CHAPTER 7

Conclusions and Path Forward

Michelle Michot Foss, Anna Mikulska, and Gürcan Gülen

Natural Gas Monetization and the New "New Deal" Economies

Natural gas—the general combination of hydrocarbon molecules varying in number of carbon atoms up to C_5 and sometimes higher, but especially C_1, methane—is a critical fuel and feedstock. That natural gas will play an important role in global energy mix at least for several decades seems certain. Yet, divergent positions across geographies around resource wealth and need for energy to grow economies impact investment flows. Differences in energy and environmental policies and attitudes also influence commercial frameworks and investments. We cover a great many of these considerations in our book around the core challenge of natural gas monetization across global value chains.

M. Michot Foss (✉) • A. Mikulska
Baker Institute for Public Policy, Rice University, Houston, TX, USA
e-mail: michelle.m.foss@rice.edu; anna.b.mikulska@rice.edu

G. Gülen
Independent Consultant, West Brookfield, MA, USA
e-mail: gurcan@g2eis.com

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- Chapter 1 progresses from the broad acknowledgment of oil and gas industry resilience, rooted in the technology pathway that defines industry advances over roughly two centuries and continues to unfold. Chapter 1 combines a quest to "understand the present" with a more nuanced view of upstream, using a ten-year history of producer benchmarks, at a time when the U.S. shale plays dominated perceptions and perspectives. The chapter points to the midstream field-to-market dilemmas, repercussions in commodity markets (eroding returns of and on capital inherent in "Frankelnomics" persistent surpluses), and influence on regional and global trade that play out through the remainder of the book, implicitly and explicitly.
- Chapter 2 tackles the role of natural gas in the U.S. electric power generation drawing on experience with long-term dispatch modeling and analysis of organized market designs. Lower-cost natural gas has undermined coal (and nuclear) but encountered competition from alternative energy sources that are rooted in sociopolitical preferences and declining cost of equipment. We capture the conundrums of politicized choice of generation technologies undermining electricity markets across the U.S. and the resulting wide uncertainties surrounding future gas use in the power generation mix.
- Chapter 3 captures the story of the petrochemicals expansion in the U.S. as downstream investment, described from a project database, mobilized to respond to low-cost natural gas liquids (NGLs). The "renaissance" in petrochemicals and the emergence of new NGL exports reside in a context of petrochemical expansions worldwide and in uncertainties emanating from lower oil prices, which reduce the cost of competing feedstocks. But low oil prices also raise questions about supply and pricing of NGLs given the sensitivity of drilling in liquids rich plays in the U.S. to the oil price.
- Chapter 4 sets ambitions of the U.S. exporters within a global liquefied natural gas (LNG) supply picture that stands to gain from large project expansions and new competing sources, keeping the world well stocked. The dominance of trade patterns toward emerging markets, especially in the Asia-Pacific region, and the influence of commercial strategies and practices emanating from the U.S. projects set the tone for LNG transactions ahead.
- Chapter 5 turns to worldwide demand and delineates strategic differences between emerging market, "New World", and established "Old World" customers. We pick up directly the themes of decarbonization and affordability laid out in the Foreward to our book and incorporate

them into the New World and Old World characterization. Mature, stable, and even declining natural gas demand in the Old World, where decarbonization is a stronger political driver, will impact global balances and could influence Old World members that are net exporters. New World suppliers and buyers are connecting in ways that deepen trade and liquidity but, given economic development imperatives and dominance of sovereign interests and control, do not necessarily expand market-based approaches and commercial practices.

- Chapter 6 points to the challenges for mobilizing investment to build natural gas supply chains to create value for participants and deepen gas market liquidity. We use a decision tool for identifying roadblocks to infrastructure investment. These are rooted in systemic proclivities toward sovereign dominance and, thus, implications for institutional capacity, transparency, and market-based pricing. We highlight the problem of building and implementing commercial frameworks within the complex sociopolitical and sociocultural milieu of any country or jurisdiction (the task of achieving sufficient convergence for "license to operate").

Now we come to the hard part of translating observation and analysis throughout our book into a path forward.

As noted in the Preface, our choice of book title reflects perceptions and realities that are currently in the state of play. Public sentiment and a long-established predilection for the "next new thing"[1] have set up a Rorschach test for natural gas in which its merits or demerits are all in the eyes of beholders. Chapter 1 closes with the prevailing bottom line problem statement—valuations of technology enterprises, including "clean tech" and "green tech" (all generally non-fossil fuel businesses) swamp those of traditional oil and gas issues (see The Patch and Money section and accompanying Fig. 1.37). Longer-term returns for clean/green tech suggest a more complicated, less rosy picture, especially when the backdrop of government support for alternative energy projects and businesses is considered. It could be that improved energy demand will lift oil and gas prices and asset values sufficiently to salve investor wounds. No matter, the perception that fossil fuel industries are a dying breed is firmly in place, with serious implications for investment in the legacy natural gas businesses and, crucially, underlying oil and gas resource development and delivery. Opinions are driven by climate activism and heightened sensibilities stemming from the political correctness that surrounds climate and the push for environment, social, governance (ESG) disclosures, especially vis-à-vis legacy oil and gas operations and businesses. Pandemic-induced economic dislocation, including a historic collapse in oil price amid demand erosion, is spurring notions of combining clean/green tech with post-pandemic economic recovery for an extra boost of stimulus in ways that have broad consequences for energy choices and markets.

As we describe later in detail, all of this is much more complex than pundits, and a good many energy and equities analysts and researchers, make it out to be. Efforts to accelerate an energy transition also will expose environmental footprints of substitute fuels and technologies, which are sizeable, along with labor, trade, and geopolitical conundrums for which there are no easy solutions. ESG risks for clean/green tech are largely unexplored and widely ignored.

Scaling up alternative energy, electrifying transportation, and many other ideas will draw more attention to costs, about which proponents have revealed very little to customers. There are few options for expanding clean/green tech, including all supporting infrastructure requirements, without extensive government and, thus, public support. This means socializing costs through rates paid by consumers, or by the state (the sovereign), which may mean taxpayers and voters will pick up the tab as it has been happening all over the world. Realities of cost and financial risk lead to the notion of "socialized energy", with the role of government enlarging as investors seek protections and guarantees, and to growing pressures to "pick winners" among intensely competing clean/green technologies. How these conditions play out against hard-won gains for greater transparency in energy goods and services, including price discovery, is an open question. So is the cost-benefit accounting of current policies versus externalities they are supposed to mitigate. Strategies that help to "de-risk" projects, such as bilateral contracts, also reduce liquidity and thus diminish price discovery.

The various "energy transition" stakeholders rarely debate the market-government tradeoffs. It is important to recognize that all of these dynamics are unfolding in a world in which pandemic economics are encumbering societies deeply affected by and still in recovery from the 2007–2008 recession, mostly Old World countries. The 2007–2008 recession cycle left an indelible, negative mark, especially in the U.S. and Western Europe, on public psyches about markets and capitalism. Public psyches in New World countries, never fully comfortable with the Western market capitalism, suffered a similar experience following the Asian financial crisis in 1997–1998. These pre-existing conditions are matched by arguments that "climate" is a global emergency, which can only be addressed through international cooperation led by governments.

Altogether, open markets and capitalism have taken serious hits during the past two decades. Historic and crucial accomplishments by Old World natural gas industries to embrace competition, provide nondiscriminatory access and common carriage on pipelines, foster price discovery, and invent and spread compelling commercial practices risk getting trampled upon in the scramble toward new "new deal" economies. This is nothing short of ironic, considering the hopes and beliefs that markets and strategies honed for natural gas could inform how we think about electric power, the single largest focus of energy transition.

The Climate Crux of the Matter

Methane, the main component of natural gas that garners concern, constitutes about 17 percent of total greenhouse gases (GHGs).[2] Estimates put oil and natural gas operations, all together, at about 25 percent of industrial emissions of methane and about 15 percent of total methane releases, including natural sources.[3] Combustion of methane produces other gases—including carbon dioxide (CO_2), nitrogen oxide (NO_x)—that are targets for both climate and urban air quality (NO_x is a precursor to ground-level ozone). Methane flaring during the height of oil and gas upstream industry activity pre-pandemic was a visible sore point. Opinions are that thermal properties of methane in the atmosphere are stronger than CO_2, but neither one is the most potent component of GHG. That honor goes to SF_6, sulfur hexafluoride, one of the class of fluorinated gases, and one with global warming potential that is orders of magnitude beyond CO_2 and methane.[4] Unlike other gases, SF_6 can be directly toxic with exposure to electrical switchgear. This last is tremendously inconvenient given that SF_6 is a widely used insulator for electrical equipment. With expansion of electrical systems, SF_6 and other fluorinated gases already have escalated in emissions and have increased in atmospheric concentration. Although still considerably lower than other GHGs in the atmosphere, the much greater potency of SF_6 suggests that any growth in emissions should be unacceptable. With electrification promoted to displace fossil fuels, SF_6 will increase dramatically in emissions and atmospheric concentrations. Various calls to ban SF_6 have emerged with little or no attention to tradeoffs and new risks, uncertainties, and unintended consequences. Substitutes do exist, although, as usual, with greater cost and far less attractive properties

(De La Fuente et al. 2021).[5] Policy and regulatory treatment to limit or ban SF_6 would threaten the semiconductor industry, where the gas is used in manufacturing, and so considerable resistance exists. When it comes to electric power equipment (switchgear and other components) there is little enthusiasm for the known substitutes. A great deal of risk and uncertainty exists for customers if large orders are placed for existing equipment using SF_6 that would need to be phased out and replaced well before end of life. Such is the complex, haphazard, uncertain realm of climate politics and policy that SF_6 largely is missing from topical discussions. It illustrates the pervasive problem of too little "bandwidth" for big picture considerations and tradeoffs as well as all-too-common silo effects (see next section).

