Minimization of impact on the environment and optimization of energy production/ consumption in Denmark

Centre for Energy, Environment and Health

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Abstract

The connection between air pollution, originating from the burning of fossil fuels, and human health has been well established for several years. Public concern about the consequences of air pollution on health, rising oil prices and the climatic impact of fossil fuel burning, has encouraged scientists to study these issues in more details. The combined problems of energy consumption and environmental safety in modern societies call for the need to develop new multi-disciplinary approaches and models considering the possible effects on human health and optimisation of the energy production/consumption and mitigation scenarios. The products from the Danish Centre of Energy Environment and Health (CEEH) will result in development of innovative energy production and consumption scenario management/ modelling system. Such a system could be applicable for decision-making with respect to present and future conditions, including climate, weather, and air quality related impacts on human health.

Our research is a part of CEEH studies and focused on optimization of type of energy production and consumption with respect to environmental and health impact. It is a part of CEEH modelling framework. To achieve this goal two models are used. The first model is BALMOREL - the Nordic power and district heating market model. The model takes into account explorative scenarios to open equal plausible energy futures based on variations in economic and social development, fuel prices and technological development. This model is linear optimisation model of the energy system with minimising total yearly costs in the system. It constraints balance equations for power, heat, and hydrogen balances and limitations like resource limits (e.g. max available biomass resource).

The second model is the Danish Emergency Response Model for the Atmosphere (DERMA). It is off-line 3D Lagrangian long-range dispersion model using a puff diffusion and particle-size dependent deposition parameterisations; and having two options of integration - forward and backward in time. It can use different meteorological data from numerical weather prediction models, such as regional DMI-HIRLAM (HIgh Resolution Limited Area Model) and global ECMWF (European Centre for Medium-Range Weather Forecasts) models with various horizontal resolutions.

Background

There is a challenge to construct an optimal scheme for integrated 'Energy-Environment-Health' modelling framework. The proposed interconnection between the modules is presented in Figure 1. The general idea is to put the modules into the chain and make iterations before we get converged optimal solution/ solutions for the future energy system of Denmark with minimal impact on human health and environment (Figure 2).

HIRLAM+CAMx

The off-line Eulerian Atmospheric Chemistry Transport (ACT) modelling system based on the HIRLAM (HIgh Resolution Limited Area Model), http://hirlam.org) + CAMx (Comprehensive Air quality Model with extensions, http://www.camx.com) had been run (in long-term mode) to simulate of atmospheric transport, dispersion and transformation of chemical species over the European domain (see example in Figure 3 of annual averaged surface concentration for the reference year 2000).

