Carbon Capture and Storage (CCS) renewable energy systems and economy

Klimaforum09

DGI-Byen

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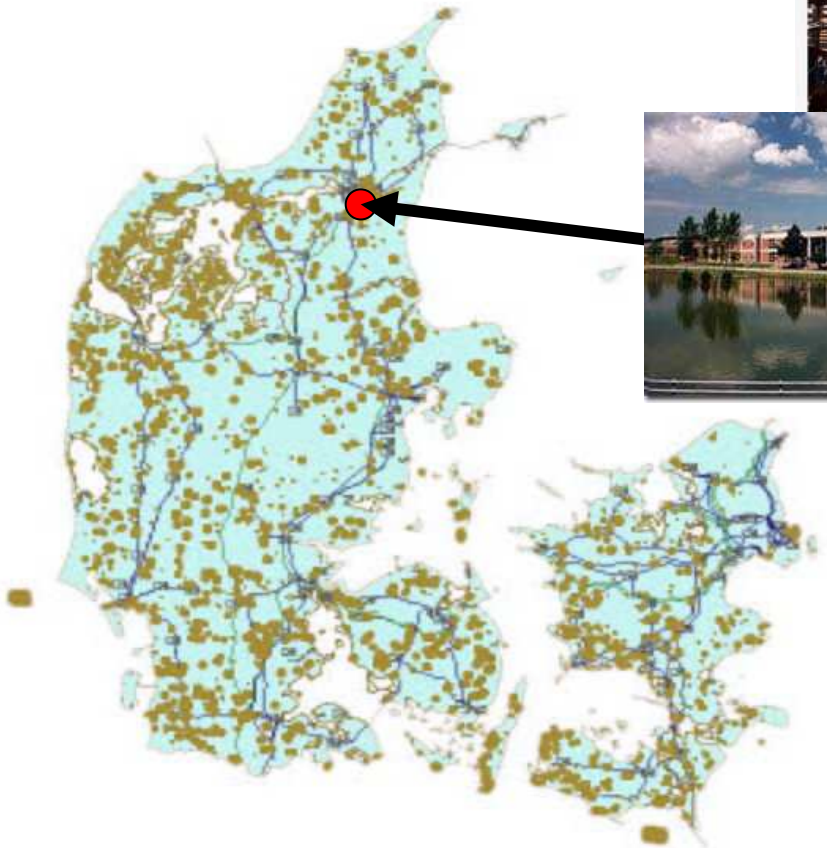
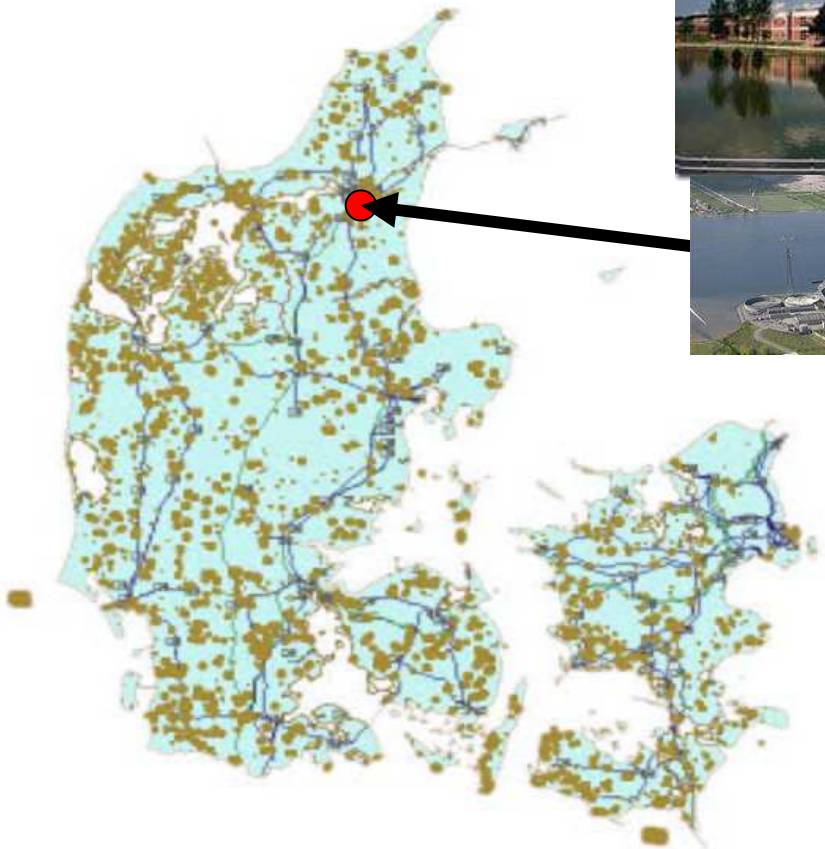
General introduction



Aalborg University, Denmark

- Master of Sustainable Energy Planning and Management
- PhD courses within the area
- More information at www.energyplanning.aau.dk

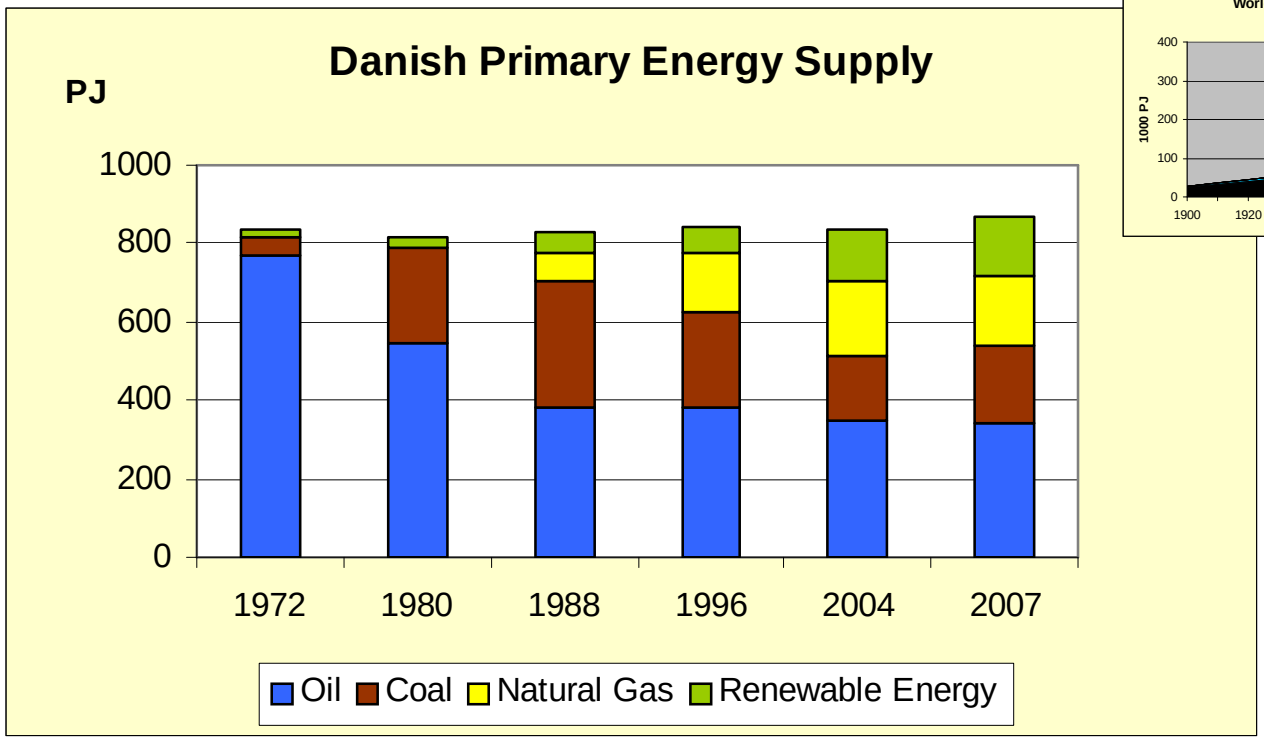
General introduction

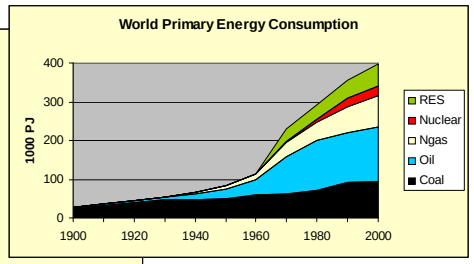


Denmark (Jylland)

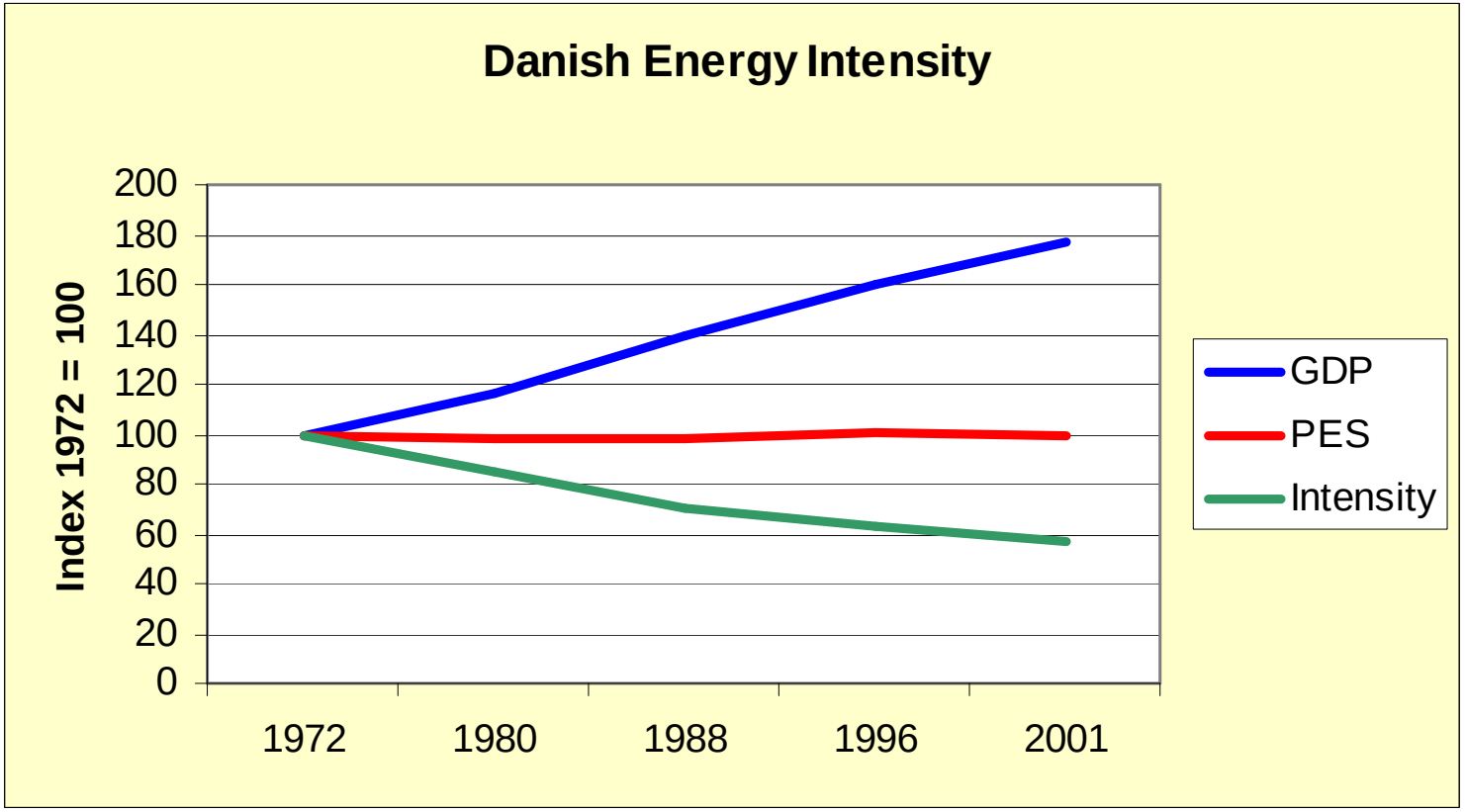
- 20% (25% west) wind power
- 120,000 owners of wind turbines
- High share of the world's offshore power
- More than 30% distributed generation
- 50% of electricity from CHP
- Comprehensive energy conversation policy
- Company plans CCS plant

