Heating technology mix in a future German energy system dominated by renewables

Prof. Dr. Hans-Martin Henning

Fraunhofer Institute for Solar Energy Systems ISE

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Overview

- German climate policy targets and the building sector
- Technologies for decarbonizing the heating sector
- Transformation pathway of the German energy system
- Summary & conclusions

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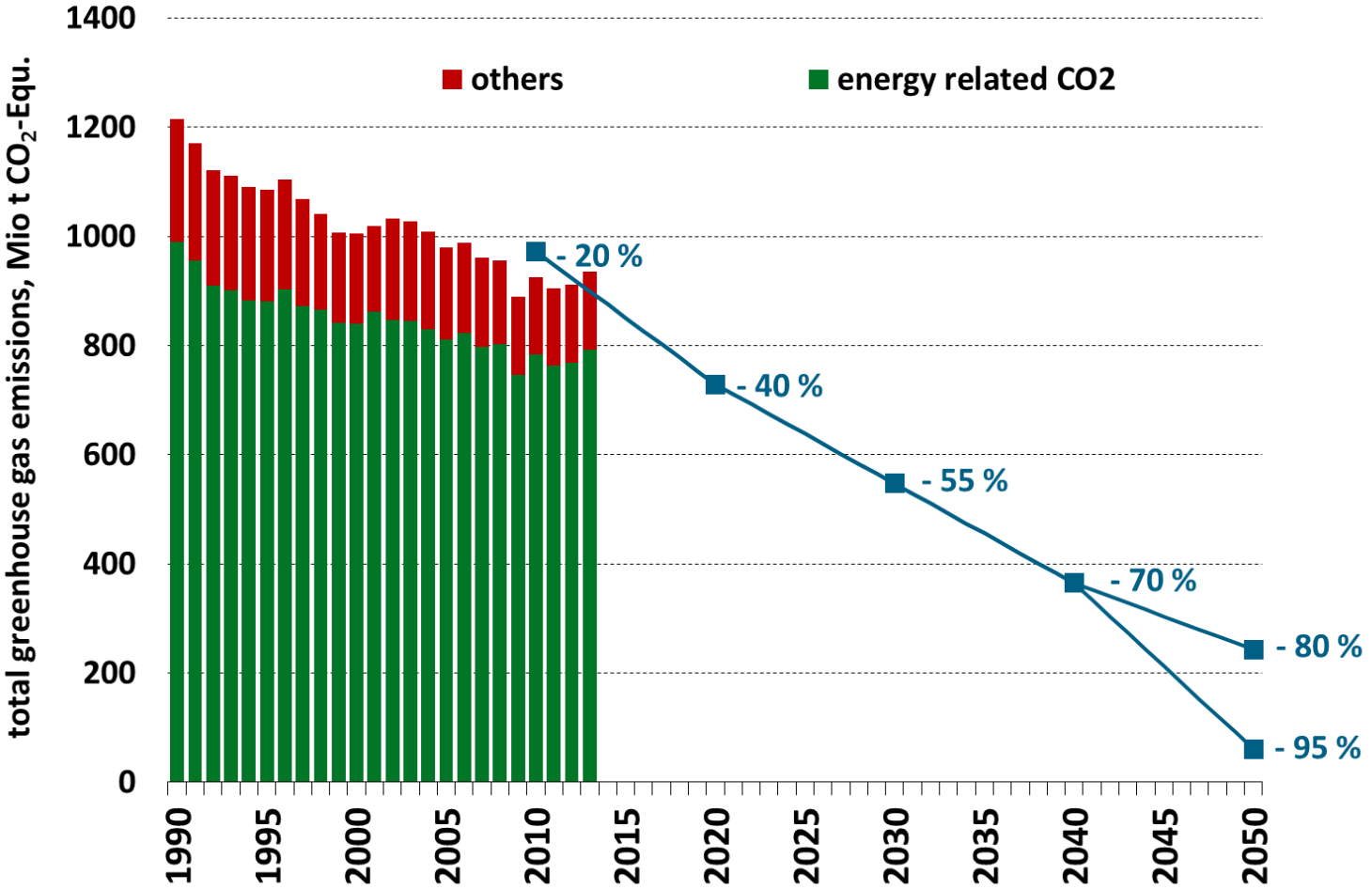
Development of German GHG emissions 1990 – 2013 & target values until 2050



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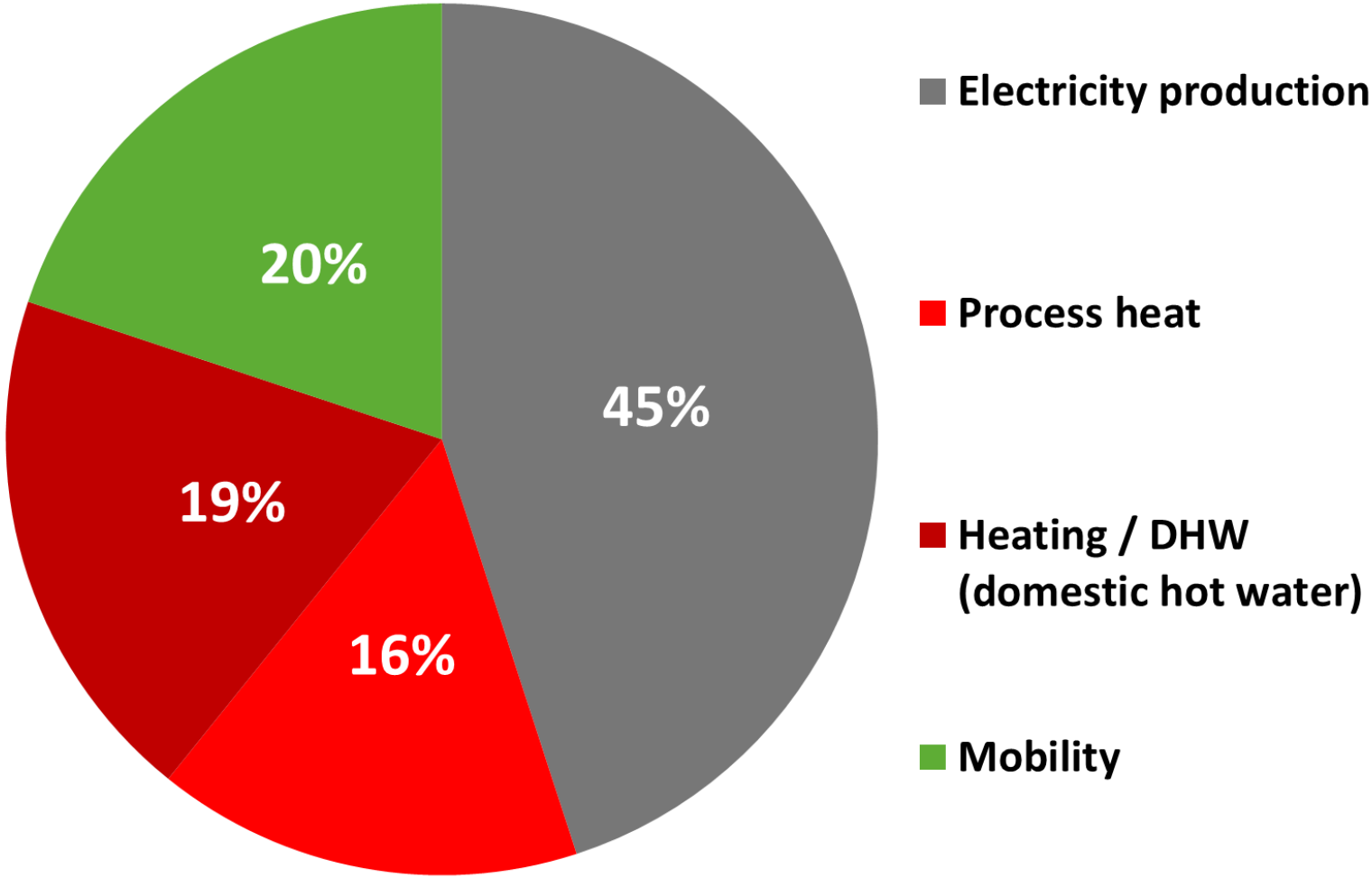
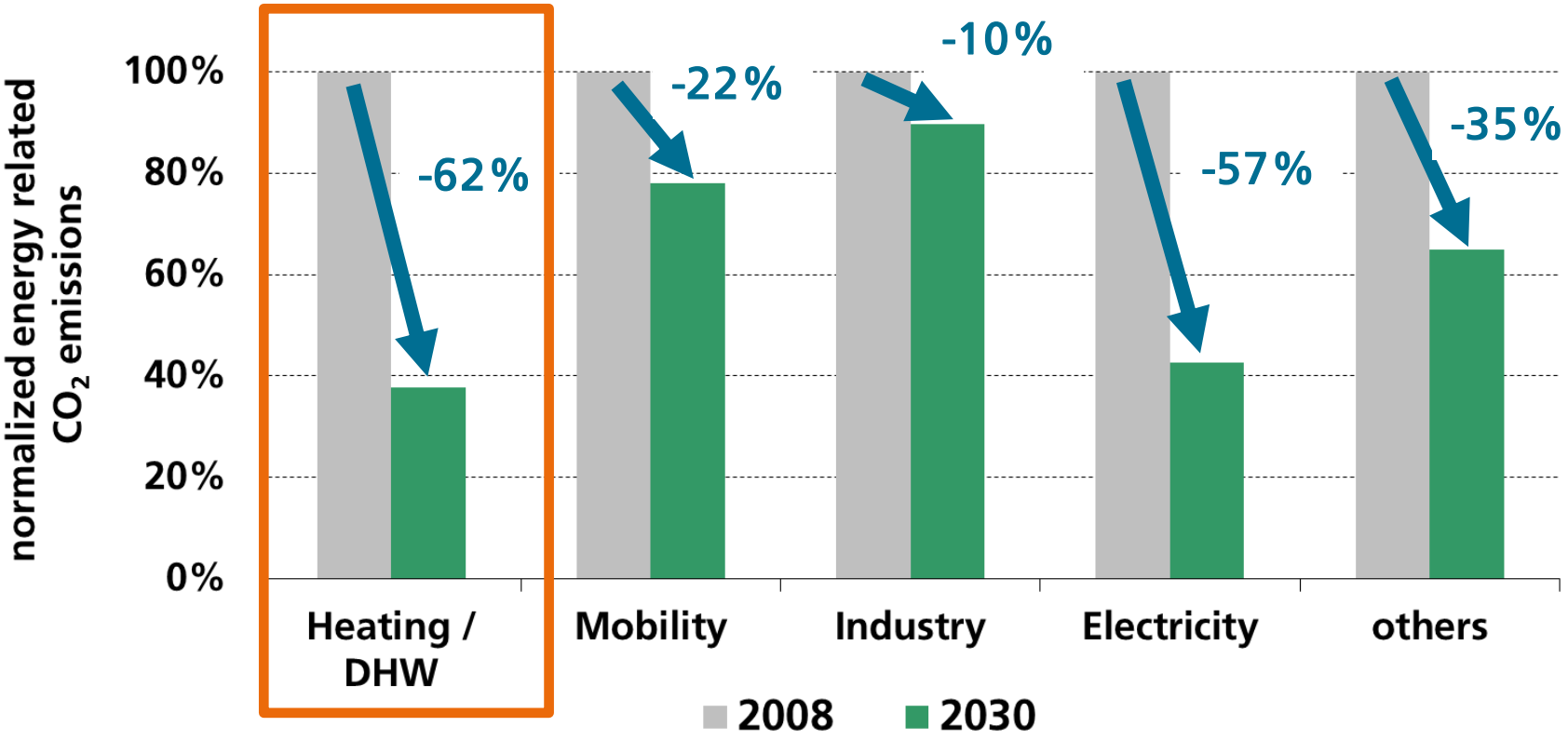
Energy related CO_2 emissions – Germany 2013



Development of energy related CO_2 emissions

Expected sectorial reductions from 2008 until 2030



➔ Strongest reduction expected for low temperature heat

source: "Politikszenarien für den Klima-schutz VI - Treibhausgas-Emissions-szenarien bis zum Jahr 2030„ Öko-Institut et al. im Auftrag des Umwelt-bundesamtes (UBA), März 2013

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Reduction of CO_2 emissions in the heat sector

