P·O·W·E·R
Pushing Offshore Wind Energy Regions

Final Report

Software & Decision Support Systems for Offshore Wind Energy Exploitation in the North Sea Region

April 2007

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Meteorological and Technical
Information Systems
Wind Energy Consulting

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Title:	Final Report „Software & Decision Support Systems for Offshore Wind Energy Exploitation in the North Sea Region“
Date:	2007-05-18
Editing:	Overspeed GmbH & Co. KG
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Version:	Final 1.1
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File:	POWER_SDSS_Final-Report_1.1_2007-06-04.doc

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1. Introduction

This study investigates and reports on potentials of the application of software (and) Decision Support Systems (SDSS) in the course of the planning and realization processes of offshore wind farms in the North Sea Region.
Main goal of the study is to report on existing Decision Support Systems and software tools for on- and offshore planning. Gaps shall be identified and current demands of the offshore wind energy sector shall be analysed. Potential user groups should be identified.

The study is integrated in the POWER (Pushing Offshore Wind Energy Regions) EU project. Findings from this study will be published as part of POWER. More information about the overall project can be found at http://www.offshore-power.net/.

Decision Support Systems

The definition of Decision Support Systems is broad and there is no universal definition beside that those systems are build to assist in decision processes and help to identify and solve problems. Generally Decision Support Systems are multidisciplinary and often include weighting and analysis functions. A wide range of sources is handled including data, information, knowledge and methods.
The structure of Decision Support Systems may be different from communication oriented systems to data orientated, knowledge base or model and analysis based systems, etc..
For instance communication oriented systems focus on the collaboration of different specialists, the appropriate communication and organization structure and transaction rules. Data oriented systems focus on data storage, data network and management. Knowledge based systems focus on experience, rules and facts. Model and analysis based systems focus on mathematical models and methods including simulation models. The main focus may be very different dependent on the main field of application.
Corresponding the area of application of Decision Support Systems is wide ranged including medical diagnostics, science, financing, project planning, maintenance management, raw material exploration, logistics, economics, industrial development, investigations, approval procedures, test procedures etc.. Further developments may reach nearly every area of knowledge.

Commonly most Decision Support Systems are aligned to interactive computer software systems in the following called ‘Software Decision Support Systems’ (SDSS or SDS-Systems). As mentioned above the definition of Decision Support Systems is very unsharp and the question arises, at which stage can software be termed as a Decision Support System? From the very basic view every software tool which

processes and/or analysis data can be used as a basis for a decision. A Decision Support System is related to different disciplines. On one hand several separated software tools on different disciplines can be seen as a entirety and SDSS, on the other hand software which already handles several disciplines can be seen as a SDSS. A further level of development is the implementation of weighting and analysis functions for the different disciplines and therefore the implementation of optimisation processes.

Decision Support Systems in the Offshore Context are designed to support the development, construction and operation of offshore wind farms. For instance, during the planning process a whole series of requirements from various fields show up (engineering, costs, financing, ecological environment, shipping, military, exclusion zones, sediment properties, accessibility ...). Those Decision Support Systems integrate various data, general information and mathematical models, in order to support problem identification and solving, optimisation and decision-taking processes.
According to current information, Decision Support Systems are used rarely in the offshore wind energy field. That is why this survey also relates to supporting software products. GIS systems, which are usually applied in this field, are a good example for basic Decision Support Systems in which exclusion criteria play a major role, but which generally do not include explicit evaluations and weighting functions.

In the framework of the POWER project a Case Study [2] and Supply Chain Studies [3] [5] were performed to evaluate experiences from planning, developing and building offshore wind farms. Bottlenecks were found and corresponding recommendations were derived. Some of the main identified bottlenecks are different aspects of the approval process, offshore site selection, hardware testing procedures and quality management, contracting (including risk analysis), on- and offshore logistics, time and cost management, and financing concepts. It is expected that a reduction of those bottlenecks is possible by the application of appropriate Decision Support Systems.

Approach

As a basis for the study on Software and Decision Support Systems in the planning and implementation process of offshore wind farms in the North Sea region a survey was performed. The goal was to provide an overview of existing Decision Support Systems and individual software tools as well as to define the demand for and requirements of Decision Support Systems for the planning and implementation of offshore wind farm projects in the North Sea area. The parties addressed here were developers, planners, authorities, manufacturers, universities, financing groups etc.

An internet research and a literature research on existing Software and Decision Support Systems was performed. A short evaluation and rating did follow. A questionnaire regarding the use of Decision Support Systems in the offshore sector and related software tools was developed and sent out to relevant parties in Western Europe. Supplementing researches were done. The responses were evaluated and analysed. Personal communications did complement the assessment.

2. Existing Decision Support Systems

2.1 Overview

The following three subchapters give a short overview on existing Decision Support Systems related to the offshore wind energy sector gathered mainly by an internet and literature research and own experience. Listed issues like ‘suitability’ and ‘constrains’ are assessments on current information status.

The item ‘suitability’ in this context refers to the suitability as a Decision Support System (type: integrated) or a part of a DSS (type: specific) for offshore wind energy. Suitability is rated in three categories: high, medium and low. “High” stands for SDS-Systems which are developed for offshore wind energy or systems which can easily be adopted, “medium” for systems which may be adopted with medium effort, and “low” for systems for which the effort seems to be too high and/or which have a different assignation. The rating is generally subjective.

In category ‘Type’ the classification into ‘Integrated’ (Integrated System) and ‘Specific’ (specific software tool) is in some cases problematic. ‘Specific’ was chosen for software which ‘mainly’ works in one specific area and ‘Integrated’ was chosen for systems which cover different specific areas like wind farm layout, restriction areas, geological items, cable route, costs etc..

2.1.1 Existing Software Decision Support Systems or Related Software Tools, Offshore

In the offshore sector several SDS-Systems are found, most of them under development but already supporting concrete offshore plannings.

Table 1: Existing SDS-Systems/Tools offshore

Offshore				
Name	**Company**	**Area**	**Type**	**Suitability**
OWECOP	ECN, The Netherlands	Project development	Integrated	high
O&M DSS	ECN, The Netherlands	Operation, Maintenance	Integrated	(under dev.)
OWFLO	Uni. of Massachusetts, USA	Project development	Integrated	(under dev.)
ANEMOS	ICBM, Germany	Education Project develop.	Integrated	not rated
Ventum	TU Delft, Netherlands	Education Project develop.	Integrated	Low
EeFarm	ECN, The Netherlands	Grid Integration, Costs	Specific	high
Maintenance Manager	ECN, The Netherlands	Operation, Maintenance	Specific	high
GIS – cable route	ICBM, Germany	Project development	Specific	high, development discontinued
BMT MWCOST	BMT Cordah Ltd, UK	Operation, Maintenance, Costs	Specific	high

More general SDS-Systems for offshore wind farms (Table 1) are mainly developed by ECN (Netherlands, OWECOP) and the University of Massachusetts (USA, wind farm Middelgrunden Denmark, OWFLOW). Those systems cover the whole area from project development, wind farm layout, restriction areas, geological items, cable route, grid connection and operation and maintenance in different detail. Other software systems are for educational training or more specific areas like grid integration.

2.1.2 Existing Software Decision Support Systems or Related Software Tools, Onshore

In the onshore sector several integrated SDS-Systems from different countries are found (Table 2). They are specific to onshore developments and only parts of those systems may be transferred to the offshore sector.

Table 2: Existing SDS-Systems/Tools onshore

Onshore				
Name	**Company**	**Area**	**Type**	**Suitability**
WEPA	Energy Research Group, India	Project development	Integrated	Low
RETScreen	Energy Diversification Research Laboratory, Canada	Project development	Integrated	low / medium
RES-DSS	National Technical University of Athen, Greece	Project development	Integrated	low
Multi-Criteria Analysis with ArcGIS Spatial Analyst	National Environmental Research Institute, Denmark	Project development	Integrated	Promising

Most promising projects for the onshore sector seems to be the ‘Multi-Criteria Analysis with ArcGIS Spatial Analyst (NERI Denmark) and RES-DSS (University of Athens, development state unclear). The ‘Multi-Criteria Analysis’ seems to implement a good concept also for offshore SDS-Systems.
The RETScreen concept (Energy Diversification Research Laboratory, Canada) which implements different project analysis tools on a Microsoft Excel sheet base, meets the interest of several wind farm developers.

2.1.3 Existing Software Decision Support Systems or Related Software Tools, Different Thematic Fields

In the following exemplarily some Decision Support Systems and tools are listed for which a relation to offshore wind energy can be found.

Table 3: Existing SDS-Systems/Tools of different thematic fields

Different Thematic Fields				
Name	**Company**	**Area**	**Type**	**Suitability**
DIgSILENT Power Factory	DIgSILENT GmbH, Germany	Grid Integration	Specific	High
PSS™SINCAL	SimTec GmbH, Siemens AG, Germany	Grid calculation	Specific	High
WILMAR	Risø National Laboratory, Denmark	Integration of renewables in power markets	Integrated	High
RamCo	National Institute for Coastal and Marine Management, Netherlands	Coastal zone management	Integrated	Medium
Nijhum Dwip DSS	CEGIS, Bangladesh	Coastal zone management	Demonstration	Low
RODOS	Forschungszentrum Karlsruhe GmbH, Germany	Nuclear emergency management, safety management	Integrated	Low
OSCAR	Sintef Group, Norway	Oil spill management	Integrated	Low
AKSIO	Statoil ASA, Hydro ASA, Computas AS, Institute of Energy Technology, Det Norske Veritas, the Norwegian Univercity of Sience and Technology, UniK (University Graduate Studies at Kjeller), Norway	Oil Drilling	Integrated	Low

In the area of grid integration / grid calculation systems like PSS SINCAL (Siemens) and Power Factory (DigSilent) are playing an important role as specific tools for SDS-

Systems also suitable for the offshore. They are highly-developed and the basic tools for grid operators etc.. SDS-Systems for coastal zone management like RamCo may also be a part of a more general offshore SDS-System related to authorities.
From SDS-Systems for Oil spill management a relation could be found to offshore wind farms and oil tanker accidents. Risk analysis reports on this subject are a must for every offshore wind farm application.

2.2 Offshore Wind Energy

2.2.1 OWECOP - Integral Analysis of the Cost and Potential of Offshore Wind Energy

Developer:	ECN, The Netherlands
Short description:	Extended GIS for cost and wind potential analysis offshore
Covered Issues:	Wind speed, water depth, distance to electrical grid, GIS implemented, levelized wind energy production cost, protection and restriction areas
Addressed to:	Project developers, policy makers, authorities, investors, banks, utilities.
Suitability:	high
Reference:	http://www.ecn.nl/en/wind/products-services/services/software/owecop/

Description:
OWECOP (Offshore Wind Energy COst and Potential) is a software program for the analysis of wind energy exploitation at sea. It has been developed by The Energy research Centre of the Netherlands (ECN). Remarkable is that it couples a geographic information system (GIS) to a spreadsheet model that calculates the costs of wind farming.
For each location the site specific parameters like average wind speed, water depth, and distances to the electrical grid and harbour facilities are translated to costs and energy yield for a user-specified wind farm. As a typical result maps show the geographic distribution of the levelized wind energy production costs at sea. OWECOP addresses to policy makers, project developers and investors to investigate their opportunities for offshore wind power, to verify their project details and to pinpoint promising offshore locations based on an integrated analysis.

2.2.2 Maintenance Manager

Developer:	ECN, The Netherlands
Short description:	Information system for maintenance of wind turbines
Covered Issues:	Data base, maintenance and failure data, information on spare parts
Addressed to:	Manufacturers, operators,
Suitability:	high for maintenance
Reference:	http://www.ecn.nl/en/wind/products-services/services/software/maintenance-manager/

Description:
The *Maintenance Manager* has been developed by ECN to support operation and maintenance. The *Maintenance Manager* is structured such that a wind turbine manufacturer, its maintenance departments (sometimes located in different countries) and their technicians can be provided with turbine data like design information, information on spare parts and maintenance procedures. Maintenance and failure data can be analysed by the maintenance departments and/or by the manufacturer. These data are systematically recorded by the technicians and maintenance departments. The Maintenance Manager is equipped with analysis tools to derive relevant information from large wind turbine populations. Data can be ranked (costs, number of failures, downtimes) and components can be analysed in detail (MTTF values, trend analyses) by the various departments involved.

2.2.3 EeFarm - Grid Integration of Large Offshore Wind Farms

Developer:	ECN, The Netherlands
Short description:	Design of electrical infrastructure
Covered Issues:	Electrical infrastructure, AC and DC connections, dynamic effect on the high voltage grid, turbine size, farm size, distance to shore
Addressed to:	Project developers, investors, banks, utility
Suitability:	high for electrical infrastructure
Reference:	http://www.ecn.nl/en/wind/products-services/services/software/eefarm/

Description:

For the design of the electrical infrastructure of offshore wind farms ECN has developed a computer program called EeFarm.

The EeFarm program helps to identify the most cost effective electrical infrastructure for offshore wind farms. The dynamic program will assists in farm control design. It is also used to calculate the dynamic effect of large wind farms on the high voltage grid. EeFarm calculates the steady state voltages and currents in the farm and in the connection to shore. It can handle a number of different designs with AC and DC connections. The user can specify several other design parameters such as: turbine size, farm size and distance to shore.

