Hard Paths to Decarbonization?/Assessing Ottawa's paths to net zero through an energy sustainability lens.

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Introduction

Prime Minister Justin Trudeau's federal government has committed to ambitious targets for the reduction of Canada's Greenhouse gas (GHG) emissions. The 2021 *Canadian Net-Zero Accountability Act* sets goals of a 40-45% reduction in emissions by 2030 relative to 2005, and the achievement of net-zero emissions by 2050.[1] In support of these objectives, the government has committed to increase its 'backstop' federal carbon price to from $50/tonne in 2022 to $170/tonne by 2030.[2]

The December 2020 *Heathy Economy Health Environment* (HEHE) paper[3] has provided the Trudeau government's most detailed expression of its overall strategy for achieving its climate change goals so far. The paper was followed-up with specific implementation measures in the 2021 and 2022 federal budgets. While the 2020 paper emphasized the central role of carbon pricing in the government's strategy, it also made it clear that a wider range of tools would be needed. These include regulatory measures, such as a phase-out of coal-fired electricity by 2030, clean fuel standards, and potential regulatory caps on emissions from the oil and gas sector. There would also be extensive use of subsidies and fiscal incentives for the development and application of new technologies in relation to buildings, transportation, industry, agriculture and waste management.

This chapter examines the federal government's approach to designing a net-zero pathway, and looks at the implications of some of the key choices that are emerging from an energy sustainability perspective. The chapter finds that although the Trudeau government has adopted a broadly 'ecological modernist' discourse around its approach to decarbonizing the Canadian economy, there appears to be no consistent framework for evaluating or making choices around specific pathways and technologies towards that end, other than to pursue "every tool in the toolbox."[4] The situation presents potentially significant problems, as some of the technologies that are being emphasized are far from mature and their potential contributions to achieving significant reductions in GHG emissions within the required timeframes open to serious question. Many also carry very serious environmental, social, cultural, economic, legacy and lock-in risks of their own.

The chapter does not attempt to assess the likely effectiveness of the Trudeau government's current strategy in achieving its climate change goals per se, although it notes that many of the key elements of that strategy have yet to be fully implemented. Rather it seeks to assess the choices that the government has made in designing its strategy from an energy sustainability perspective, and to identify key trade-offs and risks in those choices, many of which have not been fully acknowledged by the government itself.

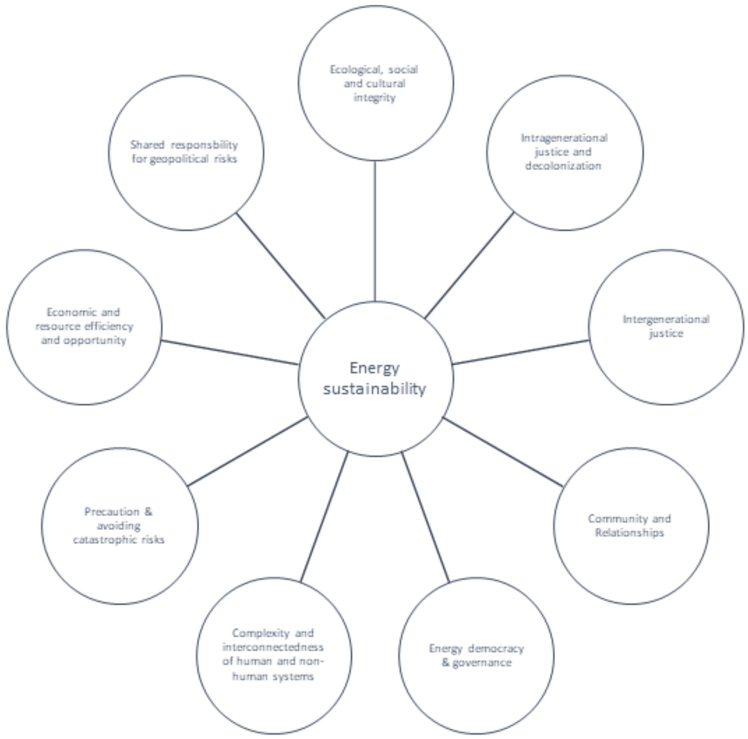
Energy Sustainability and Energy Systems Transitions

In the context of the growing evidence of the impacts of an already changing climate, many argue the urgency of the climate crisis requires an overriding focus on the (cost-effective) achievement of the net zero target by mid-century if not sooner.[5] Others argue that energy system transitions in the direction of net zero need to advance wider sustainability goals, such as reconciliation with Canada's Indigenous peoples as outlined in the introduction to this volume. "Clean and Affordable Energy" and "Climate Action" constitute only two of the United Nations' seventeen Sustainable Development Goals (SDGs),[6] and therefore can only been seen as part of a wider transition in the direction of sustainability.

