BRIEFING PAPER

ATLANTIK-BRÜCKE CANADA

THE ENERGY TRANSITION IN GERMANY AND CANADA: DIFFERENT TRAJECTORIES, MANY COMMON CHALLENGES

PIERRE-OLIVIER PINEAU

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EXECUTIVE SUMMARY

Germany is the 5th largest economy in the world and Canada the 5th largest energy producer. Their strong relationship and common values can help them build on their complementarities to work on the energy transition they both want to realize. With 80 million, Germany has twice the population of Canada, and an even larger gross domestic product (GDP). Despite these two important energy demand drivers, the German energy consumption is only just slightly greater than the Canadian one. It is also on a decreasing trajectory, in absolute terms, while the Canadian energy consumption continues to grow. Greenhouse gas (GHG) emissions follow a similar path. These two differences, in energy intensity and trend, should not eclipse the fact that the final energy consumption in Germany and Canada relies on a similar mix of energy types (about 45% of oil products, 25% of natural gas, 20% of electricity, with biofuels, waste and coal making up the remaining shares). In addition, energy consumption in the two countries is distributed very similarly across sectors: about 25% in industry, 30% in transport, around 20% in the residential sector, 12% in the commercial sector, 3% in agriculture and 10% in non-energy uses.

The German approach to the energy transition is however very distinct from the Canadian one. Germany develops its energy transition around a clear "energy concept" based on energy efficiency, renewable energy and electricity. The strong central leadership of the German government comes from the Federal Ministry for Economic Affairs and Energy (BMWi), with little independent action from the 16 German states. The European Union is also playing a regional role in coordinating energy and climate action.

In Canada, the federal government has less power to lead, because of the constitutional distribution of responsibilities with provinces. In addition, energy and climate leaderships are shared between various ministries (mostly natural resources and environment), with less coordination with ministries in charge of economic development. To date, from a decarbonization perspective, changes in the German energy sector are much more convincing than the Canadian decentralized approach.

Both countries face common challenges to continue their action on the energy transition. Five key ones are identified.

1) **Private sector adhesion and leadership should be secured**.
2) A convincing and socially acceptable **phase out of the fossil fuel sectors** must be developed.
3) **Grid transformation, to increase its capacity, flexibility and integration**, must be stepped up.
4) The **role of nuclear power and the consequences of not counting on it should be clarified**, because of the implication on the grid and on the entire energy system.
5) The **future of hydrogen in the energy mix should be discussed**, with different upstream and downstream challenges.

TRANSITION ÉNERGÉTIQUE EN ALLEMAGNE ET AU CANADA : TRAJECTOIRES DIFFÉRENTES, NOMBREUX DÉFIS COMMUNS

Pierre-Olivier Pineau

RÉSUMÉ

L'Allemagne constitue la 5e plus grande économie au monde alors que le Canada est le 5e producteur d'énergie. Leur forte relation et les valeurs qu'ils partagent peuvent les aider à tirer parti de leurs complémentarités pour œuvrer à la transition énergétique qu'ils souhaitent tous deux réaliser. Avec 80 millions d'habitants, l'Allemagne a deux fois la population du Canada et un PIB encore plus important. Malgré ces deux importants moteurs de la demande d'énergie, la consommation allemande n'est que légèrement supérieure à celle du Canada. Elle est également sur une trajectoire décroissante, en termes absolus, alors que la consommation énergétique continue de croître au Canada. Les émissions de gaz à effet de serre (GES) suivent une trajectoire similaire. Ces deux différences, soit celle de l'intensité énergétique et celle de la tendance, ne doivent pas occulter le fait que la consommation finale d'énergie repose sur un mix énergétique semblable en Allemagne et au Canada (environ 45 % de produits pétroliers, 25 % de gaz naturel, 20 % d'électricité; les biocarburants, les déchets et le charbon constituant la part restante). De plus, la consommation d'énergie dans les deux pays se répartit de manière très similaire entre les secteurs : environ 25 % pour l'industrie, 30 % pour les transports, environ 20 % pour le secteur résidentiel, 12 % pour le secteur commercial, 3 % pour l'agriculture et 10 % pour l'usage non énergétique.

L'approche allemande pour la transition énergétique est cependant bien distincte de celle du Canada. L'Allemagne a une vision beaucoup plus claire du nouveau « concept énergétique » qu'elle s'emploie à mettre en œuvre. Il s'agit d'un concept basé sur l'efficacité énergétique, sur les énergies renouvelables et sur l'électricité. Le leadership fort du gouvernement allemand est assuré par le ministère fédéral de l'Économie et de l'Énergie (BMWi), avec peu d'action indépendante de la part des 16 lands du pays. L'Union européenne joue également un rôle régional dans la coordination de l'action énergétique et climatique. Au Canada, le gouvernement fédéral a non seulement moins de leadership (en raison de la répartition constitutionnelle des responsabilités), mais le leadership en matière d'énergie et de climat est partagé entre divers ministères

(principalement des ressources naturelles et de l'environnement), avec moins de coordination avec les ministères responsables du développement économique. Du point de vue de la décarbonisation, les changements observés dans le secteur énergétique allemand sont jusqu'à présent beaucoup plus convaincants que ceux qu'on note au Canada.

Les deux pays font face à des défis communs dans la poursuite des actions vers la transition énergétique. Cinq principaux défis se dégagent. En effet, il importe de garantir l'adhésion et le leadership du secteur privé. Il faut aussi prévoir une sortie progressive convaincante et socialement acceptable du secteur des énergies fossiles. Il faut également accélérer la transformation du réseau pour en accroître la capacité, la flexibilité et l'intégration. Il convient par ailleurs de préciser le rôle du nucléaire et clarifier les conséquences de ne pas y souscrire, en raison de ses répercussions sur le réseau et sur l'ensemble du système énergétique. Enfin, il faut discuter de l'avenir de l'hydrogène dans le mix énergétique, avec ses exigences tant en amont qu'en aval.

DIE ENERGIEWENDE IN DEUTSCHLAND UND KANADA: UNTERSCHIEDLICHE WEGE, VIELE GEMEINSAME HERAUSFORDERUNGEN

Pierre-Olivier Pineau

ZUSAMMENFASSUNG

Deutschland ist die fünftgrößte Volkswirtschaft der Welt und Kanada ist der fünftgrößte Energieproduzent. Ihre starke Beziehung und ihre gemeinsamen Werte können ihnen dabei helfen, auf ihrer Komplementarität aufzubauen, um an der Energiewende zu arbeiten, die sie beide verwirklichen wollen. Mit 80 Millionen Einwohnern hat Deutschland doppelt so hoch Bevölkerungszahl wie Kanada und ein noch größeres BIP. Trotz dieser beiden wichtigen Energiebedarfstreiber liegt der deutsche Energieverbrauch nur knapp über dem kanadischen. Auch in absoluten Zahlen ist es rückläufig, während der kanadische Energieverbrauch weiter wächst. Treibhausgasemissionen (THG) folgen einem ähnlichen Pfad. Diese beiden Unterschiede in Energieintensität und -trend sollten nicht darüber hinwegtäuschen, dass sich der Endenergieverbrauch in Deutschland und Kanada auf einem ähnlichen Energiemix verlasst (etwa 45 % aus Erdölprodukte, 25 % aus Erdgas, 20 % aus Elektrizität, wobei Biokraftstoffen, Abfälle und Kohle die restlichen Anteile ausmachen). Zudem verteilt sich der Energieverbrauch in beiden Ländern sehr ähnlich auf die Sektoren: etwa 25 % in der Industrie, 30 % im Verkehr, etwa 20 % im Wohnsektor, 12 % im gewerblichen Bereich, 3 % in der Landwirtschaft und 10 % bei nicht-energetischen Anwendungen.

