Carbon Tracker Initiative

Myths of the energy transition

Hard-to-solve sectors prevent an energy transition

Analyst Note

November, 2018

About Carbon Tracker

The Carbon Tracker Initiative is a team of financial specialists making climate risk real in today's capital markets. Our research to date on unburnable carbon and stranded assets has started a new debate on how to align the financial system in the transition to a low carbon economy.

www.carbontracker.org | hello@carbontracker.org

About the Author

Kingsmill Bond – New Energy Strategist

Kingsmill Bond is the New Energy Strategist for Carbon Tracker, and part of the investor outreach team. His role is to communicate to investors the dramatic implications of the energy transition. He believes that this revolution is the most important driver of financial markets and geopolitics in the modern era.

Kingsmill has worked as a sell-side City equity analyst and strategist for over 20 years, including for Deutsche Bank, Troika Dialog and Citibank in London, Hong Kong and Moscow. He has written strategy on emerging markets and global themes, including the wider significance of the shale revolution. He worked for many years in Russia, which is the world's largest exporter of fossil fuels, and deeply impacted by the transition.

Kingsmill has an MA in history from Cambridge University, trained as an accountant (CIMA), and is a Chartered Financial Analyst (CFA).

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1 Key Findings

Myth 3: In sectors such as petrochemicals, cement, steel, trucking, airlines, and shipping it is not possible to find non-fossil alternatives, and demand keeps rising. Therefore, there will be no energy transition.

Mythbusters

Hard-to-solve sectors are an endgame problem. All transitions take place in stages, and the hardest sectors can be solved last. Long before we get to the last 21% of primary energy supply required directly by the hard-to-solve sectors, the market will have reacted, and incumbents will have changed strategy.

There is plenty of room for progress in other areas. We have already started on the path to decarbonise electricity and to electrify light industry, buildings and light transport. With today's technology we can already increase the share of cost-competitive non-fossils from 20% of primary energy supply to 30%.

Technology keeps raising the ceiling of the possible. The continued fall in the cost of solar, wind, batteries and electrolysers means that there will be cost-competitive renewable solutions for half of primary energy by the mid 2030s.

Hard-to-solve sectors already have solutions. Electricity, heat and biomass already make up more than a quarter of total final energy consumption of heavy industry. Technology is chipping away at the easier parts of the hard-to-solve sectors such as light trucking in transport or low-temperature heat in industry.

Hard-to-solve sectors are smaller than ones where we have solutions. Cars use four times as much oil as planes. Electricity uses ten times as much primary energy as iron and steel. And meanwhile the world is electrifying, so electricity will make up most of the growth in energy demand. It is not credible to argue that growth in these small sectors can outweigh decline in the large ones.

Reality

The hard-to-solve sectors are islands of enduring fossil fuel demand, but no impediment to a transition. And as renewable energy sources become increasingly prevalent, so each of the islands will be overwhelmed by the rising renewable tide. Meanwhile, financial markets react during the peaking phase of the energy transition, long before the last sources of fossil fuel demand need to be replaced.

2 The myth

Myth

Renewable energy sources will never be able to replace fossil fuels in petrochemicals, aeroplanes, heavy trucking, shipping, and a series of other sectors which require fossil fuels. Demand in many of these areas continues to grow, and as a result there can be no energy transition.

Examples

"Why is oil so resilient? Because demand growth for oil in sectors like petrochemicals, heavy industry, aviation and other heavy transport keeps expanding significantly. And these segments are largely insulated from fuel switching." Forbes, March 2018

"Petrochemicals are set to account for more than a third of the growth in world oil demand to 2030, and nearly half the growth to 2050". The Future of Petrochemicals, IEA, 2018

"Oil and gas have a diverse set of end-uses. In some uses, like aviation, marine, freight and petrochemicals, there are few, if any, cost-effective and scalable alternatives to oil." Chevron, Climate Change Resilience, A Framework for Decision Making, 2018

