



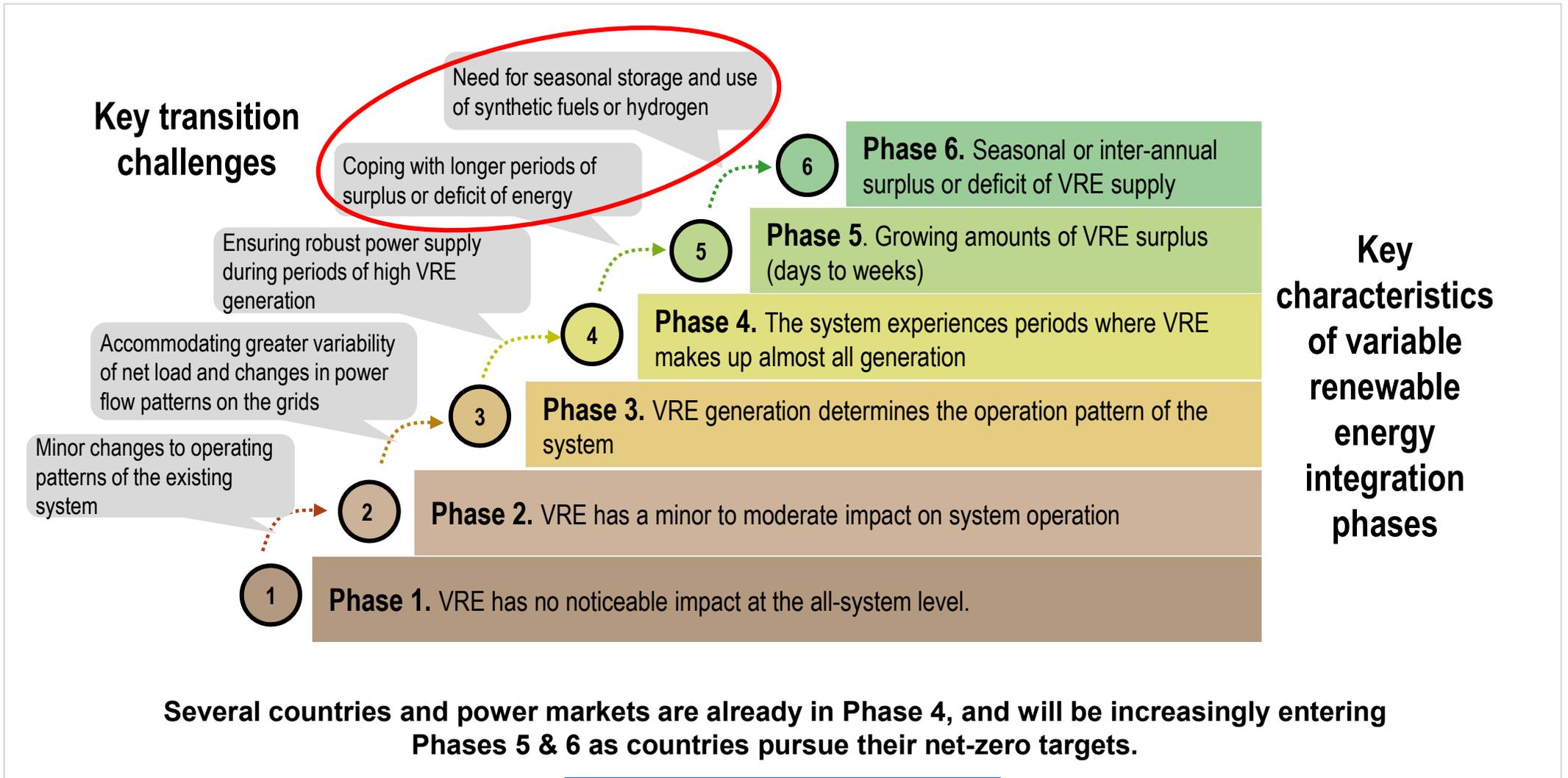
# **Role of low-emissions fuels in managing seasonal variability of renewables**

