Roadmap to Reducing Carbon Emissions

WORLD GOVERNMENT SUMMIT 2019

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Introduction

Since the dawn of history, human's ability to transform energy into heat, light or motion has always been the main driver for progress and prosperity. Through innovation, humans never stopped looking for new ways to extract energy from nature, and this continuous quest has been always the starting point of a revolution that deeply changed society and businesses. In the last two hundred years, we have witnessed the most miraculous advances in human conditions, and most of the time those advances can be linked to new ways of producing energy.

Despite the fact that energy has always supported human prosperity, the way we are harvesting it is coming with a significant price. In fact, it took us more than one hundred years after the industrial revolution to notice the consequences of our actions. When the first computer models of global climate were developed in the 1960s, many scientists supported the idea that the rise in greenhouse gases in the atmosphere would result in a warming climate, by the 1980s when global temperature began rising sharply, more voices from the media and the public joined the scientists to raise the attention of policy makers to the size of the challenge ahead.

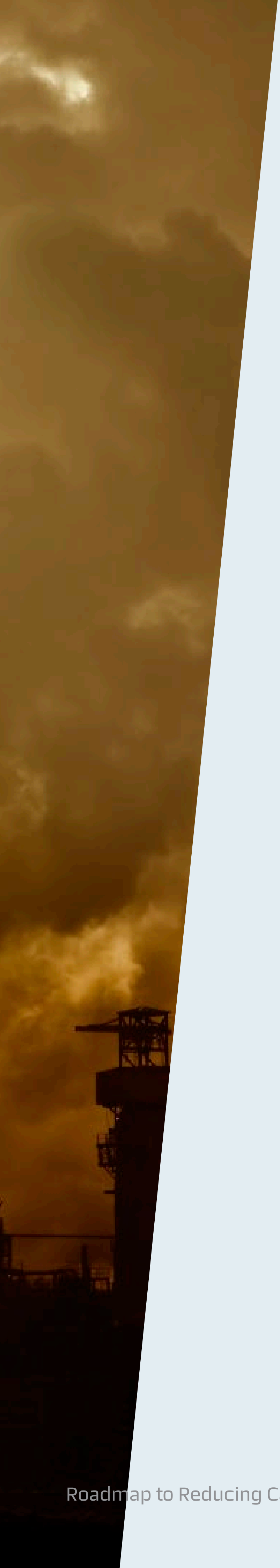
Climate change has become the main challenge that we face as a species in the twenty first century, the world that our children and all generations to come will live in depends on our ability to take the right decisions and our capacity to deliver on them. This challenge must be a concern for everyone; citizens, businesses and policy-makers alike. The only way to overcome it, is by combining efforts at all levels, through collaboration and innovation.

In its Special Report on Global Warming of 1.5 °C (SR15) released in October 2018, the Intergovernmental Panel on Climate Change (IPCC) states that meeting a 1.5 °C target is still possible, but it requires "rapid, far-reaching and unprecedented changes in all aspects of society"; Global emissions of carbon dioxide (CO_2) would need to fall by about 45% from 2010 levels by 2030, reaching 'net zero' around 2050.

If history showed that energy played a major role in past industrial revolutions, the one we are witnessing in this 21st century is fundamentally different. Unlike its predecessors, the 4th Industrial Revolution is fueled by Data. From sensors and connected objects that collect data to artificial intelligence that transforms raw data into insightful information, the digital technologies that are at the core of the fourth industrial revolution extend our abilities to embrace the complexity of the world and find new ways to tackle problems the scale of climate change. However, achieving the full potential of digital technologies in fighting climate change requires tremendous and coordinated efforts from governments and businesses.

This paper explores the opportunities offered by digital technologies and the extensive use of data to foster the collective efforts to reduce carbon emissions, and shows how data-driven policy making based on digital technologies can set a realistic roadmap to reduce carbon dioxide emissions.

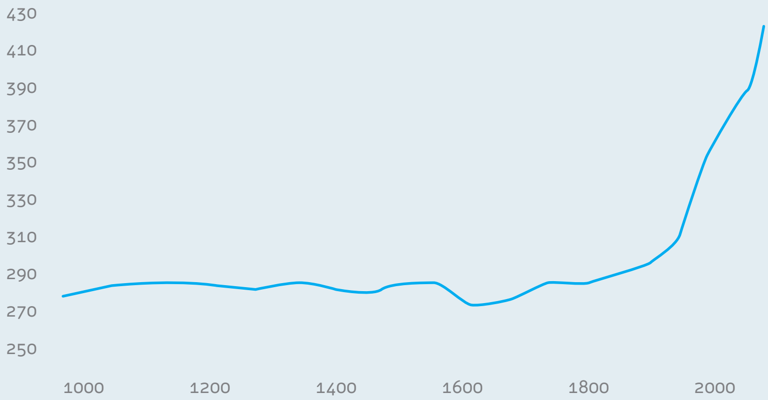
The signs are already here



Over the last 800,000 years, the presence of carbon dioxide in our atmosphere fluctuated between 180 and 280 ppm (parts per million), following glacial periods. This stable trend has been disrupted since the advent of the first industrial revolution in the middle of the 19th century. The levels of carbon dioxide kept rising at a rapid pace to reach more than 415 ppm in 2018.

Despite many sceptical voices, claiming that all we are witnessing is part of the earth's natural cycle, many scientific studies have demonstrated the strong link between high levels of carbon dioxide and human activity.

Moreover, the consequences of this trend on the planet's climate can be observed as follows.



