

# THE FUTURE OF NATURAL GAS IN A DEEPLY DECARBONIZED WORLD

Expert Workshop Summary Report

June 2021



ENERGY FUTURES  
— INITIATIVE —

# Acknowledgements

**EFI:** Alex Breckel, Tomas Green, Joe Hezir, Minji Jeong, Melanie Kenderdine, Ethan King, Alex Kizer, Nicole Pavia, Sam Savitz

**Goldwyn Global Strategies:** Andrea Clabough, David Goldwyn

**Regional Think Tank Partners:** Alain Ebobissé (Africa50), Randy Bell & Jason Marczak (Atlantic Council), Dr. Ken Medlock III (Baker Institute), Ruslan Stefanov & Martin Vladimirov (Center for the Study of Democracy), Dr. Ken Koyama (Institute of Energy Economics, Japan), Faris Al-Otaibi, Kaushik Deb, Rami Shabaneh, & Adam Sieminski (King Abdullah Petroleum Studies and Research Center), Ashley Johnson (National Bureau of Asian Research), Dr. James Henderson & Dr. Anouk Honoré (Oxford Institute for Energy Studies)

**Study Funders:** Gas Technology Institute (GTI), the Hewlett Foundation, Sempra

**Design:** Jami Butler

# Table of Contents

Study Framing .....	1
Introduction.....	1
About the Workshops.....	1
Global Natural Gas Markets:	
Context and Key Trends .....	5
Natural Gas and the	
Global Fuel Mix.....	5
Global Decarbonization and Climate Policy .....	10
Global Trends that Could Impact Natural Gas Markets.....	16
Cross-Cutting Insights from the Regional Workshops.....	22
Regional Workshop High-Level Insights.....	29
Central & South America .....	31
Sub-Saharan Africa.....	41
South Asia .....	51
Southeast Asia .....	59
Northeast Asia .....	67
Europe.....	76
Middle East & North Africa.....	89
North America.....	97
Endnotes .....	110

# List of Figures and Tables

## Figures

Figure 1: Regional Workshop Overview .....	2
Figure 2: Global Primary Energy Consumption by Source .....	5
Figure 3: Natural Gas in the Context of Total Energy Supply by Region, 2018 .....	6
Figure 4: Liquefaction, Regasification Facilities by Country, Region, and Continent, 2019 .....	7
Figure 5: 2019 Imports (Million Metric Tons) and Market Share (%) by Country .....	8
Figure 6: 2019 Exports (Million Metric Tons) and Market Share (%) by Country .....	8
Figure 7: Major Natural Gas Trade Movements, 2019 (Billion Cubic Meters) .....	9
Figure 8: Global CO <sub>2</sub> Emissions (Billion Metric Tons) by Fuel Type, 2019.....	10
Figure 9: Global Methane Emissions by Source .....	10
Figure 10: Global Greenhouse Gas Emissions by Sector, 2016 .....	11
Figure 11: Per Capita CO <sub>2</sub> Emissions by Country, 2019 (tons).....	12
Figure 12: GHG Emissions by Region, 1990-2018.....	13
Figure 13: Countries that Have Achieved or Have Laws, Policies, or Proposals Under Discussion for Net-Zero Emissions Targets .....	14
Figure 14: Total Investment Needed by 2030 for Implementation of Renewable Energy Targets in NDCs.....	15
Figure 15: World Population and Annual Growth Rate, 1950-2021 with Projections to 2100 .....	16
Figure 16: Average Projected Annual Rate of Population Change by Country, 2025-2030 .....	17
Figure 17: Global Urban Population by Size Class of Settlement, 1990-2030 .....	18
Figure 18: Global Energy Indicators with Projections, 2010-2050, .....	19
Figure 19: The Olivares Alfa Glacier in Chile, 1953 and 2019 .....	32
Figure 20: Changes in Hydropower Capacity Factor by Latin American Subregion, 2020-2099, Relative to 1970-2000 Baseline .....	32
Figure 21: Primary Energy Demand, World and Central & South America.....	33
Figure 22: Power Generation by Technology, World and Central & South America .....	33
Figure 23: Natural gas imports vs. exports in Central & South America .....	35
Figure 24: Anticipated Regional Population, 2040 .....	42
Figure 25: Total primary energy demand, South Africa and rest of Sub-Saharan Africa .....	43

## Figures (continued)

Figure 26: Gas discoveries and gas net exports and demand in Africa .....	43
Figure 27: GHG Emissions, Sub-Saharan Africa and the World.....	44
Figure 28: Potential 2050 Natural Gas Demand in Sub-Saharan Africa.....	45
Figure 29: Total Energy Supply, South Asia .....	52
Figure 30: Gas Demand by Region 2018-2040.....	52
Figure 31: Electricity Generation by Source in India, Historical and Projected (STEPS).....	54
Figure 32: GHG Emissions, South Asia, 1990-2016.....	56
Figure 33: Primary Energy Consumption and Power Generation by Region, 2019 and 2040 .....	60
Figure 34: Natural Gas Demand in ASEAN Countries, 2017-2050 (mtoe).....	61
Figure 35: Southeast Asia's Key Gas and LNG Infrastructure .....	63
Figure 36: CO <sub>2</sub> Emissions in Cambodia, Laos, Myanmar, Vietnam, and Thailand, 2017 and 2050, Business-as-Usual vs. Alternative Policy Scenario.....	65
Figure 37: South Korean Power Capacity Mix Forecast .....	68
Figure 38: Varied Projections of Natural Gas Demand in China through 2060 .....	68
Figure 39: CO <sub>2</sub> Emissions and Emissions Reductions Pathways in China, 2015-2060.....	69
Figure 40: China Regasification Capacity Additions, 2018-2022.....	71
Figure 41: Regional CO <sub>2</sub> Emissions Savings from Coal to Gas Fuel Switching, 2010-2018.....	74
Figure 42: Primary Energy and Electricity Generation by Source in the EU28 .....	77
Figure 43: Electricity generation by source in the EU, 2019-2050, IEA Sustainable Development Scenario.....	77
Figure 44: Remaining CO <sub>2</sub> Emissions in the EU, IEA Sustainable Development Scenario, 2050.....	78
Figure 45: U.S. LNG Export Destinations by Volume (mcf) and % Total, 2019.....	81
Figure 46: Conceptual Design of a Hydrogen and Carbon Capture Project Supporting the UK's 2050 Net-Zero Target.....	87
Figure 47: Fuel Mix for Power Generation by Country, 2019.....	90
Figure 48: Power Generation by Energy Source in MENA.....	90
Figure 49: Natural Gas Demand in MENA, 2010-2040.....	91
Figure 50: Global Carbon Capture and Storage (CCS) Projects, 2019.....	93
Figure 51: The Circular Carbon Economy .....	96
Figure 52: Planned U.S. Utility-scale Electricity Generation Capacity Additions, 2021 .....	98
Figure 53: Total Energy by Source in Canada, 2016, and Trends of Consumption of Non-hydro Renewable Energy, 1995 to 2016 .....	98

## Figures (continued)

Figure 54: Monthly Natural Gas Balance in Mexico, January 2017 to September 2020 .....	100
Figure 55: Cumulative Projected Generation Capacity Additions in Mexico by Fuel Type, 2015-2029.....	103
Figure 56: Global Methane Emissions, United States and Rest of World .....	106

## Tables

Table 1. Central & South America Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019.....	34
Table 2: Sub-Saharan Africa Region Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019.....	44
Table 3: South Asia Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019.....	53
Table 4: Southeast Asia Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019.....	61
Table 5: Northeast Asia Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019.....	69
Table 6: Europe Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019.....	78
Table 7: MENA Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019.....	90
Table 8: North America Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019.....	101

# Study Framing

## INTRODUCTION

Natural gas has become an increasingly important fuel in the global energy mix over the last several decades, reaching its highest-ever share of global demand in 2019 (23 percent) and nearly doubling its share from a half-century ago.<sup>1</sup> It has displaced higher-emitting fuels in some regions, improving local air quality and reducing greenhouse gas (GHG) emissions. Natural gas is also a critical industrial fuel and feedstock, offering pathways for economic growth in the developing world, as well as sustaining industrial and economic activity in the developed world.

At the same time, natural gas is a major contributor to climate change: burning natural gas emits CO<sub>2</sub> and its production and transportation emits methane, a powerful greenhouse gas. Emissions from natural gas and other fossil fuels must be dramatically reduced to meet 1.5 degree or net-zero emissions targets by midcentury. Addressing the tensions raised by growing global demand for gas, its critical role in industry and economic development, and its major contributions to climate change is the primary motivation for this study.

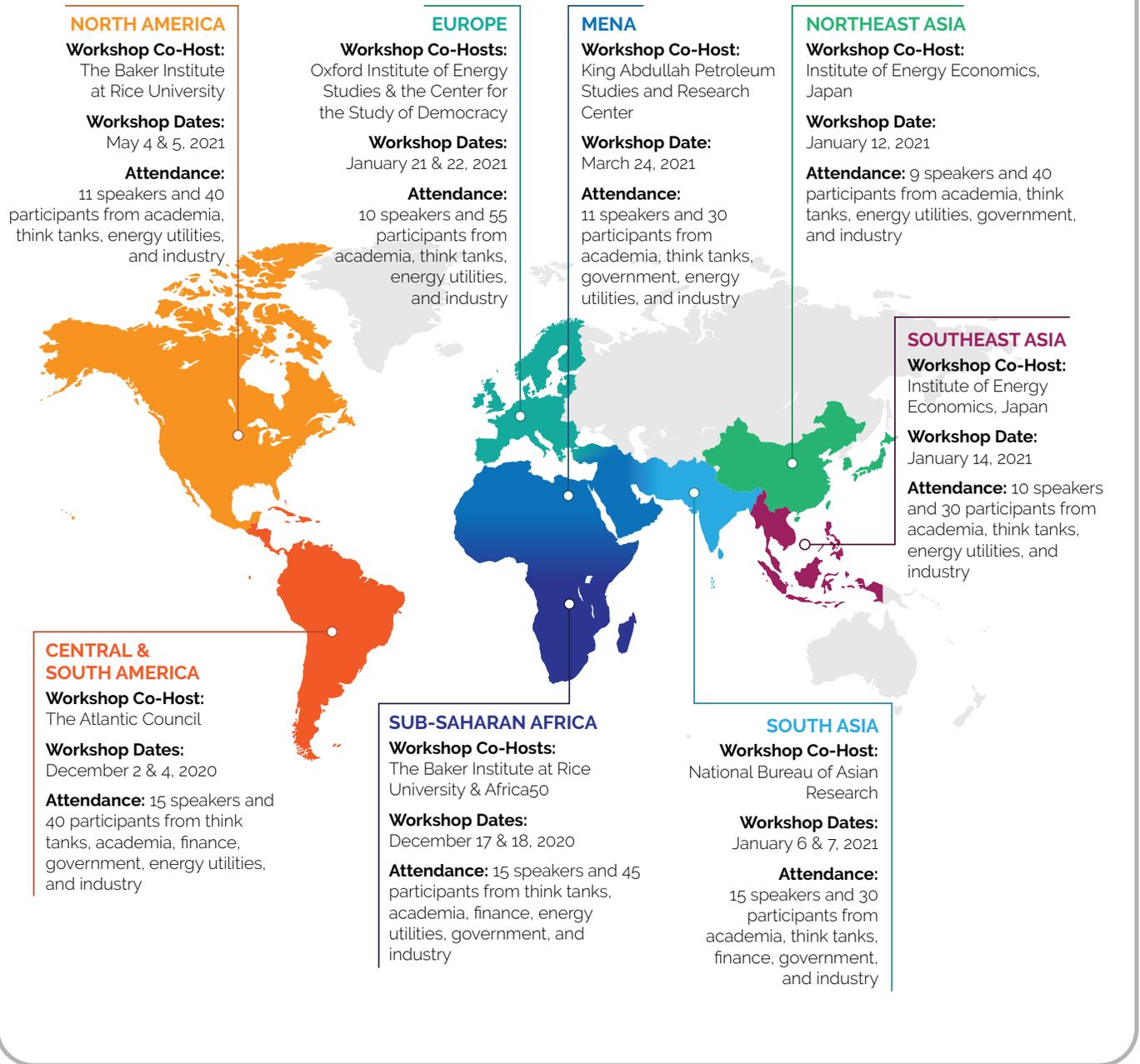
The Energy Futures Initiative (EFI) is conducting a major study titled *The Role of Natural Gas in a Decarbonized World* to identify options, develop pathways, and inform policy that directly address these tensions. This report summarizes the discussions of more than 200 experts from research organizations, think tanks, investment firms, and other disciplines to discuss the potential role of natural gas in a low carbon future. The eight regionally-focused workshops led to the cross-cutting and region-specific insights described in this report. These and other insights will inform future analyses of global

natural gas supply and demand in the context of the technology options, infrastructure and investment requirements, and policies needed to meet both regional development and deep decarbonization needs by midcentury.

## ABOUT THE WORKSHOPS

EFI partnered with six regionally-focused think tanks to host eight workshops designed to understand and evaluate the key trends shaping the energy economy at a regional level, including a specific focus on the role of natural gas in a world committed to deep decarbonization by midcentury. Workshop attendees included experts in regional energy and economic activities from a range of backgrounds and experience. The workshops examined demographic and economic trends, policy priorities shaping energy production and end use, the current and anticipated role of natural gas in regional energy mixes, and outlooks for GHG policy. The regional workshops, conducted from December 2020 through May 2021, are shown in Figure 1.

# FIGURE 1: REGIONAL WORKSHOP OVERVIEW



In collaboration with partners and think tanks, EFI set a regional scope for this study that optimized workshop logistics while representing a diverse range of experiences with economic development, economic specialization, industrialization, GHG emissions, energy production, energy resource potential, climate policy, and energy access.<sup>a</sup> Each workshop featured a diverse range of participants and viewpoints from regional and international think tanks, nonprofit and development organizations, regional governments, academia, and the private sector. The workshops were held under Chatham House rule to encourage open dialogue. EFI provided the following questions to frame the discussion:

1. What is the current role of natural gas in this region, and how is its role expected to change under current energy transition plans?
2. What key economic and demographic trends, and/or regional imperatives (e.g., national and energy security, poverty alleviation) drive natural gas demand and use in the region?
3. What key trends and/or regional imperatives drive overall energy demand? What are influences that are in flux or, perhaps, harder to fully predict or understand?
4. Given regional drivers, what do you see as the range of potential futures for natural gas markets, including supply and demand estimates and geographical distribution in the 2030 timeframe? 2050 timeframe?
5. Are countries in the region on track to meet their Nationally Determined Contributions as part of the Paris Agreement? Have regional approaches been discussed or designed to address climate change mitigation? If not, what are significant factors that impact efforts to meet targets?
6. What key GHG emissions and stated energy policies are anticipated to impact gas supply and demand?
7. Can you highlight the decarbonization strategies of the countries in your region to achieve climate and energy security goals?
8. Do you envision scalable, deployed substitutes available for natural gas in the 2030 and midcentury timeframes? What are they? What kind and/or level of investments is being made in alternatives to natural gas?
9. Are countries in your region focused on policies to limit stranded assets from legacy natural gas infrastructure?
10. What do you see as the role of natural gas and/or liquefied natural gas (LNG) in addressing developing country energy needs, and comparisons with alternative clean energy development scenarios?
11. Are corporate environmental, social, and governance (ESG) policies and financial institution guidelines for investments in new natural gas infrastructure projects being considered or incorporated in decision-making?
12. What role do natural gas emissions abatement technologies (such as carbon capture and sequestration, advanced leak detection and repair, enhanced management of methane emissions) and emerging gas technologies (such as renewable gases) have to play in the region's energy transition outlook?
13. What trends may lead to beneficial displacement of natural gas end uses, through greater electrification of end uses, displacement of gas generation with renewable resources, and/or access to gas alternatives like "green" ammonia or hydrogen?

---

a Two major natural gas producers, exporters, and consumers whose export contributions to global supply were analyzed but whose domestic markets were not independently covered in workshops are Russia and Australia. Russia was discussed in the European workshop in the context of pipeline natural gas imports, and Australia was explored in our analysis of the LNG market as provided in the "Global Natural Gas Markets: Context and Key Trends" section, as well as in the Northeast and Southeast Asia workshops in the context of the LNG trade. Other Central Asian countries with natural gas reserves and geopolitical importance including Turkmenistan, Uzbekistan, Kazakhstan, Kyrgyzstan, and Tajikistan were discussed both in the European and Northeast Asian contexts.

For each region, this analysis provides upfront data and information about the region's energy use, emissions, and other relevant trends, followed by summaries of the regional workshops. These workshop summaries are designed to provide readers with key points raised by panelists; they present a range of views from the panelists, do not necessarily represent consensus views, and are not the views of EFI. EFI assisted with workshop organization and the convening of the workshops, opened each workshop with a few high-level points, participated in the discussions, and edited the workshop reports for consistency in structure and format.

# Global Natural Gas Markets: Context and Key Trends

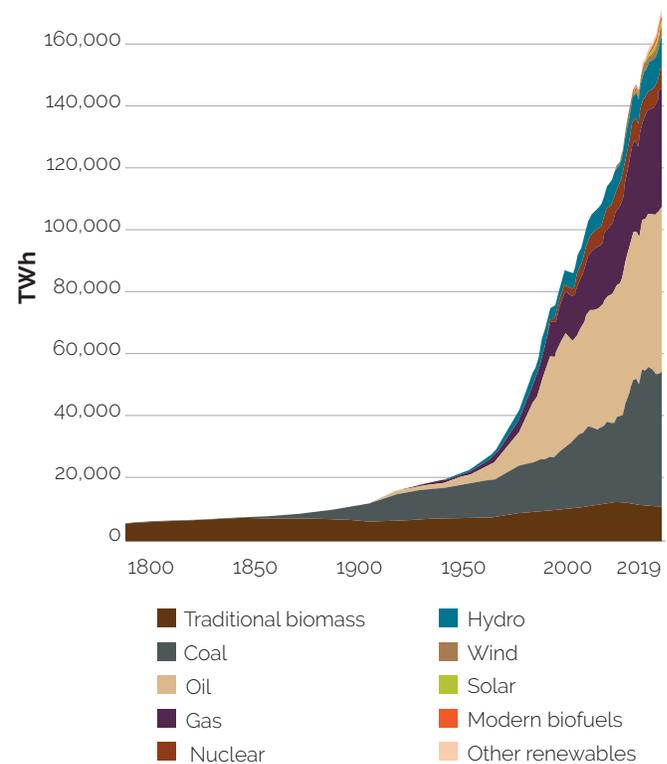
This section provides a summary of overarching trends that have affected, and will continue to affect, the global supply and demand of natural gas and energy more broadly. As a fossil fuel, the production, infrastructure needs, and uses of natural gas will also be affected by national and regional climate and clean energy policies, which are necessarily becoming increasingly aggressive. This analysis focuses on the impacts of these demand trends in the context of global and regional decarbonization policies.

## NATURAL GAS AND THE GLOBAL FUEL MIX

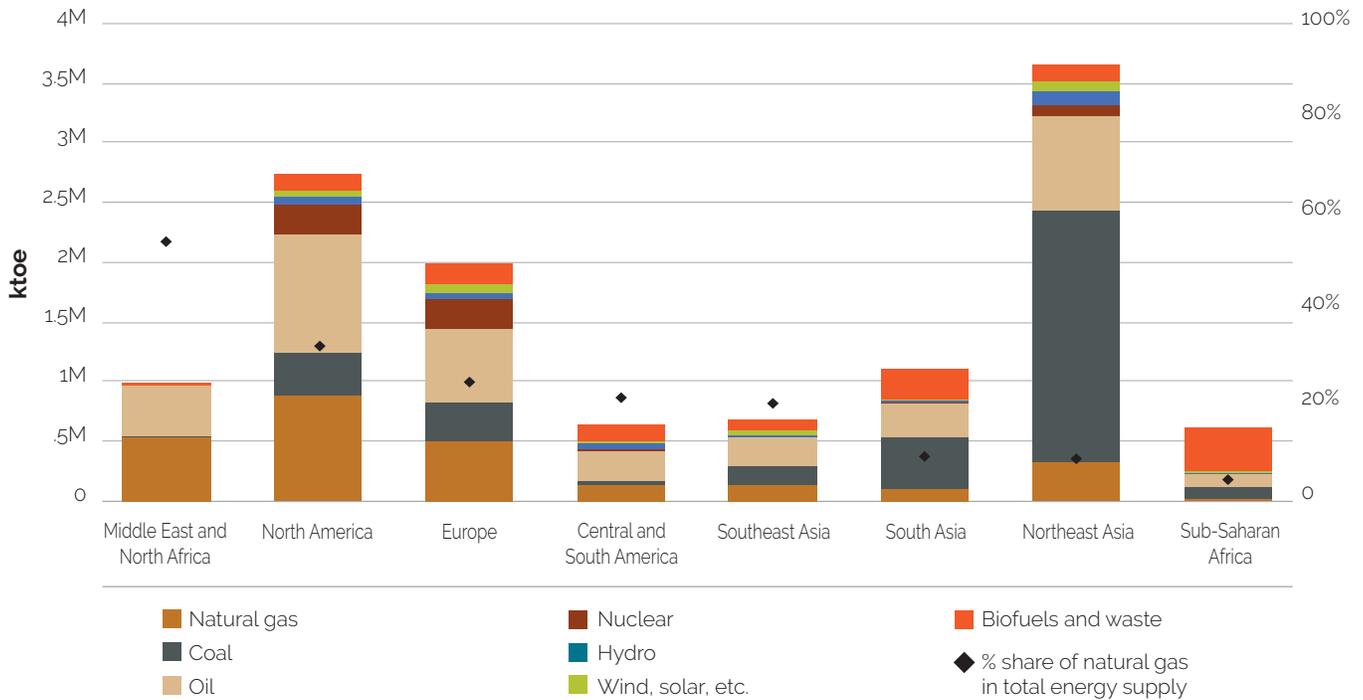
Natural gas is a versatile fuel used across the world for power generation, residential and commercial building heating, and as a feedstock for industrial processes. Figure 2 shows steady increases in natural gas consumption, with especially large increases in the last 30 years. Over the past two decades, global gas consumption has increased by 21 percent, compared to increases of 10 percent for oil and 3 percent for coal. In 2019, global gas consumption reached 23 percent of total global energy demand, its highest-ever share of total energy demand.

While global gas consumption has risen steadily, there are significant differences in natural gas supply between global regions (Figure 3). Northeast Asia, North America, and Europe have the greatest total energy supply overall, but natural gas makes up a much greater share of supply in North America and Europe than in Northeast Asia, where coal dominates. As a proportion of total energy supply, the Middle East & North Africa (MENA) region has the highest natural gas supply. Sub-Saharan Africa has both the lowest overall energy supply and the lowest fraction supplied by natural gas (as well as coal and oil), with biomass comprising the majority of regional energy supply.

Figure 2: Global Primary Energy Consumption by Source<sup>2</sup>



Source: Our World in Data, 2021. Data from Smil, 2017; BP Statistical Review of World Energy, 2020. **Note:** Our World in Data normalized all BP fossil fuels data to terawatt-hours (TWh) using a conversion factor of 277.778 to convert from exajoules (EJ) to TWh. This data presents primary energy consumption corrected for the inefficiencies in fossil fuel and biomass conversion by correcting nuclear and modern renewable technologies to their "primary input equivalents" if the same quantity of energy were to be produced from fossil fuels.

**Figure 3: Natural Gas in the Context of Total Energy Supply by Region, 2018<sup>3</sup>**

Overall, global regions have unique energy supply profiles. The MENA, North American, and European regions have the highest gas supply. The Northeast Asian region has the highest total energy supply overall and its market today is dominated by coal. Data from IEA, 2020.

### The Evolution of Natural Gas Markets

Several developments over the last half century have shaped the current global profile of natural gas supply and demand. Technological advances in natural gas exploration, production, and combustion have made the fuel more accessible while increasing its value as an energy product distinct from oil. The commercialization of combined-cycle power plant configurations in the 1960s and 1970s—in which plant efficiency is improved by using combustion exhaust to generate steam for a secondary turbine—brought these plants into common usage in the United States and elsewhere.<sup>4</sup>

Starting in the late 2000's, new approaches to oil and gas extraction—including hydraulic fracturing and horizontal drilling—lowered natural gas prices in the United States and greatly increased gas supply and consumption. As a result, the United States is a

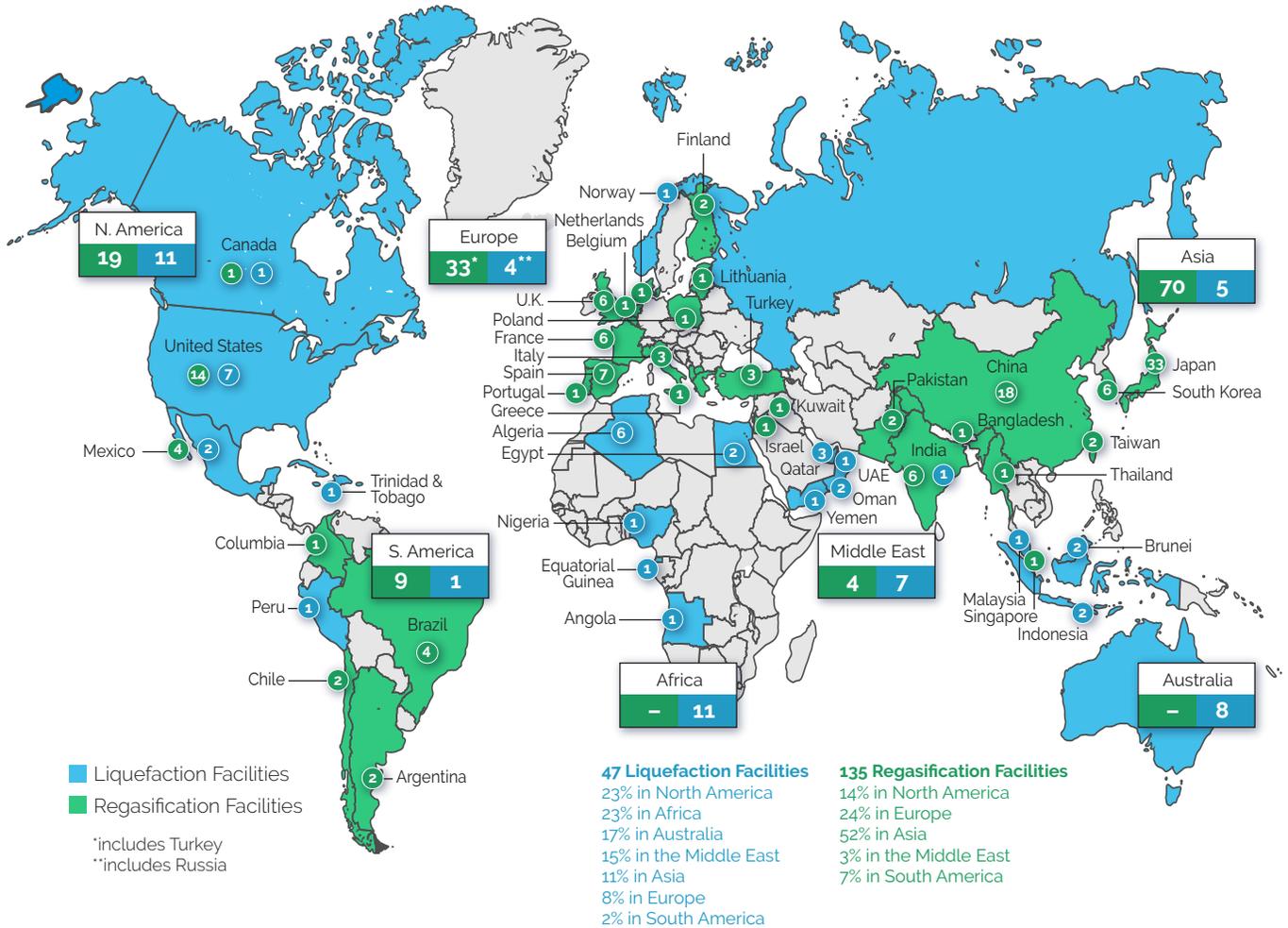
net exporter of natural gas and has displaced more carbon-intensive coal with relatively cheap natural gas for some domestic electricity generation. New gas exploration and production technologies have also opened possibilities for developing gas resources in parts of the world that have not historically been major natural gas-producing regions.<sup>5,6</sup>

These technological changes have also facilitated an expansion of the global LNG market. LNG has historically provided natural gas to countries with fewer domestic resources or opportunities for pipeline infrastructure, allowed countries to diversify or increase their energy imports, and provided a new source of revenue for regions with excess supply. Over the past decade, companies have accelerated the development and deployment of LNG infrastructure, including floating liquefaction,

storage, and regasification facilities. The average cost of LNG infrastructure development has declined over the same period, from a peak of over \$2,000 per ton of capacity in 2012 to around \$900 per ton in 2020 (with some projects coming in at even lower cost).<sup>7</sup> Billions of dollars of LNG infrastructure investment

have facilitated this growing international market, with a record \$65 billion worth of final investment decisions taken in 2019 alone.<sup>8</sup> Figure 4 shows number of LNG liquefaction and regasification facilities by continent, region, and country for 2019.

**Figure 4: Liquefaction, Regasification Facilities by Country, Region, and Continent, 2019<sup>9</sup>**

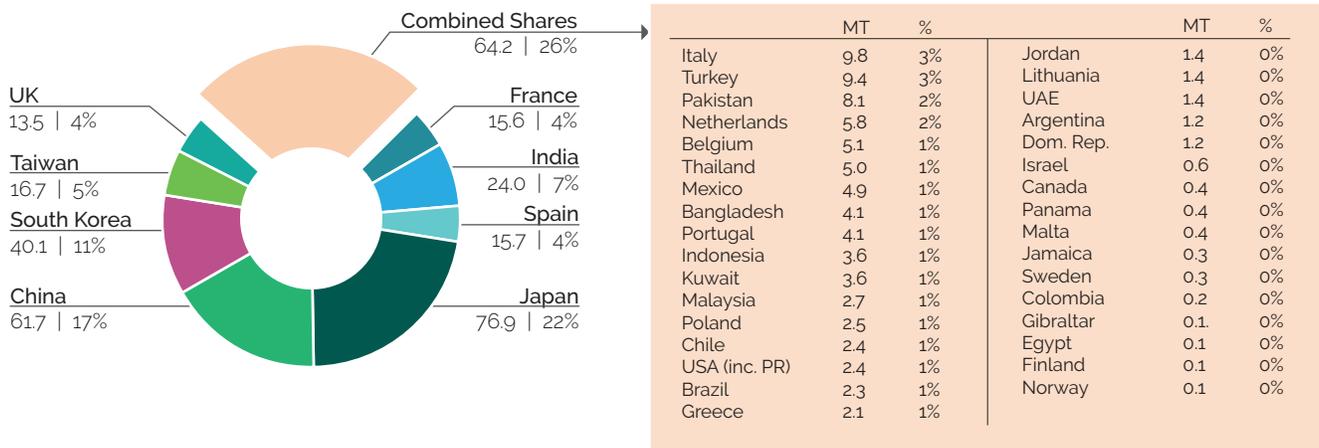


Data from International Group of LNG Importers, 2020.

The number of countries with access to LNG nearly doubled over the last decade, from 23 to 43; new exporters have also emerged, such as Peru, Papua New Guinea, and Angola.<sup>10,11</sup> Figure 5 shows LNG importers and by volume and percentage of import markets by country. Over half of net LNG import

growth from 2009 to 2019 came from Northeast Asia, with China alone accounting for a third of global growth; South and Southeast Asia, Europe, Central & South America, and the Middle East also saw increased imports over this period.<sup>12</sup>

**Figure 5: 2019 Imports (Million Metric Tons) and Market Share (%) by Country<sup>13</sup>**

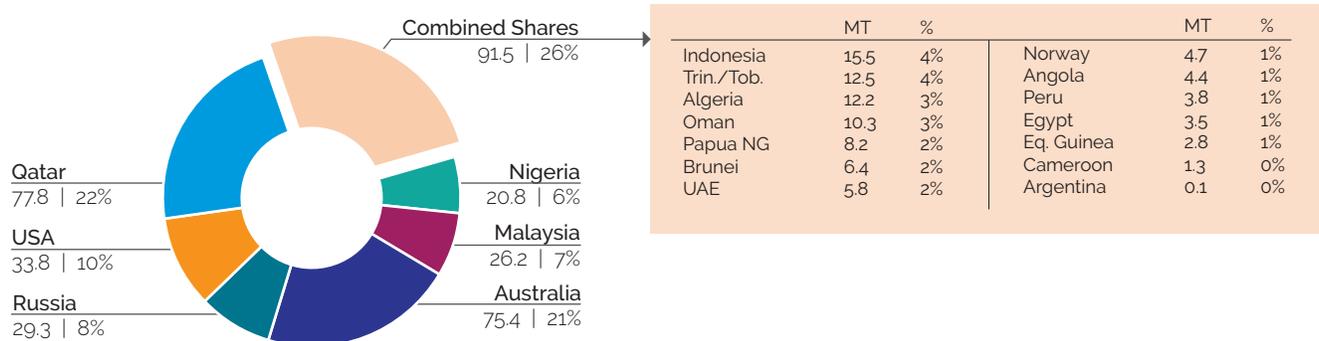


Northeast Asian nations comprised 55 percent of the global LNG import market in 2019. Source: International Gas Union, 2020. Data from International Group of LNG Importers, 2020.

The majority of new net exports over this period came from the current three largest exporters: Australia, Qatar, and the United States (Figure 6).<sup>14</sup> These shifts in the LNG market have been accompanied by lower gas prices, demand from new sources (e.g.,

combined-cycle plants) and regions, and significant gas production and supply in the United States. As a result, the global LNG trade grew by nearly half between 2009 and 2019 and LNG markets have become more liquid, flexible, and interconnected.<sup>15,16</sup>

**Figure 6: 2019 Exports (Million Metric Tons) and Market Share (%) by Country<sup>17</sup>**

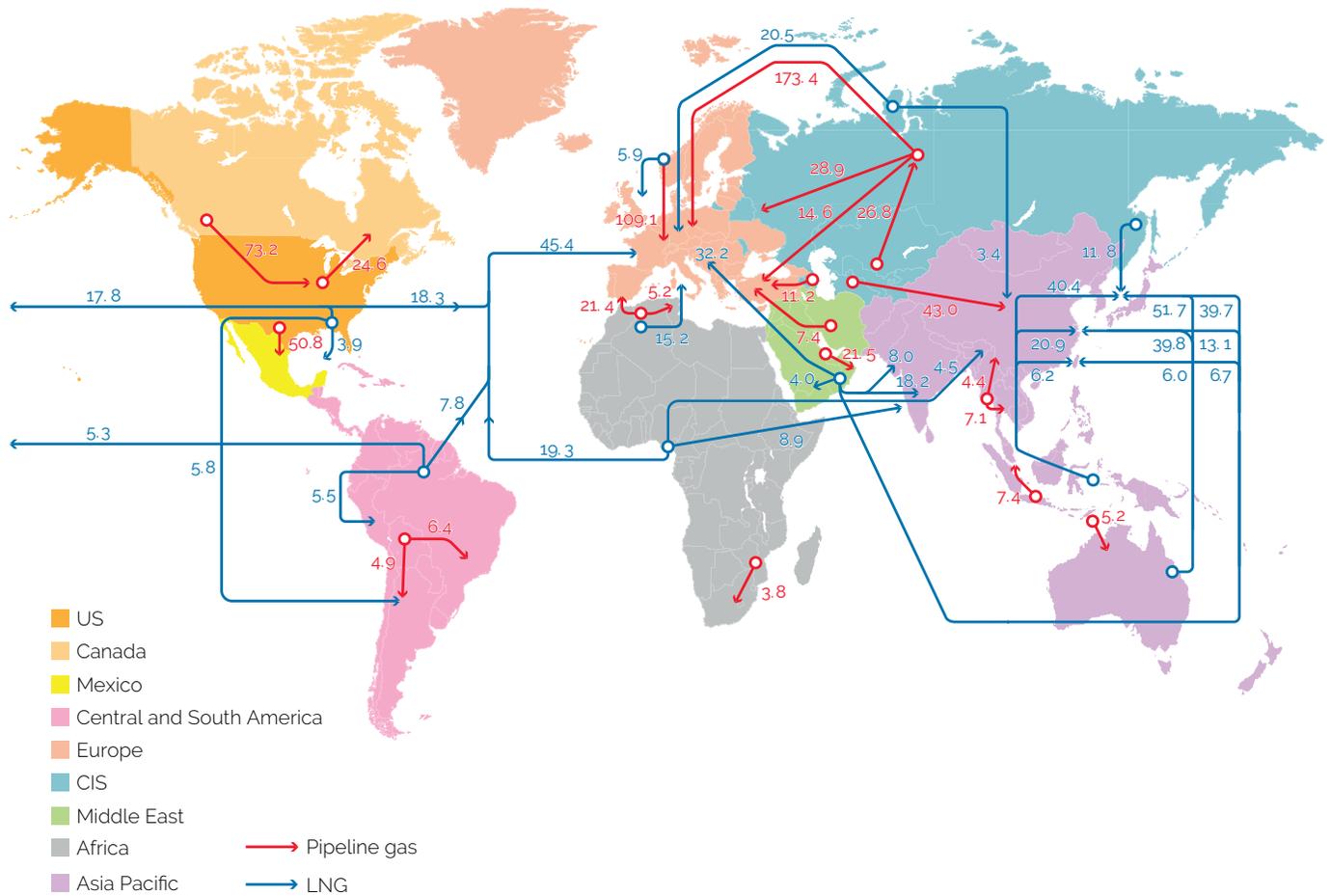


This figure shows LNG exporters by volume and percentage of export markets by country in 2019. In that year, Qatar, Australia, and the United States comprised 53 percent of the global LNG export market. Source: International Gas Union, 2020. Data from International Group of LNG Importers, 2020.

In 2019, LNG reached its highest-ever share (49 percent) of the international natural gas trade, nearly equaling the volumes traded through international pipelines (Figure 7).<sup>18</sup> Current LNG price volatility—

driven by both the exigencies of 2020 and long-standing financial stability issues—poses challenges to further expansion of that market, particularly in emerging economies.<sup>19</sup>

**Figure 7: Major Natural Gas Trade Movements, 2019 (Billion Cubic Meters)<sup>20</sup>**



This map shows major natural gas trade movements for both piped gas and LNG in 2019. Source: BP, 2020.

## GLOBAL DECARBONIZATION AND CLIMATE POLICY

To understand the role of natural gas in a deeply decarbonized world and the evolution of global climate policy, it is first important to understand the total global emissions of both CO<sub>2</sub> and methane from natural gas production and use. Natural gas, as a fossil fuel, emits substantial volumes of CO<sub>2</sub> but its emissions worldwide are lower than either coal or oil emissions. Figure 8 shows a breakdown of global CO<sub>2</sub> emissions by fossil fuel type. Decarbonization policies that cover economywide and sector-specific targets could have dramatic impacts on the future of natural gas.

Fugitive emissions from energy production—mostly methane, which has around 25 times the warming potential of CO<sub>2</sub> over 100 years—are 6 percent of the world’s total greenhouse gas emissions. The International Energy Agency (IEA) estimates that current technologies could reduce total oil and gas methane emissions by 75 percent.<sup>21</sup> Global, regional,

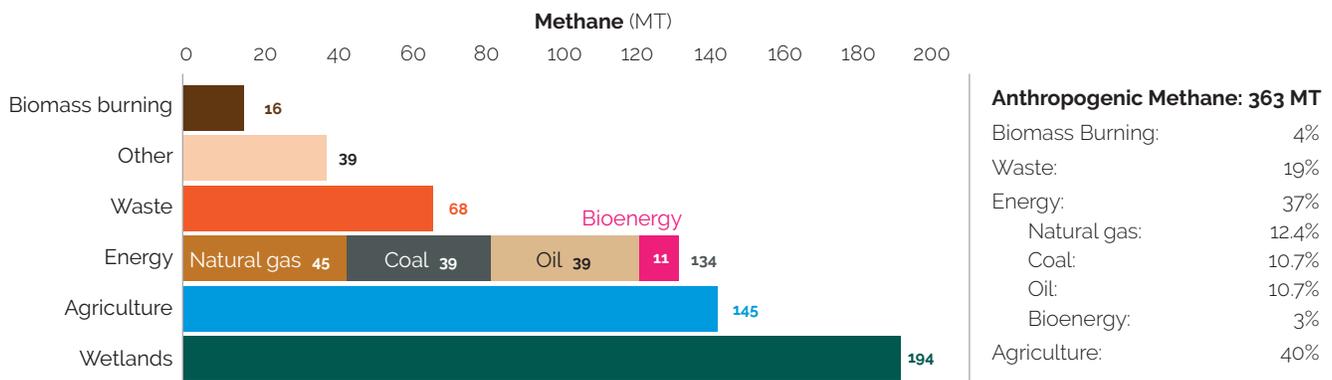
and national policies on methane emissions are critical for deep decarbonization and will have specific impacts on natural gas consumption, transportation, and use. It is important to note that non-energy methane emissions from livestock, rice cultivation, landfills, and wastewater treatment are almost twice those of fugitive emissions from energy production (Figure 9).

**Figure 8: Global CO<sub>2</sub> Emissions (Billion Metric Tons) by Fuel Type, 2019<sup>22</sup>**



Source: Global Carbon Project, 2020.

**Figure 9: Global Methane Emissions by Source<sup>23</sup>**

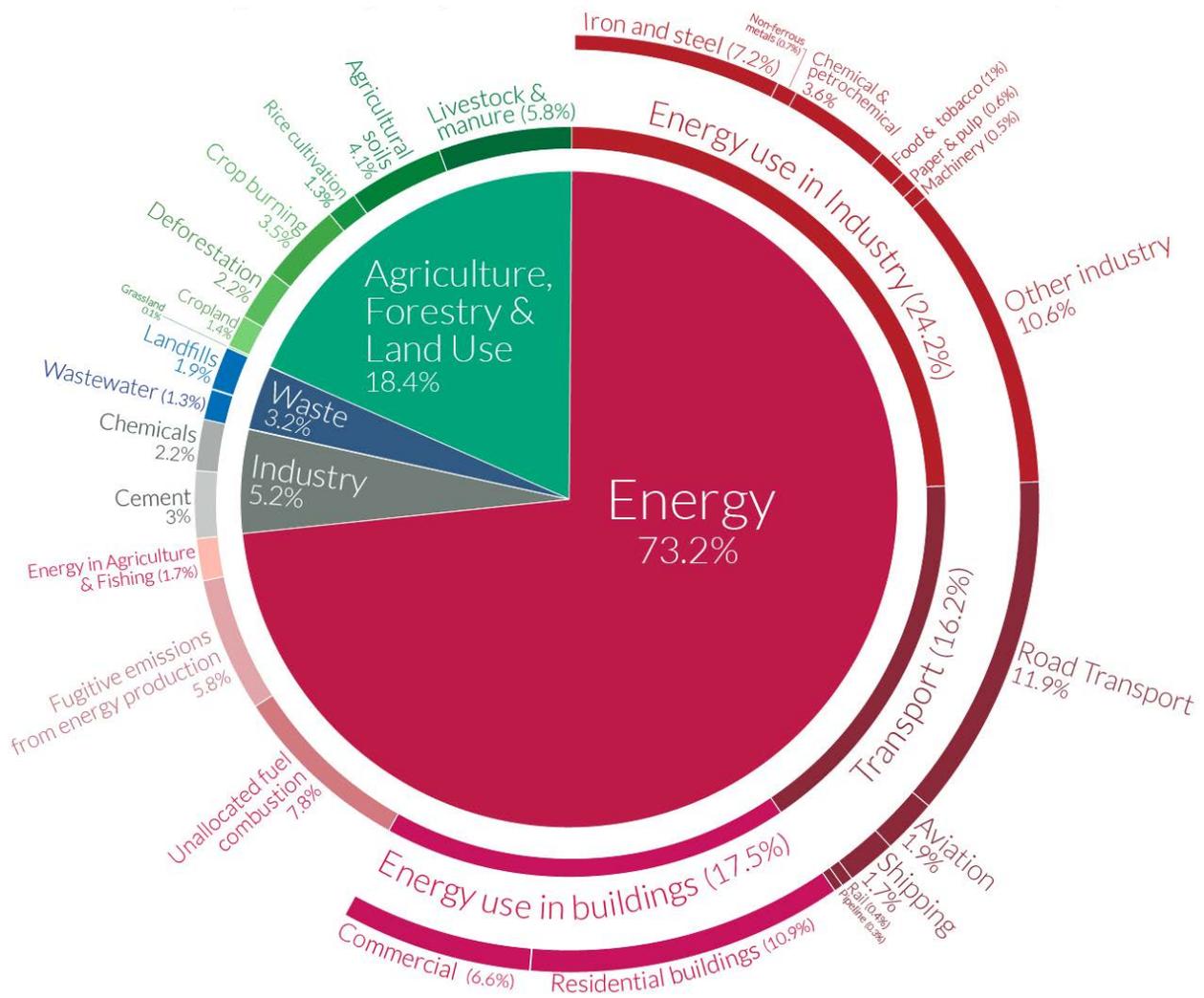


134 million metric tons of methane were released from the energy sector in 2019, with the natural gas value chain emitting the largest share of energy sector emissions. 40 percent of methane emissions derive from natural sources, such as wetlands. The largest anthropogenic source of methane emissions is the agricultural sector, emitting approximately a quarter of all global methane emissions. Source: IEA, 2020.

Decarbonization policies that cover economywide and sector-specific targets could have dramatic impacts on the future of natural gas. Figure 10 shows global greenhouse gas emissions (GHG) by source, sector,

and subsector; the industrial sector was the largest source of emissions in the world in 2016, contributing 24 percent of the total.

