



This project is co-funded by
the European Union

Ukraine Energy Profile

International
Energy Agency



INTERNATIONAL ENERGY AGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 30 member countries, 8 association countries and beyond.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea
Luxembourg
Mexico
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA

IEA association countries:

Brazil
China
India
Indonesia
Morocco
Singapore
South Africa
Thailand

Please note that this publication is subject to specific restrictions that limit its use and distribution. The terms and conditions are available online at www.iea.org/t&c/

Source: IEA. All rights reserved.
International Energy Agency
Website: www.iea.org



Table of contents

Ukraine	4
Country overview	4
Key energy data.....	7
Energy sector governance	8
Key policies	10
Chapter 1. Energy security	14
Resource endowment.....	14
Energy security and diversification	15
Energy infrastructure and investment.....	18
Emergency response	24
Chapter 2. Market design	25
National market structure.....	25
Regulatory framework.....	29
Regional markets and interconnections	33
Chapter 3. Sustainable development	35
Renewable energy	35
Energy efficiency.....	36
Fuel switching	39
Environmental protection	40
Climate change	40
Technology research, development and deployment.....	41

Ukraine

Country overview

Ukraine has a population of 41.9 million¹ and at 603 549 square kilometres (km²) is the second-largest country in Europe by area. Located at the crossroads of the European Union, the Russian Federation (Russia), and the Black Sea and Caspian regions, Ukraine has abundant mineral resources including oil, natural gas and coal, and great hydro and biomass potential. With its considerable population and high energy consumption, it is one of Europe's largest energy markets. It is also the country that transits the most natural gas in the world, playing a key role in delivering Russian gas to European markets.

Ukraine experienced a long period of very strong economic growth in 2000-07, owing to low gas prices, a strong national currency (the hryvnia [UAH]) and high foreign steel demand and prices. Ukraine's economy remained open and export-oriented, and it joined the World Trade Organization in 2008.

Nominal gross domestic product (GDP) was UAH 3 559 billion in 2018 (USD 130.8 billion in 2018 USD). After sharp currency devaluation in 2014-15, per-capita GDP declined in 2018 to USD 3 095 (in 2018 USD) according to the World Bank. The share of steel and non-ferrous metals in total exports declined about twofold in recent years, to 21.7% in 2019, but the share of agricultural and food industry products reached 48% according to National Bank of Ukraine statistics. Machinery and manufacturing's share in total exports decreased in 2014-19 mainly due to trade restrictions imposed by Russia in 2013-15. As its key trade partner, the European Union received 37.1% of total exports in 2019, whereas Russia accounted for only 10%, a dramatic decrease from 29% in 2013. Total exports to Commonwealth of Independent States (CIS) countries also declined in 2019, to 17.4% (<https://bank.gov.ua/statistic/sector-external/data-sector-external#1>).

¹ Excluding the temporary occupied Autonomous Republic of Crimea, Sevastopol-City and parts of Donetsk and Luhansk regions.

Ukraine remains heavily reliant on oil product and gas imports. Variations in the UAH–USD exchange rate, access to export markets, closure of Russia’s market, external construction activity in Asia and the Middle East, agriculture, and energy supply and price trends have a substantial impact on its domestic economy.

Despite strong growth up to 2007, Ukraine underwent two severe economic crises between 2008 and 2017. Because of its exposure to foreign markets, Ukraine has been severely affected by the global economic and financial crises that began in autumn 2008: its economy fell into deep recession in 2009, with real GDP down 14.8% and industrial output plummeting almost 22%. The International Monetary Fund (IMF) offered support and agreed to a USD 16.4-billion Stand-By Arrangement (SBA) in November 2008 to stabilise the banking system and mitigate the impact of Ukraine’s collapse in output. A total of approximately USD 11 billion was released by the IMF under the arrangement, as well as USD 3.4 billion under a second SBA in mid-2010. Ukraine’s real GDP recovered 4.2% in 2010 and a further 5.2% in 2011.

Ukraine entered another recession in mid-2012, with GDP growth falling to 0% in 2013, -6.8% in 2014 and -9.9% in 2015. Due to factors such as insufficient capital investment, lower steel demand, high energy import prices, a lack of structural reforms, and corruption, the economy never recovered from the 2009 crisis. Month-long street protests in Kiev led to a change in government in March 2014, followed by loss of control of Crimea and the beginning of military conflict in Ukraine’s eastern regions, which resulted in casualties, significant damage to infrastructure and considerable economic loss. This has provoked strong depreciation of the hryvnia (from UAH 8 = USD 1 in December 2013 to UAH 26 = USD 1 in June 2018), far lower budget revenues and a 24% drop in industrial output in 2014-15. In 2016-2019, the economy showed tentative signs of recovery: real GDP increased by 2.4% (2016) and 2.5% (2017) according to the State Statistical Service of Ukraine, and by 3.4% in 2018 and 3.2% in 2019. This precarious economic recovery may, however, be threatened by the COVID-19 pandemic. In April 2020, the World Bank projected a real GDP decline of 3.5% in 2020 but, according to this forecast, growth is expected to recover to 3% in 2021 and 4% in 2022 given swift progress on key pending reforms as well as prudent macroeconomic [policy](#).

Deep structural changes and an overall decline in economic activity caused total gas consumption to fall from 50.4 billion cubic metres (bcm) in 2013 to 29.8 bcm in 2019 and caused natural gas’s self-sufficiency² to increase from 43% to 69%. Also during

² Domestic production/TPES

this period, a dispute with Gazprom over the price of gas and its transit through Ukrainian territory prompted Ukraine to source its imports from European suppliers instead, so Gazprom's share in total gas imports shrank from 92% in 2013 to 0% in 2016-19. Coal production and transportation have been severely disrupted in the Donbass region, as has electricity generation from co-generation plants,³ especially in conflict areas.

In 2014, the Ukrainian government benefited from another IMF SBA and the disbursement of two financial tranches of USD 3.6 billion and USD 1.4 billion. The government of Ukraine agreed with the IMF to conduct structural reforms to stabilise its economy and put it back on a sustainable growth path. Strong financial support has also been provided by the European Union, the World Bank, the European Bank for Reconstruction and Development (EBRD) and several countries on a bilateral level. In March 2015, the IMF and Ukraine concluded a new Extended Arrangement for over USD 17.5 billion, cancelling the previous SBA. The parties agreed on policies to strengthen public finances, advance structural reforms and secure financial stability. In April 2017, the IMF disbursed USD 1 billion after the third review of Ukraine's Extended Fund Facility (EFF) arrangement was complete, which resulted in a total disbursement of USD 8.38 billion. In December 2018, the EFF arrangement was replaced by a new 14-month SBA for USD 3.9 billion, of which only USD 1.4 billion was disbursed. In December 2019, Ukraine and the IMF agreed on a new USD 5.5-billion EFF arrangement, but no funds had been disbursed as of 20 April 2020 due to Ukraine's delay in meeting the prior actions required under the agreement.

