



Capital
Markets

RBC Europe Limited
Biraj Borkhataria, CFA
(Analyst)
+442070297556
biraj.borkhataria@rbccm.com
Erwan Kerouredan (Analyst)
+44 20 7029 0855
erwan.kerouredan@rbccm.com

John Musk (Analyst)
+44 20 7029 0856
john.musk@rbccm.com
Mitchell Wotton (Senior Associate)
+44 7523 929 607
mitchell.wotton@rbccm.com

October 19, 2020

Navigating the Energy Transition

#2: Hydrogen or Hype-rogen?

Our view: Last week we hosted the second session in RBC's Navigating the Energy Transition series, focusing on the Hydrogen economy. Growing supply of hydrogen could have implications for many sectors over time. In this note, we outline the key takeaways from the session, while also providing more context and background on the topic. Please contact your RBC Capital Markets representative for replay details.

The importance of Hydrogen: Both blue and green hydrogen look set to play a key role in a cleaner economy globally over time, but today hydrogen remains a minimal part of the economy. As part of the European Green Deal, the European Commission has published targets for hydrogen including 40GW of electrolyser capacity in the EU by 2030, and many countries have followed suit, including Germany, Japan and South Korea. Hydrogen is likely to be a solution to de-carbonize longer-distance travel, while it is also a solution for processes where electrification is not viable. Its function as a store of energy, as well as its characteristics as an energy dense fuel leave it well placed for a number of applications.

Deflating costs of renewable power and rising carbon prices likely to make hydrogen more competitive: Blue hydrogen today costs ~\$2-2.5/kg, versus green hydrogen in the \$2.5-6/kg range. In a \$50/t carbon price scenario, our midstream team expects these to fall to \$1.5/kg and \$2.6/kg, respectively by 2030. We think an even higher carbon price would swing economics towards Green over Blue. That said, for green hydrogen, around 75% of the total cost of production comes from power generation, and with both solar and wind costs deflating, costs could fall further over time. While some companies (e.g. Shell) have pushed the merits of hydrogen for some time, growing investor & societal pressure to de-carbonize all sectors has put the emphasis on many corporates, from energy producers to consumers, to collaborate in order to accelerate development over the next decade.

Who benefits from a growing hydrogen economy? We expect hydrogen to play a meaningful role in fuel supply to multiple sectors, including heavy duty trucking, marine, steel, cement, chemicals and potentially even aviation over time. If carbon capture costs deflate as we expect, blue hydrogen will likely be an area of growth over 2020-30, while Green hydrogen could become more meaningful thereafter. As blue hydrogen grows, this could create [a new lease on life for gas infrastructure globally](#), as hydrogen can be blended with natural gas for transport purposes. The world would also demand more electrolyser capacity, and this segment is likely to need to grow by an order of magnitude relative to today. Finally, as the green hydrogen segment grows, we expect water management, treatment and availability to become critical factors in sustainability over time.



ESG Stratify™
Separating the signal from the noise



Table of contents

Navigating the Energy Transition: #2 Exploring the Hydrogen economy.....	3
What is Hydrogen?	3
How is it produced?	3
Not a new concept	3
Why hasn't Hydrogen taken off already? Is this time different?	4
Where does it go?	4
Zooming in on ZeroAvia, and hydrogen for aviation	5
Private support – Industry, Utilities, Transport and Energy	5
Policy support across key markets	6
Key challenges for the Hydrogen sector	7
Economics relative to incumbent fuels	7
The availability of renewable power	7
The supply chain.....	8
Other factors	9

Navigating the Energy Transition: #2 Exploring the Hydrogen economy

Last week we hosted the second session for RBC's Navigating the Energy Transition Series. We focussed on the potential of Hydrogen. Clearly this is a complicated topic and one that cannot be given true justice in a one hour call. Later on in the series we will look to focus on hydrogen's applications in key end markets. This note runs through the takeaways from the conversation while we also include more details and background on the role and potential of Hydrogen as a fuel and storage source. We do so in order to help broaden knowledge on what has become a household name as policy makers set ambitious targets to reduce carbon emissions.

The panel included:

- **Grete Tveit**, SVP & Head, Low Carbon Solutions for Equinor
- **Thorsten Herbert**, Director Market Development & Public Affairs for NEL Hydrogen
- **Andy Brown**, Senior advisor to McKinsey, ex-Shell Head of Upstream, Advisor to ZeroAvia, a hydrogen based aviation company

What is Hydrogen?

