International Actuarial Association
Association Actuarielle Internationale

Decarbonization: A Briefing for Actuaries

Discussion Paper

Resource and Environment Working Group

September 2018

Decarbonization: A Briefing for Actuaries

This Discussion Paper (paper) was prepared by the Resources and Environment Working Group (REWG) of the International Actuarial Association (IAA).

The paper was primarily an effort of a subgroup of the REWG led by Paul Meins with Caterina Lindman and Frank Grossman. Important input was also provided by Sam Gutterman and Rade Musulin. Constructive comments were made by other members of the REWG and the Scientific Committee.

This paper has been approved for publication by the REWG and the Scientific Committee of the IAA.

The IAA is the worldwide association of professional actuarial associations, with several special interest sections and working groups for individual actuaries. The IAA exists to encourage the development of a global profession, acknowledged as technically competent and professionally reliable, which will ensure that the public interest is served.

The role of the REWG is to identify issues related to resources and the environment of interest to actuaries and to which the actuarial profession, at an individual or national level, can make a useful contribution in the public interest.

The views expressed in this paper are not necessarily the views of the IAA.

International Actuarial Association
Association Actuarielle Internationale

Tel: +1-613-236-0886 **Fax:** +1-613-236-1386
Email: secretariat@actuaries.org
1203-99 Metcalfe, Ottawa ON K1P 6L7 Canada
www.actuaries.org

Table of Contents

1. Introduction

The nations of the world have agreed[1] to "decarbonize" in order to mitigate climate change. *Decarbonization* refers to policies that will result in a reduction of greenhouse gas (GHG) emissions by substituting lower-carbon sources of energy or taking equivalent actions such as reducing the consumption of goods and energy. In both the near and medium term, decarbonization will affect every economy in the world and most aspects of economic activity. It will lead to a transformation in how goods and services are produced and consumed, similar in scope to the industrial revolution or the rise of the internet.

This transformation and the changes in Earth's climate driving it will affect many aspects of actuarial work, although it is not possible to foresee all these effects. For example, property insurers need to cover solar panels and wind farms. Insurers' and pension funds' asset mix and returns are being increasingly affected. Weather patterns may change, affecting property and agriculture insurance losses. Rates of mortality and morbidity may change due to such factors as migration, increasing heat and changes in precipitation. Rising seas may pose significant challenges for coastal flood insurance.

The Resources and Environment Working Group (REWG) of the International Actuarial Association (IAA) "serves as a working group within the IAA devoted to environment issues that can affect the work of actuaries in their various areas of practice". In coming years, decarbonization will lead to many opportunities for actuaries. To provide background and to facilitate enhanced understanding of the issues involved, the REWG has prepared this paper.

The objective of this document is to provide an introduction for actuaries globally to the decarbonization process, including (1) the background to decarbonizing, (2) the main sources of GHG emissions, (3) the commitments already made, (4) policies which have been adopted and (5) likely future developments. Brief observations on the potential actuarial implications are also included. This paper does not cover other aspects of climate change, such as its likely effects/consequential damage or measures to adapt to it. This document was mainly written in the latter half of 2017; because this is a fast-moving and important topic, we expect that it will need to be updated by 2020.

[1] One hundred and ninety-seven Parties (including all the countries of the world) to the United Nations Climate Change (formerly the United Nations Framework Convention on Climate Change) signed the Paris Agreement of 2015, although the United States has indicated its intention to withdraw from it.