Pre-Covid-19 pandemic, calls for climate action were escalating as gaps between promised and actual emissions reductions were scrutinized.[6] The EU in particular has announced extremely ambitious plans for decarbonizing its economy. Since 2004, EU GHG emissions declined about 13 percent (with some members more successful than others).[7] For the same time period, the U.S. reductions were about 11 percent in spite of fugitive methane as oil and gas industry activity grew.[8]

As pointed out in Chap. 5, randomized surveys indicate higher levels of public concern about climate change in the U.S., Germany, and the UK than in China and India. All attempts to analyze attitudes toward climate and environment are heavily nuanced depending upon how questions are framed, proximity to elections, and contextual factors such as economic status and geopolitical risks. Coupled with these trends are those regarding confidence in science and institutions.[9] Overall, climate concerns and support for action tend to be linked positively to education, youth, and moderate-to-liberal political stance, more common among women than among men, and higher in developed economies than in developing ones.

Politics and ultimately policy in any given country will be influenced by the complex interplay of views and how these translate into political support—or lack thereof—for specific actions and how drastic those actions should be. A test, of sorts, is occurring in the wake of the Covid-19 experience. With the onset of the pandemic and tremendous economic dislocations, post-pandemic economic recovery stimulus and climate action have converged into an assortment of green new deal schemes. As we completed our book, of roughly $11 trillion in various post-pandemic recovery stimulus proposals and plans, only about 2 percent constituted actual, funded commitments for climate-related policies and programs.[10] Importantly, and as discussed in Chap. 5, for some governments, including those in Australia and Argentina, their country's natural gas resources and infrastructure are targets for post-pandemic economic stimulus. The natural gas industry is an obvious stimulus vehicle for major exporters such as Qatar and Russia, but that stimulus only works because there are many willing importers (see Chap. 5).

How can we elucidate the incredibly convoluted politics regarding earth's climate?[11] Given the wide range of uncertainties associated with climate modeling outputs and the distinct dilemma in accommodating dynamic socioeconomic factors—that constantly alter emissions trajectories and thus potential future outcomes—a probabilistic approach based on decision science seems promising. Hausfather and Peters (2020) suggest a risk-based scenario approach that can help policy-makers to focus on likely scenarios and hence allocate funds and develop policies to maximize the benefits at the least cost (Fig. 7.1).

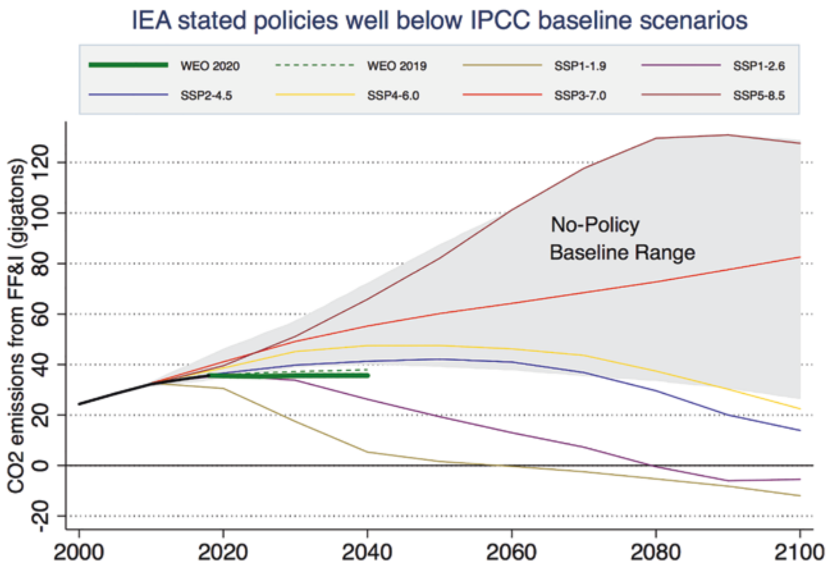

Fig. 7.1 Possible emissions in future and theorized climate responses. (Source: Provided by Zeke Hausfather. FF&I fossil fuels and non-fossil fuels industry, SSP shared socioeconomic pathway. Each SSP represents different potential scenarios of global temperature response with SSP5 being the worst case, considered highly unlikely. See Hausfather and Peters (2020) for excellent treatment of decision-making disparities related to climate policies)

In the end, politicians must make promises (or shed policy-making, for instance, to courts, in order to avoid having to meet voter expectations). Policies that address climate bear a particular burden: that effort undertaken sooner will result, at some point in the future, in an outcome in atmospheric chemistry and physics such that responses in the natural environment could be different from what we might imagine otherwise. That is a tough proposition, especially for elected bodies that depend upon popular votes and thus govern, by design, on short-term objectives. This makes "climate", in so many respects, the poster child for broader discontents regarding societies (the intrusion of economic and social justice being emblematic) and politics (everything from organization of political systems to the markets and government schisms). It also makes "climate" a perfect foil for promoting an array of ideas that can only exist with alignment of interests between politicians and financiers. In everyday positioning, it has never been about "climate", per se, even including broader discontents, but rather about the business propositions around which companies and investors of every stripe have congregated, including, now, tendencies to grab pandemic recovery in order to push agendas. It creates a form of crony capitalism, as risk-taking investors seek government backing to de-risk in the name of net social welfare improvements, some of which might be very real (local air quality being a commonly cited side benefit of actions taken in the name of mitigating anthropogenic climate change).

Silo Effects?

A problem is whether alternative energy promises might be oversold and, if so, what the potential ramifications are. Not least of these would be the "call" on fossil fuels and legacy systems, in particular natural gas, if investors and governments cannot scale up alternative energy capacity as quickly as envisioned in more aggressive climate policy schemes.

Apart from GHG emissions, there is the overall environmental footprint of alternative energy technologies widely expected to compete favorably with natural gas. We use the term "renewable" liberally in this book, following common practice in the world of energy. "Renewability" refers to the energy source such as wind, solar, water (hydroelectric dams), marine (tidal and wave), and biofuels (with replenishment of crops). Crucially, the components we use to mechanically, and/or chemically, convert these potential sources of energy to perform work are not renewable.

In fact, alternative energy involves large-scale industrial projects and equipment, including large supply chains to mine, process, and transport raw materials and transform them into equipment such as windmills, solar panels, and batteries. These footprints will only grow with the expansion of alternative energy installations around the world. Alternative energy also entails substantial new infrastructure such as long distance, high-voltage transmission lines to move produced energy from often-remote locations to market centers (see Chap. 2). Public opposition to infrastructure such as gas pipelines is mentioned in Chap. 1 and addressed in a later section, and extends well beyond the U.S. and North America. This opposition also extends to electric power systems and the difficulty of winning public support for high-voltage transmission to carry electricity from new generation sources, regardless of what they may be. Raw material requirements for renewable energy and battery storage—to displace foregone storage inherent in natural gas, other fossil fuels, and uranium—are considerable.[12] *Materials intensity for alternative energy, including electrification of transport, exceeds that of legacy fuels and systems.*[13] Battery manufacturing is a process that is particularly energy- and emission-intensive.[14] *Renewable energy and battery life cycles incorporate end of life management challenges on par with other industrial systems, including legacy fuels.*[15]

Growing awareness of stresses imposed on critical minerals is raising new questions about strategies for decarbonization. The ESG dilemmas range from environmental and societal impacts of mining and mineral processing to access and control of resources and associated geopolitical security and supply chain risks.[16] The decline in cost of solar panels and battery storage derives mostly from the vast scale-up of and market power associated with Chinese capacity. Chinese manufacturing growth and dominance of energy and sensitive information technologies, Chinese control of critical minerals supply chains (FP Analytics 2019; Braw 2017; CEMAC 2017), including positioning in frontier minerals resources such as seabed extraction (Reuters 2019), and its capture of intellectual property are all complicating trade and geopolitical balances. By many accounts, manufacturing in China comprises 60 of global capacity for wind and 70 percent for solar, while battery manufacturing (electronics and EVs) is upward of 80 percent (Yergin 2020).[17] To finance aggressive build-out of manufacturing as well as to support domestic wind and solar installations, the national government has provided generous subsidies, and some provincial governments and funds, and banks have supported with low-cost debt what many consider to be an overt national strategy to establish Chinese dominance in alternative energy and electric vehicles.[18]

While China is the emerging power in "new" energy technologies, it remains the largest single coal-consuming country, with nearly 52 percent of global coal consumption.[19] These facts are related. As we note earlier, battery manufacturing is one of the more energy-intensive undertakings and as such contributes considerably to industrial GHG emissions (Frith 2019). While many believe that China can re-jig its economy to rely more on renewable energy, maintaining and growing its position in critical manufacturing for advanced technologies clearly is a high priority. It remains to be seen whether the competitive pressures inherent in "new" energy supply and value chains can accommodate fundamental realignments in old ones. China is also one of the magnets for oil and natural gas monetization. Nearly every large LNG exporter strategy has China as the cornerstone for robust Asia-Pacific sales (see Chaps. 4 and 5). China could use more natural gas to balance emissions from its energy-intensive industries—that much is obvious. As noted in Wainberg et al. (2017), however, the evolving wealthier coastal urban enclaves are better able to absorb the cost of LNG imports or pipeline gas delivered from Russia and Central Asia. Interior locations are likely to remain wedded to baseload coal generation. Nuclear power additions could represent a "ringer".

