The use of natural refrigerants in heat pumps;
a way to de-carbonization

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International reporting related to de-carbonization & the operation of heat pumps on natural refrigerants

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refrigerants delivered by mother nature

To start with ....

Several issues and a number of considerations one needs to look at first as an intro for this presentation

On the Symposium Title

Heating and cooling with natural refrigerants; (on) a way to de-carbonization, the 3 items presented are -- in sequence:

1. **Heating and Cooling**
2. **Natural refrigerants**
3. **De-carbonization**

Should the 3 items be prioritized this way, or "in a different order" ?

The Title items priority-listed (differently)

- 1st: De-carbonization (3)
- 2nd: Heating and cooling (1)
- 3rd: Natural refrigerants (2)

How to use NatRefs -- should be an “important part” of the conclusion

Use of NatRefs by themselves is not a direct way to de-carbonize -- !

So, in principle ....

There is one important issue to deal with first :

1. **(Future) available renewable energy supply**

Looking at the "renewables picture" first = VERY important

and that will then have direct connections with

2. **(Future) available and sustainable (efficient) heating & cooling**

   (and the role of natural refrigerants therein)

De-carbonization

- **De-carbonization is normally defined as:**
  "away from using fossil (carbon based) energy sources – emitting CO_2"
  However, the carbon cycle is the essential one in nature,
  also used in renewable energy sources (bio- and synthetic fuels)

- **Is "de-carbonization" the proper definition ?**
  related to "low or zero net CO_2 emissions" (to de-fossilizing), it should be
  "Carbon Neutrality"

(capacity, consumption, emissions in CO_2-eq. are all (often) used in various studies; they are difficult to compare – here only comparisons related to demand - or consumption are given)

For energy demand, the approach to "sufficiency" is important

Several "step-approaches" found in various reports, HERE .. the EPEE (5-step) approach:

(1) Optimize the need for cooling

(2) Improve the energy and resource efficiency of cooling equipment

(3) Mitigate the climate impact of refrigerants

(4) Address the investment cost for higher efficiency solutions

(5) Shift to renewable energy sources

Where (5) can also be the start as step (1) – see next slide

The above includes direct behavioral changes that are, of course, very important

In the list given in the 2019 Economist "The Cooling Imperative" report it says:

"Reduce the need for cooling through passive building design, urban planning, cooling by nature, and behavior change"

For en… … is important

Several … ONE is …

(1) Optim…

(2) Impro…

(3) Mitiga…

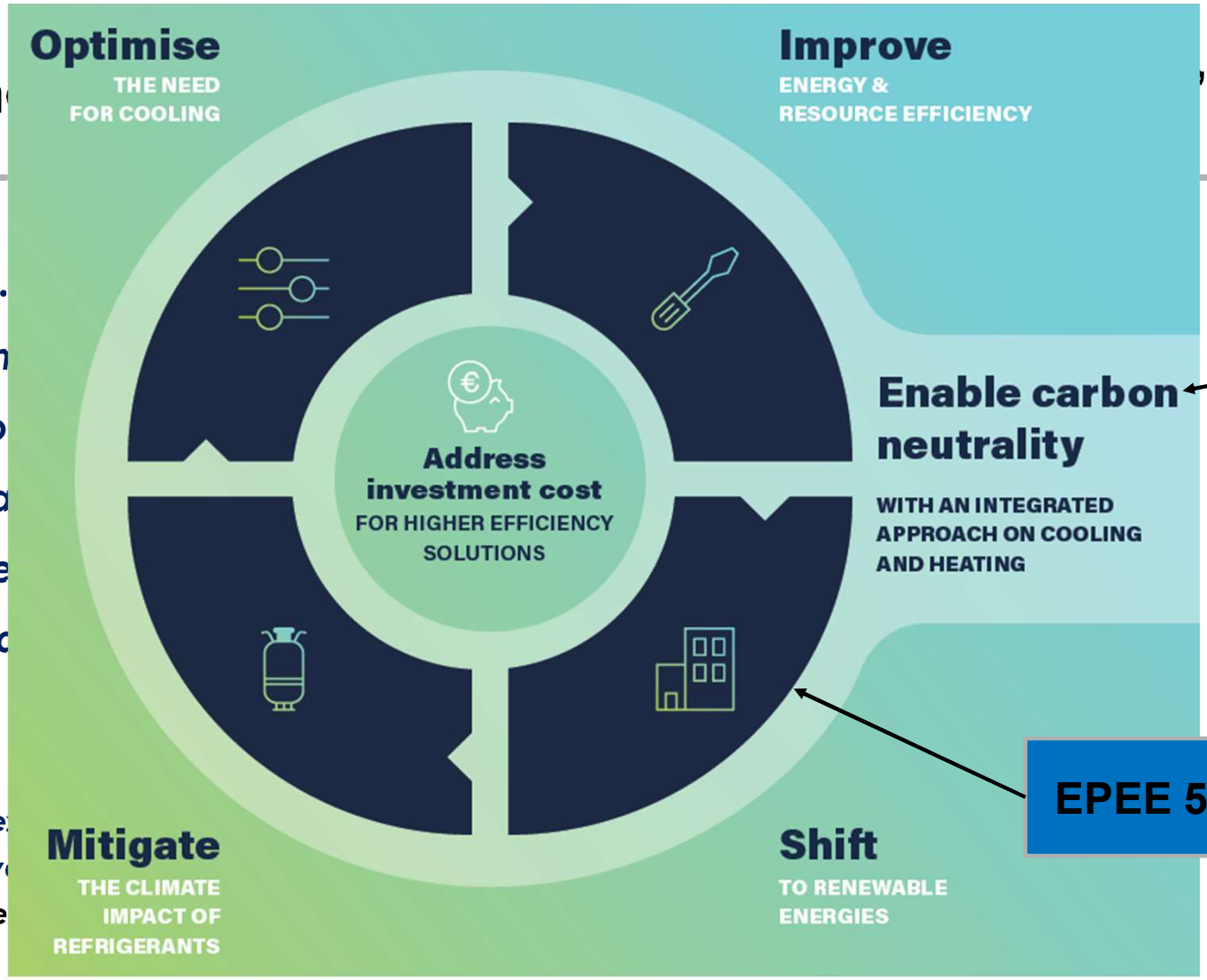
(4) Addre…

(5) Shift to…

The above e…

In the list giv…

"Reduce the…



carbon neutrality !

