Energy Modelling for EU Energy and Climate Roadmap to 2050

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Recent studies by the EC

Impact Assessments

- DG CLIMA Roadmap 2050
  - March 2011
  - Defined the emission path for all GHGs
  - Explored different pathways
- White Paper on Transport sector
  - July 2011
  - Analyzed policies and pathways for the transport sector to comply with emission reduction requirements of DG CLIMA Roadmap
- DG ENER Roadmap 2050
  - Expected in December 2011
  - Accepted the emission pathway of DG CLIMA Roadmap
  - Explored different energy system pathways and analyzed policies

Models used

- GEM-E3 for macro-economic scenario and macro impacts
- POLES (and Prometheus) for world energy outlook
- POLES for world emission scenarios
- PRIMES for EU energy system
- IIASA's GAINS for non CO2 GHGs and air quality
- CAPRI and GLOBIOM for agriculture, forestry, land use
- PRIMES-TREMOVE for transport sector

Methodology for Emission Targets

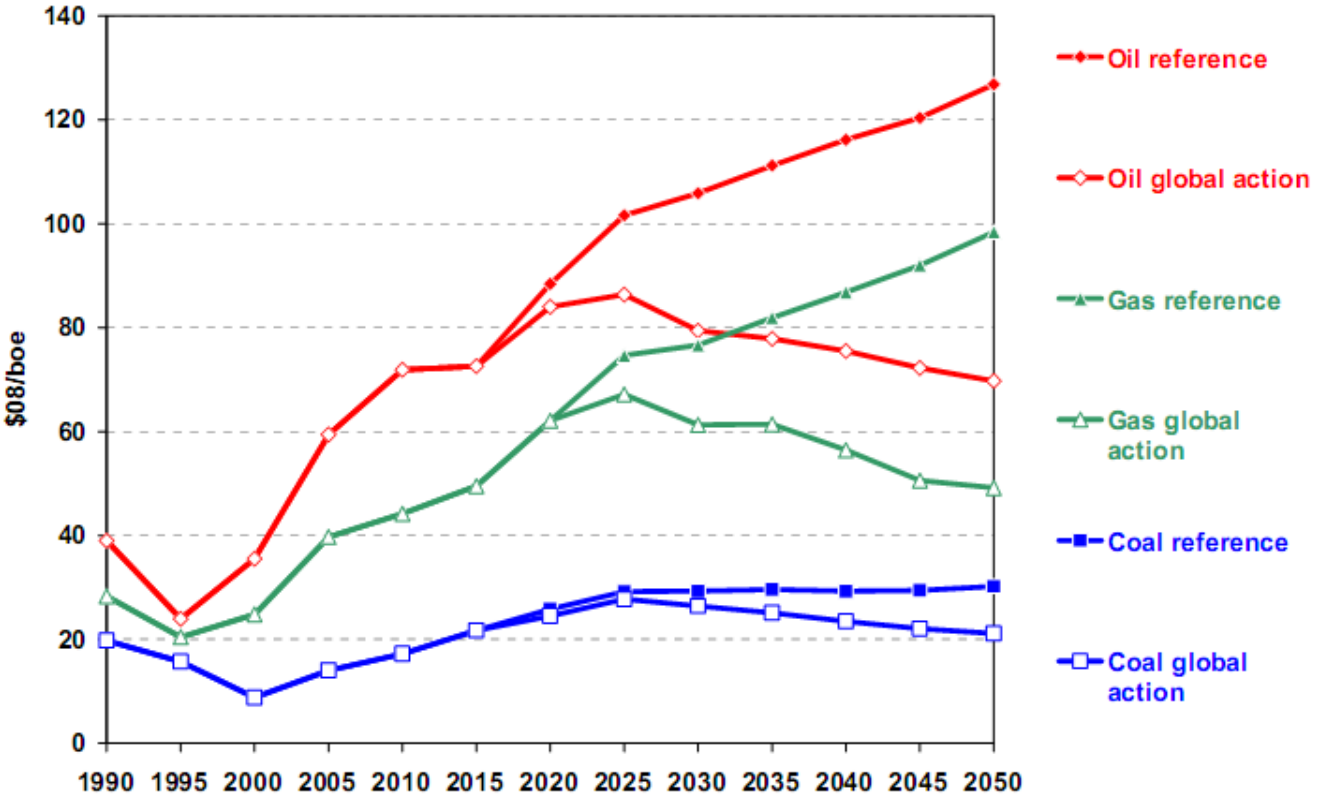
- Temperature objective: 2 degrees C by 2100
- GHG concentration target: 450 ppm
- Using POLES model, a global emission reduction target (-50% by 2050) is allocated to world regions
- Developed countries will have to reduce at 20%

Table 2: Greenhouse gas emissions in the Baseline and Global action scenario

Region		1990	2000	2005	2010	2020	2030	2040	2050
1990 = 100%									
World	Global baseline	100	112	128	140	160	180	201	220
	Global action	100	112	128	139	139	109	75	51
Developed	Global baseline	100	95	96	91	88	86	85	82
	Global action	100	95	96	91	72	51	33	20
Developing	Global baseline	100	143	190	232	296	354	414	477
	Global action	100	143	190	232	265	211	141	95
EU27	Global baseline	100	93	95	88	82	77	71	66
	Global action	100	93	95	86	73	55	36	22

Emission Paths and World Fossil Fuel Prices

- Prices increase in reference scenario
- Under Global Climate Action, demand for fossil fuels decrease inducing lower prices
- Under Fragmented Action (only in the EU), prices remain unchanged from reference



Roadmap Scenarios for the EU

- Reference scenario
  - Achieves 20% RES and 20% emission reduction by 2020
  - Legislation until end 2009 included:
    - ETS emission allowances and auctioning from 2013 onwards
    - non ETS targets per Member-State
    - Renewable targets per Member-State
    - Biofuels obligations
    - Eco-design, buildings and other energy efficiency measures
  - After 2020, continuation of trends and reduction of ETS allowances but no new legislation or targets
  - The projection shows GHG emission reduction :
    - -20% by 2020 (domestically)
    - -30% in 2030
    - -40% in 2050