"Hydrogen is a versatile, clean, and safe energy carrier that can be used as fuel for power or in industry as feedstock. It can be produced from (renewable) electricity and from carbon-abated fossil fuels. It produces zero emissions at point of use. It can be stored and transported at high energy density in liquid or gaseous form. It can be combusted or used in fuel cells to generate heat and electricity" Hydrogen Council.

As such, hydrogen has many commercial uses, including energy production and storage, creating a substitute to viable industrial energy applications and hydrogen has become the 'next new thing' on a journey through the energy transition. However, the technology is not new, but it has been a niche area of the energy sector for some time.

How is it produced?

Hydrogen is everywhere, although bonded when found in nature and must undergo industrial processes to be captured in a pure form. Hydrogen is most commonly found in a compound form such as water (H₂O), natural gas methane (CH₄), among other fossil fuels and biomass and therefore must be separated for isolated use. There are different denominations for the type of industrial hydrogen based on the method by which it is produced as seen below:

- **Green Hydrogen** is formed through electrolysis where an electrical current splits water into hydrogen and oxygen. When electricity is obtained through renewable sources, no carbon is emitted.
- **Grey Hydrogen**, often called steam reforming, is the process of splitting fossil fuel hydrocarbons (mainly natural gas) with high temperature pressurized steam. Carbon waste remains an unfortunate outcome of grey hydrogen.
- **Blue Hydrogen** is the process of producing grey hydrogen, and capturing the carbon emissions, often called carbon capture storage (CCS). This was the topic for our first energy transition segment found [here](#).

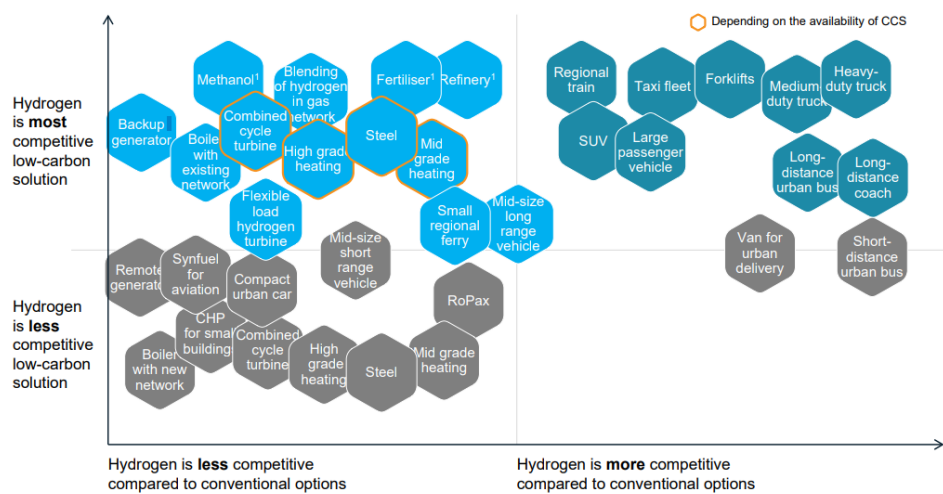
Not a new concept

Discovered in 1800, electrolysis and the process for creating industrialised hydrogen are not new. However, in recent years hydrogen has become a household name as policy makers set ambitious goals to reduce emissions. **The EU is currently targeting to reduce emissions 60% by 2030, and grow installed hydrogen capacity from 1GW today to 6GW by 2024 and 40GW by 2030.** The UK has also ambitiously targeted 'net zero' emissions by 2050. In addition, as electrification cannot solve all emissions related problems as many industrial processes such as steel, cement and chemicals manufacturing result in carbon byproducts, where hydrogen can substitute. Emissions targets are in place, and hydrogen is becoming more commonly seen as a viable alternative to the current carbon producing fuels in our energy and industrial mix.

Why hasn't Hydrogen taken off already? Is this time different?

Shell is well known for being one of the early pioneers in Hydrogen and is currently the #1 seller of hydrogen fuels globally. On the call, Andy Brown noted that Shell's initiatives began in 1999, and Shell Hydrogen was created a year later. Unfortunately, development never took off as expected, as stakeholders were not necessarily aligned. At the time, development was focussed on the auto industry. NEL highlighted the "Scope 3" debate as a critical factor that has pushed hydrogen back on the agenda, as many corporates in other sectors need to find a way to reduce absolute emissions, and hydrogen is now seen as a solution where electrification is not viable. Given blue hydrogen is likely to help and boost the development of green hydrogen over time, there is some complementarity between hydrogen and CCS development, and based on our prior call, we think there is likely to be significant cost deflation in both segments over time.