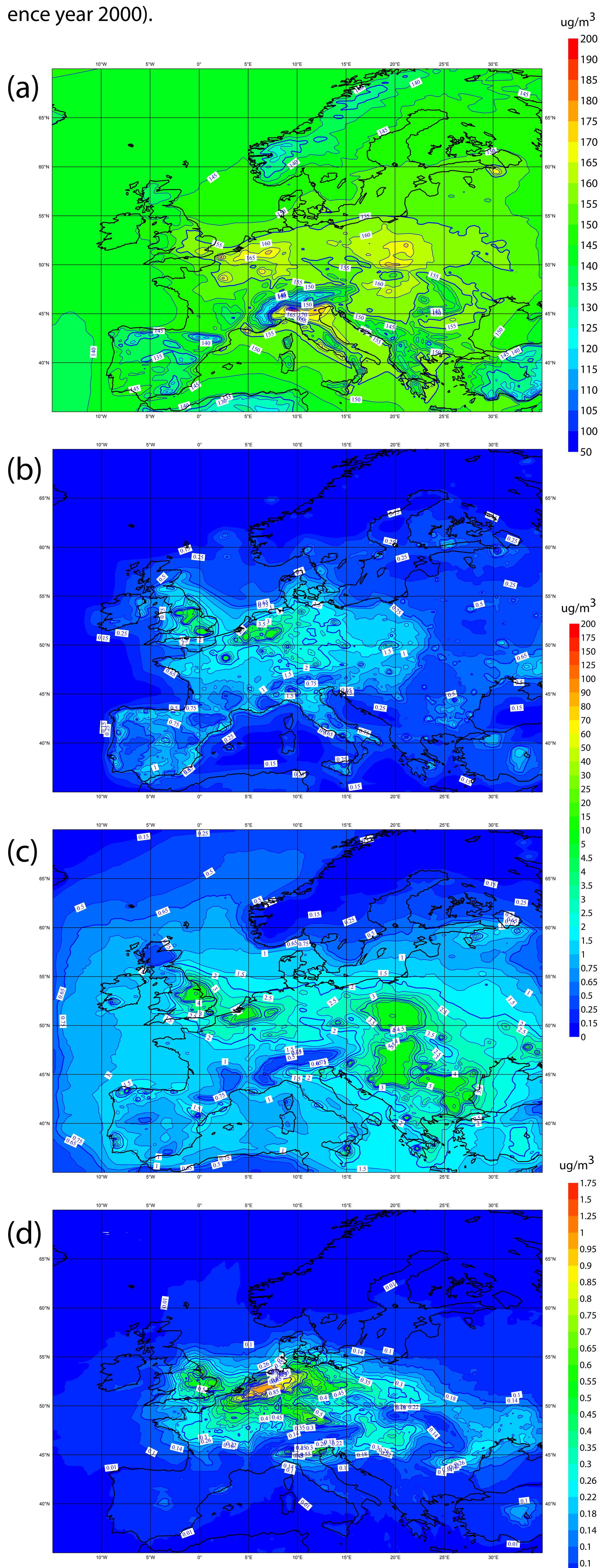

Figure 3 : Annual average for:
(a) carbon monoxide, (b) nitric dioxide, (c) sulphate, (d) nitrate for the year 2000 (based on HIRLAM+CAMx modelling).