Based on component prices, the power production and the electrical losses, the contribution of the electrical system to the costs of one kWh is calculated.

2.2.4 Operation and Maintenance Decision Support System

Developer:	ECN, The Netherlands
Short description:	Decision Support System for maintenance offshore
Covered Issues:	Weather prediction, logistics, contracts, guarantees, wind measurements, maintenance cost prediction
Addressed to:	Operators, manufacturers, banks.
Suitability:	high for maintenance, under development
Reference:	http://www.ecn.nl/en/wind/rd-programme/wind-farm-operation-and-maintenance/

Description:
The Energy research Centre of the Netherlands is developing a decision support model for the maintenance of offshore wind farms amongst others taking into account weather predictions, logistics, contracts and guarantees. Operational data and available measurements shall be used to predict the future maintenance costs with a limited uncertainty. The software system will be addressed to wind farm operators to plan the maintenance.

2.2.5 OWFLO: Offshore Wind Farm Layout Optimisation

Developer:	University of Massachusetts, USA
Short description:	Software tool for offshore wind farm layout analysis and optimisation
Covered Issues:	Cost models for electrical interconnection, support structure, operation&maintenance, Installation&removal, rotor-nacelle assembly, turbine power production model, wake model, electrical line loss model, availability model
Addressed to:	Project developers, policy makers, authorities, investors, operators, manufacturers, banks, utilities
Suitability:	Promising
Reference:	http://masstech.org/renewableenergy/Owec_pdfs/ASME2006Paper.pdf

Description:

OWFLO is a project of the Massachusetts Technology Collaborative (MTC), GE Energy, and the US Dept. of Energy (US DOE) in which the University of Massachusetts is involved. The primary objective of the OWFLO project is the development of a software tool that can be used to model and understand the cost and energy trade-offs inherent to the micrositing process for offshore wind farms. The tool is being designed to perform two functions: layout analysis and layout optimisation. A simple, proof-of concept analysis routine has recently been developed. The software combines individual cost and energy models to estimate the investment costs and energy production of an offshore wind farm as specified by the user. It has been applied to the Middelgrunden offshore wind farm (located 2 km outside Copenhagen harbour in Denmark) and the calculated results have been compared with the cost and energy data from this wind farm. The results were promising. The optimisation routine will be developed next. The software tool addresses to project developers and investors to study the costs and the energy production involved in offshore wind farm micrositing.

2.2.6 ANEMOS

Developer:	ICBM, Junior Research Group IMPULSE, University of Oldenburg, Germany
Short description:	Decision Support System offshore - game
Covered Issues:	Creating offshore wind farms – role playing game,
Addressed to:	Project developers, policy makers, authorities, investors, operators
Suitability:	Not rateable at this stage of development
Reference:	http://www.icbm.de/nfg-impulse/ http://www.icbm.de/anemos/

Description:

ANEMOS is an interactive role game for Offshore Wind Energy. In ANEMOS players assume the roles of characters – either offshore wind farm developer or approval authority – and collaboratively create offshore wind farms. The game plays progresses according to a predetermined system of rules and guidelines, within which players may improvise freely. Player choices shape the direction and outcome of ANEMOS. At this development stage the game extends over a fictitious planning period and covers three hearings. Up to three people take part in the game - one approval authority and one or two project developers. The project planners have to develop a project design amongst others considering spatial position, restricted areas, costs, benefits and send their proposal to the approval authority. The authority will be also informed of potential conflicts or synergy with other interest groups, politics and society in the first hearing round. Based on this the authority decides whether or not the wind farm can be approved in its actual design. Then the developers have the chance to improve their project and make a new proposal.

ANEMOS is developed by the Junior Research Group IMPULSE at the Institsute for Chemistry and Biology of the Marine Environment, Carl-von-Ossietzky-University of Oldenburg, Germany. The development of ANEMOS was especially supported by the POWER project. ANEMOS aims at helping project planners to master offshore wind energy projects.

2.2.7 Ventum©

Developer:	TU Delft, The Netherlands
Short description:	Role-playing simulation-game
Covered Issues:	Design and build offshore wind farm
Addressed to:	Project developers, project managers, authorities, banks, students
Suitability:	low for real projects
Constraints:	Not developed for real wind farms, just for education in general project management
Reference:	http://www.gymnasion.tudelft.nl/pagesUK/ventum.html

Description:

The simulation game Ventum© was developed by the Academic Centre for Experiments on gaming and Simulation (ACES) for educational purposes at the faculty of Technology, Policy and Management. In this game participants can experience and experiment with managerial strategies in an engineering context. Participants are instructed to design and build an offshore wind farm, consisting of several turbines. They have to face strategic and operational interdependencies of actors within the project.

Ventum is designed as a role-playing simulation-game, initially intended to provide an environment for experimental learning in a graduate course Management of Technical Complex Projects (MTCP) for engineering students at Delft University of Technology. A second version, an internet mediated game, was published in 2004. Both versions are modelled after actual developments in the Netherlands, i.e. the decision to experiment with offshore wind energy winning.

The simulation context consists of the parties who are involved in designing and constructing the wind farm Ventum. In the game, groups of e.g. students form a consortium by setting initial agreements among the various companies involved. Next they negotiate and agree upon a tender proposal to submit to the national government. After the tender has been granted, the consortium members have to actually design and build the offshore wind farm according to their own specifications. Each company can perform R&D, make decisions for design, can buy information about aspects such as wind speed or wave heights from consultants. Overall, the game is characterized by a high level of uncertainty, distributed information and interconnected decisions. The main challenge for the consortium members is to co-ordinate their activities and to manage the tensions and conflicts that will arise among them.

For students the game offers the possibility to understand the complexities of the managerial challenge in complex technological projects and apply earlier acquired skills and knowledge. For more experienced project managers it offers the ability to

reflect on their own management approach in a protected environment. They are invited to reflect on blind spots in their practice and knowledge.
Ventum has been played for several years with students of the faculty of TPM at the TU Delft, Netherlands.

2.2.8 GIS Based Assessment of Alternative Cable Routes for Interconnection of Offshore Wind Farms

Developer:	ICBM, University of Oldenburg, Dr. Kai Wirtz, Germany
Short description:	GIS based assessment of cable routes
Covered Issues:	Environmental impact of cable routes, special issue regarding the wadden sea, environmental data, sediment types, protection and restricted areas
Addressed to:	Project developers, authorities, environmental inst.
Suitability:	high for cable route planning
Constraints:	Complex weighting functions incl. valuation – not comprehensible for authorities
Description:	GIS based value benefit analysis for cable route alternatives Development discontinued

2.2.9 BMT MWCOST – Offshore Operations Assessment Tool

Developer:	BMT Cordah Ltd, United Kingdom
Short description:	Modelling of wind farm installation process, operation and maintenance
Covered Issues:	Cost models, energy-weighted and revenue-weighted availability modelling, grouped failure modes, environment parameters included, Monte-Carlo type simulation
Addressed to:	Project developers, operators
Suitability:	high for modelling cost, installation, operation and maintenance
Reference:	http://www.bmtrenewables.com/

Description:
BMT MWCOST is a statistical simulation software for installation, operation and maintenance of offshore wind farms. It supports the developer/operator to determine predicted unavailability, loss of revenue, operation and maintenance planning, and costs. The outputs of availability are “energy-weighted” respectively “revenue-weighted” and are based on failure rates which can be random or time-dependent.
MWCOST models the complex behaviour of a wind farm and support services over warranty and post-warranty periods in order to predict uncertainty profiles for costs,

availability, energy yield and periodic net cash flows. Wind, waves and tides are taken into account using a range of weather data like wind speed at hub height and significant wave height. As well as dealing with disruption caused by weather, the effects of random and non-random equipment failures and regular and corrective maintenance processes are included. Maintenance delays are considered due to spare part waiting, vessel capabilities, and bad weather situations.

MWCOST is based on the “BMT SLOOP” modelling software which was developed for a consortium of oil majors and has been used to evaluate offshore oil and gas developments for over a decade. The MWCOST offshore operations simulations have been performed for 3 major offshore wind farms, two in the UK and one in North America.

2.3 Onshore Wind Energy

2.3.1 WEPA: Wind Energy Potential Assessment Spatial Decision Support System

Developer:	Energy Research Group, India
Short description:	Decision Support System onshore
Covered Issues:	Wind potential assessment, wind speed measurements, climatological data, GIS based visualisation
Addressed to:	Project developers, authorities, investors, operators
Suitability:	low for offshore planning at current stage
Constraints:	Not developed for offshore wind farms.
Reference:	http://wgbis.ces.iisc.ernet.in/energy/paper/wepa/wepa.htm

Description:

WEPA is a Software Decision Support System designed for assessment of wind potential spatially. It is designed to assist the decision makers in regional planning in making appropriate decisions and also visualisation of decisions. It was developed for onshore wind energy projects in India by the Energy Research Group, Centre for Ecological Sciences, Indian Institute of Science in Bangalore, India. With climatological data, land use data, topographical and geological data WEPA assesses the wind potential of specified regions. An overview is given in Figure 1. A Geographic Information System (GIS) is embedded in the WEPA SDSS to generate wind potential maps. The Graphic User Interface (GUI) is developed using Microsoft Visual Basic 6.0 as frontend with MS Access database as backend.

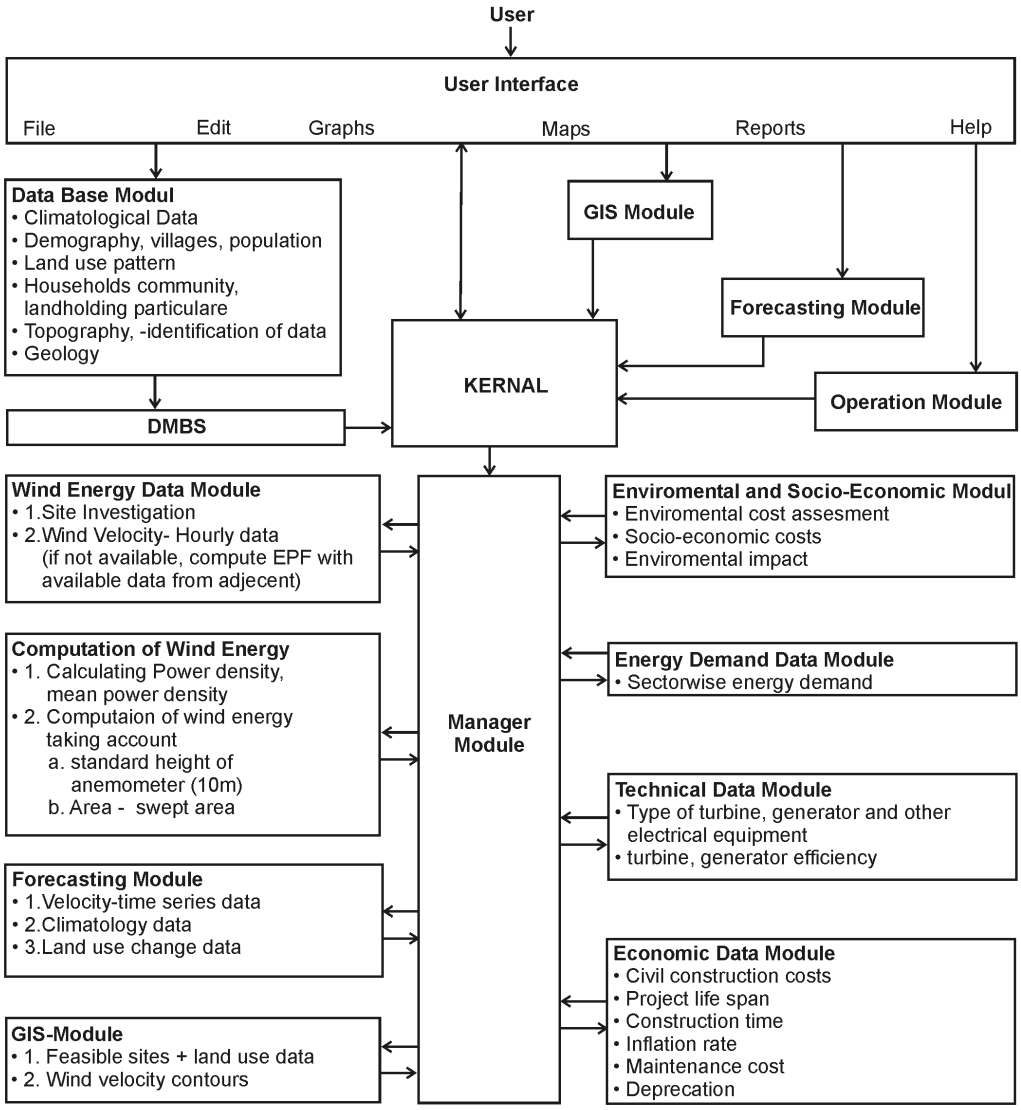

Figure 1: Overview of the WEPA SDSS (Indian Institute of Science)

Validation and pilot testing of WEPA SDSS has been done with the data collected for 45 locations in Karnataka, India.

