Centre for Energy, Environment and Health

Work Packages and Work Programme for the first year

Summary of Work Programme

The connection between air pollution, originating from the burning of fossil fuels, and human health has been well established for several years. More people succumb every year to particle pollution from cars than from traffic accidents. Public concern about the consequences of air pollution on health, rising oil prices and the climatic impact of fossil fuel burning, has encouraged politicians and the media to address these issues more frequently. This has condoned many to view the emergence of new environmentally friendly methods for energy production (bio fuel, hydrogen cells, etc.) with great optimism. In the complicated network of health consequences, economical repercussions and climatic impacts, connections are dubious, but still economical dispositions are paramount, on both a private and a national level. Our common future is best safeguarded if these dispositions are made on a sound basis. Indeed, the purpose of the Centre of Energy, Environment and Health (CEEH) is to develop such a decision support system. This is best done in the context of a unified interdisciplinary research effort which can clarify the connections between the future energy production in Denmark, environment and health, and optimise these with respect to economy. In order to achieve such multidisciplinary experts from meteorology, environmental and health science, energy and economy will be working closely together in the confine of the Centre which will comprise the University of Copenhagen (UoC), the Danish Meteorological Institute (DMI), the National Environmental Research Institute (NERI), Risø, the National Institute of Public Health (NIPH), the University of Southern Denmark (SDU) and the University of Aarhus (AU). The main goals of the Centre, which are all highly strategic for the Danish society, will be: (i) to study the future production of energy in Denmark and consequences of different scenarios with respect to environmental and human health aspects, and (ii) to optimize the type of energy production and consumption with respect to economy from environmental and health viewpoints. The proposed research will be realised in seven work packages:

WP1: Baseline energy system modelling and emission scenarios.
Participants: Risø, NERI
WP leader: Kenneth Karlsson, Risø

WP2: Modelling of the environmental impact of the energy production /consumption.
Participants: UoC, Risø, DMI, NERI
WP leader: Eigil Kaas, UoC

WP3: Health impact of air pollution - the link between epidemiology and toxicology.
Participants: AU, NIPH
WP leader: Torben Sigsgaard, AU

WP4: Quantification of pollutants and climate on population health.

Participants: NIPH, AU, DMI, NERI, SDU
WP leader: Henrik Brønnum-Hansen, NIPH

WP5: Minimization of risk/impact on environment/health and optimization of energy production/ consumption.

Participants: DMI, Risø, NERI, UoC, SDU
WP leader: Allan Gross (DMI)

WP6: Recommended scenarios for Denmark.

Participants: NERI, Risø, UoC, SDU, DMI
WP leader: Jørgen Brandt, DMU

WP7: Management

Participants: All partners with UoC as a lead
WP leader: Eigil Kaas, UoC

The Centre will also contain a substantial inter-disciplinary educational component through Ph.D. studies, taught courses and exchange of both students and researchers between the Centre collaborators for short and long periods.

Objectives

The objective of the Centre of Energy, Environment and Health (CEEH) is to provide advanced research of energy production and related environmental/health issues and thereby integrate different groups from these areas. The main goals will be

• to study the future production of energy in Denmark and consequences of different scenarios with respect to environmental and human health aspects, and
• to optimize the type of energy production and consumption with respect to environmental and health economics.

Furthermore, CEEH includes a strong inter-disciplinary educational component and career opportunities for young scientists in its broad scientific and practical fields. Exchange of Ph.D. CEEH proposal 14 September 2006 2 students as well as established scientists over longer periods of time between the participating institutes will secure the necessary sharing of inter-disciplinary knowledge. Methodology A key element of the CEEH will be to expand, evaluate and apply integrated models for all impact pathways, including integrated

energy systems, emissions, atmospheric chemistry/transport, human exposure, human health models as well as cost models. This chain of models will be used to optimize the energy production system from a grand economical viewpoint, and will be used to provide qualified guidelines for all sectors of the future energy planning in Denmark. When implementing cost estimates of pollution damage (externalities) from energy production and consumption it is possible to determine the cost effectiveness of air pollution, health effect prevention, mitigation methodologies/technologies, or to compare and optimize the total energy cost options for the society. The results of energy system optimization models depend crucially on the basic cost functions used in the models, i.e. functions describing all the different costs related to different types of impacts from energy production and usage, changes in the production systems, etc. So far cost functions are not well known and the work in the CEEH will partly be devoted to studies of the mechanisms, processes and underlying assumptions behind the cost functions related to the impact of airborne pollution on the environment and human health. The basic idea is to combine efforts from different research areas in order to improve the relevant cost functions and the understanding of the underlying processes, and to apply the improved energy system models to different realistic future scenarios for energy production and usage.

The research areas include:

• Modelling and research in atmospheric transport, dispersion, chemistry and fate of pollutants due to energy production and consumption. Both aerosol particles and chemical gas-phase constituents will be considered. Knowledge of the regional and local environmental burden related to emissions of pollutants and accidental risks from power production is needed for estimation of environmental and health costs.

• Toxicological and statistical studies of the impact of atmospheric pollutants on the human body and on health in general. Based on the atmospheric burden these studies will be used to quantify the relative importance and costs of different types and amounts of emissions (as well as other types of environmental impacts).

• Set up and application of improved energy system models based on the process studies above. This work includes the specific formulation and implementation of the cost functions in the models, sensitivity studies for the system optimisation.

• Application of possible future scenarios of energy production and consumption on three scales: Northern Hemisphere, Europe and Denmark; using feasible energy system models. Description of the work

The work in CEEH is divided into the six work packages (WPs) described below. It is noted that long term strategic research is carried out in all of them and that the components of the CEEH are highly inter-disciplinary implying strong interactions between the WPs throughout the existence of the Centre.

Work Packages

WP1: Baseline energy system modelling and emission scenarios

Participants: Risø, NERI

Objectives and methods

The purpose of WP1 is to create a baseline energy and emission scenario for the Nordic countries and for the Northern Hemisphere for the period 2005 to 2050. A review of all relevant emission coefficients and future technologies will be carried out. A review of existing global and regional energy scenarios (IPCC, IEA, NEEDS etc.) will be carried out and on behalf of these a base scenario will be defined and used as boundary conditions to the Nordic energy system. A baseline scenario for the Nordic energy system will be modelled using the Nordic power and district heating market model – Balmorel [Ravn, 2001].
This baseline model system is intended as a quick start-up of the centre and will not include modelling of all sectors and energy production methods. Development in sectors not included in the baseline model will be taken from existing relevant studies.
The baseline scenario description will include macro variables (GDP, population, fuel prices etc.); energy technologies; end-use technology; and transport technologies.
The baseline scenario, which is the main output from WP1, will be a combination of existing complementing scenarios and emission data covering the Northern Hemisphere and model simulations of the Nordic energy system.

Interaction with other WP's

The output from WP1 is detailed data on related emissions of various pollutants in the base scenario. The data is determined by a tree dimensional vector describing: geography; time; and level.
The output from WP1 is needed in appropriate gridded data formats in WP2 for the 3D ACT atmospheric model.

