UNECE

The Potential of Natural Gas to Penetrate New Markets

UNITED NATIONS

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

The potential for natural gas to penetrate new markets

UNITED NATIONS
GENEVA, 2020

Acknowledgments

This publication is one of the outcomes of the project called *"Improved understanding of the UNECE member States on the role of natural gas in achieving 2030 Agenda for Sustainable Development and the Paris Climate Agreement*" that complements the project "*Strengthening capacity of the UNECE member States to achieve the energy-related Sustainable Development Goals".*

The Project was led by Iva Brkic under strategic guidance and advice of Scott Foster, Director of the Sustainable Energy Division. The Project was run under the auspices of the UNECE Committee on Sustainable Energy and served to support the programme of work of Group of Experts on Gas.

This publication was drafted by independent consultant John Roberts.

The author and the project team wish to thank to the Chairs and Secretaries of the Group of Experts on Gas, Francisco de la Flor Garcia and Branko Milicevic, for input provided and facilitation in engagement with their respective Group of Experts.

The UNECE Secretariat thanks to the following external researchers and experts who contributed with background papers and technical inputs to this work: Hans-Josef Fell, Energy Watch Group, Berlin, Germany; Sigurd Heiberg, Petrad Foundation, Stavanger, Norway; Denis Hicks, High Delta, London, United Kingdom; Richard Holtum, Trafigura, Geneva, Switzerland; Łukasz Kroplewski, PGNiG, Warsaw, Poland; Francisco Laverón, Iberdrola, Bilbao, Spain; Boyko Nitzov, Agency for the Cooperation of Energy Regulators (ACER), Ljubljana, Slovenia; Kamila Piotrowska, International Association of Oil and Gas Producers (IOGP), London, United Kingdom; Nazir Ramazanov, Chair of the Group of Experts on Renewable Energy; Holger Rogner, International Institute for Applied Systems Analysis (IIASA), Vienna, Austria; Jeffrey Seisler, Clean Fuels Consulting, Washington DC, United States; Ángel Landa Ugarte, Iberdrola, Bilbao, Spain; Behnam Zakeri, International Institute for Applied Systems Analysis (IIASA), Vienna, Austria.

Disclaimer: The document does not necessarily reflect the position of reviewers and partners listed above who provided their comments and helped to develop this publication.

Contents

Executive Summary

Natural gas has considerable potential to penetrate new geographic markets and to carve out new opportunities. Investment plans will need to be put in place now if it is to sustain demand in the United Nations Economic Commission for Europe (UNECE) region post-2030.

Overall, the UNECE region is well supplied with gas and those parts of it that could benefit from increased access to, and use of, natural gas will only require limited additional volumes.

The European Network of Transmission System Operators for Gas (ENTSOG) considers that the potential for LNG supply from all sources will almost double over the next 20 years, from 115 bcm in 2020 to 228 bcm in 2040, while the maximum capacity for pipeline gas delivery will rise by around 50 bcm.

There is a considerable scope for the expansion of natural gas use, both as LNG and CNG, in road transport while there are also openings for LNG in rail.

At sea, the International Energy Agency anticipates that an increase in LNG-fuelled shipping will lead to considerable growth in maritime gas demand, rising from between 11.6 mt and 23.9 mt in 2025 to between 18.8 mt and 29.7 mt in 2030 and then to between 37.0 and 41.3 mt in 2040.

New LNG shipping is mainly focussed on ocean going vessels, but in June 2019 two different companies began operating LNG bunker vessels in the Netherlands for use on Europe's inland waterways.

The development of small-scale on-shore and floating LNG regasification terminals has the ability to open up new markets for gas, notably in the Western Balkans, particularly if their introduction is coordinated with the development or expansion of regional pipelines.

If gas is to be able to take advantage of new geographical markets and new applications, then investment plans need to be put in place now. The investment imperative goes to the heart of the energy transition equation. Modelling carried out by International Institute for Applied Systems Analysis (IIASA) for UNECE shows that the 56 UNECE member States will have to spend an extra 23% – $5.6 trillion, or $186.8 bn a year for the next 30 years – to ensure there are limits to the devastation from climate change.

However, placed in context, this sum is not quite as big as it might appear. It amounts to 1.15% of the national budgets of the 56 UNECE member States, and, of course, governments will not be picking up the whole bill. In addition, the Global Commission on the Economy and Climate has noted that "disasters triggered by weather- and climate-related hazards were responsible for thousands of deaths and US$320 billion in losses in 2017."

Moreover, in Russia and Central Asia, IIASA's modelling shows that the gas producers of Eurasia will require less investment if they implement policies to secure the 2015 Paris climate target, since their investment requirements for fossil fuels would decline. The scenario analyses show that Russian gas exports would be marginally higher if the country succeeded in implementing the Paris target, while gas exports in Central Asia would only be a little less than if they carried on with their current policies.

Political imperatives concerning the climate emergency may work to the detriment of gas if greater emphasis is placed on investment in renewable energy. However, there are also sound strategic reasons for investing in gas, both as a route to improve energy security and to enhance the quality of life quickly by using readily available technologies for power and heating.

Moreover, the rationale for gas use will increase markedly if the gas industry embraces carbon capture, use and storage (CCUS) to position itself as a carbon neutral fuel – guaranteeing to sequestrate the CO_2 resulting from using gas in order to compete with renewable energy technologies.

There is a clear dichotomy between the advances in technology that demonstrate that natural gas is capable of playing a larger role in transportation and modelling that indicates its role in this key sector is likely to shrink considerably. This gap appears to reflect the possibility that advances in the use of gas will be overtaken by swifter progress in developing and adapting renewable energy, notably through improvements in battery and fuel cell technology.

Overall, such uncertainty indicates that both governments and the gas industry will have to work together to craft a clear set of policies and regulations to enable gas to play a major role in the transportation element of the energy transition. The same point can be made in terms of basic provision of gas to more remote areas in the UNECE region that currently lack access to gas. Market design is everything.

1. Introduction

Gas is a very versatile commodity. It can be used for heat, including precision heat at very high temperatures, for power, for combined heat and power (CHP), for petrochemicals and fertilisers, and in internal combustion engines. It can also be used as a source of hydrogen, for example in the production of ammonia for nitrogen fertilisers.

These properties give it great potential strength. But how it penetrates new markets will be dependent on two very different approaches.

The first concerns geography. This covers the wholesale export, either by pipe or in the form of liquefied natural gas (LNG), to new geographical markets that are currently poorly served by gas. In the UNECE region such markets include the western Balkans, and parts of Russia and Central Asia. There are also existing markets in areas where energy consumption is increasing and where there might also be increasing demand for gas compared to alternatives.

The second concerns new opportunities regarding the application of various forms of gas, notably as a substitute for oil. There is a prospective major role for gas in transport, including LNG-fuelled ships (bunker fuel) and LNG-fuelled heavy-duty trucks on land. Both compressed natural gas (CNG) and biogas have the potential to increase their share of the automotive market. The use of gas in shipping as a bunkering fuel may also reduce marine pollution.

While natural gas has considerable potential to penetrate new geographical markets and to carve out new opportunities for use, investment plans will need to be put in place now if it is to sustain demand in the UNECE region post-2030. Such investment cannot be taken for granted, however, since challenges posed by regulation and the need for new infrastructure to facilitate the development of new markets as well as rapid cost reductions in electricity generation from renewable energy may require investments that entail significant commercial risk.

It also means that the nature of the investment must change. In terms of infrastructure, the balance of investment may move from pipeline infrastructure to LNG shipping and handling. To penetrate new markets, investments will be needed to focus on creating demand which may not be expensive but takes time, specialist resources and the ability to form a coalition across markets.

These topics are addressed in this paper; first by considering geographical prospects for gas by UNECE sub-region and then by exploring the new applications for gas within the region as a whole.

2. New Geographical Markets

There is considerable scope for gas market development in various UNECE sub-regions, notably Southeast Europe, Russia and Central Asia. There are also opportunities in Northern and Western Europe, but the intensity of the debate over climate change in those regions makes it much harder to assess the extent of further penetration in already developed markets (*see Paper Two: How Natural Gas Can Displace Competing Fuels*).

The development of small-scale on-shore and floating LNG regasification terminals has the ability to open up new markets for gas, notably in the western Balkans, and particularly if their introduction is coordinated with the development or expansion of regional pipelines.

Gas supply is more than adequate to meet any new geographical demand given the resource base of producers within the UNECE region, such as Norway, Russia, the United States, Azerbaijan, Kazakhstan and Turkmenistan. For energy security, gas can also be imported to the region by pipeline from North Africa or as LNG from much further afield, notably the Gulf Coast of the United States, Qatar, Iran, Nigeria and Trinidad. The technology for producing countries to ship their gas to customers in the UNECE region is well established since the *Methane Pioneer* carried the first LNG cargo from Louisiana to the UK in 1959. The European Network of Transmission System Operators for Gas (ENTSOG) considers that the potential for LNG supply from all sources will almost double over the next 20 years, from 115 bcm in 2020 to 228 bcm in 2040, while the maximum capacity for pipeline gas delivery will rise by around 50 bcm – on the assumption that at some stage a 30 bcm/y capacity line is built to connect Turkmenistan to major European consumers further west.

Indeed, with regard to the UNECE's biggest cross-border supplier, ENTSOG considers Russia has the potential to expand its pipeline capacity to European customers from a maximum 194 bcm/y at present to a maximum 226 bcm/y by 2040, although it also anticipates that Norway's ability to pipe gas will actually shrink. In December 2017, ENTSOG assessed Norwegian pipeline export capacity at a maximum of 110 bcm/y and anticipated it would fall to 91 bcm/y by 2040. In fact, Norway exported no less than 114.3 bcm by pipeline in 2018.

According to ENTSOG, maximum pipeline capacity from both Algeria and Libya remain static at 45 bcm/y and 11 bcm/y respectively, while the maximum for pipeline gas from Azerbaijan in 2040 is put at just 10 bcm/y, ignoring the fact that the Southern Gas Corridor, the vehicle for carrying Azerbaijani gas exports, has a built-in ability to raise capacity to at least 20 bcm/y to customers in the EU (and to deliver 33 bcm/y as far as Turkey). Turkmenistan is listed as having the potential to deliver a maximum of 30 bcm/y by pipeline to Europe by 2040, reflecting discussions that have been ongoing for at least 20 years but which have so far failed to deliver a concrete export project, whether to Azerbaijan, to Turkey or to the EU.

2.1. Southeast Europe

Overall, the UNECE region is already well supplied with gas and those parts of it that could benefit from increased access to, and use of, natural gas will only require limited additional volumes. But to the communities of those regions, which are mainly in Southeast Europe but which are also to be found in parts of Russia and Central Asia, securing even limited volumes of additional gas is potentially very important both for economic development and for their energy security.

Much of Southeast Europe still has only limited access to gas and particularly to diversified supplies. The situation is improving as a result of both new pipeline connections and LNG regasification terminals. However, particularly for smaller and generally poorer countries in the region, internal distribution networks are limited and it will be some time before much of the region can benefit from attractively priced gas. There is also potential for natural gas to be used increasingly both for power generation and heating, not least by replacing lignite.