Ukraine co-operates with the European Union through the Eastern Partnership, which aims to foster political association and economic integration between the European Union and the Eastern Neighbourhood countries (Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine).

Ukraine became an Observer to the Energy Community Treaty in November 2006 and a full Member in September 2010, and has begun adopting and implementing the energy acquis, namely the legislative frameworks for the electricity and gas sectors and requirements in the areas of renewable energy, competition and the environment.

The Ukrainian government also signed and ratified an Association Agreement with the European Union in 2014, and the Deep and Comprehensive Free Trade Agreement between Ukraine and the European Union entered into force on 1 January 2016.

³ Co-generation refers to the combined production of heat and power.

Key energy data

Supply

- Ukraine produces all fossil fuels (in 2018: 14.4 million tonnes of oil equivalent [Mtoe] of coal, 16.5 Mtoe of natural gas and 2.3 Mtoe of crude oil), but in quantities insufficient to meet total energy demand.
- Still, nearly 65% of Ukraine's total energy demand is covered by domestic production. This high self-sufficiency is explained by nuclear energy production, as Ukraine is the world's seventh-highest producer (83 terawatt hours [TWh] in 2019). Over half of the country's electricity is produced with nuclear power, and Ukraine and Armenia are the only EU4Energy countries that produce nuclear energy.
- Ukraine is the top energy consumer among EU4Energy focus countries. Its primary energy supply was 93 Mtoe in 2018, corresponding to around 90% of Poland's consumption.
- Ukraine's energy mix is relatively diversified, with no fuel representing more than 30% of the energy mix. In 2018, the share of coal (the country's primary fuel) dropped to 30%, followed closely by natural gas (28%) and nuclear (24%).

Imports/exports

- Ukraine depends on imports for around 83% of its oil consumption, 33% of its natural gas and 50% of its coal. In 2018 Ukraine imported 8.5 Mtoe (10.6 bcm) of natural gas, 13.8 Mtoe of coal and 10.4 Mtoe of oil products. Belarus is Ukraine's main supplier of refined products.

Demand

- In 2018, Ukraine's total final consumption (TFC; excludes transformation sector) accounted to 51.5 Mtoe.
- Industry is the largest final energy consumer (19.1 Mtoe in 2018). The residential sector is second (16.7 Mtoe), with households being the major users of natural gas (8.7 Mtoe in 2018). The share of coal in final consumption is very small (12%) because most of the coal consumed in the country is used to produce electricity and heat.
- Energy intensity per GDP at purchasing power parity (PPP) is very high: at 0.25 tons of oil equivalent (toe) per thousand 2015 USD PPP, it is the second-highest among EU4Energy countries, after Turkmenistan, and over twice the world average (0.11 toe /1000 USD).

- Renewables accounted for only 5% of the energy mix in 2018, and for 9% of electricity generation (13.4 TWh in 2019).

Energy sector governance

Executive

The [Cabinet of Ministers](#), the ultimate decision-making body, is responsible for policy co-ordination and the oversight of state energy companies. Energy policy is high on its political agenda, with the parliament and the president also involved in decision-making. Seven main national-level institutions have energy policy responsibilities:

- The [Ministry of Energy and Environmental Protection \(MEEP\)](#) is responsible for most energy supply policies, sustainable energy policy and climate change policy, and for co-ordinating energy policies across the government and advising the parliament.
- The [Ministry of Finance](#) is responsible for taxation relevant to the energy sector.
- The [Ministry of Regional Development, Construction and Housing \(Minregion\)](#) develops local-level policies and programmes.
- The [State Agency on Energy Efficiency and Energy Saving \(SAEE\)](#), under MEEP, is the central government body responsible for advancing and promoting energy efficiency and renewable energy developments and technologies.
- The [National Commission for State Regulation of Energy and Public Utilities \(NKREKP\)](#), established by Presidential Decree No. 715/2014 in September 2014, supervises the natural gas and electricity markets as well as the heat sector. The NKREKP replaced the National Commission for the Regulation of State Energy Markets (NKRE) (liquidated by Presidential Decree No. 693/2014 in August 2014) and the National Commission for the Regulation of Municipal Services Markets. The NKREKP is subordinate to the president and accountable to the parliament.
- The [Anti-Monopoly Committee](#) is responsible for preventing excessive concentration of market power.
- The [State Nuclear Regulatory Inspectorate](#) has regulatory responsibility for the operation of nuclear facilities, including uranium mining, radioactive waste storage and decommissioning at Chernobyl.

Legislative

Ukraine's legislative process is defined in its constitution. The president, the cabinet of ministers, members of parliament and the National Bank of Ukraine are entitled to

initiate draft legislation in the single-chamber parliament. For parliament to adopt a draft law, it must go through three readings (but quite often it is adopted on the second). After receiving the speaker's signature, the law goes to the Office of the President: the president may either sign the law or return it to the parliament with a veto that may be overruled by a two-thirds constitutional majority of the parliament (300 votes). The law comes into force after its official publication, unless otherwise stipulated in the law itself.

Those entitled to issue normative acts in the form of decrees, resolutions, orders, etc., are the president, the cabinet of ministers, ministries, the National Bank of Ukraine and government state agencies – within the scope of their responsibilities and the general provisions of the law. These documents are registered at the Ministry of Justice.

Sub-local governments adopt their regional budgets as prescribed by the Law on State Budget of Ukraine and issue local resolutions and orders within the limits of their competence.

Judiciary

In mid-2016 the parliament adopted a judiciary reform that will result in large-scale transformation of the judicial system. The new legislation stipulates a three-pillar structure for the court system: 1) courts of first instance, consisting of circuit courts (criminal and civil jurisdiction), circuit administrative courts and circuit commercial courts; 2) courts of appeal, consisting of appellate courts (criminal and civil jurisdiction), appellate administrative courts and appellate commercial courts; and 3) a supreme court (<http://www.lexology.com/library/detail.aspx?q=8bc6f8b6-1c53-4e3c-a56f-0cbf8519a729>).

With Ukraine's ratification of the Energy Charter Treaty, investors may appeal for international arbitration within the framework of the investment protection mechanism, or provisions for international arbitration may also be made in the contract, as in the gas supply and transit contracts between state-owned Naftogaz and Russia's Gazprom. Recent cases include the JXX Oil & Gas appeal under the arbitration rules of the Stockholm Chamber of Commerce in 2015 after Ukraine increased royalties on gas production from 28% to 55%, and the request from Naftogaz production subsidiary Ukrgasvydobuvannya to the Arbitration Institute of the Stockholm Chamber of Commerce to terminate its agreement with LLC Karpatygas and Misen Enterprises AB.