List of activities

The main tasks in WP1 are:

1.1. Literature screening for examination of the present impact of the existing energy production on the anthropogenic emission. From literature and international emission databases, emission data for the present energy system are collected and prepared as input to the 3D ACT atmospheric model. There will also be focus on collecting data for emissions from sources other than energy conversion e.g. from farming and chemical processes in industry.

1.2. Literature screening of existing global and regional energy scenarios. Task 2 will include a screening of potential models for EU-29 and the northern hemisphere. Especially the TIMES model (www.etsap.org) seams interesting, while an EU-project (NEEDS) is building up a TIMES model for EU-29 and existence of a global network working on a global TIMES model are supporting this. TIMES is a linear optimisation model like Balmorel covering the energy supply and demand system and in some cases also trade of related commodities such as steel. Also models and scenarios used by IPCC and IEA will be examined.

1.3. Preparation of technology catalogue for possible future energy production, energy saving and transport technologies. To create scenarios for a future energy system it is important to list future possible energy producing technologies, energy consuming technologies, transport technologies and macro development variables. A scenario is defined as a realisable combination of macro variables and technologies. Base assumptions for the scenarios can be categorised as shown in the table. Start-year data and "forecasts" or possible developments for these data are collected in a database.

Group	**Variable**	**Source**
Macro variables	GDP, population, service level, fuel prices, other relevant prices ….	Danish Energy Plan 2007, IPCC, IEA, macro economic models
Energy supply technologies	Power plants, heat plants, individual boilers, heat pumps, fuel cells etc.	IEA, Danish Energy Agency Technology Catalogue, …..
Energy consumption	Different technologies and their efficiency improvement potential; e.g. ventilation, cooling, heating, process heat etc.	Danish Energy Saving Plan, Green-X (EU-project), ……
Transport technologies	Cars, busses, trains, planes – different fuels	…..

These data will be collected on the three levels: The Nordic countries, EU-29 and the northern hemisphere. Some technologies will be relevant in some countries and not in others e.g. hydro power.

1.4. Creation of scenarios for future energy service and transport service demand. The demand modelling in WP1 will lean against existing scenarios (IPCC, IEA and EU-projects) and spreadsheet modelling based on development in the macro-variables. In WP5 more advanced modelling of demand will be carried out and implemented in the Balmorel model. In that way demand for energy and transport can be included in the optimisation of the whole system.

1.5. Setup of a Balmorel model for the target years. A Balmorel model covering the Nordic countries is prepared to run on data collected in task 2 and demand scenarios from task 3. The Balmorel scenarios will create future energy supply

systems as a consequence of the chosen inputs from task 2 and 3. The result will describe technologies in the supply system, their fuel consumption, emissions and their costs. The Balmorel scenarios will be combined with scenarios for EU-29 and for the northern hemisphere.

1.6. *Converting of energy system scenario results into gridded datasets*. The 3D ACT atmospheric model need input data on grid form. All emission data from task 1 has to be combined with emission data from the energy system modelling (task 5.) and on grid form placed in a common database ready for use in the atmospheric model in WP2.

External collaboration partners

See separate document.

Ph.D. and post doc projects

There are no Ph.D projects or post doc's related to WP1.

Diagram showing the activity plan for WP1 tasks (#)

The work will be iterative in the sense of exchanging data with other WP's.

WP No	Lead	Year 1		Year 2		Year 3		Year 4		Year 5		Person months.
1.1	Risø											
1.2												
1.3												
1.4												
1.5												
1.6												

WP1 milestones for the first year of CEEH:

Milestones for the first year - responsible partner for each milestone are indicated in parenthesis.

Milestone Number	Milestones	Time	Input to and output from other WPs
2-1-a	Presentation at the International Energy Workshop, Stanford University, California. Meeting in the international modelling forum ETSAP also in California. (Risø)	25/6 2007	
2-1-b	Technology catalogue for possible future energy production, energy saving and transport technologies (Risø)	31/12 2007	
2-1-c	First draft of report on present impacts of the existing energy production (NERI)	31/12 2007	
2-1-d	Test version of emission database covering: Northern Hemisphere, Europe, Denmark (and Nordic countries) (NERI, Risø)	31/12 2007	WP2
2-1-e	Test simulations with Balmorel (Risø)	1/10 2007	

WP2: Modelling of the environmental impact of energy production/consumption

Participants: UoC, Risø, DMI, NERI

Objectives and methods

To understand the future environmental impact of different types of energy production/consumption, long-term simulations using three-dimensional Atmospheric Chemical Transport (ACT) models are crucial. Two long-range ACT models will be applied and operated at different spatial resolutions: the Danish Eulerian Hemispheric Model (DEHM) [Christensen, 1997; Frohn et al., 2002; Geels et al., 2002; Hansen et al., 2004] and ENVIRO-HIRLAM [Chenevez et al., 2004; Gross and Baklanov, 2004]. The main advantages of using two different models are that DEHM is faster to run since it is an off-line model (enabling large-scale coverage with possibility for long-term applications), while ENVIRO-HIRLAM is an "on-line" model where the pollution and the dynamical meteorological fields are consistently coupled allowing for direct feedbacks between pollution and meteorology. Furthermore, local urban air pollution models with very high resolution will be applied: the Urban Background Model, UBM [Berkowicz, 2000a], and the Operational Street Pollution Model, OSPM [Berkowicz, 2000b].

In CEEH we will improve the DEHM and ENVIRO-HIRLAM systems with the goal of setting up a new Danish long-range ACT model system. This implies implementation and tests of new efficient and accurate combined Eulerian and semi-Lagrangian numerical methods in both models. Also the chemical components in DEHM and ENVIRO-HIRLAM, particularly for aerosols, will be improved in the new Danish ACT community model system.

The input to the model systems will be emission scenarios defined in WP1 (the baseline) and later in WP5 and WP6. The basic idea is to feed the pollution emission data into the ACT models and then using these models to simulate the subsequent fate and concentration of the pollutants at different regions and locations. The emission scenarios and ACT model will be used at three different spatial scales domains:

- The entire Northern Hemisphere (NH). These simulations will be performed with the DEHM system in a configuration with spatial resolution of order 100-200 km. The meteorological dynamical fields driving the DEHM model will be obtained from the DMU standard setup where a meteorological model (MM5) is nudged towards meteorological analysis data or – in some simulations – towards simulated global climate model data.
- Danish / Northern European regions. These experiments and the associated emissions will be performed with higher resolution versions of both the DEHM and the ENVIRO-HIRLAM models. The pollution at the lateral boundaries of these simulations will be taken from the NH simulations. The resolutions will range from

about 50 km's in some simulations to about 15 km's. As a final goal near the end of the Centre it is the aim to run – at least in test mode – the models at resolutions "down" to about 1 km.