Dr Paolo Frankl, Head Renewable Energy Division

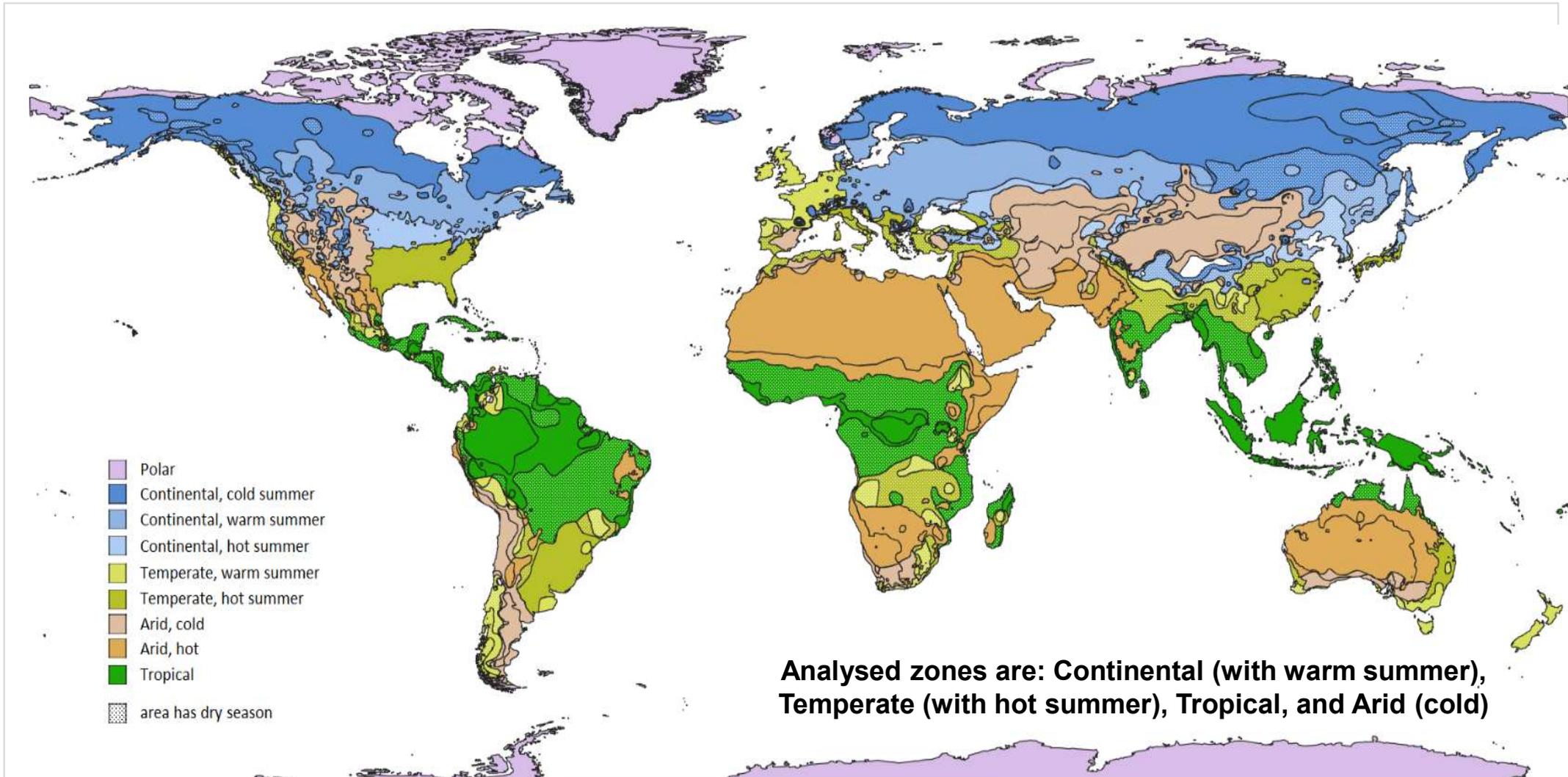
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- 2021 study on the Role of low-carbon fuels in power systems:
  - Low-emissions hydrogen and ammonia can play an important role to help ensure electricity security in clean energy transitions.
  - They have important potential in regions where the thermal fleet is young, or the availability of other low-emissions dispatchable resources is constrained.
  - The value of hydrogen and ammonia depends on system contexts and regional conditions.
- Research questions for the ongoing work:
  - What kind of seasonal variation can be expected at very high shares of renewables?
  - How does seasonal variation depend on different climatic conditions?
  - What is the potential role of low-emissions fuels in managing seasonal variation?