The EU has estimated that a cluster of eight countries in central and southern Europe – Bulgaria, Croatia, Greece, North Macedonia, Romania, Serbia, Slovenia and Slovakia – can expect to see their combined gas consumption rise by around 13 bcm by 2040. If countries in this region with minimal current use of gas are included – namely, Albania, Bosnia-Herzegovina, Kosovo[1], Montenegro – this might raise the total to 16 or 17 bcm/y. These are tiny figures compared to current or prospective markets elsewhere in Europe, and particularly when compared to potential growth in Turkey (*see below).* Moreover, while such growth projections are at the more optimistic end of the scale for regional gas demand, a key factor is that even growth on this scale can largely be secured by completion of infrastructure that is already under construction, such as the Trans Adriatic Pipeline, or that is close to a final investment decision, such as TurkStream 2. In addition, the creation of new LNG regasification terminals, such as at Krk island in Croatia or at Alexandroupolis in northern Greece, as well as expansion projects such as the current plan to double capacity at Greece's current main LNG import terminal at Revithoussa, will ensure there is the infrastructure necessary to deliver such a capacity increase. Various EU-supported interconnector projects will likewise ensure a flexibility for distributing imported gas, whether it arrives by pipe or as LNG, substantially reducing the prospect that any UNECE member State in this area will long continue to find itself dependent on a single supplier for gas imports.

The region specifically stands to gain from the construction of the Trans Adriatic Pipeline (TAP) between Turkey and Italy via Greece and Albania and the second string of Gazprom's TurkStream (TurkStream 2), which is expected to run from Turkey to Austria, via Bulgaria, Serbia and Hungary. There are plans for spurs from both these lines. In the case of TAP, a project which should become operational in 2020, a connection to Bulgaria, the Interconnector Greece Bulgaria (IGB), is now under construction backed by a contract for the supply of one bcm/y of Azerbaijani gas to Bulgaria. A gas connection with TAP will also ensure the gasification of much of Albania while small-scale connections to Kosovo and North Macedonia are under serious study.

There is also a more ambitious plan for a project, known as the Ionian Adriatic Pipeline, which would connect TAP with Croatia's national system via Montenegro and with a side connection to Bosnia-Herzegovina.

In the case of TurkStream 2, a 16 bcm/y capacity system, matters are not quite so clear since the terms under which it would operate are in dispute between Gazprom and the European Union and some elements of the actual route have yet to be determined. But almost certainly TurkStream 2 (which is sometimes called Balkan Stream) will be built and will not only transit Serbia but include a major spur from Serbia to Bosnia-Herzegovina.

[1] references to Kosovo shall be understood to be in the context of Security Council Resolution 1244 (1999)

In much of Southeast Europe – essentially from Croatia and Serbia to Greece and Turkey – the need is not so much for big new pipelines to bring gas into the region as for relatively small-scale interconnectors and local distribution systems to enable towns and districts that lack access to distribution systems to be connected to major cross-border pipelines and LNG import terminals that are already in existence.

The countries and districts that stand to gain most from improved access to natural gas are Albania, Bosnia-Herzegovina, Kosovo, Montenegro and North Macedonia, together with southern districts of Croatia and various regions of Serbia. Neighbouring countries such as Bulgaria, Greece, Romania and Slovenia would also gain should gas be used to replace lignite in power generation.

One recent study, from the Oxford Institute for Energy Studies (OIES), describes the situation as follows: "Southeast Europe remains Europe's most polluting and least energy efficient region in relative terms and compared to its GDP. It is energy intensive but it is also intensive in CO_2 per unit of used energy. Its energy (and in particular electricity) consumption per capita is in line with the World average but far below the OECD average."[1]

This means there is a case for the countries listed above to benefit from the expansion – or in some cases introduction – of gas. This is because it would generally replace coal, especially lignite, and because new or expanded regional interconnections would end the reliance of some states on a single supplier. The OIES study, by Serbian energy analyst Aleksandar Kovacevic, notes: "Lignite is a critical source of electricity in Serbia, Kosovo, Bosnia and Herzegovina, Montenegro, North Macedonia, Greece, Bulgaria and Romania as well as Slovenia. In these countries lignite combustion provides 50 to 90% of domestic electricity generation."[2]

One problem is that a good case for regional access to gas may become distorted by incorporation into much larger claims concerning rapid growth of gas requirements throughout a broader region. For example, a June 2018 study for the Balkan Gas Hub, which seeks to secure the development of a gas hub in Bulgaria to serve Southeast Europe, argued that between 2016 and 2040, natural gas demand in countries that might be served by such a hub would rise 41.5 bcm from 214.3 bcm in 2016-7 to 255.8 bcm in 2040.

This EU-financed study used this 41.5 bcm projected increase to support its argument that "Regional demand growth forecast is much higher than in rest of Europe."[3] However, while this argument is used to advocate the utility of a Bulgarian hub, almost all of this projected increase was expected to come from Italy and Turkey, which might not necessarily be considered part of Southeast Europe. In addition, the use of market figures in excess of 200 bcm/y conveys an impression that a vast amount of the gas needed to serve this market would pass through the Bulgarian hub, a most unlikely development. Moreover, Italy is already well-served with hubs while Turkey is seeking to develop its own role as a gas hub. Indeed, as Kovacevic's later OIES study notes, "almost all Southeast Europe jurisdictions (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Kosovo, North Macedonia, Montenegro, Romania, Serbia, Slovenia and Turkey) envisage themselves becoming a gas and /or electricity hub in one or another context."[4]

Moreover, the Balkan Hub study only offers specific country-by-country data for the years 2020-2040. These show a 34.0 bcm increase from 221.8 to 255.8 bcm, with Turkey accounting for 20 bcm and Italy for 12.2 bcm (*see below for further discussion of Turkish gas demand*). In other words, the study envisages only a tiny 1.8 bcm increase for all of the other 11 countries in the study: Austria, Bulgaria, Greece, Croatia, Hungary, North Macedonia, Romania, Slovenia, Slovakia, Serbia and Ukraine.

On the other hand, the OIES study, which has both actual demand figures for 2013 and projected demand figures for 2025, indicates a somewhat faster rate of growth over its 12-year span. This amounts to 4.25 bcm, although that is still less than one per cent of total European annual consumption – regardless of how 'Europe' is defined (*See Table 1).*

Table 1
Gas Demand in Southeast Europe 2013-2025
(Final consumption, in cubic metres)

Country	**2013**	**2025**
Albania	6,842	523,741
Bosnia and Herzegovina	136,500	612,972
Bulgaria	1,666,526	2,499,495
Croatia	1,700,632	1,977,717
Greece	1,504,605	2,300,190
Kosovo*	0	207,858
North Macedonia	33,053	355,764
Montenegro	0	120,681
Romania	7,900,079	8,092,248
Serbia	1,226,816	1,726,638
TOTAL	**14,175,053**	**18,417,303**

* references to Kosovo shall be understood to be in the context of Security Council Resolution 1244 (1999)
Source: OIES[5]

The development of new pipelines and LNG regasification terminals both in and around the region also means that overall competitiveness of gas will be improved, whilst ending the reliance of various consumers in Southeast Europe on a single supplier, Russia's Gazprom. From 2020 onwards, gas can come in by pipeline from the Caspian, via the Trans Adriatic Pipeline, as well as from new and expanded LNG terminals in Greece and the planned LNG terminal in Croatia. The ongoing development of reverse-flow capabilities on existing pipelines will also help. In the longer-term, proposals for a pipeline to carry gas from the Eastern Mediterranean might also increase supply.

In 2021 or 2022, gas should also reach the region through new and existing pipelines from Russia, notably the planned TurkStream 2 pipeline through Bulgaria, Serbia and Hungary to Austria and the existing Brotherhood system (assuming there is still some Russian gas transit across Ukraine from 2020 onwards).

Such developments, together with the development of offshore gas resources in Romania and Bulgaria and the expansion of Romania's pipeline system, all point to the emergence of an increasingly promising market for natural gas in Southeast Europe, provided, of course, that various regulatory reforms are not merely promulgated but are actually implemented.

2.2. Turkey

Turkey is the great unknown. Its gas consumption has varied considerably in recent years, partially reflecting the country's overall economic condition and partially reflecting international gas prices. In the early 2010s there was a widespread assumption that the country's energy future would largely rest on gas but this no longer seems quite so certain. Although Turkey's gas demand has risen over the last decade, climbing steadily from 35.3 bcm in 2008 to 51.6 bcm in 2017 (with a hiccup in 2016), it fell back to 47.3 bcm in 2018 while initial figures suggest a further fall in 2019.[5] At the height of the gas boom in 2012, when the country consumed 45 bcm, Turkey's state-owned gas company, BOTAŞ, anticipated that consumption would rise to no less than 81 bcm by 2030. More recent estimates, however, are much more cautious. In 2017, the OIES anticipated that Turkish gas demand would rise to about 55-56 bcm in 2025 and then to 60-62 bcm in 2030.

Turkey faces several problems. One is the slow pace of gas market liberalization; a second is continuing price disputes with one of its main providers, Russia; a third is the challenge of renewable energy; a fourth is the inbuilt desire of some energy nationalists to find a way to increase the country's reliance on its most abundant indigenous resource, lignite. Nonetheless, Turkey should still be regarded as a growth market for gas and it is quite reasonable to assume that its current major pipeline suppliers – Russia, Azerbaijan and Iran – will seek to expand their share of a growing market for at least the next ten years or so. However, they will face increasing competition from both renewable energy and LNG, notably US-origin LNG.

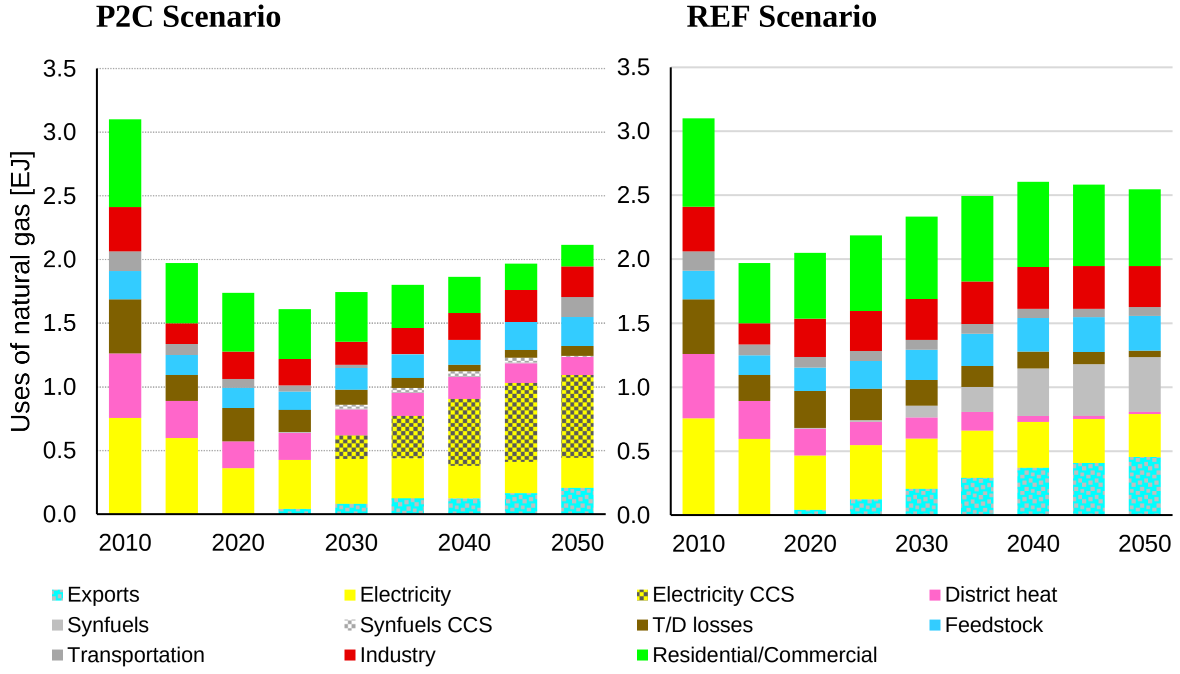
2.3. The BMU region: Belarus, Moldova and Ukraine

The BMU region – Belarus, Moldova and Ukraine – is forecast to see a doubling in gas production by 2050. The use of that gas is very different depending on the sub-region's attitude to climate change. Modelling for these papers carried out by the IIASA shows that if the countries choose to implement the Paris Agreement targets, the requirement for gas imports would be significantly lower than if they proceed with the current policies.