Exhibit 1: Cost competitiveness of hydrogen applications versus low-carbon conventional alternatives



1. Hydrogen is the only alternative and low-carbon/renewable hydrogen competing with grey (optimal renewable or low-carbon shown)

Source: Hydrogen Council

Where does it go?

Given the versatility of Hydrogen, it could be utilized in many sectors, although this is subject to the cost competitiveness with the incumbent fuels used. One key application would be converting hydrogen into heat, power or electricity. In addition, commercial uses of hydrogen for grid applications include the following:

- Green hydrogen can be used for **heat and power** for buildings through existing infrastructure contributing to a small part of the fuel mix within natural gas networks.
- Green hydrogen can be created by **using** excess renewable electricity, **storing** green hydrogen created through electrolysis, and **producing power** back into the grid cleanly as hydrogen fuel produces no carbon emissions.
- For sectors where high energy density is needed to create heat, hydrogen is a more natural solution than batteries due to its greater energy density.

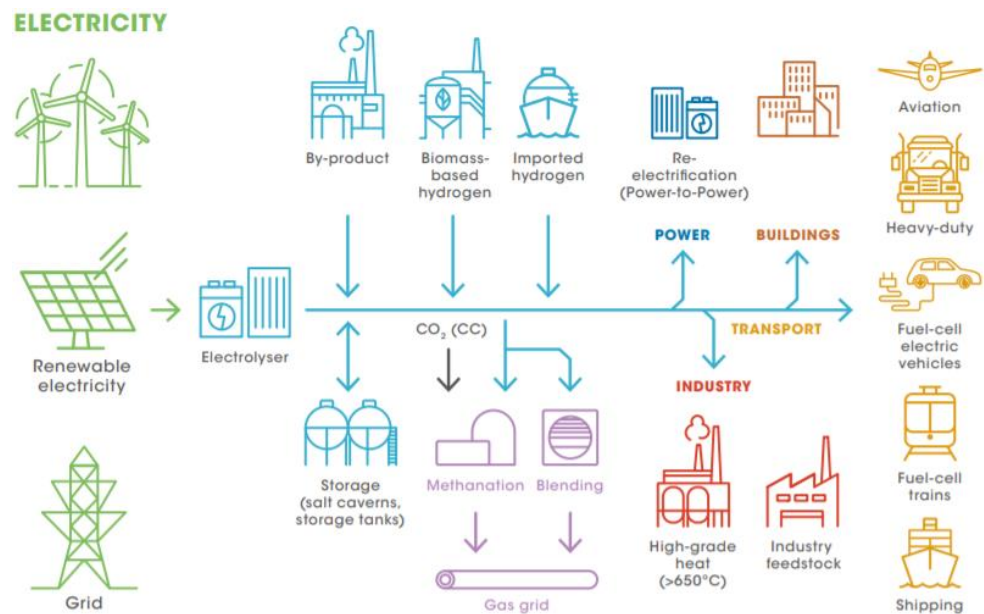
Effectively, hydrogen could be a solution for where electrification is not feasible, i.e. where a large amount of energy is needed. Over the coming decades, **we would expect heavy duty transport, Chemicals, Cement and Steel to all be key end users of hydrogen.**

Zooming in on ZeroAvia, and hydrogen for aviation

Andy Brown (ex-Shell's head of upstream) is working alongside ZeroAvia, a hydrogen focused aviation company. Andy believes hydrogen based aviation is a fast-growing segment given consumers enjoy travelling but are becoming more cautious about their CO2 footprint. Alternatives such as biofuels could be an option, however are more difficult from a land-use perspective, while batteries are unlikely to be a viable solution for aviation due to energy density.

ZeroAvia recently conducted its first hydrogen-electric flight last month, and the company is targeting air travel for 500 mile short-haul trips, at half the current cost, with commerciality targeted in the early to mid 2020s.

Exhibit 2: Industrial process for sources and uses of hydrogen



Source: IRENA

Private support – Industry, Utilities, Transport and Energy

Recent project announcements or statements of intention from major industrial players include Mitsubishi Power, with plans to build three green-hydrogen plants in the US and collaborate with utility firm Entergy for green hydrogen production, storage and transportation.