Integrated Modelling Framework

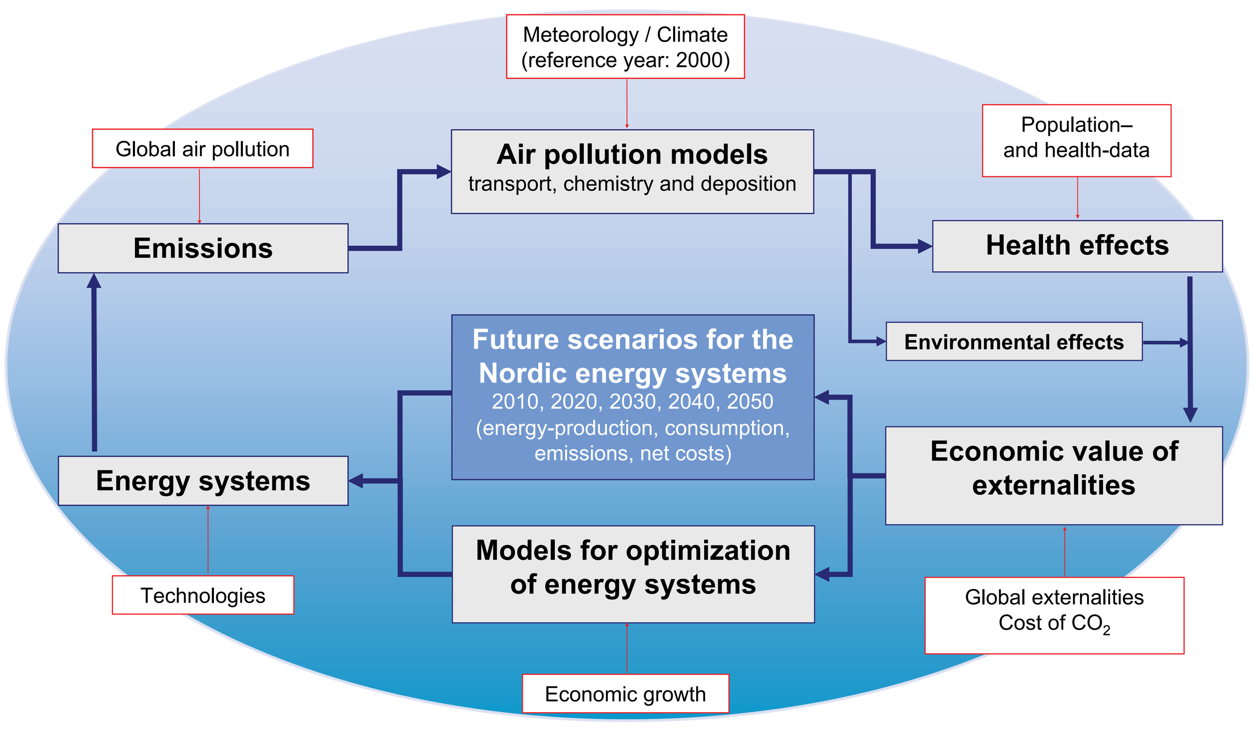

Figure 1 : Scheme of CEEH integrated modelling framework.

