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Transitioning to a Low-Emission Energy System in Canada: Policy Considerations and Technological Limitations

Anthropogenic climate change is occurring and its possible effects on populations globally may be catastrophic unless emissions are curbed.[1, 2] Warming of the earth's climate system has been clearly established but finding acceptance for the root causes of climate change is more difficult to establish and the topic remains, despite substantial scientific evidence, controversial. For the purposes of the following work the reader is imply directed to the most recent assessment by the International Panel on Climate Change's (IPCC) and references therein.[2]

A more recent research article published in Atmospheric Chemistry and Physics by Hansen et al., highlights the importance of working towards reducing greenhouse gas (GHG) emissions to curb climate change to warming below 2 °C.[1] The negative implications of climate change are expected to be drastic particularly in drier regions as well as at the poles. The Canadian Prairies for example are experiencing more extreme flooding more frequently while also having to deal with extended drier periods that have aggravated farmers and have extended the wildfire season.

In the IPCC assessment the authors found "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent Climate changes have had widespread impacts on human and natural systems". As a result of this report and the efforts of many in the international community an historic agreement was reached at the 21st session of the Conference of the Parties (COP21) in Paris. The Agreement, the first universal climate agreement ever achieved, set a temperature limit to 'well below' 2 °C and tasked countries with setting their own greenhouse gas reduction targets. Canada has since ratified the historic agreement and has pledged to, by 2030, cut its emission by 30 per cent from 2005 levels.

At the core of Canada's greenhouse gas emissions is an energy system that has become dependent on fossil fuels. According to Canada's second biennial report to the United Nations Framework Convention on Climate Change (UNFCCC) in 2013 81 % (See figure 1 below) of Canada's greenhouse gas emissions were from energy system related sources.[3] The World Resources Institute (WRI) also publishes figures on greenhouse gas emissions by sector and pegs greenhouse gas emissions from energy systems in Canada at 71 % (See figure 2).[4] As a result, no substantial emissions reductions can take place without a major reimagining of Canada's energy systems. This reimagining is not a small undertaking and requires a strong long-term commitment. Below an argument for compulsory policy will be presented along with some of the associated challenges. Additionally, a brief review of the current state of Canada's energy systems will be presented along with some insights into appropriate policy options. Finally, the arguments for transitioning to a low-emission energy system for Canada will be grounded in a look at current technological limitations.

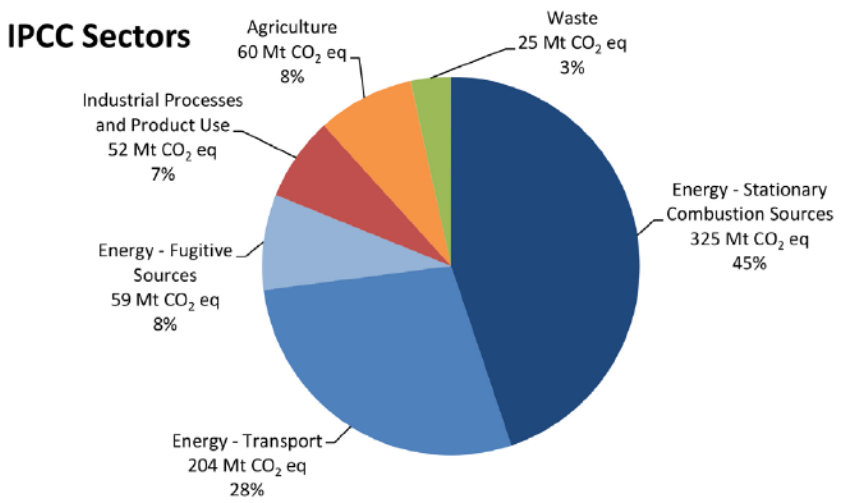

Figure 1. Canada's 2013 Emissions breakdown by IPCC sector. Note numbers may not add up due to rounding. (From Canada's Second Biennial report on Climate Change)[3]