Global CO_2 level (ppm)

National Oceanic and Atmospheric Administration

Global temperature rise

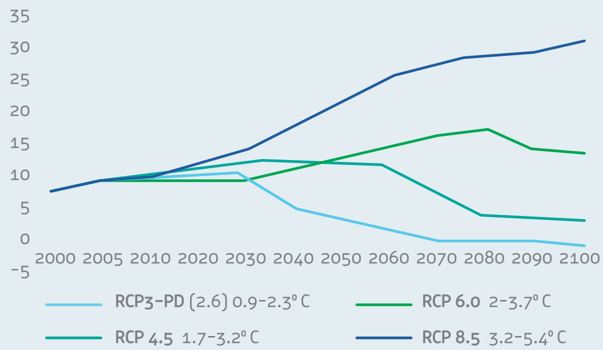
The global average temperature has risen 0.95 Celsius since the 19th century, and this trend will accelerate in the 21st century. If we don't cut dramatically our greenhouse gas emissions, scientists predict that the global average temperature would rise 4 Celsius by 2100. Reaching those high levels of temperature could lead to the extinction of many plant and animal species, as well as the migration of large chunks of populations, as some part of the world would become inhabitable. It would also lead to serious risks for regional and global food security, as it would become difficult to produce rice, wheat and corn in warmer climate regions.

Sea level rise

Two main reasons related to global warming explain the rise of sea levels: the melting ice and glaciers, and the expansion of seawater as it warms. The sea level has already risen by 18 cm over the last century, and the Intergovernmental Panel on Climate Change of the UN (IPCC) said that the sea levels would rise between 0.5 and 1m by the end of the century if global warming continues at its current pace. This means that cities such as Amsterdam or Miami would disappear under the sea. Also, the rise of sea temperature, and the acidification due to the absorption of carbon dioxide, would have disastrous consequences on maritime life and interfere with food supply around the world.

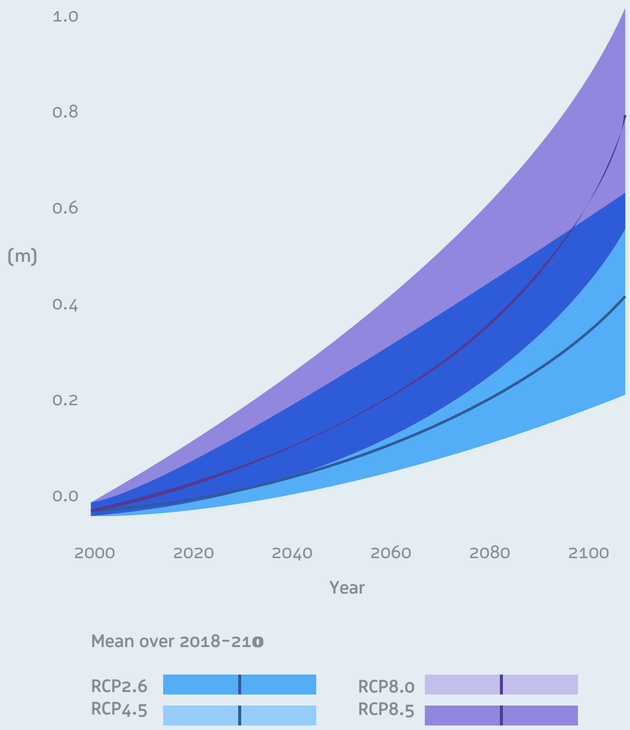
Extreme events

Every time a new cyclone hits the US, or a region in India gets flooded, the question of the link with global warming is raised. Despite the fact that it is very hard to link every disaster to climate change, the increase in global surface temperatures raises the possibility of more droughts and stronger storms. This year, the World Economic Forum ranked the risk of extreme climate events as first among global risks in terms of likelihood, and the second after mass weapons, in terms of impact.



Carbon emissions projections

Global Carbon Project



Global mean sea level rise

European Environment Agency (EEA)

Many scientific studies have demonstrated the strong link between high levels of carbon dioxide and human activity.

Moving to a low carbon economy

Reducing CO_2 emissions requires simultaneous action on several fronts, such as: decarbonizing energy production, enhancing energy efficiency, adopting climate friendly behaviours and accelerating the planet’s healing process through geoengineering.

The solutions to climate change are varied in nature, maturity and cost. The role of policy makers is to draw guidelines and to design the right tools (such as regulations, tax system...) in order to push all stakeholders to collaborate and fulfil their role in achieving climate change mitigation objectives.

Decarbonizing the energy production

According to the International Energy Agency, energy production accounts for 25% of carbon emissions globally. The electrification of China and India was one of the main sources of global carbon emissions in the last years, although both countries are becoming world champions in solar power. The move to sustainable energy sources like solar or wind has already started, and the continuous decrease of technology cost will make it easier for developing countries to move directly to green energy sources. However, there are still many challenges to guarantee the security of energy supply with high shares of renewables. The development of storage and the advancements in forecasting models are some of the possible tools that experts are exploring to tackle those challenges.

Enhancing energy efficiency

Achieving energy efficiency means creating the same economic value (product or service) with less energy. Investment in energy efficiency fights climate change in two ways. Firstly by using less energy which means producing less carbon emissions. And secondly because using less energy achieves emissions reduction at a low cost, which in turns contributes to reducing the global cost of achieving climate change goals.

A report from the International Energy Agency states that by 2050, energy efficiency will contribute by 38% to carbon emissions reduction, which makes it the biggest contributor to the carbon emissions efforts. For that reason, many countries have put efforts in promoting and incentivising initiatives seeking energy efficiency across all economic activities.