**Figure 10: Global Greenhouse Gas Emissions by Sector, 2016<sup>24</sup>**

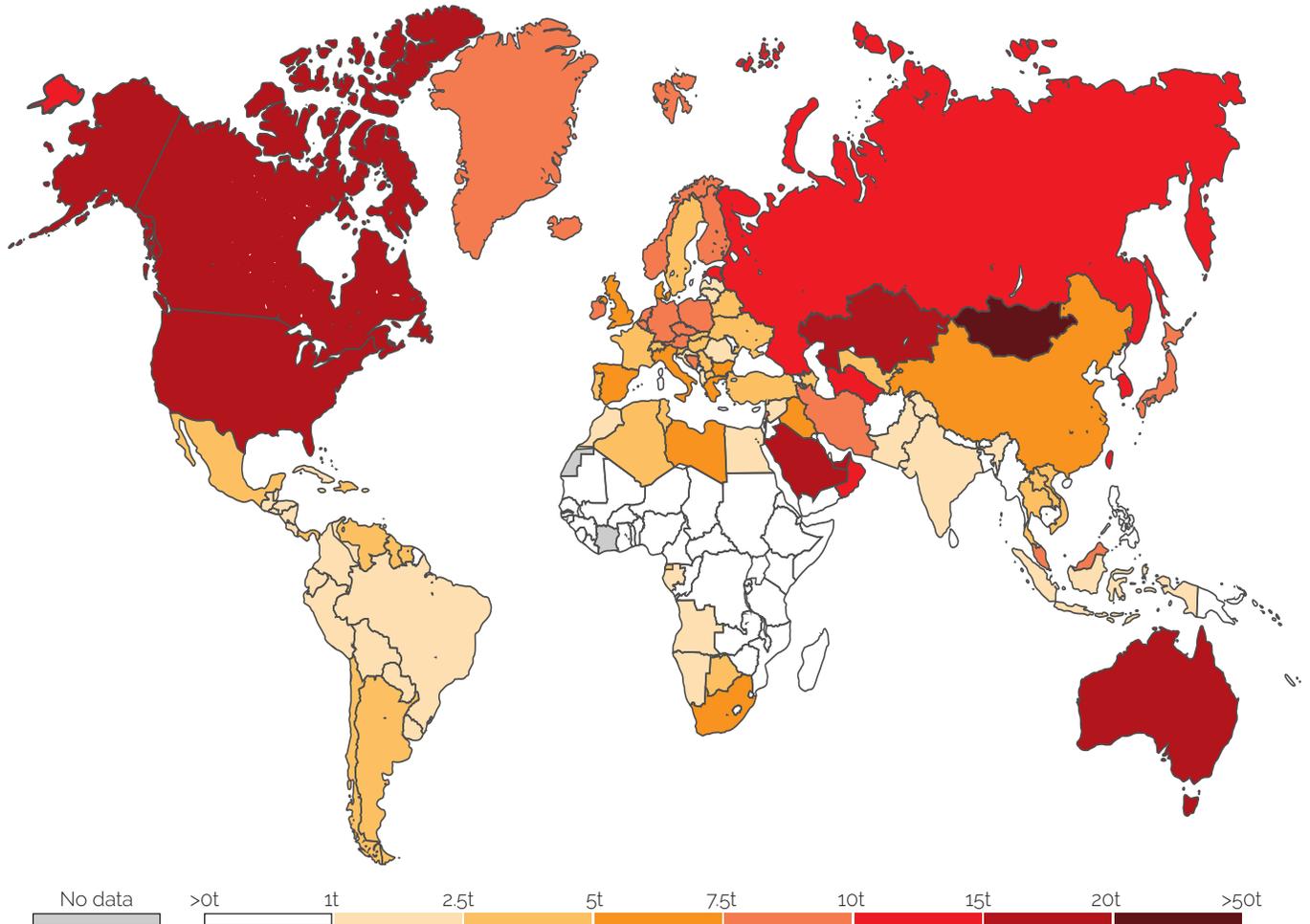


Source: Our World in Data, 2020. Data from Climate Watch, 2020.

Energy demand, economic growth, and environmental policies in developing countries will be major drivers of the world's ability to reach deep decarbonization targets by midcentury. Fossil fuel emissions vary

greatly by region and country, and on a per capita basis, and will and should affect policies for emissions reductions in the developed and developing world. Per capita emissions by country are found in Figure 11.

**Figure 11: Per Capita CO<sub>2</sub> Emissions by Country, 2019 (tons)**



*This map shows per capita CO<sub>2</sub> emissions from fossil fuel use for energy and cement production. Land use is not included.  
Source: Our World in Data, 2020. Data from the Global Carbon Project, 2020; BP, 2020; The Maddison Project, 2018; Gapminder, n.d.; UN Department of Economic and Social Affairs, 2019.*

## The Evolution of Climate Policy

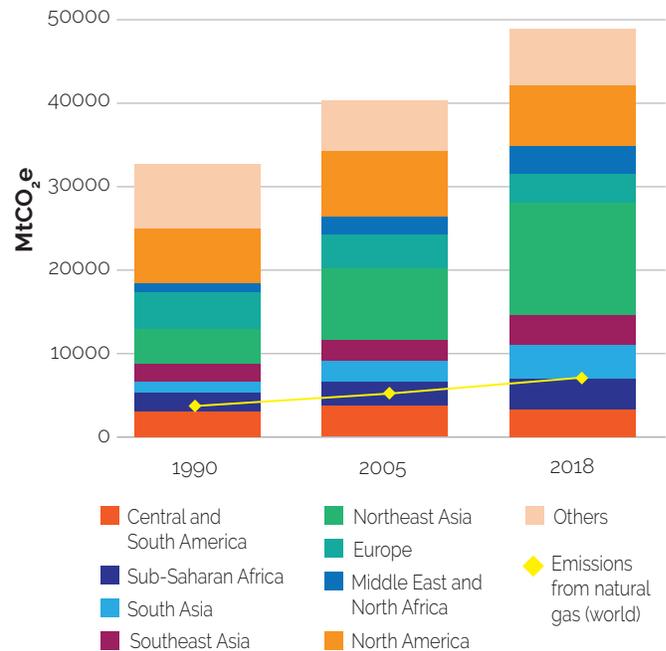
Since the start of climate negotiations in the 1990s, countries outside of North America and Europe have stressed the need to balance emissions reductions with the imperatives of economic growth and human development—exemplified by Nationally Determined Contributions (NDCs) that are contingent on gross domestic product (GDP) growth. This differentiation has historically been a flashpoint in international climate negotiations.

The need for diversified approaches for addressing climate change is reinforced by recent regional trends in emissions. Since 2005, emissions have declined in Europe, North America, and Central & South America, though not at a pace consistent with net-zero targets (Figure 12).<sup>25</sup> In every other region, emissions have increased, driven by growing populations and industrializing economies; the highest-emitting countries in these regions, China and India, are now the largest and third-largest emitters in the world.

The policy response to climate change has and will continue to impact global gas markets. In the wake of the Paris Agreement and the Intergovernmental Panel on Climate Change's Special Report on Warming of 1.5°C, governments, companies, and other market players are adopting or considering adopting net-zero emissions targets (see Figure 13 for national commitments as of February 2021). The new focus on net-zero emissions raises questions about the role of natural gas in a deeply decarbonized world,

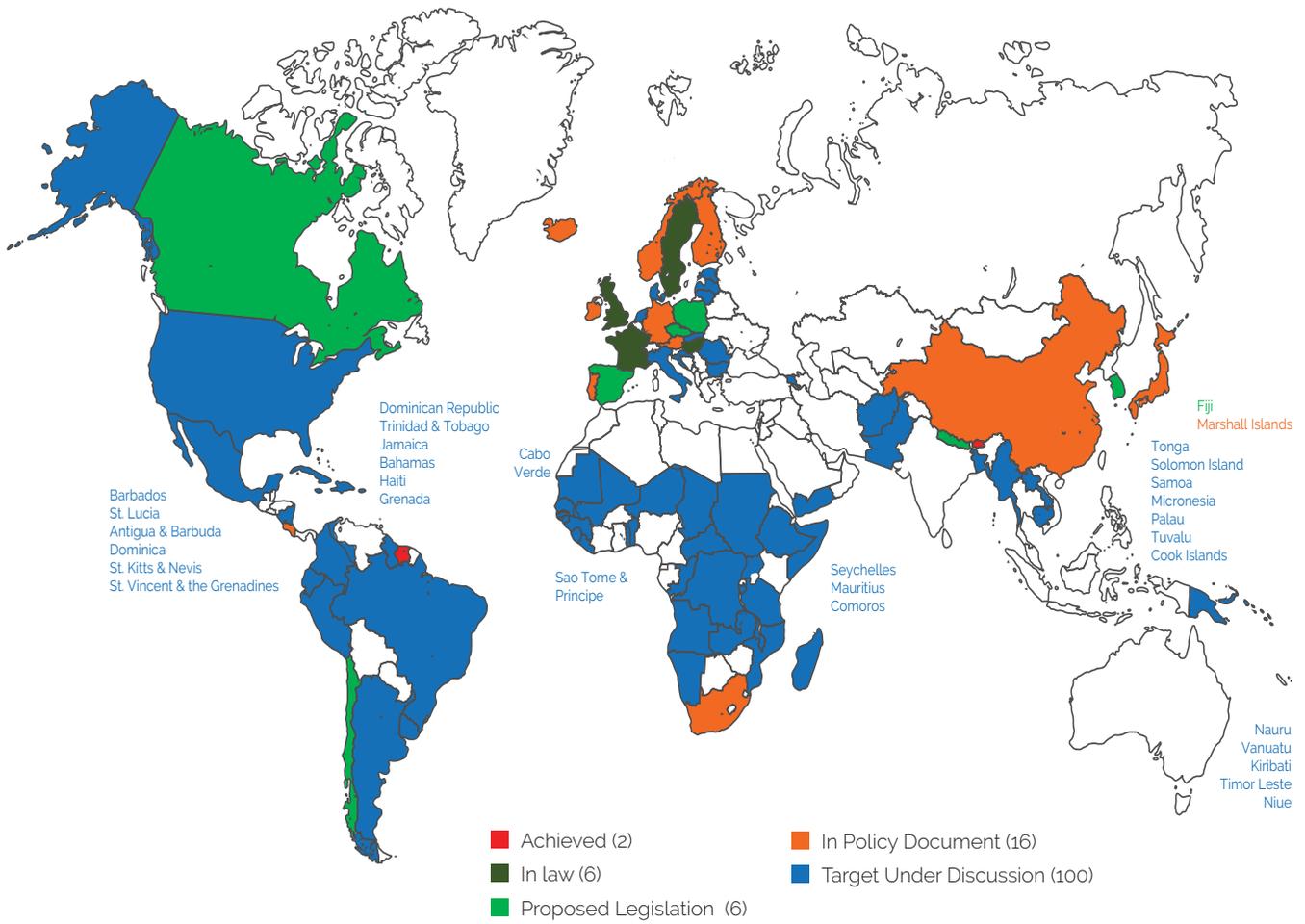
how to curb fugitive emissions, whether and where natural gas can serve as a “bridge” to zero-carbon solutions, and what the implications are for new gas infrastructure investment. Strategies to help achieve net-zero targets have also resulted in innovation in and expansion of new technologies, such as renewable energy sources, which have seen steep cost declines.

**Figure 12: GHG Emissions by Region, 1990-2018<sup>26</sup>**



*This graph shows GHG emissions globally and by region over time, as well as the share of global emissions from natural gas use. In most regions, emissions have either increased or stayed relatively constant between 1990 and 2018. Some regions, like Europe, Central & South America, and North America, have reduced GHG emissions since 2005. The “Others” category includes Australia, New Zealand, and Eurasia. Data from Climate Watch, 2021.*

**Figure 13: Countries that Have Achieved or Have Laws, Policies, or Proposals Under Discussion for Net-Zero Emissions Targets<sup>27</sup>**

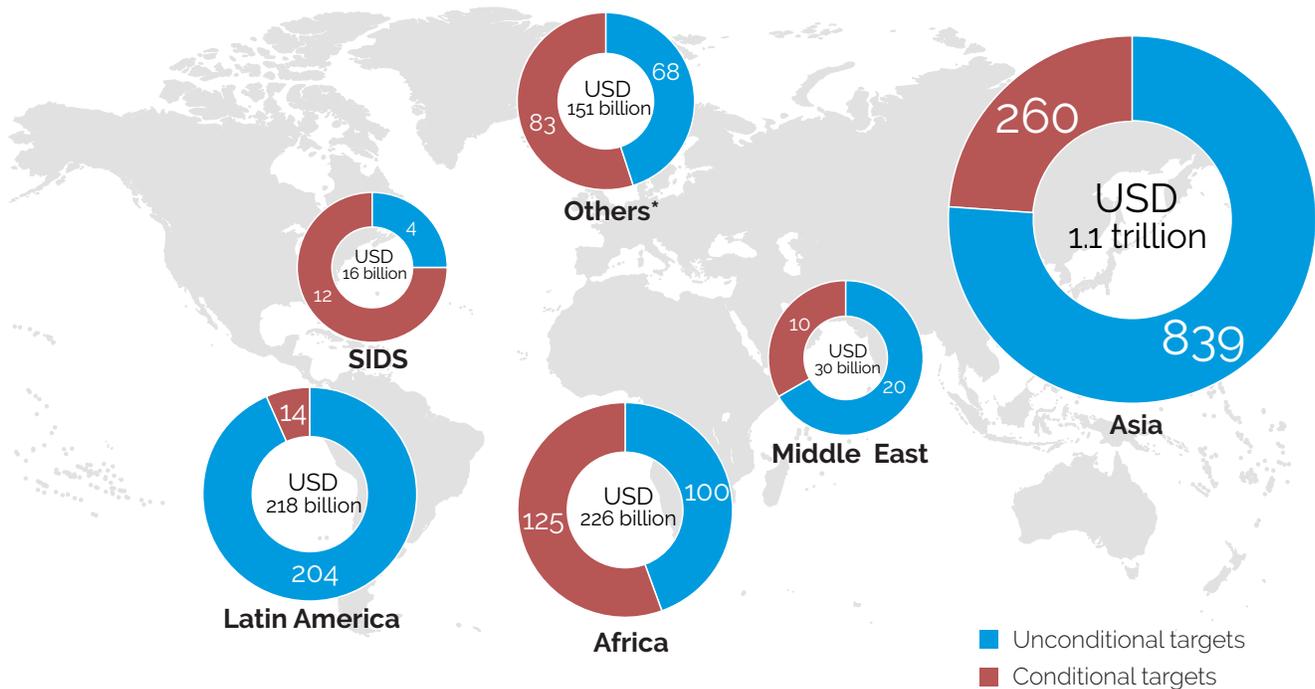


130 countries have either achieved, implemented, or are considering implementing net-zero targets.  
Data from Energy & Climate Intelligence Unit, 2021.

Meeting net-zero targets will require massive investments in technology, infrastructure, and innovation. Figure 14 shows investment estimates needed in key regions to meet 2030 conditional and unconditional renewable energy deployments implied by NDC targets submitted as part of the Paris

Agreement. Investments are substantial and vary widely by region. The levels of these investments and the availability of funds could affect energy investments broadly, including investments in natural gas.<sup>a</sup>

**Figure 14: Total Investment Needed by 2030 for Implementation of Renewable Energy Targets in NDCs<sup>28</sup>**



*"Others" includes Eurasia, Europe, Oceania, and North America; SIDS stands for "Small Island Developing States."   
 Source: International Renewable Energy Agency, 2017.*

<sup>a</sup> These data are from 2017, the year the Trump Administration announced the United States' withdrawal from the Paris Accord. The United States has re-engaged on national climate commitments and targets and the Biden Administration has announced a 50 percent emissions reduction target by 2030.

## GLOBAL TRENDS THAT COULD IMPACT NATURAL GAS MARKETS

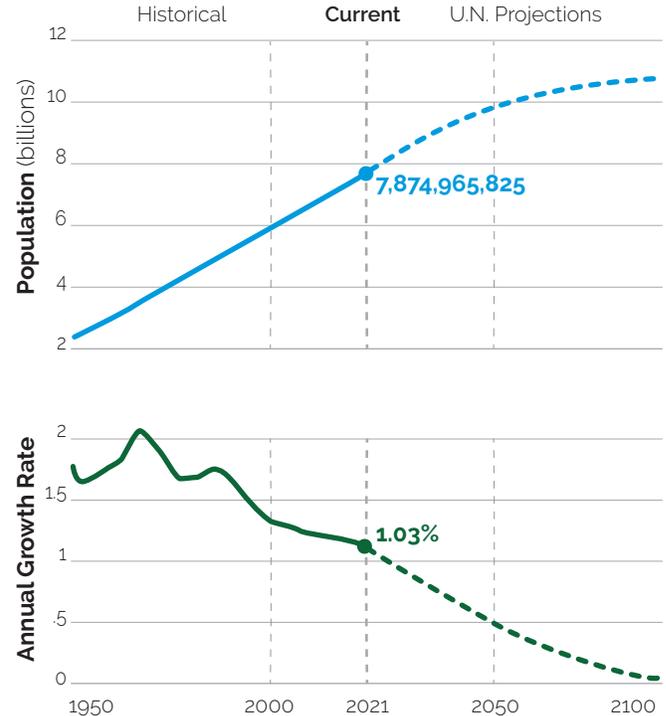
To place this discussion in context, it is important to understand some overarching trends that will affect energy supply and demand going forward, including natural gas supply and demand in a net zero world. Global population growth, urbanization, energy and electricity demand growth, sectoral emissions, climate policy changes, and sources of other pollutants are essential for understanding the role of natural gas in a deeply decarbonized world.

### Population Growth

Population growth, and its global distribution, is a key driver of energy demand, including natural gas demand. Figure 15 shows total world population and the annual growth from 1950 to 2021, with projections to 2100. Between 1950 and 2021, the world's population grew by almost six billion, quadrupling in 70 years.

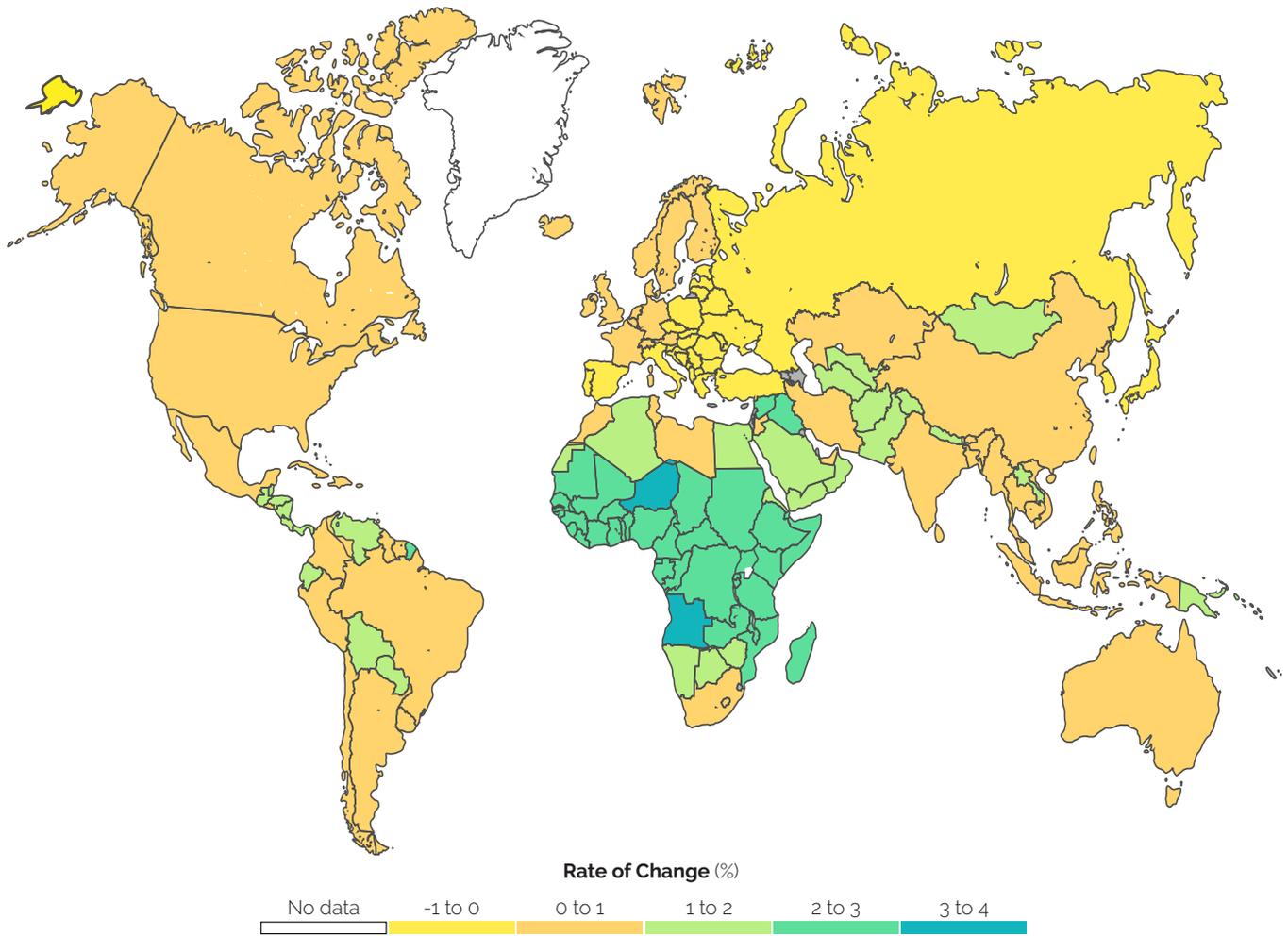
This growth is expected to continue, albeit at a slightly slower rate, and with significant differences among regions. Figure 16 highlights how regions like Sub-Saharan Africa, Central America, and MENA are projected to grow more quickly than the rest of the world between 2025 and 2030. This growth takes place within a critical decade for addressing climate change.

**Figure 15: World Population and Annual Growth Rate, 1950-2021 with Projections to 2100<sup>29</sup>**



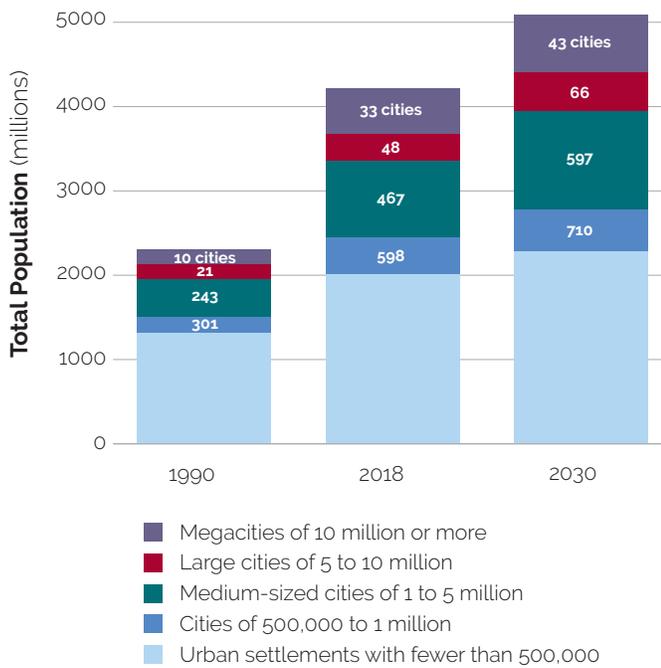
Source: Macrotrends, 2021. Data from UN Department of Economic and Social Affairs, 2019.

**Figure 16: Average Projected Annual Rate of Population Change by Country, 2025-2030<sup>30</sup>**



*The reported estimates for rate of population change use the "medium-variant" projection.  
Source: UN Department of Economic and Social Affairs, 2019.*

**Figure 17: Global Urban Population by Size Class of Settlement, 1990-2030**



This figure shows the population classification and number of cities, as well as the global urban population, in 1990, 2018, and 2030. Urbanization is expected in many regions—the UN anticipates that, between 2018 and 2030, the world will add 10 new megacities with populations of 10 million or more people and 18 new large cities with populations of between 5 and 10 million people. Source: UN Department of Economic and Social Affairs, 2019.

## Urbanization

Urbanization is another key trend that will affect the future of the global energy system. The United Nations (UN) estimates that by 2030 there will be 10 new megacities globally with over 10 million inhabitants each, and around 150 new medium and large cities (Figure 17). Large-scale power generation and new transportation infrastructure will likely be needed to meet these cities' needs. Many factors, including climate policy commitments, as well as cost, timing, and overall system needs, will influence how these trends are met.

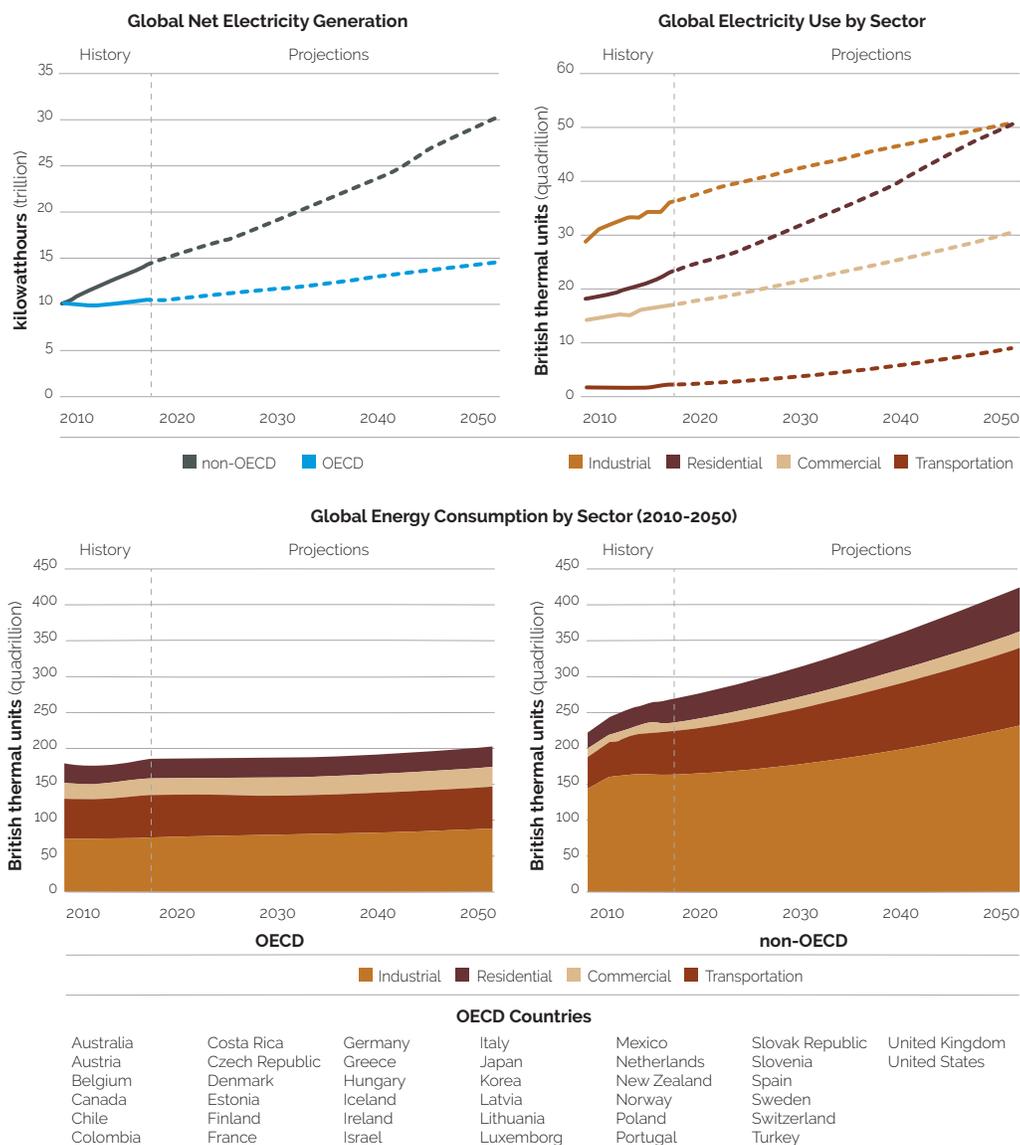
## Global Energy Demand

Population growth and urbanization have historically correlated with growth in energy consumption. In many regions, this has resulted in increased GHG emissions and air quality degradation. Existing regional and country-level variation in emissions and the links between energy demand and growth necessitate climate policy that considers different issues faced by developing and developed countries.

A comparison between energy trends of the developed economies that comprise the Organization for Economic Cooperation and Development (OECD) and non-OECD economies illustrates these variations. Overall energy demand is expected to grow less quickly in OECD countries than in non-OECD countries; non-OECD energy demand could increase by two-thirds by 2050 while OECD demand remains flat such that non-OECD energy demand is roughly twice OECD demand by 2050. This difference

in energy demand is especially stark in the industrial and transportation sectors.<sup>31</sup> By midcentury, non-OECD electricity demand could also be roughly double that of OECD countries (Figure 18).<sup>32</sup> The projections of dramatic increases in electricity consumption in the residential and industrial sectors is important for energy system planning, as these sectors present unique challenges and opportunities for decarbonization.

**Figure 18: Global Energy Indicators with Projections, 2010-2050**<sup>33,34</sup>



This figure shows energy trends between non-OECD and OECD countries, and specific trends in electricity and sectoral energy use. Non-OECD countries are anticipated to generate and consume significantly more energy and electricity than OECD countries through 2050. These differences are especially clear at the sectoral level—non-OECD countries' comparatively higher energy consumption in the industrial and transportation sectors reflects increasing industrialization and economic development in these economies over time. Source: EIA, 2019.

Today, per capita emissions in OECD countries are generally higher than in non-OECD countries. At the same time, many non-OECD countries have higher populations and population growth projections than their OECD counterparts, and these countries are understandably interested in economic development and improving quality of life for their citizens. As a result, they will likely consume more energy. Absent extremely aggressive mitigation actions, these trends present a perfect storm for global GHG emissions.

IEA developed two scenarios of primary energy consumption between now and 2050 that provide helpful global context for anticipating the future of natural gas in a deeply decarbonized world.<sup>35</sup> The first is the Stated Policies Scenario (STEPS), which estimates future energy demand based on existing and announced policies, a scenario that falls far short of global climate goals. This scenario forecasts global energy demand between 2010 and 2040 to increase by about 27 percent. The second IEA scenario, the Net-Zero Emissions by 2050 Scenario (NZE), assumes that countries implement new policies consistent with limiting the rise of global average temperature to 1.5 C.

The STEPS scenario and the NZE scenario suggest different trajectories for the future role of natural gas. Under the STEPS scenario, natural gas use increases by more than 45 percent by 2050, with a relatively consistent annual growth rate. The NZE scenario suggests that natural gas use peaks in the mid-2020s and declines by 55 percent by 2050 relative to today. Despite this sizable reduction in demand, IEA finds that natural gas may make up roughly 10 percent of the 2050 fuel mix, in part due to deployment of CCUS

plants to manage natural gas's emissions intensity, and limited industrial combustion. This finding highlights continued but more limited roles for natural gas in a deeply decarbonized future.

### Air Quality Concerns

In addition to addressing climate change, countries are also grappling with other environmental challenges, such as the need to improve local air quality. According to the World Health Organization (WHO), 80 percent of people living in urban areas are exposed to poor air quality,<sup>b</sup> with the highest exposures in low- and middle-income countries. This is a crucial public health concern, causing 7 million premature deaths annually.<sup>36</sup> Many of the major sources of air pollution are combustion of fuels or biomass for energy, with over 3 billion people—in both urban and rural areas—relying on polluting technologies<sup>c</sup> for household cooking, heat, and light. Some air pollutants, such as ozone and black carbon, can also have impacts on the climate. Natural gas—which emits relatively lower quantities of pollutants such as sulfur, mercury, nitrogen oxides, and particulates than other fuels—can help address these issues in some places.<sup>d,37</sup>

### Impacts of the COVID-19 Pandemic

The COVID-19 pandemic and its aftereffects create further uncertainty for the global energy ecosystem, including for natural gas. The pandemic and ensuing economic contraction led to a 5 percent dip in total energy demand, including a 3 percent dip in natural gas demand.<sup>38</sup> Falling oil prices and an LNG oversupply both impacted the global gas market. While global consumption is expected to recover

b Above the WHO-recommended level of 10 micrograms per cubic meter.

c Such as biomass, coal, or kerosene.

d According to the Union of Concerned Scientists, "Cleaner burning than other fossil fuels, the combustion of natural gas produces negligible amounts of sulfur, mercury, and particulates. Burning natural gas does produce nitrogen oxides (NOx), which are precursors to smog, but at lower levels than gasoline and diesel used for motor vehicles. DOE analyses indicate that every 10,000 U.S. homes powered with natural gas instead of coal avoids the annual emissions of 1,900 tons of NOx, 3,900 tons of SO<sub>2</sub>, and 5,200 tons of particulates. Reductions in these emissions translate into public health benefits, as these pollutants have been linked with problems such as asthma, bronchitis, lung cancer, and heart disease.."

somewhat from 2020 levels in 2021, it is unclear what the pace of recovery will be—though it certainly will be uneven across the globe.

The combination of inexpensive natural gas, more advanced and accessible technologies, emerging industrialized economies, and growing LNG markets has expanded natural gas use in many countries, sectors, and subsectors, while making the global gas system more interconnected. The lingering effects of the pandemic, climate policy, and many other factors contribute to uncertainty around the future of natural gas. This uncertainty poses problems for investment decisions and capital-intensive infrastructure development in all stages of the natural gas value chain.

# Cross-Cutting Insights from the Regional Workshops

Ten major insights emerged from the workshop discussions that cut across the energy sectors and economies of all regions.

## **1** In all regions, workshop participants expressed strong commitments to reducing greenhouse gas emissions and each region had a distinct approach to mitigation.

There is consensus among experts that reducing emissions is necessary to slow the most serious global and regional impacts of climate change, underscored by the strong country-level emphasis on meeting Nationally Determined Contributions (NDCs) as part of the 2015 Paris Agreement. While each region is taking a series of local approaches to emissions reductions, ranging from electrifying on-road transportation in South Asia to scaling back coal generation in Northeast Asia, it is uncertain whether local solutions are sufficiently robust to translate into national emissions reductions in many regions of the world.

The global clean energy transition will take considerable time and resources due to the effort required to replace incumbent systems, the lack of cost-effective low-carbon alternatives for key industrial processes, and the absence of a coordinated approach to deep decarbonization in some regions of the world. Moreover, other policy objectives are considered equally important to significantly reducing carbon emissions; among them are economic development, energy access, and energy security. Regional approaches to emissions reduction reflect a range of policy priorities as well as energy supply and demand dynamics, the cost and performance of clean energy technologies, existing energy infrastructure, anticipated demographic changes, vulnerability to climate change impacts, and an equitable distribution of contributions to international climate mitigation efforts.

*The global clean energy transition will take considerable time and resources due to the efforts required to replace incumbent systems, the lack of cost-effective low-carbon alternatives for key industrial processes, and the absence of a coordinated approach to deep decarbonization in some regions of the world. Moreover, other policy objectives are considered equally important to significantly reducing carbon emissions; among them are economic development, energy access, and energy security.*

## **2 There is shared agreement that there may be a continued role for natural gas in a decarbonized global economy, although there may be significant regional differences and conflicts with local decarbonization goals.**

Workshop participants expect three major demographic shifts: population growth—particularly in Sub-Saharan Africa and South Asia—urbanization, and a growing middle class. These trends will rely on expanding energy services and robust industrial sectors. One of many strategies discussed to address these trends was a continued role for natural gas, and the extent and scope of that potential role would depend on regional characteristics.

In all global regions, natural gas may be seen as a “transition fuel” for fuel switching away from more carbon-intensive fuels (especially away from coal and oil in power generation), as a feedstock for existing or burgeoning industrial sectors, as a fuel for end uses that require high-temperature heat, and as a backup fuel in multiple end use sectors. In the MENA region, natural gas and renewables are anticipated to displace oil in the power sector, and gas is seen as a means of economic diversification through industrial uses in ammonia and hydrogen production. Northeast Asia looks at natural gas as a potential substitute for both coal and nuclear. While Europe is scaling down domestic production of natural gas, it anticipates the need for some gas through at least the 2030 timeframe for hard-to-abate sectors and to phase out coal use in Central and Southeastern Europe.

In the developed world in particular, natural gas may be seen as an enabler of—and complement to—decarbonization. For example, natural gas can support the electric grid's deployment of intermittent renewables for power generation. In Europe, Northeast Asia, North America, and other regions adopting or moving toward net-zero emissions targets, any continued natural gas use will require accompanying carbon capture or alternative emissions abatement technologies. In the developing world, natural gas may be viewed as a next step for energy and economic development, improving grid reliability and managing local air quality issues.

*In all global regions, natural gas may be seen as a “transition fuel” for fuel switching away from more carbon-intensive fuels (especially away from coal and oil in power generation), as a feedstock for existing or burgeoning industrial sectors, as a fuel for end uses that require high-temperature heat, and as a backup fuel in multiple end use sectors.*

### **3 Workshop participants noted that global emissions reductions may fall far short of what would be necessary to prevent the worst outcomes of climate change, and even those countries with ambitious commitments have too few interim policies in place.**

Nations are in early stages of validating emissions reduction policy approaches. Until more is known, there is no playbook to successfully reducing emissions across all sectors at the national level, let alone at the regional or international levels. Workshop participants noted that current decarbonization activities—public and private sector investments, revamped regulatory structures to support low-carbon systems, policy incentives to switch to clean alternatives, etc.—do not always appear to closely align with Paris Agreement NDC targets for many countries in the Central & South America, Southeast Asia, MENA, South Asia, and Sub-Saharan Africa regions.

*In Northeast Asia, countries have net-zero ambitions in the midcentury timeframe. However, interim policies do not provide a clear pathway to net-zero. The region anticipates technology innovation to offset or eliminate emissions through midcentury while significantly increasing the share of natural gas and reducing the share of nuclear in the energy mix through at least 2030.*

In Northeast Asia, for example, countries have net-zero ambitions in the midcentury timeframe. However, interim policies do not provide a clear path to net-zero. The region anticipates technology innovation to offset or eliminate emissions through midcentury while significantly increasing the share of natural gas and reducing the share of nuclear in the energy mix through at least 2030.

Countries in Central & South America have struggled to develop new energy infrastructure to facilitate more ambitious climate action due to regulatory, political, and financial roadblocks. Participants in the Sub-Saharan Africa workshop mentioned the region's minimal contribution to global greenhouse gas (GHG) emissions and the conflicts inherent to addressing climate and development goals, such as energy access, economic development, and alleviation of energy poverty, simultaneously.

The interconnected nature of trade and economic systems requires a comprehensive approach to decarbonization that many policy instruments have yet to address (e.g., accounting for carbon across supply chains, cross-border adjustments for national or regional carbon pricing). In North America, for example, Canada and the United States have set ambitious climate targets. At the same time, the two countries project increased liquefied natural gas (LNG) exports, particularly to Asian markets. Emissions associated with production of LNG would accrue to greenhouse gas inventories in North America, but emissions associated with shipping and natural gas end use are either not accounted for or could fall under the responsibility of the importing nation. Policy instruments could change the dynamics of carbon accounting and other aspects of energy trading.

---

## **4 Participants found that impacts of COVID-19 on decarbonization efforts vary widely across regions.**

In Central & South America, the pandemic created major headwinds for decarbonization efforts caused by reallocation of public spending to the health sector and a narrowing of national priorities toward economic growth and job creation. Workshop participants noted that COVID-19 has highlighted to Central & South American countries the importance of developing domestic energy resources to reduce exposure to international energy price fluctuations and supply chain disruptions.

Some countries are using COVID-19 recovery efforts to provide financial support to clean energy and emissions reduction technology. In Europe, COVID-19 recovery packages fund electrification, renewables, and efficiency measures while providing little support for the natural gas industry. The United States expanded tax credits and created new government spending programs for clean energy in an omnibus government spending and COVID-19 relief bill at the end of 2020.<sup>39</sup>

---

## **5 Innovations in clean energy technologies are needed to power the growing and multi-faceted needs of regional economies while eliminating greenhouse gas emissions, many workshop participants stated.**

Existing clean technologies are perceived to be insufficient or not available at the necessary scale to meet these objectives. Clean energy innovation is critical to reducing the costs and tradeoffs of deeply decarbonizing the global economy and will shape the trajectory of every region's energy system over the coming decades. Offsets will be needed on a limited basis where direct abatement proves too complex, costly, or unjust. Promising early-stage technologies include green hydrogen, carbon dioxide removal, and carbon capture, utilization, and storage.

*Clean energy innovation is critical to reducing the costs and tradeoffs of deeply decarbonizing the global economy and will shape the trajectory of every region's energy system over the coming decades. Offsets will be needed on a limited basis where direct abatement proves too complex, costly, or unjust. Promising early-stage technologies include green hydrogen, carbon dioxide removal, and carbon capture, utilization, and storage.*

---

## **6 The cost of natural gas relative to alternative sources of energy, including renewable energy and associated technologies, will factor heavily into regional natural gas use, particularly in the power sector.**

Falling renewable energy and battery electric storage costs could reduce natural gas use in regions where gas is currently consumed or where gas infrastructure is under development. In some regions that use little to no natural gas today, future availability of low-cost clean energy technologies may mean avoiding natural gas use altogether in the energy transition; that is, regions like South Asia might transition from lower-cost fossil resources like coal to low-cost renewable generation without investing in natural gas in the interim.

There is pressure in some regions to develop more robust energy markets to support economic growth while managing energy costs. Due to Northeast Asia's reliance on LNG imports, affordability and price stability are vital to the ongoing use of the fuel in the region. Some regional actors are pushing for changes in traditional contracting and pricing, as well as mechanisms to stabilize or manage LNG price volatility.

---

## **7 Innovative business models and project financing mechanisms are needed to build out energy infrastructures.**

All regions seek to attract private investment to develop energy infrastructures that will provide energy security, abate emissions, and improve health outcomes. Regions with highly developed natural gas infrastructure, such as North America and Europe, anticipate that natural gas can displace more carbon-intensive fossil fuels like coal and provide reliable electricity generation while renewable resources and battery electric storage scale up. Through 2050, both regions also envision repurposing natural gas infrastructure for low- or zero-carbon gases like renewable natural gas and hydrogen.

Northeast Asia and Southeast Asia, regions increasingly reliant on LNG imports, continue to build natural gas infrastructure, buoyed by gas-friendly government policy and continued investment in fossil fuel projects by Asia-Pacific banks and lenders. Development and deployment of new technologies such as clean hydrogen, energy storage, and advanced nuclear will rely on creative business models and supportive policy mechanisms to drive adoption and lower costs.

---

## **8 Infrastructure investor and financial institutions are shifting their focus on low-carbon solutions.**

European banks and investors are increasingly hesitant to fund new fossil fuel infrastructure projects; this trend could impact natural gas development by Europe-based companies in regions like Sub-Saharan Africa. In other regions, investors do not yet pose roadblocks to fossil fuel infrastructure development to the same degree. Many Asian investors and banks have not limited investment in domestic and international fossil fuel ventures. Northeast and Southeast Asian countries, already some of the largest LNG importers in the world, continue to scale up LNG import infrastructure. Oil and gas infrastructure is also still seen as a reliable investment in the MENA region.

*Security of energy supply is a perennial concern across all regions, particularly in areas without sufficient domestic energy resources. In the two largest LNG importing regions today, Northeast Asia and Europe, LNG will likely continue to play a key role in energy security particularly as Europe decreases domestic natural gas production. Southeast Asia will likely increasingly rely on LNG to meet growing energy demand, particularly in its industrial sector.*

---

## **9 The need for resilient, reliable, secure energy systems is growing in importance as climate risks increase.**

Security of energy supply is a perennial concern across all regions, particularly in areas without sufficient domestic energy resources. In the two largest LNG importing regions today, Northeast Asia and Europe, LNG will likely continue to play a key role in energy security particularly as Europe decreases domestic natural gas production. Southeast Asia will likely increasingly rely on LNG to meet growing energy demand, particularly in its industrial sector.

While impacts from climate change are different across the globe, all regions are experiencing climate shifts and more severe weather, compounding security concerns and impacting electric reliability and other energy services. These effects are especially troublesome in areas like South America where key sources of clean energy generation—hydroelectric systems—are at risk due to glacial melt. Here, the opportunities to expand hydropower generation to meet increasing demand are limited and the resource is particularly vulnerable to climate change. Where infrastructure currently exists or could feasibly be developed, natural gas is a candidate fuel to manage variability in hydroelectric resources.

---

## **10** North America's significant domestic natural gas supply presents opportunities and challenges for gas use in the region and the world going forward.

Due to use of advanced extraction techniques like hydraulic fracturing and horizontal drilling, the United States has become the largest producer of natural gas in the world. Significant natural gas supply on the North American continent has driven down gas costs. Companies in the region are increasingly exporting LNG to high-demand areas like Europe and Northeast Asia, both to develop another income stream and to hedge business risks associated with national and state-level climate legislation. The low cost of North American LNG is attractive in other regions of the world, but the export growth will depend upon carbon abatement policies, such as border adjustments, the inclusion of shipping emissions in NDCs (international shipping is currently included in no nation's NDC), and other national policies to reduce emissions. U.S. LNG is also an important enabler of fuel switching from coal to natural gas generation and the associated emissions reductions.

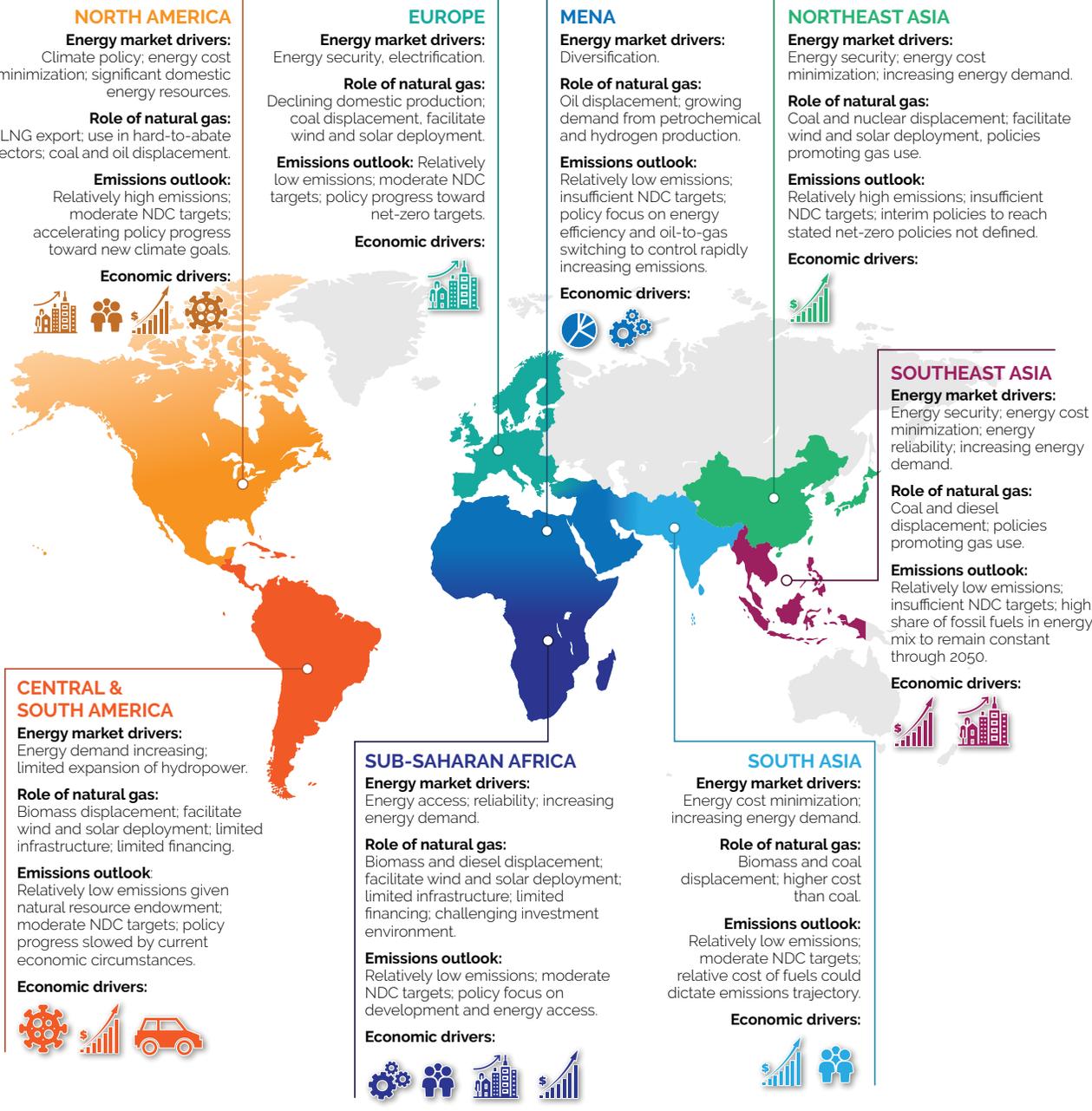
*The low cost of North American LNG is attractive in other regions of the world, but export growth will depend on carbon abatement policies, such as border adjustments, the inclusion of shipping emissions in NDCs (international shipping is currently included in no nation's NDC), and other national policies to reduce emissions. U.S. LNG is also an important enabler of fuel switching from coal to natural gas generation and the associated emissions reductions.*

# Regional Workshop High-Level Insights

The eight regional workshops highlighted the variability of circumstances for each region and how this variability will shape the role of natural gas in a deeply decarbonized world. This section summarizes key insights from the workshops divided into four categories: **economic drivers**, or demographic, development, or economic trends anticipated in the region through midcentury; **energy market trends**, or non-resource-specific trends and priorities shaping energy production and end-use; **role of natural gas**, or the current and anticipated role of natural gas in the regional energy mix; and **emissions outlook**, or the region's greenhouse gas trajectory and policy ambition.

