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CANADA and the ENERGIEWENDE

Understanding hydrogen as an opportunity for Canadian-German partnership

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Executive summary

On August 23, 2022, German Chancellor Olaf Scholz and Canadian Prime Minister Justin Trudeau signed a *Joint Declaration of Intent* to establish a German-Canada Hydrogen Alliance. The Joint Declaration marks a new milestone in efforts to establish hydrogen as a medium-term solution to Germany's energy needs, as the country advances the *Energiewende*, or energy transition. Both countries previously signed an energy partnership in March 2021. While Canada is increasingly unlikely to provide any liquified natural gas (LNG) to the continent, there is time and political support on both sides to develop hydrogen exports.

This paper outlines the ways in which German-Canadian partnership on hydrogen represents an opportunity for both countries and the ways in which this partnership will face logistical, economic and regulatory challenges. Canada has the potential to become a key exporter of CO2-reduced energy sources, including hydrogen, for Germany and Europe. Yet green hydrogen needs substantial government support to get off the ground. The German-Canada Hydrogen Alliance represents an important step in that regard.

Germany will need large quantities of green molecules in the course of its transformation to a climate-neutral economy. Imports will have to cover the major part of the expected demand by 2030. This is why Germany has a vital interest in establishing new energy partnerships and deepening existing ones. The current gas crisis in Germany also requires an acceleration of the hydrogen ramp-up in conjunction with the need to substitute Russian natural gas supplies in the short-term.

Against this background, Canada – as an exporter of fossil fuels with simultaneously high potential for renewable energies – is an extremely attractive partner. Canada has what few other countries have: an ability to produce more energy than it could ever consume, thanks to its small population and enormous land and resource base.

Yet there are challenges. These range from the cost of green hydrogen production; the lack of market demand and existing use cases; the investment attractiveness for hydrogen when compared to other energy products with

more immediate returns; internal EU policies that restrict some more obvious sources of green hydrogen production in Canada; and regulatory frameworks in both countries that are likely to complicate or delay the production, transportation and end use of hydrogen.

Both Canada and Germany share common values such as a clear commitment to universal human rights, democratic principles, a rule-based world order, free trade, resolute climate protection and effective multilateralism. Hence, Canada has the potential to become a key exporter of CO2-reduced energy sources, including hydrogen, for Germany and Europe. Unlike LNG, hydrogen has support across political and geographic lines, for now, and as such the social license to move more quickly.

As a next step, it is important to prioritize the concrete implementation of the German-Canadian hydrogen partnership, which needs to be embedded in a conducive hydrogen import strategy that includes instruments to activate the market ramp-up for imports of hydrogen and its derivatives to Germany and Europe in the short- and medium-term.

Sommaire

Le 23 août 2022, le chancelier allemand Olaf Scholz et le premier ministre canadien Justin Trudeau ont signé une *déclaration d'intention conjointe* pour la création d'une alliance germano-canadienne dans le domaine de l'hydrogène. Cette déclaration d'intention marque une nouvelle étape dans les efforts visant à faire de l'hydrogène une solution pour répondre aux besoins énergétiques de l'Allemagne à moyen terme, alors que ce pays fait avancer l'*Energiewende*, ou « transition énergétique ». Les deux pays avaient déjà signé un partenariat énergétique en mars 2021. Bien qu'il soit de plus en plus improbable que le Canada fournisse du gaz naturel liquéfié (GNL) au continent, les deux parties disposent de suffisamment de temps et de soutien politique pour développer les exportations d'hydrogène.

Ce document décrit les possibilités que représente le partenariat germano-canadien sur l'hydrogène pour les deux pays et les façons dont ce partenariat fera face aux défis logistiques, économiques et réglementaires. Le Canada a le potentiel de devenir un exportateur clé de sources d'énergie à faible émission de CO2, notamment d'hydrogène, vers l'Allemagne et l'Europe. Néanmoins, l'hydrogène vert a besoin d'un soutien gouvernemental substantiel pour être produit. L'Alliance germano-canadienne de l'hydrogène représente une étape importante à cet égard.

L'Allemagne aura besoin de grandes quantités de molécules vertes dans le cadre de sa transformation vers une économie neutre en carbone. Les importations devront combler la majeure partie de la demande attendue d'ici 2030. C'est

pourquoi l'Allemagne a un intérêt vital à établir de nouveaux partenariats énergétiques et à approfondir ceux qui existent déjà. La crise actuelle du gaz en Allemagne nécessite également d'accélérer le déploiement de l'hydrogène, en parallèle avec le remplacement à court terme des approvisionnements russes en gaz naturel.