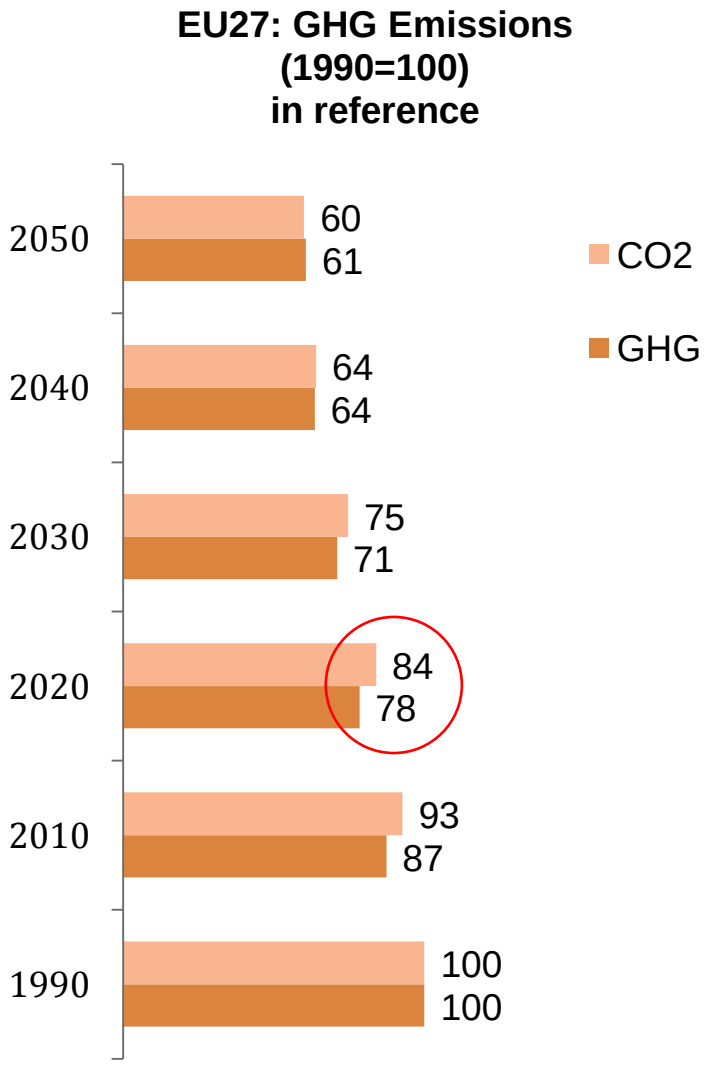
Decarbonisation Scenarios using PRIMES for EC Roadmaps

- Diversified Technologies under Global Climate Action
  - Effective and widely accepted technologies – all options
    - All emission reduction options are open, including energy efficiency improvement, RES, CCS, nuclear and restructuring in transport sector
    - The mix of options depend on least energy system cost at the EU level, assuming that excessive deployment of a single option implies high costs
  - Very high RES and efficiency (and so low CCS and low nuclear)
  - High efficiency and RES (and so low CCS and low nuclear)
  - Delayed CCS and so higher nuclear
  - Low nuclear and so higher CCS
  - Delayed electrification in transport sector (only DG Clima)
  - Delayed climate action (only DG Clima)
- Under Fragmented Climate Action (only DG Clima)
  - All scenarios but with high fossil fuel prices (as in Reference)
- All scenarios deliver the same carbon budget (cumulative emissions until 2050) but follow different time profiles

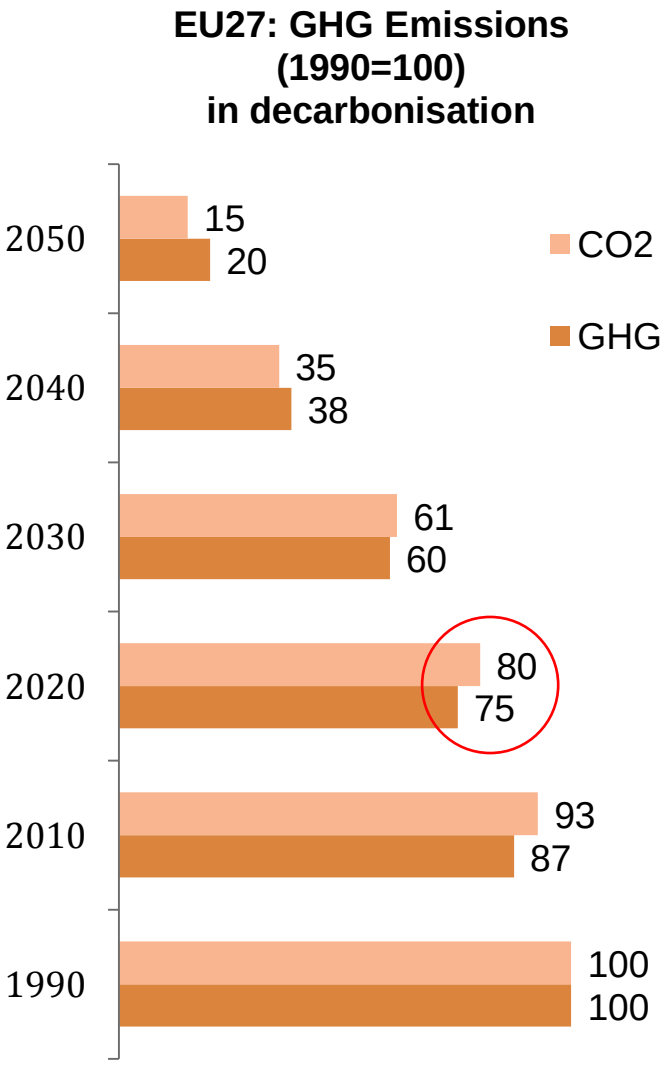
Common Policies for Decarbonisation

- Power generation becomes almost emission free by 2050; emission reduction is strong already in 2030
- Renewables in all sectors develop strongly and are further supported and facilitated
- Energy efficiency improvement policies strongly develop for buildings, appliances and other equipment
- Electric mobility in road transport and biofuels
- Crops and waste management for bio-energy
- Internal market infrastructure, smart grids
- Strong R&D support ensuring learning

