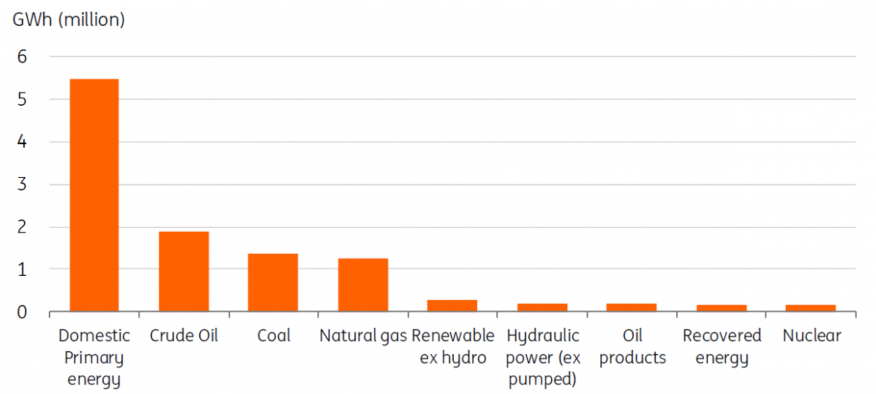
Asia's race to net-zero: Japan

Japan aims to be net-zero carbon by 2050. Although it's at the forefront of many technologies, it's made little progress in terms of decarbonising its economy and fossil fuels make up more than two-thirds of its primary energy supply. We estimate the electricity-generating transformation costs for Japan's transport sector are around US$1tr

Pollution in Kawasaki, Japan, has already led to tough environmental measures

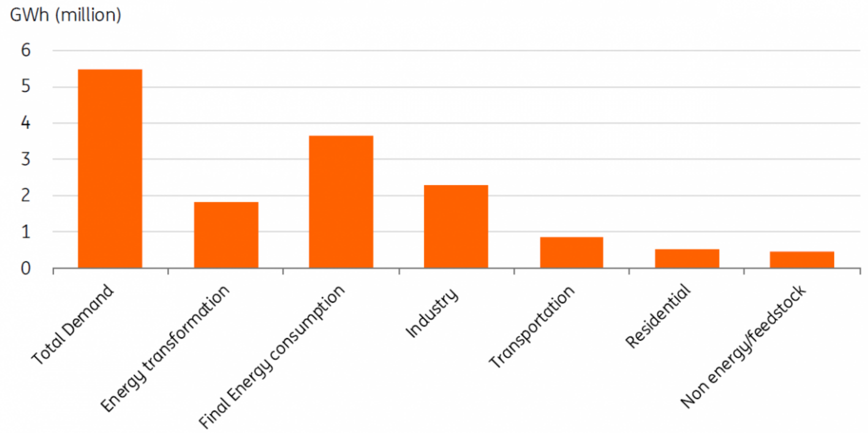
Japan's energy sources



Source: Japan Bureau of Statistics - statistical yearbook 2021

Japan is a heavy emitter of greenhouse gases even by developed market standards, but that also means there is a lot of low hanging fruit in the transport sector and in the electricity generating sector that will enable it to make some quick wins if it is determined to do so. That said, transport only accounts for a small proportion (23%) of Japan's final energy demand.

Demand for energy by sector: Japan



Source: Japan Bureau of Statistics - statistical yearbook 2021

The Japanese government issued its "Green growth Strategy Through achieving Carbon Neutrality in 2050" shortly after PM Suga declared this objective in October 2020.

In the MITI paper that followed, the government set out a goal to generate 50-60% of all electricity demand with renewables by 2050, with 10% coming from hydrogen and ammonia power generation, and 30-40 from nuclear and thermal power plants with carbon capture and storage to cover the rest.

What we have done is to take these rough targets as guides for Japan's electricity generating capacity*. We have used IEA figures for capacity factors** for different types of generation (how much a type of generation can be relied on compared to its theoretical maximum capacity) as well as capital costs per KWh*** and calculated the weighted costs for incremental electricity capacity requirements stemming from the transition to net-zero carbon.

*IEA Japan 2021 Energy Policy Review

**IEA World Energy Outlook Annex B Table B 2b

***IEA Projected costs of Generating Electricity 2020

Japan's electricity generating mix - 2050

	Nuclear	Gas CC	Solar PV	Offshore wind	Onshore Wind	Hydro	Hydrogen
Japan Prospective weighting	0.15	0.15	0.25	0.125	0.125	0.1	0.1
Capacity factor	0.8	0.5	0.18	0.38	0.26	0.45	0.5

Source: IEA, ING

For each part of the transport transition, we calculate the demand for transport by 2050 and then derive the electricity demand that the most practical zero-carbon alternative would require. We take account of losses in electricity transmission and work backwards from this calculated energy requirement. We back out the capacity change needed to provide that additional power and the cost of installing that capacity.