2. Context

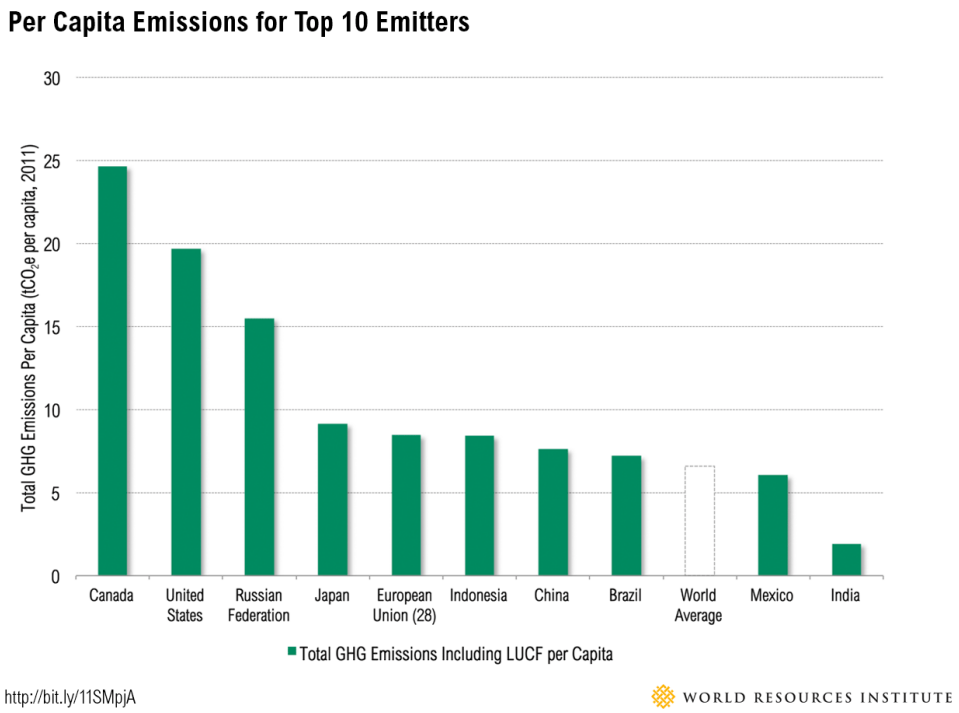
The industrial revolution, continuing around the world, has transformed human society, massively reducing poverty and substantially increasing life expectancy. But at the same time, it has depended on cheap and powerful energy sources: principally coal, oil and gas, which are now precipitating potentially disastrous climate change. Burning these fossil fuels produces GHGs, including carbon dioxide and methane, and endemic global warming. GHG emissions are also created by, among other human activities, deforestation and livestock farming.

International action on GHGs (decarbonizing) has its origins in the United Nations Framework Convention on Climate Change (UNFCCC), which was signed by world leaders at the Earth Summit in Rio de Janeiro in 1992. Article 2 of the convention commits countries to stabilize GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

In 1997, 193 countries signed the world's first binding agreement to cut emissions: the Kyoto Protocol. The treaty set limits on countries' emissions, taking into account their historical contribution to climate change and development status. After being ratified by 160 countries, the protocol eventually came into force in 2005. Developing countries had no explicit reduction targets, reflecting the fact that their per capita and historical emissions were low, and an increase in emissions would be beneficial for development and poverty reduction. The fully participating developed nations, including those in the European Union (EU), Russia, Japan and Australia but accounting for only 18% of global emissions, were able to reduce their emissions by 22.6% from 1990 levels in the 2008–2012 period. However, the significance of this result has been questioned; for example, in *New Scientist*: global emissions still rose and the collapse of the USSR post-1990 would have resulted in massive emissions reductions in any event.

A replacement for the Kyoto Protocol was agreed to by 197 countries and organizations (like the EU) under the UNFCCC in Paris in 2015. It will be legally binding from 2020 and has already been ratified by the necessary 55 parties representing at least 55% of emissions, including China, the EU and the United States. While the United States announced in June 2017 that it intends to withdraw from the treaty, this will not affect the legal process for other parties.

The Paris Agreement does not include specific decarbonization targets, but states the need for global emissions to peak as soon as possible (recognizing that this will take longer for developing countries), and for rapid reductions thereafter in accordance with the best available science. The target is to limit the increase in global average temperature to well below 2.0°C, and no more than 1.5°C, from pre-industrial levels. It also includes provisions to support developing countries in this task, aiming to mobilize US$100 billion per annum by 2020. In this connection, the following shows the contrast between per capita emissions for developed and developing countries:



In the above chart emissions are those produced in each location, in line with UNFCCC definitions. (*LUCF* is an acronym for Land Use Change and Forestry, which impacts emissions because forests store carbon while deforestation releases carbon.) This approach to measurement of per capita emissions can be contentious where goods are produced for export and consumption in another country, and there is an imbalance of trade; for example, in relation to Chinese exports in recent years. However, emissions based on consumption may be more difficult to estimate if they require data for imports from other countries. The table also does not attribute emissions to countries exporting fossil fuels such as Australia (coal), Norway (oil and gas) and those in the Middle East.