Reference



Decarbonisation



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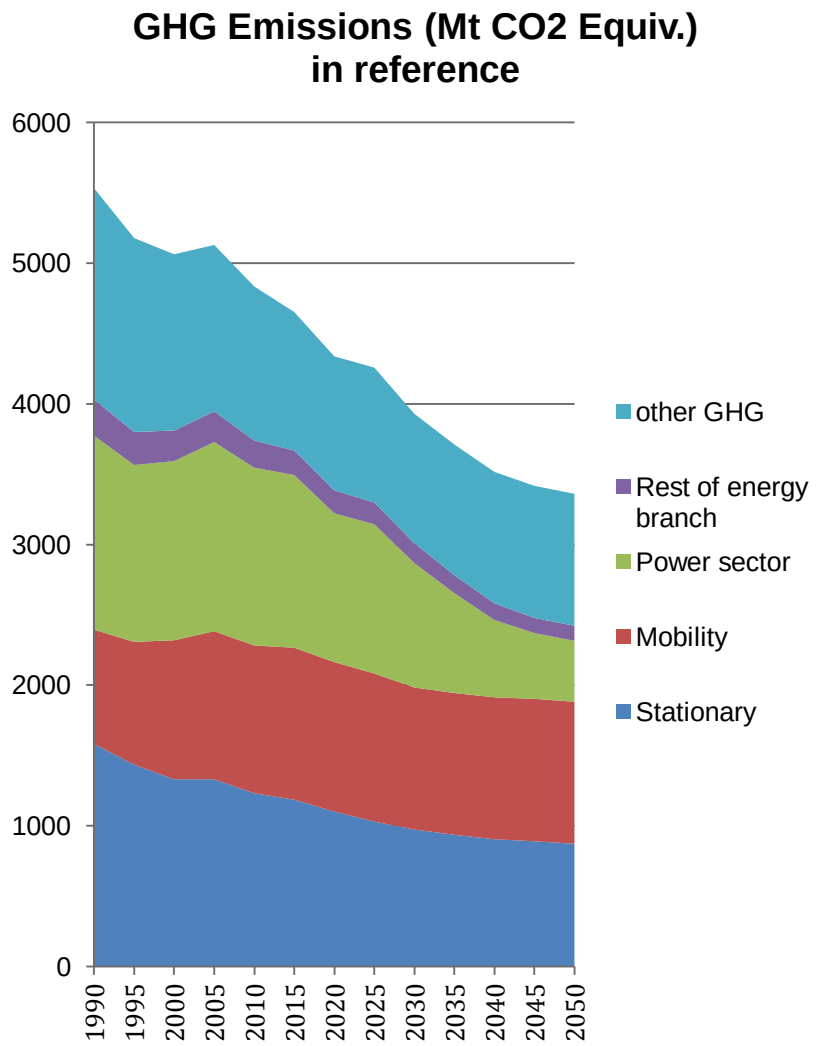

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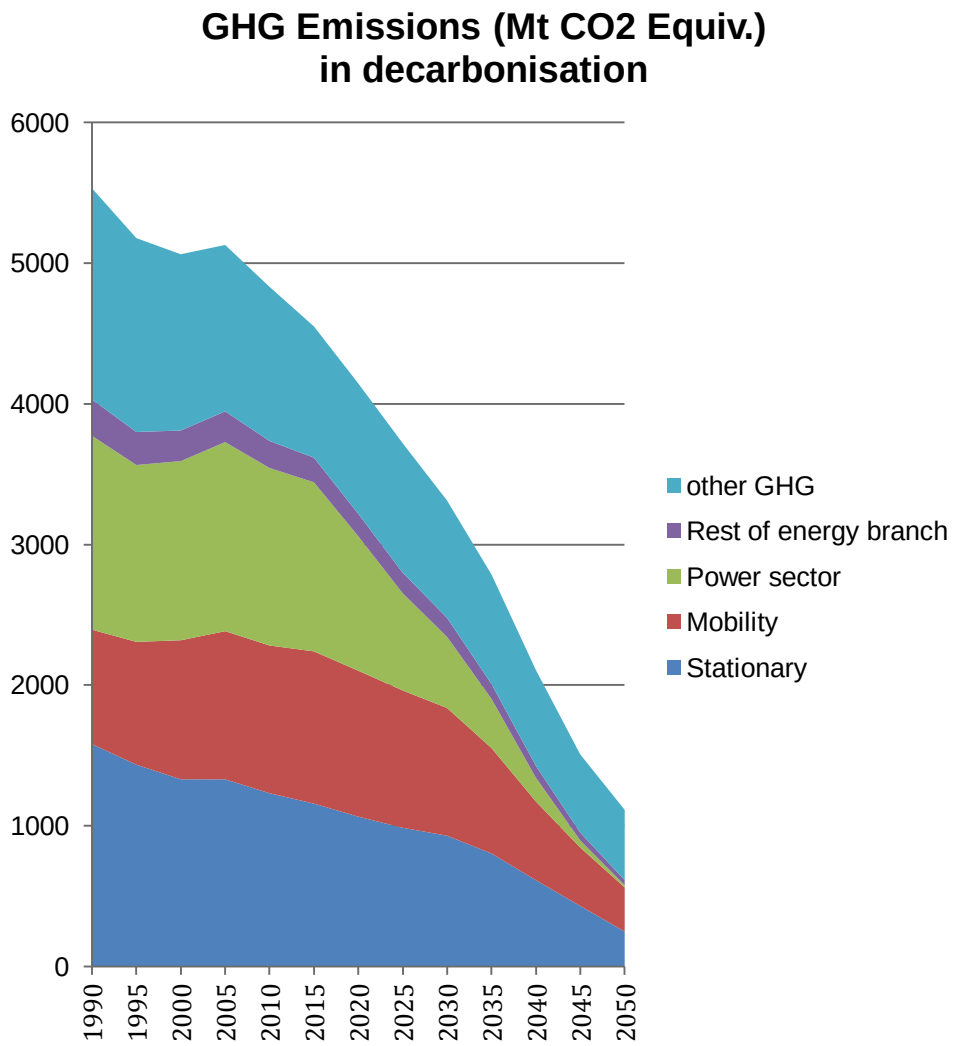
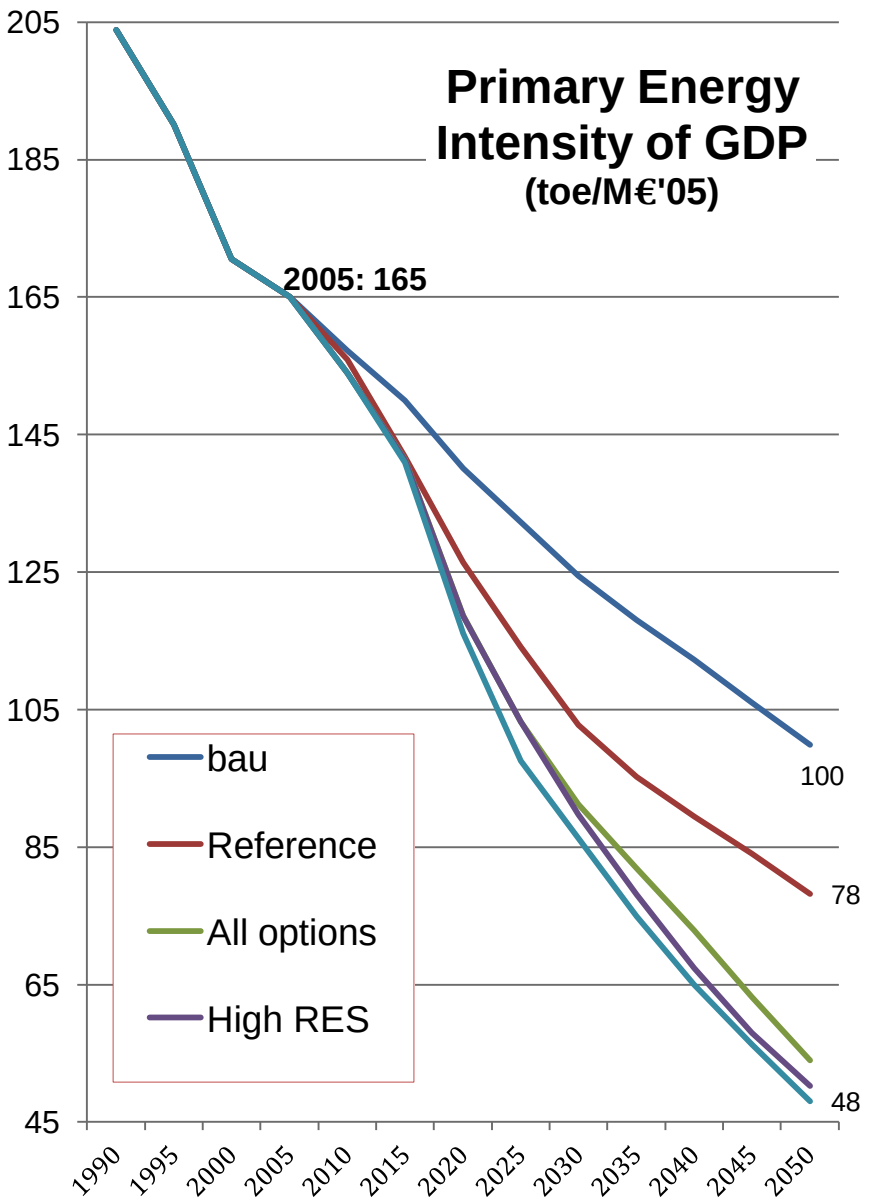


