Sources for the ETC energy security explainer series

The drivers of the winter 2021-2022 gas crisis

Page 1

What happened to gas prices in 2021?

Comments	• Dutch TTF gas prices are used to represent European gas markets.
Sources	• BNEF (2022) *E.U. Power and Fuel Prices* • BNEF (2022) *APAC Power Market Monthly* • EIA (2022) *Henry Hub Natural Gas Spot Price*

What happened to electricity prices in 2021?

Comments	• Average power prices of France, Germany, Italy, Netherlands and Nordpool are used to represent European power markets. • ERCOT Houston prices are used to represent the US power markets. • Japan and Korea prices are an average of the two markets.
Sources	• BNEF (2022) *E.U. Power and Fuel Prices* • BNEF (2022) *APAC Power Market Monthly* • BNEF (2022) *U.S. Power and Fuel Prices: Monthly*

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LNG is more expensive than piped gas

Sources	• BP (2021) *Statistical Review of World Energy*

EU and Asia reliant on LNG

Sources	• BP (2021) *Statistical Review of World Energy*

Fierce competition for LNG between EU and Asia

Comments	• Map based on 'Net LNG Exports and Imports to 2035' data. Numbers illustrative only.
Sources	• BP (2017) *BP Energy Outlook*

Percentage of 2021 EU gas storage filled

Comments	• Derived from IEA chart - 'Inventory levels in EU underground storage sites, 2016-2022'.
Sources	• IEA (2022) *Gas Market and Russian Supply*

The energy security implications of Russia's invasion of Ukraine

Page 1

Russian percentage of European primary energy supply

Sources	• Eurostat (2022) *The EU imported 58% of its energy in 2020* • BP (2021) *Statistical Review of World Energy*

Russian percentage of German gas imports

Sources	• Eurostat (2022) *Imports of natural gas by partner country*

Which countries are most dependent on Russian gas?

Comments	• Reproduced from *Bruegel Attribution of Gas Imports to Individual Sources in 2021*. Please see https://www.bruegel.org/2022/02/preparing-for-the-first-winter-without-russian-gas/ for detailed methodology.
Sources	• Bruegel (February 2022) *Preparing for the first winter without Russian gas,* McWilliams, B. Sgaravatti, G. Tagliapietra, S. and G. Zachmann

What is gas used for in Europe?

Sources	• Eurostat (2022) *Supply, transformation and consumption of gas*

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How important is European energy demand to Russia?

Sources	• BNEF (October 2021) *Russia Insight: Why Putin Can Afford to Squeeze Gas Supplies.* • IEA (April 2022) *Frequently Asked Questions on Energy Security.* • BBC (November 2021) *Will Russia ever leave fossil fuels behind?*

What has Russia's gas revenue been since the beginning of the war?

Comments	• First quarter 2022 revenue estimates have been calculated by assuming constant imports at 2021 levels (1515 TWh), with 2022 q1 imports calculated by dividing 2021 imports by 4.
Sources	• BNEF (2022) *E.U. Power and Fuel Prices*

How long will high gas prices last?

Sources	• BNEF (2022) *E.U. Power and Fuel Prices* • Powernext (data extracted 30 March 2022 and 26 April 2022) *Futures market data*

Sources for the ETC energy security explainer series

How far can Europe reduce use of Russian gas this year?

How much gas does Russia supply to Europe and where is it used?

Comments	• Other EU gas use includes storage injections (200 TWh), chemical feedstock (200 TWh), and smaller sectors including transport, agriculture forestry and fishing, and energy sector energy use (250 TWh).
Sources	• Eurostat (2022) *Imports of natural gas by partner country* • Eurostat (2022) *Supply, transformation and consumption of gas*

What are the options to replace Russian gas in the next year?

Sources	• European Commission (March 2022) *REPowerEU*

How far can Europe reduce the use of Russian gas this year?

