European Commission
TEMPUS

Centre for Energy, Environment and Health

Application of models to different integrated systems and studies

An example: The optimization model in Centre for Energy, Environment and Health.

Eigil Kaas, Niels Bohr Institute, University of Copenhagen, Denmark

MUSCATEN / NETFam Young Scientist Summer School – 2011,

Odessa State Environmental University

Interdisciplinary effort

CEEH is a collaboration between seven Danish institutions working within the subject areas of

- Meteorology and air pollution (UoC, DMI, DMU/AU)
- Toxicology (AU, DMU)
- Epidemiology (NIPH/SDU, AU)
- Public health/health economics (SDU)
- Energy and system analysis (RISØ, DMU/AU, DMI)

CEEH is financed by the Danish Council for Strategic Research and runs over 5.5 years beginning in January 2007.

Output

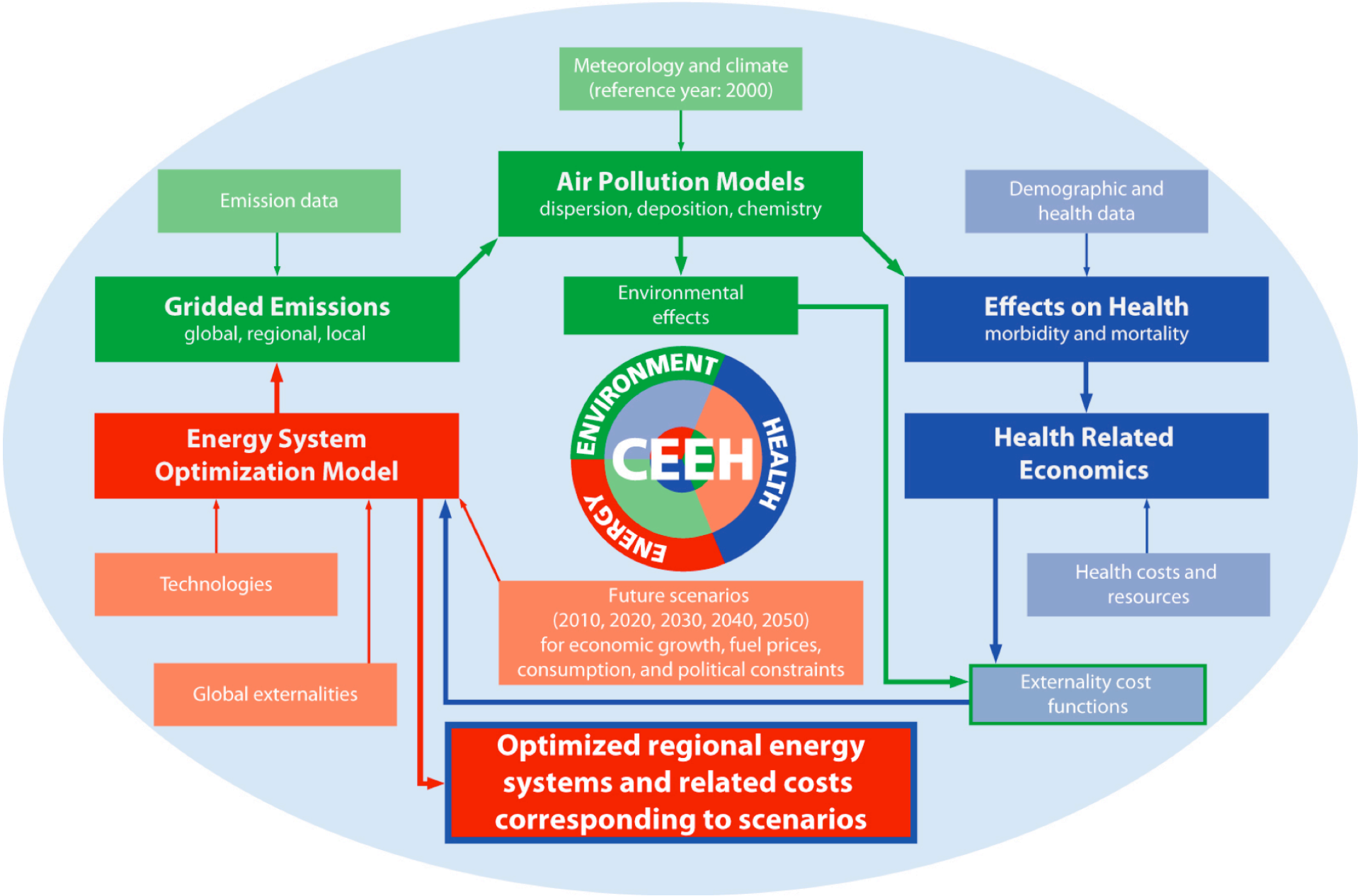
A chain of different models is used to obtain economically optimized energy systems in Denmark for a number of different “scenarios” and at different time horizons: 2010, 2020, 2030, 2040 and 2050.

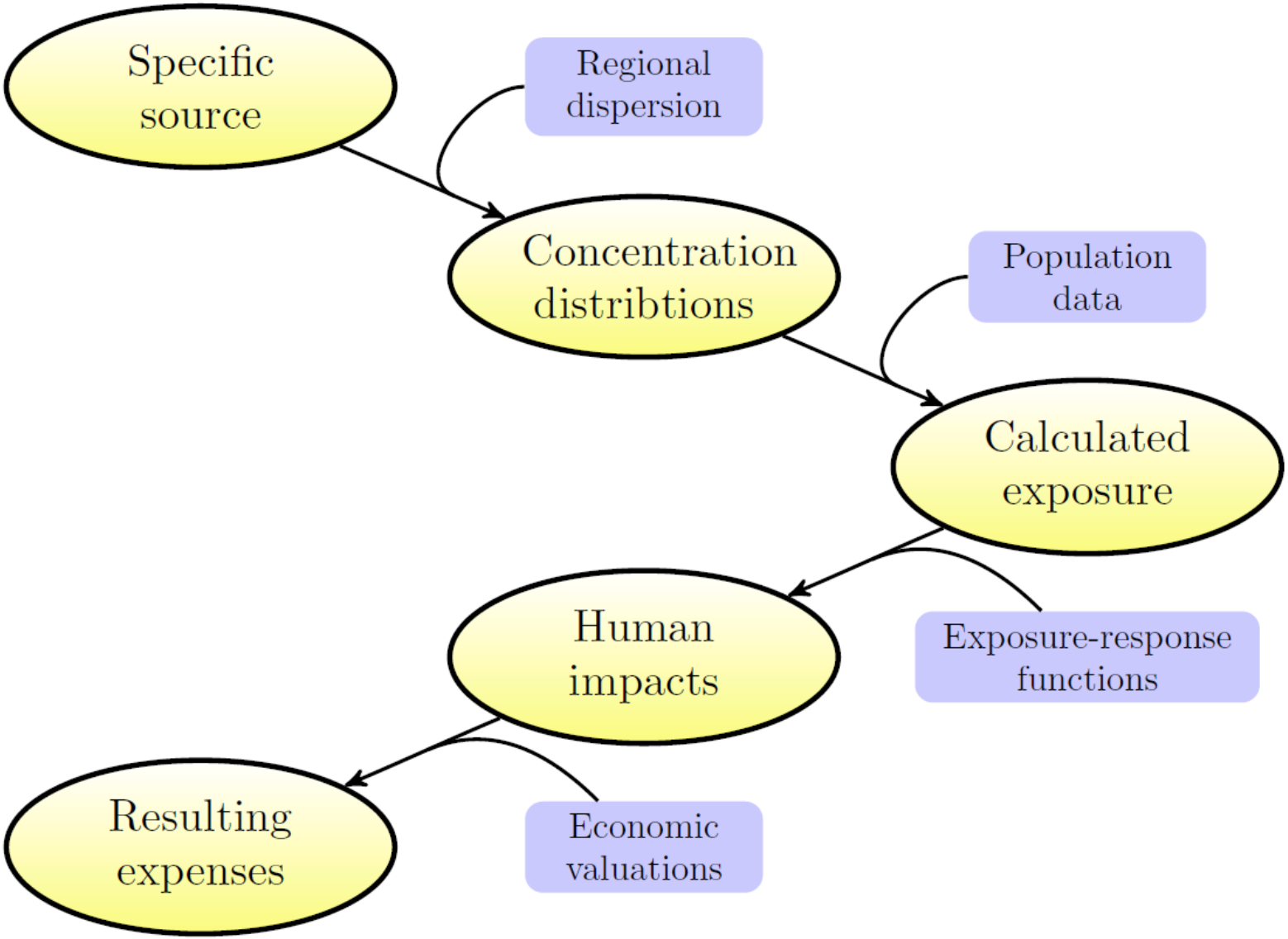
In CEEH we have particular focus on “externality costs” i.e. indirect environmental and health costs associated with a given setup of the Danish energy system.

