Solving Global Energy Challenges

OUTLOOK 2020

Contents:

Our planet has vast areas of semi-arid land that could be converted into agro-forestry. This would make carbon sequestration from the atmosphere possible, while improving farming capabilities in the most vulnerable regions.

#0

Welcome to Solve Global Energy Challenges

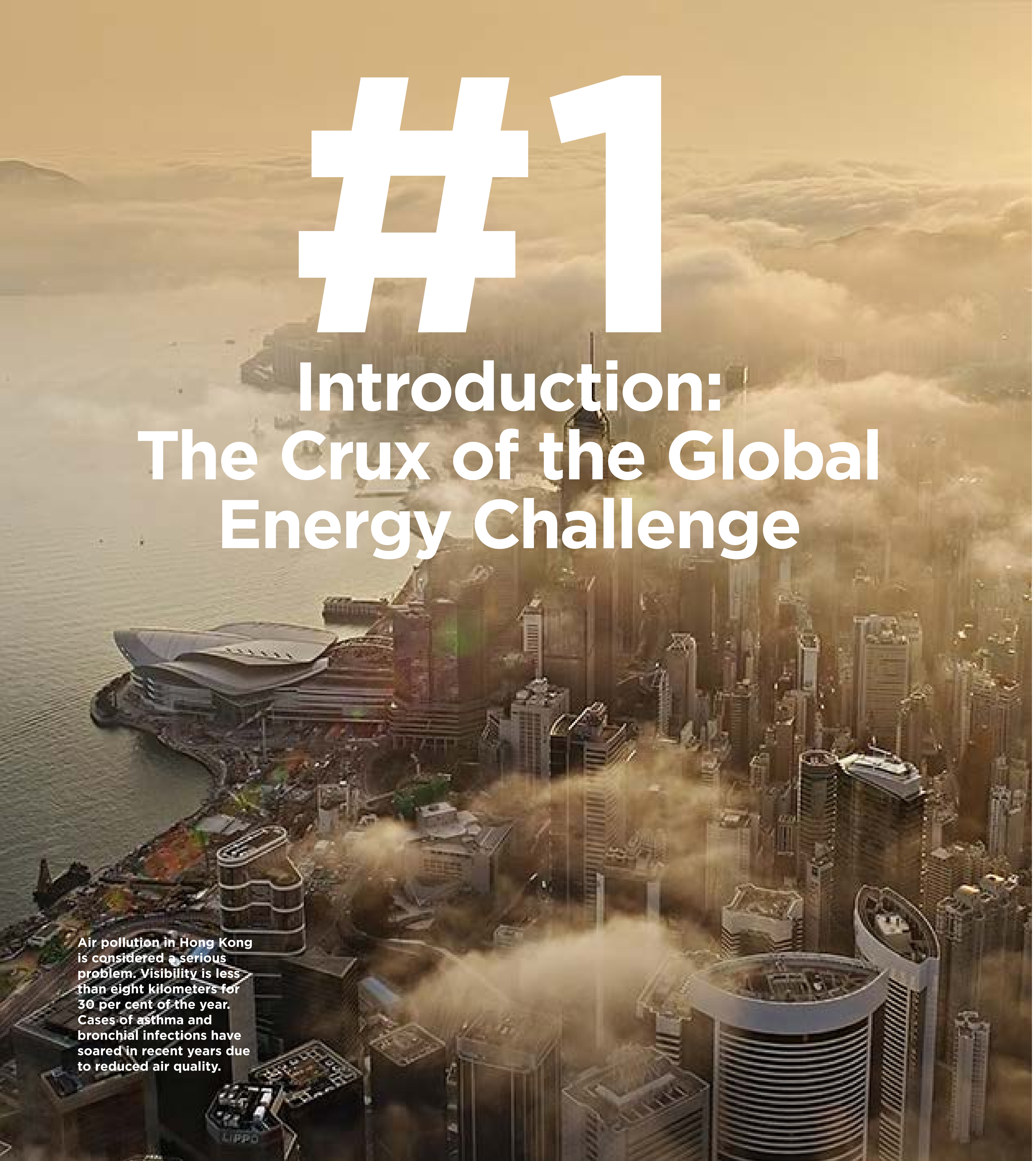
This document aims to give the ‘bigger picture’ on climate change, global energy challenges and consider how we can reverse the situation.

We will demonstrate how complex an issue climate change is, and that there’s no single solution that will solve the problem. Energy is at the core of the matter. Therefore, this document will consider the complexity of the energy system and how it needs to be changed a bit at a time, in conjunction with the continuation of our modern life on this planet.

Most of the data in this document is taken from respected sources like IEA and IPCC and is used with the intention of delivering the core messages. Any actions taken should be derived from science and research-based knowledge, and must focus on delivering global solutions to the global energy and climate challenge.

The ideas and solutions presented in this document will focus on total life cycle emissions. This is the only way to have meaningful solutions with positive impact. All other ways are a suboptimisation of the problem.

Our vision is to be the leading CO_2 -aware producer and seller. This means that we solve global energy challenges in a way that enables societal and climate well-being now and in the future. All our actions are aimed at positive societal impact.



Air pollution in Hong Kong is considered a serious problem. Visibility is less than eight kilometers for 30 per cent of the year. Cases of asthma and bronchial infections have soared in recent years due to reduced air quality.

The business of powering our everyday needs in regional silos has come to an end. The climate emergency has changed this. The energy challenge that we and future generations face, if not solved quickly, will have serious consequences.

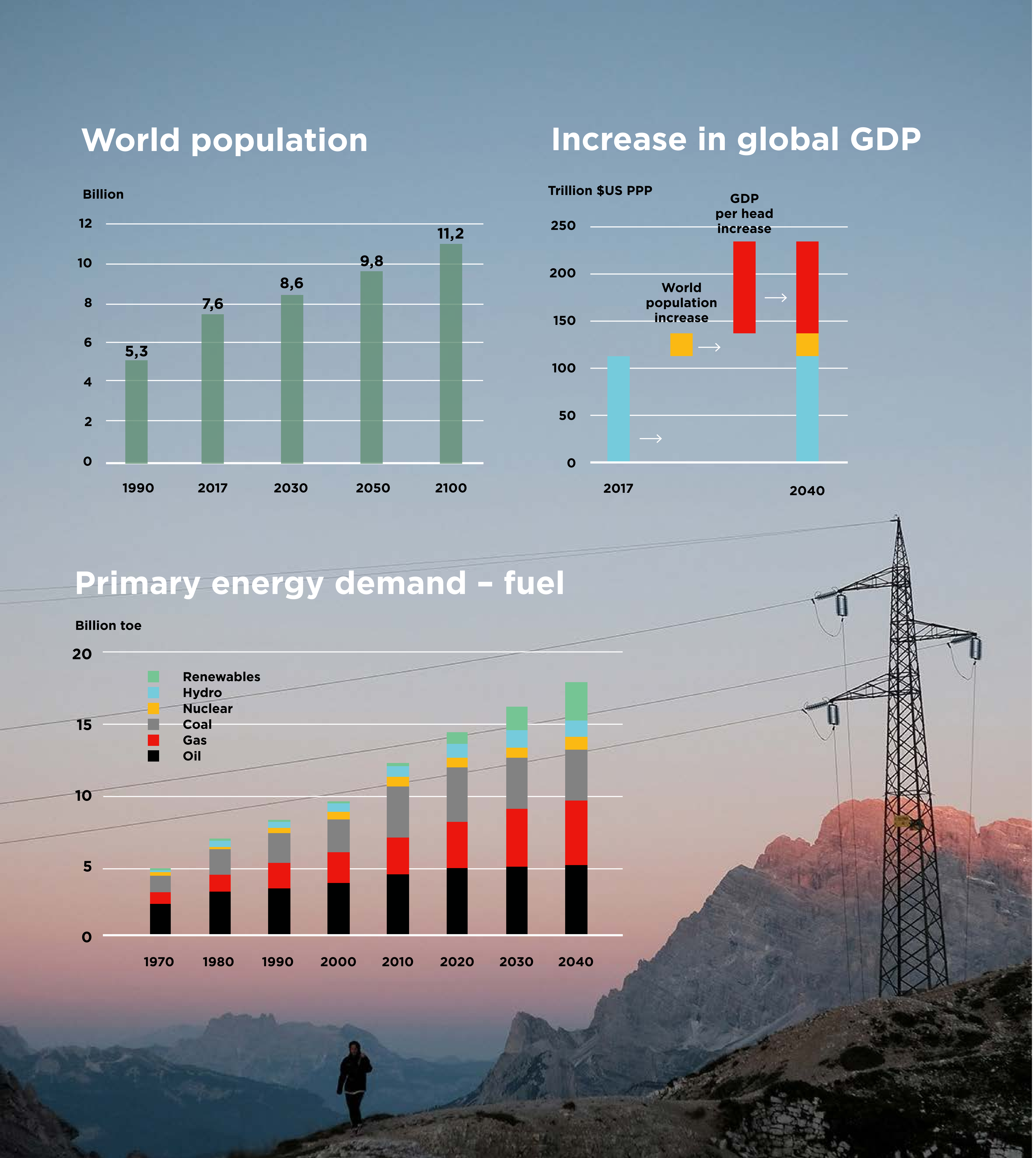
Where problems once used to be geographically restricted, climate change is turning out to be a global and unprecedented challenge for humanity. The issue we are facing is all about an excess of gases accumulating in our planet's atmosphere. Neither greenhouse gases nor trapped heat are restricted by national borders, fences and checkpoints. Rather, they distribute evenly everywhere, causing problems for us all – especially for future generations. We cannot afford to delude ourselves, we cannot solve this challenge at a local level. We must show solidarity and cooperate on a global level.

There is too much CO_2 in the atmosphere, and given that the major part of this CO_2 originates from our energy system, there is a need for radical changes. Such a makeover demands international cooperation on a scale that we are not used to, open-minded solutions that work, and a willingness to act fast. The energy sector hasn't historically been the quickest to transform itself – rather opting for incremental changes and improvements.

We no longer have the luxury of the option of incremental change, and slow and steady won't achieve the results we need.

As with all global emergencies, this one requires a global perspective. Our consumption of fossil energy keeps growing, when it should be decreasing dramatically. We are still adding carbon into the atmosphere, and not removing it. A global point of view also tells us that we must start working together across and beyond national and regional borders. Greenhouse gases do not adhere to any administrative and theoretical borders. Our solutions should be just as transgressive.

Over the coming decades we need to make wise political decisions, and reach conclusions backed by verified science. Disruptive and smart innovations, and individual consumer choices will also push companies in the right direction. We do, however, have a long way to go. The situation is critical and various future forecasts continue to create additional causes for alarm.



The population and GDP growth dilemma
Though the annual growth rate of our population has been declining compared to the recent past, (currently around 1%), there will still be around 81 million newcomers into this world – annually. It is hard to comprehend that there are currently over 7.7 billion of us inhabiting this planet as we speak, and by 2057 there will be 10 billion. That's far more than our planet can endure with the current situation. Simultaneously, we're facing a socioeconomic challenge to provide the whole population with similar living conditions, and possibilities for financial stability. The global population is growing, and so are the standards of living. Our global gross domestic product (GDP) is expected to double by the year 2040, but as GDP does not take into consideration welfare distribution, this is not to say that a global increase in living standards is equally distributed. The big drivers for both global population and GDP growth will be emerging markets and developing economies, especially in Africa and Asia.

This imbalanced development has consequences for our energy systems and provides us with a dilemma in terms of energy efficiency, and a need to transition towards a more sustainable energy mix.

An increase in people with higher standards of living creates a higher global energy consumption.

Likewise, as more infrastructure is needed for this population growth, more energy will be consumed globally, because each one of us consumes energy and wants to have a roof over our head, and goods and services to support our living. Addressing the carbon intensity of this additional energy should be one of our most fundamental priorities.

Primary energy consumption and CO_2 emissions
We all need energy – it is that simple. According to the International Energy Agency (IEA), our global energy consumption grew by 2.3 per cent in the year 2018 – faster than ever – resulting in higher global CO_2 emissions. As the consumption of energy rose, so did the demand for primary energy sources like coal, oil and natural gas. Although there's been a significant increase in the use of renewable energy sources, the increase in demand was primarily met with fossil energy.

According to IEA, global energy-related CO_2 emissions in 2018 were the highest ever, approximating 33.1 gigatons (Gt). In 2019 the emissions flattened at around 33 Gt.

Energy-related CO_2 emissions by sector

Power 39%
Industry 24%
Transport 23%
Buildings 9%
Other 5%

We've outlined, in the premise of our report, the global energy challenge we see as an energy company. In the following chapters, we'll delve into these rather concerning issues in more detail, but we shall also explore possible solutions.

#2

Homo Flammabus Caused an Unsustainable Carbon Cycle

In 2019, online platform Global Forest Watch Fires (GFW Fires) counted over 4.5 million fires worldwide that were larger than one square kilometer. The reasons fires start and take hold in the first place are complex. But experts are now suggesting that the increasing risk of wildfires and warmer ocean temperatures could be a direct result of climate change.

Our behaviour lies at the root of our energy challenge and the increasing population, economy and energy demand multiply its effect.

Carbon is the basic source for material and energy. In its natural state, carbon circulates between the land, the atmosphere and the ocean. It's one of nature's oldest substances, and every living being depends on it. Through photosynthesis, nature has found an incredible way of distributing this carbon evenly, keeping everything and everyone on our planet alive. Nature captures significant storages of carbon into its biomass, soil, oceans, and fossil raw materials. This is called the carbon cycle, and it remains sustainable only when the uptake and release of carbon are balanced.