2030 targets

space heating demand (today = 100 %)	specific CO_2 emissions heating technologies (today = 100 %)												
	100%	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%	45%	40%
100%	100%												40%
95%	96%												38%
90%	91%	87%	82%	78%	73%	69%	64%	59%	55%	50%	46%	41%	37%
85%	87%	83%	78%	74%	70%	65%	61%	57%	52%	48%	44%	39%	35%
80%	83%	79%	75%	70%	66%	62%	58%	54%	50%	46%	41%	37%	33%
75%	79%	75%	71%	67%	63%	59%	55%	51%	47%	43%	39%	35%	31%
70%	74%	71%	67%	63%	60%	56%	52%	48%	45%	41%	37%	33%	30%
65%	70%	67%	63%	60%	56%	53%	49%	46%	42%	39%	35%	32%	28%
60%	66%	63%	59%	56%	53%	49%	46%	43%	40%	36%	33%	30%	26%
55%	62%	59%	55%	52%	49%	46%	43%	40%	37%	34%	31%	28%	25%
50%	57%	54%	52%	49%	46%	43%	40%	37%	34%	32%	29%	26%	23%
45%	53%	50%	48%	45%	42%	40%	37%	34%	32%	29%	27%	24%	21%
40%	49%	46%	44%	41%	39%	37%	34%	32%	29%	27%	24%	22%	20%
35%	45%	42%	40%	38%	36%	33%	31%	29%	27%	24%	22%	20%	18%
30%	40%	38%	36%	34%	32%	30%	28%	26%	24%	22%	20%	18%	16%

Building energy retrofit

Decarbonizing of heating techniques

Target region

Average value of specific CO_2 emission of heating technologies today about 220 g/kWh

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Reduction of CO_2 emissions in the heat sector

2030 targets

space heating demand (today = 100 %)	specific CO_2 emissions heating technologies (today = 100 %)												
	100%	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%	45%	40%
100%	100%	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%	45%	40%
95%	9		86%	81%	77%	72%	67%	62%	57%	53%	48%	43%	38%
90%	91%			78%	73%	69%	64%	59%	55%	50%	46%	41%	37%
85%	87%	83%		70%	65%	61%	57%	52%	48%	44%	39%	35%	
80%	83%	79%	75%		62%	58%	54%	50%	46%	41%	37%	33%	
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45%	53%	50%	48%	45%	42%	40%	37%	34%	32%	29%	27%	24%	21%
40%	49%	46%	44%	41%	39%	37%	34%	32%	29%	27%	24%	22%	20%
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Needed pathway

Target region

Average value of specific CO_2 emission of heating technologies must be reduced until 2030 by almost 50 % compared to today

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Reduction of CO_2 emissions in the heat sector

2050 target: climate neutral building sector

space heating demand (today = 100 %)	specific CO_2 emissions heating technologies (today = 100 %)												
	100%	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%	45%	40%
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60%	66%	63%	59%	56%	53%	49%	46%	43%	40%	36%	33%	30%	26%
55%	62%	59%	55%	52%	49%	46%	43%	40%	37%	34%	31%	28%	25%
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45%	53%	50%	48%	45%	42%	40%	37%	34%	32%	29%	27%	24%	21%
40%	49%	46%	44%	41%	39%	37%	34%	32%	29%	27%	24%	22%	20%
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Long term (2050) target

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Low carbon heating technologies

- Solar thermal
  - Very low CO_2 emissions
  - Potential in particular for domestic hot water
  - Limited potential for solar assisted space heating
  - Close to economic operation for hot water systems (life cycle cost)
  - Large plants connected to district heating (Denmark)

- Biomass
  - Today dominating renewable heat
  - Very limited long term potential due to competition with other uses (energy, non-energy)
  - High exergy content ➔ potential for high temperatur processes or cogeneration

Low carbon heating technologies

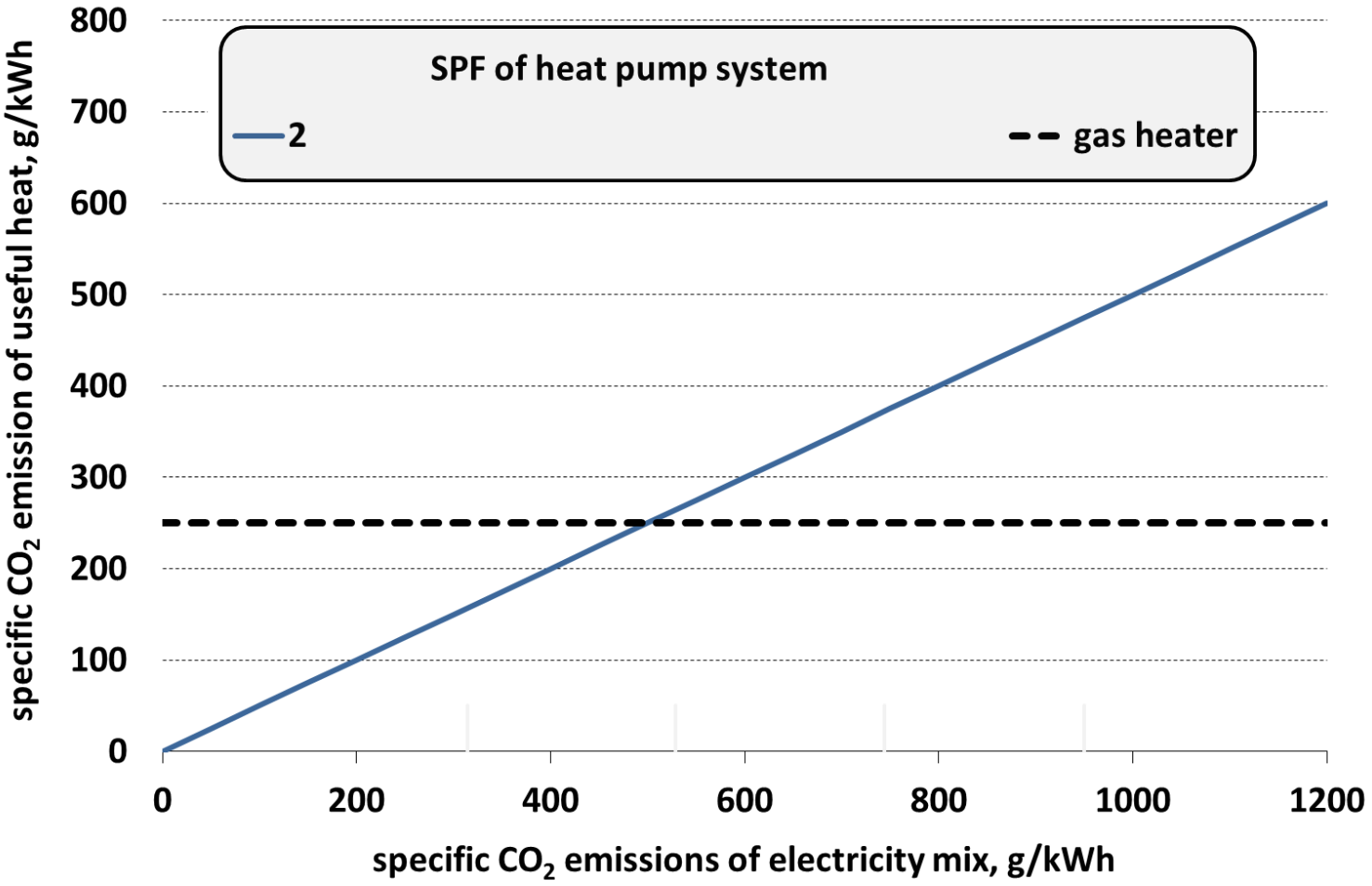
- District heating
  - Crucial regarding economic perspective for districts with strongly reduced heat density (due to building energy retrofit)
  - Promising potential for urban energy management in dense areas including large scale heat storage (➔ Denmark)
  - Various heat sources such as medium and large scale CHP, large scale heat pumps, solar thermal, industrial waste heat, deep geothermal
- Gas heat pumps
  - Emerging technology; yet still small market
  - High potential as follow-up technology for gas boilers ➔ highly efficient use of fuel (fossil, renewable) for heating application

Low carbon heating technologies

- Cogeneration system (combined heat & power)
  - Decreasing attractiveness with decreasing primary CO_2 emissions of electricity production
  - Increasing operation control following electricity demand ➔ interaction with electricity grid
  - Fuel cell CHP promising, but far from economic operation today

- Electric heat pumps
  - Increasing attractivness with decreasing primary CO_2 emissions of electricity production
  - Operation allows flexible electricity use (➔ smart grid), in particular in combination with heat storage or hybrid heat pumps (energy switch)

Specific CO_2 emissions of heat from heat pumps



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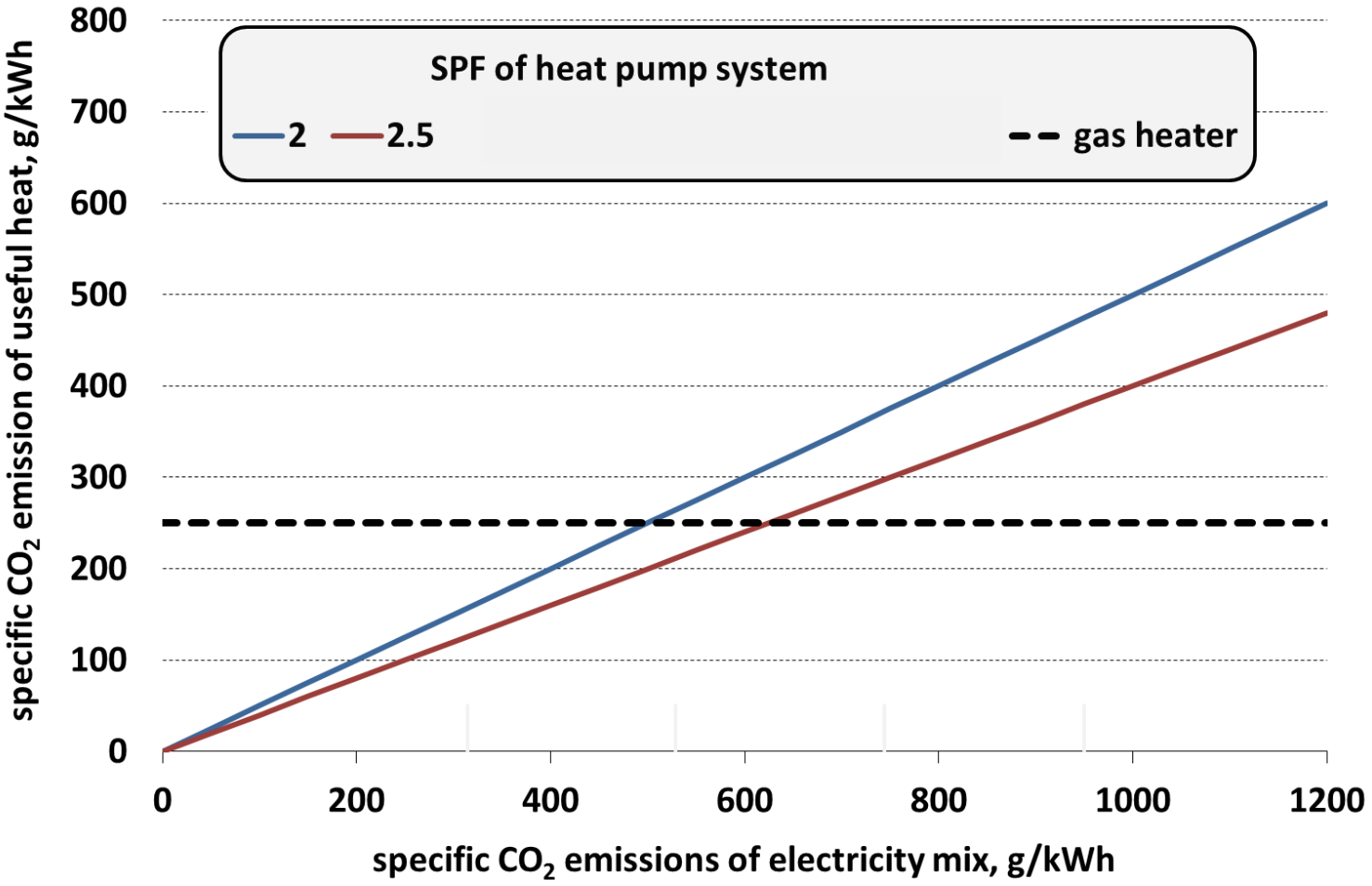

