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Sektorenkopplung

The Role of Hydrogen in the Energy Transition

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HOCHSCHULE HAMM-LIPPSTADT

IfSK Institut für Sektorenkopplung in der Energiewende

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REN'S SHARE IN THE ENERGY SECTORS IN 2024

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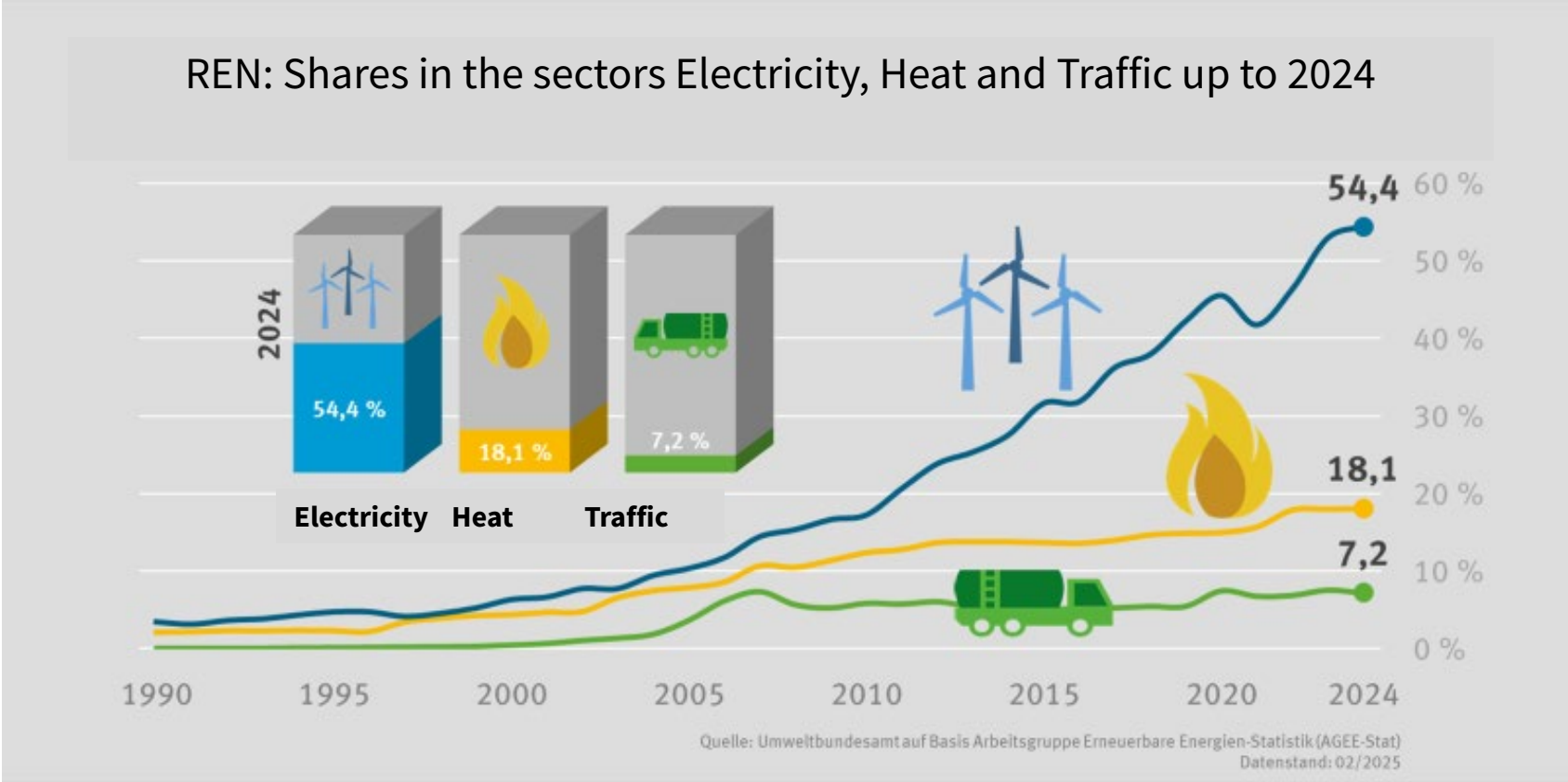
- Electricity sector:
  54.4 % (2024), rising
- Heating sector:
  18.1 %, stagnating
  (mainly biomass, not expandable)
- Transport sector:
  7.2 %, stagnant
  (mainly biomass, not expandable)