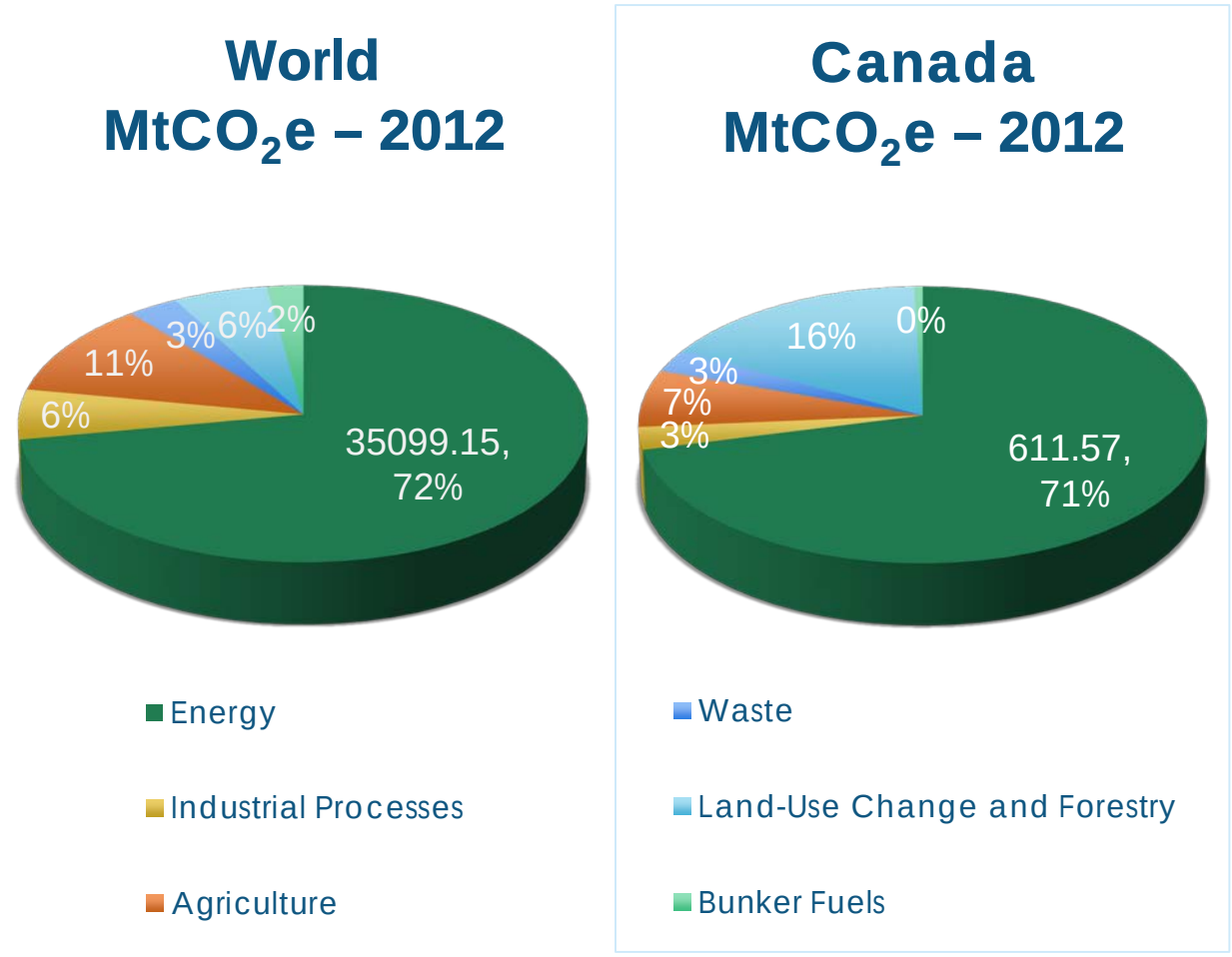

Figure 2. Greenhouse gas emissions by sector. $MtCO_2e$: Megatonnes of carbon dioxide equivalent. Prepared from data available online on the World Resources Institute's CAIT climate Data Explorer.[4]