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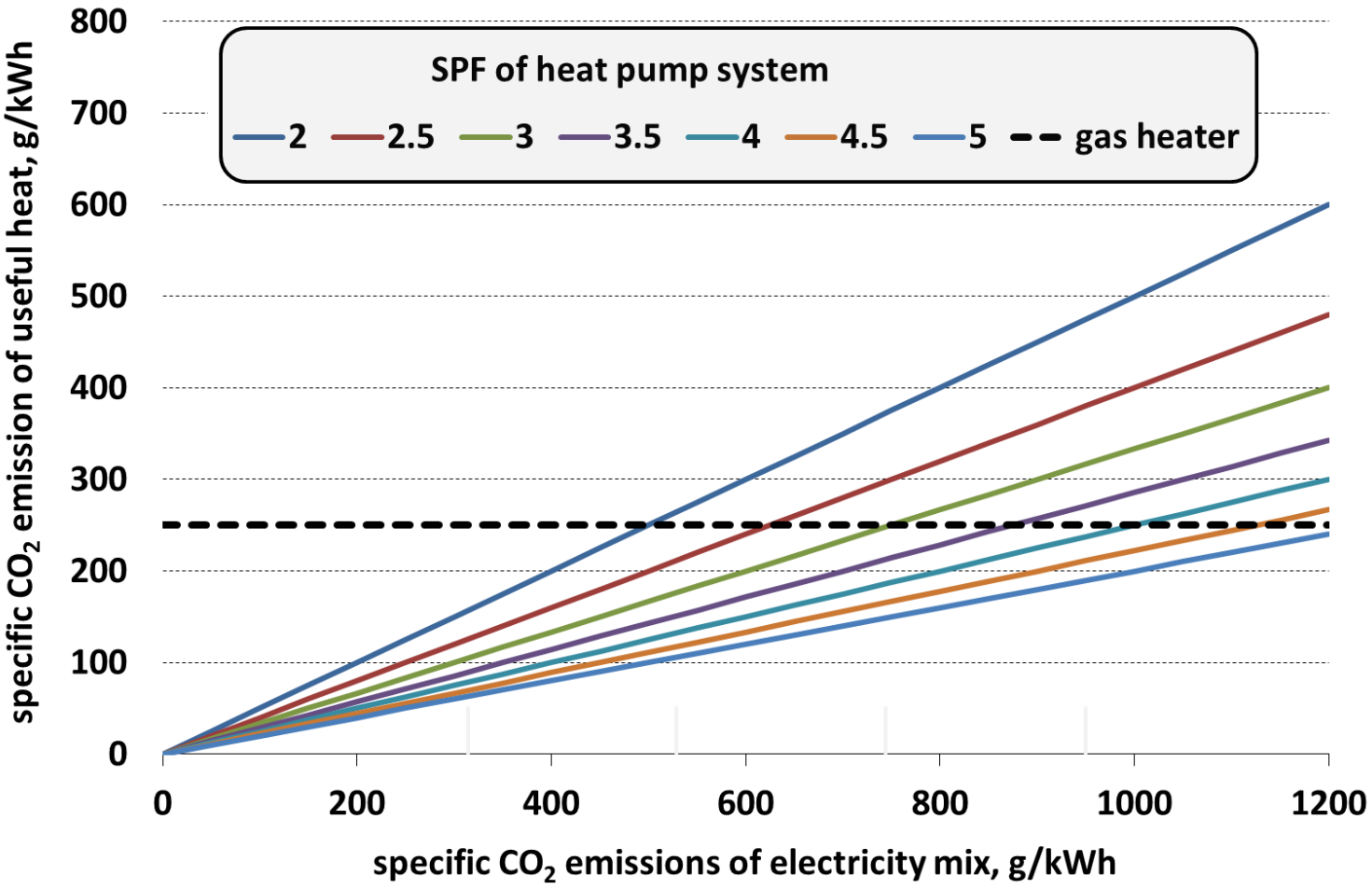

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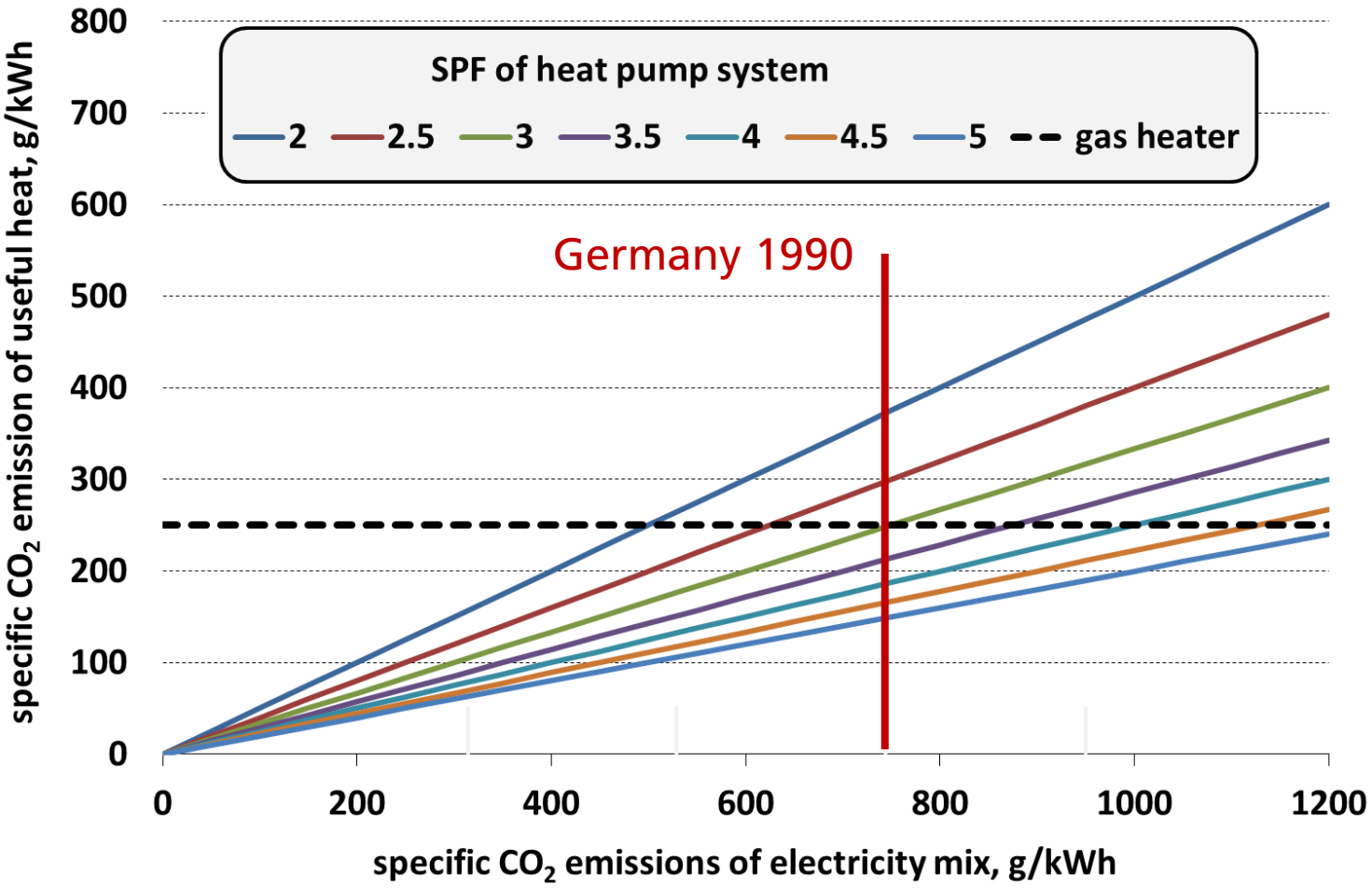

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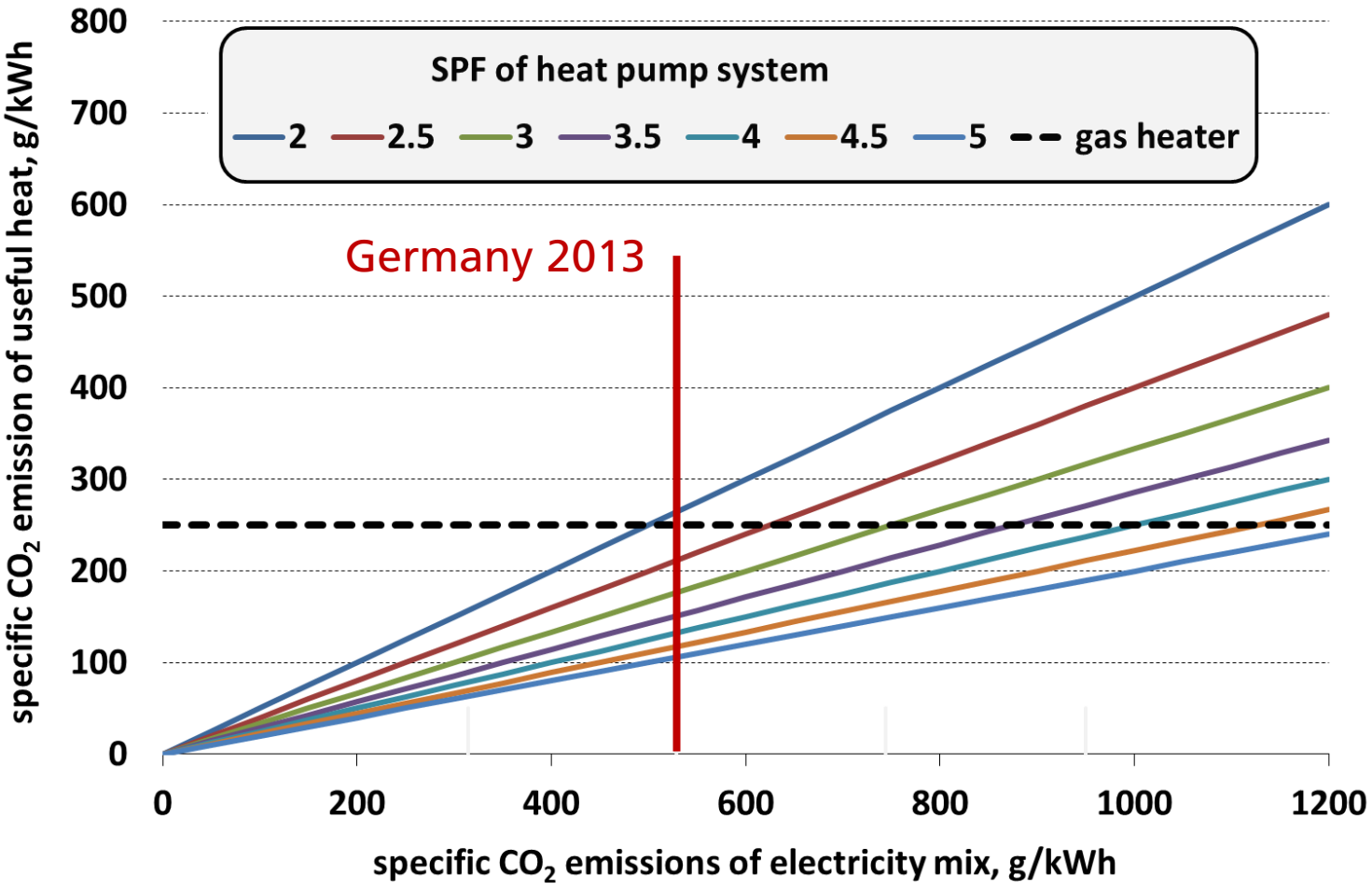
Specific CO_2 emissions of heat from heat pumps