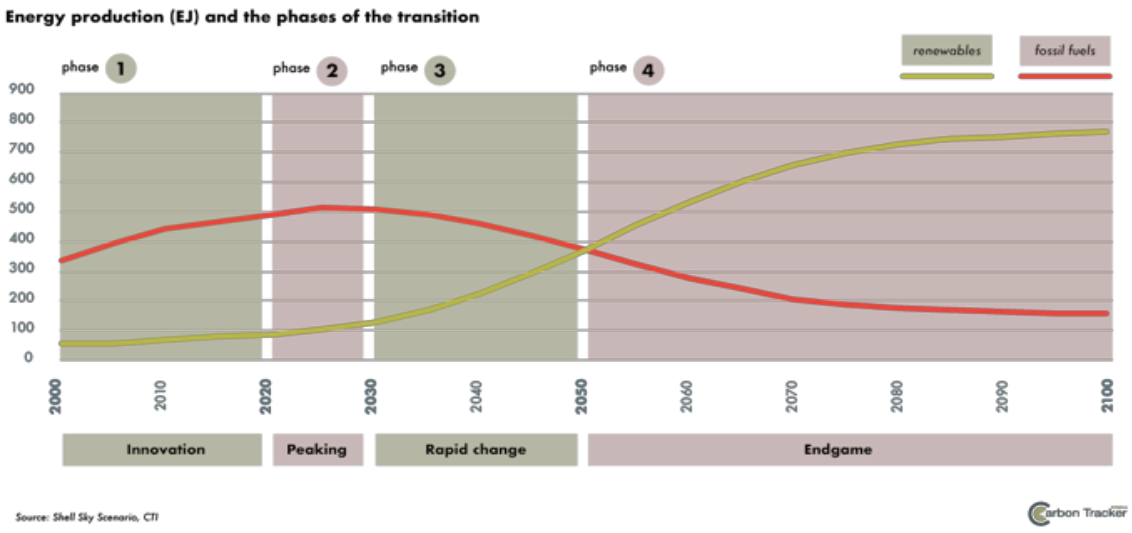
3 Why the myth is wrong

3.1 Hard-to-solve sectors are an endgame problem

If we look at the energy transition as a whole, it is clear that the hard-to-solve sectors can be solved in the final stage. We noted in 'Vision 2020'[1] that transitions take place in four stages – innovation, peaking, rapid change and endgame. The endgame comes when non-fossil sources are larger than fossil fuels, when fossil fuels therefore still have a market share of 50%. Financial markets react during the peaking stage, and by the time we reach the endgame, investors have long ago forced company and sectoral restructuring. We set out the framework for this below, using the Shell Sky Scenario as the template.

[1] *'Vision 2020 – Why you should see the fossil fuel peak coming', Carbon Tracker report, September 2018. Available at https://www.carbontracker.org/reports/2020-vision-why-you-should-see-the-fossil-fuel-peak-coming/*

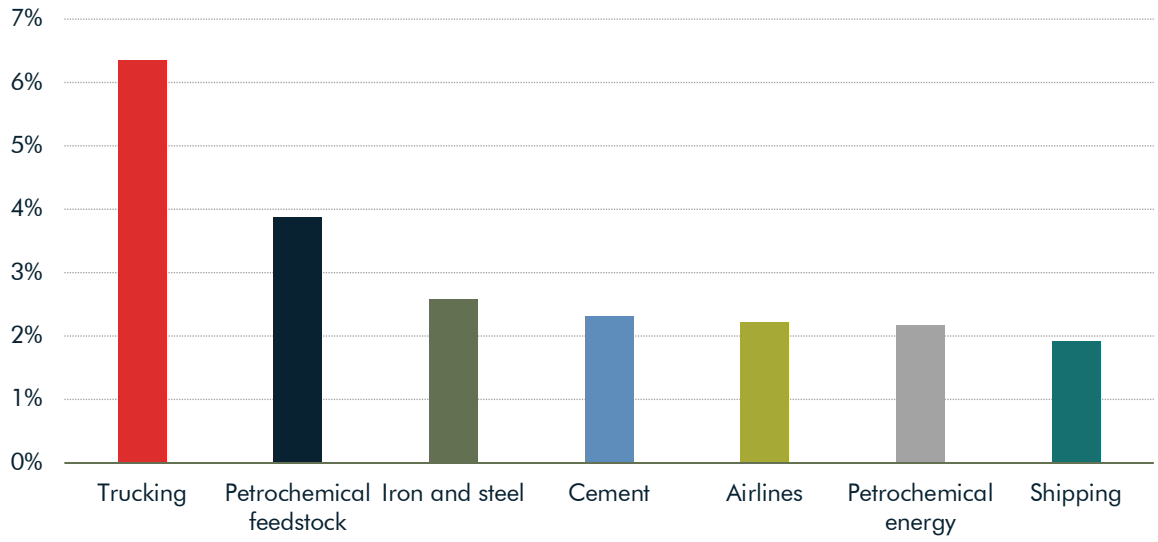
FIGURE 1 - THE FINANCIAL MARKET PHASES OF TRANSITION



In Mission Possible[2], the Energy Transitions Commission (ETC) identified the six primary hard-to-solve sectors as petrochemicals, cement, steel, trucking, airlines and shipping.

Because electricity itself is decarbonising (35% of TWh came from non-fossil sources in 2017), it is important to calculate the energy use of these sectors excluding their use of electricity. The total amount of direct energy required by these sectors in 2016 was 123 EJ, which is 21% of total primary energy consumption. This means that these sectors fit comfortably into the endgame.

FIGURE 2 – SHARE OF PRIMARY ENERGY DEMAND FROM HARD-TO-SOLVE SECTORS 2016



Source: IEA. Note this excludes energy used to generate electricity

It is quite normal for harder sectors to solved later in an energy transition. The cheaper, easier sectors are solved first, and then the more expensive and difficult ones.