EPEE 5-step approach

Heating & Cooling

47%

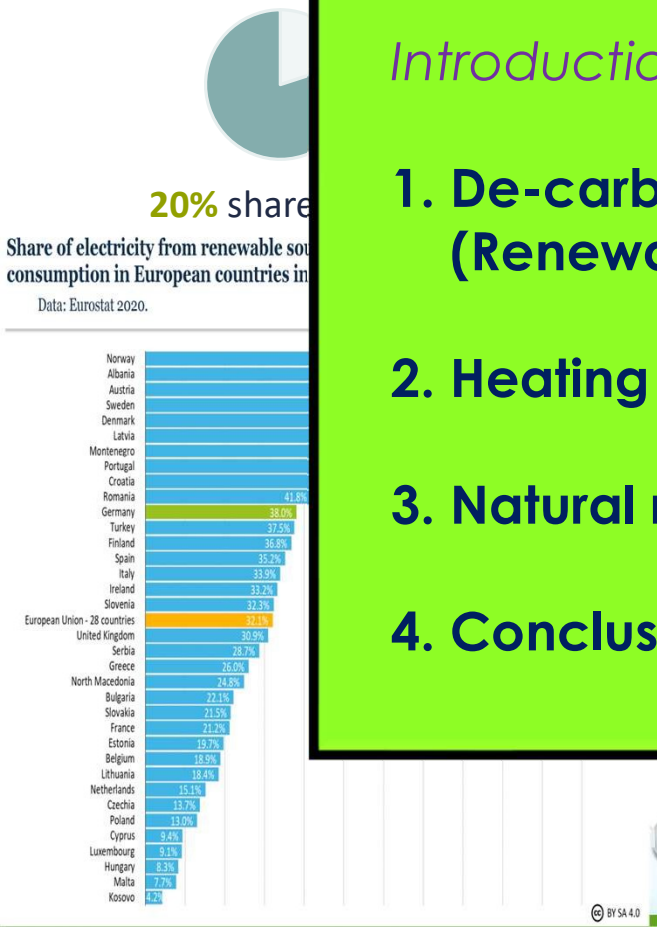
Transport

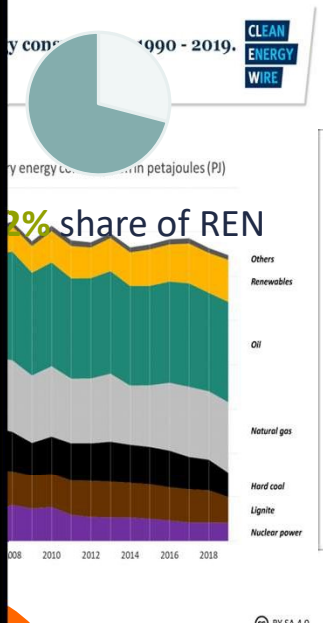
Electricity

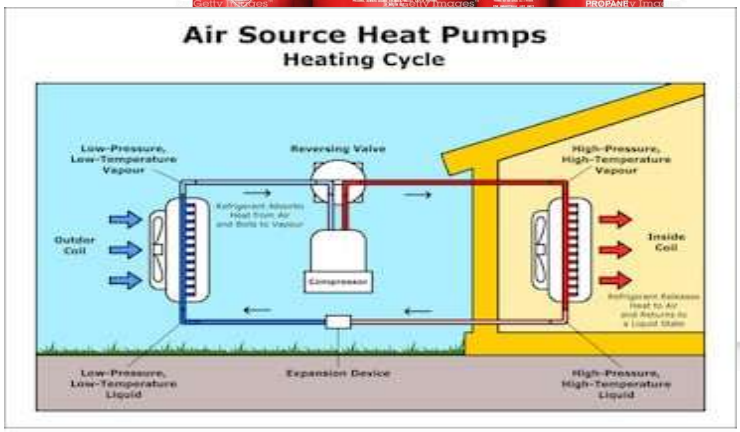
OUTLINE

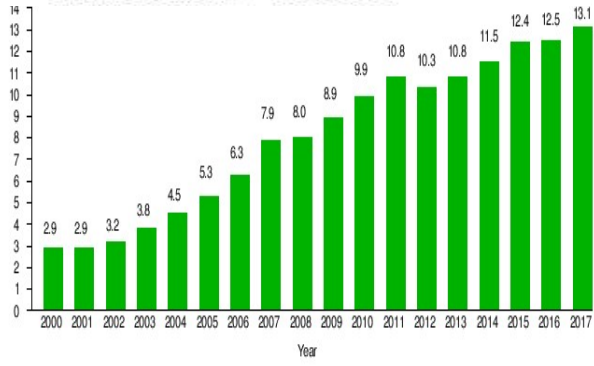
Introduction (done)

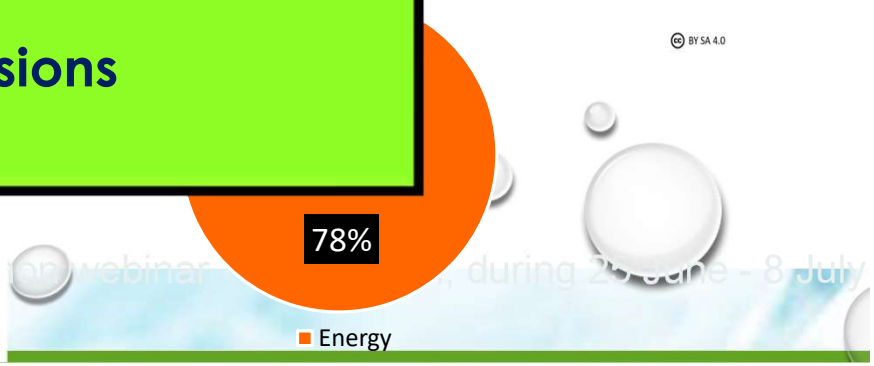
1. **De-carbonization (Renewables)**
2. **Heating and cooling**
3. **Natural refrigerants**
4. **Conclusions**





