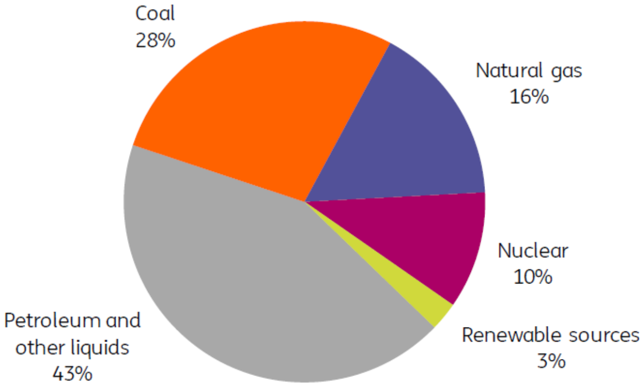
Asia's race to net-zero: South Korea

Like Japan, Korea's primary energy demand is heavily reliant on fossil fuels, with petroleum and other liquids accounting for 43% of all energy consumption, and coal 28%. Nuclear fuel accounts for around 10%, and renewables only 3%.

Visitors wear masks to protect themselves from air pollution along the Han River at a park in Seoul

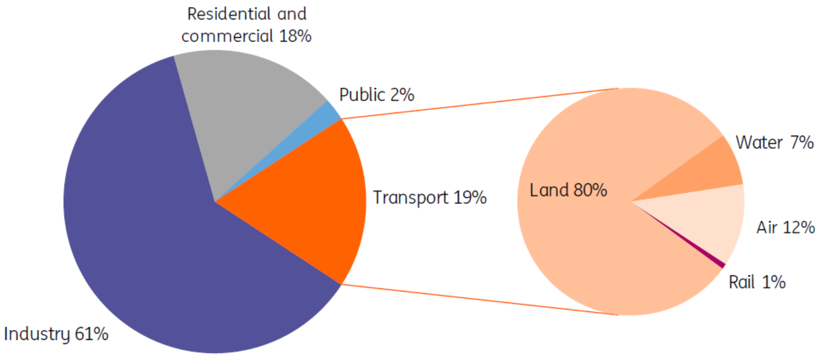
South Korea's total primary energy consumption by fuel type, 2019



Source: BP Statistical Review of World Energy 2020

In 2018, the entire economy energy usage for Korea was 2.7 million GWh, of which transport accounted for only 19%, with industry using the lion's share of 61%. Of this 19%, about 80% was used by Korea's road transport, with rail hardly even registering, and marine and air picking up the difference.

South Korea's energy usage

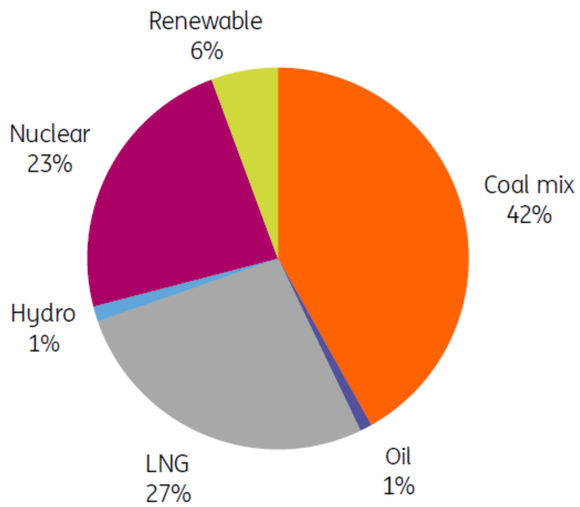


Source: Korean yearbook of energy statistics: 2019

For electricity generation, Korea relies on coal and natural gas for almost three quarters of its generation. A little oil (most of which is imported for use in oil product production (gasoline etc), with 23% of electricity generation coming from nuclear, 1% hydroelectricity and just 6% from renewables and waste*.

*Yearbook of energy statistics, 2019. Korea Energy Economics Institute. http://www.keei.re.kr/web_keei/d_results.nsf/0/3E7B1890D202597E492585150021D4C9/$file/YES2019.PDF

Electricity generation by fuel (GWh)



Source: Korean yearbook of Energy Statistics

The net result of this is that in 2019, Korea emitted about 650m tonnes of CO_2, which is less than the 1.1bn tons Japan emitted, though at about 12 tons per capita per annum, is about 30% more per person in Korea than in Japan*.