Decomposition of cumulative emission reduction by option, in % relative to bau

	All options	High Efficiency	High RES	Low CCS	Low Nuclear
Energy Efficiency	**35.6**	**40.6**	**33.3**	**35.8**	**36.9**
Renewables	**34.4**	**34.1**	**45.4**	**35.8**	**34.3**
Nuclear	**9.4**	**7.9**	**6.2**	**10.2**	**5.1**
CCS	**6.4**	**3.8**	**1.7**	**3.7**	**9.9**
Fossil Fuel Mix (gas)	**14.2**	**13.6**	**13.4**	**14.5**	**13.7**
TOTAL	100.0	100.0	100.0	100.0	100.0

The main priority in all scenarios is energy efficiency

% change on energy intensity from bau						
	Overall		**Industry**		**Residential**	
	2030	2050	2030	2050	2030	2050
Reference	-17%	-22%	-11%	-11%	-16%	-22%
All options	-27%	-46%	-16%	-34%	-26%	-49%
High RES	-28%	-50%	-15%	-33%	-24%	-49%
High efficiency	-31%	-52%	-15%	-37%	-33%	-55%
			Tertiary		**Transport**	
			2030	2050	2030	2050
Reference			-15%	-21%	-19%	-25%
All options			-28%	-54%	-26%	-54%
High RES			-26%	-56%	-26%	-54%
High efficiency			-37%	-63%	-29%	-55%



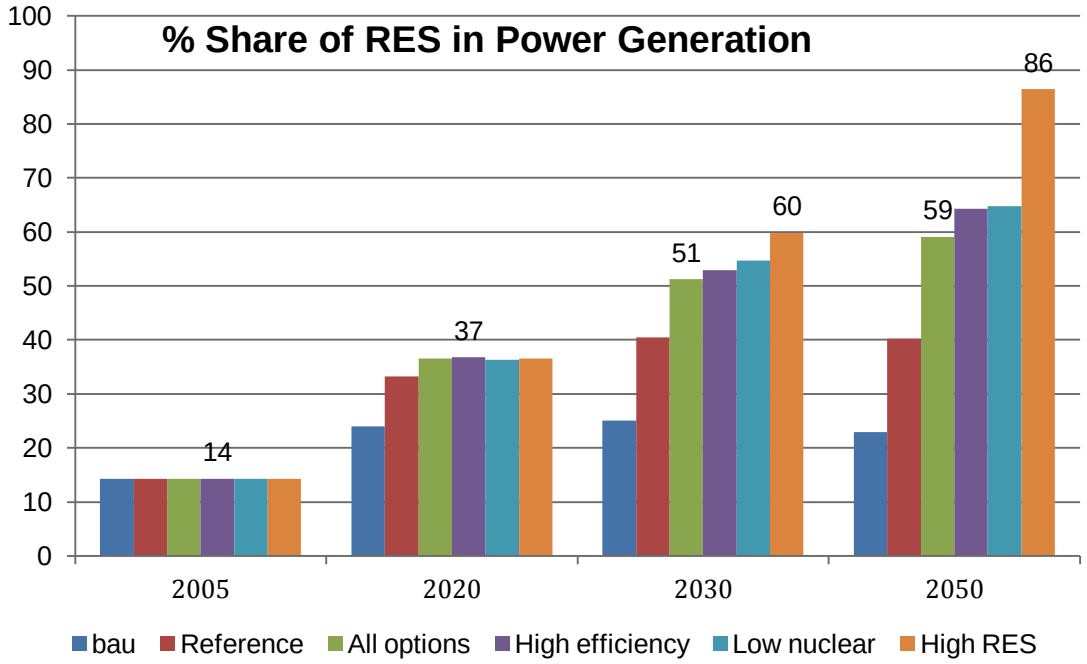
The biggest share of energy supply technologies in 2050 will come from renewables

