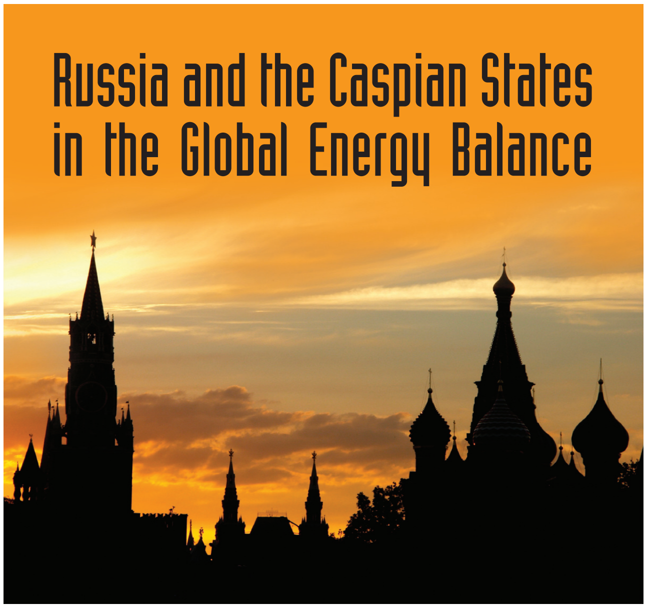
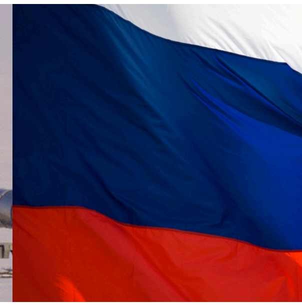
# Russia and the Caspian States in the Global Energy Balance





## Scenarios for Russian Natural Gas Exports: The Role of Domestic Investment, the Caspian and LNG

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# Scenarios for Russian Natural Gas Exports: The Role of Domestic Investment, The Caspian, and LNG

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# About the Study: Russia and the Caspian States in the Global Energy Balance

Russia's position as a major energy supplier has great significance not only for its foreign policy but for its relationships with major energy-consuming countries. The nature of Russia's future geopolitical role in world energy markets has become a major concern of international energy security with important implications for Europe, Japan, and the United States. Given a range of economic and geopolitical uncertainties, the fate of Russian and Caspian natural gas exports remains a major risk factor in global energy supply. For this study, researchers examined several scenarios for Russian and Caspian oil and natural gas production, possible export routes, and the geopolitics involved.

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## Abstract

Russia is the largest global natural gas supplier and has the potential to expand its production significantly. Europe depends on Russia for more than a quarter of its natural gas supply, placing Russia in a position to project its power to achieve political goals, higher prices, or both. However, pricing disputes that have led to short term supply reductions, most notably with Ukraine in the winters of 2005–06 and 2008–09, have caused European gas consumers to reconsider Russia's role in European energy security. Specifically, many European nations have significantly expanded liquefied natural gas (LNG) import capability, and there has been substantial effort devoted to looking at the development alternative pipeline routes to Europe for natural gas from the Caspian states of the Former Soviet Union.

Scenario analysis using the Baker Institute World Gas Trade Model (BIWGTM) indicates that Russia may be less able to negatively influence the Western European gas market in future years. In general, as a global market for natural gas continues to develop the diversity of alternative suppliers will increase thereby lessening the effects of instability in any single region. Specific to Europe, while increased LNG import capability certainly plays an important role, the response of European consumers to future supply disruptions also accelerates other import avenues. Specifically, natural gas supplies imported by pipeline from the Middle East, in particular Iraq, could play a key role. The importance of the Middle East to European supply diversification, however, means any collusion between Russia and the major producers in the Middle East could pose a significant threat to global energy security.


## I. Introduction

According to the U.S. Energy Information Administration (EIA), Russia is the largest natural gas supplier, with dry gas production in 2007 of 23.1 trillion cubic feet (tcf) representing over 20 percent of global output. Russia could also significantly expand production. The *Oil & Gas Journal* reported Russian-proved natural gas reserves of 1,680 tcf in 2007, and the U.S. Geological Survey (USGS) reports a mean estimate of undiscovered, technically recoverable natural gas resources of 1,168 tcf and an additional 358 tcf of potential reserve growth in existing fields, yielding a total of more than 3,200 tcf of recoverable natural gas resource.

In 2007, Russian net exports, primarily to Europe, equaled 6.6 tcf. Europe as a whole now relies on Russia for about one quarter of its natural gas supply, with the reliance of some countries even higher. For example, Russia supplies over one-third of Germany's requirements, and East European and Baltic countries, which were closely integrated with Russia in the Communist era, are even more dependent.

Gazprom produces more than 80 percent of Russia's natural gas and controls access to Russia's domestic natural gas pipeline system. While renegotiating export prices to Ukraine in the winter of 2005–06, and again in 2008–09, when demand in both Ukraine and Western Europe was high, Gazprom temporarily reduced supply to Ukraine. While the principal motivation may have been a desire to raise Ukrainian prices closer to European netback parity, since the 2005–06 cut-off occurred not long after a new government less friendly toward Russia took office in Ukraine, it was widely interpreted as an attempt to interfere in Ukrainian politics.[1] Regardless of the motivation, the event substantially raised energy security concerns among European consumers.

[1] Stern (2006) discusses the January 2006 crisis in some detail.

## Table 1: LNG Import Terminals and Capacity in Europe

| Terminal | Location | Country | Current Capacity (Bcm/yr) | Current Capacity (bcf/d) | Initial Start-up |
|---|---|---|---|---|---|
| ***Existing*** | | | | | |
| Fluxys LNG | Zeebrugge | Belgium | 9.1 | 0.8805 | 1987 |
| Fos Sur Mer | Fos sur Mer, Marseille | France | 4.5 | 0.4354 | 1972 |
| Montoir De Bretagne | Montoir-de-Bretagne, Nantes | France | 10 | 0.9675 | 1982 |
| Revithoussa | Revithoussa, Athens | Greece | 4.5 | 0.4354 | 2000 |
| GNL Italia | Panigaglia | Italy | 3.5 | 0.3386 | 1971 |
| Sines LNG | Sines | Portugal | 5.2 | 0.5031 | 2003 |
| Barcelona | Barcelona | Spain | 14.45 | 1.3981 | 1969 |
| Bilbao | Bilbao | Spain | 8 | 0.7740 | 2003 |
| Cartegena | Cartagena | Spain | 10.5 | 1.0159 | 1989 |
| El Ferrol LNG | Murgados | Spain | 3.6 | 0.3483 | 2007 |
| Huelva | Huelva | Spain | 11.83 | 1.1446 | 1988 |
| Saggas | Sagunto, Valencia | Spain | 6.57 | 0.6357 | 2006 |
| Aliaga | Aliaga | Turkey | 6 | 0.5805 | 2006 |
| Marmara Ereglesi | Marmara Ereglisi | Turkey | 5.2 | 0.5031 | 1992 |
| Grain LNG | Isle of Grain, Kent | UK | 13 | 1.2578 | 2005 |
| Teeside Gasport | Teesside | UK | 4.13 | 0.4000 | 2006 |
| ***Total*** | | | ***120.08*** | ***11.62*** | |
| ***Under Construction*** | | | | | |
| Fos Cavou | Fos Cavaou | France | 8.25 | 0.7982 | 2009 |
| OLT Offshore LNG Toscana | Offshore Port of Livorno | Italy | 4.7 | 0.4547 | 2011 |
| Terminale LNG Adriatico | Offshore Rovigo | Italy | 8 | 0.7740 | 2009 |
| Dutch Gate Terminal | Rotterdam | Netherlands | 12 | 1.1610 | 2011 |
| Dragon LNG | Waterston, Milford Haven, Wales | UK | 6 | 0.5805 | 2009 |
| South Hook LNG | South Hook, Milford Haven, Wales | UK | 10.5 | 1.0159 | 2009 |
| ***Total*** | | | ***49.45*** | ***4.78*** | |
| ***Approved/Applied*** | | | | | |
| ASG Power | Albania | Albania | 20 | 1.9351 | 2011 |
| Adria LNG | Krk Island | Croatia | 10 | 0.9675 | 2014 |
| Pegaz LNG | Le Verdon, Port of Bordeaux | France | 9 | 0.8708 | 2013 |
| sche Fluesigerdgas Terminalgasellscha | Wilhelmhaven | Germany | 10.7 | 1.0353 | 2017 |
| Shannon LNG | Shannon Estuary | Ireland | 4.12 | 0.3986 | 2011 |
| API Nova Energia | Offshore Falconara | Italy | 4 | 0.3870 | 2011 |
| Brindisi LNG | Brindisi | Italy | 8 | 0.7740 | 2010 |
| Endesa | Offshore Trieste | Italy | 8 | 0.7740 | 2010 |
| Gas Natural | Taranto | Italy | 8 | 0.7740 | 2009 |
| Gas Natural - Trieste | Port of Trieste-Zaule | Italy | 8 | 0.7740 | 2014 |
| Ionio Gas LNG | Priolo-Augusta area in Sicily | Italy | 5.8 | 0.5612 | 2013 |
| LNG Medgas | Gioia Tauro, Calabria | Italy | 12 | 1.1610 | 2013 |
| Nuove Energie | Offshore Porto Empedocle, Sicily | Italy | 8 | 0.7740 | 2011 |
| Rosignano Maritomo | Livorno | Italy | 4.1 | 0.3967 | --- |
| Polskie LNG | Swinoujscie | Poland | 2.5 | 0.2419 | 2014 |
| El Musel LNG | Gijon | Spain | 6.4 | 0.6192 | 2013 |
| Liongas LNG | Rotterdam, Europoort area | Netherlands | 9 | 0.8708 | 2012 |
| Essent | Eemshaven | Netherlands | 12 | 1.1610 | 2015 |
| Anglesey | Anglesey, Wales | UK | 31.01 | 3.0000 | 2012 |
| ***Total*** | | | ***180.63*** | ***17.48*** | |

Source: *Platt's LNG Daily's Terminal Tracker* (February 10, 2009)

The more recent episode during the winter of 2008–09 has again heightened concerns about energy security. It appears that this event is less related to political developments in Ukraine and more related to a dispute over the appropriate price for Russian supply to Ukraine. It may be reasonable, therefore, to hope that, once a price and other contract terms were agreed, a long term arrangement would limit the recurrence of supply disruptions. Nevertheless, the fact that Russian supplies have been cut in the winter heating season twice in the past few years has left European consumers resolved to minimize their exposure.

For countries in Western Europe, liquefied natural gas (LNG) is becoming a viable direct alternative to Russian gas. Central European countries also will benefit indirectly from LNG to the extent Western European countries at the “end-of-the-pipe” can replace Russian supply by displacement. Table 1 lists European LNG import facilities that currently exist, are under construction, or are in the approval stages along with capacities and start-up dates.

In 2009, the total capacity for LNG imports into Europe will be in excess of 15 billion cubic feet (bcf) per day (160 billion cubic meters [bcm] per year). This equates to roughly 27 percent of annual projected demand in Europe. This, coupled with storage capability, could allow many countries in Europe to withstand a prolonged shortage of Russian supply, be the cause political or commercial. By 2011, LNG import capacity in Europe could amount to almost 40 percent of annual demand, as import capacity could nearly triple from its level in 2000.

Concern over security of supply has heavily influenced the pace at which LNG import capacity is expanding (or being planned) in Europe. Many of the terminals listed in Table 1 were either first proposed or their timelines were accelerated following the Russia–Ukraine incident in the winter of 2006. Each cut in Russian supply increases the perception that alternative sources of supply will be needed. In turn, the availability of import options that seem more secure encourages European diversification away from Russian supply. In the long term, this could produce a European market immune to prolonged shortfalls in Russian supply.

Concern is also mounting over Russia’s ability to meet its future contractual commitments. Although Russian natural gas production was about 10 percent below 1992 levels by 1997, it was above 1992 levels by 2005. Nevertheless, strong growth in domestic demand and exports has required Russia to increase its imports of gas from Caspian states. This, however, may not be sustainable, and prompted the Ministry of Industry and Energy to state in October 2006 that Russia could face a natural gas shortage as early as 2010.

One factor that may alleviate concerns of Russia's ability to meet its internal and external demands in the short term is the effect that the global economic crisis may have on demand. In particular, the reductions in demand resulting from lower economic activity will reduce the pull on Russian supplies from Europe as well as from domestic consumers. To the extent that demand is reduced, it could delay the onset of any impending gas shortage in Russia.

Growth in domestic production requires new investments, but Gazprom is restricted in its ability to use external capital. In addition, Gazprom has difficulty generating internal investment funds since more than 70 percent of its production is sold domestically at highly subsidized prices (currently approximately $0.80 per thousand cubic feet (mcf) according to EIA (2008)).

In late 2006, the Russian government proposed a gradual increase in natural gas prices to market-based levels and in May 2008, the government approved tariff increases of up to 28.6 percent in 2008, followed by 19.9 percent in 2009, 28 percent in 2010, and 40 percent in 2011. Fearing the inflationary consequences, the government has stopped short of the original goal of complete liberalization by 2011, at least for the industrial sector. In addition, a commitment to raise future prices may perversely discourage production in the near term. To the extent that Gazprom can sell less natural gas domestically at current low prices (for example, through quantity rationing or by ceding market share), it will have more gas to sell at future higher prices.

Russian natural gas production in 2006 was 2.4 percent above 2005 output,[2] but Gazprom's share declined from 85.9 percent to 83.9 percent. Novatek, Lukoil, and Rosneft collectively had total production capacity of about 6.4 tcf per year in 2006, or about one-third of Gazprom's output. The production share of independent producers is expected to increase in coming years as the Ministry of Industry and Energy has stated that Russian independent producers are expected to supply more than half of the country's industrial needs by 2015 (Blagov (2007)). However,

[2] Preliminary data from the EIA suggests that total production declined slightly between 2006 and 2007.

growth of output from these independents may require investments in pipeline capacity, and, perhaps more importantly, full access to Gazprom's existing pipeline infrastructure.[3]

Over half of Gazprom's production comes from mature fields in West Siberia that are declining at an average rate of 0.7 tcf per year according to a recent International Energy Agency report (IEA (2006)). Gazprom therefore needs to develop new fields. According to Glazov (2007), total domestic production must increase substantially by 2030 to meet projected domestic demand and contracted exports. This will have to come from a combination of Gazprom's own production, the production of independents, and imports from Caspian states.

In 2005, Gazprom entered a joint venture to construct the offshore pipeline Nordstream to transport gas through the Baltic Sea from Russia to Germany.[4] Gas supply is projected to come from the Yuzhno-Russkoye oil and gas reserve in the Yamal Peninsula, and the Ob-Taz bay and Shtokmanovskoye fields.[5] In 2007, Gazprom also announced plans to develop two other fields in the Yamal peninsula to supply existing pipelines through Ukraine and Belarus and financed partly by projected revenues from the price increases to those countries. Finally, Gazprom has also announced plans to upgrade production and transmission systems in Eastern Siberia with a goal of exporting to China (Gazprom (2008)). Despite these announcements, the projects are not much beyond the planning stage and, therefore, the future of Russian gas exports remains uncertain.

In this paper, we use the Rice World Gas Trade Model (RWGTM) to compare the behavior of the world natural gas market in a reference case with corresponding outcomes under six scenarios effecting Russian production and exports:

- Scenario 1: Yamal Peninsula and Kara Sea resources remain undeveloped.
- Scenario 2: Russian exports are severely, but only temporarily, reduced in 2010, perhaps for political reasons.
- Scenario 3: Pipeline infrastructure from Russia to Asia remains undeveloped.

[3] Access is vital to expanded use of associated gas, rather than simply flaring it, and both former President Vladimir Putin and current President Dmitry Medvedev have publicly demanded that Gazprom facilitate third party access.
[4] Gazprom's partners in the project are BASF/Wintershall, E.ON Ruhrgas and N.V. Nederlandse Gasunie.
[5] See http://www.nord-stream.com/en/ for more detail.

- Scenario 4: The development of some proposed Russian export infrastructure is accelerated. In a variant on this scenario, we also examine the consequences if, in addition, pipeline infrastructure to move Middle East gas through Turkey, and from Iraq to Iran, is indefinitely delayed.
- Scenario 5: The development of proposed infrastructure to bypass Russian pipelines—such as the TransCaspian and Nabucco Pipelines—is accelerated. Once again, we also examine the consequences of accompanying this scenario with an indefinite delay in getting Iraqi gas out to either the West or East.
- Scenario 6: Russia, Iran and Qatar—the "Gas Troika"—coordinate natural export activities such that each seeks a higher return to exported volumes. We also examine a variant of this case where Iraqi gas development is indefinitely delayed.

## II. The Rice World Gas Trade Model

We use the Rice World Gas Trade Model (RWGTM) to analyze options for Russian natural gas. The RWGTM is a dynamic spatial general equilibrium model where supply and demand is balanced at each location in each period such that all spatial and temporal arbitrage opportunities are eliminated. The model, therefore, proves and develops reserves, constructs transportation routes and associated infrastructure, and calculates prices to equate demands and supplies while maximizing the present value of producer rents within a competitive framework. By developing pipeline transportation routes and LNG delivery infrastructure, the RWGTM provides a framework for examining the effects of critical economic and political influences on the global natural gas market within a framework grounded in geologic data and economic theory. Moreover, it provides insight as to the location and conditions under which resources are competitive in a global market.

The resource data underlying the model is based on the World Resource Assessment of the USGS, as well as data for existing reserves from the *Oil & Gas Journal* database. The USGS data includes both associated and unassociated natural gas resources. For North America, the resource assessment has been supplemented by the Potential Gas Committee and the U.S. Minerals Management Service for areas offshore and assessments of shale gas for the United

States and Canada collected from a variety of sources. Outside North America, the USGS assessment is confined to conventional gas resources, reflecting the lack of commercial data on unconventional natural gas deposits in other regions of the world. Australia is a major exception, where there has been tremendous activity in developing coal bed methane (CBM) deposits. Thus, our resource estimates are supplemented, where available, by local data sources, such as Australian Bureau of Agriculture and Resource Economics (ABARE) in the case of Australia. Long- and short-run capital and operating cost curves for resource development are derived using data from the National Petroleum Council (NPC).

Demand for natural gas is determined endogenously as the equilibrium price of natural gas adjusts, although there are also exogenous influences such as the level of economic development, the price of competing fuels, and population growth. The data used in estimating the demand relationships were obtained from the Energy Information Administration (EIA), the International Energy Agency (IEA), the World Bank, Organization of Latin American Developing Economies (OLADE), and the Organization of Economic Cooperation and Development (OECD). In the United States and Canada, ample availability of data allows demand to be modeled by major end-use sector using state-level panel data spanning the time period 1986–2006.

Demand for other regions of the world is modeled in multiple steps and for two broadly defined sectors: electric power and direct use. To begin, energy intensity (defined as the ratio of energy consumption to gross domestic product [GDP]) is estimated to decline as per capita income rises. The proportion of primary energy that is used to generate electricity is then modeled, so that a distinction between electricity and all other uses (direct use) can be made. Then, the shares of natural gas in electricity and direct use energy are modeled. First, the relative price of natural gas to other fuels matters, such that increasing natural gas prices will promote fuel switching in both the short and long run. However, the price elasticity is influenced by the degree to which an economy is already dependent on natural gas. For example, if natural gas share is already very high, the price elasticity will tend to be low. But, if the natural gas share is low, the price elasticity will tend to be high. This reflects the fact that energy use requires installed capital. An economy that is dependent on gas will have a lot of capital installed to use that fuel, and will likely be less able to switch away from it. The opposite would be true of an economy with very little natural gas using capital equipment.

In forecasting demand, we need forecasts for both economic and population growth. For the latter, we rely on population projections from the United Nations. For economic growth, we develop a model based on the notion of conditional convergence. Countries are assumed to converge to a reference growth rate, which is modeled as a per capita income dependent path using a spline knot regression of the per capita income growth rate of the United States on per capita income since 1840. Each country is then modeled as converging to this fitted long-run path where the rate of convergence is estimated using panel data for 78 countries.

Economic growth, expanding power generation requirements, and environmental considerations are the primary explanations for recent and projected rapid increases in natural gas demand. In developed economies, demand has been spurred by increasingly stringent environmental controls. However, development of coal gasification technologies, as well as nuclear and renewable energy technologies, could slow the increase in demand for natural gas as a fuel for generating electricity. Furthermore, the estimated elasticity of demand incorporated into the model reflects the substitution possibilities between gas and other fuels that were available in the historical data. This does not reflect new technologies that may increase substitutability, particularly at prices for natural gas that have not yet been observed. Thus, we also allow for the possibility that two backstop technologies—one based on the costs of coal gasification and another based on the costs of solar—could begin to displace natural gas late in the model time horizon.

The costs of constructing new pipelines and LNG facilities were estimated using data on previous and potential projects available from the EIA, IEA, and various industry reports. Transportation links connecting markets transmit price signals as well as volumes of physical commodity. Thus, for example, building a new link to take gas to a market with high prices will raise prices to consumers from the exporting region and lower prices in the importing region. More generally, it is in this manner that markets become increasingly connected over time, as profitable spatial arbitrage opportunities are exploited until they are eliminated. In a global natural gas market as predicted by the RWGTM, events in one region of the world generally influence all other regions. For instance, political factors affecting relations between Russia and China will affect gas flows and prices throughout the world, not just in Northeast Asia.

The model uses a weighted average cost of capital to determine the net present value of each increment of new capital. The debt-equity ratio is allowed to differ across different categories of investment (proving resources, developing wellhead delivery capability, constructing pipelines, and developing LNG infrastructure). Within the United States, Federal Energy Regulatory Commission (FERC)-filed tariff rates are used to determine the cost of transporting natural gas via pipeline. For regions outside the United States, a rate-of-return calculation is generally used to construct the tariffs on pipelines, such that the present value of the tariff revenue at 50-percent capacity utilization just recovers the up-front capital cost in 20 years. For LNG, facility throughput tariffs and shipping rates are based on information obtained from various industry reports.

The extent of regional detail in the model varies based primarily on data availability and the potential influence of particular countries on the global natural gas market. For example, large consuming and producing countries, such as China, the United States, India, Russia, and Japan, to name a few, have extensive sub-regional detail in order to understand the effect that existing or developing intra-country capacity constraints could have on current or likely future patterns of natural gas trade. In sum, there exist over 280 demand regions and more than 180 supply regions. Output from the model includes regional natural gas prices, pipeline and LNG capacity additions and flows, growth in natural gas reserves from existing fields and undiscovered deposits, and regional production and demand.