Reverberations for Natural Gas

All of these facts should cloud views of energy transition. At the core of the conundrum in which the natural gas industry finds itself is whether natural gas use in key applications such as electric power should or can be discouraged and, if so, in which geographies.

Twin phenomena exacerbated debates about the role of natural gas in power generation in recent years. One is tenaciously low methane prices that have made gas-generated electricity cheap and raised the bar for other power generation sources, including coal and nuclear, while making renewables difficult without extensive public support. Can natural gas (methane) remain as cheap as it has been? As detailed in Chap. 1, pre-pandemic, the clear link between relatively high oil prices and oil-directed drilling yielded the huge volumes of associated gas that U.S. industry players have been striving to monetize. Drilling levels toward the close of 2020 are insufficient to sustain these volumes. Coincidentally, the persistently low Henry Hub price signal has discouraged drilling in locations that are less attractive for liquids. The long-run Henry Hub average of $3 per MMBtu and long-run median of close to $4 are indicative of price adjustments that could occur. Appreciation in natural gas prices would translate into higher wholesale electricity prices, improving revenues for gas-fired generators as well as competitors in the alternative energy space along with coal and nuclear. Customers would be less enthralled.

The other phenomenon is the falling costs for renewable energy components and chemical energy storage—wind, solar photovoltaics (PV), and mainly lithium-based batteries. However, declining costs of equipment do not always translate into cheaper electricity to end users. Most important, the levelized cost of energy (LCOE), the common measure used to compare different power generation technologies, is highly misleading when the inputs of the LCOE formula are not adjusted for local conditions and, more importantly, represent only the tip of the iceberg of system integration costs. These costs can be very high for intermittent and variable wind and solar technologies, especially if the best resources are located away from load centers or capacities are installed in poor-resource locations (see Chap. 2 and Gülen 2019). In a nutshell, the scope and scale requirements of "new" energy technology supply and value chains are not being scrutinized nearly enough.[20]

Fitting subsidized intermittent energy sources into competitive markets with their legacy coal, nuclear and natural gas generation has led to numerous market design conflicts (see Gülen 2019 for the US case). Although gas-fired generation is often seen as the most dispatchable and cleanest complement to intermittent renewables, this load-following use of gas-fired plants is probably unsustainable for operators under current market designs that do not always provide sufficient revenues. There is a growing movement, strongest in Western Europe and parts of the U.S., away from markets toward planning of electricity systems, inclusive of generation portfolios, distributed resources and energy efficiency, with decarbonization as a key objective. All generation fuels and technologies bring distinct pros and cons. The issue is how best to build level playing fields, which many assume can happen with carbon policies. *On that point, it is not clear, at all, that the natural gas industry is advantaged by climate-related policies, and in particular carbon pricing or taxation.* When it comes to the cost of adapting to these, or other, approaches, the affordability question plays a large role. Although carbon reduction is a distinct industry strategy, there are many, and very good, reasons to expect that decarb policies would not be friendly to natural gas use. Indeed, the industry's advertising of the lower CO_2 benefits of natural gas combustion and the even smaller GHG contribution when methane is used as feedstock for hydrogen seem to have whiplashed in the politics of methane emissions.[21]

When it comes to decarbonization, the natural gas industry system sits squarely in a conundrum with divergent geographical characteristics. That natural gas provides a lower emissions alternative to many other fuel and feedstock options is well established and ensconced in hallmark publications such as the International Energy Agency's (IEA's) "Golden Age of Gas" (IEA 2011). Natural gas is now helping China and India, among others, to clean their urban environments (Chap. 5). However, the major component of natural gas delivered to customers is methane, a GHG. Methane came under greater scrutiny as climate evolved to dominate conversations about environment rather than local air quality. Fugitive methane emissions and GHG emissions from flaring are estimated to negate lower CO_2 benefits of combusting gas rather than coal to generate electricity (about 50 percent less).[22] Perceptions have shifted accordingly and, along with these, agitation to regulate or even prevent natural gas drilling, transportation, and distribution. These trends underscore another IEA effort to outline best practices in drilling, completions, and production of gas, especially from unconventional plays (IEA 2012).[23] Already, fugitive methane emissions and flaring are targets for regulatory control. The industry is also motivated because any methane molecule that is not sold at the market represents financial leakages. Upstream and midstream operators can and do retrofit their facilities to reduce and eliminate emissions. A distinct hurdle to preventing field production losses is pipeline connectivity. If the cost of reducing or capturing fugitive methane associated with drilling operations exceeds the cost of other options, reducing methane losses can be difficult to achieve.

More obvious than fugitive emissions is flaring, the occasional combustion of natural gas at drill sites as wells are being tested or in locations where there are no pipeline connections to exit gas from leaseholds. Nevertheless, even when pipelines may be present, there are issues. Why would operators flare if gathering and pipeline access is available? In simplest terms, if flaring is cheaper than the costs to connect and the shipping tariff charged by the midstream operator—even after the producer pays royalties owed to minerals owners!—then flaring becomes the more economic choice. A crucial question, at the interface between field production and pipelines to markets, is how pipeline capacity risk and financing are allocated between producers and pipeline operators. It may seem simple to resolve, but there are no easy answers.[24] Adversity attracts inventors, and so a growing and increasingly diverse array of options for capturing leasehold gas are entering the marketplace. Concepts range from power generation for field operations, including to support new electrified pressure pumping, to established concepts for converting natural gas to liquids (GTL; Jacobs 2020). These best practices are likely to spread around the world driven by a desire to create greater value from the resources as well as to reduce environmental footprint.

More problematic is the opposition to pipeline projects, a tactic that has emerged as a means of prohibiting natural gas resource extraction and consumption. Although safety has often been presented as a primary concern, as Wang and Duncan (2014a, b), among others, have shown, methane pipeline incidents are relatively rare. However, when they do occur, they garner deserved attention and can complicate approvals for new projects. The U.S. Government Accountability Office, GAO, investigations regarding pipeline safety, such as the aftermath of the Pacific Gas & Electric pipeline explosion in San Bruno, California, in 2010 (GAO 2017a, 2018a, b), are representative.[25] There is no doubt that pipelines and natural gas storage facilities have functioned, and will continue to function, safely, not only in the U.S. but also around the world. Hundreds of thousands of miles of transmission and distribution pipelines have been operating for decades with minimal incidents wherever competent regulatory oversight is provided.

Finally, we must acknowledge the importance of oil price as a driver for hydrocarbon exploitation, including methane. The direct link is gas that is associated with oil; as explained in Chap. 1, the pursuit of oil targets that yield associated gas results in natural gas supply that is oil price sensitive. Even non-associated gas production can benefit if oil-directed exploration efforts result in gas discoveries (wet gas with NGLs; or dry gas, which may include other components). Over the course of the long history of the oil and gas industries, we have seen repeated cycles in which more valuable crude oil, on a barrel equivalent basis, has been key to at least initial developments for natural gas as a by-product of oil production, with monetization usually as LNG and traditionally on an oil-indexed basis. As value chains mature, it is easier to find the business case for expansion and new opportunities that are rooted in the value of the natural gas content and gas-based pricing. As discussed in Chap. 5, most gas still is traded indexed to oil, especially in Asia-Pacific where gas demand is expected to grow the most. Energy outlooks released in 2020 tend to depress the role of oil worldwide and among regions while emphasizing continued supply of and demand for natural gas. Thus, a crucial question is what the consequences for gas resource development and monetization could be if investment in crude oil exploration and production decreases over the next decades.

New "New Deal" Solutions?

Flowing from the previous section, we can boil down challenges faced by the natural gas industry into two interrelated areas. One is the public and political acceptance of the aggressive carbon taxing approaches that would be needed to garner meaningful GHG emission reductions not just for natural gas or energy, but all industrial, and many non-industrial, activities. The second and more difficult to measure is public perception of natural gas as a fossil fuel harmful to climate, ignoring all of the local air, water, land, and environmental benefits when replacing coal and liquids or even relative to alternatives.

For customers already challenged by affordability of natural gas, carbon costs on top of already expensive value chains are not a happy mix. Technological solutions to decarbonize natural gas include “green LNG”, “blue hydrogen”, and carbon capture and sequestration (CCS), among others. Pipeline and local distribution system owners and operators often see biogas as a solution, albeit a competitor to natural gas but one that enables continued use of legacy pipeline and local distribution systems. All will add to the cost of energy delivered to consumers, but the specifics can favor one over the other in different locales.