The global housing sector accounts for 30% of final energy consumption , and if combined with the construction sector, they account together for 40% of total direct and indirect CO_2 emissions . The potential of carbon emission reduction is very large, and will be delivered through two main drivers:

• **Technological advancement** in construction materials and design that will require less energy to offer the same level of comfort, and the rise of meters and sensors that will enable the optimization of energy use, through big data and analytics;

• **New policies and codes** that set requirements in terms of energy efficiency for new constructions, and offer incentives for existing building to invest in reducing their energy footprint through retrofit.

The manufacturing sector also offers great opportunities to achieve carbon emissions reduction goals. In the recent years, many industrial companies invested in implementing energy management systems and international standards, such as ISO50001, helping them monitoring energy consumption and improve energy efficiency. Between 2000 and 2016, developed countries (members of IEA) and other emerging economies achieved an average 30% reduction in their energy intensity, which is the energy consumption per produced unit of gross value added (GVA).

In 2016, the transportation sector accounted for more than 28% of global final use of energy, 90% of which came from oil products, the potential of improvement is here again enormous. Many options are considered by local governments and cities to improve the energy efficiency of their transportation systems, from policies encouraging the use of public transportation, to investments in R&D for alternative fuels, such as for electric vehicles. Government and businesses are seeking new ways to move around with a smaller footprint.

Changing behaviours

The major part of carbon emissions is directly or indirectly related to human activities. What we eat, what we buy, and how we consume products, do matter when it comes to evaluating our carbon footprint. Therefore, taking into consideration the environmental consequences of our everyday habits, and taking decisions based on our carbon footprint, can lead us to achieve great results in terms of carbon emissions reduction.

Many studies have shown for example that heavy-meat diets, in addition of being unhealthy, are resource-consuming and high carbon dioxide emitters. The solution is not impose vegetarian diets to everyone, but it goes through moderating weekly meat intake, and following low-meat diets such as the “Mediterranean” one, that can have a big impact at scale.

Other behaviours like moderating the use of heating or cooling, favouring public transportation or biking, keeping electronic devices for a longer time, if adopted by large numbers, can lead to significant reduction in carbon emissions, among other benefits to the planet, such as the preservation of resources, the reduction of waste and more.

Restoring the planet

Another way to compensate for carbon emissions is by capturing carbon dioxide from the atmosphere itself, either by natural means through reforestation

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(biosequestration of CO_2) or by new technologies that are today mostly in their experimental stage.

Many tropical countries are struggling to curb emissions from deforestation. Beef production, agricultural crops and large industrial oil palm plantations are the main causes of tree cover loss. Forest preservation programs and reforestation initiatives are the most direct response to these issues, but importing countries can also play a role in incentivising producing countries to moderate the environmental impact of their agricultural activities.

More recently, the development of new technologies for carbon capture and storage (CC&S) is opening new opportunities to reduce the concentration of carbon in air. The most advanced technologies use chemical processes that extract carbon from the air coming through large fans. The technology is still in its infancy stage and still require large investments in R&D to become scalable.

This set of techniques is becoming more and more important as many scientists start to show that reducing carbon emission might not be enough to achieve climate change goals, and that carbon dioxide should be literally removed from the air, to boost emissions reduction efforts.

Incentivising the change

All the previously mentioned solutions come with costs of implementation that sometimes would slow down or even stop the progress towards reducing carbon emissions. To incentivise the decarbonisation of the economy, governments also use regulatory and financial tools to lean the economic balance towards more environment-friendly decisions and behaviours.

One of the most known measures is the "carbon tax", based on a simple idea, the "polluter pays" principle. It intends to make the party responsible for emitting carbon dioxide, pay for the damage done to nature. It also makes the carbon-intensive solutions less economically viable, and incentivises businesses to prefer less polluting alternatives.

The revenues collected through this tax can be used to subsidise other environmental policies, such as energy efficiency incentives. Carbon tax is still not common, because many countries fear the potential negative

	Carbon Tax	Carbon emission trading	Regulations and environmental norms
Main target	Consumers, consumer goods	Large emitters of carbon dioxide	States, industrial sectors
Potential of carbon emission reduction	+++	+++	++
Regulation control over the measure	+++	++	+
Complexity of implementation	+	++	++
Economic impact	+	++	++
Degree of behavioural change	++	+	++
	Reflect the externalities related to the environmental impact in prices	Control carbon emissions by setting quotas that can be exchanged on the market	Limit carbon emissions through regulatory instruments: incentives, sanctions...

Figure: Financial instruments to support carbon emission reduction policies impact on the competitiveness of their economy.

And even the countries that have set up a carbon tax are struggling to put an accurate price for carbon emissions: only Liechtenstein, Sweden and Switzerland have a carbon price that is coherent with the levels recommended by the Carbon Pricing Leadership Coalition.

Carbon emission trading is a market-based tool, that was first used to help countries achieve their Kyoto Protocol goals by enabling them to buy and sell rights to emit more carbon dioxide. Unlike the carbon tax, the price of carbon is not set by the government; instead, a carbon cap (maximum volume of carbon emissions) is set by the government, and the price of the carbon is defined by the market.

The effectiveness of those financial tools is still a matter of discussion between economists and policy-makers, more research and development seems necessary to avoid any undesirable outcome or unexpected market behaviour that would undermine the main purpose of those measures.

Ramping up the decarbonization speed with the use of Artificial Intelligence

As we experience the new revolution of data, decision-making cycles on climate change actions can be ramped up, by embracing the new possibilities opened by so-called “Big Data” and Artificial Intelligence (AI).

Digital technologies are providing us with two main gifts to enhance our decision-making processes: data and artificial intelligence and data analytics.