2.3.2 RETScreen

Developer:	Energy Diversification Research Laboratory, Canada
Short description:	Decision support tool onshore
Covered Issues:	Onshore wind energy projects, energy production, cost analysis, excel spreadsheet, energy model, greenhouse gas emission reduction, weather data, wind speed,
Addressed to:	Project developers, policy makers, authorities, investors, banks, utility
Suitability:	low for offshore projects at this stage
Constraints:	only for onshore

Reference: http://www.retscreen.net/

Description:

RETScreen® International is a clean energy awareness, decision support and capacity building tool. The core of the tool consists of a standardised and integrated clean energy project analysis software that can be used world-wide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of energy efficient and renewable energy technologies (RETs). Each RETScreen technology model (e.g. Wind Energy Project, etc.) is developed within an individual Microsoft® Excel spreadsheet "Workbook" file. The Workbook file is in-turn composed of a series of worksheets. These worksheets have a common look and follow a standard approach for all RETScreen models. In addition to the software, the tool includes: product, weather and cost databases; an online manual; a Website; an engineering textbook; project case studies; and a training course.

2.3.3 RES-DSS

Developer:	National Technical University of Athen
Short description:	Decision Support System onshore
Covered Issues:	Onshore, GIS data base, wind, topography, urban areas, mapping of Renewable Energy Resources
Addressed to:	Project developers, policy makers, authorities, investors, banks, utility
Suitability:	low for offshore projects at this stage
Constraints:	only for onshore

Reference: D. Voivontas, D. Assimacopoulos, A. Mourelatos, J.Corominas. *Evaluation of renewable energy potential using a GIS decision support system*. Renew. Energy 1998;13:333-344.
http://environ.chemeng.ntua.gr/Default.aspx?t=56

Description:

A GIS Decision Support System has been developed for the evaluation of Renewable Energy Sources potential and the financial analysis of RE investments. A GIS database with data on wind, topography, urban areas, and special activities has been developed and used for the evaluation of theoretical potential through the spatially continuous mapping of Renewable Energy Resources. The available and technological potential are evaluated by the application of availability and technological restrictions. The evaluation of economical potential is performed by a precise estimation of the expected energy output and installation cost. The financial analysis based on the Internal Rate of Return, identifies the financial viability of alternative investments. The evaluation of wind energy potential for the island of Crete, Greece and the financial analysis of a wind park installation are presented as a case study.

2.3.4 Multi-Criteria Analysis with ArcGIS Spatial Analyst

Developer:	National Environmental Research Institute, Denmark
Short description:	Decision Support System for spatial planning of onshore wind energy in the Baltic Sea Region.
Covered Issues:	Onshore, ArcGIS Spatial Analyst, fuzzy logic, wind potential, topography, site selection criterias, baltic sea region,
Addressed to:	Project developers, policy makers, authorities, investors, banks, utilities
Suitability:	Promising for offshore projects
Constraints:	Just for onshore projects at this stage
Reference:	H. S. Hansen. *GIS-based Multi-Criteria Analysis of Wind Farm Development*. Report of the EU / INTERREG III B project *Wind Energy in the Baltic Sea Region*, January 2005. http://www.windenergy-in-the-bsr.net/download/Multi_criteria%20Analysis%20Wind%20Energy.pdf

Description:

Due to the negative impact on the environment of traditional power generating methods, especially coal and oil-fired power stations wind power has increased in popularity. Achieving the goal set by the EU due to the implementation of the Kyoto protocol will require further expansion, and in order to facilitate this process around the Baltic Sea. A project – Wind Energy in the Baltic Sea Region - financed by EU / INTERREG III B was initiated in order to develop methods and tools to support spatial planning in relation to wind energy. The aim of the current study is to develop multi-criteria evaluations, which can provide tools for analysing the complex trade-offs between choice alternatives with different environmental and socio-economic impacts. The weaknesses of the Boolean logic have been recognised in recent years and a fuzzy logic approach is applied in the system design. The developed methodology is based on data from Northern Jutland, but later on this kind of multi-criteria will be used in the in Finland and Estonia. For Implementation the software tool ArcGIS Spatial Analyst has been used.

2.4 Different Thematic Fields

2.4.1 WILMAR - Wind Power Integration in Liberalised Electricity Markets

Developer:	Risø National Laboratory, Denmark
Short description:	Analysis of the integration of renewable power
Covered Issues:	Integration of wind power, cost of integration, liberalised electricity market, Meteorological data, wind speed forecast, Joint Market model, wind power production forecasts
Addressed to:	System operators, power producers, energy authorities,
Suitability:	high for market integration
Reference:	www.wilmar.risoe.dk

Description:
A fast introduction of large amounts of intermitting renewable power production as wind power can cause technical and economic problems of power systems. These problems might arise due to unpredictability of wind power or due to unbalance between local power demand and intermitting power produced causing grid instabilities.

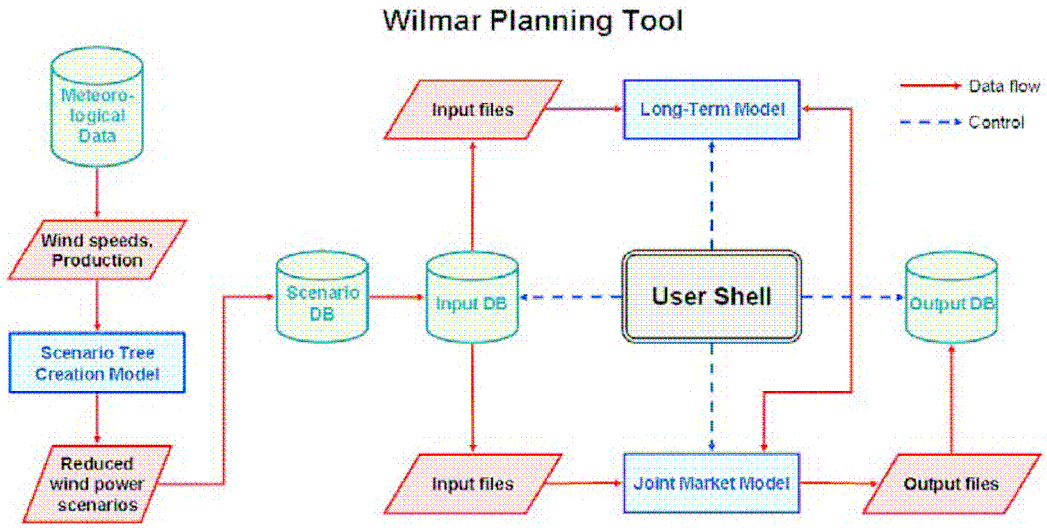

Figure 2: Overview of Wilmar Planning tool. The green cylinders are databases, the red parallelograms indicate exchange of information between sub models or databases, the blue squares are models. The user shell controlling the execution of the Wilmar Planning tool is shown in black (Source: Risø).

Within the scope of the research project WILMAR (Wind Power Integration in Liberalised Electricity Markets) supported by the European Commission the WILMAR

planning tool was developed. It enables the model based analysis of wind power integration. An overview of the sub-models and databases constituting the planning tool is given in Figure 2.

The Joint Market model is a linear, stochastic optimisation model with wind power forecasts as the stochastic input parameter, hourly time-resolution and covering several regions interconnected with transmission lines. It has been tested on German and Nordic data. A wind speed forecast model has been developed, which incorporates the correlations between wind speed forecast from one time step to the next and the correlations between wind speed forecasts in different regions.

WILMAR addresses to system operators, power producers and energy authorities. The Planning tool has been made openly available on www.wilmar.risoe.dk.

2.4.2 DIgSILENT Power Factory

Developer:	DIgSILENT GmbH, Germany
Short description:	Power system planning, analysis and optimisation tool
Covered Issues:	Power system models, data base management, system modelling, GIS and SCADA interfaces, load flow analysis, low voltage grid analysis
Addressed to:	Project developers, power producers, utilities, energy authorities,
Suitability:	high for grid calculation and planning
Reference:	http://www.digsilent.de/Software/PowerFactory_Features/

Description:
DIgSILENT PowerFactory software is an integrated power system analysis tool that combines reliable and flexible system modeling capabilities. Some of PowerFactorys simulation functionalities are: Load flow and fault analysis of complete AC/DC network representation, low voltage grid analysis, distribution network optimisation, IEC cable sizing, dynamic simulation, voltage stability analysis, interface for SCADA/GIS/NIS.

2.4.3 PSS™SINCAL – Power System Simulator Siemens Network Calculation

Developer:	SimTec GmbH, Siemens AG Power Transmission and Distribution, Germany
Short description:	Tool for analysis, planning and design of supply networks
Covered Issues:	Grid calculation and optimisation, simulation of equipment outage, reliability and stability simulations, weak-point determination in the network, economic efficiency, interconnection to GIS and SCADA systems, open data base structure, universal user interface for all fields – electricity, natural gas, water, district heating.
Adressed to:	Municipal power companies, regional and national utilities, industrial plants, power stations, engineering consultings
Suitability:	high for grid calculations
Reference:	http://www.simtec-gmbh.at/sites/sincal-start.asp

Description:

The PSS™SINCAL program was developed by Siemens and is now maintained by SimTec GmbH. It was created for simulate, display and evaluate power transmission networks. PSS™SINCAL is available for electricity networks and for flow networks (water, gas, district heat). The type of user interface and the access and exchange are the same for all fields.

The graphic user interface makes it possible to enter and display networks in true-location or schematic form. The network and additional graphic information can be drawn and organised in different graphical layers. Different variants can be conveniently handled by variant management tool. Various steady-state and dynamic calculation methods are available. It is also possible to simulate the effect of time series (e.g. load curves) or time events (e.g. open circuit) on the network.

The program system possesses computer network capability, i.e. IT resources such as printers and plotters, data security systems, etc. can be utilised. If required, data and results can be made accessible to other users.

Input data of the networks to be calculated, equipment data and graphics data for true location or schematic network representation, as well as results of the various calculation methods are stored in a commercial data base.

This means: data access is possible by standard methods, even when PSS/SINCAL is not being used.

Interfaces to GIS and SCADA systems are available/customisable as additional components. This could be standard ASCII-file definitions or direct OLE or ODBC links, SQL procedures etc.

PSS™SINCAL has modular structure. It is possible to create a customised network planning tool with the different calculation methods (electricity load flow, short circuit analysis: 1-, 2- and 3-phase according to IEC/VDE with pre-load, dimensioning of

low-voltage networks, optimal branching, optimal load flow, multiple fault, stability, harmonics, ripple control, distance protection, over-current-time protection, protection simulation, motor start-up ,load profile calculation, reliability. Natural gas: thermal and hydraulic calculation, load profile calculation, dynamic simulation.
water: thermal and hydraulic calculation, water tower filling, load profile calculation, dynamic simulation. district heating: thermal and hydraulic calculation, load profile calculation, dynamic simulation).

2.4.4 RamCo

Developer:	National Institute for Coastal and Marine Management, The Netherlands
Short description:	Decision Support System for coastal zone management
Covered Issues:	GIS implemented, natural and anthropogenic processes, economic activities
Addressed to:	Policy makers, authorities
Suitability:	medium
Reference:	http://www.riks.nl/projects/RamCo

Description:

RamCo (*Rapid Assessment Module Coastal Zone Management*) is a generic decision support environment for the Integral (or Rapid) Assessment of Coastal Zone Management problems, which is been laid out for nearly all coasts of the world.

RamCo was financed by and is a product of the National Institute for Coastal and Marine Management (RIKZ) and the associated Coastal Zone Management centre (CZM), the Hague, the Netherlands. It was developed by the consortium consisting of INFRAM BV (Zeewolde, the Netherlands), RIKS, Twente University (Enschede) and Maastricht University.

RamCo was designed for policy makers that are faced with the difficult task of interfering in coastal processes that are complex due to their interconnection and interrelation. *RamCo* aims to describe the natural and anthropogenic processes in a coastal zone under the influence of the dynamic behaviour and interaction of spatial agents, such as inhabitants of the coastal area, economic activities (fishery, cultivation of shrimps, agriculture, industry, tourism and commerce). Characteristic of *RamCo* is the way in which processes are reciprocally linked on different spatial levels to form one system, and how these sub-models use detailed data layers from a built-in Geographical Information System (GIS). The models are part of an information system that makes it possible to design, test and evaluate policy alternatives. It is possible to design scenario and to define policy parameters and policy criteria.

2.4.5 Nijhum Dwip DSS

Developer:	CEGIS, Bangladesh
Short description:	Demonstration of a Decision Support System for coastal zone management
Covered Issues:	Economic criteria, geographical and socio-economic features
Addressed to:	
Suitability:	low
Constraints:	Not for real decision-making processes
Reference:	http://www.cegisbd.com/projects/dssweb.htm#NijhumDSS

Description:

A demonstration of a Decision Support System (DSS) has been developed by EGIS in co-operation with Resource Analysis of the Netherlands in order to develop capacity in building DSSs and to demonstrate its utility in decision making for natural resource management and planning in Bangladesh. The objective of building this demonstration DSS is to acquire experience in the development of DSSs and to demonstrate their potential for Integrated Coastal Zone Management in Bangladesh. It is not intended for use in support of any real-life decision-making process. The Nijhum Dwip Integrated Development Project (NDIDP) was taken as a case study. The users get an overview of the geographical and socio-economic features of the Nijhum Dwip area and the processes that could influence the decision making process. They are allowed to define their own objectives and select the relevant criteria from a predefined list. The criteria translate the objectives into measurable entities such as ‘benefit/cost ratios’, and ‘protection of local population from cyclones and storms’.