# Six phases of renewables integration



# Current analysis focuses on four key climatic zones



# Seasonal patterns emerge from the interaction of demand and renewables supply

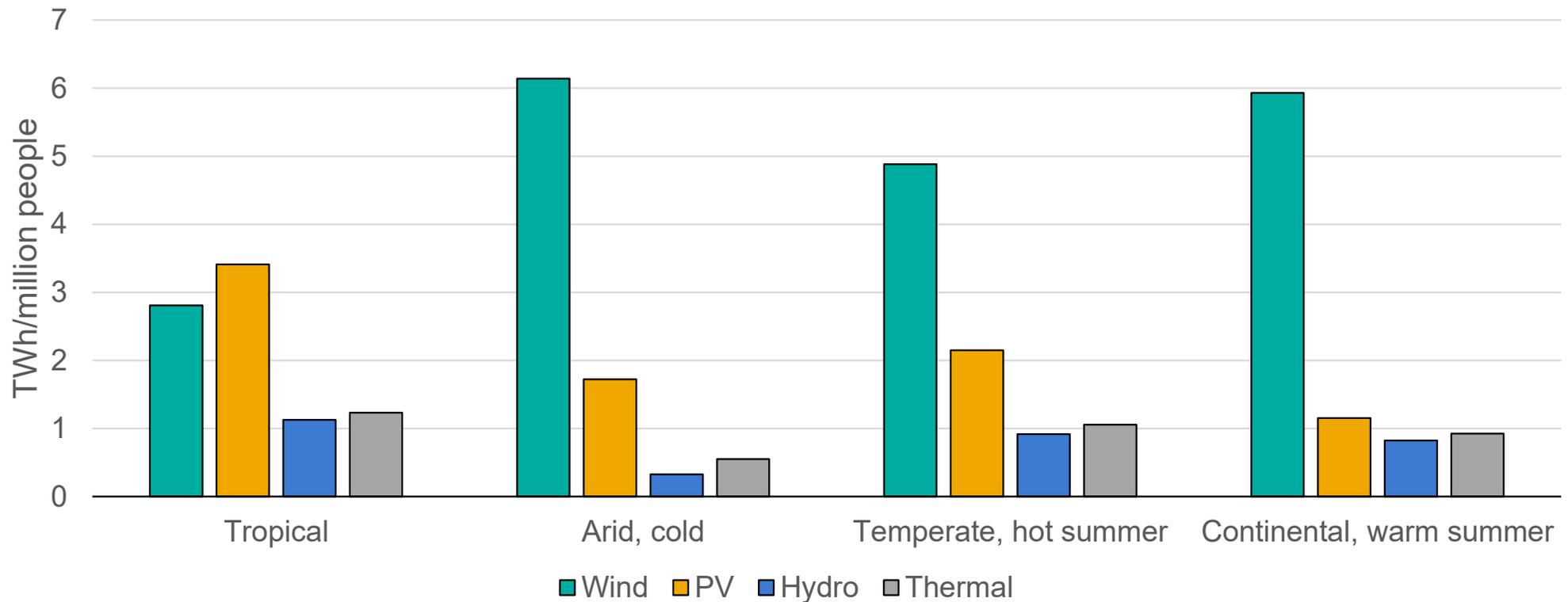
Key seasonal attributes of analysed climate zones.