Here is where humans come into the picture. Ever since our species discovered fire, throughout the industrial revolution and even to this day, we have disturbed the balanced carbon cycle of nature.

Our societies have developed based on our addiction to burning carbon.

This addiction has resulted in excess amounts of carbon being released into our planet's atmosphere, and over time we have created a significant dent in the initially sustainable carbon cycle. This carbon is now stored in the atmosphere in the form of CO_2, disturbing our nature and causing our climate to change dramatically.

As we humans are addicted to burning, a more adequate name of our species could be Homo Flammabus.

Human activities that underpin the unsustainable carbon cycle can be divided into three main categories:

- Fossil energy and material use
- Deforestation and land use change
- Consumption behavior

We have become very skilled at refining fossil energy – specifically crude oil. Our efficiency improvements have kept the energy prices low and given our consumption habits room to grow. In our eagerness for cheaper energy, we've completely forgotten to calculate the climatic cost and factor it into the price. Changing our consumption habits would require a change in how we view and value energy. The price of fossil-based energy should reflect the costs that it inflicts on our carbon cycle and our climate. Unfortunately, as a result of what we call the distillation curve challenge (see chapter #5), an immediate reduction of all our fossil-based products is unlikely.

Unsustainable carbon cycle

Ton of carbon= 3.67 tons of CO_2 – All figures are in billions of tons

As the amount of excess carbon in the atmosphere is currently approximately 200 to 300 billion tons, we need to start capturing carbon from the atmosphere in addition to controlling the increase of carbon with emission reductions.

A. Nature has it's balance in plant and ocean cycle
B. This balance has been disturbed by deforestation and land-use change resulting in carbon leakage from land
C. Fossil fuels and fossil industry are amplifying this imbalance which causes unsustainable carbon cycle

Budget imbalance 1 Gt due to roundings

#3 Climate Changes Everything

The Atlantic Forest in Brazil has ecoregions within the following biome categories: seasonal moist and dry broad-leaf tropical forests, tropical and subtropical grasslands, savannas, shrublands and mangrove forests. The Atlantic Forest is characterised by a high biodiversity and endemism.

There are good reasons to believe that current policies and mitigation tools are far from what we need. They are not strong enough to achieve the objective of the Paris Climate Agreement of limiting global warming to well below 2°C.

Climate change is the biggest problem facing humankind, as it's leading to rapid and dramatic changes in our planet's ecosystem.

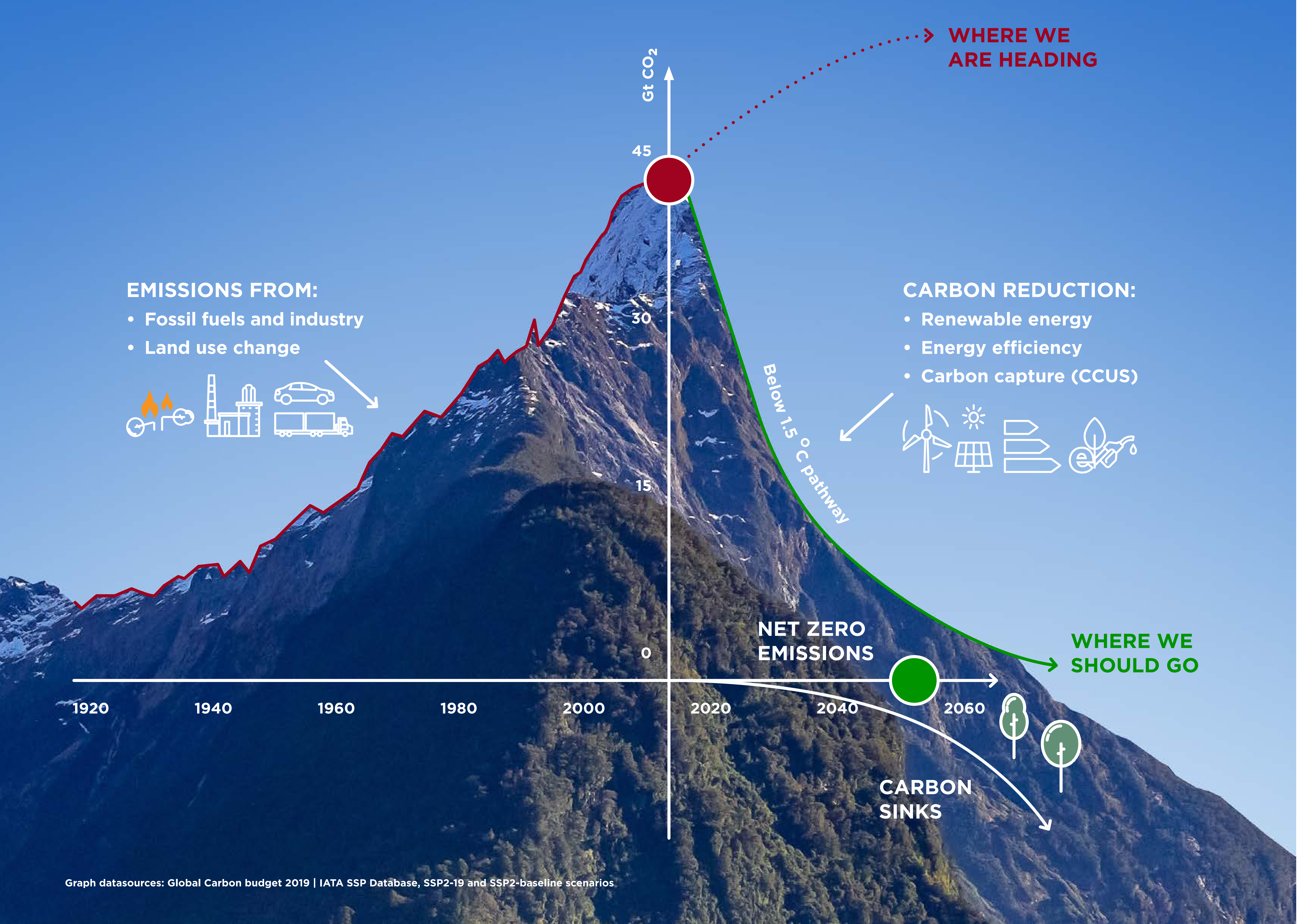
A special report by the Intergovernmental Panel on Climate Change (IPCC) confirms the impossibility of achieving the objective of limiting global warming with the current means. It highlights that the necessary range of solutions requires carbon sinks, such as new forests. UNEP's Gap Emissions Report states the same and describes how far we are from achieving our goal. We've been living on carbon credit instead of carbon debit, and we continue to do so.

To achieve our goal of limiting the temperature increase to below 2°C, or the even more ambitious goal of 1.5°C, our CO_2 emissions must be almost halved from 2010 levels by 2030. This means we have less than a decade to carry out the corrective actions needed. It's clear, that in order to reach the targets reducing emissions is not enough – **we need to balance our debt by removing the already emitted CO_2 from the atmosphere.**

Global climate is a highly interconnected and complex system that includes dynamic processes between the atmosphere, the ocean and the soil. Change in one part of the system usually influences the other parts as well and may lead to self-enhancing developments such as the ice-albedo feedback process (the melting of the polar caps).

Interconnectivity of the climate system can be seen in key climate indicator statistics. Greenhouse gas levels in the atmosphere are higher than ever before, which has led to recent all-time high records in global mean surface temperatures and ocean acidification. As the ocean absorbs heat trapped in the system, the ocean heat content has increased. This in turn leads to a sea level rise, which is further increased by the melting of polar ice. These changes have an impact on weather, resulting in an increase in heavy precipitation, heat waves and droughts. Another severe consequence is biodiversity loss, which has knock-on effects on important ecosystem functions. Climate change is reducing

ILLUSTRATIVE PATHWAY OF GLOBAL NET CO_2 EMISSIONS LIMITING GLOBAL WARMING TO 1.5 °C



Graph datasources: Global Carbon budget 2019 | IATA SSP Database, SSP2-19 and SSP2-baseline scenarios

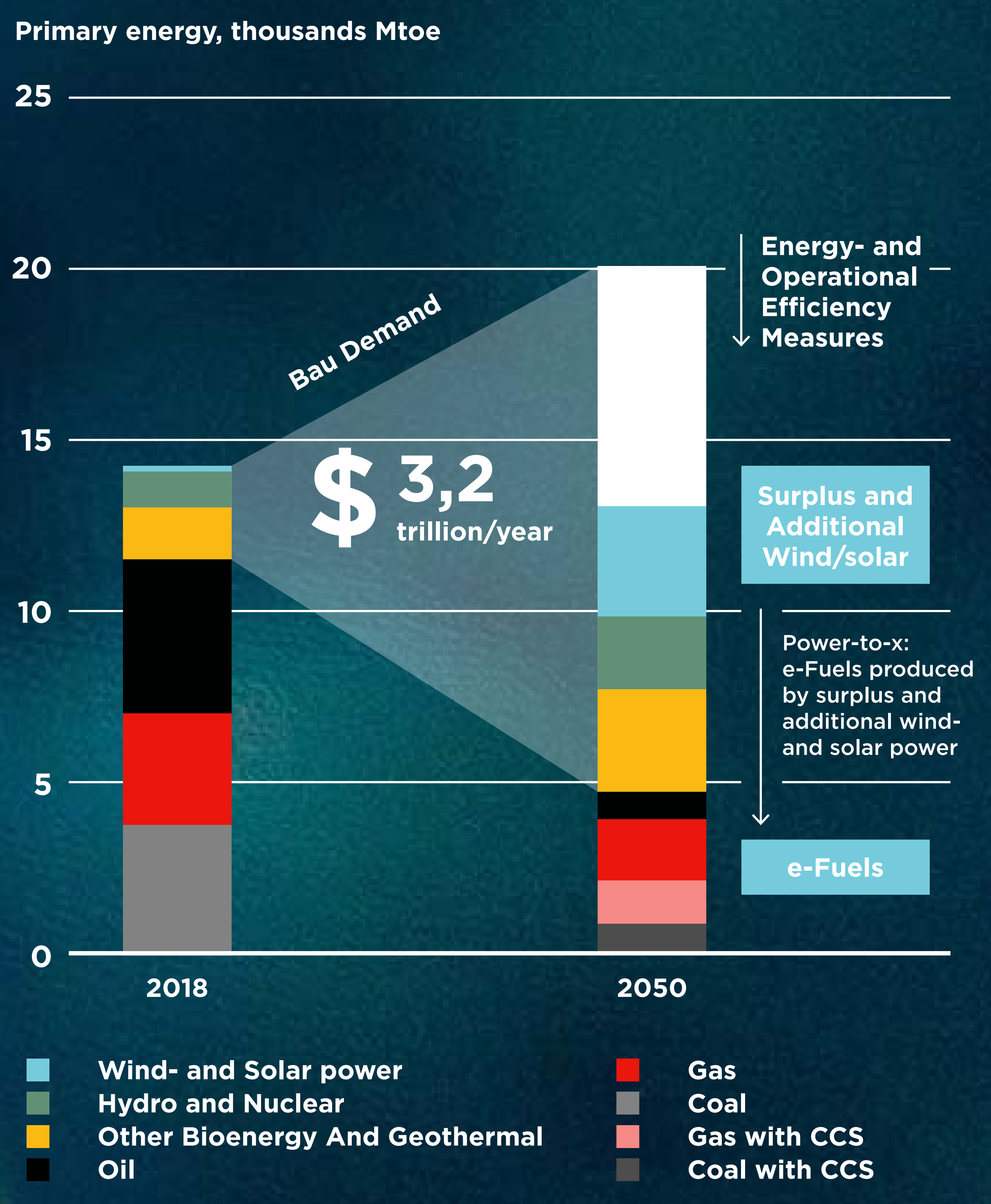
biodiversity, and biodiversity loss is crippling nature's ability to adapt to climate change. In other words, the current species – flora and fauna – inhabiting this planet are incapable of responding to such a dramatic change in time.

Left unchecked for long enough, the climate will reach its so-called tipping point, where reversing the process is no longer possible despite significant efforts.

The climate is a complex and intertwined ecosystem which is being altered by our emission of greenhouse gases. Keeping this and the above-mentioned complex causality chains in mind, it's clear that the energy sector plays a central role in combatting climate change. Energy accounts for two-thirds of total greenhouse gas emissions, which is why we must concentrate our efforts on measures that focus on reducing emissions from the energy sector.

#4

A Road We've Not Yet Taken Is the Way



Major rebalancing of investments from fossil fuels toward renewables is needed. The annual growth in renewable energy needs to be 10 times higher than today for replacing the use of fossil energy.

The decisions for tomorrow are made today. Currently, we're on track to produce more fossil fuels by 2030 than is required for keeping global warming below 1.5°C or even 2°C.

Investments are the lifeblood of the global energy system and will eventually determine how successful we are in changing it into a less CO_2-intensive one. There's a monumental gap between the flexible, renewables-driven and CO_2-aware energy system we need, and the reality of today's energy system in which reliance on fossil fuels remains stubbornly high. The green energy transition we've been talking about for some time is disappointingly slow. Annual energy sector investments amount to about $2 trillion, which provides an important indicator of the way the system is evolving. In recent years, most of these investments have been related to the supply side of fossil fuels. Between 2014–2018, average annual investments in fossil fuels have been about $1 trillion, while investments in renewables have been some $0.3 trillion.