In political terms, the rise of populist challenges to climate change policies,[7] such as carbon pricing, and developments like the February 2022 'freedom' convoys,[8] have drawn attention to the potential distributional impacts of these policies. There is increasing recognition that the political survival of climate policies may ride, in part, on addressing the economic and social concerns of those who see themselves as potentially further marginalized by them, particularly in rural, low-income and otherwise disadvantaged communities.[9]

Winfield, Hill and Gaede, reviewing Canadian, international and Indigenous literatures relevant to energy and sustainability, identify nine principles outlined in **Figure 1** as contributing to energy sustainability. These principles are used in the chapter to provide a framework for evaluating the federal government's approach to a net-zero transition.

Figure 1: Key Features of Energy Sustainability[10]



Literatures dealing with multidimensional approaches to sustainability, such as those on sustainability assessment,[11] highlight the importance of identifying the impacts of different choices and pathways on the achievement these goals. Potential trade-offs among sustainability goals, where a particular approach may advance some goals significantly but can result in significant losses in other areas require specific attention. Pathways that cause substantial losses in relation to sustainability goals, or that replace one problem with equally serious, but different, problems should be avoided. Rather the importance of focussing on transitional pathways that minimize or avoid such trade-offs or outcomes to the greatest extent possible is emphasized. Such an approach, elements of which were incorporated into the federal *Impact Assessment Act* adopted in 2019, guides this chapter's assessment of the federal government's policy and technological choices in its climate strategy.

'Hard' and 'soft' energy pathways

Energy systems transitions can follow a range of different system models and pathways. Amory Lovins, writing more that forty years ago,[12] characterized energy system models in two ways. Conventional, and still largely dominant, "hard" paths focussed on large, centralized, capital-intensive energy technologies, like major hydro dams and fossil and nuclear power plants. In a climate context these might now include options like geoengineering, carbon capture and storage and certain hydrogen-based technologies.

In contrast, Lovin spoke about "soft" paths - relatively distributed system models that rely on the cumulative contributions of large number of small-scale and lower cost, risk and impact options like energy efficiency and renewable energy sources. Pathways grounded these technologies have generally been seen to be more easily aligned with sustainability principles like those outlined in **Figure 1**. Renewable energy technologies, energy storage, and energy systems integration and management (a.k.a. smart grids) have all undergone substantial maturation of the past two decades, greatly expanding their technological and economic potential to make large scale contributions to energy systems transitions in the direction of net-zero emissions.[13]

The tensions between these different kinds of pathways remain present in the federal government's approach to climate change. New actors and voices have advocated for more distributed, softer pathways, but as will be come apparent in the chapter, much of the conversation has continued to be dominated by 'hard' path incumbents. The voices of well-established actors in sectors like fossil fuels, nuclear energy, mining and industrial agriculture have been particularly strong in this context.

Federal government's approach to a net-zero transition

The Trudeau government's framing of its approach to climate change and a net-zero transition can be described as broadly ecological modernist,[14] emphasizing the potential to advance both environmental sustainability and economic prosperity. This orientation is reflected in the very titles of the government's core policy documents around climate change: the 2016 *Pan Canadian Framework for Clean Growth and Climate Change* (PCF); the 2020 *Health Economy, Healthy Environment* (HEHE) paper; and the 2022 *Clean Air; Strong Economy,* 2030 emissions reduction plan.

Ecological modernization has generally been defined to imply a restructuring of capitalist economic structures along more environmentally sound lines. Challenges like climate change are seen as structural problems which will require changes in the way the economy is organized, but not in a way that requires a different kind of political and economic system.[15] The concept is widely understood to provide the foundation of environmental and climate policies in Western Europe, with Germany, the Netherlands, and the Nordic countries frequently being cited as the leading examples of putting the concept into practice. An ecological modernist framework is strongly reflected, for example, in the European Union's REPowerEU energy plan in response to Ukraine war, emphasizing energy conservation, renewable energy, clean industry and the diversification of energy sources.[16]