Regulatory framework

The NKREKP or Regulator (called the National Electricity Regulatory Commission until 2011) regulates both energy and communal services. It is responsible for economic regulation of the market and for its transparent, predictable, non-discriminatory and efficient functioning. In November 2016 Ukraine adopted the Law on NKREKP to fulfil its duties in line with Energy Treaty requirements. The law aims to establish the NKREKP's legal status and its regulation authority, and to ensure its economic and financial independence for effective regulation of the energy market.

The NKREKP sets prices for gas transportation, distribution and supply, and has the authority to set tariffs for electricity transmission and distribution, nuclear and hydropower plant generation, and steam coal prices for coal-fired power plants. It also approves tariffs for heat and hot water supplies for the largest district heating companies and approves feed-in tariffs for renewable energy source (RES) developers after project completion. According to the Law on the Natural Gas Market, the cabinet of ministers is responsible for regulating public service obligations (PSOs) in the gas sector. It currently sets the price of gas as a commodity for a regulated segment of the market (households and district heating companies) for heat production in the residential sector, but PSOs are expected to be abandoned with residential gas market liberalisation in 2020. For the international transit of oil and gas, tariffs are set by intergovernmental agreements.

The State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) (called the State Nuclear Regulatory Committee until 2010) has regulatory responsibility for the operation of nuclear power plants and two research reactors; decommissioning of the Chernobyl Nuclear Power Plant (Units 1, 2 and 3) and construction of the New Safe Confinement for Chernobyl Unit 4; two spent-fuel storage facilities and one under construction at Chernobyl; radioactive waste storage facilities; uranium mining; radioactive material transportation; and the production and use of ionising radiation sources. The SNRIU also informs the public about the safety of the country's nuclear installations through its website and public consultation meetings.

Key policies

In August 2017, the government adopted the new Energy Strategy of Ukraine (ESU) to 2035 (<http://zakon3.rada.gov.ua/laws/show/605-2017-%D1%80>). It replaced the Energy Strategy to 2030, which was already outdated at the time of its adoption in July

2013. The new ESU envisions the decoupling of energy consumption and economic growth: GDP in 2011 USD at PPP is projected to increase by 2.3 times over 20 years, at an average annual rate of 4.2%, while total primary energy supply (TPES) expands just 7%. As a result, energy intensity is projected to drop more than twofold from 0.28 to 0.13. Furthermore, the structure of TPES changes considerably, with the total RES share jumping from 4% in 2015 to 25% in 2035, and Natural gas self-sufficiency is expected in 2020.

Liberalised competitive energy markets are prerequisites for sustainable energy sector development. The ESU ensures full compliance with commitments to reduce carbon dioxide (CO₂), nitrogen oxides (NO_x) (nitric oxide and nitrogen dioxide) and dust emissions of large combustion plants, and to introduce an emissions trading system (ETS), by 2035. At the same time, coal will continue to fuel electricity generation through 2035. Although major modernisation of coal-fired generation plants is projected to begin after 2025, their electrical efficiency will increase to a modest 36.8% by 2035.

ESU implementation is divided into three stages:

- The first stage (2018-20) aims to create liberalised, competitive energy markets and minimise state interference in their performance.
- The focus of the second stage (2021-25) is on developing energy infrastructure and integrating it with the European system, and attracting necessary energy sector investments.
- Finally, the third stage (2026-35) is concerned with sustainable development: meeting greenhouse gas (GHG) emissions reduction commitments; rapidly developing renewables; and ensuring energy security by further boosting gas production, including unconventional gas and offshore drilling, after achieving gas self-sufficiency in the second stage.

Instead of modelling total final energy consumption by sector, the ESU focuses solely on Instead of TPES. The government is, however, scheduled to conduct comprehensive energy modelling of energy demand through 2035 for its National Action Plan (NAP) on Energy Strategy of Ukraine Implementation for 2018-2020 (task 171 of the NAP: <http://zakon2.rada.gov.ua/laws/show/497-2018-%D1%80>). The NAP also envisions that all Ministry of Energy and Coal Industry (MECI) plans, strategies and other documents will be based on energy modelling after 2020.

The National Renewable Energy Action Plan (NREAP) was adopted in 2014 in accordance with Ukraine's Energy Community commitments. According to the SAE, E,

the NREAP's ambitious goals require investment of UAH 60 billion to UAH 70 billion (USD 3.5 billion to USD 4.3 billion) to raise the country's wind energy capacity to 2.28 gigawatts (GW) by 2020 – a 500% increase from the 410 megawatts (MW) of capacity when the NREAP was approved. Solar energy would expand from 450 MW to 2 300 MW and small hydro capacity would be boosted from 120 MW to 150 MW. Last but not least, the installed capacity of biomass electricity generation is set to increase 40 times, from 24 MW to 950 MW. The NREAP's overall intention is to raise current installed capacity (excluding large hydro) by more than five times, from 1 024 MW to 5 700 MW.

Ukraine also adopted a National Energy Efficiency Action Plan (NEEAP) in 2015 aligned with the Energy Community Treaty. The NEEAP outlines energy efficiency measures to achieve energy savings of 9% in 2020, compared with average domestic final consumption during 2005-09. However, two major recessions in 2009 and 2013-14 and the loss of government authority over Crimea and part of the Donbass region already reduced total final consumption 29.6% in 2015 compared with the 2005-09 reference average, far exceeding the approved target for 2020. Since this consumption decline can be attributed mostly to structural changes in industry and an overall drop in activity, the NEEAP energy efficiency targets should be revised to capitalise on Ukraine's significant untapped energy efficiency potential.

The approved NAP therefore prescribes that a new NEEAP and an updated NREAP be drafted, both effective through 2030, assuming that all plans through 2019 (for the NEEAP) and 2020 (for the NREAP) have been implemented. In June 2019 the NAP also made the Ministry of Regional Development responsible for reporting estimated energy efficiency indicator (EEI) values to the SAEE, based on International Energy Agency (IEA) methodology, and publishing the EEIs for industry, agriculture, services, construction and the residential sector by the end of 2019. EEIs are essential to gauge untapped energy-savings potential, set energy efficiency targets and ensure the monitoring of progress.

Energy statistics

The State Statistics Service of Ukraine (SSSU) is responsible for publishing the country's official statistics data.