REN SHARE OF GROSS ELECTRICITY GENERATION IN 2025

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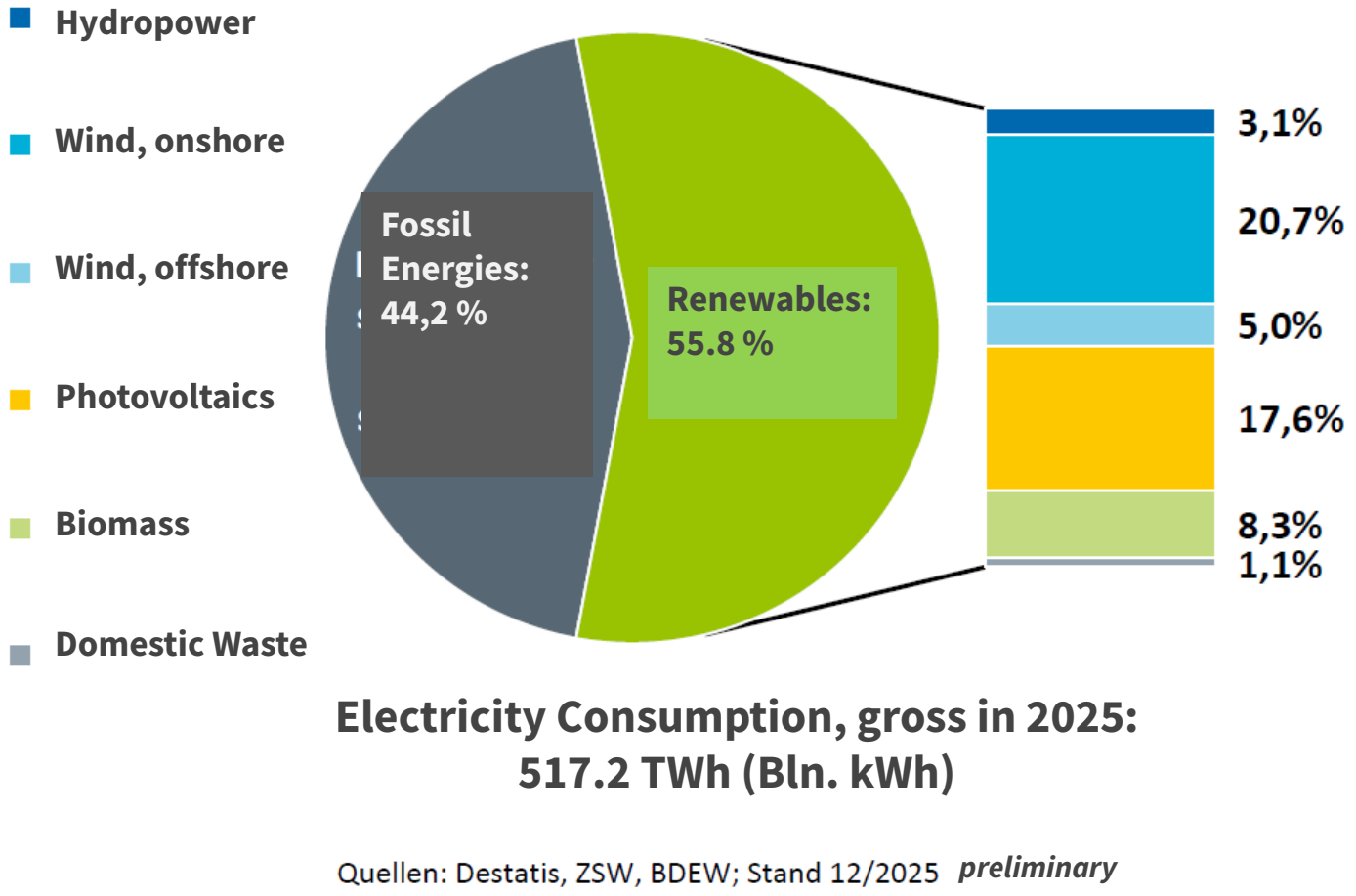
- REN share of gross electricity generation in Germany in 2025:
  - ➢ 55.8%