> **We will need to see a major rebalancing of these investment flows from fossil fuels toward renewables, energy efficiency and low-carbon technologies.**

Unfortunately, current country commitments are not in line with the requirements necessary for an energy system transition. The Nationally Determined Contributions (NDCs) made under the Paris Agreement and domestic energy policy plans fail to bring about a sufficiently rapid transition. Based on the IEA Stated Policies Scenario, these commitments will lead to a steady increase of energy-related CO_2 emissions. Such a trajectory is consistent with limiting the temperature increase to below 2.7°C above pre-industrial averages with a 50 per cent probability, or below 3.2°C with a 66 per cent probability. Moreover, based on UNEP's most recent Production Gap Report, countries are planning to increase fossil fuel production to levels that exceed those consistent with fulfilment of their nationally determined contributions. This overinvestment in coal, oil, and gas supply locks in place a fossil fuel infrastructure, that will make emissions reductions even harder to achieve.

Investment patterns must change. Based on the International Renewable Energy Agency's (IRENA) Energy Transformation scenario, $3.2 trillion (2 per cent of global GDP) must be invested annually for the next three decades in renewables, energy efficiency measures and end-use electrification to achieve the required low-carbon energy transition. This is about $0.5 trillion more than in the current plans. These investments include investments in wind- and solar-based power generation capacity, power grid extension and reinforcement, energy efficiency efforts in end-use sectors, electrification of end-use sectors, as well as direct applications of renewables. In IRENA's scenario, the annual average fossil fuel investments over the same period must fall to $0.5 trillion – about half of what fossil fuel investments have been in recent years.

#5

There's a Curve We All Should Be Watching

THE DISTILLATION CURVE CHALLENGE

Direct electrification of the road transport sector is a positive development, but it does not really address the global energy challenge as it stands today.

The distillation curve challenge
As long as there's demand for oil distillates that drive up the overall demand for crude oil, battery electric vehicles will only be a 'patch' solution. Although they might be good for local pollution, it will be difficult to reduce global CO_2 emissions.

Crude oil refining always yields the same output, which we can divide into four groups:

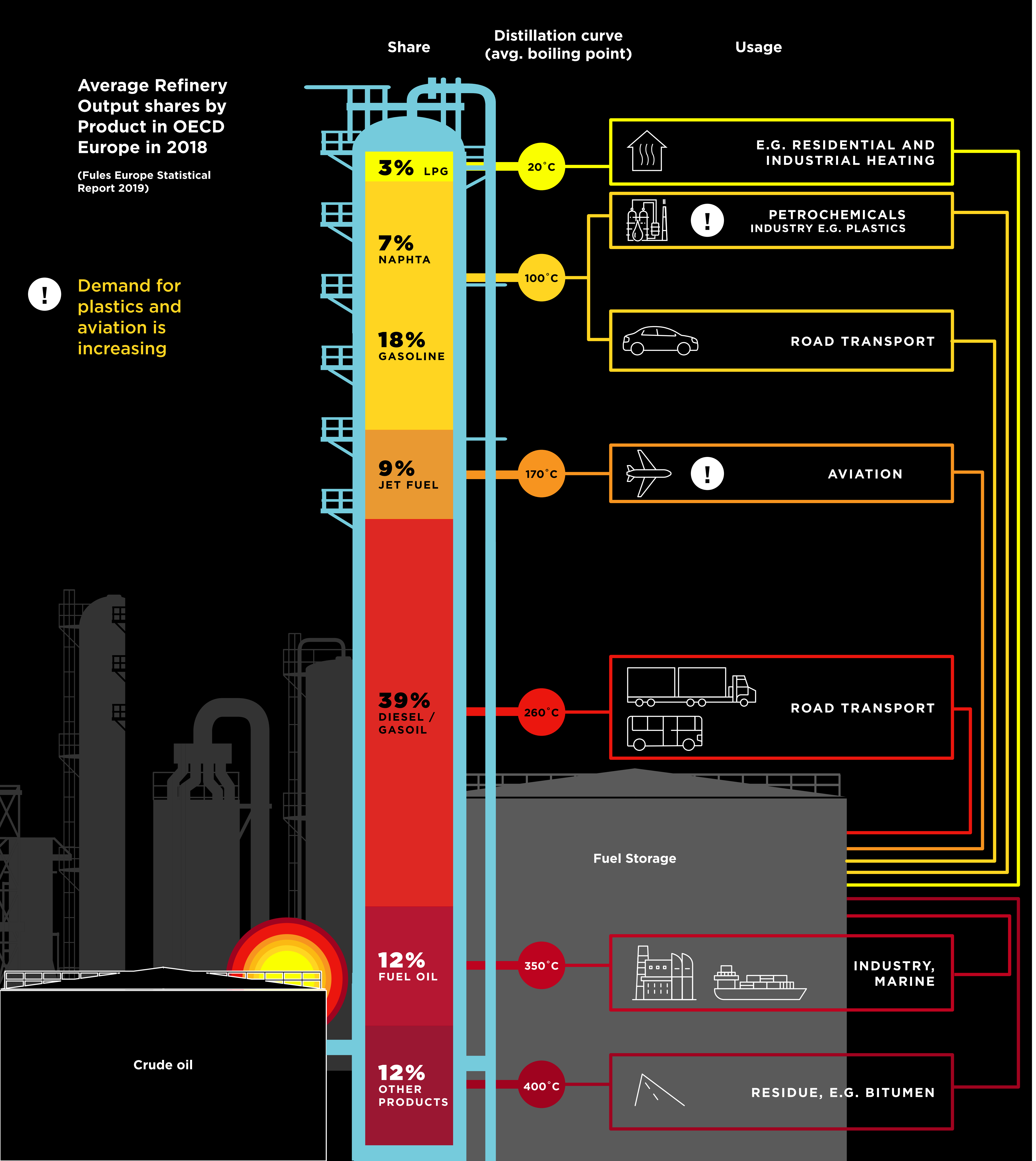
- Light distillates (liquefied petroleum gas (LPG), gasoline, and naphtha)
- Middle distillates (kerosene, jet fuel, diesel and gasoil)
- Heavy distillates (fuel oil, bunker fuel, lube oil, residual fuel, vacuum gas oil (VGO))
- Residuum (bitumen for asphalt or production of roofing felt)

This is how hydrocarbons are refined and it has some direct implications for the decarbonisation of our energy system.

> **One unit of crude oil gives us the same fraction of each distillate group every time.**

So even if we reduce the demand for one group of distillates to zero, that group will still be produced if we produce any of the other groups. And if the demand for a distillate group goes up, then the production of all the other groups goes up as well.

To give an example: the demand for jet fuel (and therefore middle distillates) is increasing and is expected to continue to increase due to a growing global middle class travelling more, low oil prices and growing freight markets.



THE DISTILLATION CURVE CHALLENGE

In the worst-case scenario, the leftover distillates originating from the production of jet fuel would be burned to produce electricity, since they would not be used for meeting either of the demands.

This demand cannot be met without producing the other distillates. Let's imagine a world of a 100% electrified road traffic but with jet-fueled air traffic, and focus on this distillation curve challenge; in the worst-case scenario, the leftover distillates originating from the production of jet fuel would be burned to produce electricity, since they would not be needed for meeting the other demands. From the perspective of a refinery, these leftover distillates would be sold for a lower price and would end up in incineration.

The utilisation of different end products is regulated through legislative actions, resulting in an imbalance between supply and demand. As an illustrating example, let's look at the current situation of marine fuel production: The Sulphur Directive dictates the maximum sulphur content of the product utilised in marine fuels. This results in declining demand for marine fuel oil (a heavy distillate in the current distillation process), creating a situation where most refineries are still producing high sulphur content fuel oil without any market to sell it to. As the marine sector demand moves on from the heavy distillates to the middle distillates, the overall crude demand goes up. This is especially true when we look at the shift in the marine sector in combination with the increased demand for jet fuel, which is also a middle distillate. Instead of solving the "energy crisis" with this kind of limited scope, current legislative actions should perhaps consider the 'bigger picture' and all its consequences.

Climate policies must consider the implications and the consequences which a limited action might have on the system.

How then, do we curb the use of fossil crude oil? Reducing overall crude demand must be done either by replacing the current oil products – including the increased use of so-called bottleneck products which drive total crude demand – with sustainable alternatives. Alternatively, the crude oil intake into the distillation column must be replaced with synthetic and renewable crude oil.

A closer look at the challenges

25%

of global greenhouse gas emissions come from the industrial sector

95%

of transport sector emissions come from oil

90%

of heat production is based on non-renewable sources

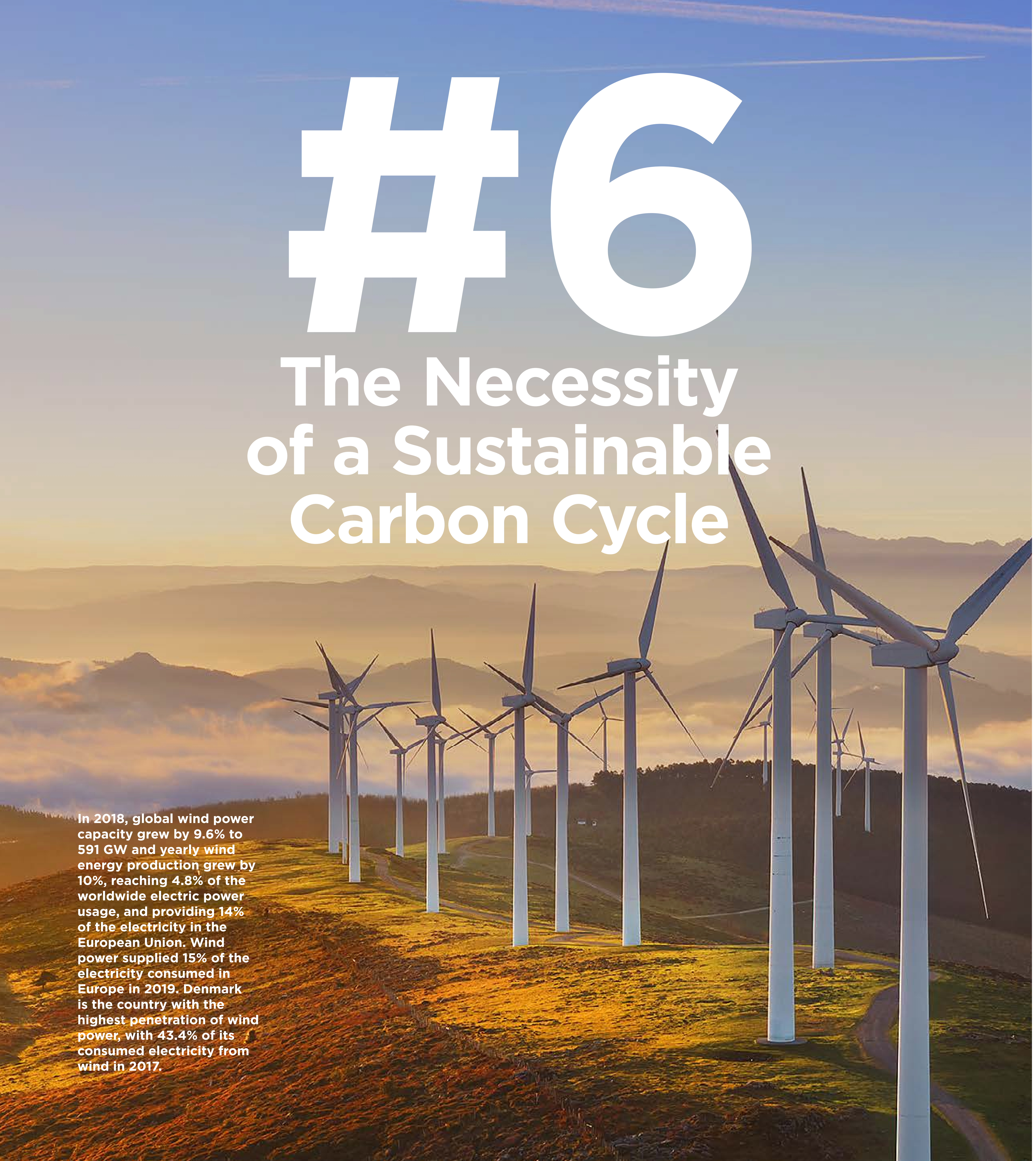
...and how to solve them

+200%

Increase in global wind energy capacity by 2030 compared to 2018

= 100 GW

Additional wind energy capacity each year for the next decade



#6 The Necessity of a Sustainable Carbon Cycle

In 2018, global wind power capacity grew by 9.6% to 591 GW and yearly wind energy production grew by 10%, reaching 4.8% of the worldwide electric power usage, and providing 14% of the electricity in the European Union. Wind power supplied 15% of the electricity consumed in Europe in 2019. Denmark is the country with the highest penetration of wind power, with 43.4% of its consumed electricity from wind in 2017.

What we need is a sustainable carbon cycle, that captures carbon and releases it back into the atmosphere in equal measure.

The key to a sustainable carbon cycle lies in reducing our ever-growing carbon debt.

We must both reduce the continuously growing emission of new carbon and simultaneously capture the already emitted carbon.