Dans ce contexte, le Canada – en tant qu'exportateur de combustibles fossiles à fort potentiel en matière d'énergies renouvelables – est un partenaire extrêmement attrayant. Le Canada a ce que peu d'autres pays possèdent : la capacité de produire plus d'énergie qu'il ne peut consommer, grâce à sa petite population, son immense territoire et ses ressources.

Toutefois, il y a des défis à relever. Il s'agit du coût de production de l'hydrogène vert; de l'absence de la demande du marché et des cas d'utilisation existants; de l'attractivité des investissements pour l'hydrogène par rapport à d'autres produits énergétiques aux rendements plus immédiats; des politiques internes de l'UE qui restreignent certaines sources évidentes de production d'hydrogène vert au Canada; et des cadres réglementaires des deux pays susceptibles de compliquer ou de retarder la production, le transport et l'utilisation finale d'hydrogène.

Le Canada et l'Allemagne partagent des valeurs communes telles qu'un engagement clair envers les droits universels de la personne, les principes démocratiques, un ordre mondial fondé sur des règles, le libre-échange, une protection résolue du climat et un multilatéralisme efficace. Par conséquent, le Canada a le potentiel de devenir un exportateur clé de sources d'énergie à faible émission de CO_2, notamment d'hydrogène, vers l'Allemagne et l'Europe. Contrairement au GNL, l'hydrogène bénéficie d'un soutien qui dépasse, pour le moment, les cloisonnements politiques et géographiques et, au même titre, l'acceptabilité sociale autorisant à agir rapidement.

Comme prochaine étape, il sera important d'accorder la priorité à la mise en œuvre concrète du partenariat germano-canadien sur l'hydrogène. Le partenariat devra être intégré, à court et à moyen terme, à une stratégie d'importation d'hydrogène efficace axée sur des instruments d'activation des marchés de l'hydrogène et de ses dérivés pour l'Allemagne et l'Europe.

Introduction

On August 23, 2022, German Chancellor Olaf Scholz and Canadian Prime Minister Justin Trudeau signed a *Joint Declaration of Intent* to establish a German-Canada Hydrogen Alliance. The goal is to create a transatlantic supply chain for hydrogen, with the hope of the first deliveries arriving in Germany in 2025. A wind farm and green hydrogen plant were also announced on that day, though it has yet to approved, and it is not clear at what price it can deliver hydrogen to German markets. But optimism reigns.

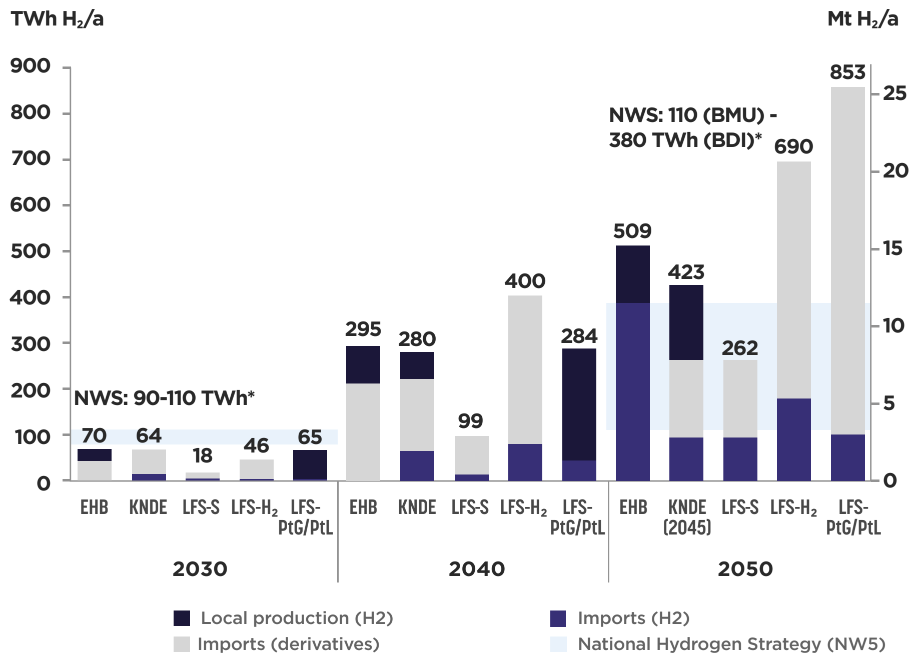
The Joint Declaration marks a new milestone in efforts to establish hydrogen as a medium-term solution to Germany's energy needs, as the country reduces its dependence on Russian gas and advances the *Energiewende*, or energy transition. The declaration is built on an energy partnership entered into by the two countries in March 2021, which positioned "Canada as a clean energy partner of choice for Germany, notably for hydrogen, critical minerals and liquefied natural gas" (BMWi 2021). While Canada is increasingly unlikely to provide any liquified natural gas (LNG) to the continent, there is time and political support on both sides to develop hydrogen exports.