China, representing about 25% of global emissions, has committed to peak its emissions by 2030 and to make best efforts to peak earlier. It will increase non-fossil energy to 20% of its energy consumption by 2030, which will require it to install 800 to 1,000 gigawatts in non-fossil capacity, equivalent to the entire current U.S. generating capacity. It is putting a price on carbon by launching a national cap and trade system, initially covering its power generation sector, which is already the world's largest. See Carbon Brief's analysis.

In 2014, **the United States** represented about 14% of global emissions. The U.S. plan submitted to the UNFCCC in advance of Paris in 2015 is to reduce emissions by 26–28% below 2005 levels by 2025. This translates to a reduction of 13–15% below 1990 levels by 2025. The 2014 emissions were already 9% below 2005 levels, partly as a result of a switch from coal to gas with the growth of fracking. See this U.S. Environmental Protection Agency (EPA) report.

EU targets (representing about 10% of global emissions and 28 countries – including the UK, currently negotiating its withdrawal from the EU) are presently:

2020	2030	By 2050
20% cut in GHG emissions compared with 1990 20% of total energy consumption from renewable energy 20% increase in energy efficiency	At least 40% cut in GHG emissions compared with 1990 At least 27% of total energy consumption from renewable energy At least 27% increase in energy efficiency	Cut emissions substantially – by 80–95% compared to 1990 levels as part of the efforts required by developed countries as a group

Based on 2014 figures, EU emissions were already 23% below 1990 levels and the use of renewable energy was over 15% of the total energy consumption.

India, representing about 7% of global emissions, has Paris targets to lower the emissions intensity of GDP by 2030 to 33% to 35% below 2005 levels, to increase the share of non-fossil-based power generation capacity to 40% of installed electric power capacity by 2030 (equivalent to 26–30% of generation in 2030), and to create an additional (cumulative) carbon sink of 2.5–3.0 gigatonnes of equivalent carbon dioxide ($GtCO_2e$) through additional forest and tree cover by 2030 (India's *annual* emissions are currently about 3 Gt). For 2020, India had earlier put forward a pledge to reduce the emissions intensity of GDP by 20% to 25% below 2005 levels. Reducing emissions intensity can still result in increases in emissions, depending on corresponding GDP growth rates.

Canada (representing about 2% of global emissions) committed to be 25% below 1990 emission levels by 2030.

According to a UNFCCC report issued in 2015, the non-binding pledges then submitted by countries could still result in a 2.7°C global temperature increase by 2100, which means that additional efforts will be necessary to keep warming below 2°C. Moreover, it is not clear that all countries will deliver on their non-binding pledges. There is also a margin of uncertainty around the amount of GHGs that can be emitted to keep warming below 2°C, implying that it might be prudent to reduce emissions more quickly in order to achieve a stable climate. These concerns are illustrated by the graphics in a November 2017 article from the *New York Times*.

According to PwC, the average decarbonization rate (the rate at which GHG emissions per $GDP reduces) pledged by the G20 is 3%. This can be contrasted with the 6.3% decarbonization rate needed to achieve the 2°C target.[2]

The Paris Agreement indicates that there will be a meeting in 2020 to agree to more ambitious targets. A roadmap was published by developed countries in 2016 and shows how the US$100 billion per annum for developing countries may be achieved.

[2] The Low Carbon Economy Index 2017. PwC.

While the principles are clear, the Kyoto Protocol and the Paris Agreement are highly complex in practice, involving such issues as:

- Transparency and independent verification;
- Which GHGs are covered and how each should be treated, given their differing climate impacts;
- How emissions should be estimated;
- Whether and to what extent "carbon trading" is allowed;
- The allowance to be made for "carbon sinks", such as forestry;
- Whether emissions should relate to where goods are manufactured or where they are consumed (for example, China's emissions are relatively large partly because it manufactures products used in the developed world); and
- The allocation of emissions from international travel and transport.

3. Main areas for decarbonization

The main GHGs, their approximate climate impact and sources are summarized below:

Gas	**Indicative lifetime in atmosphere**	**Indicative 100-year warming impact (CO_2 shown as 1)**	**Sources**
Carbon dioxide	Indefinite, but some absorbed by oceans and other natural processes	1	Mainly burning fossil fuels, including cement production, and destruction of trees reduces CO_2 absorption
Methane	10 years	30	Production and transport of fossil fuels, livestock and organic decay
Nitrous oxide	100 years	300	Burning fossil fuels, fertilizer and various industrial processes
Fluorinated gases (including hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride)	Varies, some 1,000+ years	Varies, some 1,000+	Various industrial processes, and household products including refrigerators

Based on www.epa.gov/climate-indicators/greenhouse-gases. The warming impact indicator shown is for the same mass of gas.