Under IIASA's P2C scenario, which would see the UNECE region as a whole implementing policies that would limit global warming to the Paris Agreement targets, the BMU would be expected to import 0.324 EJ (about 8.6 bcm) in 2050.[2] in comparison, IIASA's Reference scenario, which only takes into consideration existing policies or policies that have already been announced, anticipates that BMU imports would total around 0.900 EJ (about 23.85 bcm) in 2050 (*see Figure 1*).

[2] There is no standard formula for converting exajoules (EJ) into billions of cubic metres (bcm), simply because the joule system measures the energy content of fuels while natural gas is commonly measured by volume, in cubic metres. Since different sources of natural gas have different calorific values, conversions are essentially approximations. The International Energy Agency standardises energy usage in terms of millions of tonnes of oil equivalent (mtoe), and then converts mtoe into EJ using the formula 1 mtoe = 0.041868 EJ. Conversely, that makes 1 EJ equal to 23.8845897 mtoe. By converting mtoe into bcm at a standard rate of I mtoe = 1.11 bcm, 1 EJ can be regarded as the equivalent of 26.51 bcm. This is the conversion formula used in this paper.

Figure 1
Gas Use in the BMU Region under the P2C and REF Scenarios, 2010 - 2050



Moreover, the P2C scenario even envisages a modest element of actual gas exports from the BMU region. These would amount to just 0.166 EJ (about 4.4 bcm) in 2050, offsetting roughly half the region's projected imports under the P2C scenario. Most of these changes would take place in Ukraine, since it accounts for the majority of BMU gas use.

The most striking difference between the P2C and the Reference scenario concerns how gas is used. There would be greater use of gas for electricity under the P2C scenario while much less gas would be used in the residential and commercial sector. Regardless of scenario, there is an expectation that actual gas production will rise considerably from 0.628 EJ in 2015 to 1.551 EJ in 2050 under the P2C scenario and to 1.550 EJ under the Reference scenario. That constitutes an increase from around 16.65 bcm in 2015 to around 41.1 bcm in 2050.

2.4. Russia

Russia has both the scope and incentive for increased domestic use of gas. The scope is provided by both the abundance and distribution of its gas resources. The incentive is development of new markets within Russia that can free up oil for export (Russia earns roughly four times as much from oil exports as from gas exports). However, there is a major disincentive to further internal growth: the fact that domestic gas prices remain well below export price levels and the limited prospect that this gap will diminish in the near future.

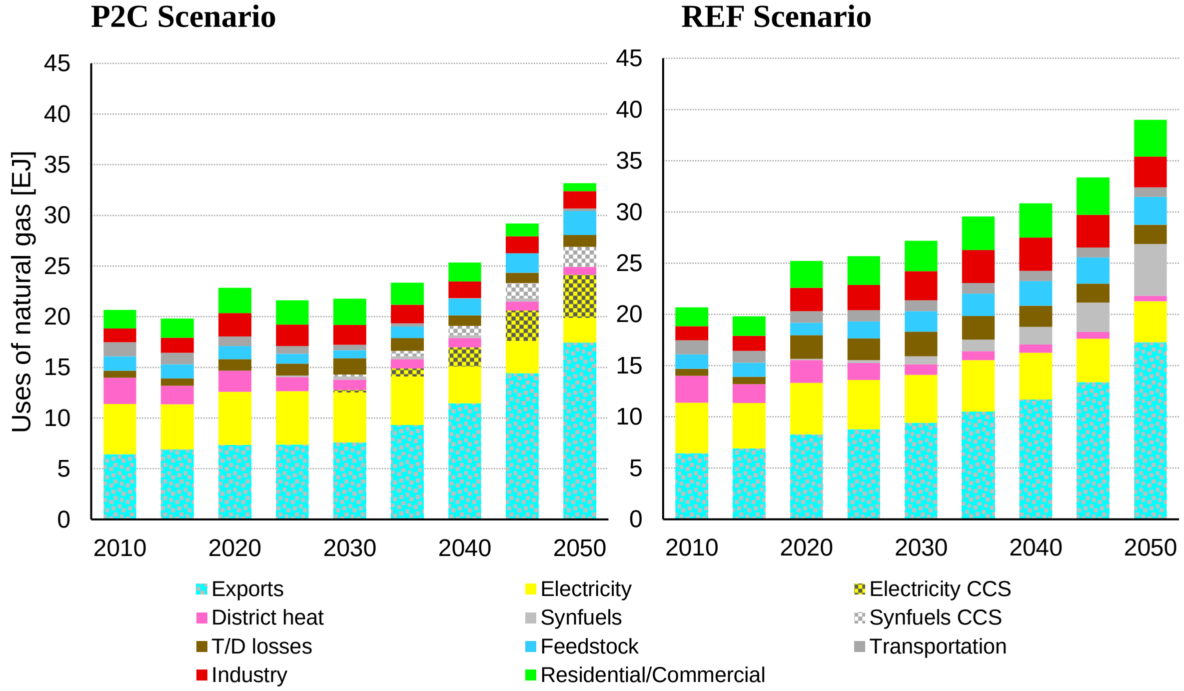
Overall, Russia's use of gas looks set to grow considerably in the decades to 2050, regardless of whether it takes the P2C or Reference scenario path. But IIASA does note significant differences between scenarios when considering both the amount of gas that Russia would produce and the amount of gas it would use domestically. The IIASA data does not include specific figures for gas production, but since it provides data for both gas use and for exports, and since Russia produces almost all the gas it consumes, the general trajectory of gas production under both scenarios is fairly clear.[3] Overall gas use under the P2C scenario, which IIASA considers to have totalled 19.82 EJ (525.5 bcm) in 2015, would initially witness a decline from 22.86 EJ (605.9 bcm) in 2020 to 21.63 EJ (573.3 bcm) in 2025 before starting a limited recovery to reach 21.78 EJ (576.6 bcm) in 2030 and then powering ahead to hit 25.35 EJ (671.9 bcm) in 2040 and 33.17 EJ (879.2 bcm) in 2050.

Under the Reference scenario, however, production would be set to exceed one trillion cubic metres a year 30 years from now. Starting from EJ 19.82 (525.5 bcm) in 2015, overall gas use would then climb to 27.18 EJ (720.6) bcm in 2030, to 30.83 EJ (817.3 bcm) in 2040 and to no less than EJ 39.00 (1,033.8 bcm) in 2050. Almost certainly, this indicates that actual gas production would, under this scenario, hit the trillion cubic metre mark.

The real difference concerns domestic demand. The P2C scenario envisages a 20-year fall in demand and, despite a recovery in the 2040s, it still envisages that domestic demand in 2050 would be only just above demand in 2020. In contrast, the Reference scenario postulates a 233 bcm increase in gas demand between 2015 and 2050, considerably more than the 189.4 bcm that Russia's Gazprom exported to the whole of Western Europe, its chief export market, in 2018 (*See Figure 2)*.

Figure 2

Gas Use in the Russian Federation under the P2C and REF Scenarios, 2010 - 2050



In specific terms the P2C scenario postulates domestic gas demand rising from EJ 12.92 (342.6 bcm) in 2015 to EJ 15.49 (410.72 bcm) in 2020. But it would then fall to EJ 14.24 (377.6 bcm) in 2025; to EJ 14.18 (bcm 375.10 bcm) in 2030; to EJ 14.06 (372.8 bcm) in 2035; and to EJ

[3] Gas use and gas production are not identical, since the differential between input and output on the Russian pipeline system, due to such factors as the powering of compressor stations and losses through leakages, can be anything up to 10 per cent. In addition, Russia also imports gas from Central Asia.

13.88 (367.88 bcm) in 2040. It would then recover to reach EJ 14.76 (391.2 bcm) in 2045 and EJ 15.70 (416.1 bcm) in 2050.

Under the Reference scenario, domestic demand, defined as above, would climb from EJ 12.92 (342.6 bcm) in 2015 to EJ 16.92 (448.7 bcm) in 2020; then to EJ 17.76 (470.8 bcm) in 2030; to EJ 19.14 (507.5 bcm) in 2040; and on to EJ 21.72 (575.7 bcm) in 2050.

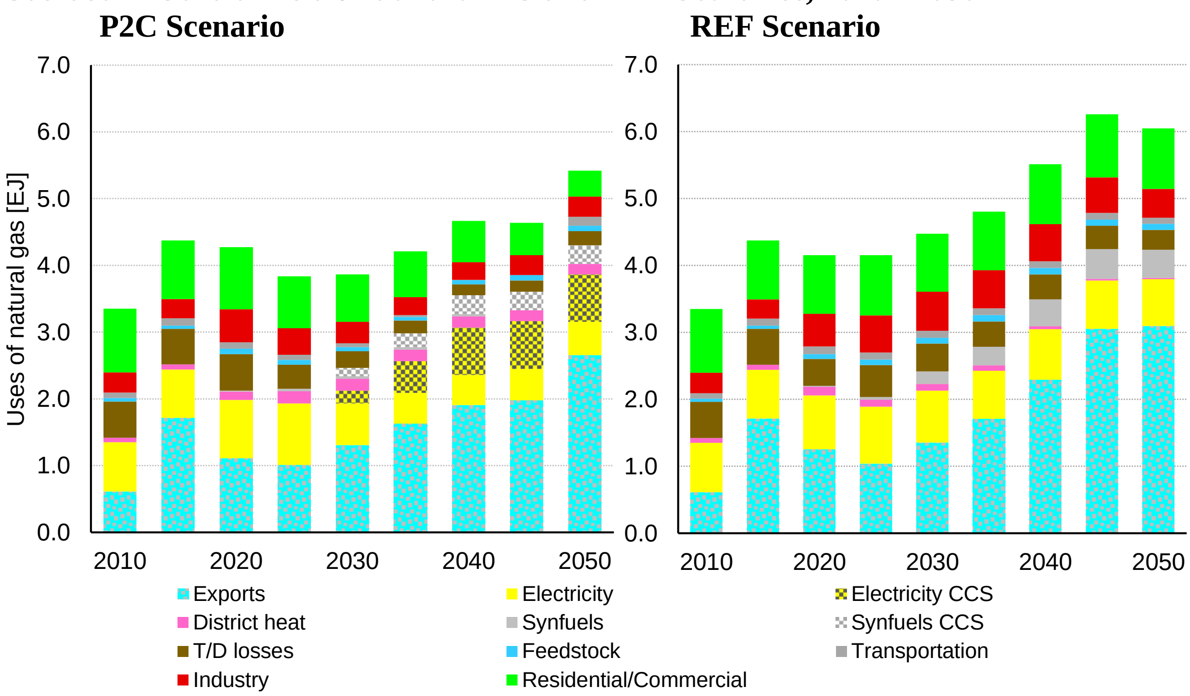
Moreover, IIASA's modelling does show one striking further difference: if Russia were to pursue policies to deliver the Paris Agreement climate targets, then it could actually expect to see a greater volume of gas exports than if it chose to implement only its current policies. Under the P2C scenario, IIASA postulates that Russian gas exports would total 468.9 bcm in 2050; under the Reference scenario they would total 463.8 bcm (*see Box on p. 23: The P2C Scenario and Eurasian Energy Producers*).