Sources	• Aurora (March 2022) *Impact of Russia-Ukraine war on European gas markets: can Europe cope without Russian gas?* • European Commission (March 2022) *REPowerEU* • IEA (March 2022) *A 10-Point Plan to Reduce the European Union's reliance on Russian Natural Gas*

Importing Liquified Natural Gas (LNG)

Page 1

Where is LNG produced?

Comments	• Asia Pacific = Malaysia, Indonesia, Papua New Guinea, Peru, Brunei Darussalam. • Other MENA = Oman, UAE, Egypt, Algeria. • Other = Nigeria, Angola, Cameroon, Equatorial Guinea, Norway, Argentina, Trinidad & Tobago.
Sources	• BNEF (Jan 2022) *Global LNG Trade Flows: 2021 Review*

How much LNG does Europe use today and how much can LNG help this year?

Sources	• European Commission (March 2022) *REPowerEU* • IEA (March 2022) *A 10-Point Plan to Reduce the European Union's reliance on Russian Natural Gas*

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Methane emissions per unit of gas produced

Comments	• Methane leakage rate measurements include high degree of uncertainty. Minimum supply chain LNG estimates are around 6 ktCH4/bcm, whereas maximum estimates are upwards of 75 ktCH4/bcm.
Sources	• Sustainable Gas institute (2015) *White Paper – Methane and CO2 emissions*

Natural gas consumption

Sources	• ETC (2020) *Making Mission Possible*

Global LNG imports

Comments	• Other Asia includes South Korea (5.1 bcm), Turkey (2.8 bcm), and India (2.1 bcm) and 'Other Asia' (5.1 bcm).
Sources	• BNEF (April 2022) *Global LNG Monthly: No Price Relief This Shoulder Season*

How increased renewable deployment can deliver energy security

Page 1

What is the role of renewables in power generation?

Comments	• Other renewables include hydro, tidal, wave, solar thermal and geothermal and bioenergy. • 2030 value is the projected power generation mix under the Fit for 55 package. • 2050 value is taken as the projected power generation mix in the IEA's Sustainable Development Scenario in Europe. A more ambitious Net Zero scenario would likely see higher levels of power generation in Europe.
Sources	• European Commission (2021) *'Fit for 55' mix scenario energy model* • IEA (2021) *Sustainable Development Scenario dataset*

Is the deployment of renewables on track?

Comments	• Values for average capacity additions between 2022-2030 are computed based on the difference between current installed capacity and capacity (or equivalent production-derived capacities) targets for 2030 in reference net-zero consistent scenarios for selected geographies.
Sources	• European Commission (2021) *'Fit for 55' mix scenario energy model* • European Commission (March 2022) *REPowerEU* • TERI (2020) *Renewable Power Pathways: Modelling The Integration Of Wind And Solar By 2030* • RMI (2021) *China Zero-Carbon Electricity* • Princeton University (2020) *Net-Zero America Report – E+ high electrification scenario*

Sources for the ETC energy security explainer series

Page 2

Lowest-cost bulk generation cost

Comments	• Levelised costs (LCOEs) for gas CCGTs in Italy and Spain are taken as the average LCOE for France and Germany. • Presented LCOEs are unsubsidized and include carbon pricing.
Sources	• BNEF (2022) *LCOE data for selected countries* • ETC (2021) *Making Clean Electrification Possible Report*

All-in generation cost

Sources	• ETC (2021) *Making Clean Electrification Possible Report*

Offshore wind potential

Sources	• ETC (2021) *Making Clean Electrification Possible Report*

Cumulative resources needed for transition by 2050

Sources	• ETC (2021) *Making Clean Electrification Possible Report*

Page 3

What are the bottlenecks for rapid scale up of renewables in Europe?

Sources	• Italy – Wind Europe (2022) *Messy permitting leads to yet another undersubscribed wind auction in Italy* • Sweden – F.Jalkenas (KTH) (2019) *Evaluation tool for large scale onshore wind power projects*

The opportunities, limits and trade-offs to using bioenergy-based power and heat to deliver energy security

Page 1

What is the role and potential of biomass in Europe?