Atmospheric water vapour is also an important GHG and it increases with temperature (from evaporation), so global warming results in an adverse feedback loop in this respect. On the other hand, clouds (condensed water vapour) reflect solar energy. The overall impact is currently being researched.

Over 80% of recent global warming is attributed to increased carbon dioxide, while fluorinated gases contributed less than 5%, despite their higher relative impact. In any event, as most GHGs mainly arise from the use of fossil fuels, reducing their use has an impact on all the main GHGs listed above.

Apart from mitigating global warming, reducing fossil fuel burning also has wider environmental benefits such as reducing pollution and improving air quality and health.

The main opportunities for decarbonization depend very much on the circumstances of individual countries; for example, on their size and population density, the nature of the climate, their relative development status and the availability of renewable resources. For developing countries, decarbonization is also sensitive to the extent to which their growth can be made less carbon intensive with assistance from the developed countries. For more developed countries, decarbonization will pose many challenges to the status quo.

In some cases, mitigation can be achieved by the substitution of one technology or fuel for another; for example, LED lighting or replacing coal with gas. In other instances, behavioural changes are likely to be required, such as greater use of public transit and more cycling and walking. Reduced consumption is also likely to have to be encouraged; for example, smaller homes, less flying and reduced meat consumption.

Mitigation of emissions also calls into question preferences for relatively low-cost, disposable goods, rather than items made to last and which can be repaired or recycled. Also, planned obsolescence increases emissions; for example, in relation to cell phones, cars, and fashion generally. Although individuals have some control over what they buy and how they use energy, society and governments are also likely to have to play a role in how available, convenient and affordable are low-emission choices and recycling.

The main uses for fossil fuels, and the scope to reduce them, are summarized below.

Coal

- Coal is used extensively for electricity generation around the world, with consumption increasing in most developing countries. However, China reported that coal consumption was reduced in 2016, for the third year in a row, which was reflected in a small reduction in world consumption. Coal is also used for heating.
- Clearly, there is considerable scope to replace coal for electricity generation with less-carbon-intensive (and in many cases less expensive) fuels like gas, with renewables (for example, solar, wind, tidal, hydropower, or geothermal) or with nuclear (although some new nuclear projects are beset by technological problems).

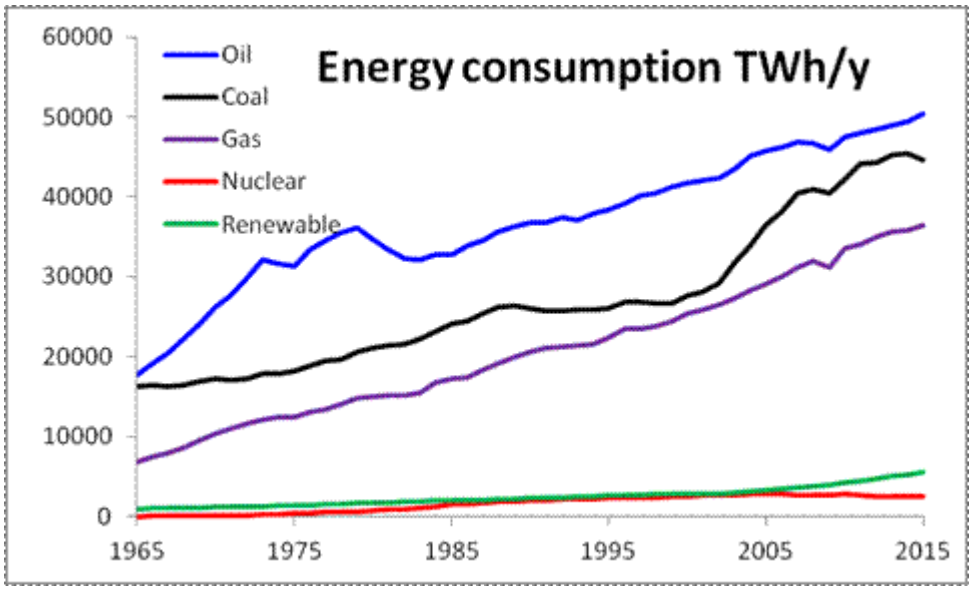
Oil

- Oil is mainly used for transport – cars, planes, ships and trains – as well as for heating and electricity generation and in the manufacture of many other products.
- As technology improves, GHG emissions from oil should be able to be reduced or eliminated for most of these uses, by means of more efficient engines and design and switching to electric engines and batteries, although planes (and ships to some extent) are clearly more of an intractable problem. Aviation presently seems primarily a question of minimizing emissions and reducing growth in air miles.