Our climate is like an overflowing cup and we need to stop filling it up quicker than we can drain it. Luckily, there are ways in which we can do just this, and the carbon that we have released into the atmosphere offers us opportunities we have not yet even fully grasped. We have an abundant resource at our disposal, which we can use to reduce the CO_2-intensity of our energy system.

Everything starts with the realisation that we can, in fact, reduce the amount of already emitted carbon by sequestrating CO_2 directly from the air, and at the same time displace fossil energy sources with renewables, and capture CO_2 from industrial processes. Figuratively, we can start emptying our already overflowing cup.

The great advantage of renewable energy production is that it emits very little fossil CO_2 into the atmosphere.

Bearing this in mind, the combustion-based energy production can be decreased, but for us to actually achieve our ambitious climate targets, the change should also apply to biomass-based energy. There are a few solutions that we can implement:

- Increase the share of wind power based electricity substantially
- Take advantage of geothermal heat, heat storages and excess heat from for example industry and data centres
- Produce solar energy in areas where the sun is shining

The advantage we can achieve through solar, hydro and wind depends on the commitment from the world's nations. It's also worth noting that different geographical regions have different conditions for renewable energy production. Solar energy is more suitable in the Mediterranean countries than in the Arctic region, and for wind power it's the other way around.

Nature can provide the negative emissions we need

Whatever the global community or the EU decides to do with continuously growing greenhouse gas emissions, we need to start sequestering the atmospheric CO_2 already emitted. It has to be done immediately and on an unprecedented scale. We must start paying the global carbon debt - now.

The good news is that we already have a well-functioning tool that's globally recognised: nature's ability to absorb carbon. As we live our daily lives, we emit carbon through our activities. We drive, we produce goods, we travel, we send packages around the globe. Whilst this is happening, nature – the soil, plants and trees – is absorbing a part of

Less than 1-year old is the Morigna Oleifera plantation - St1's afforestation pilot plant based in Morocco. This pilot is the first step towards creating a validated and approved tool for combating climate change through carbon sinks created via afforestation.

our emitted carbon. Not all of it, but a very crucial amount.

So, should planting trees and increasing forest plantation areas be considered as one of the solutions for climate change? The afforestation and reforestation possibilities exist and are already noted in every international climate agreement as efficient and cost-effective tools. This is good news! We are, unfortunately, extremely slow in deploying these methods.

In many areas, like the Nordics, the natural forests are still growing, and are, to a large extent, managed sustainably, and in East Asia, there is a tremendous increase in forest areas due to rehabilitation activities. Globally, however, we are moving in the wrong direction. Extreme weather conditions such as the devastating forest fires in Australia, and the constant increase in meat demand leading to Brazilian rainforests being burned for grazing lands, should already be forcing us to think. We need to preserve the 'lungs' of our Earth better. It is everyone's responsibility to acknowledge how our population growth, and therefore the increase in consumption, takes a toll on our planet. These consequences apply to us all, we need to understand that more sustainable living is needed.

Think Global - Act Global should be the new norm in our thinking

The carbon sequestration capability of a forest or a single tree depends on the age and the tree species. For this reason, the carbon sequestration capability of our carbon sinks should be highly important, and we should focus on increasing forest plantation areas in order to promote versatile, and effective, carbon sequestration. In order to make that happen, we should create incentivised mechanisms that promote this kind of vital development.

One way to incentivise nature-based carbon sequestration is to motivate the market and drive investments in carbon sequestration. We need mechanisms that promote sequestration efforts like afforestation, but today we do not have these tools in place. This however should not be the only solution to reduce our carbon debt, and it should not be a get out of other efforts for large emitters. If we are serious about restoring the balance to our carbon cycle, we need to consider and use all the means available. Nature is the oldest tool we have and we should utilise it.

In conclusion, for us to balance the carbon cycle we have disturbed during our anthropocentric era, we need behavioral change and systematic energy efficiency. Our current consumption patterns are overloading our very own planet and we need to change. Becoming more efficient in terms of societal energy and resource consumption gives us opportunities. Developing our energy intense processes to make them more efficient, and introducing more circular solutions to our current offerings gives us the potential to change the way we live. Imagine a world where we would not need to harvest or mine any resources for our production processes; a world where we have achieved a closed loop carbon cycle, and a resource efficient economy through the use of circular business models and efficient recycling methods. This world is completely plausible and achievable - it is up to us all to change the way we live and do business.

Sustainable carbon cycle

Massive investments for combatting climate change are needed in:

A. Carbon sinks
B. Carbon capture and utilization (CCU e.g. Power-to-X)
C. Renewable energy
D. Energy efficiency

#7 Electrification Needs Us to Combine Our Powers

Large-scale electrification is an absolute requirement for the transition toward a less carbon intensive energy system. And for large-scale electrification to happen, the big spenders of the energy sector must come together.

The production and consumption of energy are the fundamentals of an energy system. In between lies energy storage and energy distribution. There's much talk of energy production and consumption patterns, but the storage capabilities and the infrastructure needed for energy distribution are less discussed.

- Energy storages manage the inevitable imbalance between production and consumption. Energy demand is unstable and fluctuating, and the surplus of produced energy must somehow be stored. From an energy security standpoint, storages are also critical.
- The distribution networks deliver the energy to the end users. In the conventional fossil fuel-based energy system, where liquids are a primary energy carrier, fuel terminals and tanks at end-use points (e.g. service stations, terminals for marine and aviation and fuel tanks at industry sites) serve this role.

As we move toward a cleaner energy system, renewable electricity plays an increasingly important role.

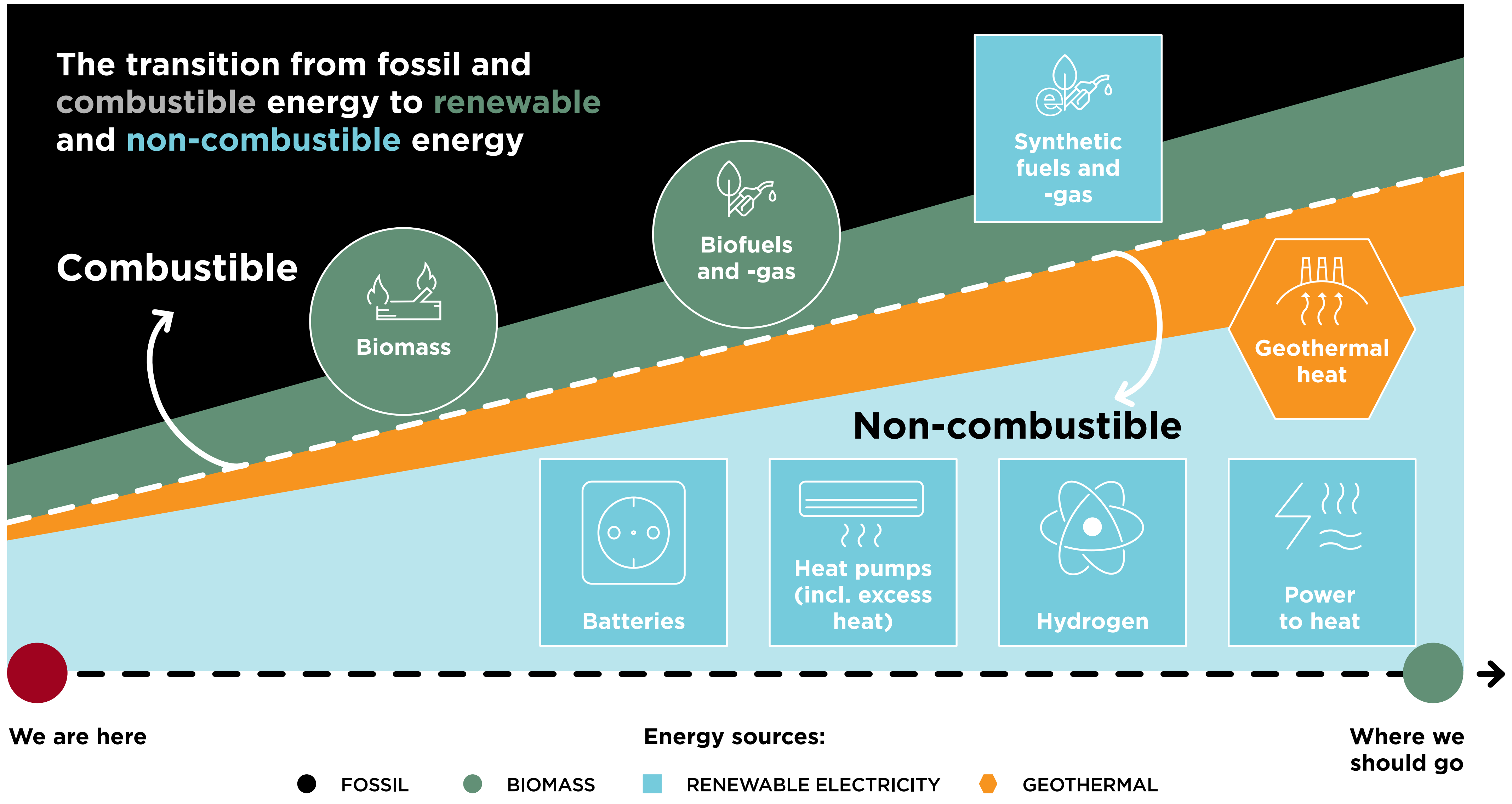
This is true especially in energy intensive sectors – buildings (heating and cooling), transport and industry – which still rely heavily on fossil fuels. In order to successfully complete this transition, the energy system as a whole – including storage and distribution – must adapt to, and support, electrification.

Renewable electricity storage is necessary for managing the imbalance between supply and demand – a need complicated by the variability and unpredictability of our most important renewable energy sources, namely solar and wind power.

Storing electrical energy isn't as straightforward as in the case of fossil fuels. The electricity must be converted to a different form: chemical (batteries), potential energy (pumped hydro, compressed air), or thermal energy (heat). In addition, electricity can be used to produce gases or liquid fuels which can be stored. From an energy end-use point of view, converting electricity to heat or using it in fuel production are the most viable alternatives for replacing fossil fuels.

The common term for this is power-to-x (P2X) solutions, and it refers to the conversion of

Energy production in the post-flammabus era



electricity into another form of energy. The beauty of this solution is that it goes a long way in solving the challenge of storing and distributing the electricity. Power-to-x takes advantage of our current networks of storage and distribution, which are centered around liquid and gaseous energy. This brings down the costs of transitioning toward a carbon neutral energy system. Moreover, it will join the power sector and end-use sectors together, bringing flexibility and reliability to the overall system – in general referred to as sector coupling (power-to-x is covered in more detail in the next chapter).

The following sections describe how direct and indirect electrification will play an important role in the energy transformation of our main end-use sectors.

Transport
Transport sector decarbonisation includes the use of biogas or biofuels, batteries, hydrogen or synthetic fuels.

Apart from biogas and biofuels, all other alternatives are connected to the power system. Either directly in the form of battery electric solutions, or indirectly in the form of power-to-gas solutions like hydrogen and synthetic natural gas, or power-to-liquid solutions like liquid synthetic fuels.

The three sectors – aviation, marine and road freight transport – have the highest potential for using power-to-x-based synthetic fuels. Direct electrification is not an option, and biofuels have limited scalability due to sustainably available biomass.

Heating and cooling
The heating and cooling sectors are moving away from combustion-based production. Decarbonisation is driven by solar thermal and geothermal installations, as well as power-to-heat installations, and, to some extent, through the use of biomass and power-to-gas installations. In geothermal heating and cooling production, medium deep and deep boreholes will make a breakthrough. To better integrate the heating sector into the electricity-based energy systems, heat pumps are considered a key technology. Heat pumps use electricity to circulate hot and cold liquids, using the heat from the air, geothermal heat or ground water.

Another power-to-heat solution focuses on using excess electricity to heat up large amounts of water, which can either be stored for seasonal use or used directly in district heating networks. Excess heat from industry and data centres will also be important elements in the future for district heating system. In addition, synthetic gases can be used in the heating sector instead of fossil natural gas.

Industry
Depending on the specific industrial process needs, all power-to-x technologies such as power-to-gas, power-to-heat or power-to-liquid can be used to electrify the industry sector. It's important however, to remember that measures to reduce CO_2 often drive up the overall electricity demand, although CO_2 intensity of the energy system goes down. To illustrate, one prominent technology in the low-carbon steel industry is to use hydrogen for iron reduction instead of coal.

This has a dramatic impact on the electricity demand but doesn't necessarily increase the net energy consumption. Coal has a higher energy density and a higher CO_2 content than renewable electricity. Replacing coal in the steel industry with hydrogen made from renewable electricity requires a lot of power.

Industry has another important interface with power-to-x technologies. Industry can provide the CO_2 needed in a power-to-x supply chain by utilising carbon capture technologies. Carbon capture and utilisation (CCU) is an important part of the industry decarbonisation toolbox as there are emissions which are difficult to avoid in production of e.g. steel and cement.