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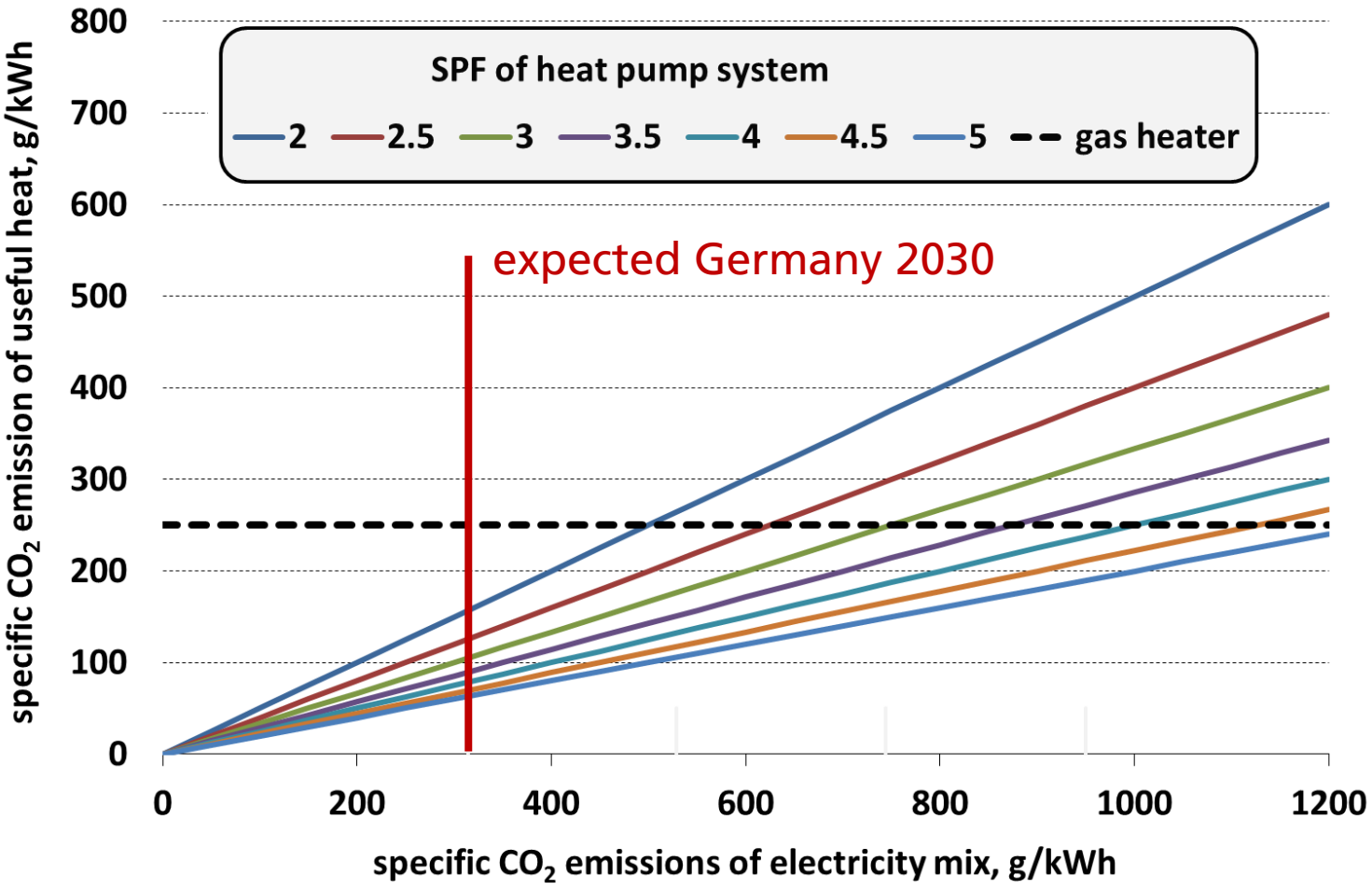

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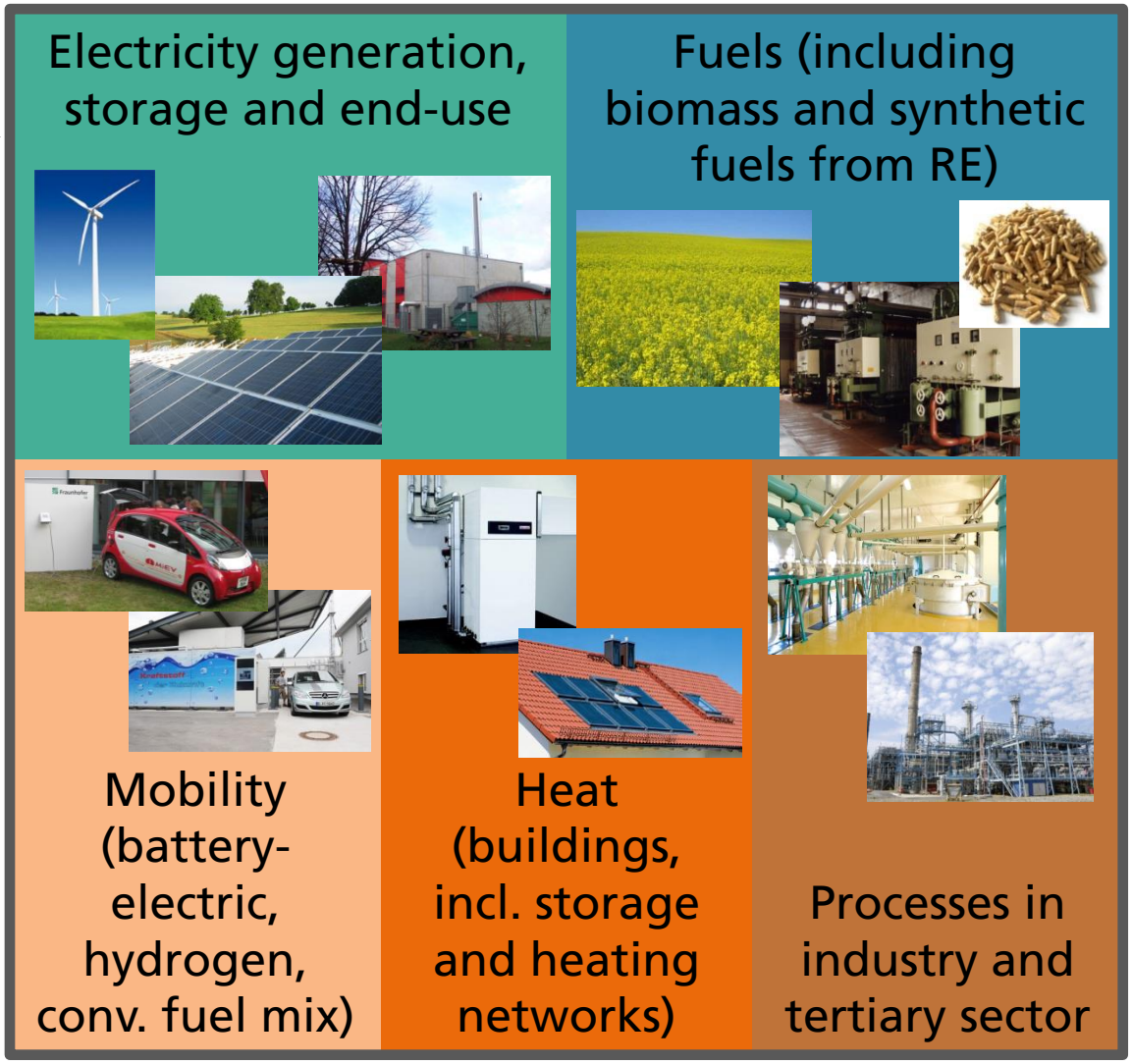
Optimization of Germany's future energy system

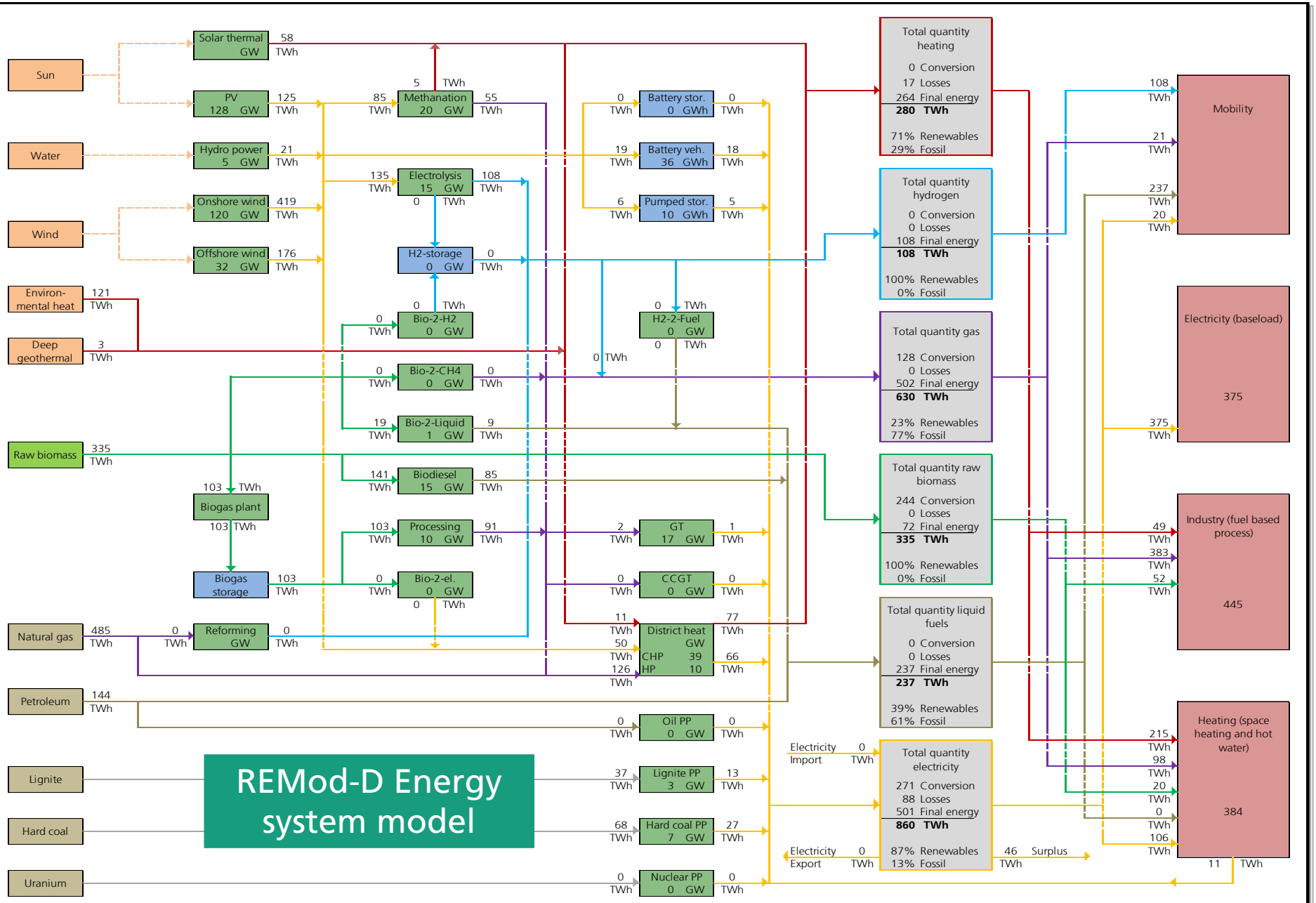
Mimimize total annual cost (operation, maintenance, …)

REMod-D

Renewable Energy Model – Deutschland

Techno-economic optimization based on comprehensive simulation (hourly time scale)





Guiding question

What is the cost-optimal transformation pathway of the German overall energy sytem including all end-use sectors under the boundary condition that the political goals of reducing greenhouse gas emissions are fulfilled – both for the target value and in each single year?