Need for Compulsory Policy

It was with great optimism and fanfare that Canada, and other nation states, agreed to reduce their emissions to meet the target of limiting warming to less than 2 °C. Unfortunately, Canada has a poor track record when it comes to following through on emission reduction agreements. In the past Canada, and many of its international counterparts, have come to ignore their commitments. This is particularly troubling when one reviews the long history leading up to COP21. In 1988 it was in Toronto that the G7 met and agreed to setting an immediate timetable to establish zero increases in carbon emissions.[5] Following that G7 summit the World Conference on the Changing Atmosphere also took place in Toronto. In 1992 the Rio Earth Summit took place establishing the UNFCCC.[6]

In 1997, as a result of a large amount of politicking the Kyoto protocol was adopted by many of the world's nations, including Canada. Canada at the time had agreed to a 6% reduction in greenhouse gas emissions compared to 1990 levels and it was to do so by 2012. With neither the United States nor China signing on to the Kyoto protocol the agreement failed to move nations to act. Not to be outdone Canada was the only nation to accept the Kyoto protocol and later officially back out, repudiating its commitment to the protocol.[7] The ministry of the environment at the time argued the lack of commitments from the US and China as the reason for backing out. It was also clear that by doing so Canada was avoiding $14 billion in penalties for failing to achieve its goal.[7]

In the Second biennial report submitted by the government of Canada to the UNFCCC figure 3 (see below) showing current trends in GHG emissions is provided. According to the Kyoto protocol Canada was to achieve GHG emissions of 433 megatonnes of CO_2eq per year by 2012. Instead the figures show that by 2012 Canadian emissions grew to over 700 megatonnes of CO_2eq per year. In 2009 Canada signed onto the Copenhagen Accord and agreed to lower emissions to 17% below 2005 levels by 2020. Most recently Canada's 2015 Nationally Determined Contribution to the UNFCCC commits Canada to lowering emissions to 30% below 2005 levels by 2030. To meet this 2030 As can be seen in Figure 3 below, Canadian emissions continue to grow under the business as usual policy scenario. The only instances where GHG emissions appear to decrease are tied to global economic cycles, including the 2008 economic crisis that hit several sectors of Canada's economy. If Canada is to meet its current targets a vastly different policy approach is necessary.

There has been a lot of recent interest in attempting to examine appropriate policy options for transitioning to low-emission energy systems. The scientific interest is most clearly demonstrated by the joint Nature Energy and Nature Climate Change special joint issue that tackled many policy options.[8, 9] Additionally in the Canadian context the council of Canadian academies have prepared a report titled: Technology and Policy Options for a Low-Emission Energy system in Canada.[10] The Council of Canadian Academies review the current state of Canada's energy systems and presents the case for a combination of stringent, compulsory as well as flexible policy options. The combination of policy tools they argue are a viable option to increase the uptake the costlier lower emission energy alternatives by both the public and industry.