Der deutsche Ansatz zur Energiewende unterscheidet sich jedoch stark vom kanadischen. Deutschland hat einen viel klareren Blick auf das neue „Energiekonzept“, an dem es arbeitet, basierend auf Energieeffizienz, erneuerbaren Energien und Elektrizität. Die starke Führung der Bundesregierung kommt vom Bundesministerium für Wirtschaft und Energie (BMWi), mit wenig eigenständigem Handeln der 16 Bundesländer. Die Europäische Union spielt auch eine regionale Rolle bei der Koordinierung von Energie- und Klimaschutzmaßnahmen. In Kanada hat die Bundesregierung nicht nur weniger Führungsbefugnisse (aufgrund der verfassungsmäßigen Verteilung der Zuständigkeiten), sondern die Energie- und Klimaführung wird von verschiedenen Ministerien (hauptsächlich natürliche Ressourcen und Umwelt) geteilt, mit weniger Koordination mit den Ministerien zuständig für die Wirtschaftsentwicklung. Bisher sind die Veränderungen im deutschen Energiesektor aus Sicht der Dekarbonisierung viel überzeugender als in Kanada.

Beide Länder stehen vor gemeinsamen Herausforderungen, um ihre Maßnahmen zur Energiewende fortzusetzen. Fünf Schlüsselbereiche sind identifiziert. Die Haftung und Führung des Privatsektors sollte sichergestellt werden. Ein überzeugender und sozialverträglicher Ausstieg aus den fossilen Sektoren muss entwickelt werden. Die Stromnetz-transformation zur Erhöhung ihrer Kapazität, Flexibilität und Integration muss forciert werden. Die Rolle der Kernenergie und die Folgen des Verzichts auf sie sollten wegen der Auswirkungen auf das Stromnetz und das gesamte Energiesystem geklärt werden. Schließlich sollte auch die Zukunft von Wasserstoff im Energiemix, mit seinen vor- und nachgelagerten Anforderungen diskutiert werden.

INTRODUCTION

Germany (Federal Republic of Germany) and Canada are two of the largest economies in the world. Germany was the 5th largest world economy[1] in 2020 (behind China, the United States, India and Japan) and Canada was the 16th. While the Canadian economy is not as significant as the German one, Canada is one of the top energy producers in the world: it was the 5th largest in 2019, only behind China, the United States, Russia and Saudi Arabia. Germany was the 24th (EIA, 2022). Given their close friendship (both countries are notably members of the G7 and G20) and strong trade relations, they can both gain from their respective position.

Germany embarked on an *Energiewende* ("Energy transition") since at least 2010. Canada could learn some lessons from its achievements since it aims to achieve net-zero emissions by 2050 and more than 80% of its greenhouse gas (GHG) emissions are directly related to energy. How the energy transition is managed in Germany could therefore contain interesting messages for Canada. Germany, on its side, could gain from closer ties with Canada, one of the largest exporters of energy in the world. As Germany imports more than twice its domestic energy production, with a large share coming from Russia, an energy supply diversification is more important than ever for Germany.

This paper starts by providing an overview of the very distinct, and possibly complementary, energy situations in Germany and Canada. The respective approaches to the energy transition are then described in section 2. Then five key challenges are discussed in section 3.

1. ENERGY AND GHG IN GERMANY AND CANADA: VERY DISTINCT SITUATIONS

Germany and Canada have followed very different energy trajectories between 1960 and 2020. While in the 1960s Germany was producing more energy than Canada and more than it consumed, Canada's energy production rose almost continuously during these 60 years. This growth was faster than consumption, allowing increasing energy export opportunities. Germany on its hand became a country gradually relying more on energy imports.

The key difference between Germany and Canada is the shift in energy consumption that happened in the 1970s in Germany, but not in Canada. Absolute total energy consumption stabilized and then declined in Germany, while Canada only saw a decline in the rate of growth of the energy consumption. Meanwhile, both German and Canadian GDP grew steadily. Figure 1 illustrates these strikingly different paths. This section provides a more in-depth view on their respective energy situation.

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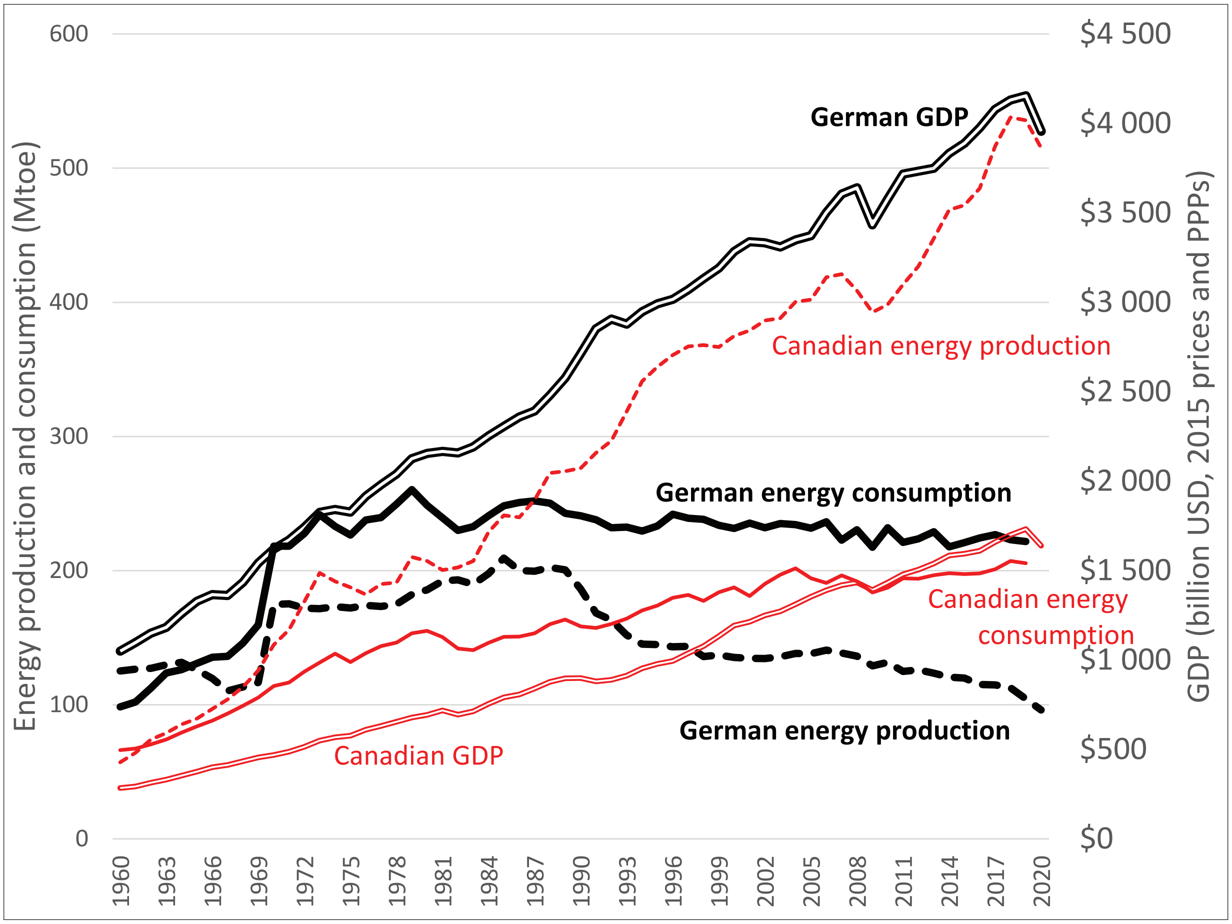
1 Based on gross domestic product (GDP) expressed in current international dollars, converted by purchasing power parity (PPP), World Bank (2022).

Figure 1. German and Canadian GDP, energy production and consumption, 1960-2020 (IEA, 2022a)



1.1 THE ENERGY LANDSCAPE

While Canada is a much larger country than Germany (Germany would fit 28 times within the land size of Canada), the German population is much larger: close to 80 million compared to less than 40 million in Canada. Its economy is also larger, by a factor of 2.4, as summarized in Table 1. Consequently, the German GDP per capita is higher than the Canadian one. This could seem surprising since the per capita energy consumption in Germany is only half the Canadian one. Given the historically strong relationship between energy consumption and wealth, there could be an apparent paradox in the fact that Germany is richer while consuming proportionally much less energy. The reality of these two countries is a proof that economic development can happen with less energy, even if the lower population density and milder climate in Germany contribute to a lower demand in energy services.