- Local areas of special interest, i.e. around major Danish cities. These simulations are performed at very high spatial resolution (i.e. from meters to less than 1 km) with the UBM, M2UE and the OSPM models.

In CEEH we aim at optimising the Danish energy production systems. This mean that we are only interested in emissions from the rest of the world as a boundary condition for the problem. Therefore the NH simulations will form a fixed set of external boundary conditions where the emissions will not be varied. However, for optimising the costs of the Danish energy production emissions will be varied in the regional and local area listed above. These emissions are specified from the scenarios in WP1 and WP6.

The emission scenarios will be defined in WP6 for the years 2010, 2015, 2020, 2030, 2040 and 2050. These data will serve as input for the ACT model simulations. The driving meteorological dynamical conditions for the ACT simulations will generally all be chosen from observed weather situations in the reference year 2000. Some simulations will only cover a few weeks to a month while others will cover the whole calendar year. To include the impact of future anthropogenic climate change (IPCC SRES-scenario B2) on the fate of pollutants a set of additional ACT simulations, covering the same spatial domains, will be performed (only with DEHM). The meteorological background conditions for these simulations will be obtained from global climate simulations provided by DMI (these simulations are not part of CEEH).

Interaction with other WP's

The numerical simulations WP2 bridge the gap between emission scenarios (WP1) and evaluation of the impact of different energy types on the environment and population health, i.e. the work in WP3 and WP4. The results will also be employed in WP5 and WP6.

The input from WP1 is needed in appropriate gridded data formats and resolutions for the different types of models listed above. The output to WP3, WP4, WP5 and WP6 must be delivered in formats needed for estimation of dose-response calculations and for estimation of costs in the natural environment.

List of activities

The main tasks in WP2 are:

2.1 Improvements of the 3D ACT models and setup of experiment designs. Most of the man power in WP2 will be spent in this task. It includes development, implementation and tests of new numerical methods and improved simulation of chemistry in the DEHM and the ENVIRO-HIRLAM systems, and setup of the

technical details of the models. The work on model development and experimentation/testing will be done in close collaboration between NERI, KU and DMI.

2.2 In collaboration with WP3 and WP4 define the full set of relevant pollutants to be included in the simulations (DMU and DMI plus SIF and AU).

2.3 Verification / validation / evaluation of the ACT for specific case studies for different scales (Hemispheric, European, Danish, city) including accidental releases and emission scenarios. Preparing for task 2.3 these simulations will involve emissions from all known types of air borne polluting energy production types, e.g. fossil fuels, nuclear power and bio fuel. All four WP2 participants will be actively involved in this task.

2.4 Running 3D ACT models including all the present and future emission scenarios for the years specified in WP6 as well as (monthly) case studies at finer spatial resolution. All four WP2 participants will be actively involved in this task.

2.5 Analysis of modelling output. (parters: DMI, KU and DMU)

External collaboration partners

See separate document.

Ph.D. and post doc projects

KU: The Ph.D study will be on combined Eulerian grid and Lagrangian tracer point model approaches for solving the continuity (i.e. the full transport) equation for chemical constituents and eventually for solving the continuity equation for (all) air. The detailed work of the Post Doc has not been defined yet but it could include systematic comparisons of the impact of fully coupling the air chemistry transport model component to the driving dynamical model. Both the Ph.D. and the Post Doc work will be done in very close collaboration with NERI and DMI.

DMI: To be defined as part of Milestone 2-1-c (see below)

NERI: Working title: “A study of particles aiming at understanding and reducing the mass closure problem in ACT models”.

Diagram showing the activity plan for WP2 tasks (#)

The work will be iterative in the sense, that model improvements are gradually introduced and that the interactions with other WP's will be performed in several steps.

WP No	Lead	Year 1		Year 2		Year 3		Year 4		Year 5		Person months.
2.1	UoC											
2.2												
2.3												
2.4												
2.5												

WP2 milestones for the first year of CEEH:

Milestones for the first year - responsible partner for each milestone are indicated in parenthesis.

Milestone Number	Milestones	Time	Input to and output from other WPs
2-1-a	A brief report describing the types of pollution data and the data format for all the baseline input data from WP1 and the output data to WP3, WP4, WP5 and WP6 (responsible partner: KU).	30/9 2007	WP1, WP3, WP4, WP5, WP6
2-1-b	Implementation and first tests of a new numerical method (ref Kaas) to solve the advection in the DEHM model. Comparison with results from the existing method based on ASD f ex with the classical rotation test extended to include chemistry (NERI in collaboration with UoC)	31/1 2008	
2-1-c	Formulation of project descriptions for all WP2 Ph.D. students at NERI, DMI, and UoC	31/8 2007	
2-1-d	Formulation of strategy for obtaining "mass-closure" for PM10 and PM2,5. Development and first tests of routines describing wildfires and organic particles in the long-range transport model DEHM (NERI)	31/10 2007	WP5
2-1-e	Formulation of a strategy for improvement of the definition of natural emissions in DEHM e.g. DMS (NERI)	31/10 2007	WP5
2-1-f	Coupling of DEHM to the ECHAM5 data in order to prepare DEHM to be running in climate mode (NERI and DMI)	31/8 2007	WP5
2-1-g	Preparation of data to be used as boundary conditions for ENVIRO-HIRLAM in collaboration with DMI (DMI and NERI)	31/10 2007	
2-1-m	First test simulations with DEHM and ENVIRO HIRLAM based on the emission from WP1 (DMU and DMI)	31/12 2007	WP1
2-l-n	Definition of Milestones (on the home page) for the second year of CEEH (KU)	31/12 2007	

WP3: Health impact of air-pollution; The link between epidemiology and toxicology

Participants: AU, NIPH, DMI, NERI

Objectives and methods

The purposes of WP3 are 1) to quantify the relative importance of different pollutants on respiratory and cardiovascular diseases, 2) to investigate the effect of the chemical composition on toxicological impact, 3) to build health risk input for statistical population studies in WP4.

Several combustion products have been linked to negative health effects in humans. Depending on the disease mechanisms and on the concentrations of the specific pollutants, either gases or particles may elicit the strongest effects. A common pathway for many of the pollutants is inflammatory reactions in the airways and systemic release of mediators of inflammation resulting in both respiratory and cardiovascular effects. Another common pathway for the non-gaseous pollutants appears to be changes in blood coagulability, stressing the cardiovascular system. Proper toxic effects, e.g. by CO binding to haemoglobin, also plays an important role in some cases. Since many potent combustion products are present simultaneously, their health effects are enhanced by synergy between them and cannot be ascribed to any single component. Furthermore, the concentrations of the combustion products are highly correlated. It is, thus, rarely possible to disentangle the effects of the different combustion products such as particles, NO2, SO2, ozone, and CO. Accordingly, several studies have successfully linked negative health effects with distance to combustion sources rather than with measured concentration of combustion products. Many other epidemiologic studies, however, have found the strongest effects on health from the particulate matter. From the medical literature, we will extract the available information on negative health effects related to the combustion products selected in cooperation with WP1, alone and in combination. Sources, such as reports by international boards and estimates in pre-existing computer models that are outside the medical literature, also exist and will be consulted. Data from these sources will be corrected, if necessary by more recent results. This may be necessary because the field of health effects of air pollution is constantly evolving, with hundreds of published papers just on population based studies and new publications coming every week.