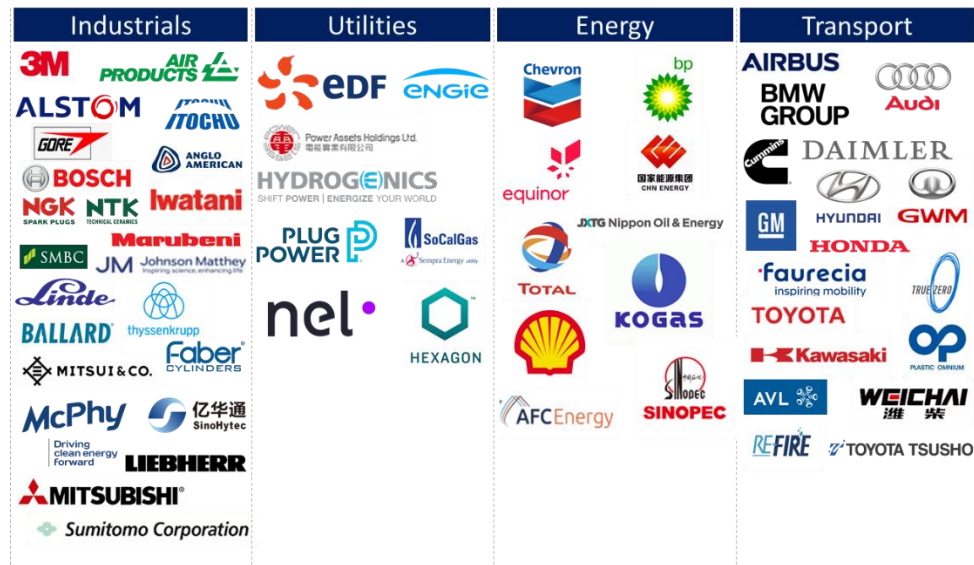
Other illustrations in the Utilities sector include RWE, which plans to supply hydrogen to steel maker Thyssenkrupp and use it at its future LNG facility in Germany. Orsted recently backed a project to power fleet buses and trucks using green hydrogen, with end users including shipping firm Moller-Maersk and Scandinavian airline SAS.

In the transportation space, Airbus expects the first zero-emission commercial aircraft to fly by 2035 as it is working on several hydrogen-powered planes. Hyundai announced the introduction of a fleet of 50 hydrogen-powered trucks in Switzerland.

In the Energy sector, Chevron has recently joined the Hydrogen council alongside European Supermajors. During Total's Capital Markets Day last week, CEO Patrick Pouyanne stated that

the development of Hydrogen was a major driver behind the firm’s solar and wind ambitions, which have been increased from 25GW to 35GW by 2025.

Exhibit 3: Hydrogen Council members



Source: Hydrogen Council, RBC Capital Markets

Policy support across key markets

Current policy frameworks are in early stages with most jurisdictions maintaining high level renewable or carbon reduction targets, although we expect this to change as regions focus in on specific technology support over the next decade. **The EU has set precedent, outlining targets for 40 GW of hydrogen electrolyzers by 2030, setting aside up to €470bn by 2050**, in turn creating a global marketplace for hydrogen, which could be traded as a commodity. In Germany, the gov’t sees green hydrogen as key in “rebuilding” Germany’s industry towards the zero emissions target by 2050. **Germany has a stated goal of installing 5GW of green hydrogen by 2030 and an additional 5GW by 2040.** Similarly, France has outlined €7.2bn in support for hydrogen projects to grow to 6.5GW by 2030. The UK has not formally implemented hydrogen targets, but has committed to investing £800m by 2030 in CCUS project (blue hydrogen) as part of their ‘net zero’ by 2050 goals. The world’s largest economies, US and China, have not formalised stringent hydrogen policy, although have focused goals more pointedly in hydrogen fuel cells for vehicles, rather than grid applications.