These key insights derive from the regional workshop reports developed by the lead think tanks that summarized insights from workshop presentations and the robust discussions among workshop participants. This section of the study includes framing of regional issues and trends, as well as summaries of workshops for each region.

# WORKSHOP REGIONS & FOCUS CRITERIA



## DEFINITIONS

- Economic drivers:** demographic or economic trends
- Energy market drivers:** trends and priorities shaping energy production and end-use
- Role of natural gas:** current and anticipated role of natural gas in regional energy mix
- Emissions outlook:** greenhouse gas emissions trajectory and policy ambition

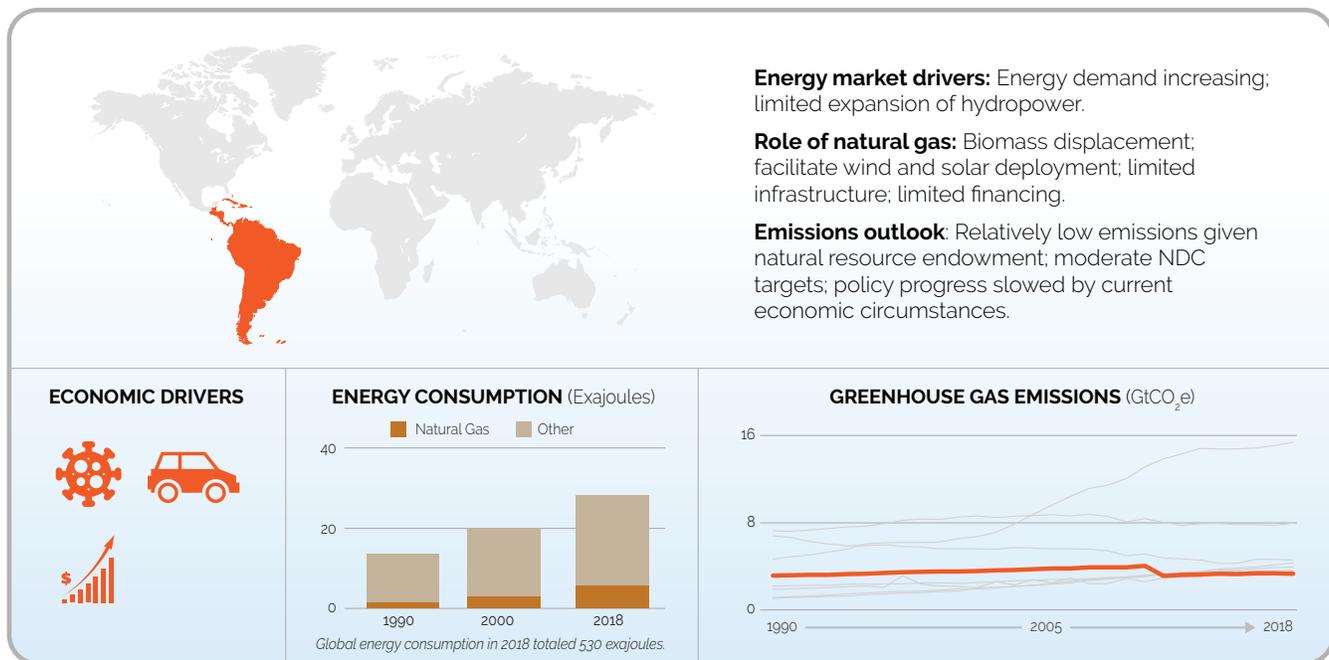
## ECONOMIC DRIVERS

- Urbanization
- Covid Recovery
- Economic Development
- Vehicle Adoption
- Industrialization
- Population Growth
- Economic Diversification

# CENTRAL & SOUTH AMERICA

The Atlantic Council's Adrienne Arsht Latin America Center and Global Energy Center hosted an invitation-only expert workshop on the future of natural gas in Central & South America in a low carbon world.

15 speakers and 40 participants from academia, think tanks and the private sector took part in the discussion. The two-day event, held under Chatham House rule, took place on December 2<sup>nd</sup> and 4<sup>th</sup>, 2020. The following is a summary of the workshop discussion.



## REGIONAL OUTLOOK

Economic development is expected to significantly increase the Central & South American region's energy demand over the coming decades. Approximately 128 million people are anticipated to join the middle class by 2030,<sup>a</sup> increasing energy consumption per capita as more people purchase appliances and vehicles.<sup>40,41</sup> The region is recovering from the COVID-19 pandemic, which has delayed the overall trend of economic development.

### Energy Market Drivers

By 2040, primary energy demand is expected to be at least 80 percent higher than it is today and electricity requirements will increase by more than 91 percent.<sup>42</sup> Many nations in South America are currently heavily dependent on glacier-fed hydropower for electricity generation, and there is evidence that these hydropower feedstocks are shrinking due to climate change (Figure 19).<sup>b,43</sup> According to IEA, by 2100,

a Ferreira et al. (2012) sets the lower bound for a middle-class income in Latin America at US\$10 per day per capita and the upper bound at US\$50 per day per capita.

b IEA analysis found that the region's hydropower capacity is expected to decrease by around 8 percent on average between 2020 to 2059 and by 11 percent on average between 2060 to 2099 compared to hydropower capacity between 1970 and 2000 due to changing climate conditions.

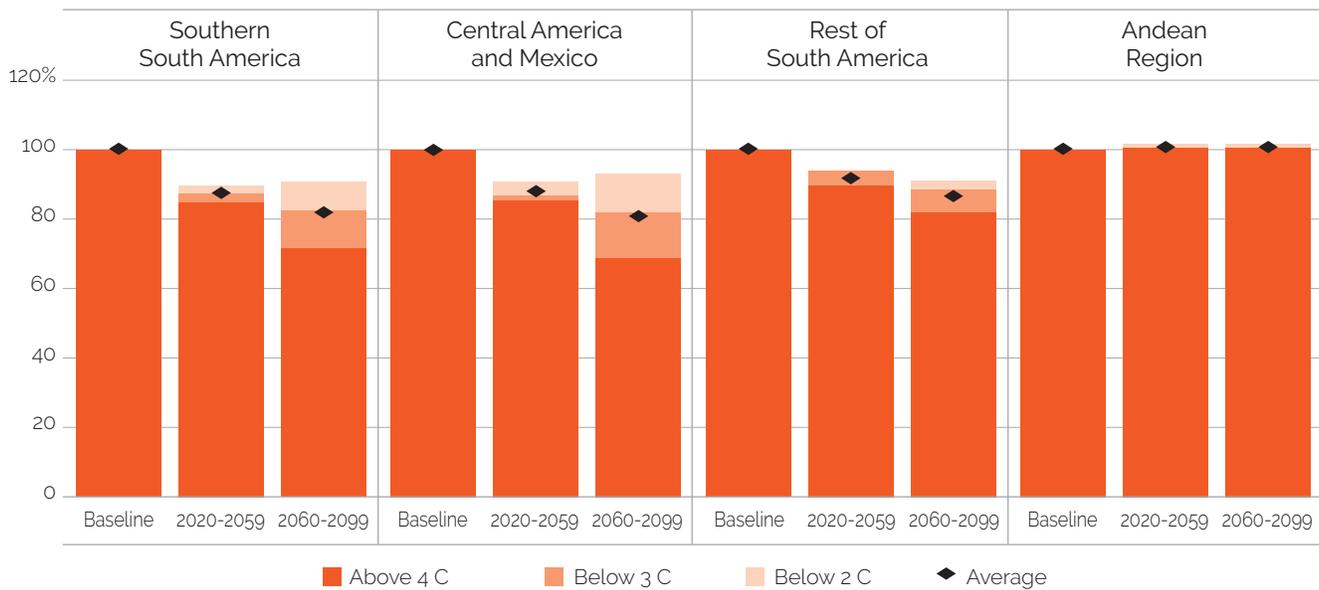
Central America, Argentina, and Chile can expect a “consistent decrease in mean hydropower capacity factors due to the decline in mean precipitation and runoff,” while Brazil, Venezuela, Paraguay, and Uruguay should expect milder decreases (Figure 20). Fuel substitution and innovation in long-term solutions for power generation will likely be necessary for several subregions.

**Figure 19: The Olivares Alfa Glacier in Chile, 1953 and 2019<sup>44</sup>**



The Olivares Alfa glacier in Chile has lost 66 percent of its ice mass since 1953. Photo credit Louis Lliboutry (top image); Alex Cattán and Marc Turrel.

**Figure 20: Changes in Hydropower Capacity Factor by Latin American Subregion, 2020-2099, Relative to 1970-2000 Baseline<sup>45</sup>**



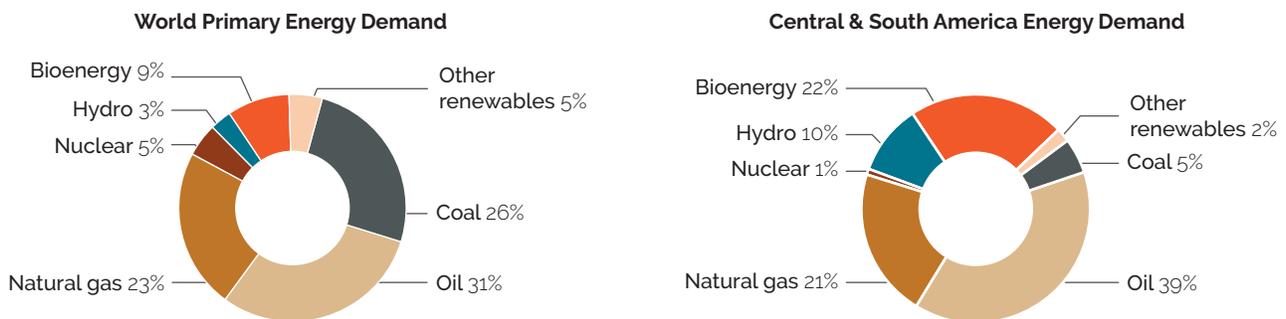
This figure shows anticipated changes in hydropower capacity factors based on three scenarios (Above 4 C, Below 3 C, and Below 2 C) representing different GHG concentrations and resulting global average temperature outcomes by 2100. Central America and the countries of Southern South America (Argentina and Chile) are projected to experience the most significantly reduced hydropower capacity factors in the region through 2100 across all scenarios. Source: IEA, 2021.

### Role of Natural Gas

Compared to the rest of the world, Central & South America rely more on hydropower and bioenergy for primary energy and significantly less on coal. Figure 21 compares global primary energy demand to that of Central & South America. Together, hydropower, bioenergy, and other renewable energy account for 34 percent of primary energy demand while coal provides 5 percent; on average globally, renewables provide for 17 percent of energy demand and coal provides for 26 percent. Shares of bioenergy, particularly in the transportation and industrial sectors, are also higher than global averages, driven by significant bioenergy production and policy support.

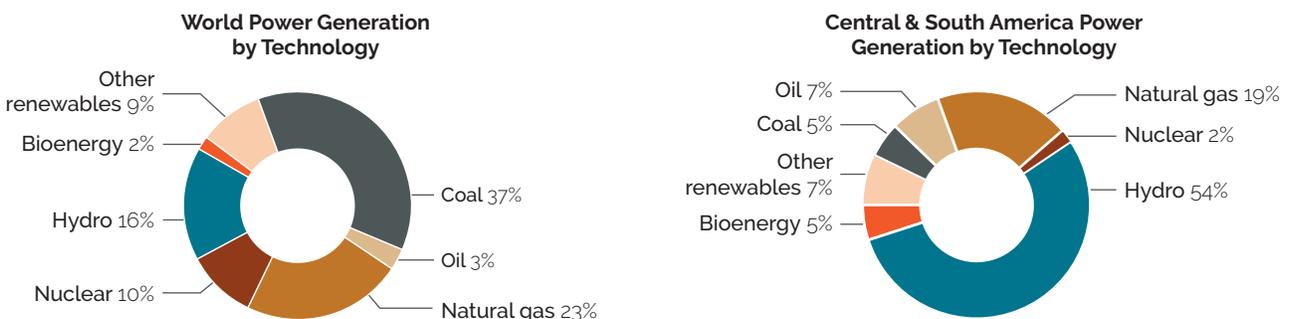
Figure 22 compares the power generation shares by technology of Central & South America to global shares. In Central & South America's electric sector, hydroelectric power comprises a much higher share of the region's power mix (54 percent) than the world average (16 percent). Bioenergy use in the power sector also exceeds global averages (5 percent versus 2 percent). The Central & South America region has the cleanest electric grid in the world driven by legacy hydropower development and increasing variable renewable deployment. As hydropower capacity factors are expected to decrease over time due to climate change and electricity demand is expected to increase, natural gas could gain market share as a back-up fuel for intermittent renewable power if gas infrastructure is built out sufficiently.

**Figure 21: Primary Energy Demand, World and Central & South America<sup>46</sup>**



Source: IEA, 2020.

**Figure 22: Power Generation by Technology, World and Central & South America<sup>47</sup>**



Source: IEA, 2020.

## Emissions Outlook

Countries in the region have committed to varying levels of climate ambition with room for improvement in implementation. In 2019, nine countries announced a target of 70 percent renewable-generated electricity by 2030. As ambition to deploy renewables in the region grows and global conversations around climate change intensify, heightened electricity demand and low potential for additional hydropower development will put pressure on the legacy electricity system.<sup>48</sup>

Table 1 provides information on Central & South America's per capita fossil fuel emissions compared to global averages, and its share of total CO<sub>2</sub> emissions from fossil fuels relative to its share of total population. Both metrics in this region overall are lower than global numbers. Caribbean island nations in the region, however, have a unique energy story compared to the region as a whole. While their contributions to global emissions are quite low, Caribbean nations' per capita emissions from fossil

fuels are very high. In Curacao for example, per capita emissions are almost 47 tons, where regional and global averages are approximately five tons. Trinidad and Tobago emits 28 tons per capita and Barbados emits 11. This difference underscores the emissions value of legacy hydropower, other renewables, and natural gas generation in the rest of the region relative to oil-dominated generation on most island nations.

**Table 1. Central & South America Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019<sup>49</sup>**

CO <sub>2</sub> per Capita per Year from Fossil Fuels	Share of World CO <sub>2</sub> Emissions from Fossil Fuels	Share of World Population
<b>2.5 tons</b>	<b>3.4%</b>	<b>6.8%</b>
4.9 tons World Average	38,017 MT World Total	7.71 Bn People World Total

42 countries in analysis. Numbers are rounded. MT = Megatons.

Data from Crippa et al., 2020.

## SUMMARY OF PANELIST DISCUSSION *(Authored by the Atlantic Council)*

The workshop hosts and participants were provided with framing questions from EFI, which can be found on page 3 of this report.

### ***The role of natural gas in the energy transition***

While the global electricity sector is responsible for 40 percent of emissions worldwide, that share is much lower for most Central and South American countries (e.g., less than 20 percent in Brazil and Colombia). Historically, countries in the region have prioritized renewable energy development over natural gas or natural gas with carbon capture development in the power sector. Workshop participants noted that the most important applications for natural gas in the region going forward is likely in power generation.

Renewables and natural gas are the only sources of generation that have increased in Latin America in recent years. Energy diversification, grid modernization, and security will be policy priorities, particularly as longer and more intense El Niño events hit the region; resilience will become a key consideration in how the region thinks about fulfilling energy demand.

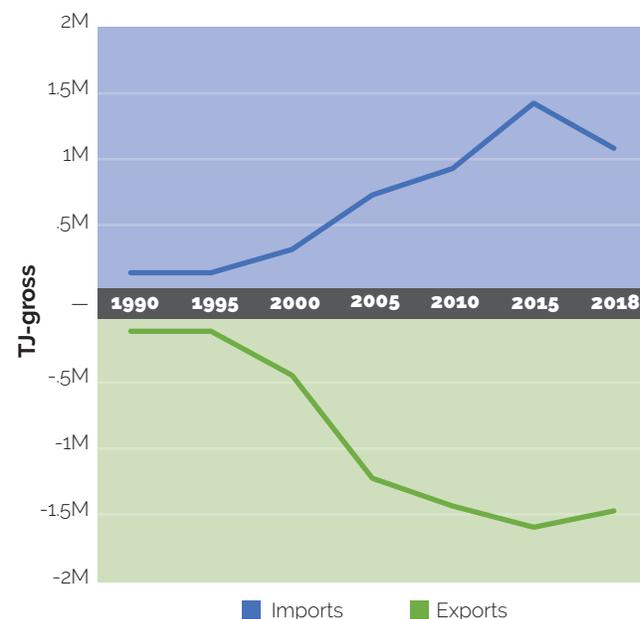
Natural gas will likely play a critical role in supporting increased variable renewable power, replacing any hydropower generation capacity lost to glacial melt (it is worth noting that as glaciers melt, there is an initial increase in water availability, then a sharp decline), reducing the share of bioenergy in energy production, and displacing other, more carbon-intensive fossil fuel use. Chile relies on coal and faces a power generation deficit, both of which gas could help address. Brazil is more diversified, but natural gas could still play a role in firming up the power supply.

Natural gas can also play an important role in decarbonization efforts in other sectors and areas. A significant share of the region's GHG emissions comes from land-use and deforestation. Natural gas

is potentially a “low-hanging fruit” to substitute for biomass consumption, thereby reducing deforestation. Gas has also made inroads as a substitute for fuel oil and diesel.

Brazil and Chile have invested heavily in natural gas power plants. However, there has been a deficit of natural gas production in the region, particularly over the past two years. Imports of natural gas have increased 14 percent over the past decade to meet increasing demand (demand in Central & South America grew 27 percent during this period), but LNG imports may increase further to satisfy gas demand (Figure 23).

**Figure 23: Natural gas imports vs. exports in Central & South America<sup>50</sup>**



*Natural gas imports to Central & South America have generally increased over time, despite a dip between 2015 and 2018. Data generated on IEA website comparing natural gas imports versus exports in Central & South America. Data from IEA, 2021.*

Despite recent deficits in hydrocarbon development, existing regional natural gas reserves are adequate to cover consumption for the next 30 years or more and opportunity exists to grow regional production. Natural gas infrastructure projects in Trinidad and Tobago and Brazil coming online over the next few years are anticipated to increase gas supply, putting downward pressure on price in the region and potentially accelerating natural gas' share of energy demand.

### **Key economic and regional trends driving natural gas demand**

Population growth rates in the region are declining, and industrial production is not expected to expand significantly. For many countries in Central & South America, natural gas, wind, and solar power will be needed to fill new residential electricity demand as the middle class grows and to supplement hydropower. Investment in wind and solar is currently concentrated in Brazil and Chile. As countries in the region increasingly turn to variable renewable energy resources, the roles of oil and coal in the energy mix are expected to decline. Natural gas may continue to be a necessary complement to renewable energy, particularly in the power generation and possibly in the transportation sectors.

The integration and adoption of emerging energy sources will vary on a country-by-country basis. Brazil, for example, has high industrial demand, while other countries have more significant residential and commercial demand. Energy- and heat-intensive industrial processes are typically more challenging to electrify than residential and commercial end uses and may require natural gas or other fossil fuels as industrial technologies advance, suggesting that Brazil may have an ongoing need for natural gas for industrial processes.

Most energy imports in the Central & South America region are liquid fuels, and the high cost of these fuels impacts the region economically. To reduce reliance on these imports and lower costs, regional

*Most imports in Central & South America are liquid fuels, and the high cost of these fuels impacts the region economically. To reduce reliance on these imports and lower costs, regional governments have expressed interest in diversifying energy use. This diversification could create an opportunity to expand natural gas use. However, the region's fiscal deficit in the wake of COVID-19 will hinder governments in their ability to invest in new infrastructure projects. Thus, the private sector will need to play an important role in developing any new natural gas infrastructure.*

governments have expressed interest in diversifying energy use. This diversification could create an opportunity to expand natural gas use. However, the region's fiscal deficit in the wake of COVID-19 will hinder governments in their ability to invest in new infrastructure projects. The private sector will need to play an important role in developing any new natural gas infrastructure.

### **Major drivers of regional energy supply and demand**

The region has been hit hard by COVID-19; the economic and social effects of the pandemic have exacerbated the negative impacts from the end of the commodity "boom cycle" in the 2000s, when Brent crude peaked at \$140 per barrel in June 2008 and fell to \$45 per barrel by December 2008; and in the 2010s when Brent crude peaked at \$125 per barrel in April 2011 and fell to \$35 per barrel in January 2016. Political crises that emerged throughout the region before COVID-19 are expected to persist in its wake. Pandemic response may shift priorities away from climate change and the energy transition in favor of recovery and healthcare infrastructure.

*In the short-term, workshop participants said that natural gas development and consumption can align with the post-COVID-19 economic recovery of countries throughout the region (e.g., its use in the power sector could reduce electricity prices) while also preparing countries for longer-term emissions reductions. Natural gas development may, however, be slowed by macroeconomic challenges, political instability, and regulatory frameworks that disincentivize critical foreign direct investment.*

Countries dependent on oil and gas production (e.g., Trinidad and Tobago) are expected to continue investing in domestic hydrocarbon sectors, even in the face of market headwinds, due to their reliance on hydrocarbon revenues. Despite economic and political challenges, workshop participants described the region as “open for business” with significant interest in attracting private and foreign direct investment, particularly in energy development.

COVID-19, in part, has demonstrated to some countries in the region the importance of developing domestic markets and not solely relying on international markets and trade. Overall, a transition in the region toward domestic market development is underway; this includes broader infrastructure and development goals in banking and telecom, as well as in energy.

At the same time, the region is expected to realize slower economic and population growth over the coming years compared to other regions, and regional energy demand is also expected to grow more slowly than in other regions. In general, workshop participants expressed the view that creating more dynamic infrastructure and changing regulation

should be priorities for Central & South American countries that will have longer-term effects on the energy mix.

Workshop participants discussed two potential opportunities for countries in the region to tackle the dual challenge of economic recovery and energy transition goals. First, countries could use stimulus spending to focus economic recovery investment on new infrastructure development that supports the energy transition; and second, domestic energy subsidies could be reduced or eliminated, and these funds could be allocated instead to sectors and individuals.

### ***The range of potential futures for natural gas markets***

Natural gas can serve as a transition fuel from coal and bioenergy to the emerging renewable system in the region. In the short-term, workshop participants said that natural gas development and consumption can align with the post-COVID-19 economic recovery of countries throughout the region (e.g., its use in the power sector could help reduce electricity prices) while also preparing countries for longer-term emissions reductions. Natural gas development may, however, be slowed by macroeconomic challenges, political instability, and regulatory frameworks that disincentivize critical foreign direct investment. The economic stress of COVID-19 on both governments and the private sector may also challenge future energy investments in the region.

Colombia was highlighted as a case study to illustrate the multiple factors impacting development of domestic gas markets. Participants noted that the Colombian government has provided comprehensive climate and energy transition plans—the country set a 51 percent emissions reduction goal by 2030 and recently upgraded its NDC to reflect increased energy transition ambition (though there is no national policy to reduce transportation emissions). The country's

natural gas industry has signaled interest in expanding its role in the economy beyond that of a bridge in the clean energy transition,<sup>c</sup> but natural gas demand in Colombia has not been increasing and domestic producers cannot compete at current energy prices. These dynamics have prompted discussions around pursuing shale development as an export option that could fuel in-country economic growth instead of developing the domestic market and using the gas for domestic end uses.

An important question for the region going forward is how to manage any energy shortages over the next decade, particularly with at-risk glacial feedstocks to hydropower generation and a dearth of projects under development that could help meet demand. Addressing these declines may involve a key role for natural gas, but how countries intend to square potential emissions increases from replacing hydropower with natural gas with climate goals remains to be seen.

### ***NDCs and climate targets***

Participants expressed the view that Central & South American countries' Nationally Determined Contributions (NDCs) and compliance with those targets are lagging compared to most other regions. Emissions in the region did decrease in 2020 but only as a temporary effect of COVID-19; emissions are expected to return to their higher levels as economies recover.

*Central and South America's high electrification rate and the power sector's low share of emissions give the region a head start in transitioning to clean power sources, but harder-to-abate sectors remain a challenge.*

According to data from Climate Action Tracker, only Costa Rica's NDCs were compatible with a two-degree warming target.<sup>51</sup> Costa Rica is the most successful at transitioning thus far, with nearly all its energy needs currently fulfilled by renewable energy sources and additional ambitious climate goals in place. Nicaragua, Haiti, and Chile appear to be in position to reach their targets, but Chile's new 2030 NDC target is still inconsistent with 2 degrees of warming.<sup>52</sup>

Brazil, Argentina, and Paraguay are furthest from compliance. Brazil still lags behind its targets despite its 2030 renewable energy goals and progress on electrification. Argentina is struggling to meet short-, medium-, and long-term targets, facing issues with infrastructure financing. Most countries in the region announced they would establish new NDCs five years after the Paris Agreement, but with current targets still out of reach, it is uncertain whether new targets will be ambitious enough or possible to achieve; the COVID-19 pandemic has further complicated progress on targets.

### ***Climate policy impact on natural gas supply and demand***

Central & South America's high electrification rate and the power sector's low share of emissions give the region a head start in transitioning to clean power sources, but harder-to-abate sectors remain a challenge. One decarbonization priority must be the transportation sector. Latin America has the highest

<sup>c</sup> According to the IEA, natural gas comprised 14 percent of 2019 power generation and 26 percent of 2019 total energy supply in Colombia.

transportation growth rate in the world, contributing to local pollution and air quality concerns as well as to climate change. Recent country-level pushes for decarbonization policies, including for a national carbon tax in Colombia and a “national registry of mitigation” in Peru, show promising models as the region begins to become more ambitious in its climate goals.

Panelists also stressed that more bilateral and multilateral support is needed for Central & South American countries to recover from the pandemic and advance the energy transition at the same time. COVID-19 has even further constrained countries’ ability to borrow, disadvantaging them in recovery compared to developed and Organization for Economic Co-operation and Development (OECD) countries<sup>d</sup> outside the region. Countries may not be able to afford energy transition initiatives, particularly if those initiatives affect important employment sectors, such as hydrocarbon production. A focus on short-term priorities—and accompanying neglect for long-term goals—may hinder advancements in the energy transition.

In addition to these trends, workshop participants believe decarbonization initiatives should begin with fuel regulations and public transport, as a lack of necessary infrastructure will delay any shift to electric vehicles (EVs) in the region. With policy support, growing EV deployment could drive major growth in power demand throughout the region. If that increased power demand is not met by renewables, EV deployment could lead to higher demand for fossil fuels, including natural gas, in the power sector.

### ***Substitutes for natural gas in the 2030 and midcentury timeframes***

Hydroelectric power’s significant role in the regional energy mix is projected to change, with little potential for growth. The effects of climate change could also

*Chile has expressed interest in developing and scaling up hydrogen for use in transportation. The country anticipates high vehicle adoption and aims to supplement current private sector investment in electrified buses with hydrogen. Deployment of hydrogen could lessen the extent of required transportation electrification, reducing increased power sector demand and consequently additional natural gas use in power generation. The country is also discussing hydrogen for use in mining and other industrial processes, which could displace natural gas or more carbon-intensive fuels used to power these processes.*

constrain hydropower resources in the region, forcing countries to find new sources of generation to replace any lost renewable power. Replacing this supply while increasing electrification will be a priority over the medium-term. Development of other renewable technologies such as wind and solar could potentially replace natural gas, depending on how quickly and effectively renewable technologies are deployed and how rapidly long-duration storage options are developed. Liquefied petroleum gas, which can create more flexibility for electricity demand in countries across the region, is another energy source that, like natural gas, can address deficits in energy generation.

Chile has expressed interest in developing and scaling up hydrogen for use in transportation. The country anticipates high vehicle adoption and aims to supplement current private sector investment in electrified buses with hydrogen. Deployment of hydrogen could lessen the extent of required transportation electrification, reducing increased

---

<sup>d</sup> Colombia and Chile are OECD member countries.

power sector demand and consequently additional natural gas use in power generation. The country is also discussing hydrogen for use in mining and other industrial processes, which could displace natural gas or more carbon-intensive fuels used to power these processes.

### ***Policies to repurpose natural gas infrastructure for clean energy alternatives***

Panelists stated that the region aspires to expand its gas infrastructure, which could then be repurposed for other fuels like hydrogen in the future. Where gas and other fossil fuel infrastructure does exist, a rapid transition away from fossil fuels toward renewables could lead to stranded assets. Limited public financial support is available to manage stranded asset fallout.<sup>53</sup> Some countries have concrete aims to utilize natural gas infrastructure for alternative fuels. For example, in its National Green Hydrogen Strategy, the government of Chile stated its intention to investigate the physical capability of its natural gas infrastructure to safely incorporate hydrogen blending.<sup>54</sup>

### ***The role of natural gas/LNG in addressing developing country energy needs***

Poverty is a major challenge in the region, compounded by commodity crises and the COVID-19 pandemic. Government funding for energy infrastructure that was planned for the near-term could be redirected to healthcare and COVID-19 recovery efforts. Oil- and gas-exporting countries in the region, including Venezuela, Brazil, Peru, and Trinidad and Tobago, will rely on revenues from these industries during economic recovery.

### ***Incorporation of corporate ESG policies and financial institution guidelines for investments in new natural gas projects***

Many governments in the region do not have the financial means to invest sufficiently in new natural gas infrastructure and depend on foreign or private investment. Hesitancy of private or foreign financial institutions to fund fossil fuel projects could pose challenges to natural gas development in the region.

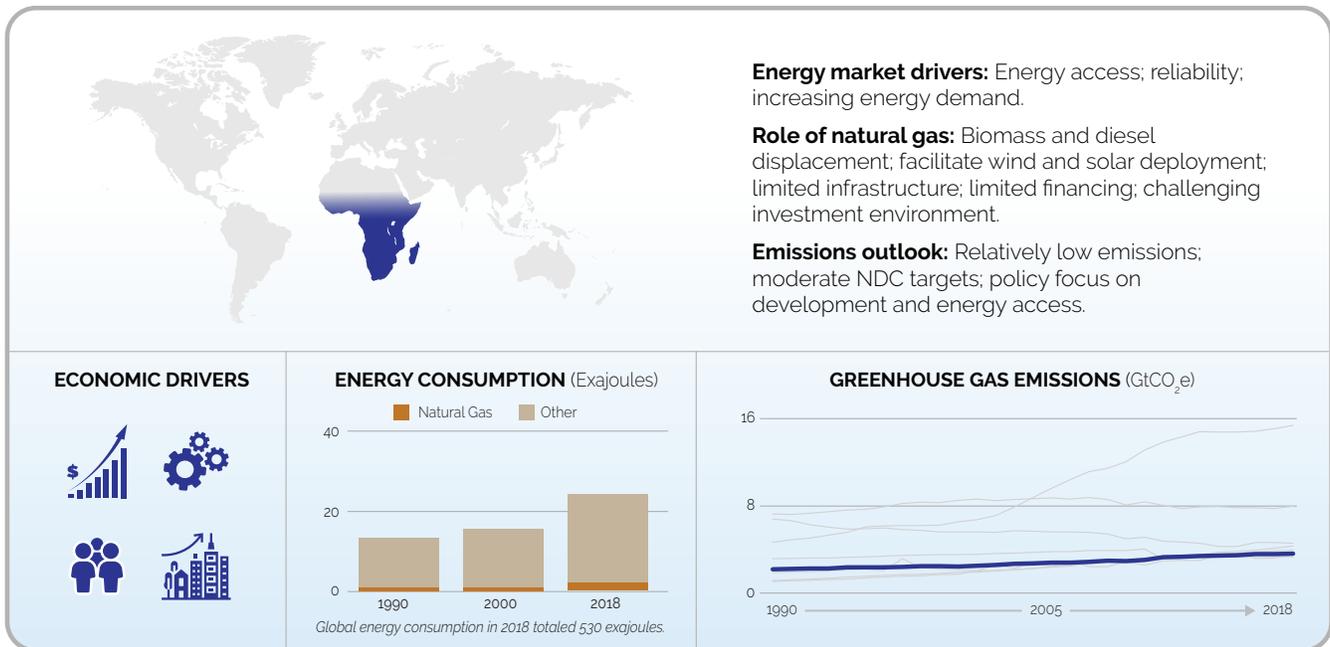
### ***The role of emissions abatement technologies***

There was limited panel discussion about both carbon capture, utilization, and storage and mitigation of methane as the role of natural gas in the regional energy mix advances. Though these technologies were deemed important to the role of natural gas vis-à-vis regional climate goals, pathways for the deployment of these technologies were not discussed at length.

# SUB-SAHARAN AFRICA

The Center for Energy Studies at the Baker Institute at Rice University, with the cooperation of Africa50, hosted an invitation-only expert workshop on the future of natural gas in Sub-Saharan Africa in a low-carbon world.

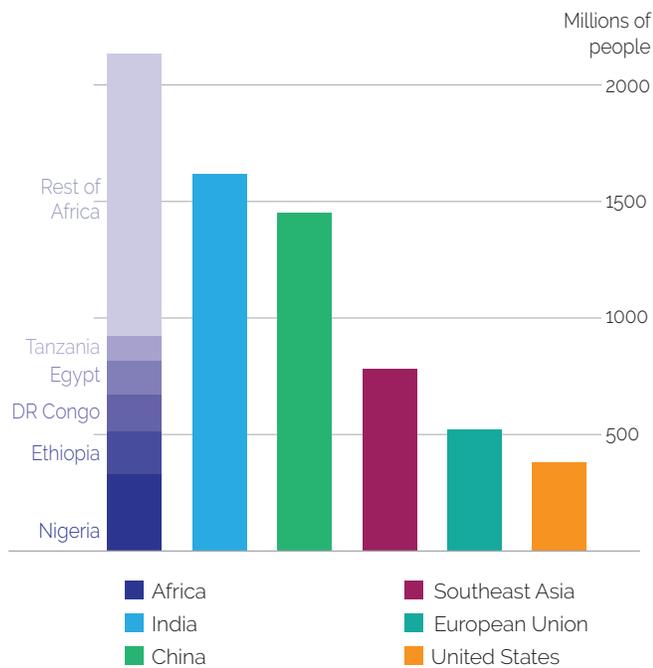
15 speakers and 55 participants from academia, think tanks and the private sector took part in the discussion. The two-day event, held under Chatham House rule, took place on December 17<sup>th</sup> and 18<sup>th</sup>, 2020. The following is a summary of the workshop discussion.



## REGIONAL OUTLOOK

Sub-Saharan Africa anticipates rapid growth in energy demand over the coming decades, driven by rising population, urbanization, and industrialization. Growing population will play a key role in increased energy consumption. The African continent's population is expected to increase by 800 million through 2040, when it will be home to more than 2 billion people

(Figure 24). Nigeria is projected to be the third most populous country in the world and other countries like the Democratic Republic of the Congo and Ethiopia expect their populations to approximately double by 2050.<sup>55</sup> Between 2010 and 2050, Africa's urban population will rise from 400 million to 1.26 billion—the largest urbanization in history.

**Figure 24: Anticipated Regional Population, 2040<sup>56</sup>**

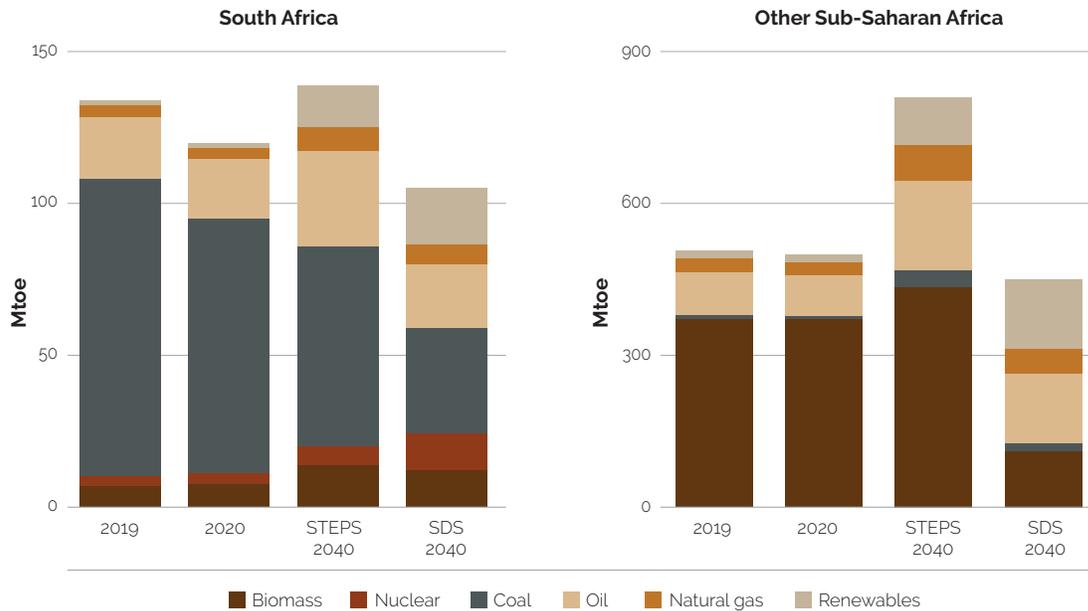
*This figure shows anticipated population by global region in 2040. Africa's population overall is expected to surpass 2 billion people, far exceeding the populations of Southeast Asia and the European Union. Source: Arsalane, 2020.*

## Energy Market Drivers

The confluence of population growth and urbanization will drive up energy demand in the Sub-Saharan Africa region. The average urban household in Sub-Saharan Africa consumes three times more energy than the average rural household.<sup>57</sup> Population shifts to cities will likely increase overall energy demand and stimulate industrial development, and energy-intensive industrial processes require significant heat and power. Across the region, renewable growth is projected to meet the largest share of electricity demand by 2040, but the infrastructure buildout required to provide universal access to reliable, modern, and affordable energy will be a challenge. Today, nearly half the population does not have access to electricity.<sup>58</sup>

After a drop in energy demand in 2020 due to COVID-19, renewables and gas are expected to lead the rebound in the Sub-Saharan Africa region, while coal demand is not anticipated to return to pre-crisis levels. This expected decline of coal is especially relevant to South Africa, a country endowed with significant domestic coal resources (Figure 25). The energy sources used to meet Africa's demand growth going forward will depend on policy, regulatory, trade and infrastructure project financing dynamics.

**Figure 25: Total primary energy demand, South Africa and rest of Sub-Saharan Africa<sup>59</sup>**



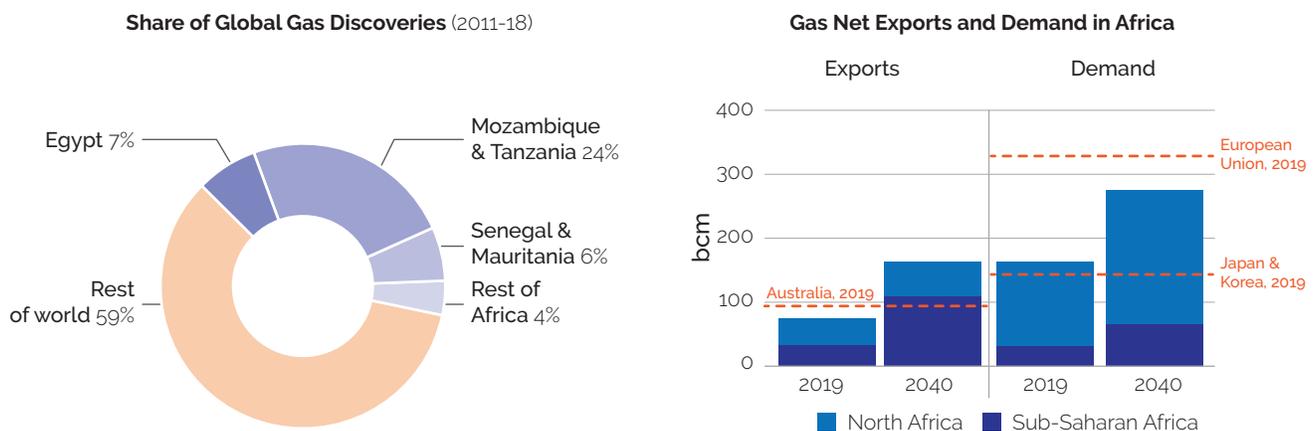
Coal dominates South Africa's total primary energy demand today and it is anticipated to play a significant role through 2040. In the rest of Sub-Saharan Africa, coal plays and is expected to play a minor role in the region's energy mix, though coal demand is expected to increase slightly through 2040. Source: Arsalane, 2020.

### Role of Natural Gas

Natural gas is a contender for supporting economic development, promoting energy access, and powering increased industrialization; however, natural gas is at an inflection point in the region. At present, domestic gas infrastructure is not well-developed, and gas produced in the region is mostly exported (Figure 26). Recent oil and gas discoveries

across the continent could assist in the region's push for industrial growth and its need for reliable electricity but developing infrastructure will require strong country- and regional-level policy support. Increasing oil and gas production in the region is also responsible for a significant percentage of global methane emissions.<sup>60</sup>

**Figure 26. Gas discoveries and gas net exports and demand in Africa<sup>61</sup>**

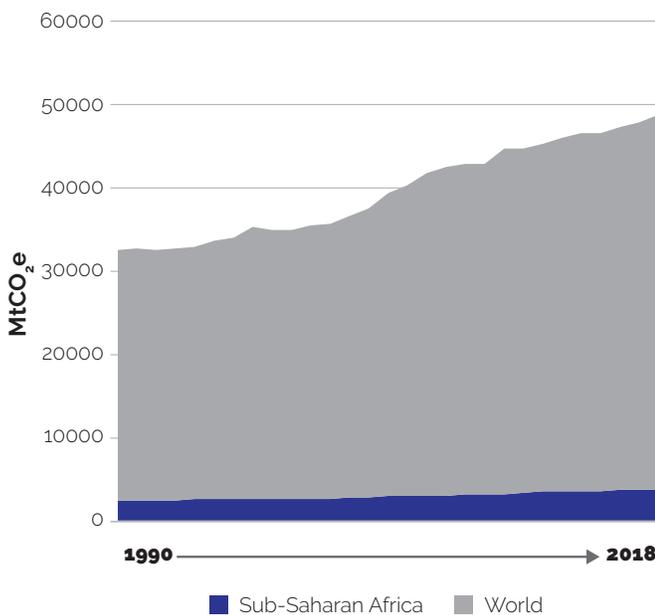


Between 2011 and 2018, 41 percent of all global gas discoveries were in Africa. Sub-Saharan Africa today exports more natural gas than it demands on net, and exports are anticipated to grow through 2040. Source: Arsalane, 2020.

### Emissions Outlook

Sub-Saharan Africa is extremely vulnerable to the impacts of climate change. The United Nations reports significantly reduced precipitation is expected as warming increases to 2 degrees C.<sup>e,62</sup> 40 nations in the Sub-Saharan Africa region have submitted Nationally Determined Contributions (NDCs) or Intended Nationally Determined Contributions (INDCs). At the same time, as noted, the region contributes minimally to global greenhouse gas (GHG) emissions today (Figure 27). However, these dynamics could change as populations and standards of living rise.

**Figure 27: GHG Emissions, Sub-Saharan Africa and the World<sup>63</sup>**



Data generated on Climatewatch website comparing Sub-Saharan Africa GHG emissions to World GHG emissions. Data from Climate Watch, 2021.

Table 2 provides some information about Sub-Saharan Africa's per capita fossil fuel emissions compared to global averages, and its share of total CO<sub>2</sub> emissions from fossil fuels relative to its share of total population. The region is home to nearly 14 percent of the global population but emits only slightly over 2 percent of global CO<sub>2</sub> emissions from fossil fuels. Emissions from 16 of 48 countries represented at the regional workshop are negligible. The differences between Sub-Saharan Africa's contributions to global emissions and North America's, Europe's, or Northeast Asia's contributions are stark.

**Table 2: Sub-Saharan Africa Region Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019<sup>64</sup>**

CO <sub>2</sub> per Capita per Year from Fossil Fuels	Share of World CO <sub>2</sub> Emissions from Fossil Fuels	Share of World Population
<b>0.8 tons</b>	<b>2.2%</b>	<b>14.3%</b>
4.9 tons World Average	38,017 MT World Total	7.71 Bn People World Total

47 countries in analysis. Numbers are rounded. MT = Megatons.

*Data from Crippa et al., 2020.*

<sup>e</sup> "A warming world will have implications for precipitation. At 1.5 C, less rain would fall over the Limpopo basin and areas of the Zambezi basin in Zambia, as well as parts of Western Cape in South Africa. But at 2 C, Southern Africa is projected to face a decrease in precipitation of about 20 percent and increases in the number of consecutive dry days in Namibia, Botswana, northern Zimbabwe, and southern Zambia. This will cause reductions in the volume of the Zambezi basin projected at 5 percent to 10 percent."

## SUMMARY OF PANELIST DISCUSSION *(Authored by the Baker Institute)*

The workshop hosts and participants were provided with framing questions from EFI, which can be found on page 3 of this report.

### ***The role of natural gas in the energy transition***

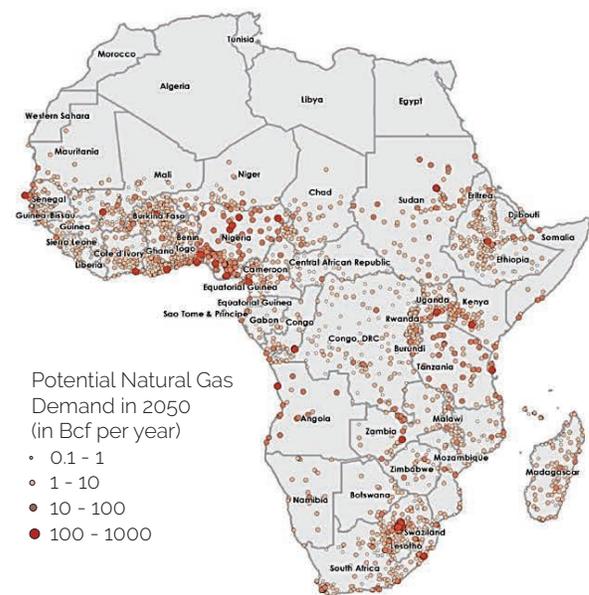
Natural gas plays a relatively small role in the energy mix across the region, and there is significant economic, political and energy market heterogeneity across countries in the region. Currently, natural gas production is heavily focused on exports, but there is a gradual shift to domestic use supported by infrastructure investment by large energy-producing companies. These upstream-focused companies—both state- and non-state-owned—can significantly influence policymaking significantly, especially given the expertise and investment capacity they bring to resource development, which can provide a source of wealth as well as the means to expand energy access.

