

Optimisation of the Danish Energy System in the Light of Externality Cost

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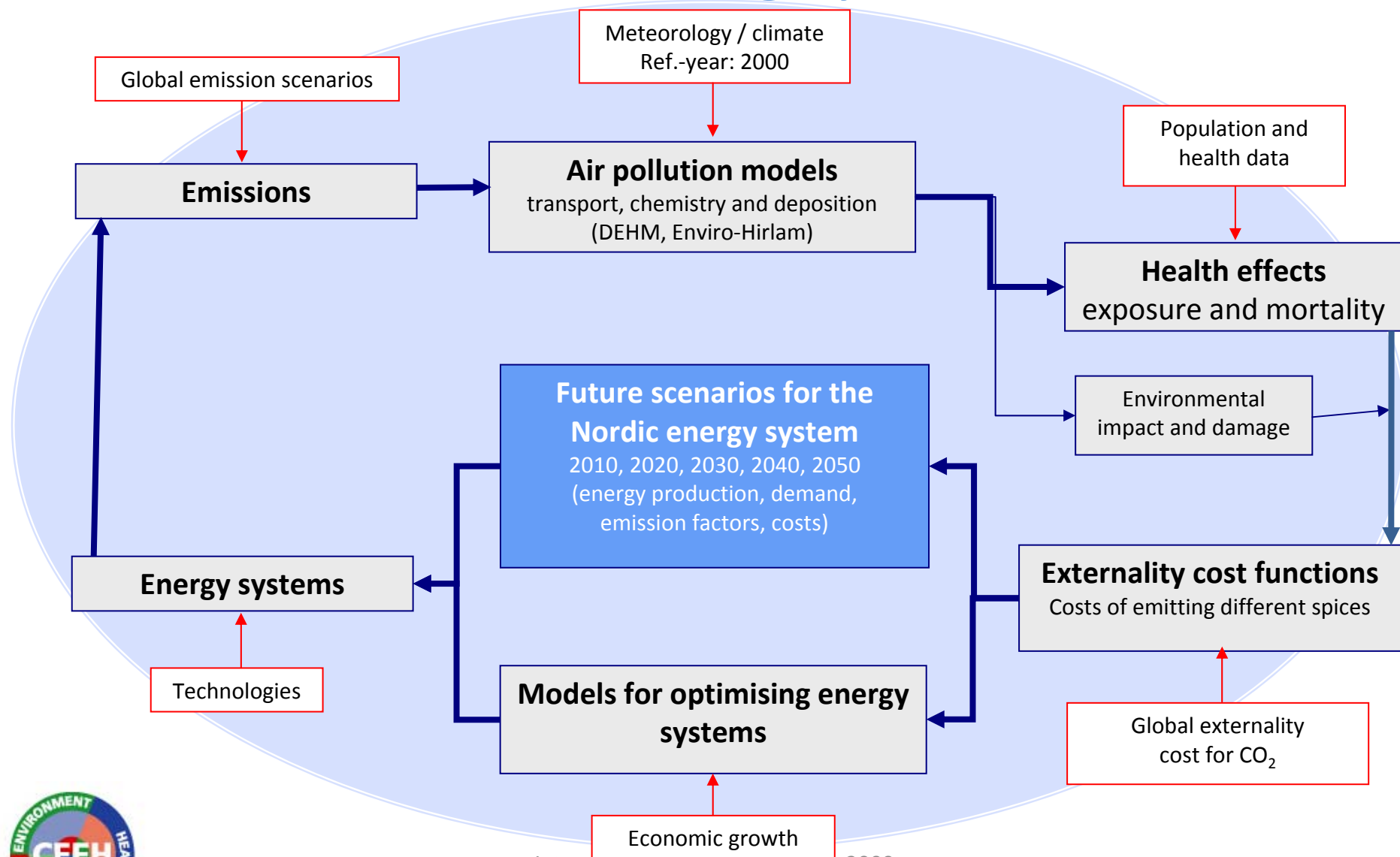
Agenda

A method for iterative/dynamic inclusion of health externalities in energy system optimisation

- model setup
- some preliminary results
- perspectives for such a system

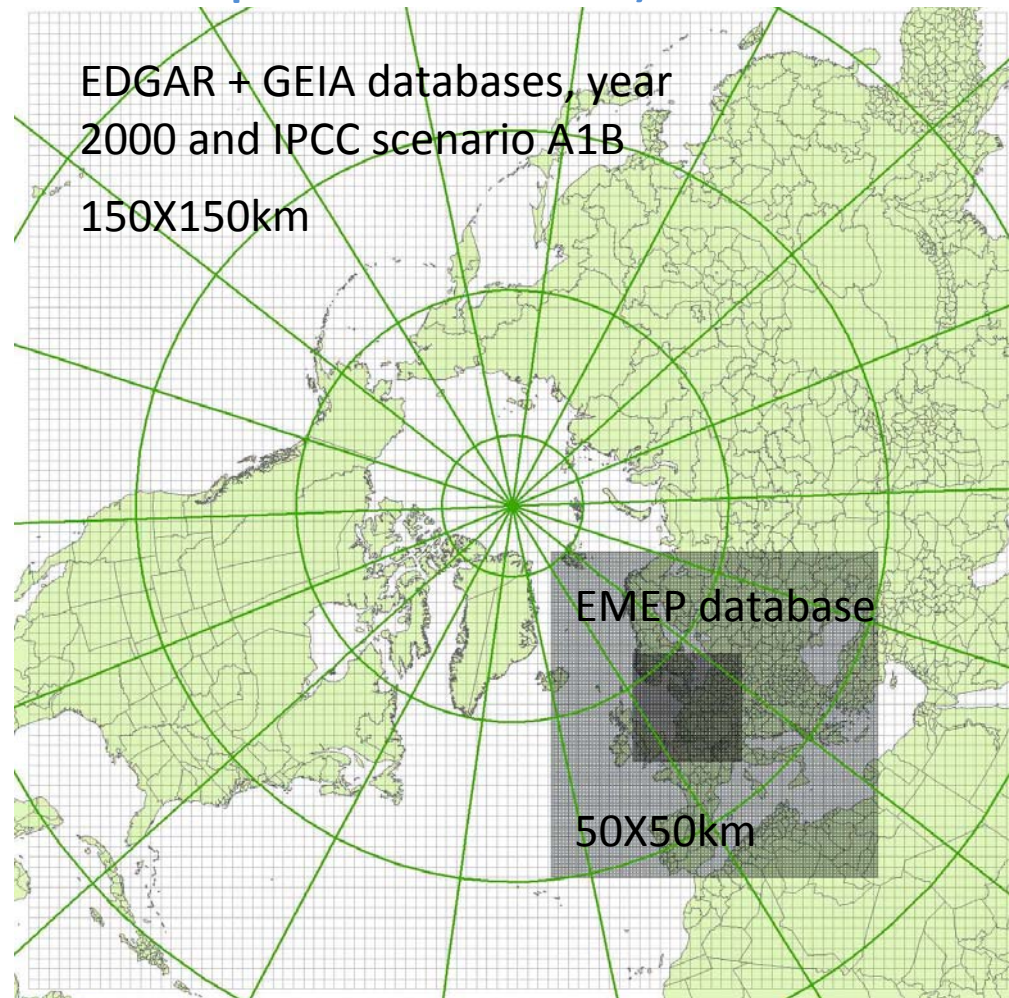


CEEH modelling system



DEHM (Danish Eulerian Hemispheric Model)

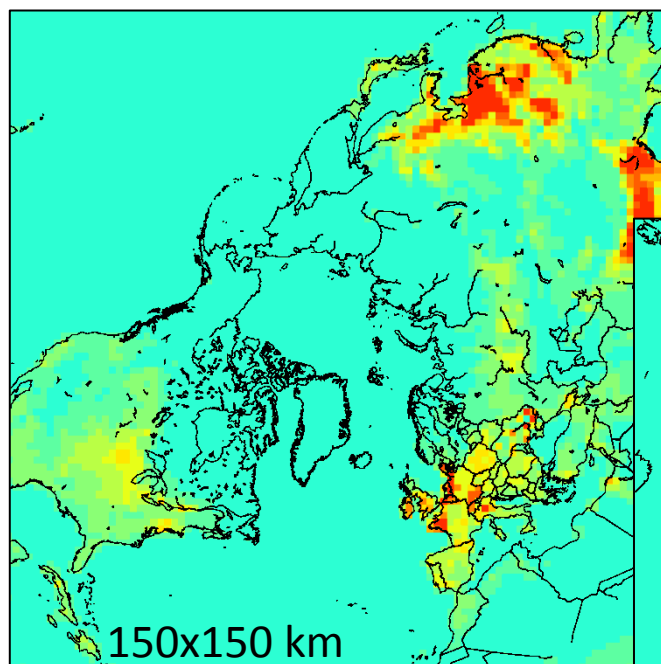
- Long-range transport of air pollution in the Northern Hemisphere and/or Europe
- Full three dimensional advection/diffusion equations, chemistry, and deposition
- Two-way nesting capability over Europe
- 150 / 50 / 16.67 / 5.56 km grid resolutions
- 29 vertical levels up to ~16 km
- Different DEHM flavours exist
- Model run and validation for a period of 20 years (1989 to 2008)
- Meteorological driver; MM5 nested over Europe or Eta (Europe)



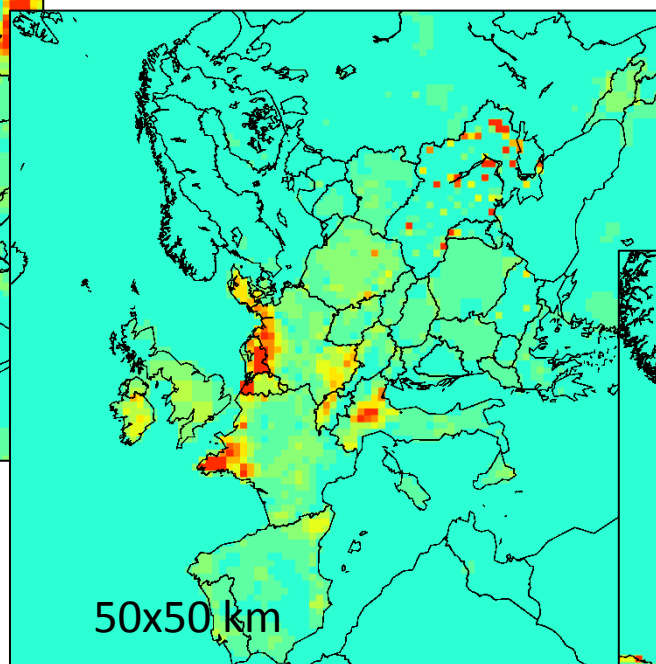
Domains in the DEHM System

from the Danish National Environmental Research Institute (NERI)