Further boundary conditions

- Fade-out of nuclear energy until 2022
- No large scale implementation of CCS technology (carbon capture and sequestration) in fossil power plants

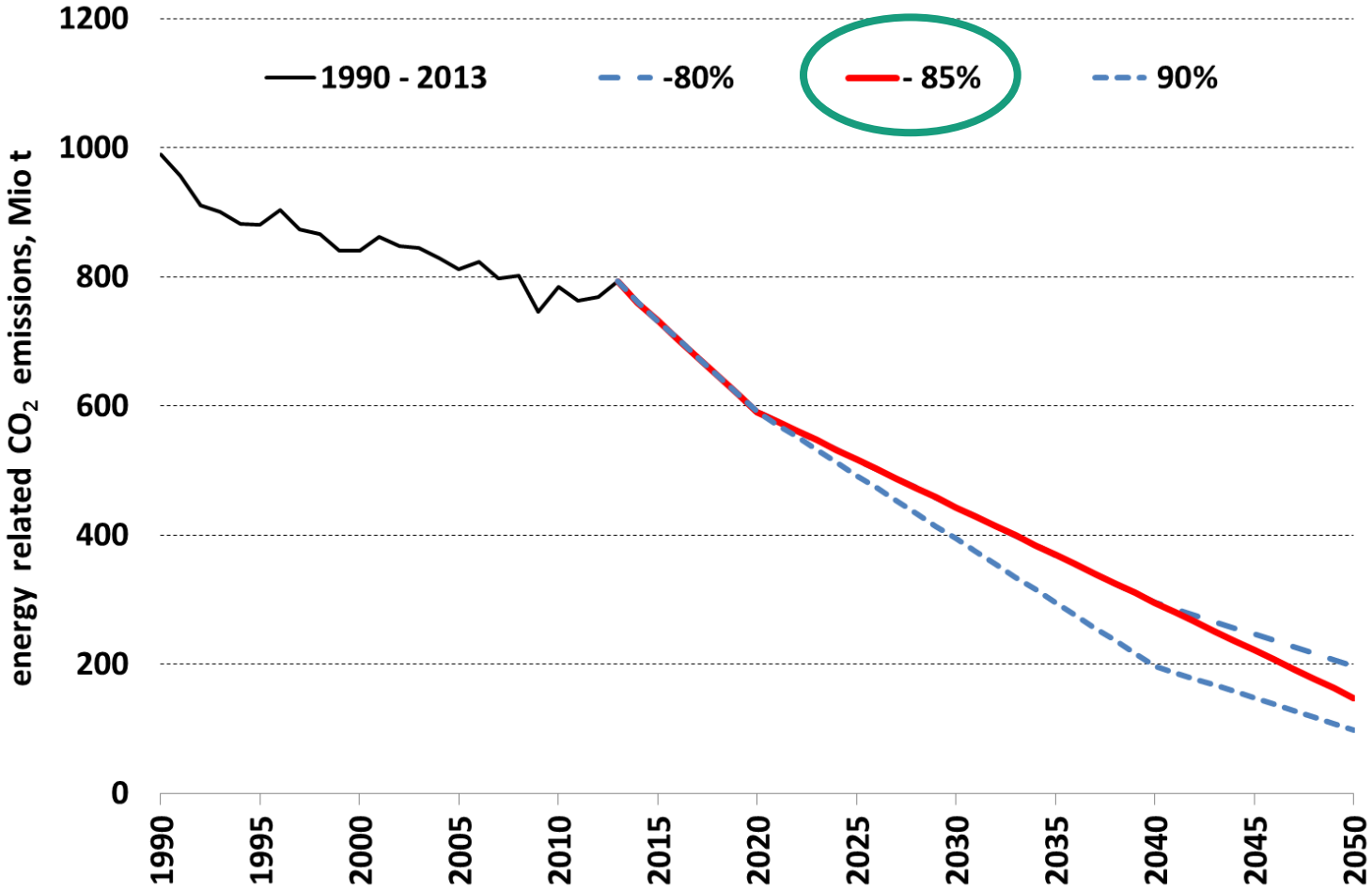
Methodology

- Hourly simulation of the total energy system from January 1, 2014 until December 31, 2050 (using data from 2011, 2012 and 2013)
- Optimization of the development of the system composition considering all future options
  - Renewables
  - Storage and power-to-gas/fuel/heat technologies
  - Energy retrofit of building sector
- Goal function: minimal overall transformation cost

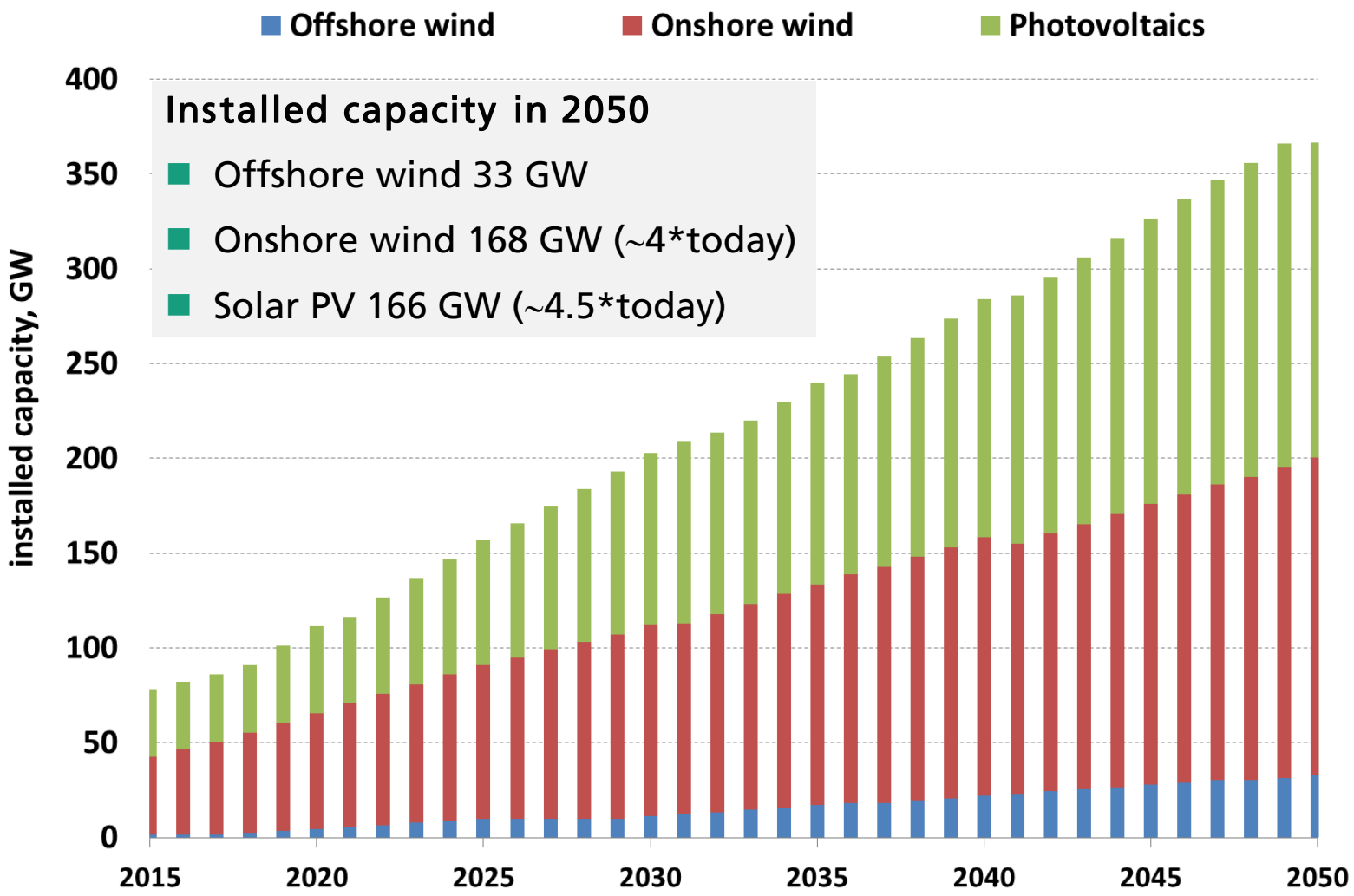
➔ Results of a scenario with a reduction energy related CO_2-emissions by 85 % compared to 1990 (Kyoto protocol reference value)

➔ Presentation of the full study: November5, 2015 in Berlin

Boundary condition – CO_2 reduction pathway



Fluctuating renewable energies: solar, wind



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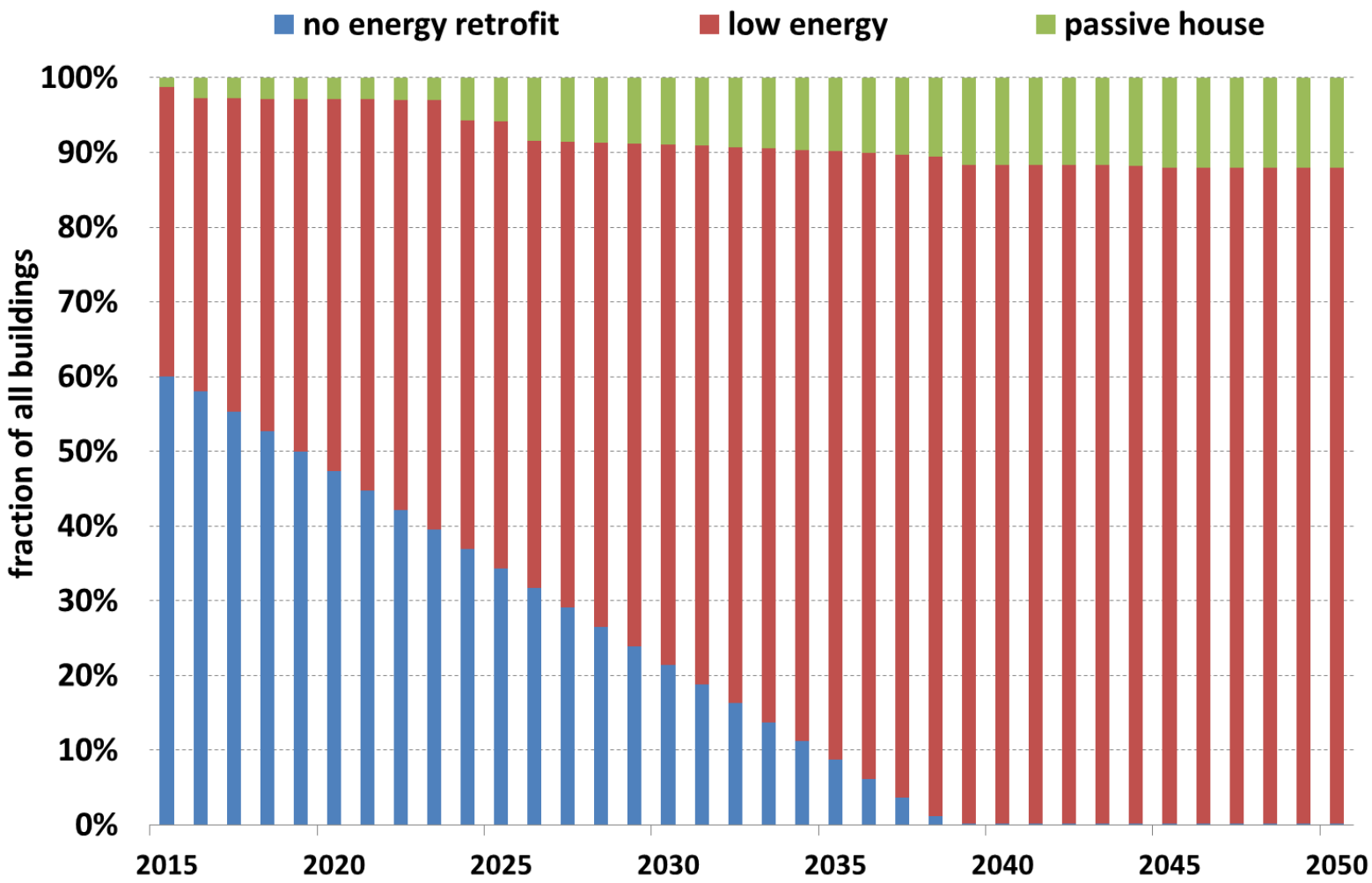
Development of building energy efficiency