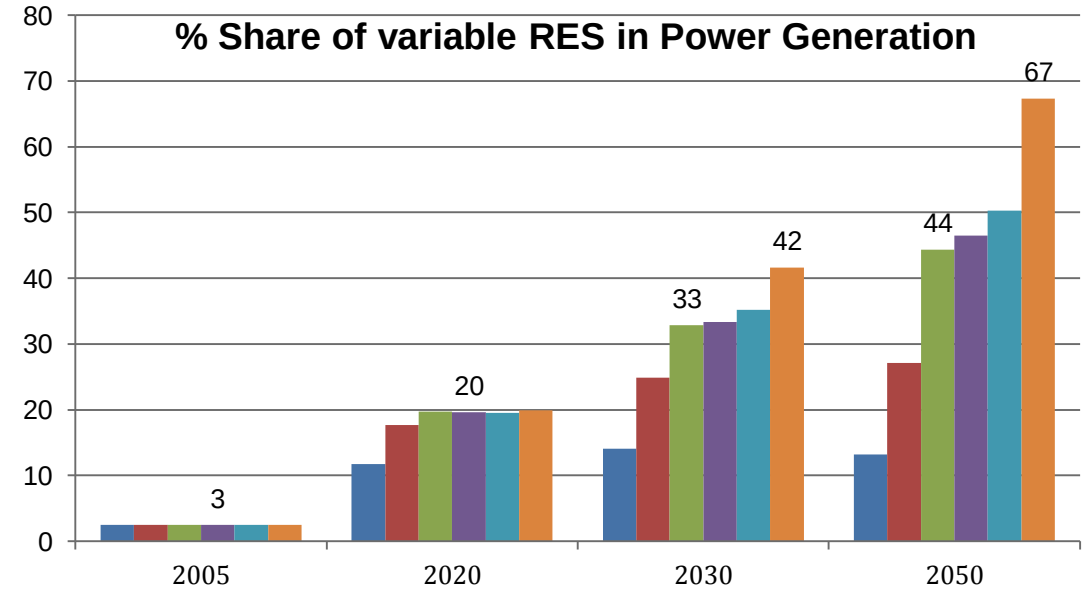
Detailed simulation of power generation shows challenges addressed by

- large backup and balancing services by gas plants
- development of hydrogen production from RES to avoid curtailment in RES power and smooth load curve
- Further development of hydro pumping storage
- Smart systems managing EV charging and highly decentralised generation

Other RES development

- Biofuels initially for cars, later mostly for trucks and aviation
- Direct heating and cooling RES





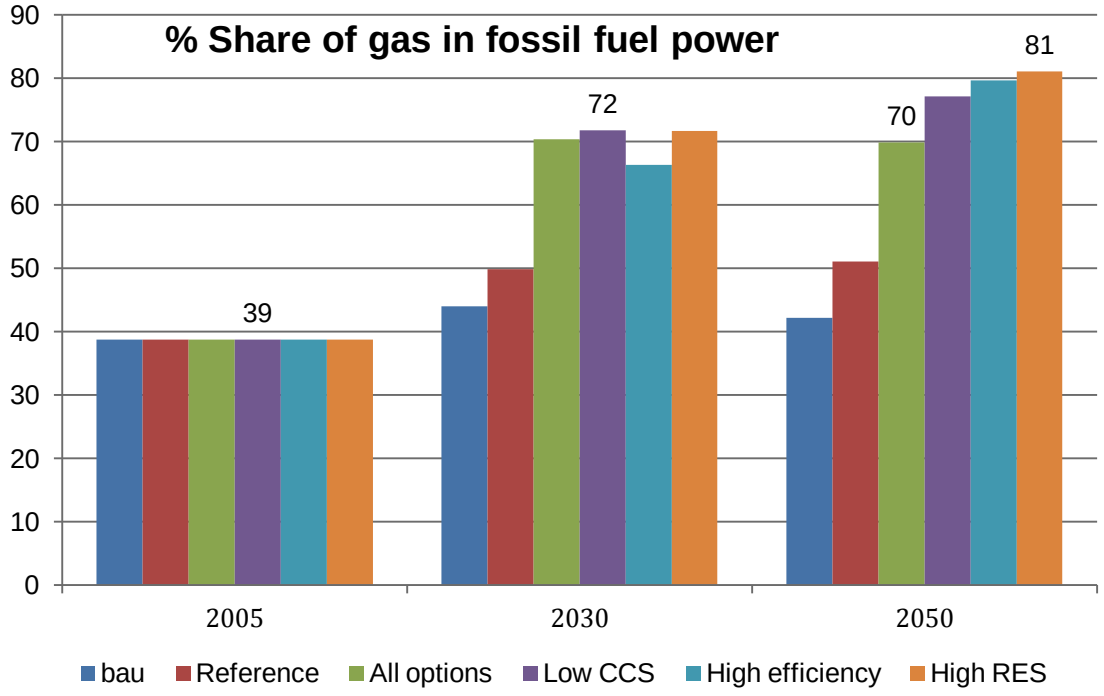
Substitution of coal and oil with gas in the short and medium term to reduce emissions and facilitate balancing

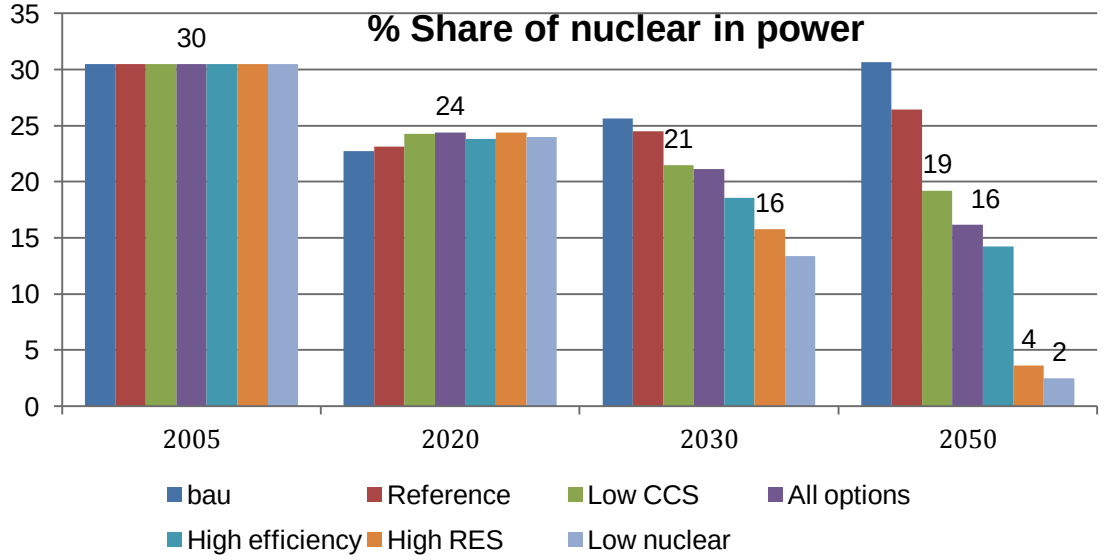
Gas fired power generation is the only non RES technology which maintains an important role in power system (in terms of capacities and a generation share between 10 and 20% by 2050)

Hydrogen and biogas are mixed in gas distribution (up to 30% in the max case) and help reducing emissions, while maintaining CHP and DH