In the case of the Canadian governments, there have been critiques that the embrace of these concepts has been more rhetorical than real. Rather than integrating environment, economy and climate change policies, there has been a tendency to 'stack' often contradictory policies on top of each other. The result has been a tendency to paper over key challenges, such as the future role of the fossil fuel industry in a decarbonizing world, and the simultaneous adoption of deeply conflicting policies, like carbon pricing and the continued, and even expanded, subsidization of the fossil fuel sector.[17]

The December 2020 HEHE[18] paper gives the clearest overall sense of the Trudeau government's approach to achieving its climate change targets. The paper made it clear that carbon pricing would remain at the core of the government's policies, with the 'backstop' federal carbon price rising to $170/tonne by 2030. The paper also placed a strong emphasis on retrofits of residential, commercial and institutional buildings for energy efficiency, and the electrification of transport, including the development of EV manufacturing and supply chains, and 'clean' electricity supplies.

With respect to industry there was a strong emphasis on the role of a $3 billion Strategic Innovation Fund to rapidly expedite decarbonization projects with large emitters, scale-up clean technology and accelerate Canada's industrial transformation across all sectors. The roles of carbon capture, utiliization and storage (CCUS), hydrogen-based technologies and a federal clean fuel standard were all highlighted. The sections dealing with agriculture focus on 'clean' technologies and fertilizer supply chains, while the elements related to waste management emphasized methane capture from landfills and other waste management facilities, and plastic waste reduction. A final section of the HEHE paper addressed "nature-solutions" including the planting of two billion trees, and the restoration and enhancement of wetlands, peatlands, grasslands and agricultural lands to boost carbon sequestration.

Further documents, including sectoral roadmaps around small modular nuclear reactors (SMRs)[19] and the hydrogen economy,[20] have provided greater detail around specific technologies and strategies. The 2021 budget included interest-free loans for home energy retrofits and proposed an investment tax credit for CCUS projects, as well as $319 million in CCUS research and development funding.[21] The 2022 budget contained more substantive measures, implementing the CCUS tax credit at an estimated annual cost of $1.5 billion/yr. The budget also included a proposal for a 100 per cent zero emission light duty vehicle sales mandate for 2035, and a medium-duty vehicle mandate by 2040, additional incentives for EV purchases, funding for EV charging infrastructure, and support for clean agricultural technologies and on-farm climate action. With respect to electricity the budget included $600 million over seven years for renewable electricity and grid modernization projects, and $250 million over four years on interprovincial grid connections and SMRs. SMRs received an additional $120 million in dedicated funding for their development.[22]

In a nod to longstanding commitments to remove of fossil fuel subsidies, the 2022 budget announced the elimination of flow-through shares for fossil fuel sector activities, including oil, gas and coal exploration and development. At the same time the budget committed $3.8 billion over 6-7 years for infrastructure to support "critical" minerals development, "critical" minerals projects, and funding for NRCan and the National Research Council for "critical" minerals supply chain development and applications. There was also a new 30 per cent Critical Mineral Exploration Tax Credit for specified mineral exploration expenses incurred in Canada and renounced to flow-through share investors at an estimated cost of $400 million over 5 years.[23]

The government's March 2022, *2030 Emissions Reduction Plan*, [24] outlining its specific plan to achieve is 2030 target of a 40-45% reduction GHG emissions, anticipates major (>100mtCO2e/yr) reductions in emissions from the electricity sector, largely due to the phase-out of coal-fired generation by 2030. [25] The oil and gas sector is expected to contribute 42mt/yr through CCUS, the regulation of methane emissions and fuel-switching. Additional significant reductions are anticipated from heavy industry (33mt), particularly the pulp and paper, iron and steel, cement and chemicals and fertilizers sectors, and residential, commercial and institutional buildings (25Mt).

Assessing the federal government's approach to a net-zero transition

As noted earlier, the federal government has no stated framework for assessing the policy and technological choices it has made in its climate policies. There is an implicit assumption that the choices being made reflect the most cost-effective options for reducing GHG emissions, although the modelling underlying the 2030 emissions plan suggests that even this might not entirely be the case. There is no evidence of any systemic consideration of the wider implications of the choices being made, such as those introduced through Figure 1. Substantial lobbying has taken place on the part of existing economic interests, particularly from the energy sector, around the formulation of the government's strategies.[26] These efforts, often with very strong support from provincial governments, have been particularly focussed on CCUS, SMRs, hydrogen-based pathways and 'critical' minerals.