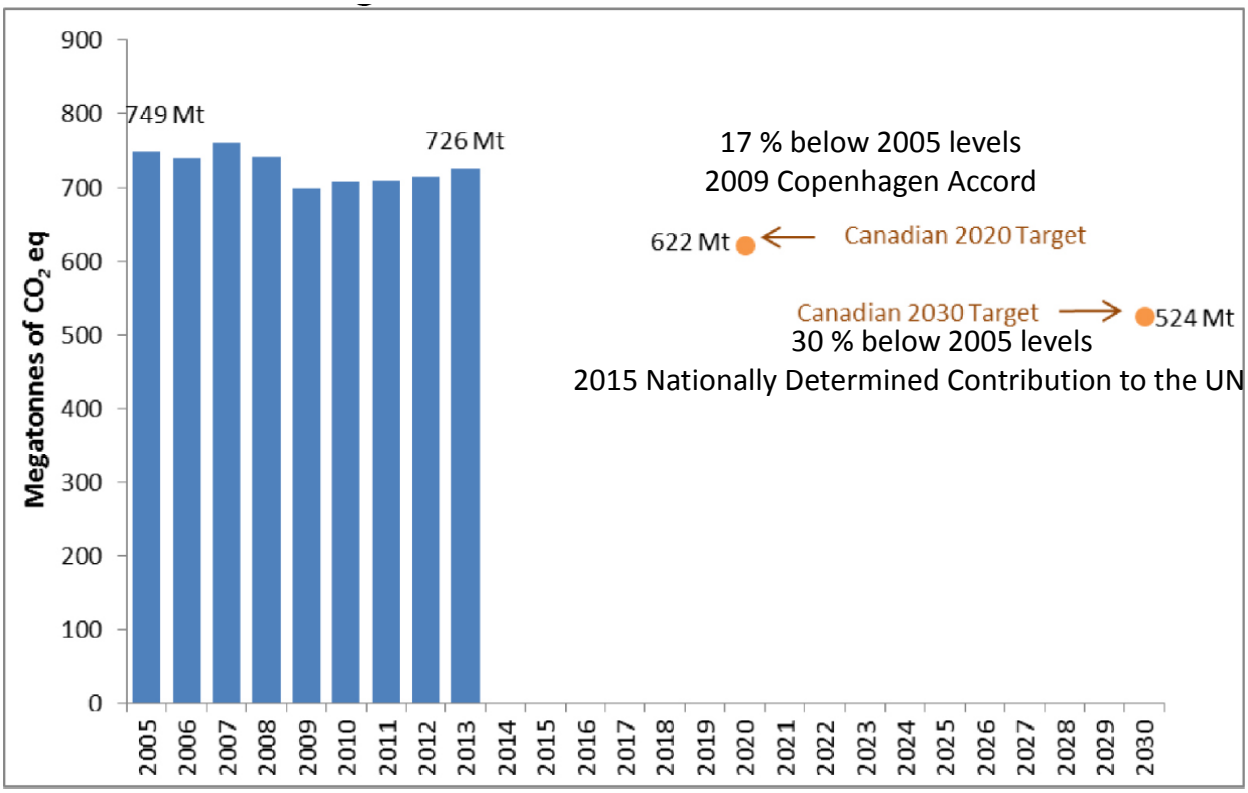

Figure 3. Canadian greenhouse gas emissions trend (2005 – 2013) and 2020 target and announced 2030 target. (Adapted from Canada's second biennial report to the UNFCCC)[3]

It is clear from Canada's recent track record that compulsory policy is necessary. The previous Harper governments 'Made in Canada' solution is clearly not enough to achieve the necessary reduction in GHG emissions. Additionally, Canada's energy systems have become integrated in the lifestyle of Canadians. As such implementing compulsory policy tools is to attempt to force a lifestyle change, a social change. This had made tackling climate change a major political non-starter for previous Canadian governments. The political capital to enact such dramatic changes is tremendous. Furthermore, due to the nature of energy systems transitions are slow and necessary infrastructure costly and time consuming to implement. This translates into the necessity of public buy-in as there is always the danger that an incoming government, perhaps of a populist nature, may re-establish the previous status quo upon election.

It is in this light that it is recommended that any implementation of policy needs to be accompanied with the consultation of voters. Programs that increase awareness of climate change and educate the public about the realities of the current predicament and its implications are necessary to increase levels of public buy-in. There is also a rising sentiment that Canada's role in the global context is minor when it comes to GHG emissions. This is simply false. Between 1990 and 2012 Canada was responsible for 2 % of global GHG emissions.[4] Canada is the world's 13th (out of 219) largest emitter of CO_2, emitting 1.4 % of global emissions.[4] This is equivalent to the emissions form the 131 lowest emitting countries combined. Per Capita Canadians emit 20.94 tons of CO_2 per year, this is more than double the European Union average

of 8.81 tCO_2/Capita.[4] Canada is clearly a large emitter and has a role to play in reducing GHG emissions.