Gas

- Gas is mainly used for electricity generation and heating.
- The scope for replacing gas is similar to that summarized above for coal.

The following chart shows worldwide energy consumption.



By Martinburo – Own work, CC BY-SA 4.0,
https://commons.wikimedia.org/w/index.php?curid=53803246

Note that consumption has increased for all sources of energy in recent years, with the exception of coal. However, the apparent reduction in coal consumption has been questioned.[3] The chart above also illustrates the scale of the huge global challenge to radically reduce emissions. Despite increasing demands from the developing world, all the fossil fuel lines will eventually need to trend sharply downwards, with energy consumption reduced through efficiencies and lifestyle changes, and renewables massively expanded.

[3] See Barry Saxifrage's article, These missing charts may change the way you think about fossil fuel addiction. *National Observer*. July 2017.

The practicality of technological solutions to decarbonization are also being researched, such as capturing and storing carbon from burning fossil fuels, large-scale sequestration of atmospheric GHGs, and nuclear fusion. The demand for energy can also be reduced by better insulation, better power management, better city design and changes in lifestyles.

Carbon budget

The fifth Intergovernmental Panel on Climate Change report stated that the world can only emit 1,000 Gt of CO_2 after 2010 in order to have an estimated two-thirds chance of keeping global warming below 2°C. The rate of emissions is currently at about 40 Gt of CO_2 per year – it has been estimated that emissions need to peak before 2020 in order for the world to have a reasonable chance of living within the 1,000 Gt CO_2 carbon budget. "The core message of the carbon budget is that emissions need to go down at an unprecedented rate," said Glen Peters, senior researcher at the Center for International Climate Research.[4] Again, this means that the use of oil, coal and gas needs to start trending downwards, in contrast to the combined upward trend shown in the graph on the previous page.

Other areas for decarbonization

It appears that agriculture is directly responsible for about 11–14.5% of global GHG emissions ignoring emissions related to changes in land use – which can release carbon as forests are converted to pasture or used to grow crops – and transportation. The total emissions from this sector are estimated to amount to 25% or more of total emissions.[5] Agricultural emissions could be reduced with changes in diet towards less meat, eggs and dairy, and with changes in farming practices, although as significant parts of the global economy develop these shifts will be challenging to achieve. A co-benefit to orienting diet towards more whole, plant-based foods would be the likely prevention and reversal of the frequency of many chronic diseases.

The cement industry is responsible for about 4% of GHG emissions and is looking at various ways to reduce this, including carbon capture.

4. Existing policies

Decarbonization policies are affected by a variety of influences; for example:

- Market forces, which can be influenced by fiscal or regulatory policies, etc.;
- Availability of renewable sources, such as hydro, tidal, wind and solar;
- Energy security – policies should not be overly dependent on external sources or monopoly suppliers, or exposed to natural disasters or technological risks;
- Public opinion – whether supportive or whether concerned about cost increases or safety (for example, for nuclear power);

[4] See The Carbon Budget for Dummies.
[5] CO_2 and other greenhouse gas emissions. Hannah Ritchie and Max Roser, Our World in Data.

- Lobbying from and actions by the fossil fuel industry; and
- Impact on business competitiveness – mainly related to international comparisons, a "level playing field", which can be highly complex and involve trade negotiations and whether exports or imports are being unfairly subsidized or penalized.

The types of policy which are being used to reduce emissions are summarized below:

- Carbon tax – this is typically a tax related in some way to emissions associated with the product, included in the price paid and collected by the vendor. It could include, for example, a petrol/gasoline tax or a tax paid by electricity generators according to the fuel and the quantity used. Revenues can be used to offset cost increases for low-income users, to reduce other taxes or to build infrastructure for a decarbonized economy;
- "Cap and trade" schemes for business – these set a cap or limit on total annual emissions for a defined business sector and a mechanism by which emissions can be traded between businesses. The trading of permits is designed to provide flexibility and incentives to reduce emissions in a scenario where the cap reduces steadily;
- Incentives and charges – these would not typically be directly related to emissions, but include grants for housing insulation, subsidization of public transport, grants and on-going support for electric vehicles and solar power installation, and favourable tax regimes for renewable energy investments. Charges could include airport or flight taxes, and vehicle congestion charges such as in London, Milan, Singapore and Stockholm;
- "Smart" electricity distribution systems to facilitate efficient energy use and localized renewable production;
- Changes in the regulations on building construction to require better insulation and/or more efficient cooling, also extending to city design and including ease of transport;
- Regulations governing institutional funds clarifying fiduciary duty and requiring the disclosure or special treatment of investments in carbon-intensive industries or the insurances for such industries; and
- Other laws or regulations stipulating actions by business or by nationalized industries; for example, in China.

A carbon tax directly increases the cost of carbon-intensive energy, thereby making renewable energy and conservation of carbon-intensive energy more attractive. A feature of a carbon tax is that the market response as to the amount of emission reductions is difficult to predict. Canada has set a federal carbon price of US$30 a tonne in 2018, increasing to US$50 a tonne by 2022. The UK, like most of Europe, has long had relatively high taxes on petrol and diesel, amounting to over 60% of the retail price in many cases. An issue here is replacing this taxation revenue if fossil fuel vehicles are replaced by electric vehicles.

The EU cap and trade market failed initially for several reasons, including too high a cap and emissions falling due to the recession so the cost of emissions permits fell drastically. However, cap and trade systems are more common than carbon taxes, with the EU, China and the Western Climate Initiative (California, Ontario and Quebec) having systems or intending to have systems in

place by 2018.[6] Some schemes also included trading in "offsets", whereby claimed reductions in emissions in one part of the world – for example, through tree planting – were offset against emissions elsewhere; however, the credibility and efficacy of such arrangements has been questioned.

Feed-in tariffs guarantee renewable energy suppliers a fixed retail price for a given period. This encourages investment both by business and by individuals (for example, in relation to the installation of solar panels).

Quota systems are where a renewable energy quota is set, and each electricity supplier must maintain a minimum percentage of their total energy provided by renewables. Electricity suppliers can then purchase green electricity certificates, if they are unable to meet their quota, from those suppliers that have a surplus. Tender schemes can also be used, where support is allocated to renewable energy suppliers in a competitive bidding procedure. Tender schemes are in use, for example, in Denmark, the Netherlands and France.[7]

Replacing fossil fuel vehicles with electric vehicles will be a key action to reduce GHG emissions, provided that the electricity used to power the vehicles is not reliant on coal (or other fossil fuels). For example, the average U.S. car fleet in 2010 uses 110 tonnes of CO_2 over the life of the vehicle, while a Nissan Leaf uses 80 tonnes of CO_2 if the electricity is generated from coal, contrasted with just 14 tonnes if the electricity is from Quebec, which uses mainly hydro-electric power. As well as reducing GHG emissions, electric vehicles reduce air pollution, particularly when compared with diesel vehicles.

Some jurisdictions offer incentives to people who purchase electric vehicles. Incentives are in place in Ontario, British Columbia, Quebec, the United States, the UK, the EU, and China. Many countries have announced bans on the future sale of fossil-fuel-powered cars; for example, France and the UK from 2040, with similar initiatives in Germany, Norway and India.

The most expensive component in an electric vehicle is the cost of the battery. Battery costs are falling dramatically – the cost of large orders of lithium ion battery packs was about US$1,000 per KWh in 2010[8] and US$542 in 2012, and is at US$139 in 2017.[9] Bloomberg New Energy Finance projects that 35% of new vehicle sales will be electric by 2040.[10]

Nuclear power has very low carbon emissions once built, but passes on decommissioning and waste disposal costs, and their associated risks, to future generations. Recent years have also revealed its exposure to potential natural disasters (and perhaps terrorism). On top of this there are currently huge cost overruns and long delays associated with some new nuclear projects. Most

[6] See Evaluating the EU Emissions Trading System. Mirabelle Muûls, Jonathan Colmer, Ralf Martin, Ulrich J. Wagner, Imperial College London. October 2016.
[7] Renewable Energy Support Policies in Europe. Climate Policy Info Hub.
[8] Here's how electric cars will cause the next oil crisis. Bloomberg News. February 2016.
[9] Lithium ion batteries are now selling for under US$140/kWh – New York hears on Benchmark World Tour 2017. Benchmark Mineral Intelligence. May 2017.
[10] Here's how electric cars will cause the next oil crisis. Bloomberg News. February 2016.

governments do not appear to see nuclear as a significant part of decarbonization, and indeed, existing nuclear power stations will need to be replaced as their working lives come to an end.