[2] *'Mission Possible. Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century', Energy Transitions Commission, November 2018. Available at http://www.energy-transitions.org/mission-possible*

For example, when internal combustion engines started to replace horses in the transport sector after 1900, they were not powerful enough to move heavy loads. As a result, for a number of years, teams of packhorses continued to pull heavy wagons of goods. Eventually of course technology evolved, and engines became powerful enough to move heavy loads. This is a very similar situation to the position today where electric drive trains are able to move cars, but the economics of moving large trucks is harder.

Or when steamships started to replace sailing ships after 1840, they were initially used only in niche applications in harbours. Then they moved to dominate the industry, but there were still areas where sailing ships were able to deliver superior performance, such as in very rapid transit. The Cutty Sark, built in 1869, a decade after sailing ship tonnage peaked, was one of a group of such ships built to deliver tea from China to Europe faster than steamships. And yet its era has long passed, and it sits on a dry dock in London.

3.2 There is plenty of room for progress in other areas

There are three impediments to the growth of renewables: technology, economics, and implementation. Technology solutions have been around for a while, but it is the economics of the alternatives that has changed in the last decade thanks to the fall in the costs of solar, wind and batteries. The primary challenge today is not technological nor even economic, but one of implementation. Even when new renewable energy options are cheaper, they need to be deployed, and sometime that requires waiting for the existing fossil fuel asset to reach the end of its useful life.

We set out below the current position and likely developments in the electricity and light transport sectors. The conclusion is that, for many years to come, the cutting edge of the energy transition will be the implementation of existing technologies in sectors where they are already cost competitive.

There are three main ways to reduce fossil fuel consumption: efficiency; decarbonisation of electricity; and electrification of end-use sectors.

3.2.1 Decarbonisation of electricity

The main new development over the last decade has been the falling cost of renewable electricity from solar and wind, and the widening range of what share of electricity can come from variable renewable sources.

In 2017, 10% of electricity (measured by TWh) came from hydro, 16% from nuclear and 2% from biomass. Solar and wind provided 6% of the total. As we noted in 'Myths of the energy transition: intermittency'[3], it is possible for solar and wind to increase (at lower cost) to 15%- 25% of the electricity provision of a nation, a share that is rising as experience grows.

That implies a global opportunity for a further 9-19% of electricity to come from variable solar and wind, using existing technology.

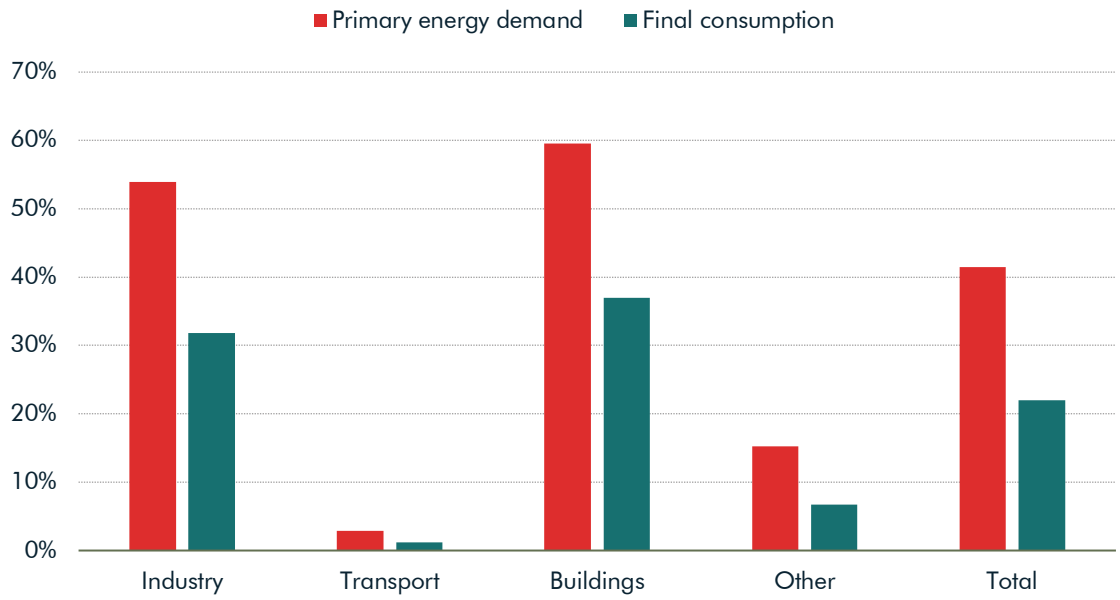
Electricity is the largest user of primary energy, using 38% of the total in 2017. So if 19% of this can be provided by renewables, that implies 7% of primary energy demand as an area of potential expansion.