Among a number of new technologies, the Internet of Things (or the capacity to capture all sorts of measurements through miniaturised sensors and to carry that data between processing units) is providing individuals, businesses, cities and governments with huge quantities of valuable information.

Every day, machines prove to the world that they can be better than humans at solving complex problems, providing aggregated analysis that can guide or help decision-making.

Until now, decisions regarding carbon reduction mechanisms are made on a top-down approach, based on trends simulation and theoretical behavioural patterns. Using some of the above mentioned technologies can put us on the path towards more agile and more data-driven policy-making, basing ourselves on real emissions data in order to get faster to more accurate decisions.

Data is now becoming more accurate and can produce more realistic scenarios than the ones that were previously built, built. For example, it is now easier to merge information collected from various sectors. For instance, information on air pollution and carbon emissions from the energy sector (which historically has been the biggest CO_2 emitter, but also the easiest to measure and monitor) can now be combined with transportation data, as public or private transportation means can be monitored using sensors and emission detectors directly installed on the vehicles. The combination of such data can provide less biased trade-off, and more balanced decisions regarding the measures worth adopting to reduce emissions.

1 - Data to enhance our knowledge

As the new fuel of the Fourth Industrial revolution is data, the unexplored possibilities of their use can open the door for new ways of fighting climate change and reducing carbon emissions. AI and other technological advances, such as unmanned vehicles, robots, or satellites, now offer a possible leapfrog in data gathering and mitigation options that weren't predictable when the climate change fight started in the 1980's. This means we can now rely not only on top-down scenarios, but also on bottom-up real use cases to inform decisions and reduce emissions.

1.1 – Fighting global warming with new weapons: data

The world is investing massively in Internet of Things (IoT) technologies, with roughly 50 billion devices predicted to spread around the world by 2020. Data coming from sensors can be stored, shared and processed towards multiple purposes.

The devices can detect, for instance, the impact of different carbon reduction measures:

- energy efficiency (with buildings consumption detection, industrial processes optimization, and transport emission detection);
- behavioural change (through sensors embedded in telephones which can gather data on people movements or spending habits); and
- negative emission solutions (such as reforestation improvements, or carbon capture).

Smart grid technologies are an excellent example of connecting the decarbonisation of energy production means with energy efficiency and energy management. Thanks to the dissemination of sensors around the grid, power distribution companies are now able to more accurately follow and predict the consumption of households, the injection of power from rooftop solar panels, the charging of electric vehicles plugged into homes' garages or parked in the street, avoiding excessive power production capacity margins, hence extra charges to end consumers.

In fact, more predictability and anticipation reduce the need to balance the grid, reducing overall balancing charges.

Useful data is also getting more and more available through open sources and shared databases, a concept referred to as "Open Data". Multiple sources of data become openly available, as the revolution is led by information technology, telecommunication or software companies, with many start-ups creating solutions tailored to sector needs.

1.2 – With new solutions come new challenges

The pace of change and evolution of technologies for capturing and storing data is exponential, with huge amount of diverse data becoming available. A number of challenges therefore need to be tackled, to make the best out of AI and data in the fight against carbon emissions.

1. Cutting the noise from Data

New miniaturised devices and sensors can now collect measurement data several times per second, and transmit it to aggregators through new communication channels using latest wireless technologies.

The possibilities offered by collecting and analysing such "near real-time" data are immense, and go far beyond the current decision-making process we apply to emission reductions, such as national environmental policies approval, or international gathering of stakeholders such as the annual Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC).

Not only do such technologies challenge the usual pace of reforms and policy-making, but they also enable the provision of better services to users, with positive consequences on carbon emissions reduction, even if they were not intended to directly reduce emissions in the first place.

As an example, optimising public or private vehicle fleets, sometimes referred to as "captive" fleets managed by a single entity and that often include an ever-larger share of electrical vehicles, can be fostered for traffic removal and circulation purposes. But on top of that, lower traffic congestion also means reduced carbon and other emissions deriving from fuel combustion.

The re-direction of existing and future technologies to low-carbon impact objectives can enhance the contribution to emission reduction.

Another example is the introduction of a carbon-neutral component in predictive maintenance schemes and decision criteria of infrastructures and manufacturing facilities. By optimising maintenance schemes, industries can decide to value those actions or pieces that contribute to lowering carbon emission, with

limited financial impact.

2. Striking the right balance between public and private data

In this digital age, data often dive deep into personal preferences and behaviours, or into production processes and their fine tuning; for this reason, governments face the difficult task of managing the availability and publicity of certain essential data, that is used to drive emission mitigation solutions.

Furthermore, data processing technologies, such as software that gather, consolidate and store precious information, should never lock-in users and particularly not the public sector entities (such as ministries, government agencies and independent authorities) by forbidding to rely on widespread standards or seamless interfaces, or by making it difficult for data-centres to "talk" to each other.

The cooperation of private and public sectors, in harvesting the collected data is essential and conducive to more accurate and targeted policies to cut carbon emissions. When cooperation works, it can deliver surprising results, as some best practices show.

1.3 – Data is already contributing to reduce our carbon footprint

Many countries and local communities have started initiatives to automate environmental data collection and make it available for citizens, researchers and policy-makers. Those initiatives show the importance of making data available and the benefits that they can bring to communities.

Air pollution monitoring is one of the most common initiatives taken by cities around the world. Sharing this information contributes to the effort of enhancing air quality, and raises the competition between cities that seek to offer the highest standards in terms of quality of life. Cities like Dubai, Paris or London have set up Open Data platforms to offer real-time air quality monitoring, and they are exploring ideas to use these data in their decision-making processes. For instance, air pollution forecasts are used by Paris Municipality to impose car speed limits reductions, as well as increasing free public transportation means on a temporary basis.