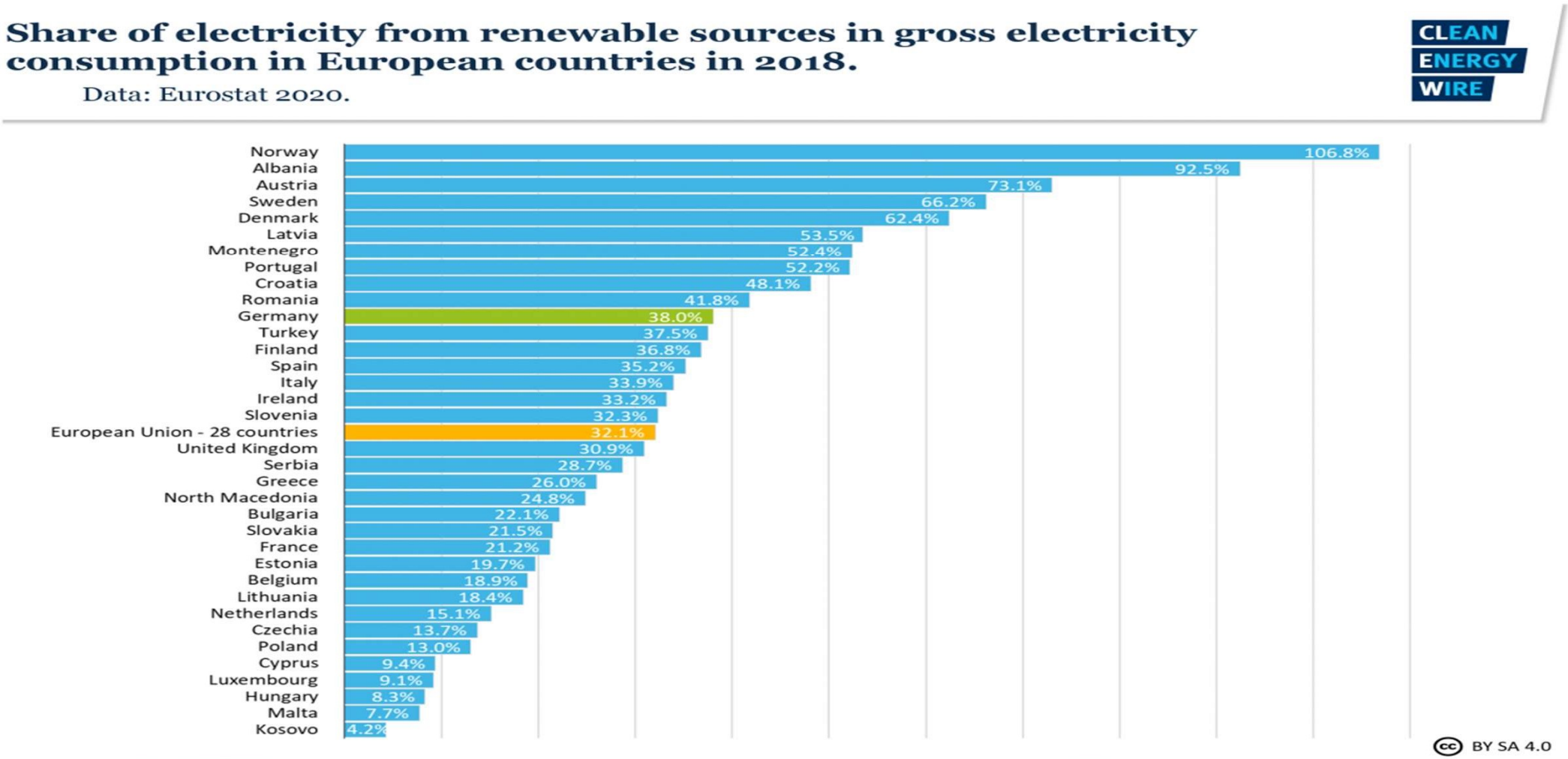






1. De-carbonization (Renewables)

EUROSTAT REPORTED FIGURES (2020 for year 2018)