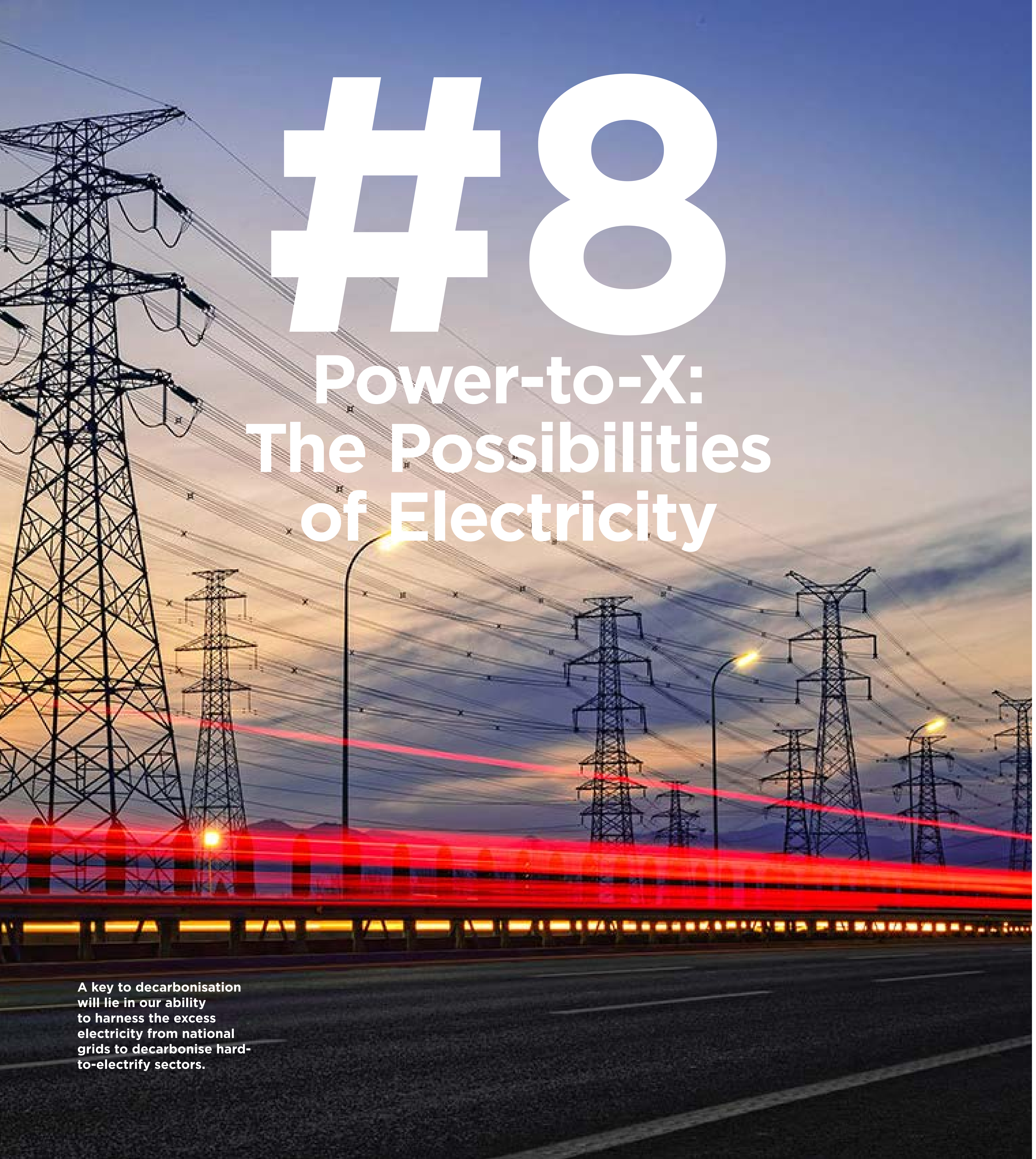
All in all, most if not all the decarbonisation efforts rely on direct or indirect electrification. The takeaway from this is that we're going to need a lot more renewable electricity production if we're to succeed with the ongoing energy transition.

Sector-integration
The energy transition can only be achieved if the methods used to supply, transform and use energy change. Sector coupling will play a significant role in creating the pathway towards a renewable-based energy system. Sector coupling can be defined by two overlapping approaches; end-use sector coupling and cross-vector integration.

- End-use sector coupling deals mostly with direct electrification of end-use sectors such as heating and transportation. In the transport sector, this means for example, using electric and hydrogen-powered vehicles or a modal shift from road to rail transport. In the heating sector, electric heat pumps can substitute fossil-fueled furnaces, for example.

- Cross-vector integration means supply-side integration and indirect electrification by using electricity to produce heat, gaseous or liquid energy carriers for use in the end-use sectors – in other words power-to-x, as referred to earlier.

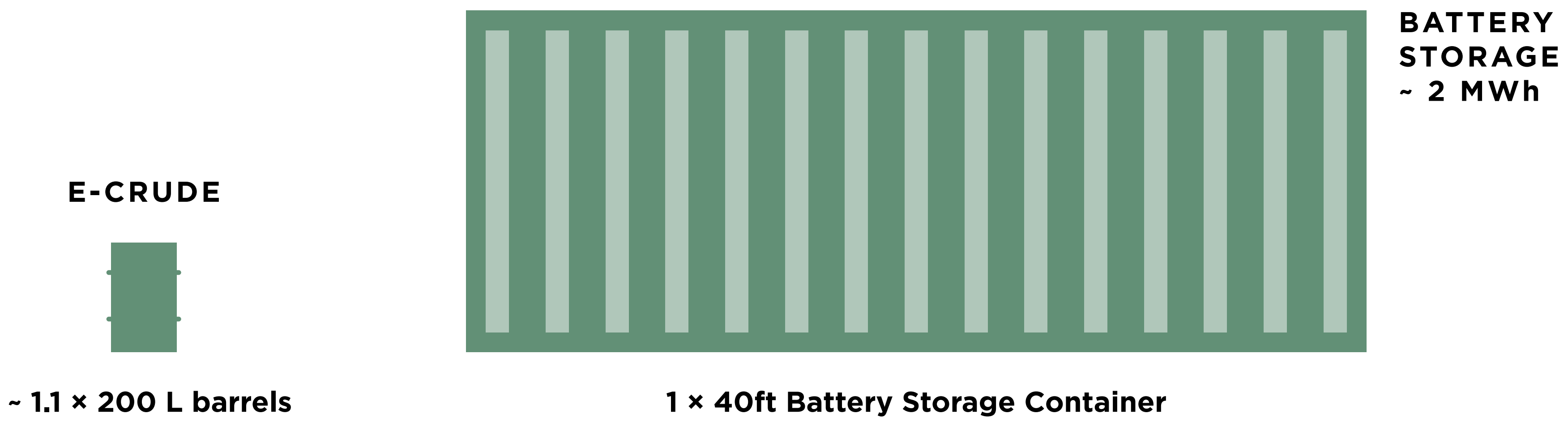
- The combination of end-use sector coupling with cross-vector integration is the preferable pathway towards a renewable-based energy system.



#8 Power-to-X: The Possibilities of Electricity

A key to decarbonisation will lie in our ability to harness the excess electricity from national grids to decarbonise hard-to-electrify sectors.

Enormous potential lies in developing synthetic fuels. They could feed off of the carbon in the atmosphere, as well as the green electricity production we still need to invest in.



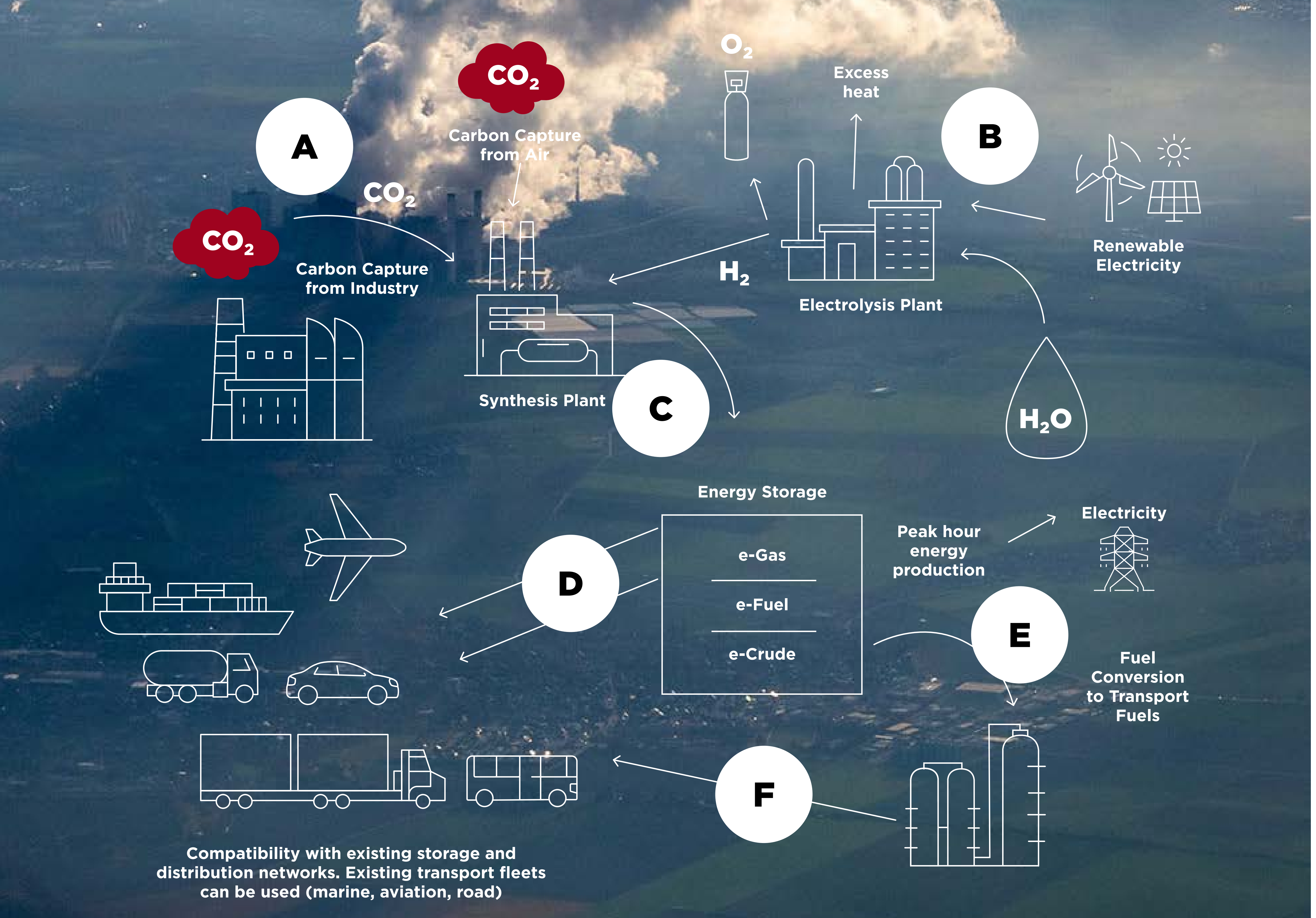
Liquid fuels are more condensed in energy than batteries.

Synthetic fuels are the missing link between renewable electricity and the sectors where electrification is most needed and yet most difficult. Through power-to-x (P2X) solutions, we can decarbonise transport segments like aviation and marine as well as energy intensive industries like steel production. The potential is enormous, and the possibilities endless.

Synthetic fuels are the most prominent long-term solution for transferable energy storage, and they represent a probable pathway for displacing fossil fuels from the transport sector. This happens through a power-to-x process, e.g. in which hydrogen is produced from water with renewable electricity through electrolysis. This hydrogen could then also be used in other processes, e.g. in the production of ammonia as fuel for the marine sector. The elements for synthetic fuels production are:

- low-cost renewable electricity
- hydrogen (H_2) created by the electrolysis of water
- carbon dioxide (CO_2) extracted from the atmosphere or captured from industry

Power-to-X process



- **A** Carbon dioxide is captured from air or industrial sites by using carbon capture technologies
- **B** Water is split into oxygen and hydrogen by using low-cost renewable electricity. Excess heat can be utilized in district heating networks.
- **C** Carbon dioxide and hydrogen are combined into hydrocarbon products
- **D** Synthetic hydrocarbon products are stored, thus providing converted solution for electricity storing. Fuels can be used for transportation
- **E** e-Crude can replace fossil crude oil in refineries
- **F** Refined fuel products for transportation

There are no limitations for the availability of carbon as a feedstock in the form of CO_2 and the distillation curve challenge can be avoided.

In a synthesis plant, carbon dioxide and hydrogen can be combined into hydrocarbon products like methane, gasoline, diesel, jet fuel or methanol. Production of synthetic ammonia is a similar process, except that the CO_2 is replaced by nitrogen (N2). Ammonia is an important raw material for fertilisers and a potential low-carbon fuel for shipping.

Synthetic fuels can be used in traditional combustion engines or gas turbines, and can also be blended gradually into the existing fossil fuel mix, displacing an ever-growing portion of the fossil energy.

One of the biggest advantages of synthetic fuels is the compatibility with existing liquid and gaseous fuel storage and distribution infrastructure.