There is a strong interest in expanding domestic use of natural gas in many Sub-Saharan African nations. This interest will require the development of appropriate market structures with transparency to facilitate adequate incentives for investment in infrastructure that supports domestic power markets and industrial activities.

It was noted that expanded use of natural gas and the requisite investment in pipelines and distribution infrastructure will improve energy access; help establish power grid stability by facilitating large-scale, dispatchable electricity options; support increased urbanization and growth of the middle class; foster economic growth and development critical to the infrastructure development that will ultimately allow for expanded use of renewable power and energy storage options; reduce the use of biochar, biomass, diesel and coal that dominates distributed energy applications for sources of heat;

and improve local air quality. Figure 28 shows a projection of potential locations and volumes of increased Sub-Saharan African natural gas demand in 2050. Demand would be most concentrated on the northwest and southeast coasts, with additional strong demand expected in Kenya, Uganda, and Rwanda.

**Figure 28: Potential 2050 Natural Gas Demand in Sub-Saharan Africa**



*Source: Van Eeden and Kundani, 2015.*

As noted, the region has very small energy and GHG footprints compared to more developed regions of the world. Workshop participants argued that even a very large increase in the use of natural gas, particularly when accounting for positive local environmental benefits like the reduction or avoidance of diesel and biomass use, would not have a substantial impact on global GHG emissions.

### **Key economic and regional trends driving natural gas demand/uses**

Several factors, such as population growth, urbanization, industrial policy, the need for fertilizer, economic development aspirations, and the increasing purchasing power of a growing middle class, were noted as drivers of future energy demand. Additionally, large domestic hydrocarbon discoveries in the region and significant natural gas resource endowments in certain countries could drive supply of these fuels. These factors could drive an expanded role for natural gas in the future energy mix of Sub-Saharan African nations.

Notably, there are some major impediments to the development of a robust, transparent gas market in the region. These include lack of access to adequate legal and consulting expertise when negotiating supply contracts and investment agreements, and the high cost of borrowing. Another impediment is the announced shift by members of the international investment community, such as the European Investment Bank and the World Bank, away from fossil energy resource infrastructure investment.

### **Major drivers of regional energy supply and demand**

There are several key drivers of energy demand in Sub-Saharan Africa. First, the grid in many African countries is unreliable. Workshop participants noted that many Nigerians, for example, use more expensive and environmentally detrimental diesel generators because they cannot rely on the grid. The Global Commission on Climate Change identified the lack of adequate distribution systems as a clear barrier to universal electrification in Africa.

National strategies to expand energy access will contribute to energy demand. Infrastructure development and domestic resources will also play a role – for example, in some countries, hydropower

*Several trends are expected to impact energy supply and demand in the Sub-Saharan Africa region. These include increased private sector participation in the energy sectors of many countries in the region; the need for scalable energy systems to support economic growth; and the need for grids to support urbanization, for which distributed generation resources, both urban and rural, are considered inadequate.*

resources are adequate with suitable investment so other energy resources may not play a significant role. Regional heterogeneity will, however, underscore differences in approaches to energy and climate change. Efforts are underway to support cross-border collaboration between producing and consuming countries that could support greater regional integration, more regional energy trade, and greater energy security.

Several trends are expected to impact energy supply and demand in the Sub-Saharan Africa region. These include increased private sector participation in the energy sectors of many countries in the region; the need for scalable energy systems to support economic growth; and the need for grids to support urbanization, for which distributed generation resources, both urban and rural, are considered inadequate. Increasing urbanization along with growing populations will result in multiple “mega” metropolises by 2050, driving up energy demand in urban areas especially. Announced plans for energy access for all by 2030 will also drive significant growth in electricity and overall energy demand. In addition, development and finance groups are undertaking concerted efforts to expand access to finance for infrastructure and to support the creation of domestic energy markets.

It was also noted that the outcomes of several dynamics are difficult to forecast or fully understand and analyze. One is the role of direct foreign assistance and development banks in targeting specific energy sources to finance. Panelists were concerned that consumers may not choose to connect to a grid if preferential financing is not made available to the most abundant or reliable energy option, which could dissuade further investment. It is unclear whether investments will focus on domestic demand opportunities, increased production and export, or midstream opportunities in the transmission and distribution system.

Reliability and distribution of energy supply depends on the ability of actors along the entire value chain to successfully coordinate to develop infrastructures that rely on co-dependency. This co-dependency is rooted in "coordination theory," where failure at any point along an integrated venture will result in failure of the entire venture. The creditworthiness of main power off-takers, utility companies, and all actors along the energy value chain are also critical for development. Additional uncertainty exists around how contracting practices and market transparency will evolve, as well as the availability of high-quality legal and financial advisory services for large projects for governments and local stakeholders.

### ***The range of potential futures of natural gas markets***

Different countries have unique regimes that can facilitate or dissuade domestic gas use and set the pace for domestic natural gas development. Hence, the potential future for natural gas depends on the country and the current state of the natural gas market.

As noted, access to electricity and reliable power are critical for economic development in Sub-Saharan Africa, which is expected to see large population

increases. For the region to take advantage of any economic benefit associated with natural gas, infrastructure buildout will be essential. Transparent pricing and value chain reliability also remain pivotal to unlock the potential for natural gas markets.

Workshop participants noted that sufficient capital to finance infrastructure is critical for reliability and subsequent market growth. These participants presented a "virtuous cycle" — with adequate finance, offtake agreements are more commercially desirable. In turn, as market offtake increases, future infrastructure projects are de-risked. As this occurs, private investment may find the growing market more attractive. As investment occurs and infrastructure expands, market conditions improve thereby attracting more investment.

It was argued that market development would require the establishment of policies and pricing options for domestic markets, as well as a framework for collaboration with private investors and other countries, either as an exporter or importer. Nigeria was also referenced as a case study in unsuccessful outcomes, where it was noted that its distribution systems and policy frameworks are insufficient for a domestic gas market development.

### ***NDCs and climate targets***

Overall, workshop participants agreed that the region's decarbonization strategies should be aligned with other nations' NDCs to obtain financing; allow for industrialization and economic growth pathways that consider the use of natural gas; provide for an expanding population and growing middle class; and consider how few GHGs most countries in the region emit. A "new deal for energy" in Africa was mentioned, noting the development of 160 GW of installed power generation capacity by 2030 that would be 100 percent renewable or zero-carbon whenever and wherever possible.

Sub-Saharan Africa represents a significant portion of global energy poverty. The alleviation of energy poverty dominates local concerns. Workshop participants noted that many countries in the region were much more concerned about economic growth and development than climate mitigation, particularly since their GHG emissions impact on climate have been, and continue to be, relatively small compared to other regions of the world.

In this context, it was stressed that in global climate discussions, it is important to mobilize the global community to end energy poverty and encourage private investment; encourage a more integrated way of thinking about human welfare focused on energy access as well as environmental sustainability; and recognize that a one-size-fits-all approach to climate change is not viable. In short, regional strategies are needed.

Some workshop participants also argued that oil and gas investments should be considered separately; lumping them together from a policy or investment perspective risks limiting access to capital for natural gas projects, something the participants thought could be important for economic development. This categorization would complicate improving natural gas infrastructures that could enable growing energy demand while meeting stated climate targets in most African countries.

*Sub-Saharan Africa represents a significant portion of global energy poverty. The alleviation of energy poverty dominates local concerns. Workshop participants noted that many countries in the region were much more concerned about economic growth and development than climate mitigation, particularly since their GHG emissions impacts on climate have been, and continue to be, relatively small compared to other regions of the world.*

### **Impact of climate policies on natural gas supply and demand**

Even if natural gas use in power generation tripled overnight, the region's emissions would amount to less than 1 percent of the global total. It was argued that future climate policy across the region could and/or should integrate natural gas in power generation and industrial development.

In discussing climate policy in this region, two questions emerged from the workshop participants' discussion. Is focusing on reducing emissions in Sub-Saharan Africa at the expense of economic development and industrialization in the region worth it? Also, how much capital are nations willing to expend to reduce emissions in a region that emits very few emissions compared to other regions of the world?

Fossil fuel divestment is also a concern in the Sub-Saharan Africa region. Because natural gas is often coupled with oil in fossil fuel discussions, the cost of borrowing increases. Financing for distribution and transmission is likely to be government-financed, but most governments in the region lack sufficient access to capital, a problem exacerbated by policies that restrict fossil energy investment.

Flaring policies were not widely discussed. It was noted that flaring is associated with oil production, and that flaring occurs primarily due to a lack of local and regional markets and accessible gas infrastructure. Natural gas infrastructure investment could help alleviate this problem.

### **Substitutes for natural gas in the 2030 and midcentury timeframes**

Participants noted the lack of viable industrial scale energy options that could reduce carbon intensity while supporting industrial activity. Also, as seen in the United States and elsewhere, natural gas could displace existing coal projects, reducing overall emissions from the energy sector.

The prospect of displacing current natural gas is not great given its relatively small regional footprint and its use for industrial processes in Africa.

Workshop participants expressed the view that new technologies, if competitive, would likely not displace the small amount of natural gas used in the existing energy mix; rather, they would capture the margin of growth in an emerging market relative to the growth of natural gas. Given energy needs and the current state of infrastructure and energy technologies, the displacement of natural gas by more advanced technologies was generally not viewed as a near-term possibility.

Significant storage capacity is unlikely to be found in Africa in the near term due to the nascent stage of battery development and the current limitations of battery storage technology. In this context, it was noted that in regions where renewables and utility-scale storage have been deployed, well-developed grids have enabled effective distribution.

Solar home systems, a desirable option for nations with very low rural electrification rates, need to be tailored for rural applications. It was noted that the biggest impediment to scaling these systems is manufacturing.

Hydropower and geothermal energy are unlikely to be adequate to meet new energy demand, absent new geothermal energy discovery and subsequent infrastructure investment. This constrains the potential of these sources to compete with natural gas.

### ***Policies to repurpose natural gas infrastructure for clean energy alternatives***

Stranded asset risks were not specifically discussed. Rather, the relatively underdeveloped regional infrastructure in the region centered the conversation around greenfield infrastructure development in many cases. For new investments, participants did not express concern about those assets being stranded

prior to the end of their planned useful life, largely because these assets would expand energy access to address growing economies and populations.

### ***Role of natural gas/LNG in addressing developing country energy needs***

Natural gas could provide much-needed flexibility in the energy mixes of countries at different levels of development. Currently, approximately 3 billion people—many of them in Sub-Saharan Africa—cook using open fires or simple stoves fueled by kerosene, biomass (wood, animal dung and crop waste) and coal. In addition to contributing to deforestation, this practice contributes to premature deaths attributable to household air pollution from inefficient cooking practices using polluting stoves paired with solid fuels and kerosene. This especially impacts women; modernized energy services and technologies could enable greater participation of women in developing clean and robust economies.

Natural gas can help the transition away from biochar and coal, two major contributors to air pollution and bad air quality, while providing reliable and affordable electricity. The increased use of liquefied petroleum gas (LPG)—along with more efficient cook stove technologies—would help reduce air pollution and support decarbonization efforts in Sub-Saharan Africa. Some countries have already started to encourage LPG adoption through subsidies or other government programs, with mixed success.

Countries in this region are prioritizing industrialization and expanded access to electricity. Natural gas can help unlock the economic potential in these countries by providing less carbon-intensive and more efficient option than coal, oil, or biomass. Participants noted that natural gas can support climate and environmental justice goals in this region. In addition, the integration of renewables into the energy mix could require power-firming options to overcome challenges associated with intermittency.

However, investments are needed to expand the use of gas in the region. The keys for successful regional investment include adherence to the rule of law and sanctity of contracts; transparency; insulation of national projects from other national issues and risks; and promotion of private sector involvement.

### ***Incorporation of corporate ESG policies and financial institution guidelines for investments in new natural gas projects***

Companies with significant public profiles, many of which are engaged in Africa and critical for the necessary investments, are especially exposed to the pressures of ESG-motivated investors. Because many financial institutions that incorporate ESG policies are increasingly disengaging from natural gas and other fossil fuel projects, access to capital needed to build a robust gas market could be severely impeded. Participants felt that this could compromise energy access and economic development goals, and that ESG sentiments should be supported with a vision to make them commercially applicable to the broader goals of nations in Africa to promote investment in the region. Participants also noted that African voices in attendance at COP 26 in Glasgow can lead a paradigm shift in this regard.

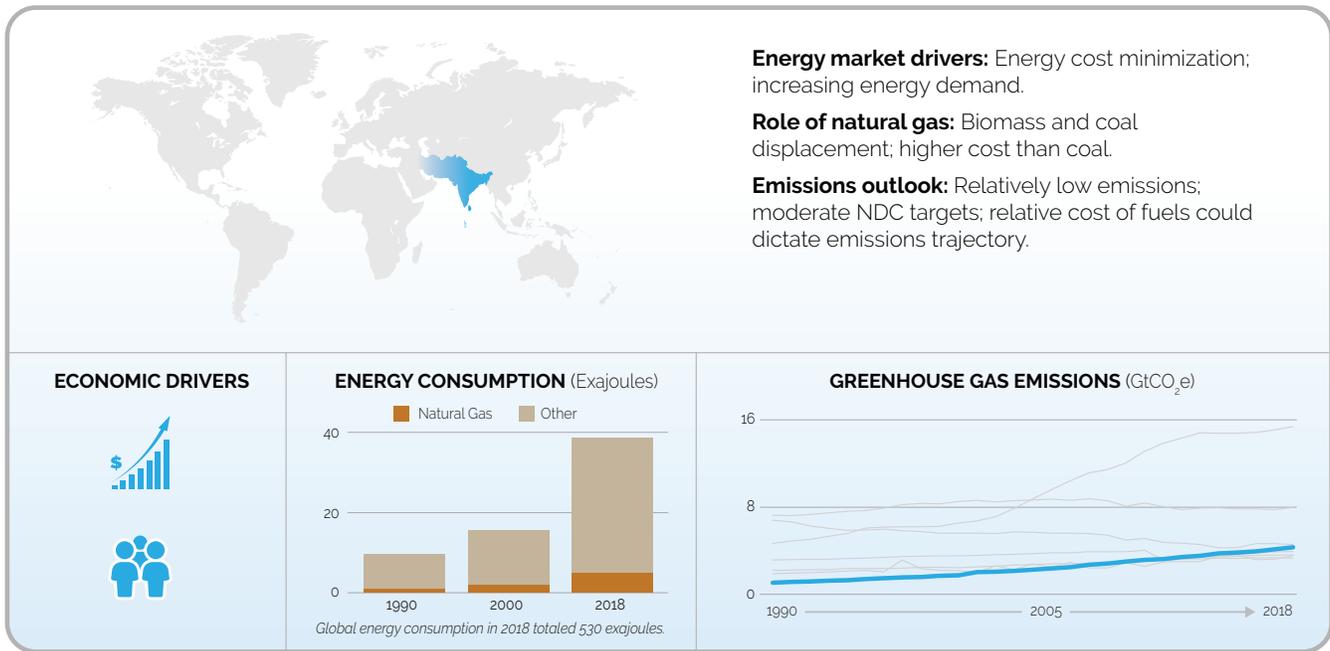
### ***The role of emissions abatement technologies***

There was limited discussion of carbon capture, utilization, and storage. It was mentioned that large LNG companies are assessing emissions and methane leakage throughout their global supply chains and learning what is needed to develop and supply natural gas with a low carbon footprint. This experience can be applied in Africa as new infrastructure is developed that can prioritize efficiency and integrate emission mitigation technologies.

# SOUTH ASIA

The National Bureau for Asian Research hosted an invitation-only expert workshop on the future of natural gas in South Asia in a low-carbon world.

15 speakers and panelists and approximately 50 participants from academia, think tanks, government, and the private sector took part in the discussion. The two-day event, held under Chatham House rule, took place on January 6<sup>th</sup> and 7<sup>th</sup>, 2021. The following is a summary of the workshop discussion.



## REGIONAL OUTLOOK

The South Asia region includes India, Pakistan, Bangladesh, Bhutan, Nepal, Sri Lanka, and Maldives. Energy demand in the region is increasing at about twice the rate of China's energy demand due to high population growth, urbanization, industrialization, and a growing middle class.<sup>65,f</sup> IEA anticipates that India will see the largest energy demand increase of any country through 2040, with an energy demand growth rate three times the global average.<sup>66</sup>

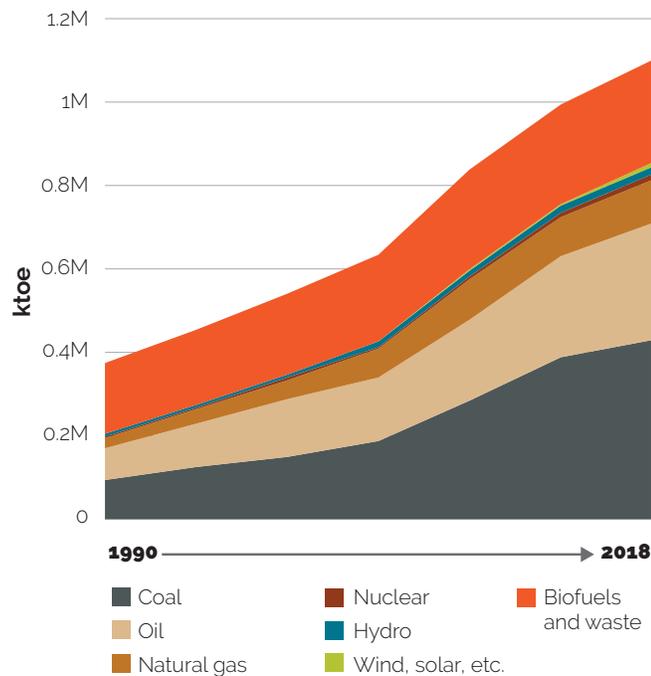
### Energy Market Drivers

The amount and share of coal in the region's energy mix has grown over time. In 1990, coal's share of the total energy supply was 25 percent; in 2018, it comprised 39 percent (Figure 29). In 2020, approximately 70 percent of India's electricity was generated by coal-fired power plants, with renewables generating approximately 23 percent. India has about 10 percent of the world's proven reserves of coal, and it is the second largest importer of coal. While

<sup>f</sup> China's annual population growth rate dropped under 1 percent in 1998 and decreased to 0.35 percent in 2019. India's annual population growth rate dropped under 2 percent in 1993 and decreased to almost 1 percent in 2019. In 2018, India's primary energy consumption grew by 8 percent and China's grew by 4.3 percent.

launching an auction of 41 coal mines for commercial mining in June 2020, the Prime Minister announced that India will aim to reduce its dependence on imports and to be the world's largest coal exporter.<sup>67</sup>

**Figure 29: Total Energy Supply, South Asia<sup>68</sup>**



Total energy supply in South Asia has increased more than three-fold over the past two decades. Coal's share of the total energy supply has increased from 25 percent in 1990 to 39 percent in 2018. The share of other energy resources, like oil, natural gas, and wind and solar, have also increased over time. Figure excludes Afghanistan, Bhutan, and Maldives. Data from IEA, 2020

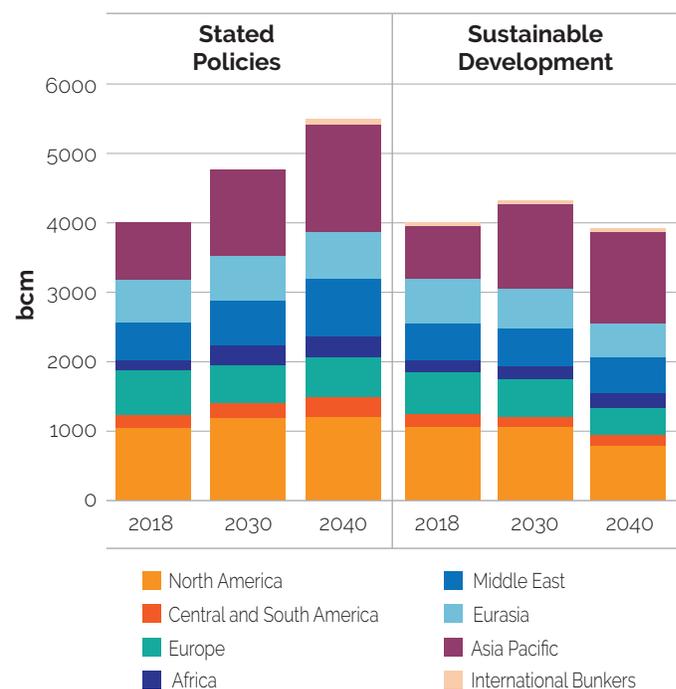
Despite some regional energy resource availability, many countries in the region have underdeveloped domestic energy infrastructures and, like India, rely heavily on coal for power generation and on biomass for cooking. Together, these fuels contribute to GHG emissions, poor air quality, environmental degradation, and energy reliability issues in a region that is highly susceptible to the impacts of climate change. To address the underdevelopment of regional infrastructure, countries in the region have taken regulatory and policy measures to diversify, secure, and attract investment to the energy sector, for both

fossil and renewable resources. Renewables are expected to play an increasingly important role as countries advance various clean energy initiatives.

### Role of Natural Gas

In the Asia-Pacific region<sup>9</sup>, coal- and gas-fired generation declined due to the COVID-19 pandemic while the share of renewables stayed the same or increased.<sup>69</sup> However, the coal and natural gas demand declines in 2020 are expected to reverse over the course of 2021, supplemented by growth in emerging Asian markets and attractive gas prices. Consequently, the Asia-Pacific region is expected to be a major driver of global natural gas demand through midcentury. As shown in Figure 30, in IEA's Stated Policies scenario and Sustainable Development scenario, gas demand increases in the region, even as it declines in Europe and North America.

**Figure 30: Gas Demand by Region 2018-2040<sup>70</sup>**



Source: IEA, 2019.

g The Asia-Pacific region, as defined by IEA, is inclusive of South Asian countries.

## Emissions Outlook

The South Asia region is endowed with diverse, rich natural energy resources such as coal, wind, water, natural gas, solar and geothermal. About 68 percent of electricity produced in the region is fossil-generated, and the region accounts for about 8 percent of global CO<sub>2</sub> emissions.

**Table 3: South Asia Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019<sup>21</sup>**

CO <sub>2</sub> per Capita per Year from Fossil Fuels	Share of World CO <sub>2</sub> Emissions from Fossil Fuels	Share of World Population
<b>1.6 tons</b>	<b>7.9%</b>	<b>23.8%</b>
4.9 tons World Average	38,017 MT World Total	7.71 Bn People World Total

*8 countries in analysis. Numbers are rounded. MT = Megatons.*

*Data from Crippa et al., 2020.*

Table 3 provides some information about South Asia's per capita fossil fuel emissions compared to global averages, and its share of total CO<sub>2</sub> emissions from fossil fuels relative to its share of total population. As in Sub-Saharan Africa, these data illustrate the relatively low per capita emissions contributions of developing regions compared to developed regions. The region is home to nearly 24 percent of the world's population, and despite the fact that India—the region's most populous country and the world's second-most populous country—generates 70 percent of its electricity from coal, the region emits a small percentage of the world's emissions and its per capita emissions are less than a third of the global average.

## SUMMARY OF PANELIST DISCUSSION *(Authored by the National Bureau of Asian Research)*

The workshop hosts and participants were provided with framing questions from EFI, which can be found on page 3 of this report.

### ***The role of natural gas in the energy transition***

There is great potential and need for greenhouse gas (GHG) emissions reductions due to the prevalence of coal-generated electricity in the region. However, the potential for natural gas to directly replace coal in the power sector in South Asian countries is limited because gas is either too expensive relative to coal or too carbon-intensive relative to renewables. Where infrastructure permits, gas will likely instead help fill gaps in the region's rapidly expanding but variable renewable electricity supply and provide relatively cleaner firm power, absent inexpensive and long-duration storage options.

Natural gas use varies widely among South Asian countries. India lacks significant gas pipelines and meets only 6 percent of its primary energy needs with gas today but aims to increase this figure to 15 percent by 2030. Pakistan has widespread gas infrastructure and natural gas accounting for nearly 27 percent of its energy consumption. 70 percent of the power in Bangladesh is generated using natural gas.

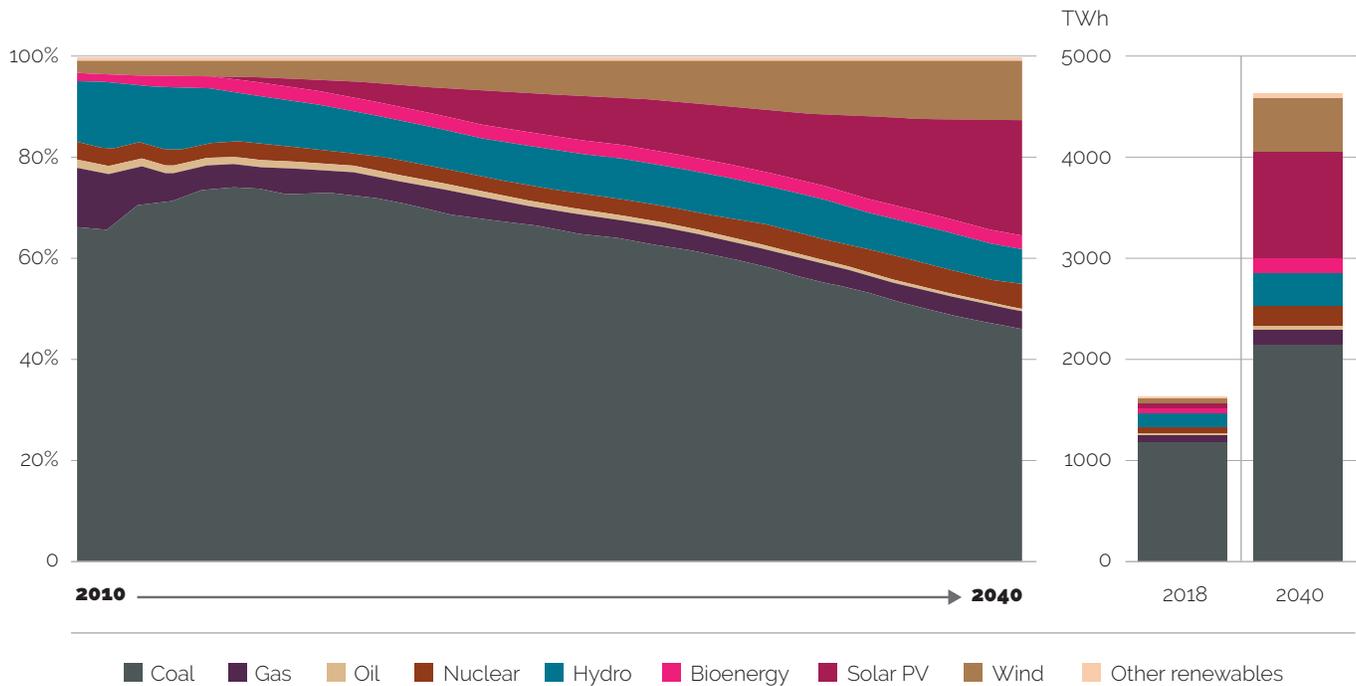
India is the third-largest energy consuming country in the world, due to its large population, rising incomes, and a growing middle class. Energy use in the country has doubled since 2000, and 80 percent of energy

demand is still met with coal, oil, and biomass (Figure 31).<sup>72</sup> According to IEA, to meet anticipated growth in electricity demand through 2040, "India will need to add a power system the size of the European Union to what it has now."<sup>73</sup>

India's building sector is also rapidly expanding to match its increasingly urbanized population. The country is expected to double its building space by 2040.<sup>74</sup> This will likely mean a transition away from biomass (a significant health hazard, particularly for women) to natural gas and electricity for heating, cooling and cooking.

Natural gas is only 6 percent of India's energy mix but could grow, along with the buildings and power sectors. As noted, 70 percent of India's power generation is coal-fired, and 96 percent of its electricity sector emissions are from coal. India currently imports 7 percent of global LNG supplies and had, until recently, restricted its use to high-value industrial sectors. It is slowly opening up its uses of imported LNG to allow for limited use in power generation.

**Figure 31: Electricity Generation by Source in India, Historical and Projected (STEPS)<sup>75</sup>**



*This figure shows electricity generation by source in India, as projected by the IEA STEPS scenario. India will require triple the electricity it did in 2018 to meet its projected 2040 electricity demand. Historically, most of India's electricity has been coal-generated; over time, IEA expects coal to remain a key generation resource while solar and wind generation grows significantly. Source: IEA, 2019.*

### ***Key economic and regional trends driving natural gas demand/uses***

Government action is a key energy driver throughout the region, and significant political will is required to make changes. A key example is in transportation. Due to concern from the public and environmental groups around air quality in India, the country's Supreme Court ruled diesel-powered vehicles would be strictly limited in its cities, resulting in large numbers of compressed natural gas (CNG)-powered vehicles in cities like New Delhi.

India, Pakistan, and Bangladesh are home to manufacturing, textiles, and agriculture and fertilizer industries that are large consumers of natural gas. To reduce dependence on imports of these goods, the countries are investing in these and other industrial sectors, which will likely result in more gas use in the medium- to long-term.

### ***Major drivers of regional energy supply and demand***

India, Pakistan, and Bangladesh have set energy policy goals focused on energy security and reduced import dependence. Rapid development, population growth, and a desire for energy security are increasing energy demand across the region. Pakistan's population has grown by almost 13 million since 2017 alone, from over 212 million to over 225 million. India's population grew by 56 million Bangladesh's by 6 million over the same period.

According to the World Bank, in 2019, 98 percent of India and 92 percent of Bangladesh had electricity access, but only 74 percent of Pakistan did. As noted, despite increases in natural gas demand, coal remains the predominant source of electricity generation in

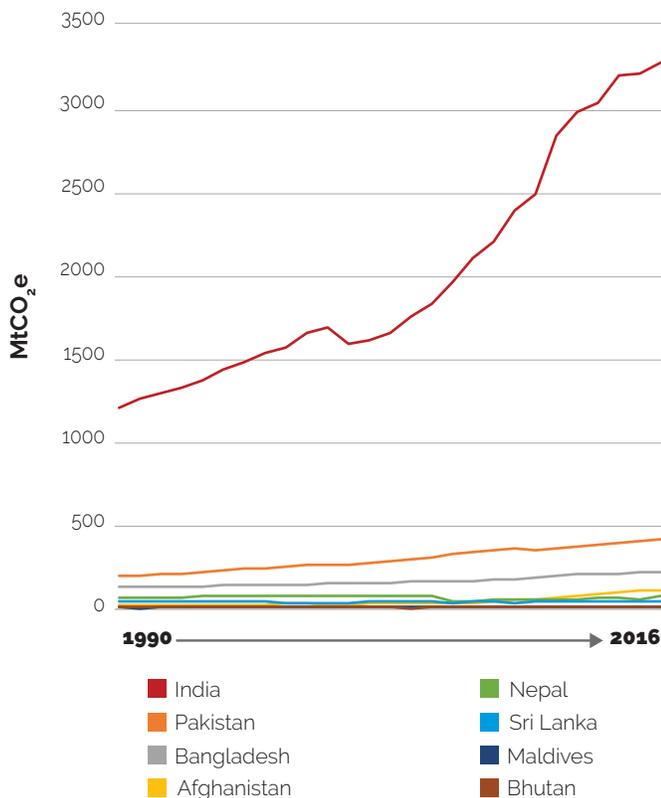
India due to its affordability and its easy integration into existing infrastructure. Pre-existing contracts with utilities also favor coal. It is challenging for alternative fuels (e.g., natural gas, renewables, and hydropower) to fill the need of rising energy demand due to a relative lack of investment, inadequate infrastructure, and high costs.

### ***The range of potential futures of natural gas markets***

The potential role of natural gas varies across the region. In the smaller countries of the region (e.g., Nepal), a large natural gas market for power generation is not expected to develop due to established hydropower resources, capacity, and infrastructure. In other, larger countries, natural gas may be more attractive than coal in the future if gas infrastructure buildout is sufficient to facilitate gas use over abundant domestic coal resources. Substitution away from coal in favor of natural gas could help South Asia reach its climate goals. These goals largely focus on reducing oil and coal in the energy mix. However, as storage for renewables becomes more affordable and efficient, panelists felt that natural gas will have a harder time competing with renewables and will likely be pushed out of the market.

### ***NDCs and climate targets***

Many countries in South Asia focus on climate change adaptation rather than mitigation, but the region's Nationally Determined Contributions (NDCs) still commit to action for both adaptation and mitigation. As shown in Figure 32, apart from India, the region contributes minimally to global GHG emissions today. However, these dynamics could change as populations and standards of living rise.

**Figure 32: GHG Emissions, South Asia, 1990-2016<sup>76</sup>**

Data generated on Climate Watch website comparing South Asian country GHG emissions. Source: Climate Watch, 2021.

Most countries in the region have some version of a “stated policies scenario” and “sustainable development scenario” in their NDCs. While countries in the region have made notable progress toward climate targets, the key difference in achieving the more ambitious plans is external financial support from international development organizations or more developed economies. For example, in its revised NDC, Maldives aims to reduce its GHG emissions by 24 percent by 2030, but this is conditional on external support; absent such support, it has committed to emissions reduction targets of 10 percent.

India is currently on track to meet two of its three main NDC targets: 40 percent of non-fossil fuel installed power capacity, and a 33 to 35 percent reduction in emissions intensity per GDP.<sup>77</sup> The country’s “stated

policy scenario” will allow emissions of over 500 gCO<sub>2</sub>e/kWh from power plants, while the “sustainable development” option would limit their emissions to 350 gCO<sub>2</sub>e/kWh.

Although some of the larger investments in power generation will rely on external support to be realized, efforts to improve energy efficiency and reduce leakage are well underway through domestic programs, ranging from policies to support increase LED lighting to reducing leaks from natural gas transport.

Regional organizations like the South Asian Association for Regional Cooperation (SAARC) and the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) have made climate change a priority.

### ***Climate policies’ impact on natural gas supply and demand***

Participants expressed concern that the current pace of fossil fuel development in the region surpasses Paris Agreement limits. LNG transport generates GHG emissions that are not adequately counted in the emissions totals for reporting per the Paris Agreement. Adjustments to emissions reporting standards may affect how countries in the region scale up gas development and trade in the future.

In Bangladesh, industry accounts for half of total energy consumption, and as previously highlighted, over two-thirds of its power generation is gas-fired. The country has a target of a 21 percent reduction in energy consumption by 2030; this makes energy efficiency in lighting and other electric-powered components, especially in factories, a critical decarbonization pathway. Natural gas may still make up a large portion of the country’s energy mix, but the total volume may decrease.

### ***Substitutes for natural gas in the 2030 and midcentury timeframes***

Many countries in the South Asia region are making serious efforts to increase their renewable capacity over the next two decades. Sri Lanka aims to achieve 100 percent renewable power by 2050 through hydropower and wind power. India has nearly a quarter of its energy supplied by renewables (the fourth-largest renewable energy capacity in the world) and aims to increase renewable capacity to 175 GW by 2022 and to 450 GW by 2030.

Nepal and Bhutan can satisfy their energy demand with hydropower and are not likely to consider adding natural gas to their energy mixes; their lack of industrial demand reduces the need for natural gas or other fuels for high quality process heat.

### ***Policies to repurpose natural gas infrastructure for clean energy alternatives***

If interest rates remain high and a country is undergoing rapid economic development, investment in natural gas infrastructure does not pose an immediate concern about stranded assets. The impacts of stranded assets on consumers, such as CNG vehicle owners turning to electric vehicles, must also be considered. Short-term debt repayment for possible stranded assets could help alleviate concerns.

For developing economies with less gas infrastructure and aggressive renewable electricity goals, asset stranding is less likely. However, questions regarding stranded assets remain for countries like Bangladesh and Pakistan, where coal has recently gained market share relative to natural gas.

### ***Role of natural gas/LNG in addressing developing country energy needs***

Natural gas is often characterized as a bridge fuel for enabling higher utilization of renewable power. In this role, natural gas could help developing countries

in the South Asia region meet their energy needs without sacrificing reliability and accessibility while more carbon-intensive fuels like coal are phased out. However, in this region, natural gas is still too expensive to truly compete with coal and may have limited use as a bridge fuel while more renewables are deployed and while innovations are being developed to reduce the high costs and duration limitations of battery storage.

### ***Incorporation of corporate ESG policies and financial institution guidelines for investments in new natural gas projects***

The Asian Development Bank and Asian Infrastructure Investment Bank, as well as state-run entities, have funded and are expected to continue to fund natural gas projects in the region. In India, Petronet and GAIL are investors in current LNG projects involving exports, imports, and infrastructure development. Thailand's state-owned utility, PTT, is an emerging player in

*Many countries in the region are making serious efforts to increase their renewable capacity over the next two decades. Sri Lanka aims to achieve 100 percent renewable power by 2050 through hydropower and wind power. India has nearly a quarter of its energy supplied by renewables (the fourth-largest renewable energy capacity in the world) and aims to increase renewable capacity to 175 GW by 2022 and to 450 GW by 2030...Nepal and Bhutan can satisfy their energy demand with hydropower and are not likely to consider adding natural gas to their energy mixes; their lack of industrial demand reduces the need for natural gas or other fuels for high quality process heat.*

the regional gas market, and Petronas (owned by the Government of Malaysia) and Pertamina (owned by the Government of Indonesia) are continuing their investments.

The World Bank announced that it will limit funding for gas projects by ceasing to finance exploration and production, although this is a small portion of its portfolio. The bank will continue providing funding for midstream LNG and gas-fired power projects.

UK Export Finance will end direct support of overseas fossil fuel projects after completing a consultation period. This policy should come into force before COP26 in November 2021. However, during this period of consultation, the UK Export Finance will continue to consider applications that support the oil and gas sector. Government-owned banks and China's Belt and Road Initiative still provide gas infrastructure project financing.

### ***The role of emissions abatement technologies***

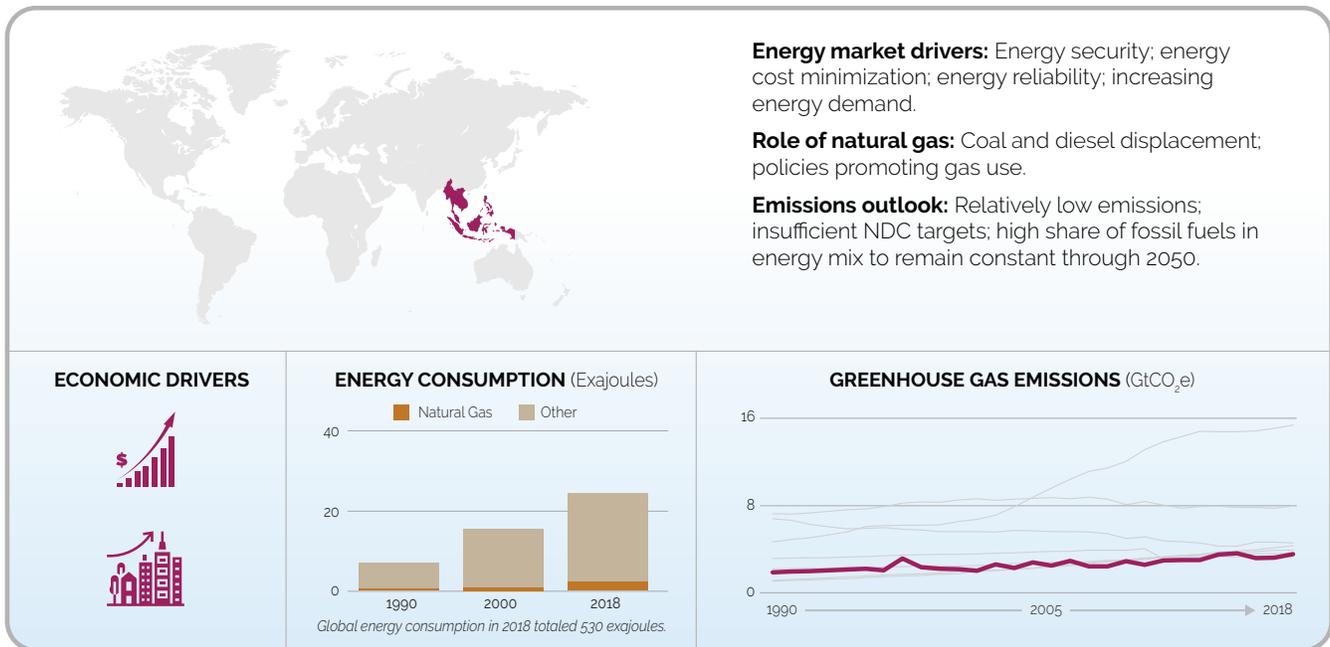
Emissions from future LNG and domestic gas in the region could be offset by increased deployment of carbon capture, utilization, and storage (CCUS), but infrastructure buildout for these technologies is nascent and their practicality in South Asian countries is uncertain. Workshop participants felt that because coal is likely to remain a large part of the energy mix in South Asia, and countries are demanding improved air quality alongside reduced GHG emissions, there could be a push for CCUS. Better scrubbing technologies and carbon utilization could benefit the long-term viability of LNG.

Even with CCUS technologies, workshop participants expressed concern about the feasibility of net-zero goals. While Maldives has pledged to become carbon neutral by 2030 and Nepal by 2050 (Bhutan is already carbon negative), these countries represent smaller markets with less impact on regional gas trends and global emissions.

# SOUTHEAST ASIA

The Institute of Energy Economics, Japan hosted an invitation-only expert workshop on the future of natural gas in Southeast Asia in a low-carbon world.

10 speakers and 30 participants from academia, think tanks and the private sector took part in the discussion. The event, held under Chatham House rule, took place on January 14<sup>th</sup>, 2021. The following is a summary of the workshop discussion.

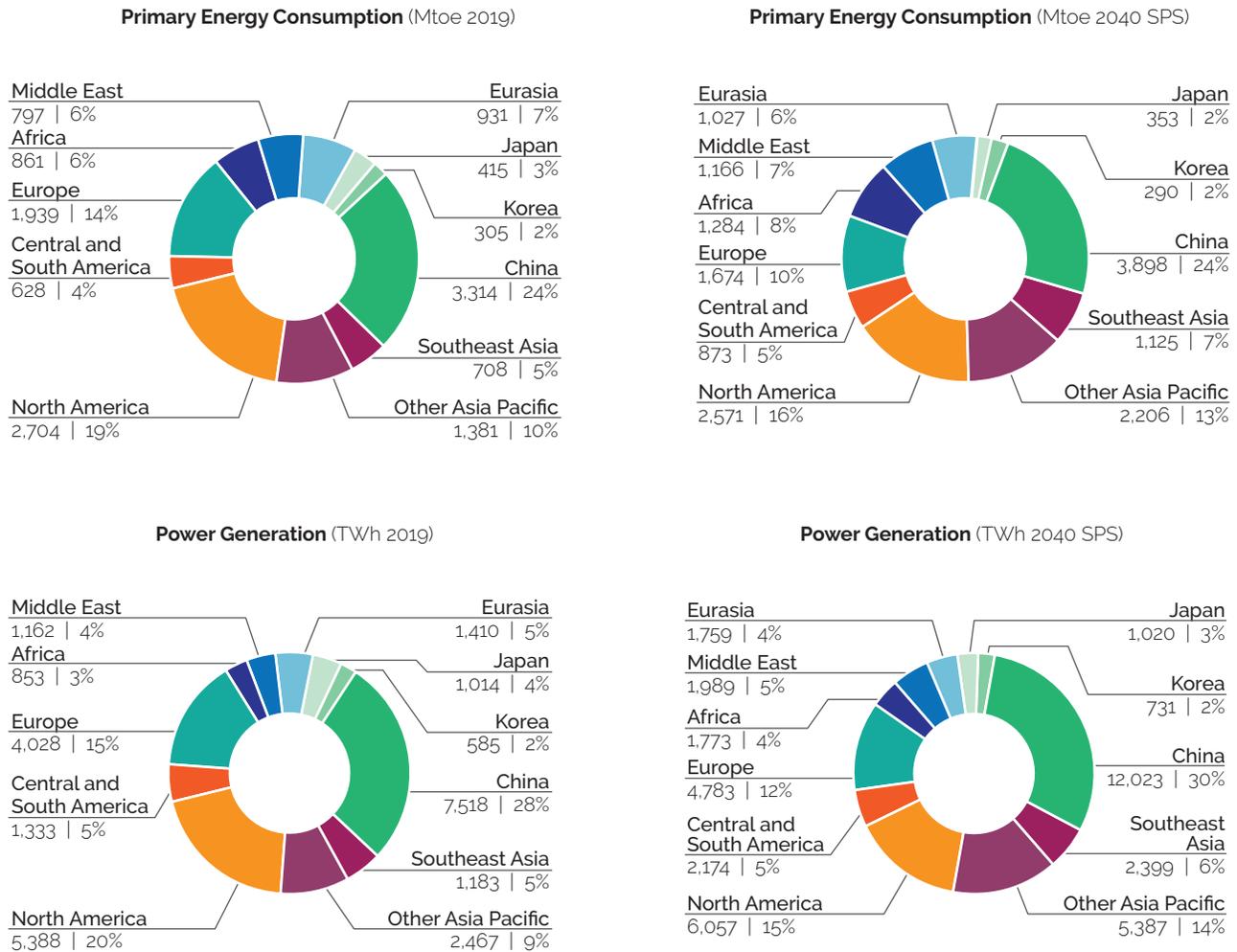


## REGIONAL OUTLOOK

The Southeast Asian region, for the purposes of this study, comprises the countries of the Association of Southeast Asian Nations (ASEAN). These countries are at a critical junction in their energy pathways. Energy demand in Southeast Asia, driven by economic development and urbanization, has increased by an average of 3.4 percent per year since 2000, a much higher rate than the global average of 2 percent per year, and its total primary energy supply is expected to increase almost three-fold by midcentury.

## Energy Market Drivers

The region's primary energy consumption and power generation are expected to grow faster than the projected global averages by 2040 (Figure 33). Fossil fuels overall are expected to comprise more than 80 percent of the energy mix by 2050, about the same share as today. Increasing vehicle ownership and demand for mobility drives oil demand, while growing energy demand from the power generation and industrial sectors has driven both coal and natural gas consumption, as well as LNG imports. Electrification of transport is not anticipated to make significant inroads in the coming decades, further contributing to poor urban air quality; natural gas is a desirable fuel in the region from an air quality perspective.