Finally, Canada is the world's 5th largest energy producer. with 280 000 Canadians directly employed by Canada's energy sector. Many more Canadians are indirectly employed by Canada's energy sector particular in provinces that rely heavily on oil and gas such as Alberta and Saskatchewan. Furthermore, Canada's economy is heavily tied to growth in the energy sector. A transition away from a heavily fossil fuel based economy is one that will directly impact many Canadians. For those directly impacted there must be some government assistance provided that helps these individuals transition into other careers.

Canada's Energy System

An energy system is composed of all resources, processes, technologies, and applications involved in the production, conversion, distribution and use of energy.[10] Energy can be classified into two very broad categories: primary and secondary. Primary energy is defined as energy embodied in resources in their natural state.[10] This can include energy stocks (oil well, uranium mine, etc.) or energy flows (solar radiation, flowing water, etc.). Secondary energy may be defined as a non-primary more usable form of energy.

Regardless of the type of primary energy, conversion to secondary energy is always necessary. A coal fired power plant for instance can have 62 % loss of energy during that initial conversion of coal to power.[11] With typical transmission lines and an incandescent light bulb you could potentially have up to 34 % more in lost energy to light a home.[11] Conversion losses are prevalent. The Sankey diagram in Figure 4 below, obtained from the Canadian Energy Systems Analysis Research's (CESAR) Canadian Energy Systems Simulator (CanESS), showing Canada's energy flows highlights the size of conversion losses. Systematically identifying inefficiencies and funding research into reducing them appears necessary in transitioning to a low-emission energy system.

In their report on Canada's energy systems the Council of Canadian Academies divided GHG emissions into four energy sectors: electricity, transportation, buildings and industry.[10] Figure 5 below shows the change in total GHG emission from these four sectors between 1990 and 2012. Emissions from both electricity and buildings sectors changed very little in this time period. In contrast emissions from transportation and industry increased substantially.

Electricity Sector

Canada's electricity sector maintained similar GHG emissions between 1990 and 2012 despite a significant increase in Canada's population. Emissions from this sector peaked in 2003 and have been declining since. This is largely due to a decreased dependence on coal and oil with 70 % of Canadian electricity generation coming from low or zero carbon-emitting sources.[12] Hydropower is prevalent in Quebec, Manitoba, British Columbia and Ontario and is responsible for 63 % of Canada's electrical generation.[12] Emissions from electrical generation are as such concentration in Alberta, Saskatchewan, New Brunswick and Nova Scotia. Enacting policies to phase out coal in these provinces is necessary for the immediate reduction in GHG emissions.