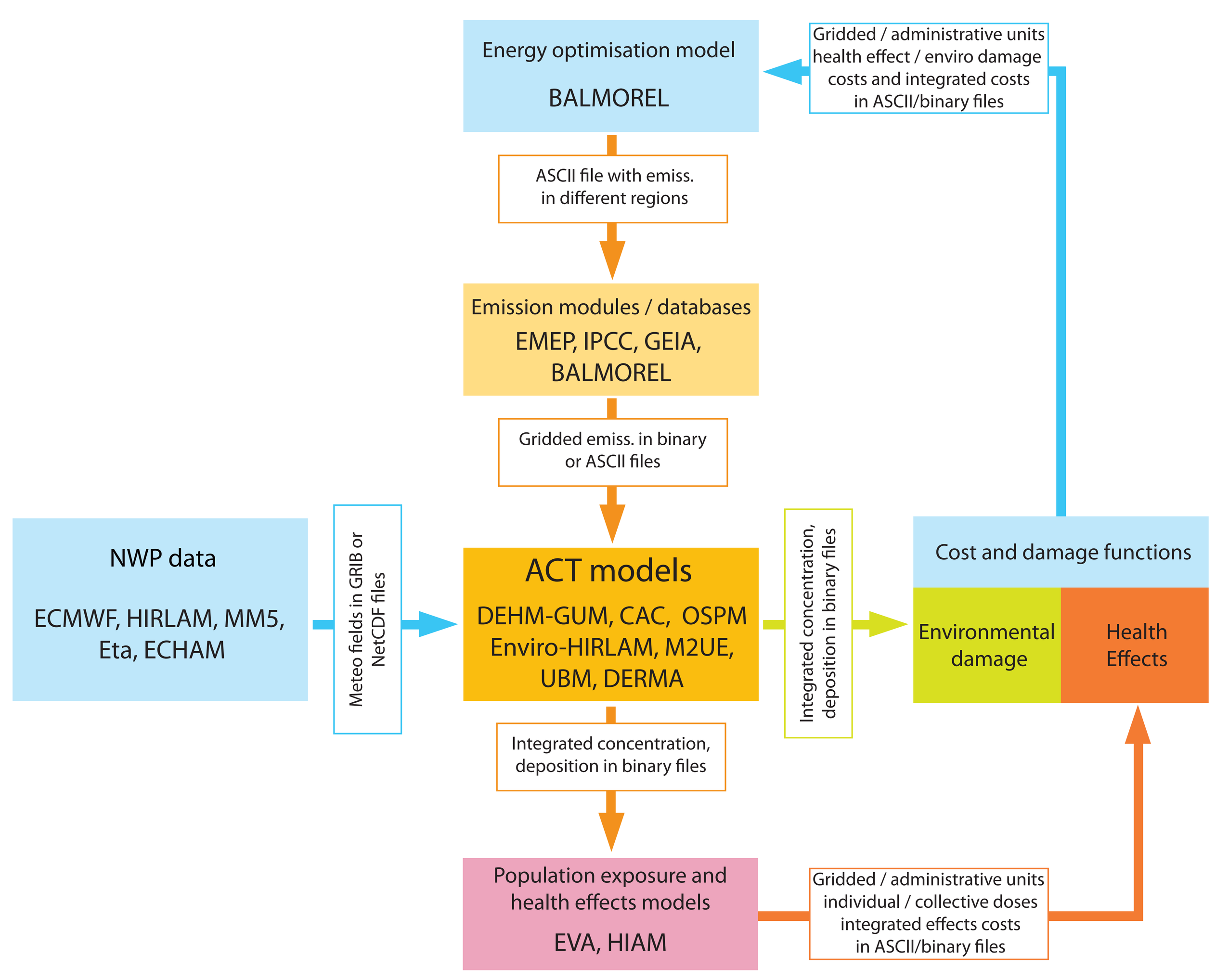

Figure 2 : Dataflow diagram and input/output file formats in the CEEH model framework.

BALMOREL

The next step is calculation of new emissions for Denmark (Figure 4) with BALMOREL (*Nielsen, Karlsson, 2007*; http://www.balmorel.com/) model (without/ with external costs); these model runs should cover all the scenario years. Then the exploration of the impact of different future scenarios (future emissions scenarios) will be done to find the level of externalities with an alternative global economic development and thereby another level of emissions.

The final step is focused on replacement of the cost functions (from EVA (External Valuation of Air Pollution) or HIA (Health Impact Assessment) model; *Baklanov et al., 2010*) used in the Baseline modelling system by new ones developed within CEEH. These will be done basing on the ACTM's runs for 2020, 2030, 2040 and 2050 with emissions from BALMOREL with and without externalities.

Table 1 : Overview of the combination of CO_2 price and inclusion of externalities in the model runs.

	Run1	Run2	Run3	Run4	Run5	Run6
Externalities	No	Yes	Yes	Yes	Yes	No
CO_2-price (€/ton CO_2)	0	10	25	50	0	50

The results of the optimisation process by means of BALMOREL with respect to the investments in new technologies (Table 1) up till year 2030 are shown in Figure 5a. The various runs differ according to the assumptions used: no inclusion of any externalities in Run1, different CO_2 prices (10, 25, and 50 EUR/tonne) in runs 2 to 4 together with constant prices for other pollutants, no CO_2 charge in Run5, and only CO_2 charge of 50 EUR/tonne in Run6. All of them are based on the same fuel prices from WEO 2007 (IEA 2007, http://www.iea.org/weo/2007.asp).

One can see how different technologies are favoured depending on the degree to which externalities are included and the corresponding price. For example, Run1 and Run5 (both do not include any CO_2 charge) contain investments in the coal-based technologies, but not wind. However, directly the opposite is valid whenever the CO_2 charge is in place. In Run6, which is characterised by the highest externality charges even the expensive Carbon Capture and Storage technology are introduced.

Emissions of CO_2 differ dramatically depending on the run (see Figure 5b). The minimum value achieved in the Run4 is approximately 35 times lower than the maximum observed in the Run1. Even though, no charge was applied for the CO_2 emission in the Run5, its level is considerably lower than in the worst case.

DERMA

The inverse technique of the DERMA model (*Sørensen et al., 2007*) was used for risk/ impact minimization of damaging effects on the environment and public health from new planned national power plants (Figure 6). The inverse modelling was applied for winter when energy consumption and heat production are the most substantial. Nine most populated cities (receptors) of Denmark (Copenhagen, Køge, Roskilde, Frederikssund, Hillerød, and Helsingor) and Sweden (Malmo, Lund, and Landskrona) were used for assessment from planned power plants with respect to areas with high potential risk and vulnerability on the Zealand Island (Denmark) and southern Sweden.

Several zones were identified for optimal construction of new plants which are in Amager Island and in the eastern coast of Zealand (Figure 6).