Exhibit 4: Hydrogen policy targets by countries

Region	Key policy elements
European Union (EU)	<ul style="list-style-type: none"> - EU can turn clean hydrogen into a viable solution, installing at least 6 GW of renewable hydrogen and electrolyzers in the EU by 2024 and 40 GW of renewable hydrogen electrolyzers by 2030 - EU's €750bn recovery plan for 'Next generation EU' - €1tn of support over 2021-30 in the EU Green Deal to help the EU hit net zero targets by 2050
UK	<ul style="list-style-type: none"> - Target 'Net Zero' greenhouse gas emissions by 2050 - Committed to investing at least £800m on CCUS (blue hydrogen) deployment in at least two sites; one by the mid-2020s and a second by 2030
Germany	<ul style="list-style-type: none"> - Carbon neutral by 2050 - 5GW of hydrogen production capacity by 2030, with another 5GW by 2040 - €7bn earmarked for green hydrogen, and another €2bn to build up partnerships with other countries.
France	<ul style="list-style-type: none"> - €7.2bn euros by 2030 and a hydrogen production capacity of 6.5GW by 2030 - National H2 committee established
Japan	<ul style="list-style-type: none"> - Target based policy - Targeting cost of hydrogen for power generation to 17 JP¥/MWh (~£125/MWh) by 2030
Australia	<ul style="list-style-type: none"> - Advancing Hydrogen Fund has up to \$300 million available to support the growth of a clean, innovative, safe and competitive Australian hydrogen industry - In 2019, ARENA announced the Renewable Hydrogen Development Funding Round of up to \$70 million for hydrogen
South Korea	<ul style="list-style-type: none"> - 15 GW of fuel cell for power generation by 2040
China	<ul style="list-style-type: none"> - 1 million Hydrogen fuel cell vehicles by 2030
US	<ul style="list-style-type: none"> - Department of Energy (DOE) to invest up to \$100m over five years - DOE announced approximately \$64m for funding for 18 projects that will support affordable hydrogen production, storage, distribution, and use - No formalized national policy

Source: Country reports

Key challenges for the Hydrogen sector

In our view three main challenges limit the development of green hydrogen: Cost, power grid and supply chain constraints.

Economics relative to incumbent fuels

Neither green nor blue hydrogen are currently competitive compared to fossil-based hydrogen. According to various estimates Blue hydrogen typically costs around \$2-2.5/kg while green Hydrogen falls in the wider range of \$2.50-6/kg. By comparison, the cost of grey hydrogen is below \$1.5/kg. In a \$50/t carbon price scenario, [our midstream team expects these to fall to \\$1.5/kg and \\$2.6/kg, respectively by 2030](#). A higher carbon price would swing economics towards Green over Blue. Based on comments from NEL, around 75% of the cost of green hydrogen comes from the power cost, so as solar and wind cost shave deflated, this should help Green hydrogen become more competitive. As highlighted in our prior note on carbon capture, as the industry scales up, costs should also fall.

Reducing the cost of electrolysis is key to improving the economics of green hydrogen. According to the European Commission **the cost of electrolyzers has already been reduced by 60% since 2010 and is expected to be reduced by a further 50% over the next decade driven by improved economies of scale**. We expect an unequal development of blue / green hydrogen across geographies, with blue and green approaches converging in regions where renewable energy is more widely available and less costly.

The availability of renewable power

Power grids will undergo strain over the next decade as economies shift focus to a less carbon intensive future. Growth in electric vehicles (EV's) as consumers move away from fossil fuel internal combustion engines (ICE's) in the coming generation for autos would create heightened grid demand. There will also be a continued focus on renewable electricity, which requires a flexible and reliable grid to cope with the unpredictable nature of renewable output. **According to National Grid, record grid balancing costs have reached over £1bn YTD which**

is ~55% higher than last year and in part due to the increased renewable penetration on the UK electricity system. There is both a challenge and opportunity for green hydrogen in the next decade to utilize excess grid capacity for storage.

There is also a grid application for hydrogen in CCUS and as a fuel source to decarbonise the generation and reach 'net zero' country emission targets. **The UK's Committee on Climate Change (CCC) estimate that 270TWh of low carbon hydrogen could be needed to reach net zero targets by 2050, where hydrogen obtained and stored through low carbon methods (green hydrogen) could be used as a fuel source in peaking plants, or as a mix with traditional fuel sources such as natural gas. Currently, around 50% of the UK electricity demand is met by gas generation.**

The supply chain

The efficient, safe and reliable storage of hydrogen is vital to commercial feasibility in transport, delivery and fuel applications. Hydrogen is complex to store, transport and deliver given its low density as the lightest molecule. At atmospheric pressure, 1kg of hydrogen occupies over 11m³ at room temperature, requiring high degrees of pressure or energy to store at commercial scale volumes. With that, there are three main mediums for storing hydrogen:

- **Storage as a gas** is the most common current storage solution for hydrogen, requiring high pressure tanks at 350–700 bar (5,000–10,000 psi). According to Air Liquide, 5kg of hydrogen can be stored at 700 bar in a 125L tank, which would equate to roughly 500km of range in a consumer vehicle. Compressed gas would also be the most viable industrial solution for producing power.
- **Liquefied hydrogen** which must be stored at –253 °C. The process for liquefied hydrogen in energy intensive and expensive. Major applications for liquefied hydrogen have been as a fuel source in space where ambient temperatures prevent liquefied hydrogen from warming and expanding.
- **Materials based storage** involves absorbing hydrogen into reversible chemical compounds where hydrogen can later be extracted. Natural gas is a natural carrier of hydrogen, however ammonia and some solid metallic hybrids can be used to store low volumes of hydrogen.