2.5. Central Asia

Central Asia would see a modest smaller increase in gas production were it to pursue policies to implement the Paris Agreement climate targets or to continue with current policies as envisaged in IIASA's Reference scenario. IIASA assessed total gas use in Central Asia in 2015 at 4.37 EJ (115.9 bcm) in 2015 and postulated it would rise to 5.42 EJ (143.7 bcm) in 2050 under the P2C scenario and to 6.05 EJ (160.3 bcm) under the Reference scenario.

Regional gas exports in 2050 would also be lower under under the P2C scenario – but overall investment in energy between 2015 and 2050 would actually be lower under the P2C scenario than in the Reference scenario, as investment in upstream and midstream fossil fuel development would be significantly lower if the P2C path were pursued than under current policies (*see Box on p 23: The P2C Scenario and Eurasian Energy Producers*).

Figure 3
Gas Use in Central Asia under the P2C and REF Scenarios, 2010 - 2050



3. New Applications

3.1. Power generation

Conventional wisdom says that gas is in a remarkably strong position to play a leading role in the phasing out of coal in power generation, thus contributing significantly to reduced CO_2 emissions and enabling renewable energies by providing very flexible power generation. This requires clear policy initiatives. As discussed in *Paper Two, How Natural Gas Can Displace Competing Fuels*, this argument is losing impact as the costs of renewable energy for electricity generation fall faster than expected and as the necessity for baseload provision and coverage for the intermittency of renewable energy appears to be reduced. The steady increase in renewable energy output will impact on the average load factor of thermal generation, and therefore the economics of using gas, but It is far from clear how these two factors will affect each other. Within the EU, there is a clear aim to see the decarbonisation of power generation with the EU's association for electricity producers, Eurelectric, committed to achieving net zero carbon emissions by 2050.

3.2. Transport

Gas is already playing a significant role in transport technology. There are LNG trucks on land and LNG-fuelled ships at sea; there are CNG taxis in Uzbekistan and biogas-fuelled vehicles in Germany, Sweden, Switzerland and the UK. CNG buses are found across the UNECE region from Seattle and Las Vegas through Paris, Ljubljana, Vilnius and Moscow to Tashkent, Bishkek and Almaty.

At sea, a new generation of LNG-powered liners is entering the tourist cruise market while new rules on marine emissions being introduced by the International Maritime Organisation (IMO) are expanding the market for both LNG vessels and bunkering.

Natural gas for railway applications is at the proof-of-concept and demonstration phases.

On both land and sea there is a need to confront the chicken-and-egg conundrum. LNG and CNG vehicles need filling stations – but which comes first? Ship owners will only invest in LNG if the bunkering infrastructure exists – and vice-versa.

3.2.1. Road Transport

There are more than 26 million natural gas vehicles (NGVs) on the world's roads. Most of these are in Asia, notably China, Iran, India and Pakistan. But there are more than a million NGVs in Italy and a further 800,000 in Uzbekistan. Light duty passenger cars constitute the overwhelming majority of the global NGV fleet, and almost all these cars run on CNG, derived either from natural gas or biogas.

At present, a majority of these vehicles have been converted from running on gasoline to dual-fuel vehicles that can run on either gasoline or CNG. As NGV markets develop, however, purpose-built NGVs are likely to become increasingly prevalent. In Europe, no less than ten motor manufacturers are, between them, currently offering 28 models of NGV passenger cars. However, in the US, only four manufacturers offer factory-built NGV vehicles – and all of their nine models are either pickup trucks or vans; there are no saloon cars.

There are considerable prospects for the use of LNG in road freight. In fact, the transition fuel argument used for electricity generation is probably more valid for road freight as renewable technologies are harder to implement in this segment. Gas, as LNG or CNG, helps to curb greenhouse gas emissions and, despite higher initial capital costs, is commercially cost-effective in the short- to medium-term.

The general rule of thumb used in the industry is that natural gas must be 30-50% cheaper than petroleum fuels to create economic viability and ensure simple payback over three to five years. This takes into account such variables as fuel storage capacity, which governs the range of the vehicle; higher initial costs for the vehicle itself; and the cost differential between gas and alternative petroleum-based fuels.

Well before 2050, however, it is highly likely that gas-fuelled vehicles will face strong competition from vehicles powered by fuel cells backed up by batteries. One indication comes from China, where there is heavy demand for gas-fuelled vehicles but where electric vehicles (EVs) are on the rise, demand for gas is actually expected to fall by 2030 (*see Table 2*).

As of May 2019, there were already 6,000 LNG trucks on the road in Europe along with some 230 LNG filling stations and approaching 3,700 CNG filling stations. Trucks accounted for around 7% of NGV vehicles on European roads, while busses accounted for around 9%. For its part, the US currently has some 25,000 LNG trucks serviced by around 120 filling stations, while LNG trucks are also in use in Canada. Such figures, however, pale by comparison with China, where there are already some 330,000 LNG trucks and more than 2000 filling stations, and where the truck fleet is growing by around 60,000 vehicles a year and the number of filling stations is soaring.[4] In effect, while there is one truck for every 4,200 people in China, and in the US one truck for every 13,000 people, in the regions covered by the EU, Switzerland and Norway, there is just one truck for every 900,000 people.

This demonstrates that in the UNECE region, including North America, there is considerable scope for growth both in regions where they are already operational and in regions that are not currently served by such vehicles.

This requires infrastructure. At present, lack of infrastructure in many parts of the UNECE restricts use of CNG to fleet owners that can provide their own infrastructure. This favours the use of CNG buses for urban transit and garbage trucks for urban refuse collection. In general, around 600 to 1000 vehicles per fuel station are needed to sustain a publicly-used NGV market.

In 2016, discussing the development of LNG and CNG lorries for commercial transportation, Rune Bjornson, a senior vice president at Norway's Equinor, had this to say: "To what extent this actually develops and materialises I still think it is early days, but what we do know is that gas from a commercial point of view is very attractive. I think what is missing is more the infrastructure around it and the car fleet as such converting to natural gas, whether that would be compressed natural gas or liquefied natural gas."[6]

At present, with the notable exception of Turkey, there are no filling stations south or east of Austria and Poland, barring a single station in Romania and a planned establishment in Budapest. Nor are there any in Russia or the BMU sub-regions. There is, however, major use of CNG-fuelled vehicles in both Uzbekistan and Armenia, while in the Nordic countries,

[4] China plans 12,000 LNG and CNG stations by 2020.

Norway, Sweden and Finland, a further 50 new LNG and/or CNG filling stations are due to be in place in or around 2022.

An indication of just how great future growth might be can be found in a table of estimated demand for gas in road transport produced by the OIES in April 2019 (*see Table 2*).

Table 2
Estimated Demand in 2030 for Gas in Road Transport
(demand in Bcm)

Region	2017 (estimated)	2030 (forecast)
China	36	30
India	3	10
North America	2	10
Europe	2	15
Rest of the World	10	15
Total	**53**	**80**

Source: OIES

LNG trucks can travel very long distances, which means there is no need for nearly as many LNG refuelling stations as are required by vehicles fuelled by petrol or diesel. Iveco's new standard truck, for instance has a routine range of 1,600 kms and one these has already undertaken a 1,728 km trip from London to Madrid without refuelling. The main advantage that LNG trucks have is that they are more environmentally friendly than their diesel or gasoline counterparts and that natural gas is less expensive than diesel. Although natural gas vehicles contribute only a little to CO_2 reduction, they do have a considerable impact of NOx emissions and particulates, according to Kalev Reiljan of Estonia's AS Eesti Gaas. Reiljan says that NGVs reduce CO_2 emissions by between 10 and 25% and NOx emissions by some 80% compared to gasoline or diesel vehicles, and produce virtually no particulates at all.[7]

A study by academics at the University of Zagreb published in February 2019 on LNG truck development noted that in the EU-28, in 2015, "road transport was responsible for almost 73% of the total greenhouse gas emissions from transport."[8] The study cited various reports to the effect that while LNG and CNG vehicles emit 10–20% less greenhouse gas emissions than gasoline and 5–10% less than diesel vehicles – which might not appear to be that great a reduction – the "benefits of introducing LNG as alternative fuel including the clean combustion of LNG causing nearly 99% less particle (PM) and sulphur oxide (SOx) emissions, around 80% less nitrogen oxides (NOx) and around 20% less CO_2 compared to diesel fuel." The Zagreb study assumes that an LNG truck costs around 35% more than its diesel equivalent, and that it costs about 20% more to maintain, but that it is still commercially viable because of the lower costs of fuel input. Over 15 years, the study argues, an "LNG truck would have saved around 138,000 euros and would become more cost effective after 2.16 years."[9]

It should be noted, however, that the question of how much CO_2 emissions can be reduced through use of natural gas vehicles, or, indeed, whether there is any real emissions reduction when whole life elements are taken into account, is a subject of considerable controversy. It should also be noted that a study by the Netherlands TNO for the Dutch Government found that CO_2 and methane (CH_4) emissions from a 2018 Euro VI LNG-diesel, dual fuel truck, running primarily on LNG for an average long haulage trip, were significantly less – about 19% – than those from a comparable 2013 diesel truck. However, the TNO study also noted that "for an average long haulage trip, the emissions of the criteria pollutants NOx and particulate number of the test vehicle were at a comparable level as for a group of tested comparable Euro VI diesel heavy-duty vehicles."[10]

As technologies improve, the question of whether it costs more to maintain heavy duty NGV vehicles is also disputed, with proponents of gas-based fuels arguing that the maintenance of new NGV trucks is now much the same as that of diesel trucks, and that the cost of maintaining busses can sometimes be higher, and sometimes lower, than for conventionally fuelled busses.

There are clearly prospects for substantial market growth for natural gas vehicles in the UNECE region, but converting this into reality will also require considerable infrastructure development.