The negative health effects of particle pollution, particularly in relation to respiratory diseases and cardiovascular diseases have been known for a long time [WHO, 2000; Boldo, 2006; Pope et al., 2002; Barnett, 2006; Rosenlund, 2006]. Since the change to new energy sources will have an impact on the chemical composition of the resulting particles, we will study the toxicological impact of particles with different chemical composition. If possible to model, these changes may also render inclusion of volatile organic compounds such as aldehydes (produced by ethanol driven vehicles) necessary. Some particle related health

effects might in part be mediated by particles generated by tear and wear of tires and roads rather than combustion itself. Another potential cause of inflammation and negative health effects is endotoxin (and other organic material) carried by particles. Decisions on how to handle such causes of negative health effects associated with but not directly caused by combustion products will have to be made in cooperation with WP1 and 5.

Effects of small particles are recognised as the most serious health problem in relation to air pollution [Pope and Dockery 2006]. Furthermore, the relative contribution from local Danish emissions as compared to non-Danish emissions to the total particle concentration is much larger for small than for medium and larger particles. Therefore special attention will be paid to the small particles.
An effort will be made to investigate the effects caused by the small particles by using particles sampled from 9 different sites in DK and NL covering relevant scenarios for a future energy consumption profile, from urban background to modern traffic using biofuels. These particles will subsequently be tested in an assay for oxidative capacity and for inflammatory capacity in *in vitro* [Hetland 2004, Roepstorff 1997] and *ex vivo* [Kruger 2004] models. These models, which rely on human cells or blood only, allow for direct comparisons of potencies of differently composed pollutants to elicit inflammatory responses.

The core of WP3 is the literature search from which risk estimates will be produced. In the epidemiologic literature estimates for respiratory diseases such as asthma, chronic obstructive pulmonary disease/chronic bronchitis, lung cancer, and airway infections and cardiovascular diseases such as stroke, haemorrhage, and myocardial infarct will be identified. Both morbidity and mortality risks will be identified. In addition the risks among children of becoming allergic, of sudden death and of growth retardation in utero as well as after birth will be evaluated. These risk estimates will be specified for specific diagnoses, coded according to the ICD-10 system. High emphasis will be put on dose-response estimates in the cases where these have been estimated and non-linear responses may have to be accounted for in some cases. Currently, the literature suggests that for most of the relevant pollutants there is no identifiable lower limit of effect. Because the existence of a lower limit will be crucial to the effects in scenarios including combustion free vehicles or the like, it is pertinent to take a decision on how to handle the lowest exposures in cooperation with WP4 and WP5. When possible and relevant, separate estimates will be assigned to different age groups, gender, smokers and non-smokers, as well as those with pre-existing co-morbidities.
The toxicological literature will be reviewed in order to identify differences in potency between combustion products of different origin and composition as well as effects of combined exposures. Such differences will be used in conjunction with the tests performed under WP3. Together this information on toxicology will allow for adjustments of the risk estimates related to specific diagnoses. This will enable a more refined modelling of the health impact of different energy scenarios in the subsequent epidemiological model studies.
The relative risks identified in WP3 will be used for calculation of the population attributable fractions in WP4.

Whereas cumulated exposure may contribute to the development of cardiovascular diseases, respiratory diseases and cancer, peak exposures may trigger acute events such as asthma attacks and acute myocardial infarction, especially in high-risk groups such as children, elderly, and people in poor health. In cooperation with WP4, decisions on how to handle acute effects caused by short-term peak exposures, less acute effects (i.e. weeks to months following one or more peak exposures) and chronic effects (which ideally reflect disease development caused by long-term exposures) will be taken. In the literature, effects with different lag time may not always be available for all the relevant diseases. In these cases decisions on how to handle differences in accuracy between estimates relating to different pollutants or diseases will have to be taken. The impact of particle pollution from regional (European) and local (Danish) sources on various health endpoints will be analysed by linking data on air pollutants and their different toxicological impact with registered data on hospitalisations and causes of death [Andersen et al., 1999; Juel and Helweg-Larsen, 1999]. Meteorological and biological conditions such as temperature, humidity, pressure, pollen and mould spores affect health and will be taken into account in the analyses.
Another specific problem that will be addressed is whether assigning residence based pollution levels is equally relevant in all age groups or not. Relevant questions include whether assessment of children's exposures should also put emphasis on levels at school, exposure assessment of adults should assume high levels during commuting, and exposures of aged people should be assumed to be lower than at their doorstep because they spend more time indoors.

Interaction with other WP's

As for input from and output to other WPs, the interactions are described in the previous section It is essential that decisions on selection of pollutants (modellable in WP2 and 5 and with enough relevant information on health effects) are taken with the other WPs. Discussions on threshold levels should be taken with other WPs as indicated previously. With WP4 selection of diagnoses, decision on how to handle causes of negative health effects associated with but not directly caused with combustion products, how to handle differences in accuracy, how to handle acute versus chronic effects, and how to handle co-factors such as smoking and co-existing disease.

List of activities

3.1 Identify relevant combustion products in cooperation with other WPs.
3.2 Perform medical literature search for the effects on respiratory and cardiovascular diseases of the selected combustion products and obtain estimates of relative risks and lag time from the literature.
3.3 Identify other existing sources of information on risks and negative health effect and extract and compare their estimates with recent literature.

3.4 Establish the toxicological impact of particles with different chemical composition emitted under different scenarios.
3.5 Review the relative risks derived from the literature and adjust them for results obtained in 3.4. Deliver data and adjust output in cooperation with WP4.

External collaboration partners

Flemming Cassee, National Institute for Public Health and the Environment, NL

Ph.D. projects and post doc projects

AU: A post doc study including sampling of and development of laboratory methods for toxicological testing of particles under different scenarios.