*Our World in Data https://ourworldindata.org/co2/country/south-korea

Following its very limited "Green New Deal" announcement in May 2020, in December 2020, the Korean government announced that it would be joining the ranks of other countries aiming for a carbon neutral future with the publication of the chunky yet unimaginatively titled "2050 Carbon Neutral Strategy of the Republic of Korea – Towards a sustainable and Green Society*". This is the starting point for the assumed electricity generating mix we use in our subsequent calculation

*https://unfccc.int/sites/default/files/resource/LTS1_RKorea.pdf

However, the 2050 strategy is extremely thin on hard figures, builds in a substantial contribution from fossil fuels though offsets this with considerable reliance on carbon capture and storage. This might well enable Korea to keep some reliance on coal-generated electricity, given that its green technology options are perhaps more limited.

Nonetheless, we get the feeling that the "2050 Carbon Neutral Strategy" should be considered more of a "work in progress" than a fully fleshed-out plan. For example, the talk of green hydrogen fuel cell power generation doesn't sit credibly with expectations for renewable energy by 2040 of only 35% of total electricity generation.

If used, hydrogen fuel cells only fit in the electricity supply mix as storage for surplus renewable energy or as a remote fuel source for off-grid supply. Otherwise, you are simply using renewable energy to create hydrogen, which you then use to produce electricity. This is not a costless round trip and suggests that a great deal more thought is required before we can start taking these official figures more literally. There will be hydrogen demand from transport sectors, but there is no credible incremental energy supply from this source, certainly not without a much more significant contribution from renewable sources.

We have consequently taken inspiration from other sources* and applied our estimates for what we think might make sense for Korea.

*Long-term energy strategy scenarios for South Korea: Transition to a sustainable energy system Jong Ho Hong et al April 2019
https://www.sciencedirect.com/science/article/pii/S0301421518307936

Our generating mix assumes wind and solar PV generating just under 60% of Korea's electricity by 2050, nuclear 13%, Gas with CC 13%, coal with CC 7%, with the rest picked up by hydroelectric, bio, and ocean power (heat pumps and wave). As before, we have taken our capital cost estimates from the IEA, applied the usual efficiency gains for new technology and learning cost reductions to arrive at our 2050 capital cost estimates. But first, we need to calculate the energy needs for transport in 2050.

Korea's electricity generating mix, 2050

	Nuclear	Gas CC	Solar PV	Wind	Coal	Hydro	Ocean	Bio
Korea Prospective weighting	0.13	0.13	0.42	0.17	0.07	0.02	0.04	0.02
Capacity factor	0.85	0.85	0.15	0.265	0.85	0.45	0.45	0.89

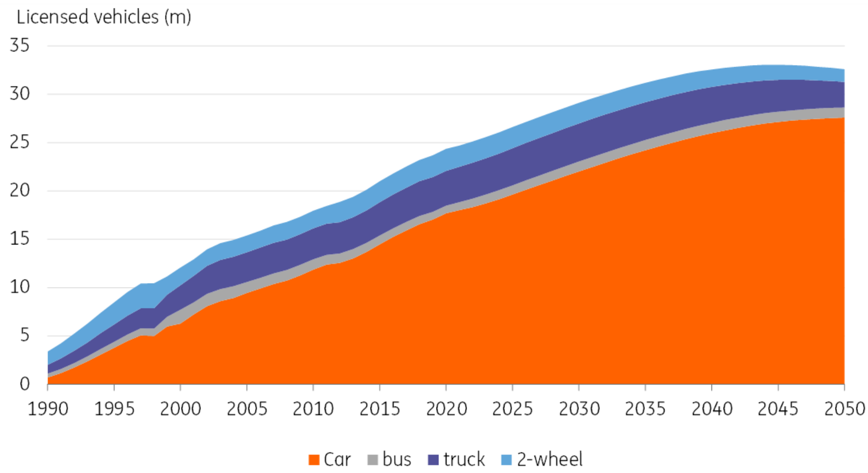
Source: Government of Korea, ING

Road transport

We have less detailed energy consumption data by road transport type for Korea than we had for Japan, and much of this is derived from data on licensed vehicles, which we project to 2050 using assumptions about GDP growth, population, and the relative cost of private transport using variables such as crude oil prices.

These projections differ from those for Japan, showing, for the most part, a substantial rise in road transport though one which begins to top out in around 2040. Most of the gain is in private passenger cars.