30 years of stable energy consumption with an active energy policy





Energy and Economic Growth in Denmark



The long-term Objective of Danish Energy Policy

Expressed by former Prime Minister Anders Fogh Rasmussen in his opening speech to the Parliament in 2006 and in several political agreements since then:

To convert to 100% Renewable Energy

Former Prime Minister Rasmussen
16 November 2008:
"We will free Denmark totally from fossil fuels like oil, coal and gas"
"… position Denmark in the heart of green growth"

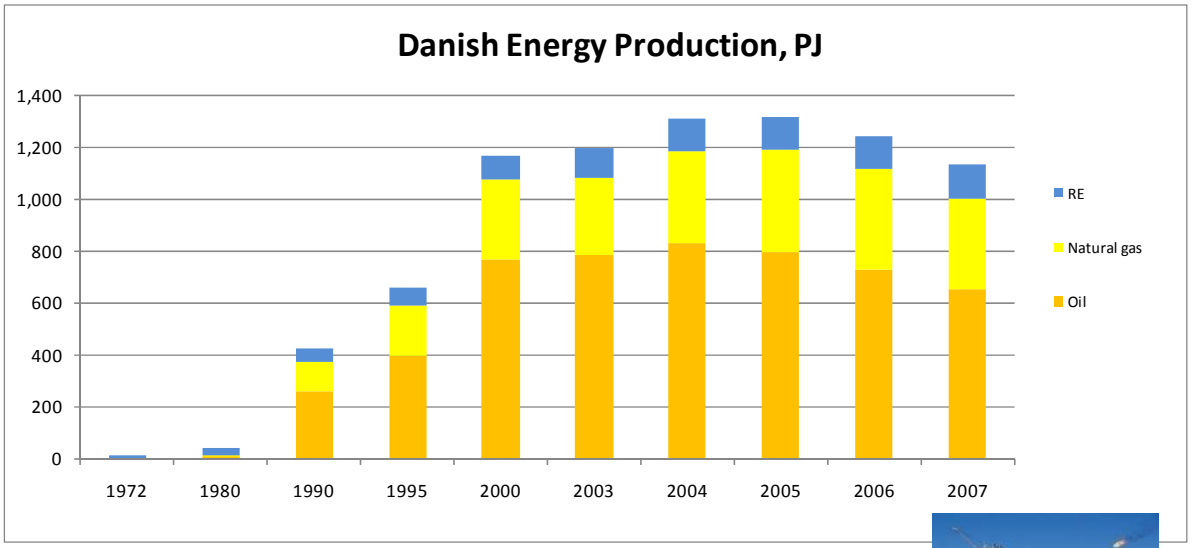
Prime Minister Rasmussen
6 October 2009:
"… before the next general elections we will present a plan of how and when Denmark will be free of fossil fuels"

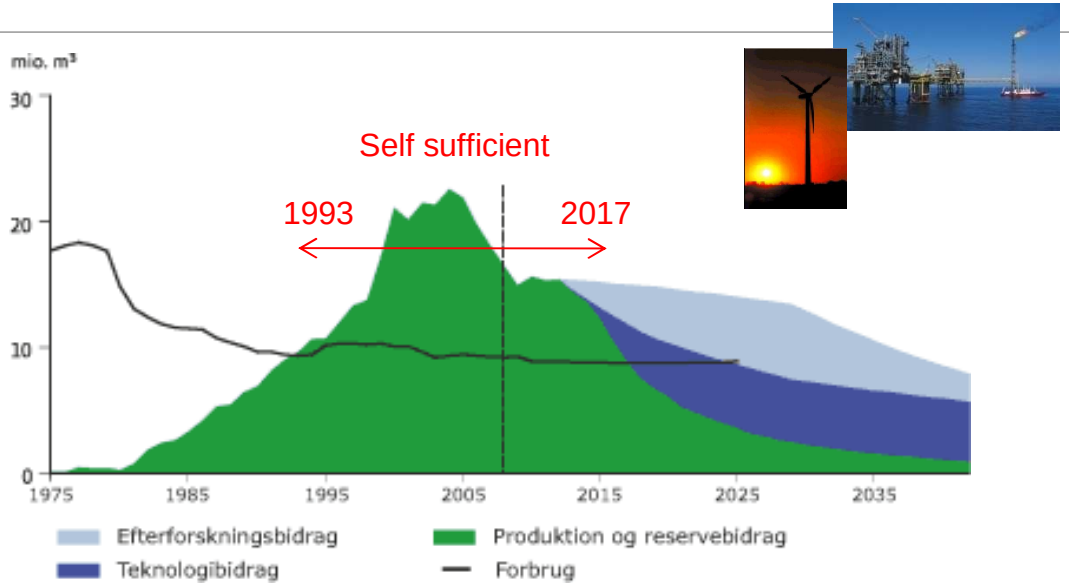
One scenario out of many possible pathways

- IDA's Climate Plan 2050

The IDA Climate Plan 2050

- 4 targets
  - To reduce the emission of green house gasses by 90% in 2050 (including farming)
  - To maintain security of energy supply
  - To expand Denmark's position within energy and climate technologies
  - To improve the Danish economy and prosperity





Danish Energy Authority, 2008

Future Climate
Engineering Solutions

The IDA Climate Plan 2050

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  - To maintain security of energy supply
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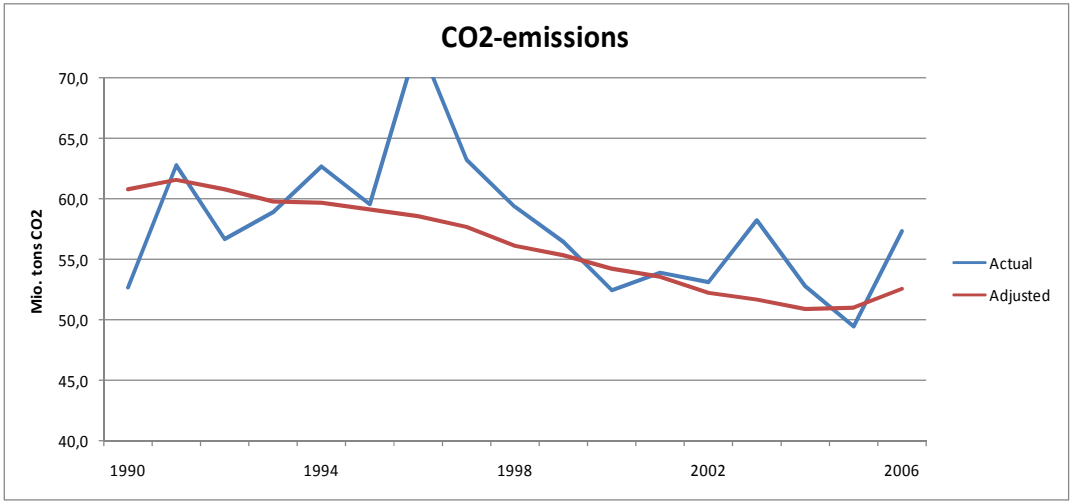
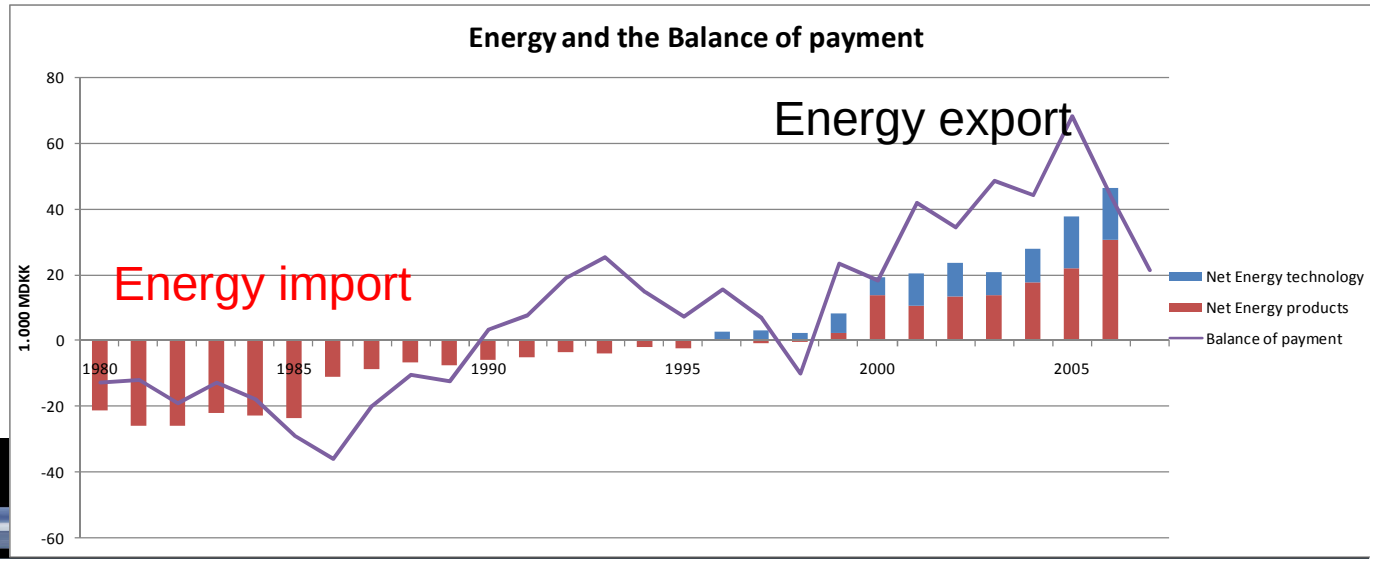