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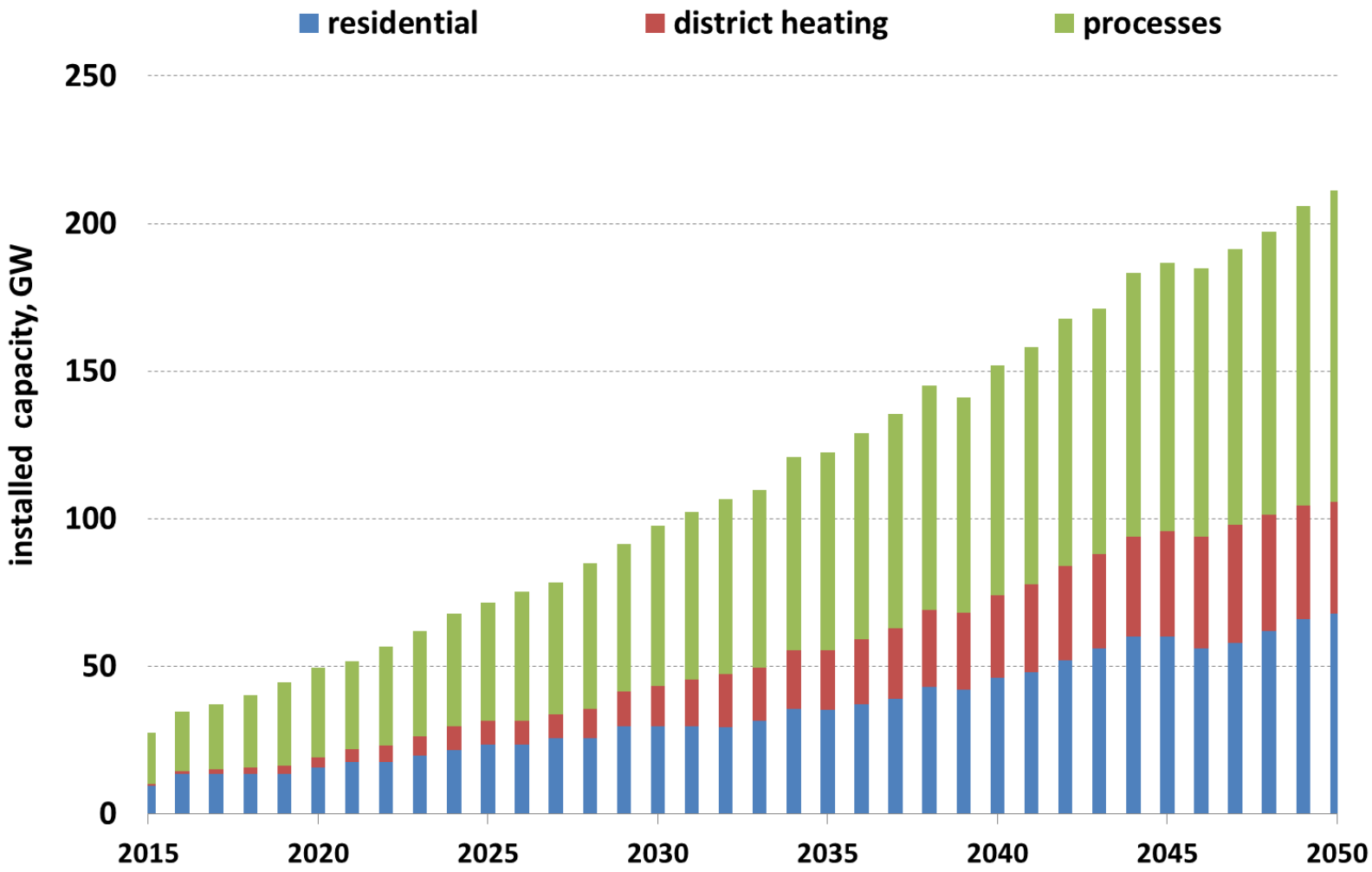
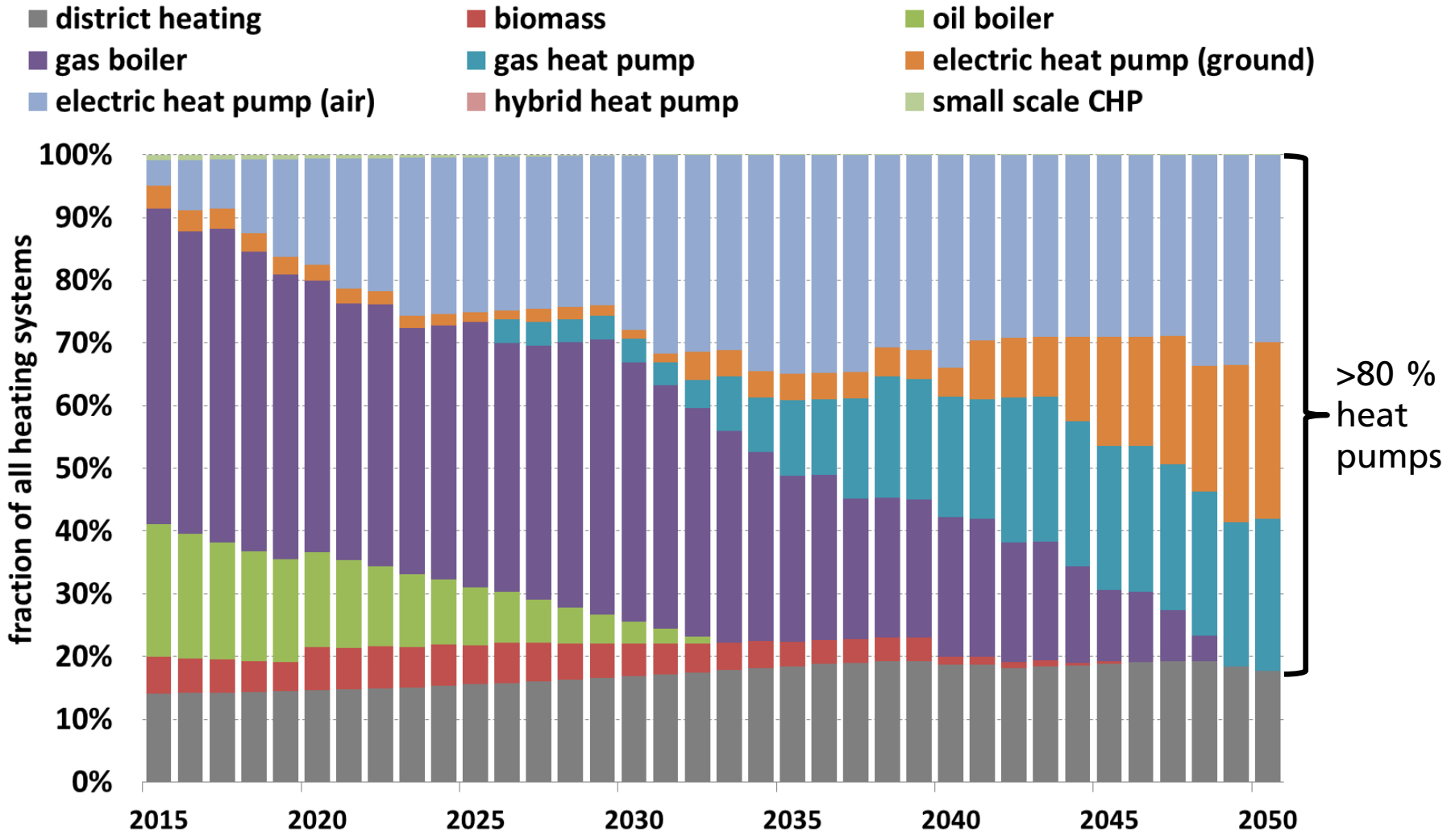
Solar thermal collectors



Development of heating technologies



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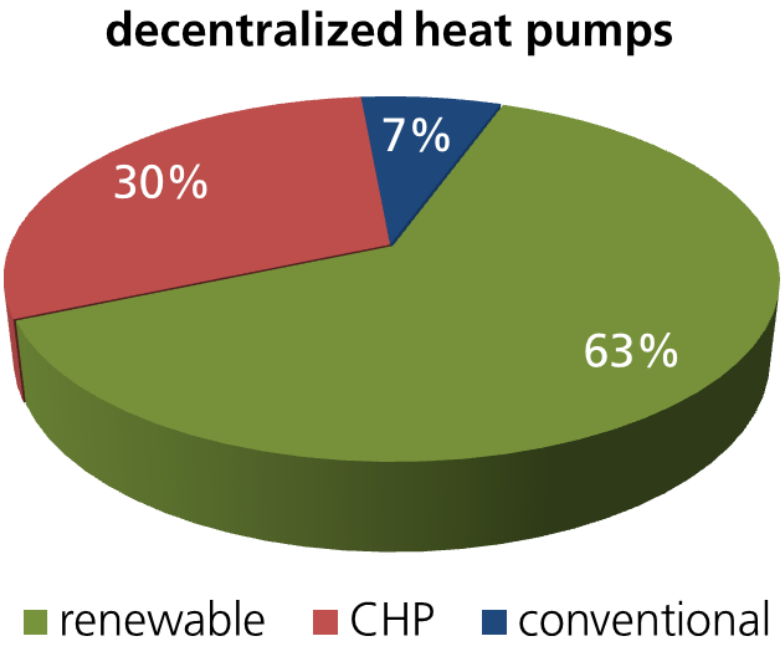
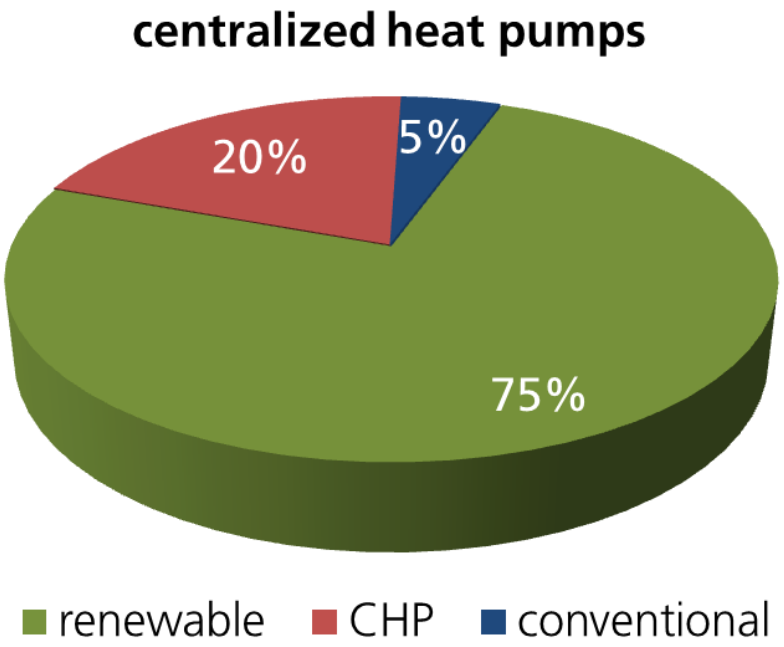
Origin of electricity for heat pump operation

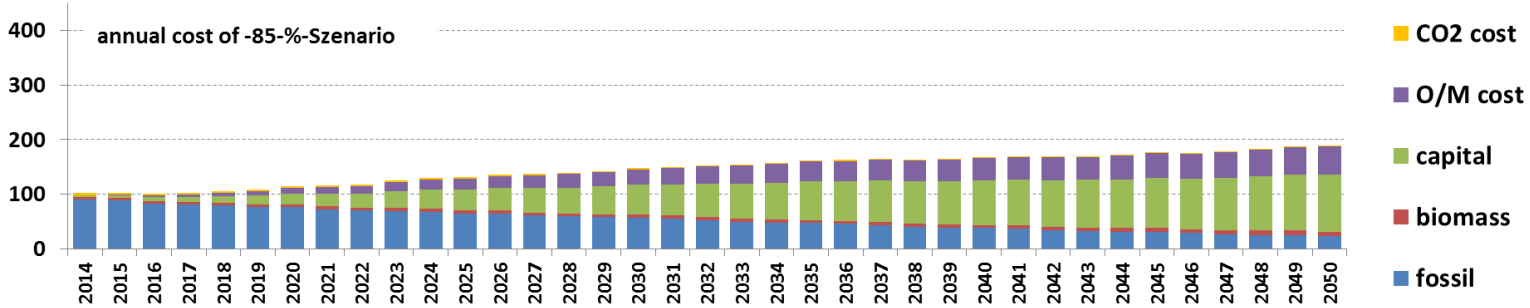




- Based on hour-by-hour analysis of electricity composition
- Electricity from fluctuating renewable energy sources dominant
- Thermal buffer storage important for flexible operation

Cost development (in bn € p.a.)

