



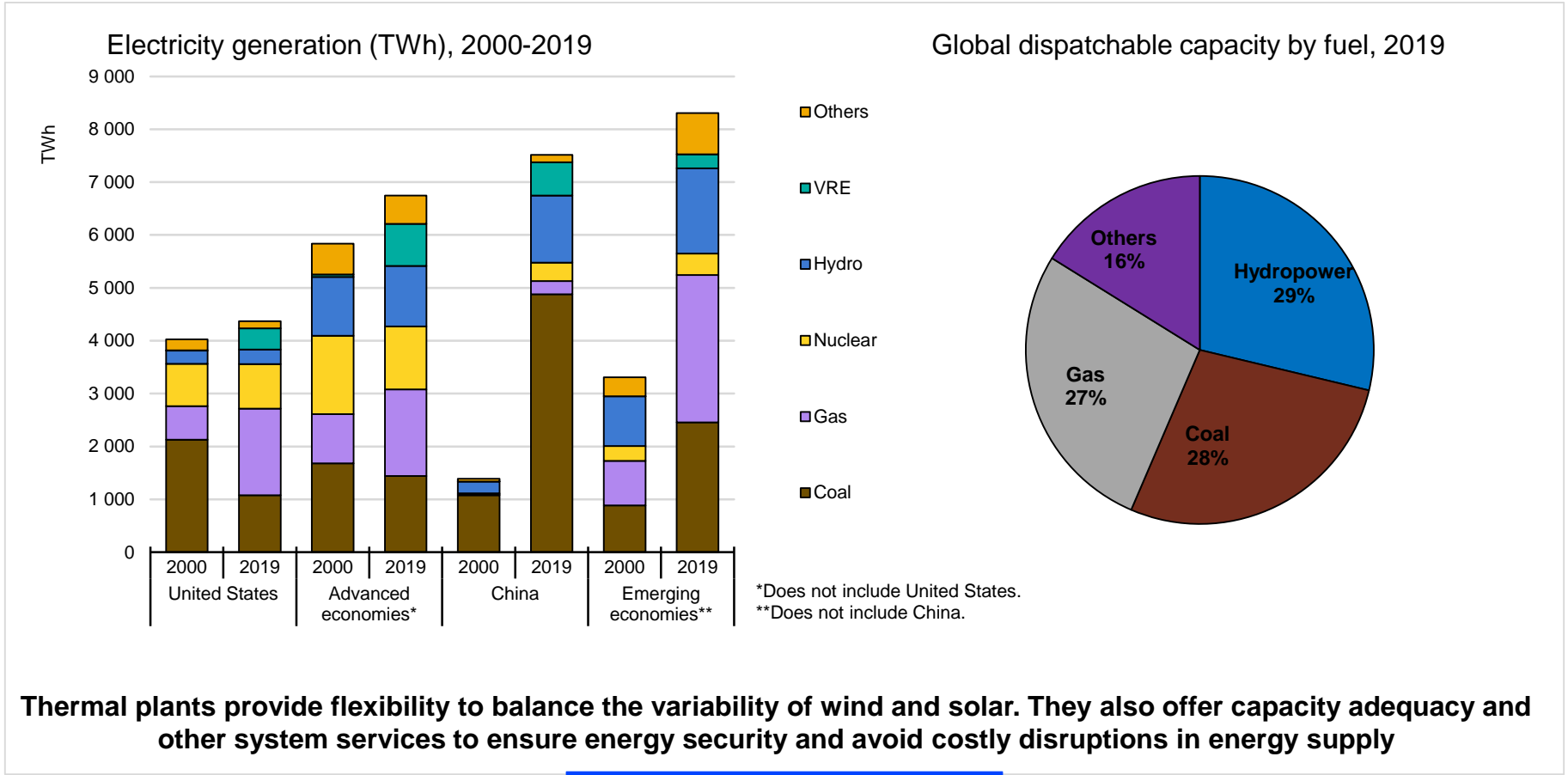
The Role of Low-Carbon Fuels in Clean Energy Transitions of the Power Sector

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- Governments around the world are faced with the challenge of ensuring electricity security and meeting growing electricity uses while simultaneously cutting emissions.
- Massive deployment of solar PV and wind is rapidly transforming power systems. Their variable nature requires more flexible resources in order to maintain a secure system operation.
- Deep power sector decarbonisation requires a significant expansion of all flexible resources, including low-carbon dispatchable power plants, energy storage, demand response & grids.
- Thermal generation from fossil fuels currently provides key flexibility services that contribute to security of electricity supply.
- Using low-carbon hydrogen and ammonia in fossil fuel power plants is an additional tool for decarbonising the power sector, while simultaneously maintaining flexibility services of existing fleets.