The simple proposition for **green LNG** is to reduce GHG emissions or offset them as part of LNG project and value chain development (Medlock et al. 2020). Reductions can come from using alternative energy sources for LNG processes, deploying CCS or other measures. In addition, emissions can be offset with certified carbon credits from other projects. Steam reformation of natural gas to obtain **gray (blue if CCS is used) hydrogen** currently is the most practical way to move toward the “hydrogen economy” because hydrogen already is produced in many refining and petrochemicals complexes. Since hydrogen is an energy carrier and not an energy source, leveraging existing operations that yield hydrogen routinely bypasses significant cost of hydrogen production.[26] Repurposing existing natural gas facilities such as pipelines for hydrogen makes hydrogen an attractive energy carrier, but it also needs refurbishment of pipelines and other equipment to make them suitable for safe handling of hydrogen. Many see the most attainable on-ramp for hydrogen as a blend with existing delivered natural gas (blends of 20 percent or more would require changes to infrastructure and end-use equipment such as turbines for power generation to address gas quality issues; see K&L Gates 2020 for abundant examples, opportunities, and caveats). The use of hydrogen for vehicle transportation requires appropriate hydrogen fuel cell vehicle (HFCV) designs. These currently encompass platinum catalysts, which encumber HFCV commercialization due to high cost and critical minerals’ ESG risks. **CCS** could enter natural gas value chains in a number of ways, but gas-fired power generation is probably the best-known route, as coal-fired power plants are key targets of CCS. Few experimentations exist for CCS associated with natural gas-fired generation.

The lack of data and published information from actual commercial deployment introduces large uncertainties into outlooks such as those presented in the Foreword. Neither coal nor natural gas CCS is considered to be commercially attractive with the rare exceptions when captured CO_2 found customers willing to pay for it and its transportation in operators of oil fields who wanted to enhance oil recovery.

These and many other schemes are highly dependent upon assumptions about prices of oil, gas, electricity, as well as carbon or other policy measures including outright government support that would induce people to internalize the posited GHG externalities (e.g., tax incentives for wind, solar, and CCS). Nor has massive scale-up of other "low carbon" or "zero carbon" technologies, including those proposed for vehicle transport, been fully exposed to commercial tests and due diligence for costs, net decarbonization benefits, and economic impacts, including affordability. This lack of market-based commerciality proof makes typical growth

Commercial Framework Uncertainties

All of the options we touch on are burdened by the usual complications. These include:

- High cost (with government support as an enabler for financing and de-risking).
- The need to win approvals for resource development and delivery infrastructure (decarbonization strategies, including alternative energy projects and their infrastructure requirements such as high-voltage transmission, are not assured of public acceptance or regulatory approvals).
- Lack of markets to support pricing and to establish values of credits for offsets, with implications for bankability and financing.
- Lack of common standards and practices for certifying and guaranteeing the ESG benefits that would be valued.
- Lack of common policies on carbon taxing.
- Lack of clarity on "firmness" of commitments to carbon reductions in target markets. While related to the previous risks and uncertainties on policies, the underlying firmness reflects shifting public attitudes and thus political support that would be essential for large scale investments.
- Lack of common approaches and metrics for monitoring and enforcement.

trajectories for alternative energy sources seem fragile and raises the risk of perpetual state support to either project developers or consumers or both. Nevertheless, perception trumps reality any day, and the natural gas industry finds itself in the most difficult messaging environment it has faced since the 1976 supply curtailments that led to the tangle of Carter administration laws and policies (see the Appendix).

All of the options are, therefore, fully exposed to the set of "license to operate" conditions—the conceptual space for commercial frameworks—explored in Chap. 6 and illustrated in Fig. 6.1. The bottom line is that there can be no certainty that political and/or public backing can or will exist even for options that move natural gas into compliance with climate politics-directed perceptions and expectations. The picture is more complicated once we overlay it with divergent country resources, political cultures, economic needs, and societal perceptions. The acceptance of natural gas grows in most of the growing economies of the world, although its affordability and competitiveness against coal, nuclear, and renewables remain in doubt in some.

Divergence of "New Deal" Economies Across Geographies

We can summarize the major themes and findings in our book by exploring the natural gas chessboard—the distribution of resource endowments, supply, and demand across political boundaries, and how these distributions play into attitudes, positions, potential conflicts, and room for cooperation. The divergence in viewpoints regarding the role of natural gas, and their non-random assignments across jurisdictions, have important implications for monetization of natural gas on many levels. To begin, they amplify the growing misalignments in the geographies of global natural gas supply and demand.

Supply derives from reserves, a small portion of the resource base that, at the time of reporting, producers can deliver with current technologies and market prices. Over the past two decades the proved reserves increased about 2100 trillion cubic feet (Tcf), or 43 percent, despite global consumption of about 2200 Tcf. Figure 7.2, panels (a) and (b), shows the proportional split of proved gas reserves between the OECD and non-OECD worlds remained the same between 2000 and 2019 (10 and 90 percent, respectively). As panel (c) shows reserves increased in traditional areas such as Russia, Turkmenistan, some other Commonwealth of Independent States (CIS) countries, Qatar, and Iran. Reserves growth in China and the U.S., roughly equivalent in Tcf, increased the share of China

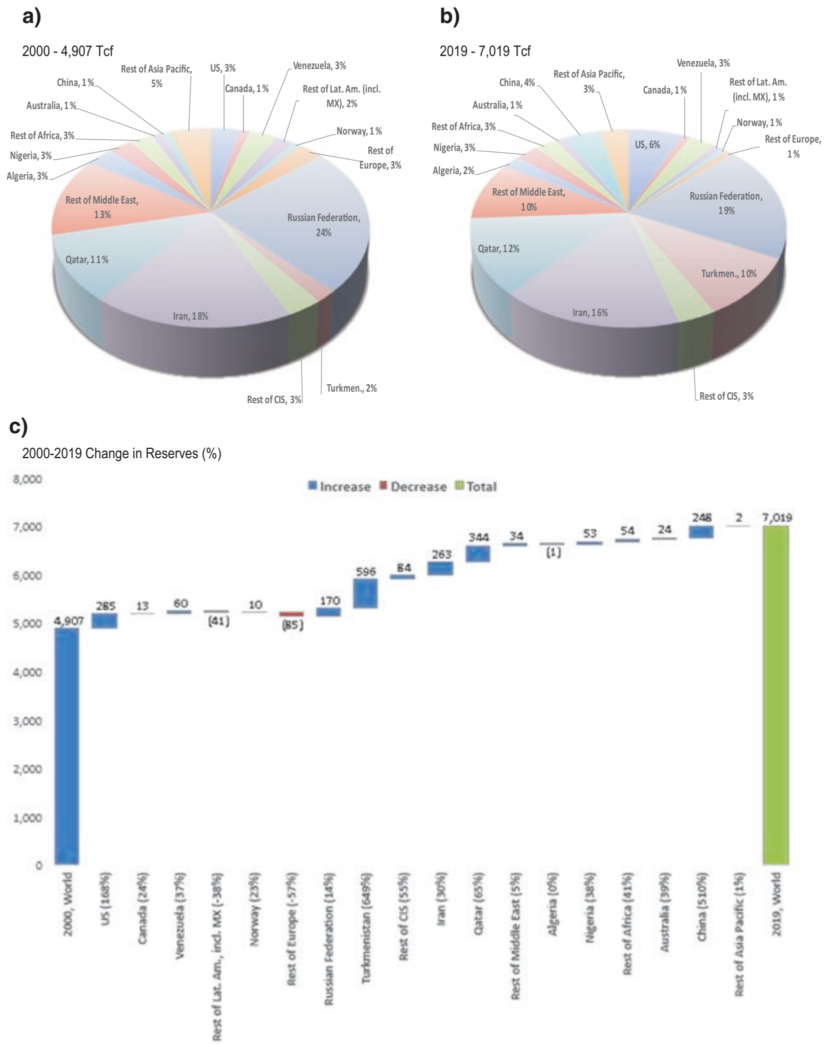

Fig. 7.2 Shifting fortunes—proved reserves. (**a**) 2000 - 4,907 Tcf (**b**) 2019 - 7,019 Tcf (**c**) 2000-2019 Change in Reserves (%) (Source: For all panels, authors' depiction based on BP Annual Statistical Review of Energy 2020, www.bp.com)

from 1 to 4 percent and of the US from 3 to 6 percent. Reserves increases were multifold in Turkmenistan, China, and the U.S. (see the percentages in panel (c) of Fig. 7.2). In the meantime, European reserves declined.

In contrast to 10–90 split of OECD and non-OECD reserves, OECD continues to supply a substantial share of global gas production at 38 percent, albeit down from 44 percent in 2000. Moreover, although OECD share of demand fell to 46 percent from 56 percent, its gas deficit increased slightly. The OECD is not a monolith when it comes to gas supply and demand. The U.S., Canada, Norway, and Australia constitute much of the OECD production story, and surpluses from the U.S., Norway, and Australia feed into global trade beyond their regions. Should developers succeed in commissioning major LNG export projects in Western Canada, that country could be an additional player globally. Europe, overall, is falling "short" in natural gas production, leading to the dominance of Russian supply, although increasing capacity to import LNG from around the world in addition to pipelines from North Africa helps the continent. China, for all of its efforts to boost reserves, faces a growing deficit, with the rest of the Asia-Pacific following suit. In both parts of the world, this could mean faster penetration of competing fuels and substitutes (primarily alternative energy in Europe, coal in Asian markets) (Fig. 7.3).