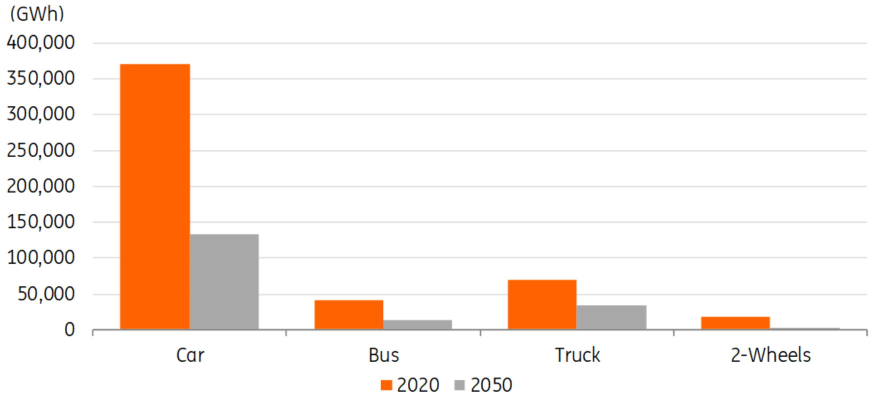
Road vehicle projection



Source: CEIC, ING

Using the same methodology – shows the familiar sight of a distinctly lower energy requirement in 2050 notwithstanding the increase in vehicles, thanks to the efficiency gains of BEVs and smaller gains for fuel cell vehicles (we assume again a 40% take-up for hydrogen fuel cells for trucks, but assume battery electric vehicles elsewhere).

Road transport energy usage 2020 vs 2050 (GWh)



Source: 2050 Carbon neutral strategy of the Republic of Korea Dec 2020

Rail

Rail is a tiny proportion of all the transport used in Korea, and it is almost entirely passenger traffic. Given Korea's geographical location, most goods arrive by sea and air, and the remaining transport of goods to their point of sale takes place by road. With the route north out of Korea effectively closed, there is no realistic prospect of a more significant role for rail transfer in Korea without a route out into China. We don't foresee this happening over our forecast horizon. In any case, it makes little sense to plan for something so unpredictable, and at present, seemingly unrealistic.

President Moon has already pledged to replace all existing diesel passenger trains with electric bullet trains by 2030* and claims this will reduce carbon emissions from rail transport by around 30%.

*"The future of rail" - https://www.iea.org/reports/the-future-of-rail

At present, 85% of Korea's rail network is already electrified. So a claim of a 30% reduction of carbon emissions already looks ambitious. The IEA does not believe that a move to high-speed rail will necessarily translate into significant carbon emissions savings, according to a 2019 report*.

*"The future of rail" - https://www.iea.org/reports/the-future-of-rail

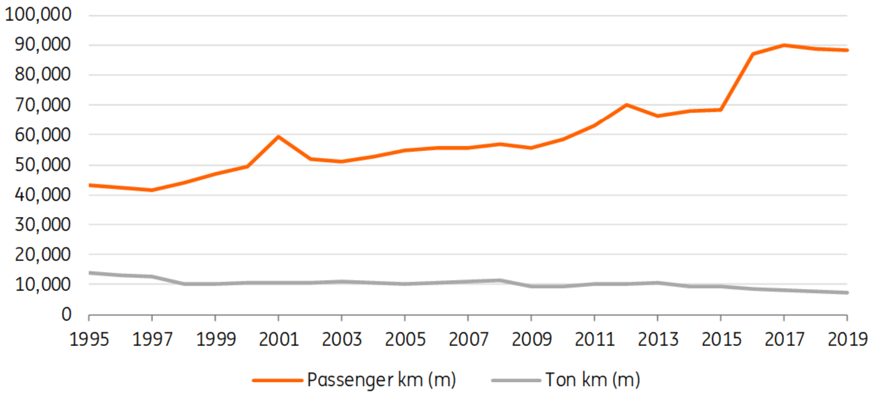
To generate the carbon savings predicted, the new high-speed services must be energy efficient during construction, run on clean electricity, run frequently and near capacity and entice people out of polluting air and road transport alternatives while simultaneously not generating significantly more travel demand*.

*https://www.railway-technology.com/features/high-speed-rail-sustainability/

In terms of our calculations, we aren't interested in official claims. Instead, we will focus on a 100% electrified system of rail transport powered by the energy mix we have assumed earlier, with a more significant proportion of renewable energy in production.

Our modelling suggests that rail passenger km travelled will roughly double from 100bn passenger km per year travelled currently. With no changes, this will increase the annual energy usage of rail from 5000GWh to about 10,000 GWh by 2050.