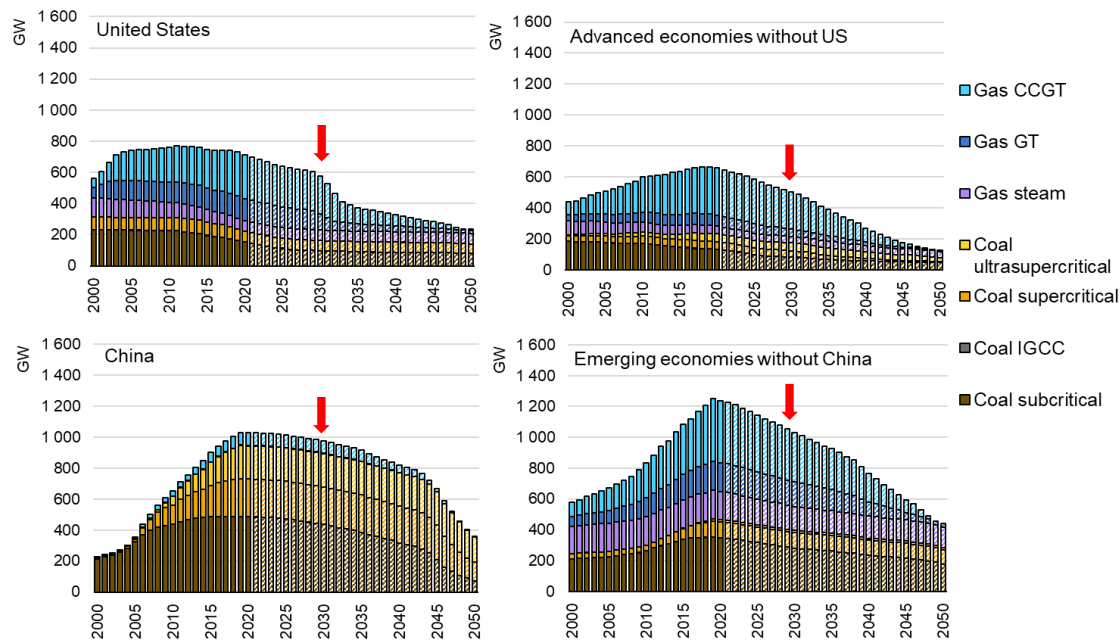
Thermal generation is the main provider of flexibility services today



Thermal plants provide flexibility to balance the variability of wind and solar. They also offer capacity adequacy and other system services to ensure energy security and avoid costly disruptions in energy supply

Fossil fleets have technical lifetimes that extend well into the future

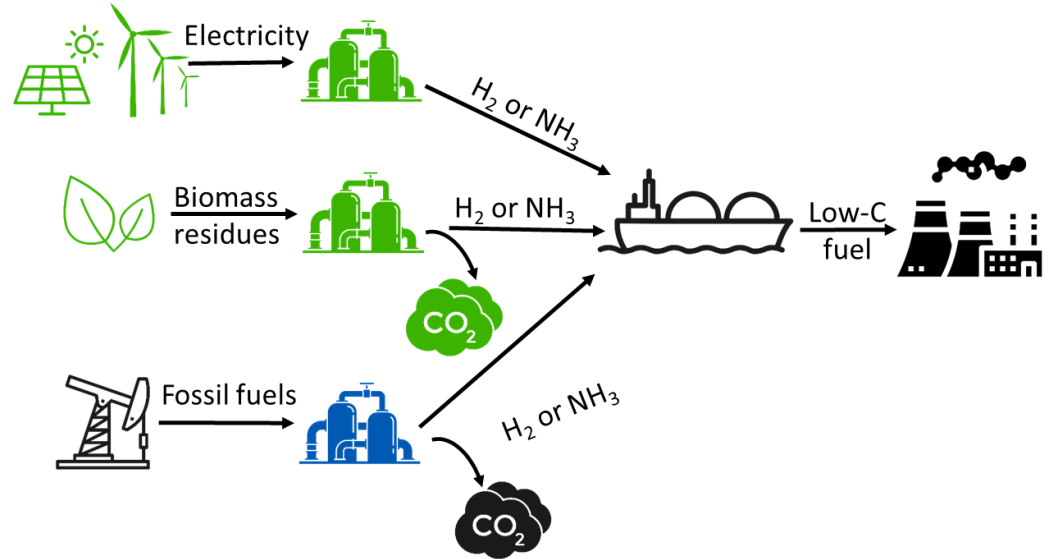
Cumulative capacity by 2019 and expected retirement of the existing fleet by 2050 based on technical lifetime (GW)