Some of the choices made by the federal government fit well within energy sustainability framework, in the sense that they potentially advance many of the key principles simultaneously, and avoid significant trade-offs among them. Support for building energy efficiency retrofits, methane capture in waste management, plastics waste reduction, the regulation of methane emissions from oil and gas operations, and nature -based solutions, particularly the conservation and enhancement of carbon sequestration sites, all likely fall, subject to good program design, into this category. The agriculture-related initiatives might also be included this category. However, voluntary action in the sector, even when supported through financial incentives, has a relatively poor record of performance on environmental issues, and the government's commitment to address emissions related to fertilizer supply chains may be wavering in the face of very strong pressures from agribusiness.[27] CHECK ON STATUS OF FERTILIZER REGS

Other dimensions of the federal government's strategy for achieving its climate change goals present more complex questions from an energy sustainability perspective.

Carbon Pricing

Carbon pricing remains the centrepiece of the government's overall plan. Pricing carbon is widely accepted as an efficient way of achieving economy-wide reductions in GHG emissions, advancing intergenerational justice and ecological integrity as a result. However significant intragenerational distributional justice issues can arise in the design and application of carbon pricing systems.

In the case of the federal 'backstop' carbon price, the overwhelming bulk of the system's impact falls on households, small business and individual consumers through the carbon levy applied to fossil heating and transportation fuels. In contrast, large (>50,000 tonnes CO2e/yr) industrial emitters, operating under the Output Based Pricing System (OBPS), only pay the carbon price on the portions of their emissions above a set average per unit of output for their sectors.[28] The arrangement was seen as necessary to keep industrial interests onside with the pricing scheme and prevent 'carbon leakage' (i.e. the movement of industry to jurisdictions without carbon pricing) although range of sectors that are really trade-exposed and carbon intensive is likely much smaller than those covered by the system.[29]

As the backstop carbon price increases, there will be an increased need to pay attention to its impacts on low-income and otherwise marginalized communities. These constituencies often have little or no margin to absorb increased energy costs, even where they are eventually rebated through the tax system. Low-income households may also lack the resources necessary to make capital investments in things like home energy efficiency in response to the price signals being sent through the pricing system. Tenants may have little or no control over energy use in their homes.[30]

Electrification of Road Transportation

The electrification of road transportation is widely accepted as an essential component an effective climate plan given the role of road transportation-related GHG emissions (24 per cent of total emissions 2020).[31] However questions have been raised around the cost-effectiveness of EV subsidy programs as a GHG emission reduction strategy,[32] as well as their relevance to low-income households who may not have the means to purchase new vehicles.[33]

Although EVs outperform conventional vehicles by a wide margin in terms of their direct emissions and energy use, they raise a number of wider sustainability issues when viewed on a lifecycle basis. Two major questions that arise, and are reflected in the federal strategies, are the issues of the need for additional 'clean' electricity supplies to meet the additional demand from the widespread adoption of EVs, and the materials and supply chains for EV manufacturing, and especially batteries.

'*Clean' Electricity*

The 2020 HEHE paper makes an explicit link between 'clean' electricity and the electrification of transportation. The 2022 budget included funding for renewables, grid modernization and the strengthening of regional interties. The latter have been long discussed but have proven difficult to implement given the levels of provincial autonomy and control over electricity infrastructure, and the strong appeal of US export markets. Clean electricity regulations were proposed[34] in July 2022 for the purpose of bringing the grid's greenhouse gas emissions to net-zero by 2035, specifically through the phase-out of coal-fired generation and the "phase-down" of natural gas and diesel fired generation.

Technologies identified in the proposal as potentially 'clean' and to be encouraged included energy efficiency, demand side management, dynamic pricing, solar, wind, hydropower, distributed energy systems, grid interties, energy storage and geothermal. These are all relatively low-impact options, with low risks of technological lock-in. They are generally seen to fit well within an energy sustainability framework as a result. New large hydro projects, in contrast, would face significant challenges in a sustainability context. The Site C and Muskrat Falls projects in BC and Labrador respectively, have raised major questions of the economic viability of such projects.[35] Significant issues around ecological, social and cultural integrity, particularly in terms of their impacts on Indigenous communities, would be certain to emerge as well.

Small Modular Reactors (SMRs)

Other technologies that are proposed to be classified as 'clean' or 'non-emitting' also present significant sustainability challenges. These include CCUS (discussed below), and nuclear energy in general and small modular nuclear reactors (SMRs) in particular, as well hydrogen-based technologies (discussed below). SMRs have been the subject of an aggressive promotional campaign on the part of Natural Resources Canada (NRCan), the provinces of Ontario, New Brunswick, Saskatchewan and Alberta, the Canadian Nuclear Association and nuclear operators, notably Ontario Power Generation and New Brunswick Power. An SMR roadmap was published in November 2018.[36] Proposals have been made for SMR installations at the Darlington Nuclear Power Plant in Ontario and Point Lepreau facility in New Brunswick.