This paper outlines the ways in which German-Canadian partnership on hydrogen is an opportunity, and the ways in which it will face logistical, economic and regulatory challenges. Green hydrogen needs substantial government support to get off the ground; with the German-Canada Hydrogen Alliance at least, it has found it.

Context-setting

The rapid decarbonization of global economies is crucial for the timely and effective mitigation of climate change. Many processes can be de-fossilized and de-carbonized by direct electrification. In other cases, the use of hydrogen and its derivatives is advantageous from an economic perspective. In several areas, a sustainable transition is particularly efficient with climate-friendly hydrogen or its derivatives, such as ammonia, methane or methanol. For cases requiring the chemical element hydrogen (H2), such as in the chemical

FIGURE 1: HYDROGEN DEMAND IN GERMANY UNTIL 2050



Projections: NWS: National Hydrogen Strategy; **EHB:** European Hydrogen Backbone; **KNDE:** Climate-Neutral Germany 2045; **LFS:** Langfristszenarien (-S: electricity scenario; -H2: hydrogen scenario; -PtG/PtL: power-to-liquid/power-to-gas scenario).

* includes both hydrogen and PtG/PtL demand.

Source: Klessmann et al. *2022*

and petrochemical industries, the use of hydrogen is without alternatives. In other areas, the use of hydrogen is in competition with other technologies.

In Germany, the demand for hydrogen and its derivatives is expected to increase to about 90-110 terawatt hours (TWh) or 2700-3300 metric tonne (Mt) by 2030 (BMWi 2020). In a net-zero system in 2045, demand could even grow to about 700 TWh or 21,000 Mt (Dena 2021). Assuming production by electrolysis, this suggests an electricity demand of 1000 to 1500 TWh just for the production of hydrogen and downstream products. By comparison, in 2021, net electricity generation from renewables in Germany was 219.9 TWh, or 42.4 percent of total electricity generation (Federal Statistical Office of Germany 2022).

It is not realistic that domestic hydrogen production alone will be sufficient to meet this demand. Due to limited land potential for the expansion of wind and photovoltaic (PV) capacity, the majority of additional renewable energies will be used to meet the demand and directly substitute fossil power plants in the electricity sector. The coalition agreement of the current German government stipulates that at least 10 gigawatt (GW) of electrolysis capacity will be installed in Germany by 2030 (SPD, Bündnis 90/Die Grünen and FDP 2021). But even if this is achieved, extensive imports will be necessary to cover the entire hydrogen demand. This is also demonstrated by the relevant studies on the topic, even if they come to different results regarding the extent of H2 imports: around 12-70 TWh per annum or 360-2100 Mt per annum in 2030, which can increase to 170-750 TWh per annum or 5100-22,500 Mt per annum by 2050 (Figure 1).

Germany will therefore remain a net energy importer in the medium- and long-term. Moreover, due to expected lower production costs abroad, the import of hydrogen and its derivatives seems not only reasonable but also necessary from an economic perspective. Some regions of the world are ideal for the production of cost-efficient hydrogen and its derivatives, due to their excellent conditions for renewable energy and low population density. Partnerships need to be developed to leverage this potential, and Canada has been identified as a partner of first choice.

Canadian hydrogen potential

Canada has what few other countries have: an ability to produce more energy than it could ever consume, thanks to its small population and enormous land and resource base. This is true for both "blue hydrogen" produced from natural gas with carbon capture and storage, due to its enormous reserves of natural gas, and "green hydrogen" produced using clean electricity from renewables, arising from its low carbon and export-oriented electricity grid, supported by high quality hydropower. Table 1 provides further information on blue and green hydrogen, alongside other types of hydrogen. Canada also has strong potential in biomass and wind power, as well as excellent freshwater resources, a feedstock of green hydrogen.

For many countries, the pressure to electrify their energy sources will compete with their ability to produce hydrogen through electrolysis. Canada is attractive in this manner as it has significant untapped resources. It is the world's third-largest net exporter of electricity, fourth-largest exporter of oil, and sixth-largest exporter of natural gas. In addition, Canada is the second-largest producer of hydroelectricity in the world, an especially compatible sector for green hydrogen production.

And yet there are challenges. Aside from the market challenges that apply to all would-be hydrogen producers and consumers at this point, the following are unique challenges to Canadian hydrogen production.