Table 1. Basic Information on Germany and Canada (CIA, 2022a and b; IEA, 2020b & 2022b; UNFCCC, 2022)

	Germany	Canada	Ratio Germany/Canada
Population, 2021 *(million)*	79.9	37.9	2.11
GDP purchasing power parity, 2020 *($ trillion)*	4.239	1.743	2.43
GDP per capita, 2020 *($ PPP)*	50,900	45,900	1.11
Area *(square km)* Populated area[2] *(square km)*	357,022	9,984,670 1,654,200	0.04 0.22
Urban population, 2022 *(%)*	77.6%	81.8%	0.95
Energy production, 2019 *(EJ)*	4.37	22.42	0.19
Total energy supply, 2018 *(EJ)*	12.23	12.79	0.96
Final energy consumption, 2019 *(EJ)*	9.28	8.60	1.08
Energy consumption per capita *(GJ)*	116	227	0.51
Greenhouse Gas Emissions (GHG), 2019 *(Mt)*	810	730	1.11
GHG per capita, 2019 *(t)*	10.1	19.3	0.53
Energy prices			
Diesel - commercial use, 1Q 2020 *(US$/l)*	1.168	0.721	1.62
Gasoline (98 octane), 1Q 2020 *(US$/l)*	1.679	0.967	1.74
Natural gas – households, 1Q 2020 *(US$/MWh)*	75.9	17.9	4.24
Electricity – industry, 2019 *(US$/MWh)*	146.0	90.5	1.61
Electricity – households, 2019 *(US$/MWh)*	333.9	112.5	2.97

On the energy production side, Canada has now an aggregate energy production five times larger than Germany (Figure 1 and Table 1). Crude oil, natural gas and hydroelectricity are the three primary energy sources dominating the Canadian energy production. The much larger natural endowment in these resources explains the scope of the Canadian production. Table 2 and 3 provide the key figures on energy production and consumption in the two countries. Germany is however a larger producer than Canada for four types of energy: geothermal, wind and solar, biofuels and heat. These types of energy remain, nevertheless, relatively small in the German energy mix, with only 12% of the final energy consumption. However, this figure excludes the growing renewable contribution to electricity generation, which accounted to 44% of Germany's power generation in 2020 (SMARD, 2021; see also Figure 4).

Coal production is equivalent in the two countries, but Germany imports as much as it produces and Canada exports a large share of its production (out of which a small quantity goes to Germany, see Table 4). Nearly half of the coal produced in Canada is thermal, used mostly for electricity generation. However, a phase out of coal in electricity generation is planned for 2030 and is already declining (see Figure 4). The other half is metallurgical, for coking and steelmaking (NRCan, 2022). Germany

2 The overwhelming majority of the Canadian population lives within 300 km of the United State border, in the South of the country.

and Canada each have a large refining capacity, transforming similar amounts of crude oil into oil products (such as gasoline or diesel). Their transformation of uranium into nuclear power (electricity) was also of the same magnitude, but nuclear power is rapidly phased out in Germany. Total electricity generation is similar in the two countries. Heat production is much more developed in Germany. Heat is produced mostly from natural gas, biofuels and waste, but also from coal, oil products and even geothermal sources. Germany produces 5.5 times more heat from biofuels and waste than Canada.

On the consumption side, the total final energy consumption in Germany is higher than in Canada (9,281 PJ compared to 8,605 PJ). However, Germany meets this higher energy demand with a slightly lower total energy supply (12,323 PJ compared to 12,795 PJ). This is explained by the higher energy efficiency of the German energy system. For instance, heat is produced as a by-product of other uses on a larger scale (such as industrial consumption or electricity generation), so that a lower energy supply can fuel a higher total energy consumption, instead of being wasted, as it is more often the case in Canada.

The share of energy consumption across sectors is mostly similar in Germany and Canada (Table 2 and 3). The transportation sector dominates energy consumption with 26% in Germany and 33% in Canada. Industry accounts for about a quarter of the consumption (25% in Germany and 23% in Canada). The residential buildings sector accounts for 26% of the energy use in Germany but only 17% in Canada. This can be explained by the larger size of the transportation sector in Canada and the fact that, once energy needs are met in buildings, demand hardly grows – unlike energy demand in productive activities that can grow as long as the industry grows. Commercial buildings use 12% of the energy in Germany and 14% in Canada. Finally, agriculture accounts for 3% of Germany's and 2% of Canada's total energy balance, while non-energy uses (asphalt, plastics, petrochemicals) accounts for 10% in both countries.

Despite a similar distribution across sectors and close levels of total final energy consumption (around 9,000 PJ), the much larger population and GDP of Germany make of this country, compared to Canada, a more efficient energy consumer, per capita and per dollar of wealth. Energy prices certainly play a role in this, as they provide incentives for energy efficiency when they are high. Germany has much higher energy prices, as illustrated in Table 1: diesel and gasoline are 60 to 70% more expensive than in Canada, while residential prices are four times higher than in Canada for natural gas and three times for electricity.

The key difference in the two countries' energy situation is the divergence in their self-sufficiency ratios. While Germany imports 50% of its coal, 100% of its crude oil and 90% of its natural gas (with self-sufficiency ratios of 0.5, 0 and 0.1; see Table 2), Canada is a net exporter of these three fossil fuels, with self-sufficiency ratios of 2.1, 2.4 and 1.4 (Table 3). This dependency over imports is particularly problematic for Germany, from a geopolitical perspective. In 2020, the three most important types of energy (crude oil, natural gas and coal) in its supply mix came from Russia, more than from any other countries, as shown in Table 4. Canada is a small supplier of hard and coking coal to Germany, but only 5th and far behind Russia.

As mentioned earlier, the large refining capacities of Germany and Canada allows them to produce more oil products than they use, with a similar self-sufficiency ratio of 1.1.

Table 2. Energy Balance in Germany (PJ), 2019 (IEA, 2022b)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geothermal	Solar & wind	Biofuel & waste	Electricity	Heat	Total
Production	1,190	135	4,183	183	819	71	14	651	1,309	1,674	107	4,371
Imports	1,180	3,655	1,797	3,168	0	0	0	0	98	144	0	10,043
Exports	63	5	913	0	0	0	0	0	114	262	0	1,357
Total energy supply[3]	2,255	3,767	405	3,166	819	71	14	651	1,293	-118	0	12,323
Ratio of self-sufficiency[4]	0.5	0	1.1	0.1								
Total final consumption	257	0	3,790	2,336	0	0	3	31	662	1,798	403	9,281
Industry (25%)	226	0	140	815	0	0	0	0	168	804	179	2,333
Transport (26%)	0	0	2,192	33	0	0	0	0	112	42	0	2,378
Residential (26%)	14	0	496	937	0	0	1	29	269	456	166	2,368
Commercial and public services (12%)	0	0	116	396	0	0	2	1	82	477	58	1,133
Agriculture and other (2%)	0	0	91	11	0	0	0	0	32	19	0	153
Non-energy use (10%)	17	0	756	144	0	0	0	0	0	0	0	917
% of final consumption	3%		41%	25%			0.04	0.33	7%	19%	4	100%

3 Total energy supply is not equal to production plus imports minus exports because of stock changes and transformation. It can be negative due to losses in energy transformation (to produce oil products and electricity), as reported by IEA (2022a).