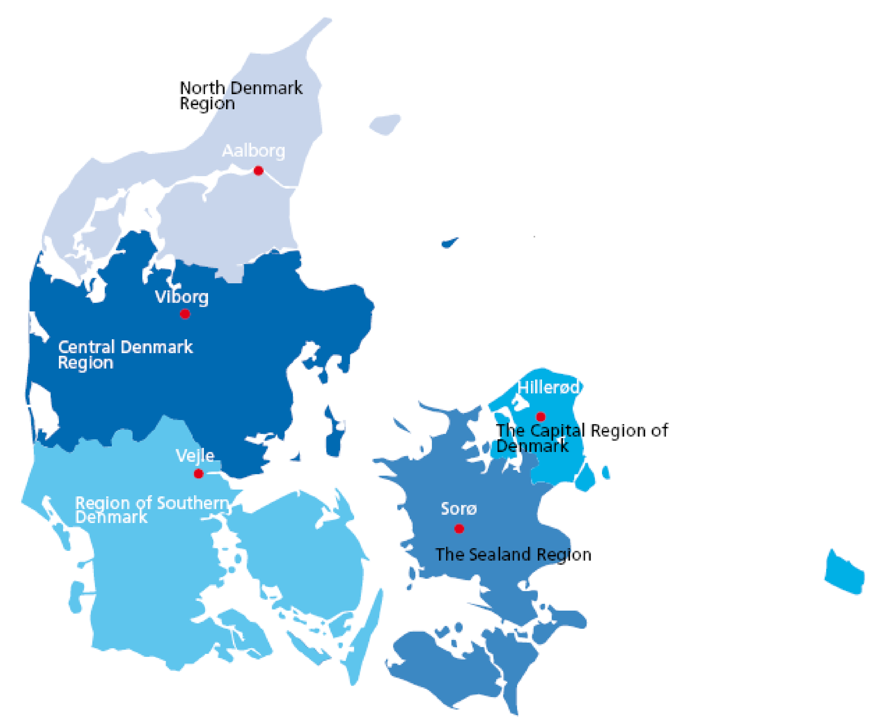

Figure 4 : Regions of Denmark used in BALMOREL simulations.