*Market structure in the RWGTM*

Global increases in natural gas demand, a push to monetize vast stranded natural gas resources, and improvements in LNG transportation technology have catalyzed unprecedented growth of the LNG market. This is a process that reinforces itself. As the alternatives available to both producers and consumers expand, the risk of investing in infrastructure is reduced and market liquidity increases as the number of possible trading partners grows. The implication of this outcome is that the market could move very quickly away from long-term bilateral contracts.

The RWGTM assumes that LNG is traded in a similar manner to the way oil is traded. Recognizing that the LNG market will most likely be dictated by some contract rigidities in the short term, we assume the market will be characterized by more flexibility in the long term. This does not mean that we have disregarded the importance of the long-term contract. Rather, we have assumed that while contracts are important for financing projects, they do not necessarily dictate physical flows of gas. Evidence of this is growing in the LNG market over the past several years, as the number of swap agreements and spot sales have grown.

## III. Reference Case[6]

The reference case supply projections in Figure 1 indicate Russia will remain the largest single producer throughout the model time horizon.[7] It remains the largest single supplier of natural gas to the European market, primarily by pipeline, but it does see a slightly diminished market share as LNG and other pipeline supplies compete into Europe. European consumers have supported the proposed Nabucco pipeline, carrying natural gas from the Caspian states to Europe via Turkey, as a way of lessening dependence on Russia. The reference case implies, however, that Turkey only becomes a significant corridor for natural gas imports to Europe once Iraqi supplies are developed.[8] The "East of the Caspian" group of countries (Kazakhstan, Turkmenistan, and Uzbekistan) export gas primarily through Russia. Moreover, exports to Western China via Kazakhstan do not appear economic, although the option is allowed in the model.

[6] It is important to note that we have not modeled the current economic and financial crisis. However, the analysis herein focuses primarily on long term ramifications of various changes to the system.
[7] The figures generally present the data in regional aggregates in order to clearly discern trends. Some countries substantially affected in some of our scenarios have been separately identified.
[8] The cases all assume that political turmoil in Iraq prevents development there until 2015.

**Figure 1. Reference Case Supply**

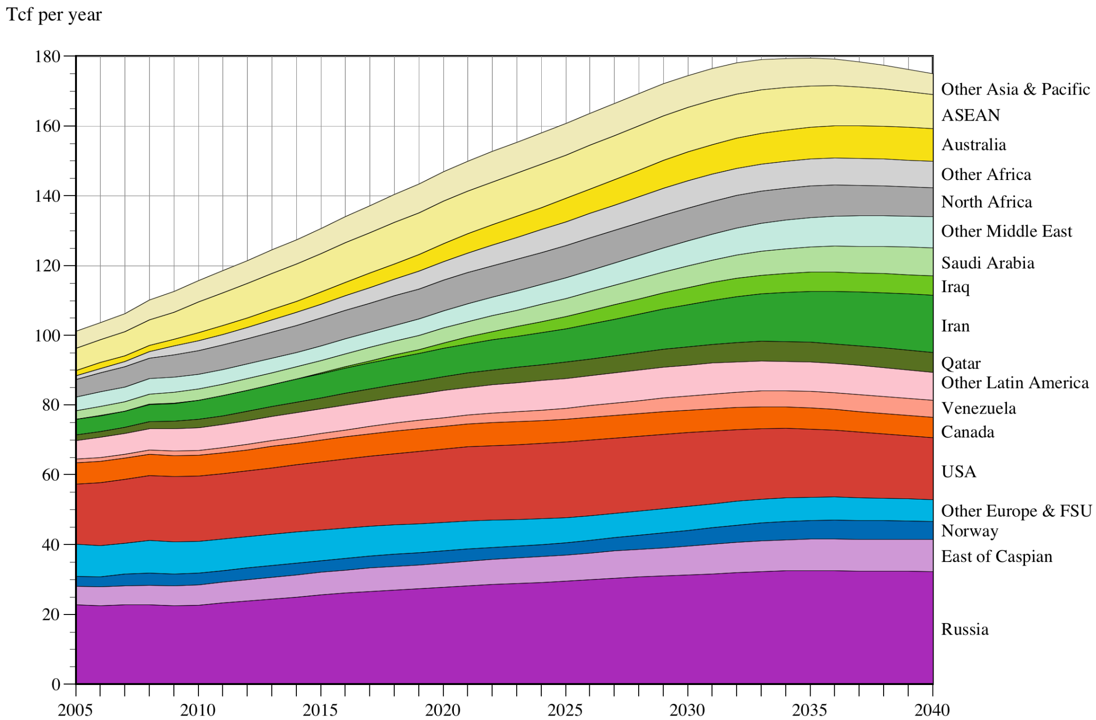
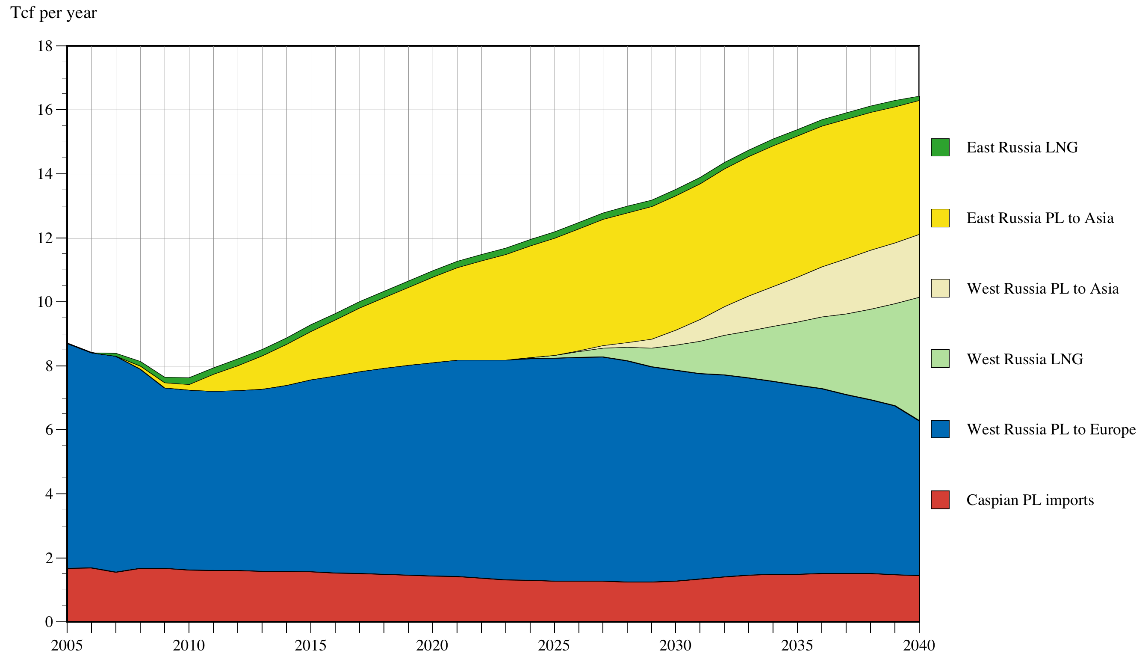


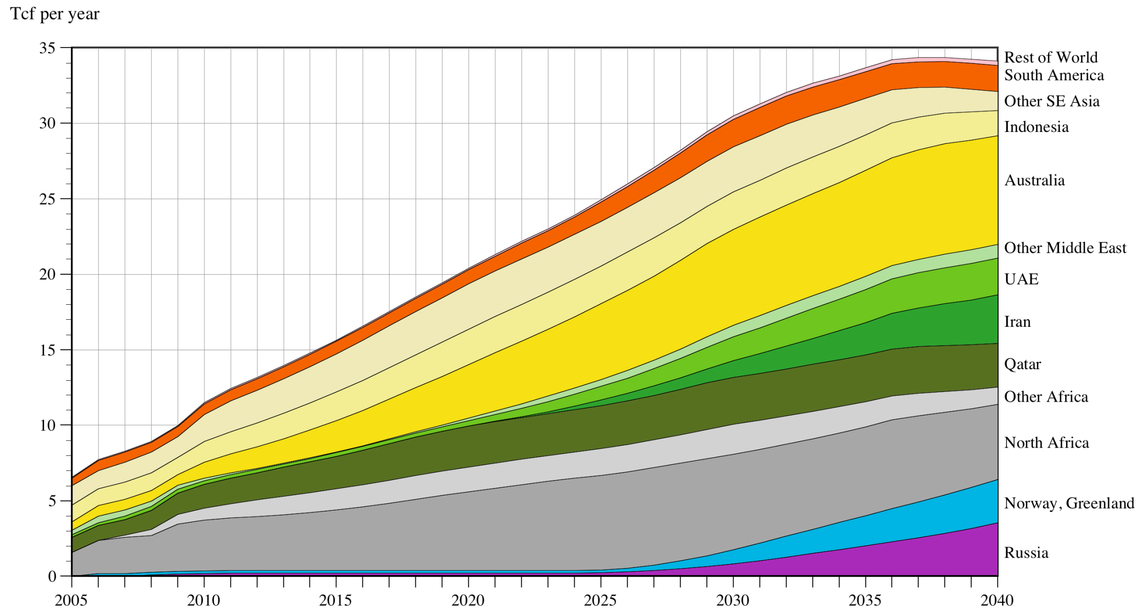

Figure 2 focuses on the Russian exports by source and destination. The figure indicates that Russian exports destined for Northeast Asia grow most strongly. Eastern Siberian natural gas begins flowing into Northern China at the beginning of the next decade and eventually flows into the Korean peninsula as pipeline capacity is developed. Toward the end of the 2020s, fields in West Siberia are also used to supply the Asian market. About the same time, Russia also begins exporting LNG from the Northwest. As these LNG exports increase, pipeline exports to Europe decline. Incremental production in the West comes primarily from supply developments in the Yamal Peninsula, Kara Sea, and Barents Sea, and serves to replace declining production in the mature fields in West Siberia, the Russian Caspian, Volga Urals, and Black Sea in addition to providing new sources for exports.

**Figure 2. Russian Exports by Origin (Basin Aggregates)**




Again referencing Figure 1, we see strong supply growth in the Middle East (indicated in shades of green), with its share of world production projected to rise from about 12 percent to more than 18 percent by 2025, and more than 24 percent by 2035. The largest Middle East exporter is Qatar, although Iran and Iraq are also projected to become significant exporters in later decades (see Figure 6). Although Figure 1 shows very strong supply growth in Iran, demand growth also is strong. This follows, in part, because Iran uses natural gas to enhance oil production, thus mitigating the ability to export natural gas. It also follows from the fact that Iran is projected to have a relatively large population growth rate, so domestic demands are projected to increase for uses in power generation in particular. Nevertheless, Figure 3, summarizing LNG exports, shows that substantial quantities of Iranian natural gas are eventually exported as LNG after the mid 2020s. Longer term export growth from Iran comes largely via the development of a pipeline to Pakistan and India beginning in 2025. Flows from Northern Iran to Azerbaijan, Armenia, and Turkey are also expanded, but are highly dependent on developments in Turkmenistan and Iraq. Iraq eventually becomes the dominant source of exports by pipeline from the Middle East, exporting natural gas produced in the Northern and Western provinces to Europe through Turkey.

**Figure 3. Reference Case LNG Exports**




Russian production in the Sakhalin region is exported as LNG, but also is eventually exported via pipeline to Japan, Northeast China, and the Korean peninsula. In the Atlantic basin, Barents Sea production eventually facilitates LNG exports beginning in the mid-2020s, but the majority of the gas produced in the region is exported via the Nordstream pipeline to Germany. Once Russia is supplying both the Atlantic and Pacific basins, it plays a key role in global price arbitrage since the netback price from sending supplies in any direction must be the same. Although the producing basins are not directly interconnected, they have common points of downstream reference once a pipeline connecting West Siberia to China is constructed in the mid 2020s.

Figure 3 also shows that overall growth in LNG supply is strongest from Australia and the Middle East, with the latter projected to supply from 25 to 30 percent of LNG shipments beyond 2035. Since the Middle East has better access to the sea than Russia, Turkmenistan, or Kazakhstan, but is at a relative disadvantage for supplying exports via pipeline (at least until Iraqi production grows dramatically from 2025), most Middle East exports are in the form of LNG. Qatar is the largest exporter of LNG from the Middle East until 2040. In the near term, Qatar is the beneficiary of first-mover advantage, largely due to its vast reserves and openness to Western interest, and thus is an early leader in the export of LNG. Other resource-rich countries must delay entry until prices increase enough to justify the substantial fixed costs of incremental infrastructure. Early entry would drive down prices and lead to inadequate returns on investment.

Another interesting note is that roughly half of Middle East LNG production is projected to flow into the Atlantic basin. While the Pacific basin is generally more dependent on LNG for balance, there are a greater number of suppliers—Australia, Indonesia, etc.—situated more closely to major demand regions in Asia. Thus, Middle East LNG exports tend to be distributed fairly evenly between the Atlantic and Pacific basins.

Figure 4 illustrates the reference case demand projections. The traditional markets of North America, Europe, and the former Soviet Union (FSU) are the largest consuming regions. The fastest growing region, however, is Asia, where demand growth exceeds 6 percent per year through 2020. Hence, global gas flows shift toward Asia over time.

**Figure 4. Reference Case Demand**

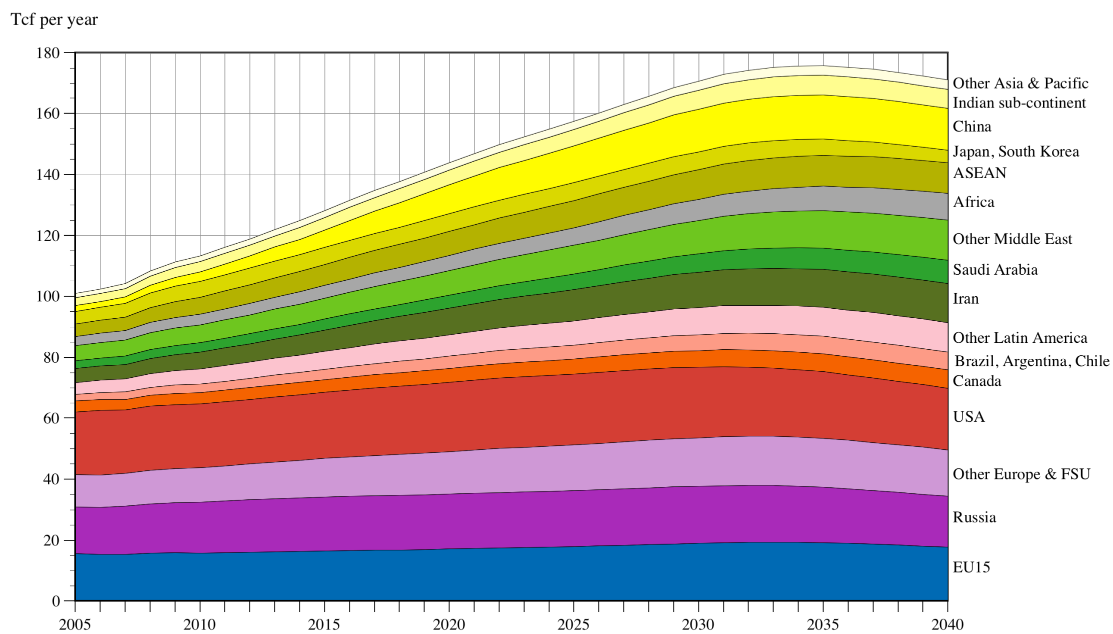
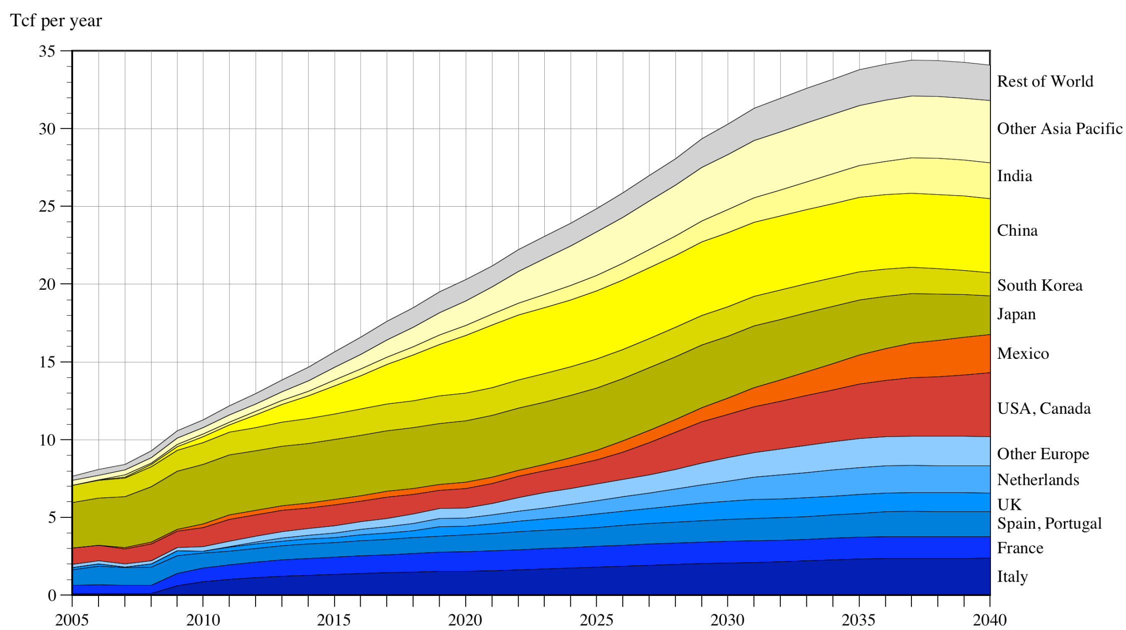



Figure 5, which summarizes global LNG imports, shows Chinese LNG imports growing substantially through 2030, commensurate with its rapid demand growth and lack of indigenous supply. In fact, LNG imports grow such that the market share plateaus at about 30 percent of the

Chinese gas market around 2020, thus indicating the importance of LNG for incremental demand growth over the next decade or so.

As demand growth in North America, Europe, and Asia outstrips domestic supply, LNG imports into these regions generally see substantial growth. The availability of unconventional gas supplies, in particular shale gas, in the United States delays substantial growth in imports until after 2025.[9] Thus, capacity that exists or is under construction is projected to be used with relatively low load factors for awhile. Beyond 2025, imports into the U.S. Lower 48 begin to grow. In addition, a substantial amount of LNG imported into Mexico and Canada is aimed to serve demand in the United States.

**Figure 5. Reference Case LNG Imports**




In Europe, strong demand growth and dwindling domestic supply stimulate imports from many sources. Europe imports gas by pipeline from Africa, the Middle East, and Russia and also as LNG from North and West Africa, the Middle East, South America, and eventually, the Russian Arctic.

[9] Shale assessments were developed from literature from the Association of American Petroleum Geologists, the Potential Gas Committee, and the USGS. The assessment of shale that is *technically recoverable* in the United States and Canada totals to 324 trillion cubic feet. Development costs are constructed using industry data on break-even economics in each of the 27 plays represented. More information is available from the authors upon request.

Figure 6 summarizes overall trade in natural gas, showing the rapid growth in exports by the Middle East and imports by Western Europe, Northeast Asia and, after 2025, North America. Russian exports are projected to decline from 2008, with a modest recovery beginning in the early 2010s and continuing until 2040 when exports are projected to be just under twice what they were in 2008 (see Figure 2), with the majority of growth coming from gas directed to Asia.

**Figure 6. Reference Case Gas Trades**

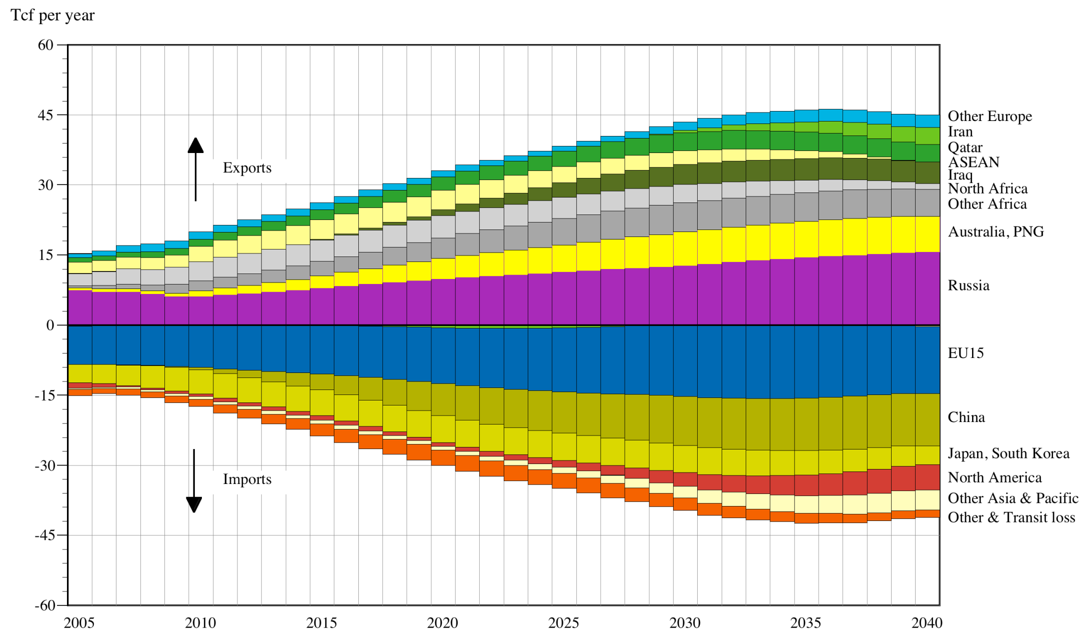



Figure 7 presents a few selected price paths from the model. Prices at Henry Hub and the National Balancing Point (NBP) are of interest because these are liquid points commonly used for contract and derivatives trading. Prices at the German–Austrian border are of interest because they are the highest prices in Europe, and are often used to evaluate pipeline projects from Russia and the Caspian. This particular location represents the balance point in Europe between flows from the North Sea, LNG imports, flows from North Africa, and flows from Russia and other former Soviet republics. The two prices in Northeast Asia (Tokyo and Beijing) represent the other major markets served by Russia. The Sydney price has been included to indicate how low prices can be in an exporting country with high transport costs.

