Universiteit Utrecht

Copernicus Institute of
Sustainable Development

Machteld van den Broek

Role of CCS in the power system

CCS in the power sector

Climate agreement: CCS for power

Climate agreement

- < 3 Mt
- Temporary solution
- Focus on wind and solar.

but power sector should be

- cost-effective and reliable

and need for negative emissions

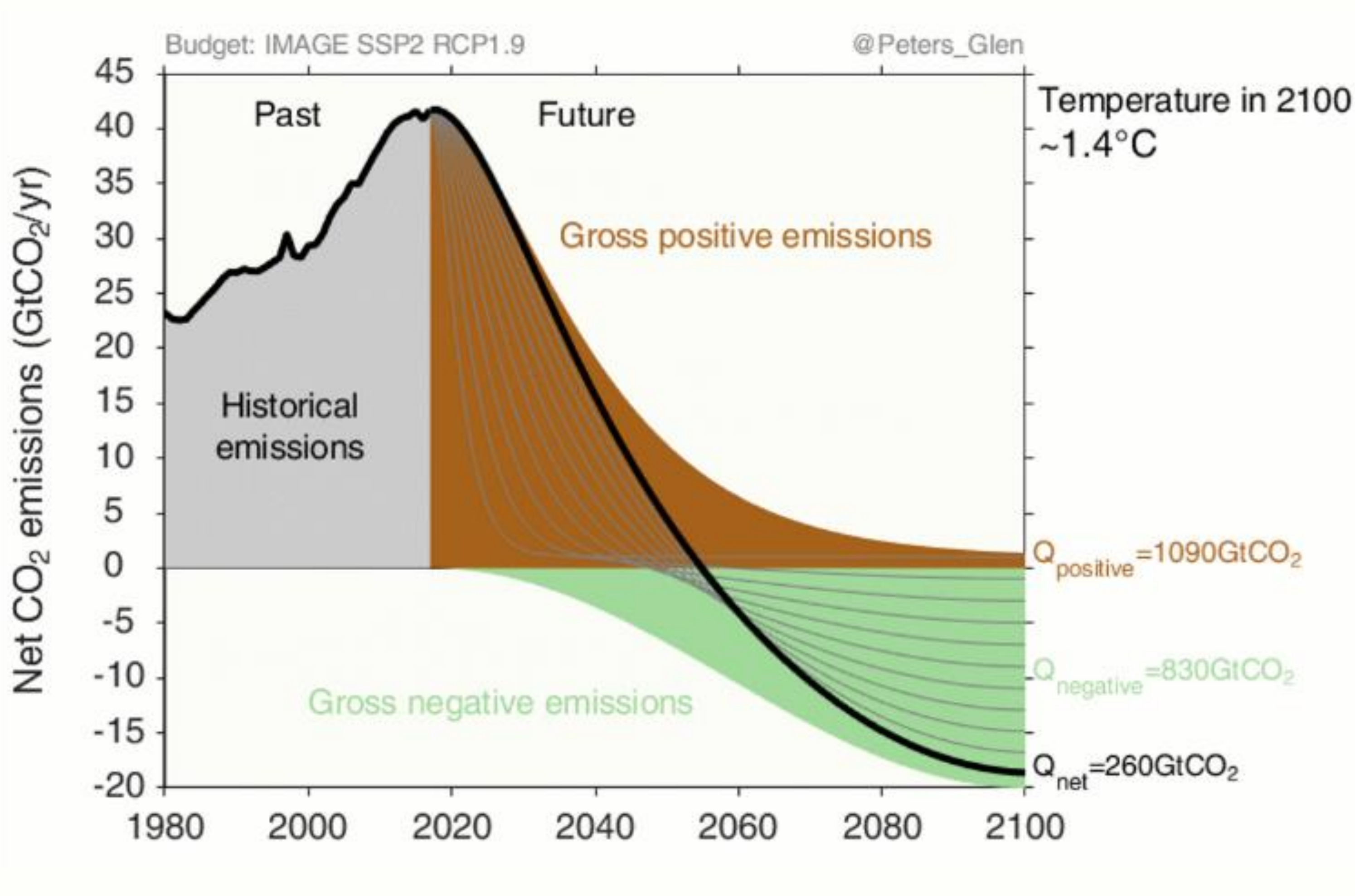
Main message

- Exploit benefits of CCS in power sector

Why CCS in the power sector

- Four reasons
  1. Negative emissions
  2. Cheaper
  3. Reliability power system
  4. Use existing assets