Future Climate
Engineering Solutions

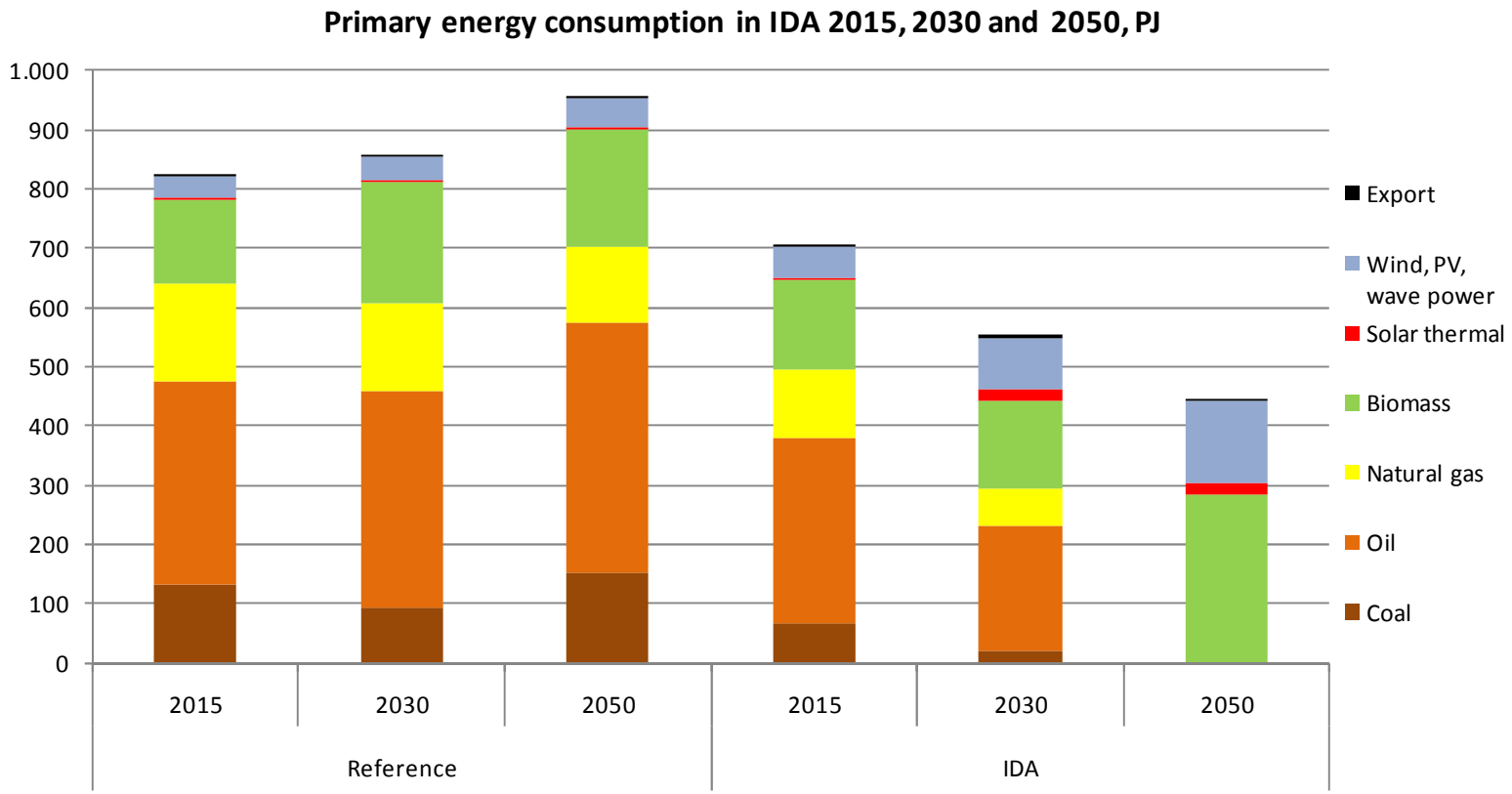
The IDA Climate Plan 2050

- Builds on two previous plans:
  IDAs Energy Plan 2030 (2006), Green future (2008)
  - Inputs based on 40 meetings and seminars conducted by the IDA groups and societies
  - More than 1600 participants
- More than 15 seminars and workshops following up on with updates of inputs
  - Draft report presented on the May 11, 2009
  - Subject to a public hearing until May 21, 2009
  - Coordination by the IDA Committee for energy and climate and 12 groups of professionals
  - Part of international efforts of engineers in the Future Climate – Engineering solutions as COP15 input from 13 countries
  - Overall technical and socio-economic analyses at Aalborg University

AALBORG UNIVERSITY

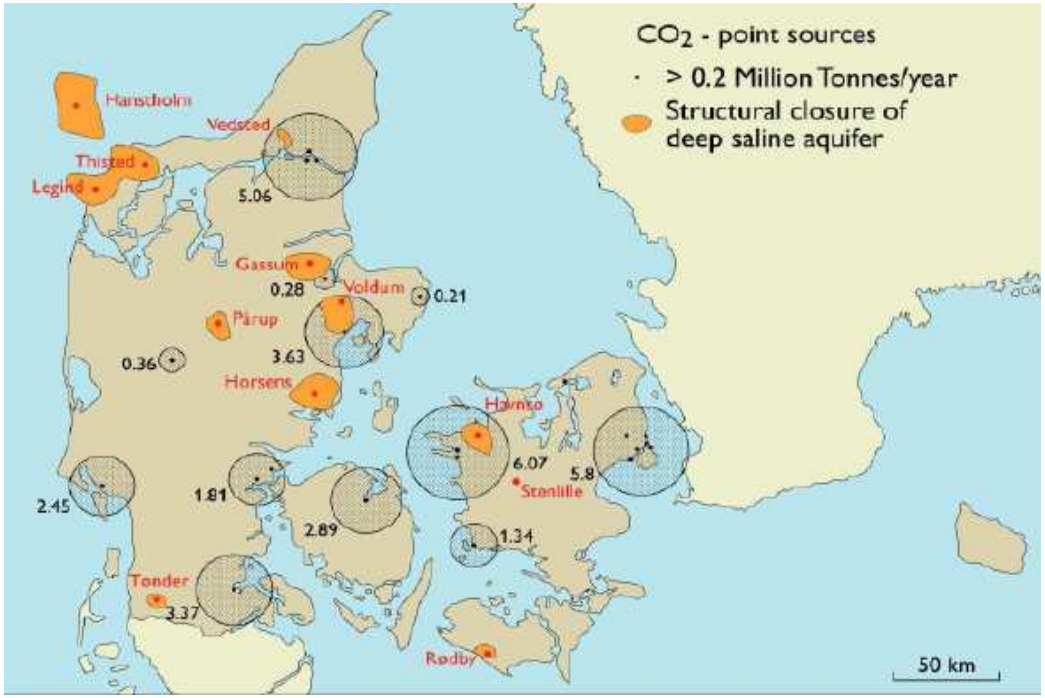
Future Climate
Engineering Solutions

Technical comparison



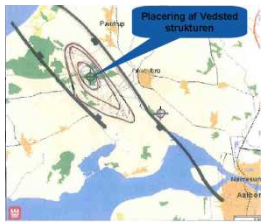
CCS in Denmark

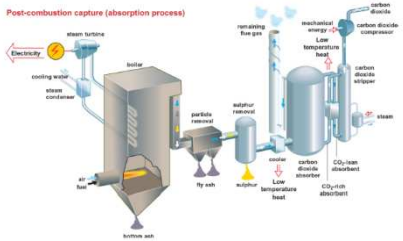
- Test and research project in Esbjerg (Castor) 2006
- Plan for large-scale demonstration in Aalborg (original target 2013)



CCS – the case of Nordjyllandsværket

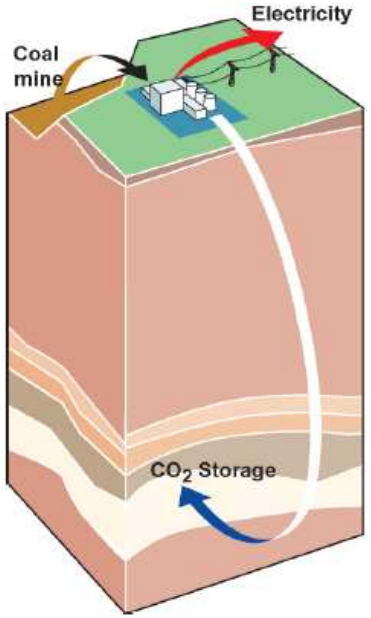
- Nordjyllandsværket worlds most efficient (91%)
- 100% Post-combustion facility
- 30 km pipeline to Vedsted
- Seismic survey and appraisal drilling (ongoing)
- Application at the Danish Energy Authority
- Vedsted structure storage for approx. 40 years, 40 – 80 mio. ton CO_2 and 5,500 m^2
- Operation in 2015?
- Local protest group

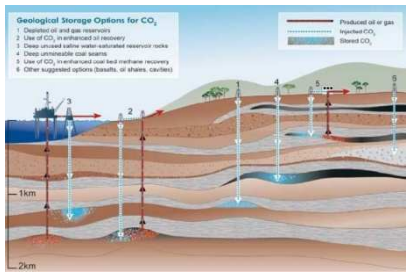




CCS – The case analysed

- Capacity 301 MW (reduced from 372 MW)
- Extra capacity needed 71 MW (10 mill. DKK/MW)
- Increased district heating production
- 90% reduction in CO_2-emissions
- Approx. 20% extra coal
- CC costs 1.7 billion DKK (lifetime 25 years)
- Pipeline and storage costs 1.3 billion DKK (lifetime 50 years)
- Operations and maintenance 2%
- Socio-economic interest rate 3%
- Coal prices 31.1 DKK/GJ