The main statistics sources are monthly and annual surveys on industrial production, electricity generation and consumption of energy by enterprises, including for

transformation purposes. These are complemented by data from household surveys and administrative sources, including from the State Customs Service.

Since 2012, the national energy balance has been compiled and published in the Statistical Yearbook of Ukraine. Commodity and energy balances are also published in the dedicated publication [Fuel and Energy Resources of Ukraine](#), available online in electronic format, with downloadable Excel sheets. The layout and quality of the energy balance meet the International Recommendations for Energy Statistics (IRES), and data are accompanied by key graphics. Since 2016, a leaflet has been issued summarising the key findings in a more compact format.

SSSU shares data with the UN Statistics Division (UNSD), the IEA and Eurostat through the joint IEA/Eurostat/UNECE joint questionnaires. Ukraine also contributes to the Joint Organisations Data Initiative (JODI) by sending monthly oil and gas data to the UNSD.

In addition, every year SSSU organises a meeting to present the energy balance to the main data providers and users. It also oversees a large energy-statistics working group, involving energy associations and various ministries including those for the economy, the environment and energy.

Despite its difficult political situation, the quality of Ukraine's energy data has improved each year. SSSU is actively engaged with data providers to resolve identified data gaps and divergences with other sources. Plans for development are closely linked with Ukraine's reporting requirements as a Contracting Party to the Energy Community, such as collecting modelling data on end-use consumption in households and complying with Directive 2008/92/EC on the transparency of gas and electricity prices.

In 2019, SSSU proactively adopted the responsibility of compiling energy efficiency indicators that will strongly support energy efficiency planning in the country.

Chapter 1. Energy security

Resource endowment

Ukraine has a century-long history of oil and gas production and possesses substantial conventional and unconventional hydrocarbon reserves, estimated at 9 billion tonnes of oil equivalent (Btoe). Natural gas reserves are estimated at 5.4 trillion cubic metres (tcm), with proven reserves of 1.1 tcm of natural gas, more than 400 million tonnes (Mt) of gas condensate and 850 Mt of oil reserves. The loss of jurisdiction over Crimea, whose significant offshore gas resources are no longer accessible to Ukraine, means natural gas reserve estimates must be revised downwards.

Hydrocarbon resources in Ukraine are concentrated in three regions: the Carpathian region in the west; the Dnieper-Donetsk region in the east; and the Black Sea-Sea of Azov region in the south. The Dnieper-Donetsk region accounts for 80% of proven reserves and approximately 90% of gas production, and the Carpathian region has 13% of proven reserves and 6% of production. The remaining 6% of proven reserves are in the southern region, where production is conducted both onshore and offshore on the shallow shelves of the Black and Azov seas. The aggregate production in this region is 5% of Ukraine's total oil and gas production.

Ukraine has considerable unconventional gas potential in the form of coalbed methane in the main coal mining areas of eastern Ukraine and in two shale gas basins: a portion of the Lublin Basin, which extends into Poland, and the Dnieper-Donetsk Basin in the east. Coalbed methane resources are estimated at close to 3 tcm, and technically recoverable shale gas resources at 1.2 tcm (www.iss.europa.eu/uploads/media/Brief_11.pdf; www.globalsecurity.org/military/world/ukraine/energy.htm). The Ukrainian section of the Lublin Basin is large and reportedly has a higher average total organic content than the Polish section and lower average depth. The Dnieper-Donetsk Basin, which provides most of Ukraine's conventional oil, gas and coal production, also has high organic content but is deeper.

Ukraine's abundant coal reserves account for more than 90% of the country's fossil fuel reserves. They include the full range of coal types, from anthracite to lignite, including thermal and coking coal. Reserves of anthracite and bituminous coal are estimated at

32 gigatonnes (Gt), and resources are estimated at 49 Gt, ranking Ukraine sixth in the world for hard coal reserves after the United States, China, Russia, Australia and South Africa. Reserves of sub-bituminous coal and lignite are estimated at 2 Gt (15th in global ranking of lignite reserves), and resources are estimated at 5 Gt; the government estimates 117 Gt of hard coal reserves (including sub-bituminous) and 8.6 Gt of lignite, and recoverable reserves at existing mines at more than 6 Gt – or around 75 years of production at peak levels.

Most coal in Ukraine is in the Donbass region (Donetsk Coal Basin) in eastern Ukraine in the regions of Donetsk, Luhansk and Dnipropetrovsk. There are two other smaller basins, the Lviv-Volyn Coal Basin in western Ukraine (this basin extends into Poland) and the Dnieper Coal Basin, a lignite basin in central Ukraine. Intensive mining for more than a century in the Donetsk region has exhausted the best deposits.

Ukraine has substantial renewable energy potential, including significant biomass resources and waste management possibilities, which remains largely untapped.

Energy security and diversification

Ukraine's energy security was seriously challenged in 2014 following prolonged gas price negotiations with Russia, military action in the eastern part of the country and the loss of governmental authority in Crimea. Facing possible natural gas, coal and electricity supply shortfalls, and disruption risks in the short to medium term, Ukraine's need for sound energy policies and measures is urgent.

Coal production in the Donbass basin has been severely curtailed. Damage caused to the coal mining and energy-intensive industries by military action in this region is immense, leaving many flooded mines and destroyed energy and transport infrastructure, and subsequent logistical problems. Coal supplies from the Donbass region to central Ukraine and to the thermal power plants stalled almost entirely in mid-2014 and in the winter of 2015 due to discontinued rail operations and damaged or destroyed roads and bridges. This destruction poses major, irreversible damage for the coal and industry sectors, and its impact on the country's energy and economic outlook has yet to be fully assessed.

Ukraine is actively attempting to reduce its gas import dependency and diversify its supply sources and routes. The government has put numerous emergency measures in place to reduce gas demand, increase domestic gas production and expand

reverse-flow import capacities from more competitive European markets. There is large scope for further domestic gas development, with estimates putting natural gas production at 27 bcm to 30 bcm by 2025.

First, however, UkrGazVydobuvannya requires substantial investments to stabilise and possibly increase its own production (75% of its current fields are being depleted) using capital-intensive modern technology and equipment. As part of its agreement with the IMF, the Ukrainian government phased out residential gas subsidies by increasing the price for UkrGazVydobuvannya to full import parity (UAH 4 849/tcm) in May 2016 (<http://www.kmu.gov.ua/control/ru/cardnpd?docid=249005214>). The residential gas market was to be fully liberalised by May 2020 as a part of the Ukrainian government's commitments under its Memorandum of Economic and Financial Policies with the IMF.

Regarding nuclear fuel supplies, traditionally provided by the Russian company TVEL, Energoatom has signed contracts with Westinghouse for fuel assemblies for some nuclear power reactors as part of Ukraine's nuclear fuel supply diversification policy. At the same time, co-operation with TVEL is continuing.