The first is competition for capital. The high prices for fossil fuels today offer competing incentives for the larger energy and resource companies who may otherwise be able to assume the risk of long-term hydrogen development.

TABLE 1: THE HYDROGEN COLOUR SPECTRUM

Green	Made by using clean electricity from renewable energy sources, such as solar or wind power, to electrolyse water
Blue	Produced primarily from natural gas using steam methane reforming, with the carbon dioxide by-product sequestered through carbon capture, utilization, and storage (CCUS)
Grey	Extracted from natural gas using steam methane reforming (SMR), with no sequestration of resultant carbon dioxide emissions
Pink/Red	Produced by electrolysis using nuclear power
Turquoise	Produced by thermal splitting of methane (methane pyrolysis) to produce solid carbon instead of carbon dioxide
Brown	Extracted from fossil fuels, usually coal, using gasification

Any investment that makes its way into capital expenditures rather than share buy backs and dividends – the preferred choice by energy investors after a lost decade for returns – may more easily find its way into oil and natural gas rather than hydrogen, where there are more immediate market signals to bolster production.

In addition, despite its enormous natural resources, Canada faces significant political and regulatory challenges to development. Public support for building pipelines or developing its oil and natural gas reserves has been low in the past decade, resulting in economic projects being cancelled by the federal government, stymied by provincial ones, or simply not pursued by the private sector in anticipation of regulatory uncertainty, legal challenges, and long timelines.

But renewable projects, including new hydroelectric dams, wind farms, and transmission lines, have faced environment opposition. The same is true for nuclear power plants and waste. The patchwork of jurisdiction over the environment, including federal, provincial, territorial and Indigenous authorities, means any number of actors can object to or delay a project, and there are many legal grounds on which to do so.

Such objections could pose setbacks to the development and export of hydrogen, especially if it is transported by pipeline to export terminals. Regardless of what is *in* the pipeline, there will be environmental impacts from constructing it, accompanied by significant efforts and costs to mitigating those impacts under Canadian regulations. The timeline and cost overruns of the most recent major pipelines, the Trans Mountain Expansion (crude oil) and Coastal GasLink (natural gas), will deter future investment into any pipelines.

With regards to shipping, transporting green hydrogen as green ammonia may also spark concerns about marine disturbance and pollution. Canada has recently applied a tanker ban to crude oil exports along British Columbia's northwest coast for this reason, although LNG and propane exports, for example, were not included. However, an LNG export facility in Quebec was rejected by the federal government in February 2022, in part due to the anticipated impact on marine mammals.

> *Canada faces significant political and regulatory challenges to development.*

Another challenge is export capacity. Canada has a very limited offshore export capacity, resulting in nearly all of its energy exports, not only from electricity but oil and gas as well, going to the United States. Canada's lack of regulatory clarity and construction capability, as demonstrated in its challenges in building LNG expert terminals over the past decade, will similarly affect offshore hydrogen exports. While 18 LNG export facilities have been proposed in Canada since 2011, only two (LNG Canada and Woodfibre LNG) are under construction, and none are finished.

That said, there will likely be less public opposition to hydrogen than to fossil fuels, and hydrogen – including blue hydrogen with CCUS (carbon capture, utilization, and storage) – is currently supported not only by both federal Conservative and Liberal political parties, but by all provinces with export potential. That suggests that approvals may come quicker and with less political interference than with oil or natural gas. The feedstock for any Canadian hydrogen projects (be it natural gas or freshwater) and the energy sources for electrolysis (be they wind or hydropower) will still likely face regulatory burdens under current processes.

A flurry of strategies

Despite this, there is optimism across political and geographic lines in Canada that they can be part of the nascent global hydrogen market. This is supported by the plethora of strategies that have been developed in the past three years from the federal government and provinces alike, including in British Columbia, Alberta, Ontario, and Quebec, and with endorsed feasibility studies emerging out of Atlantic Canada and Newfoundland and Labrador.

Released in December 2020, and led by Natural Resources Canada, the federal *Hydrogen Strategy for Canada* outlines plans to become one of the top three producers of clean hydrogen in the world, drawing on its rich feedstock reserves, skilled energy labour force, and energy infrastructure (Natural Resources Canada 2020). It identifies the following as Canada's competitive edge:

1. Hydroelectricity potential, especially on the East Coast;
2. Abundant fossil fuel reserves with world class carbon dioxide (CO2) storage geology;
3. Potential for growth in variable renewables;
4. Freshwater resources; and
5. Strong energy economy that can be leveraged into hydrogen.