	Seasonal demand profile	Size of peak load	Hydro availability	Seasonal wind & PV complementarity
Tropical				
Arid, cold				
Continental, warm summer				
Temperate, hot summer				

**Challenges to integrate renewables over long time periods increase with strong mismatches between energy demand and renewables supply on a seasonal scale.**

# Climate conditions influence the electricity mix

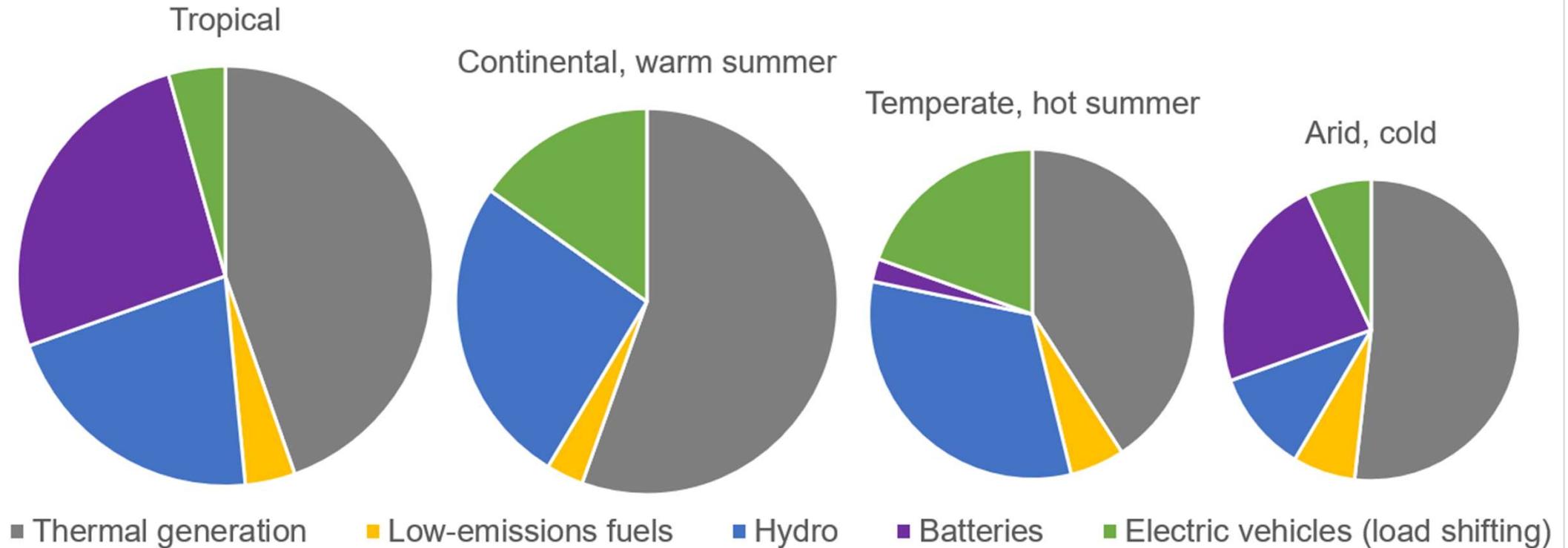
Breakdown of annual domestic electricity generation for the analysed climate zones.