Diagram showing the activity plan for WP3 tasks (#)

Task No	Lead	Year 1		Year 2		Year 3		Year 4		Year 5		Person months.
3.1	AU											N/A
3.2 + 3.3												6
3,4												66
3.5												6

WP3 milestones for the first two years of CEEH:

Milestone Number	Milestones	Time	Input to and output from other WPs
3.1	Decision taken on what pollutants, health effects and dose-response estimates to evaluate from the literature	1/11 2007	WP4
3.2	Review and publish paper on health effects of particulates in Denmark	1/8 2008	
3.2	Complete evaluations of the most important dose-response estimates for CEEH modelling	1/6 2008	WP4
3.3	Identify and use other sources of information on the most important dose-response estimates and compare with our estimates	1/6 2008	
3.4	Establish and test the toxicologic model with combustion particles from existing projects	31/10 2008	

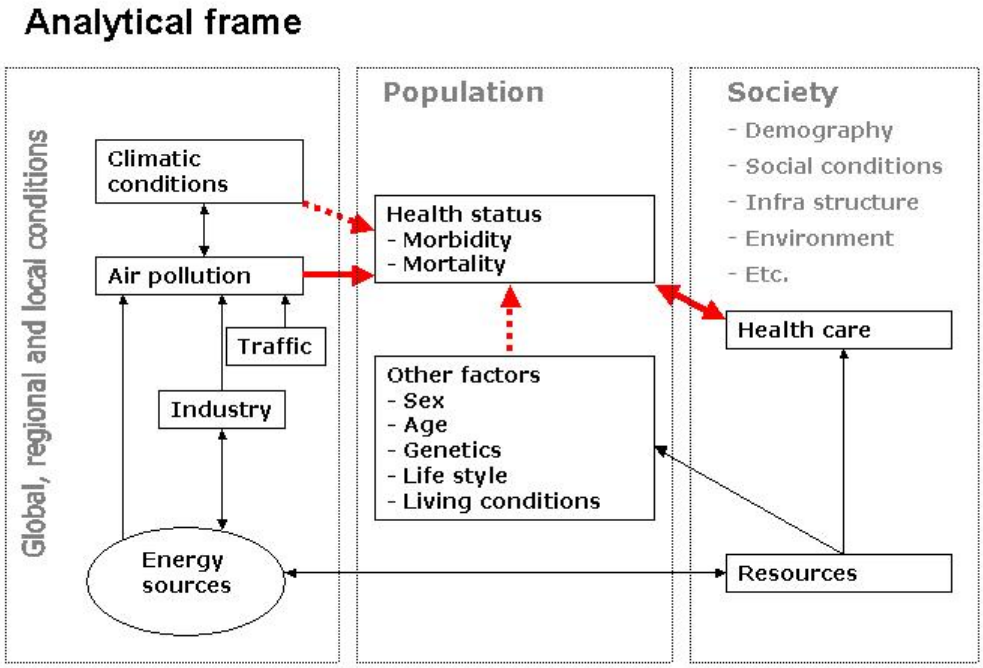
WP4: Quantification of impacts of pollutants on population health

Participants: NIPH, AU, DMI, NERI, CAST/SDU

Objectives and methods

The purposes of WP4 are to quantify the health impact of pollutants on a macro-scale level based on statistical methods and inputs from WP2 and WP3, and to set up health cost functions for the various emission scenarios from WP5 in a way suitable for the energy system optimisation models.

The total impact of air pollution levels on human health depends on the population structure and density, type of activities, protection measures, risk perception etc. [FUMAPEX, 2005]. Therefore, the effect on the health status of the Danish population will be estimated for different risk categories and types of activities (age, home address, indoor, outdoor, in transport, working places, etc.) taking regional characteristics (e.g. urbanisation) and demographic data into account. As temperature, humidity, wind and pressure affect health, also meteorological conditions and the effect on air pollution need to be included. The thick red arrows on the figure below illustrate the main central factors to be studied in WP4.



In particular, light will be thrown on the impact of various pollutants on respiratory and cardiovascular diseases. Dynamic models combining demographical and epidemiological data and theory will be developed and used to achieve this. A central measure for estimating the proportional reduction of disease in the population resulting from a change in the distribution of exposure is the population attributable fraction (PAF), which is composed of relative risks and prevalence of risk factor exposures. PAF estimate input comes from WP3.

As air pollution exposure data are not available at the individual level indirect methods and macro simulation models are needed to quantify the health impact of air pollution as those developed in relation to studies of the impact of tobacco smoking and other risk factors [Peto et al., 1992; Baan et al., 1999; Brønnum-Hansen, 1999]. The applied methods will be based on input from the dose scenario outputs in WP2 and the relative risks from the combined toxicology and epidemiologic evidence in WP3.

Evaluation of long-term (cumulative) effects of pollutants and short-term effects (exacerbation of prevalent diseases or new disease events) has to be distinguished and clarified in collaboration with WP3. Seasonal variation, the interaction between pollution and meteorology and multi-factorial effects of other risk factors are some other important challenges that need consideration. The construction of health cost functions requires multidisciplinary effort where the feedbacks in the energy system optimisation models must be understood. An important component will be to analyse and understand the uncertainties in final cost functions, used as basic input in WP5.

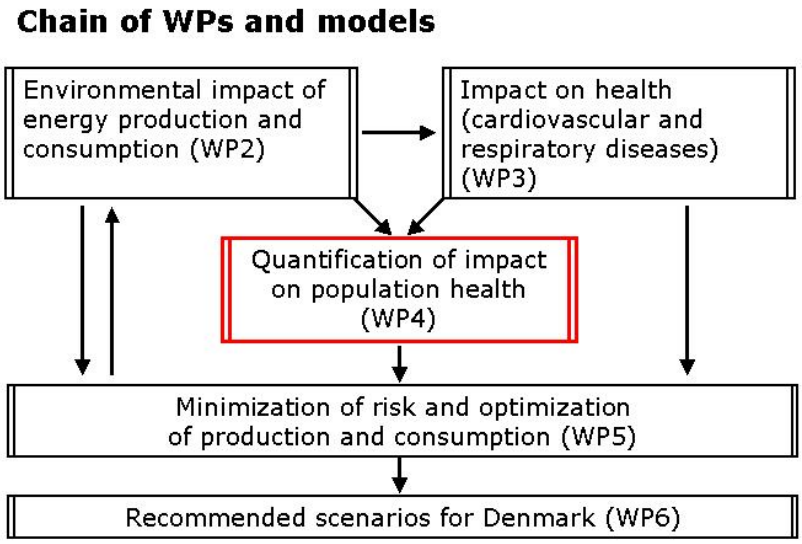
The health consequences and derived use of health care resources will be modelled based on scenario descriptions at a national level. These analyses will include the focus of health sector resources (primary and hospital care) and an attempt will be made to assess the consequences on the social care sector. The analysis will also assess the broader consequences in terms of absence from the work force and the associated loss in societal production. A special effort will be made to establish national valuations relating to mortality, lost (quality-adjusted) life years, and time without severe disabilities.

Furthermore, an attempt will be made to assess the broader consequences of pollution on the broader environment including effects on natural resources, animals and infrastructures. Together with the direct cost of energy production and distribution, the health and environmental cost will form central components in the overall cost function that will be used as one of the important objective functions for the simulations of different scenarios of energy production.

Various scenarios running until 2050 will be defined. The scenarios will be based on different assumptions as to future energy production and consumption (from WP5) and trends in population health status and mortality rates. Furthermore, sensitivity test as to central parameters (from WP3) will be made.