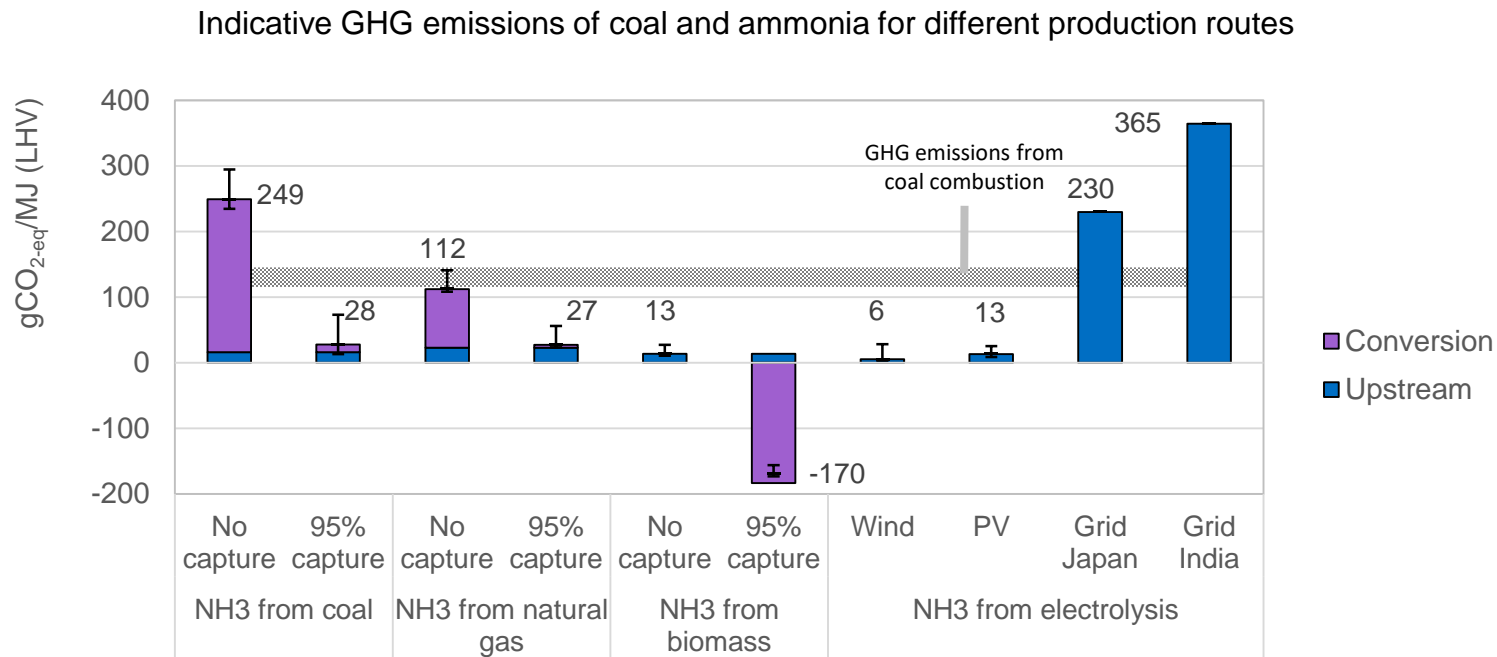
Fossil fuel based generation was responsible for 13.7 Gt of CO₂ emissions in 2019 globally. This generation must be decarbonized to be on track to achieve long-term climate targets

Low-C fuels can decarbonise existing fossil generation

- Three major options for decarbonising fossil fuel electricity generation
 - Early retirement / reduced operation
 - CCUS retrofit to power plants
 - **Co-firing with low-carbon fuels**
- Technology is progressing rapidly
 - Small gas turbines already operating at >90% share of hydrogen
 - 20% co-firing with coal tested with ammonia at pilot scale
 - Large-scale projects with higher co-firing rates are under development