Implicit in the focus on SMRs is a recognition that large new build nuclear facilities are not economically viable even the context of strong carbon pricing regimes. This is due to their high initial capital costs and extremely long planning and construction timeframes.[37] From a sustainability perspective nuclear energy offers the potential for large energy outputs with relatively low greenhouse gas emissions. In a Canadian context, nuclear also offers a low geopolitical risk fuel supply. Northern Saskatchewan is a major uranium producer and fuel processing and manufacturing takes place in Ontario. [38]

Against these potential advantages nuclear offers a series of extremely serious negative trade-offs from a sustainability perspective. These include very high non-GHG environmental and health impacts, notably the production of extremely hazardous and long-lived waste streams, particularly uranium mining tailings and waste, and waste reactor fuel bundles. These materials will require care for environmental and security reasons on timescales of hundreds of thousands of years, effectively transferring significant risks and costs onto future generations. Nuclear generation facilities are associated with high lock-in effects, and low operational flexibility. They also suffer from unique and uniquely severe risks of catastrophic accidents, as demonstrated by the 1977 Three Mile Island, 1986 Chernobyl and 2011 Fukushima disasters. Civilian nuclear technologies and materials can be transferred to military purposes by determined governments, and nuclear facilities themselves can be significant terrorist, or as seen recently in the Ukraine war, military targets. Governments have had to assume ultimate liability for nuclear waste management, decommissioning and accident risks as both a market and regulatory requirement.[39] These considerations have generally made nuclear an unacceptable option from an energy sustainability perspective.[40]

The SMR concept seeks to avoid some of these problems by offering scalability, and reduced costs and risks of path dependence with shorter planning and construction timelines, although the challenges related to fuel cycles, and accident and security risks would largely remain the same. The SMR technologies being proposed for Canada are immature, with no existing functional examples or even prototypes.[41] The business models for SMRs are undefined, as is their ability to attract private investment. Their construction and operation would still require governmental assumption of ultimate liability for waste management, decommissioning and accident risks for both market and regulatory reasons.[42] SMR design issues remain unresolved,[43] and their outputs /wastes remain uncertain. Serious questions about weapons proliferation, and even potential violations of the Nuclear Weapons Non-proliferation Treaty, have been raised in relation to the potential for Plutonium production at the SMR proposed for the Point Lepreau site.[44]

EV manufacturing, battery supply chains and 'critical' minerals

The potential for the transition of the Canadian automobile manufacturing sector to EV production has come to be seen as essential for the survival of the sector, and to offer considerable industrial development potential. As such it fits well with the ecologically modernist orientation of the federal government. Even the Ford government in Ontario, which has a strong record of opposition to climate action,[45] has come to see the development of the sector as essential.[46]

At the same time, both the federal and Ontario governments have linked EV manufacturing development to EV battery supply chains, which has in turn been linked to 'critical' minerals strategies.[47] These received substantial new support through the 2022 federal budget. Critical mineral supplies also formed part of the August 2022 energy related agreements with Germany in the context of the Ukraine war.[48] Here more serious trade-offs may arise in terms of environmental and climate impacts, and potential effects on Indigenous communities on whose treaty or traditional territories 'critical' minerals may be found. The March 2022 Ontario Critical Minerals Strategy,[49] for example, largely restated long-standing industry wishlists for around land access, financing and accelerating approvals, and has been criticized for paying little attention to Indigenous interests or concerns.[50]

The question of the climate implications of major mining developments in the boreal region, the location, for example of Ontario's much touted 'ring of fire' mineral deposits does not appear to have been considered by the federal or provincial governments.[51] The region is a major carbon sink and sequestration site.[52] Regulatory frameworks around the disposal or recycling of end-of-life EV batteries, which could have significant implications for the future need and demand for 'critical' materials and components, remain non-existent at the federal and provincial levels.[53]

Industry

The government's approach to industrial emissions is focussed on the sector and facility-specific investments through the Strategic Innovation Fund/Transition Accelerator. There have been major federal investments in particular in the transition of the auto manufacturing sector to EV production ($920 million),[54] and in hydrogen 'ready' transitions for the steel sector ($820 million) in Ontario,[55] matched by contributions from the province.