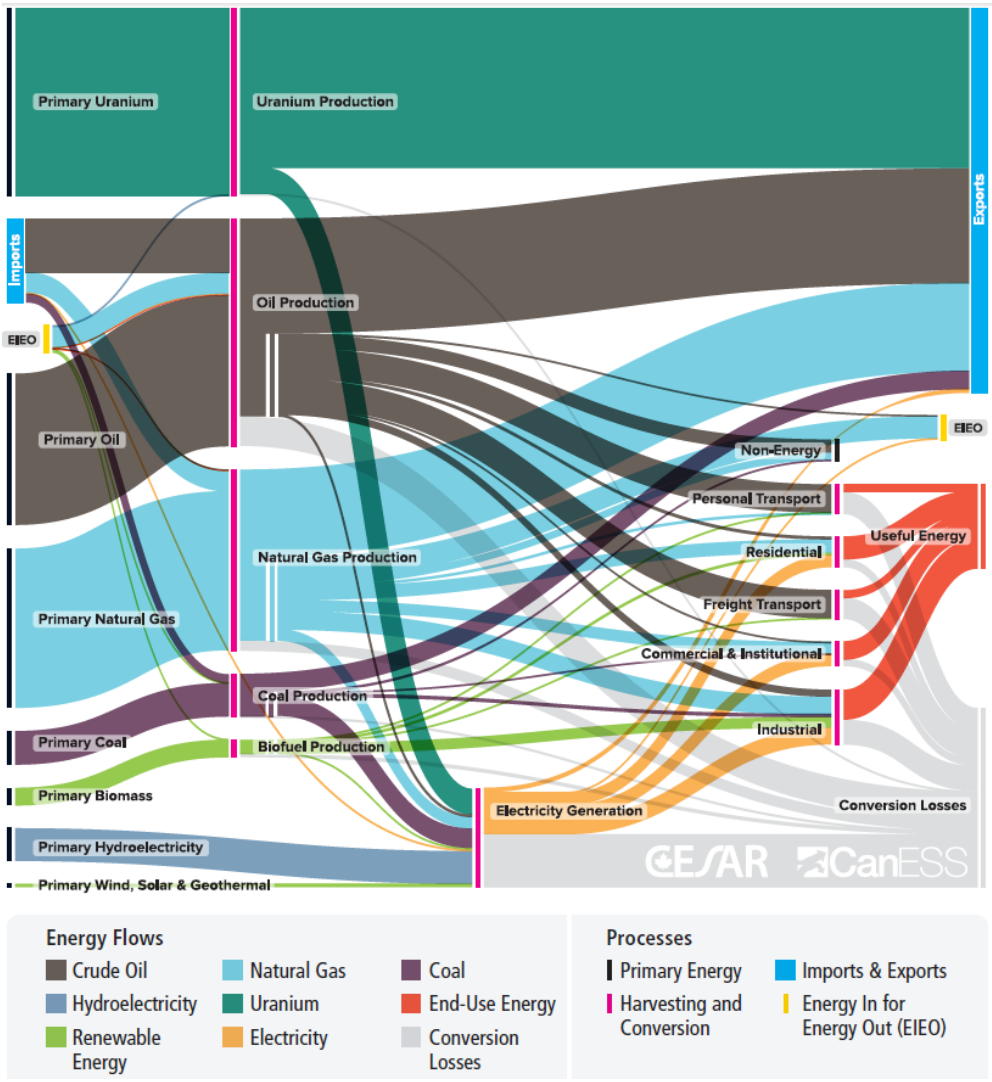

Figure 4. Sankey diagram of Canada's energy systems. (from CESAR CanESS)[13]

Figure 5. Greenhouse gas emissions by Energy sector.[10]

A trans-Canadian modernized electrical grid would also help Canada reduce GHG emissions. Canadian provinces that have electricity generated by renewables could transmit their low emission power to those provinces that do not have the renewable electrical generation capacity. Transmitting electricity via long distance power lines does not come with its challenging particularly transmission losses. These could be limited with high-efficiency transformers and high voltage DC current transmission lines. Additionally, upgrading Canada's electrical grad to a smart grid in the long term is necessary. A smart grid is defined by the Canadian Electricity Association as a grid that allows "two-way communication, control and automation capabilities".[14] Longer term such a grid is paramount as more localized renewable electricity sources (e.g. solar panels on homes) will become more common. A smart grid will better allow the integration of these more localized sources and will help reduce the running load of larger regional electrical generation plants.

The last note to consider regarding Canada's electricity sector is pricing. Currently Canadians are fortunate enough to pay one quarter of the OECD (Organization for Economic Co-operation and Development) average for electricity.[15] Increasing the price of electricity will aid in highlighting the importance of reducing electricity usage.

Transportation Sector

Canada's transportation sector (road, aviation, marine and rail) emissions increased between 1990 and 2012 despite great improvements in fuel efficiency. The sector saw a 73 % increase in demand for diesel largely driven by just-in-time delivery and stocking schemes.[10] The reemergence of rail for freight transport as an alternative to heavier trucks might help reduce some of these additional emissions. Additionally, more people are transitioning to larger vehicles including an explosion in the popularity of crossovers and sports utility vehicles. The Council of Canadian Academies report related studies that show that 50 % decrease in the cost of fuel leads to a 15 % increase in driving. The opposite should be true and as such the price of fuel must be increased.

