

52

Project proposal

**STUDY ON THE COMPARATIVE MERITS OF  
OVERHEAD ELECTRICITY TRANSMISSION LINES  
VERSUS UNDERGROUND CABLES**

- Confidential -

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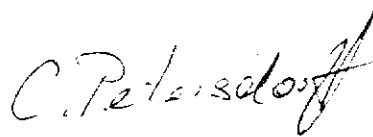
Project number PPSMDE081295

Study on the Comparative Merits of Overhead Electricity Transmission Lines versus Under-  
ground Cables

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On behalf of:  
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# 1 Introduction

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On 12 March 2007 the Government White Paper *Delivering a Sustainable Energy Future for Ireland – The Energy Policy Framework 2007-2020* was launched which, inter alia, committed to ensuring completion of the ongoing capital investment programme in the transmission and distribution network by 2010 and overseeing further extensive investment. The White Paper also specifically committed to the delivery of the second North South electricity interconnector by 2011 and the East-West interconnector by 2012.

EirGrid plc, a State owned company under the aegis of the Department of Communications, Energy and Natural Resources, among others is responsible for planning the construction of high voltage transmission lines. As part of its ongoing transmission development plan, and in line with the Government's Energy White Paper, EirGrid is currently planning the construction and reinforcement of a number of transmission lines. The recently published All Island Grid Study also estimated the transmission infrastructure investments needed to accommodate increasing levels of renewable electricity and noted that up to 42% renewable energy penetration is potentially feasible, requiring over 600 km of additional transmission lines (230 km at 110 kV and 370 at 220 kV or 275 kV, respectively).

EirGrid is currently progressing a number of projects including a North-South Line, Meath-Cavan Line and proposed East-West interconnector. Two of these projects which are currently the subject of a public consultation process, undertaken by EirGrid, as follows:

1. The North-South 400kV transmission line which will more than double the current power transfer capacity between the two jurisdictions. This new line will span approximately 80km from a proposed new substation near Kingscourt in Co Cavan, to Co Tyrone.
2. Upgrading of the transmission system in Meath and Cavan through the building of new 400kV transmission lines between Woodland, Co Meath, and Kingscourt, Co Cavan. This line will be 58km long and will connect to the North South transmission line at Kingscourt, Co Cavan.

In the course of EirGrid's public consultation on the construction of the North South and Cavan Meath transmission lines, considerable concerns have been expressed by local communities in these regions as to the impact of overhead transmission lines in their locality.

In response to these concerns and noting that the issue of overhead transmission lines versus underground cables is likely to arise as a matter of public concern in future transmission development proposals by EirGrid, the Minister for Communications, Energy and Natural Resources announced on 6th February 2008, that his Department would commission an independent study in relation to overhead and underground transmission lines. The aim of this initiative is to provide clarity on issues in relation to overhead versus underground transmission lines, thereby informing policy decisions on all current and future transmission line projects.

The challenge summarised above is not exclusive to Ireland. Similar investigations and policy efforts are existing in a variety of European countries as well as overseas. In a number of European regions (e.g. Germany: coastal areas of Schleswig Holstein and Lower Saxony<sup>1</sup>; Italy, in particular Tuscany; Denmark) regulation has been put into force factually resulting in an obligation to apply underground cabling for new 110<sup>(+)</sup> kV transmission projects instead of overhead lines. A comprehensive analysis as requested by the Minister has to reflect such existing international experience with the relevant technology options and their implications.

A thorough assessment and consideration of all existing technology alternatives to overhead transmission lines will be an inevitable part of a successful energy policy. However, a number of expectations and claims used by opponents of OHL require thorough consideration of the context where they are justified or even need to be testified.

From a planning perspective, the major expected benefit of designing new electrical infrastructure using underground cables instead of overhead lines is project acceleration. However, the validity of this assumption has to be verified on a case by case basis and has to be balanced with potential drawbacks, including increased life cycle costs and compromised security of supply.

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<sup>1</sup> "Niedersächsisches Erdkabelgesetz"

## **2 Objectives and deliverables**

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### **2.1 Objectives**

According to the tender request, "the purpose of this study is to provide the best available professional advice to the Minister on the relative merits of constructing and operating overhead transmission lines compared to underground cables, having regard to technical characteristics, reliability, operation and maintenance factors, environmental impact, possible health issues and cost".

