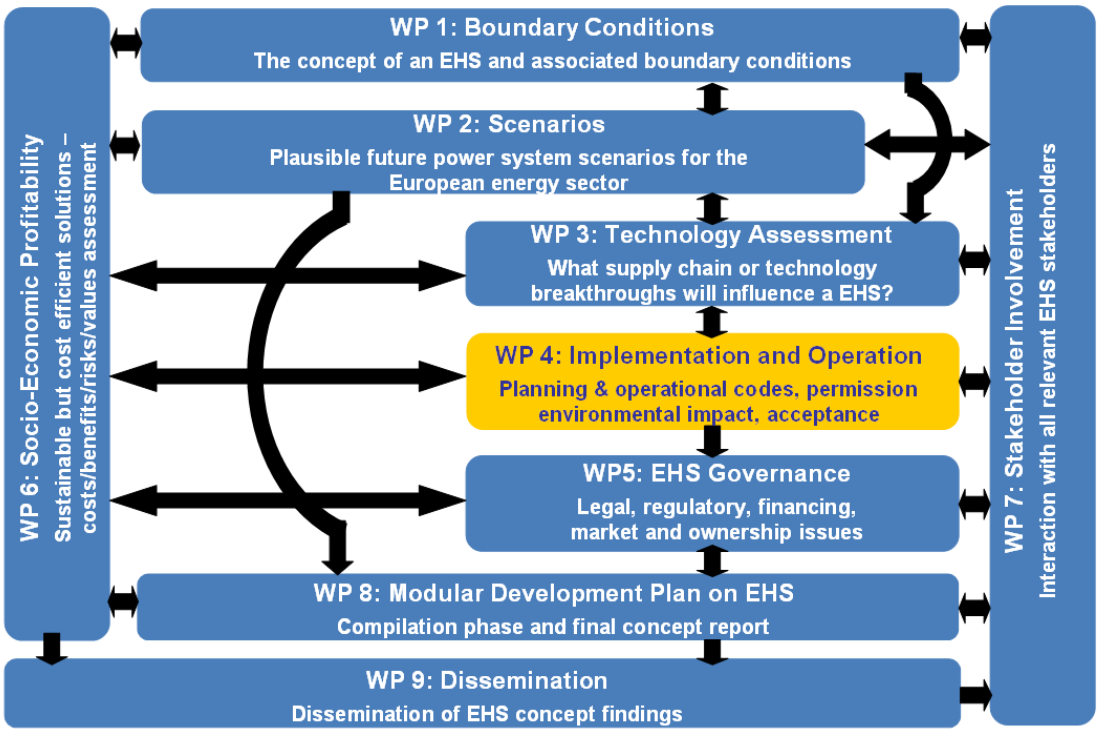

Figure 14: Placement of WP4 within programme structure

The technical/technological challenges of planning, constructing and operating a 2050 Electricity Highways system are substantial but not insurmountable. A lot of industry thought leaders claim that this project could be built using only proven technology and that there are no meaningful obstacles left. Others are being more cautious, reminding planners and developers that there is a difference between what is technically possible and equipment being commercially available. In any case, it is widely understood that a step change in the way the energy infrastructures and networks are planned, constructed, implemented and operated is needed.

ENTSO-E has already highlighted in the Pilot Ten Year Network Development Plan (TYNDP 2010) main barriers that hinder the development of the electricity networks, as e.g. the uncertainty that prevails over the future power system, the inefficient and slow permitting procedures and the overall lack of social acceptance for the grid restructuring and extension

Work Package 4 has significant dependency on most other Work Packages (especially 1, 2 and 3). WP 6 (Socio-Economic Profitability) has a significant dependency on this Work Package and as a result will deliver its outputs later in the programme. As with all Work Streams stakeholder involvement (WP 7) will be critical.

It will be necessary to review the results of this WP4 depending on the outcomes of WP 5 (EHS Governance) and WP 6 (Socio-Economic Profitability). This iterative mode will ensure consistency throughout the programme.

3.4.1 Rationale for Inclusion in ENTSO-E Study Roadmap Package

The intention for the inclusion of this Work Package is to provide an insight on the practicalities and difficulties that are expected to be incurred around the Electricity Highways implementation phase. Without such analysis, there is a risk that the range of scenarios proposed for assessment could be too broad in practice and therefore unrealistic due to technological factors, supply chain issues or other constraints which would otherwise not be revealed.

This Work Package will provide a detailed appreciation / assessment of the practical issues associated with the physical delivery of the evolving infrastructure. There is a major dependency on stakeholder information in feed (as with most of the Work Packages) and output data from this section will be critical in informing the assembly and delivery of the investment costs for Work Package 6. Project contributors will need to work closely with interfacing units to provide a sensible vision of what can be achieved.

3.4.2 Project Objectives

The European Commission adopted on 10 November 2010 the Energy 2020 Communication, calling for a step change in the way energy infrastructures and networks are planned, constructed and operated. Energy infrastructures are at the forefront of the flagship initiative "Resource efficient Europe".

It was clearly stated in the communication paper that delivering the energy infrastructures that Europe needs in the next two decades and onwards requires a completely new infrastructure policy based on a European vision. This also means changing the current

practice of the Trans-European Energy Networks (TEN-E) with long predefined and inflexible projects lists. The European Commission proposed a new method which includes the following steps:

- Identify the energy infrastructure leading towards European smart interconnecting networks at continental level.
- Focus initially on a limited number of European priorities which must be implemented by early to meet the long-term objectives and where European action is most warranted.
- Based on an agreed methodology, identify concrete projects from the ENTSO-E TYNDP necessary to implement priorities – declared as projects of European interest – in a flexible manner and build on regional cooperation so as to respond to changing market conditions and technology development.
- Support the implementation of projects of European interest through new tools, such as improved regional cooperation, permitting procedures, better operating and system management methods and provide information for decision makers and citizens and more innovative financial systems and instruments.

ENTSO-E has strongly welcomed the European Commission's Communication on energy infrastructure priorities, which are in line with those of the Pilot TYNDP that was released in June 2010. In this context, the project consortium and stakeholders as ENTSO-E are now also seeking a detailed assessment of the potential corridors, examining the ease of establishment and use needed to facilitate each one of them.

The ENTSO-E Pilot TYNDP includes an extended list of existing infrastructure projects in the planning phase which might be affected by the introduction of new environmental/permits requirements, as part of the pan-European Electricity Highways development. This Study Roadmap seeks for information on the potential hurdles that certain grid related technologies will be required to overcome in the course of the infrastructure development, e.g. clearance issues arising from different Electricity Highways technology options or the effect on the environment and landscape of new infrastructures. The project should establish a view on how the new technical solutions should look like and advise on their implementation plan, in order to move towards a pathway of least regret for the development of Electricity Highways.

3.4.3 Project Scope

The scope of this Work Package is to perform an inclusive view of the whole power system and its functions and to articulate any changes or adjustments of the existing operational criteria that will need to be implemented as part of the MoDPEHS. The consortium partners and stakeholders as ENTSO-E seek to understand whether the Highways should be planned, operated and congestion-managed seamlessly with the existing grids - to ensure (n-1) secure and reliable operations at all times and in a cost-effective manner - or a different suite of system analysis is needed. Moreover, this Work Package will significantly contribute the ultimate project deliverable, especially the concrete modular implementation and operation solutions for the needed grid investments throughout Europe and to relevant neighbouring areas. This includes the proposal of a concrete modular Electricity Highways architecture (map). In cooperation with the respective ENTSO-E bodies and taking into account the identified capacity needs as identified in Work Package 2, the lines should be designed as point to point measure (meaning specific region to specific region) with proposed technical transmission principles but no concrete geographical routing can be done at this stage, this task is outside of the MoDPEHS scope and will be given to the respective ENTSO-E members (Regional Groups and bilaterally at TSO's level).

Based on the results from connected Work Packages but also on already existing knowledge elaborated on other studies dealing with Electricity Highways System, this Work Package has to answer the following questions and also to deliver iterative input backwards to WP 2 and 3. Questions to be answered:

- Are the existing criteria, methodologies and approaches for assessing the needs of future Electricity Highways fit-for-purpose and do they work alongside existing regional and national approaches?
- What are suitable Network planning requirements for the purpose of an Electricity Highways system?
- How could a concrete modular (2030, 2035, 2040, 2045, 2050) Electricity Highways realization concept look like including aspects of usage of existing transmission routes as well as bundling of routes and storage opportunities with other infrastructures as e.g. gas? Close cooperation with respective ENTSO-E bodies is

necessary to answer this question and the assessment has to be based on the grid architecture implications from WP2.

- Which are suitable operational requirements as the following?
  - Security assessments, probabilistic, n-1/n-2/n-3(?) reserve requirements, national, regional, Europe wide etc;
  - How to operate and protect an electricity system which is mainly based on fluctuating renewable energy sources i.e. mainly converter in-feeded system;
  - What kind of data feeds (frequency and granularity) are required to operate a system(s) that is tasked with optimising Europe wide renewable resources, minimising Europe wide operating cost, while maintaining Europe wide security (also to manage wide area risks, e.g. inter-area oscillations)?
  - What are requirements regarding training and certification of operative staff.
- What are permission requirements also considering the different priorities as local aspects (Natura 2000) vs. regional/global aspects (RES integration as climate measure)
  - Elaboration of European map showing the regional degree and specific kind of expected permission obstacles.
  - Analysis of measures to enhance the permitting process for lines of the EHS.
  - Indication of the necessary changes in current environmental policy to make the construction of new infrastructure needed for the EHS possible.
- What is the environmental impact for each kind of considered transmission technology?
- How can the issue of lack of social acceptance be overcome?
  - Elaboration of European map showing the regional degree and specific kind of expected acceptance obstacles.
  - Analysis of measures to overcome the acceptance issue, e.g. analysis of financial, technical, political, informational concepts or optimal level of participation of local stakeholders (as input for respective MoDPEHS guideline)
  - Elaboration of an integrated strategy to enhance social acceptance

3.4.4 Project Deliverables

The initial deliverable will be the assessment of possible inputs from other study projects dealing with the implementation issue, especially any relevant FP7 projects already realized or still ongoing (certain access provided).

Required project deliverables for this Work Package include:

- **Implementation and Operation Report** (key deliverable);
- **Planning requirements;**
- **Permission requirements and environmental impact assessment;**
- **Operational requirements** in aspects of controllability and observability;
- **European implementation obstacles map (e.g. acceptance, permission);**
- **Measures to overcome the acceptance issue;**
- **Proposal on concrete modular Electricity Highways architecture** throughout Europe and to neighbouring areas (map).