Negative emissions



Source:G. Peters https://www.cicero.oslo.no/no/posts/klima/stylised-pathways-to-well-below-2c

CCS for negative emissions

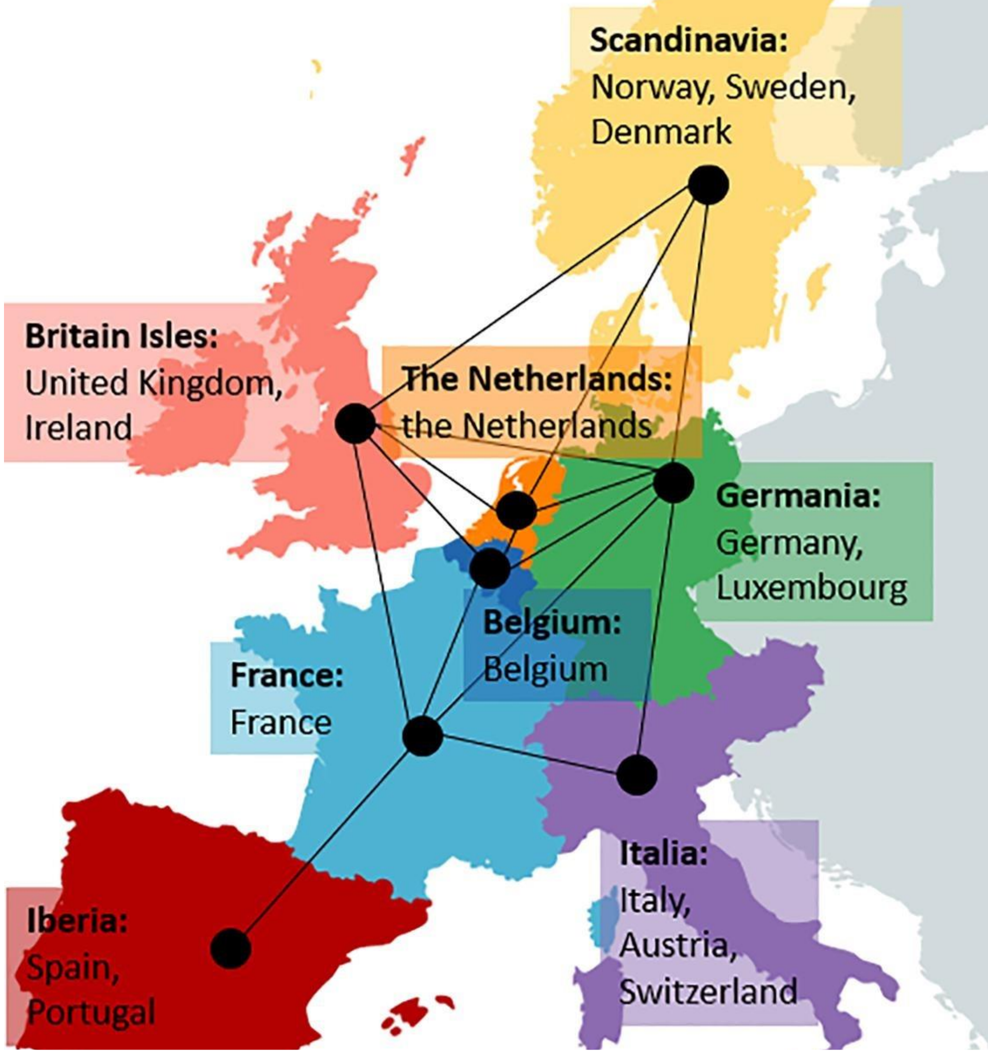
900 tonnes/year

Performance (future):
0.3 MWh electricity/tonne CO_2
6 GJ heat/tonne CO_2

Source: https://www.climatecentral.org/news/first-commercial-co2-capture-plant-live-214