**Figure 7. Reference Case Selected Prices**

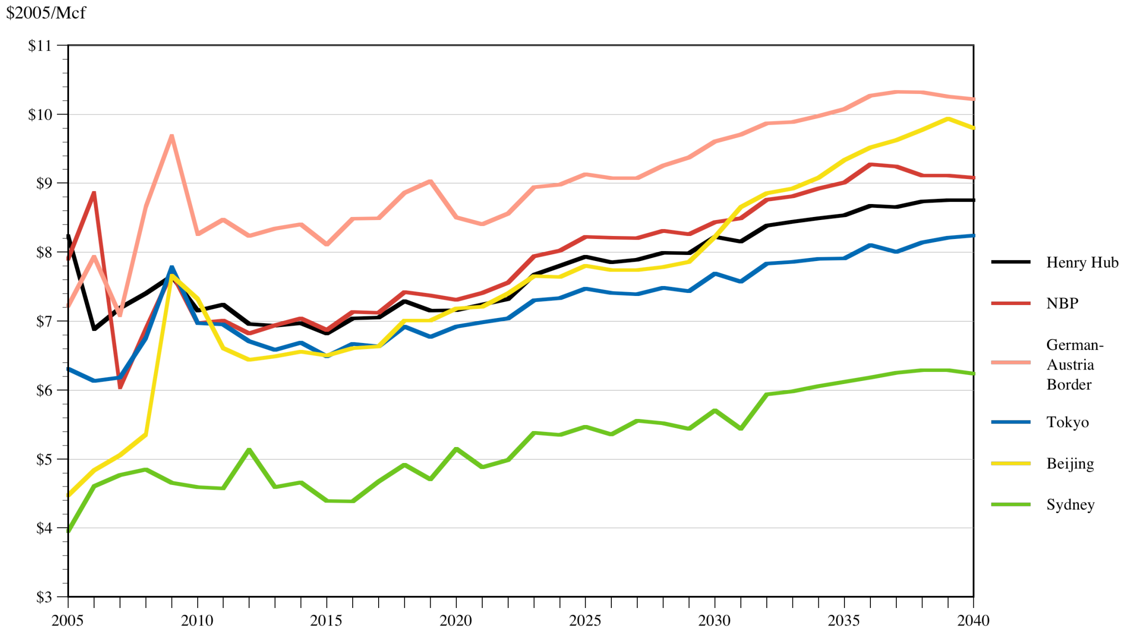



Figure 7 indicates that prices in different locations tend to move closely together beyond 2012, as LNG trade eliminates arbitrage opportunities. Prices in Japan and China move closely together until the late 2020s, during which period they both rely on LNG from similar sources. Beyond that date, Chinese prices rise toward prices in Eastern Europe as China becomes more dependent on imports from Russia via pipeline. It is important to note here that prices in Southeast China (not pictured) do not experience this phenomenon as the region remains more heavily linked to LNG. Long run prices at Henry Hub and NBP are closely related after 2010 as LNG of similar cost provides marginal supply to each location.

## IV. Summary of Key Results from Scenario Analysis

In this section, we present a summary of select results across all scenarios in order to highlight some of the key findings. Recall, the scenarios we considered were:

- Scenario 1: Yamal Peninsula and Kara Sea resources remain undeveloped.
- Scenario 2: Russian exports are severely, but only temporarily, reduced in 2010.
- Scenario 3: Pipeline infrastructure from Russia to Asia remains undeveloped.

- Scenario 4: The development of some proposed Russian export infrastructure is accelerated—including the Nord Stream and South Stream pipelines and pipelines to Asia from East and West Siberia and Sakhalin. In a variant on this scenario, we also examine the consequences if pipeline infrastructure to move Middle East gas through Turkey, and from Iraq to Iran, is indefinitely delayed.
- Scenario 5: The development of proposed infrastructure to bypass Russian pipelines—such as the TransCaspian and Nabucco Pipelines—is accelerated. Once again, we also examine the consequences of accompanying this scenario with an indefinite delay in getting Iraqi gas out to either the West or East.
- Scenario 6: Russia, Iran, and Qatar—the "Gas Troika"—coordinate natural export activities such that each seeks a higher return on exported volumes. We also examine a variant of this case where Iraqi gas development is indefinitely delayed.

In this section, we focus specifically on Russian production and Russian market share in Europe and Asia. A detailed description of each of the scenarios follows in section V. Figure 8 indicates Russian production through 2030 across all cases, and Figure 9 indicates the incremental impact on scenarios 4 through 6 of not allowing Iraqi gas development. In Figure 10, the Russian market shares in Europe for 2020 and 2030 across all cases are presented. Figure 11 indicates market shares in Asia.

Figure 8 reveals that Russian production grows in all scenarios. However, production growth is substantially lower in the scenario in which developments in the Yamal peninsula and Kara Sea are indefinitely delayed. Production growth is greatest in the scenario in which developments to move Russian supplies are accelerated, so the two cases which represent the highest and lowest production growth emphasize the importance of developing Russia's polar resources.

When Caspian development is accelerated to bypass Russian infrastructure, Russian production is lower than the reference case until around 2025, but becomes one of the highest-production scenarios longer term. This occurs because accelerating Caspian supplies in the near term raises the cost of supply in those countries in the longer term—allowing Russian production to increase as it becomes *relatively* less expensive.

**Figure 8. Russian Production Across Scenarios**

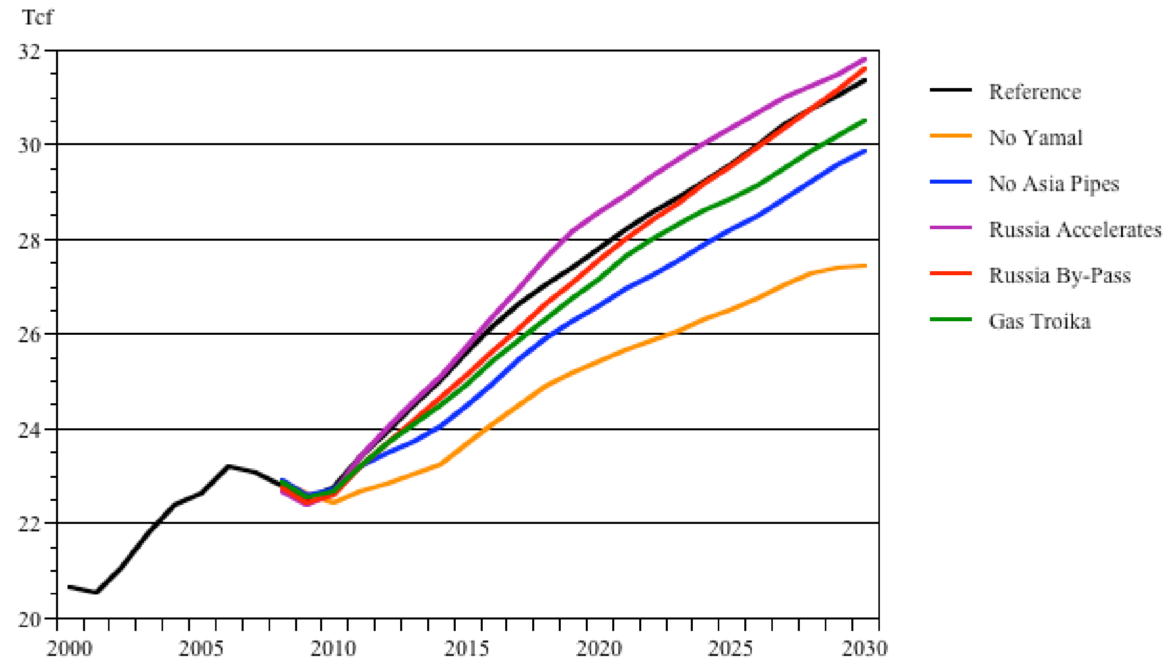



**Figure 9. Incremental Impact on Russian Production of Disallowing Iraqi Exports**

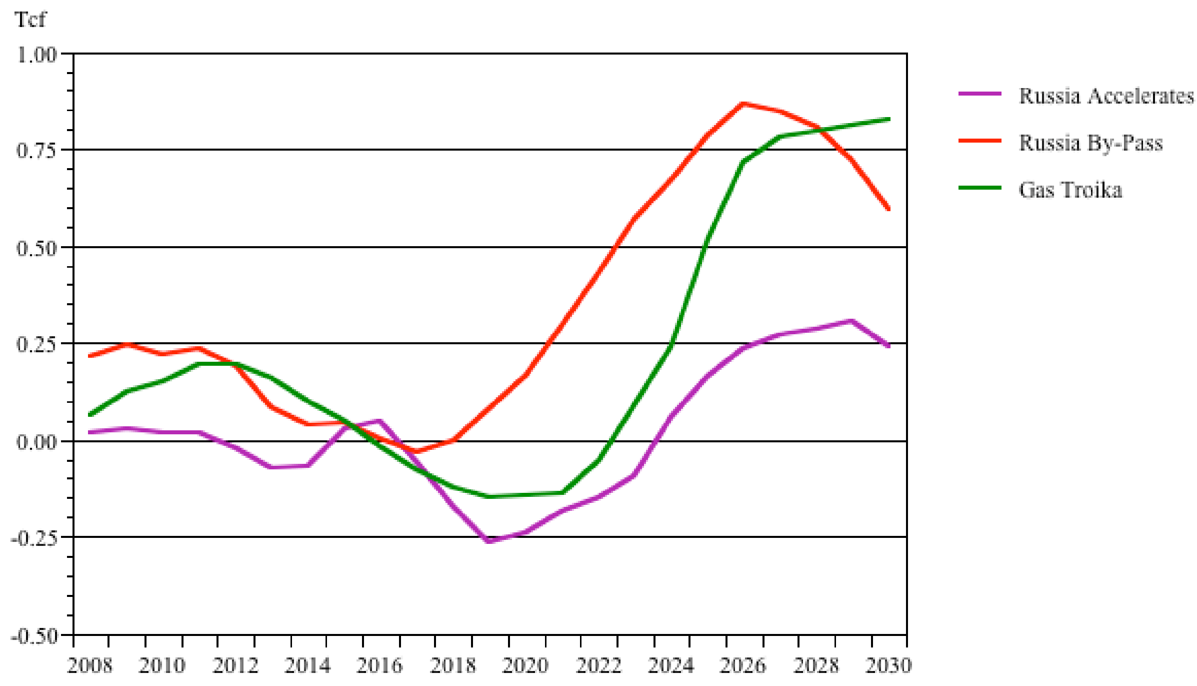


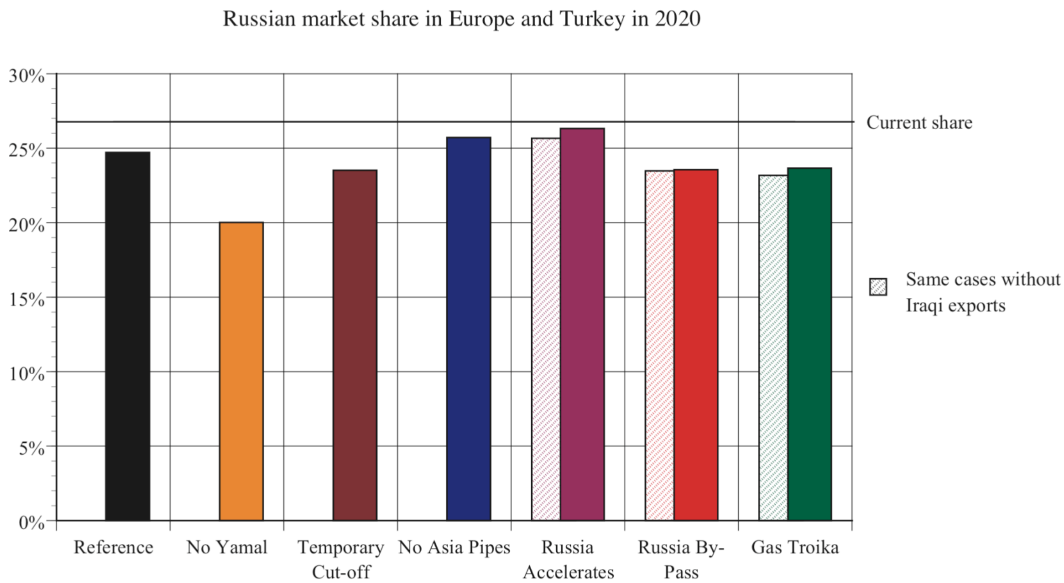
Figure 9 reveals the cumulative effect of Iraqi gas exports can be quite substantial. For example, the "Russia By-pass" case reveals that in no year does production increase by more than 0.8 tcf, but the cumulative increase is in excess of 6 tcf. Thus, the potential revenue reducing impact of Iraqi natural gas to Russia is substantial.

Regarding market share, the Reference Case indicates that Russia will lose market share in Europe in due course. This results primarily from an increase in LNG imports to Europe over time, a result of demand growth in Western European markets, which are well-situated to be served at lower cost by LNG from Africa and the Middle East. The drop in market share is exacerbated in later time periods as supplies from the Middle East, primarily Iraq, move into southern Europe via pipeline.

In all cases except "No Asia Pipes," Russia loses market share in Europe relative to its position in 2008. In the "No Asia Pipes" case, disallowing infrastructure to Asia provides more Russian resources that can be moved by pipeline to Europe. The other case in which long-term market share is at least maintained is the one in which Russian infrastructure developments are accelerated *and* Iraqi developments are disallowed. Therefore, absent forces that prevent substantial pipeline infrastructure developments in Northeast Asia or from the Middle East to Europe, Russian market share in Europe will likely fall.

In Asia, market share increases above the 2008 level of zero percent in all cases, although the degree of increase is different across cases. The smallest increase in market share arises when pipeline developments are restricted, limiting market penetration to supplies from LNG in Sakhalin. The largest increase generally comes about when Russian infrastructure is accelerated. Thus, the ranges of outcomes in Asia are bracketed by cases in which no pipeline infrastructure is allowed and pipeline and LNG infrastructures are accelerated.

**Figure 10. Russian Market Shares in Europe Across all Cases in 2020 and 2030**



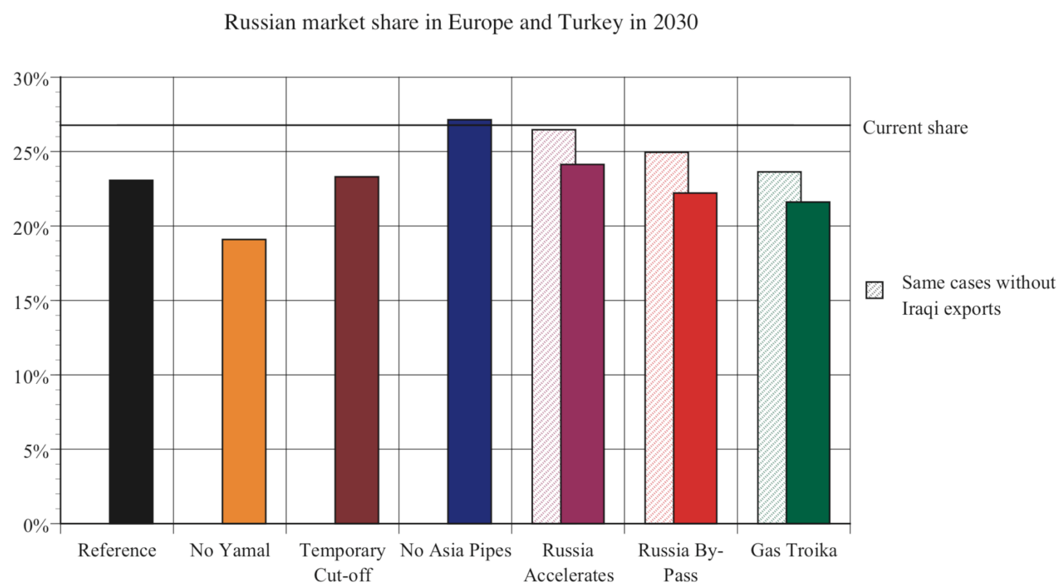
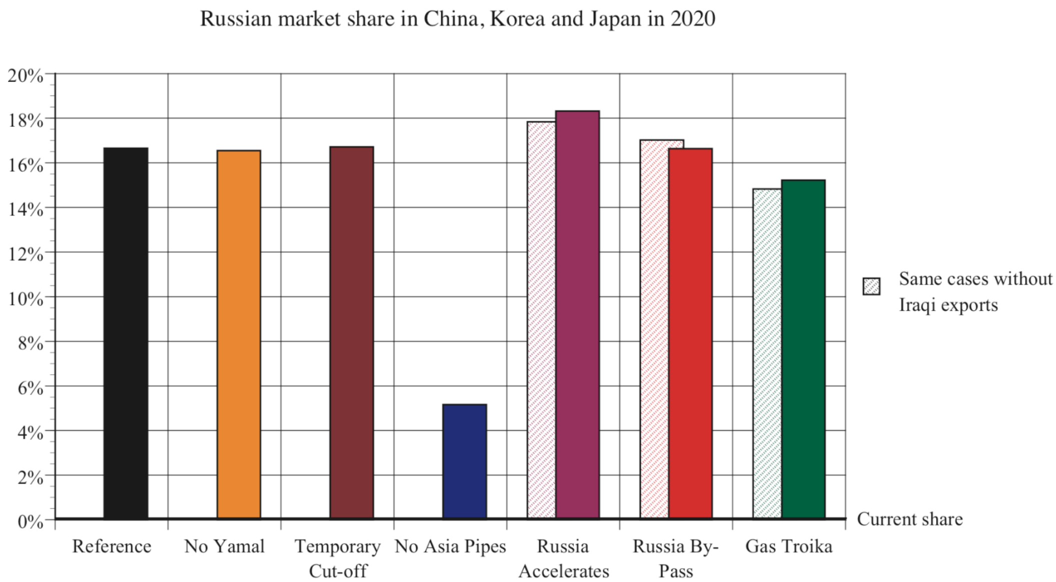
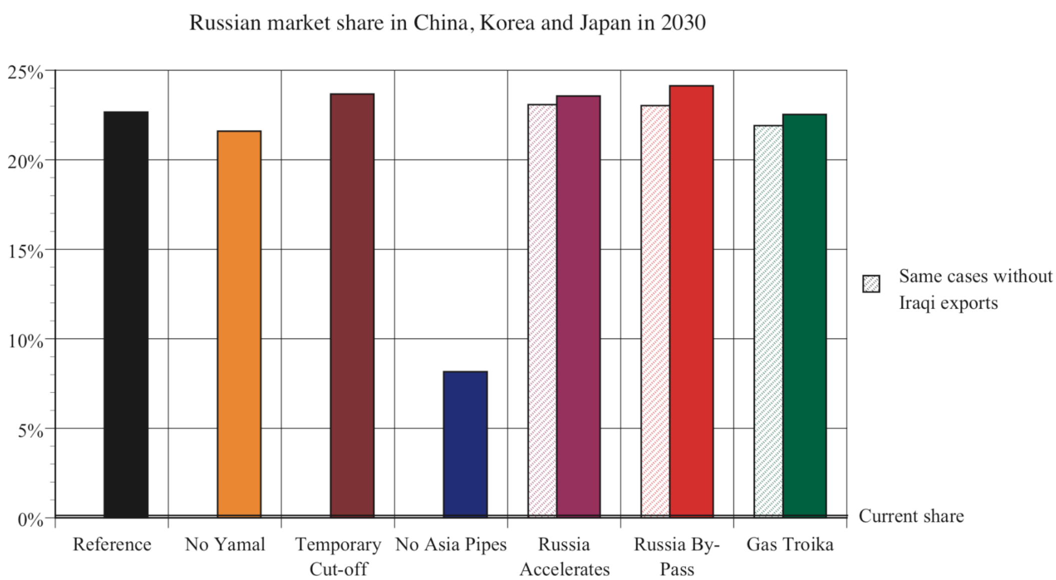



**Figure 11. Russian Market Shares in Asia Across all Cases in 2020 and 2030**




## V. Detailed Descriptions of Scenario Analysis

*A. Scenario 1: Yamal Peninsula and Kara Sea resources remain undeveloped*

In this scenario, we prohibit the development of natural gas resources in the Yamal Peninsula and Kara Sea, thus removing 440 tcf of the estimated 1,168 tcf of Russia's technically recoverable natural gas from potential development.

**Figure 12. Supply Changes Under Scenario 1**

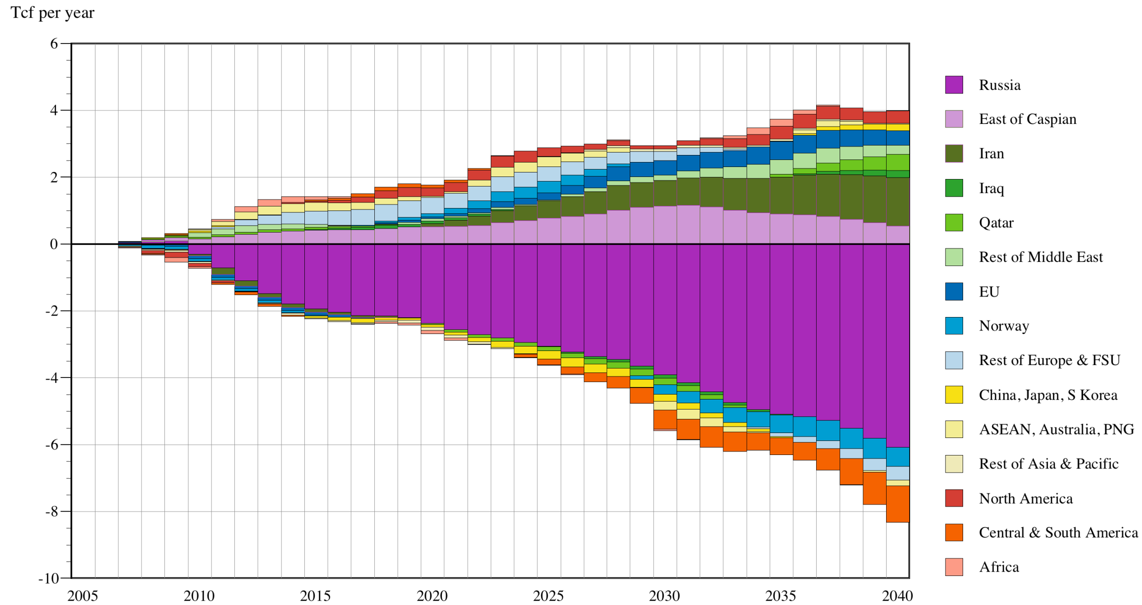



Figure 12 depicts the changes in supply *relative* to the reference case. The decline in overall Russian production becomes more pronounced over time and reaches more than 6 tcf per year by 2040. Russian production in the Southwest and East rises slightly, but the increased production, especially in the Southwest, is not sustained. The East of Caspian group of countries exhibits a persistent positive supply response, but falls short of offsetting declines in Russia.