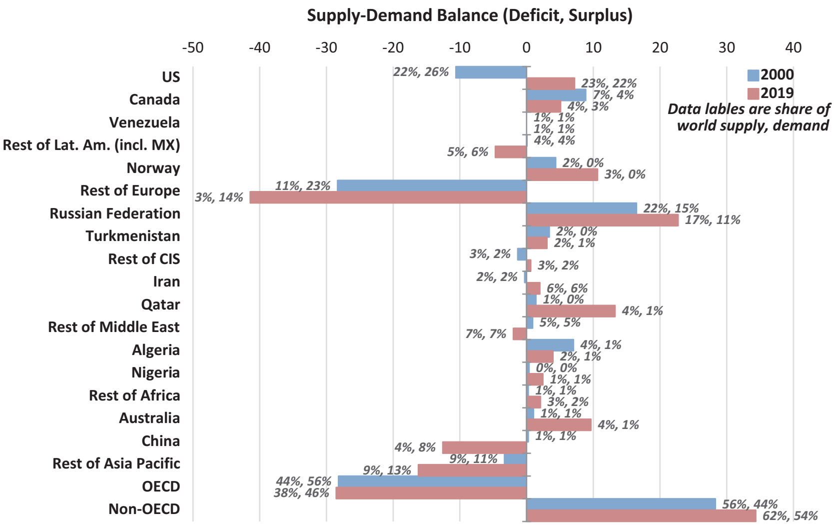

Fig. 7.3 Supply–demand balance, 2000 and 2019 deficits and surpluses. (Percentages represent shares of world supply and demand)

Among the contiguous, nationwide natural gas industry systems in existence, the U.S. industry and marketplace persist as the world's largest, at roughly 30 Tcf, comprising about 22 percent of global gas consumption. The extent of the U.S. natural gas infrastructure network supports natural gas electric, industrial, and local distribution systems for end users, including from the largest to the smallest. Russia's internal market is just over half that size at 16 Tcf and about 11 percent of global gas use. China's is just over one-third the size at 11 Tcf, with about an 8 percent market share.[27]

The North American continent, in particular Canada and the U.S., represents the largest, openly competitive, free-flowing volume of international natural gas sales across a single border globally. Canada-U.S. exchanges constitute about 12 percent of global gas pipeline (methane) trade. When the U.S. exports to Mexico are included, the North American share of global gas pipeline trade bumps up to about 18 percent. While Russian exports account for nearly 28 percent of global gas pipeline trade, they involve many more receiving countries in Europe and myriad complex and often fraught relationships with transit countries like Ukraine.[28]

In sum, between 2000 and 2019, the balance of natural gas demand and supply shifted toward non-OECD countries even as the huge global natural gas reserves expanded 43 percent and production and consumption grew more than two-thirds.

These realities, the positions of pieces on the chessboard, raise several interrelated issues. One is the obvious question of how some OECD governments (most part of the Old World in Chap. 5 parlance) could influence gas supply should they impose decarbonization ("decarb" in common parlance) policies. Output from those countries would become more expensive and could be curtailed. Chapter 1 touches on vulnerabilities in the U.S., but producers in other OECD countries, especially in Europe, are under varying degrees of stress. It is also possible that these pressures could impact international operations of companies based in these countries as exemplified by announcements of Shell, BP, and to a lesser extent Statoil and Total, although all of them seem to emphasize the future role of gas in their decarbonization efforts, given their large investments in gas resource development and LNG supply chains.

The current layout of the natural gas chessboard also affects the energy security dilemma, discussed in Chap. 5, which plagues all countries that are not self-sufficient in energy, but particularly those in the New World (including some OECD countries), as their energy needs are and will be growing into the future. Customers and governments do not take decisions lightly to move toward natural gas, given the serious infrastructure investment shortcomings in these geographies. Developing countries not only lack funds but also have trouble with attracting investment from outside, as noted in Chaps. 5 and 6. Suboptimal choices, when it comes to slating energy sources and infrastructure, can negatively affect economic growth while also increasing geopolitical risk, in particular if natural gas suppliers become less diverse. A smaller pool of suppliers could use natural gas exports to influence domestic policies of import-dependent customers.[29]

Scenario Games

So: what if the major producers in OECD (the U.S., Norway, Australia) took actions that significantly reduced or completely exited their natural gas output, potentially removing 30 percent of global supply?

With their massive surpluses, it is quite imaginable that more could come from non-OECD countries, particularly where natural gas production already exists. This includes mainly the big players like Russia and Qatar, who could be the winners in the gas monetization game. Much less swayed by issues of climate and relatively insulated (in the short term at least) from societal moods and preferences, they can invest in development of new gas resources and the needed infrastructure. As documented in Chaps. 4 and 5, they have been doing so already, even during the COVID-19-related slump in demand to ensure their market share now and in the future. Qatar could be, in fact, the big winner if politics and policies in developed countries played out in the worst case. The country houses some of the cheapest gas to develop, largely a consequence of condensate and natural gas plant liquids production that comes as by-products. With all of its exports as LNG, Qatar seems to have more flexibility in terms of accessing markets around the world than Russia, which is still heavily dependent on pipeline exports to Europe.

Russia also has been forging ahead to ramp up its flexibility when it comes to deliveries and ability to access new markets. As described in Chap. 5, strong decarbonization policies among large European customers, along with diversification via alternative pipeline and LNG supplies, are challenging Russia's Gazprom. In addition, geopolitical considerations are pushing many countries in Central and Eastern Europe (CEE) and Southeastern Europe (SEE) toward non-Russian sources of gas even if that implies higher prices featuring what some call a "security premium".[30]

The Russian government recognizes these issues, and it has long worked to diversify its own customer base. China, in particular, is the market that Russia has been keen to win for decades. Until recently, Russia had great difficulty convincing Chinese leaderships to build pipeline connections.

Historically, Russia (previously the Union of Soviet Socialist Republics (USSR)) and China have not seen eye to eye. Within the international realm, these countries have always occupied very different positions and pursued diverse strategies and tactics. Today their relative status has pretty much flipped, with China being a leading economic power and Russia diminished by loss of geopolitical influence and generally slow economic growth. Both countries have been vying for greater international influence. Under the leadership of Vladimir Putin, the Russian government has pursued two strategies. In the "Near Abroad" region, the Putin regime has used typical "hard power" instruments ranging from geopolitical influence to direct aggression to reestablish control (e.g., the invasion of Ukraine and annexation of Crimea). Elsewhere, the regime has deployed campaigns of disinformation and/or interference in elections. Both strategies are generating increasing backlash from the international community, including multilateral and unilateral sanctions and general distrust toward Russia.

Under Xi Jinping, China has increasingly relied on its economic prowess and its position as center of both supply and demand as a way to position itself in the world, particularly vis-à-vis the U.S. and other developed countries. China's increasingly significant geo economic position, along with harder approaches toward smaller governments in China's orbit, has been a worry for other international players for some time. Xi's Belt and Road Initiative, touched on in Chap. 5, has only worsened concerns, as Chinese outbound investments, especially in weak and fragile countries, are more widely reported. These developments underscore the recent US–China trade war and the EU's caution when it comes to allowing Chinese direct investment in the community. Tensions have become even more vivid during the COVID-19 crisis as supply chain dependencies on China for everything from critical minerals to pharmaceuticals and healthcare equipment receive greater scrutiny. There has been an economic backlash for China as countries move, at least partially, toward shifting supply chains to domestic markets or diversifying supply chains. However, a joint survey of 25 companies by AmCham China and PwC in March 2020 suggests that, rather than pulling out from China, companies may pursue a "China+1" strategy (Forde 2020). In the face of these tensions, China could pull back to focus more on its domestic economy. Pre-pandemic, the Xi regime began placing more emphasis on domestic consumption and on industrial sectors like services, which includes information technology, that are less dependent upon exports for economic growth.[31] China is not likely to pull back fully from its engagement in South and Southeast Asia and Africa, although digital technology may gain prominence over more expensive projects such as energy infrastructure (e.g., Blanchette and Hillman 2020). Importantly, however, we must acknowledge the real dangers facing the Chinese economy: an aging population, large debt, intractability of banking system and SOEs, the communist party dynamics (e.g., central versus local power balance), and so on. Magnus (2018) and McMahon (2018) provide detailed analyses of these and other risks facing the Chinese economy. Fundamentally, the challenge seems to be the deficiency of stable economic and political institutions as aptly demonstrated in Acemoglu and Robinson (2012). These analyses suggest that opaque and non-inclusive communist party regime is a risk in China. None of this should be taken as evidence of Chinese economy imploding in the near future, but a more inward-looking economy growing much more slowly should be seen as a real possibility.

The increasingly evident lack of trust among many countries toward both Russia and China has fostered, ironically, a platform for collaboration between these rivals. We already see this in the energy sphere where the U.S. and EU stance regarding Russian territorial grabs spurred Chinese investment in new gas ventures such as the Yamal LNG project. Chinese financing and its involvement as a shareholder have been extremely useful given sanctions imposed on Russia. Chinese entities hold 29.9 percent of shares in the project (with China National Petroleum Corporation (CNPC) owning 20 percent and the Silk Road Fund 9.9 percent). China National Offshore Oil Corporation (CNOOC) and CNPC will each take 10 percent of shares in the Arctic LNG, the next project of Russian private company, Novatek.[32] For China, this engagement is consistent with its push for the so-called Silk Road on Ice, trading along the Arctic route, including in winter with massive new icebreakers (Roston 2018) and its strategy of diversification of energy sources. Russian LNG provides an alternative to LNG coming from Australia, Qatar, or the US as well as pipeline gas from Central Asia or Myanmar.