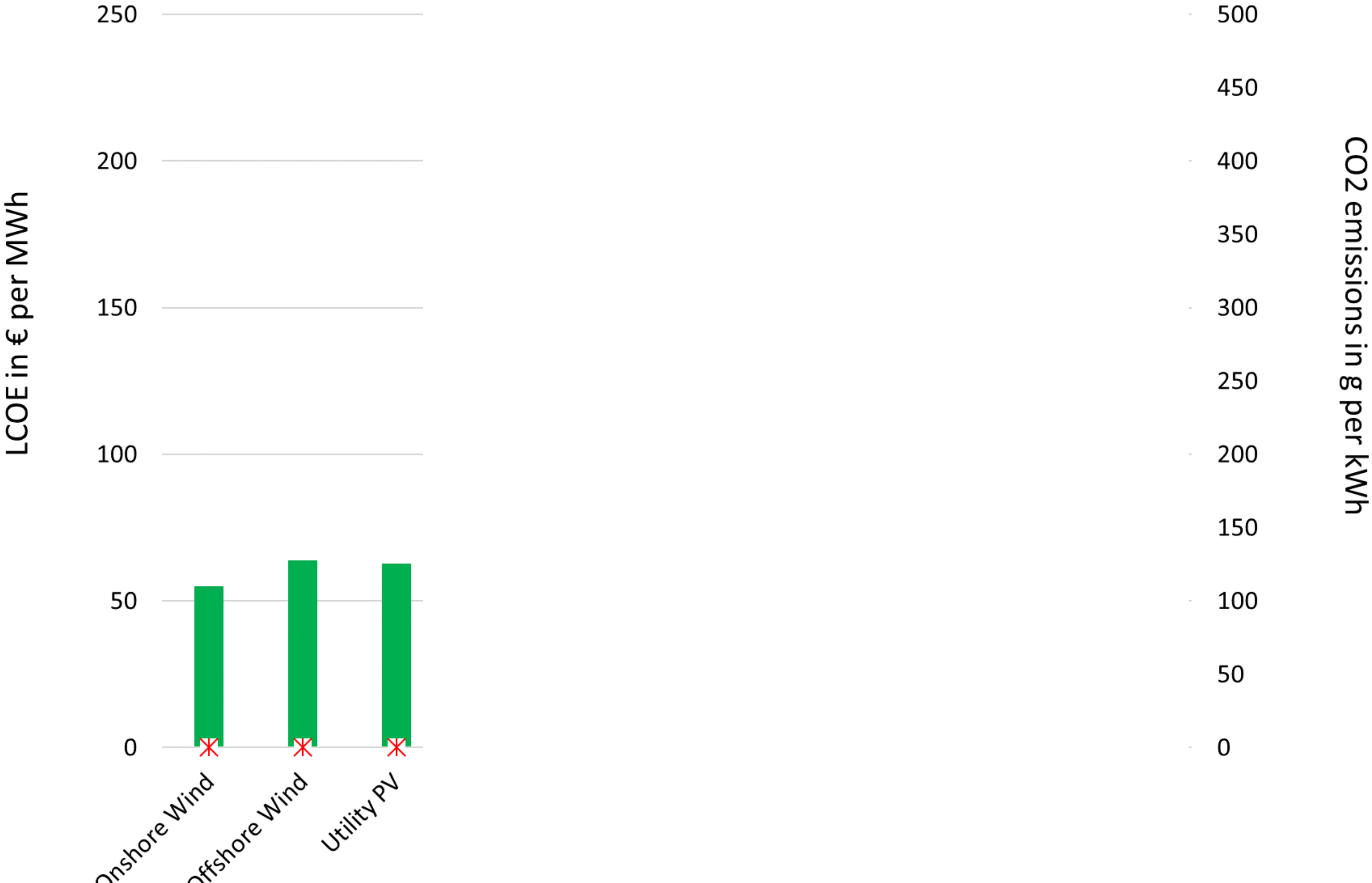
Power system modelling

- Cost-effective portfolios

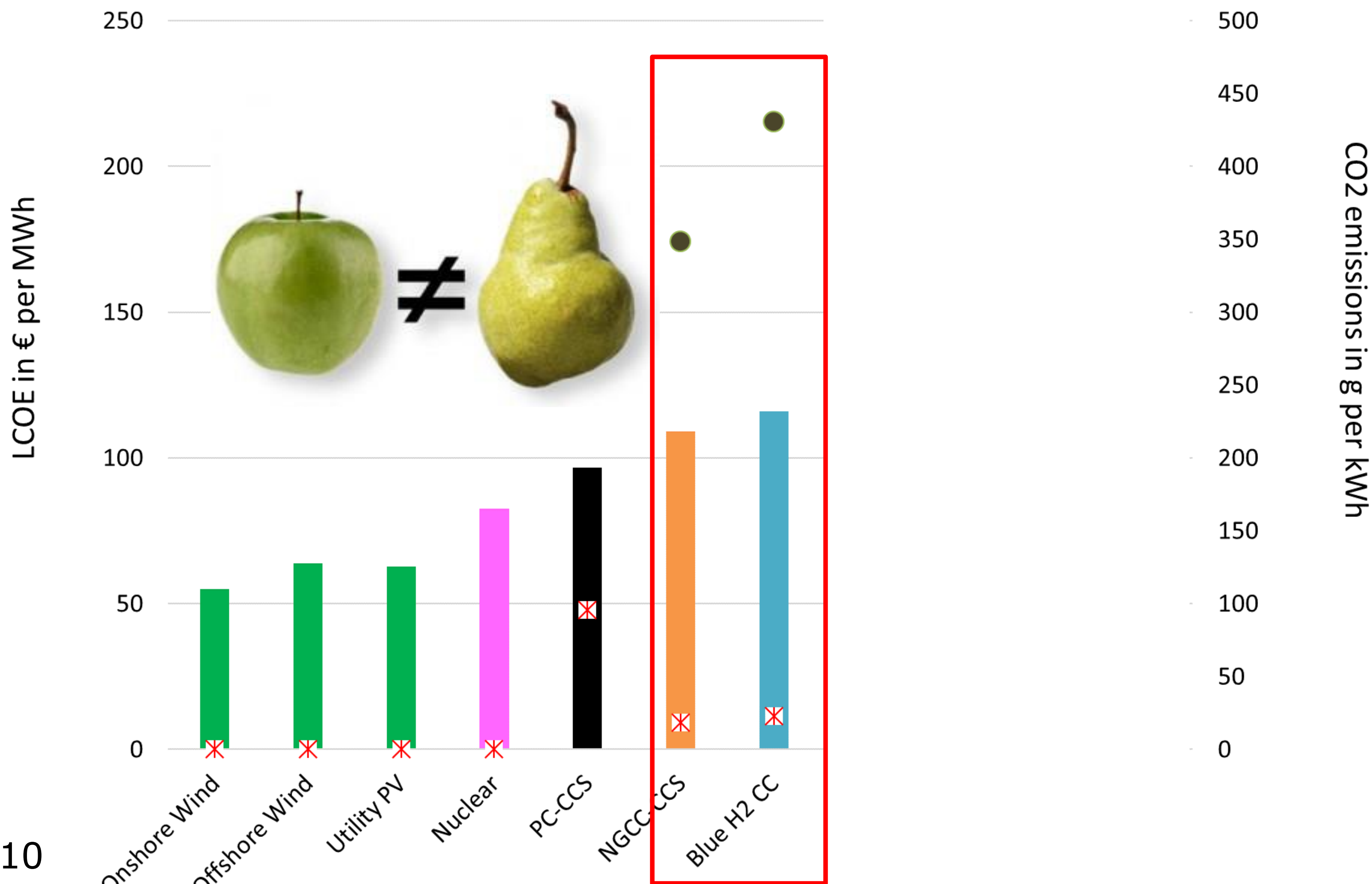