Exhibit 5: Transporting & storing hydrogen in various states



Source: Royal Dutch Shell

There are current developments for grid scale hydrogen across Europe and Asia. Earlier in 2020, Japan unveiled the world's current largest green hydrogen plant in Fukushima at 10MW. The plant is currently powered by a 20MW solar and the hydrogen storage facility

There are other grid scale projects across Europe such as Iberdrola and Fertiberia's €150m green hydrogen plant in Puertollano that will have a 100MW photovoltaic solar plant, a lithium-ion battery system with a storage capacity of 20MWh and a 20MW electrolytic hydrogen production systems.



Other factors

For Green hydrogen, another factor that is relevant is water availability, given electrolysis is used to split water (H_2O) into hydrogen and oxygen. According to various studies, every kilogram of hydrogen involves ~9kg of water, both in the electrolysis process, and in the fuel cell. Thus, as the green hydrogen economy grows, water management, treatment and distribution could become critical factors in its success over time.

Required disclosures

Non-U.S. analyst disclosure

Biraj Borkhataria, Erwan Kerouredan, John Musk and Mitchell Wotton (i) are not registered/qualified as research analysts with the NYSE and/or FINRA and (ii) may not be associated persons of the RBC Capital Markets, LLC and therefore may not be subject to FINRA Rule 2241 restrictions on communications with a subject company, public appearances and trading securities held by a research analyst account.

Conflicts disclosures

The analyst(s) responsible for preparing this research report received compensation that is based upon various factors, including total revenues of the member companies of RBC Capital Markets and its affiliates, a portion of which are or have been generated by investment banking activities of the member companies of RBC Capital Markets and its affiliates.

Distribution of ratings

For the purpose of ratings distributions, regulatory rules require member firms to assign ratings to one of three rating categories - Buy, Hold/Neutral, or Sell - regardless of a firm's own rating categories. Although RBC Capital Markets' ratings of Outperform (O), Sector Perform (SP), and Underperform (U) most closely correspond to Buy, Hold/Neutral and Sell, respectively, the meanings are not the same because our ratings are determined on a relative basis.

Distribution of ratings RBC Capital Markets, Equity Research As of 30-Sep-2020				
Rating	Count	Percent	Investment Banking Serv./Past 12 Mos.	
			Count	Percent
BUY [Outperform]	788	52.96	248	31.47
HOLD [Sector Perform]	619	41.60	135	21.81
SELL [Underperform]	81	5.44	11	13.58

Conflicts policy

RBC Capital Markets Policy for Managing Conflicts of Interest in Relation to Investment Research is available from us on request. To access our current policy, clients should refer to

<https://www.rbccm.com/global/file-414164.pdf>

or send a request to RBC Capital Markets Research Publishing, P.O. Box 50, 200 Bay Street, Royal Bank Plaza, 29th Floor, South Tower, Toronto, Ontario M5J 2W7. We reserve the right to amend or supplement this policy at any time.

Dissemination of research and short-term trade ideas

RBC Capital Markets endeavors to make all reasonable efforts to provide research simultaneously to all eligible clients, having regard to local time zones in overseas jurisdictions. RBC Capital Markets' equity research is posted to our proprietary website to ensure eligible clients receive coverage initiations and changes in ratings, targets and opinions in a timely manner. Additional distribution may be done by the sales personnel via email, fax, or other electronic means, or regular mail. Clients may also receive our research via third party vendors. RBC Capital Markets also provides eligible clients with access to SPARC on the Firms proprietary INSIGHT website, via email and via third-party vendors. SPARC contains market color and commentary regarding subject companies on which the Firm currently provides equity research coverage. Research Analysts may, from time to time, include short-term trade ideas in research reports and / or in SPARC. A short-term trade idea offers a short-term view on how a security may trade, based on market and trading events, and the resulting trading opportunity that may be available. A short-term trade idea may differ from the price targets and recommendations in our published research reports reflecting the research analyst's views of the longer-term (one year) prospects of the subject company, as a result of the differing time horizons, methodologies and/or other factors. Thus, it is possible that a subject company's common equity that is considered a long-term 'Sector Perform' or even an 'Underperform' might present a short-term buying opportunity as a result of temporary selling pressure



in the market; conversely, a subject company's common equity rated a long-term 'Outperform' could be considered susceptible to a short-term downward price correction. Short-term trade ideas are not ratings, nor are they part of any ratings system, and the firm generally does not intend, nor undertakes any obligation, to maintain or update short-term trade ideas. Short-term trade ideas may not be suitable for all investors and have not been tailored to individual investor circumstances and objectives, and investors should make their own independent decisions regarding any securities or strategies discussed herein. Please contact your investment advisor or institutional salesperson for more information regarding RBC Capital Markets' research.