3.2.2. LNG for Rail

There is also a large potential market for the use of LNG in rail transport, particularly in the US, but this will require a change in the regulatory framework governing railway use and transport of different fuels as well as LNG fuelling. The potential market share of methane for the rail sector also depends on the current usage of diesel versus electric trains, since it is diesel that LNG would largely replace. In Europe, only 20% of the trains use diesel; in Asia, the proportion is 71%; in Africa, 82%; and in the US 99% of the trains run on diesel. A 2014 study by Cedigaz considered that by 2035 there could be a modest global demand for some six million tonnes (6.67 bcm) a year of LNG for rail transport.[11]

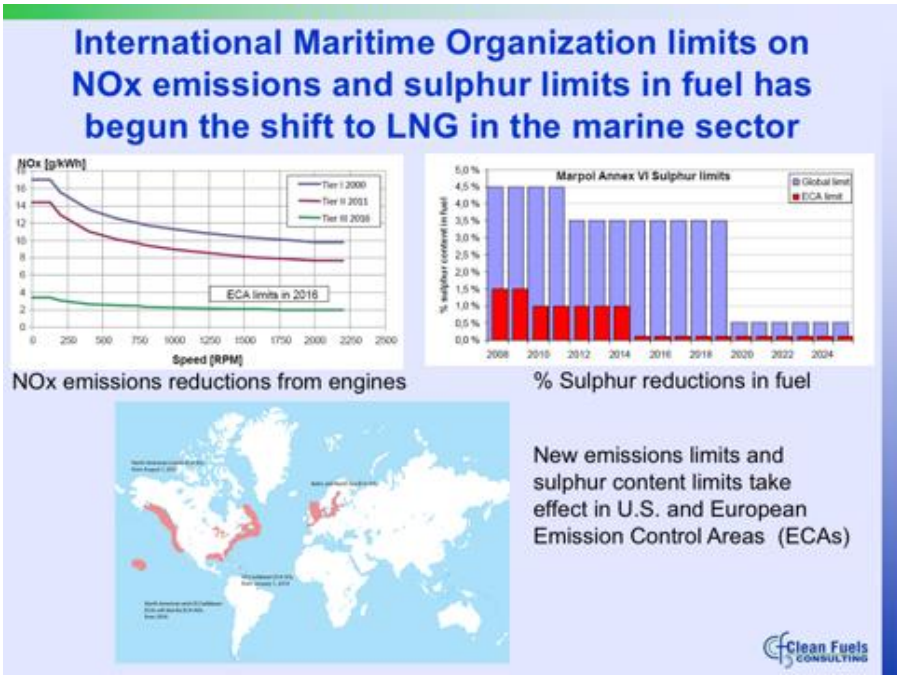
LNG for trains is most advanced in the US, where significant developments and changes in the regulatory framework for railway transport and use of LNG will likely see the railway market and fuel infrastructure begin to develop. However, LNG rail technology is also being explored in parts of Europe and in Russia. The European Commission has funded a project, LNG HIVE-2, Infrastructure and Logistics Solutions, aimed at developing natural gas markets for both the rail and maritime sectors.

3.2.3. Marine: LNG Vessels

There are considerable prospects for LNG-fuelled vessels in the UNECE region in view of three main elements: large volumes of the kind of shipping that would specifically gain from using LNG; the existence of extensive – and expanding – infrastructure to serve LNG shipping; and the desire of ship operators to embrace LNG-fuelled vessels. These come from an increasingly strict control of marine emissions developed by the IMO in the form of Emission Control Areas and tighter regulations on air pollutants which discourage the use of fuel oils.

The market for LNG in the shipping sector received a significant boost when the IMO in 1997 created progressively stricter regulations for NOx emissions and the sulphur content of diesel bunker fuel (*see Figure 4*).

Figure 4
IMO limits on NOx help promote marine LNG



Source: Dr Jeffrey Seisler, Clean Fuels Consulting

The regulations came into force in 2005, with an extended timeframe on a transition to lower pollution and cleaner fuels. The creation of Emission Control Areas (ECAs) for both NOx and low sulphur fuels in the Baltic, North Sea, and on both coasts of the US. These ECAs might be expanded to the Mediterranean Sea and the coasts of Japan. These moves underpin the impetus to develop maritime use of LNG since natural gas engines can make a significant contribution to emissions reduction compared to traditional marine oil fuels.

A 2018 study by the OIES considers some shipping sectors to be particularly promising, notably "ro–ro ferries, cruise ships, bulk carriers, large container vessels, and, of course, LNG tankers."[12] In the UNECE region, the basis for this is the extensive nature of ferry and ro-ro traffic in the North Sea, the Baltic and the Mediterranean; a steady expansion of cruise ships in all these seas, also in North America and on Russia's river system; and the industrialised and trading nature of so much of the UNECE region that requires extensive use of intercontinental container and LNG traffic.

The potential for growth is also supported by the rapid development in recent years of land-based infrastructure in much of the UNECE region. On one side of the Atlantic, there are already at least 33 regasification facilities in operation, from Finland, Russia and the Baltic states in the north to Spain, Portugal and Greece in the south; from France and the UK in the west to Turkey and Israel in the east. On the other side there are 14 in North America – 13 in the US and one in Canada. More than a dozen additional plants are planned on the European side of the Atlantic, and eight more in the US, although not all of these 20-odd projects will come to fruition.

The regasification facilities, which increasingly consist of floating storage and regasification units (FSRUs) that can be established offshore at relatively low cost, not only serve in some cases to provide vessels directly with LNG as fuel but also serve to facilitate inshore distribution that enables LNG to be trucked to smaller ports.

The number of vessels under construction or with firm orders for construction that would use LNG as their primary fuel is rising steadily. As of April 2018 DNV-GL (Det Norske Veritas, Norway) and Germanischer Lloyd (Germany) estimated there were 121 LNG ships operating outside of China and another 126 new LNG ships on order. (Unsubstantiated data from China indicates as many as 280 LNG vessels may be operating there.) For example, Carnival, the world's biggest operator of cruise liners, expects a further seven new LNG fuelled liners to enter service by the end of 2022 following the maiden voyage of its first LNG liner, the *AIDAnova*, in the Mediterranean in April 2019.

Some of the new vessels, notably those required for short-range or inland shipping, will be dedicated LNG-only. Many will be dual-fuel, capable of running on diesel or using small amounts of diesel as pilot injection to ignite the methane in a 2-stroke, compression ignition engine. Major marine engine manufacturers such as MAN, Wärtsilä, Rolls-Royce, MaK/Caterpillar and others are developing natural gas technology to retrofit existing vessels and to develop new ships that can be expected to operate to 2060 or beyond. Likewise, a new generation of LNG storage has emerged, turning a ship's hull into a giant LNG storage tank.

There are, however, doubts concerning the future trajectory for maritime LNG development in view of environmental, technical and commercial challenges. The IEA anticipates that, globally, the increase of LNG-fuelled shipping will lead to considerable growth in gas demand, rising from 11.6 mt in 2025 to 18.8 mt in 2030 and to 37 mt in 2040 under its Sustainable Development scenario and from 23.9 mt in 2025 to 29.7 mt in 2030 and then to 41.3 mt in 2040 under its New Policies scenario. The OIES study is more cautious. It notes that as of May 2018, there were 122 LNG-fuelled vessels in operation and 132 on order or under construction. But it also concludes: "Most forecasts suggest that global demand should be in the range of 25 to 30 mtpa of LNG by 2030. This would require that, very approximately, between 2,000 and 6,000 new or converted vessels would be fuelled by LNG by then. Reaching a fleet of this size would appear challenging at the present level of new builds. It is considered, therefore, that a demand level of around 15 mtpa by 2030 is a more realistic prospect."[13]

The OIES study does accept that this outlook could change rapidly "if a number of large shipping companies were to commit to LNG" – and notes that all the forecasts for LNG-fuelled vessels actually exclude LNG carriers. It adds: "If all of these were to switch exclusively to LNG, this alone could represent around 17 mtpa of demand by 2030."[14]

After 2030, however, there may be additional challenges from various other technologies, such as battery technology, wind, or, notably in Russia, nuclear power. These may then enable the construction of ships that require little or no use of fossil fuels. But such developments will be expensive and take considerable time to become a commercial reality. In the meantime, LNG appears to be a very economical and environmental alternative to the use of highly refined and expensive low sulphur fuels.

Much will depend on technological progress, particularly with regard to the construction or retrofitting of vessels to enable them to operate on a dual fuel basis. Indeed, major engine manufacturers are working on a new generation of engines for use both on new vessels and in retrofitting. There are also changes in the LNG tankers themselves. Many tankers carrying LNG to market already use boil off gas (BOG), the gas produced as a result of temperature increases in the liquefied cargo, as an additional fuel for powering the vessel. Now there is an increasing focus on the development of purpose-built oil tankers designed to operate on a dual fuel basis. These would use LNG as their primary fuel but would also be able to recover volatile oil compounds (VOC), in effect, they would capture the gas that evaporates from the oil cargoes that are actually being shipped, and use these as additional fuel. In addition, a new form of LNG storage is emerging, with the hull of LNG vessels becoming a giant LNG storage tank.

3.2.4. Bunkering & LNG Use on Inland Waterways

Bunkering also provides fresh opportunities for LNG, not least since the IMO is introducing new rules on marine emissions, thus reducing maritime pollution. The technologies are proven but the size of the market niche is open to question. There are competitive low emission technologies, the issues of new build versus retrofitting existing ships are different, and there is a chicken-and-egg situation where ship owners will only invest in LNG if the bunkering infrastructure exists and vice versa.

Bunkering has an essentially indirect environmental impact since its principal role is to provide the necessary infrastructure and services for greater use of LNG-fuelled vessels. The world's largest LNG bunker vessel, the 7,500 cubic metre (cm) capacity *Kairos*, began operating in northwest Europe in 2018 and a new 18,600 cm capacity vessel is currently under construction in China for Japan's Mitsui O.S.K. Lines (MOL) and France's Total Marine Fuels Global Solutions (TMFGS) and is due to enter service in 2020. It will primarily serve TMGFS's new fleet of nine LNG-fuelled super-containerships, each capable of carrying 22,000 standard 20-foot containers.

Currently, there is an extensive effort to create international standards and regulations to provide for safe refuelling of LNG in the form of bunkering, both from ship-to-ship and from shore-to-ship. The standards include fuel connectors, articulated fuel hoses, safety on-board and on-land in fuel storage, and all the related architecture and logistics involved in creating seaports with LNG capacity for fuelling. Adoption of such standards should serve to speed up marine LNG development.

The UNECE itself has a role to play in development of marine LNG since it is the body that sets standards for use of LNG in vessels on inland waterways. On 24 June 2019, Shell's *LNG London* bunker vessel began operations in Rotterdam, with Shell describing the vessel as "Europe's first inland-waterway liquefied natural gas (LNG) bunker vessel."[15] Two days later, Titan officially christened its *Flexfueler001 in t*he port of Amsterdam, saying the event "marks the official commencement of safe, efficient and cost-effective inland waterway LNG bunkering in the ARA (Amsterdam-Rotterdam-Antwerp) region."[16] On 31 October 2019, Europe's first shore-to-ship LNG bunker station for inland shipping was opened at the Niehler Hafen in Cologne. Proposals for the use of LNG vessels and the establishment of LNG fuelling stations along Europe's Rhine-Main-Danube artery are under active consideration.

In the US, the Pittsburgh Region Clean Cities initiative was in 2016 working on a project to enable two diesel-powered vessels also to run on LNG, but there are issues concerning the price of LNG as a fuel, since taxation by volume puts it at a disadvantage compared to oil-based fuels. At present, the main development of relatively small-sized LNG vessels in the US is the use of five dual-fuel supply vessels that serve oil platforms in the Gulf of Mexico.

3.2.5. Aviation

A number of aircraft manufacturers and operators are continuing to experiment with biofuels and electrofuels as additions to oil-based aviation fuel in order to help 'green' aviation fuel. The Sustainable Alternative Jet Fuel (SAJF) initiative, which groups a number of international aircraft manufacturers, includes waste gases amongst the prospective ingredients for propulsion systems largely based on fuels derived from biomass.

The first use of natural gas in aircraft was in 1983 when Russia developed a proof-of-concept helicopter to demonstrate that LNG possessed airborne potential. In 1987/1988, the Soviet Union began testing the Tupolev 155, a modification of the standard Tupolev 154, but designed to test one engine that would run on LNG and another that would run on hydrogen (whilst also fitted with two standard jet-fuel engines). The aim was then to produce a second test aircraft, the Tupolev 156, while longer-term ambitions included the development of a series of commercial aircraft powered by LNG and the possible use of hydrogen to fuel military aircraft that could operate in lower space. However, the fall of the Soviet Union ended this effort before any assessments could be made regarding practicality and commerciality.