Electricity Consumption, gross in 2025: 517.2 TWh (Bln. kWh)

Quellen: Destatis, ZSW, BDEW; Stand 12/2025 *preliminary*

REN'S SHARE IN THE HEATING SECTOR

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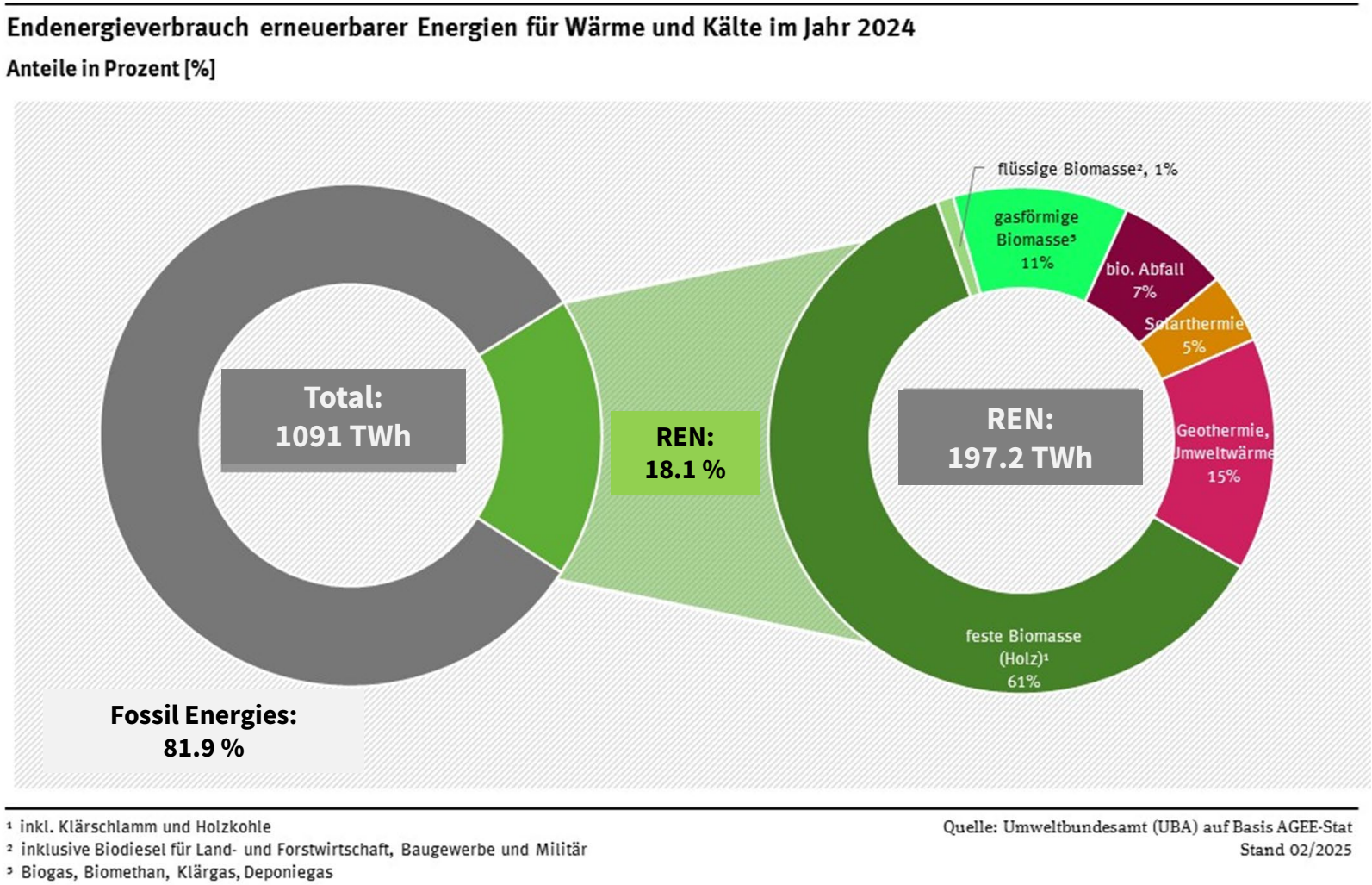
- Main share (73 %): Biomass
- Cannot be further expan-ded in Germany
  - ➢ food-versus-fuel (ff) debate
  - ➢ already **14 % of agricultural area** for **energy plants** in Germany
- What can be done?
- Burning H_2 for heating purposes is very expensive
- **Coupling the sectors: With electricity**
- Heating with heat pumps