- Constant penalty for CO_2 emissions 5 €/ton
- No increase of prices for fossil fuels



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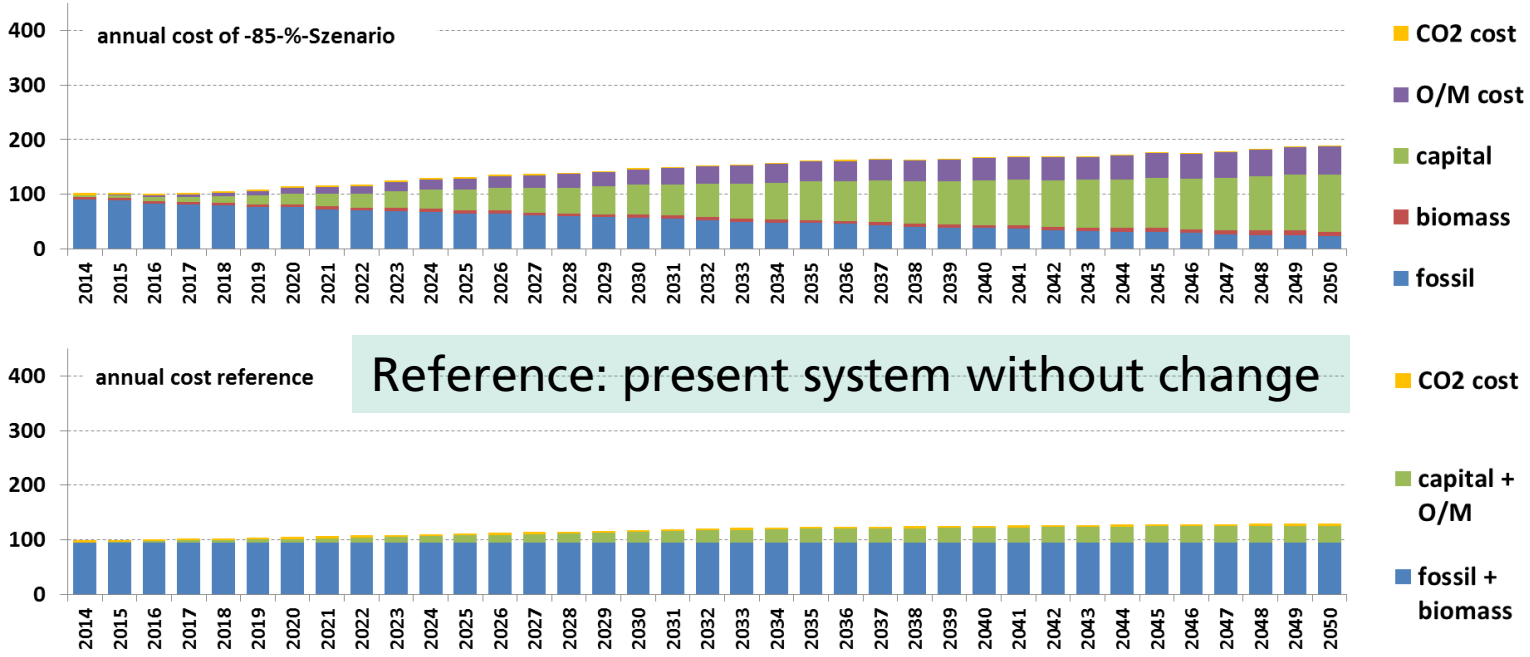

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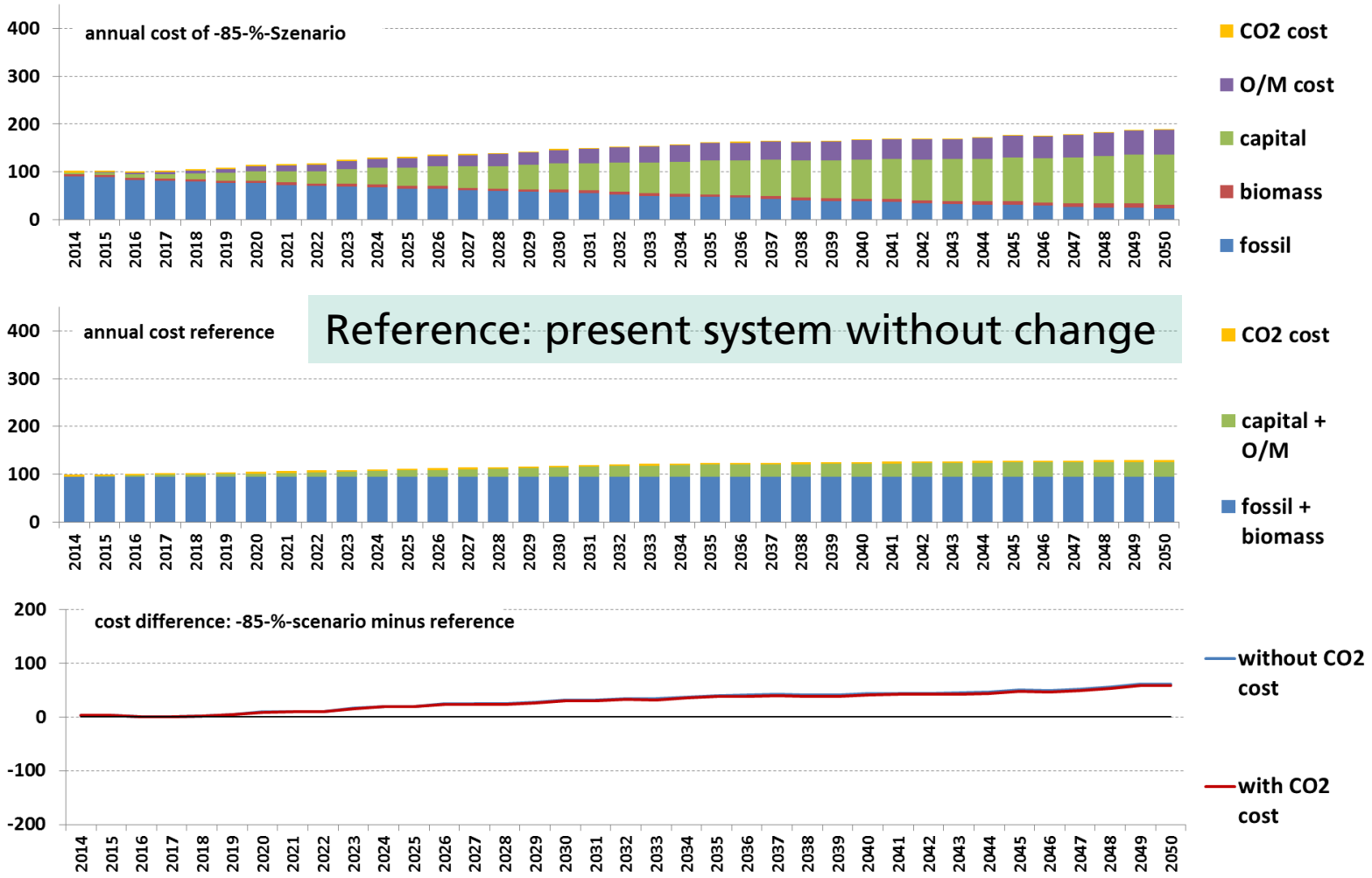

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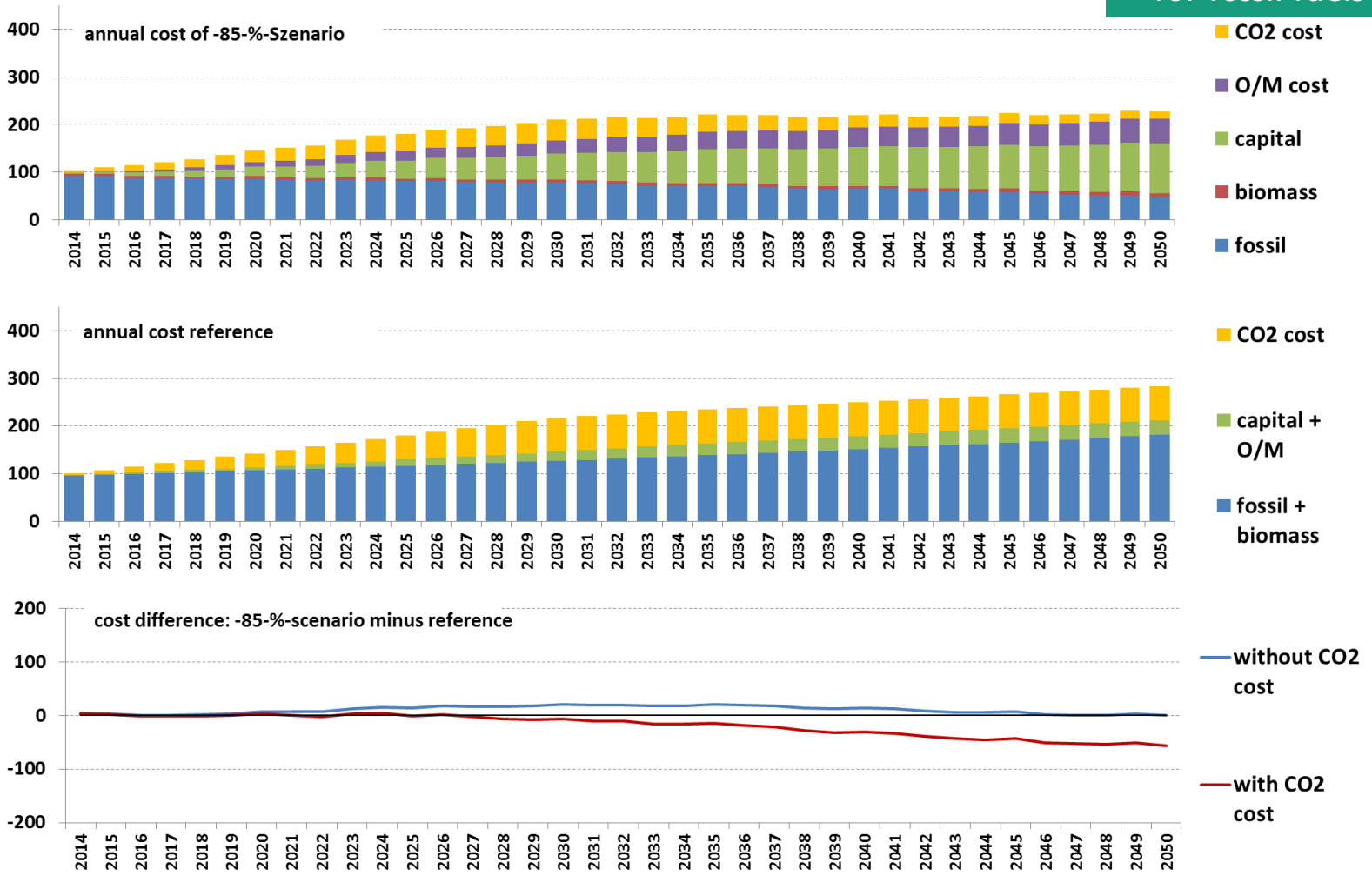
Cost development (in bn € p.a.)