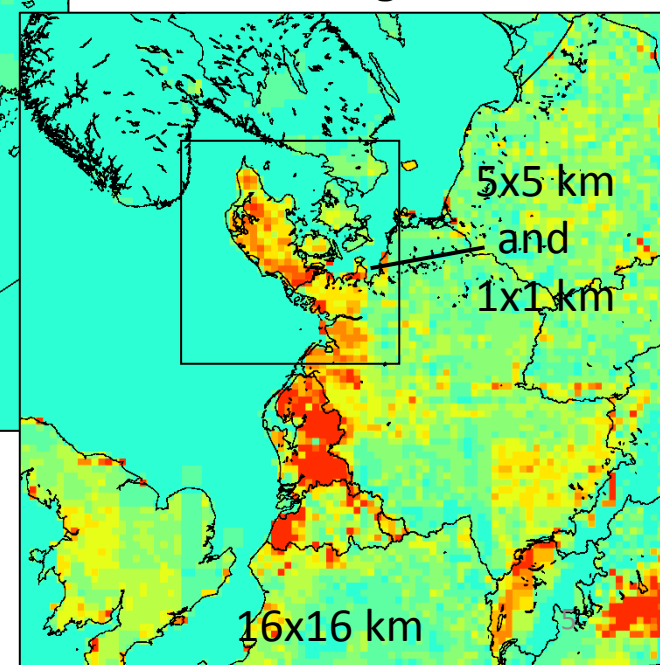
Hemispheric domain



Europe domain



Denmark and surroundings



First nest

Second nest

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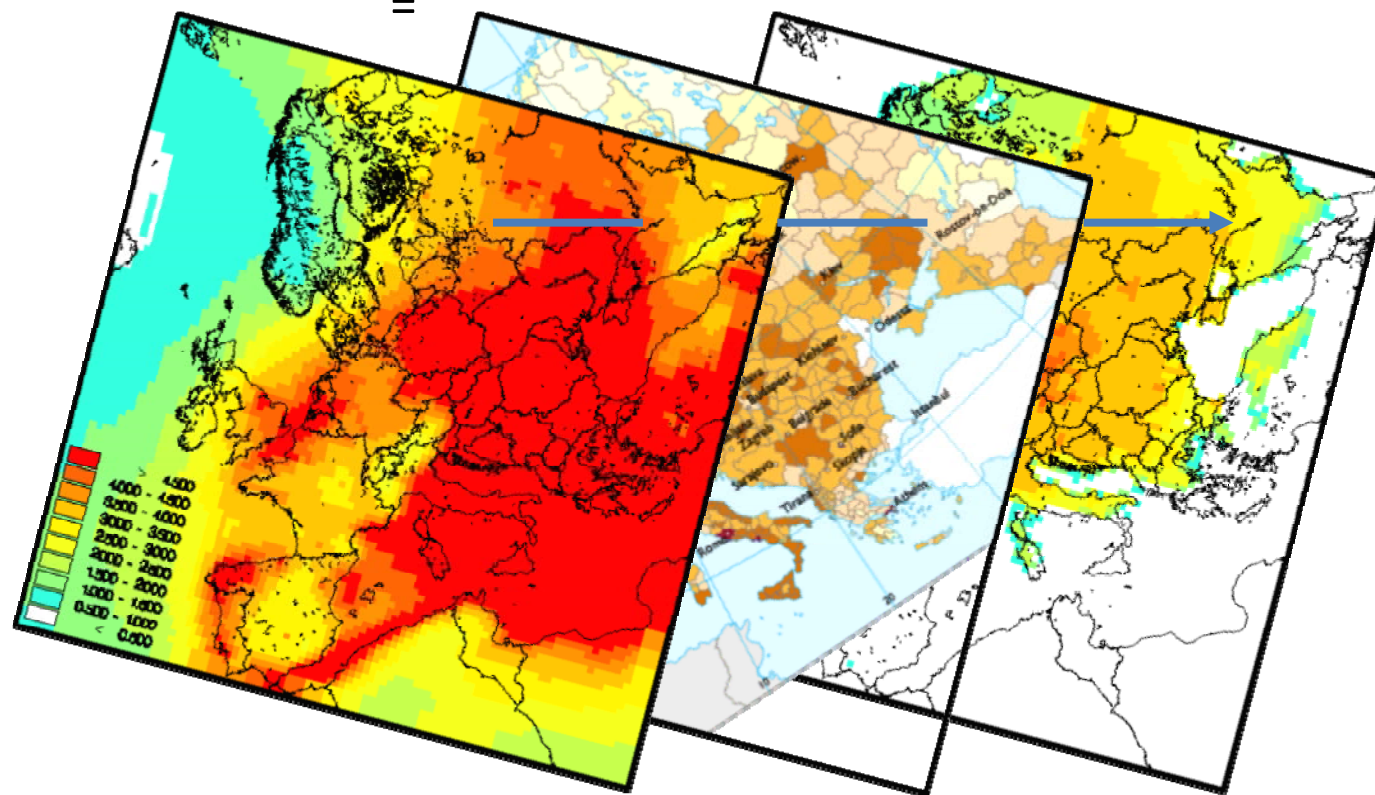
EVA-tool (Economic Valuation of Air pollution)

from the Danish National Environmental Research Institute (NERI)

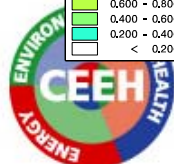
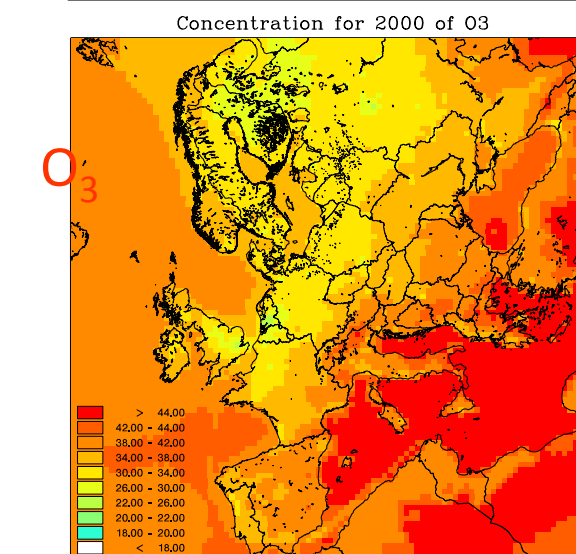
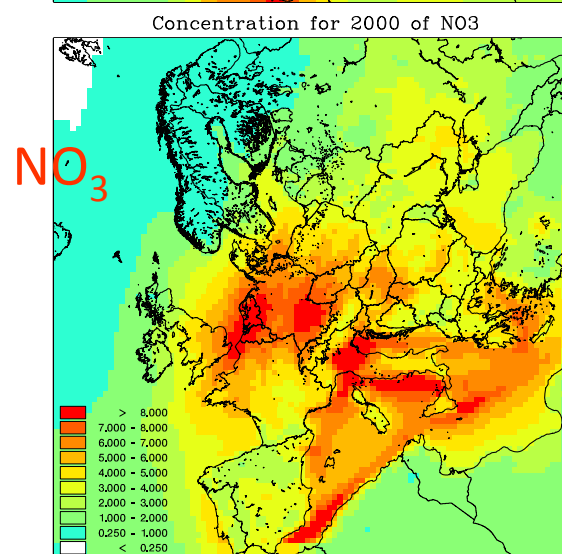
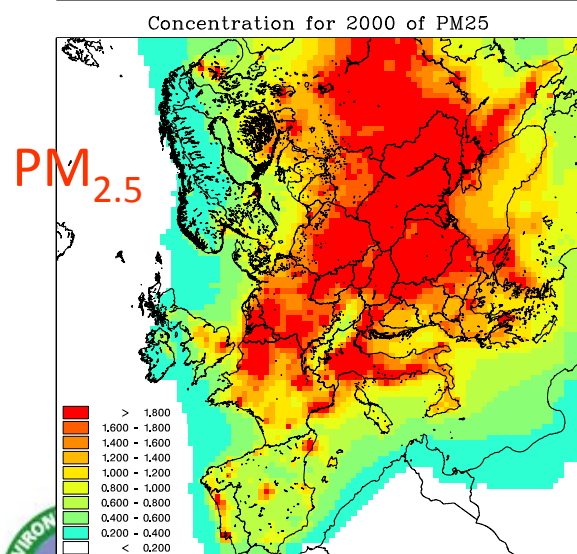
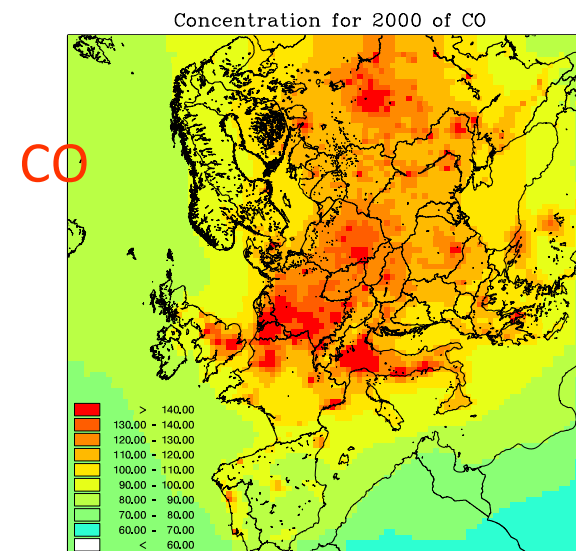
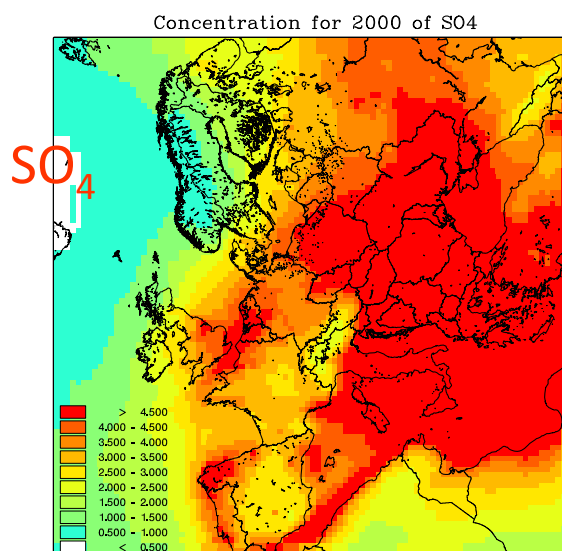
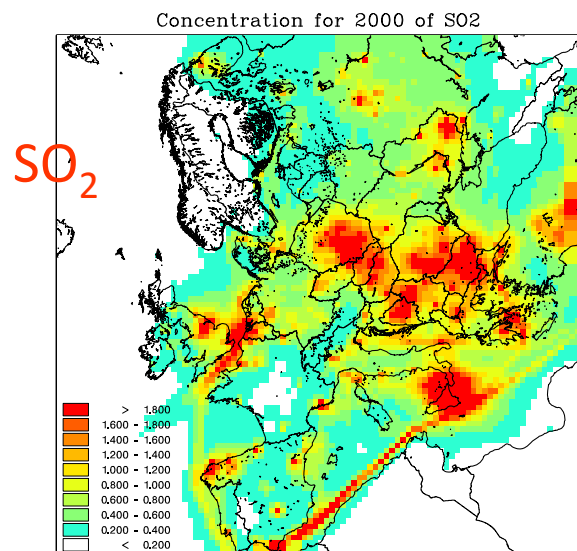
Concentration + Population