**Technologies remain the same, but climatic and energy system conditions govern their contribution. In the results, VRE share is 70-80% with legacy thermal fleets representing 5-15% of annual generation.**

# Thermal plants are an important source of flexibility in high VRE systems

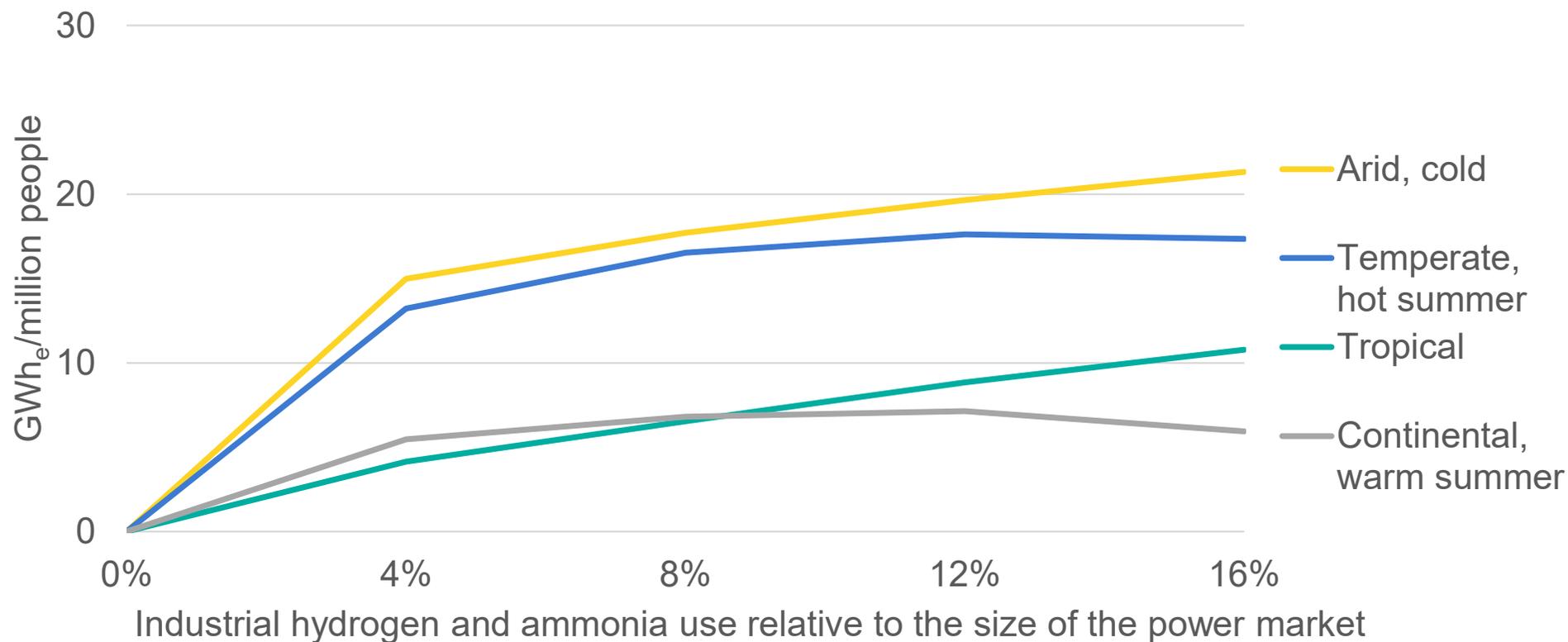
Main technologies responsible for supplying annual electricity storages in the analysed climate zones.



**VRE share 70-80% of annual generation with legacy fossil-fired plants and fossil fuel supply chains. Despite high share of thermal generation, the potential to use low-emissions fuels produced from domestic resources remains limited due to high cost.**