5. Likely policy trends and their actuarial implications

The political context for decarbonization is evolving, and in ways that may make comprehensive policies more difficult to adopt. There seems to be diminished trust in governments, institutions and accepted doctrines (for example, globalization). There is also an increasing willingness to defect from established political processes and take independent action – nation states from international institutions, subnational governments from their national governments, and local governments acting on their own initiative. Additionally, some political actors are willing to sow doubt about the basic science itself, assisted by "fake news". But, on the other hand, localism can be supportive of decarbonization and social media a powerful positive force in many areas.

It may be instructive to briefly consider the relative success of the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer vis-à-vis the United Nations Climate Change processes to limit GHGs. The protocol mandated the replacement of chlorofluorocarbons (CFCs) with other coolants in refrigerators, and set out targets and timelines for their elimination. Prescribing a particular standard worked in this instance because there was broad acceptance of the problem and urgent need for a solution, developing countries were afforded financial support for their transition, and the protocol encouraged government and business to collaborate to deliver an effective technological fix. As such, the Montreal Protocol had a narrow scope and eschewed reliance on indirect or market-based solutions (for example, an emissions trading scheme or a carbon tax). CFCs were effectively banned from new refrigerators worldwide, and the cost of developing and implementing the improved technology was passed on to consumers.

In contrast, with decarbonization the need to act has only become generally accepted at the political level in recent years and it has major implications for many aspects of society and business. Desired actions may be delayed, unless climate change itself (floods, storms, heatwaves and droughts) accelerate political change, although the reaction to disasters could lead to priority being given to short-term adaptations to climate change, rather than longer-term mitigation.

Nevertheless, market forces can themselves generate momentum, as seems to be happening with electric vehicles and renewable energy infrastructure. Also, pollution arising from fossil fuels is becoming a major driver of change in the many cities beset by poor air quality, such as London and Beijing.

There are clear trends that the importance of sustainability and combating climate change is being recognized by business; for example:

- The World Economic Forum, in its 2018 Global Risks Report, once again (for the eighth year running) ranked extreme weather events, major natural disasters and failure of climate change mitigation and adaptation in the high-risk, high-impact category;
- Nearly 900 companies and investors in the United States signed a letter (April 2017) addressed to the U.S. President, the U.S. Congress and global leaders, expressing support for the implementation of the Paris Climate Agreement commitments;
- The Financial Stability Board (FSB) Task Force on Climate-related Financial Disclosures published its Recommendations Report in June 2017 and has received widespread support;
- The Sustainability Accounting Standards Board expanded its set of material sustainability indicators across sectors and industries and expanded the reach of its efforts beyond the United States, while the Global Reporting Initiative (GRI) reformulated its existing GRI Guidelines into a set of reporting standards;
- The green finance market continues to grow, with labelled green bonds reaching US$118bn outstanding (as at July 2016). Poland issued the first sovereign green bond (November 2016);
- In December 2017[11] the World Bank announced several measures to support decarbonization, including that it will generally cease to finance oil and gas exploration from 2019; and
- Many groups are working with businesses, such as the Climate Group, Accounting For Sustainability, Climate Action 100+ and the Global Investor Coalition on Climate Change.

As an example of the variety of plans now being put forward, a prestigious group of academics, business representatives, environmentalists, politicians and others have produced a comprehensive plan to reverse global warming, called Drawdown. The plan aims to reduce, avoid or absorb GHGs, so that atmospheric concentrations will decline before 2050, by focusing just on technological, ecological and behavioural solutions (as opposed to governmental or financial policies). This plan is a result of studying 100 potential solutions, and choosing and ranking the best 80 according to their effectiveness, costs and benefits. For example, the top 10 solutions are: refrigerant management, on-shore wind turbines, reduced food waste, increased plant-based diets, tropical forest conservation, educating girls (which reduces family size and increases economic growth), family planning, solar farms, silvopasture (integrating trees and livestock) and rooftop solar power. This list illustrates that decarbonizing is eventually likely to have a pervasive impact on society, involving a great many disparate policies globally.