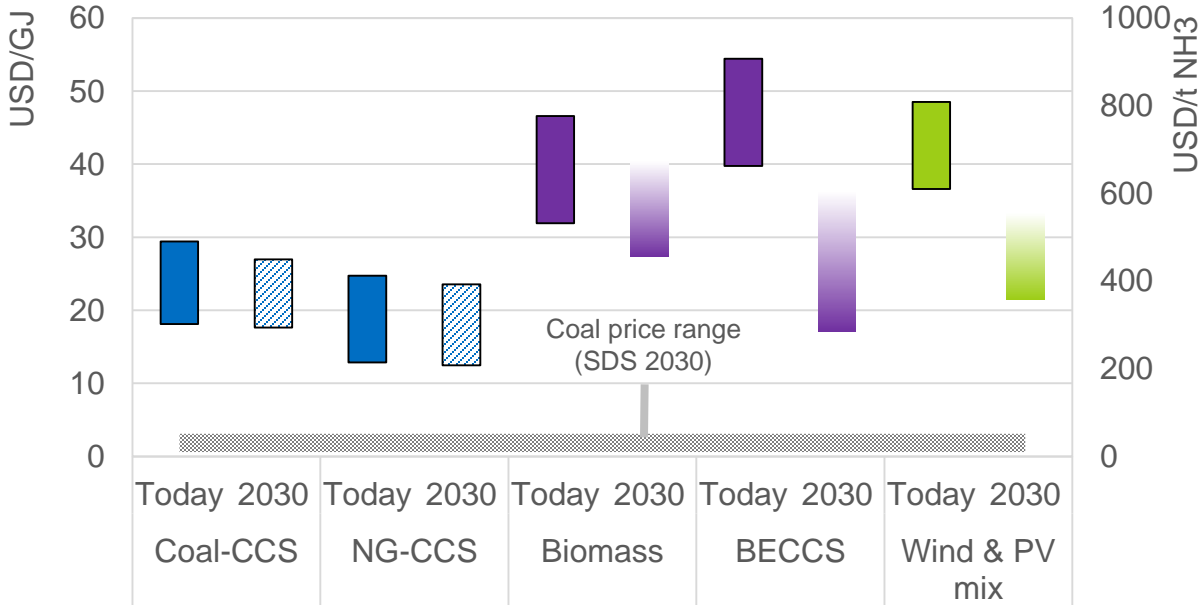
Using low-C fuels can lead to significant reduction in GHG emissions



International standards are required to ensure that use of low carbon fuels lead to global emission cuts.

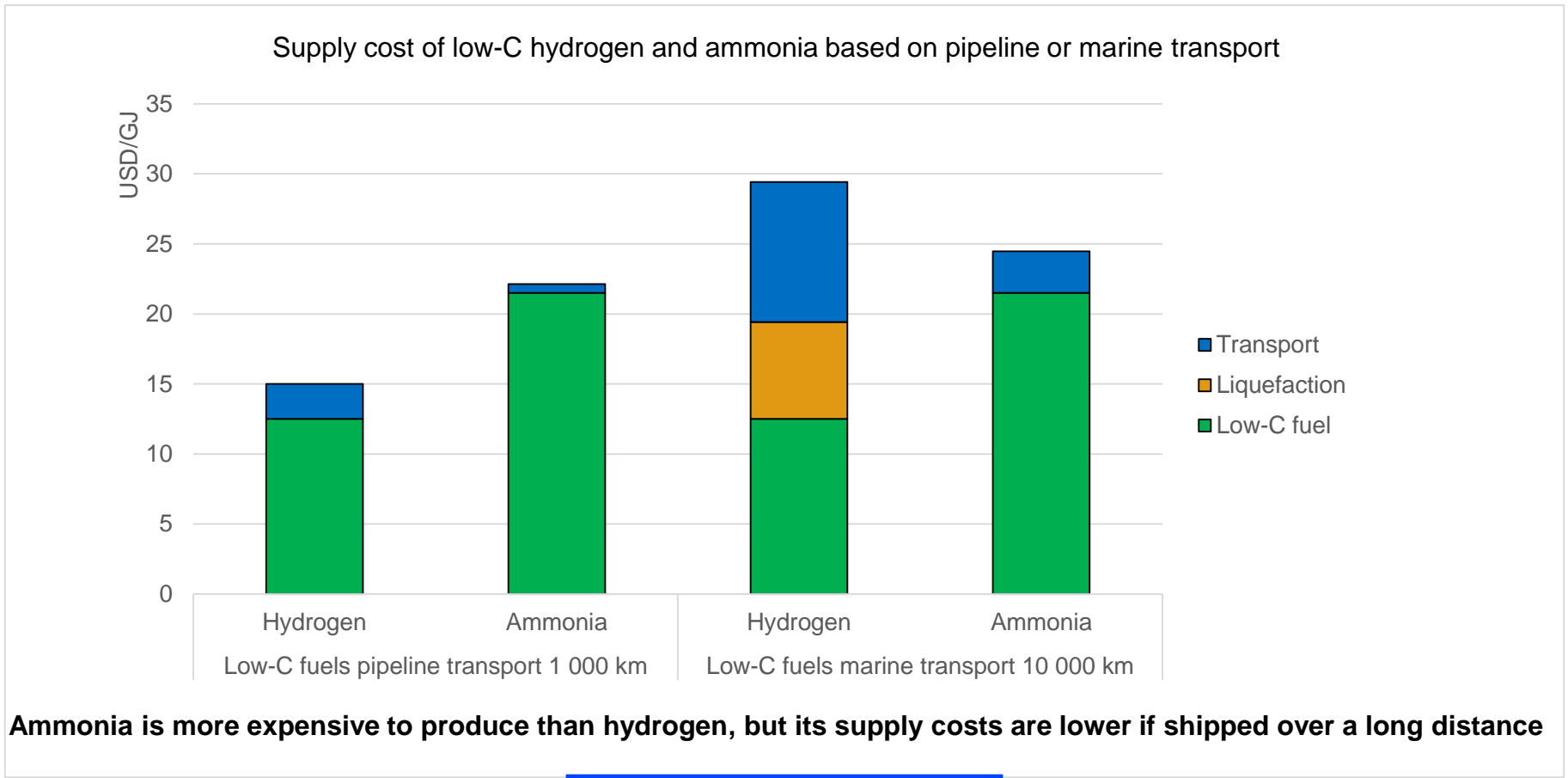
Production costs of low-carbon fuels must decrease further