=

Exposure

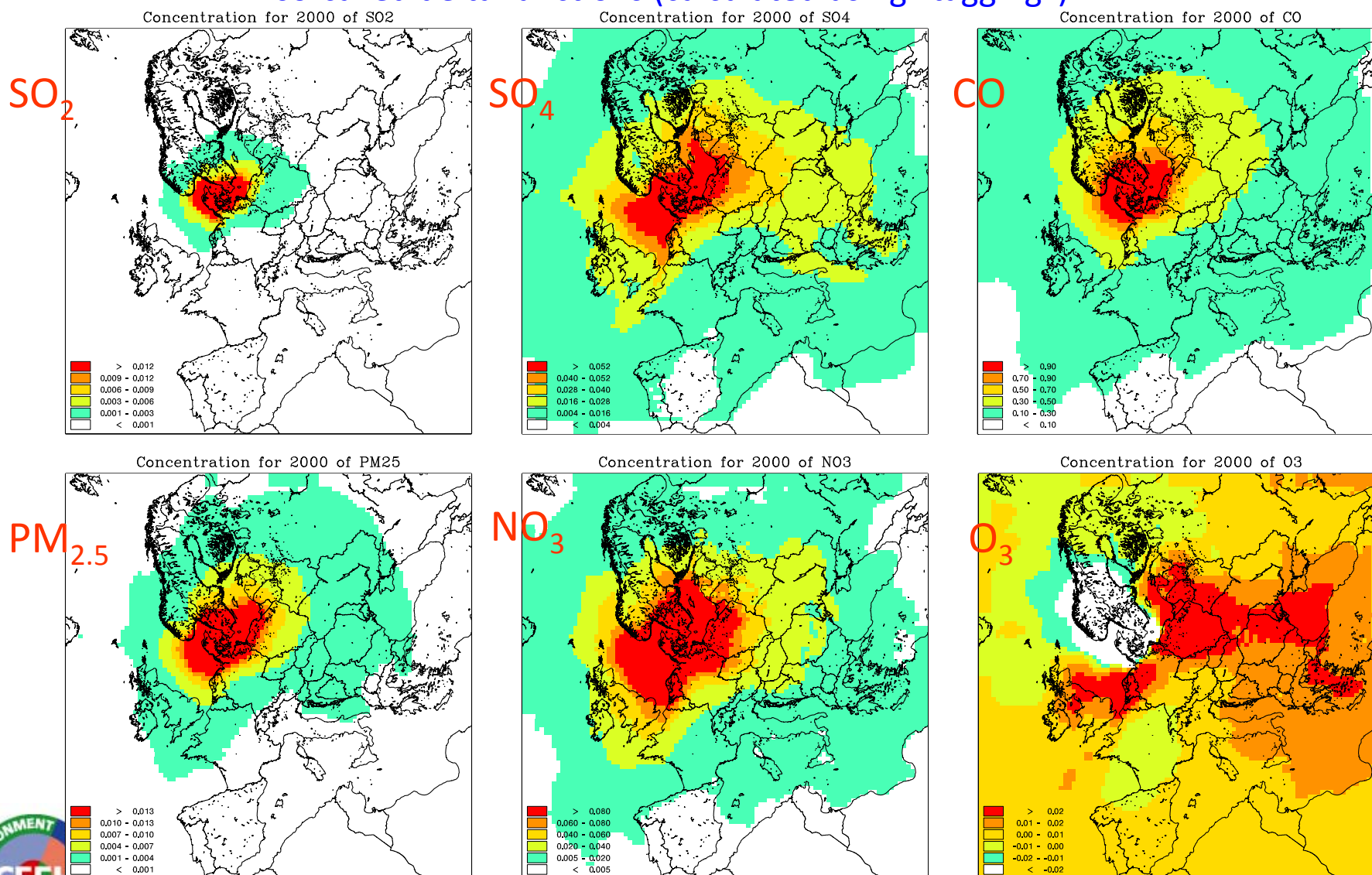


Annual Mean Concentration (2000)

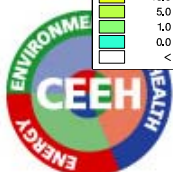
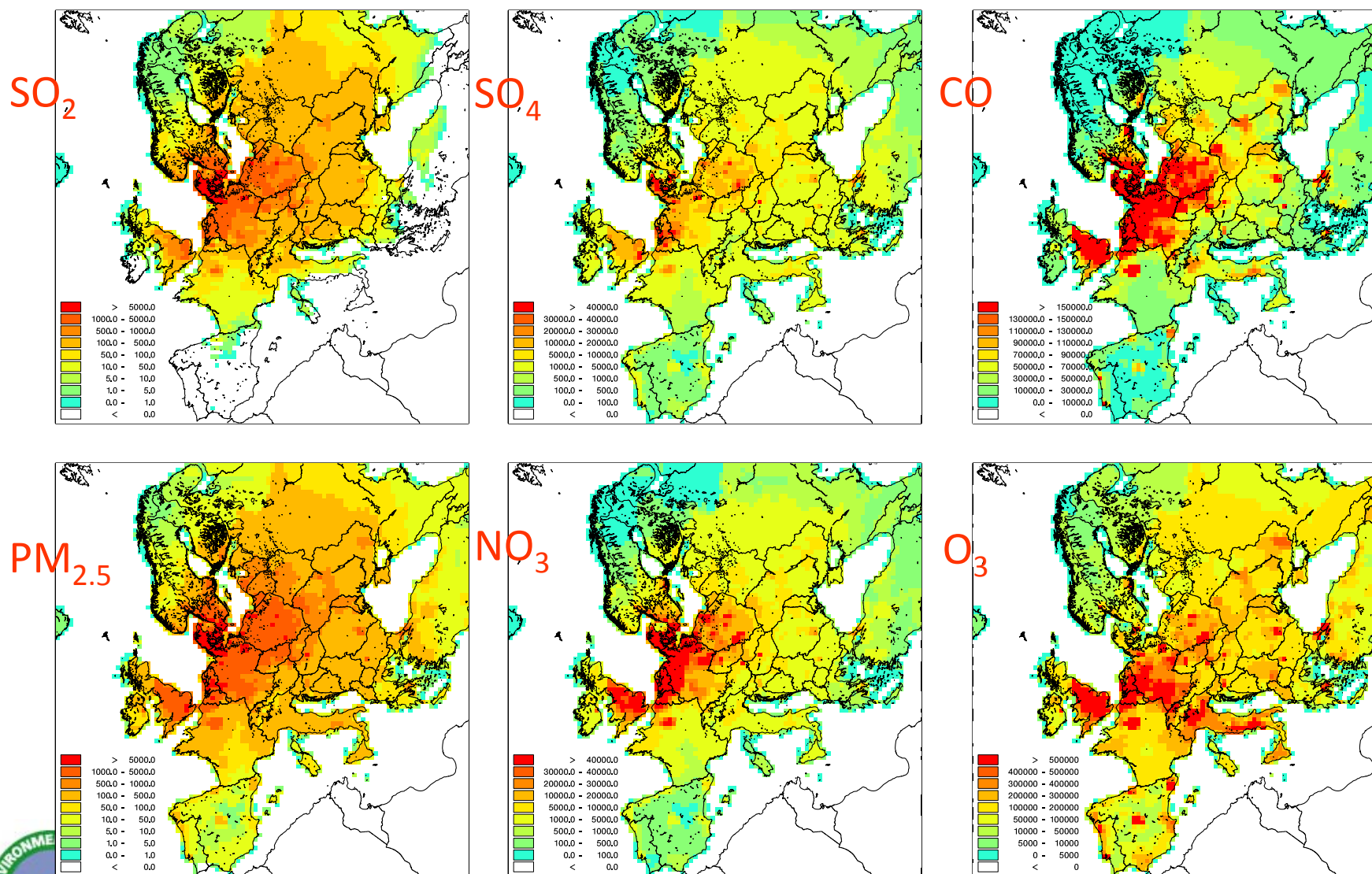


Contribution from Danish emissions to air pollution levels in Europe

so-called delta functions (calculated using “tagging”)



Human Exposure (2000)



<i>Health effects (response)</i>	<i>Exposure-response function</i>	<i>Valuation Euros (2006-prices)</i>
MORBIDITY (Particulate matter) (Valuation by Prof. Mikael Skou Andersen, AU, DK)		
Chronic Bronchitis	8.2E-5 cases/ μgm^{-3} (adults)	52,962 per case
Restricted activity days	8.4E-4 days/ μgm^{-3} (adults)	131 per day
Hospital admissions		
- respiratory	3.46E-6 cases/ μgm^{-3}	7,931 per case
- cerebrovascular	8.42E-6 cases/ μgm^{-3}	10,047 per case
Congestive heart failure	3.09E-5 cases/ μgm^{-3}	16,409 per case
Lung cancer	1.26E-5 cases/ μgm^{-3}	21,152 per case
Asthma children (7.6 % < 16 years)		
- bronchodilator use	1.29E-1 cases/ μgm^{-3}	23 per case
- cough	4.46E-1 days/ μgm^{-3}	59 per day
- lower respiratory symptoms	1.01E-1 days/ μgm^{-3}	16 per day
Asthma adults (5.9 % > 15 years)		
- bronchodilator use	2.72E-1 cases/ μgm^{-3}	23 per case
- cough	2.8E-1 days/ μgm^{-3}	59 per day
- lower respiratory symptoms	1.01E-1 days/ μgm^{-3}	16 per day
MORTALITY		
Acute mortality (SO ₂)	7.85E-6 cases/ μgm^{-3}	2,111,888 per case
Chronic mortality (PM)	1.138E-3 YOLL/ μgm^{-3} (>30 years)	77,199 per YOLL
Infant mortality (PM)	4.68E-5 cases/ μgm^{-3} (> 9 months)	3,167,832 per case
Acute mortality (O ₃)	3.27E-6*SOMO35 cases/ μgm^{-3}	2,111,888 per case

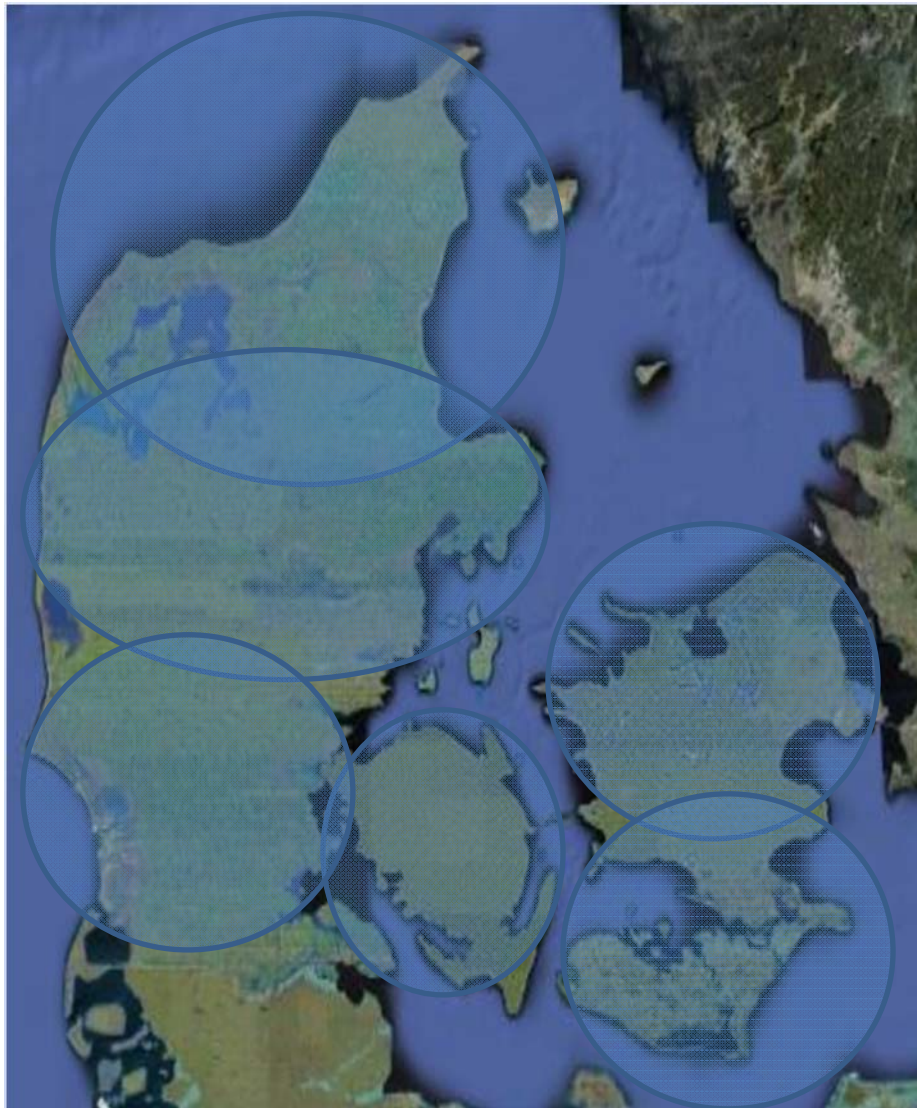
Total emissions, total cost and cost per kg emissions for the different sectors and different species (2006 prices)