3.2.6. Long-term Forecast Demand for Gas in Transportation

While the technologies for harnessing gas to transportation are being expanded worldwide, it is not clear that this will translate into actual long term, sustainable commercialisation of the use of gas in the transport sector. Already, there is fierce competition from electric vehicles (EVs), not least as a result of promotion by governments, and, in some cases, to the detriment or omission of other fuels. The uptake of EVs will depend on a wide range of factors, including recharging considerations, battery materials and energy storage capacity, and the widespread availability of renewable electricity on a grid-wide basis. NGV sector stakeholders, meanwhile, will continue to advocate for a balance of fuel alternatives. In the next few decades, global demand for all forms of transportation fuels, whether based on methane, other fossil fuels or renewable energy, is expected to grow, though the extent of such growth will obviously be affected by such factors as the speed of economic development, the spread of private automobile use and, of course, the energy efficiency of new vehicles. The real revolution in transport will have to await the replacement of the internal combustion engine.

In this context, it should be noted that the window for increased use of gas in transportation in the UNECE region may be limited. The IIASA data notes that transportation accounted for some 3.5% of total gas supply in the UNECE region in 2015 (2.34 EJ out of a total of 66.73 EJ) but anticipates that by 2050 its share will shrink, regardless of scenario, falling to around 1.5% (1.25 EJ of a total 83.38 EJ) under the P2C scenario and to 1.6 % (1.33 EJ of a total 94.79 EJ) under the Reference scenario.

If the gas industry wants to change this forecast, it needs to put more effort into developing the use of gas in transportation by engaging all the stakeholders involved.

3.3. Heating and District Heating

The use of gas for heating, according to the IIASA modelling, likewise appears set to fall in both relative and absolute terms, though in a quite different manner to transportation (*see Table 3)*.

In 2015, heating accounted for 3.9% of total gas use, or around 2.59 EJ of 66.73 EJ, in the UNECE region. Under the P2C scenario, this would slip to 2.9% of total use in 2050, although growth in the overall gas supply would limit the fall in absolute terms. Despite this, gas can still play a significant role, along with energy efficiency, in the provision of heating in parts of the UNECE region. Gas suppliers, such as Equinor, are looking to find new markets in combined heating and power (CHP).

One major question is the extent that new district heating developments should rely on gas rather than renewable energy. In the south of the UK, the town of Woking is using delivery of predominantly gas-fired combined heat and power to council buildings and a conference centre and hotel complex in the centre of the town – coupled with widespread use of photovoltaics and small fuel cell power producers – to reduce the council's own carbon emissions by 82%. Although it is being extended, this is still a limited operation but it does demonstrate how innovative technologies can team up to facilitate decarbonisation. The model is already being replicated in another southern English town, Milton Keynes.

The UK also provides an example of another approach that may impact on gas markets for heating. Hydrogen and biogas have the potential to displace natural gas. In the northern England city of Leeds, the authorities have permission to conduct trials to see whether new polyethylene pipes can deliver hydrogen safely and at scale to provide heating and serve cookers in place of natural gas currently being delivered through cast-iron pipes that require replacement. The hydrogen would be made by using natural gas in steam reformers with the carbon dioxide emissions being captured, transported and then stored in reservoirs under the North Sea. If the trials are successful, the aim is to replicate this across much of the north of England.

Table 3

UNECE & Sub-Regions: Gas Use for Transportation and Heating 2015-2050 (in exajoules)

2015	Scenario	BMU	CAS	EEU	NAM	RUS	SCS	WEU	UNECE
Gas TPES EJ)	Actual	1.84	3.15	2.06	29.25	15.23	0.55	14.64	66.73
District heating	Actual	15.90%	2.50%	6.40%	0.00%	12.00%	1.20%	1.70%	3.90%
Transportation	Actual	4.60%	3.60%	1.70%	2.90%	7.50%	4.80%	0.80%	3.50%
Industry	Actual	9.00%	10.10%	24.90%	18.90%	9.80%	8.90%	21.80%	16.90%
Residential/Commercial	Actual	25.70%	29.30%	37.00%	30.00%	12.50%	29.50%	40.60%	28.40%
Other (electricity, exports et al)	Actual	44.80%	54.50%	30.00%	48.20%	58.20%	55.70%	35.10%	47.30%
2035		BMU	CAS	EEU	NAM	RUS	SCS	WEU	UNECE
Gas TPES (EJ)	P2C	1.67	2.44	3.03	27.03	13.68	0.41	22.62	70.87
Gas TPES (EJ)	REF	2.17	2.87	2.86	31.87	18.39	0.52	22.89	81.58
District heating	P2C	10.90%	7.20%	10.90%	1.80%	6.80%	3.30%	2.10%	3.70%
District heating	REF	6.70%	2.80%	0.70%	0.10%	4.90%	0.00%	1.20%	1.80%
Transportation	P2C	0.10%	1.20%	0.00%	0.00%	2.20%	0.00%	0.80%	0.70%
Transportation	REF	3.40%	3.60%	0.00%	1.40%	5.60%	4.20%	0.90%	2.30%
Industry	P2C	11.70%	10.90%	16.90%	12.20%	13.50%	6.20%	22.00%	15.70%
Industry	REF	15.30%	19.80%	7.90%	10.20%	17.40%	6.40%	10.40%	12.20%
Residential/Commercial	P2C	21.30%	28.20%	34.40%	24.30%	15.70%	23.60%	34.50%	26.40%
Residential/Commercial	REF	30.70%	28.80%	68.60%	21.90%	17.80%	28.10%	40.80%	28.40%
Other (electricity, exports et al)	P2C	56.10%	52.50%	37.80%	61.70%	61.90%	66.90%	40.50%	53.50%
Other (electricity, exports et al)	REF	43.80%	45.00%	22.70%	66.30%	54.30%	61.30%	46.80%	55.20%
2050		BMU	CAS	EEU	NAM	RUS	SCS	WEU	UNECE
Gas TPES (EJ)	P2C	1.91	2.52	3.29	27.86	15.32	0.25	30.24	81.38
Gas TPES (EJ)	REF	1.98	2.67	3.13	34.56	21.26	0.52	30.67	94.79
District heating	P2C	7.70%	6.00%	10.30%	0.30%	4.90%	3.30%	2.90%	2.90%
District heating	REF	1.00%	0.70%	0.30%	0.00%	0.025	0.00%	0.00%	0.60%
Transportation	P2C	9.80%	6.40%	3.60%	0.00%	1.90%	0.00%	1.60%	1.50%
Transportation	REF	3.30%	3.50%	0.00%	0.40%	0.044	3.40%	0.80%	1.60%
Industry	P2C	12.60%	12.10%	19.40%	6.60%	10.80%	10.70%	15.80%	11.60%
Industry	REF	16.20%	16.00%	4.90%	10.40%	0.142	3.80%	12.80%	12.10%
Residential/Commercial	P2C	9.50%	15.40%	9.80%	11.00%	4.90%	14.70%	9.60%	9.40%
Residential/Commercial	REF	30.30%	34.00%	57.40%	19.30%	0.168	27.50%	29.70%	24.10%
Other (electricity, exports et al)	P2C	60.40%	60.10%	56.80%	82.10%	77.40%	71.40%	70.20%	74.55%
Other (electricity, exports et al)	REF	49.20%	45.80%	37.40%	69.90%	0.621	65.40%	56.80%	61.70%

Source: IIASA

3.4. Gas-to-liquids (GTL)

In the UNECE's more easterly regions, notably Russia and Central Asia, there are considerable opportunities for gas to play a significant role in the energy transition by playing a greater role in the provision of liquid fuels. Turkmenistan, for example, officially opened its first gas-to-liquids plant at Ovadan Depe near Ashgabat, on 28 June 2019. The plant will process some 1.785 bcm of natural gas a year, producing 600,000 tons a year (about 12,000 b/d) of A-92 (Euro-5 standard) gasoline. It will also produce 12,000 tons of purified diesel fuel and 115,000 tons of liquefied gas a year.

Uzbekistan's first GTL plant, to produce around 38,000 b/d, is due to be commissioned in 2020. Uzbek reports in mid-2019 said the turnkey contract for the Oltin Yo'l GTL plant at Kashkadarya plant was 76.6% complete, with actual construction around one-third complete. What is not so clear is the impact on CO_2 emissions, since the synthetic fuel will still be burned in conventional engines. In time, both commercial and environmental requirements might prompt Central Asia's gas producers to consider using gas to produce increased electricity to serve an increased use of electric vehicles.

4. Gas to Power, Power to Gas – and Hydrogen

Gas can also be exported indirectly, in the form of gas-fuelled electricity generation. In Azerbaijan, which relies on gas for 85% of its power production, electricity has for some years been exported to Georgia, Turkey, Russia and Iran. In 2019 it was selling its electricity as far afield as Bulgaria, Greece, Romania and Hungary and there were active plans for sales to Italy. Such gas to power exports may well appeal to the landlocked energy producers of Central Asia, notably Turkmenistan and Kazakhstan.

Power to gas (P2G) technology may also be applied to make use of the small quantities of intermittent renewable power that would otherwise have to be curtailed. P2G essentially involves the conversion of electrical power – which might be derived from wind, solar or other renewable forms of energy – into a gas fuel through the use of electrolysis to split water into hydrogen and oxygen. When burned with oxygen, hydrogen constitutes a zero emission fuel and is already used in fuel cells. If the hydrogen is combined with carbon dioxide, it creates both methane and water, the former being the prime component of natural gas. Hydrogen and carbon dioxide can also be used to produce methanol – a liquid which is already blended into the gasoline pool. If the carbon dioxide is itself derived from direct air capture, the resulting methane is carbon neutral.

On its own, hydrogen can be added to gas supplies to reduce carbon levels, with existing natural gas transportation and distribution pipelines capable of carrying a blend in which hydrogen constitutes some 10 to 20 per cent of the mix.

Overall, hydrogen is considered one of the most promising avenues for energy development and both research and active development into hydrogen-fuelled economies are being conducted in many parts of the UNECE region. However, the scope for P2G to play a significant role may prove to be limited, since if P2G were to make use of fully priced electricity, then the cost of the resulting methane or hydrogen might well prove to be significantly more than either natural gas or hydrogen derived from natural gas through steam reforming. A separate study on hydrogen is currently under assessment as part of the UNECE Pathways project. The issue of methane is addressed in a supplement to this series.

5. New Technologies

Decarbonisation of gas can take various forms. In Texas, a 50MW demonstration plant at La Porte near Houston is using the Allam Cycle process to produce electricity from gas whilst capturing the CO_2 so that it can be directly injected into pipelines. Construction was completed in 2017 and reports during the summer of 2019 indicate that operations are both successful and cost efficient, producing electricity at low cost and carbon in a form that can be used for a variety of industrial purposes, including injection into oil reservoirs to boost output through enhanced oil recovery. The project is backed by several large companies and the developer, NET Power, is reported to be planning to sell full production plants using this process in the next two years or so. In Houston itself, research is continuing on processes that would use gas to produce hydrogen for fuel cells (the UNECE is planning a separate activity on hydrogen).

6. The Investment Issue

Gas, in its various forms, has considerable potential to penetrate new markets but investment plans will need to be put in place now if it is to sustain demand in the UNECE region post-2030. Policies to combat the climate crisis and to promote decarbonisation, however, mean that investment plans will need to be very carefully assessed because of such risks as low rates of use, limited profitability, and stranded assets. Moreover, while the focus of these papers is sustainable energy, and, specifically, the role of gas in the energy transition, the question of the level of investment needed to meet UNECE energy requirements cannot easily be separated from consideration of climate change. This is particularly relevant to these papers in view of the modelling used to frame prospective developments.