The final product will – for each scenario – be detailed suggestions for optimal Danish energy systems.

Common language: Money and cost minimization - but intermediate results are just as interesting.

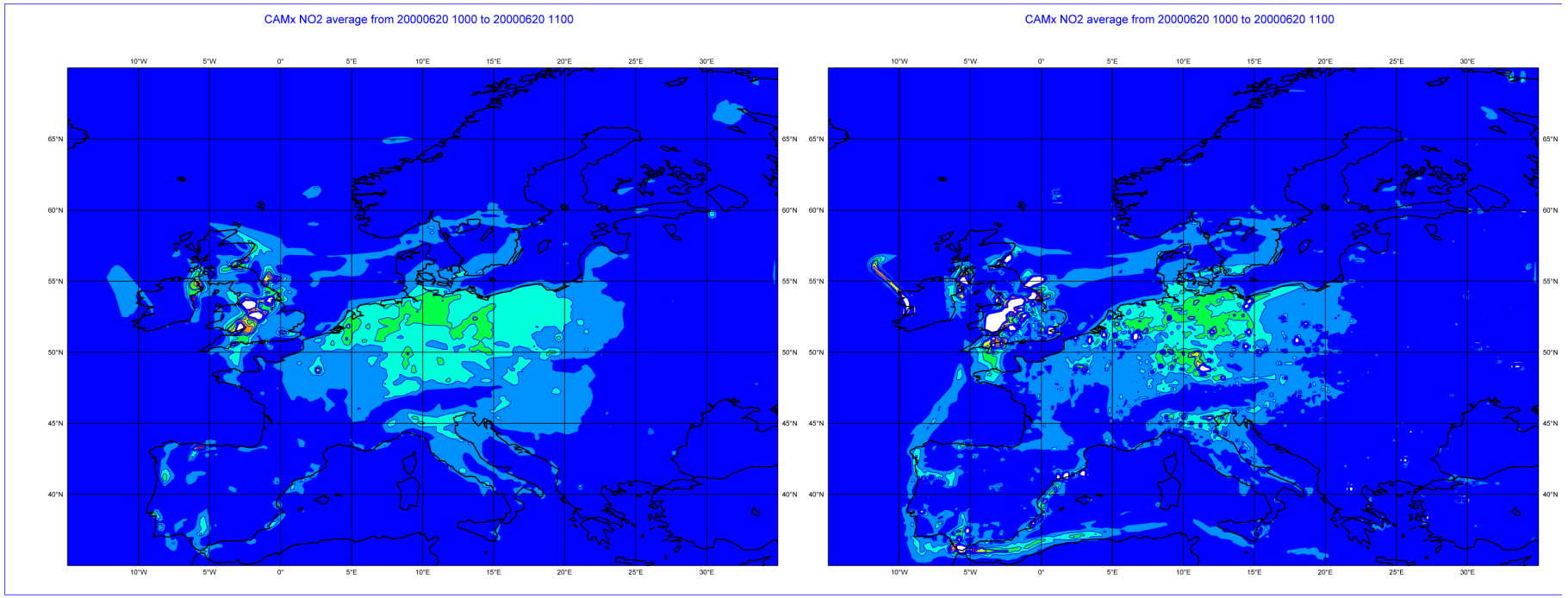
Centre for Energy, Environment and Health




Specific source
Regional dispersion
Concentration distribtions
Population data
Calculated exposure
Human impacts
Exposure-response functions
Resulting expenses
Economic valuations

Region/ SNAP	Emission year	Emission scenario (or the "tag")
DK/1	2000	Combustion in energy and transformation industries, Denmark
DK/2	2000	Non-industrial combustion plants (in Denmark this equals the domestic heating)
DK/3	2000	Combustion in manufacturing industry, Denmark
DK/4	2000	Production processes, Denmark
DK/5	2000	Extraction and distribution of fossil fuels and geothermal energy, Denmark
DK/6	2000	Solvents and other product use, Denmark
DK/7	2000	Road transport, Denmark
DK/8	2000	Other mobile sources and machinery, Denmark
DK/9	2000	Waste treatment and disposal, Denmark
DK/10	2000	Agriculture, Denmark
DK/1-10	2000	Sum of the above 10 SNAP categories, Denmark
DK/all	2000	All anthropogenic emissions from Denmark (SNAP 1- SNAP 10)
All/15	2000	Int. ship traffic for the year 2000, (S=2,7%)*, whole model domain (EMEP=2000)
All/15	2007	Int. ship traffic for the year 2007, NS/BS: S=1.5%*, whole domain (EMEP=2006)
All/15	2011	Int. ship traffic for the year 2011, NS/BS: S=1.0%*, whole domain (EMEP=2006)
All/15	2020	Int. ship traffic for the year 2020, NS/BS: S=0.1%*, whole model domain, (NEC-2)
BaS-NoS/15	2000	Int. ship traffic for the year 2000, (S=2,7%)*, whole model domain (EMEP=2000)
BaS-NoS/15	2007	Int. ship traffic for the year 2007, NS/BS: S=1.5%*, whole domain (EMEP=2006)
BaS-NoS/15	2011	Int. ship traffic for the year 2011, NS/BS: S=1.0%*, whole domain (EMEP=2006)
BaS-NoS/15	2020	Int. ship traffic for the year 2020, NS/BS: S=0.1%*, whole model domain, (NEC-2)
All/all	2000	All emissions (anthropogenic; GEIA/EDGAR; EMEP 2000 + natural)
All/all	2007	All emissions (anthropogenic; GEIA/EDGAR; EMEP 2006 + natural)
All/all	2011	All emissions (anthropogenic: GEIA/EDGAR, EMEP 2006 + natural)
All/all	2020	All emissions (anthropogenic: GEIA/EDGAR; NEC-2 + natural)

Comparison of NO_2 concentrations in CAC runs with EMEP and MEGAPOLI/TNO emission inventories



EMEP emission inventory
(50 x 50 km resolution)

TNO/MEGAPOLI emission inventory
(6 x 6 km resolution)

Surface values of nitric dioxide (ppm)

Source DMI

Two lines for estimating externality costs:

- The EVA line
- The HIA line

Effects included in the EVA - line

Response	Component	Population component
Acute mortality (deaths)	SO_2, O_3	All
Respiratory hospital admissions (cases)	SO_2, $PM_{2.5}$, NO_3, SO_4	All
Congestive heart failure (cases)	CO, $PM_{2.5}$, NO_3, SO_4	> 65
Cerebrovascular hospital admission (cases)	$PM_{2.5}$, NO_3, SO_4	All
Chronic mortality (years of life lost)	$PM_{2.5}$, NO_3, SO_4, Dioxin	All
Bronchodilator use (cases)	$PM_{2.5}$, NO_3, SO_4	Asthma
Cough (days)	$PM_{2.5}$, NO_3, SO_4	Asthma
Lower respiratory symptoms (days)	$PM_{2.5}$, NO_3, SO_4	Asthma
Chronic bronchitis (cases)	$PM_{2.5}$, NO_3, SO_4	> 16
Restricted activity days (days)	$PM_{2.5}$, NO_3, SO_4	> 16
Lung cancer (cases)	$PM_{2.5}$, NO_3, SO_4	> 16
Infant mortality (cases)	$PM_{2.5}$, NO_3, SO_4	Baby
Loss of IQ-points (points)	Bb	Baby
Loss of IQ-points (points)	Hg	Embryo