The strategy is focused on export potential, although it seems more bullish on blue hydrogen than green. It highlights Canada's port infrastructure along both coasts; an integrated, country-wide natural gas and pipeline network connected with large US markets, especially California and the East Coast, as well as deep technical experience in the energy sector. It identifies the five export markets with greatest potential as the US (particularly California and the Eastern US), Japan, South Korea, China, and the European Union.

British Columbia and Alberta's strategies are focused on export of blue hydrogen (Alberta, Ministry of Energy 2021; Government of British Columbia 2021), while Ontario and Quebec are more focused on hydrogen as a domestic energy source to reduce their own greenhouse gas (GHG) emissions (Government of Ontario 2022; Government of Quebec 2022). Meanwhile, the Offshore Energy Research Association released studies that explored the feasibility of various export types and locations in the Maritimes and the Atlantic (OERA 2020; 2021). Of note, only these studies focused on German and European exports. Although the Ontario strategy explicitly mentions the 2021 Canada-Germany Energy Partnership, it does not anticipate exports there from Ontario in the medium-term.

Potential competitors to Canada for the European hydrogen market include Saudi Arabia, Brazil, and the US. However, the market is still in very early stages and the upheaval in global electricity and natural gas markets make predictions and assessments of competitiveness difficult.

Divergence in in the Canadian emissions-based approach and the German colour-coding approach

In line with the political agenda of complete climate neutrality, the long-term goal of Germany's sustainable hydrogen economy is the use of green hydrogen. However, the demand for hydrogen, which already exists to a significant extent today and will increase in the future, can be met only to a limited extent by green hydrogen in the short- and medium-term due to a lack of production capacities for electrolysis plants and high hydrogen production costs. It also needs to be further specified at what point green hydrogen will be available to other applications and consumers in terms of competitive production costs and large-scale volumes, among other factors. Blue hydrogen production can potentially open up the opportunity to achieve more rapid scaling up of a global carbon-neutral (or emissions-reduced) hydrogen value chain.

However, blue hydrogen is controversial in Europe and Germany. So far, there is no clear legal framework for the credible use of blue hydrogen in Europe. Furthermore, the German government largely excludes the use of blue hydrogen. Also, instruments intended to flank the import of hydrogen and its derivatives, such as the German funding instrument H2Global, have so far been designed exclusively for green products. However, the expectation that blue hydrogen can serve as a transitional solution cannot become reality if this technology path is not actively developed and planning security is not created for companies. Private-sector investments in blue hydrogen risk becoming stranded assets in many regions, since green hydrogen will become more price-competitive in the long-term and blue hydrogen is not completely climate-neutral along its production chain (owing to the so-called "methane slip" and insufficient CO2 capture). Hence the role of blue hydrogen and its temporary use should be explicitly addressed and specified in a comprehensive and coherent hydrogen import strategy (Klessmann et al. 2022).

In Canada, on the other hand, there is a much more pragmatic and CO2 emissions-based approach, which focuses on "clean" hydrogen – anything of low carbon intensity. There is no universally accepted definition of low carbon intensity, and such a standard will need to be developed by governments, industry and consumers. However, the Canadian government, in its Hydrogen Strategy, recommends the threshold be set at 60 percent below the intensity of hydrogen produced from natural gas, currently set at 36.4 grams of carbon dioxide equivalent per megajoule of energy (gCO2e/MJ) (Natural Resources Canada 2020).

Federal incentives that encompass clean hydrogen development include the $1.5 billion Clean Fuels Fund, announced in 2021, which de-risks capital investment required to build new or expand existing clean fuel production facilities, including facility conversions; a refundable investment tax credit, announced in 2022, relating to the purchase of equipment for CCUS, including to enable the production of clean hydrogen from natural gas; and a Clean Technology investment tax credit of up to 30 percent, focused on net-zero technologies, battery storage solutions and clean hydrogen, which is expected to be announced in the fall of 2022.

Definition of green hydrogen in the EU (RED II)

The delegated acts (*Delegated Acts* under Art. 27(3) and Art. 28(5) of the EU Renewable Energy Directive II (RED II)) regulate the requirements for the use of renewable energies for hydrogen production.

The reduction of greenhouse gases in relation to conventional hydrogen production (94 gCO2eq/MJ) must be at least 70 percent to qualify as "green." Three different scenarios for the power purchase are defined, which allow the produced hydrogen to be classified as green according to RED II:

Case 1: Grid Mix
The electrolysis plants use electricity from the grid for the production of green hydrogen. The share of renewable energy in the previous year must be at least 90 percent in the respective bidding zone.