Still a key transit country important to European energy security, Ukraine benefits from substantial transit revenues. Having the largest gas transit infrastructure in the world, Ukraine currently transports 82 bcm to 93 bcm of Russian gas per year to European markets, although a record low of only 60 bcm was transited in 2014. Overall, the volume of Russian gas being transited through Ukraine has dropped significantly from the 120 bcm per year (bcm/y) in the mid-2000s because of several factors, including stagnating demand in Europe and Gazprom's export route diversification. In fact, Gazprom reduced transit through Ukraine from over 65% of total Russian gas exports to Europe in 2007 to below 50% in 2014; instead, it now delivers a portion of its gas to Germany, France and Belgium via the Nord Stream pipeline in the Baltic Sea. In addition, Gazprom's 100% purchase of Gazprom-TransGaz (the gas transmission company in Belarus) at the end of 2011 should provide greater incentive for the Russian supplier to load the Belarusian Yamal or the Northern Lights routes, as transportation costs would be lower. The Slovak transmission system operator (TSO), Eustream, is planning for reduced volumes of Russian transit gas, as is the Czech TSO. Gazprom launched the TurkStream pipeline in January 2020, and if the Nord Stream II pipeline also materialises, Russian gas in transit through Ukraine will decrease much more, creating serious challenges for the system's economic and technical operations. Reconfiguration of the entire gas transmission system would be

required to enable Ukraine to handle much lower gas transit volumes and continue supplying all regions of the country in an efficient manner. The current Gazprom-NaftoGaz gas transit contract terminates on 31 December 2024.

In February 2018, the tribunal of the Arbitration Institute of the Stockholm Chamber of Commerce made its final ruling on the transit gas dispute between Naftogaz and Russia's Gazprom. It decided to:

- Award Naftogaz USD 4.63 billion for breaking its contract obligations to transit 110 bcm annually through Ukraine.
- Reject Naftogaz's claim of gas tariff revision specified in the contract as well as its transit contract revision claim based on European and Ukrainian energy and competition laws, noting that the implementation of regulatory reforms on Ukrainian territory is a task for the Ukrainian authorities.

The tribunal's final December 2017 ruling on the dispute between Naftogaz and Gazprom over gas prices and contracted volumes also favoured Naftogaz but satisfied only part of its claims:

- The tribunal completely rejected Gazprom's take-or-pay claims to Naftogaz, amounting to USD 56 billion for 2012-17.
- The annual contract volume obligation was reduced by more than ten times (from 52 bcm to 5 bcm), relative to Naftogaz's actual import needs.
- The price Naftogaz owed for gas supplied by Gazprom in the second quarter (2Q) of 2014 was reduced from USD 485/tcm to USD 352/tcm. Thus, the ruling rejected the contract's oil products price peg (the latter price) in favour of the spot price at the closest European hub. Naftogaz also asked for a price review from May 2011, but the tribunal ruled for a price revision starting from 2Q2014. Naftogaz must redeem the arrears of USD 2.019 billion for gas supplied by Gazprom in 2Q2014.

On a net basis, Gazprom paid Naftogaz USD 2.6 billion in December 2019, which amounts to close to Ukraine's total annual gas import needs or 7% of Gazprom's European gas export revenue for 2017. The 2009 gas contract between Naftogaz and Gazprom stipulates that the Stockholm tribunal's decisions are final and cannot be appealed.

Because Ukraine's refinery system dates to the Soviet era, total refinery capacity exceeds oil product demand by several times, and Ukraine has to meet most of its oil demand through imports. According to the 2018 energy balance compiled by Ukrstat, total final consumption of oil products was 10 599 thousand tonnes of oil equivalent (ktoe) while oil product imports were 10 365 ktoe. The State Fiscal Service (SFS) estimated the

cost of oil product imports at USD 5.5 billion in 2018. SFS data also indicate that 38.7% of oil products were imported from Belarus, 37.3% from Russia, 10.3% from Lithuania and 14.2% from other countries in 2018. Given that Belarusian refineries depend on crude oil from Russia, Ukraine's current oil product import mix puts the country at significant risk of an oil product supply shortage if Russia decides to provoke a crisis in the Ukrainian oil market.

Ukraine is reported to have only small stocks of oil (exact levels are a state secret), and there is no emergency oil supply legislation in place that would regulate the use of strategic oil stocks in the case of supply disruptions. The country would benefit from gradually building up oil stock reserves to the equivalent of at least 90 days of net imports or 61 days of inland consumption by 2025. This level is similar to the oil stockholding commitments of IEA member countries, except that the IEA has a collective action mechanism.

Energy infrastructure and investment

Electricity

Ukraine's transmission network, made up of 220-kilovolt (kV) to 750-kV lines, is more than 22 000 km long, and the total length of the distribution network is more than 1 million km. Total installed generation capacity in 2013 was 56 GW, made up of 64% thermal power plants, 25% nuclear and 10% hydro. The remaining 1%, offset by some hydro storage, is accounted for by solar, wind and other small generators.

Most thermal plants burn coal, but a portion (about 5.4 GW) burns gas or oil and is used at peak demand times. Four nuclear plants with a total of 15 units account for 13.8 GW of installed capacity. Several large run-of-the-river and pumped storage hydropower stations with capacity of 5.9 GW along the Dnieper and Dniester rivers play an important role in electricity system operations, compensating for ageing thermal plants' lack of flexibility.

Large investments are needed to modernise Ukraine's generation capacity, particularly hydro and thermal power plants, to remove bottlenecks in high-voltage transmission capacity and to reduce distribution system losses.

In the hydro sector, UkrHydroEnergo, the state-owned company that manages the Ukrainian power grid, operates nine hydroelectric stations on the Dnieper and Dniester

rivers with a total capacity of 5 900 MW. Long a supporter of modernising and expanding Ukraine's large hydro capacity, the World Bank sponsored the replacement of turbines in the Dnieper and Dniester river plants as part of UkrHydroEnergo's programme to increase the safety, efficiency and capacity of its hydroelectric system.

The extension of the Dniestrovski hydropower plant on the Dniester River was completed in 2016, adding 324 MW of capacity, and a second hydropower plant could also be built on the Dniester. In total, a further 3 000 MW of capacity could be added in this sector if financing is available, and another 600 MW of small hydro generation could be developed.

Though decisions on constructing new nuclear units were expected by 2018, none had been made as of April 2020. EnergoAtom has indicated that it will put out a tender to international vendors for a standard Generation-III/III+ plant, but a large share of the supply chain for the plant's construction is expected to be allocated to Ukrainian industries.