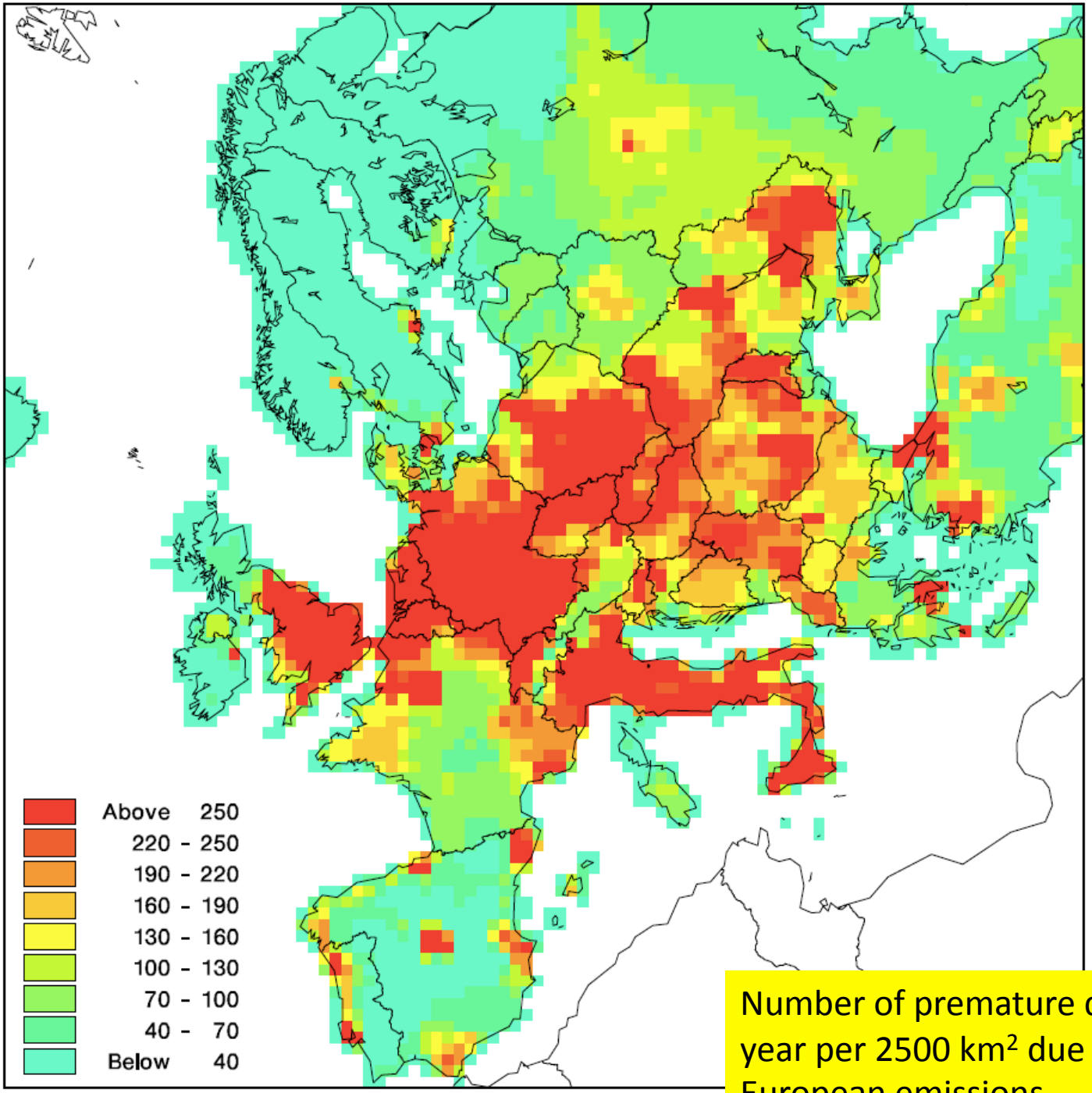
Source NERI/AU

Valuation of costs based on the EVA system (NERI)

Health effects (response)	*Exposure-response function*	*Valuation Euros (2006-prices)*
MORBIDITY (Particulate matter)		
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 number of cases of the different impacts related to all Danish anthropogenic (scenario: **DK/all) for the year 2000**

Health impact	Number of cases in Europe	Number of cases in Denmark
Chronic Bronchitis	4.35E+03	8.02E+02
Restricted Activity Days	4.44E+06	8.20E+05
Respiratory Hospital Admissions	2.34E+02	4.44E+01
Cerebrovascular Hospital Admissions	5.56E+02	1.01E+02
Congestive Heart Failure	3.24E+02	6.90E+01
Lung Cancer	6.66E+02	1.23E+02
Bronchodilator Use Children	1.28E+05	2.16E+04
Bronchodilator Use Adults	8.51E+05	1.57E+05
Cough Children	4.41E+05	7.46E+04
Cough Adults	8.76E+05	1.62E+05
Lower Respiratory Symptoms Children	1.70E+05	5.28E+04
Lower Respiratory Symptoms Adults	3.16E+05	5.83E+04
Acute YOLL	8.52E+01	-8.49E+00
Chronic YOLL	4.90E+04	8.52E+03
Infant mortality	4.99E+00	1.02E+00



Number of premature deaths per year per 2500 km^2 due to all European emissions.

Total costs in Europe due to Danish Emissions. Unit is Euro per year

Region/ SNAP	Emission year	CO	Total S	Total N	NH_3	$PM_{2.5}$
DK/1	2000	4.77E+03	1.48E+08	4.20E+08	-	1.52E+07
DK/2	2000	1.23E+05	8.21E+07	1.25E+08	-	3.24E+08
DK/3	2000	8.53E+03	9.18E+07	1.83E+08	-	2.63E+07
DK/4	2000	1.32E+03	4.31E+07	5.71E+07	-	1.02E+07
DK/5	2000	2.49E+03	3.46E+07	6.21E+07	-	1.31E+06
DK/6	2000	8.81E+03	5.60E+07	9.45E+07	-	3.92E+04
DK/7	2000	3.59E+05	3.29E+07	7.58E+08	-	2.08E+08
DK/8	2000	8.90E+04	3.14E+07	3.36E+08	-	7.95E+07
DK/9	2000	-1.26E+01	2.80E+05	3.19E+07	-	1.61E+05
DK/10	2000	1.18E+03	1.00E+09	1.39E+09	-	3.22E+07
DK/sum 1-10	2000	5.98E+05	1.52E+09	3.46E+09	-	6.97E+08
DK/all	2000	5.93E+05	1.30E+09	2.92E+09	-	7.04E+08

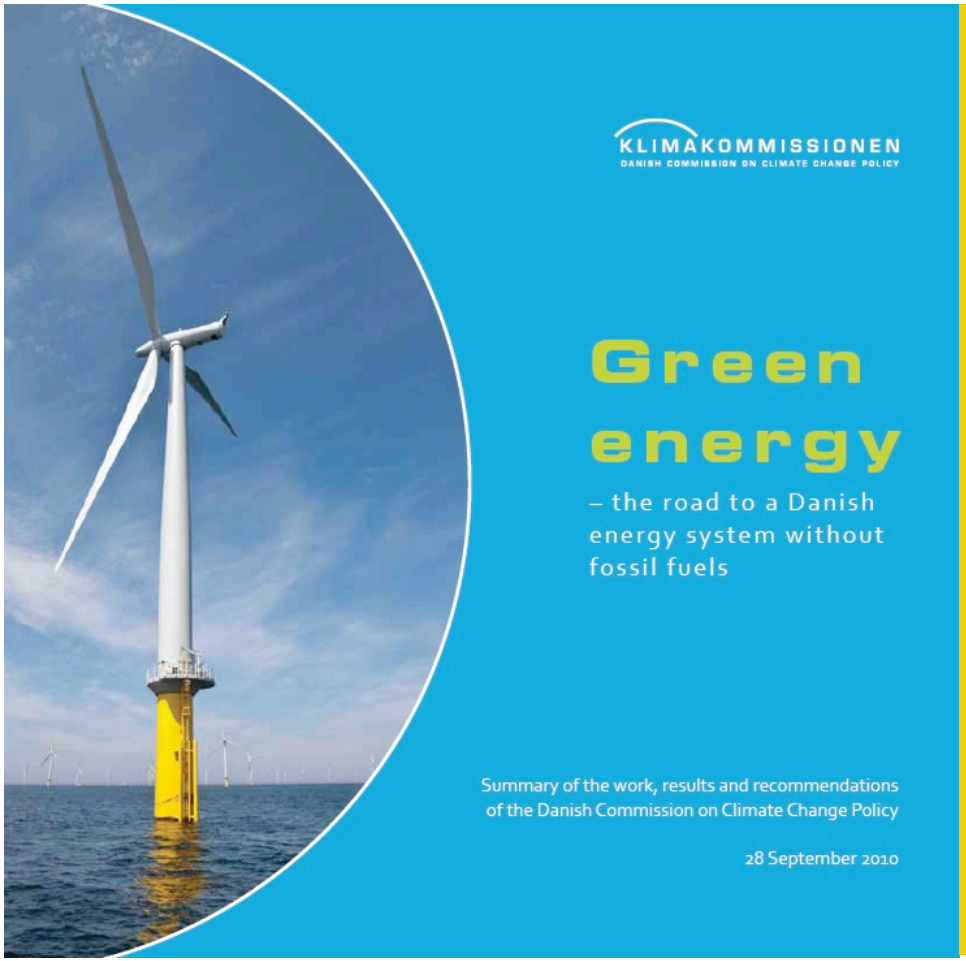
Total costs in Europe due to Danish Emissions. Unit is Euro per year

Region/SNAP	Emission year	Sum Europe Euros	Sum DK Euros
DK/1	2000	5.84E+08	5.50E+07
DK/2	2000	5.31E+08	1.58E+08
DK/3	2000	3.01E+08	4.15E+07
DK/4	2000	1.10E+08	3.04E+07
DK/5	2000	9.80E+07	2.19E+07
DK/6	2000	1.50E+08	2.43E+07
DK/7	2000	9.99E+08	1.87E+08
DK/8	2000	4.47E+08	6.96E+07
DK/9	2000	3.23E+07	1.14E+06
DK/10	2000	2.43E+09	3.82E+08
DK/sum 1-10	2000	5.68E+09	9.71E+08
DK/all	2000	4.92E+09	8.17E+08

Reference for the above:

CEEH Scientific Report No 3 (2011): Assessment of Health Cost Externalities of Air Pollution at the National Level using the EVA Model System. Authors: Jørgen Brandt, Jeremy D. Silver, Jesper H. Christensen, Mikael S. Andersen, Jacob H. Bønløkke, Torben Sigsgaard, Camilla Geels, Allan Gross, Ayoe B. Hansen, Kaj M. Hansen, Gitte B. Hedegaard, Eigil Kaas and Lise M. Frohn. ISNN 1904-7495. (available from www.ceeh.dk)

Case 1. Scenarios from the Danish Commission on Climate Change Policy



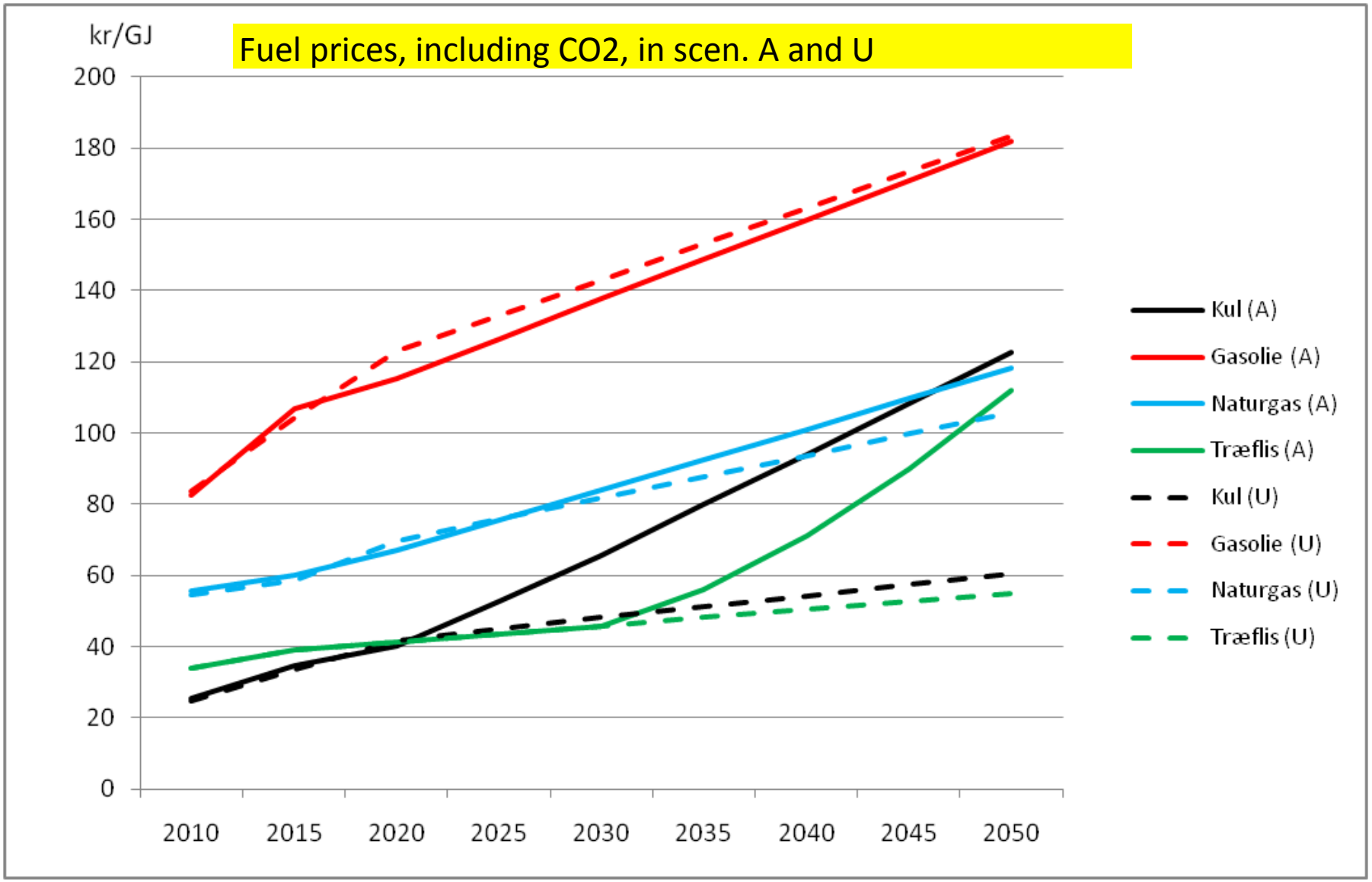
Goal:
Show how Denmark can become independent of fossil fuels

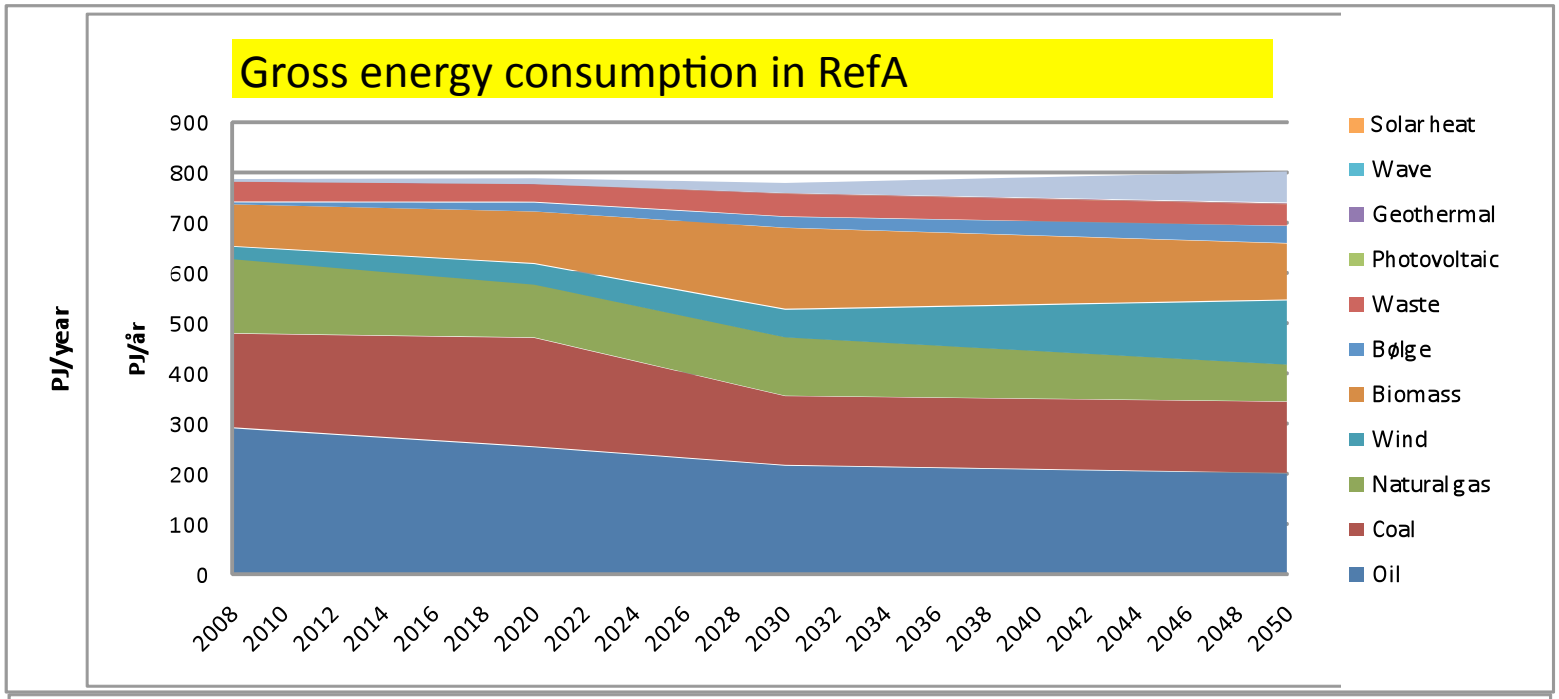
Two sets of scenarios:

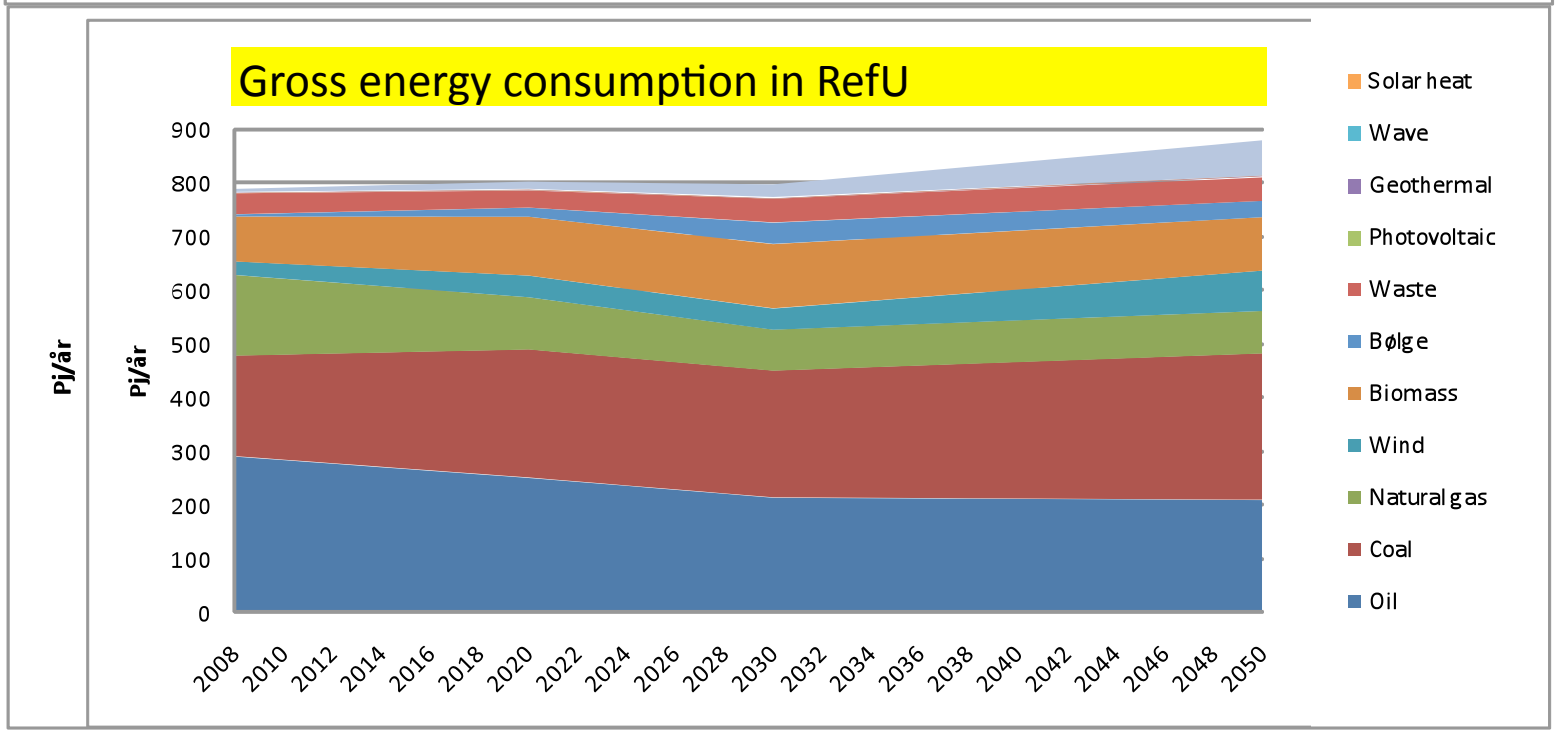
Ambitious world – high CO2 price, slow increasing fossil fuel prices
Reference scenario: RefA
Policy scenario: FremA (Wind scenario)

Un-ambitious world – low CO2 price, fast increasing fossil fuel prices
Reference scenario: RefU
Policy scenario: FremU (Biomass scenario)

Growth in energy services (2008=100)	2008-2020	2008-2050
Personal transport	121	172
Transport of goods	127	249
Production businesses	120	236
Trade and service	122	220
Household electricity	124	235
Heating (rooms)	111	151


kr/GJ
Fuel prices, including CO2, in scen. A and U
200
180
160
140
120
100
80
60
40
20
0
2010
2015
2020
2025
2030
2035
2040
2045
2050
Kul (A)
Gasolie (A)
Naturgas (A)
Træflis (A)
Kul (U)
Gasolie (U)
Naturgas (U)
Træflis (U)


Gross energy consumption in RefA
PJ/year
PJ/år
900
800
700
600
500
400
300
200
100
0
2008
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048
2050
Solar heat
Wave
Geothermal
Photovoltaic
Waste
Bølge
Biomass
Wind
Natural gas
Coal
Oil


Gross energy consumption in RefU
Pj/år
Pj/år
900
800
700
600
500
400
300
200
100
0
2008
2010
2012
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2020
2022
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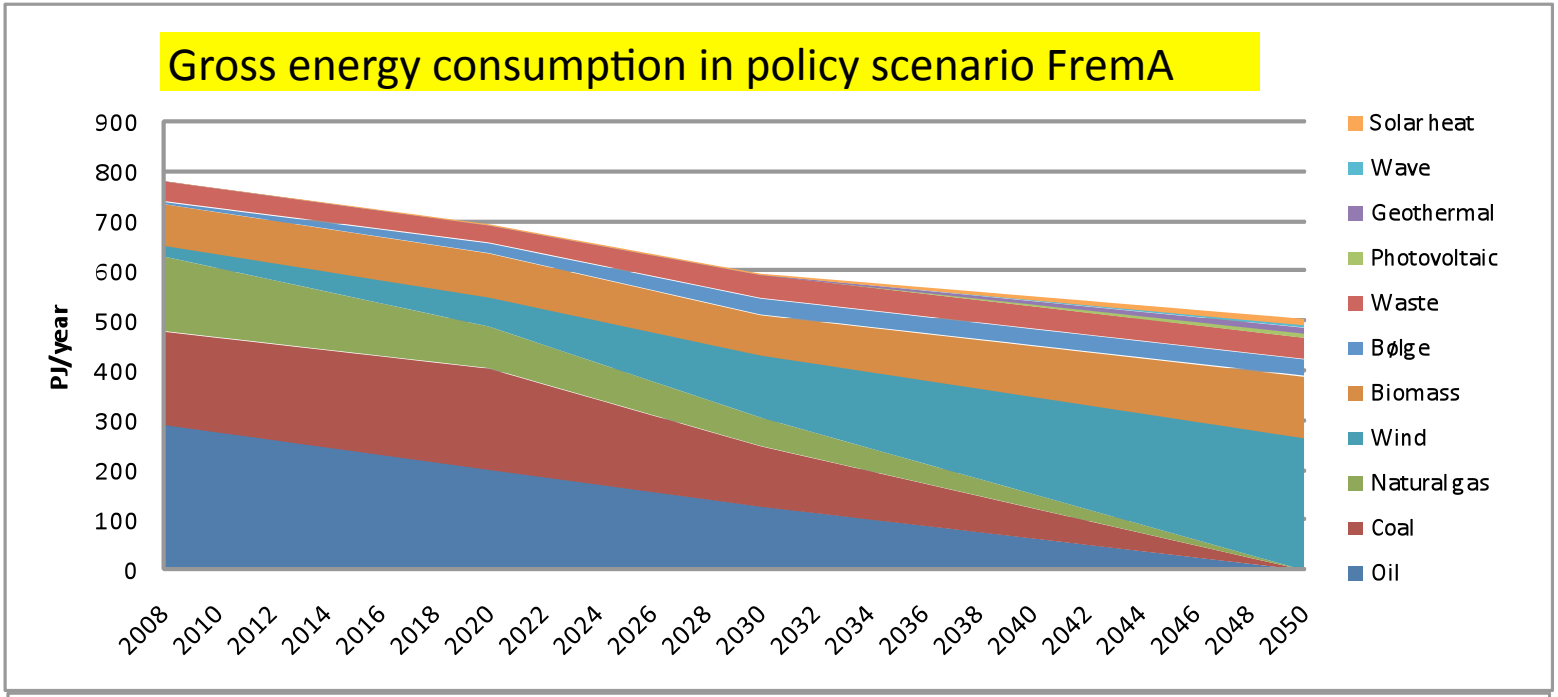
2050
Solar heat
Wave
Geothermal
Photovoltaic
Waste
Bølge
Biomass
Wind
Natural gas
Coal
Oil