This advice has to enable the Minister to further develop the policy areas affecting electrical infrastructure in Ireland from an informed position. These policies cover the next decade and will be decisive for the success in a number of key policy areas (including security of supply, renewable energy and climate targets, economic growth). In this perspective, an underlying objective of the study is to incorporate recent international achievements and the best available knowledge, assuring a strategic and societal view on the matter.

Nowadays, the issue of most appropriate technology choices for new electrical infrastructure projects is discussed intensively by a variety of stakeholders. Public acceptance became vital to permission and project planning. Though clearly addressed to the department, an additional objective of the study is to provide a balanced and unbiased evaluation of the technology options and their implications to support the creation of a common view across society. Therefore, study conclusions need to be applicable and accessible for a non-technical audience.

### **2.2 Deliverables**

The primary deliverable resulting from this study will be the (draft) final report, including the related presentation. This report will contain the outcome of the comparative analysis. Additionally, it will summarise the major issues raised in the stakeholder submissions as well as the findings related to these issues.

If desired by the client, the consultants will present their findings in a meeting with the Joint Oireachtas Committee on Communications, Energy and Natural Resources. The necessity of such a presentation will be decided by the client at project inception.

### 3 Scope

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According to the tender request, the scope of the study is a comparative analysis of the options for power transmission using overhead lines (OHL) or underground cabling, respectively. The comparison of the benefits and limitations of these options will cover technical, environmental, social, economic and planning aspects.

In addition to the issues explicitly specified in the tender, the proposed scope includes the following elements:

- The impact of AC (alternating current) as well as DC (direct current) technologies in terms of the option characteristics;
- Specific configurations for underground cables offering additional benefits (e.g. compact routing in combination with optimised thermal management, reduced magnetic fields, temporary redundancy during fault conditions); and,
- Specific configurations and technologies for overhead lines (e.g. high temperature conductors, low-loss conductors with larger cross-section, thermal monitoring (dynamic line rating), DC transmission and respective tower configurations).

The strategic importance of medium and long term technology options which may be applicable to underground transmission cables, e.g. High Temperature Superconductors for extended distances at voltages of 110 kV or higher, will be discussed. However, these options will not be included in the techno-economic and environmental impact analysis.

The analysis will reflect societal as well as stakeholder perspectives. This difference is of particular importance for planning and economic issues. In accordance with the tender requirements, the scope will incorporate an international perspective and take into account technical innovations relevant for the near future.

The scope of the study does not include assessments regarding the impact of the technology options on power systems operation (such as dynamic stability, changes of load flow patterns in the existing system in Ireland).

## 4 Project phases & activity planning

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### 4.1 Project work packages and tasks

The following section describes the particular tasks and the proposed approach related to each.

#### Work package 1. Review of electrical power transmission technologies

##### Scope according to tender

Provide advice on "review of electrical power transmission technologies currently in use for transmission of electricity at voltages of 110kV and above" from an international perspective.

##### Objective

The objective of this work package is twofold: on one hand the technology review has to create a consistent structure and framework for all following analyses. In particular, the technology options which have to be distinguished, also depending on application context, have to be specified. On the other hand, the information gathered in this work package has to directly support a qualification of technology options with respect to existing experience, constraints, current applicability and expected short term developments.

##### Approach and tasks

#### 1. Methodology definition

Specification of technology options, containing at least:

- Overhead lines (OHL) in AC and DC technologies;
- Underground cabling in AC and DC technologies;

further distinguishing relevant voltages and distance ranges applicable to the Irish situation for each of the combinations.

Simultaneously, for the complete set of combinations, the criteria for evaluation and comparison are defined as a basis for the analysis in the following work packages.

#### 2. Technology characterisation:

The technical, economic and environmental characteristics for the technologies are described. Also the stage of development and specific framework conditions for application are characterised. The information will be based on existing experience of the consortium, publications and will be updated by a poll with industry contacts (WP2). The work delivers a comprehensive evaluation of current and potential options for transmission network extension. This overview will be presented in a matrix.

**Expected result:** Matrix with technologies and evaluation criteria

## Work package 2. Current international praxis

### Scope according to tender

Provide advice on "the factual position regarding current practice for constructing transmission lines worldwide, in terms of when such lines are constructed as underground cables and why".