	Total S			Total N		
Total Emissions	CEEH (€/kg)	SO2	NOx	CO	PM2.5	PM2.5
	Road traffic	32.6	9.2	0.0022	29.4	14.990.000
	Power plants	9.2	5.8	0.0008	10.9	2.120.000
	Ships	19.6	10.8	0.0009	----	720.000
Total cost	Indiv. heat	missing				-----
	DK road traffic	13.010.000	687.100.000	281.600	61.900.000	
	DK power plants	125.300.000	287.300.000	4.411	7.837.000	
	Baltic+Northsea ships	13.380.000.000	10.790.000.000	32.770	-	
Cost per kg emission		Euro/kg-S	Euro/kg-N	Euro/kg-CO	Euro/kg-PM2.5	
	DK all sectors	85,5	40,3	0,0020	21,4	
	DK road traffic	65,1	30,3	0,0022	29,2	
	DK power plants	18,2	19,3	0,0008	10,9	
	Baltic+Northsea ships	39,2	35,5	0,0009	-	

New method e.g. compared to ExternE's Ecosense model and existing Danish approach. Tracking emissions from whole sectors instead of point sources



Regional health costs

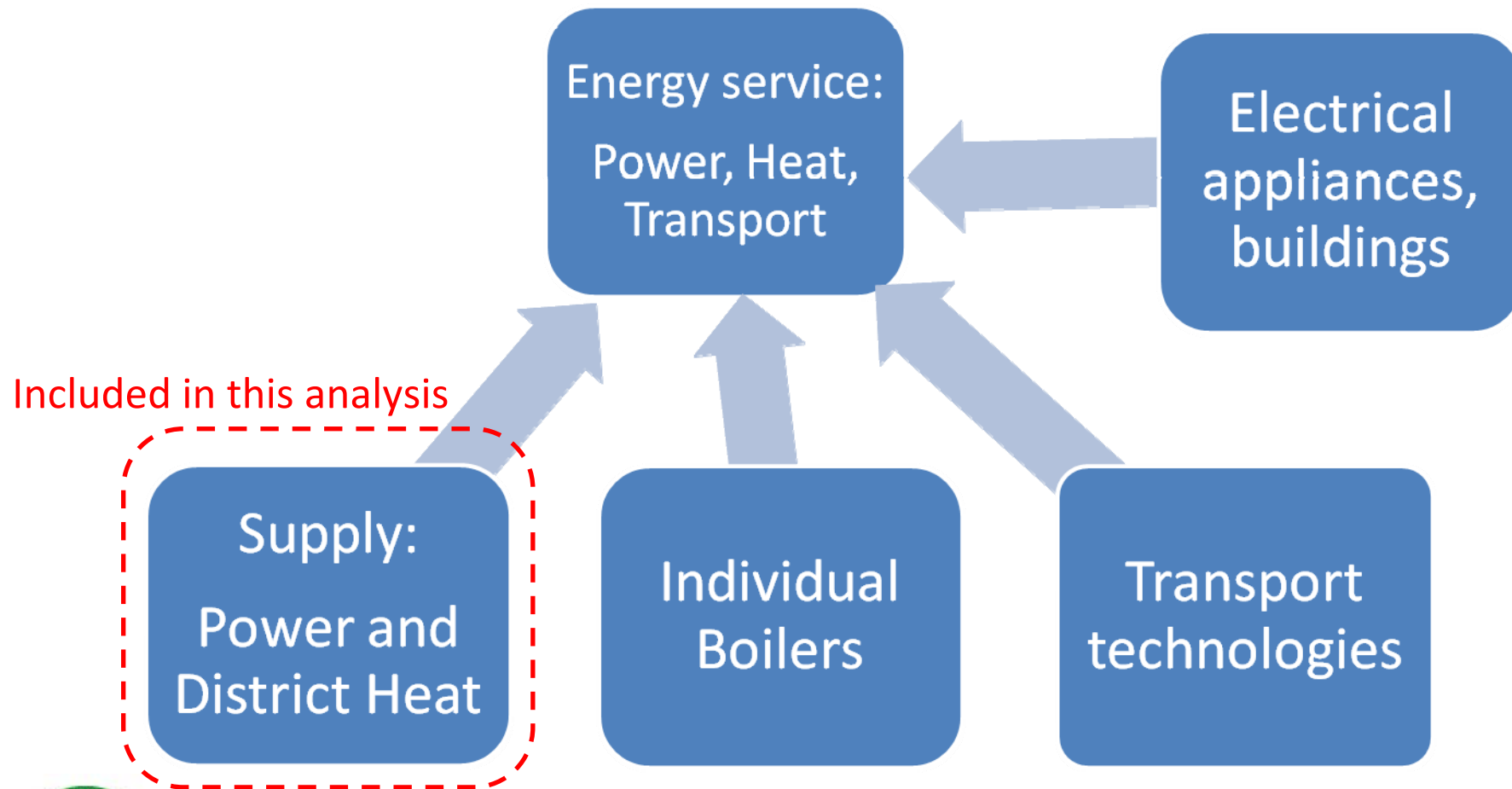


By running the air pollution model (DHEM) excluding smaller regions in Denmark one by one, sector by sector, it will be possible to find area specific health costs for each sector.

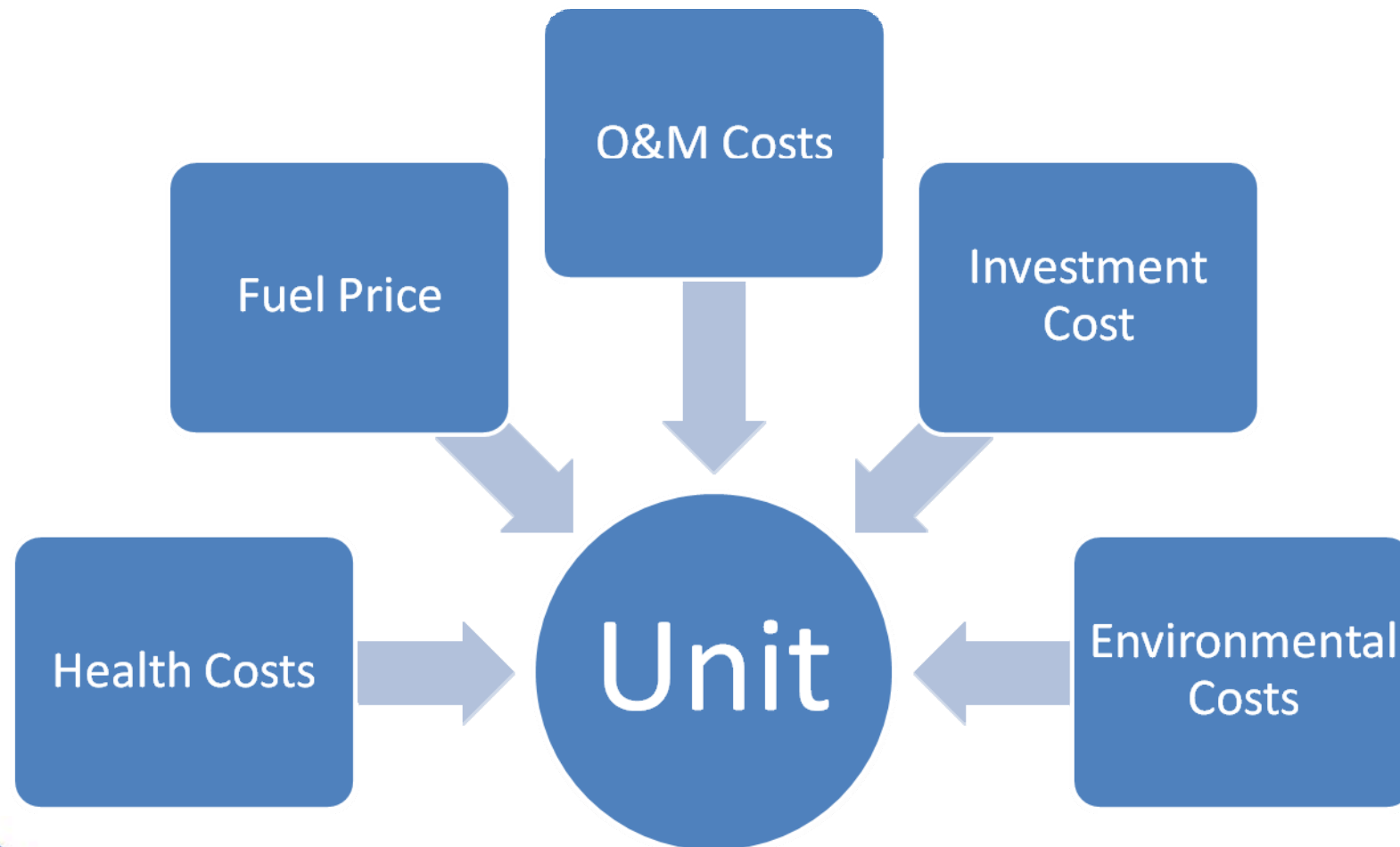
(This will be done in the next phase of the project)