The HEHE paper placed a strong emphasis on the roles of CCUS and hydrogen-based technologies in the decarbonization of major industries. Both of these pathways, which have been the subject intensive industry and provincial lobbying, and raise complex questions in a sustainability context.

CCUS

CCUS is consistently identified by the federal government and the oil and gas industry as a key technology for the achievement of net-zero goals.[56] As noted earlier a major tax credit for CCUS was introduced through the 2022 federal budget, along with program support for CCUS development. The Alberta for its part, reflecting the centrality of CCUS to the future of the oil and gas industry in a decarbonizing world, has committed $1.24 billion to commercial-scale carbon capture and storage projects.[57] The federal government's introduction of a CCUS tax credit was highly controversial, and was strongly opposed by many environmental organizations as well as through a January 2022 open letter signed by more than 400 Canadian academics, scientists and energy modellers. [58]

CCUS involves the capture and (usually) underground storage of CO2 associated with the combustion of fossil fuels or industrial processes that generate CO2 as a by-product. CCUS proponents argue that GHGs managed in this way will stay sequestered indefinitely.[59] The most common applications of CCUS have been in relation to coal or gas-fired electricity generation facilities, although significant potential applications are anticipated in relation to oil sands production in Alberta and Saskatchewan and 'blue' hydrogen production from natural gas (see below).[60]

Underground injection of CO_2 has long been used as a method for enhanced oil recovery in conventional oil fields. However, the technology's use for the purpose of capturing and provide long-term storage of CO_2 suffers from a number of significant drawbacks.[61] These include the high capital and higher operating costs associated with adding carbon capture and storage to industrial facilities,[62] significant losses of efficiency (15-30% depending on technologies) as a result of the need to use additional energy to capture and compress CO_2,[63] effectiveness in capturing CO_2 emissions,[64] and concerns over the potential for leakage from underground storage over the long term.[65] The technology is also limited to areas with appropriate geological structures. It cannot be employed in locations defined by solid rock formations, like the Canadian shield, or places subject to high levels of fracturing. In theory CO_2 could be transported by pipeline from locations without appropriate geology to storage sites, although that would add further significant capital and operating costs.

A major concern over public financial support for CCUS is its potential lock-in effects. The January 2022 letter opposing the introduction of a CCUS tax credit stated:

> "Put simply, rather than replacing fossil fuels, carbon capture prolongs our dependence on them at a time when preventing catastrophic climate change requires winding down fossil fuel use. Relying on CCUS preserves status quo fossil fuel development, which must be curtailed to meet global climate commitments. Introducing a tax credit for CCUS for the energy sector will lock- in continued dependence on Canada's largest and most rapidly growing source of greenhouse gas emissions."[66]

Indeed, a large part of the technology's appeal to the fossil fuel industry and fossil fuel export dependent provinces can be seen as its potential to facilitate the continuation and even expansion of fossil fuel production. Federal support for CCUS has been seen as essential, in this context, to maintain some degree of support within fossil fuel producing provinces and the fossil fuel industry for the government's overall climate change strategy. At the same time, CCUS does nothing to reduce the downstream use of fossil fuels for transportation and other GHG emission intensive applications.[67]

The hydrogen economy

Hydrogen-based pathways figured significantly in the HEHE paper. A federal hydrogen strategy was released at the end of 2020. The strategy envisioned a future where hydrogen would constitute 30 per cent of the energy system, including 5 million fuel cell vehicles and replacing 50 per cent of fossil gas in pipelines.[68] Hydrogen strategies have also been released by Ontario,[69] Alberta[70] and BC,[71] with strong support from the nuclear and natural gas industries. It is important to note that, with the exception of the streel sector investments, direct federal financial support for a 'hydrogen' economy has, so far, been limited, although a major hydrogen export agreement was signed with Germany as part of Canada's response to the Ukraine War in August 2022.[72]

Hydrogen is seen as a potential replacement in for fossil natural gas in space heating, electricity generation, and as a transportation fuel, principally for fuel cell vehicles. Significant industrial applications are also envisioned, particularly in the decarbonization of certain hard to decarbonize sectors like steel, cement and fertilizer production where CO2 generation is an inherent by-product of current production technologies.

Hydrogen can be produced in a number of different ways, as reflected in the 'Hydrogen Spectrum' in **Figure 2** below. The most common has been 'grey' hydrogen produced by splitting natural gas (principally methane) into carbon dioxide and hydrogen. 'Blue' hydrogen involves the same process as grey but the resulting CO2 is subject to CCUS. 'Green' hydrogen uses electricity provided from renewable sources to split water molecules into H2 and O2.