Figure 12 also shows that several other countries exhibit increases in supply. The most prominent among these are Iran, Qatar, and the rest of the Middle East, although production also responds positively in North America and the EU. In some countries or regions, such as Norway or the rest of the FSU, supply increases in some years are accompanied by reductions in other years, so some supply increases can also be regarded as intertemporal shifts in production.

**Figure 13. Changes in Russian Exports by Origin Under Scenario 1**

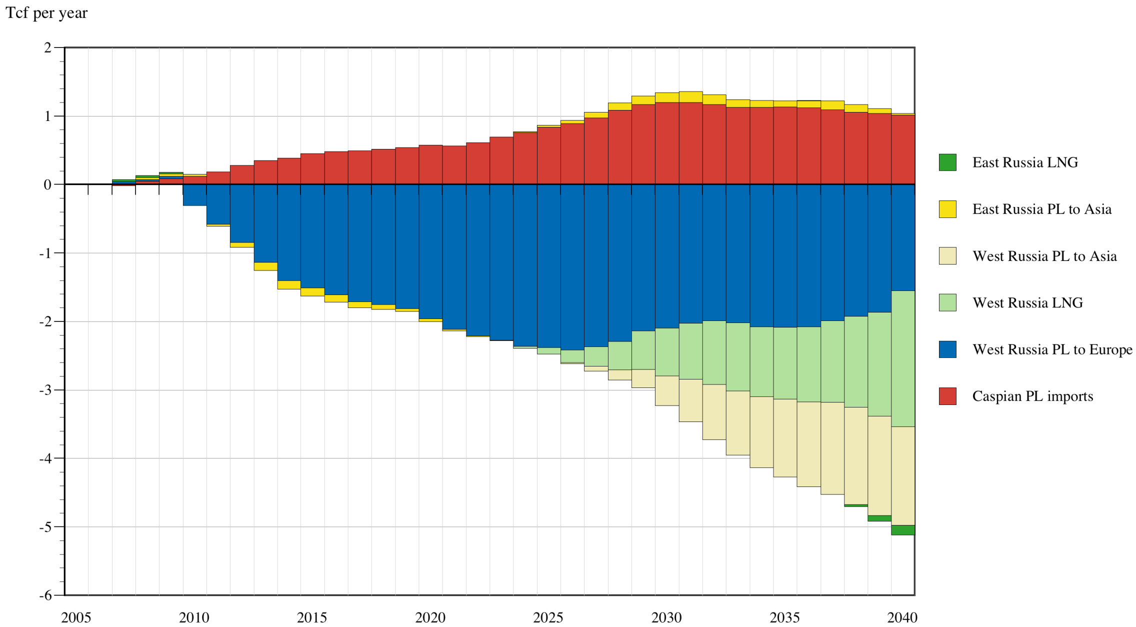



Figure 13 focuses on Russian exports. Imports from the East of Caspian countries increase relative to the reference case. This occurs as those supplies fill Russian pipeline infrastructure to Europe in the absence of Russian production. Reduced supply in the West also cuts exports of LNG from the Barents Sea and the exports from West Siberia to Asia. The slight increase in exports from East Siberia to Asia via pipeline does little to compensate for the reduced exports from West Siberia. The lack of Russian supplies tends to lift prices in Europe and increase competition for LNG. Thus, as prices rise, demand is cut around the world, including in Northeast Asia.

**Figure 14. Demand Changes Under Scenario 1**

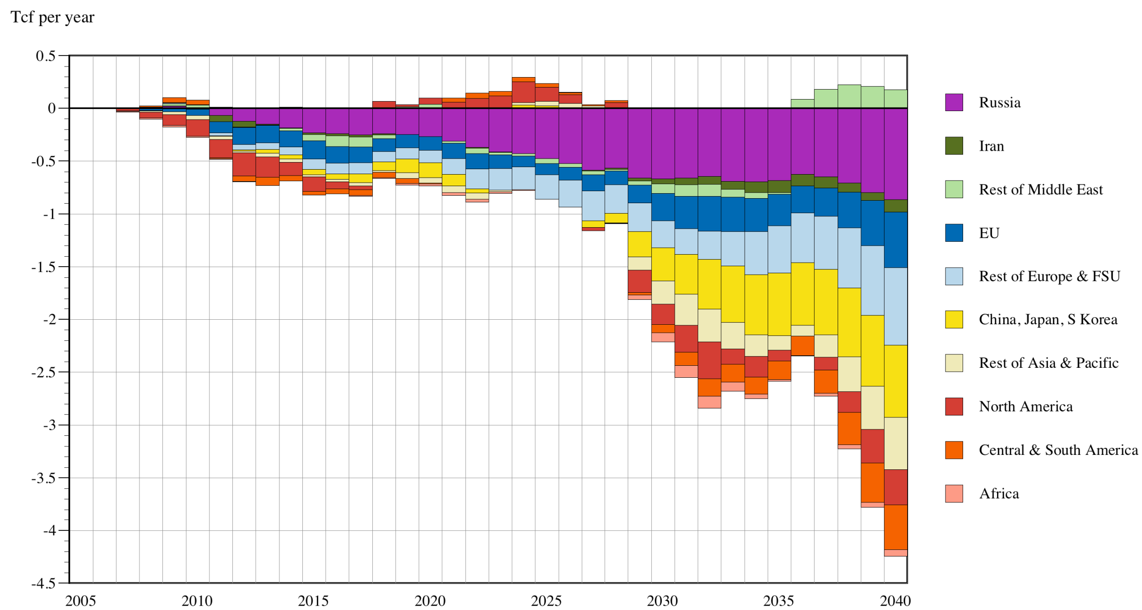



Figure 14 focuses more explicitly on the demand reductions relative to the reference case. As LNG and long distance pipelines transmit price changes across regions demand falls across the globe. Differences in marginal supply and demand elasticities and the ability of alternatives to take market share from gas lead to some different responses, but all regions are affected in a similar manner. The largest declines are in Russia and neighboring regions dependent on Russian exports, such as the rest of the FSU, Europe, and China.

**Figure 15. Selected Price Differences in Scenario 1**

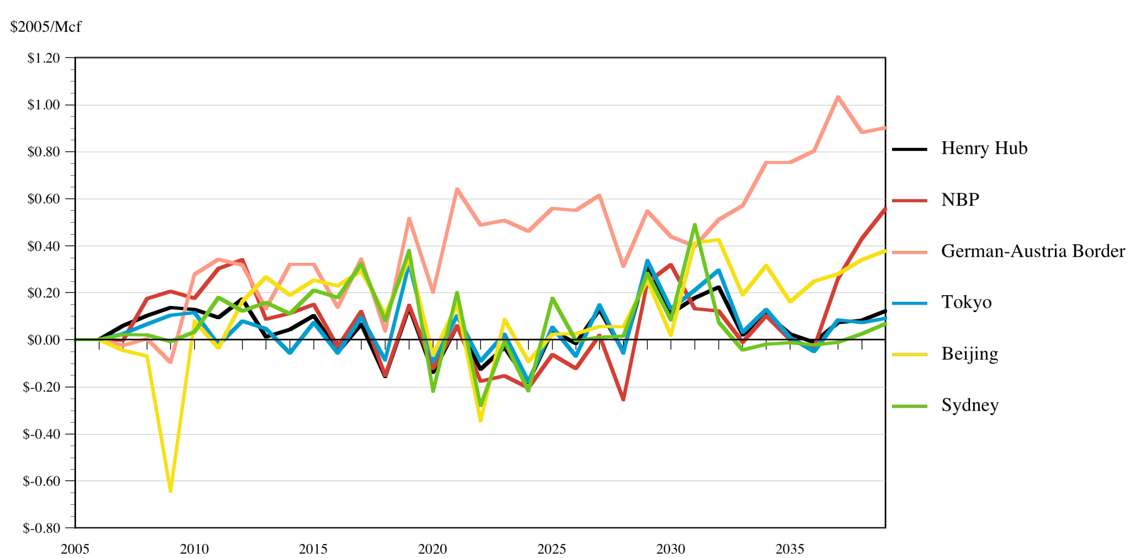
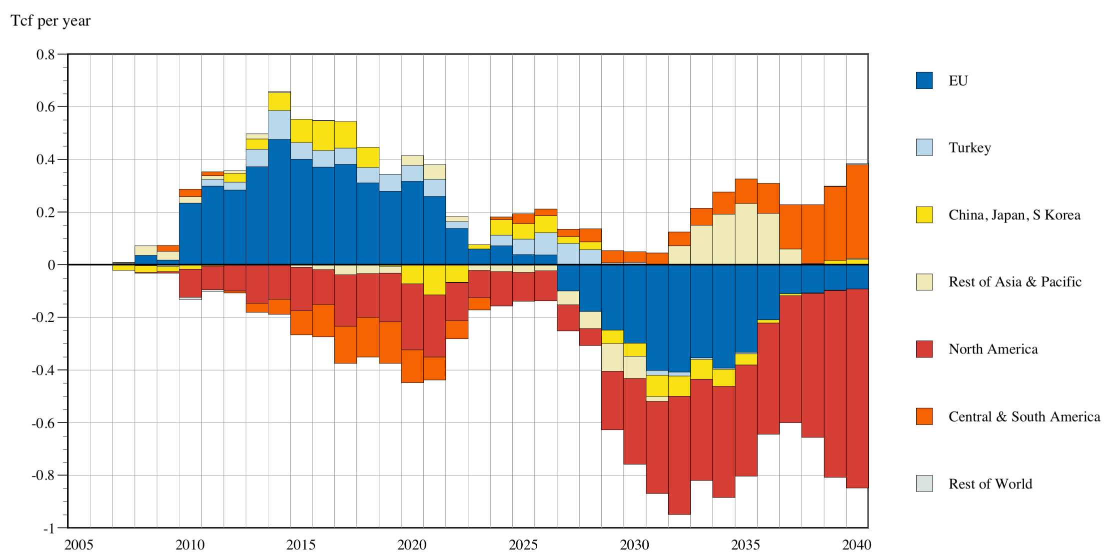


Figure 15 illustrates the change in prices relative to the reference case in select locations. The largest price changes among the locations presented in the figure occur at the German-Austrian border, where the supply shortfall from Russia has greatest impact. Prices in Beijing also rise substantially beyond 2030 as higher priced imported LNG replaces natural gas that is sourced from West Siberia in the reference case. In the remaining locations, price movements tend to be similar, reflecting the fact that they are all linked via LNG at the margin.

Figure 16 indicates the effects of reduced Russian supply on global LNG exports. Russian LNG exports are lower beyond 2025 as supplies from the Barents Sea are diverted to pipeline infrastructure. Iran sees the greatest expansion of LNG exports. The decline in LNG exports from Norway may appear anomalous, but it accommodates increased pipeline exports to Europe that replace lost Russian imports.

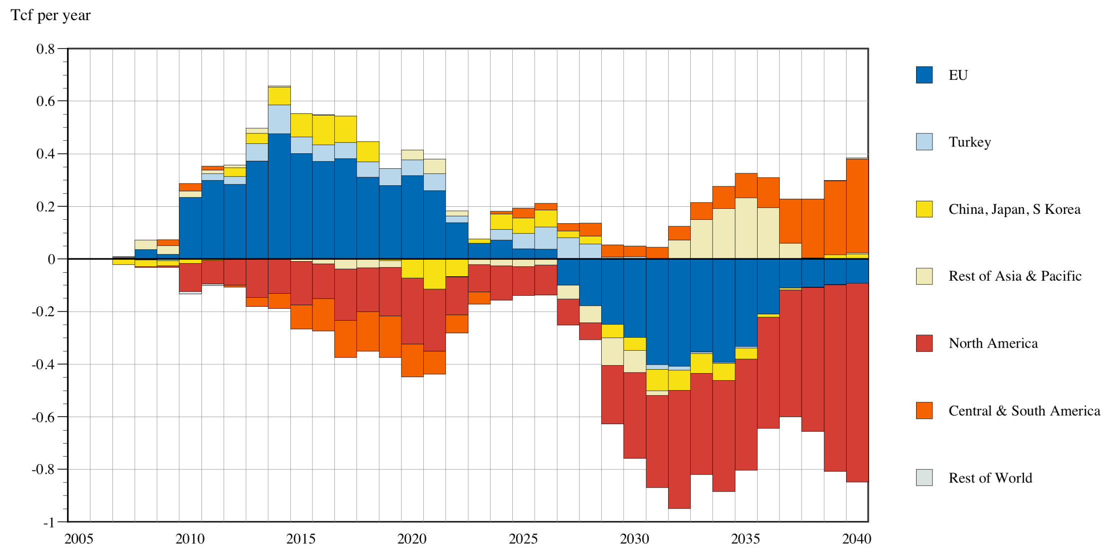
**Figure 16. Changes in LNG Exports in Scenario 1**




Reduced pipeline flows from Russia to Europe in earlier years are offset, to some extent, by increased LNG imports to Europe. Figure 17 indicates that LNG imports into Western Europe rise collectively by as much as 0.256 tcf per year, or 700 million cubic feet (mcf) per day, which is similar to the capacity of an average-size LNG import terminal. The increased pipeline imports from Norway in later years allow LNG imports to Europe to decline beyond the late 2020s.

The large decreases in LNG imports into the United States are noteworthy. The added competition for LNG supplies tends to raise prices everywhere. This tends to raise domestic production in North America while lowering demand, thereby reducing North American LNG imports.

**Figure 17. Changes in LNG Imports in Scenario 1**




*B. Scenario 2: Russian exports are severely reduced in 2010*

In this scenario, we consider an abrupt but temporary suspension in 2010 of roughly one-third of the reference case Russian natural gas exports to Europe. The idea is to simulate a four-month cutoff of Russian supplies to Europe that could be prompted by political forces, commercial disagreements over pricing, or result from severe physical shortages.

The immediate impact of the cutoff is a large increase in European prices (nearly double at the German-Austrian border and almost 10 percent in the United Kingdom). These price increases, especially those in Ukraine, would be larger had we not assumed that the Ukrainian government would respond to the emergency by imposing non-price rationing equal to 20 percent of the reference case Ukrainian demand.

While the resulting price spike generates large rents for Russia in the short run, the scenario highlights the longer term risks for Russia. Europe responds to the short-term disruption by reducing demand and increasing supply and imports from elsewhere. While the ability to do so is limited by available infrastructure in the short term, the cutoff changes the growth and distribution of natural gas demand within Europe for many years to come. Moreover, the available LNG import infrastructure in 2010 is higher than what is available today, a point highlighted by the data and discussion above, around Table 1.

The fact that the shock has lingering effects is a product of both demand and supply changes. In particular, the autoregressive nature of demand in the RWGTM explains some of the delayed effects of the temporary cutoff. The more significant factor, however, is that the cut in supply triggers investments in alternative sources of supply that have longer-term effects by permanently displacing Russian exports to Europe. Therefore, Russia sacrifices future revenue for short-term gain.

**Figure 18. Supply Changes Under Scenario 2**

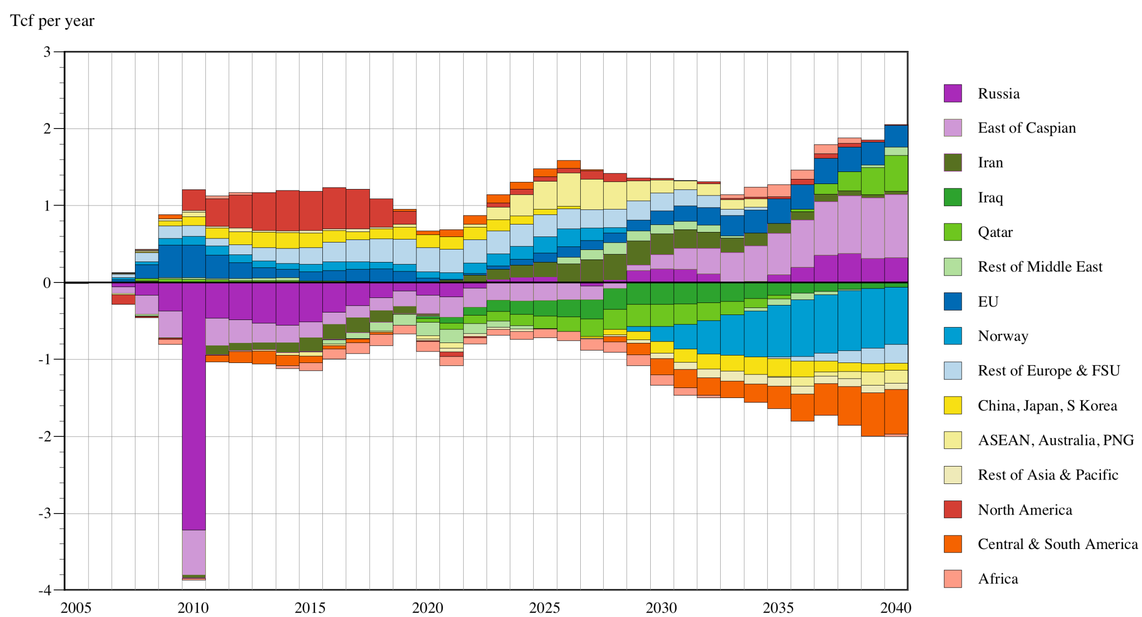
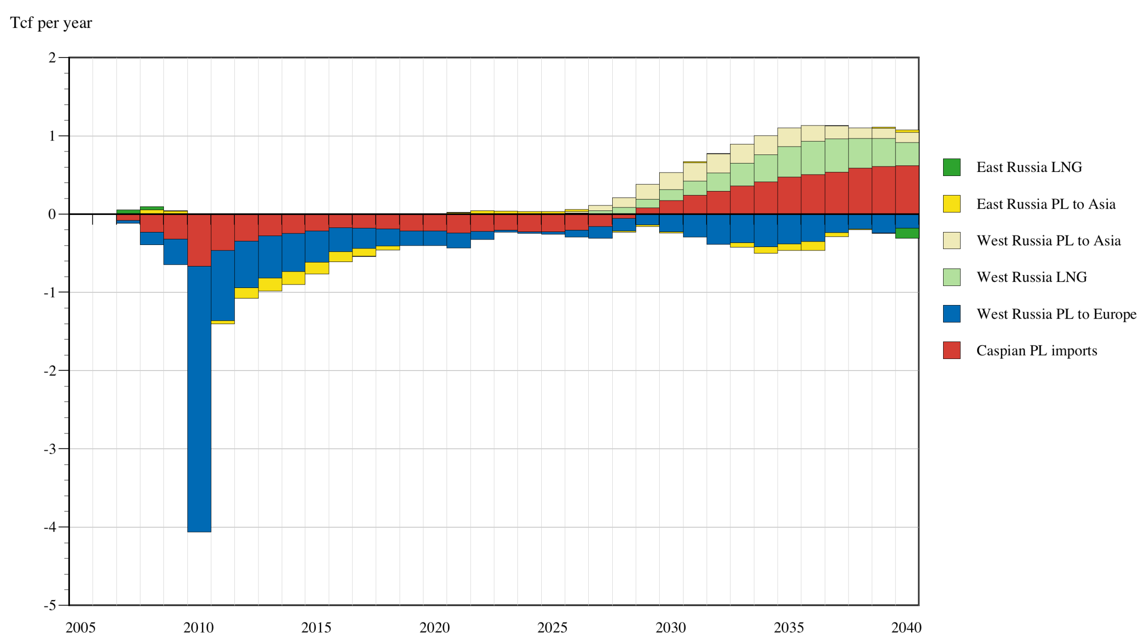



Figure 18 indicates the changes in supply relative to the reference case. While Russian supply is significantly lower in 2010, so is supply from the East of the Caspian countries whose production is captive to Gazprom's infrastructure. Alternative export routes across the Caspian and through Turkey, south through Iran, or east to China would allow these countries to escape the effects of Russia's curtailment of exports, but no such options exist in 2010.

Figure 18 also reveals that the sum of lost Russian production from 2010 through 2020 is almost as great as the cutoff itself. Beyond 2030, Russian supplies exceed the reference case as they replace declining production elsewhere. The East of Caspian countries increase supply beyond the late 2020s. A number of countries, including Iran, Iraq, and Qatar, exhibit supply responses that are negative in some years and positive in others, reflecting intertemporal shifts in production and export patterns. Other countries, however, see an immediate increase in production. Specifically, the cutoff triggers an increase in supply in Europe and the FSU countries west of the Caspian, as well as the United States. Moreover, the increases tend to persist for the next decade. Thus, the temporary increase in prices brought about by the cutoff stimulates new investments that have lasting effects.

Figure 19 provides additional detail on Russian exports. In particular, it shows that although Russian production rebounds after 2025, pipeline exports to Europe are permanently reduced. The increased Russian exports after 2025 are directed to Asia or leave as LNG.

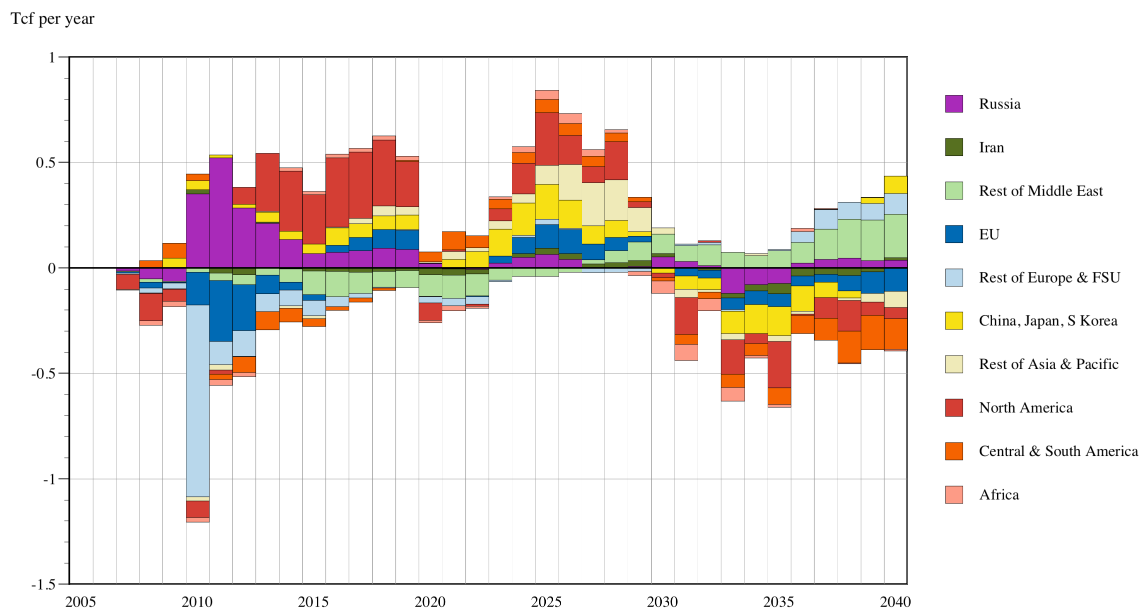
**Figure 19. Changes in Russian Exports by Origin Under Scenario 2**




The change in supply in the years preceding the shock is the result of producers anticipating the shock and beginning to develop supplies accordingly. However, given the lead times for development, they do not have enough time to fully adjust supplies to counter the Russian disruption. This can be viewed as the anticipatory element of rising tensions between Russia and Ukraine or Russia and Europe more generally.