**Figure 33: Primary Energy Consumption and Power Generation by Region, 2019 and 2040<sup>8</sup>**

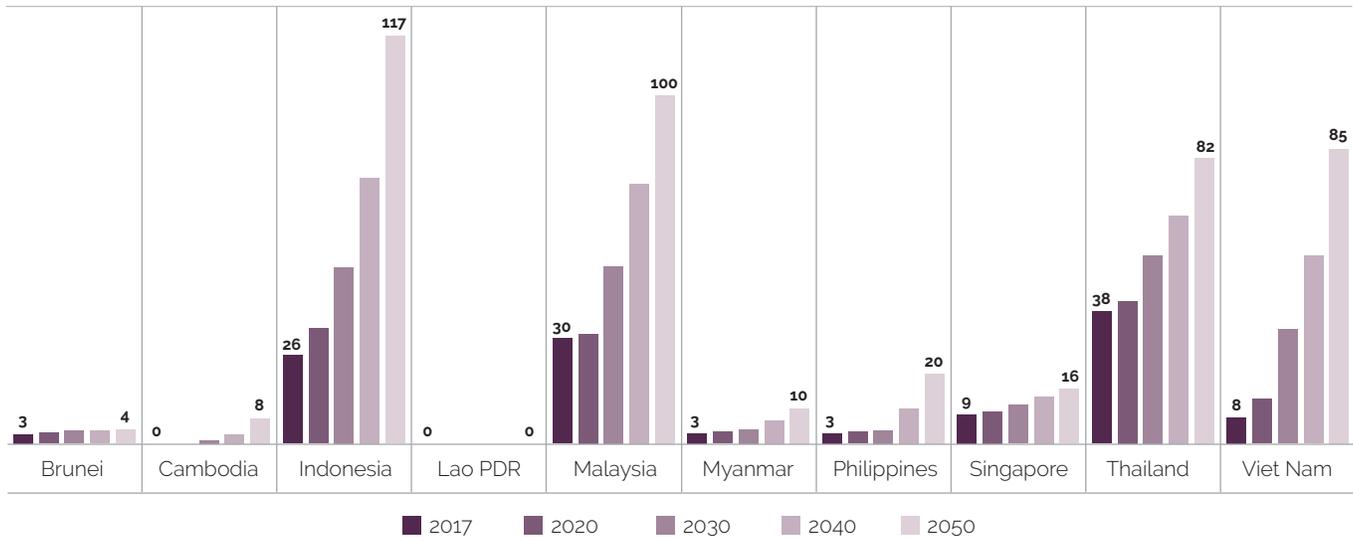
*Though comprising a relatively small percentage of global energy consumption and power generation, Southeast Asia's share of both is expected to grow more quickly than projected global averages through 2040. Source: IEEJ, 2021. Data from IEA, 2020; BP, 2020.*

The share of fossil fuels in the region's energy mix has increased from 56 percent in 1990 to 79 percent in 2018. Coal's share of the energy mix has risen significantly—from five percent in 1990 to 24 percent in 2019.

### Role of Natural Gas

In Indonesia, Malaysia, Thailand, the Philippines, and Vietnam, natural gas consumption is expected to increase significantly. Figure 34 shows natural gas demand in ASEAN countries between 2017 and 2050. The Philippines' domestic gas demand is so large

that its domestic gas reserves will soon be depleted. Vietnam has implemented policy to promote gas in power generation. Countries that have not historically consumed natural gas, like Cambodia, are expected to start using natural gas for power generation and transportation. Natural gas demand in all ASEAN countries is expected to increase, with Indonesia and Malaysia leading. In Cambodia, gas demand increases are small in absolute terms, but in percentage terms over time, are increasing rapidly.

**Figure 34: Natural Gas Demand in ASEAN Countries, 2017-2050 (mtoe)<sup>79</sup>**

Source: Phoumin, 2021.

## Emissions Outlook

The population of the ASEAN countries largely resides along the coastlines, making it very vulnerable to climate change impacts, particularly sea level rise. An Asian Development Bank study estimated that, since the 1950s, sea levels in the region have risen between 1 to 5 millimeters per year.<sup>80</sup> Severe weather events such as heat waves, flooding, droughts, and typhoons endemic to the region are made worse and occur more frequently, as a consequence of climate change.<sup>81</sup>

While the policy outlook in the region is currently heavily reliant on fossil fuels, governments and financial institutions could shift the trajectory by capitalizing on decreasing renewable costs and the region's renewable potential, prioritizing energy efficiency, and phasing out fossil fuel subsidies.

**Table 4: Southeast Asia Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019<sup>82</sup>**

CO <sub>2</sub> per Capita per Year from Fossil Fuels	Share of World CO <sub>2</sub> Emissions from Fossil Fuels	Share of World Population
<b>2.6 tons</b>	<b>4.6%</b>	<b>8.6%</b>
4.9 tons World Average	38,017 MT World Total	7.71 Bn People World Total

11 countries in analysis. Numbers are rounded. MT = Megatons.

Data from Crippa et al., 2020.

Table 4 provides some information about the Southeast Asian region's per capita fossil fuel emissions compared to global averages, and its share of total CO<sub>2</sub> emissions from fossil fuels relative to its share of total population. Its percentage of global CO<sub>2</sub> emissions relative to its population is low, and its per capita CO<sub>2</sub> emissions from fossil fuels are significantly lower than the global average.

## SUMMARY OF PANELIST DISCUSSION *(Authored by the Institute of Energy Economics, Japan)*

---

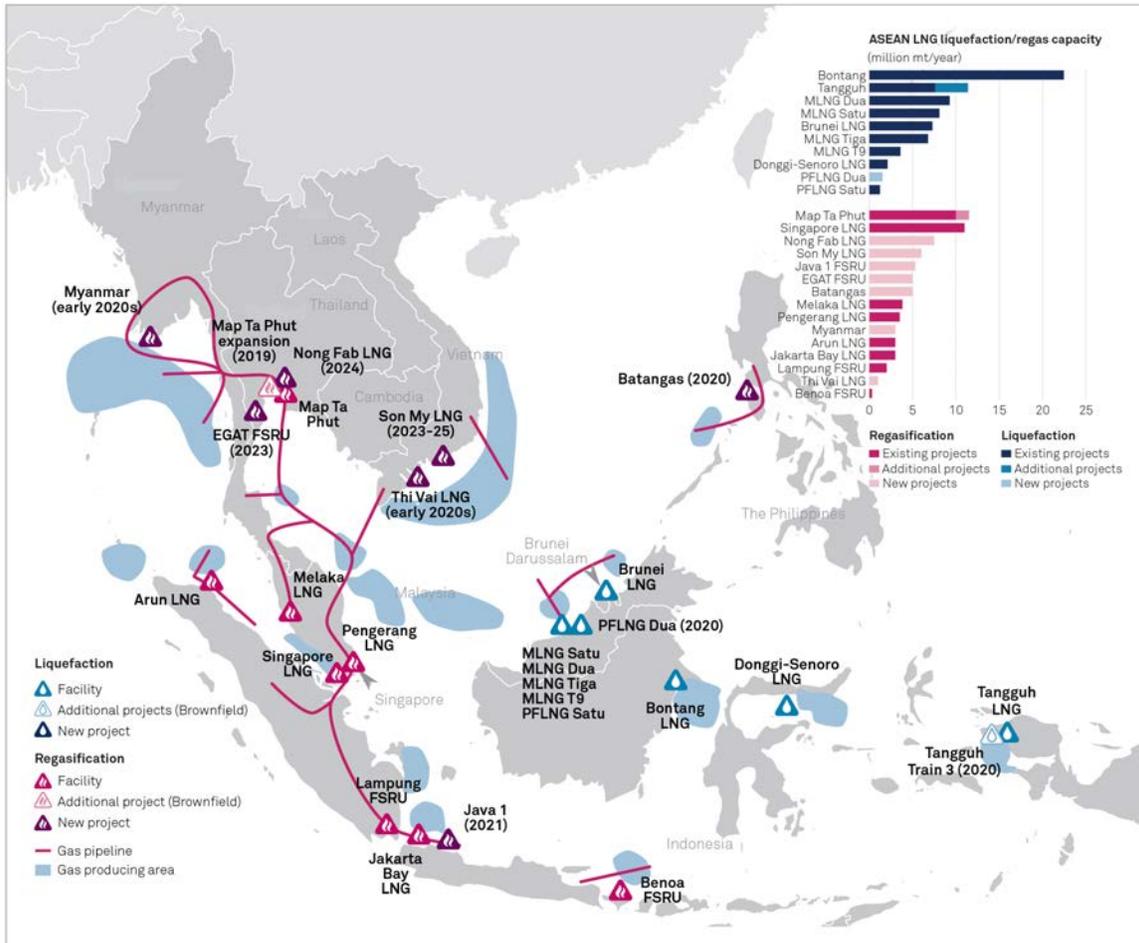
The workshop hosts and participants were provided with framing questions from EFI, which can be found on page 3 of this report.

### ***The role of natural gas in the energy transition***

Panelists anticipated that many ASEAN countries are expected to become net importers of natural gas to meet growing domestic demand.<sup>83</sup> Some countries in the region both export gas and import LNG. ASEAN LNG imports total 14.6 million metric tons per annum (mtpa)—Thailand imports 5 mtpa, Indonesia 3.6 mtpa, Singapore 3.3 mtpa, and Malaysia 2.7 mtpa. Future growth, however, depends on the stability of natural gas and LNG prices in the market and whether ASEAN and East Asia can create a competitive natural gas and LNG market in the future.

Achieving increasing LNG imports will require investment in infrastructure like LNG receiving terminals, pipelines or virtual pipelines, transportation, and storage facilities. The region currently has 13 cross-border pipelines with a total length of 3,600 kilometers, connecting six countries. The region also has nine LNG regasification terminals in four countries. Total combined system capacity is approximately 29 mtpa.

Although many infrastructure facilities, including LNG receiving terminals and pipelines, have been developed (Figure 35), they are insufficient to meet potential demand. Leaving investment decisions in major infrastructure to market forces has proven difficult; to date, concrete actions by governments or national oil companies have been the most important factor in the development of infrastructure and there are significant investment opportunities and infrastructure development plans. Interesting ideas include floating LNG receiving terminals, which are already in place in Myanmar, Indonesia, and Malaysia, and could be installed in the Philippines and Vietnam.

Figure 35: Southeast Asia's Key Gas and LNG Infrastructure<sup>64</sup>

This figure shows the location and project status of key natural gas and LNG infrastructure in the Southeast Asia region, as well as project regasification and liquefaction capacity. Source: Desmarescaux and Abreu, 2021

### Key economic and regional trends driving natural gas demand/uses

Domestic natural gas market liberalization is an ongoing policy agenda item for ASEAN countries. Governments can synergize and support development by sharing their rule- and regulation-making. Flexibility of LNG trading and long-term LNG contracts are also important issues.

Gas consumption and associated infrastructures in the region are largely designed and limited to meet demand in key economic sectors, especially industry. Participants asserted that natural gas demand would likely continue to increase to support economic

growth, particularly in the region's industrial sector, enabled by ongoing infrastructure development. Because of high coal use in the region, coal to gas switching could help lower emissions.

LNG regasification terminals have been the key to meeting the region's natural gas demand. By 2030, it is forecast that small-scale LNG demand in the ASEAN region will reach 10 to 16 mtpa total (Indonesia has a potential of 4.5 mtpa, the Philippines 2.3 mtpa, and Thailand 1.8 mtpa). Of that demand, 3 to 5 mtpa in the year 2030 is expected to be for small-scale LNG in Thailand, Malaysia, and Indonesia, and for LNG bunkering in a country like Singapore that requires many cargo ships.

While the region's countries may have high-level policy support for gas as a fuel, the state of market liberalization and competition varies by country. In some countries, prices are market-driven, and in other countries the government controls prices. Since natural gas is regarded as an important transition fuel in the ASEAN region, some governments provide policy support for use of natural gas. In Thailand and Vietnam, governments have promoted the development of floating LNG receiving facilities. The markets in Malaysia and Singapore are fully liberalized and open to competition.

Region-wide infrastructure will also promote regional natural gas demand. The Trans-ASEAN Natural Gas Pipeline is one of seven regional infrastructure projects discussed in the latest Energy Minister Meeting of ASEAN governments.

Promotional policies have been implemented to enable construction of LNG receiving terminals via regulatory arrangements. In Malaysia, a third-party access (TPA) system to LNG receiving facilities has been introduced. A participant noted that this policy will incentivize private actors to take part in natural gas business and invest in the natural gas infrastructure. Another participant added that, apart from the TPA system, the opportunity for small-scale LNG would encourage new players to join the natural gas business and invest in relevant infrastructure because the size of initial investment is relatively small. The creation of an LNG hub, by the Singaporean government for example, is expected to help improve the visibility of the LNG market and accelerate investment in LNG-related infrastructure.

### ***Major drivers of regional energy supply and demand***

Economic development is expected to increase electricity demand in the region, which will be supported by government policies. As previously noted, some governments in the region support natural gas use and infrastructure development. For

example, the Indonesian government's commitment to reduce GHG emissions up to 29 percent by 2030 promotes the use of cleaner fossil fuels, including the use of natural gas in power generation, as well as increasing renewable energy use, and energy efficiency. To promote strategic industry growth, which necessarily includes increased use of natural gas, the government has issued several decrees to regulate the plant-gate gas prices for certain industries and power plants.

### ***The range of potential futures of natural gas markets***

There are limited policies focused on restricting coal consumption in the ASEAN region. Existing infrastructure for coal-fired power generation is viewed as important for ongoing economic development and many national power sectors intend to maintain the use of this infrastructure to ensure reliable power and economic development. Continued use of coal limits key opportunities for increased natural gas use for power generation in the region.

### ***NDCs and climate targets***

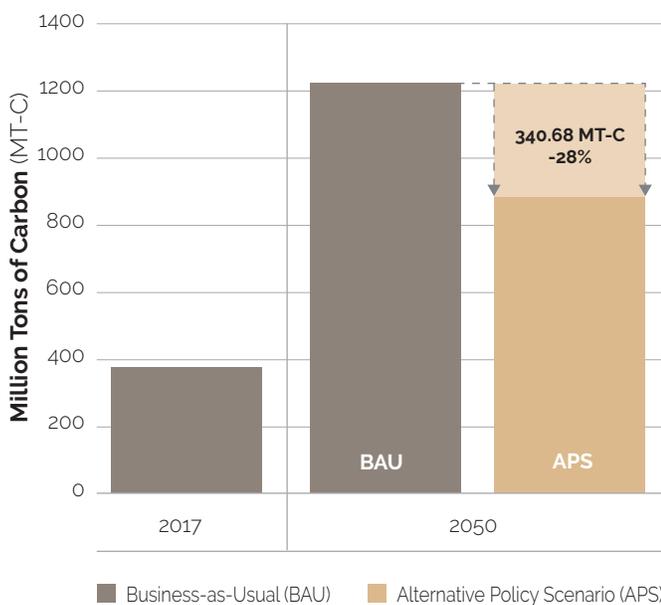
From 1960 to 2019, Southeast Asia's rate of emissions increase was 10 times the global rate. Post-2005, as regional concerns about greenhouse gas emissions grew and policies and programs for GHG mitigation were implemented, emissions growth in the region slowed—global emissions increased by a factor of 1.2 and Southeast Asia's emissions increased by a factor of 1.7.

There was limited discussion of Nationally Determined Contributions (NDC) in the workshop; participants noted that though ASEAN continues to pursue cleaner environment policies, the region's prospects for reaching net-zero targets is unlikely in the foreseeable future.

## Impact of climate policies on natural gas supply and demand

To support economic and population growth in the ASEAN regions, countries are focused on three key objectives—energy security, affordability, and environment—and have implemented policies to meet the Paris Agreement NDC commitments and the United Nations Sustainable Development Goal No.7.

**Figure 36: CO<sub>2</sub> Emissions in Cambodia, Laos, Myanmar, Vietnam, and Thailand, 2017 and 2050, Business-as-Usual vs. Alternative Policy Scenario<sup>85</sup>**



Adoption of an alternative policy scenario less favorable to coal in Cambodia, Laos, Myanmar, Vietnam, and Thailand could reduce 2050 emissions by approximately 28 percent, compared to a business-as-usual policy regime generally favorable to coal. Source: Phoumin, 2021.

Because there is significant coal generation in the region, increased use of natural gas could reduce regional GHG emissions and help countries meet their Paris targets. If the region considers “alternative” energy policies and practices, such as increased use of natural gas, clean fuels, and renewables to displace coal, regional emissions will decline compared to a “business-as-usual” scenario (Figure 36). As noted, however, willingness to reduce coal-fired generation in the region is generally limited.

The Philippines is one of the better performers in the region in terms of emissions reductions. Its Department of Energy announced a moratorium on new coal plants, a move that could help reduce emissions by 35 percent in 2030 and bring the country closer to its NDC target. The Department also intends to increase the country’s share of renewables, promote new technologies, increase flexibility, and adhere to higher environmental standards. Private and public alignment on natural gas in the Philippines could lead to an opportunity for natural gas to help decarbonize the country’s electricity sector.

Another example: Malaysia’s Petronas declared its ambition to reach net-zero carbon emissions by 2050. The target has four drivers: (1) building operational excellence, such as reducing hydrocarbon venting; (2) making cleaner energy, like natural gas and renewables, more accessible; (3) accelerating technology and innovation in low and zero carbon fuels, such as ammonia and hydrogen, and in CCUS; and (4) investing in carbon offset and natural based solutions.

*The Philippines is one of the better performers in the region in terms of emissions reductions. Its Department of Energy announced a moratorium on new coal plants, a move that could help reduce emissions by 35 percent in 2030 and bring the country closer to its NDC target. The Department also intends to increase the country’s share of renewables, promote new technologies, increase flexibility, and adhere to higher environmental standards.*

### ***Substitutes for natural gas in the 2030 and midcentury timeframes***

Workshop participants discussed substitution of other fossil fuels with a combination of natural gas and renewables; they did not focus on substitutes for natural gas.

The Energy Minister Meeting of ASEAN countries discussed a target of 23 percent renewable energy in power generation and 35 percent in installed generation capacity by 2025, a difficult goal to meet for development at this scale and in such a short period. Natural gas is expected to play an important role as a transition fuel for ASEAN countries, particularly for meeting increased electricity demand with new generation facilities (again, there was a general reticence to phase out existing coal generation in advance of expected facility lifespans).

### ***Policies to repurpose natural gas infrastructure for clean energy alternatives***

The countries in the region aim to reduce fossil fuel consumption and invest more in cleaner energy sources like renewables to achieve the goal of emissions reduction. However, many actors in the region believe that natural gas is complementary to renewables and will play an important role as a transition fuel. Thailand's 2018 power development plan anticipates a bullish future for natural gas in the long run based on three key tenets: security, economy, and environment. In 2037, at the end of the plan, natural gas will maintain its relative proportion in the energy mix, making up approximately 53 percent compared to 60 percent in 2018. Many countries in the region anticipate natural gas infrastructure expansion rather than repurposing.

### ***Role of natural gas/LNG in addressing developing country energy needs***

Small-scale solutions such as LNG bunkering vessels are affordable means to serve small and niche, but growing, demand. Some areas like remote islands in

*The countries in the region aim to reduce fossil fuel consumption and invest more in cleaner energy sources like renewables to achieve the goal of emissions reduction. However, many actors in the region believe that natural gas is complementary to renewables and will play an important role as a transition fuel.*

the eastern Indonesia have no access to significant natural gas pipeline networks. These areas are good candidates for small scale LNG and LNG bunkering. LNG-powered electricity generation could replace costly diesel generation in these remote areas.

### ***Incorporation of corporate ESG policies and financial institution guidelines for investments in new natural gas projects***

Despite minimal policy barriers to coal use, the construction of new coal power plants is increasingly difficult because of ESG concerns. Over the past years, coal has faced many non-governmental pressures in the region. In Thailand, for example, after a new coal-fired power plant was approved by the government's power development plan, construction was forced to stop however due to protests by residents of the region.

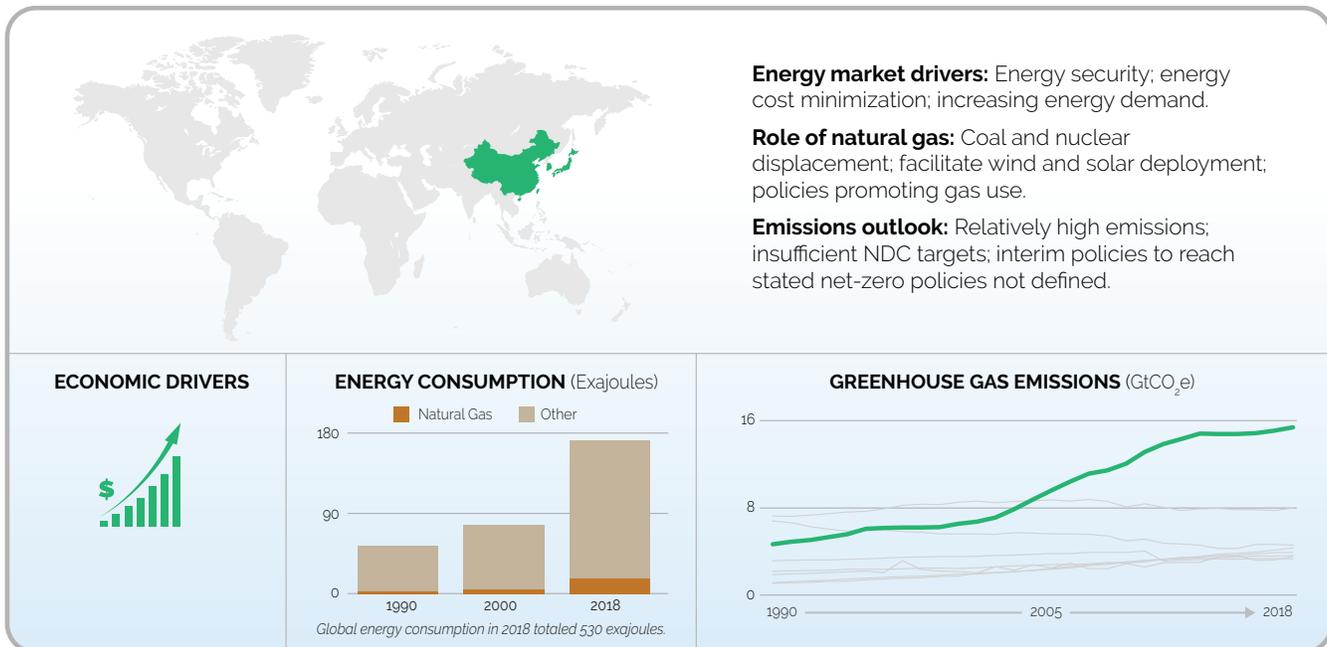
### ***The role of emissions abatement technologies***

In the long term, participants felt that the region should focus on hydrogen, value chain development, and renewable integration solutions. Apart from discussion of CCUS and carbon offsets as included in Petronas' net-zero plan, there was limited discussion of emissions abatement technologies applied directly to the natural gas system. As the region pursues carbon neutrality, members should have the ability to properly account for carbon accounting. Policy measures such as a carbon tax could provide price signals.

# NORTHEAST ASIA

The Institute of Energy Economics, Japan, hosted an invitation-only expert workshop on the future of natural gas in Northeast Asia in a low-carbon world.

Nine speakers and 40 participants from academia, think tanks and the private sector took part in the discussion. The event, held under Chatham House rule, took place on January 12<sup>th</sup>, 2021. The following is a summary of the workshop discussion.



## REGIONAL OUTLOOK

The Northeast Asia region—China, Japan, and South Korea—has seen significant economic development since the turn of the century. Development in the region has led to a doubling of energy consumption between 2000 and 2018 and a significant rise in emissions after 2005.

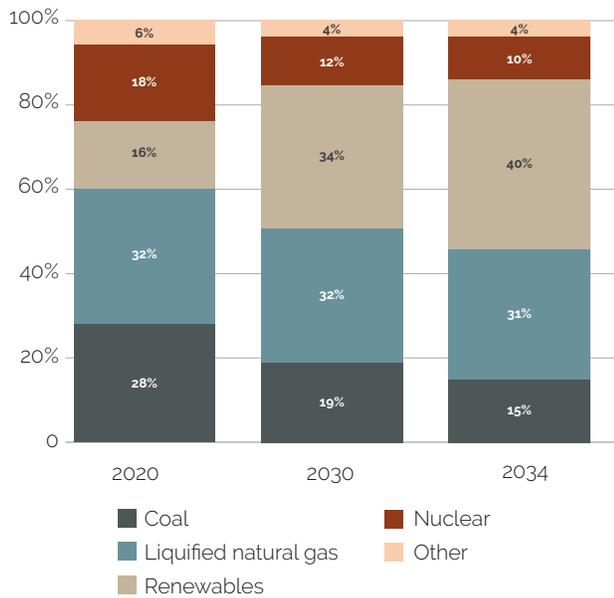
### Energy Market Drivers

While the region is still heavily reliant on fossil fuels, particularly coal, all three countries have set net-zero goals for the 2050 to 2060 timeframe and their energy mixes are undergoing transformation. To meet its 2060 carbon neutrality goal, China would, for example, need to reduce energy-related emissions

70 to 90 percent in 30 to 35 years. This would require the country to transform its energy use economywide, given its construction activity, large domestic coal supply, high per capita emissions, and the scale of its hard-to-abate emissions from key sectors.

Lacking sufficient domestic energy resources, South Korea and Japan rely heavily on energy imports. In 2019, fossil fuels accounted for 88 percent and 83 percent of total energy supply in Japan and South Korea, respectively. In Japan, nuclear power supplied about 15 percent of energy before the Fukushima nuclear incident in 2011; its share dropped below 1 percent after the incident and rebounded to only 3 percent in 2019.

**Figure 37: South Korean Power Capacity Mix Forecast<sup>86</sup>**



Source: South Korean Ministry of Trade, Industry, and Energy, 2020.

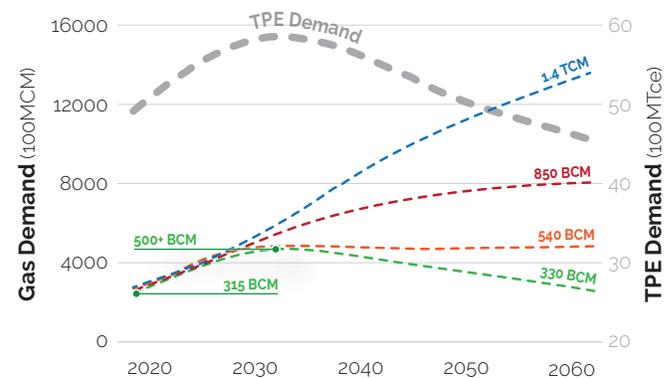
South Korea and Japan recently committed to net-zero emissions by 2050, which will require changes to their existing carbon-intensive energy mixes. To meet these commitments, the Japanese Prime Minister announced that Japan will fundamentally shift its policy on coal-fired power generation. In July of 2020, the Japanese Economy, Trade, and Industry Minister announced plans to shutter approximately 100 inefficient coal power plants by 2030.<sup>87</sup> Japan will revise its strategic energy plan in the summer of 2021 to reflect its carbon neutrality goal and the Green Growth Strategy it announced in 2020.

South Korea pledged \$7.1 billion for a Green New Deal that would replace coal with renewables. According to the 9<sup>th</sup> Basic Plan for Long-term Electricity Supply and Demand announced in 2020, South Korea will also move to phase out nuclear power over the long term<sup>h</sup>, drastically decrease its coal-fired power generation, and accelerate investments in renewable energy. Figure 37 shows South Korea's power capacity mix forecast through 2034. LNG is anticipated to serve as a bridge fuel and is projected to account for 31 percent of electricity generation in 2034, slightly down from 32 percent in 2020.

**Role of Natural Gas**

China, South Korea, and Japan are major energy consumers and are the largest LNG importers in the world. Regional demand for natural gas is growing, driven mostly by fuel switching from coal or nuclear power. In China, there is not yet consensus on the role of natural gas in energy transition. Projections of natural gas use vary—some researchers expect higher demand of natural gas as a complement to renewables through 2050 while others anticipate peak gas demand around 2030 (Figure 38).

**Figure 38: Varied Projections of Natural Gas Demand in China through 2060<sup>88</sup>**



The green line is the projection of the research team including Tsinghua University and the Rocky Mountain Institute. The orange, red, and blue lines are the projections of the research team that includes CNPC and CNOOC. Source: Shan, 2021.

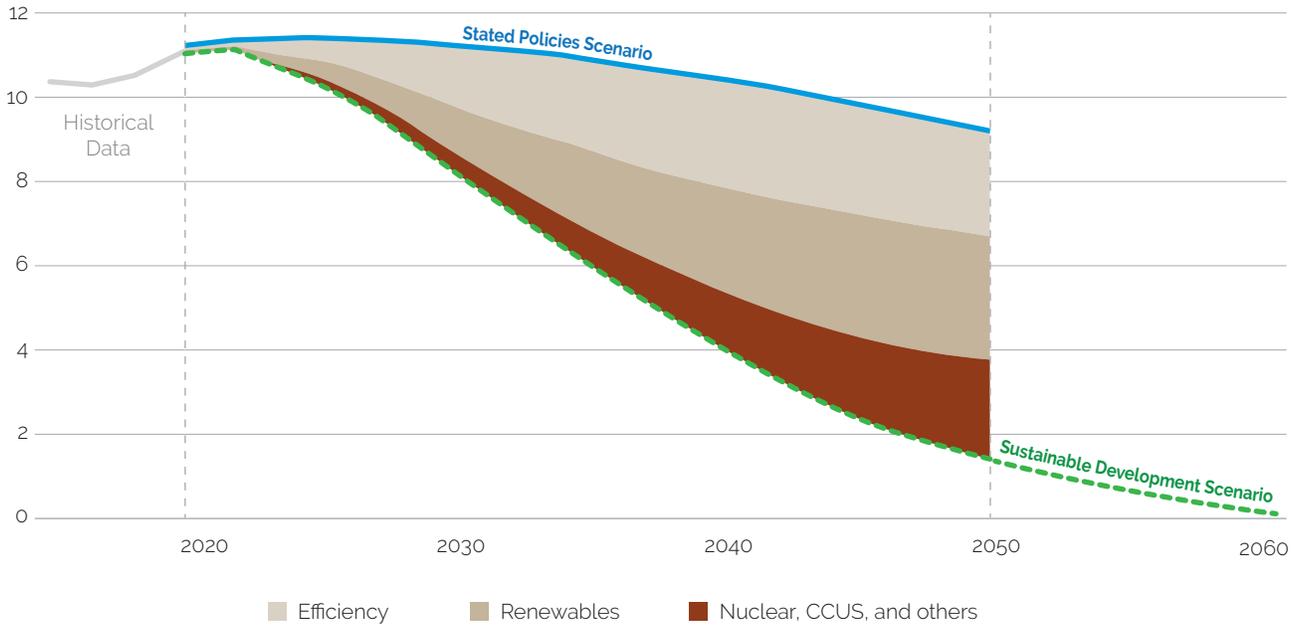
<sup>h</sup> According to EIA, Korea's nuclear phase out plan was proposed in part due to safety concerns following Japan's Fukushima incident.

### Emissions Outlook

China's current plans for achieving its emissions reduction targets prioritize energy conservation, promote the clean and efficient use of fossil energy, and support an innovation-driven development

strategy. The country is also investing heavily in renewable resources; in 2020, it was the world's largest renewable investor. More action, however, will be required across the economy to reach the country's net-zero target (Figure 39).

**Figure 39: CO<sub>2</sub> Emissions and Emissions Reductions Pathways in China, 2015-2060<sup>89</sup>**



*This figure shows China's historical emissions and China's projected emissions as forecast by IEA's Stated Policies Scenario and Sustainable Development Scenario. Current policies in China are not expected to achieve net-zero economywide emissions by the target year of 2060. Additional and more sweeping efficiency policies, renewable deployment efforts, and investment in nuclear, carbon capture, and other cleaner energy technologies are needed to achieve net-zero. Source: IEA, 2020*

Table 5 provides some information about the Northeast Asian region's per capita fossil fuel emissions compared to global averages, and its share of total CO<sub>2</sub> emissions from fossil fuels relative to its share of total population. The story told in the table is stark: these three countries, while comprising 21 percent of the global population, are emitting 36 percent of the world's CO<sub>2</sub> emissions from fossil fuels. The region's per capita emissions are almost 70 percent higher than the global average. Emissions reductions are urgently needed in the region, where, in China, for example, coal-to-gas fuel switching has already demonstrated actual and significant emissions reductions from the power sector.

**Table 5: Northeast Asia Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019<sup>90</sup>**

CO <sub>2</sub> per Capita per Year from Fossil Fuels	Share of World CO <sub>2</sub> Emissions from Fossil Fuels	Share of World Population
<b>8.2 tons</b>	<b>36%</b>	<b>21.4%</b>
4.9 tons World Average	38,017 MT World Total	7.71 Bn People World Total

6 countries in analysis. Numbers are rounded. MT = Megatons.

*Data from Crippa et al., 2020.*

## REPORT OF PANELIST DISCUSSION *(Authored by the Institute for Energy Economics, Japan)*

---

The workshop hosts and participants were provided with framing questions from EFI, which can be found on page 3 of this report.

### ***The role of natural gas in the energy transition***

The region is largely dependent on LNG imports for its natural gas supply, as it does not have sufficient domestic gas resources or production. China, Japan, and South Korea together account for about half of global LNG imports, and imports continue to grow. China is also planning on pipeline imports from Central Asia and Russia and an increase in domestic production.

The region's natural gas consumption in 2018 was 253 mtoe in China, 89 mtoe in Japan, and 50 mtoe in Korea. The share of natural gas in the primary energy mix is slightly smaller than the world average of 20 percent: in 2018, it was 8 percent of China's energy consumption, 20 percent of Japan's, and 16 percent of Korea's. Use of natural gas in power generation differs among countries. Japan and Korea generate 34 percent and 26 percent of their electricity, respectively, using natural gas, while China has a much lower percentage of gas-fired generation.

China is heavily reliant on coal; 77 percent of its power generation is coal-fired. At the same time, China's natural gas consumption has grown rapidly, driven by a considerable amount of coal to gas switching. Gas consumption increased by 15 percent in 2017, 18 percent in 2018, 9 percent in 2019 and 6 percent in 2020, and gas consumption totaled 292.5 mtoe last year.

Korea has an Energy Master Plan, a Basic Plan for Long-term Electricity Supply and Demand, and a Long-term Natural Gas Supply and Demand Plan. Its Basic Plan includes expansion of natural gas use, but there have been no statements around nor plans for how this will be accommodated within its net-zero commitments. According to the country's energy transition policy, LNG demand in the power sector in Korea will increase after the mid-2020s, with plans for natural gas generation to replace both coal and nuclear baseload generation.

### ***Key economic and regional trends driving natural gas demand/uses***

Economic growth and energy policy, including policy measures for nuclear power, impact natural gas demand in the Northeast Asia region. As gas import dependency is high in the region and the region plays a major role in the global LNG market, developments in the region's natural gas demand can have global LNG market impacts.

Affordability and price stability of natural gas are important factors impacting demand in the region. Several panelists pointed out that commoditization and flexibility of the LNG market are key to its expansion. The entry of the U.S. into global LNG markets and flow of LNG from the U.S. into Asia have contributed to gradual changes in regional

*Economic growth and energy policy, including policy measures for nuclear power, impact natural gas demand in the Northeast Asia region. As gas import dependency is high in the region and the region plays a major role in the global LNG market, developments in the region's natural gas demand can have global LNG market impacts.*

LNG pricing. Spot and short-term transactions are expected to increase in the future, and suppliers are changing contracting and pricing practices.

It should be noted, however, that LNG/natural gas consumers want to see stability or predictability of prices to mitigate volatility; consequently, there may be more changes to how future LNG volumes are contracted and priced. Regulations of the International Maritime Organization (IMO) strengthen LNG's position as bunkering fuel, but LNG demand uncertainty could intensify as renewables proliferate and temperature volatility increases.

The global spread of COVID-19 has also impacted energy use in the region. China's natural gas consumption was significantly influenced by COVID-19 in the first half of 2020, but gas consumption has increased rapidly since the second quarter, reflecting the growth of the Chinese economy. Its domestic natural gas production maintains an average annual growth rate of 10 percent. Natural gas production in 2020 was projected to reach 172.8 mtoe, an increase of 8 percent. Unconventional natural gas output comprised 34.2 mtoe, a growth rate of almost 26 percent. Seasonal fluctuation of natural gas demand has been amplified by various factors, including greater emphasis of renewable energy sources and policy measures to switch from coal to gas in China.

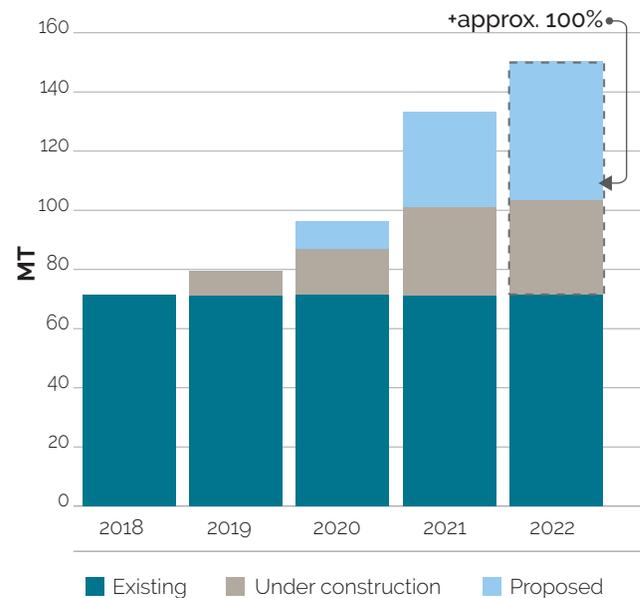
### **Major drivers of regional energy supply and demand**

Energy security remains the highest priority in the region due to a dependence on imports and generally low availability of domestic energy resources. Japanese, Korean, and Chinese ambitions of carbon neutrality by midcentury are also anticipated to impact future supply and demand for natural gas, coal,

nuclear, and renewables. The economic and energy system development and transformation required to reach these goals, particularly in China, will have ripple effects on regional and global energy markets.

Figure 40 shows LNG regasification additions in China for 2018 to 2022, where capacity is expected to almost double over this four-year period. This strongly suggests that China is committing to more natural gas over the long term, where it will have applications in industry and power generation while improving air quality in China's cities. However, the country will have to reconcile its plans for increased LNG imports with its net-zero ambitions.

**Figure 40: China Regasification Capacity Additions, 2018-2022**



Source: Royal Dutch Shell, 2019. Data from IHS Markit, 2018.

### ***The range of potential futures of natural gas markets***

Participants noted that to achieve ambitious climate goals, innovative technologies including decarbonization of fossil fuels should be emphasized. Since natural gas is a highly versatile, relatively low-carbon fossil fuel compared to oil and coal, its future supply and demand ranges will likely vary dramatically depending on how its role is viewed in the clean energy transition, balanced with other national drivers that support its continued use, including energy security.

In this regard, Japan is studying offshore options for carbon sequestration; success in this arena could affect future gas demand, as carbon capture, utilization, and storage (CCUS) from gas plants could enable ongoing activities in both hydrogen and power generation while enabling Japan to meet its emissions targets.<sup>i91</sup>

In Korea, policy priorities will likely increase LNG demand in the power sector after the mid-2020s when nuclear power will be phased out, coal-fired power generation will be drastically reduced, and renewable energy will be expanded to move to a safe and clean power mix. The country's 2013 3<sup>rd</sup> Energy Master Plan set the target share of renewable energy in the power mix at 20 percent in 2030.

To promote gas consumption, the Korean government announced a new tariff system and gradually opened the energy market to the private sector to lower LNG prices, which will contribute further to increased gas demand and the energy transition. The role of LNG in Korea is expected to be increasingly important going forward. LNG could be used as an alternative fuel for power generation to replace drastic decreases

in power from coal and as backup generation for intermittent renewables.

Government policy and carbon pricing are the most important factors in the growth of China's gas market. China established a nationwide carbon market in January 2020, which will likely increase coal prices and make gas more economically competitive in the future. China has LNG and pipeline gas import contracts, which are linked to oil prices. International oil prices are expected to be lower relative to prices over the past five years, leading to cheaper gas. These factors could contribute to more coal-to-gas switching.

### ***NDCs and climate targets***

As noted, governments and companies in the region have policies or ambitions of carbon neutrality. China, the world's second largest economy and a key producer of greenhouse gases, has announced plans and policies to achieve carbon neutrality before 2060. Workshop participants conceded that this goal would be a very difficult one to achieve in such a short time. The goal requires lower energy demand growth, prioritization of energy efficiency and conservation, promoting the clean use of fossil energy by capturing, sequestering, and using carbon dioxide, and implementing an innovation-driven development strategy.

Participants noted that Japan and Korea have not yet reconciled the anticipated increase of natural gas use with net-zero climate ambitions. In 2019, a Japanese utility became the first energy utility company in the region to formulate and announce its plans for achieving net-zero emissions. The company said it would achieve net-zero for all its business activities,

i According to news reports, "U.S. engineering and construction giant KBR has been awarded a contract for Carbon Capture and Sequestration works at JX Nippon's offshore oil and gas fields in Southeast Asia...Under a Master Service Agreement (MSA) and Feasibility Study awarded to KBR by Japan-based oil and gas company JX Nippon, KBR will assess options for Carbon Capture and Sequestration (CCS), alongside blue hydrogen production relating to oil and gas fields in Southeast Asia. KBR will also evaluate the feasibility of conversion and transport of hydrogen in other forms for sale into the market, including liquified cryogenic hydrogen, liquid organic hydrogen carrier (LOHC), ammonia, and methanol (utilizing CO<sub>2</sub>)."

including emissions from its customers. Measures it identified to help reach this goal include emission reduction strategies on both the supply and demand sides. Examples of demand-side measures include building smart energy networks and residential fuel cells; supply side measures include more coal-to-gas fuel switching, supplying carbon-neutral city gas using CO<sub>2</sub> credits, and introducing renewable energy in Japan and overseas. To achieve future decarbonization, the company intends to pursue innovation in core technologies like hydrogen production and CCUS.

### **Impact of climate policies on natural gas supply and demand**

As noted, in the second half of 2020, Japan, South Korea, and China expressed ambitions of carbon neutrality by midcentury. Significant impacts on future natural gas demand are expected, as all countries in the region depend on imports for gas supply. Countries in the region are invested in innovation and progress on key technology development that will affect future demand for natural gas.

In March 2020, the Japanese Ministry of Economy, Trade and Industry (METI) announced a strategy based on “3E+S”—energy security, economic efficiency and environment plus safety. The strategy emphasized diversification of LNG supply sources and transportation routes and a flexible international LNG market to meet Asian demand. Innovation, such as next-generation solar cells and carbon recycling, could lead to future economic growth and environmental protection. In December 2020, the government also announced a strategy calling for 50 to 60 percent renewables in the power mix that, if achieved, could as much as triple renewable generation. METI also announced plans to eliminate inefficient coal-fired power plants, which comprise 15 percent of the nation's total power generation capacity. Some Japanese power companies are aiming for deeper reductions in carbon emissions intensity than those proposed by the government.

*In March 2020, the Japanese Ministry of Economy, Trade and Industry (METI) announced a strategy based on “3E+S”—energy security, economic efficiency and environment plus safety. The strategy emphasized diversification of LNG supply sources and transportation routes and a flexible international LNG market to meet Asian demand.*

South Korea plans to reduce its number of coal-fired power plants. While this will help mitigate GHG emissions and achieve its NDC goals that could lead to net-zero emissions or carbon neutrality by 2050, Korea expects to increase its use of natural gas in power generation, with uncertain long-term impacts on its emissions targets.

China's carbon neutrality goals are expected to accelerate the country's green and low carbon transition, and workshop participants discussed five potential roles that natural gas could play in that transition. It can serve as a transitional energy and a “bridge” from high-carbon to low-carbon fuels; it is a pragmatic energy source by which to improve air quality; it can enable acceleration of non-fossil development; it is a popular energy choice for heating; and it is an important resource for the development of blue hydrogen.

Although increasing natural gas use will emit carbon, natural gas in the Northeast Asia region was framed by several workshop participants as a transition fuel in a “realistic” world. Affordability and commoditization are key to increasing demand for LNG in the Asian market. Market mechanisms designed by the government that minimize the cost of the transition are important policy objectives. Co-firing ammonia and coal, or hydrogen and gas, could be used during the transition period. Workshop participants highlighted the criticality of a step-by-step approach.

### **Substitutes for natural gas in the 2030 and midcentury timeframes**

Technology, such as ammonia co-combustion with different fossil fuels, may not necessarily substitute for natural gas but may supplement its use. There are also other technological innovations in hydrogen that could, depending on how the hydrogen is made, augment or complement gas consumption, including small hydrogen fuel cell technologies and fuel cell buses.

In the long run, the futures of natural gas and renewable energy are connected. This relationship will likely continue for some time absent technology breakthroughs in long-duration storage and storage cost reductions.

In Korea, the government is investigating hydrogen potential and has selected KOGAS as its hydrogen distributor. The target is to first produce and use blue hydrogen with carbon capture and storage (CCS); this could pave the way for green hydrogen in the long term, which could displace natural gas in the midcentury timeframe.

### **Policies to repurpose natural gas infrastructure for clean energy alternatives**

There was limited discussion around repurposing natural gas infrastructure for clean energy alternatives. In fact, as noted earlier, China is accelerating construction of natural gas infrastructure including pipelines, LNG terminals and gas storage facilities. The establishment of PipeChina, a state-owned company created to consolidate pipeline assets from oil and gas companies in 2019, has reshaped the natural gas industry in China and is helping to accelerate the construction of other gas infrastructure. Chinese representatives did mention the possibility of using pipeline infrastructure to transport hydrogen in the future as prices come down for green hydrogen or CCS is developed for blue hydrogen.

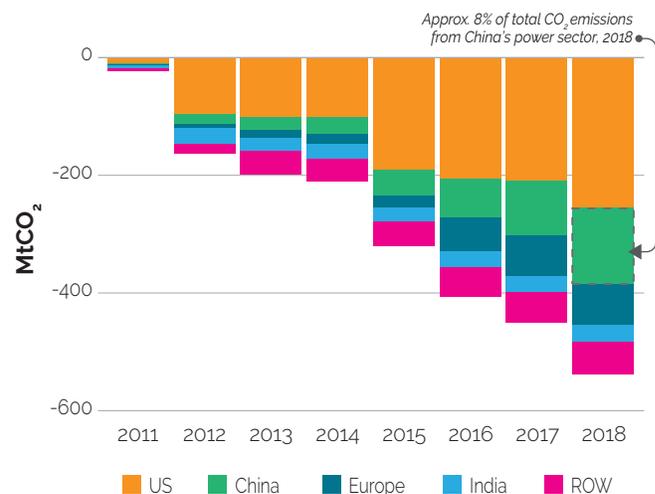
Korea is also continuing to expand its natural gas infrastructure to meet energy demand. This is consistent with the government's energy transition policy calling for more gas and renewables to achieve a decarbonized economy. Like China, South Korea's natural gas utilities are investigating the feasibility of hydrogen blending and distribution.

### **Role of natural gas/LNG in addressing developing country energy needs**

Northeast Asian companies are working to develop downstream and midstream natural gas businesses in developing economies. These companies have LNG capacity or equity volumes in the United States and Europe and are developing concrete ideas to improve and streamline LNG physical flows and logistics to reduce cost and increase the commercial viability of LNG.