Case 2: Direct Connection
The electrolysis plant obtains the required electricity directly from a renewable source. The public power grid must not be used for this purpose. The plant must not be an existing plant, but a new installation that came into operation not earlier than 36 months before producing renewable fuel (the so-called "additionality criterion").

Case 3: PPA
The operator of the electrolysis plant purchases the green electricity through Power Purchase Agreements (PPA). The purchase of electricity from biomass is excluded. Even if electricity is purchased through a PPA, the renewable energy plants must be *additionally* constructed. There is also the need for temporal and geographic correlation. The temporal correlation element means the electrolysis plant can only produce green hydrogen during the same one-hour period as the renewable electricity produced under the renewable PPA (i.e., *simultaneously*). However, when the sun is not shining or the wind is not blowing, it is possible to use previously stored energy to produce hydrogen. The geographic correlation element, on the other hand, specifies that the PPA can only be entered into with a producer within the same bidding zone.

Transition periods apply to the additionality and simultaneity criteria described above. The additionality criterion does not apply to plants commissioned before January 1, 2027. For the criterion of temporal correlation, a transition period until December 31, 2026 applies.

All criteria must also be met for imported hydrogen. Despite the high share of renewable energies of almost 70 percent in Canada overall and in specific regions, this means that hydrogen production by electrolysis plants that purchase electricity directly from the grid is not possible. For the production of green hydrogen according to case two or three, new renewable capacity will have to be built if the plant comes online after the transition period. In particular, the criteria for temporal correlation and additionality could pose a challenge for hydrogen production under RED II in Canada. This means, for example, that the huge potential of already existing and depreciated hydropower plants would remain largely untapped.

Infrastructural challenges for different derivatives

Canada has built up extensive infrastructure for the export of fossil resources in recent years. Parts of this infrastructure can potentially also be used for the export of CO2-reduced energy sources. So far, however, it has not been conclusively clarified in which forms hydrogen will be traded worldwide. However, the development of global hydrogen supply chains will probably be driven by derivatives in large part. Hydrogen can also be transported in its elemental form, but these methods are not (yet) suitable for transport from Canada to Germany. Gaseous hydrogen can only be transported economically over long distances via pipelines. For liquid hydrogen (also called cryogenic hydrogen), on the other hand, there are no tankers on an industrial scale.

It is likely that various derivatives will be used for trading. Carbon-based derivatives such as methanol, naphtha or jet fuel have the great advantage that they can be fed directly into existing infrastructures and applications. However, the production of these derivatives requires the use of carbon. This would either have to be provided by biomass or extracted from the atmosphere by direct air capture. Due to the low technology readiness level of direct air capture and the comparatively large potential of biomass in Canada, the latter could be an attractive option for energy trade between Canada and Germany.

In addition to carbon-based energy carriers, ammonia is being discussed as one of the first, if not the first, hydrogen energy carrier. For a sustainable ammonia route, many components of the conventional supply chain can be used (e.g., air separation, Haber-Bosch process, transport infrastructure). Nitrogen is used as a co-reactant, which is also much easier to obtain due to its much higher concentration in the atmosphere. Air separation is already in use at industrial scale. The only innovation in the production of blue or green ammonia is CO2-reduced hydrogen production.

However, the use of ammonia is limited in Germany. It is mainly used in the fertilizer industry, but could also be used in the future, for example, to provide high-temperature process heat. To leverage the full potential of ammonia as a transport vector, the process of cracking the ammonia back into its constituents, hydrogen and nitrogen, will require greater focus. Such crackers do not yet exist on an industrial scale and have a very low technology readiness level. The German company Uniper is currently planning the construction of an ammonia terminal in Wilhelmshaven, which is scheduled to be completed by 2025. An ammonia cracker is also planned for this terminal, which will be able to release the bonded hydrogen.

Hydrogen production in Canada

Canada has a near-term opportunity to expand its hydrogen exports from grey hydrogen (which does not use CCUS) and blue hydrogen (which does use CCUS). This is due to its existing infrastructure, use, and cost competitiveness. Canada is one of the top 10 hydrogen producers in the world today, producing about 3 million tonnes per year from natural gas (National Resource Canada 2020), and even exporting $13.7 million in 2020 to Germany.

Hydrogen in Canada is currently produced as a by-product of industrial processes and is used as a feedstock for petroleum refining, bitumen upgrading, ammonia production, methanol production, and steel production. Steam-methane reforming (SMR) is the most widely used technology for hydrogen production in Canada and is expected to remain one of the primary pathways, with the addition of CCUS, to achieve lower carbon intensities.