This modelling specifically explores alternative policies designed within the context of delivering the 2°C limit on global warming to which UNECE member States agreed in 2015 (the P2C scenario). In comparison to a ‘business as usual’ scenario. This ‘business as usual‘ scenario – the Reference scenario – assumes policies already adopted and only takes into account policy changes to which governments are already committed.

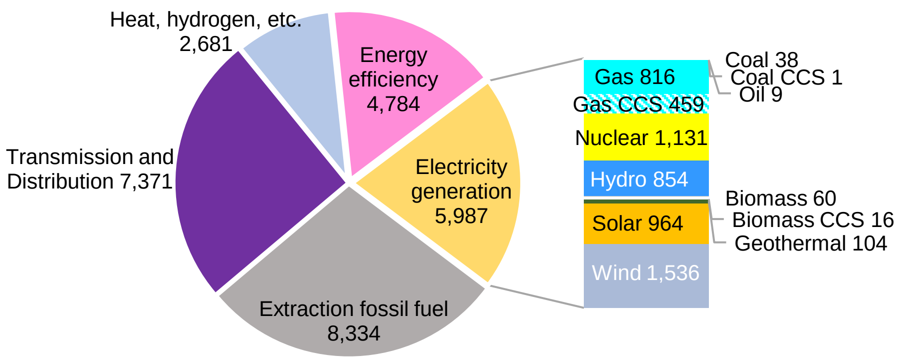
In this context, the investment issue primarily concerns the cost of prevention or adaptation versus the cost of remediation and/or the losses suffered as a result of failure to address climate change. This moves decision-making out of normal market mechanisms and requires the involvement of governments. However, there are major hurdles that need to be overcome if governments, companies and citizens are to be convinced of the necessity to play their role in paying for the kind of policies that would implement the Paris target.

The first hurdle is the sheer scale of the sums involved and how they should be expressed in a meaningful way. The second is that while the costs of prevention, of addressing climate change and energy transition issues directly, are commonly and openly presented as upfront costs, the costs associated with failing to address these issues tend to be unclear. They are expected to be large but difficult to quantify. They remain hidden at present, but will have to be paid as and when climate disasters strike specific communities, such as the wave of bushfires that engulfed much of southeastern Australia in December 2019 and January 2020, or when there is a breakdown in just-in-time delivery mechanisms for energy. A third concerns the issue of historical justice, that the more developed economies should bear more of the costs. Finally, there is a lack of global solidarity which inhibits paying costs if the benefits are accrued by other groups.

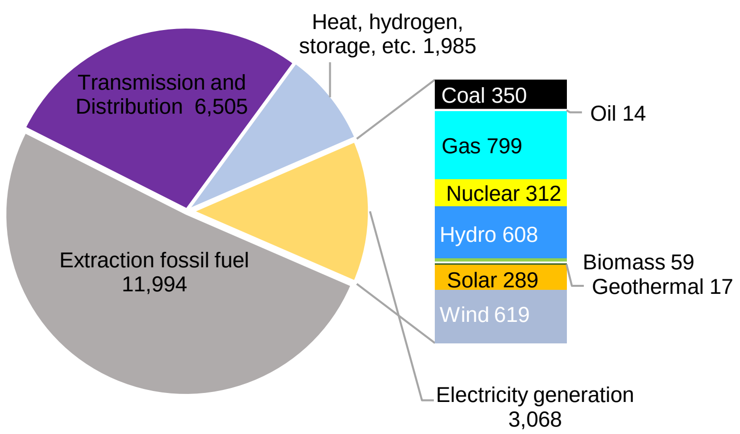
The sums involved in assessing the costs – and opportunities – associated with climate change and the energy transition are truly staggering; they are so big, so far beyond the scale of national budgets of all but the richest countries, that they appear incomprehensible. How do you explain the cost of paying an *extra* $5.6 trillion in energy investments over the next 30 years or so in order to ensure that the UNECE member States implement policies that would limit climate change to the two-degree-centigrade limit agreed in Paris in 2015?

How is this *extra* $5.6 trillion figure derived? It's the difference of $5,605 bn between IIASA's Reference scenario estimate of $23,552 billion in cumulative investments that will likely be made in energy to 2050 and its P2C scenario estimate of $29,157 billion (*See Figure 5*).

Figure 5
Cumulative Energy investments in the UNECE Region 2020-2050
P2C Scenario



REF Scenario



Source: IIASA

Box 1

The P2C Scenario and the Eurasian Energy Producers

One group of UNECE member States actually stand to save money through the adoption of policies designed to implement the Paris climate targets: the energy producers of Eurasia. This is particularly true of Russia, which might be expected to spend $5,903.9 bn between 2020 and 2050 if it continues, as IIASA's Reference scenario postulates, to develop its energy on a business-as-usual basis. But if Russia were to pursue a P2C trajectory, the investment costs would come down to $5,678.1 bn. This is largely because the increased investment in renewable energy is more than offset by the falling amount of investment in fossil fuel extraction, transportation and processing, which would total $4,890.4 bn under the Reference scenario but only $3,376.3bn under the P2C scenario. Curiously, there would even be a modest boost to exports, with IIASA postulating that Russian gas exports in 2050 would reach 463.8 bcm (17.280 EJ) under the Reference scenario but would total 468.9 bcm (17.469 EJ) under the P2C scenario.

Much the same applies to Central Asia, albeit on a more modest scale and with no boost to exports. Overall energy investment would total $1,684.1 bn under the Reference scenario but would be a little lower, $1,646.0, under the P2C scenario. The upstream and midstream investment requirement for fossil fuel extraction, transportation and processing would fall from $1,441.6 bn to $1,002.2 bn on the same basis. But while exports would total 83.1 bcm (3.095 EJ) in 2050 under the Reference scenario, under the P2C scenario, they would total 71.3 bcm (2.655 EJ).

In the South Caucasus region, although the total amount for energy investment envisaged by the P2C scenario is slightly higher than that postulated by the Reference scenario, $366.1 bn against $357.6 bn, the most striking element is the difference in upstream and midstream investment requirements, which total $309.1 bn under the Reference scenario but only $219.6 bn in the P2C scenario. This 29.0% difference – in line with both the 31.0% difference in Russia and the 30.5% difference in Central Asia – indicates that Azerbaijan, the only major fossil fuel producer in the region, would also see its overall energy investment requirements fall if it were to pursue policies to implement the Paris climate change targets. However, gas exports would be 16.1% lower. IIASA postulates South Caucasus (effectively Azerbaijan) exports in 2050 would total 28.3 bcm (1.056 EJ) under the Reference scenario and 23.8 bcm (0.886 EJ) under the P2C scenario.

7. The Bottom Line

Perhaps a better way to express the situation is to argue that, one way or another, the governments, companies and citizens of the UNECE region are expected to invest close to $25 trillion in energy by 2050, so why not spend an *extra* 23% – $5.6 trillion, or $186.8 billion a year for the next 30 years – to ensure there are limits to the devastation from climate change. Moreover, it's not as if the Reference scenario comes without additional costs; it's just that the costs of failing to address climate change do not necessarily come out of public or private sector expenditure that is directly related to energy and, because they are in response to events, the timing of such expenditures remains unknown.

$186.8 bn a year is certainly a big sum, but it should be seen in context. It's actually the equivalent of just 1.15% of the totality of the national budgets of all the UNECE's 56 member States. These amounted to to $16.4 trillion in 2017, of which $6.8 trillion was accounted for the US alone and $7.75 trillion by the 28 member States of the EU.

Moreover, this equivalence ignores two salient points. The first is that not all the extra money will come from government budgets, since companies and customers will also play their part; the second is that these figures include vast sums required for investment in various forms of energy and energy efficiency, and those will, of course, yield a return on their investment.

7.1. Financial losses

So how does such potential expenditure to avert global catastrophe compare with possible losses if such investments are not made? As noted above, the *extra* investment requirement of $5.6 trillion envisaged under IIASA's P2C scenario averages out at $186.8 billion a year. By comparison, the Global Commission on the Economy and Climate noted in 2018: "Disasters triggered by weather- and climate-related hazards were responsible for thousands of deaths and US$320 billion in losses in 2017." Of course, the former figure relates to the UNECE region, and the latter to the whole world, but they do a least point to a similar scale of magnitude.

In specific energy terms, the Commission also noted in its 2018 report that: "Estimates suggest that mixed signals could lead to US$12 trillion of stranded fossil fuel assets by 2035." In non-energy terms it added such elements as:

"Without adaptation, climate change may depress growth in global agriculture yields up to 30 percent by 2050."

"The number of people who may lack sufficient water, at least one month per year, will soar from 3.6 billion today to more than 5 billion by 2050."

"Rising seas and greater storm surges could force hundreds of millions of people in coastal cities from their homes, with a total cost to coastal urban areas of more than $1 trillion each year by 2050."

"Climate change could push more than 100 million people within developing countries below the poverty line by 2030."

It should also be noted that the leading Australian economist John Quiggin considers that the costs of the bushfires raging in Australia at the time of writing may eclipse A$100 bn (US$70 bn). Writing in January 2020, while the fires were still burning, Professor Quiggin argued:

“When environmental and health costs are taken into account, I estimate that it will probably cost the country more than 100 billion Australian dollars (about US$70 bn). In a country of just 25 million people, the impact of the fires will loom much larger than the effects of Hurricane Sandy, which hit 12 US states.”[17]

7.2. Financial gains

There are also gains to be made from implementing programmes to meet the challenges of energy transition and climate change. A 2016 report from the International Renewable Energy Agency (IRENA), found that “doubling the share of renewable energy in the global energy mix by 2030 is feasible and actually less expensive than not doing so. It can save up to $4.2 trillion annually by 2030 – 15 times more than the costs – all while achieving numerous economic, social and environmental goals.”

In 2018, the Global Commission on the Economy and Climate argued in its report that in just 12 years the world stood to gain as much as $26 trillion in economic benefits from taking immediate steps to combat climate change. However, it also warned: “We have now run out of time for incremental steps, generic proposals, or statements of broad principle.” It added that “to capture the net economic benefits of US$26 trillion through to 2030 and shift the world economy onto a more stable climate pathway,” a host of specific measures were required.

The Commission began its list of measures with this: “First, governments should put a price on carbon and move toward mandatory climate risk disclosure for major investors and companies.” It then added: “The major economies, led by the G20, should put a price on carbon of at least US$40-80 by 2020, with a predictable pricing pathway to around US$50-100 by 2030, as recommended by the High-Level Commission on Carbon Pricing.” The G20 grouping embraces eight UNECE member States, or nine if the EU is included.

There are other financial incentives to pursue policies in line with the Paris Agreement climate targets. In September 2019, the Global Commission on Adaptation issued a report saying that “our research finds that investing $1.8 trillion globally in five areas from 2020 to 2030 could generate $7.1 trillion in total net benefits.”

These five areas did not specifically embrace energy, although one of them is climate-resilient infrastructure, but the point is clear: there is a need for immediate investment since the goal is to generate income for development rather than to rely on supposed savings now that will later have to be spent on covering the cost of environmental catastrophes.

In this context, the *extra* $5.6 trillion required for the UNECE region to meet the Paris Agreement targets remains substantial, but such spending is, at least, accompanied by the prospect of trillions of dollars, perhaps tens of trillions of dollars, of savings and investment returns.