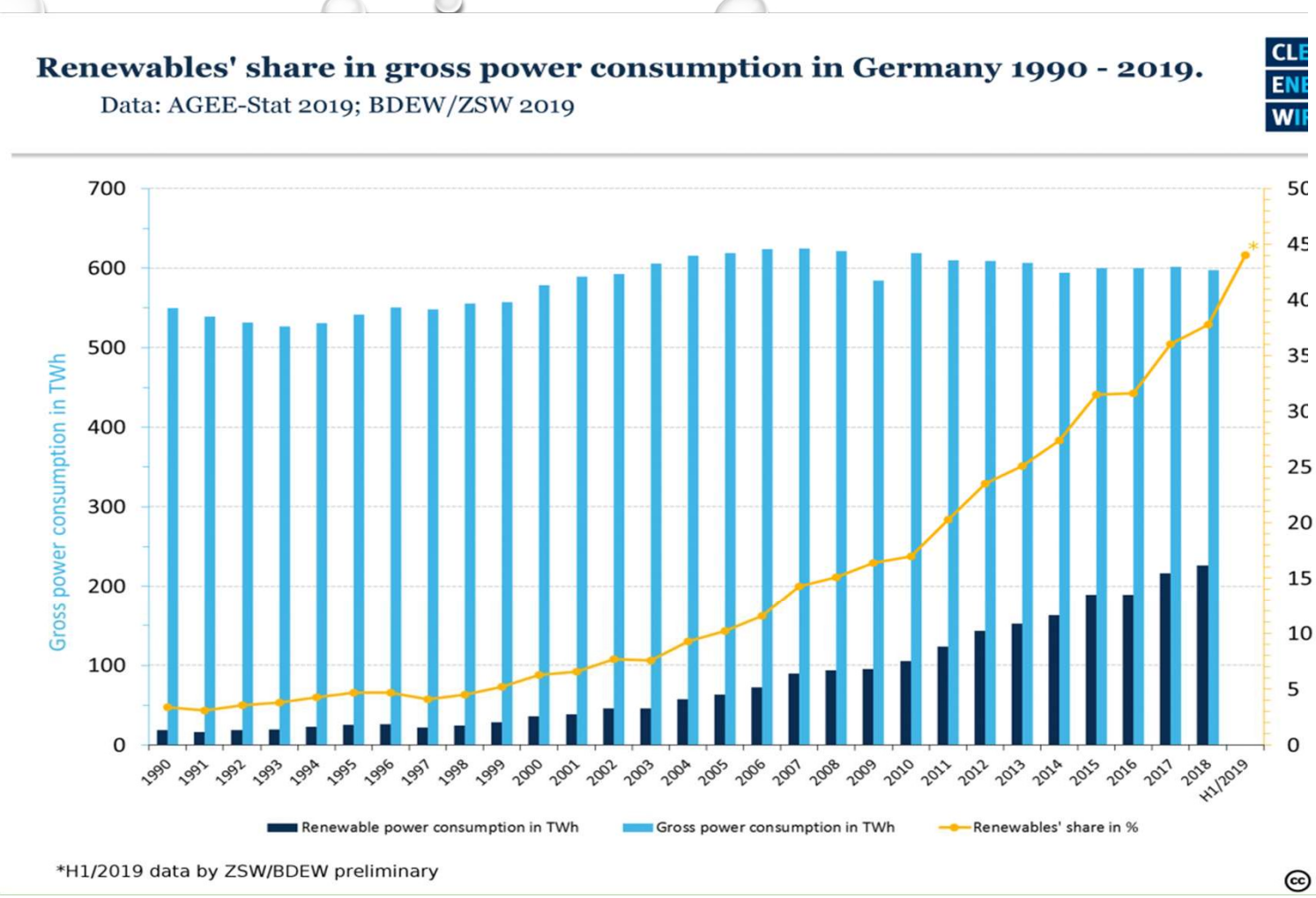


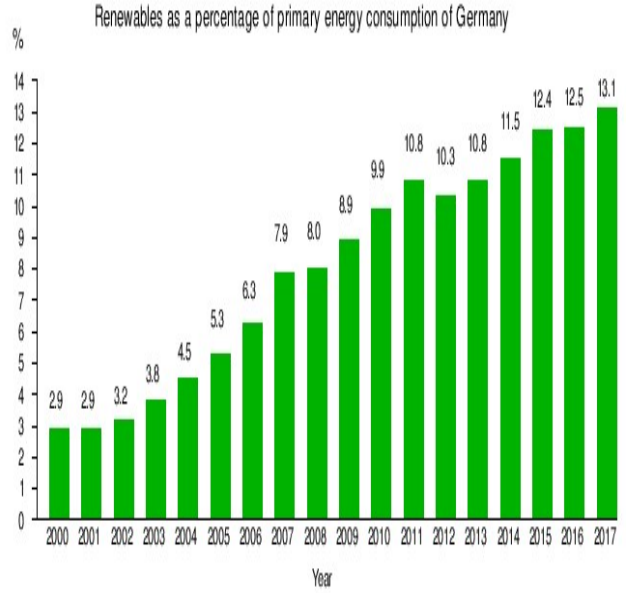
Observations (ELECTRICITY only)

- Enormous difference in %-ages amongst European countries
  - "Hydro and bio-fuel"'- countries show highest percentages
  - 10-15 European countries < "28% renewable" in electricity
    Belgium, Netherlands, Hungary etc., are below 18%
- EU as an average has about 32% -- renewables (electricity production!)

(EU is one of the major regional economies with lowest per capita CO_2 emissions)

Renewables share in Germany 1990-2019





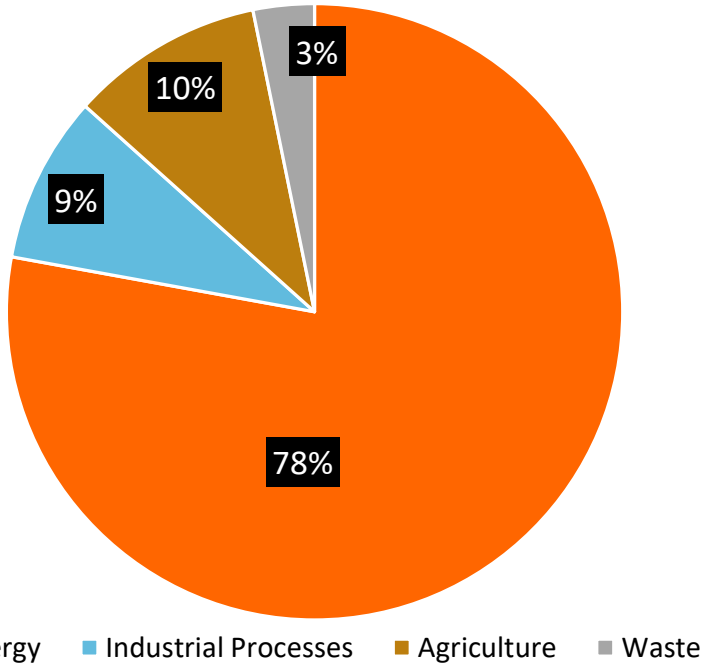
Total renewables

- Talking about the TOTAL of renewables in all sectors and then, how to de-carbonize - with the use of natural refrigerants in heating - is BOTH a special AND a specific issue
- Some further analysis – related to various "energy demands" in sectors

Done by REN 21 (2018 overview); EPEE (Count on Cooling) interpretation is given here

The CHALLENGE again

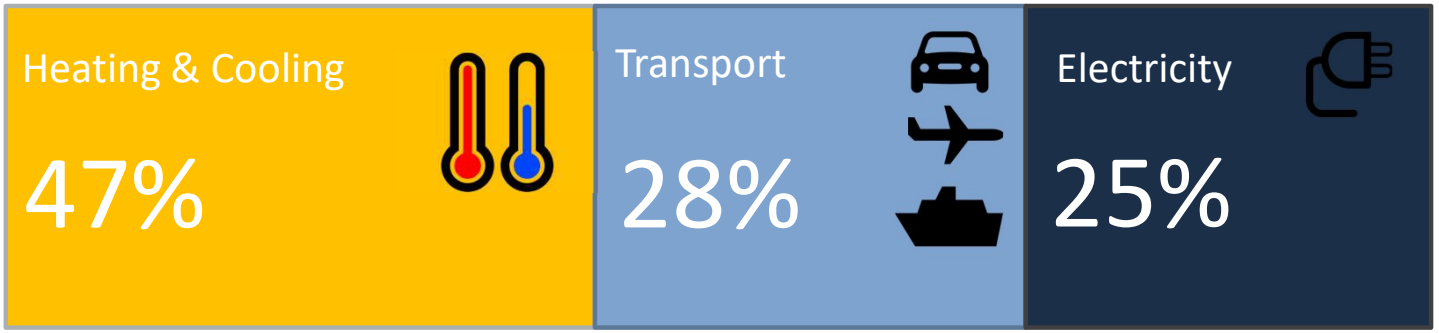
- ➔ **Most EU's GHG emissions related to energy**
- ➔ **For climate neutrality, first priority is addressing energy sources**

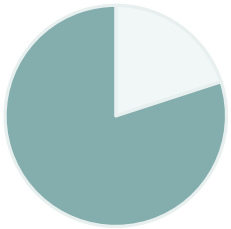


Annual European Union greenhouse gas inventory 1990–2017 and inventory report 2019

Following EPEE's COUNT ON COOLING (March 2020):

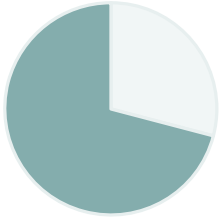
Heating & Cooling = almost half of the EU's final energy consumption *(Eurostat)*