Manufacturing companies are also harvesting the benefits of data to optimize their processes, and at the same time to reduce their carbon footprint. The transportation and logistics sectors, for example, are using data to measure the performance of each equipment and each step of their process, and then use the data to identify opportunities to reduce waste of resources, or energy that in turns can be translated in carbon emission reduction.

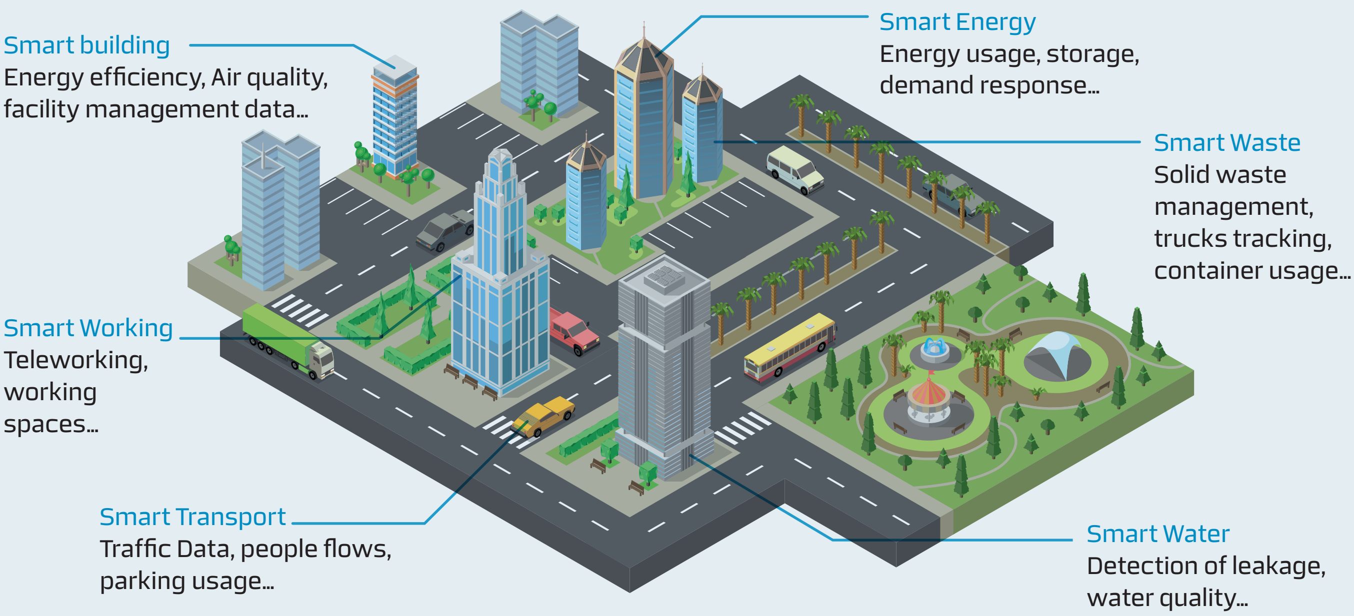

Figure: Every component of the Smart City is a source of valuable Data

2 - Artificial Intelligence to experiment and explore unknown scenarios

When Google revealed its AlphaGo in October 2015, the whole world was watching how a new machine was taking the lead in one of the oldest strategy games that humans invented. Despite the fact that this event in itself is one of the most outstanding achievements in technology history, the story of how it happened and the development that followed are eye-opening to the tremendous opportunities that AI can offer to humanity.

The first version of Google AlphaGo was trained to imitate human players by watching tens of thousands of plays, then it played millions of times against itself using reinforced learning techniques to improve its performance. While playing against the Korean World Champion Lee Sedol, AlphaGo demonstrated a different style of playing Go, and used strategies that were strange at first sight, like the 37th move in the second game, that all the experts called 'a mistake', but that turned the course of the game and showed the pure genius of AlphaGo. That was the proof that machines can also outperform humans in 'Creative Thinking'.

Two years after this historic win, a new version of AlphaGo, called AlphaGo zero, was announced with a set of overwhelming developments; AlphaGo zero can train itself with no data coming from humans and in only 3 days, it achieves the same level that took several months of training to the first version to reach. These developments show that AI can now reach superhuman capabilities in only few days and in some cases overcome the challenge of poor data inputs.

2.1 - What if Climate Change becomes the next AI challenge?

Artificial intelligence (AI) is already helping us in optimizing many aspects of our lives; it is used to enhance our comfort at home, to reduce traffic jams in cities, and to optimize productivity in different industries. Most of those "use cases" are narrow-purposed and intend to help humans take better decisions in some limited specific areas of their tasks.

The latest developments in artificial intelligence can now enable more powerful tools to simulate complex environments, by creating a digital duplicate of real objects and simulate real phenomenon. Manufacturing companies call this a Digital Twin, and they are betting on this technology to achieve better decision making using the data coming from sensors and advanced algorithms, simulating all scenarios and selecting the best ones. For example, manufacturing companies can use the Digital Twin and AI to simulate different scenarios for their asset management, and then select the best strategy.

When applying the same thinking process to our planet, creating a "digital twin" mirroring the real state of the earth, based on data coming from different sources, and using the same abilities that AlphaGo had developed to simulate millions of scenarios, we would build a strong tool to help making decisions on policies and roadmaps achieving carbon emissions reduction, possibly with the least impact on the economy or our society. We would probably find out new pathways to reducing carbon emissions that we have never thought of.