3.4.5 Resources

The following matrix shows human resources needed to grasp all relevant issues of Work Package 4 (Implementation and Operation). This needed expertise will be covered - apart from the required TSO involvement – also by other consortium partners as shown in the table below.

Table 8: WP4 Resources

Specialists / Workstreams	TSOs	Energy Economics / Law Partners*	Policy / Regulatory Partners*	Manufacturer	GenCos and RES Partners*	DSOs/Smart Grid Partners*	NGOs	Person-months per workstream
WP4 Management	*** CONFIDENTIAL *** ESTIMATED NUMBER AND DISTRIBUTION OF PERSON-MONTHS IS KEPT CONFIDENTIAL BEFORE CONSORTIUM ESTABLISHMENT							
Implementation and Operation Report (key deliverable)								
Study review								
Planning requirements								
Permission requirements and environmental impact assessment								
Operational requirements								
European acceptance obstacles map								
Measures to overcome the acceptance issue								
Proposal on concrete modular Electricity Highways architecture (map)								
Person-months exclud. WP4 Management								

*includes respective R&D performers

3.5 Work Package 5: Electricity Highways System Governance: Legal, regulatory, financing, market and ownership issues

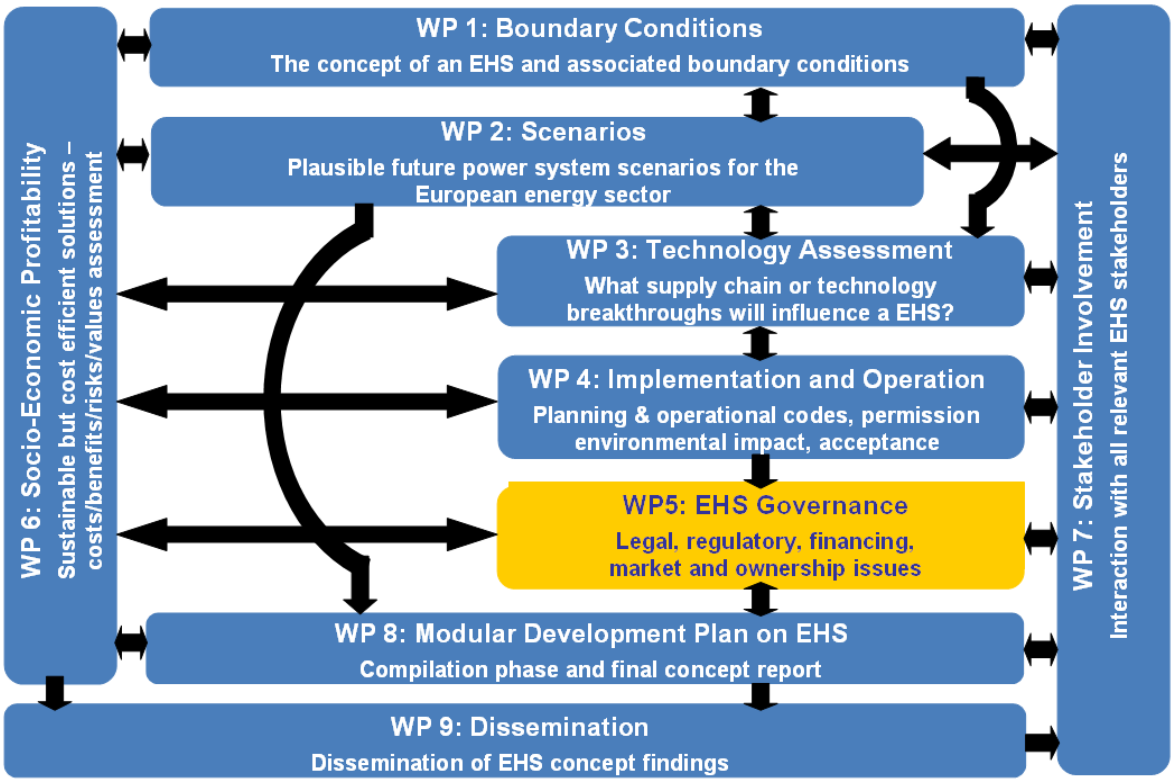

Figure 15: Placement of WP5 within programme structure

3.5.1 Introduction

Currently, the European electricity market is mainly characterised by fragmented national markets, dominated by a few national, vertically integrated, companies. Electricity policy is still largely a national matter, rather than a European one. With the Lisbon Treaty, the EU ETS and the Renewables Directive as well as the third market liberalisation package, the European dimension has gained importance, but the impact of this is not yet clear. All renewable electricity support schemes and other renewables policy implementation instruments are still strictly national.

The European Commission has initiated a market design project with a view to delivering a roadmap of a single EU regional market by 2015. It is clear that a fully interconnected and harmonised European power system is needed if we are ever to achieve a well-functioning

single market for electricity (and real competition) to the benefit of consumers. This in turn will positively contribute to Europe's 2020 policy objective of maintaining a strong, diversified and competitive industrial base in Europe. This Study Roadmap should consider these and other challenges facing the region's current power systems and examine whether such a vision of Europe, possibly in combination with other continents such as North Africa and / or neighboring Asian countries, can support a 2050 vision in developing an integrated power grid with an evolving mix of electricity generation driven predominantly by renewable sources by 2050.

In order to enable the fundamental changes in the electricity market and move from the complex power system of today to the 2050 vision, appropriate governance structures and a uniform legislative framework will need to be put in place.
Regional Initiatives will eventually converge into a single European market, complemented by the establishment of common standards and agreements for the operation of the power system.

Any investment decisions in Europe will be impacted by the understanding of how transparent, predictable and fast the planning permissions will be, the availability of long term commitments and the contract security, whether there is guaranteed and free access to the network (including any grid connection standards), the likelihood and amount of any possible network losses, and the challenges associated with grid connection and other supply and demand side issues.

It is evident, therefore, that a shift even further to a 100% renewable electricity supply in 2050 relies to a great extent on the legal framework that will have to be implemented. Although the transition to a fully decarbonised future is challenging, appropriate governance structures and a pan-European approach to dealing with challenges, will deliver the targets of the 2050 Electricity Highways System.

This Study Roadmap must therefore clearly identify whether the existing criteria, methodologies and approaches for assessing the needs of the new systems are fit-for-purpose and whether they can be applied alongside existing regional and national approaches. What is more, the project consortium and the stakeholders as ENTSO-E are seeking clarification around the approach by which investments will be judged by the regulatory authorities. Or with other words: Who should finally pay the investments

(costumers, tax payers, …?) , who should realize and who should operate and own the Electricity Highways?

One further main area that need to be addressed in the course of the Electricity Highways development is policy harmonisation towards a pan-European network. In this regard the European Commission will need to redefine the policy agenda and build effective mechanisms to accommodate the renewable vision and facilitate the step change. Policy-makers will face the challenge of having to design instruments and regulatory frameworks to achieve very long-term objectives given high uncertainty and widely diverging incentives between stakeholders, i.e. international vs. regional levels, producers vs. consumers, etc.

This Work Package 5 (EHS Governance) depends on results of almost all Work Packages – WP 3 is the only exception. Work Packages 6 (Socio-Economic Profitability) and 8 (MoDPEHS) will depend on this Work Package for certain policy and governance related impact assessments as inputs. Stakeholder Involvement will be crucial throughout.

3.5.2 Rationale for Inclusion in ENTSO-E Study Roadmap Package

A key feature of pan-European Electricity Highways is the establishment of a single internal market for electricity. Power will be delivered from jurisdiction to jurisdiction, and as a result the issues associated with market fragmentation and the regionally focused energy policy will have to be managed and dealt with. It is only logical, therefore, to raise the question of an appropriate governance system for this multinational infrastructure development.

Legal framework and regulatory framework are both a national and Europe-wide concern. Besides uniform market schemes, also licensing requirements, taxes and emission permits and emission trading are of importance for elaborating the MoDPEHS.

The inclusion of the governance structure and legal framework implementation in the MoDPEHS must be fully justified and supported by detailed analysis in order that the project consortium and stakeholders as ENTSO-E are able to systematically judge the level of added value in terms of cost / performance / risk / efficiency that can be attained by inclusion in forward network plans; and by doing so a full range of priorities and issues associated with

the development of the pan-European power system could be assembled. It is considered important that the consortium has a robust analysis of the technologies that will be mature both in terms of those that will facilitate connect to the grid and those that will facilitate the formation of the grid.

The Governance Work Package has significant implications on the programme in terms of how broader based policy, legal frameworks and Member State regulation will be harmonised to support common application. Enabling a pan-European power system with cross continent possibilities, therefore has huge policy based (and political) issues that need to be evaluated and assessed in terms of their economic / physical / practical impact on the programme.

3.5.3 Project Objectives

There is a number of governance related barriers that will need to be overcome such territorial rights, royalties for crossing territory, security of transmission and technical standards of the grid as a whole and last but not least aspects of terrorism and natural disasters' prevention for the single Electricity Highways. To succeed, it will require careful negotiation through the regulatory systems of dozens of national authorities, considerable investment in infrastructure, and potentially wide-ranging alterations to the design of institutions, regulations and markets.

Even if all planning and permitting issues are resolved there is still a risk of delaying infrastructure development due to cost allocation issues. ENTSO-E is seeking to establish a view on further improving the allocation rules in order to leverage any expected issues between members and private and public investors. Concerns regarding regions where power is more competitively priced (e.g. Scandinavia) in terms of internal issues relating to the justification of export power will need to be dealt with also. Assessments will be required to understand the extent of such issues and how this feeds into the bigger stakeholder picture.

The objective of this Work Package is to outline the existing policies that are assumed to require changes / revisions if EHS is to be demonstrated as beneficial to Member States and

the Union as a whole. In addition detailed investigations should be carried out regarding the use of best practice examples from different countries to develop an initial policy proposal.

3.5.4 Project Scope

In the scope of this Work Package are the legal, regulatory, financing, market and ownership requirements needed for the Electricity Highways System.

So, this Work Package will focus on the overall legal framework that should be established in order to support the implementation of the pan-European power network. More specifically, the following questions (among others) should be addressed:

- What legal/corporate form would be most appropriate?
- Tax implications?
- Financing implications?
- Public funding implications?
- Regulation implications, esp. how will the investments be judged by the regulatory authorities?
- Principles for cost allocation? – Compensation of countries for infrastructure, which is build for transnational reasons?
- Role of financing institutions as European Investment Bank or experienced national banks in supporting EHS investments?
- What market concepts are needed for the most efficient operation of the future grid?
- Is there a need for a European approach to redispatching?