For a list of all recommendations on the company that were disseminated during the prior 12-month period, please click on the following link: <https://rbcnew.bluematrix.com/sellside/MAR.action>

The 12 month history of SPARCs can be viewed at <https://www.rbcinsightresearch.com>.

Analyst certification

All of the views expressed in this report accurately reflect the personal views of the responsible analyst(s) about any and all of the subject securities or issuers. No part of the compensation of the responsible analyst(s) named herein is, or will be, directly or indirectly, related to the specific recommendations or views expressed by the responsible analyst(s) in this report.

Third-party-disclaimers

The Global Industry Classification Standard ("GICS") was developed by and is the exclusive property and a service mark of MSCI Inc. ("MSCI") and Standard & Poor's Financial Services LLC ("S&P") and is licensed for use by RBC. Neither MSCI, S&P, nor any other party involved in making or compiling the GICS or any GICS classifications makes any express or implied warranties or representations with respect to such standard or classification (or the results to be obtained by the use thereof), and all such parties hereby expressly disclaim all warranties of originality, accuracy, completeness, merchantability and fitness for a particular purpose with respect to any of such standard or classification. Without limiting any of the foregoing, in no event shall MSCI, S&P, any of their affiliates or any third party involved in making or compiling the GICS or any GICS classifications have any liability for any direct, indirect, special, punitive, consequential or any other damages (including lost profits) even if notified of the possibility of such damages.

RBC Capital Markets disclaims all warranties of originality, accuracy, completeness, merchantability or fitness for a particular purpose with respect to any statements made to the media or via social media that are in turn quoted in this report, or otherwise reproduced graphically for informational purposes.

References herein to "LIBOR", "LIBO Rate", "L" or other LIBOR abbreviations means the London interbank offered rate as administered by ICE Benchmark Administration (or any other person that takes over the administration of such rate).

Disclaimer

RBC Capital Markets is the business name used by certain branches and subsidiaries of the Royal Bank of Canada, including RBC Dominion Securities Inc., RBC Capital Markets, LLC, RBC Europe Limited, Royal Bank of Canada, Hong Kong Branch and Royal Bank of Canada, Sydney Branch. The information contained in this report has been compiled by RBC Capital Markets from sources believed to be reliable, but no representation or warranty, express or implied, is made by Royal Bank of Canada, RBC Capital Markets, its affiliates or any other person as to its accuracy, completeness or correctness. All opinions and estimates contained in this report constitute RBC Capital Markets' judgement as of the date of this report, are subject to change without notice and are provided in good faith but without legal responsibility. Nothing in this report constitutes legal, accounting or tax advice or individually tailored investment advice. This material is prepared for general circulation to clients and has been prepared without regard to the individual financial circumstances and objectives of persons who receive it. The investments or services contained in this report may not be suitable for you and it is recommended that you consult an independent investment advisor if you are in doubt about the suitability of such investments or services. This report is not an offer to sell or a solicitation of an offer to buy any securities. Past performance is not a guide to future performance, future returns are not guaranteed, and a loss of original capital may occur. RBC Capital Markets research analyst compensation is based in part on the overall profitability of RBC Capital Markets, which includes profits attributable to investment banking revenues. Every province in Canada, state in the U.S., and most countries throughout the world have their own laws regulating the types of securities and other investment products which may be offered to their residents, as well as the process for doing so. As a result, the securities discussed in this report may not be eligible for sale in some jurisdictions. RBC Capital Markets may be restricted from publishing research reports, from time to time, due to regulatory restrictions and/or internal compliance policies. If this is the case, the latest published research reports available to clients may not reflect recent material changes in the applicable industry and/or applicable subject companies. RBC Capital Markets research reports are current only as of the date set forth on the research reports. This report is not, and under no circumstances should be construed as, a solicitation to act as securities broker or dealer in any jurisdiction by any person or company that is not legally permitted to carry on the business of a securities broker or dealer in that jurisdiction. To the full extent permitted by law neither RBC Capital Markets nor any of its affiliates, nor any other person, accepts any liability whatsoever for any direct, indirect or consequential loss arising from, or in connection with, any use of this report or the information contained herein. No matter contained in this document may be reproduced or copied by any means without the prior written consent of RBC Capital Markets in each instance.