Comments	• Net imports = Imports – Exports to EU27 • Additional potential from diet shift is computed assuming all biomass used for animal feed is directly converted to consumable calories in a plant-based diet, with land intensity for meat assumed 100 times greater than that of vegetables for the production of one kilocalorie
Sources	• Eurostat (2021) – *EU27 Energy balances* • Material Economics (2021) – *EU Biomass Use in a Net-Zero Economy* • Energy Transition Commission (2021) – *Bioresources within a Net-Zero Emissions Economy: Making a Sustainable Approach Possible* • J. Hewitt (2011) – *Flows of biomass to and from the EU: an analysis of data and trends*

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How is bioenergy used in Europe?

Comments	• n/a
Sources	• Eurostat (2021) – *EU27 Energy balances* • Material Economics (2021) – *EU Biomass Use in a Net-Zero Economy*

How to reprioritize and optimize the use of bioresources?

Comments	• n/a
Sources	• Energy Transition Commission (2021) – *Bioresources within a Net-Zero Emissions Economy: Making a Sustainable Approach Possible*

Sources for the ETC energy security explainer series

How green hydrogen can deliver energy security

Page 1

What is green hydrogen and how is it used in Europe?

Comments	• Electrolysis accounts for both grid connected and renewables only production • others include energy, transport, other chemicals and other industries (food processing, steel & glass manufacturing)
Sources	• Hydrogen Europe (2021) – *Clean Hydrogen Monitor 2020* • ETC (2021) – *Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy*

Where can green hydrogen be used?

Comments	• Note: Potential for hydrogen to substitute natural gas, oil and coal consumption in certain uses
Sources	• Eurostat (2022) – *EU27 Energy balances* • ETC (2021) – *Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy* • Madeddu & al. (2020) – *The CO_2 reduction potential for the European Industry via direct electrification of heat supply (power-to-heat)* • IRENA & AEA (2022) – *Innovation Outlook Renewable Ammonia* • UNFCCC (2022) – *GHG Database*

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How cost-competitive is green hydrogen?

Comments	• USD to EUR conversion factor taken as 0.95 (25/05/2022) • T&S: transport, distribution and storage
Sources	• ETC (2021) – *Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy* • European Commission (2021) – *Assessment of Hydrogen Delivery Options*

What are the EU's ambitions for green hydrogen?

Comments	• Hydrogen production from the Fit for 55 package has been computed based on installed electrolyser capacity targets
Sources	• European Commission (2021) – *Fit for 55 package* • European Commission (2022) – *REPower EU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition*

Page 3

Where can the EU get green hydrogen from?

Comments	• n/a
Sources	• S&P Global (2022) – Atlas of Energy Transition – *Hydrogen* • European Hydrogen Backbone (2022) – *A European Hydrogen Infrastructure vision covering 28 countries*

What is needed for green hydrogen to develop and meet targets?

Comments	• PPA = Power Purchase Agreement
Sources	• ETC (2021) – *Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy*

The role nuclear power might play in supporting energy security

Page 1

What is the role of nuclear power in Europe?

Comments	• RHS bar graph: 2030 values are taken from the Fit for 55 trajectory for power production in the EU
Sources	• IAEA PRIS (2021) – *Nuclear Power Reactors in the World 2021 (RDS-2)* • Eurostat (2021) – *EU27 Energy balances*

What are the benefits and drawbacks of nuclear power?

Comments	• Note that pros and cons list is not exhaustive and selected facts have been chosen to illustrate further points in the explainer • Note that only leading countries for nuclear in Europe have been selected as illustration
Sources	• ETC research of publicly available strategies for nuclear power • Greenpeace (2018) - *Lifetime extension of ageing nuclear power plants: Entering a new era of risk*

How much nuclear is set to come offline in the coming decade?