Indicative production costs for low-carbon ammonia for today and 2030



Low-carbon fuel ammonia is expected to be significantly more expensive than coal in 2030 in the SDS. Production costs in 2030 are within commodity price ranges (USD 160-700/t) in recent years

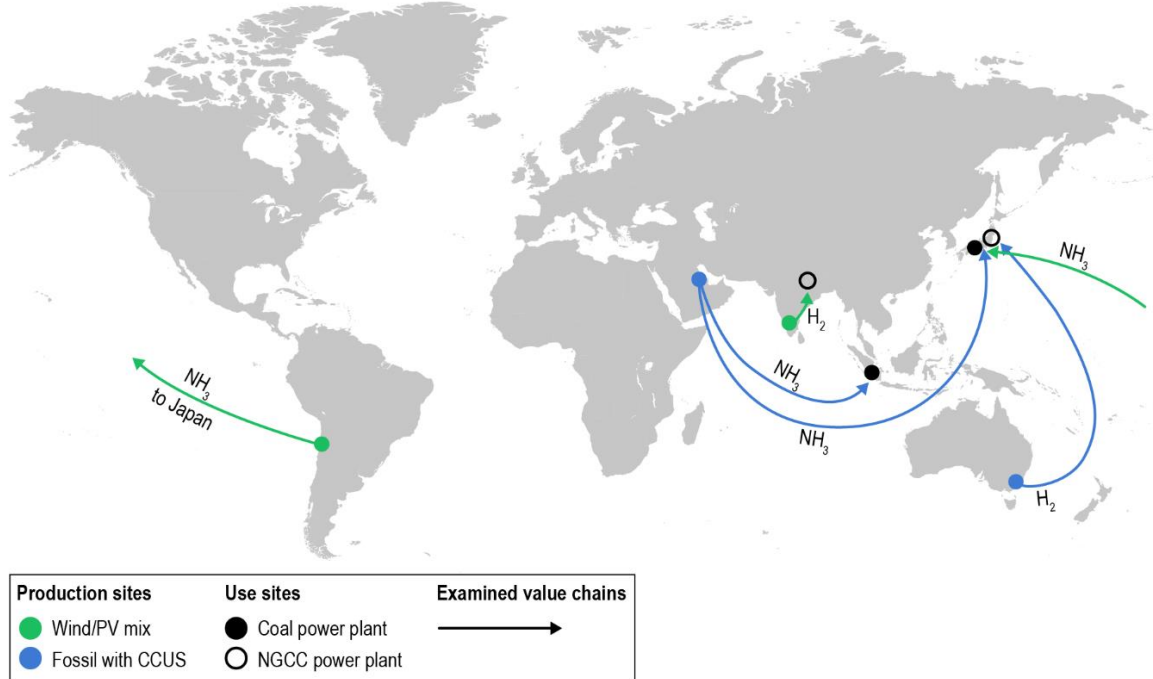
Transport is a key component of total supply cost of low-carbon fuels



Ammonia is more expensive to produce than hydrogen, but its supply costs are lower if shipped over a long distance