Coal-to-gas switching for strategic end uses in China has also helped alleviate significant air quality issues and reduce CO<sub>2</sub> emissions (Figure 41). As seen in the figure, between 2011 and 2018, China was able to reduce its CO<sub>2</sub> emissions from the power sector by about 8 percent by switching from coal to gas power generation.<sup>92</sup>

**Figure 41: Regional CO<sub>2</sub> Emissions Savings from Coal to Gas Fuel Switching, 2010-2018<sup>93</sup>**



Source: IEA, 2019.

Northeast Asian companies are working to develop downstream and midstream natural gas businesses in developing economies. These companies are developing concrete ideas to improve and streamline LNG physical flows and logistics to reduce cost and increase the commercial viability of LNG.

***Incorporation of corporate ESG policies and financial institution guidelines for investments in new natural gas projects***

Liquefied and piped natural gas projects are underway throughout the region. Workshop participants did not discuss any slowdown in regional investment due to ESG or financial institution guidelines on fossil fuel investment. Some participants in the Northeast Asia region expressed concerns about the uncertainty of the Biden Administration's position on LNG exports, worried that the "keep it in the ground" movement could affect U.S. natural gas production and its LNG supplies for their countries. Natural gas plays a key role in Northeast Asia's economic, air quality, and climate policies that rely, in part, on the availability of U.S. exports, investments, and businesses.

*Some participants in the Northeast Asia region expressed concerns about the uncertainty of the Biden Administration's position on LNG exports, worried that the "keep it in the ground" movement could affect U.S. natural gas production and its LNG supplies for their countries. Natural gas plays a key role in Northeast Asia's economic, air quality, and climate policies that rely, in part, on the availability of U.S. exports, investments, and businesses.*

***The role of emissions abatement technologies***

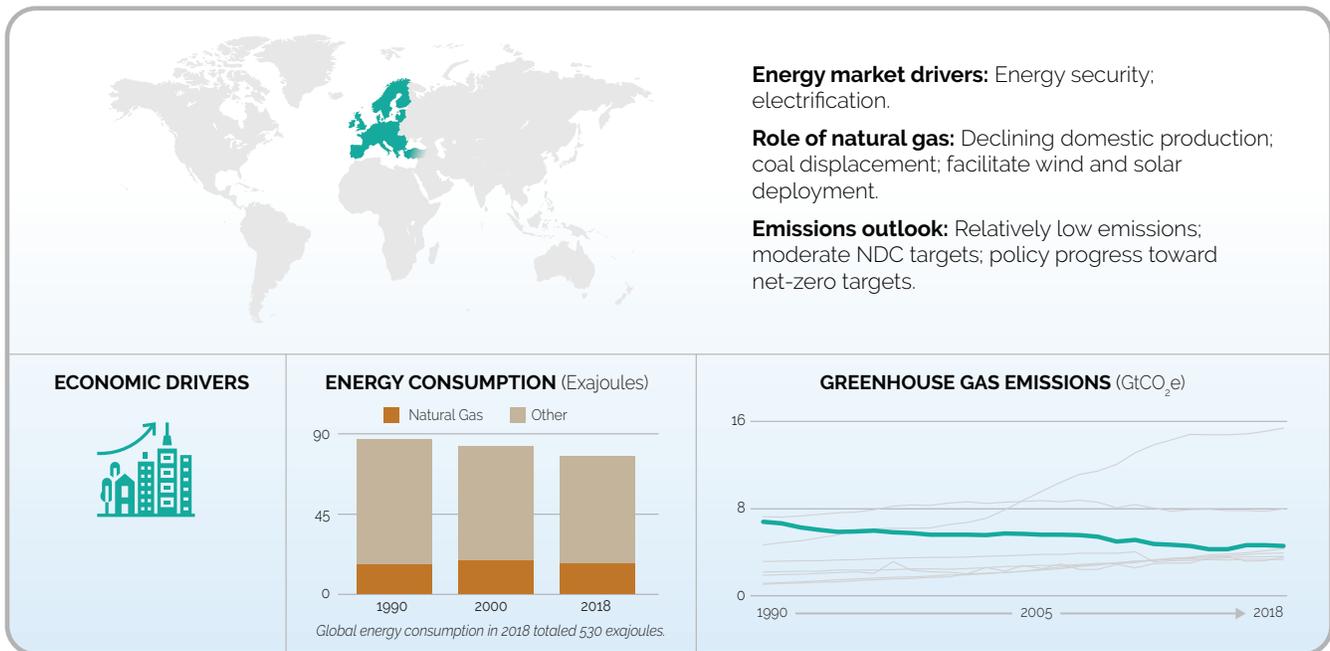
There is recognition in the region that increased natural gas use will have to be offset elsewhere in energy systems. Offset or emissions reduction options discussed included management of CO<sub>2</sub> using CCUS, methane management, renewable gas, and re-forestation and other nature-based offsets.

Korea is developing CO<sub>2</sub> mitigation and decarbonization technologies such as CCUS. Japanese utilities are pursuing long-term technologies like microbubble CCUS and methanation, as well as energy efficiency technologies. Innovation in areas such as ammonia transportation from Saudi Arabia to Japan and co-combustion with different fossil fuels will also shape natural gas use. The region has seen innovation in other energy areas, such as hydrogen using fuel cell technologies and fuel cell buses. Integrated project management on the upstream side, a service provided by many Japanese engineering companies, or integrated energy use in downstream areas may also be considered and bring additional opportunities for innovation. Existing knowledge can be repurposed into different applications.

# EUROPE

The Oxford Institute for Energy Studies (OIES), with the cooperation of the Center for the Study of Democracy (CSD) in Bulgaria, hosted an invitation-only expert workshop on the future of natural gas in Europe in a low-carbon world.

10 speakers and 55 participants from academia, think tanks and the private sector took part in the discussion. The two-day event, held under Chatham House rule, took place on January 21<sup>st</sup> and 22<sup>nd</sup>, 2021. The following is a summary of the workshop discussion.



## REGIONAL OUTLOOK

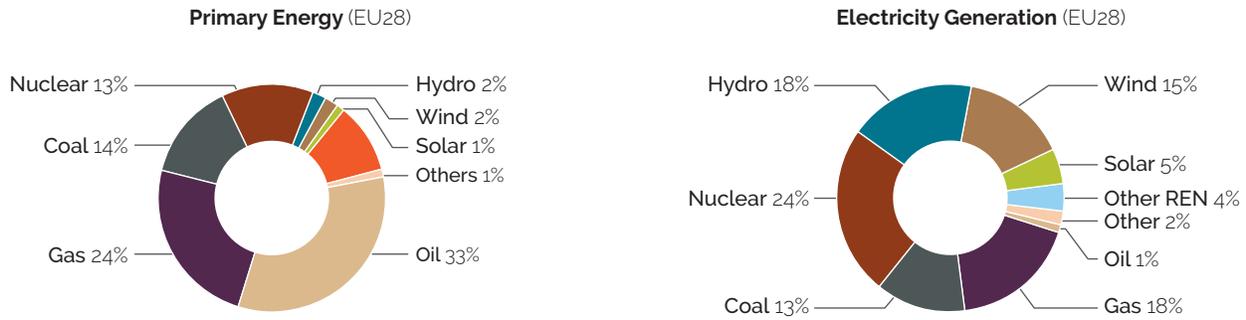
The European regional workshop covered the 27 member states of the European Union (EU), as well as the United Kingdom and the countries of Central & Eastern Europe (CEE) and Southeast Europe (SEE). The region is relatively urban and emissions overall have been declining over time in part due to ambitious decarbonization policies.

### Energy Market Drivers

The EU and the United Kingdom have taken significant steps to decarbonize the power sector through deployment of renewable technologies and coal-to-gas fuel switching (Figure 42). In 2019, the

European Green Deal (EGD) laid out a framework for achieving greenhouse gas (GHG) emissions neutrality by 2050. While strong policy instruments such as Renewable Energy Directive (RED) I & II and the EU Emissions Trading System (ETS) provide carbon price signals, more renewables deployment and fuel switching are needed in the transport, industrial, and buildings sectors to achieve carbon neutrality. Fuel switching is also promoted by the Directive on the Deployment of Alternative Fuels Infrastructure, which requires that member states provide a minimum infrastructure for alternative fuels such as electricity, hydrogen, and natural gas. A revision of the Directive is planned for 2021.

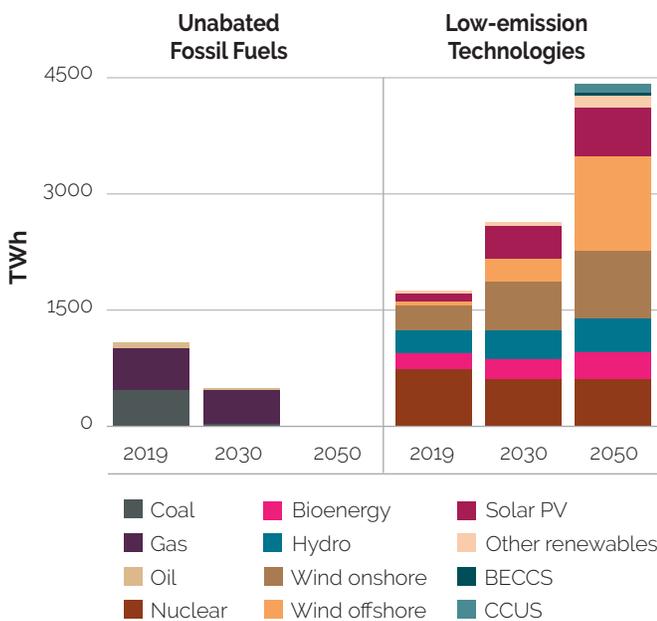
**Figure 42: Primary Energy and Electricity Generation by Source in the EU28<sup>94</sup>**



Despite the fact that 71 percent of primary energy in the EU and the United Kingdom derives from fossil fuels, hydropower, wind, nuclear, solar, and other renewables comprise 66 percent of electricity generation in these countries. Data includes the United Kingdom. Source: Honoré, 2021. Data from IEA and ENTSOE.

Figure 43 shows that in the IEA’s Sustainable Development Scenario (SDS), virtually all unabated coal is phased out of the EU electricity mix by 2030. More than 80 percent of EU electricity comes from renewables in 2050.

**Figure 43: Electricity generation by source in the EU, 2019-2050, IEA Sustainable Development Scenario<sup>95,96</sup>**



Source: Gould, 2021.

### Role of Natural Gas

On the supply side, the ongoing decline in domestic natural gas production in Europe is expected to continue. Additional production of lower-carbon gases (at low volumes) is expected, but many challenges lie ahead. Energy security in Europe, for example, is a key consideration as low domestic production leaves the region reliant on LNG and pipeline gas imports from Russia, the U.S., and the Middle East; reliance on Russia will substantially increase when the Nord Stream 2 pipeline becomes operational. The energy security issue in the CEE and SEE areas is particularly acute as countries in these regions have more fossil-intensive legacy energy mixes than other European countries and remain highly dependent on fossil fuel imports. Switching from coal to natural gas for electricity generation in CEE and SEE would help improve poor air quality in these areas but could amplify energy supply and security challenges.

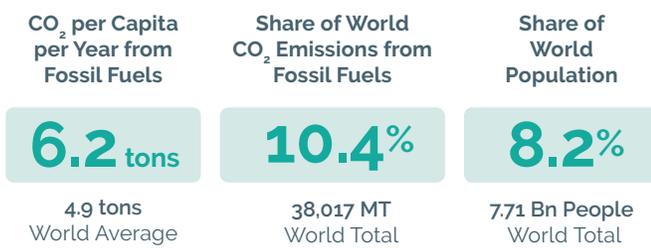
On the demand side, natural gas imports will remain essential although assumptions on demand will determine if imports increase and by how much in the 2020s. On the supply side, there will be continued uncertainty regarding energy security, import dependence, flexibility, and price. The EU’s net-zero 2050 goal and high GHG emissions reduction targets by 2030 will require a very rapid transition over the

next decade. Participants felt that, at this point, there is still no clear pathway to net-zero emissions by 2050 in many sectors. While full electrification has been the focus of policy discussions, there are ongoing debates about the role of and need for gases (low- or zero-carbon gases) in the energy mix for net-zero scenarios. A combination of options must be considered to reach targets and adapted to local circumstances. Natural gas, however, is not the only solution and not necessarily the first choice, even in hard-to-abate sectors.

### Emissions Outlook

Table 6 provides information about the European region's per capita fossil fuel emissions compared to global averages, and its share of total CO<sub>2</sub> emissions from fossil fuels relative to its share of total population. One of the world's most developed regions, Europe has a higher percentage of emissions from fossil fuels than its percent of the global population. Its per capita emissions are also 26 percent higher than the global average. These statistics, as well as EU and UK primary energy consumption dominated by fossil fuels (approximately 70 percent), pose challenges to rapid decarbonization.

**Table 6: Europe Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019<sup>97</sup>**



*EU + 12 countries in analysis. Numbers are rounded. MT = Megatons.*

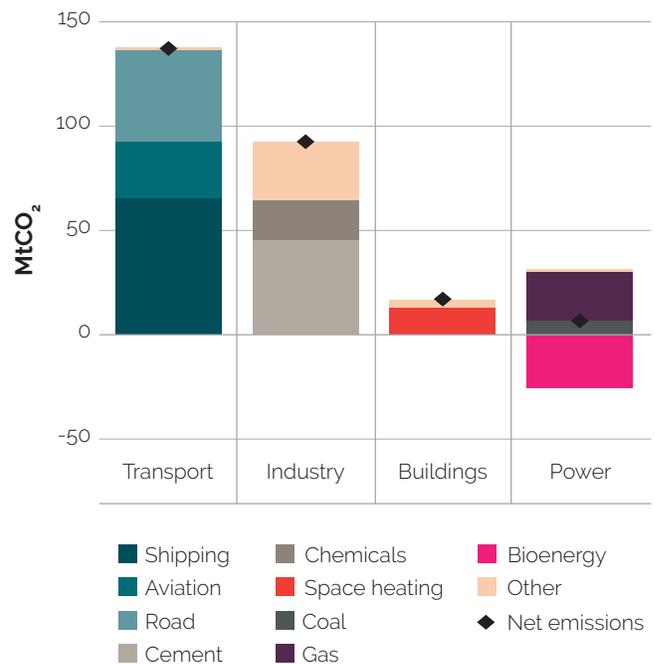
*Data from Crippa et al., 2020.*

The EU has officially endorsed a binding target of at least a 55 percent emissions reduction by 2030 from a 1990 baseline. To reach this target, commercially available emissions abatement technologies will need to be rapidly deployed and scaled, and assets may be stranded in the process. While natural gas is not favored by many policymakers in the region, it may be useful in the near-term to achieve emissions reductions as coal and oil scale down.

In the IEA's SDS, there are still some residual emissions in the economy in 2050, as shown in Figure 44. Emissions most notably remain in transport and industry, the sub-sectors that are most difficult to fully electrify; natural gas or other gaseous fuels could play a role here as well.

In addition, emissions across the supply chain are a growing concern--importers are concerned about upstream emissions in exporting countries that could affect or inform border adjustments considerations underway in the EU. This could also affect the import of key metals and minerals.

**Figure 44: Remaining CO<sub>2</sub> Emissions in the EU, IEA Sustainable Development Scenario, 2050<sup>98</sup>**



*Source: Gould, 2021.*

## REPORT OF PANELIST DISCUSSION *(Authored by the Oxford Institute for Energy Studies)*

The workshop hosts and participants were provided with framing questions from EFI, which can be found on page 3 of this report.

### ***The role of natural gas in the energy transition***

Fossil fuels today meet 71 percent of European primary energy needs; natural gas consumption is 24 percent of the total. In electricity generation, coal still accounts for 14 percent and oil accounts for 33 percent. The mix of energy demand and electricity generation varies significantly across countries.

*Given building renovation rates and the lack of options for high temperature process heat needed in industry and feedstocks, it is likely that natural gas will continue on its current consumption path, although efficiency improvements in both buildings and industry could lower overall energy demand and requirements. Efficiency improvements in buildings could, over time, also change energy sources, using, for example, heat pumps for heating in place of natural gas. Changeovers of this type will, however, take time.*

So far, most decarbonization efforts and policies have been focused in the power sector, but there are still large disparities regarding carbon intensity of electricity generation across Europe. Most carbon-intensive countries still rely on coal for a large share of generation. Many countries, especially (but not only) in Western Europe, have set a date for coal phase out. Most are looking at this decade to make it happen. Some nuclear is also expected to shut down in Germany and Belgium.

To reach the new EU 2030 emissions targets, coal generation will have to decline in all countries and at a faster pace than initially planned, even in countries that do not plan a total phase out by 2030 (i.e., Eastern Europe). It is uncertain how this coal will be replaced, and by what. In the long term, the objective is to replace it with renewables; however, the new 2030 emissions target means that it is likely that gas-fired plants may play a bigger role for both baseload and as an enabler of more rapid integration of renewables into the generation mix over the next decade. This will be critical absent breakthroughs in long-duration storage technologies needed to manage renewable generation intermittency.

The next step will be the decarbonization of transport and heat for industry and buildings. There is a large diversity of sources of heat generation across Europe. As a result, challenges and solutions vary greatly from one country to another, but the solutions will be complicated and take time. These solutions, however, need to be developed in the next decade to meet emissions goals.

Given building renovation rates and the lack of options for high temperature process heat needed in industry and feedstocks, it is likely that natural gas will continue on its current consumption path, although efficiency improvements in both buildings and industry could lower overall energy demand and requirements. Efficiency improvements in buildings could, over time, also change energy sources, using, for example, heat pumps for heating in place of natural gas. Changeovers of this type will, however, take time.

In the transportation sector, there is limited diversification from oil, and for passenger vehicles the path to decarbonization is likely to be through electric vehicles (EVs). Natural gas use in European transport is quite small, comprising only 1 percent of total gas demand and 0.5 percent of the vehicle passenger fleet (half of which is in Italy).

Decarbonization of heavy-duty transport could however mean an increase in natural gas demand, contrary to other sectors where it will mean a decrease. How much more gas and what sort of gas is yet unclear. LNG is considered appropriate and desirable for trucks, buses, and coaches, and the number of LNG refueling stations in Europe has doubled in last two years. There are also increasingly common discussions around other options, including electric solutions and hydrogen.

Overall, up to 2030, natural gas is expected to continue to play an important role for natural gas in Europe, with flat demand or a small decline in the second half of the decade due to improved efficiency and a shift toward renewables and other low- or zero-carbon sources. Beyond 2030, gas demand will have to decline across all sectors if Europe is going to meet its climate targets.

There may be some increased role for natural gas if it is used as a major source for blue hydrogen via steam reforming. The debate about the potential role of hydrogen in Europe and how it should be produced is now underway, but it seems clear that some form of gaseous fuel will be part of the European energy mix to allow greater flexibility in the system and to avoid leaving billions of dollars of stranded gas infrastructure.

### ***Key economic and regional trends driving natural gas demand/uses***

The economic impacts of and recovery from measures taken to limit the spread of COVID-19 could affect the energy sector in the 2020s, especially as recovery packages focused on "green" recovery fund

further electrification, renewables, and efficiency measures while providing limited support to the natural gas industry. Also, significant population growth in Europe is not expected and some countries (e.g., Germany, Russia) will see population declines. At the same time, Europe's population is becoming more urban, changing both the problem and solution sets needed for a zero-carbon economy.

Many Eastern European countries are receptive to ambitious emissions reductions targets proposed and adopted by the European Union, but there is still a lot of uncertainty in Eastern Europe on decarbonization strategies (gas, nuclear, etc.) and how to finance those strategies.

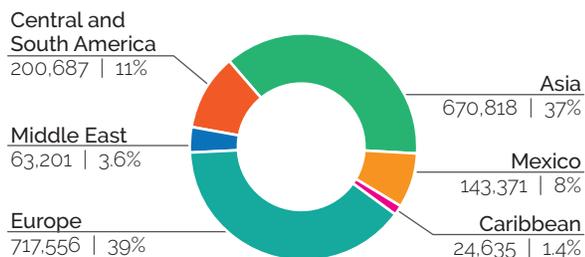
In Europe's industrial sector, structural change from energy-intensive toward less-intensive industries and efficiency improvements has already happened in Western Europe; progress is slower in Eastern Europe. In addition, for the CEE and SEE areas, the discussion about phasing out coal is as much about improving air quality, which is seen as significant problem for several countries in the region (e.g., Poland).

The major trend affecting European gas supply and its need for both LNG and pipeline imports is the ongoing decline of domestic production. By 2030, conventional European gas production, including that of Norway and the UK, could decrease by 20 percent. There is little interest in shale gas development, although Eastern Europe has shale gas potential. Green gas (low- or zero-carbon gas) production will grow, but volumes are expected to be limited through at least 2030. As a result, gas imports will remain essential in the coming decade.

Traditional concerns about security of supply, import dependence, flexibility and prices will continue to have a prominent place in any discussion about the role of gas in Europe. Price signals are indicators of LNG flows. There are times when Europe, not Asia, is the primary market for LNG. However, Asia has fewer supply options and less storage flexibility. Thus, Asia is the premium and the price setting market. Europe

has options that alleviate its concerns when Asia is the primary LNG import market, including pipeline supply, fuel-switching capability, and reliable storage. Figure 45 shows Europe as the top destination for U.S. LNG exports in 2019.

**Figure 45: U.S. LNG Export Destinations by Volume (mcf) and % Total, 2019<sup>99</sup>**



Source: EIA, 2021.

Monthly LNG volume fluctuations are increasing, and there is a need for flexible capacity, which is of increasing importance to energy security; energy has to be available at the exact time and place and in the form it is needed. The seasonal need for natural gas is well established (e.g., for winter heating) but its ability to manage intermittency from renewable could become more valuable as renewables are increasingly brought onto the system as part of the energy transition.

Western Europe has a robust natural gas infrastructure, while markets in Eastern Europe are still maturing. Supply security issues are very important in CEE and SEE, which have less diversification of supply options when compared to western European countries. Some long-term supply contracts in CEE and SEE are expiring in the early 2020s. There is uncertainty around the competitiveness of LNG and Russian gas in the 2020s. Russian influence in SEE has weakened as the ability to move gas around the region has improved in recent years. Now, the discussion centers more on coal displacement.

### **Major drivers of regional energy supply and demand**

The main driver for future natural gas and energy demand and uses in Europe and in European countries (including the UK, which has similar emission reduction ambitions) will be the EU Green Deal, which provides the path to climate neutrality in 2050 and reflects the decarbonization policies of the EU. To reach this goal, the EU will need to decarbonize all the sectors of the economy.

As noted, in the nearer term, the region set an enhanced emissions target in December 2020 to reduce emissions 55 percent by 2030 compared to 1990 levels. This has a huge impact on how the region is designing its energy future, not only through policy development but also via underlying legislative and regulatory frameworks. A complete overhaul of energy and climate legislation is anticipated over the course of 2021 to 2022 and was kicked off with the "Ten-E" regulation, an infrastructure proposal from the European Commission. This regulation declared natural gas projects ineligible for Project of Common Interest (PCI) status and barred their access to "connecting Europe facility" funding. In place of natural gas infrastructure, the Commission now includes hydrogen (including electrolysis) and offshore wind infrastructure.

The region is targeting a minimum share of renewables and efficiency improvements; both are major drivers of regional energy demand. In June of 2021, a complete package is anticipated in which this renewable and energy efficiency directive will be revisited. The European framework prioritizes electrification based on renewable electricity; where electrification is possible, it is prioritized. However, electrification has its limits. There will be a need to develop renewable and low-carbon gases, like hydrogen, biomethane, biogas and others.

Over the next decade, there will not likely be many significant changes in the use of natural gas, though experiences will vary across member states, particularly between those in Western and Eastern Europe. Emissions from the upstream sectors and gas imports, and reliability of data on emissions, will become increasingly important. Both could play a role in the decisions that will shape the future energy mix, including the future role of gas. More clarity around what to expect for U.S. LNG exports from the Biden Administration is needed. In October of 2021, Europe will unveil a “gas package,” which will include natural gas market reform and mirror some provisions introduced in electricity market design. The focus will be on establishing a hydrogen legislative and regulatory framework.

### ***The range of potential futures of natural gas markets***

Some workshop participants perceived energy policies as increasingly divergent from actual energy consumption pathways in the EU. While natural gas may not be viewed as a policy solution through 2030, these participants noted that the reality looks quite different, where gas will still play a significant role in Europe's economy and energy security. By 2050, it seems very likely that gas demand will decline sharply. In the power generation sector gas demand is expected to fall to nearly zero and industrial demand is also expected to fall sharply, although gas or some fuel alternative will still be needed for process heat. Residential demand may be harder to reduce due to existing infrastructure, housing stock characteristics, and customer preferences.

Analysis of the future European energy system optimized to meet decarbonization targets suggests that electrification will play a major role, but backup

generation will still be needed. Some form of gaseous fuel, according to workshop participants, will very likely be needed to “glue the system together.” This decarbonized gaseous fuel will need to be available, produced at scale, easily transportable, and storable. Hydrogen appears to be the most obvious solution, as it is flexible enough to provide back-up if renewables are used as baseload.

On the supply side, natural gas production in Europe is expected to decline sharply by 2050 – Norway will likely be the only major European producer left. The key question is how hydrogen will be supplied. If green hydrogen plans are advanced, hydrogen will have to be produced via electrolysis using electricity generated from renewable sources, mainly from large-scale offshore wind and solar PV.

There is considerable debate, however, as to whether green hydrogen can scale up fast enough to meet European targets; it is also a very costly option. Workshop participants anticipated that blue hydrogen—conversion of methane using steam reforming or auto reforming—will need to play an important role in the transition process. This raises questions about natural gas sourcing and CO<sub>2</sub> storage. Natural gas will increasingly have to be imported, most likely via LNG or via pipeline gas from Russia. Plans for CO<sub>2</sub> storage are being developed, especially in the North Sea (with a current focus on Norway), but the issue will remain as countries without access to offshore CO<sub>2</sub> storage are unlikely to accept storage onshore close to population centers.

Another option for hydrogen is imports. Italy is already considering importing hydrogen from North Africa. The use of solar power to generate electricity for electrolysis is seen as potential strategy for providing hydrogen that can then be piped to Southern Europe.

### ***NDCs and climate targets***

As noted, the EU is committed to net-zero emissions by 2050. All member countries were required to submit plans in early 2020 detailing how they plan to reach their 2030 targets. Some have submitted 2050 plans. The UK, which left the EU on January 1, 2021, also has a national net-zero target for 2050 and has published national plans and policies to reach this target.

Member states have different legacy energy mixes, so each needs to set its own milestones toward climate targets. Different initial energy mixes also require different investments. In CEE, many countries lag in efforts to fulfil their energy transition targets due to lack of policy consistency or long-term planning. There will be a need for further cooperation with Brussels, but also for transatlantic cooperation which has been renewed after four years of disconnection.

### ***Impact of climate policies on natural gas supply and demand***

The EU has multiple policies and targets for reducing its energy-related carbon emissions. In 2021 alone, legislation will be considered that could significantly impact the future of gas and other fuels.

The first and most important piece of legislation under consideration is the European Climate Law, which will amend Regulation EU 2018/1999 to make legally binding the net-zero by 2050 target and the 55 percent emissions reduction by 2030 target. The EU Parliament voted in favor of the new 2030 targets in October 2020, and the EU Council representing Member States also approved the targets in its December 2020 meeting, clearing the way for legislation in 2021.

By the end of Q2 2021, the Commission will come forward with proposals to revise the EU ETS. Currently, this covers sectors responsible for 55 percent of EU emissions, such as industry. Reform could include extending the scheme to sectors not covered and removing free allowances for sectors at risk of carbon leakage in combination with a Carbon Border Adjustment Mechanism (CBAM). Revenues from the ETS are also used to fund decarbonization projects via the ETS Innovation Fund and increasing the price of carbon is seen as key to incentivizing decarbonization. Sectors not covered by the ETS are subject to member states' commitments under the Effort Sharing Regulation, for which revision proposals are also due in Q2. Member states have different emissions reduction targets which, when combined, meet the overall EU target.

The Commission will also make proposals for a CBAM in Q2. Imports from countries that have less stringent emissions targets than the EU would be taxed to level the playing field for EU production of such goods. It would thereby prevent "carbon leakage" from imports if and where EU production moves abroad or closes. Currently, sectors at risk of carbon leakage receive free ETS allowances. However, if a CBAM was introduced, any carbon tax on imports would also need to be applied to EU goods to comply with World Trade Organization rules. The EU would also need a methodology to determine the carbon footprint of imports produced by different firms in different countries.

Revision of the Energy Tax Directive, aimed at aligning taxation of energy products with EU energy and climate policies, is also due in Q2. This could, for example, impact the taxation of electricity used for electrolysis, which would affect the competitiveness of green hydrogen. The Commission has also proposed the idea of Carbon Contracts for Difference as a means of supporting low-carbon or renewable hydrogen production.

There is potential linkage between CBAM and proposals to implement the Commission's Methane Emissions reduction strategy, also due in Q2. Although most methane emissions from natural gas occur in production and transport outside of the EU, the EU has stated that it will use its position as the world's largest importer of fossil fuels to promote methane reductions by its global partners. It has also stated its intent to introduce legislative measures if partners do not take steps to reduce methane emissions. Much will depend on the design of such measures, but it is possible that they could be combined with a CBAM. A key element of the strategy is improving the measurement, reporting and verification of methane emissions.

Even if such information is not used as part of efforts to target natural gas imports, it could be relevant to hydrogen production from natural gas. This owes to the Commission's commitment to introduce a comprehensive terminology and European-wide criteria for the certification of renewable and low-carbon hydrogen. The vehicle for this will likely be a revised RED later this year, updating the current version known as RED II. RED II already contains provisions for Guarantees of Origin for hydrogen, as well as for other renewables, and efforts are underway to include carbon footprint information. A revised RED II could also contain demand-side measures like quotas.

Proposals for revision of the Third Energy Package for gas are due in Q4. The aim is to update the package to regulate competitive decarbonized gas markets and thereby enable hydrogen deployment. This will be a major effort because of the highly prescriptive nature of the current gas regulatory framework and the complex issues involved, including tariffs, investment in or repurposing of networks, interoperability between hydrogen and natural gas, and third-party access.

Also due in towards the end of this year are proposals for the revision of Energy and Environmental State Aid guidelines. This effort will be crucial to ensuring that the necessary government support for decarbonization and hydrogen projects is compatible with state aid rules. State aid will also be influenced by the Taxonomy Regulation, which establishes a framework to facilitate sustainable investment. The rules for this are undergoing finalization in early 2021.

The consultation process for many proposals has already started. However, it will take time for the Commission to develop full legislative proposals and for those to be agreed upon by the Parliament and member states, with further lead time before the measures come into force. The direction is clear—both the Council and the Parliament support both the stricter 2030 targets and the 2050 net-zero target. The timing and the exact form of the future legislation is less certain.

*Although most methane emissions from natural gas occur in production and transport outside of the EU, the EU has stated that it will use its position as the world's largest importer of fossil fuels to promote methane reductions by its global partners. It has also stated its intent to introduce legislative measures if partners do not take steps to reduce methane emissions. Much will depend on the design of such measures, but it is possible that they could be combined with a CBAM. A key element of the strategy is improving the measurement, reporting and verification of methane emissions.*

### **Substitutes for natural gas in the 2030 and midcentury timeframes**

Participants noted that it is unlikely that electricity alone will carry Europe's clean energy transition; its specific role will take shape over the next decade. In the context of this transition and the limitations of electricity, the viability of gaseous fuels and their range of uses will depend on options for emissions mitigation and on how the infrastructure debate plays out. In the 2050 timeframe, hydrogen is the main natural gas substitute being discussed, though the region is also examining biogas and biomethane.

At present, hydrogen is the most likely widescale alternative given its flexibility and its ability to use a repurposed natural gas system. Biogas is also part of the EU plan, but it is hampered by the local, distributed nature of its production and use. The European Commission plans to adjust its Third Energy Package to allow biomethane interconnection to the natural gas grid, which could widen biomethane use, but it seems unlikely that biomethane would ever account for more than 20 percent of current European gas demand.

Currently, the level of investment in natural gas alternatives is quite low, mainly because companies are not sufficiently incentivized to invest. There is a wide debate on the appropriate forms of regulation needed to incentivize investment. At present, the natural gas market is fully liberalized and unbundled to encourage as much competition as possible. This market structure at present does not seem suitable for the introduction of a new option such as hydrogen, which has technical and economic challenges to overcome. New guidance in the revised RED II pertaining to hydrogen is anticipated later this year, which may shift these dynamics. Still, there is ongoing discussion of how cooperation across the

*At present, hydrogen is the most likely widescale alternative given its flexibility and its ability to use a repurposed natural gas system. Biogas is also part of the EU plan, but it is hampered by the local, distributed nature of its production and use. The European Commission plans to adjust its Third Energy Package to allow biomethane interconnection to the natural gas grid, which could widen biomethane use, but it seems unlikely that biomethane would ever account for more than 20 percent of current European gas demand.*

value chain can be encouraged without undermining the principles of competition, but no specific answer has emerged.

As a result, most investment in hydrogen is in demonstrations and small initial projects, which could later be expanded. The H21 North of England project is one such example. Plans for more significant expansion of hydrogen use in the Netherlands are being actively discussed, and concrete investment options could be announced in 2021. In addition, a major CO<sub>2</sub> storage project in Norway, Northern Lights, is being supported by Equinor, Shell, Total, and the Norwegian government, indicating progress on significant CCS projects.

### **Policies to repurpose natural gas infrastructure for clean energy alternatives**

As noted, the repurposing of natural gas infrastructure is underway and is part of the debate around decarbonization in Europe. In the UK, National Grid is investigating how a transition from natural gas to

hydrogen infrastructure can work and how to maintain the integrity of the system during the transition.

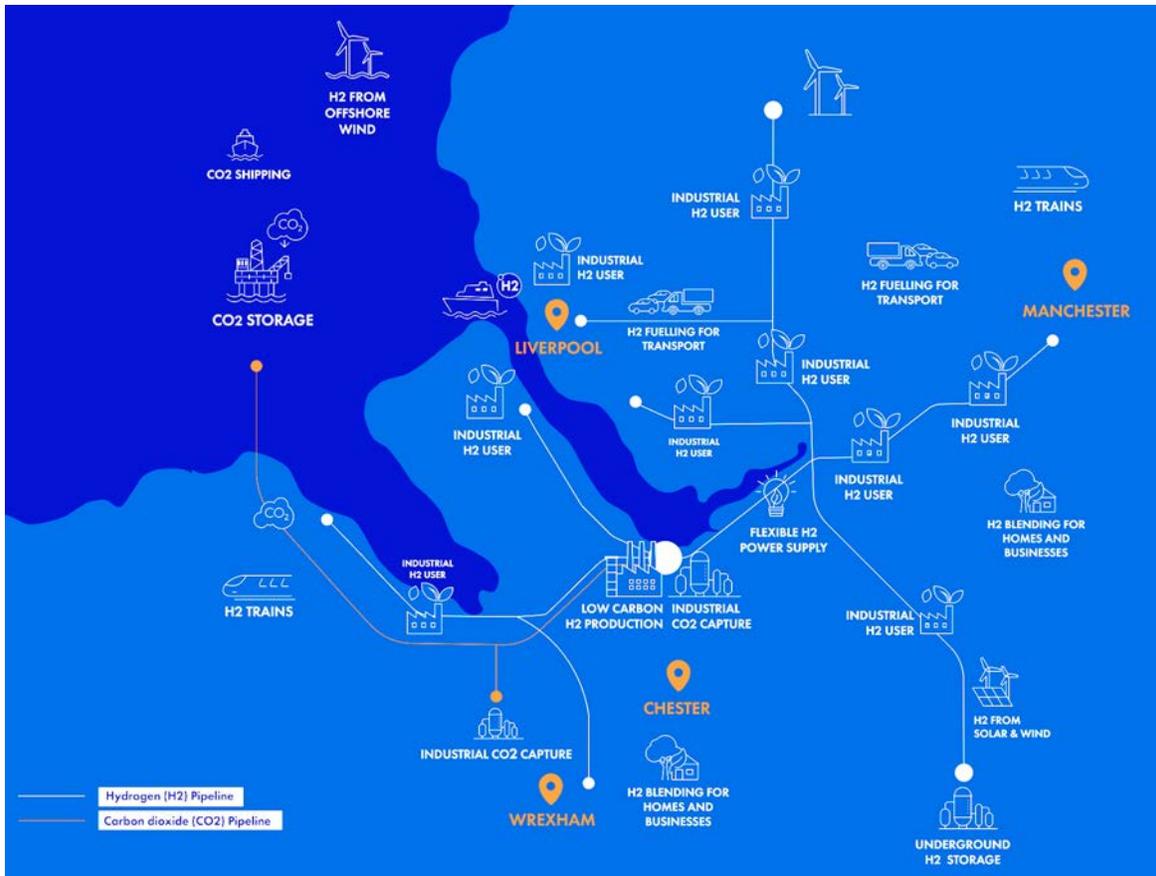
In Italy, SNAM has been working to repurpose its natural gas infrastructure in anticipation of hydrogen entering the system. SNAM believes that its pipes are hydrogen-ready, although compressor stations and other connecting assets may need to be upgraded. Meanwhile, in the Netherlands, plans are underway to repurpose the “low-calorie” gas pipeline system for hydrogen and thus to create complimentary hydrogen, natural gas, and electricity grids.

Similar discussions are emerging across Europe, including serious dialogue on the creation of a hydrogen “backbone.” These discussions are in the relatively early stages, but conversations about how this backbone would be put together, operated, and regulated are occurring both country and regional levels. The European Commission would ultimately coordinate a European response.

Alternative options for hydrogen production are being discussed. Gazprom has proposed pyrolysis, which would take methane and transform it into hydrogen and carbon black (solid carbon), which could be stored more easily or used in construction

and other industrial purposes. Hydrogen imports could also avoid the storage problem, and the EU hydrogen strategy envisions a significant amount of imported hydrogen beyond 2030. It is not yet clear where this hydrogen would originate (North Africa, the Middle East and Ukraine have been mentioned); the discussion is in early stages.

Blue hydrogen options would need the transportation of CO<sub>2</sub> for sequestration. The Norwegians are suggesting the use of existing infrastructure to pipe CO<sub>2</sub> back into North Sea fields (Northern Lights), while other options under discussion include using barges on the Rhine to bring CO<sub>2</sub> out of Germany for storage offshore. Inevitably, there are several countries in Europe where transport and storage of CO<sub>2</sub> could become a major issue and could inhibit the use of the blue hydrogen option. Last month, the UK announced a program to provide cash to support for the buildout of carbon capture, GHG removal, and hydrogen technologies as part of the government’s 10 Point Plan for a Green Industrial Revolution, which includes a target of 5 GW of installed low-carbon hydrogen production by 2030.<sup>100</sup> Figure 46 shows a conceptual design of the HyNet North West project, a hydrogen and CCUS hub project under development in the UK.

Figure 46: Conceptual Design of a Hydrogen and Carbon Capture Project Supporting the UK's 2050 Net-Zero Target<sup>101</sup>

Source: HyNet, 2021.

### **Role of natural gas/LNG in addressing developing country energy needs**

Despite the enthusiasm for hydrogen and decarbonized gas in number of European countries and at the Commission, participants noted that the realities of CEE countries mean that natural gas (piped and LNG) may still have an extended role to play. The substitution of coal and nuclear with natural gas is likely to continue, although renewables will also play a greater role. The major countervailing concern is the security of supply risk felt in many CEE countries regarding Russian gas. Poland is a prime example of

a country where high coal use could be replaced with gas, but also where that gas fuel switching is comes with a security risk. LNG is the obvious alternative being explored, albeit with its own supply and price risks.

Over time, the countries of CEE will need to comply with EU targets. Therefore, the role of unabated gas must diminish. The timing may be slower in CEE than in the rest of the Europe, so gas could have an extended role as a transition fuel, but the ultimate decline of gas seems inevitable.

### ***Incorporation of corporate ESG policies and financial institution guidelines for investments in new natural gas projects***

European energy companies are leading the development of low-carbon energy options, driven by their shareholders and other constituencies like governments and banks. BP has redefined itself as an "International Energy Company" while Equinor, Shell and Total are taking leading positions in renewable and low-carbon energy supply.

These companies all view gas as playing a major role in the energy transition period. Ultimately, natural gas will need to be decarbonized, and companies are planning longer-term to either move into electricity and/or to provide decarbonized gas options as discussed above.

Companies are deliberating how much of a focus they want to place on Europe. An alternative is to re-focus efforts on markets where natural, unabated gas still has a strong future (e.g., Asia). There is little evidence of major gas companies looking to move away from Europe, but given their global portfolios, it is an option.

Gas system operators are also thinking about how their infrastructure assets will be used in future, and the economic and practical considerations of a transition from natural gas to other fuels like hydrogen. Debates around what new investments could be included in a regulated asset base are already underway, and grid operators are generating strategies for alternative fuels. National Grid in the UK is a prime example, as mentioned above, as it develops scenarios around the introduction of different forms of hydrogen into its natural gas grid. SNAM is another example of a national system operator making plans to use its system for different forms of gas.

### ***The role of emissions abatement technologies***

The European framework clearly prioritizes electrification of fossil-powered end uses with renewable electricity where possible. Where electrification is not possible, other fuels are used or are being explored, along with accompanying emissions abatement strategies.

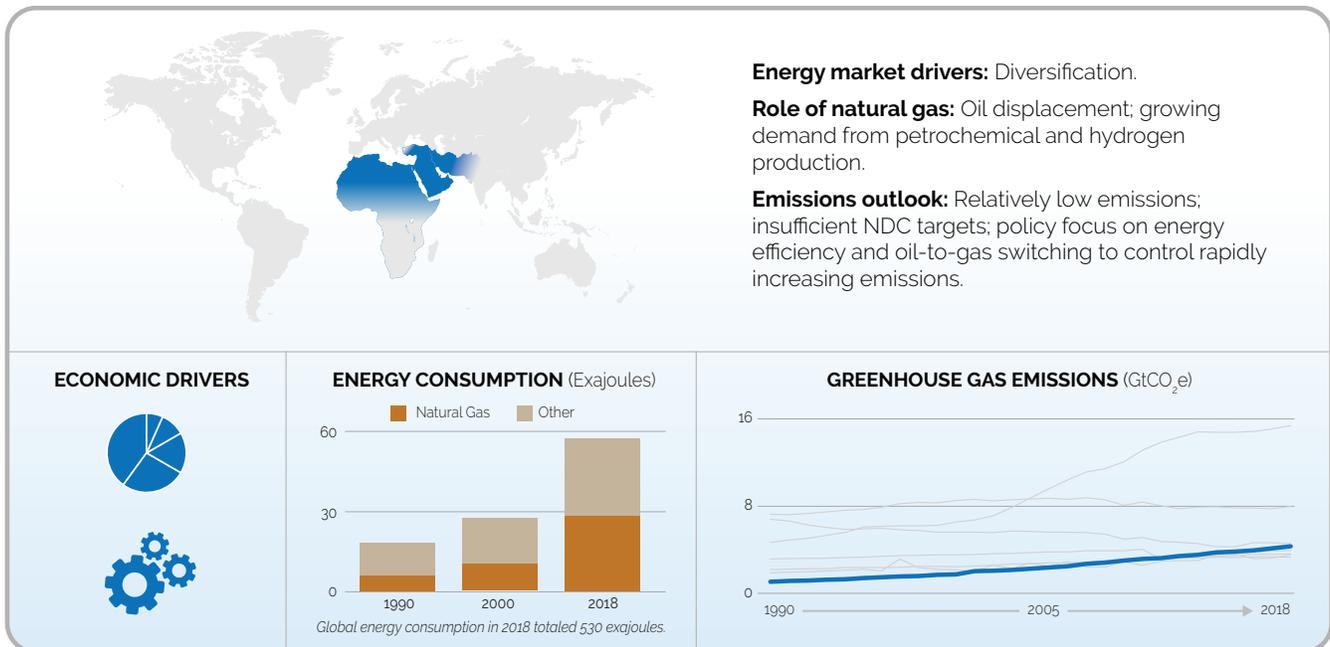
The EU, through the proposal of the European Commission's Methane Emissions reduction strategy, aims to leverage its position as the world's largest importer of fossil fuels to promote methane reductions from its global partners. A key element of this strategy is to improve measurement, reporting, and verification of methane emissions. Action on methane will be relevant to both natural gas and hydrogen produced using natural gas.

Plans to develop CO<sub>2</sub> storage are underway, especially in the North Sea, but countries without access to offshore CO<sub>2</sub> storage may face challenges.

# MIDDLE EAST & NORTH AFRICA

The King Abdullah Petroleum Studies and Research Center hosted an invitation-only expert workshop on the future of natural gas in the Middle East and North Africa (MENA) in a low-carbon world.

11 speakers and 30 participants from academia, think tanks and the private sector took part in the discussion. The event, held under Chatham House rule, took place on March 24<sup>th</sup>, 2021. The following is a summary of the workshop discussion.



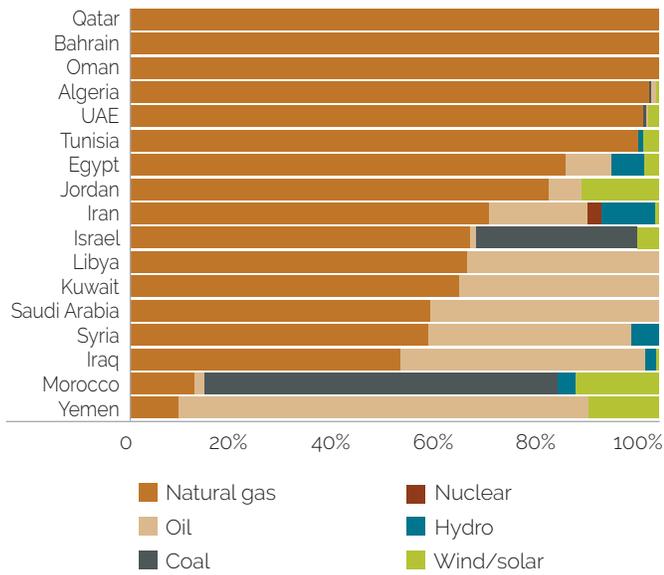
## REGIONAL OUTLOOK

The MENA region faces the significant challenge of diversifying its hydrocarbon-dependent economic models. Hydrocarbon revenues are projected to decline due to the global low-carbon transition and increasing oil and gas production in the United States. The region is also industrializing with the support of low-cost fossil fuels.

## Energy Market Drivers

In recent decades, the region's energy demand has rapidly grown, driven by economic growth, energy-intensive industrial development, and the heavy subsidization of gas, electricity, and water. Renewable energy is becoming more competitive as technology costs have declined. There is also high regional renewable energy resource potential, but the region is still in early stages of renewable deployment (Figure 47). In the near term, increased renewable generation is likely to replace oil in power generation rather than natural gas.