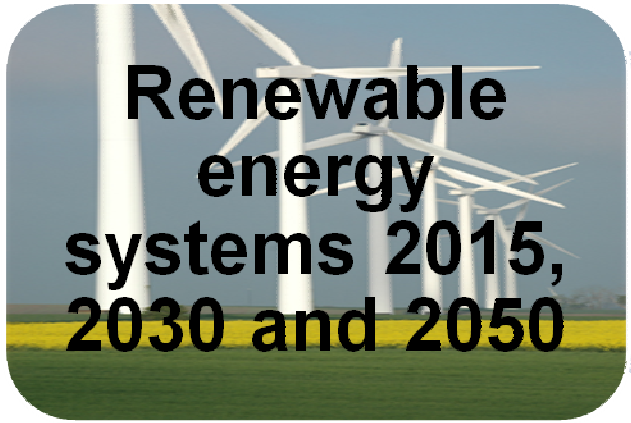


CCS – The case analysed

	Without CCS	With CCS
Capacity	372 MW	301 MW
Coal consumption	792 MW	792
CO_2-emissions	100%	10%
For 1 TWh electricity		
Electricity	1.00 TWh	1.00 TWh
Coal consumption (47%)	2.13 TWh	2.63 TWh
Extra coal		0.50 TWh
CO_2-emissions	0.728 Million ton CO_2	0.900 Million ton CO_2
CCS (90% reduction)		-0.810 Million ton CO_2
Net CO_2-emmisions	0.728 Million ton CO_2	0.090 Million ton CO_2
Net CO_2-emmisions reduction	-	0.638 Million ton CO_2

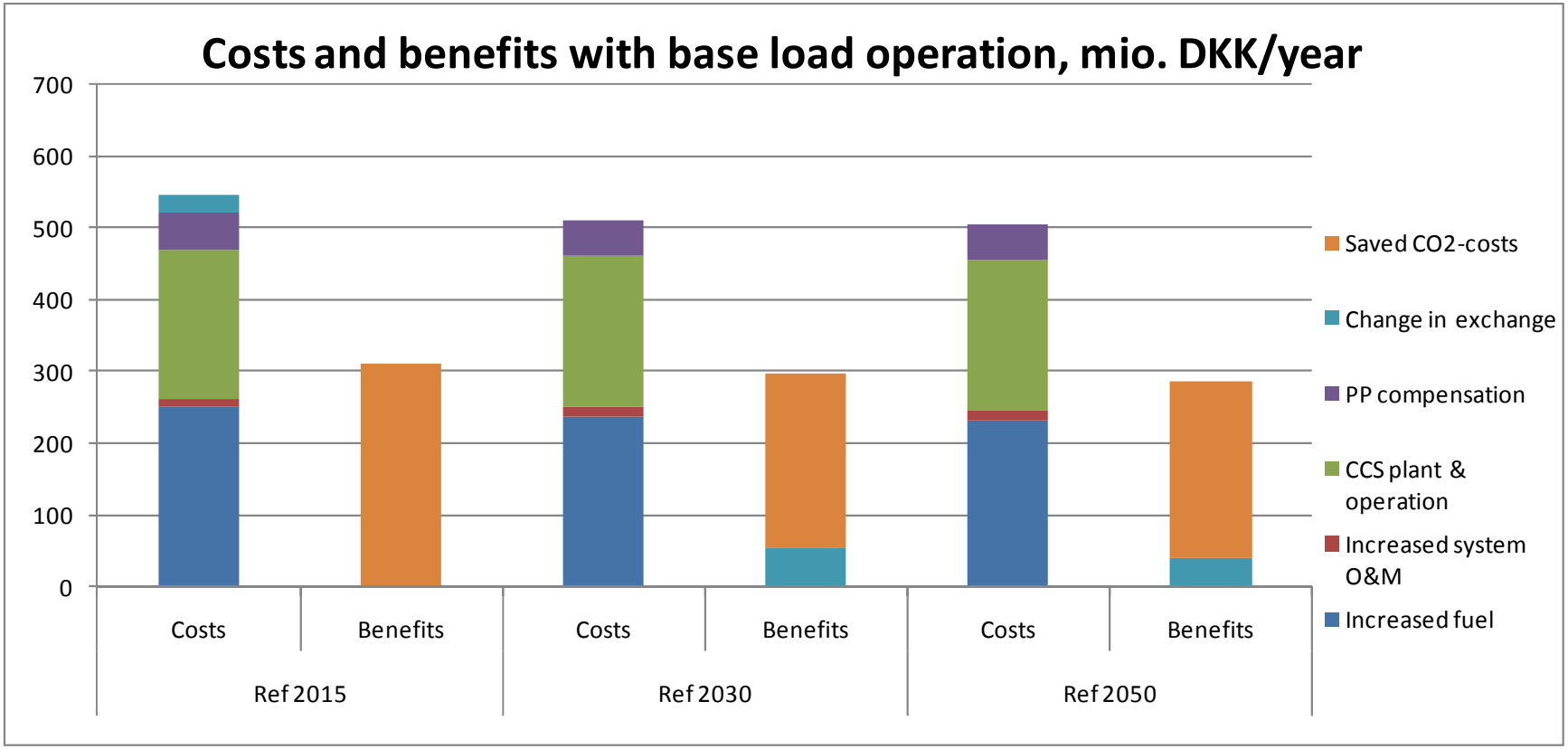
CCS analysed with two operation strategies and two fundamentally different energy systems

- CCS CHP plants analysed:
  - Constant base load operation - 8,000h
  - "Normal" operation - 3,900 to 4,200h

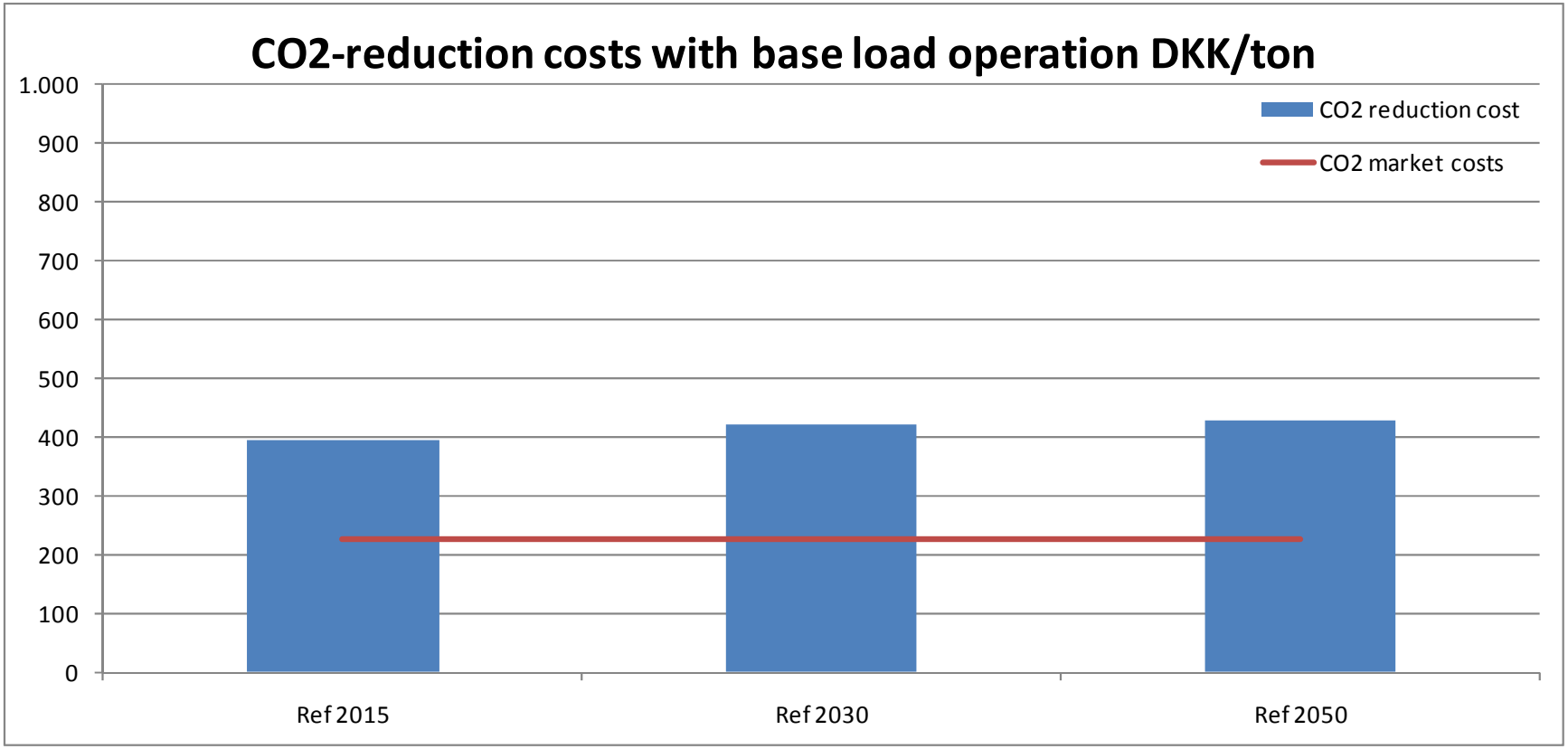


- CCS CHP plants analysed:
  - Constant base load operation - 8,000h
  - "Normal" operation - 3,900; 2,600 and 1,200h in 2015, 2030 and 2050 repectively