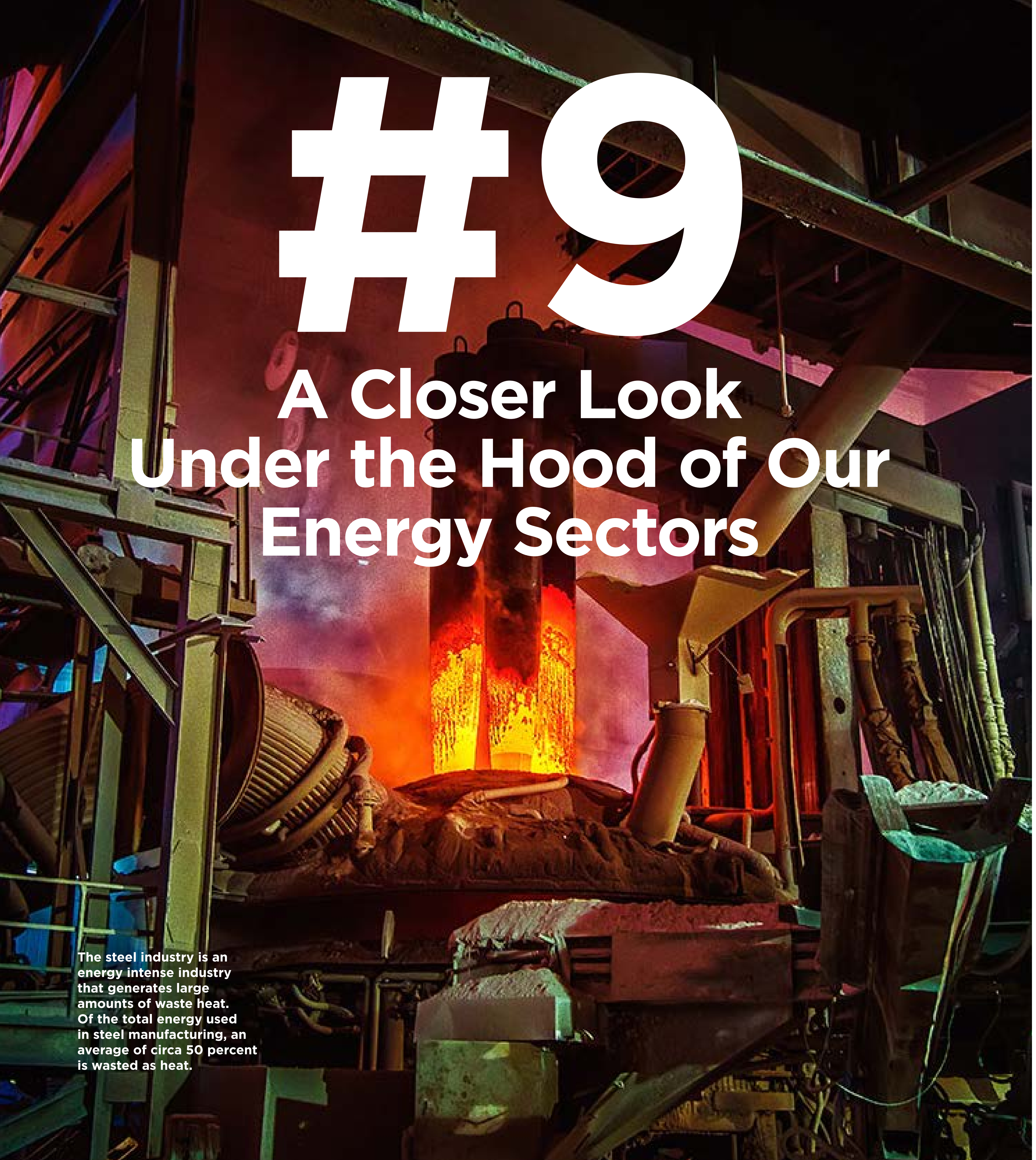
This minimises the need for renewal of infrastructure and vehicle fleets, massively reducing the overall costs associated with decarbonisation.

There are no limitations for the availability of carbon in the form of CO_2 and the distillation curve challenge (as explained in chapter #5) can be avoided. Power-to-x can achieve near carbon neutrality with enough renewable electricity and excess CO_2 as input.

Production of synthetic fuels requires carbon capture technologies, and the CO_2 can be separated from large point sources, such as cement and steel production and pulp mills. CO_2 can also be separated from air through what is called Direct Air Capture (DAC) or from the sea. On the other hand, low CO_2 concentrations drive up the size of the equipment and the cost of each tonne of captured CO_2

A comparison between hydrogen and hydrocarbon-based synthetic fuels show that the latter have properties which make them much more favourable as energy carriers. Using pure hydrogen as an energy carrier will be limited as a result of its poor volumetric energy density and its value chain shortcomings like distribution, storage and end-user applications.

To conclude, we believe synthetic fuels will play a crucial role in the energy system of the future. The biggest bottleneck is – and will continue to be for the next decade – the availability of clean and cheap electricity. We must invest significantly in additional renewable electricity production and an accompanying electricity grid. It will also be important, and necessary, to research and develop solutions for lowering the production costs of synthetic fuels.



#9 A Closer Look Under the Hood of Our Energy Sectors

The steel industry is an energy intense industry that generates large amounts of waste heat. Of the total energy used in steel manufacturing, an average of circa 50 percent is wasted as heat.

The energy sectors of the world make our everyday lives possible. They are the main contributors to global CO_2 emissions, and as such they hold the key to our salvation.

Industry
Almost a quarter of global greenhouse gas emissions come from the industrial sector. Steel and cement are the two highest-emitting industry subsectors, followed by the chemical subsector. Together, these three contribute nearly 70 per cent of total industrial emissions. Cement and steel are the basic elements in buildings and infrastructure. The chemical sector produces fertilisers needed to feed our growing populations, as well as plastics. Demand for these products will remain strong in the following decades to support a growing and increasingly urbanised global population.

> Industry-related emissions are among the most challenging to decrease mainly due to:
>
> - process emissions from chemical or physical reactions
> - the need for high-temperature heat

Emissions from non-combustion processes account for nearly a quarter of industrial emissions. These can't be avoided by switching to alternative fuels or through energy efficiency improvements. This is particularly challenging in cement production where 65 per cent of emissions come from the calcination of limestone. Process emissions are also considerable in iron and steel, aluminium and ammonia production.

A large share of industrial CO_2 emissions comes from burning fuel to generate high-temperature heat – a primary reason for the fossil-fuel reliance of industry. Process temperatures range between 700°C to over 1600°C. Abating these emissions by switching to alternative fuels or zero-carbon electricity is difficult and costly. Additionally, in iron and steel production, coke has multiple roles alongside heat production. This makes it impractical to replace coke combustion with an alternative source of process heat. One potential solution is to replace coke with hydrogen produced with renewable electricity. This way, the process emits water instead of carbon dioxide.

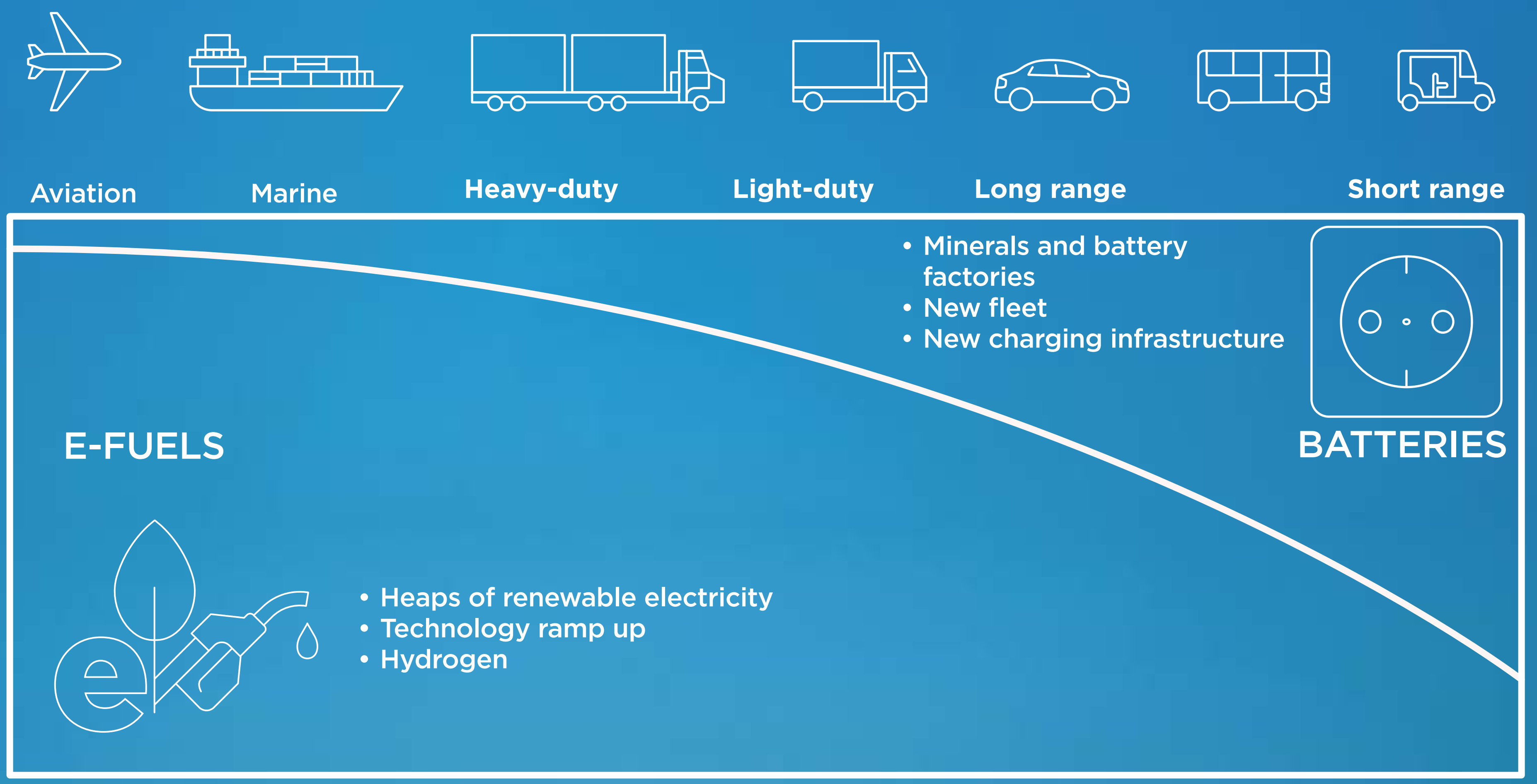
Other industry related elements:
Long-lived assets, of up to 50 years, potential lock-in of CO_2 emissions from existing production facilities and those under construction.

High exposure to global competition:
Competitiveness of globally traded products are highly sensitive to even small increases in production costs. Expensive low-carbon technologies driving up production costs is

ENERGY SECTORS:

Transport

The balance between direct- and indirect transport electrification



potentially bad for business – especially when the costs of carbon emissions are not factored into the price or regulated in other ways. In a worst-case scenario, this could lead to carbon leakage, which undermines decarbonisation efforts in the industry sectors.

Different approaches and technologies are needed in the industry sector's energy transition.

Alongside energy and material efficiency, electrification (including electrolytic hydrogen) and direct use of renewables, we expect carbon capture, utilisation and storage (CCUS) to play a critical part.

CCUS can directly address key challenges related to process emissions, the combustion of fossil fuels for high-temperature heat and the lock-in of existing infrastructure. While CCUS is especially a solution for key industry sectors (cement, iron and steel, chemicals), it's also applicable in other heavy polluting sectors. Additionally, CCUS can support the generation of negative emissions through bioenergy with CCS (BECCS). This can for example involve processes where biomass is burned to generate energy (e.g. power plants, pulp mills) and refineries producing biofuels through fermentation (bioethanol).

CCUS also has a wider connection to the whole energy system transition where electrification, power-to-x technologies and sector coupling are key elements. Captured carbon can be utilised in production of synthetic fuels, which is an important element in the decarbonisation of the transport sector. In the future we might see industrial hubs, multi-user hub-and-cluster facilities, where industry and production of synthetic fuels are coupled together.

Transport
Transport is the largest oil-consuming sector today, it accounts for a fifth of global energy demand and the sector is responsible for a quarter of energy-related CO_2 emissions. More than 95 per cent of transport sector emissions come from oil, and transport demand is projected to increase significantly through to 2040 as a result of both population and economic growth.

Road transport
If we delve into the subsectors,

road transport accounts for nearly half of today's global oil demand and 75 per cent of emissions from the transport sector.

No wonder we're focusing so intently on cutting emissions from road transport – there's much to do here.

The three main tools for cutting transport emissions have been biofuels, electrification and efficiency improvements. And they'll all continue to play an important role. A further diversification of powertrain solutions, for example battery electric vehicles and plug-in hybrids, will continue to be developed alongside further improvements in conventional powertrain technologies. However, biofuels, electrification and efficiency improvements will not alone be enough if we are to decarbonise sufficiently in the transport sector.

When considering biofuels and electric vehicles, there are two very important points to remember. First and foremost, both battery-stored electricity and biofuels can – and should – play a role in reducing emissions from the transport sector. Secondly, both forms of energy have their limitations. Biofuel production will in many cases compete with other forms of land use, and it's

ENERGY SECTORS:

Transport

For now, fossil jet fuel remains the only energy solution for commercial air travel.

unrealistic and even unwise to work toward a transport sector fuelled solely with bioenergy. The use of battery-stored electricity in the transport sector is limited by factors like weight, distance and too slow and cumbersome charging solutions. The flexibility and energy density offered by liquid fuels is unmatched, and the more energy-demanding segments of the transport sector will need liquid energy in the unforeseeable future. This is where other low-carbon liquid fuels like synthetic fuels can play an important role.