2.4.6 RODOS - Real-Time Online Decision Support System for Offsite Emergency Management in Europe

Developer:	Forschungszentrum Karlsruhe GmbH, Germany
Short description:	Decision Support System for nuclear emergency management
Covered Issues:	Radiological situation, weather prediction, emergency planning, population, topographical data, rivers, roads, vegetation areas, food production, distribution of stable iodine tablets, short and long term decisions
Addressed to:	Emergency centres, policy makers
Suitability:	low
Reference:	http://www.rodos.fzk.de/RodosHomePage/RodosHomePage/rodoshome.html

Description:

The integrated and comprehensive Real-time On-line Decision Support System, RODOS, for off-site emergency management of nuclear accidents is being developed with support of the European Commission and the German Ministry of Environment. Designed as a generic tool, the RODOS system will be applicable from the very early stages of an accident up to many years after the release and from the vicinity of a site to far distant areas. Decision support will be provided at various levels, ranging from the largely descriptive, with information on the present and future radiological situation, to an evaluation of the benefits and disadvantages of different countermeasures' options. A large number of West and East European institutes are involved in its development to operational use.

The Karlsruhe Research Centre in Germany co-ordinates the development of RODOS. RODOS uses meteorological data, weather predictions and measurements of radiation exposure. So the propagation of the radioactive material in the atmosphere and the exposure of human beings and environment can be estimated. With simulations different safety measures (for example the recommendation to stay in buildings or the distribution of stable iodine tablets) can be assessed.

RODOS assesses alternative measures as to technical feasibility and the arising expenses. With this analyses decision makers are to make the best possible measure recommendations. RODOS has been installed for operational use in a number of emergency centres of European states.

2.4.7 OSCAR - Oil Spill Contingency And Response

Developer:	Sintef Group, Norway
Short Description:	Supply tool for objective analysis of alternative oil spill response strategies
Covered Issues:	Oil weathering model, three dimensional Oil trajectory model, chemical fates model, oil spill combat model, esposure model for fish, ichthyplankton, birds and marine mammals
Adressed to:	Oil industry, regulation industry, marine insurance industry
Suitability:	low
Reference:	http://www.sintef.no/content/page1 5560.aspx

Description:
The concept behind the OSCAR system builds on established strengths in hydro-carbon chemistry, encompassing in addition a coupled set of databases, models, and accompanying competencies to deliver comprehensive contingency planning and response support services. The OSCAR system meets the following needs: establishment of objective, quantitative criteria for regulation and management purposes, oil spill training and contingency planning, support of oil spill response actions, evaluation of alternative oil spill response strategies and logistics, environmental risk and impact assessment, environmental assessment of dispersant usage, cost-benefit analysis and optimisation for equipment purchase and disposition and net environmental benefit analysis. The OSCAR model is based on SINTEF's data-based oil weathering model, a three-dimensional oil trajectory and chemical fates model, an oil spill combat model, and exposure models for fish and ichthyoplankton, birds, and marine mammals. The model is embedded within a graphical user interface in WINDOWS NT, which facilitates linkages to a variety of standard and customised databases and tools. These latter allow the user to create or import wind time series, current fields, grids of arbitrary spatial resolution, map and graph model outputs. Oil and chemical databases supply chemical and toxicological parameters required by the model. Results of model simulations are stored at discrete time-steps in computer files which are then available as input for biological exposure models.

2.4.8 AKSIO - Active Knowledge System for Integrated Operations

Developer:	Statoil ASA, Hydro ASA, Computas AS, Institute of Energy Technology, Det Norske Veritas, the Norwegian University of Sience and Technology, UniK (University Graduate Studies at Kjeller) , Norway
Short Description:	In Development: Knowledge Management System based on Semantic Web Technology
Covered Issues:	Sustained knowledge creation and sharing, manual and autonomous monitoring of the drilling process situation assessment, guidance to optimise performance of work process operations, assistance in identification of needed information sources
Adressed to:	Operators of drilling platforms, service companies,
Suitability:	low
Reference:	Http://www.computas.com/upload/Fagartikler/AKSIO-ESWC2006%20Paper.pdf

Description:

Active Knowledge Support in Integrated Operations (AKSIO) is an active socio technical system for knowledge transfer between drilling projects, through documented experiences, best practices, and expert references. The system is designed to capture and qualify knowledge gained in drilling operations and to supply relevant and timely knowledge for planning of new drillings.

The major aspect of the AKSIO concept is that engineers and other decision-making staff at an onshore operation center perform work tasks as part of certain work processes. To make the decisions, they access data sources (historical and real-time data), use specific IT tools, and interrogate colleagues in knowledge networks for specific pieces of knowledge. This knowledge must be timely and contextual related to the decision task and work process at hand.

2.5 Studies

2.5.1 Study of Offshore Wind Energy Potential in Japan

Developer:	University of Tokio; Japan
Short description:	GIS based assessment of offshore wind energy potential in Japan - Study
Covered Issues:	Wind energy potential, GIS, ArcInfo, mesoscale model, wind climate assessment, spatial distribution of annual mean wind speed, social and economic criteria
Addressed to:	Project developers, policy makers, authorities, investors, banks, utility
Suitability:	
Constraints:	no software program, just a study in Japan
Reference:	A. Yamaguchi, T. Ishihara and Y. Fujino. *An Assessment of Offshore Wind Energy Potential Using Mesoscale Model and GIS.* In: Proceedings of European Wind Energy Conference 2004, London, UK.

Description:
Development of the offshore wind energy would be a key strategy to increase wind penetration in Japan. In this study, the offshore potential around Kanto Plain was investigated by using mesoscale models and geographical information system (GIS). A mesoscale model with the minimum horizontal resolution of 2km was used to estimate the theoretical potential. Considering the area 50km from the shore and 2MW wind turbines situated with 8D by 8D spacing, total theoretical potential reaches 277TWh/year accounting for 94% of the annual demand for Tokyo Electric Power Company, which supply 1/3 of Japan total electricity demand. Imposing economical and social restrictions using GIS, the available potential becomes 94TWh/year, in which 99.6% is exploited by the floating foundations and 0.4% by the bottom mounted foundations.

2.5.2 Studies of Different Thematic Fields

Shattri Mansor and Seyedeh Zahra Pourvakhshouri, Malaysia: *Oil Spill Management via Decision Support System.* Proceedings of the 2nd FIG Regional Conference Marrakech, Morocco, December 2-5, 2003.
https://www.fig.net/pub/morocco/proceedings/TS13/TS13_5_mansor_pourvakhshouri.pdf

Pål Skalle and Agnar Aamodt*: Knowledge-Based Decision Support in Oil Well Drilling.* Norwegian University of Science and Technology, Trondheim, Norway, 2004.
http://www.idi.ntnu.no/~agnar/publications/iciip-04-volve.pdf

Rehan Sadiq et al.: *An Integrated Approach to Environmental Decision-Making for Offshore Oil and Gas Operations.* Canada-Brazil Oil & Gas HSE Seminar and Workshop, Canada, 2002.
http://www.cormix.info/pdf/Veitch.pdf

Patrick R. Thorsell: *Decision Support System for Oil Spill Financial Responsibility.* Department of Resource Analysis, St. Mary's University of Minnesota, USA, 2001.
http://www.gis.smumn.edu/GradProjects/ThorsellP.pdf

3. Classical Software Tools in the Offshore Wind Energy Sector

3.1 Overview

The following listed classical software tools are playing a more or less important role for the addressed institutions. The compilation is based on own researches and on results of the questionnaire.
ESRI-Products like ‘ArcView’, ‘ArcInfo’ and ‘MapInfo’ are the most used Geographical Information Systems in this context. In the wind energy specific area ‘Wasp’ and ‘Wind-Pro’ have great shares in the market. In the area project planning ‘Microsoft Project’ is established. For electrical systems ‘Power Factory’, ‘PSS SINCAL’ and ‘PSS/E’ are favoured systems. In the financing and economy sector ‘Microsoft Excel’ plays an important role.
The item ‘suitability’ in this context refers to both the suitability of the software tools for the special purpose it was designed for and as a tool for a Decision Support System.

3.2 Geographical Information Systems (GIS)

Arc-View

Developer:	ESRI
Description:	Desktop GIS
Covered Issues:	Mapping, geographical data base, visualisation, data analysis, external data base connection, spatial analysis,
Addressed to:	Authorities, environmental inst., marketing inst., banks, utility, military
Suitability:	high
Constraints:	Concentrated on spatial analysis, not on financial analysis and optimisation

Arc-Info

Developer:	ESRI
Description:	Desktop/Server GIS
Covered Issues:	Mapping, geographical data base, visualisation, data analysis, external data base connection, spatial analysis, geographical data editing
Addressed to:	Authorities, environmental inst., marketing inst., banks, utility, military
Suitability:	high
Constraints:	Concentrated on spatial analysis, not on financial analysis and optimisation

MapInfo

Developer:	MapInfo Corporation
Description:	Desktop GIS
Covered Issues:	Mapping, geographical data base, visualisation, data analysis, external data base connection, spatial analysis, geographical data editing
Addressed to:	Authorities, environmental inst., marketing inst., banks, utility, military
Suitability:	high
Constraints:	complex

Grass

Developer:	Open Source, GPL
Description:	Desktop / server GIS
Covered Issues:	Mapping, geographical data base, visualisation, data analysis, external data base connection, spatial analysis, geographical data editing, image processing, simulation models
Addressed to:	Research and commercial inst., authorities, environmental inst.
Suitability:	high
Constraints:	Concentrated on spatial analysis, not on financial analysis and optimisation

3.3 Wind Energy Specific

EMD Wind-Pro

Developer:	EMD
Description:	Module-based software for wind energy projects
Covered Issues:	Wind speed evaluations, wind farm layout optimisation, energy calculation, environmental impact, electrical grid, financial analysis, basic GIS functionality
Addressed to:	Wind farm developers, turbine manufacturer, consultants, utilities, authorities
Suitability:	high, designed for developing offshore and onshore wind energy projects
Constraints:	Only basic GIS functionality, limited suitability for permitting process, no external data base connection, limited financial analysis

Windfarmer

Developer:	Garrad Hassan
Description:	Module-based software for wind energy projects
Covered Issues:	Advanced wind speed evaluations, wind farm layout optimisation, energy calculation, environmental impact, electrical grid, financial analysis, basic GIS functionality
Addressed to:	Wind farm developers, turbine manufacturer, consultants, utilities, authorities
Suitability:	high
Constraints:	Only basic GIS functionality, limited suitability for permitting process, no external data base connection, limited financial analysis

WaSP Version 4-5

Developer:	Risoe
Description:	Wind climate and wind turbine energy analysis software
Covered Issues:	Wind speed, energy, wind turbine siting, spatial calculations
Addressed to:	Consultants, wind farm developer, turbine manufacturer, research
Suitability:	medium
Constraints:	DOS-version, only oriented to wind speed and energy calculations

WaSP for Windows (Wasp Version 8)

Developer:	Risoe
Description:	Wind climate and wind farm energy analysis software
Covered Issues:	Wind data analysis, energy, wind turbine siting, spatial calculations, vector maps, mirositing, wind farm efficiency
Addressed to:	Consultants, wind farm developer, turbine manufacturer, research
Suitability:	high for this special purpose
Constraints:	Only oriented to wind climate and energy calculations

Surfer

Developer:	Golden Software
Description:	Contouring, Gridding, and Surface Mapping Software
Covered Issues:	Vector and pixel maps, visualization, advanced gridding issues, grid interpolation, basic GIS functionality
Addressed to:	Engineers and scientists
Suitability:	medium
Constraints:	Only basic GIS functionality, limited suitability for permitting process, no external data base connection

3.4 Project Planning

MS-Project

Developer:	Microsoft
Description:	Project management software
Covered Issues:	Project management, portfolio management, modelling, resource management, project collaboration, time management
Addressed to:	Project manager, developer, authorities
Suitability:	high for this special purpose
Constraints:	Limited to the area of project management

Open Workbench

Developer:	Open Source
Description:	Project management software
Covered Issues:	Project management, portfolio management, modelling, resource management, project collaboration, time management
Addressed to:	Project manager, developer, authorities
Suitability:	high for this special purpose
Constraints:	Limited to the area of project management, beta stage

3.5 Electrical System

DIgSILENT Power Factory

Developer:	DIgSILENT GmbH
Description:	Power system planning, analysis and optimisation tool
Covered Issues:	Power system models, data base management, system modelling, GIS and SCADA interfaces, load flow analysis, low voltage network analysis
Addressed to:	Project developers, power producers, utility, energy authorities,
Suitability:	high for grid calculation and planning
Constraints:	-

PSS™SINCAL

Developer:	SimTec GmbH, Siemens AG Power Transmission and Distribution
Description:	Tool for analysis, planning and design of supply networks
Covered Issues:	Grid calculation and optimisation, simulation of equipment outage, reliability and stability simulations, weak-point determination in the network, economic efficiency, interconnection to GIS and SCADA systems, open data base structure, universal user interface for all fields – Electricity, Gas, Water, District Heating
Adressed to:	Municipal power companies, regional and national utilities, industrial plants, power stations, engineering consulting firms.
Suitability:	high for grid calculations
Constraints:	-

PSS/E

Developer:	Siemens AG Power Transmission and Distribution
Description:	Tool for analysis, planning and design of energy networks
Covered Issues:	Grid calculation and optimisation, simulation of equipment outage, reliability and stability simulations
Adressed to:	Municipal power companies, regional and national utilities, industrial plants, power stations, engineering consulting firms.
Suitability:	high for grid calculations
Constraints:	-