10-20% share of REN

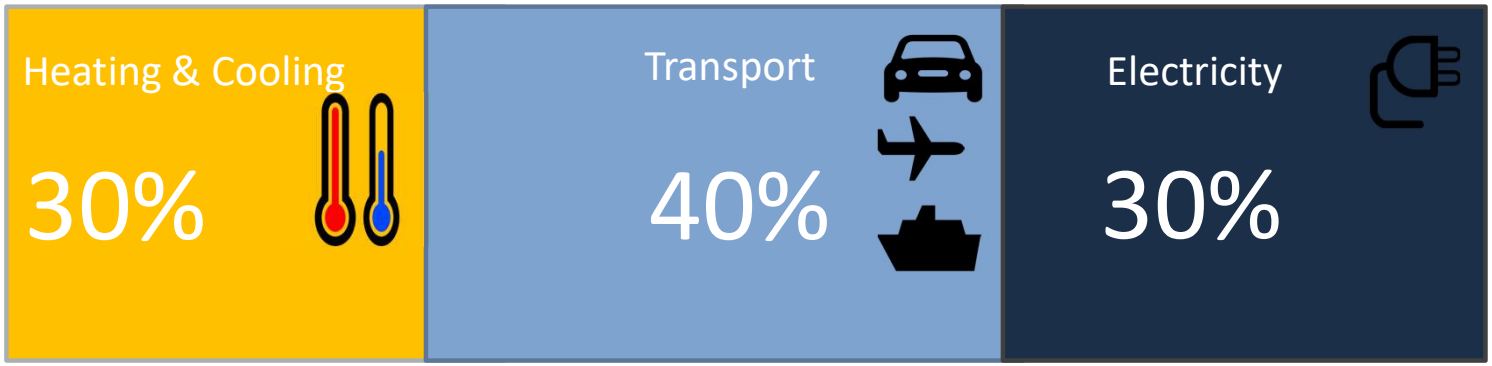
8% share of REN



32% share of REN

Important: ENERGY DEMAND "is not" CO_2 emissions

Background: As to EMISSIONS, the Heating & Cooling sector represents ~30% in the (EU) total, with transport and electricity ~40% and ~30%



Even when two issues (energy demand and emissions from electricity generation) are both important (but different), this presentation only focuses on "demand"

Slide based on EPEE data and CO_2 emissions per sector

All these percentages

- In electricity production (in ~20 EU Member States), 20-35% of the total is NOW renewable
- It is only 5-7% of today's TOTAL energy use/supply (country-dependent)

Also:

- In heating and cooling (at about 15%), and in transport (at about 9%) the use or "consumption" of renewables is still **"small" -** at present

To make the whole energy supply renewable … is MORE than a (HUGE) undertaking

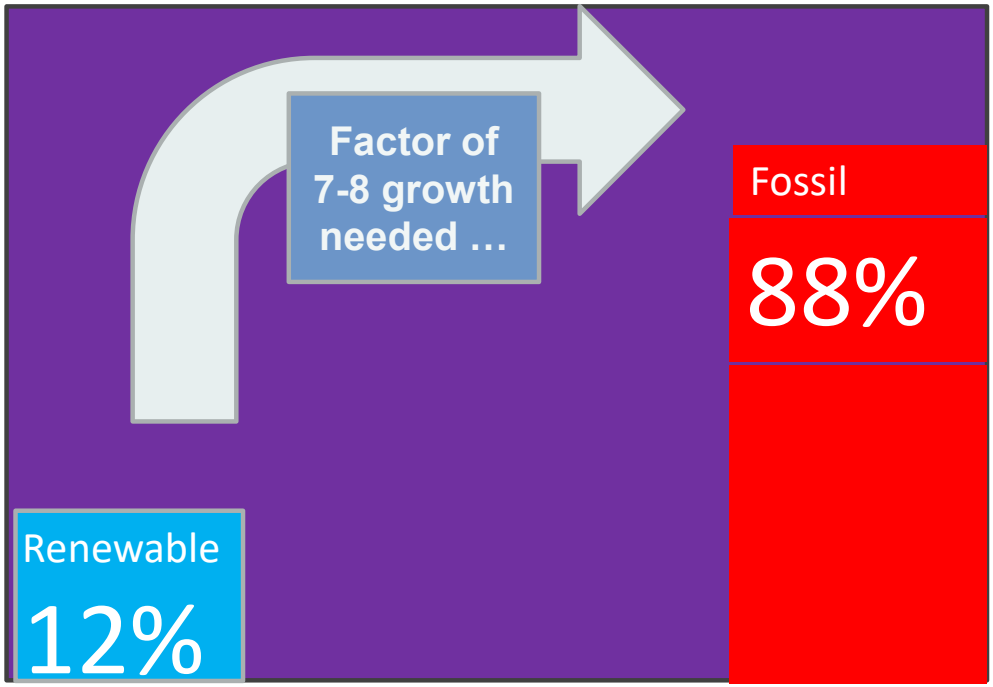
(not looking at price "structures" that are rapidly changing)

So, if one wants to (totally) de-carbonize demand

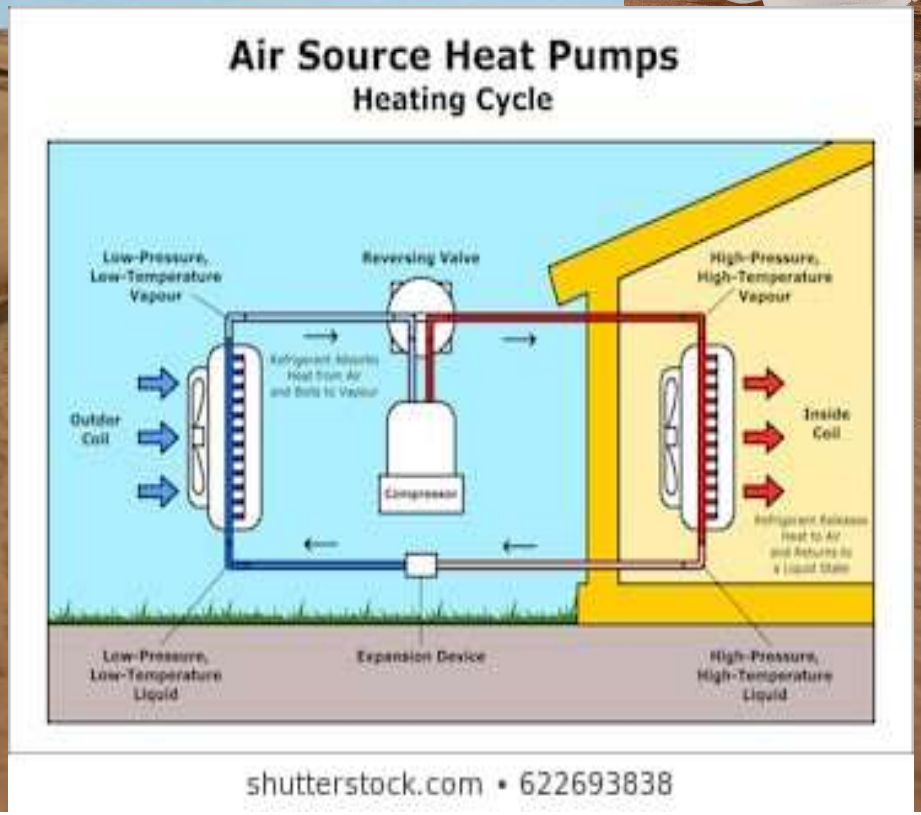
For a (virtual) TOTAL de-carbonization,

it means that the TOTAL of about 12% of renewable energy, used "over" all sectors at present, has to INCREASE by 7-8 times this amount, to achieve the "virtually total of 100%"

This is demanding, is it also feasible in the time-scales used?