Furthermore, the market requirements will be analysed as e.g. the market principles, price formation, settlement, tariff setting, cost reflective charging arrangements, etc.

Besides the market and legal requirements, in scope of this Work Package must also be the analysis for any need for policy change and the assessment of expected political will.

3.5.5 Project Deliverables

The initial deliverable will be a **study review**, the assessment of possible inputs from other study projects dealing with the governance issue, especially any relevant FP7 projects already realized or still ongoing (certain access provided).
Required project deliverables for this Work Package include:

- **Electricity Highways Governance Report** (key deliverable);
- Articulate the **market requirements** of the pan-European power network;
- Appropriate **legal and corporate construct** for Electricity Highways;
- **Regulation implications** that are expected to arise;
- **Need for policy change**;
- **Political will assessment**.

3.5.6 Resources

The following matrix shows human resources needed to grasp all relevant issues of Work Package 5 (Electricity Highways System Governance). This needed expertise will be covered - apart from the required TSO involvement – also by other consortium partners as shown in the table below. The estimated person-months need to be updated when the Project Consortium is set up.

Table 9: WP5 Resources

Specialists / Workstreams	TSOs	Energy Economics / Law Partners*	Policy / Regulatory Partners*	Person-months per workstream
WP5 Management	*** CONFIDENTIAL *** ESTIMATED NUMBER AND DISTRIBUTION OF PERSON-MONTHS IS KEPT CONFIDENTIAL BEFORE CONSORTIUM ESTABLISHMENT			
Electricity Highways Governance Report (key deliverable)				
Study review				
Market requirements				
Legal and corporate construct				
Regulation implications				
Need for policy change				
Political will assessment				
Person-months exclud. WP5 Management				

*includes respective R&D performers

3.6 Work Package 6 Socio-Economic Profitability of an Electricity Highways System

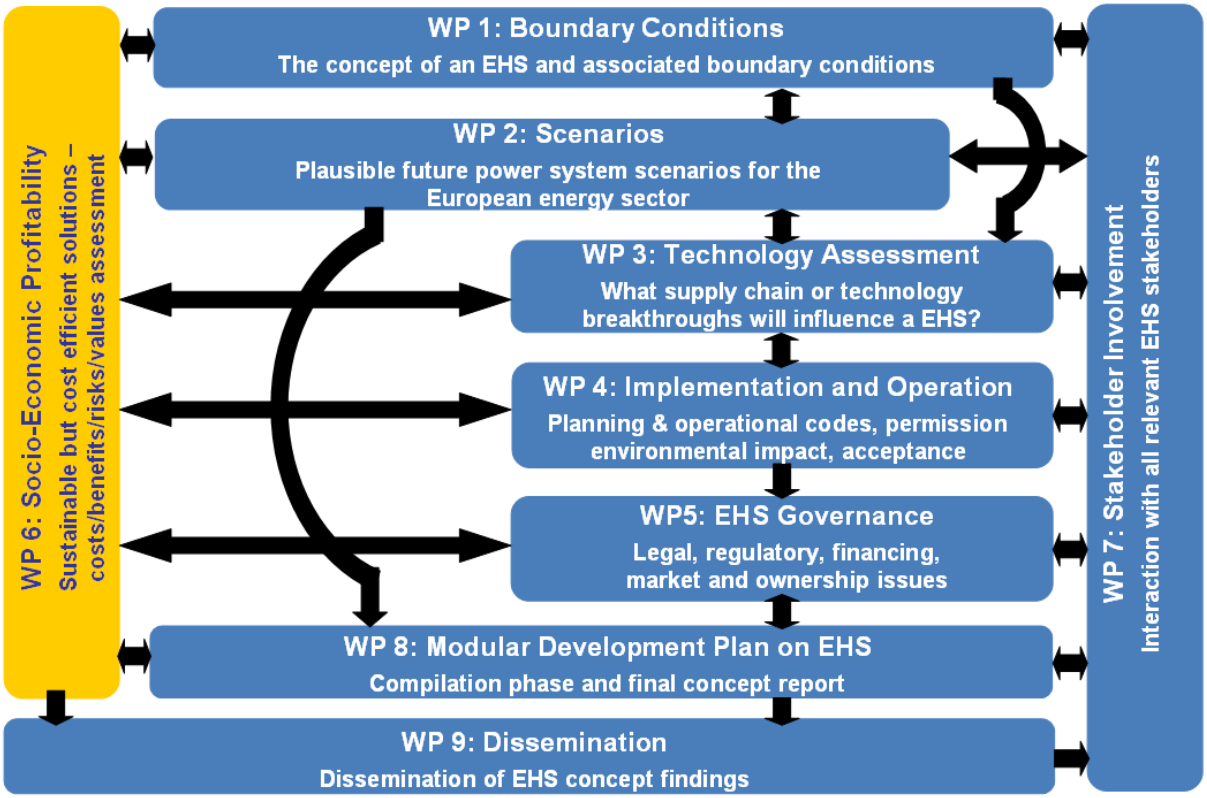

Figure 16: Placement of WP6 within programme structure

3.6.1 Introduction

The success of the realisation of an Electricity Highways Vision depends to a large extent on the acceptance of the new system by all affected stakeholders. This Work Package therefore needs to describe and quantify in detail all costs and benefits, the non-monetary values but also risks that are connected to a new Electricity Highways System – looking at it from every stakeholder's angle.

The Socio-Economic Profitability Analysis needs to deliver an understanding of the scale of investment required compared to the long term benefits that are likely to be realised by individual states, and collectively as a combined European entity participating in such a large scale undertaking. In this context the optimal allocation of the welfare gains has to be ensured by setting up mechanisms to share value added benefits and compensations between winners and losers.

Not only financial aspects need to be taken into account. The challenge must be to quantify the non-financial values or risks that are likely to be realised from the development and realisation of the Electricity Highways vision.

This section links to all other Work Packages in the Study Roadmap. Other Work Packages have been designed to provide value assessments that should be revisited here. It will be important to identify any gaps or possible oversights in analysis carried out elsewhere at this point.

The appointed partners will be responsible for interfacing and close working with other participating organisations. This will be particularly important when considering the network / asset optimisation potential that could be possible across EU Member States and those states with IEM relationship but also taking into consideration the links to neighbouring countries.

By developing a detailed understanding of long term energy requirements and ambitions throughout Europe, and aligning this to the long term requirements of the European Commission this Study Roadmap will provide an informed framework for the investment decisions and policy planning that will be needed to support an efficient unified infrastructure fit for purpose over the 2050 planning time frame.

This Work Package (Socio-Economic Profitability of EHS) has dependencies on all interfacing Work Packages, as an area of critical assessment that is highly reliant on data in feeds from all areas. It follows then that the economic appraisal of the entire programme (aligned to selected and agreed scenarios) will take place at a later stage in the overall delivery process. In this way the participating partners selected to perform the analysis will have available, in large part, the data and criteria required to get the Work Package under way.

3.6.2 Rationale for Inclusion in ENTSO-E Study Roadmap Package

The rationale for including a Socio-Economic Profitability Work Package in the overall development of the Study Roadmap is to ensure that a full and detailed assessment of all costs and benefits, values and risks (associated with preparation and delivery) is documented and available for inspection and comment.

The inclusion of this Work Package will provide the European Commission and those states with IEM relationships, other key stakeholders and the public in general with a full

appreciation of the extent of finance that will be required alongside the key benefits that are likely to be realised over the term of the project; and how these benefits (whether utility related or socially based) are categorised in relation to stakeholder groups and countries in general. In addition a dedicated risk assessment will assure the full picture.

The results from this Work Package will include non-economic aspects as e.g. the assessments of carbon saving potential that could be realised by the introduction of pan-European Electricity Highways System as well as any economic benefits that might be realised by individual states, and collectively by the wider Europe over the term of the project. This part of the programme will underpin the practical and financial justification of any planned infrastructure that is eventually sanctioned.

Throughout this piece of work it will be necessary to identify ways and means of assessing realistic costs and benefits for infrastructure and grid related technology that has, as yet, not achieved mature levels of commercialisation, and this element of the Socio-Economic Profitability Assessment will align closely to Work Package 3 (Technology Assessment). Identification, explanation and assessment of the severity of key market barriers such as supply chain bottlenecks (and an assessment of the severity of those barriers/bottlenecks) both overall for the sector and for each element of selected and supported technology will also need to be considered and informed in the development of this Work Package.

As such it must deliver a level of economic detail that satisfies the overall stakeholder scrutiny as well as the obvious interest from the media and the industry in general. The sources of supporting information must therefore be based on firm engineering, environmental and technological foundations and, where ever practically possible, international evidence of similar engineering/technology applications that can be reference accordingly.

Certain stakeholder information and outputs from earlier deliverables will need to be revisited and reviewed to ensure all aspects of the profitability assessment are included.
Where it is found that any level of required detail is lacking, stakeholders will be re-engaged to test and / or refresh certain data sets and working assumptions. The Socio-Economic Profitability Work Package therefore provides a certain level of sense checking of delivered outputs from other Work Packages.

The rationale for the inclusion of a Work Package focused specifically on the added value that can be created from the implementation and operation of Electricity Highways is therefore aimed at ensuring that a fully balanced business case can be presented in support of the long term objectives as e.g. the European Commission's developing carbon reduction programme.

3.6.3 Project Objectives

Through this Work Package it will be ensured that a common approach is developed towards understanding the costs and benefits, risks and values associated with delivering a unified Electricity Highways System and hence also the level of investment that will be required to support its development. It will also be critical in an ambitious project of this kind that all stakeholders are aligned in terms of their vision of what will be delivered (and why) and the schedule of benefits that will be realised from its introduction.

In order to ensure the success of the project a comprehensive benefits analysis is needed to convince all affected stakeholders. All non-financial benefits for society, individual states, Europe as a whole and even beyond have to be defined and preferably quantified.

Results of this benefits analysis will then be input for a dedicated Cost-Benefits-Analysis. An extensive mathematical/economic model will be required to hold, manage and manipulate industry data relating to the full and final financial appraisal of the proposed system. The specification and assembly of the model will be a key objective of this Work Package. Selected partners will work with ENTSO-E representatives (stakeholders) to develop the model and agree the underpinning logic. This central requirement therefore forms a key Work Package objective.