Gross energy consumption in policy scenario FremA
PJ/year
900
800
700
600
500
400
300
200
100
0
2008
2010
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2014
2016
2018
2020
2022
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Solar heat
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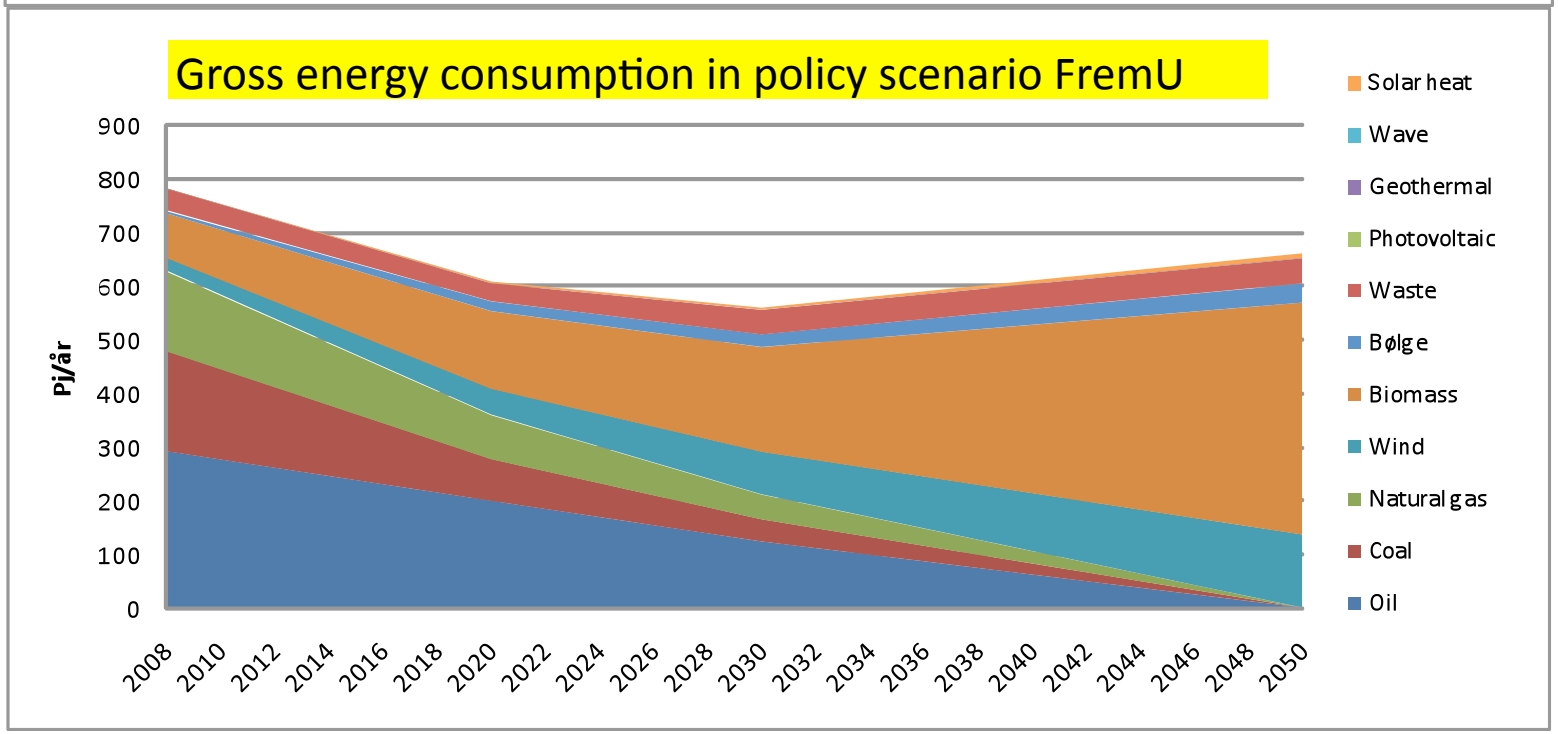
Geothermal
Photovoltaic
Waste
Bølge
Biomass
Wind
Natural gas
Coal
Oil


Gross energy consumption in policy scenario FremU
Pj/år
900
800
700
600
500
400
300
200
100
0
2008
2010
2012
2014
2016
2018
2020
2022
2024
2026
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2032
2034
2036
2038
2040
2042
2044
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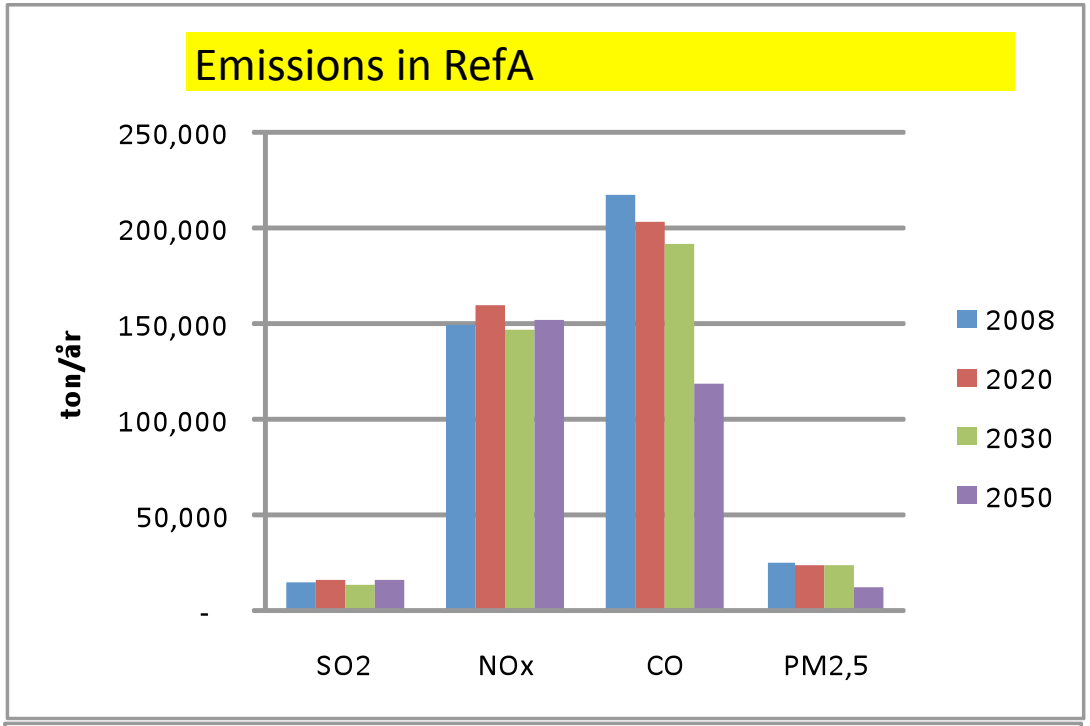
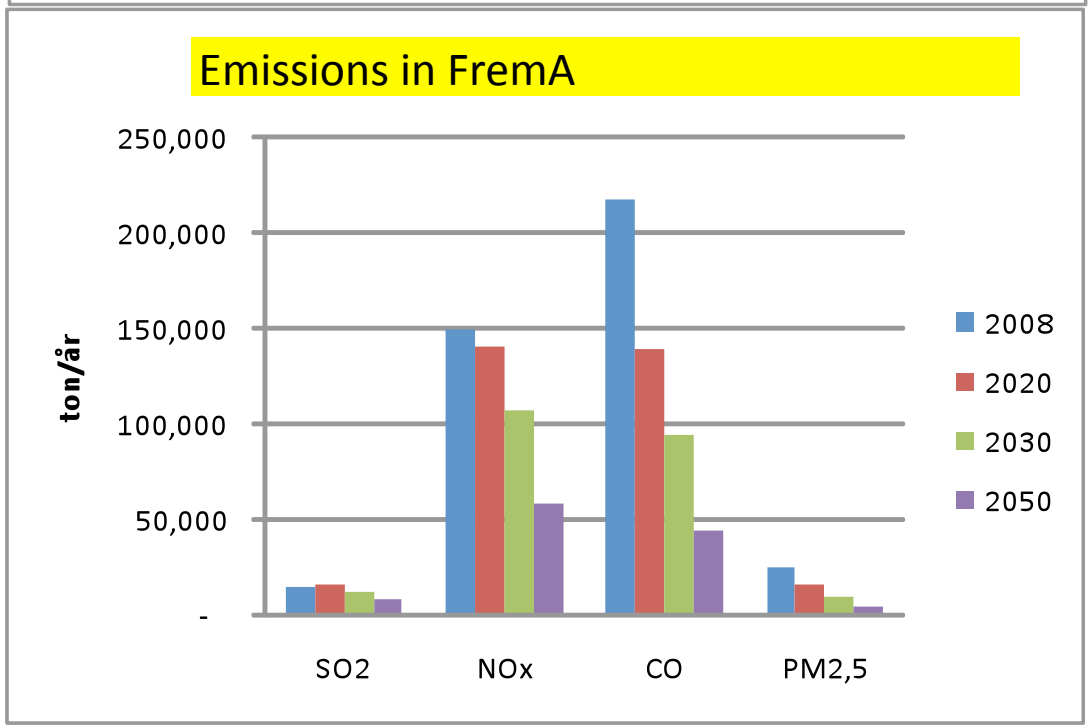
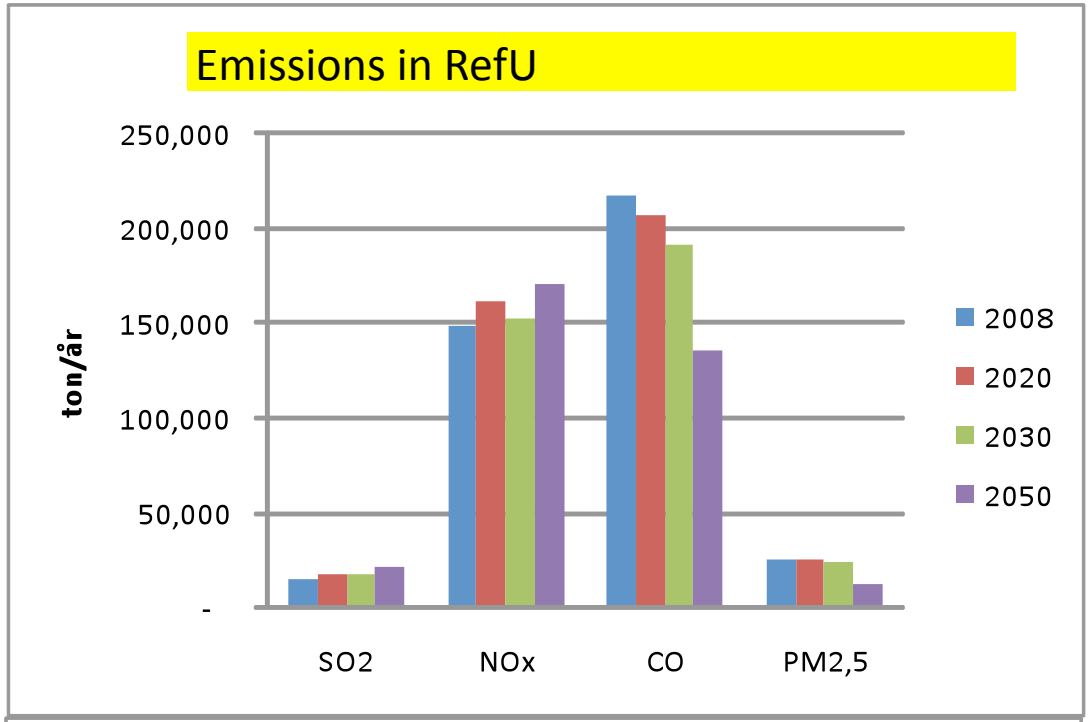
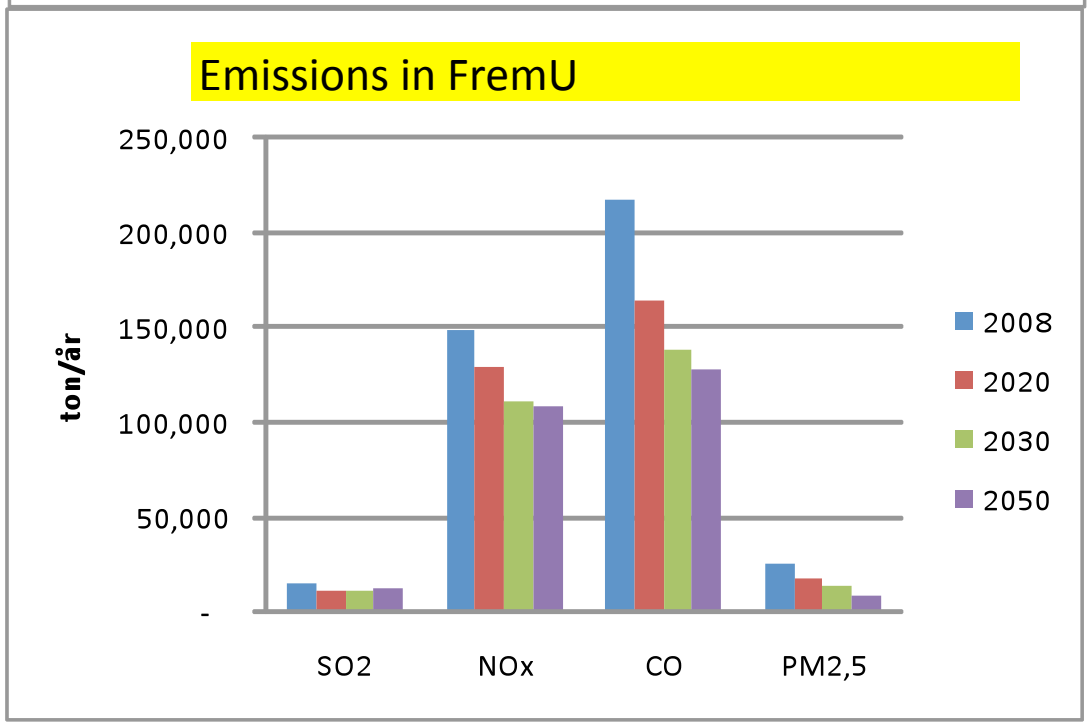
Wind
Natural gas
Coal
Oil