[3] *'Myths of the transition: The intermittency of renewables prevents an energy transition', Carbon Tracker Analyst Note, November 2018. Available at https://www.carbontracker.org/myths-of-the-transition-intermittency/*

3.2.2 Electrification of end-use sectors

Electricity (with associated heat) already provides 22% of total final consumption in the main end-use sectors covered by the IEA, and nearly twice as much if we gross up the energy required to make the electricity[4].

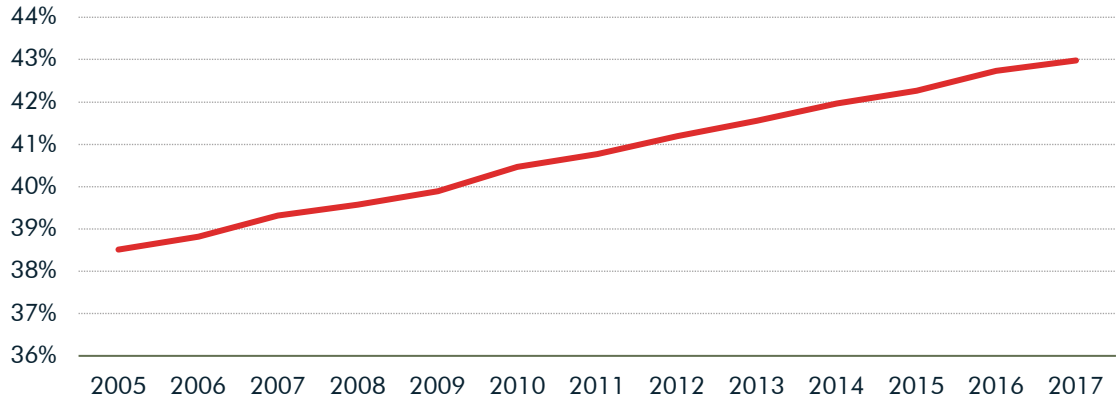
FIGURE 3- SHARE OF ELECTRICITY WITHIN END SECTOR 2017



Source: IEA WEO 2018. Total primary energy demand (TPED) calculations are done on a pro-rata basis

The share of electricity in primary energy demand has been rising over time. We show the share of primary energy demand accounted for by electricity, using the BP methodology and data, which are slightly higher than those used by the IEA, but still comparable.

FIGURE 4 - ELECTRICITY SHARE OF PRIMARY ENERGY DEMAND



Source: BP

[4] *Using IEA data, only 40% of primary energy inputs into electricity become final consumption of electricity and heat. The gap is thermodynamic losses.*

We can identify some specific sectors where electricity is likely to rise in the course of the next decade. In transport for example, it is likely that the over the course of the decade electric vehicles will become cheaper than internal combustion vehicles, opening up the global car fleet for replacement by electric vehicles. At the same time, electric drivetrains are moving into trucking. And there are areas such as home heating and low-temperature industrial heat that are opening up to electrification thanks to heat pumps.

3.2.3 The rising ceiling of the possible

It is therefore possible to work out how renewable penetration can expand into the hard-to-solve sectors. To illustrate this, we divide energy supply into four parts.

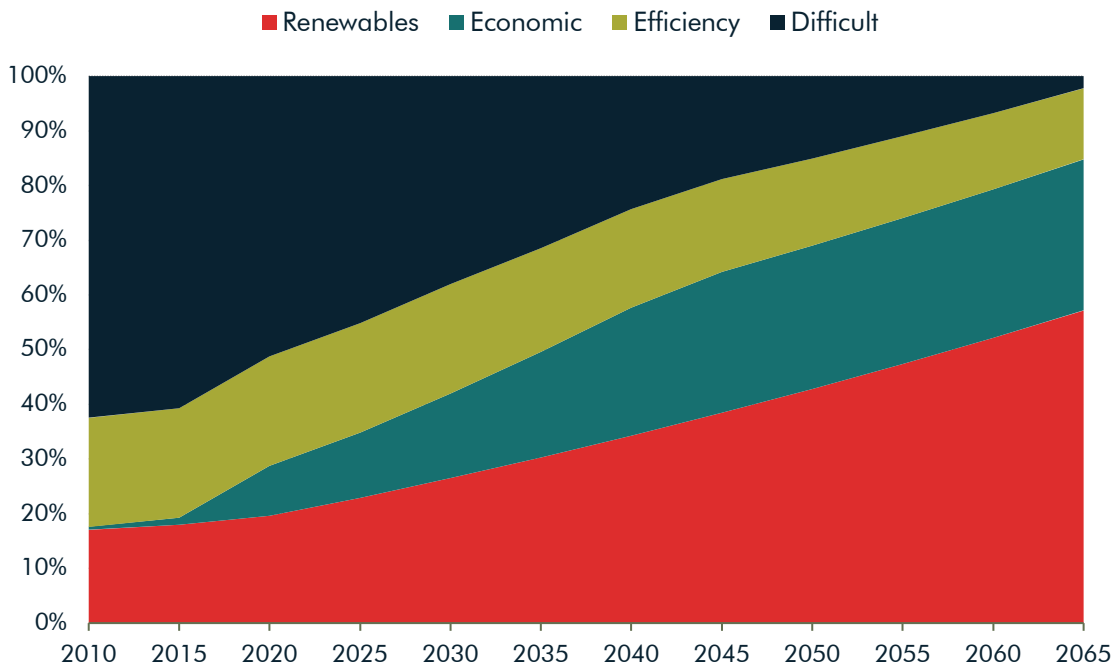
- **Renewables** – Where non-fossil technologies have been implemented.
- **Economic** – Where renewables are cheaper than fossils and can be implemented.
- **Efficiency** – A longstanding observation by the great Amory Lovins of the Rocky Mountain institute[5] is that there are many efficiency gains possible, but not necessarily taken. We make a blanket assumption of 20% of total demand, falling over time as opportunities are taken up.
- **Difficult** – The rest. Those areas (including the hard-to-solve sectors) where it is not currently possible to implement renewables because costs are too high, or technology does not allow it.