Once the model is available the participating bidders will be responsible for sourcing the relevant data from stakeholders, industry participants, regulators and government bodies and validating this against known industry information / international standards, or by developing assumptions in association with the relevant industry stakeholder and / or ENTSO-E participants.

The objective is then to run the model for each of the scenarios agreed in Work Package 2 (against agreed a counterfactual or business as usual case) to understand the economic / financial impact on participating states, industry participants and the European Commission as a whole. The participating bidders will then be responsible for presenting the findings of this Cost-Benefit-Analysis to all stakeholders and participants engaged in the process and for managing updated data requests and modelling iterations.

This is a significant modelling exercise and should not be under estimated in terms of its scope or its impact on key stakeholders and the broader industry audience.

In addition all possible risks have to be assessed that might have an effect on planning, implementation and operation. These risks also need to be quantified and integrated in the Cost-Benefits-Analysis:

3.6.4 Project Scope

ENTSO-E view the Study Roadmap project as a long term commitment that will deliver a range of findings through a number of different participating consulting organisations, industry consortia and academic institutions working with the ENTSO-E transmission system operators so that all system dimensions, definition criteria and operating requirements are considered in detail before the crucial next steps of infrastructure modification / execution are finally committed and funded.

In advance of progressing the Socio-Economic Profitability Assessment, it is planned that foundation Work Packages in the programme will have delivered (or be in an advanced phase of delivery) significant outputs in relation to the Boundary Conditions governing the working framework of the programme and the Scenario assumptions around which the Cost-Benefits-Analysis (CBA) modelling process will be structured. This phase of the project and indeed the scope of the Socio-Economic Profitability Assessment (especially the CBA) will therefore be reliant on this work having reached a fairly mature stage in its delivery and on the contributing organisations in all relevant Work Packages cooperating closely throughout the development and delivery of the programme.

All contributors will be responsible for working together to structure the framework of the CBA and design the supporting logic such that the end results are meaningful to stakeholders and bear tangible relation to the social consequences (positive and negative) associated with programme implementation.

This Work Package will include the design, development and delivery of a robust cost benefit model that will be fit for purpose in the context of valuing all dimensions of programme implementation. All related analysis tools and / or allied mathematical / economic / macro economic models, spreadsheets and / or proprietary software related to the main model or related evaluation tools must be included in the development of the CBA solution.

All participating parties should be mindful that large scale industry related cost benefit exercises have, of late, generally been confined to smart metering feasibility programmes in most Member State countries and in other countries around the world. However, despite the experience gained by many organisations through this process the scale and detail required by the Study Roadmap programme is in many ways unprecedented.

In this regard the Socio-Economic Profitability Assessment must draw on the outputs and take account of:

- The views, experiences and ambitions of all relevant stakeholders in the process;
- Structure and results of other cost-benefit-analysis (e.g. ENTSO-E EPS, ENTSO-E TYNDP; FP7-project REALISEGRID)
- The key outputs from interfacing Work Packages, particularly boundary conditions and scenario based options, including but not limited to:
    - Emergent transmission technologies (enabling more efficient and widespread operation of future networks);
    - Implementation issues;
    - Added values;
    - Technology choices and control considerations;
    - System implications;
    - Viable large scale storage solutions;
    - Generation technologies that will need to be incorporated to provide system security and enable efficient operation of the system;
    - Demand response initiatives; and
    - Environmental issues
- Considerations of prioritisation, financing and cost allocation of Electricity Highways.
- And any other key factors that should be assessed and included in the analysis.

Within the scope of this Work Package, the key elements that need to be assessed and evaluated (qualitative and quantitative) according to costs and benefits, risks and values are:

- Expected contribution to Europe's long term energy requirements (supply / demand etc);
- Expected contribution to the generation mix and how this will develop over time (2050 time horizon); how can a EHS improve the usage of optimal RES possibilities across Europe and Northern Africa; expected value of Electricity Highways in enabling RES and other energy targets to be met.
- Added values and risks from expected technology developments/breakthroughs (linking specifically to Work Package 3); What is the value of Electricity Highways in keeping technology options open? What new options do Electricity Highways create? What is the value of Electricity Highways in managing technology risks – e.g. if smart grid and demand response technologies are not deployed as quickly as assumed, or technology developments in CCS or certain renewable technologies fail to materialise?
- Efficiency and carbon reduction benefits derived from the inclusion of advanced components, devices, technologies and / or systems; and

- Economic assessments associated with the cost benefit of realizing the vision and the potential added value through the inclusion of advanced components, devices technologies and / or systems along with the mechanism of sharing welfare gains.
- Expected contribution to a more transparent wholesale electricity market.
- By usage of special analysis tools: Expected benefits that the Highways could have on system security as very crucial aspect and how this can be translated into derived added value in support of the overall business case and implementation plan. Following key factors that must be considered in this special context:
    - EHS contribution to secure the level of system security as today with increased RES-share.
    - Probability weather events should be planned for if a secure system is to be maintained at all times? (e.g. 1 day of low wind, 1 day no wind, 5 days low wind).
    - Improved resilience of the broader European system compared to a supply model without Electricity Highways?
        - Energy import dependency
        - Most suitable / efficient back-up fuel source
        - Role of large-scale hydro generation and storage in the Alps and Scandinavia
        - Events to be planned for (degree of vulnerability) and how frequently are they likely to occur?
    - Are Electricity Highways essential (or a part of – e.g. the off-shore “Ocean Grid”) for a secure electricity supply in Europe by 2050 if the development and increase of indigenous renewable electricity production is (i) not at all or (ii) only moderately or (iii) extensively supported / subsidized?
    - How will (in the context of 2050 vision) less self sufficient regions prepare for events of outage? These must be identified and categorised in terms of supply security risk and evaluated in the broader context of Electricity Highways benefits and mitigation actions that need to be addressed over a predefined timeframe. (This is aimed at addressing 'islanding' situations in the event of a large scale transmission outage where certain regions reliant on neighbouring states for supply / generation balance have, in the future, the potential to experience less secure supplies than was previously the case).

In carrying out such an assessment it is critical that this Work Package provides a detailed summary of likely broader scale economic, technological and (socio-)political impact that might result from the development and introduction of a pan-European Electricity Highways. This should be aligned to the scenarios previously identified and agreed with the

representatives of ENTSO-E and structured to demonstrate the relative merits of the proposed approaches.

3.6.5 Project Deliverables

The initial deliverable will be a study review, the assessment of possible inputs from other study projects dealing with the Socio-Economic Profitability issue, especially any relevant FP7 projects already realized or still ongoing (certain access provided). Possible input could be the ENTSO-E EPS and ENTSO-E TYNDP, as well as the FP7-project REALISEGRID (D3.3.1).

Required project deliverables for this Work Package include:

- **Socio-Economic Profitability Report** (key deliverable)
- **Assessment of financial and efficiency benefits** based on the mechanism of cost and benefit sharing **and carbon reduction effects:** Detailed assessment of the added value benefits (aligned to an agreed number of identified / described scenario options) that the pan-European vision will deliver and what precise components, devices, technologies and / or systems will make this delivery possible. This will include:
    - Qualitative and quantitative reviews
    - Cross reference to other interfacing Work Packages
- Detailed **assessment of system security benefits** and of the maximum variation or unpredictability that the future power system could accommodate:
    - Prerequisited: same level of system security as today has to be ensured
    - Variability of power supplies and power flows
    - Reserve assessment and options to cover known events
    - Impact on reserve needs
    - Assessment of influence on reserve capacity and therefore on the system security and their benefits for society
    - Potential of large-scale hydro storage and generation in the Alps and Scandinavia for stabilizing this system
    - How would Electricity Highways enable the accommodation of greater variability
    - Policy measures and incentives to encourage greater DSR
    - Appraisal of unknown factors and potential for unknown / difficult to predict events and measures to avoid / minimise occurrences
- **Detailed Risk Assessment Report**
    - Analysis and quantification of potential risks during project realization

- Analysis and quantification of potential risks resulting from the running future EHS (i.e. dependence on certain restricted routes; use of conventional supply from outside Europe counteracts to 100% RES strategy)

- Detailed assessment of the impact that Highways are likely to have on system security and the risk and/or added value derived through this.
- **Cost Benefit Analysis:** Full scenario based economic appraisal of the proposed roadmap process including but not limited to:
  - Costs and benefits summary;
  - Stakeholder impact;
  - Impact on Member State countries;
  - Impact on Europe as a whole;
  - Impact on desert power exporting countries from the MENA region and implications of this impact on Europe (e.g. economic and political stability, immigration flows, etc.)
  - Social impact;
  - Any business value creation that might be realised by Member State countries or others
  - Environmental impact;
  - Impact on customers and prices; and
  - Economic consequences relating to system security etc
- A detailed **economic and financial assessment of the design, implementation and technological implications** of each of the scenario options selected and agreed in Work Package 2 (plausible future power system scenarios for the European energy sector). This will include:
  - Qualitative and quantitative reviews;
  - Development and validation of working assumptions in line with the output of other Work Packages;
  - Stakeholder coordination through a series of structured workshops, interviews and related fora; and
  - Data collection, compilation and validation
- Development and construction of a fully functioning **economic model and related analysis tools** specifically developed (or suitable adapted existing tools) for the purpose of supporting the Study Roadmap CBA:
  - Delivery of viable design and description for approval;
  - Delivery of development and build programme for approval;
  - Delivery of the model (and supporting analysis tools where appropriate);
  - Validation and acceptance testing procedures and methodology for approval; and
  - Delivery of validated model fit for purpose in the planning and development phase of the project.

Throughout the term of the programme the team(s) managing the progress of the Socio-Economic Profitability Assessment will be responsible for all stakeholder contact and management, and for accessing the information and data required to enable the CBA process. ENTSO-E and consortia drawn from ENTSO-E will be available to assist, validate and oversee key stages of development as the solution progresses.

Whilst preparing the output of this Work Package the partners will be required to alert ENTSO-E personnel to any other key factors affecting or impeding the design and realisation of the Modular Plan and the means by which such limiting factors might be assessed, addressed and progressed.

3.6.6 Resources

The following matrix shows human resources needed to grasp all relevant issues of Work Package 6 (Socio-economic profitability of EHS). This needed expertise will be covered - apart from the required TSO involvement – also by other consortium partners as shown in the table below. The estimated person-months need to be updated when the Project Consortium is set up.