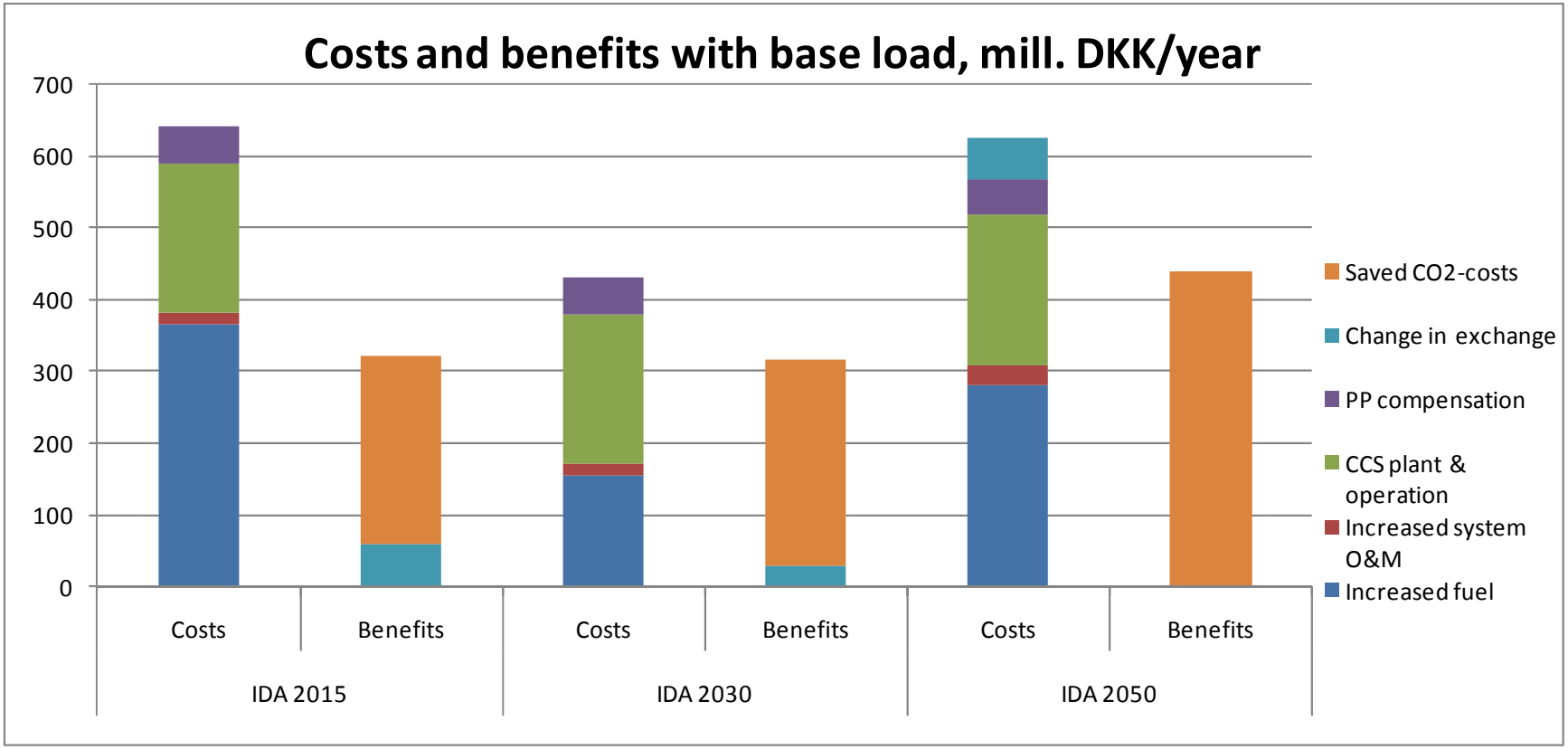
CCS – results with base load operation in conventional energy systems



CCS – results with base load operation in conventional energy systems



CCS – results with base load operation in Renewable energy systems



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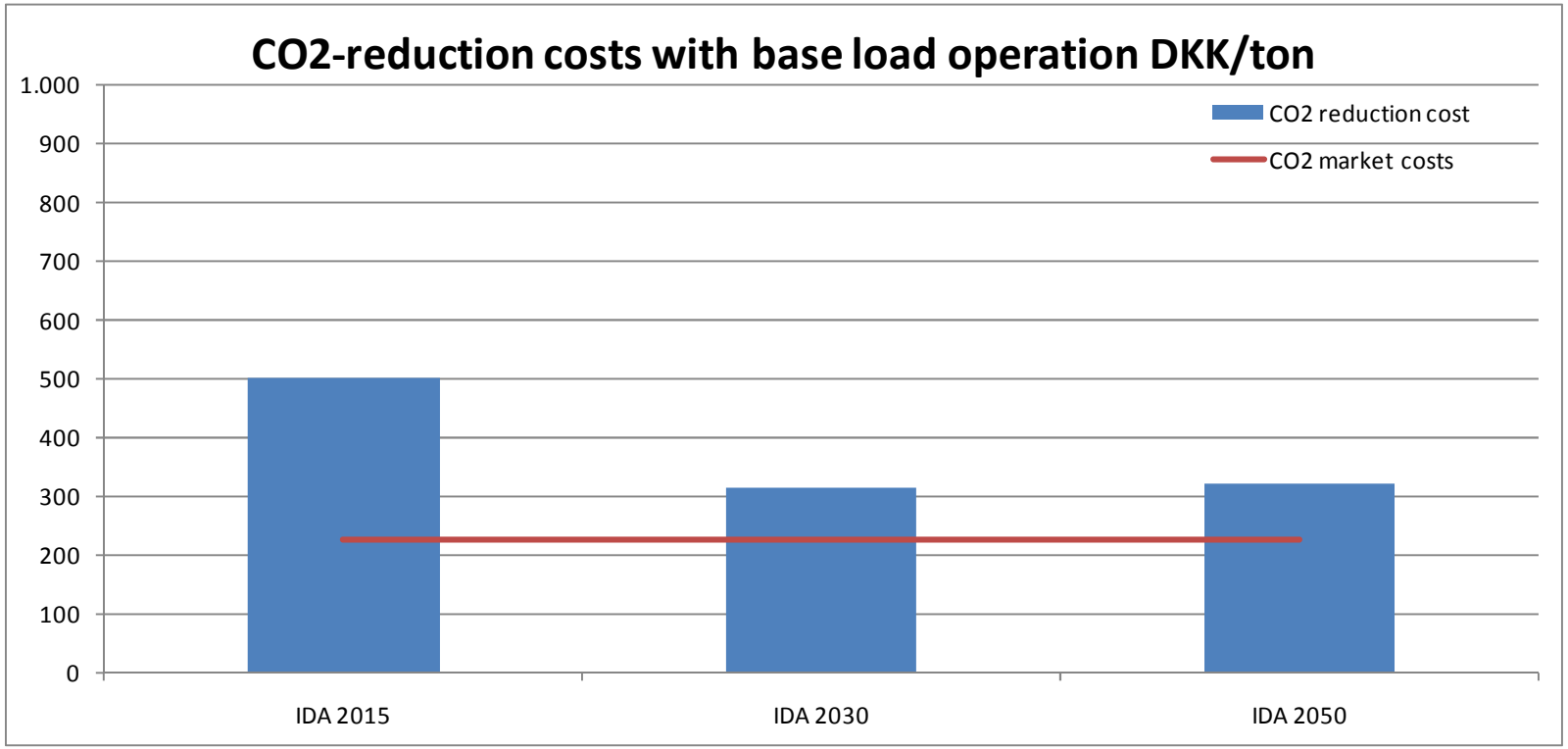
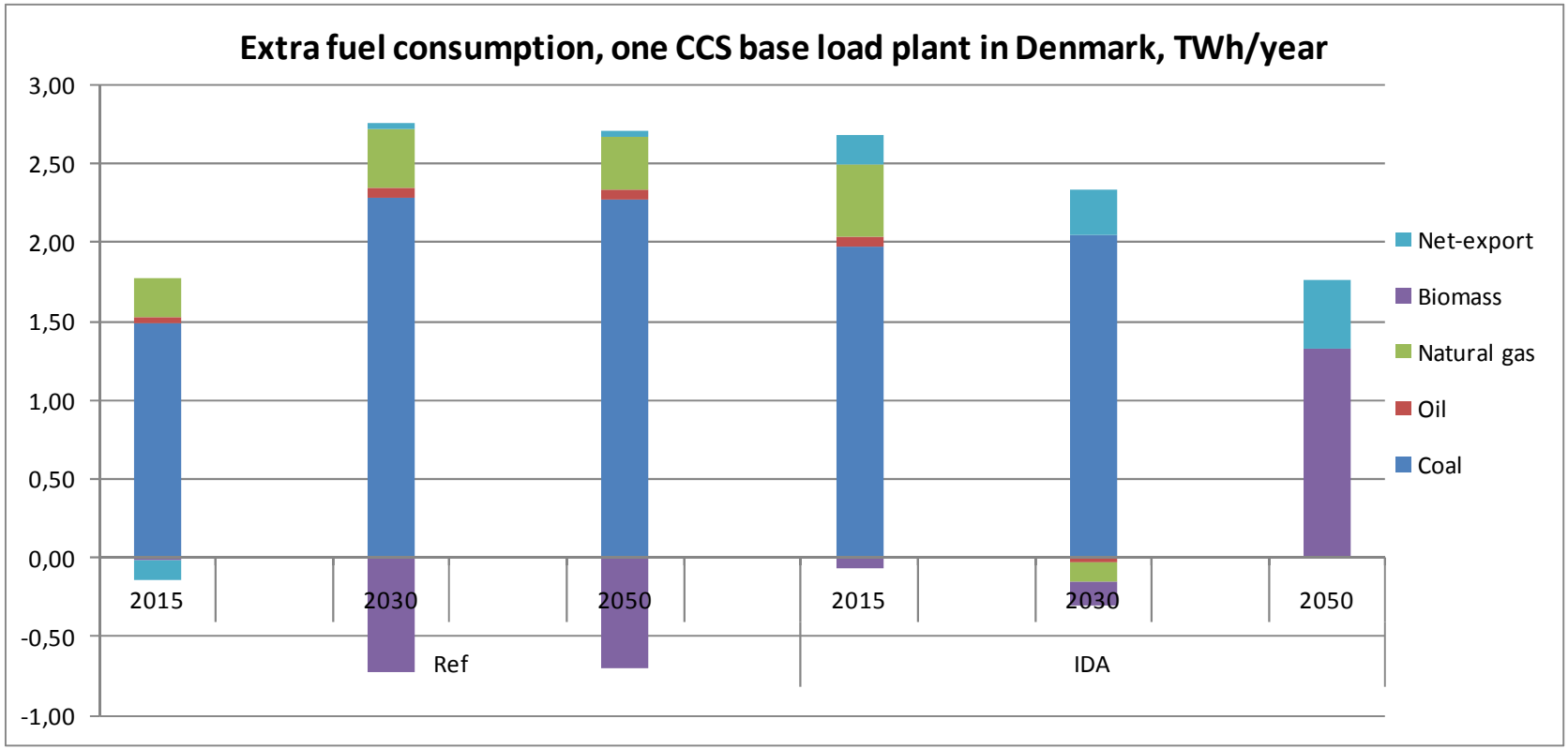
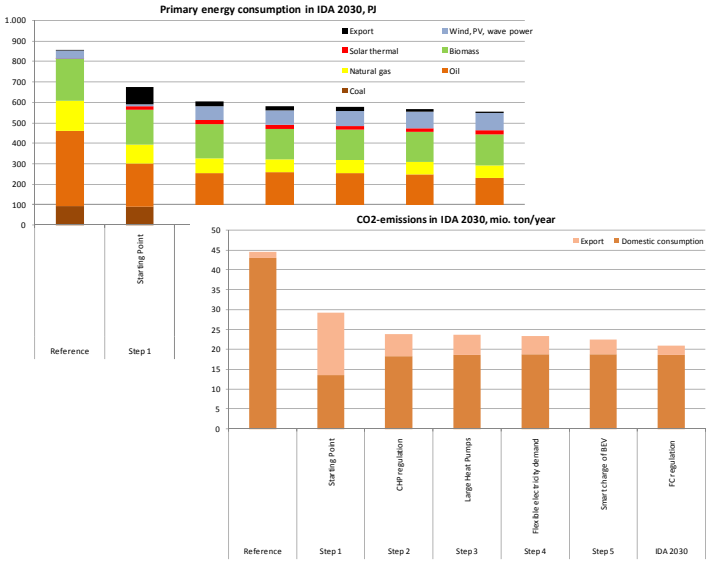