As referenced above, since demand responds dynamically to prices, the high prices caused by the supply disruption lead to reduced demand relative to the reference case for several years. Figure 20 indicates that the negative response is greatest in Europe and FSU countries west of the supply reduction point on Russia's western border. These are the countries that are most directly affected by the disruption. Demand in most other locations increases in some years and declines in others, but the overall changes in any one country tend to be small.

**Figure 20. Demand Changes Under Scenario 2**




Demand in North America increases noticeably from 2012 through 2019. However, after one takes account of the difference in scale between Figures 18 and 20, it is apparent that the supply increases over the same period are greater. The resulting decline in imports of LNG is reflected in Figure 21, which gives the change in LNG imports as a result of the shock. LNG imports destined for the United States in 2010 are instead diverted to Europe and Turkey to make up for the Russian supply shortfall.

**Figure 21. Changes in LNG Imports in Scenario 2**

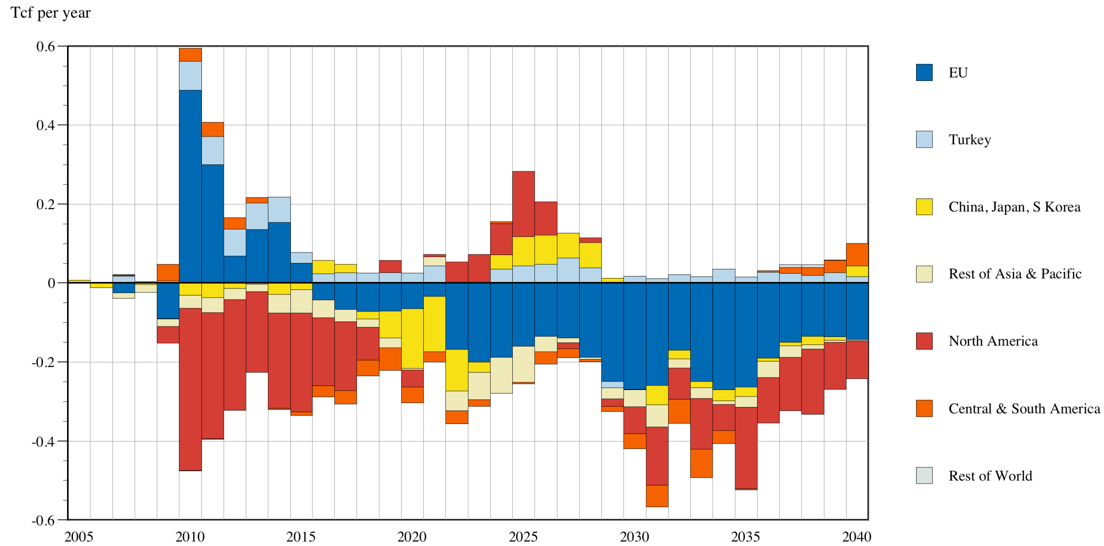
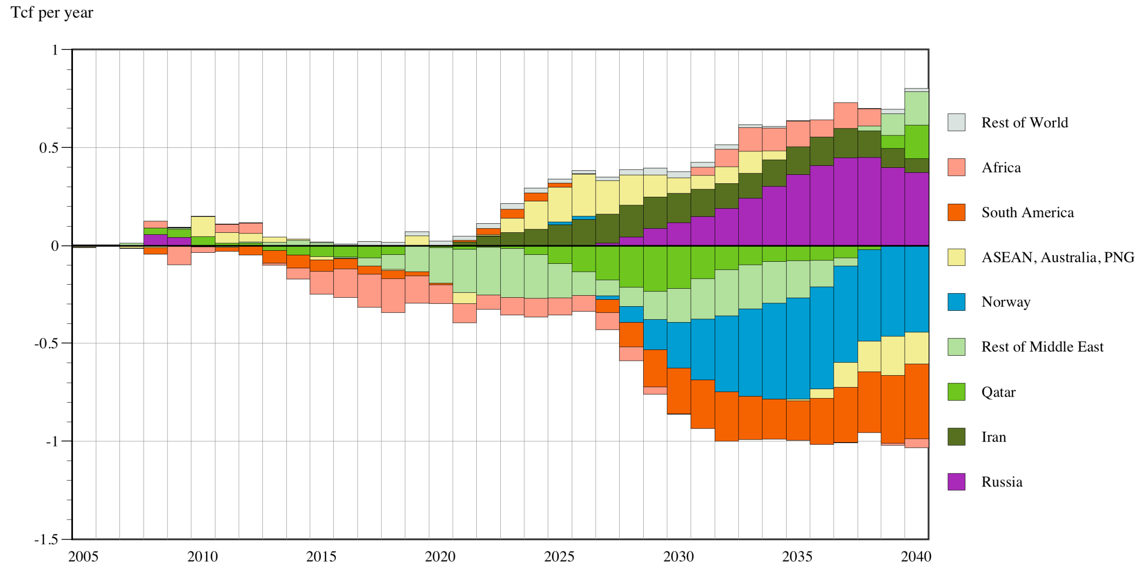



Figure 22 illustrates the corresponding changes in LNG exports. Slight increases in LNG exports from ASEAN countries, Australia, and Qatar also allow aggregate world supply of LNG to expand marginally in 2010. The increased production in ASEAN countries and Australia, coupled with reduced LNG imports into Northeast Asia and increased supply in Qatar, also facilitates increased LNG imports into Europe.

Figures 21 and 22 once again illustrate how the temporary supply disruption can have lasting effects. In particular, although European LNG imports are higher in 2010 and the years immediately following, they are lower in all years beyond 2016. Figure 22 also reveals noticeable changes in LNG exports from Norway, Russia, South America, and various countries in the Middle East more than fifteen years after the temporary supply disruption.

**Figure 22. Changes in LNG Exports in Scenario 2**




Iran, Australia, and Russia (especially after the late 2020s) are prominent among countries increasing their supply of LNG. The United Arab Emirates produce less LNG relative to the reference case beginning in the late 2010s, as do Qatar, Norway, and South America from the mid 2020s. The reductions in the United Arab Emirates and Qatar are partially compensated by increased production from Iran. The United States and Europe experience most of the net declines in LNG imports beyond the late 2020s. The large increase in Russian exports of LNG in the 2030s displaces some exports from Norway. Increased Russian exports into the Atlantic basin later in the time horizon also compensate for the reduced exports from South America.

*C. Scenario 3: Asian pipeline infrastructure from Russia remains undeveloped*

In this scenario, we prohibit the development of pipelines from Russia to Northeast Asia (specifically China, Korea, and Japan). Since no such infrastructure currently exists, by preventing these greenfield expansions we are able to discern the costs of political barriers to developments that the reference case results indicate are commercially viable.

**Figure 23. Changes in Supply Under Scenario 3**

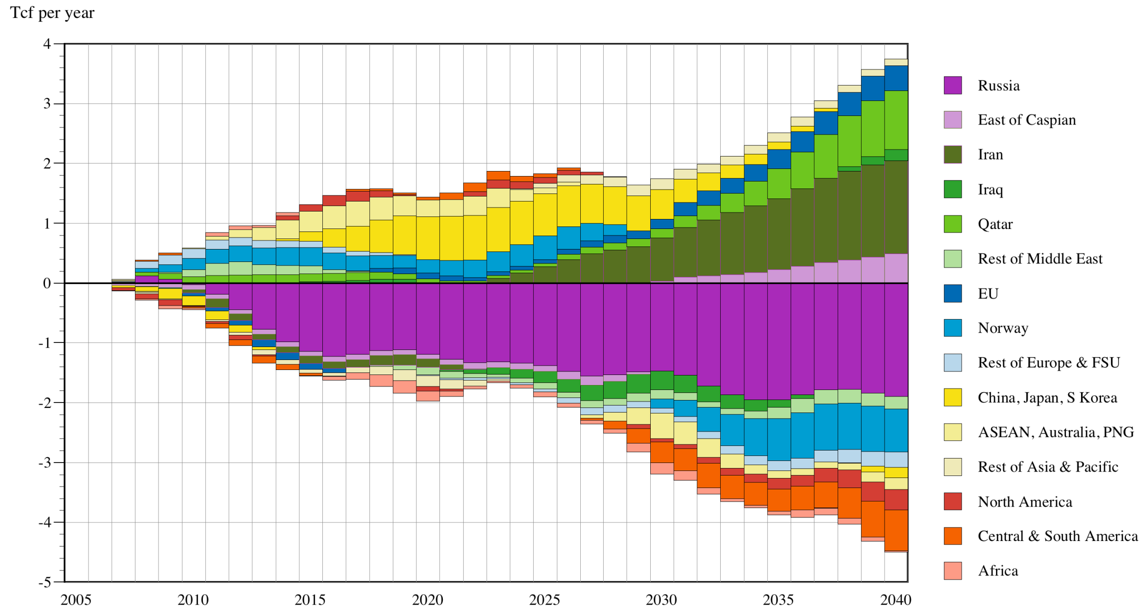



**Figure 24. Changes in Russian Trade Under Scenario 3**

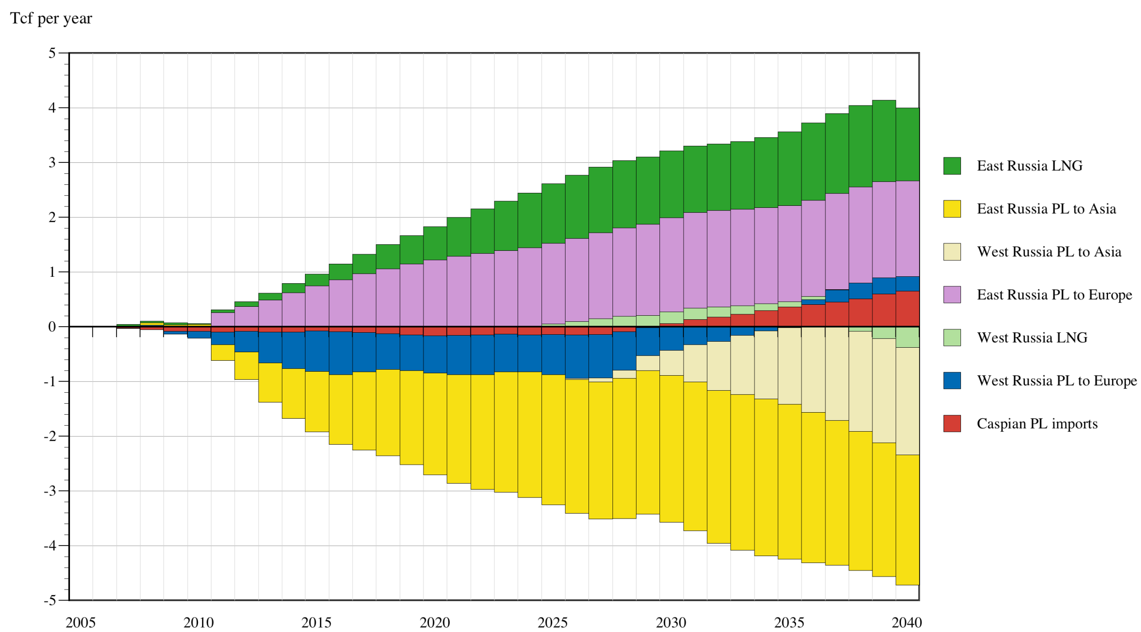



Figure 23 presents the changes in supply relative to the reference case, and Figure 24 focuses on changes in Russian exports. We see that East and West Siberian resources that are shipped to Northeast Asia in the reference case are instead redirected west, although higher transport costs to market result in lower production. The increased flow of East Siberian supplies to the West slightly reduces production in West Russia and the East of Caspian countries up to the late 2020s, although production rebounds somewhat in both areas in later time periods. Proposed pipelines from the Caspian region to China remain undeveloped even through they are allowed. The reduced flow of gas from Russia to Northeast Asia via pipeline is also compensated in part by increased flow of LNG from Sakhalin Island.

In Figure 23 we also see a slight increase in Chinese domestic supply as a result of higher prices. The Middle East—Iran in particular—is once again a major source of marginal supply, especially beyond 2025. Qatari output expands in all years, but the increases are larger after 2030. Supplies from Norway and South America are negatively impacted by the increased Russian exports to the West from the late 2020s.

**Figure 25. Changes in LNG Exports in Scenario 3**

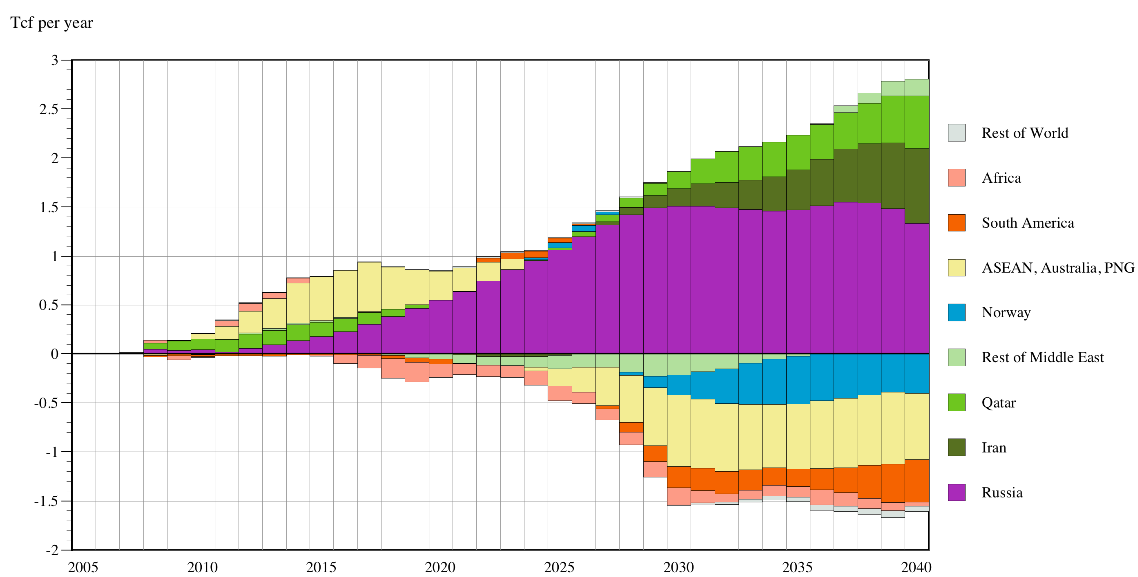



Figure 25 reinforces the conclusion from Figure 24 that the supply shortfall from decreased pipeline shipments from Russia to Asia is met largely by Russia itself as Sakhalin supplies that were exported via pipeline in the reference case are instead exported as LNG. Higher Asian reliance on LNG also stimulates greater LNG production in the ASEAN countries and Australia through 2025, and in Iran and Qatar in all years, with the greatest increases beyond the mid-2020s. Figure 25 also again illustrates the dampening effect of increased Russian exports to the West on Norwegian and South American LNG exports beyond the late 2020s.

Figure 25, which depicts changes in LNG imports relative to the reference case, shows that world LNG imports expand in the aggregate, with China, South Korea, and Japan, and to a lesser extent the rest of Asia, taking the majority of the increase. Europe and Turkey experience most of the reductions in LNG imports. This shift is facilitated by increased pipeline flows from Russia to the west. LNG imports into North and South America also increase beyond 2030 as LNG exports from the Middle East expand. In the case of South America, both exports and imports of LNG rise with different countries on the continent doing the exporting and importing.

**Figure 26. Changes in LNG Imports in Scenario 3**

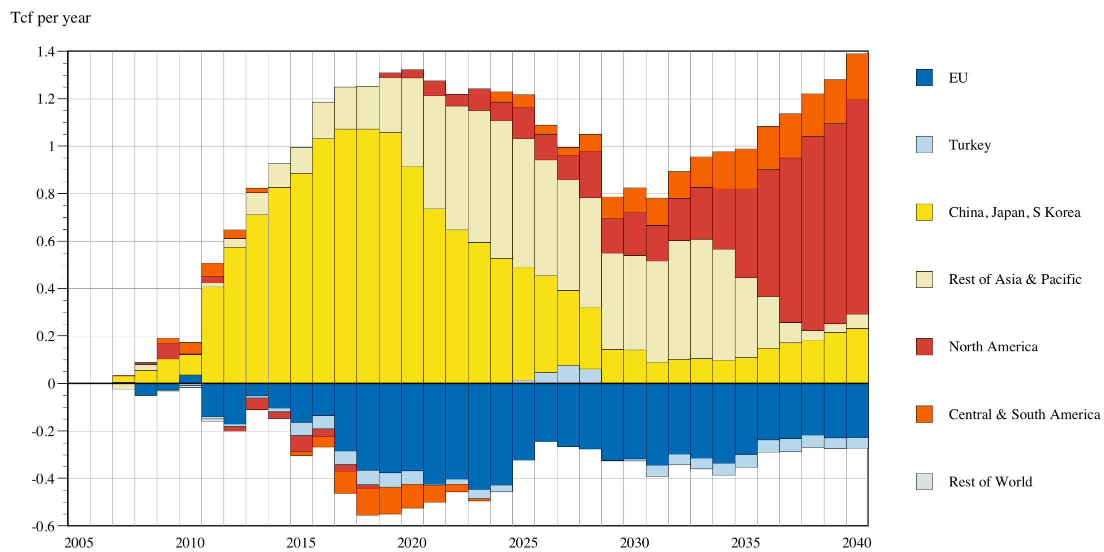
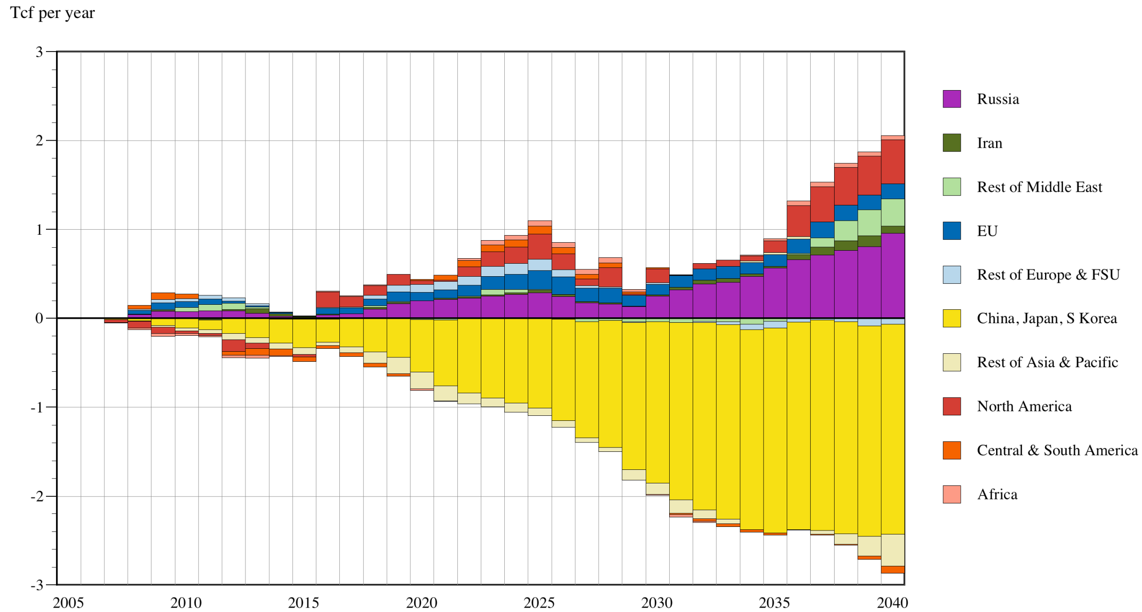



Figure 27 reveals that an absence of Northeast Asia pipeline infrastructure primarily reduces demand in China as it no longer benefits from lower-priced Russian pipeline gas. The main beneficiaries are consumers in Russia and its immediate neighbors, all of whom benefit from lower prices. The increased demand in North America is facilitated by lower demand for LNG in Europe as pipeline imports from Russia grow.

## Figure 27. Changes in Demand Under Scenario 3




## Figure 28. Selected Price Differences in Scenario 3

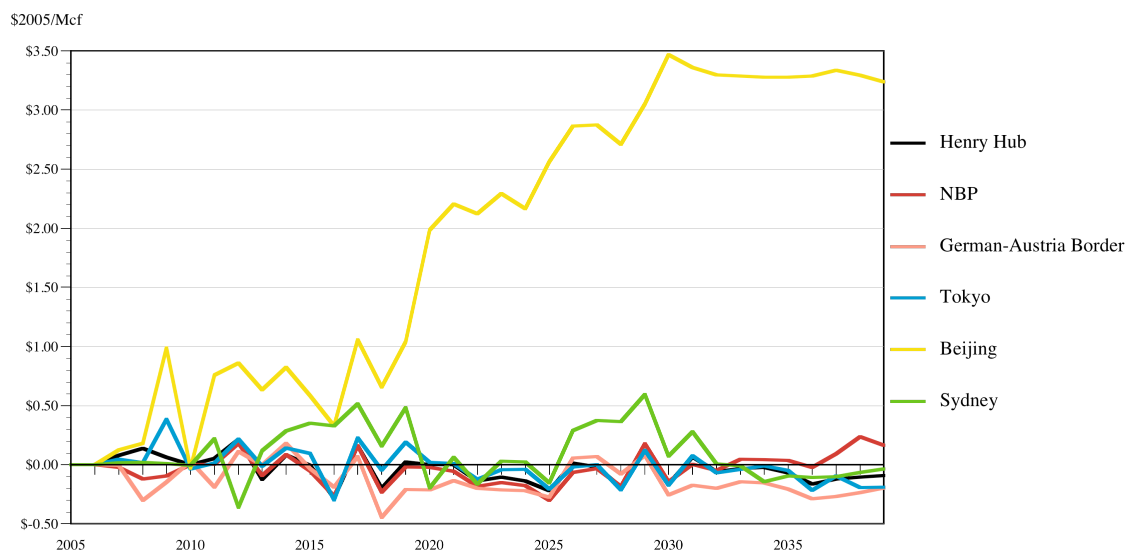



Figure 28 shows that the largest price increases occur in China. Prices actually decline slightly in Central and Eastern Europe and in the former Soviet Union countries as supplies are bottlenecked in Russia, forcing prices down and shifting supplies westward.