4 The self-sufficiency ratio is "Production/Total energy supply" except for oil products where it is "Production/Total final consumption"

Table 3. Energy Balance in Canada (PJ), 2019 (IEA, 2022b)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geothermal	Solar & wind	Biofuel & waste	Electricity	Heat	Total
Production	1,208	11,405	4,276	6,627	1,104	1,367	0	134	580	2,069	4	22,424
Imports	250	1,898	553	920	0	0	0	0	56	48	0	3,725
Exports	866	8,552	953	2,705	0	0	0	0	59	217	0	13,352
Total energy supply[2]	580	4,710	-401	4,894	1,104	1,367	0	134	577	-169	0	12,795
Ratio of self-sufficiency3	2.1	2.4	1.1	1.4								
Total final consumption	107	0	3,901	2,206	0	0	0	2	459	1,907	24	8,605
Industry (23%)	102	0	263	671	0	0	0	0	229	681	23	1,969
Transport (33%)	0	0	2,575	152	0	0	0	0	92	28	0	2,847
Residential (17%)	0	0	67	658	0	0	0	0	137	620	0	1,482
Commercial and public services (14%)	0	0	75	576	0	0	0	0	1	540	0	1,193
Agriculture and other (3%)	0	0	215	39	0	0	0	2	0	38	1	295
Non-energy use (10%)	5	0	706	109	0	0	0	0	0	0	0	820
% of final consumption	1%		45%	26%				0.02	5%	22%	0.3	100%

Table 4. Origins of crude oil, natural gas and coal imports in Germany, 2020 (IEA, 2022c, d, e)

Crude oil		Natural gas		Coal (all types)	
Russia	34%	Russia	51%	Russia	52%
United Kingdom	12%	Netherlands	36%	United States	17%
United States	11%	Norway	3%	Australia	10%
Norway	10%	Other	10%	Colombia	7%
Kazakhstan	9%			Canada	3%
Other	24%			Other	12%

Canadian exports suffer from an even higher dependency than Germany to a single trade partner in oil and natural gas. As shown in Table 5, almost all its oil and natural gas exports are going to the United States (2020 data). Canadian coal exports are more diversified, but less important in volume (see Table 3) and in value since the price of coal is lower than the price of crude oil and often also than the price of natural gas. We can note that some very small amounts of Canadian oil are exported to Germany (0.3% of Canadian exports).

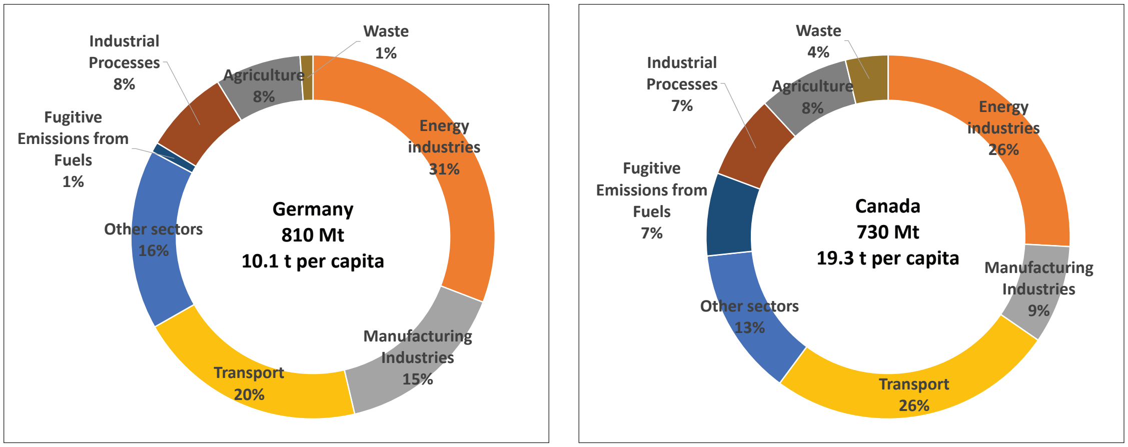
Table 5. Destination of crude oil, natural gas and coal exports from Canada, 2020 (IEA, 2022c, d, e)

	Crude oil		Natural gas		Coal (all types)
United States	97%	United States	99.99%	Korea	55%
United Kingdom	0.9%	China	0.01%	Japan	27%
Italy	0.5%			Chile	6%
Belgium	0.3%			Germany	5%
Spain	0.3%			Turkey	3%
Germany	0.3%			United States	2%
Other	0.4%			Other	3%

1.2 THE GHG LANDSCAPE

Mirroring the energy situation to a large extent, German GHG emissions (810 Mt) in 2019 are equivalent to Canadian emissions (730 Mt), but for a population twice as large. Figure 2 illustrates how these emissions are distributed across sectors. Energy industries, dominated by the power sector in Germany and by the oil and gas production in Canada, account for the largest share of emissions in both countries. However, the transport sector has the same level of emissions in Canada (26%) and comes second in Germany (20%). It is the quasi-exclusive use of oil products in transport that explains the higher share of emissions in transport compared to the building sector (included in "other sectors" in Figure 3), despite a lower energy consumption (see Tables 2 and 3). Indeed, natural gas and electricity dominate in buildings, and are less GHG-intensive than oil products.

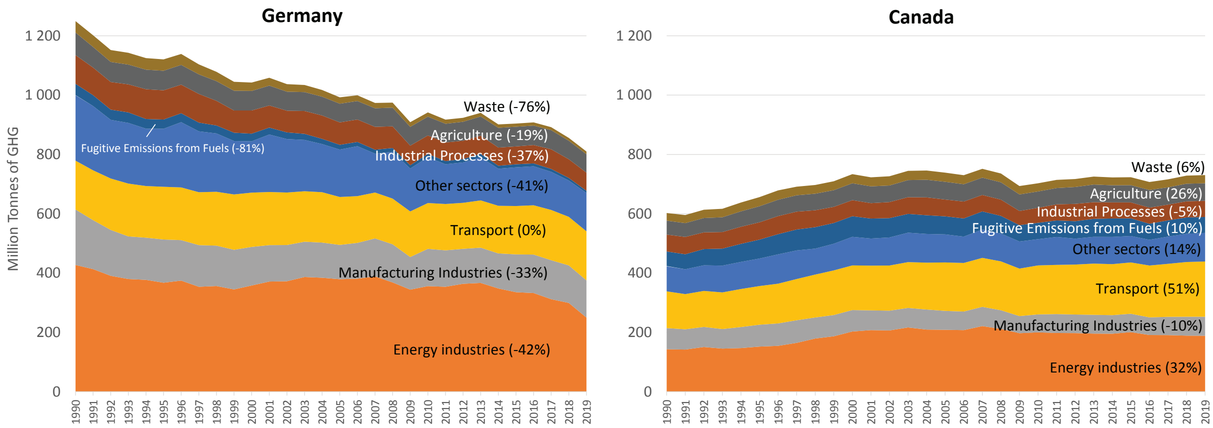
Figure 2. GHG emissions in Germany and Canada by sector (Mt), 2019 (UNFCC, 2022)



What is remarkable in the comparison between German and Canadian GHG emissions, as shown in Figure 2, is the much lower share of fugitive emissions from fuels (1% of German GHG emissions compared to 7% in Canada) and of emissions from the waste sector (1% again in Germany against 4% in Canada). These emissions being mostly methane (CH_4), the main component of natural gas, a particular attention seems to be dedicated to minimizing losses and capture as much methane as possible in Germany. This probably results from the small self-sufficiency ratio for natural gas, and other dominant energy sources, in the German context.

Since 1990, GHG emissions in Germany have steadily decreased in all sectors except transport where they remained stable, as illustrated in Figure 3. Meanwhile, in Canada, they have grown in all sectors (except for industrial processes and manufacturing industries). Canadian emissions have particularly increased in transport, which is a trend that the Canadian geography cannot explain since the size of Canada didn't change between 1990 and 2019.

Figure 3. GHG emissions in Germany and Canada by sector (Mt), with 1990-2019 change (UNFCC, 2022)



The very distinct GHG emissions trajectories of Germany and Canada illustrate two approaches to emission management. One that is very proactive and seeking improvements without destroying economic growth opportunities, and another one that is very soft and mostly based on encouragements. This latter one has been ineffective at reducing emissions in most sectors. The next section expands on the two approaches to the energy transition and their institutional context.

2. TWO APPROACHES TO THE ENERGY TRANSITION

Both Germany and Canada have a federal government. Germany is composed of 16 *Länder* (states) while Canada has 10 provinces and 3 territories. The key difference in the energy policy governance between the two countries lies in the level of decentralization. The federal government in Germany oversees most aspects of the energy policy, while Canadian provinces have most of the energy policy responsibilities. Furthermore, in Germany the key responsibilities are centralized under the federal Ministry for Economic Affairs and Energy (BMWi), while in Canada climate change, energy and economic policies are under different ministries. In short, in Germany, the energy transition is centrally managed under one ministry at the federal level. In Canada, responsibilities are disseminated under various ministries at the federal and provincial levels, with important powers at the provincial level. This section provides more details on these two approaches.