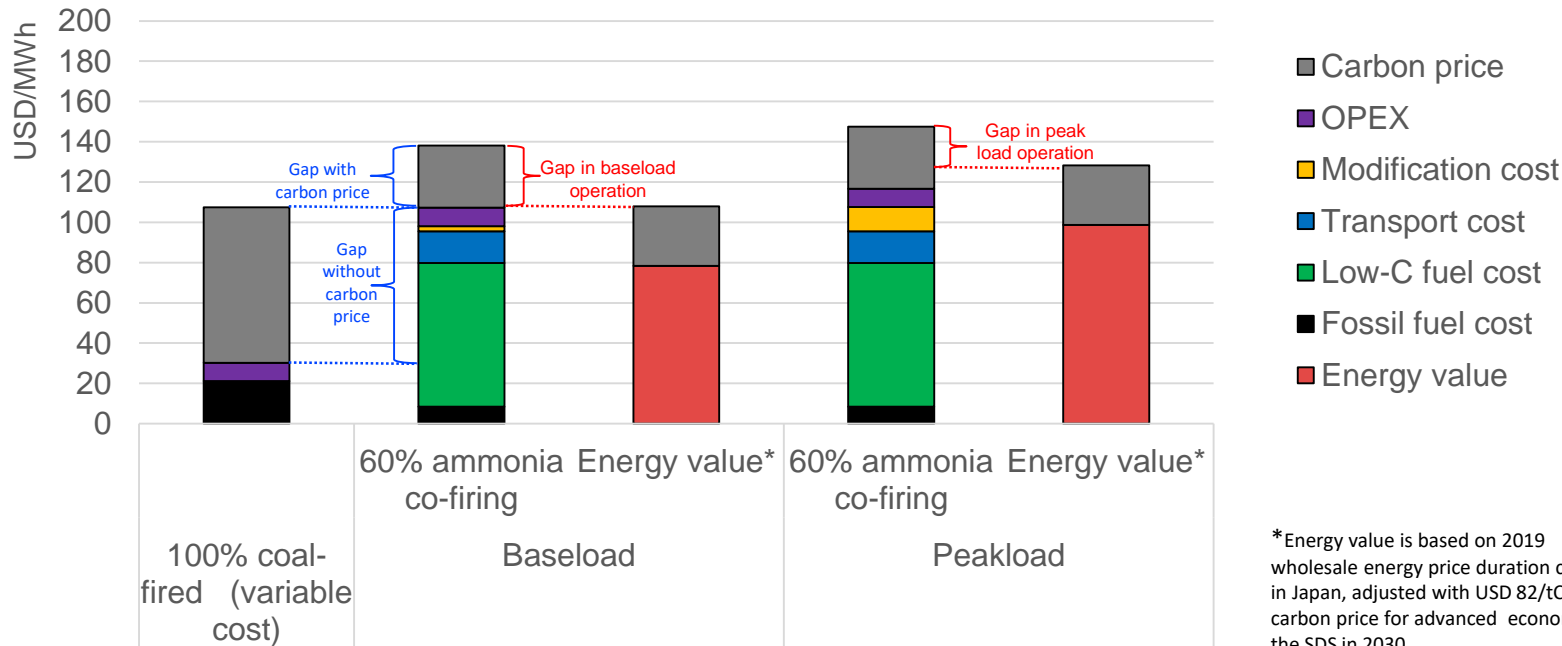
Detailed analysis of selected low-carbon fuel supply chains

Analysed supply chains for the production and use of low-C fuels in thermal power plants



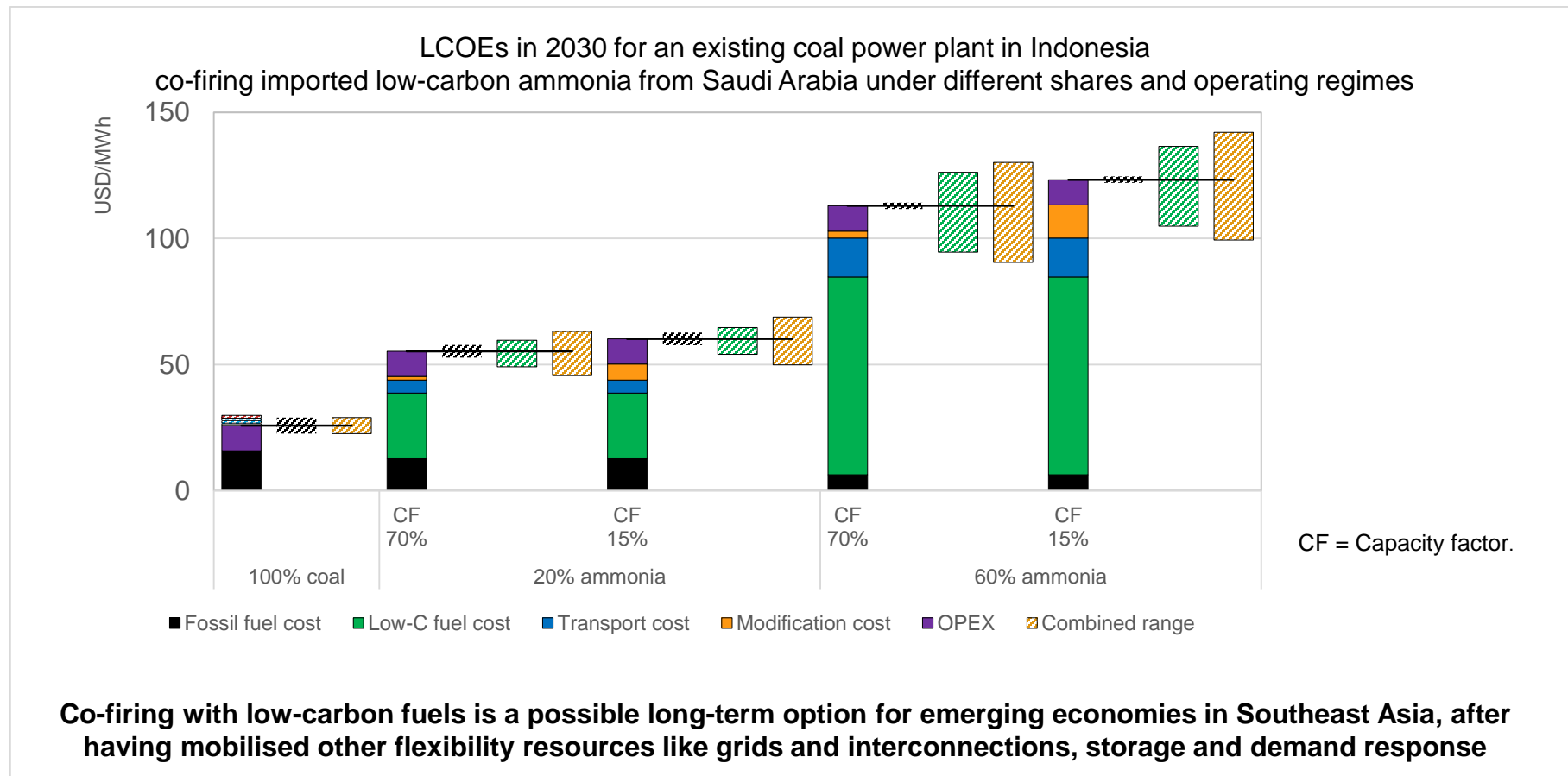
Examined cases: importing low-carbon fuels to an advanced economy with a carbon price (Japan); importing low-carbon ammonia to an emerging economy without a carbon price (Indonesia); using domestically produced low-carbon hydrogen in an emerging economy without a carbon price (India).