CCS – results with base load operation in Renewable energy systems



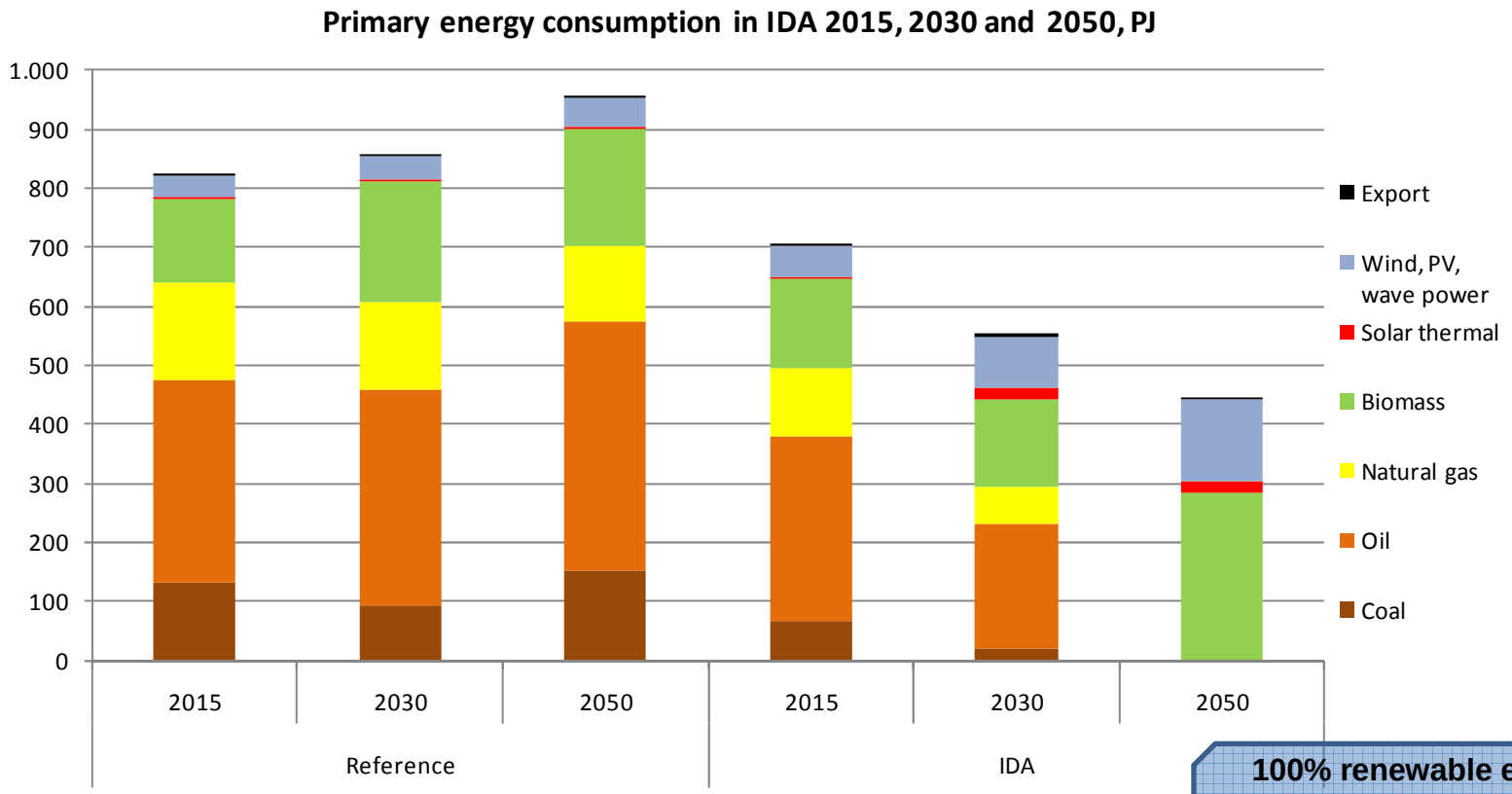
Technical energy system analyses of IDA 2030

- Objectives:
  - Reduce excess electricity
  - Decrease fuel demand



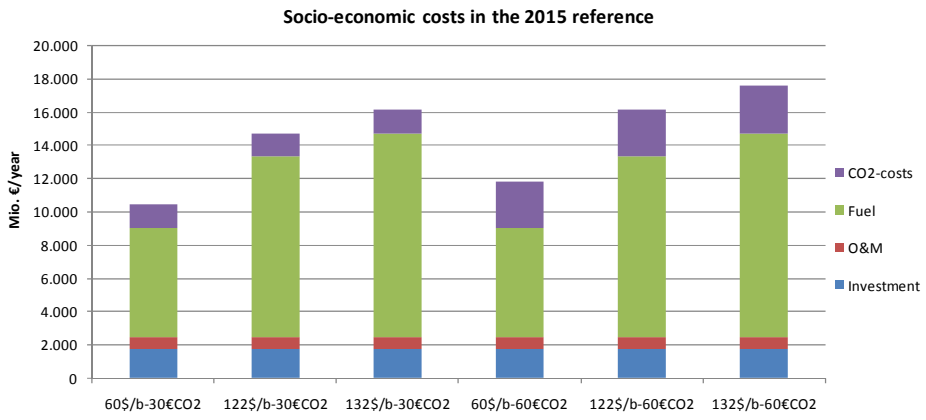
	Excess electricity	Boiler share
Step 1: Starting Point	44%	10%
Step 2: CHP regulation	17%	36%
Step 3: Large Heat Pumps	16%	15%
Step 4: Flexible electricity demand	14%	16%
Step 5: Smart charge of battery electric vehicles	10%	20%
Step 6: FC regulation	5%	23%

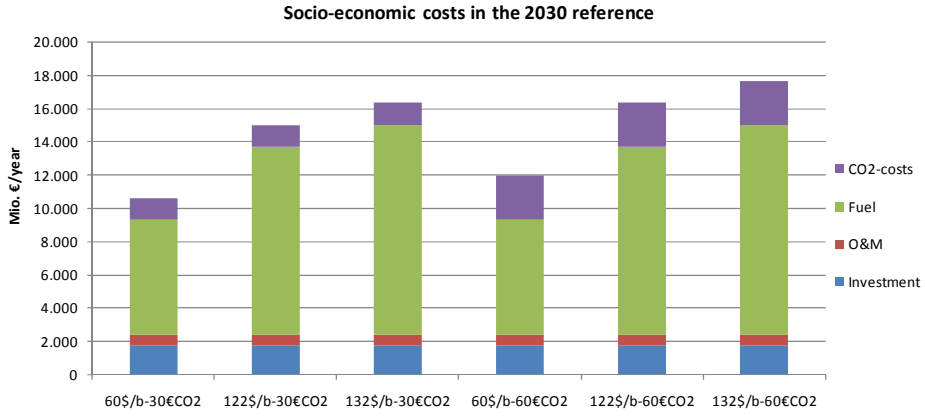
Technical comparison

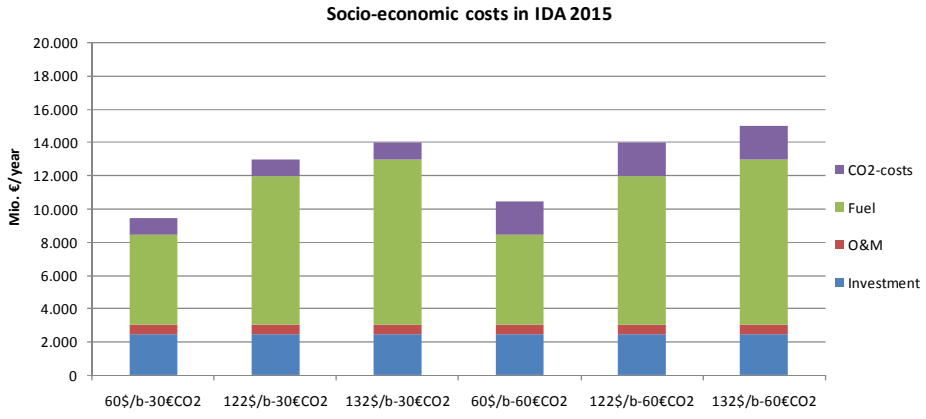


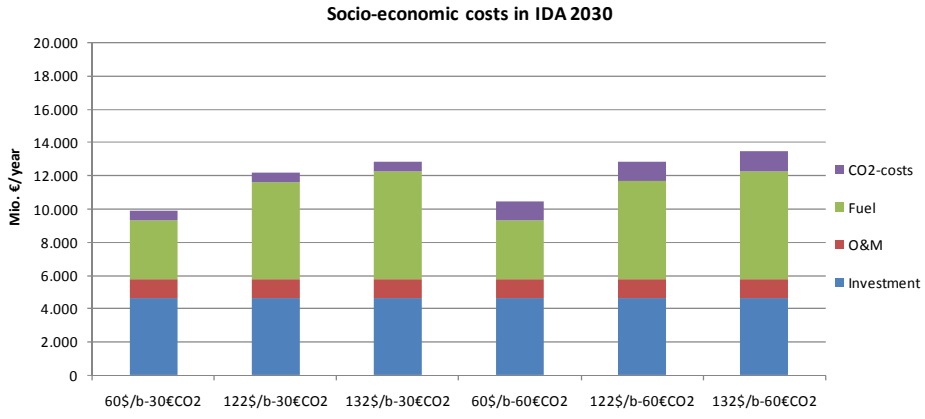
100% renewable energy strategy to be presented in the Green Room, Tuesday at 14.15.