2.1 THE GERMAN *ENERGIEWENDE*

In 2010, the German government released an "Energy concept" document (BMWi, 2010) that laid out the principles on which it would operationalize its energy transition. Nine driving principles have been clearly expressed, along which the energy (and climate) policy is largely aligned. A major changed happened in 2011, after the Fukushima nuclear accident in Japan, changing the role of nuclear power plant (principle #3), which are phased out and shut down by the end of 2022 (CLEW, 2021). These nine principles are the following:

1) *Renewable energies as a cornerstone of future energy supply*

2) *Energy efficiency as the key factor*

3) *Nuclear power and fossil-fuel power plants* [Initially planned to play an active role in the transition, both nuclear and coal plants are phased out, respectively by 2022 and 2038 at the latest]

4) *An efficient grid infrastructure for electricity and integration of renewables*

5) *Energy upgrades for buildings and energy-efficient new buildings*

6) *The mobility challenge* [Developing mobility based on electric vehicles, freight trains and alternatives to individual motorised transport]

7) *Energy research towards innovation and new technologies*

8) *Energy supply in the European and international context* [Diversification of energy sources, competition and integration with European Union policies are core principles]

9) *Transparency and acceptance*

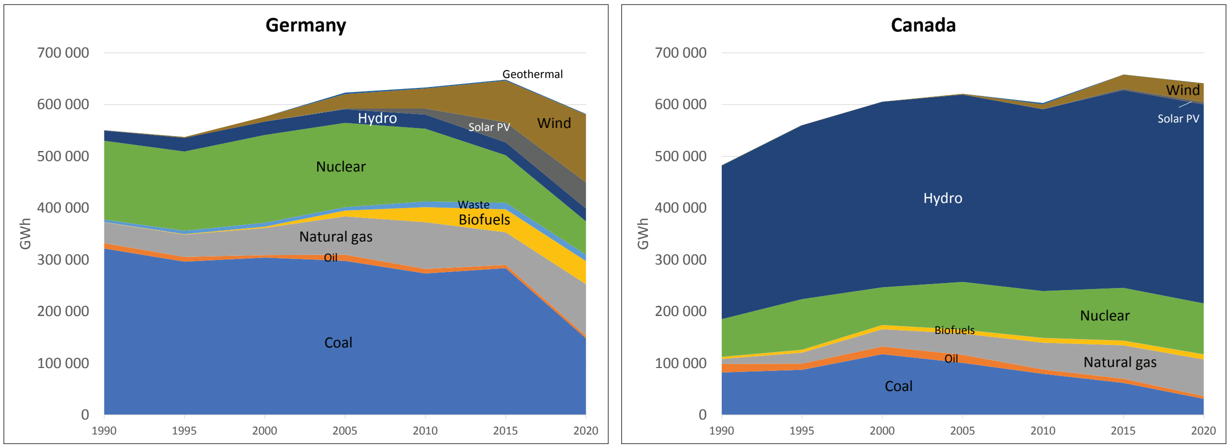
These principles guide the overall energy transition and are deployed through a large set of programs and initiatives that are coordinated and monitored. The federal Ministry for Economic Affairs and Energy (BMWi) oversees the energy policy, but also the industrial policy, to avoid damaging one sector while acting on the other one. Other federal ministries are involved (environment, transport, agriculture, education and finance) to deal with energy transition aspects that affect their areas of responsibility.

To oversee the electricity sector and other networks, that play a central role in the energy transition, the country can benefit from an independent federal authority: the

Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur). This agency regulates and monitors the country's networks, so that harmonized rules prevail across the 16 German states. In addition, Germany must comply with the European Union (EU) requirements in terms of energy policy, with its strong focus on an integrated internal (EU) energy market, energy efficiency and renewable energy (Ciucci, 2021).

The energy transition is closely monitored by the BMWi, through annual reports on progresses. GHG emissions are tracked, but also renewable energy (and its share of final energy consumption, share of electricity, share of heat), as well as different efficiency and consumption indicators (such as primary energy consumption, energy productivity, heat consumption in building, etc.). While some challenges remain on the likeliness to reach the ambitious 2030 targets Germany has, trends are nevertheless going in the right direction, as Figure 1 shows for total energy consumption, Figure 3 for GHG and Figure 4 for renewable energy in electricity. It can indeed be seen in Figure 4 that while wind, solar and biofuels provide an increasing amount of electricity in Germany, the share of coal and nuclear is decreasing. Natural gas, while remaining significant, does not increase since 2005. These developments, in an economic context that remains favorable for Germany, are strong indications that their energy transition plan has some positive outcomes.

Figure 4. Electricity generation in Germany and Canada by source, GWh, 1990-2020 (IEA, 2022f)



About 250 measures are described and reviewed in the annual report on the energy transition (BMWi, 2021), each related to some specific sector: international relations, renewable energy, energy efficiency, buildings, transport, grid infrastructure, affordability and competition, among others. It is worthwhile to mention that Germany does not shy away from using price signals, as it fully recognizes that "rising energy prices give consumers a major incentive to save energy or use it more efficiently" (BMWi, 2010). With an average electricity price for private households of 32.06 Euro¢/kWh in 2020 (BMWi, 2021), or about 44 Can¢/kWh, the energy efficiency financial incentive is more important than in Canada, where the residential electricity price ranged from 7.39 (in Quebec) to 17.26 Can¢/kWh (in Alberta) in 2021 (Hydro-Québec, 2021). Such price differential between Germany and Canada is also observed in liquid fuels: gasoline costs significantly more in Germany than in Canada (Table 1). It certainly contributes to explain the per capita consumption differences mention in section 1 (Table 1) and detailed in Figure 6, as well as the overall energy consumption trend (Figure 1).

In its German energy policy review, the IEA (2020a) summarizes the energy transition through three objectives:

- Reduce energy consumption in all sectors (under the principle of "efficiency first").
- Use renewable energy directly wherever it makes economic and ecological sense.
- Cover the remaining need for energy by renewables-based electricity.

While much progress remains to be achieved in Germany towards meeting its 2050 goals (GHG neutrality, 50% reduction in primary energy consumption, 25% reduction in gross electricity consumption, among other more specific ones; BMWi, 2021), the overall energy transition approach in Germany is coherent and strong.

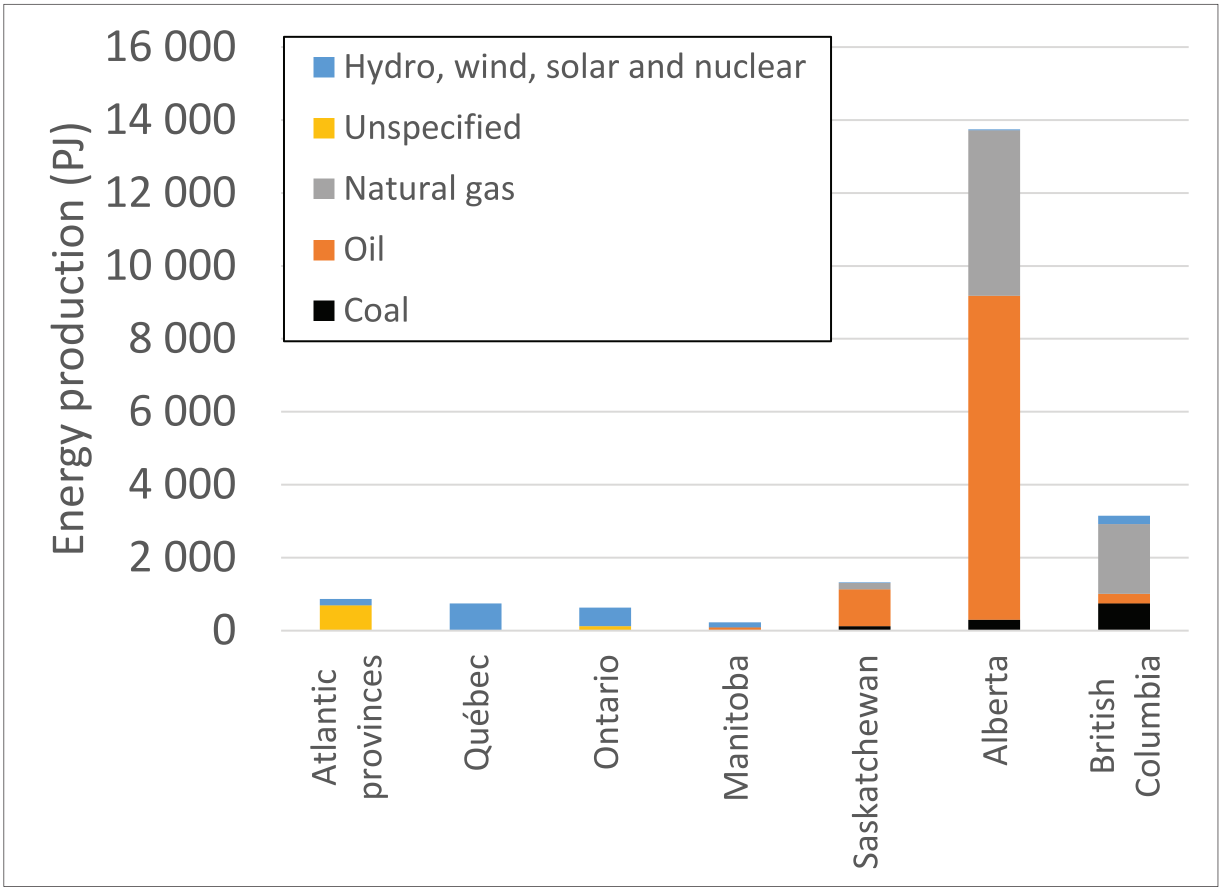
2.2 THE CANADIAN FEDERAL-PROVINCIAL APPROACHES