Energy market value and LCOE of co-firing for Japan in the SDS 2030



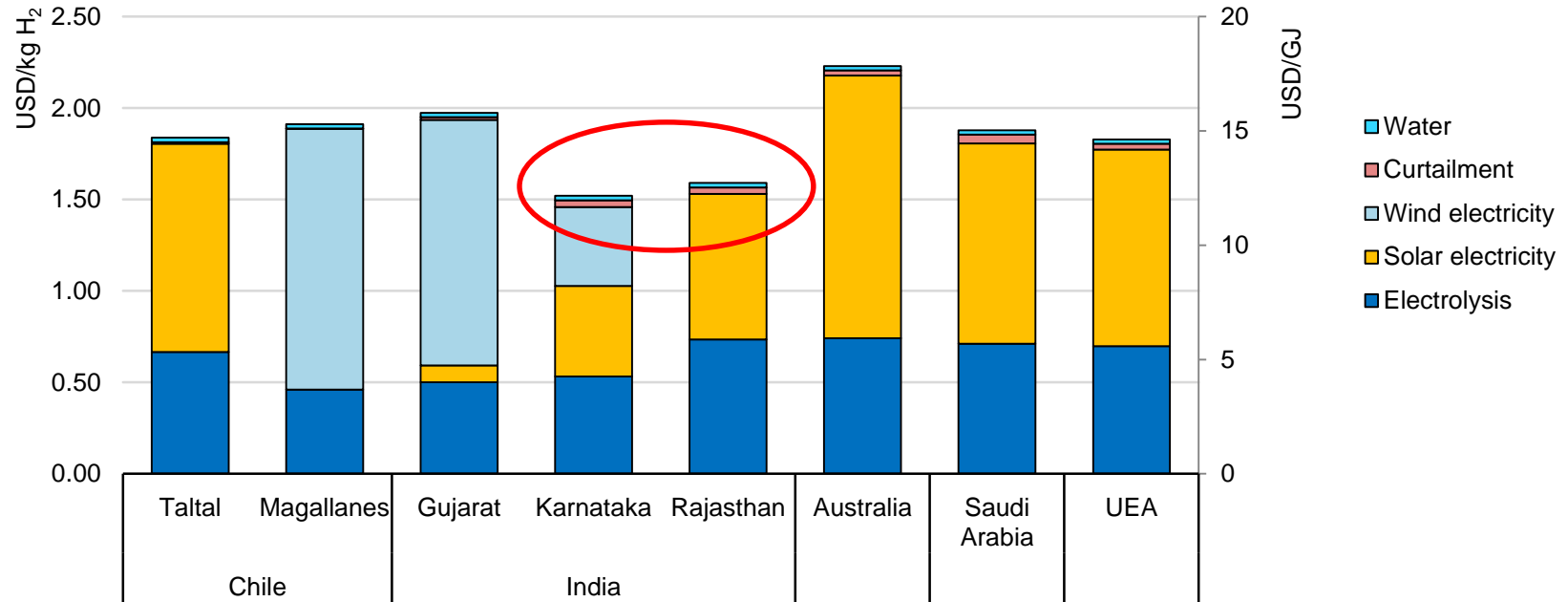
In an efficient wholesale electricity market, co-firing of low-carbon ammonia can have a better business case for peak load than baseload operation