*D. Scenario 4: The development of proposed Russian infrastructure is accelerated*

The above three scenarios all examine cases where Russian development is curtailed for some reason. In this scenario, we instead examine a case where Russian development is accelerated. This might happen, for example, if Gazprom were to obtain additional financing to advance various projects, or if a concerted effort were made to capture markets threatened by competing projects. Specifically, we assume that the South Stream Pipeline is built in 2012 even though it is not constructed at all in the reference case. We also force Murmansk LNG to begin in 2016 even though it does not begin until 2025 in the reference case.

An important variation on this scenario that we also consider involves the development of natural gas in Iraq. Since many of the above analyses have shown that the Middle East is a prime competitor for Russia in supplying gas to Europe, we also discuss a variant on this scenario where pipeline exports from the Middle East through Turkey are prohibited.

Figure 29 shows the consequences for supply of accelerating Russian development. Figure 30 illustrates the additional effects on supply of prohibiting Middle East exports via Turkey or from Iraq to Iran.

Figure 29 shows that accelerating the development of Russian export infrastructure, not surprisingly, increases supply from Russia and, to a lesser extent, the East of Caspian group of countries. Increased competition from Russian LNG reduces supply from South America. By contrast, production in North America expands in all years except for the early 2020s. Most other regions are best described as shifting production intertemporally. Supply in China increases through the mid 2020s, but decreases in later years. The EU displays the opposite pattern, as supply decreases through the mid 2020s then increases in later years.

Apart from the late 2030s, supply from Middle East countries other than Iran is lower in the face of increased competition from Russia. Iranian supply also decreases through the early 2020s, but then expands noticeably from the mid-2020s through the mid-2030s.

**Figure 29. Changes in Supply Under Scenario 4**

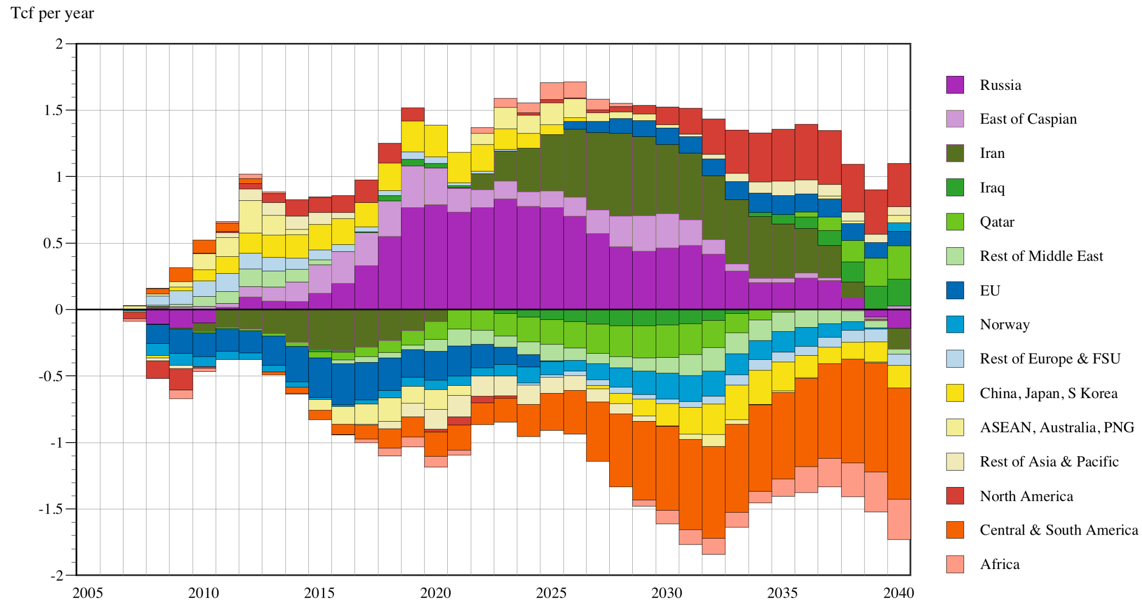
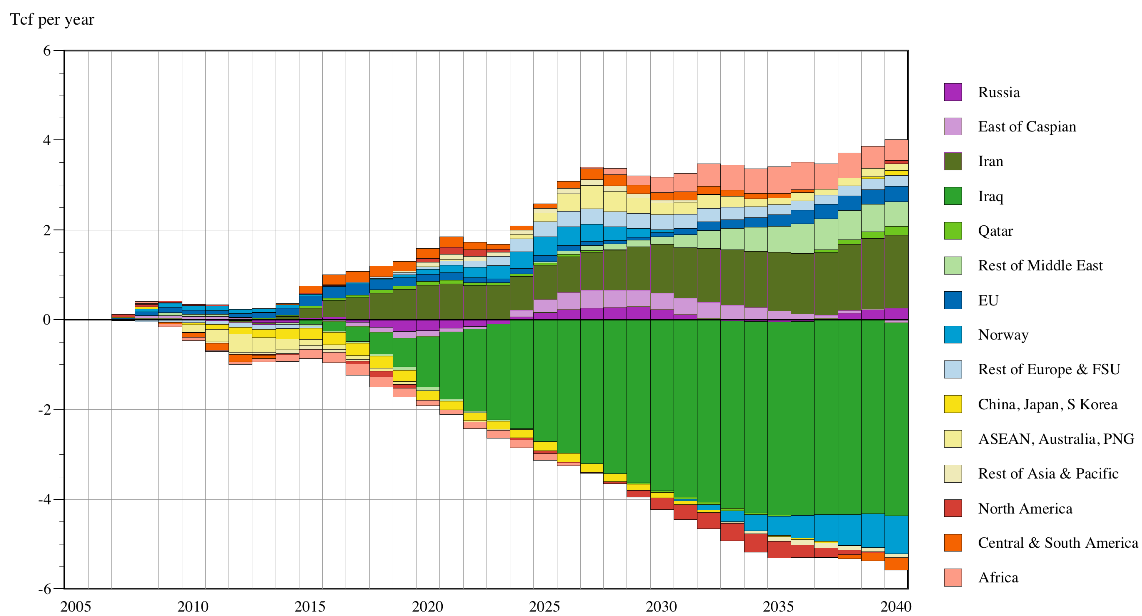



**Figure 30. Additional Changes in Supply with Middle East Constrained**




Iranian supply expands more when the export routes through Turkey from the Middle East are not developed. The additional Iranian supply is needed to satisfy Iranian demand, however, particularly because Iran is not allowed to import gas from Iraq. This also results in a decline in Iranian LNG exports in most years relative to the case where only Russian export infrastructure is accelerated. Figure 31 illustrates the difference in LNG exports in these two cases.

Another prominent feature evident in Figure 31 is the decline in Norwegian LNG exports when exports from Iraq through Turkey are not allowed. With reduced pipeline supply from the Middle East, Europe imports more Norwegian gas via pipeline, leaving less to be exported as LNG.

**Figure 31. Additional Changes in LNG Exports with Middle East Constrained**

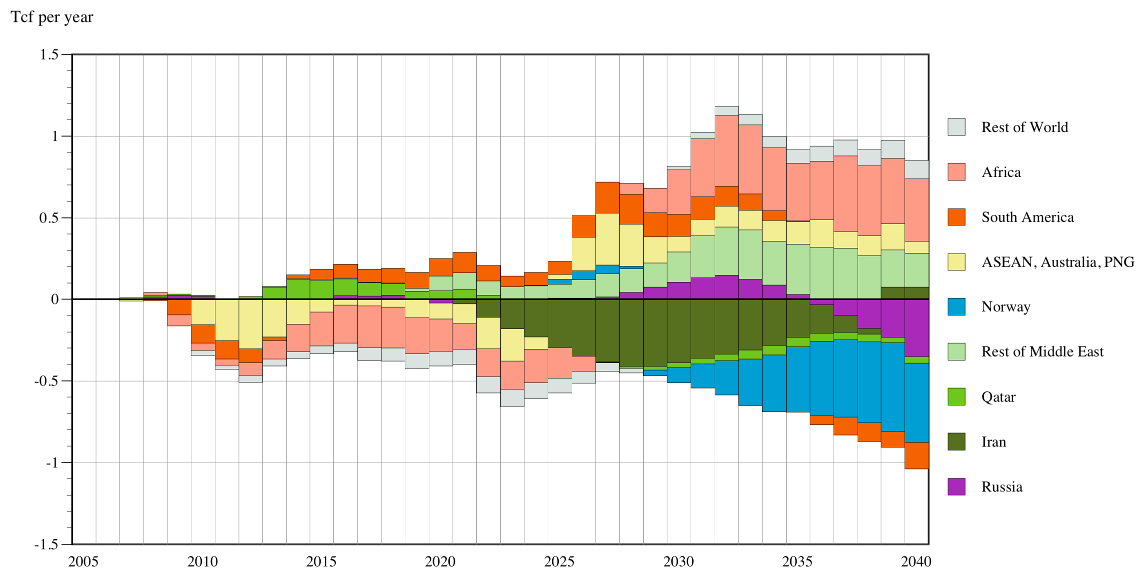



**Figure 32. Changes in LNG Exports Under Scenario 4**

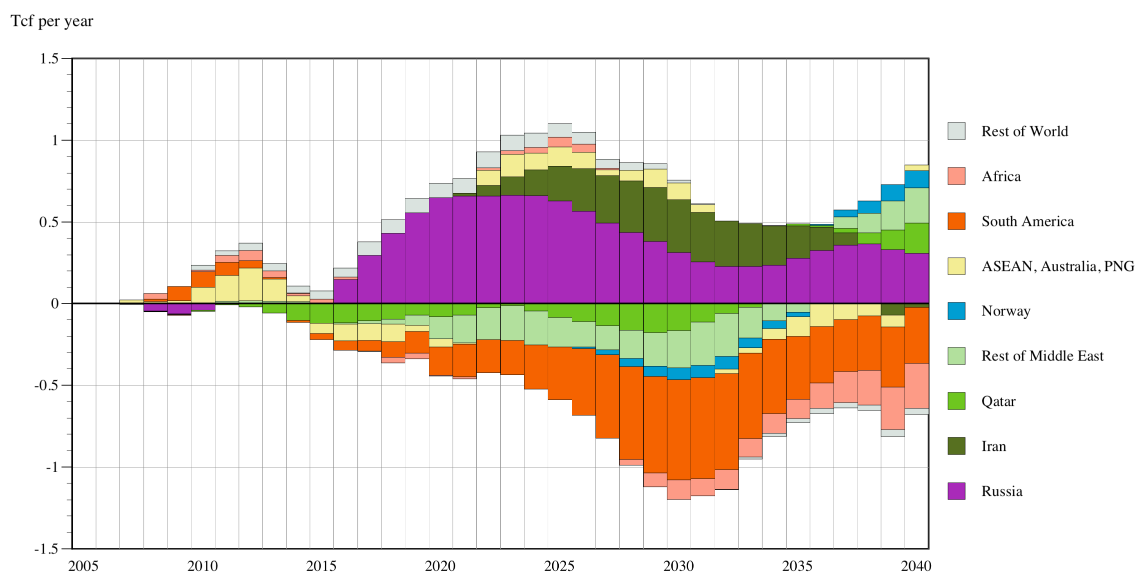


Figure 32 presents LNG exports in the Accelerated Russian Development Case relative to the reference case. Prominent features in Figure 32 are the increase in Russian LNG exports, the decrease in LNG exports from South America, and the generally negative effect of accelerated Russian development on LNG exports from the Middle East, notwithstanding Iran.

**Figure 33. Changes in Russian Exports Under Scenario 4**

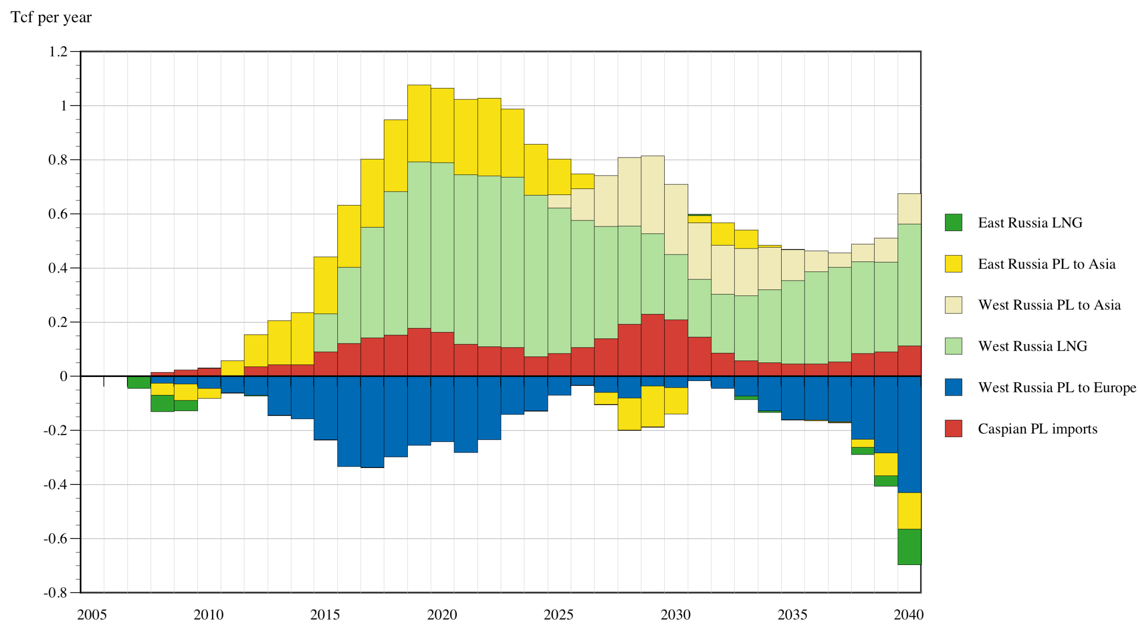
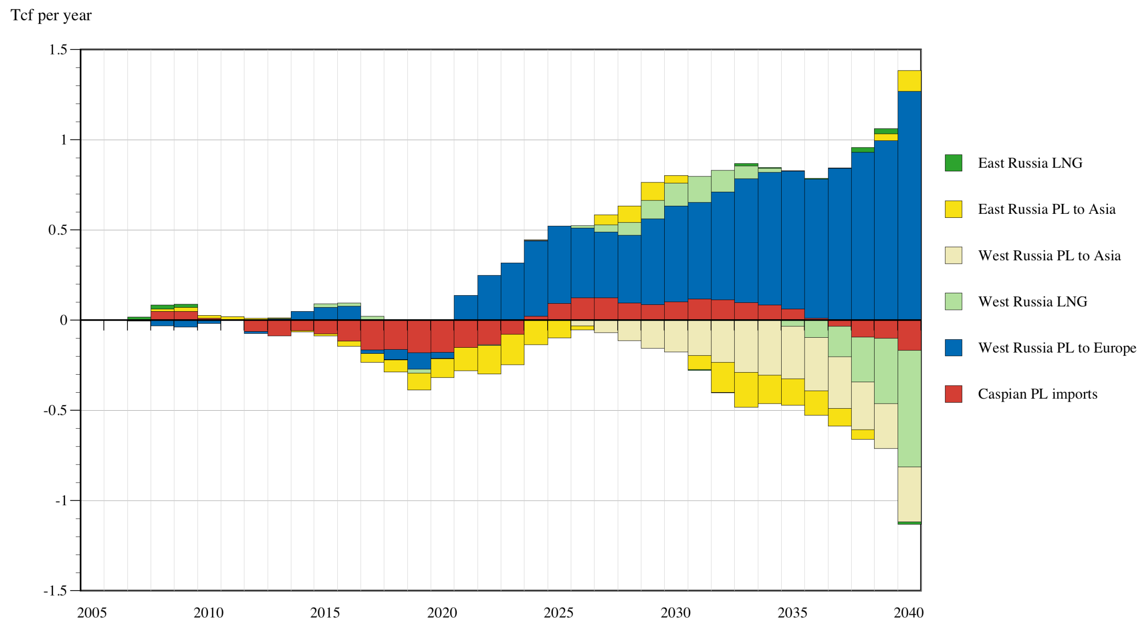



Figure 33 focuses on Russian exports under accelerated development, and Figure 34 presents the additional effects of constraints on Iraqi exports. The increase in Russian LNG exports is a prominent feature in Figure 33. Given the accelerated development of the South Stream pipeline, however, it is somewhat surprising that Russian pipeline exports to Europe decline relative to the reference case. The explanation is that Europe imports more LNG. At the same time, the generally lower prices for LNG under this scenario encourage increased demand in Northeast Asia, part of which is met by increased Russian pipeline exports from Russia to Asia.

**Figure 34. Additional Changes in Russian Exports with Middle East Constrained**




When Iraqi exports are curtailed on top of the expanded Russian trade, Figure 34 shows that Russian pipeline exports to Europe expand. The additional gas comes partly from expanded Russian and East of Caspian production, but also in part from reduced shipments to the east and, after 2035, reduced LNG exports from Murmansk.

Figure 35 graphs the changes in demand resulting from accelerated Russian development. These changes, which are mainly positive from 2012 through 2028 and negative from 2030–2040, are spread across several regions and tend to be small in any one country or region.

**Figure 35. Changes in Demand Under Scenario 4**

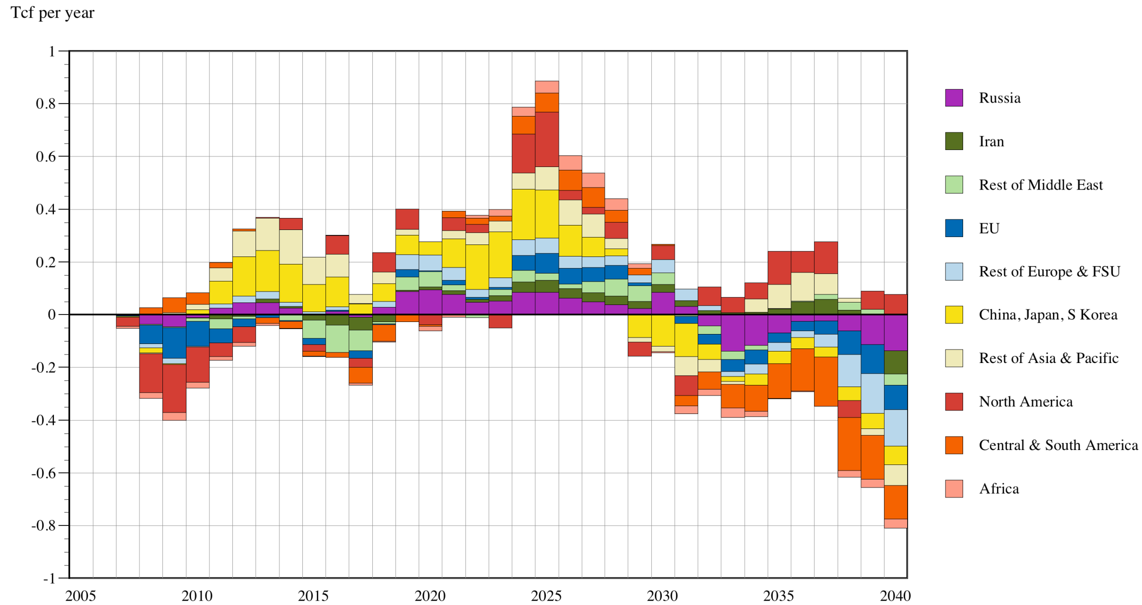



Figure 36 graphs the changes in LNG imports alone. As we noted above, higher Russian exports of LNG tend to lower prices in the Atlantic and encourage European imports of LNG. On the other hand, the expanded pipeline exports to Northeast Asia reduce LNG imports into those countries. Beyond 2030, North America experiences the largest reductions in LNG demand and South America the largest increases.