Compared to the complexities of nature, economy and society, and the tremendous number of parameters and interactions that govern our world, the game of Go becomes a smaller problem for AI to tackle. But the exponential development that we are witnessing in this field, makes the idea of using AI to simulate the world and explore scenarios in the search of the best path to save the planet, a less fictional one.

2.2 - Challenges to reach the full potential of AI

The balance between data and models

Models are the translation of the rules that govern the world and of the interaction among them. Artificial Intelligence can sometimes overcome the need for models, by looking for patterns in large sets of data: for example, AI can detect cancer from MRI without understanding what cancer is from a medical perspective.

The fundamental difference between models and Artificial Intelligence is that the first doesn't need previous data because it bases its decision on understanding the problem from its first principals, whereas the second can take decision from pattern recognition and doesn't need to understand the underlying law that explains the accuracy of its decisions.

The mixing of those two different ways of seeing and

understanding the world is the key to building systems that can go beyond the complexities of the interactions, or beyond the lack of sufficient or sufficiently reliable data.

The balance between microscale and macroscale

Using microscale and macroscale models can offer different insights to the same problem. When it comes to carbon emissions, the use of either one of the approaches depends on the data collection and the spatial scale of the modelling.

For instance, cities can use microscale approaches to model the carbon footprint of transportation means, based on sensors and data modelling; whereas, when it comes to modelling the carbon footprint at a continent-level, a macroscale approach becomes more credible and feasible.

There are many studies on the effectiveness of each approach and the different criteria to consider in order to choose the best approach. Mixing the two approaches can be very effective to create an accurate duplicate of phenomenon related to carbon emissions.

Combatting Algorithm bias

One of the biggest fears that experts express when discussing the future of AI, is the risk of bias. AI machines base their decisions on training data, and they function as a black box where the rationale that explains their decision can be very hard for humans to understand.

While it can be the opportunity for machines to suggest creative solutions, it is also a risk that the solutions might be wrong or worst, especially when it comes to taking very important decisions.

In our case, the risk is to take decisions based on bad simulations of the outcomes of a given scenario. Further research needs to be undertaken to improve our ability to detect algorithmic bias and the explanation clarity of AI.

3 - Towards an Agile data-driven policy making

One of the challenges of carbon emissions reduction is linked to policy-making. The current governance cooperation systems are driven by top-down approaches within international cooperation frameworks, such as the UNFCCC.

It relies mainly on the collection and monitoring of data that are not necessarily linked. For example energy policies are sometimes disconnected from climate policies and require different sets of data within different timeframes.

The 2011 Cancun Agreements under the UNFCCC required developed countries to establish low carbon development strategies (LCDS) or plans. Accordingly, the Member States of the European Union had to report information on those strategies to the EU in 2015.

As it was not mandatory, only 13 countries out of 27 actually developed and reported an LCD to the European Commission. On their behalf, European member states, and the international community, considered that the information that was to be provide in the LCDS was not clear. However, after the Paris agreement, that provided further guidance, the required strategies have not been submitted.

The Conference of the Parties (COP), by its decision 1/ CP 21, paragraph 35: "invites Parties to communicate, by 2020, to the secretariat mid-century, long-term low greenhouse gas emission development strategies in accordance with Article 4, paragraph 19, of the Agreement."

As of June 2018, only six G20 countries (Canada, France, Germany, Mexico, the United Kingdom, and the United States) and two other countries (Benin and the Czech Republic) had formally communicated long-term strategies to the United Nations Framework Convention on Climate Change (UNFCCC).

Data, however, are collected yearly for "full time series of emissions" and their calculation is sometimes based on top-down approaches or on theoretical emissions, rather than on actual measurements. For instance, the European Union has built an approach to calculate transportation sector emissions based on the annual carbon emissions of a whole country. This is calculated either with the fuel sold and / or adding a series of parameters that take into account the model of the transportation and the type of fuel. In the energy sector, emission factors by fuel are used to calculate the emissions from different energy sources.

The Global Warming 1.5C report published October 2018 by the Intergovernmental Panel on Climate Change (IPCC) and the Emission Gap Report published November 2018 by the United Nations Environment Programme, base their analysis of national submissions, or on data provided by BP's own and very recognised Statistical Review of World Energy report and by the International Energy Agency's Global Energy & CO2 Status Report. All these institutions therefore mainly use theoretical data and not enough actual / measured data.

3.1 - Moving towards real data policy making cycles...

The first step towards policy making with real data, is to make a widespread usage of measured emissions to update the current projections.

While estimates on electricity production are updated through actually consumed quantities, measured and calculated by electricity transportation & distribution operators, the calculations regarding emissions is still based on the emission factors. The first step is therefore to incorporate real data collected by sensors in order to draw a real scenario.

The next step is to simulate multiple real scenarios through the use of advanced machine learning and deep learning technologies. Using these technologies allows to elaborate scenarios that are not yet conceived by humans. The decision-making will therefore be based on closer to reality scenarios.

Once decisions are made and start being implemented, pervasive monitoring & measurement technologies, such as the ones made possible by the Internet of Things (IoT), will help following-up the actual evolution of measuring points and aggregating such results. Advanced technologies can also suggest analysis on the reasons behind eventual gaps: economic drive or slow down, behavioural patterns, environmental disasters or extreme weather, to name a few.