Interaction with other WP's

From the WP4's point of view the interaction between WP's could be illustrated as shown in the diagram below. Thus, the emission scenarios from WP1/WP5 are evaluated through WP2 as to the environment impact of various choices of energy, establishing the basic input for quantifying the effect of chemical composition and toxicological impact in order to build health risks and cost functions and estimate the impact on population's health. As the developments in WP5 (and WP6) are based on results from WP2, WP3 and WP4 strong interactions and feedbacks between WP2-WP4 and WP5 are necessary.



List of activities

The main tasks in WP4 are:

3.1 Literature study identifying public health (simulation) models and methods suitable for quantifying the impact of air pollution on health. This task includes identifying models that might be useful tools for estimating the effect of pollution on health. In particular, the EVA system at NERI could be the platform for further developments in this respect.

3.2 Simple testing (verifying, validating and evaluating) simulation models and methods identified from the literature (task 4.1) or extensions of the EVA system in collaboration between NIPH, NERI, and DMI.

3.3 Preparing a Ph.D. study with weight on statistical modelling.

3.4 Establishing data on incidence of specific diseases and death rates from national registers on hospitalisation and causes of death in collaboration with UoAa/WP3.

3.5 In collaboration with WP2 and WP3 defining and establishing the full set of relevant data and parameters on pollutants to be included in the public health simulations.

3.6 Modelling scenarios on future population health on the basis of results from epidemiological/toxicological studies (WP3), demographic development, regional characteristics and emission scenarios from WP2/WP5.
3.7 Creating scenarios on the impact on health service and economic consequences of various energy policies.
3.8 Interpretation of modelling output in collaboration with all partners.

External collaboration partners

School of Population Health, University of Queensland, Australia, Jan J Barendregt.
Department of Public Health, University Medical Center Rotterdam. See further separate document.

Ph.D. projects and post doc projects

NIPH, DMI and NERI: A post doc study estimating the need up to 1 or 2 weeks in advance for hospital contacts and the number of occupied beds in hospitals on the basis of weather- and air pollution- forecasts. The study on short-term effects of pollutant exposure might be included in the Ph.D. study described below:
NIPH and CAST/SDU: A Ph.D. study on modelling the impact of air pollution on public health and the implication on health economy. The study has to be prepared in the start of 2008.

Diagram showing the activity plan for WP4 tasks (#)

The work will be iterative in the sense, that model improvements are gradually introduced and that the interactions with other WP's will be performed in several steps.

Task No	Lead	Year 1		Year 2		Year 3		Year 4		Year 5		Person months.
4.1	NIPH											2
4.2												3
4.3												2
4.4												1
4.5												2
4.6												18
4.7												18
4.8												4

WP4 milestones for the first two years of CEEH:

Milestone Number	Milestones	Time	Input to and output from other WPs
4.1	A brief report describing the models and methods identified from the literature study (responsible partners: NIPH, UoAa and NERI).	1/7 2008	WP3
4.2	Simple testing (verifying, validating and evaluating) simulation models and methods identified from the literature or extensions of the EVA system (NIPH, NERI, and DMI).	31/12 2008	
4.3	Finishing a Ph.D. study application.	1/7 2008	
4.4	Data on incidence of specific diseases and death rates from national registers on hospitalisation and causes of death defined and extracted.	31/12 2008	
4.5	The full set of relevant data and parameters on pollutants to be included in the public health simulations defined.	31/12 2008	WP2, WP3

WP5: Minimization of risk/impact on environment/health and optimization of energy production/consumption

Participants: DMI, Risø, NERI, UoC, SDU

Objectives and methods

The **purpose** of this WP will be to
1) build new generation integrated energy system models and
2) employ them in sensitivity studies of future energy scenarios for Denmark.

WP5 contributes to main CEEH goal:

- to optimize the type of energy production and consumption with respect to environmental and health economics.

Modelling base: Balmorel, MARKAL-TIMES energy system models, ACT modelling system (including DMI and DMU models), its adjoint version and optimisation models. It is not decided yet which model to use at European and Northern Hemisphere level. It is a part of WP1 to decide on the model framework, but it will probably be based on a model called TIMES or MARKAL-TIMES (www.etsap.org).
The **developments in WP5** will encompass and consider the sectors, production methods and energy carrying technologies, which are not part of the baseline system in WP1, including nuclear power and the potentials of new bio-fuels and hydrogen power technologies and their usage in different sectors. The procedure of improving the model systems will be iterative involving strong interactions and feedbacks between WP2 through WP5, since emission scenarios associated with the economic optimization will differ as the models will be improved (see Figure 1).
The improved model systems will include further development of the Balmorel integrated model [Ravn, 2001, Nielsen and Karlsson, 2006] by implementing health effects/cost functions (based on WP3 and WP4 outputs) in the optimisation, and adjoint ACT models, based on the variational approach [Penenko and Baklanov, 2001; Baklanov, 2007], for optimisation and sensitivity studies.
Basically the modelling future scenarios for energy systems will be realised on tree levels: Denmark (and the Nordic countries), Europe and the Northern Hemisphere. This involves modelling energy demand, including energy for transportation, and energy supply. Compared to WP1 the models in WP5 are expanded to model demand for energy and to include externality cost-functions derived from WP3 and 4.
An important part will be to evaluate and understand the sensitivity of the results due to uncertainties in the cost functions and model parameters and due to the actual choices of basic scenarios for WP6.