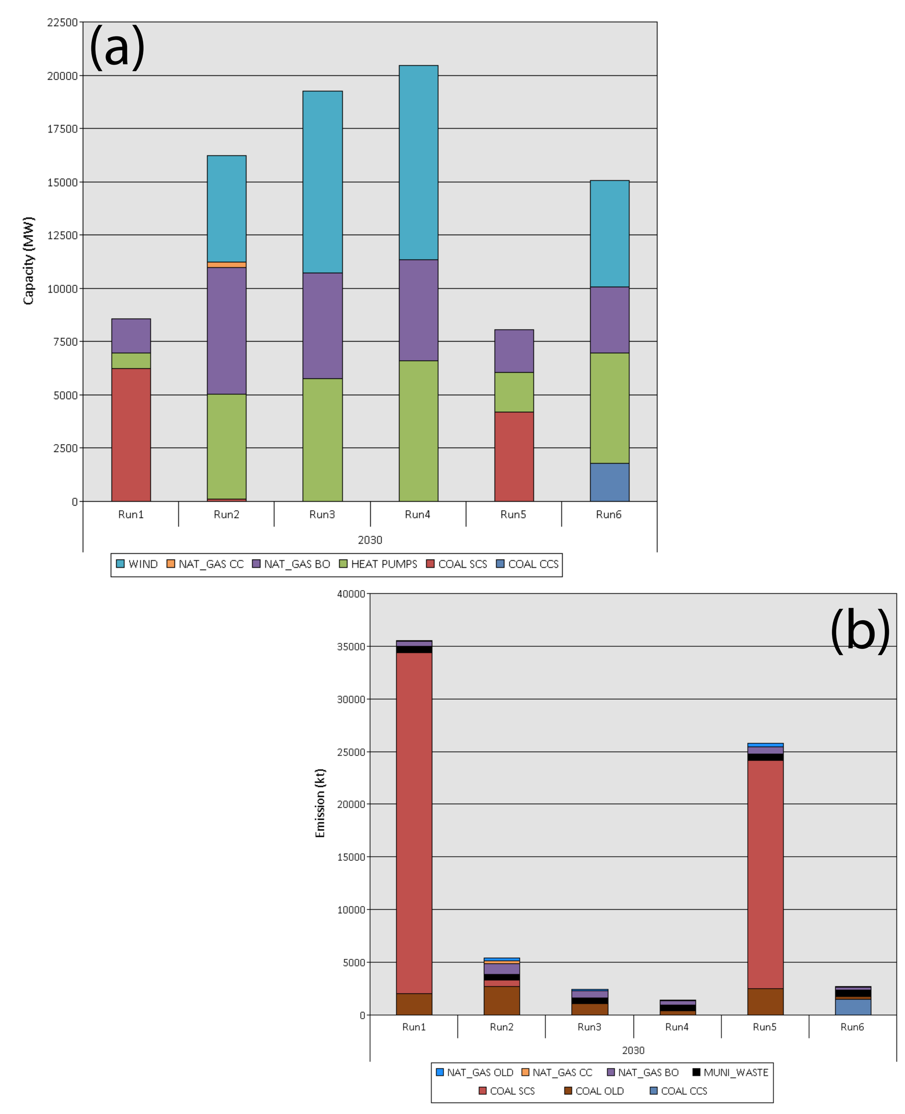

Figure 5 : BALMOREL (a) Heat and power generation capacity added during the simulation year; (b) CO_2 emissions from the heat and power generation in the simulation year from different fuels (*Baklanov et al., 2010*).

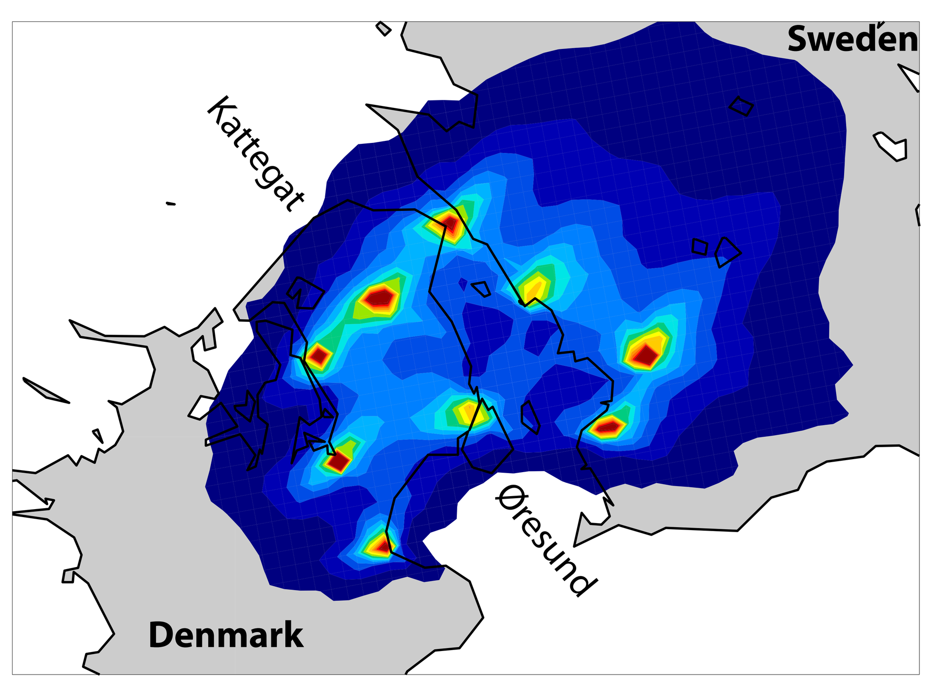

Figure 6 : Assessment (based on DERMA) of areas with high potential risk and vulnerability with respect to nine cities (receptors) of Denmark (Copenhagen, Frederikssund, Helsingør, Hillerød, Køge and Roskilde) and Sweden (Malmo, Landskrona and Lund).

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