Canada does not have an energy transition "concept" document. The ten Canadian provinces each have the control over their energy sectors, as the Canadian constitution gives them exclusive jurisdiction over non-renewable natural resources and forestry resources, as well as over the power sector (Stefaniuk, 2019). This has one major consequence: each province has developed its own energy policy, institutions and internal dynamics. The corollary is that there is no central authority in charge of coordinating the regulatory and fiscal framework governing components of the energy sector. The notion of a Canadian "energy transition" is therefore an abstract concept for Canada, not only because of the cheap and relative energy abundance it is endowed with (Table 3), but also because there are huge asymmetries in energy production and consumption across Canada, as illustrated in Figures 5 and 6.

Oil and gas production is concentrated in Alberta, with some production in neighboring provinces (British Columbia and Saskatchewan), and a little bit in the Atlantic provinces. Alberta is responsible for 80% of the crude oil production and 68% of the natural gas production. Oil and gas royalties go directly to the provincial government's budget. Other provinces and the federal government only indirectly benefit from oil and gas wealth in Alberta through the induced economic activity and through higher federal income taxes, resulting from the higher revenues in Alberta. Some redistribution occurs across provinces through the so-called "equalization payments", made by the federal government to lower-income provinces. These equalization payments are however only indirectly related to oil and gas revenues.

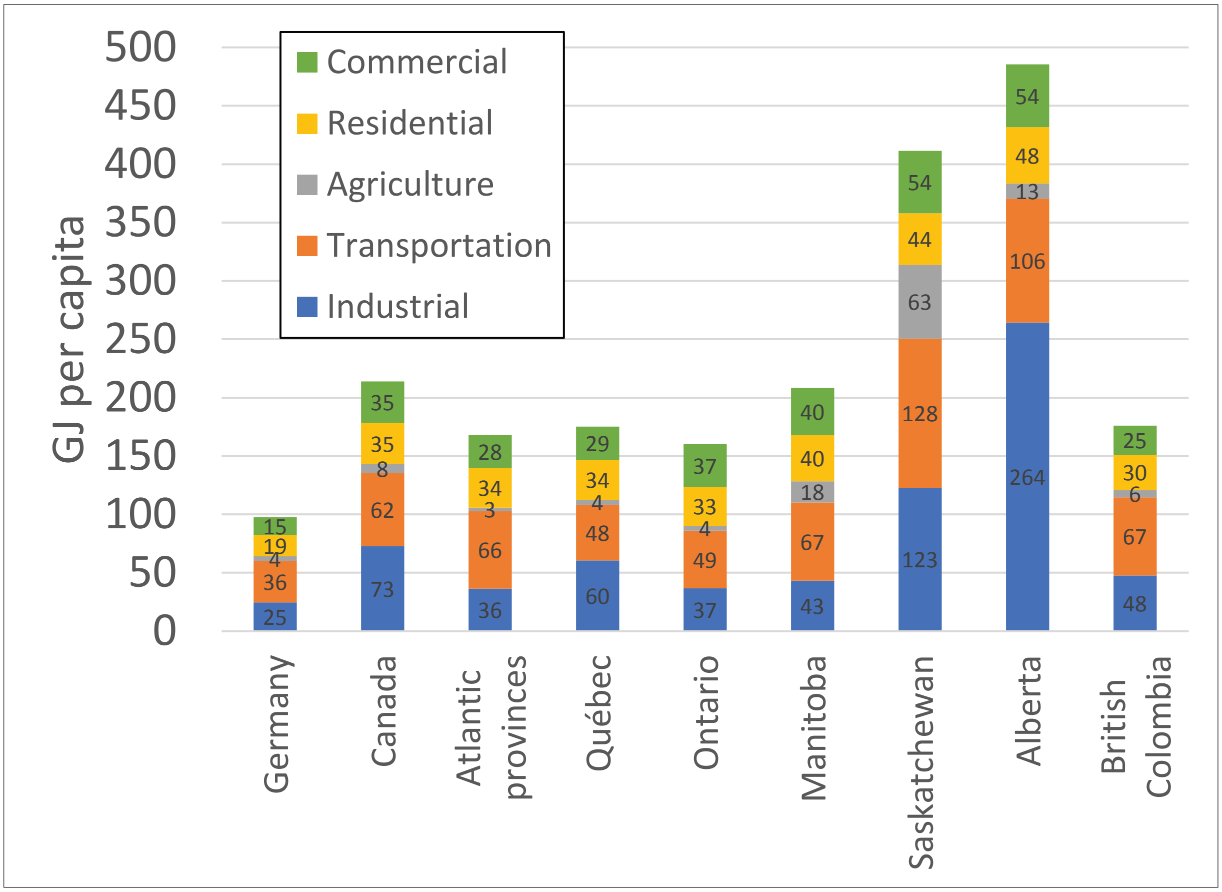
Non-emitting (renewable and nuclear) electricity generation is dominated by hydropower, as illustrated in Figure 4, and is concentrated in Québec (40%) and Ontario (27%), as shown in Figure 5. Contrary to the oil and gas sector, which is competitive and where private companies are fully in charge of production, transportation, refining and distribution, the electricity sector in Canada is mostly regulated and under the control of government-owned companies. Each province has its own regulation and structure, with only two provinces (Ontario and Alberta) that have an unbundled sector with competitive generators. See Pineau (2021) for a detailed presentation of the Canadian power sectors.

Figure 5. Primary energy production in Canadian provinces by type, PJ, 2020 (Statistics Canada, 2022)



Energy consumption is equally asymmetric across provinces, as detailed in Figure 6. While the average Canadian energy consumption was around 200 GJ per capita in 2020, the three most populous provinces (Ontario, Québec and British Columbia) have an energy consumption close to 170 GJ, while the energy powerhouse province of Canada, Alberta (which is the 4th most populous province) is almost at 500 GJ per capita (485 GJ in 2020). These levels of consumption are 1.6 to 5 times higher than in Germany, and as one can see from the sectoral breakdown, geography and climate have little influence on these consumption levels. All Canadian provinces have a large area (except some Atlantic provinces) and winters are cold in all parts of Canada (with some coastal exceptions). What really drives energy consumption are the industrial and the transportation sectors. Building energy consumption (in the residential and commercial sectors), while significantly larger, per capita, than in Germany, varies less across provinces – but remains larger in Alberta.