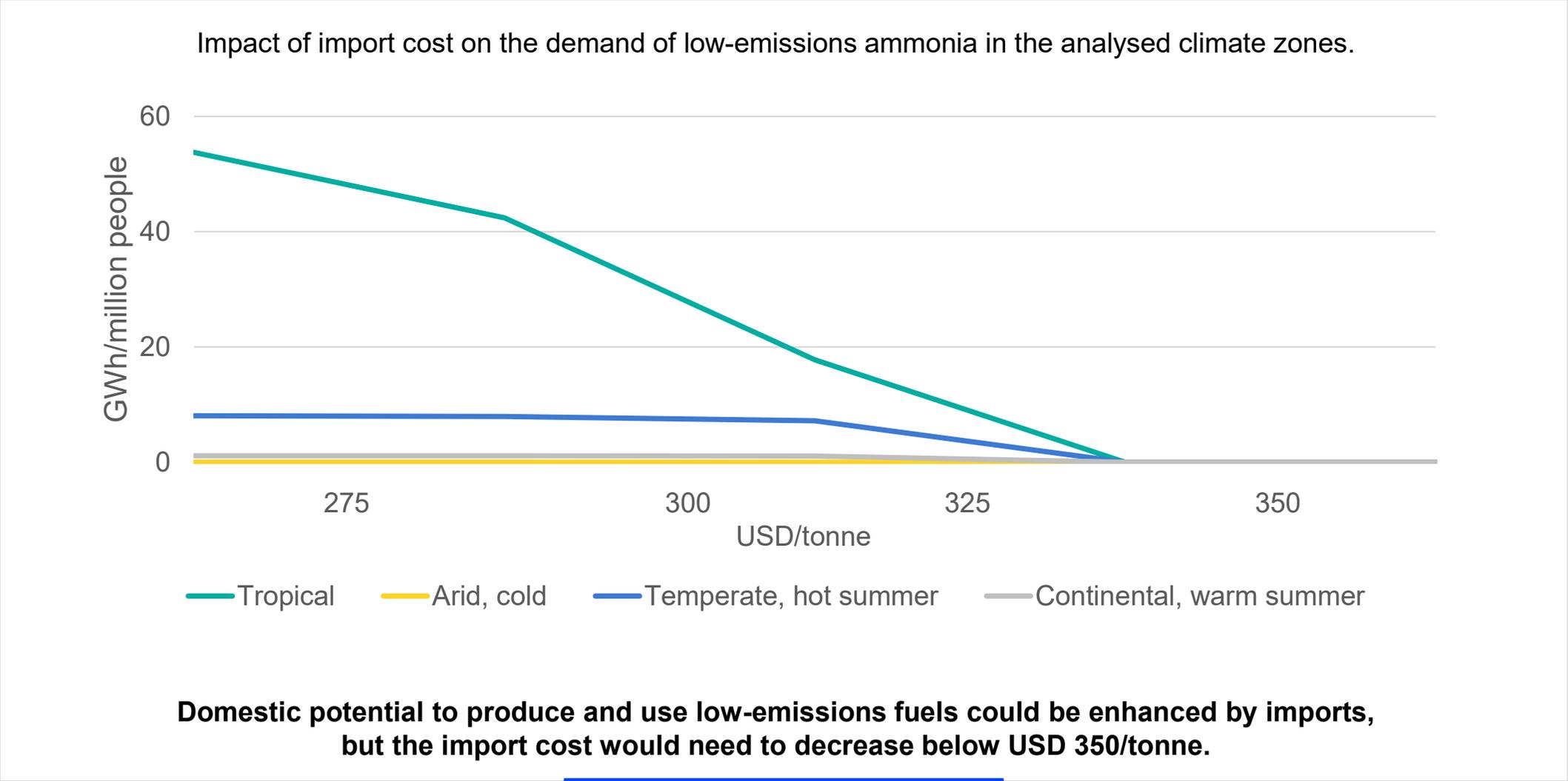
# Industrial use of low-emissions fuels reduces the cost of co-firing

Impact of industrial hydrogen and ammonia use on co-firing in thermal power plants based on domestic renewable resources.