Source: www.electricitymap.org

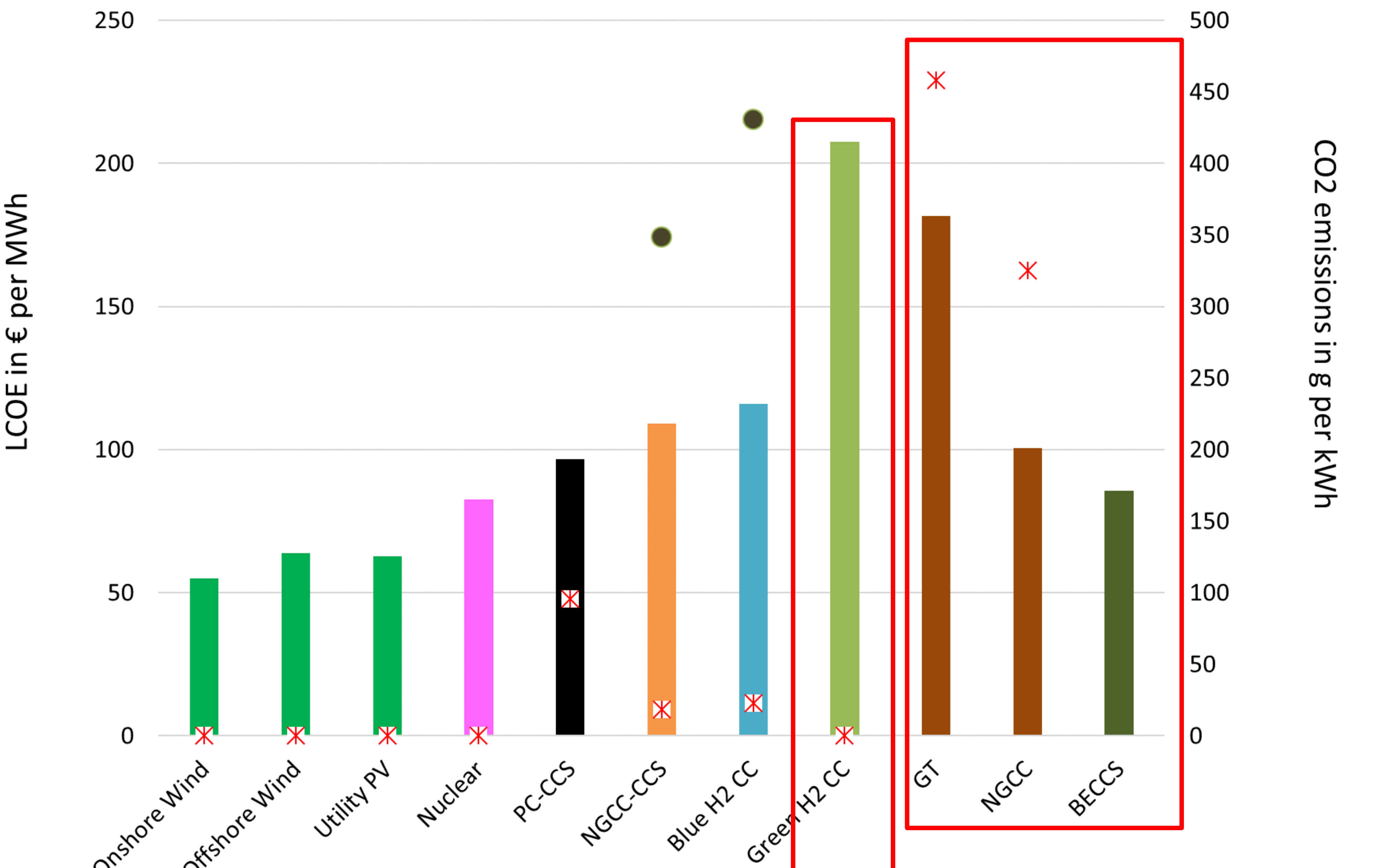
Levelised cost of electricity



