Decarbonizing Germany’s heating sector*
Presentation for ERRA, March 2024

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*** Based on OIES paper ET 29**

From IPCC report on 1.5°C to the German CPA*

BVG (Constitutional Court) ruling of 29.4.2021 on original CPA (of 2019)

- Followed IPCC report on 1.5°C: keeping with 1.5°C = keeping a CO2 budget of 570 Gt CO2 *
- Germany can not claim more than its share in global population (ca 1%)
- The original CPA disadvantages younger generations, because it is not stringent on CO2 reductions now, resulting in a higher burden later

=> amended CPA (18.8.2021): stricter limits, binding net zero for 2045

CPA neutral on

- possible technical approaches:

  (i) saving (ii) CO2 free energy (iii) fossil with CCS (iv) DAC /CDR for much later

- ways of implementation:

  (i) standards (ii) Pigou taxes to compensate for damages or subsidizing costs for avoiding emissions (iii) cap and trade (Coarse theorem)

* CPA = Climate protection act

** as of 2015 (with GMST- global mean surface temperature- method, 66 percentile likelihood)

Policy making and regulation of decarbonization

- Avoiding climate damage is a global public good/ externality, addressed by NDCs*
- German CPA: net zero by 2045 time is of the essence
- Issues for policy making / regulation:
  - Technology approach and instruments to cover externalites like climate, reliabiltiy (policy)

  Most decarbonization technologies need some infrastructure (power, CH4/H2, DH, CO2)
  - What infrastructure is neded (policy)
  - What infrastructure to be regulated, or left to market forces (contestability)? (policy)
  - Coordination between infrastructures (policy/ regulation)
  - Regulation of specific infrastructures (regulation)
- Potential pitfalls: overlaps / gaps in responsibiltiy ; politicians tend to shift responsibility to regulators, TSOs, markets

* NDC: Nationally Determinded Contributions

The heat sector in Germany

In 2021 heat is 59% of overall final energ consumption, traffic another 30%

Industrry:

- Heat is 75.7% of final energy in industry
- Dominated by process heat (100°C to 1500°C)
- Not dependent on ambient temperature

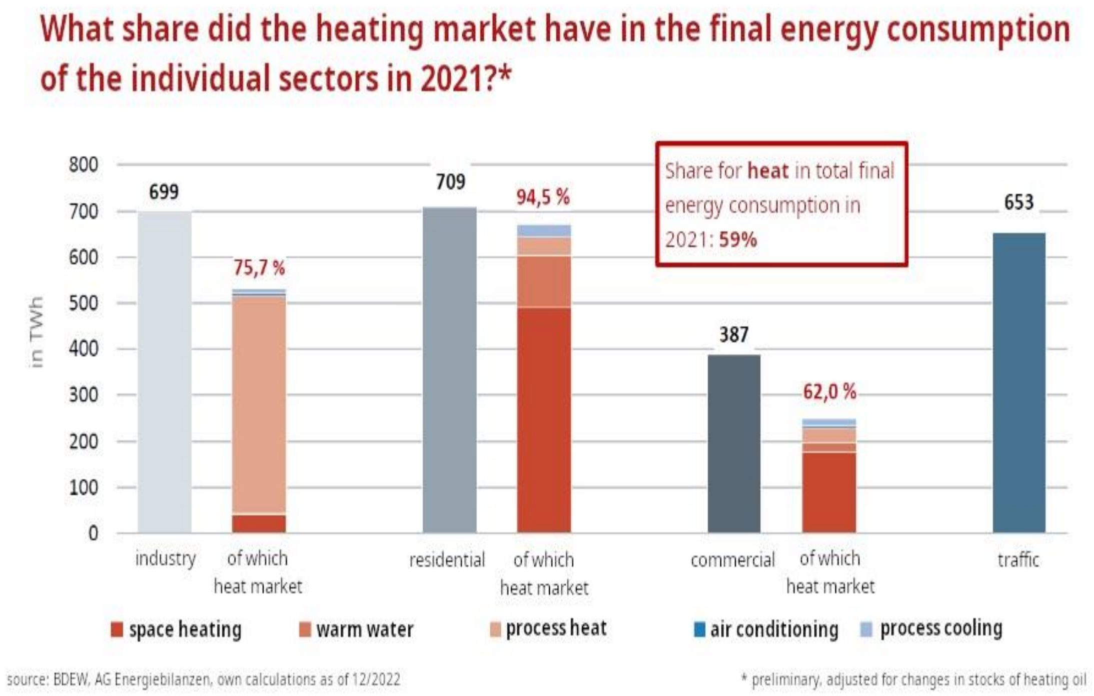
Residential and Commercial:

- Heat + warm water: 94.5% / 62%   in res. / com.
- Dominated by space heat and warm water (< 100°C)
- Strong dependence on ambient temperature

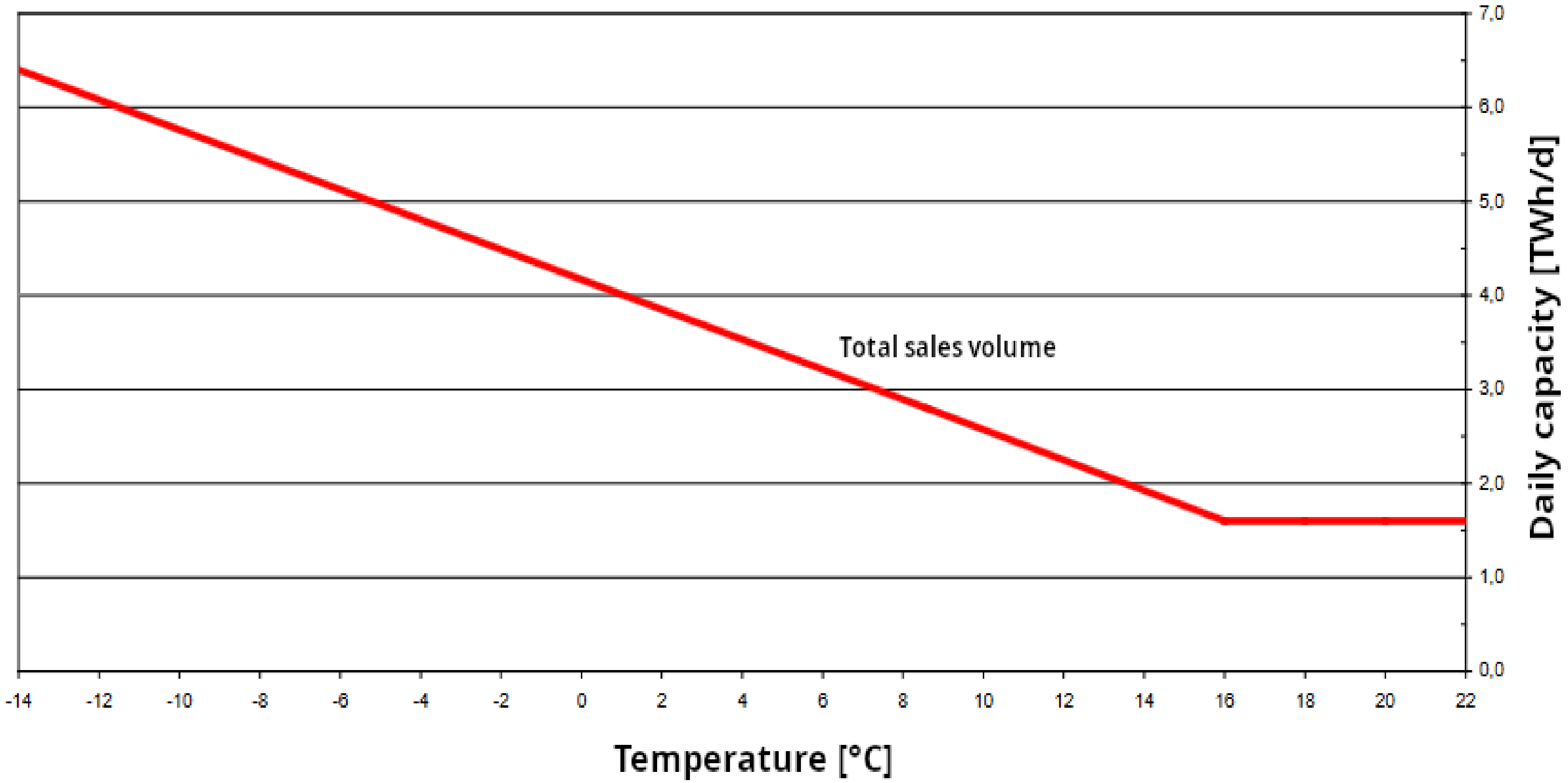
Net zero CO2- de facto zero CO2- implies:

- No gas/oil as final energy unless decarbonized
- Gas with CCS as primary energy needed to cover shortfalls of renewables in volumes and reliabiltiy

=> Gas has no future as final but as primary energy

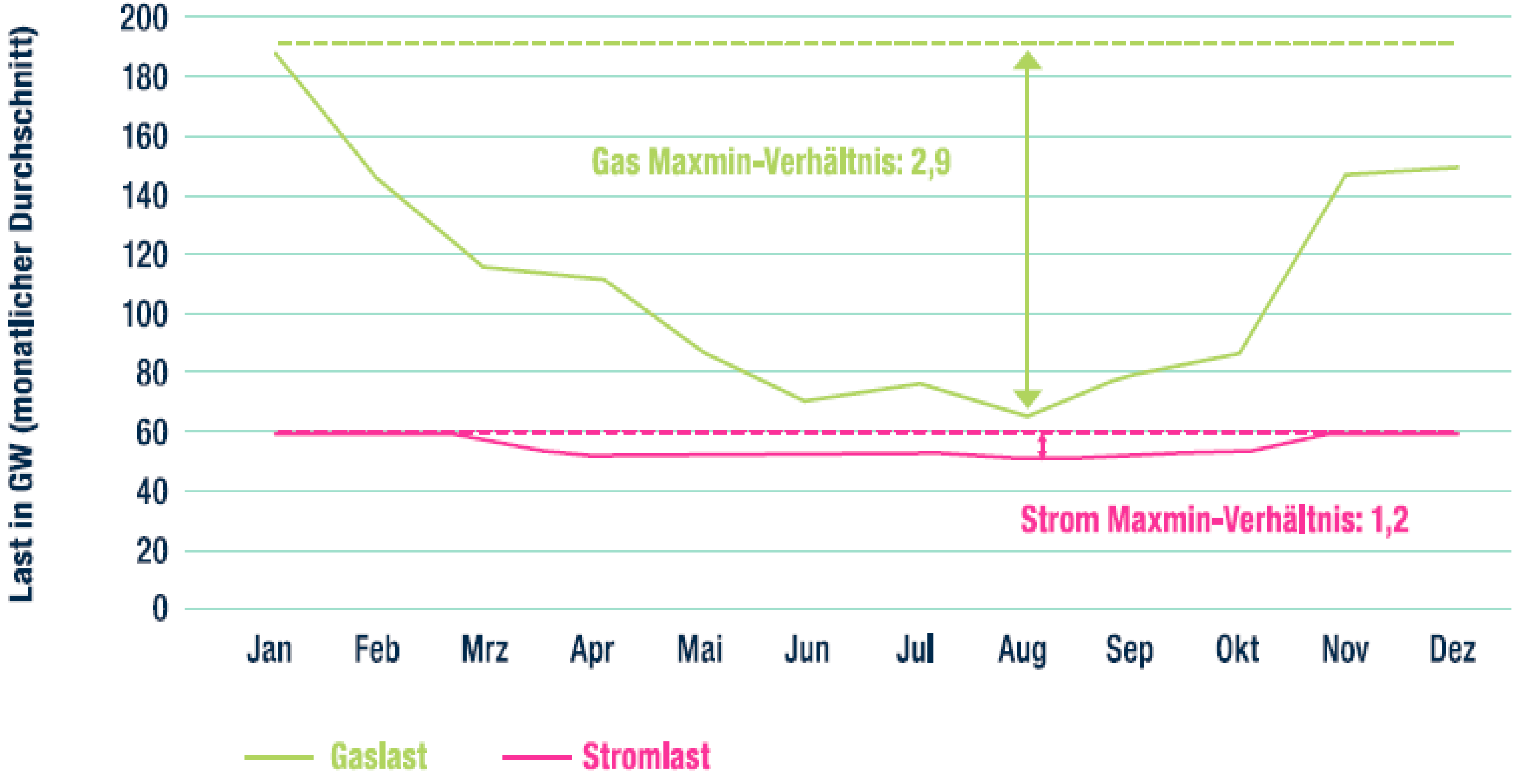


Temperature dependence of space heating



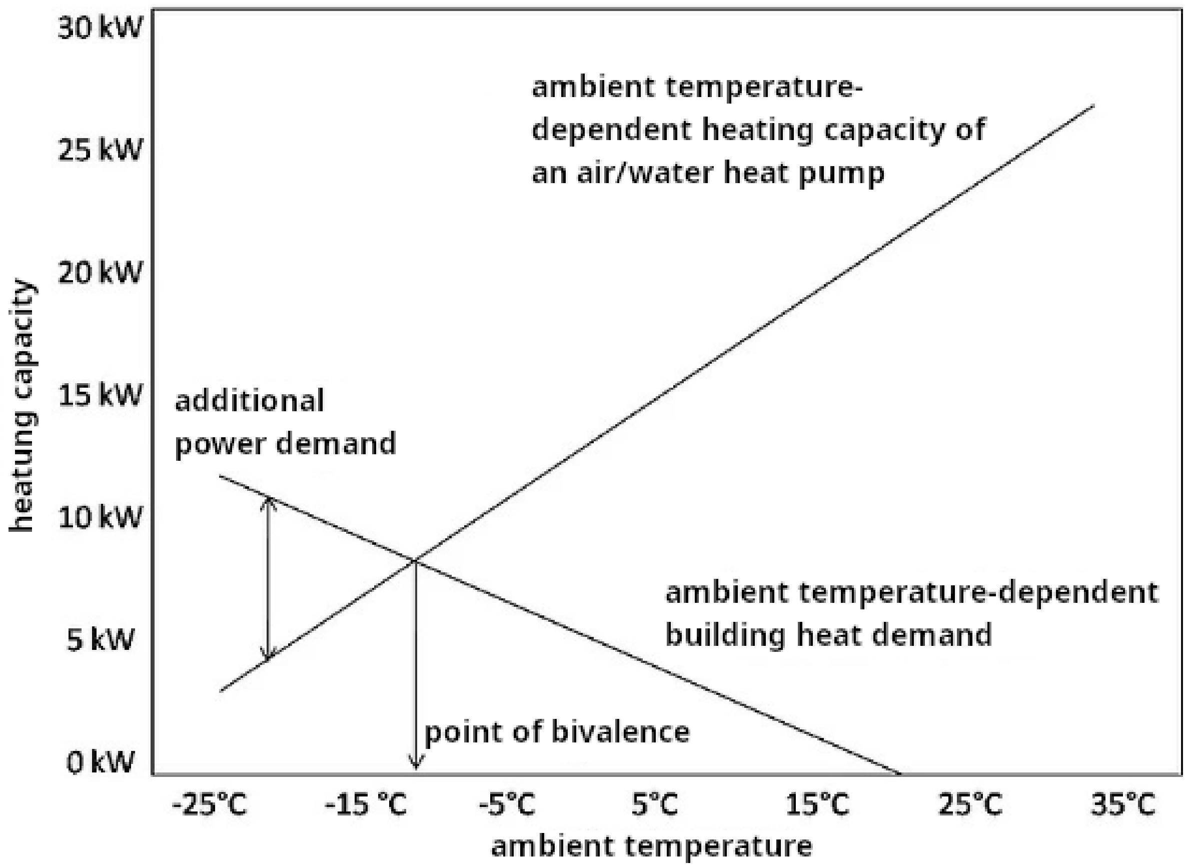
Derived from Möller, A., Zander, W. (2002, November 18) p. 4