Table 10: WP6 Resources

Specialists / Workstreams	TSOs	Energy Economics / Law Partners*	Policy / Regulatory Partners*	GenCos and RES Partners*	DSOs/Smart Grid Partners*	Manufacturer	Consumers	NGOs	0
WP6 Management	*** CONFIDENTIAL *** ESTIMATED NUMBER AND DISTRIBUTION OF PERSON-MONTHS IS KEPT CONFIDENTIAL BEFORE CONSORTIUM ESTABLISHMENT								
Socio-Economic Profitability Report (key deliverable)									
Study review									
Development of economic assessment tool-box									
Risk Assessment Report									
Economic assessment of design, implementation and technological implications									
Cost/Benefit Analysis Report									
System security impact assessment									
Assessment of financial and efficiency benefits and carbon reduction effects									
Person-months exclud. WP6 Management									

*includes respective R&D performers

4 PROGRAMME MANAGEMENT AND COMMUNICATIONS

4.1 Introduction

The following sections are best described as programme management and communications Work Packages and are differentiated from the earlier 'delivery' sections by their embedded objectives of either or collectively:

- Managing, validating, co-coordinating, compiling and (quality) controlling the outputs from the six Work Packages (described earlier) to deliver the final version of the MoDPEHS for review and acceptance by steering group members;
- Establishing a stakeholder consortium aligned to the objectives of the MoDPEHS;
    - Seek to avoid competitive actions / behavior between stakeholders;
    - Draw up agreements for acceptance between the parties;
        - Consortium master agreement
        - Sub group contractual arrangements
        - Confidentiality of information / data and IP
    - Co-ordinating and administering stakeholder party agreements
- Co-ordinating and controlling the dissemination of information and project output among the various participants, working groups, programme managers and steering committee members throughout the entire programme
- Providing dedicated communications channels to cover the underlying information exchange associated with the programme; with the primary objective of delivering;
    - Dedicated resource partners (and processes) for project consultation management as required by project managers, co-ordinators, working groups, stakeholders (internal and external) and steering group members
    - Project progress bulletins
    - Workshop organisation and facilitation
    - Provision of conferencing and delegate management
    - Media management

As such all elements of the programme have key dependencies on the Project Management and Communications functions being available and fully effective throughout the entire programme. The following sections describe the outline needs of these functions in more detail.

4.2 Work Package 7: Stakeholder Involvement and Communications

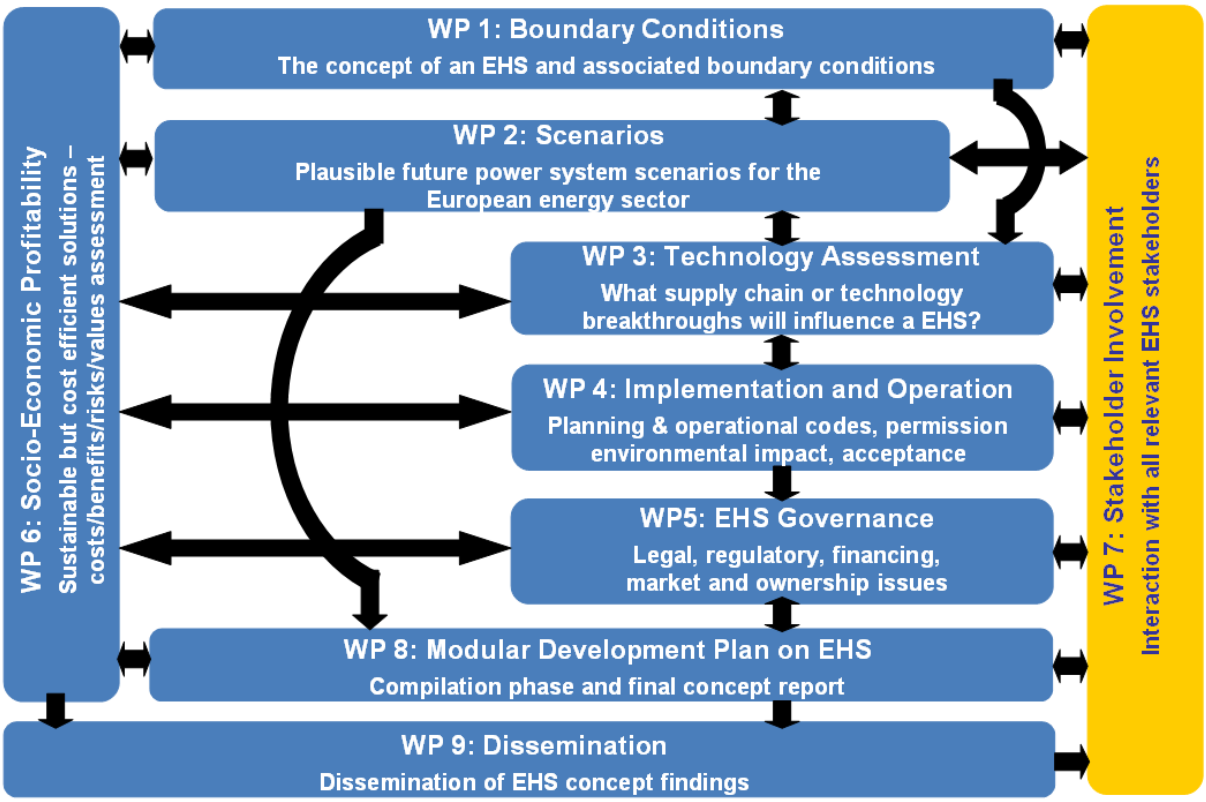

Figure 17: Placement of WP7 within programme structure

4.2.1 Objectives

The success of the realisation of an Electricity Highways Vision depends to a large extent on the acceptance of the new system by all affected stakeholders. Stakeholder involvement therefore will be crucial to the success of the programme, particularly as much of the data and regional analysis will exist (or partly exist) and be available through the offices and executive of the key European transmission players. In managing and co-ordinating stakeholders throughout the process there will obviously need to be close links and correlations established between the compilation of the Modular Plan (co-ordination and management of inputs) and involvement of key stakeholders.

In December 2010 the Florence Forum supported the DG Energy proposal to set up a dedicated "Electricity Highways Platform" led by the European Commission in cooperation with ENTSO-E and the Regulators and with the involvement of all relevant stakeholders. In this context it would be advisable to include representatives from non-EU countries into the platform as the interaction/interconnection and the mutual interdependencies of EU and

neighbouring countries will be assessed and analysed throughout the project. The platform should focus on:

- Establishing generation scenarios
- Assessing ENTSO-E's concepts of pan-European grid architecture
- Analysing consequences of deployment
- Supporting necessary research and development
- Designing an appropriate legal, regulatory and organisational framework

The platform will be managed by a steering committee composed of the European Commission, ENTSO-E and ACER – supported by underlying Working Groups The steering committee has started organising work in early 2011. The discussion on selection of stakeholders has started with the EC and could lead to the following structure:

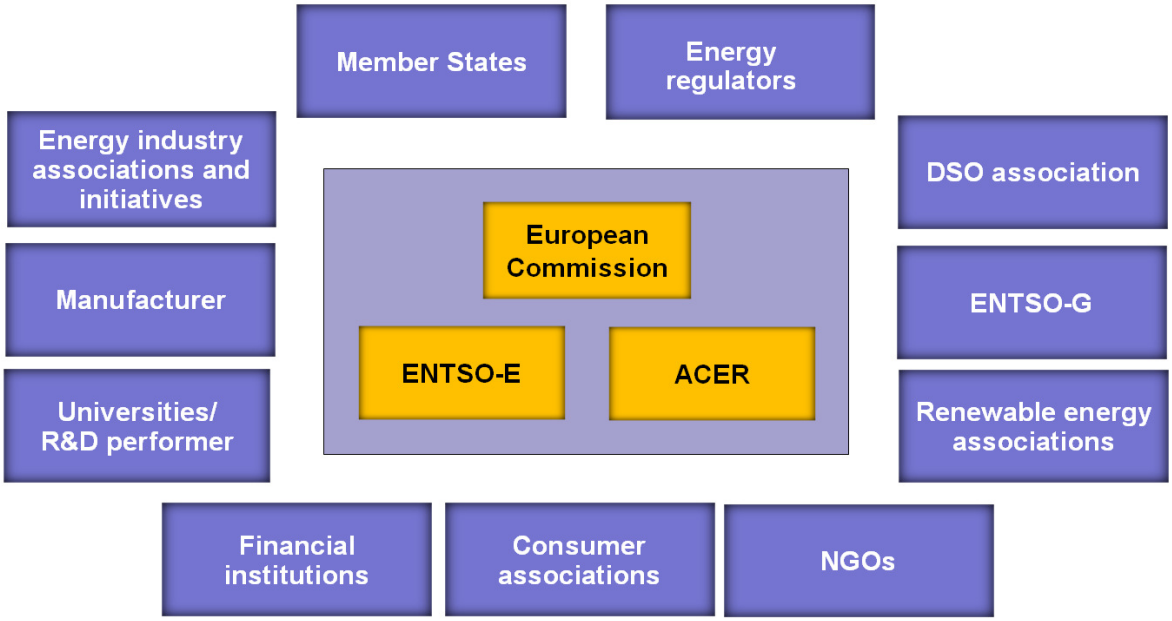

Figure 18: Relevant players for the Electricity Highways Stakeholder Platform

An Advisory Board shall be established in accordance with this Electricity Highways Stakeholder Platform within the overall governance structure as shown in the figure 19 below. Figure 20 shows the internal organisational structure of the Advisory Board-

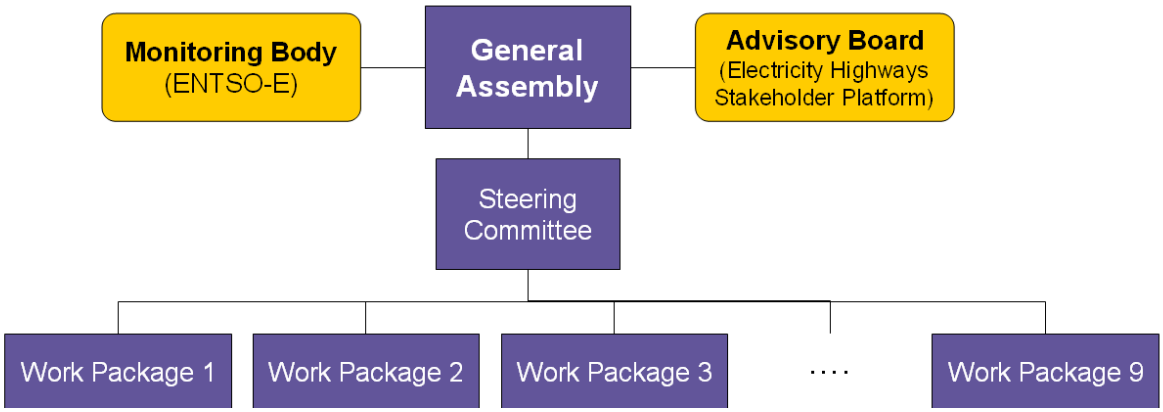

Figure 19: Stakeholder relationships within the overall governance structure of the project