As matters stand today, around 20% of primary energy supply comes from non-fossil sources. The fall in solar and wind costs has opened up a further 7% of supply to renewable solutions as we saw above. Given other low-cost opportunities such as home heat electrification, we may conservatively say that 30% of primary energy supply could today be provided by renewables at lower cost than fossil fuels.

If we then assume that engineers keep increasing what share of electricity can be deployed from variable renewables and that falling battery costs open up the transport sector to electrification, we end up with a chart like the one below. What is interesting about this is not so much the spot forecasts as the observation that the cutting edge of the energy transition is the implementation of known technologies in sectors where renewables are already cheaper than fossil fuels. Moreover, the share of energy where renewables can be developed economically is likely to continue to increase more rapidly than implementation. The reason why is clear – it is faster for engineers to reduce the price of renewable technologies than to install them at massive scale.

[5] *'How big is the energy efficiency resource', Amory Lovins, 2018.*

FIGURE 5 - SHARE OF ENERGY SUPPLY FROM NON-FOSSIL SOURCES



Source: Carbon Tracker

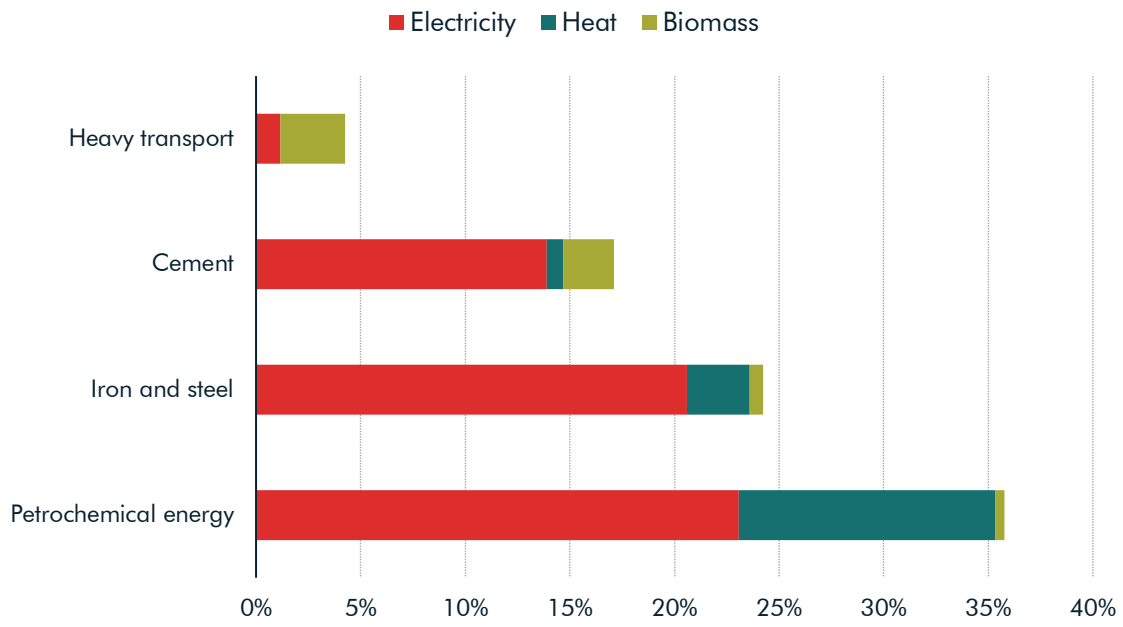
The implication is that the hard-to-solve sectors are not an impediment to change. By the time implementation catches up with them, technology will have shifted the ceiling still higher. This is not in any way to belittle the importance of innovation or the importance of thinking today about the problems to be faced in the decades to come. Both are necessary, but the existence of the hard-to-solve sectors is no impediment to the energy transition for many years.