Emissions in RefA
250,000
200,000
150,000
100,000
50,000
-
ton/år
SO2
NOx
CO
PM2,5
2008
2020
2030
2050


Emissions in FremA
250,000
200,000
150,000
100,000
50,000
-
ton/år
SO2
NOx
CO
PM2,5
2008
2020
2030
2050

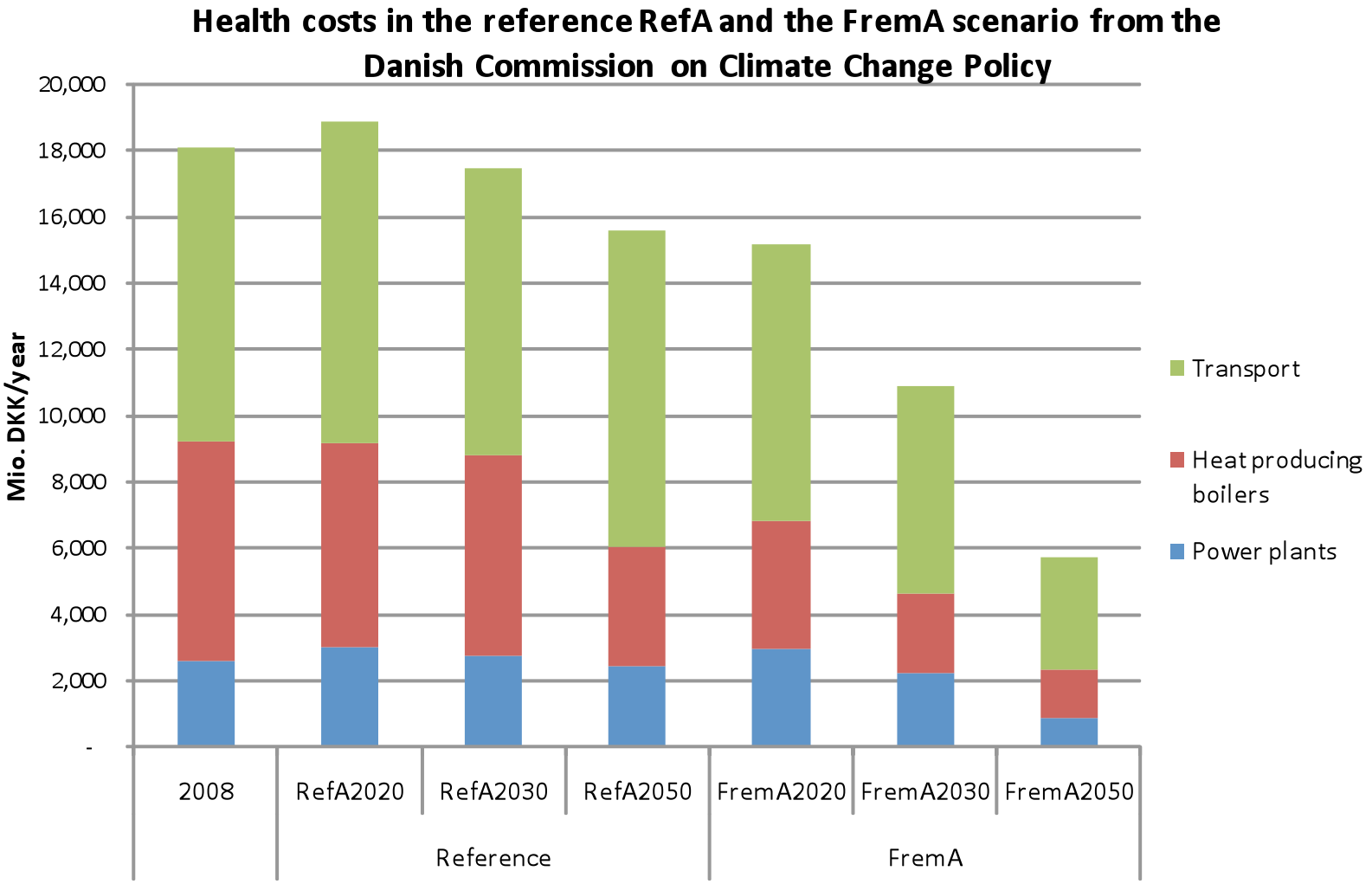

Emissions in RefU
250,000
200,000
150,000
100,000
50,000
-
ton/år
SO2
NOx
CO
PM2,5
2008
2020
2030
2050


Emissions in FremU
250,000
200,000
150,000
100,000
50,000
-
ton/år
SO2
NOx
CO
PM2,5
2008
2020
2030
2050