Figure 6. Energy consumption per capita in Germany, Canada and Canadian provinces by sector, GJ, 2020 (IEA, 2022b; Statistics Canada, 2022)



Given the absence of institutional and market alignment across Canadian provinces, the emergence of a shared notion of an energy transition is difficult. The federal government, through its constitutional responsibilities in environment and its commitments to fight climate change and reduce GHG emissions, released in 2016 the Pan-Canadian Framework on Clean Growth and Climate Change: Canada's plan to address climate change and grow the economy (ECCC, 2016). This plan was developed by the ministry of the environment. However, unlike the German approach, the federal ministry of energy (called "Natural Resources Canada") and the ministry of industry (called "Innovation, Science and Industry") are not directly involved in the plan.

The plan comprises a series of measures, dominated by a carbon price that rose from Can$20 per tonne (about 15 Euro) in 2019 to Can$50 (37 Euro) in 2022. This carbon price is scheduled to increase by Can15$ each year, to reach Can$170 (125 Euro) in 2030 (ECCC, 2022). While such carbon price can appear significant, it remains relatively modest compared to the additional $1/litre in the gasoline price in Germany, compared to Canada. It would take a carbon price of more than $430 per tonne of GHG to make up for this $1 difference, and Canada is far from there. It is also important to highlight that because some provinces already had a carbon pricing system before the creation of the federal carbon pricing approach, both provincial carbon pricing approaches (a carbon tax in British Columbia and a cap-and-trade system covering all sectors except agriculture and waste in Québec) and the federal approach can be found across Canada. This heterogeneity in carbon prices across a country much smaller than Germany (in population and GDP) could represent an unnecessary inefficiency for economic actors trying to adapt to different price signals across the country.

Other key measures in the 2030 Emissions Reduction Plan are (ECCC, 2022):

- Electricity: Coal phase out by 2030
- Methane: Planned reductions of methane emissions under the Global Methane Pledge (30% reduction below 2020 levels by 2030).
- Transportation: Can$5,000 financial incentive for the purchase of electric vehicles and mandatory target for 100% of new light-duty cars and passenger truck sales to be zero emission by 2035.

More measures are already in place (such as different types of financial assistance to renovate buildings, built electric interties between provinces, etc.) and are planned to be implemented (clean fuel standards, clean electricity standard, new building code, etc.). These measures, however, lack specific sector-specific targets such as the ones Germany has developed to monitor its energy transition. They also lack the centralized coordinating ministry that would have the authority to intervene across the ten provinces, that remain constitutionally entitled to manage their energy sector according to their own economic interest, sometimes over the national one.

3. KEY CHALLENGES

While the scope of this report does not allow to cover all possible energy transition challenges in-depth, five key challenges are identified and discussed:

- Private sector and the energy transition
- Dealing with an important fossil industry
- Grid transformation
- Role of nuclear power
- Hydrogen: Upstream and downstream implications

3.1 THE ROLE OF THE PRIVATE SECTOR IN THE ENERGY TRANSITION

Given the traditional importance of energy in economic growth, and the competitive challenges that high energy prices create, the energy transition can be perceived as a threat for businesses. In Germany, if the industry initially resisted the *energiewende* (Gochermann, 2021), it started to largely embrace it after 2010. Massive investments in renewable energy infrastructures and new industrial developments (in green chemistry, green steel) were strong drivers and perspective enabling the adhesion of most industrial players.

In Canada, some business voices can be heard in support of a climate policy, such as the coalition Canadian Business for Climate Policy.[5] There are still, however, many concerns voiced by industrial groups over the impacts of carbon pricing, the extent to which environmental regulation should constrain businesses or how fiscal support and subsidies should be oriented.

The German track record clearly demonstrates that the economy can thrive while energy consumption and GHG emission decline. The higher energy price levels in Germany do not even seem to structurally decrease German's competitiveness. On the contrary, it could be that high energy price have induced a higher competitiveness in German businesses, through the improved efficiencies they induced over time to minimize their energy expenditures.

3.2 DEALING WITH AN IMPORTANT FOSSIL INDUSTRY

As Canada is a very important fossil fuel producer, legitimate concerns for this industry and its workers emerge as Canada considers more seriously an energy transition. The German example can once again be useful to consider, to some extent. Germany was the 4th coal producer in the world in 1981, behind Russia, the United States and China (BP, 2021). In 2020, it was down to the 8th position, with a production decline of almost 80%, when the world coal production nearly doubled. The decline of the coal industry in Germany is significant shift in the country's economic landscape, especially since it shifted from being a net exporter of coal until 1982 to a net importer (BP, 2021). That Germany could still experience economic growth during such a contraction of a large industry is a sign that the fossil fuel phase out can be organized over time without jeopardizing the economy.

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5 https://climatepolicy.ca/

Brauers et al. (2018) and Oei et al. (2020) have studied the German coal phase out in detail and highlight the key explanatory factors that contributed to this successful transformation. Policies have addressed unemployment and the attraction of new companies, while measures developing infrastructure, education and research facilities were also taken. They also note that protections that were provided to the declining industry increased the transition cost. The earlier these protections can be removed, the more efficient the transition is. The role of cooperation among institution and different layers of government can also greatly facilitate the transition.

Such experience could certainly be useful for Canada, as reaching the net-zero emission target for 2050 can only happen in a context of much smaller oil, natural and coal production and consumption in Canada.

3.3 GRID UPGRADE, MODERNIZATION AND INTEGRATION

Electricity has been the world fastest growing form of energy consumed in the last 50 years: final consumption was multiplied by 4.6 between 1973 and 2019, a factor much greater than for natural gas (2.5) and oil products (1.8); see IEA (2021). This growing electrification of modern energy systems could accelerate with decarbonization objectives, since many energy uses will be electrified, notably for heat and transportation. The grid will therefore have to play an even greater role in the future. Furthermore, as more intermittent renewable generation sources are likely to be integrated in the power system to supply non-emitting electricity, adequate transmission lines will be extremely useful to move energy from locations with available power to other ones short of power. Electrification and the higher penetration of wind and solar, both variable energy sources, will require (1) a larger network (in capacity), (2) a network more dynamic and better able to balance various sources of supply and demand fluctuations; and (3) a grid more integrated with neighboring ones and with other energy networks (heat and gas) to optimize energy transfer opportunities and minimize capacity and storage requirements.

Both Germany and Canada face these important grid challenges. Germany starts with a power system with less non-renewable sources (Figure 4), but benefits from a more integrated institutional context, covering the entire country with similar market rules, and from the EU, a supra-national layer that strongly supports international interconnections to foster decarbonization and competitiveness.

Canada, on the other hand, starts with an already highly decarbonized power system. But its highly decentralized and heterogeneous power institutions constitute an obstacle. Aligning the different industry players and implementing reforms is a totally new challenge. The absence of federal, let alone supra-national, power sector institutions is an additional problem, as no one is in charge of conceptualizing and guiding actions to build the grid of the future.

3.4 NUCLEAR POWER

Germany decided to phase out nuclear power quickly, without an available alternative centralized solution. Coal power plants are indeed simultaneously phased out, albeit over a longer period. In Canada, not only is nuclear power not phased out, but it remains strong in the electricity mix of some provinces (Ontario and New Brunswick, an Atlantic province). There is even a vision for an increased role for Small Modular Reactors (SMRs), see the Canadian Small Modular Reactor Roadmap Steering Committee (2018). The provinces of Ontario, New Brunswick, Saskatchewan and Alberta are developing a common strategy for SMRs, through their "strategic plan for the deployment of small modular reactors" (Governments of Ontario, New Brunswick, Saskatchewan and Alberta, 2022).

More nuclear power plants could help decarbonize the power sector of these provinces that still rely on fossil fuels. The extent to which these provinces will need to develop new nuclear facilities will depend on their cost and on the level of success in taking on the grid challenges presented in the previous subsection. More nuclear power could allow the grid to operate along the 20^{th} century "centralized and vertical" paradigm. Trust, safety, waste, social acceptability, and costs remain key issues that must carefully be handled.

3.5 HYDROGEN POTENTIAL AND CHALLENGES

A lot of attention is now given to hydrogen, as a potential energy vector to replace oil and gas in some applications. The key advantages of hydrogen are its non-emitting combustion (H_2 combines with oxygen to produce energy and water, H_2O), its light weight and fast transfer (compared to electricity in heavy batteries) and more direct substitutability to natural gas for heat applications. It can also decarbonize some industrial processes in steel and fertilizers production. The key concerns for a large-scale hydrogen deployment are the upstream power capacity needed to produce "green" hydrogen (from non emitting power sources), the midstream storage and transportation infrastructure that are needed to bring it to markets, and finally the new equipment to use hydrogen. Indeed, unlike biofuels that require minimal adjustments to vehicles or burners, an entirely new fleet of cars and burners would be needed to be fueled by hydrogen.