German seasonal demand for power and gas



DVGW 2022 p. 11

Point of bivalence of air-to-water heat pumps



Greenhouse Media GmbH (2022, December 20)

Seasonal heat demand in Germany

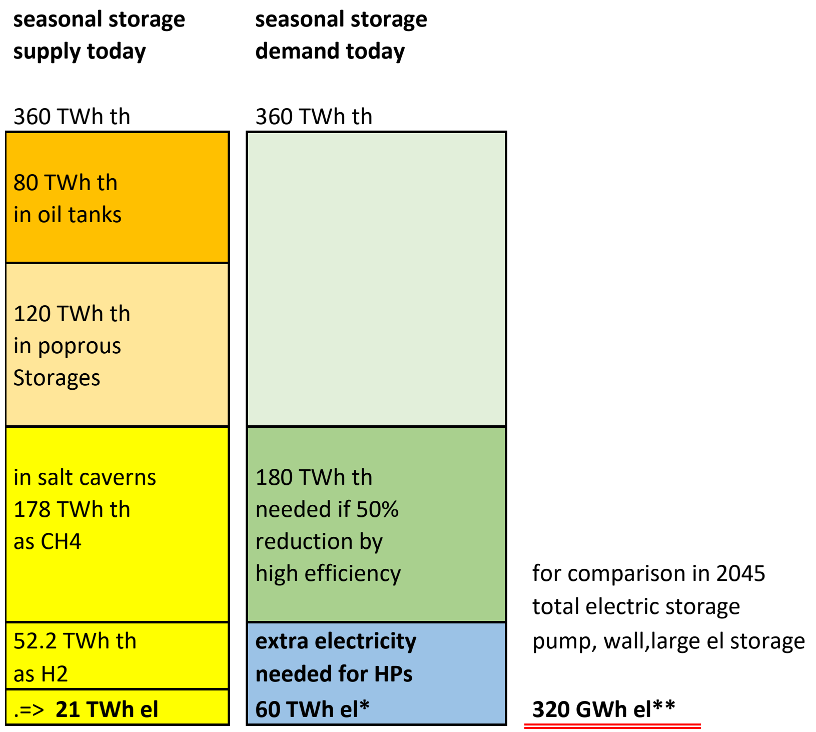
Principal issues:

Space heat and warm water, demand for heat< 100°C
Space heat demand a linear function of ambient temperature

Storage volume to cover seasonal demand:

Seasonal demand requires high seasonal storage volumes
Seasonality of demands stays, changes by insulation and HP
Present gas storage plus oil tanks cover seasonal demand
BUT not enough when operated on hydrogen

Supply and demand for seasonal storage



* assuming 3 kWh th / kWh el for mix heat pumps
** The double line at the bottom exaggerates the electric storage volume
Source: own compilation

Heating of buildings : status and decarbonization at heating point

Status:

- Stock in 2019: 19 million buildings, **9.5 m gas heated, 6 m oil heated**
- Gas distribution grids 550 000km. DH grids 33 000 km

Options to decarbonize at the point of heating:

1. individual heat pumps a must for 5 million oil heated buildings,
   BUT not feasible for 15 million buildings
   - All renewable: lack of seasonal storage, power grid bottlenecks, too slow roll out of renewables*, heat pumps
   - 15 million HPs plus local fossil power with CCS: local power bottlenecks, limited roll out of HPs, unnecessary high power capacity to back HPs, wasted possibilities of cogeneration and use of CO_2 free sources for DH

Pragmatic approach for 10 million gas heated buildings: (i) 50% switch to DH, (ii) 50% switch CH_4 to H_2

(i) Expand DH systems to supply 4- 5 million buildings (in high energy density areas, with a must connect policy) requires a doubling or tripling of DH grids, very ambitious, but feasible

(ii) For the rest: Switch gas distribution grid to CO_2 free hydrogen (95% of grid is H_2 ready, H_2 ready appliances available, quarter by quarter switching not trivial but feasible)

* See OIES paper ET 13

Heating of buildings: decarbonization of energy input

Options to decarbonize the energy input to the point of heating:

1. **Heat pumps**:

CO_2 free power needed: Increase renewable production, use back up power from fossil with CCS,

2. **DH systems:**

CO_2 free input like geothermal, large HPs (from waste water, rivers, projects lakes, up to 100 MW, standardization useful, waste from decarbonized industrial heat, CHP with CCS (power and heat demand in sync)

3. **Switch CH_4 to H_2**

Switch gas distribution grids to CO_2 free hydrogen (95% H_2 ready), availability of green / blue Hydrogen?

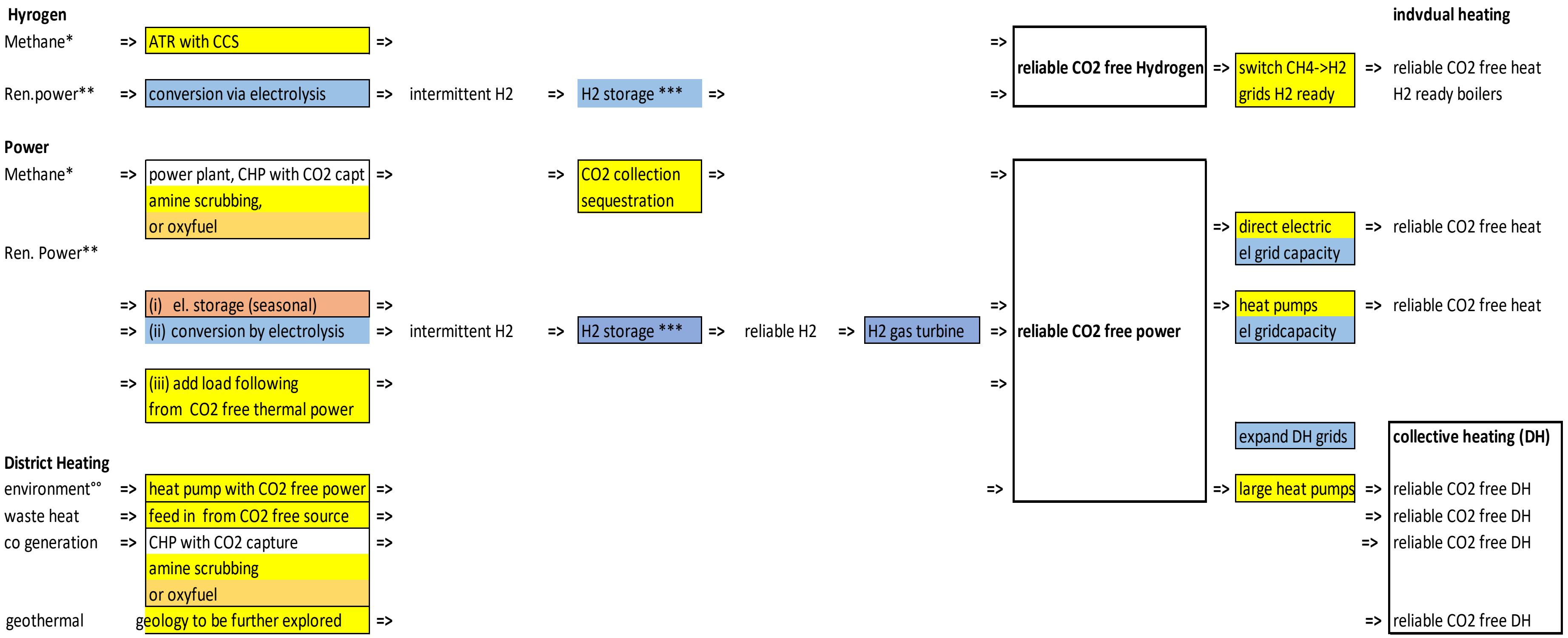
CCS needed for all three options:

- For reliable power / heat supply for HPs / DH under 1. and 2.: CHPs with CCS
- as basis for blue Hydrogen under 3.

=> include CO_2 collection now : may or may not be regulated

collection by pipeline contestable by ships; no grid character, a CO_2 pipeline smaller than overall market

Supply chains for reliable, CO2 free heating



* storage needed for supply chain optimisation, not to overcome intermittence ** wind, PV *** short term and seasonal °° waste water, rivers, lakes

Status of processes

[yellow]	manageable, depending on funding to pay for externalities
[blue]	manageable depending on funding and large, fast roll out
[light orange]	technology development needed to TRL 9
[salmon]	technology not availbale in the foreseeable furture

Interfaces and trade off between various grids

power / power	**power / gas**	**power /H_2**	**power / DH**	**power / CO_2**
local vs national upgrade invest for north South debottling for HPs by ren / CHPs with CCS	transport of winter capacity via gas grid or power grid gas to power with CCS power for compression	use power grid for local elctrolysis vs H_2 system H_2 grid for H_2 ready turbines	use of cogeneration geothermal avoids power upgrade power supply for large HPs	CO_2 collection for thermal decarbonized power CO_2 free, dispatchable power close to consumption
	gas / gas	**gas / H_2**	**gas / DH**	**gas / CO_2**
	keepiimg national gas grid to transport high capacities (winter peks, season) keep distribution grids as back up convert to H_2	conversion from CH_4 to H_2 local and ? National locatoion of ATRs rededicating ? Differene in capacity H_2 needs ca 4x compression H_2 ready turbines vs. decarb gas power	gas CHP beyond DH reach switch CH_4-H_2 keep gas distribution grid in reserve	gas plusCHP with CO_2 collection instead of H_2 grid plus H_2 turbines
		H_2 / H_2	**H_2 / DH**	**H_2 / CO_2**
		H_2 is manufactured product (green/blue) local vs a national grid load of ATRs central plus storage vs local H_2 stroage only in caverns, only 1/3	H_2 grid beyond DH reach use exhaust heat from electrolysers for DH	location of ATRs at customer or at import
			DH / DH	**DH / CO_2**
			local by neture possibility for heat storage large vs small DH	from CHPs with CCS
				CO_2 / CO_2
				by grid, contested by ships disposal in Norway CO_2 can be pumped (cheaper) in super critical stage

Early actions needed / robustness

In keeping with the CO_2 budget (to avoid costly desasters) there is no credit line by nature => effectivenes first, efficiency second

- Early actions
  - No time for consecutive testing out, paralell building of avenues
  - Target final design, use of upfront economies of scale
  - Secured market for CO_2 free energy supply (due to CPA) => investment into upfront economies of scale is a financing issue
- Robustness
  - Diversification of approaches
  - Use of existing investment (to save time and avoid risks)
  - Keep it regional if possible

Pour ce qui est de l'avenir, il ne s'agit pas de le prévoir, mais de le rendre possible

Antoine de Saint-Exupéry