The investment costs that each of the UNECE areas would have to find under IIASA’s P2C and Reference scenarios are set out in *Table 4*.

Table 4
Energy Investments to 2050, by Sub-Region (In $ bn)
(demand in Bcm)

Sub-region	P2C Scenario	REF Scenario
Belarus-Moldova-Ukraine	515.3	368.9
Central Asia	1,646.0	1,684.1
Central and Eastern Europe	1,304.6	771.1
North America	13,928.9	10,597.7
Russian Federation	5,678.1	5,903.9
South Caucasus	366.1	357.6
Western Europe	7,138.2	5,234.7
UNECE Total	**30,577.2**	**24,918.1**

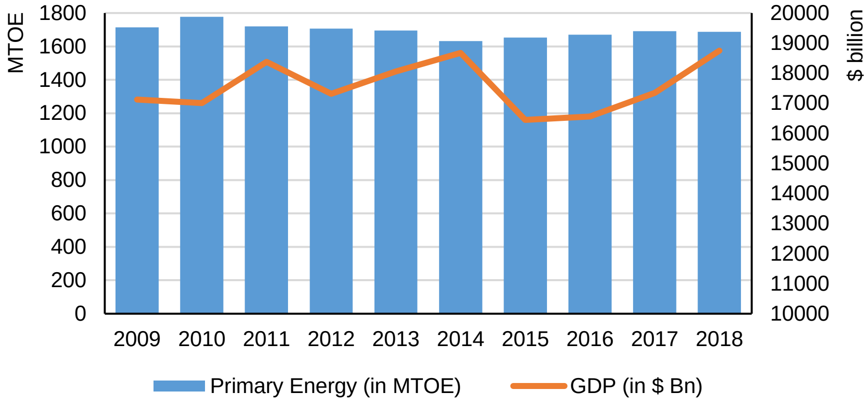
Source: IIASA

8. Energy Efficiency: The Case of the EU

How much the spread of penetration of gas into new markets, whether geographical or technical, will impact on the twin issues of delivery of sustainable energy and decarbonisation will largely depend on a quite different factor: energy efficiency. In this respect, the example of the European Union, which accounts for 45% of both the UNECE's population and its GDP, may prove instructive.[5]

One of the most striking developments in the EU recent years has been the ability of this bloc to secure economic growth without witnessing any real growth in the actual use of energy. In the wake of the global financial crisis of 2008, the EU's primary energy consumption and its GDP both fell significantly, but the economic recovery only saw an initial return to increased energy consumption. Since 2012, total primary energy consumption has been relatively stable, ranging from 1,705 mtoe in 2012 to 1,688.2 mtoe in 2018, with a low of 1631.7 mtoe in 2014. Meanwhile, however, GDP has risen from $17,316.99 bn to $18,748.57 bn (*see Figure 6*).

Figure 6
EU Primary Energy & GDP 2008-2018



Source: BP Statistical Review of World Energy 2019 and Trading Economics, World Bank 2019

[5] The UNECE's Statistical Database provides information showing that the total population of the 56 member states in 2017 was 1,127,525,649, with 511,876,259 people inhabiting the 28 EU member states. The Database provides GDP figures, in absolute value and adjusted by purchasing power parities, which show that the collective GDP of all 56 UNECE member states totalled $48,446,850.6 million in 2017, of which the 28 member states of the EU accounted for $21,820,931.3 million.

The new European Commission that took office on 1 December 2019 can be expected to pursue policies aimed at further weakening the link between economic growth and energy consumption, so it is reasonable to expect that energy efficiency will yield further positive results in the campaign to secure both decarbonisation and energy sustainability within the EU. But it cannot automatically be expected that other parts of the UNECE, notably where there are major fossil fuel energy producers, will succeed in promoting energy efficiency to the same extent.

9. Conclusion

The future of gas, and prospects for new geographical markets and for new applications, have to be considered against a background of increasing urgency about the need to tackle the climate emergency. The 56 national governments in the UNECE region will have to craft a way to find the extra $186.8 bn that needs to be spent every year for the next 30 years if the region is to meet the Paris Agreement target of limiting the increase in global temperature to no more than two degrees. The burden will fall on general taxation, on industry and on ordinary consumers. Striking the right balance will not be easy.

At the same time, the overall demand for energy is likely to increase while the position of gas is changing. The conventional wisdom of gas as a transition fuel for electricity production is being overtaken by the dramatic changes in the costs and deployment of renewables. Combined with political imperatives around a climate emergency, gas may increasingly be dismissed as countries invest directly in renewable energy. This leaves the main strategic argument for investing in gas as a route to improving energy security and enhancing the quality of life quickly by using readily available technologies for power and heating.

This may change if the gas industry embraces carbon capture, use and storage to position itself as a carbon neutral fuel – guaranteeing to sequestrate the CO_2 resulting from using gas in order to compete with renewables.

The development of new market applications is particularly favoured where renewables are a long way from being feasible, let alone economically competitive. Renewable energy is focused on electricity which is a major sector, but not the only sector. In areas such as transport fuels, either as CNG, LNG or GTL, there are market segments where the competitive technology is still oil. In the process and manufacturing industries gas is a feedstock and clean fuel to obtain high process temperatures. The development of these segments will require the gas industry to be proactive in developing downstream markets and lobbying for enabling regulations. Such markets can be sophisticated and require both technology to be developed and also the service industry that goes with it.

While there are some sub-regions of the UNECE where the future of gas appears bright, in the main there is pressure to reduce gas usage. The gas industry can no longer be complacent and will have to fight harder to maintain its position.

There is a clear dichotomy between the advances in technology that demonstrate that natural gas is capable of playing a larger role in transportation and the modelling that indicates its role in this key sector is likely to shrink considerably. This appears to reflect the possibility that advances in the use of gas will be overtaken by swifter progress in developing and adapting renewables, notably through improvements in battery and fuel cell technology.

Overall, such uncertainty indicates that both governments and the gas industry will have to work together to craft a clear set of policies and regulations to enable gas to play a major role in the transportation element of the energy transition. The same point can be made in terms of basic provision of gas to more remote areas in the UNECE region that currently lack access to gas.

In sum, market design is everything.

Abbreviations

bcm	billion cubic meters
BMU	Belarus, Moldova and Ukraine
CHP	combined heat and power
CNG	compressed natural gas
ECA	emission control area
EJ	exajoules
ENTSOG	European Network of Transmission System Operators for Gas
EU	European Union
EV	electric vehicles
GTL	Gas-to-liquids
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IMO	International Maritime Organisation
GDP	Gross domestic product
LNG	Liquified natural gas
Mt	million tonnes
Mtoe	millions of tonnes of oil equivalent
NGV	natural gas vehicles
OIES	Oxford Institute for Energy Studies
TAP	Trans Adriatic Pipeline
US	United States

References

[1] Aleksandar Kovacevic. *Towards a Balkan gas hub: the interplay between pipeline gas, LNG and renewable energy in South East Europe.* Oxford Institute for Energy Studies, 2017. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/02/Towards-a-Balkan-gas-hub-NG-115.pdf?v=f214a7d42e0d
[2] Kovacevic, OIES. Op cit.
[3] Markus Schneider. *Feasibility study for the Balkan Gas Hub. Interim Report* 12 June 2018. Balkan Gas Hub, Brussels. https://www.europeangashub.com/wp-content/uploads/2018/06/Balkan-Gas-Hub_12062018.pdf
[4] Kovacevic, OIES. Op cit.
[5] Turkey's BOTAŞ has reported imports of 46.83 bcm in 2019. Somewhat frustratingly, reports in the Turkish media, including the official Anadolu agency, cite the comparable 2018 figure as being "around 50 bcm" (See: *https://www.aa.com.tr/en/economy/total-inflow-to-turkish-gas-system-down-633-in-2019/1692182*). Demand is usually slightly lower than imports, with Anadolu citing a demand figure for 2018 of 49.33 bcm. The demand figures quoted in the text of this paper come from the *BP Statistical Review of World Energy 2019*.
[6] Kovacevic, OIES. *Towards a Balkan gas hub: the interplay between pipeline gas, LNG and renewable energy in South East Europe*. OIES PAPER: NG 115, Aleksandar Kovacevic. Oxford Institute for Energy Studies, February 2017. 2013 figures from Table 3, page 10; 2025 figures from Table 12, page 77
[6] Bjornson. Interview with Natural Gas World. 4 February 2016. Author's notes.
[7] Reiljan. Address to the Baltic Gas Conference, Tallinn, 27 November 2019. Author's notes.
[8] *Fuel Switch to LNG in Heavy Truck Traffic* by Ivan Smajla, Daria Karasalihović Sedlar, Branko Drljača and Lucija Jukić, Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Pierottijeva 6, 10 000 Zagreb, Croatia. The study is available at: https://www.mdpi.com/1996-1073/12/3/515
[9] Zagreb Op Cit.
[10] TNO report. TNO 2017 R11336. *Emissions testing of two Euro VI LNG heavy-duty vehicles in the Netherlands: tank-to-wheel emissions.* https://publications.tno.xn--nl%20%***20 publication***%20%***20 tno***-2019-r10193
[11] Cedigaz. Madden, Mike, White, Nick, & Le Fevre, Chris (Sep 2014). LNG in transportation (INIS-FR--15-0528). France.
[12] OIES. Chris Le Fevre, A *review of demand prospects for LNG as a marine transport fuel*. June 2018. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/07/A-review-of-demand-prospects-for-LNG-as-a-marine-fuel-NG-133.pdf
[13] OIES. Op cit.
[14] OIES. Op cit.
[15] https://www.shell.com/energy-and-innovation/natural-gas/lng-for-transport/news-and-media-releases/lng-london-bunker-vessel-begins-operations-in-europe.html
[16] https://worldmaritimenews.com/archives/279371/titan-lng-names-europes-1st-dedicated-lng-bunker-barge/
BP (2019), BP Statistical Review of World Energy 2019 https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf
World Bank (2019), Trading Economics; World Bank, https://tradingeconomics.com/european-union/gdp
[17] John Quiggin, Australian Laureate Fellow in Economics, University of Queensland, Article for CNN Business Perspectives, 10 January 2020. https://edition.cnn.com/2020/01/10/perspectives/australia-fires-cost/index.html

The Potential of Natural Gas to Penetrate New Markets

The versatility of gas means it can be used for heat, for power, for combined heat and power (CHP), for petrochemicals and fertilisers, and in internal combustion engines. Natural gas can also be used as a source of hydrogen, and with biogas can contribute to decarbonization.

Flexibility means there are considerable opportunities for expanded use of liquefied natural gas and compressed natural gas in land transport and for LNG at sea. New geographical markets are also available for natural gas in Southeastern Europe, and, especially, in parts of Russia and Central Asia.

Prospects for new geographical markets and for new applications have to be considered against a background of increasing urgency about the need to tackle the climate emergency. Modelling carried out for the UNECE indicates that If the UNECE region is to meet the Paris target of limiting the increase in global temperature to no more than two degrees, then its 56 member States will have to invest an extra $180 bn a year for the next 30 years over and above what they might otherwise be expected to invest in energy. Yet the potential costs of failing to address the climate emergency are of a comparable magnitude. Striking the right balance will not be easy.

Information Service
United Nations Economic Commission for Europe

Palais des Nations
CH - 1211 Geneva 10, Switzerland
Telephone: +41(0)22 917 12 34
E-mail: unece_info@un.org
Website: http://www.unece.org