### Objective

The objective of this work package is to illustrate the state-of-the-art in transmission system extension and to qualify the technology options by international reference projects. This review provides a clear understanding for fundamental design choices and investment decisions. Simultaneously, this work package identifies the realistic options for implementation in the Irish context and acts as a filter for the complete set of options reviewed in the first work package.

### Approach and tasks

The consultants will gather and analyze information related to recent and ongoing international transmission projects (references), safeguarding a representative and balanced mix of OHL and cabling projects. In addition to public domain, information will be sourced from the industry network of the consortium. Given the fact that the project team directly supports project developers in design and implementation of their projects, it has access to technical and economical parameters related to these projects. For verification and qualification of the gathered information, a consultation with Eirgrid will be organised before compiling the task report.

Based on a thorough analysis of the projects framework conditions and design criteria, the relevance of the projects for the Irish context will be evaluated. The analysis will consider technical performance, economics, public acceptance, environmental impact and other relevant aspects driving the design choices of the references.

The results will be documented in a format accessible for an informed but non-technical public.

### Expected result

The outcomes of this work package are documented in a dedicated section in the study's report. The data compiled form the basis for the further analysis. Options which are not relevant for the Irish situation are identified and excluded from further analysis based on transparent criteria.

### Work package 3. Comparative analysis of technical performance

#### Scope according to tender

Provide advice on "the relative technical performance of overhead lines and underground cables, in terms of losses, reliability/availability/security of supply, impact on delivered power quality and electromagnetic field generation".

#### Objective

The objective of this work package is to provide a detailed evaluation and comparison of technical performance of the relevant technology options. In addition to the direct comparison, the results gained form key input for the following work packages (e.g. magnetic fields

- WP4 environmental impact, transmission losses and associated life cycle costs
- WP6 economics).

#### Approach and tasks

For the technology options and their variants the following aspects are evaluated in a consistent manner:

- Specific losses and typical cumulative losses over the life of the asset;
- Impact of the technology on reactive power balance and voltage control in terms of investment and operations;
- Reliability and availability, (n-1) security of supply also taking into account probabilistic concepts and temporary overloading capability, monitoring and operations;
- Impact on power quality (severity of higher harmonics and resonances); and,
- Electro-magnetic fields for the technology options and their variants.

#### Expected result

The assessment will generically characterise the technical parameters as listed in the scope for each of the options and their variants. More important, the work package results will indicate the range for these parameters and possible improvements which can be achieved by technical measures. The ranges will be qualified in terms of potential drawbacks as, for example, additional costs or extended space requirements.

## Work package 4. Comparison of environmental impacts

### Scope according to tender

Provide advice on “the comparative environmental impact of both options in terms of land use, geology and soils, water resources, ground restoration, ecology and nature conservation, landscape and visual impact, cultural heritage, traffic and noise, air quality and recreation, electromagnetic fields, communities and tourism”.

### Objective

The objective of this work package is to provide a spatial and temporal comparative assessment of the environmental impacts related to the construction, operation and maintenance of both overhead power lines and underground cables. Consideration will be given to available, evidence-based international best practice, which will then be applied to the Irish environmental and social context. Mitigation and monitoring strategies will be provided to minimize potential anticipated impacts. Based upon the implementation of the suggested mitigation and monitoring measures, any anticipated residual impacts will be described.

### Approach and tasks

The proposed approach to the assessment is strategic environmental assessment (SEA). SEA is recognized as a systematic method for considering the likely environmental impacts related to any large scale plan, programme or strategy. It ensures that environmental considerations are addressed as early as possible and are in balance with the technical and economic factors of a proposed development. The SEA approach involves the identification of key environmental issues, definition of environmental objectives and appraisal criteria, and provides a means of driving environmental gain through plan implementation. This will provide a clear understanding of the environmental and social implications which need to be considered in the decision-making process. The tasks related to this approach and project are described below:

1. Scoping
  - Identification of available existing information
  - Review of third-party submissions, as required
  - Consultation with agencies, as required