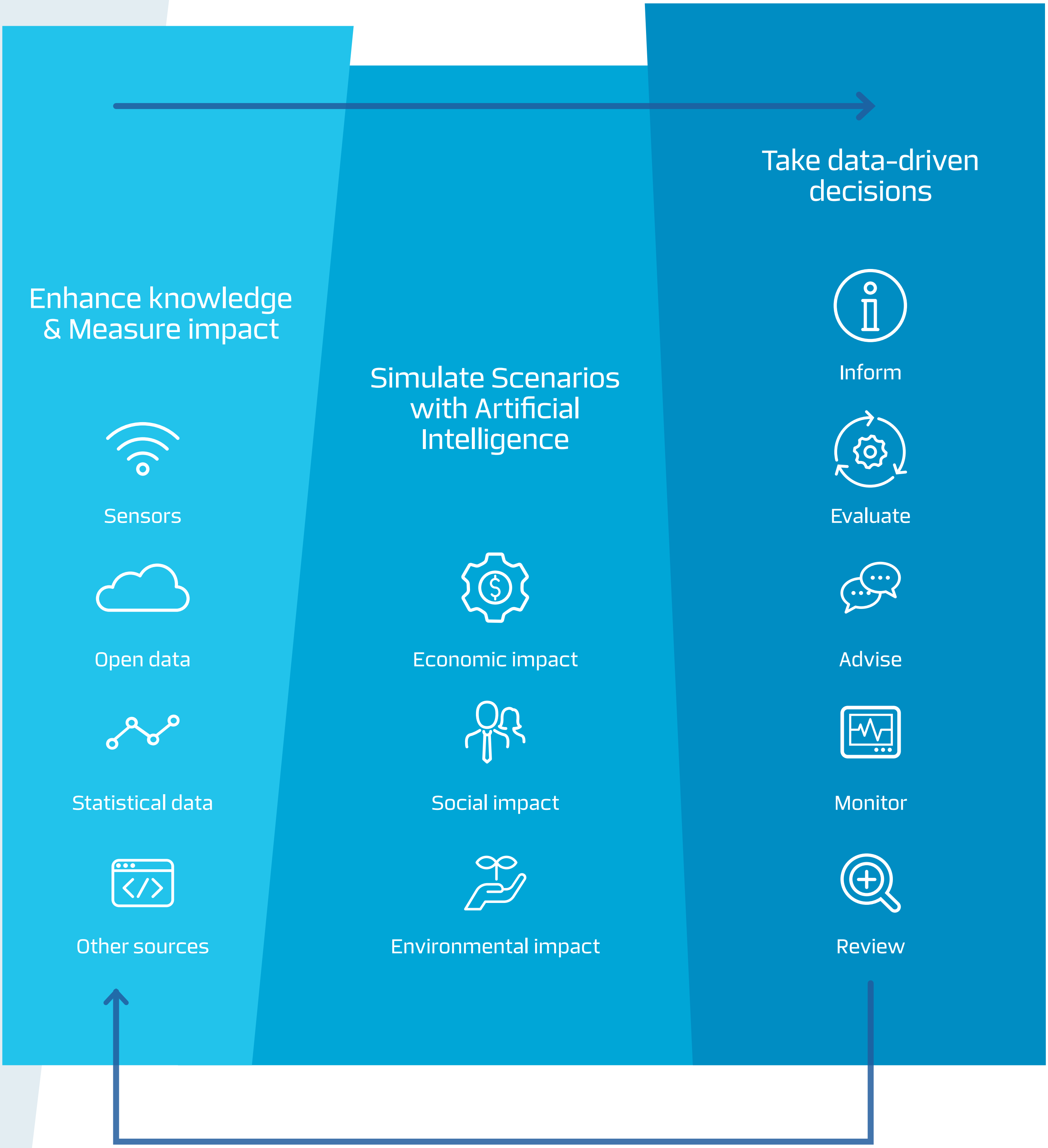

Figure: Data-driven policy making is based on a cycle process

Policy trajectories can then be adapted, and other cycles of data collection, then decision making, can start.

3.2 - ...requires reinforced cooperation in data sharing

Data ownership
The first challenge to grasp and tackle for adopting this new model, is the one of data ownership.

Sectors' needs, regulations and technologies have driven the development of technological solutions capable of capturing emissions data. In the private sector, the disclosure of emissions data is now a measurement of performance and competitive advantage.

The example of Automobile industry, in which tracking and sharing carbon emission data is a very sensitive topic, reminds how regulation can tackle emissions reduction, but also illustrates how private companies are responsible for developing and rolling out the corresponding technologies without damaging their image. Despite the push for more transparency on emission data, driven by the market attractiveness of low-carbon products, a gap remains between laboratory-tested products and the emissions actually measured on the field.

Governments must incentivise private companies to share their data by efficiently protecting commercially confidential information, and by sharing in their turn, the result of their analysis or best practices, further improving emissions efficiency.

Adjusting the governance
The second challenge lies in integrating these new measured data into existing governance schemes.

The submission process of emissions data has been structured over the years, and it's based on a harmonized nomenclature, split by sectors. Any new system involving data in larger quantities and refreshed at a more frequent pace, would require new ways of including such real measured data into scenarios planning exercises.

This can be done by adjusting the emission factors, on the basis of actual measured emission data; which is easily done in the energy sector, where sensors capture the real emissions during combustion of fossil fuels; or in the manufacturing sector, where sensors collect the emissions at different steps in the production process.

Even in agriculture, sensors can help gather information on emissions from different crops and different growing, harvesting and transformation techniques. Relying on real measured data can also be achieved by collectively changing the way emissions are calculated, and by gathering actual emission figures. This process is already applied through air pollution sensors, alerting on high levels of greenhouse gases (GHG) in the atmosphere, and triggering immediate policy responses at local levels.

It seems however ambitious and possibly more delicate to reproduce such concepts at national or international levels, where the amount of data gathered would be immense, and where the difference in standards and systems would require conversions and complex adjustments.