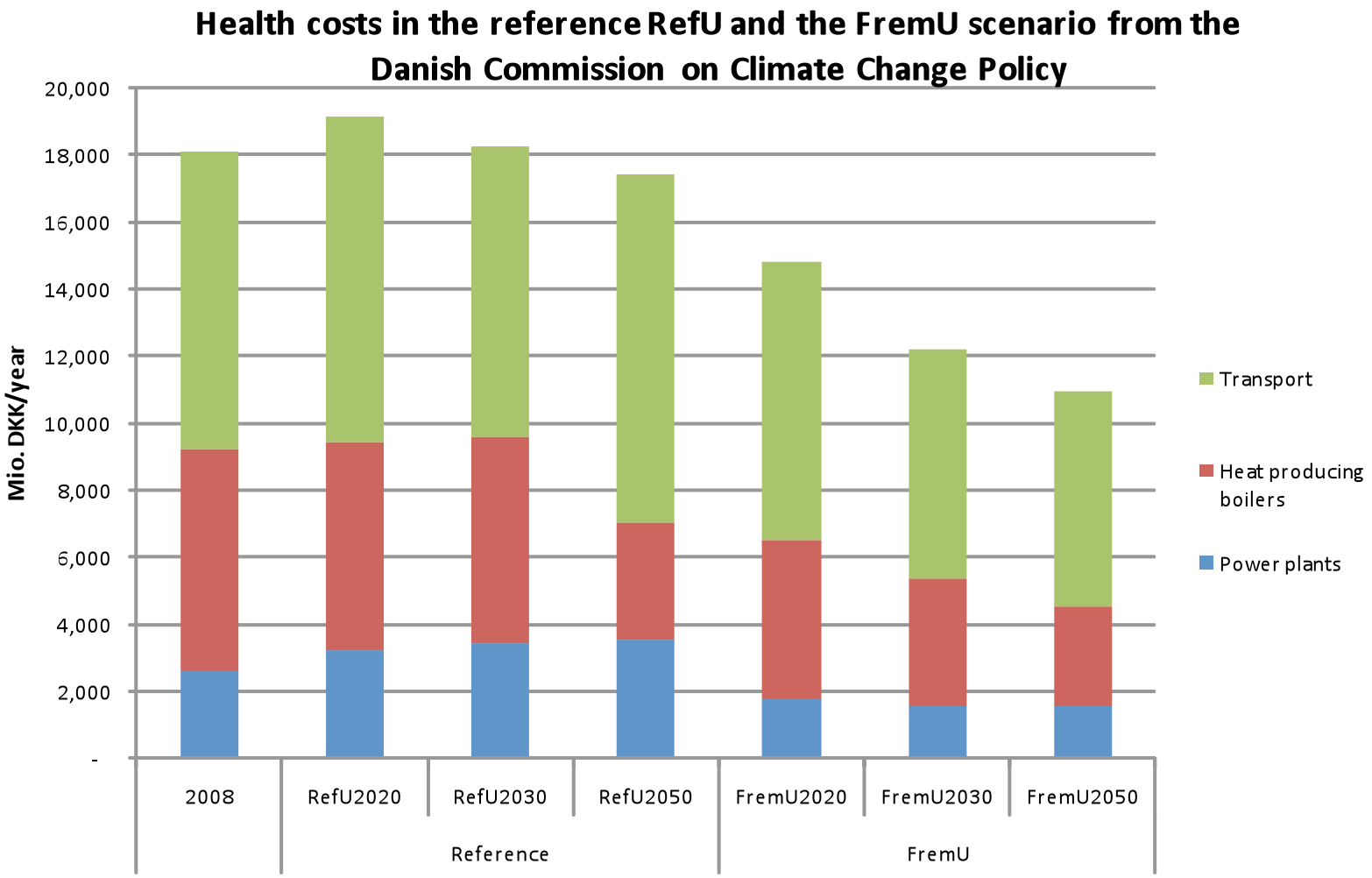
Costs per kg emitted species distributed on various sectors.

Kr./kg	Kraft-værker	Vejtrafik	Industri	Individuel opvarmning	Skibstrafik	Andre mobile
PM2,5	142	328	146	210	127	252
NOx og nitrat	62	78	82	132	60	67
SO2 og sulfat	87	681	114	160	77	80
CO	0.008	0.021	0.010	0.014	0.000	0.016

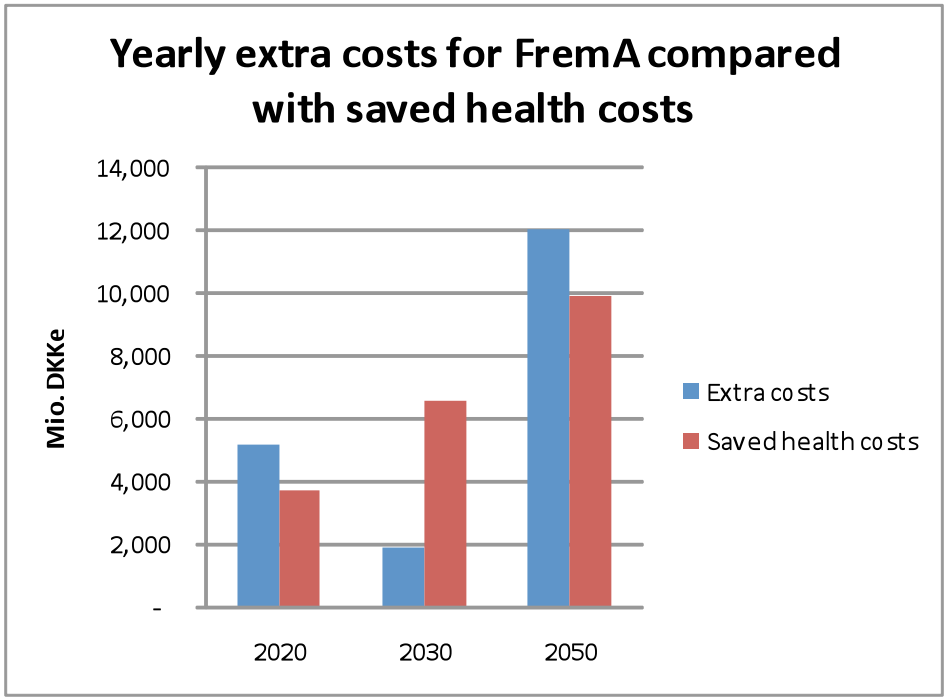
Health costs for RefA and FremA – the wind scenario

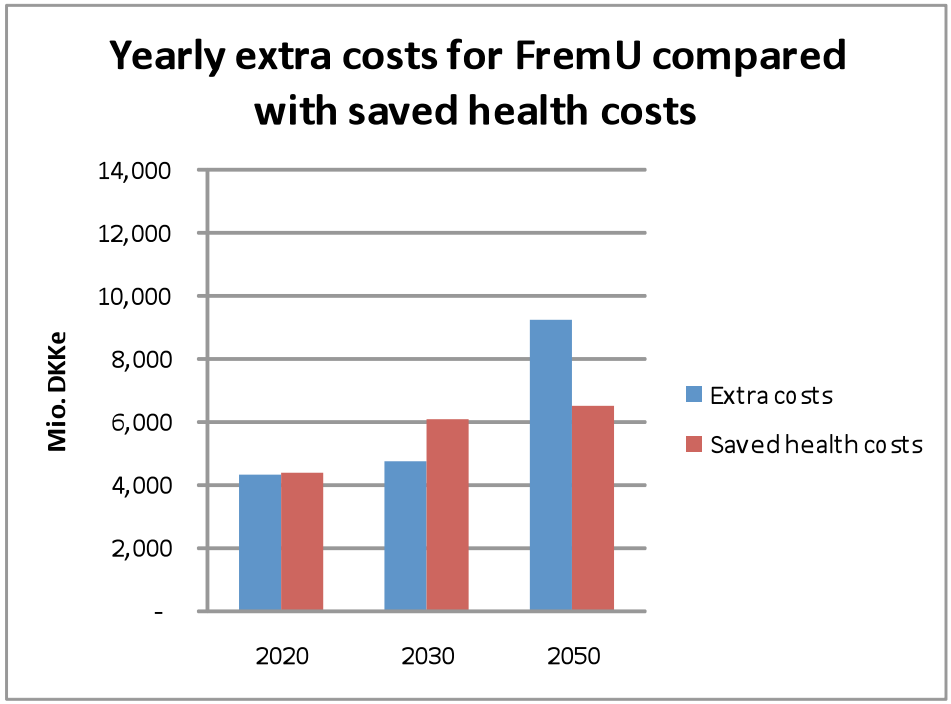


Health costs for RefU and FremU – the biomass scenario



Extra costs for each policy scenario compared with saved health costs





Overall conclusion of the climate commission study:

It is, seen from the societal point of view, essentially free to implement the CO_2 free scenarios of the Danish climate commission.