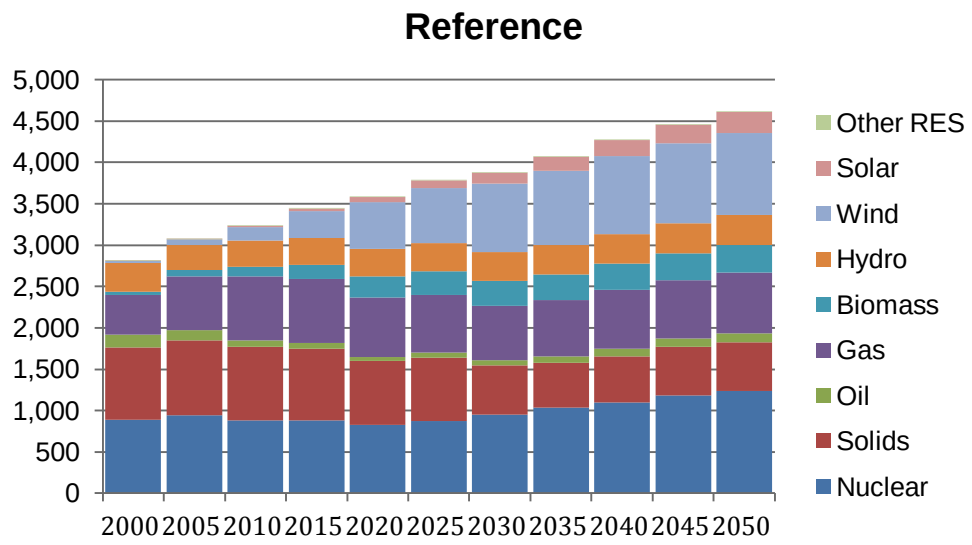
CCS coal develops less than CCS gas in scenarios with CCS success (highest CCS share 28%, lowest 7%)

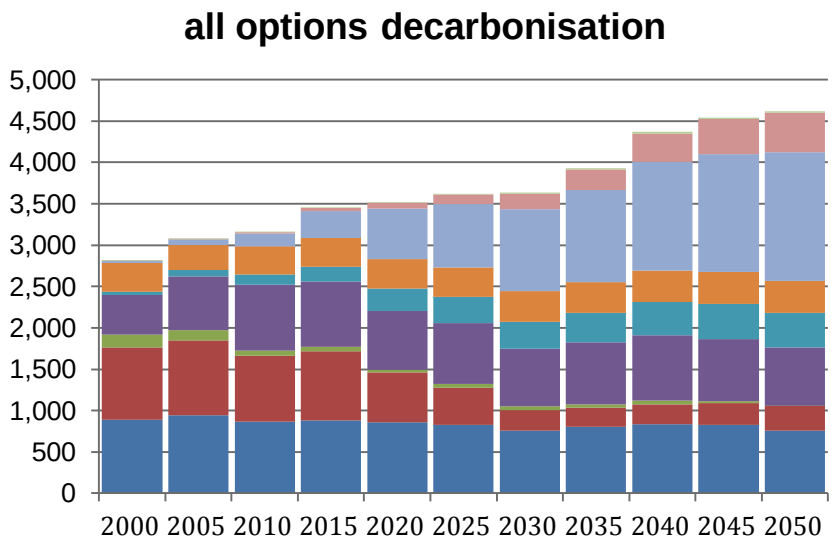
Nuclear share significantly declines in all decarbonisation scenarios, ranging between 2 and 19% by 2050, down from 30% today.