Korean rail traffic



Source: CEIC

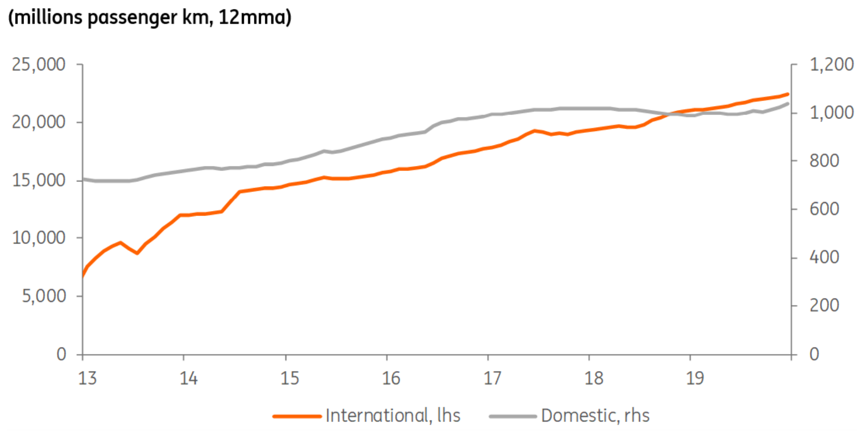
With efficiency gains assumed from the electrification of the remaining 15% of the network, what is currently still supplied by diesel, will reduce that total to 7,500GWh (assumes running energy costs per passenger km 70% more efficient than diesel). Allowing for further efficiency gains and offsetting losses due to transmission, we get to an end 2050 figure for rail of 6,933GWh, only a marginal increase over current energy requirements despite a near doubling of passenger km per year. This will require about an additional US$5bn of more capacity installation, of which about US$2.4bn would be for solar PV and US$1.2bn wind power.

Aviation

Air transport accounts for about 12% of total Korean transport energy consumption and is much more evenly split, with about 60% accounted for by passenger km and 40% by freight tonnage.

Before the global pandemic, passenger transport had been relatively flat, with some tendency for an increase in international travel, but flat domestic travel. Domestic travel is dwarfed by international travel.

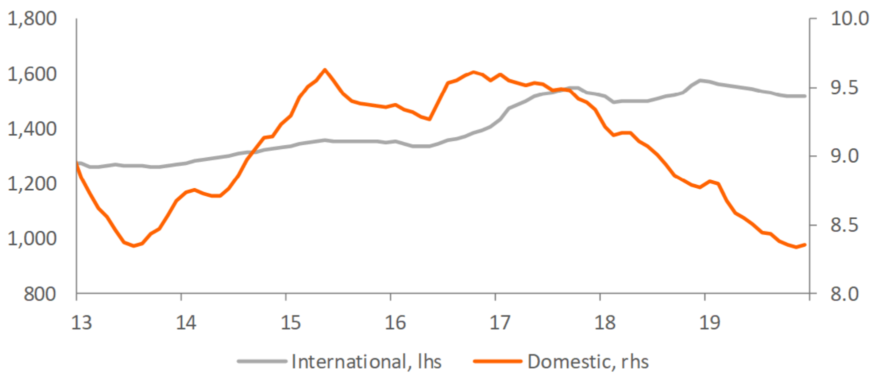
Domestic and international air-passenger transport



Source: CEIC

In the cargo sector, international cargo transport also dominates domestic cargo transport, and before the pandemic, it had been inching higher.

Cargo ton km (millions, 12mma)

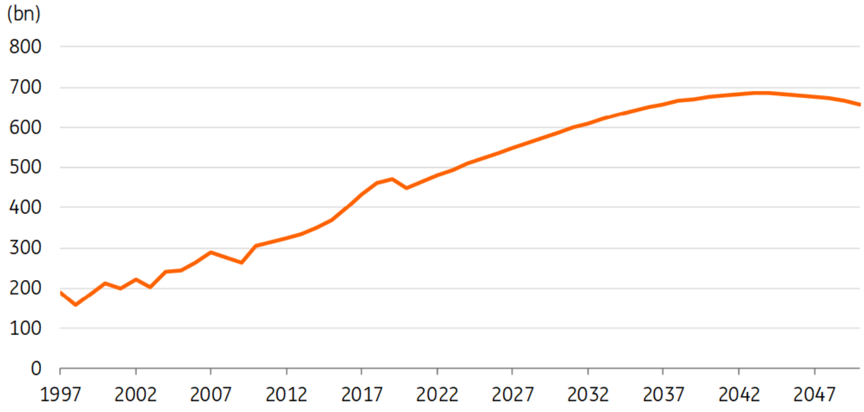


Source: CEIC

With 95% of Korea's passenger transport international and 99% of Korea's cargo transport international, our calculation will assume that domestic aviation moves entirely to rail and road transport.