The cooperation of private and public sectors in harvesting and processing the data is therefore essential, and it is conducive to more accurate and targeted policies to cut carbon emissions.


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Conclusion

Last December 2018, the world's eyes were turning in the direction of Poland where the COP24 was taking place. "If we don't take action, the collapse of our civilisations and the extinction of much of the natural world is on the horizon," the natural historian Sir. David Attenborough said, in his address.

Although different countries have launched initiatives to tackle climate change, we still need more efforts at all levels to secure our path towards a carbon-free world. The energy transition to more clean energy sources, and the impact of energy efficiency measures, are delivering a part of the journey towards solving climate change problems.

The digital revolution can also lead to a more sustainable world, by harnessing the power of data and algorithms. In fact, new technologies such as the Internet of Things and Artificial Intelligence can achieve tremendous results in helping all sectors reducing their carbon emissions.

While those technologies can help improving our carbon footprint, they can also change our policy-making process and provide governments and industries alike with new tools to create feasible and accurate carbon emission reduction roadmaps. The outcomes of the COP24 – that essentially agreed on rules to measure and communicate emissions that will only enter into force by 2024 - are the perfect example of the necessity of such tools to foster international cooperation.

In this report, we explored the **importance of data collection as a first building block of the policy-making process.** Enhancing our knowledge about carbon emissions in all human activities is the key to understand the impact of each sector on the environment, and to identify the most relevant actions to be undertaken. The rules and mechanisms put in place by the international community during COP24 to report and monitor carbon emissions can benefit from the extensive use of data collection innovations such as IoT and Open Data.

As COP 24 and the previous conferences show us, we have spent more time on negotiation and diplomacy than delivering actual action. The current policy-making process needs to gain more agility and flexibility because the window for action is getting smaller every year.

Artificial intelligence is the second building block that can help simulate a large number of possible scenarios and strategies for reducing carbon emissions, and for identifying the most feasible ones, mitigating the impact on economy and society.

The same data used to monitor human activities and set up environment policies will be used to track the outcomes of those policies and judge their effectiveness, this only will enable a more data-driven and agile policy-making culture.

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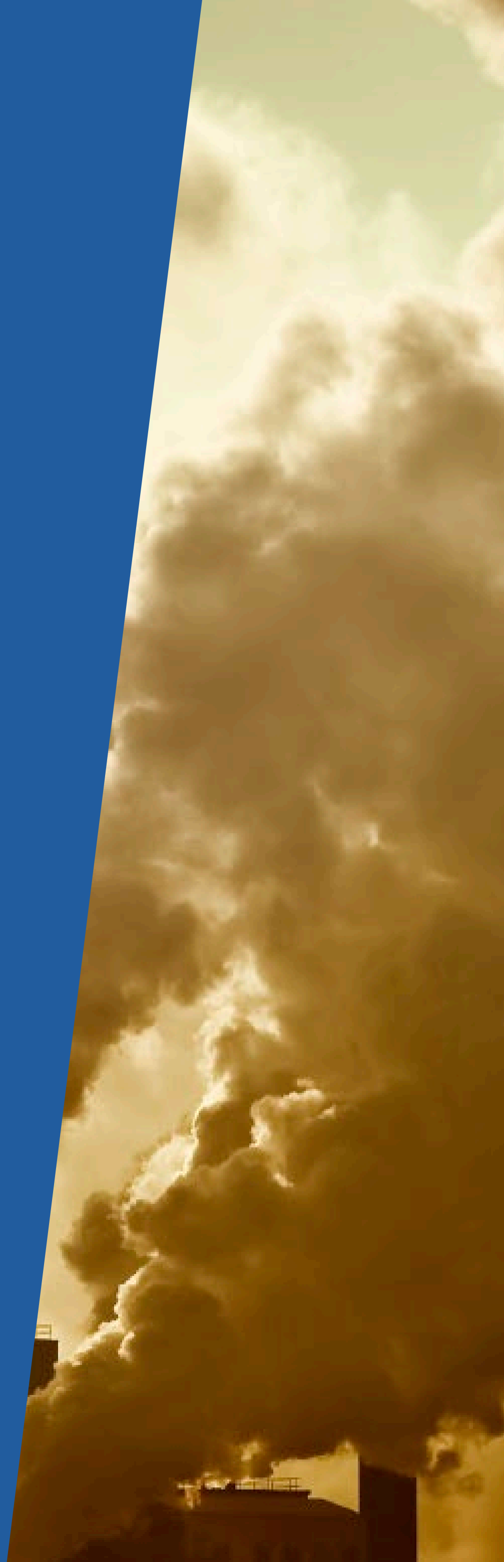

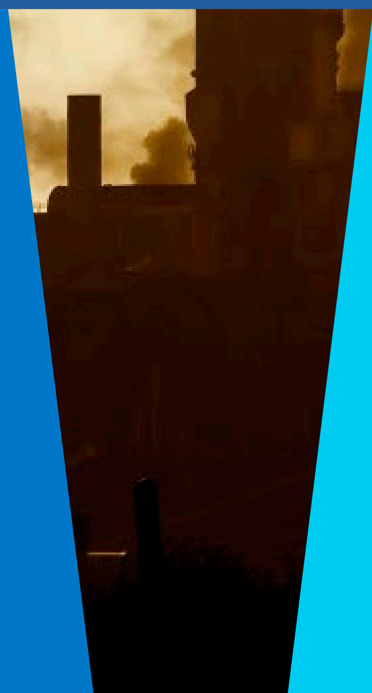

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