Additional information is available on request.

To U.S. Residents:

This publication has been approved by RBC Capital Markets, LLC (member FINRA, NYSE, SIPC), which is a U.S. registered broker-dealer and which accepts responsibility for this report and its dissemination in the United States. Any U.S. recipient of this report that is not a registered broker-dealer or a bank acting in a broker or dealer capacity and that wishes further information regarding, or to effect any transaction in, any of the securities discussed in this report, should contact and place orders with RBC Capital Markets, LLC.

To Canadian Residents:

This publication has been approved by RBC Dominion Securities Inc. (member IIROC). Any Canadian recipient of this report that is not a Designated Institution in Ontario, an Accredited Investor in British Columbia or Alberta or a Sophisticated Purchaser in Quebec (or similar permitted purchaser in any other province) and



that wishes further information regarding, or to effect any transaction in, any of the securities discussed in this report should contact and place orders with RBC Dominion Securities Inc., which, without in any way limiting the foregoing, accepts responsibility for this report and its dissemination in Canada.

To U.K. Residents:

This publication has been approved by RBC Europe Limited ('RBCEL') which is authorized by the Prudential Regulation Authority and regulated by the Financial Conduct Authority ('FCA') and the Prudential Regulation Authority, in connection with its distribution in the United Kingdom. This material is not for general distribution in the United Kingdom to retail clients, as defined under the rules of the FCA. RBCEL accepts responsibility for this report and its dissemination in the United Kingdom.

To German Residents:

This material is distributed in Germany by RBC Europe Limited, Frankfurt Branch which is regulated by the Bundesanstalt für Finanzdienstleistungsaufsicht (BaFin).

To Persons Receiving This Advice in Australia:

This material has been distributed in Australia by Royal Bank of Canada, Sydney Branch (ABN 86 076 940 880, AFSL No. 246521). This material has been prepared for general circulation and does not take into account the objectives, financial situation or needs of any recipient. Accordingly, any recipient should, before acting on this material, consider the appropriateness of this material having regard to their objectives, financial situation and needs. If this material relates to the acquisition or possible acquisition of a particular financial product, a recipient in Australia should obtain any relevant disclosure document prepared in respect of that product and consider that document before making any decision about whether to acquire the product. This research report is not for retail investors as defined in section 761G of the Corporations Act.

To Hong Kong Residents:

This publication is distributed in Hong Kong by Royal Bank of Canada, Hong Kong Branch, which is regulated by the Hong Kong Monetary Authority and the Securities and Futures Commission (SFC) in Hong Kong, RBC Investment Services (Asia) Limited and RBC Global Asset Management (Asia) Limited, both entities are regulated by the SFC. This material is not for general distribution in Hong Kong to persons who are not professional investors (as defined in the Securities and Futures Ordinance of Hong Kong (Cap. 571) and any rules made thereunder.

To Singapore Residents:

This publication is distributed in Singapore by the Royal Bank of Canada, Singapore Branch, a registered entity licensed by the Monetary Authority of Singapore. This material has been prepared for general circulation and does not take into account the objectives, financial situation, or needs of any recipient. You are advised to seek independent advice from a financial adviser before purchasing any product. If you do not obtain independent advice, you should consider whether the product is suitable for you. Past performance is not indicative of future performance. If you have any questions related to this publication, please contact the Royal Bank of Canada, Singapore Branch. Royal Bank of Canada, Singapore Branch accepts responsibility for this report and its dissemination in Singapore.

To Japanese Residents:

Unless otherwise exempted by Japanese law, this publication is distributed in Japan by or through RBC Capital Markets (Japan) Ltd. which is a Financial Instruments Firm registered with the Kanto Local Financial Bureau (Registered number 203) and a member of the Japan Securities Dealers Association (JSDA) and the Financial Futures Association of Japan (FFAJ).

® Registered trademark of Royal Bank of Canada. RBC Capital Markets is a trademark of Royal Bank of Canada. Used under license.

Copyright © RBC Capital Markets, LLC 2020 - Member SIPC

Copyright © RBC Dominion Securities Inc. 2020 - Member Canadian Investor Protection Fund

Copyright © RBC Europe Limited 2020

Copyright © Royal Bank of Canada 2020

All rights reserved