In addition, after decades of negotiations and lobbying by Russia, China agreed to a new integrated pipeline project, Power of Siberia, which has been transporting Russian gas to China since year-end 2019. China was able to leverage Russia's desire to find new markets for its gas and negotiated extremely beneficial terms. Russia hopes that Chinese participation will lead to Power of Siberia 2, which would connect China to the same gas resources that currently supply Europe. Such a move would give Russia arbitrage opportunities and strengthen its position against European governments and customers. All in all, the practical bonds between the two countries have been growing, encouraged by developments in international relations. The COVID-19 pandemic may propel further collaboration between the two countries. This could include subsequent arrangements for natural gas trade, as the EU pursues decarbonization policy and both the EU and the U.S. move to protect their respective interests relative to Chinese dominance and influence on myriad fronts.

Iran could be another candidate to fill the potential void in natural gas supply, but also must first contend with sanctions. The country increased its production nearly fivefold since 2000 although its proved reserves increased only 30 percent. Almost all of the production is consumed domestically. The country needs to prove up more reserves to meet its domestic needs, let alone to become a major exporter. As long as the sanctions limit foreign investment in Iran, the country's ailing economy is not likely to corral the financial resources necessary to prove up gas reserves, especially if oil prices remain low. Even without sanctions, exploration and development would take numerous years, given the need to develop new fields (including its share of offshore South Pars or North Field as Qatar calls it).

As described in Chap. 5, countries in Africa and Latin America could grow gas supply but pervasive above-ground issues related to political stability, corruption, and regulatory regimes are ongoing burdens for both domestic and foreign investors. These regions also face prospects for growing demand and a broad range of geographic and political barriers to achieving internal, regional trade. Both regions represent sources of ESG risks and uncertainties to investors. Also, decarbonization policies of the traditional donor countries and institutions limit investment in developing domestic gas resources for local economies. The influx of Asian, in particular Chinese, capital in recent years has filled some gaps, albeit with trade-offs such as loan obligations and external influence on weak and fragile governments. Inbound investment from Asia could expand under certain conditions, especially to support export-oriented projects, and especially in raw materials. Investment to support internal consumption growth and energy security needs in Africa and Latin America will hinge on sustained, high-quality commercial frameworks, as presented in Chap. 6, and ability to mobilize domestic capital and entrepreneurship.

To sum up, geographical misalignments of supply and demand create opportunities for natural gas monetization, but with, at times extreme, complexity. Demand increasingly derives from relatively resource-scarce locations in the developing world. The risks and uncertainties along the energy transition front are substantial. In spite of treaties, no unity exists among governments in their approaches, and countries are moving toward "decarb" mandates at quite different speeds and with considerable variation in commitment among their polities. Even within the European Union, disunity exists between the West and the rest. Non-OECD natural gas supply, already dominating worldwide natural gas consumption and trade, is poised to become even more important with interesting new geographical alignments that could test established international mores and alliances.

All of these suggest higher gas consumption and trade volumes (i.e., a continuation of the past trend, perhaps even picking up speed), but profound geographical misalignments could also undermine gas monetization as governments react to various signals. These include security of supply considerations on the part of the New World that would keep coal in play and/or hasten introduction of competing new energy alternatives. Supply security fears could be minimized, however, given proven natural gas endowments present in the developing world and the extent to which creative, innovative solutions could be implemented for de-risking large-scale exploitation and monetization. The winning parties would be those that can ramp up investment and production, are minimally constrained by societal pressures, and can be seen as reliable suppliers capable of minimizing energy security concerns.

Commercial Frameworks and Natural Gas Value Chains

The expectation of market-driven supply responding to demand that is ever more price sensitive within an increasingly liquid global marketplace has become a hallmark of developments over the last decade or so. As we show throughout this book, these developments have been related to increased depth of the market, with growing numbers of both suppliers and consumers. The natural gas industry is now host to new market structures and commercial practices that include shorter, more flexible contracts, increasing reliance on gas-on-gas pricing, and expanding use of spot transactions. The entrance of the U.S. as a major natural gas exporter, carrying with it influence stemming from the organization of North American gas market, has propelled many of these advances.

The U.S. participation as a global supplier has neither shielded the U.S. gas producers and LNG exporters from challenges nor pushed non-U.S. suppliers to transform themselves to look and function more like the U.S. producers. As such, while international gas transactions become more market-based, many of the participants in those transactions are state-owned and do not rely on market principles in their organization and functioning. Hence, those producers stay insulated, while reliance of U.S. companies on market forces exposes them to sometimes-punishing market fluctuations such as those experienced during the COVID-19 pandemic, and uncertainties associated with decarbonization politics.

Yet, crucially, it is also reliance upon and the degree of sophistication in using market-based approaches and commercial practices for risk management and mitigation that so strongly define the U.S. oil and gas industry resilience even when individual companies fail, as mapped in Chap. 1. Low level of governmental involvement in the U.S. oil and gas sector often makes those companies more desirable as business partners since geopolitical risk is minimal, even if the U.S. mixed economy style fosters the presence of federal and state governments in the U.S. oil and gas business affairs. Also, again discussed in Chaps. 4, 5, 6, and elsewhere, the U.S. companies will seek partners and anchor customers who benefit from support of their sovereigns in order to de-risk and achieve bankability for large-scale capital projects such as LNG value chains. All of that said, the separation of business and government when it comes to market-based pricing and commercial transactions and practices are fundamental to the U.S. model. Many countries may never reach nor want to reach the size and scope of market openness and financial liquidity of the U.S., but the U.S. model is the biggest influence as countries develop their commercial frameworks for a natural gas market.

The U.S.

In the US, recognition of the increasing reliance on natural gas and its attractiveness underscored the push to modernize and to reconsider how natural gas markets might function. For sure, there were plenty of commercial interests at stake, but there also were visionary moments. Since the 1970s, the federal government with an agglomeration of industry and customer groups and some help from academics restructured the natural gas industry from wellhead to end-user marketplace in ways that:

- Increased competitiveness and thus efficiencies
- Improved deliverability (pipeline, storage, and associated infrastructure)
- Provided greater market access for both suppliers and customers
- Increased the transparency of price signals
- Streamlined policy and regulatory oversight

This process was not without its "bumps", but the payoff was substantial. More importantly, as legislators and regulators were making crucial decisions and implementing the open access regime, the marketplace did not collapse. Nor were there many, or even very serious, attempts to roll back or weaken the commitment to a more open, competitive landscape.

The U.S. natural gas industry remains the best funded (based on IEA 2019), the most diverse in terms of market participants from upstream to downstream, and the best equipped in oil and gas field services capacity. The U.S. hosts a robust, still growing field-to-market midstream segment. Money and market participants together are measures of "liquidity" and indicative of the ease of "doing business". The U.S. natural gas marketplace is emblematic of organizational structures in which "the whole" truly is more than"the sum of its parts," all of which must cooperate, often across intensely competing interests.

The market evolution within the U.S. is set within a context of periods of historic supply abundance with every progression along the oil and gas technology pathway yielding favorable pricing for customers but diminishing returns upstream. After topping records set during 2018, the U.S. natural gas-marketed production during 2019 hit a new high, averaging 100 Bcf/d (EIA data). Henry Hub, the main natural gas price index, sits well below the $3/MMBtu depicted in the Chap. 1 gas price thermostat (Fig. 1.4). As 2020 opened, Henry Hub had fallen below a pronounced psychological barrier of $2. Traded U.S. light crude oil has remained firmly in the mid $50s until pandemic lockdowns, and then firmly entered the low $40s. These prices are well below hurdle rates that lured investors first to "shale gas" ($8 with views to $15 and a rush to imported liquefied natural gas, LNG) and then to "shale oil" ($80 with views to $120 and the rush to export LNG).[33] In light of the long history of natural gas as by-product to oil, these price relationships matter. Frankelnomics rules. The "ignorance of sunk costs" and tendency to surplus hasten the erosion of commodity prices. Drilling activity has been flat to declining across the U.S. Valuations for publicly traded oil and gas companies have pushed them off investors' radars. Credit stress across independent producers has complicated exit strategies. Oil field suppliers are in doldrums, and some midstream operators are under scrutiny mainly where producer commitments are in question given the shaky upstream finances.

Against a backdrop of natural gas supply robustness, natural gas has entered a prolonged "buyers' market". A takeaway from the U.S. experience, which applies to many other situations (in particular where natural gas is "stranded"), is that most of the time monetization comes with "supply push". That means, mainly producers put up the necessary guarantees for field-to-market linkages. This is a much more frequent state of affairs than "demand pull", which often means someone else willing to fund those vital connections. In this book, we discuss monetization strategies in power generation (Chap. 2), petrochemicals (Chap. 3), and LNG (Chap. 4). Altogether, expansions and greenfield projects in these segments account for all of the additional roughly 42 Bcf/d of production as it doubled from 2005. Along the way, with gas exports rising and oil and refined product imports declining, the U.S. reached a status in which, on a barrel of oil equivalent basis, it exports about as much natural gas as it imports crude oil and oil products. Notably, this change in hydrocarbon trade balance helped to narrow the U.S. trade deficit, an accomplishment that, as we went to press, was highlighted by pandemic-induced widening of the trade deficit.