We note that both the generating processes and end-use transport are becoming more efficient over time. And so, our average cost per GWh of electrical work, energy and per GW of capacity will be lower by 2050.

As noted in the introductory section, we make the simplest assumption possible about the installation process, and our capacity costs are consequently a simple average of the 2020 costs and the expected 2050 costs.

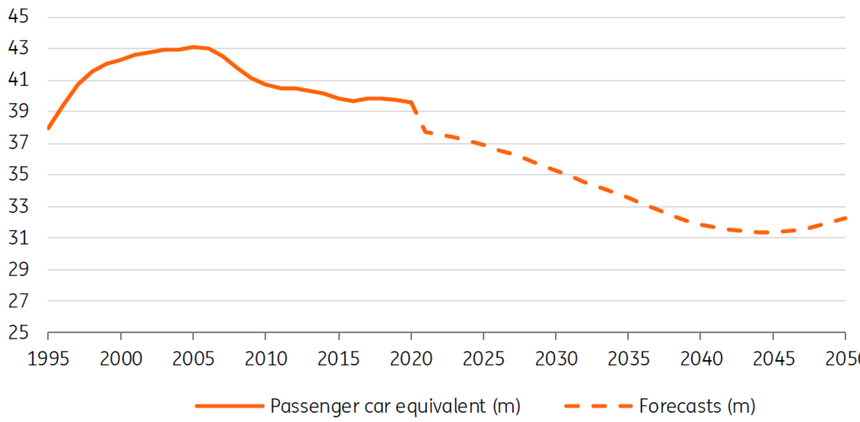
Land transport – Passenger cars

Total transport energy demand for Japan in 2019 was about 15.5% of the total primary energy demand, accounting for approximately 850,000 GWh. Of this, about 59% was passenger traffic, and 59% of that was passenger cars.

With 98% of the Japanese vehicle fleet conventional or hybrid, a net zero-carbon passenger vehicle world will require replacing almost the entire fleet.

With its shrinking and ageing population, together with its slow GDP growth, our modelling of the passenger vehicle segment for Japanese road transport shows the continuation of the trend decline evident since around 2005 continuing until about 2045 before it starts to level off.

Japan passenger vehicle forecast



Source: CEIC and ING

For simplicity, we have assumed that all passenger vehicles by 2050 are battery plug-in electric vehicles. Japan has made a big play for the hydrogen fuel cell as a potential future source of clean energy for vehicles. But compared to battery EV's, these are less efficient and do not benefit to the same degree from regenerative braking in an urban traffic environment, which seems most appropriate to Japan's case.

Even today, plug-in electric vehicles are considerably more efficient than conventional internal combustion engines* **. By 2050, assuming a continuation of trend efficiency gains, they will be more efficient still. And if autonomous driving is also more widespread, which we think likely, reducing costly braking and acceleration, efficiency gains will be further improved***. With the decline in total vehicles on the road by 2050 and allowing for transmission losses at charging, distribution to the grid and substations, total energy demand from passenger vehicles in 2050 could be as low as 70-75,000GWh.

*https://www.fueleconomy.gov/feg/atv.shtml

**https://www.fueleconomy.gov/feg/atv.shtml

***Energy Efficiency trade-offs in small to large electric vehicles. Environmental Sciences Europe, 18 March 2020.

Backing out the electricity generating capacity required to deliver that, and accounting for Japan's projected generating mix, this requires only around 20GW of additional generating capacity at a total cost of US$54bn, or less than 0.1pp of GDP on an annual basis if spread out over the entire horizon. This low result is a result of:

i. The decline in vehicles on the road and passenger km by 2050

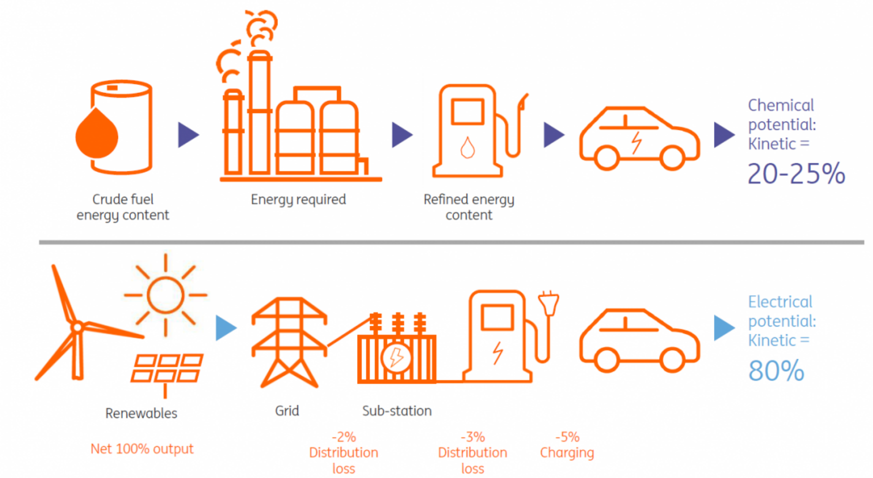
ii. The inherent efficiency improvements of BEVs compared to the current fleet

iii. Additional energy gains for BEVs in 2050 from now

iv. Decline in costs, especially for renewable energy as it becomes more widespread.

This is only one part of the transport sector, however. Let's now consider the other parts.

The efficiency of battery electric vehicles (BEVs) versus internal combustion engines (ICEs)



Source: US Department of Energy, ING

Commercial vehicles

We perform much the same calculation for buses and road haulage using trucks. Where BEVs were unambiguously the technology of choice for the urban passenger segment, this is less clear for commercial vehicles. For short-haul commercial transport, including buses, the efficiency gains and restorative braking technology mean that battery electric vehicles will likely be the clear economic choice. But for longer range traffic, it is not so obvious.

For fuel cell-driven vehicles, the issue of hydrogen generation requires some consideration to allow for net-zero carbon production. The electrolysis step is not 100% efficient, and then there are further leakages and efficiency losses at each stage of compression, liquefaction, transportation and filling. Even if, ultimately, hydrogen fuel cell vehicles are very efficient at turning that chemical potential energy into kinetic energy to shift the vehicle forward* **, the process for getting there is extremely complicated, and the overall efficiency gains smaller than for battery electric vehicles. That said, Japan's government has placed some considerable weight on hydrogen as part of its sustainability plans* and we believe it will be part of the land transport solution, though it will play a much bigger role, in marine transport (as ammonia).

*https://afdc.energy.gov/vehicles/how-do-fuel-cell-electric-cars-work

**Basic Hydrogen Strategy December 26, 2017. Ministerial Council on Renewable Energy, Hydrogen and related issues https://www.meti.go.jp/english/press/2017/pdf/1226_003b.pdf

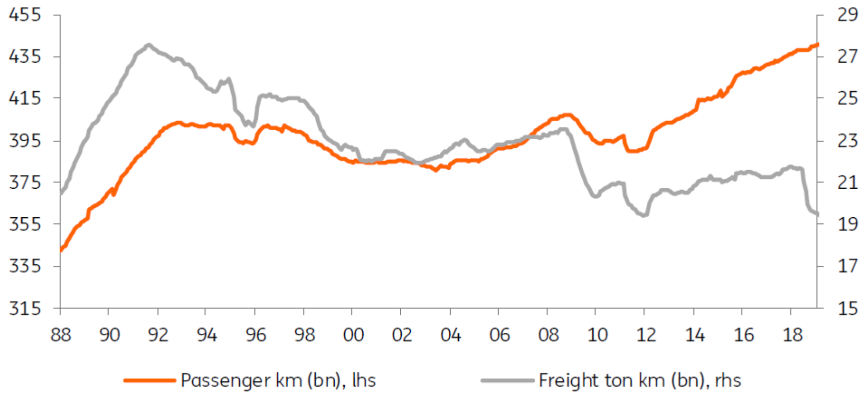
Splitting the commercial vehicle sector into long haul, which could make good use of hydrogen fuel cell technology, and short-haul, which is more likely to benefit from battery power, we can make similar calculations to those done for the passenger vehicle segment. Doing this, we calculate this will require an additional 20GW of capacity and a further US$60bn of capital costs.

Japan's rail system

Rail is extensively used in Japan compared to many developed countries, and it accounts for 29% of current passenger transport energy consumption. Only about 5% of this rail transport is freight traffic.

Passenger transport was edging up prior to the pandemic when it collapsed (we show it only pre-pandemic for clarity). But for Freight, ton kms have been edging down for some time. With 85% of Japan's rail network already electrified, the only real gains to be made here are from full electrification of the remaining 15% of the network.

Annual passenger and freight ton km travelled



Source: CEIC

Even with the possibility that a falling and ageing population results in reduced rail usage over time, we are reluctant to convert this into a reduced rail energy usage. Timetabling constraints make it more likely that trains simply run a little less full as the population drops. Likewise, for a transport mode that is so mature, we struggle to see substantial efficiency gains over the coming decades.