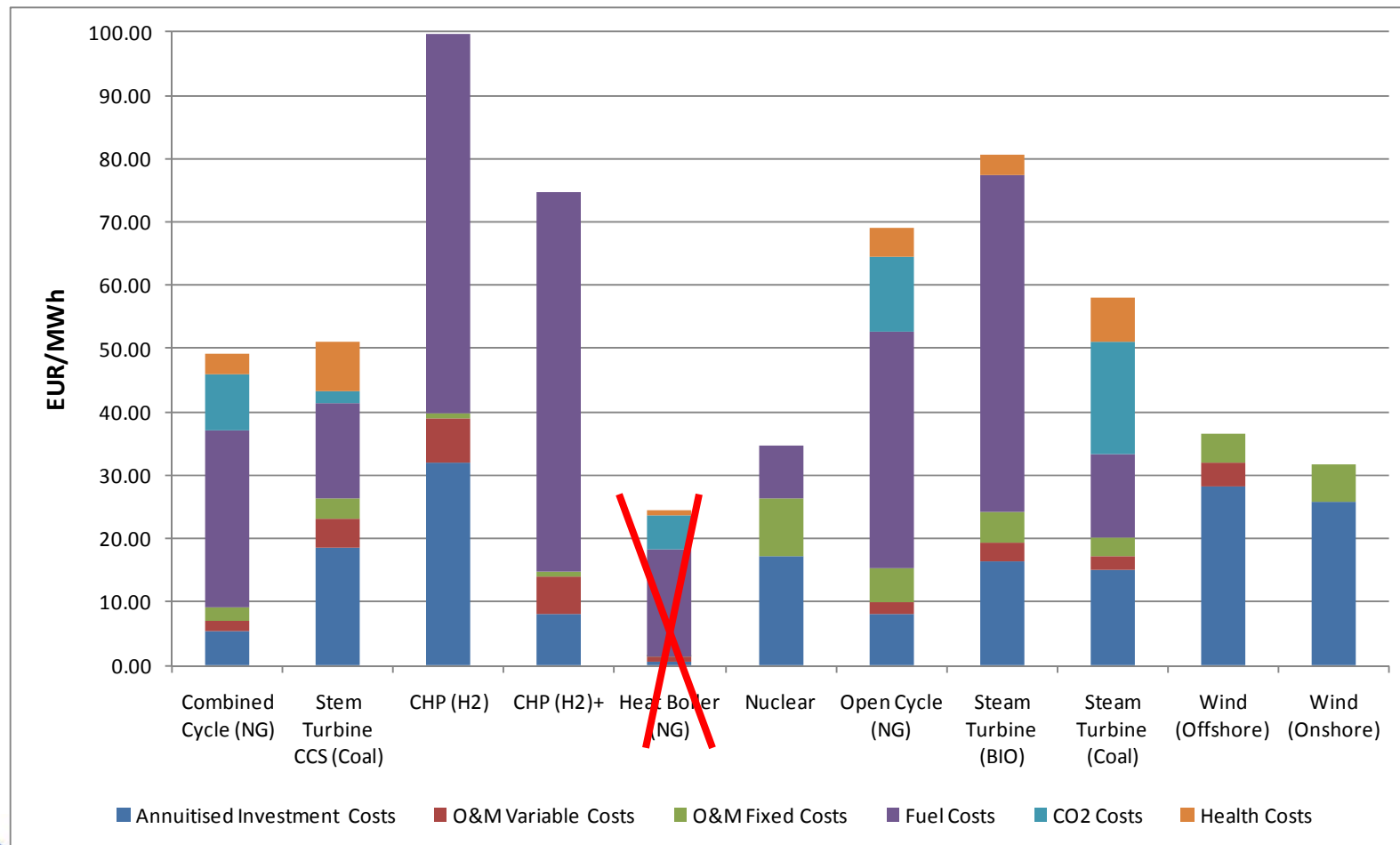
Energy System



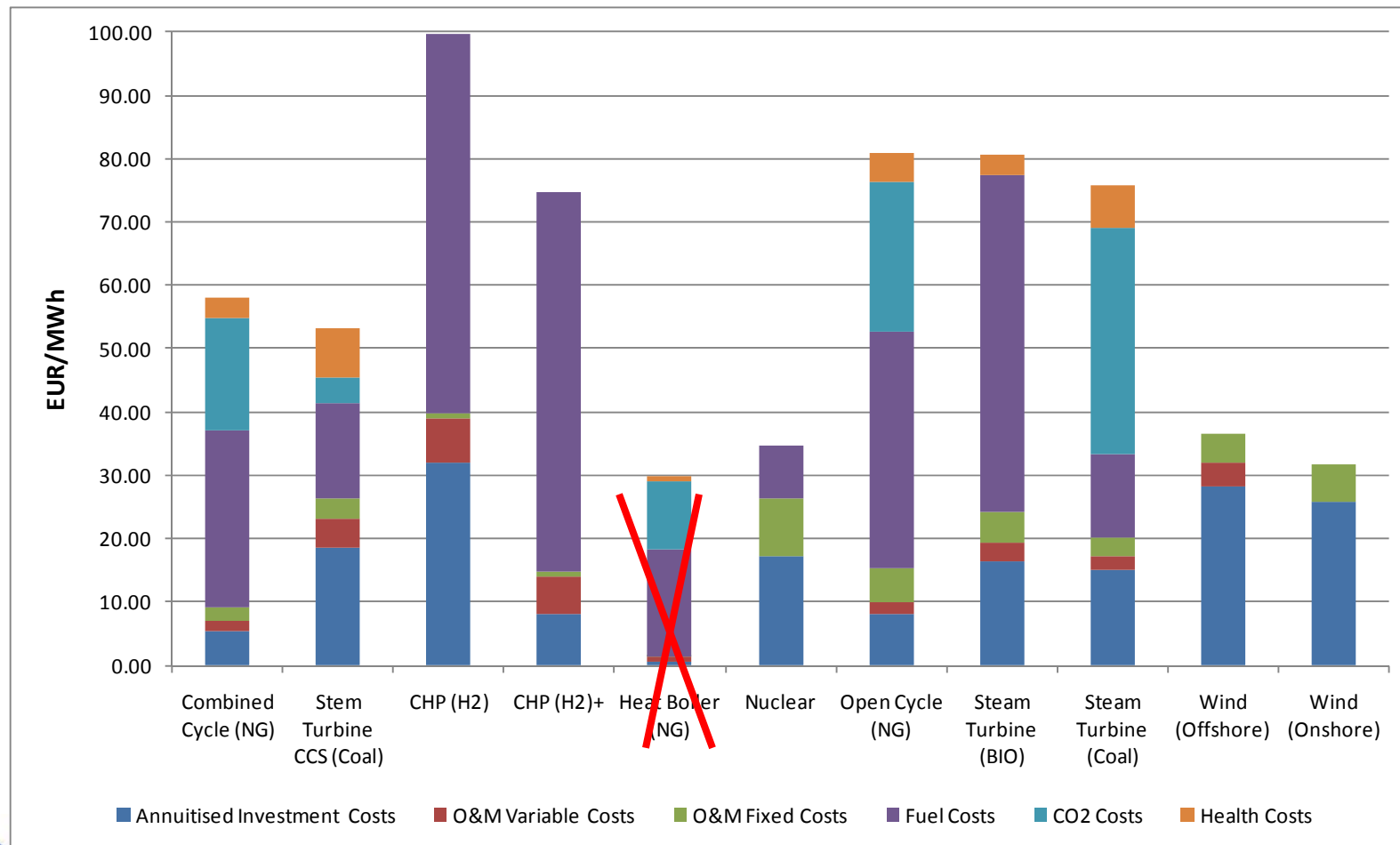
Energy System Modelling: Costs of Running a Unit in the Energy System



Levelised Electricity Cost (CO₂ price 25€/ton)



Levelised Electricity Cost (CO₂-price 50€/ton)



Balmorel (www.balmorel.com)

Model:

Multi region linear optimisation model

Interregional power market

Regional district heat markets

New coming modules:

End use technologies (electricity, heat)

Transport (car technologies)

Exogenous input:

Energy prices,

Electricity demand in regions,

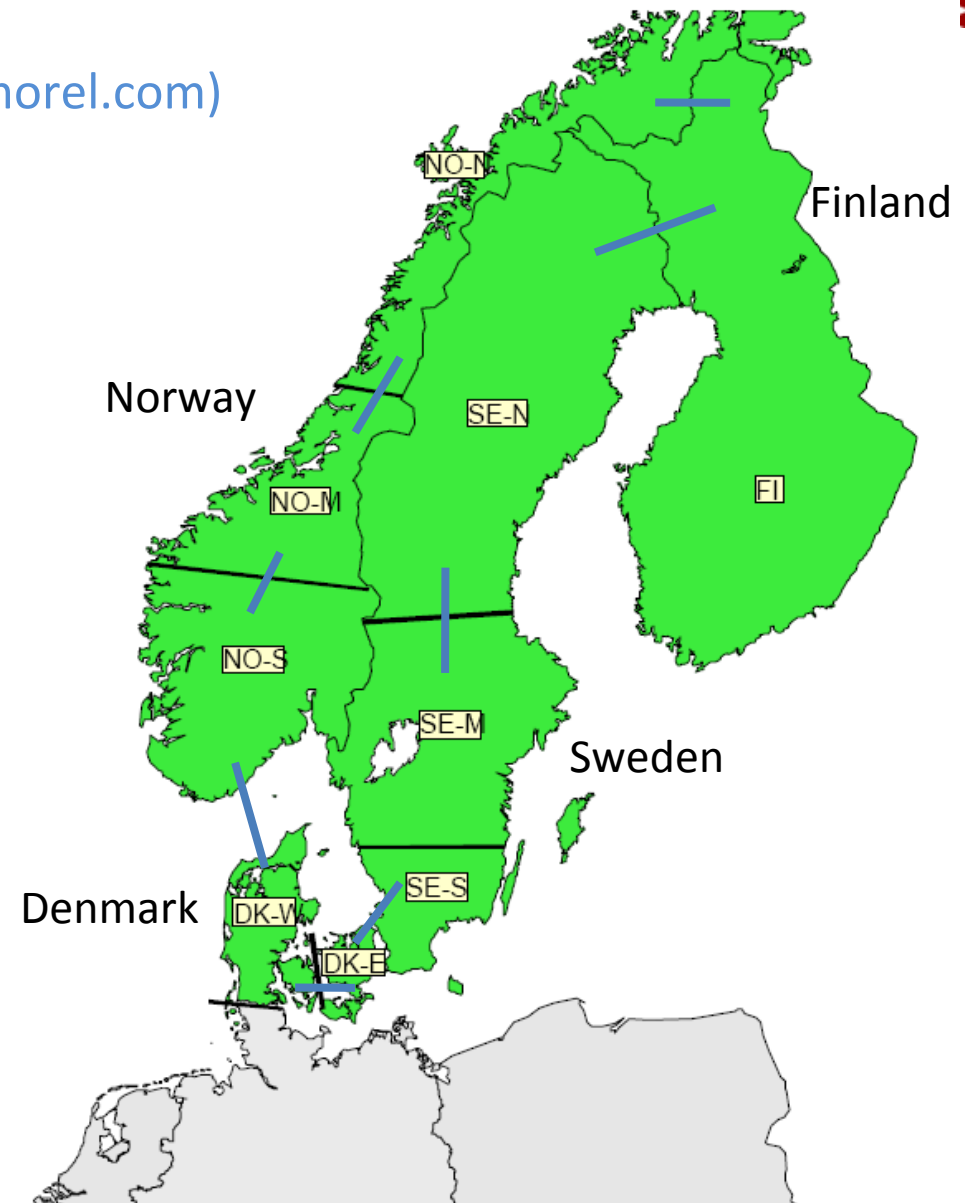
Heat demand in district heat areas.

Results:

Prices on traded energy,

Investments in power plants and transmission lines,

Fuel use and emissions from each region



Model runs

Balmorel is run for year 2030

WEO2007 Oil Price:
55 USD/bbl

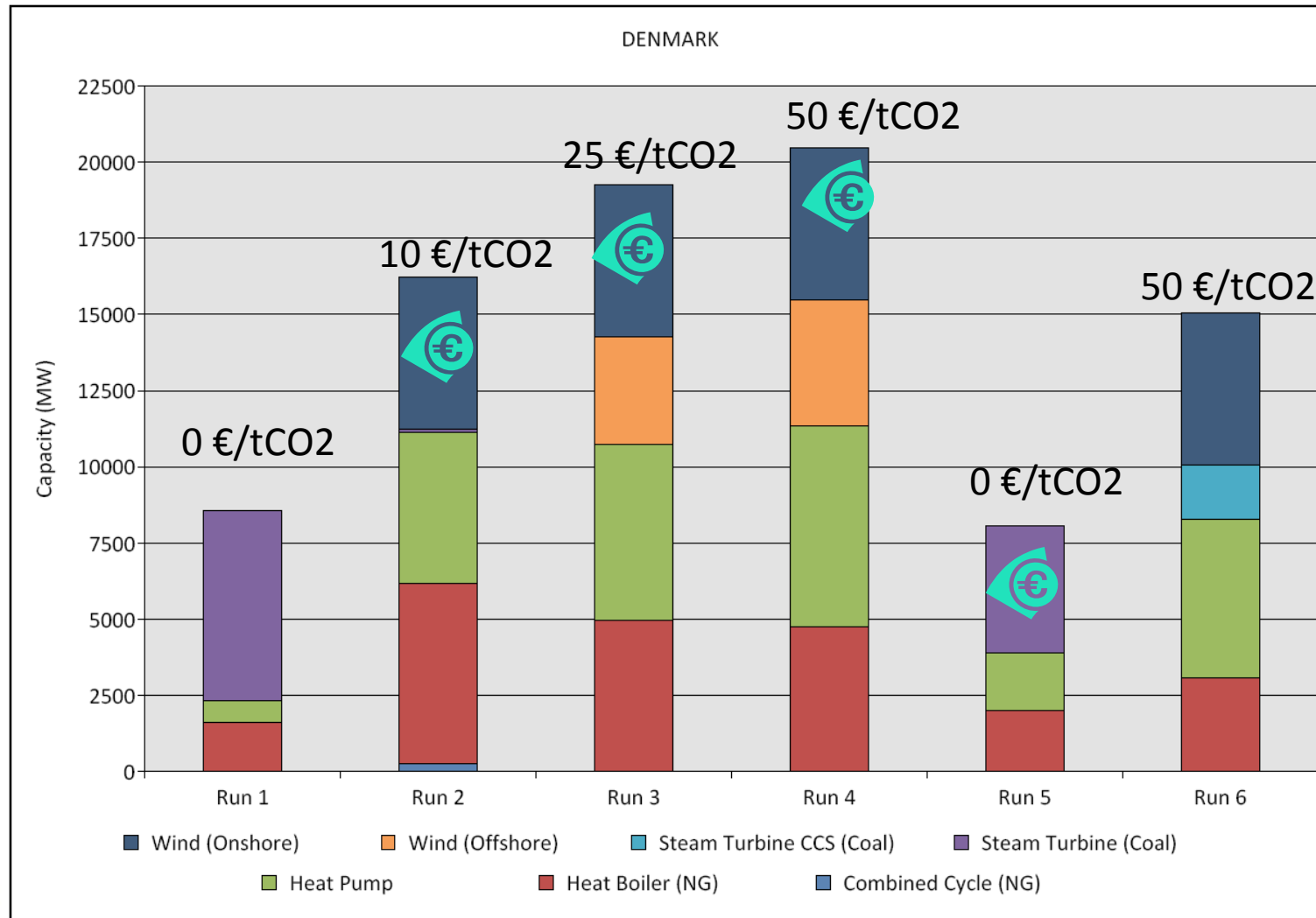
Fuel prices WEO 2007:

Case	SO ₂ , NO _x , CO and PM _{2.5} Pricing	CO ₂ price, Euro/t
Run1	no	0
Run2	yes	10
Run3	yes	25
Run4	yes	50
Run5	yes	0
Run6	no	50

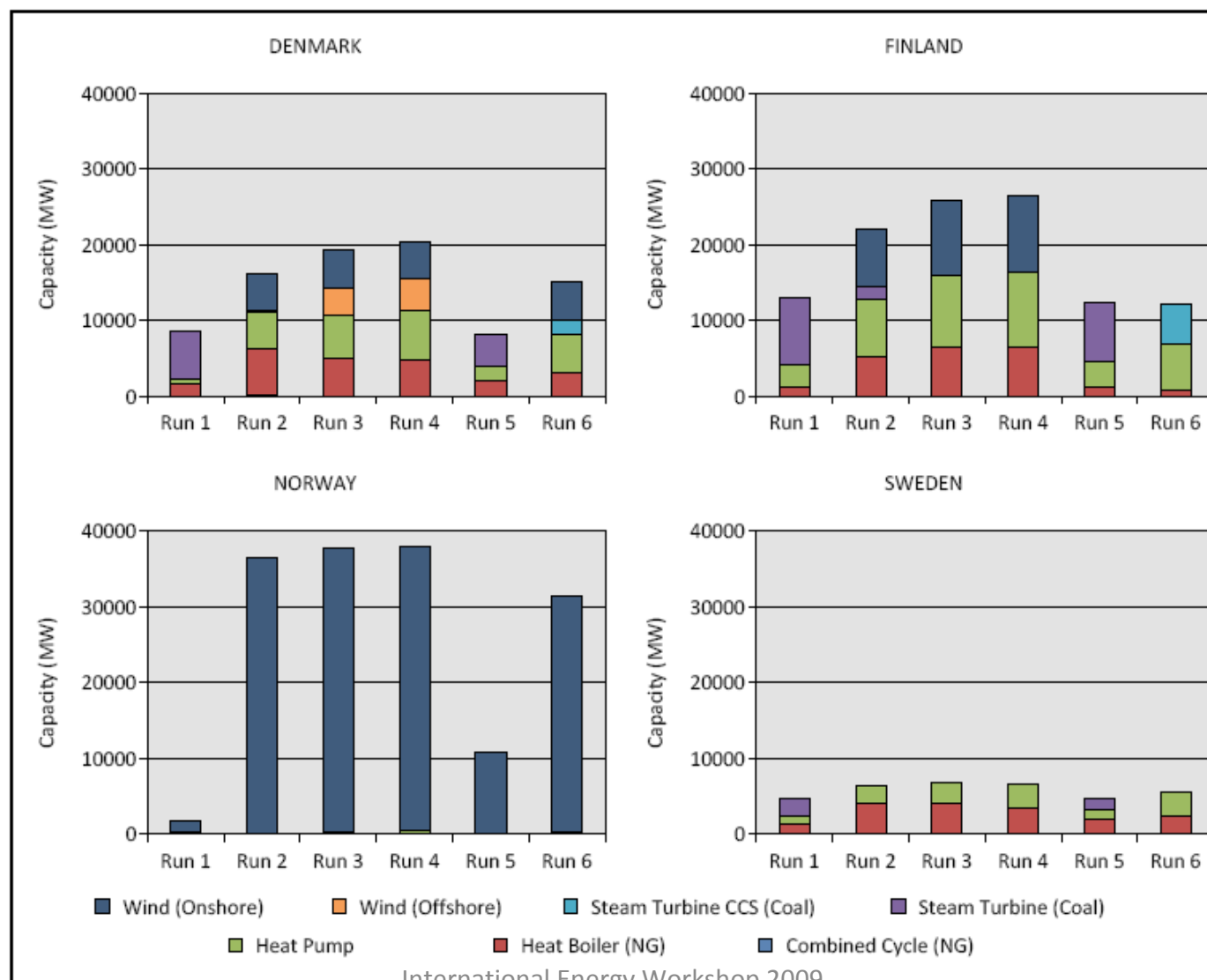
Fuel	Unit	Price
Oil	EUR/GJ	5.70
Gas	EUR/GJ	4.46
Coal	EUR/GJ	1.75
Biomass	EUR/GJ	6.36
Waste	EUR/GJ	-2.28
Uranium	EUR/GJ	0.80



New installed capacities in Denmark (2030)



New installed capacities (2030)