REN'S SHARE IN THE TRANSPORTATION SECTOR

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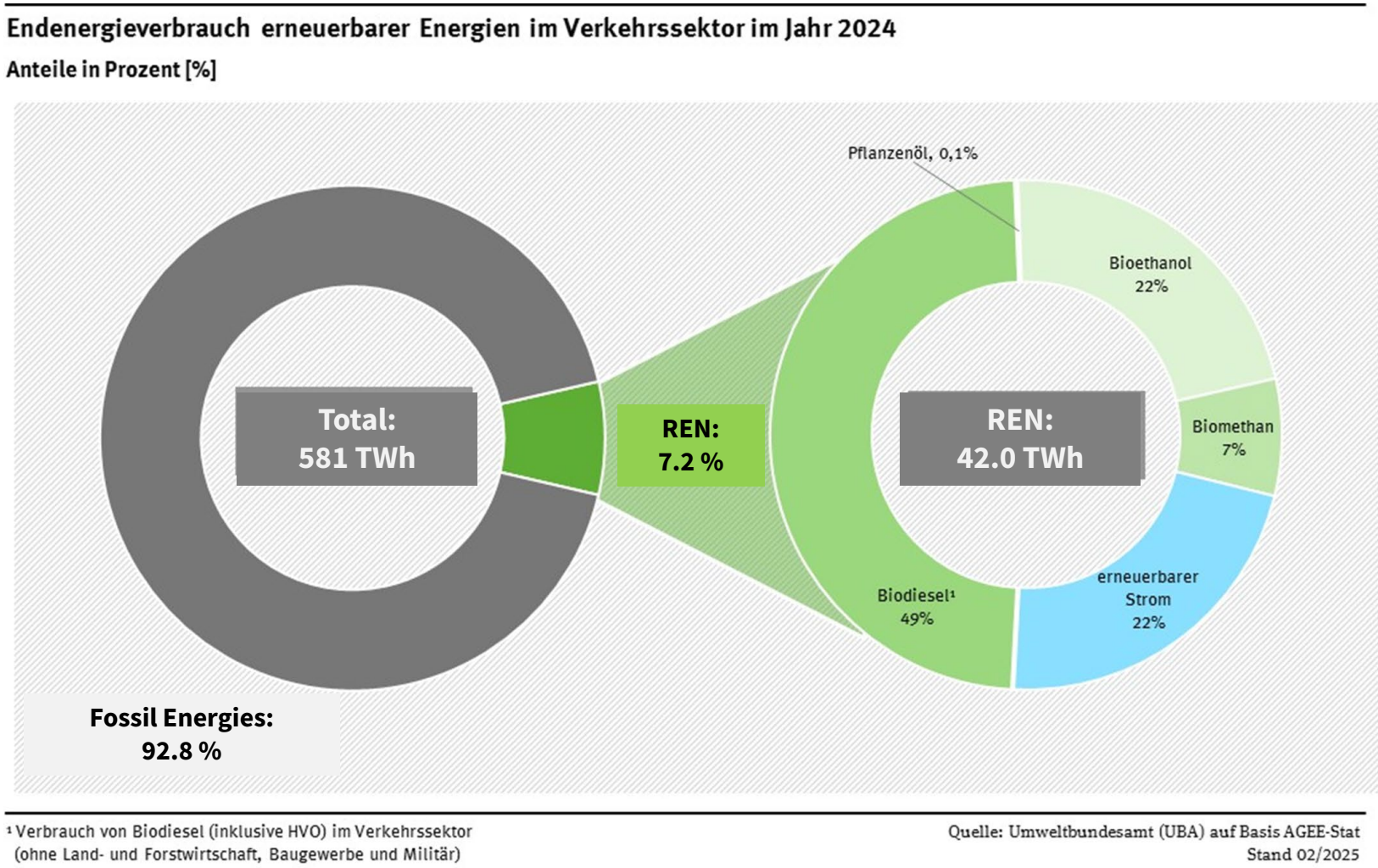
- Main share (78 %): Biomass
- Cannot be further expanded in Germany (food-versus-fuel debate)
- What can be done?
- Running cars on H_2 is very expensive
- **Coupling the sectors: With electricity**
- Electric mobility