Urban and Land-use planning should also be modified in order to reduce the carbon footprint of the transportation sector. Well thought out public transport and neighborhood design promoting walkability and bike use could go a long way. Additionally, with alternative transportation fuels making their way into consumer vehicles it is necessary for land use-planning to take into account the larger footprint of charging stations. Although smaller in size for charging to become mainstream a widespread array of charging stations will need to make its way into the urban environment and into parking garages. This will surely require very different electrical connectivity and will bring many of its own challenges that need to be addressed. Additionally, to increase the uptake of low emission vehicles subsidies have been effective in jurisdictions both inside and outside Canada. Adequate technology exists for initial uptake but uptake has been limited due to the high costs associated with low emission vehicles.

Buildings Sector

The buildings sector includes space and water heating, air conditioning, lighting, refrigeration, cooking as well as appliances and electronics.[10] Surprisingly Canada's emissions in this sector have decreased between 1990 and 2012 despite large population growth, increased floor space from larger houses and the increased uptake of electronics. This is undoubtedly a result of large improvements in building related efficiencies. Nonetheless there is still much room for improvement. With the Canadian climate it is not unexpected that fifty-five percent of building related GHG emissions are from space heating and the adoption of the Passive House Standard could greatly reduce this. The standards call for a highly aggressive building design that can reduce heating requirements to as little as 4% of their initial requirements. Furthermore 60 – 90 % more efficient buildings could be achieved with a cost increase of 15 % or less.[10]

Industry Sector

Canada's industrial energy sector is dominated by energy-intensive industries: iron and steel, aluminum, cement, chemicals and fertilizers, pulp and paper, mining and quarrying, and oil and gas extraction. Together these are responsible for 80 % of Canada's industrial energy demand.[10] Process heating and motor systems (pumps, compressors and other mechanical equipment) make up 75 % and 25 % of industrial energy usage respectively. For these purposes low-emission electricity could be used where available. Making such electricity available to industry through modernized Canada's electrical grid and electrical generation systems is the easiest way to ensure industrial uptake. Through a price on carbon industry will be incentivized to adopt practices that reduce greenhouse gas emissions. Recycling and integrated processing could be utilized where possible. Carbon capture and storage also has the potential to be used in many industrial sites. More broadly all industrial application will need to be examined from an energy perspective.

Between 1990 and 2012 42 % of greenhouse gas emission increases in the industry sector came from oil and gas. This sector is notorious for emissions and could work towards lowering emissions. Eliminating fugitive emissions from this sector alone could reduce Canada's greenhouse gas emissions by 8 %.[10]

National Energy Policy

With the interdependence of Canada's energy sectors on one another and with extreme disparity between the resources available to individual provinces a binding national energy policy appears appropriate. Cooperation between provinces and territories could help the country transition to a low-emission energy system. A national energy strategy could prioritize larger projects and provide the necessary framework as well as funding to build the necessary low-emission energy infrastructure.

Limitations

Although it is clear that a transition to a low-emission energy system both in Canada and globally is necessary this is commonly construed as a complete shift away from fossil fuels. This is not something that is possible in the near or medium terms. It needs to be understood that as

civilized societies we have become dependent on fossil fuels in many ways.[16, 17] Polymers, mass produced from fossil fuel extraction byproducts, have made their way into every aspect of our daily lives. Concrete and steel which we have used to develop our urban centers vertically both rely heavily on a steady industrial scale output of fossil fuels. Additionally, both concrete and steel are required for any large scale renewable energy infrastructure including photovoltaic solar and wind turbine technology. Most worryingly the population growth of the last century was only possible with the aid of sulfur and nitrogen rich fertilizers both of which are obtained industrially as a byproduct of fossil fuel extraction.

Our dependence on fossil fuels must clearly be taken into account moving forward. Research into alternative pathways to obtaining some of the key building blocks of modern civilization must be supported. Furthermore, our assessment of renewables must factor in the carbon footprint associated with building and maintaining the renewable infrastructure. There need also be a concerted effort to understanding the necessary adjustments needed by transitioning away from more regional energy sources (read power plants) to more localized (read renewable) energy sources.

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