2. Heating and Cooling



For heating (and cooling)

- If a very-very large energy demand in future has to be covered by renewable capacity still to be installed (as e.g., for heating and cooling, transport) …
- there will be a major issue WHERE the NEW supply – coming from expansion of renewable electricity capacity – is gradually going to go over the next 20 years,
  to transport and/or to heating (and cooling) or to electricity supply ??
- Who decides? It's part of the **complexities** of the de-carbonization !

To make an interim score

- **Europe is now "ahead" in renewable production, however**
  - **There are huge challenges (is one ready for this massive "renewable" electrification ?)**
  - **One should continue to explore all solutions, with electrification being an important one (next to hydrogen, synthetic fuels using the carbon cycle etc.)**
  - **Energy efficiency on its own is NO "extra" source, as often "pretended"**
  - **Would the issue not be more in line with "using energy efficiently, optimizing all factors to come to a much lower (total - FOS & REN) energy demand ?"**

To make an interim score (for heating and cooling) (2)

- In heating and cooling the use of renewables and the change to renewably driven operations is complicated, due to
  - Consumer attractiveness overall
  - Investments for new installations (in new & existing buildings)
  - The operating cost issue related to cost differences between electricity from fossil fuels, from other sources and from renewable electricity which all vary so much (time scale, countries, type of buildings)

Costs of fossil and renewable energy cannot be used as a real argument here, given all economic and technical recent developments

Can a "consumer" be convinced to choose for (large) investments for a heat pump, compared to money for a (nice) electric car ?, i.e., to invest in the "core business" ?

3. Natural Refrigerants

So, now the issue of using natural refrigerants …

- Once there is more concrete "societal or policy guidance" on the de-carbonization issue, including behavioral changes in the use of heating/cooling – making a (price-based) attractive choice, the question is:
- **Natural Refrigerants**, do they provide "a better" means to operate – at "higher efficiency" than others ? Is their equipment more attractive ?

- Any good heat pump will (have to) have capacity control and control of operation of auxiliaries
- Any good heat pump will have to have a strategy over the season to perform best, it may also have storage, sophisticated control
- What can one do with heat pumps on natural refrigerants to give them a real opportunity here ??

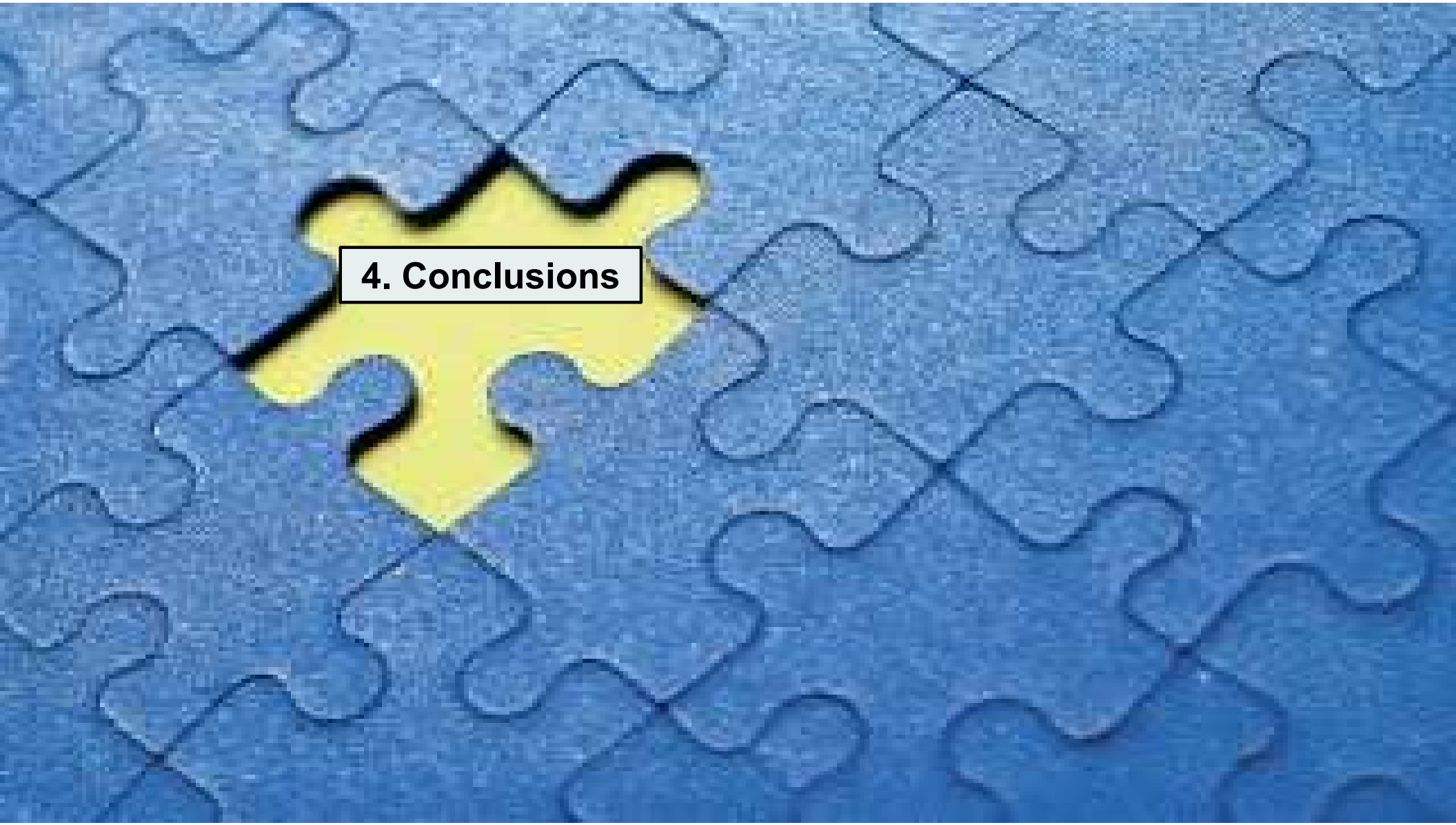
Performances of heat pumps (1)