Consumer choices & SUVs: Consumer choice plays a big role in how future road transport will develop. Many factors influence the decisions people make about buying a car, and what type. Recently there's been a marked rise in sales of sports utility vehicles, which on average consume around 25 per cent more fuel than medium-size cars. They can also be challenging to electrify fully because of power and battery size requirements. Additionally, the recharging infrastructure plays an important role in how fast electric mobility grows.

Electric vehicles are best suited to urban and densely populated areas and light- to mid-duty freight. On the other hand, renewable fuels work best in replacing liquid fossil fuels in long-distance and heavy-duty vehicles. Heavy duty vehicles are most difficult to electrify, especially in the Nordics, where the vehicles are large, the distances long and the temperatures low.

Aviation

In aviation, the number of flight passengers is expected to grow 4 per cent annually during the next 20 years, from 4.2 billion in 2018 to 10 billion passengers in 2040. That amounts to some 90 million departures. Energy efficiency is expected to improve more slowly than transportation need, meaning that if we continue on the current path, the fuel demand is estimated to grow with 200 per cent over the next 30 years. For now, fossil jet fuel remains the only energy solution for commercial air travel.

Cutting emissions in the aviation sector is a huge challenge, and one we've not solved.

The distillation curve challenge explained in chapter 5, illustrates that the growing demand for jet fuel increases the overall demand for crude oil, which in turn leads to an increased supply and production of other petroleum products.

In the coming decade, decarbonisation in the aviation sector will happen through energy efficiency improvements and the use of biofuels and synthetic fuels. Despite recent hype, electrification of aviation is very challenging and not deemed a likely pathway for reducing emissions before 2030. Biofuels for aviation have the same feedstock limitations as biofuels in other sectors, meaning that all sectors using biofuels to reduce emissions compete over a limited solution.

St1 believes that it would be wise to prioritise the use of biofuels in those segments of the transport sector that:

- Do not have other options to decarbonise
- Drive up the overall demand for crude oil, i.e. the distillation curve challenge (see chapter5)

ENERGY SECTORS:
Transport

Terntank product tanker time-chartered for NEOT maritime transport in Baltic sea is using LNG and LBG as a fuel. Tanker is equipped with Wärtsilä dual fuel engine. LNG is potential bridging fuel for carbon-neutral alternatives such as biomethane/liquefied biogas (LBG) and synthetic methane, which could utilize existing and upcoming LNG bunkering infrastructure.

Shipping

Maritime shipping represents 80–90 per cent of international trade, and virtually all commercial shipping activities are powered by fossil fuels. International shipping is responsible for 2–3 per cent of all global greenhouse gas emissions and roughly 10 per cent of the transport sector emissions. As global GDP is expected to grow, the demand for shipping will grow at a similar rate.

In 2018, the International Maritime Organisation (IMO) adopted a comprehensive and ambitious strategy for emission reduction, with the aim of halving emissions by 2050. The stated policies and the currently available solutions therefore leave us with a large emission gap.

> **A global sulphur cap was introduced on the 1st of January 2020, banning the use of marine fuel with a high sulphur content, but this is far from enough to achieve the IMO stated goal of a 50 per cent emissions reduction by 2050. Decarbonisation of the deep-sea segment is particularly challenging, and it generates 80 per cent of the global fleet's CO_2 emissions.**

Global sulphur cap: The sulphur cap is expected to have a major impact on the fuels market in 2020 – not only in the marine sector. There are conflicting views whether the global refining capacity will be sufficient in 2020 to supply enough low sulphur products. Most vessels are expected to either switch to low-sulphur fuel oils, LNG, or retrofit scrubbing systems to reduce sulphur dioxide emissions.

The future marine sector will be characterised by an increasing diversity in fuel choices. A wider range of alternative and carbon-neutral fuels will find its place alongside traditional bunker fuels and more established alternatives like LNG. The alternatives include biofuels and synthetic fuels such as ammonia, methanol and hydrogen. Electric ships powered by batteries are viable for short distances, like ferries travelling up to 100 km.

All transport sectors need additional solutions in order to meet global climate obligations. This goes for road transport, aviation and marine. In all of these segments, new alternatives and more efficient powertrains will come about, but the transformation takes time. A car or truck bought today will most likely be in use well beyond 2030, and a ship or an airplane built today will be in use beyond 2045.

As discussed in earlier chapters, electrification is an incredibly important tool in our efforts to reduce emissions, but where some sectors and segments can be electrified directly, others must be electrified indirectly. Synthetic fuels are a potential alternative for fossil fuels and best suited for heavy-duty road transport, shipping and aviation – these are the most difficult to electrify directly. In these segments of the transport sectors, biofuels will also play an important role for many years. But the limited availability of biofuels has to be kept in mind and thus the limited role biofuels can play in our decarbonisation efforts. Biofuels should be prioritised in those segments where direct electrification proves most difficult, i.e. heavy-duty road transport, shipping and aviation.

There are other elements which will shape the future of mobility. Ride sharing, vehicle digitalisation and automation and better public transportation are other factors that will determine how many, and how much, cars will be used in the future.

ENERGY SECTORS:

Biofuels and Advanced Biofuels

Cellulosic ethanol hydrolysis process researched at St1's laboratory. Saw dust from sawmills is used as feedstock in Kajaani biorefinery for producing bioethanol as well as lignin, furfural, turpentine and wood syrup used in several sustainable applications. For example lignin based biocomposite can be used as a replacement for plastics.

Biofuels

The global transport sector is dominated by fossil fuels, and biofuels only account for around 3.5 per cent of global transport fuel demand. The global car fleet consists of less than 1 per cent electric vehicles, and the main fuels in the road sector are gasoline and diesel. Low quality residual fuels dominate the maritime sector, and conventional kerosene the aviation sector. To reach the goal of having 10 per cent of global transport fuel demand covered by biofuels, the current production must be tripled to 280 Mtoe by 2030. Global biofuel production is not increasing fast enough to meet this goal.

Most biofuels are produced by using conventional production methods and feedstocks. Feedstocks used in biofuels are often the same as those used in agricultural food production, and the limits of arable land naturally limits the scalability of biofuels as a comprehensive solution for the transport sector.

Advanced biofuels

So called advanced biofuels are getting more interesting, as they can help us avoid the concerns mentioned above. Advanced biofuels are produced from non-food feedstocks that don't compete with food and feed crops for agricultural land. Commercial scale deployment of advanced technologies is crucial in enabling wider feedstock pool in otherwise limited feedstock availability. However, additionality of biomass must be ensured before utilization.

Technologies to produce biodiesel and hydrotreated vegetable oil from waste oils and animal fats are technically mature, and production is growing. However, competition for waste oil and animal fat feedstock is intensifying, elevating their cost. The supply of these feedstocks could be increased, but their availability is ultimately limited.

Cellulosic biofuels and biomass-to-liquid fuels can be produced from less expensive feedstocks with a higher availability, such as municipal solid waste, forestry and agricultural residues. Cellulosic ethanol offers significant CO_2 emission reductions compared with fossil-based transport fuels. It's suitable for passenger vehicles, as well as trucks and buses when used as 95 per cent ethanol fuel (ED95).

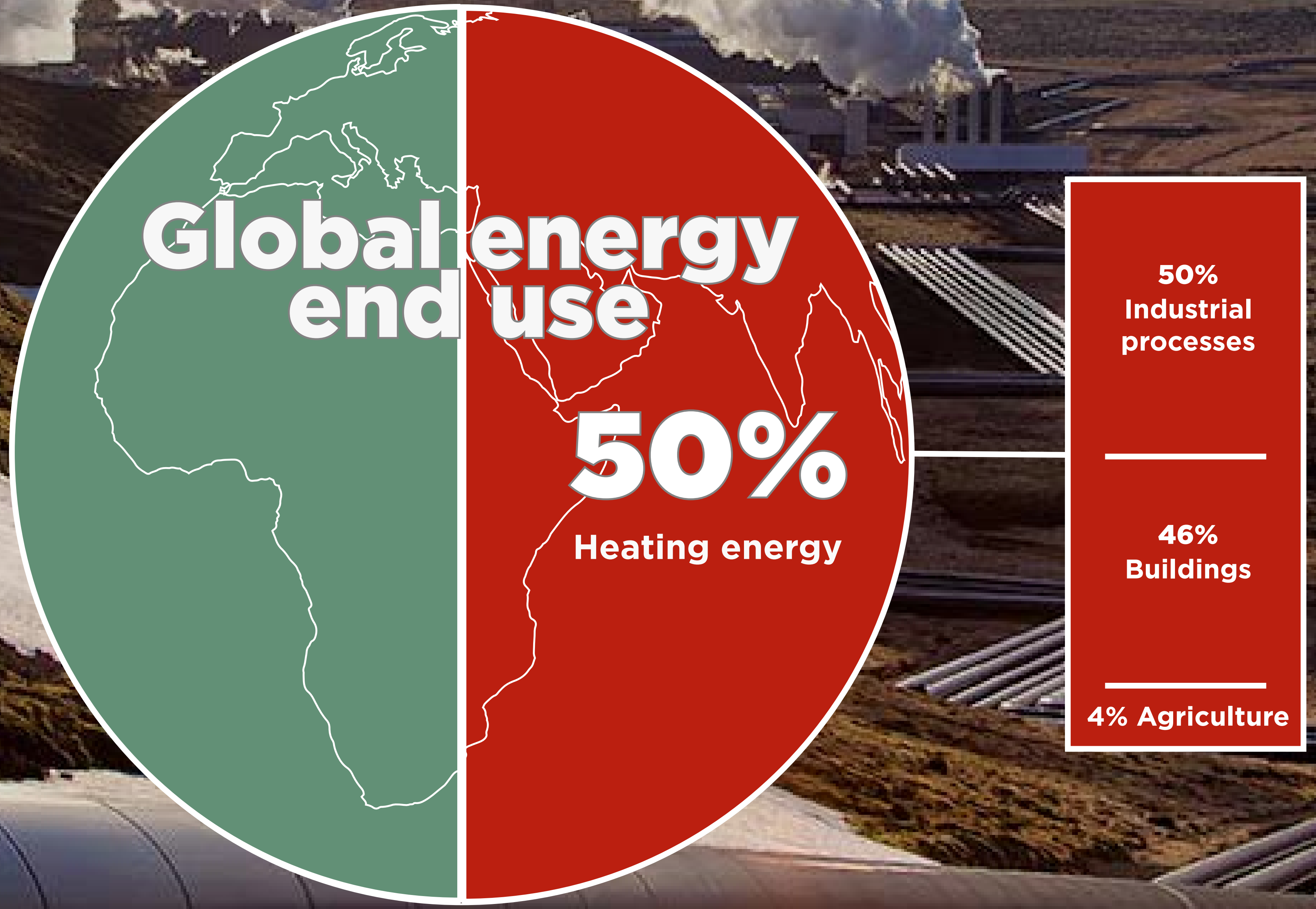
Although regular vehicles can use ethanol at low blend rates, CO_2 emissions reductions are maximised when the ethanol is used at high blend shares or unblended in flexible-fuel vehicles. Traditional vehicles can be converted to use E85 with conversion kits.

The main advantage of biofuels is their compatibility with existing vehicles and fuelling infrastructure at low blending levels.

To displace a greater portion of the crude oil demand with biofuels will either require a greater consumption of unblended biofuels or higher biofuel blend shares. Of these options, higher-rate biofuel blending is more challenging, because it would require expanding the fleet of suitable vehicles and changes in the fuelling infrastructure.

Biofuels are used primarily in road transport with passenger cars accounting for most of the consumption. The use of biofuels in aviation is still marginal, and even more so in maritime transport. Given the difficulties of electrification in these segments, a higher share of biofuels is an attractive pathway for reducing emissions. Biodiesel is one of a few viable options for long-distance road freight transport, and biokerosene for the aviation sector. For the marine sector, ammonia, biodiesel, hydrogen, and methanol are possible pathways, with biodiesel being the only one that can be properly implemented today.

ENERGY SECTORS:
Heating and Cooling



Accounting for 50% of global final energy consumption in 2018, heat is the largest energy end-use and contributes 40% of global carbon dioxide (CO2) emissions. About 50% of total heat produced was used for industrial processes, another 46% was consumed in buildings for space and water heating and, to a lesser extent, for cooking, while the remainder was used in agriculture, essentially for greenhouse heating.

Iceland is a pioneer in the use of geothermal energy for space heating. Geothermal power facilities currently generate 25% of the country's total electricity production.

Heating

Heat is the largest energy end-use sector, accounting for around half of the global energy consumption. Heat production is heavily based on fossil fuels, with only 10 per cent produced from renewable sources. Industry consumes roughly 50 per cent of the heat produced, the building sector 46 per cent, with the remainder being used in agriculture.

> **Over the coming years, combustion-based heating will be mostly replaced by sustainable, recycled and stored heat.**

This transformation is supported by strong electrification, where coupling of power and heating (power-to-heat, P2H) plays a central role. In practice, power-to-heat is made possible by electric boilers and heat pumps. Short- and long-term heat storages – a cheap and reliable way to store energy – can maximise this potential. These storages can also be used on a much larger scale than is the case today and can be linked more tightly to P2H schemes.

Heat pumps are among the most cost-effective options when it comes to increasing the amount of heating with low-carbon energy, and their efficiency is reinforced by the growth in renewable electricity production. Large, industrial sized heat pumps can utilise renewable energy from air, water or ground, and also waste energy from buildings, data centres and industrial processes to provide heating and cooling. Furthermore, heat pumps could be used in demand-response systems to augment power system flexibility.