**Figure 47: Fuel Mix for Power Generation by Country, 2019<sup>102</sup>**



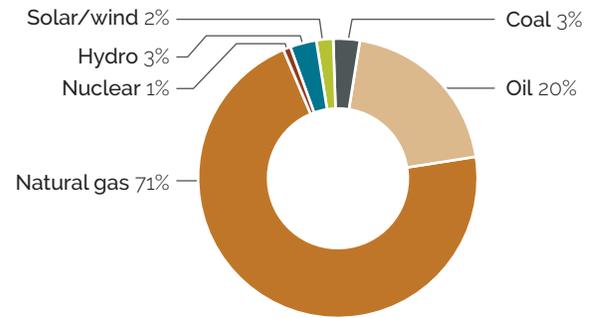
This figure shows the fuel mix in power generation for several MENA countries. Natural gas is used extensively in power generation throughout the region. Solar and wind generation is growing, but these resources comprise up a small percentage of power generation in the region today. Source: Adibi, 2021.

### Role of Natural Gas

Natural gas has become a major energy source in the region over the past decades and now accounts for more than half of its total energy supply. In 2019, the share of natural gas in the region's power generation mix was more than 70 percent (Figure 48). The rapid growth in natural gas demand was driven, in part, by low and subsidized gas prices.

Natural gas is expected to remain a dominant fuel in the power sector and as a reliable backup for solar and wind generation. Further growth of natural gas demand in the region, however, will likely be slower than in the past due to factors such as increased efficiency of newer gas turbines, reduction or elimination of gas subsidies, and fuel diversification policies in the power sector. An energy price subsidy reform that leads to significant price hikes is unlikely, at least in the near term.

**Figure 48: Power Generation by Energy Source in MENA<sup>103</sup>**



Source: Adibi, 2021.

### Emissions Outlook

Table 7 provides information about the MENA region's per capita fossil fuel emissions compared to global averages, and its share of total CO<sub>2</sub> emissions from fossil fuels relative to its share of total population. Partly due to the abundance of natural gas and oil in the region, per capita emissions are higher than the global average of 4.9 tons per year (and some countries are much higher still). Per capita emissions are 37 tons per year in Qatar, 24 in Kuwait, 22 in the United Arab Emirates (UAE), and 19 in Saudi Arabia. The region's share of emissions from fossil fuel is about 20 percent higher than its share of the world's population.

**Table 7: MENA Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019<sup>104</sup>**

CO <sub>2</sub> per Capita per Year from Fossil Fuels	Share of World CO <sub>2</sub> Emissions from Fossil Fuels	Share of World Population
<b>5.9 tons</b>	<b>7.6%</b>	<b>6.3%</b>
4.9 tons World Average	38,017 MT World Total	7.71 Bn People World Total

22 countries in analysis. Numbers are rounded. MT = Megatons.

Data from Crippa et al., 2020.

## REPORT OF PANELIST DISCUSSION

The workshop hosts and participants were provided with framing questions from EFI, which can be found on page 3 of this report.

### ***The role of natural gas in the energy transition***

Over the last decade, gas consumption has grown to nearly match oil's contribution to the region's energy mix. Despite recent efforts by governments in the region to raise natural gas prices, per capita natural gas consumption remains the highest in the world.

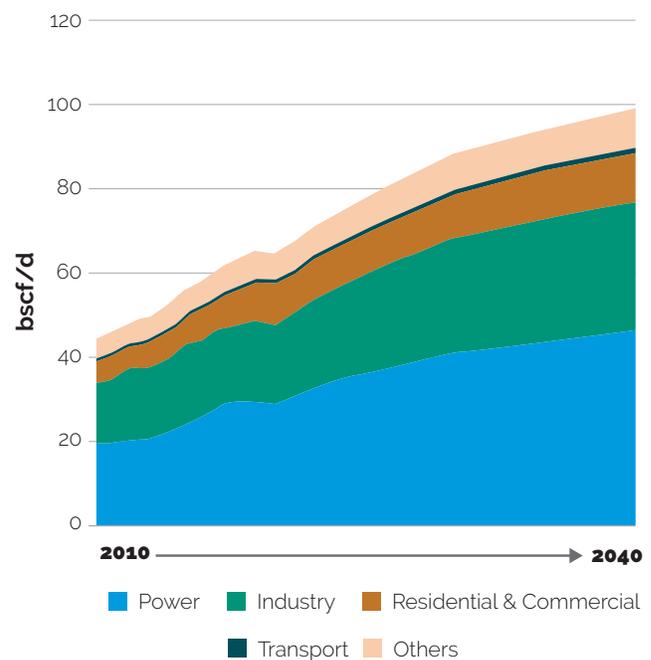
Most gas produced in the region, except in Qatar, is associated with oil production. This is changing, however, as national oil and gas companies are shifting strategies and producing non-associated gas to meet future expected energy demand and to diversify income streams. Consequently, gas is considered a strategic—and relatively environmentally beneficial—fuel for the region.

There are major subregional differences in economies, demographics, and dynamics around gas. North African producers lag behind the Gulf Cooperation Council (GCC) countries in terms of energy transition planning. Nationally Determined Contributions (NDCs) for GCC countries all call for gas to play a major role in reducing emissions and aim to improve efficiency, especially at power plants.

### ***Key economic and regional trends driving natural gas demand/uses***

Total regional demand for natural gas is anticipated to grow from 1.6 to 2.4 mtoe per day by 2040, about 2 percent per year (Figure 49). This growth is about half of what the region experienced between 2010 and 2020 but is still significant. Power generation is expected to drive most of this growth, with industry also contributing. Some solar and wind growth is also expected.

**Figure 49: Natural Gas Demand in MENA, 2010-2040<sup>105</sup>**



*Natural gas demand in the region is anticipated to more than double between 2010 and 2040. Power and industry are expected to drive this demand growth. Source: Adibi, 2021.*

Geopolitical tension is a constant feature of the region, but generally, economic opportunity prevails. Today, most trade is done with countries outside of the region, but commercial interests can explain this limited intra-regional oil and gas trading.

Heavily subsidized domestic energy pricing throughout the gas value chain can hinder energy efficiency efforts and distort global energy trading markets. Price reform is on the table in many countries, including Saudi Arabia and the UAE, but significant price hikes are not anticipated in the near term. Access to plentiful low-cost and lower-carbon gas assets throughout the region helps to justify depressed regional natural gas prices. To

evolve industry in the region, however, value chains (particularly the upstream oil and gas industries) need to be exposed to private sector investment, and the value of gas needs to be more directly linked to international markets.

This year, the oil and gas industry has pledged around \$300 billion in investment in upstream oil and gas in the region, with investment in gas comprising 75 percent of that total. While this is the lowest total in 15 years, in part due to the COVID-19 pandemic, the industry is still attractive to infrastructure investors, hedge funds, and private investors. To diversify income streams, capture more global market share, and prepare for increasing climate concern from investors, many gas producers in the region are positioning themselves in the race toward carbon neutrality. There is also increasing investment in petrochemicals, where gas can be used directly to power processes or to produce petrochemical inputs such as ammonia, hydrogen, and methanol.

### **Major drivers of regional energy supply and demand**

Looking ahead, power sector decarbonization in the MENA region will most significantly impact oil demand. Currently, 800,000 barrels of oil are burned for power every day, all of which could be replaced with lower-carbon options. Saudi Arabia's plan to switch from oil to natural gas could double power generation demand for natural gas over next 20 years.

Many countries in the region rely on natural gas for 60 percent or more of their power generation, but workshop participants anticipate that this could change over time depending on battery and storage innovation. Renewables could flourish in the region due to the declining cost of renewable technologies and high solar potential; however, this proliferation would require sufficient storage, a technological constraint that has yet to be solved. Currently, large-scale renewable and storage projects remain cost-prohibitive compared to natural gas and other fuels.

*Many countries in the region rely on natural gas for 60 percent or more of their power generation, but workshop participants anticipate that this could change over time depending on battery and storage innovation. Renewables projects could flourish in the region due to the declining cost of renewable technologies and high solar potential; however, this proliferation would require sufficient storage, a technological constraint that has yet to be solved.*

The combination of low-cost gas resources and renewable potential could position the MENA region to be a significant exporter of blue and/or green hydrogen, as well as net-zero ammonia. Saudi Arabia, Qatar, the UAE, and others are currently investigating this emerging area with exports, not domestic consumption, in mind.

### **The range of potential futures of natural gas markets**

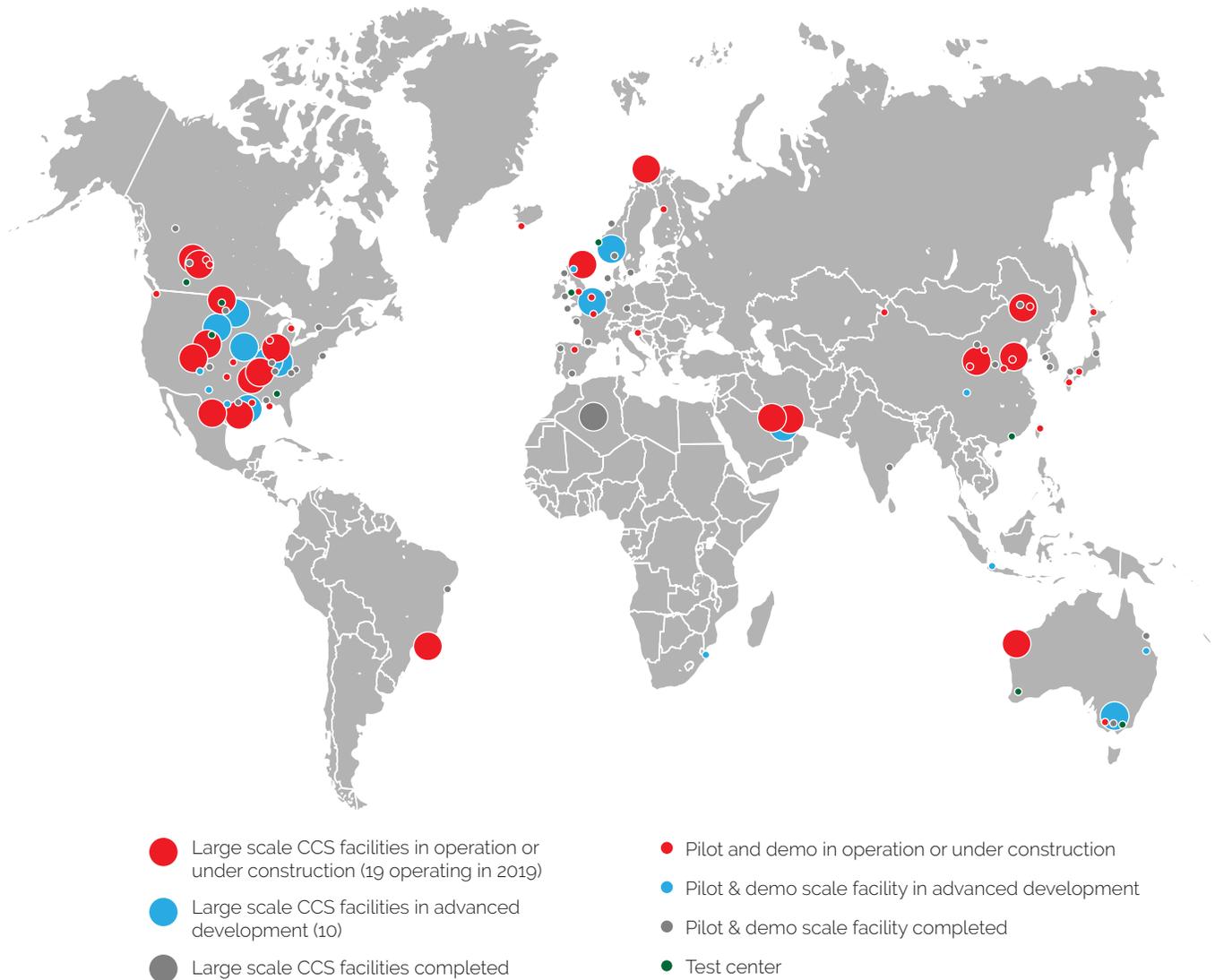
Projections of oil and gas use through 2040 vary widely. If the cost of battery storage decreases, renewable projects could flourish in the region and cut into the natural gas market. Despite recent renewable technology cost declines, renewables are still in their infancy in the region. It is likely that natural gas will serve as a complement to renewables through 2040.

Natural gas is well-positioned to support an expansion of the petrochemical industry at low cost. The region anticipates producing ammonia and methanol as energy carriers. Questions remain as to how green and blue hydrogen will factor into petrochemical and fertilizer production.

The region could have a major role in global emerging markets that could either leverage natural gas or reduce natural gas demand. Biofuels, hydrogen, and chemicals represent multitrillion-dollar global markets. The environment for carbon capture and storage (CCS) investment and funding is growing; there is a recognized need to abate emissions from industry and power generation that currently account

for about 70 percent of total global emissions. The global carbon capture market could be a \$2 trillion market, and the global market for offsets could grow to over \$200 billion in 2040. Figure 50 shows the location of major CCS projects in the world; in 2019, there were four projects in the MENA region at various stages of development.

**Figure 50: Global Carbon Capture and Storage (CCS) Projects, 2019<sup>106</sup>**



Source: Global CCS Institute, 2020.

Given the MENA region's reliance on hydrocarbon production, processing and consumption, it is worth restating IEA's assessment of its value:

- CCUS technologies offer significant strategic value in the transition to net-zero;
- CCUS can be retrofitted to existing power and industrial plants, which could otherwise emit 8 billion metric tons (Gt) of CO<sub>2</sub> in 2050;
- CCUS can tackle emissions in sectors where other technology options are limited, such as the production of cement, iron and steel or chemicals, and to produce synthetic fuels for long-distance transport (notably aviation);
- CCUS is an enabler of low-cost, low-carbon hydrogen production; and
- CCUS can remove CO<sub>2</sub> from the atmosphere by combining it with bioenergy or direct air capture to balance emissions that are unavoidable or technically difficult to abate.<sup>107</sup>

### ***NDCs and climate targets***

The MENA region is a major hydrocarbon demand and supply center and is export focused. At present, the region emits only 10 percent of global emissions. However, CO<sub>2</sub> emissions in the region are growing. Emissions are projected to grow by more than 40 percent by 2040, compared to 2020 levels.

As of the time of the workshop, countries in the region have not yet submitted updated NDCs, and current NDCs do not indicate how emissions reduction targets will be implemented, or achieved. Natural gas is considered key to reaching NDC targets because it could replace significant amounts of oil still used in the power generation and industrial sectors. There will be an increased role for renewable energy sources, independent of whether renewable deployment reaches the scale projected through 2040. Some countries in the region, including the UAE, also call for increased energy efficiency in their NDCs.

North Africa, Algeria, and Egypt focus on the use of natural gas in their NDCs. Egypt also includes nuclear power; Algeria quantifies targets for flaring.

### ***Impact of climate policies on natural gas supply and demand***

Overall, the region understands and appreciates the severity of the climate crisis and agrees that it is an issue to be addressed. At the same time, some believe that an express, narrow focus on fossil fuel reduction is not the most efficient or helpful path, due to expansive existing fossil fuel infrastructure assets, hard-to-abate sectors and processes, and energy access challenges both within and outside the region.

There is limited concerted government action to reduce greenhouse gas (GHG) emissions in line with 1.5 degrees of warming. Saudi Arabia and Qatar have plans to deploy new renewable generation, and Qatar is working to measure carbon intensity (via a contract with Singapore). However, there is no standard regional approach to measure and report GHG emissions throughout supply chains, let alone to abate or offset emissions. Iraq and Iran, countries with significant natural gas flaring, have zero-flaring policies in place but are not on track to meet established goals. Regulations to improve building codes and improve end-use efficiency in homes and in industry are currently in place in the region; however, state-subsidized energy prices can disincentivize energy use reductions.

In the North Africa subregion, countries have instituted plans to expand renewable energy generation and implement energy efficiency measures. Algeria, for example, plans to increase renewable generation thirty-fold by 2035. Renewables are largely viewed as a potential solution to meet increasing domestic energy needs, not exclusively or primarily as a means of decarbonization.

### **Substitutes for natural gas in the 2030 and midcentury timeframes**

While renewables deployment is anticipated to increase in the region through 2040, complementary battery and storage technology is not yet affordable or of sufficient duration. As a result, natural gas is currently predicted to enable and accompany renewable generation through the 2040 timeframe. This could change if technologies improve and policy and pricing regimes shift to further incentivize renewables investment.

The UAE opened its first nuclear power plant only a year ago. Other countries, including Saudi Arabia and Egypt, have expressed interest in developing nuclear generation capabilities. In Egypt, nuclear power could be essential in meeting energy demand growth, as gas production in the country is in decline. In other parts of the region, nuclear energy is considered a relatively expensive option with a slow ramp-up period and is not expected to gain much traction.

### **Policies to repurpose natural gas infrastructure for clean energy alternatives**

Qatar Petroleum has committed to produce “low-carbon” liquified natural gas (LNG) using CCS, reducing emissions from natural gas liquefaction and storage by about 25 percent. The low-carbon and carbon-neutral LNG market is expected to grow to more than 30 million metric tons per annum (mtpa) over the next few years. The MENA region is well-positioned to be a major provider of carbon-neutral LNG and could potentially use it domestically. Currently, most carbon-neutral LNG is exported to Asia.

The region is also scaling up its ambitions in green ammonia production; the UAE recently struck a deal with Japan to provide it with green ammonia. Both efforts leverage existing infrastructure, providing producers in the region with a cost advantage. Currently, both blue and green hydrogen are mostly discussed with export, not domestic use, in mind.

*Qatar Petroleum has committed to produce “low-carbon” LNG using CCS, reducing emissions from natural gas liquefaction and storage by about 25 percent. The low-carbon and carbon-neutral LNG market is expected to grow to more than 30 million metric tons per annum over the next few years. The MENA region is well-positioned to be a major provider of carbon-neutral LNG and could potentially use it domestically. Currently, most carbon-neutral LNG is exported to Asia.*

### **Role of natural gas/LNG in addressing developing country energy needs**

The energy transition brings about unique challenges in countries across the region. Deep economic transformation is needed to diversify exports and reduce reliance on fossil fuel products. North Africa still uses gas to meet about half of its energy demand, and gas will likely play a crucial role for countries on the way to more renewable energy generation. Improved financing, regulatory, and economic frameworks can promote more efficient energy use across all sectors.

Over the last decade, North Africa has increased its renewable energy production by 40 percent despite social and political unrest in the region. Morocco, for example, went from a state of energy scarcity to surplus thanks to increased use of gas and investment guarantees, feed-in tariffs, and other incentives to simultaneously develop renewable energy technologies. Many countries in the region plan to increase renewables development through 2040, primarily as a potential solution to meet increasing domestic energy needs. Emerging resources, like green hydrogen, could be significant to the development of various sectors (e.g., green ammonia for fertilizer, to backup grids with high shares of renewables, for export to Europe). Green hydrogen

and other emerging technologies will need to transition from ideas into practical and commercially available applications, and address issues like cost competitiveness.

### ***Incorporation of corporate ESG policies and financial institution guidelines for investments in new natural gas projects***

Investors recognize that climate risk is a growing problem for oil and gas producers. Today, most investors are not abandoning the sector over ESG risks. Even in Europe, debates are ongoing as to whether to label gas as partially sustainable. For hedge funds and private investors, the industry is still appealing, especially when it comes to gas and petrochemicals. There is movement within the industry, however, toward carbon neutrality, diversified income streams, and integration of technology into operations. Fossil fuel companies with longevity will likely be exporters of lowest-cost, net-zero resources, whether fossil-derived or renewable.

### ***The role of emissions abatement technologies***

The workshop presented the idea of a “circular” carbon economy (CCE), which adds the “Remove” option to the canonical “Reduce, Reuse, Recycle” and aims to minimize the generation of GHG emissions and their release to the atmosphere via energy efficiency, lower-emitting generation resources, and carbon capture (Figure 51). While reducing energy use remains critical, it is a necessary but not sufficient condition to reaching global climate goals. Many countries in the MENA region already have energy efficiency regulations in place. A CCE approach is a key enabler for continued use of natural gas in a decarbonizing world.

**Figure 51: The Circular Carbon Economy<sup>108</sup>**



*The circular carbon economy aims to achieve a carbon balance or net-zero emissions by midcentury. Resource use is “reduced” by providing goods and services using energy inputs (e.g., hydrocarbons, nuclear, and renewables) more efficiently and lowering energy waste. Carbon can be “recycled” into natural sinks via the carbon cycle and used as bioenergy. Carbon capture and direct air capture can “remove” carbon from the air to be stored or to be “reused” as a direct input into industrial and economic processes. Source: King Abdullah Petroleum Studies and Research Center, 2020.*

There is growing interest among regional producers in blue hydrogen and the co-location of hydrogen and CCUS assets. The region has significant geologic carbon storage capacity, and Saudi Arabia, UAE, Qatar, and Morocco have developed CCS pilot projects over the past two years. Morocco is developing a hydrogen roadmap, which is expected to consider both blue and green hydrogen.

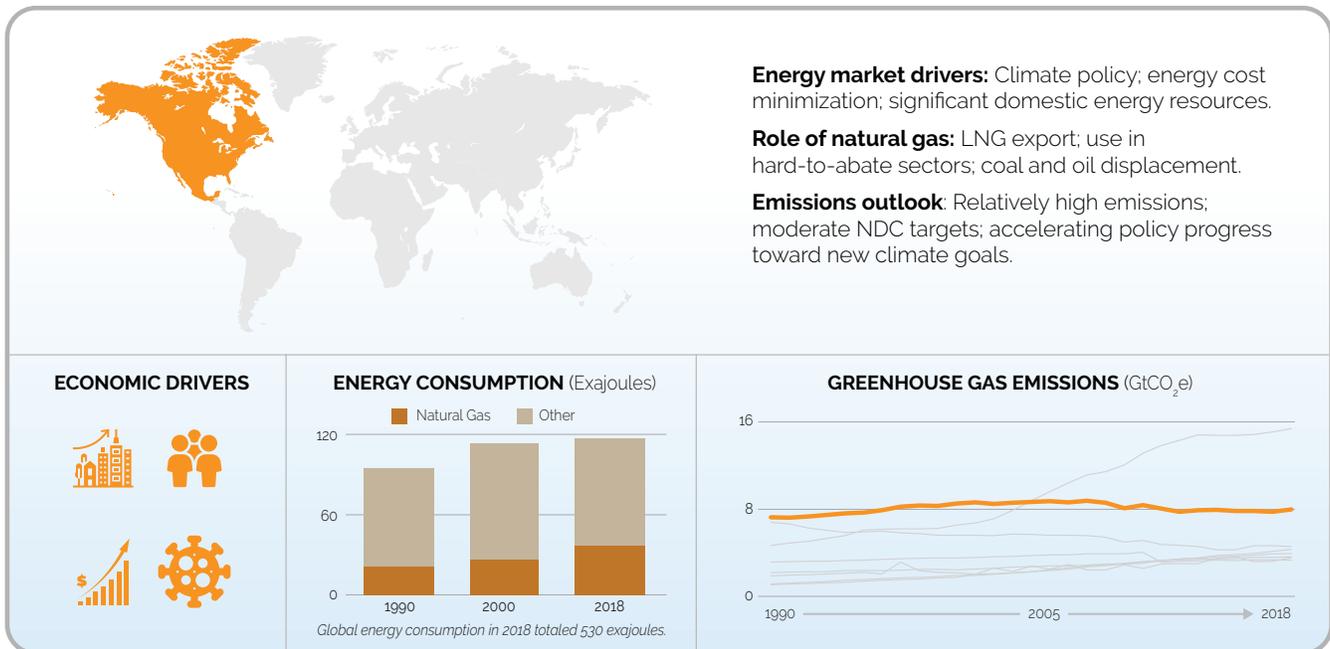
GHG emissions accounting and tracking are high priorities in the region. KAPSARC, among other organizations, is working on measurement and standards for GHG emissions accounting and carbon sequestration. Many new technologies that the IPCC is investigating to reduce methane emissions from oil and gas operations are not expected to become economical in the short term.

Countries in the region have policies to reduce or eliminate flaring from oil and gas operations. As noted, however, countries like Iraq and Iran are not currently on track to meet their stated goals.

# NORTH AMERICA

The Center for Energy Studies at Rice University's Baker Institute hosted an invitation-only expert workshop on the future of natural gas in North America in a low-carbon world.

11 speakers and 40 participants from academia, think tanks and the private sector took part in the discussion. The two-day event, held under Chatham House rule, took place on May 5th and 6th, 2021. The following is a summary of the workshop discussion.



## REGIONAL OUTLOOK

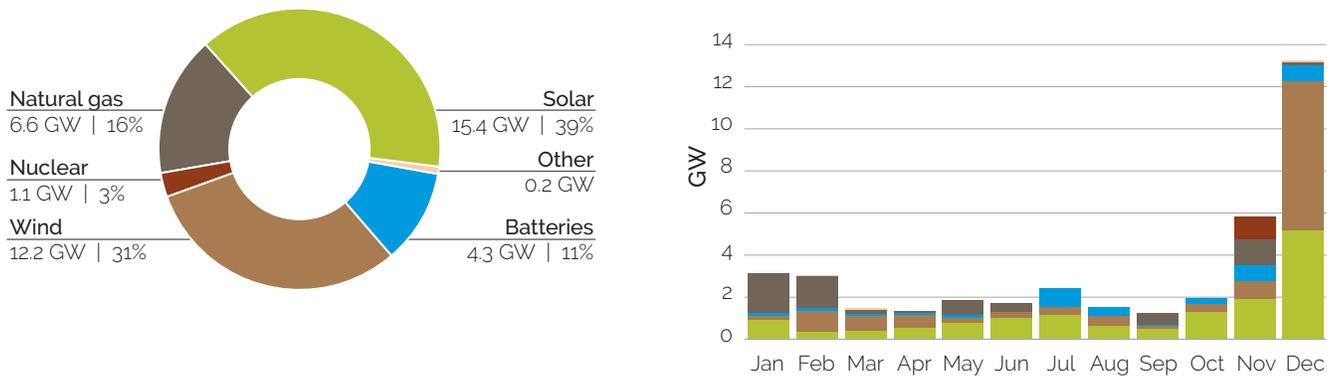
The North America region is comprised of the United States, Canada, and Mexico, and is endowed with abundant coal, oil, gas, hydropower, and renewable resources.

### Energy Market Drivers

To meet state and national targets, the United States is rapidly deploying large-scale renewable energy. In 2021, solar will account for the largest share of new electricity capacity (39 percent) in the United

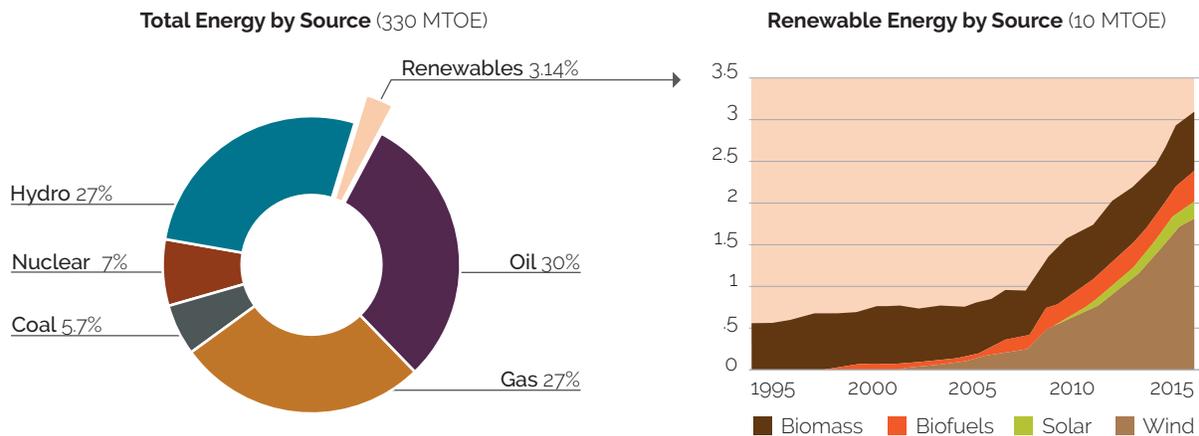
States, followed by wind (31 percent); natural gas will account for 16 percent (Figure 52).<sup>109</sup> The addition of renewable capacity is driven by falling costs coupled with government support. If government subsidies are included and costs of storage excluded, the cost of utility-scale solar and onshore wind is competitive with the marginal cost of combined cycle gas generation.<sup>110</sup>

**Figure 52: Planned U.S. Utility-scale Electricity Generation Capacity Additions, 2021<sup>111</sup>**



This figure shows planned utility-scale power generation capacity additions in 2021 and in which month those additions are anticipated to come online. Solar will account for 39 percent of new electricity generation capacity in the United States, the largest share, followed by wind and natural gas. Source: EIA, 2021.

**Figure 53: Total Energy by Source in Canada, 2016, and Trends of Consumption of Non-hydro Renewable Energy, 1995 to 2016<sup>112</sup>**



This figure shows Canada's total energy by source and non-hydro renewable energy consumption over time. 27 percent of Canada's energy comes from hydropower, and the country has significant oil and gas reserves that comprise 57 percent of total energy. Wind energy has driven growth of non-hydro renewable energy sources over the past two decades. Source: Hughes, 2018. Data from BP, 2017.

Canada's electricity grid is one of the cleanest in the world due to significant renewable and hydroelectric power generation (Figure 53).<sup>113</sup> The existing nuclear reactors—whose lifespans have been extended—also help keep power sector emissions low.<sup>114</sup> The country has significant fossil fuel resources as well, which face increasing environmental opposition.<sup>115</sup>

Mexico's energy demand is expected to increase significantly through 2050 due to population growth and economic development.<sup>116</sup> The energy supply in Mexico is dominated by oil and gas, with oil accounting for almost 50 percent. Mexico has a rapidly growing electricity sector, with demand doubling between 2000 and 2014. The fastest-growing sector is the buildings sector.<sup>117</sup>

Natural gas is the main source for electricity, which Mexico imports largely from the United States.<sup>118</sup> Power generation from renewable resources has increased significantly, but development has stalled due to shifting electricity market policies and declined state support.<sup>119</sup> Oil use for electricity has declined dramatically over the past 15 years but remains higher than in many other countries.<sup>120</sup>

### Role of Natural Gas

Natural gas production in the region has grown rapidly due to advances in hydraulic fracturing and horizontal drilling technology. However, commitments by Canada and the United States to reduce emissions to net-zero by 2050 brings uncertainty to the future of natural gas.

The shale revolution enabled the United States to become the largest producer of natural gas in the world.<sup>121</sup> In addition, the United States converted from a net energy importer into a net energy exporter; total energy exports from the United States exceeded imports in 2019 for the first time in 67 years.<sup>122</sup> Natural gas use in power generation has increased due to its abundance and low cost. Demand growth in the power sector and exports will be sensitive to accessible gas resources and extraction costs of gas. Industrial use of natural gas, which is less sensitive to costs, will see the largest increases and will drive future demand.<sup>123</sup>

Canada was the fourth-largest producer of natural gas in 2019, after the United States, Russia, and Iran.<sup>124</sup> Currently, almost all of Canada's natural gas exports flow to the United States by pipeline, but Canada anticipates exporting liquefied natural gas (LNG) starting in 2024. LNG Canada, a joint venture of five energy companies—Shell, Petronas, PetroChina, Mitsubishi Corporation, and KOGAS—invested in the construction of the first significant LNG export facility in Canada in 2018.<sup>125,126</sup> The project can take advantage of abundant natural gas in British Columbia and shorter shipping routes to Northeast Asia (compared to the routes originating from the U.S. Gulf of Mexico).

The government of Mexico expects natural gas consumption to increase 30 percent from 2017 to 2032, mostly in the electricity sector.<sup>127</sup> As domestic natural gas production has stagnated in recent years, Mexico has relied on increased imports of natural gas, mostly from the United States (Figure 54). Exports of natural gas to Mexico by pipeline accounted for 40 percent of U.S. natural gas exports in 2019.<sup>128</sup> To support the growth in natural gas exports from the United States, Mexico has expanded its natural gas pipelines since 2016.<sup>129</sup> LNG imports have declined in recent years as natural gas from the United States by pipeline replaces more expensive LNG.

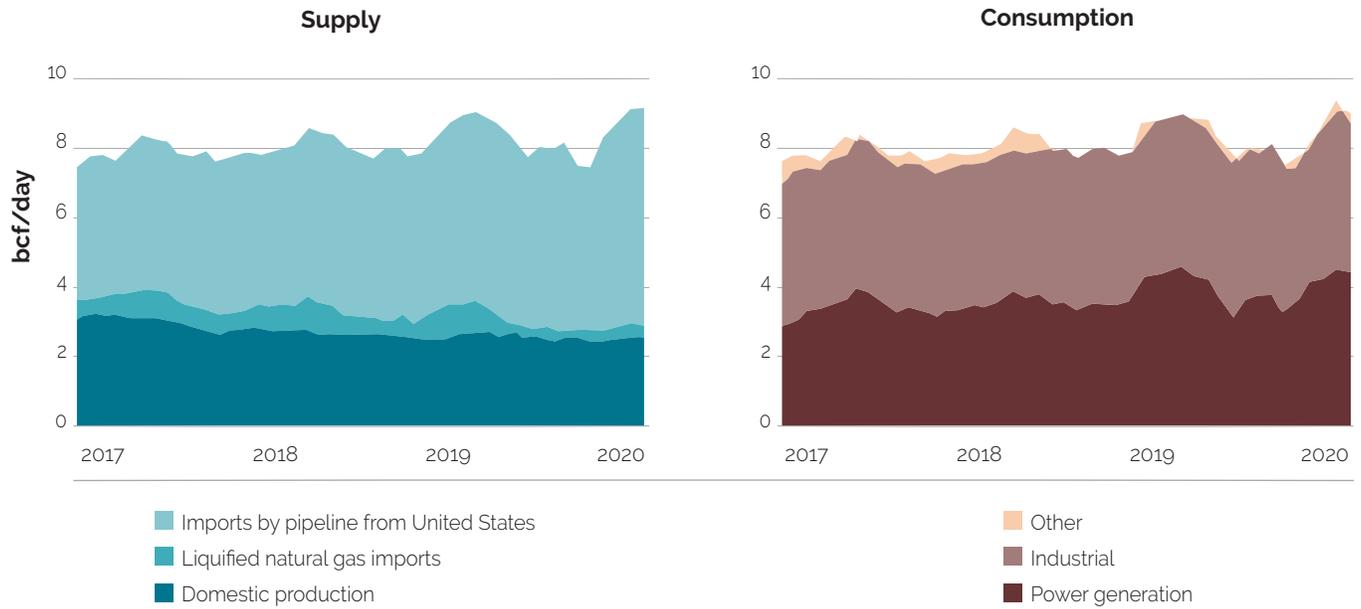
### Emissions Outlook

The United States is the second largest emitter of global greenhouse gas (GHG) emissions in the world after China and has no economywide emissions reduction policy in place as of June 2021.<sup>130</sup> However, the Biden Administration recently recommitted the United States to the Paris Agreement and proposed a new NDC of 50 to 52 percent reduction in GHG emissions by 2030.<sup>131</sup> The Biden Administration has also expressed an ambition for net-zero emissions economywide by 2050. Historic climate policy reversals and inaction—coupled with narrow

legislative majorities—inject uncertainty into forecasts of natural gas use and development going forward.

Canada pledged to reduce GHG emissions 30 percent below 2005 levels by 2030 and set statutory targets to achieve net-zero emissions by 2050.<sup>132,133</sup> While switching to natural gas from coal generation contributes to modest emissions reductions, a transition to net-zero emissions requires replacing natural gas-fired power plants entirely or outfitting these plants to use CCS technology or cleaner fuels, e.g., hydrogen or renewable gas.

**Figure 54: Monthly Natural Gas Balance in Mexico, January 2017 to September 2020<sup>134</sup>**



*This figure shows natural gas supply and consumption in Mexico between 2017 and 2020. U.S. pipeline exports of natural gas to Mexico comprise the majority of Mexico's natural gas supply. Industry and power generation accounts for nearly all natural gas consumption in Mexico. Source: Zaretskaya, 2020.*

Table 8 shows the North America region's per capita fossil fuel emissions compared to global averages, and its share of total CO<sub>2</sub> emissions from fossil fuels relative to its share of total population. Compared to its share of the global population, the North America region is the largest source of fossil fuel emissions in the world. It also has the highest per capita emissions of any region analyzed in this study (2.5 times the global average). Achieving net-zero targets by 2050 will be extremely difficult for Canada and the United States, although both countries have a substantial innovation infrastructure for meeting midcentury targets. Meeting near-term goals for all countries in the region will likely need to accommodate existing infrastructures and workers.

**Table 8: North America Population, Percent of World Emissions and Per Capita Emissions from Fossil Fuels, 2019<sup>135</sup>**

CO <sub>2</sub> per Capita per Year from Fossil Fuels	Share of World CO <sub>2</sub> Emissions from Fossil Fuels	Share of World Population
<b>12.3 tons</b>	<b>16.3%</b>	<b>6.5%</b>
4.9 tons World Average	38,017 MT World Total	7.71 Bn People World Total

3 countries in analysis. Numbers are rounded. MT = Megatons.

*Data from Crippa et al., 2020.*

## SUMMARY OF PANELIST DISCUSSION (Authored by the Baker Institute)

The workshop hosts and participants were provided with framing questions from EFI, which can be found on page 3 of this report.

### ***The role of natural gas in the energy transition***

A third of North America's energy comes from natural gas.<sup>136</sup> Natural gas has contributed greatly to reducing CO<sub>2</sub> emissions in power generation and is considered by some participants as a critical, reliable backup for intermittent renewable energy. Natural gas also presents an opportunity to decarbonize high-emission industries and industrial processes, especially when combined with carbon capture technologies and/or hydrogen pathways.

Energy-related CO<sub>2</sub> emissions have declined in the United States over the last 15 years, from about 6 billion metric tons per year in 2004 to 5.1 billion metric tons in 2019, and, in part, this reduction has been enabled by increased natural gas consumption.<sup>137</sup> The combination of fuel switching from more carbon-

intensive fuels to gas, increased integration of renewable energy leveraging a reliable and flexible gas system, and implementation of energy efficiency measures has decreased the emissions intensity of the energy system. CO<sub>2</sub> emissions from natural gas have risen as natural gas generation has displaced coal, but the increase is more than offset by the reduction in coal emissions.

Greater integration of intermittent renewable resources into the energy mix has raised the profile of natural gas as a key fuel for balancing and firming power generation. Some policymakers and the environmental community have raised concerns about the use of natural gas in this capacity. Transparency on emissions throughout the natural gas value chain will be necessary to allay some environmental concerns and facilitate access to future market opportunities.

It was stated that many in the environmental community perceive natural gas as the “new coal” and that action is being taken to stem further natural gas development and end-use installation in some communities and cities. This raises an open question regarding the extent to which local policy will drive the future of gas use, especially in residential and commercial applications.

Given the abundance of natural gas in both Canada and the United States, both countries are actively exploring opportunities to monetize supply through LNG exports, with a heavy emphasis on West Coast outlets to Asia. LNG could allow both the United States and Canada to lead broader decarbonization efforts in other markets, such as developing nations in Asia that are reliant on more carbon-intensive fuels. Some workshop participants argued that this should be a driving factor in domestic natural gas development policy. Others argued that the continued production and export of LNG, as domestic climate policy becomes stricter, would allow producers to “offset” emissions elsewhere in the world.

Participants generally agreed that natural gas will continue to play a critical role in U.S. energy security. Policy will have a strong influence on the options available to provide backup for renewable power generation, and uncertainty remains regarding the long-term role of natural gas in balancing the integration of renewables into the U.S. energy market. Globally, the United States is likely to play a critical role in supplying natural gas to economies that still rely on coal and/or biomass, are looking to alleviate energy poverty with clean fuels, and are looking to increase power generation from renewable sources but still need backup power.

There was discussion of the need for general education of the public and policymakers about the potential role of natural gas in a deeply decarbonized economy. The following questions were framed as important to this aim:

- How does natural gas currently contribute to overall energy system resilience, including reliability and market stability?
- How will natural gas enable the future energy system’s response to disruptions, extreme weather events or cyberattacks?
- How do requirements for resilience change as stakeholders and policymakers develop and implement strategies to reduce greenhouse gas emissions?
- How can natural gas add optionality and de-risk GHG emissions reduction strategies?

### ***Key economic and regional trends driving natural gas demand/uses***

North America is a well-developed, industrialized set of economies with significant regional heterogeneity. There are substantial differences in natural gas use between Canada, the United States, and Mexico. Moreover, regional economic drivers, resource endowments, and existing infrastructures influence where natural gas is used most in the economy.

Natural gas in power generation is, by far, the largest source of demand growth in North America. In the United States, where the majority of North American natural gas is consumed, the demand for gas in residential applications has been relatively flat on an annual basis, and commercial demand has increased; both residential and commercial use of natural gas is highly seasonal. Industrial demand has increased over the last decade, driven in part by the low cost of natural gas and expansion of gas-intensive industrial activity.

Exports of LNG and pipeline gas are new and emerging sources of demand for U.S.-produced natural gas. The United States currently exports LNG to 33 different countries and exports pipeline gas largely to Mexico. LNG exports have significantly impacted the structure of world natural gas markets.

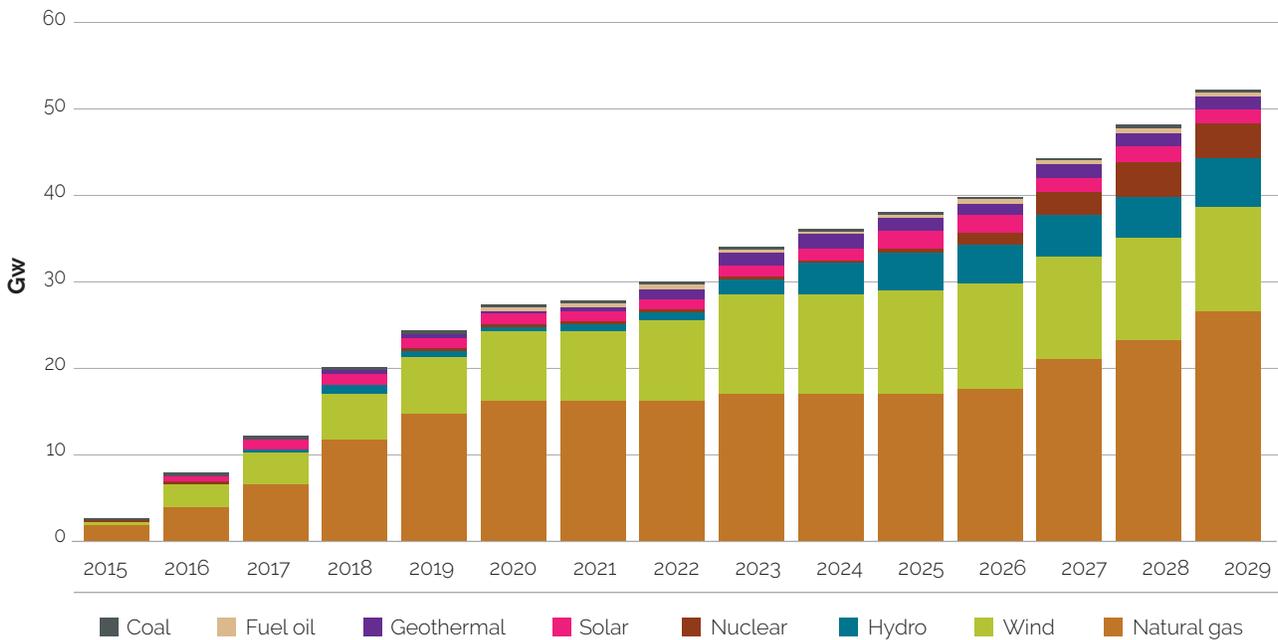
North America's geography allows it to serve markets in Asia, Europe, and Latin America. The reach of North American, and specifically U.S., LNG exports connects a significant and growing number of markets to North American resources, storage capacity, infrastructure, and flexible financing and contract structures. This access allows North America to nimbly adapt to shifting market conditions, facilitate greater liquidity, and offer security of supply, which carries broad benefits for allies around the world and for domestic national security goals.

In the face of heightened climate ambition in the region, particularly in the United States and Canada, natural gas is expected to continue to replace coal and oil, especially in the short term. Renewable resources are also gaining significant traction as costs decrease and emissions targets become more stringent. The United States' new NDC will require significant emissions reductions across the

economy by 2030, and many companies and financial organizations are instituting or supporting net-zero goals by midcentury. It is still uncertain what the specific impact of these trends will be on natural gas, particularly in the power sector—some see a longer natural gas “bridge” supporting renewable deployment, while others see a much shorter runway for natural gas use as renewable and storage technologies improve.

In Mexico, the trajectory of natural gas use is highly dependent on the political landscape, although natural gas use in the Mexican power sector has grown dramatically and is forecasted to grow even more (Figure 55). The current government has prioritized domestic production of fuel oil above imports of natural gas from the United States. Future governments may be more open to the use of natural gas and the development of related infrastructure.

**Figure 55: Cumulative Projected Generation Capacity Additions in Mexico by Fuel Type, 2015-2029<sup>138</sup>**



*This figure shows cumulative projected capacity additions in Mexico through 2029. Natural gas capacity is expected to increase by about 60 percent by 2029 from 2021 levels. Source: EIA, 2017.*

### **Major drivers of regional energy supply and demand**

Prioritizing a low-carbon economy as a national energy strategy via climate policies or NDCs could change consumer preferences for distinct energy sources, *i.e.*, emission reduction policies and market mechanisms could favor certain sources of supply. Potential sources with lower lifecycle emissions than natural gas include low-carbon gas, such as renewable natural gases from anaerobic digestion and thermal gasification, hydrogen sourced from natural gas feedstocks and methods using carbon capture technologies, nuclear, green hydrogen produced via electrolysis, and other renewable resources like wind and solar.

There is an open question about how customer choices for energy sources may be changing. Traditionally, energy sources have been prioritized first by cost, then by reliability, and then other attributes like low carbon intensity. This prioritization may be reversing in the region—an emerging group of consumers are beginning to express preferences for low-carbon sources even at higher cost and reliability risks associated with renewables and intermittency. The natural gas industry's awareness of this potential consumer shift has led to the development of systems to “certify” natural gas with a lower environmental footprint. Availability of “responsible gas” could create a differentiated natural gas product that, although higher cost, would be preferred by a particular class of consumers concerned with the environmental impact of their energy sources.

Throughout the region, people continue to move from the countryside to urban centers, increasing energy demand in densely populated areas, increasing the need for energy and distribution infrastructure in increasingly constrained areas.

### **The range of potential futures of natural gas markets**

Businesses, policymakers, and stakeholders are working to develop and implement strategies to pursue a significantly lower-carbon energy economy, particularly in the United States and Canada. These efforts could augment the role for natural gas, but only if it can be reliably merged with decarbonization strategies.

Global policy trends are prioritizing decarbonization strategies. Natural gas has the potential to ensure reliability for renewables and provide feedstock for low- or zero-emission fuels. It was argued that, for natural gas to play this role, its public perception must improve. It was also expressed that natural gas is essential to decarbonizing and/or reducing the carbon intensity of power generation and heavy industry, with gas potentially playing a primary feedstock role in hydrogen solutions.

North American LNG has significant potential in Asian markets and in other developing markets. If LNG replaces more carbon-intensive fuels in those markets, it could support broader decarbonization efforts. There is some uncertainty surrounding the United States' LNG policy given the Biden Administration's significant climate ambition.