A lot of international scientific and technical contributions have been screened on heat pumps based on natural refrigerants and their possible advantages

- HC-290 (often ground water based) is a major candidate, with an "average" of 5-15% efficiency advantage over synthetics; propene and iso-butane (HC-1270, HC-600a) might even be slightly better
- Many HFCs are applied (even HFOs are applied or developed). Heat pumps for heating (domestic, commercial concepts) are already on HFC-32. Smaller heat pumps for heating announced on R-454C
- Hot water heating using CO_2 has a good performance for high temperatures; many studies for heat pumps for heating on CO_2 being published. It is a difficult issue – where it concerns efficiency vs. costs

Performances of heat pumps (2)

- UNEP TEAP (RTOC reports, 2014-2019): HFCs and blends will be applied, some HFOs, HFC-HFO mixtures proposed, generally hydrocarbons seen as most viable solutions; R-744 considered as possible, but challenging
- IIR – ICR Congress Montreal (2019): about 100 papers in E2 commission on heat pumps; not much emphasis on refrigerant options, more emphasis on system configurations, optimizations, high temp heat pumps
- Int. Heat Pump Conference (2017); 182 papers, 10 on a variety of working fluid issues (virtually none on natural refrigerants)
- In summary, so far nothing "ground-breaking" ! So .....


4. Conclusions

Conclusion (1)

- The extent to which the supply (of all sorts) of renewable energy can grow in future is uncertain, even with current (political) targets
- How will the "de-carbonization of supply" be achieved simultaneously in the 3 main sectors, i.e., which priorities set by whom – when ?
- A MAJOR issue will be to connect the possible increase of the renewable energy capacity to increasing use of renewables in the heating and cooling sector
- Is there certainty (technical basis) that heating (and cooling) on natural refrigerants will get a "certain" priority (e.g., efficiency-wise) ?

Conclusion (2)

- The application of natural refrigerants in heat pumps needs to FURTHER show "general" significant advantages compared to other substances (i.e., efficiency, life cycle, etc., most importantly = costs for consumers)
- If so, natural refrigerants may position themselves in such a way that they can fulfill significant contributions to de-carbonizing heating and cooling
- Natural refrigerants will be attractive when, next to a lot of costs/reliability/ efficiency arguments, they will have "THE IMAGE" for policy/energy suppliers/consumers to do the job better than others !

The final - summary one !

Now the last four summarizing bullets with an emphasis on renewables and natural refrigerants
and
then we're done

It would mean that

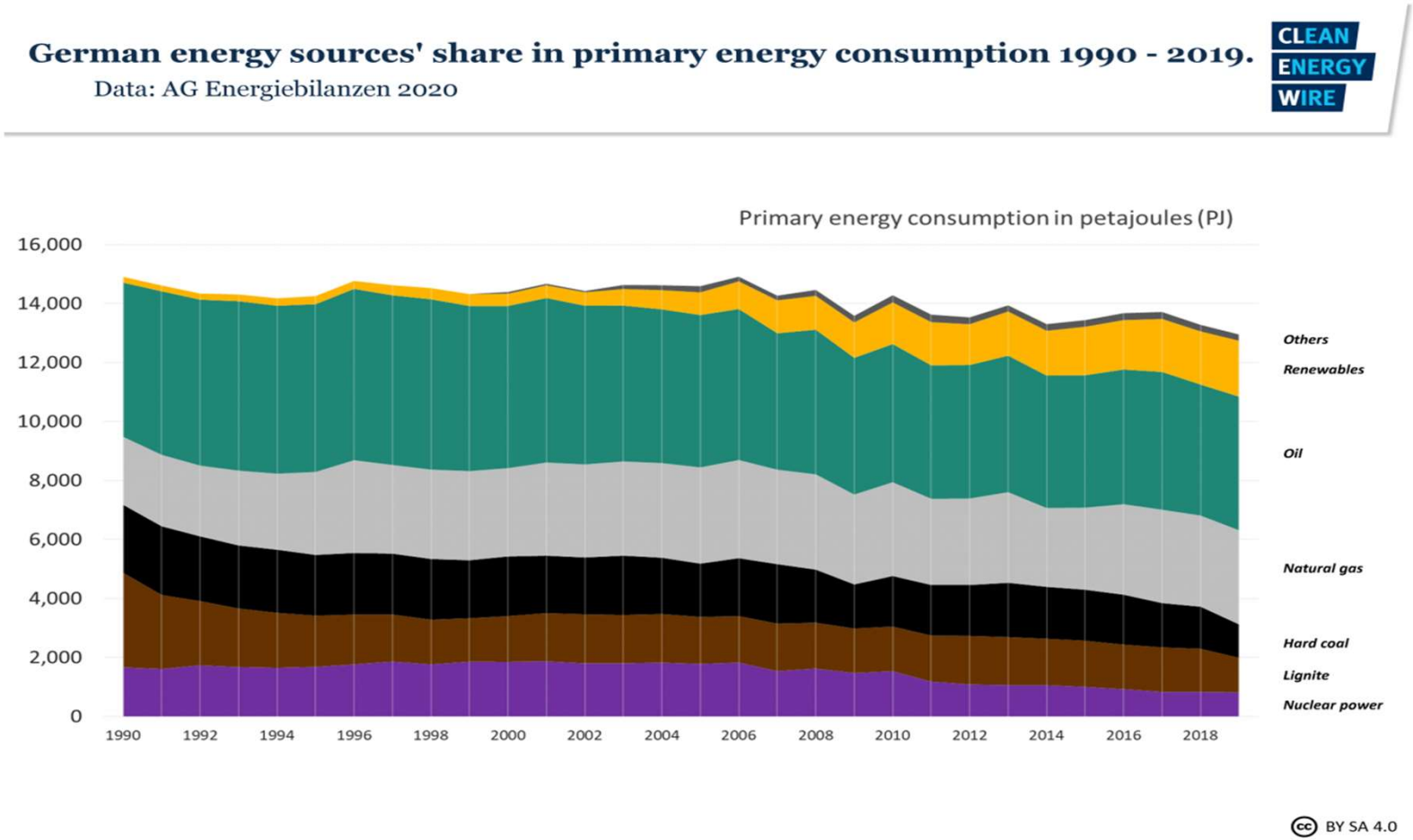
1. **Input of renewables for future de-carbonization in the relevant sectors … is an overarching & important issue (!) – and will remain so.**
2. **Installing a sustainable heating sector with efficient HPs together with supply of (electricity based) renewables should actually be priority nr. 1.**
   In how far price and consumer attitudes will determine is to be seen.
3. **Highest efficiency is very important for all operations, to reduce (renewable) demand. Natural refrigerants must present an easy way forward here!**
4. **The future will be a sectoral-competitive "renewable energy use landscape". Natural refrigerant based heat pumps have to position "their positive aspects" in that picture - in whatever way - as soon as possible!**

While developments continue

Thank you !!