District heating

According to the Ministry of Regional Development, Construction and Housing, Ukraine has 33 122 km of heat transmission and distribution networks. Transmission pipelines total roughly 3 500 km (pipes with a diameter of 125 millimetres [mm] to 1 400 mm), and distribution pipelines (diameter 50 mm to 800 mm) are owned by municipalities and total 20 800 km. In addition, there are 12 400 km of industrial pipeline networks.

District heating system capacities in Ukraine are excessive, and their technologies are inefficient and outdated; capital stock is in a critical state, with most assets close to or beyond the end of their design lifespans. Energy losses are considerable (hence much gas is wasted) and operating costs are high, largely due to inadequate maintenance.

This overcapacity, lack of maintenance and insufficient investment in system upgrades means losses are considerable. Most boilers have low efficiency factors, resulting in heat losses of 10% to 15%. While insufficient metering does not allow for accurate calculation, losses in the distribution network, mainly due to leaks and a lack of pipe insulation, are estimated to be around 17% but could be considerably higher. Leaks also mean water must be added more frequently, constituting an extra cost for the heat supplier. In modern networks of comparable size, losses are typically less than 10%. Breakdowns are also frequent in Ukraine's district heating systems, estimated at more than 1.6 breakdowns per km of network in operation, which is approximately ten

times higher than in well-maintained modern systems. What is more, up to 70% of delivered heat is lost in the end-use phase because building insulation is insufficient and heat delivery cannot be adjusted to consumer requirements.

Natural gas

When it gained independence from the Soviet Union in 1991, Ukraine inherited a gas transportation system that is a uniquely dense network of multiple primary and secondary pipelines, coupled with major storage facilities. This enables the diversion of gas flows through other pipelines should an accident or failure occur.

The system encompasses 38 600 km of pipelines: 22 200 km of main transmission pipelines and 16 400 km of distribution pipelines. It is powered by 72 compressor stations, with a total capacity of 5 443 MW. It can transport up to 80 bcm/y for domestic consumption from indigenous and imported sources and can transit up to 142.5 bcm/y of gas from Russia and Belarus to European countries.

Ukraine's gas transportation system has the second-largest storage capacity in Europe, after that of Russia. Storage is key to the security and stability of domestic supply operations, and is critical to the gas transit system. The 13 underground gas storage facilities have a total working capacity of 30.9 bcm/y; UkrTransGaz operates 12 of these facilities.

Ukraine holds sizeable untapped reserves of unconventional oil and gas, and the government has vigorously pursued legislative changes, such as streamlining production sharing agreements (PSAs), to make these reserves attractive for investors. In June 2012, it offered tenders for the Oleska and Yuzivska blocks and the Foros and Skifska areas of the Black Sea shelf under PSAs, allowing for the exploration and production of natural gas, shale gas, tight gas, coalbed methane, crude oil and oil and gas condensates for a 50-year period. In August 2012, the government selected ExxonMobil and Royal Dutch Shell to lead development of the Skifska deep-water natural gas field offshore in the Black Sea, together with Romania's OMV Petron and national joint stock company (NJSC) Nadra Ukrayny. No bids were submitted for development of the Foros field, and offshore projects have been halted indefinitely due to loss of jurisdiction in Crimea in 2014.

The Yuzivska block in eastern Ukraine has an area of 7 886 km². The minimum investment required during the exploration stage is estimated at USD 200 million, and for the commercial production stage USD 3.7 billion; however, Royal Dutch Shell,

which won the bid for gas development, decided to pull out of the project in 2015. Shell was motivated in this decision by the armed conflict taking place in Donbass, where the Yuzivska block is located, as well as by the sharp plunge in European gas prices that made costly shale gas development much less attractive. The Oleska block in western Ukraine covers an area of 6 324 km²: a minimum estimated investment of USD 163 million is required for exploration, and USD 3.13 billion for commercial production. As with Shell at the Yuzivska block, Chevron pulled out of the project due to increased geopolitical risks in Ukraine and the more than twofold collapse in gas prices in the European market.

Oil

Ukraine's main oil transportation system consists of 4 767 km of pipelines of up to 1 220 mm in diameter; 51 pump stations; and 11 tank farms with a total of 79 tanks, with a cumulative rated capacity of about 1 million cubic metres (mcm). Pumping stations have 176 units with a capacity of up to 12 500 mcm/hour and electric drive capacity of 356.5 MW. The throughput capacity is 114 Mt/y at the inlet and 56.3 Mt/y at the outlet. About 65% of the pipelines are between 30 and 40 years old; 27% are over 40 years; 6% are between 20 and 30 years; and only 2% are between 10 and 20 years old. In addition, there are 4 625 km of smaller oil product pipelines, mostly privately owned, though their level of technical operations is unclear.

Ukraine has seven refineries with a design capacity of 50.4 Mt/y, which is about four times larger than Ukraine's oil product market. However, the vast majority of this capacity is not currently in use due to a combination of ageing infrastructure, poor economics and damage from warfare in eastern Ukraine. As of early 2017, Ukraine had only one operational refinery, Kremenchug, in addition to the Shebelinsky gas processing plant in the Kharkiv region, which also produces oil products.

Ukraine has three maritime oil terminals: Pivdenny, Yuzhnyi and Feodosia (in Crimea). The Pivdenny oil terminal is equipped with tanks that store up to 200 000 cubic metres (m³) of oil. The terminal can receive large oil tankers with a maximum deadweight of 150 000 tonnes (t) and maximum draught of 12.5 m. The Pivdenny port is designed to accept and discharge crude oil, which is transported by trunk pipelines. Oil terminal capacity is 25.5 Mt/y of crude oil and oil products. The Yuzhnyi terminal, with a capacity of 60 000 m³ and an average loading rate of 1 100 m³/hour, can accommodate vessels of 125 000 t and maximum draught of 13.8 m. Ukraine lost legal control of the Feodosia oil terminal

after Russia annexed Crimea, and in response Ukraine has closed all sea ports in Crimea to international navigation.

The Euro-Asian Oil Transport Corridor (EAOTC) has been under consideration since around 2007, inspired by the Odessa-Brody oil pipeline and its proposed extension to Plotsk (about 371 km) and Gdansk, to supply Polish refineries. The Odessa-Brody pipeline has revived the concept of direct-mode use, and Sarmatia, a Polish-registered pipeline company, was designated to develop the extension. Sarmatia has brought together five shareholders to form a project consortium: Azerbaijan's SOCAR, the Georgian Oil and Gas Corporation, Lithuania's Klaipedos Nafta, Poland's PERN Przyjazn S.A. and Ukraine's Ukrtransnafta.