WHRE IS THE ROLE OF H_2, IF NEITHER IN HEAT AND NOR IN TRANSPORT?

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- **Heating sector:** Heat generation by heat pump is 6 times more efficient than burning H_2
- **Transportation sector:** Running a car on electricity is 2.5 times more efficient than on H_2
- So, where is the role of H_2 in the energy transition?
- The answer lies in the question:

➢ Where does the electricity come from, when there is neither sunshine, nor wind?

- Battery Energy Storage Systems (BESS) can only bridge daily fluctuations. Longer periods are economically not feasible.
- **This is where H_2 can come into the game:**
- Due to its high energy content (33.33 kWh / kg) it is well suited as a long term storage medium
- A kg of H_2 converted in to electricity (@ η = 60%) and then into heat by a heat pump (COP = 4) is 2.4 times more efficient than a kg of H_2 burned in a boiler.

COLOURS OF H_2

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A **colour code** has been established for the different means of H_2 production:

- Green: Electrolysis powered by electricity from renewable sources ***(the goal)***
- Grey: H_2 production from fossil hydrocarbons, resulting CO_2 into the atmosphere ***(today)***
- Blue: H_2 production from fossil hydrocarbons, resulting CO_2 captured and stored or used

HYDROGEN AS A FUEL FOR RESIDUAL LOAD

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- After the last coal-fired power plants are shut down, combined-cycle gas turbine power plants (CCGTs) will ensure the energy supply in times of no wind and no sun
- In the near future, these will be fueled by natural gas
- In the long term, this natural gas is also to be replaced by renewable fuels
- The price for nat. gas was around 2 cent/kWh before the Ukraine war
- Currently it is around 6 to 6.5 cent/kWh
- Current green hydrogen production projects show hydrogen production costs of approx. 6 €/kg
- This corresponds to an energy-specific price of 18 cents/kWh
- The price difference between green H_2 and nat. gas is significant

Assumptions for the H_2 production cost:

- Capex of electrolysis plant: 60 000 € / (kg/h)
  this equals (1200 €/kW_{el})
- η: 66,7 %
- Annuity: 9.15 % p.a.
- Opex: 2 % of Capex p.a.
- Electricity price: 8 cent/kWh
- Full load hours: 4000 h/a

HYDROGEN AS A FUEL FOR RESIDUAL LOAD

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- The price difference is significant
- How can this difference be bridged?
- Best way: Bringing down the production cost of green hydrogen
- It will be difficult to reduce H_2 production costs in Germany below 4 € / kg
- What impact could a carbon tax have?
- See table on the next slide

price conversion from nat. gas to H_2

nat. gas price			H2-Preis	
[cent/kWh]	[€/MWh]	[€/GJ]	[€/kg]	
2	20	5,56	0,67	
2,5	25	6,94	0,83	< nat. gas price prior to Ukaine war
3	30	8,33	1,00	
4	40	11,11	1,33	
5	50	13,89	1,67	
6	60	16,67	2,00	
6,5	65	18,06	2,17	< nat. gas price in August 2025
7	70	19,44	2,33	
8	80	22,22	2,67	
9	90	25,00	3,00	
10	100	27,78	3,33	
11	110	30,56	3,67	
12	120	33,33	4,00	
13	130	36,11	4,33	
14	140	38,89	4,67	
15	150	41,67	5,00	
16	160	44,44	5,33	
17	170	47,22	5,67	
18	180	50,00	6,00	< green hydrogen production cost in 2026