Given the important electricity inputs to produce green hydrogen, the entirely new transmission and distribution system that would be needed to reach customers and investment required in hydrogen-compatible equipment, the development of a significant share of hydrogen in the consumption mix will take time and a lot of efforts. Solving the four previous challenges would also facilitate solving this fifth one: with a clear role for the private sector, more certainty on where the fossil fuel industry is going, a strong grid and a know status for nuclear power development, it would be much easier to find the right balance for hydrogen in the renewed energy mix.

Over the long run, Canada could become a supplier of hydrogen to Germany, building on its vast renewable and possibly nuclear energy potential, geopolitical stability, and relative proximity. Realizing such vision requires however a commitment rarely seen in industrial policy in recent history.

4. CONCLUSION

Germany and Canada share many values and have strong common political and commercial interests. Their respective energy sectors are however very different, and their paths to a net zero economy in 2050 will therefore be distinct. Through its early actions on the energy transition, Germany can provide some valuable insights on what can work. The important Canadian energy resources could help Germany manage its energy supply. In the medium run this help could materialize through some alternative hydrocarbon supply, as Germany needs to diversify its imports. In the longer run, through some renewable forms of energy – green hydrogen, biofuels or other sustainably produced fuels. Of course, continuing and increasing exchanges of various energy-related expertise and goods can also contribute to each country's energy transition.

Key challenges will require innovative approaches to be solved. The private sector will have to embrace the energy transition so that the society could count on its innovative power and drive to obtain results. A positive approach to the phasing out of the hydrocarbon industry will have to be designed, to avoid costly divides between regions, interest groups and citizens. The technical and institutional challenges of transforming the grid could be the most critical of all challenges: electricity will be increasingly central to the energy system. Finding the right approach to build-up capacity, flexibility and integration will require strong leadership and collaboration from all players. Settling on the role of nuclear power will be important, because of the system and industry implications related to the importance of nuclear in the future energy system. Finally, defining the right amount and place of hydrogen in the energy mix could be a harder project.

Energy is essential to modern society. Its economic, social and environmental impacts have both positive and negative aspects. The failure to adequately manage the sector and its transition to a more sustainable state could lead to some problems, ranging from minor to fatal. Learning from and collaborating with partner countries, such as Germany and Canada, is one of the essential ingredients to success.

REFERENCES

Brauers H., Herpich P. and Oei P.-Y. (2018) The Transformation of the German Coal Sector from 1950 to 2017: An Historical Overview. In: von Hirschhausen C., Gerbaulet C., Kemfert C., Lorenz C., Oei PY. (eds) Energiewende "Made in Germany". Springer, Cham. https://doi.org/10.1007/978-3-319-95126-3_3

BMWi (2021) The Energy of the Future - 8th Monitoring Report on the Energy Transition – Reporting Years 2018 and 2019, Berlin: Federal Ministry for Economic Affairs and Energy (BMWi).

BMWi (2010) Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply, Berlin: Federal Ministry of Economics and Technology (BMWi).

BP (2021) Statistical Review of World Energy - July 2021, bp.

Canadian Small Modular Reactor Roadmap Steering Committee (2018) A Call to Action: A Canadian Roadmap for Small Modular Reactors. Ottawa: Ontario, Canada.

CIA (2022a) The World Energy Factbook – Germany, Washington: Central Intelligence Agency (CIA). Accessed on March 25, 2022. https://www.cia.gov/the-world-factbook/countries/germany/

CIA (2022b) The World Energy Factbook – Canada, Washington: Central Intelligence Agency (CIA). Accessed on March 25, 2022. https://www.cia.gov/the-world-factbook/countries/canada/

Ciucci M. (2021) Energy policy: general principles, Fact Sheets on the European Union, Brussels: European Parliament. Accessed on April 7, 2022. https://www.europarl.europa.eu/factsheets/en/sheet/68/energy-policy-general-principles

CLEW (2021) Q&A: Why is Germany phasing out nuclear power and why now?, Berlin: Clean Energy Wire (CLEW). Accessed on April 7, 2022. https://www.cleanenergywire.org/news/qa-why-germany-phasing-out-nuclear-power-and-why-now

ECCC (2016) Pan-Canadian Framework on Clean Growth and Climate Change: Canada's plan to address climate change and grow the economy, Gatineau: Environment and Climate Change Canada (ECCC).

ECCC (2022) 2030 Emissions Reduction Plan - Canada's Next Steps for Clean Air and a Strong Economy, Gatineau: Environment and Climate Change Canada (ECCC).

EIA (2022) Total energy production 2019, Washington: Energy Information Administration (EIA). Accessed April 1, 2022. https://www.eia.gov/international/rankings/world

Gochermann J. (2021) "German Industry has embraced the Energy Transition", IAEE Energy Forum / Fourth Quarter 2021.

Governments of Ontario, New Brunswick, Saskatchewan and Alberta (2022) A strategic plan for the deployment of small modular reactors. Accessed on April 19, 2022. https://www.ontario.ca/page/strategic-plan-deployment-small-modular-reactors

Hall R.D., Bercuson D.J., Morton W.L., Nicholson N.L. and Krueger R.R. (2022) "Canada", Encyclopedia Britannica. Accessed on April 19, 2022. https://www.britannica.com/place/Canada

Hydro-Québec (2021) Comparison of Electricity Prices in Major North American Cities, Rates in effect April 1, 2021, Montreal: Hydro-Québec.

IEA (2020a) Germany 2020 – Energy Policy Review, Paris: International Energy Agency (IEA).

IEA (2020b) Energy Prices and Taxes for OECD Countries (2020 edition), Paris: International Energy Agency (IEA).

IEA (2022a) World Indicators, IEA World Energy Statistics and Balances, Paris: International Energy Agency (IEA).

IEA (2021) Key World Energy Statistics 2021, Paris: International Energy Agency (IEA).

IEA (2022b) World Energy Balances, IEA World Energy Statistics and Balances, Paris: International Energy Agency (IEA).

IEA (2022c) OECD imports, Paris: International Energy Agency (IEA).

IEA (2022d) World – Natural Gas imports by origin, Paris: International Energy Agency (IEA).

IEA (2022e) OECD – Coal imports by origin, Paris: International Energy Agency (IEA).

IEA (2022f) Countries and regions, Paris: International Energy Agency (IEA). Accessed on April 7, 2022. https://www.iea.org/countries

IEA (2022g) Canada 2022 - Energy Policy Review, Paris: International Energy Agency (IEA).

NRCan (2022) Coal facts, Ottawa: Natural Resources Canada (NRCan). Accessed on April 19, 2022. https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/coal-facts/20071

Oei P.-Y., Brauers H. and Herpich P. (2020) Lessons from Germany's hard coal mining phase-out: policies and transition from 1950 to 2018, Climate Policy, vol. 20 (8) 963-979.

Pineau P.-O. (2021) Improving integration and coordination of provincially-managed electricity systems in Canada, Ottawa: Canadian Institute for Climate Choices.

UNFCC (2022) GHG Profiles - Annex I, Bonn: United Nations Framework Convention on Climate Change (UNFCC). Accessed on March 25, 2022. https://di.unfccc.int/ghg_profile_annex1

SMARD (2021) Bundesnetzagentur's electricity market information platform, Bonn: Bundesnetzagentur. Accessed on Aug. 27, 2021. https://www.smard.de/en/downloadcenter/download-market-dat

Statistics Canada (2022) Supply and demand of primary and secondary energy in terajoules, Table: 25-10-0029-01, Ottawa: Statistics Canada.

Stefaniuk J. (2019) Canada's Constitution and Natural Resource Development, Winnipeg: Thompson Dorfman Sweatman LLP.

World Bank (2022) "GDP, PPP (current international $)", World Development Indicators database, Washington: The World Bank Group. https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.CD

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