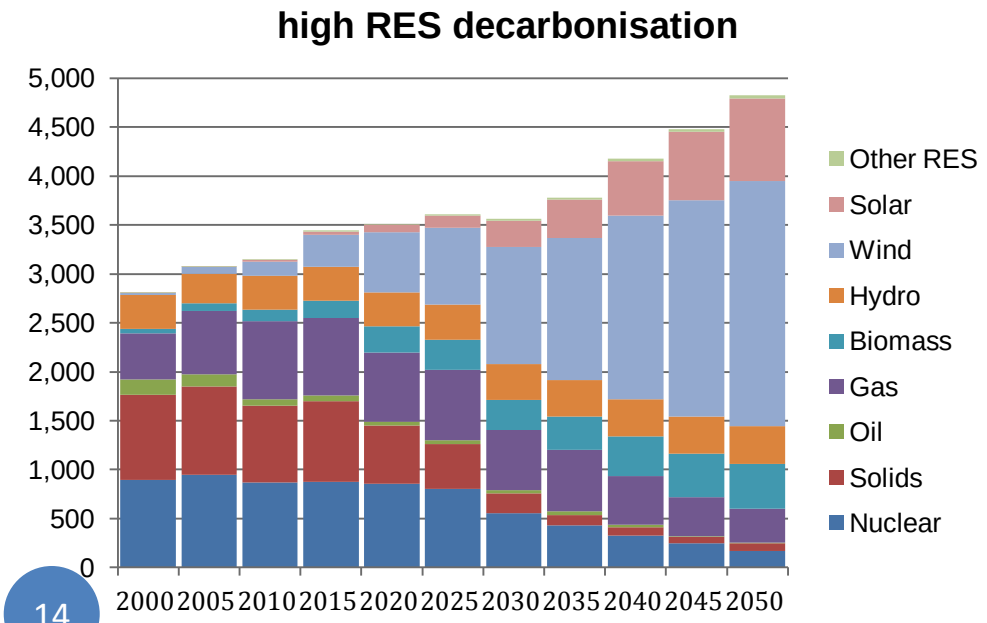


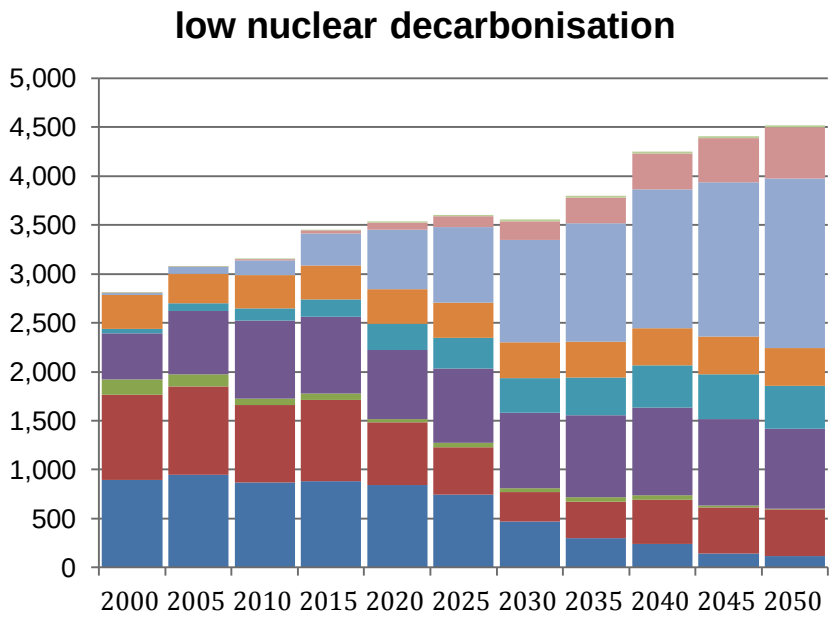


Net power generation by origin in TWh





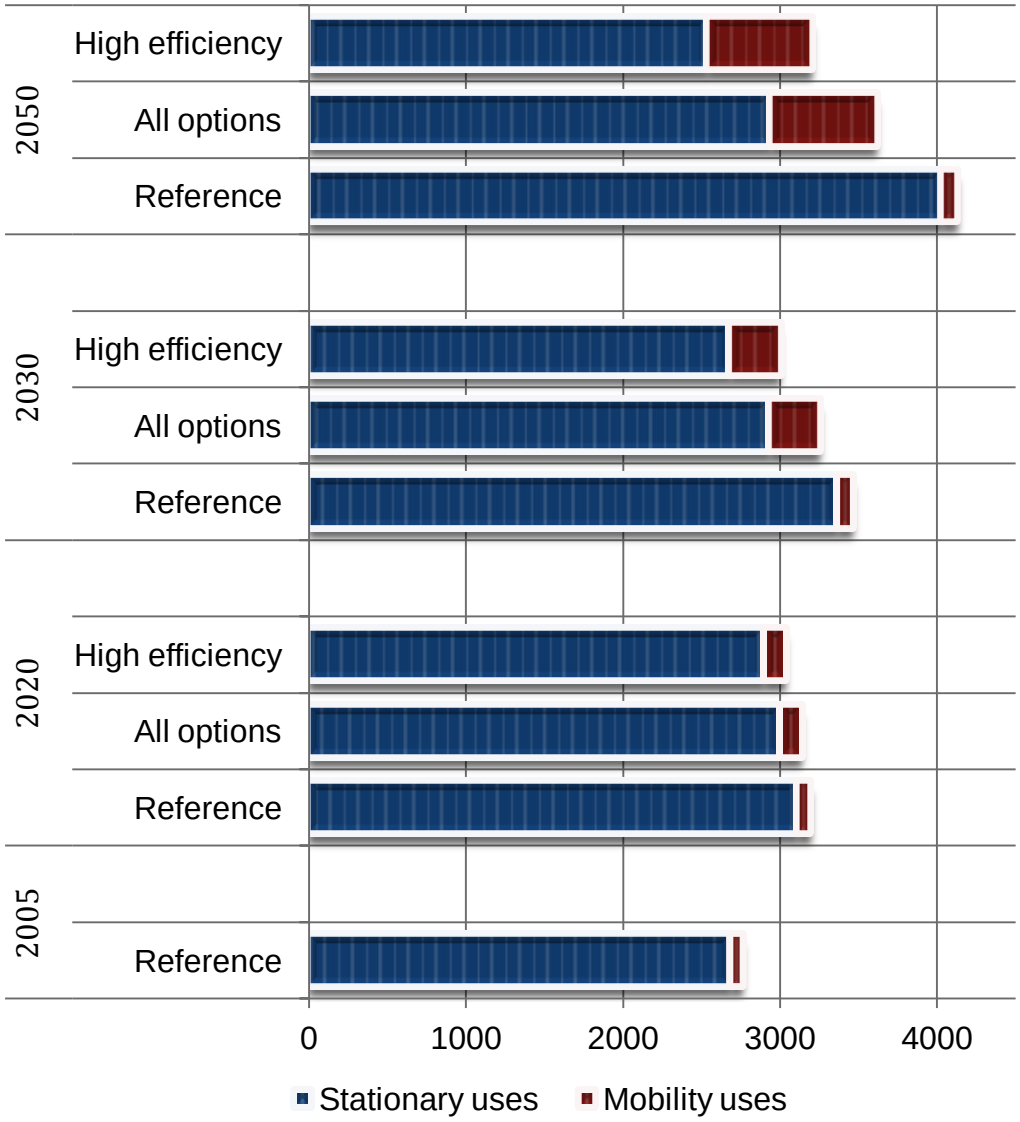




Electricity will play an increasing role, almost doubling its share in final energy demand to 36-39% in 2050 and contributing to decarbonisation of transport and heating/cooling

Decarbonisation combines strong energy efficiency improvements, which reduce conventional uses of electricity, with penetration of electricity in transport and heating

Total demand of electricity decreases from reference projection levels despite new uses