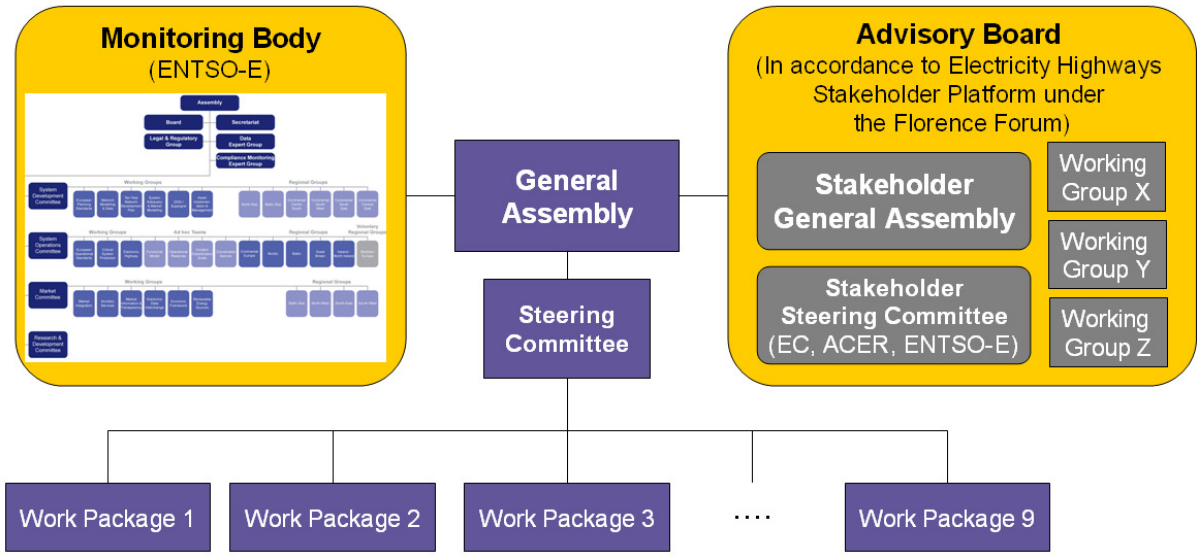

Figure 20: Electricity Highways Stakeholder Platform organisation

To ensure all stakeholders are aligned to the programme and its prime objective of delivering the final MoDPEHS by 2014, industry consortia agreements will be required at an early stage in the process. This, we suggest will involve establishing the basis of a stakeholder consortium (aligned to the key objectives of the MoDPEHS) to bring the stakeholders together under a common code of engagement and in so doing overcoming any variances or differences of opinion from company to company.

The arrangement will also need to be supported by a set of co-operation agreements drafted, negotiated and agreed as part of this Work Package. Examples of what will be required are provided in earlier text, but for completeness these are repeated below:

- Consortium master agreement
  - Resource commitments
  - Information sharing
  - Term of arrangement
- Co-operation agreements / clauses
- Sub group contractual arrangements / clauses
- Confidentiality of information / data and IP

Stakeholders will be able to contribute to the MoDPEHS work and results in several ways.

This Work Package will also support the establishment of stakeholder working groups within the Electricity Highways Stakeholder Platform (as outlined in Figure 20 above) aligned to individual Work Packages for the purpose of delivering industry specific inputs, deep specialist knowledge and directional guidance for the participating project partners. The Work Package must support stakeholder interaction and information / data exchange that is common to all (or many parts) of the overall programme. The Electricity Highways Stakeholder Platform Steering Committee will decide on the specific participating stakeholders.

A wider stakeholder group will be invited to participate in workshops, debating fora and conferences (from time to time). Thus, from a broader communications perspective the Work Package must support all aspects and elements of stakeholder involvement and support, including the management and administration of these workshops, debating fora and conferences in association with and direct support of Work Package managers as they progress the detailed elements of their assigned responsibilities.

Finally everyone interested in the MoDPEHS work can participate in the public consultation. The introduction and support of a dedicated public consultation process will be key to the process. Hereby industry participants and wider stakeholders input on matters affecting project / programme progress is sought. Its main goals will be to improve the efficiency, transparency and public involvement when gaining support for introducing infrastructure innovation, changes in market rules, policies reforms and any recommended revisions in market related law.

4.2.2 Scope and Deliverables

The general scope and responsibility related to this area concerns the management of stakeholders and their involvement in the process throughout the entire programme. This is a critical central function that all parties will need to 'tap' into from time to time. Alignment of

stakeholders from the European Commission, to industry participants and from regulators to consumer groups and the general public will be a vital requirement of the project. In discharging the responsibilities of this Work Package, participants and partners will therefore be required to work closely with senior members of the ENTSO-E Monitoring Body and the Advisory Board of the Programme. With this in mind the following deliverables are key to the requirements of this Work Package:

- Recommend and agree stakeholder framework and management structure;
- Establishing consortium and industry co-operation agreements as required;
- Design, agree and deploy (in association with the steering group and the Board) a dedicated public / industry consultation process for dissemination and iterative exchange of views and opinions leading to agreement of output information and recommendations;
- Design, agree and deploy Electricity Highways 2050 web site for future project related content and regular progress updates and links to the project information 'dissemination' process;
- Design, agree and deploy a robust media management policy including:
    - Management of press releases and public information bulletins;
    - European Commission / politician briefings;
    - Content for trade journal articles and updates.
- Co-ordinate stakeholder information and data exchange;
- Co-ordinate and manage stakeholder workshops and discussion forums as required by programme / project managers, steering group members, the ENTSO-E Board and the European Commission; and
- Manage conferencing arrangements and related facilities throughout the programme.

4.3 Work Package 8: Modular Development Plan on Electricity Highways System - Compilation Phase

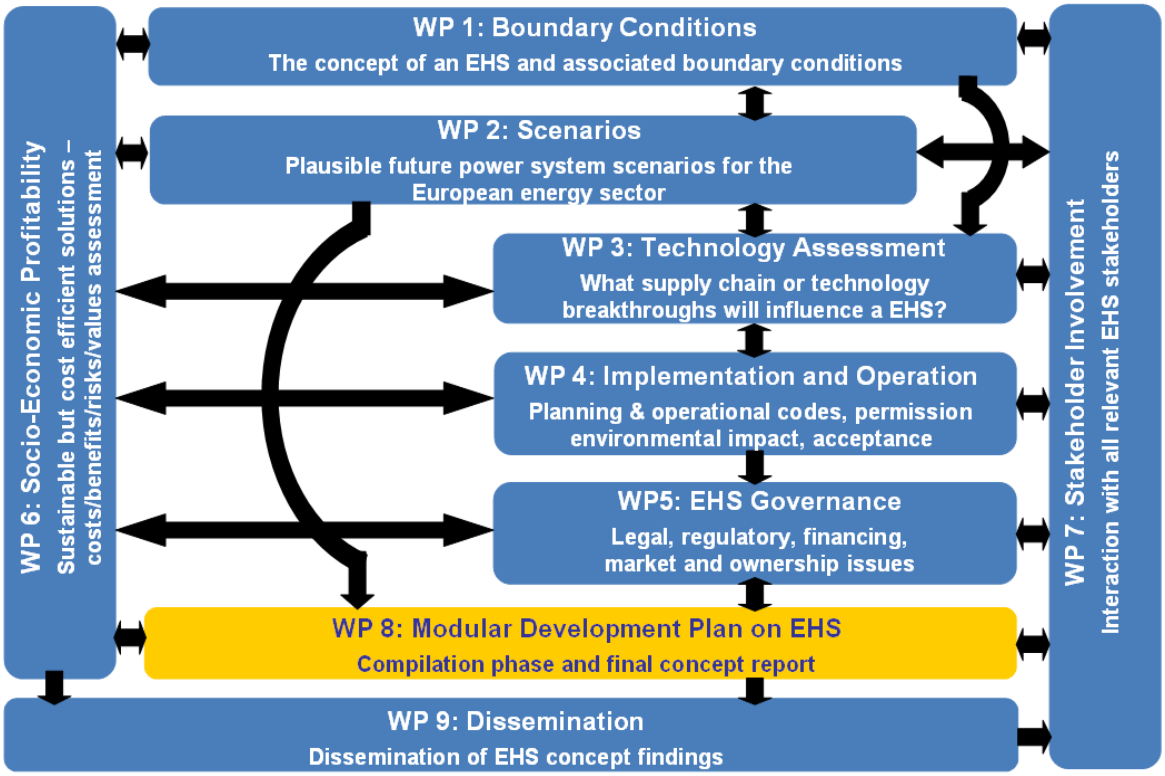

Figure 21: Placement of WP8 within programme structure

4.3.1 Objectives

The objectives of the compilation phase are related to the delivery of a high quality MoDPEHS that is consistent with the expectations of Advisory Board incl. ENTSO-E as a whole and reflective of the outputs (detailed analysis and forward recommendations) delivered through the dedicated Work Packages. The ultimate delivery of the MoDPEHS is a concrete modular proposal for architecture (map) of Electricity Highways System taking into account the time horizons 2030, 2035, 2040, 2045 and 2050.

Achieving this level of robustness, quality and consistency will require programme management partners to be appointed at the start of the programme and to remain in place through the term of the project. The role of the management partners will be to essentially 'orchestrate' the direction and sequencing of the seven 'delivery' Work Packages to ensure the overall project is delivered to budget, to time and to ENTSO-E's expectations and to the expectations of the wider stakeholder community. In this regard a high level schematic representation of the project plan is shown below.