3.3 Technology has solutions for the hard-to-solve sectors

3.3.1 Solutions exist today

Even in the hard-to-solve sectors, a certain share already comes from electricity, heat and biomass. For example, 23% of total final consumption in the energy part of petrochemicals comes from electricity, and a further 12% from heat. In the iron and steel sector, electricity is already 21% of total final consumption.

FIGURE 6 - SHARE OF TOTAL FINAL CONSUMPTION 2017



Source: IEA

3.3.2 Soluble subsectors

Even in the sectors where solutions are expensive or difficult today, technology is chipping away at the problem in some of their subsectors. An excellent example of this happening in the past is the transport sector. Electric drive trains were cost-effective first on bicycles, and then on city buses and then on cars. In recent years they have shifted to delivery trucks and medium sized trucks. Subsectors within the hard-to-solve sectors that are being targeted first for electrification include:

- Delivery vans and short-distance trucks such as those made by Chanje.
- Domestic shipping such as cruise ships.
- Short-haul planes.
- Energy (rather than feedstock) in the petrochemical sector.

3.3.3 The ETC solution

The Energy Transitions Commission (ETC) has written an excellent series of papers[6] on how to decarbonise each of the main hard-to-solve (called by them 'harder-to-abate'[7]) sectors, and we summarise their key points below.

There are three main solutions in each area:

- **Reduce end demand** – Better design of end products, recycling, sharing.
- **Efficiency** – Improve the efficiency of existing engines, reuse energy,
- **Decarbonisation** – As detailed below.

[6] *'Mission Possible. Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century', Energy Transitions Commission, November 2018. Available at http://www.energy-transitions.org/mission-possible*
[7] *For non-English speakers we have elected to use the terminology 'hard-to-solve'.*

And in turn, decarbonisation splits into:

- **Electrification –** EV batteries, electrolysis, furnace electrification.
- **Hydrogen** – Using hydrogen as a heat source and in fuel cells.
- **Biomass** – Using biomass for heat and as feedstock.
- **CCS** – Used sparingly with the fossil fuels it is most expensive to replace.

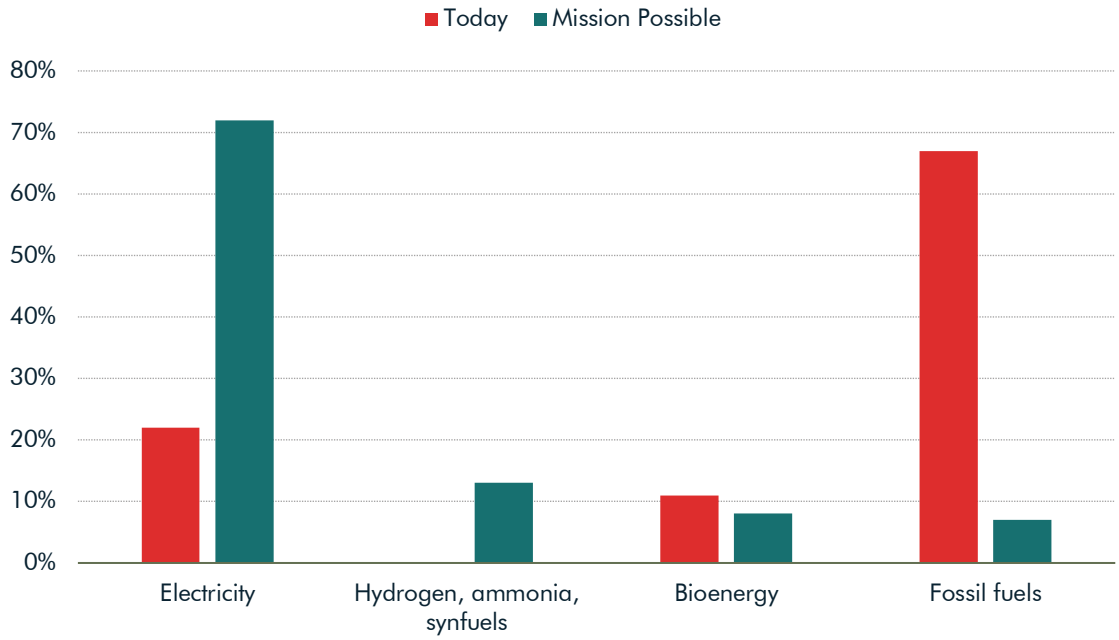
TABLE 1 – ENERGY TRANSITIONS COMMISSION SECTOR SOLUTIONS