Canada's largest oil and gas producing province, Alberta, has one of the overall lowest costs of production in the world for both SMR and CCUS and hydroelectric electrolysis (Natural Resources Canada 2020). As such, the blue hydrogen pathway is the likeliest and most competitive path forward for Canadian hydrogen exports in the short- and medium-term.

Two large projects are currently under development in and around Edmonton, Alberta. One is a $1.3 billion blue hydrogen plant being planned by Air Products, which should be in operation by 2024. The plant would capture 3 million tonnes of CO2 yearly and produce 1500 tonnes of hydrogen a day. The second is the Edmonton Region Hydrogen Hub, Canada's first, with plans underway there for more than 25 projects related to the production, transportation and end use of hydrogen, and carbon capture and storage.

To determine Alberta's global hydrogen competitiveness, Okunlola et al. (2022) assessed the delivered cost of gaseous hydrogen export from Western Canada to the Asia-Pacific, Europe, and inland destinations in North America. It found that the delivered cost of hydrogen to inland destinations in North America is between $4.81/kg and $6.03/kg, to the Asia-Pacific from $6.65/kg to $6.99/kg, and at least $8.14/kg for exports to Europe.

The shipping route to Europe was calculated through the Panama Canal and the Atlantic Ocean and delivered from Burnaby, British Columbia (near

Vancouver). Compared with delivery to Asia, the shipping and import terminal gasification specific costs increased from 11 percent to about 20 percent of the total supply chain costs, due to farther travel/shipping distance.

As such, while the cost of hydrogen delivered from Alberta was found to be cost-competitive with primary domestic hydrogen production pathways in Japan and South Korea from wind- or solar-based electrolysis, in China and Europe, the domestic supply of hydrogen through SMR with carbon capture and sequestration, coal gasification with carbon capture and sequestration, and electrolysis were found to be cheaper than the total supply chain cost of delivering gaseous hydrogen from Alberta.

Based on this analysis, there is a limited business case to deliver low-carbon hydrogen from Alberta to Europe. However, with record high electricity costs and growing demand for low-carbon hydrogen, there may still be room for blue hydrogen exports from Western Canada to Germany.

> *There may still be room for blue hydrogen exports from Western Canada to Germany.*

It is important to note that green hydrogen is, so far, Germany's political preference, and was the focus of Chancellor Scholz's visit. Atlantic Canada has undeveloped wind potential, and Quebec and soon Labrador – when the Muskrat Falls project becomes fully operational – have excellent hydropower assets that can produce electricity surplus to domestic needs. These are the most likely source of Eastern Canadian green hydrogen exports.

Quebec has one existing Proton Exchange Membrane (PEM) electrolyser, an Air Liquide facility in Bécancourt, which has been in operation since 1987. It is powered by local hydroelectricity and produces up to 8.2 tonnes of green hydrogen per day — close to 3000 tonnes annually – since undergoing expansion in 2019 to 20 megawatt (MW). Air Liquide has had a hydrogen production facility in Bécancour, Quebec since 1987.

Harnois Énergies and Hydrogenics installed Quebec's first hydrogen station to fuel government vehicles in Quebec City, with support from Natural Resource Canada and Toyota.

An 88-MW electrolysis plant is currently being built in Varennes, Quebec. It was announced in December 2020 by Hydro-Québec, the province's central producer and sole distributor of power, in a partnership with Enerkem, Shell, Suncor and Proman. It will produce hydrogen as a gasification agent for a partner facility producing biofuels. When completed in late 2023, it will be one of the world's most powerful electrolysers for green hydrogen production (Hydro-Québec 2020). However, it will not be producing green hydrogen for export.

Two projects in Atlantic Canada were announced during Chancellor Scholz's visit in August 2022. The first is a multi-phase green hydrogen and ammonia production and export facility in Point Tupper, Nova Scotia that could potentially produce 500,000 tonnes per annum of green ammonia using a mix of certified green power from the Nova Scotia grid and onshore wind power. Point Tupper is expected to reach commercial operation in early 2025, becoming the first in Atlantic Canada. The second proposed project is to build 164 wind turbines in Port au Port peninsula, near Stephenville in Newfoundland. It would use hydrogen produced by the wind power and convert it into green ammonia.

Although the announced timelines for both projects are ambitious, they have not yet secured regulatory approvals.

Next steps for developing the German-Canadian partnership

Germany and Canada agreed on an energy partnership in 2021 (Canadian-German Memorandum of Understanding 2021) and expanded on this with a *Joint Declaration of Intent to Establish a German-Canada Hydrogen Alliance* in 2022 (Natural Resources Canada 2022). These developments have received considerable political attention. As a next step, it is important to prioritize the concrete implementation of the German-Canadian hydrogen partnership.