Cross-border infrastructure

Electricity

Ukraine's electricity network is fully integrated and interconnected with those of its regional neighbours and runs in parallel with the Russian system. The exception is Burshtyn Island in the western part of the country, which is synchronised with the Central European grids and facilitates direct exports to Slovakia, Hungary and Romania.

Gas

The gas transmission system has many large entry points on the Russian-Ukrainian border, allowing both Russian transit gas and gas for domestic consumption to be dispatched to Ukraine's eastern regions. Gas is injected from Ukraine's storage sites into the east-west transit pipelines to make up for gas taken out at the eastern end for domestic use. Storage facilities hold gas from both domestic production and imported from Russia. Domestic and imported gas is put into Ukraine's storage facilities between mid-April and mid-October and is withdrawn during the winter months. During winter peak times, Ukraine's five storage sites at the western border can supply up to 40% of daily transit volumes.

Oil

Russian and Kazakh companies can transit crude oil through Ukraine via three pipelines: the southern branch of the Druzhba pipeline, which enters Ukraine from Belarus (Atyrau-Samara-Unecha-Mozyr-southern Druzhba); the Samara-Lisichansk pipeline; and the Nizhneartovsk-Lisichansk-Kremenchuk-Odessa pipeline. Volumes of oil in transit through Ukraine have been decreasing steadily in recent years.

System reliability

Outages in Ukraine's electricity sector are rare, mainly taking place in rural areas as a result of unfavourable weather conditions and/or deteriorated distribution grids. In recent years Ukraine's TSO and regional distribution system operators have taken measures such as constructing reserve lines and switching to ring connection schemes to eliminate electricity outages for end users.

Electricity transmission and distribution losses are 13% on average but have reached nearly 20% some years. Losses in generation, transmission and distribution are expected to increase without sufficient and timely investments in infrastructure. Each licensee reports to the National Energy and Utilities Regulation Commission on losses and outages on a regular basis, but quality-of-service standards related to outages have not yet been implemented by the regulator.

Natural gas transmission line losses have been estimated at 2-3% of total transmission volumes, and losses on UkrTransGaz's main pipelines are around 0.2%, which is a very good record. Technical losses in the electricity sector amount to 12%, while losses in gas are assessed at 2.3%. Reporting on losses and outages to the regulator and to the Ministry of Energy and Coal Industry is done by NaftoGaz on a regular basis.

Data on losses can vary considerably. For instance, network district heat loss was 16% on average in 2015, but some district heating companies noted losses of 40%. District heating systems in Ukraine have excessive capacity, and inefficient and outdated technologies: capital stock is in a critical state, with most assets close to or beyond the end of their design lifetimes. Energy losses are considerable and operating costs are high, largely due to inadequate maintenance. District heating companies consumed 5.8 bcm of natural gas for heat production in 2019 (down 0.2 bcm or 3.3% from 2018). Due to insufficient investment to modernise the district systems and improve end-use energy efficiency, more than half of input fuel is wasted.

By the end of December 2017, heat meter installation in buildings had increased to 90% from 32% in 2014,¹ despite Ukraine's commitment in the Memorandum on Economic and Financial Policies with the IMF in early 2015 to achieve universal gas and heat metering and move to universal consumption-based billing by 2017 (<https://www.imf.org/external/pubs/ft/scr/2015/cr1569.pdf>).

Emergency response

Emergency response policies and measures had been the responsibility of the State Emergency Service of Ukraine (until December 2012 the Ministry of Emergencies) until the country committed to build up minimum reserves of crude oil and petroleum products by 2020 under the Energy Community Treaty, in line with EU Directive 2009/119/EC. Ukraine's downstream oil sector is now fully liberalised and the government has no right to interfere with oil business: it cannot distribute oil products produced by the refineries, which are marketed at their owners' discretion. Ukraine is reported to have only small oil stocks, but the exact levels are a state secret and there is no emergency oil supply legislation in place to regulate the use of strategic oil stocks in the case of supply disruptions. Stocks are currently managed by Derzhkomreserv, the State Agency of Reserves of Ukraine.

Recent tensions with Russia and conflict with Russian-backed separatists, which provoked multi-level energy supply disruptions, triggered establishment of a Crisis Management Group under the prime minister's office to address electricity and gas supply emergency preparedness, formulate emergency scenarios, define who qualifies as an "interruptible consumer" and conduct stress tests under various scenarios.

¹ NKREKP (2018), *NKREKP Annual Report for 2017*, NKREKP, Kyiv.

Chapter 2. Market design

National market structure

Electricity

Ukraine's electricity sector is comprised of separate generation, wholesale market, transmission system operation, distribution and supply entities.

The wholesale electricity market (WEM), created in 1996, was operated by the state-owned company Energorynok as a sole wholesale trader under a single-buyer model from 2000 to mid-2019; it also acted as a settlement centre for all payments until July 2019. To meet its Association Agreement commitment to implement the EU Third Energy Package, Ukraine successfully switched from single-buyer model to one with a more competitive power market structure consisting of bilateral contracts, day-ahead, intraday, balancing and ancillary services markets in July 2019.

UkrEnergo, Ukraine's state-owned national electricity company, owns and operates the United Energy System of Ukraine (UES), including transmission networks and interconnections with neighbouring countries. UkrEnergo also provides technical and information support to Energorynok.

The electricity sector has undergone several stages of reform: it was mostly unbundled and partially privatised in the 1990s, while state-owned assets were consolidated in 2004. Most thermal generation plants have been partially or fully privatised, with the private company DTEK controlling the bulk of the market. In 1995, regional distribution and retail companies (*oblenergots*) were created, one for each administrative region. As a part of electricity market reforms and to ensure retail market competition, Ukraine enforced the unbundling of *oblenergots* into distribution system operators (DSOs) and electricity supply companies. Since 1995 there have been several rounds of privatisation, so that most DSOs and electricity supply companies are now privately owned by domestic or foreign investors. Ukrenergoatom is the state-owned operator of nuclear power plants.

Oil and natural gas

State-owned NJSC NaftoGaz, subordinated to the cabinet of ministers, is the largest company in Ukraine. Until January 2020 it was a vertically integrated company engaged in the full cycle of gas and oil exploration operations: drilling, development and production; transport, refining and storage; and supplying natural gas and liquefied petroleum gas (LPG) to consumers. However, to meet the requirements of the EU Third Energy Package, Ukraine unbundled Naftogaz by transferring the Gas Transmission System Operator of Ukraine (GTSOU) from NaftoGaz to state-owned Main Gas Pipelines of Ukraine.