Area	Cement	Steel	Plastics	Heavy road	Shipping	Aviation
Demand solutions	Design. Reuse. Substitute.	Recycle. Share. Lightweight	Ban single use. Recycle	Logistics efficiency. Modal shift	Voyage optimisation	Modal shift. Air traffic management
Efficiency solutions	Dry kilns	Gas reuse	Naphtha catalytic cracking	Engine efficiency. Aerodynamics and tyre design	Ship design. Wind assistance	Aircraft design. Engine efficiency
Electrification	Kiln electrification	Electrolysis of iron	Furnace electrification	Electric battery vehicles	Electric battery for short haul	Synfuels
Hydrogen	Heat source	Reduction agent and heat source	Heat source	Fuel cells	Ammonia or hydrogen in engine	Hydrogen for short distance
Biomass	Biomass for heat	Charcoal	Biomass for heat; biomass feedstock	Biofuel (transition fuel)	Biofuels	Biofuels
CCS	Yes	Yes	Yes			

Source: Energy Transition Commission, Carbon Tracker annotations

The ETC calls their 2050 solution 'Mission Possible'. According to this, the overall solution is one where electricity replaces fossil fuels as the primary energy source. Biomass is around the same share as today, but used in a more targeted manner to focus on those areas least amenable to replacement by other renewables. And hydrogen (with some contribution from ammonia and synfuels) is used to fill in the gaps. There is still a small role for fossil fuels, with CCS.

FIGURE 7 - FINAL ENERGY MIX FOR ALL SECTORS 2018 AND 2050

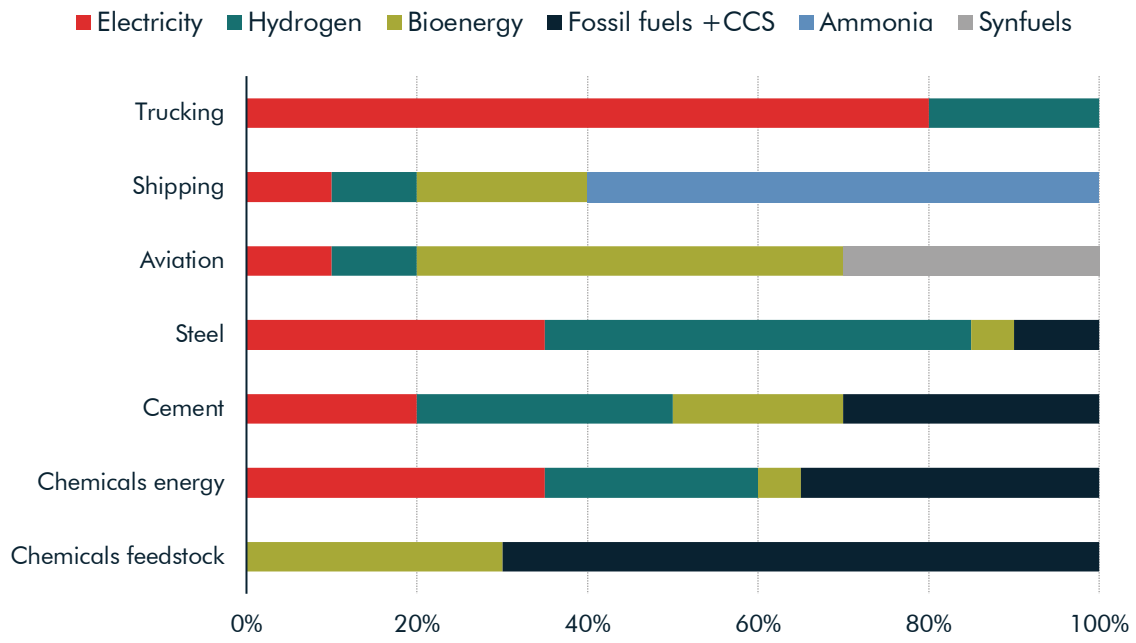


Source: ETC, IEA

The solution for each of the hard-to-solve sectors is then set out below with the share of final demand by technology

- **Trucking –** Primarily EV drivetrains, with some hydrogen for the heaviest areas.
- **Shipping –** Mainly ammonia (a fuel derived from hydrogen from the electrolysis of water), with some room for electricity, hydrogen and biomass.
- **Aviation –** Mainly bioenergy, with some room for hydrogen and electricity.
- **Steel –** A combination of electricity and hydrogen.
- **Cement and chemicals –** Mainly electricity and hydrogen, with some room for fossil fuels with CCS.
- **Chemicals feedstock –** Mainly fossil fuels with CCS, with some bioenergy.

FIGURE 8 - FINAL ENERGY MIX BY SECTOR 2050E



Source: ETC

3.3.4 Other solutions

One criticism of the ETC solutions has been that there is a cost involved in their implementation, calling into question whether or not this would happen. However, they also note that the winning technologies are not yet clear, and that it will be necessary for the various different avenues to be tried.

For example, much cheaper solar and wind (less than $20 per MWh) combined with cheap electrolysis (under $250 per KWh) and low hydrogen transport costs would open up large new markets for hydrogen, as explored in the Power to X report[8]. Or the solution may come from cheaper CCS technologies or better ways of increasing the share of electricity in each sector. It will be up to innovators and entrepreneurs to come up with solutions, and it is in reality somewhat premature for financial markets to worry about how to solve the last piece of the puzzle from the perspective of 2018. Few people, faced with the same question a decade ago, thought that the costs of solar, wind and batteries would fall as they did.