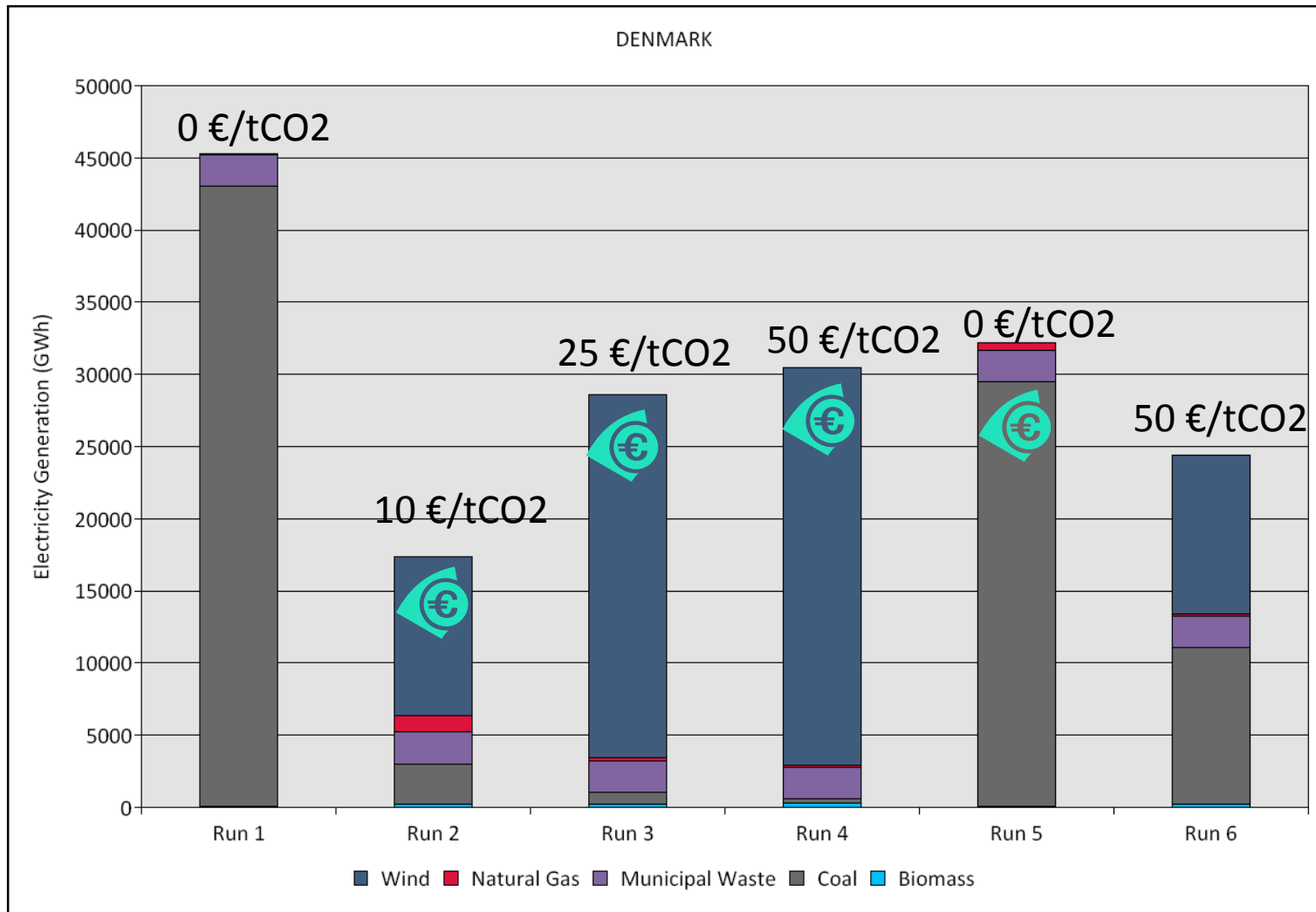


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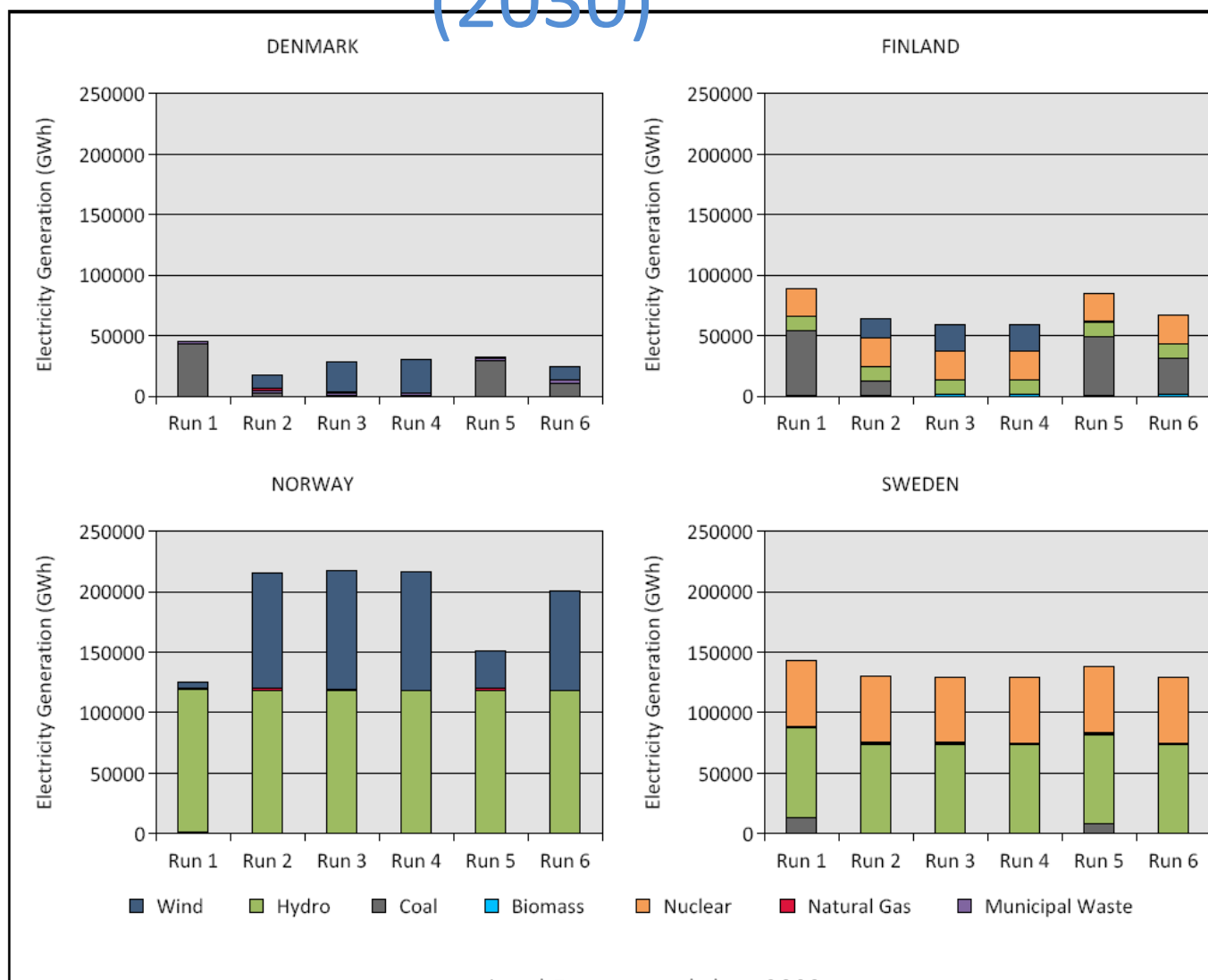
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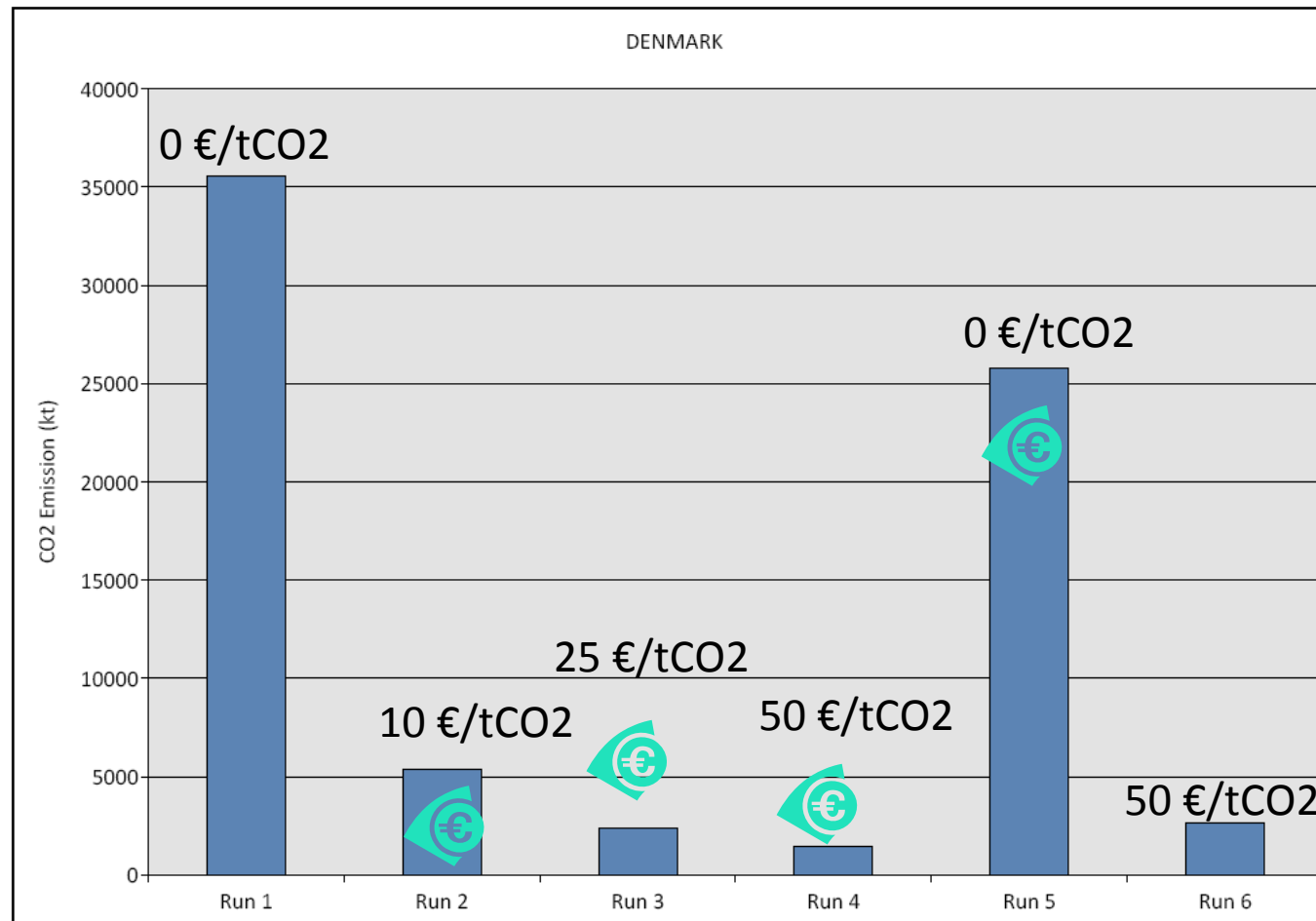
Power produced in Denmark (2030)



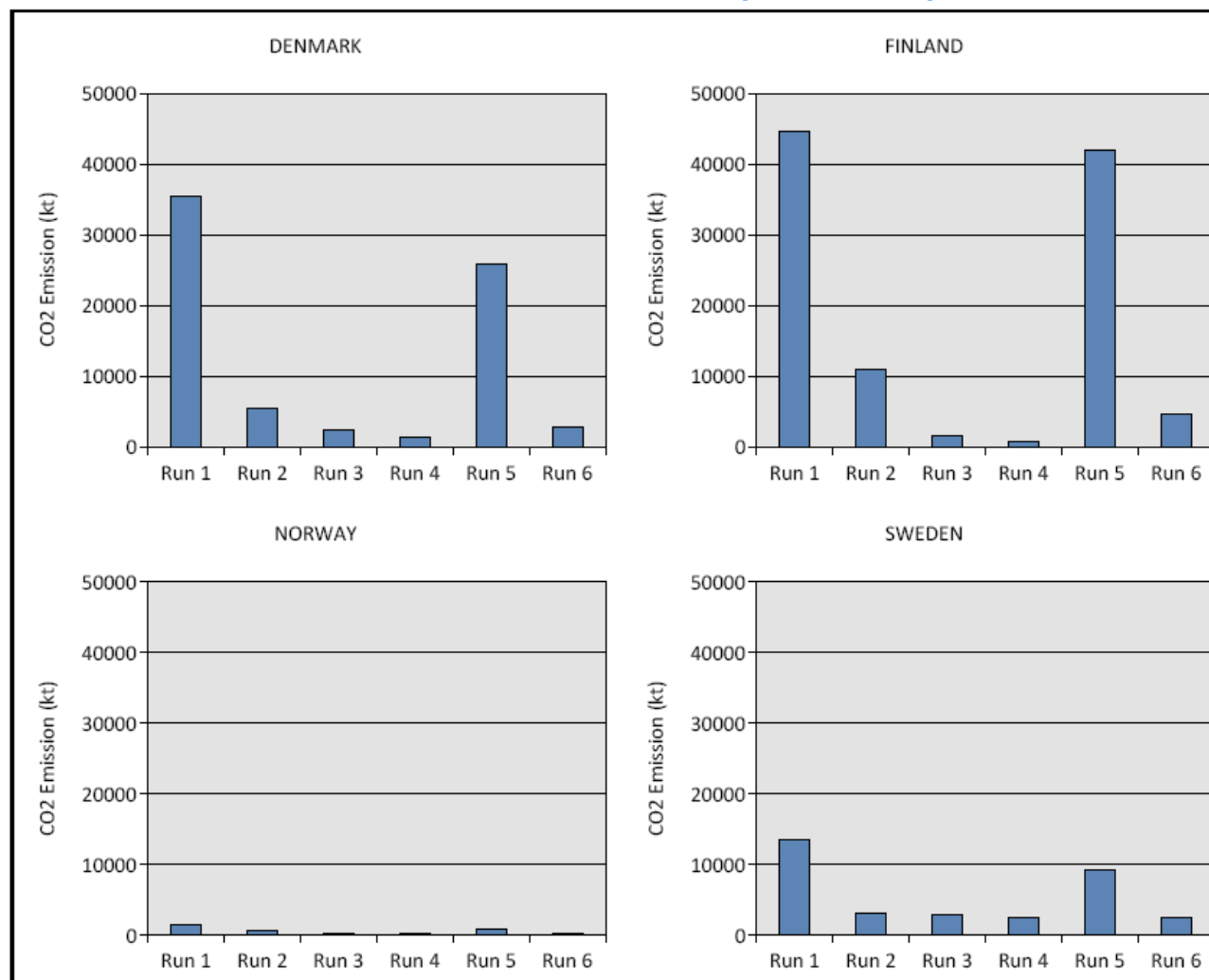
Power produced in the countries (2030)



CO2 emissions from the Danish power and heat sector (2030)