HYDROGEN AS A FUEL FOR RESIDUAL LOAD

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This table shows the CO_2-price in [€/t] which is required to reach price parity between H_2 and natural gas for various tariffs for H_2 and nat. gas

	nat. gas price [cent / kWh]	2	2,5	3	3,5	4	4,5	5	5,5	6	6,5	7	7,5	8	8,5	9
H_2-price [€ / kg]	H_2-price [cent / kWh]															
1	3,00	45,5	22,7	0,0	-22,7	-45,5	-68,2	-90,9	-113,6	-136,4	-159,1	-181,8	-204,5	-227,3	-250,0	-272,7
1,5	4,50	113,6	90,9	68,2	45,5	22,7	0,0	-22,7	-45,5	-68,2	-90,9	-113,6	-136,4	-159,1	-181,8	-204,5
2	6,00	181,8	159,1	136,4	113,6	90,9	68,2	45,5	22,7	0,0	-22,7	-45,5	-68,2	-90,9	-113,6	-136,4
2,5	7,50	250,0	227,3	204,5	181,8	159,1	136,4	113,6	90,9	68,2	45,5	22,7	0,0	-22,7	-45,5	-68,2
3	9,00	318,2	295,5	272,7	250,0	227,3	204,5	181,8	159,1	136,4	113,6	90,9	68,2	45,5	22,7	0,0
3,5	10,50	386,4	363,6	340,9	318,2	295,5	272,7	250,0	227,3	204,5	181,8	159,1	136,4	113,6	90,9	68,2
4	12,00	454,5	431,8	409,1	386,4	363,6	340,9	318,2	295,5	272,7	250,0	227,3	204,5	181,8	159,1	136,4
4,5	13,50	522,7	500,0	477,3	454,5	431,8	409,1	386,4	363,6	340,9	318,2	295,5	272,7	250,0	227,3	204,5
5	15,00	590,9	568,2	545,5	522,7	500,0	477,3	454,5	431,8	409,1	386,4	363,6	340,9	318,2	295,5	272,7
5,5	16,50	659,1	636,4	613,6	590,9	568,2	545,5	522,7	500,0	477,3	454,5	431,8	409,1	386,4	363,6	340,9
6	18,00	727,3	704,5	681,8	659,1	636,4	613,6	590,9	568,2	545,5	522,7	500,0	477,3	454,5	431,8	409,1
6,5	19,50	795,5	772,7	750,0	727,3	704,5	681,8	659,1	636,4	613,6	590,9	568,2				77,3
7	21,00	863,6	840,9	818,2	795,5	772,7	750,0	727,3	704,5							45,5
7,5	22,50	931,8	909,1	886,4	863,6	840,9										3,6
8	24,00	1000,0	977,3	954,5	931,8											1,8
8,5	25,50	1068,2	1045,5	1022,7	1000,0									795,5	772,7	750,0
9	27,00	1136,4	1113,6	1090,9	1068,2						931,8	909,1	886,4	863,6	840,9	818,2
9,5	28,50	1204,5	1181,8	1159,1	1136,4		1068,2	1045,5	1022,7	1000,0	977,3	954,5	931,8	909,1	886,4	
10	30,00	1272,7	1250,0	1227,3	1204,5	1181,8	1159,1	1136,4	1113,6	1090,9	1068,2	1045,5	1022,7	1000,0	977,3	954,5

The example shows, that at the current prices for nat. gas and green hydrogen, the CO_2 price would need to be 522 €/t in order to lead to a price parity. The current CO_2 price is below 100 €/t.