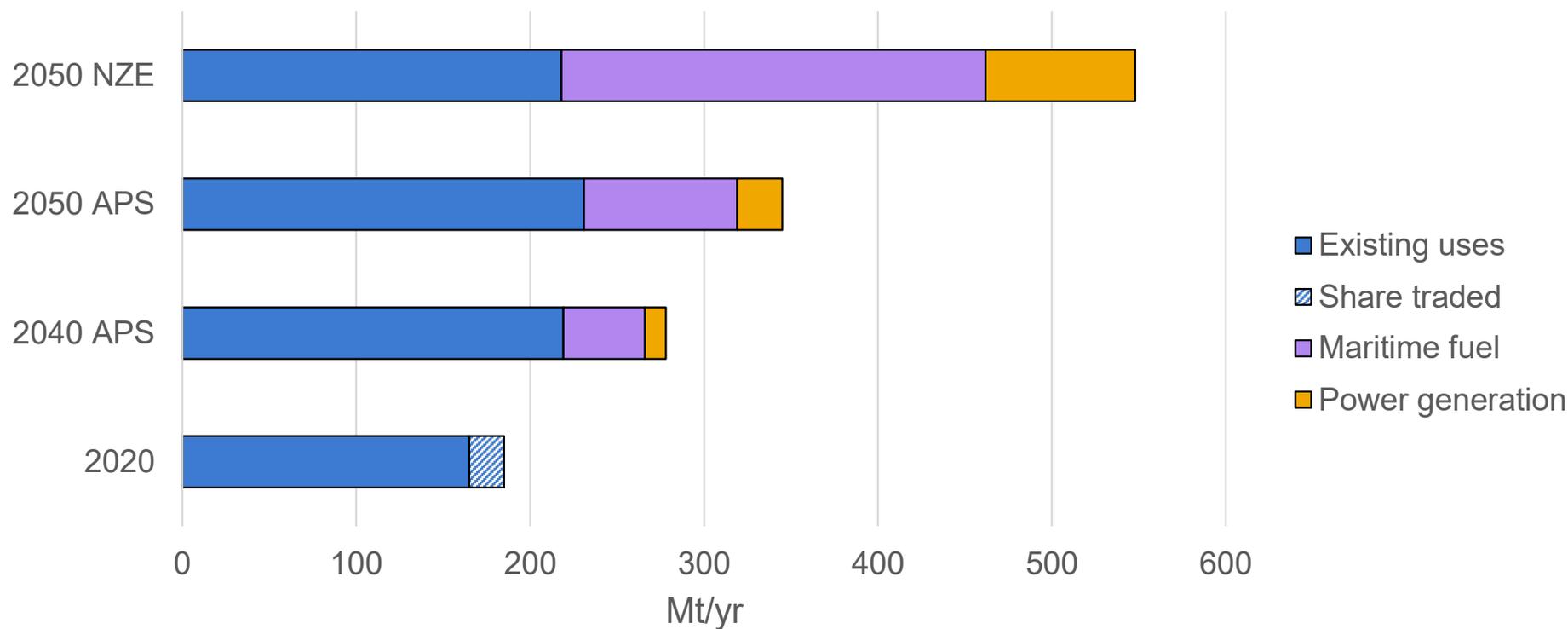
**Industrial use of hydrogen and ammonia stimulates investments in the associated supply chain infrastructure, which will lower the cost of low-emission fuels for other uses.**

# Ammonia supply costs must decrease further to enable international trade



# Role of fuel ammonia increases when approaching net-zero energy system

Ammonia demand by sector in selected IEA scenarios.



**In the NZE scenario, electricity generation from ammonia climbs to 200 TWh/yr by 2050. This compares with 86 Mt/yr of ammonia use in coal power stations, over four times current global ammonia trade.**

# Conclusions

- At increasingly high shares of wind and solar, long-duration surpluses and deficits become a key challenge of renewables integration, which are largely covered by flexibility from thermal power plants (45-60%).
- Low-emissions fuels remain expensive for electricity generation, but are a potential source of low-emissions flexibility. Their value depends on climatic and system contexts.
- Sharing infrastructure investments with industrial users helps to reduce total costs, and helps to create new value chains for the power market.
- At import prices below USD 350/tonne international ammonia trade can connect regions that have low-cost renewable resources with regions where low-emissions fuels have high value.
- To meet the rising demand for low-emissions ammonia towards net-zero, global supply chains need to grow over four times by 2050 for co-firing purposes alone.