## 2. Baseline Assessment

- Review Existing Information:
  - Literature Review / Previous Studies
  - Relevant Policies and Plans
  - International Best Practices
  - Review and evaluation of trend-setting international standards and regulation particularly related to emission of electro-magnetic fields
- External consultation, as required
- Engagement of Resource Specialists

## 3. Reporting

- Environmental Objective Analysis
- Description of Existing Environment
- Impact Assessment (spatial and temporal)
- Mitigation and Monitoring Recommendations
- Report compilation, review, edits, and draft submission
- Incorporation of agency comments into final report

### **Expected result**

The findings of this work package will form a dedicated section in the final report. The report will provide an objective, comparative assessment of the potential spatial and temporal environmental and social impacts listed in the request for tender related to both, overhead electricity transmission lines and underground cable construction, operation and maintenance. The report will also provide recommendations for mitigation and monitoring.

## Work package 5. Policy implications

### Scope according to tender

Provide advice on “implications for national policies on energy, environment and enterprise (including employment) of implementing underground cables rather than overhead lines”.

### Objective

Either option would require alignment with existing policies as well as strategic preparation for future national policies. The objective of this work package is to assess both options, in terms of their alignment with existing and anticipated national policies relating to energy, the natural and social environment, and enterprise development.

### Approach and tasks

This work package will be undertaken simultaneously with the tasks described in work package 4 to ensure efficiency. The steps related to this approach and project are described below:

1. Scoping
  - Define the boundaries of investigation, assessment and assumptions required
  - Review and respond to third-party submissions, as required
2. Baseline Assessment
  - Desk review of position papers
    - Effectively describe existing and anticipated related national policies
    - Review of position papers to source inputs on energy, environment and enterprise development needs, with selected representatives of a variety of stakeholder groups including:
      - Local and Regional Authorities
      - Government departments with energy competencies
      - Government departments with social, environmental and enterprise development competencies
      - Business networks
      - Civil society groups
      - Environmental groups
      - Industry representatives
      - Existing sector networks
      - Vulnerable groups
      - Research institutions

### 3. Reporting

- Development of a structured review implication assessment framework
- Determination of the likely implications on related existing and anticipated national policies
- Recommendations to maintain alignment with related existing and anticipated national policies for both scenarios
- Recommendations for monitoring after implementation

#### **Expected result**

Completion of this work package will result in a dedicated section of the final report.

The report will provide a comparative assessment of the implications on existing and anticipated national energy policies. The report will also comprise an assessment of implications on policies relating to environmental and enterprise development at the local, regional and national levels. The assessment will enable a comparative review of implications with respect to both overhead electricity transmission lines and underground cables.

The review of overhead and underground transmission lines will assess the implications at the various stages of project development including: construction; operation; and maintenance and apply a qualitative review to facilitate a comparative analysis.

The final report will also provide recommendations for any risks identified and propose appropriate and cost-effective mitigation and monitoring mechanisms.

## Work package 6. Cost analysis

### Scope according to tender

Provide advice on "relative capital costs, total life cycle costs (to include decommissioning costs), annualised operation and maintenance costs and impact on unit electricity prices".

### Objective

This work package has three particular objectives:

- To provide a consistent methodology for economic comparison of the technology options and their variants in a life cycle perspective;
- To identify and distinguish cost components which apply to asset owners and those needing a societal perspective;
- To deliver generic cost figures for the technology options and more specifically for typical configurations in Ireland (case study perspective).

### Approach and tasks

For the variants of both options, OHL and underground cables, the following cost aspects are evaluated allowing comparison of economic performance:

- relative capital costs,
- total life cycle costs (including costs for decommissioning),
- annualised operation and maintenance costs, and
- impact on unit electricity prices.

The analysis will use the generic data derived in work packages 2 to 5 and in that perspective will represent an international view. In addition, the economic models will be applied to up to three cases reflecting specific topographies and network configurations typical of those found in Ireland. Certainly, this assessment does not replace in depth feasibility studies. Data uncertainty will be significant. To allow robust conclusions the model outcomes will be qualified in a comprehensive sensitivity analysis.

An important aspect is the economic evaluation of acceleration of construction times for both options and their consequential impacts on security of supply. Third party approaches to include this aspect in economic evaluation will be introduced and applied. The client may desire to be informed about the position of the regulator (CER) with respect to the proposed approaches. If the client expresses an interest in such a feedback to the consultant, contact with the CER will be established in order to discuss the matter.