Consequently, we see rail as a simple calculation where we replace the existing energy generating capacity with net zero carbon capacity for a fully electrified rail network. We calculate that the total transformation will require an additional 60GW of capacity for a total cost of US$150bn.

Aviation

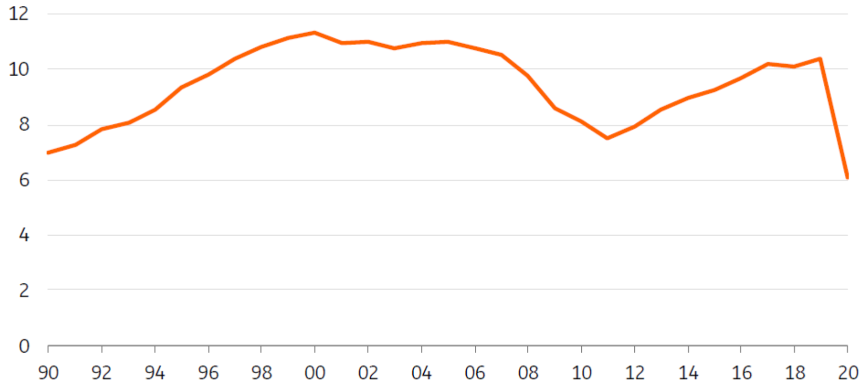
It is easy to find articles about battery-powered planes or planes using hydrogen* **. It's a lot harder to imagine the entire global fleet of commercial aircraft adjusting to a new power source, or for that matter, safely travelling on such an aircraft. For shorter flights, we consider France's recent move to ban internal flights where there is an alternative train journey of less than 2.5 hours as a more practical policy direction for countries in Asia like Japan, but ultimately, this is their choice.

*https://www.bbc.com/future/article/20210401-the-worlds-first-commercial-hydrogen-plane

**https://www.flightglobal.com/airframers/swiss-company-h55-to-provide-batteries-for-harbour-airs-electric-beaver/143359.article

For those remaining flights, the more credible alternative to hydrogen or battery power, we believe, is that current aviation fuel is replaced with sustainable aviation fuel (SAF) and used in existing aircraft. This could be done without the requirement to redesign and build an entirely new generation of aircraft. Bearing in mind that the Boeing 747, has only just been retired, after it was first used in 1970 by Pan Am, it is clear that there is a lot of life in the existing generation of commercial aircraft. If not, this could be one transport segment that requires mitigation efforts elsewhere. Though we are somewhat dubious about the credibility and scale of such measures as are currently available. And these will need to be adequately "policed" to prevent greenwashing.

Jet fuel used (kl million)



Source: CEIC

Sustainable aviation fuel, which can start off as food waste or industrial landfill, can arguably be net carbon negative in the sense that it replaces a methane source with a product that would generate a less harmful greenhouse gas, carbon dioxide. And there is apparently, no shortage of available feedstock. Though planes running on SAF still emit carbon dioxide. And we have to be very careful about how we undertake the carbon balance sheet accounting for processes like this. Are they genuinely reducing greenhouse gases from the atmosphere, or not? That needs to be made more clear.

Moreover, creating sustainable energy fuel is not an energy neutral proposition, and would require some significant energy inputs. One variant of this is described by the US Department of Energy, which requires 90MW of electricity generating capacity for each 10 million gallons of aviation fuel manufactured.

To manufacture a sustainable alternative to the 10.4 billion litres of aviation fuel Japan used in 2019 would require an additional 62GW of capacity at US$168bn, assuming that demand eventually crept back to 2019 levels and allowing for some further efficiency gains.

Marine

The Marine transport segment is perhaps the trickiest transport sector for these calculations. Japan's Marine transport sector is overwhelmingly freight, so we can ignore the passenger sector for the purposes of our calculations.

There are widely differing outlooks on the future for shipping fuel. Some advocate a short-term shift to LNG as a bridging fuel. But with increasing concern about "methane slip", one of the world's biggest shipping companies, Maersk, has come out strongly against LNG. Even ignoring methane slip, which is hard to do, countries like Japan would need to mitigate against the CO2 emissions produced, and shipping companies needing to buy new ships might find them unprofitable within their economic lifetime if they had to offset rising carbon emission costs.

The most likely alternative fuel source we know about today is ammonia. This has both advantages and disadvantages.