Socio-economic costs

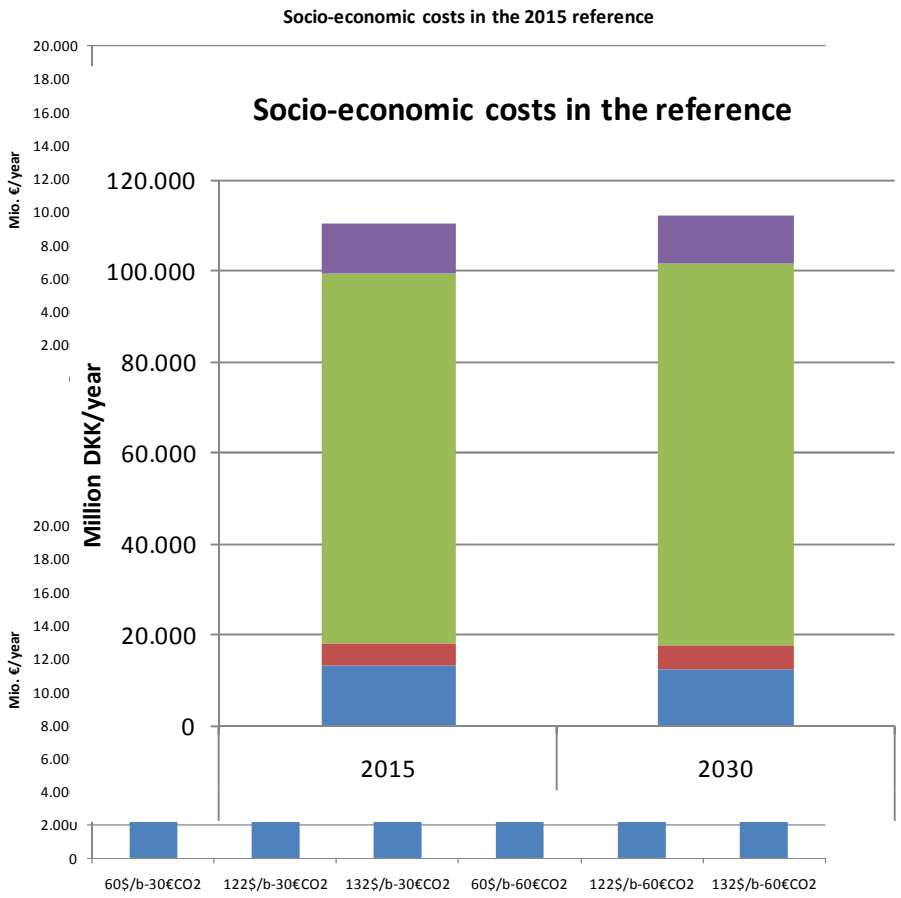


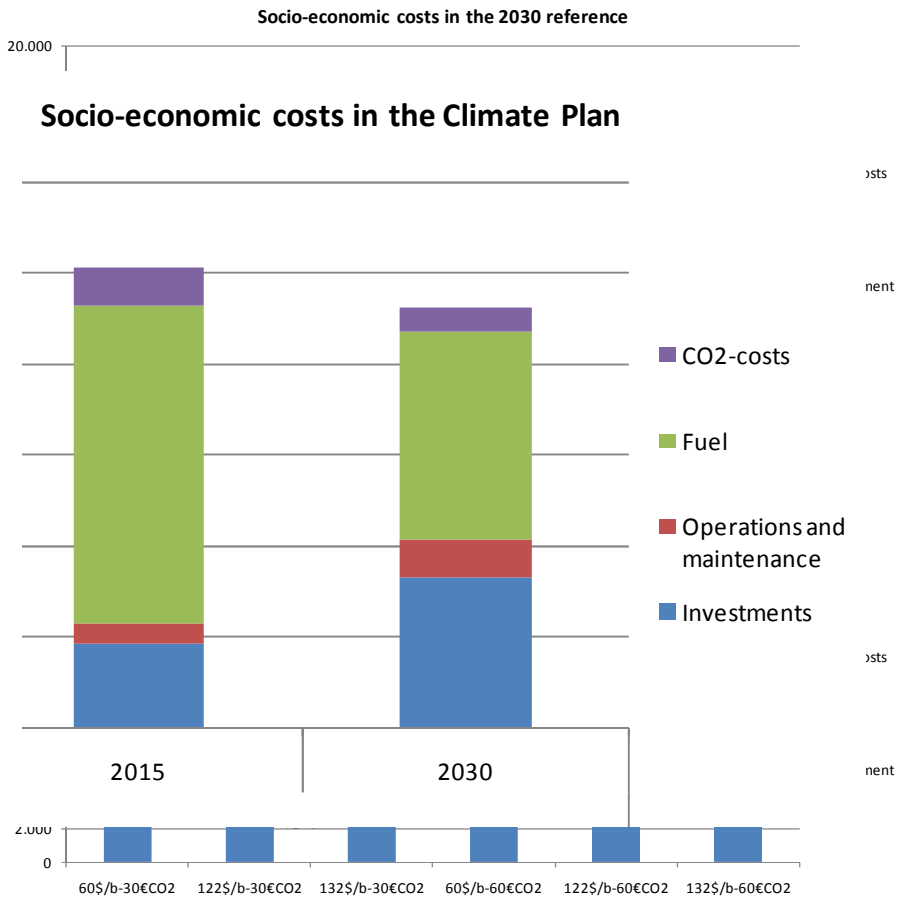


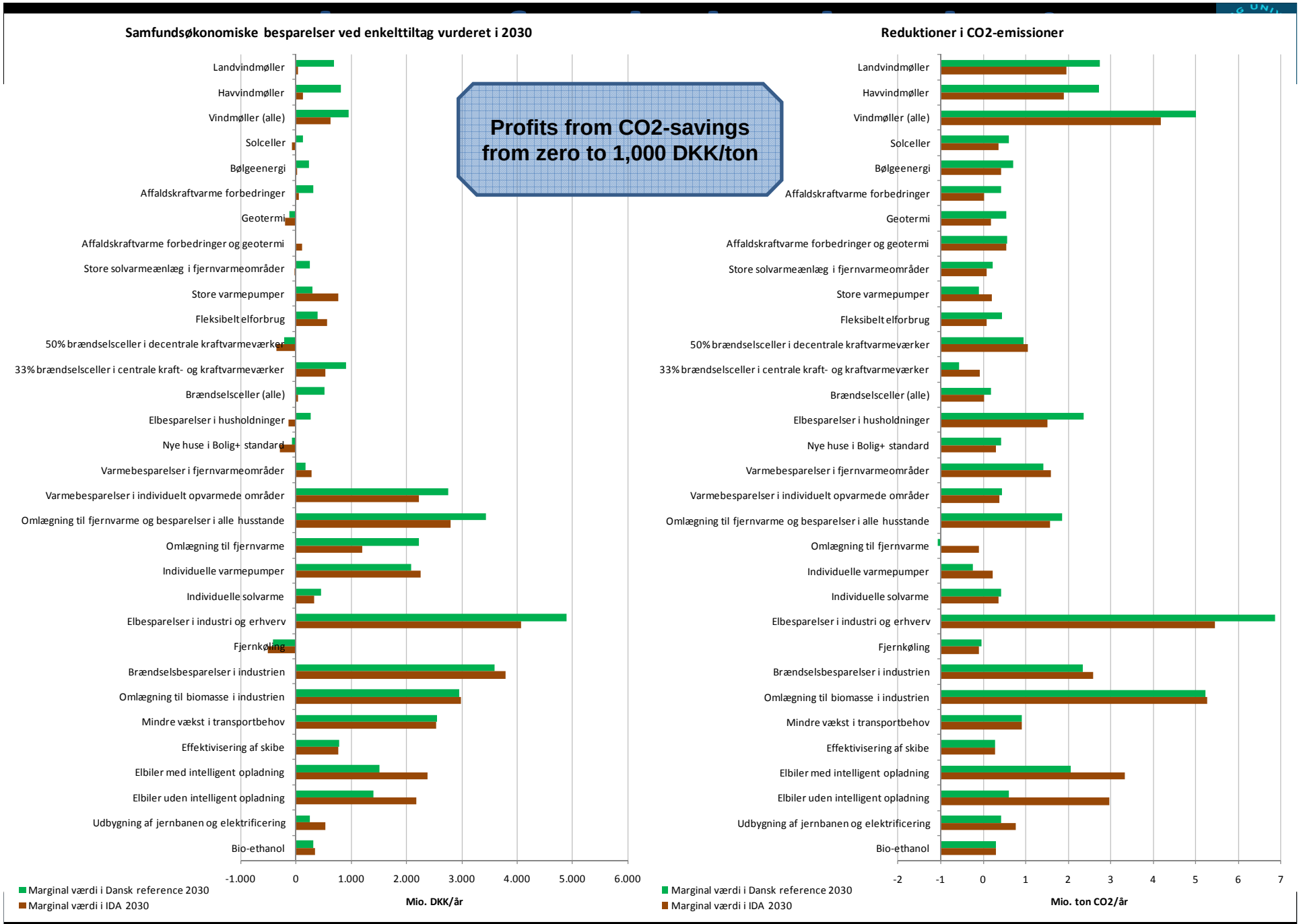




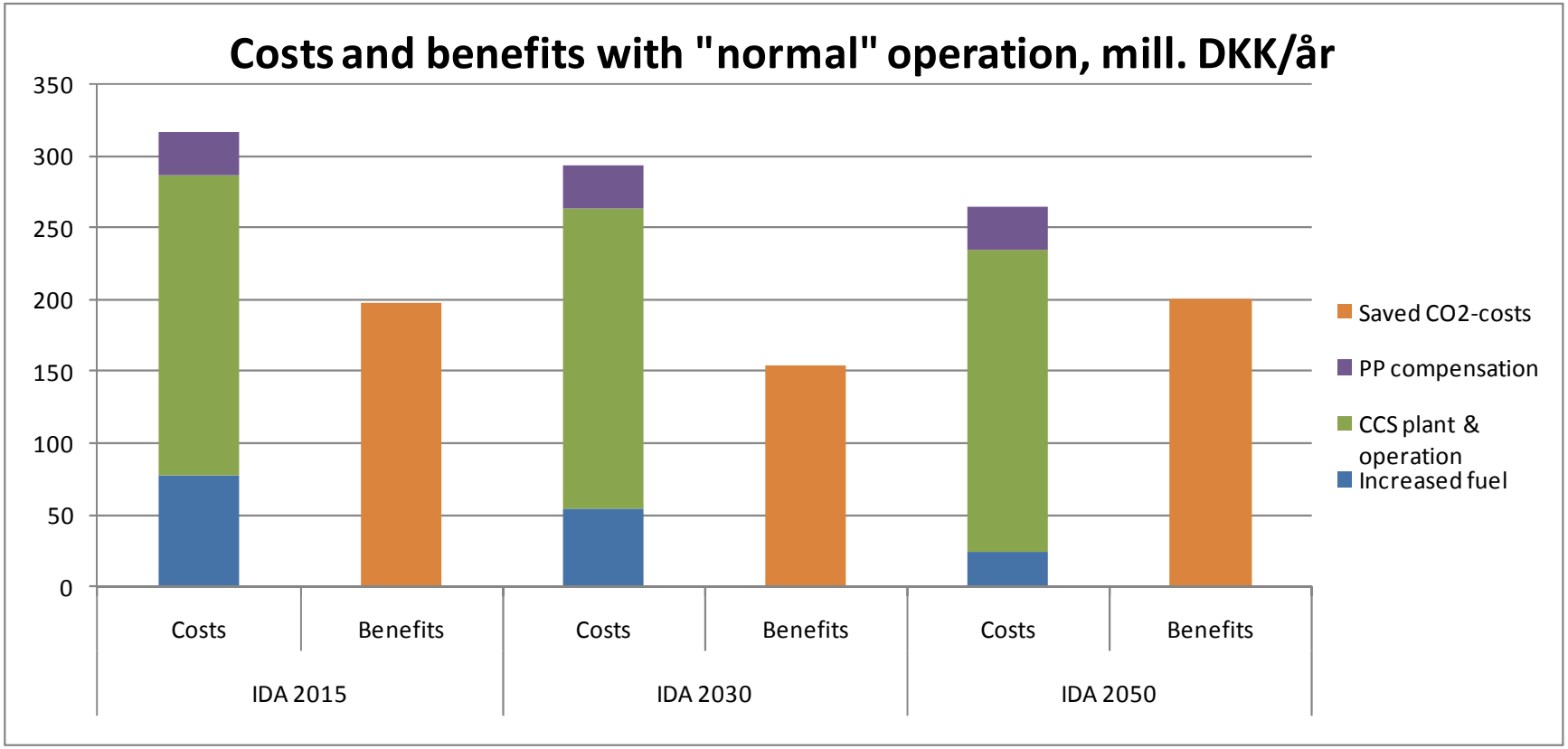
Socio-economic costs






Samfundsøkonomiske besparelser ved enkelttiltag vurderet i 2030
Reduktioner i CO2-emissioner
Profits from CO2-savings from zero to 1,000 DKK/ton
Landvindmøller
Havvindmøller
Vindmøller (alle)
Solceller
Bølgeenergi
Affaldskraftvarme forbedringer
Geotermi
Affaldskraftvarme forbedringer og geotermi
Store solvarmeænlæg i fjernvarmeområder
Store varmepumper
Fleksibelt elforbrug
50% brændselsceller i decentrale kraftvarmeværker
33% brændselsceller i centrale kraft- og kraftvarmeværker
Brændselsceller (alle)
Elbesparelser i husholdninger
Nye huse i Bolig+ standard
Varmebesparelser i fjernvarmeområder
Varmebesparelser i individuelt opvarmede områder
Omlægning til fjernvarme og besparelser i alle husstande
Omlægning til fjernvarme
Individuelle varmepumper
Individuelle solvarme
Elbesparelser i industri og erhverv
Fjernkøling
Brændselsbesparelser i industrien
Omlægning til biomasse i industrien
Mindre vækst i transportbehov
Effektivisering af skibe
Elbiler med intelligent opladning
Elbiler uden intelligent opladning
Udbygning af jernbanen og elektrificering
Bio-ethanol
-1.000
0
1.000
2.000
3.000
4.000
5.000
6.000
Mio. DKK/år
Marginal værdi i Dansk reference 2030
Marginal værdi i IDA 2030
-2
-1
0
1
2
3
4
5
6
7
Mio. ton CO2/år
Marginal værdi i Dansk reference 2030
Marginal værdi i IDA 2030

CCS – results with “normal” operation in renewable energy systems



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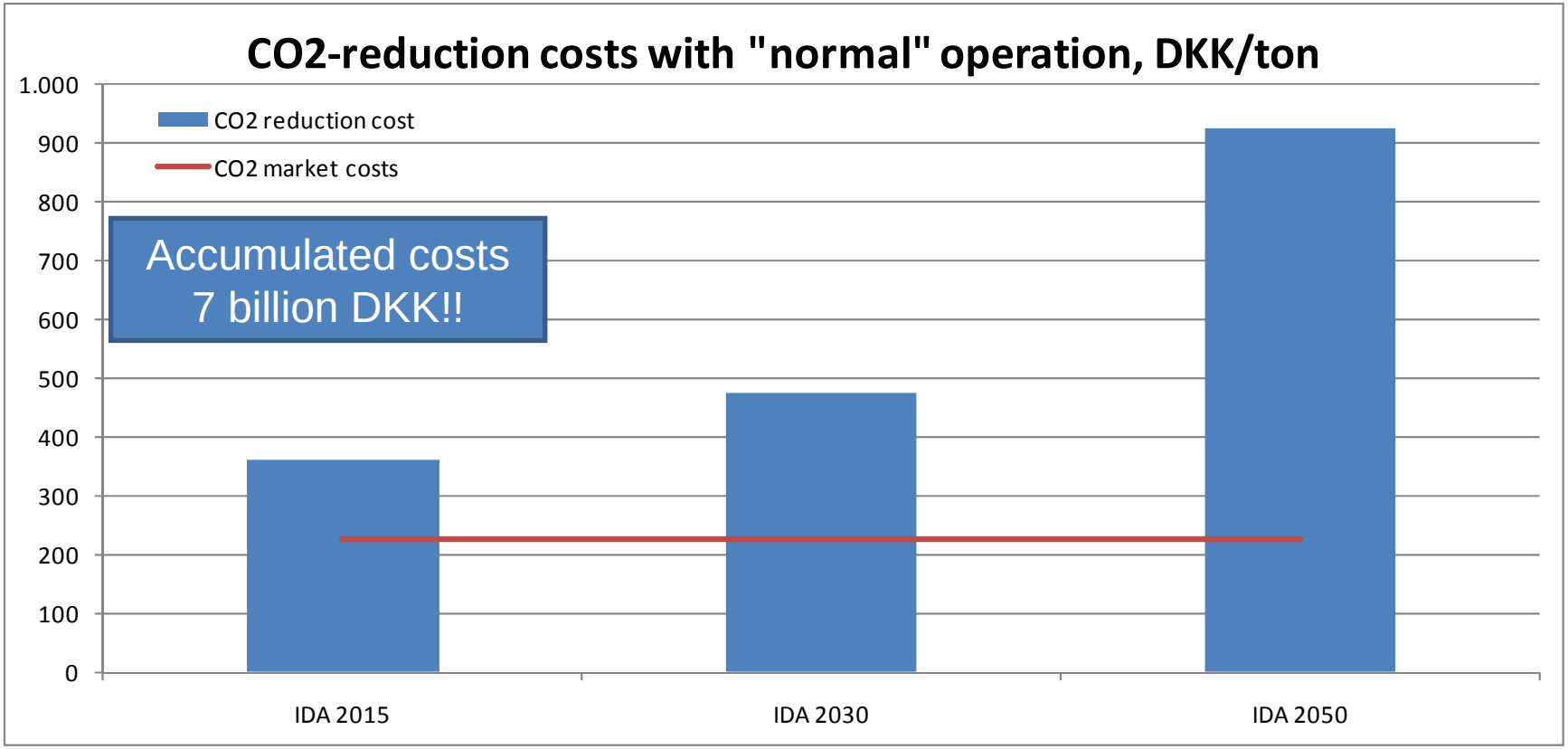

Proposal by Danish power producers

- Producers Climate Plan – Power to the people
  - 3,000 MW (7,5 of Nordjyllands værket)
- Losses with one plant: 120 – 320 mill. DKK
  - 900 – 2,400 mill. DKK for 3,000 MW