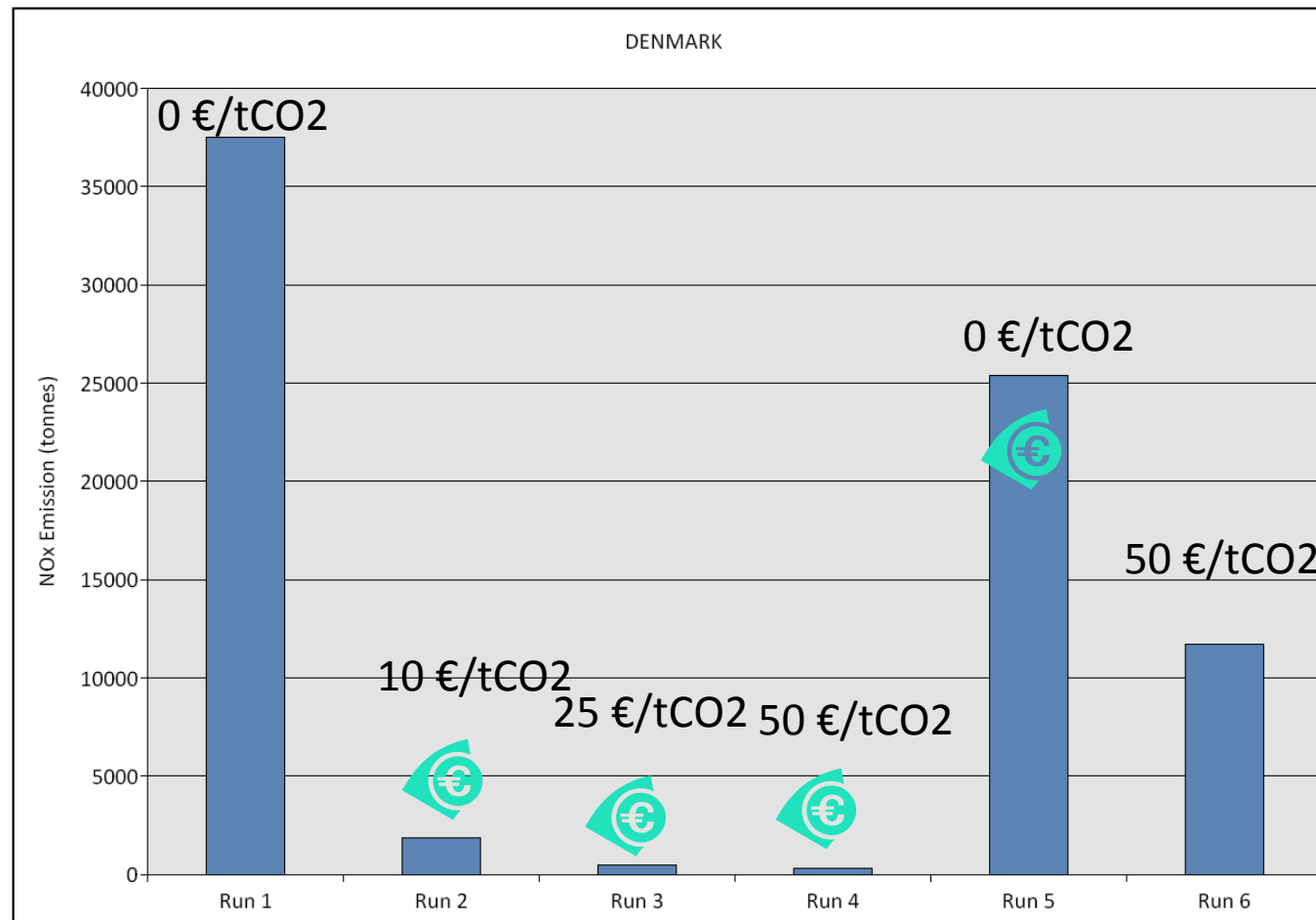
CO2 emissions from the countries power and heat sector (2030)



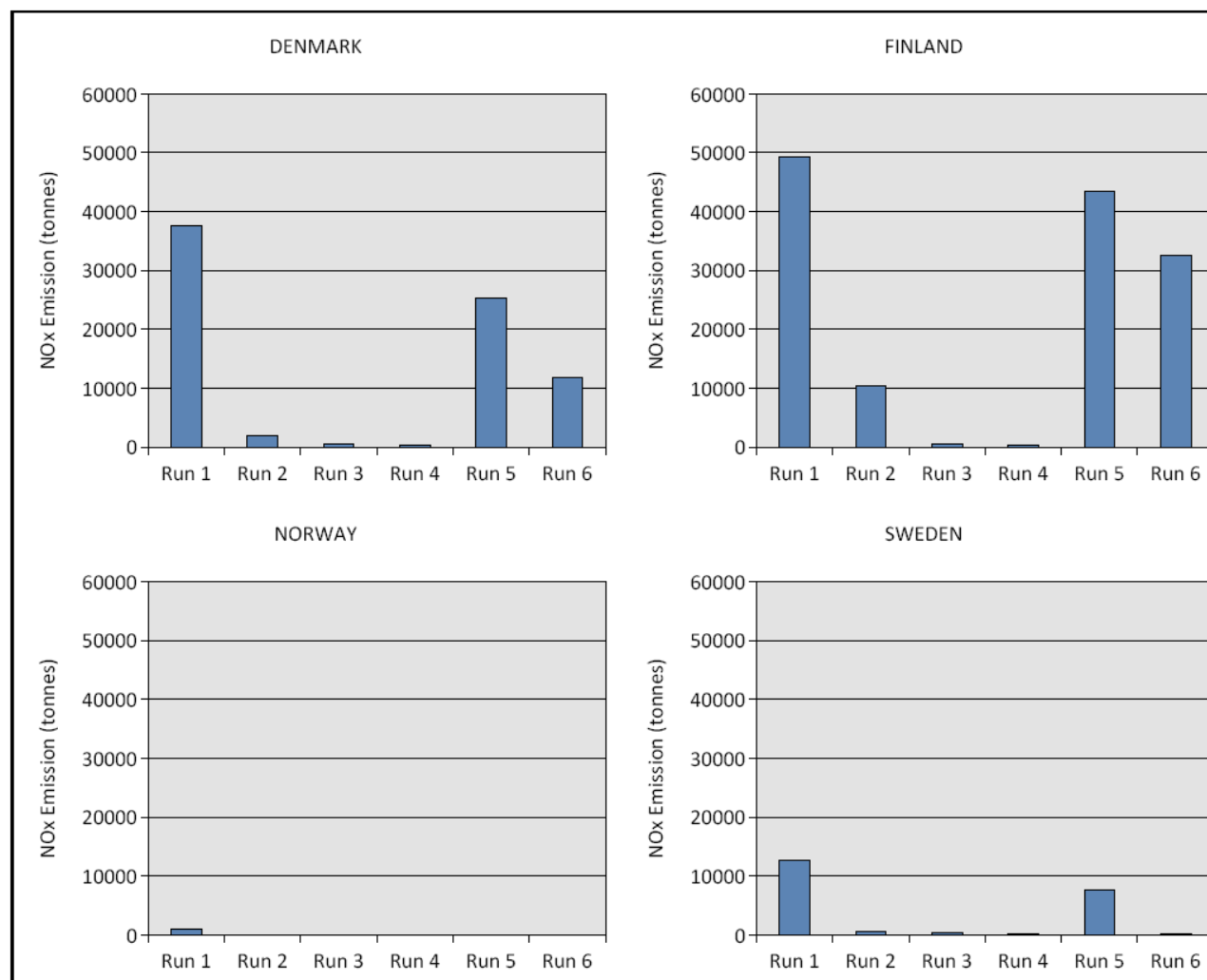
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Emissions from the Danish energy system (tonnes NO_x)



Emissions from the countries energy system (tonnes NOx)



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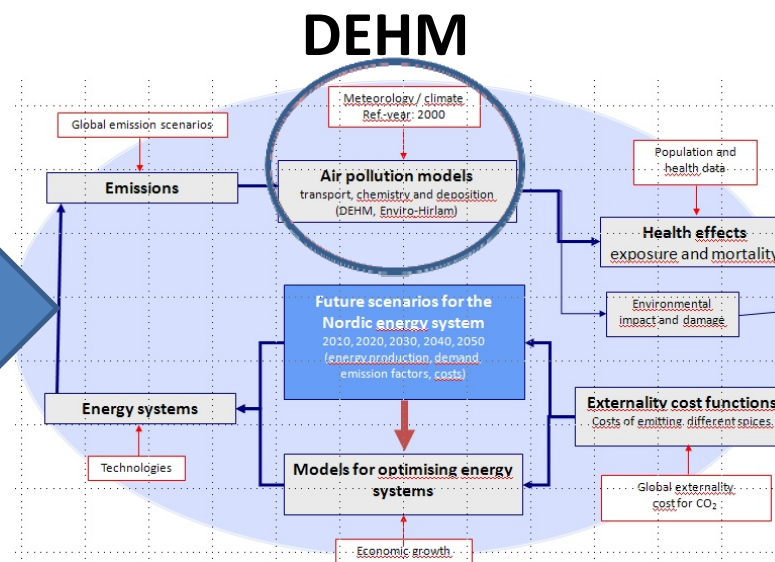
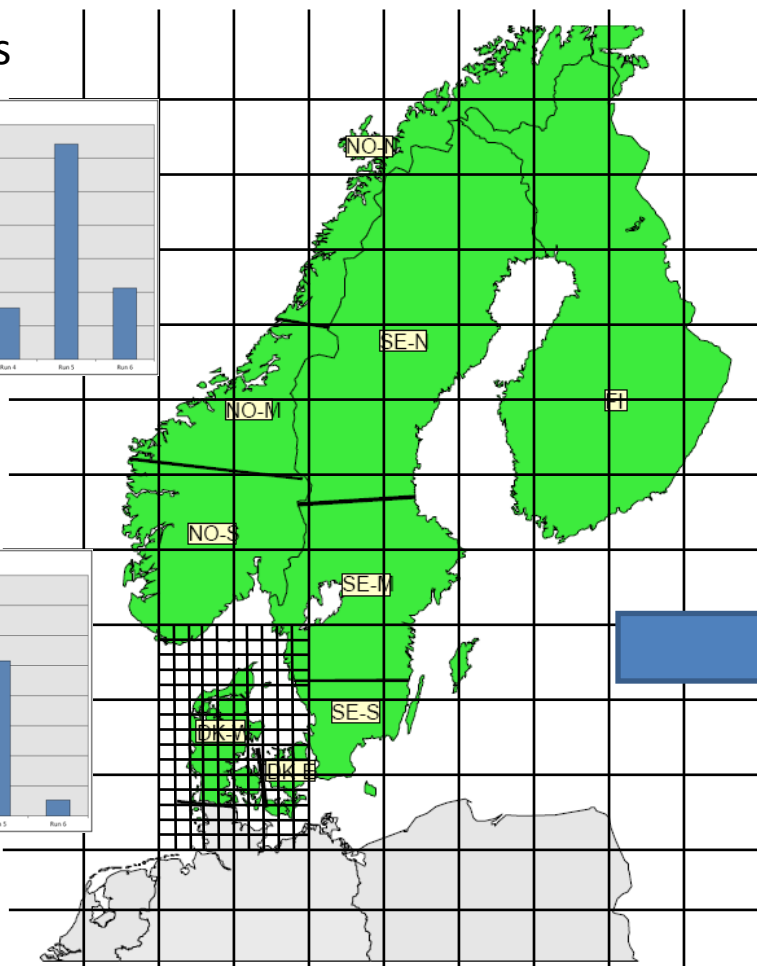
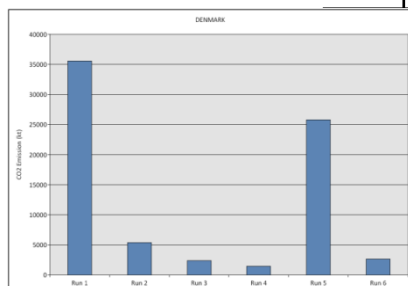


Optimal energy system investments due to health externalities – work flow

- Balmorel is run including health costs
- The new Balmorel scenarios gives new emissions
- The air emission and health costs models are run with the new emissions
- New Balmorel runs based on revised health costs



Emissions



Conclusion

- When including a price on CO₂ then health externalities from power plants becomes less important
- The important sectors related to health costs is individual heating and transport
- We have to include these sectors in the optimisation



Perspectives

- Better calculation of exposure ➡ health costs
- The system will be run for the years 2010, 2020, 2030, 2040 and 2050 giving the optimal investment pattern over the period
- Dividing Denmark into smaller regions can give separate health costs for each sector in each region
- Global use of the system ➡ together with a global energy system model (like TIAM) the system could be used anywhere at the Northern hemisphere



Thank you for your attention

Further information: keka@risoe.dtu.dk

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