Geothermal energy

Geothermal is a local and flexible renewable energy source. When integrated with smart power, heat and cooling grids, it reduces societal costs and improves local supply security. Geothermal will be a key energy source both in smart cities and smart rural communities, in addition to supplying energy for industry, services and agricultural sectors. Geothermal energy can provide solutions for smart electricity and thermal grids via an underground thermal energy storage. Underground thermal energy storages will be made for seasonal storage, with perspectives on the development of low- and high-temperature (>25°C) systems.

Geothermal technologies could help overcome multiple barriers that prevent the decarbonisation of the heating and cooling sectors. One advantage being the ability to provide heating and cooling services at the same time. Commercial buildings often have simultaneous demand for heating and cooling, and during summer, many residential buildings need cooling while domestic water resources need heating.

Biomass is often seen as the primary solution for carbon-neutral heating. However, chances to increase the availability of biomass, enough to replace fossil fuels, are very limited and costs are expected to rise. In addition, the debate on the adequacy of carbon sinks can lead to a more critical approach to the carbon neutrality of bioenergy. In the light of this information, bioenergy should be used in the future mainly as a reserve and peak power, preferably equipped with carbon capture units.

Wind energy, heat pumps and heat storage are the ingredients of a clean heating production of the future. The commercialisation of industrial-scale geothermal heat, combined with the strengthening of climate policy, means an energy breakthrough that may soon revolutionise heating production.


We're only a few steps away from enabling the transition. We should take them.
The Paris Agreement goal of limiting global warming to below
1.5°C
is unachievable with the currently planned global actions.
Global fossil fuel based CO_2 emissions in 2018 were approximately
37
billion tonnes.

#10 One Market with One Rulebook

To make more ambitious climate actions, we need more solutions. Carbon has the same results in the atmosphere regardless of its origin, which means that the rules for its emissions must be universal.

At St1 we believe that we need a carbon market for sequestered and emitted CO_2. In addition to all the efforts that must be done in every single corner of our energy system, we must incentivise CO_2 sequestration. The carbon market works so that the emitting companies will pay, and carbon sequestering companies will get an income to finance carbon removing investments, for example afforestation, carbon capture and storage or utilisation.

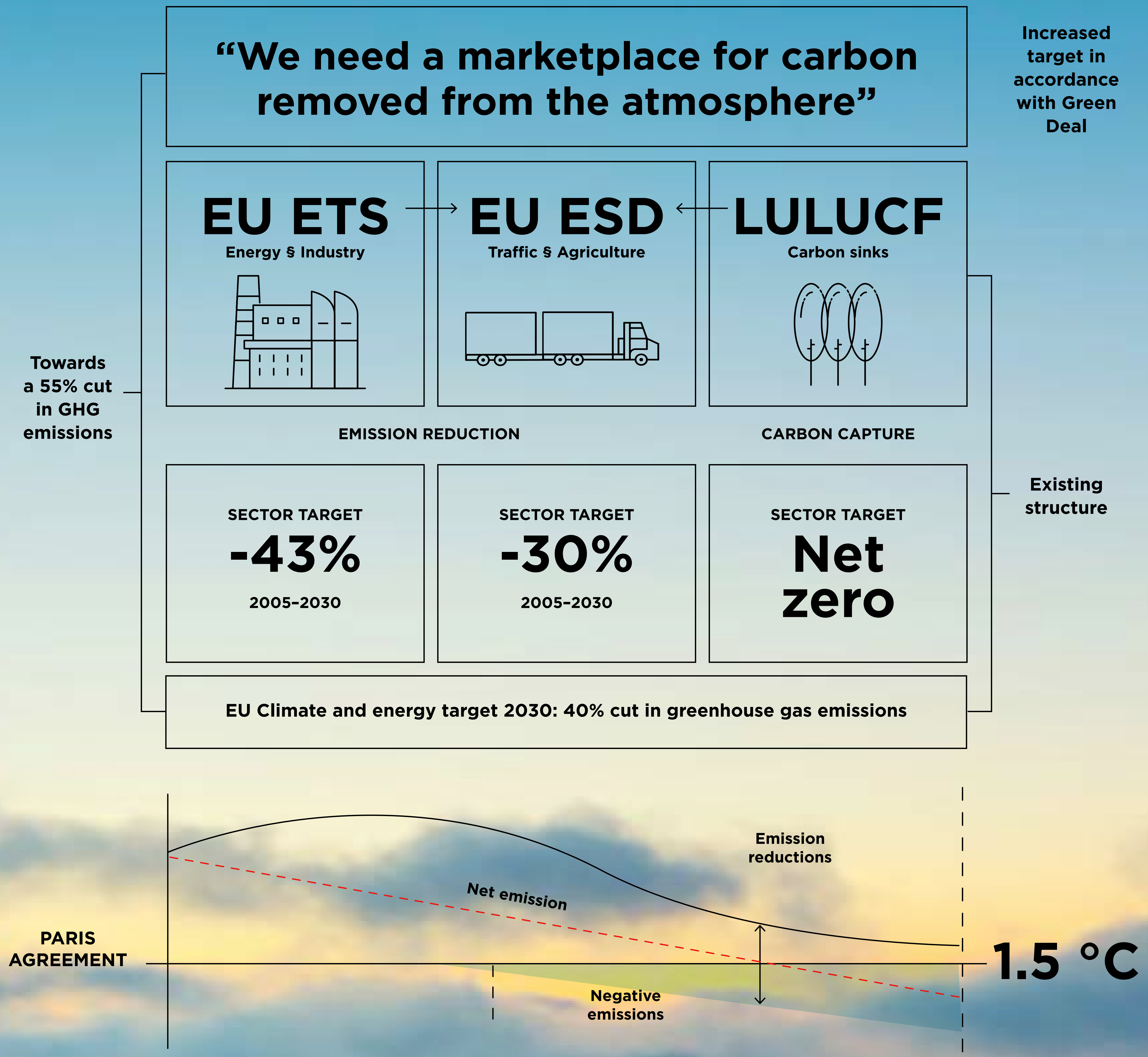
A carbon removal market would boost efficient climate actions. A tonne of CO_2 has the same impact on climate, regardless of how and by whom it has been released. However, the monetary value of a tonne of CO_2 varies for the players in different sectors. In the EU climate framework, the emissions Trading Scheme (ETS), Effort Sharing Decisions (ESD) and Land-Use, Land-Use Change and Forestry (LULUCF) all get a different amount due to the imbalance built into the EU's policies.

> **To increase the ambition level of climate targets and actions, we need more solutions.**

Binding CO_2 reduction targets for every sector as well as mechanisms that allow operators across all sectors to use the most effective ways to mitigate climate change and curb emissions. Creating a marketplace for carbon removal would harness market forces to the actions in climate change mitigation and level the playing field between sectors.

How would it work?
The carbon marketplace would serve as a trading platform for reduced carbon. Emission mandated companies and other operators could either sell verified carbon reductions gained from different types of carbon sequestration projects, e.g. afforestation projects. Or on the other hand, buy carbon credits to fulfill their mandate. Companies should be allowed to fulfil their mandates both by carrying out carbon reduction measures as well as by buying carbon removal certificates. A carbon removal marketplace would also invite new climate entrepreneurs eager to monetise carbon sequestration into an existing, regulated and robust framework. A reliable carbon market must be based on international standards for measuring carbon emission and absorption rates of various afforestation projects.

In theory the solution to all of this is simple. First, polluting companies must be subjected to CO_2 emission reduction obligations, which ultimately aim for zero emissions, for example by 2050. Without a binding reduction target, the companies would be unlikely to target the net zero emissions. Secondly, companies should be allowed to fulfil



their obligations outside their own sector, including in the land-use sector or in developing countries. This would drive companies to invest in the most cost-effective emission reduction projects. In addition, all emission reductions should be calculated or measured with standardised methods and verified, as well as fulfil all sustainability criteria.

Thirdly, we need to create at least an EU-wide common marketplace, a carbon market for CO_2 emissions and reductions. The carbon market would be pivotal in enabling companies to trade CO_2 emissions as well as eligible CO_2 reductions. This would allow the market to steer towards the most effective reduction methods, at any time.

The carbon market and why we need one
The EU Emissions Trading Scheme (ETS) has not made the necessary investments happen fast enough. An international, or at least an EU-wide, carbon market for sequestrated and emitted carbon needs to be combined with binding emission reduction targets for the responsible companies. This would also motivate investments in projects that absorb CO_2 from the atmosphere.

A key element of the carbon market is to enable flexibility between sectors, allowing companies to fulfil their obligation with activities in other sectors. This system would ensure that investments are steered in a direction where their impact would be greatest in relation to cost. Emissions grow the most in developing economies. Investments to these areas would create other beneficial effects in addition to lowering emissions.

The Paris Agreement’s goal of limiting global warming to below 1.5°C is unachievable with the currently planned and implemented global actions. The potential for emissions reductions is simply too low and the change is happening too slowly. An international marketplace for carbon could help speed up the required change.

Global fossil fuel-based CO_2 emissions in 2018 were approximately 37 billion tonnes, of which the EU accounted for 10 per cent. The growth of emissions in the rest of the world, over the next 10 years, will exceed the current EU emissions. This tells us that it’s not enough to simply set an example within the EU. This is why the EU needs to allow its companies to use emission reductions in other countries, as a way to fulfil their emission reduction obligations. This would develop emission reduction methods that can be implemented in emerging economies, where emissions growth is the highest.

The problem with the current EU climate strategy is that it rigidly separates emission sources into three sectors: The Emissions Trading Scheme (ETS), Effort Sharing Decisions (ESD) and Land-Use, Land-Use Change and Forestry (LULUCF). Each sector is required to reduce their emissions, by a politically determined rate, without cross-sector flexibility. However, focusing only on reducing emissions within each sector leads to sub-optimisation, and unnecessarily increases the cost for society. An unwanted consequence is negative public opinion against CO_2 reducing efforts due to spiralling costs and ineffective solutions. In other words, the cost of additional emission reductions can rapidly escalate out of control, often without achieving the desired climate benefits. The result being public outcry and a negative public attitude toward climate policy.

#11

Collaboration Got Us Here, It Should Get Us Out

The energy transition requires close co-operation and support from digitalisation. To achieve a system-level energy transition in time, we should first define and agree the paths toward our common target.

The challenge is that the transformation concerns all levels of the energy system – a system consisting of many stakeholders who must all contribute with their share in the transition. These stakeholders can be categorised as key actors and key enablers. Key actors are accountable for one or several activities in the energy system, such as energy production, storage, distribution or in energy end-use sectors. Key enablers are stakeholders outside the energy sectors, who influence the operation of the energy system. These can be public authorities and regulators, research and knowledge institutions, financiers, non-governmental organisations and retailers. There are also manufacturers with their own supply chains providing the products and technologies used in the energy system.

Collaboration between the key actors and the key enablers will ease the transition to a low-carbon energy system. It is, for example, important that the stakeholders involved in the transition agree on transition pathways to avoid any uncertainty around the necessary long-term investments that also have to work in tandem.

> **Uncertainty increases the risk of an imbalance between supply and demand, and it can slow down or hamper the required investment rate. It's easy to say that everyone should work together, but it's harder to actually make it happen.**

The energy system of the future will look very different to what we have been used to over the past century. The interconnectedness of the future energy system will be unmatched and the different system levels, sectors, technologies, markets and actors will change. This will happen in such a profound way that the operational principles and business models of the energy system will look remarkably different in the not so distant future.

"The information is there – what we need now is action"

—Mika Anttonen, Chairman of the Board, St1 Nordic Oy

Digitalisation
Digitalisation is an important instrument for energy transition. It will enable the flexible management of energy system networks and make the system more intelligent, reliable and efficient. This will impact both energy demand and supply.

The electricity sector and smart grids are at the center of digitalisation. Ultimately, digitalisation will extend to energy production and to all end-use sectors by providing system balance with flexible integration and optimised operation of the system. As an example, demand response programs in buildings, industry and transport provide flexibility without requiring investments in new electricity infrastructure.

In energy end-use sectors, digital technologies are already widely used. The industrial sector has used process controls and automation for decades. This development will continue and expand, improving the efficiency of energy and material use. In buildings, the role of smart home services and energy management services and applications is increasing rapidly. In the transport sector, digital solutions for trucks and logistics could reduce energy use for road freight considerably. Alternatively, impacts of automation, connectivity and shared mobility services are harder to predict.

The impact of digitalisation on energy demand is two-sided. It can bring large improvements in energy efficiency for all end-use sectors. However, the prevalence of more devices and data centres could cause a large net increase in energy use, if not managed carefully.

Parallel to the opportunities, digitalisation gives rise to new security and privacy risks, as well as disrupting markets and businesses. An example is the growth of Internet of Things (IoT) which will have significant benefits for different levels of the energy system, but it also increases the risk of the energy system being targeted in cyberattacks.

The way forward
One of the biggest challenges that St1 perceives is the difficulty of radically changing the rules dictating how the energy system works, and the underlying incentives for reducing emissions. We have outlined some of these rules and incentives in the earlier chapters, like the need for a carbon market (ref chapter 10). Not everyone will agree with our view. Some are afraid that a carbon market facilitating carbon sequestration through afforestation is just an easy way out for polluters.

We are, however, convinced that the time has come to drastically change the pace and scope of climate efforts. We no longer have the luxury of incremental change. The information is there, what we need now is action.

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