Figure 2: the Hydrogen 'Spectrum'[73]

Green Hydrogen produced by electrolysis of water, using electricity from renewable sources like hydro, wind and solar. Zero GHG emissions produced	**Turquoise** Hydrogen produced by the thermal splitting of methane – instead of CO2, solid carbon is produced	**Yellow** Hydrogen produced by electrolysis using grid electricity	**Blue** Brown or grey hydrogen with CCUS
Pink/Purple/Red Hydrogen produced by electrolysis using nuclear power	**Black/Grey** Hydrogen extracted from natural gas using methane reforming	**White** Hydrogen produced as a by-product of industrial processes	**Brown** Hydrogen extracted from fossil fuels, usually coal, using gasification

Although hydrogen-based options have drawn a great deal of attention, they are subject to some significant limitations. Hydrogen is not expected to be cost-effective decarbonization option except, potentially, in some transportation (e.g. heavy road freight, ships, air) and industrial applications, like steel production. Hydrogen storage, transportation and distribution infrastructure is virtually non-existent in Canada. The existing natural gas distribution infrastructure cannot be easily converted to carry hydrogen, except in low proportions to natural gas, and most existing end-use technologies for natural gas (e.g. engines, furnaces, stoves etc) cannot be readily converted to hydrogen. Rather they would largely need to be replaced. A number of major studies have concluded that direct electrification of end uses (vehicles, heating, etc) is much more efficient, wherever possible, than using electricity to produce hydrogen for use as a fuel.[74] The federal Commissioner for the Environment and Sustainable Development concluded in his April 2022 report to Parliament that Natural

Resources Canada’s strategy greatly overestimated hydrogen’s potential to reduce greenhouse gas emissions because unrealistic assumptions were used.[75]

All of this suggests that hydrogen may be potentially useful in a net-zero transition but is unlikely to be a panacea. Rather it is more likely to find applications in specific applications such as heavy freight, certain hard to decarbonize industries, like steel. From a sustainability perspective the best option for hydrogen production may be ‘green’ via electrolysis powered by renewable energy sources as it avoids key GHG emission, CCUS and nuclear-related trade-offs related grey, blue and red hydrogen.

Conclusions

The chapter did not attempt to assess the overall effectiveness of the federal government’s 2030 plan and net-zero strategy in terms of achieving their emission reduction targets. It is important to note, however that implementation of many key policies in the 2030 plan remain incomplete. These include specific regulatory requirements for a net zero electricity grid by 2035, emissions caps on oil and gas sector and EV sales mandates. It is also important to recall that deeply contradictory policies remain in place, particularly around the subsidization of fossil fuel resource development and export, estimated at between $4.8[76] and $18 billion annually.[77] The situation reflects a continuation of the “stacking” of contradictory climate and energy policies, rather than their integration as the government’s ecological modernist rhetoric would suggest.

Rather the chapter sought to assess the measures contained in the government’s 2020 Healthy Environment, Health Economy paper, and the 2021 and 2022 budgets from the perspective of a transition to a sustainable energy system, reflecting the principles outlined in Figure 1. The key findings of this assessment are summarized in Table 1 below. The table evaluates each of the major plan elements in terms of whether they advance the sustainability principles articulated in Figure 1, or carry risks of significant negative impacts on those principles or trade-offs among them.

Table 1: Summary Assessment: Federal climate strategy and energy sustainability

Plan Element (HEHE and 2022 Budget)	Advances sustainability	Negative trade-off risk
Carbon pricing/federal backstop	Advances ecological integrity, intergenerational justice, economic and resource efficiency; avoidance of catastrophic risks	Intragenerational/distributional justice issues: household and consumer vs. industry burden; impacts of increasing carbon price on low-income, marginalized communities