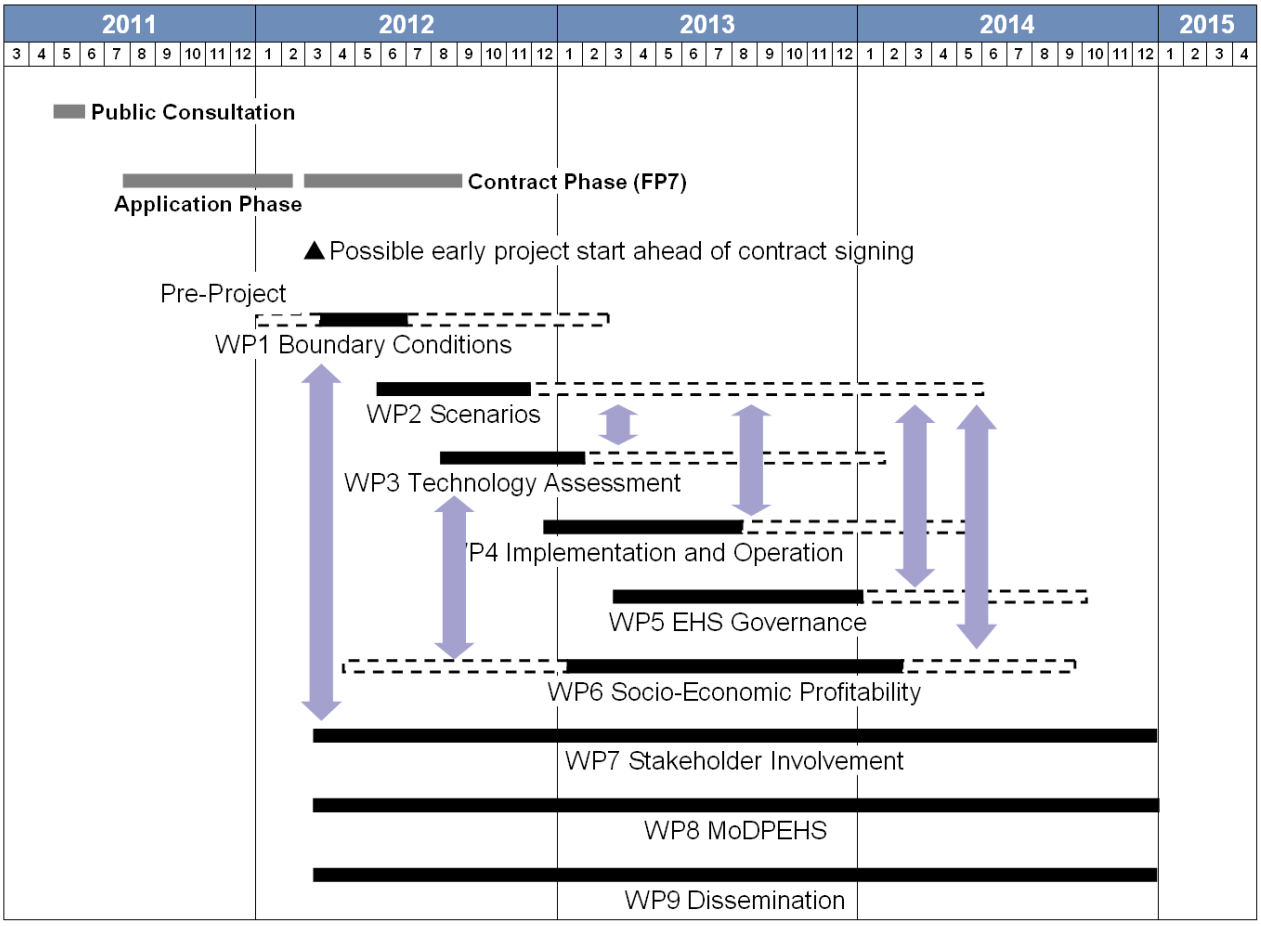

Figure 22: Schematic programme

The prime objective of this package of work will be to formulate the MoDPEHS in its entirety, ensuring along the way that all outputs from individual Work Packages are delivered to time, expectation and budget. Moreover, the deliverables must compliment each other directionally so that the final deliverable i.e. the 'Plan' is cohesive, comprehensive and fit for it's intended purpose, that is to readily, sensibly and practically address the mid and long term system needs with the aim of commissioning the first 'Electricity Highways' by 2020.

Beyond the realisation of this EU funded project, overall goal is to anchor the MoDPEHS into the EU legal framework and to establish a regular MoDPEHS update process under ENTSO-E coordination.

4.3.2 Scope and Deliverables

Considering the urgency and importance of the Programme realization, the establishment of crucial project bodies (esp. Electricity Highways Stakeholder Platform as Advisory Board) must be started significantly ahead of final project start in order to accompany the bid process, bid selection and appointment of project partners associated with the individual Work Packages. This preparation phase will be facilitated by ENTSO-E.

In conjunction with Steering Group and Advisory Board, the appointed partners supporting the Electricity Highways Concept Compilation will be required to:

- Provide a robust **programme management** supervisory and support structure for the entire programme;
    - Manage the progress of the Work Packages themselves through working groups, workshops and one to one meetings;
    - Ensure consistency of approach between Work Packages and manage project management interfaces;
    - Receive, review and test workstream outputs for inclusion in the compilation document;
    - Assist Project Coordinator and Steering Committee with consultation process;
    - Provide regular project updates and briefings to the MoDPEHS steering group and upstream European Commission counterparts.
- Coordination with Ten-Year Network Development Plan **(TYNDP) process for 2012 and 2014**
- **Compile the MoDPEHS** incl. required iterative measures with other Work Packages; and definition of **guidelines for policy and industry** on the need for changes required to licences and operating codes to support system unification and regional / cross border alignment (separation of network services, asset management, benefits / cost sharing, operating rules).

4.4 Work Package 9: Dissemination

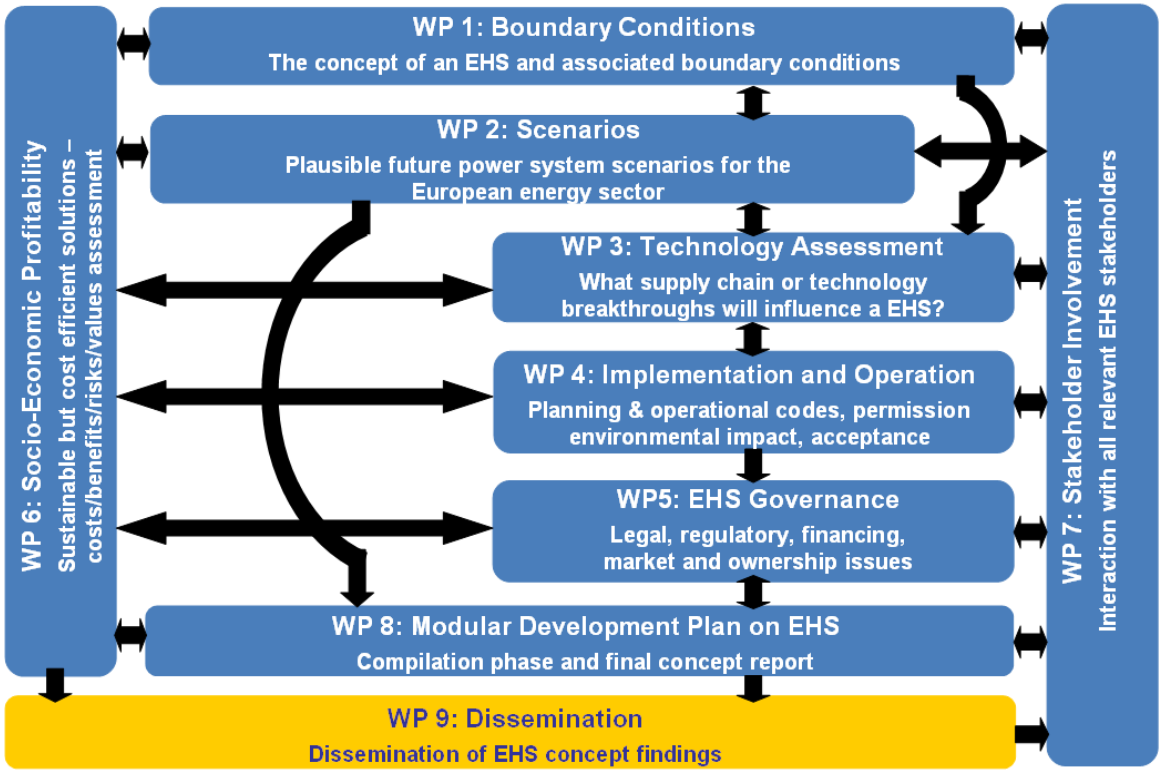

Figure 23: Placement of WP 9 within programme structure

4.4.1 Objectives

In order to have the most effective impact, a specific Work Package will be devoted to disseminating the results and experiences of the Roadmap 2050 development. The Dissemination Work Package is critical for the uptake of the assessment and analysis by the stakeholders of this project. Dissemination will ensure project materials and learning points are captured and made available to all participants and involved parties of the energy industry and the European Commission.

A core team including members of the other Work Packages will need to work closely on communicating the concepts of the Roadmap and all partners in the project should play an active role within their own areas and countries.

This Work Package will define the dissemination objectives, basic procedures to be applied and targeted audiences for information feeds. As the Study Roadmap is a European-wide project, one of the main goals to be achieved by the Dissemination Work Package is the

knowledge transfer among European states. Therefore the overall objective of this Work Package is to implement dissemination activities in view of the future development of the Electricity Highways.

Another important parameter of this Work Package will be to overcome potential barriers raised during the dissemination of the results in the course of the Roadmap development, such as how to disseminate sensitive information that is of paramount importance for the development of the programme.

To address the challenge of raising stakeholder engagement and actively promoting the diffusion of information, a dissemination plan should be developed at the very start of the project, using the input from the partners. This should include advice on how to involve the organisations and their constituencies within the network of the partners.

This will require:

- Supported secure information sharing processes;
- Work Package support and facilitation;
- Meeting management and dissemination of notes and information requests;
- Web based support (linked to the communications programme);
- Project publications management and related report management;
- Issues management.

4.4.2 Deliverables

In conjunction with Steering Committee and Advisory Board members, the appointed partners supporting the data and information requirements relating to the formulation and compilation of the MoDPEHS will be required to:

- disseminate project information, its objectives, the approaches, the results and issues;
- facilitate collaboration and information exchange between relevant Roadmap 2050 communities
- deliver, in conjunction with the communications framework, the Roadmap results to regulators and policy makers that are essential for the uptake of results in EU-27.
- create two-way communication channels with stakeholders, academic communities and industry for disseminating the project deliverables and conclusions within the wider Roadmap 2050 context.