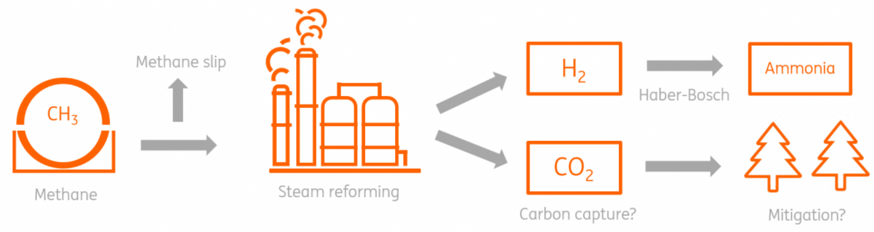
Advantages

- When burned, it emits no CO2
- It is fairly energy dense and so will not compromise marine cargo space.
- A tank of ammonia (NH3) contains more hydrogen than a tank of hydrogen (H2)
- Existing ships can be retrofitted with ammonia burning engines (though this would not be cheap)

Disadvantages

- Ammonia needs to be produced, which is an energy-intensive process deriving from reducing methane (blue ammonia), producing CO2, which needs capturing and storing (untested and potentially uncommercial), or through green ammonia production, which requires a lot of renewable energy.
- Conventional engines for burning ammonia are not very efficient. Ammonia does not burn well on its own and is much more efficient when combined with hydrogen gas which also helps to reduce harmful NO and NO2 emissions. In short, given the inefficiencies of such engines, the overall process requires a lot of energy input, for much less energy output.
- We won't consider the additional bunker costs here, but as ammonia is less fuel dense than traditional fuel, these would also be considerable.

Blue Ammonia production



Source: ING

Calculating the additional electricity generating capacity costs required to create green ammonia even if used in more efficient hybrid H2 enhanced engines would require an additional 216GW of capacity at the cost of about US$588bn.

It might be possible to do this more cheaply with blue ammonia. But that would require carbon capture and storage (CCS) or mitigation actions, the costs of both of which are unclear. While we consciously gloss over CCS in this note, we aren't dismissing it entirely. Most of the net-zero plans we have seen for Asia, including those for Japan, include a role for CCS, usually alongside LNG gas turbine electricity generation. And it does look as if CCS will become a much more important feature of net-zero carbon transformations in the coming years.

Conclusion

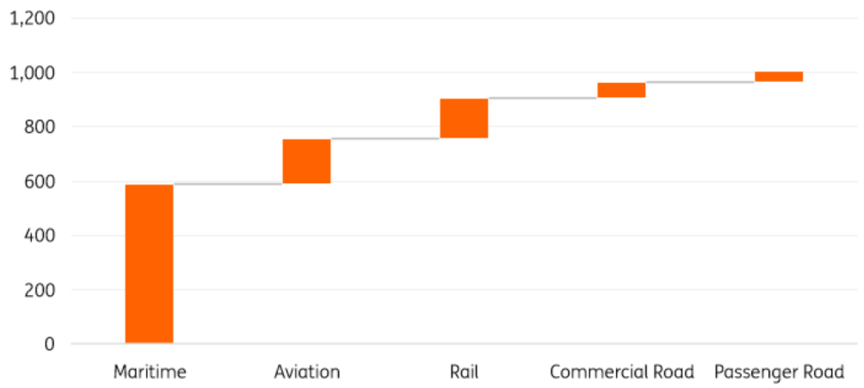
When you add all this together, the total costs for Japan in transitioning to a net-zero carbon transport system, would cost about $1tr purely in terms of the electricity generating capacity required.

In very rough terms, that is about 20% of current Japanese GDP, though this falls to around 0.6% of GDP per annum when spread between now and 2050. That's not much more in total than the Japanese government spent on Covid-19 mitigation efforts, just to throw in some more perspective.

But then this is only the transport sector, and only the electricity generating capacity cost we have considered. The whole economy transition will be far more expensive.

With government money earmarked for the transition of the entire economy less than 20% of the total for transport alone, it is clear that the private sector will be required to pay for most of this.

Additional capital cost required (US$bn)



Source: ING

That sounds alarming. But put this another way, for the transport sector alone, this transition will require additional private sector investment spending of about 0.6pp of current GDP per year. As far as GDP is concerned, one person's cost is another's income. So yes, this will be disruptive, but this is not simply a drag on growth and could reinvigorate what is currently a very lacklustre economy.

The Japanese government claim a total GDP gain from their green transition plan of US$1.8tr by 2050*. This is not a figure that we can completely dismiss. If we have any bias, it is that this might be too small.

*Overview of Japan's Green Growth Strategy through achieving Caron neutrality in 2050. Jan 2021

Author

Robert Carnell
Regional Head of Research, Asia-Pacific
robert.carnell@asia.ing.com