- Increase of penalty for CO_2 emissions up to 100 €/ton in 2030; afterwards const.
- 2 % annual price increase for fossil fuels



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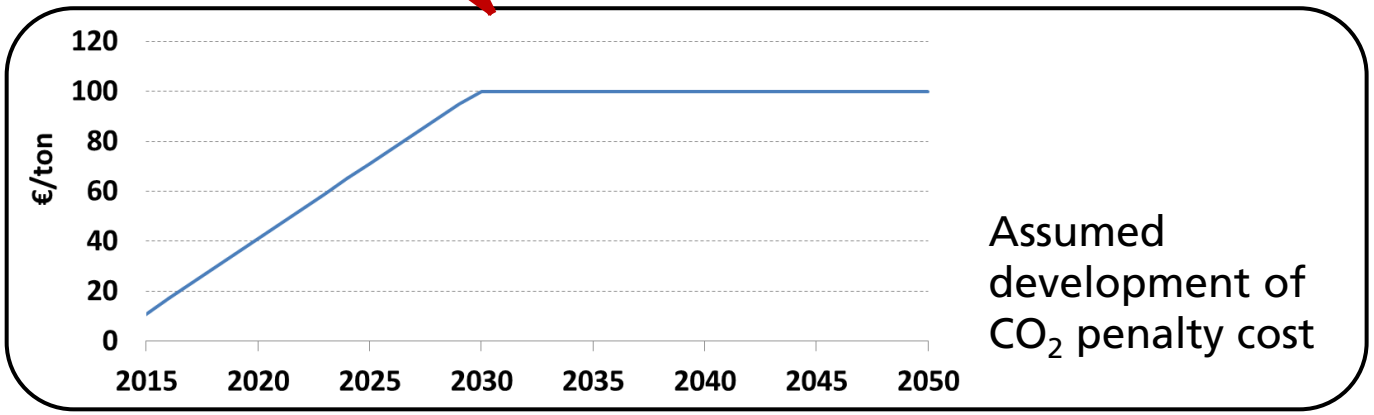
Cumulative overall cost comparison 2014-2050

CO_2 cost	price increase fossil fuels	– 85-%-scenario bn €	reference bn €	– 85-%-scenario minus reference bn € (%)
5 €/ton	0 % p.a.	5417	4322	+ 1095 (+ 25 %)
up to 100 €/ton	0 % p.a.	6346	6246	+ 100 (+ 2 %)
5 €/ton	2 % p.a.	6126	5757	+ 369 (+ 6 %)
up to 100 €/ton	2 % p.a.	7056	7681	– 625 (– 8 %)



Assumed development of CO_2 penalty cost

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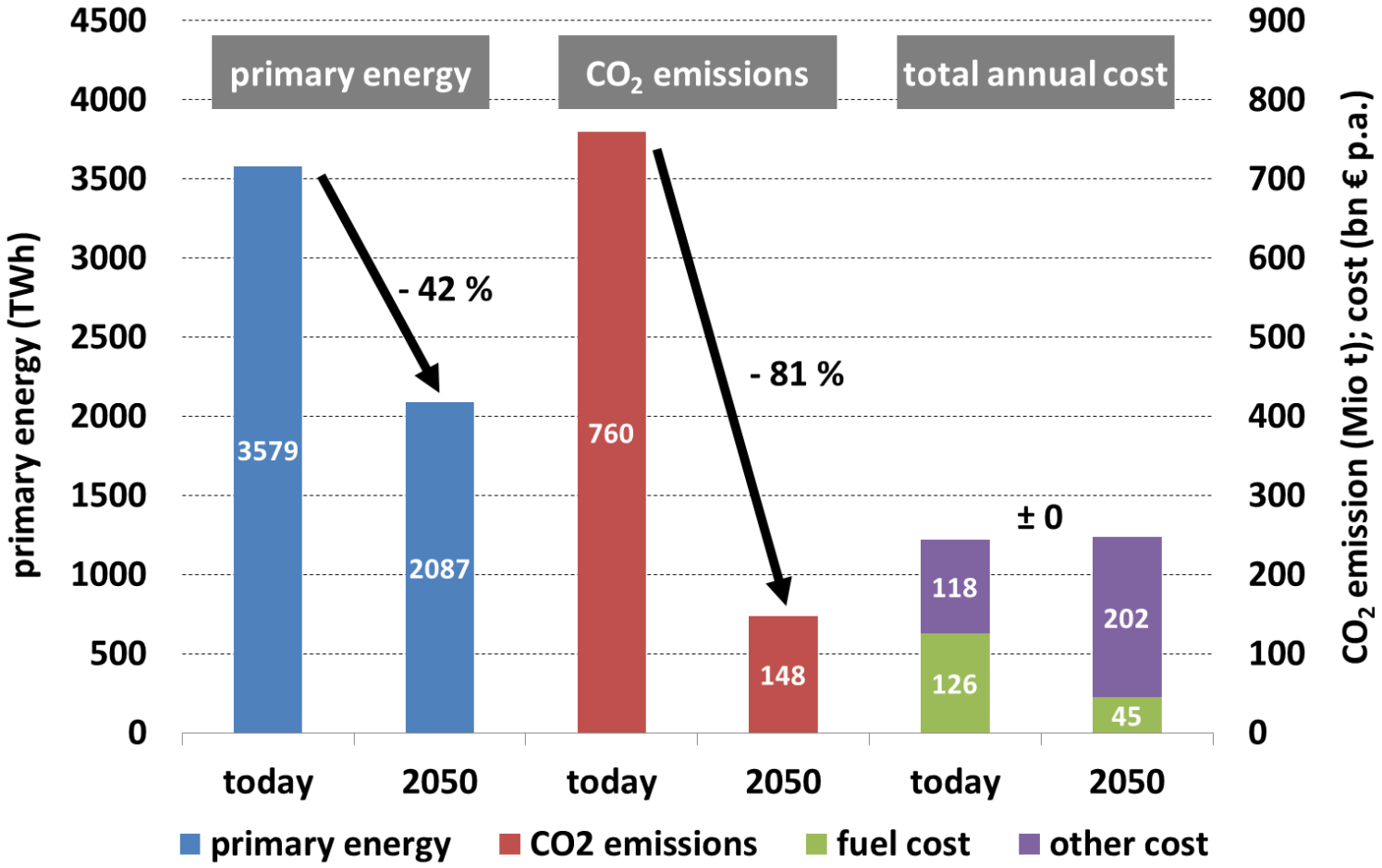
2050-system versus today – cost after completed transformation

- Constant cost for CO_2 emissions 5 €/ton
- No increase of prices for fossil fuels



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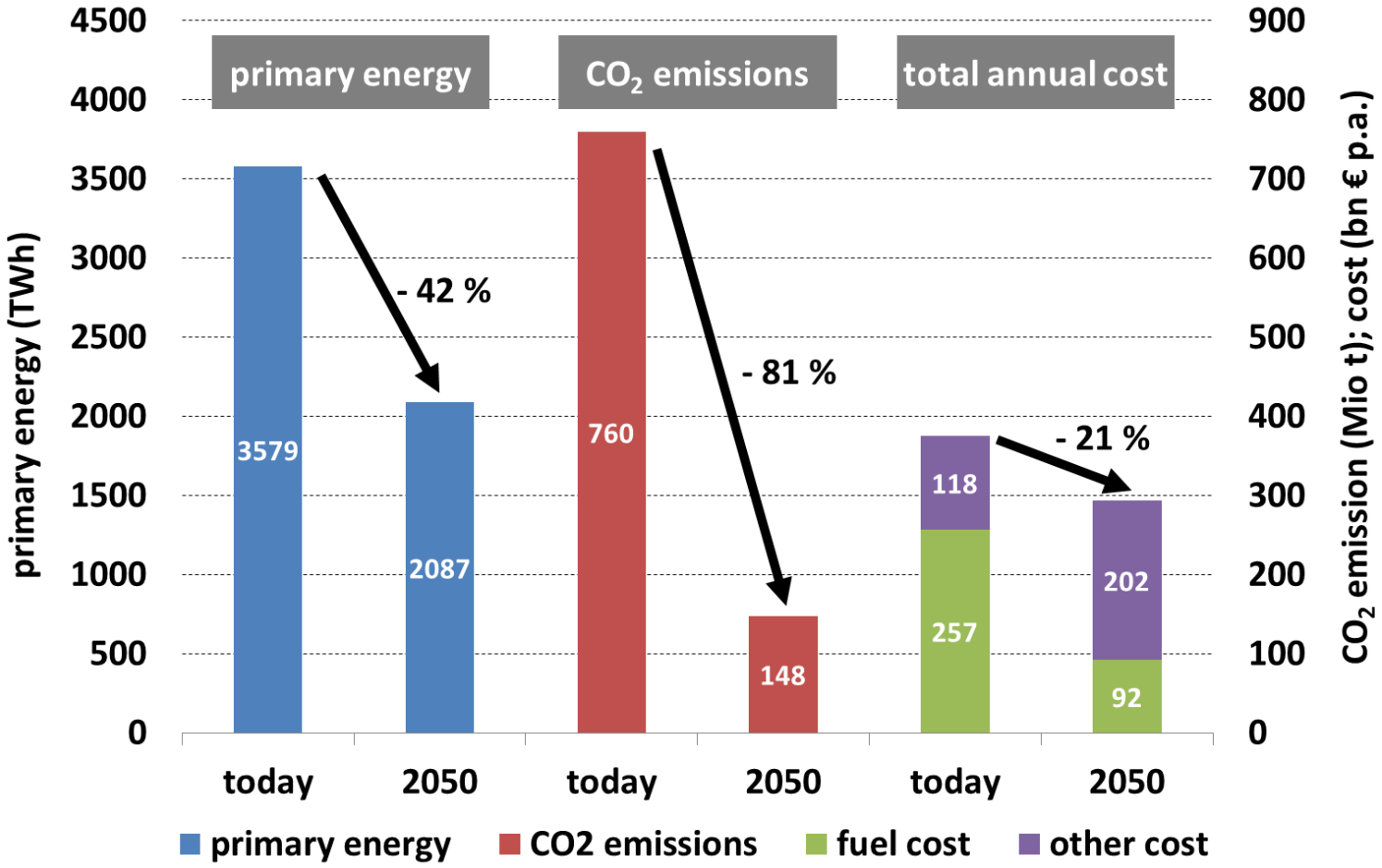

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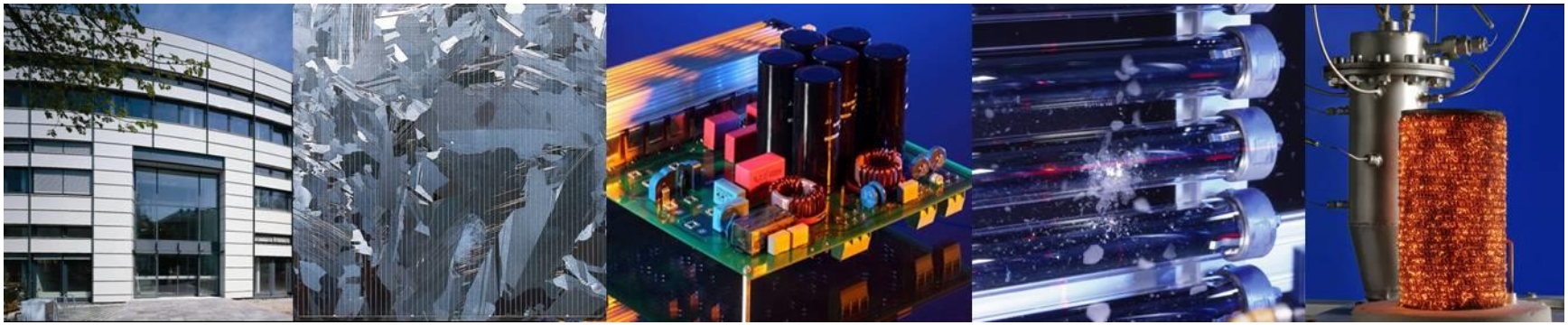
Summary (1/2)

- Energy efficient building retrofit **and** decarbonizing heating technologies are needed in order to achieve targets for GHG emission reduction in the building sector
- Efficient overall systems using renewable energy will replace todays heating systems based on burning fossil fuels
- Increasing convergence of electricity and heating sector
- The heating sector provides promissing options for flexible electricity use in combination with a strong increase of electricity from fluctuating renewables (solar, wind) ➔ smart grid
- In the medium to long term heat pumps (electric, gas) will dominate heating of buildings
- Electric heat pumps are the upmost efficient technology in combination with decarbonized electricity production

Summary (2/2)

- Achieving a CO_2 reduction of 85 % (compared to 1990) is possible by a significant increase in the use of renewable energies in combination with increased energy efficiency (e.g. in the building sector)
- Transformation of the German energy system to achieve a CO_2 reduction by 85 % will cost about 1000 bn € more for the time period 2015 – 2050 in case of stable prices for fossil energy sources and no increase in CO_2 penalties; this value corresponds to about 0.8 % of the German gross national product
- The transformation will be cost neutral in case of an annual increase of prices for fossil fuel by 2 % per year
- Once the transformation is completed the total annual cost of the energy system will not be higher than the cost of todays system, even in case of long term stable prices for fossil fuels
- The transformation of the energy system implies a shift of expenses from import of fossil fuels to local employment and value creation

… thank you for your attention.



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Hans-Martin Henning
www.ise.fraunhofer.de
hans-martin.henning@ise.fraunhofer.de