Where appropriate the difference between costs from a stakeholder perspective (asset owner) and from a societal perspective will be highlighted.

External costs (health effects, land use, etc.) and their impact on economic performance from a macro economic view are described but not included in the model. With existing knowledge, the quality of available input data is too limited to allow for a quantitative evaluation. From a stakeholders perspective these costs do not influence decision making.

**Expected result**

This work package provides a methodology for adequate evaluation and comparison of the economic performance of the options. The cases illustrate the respective position of the technologies in the Irish context. By clearly evaluating costs from a stakeholder perspective, the results support the findings of work package 5. Needs for adaptation of regulation for appropriate allocation of costs to stakeholder are identified and highlighted.

## Work package 7. Reporting and meetings

### Objective

The objective of this work package is to compile the study's results in a summary report. This report has to be comprehensive and accessible. The results will be presented at a meeting with the client after delivery of this report. An additional meeting with the Oireachtas Committee on Communications, Energy and Natural Resources is offered as an option.

The first meeting after contracting has to ensure that the suggested approach perfectly meets the clients expectations. If necessary, adjustments to the work programme and planning will be agreed upon.

### Approach and tasks

Meetings with the project steering committee are foreseen at project inception and for presentation of the draft final report. For these two meetings we assume attendance of two Ecofys representatives and two Golder representatives.

The report will be an integrated document compiled from the documented outcomes of the particular work packages. The draft modules will be submitted to the department for review already along the project. This will enable the client to control quality and comprehensiveness of the work delivered.

If desired by the client, the consultants will appear before Joint Oireachtas Committee on Communications, Energy and Natural Resources for presentation of the final results of the study (optional, budgeted separately). Attendance of the consultants has to be agreed upon during project execution (at least one representative of Ecofys and Golder, each).

### Expected result

The final report and the information communicated in the meetings with the client will provide the guidance desired by the Minister and will support further policy development on the matter of electrical infrastructure on an informed basis.

## 4.2 Activity planning

The request for tenders requires the consultant to deliver a draft final report within 40 days after contract signature. This ambitious schedule requires thorough task planning.

In the first week after the kick-off meeting, the methodology of the study is fine-tuned to the needs of the client. In parallel, the stakeholders' submissions are reviewed and integrated in the scope of work and the international information update from industrial parties commences. Applying the specified methodology, the various technology options are characterised and sound matches for comparison as well as respective criteria are derived. This task takes two weeks; however, as the analysis of the performance and implications of the options (work packages 3, 4 and 5) has already commenced, it is anticipated that less time would be required at the point of project inception. The cost analysis will be executed in parallel with finalisation of work packages 3 to 5 and, hence, the draft final report will be available in the 5<sup>th</sup> week after kick-off.

To accommodate the ambitious project schedule, Ecofys has strategically co-ordinated the study approach so that many of the tasks are executed in parallel with one another. This approach is depicted in the project schedule below. Consistency of the results will be safeguarded by careful project management (Ecofys) and close co-operation of the team members. Additionally, the existing common experience with respect to the study's subject (Ecofys / Brakelmann) supports simultaneous analysis of specific issues.