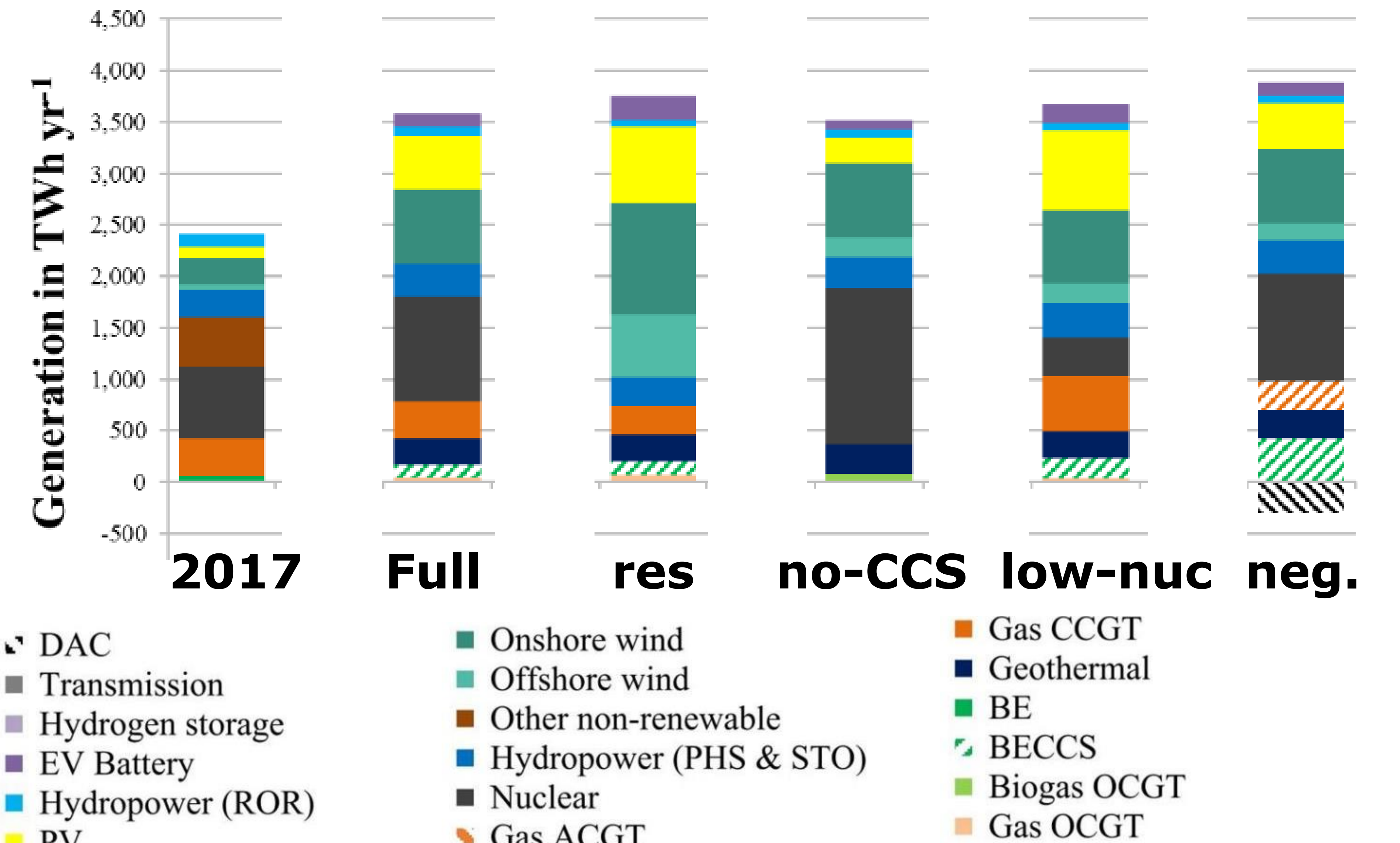
Levelised cost of electricity



Levelised cost of electricity



European power system in 2050



Use of existing assets

- in cost-effective pathway from current electricity portfolio to low carbon portfolio:

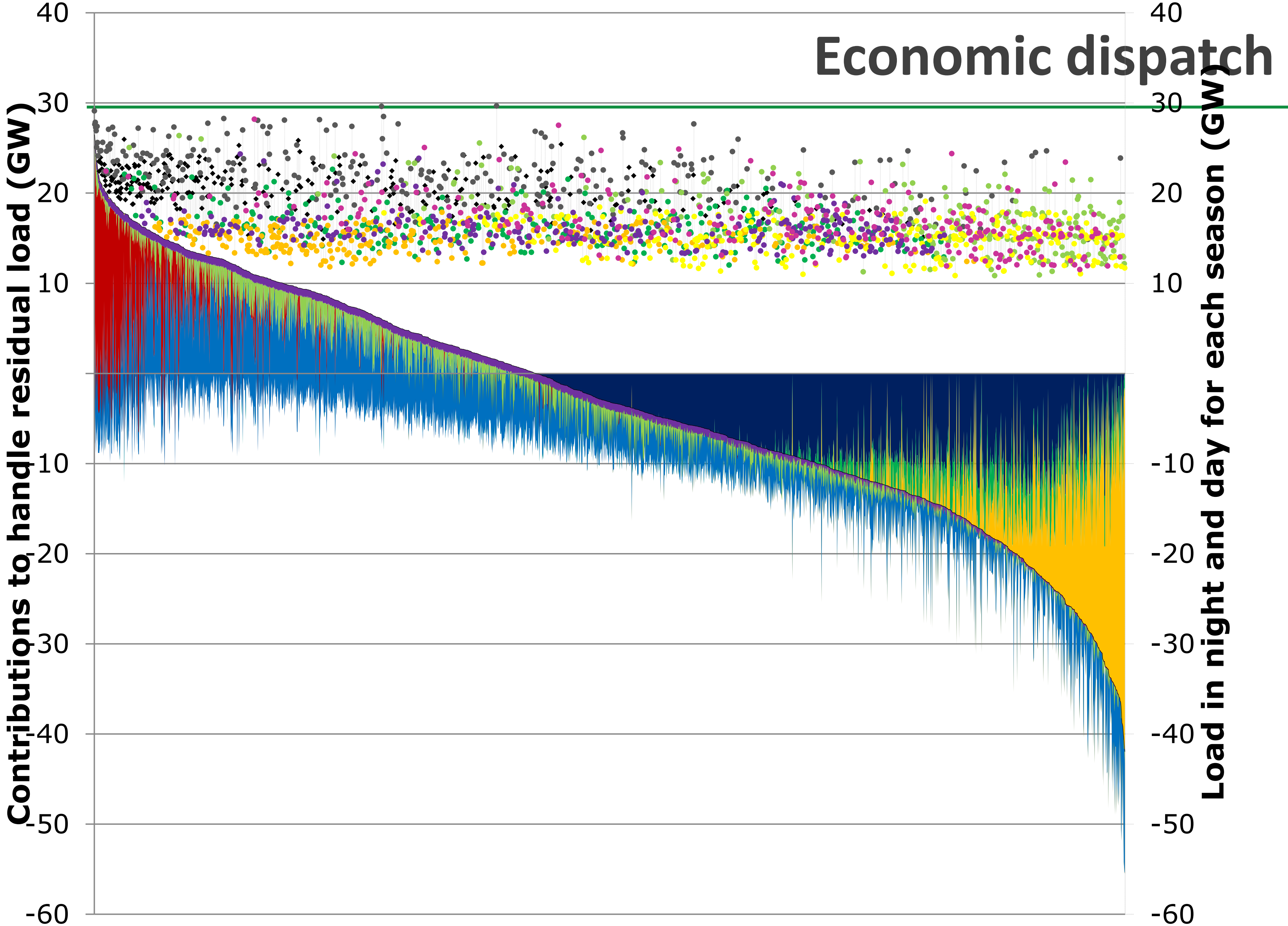
- coal-fired power plants are retrofitted to BECCS.

CCS in power sector

Backup slides + articles

- Bas van Zuijlen, William Zappa, Wim Turkenburg, Gerard van der Schrier, Machteld van den Broek, Cost-optimal reliable power generation in a deep decarbonisation future, Applied Energy, Volume 253, 2019, https://doi.org/10.1016/j.apenergy.2019.113587

- William Zappa, Martin Junginger, Machteld van den Broek, Can liberalised electricity markets support decarbonised portfolios in line with the Paris Agreement? A case study of Central Western Europe. Submitted.