Comments	• Projected offline capacities for Europe have been determined assuming the closure of reactors when reaching 40 years of operational lifetime, excluding lifetime extensions or premature shutdowns due to political decisions or unforeseen technical challenges
Sources	• M. Schneider (2022) – *The World Nuclear Industry - Status Report 2021* • ETC analysis of IAEA PRIS (2021) – *Nuclear Power Reactors in the World 2021 (RDS-2)*

Sources for the ETC energy security explainer series

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Can nuclear lifetime be extended safely?

Comments	• n/a
Sources	• M. Schneider (2022) – *The World Nuclear Industry - Status Report 2021* • Greenpeace (2018) - *Lifetime extension of ageing nuclear power plants: Entering a new era of risk* • ForoNuclear (2021) – *A life extension to 80 years approved for two units in Surry nuclear power plant in the United States*

Page 2

How much of a difference can existing nuclear make in the medium-term?

Comments	• Reference year for production is assumed as being 2020 • Note for cascade graph: TWh of power have been converted to TWh of natural gas using a 50% power conversion efficiency with 1 bcm = 10 TWh • Note: lifetime extensions excludes the 60 TWh from closure delays to avoid double counting
Sources	• ETC analysis of IAEA PRIS 2021 – Nuclear Power Reactors in the World 2021 (RDS-2) dataset • IEA 2022 – A 10-point plan to reduce the European Union's Reliance on Russian Natural Gas

Can new nuclear make a difference?

Comments	• Min-max values for selected energy import and production are presented in the bar graph (point 1) • LCOE data for nuclear is taken for Europe only while LCOE for renewables is at global-level and only takes into account unsubsidized costs
Sources	• BNEF 2022 – Global and Regional LCOE data for nuclear and renewables

Energy efficiency

Page 1

What is the role of gas in Europe?

Comments	• "Others" category includes: non heat and power transformation input, use in energy industry, use in agriculture and forestry and in transportation
Sources	• Eurostat 2022 – *2021 EU energy balances*

How can demand for gas be reduced no impact on comfort for households?

Comments	• -1°C for all buildings (households and commercial) results in a 10 bcm (eq. 100 TWh) decrease in natural gas consumption in Europe • "Medium-term" corresponds to solutions that can not be deployed before year-end (~1-2 years)
Sources	• Agora Energiewende (2022) – *Regaining Europe's Energy Sovereignty – 15 Priority Actions for REPowerEU* • IEA (2022) – *A 10 Point Plan to reduce the European Union's Reliance on Russian Natural Gas*

How can behaviour change be incentivized by governments?

Comments	• +30% energy price compared to pre-conflict average in Europe
Sources	• IEA (2022) – *Accelerating energy efficiency: What governments can do now to deliver energy savings* • BNPP Economic Research (2021) – *Energy costs – how much European household spending do they account for ?* • Allianz Economic Research (2022) – *Russia-Ukraine crisis – The (energy) price of war for European households*

Page 2

How can demand for gas be reduced in the industry?

Comments	• n/a
Sources	• Agora Energiewende (2022) – *Regaining Europe's Energy Sovereignty – 15 Priority Actions for REPowerEU* • ECEEE (2007) – *Industrial Waste-Heat Recovery: Benefits and Recent Advancements in Technology and Applications*

How can industrial natural gas uses be prioritised to further reduce demand?

Comments	• Flexibility of operation of industrial sectors depends on plant and process type. These are general indications of sector flexibility, and are mostly dependent on the temperature levels and gradient required for each specific industry process. Some disruptions in natural gas supply or process heating can incur significant costs (e.g. glass manufacturing) • Gross Added Value (GVA): measure of the value of goods and services produced in a sector of the economy
Sources	• Eurostat (2022) – *EU27 Energy Balances* • IEA (2018) – *Clean and efficient heat for industry* • Madeddu & al. (2020) – *The CO_2 reduction potential for the European Industry via direct electrification of heat supply (power-to-heat)* • OECD (2020) – *Dataset 6A. Value added and its components by activity*