We assume steady international cargo transport through to 2050 and forecast international passenger traffic subject to the usual parameters of GDP, population, demographics and airline price proxies. We simplify the process with cargo, a fraction of passenger traffic by converting the cargo component to a passenger km equivalent (about 11.1 passenger km = 1 cargo ton km). the resulting forecast shows that, like road transport, aviation in Korea will see increased demand until about 2040, where it will peak before starting a slight decline.

International aviation passenger km equivalent



Source: ING, CEIC

From the starting point of 2019, energy usage of 35,000GWh, making no other assumptions other than a change in aviation usage by 2050, would see an increase to 48,900GWh by 2050. Allowing for energy efficiency gains reduces this to about 36,171GWh, only slightly increasing over today's energy usage.

We have worked backwards from this as we did for the Japanese example. We have a requirement by 2050 for about 3.8bn litres of sustainable aviation fuel per year, which we calculate would require an additional 17.4GW of additional energy capacity compatible with net-zero carbon. Based on our energy mix assumptions, this would cost about US$31bn in overnight capacity costs – a little more than US$1bn per year over the whole period. But subject to the caveats we made earlier about whether this can be considered net carbon neutral or not.

Marine

Waterborne travel accounts for around 7% of energy usage, of about 35,000GWh. Unlike aviation, almost all of this is for cargo.

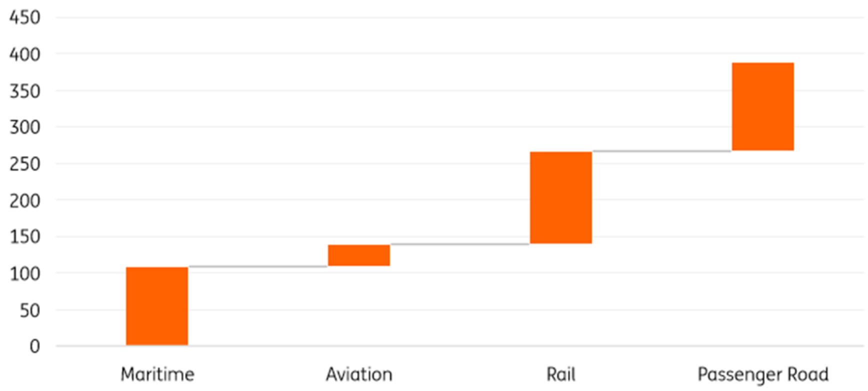
To generate Korea's current maritime energy usage entirely using green energy, assuming a hybrid ammonia combustion/hydrogen gas engine, would need about 28bn litres of ammonia according to our calculations.

Creating this by green processes is relatively energy-intensive, compared to the energy output from ammonia, even when boosted by combusting in the presence of hydrogen. Making this amount of ammonia and hydrogen would take about 166,000 GWh of energy, assuming the process becomes more efficient by 2050, which would need an additional capacity of about 44GW at a total cost of about US$109b or US$3.6bn per year.

Total requirements and costs

If you add up all the components for Korea, there is a much more even distribution of costs than for Japan, which was dominated by marine costs. In Korea's case, the total green energy capacity costs for moving the transport sector towards a net-zero carbon future are about US$400bn.

Additional capital cost required (US$bn)



Source: ING

As before, this estimate does not include any assessment of other infrastructure or fleet replacement, which would likely be at least as large again. But for this simple constrained calculation, we can see that generating capacity costs of about 22% of today's GDP. Over the next 30 years, that amounts to only about 0.6pp of today's GDP per year, and considerably less than this, assuming that GDP keeps growing over this horizon. For Korea, 0.6pp per year is the exact figure we estimated for Japan, which sounds about right.

That is not a small amount of money for just one segment of the economy, but it sounds manageable. If nothing else, it is a sum that shouldn't result in total despair as the estimation has been reached with what we feel are perhaps more realistic and rigorous assumptions than those assumed in official publications.

The current path to net-zero set out in Korea is a pretty broad brush one. On the one hand, it is incredibly encouraging that the ambition to reach net-zero carbon emissions has now been adopted. But over the next one to two years, this path that has until now only been roughly sketched needs to be set out more precisely, and many more concrete actions need to be implemented, not merely discussed. Like both the other economies we have considered, net-zero carbon looks achievable in principle for Korea on the calculations we have performed. But achieving net-zero carbon in practice could slip out of reach if decisive actions are not taken swiftly.

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