PSCAD

Developer:	Manitoba HVDC Research Centre, Canada
Description:	Tool for analysis, planning and design of energy networks
Covered Issues:	Elecromagnetic transient analysis on the electrical network, online plotting functions, interface to the EMTDC transients simulation, grid calculation and optimisation, simulation of equipment outage, reliability and stability simulations

Adressed to:	Municipal power companies, regional and national utilities, industrial plants, power stations, engineering consulting firms
Suitability:	high for grid calculations
Constraints:	-

Elaplan

Developer:	ElektraSoft, Elektrotechnik und Software GmbH
Description:	Tool for planning and analysis of electrical systems
Covered Issues:	Engineering of electrical installations, planning and design, electrical calculations, power optimisation, system status management, documentation, tender processing, project management
Adressed to:	regional and national utilities and grid operators, engineering and consulting firms.
Suitability:	high for electrical systems
Constraints:	-

3.6 Economy / Financing

EXCEL

Developer: Microsoft Corp.
Description: Spreadsheet
Covered Issues: universal
Addressed to: -
Suitability: medium
Constraints: high incidents of faults

SAP

Developer: SAP AG
Description: Business Software
Covered Issues: Financing, Integration of different business areas
Addressed to: Project manager, Manufacturer,
Suitability: medium
Constraints: complex

3.7 Databases / Spreadsheets

- Oracle
- Microsoft Access
- Microsoft SQL Server
- MySQL (Open Source)
- PostgreSQL (Open Source)
- Microsoft EXCEL

3.8 Further Software

AutoCad

Developer: Autodesk
Description: CAD-Software for making up 2D and 3D drawings
Covered Issues: CAD, Vector orinented drawings, designing, object modelling
Addressed to: Project developers, planning areas
Suitability: high for this special purpose
Constraints: Missing GIS functionality

Matlab

Developer:	The MathWorks
Description:	Mathematical software, graphic representation
Covered Issues:	Technical computing language, algorithm development, data visualization, data analysis, numeric computation, simulation
Addressed to:	Research, Operation, Experts
Suitability:	high for this special purpose
Constraints:	-

4. Questionnaire

4.1 Questionnaire Developed

The goal of the questionnaire was to get an overview about the usage of existing Decision Support Systems and individual software tools and information about the demands and requirements of possible customers with regard to Decision Support Systems in the offshore sector.

The questionnaire was addressed to members of the following groups related to offshore wind farm developments in the North Sea region:

- Project developers
- Planners
- Authorities
- Environmental associations
- Universities
- Banks
- Financing groups
- Consultants
- Grid operators
- Manufacturers
- Potential general contractors
- Research centres
- Operators

A target-oriented address research including contact persons was performed. The questionnaire was sent by mail to about 350 addresses. For comfortable online access additional an PDF-form for interactive fill in was developed which was available at the internet.

In the following you find an overview of the asked questions, for more details see the original questionnaire in the appendix:

1. *What are the areas of focus of your work relating to wind energy?*

Project development	☐ *Onshore*	☐ *Offshore*
Planning	☐ *Onshore*	☐ *Offshore*
Approval	☐ *Onshore*	☐ *Offshore*
Financing	☐ *Onshore*	☐ *Offshore*
Expert/surveyor	☐ *Onshore*	☐ *Offshore*

Consulting	☐ *Onshore*	☐ *Offshore*
Research	☐ *Onshore*	☐ *Offshore*
Manufacturer	☐ *Onshore*	☐ *Offshore*
Construction	☐ *Onshore*	☐ *Offshore*
Logistics	☐ *Onshore*	☐ *Offshore*

…

2. *Do you use Decision Support Systems? If yes, which?*

3. *Do you use Decision Support Systems for the offshore wind energy area? If yes, which?*

4. *Where in the offshore wind energy area do you see a demand for Decision Support Systems?*

☐ *Project development*
☐ *Approvals procedure*
☐ *Financing*
☐ *Ecological analysis/evaluation*
☐ *Electrical system*
☐ *Foundation development*
☐ *Cable route*
☐ *Maintenance and operation*
☐ *Construction logistics*
☐ *Transport logistics*
☐ *Ship deployment planning*
☐ *Shipping*
☐ *Safety system personnel*
☐ *Safety system technology*

…

5. *Would you like to use Decision Support Systems in your work?*

6. *Do you see more of a need for software that helps you reach decisions (individual programs) or for Decision Support Systems that integrate various areas?*

7. *Is it necessary for the basic decision-finding structures to be easily traced in detail (evaluation system), or do you think a complex evaluation which theoretically makes a better evaluation possible but is not directly traceable (complicated inter-connections / formulas) is more suitable?*

8. *What software do you use that plays an important role in decision-finding in your offshore projects?*
    - *Arc-View*
    - *Arc-Info*
    - *Grass(-Land)*
    - *EMD Wind-Pro*
    - *Windfarmer*
    - *Wasp 4-5*
    - *Wasp Windows*
    - *Surfer*
    - *MS-Project*
    - *Open Workbench*
    - *Oracle*
    - *Microsoft Access*
    - *MS SQL Server*
    - *MySQL*
    - *PostgreSQL*
    - *Excel*
    - *Own developed Software*
    - *Other software*

4.2 Evaluation

4.2.1 Participation

The evaluation of the questionnaire is based on 63 answers from about 350 addressed companies and specialists in Europe, a quota of 18%. Answers were gained from Germany, Denmark, The Netherlands, United Kingdom, Norway, Greece and Sweden. Most of the answers (about 94%) came from Germany, Denmark, The Netherlands and United Kingdom.

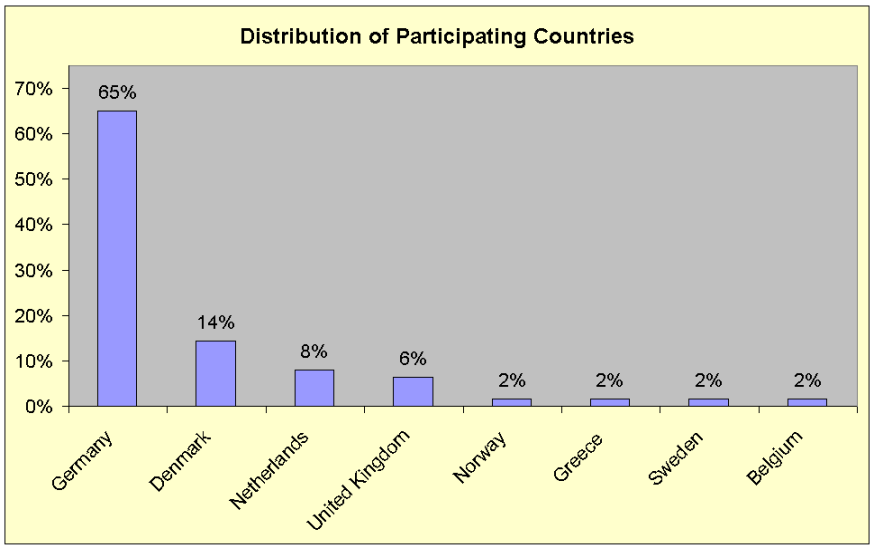

Figure 3: The Distribution of the questionnaire feed back of the participating countries

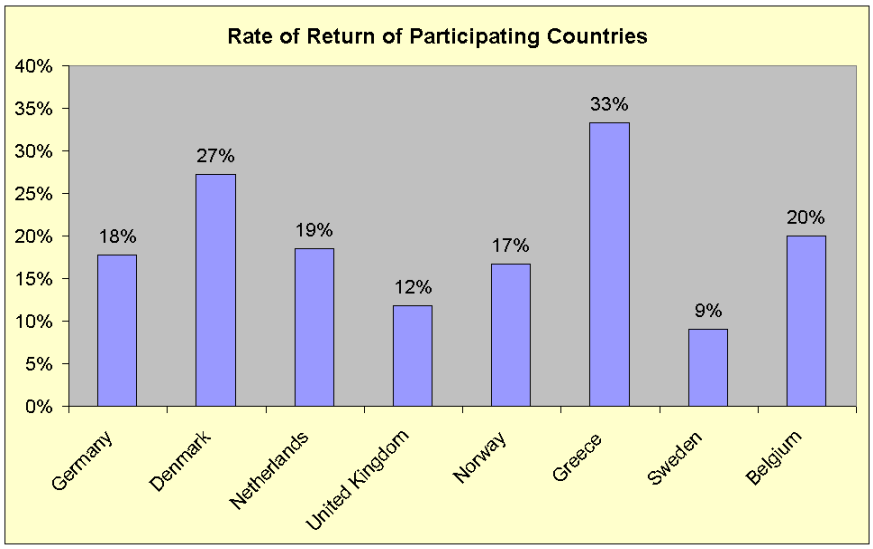

Figure 4: Questionnaires rate of return

Most answers (Figure 3) came from Germany and Denmark caused by the high amount of available addresses, personal contacts and commitments resulting from offshore plannings in Germany in which the author is involved.

4.2.2 Areas of Expertise

The area of expertise of the institutions which gave feed back is mainly in the technical sector with a fraction of 55%, ecological and economical ranges around 23%. Multiple orientations per company were possible.

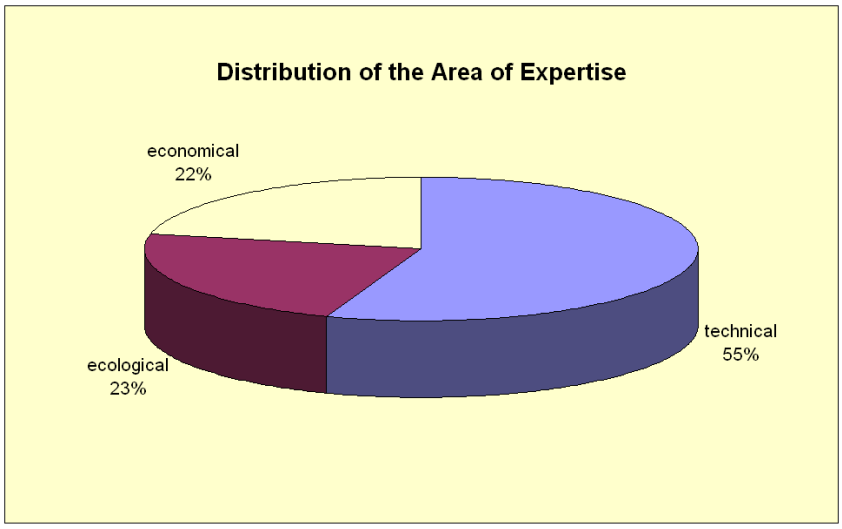

Figure 5: Area of expertise (all participants)

4.2.3 Areas of Focus of the Work Related to Wind Energy

Distributions of areas of focus of the work related to wind energy (Question1) are shown in the following figures. Multiple choices were possible. The resulting distributions are showing research, consulting, experts, planning, and project development as the main areas of focus on- and offshore.
It must be kept in mind that the results shown in Figure 6 and following depend on the composition of addressed institutions and the motivation to answer the questionnaire. The feed back of the research institutions was very high. The motivation to answer the questionnaire of for example authorities was relatively low.
The results in Figure 7 are showing that the main focus of the participated institutions is in the offshore area.