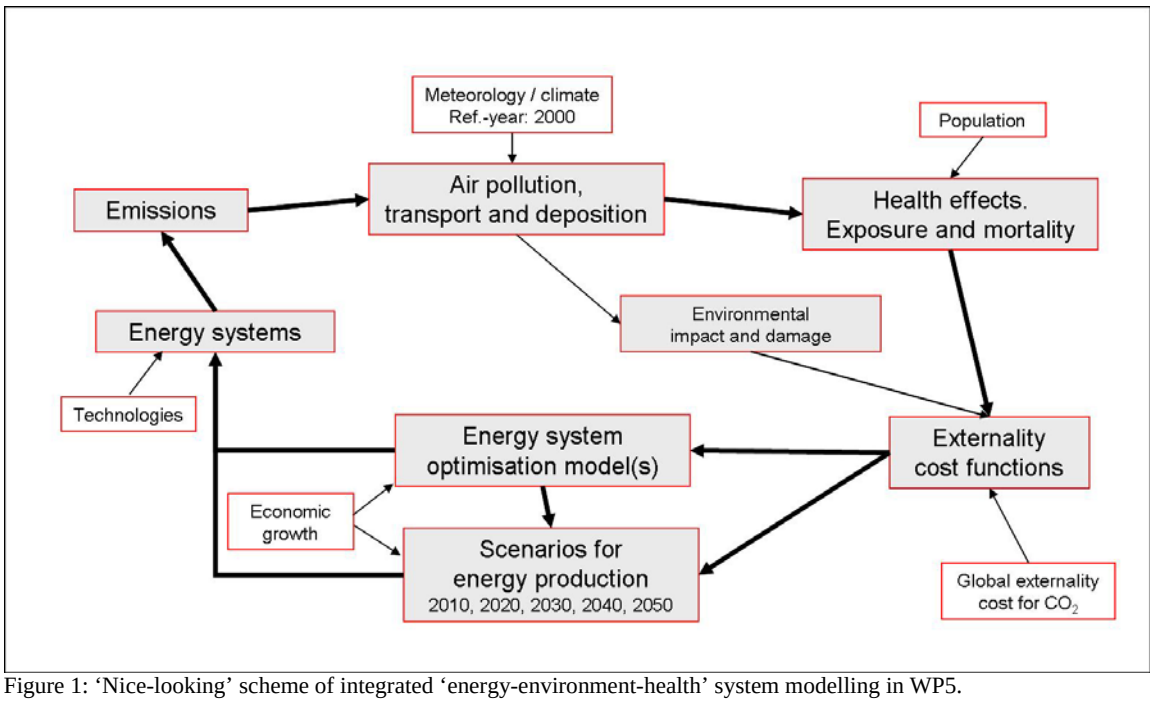


Figure 1: 'Nice-looking' scheme of integrated 'energy-environment-health' system modelling in WP5.

Interaction with other WP's

WP5 will use inputs from WPs 1, 2, 3, 4, interactions/feedbacks with WP2, and provides output to WP6.

List of activities

5.1. Building of the integrated 'energy-environment-health' modelling strategy (system) and construction of different cost functions following the main scenarios.

5.2. Expanding the energy market Balmorel modelling system to include health impact costs in the optimization of a future energy system.

5.3. Development of new generation models for sensitivity, risk/impact minimization and optimization studies, based on the variational approach, adjoint equations and control theory methods.

5.4. Sensitivity study how different energy types and scenarios will impact reduction of air pollutant emissions, and improve air quality, public health and the environment.

External collaboration partners

Cooperation with the NEEDS, EnviroRISKS & SUSTEL EC 6FP projects, TIMES community, IIASA, ICMMG, VITO, KTL, and more.
With Danish/Nordic aspect there will be synergies with other projects involving Risø: "Comparing hydrogen storage and international electricity trade". The project is financed by EFP 2005 and is running until the end of 2007. The Balmorel as a part of the project

expanded with hydrogen technologies. At European level there are several EU funded projects relevant to CEEH where DMI and Risø are participating, e.g.: (i) NEEDS (www.needs-project.org) is build a TIMES model for EU-29 plus Norway, Iceland, Rumania. This model includes modelling of energy demand (including transport), trade of some aggregated commodities and supply of energy; (ii) FP6 CA "Man-induced Environmental Risks: Monitoring, Management and Remediation of Man-made Changes in Siberia" (Enviro-RISKS) results relevant multidisciplinary studies and methodological approaches for WP5. See further separate document.

Ph.D. and post doc projects

• Optimisation models for environmental risk/impact studies (DMI)
• Economic optimisation of future energy systems including externalities (RISØ)
• Importance of on-line integrated versus off-line modelling of dispersion and chemical/physical evolution of anthropogenic aerosols (KU)
• Modelling the impact of air pollution on public health and the implications on health economy (CAST/SIF).
• Health and social economic consequences of different strategies for future energy supplies in collaboration with Risø.

Diagram showing the activity plan for WP5 tasks (#)

WP #	Lead	Year 1		Year 2		Year 3			Year 4		Year 5		PMs.
5.1	DMI												**25**
5.2													**20**
5.3													**25**
5.4													**25**

WP5 milestones for the first year of CEEH:

Milestones for the first year. Responsible partner for each milestone is indicated in parenthesis.

Milestone Number	**Milestones**	**Time**	**Input to and output from other WPs**
5-1-a	Formulation of the PhD topics and involving new PhD students (responsible partners: DMI, Risø, KU).	31/10 2007	WP5 in coop. with WP1-6
5-1-b	Defining an optimal scheme for integrated 'energy-environment-health' system modelling (DMI, Risø, KU, DMU)	30/11 2007	WP3, WP6
5-1-c	Defining data exchange between the energy system models, atmospheric models and emission models (KU, DMI, Risø)	31/12 2007	WP1, WP2
5-1-d	Expanding the energy market Balmorel modelling system to include new transport, electricity and heat demand modules (Risø)	31/12 2007	WP1, WP6

WP5 milestones (for 5 years):

Milestone Number	Milestones	Time	Input to other WPs
5a	Improved modelling system for optimization of the energy production and consumption including environmental and health impact constraints	Years 3 & 4	WP5 & ?
5b	Database including the model results available for other partners	Year 5	WP6

Additional Information for WP5 work planning:

Risø team contribution:

European level and the Northern Hemisphere:

- Define data exchange between the energy system models, atmospheric models and emission models
- Include new cost-functions in the models based on WP3 and 4
- Run scenarios with the scenario-parameters from WP1
- Sensitivity analysis

Denmark and the Nordic countries:

- Define level of data exchange between the chosen models for Europe and Balmorel
- Define data exchange between Balmorel and local emission models
- Expanding Balmorel with a transport module
- Expanding Balmorel with an electricity and heat demand module
- Include new costs-functions in the optimisation in Balmorel
- Run scenarios with the scenario-parameters from WP1
- Sensitivity analysis

DMI team contribution:

DMI will in WP5 be responsible for:

1. coordination of the WP activities,

and will contribute with:

2. development of models for sensitivity, risk/impact minimization and optimization studies, based on the variational approach, adjoint equations and control theory methods;
3. data exchange between and linking the energy system models (e.g. Balmorel) and atmospheric pollution models;
4. sensitivity study for environmental risk/impact assessments: how different energy types and scenarios will improve air quality.

Subtasks for other participants:

- NERI: Upgrading existing cost functions, participation in optimisation and sensitivity studies

- Risø, NERI, UoC: Using data from ETSAP models in atmospheric pollution models.

References:

Baklanov, A.: Environmental Risk and Assessment Modelling – Scientific Needs and Expected Advancements. In: *A. Ebel and T. Davitashvili (eds.) Air, Water and Soil Quality Modeling for Risk and Impact Assessment, NATO Science Series,* Springer, **2007**, 29-44.

NEEDS EC project: www.needs-project.org

Nielsen, S. K., and K. Karlsson: Energy scenarios: a review of methods, uses and suggestions for improvement: *Int. J. Global Energy Issues*, 2006

Penenko, V. and A. Baklanov, Methods of sensitivity theory and inverse modeling for estimation of source term and environmental risk/vulnerability areas. *Lecture Notes in Computer Science*, **2001**, V. 2074, 57-66.

Ravn, H. et al.: Balmorel: A Model for Analyses of the Electricity and CHP Markets in the Baltic Sea Region. **2001**, www.Balmorel.com.