However, even on today's numbers, around half (trucking and low-temperature heat) of the remaining 21% of primary energy demand required by the harder-to-abate sectors is likely to have solutions which do not incur additional economic costs. As technology evolves, so the share of really expensive problems will shrink.

[8] *'Power to X', World Energy Council, 2018.*

3.4 Decline elsewhere outweighs growth in the hard-to-solve sectors

Energy systems are of course extremely complex. They have many parts where demand is rising and other parts where it is falling. To state the obvious, the question is not whether demand is increasing in one part but whether it is increasing or falling in aggregate.

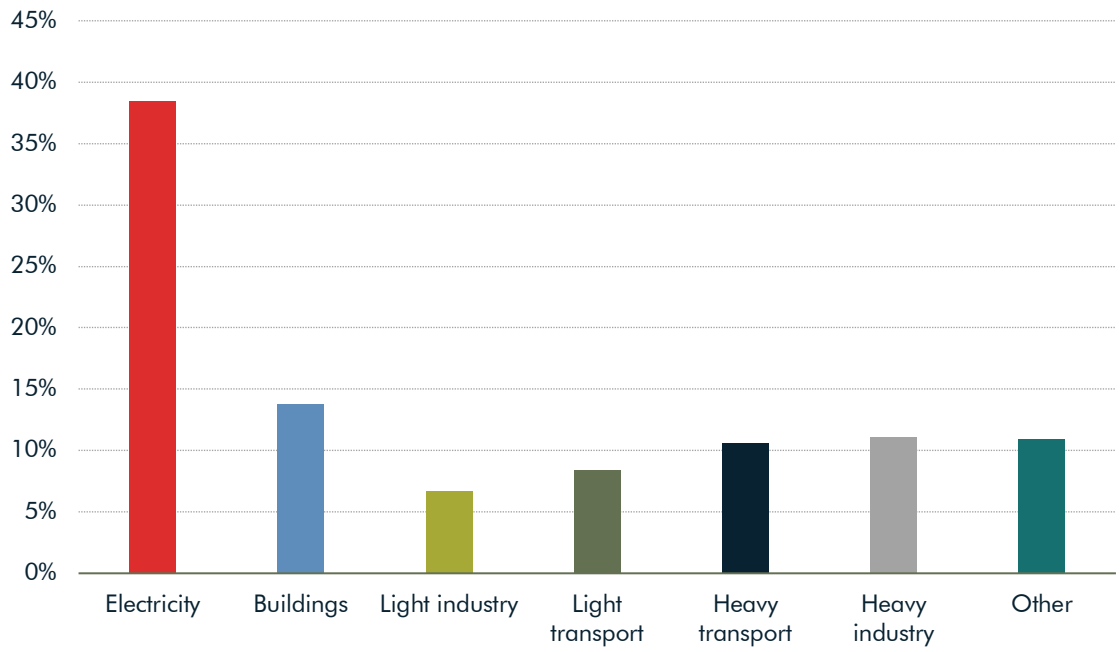
A useful analogy can be taking from dieting. Fossil fuels can be seen as cheeseburgers, chocolate and other delights, renewables as vegetables, and efficiency as exercise. Readers will appreciate that it is possible to lose weight in a number of different ways. You can increase your chocolate consumption but still lose weight if you eat less cheeseburgers and do some exercise.

The challenge is to work out whether those sectors where your fossil fuel consumption is rising outweigh those where it is falling.

3.4.1 The easier-to-solve sectors are much larger

Those sectors where renewables and/or electricity have room to expand are much larger than those where they will struggle. Electricity alone is 38% of the primary energy demand. It is possible to increase electrification using current technology in buildings, light industry and light transport (a further 28% of primary energy demand).

FIGURE 9 - SPLIT OF TOTAL PRIMARY ENERGY DEMAND 2017



Source: IEA WEO 2018

Most growth comes from electricity

Most of the growth in demand for energy is from the electricity sector, which is where renewables have most room to grow. It is easy to calculate this in simple terms. Electricity makes up nearly 40% of total primary energy demand, and is growing at 2-3% a year. If total energy demand growth is just 1%, then there is no room for net growth from the other sectors. Clearly the detail is more complex than this, but it is notable for example that BP forecasts 70% of the increase in primary energy demand to 2040 to be for the generation of electricity and the IEA forecasts 46%.

4 Reality

The hard-to-solve sectors are no barrier to an energy transition. They are problems which will need to be solved over time. We already have enough solutions to drive a near-term peak in fossil fuel demand and to embark far down the route of declining demand. And as technology evolves, so we are likely to be able to solve the hard-to-solve sectors during the endgame phase of the energy transition.

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