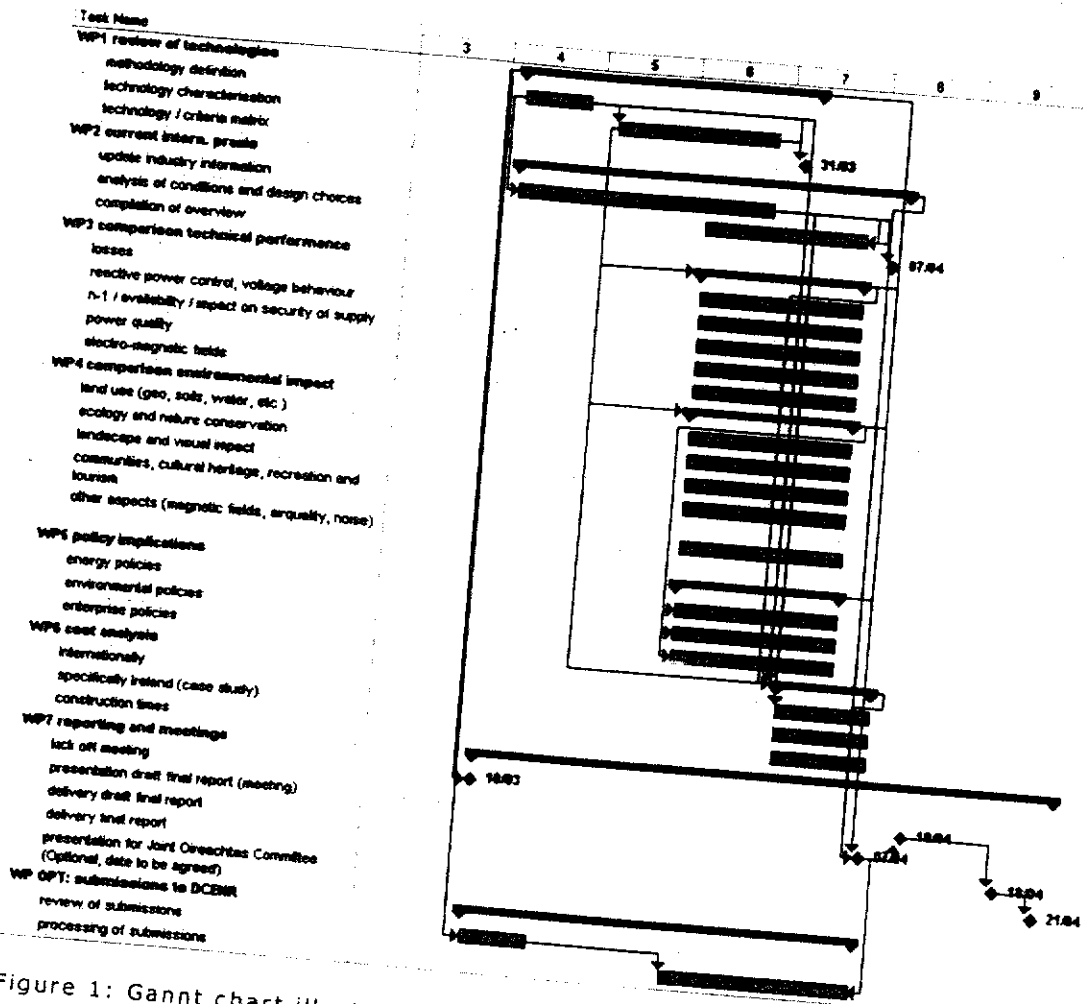


Figure 1: Gantt chart illustrating project work flow and interdependencies

## 5 Project team & project management

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### 5.1 Project team

With our team we offer an excellent combination of knowledge, international experience and skills related to the subject of the required study.

Established in 1984, **Ecofys** specialises in energy saving and renewable energy solutions. As part of the Econcert group, we offer research and consultancy services as well as product development. Over the years Ecofys has conducted extensive research and completed projects for many energy companies, housing corporations, building companies, international and local authorities, and energy consumers around the world. With more than 325 employees in twelve countries, we're one of the largest consultancy firms in sustainable energy and climate policy.

The department 'Power Systems and Markets' (PSM) is deploying Ecofys' international activities related to development of electric power systems and electricity markets with particular attention paid to efficient integration of renewable generation. To fulfill this demanding task, an interdisciplinary

approach is taken that identifies and analyses the linkages between the technical, the regulatory and the economic systems.

Recently, the PSM team delivered the Final Report of the All Island Grid Study to the Minister. With this background our experts clearly understand the challenges the Department is faced to in the near future implementing the governments targets. For years, the PSM team has been supporting developers of (onshore and offshore) wind projects in negotiations with network operators and engineering of grid connections. This gives us a detailed insight in technologies available in the market, cost structures and planning issues.

Simultaneously, we are in a close cooperation with our proposed project partner **Prof. Dr.-Ing. habil. Heinrich Brakelmann** of the **University of Duisburg – Essen** (Germany), faculty Energy Transmission and Storage. In a collaborative research project with industry we are investigating innovative concepts of underground cabling for offshore and onshore transmission (bipolar AC transmission). Drivers for the research are obvious potentials for reduction of losses, costs and magnetic fields. Prof. Brakelmann is an internationally