Economic dispatch
Contributions to handle residual load (GW)
Load in night and day for each season (GW)
40
30
20
10
-10
-20
-30
-40
-50
-60

data

Technology	TCR ($€_{2016}$/kW)[1]	FOM ($€_{2016}$/kW)	VOM ($€_{2016}$/MWh)	Efficiency (-)[2]	Lifetime (yr)	Build time (yr)
OCGT	600	17	11.0	44.0%	30	1
CCGT	1,000	22	2.5	62.0%	30	3
CCGT-CCS[3]	1,600	33	4.0	55.0%	30	4
PCSC	2,000	41	3.7	48.0%	40	4
PCSC-CCS[3]	3,300	65	5.6	38.0%	40	5
Coal-IGCC	3,000	59	5.1	47.0%	35	5
Coal-IGCC-CCS[3]	3,700	85	6.1	41.0%	35	6
Nuclear	5,300	66	2.5	38.0%	60	7
Onshore Wind	1,300	35	0.0	-	25	1
Offshore Wind	2,600	49	0.0	-	30	1
Utility PV	500	8	0.0	-	25	1
Roof PV	600	12	0.0	-	25	1
Bio energy[4]	2,500	38	3.9	38.0%	25	3
Geothermal	3,500	60	0.0	-	30	3
Hydropower (PHS)	4,000	51	5.1	-	60	3
Hydropower (STO)	4,000	51	5.1	-	60	3
Hydropower (ROR)	3,500	38	5.0	-	60	3
Hydrogen turbine[5]	1,000	19	2.5	62.0%	30	3
Hydrogen electrolyser[6,7]	400	7	0.0	65.5%	10	1
BECCS[3,8]	4,100	49	5.9	30.1%	25	4
OCGT (biogas)[9]	600	16	11.0	44.0%	30	1
DAC[7,10]	42,500	-	137	-	20	1

Abbreviations: OCGT: open cycle gas turbine, CCGT: Combined cycle gas turbine, PCSC: Pulverised coal super critical, IGCC: Integrated gasification combined cycle, PV: Photovoltaics, PHS: Pumped hydro storage, STO: dam storage, ROR: Run-of-river, CCS: Carbon capture and storage; DAC: Direct air capture of CO_2; BECCS: Bio energy with carbon capture and storage

[1] The total capital requirement (TCR) is calculated based on the total overnight costs, the build time and interest rate. The interest during construction is included assuming that the investments costs are distributed equally over the construction time.

[2] The efficiency is defined as net efficiency at full load power and at lower heating value

[3] A capture ratio of 90% is assumed

Additionally, some technologies that are not covered by the JRC reports are also included in this study. Their techno-economic parameters (including sources) are presented in Table 3.

[4] It is assumed that fluidised bed technology is used for bio energy.

[5] The techno-economic parameters are taken to be same as the Based on CCGT data

[6] Based on Siemens Silyzer projections

[7] In this case, kW refers to the electric input capacity

[8] Based on the Bio energy data and the relative cost increases and efficiency drop between PCSC and PCSC-CCS

[9] Based on the OCGT natural gas fired power plants. Biogas fired OCGT might often have smaller capacities than their natural gas fired counterparts, however, techno-economic parameters are assumed to be similar.

[10] Based on the literature overview of PBL and detailed data from Socolow et al., assuming a 100% capacity factor. Additionally, DAC's capture 2,000 kgCO_2 MWh^{-1}.

data

Fuel	Price [a] (€ GJ^{-1})	Maximum fuel usage [b] (EJ yr^{-1})	Emission factors (kgCO_2 GJ^{-1})
Natural Gas	7.0	-	56
Coal	2.1	-	101
Uranium	1.0	-	0
Solid woody biomass	6.9	4.9	0
Biogas	16.9 [c]	1.0	0

[a] *The natural gas and coal fuel costs are the European import prices taken from IEA* [32] *2DS scenario, the uranium price is taken from [5] and the solid biomass and biogas price are taken as the average weighted costs for biomass from the medium availability biomass scenario of JRC* [33]

[b] *Based on the medium availability biomass scenario of JRC* [33]. *These biomass potentials only consist of biomass that can be produced in the countries within the scope of this study. Furthermore, sugar, starch and oil crops are excluded as these are reserved for biofuel production. Black liquor and wet silage are excluded due to a lack of data availability and stem wood is reserved for heating purposes.*