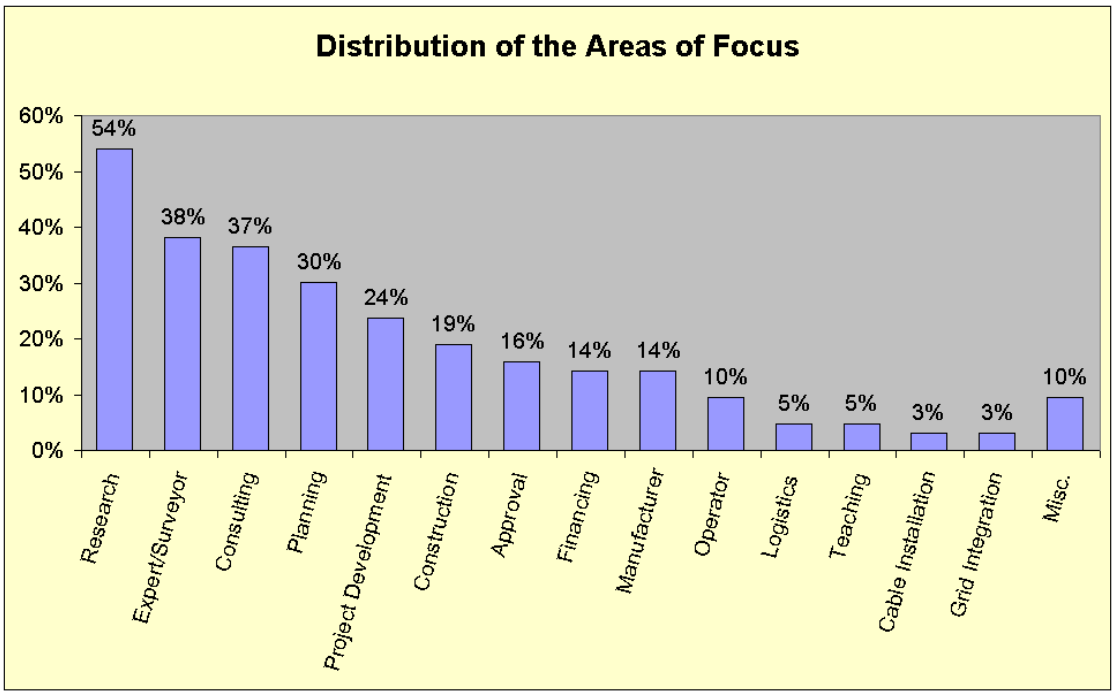

Figure 6: Areas of focus on- and offshore

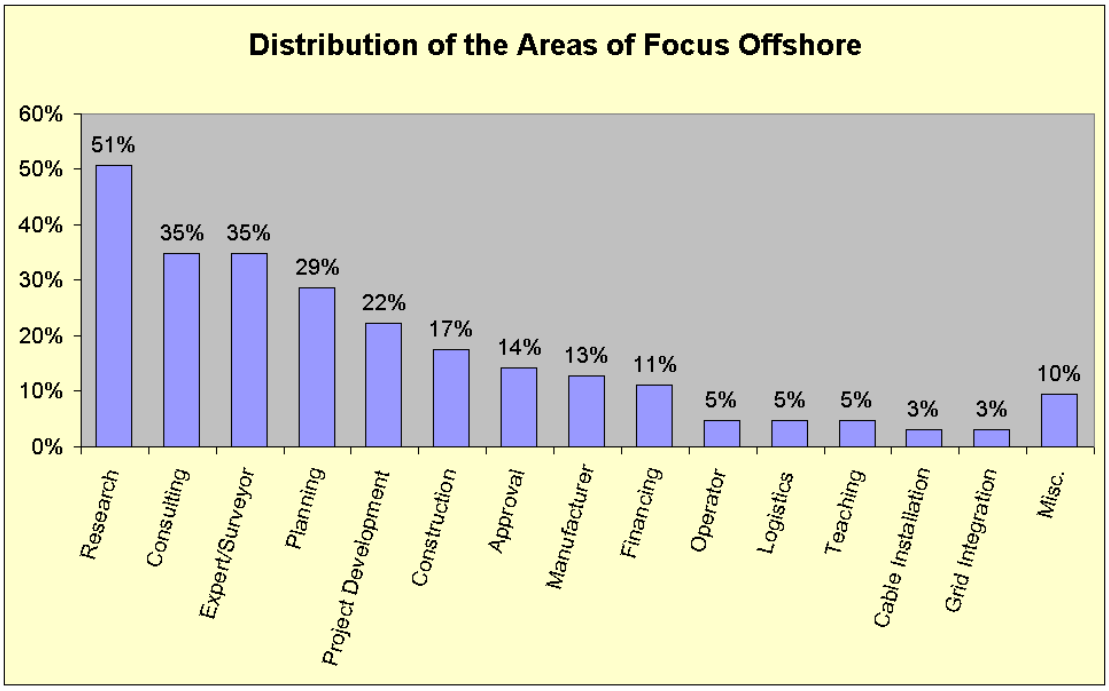

Figure 7: Areas of focus offshore

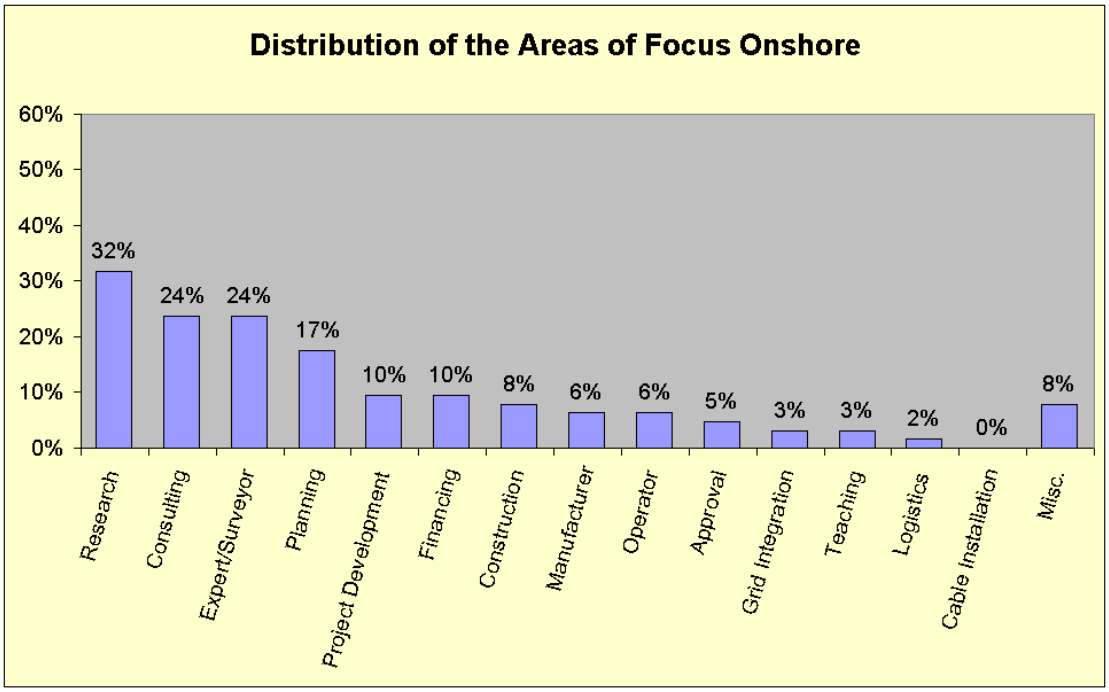

Figure 8: Areas of focus onshore

4.2.4 Current Use of Decision Support Systems

The current use of Decision Support Systems (Question 2/3) seems to be rather high with about 40% (Figure 9). An explanation for this high value is that on the one hand many institutions which develop (or possible develop) Decision Support Systems were addressed and on the other hand GIS systems as basic SDS-Systems are used. In some cases also classical software tools were named misleadingly as SDS-Systems (which do not meet). Therefore in general the use of Decision Support Systems apart from GIS-Systems is rather low.

For more detailed evaluations the participants were divided into four groups based on their main orientation: Research, Planning, Construction and Approval. The main use of Decision Support Systems is found in the research and approval area (Figure 10). In the planning and approval area at current only GIS systems are playing an important role as basic SDS-Systems. The participants did not differentiate between on- and offshore use.

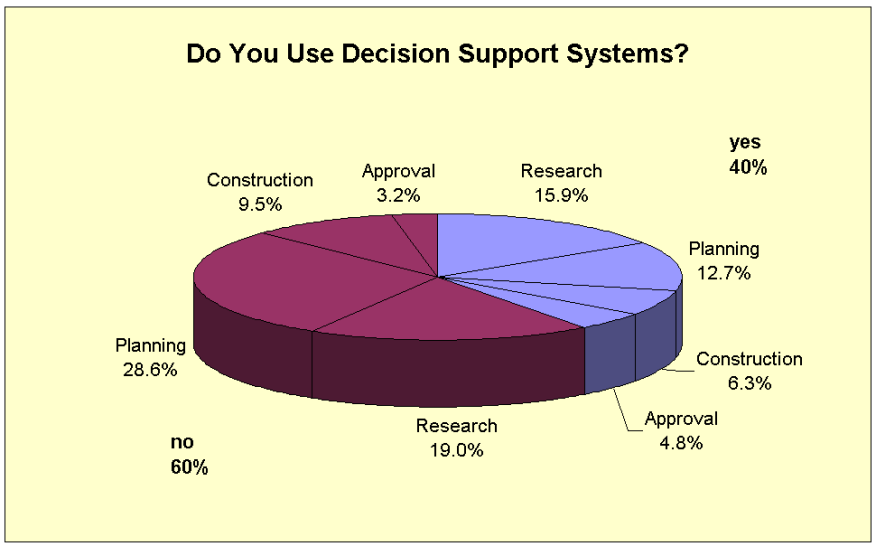

Figure 9[1]: The use of Decision Support Systems
(Entries: Research: 22, Planning: 26, Construction: 10, Approval: 5)

[1] The decimal place is not significant. For evaluation program reasons the decimal place has to be set to one.

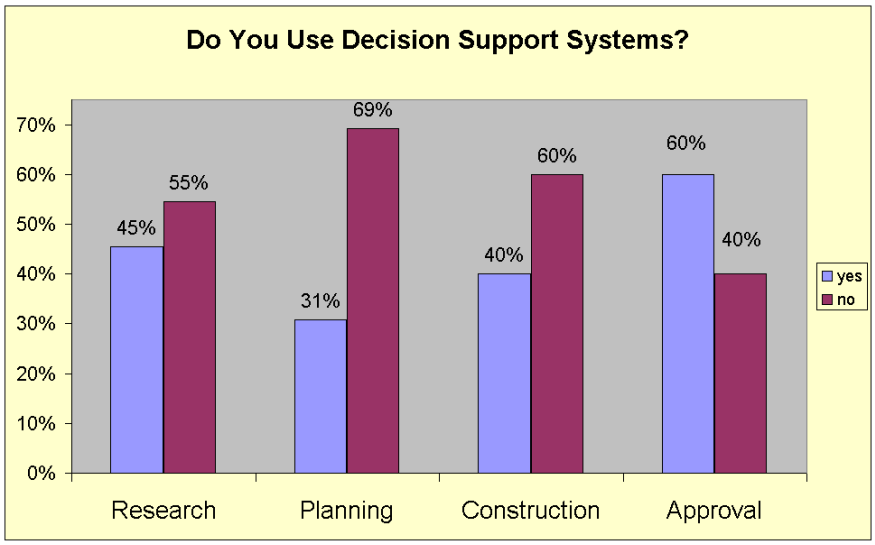

Figure 10: The use of Decision Support Systems by user groups (each group is normalised to 100%)

It must be kept in mind that it is reasonable to assume that just institutions which are not interested in Decision Support Systems did not answer the questionnaire at all. So the results must be interpreted carefully.

4.2.5 Demand for Decision Support Systems in the Offshore Wind Energy Area

The demand for Decision Support Systems in the offshore wind energy area (Question 4) is not focused on specific issues and therefore seen to be very high in many different areas leading with project development, approval, ecological evaluation and financing followed by maintenance and operation, cable route and logistics. The demand for Decision Support Systems for the electrical system and grid integration is relatively low. This may be due to the fact that for the design, analysis and optimisation of electrical systems several professional tools are existing. From personal consultations it was found that the idea of an Decision Support System is often valuated positive in general but often the own need is very unspecific and unclear.

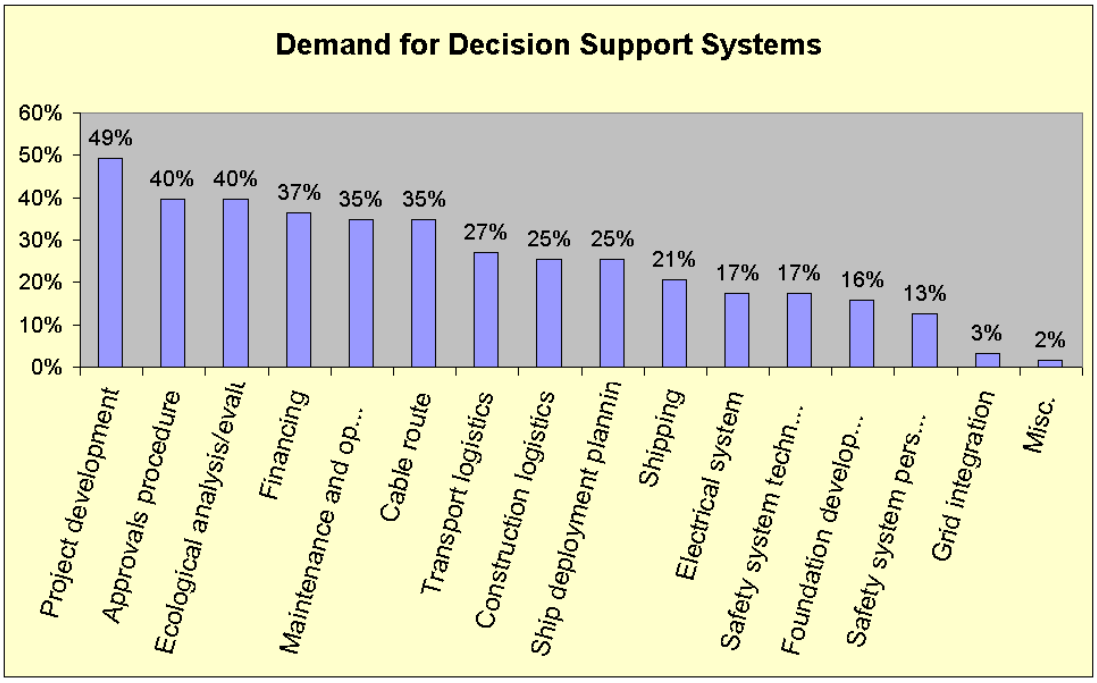

Figure 11: The demand for Decision Support Systems in different areas

4.2.6 The Potential to Use Decision Support Systems

Most of the participants would like to use Decision Support Systems in their work (Question 5) especially in the area of planning (as expected). But there is a minority of about 36% which don't like to use Decision Support Systems (Figure 12).