At the political level, in 2016 the European Commission established its High-Level Expert Group on Sustainable Finance to prepare a blueprint for reforms covering the entire investment chain. Their comprehensive report[12] was published in January 2018 to be the basis for future European legislation, including a great deal that is relevant to decarbonization. Actuaries involved with financial institutions should have a key role in its implementation.

[11] World Bank announcements at One Planet Summit. World Bank. December 2017.
[12] Final report of the High-Level Expert Group on Sustainable Finance. European Commission. January 2018.

In contemplating the likely implications of decarbonization, in the short to medium term the world is likely to be an extrapolation of the present, subject to the following possible trends and potential discontinuities:

- Coal-based businesses becoming of significantly reduced value, unless there is a breakthrough in "carbon capture and storage", of which there is little sign;
- The oil sector becoming vulnerable, at least at its present size, as electric transportation expands, government measures on various forms of carbon pricing increase and investors are reluctant to invest new capital;
- Gas is likely to continue to play an increasing role over this time period;
- Supply chains are likely to shorten to reduce transportation costs and respond to consumer and political pressure;
- A reduction in business air travel and reduced growth in leisure travel, as carbon pricing starts to be incorporated;
- Major impacts on industries reliant on relatively cheap energy, such as aluminium manufacturing and air transport;
- Rapid growth of industries associated with decarbonization, such as in renewable infrastructure, battery technology, smart meters and energy efficiency;
- International trade being subject to more restrictions as countries start to penalize imports from countries without an adequate or generally accepted carbon strategy;
- Increased political instability from restrictions on trade and fossil fuels (and from climate change itself);
- More investment and growth in the developing world; and
- Possibly lower growth in the developed world due to the reduced use of high-energy fossil fuels (and aging populations).

In addition, the world will be impacted by the physical effects of climate change, and the policies implemented to adapt to it, both of which are outside the scope of this paper.

Decarbonization is thus beginning to lead to a radical restructuring of economies. Actuaries will need to assess the impact on their clients and identify opportunities to bring to bear their professionalism and forward-looking financial skills; for example:

Pension actuaries

- Considering how their clients' ability to finance schemes may be affected and the implications for funding, investment and scheme design. This may involve on-going discussions with clients regarding their own climate change and business strategies;
- Advising pension scheme trustees/managers on their negotiations with sponsoring employers, regulators and possibly other parties, such as employee representatives;
- Advising on the impact of decarbonization on investment strategies and investment returns or at least ensuring that it is properly addressed by investment managers; and

- Considering the impact of decarbonization on long-term actuarial assumptions such as discount rates and mortality, and on any changes to regulatory requirements.

Life, general and health insurance actuaries

- Assessing the impact of decarbonization on their markets, products and customers;
- Considering how decarbonization could be reflected in investment strategies and the likely impact on long-term investment returns; and
- Considering the impact of decarbonization on actuarial assumptions and liabilities.

Investment actuaries

- Examining how decarbonization is likely to affect various economic sectors, including impact; timescale; their resilience and ability to adapt; the opportunities created; the differing effects on debt, equity and other financial instruments; and the overall impact on investment returns;
- Considering how investment strategies could be modified for various investors, taking into account their timescales, objectives, portfolios and risk appetites; and
- Assessing the relative merits of divestment from businesses heavily involved with fossil fuels and retaining stakes and engaging with company boards on their decarbonization strategy.

In view of the complexity and uncertainty involved, scenario analysis is likely to be invaluable in studying these implications. The FSB task force, which is facilitating the development of scenario analysis in this context, can be accessed through its website (it deals with both climate scenarios and decarbonization scenarios).

In addition to the examples given above, the need for business and governments to examine the long-term effects of decarbonization may provide opportunities for actuaries to bring to bear their financial modelling skills in providing clear and objective analysis in wider fields, including public policy analysis, if they are conversant with relevant actual and potential decarbonization policies, and have considered their economic implications.

6. Summary

This paper is intended to provide an introduction to decarbonization for actuaries around the world, including the international agreements, the main types and sources of GHG emissions, the commitments already made, the policies being adopted, the likely future developments and brief observations on potential actuarial implications. Although decarbonization will increasingly affect every economy in the world and will transform how and what goods and services are produced, the timing and progress of change is highly uncertain.

Actuaries will need to consider how their own countries and markets are being, and are likely to be, affected and the implications for their clients or employers, so they can continue to provide appropriate long-term financial advice.