Indonesia: Co-firing of low-carbon fuels remains an expensive option in 2030



India has excellent renewable resources to produce low-carbon fuels

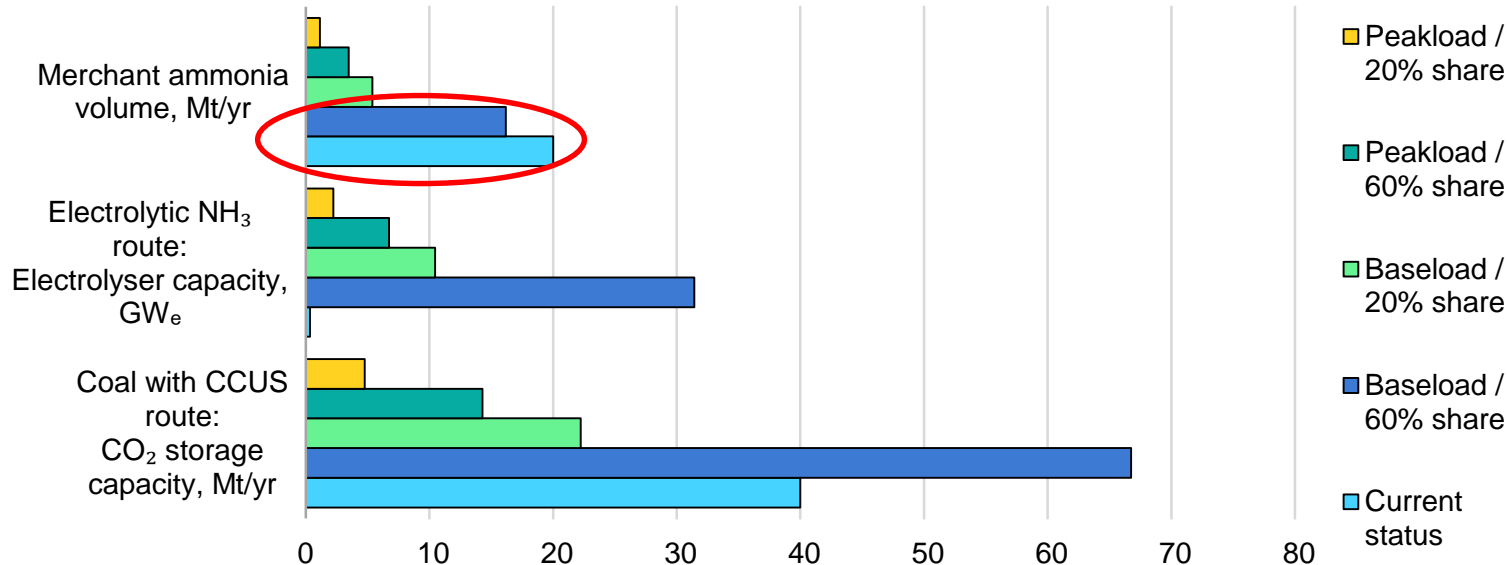
Production cost estimates for electrolytic hydrogen from a mix of wind and solar PV in 2030



India has the potential to use low-carbon fuels domestically produced at low cost from wind and solar, transported by pipeline

Major expansion of supply infrastructure is needed

Supply infrastructure scenarios for co-firing ammonia in a 10 GWe coal fleet.



Co-firing 60% of ammonia in a coal power plant fleet of just 10 GWe would mobilise an amount almost equivalent to the total ammonia traded worldwide today.

- Using low-carbon hydrogen and ammonia in fossil fuel power plants can play an important role to help ensure electricity security in clean energy transitions. Their value depends on system contexts and regional conditions
- Low-carbon fuels have an especially important potential in countries or regions where the thermal fleet is young, or when the availability of other low-carbon dispatchable resources is constrained, such as in East and Southeast Asia
- Diverse supply routes for low-carbon fuels can enhance security of supply and cost predictability
- International rules and standards are necessary to achieve measurable life-cycle emission reductions
- A portfolio of policies is required to reduce production costs and improve system value of low carbon fuels in the power sector
- Developing markets for low-carbon fuels and their supply chains by 2030 will establish significant opportunities in many countries and sectors of the economy