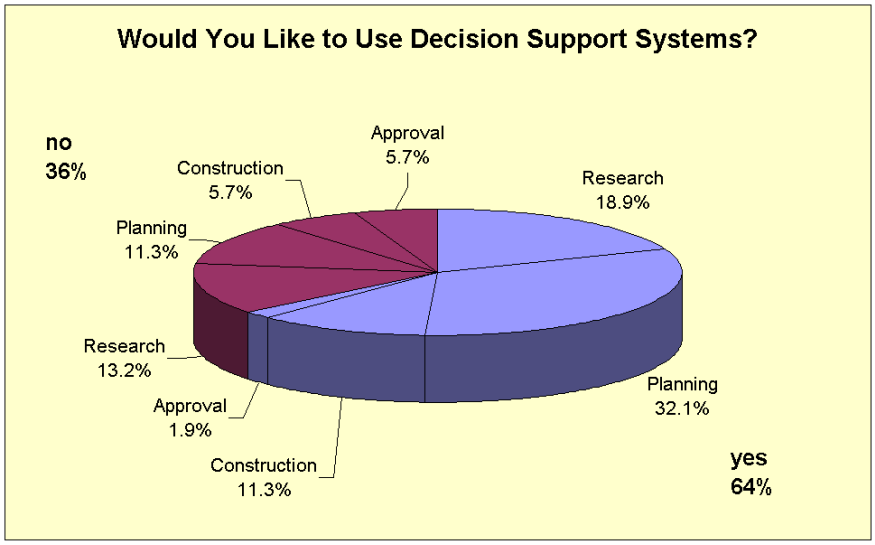

Figure 12: The potential to use Decision Support Systems

The demand to use Decision Support Systems has in the group 'planning' the greatest fraction (**Figure 13**). The category approval shows the opposite relation and a low demand to use Decision Support Systems. This is in opposite to the Decision Support System use relations seen in Figure 10.

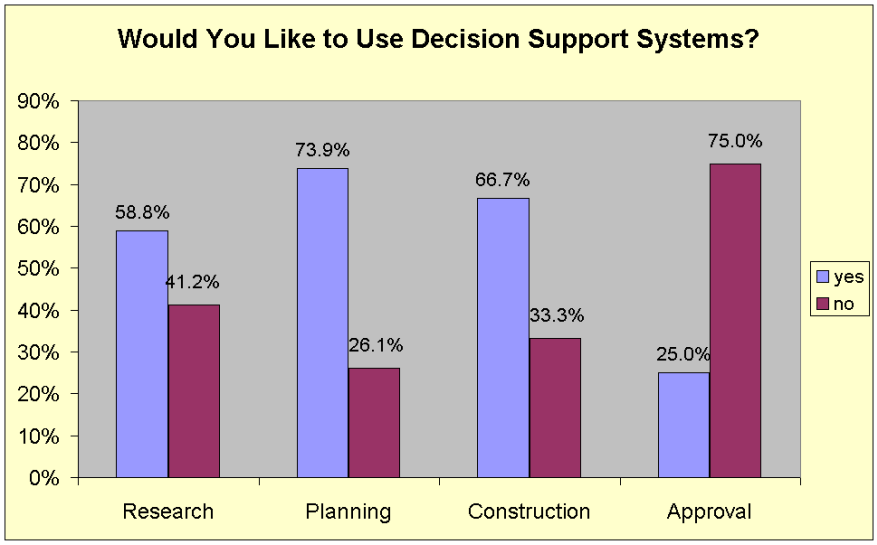

Figure 13: The potential to use Decision Support Systems by user groups

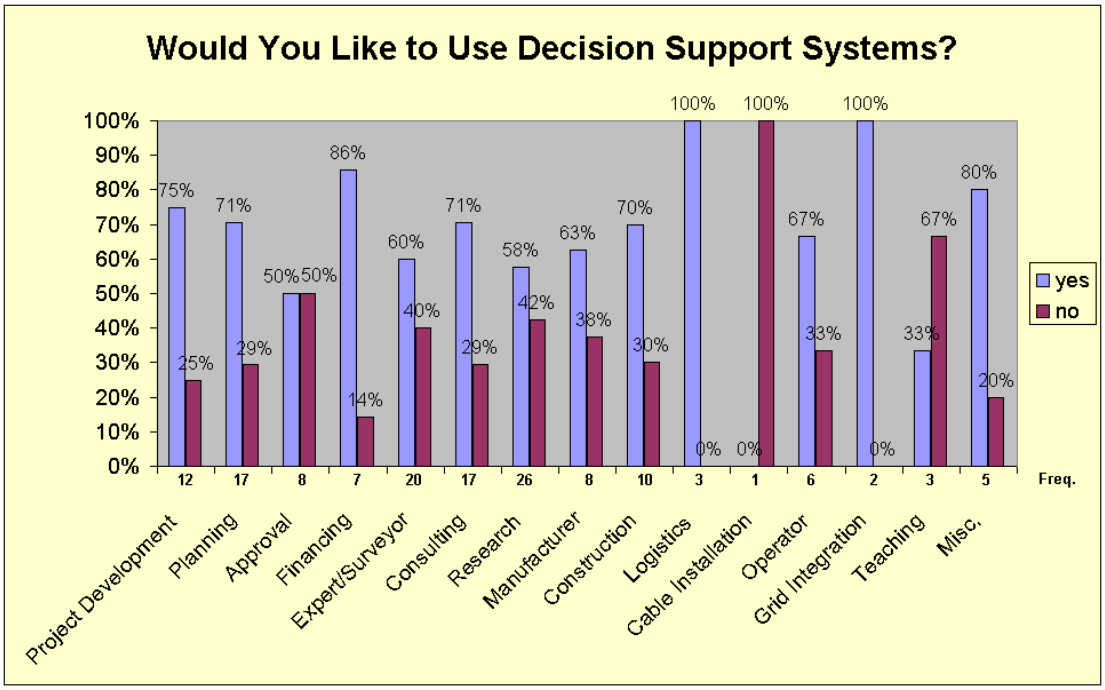

Figure 14: The potential to use Decision Support Systems by area of focus. Absolute frequencies are shown at the x-axis.

In most areas of focus the motivation to use Decision Support Systems is high, only 'Cable installation' and 'Teaching' are showing low values[2] (Figure 14). But also 'Approval' has with 50% a relatively low motivation.

It must be kept in mind that the motivation of institutions to give feed back on this questionnaire may be higher from those who are interested in Decision Support Systems as from those which are not.

[2] Interpretation of categories with low frequencies like "Cable Installation" must be done carefully - they are not significant.

4.2.7 Software Decision Support Systems as Integrated Systems or a Collection of Individual Programs?

The need of SDS-Systems as integrated systems or a collection of individual programs (Question 6) is nearly balanced (Figure 15, Figure 16). The choice 'Individual Programs'[3] has a slightly higher value. This result is rather dependent on the compositions of addressed institutions. Integrated systems are mainly demanded by approval and research institutions.

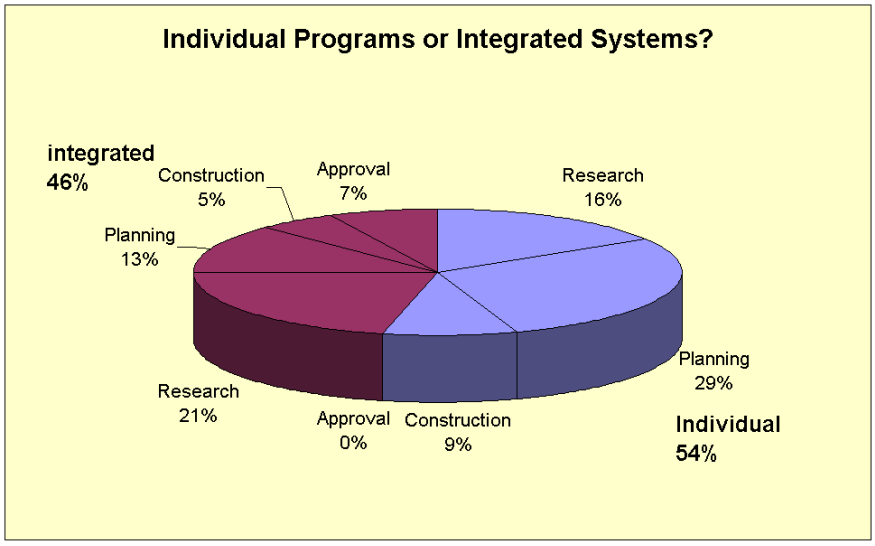

Figure 15: The desired type of SDS-Systems

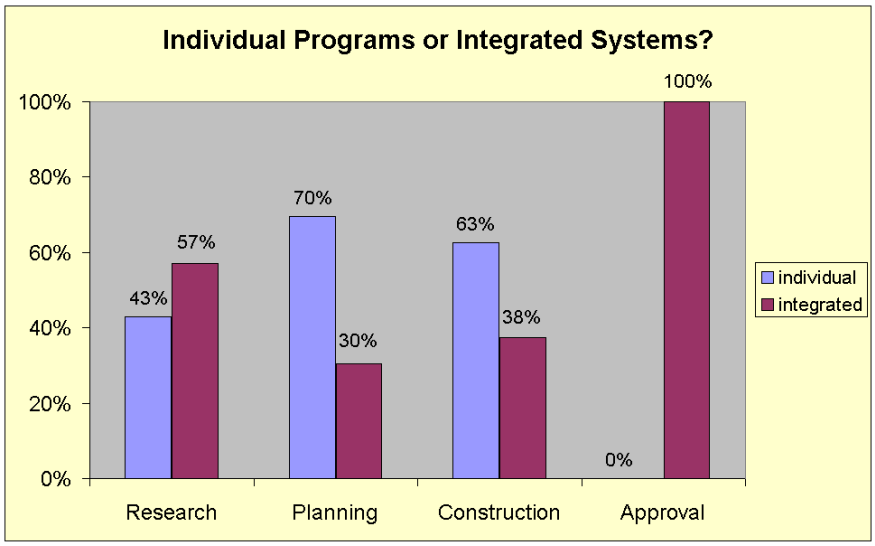

Figure 16: The desired type of SDS-Systems by user groups

[3] In this context 'Individual Programs' means separated programs with defined standard interfaces for data exchange.

From personal communication the need for individual specific software in the different areas of focus was underlined but also the need for uncomplicated data exchange (standard interfaces) between software tools.

4.2.8 Type of Decision-Finding Structure

The basic decision-finding structure (Question 7) has to be simple and easy to follow (83%) for most institutions (Figure 17, Figure 18). Complex evaluations which are theoretically better but not directly traceable are wanted by the minority which is build by parts of the research and planning category.

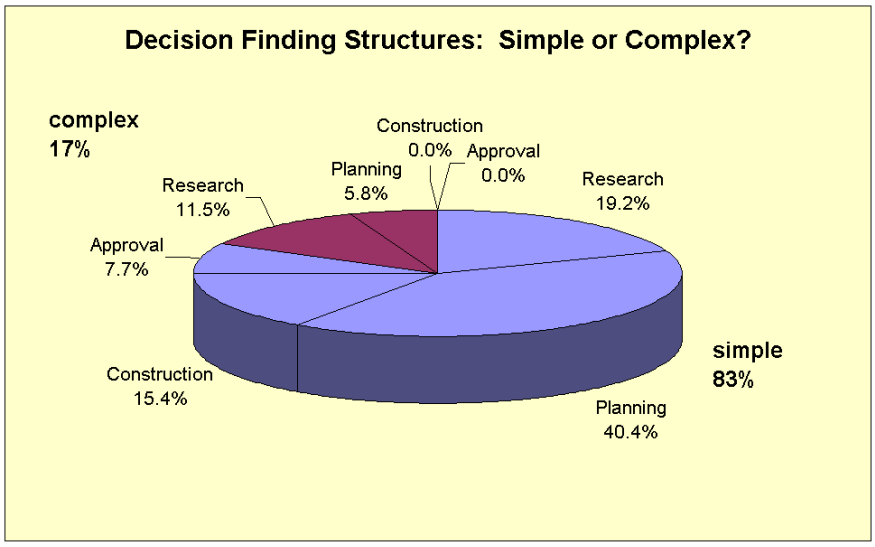

Figure 17: Type of decision finding structure

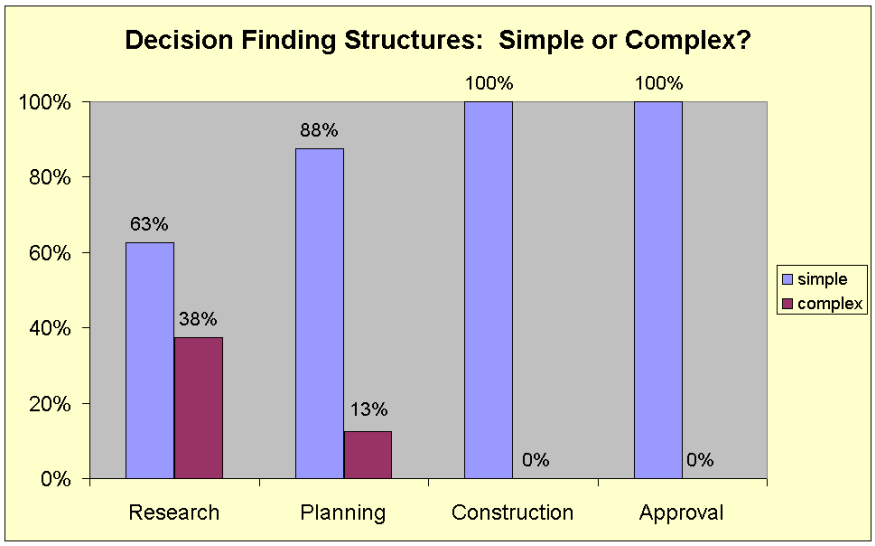

Figure 18: Type of decision finding structure by user groups

4.2.9 Software Tools which Play an Important Role in the Decision-Finding Process

Software tools which play an important role in the decision-finding process (Question8) are shown in the following (Figure 19, Figure 20). Excel sheets are leading the 'hit list' up to 60% including the project planning tool MS-Project and database MS-Access. The use of the GIS-Tool Arc-View is relatively high with 25% as the first non-standard tool (and basic SDS-System!). Wind specific software is following with Own Software (22%), 'WaSP' (17%) and 'WindPro' (16%). But also own developed software for economic calculation has to be recognised (11%).