**Figure 36. Changes in LNG Imports under Scenario 4**

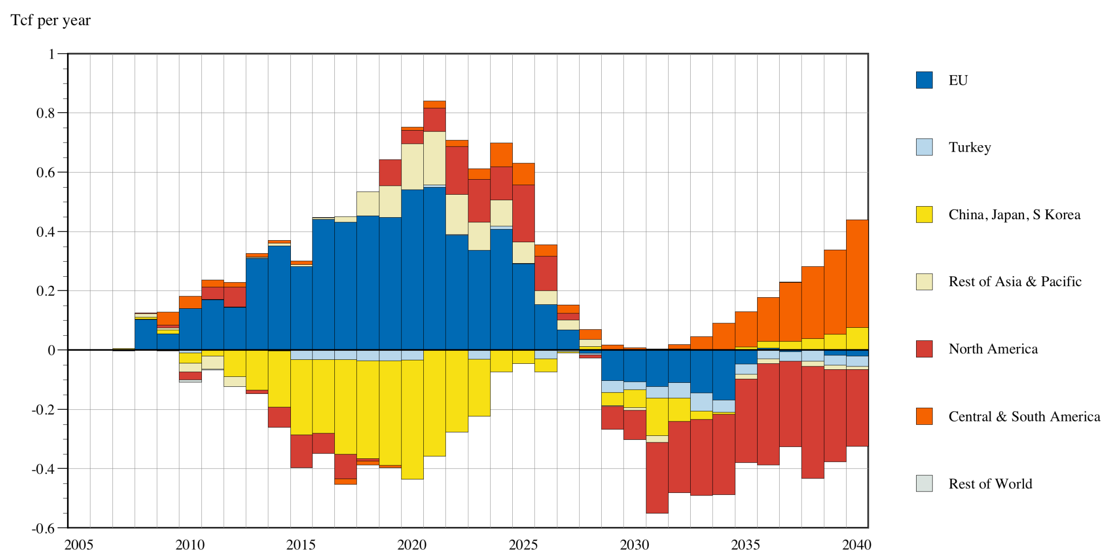


**Figure 37. Additional Changes in Demand with Middle East Constrained**

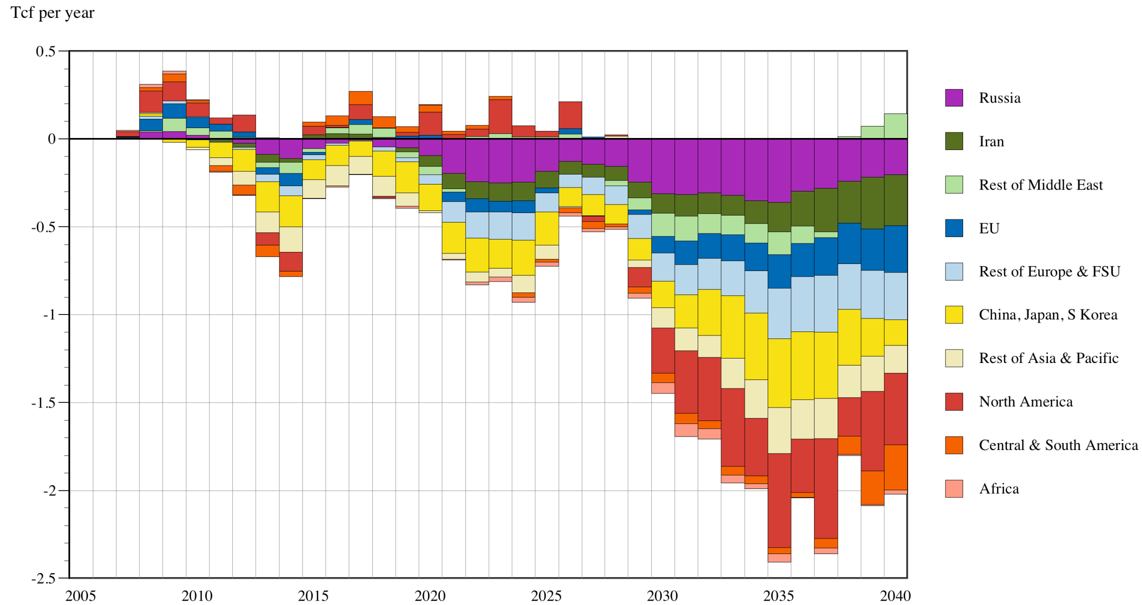
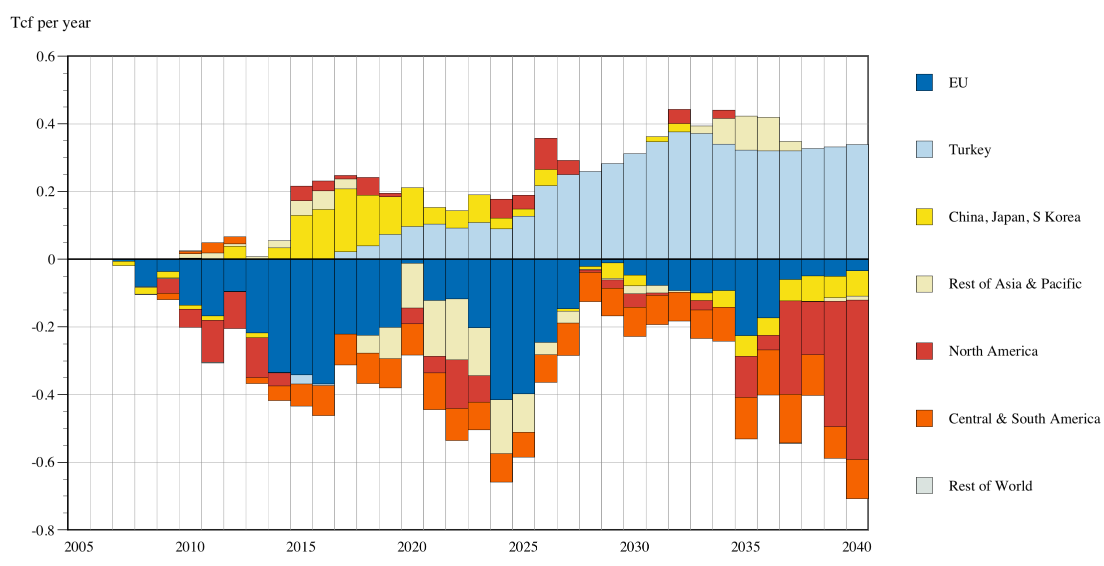



Figure 37 shows that the demand reductions beyond 2030 are much more substantial when Iraqi exports also are constrained. The declines are also spread across more regions. Curtailing Iraqi exports also exacerbates the demand reductions in Northeast Asia from 2012 through 2025. When we focus on LNG imports in particular, Figure 38 shows that reducing Middle East exports via pipeline increases Turkish, and reduces European, imports of LNG. The other changes are higher in some years, but lower in others.

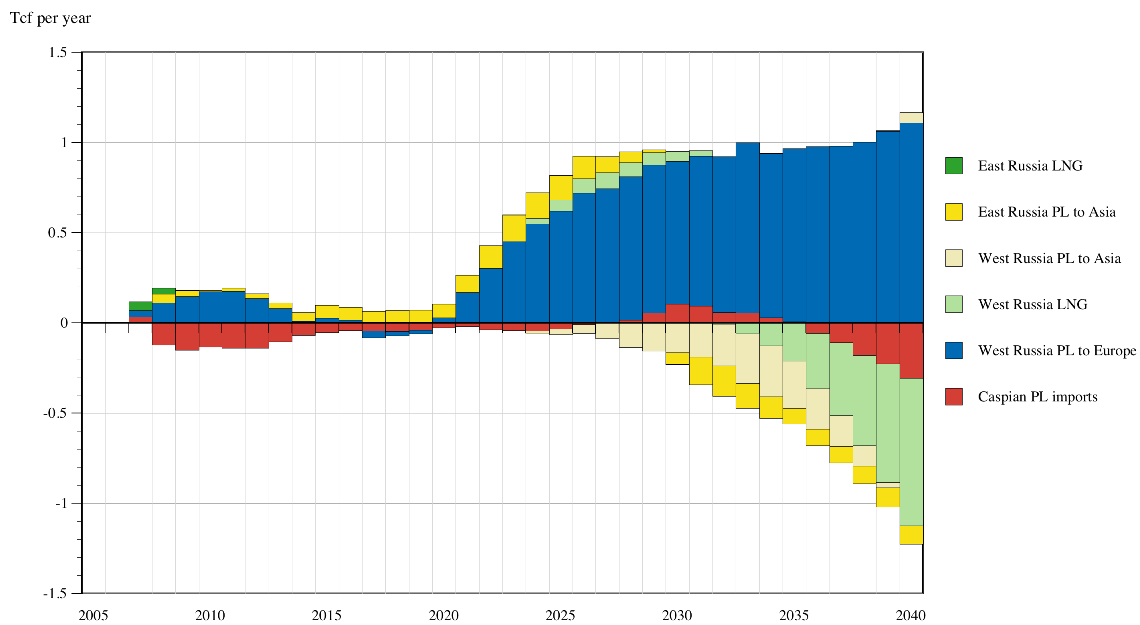
**Figure 38. Additional Changes in LNG Imports with Middle East Constrained**



*E. Scenario 5: Development of infrastructure to bypass Russia is accelerated*

The previous four scenarios have focused primarily on changes within Russia. In this scenario, we consider the consequences of accelerating the development of infrastructure, such as the TransCaspian and Nabucco pipelines, that would allow European consumers to bypass Russian infrastructure in receiving natural gas supplies from Caspian states. Similar to scenario 4, we also consider a variation to this scenario in which there is an additional set of constraints on transporting Middle East gas through Turkey and exporting Iraqi gas to Iran. Interestingly, the marginal consequences of these additional constraints are quite similar to what we found for scenario 4. For example, Figure 39, showing the impact of the Middle East constraints on Russian exports in scenario 5, is quite similar to Figure 34, which is the corresponding graph for scenario 4.

**Figure 39. Additional Changes in Russian Exports with Middle East Constrained**




The main difference between Figures 39 and 34 is that the Middle East constraints allow a somewhat larger export of pipeline gas west to Europe from Russia in scenario 5 than in scenario 4, and cause a slightly larger contraction of LNG exports from Murmansk beyond 2035. Building infrastructure to bypass Russia frees up pipeline capacity from Russia to Europe that can be used if the Middle East route through Turkey does not eventuate. Also, the greater expansion of LNG exporting facilities from Murmansk under scenario 4 allows LNG exports to remain slightly higher in that scenario. Since the marginal impacts on Russia are very similar in the two scenarios, however, it is not surprising that the other marginal effects also are quite similar. Thus, in the interests of brevity, we will not discuss them further here. However, details are available from the authors upon request.

**Figure 40. Changes in Russian Exports under Scenario 5**

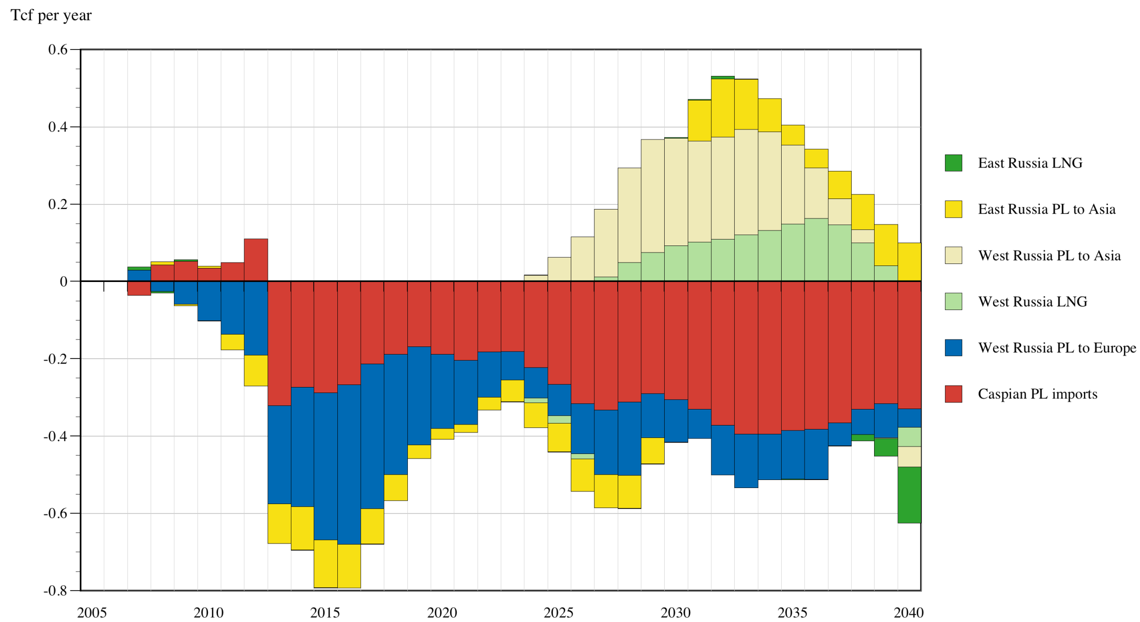



Figure 40 shows how Russian trade is affected by forcing the construction of pipelines from Central Asia to Europe that bypass Russia. The most noticeable effect is the large decline in imports from the East of Caspian group of countries. Not surprisingly, Russian pipeline exports to Europe also decline as Europe imports more gas using the Nabucco pipeline. Since Russia exports less to Europe via pipeline, it exports more as LNG from Murmansk. Russia also opts to export more gas via pipeline to West China due to reduced opportunities in Europe.

Figure 41, illustrating the overall changes in supply in scenario 5 relative to the reference case, also shows the reduction in Russian supply through the late 2020s and the increase in supply from the East of Caspian group of countries throughout the time horizon.

**Figure 41. Changes in Overall Supply in Scenario 5**

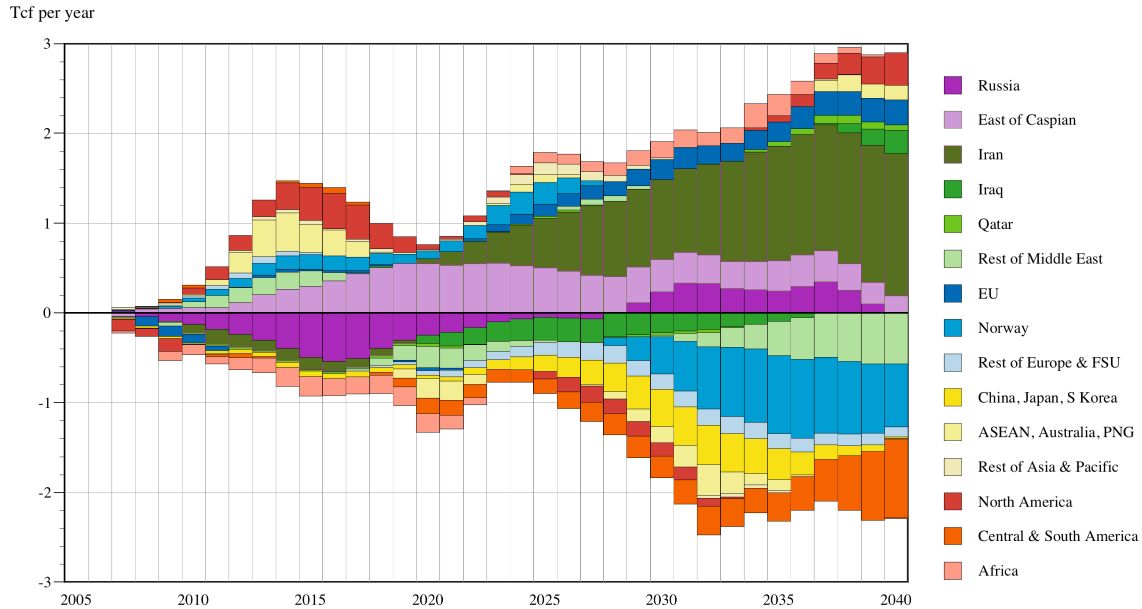



**Figure 42. Changes in LNG Supply in Scenario 5**

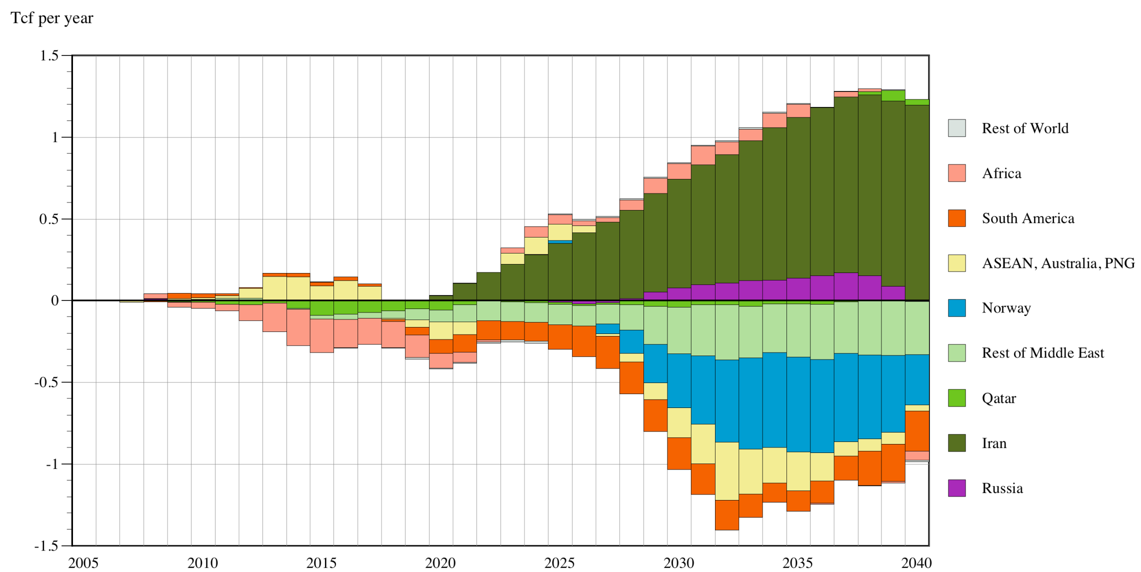



Figure 41 also shows that, once again, increased supply from Iran is a noticeable effect of the change. Figure 42, showing the change in LNG supply only, suggests that most of the increased Iranian supply is exported as LNG. With more Central Asian supply reaching Europe via a southern route, less Iranian gas would be exported north, making more available for LNG exports from the south.

Despite the increased supply from Iran, the overall net change in world LNG exports is quite small. The increased Iranian supply of LNG is partly offset by reductions in production and LNG exports from Middle East countries other than Iran and Qatar. Overall supply and LNG exports from Norway, Australia, Southeast Asia, and South America are also negatively affected.

**Figure 43. Changes in LNG Demand in Scenario 5**

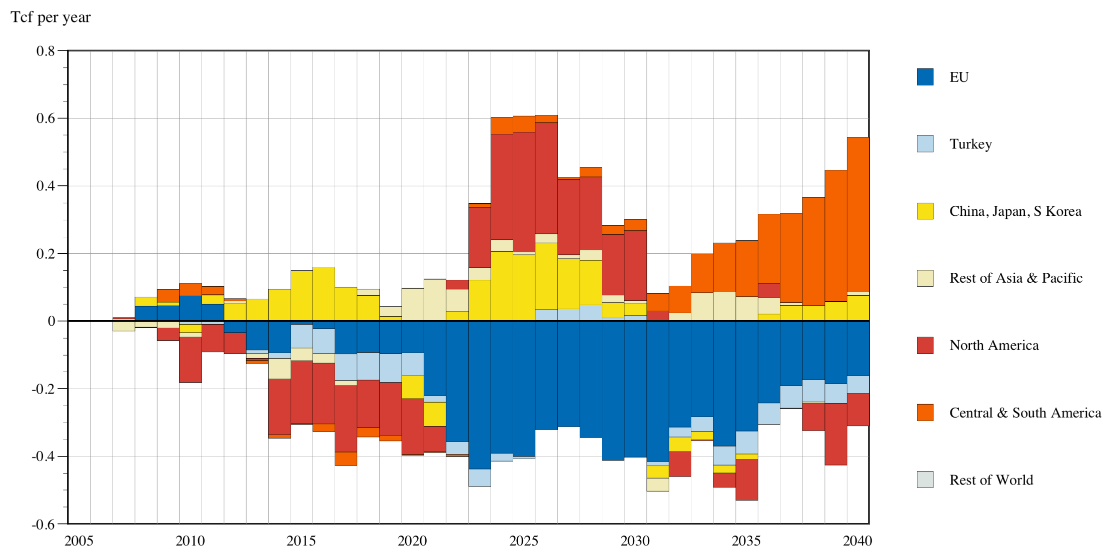
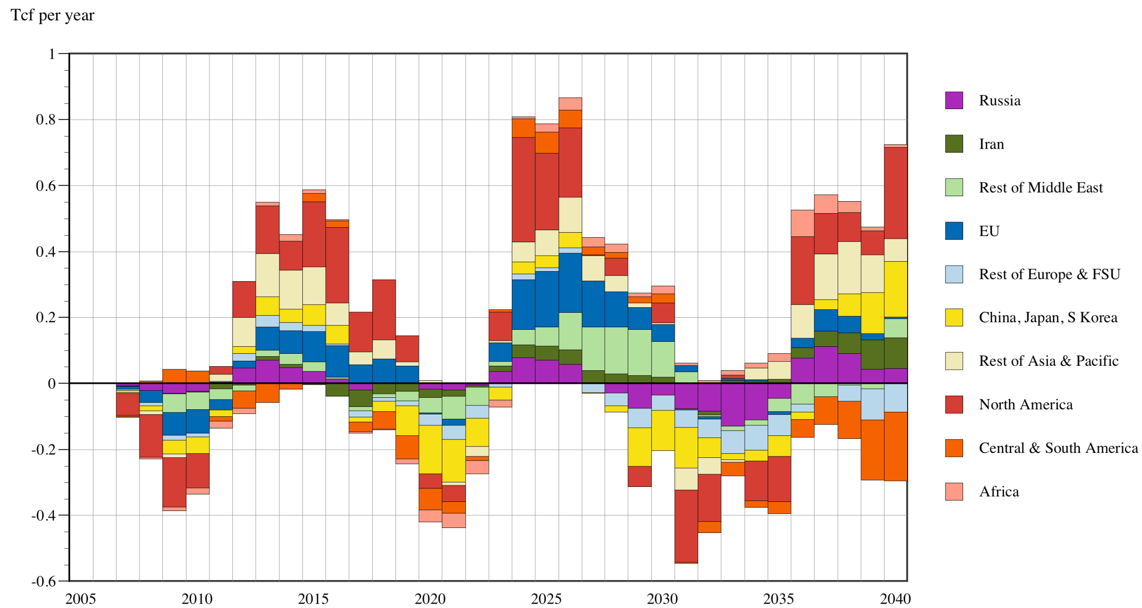



Figure 43 illustrates the comparable shuffling of LNG demand between various regions. Increased supply of pipeline gas to Europe and Turkey reduces the demand for LNG in both regions. The generally lower prices for LNG under this scenario also encourage LNG imports into Asia in most years, into North America for a decade between 2022 and 2032, and into South America after 2031.

The changes in overall demand, illustrated in Figure 44, are also quite small. In contrast to the picture for LNG, however, no regions show a consistently positive or negative demand response throughout the time horizon.

**Figure 44. Changes in Overall Demand in Scenario 5**




*F. Scenario 6: The "Gas Troika"*

In this scenario, we consider the impact of three large gas producers—Russia, Iran and Qatar, the so-called "Gas Troika"—coordinating natural gas export activities. Specifically, we investigate the impact of each of the three producers seeking a higher return, relative to the reference case, on exported natural gas volumes, where each does so in a manner consistent with the other members of the group. Similar to scenarios 4 and 5, we also consider the impact of an additional set of constraints on transporting Middle East gas through Turkey and exporting Iraqi gas to Iran. The impacts of these additional constraints are similar to those seen in scenarios 4 and 5, which highlight a major point for the broader analysis of Russian and Caspian natural gas. Iraq is a very influential force in the long term. Its abundant gas resources and relatively low domestic demand make it a prime candidate for displacing European gas imports from Russia and the Caspian states.