Back up slides

Example: German energy demand; “renewable“ devlopment



“FOSSILS” ’ FIVE-YEAR SPENDING PLAN SHOWS $17.5B FOR RENEWABLES, AND $166B FOR NEW OIL AND GAS

Example: Renewable energy targets in Germany 2020-2050

Renewable energy targets Germany (with actual figures for 2015)					
Target year	2015	2020	2030	2040	2050
Share of gross final energy consumption	14.9%	18%	30%	45%	60%
Share of gross electricity consumption	31.6%	>35%	>50%	>65%	>80%
Share of heat consumption	13.2%	14%	N/A	N/A	N/A
Share in transport sector	5.2%	10%	N/A	N/A	N/A

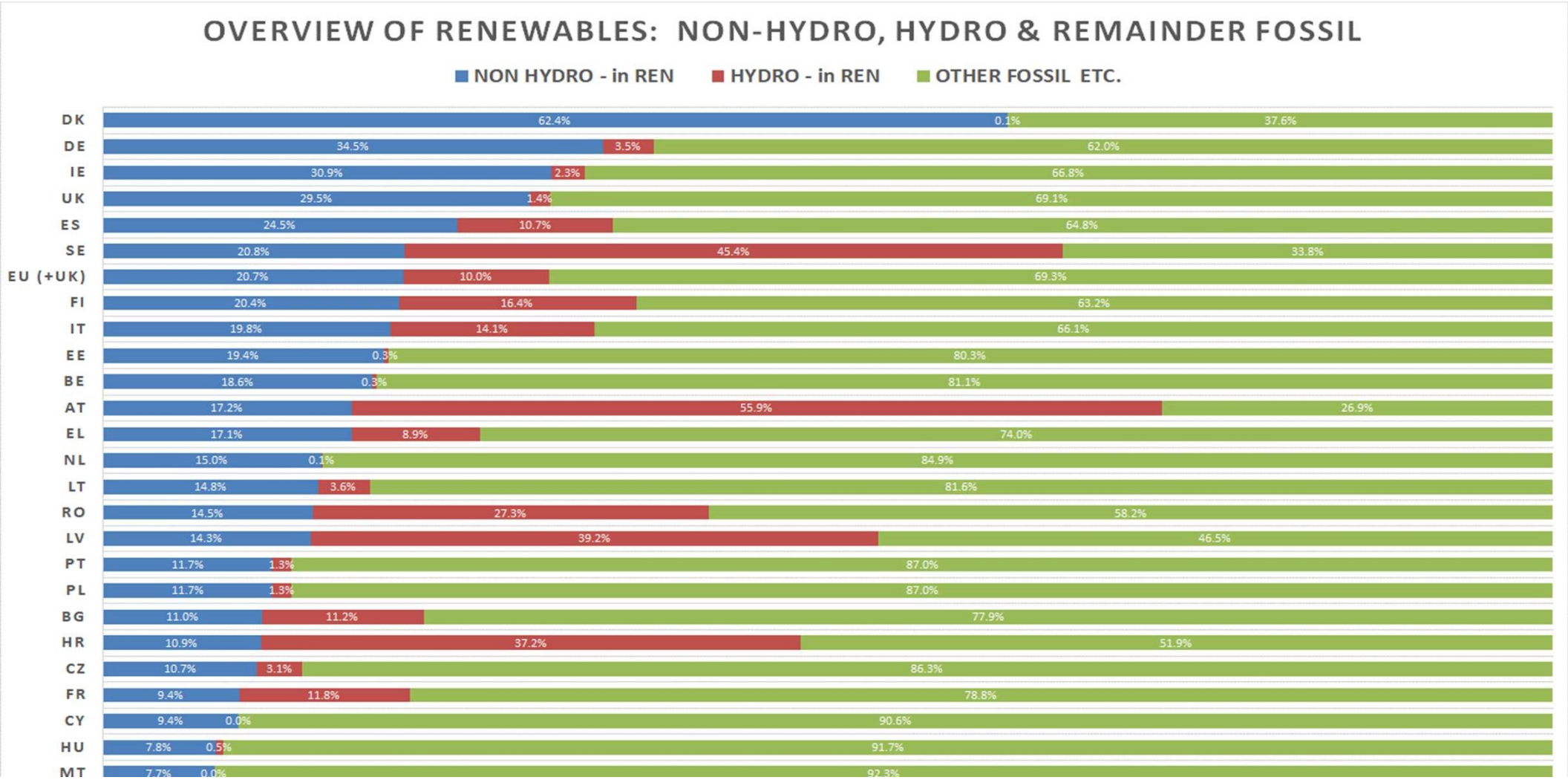
As of 2017, renewable sources account for 38% of the net electricity production. Compared to the same period of 2016, energy production from renewable energy sources increased from 182 TWh to 210 TWh. It marks the first year where solar and wind are the biggest source of energy. Power production from nuclear power plants decreased by 10%, due to maintenance. Use of hard coal decreased by 16%

Share of renewables

- Slide 11 shows the %age use of renewables per EU country – and for the EU
- It includes hydro, wind, solar, biogas, geothermal etc. (no nuclear)
- If the electricity from renewable sources has to be increased, it would be better to not include the hydro component (since it can be assumed that it would not be possible to significantly increase this one)
- So, growth has to be realized by growing the non-hydro component
- Where the average EU renewable percentage is about 30%, the percentage without hydro is about 20%

See for the various country percentages the bars in the next slide

EUROSTAT REPORTED FIGURES (2020 for year 2018)



Performances of heat pumps – one example - announcement

Manufacturers are increasing development efforts towards the introduction of new, more energy efficient versions of heat pumps – one example (e.g., Viesmann) is said to be able to deliver heating and cooling "simultaneously". What the published "combined COP" of up to 10 would mean in a "heating mode" remains an issue to be "looked further into" (..)

eurammon is always available as a sparring partner !
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Eurostat 2020
shutterstock.com, gettys images (internet)
Wikipedia (on renewable energy in Germany)

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refrigerants delivered by mother nature