The U.S. has been the fastest growing new supply source for LNG. This is due entirely to the large volumes of associated gas production in excess of domestic consumption, and a vigorous supply-push to export these volumes. LNG was the favored strategy. Mexico, by contrast, represents demand-pull, conveniently located just south of the border from major liquids-driven developments in Eagle Ford and Permian, with large volumes of associated gas and an extreme deficit in internal supply relative to consumption (as noted, the US is Mexico's largest supplier via piped gas exports; see Chap. 6 on The U.S. and North American Stories). The attraction for LNG export monetization was the headroom associated with oil-indexed supply and purchase agreements. We raised numerous caveats in our book regarding the pace and ultimate extent of gas-on-gas pricing, gas-indexed contracting, liquidity deepening, and other facets of globalizing gas trade. One of the most important considerations is the industry's ability to finance high cost of LNG supply chains and upstream gas resource development in a liquid global gas market without oil-indexed long-term contracts or another commercial arrangement that would secure sufficient future cash flows to create value. All of these realities have ramifications for the geographies and misalignments between supply sources and customers, strategies for both producers and buyers, and regional and global trade, with implications for natural gas monetization.

Beyond the US

The Canada-U.S. border has been "seamless" with respect to physical infrastructure and deliveries of natural gas as well as flows of investment and human talent. Canadian and the U.S. policy-makers and regulators have tended to respond in kind to shifts in industry activity and development patterns. They acted mostly in unison to advance (from 1988 in Canada and 1992 in the U.S.) "light-handed", nondiscriminatory open access for pipeline systems, maintaining a "hands off" approach to allow market-based pricing to flow from wellhead to end user. The UK and, for the most part, Australian business models are quite sympathetic with these core principles. Western Europe has also been moving toward competitive natural gas markets with TPA and gas pricing hubs, but there are many exceptions–perhaps due to energy security concerns driven by large import dependence—but the legacy of powerful state companies is still strong in some countries (see Chap. 5).

These more or less open market models stand in contrast to most other suppliers of natural gas where sovereign interests take much more involved positions, including through direct ownership, infrastructure buildup, or other subsidies. Mexico, though becoming increasingly integrated to the North American market, remains dominated by Pemex (Petroleos Mexicanos, the country's long-established national oil company) and CFE (Comisión Federal de Electricidad, the national electricity organization), with unclear support for and direction of regulatory reforms implemented in 2012 (see Chap. 6 and the Appendix). As discussed in Chap. 5 in detail and summarized earlier, both major exporters such as Russia and Qatar and major importers such as China, India, South Korea, and Japan depend heavily on their state entities managing their energy needs, including natural gas, and public funding to develop the necessary infrastructure. Even when private companies are involved, their investments are grounded on either direct or indirect state support and sanctioning. This can be seen as a transition from a pure statist approach to crony capitalism, but in the absence of liquid, competitive markets with independent and competent regulation, these approaches offer a way of de-risking multibillion-dollar investments in energy infrastructure.

The challenge, of course, is that public money at risk has been increasing. It is not clear that even China can sustain the levels of investment seen in the past, given, as discussed earlier, the growing geopolitical tensions that we, and others, expect to lead to at least some de-globalization and the high cost of recovering from the pandemic around the world. Importantly, crony capitalism has been increasing in the Old World as well, often driven in the energy sector by decarbonization policies that de-risk alternative energy projects for investors and developers via tax credits, surcharges in customer bills, and direct public funding. Of course, one can easily argue that crony capitalism has been the dominant form of capitalism in the energy sector given the importance of government policy and regulation across oil, gas, and electric power value chains. The share of investments, returns of which are dependent on explicit state incentives, has been rising, especially in the electric power sector, and, in some cases, has overcome market-based investments (see Gülen 2019 for the case of the US electricity markets). Since power generation is a large market for natural gas, a question then arises on whether market-based investments along the natural gas supply chain can be maintained. So far, gas replacing coal in power generation and exports has sustained demand in the US, but the future remains uncertain (Chap. 2).

Finally, as we made clear in our suggested scenario (see earlier section on Scenario Games), a distinct paradox is that strong pressures for climate action in the Old World can attain the same outcome of favoring coal in the New World if natural gas supplies from the Old World (especially the US and Australia) become too expensive. An all-inclusive pursuit of energy sources and technologies certainly seems to be the strategy in China that has been investing large sums in coal, nuclear, hydro, gas, and renewable energy infrastructure. Chinese exports of wind, solar, and battery equipment, especially to Old World countries with strong incentives, certainly help with China's trade surplus.

Overall, despite all the increase in global natural gas trade and the share of market-based trading, we can see likely limits to the expansion of commercial frameworks conducive to creating liquid gas markets from two sources. First is the tendency of governments, in those markets expected to grow the most, to manage energy needs in their economies. This means direct government incursion in a variety of ways, directly through public investments or indirectly through financing and guarantees. Second is the expansion of decarbonization policies with somewhat uncertain paths in terms of energy options. Again, we see the tendency for sovereigns and, in federalized countries, lower jurisdictions like states, provinces, territories to step into the decarbonization fray with policy and regulatory or other inducements that circumvent competitive markets to achieve comparative advantage or other goals and objectives.

Gestalt or Entropy?

As we tried to summarize earlier, the existential "issue du jour" of decarbonization and the bottom-line problem of affordability underlie much of what influences the industry and marketplace today. Policy-makers, analysts, and citizenry increasingly recognize local environmental benefits in burgeoning markets such as China and India, as they use natural gas, to the extent they can develop the necessary infrastructure, to replace coal, liquids used in transportation, and traditional biomass. At the same time, as installed capacities rise and some reach retirement age, we are starting to realize the full ESG impact of supply chains for raw materials inputs used in wind and solar components and batteries, as well as their development, operation, and end-of-life treatment.

Within this very messy milieu, natural gas monetization proceeds. A realistic view is that "modern, successful gas exploitation requires opportunities to maximize the value of the resource to the end of the value chain, whether it [is] high-efficiency power generation, combustion in high value non-substitutable applications, or feedstock use".[34] How can we build the "resource to opportunity" path for monetizing a resource that is abundant worldwide? That global resource endowment enlarges even more when subsea methane hydrates, a "hydrogen economy" that could emerge with natural gas as an accessible feedstock, and other frontier resources are included. How does the industry deal with persistent uncertainties emanating from decarbonization debates while communicating the immense local environmental benefits of the fuel?

The structure and the interdependence of typical natural gas system value chain segments, in a country or globally, have a great deal to do with underlying economics and affordability. Supply and infrastructure costs define affordability, which is harder to achieve with expensive decarb measures. *Understanding the value chain, that is, how participants create and distribute value, and separating powerful endogenous dynamics from exogenous factors is key to analysis of natural gas market systems. Otherwise,* *distinct risks and uncertainties underlie both business and government approaches to effective natural gas development and use.* Conflicting goals and ambitions continuously buffet natural gas commercial frameworks. Investment flows by private companies are returns-sensitive. Many actions taken in the name of improving affordability work directly against profitability. These include social engineering of electric power markets and the overall proclivity of governments to interfere in response to political interests and agendas, especially in the New World where gas demand is expected to grow the most.

How these debates play out, and whether realized net benefits for the environment will meet expectations, presents enormous incremental risks and uncertainties to businesses, governments, and societies. This introduces the possibility of inertia in decision-making, commitments of scarce public resources, and even ambivalence among the public—especially voting publics in countries where policy-making is subject to open elections.

In the end, our essential question is this: *How can we best achieve routine accessibility to and affordability of natural gas while also ensuring financial sustainability and durability of natural gas supply and value chains given the uncertainty around future paths? Will we see a new order managed primarily by states, but with sufficient market flavor, or will we continue in growing disorder with divergent energy and environment policies around the world amid growing geopolitical tensions?*

Notes

1. Phrases such as “next new thing” and “next big thing” are linked to the Silicon Valley information technology cluster as depicted by Michael Lewis in his iconic 1999 book, *The New New Thing: A Silicon Valley Story*, published by W.W. Norton. Slogans like “new green deal” clearly are a throwback to the original New Deal platform carried forward by then US president Franklin D. Roosevelt which was not without many critics and detractors, still today. We couple these sentiments in our book title.
2. Among many sources, Our World in Data, https://ourworldindata.org/, is convenient for published information.
3. Based on the International Energy Agency, IEA, methane tracker, https://www.iea.org/reports/methane-tracker-2020
4. See the EPA GHG site for information, https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane

5. See the BBC coverage at https://www.bbc.com/news/science-environment-49567197. See Ottersbach (2018) for a synopsis of SF_6 characteristics.
6. See the United Nations Environment Programme Gap Report 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/30797/EGR2019.pdf?sequence=1&isAllowed=y
7. See the EU reporting page, https://ec.europa.eu/eurostat/cache/info-graphs/energy/bloc-4a.html
8. See the US Environmental Protection Agency's tracking of US GHG emissions, https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane
9. Good examples of extensive survey research on attitudes can be found at the Pew Research Center. For instance, worldwide views on whether climate is a major "threat" vary hugely, https://www.pewresearch.org/fact-tank/2019/04/18/a-look-at-how-people-around-the-world-view-climate-change/ (notably, China and India are not included in this survey). Confidence in science and elected officials, who ostensibly would design and execute climate-related policies, is low in the US, https://www.pewresearch.org/science/2016/10/04/the-politics-of-climate/. Public attitudes differ strongly across partisan, age, gender, income, and educational divides, https://www.pewresearch.org/science/2019/11/25/u-s-public-views-on-climate-and-energy/
10. Based on the proprietary Carbon Tracker maintained by Bloomberg New Energy Finance, as of September 2020.
11. At heart is the sheer difficulty of modeling earth's climate, combining what is known (realizing that there are vast unknowns) regarding natural variability; the carbon cycle; whether changes in atmospheric chemistry precede, follow, or are coincident with climate shifts (requiring a level of granularity in paleoclimate data that simply does not exist); how human (anthropogenic) emissions from all sources (with reliable measurements worldwide) figure into the picture; and, worse, the role of human behavior. We recommend two recent views that pull together the abundant and varied critiques and unease with the state of understanding and modeling: Lindzen (2020) and Brady (2020).
12. Underpinnings for content in this section include a scoping workshop on energy and minerals held by Rice University and Imperial College-London, *Framing Integration Futures*, September 18–19, 2019 (unpublished materials).
13. Lower energy densities of alternative energy technologies translate to higher materials intensity. See p. 390 of the US Department of Energy's Quadrennial Technology Review, 2015, for a comparison across different electric power generation technologies in tons per terawatt hours (TWh),

https://www.energy.gov/sites/prod/files/2017/03/f34/quadrennial-technology-review-2015_1.pdf. For batteries, research on alternative vehicle designs sheds light on energy storage dilemmas. A number of sources provide inferences for materials intensity in light of specific energy and specific power tradeoffs, measured as watthours per kilogram (Wh/kg) and vehicle performance criteria such as weight. See Thomas (2009), Schlachter (2012), Vijayagopal (2016) and Vijayagopal et al. (2016) and USDRIVE (2017).

14. See endnote 12. Also based on proprietary reports by Bloomberg New Energy Finance (BNEF). From BNEF data and published life cycle analysis (see Michot Foss and Zoellmer 2020), energy requirements are roughly 400 to 1 of battery energy capacity with substantial GHG emissions as a possible outcome, depending upon where battery manufacturing is located.
15. Based on unpublished research in progress by Rachel A. Meidl and Michelle Michot Foss at Rice University's Baker Institute for Public Policy, Center for Energy Studies. For example, see presentation by Meidl at the 2020 MIT A+B Applied Energy Symposium, August 13–14, 2020, https://www.bakerinstitute.org/media/files/files/94dfa360/mit-harvard-applied-energy-symposium-2020.pdf. See Michot Foss et al. (2020) for additional comments and sources on battery end-of-life challenges and related research and development.
16. Since release of the World Bank's June 2017 report, *The Growing Role of Minerals and Metals for a Low Carbon Future*, http://documents1.worldbank.org/curated/en/207371500386458722/pdf/117581-WP-P159838-PUBLIC-ClimateSmartMiningJuly.pdf, numerous publications and research documents are accumulating knowledge on an assortment of challenges underpinning the push for alternative energy capacity. Mining and minerals processing are attracting significant attention in light of raw materials inputs. See Lee et al. (2020) for a broad view on mining-related risks, and Sonter et al. (2020) on biodiversity impacts. Energy intensity of mining and minerals processing encumbers materials intense technologies (previous endnote 13) by worsening both GHG emission potential and broader sustainability criteria. Declining grades for many critical minerals ores means increasing energy inputs and emissions outputs. See Michot Foss et al. (2020) for a review of mining and minerals considerations for G20 briefing materials including background references on critical minerals, battery chemistries and performance, life cycle analysis results on batteries, and other aspects. See congressional testimony by Michot Foss (2020) on minerals and materials inputs for energy transition for public comments and resource links including life cycle aspects.
17. BNEF proprietary reports indicate these rough shares for wind and solar.

18. Based on BNEF proprietary reports on Chinese renewable energy transactions. The financial exposure associated with subsidies paid to developers and sellers of internal wind and solar power has soared, so much so that proposals have been made for a bond issue, likely through China's State Grid, to cover the roughly $158 billion subsidy burden at its estimated peak in 2032. Various sources, including BNEF, report on plans to phase out subsidies, but similar announcements have been made in the past, to little effect.
19. Based on BP's Statistical Review of World Energy 2019 (BP 2019), https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html. China has commanded more than half of world coal use since 2011 and has ramped up coal generation capacity steadily over the past 50 or so years, fluctuating around business cycles and key events like the 2008 Olympics buildout. From BNEF data, it is clear that battery manufacturing emissions in China are worsened by coal-fired power generation. See ongoing research at Rice University's Baker Institute on China's energy infrastructure, including electric vehicle battery production for illustration, https://www.bakerinstitute.org/chinas-energy-infrastructure/ and for details and sources https://www.bakerinstitute.org/opensource-mapping-of-chinas-energy-infrastructure/. Other locations for expanding battery making, such as Poland, would face similar hurdles.
20. See presentation by Michot Foss to the Federation of Scientists-Energy Permanent Monitoring Panel, August 19, 2019, Erice, Italy, as posted, https://www.bakerinstitute.org/research/energy-transition/
21. This observation is drawn from extensive interactions [by the lead editor] with leaders of natural gas industry trade associations, senior managements, and boards. For one meeting, a request was made to not use the term "methane" in presentation materials for a trade association audience, given heightened sensitivities.
22. "Fugitive" emission is natural gas that escapes during drilling, extraction, and/or pipeline transportation. Industry typically is able to avoid fugitive emissions by deploying proactive measures. Flaring and venting are intentional in nature. As noted by the US DOE, "both of these activities routinely occur during oil and natural gas development as part of drilling, production, gathering, processing, and transportation operations. The reasons behind both flaring and venting may be related to safety, economics, operational expediency, or a combination of all three". Delays and other problems that prevent development of midstream field-to-market linkages in timely fashion can prolong flaring (see Chap. 1 on the US midstream with analogies for Canada).

23. Throughout this book, we use the term “unconventional” following the simple US EIA definition for hydrocarbon production that does not flow readily to a wellbore.
24. In many countries where natural gas is produced as a by-product of oil, insufficient capacity and market exist to capture associated gas, and flaring can be persistent. Nigeria represents a classic case of difficulty in building internal markets, especially to support gas-fired power generation, or other export strategies to reduce flaring. Many countries have penalties for flaring that are not enforced. The Global Gas Flaring Reduction Partnership (GGFR) was formed in recognition of this problem and the need for solutions, https://www.worldbank.org/en/programs/gasflaringreduction. Not everyone agrees that anti-flaring initiatives get the intended results. See Calel and Mahdavi (2020) for a recent review.
25. While it involved a natural gas storage facility, the GAO and Interagency Task Force reports on the Aliso Canyon leak near Los Angeles in 2015 (GAO 2017b and ITF 2016) also make for useful reading. The US Department of Transportation’s Pipeline and Hazardous Materials Safety Administration (PHMSA) posted its final rules on Aliso Canyon at https://primis.phmsa.dot.gov/ung/index.htm
26. Electrolysis of water using alternative energy sources such as wind and solar would supplant natural gas and provide green hydrogen as the ultimate solution, but high capital cost of dedicating wind and solar capacity to electrolysis would lead to more expensive hydrogen.
27. All from BP’s Annual Statistical Review of World Energy, June 2019, https://www.bp.com/en/global/corporate/energy-economics.html
28. Ibid.
29. The GEFC (Gas Exporting Countries Forum), established in 2001, is a good example of how the multiplicity of suppliers makes cartelization difficult, if not impossible. Both natural gas supply and demand expanded significantly in recent years, making cartelization of gas production even more difficult. Expansion of exports from countries where governments leave decisions on contracted volumes to private operators based on commercial imperatives (the US and Australia) is a major obstacle. While the link to oil pricing has been weakened, it has not been because of cartel influence but rather because of liberalization and deepening of the global natural gas market.
30. A question is reliability of the US as an LNG supplier to European buyers, should the American natural gas industry face strong decarbonization or related constraints, as noted earlier and in Chap. 1. As we completed our book, French utility Engie suspended negotiations on a $7 billion contract to purchase LNG from the proposed Rio Grande project in Texas. It is not clear whether the action was a harbinger of things to come or a reflection

of pandemic-induced impacts on demand and budgets to support transactions. See Eaton and McFarlane (2020), among many other news sources.
31. Observation of trends based on data from Statista, www.statista.com, that draws from various Chinese national data sources and reports.
32. From company web sites: http://yamallng.ru/en/project/about/ and http://www.novatek.ru/en/business/yamal-lng/. Last accessed November 19, 2020.
33. Apparently in PA and Permian gas production is currently pretty much back to 2019 levels "as if 2020 never happened".
34. Observation from a reviewer for this book, Blake Eskew, IHSMarkit, September 2019.

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