Building EE retrofits	Advances ecological and social integrity, intergenerational justice, economic and resource efficiency; avoidance of catastrophic risks; distributional justice (housing quality)	Resource efficiency risk depending on program design
Electrification of Transportation	Advances ecological integrity, intergenerational justice, avoidance of catastrophic event risks (CC).	Cost-effectiveness of EV subsidies. Distributional justice issues: Primary beneficiaries have been higher income earners; EV affordability and access.
EV Manufacturing	Significant economic opportunity; maintain/expand high quality employment.	Supply chain issues, see 'critical' minerals.
'Clean' electricity	Low-impact, low-risk, distributed options advance ecological integrity, intergenerational justice, economic and resource efficiency; avoidance of catastrophic risks; potential links to energy democracy.	Some options (nuclear, new large hydro) are high risk, high potential for significant negative environmental, social cultural impacts; adverse effects on reconciliation; intergenerational and catastrophic event risks. SMRs technology immature, raise serious geopolitical risk concerns.
'Critical' minerals	Potential contributions to EV, energy storage, supply chains. Economic opportunities in remote communities.	Risk of high negative environmental, social cultural impacts; adverse effects on reconciliation; legacy/intergenerational issues
Industry	Technological choice dependant	Technological choice dependant
CCUS	Potential contribution to avoidance of CC threats to ecological integrity, intergenerational justice.	Effectiveness; economic and resource efficiency concerns. High carbon lock-in/path dependency concerns

	Maintains economic opportunity and governance civility	Distributional/intragenerational justice concerns re: public subsidization of highly profitable industry.
Hydrogen	Potential to advance ecological integrity, intergenerational justice, maintain economic opportunity through decarbonization of hard-to-decarbonize sectors and industries. Moderate potential as energy storage medium.	High cost, inefficiency, impacts particularly for grey, red hydrogen; CCUS link for blue hydrogen. Lack of infrastructure and end-use technologies Direct electrification preferable where possible.
Agriculture	Potential to advance ecological, social integrity, intergenerational justice, strengthen communities and relationships	Impacts technology choice dependent; poor record of effectiveness around environmental issues. Apparent backdown on fertilizer supply chain issues
Waste	Potential to advance ecological, social integrity, intergenerational justice; economic and resource efficiency	Program design dependant.
Nature-based solutions	Potential to advance ecological, social, cultural integrity, intergenerational justice; economic and resource efficiency; community and relationships, reconciliation	Program design dependant.

Some elements federal strategy show strong potential to advance energy sustainability with relatively low risks of adverse impacts or negative trade offs. Carbon pricing; building energy efficiency improvement; nature-based responses; and the electrification of transportation all potentially fall into this category. At the same time, careful attention needs to be paid in all cases to program design to ensure effectiveness, efficiency, and avoid or avoid deepening adverse impacts on marginalized communities. The decarbonization of important but difficult-to-decarbonize sectors, like heavy, long-distance transportation, and steel and cement may also fall into these categories but is more dependant on technological choices, such as the sources of hydrogen used for these purposes.

Other elements of the federal strategy present more complex challenges and trade-off risks. Assessments of hydrogen-based strategies depend greatly on how hydrogen is generated (e.g. grey vs. blue vs. green vs. red). Serious concerns are also emerging regarding the economic viability of the widespread adoption of hydrogen-based technologies, the availability of the necessary infrastructures, and their economic and energy efficiency. As the federal environmental commissioner has noted, hydrogen's role in a net-zero transition may be being seriously overstated. It may well emerge as something of a 'dead-end' outside of certain relatively-specific applications.

The SMR component of the federal government's approach 'clean' electricity carries very high trade-off risks, ranging from direct impacts and to questions of geopolitical security. At the same time, the technology remains immature and unlikely to make any contribution to the achievement of Canadian or global emission reduction targets for 2030 or even by mid-century. Rather, it may represent another 'dead-end' pathway – albeit one with very significant risks of major legacy costs and impacts.

Very significant energy sustainability trade offs emerge within the federal government's strategies around the roles of CCUS and 'critical' minerals. The federal focus on CCUS has been seen as politically essential in dealing with fossil fuel export dependant provinces around climate change issues. However, in addition to the issues related to its effectiveness, cost and the appropriateness of public subsidization of a highly profitable sector, CCUS raises larger, and politically difficult, questions about the long-term role of the upstream fossil fuel sector in a decarbonizing world. The development of 'critical' mineral resources, although potentially important to energy storage technologies like EV batteries, also carries risks of very significant environmental, social, and cultural trade-offs, particularly in relation to Indigenous communities in regions where these minerals might be found. So far, these issues have been largely ignored in new strategies for the sector.

On the whole the federal government's strategy for a net zero energy transition contains elements with a strong potential to advance energy sustainability, but its overall effectiveness in achieving the government's stated climate change goals remains an open question. At the same time, the power of 'hard' path incumbents, in the form traditionally dominant actors in the fossil fuel, nuclear, mining and industrial agriculture sectors, backed by sympathetic provincial governments, is strongly apparent in the federal government's plans, and gives rise to a range of critical trade-off risks in relation to a sustainable, net-zero energy transition.

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