- deliver the project results to TSOs that are essential for replication of promising solutions in the non participating European states.
- identify information that is likely to increase transparency on grid development and public support.
- make this information publicly available.
- cooperate with a EU public-information campaign as needed.

4.5 Programme Management and Communications Resources

The following table relates to the resource estimates required by the project management and communications activities that are likely to need to be supported over the entire programme. The estimated person-months need to be updated when the Project Consortium is set up.

It assumes that dissemination resources will not be required until almost half way through the project when the early workstreams begin to deliver their outputs. Programme management will be needed throughout the entire term and it will be the same team that live with the project as it evolves, draw together and validate the outputs of the delivery Work Packages and bring together the final compilation of the MoDPEHS. This is therefore an onerous task and requires experienced dedicated programme management partners to perform the function.

The Stakeholder Involvement Work Package also requires dedicated resources as described earlier in 2.2. This requirement differs from the dissemination process in that the resource requirement is needed from the very beginning of the project.

4.5.1 Resource table

The following matrix shows human resources needed to grasp all relevant issues of Work Packages 7, 8 and 9. This needed expertise will be covered - apart from the required TSO involvement – also by other consortium partners as shown in the table below. The estimated person-months need to be updated when the Project Consortium is set up.

Table 11: Programme Management and Communications Resources

Specialists / Workstreams	TSOs	Energy Economics / Law Partners*	Policy / Regulatory Partners*	GenCos and RES Partners*	DSOs/Smart Grid Partners*	Manufacturer	Consumers	NGOs	Communication Partners	Legal Partners	Programme Coordinator	Person-months per workstream
WP7 Management	*** CONFIDENTIAL *** ESTIMATED NUMBER AND DISTRIBUTION OF PERSON-MONTHS IS KEPT CONFIDENTIAL BEFORE CONSORTIUM ESTABLISHMENT											
Stakeholder Involvement												
WP8 Management												
Overall Programme Coordination												
Coordination with TYNDP 2012 and 2014												
Compilation MoDPEHS incl. definition of guidelines (key deliverable)												
WP9 Management												
Dissemination												
Person-months WP 7,8,9 exclud. Management of WP7 and 9												

*includes respective R&D performers

5 OVERALL GANTT CHART AND RESSOURCES PLAN

Interdependencies between Work Packages (WPs)

Table 12: Deliverables Matrix

X Main interdependencies x Other interdependencies

WP	These WPs deliver needed OUTPUT ...	… as INPUT for these WPs: Boundary Conditions (WP 1)	Scenarios (WP 2)	Technology assessment (WP 3)	Implementation and Operation (WP 4)	Electricity Highways Governance (WP 5)	Socio-Economic Profitability (WP 6)	Stakeholder Involvement (WP 7)	Modular Development Plan on EHS (WP 8)	Dissemination (WP 9)
WP 1	**Boundary Conditions**									
	Boundary Conditions Report (key deliverable)		X	X			X	X		
	Study review									
	Infrastructure policy review		X		X	X	x			
	Industry code review		X	X		X				
	Appraisal of key economic factors						X			
	Vision statement of 2050 infrastructure		X							
	Assessment of effects on Member States		X		X	X	x			
	Implications on infrastructure configurations		X	X	X	X				
WP2	**Scenarios**									
	Working Scenarios Report (key deliverable)	X		X			X	X	X	
	Study review									
	Assessment of demand evaluation			X						
	Decarbonisation, demand response, storage deployment and energy efficiency impacts			X			X			
	Technology pre-assessment			X			X			
	Secure generation assessment			X		X	X			
	Market simulation and network analyses and infrastructure assessment			X	X	X	X			
	Economic impact assessment					X	X			
	Scenarios construction									
	Network analyses and Infrastructure assessment			X	X	X				
WP 3	**Technology Assessment**									
	Technology Assessment Report (key deliverable)		X		X		X	X		
	Study review									
	Summary of performance characteristics									
	Assess technology innovation				X					
	Assess possible constraints		X							
	Assess cost impact		X		X		X			
	Valuation – winners/losers		X							
	Supply chain issues and related dynamic system stability aspects		X		X		X			
WP 4	**Implementation and Operation**									
	Implementation and Operation Report (key deliverable)			X		X	X	X		
	Study review									
	Planning requirements		X	X		X	X			
	Permission requirements and environmental impact assessment			X		X	X			
	Operational requirements			X						
	European acceptance obstacles map					X	X			
	Measures to overcome the acceptance issue					X	X			
	Proposal on concrete modular Electricity Highways architecture (map)			X		X	X			
WP 5	**Electricity Highways Governance**									
	Electricity Highways Governance Report (key deliverable)						X	X	X	
	Study review									
	Market requirements		X	X	X		X			
	Legal and corporate construct				X		X			
	Regulation implications				X		X			
	Need for policy change									
	Political will assessment									
WP 6	**Socio-Economic Profitability**									
	Socio-Economic Profitability Report (key deliverable)	X	X	X	X	X	X		X	X
	Study review									
	Development of economic assessment tool-box									
	Risk Assessment Report									
	Economic assessment of design, implementation and technological implications			X						
	Cost Benefit Analysis									
	System security impact assessment			X	X	X				
	Assessment of financial and efficiency benefits and carbon reduction effects									
WP 7	**Stakeholder Involvement**	X	X	X	X	X			X	
WP 8	**Modular Development Plan on EHS**					X	X	X		X
	Overall Programme Coordination									
	Coordination with TYNDP 2012 and 2014									
	Compilation MoDPEHS incl. definition of guidelines (key deliverable)									
WP 9	**Dissemination**							X		

Table 13: Overall Resource Plan

Work Package	Work Package Management	TSOs	Energy Economics / Law Partners*	Policy / Regulatory Partners*	GenCos and RES Partners*	DSOs/Smart Grid Partners*	Manufacturer	Consumers	NGOs	Communication Partners	Legal Partners	Programme Coordinator	*Sum of Person-months*
WP 1 Boundary Conditions													
WP 2 Scenarios													
WP 3 Technology Assessment													
WP 4 Implementation and Operation													
WP 5 EHS Governance													
WP 6 Socio-Economic Profitability													
WP 7 Stakeholder Involvement													
WP 8 Modular Development Plan on EHS													
WP 9 Dissemination													
Total person-months													

*** CONFIDENTIAL ***

ESTIMATED NUMBER AND DISTRIBUTION

OF PERSON-MONTHS IS KEPT CONFIDENTIAL

BEFORE CONSORTIUM ESTABLISHMENT

*includes respective R&D performers

Figure 24: Overall Gantt Chart – Part 1

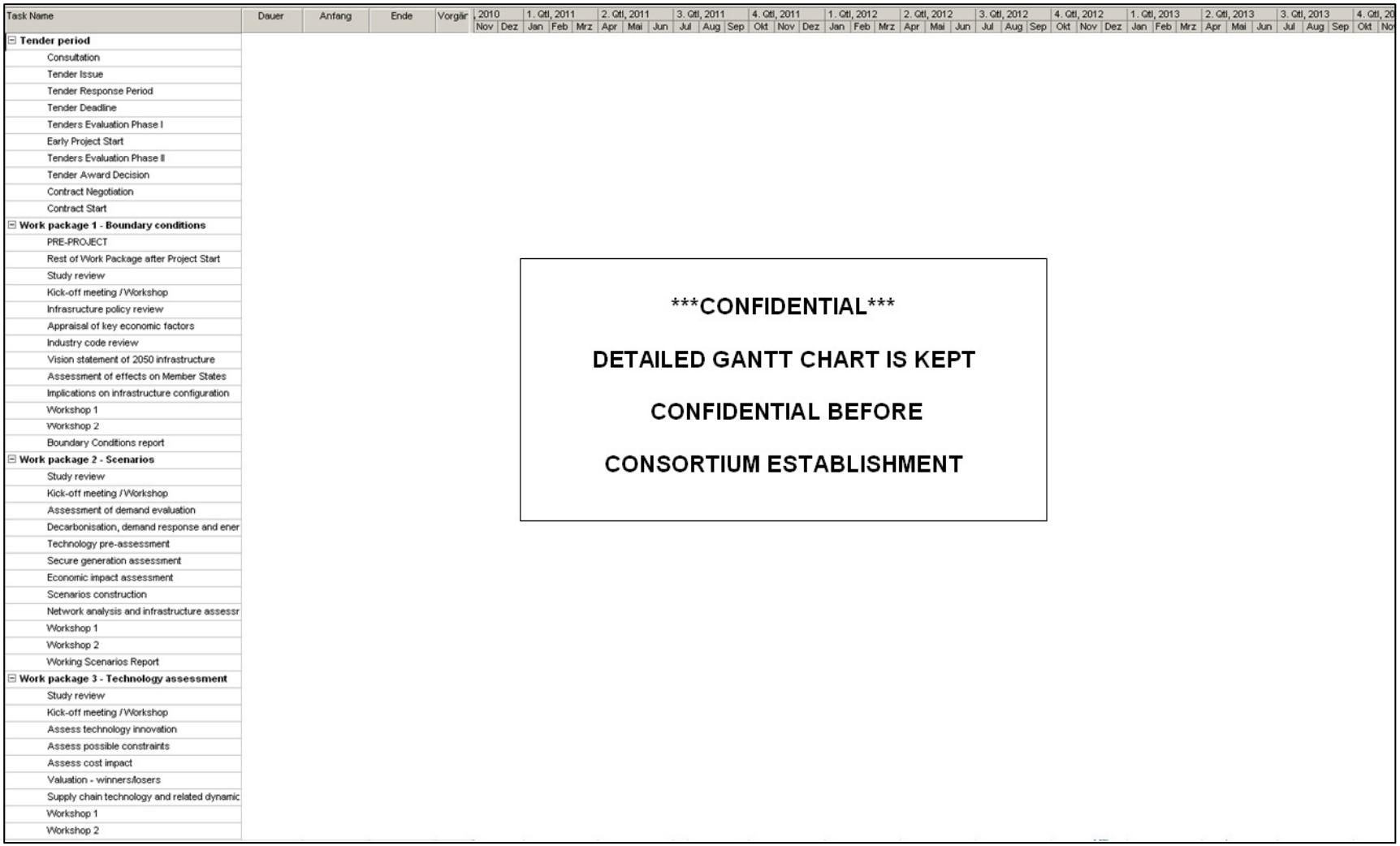

Figure 25: Overall Gantt Chart – Part 2