H2Global as an important instrument

H2Global is a funding instrument financed by the German Federal Ministry of Economic Affairs and Climate Action (BMWK) to support the ramp-up of a global hydrogen trade. The objective of H2Global is to match hydrogen producers in partner countries with hydrogen consumers in Germany and Europe. Since production and transport costs will exceed the willingness of German and European to pay for the foreseeable future, the difference between supply prices and demand prices will be required to be made up. The difference will be taken over by Hint.co GmbH, which is financed by the German state. To minimize the total subsidy amount, a double auction mechanism will be introduced. The bids with the lowest supply price and the highest demand price will be awarded the purchase and sales contract. Within this framework, Hint.co will conclude long-term purchase contracts on the supply side and short-term sales contracts on the demand side to maximize both investment security for producers and flexibility for consumers.

A total of €900 million has been earmarked for the funding instrument over a 10-year period. The first auctions of the global tender under the H2Global dual auction mechanism will take place in 2022, with the first imports of the hydrogen derivatives expected in 2024/2025 (BMWK 2021).

The products considered in this first round are ammonia, methanol, and jet fuel. The product requirements are the same as RED II and include only green products. A simplified, rapid implementation and (financial) expansion of the already planned funding instrument is key to seize the potential of double-sided purchasing auctions to close the cost gap and accelerate the ramp-up of trade.

Import guarantees as a supplementary instrument

Additionally, for H2Global, import guarantees for hydrogen producers can create a “level playing field” for German companies. These companies will be dependent on hydrogen imports in the future, but will have difficulties in competing with (state-owned) companies abroad due to factors such as high investment costs for the transformation of their sites and weaker financial ratings. Furthermore, import guarantees can create additional investment security for production and transport infrastructure to accelerate market activation.

The H2Global instrument can be used to secure default guarantees on the part of the buyer vis-à-vis the producer, giving the producer planning security for the purchase quantity. In addition, the buyer could be covered if, for example, a planned pipeline does not become available in time, since the buyer will likely bear high investment costs for the transformation of its processes. The supplier, on the other side, would have to bear the supply volume risk. Guarantees for self-inflicted shortages should not be covered, since this falls under the entrepreneurial risk. The price risk should also not be hedged with this instrument. If necessary, existing funding instruments (e.g., Carbon Contracts for Difference (CCfDs), H2Global) should be used to this end.

Hedging risks in take-or-pay contracts for hydrogen that are outside the control of the hydrogen producer – such as completion of the import infrastructure, transport and hydrogen off-take issues due to insolvency, delay or shutdowns – can increase the attractiveness of hydrogen imports and should therefore become an instrument in the toolbox of a German and European hydrogen import strategy.

The Canadian federal government, for its part, will promote hydrogen production through its $1.5 billion Clean Fuels Fund, and $8 billion Strategic Innovation fund Net-zero accelerator, and the Canada Infrastructure Bank.

The countries have agreed to conduct an annual review of activities under the Alliance.

Conclusion

The August 2022 visit by German Chancellor Olaf Scholz to Canada focused on the potential for hydrogen trade between the two countries. Regardless of whether LNG should have been the focus of that visit, hydrogen is a viable medium-term energy opportunity that merits attention and scrutiny.

Germany will need large quantities of green molecules in the course of its transformation to a climate-neutral economy. The 10 GW of domestic electrolysis capacity envisaged by the German government by 2030 will not be able to meet the predicted hydrogen demand of 90-110 TWh or 2700-3300 Mt. Imports will, therefore, have to cover the major part of the expected demand by 2030. This is why Germany has a vital interest in establishing new energy partnerships and deepening existing ones. These partnerships need to be embedded in a conducive hydrogen import strategy including instruments to activate the market ramp-up for imports of hydrogen and its derivatives to Germany and Europe in the short-term.

The current gas crisis in Germany requires an acceleration of the hydrogen ramp-up in conjunction with the need to substitute Russian natural gas supplies in the short-term. Against this background, Canada – as an exporter of fossil fuels with simultaneously high potential for renewable energies – is an extremely attractive partner. The two countries share common values such as a clear commitment to universal human rights, democratic principles, a rule-based world order, free trade, resolute climate protection and effective multilateralism. Hence, Canada has the potential to become a key exporter of CO2-reduced energy sources, including hydrogen, for Germany and Europe.

About the authors

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In 2020 Professor Grimm has been appointed to Germany's most important advisory committee for matters of economic policy, the council of five economic experts known as 'die fünf Wirtschaftsweisen.

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