- Losses over 50 years with one plant: 6-16 bill. DKK
  - 45 – 120 bill. DKK for 3,000 MW
- Extra fuel with one plant: 3,6-7,2 PJ
  - 27-54 PJ for 3,000 MW (total Danish Potential approx. 300 PJ)

Summery and conclusions

- CCS is an expensive method to reduce CO_2-emissions – even when using a low interest rate
- CCS gives socio-economic losses to the system (310.-930 DKK/ton)
- Other solutions gives profits of up to 1,000 DKK/ton CO_2 or balances
- Renewable energy reduces the operation time of power plants and increases the costs of CCS
- If CCS is establish first, the marginal costs of operation are very low, and will propone other investments in renewable energy
- CCS makes the energy system more inefficient
- CCS reduces the ability to perform on electricity markets
- Offshore storage 5-10 times more expensive if onshore not possible
- Regulation ability is uncertain
- 100% renewable energy systems will be technically possible and is profitable (hear about it tomorrow)

Thank you for your attention!

- H. Lund and B. V. Mathiesen, "Fagligt notat - Konsekvensanalyse af tilføjelse af CCS-anlæg til IDAs klimaplan 2050 (IDAs Climate Plan 2050, Analyses of CCS)," Danish Society of Engineers (IDA, Ingeniørforeningen Danmark), Copenhagen, Denmark,Aug.2009.
- B. V. Mathiesen, "100% Renewable Energy Systems in Project Future Climate - the Case of Denmark," Dubrovnik, Croatia: 5th Dubrovnik Conference on Sustainable Development of Energy, Water and Environment Systems, 2009.
- B. V. Mathiesen, H. Lund, and K. Karlsson, "IDA's Klimaplan 2050, baggrundsrapport - Tekniske systemanalyser, brændselsforbrug, drivhusgasser, samfundsøkonomiske konsekvenser, erhvervspotentialer, beskæftigelseseffekter samt helbredsomkostninger (IDA's Climate Plan 2050, Background Report),“ Danish Society of Engineers (IDA, Ingeniørforeningen Danmark), Copenhagen, Denmark,August2009.

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