**Figure 45. Changes in Overall Supply in Scenario 6**

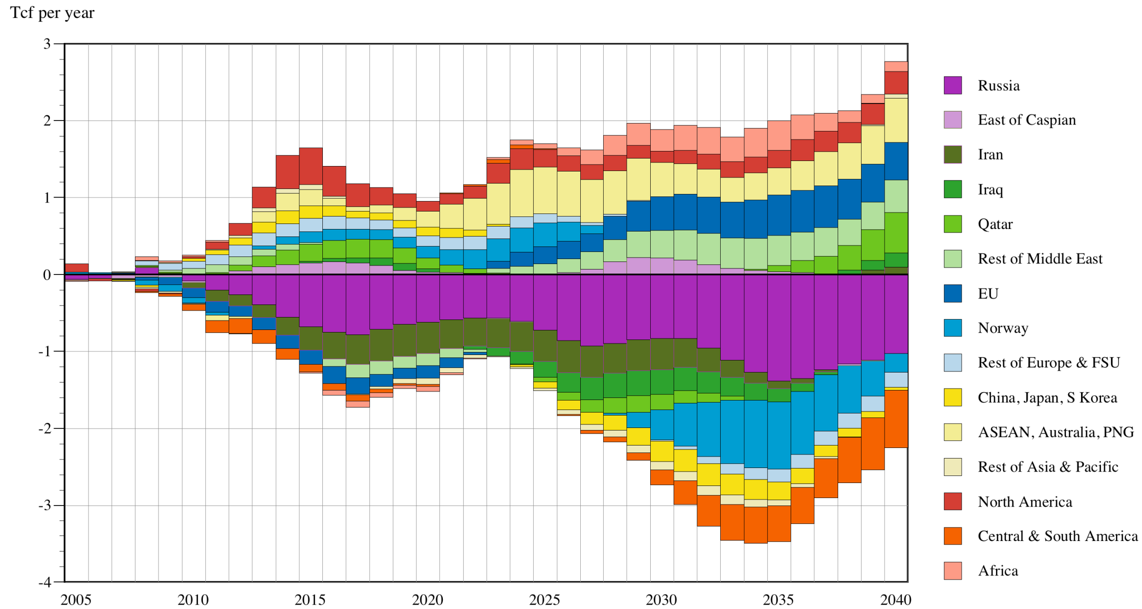
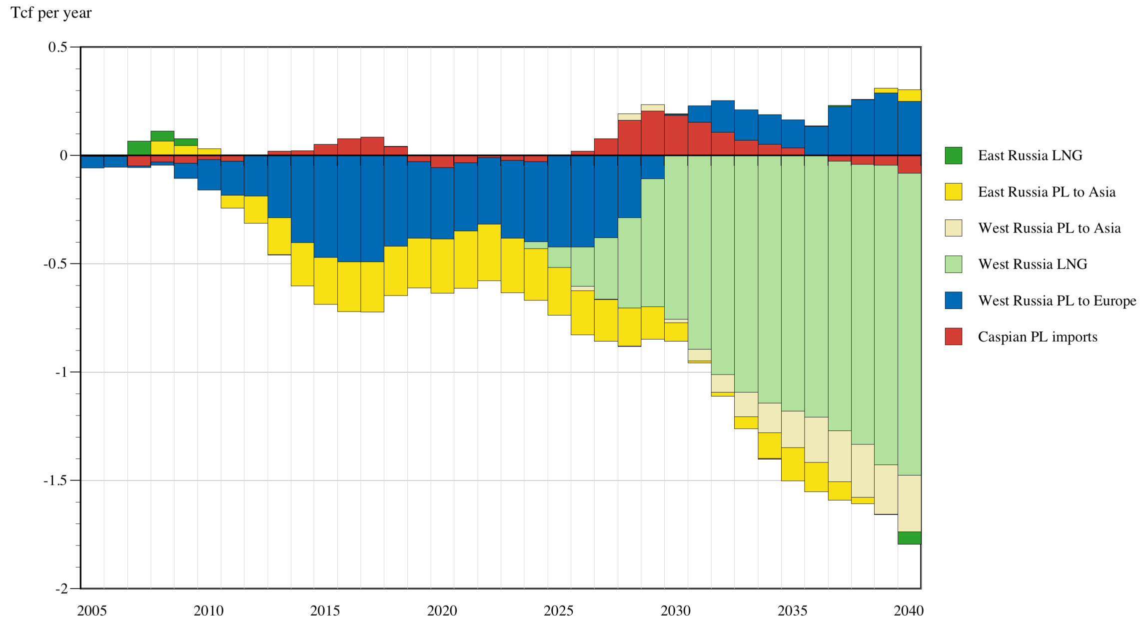



Figure 45 reveals that all three members of the coordinating Troika produce less natural gas. There are positive supply responses from a variety of other sources, including North America, North Africa, Australia, and other Middle East countries. There is an intertemporal response in Norway, as production is accelerated at the expense of the longer term.

The effects on Russia in particular are indicated in Figure 46. Exports via pipeline to both Europe and Asia are reduced. Beyond 2030, however, exports to Europe recover as higher prices ultimately attract Russian supplies. LNG exports, particularly through the Murmansk facility, are dramatically lower as the higher required return on a relatively high cost project effectively constrains its development. There is a slight increase in Caspian imports through Russian infrastructure. This results primarily because Russian demand is slightly higher due to lower domestic prices, which follows from restricting supply development for export.

**Figure 46. Changes in Russian Exports under Scenario 6**




More globally, Figure 47 shows that LNG exports from Russia and Iran decrease throughout the time horizon. Qatari LNG exports decline initially, but rise longer term as higher-priced pipeline supplies to Europe allow Qatari LNG to compete for market share. LNG exports from Australia, Indonesia, North and West Africa and other Middle East countries expand to make up for the reduction in LNG supplies from the Troika members. This result indicates the relatively elastic long run global LNG supply curve, which allows for a diversity of alternative sources if production from a select group of suppliers is constrained.

**Figure 47. Changes in LNG Exports in Scenario 6**

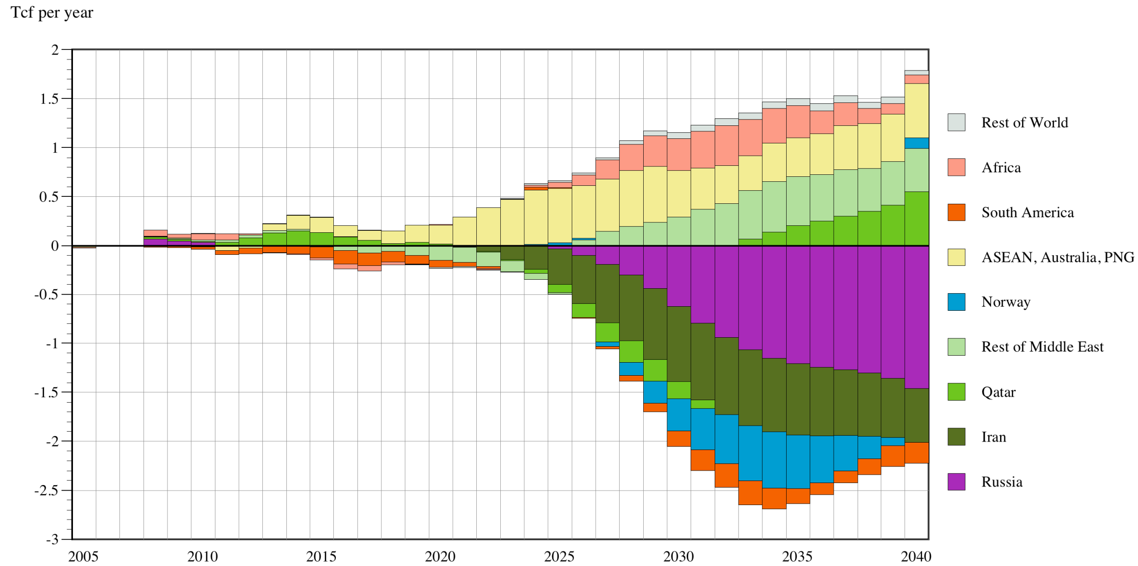
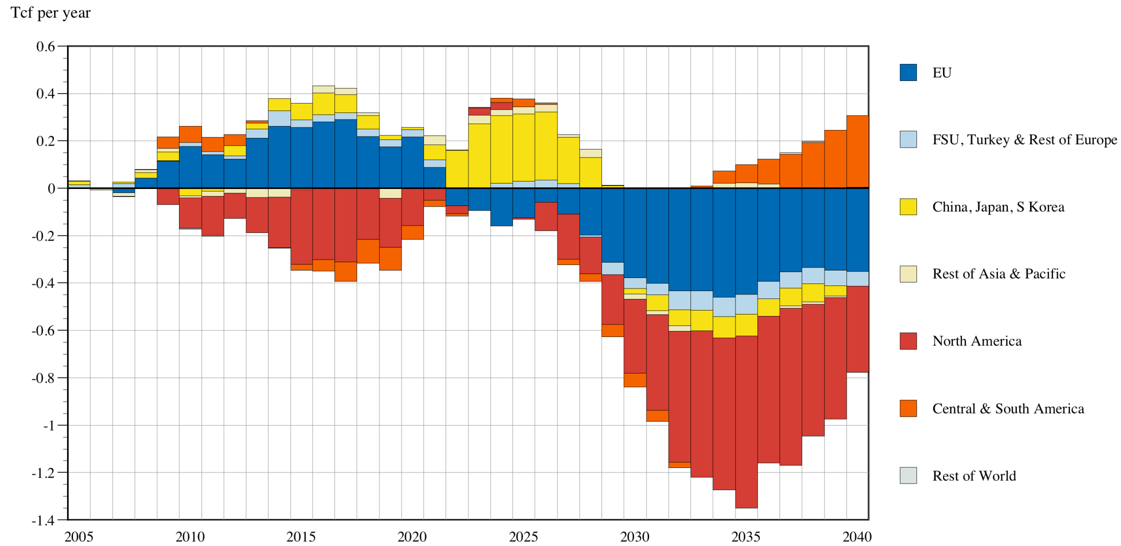


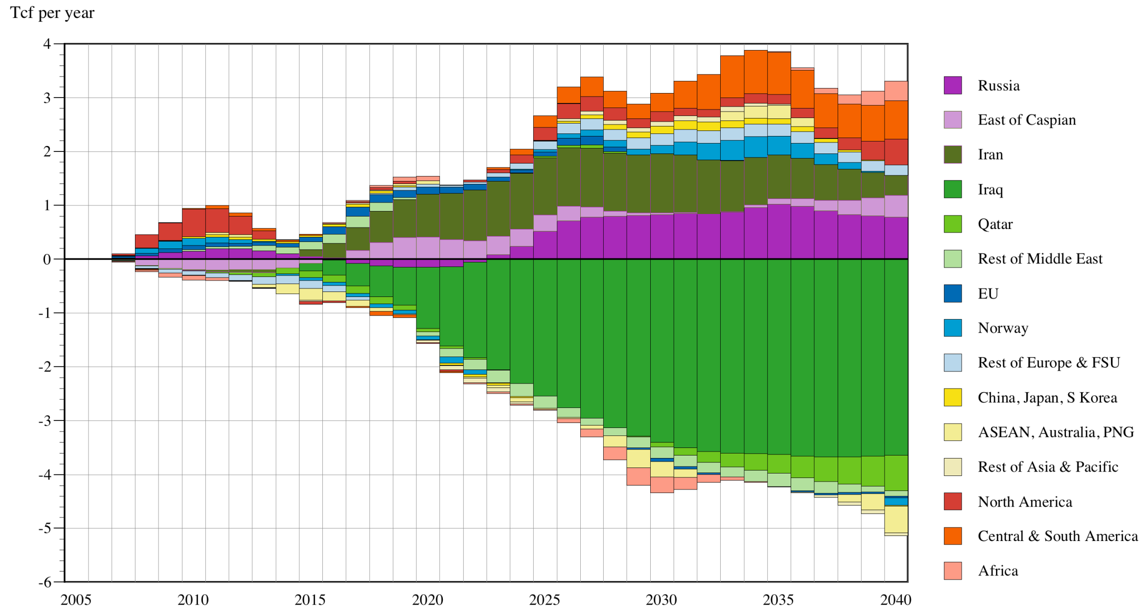

Figure 48 shows that changes in LNG imports are less dramatic than the changes in LNG exports indicated in Figure 47. This is another consequence of the relatively elastic global LNG supply curve, resulting from the availability of many alternative LNG suppliers able to fill the void left by the coordinating Troika members. Differences in transportation costs from the original and the replacement suppliers do, however, produce some effects. In particular, LNG imports are substantially lower in North America for the full time horizon, while LNG imports increase in Asia. LNG imports in Europe are higher in the short term, but lower in the longer term. The latter outcome follows primarily from the fact that Iraqi gas begins to move into Europe via Turkey after 2020.

**Figure 48. Changes in LNG Imports in Scenario 6**




The influence of Iraqi natural gas supply after 2020 is a prominent feature of all of the scenarios considered herein. Thus, as with scenarios 4 and 5, we consider a variation of scenario 6 where Iraqi gas remains constrained indefinitely. In Figure 49, we see that about half of the resulting reduction in Iraqi supply is met by increased production from Russia and Iran even though they are constraining supplies to raise rates of return. There are also marginal increases in supply from the East of Caspian group of countries. The positive supply response in Central and South America is primarily for export. It arises because the reduction in Iraqi supplies pushes Europe more heavily toward LNG, which raises prices everywhere and triggers the observed response.

**Figure 49. Additional Change in Supply with Iraq Constrained**




In Figure 50, we see that Russian production is much higher when Iraqi gas is constrained. Russian imports of Caspian gas are lower, almost completely offsetting the increase observed in Figure 46. Moreover, the increase in Russian exports indicated in Figure 50 largely offsets the reduction seen in Figure 46, a major exception being with regard to exports to Asia, where Iraqi gas has virtually no bearing.

**Figure 50. Additional Changes in Russian Exports with Iraq Constrained**

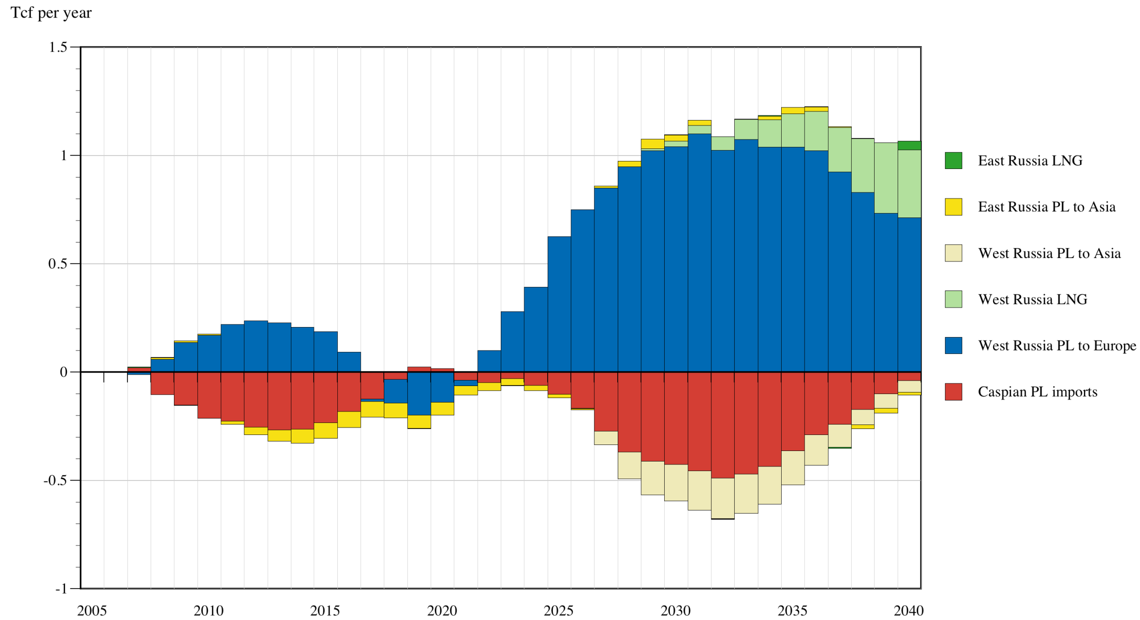
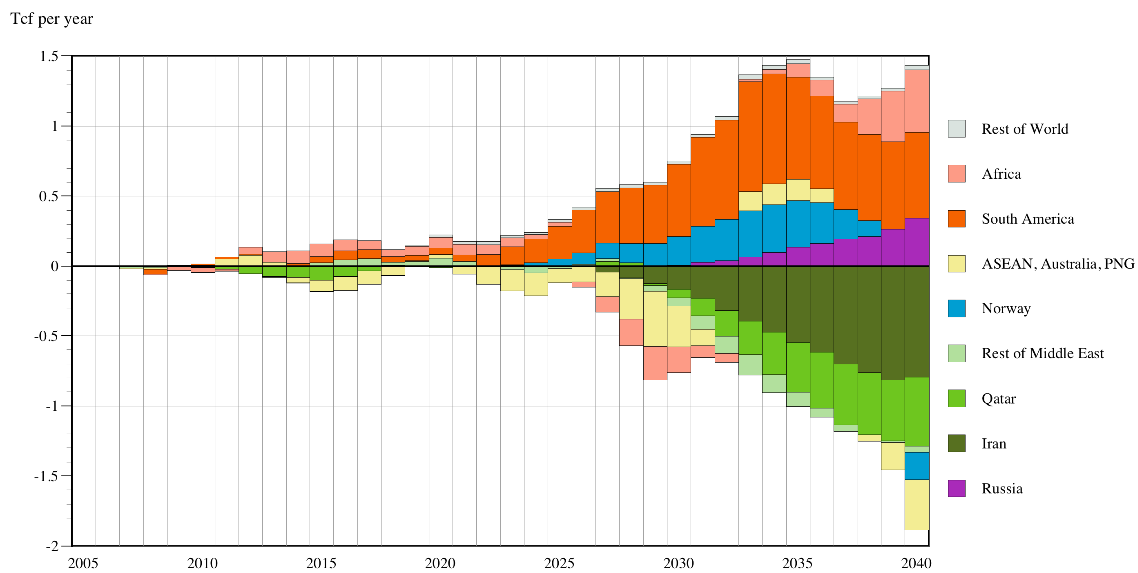


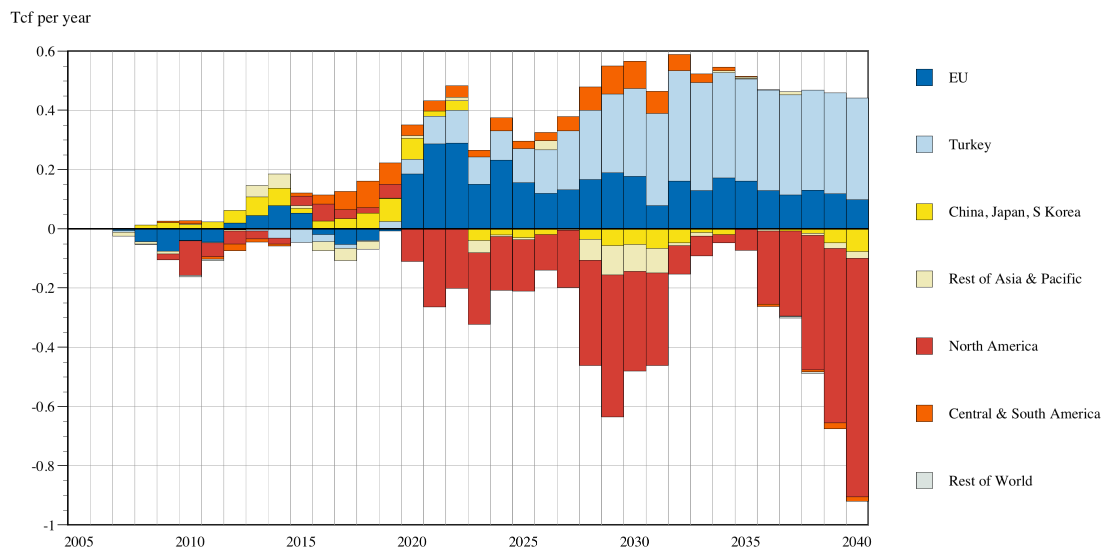

**Figure 51. Additional Changes in LNG Exports with Iraq Constrained**




The incremental changes in LNG exports and imports as a result of the additional constraints on Iraq are indicated in Figures 51 and 52, respectively. LNG exports from Iran decline even more when Iraqi gas supplies are indefinitely suspended, and the incremental impact causes a reduction in Qatari LNG exports. Higher competition for LNG supplies in Europe again pushes up price everywhere. This encourages a positive supply response from Murmansk LNG and Central and South America.

A lack of Iraqi gas also pushes Turkey and Europe more heavily into LNG imports. The higher prices result in increased production in the US, and, thereby, less LNG imports into North America.

**Figure 52. Additional Changes in LNG Imports with Iraq Constrained**




## VI. Concluding Remarks

We opened the paper by noting Russia's dominant status in the world natural gas market. It is currently the world's largest natural gas producer and has extraordinary potential for developing new resources. Russia also has a long history of exporting natural gas to Western Europe and is well situated to satisfy rapidly expanding demand in Northeast Asia.

However, there is growing unease, especially in Western Europe, that Russia may be financially unable or unwilling to meet European demands. The recent cutoffs of Russian supply to Ukraine in order to forcefully renegotiate prices and settle outstanding debt have heightened West European concerns over Russia's future reliability as a major supplier. Moreover, Russia's seemingly successful strategy in maintaining Central Asian dependence on Russian pipelines for transporting exports to European markets has only added to Western concerns. This has prompted interest in developing alternative export routes to Europe for natural gas sourced from the Caspian states. It has also spurred investment in LNG import infrastructure. Each of these moves is designed to lessen Europe's broad dependence on Russia.

In order to investigate the impacts of various natural gas industry-related developments that may unfold in Russia, we undertook scenario analysis using the Rice World Gas Trade Model. The general implication of our analysis is that Russia may have less ability to adversely affect the West European gas market than at first appears to be the case. In fact, any effort to gain excess rents in the near term will likely be offset by significant and sustained losses in the longer term. More generally, the developing global market for natural gas implies that disturbances in one location are spread across the globe. Intertemporal substitution by producers and demand response to higher prices also reduce the effects of shocks in any one period.

A very important point highlighted by our analysis regards the importance that natural gas supplies sourced from the Middle East, and Iraq in particular, could have for Europe. In fact, developments in Iraq to move gas through Turkey could present a serious threat to Russia's market share in Europe. Across all scenarios, our analysis reveals that development of Iraqi natural gas supply is the single largest factor affecting the long term development of Russian natural gas to Europe.

More generally, the importance of the Middle East as a possible counterweight to Russia also indicates that coordinated action by Russia and the Middle East could be a significant threat to the energy security of the rest of the world. In fact, our analysis highlights the common interest that the countries of Western Europe, Northeast Asia and North America have in promoting the development of an efficient worldwide market for natural gas. Any factor that undermines that development will tend to work against broader goals of energy security by introducing binding constraints and potentially limiting arbitrage opportunities.

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