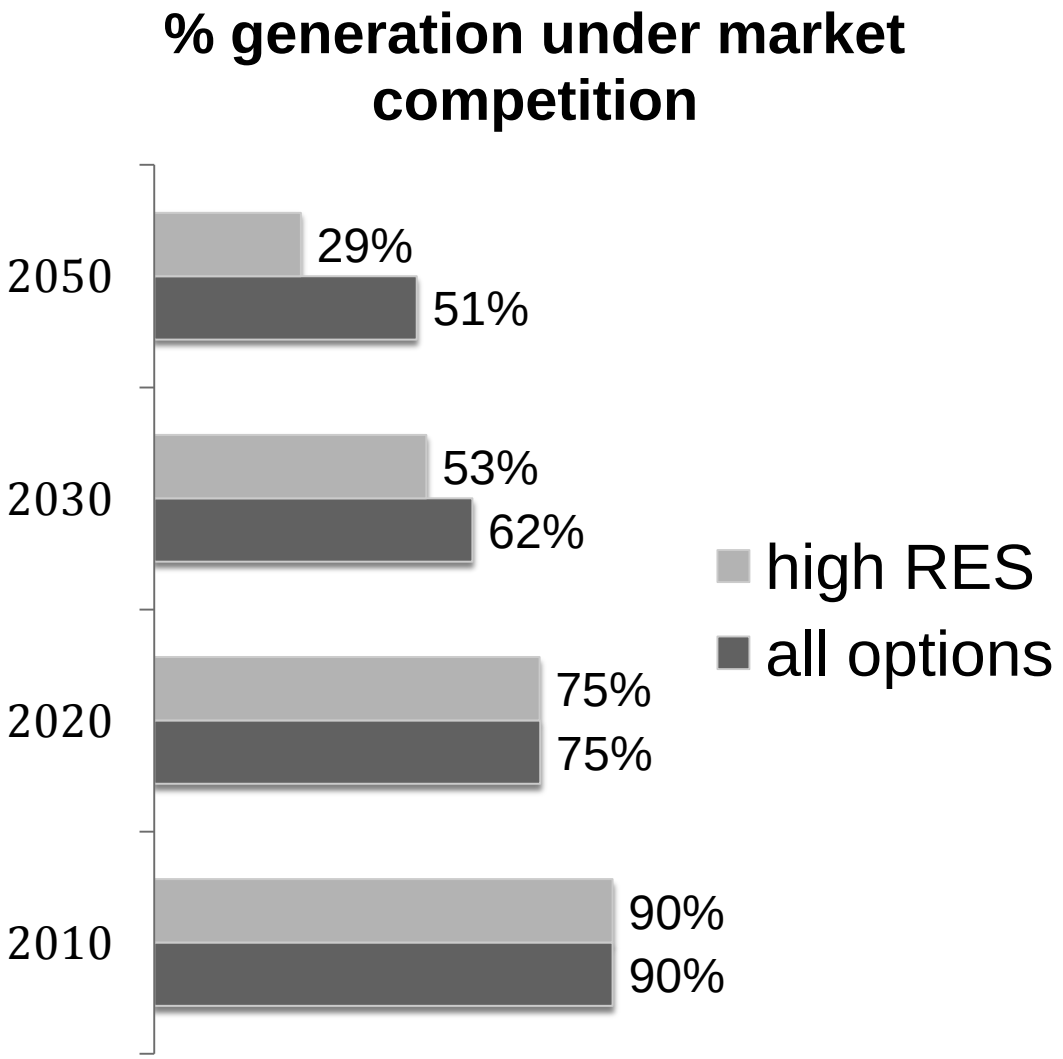


Electricity market implications

Under a “protection” regime: RES, decentralised generation, peak and back-up devices, above 50% already in 2030

As RES increase, market competition shifts to procurement of services (storage, backup, generation of variable RES)

Annual investment expenditure for transmission grid is found in decarbonisation cases to double or triple above Reference; investment in distribution increases between 40 and 70% on an annual basis until 2050, relative to Reference



Total compliance cost less than 1% of annual GDP

Under global action, climate mitigation costs partly compensated by assumed decreasing world fossil fuel prices; important effect but uncertain

All options decarbonisation cheaper than in cases which exclude options

The additional cost of the high efficiency case is mostly due to high cost of very extensive renovation of old buildings

The additional cost of the high RES case is mostly due to storage - balancing costs and to exploitation of less favourable resources

Average annual energy system cost

w/o auction payments, inclusive of cost of equipment, savings, fuel purchasing and disutility

(cumulatively 2010-2050, at 2008 prices)

	bn €/year	% of GDP	bn €/year	% of GDP
reference	2,674	14.89	Diff. from reference	
all options	2,717	15.12	42	0.24
all options and high fuel prices	2,811	15.65	137	0.76
			Difference from all options	
high efficiency	2,775	15.45	58	0.32
high RES	2,779	15.47	62	0.34
low CCS	2,744	15.28	27	0.15
low nuclear	2,752	15.32	35	0.19

Cost impacts on households: annual additional payment as % of income: changes from Reference (excl. disutility costs)

in % of households' income	All options		High efficiency		High RES	
	2030	2050	2030	2050	2030	2050
Share of energy related costs in household income	0.7	0.7	1.8	1.5	1.1	1.7
of which stationary uses	1.1	1.1	0.6	1.8	0.4	1.9
of which transportation uses	-0.4	-0.4	1.2	-0.3	0.8	-0.2
of which for CAPEX	0.9	2.7	2.2	4.2	1.5	3.1
of which for OPEX	-0.1	-2.0	-0.4	-2.8	-0.4	-1.4

Decomposition of cumulative cost changes relative to Reference scenario

Stationary uses		All options	High efficiency	High RES
Expenditures in consumer premises	Change in unit cost	11.2%	6.8%	13.7%
	Change in structure	4.9%	20.6%	2.4%
Purchase of energy from suppliers	Change in unit cost	-5.5%	-6.7%	-1.2%
	Change in structure	-1.3%	-6.0%	-0.7%
Change in unit cumulative cost of services		9.3%	14.7%	14.3%

Mobility uses		All options	High efficiency	High RES
Expenditures for transport means	Change in unit cost	30.3%	30.3%	30.3%
	Change in structure	6.4%	6.4%	6.4%
Purchase of energy from suppliers	Change in unit cost	-4.8%	-4.8%	-4.8%
	Change in structure	-1.3%	-1.3%	-1.3%
Change in unit cumulative cost of services		30.6%	30.6%	30.6%

Change in structure means change between capital and variable costs

Electricity costs and prices:
Differences from Reference

EUR/MWh	All options		High efficiency		High RES	
	2030	2050	2030	2050	2030	2050
Capital and fixed cost	6.2	9.0	6.3	8.7	14.2	46.0
Variable and fuel cost	-5.7	-14.1	-5.6	-14.2	-8.2	-19.8
Tax on fuels and ETS	-0.6	-3.8	-4.7	-3.5	-4.1	-1.3
Grid and Sales costs	3.1	3.1	2.6	3.4	5.3	14.6
Pre-tax Electricity Price	3.0	-5.9	-1.4	-5.6	7.2	39.4

EUR/MWh	Low CCS		Low nuclear	
	2030	2050	2030	2050
Capital and fixed cost	6.8	12.2	7.1	12.2
Variable and fuel cost	-5.9	-13.6	-3.3	-11.0
Tax on fuels and ETS	-0.4	-3.2	2.2	-3.4
Grid and Sales costs	3.2	3.9	4.6	5.7
Pre-tax Electricity Price	3.7	-0.8	10.5	3.6

Power generation: decomposition of cost changes in high RES relative to all options case, in 2050

EUR/MWh	Unit cost effect	Change of Structure	Total effect
RES	3.7	26.6	30.3
Conventional	-3.6	10.5	6.9
Nuclear,CCS	1.9	-38.0	-36.0
Balancing	-3.3	5.1	1.8
Storage	16.5	5.4	21.9
Total	15.3	9.6	24.8

Dynamics

- The 2020-2030 decade is the basis for decarbonisation beyond 2030. Issues:
  - Infrastructure: grids, CCS, smart, transport
  - Acceptability
  - Extension of lifetime of new nuclear
  - Alternative fuels in transport and electrification
  - Market signals (ETS)
  - Very strong renovation in buildings, houses
- If acceptability fails, CCS and nuclear may fail simultaneously, leaving RES and efficiency as options. Gas can play a higher role in the mid-term but cannot contribute in the long term without CCS
- Transport electrification involves many uncertainties (assumed high success with batteries and recharging infrastructure)