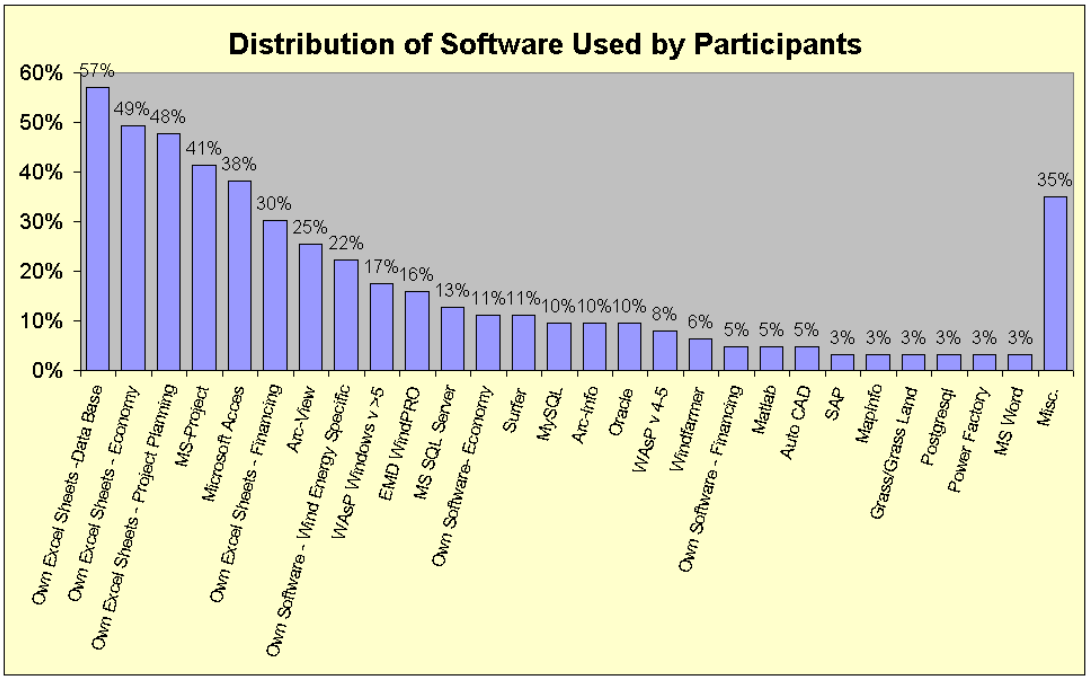

Figure 19: Distribution of software tools used by the participants, sorted by fraction. Software tools which are used only by one participant are pooled under 'Misc.'

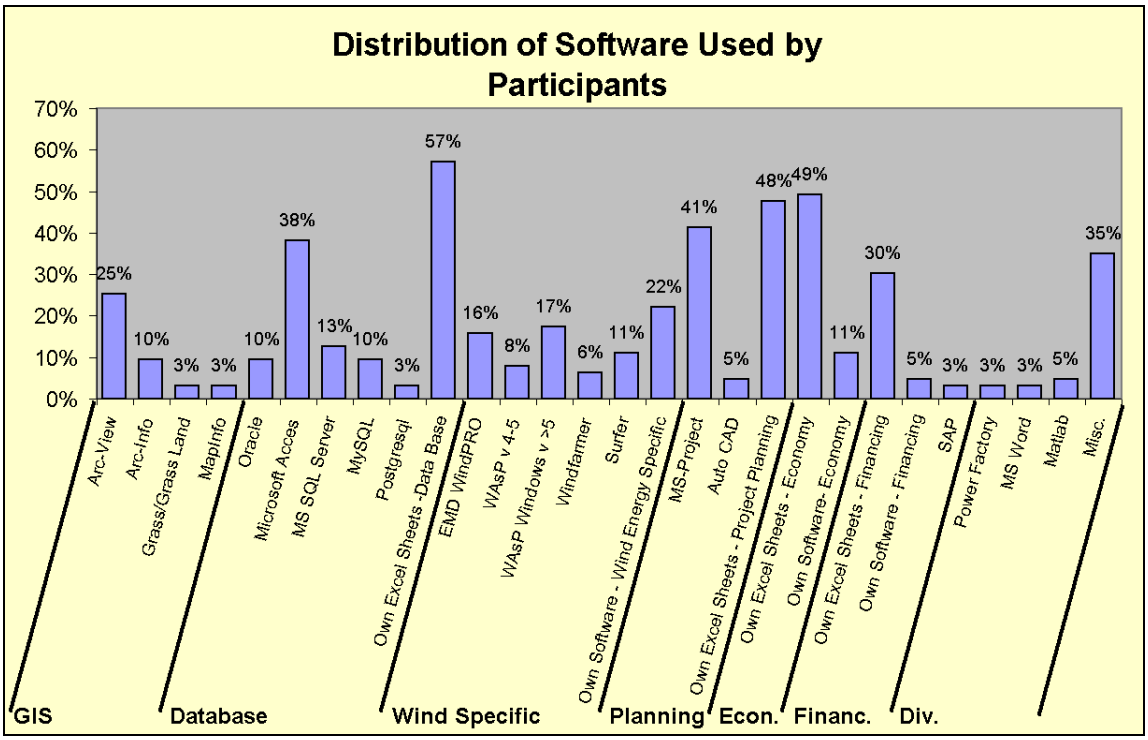

Figure 20: Distribution of software tools used by the participants, sorted by category. Software tools which are used only by one participant are pooled under 'Misc.'

An interesting result in Figure 20 is that in the economic and financial area Excel sheets and own software plays the major role. Specific software for the ecological area is not named.

5. Assessment and Conclusion

5.1 Main Fields of Applications

The evaluation of the questionnaire and personnel interviews are showing mainly needs for SDS-Systems in the area of project development and in planning processes including the approval procedure from the planner's point of view. GIS systems as basic SDS-Systems are a must in offshore planning, not only for own needs but even to exchange information with the authorities. Authorities are using GIS systems during the approval procedure in the offshore region but mainly for map generation with the different restriction areas and infrastructure items.
The need for development and application of SDS-Systems is not confirmed by the authorities as urgent as expected. Possible advantages of SDS-Systems on GIS basis must be communicated. People who are working with GIS software (and preparing the input for the GIS software) are not necessarily the people which handle the permission process. The application of related systems is also limited by the complexity of such software tools.

Main fields of applications for Decision Support Systems were identified more on a general basis (Question 4). In principle all formulated areas of offshore wind energy do have a high priority leaded by project development, financing, approval and ecological evaluation.
From personal consultations of planning people and authorities the need and the field of application was formulated in most cases very unspecific.

5.2 Adopting Existing Systems

The question "can existing systems be adopted or should new systems be developed" is answered by many project developers and planning people clearly: Existing tools should be extended with additional features in the direction SDS-Systems. Interfaces and data formats of existing software tools should be standardised for easy data exchange. A good example for extending common used standard software is the "Multi-Criteria Analysis with ArcGIS Spatial Analyst " which extends standard software with tools for complex valuations. Another approach is to integrate interfaces to other standard software tools. A basic example for this is the combination of Excel with 'Windfarmer ' – own complex financial calculations on Excel basis can be 'integrated'. The adoption, better the extension of other onshore SDS-Systems to the offshore area may be possible but this must be proved in detail.

From the Oil and Gas Industry several SDS-Systems were developed, most of them for internal use. In the area of geological survey, knowledge base for drilling and

emergency plans (oil pollution) some SDS-Systems are known as OSCAR and AKSIO. The possibility of adopting parts of those systems for offshore wind energy use must be proved in detail but seems not to be reasonable.

5.3 Expected Advantages and Disadvantages of SDS-Systems

In the following main discussed issues and expected advantages and disadvantages of SDS-Systems for offshore wind energy are listed:

Expected advantages of SDS-Systems:

- Improved project development
- Objective valuation of criteria and selection of options
- Complex valuating procedures for optimal solutions
- Faster development and permitting
- Improved optimising of layouts, routes, costs,…
- Improved logistic of erection and transport
- Improved maintenance and operation
- Completeness (integrated SDSS)
- Open databases, experience database

Expected disadvantages of SDS-Systems:

- Long time to train people
- Complex operation of software
- Missing transparency of evaluating methods

In the following expected advantages and disadvantages related to the type of software itself (integrated / tools collection) are listed:

Expected advantages of integrated SDS-Systems:

- Less single software tools
- Less interface problematics for data exchange
- Improved optimisation potential

Expected disadvantages related to integrated SDS-Systems:

- Care and maintenance of software can only be done by less people
- Included models may be too simple (more general approach)
- Expandability for own needs may be problematic
- Training time for software is high
- Only for specialists (multi area)
- From experience maintenance of ‘big’ software systems is problematic

Expected Advantages of SDS-Systems based on a tool collection:

- People can work on software they are skilled on
- Extensions can be done by several people
- Own extensions are possible
- Specialists for each specific field
- Optimal tools for each specific field can be used
- Modular concepts

Expected Disadvantages of SDS-Systems based on a tool collection:

- Module/Software interaction is problematic
- Collaboration of specialists is necessary
- Supervisor for good co-development is required

An interesting result of this study is that research institutes and planning / permitting institutions have significantly different views regarding the use of integrated systems or alternatively a collection of software tools. From research and approval institutions the integrated concept is preferred. From planning people there are big doubts that the big amount of planning details and special evaluations could be handled by ‘one big’ system. Also the transparency of decision or valuation processes of SDS-Systems was questioned. From experience decision processes are in most cases iterative processes often motivated by politics and economic short time interests.

General approaches for SDS-Systems including ‘simple’ models for different areas don’t help during detailed planning. The combination of very specific tools, modular concepts, with specialists for each part could be a solution. The maintenance of each software package could be done by specialists for the according sector.

To find acceptance for the application SDS-Systems work has to be done. Good examples have to be published and disseminated. From the questionnaire and personal communication it was found that people like the idea of Software Decision Support Systems but have some doubts of practicability.

5.4 Potential Future Customers and Target Groups

The main needs for Decision Support Systems are found on the one hand in the area of project development, planning and approval area. On the other hand build and operation including logistics, maintenance and safety in relation to the wind farm itself as well as cable, cable route, energy transmission system and energy market are playing a major role for Decision Support Systems because wind farms will be operated for a long time period of more than 20 years.

It must be kept in mind that the number of theoretical possible SDSS installations for offshore use is limited by the number of wind farm installations. To justify development effort an alignment to the global market seems to appropriate.

5.5 Conclusion

The number of available Software Decision Support Systems for the offshore sector is limited. At current accordant SDS-Systems are under development primarily by two institutions. First applications to support concrete offshore plannings are performed but commercial application is at the beginning. Different other approaches are more in the education and research stage. For onshore the situation is similar. Only less SDS-Systems could be found, most of them under development and not in a commercial stage. Software tools which may be used as a basis or a part of SDS-Systems are mentioned. GIS-Systems seems to be the most promising.

The needs for Software Decision Support Systems are found in nearly all main areas of offshore wind energy with focus on project development, approval procedure, ecological evaluation, financing, maintenance and operation, cable route and logistics. This reflects also the bottlenecks and needs formulated by preceded POWER studies ([2],[5]). It was found that many people and institutions did not (or not in detail) deal with the ideas of Software Decision Support Systems before. It must be communicated more insistent that SDS-Systems do not “make” decisions but “support” decisions and can give a high-quality data and knowledge basis for decisions. People who are deeply involved in the planning, approval and realisation processes know about the complexity of the information base and the decision processes but also see the problem to find common optimising approaches and therefore find an appropriate SDS-System structure.
On the one hand simple to use software systems are desired but on the other hand integrated SDS-Systems tend to be very complex because detailed data and knowledge of different disciplines have to be integrated. Scepticalness for the feasibility, quality and handling of complex SDS-Systems seems to be appropriate. A combination of specific software tools with standard interfaces and modular concepts seems to be a suitable solution, just if they are based established “standard” software tools which are already in use. Acceptance is a major topic.
In the areas “Planning”, “Research” and “Construction” the motivation to use SDS-Systems seems to be high. Some motivation work has to be done for “Approval” related institutions.

Because at current most of the offshore wind developments in Europe are in the planning and engineering stage the main focus is directed to project development, approval procedure, ecological evaluations, financing, maintenance and operation planning, wind farm and cable installation. The time schedule for this stage is in the area of several years for a single project. But the perspective to use SDS-Systems during the next 20 years of operation must be kept in mind. Operation, maintenance, safety and energy market etc. are main topics for SDS-Systems during this stage.

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7. Appendix

7.1 Questionnaire English

See the separate document.

7.2 Questionnaire German

See the separate document.