TIMES or MARKAL-TIMES models: www.etsap.org

WP6: Recommended scenarios for Denmark

Participants: NERI, Risø, UoC, SDU, DMI

Objectives and methods

The purposes of WP6 are:

1) to build an integrated optimisation and assessment system based on the results from WP1-WP5,
2) to make an integrated assessment of the various optimised air pollution scenarios and their impacts on human health as well as ecosystems on a national and trans-national level,
3) to quantify the uncertainties related to the integrated assessment, and
4) to disseminate the results as recommended energy scenarios for the decision makers as well as for the general public.

The major output of this WP will be a set of recommendations for Denmark, including the optimal solutions for energy production, consumption and impacts, optimised with respect to minimal cost including all possible externalities. The integrated assessment will be carried out for a number of years, including the year 2000 as a reference, as well as assessments for the years 2010, 2015, 2020, 2030, 2040 and 2050. In this way realistic scenarios can be made on the short-term, including current legislations, e.g. the NEC directive and the EU thematic strategy on air pollution in Europe; and feasible scenarios can be made on the long-term, where the full effects of a change in energy production and consumption are seen.

All major results will be published in scientific and popular journals. The policy relevant results will be disseminated directly to the decision makers and the general public via reports and the news media. The major outcome of the WP is to generate a strong inter-disciplinary scientific basis for assessing and develop the optimal energy policy for Denmark for the first half of the 21st century.

Interaction with other WP's

This WP will have interaction with all other WPs. Input from the WPs will be to update methods and data used in the impact pathway chain.(the EVA system). Scenarios are needed from WP1, Models are needed from WP2, Quantification of the health impacts are needed from WP3 and WP4 and the optimisation system is needed from WP5.

External collaboration partners

See separate document.

Ph.D. and post doc projects

COGCI PhD at DMU with the title "Impacts of climate change on air pollution levels in the Northern Hemisphere with special focus on Europe and the Arctic" will be connected to this WP. Part of the PhD will cooperate with CEEH to estimate external costs of climate change.

List of activities

The main tasks in WP6 are:

6.1 Screening of policy relevant scenarios already carried out in e.g. the EU, USA, etc., to assess limitations and possibilities in the scenario definitions.
6.2 Running the integrated assessment system for the year 2000 and evaluate the environmental and human health effects for this year. Year 2000 will be used as a reference for the scenario results.
6.3 Apply and optimise the different scenarios of energy consumption in the integrated model system developed in WP5 to produce forecasts for the years 2010, 2015, 2020, 2030, 2040 and 2050.
6.4 Assessment of environmental and human health effects for various energy and scenario types for the years mentioned in the previous item.
6.5 Assessment of uncertainties in the integrated assessment using Monte Carlo simulations.

The timing of the activities is outlined in the table below.

	Lead	Year 1		Year 2		Year 3		Year 4		Year 5	
6.1	NERI										
6.2											
6.3											
6.4											
6.5											

WP6 milestones for the first year of CEEH:

Milestones specifically for the first year and generally for the following years.

Milestone Number	Milestones	Time	Input to and output from other WPs
6-1-a	Systems design on the integrated optimization and assessment system. Establishment of the impact pathways based on the EVA system	31/12 2007	Input from all WPs
6-1-b	Preparation, setup and documentation of the EVA system (External Valuation of Air pollution) for use in the Centre. Publication as popular scientific paper.	31/12 2007	Input from all WPs
6-1-c	Preparation of paper about the interaction of CEEH with the AirGis system for human exposure on address level and utilisation in CEEH.	31/12 2007	
6-1-d	Screening of policy relevant scenarios for the baseline emissions – e.g. with focus on the IPCC scenarios.	31/10 2007	Input from WP1
1-1-x	Running the integrated assessment system for the base year 2000 and evaluate the environmental and human health effects for this year. Year 2000 will be used as a reference for the scenario results.	1/7 2008	
6-5-a	Report including an integrated assessment of recommended scenarios for Denmark	31/12 2011	
6-5-b	Report including the main assumptions, conclusions and recommendation written in a non-scientific language published in Danish	31/12 2011	
6-5-c	Press releases as well as articles in newspapers, etc. describing the main results from the Centre	31/12 2011	

WP7: Centre Management and Dissemination

Participants: All partners with UoC as lead.

Objectives

The **purpose** of this WP will be

- to ensure that the Centre objectives are fulfilled and the deliverables are achieved on time and according to the budget,
- to provide the overall co-ordination of the project,
- to ensure dissemination of project related information,
- to arrange the CEEH meetings/conferences/education program,
- to arrange steering board meetings.

Daily Management

The Centre administration will be located at UoC. The director of CEEH and a half time Centre manager will take care of the daily scientific work as well as administrative work. An important part of the Centre administration will also be to manage the CEEH home page. This web-site will be used both for dissemination of the CEEH results to the public and as a day to day management tool with logon facilities for the partners. The steering board meetings including external members will be arranged, at least, once every six month.

Scientific interactions and exchange program

In general the "CEEH-month" will be planned to maximise the interaction between the partners and the external collaborators.
There will be one scientific meeting (internal workshop or international conference) once a year. CEEH will host 2 international scientific conferences during its lifetime in the fields of the Centre to ensure outreach of the results. In addition to scientists also stake holders from ministries and politicians will be invited. There will also be arranged exchange programs and courses for the centres PhD students.

Outreach

The results obtained in CEEH will be disseminated in different ways according to the character of the findings. There will be a public outreach branch of CEEH including presentation on the Centre web-site. The director and the PIs have close contacts in the public media and will present results on TV and radio and via articles in the written press. In addition to the general description of the Centre, the web-site will include a newsletter, released when appropriate and at least once every second month. All collaborating

institutions including those from the private sector will be informed about relevant results on an ad hoc basis and at the meetings during the annual "CEEH-month".

External collaborations:

See separate document.

WP7 1.st year milestones:

Milestone Number	Milestones
7-1-a	Status report
7-1-b	Arrange steering board meetings
7-1-c	Arrange workshop in November 2007
7-1-d	Setup a CEEH homepage
7-1-e	Arrange CEEH-month and exchange programme

WP7 all-year milestones:

Milestone Number	Milestones
7a	Annual management reports
7b	Detailed status reports
7c	Workshops
7d	Conferences
7e	CEEH homepage management
7f	Exchange programme and PhD courses

List of all activities for WP7

7.1 Annual management reports, containing scientific and economical status of the Centre work in all WPs.
7.2 Detailed status reports
7.3 Arrangement of steering board meetings.
7.4 Set-up and management of the CEEH homepage.
7.5 Arrangement of workshops. All members of the Centre will meet
7.6 Arrangement of conferences.
7.7 Public Outreach
7.8 Arrangement of exchange programme for centre members and PhD students and PhD courses

Diagram showing the activity plan for WP7 tasks (#)

WP No	Lead	2007		2008		2009		2010		2011		2012		Person months.
7.1	UoC													4
7.2														4
7.3														4
7.4														4
7.5														4
7.6														4
7.7														---
7.8	all													---
		7a, 7e,	7c	7a	7c,7f	7a,7b, 7f	7d	7a	7c	7a, 7b	7d	7a,7b		