Participants noted that improvements in technology to measure and identify methane emissions will become increasingly important for methane reduction policies, and could possibly determine access to markets through regulation. There is precedent for methane emissions reductions—workshop participants claimed that methane emissions from local distribution systems have declined about 70 percent since 1990 because of pipeline replacement programs and modernization of gas infrastructure to make the system safer and more reliable. Policies establishing preference for natural gas that has been “certified” as lower-emitting could shift demands towards certain sources of gas supply in existing markets. This is important for both domestic markets and LNG exports.

Workshop participants generally agreed that North American gas demand will remain relatively strong through at least 2030, with a growing emphasis on LNG exports. Projections for the midcentury timeline are much more uncertain.

### ***NDCs and climate targets***

Given that the NDCs for Canada, the United States, and Mexico have been recently updated, there was some trepidation among workshop participants about stating whether each country is on track. However, it was stated that Mexico’s current administration has not substantially invested in options to help it meet its Paris Agreement goals. For the United States and Canada, much of the discussion centered on what is needed to achieve the goals laid out in the NDCs.

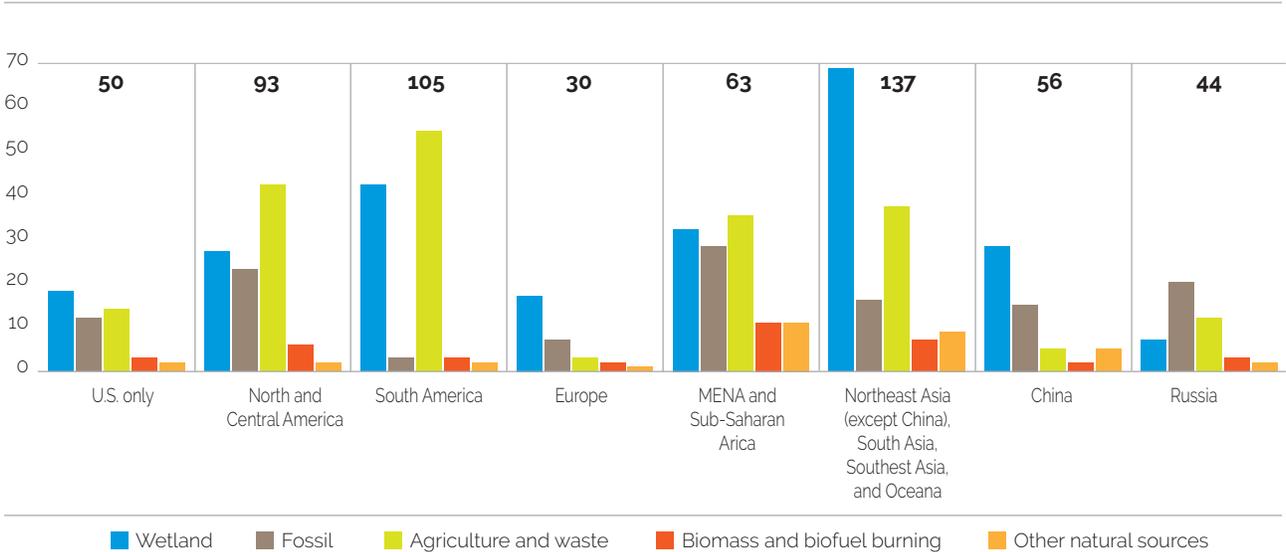
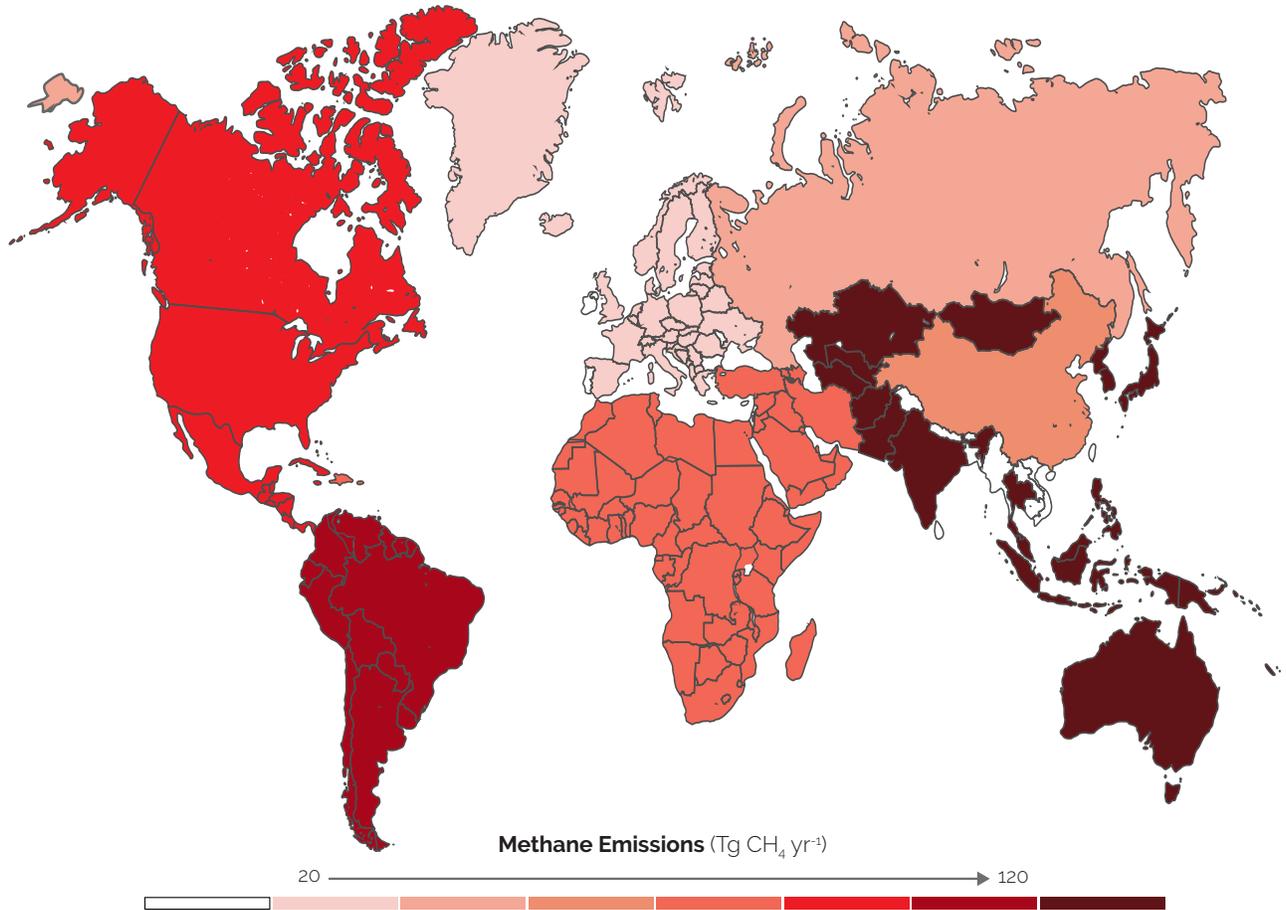
It was argued that creating a credit or taxation system to reduce and track methane emissions from oil and gas production could be a valuable first step to reducing emissions from the industry, although it was also noted that transparency around existing emissions would also be needed to reach the current NDCs. Carbon taxes were discussed as a vehicle to reducing emissions, particularly because they could accelerate the adoption of carbon capture technologies and hydrogen pathways.

As noted, participants stated that U.S. LNG exports could be key to reducing carbon emissions in other regions around the world, particularly those heavily dependent on coal.

### ***Impact of climate policies on natural gas supply and demand***

Methane emissions associated with oil and gas value chains will come under increasing scrutiny (Figure 56). Accordingly, measurement and verification of methane emissions with a widely acceptable standard for reporting and mitigation will be critical to successfully address any policy measure, be it emissions limits, tax measures, a combination of the two, or an entirely different policy mechanism. It was mentioned that the gas industry is working on initiatives to develop an appropriate measurement and verification structure, and that collaboration between government, industries, and institutions on this issue of methane emissions will be critical.

**Figure 56: Global Methane Emissions, United States and Rest of World<sup>139</sup>**



This map shows methane emissions per year by region, and the bar graphs show regional and U.S.-specific breakdowns of methane emissions sources and methane emissions totals. Over half of North and Central America's methane emissions are from the United States, and U.S. methane emissions from fossil sources comprise slightly less than half of all fossil methane emissions from North and Central America. The MENA region and Russia also emit significant amounts of methane from fossil production relative to other methane sources. Across most regions, wetlands and agriculture are responsible for most methane emissions. Source: McSweeney, 2020. Data from Jackson et al., 2020; Saunio et al., 2020.

Carbon pricing was also raised as an important factor to consider, although no clear direction regarding a potential carbon pricing mechanism yet exists. Rather, a variety of proposals, ranging from carbon border taxes, to explicit taxation, to implicit pricing mechanisms related to tax breaks, have been proposed. The impacts of these proposed policies are unknown, contributing to uncertainty around the future of fossil fuel investment and implications for gas supply and demand. It was mentioned that while the pricing mechanism for internalizing CO<sub>2</sub> emissions costs matter, other factors also matter equally as much, such as how carbon prices are implemented, how prices change over time, and how revenues from carbon pricing are allocated. Where the price is set also matters—for example, price levels could preclude or facilitate carbon capture and storage or renewable natural gas as commercially attractive options.

The role of natural gas as a balancing fuel for intermittent renewables is anticipated to keep it in the power generation mix for the foreseeable future. In the industrial sector, natural gas for processed heat is not likely to be replaced absent significant policy support for hydrogen or other options.

It was noted, however, that “public opinion” in the European Union and United States appear to be turning against natural gas, though this point was raised in the context of public policy. Investment strategies adopted by the World Bank, European Investment Bank, and other financial organizations are seen as reflective of emerging public policy in the European Union and North America. These strategies will affect the long-term potential for growth in global natural gas demand over time and the role of North America in LNG export markets.

It was argued that policies to reduce GHG emissions should consider the role of the current U.S. gas system in the face of future threats such as cyber-attacks, local energy reliability, and the ability of the

*It was argued that policies to reduce GHG emissions should consider the role of the current U.S. gas system in the face of future threats such as cyber-attacks, local energy reliability, and the ability of the existing energy system to react to disruptions. Only a holistic approach to policy, it was stated, would achieve safe, reliable, affordable transitions to low-carbon energy futures.*

existing energy system to react to disruptions. Only a holistic approach to policy, it was stated, would achieve safe, reliable, affordable transitions to low-carbon energy futures.

Hydrogen was also discussed as an emerging and key player in energy transitions, driven by various joint initiatives and state policies. The question remains regarding which hydrogen technologies to deploy; this has implications for the use of natural gas (for instance, blue would drive increased use of natural gas whereas green would push the other way).

There are several ongoing studies to evaluate the cost of projected pathways. Decarbonization strategies are evolving on a regional basis, with state and provincial governments and some municipalities taking active policy stances. There are stated goals related to the Paris NDCs at the federal level, but implementation is still evolving. The most robust action, to date, has come from the private sector where clear goals for net-zero are emerging across the board, from oil and gas to high-tech to utilities.

Carbon capture, hydrogen, renewables, battery storage, electrification, and nature-based approaches are all emerging as clear technologies and options for a broader set of decarbonization strategies. Natural gas appears to be an important part of this pathway, although the extent will depend on the evolution of policy and technology. There are different costs,

*The possible uses of gas infrastructure to add optionality and de-risk GHG emissions reduction strategies are being considered. Leveraging existing infrastructure in any effort to achieve GHG reduction goals is considered a very attractive option. In fact, it was raised that the valley of death for new energy technologies is littered with examples where deployment costs ultimately impeded wide-scale adoption. Hence, any technology that can leverage existing infrastructure avoids a significant fixed cost of deployment.*

advantages, and disadvantages of each technology and strategy option, indicating that meeting both climate and energy security goals will require a portfolio approach.

### **Substitutes for natural gas in the 2030 and midcentury timeframes**

By 2030, it is unlikely that there will be significant deployment of substitutes for natural gas in North America, but 2050 is much more uncertain.

Significant efforts to advance hydrogen as a clean energy carrier are underway, including blue hydrogen with CCS and green hydrogen from renewables with electrolysis. The potential applications of hydrogen are well-established—it can store energy to support renewables, power heavy duty long-haul transportation, and decarbonize energy intensive industrial applications.

Currently, almost all hydrogen production comes from steam reformation of methane, and this may remain the case in a low-carbon future if coupled with carbon capture technology. However, investment in green hydrogen is accelerating.

Renewable natural gas is also gaining interest, especially in regions where production can benefit from policies such as a low carbon fuel standard. However, participants noted that the potential variation of the feedstock across regions and projects is large enough to inhibit significant economies of scale across production value chains.

In Mexico, though the government has stated its intention to reduce energy dependence on the United States in particular, continued reliance on imports from the United States was not generally viewed as likely to change.

### **Policies to repurpose natural gas infrastructure for clean energy alternatives**

The possible uses of gas infrastructure to add optionality and de-risk GHG emissions reduction strategies are being considered. Leveraging existing infrastructure in any effort to achieve GHG reduction goals is considered a very attractive option. In fact, it was raised that the valley of death for new energy technologies is littered with examples where deployment costs ultimately impeded wide-scale adoption. Hence, any technology that can leverage existing infrastructure avoids a significant fixed cost of deployment.

There was discussion of the possibilities of repurposing existing infrastructure to distribute renewable natural gas and synthetic gas. Renewable gas sourced from biogenic sources is generally considered pipeline-compatible.

Participants also discussed the potential for natural gas pipelines to be repurposed to move hydrogen, but no concrete examples were discussed. Questions remain about the compatibility of hydrogen with existing infrastructure and how much hydrogen can be blended with existing natural gas systems. Given the heterogeneity of the pipeline network, with different ages of infrastructure, a uniform answer for its use is not likely.

### ***Role of natural gas/LNG in addressing developing country energy needs***

LNG provides an avenue for developing nations to reduce their emissions. U.S. natural gas exports could support these efforts and facilitate either the replacement of coal for power generation or a wider adoption of renewable energy. Natural gas poses a beneficial alternative to coal in terms of power system reliability, cost and cleanliness.

Hydrogen was raised as an option for developing economies, but the upfront fixed cost and lack of existing infrastructure pose challenges everywhere. It was also stated that technologies such as carbon capture and other mitigation techniques remain too expensive given the high up-front costs of infrastructure. Natural gas supplied from LNG can provide economic development pathways to countries seeking to displace coal, though the absolute emissions benefit may be limited by the cost of carbon capture technologies.

### ***Incorporation of corporate ESG policies and financial institution guidelines for investments in new natural gas projects***

Addressing environmental issues associated with natural gas is critical for the natural gas industry. ESG considerations in general are acknowledged in existing and future infrastructure projects, with a goal of improving corporate performance along ESG guidance. It was noted that although a uniformly accepted set of ESG performance metrics does not yet exist, the UN's Sustainable Development Goals are being referenced as a foundation for corporate action.

North American companies are increasingly adopting net-zero goals and financial institutions face pressure to or are actively limiting investments in new fossil fuel projects. Increasing investor pressure for "clean" natural gas is also a critical driver of market differentiation.

### ***The role of emissions abatement technologies***

As noted above, there was discussion about the expansion of carbon capture and storage and the role it will play in the sustainability of the natural gas industry. Gas as a feedstock for hydrogen and ammonia technologies was also mentioned, but it was recognized that carbon capture is critical to advancing those pathways if natural gas is to remain integral to the global energy mix.

CO<sub>2</sub> sequestration and storage have seen heavy increases in investments, as they are pivotal to obtain net-zero goals set by governments, companies, and other stakeholders. Tax incentives, such as 45Q, are helping drive greater interest in CO<sub>2</sub> sequestration, yet uncertainties remain regarding storage sites. One thing is certain: oil and gas industry engagement is pivotal for CO<sub>2</sub> sequestration at the required scale.

It was argued that optimizing natural gas production from unconventional reservoirs has helped decrease CO<sub>2</sub> emissions by displacing coal in the U.S. power sector. Some natural gas producers are also attempting to reduce flaring and fugitive methane emissions to position natural gas as an environmentally desirable fuel of choice in power generation and industrial applications. Lack of homogeneity across different producers was recognized as a concern, and hence a possible motivation for policy action.

Hydrogen investment has seen a significant increase but costs for infrastructure and clean production of hydrogen are still not attractive enough for a wider adoption and a beneficial displacement of natural gas. Hydrogen and the technology "rainbow" of hydrogen options are regarded as an important part of energy transitions, and hydrogen is considered both as a complement and rival to natural gas, depending on the production technology. This is where policy and cost both play a critical role in determining the most attractive hydrogen pathway. Heat pumps are considered as a solution for space and water heating, potentially a promising technology to abate emissions.

## ENDNOTES

- 1 "Global primary energy consumption by source," Our World in Data, 2021, [https://ourworldindata.org/grapher/global-energy-substitution?country=-OWID\\_WRL](https://ourworldindata.org/grapher/global-energy-substitution?country=-OWID_WRL)
- 2 "Global primary energy consumption by source," Our World in Data, 2021, [https://ourworldindata.org/grapher/global-energy-substitution?country=-OWID\\_WRL](https://ourworldindata.org/grapher/global-energy-substitution?country=-OWID_WRL)
- 3 IEA. "Data and Statistics." <https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=TPESbySource> (accessed March 30, 2021)
- 4 "Forty Years of Combined Cycle Power Plants," ASME, October 2002, <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.800.1755&rep=rep1&type=pdf>
- 5 "Natural gas explained: Natural gas imports and exports," Energy Information Administration, 2020, <https://www.eia.gov/energyexplained/natural-gas/imports-and-exports.php>
- 6 "World Shale Resource Assessments," Energy Information Administration, 2015, <https://www.eia.gov/analysis/studies/worldshalegas/>
- 7 Giorgio Bresciani et al., "The future of liquefied natural gas: Opportunities for growth," McKinsey & Company, 2020, <https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-future-of-liquefied-natural-gas-opportunities-for-growth>
- 8 Sean O'Brian and Antonio Eras Rodriguez, "Record year for gas liquefaction investment lights a path towards market flexibility," International Energy Agency, 2020, <https://www.iea.org/commentaries/record-year-for-gas-liquefaction-investment-lights-a-path-towards-market-flexibility>
- 9 "2019 World LNG Report", International Gas Union, 2019, [https://www.igu.org/wp-content/uploads/2019/06/IGU-Annual-Report-2019\\_23.pdf](https://www.igu.org/wp-content/uploads/2019/06/IGU-Annual-Report-2019_23.pdf)
- 10 Giorgio Bresciani et al., "The future of liquefied natural gas: Opportunities for growth," McKinsey & Company, 2020, <https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-future-of-liquefied-natural-gas-opportunities-for-growth>
- 11 BP. "BP Statistical Review of World Energy 2020." <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf> (accessed May 13, 2021), pgs. 40-42
- 12 BP. "BP Statistical Review of World Energy 2020." <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf> (accessed May 13, 2021), pgs. 40-42
- 13 "2020 World LNG Report", International Gas Union, 2021, <https://www.igu.org/wp-content/uploads/2020/04/2020-World-LNG-Report.pdf>
- 14 BP. "BP Statistical Review of World Energy 2020." <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf> (accessed May 13, 2021), pgs. 40-42
- 15 Giorgio Bresciani et al., "The future of liquefied natural gas: Opportunities for growth," McKinsey & Company, 2020, <https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-future-of-liquefied-natural-gas-opportunities-for-growth>
- 16 BP. "BP Statistical Review of World Energy 2020." <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf> (accessed May 13, 2021), pgs. 40-42
- 17 "2020 World LNG Report", International Gas Union, 2021, <https://www.igu.org/wp-content/uploads/2020/04/2020-World-LNG-Report.pdf>
- 18 BP. "BP Statistical Review of World Energy 2020." <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf> (accessed May 13, 2021), pgs. 40-42
- 19 Bruce Robertson, "Gas and LNG Price Volatility To Increase in 2021," Institute for Energy Economics and Financial Analysis, January 2021, [http://ieefa.org/wp-content/uploads/2021/01/Gas-and-LNG-Price-Volatility-To-Increase-in-2021\\_January-2021.pdf](http://ieefa.org/wp-content/uploads/2021/01/Gas-and-LNG-Price-Volatility-To-Increase-in-2021_January-2021.pdf)
- 20 BP. "BP Statistical Review of World Energy 2020." <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf> (accessed May 13, 2021)
- 21 "Methane Abatement Options," IEA, 2020, <https://www.iea.org/reports/methane-tracker-2020/methane-abatement-options#abstract>
- 22 "Data supplement to the Global Carbon Budget," Global Carbon Project, 2020, [doi.org/10.18160/gcp-2020](https://doi.org/10.18160/gcp-2020)
- 23 "Overview," IEA, 2020, <https://www.iea.org/reports/methane-tracker-2020/methane-abatement-options#abstract>
- 24 Hannah Ritchie, "Sector by sector: where do global greenhouse gas emissions come from?," Our World in Data, September 18, 2020, <https://ourworldindata.org/ghg-emissions-by-sector>
- 25 Climatewatch. "Historical GHG Emissions." [https://www.climatewatchdata.org/ghg-emissions?end\\_year=2018&start\\_year=1990](https://www.climatewatchdata.org/ghg-emissions?end_year=2018&start_year=1990)
- 26 Climatewatch. "Historical GHG Emissions." [https://www.climatewatchdata.org/ghg-emissions?end\\_year=2018&start\\_year=1990](https://www.climatewatchdata.org/ghg-emissions?end_year=2018&start_year=1990) (accessed March 30, 2021)
- 27 "Net Zero By 2050", Energy and Climate Intelligence Unit, Accessed on June 3, 2021, <https://eci.net/netzerotracker/map>
- 28 IRENA (2017). Untapped potential for climate action: Renewable energy in Nationally Determined Contributions, International Renewable Energy Agency, Abu Dhabi, [https://irena.org/-/media/Files/IRENA/Agency/Publication/2017/Nov/IRENA\\_Untapped\\_potential\\_NDCs\\_2017.pdf](https://irena.org/-/media/Files/IRENA/Agency/Publication/2017/Nov/IRENA_Untapped_potential_NDCs_2017.pdf)

- 29 "World Population Growth Rate 1950-2021," Accessed on June 3, 2021, <https://www.macrotrends.net/countries/WLD/world/population-growth-rate>
- 30 United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019, Online Edition. Rev. 1. <https://population.un.org/wpp/Download/Standard/Population/>
- 31 "EIA projects nearly 50% increase in world energy usage by 2050, led by growth in Asia," U.S. Energy Information Agency, September 24, 2019, <https://www.eia.gov/todayinenergy/detail.php?id=41433>
- 32 "EIA projects nearly 50% increase in world energy usage by 2050, led by growth in Asia," U.S. Energy Information Agency, September 24, 2019, <https://www.eia.gov/todayinenergy/detail.php?id=41433>
- 33 "EIA projects nearly 50% increase in world energy usage by 2050, led by growth in Asia," U.S. Energy Information Agency, September 24, 2019, <https://www.eia.gov/todayinenergy/detail.php?id=41433>
- 34 "Member Countries," OECD, 2021, <https://www.oecd.org/about/members-and-partners/>
- 35 "Net Zero by 2050: A Roadmap for the Global Energy Sector," IEA, Accessed on June 3, 2021, <https://iea.blob.core.windows.net/assets/0716bb9a-6138-4918-8023-cb24caa47794/NetZeroby2050-ARoadmapfortheGlobalEnergySector.pdf>, pgs. 30-31
- 36 "Air pollution and health: Summary," World Health Organization, 2021, <https://www.who.int/airpollution/ambient/about/en/>
- 37 Union of Concerned Scientists. "Environmental Impacts of Natural Gas" June 19, 2014, <https://www.ucsusa.org/resources/environmental-impacts-natural-gas>
- 38 IEA. "World Energy Outlook 2020." Paris: IEA. (2020)
- 39 Consolidated Appropriations Act, 2021; H.R. 133, 116th Cong. (2020).
- 40 Balza, L., Espinasa, R., and Serebrisky, T. 2016. "Lights On? Energy Needs in Latin America and the Caribbean to 2040." Inter-American Development Bank. <https://publications.iadb.org/en/lights-energy-needs-latin-america-and-caribbean-2040>
- 41 Ferreira Francisco et al., "Economic Mobility and the Rise of the Latin American Middle Class," The World Bank, 2013, <https://openknowledge.worldbank.org/bitstream/handle/10986/11858/9780821396346.pdf?sequence=5&isAllowed=y>
- 42 Balza, L., Espinasa, R., and Serebrisky, T. 2016. "Lights On? Energy Needs in Latin America and the Caribbean to 2040." Inter-American Development Bank. <https://publications.iadb.org/en/lights-energy-needs-latin-america-and-caribbean-2040>
- 43 IEA (2021). Climate Impacts on Latin American Hydropower, IEA, Paris <https://www.iea.org/reports/climate-impacts-on-latin-american-hydropower>
- 44 Jonathan Moens. "Andes Meltdown: New Insights into Rapidly Retreating Glaciers". Yale Environment 360. January 30, 2020. <https://e360.yale.edu/features/andes-meltdown-new-insights-into-rapidly-retreating-glaciers>
- 45 IEA (2021). Climate Impacts on Latin American Hydropower, IEA, Paris <https://www.iea.org/reports/climate-impacts-on-latin-american-hydropower>
- 46 IEA. "World Energy Outlook 2020." Paris: IEA. (2020)
- 47 IEA. "World Energy Outlook 2020." Paris: IEA. (2020)
- 48 IEA (2021), "Climate Impacts on Latin American Hydropower," IEA, Paris <https://www.iea.org/reports/climate-impacts-on-latin-american-hydropower>
- 49 M. Crippa et al., Fossil CO<sub>2</sub> emissions of all world countries - 2020 Report, Publications Office of the European Union, Luxembourg, 2020, [https://edgar.jrc.ec.europa.eu/booklet/Fossil\\_CO2\\_emissions\\_of\\_all\\_world\\_countries\\_booklet\\_2020report.pdf](https://edgar.jrc.ec.europa.eu/booklet/Fossil_CO2_emissions_of_all_world_countries_booklet_2020report.pdf)
- 50 IEA. "Data and Statistics." <https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=TPESbySource> (accessed May 3, 2021)
- 51 "Costa Rica", Climate Action Tracker, Accessed on June 4, 2021, <https://climateactiontracker.org/countries/costa-rica/>
- 52 "Chile", Climate Action Tracker, Accessed on June 6, 2021, <https://climateactiontracker.org/countries/chile/>
- 53 Matthew Binsted, et. al., "Stranded asset implications of the Paris Agreement in Latin America and the Caribbean". Environmental Research Letters. 15 044026. 2020. <https://iopscience.iop.org/article/10.1088/1748-9326/ab506d> (accessed May 18, 2021)
- 54 "National Green Hydrogen Strategy", Minster of Energy, Government of Chile, November 2020 [https://energia.gob.cl/sites/default/files/national\\_green\\_hydrogen\\_strategy\\_-\\_chile.pdf](https://energia.gob.cl/sites/default/files/national_green_hydrogen_strategy_-_chile.pdf) (accessed June 4, 2020)
- 55 United Nations Department of Economic and Social Affairs, World Population Prospects 2019, Online Edition. Rev. 1., United Nations, <https://population.un.org/wpp/Download/Standard/Population/>
- 56 Yasmine Aرسالane. "World Energy Outlook 2020: Implications for Africa." IEA. Presented at Energy Transitions and the Future Role of Natural Gas in Sub-Saharan Africa. December 17, 2020.
- 57 "Africa Energy Outlook 2019," IEA, November 2019, <https://www.iea.org/reports/africa-energy-outlook-2019>
- 58 Jan Corfee-Morlot et al., "Achieving clean energy access in sub-Saharan Africa," OECD, 2018, <https://www.oecd.org/environment/cc/climate-futures/Achieving-clean-energy-access-Sub-Saharan-Africa.pdf>
- 59 Yasmine Aرسالane. "World Energy Outlook 2020: Implications for Africa." IEA. Presented at Energy Transitions and the Future Role of Natural Gas in Sub-Saharan Africa. December 17, 2020.

- 60 "Methane Tracker Database," IEA, Article 18, January 2021, <https://www.iea.org/reports/methane-tracker-2020/interactive-country-and-regional-estimates>
- 61 Yasmine Arsalane. "World Energy Outlook 2020: Implications for Africa." IEA. Presented at Energy Transitions and the Future Role of Natural Gas in Sub-Saharan Africa. December 17, 2020.
- 62 Dan Shepard. "Global warming: sever consequences for Africa", United National Africa Renewal, March 2019, <https://www.un.org/africarenewal/magazine/december-2018-march-2019/global-warming-severe-consequences-africa>
- 63 Climatewatch. "Historical GHG Emissions." [https://www.climatewatchdata.org/ghg-emissions?end\\_year=2018&start\\_year=1990](https://www.climatewatchdata.org/ghg-emissions?end_year=2018&start_year=1990) (accessed April 26, 2021)
- 64 M. Crippa et al., Fossil CO<sub>2</sub> emissions of all world countries - 2020 Report, Publications Office of the European Union, Luxembourg, 2020, [https://edgar.jrc.ec.europa.eu/booklet/Fossil\\_CO2\\_emissions\\_of\\_all\\_world\\_countries\\_booklet\\_2020report.pdf](https://edgar.jrc.ec.europa.eu/booklet/Fossil_CO2_emissions_of_all_world_countries_booklet_2020report.pdf)
- 65 "BP Statistical Review China's energy market in 2018," BP Energy Economics, 2019, <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-china-insights.pdf> (accessed June 4, 2021)
- 66 "BP Statistical Review India's energy market in 2018," BP Energy Economics, 2019, <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-india-insights.pdf>
- 67 "PM Modi says India will invest Rs 20,000 crore to convert 100 MT of coal into gas by 2030", Energy World, June 18, 2020, <https://energy.economicstimes.indiatimes.com/news/coal/pm-modi-says-india-will-invest-rs-20000-crore-to-convert-100-mt-of-coal-into-gas-by-2030/76441438>
- 68 IEA. "Data and Statistics." <https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=TPESbySource> (accessed December 21, 2020)
- 69 "Electricity Market Report," IEA, December 2020, [https://iea.blob.core.windows.net/assets/a695ae98-cec1-43ce-9cab-c37bb0143a05/Electricity\\_Market\\_Report\\_December\\_2020.pdf](https://iea.blob.core.windows.net/assets/a695ae98-cec1-43ce-9cab-c37bb0143a05/Electricity_Market_Report_December_2020.pdf)
- 70 IEA. Gas demand by region and scenario, 2018-2040, IEA, <https://www.iea.org/data-and-statistics/charts/gas-demand-by-region-and-scenario-2018-2040>
- 71 IEA (2021), India Energy Outlook 2021, IEA, Paris <https://www.iea.org/reports/india-energy-outlook-2021>
- 72 IEA (2021), India Energy Outlook 2021, IEA, Paris <https://www.iea.org/reports/india-energy-outlook-2021>
- 73 IEA (2021), India Energy Outlook 2021, IEA, Paris <https://www.iea.org/reports/india-energy-outlook-2021>
- 74 IEA (2020), India 2020, IEA, Paris <https://www.iea.org/reports/india-2020>
- 75 IEA (2020), India 2020, IEA, Paris <https://www.iea.org/reports/india-2020>
- 76 Climatewatch. "Historical GHG Emissions." [https://www.climatewatchdata.org/ghg-emissions?end\\_year=2018&start\\_year=1990](https://www.climatewatchdata.org/ghg-emissions?end_year=2018&start_year=1990) (accessed March 30, 2021)
- 77 Anjali Jaiswal. "Transitioning India's Economy to Clean Energy," NRDC, November 5, 2019, <https://www.nrdc.org/experts/anjali-jaiswal/transitioning-indias-economy-clean-energy>
- 78 IEEJ. "Regional Overview." Presented at The Future of Natural Gas in Northeast and Southeast Asia. January 13, 2021.
- 79 Han Phoumin. "Current Situation and Outlook for Gas Market in ASEAN." Economic Research Institute for ASEAN and East Asia. Presented at The Global Future of Natural Gas in a Low Carbon World: The future of natural gas in Southeast Asia. January 15, 2021.
- 80 Ruben Carlo Asuncion and Minsoo Lee, "Impacts of Sea Level Rise on Economic Growth in Developing Asia," Asian Development Bank, No. 507, January 2017, <https://www.adb.org/sites/default/files/publication/222066/ewp-507.pdf>, pgs. 1-2.
- 81 "Climate risk and response in Asia," McKinsey Global Institute, November 24, 2020, <https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-response-in-asia#>
- 82 M. Crippa et al., Fossil CO<sub>2</sub> emissions of all world countries - 2020 Report, Publications Office of the European Union, Luxembourg, 2020, [https://edgar.jrc.ec.europa.eu/booklet/Fossil\\_CO2\\_emissions\\_of\\_all\\_world\\_countries\\_booklet\\_2020report.pdf](https://edgar.jrc.ec.europa.eu/booklet/Fossil_CO2_emissions_of_all_world_countries_booklet_2020report.pdf)
- 83 "Expert commentary – Future of natural gas in ASEAN's power sector," Gas Exporting Countries Forum, May 10, 2021, <https://www.gecf.org/events/expert-commentary-future-of-natural-gas-in-asean%E2%80%99s-power-sector>
- 84 Maude Desmarescaux and Abache Abreu. "Analysis: Southeast Asia's LNG balancing role in focus, as Thailand agrees import capacity expansion." S&P Global Platts. Oct 2, 2019. <https://www.spglobal.com/platts/en/market-insights/latest-news/natural-gas/100219-analysis-southeast-asias-lng-balancing-role-in-focus-as-thailand-agrees-import-capacity-expansion>
- 85 Han Phoumin. "Current Situation and Outlook for Gas Market in ASEAN." Economic Research Institute for ASEAN and East Asia. Presented at The Global Future of Natural Gas in a Low Carbon World: The future of natural gas in Southeast Asia. January 15, 2021
- 86 Ministry of Trade, Industry, and Energy. "9th Basic Plan for Long-Term Electricity Supply and Demand (2020-2034)" December 28, 2020. [https://www.motie.go.kr/motie/nc/press/press2/bbs/bbsView.do?bbs\\_seq\\_n=163670&bbs\\_cd\\_n=81](https://www.motie.go.kr/motie/nc/press/press2/bbs/bbsView.do?bbs_seq_n=163670&bbs_cd_n=81)
- 87 Reuters Staff. "Japan to shut or mothball 100 ageing coal-fired power plants: Yomiuri," Reuters, July 1, 2020, <https://www.reuters.com/article/us-japan-powerstation-coal/japan-to-shut-or-mothball-100-ageing-coal-fired-power-plants-yomiuri-idUSKBN243074>
- 88 Weiguo Shan, "Role of gas: Opportunities and challenges: Industry View" Presented at the Global Future of Natural Gas in a Low Carbon World: The future of natural gas in Northeast Asia. January 13, 2021.

- 89 IEA, "CO2 emissions reductions in China, 2015-2060 by scenario," IEA, <https://www.iea.org/data-and-statistics/charts/co2-emissions-reductions-in-china-2015-2060-by-scenario>
- 90 M. Crippa et al., Fossil CO2 emissions of all world countries - 2020 Report, Publications Office of the European Union, Luxembourg, 2020, [https://edgar.jrc.ec.europa.eu/booklet/Fossil\\_CO2\\_emissions\\_of\\_all\\_world\\_countries\\_booklet\\_2020report.pdf](https://edgar.jrc.ec.europa.eu/booklet/Fossil_CO2_emissions_of_all_world_countries_booklet_2020report.pdf)
- 91 "Japan's JX Nippon Taps KBR for CCS, Hydrogen Study," OE, May 13, 2020, <https://www.oedigital.com/news/478458-japan-s-jx-nippon-taps-kbr-for-ccs-hydrogen-study>
- 92 IEA, The Role of Gas in Today's Energy Transitions, Paris, 2019, <https://www.iea.org/reports/the-role-of-gas-in-todays-energy-transitions>
- 93 IEA, The Role of Gas in Today's Energy Transitions, Paris, 2019, <https://www.iea.org/reports/the-role-of-gas-in-todays-energy-transitions>
- 94 Anouk Honoré. "Role of gas in the energy transition (the next 10 years)." OIES. Presented at The Global Future of Natural Gas in a Low Carbon World: The Future of Natural Gas in Europe and Implications for Global Geopolitics. January 21-22, 2021.
- 95 Tim Gould. "Setting the scene: what a European net-zero economy could look like in 2050?" IEA. Presented at The Global Future of Natural Gas in a Low Carbon World: The Future of Natural Gas in Europe and Implications for Global Geopolitics. January 21-22, 2021.
- 96 Tim Gould. "Setting the scene: what a European net-zero economy could look like in 2050?" IEA. Presented at The Global Future of Natural Gas in a Low Carbon World: The Future of Natural Gas in Europe and Implications for Global Geopolitics. January 21-22, 2021.
- 97 M. Crippa et al., Fossil CO2 emissions of all world countries - 2020 Report, Publications Office of the European Union, Luxembourg, 2020, [https://edgar.jrc.ec.europa.eu/booklet/Fossil\\_CO2\\_emissions\\_of\\_all\\_world\\_countries\\_booklet\\_2020report.pdf](https://edgar.jrc.ec.europa.eu/booklet/Fossil_CO2_emissions_of_all_world_countries_booklet_2020report.pdf)
- 98 Tim Gould. "Setting the scene: what a European net-zero economy could look like in 2050?" IEA. Presented at The Global Future of Natural Gas in a Low Carbon World: The Future of Natural Gas in Europe and Implications for Global Geopolitics. January 21-22, 2021.
- 99 "U.S. Natural Gas Exports and Re-Exports by Country," EIA, Accessed on June 7, 2021, [https://www.eia.gov/dnav/ng/ng\\_move\\_expc\\_s1\\_a.htm](https://www.eia.gov/dnav/ng/ng_move_expc_s1_a.htm)
- 100 Jake Stones, "UK government launches CCUS, hydrogen funding competitions," ICIS, May 24, 2021, <https://www.icis.com/explore/resources/news/2021/05/24/10643643/uk-government-launches-ccus-hydrogen-funding-competitions>
- 101 "What is Hynet?," Hynet.co.uk, Accessed June 10, 2021, <https://hynet.co.uk/about/>
- 102 Siamak Adibi, "Changing the MENA Energy Landscape in a Decarbonized World." FGE. Presented at Energy Transitions and the Future Role of Natural Gas in the Middle East and North Africa. 24 March 2021.
- 103 Siamak Adibi, "Changing the MENA Energy Landscape in a Decarbonized World." FGE. Presented at Energy Transitions and the Future Role of Natural Gas in the Middle East and North Africa. 24 March 2021.
- 104 M. Crippa et al., Fossil CO2 emissions of all world countries - 2020 Report, Publications Office of the European Union, Luxembourg, 2020, [https://edgar.jrc.ec.europa.eu/booklet/Fossil\\_CO2\\_emissions\\_of\\_all\\_world\\_countries\\_booklet\\_2020report.pdf](https://edgar.jrc.ec.europa.eu/booklet/Fossil_CO2_emissions_of_all_world_countries_booklet_2020report.pdf)
- 105 Siamak Adibi, "Changing the MENA Energy Landscape in a Decarbonized World." FGE. Presented at Energy Transitions and the Future Role of Natural Gas in the Middle East and North Africa. 24 March 2021.
- 106 "Global Status of CCS 2020," Global CCS Institute, 2020, <https://www.globalccsinstitute.com/wp-content/uploads/2021/03/Global-Status-of-CCS-Report-English.pdf>
- 107 IEA (2020), CCUS in Clean Energy Transitions, IEA, Paris <https://www.iea.org/reports/ccus-in-clean-energy-transitions>
- 108 King Abdullah Petroleum Studies and Research Center. "CCE Guide Overview," August 2020. <https://www.cceguide.org/wp-content/uploads/2020/08/00-CCE-Guide-Overview.pdf>
- 109 U.S. EIA, "Renewables account for most new U.S. electricity generating capacity in 2021", Today in Energy, January 11, 2021, Accessed: June 2, 2021, <https://www.eia.gov/todayinenergy/detail.php?id=46416>
- 110 Lazard, "Lazard Releases Annual Levelized Cost of Energy and Levelized Cost of Storage Analyses", October 19, 2020, Accessed: June 2, 2021, <https://www.lazard.com/media/451456/lcoe-lcos-2020-press-release.pdf>
- 111 U.S. EIA, "Renewables account for most new U.S. electricity generating capacity in 2021", Today in Energy, January 11, 2021, Accessed: June 2, 2021, <https://www.eia.gov/todayinenergy/detail.php?id=46416>
- 112 J. David Hughes, Canada's Energy Outlook: Current Realities and Implications for a Carbon-Constrained Future, Canadian Centre for Policy Alternatives and the Parkland Institute, May 2018, [https://ccpabc2018.files.wordpress.com/2018/04/cmp\\_canadas-energy-outlook-2018\\_full.pdf](https://ccpabc2018.files.wordpress.com/2018/04/cmp_canadas-energy-outlook-2018_full.pdf)
- 113 International Energy Agency, "Canada", International Energy Agency, Accessed: June 3, 2021, <https://www.iea.org/countries/canada>
- 114 Paul Vieira and Peter Landers, "Canada Embraces Nuclear Energy Expansion to Lower Carbon Emissions", The Wall Street Journal, March 3, 2021, <https://www.wsj.com/articles/canada-embraces-nuclear-energy-expansion-to-lower-carbon-emissions-11614767403>
- 115 CBC News, "Province extends fracking ban 'indefinitely' after failing to meet its own conditions", CBC, June 21, 2018, Accessed: June 3, 2021, <https://www.cbc.ca/news/canada/new-brunswick/shale-gas-fracking-gallant-moratorium-14715225>
- 116 International Energy Agency, "Mexico", International Energy Agency, Accessed: June 3, 2021, <https://www.iea.org/countries/mexico>
- 117 World Energy Outlook, "Mexico Energy Outlook", International Energy Agency, 2016, <https://iea.blob.core.windows.net/assets/e911d7c8-955a-4495-ace0-da85ac4484f9/MexicoEnergyOutlook.pdf>, Page 20.

- 118 International Energy Agency, "Mexico", International Energy Agency, Accessed: June 3, 2021, <https://www.iea.org/countries/mexico>
- 119 Jason Deign, "Mexico's Renewables Fiasco Keeps Getting Worse", Green Tech Media, August 14, 2020, Accessed: June 3, 2021, <https://www.greentechmedia.com/articles/read/mexicos-renewables-fiasco>
- 120 International Energy Agency, "Mexico", International Energy Agency, Accessed: June 3, 2021, <https://www.iea.org/countries/mexico>
- 121 U.S. EIA, "The U.S. leads global petroleum and natural gas production with record growth in 2018", Today in Energy, August 20, 2019, Accessed: June 2, 2021, <https://www.eia.gov/todayinenergy/detail.php?id=40973>
- 122 U.S. EIA, "U.S. total energy exports exceed imports in 2019 for the first time in 67 years", Today in Energy, April 20, 2020, Accessed: June 2, 2021, <https://www.eia.gov/todayinenergy/detail.php?id=43395>
- 123 Stephen Nalley, and Angelina LaRose, "Annual Energy Outlook 2021", U.S. EIA, February 3, 2021, Accessed: June 2, 2021, [https://www.eia.gov/pressroom/presentations/AEO2021\\_Release\\_Presentation.pdf](https://www.eia.gov/pressroom/presentations/AEO2021_Release_Presentation.pdf)
- 124 Government of Canada, "Natural Gas Facts", Canada.ca, Accessed: June 3, 2021, <https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/natural-gas-facts/20067>
- 125 LNG Canada, "Joint Venture Participants", LNG Canada, Accessed: June 3, 2021, <https://www.lngcanada.ca/about-lng-canada/joint-venture-participants/>
- 126 LNG Canada, "One Year Later", LNG Canada, October 1, 2019, Accessed: June 3, 2021, <https://www.lngcanada.ca/news/one-year-later-1/>
- 127 Pedro Joaquin Coldwell et al., "Prospectiva De Gas Natural, 2018-2032", Secretaria de Energia, 2018. [https://base.energia.gob.mx/Prospectivas18-32/PGN\\_18\\_32\\_F.pdf](https://base.energia.gob.mx/Prospectivas18-32/PGN_18_32_F.pdf)
- 128 U.S. EIA, "U.S. natural gas exports to Mexico set to rise with completion of the Wahalajara system", Today in Energy, July 6, 2020. Accessed June 2, 2021: <https://www.eia.gov/todayinenergy/detail.php?id=44278>
- 129 U.S. EIA, "U.S. natural gas exports to Mexico set to rise with completion of the Wahalajara system", Today in Energy, July 6, 2020. Accessed June 2, 2021: <https://www.eia.gov/todayinenergy/detail.php?id=44278>
- 130 Kate Larsen et al., "China's Greenhouse Gas Emissions Exceeded the Developed World for the First Time in 2019", Rhodium Group, May 6, 2021. Accessed: June 2, 2021. <https://rhg.com/research/chinas-emissions-surpass-developed-countries/>
- 131 The White House Briefing Room, "Fact Sheet: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies", April 22, 2021. Accessed: June 2, 2021. <https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/>
- 132 Government of Canada, "United Nations Framework Convention on Climate Change", Canada.ca, April 27, 2020, Accessed: June 3, 2021, <https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-organizations/united-nations-framework-climate-change.html>
- 133 Government of Canada, "Government of Canada charts course for clean growth by introducing bill to legislate net-zero emissions by 2050", November 19, 2020, Accessed: June 2, 2021, <https://www.canada.ca/en/environment-climate-change/news/2020/11/government-of-canada-charts-course-for-clean-growth-by-introducing-bill-to-legislate-net-zero-emissions-by-2050.html>
- 134 Victoria Zaretskaya, "U.S. natural gas exports to Mexico have increased in the first nine months of 2020," Today in Energy, U.S. EIA, October 22, 2020, <https://www.eia.gov/todayinenergy/detail.php?id=45576>
- 135 M. Crippa et al., Fossil CO<sub>2</sub> emissions of all world countries - 2020 Report, Publications Office of the European Union, Luxembourg, 2020, [https://edgar.jrc.ec.europa.eu/booklet/Fossil\\_CO2\\_emissions\\_of\\_all\\_world\\_countries\\_booklet\\_2020report.pdf](https://edgar.jrc.ec.europa.eu/booklet/Fossil_CO2_emissions_of_all_world_countries_booklet_2020report.pdf)
- 136 "Total Primary Energy Supply, 2018," IEA, Accessed on June 7, 2021, <https://www.iea.org/regions/north-america>
- 137 "U.S. energy-related carbon dioxide fell by 2.8% in 2019, slightly below 2017 levels," EIA, May 5, 2020, <https://www.eia.gov/todayinenergy/detail.php?id=43615>
- 138 "Natural gas-fired power plants lead electric capacity additions in Mexico," EIA, January 18, 2017, <https://www.eia.gov/todayinenergy/detail.php?id=29592>
- 139 Robert McSweeney, "Scientists concerned by 'record high' global methane emissions," Carbon Brief, July 14, 2020, <https://www.carbonbrief.org/scientists-concerned-by-record-high-global-methane-emissions>