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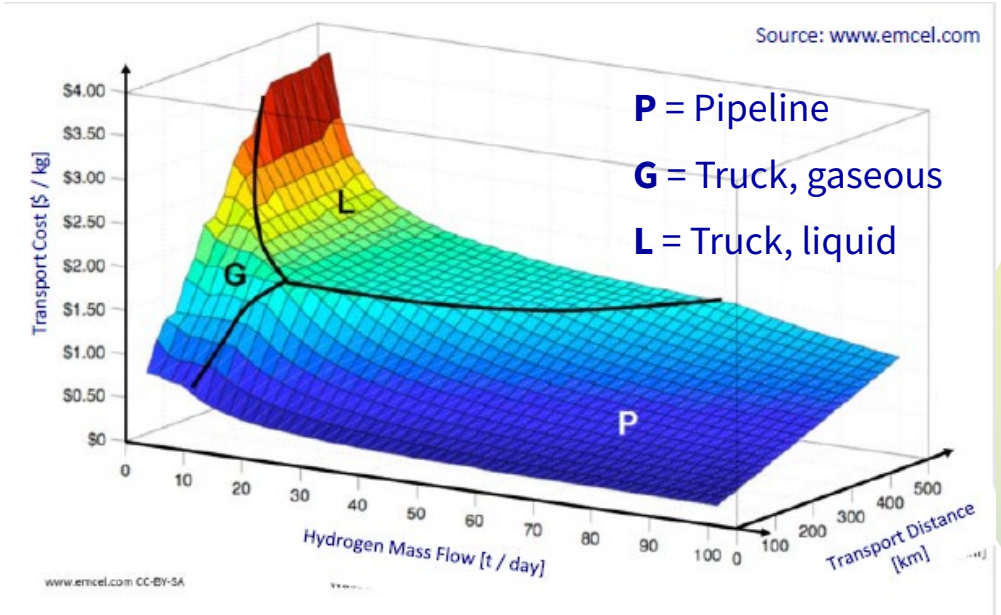
- The H_2 production cost of 6 €/kg is the cost at the production plant
- When used as a seasonal storage, the following costs have to be added:
    1) Transport to the underground storage (0.5 €/kg)
    2) Cost of (seasonal) storage (1 €/kg)
    3) Transport to the power plant (0.5 €/kg)
- With the given assumptions, the price at the power plant will be: 8 €/kg = 24 cent/kWh



THE IMPACT OF FUEL COST ON ELECTRICITY GENERATION COST, EGC

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$$EGC = \frac{CAPEX/Capacity * (annuity\ rate + O\&M\ percentage)}{FLH} + Fuel\ Cost$$

Example: combined cycle gas turbine, CCGT:

- CAPEX/Capacity: 800 € / kW
- O&M cost: 2% of CAPEX p.a.
- Full-load hours: 2000 h/a
- Nat. gas price: 0.06 €/kWh
- H_2 price: 8 € / kg, (Fuel price = €6/kg / (33.33 kWh/kg) = 0.24 €/kWh)
- $\eta_{Power\ plant,\ net}$: 60 %
- Annuity: 10 %/a
- $EGC_{nat.gas} = \frac{800\ €/kW\ (10\%\ /a + 2\%\ /a)}{2000\ h/a} + \frac{6\ cent}{kWh * 0.6}$ = (4.8 + 10) ct/kWh = **14.8 ct/kWh**
- $EGC_{green\ H_2} = \frac{800\ €/kW\ (10\%\ /a + 2\%\ /a)}{2000\ h/a} + \frac{24\ cent}{kWh * 0.6}$ = (4.8 + 40) ct/kWh = **44.8 ct/kWh**

STATUS OF THE HYDROGEN VALUE CHAIN

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- Hydrogen production (Electrolysers) is making great progress
- Hydrogen Transport in pipelines is cost efficient and feasible
- **The problem is the offtake**
- The high energy-specific costs of green H_2 compared to natural gas are reflected in the current demand for green H_2 in the energy sector.
- In other words, given the current price situation, the market is not yet ready for green H_2 as a substitute for natural gas.
- H_2 Producers would be well advised to look for customers who require H_2 as a feedstock.
- The policy framework should introduce quotas for steel produced through direct reduction using green H_2, such as for federal infrastructure projects.

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Thank you for your kind attention

https://www.hshl.de/studieren/studiengaenge/bachelorstudiengaenge/energietechnik-und-ressourcenoptimierung/

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