GTSOU operates the gas transmission trunk lines but Naftogaz continues to operate the gas storage facilities since unbundling. Regional gas distribution and supply companies (*oblgazes*) hold permits from UkrTransGaz to transport gas through main and regional transmission pipelines and are responsible for gas distribution.

State participation in oil and gas exploration and production activities is carried out by NJSC Nadra Ukrayny, which conducts geological surveys, provides resource and economic estimates and enters into joint-venture agreements with private investors. NaftoGaz and its 11 subsidiaries hold the largest share of all oil and natural gas produced in Ukraine. UkrGazVydobuvannya is the company affiliated with NaftoGaz responsible for gas production and LPG/compressed natural gas (CNG) production; it extracts about 15 bcm/y, or 75% of total production. Gas production of the numerous independent oil and gas producers operating in Ukraine has been increasing steadily, to make up 22% of total production in 2017. UkrTransNafta, another subsidiary of NaftoGaz, operates the oil pipeline system. In theory state-owned, but in practice controlled by a private company, UkrNafta is the main oil producer and also produces a small amount of gas.

Coal

Endowed with considerable coal resources, most of Ukraine's mines are in the Donbass region. Of Ukraine's approximately 300 mines, many profitable ones have been either privatised or transferred to long-run concessions, predominantly by DTEK. The remaining mines, requiring subsidisation, remain in the ownership of state-controlled companies. Ukraine's largest mining region in the east has been severely affected by the recent political instability and, furthermore, hundreds of illegal (often smaller) mines are operating in the region.

Nuclear

Nuclear energy was responsible for roughly 54% of Ukraine's electricity production in 2019. Net nuclear capacity is 13.1 GW (13.8 GW gross capacity) or 28% of Ukraine's installed electrical capacity, supplied by 15 Soviet-designed VVER reactors in four nuclear power plants: two 440-MW V-213 models and 13 1 000-MW units, of which 11 are V-320 models and two are older V-302 and V-338 models. Zaporizhia is Europe's largest nuclear power plant at a net capacity of 5.7 GW (6 GW gross). All of Ukraine's operating nuclear plants are owned and operated by Energoatom, which also operates small hydro and pumped-storage power plants used for load-following.

Ukraine's power system lacks load-balancing capabilities: instead, baseload coal power plants are used for this purpose. Insufficient transmission capacity also limits the output of some nuclear plants. Long-term operation of the existing reactors is a cornerstone of the nuclear energy programme, so it is concerning that most reactors are reaching the end of their original design lifetimes in 2020. Rivne Units 1 and 2 have already received a licence to operate for an additional 20 years with a mandatory safety reassessment after 10.

Large hydro

Large hydro provided about 5% of electricity generation in 2019. The nine large hydropower stations on the Dnieper and Dniester rivers (total installed capacity of 5.9 GW) are all operated by state-owned UkrHydroEnergo. Hydro generation is important for electricity system stability because it provides peak-load supplies, regulates the frequency and capacity of the system, and offers the emergency reserves that outdated fossil-fuelled power plants are unable to guarantee. In 2016, the government approved a programme for hydropower development aimed at increasing installed generation capacity by 3.3 GW and raising hydro's share in electricity generation to 15.5% by 2026 (<http://zakon2.rada.gov.ua/laws/show/552-2016-%D1%80>). There are currently no plans to privatise UkrHydroEnergo.

Renewable energy

Renewable energy accounted for 4.6% of TPES in 2018: 3.4% biofuels and waste, 1% hydro and 0.2% other renewable power. Ukraine experienced a renewable power deployment boom in 2018-19. The share of renewable power in the electricity generation mix increased by 3.6 times – from 1% in 2015 to 3.6% in 2019. According

to MEEP projections, the renewables share will increase further to 6.8% or 10 284 gigawatt hours (GWh) in 2020. Despite Ukraine's low share of renewables in TPES compared with European Union (30% in 2018), it has significant technical potential for further RES development. The economic feasibility of developing this potential, however, depends on factors such as fossil fuel prices, technology availability and public support.

Until recently, other fuels could not compete with highly subsidised natural gas in the residential heating sector. However, the government's decision in 2016 to completely phase out price subsidies makes heat produced from renewables fully competitive with heat produced from natural gas and provides considerable opportunities for biomass use, especially in the heating sector.

The comprehensive 2011 study "Energy Potential of Biomass in Ukraine" by Lakyda et al. found that the technical potential of forest biomass is 2.1 Mtoe and that of agricultural waste is 12 Mtoe, based on 2008 data. The Biomass Centre estimates that the sizeable agricultural waste generated by Ukraine's agriculture sector could produce enough biogas to replace 2.6 bcm of natural gas per year, and with agricultural expansion biogas potential could grow to the equivalent of 7.7 bcm of natural gas. It is estimated that organic matter from livestock could support 4 000 biogas installations.

The SAEE under MEEP is responsible for renewables development.

Energy efficiency

Ukraine has enormous untapped energy efficiency potential: although end-use data are still limited, current indications are that energy efficiency potential is greatest in industry (34% of the total), the residential sector (33%) and energy transformation at coal-fired power plants (22%). "Energy Efficiency Monitoring for Ukraine" (Dodonov, 2016) claims that by implementing comprehensive and effective policies that reduce sector and industry energy intensity to EU levels, Ukraine could save up to 27.1 Mtoe or 29.9 bcm of natural gas, based on figures for 2014.

MEEP has been the main state authority responsible for efficient energy use, energy savings and renewable energy since 2019, and the SAEE under MEEP is the central governmental body charged with advancing energy efficiency and renewable energy developments, and promoting the deployment of energy-efficient and renewable energy technologies.

Donor support for implementing energy efficiency measures in Ukraine is considerable: numerous international financing institutions (IFIs) such as the World Bank Group, the EBRD, the European Investment Bank (EIB), the KfW, the US Agency for International Development (USAID) and the Global Climate Partnership Fund are active in Ukraine. According to Minregion, several projects of the World Bank (including District Heating Energy Efficiency), the KfW and the EIB in 2016 alone amounted to USD 1.4 billion (<http://www.minregion.gov.ua/wp-content/uploads/2016/12/Detsentralizatsiya-y-energoefektivnist.pdf>).

However, successful project implementation requires that Ukraine improve project management. According to former World Bank Country Director in Ukraine Qimiao Fan, the investment portfolio disbursement ratio has declined by three times in recent years to just 10% (<https://www.unian.info/economics/1382372-world-bank-country-director-for-ukraine-there-is-a-risk-that-reforms-will-not-move-forward.html>). The World Bank estimated the overall risk of implementing its District Heating Energy Efficiency project launched in 2014 as “substantial,” while progress was ranked as “moderately unsatisfactory” in April 2018 (<http://projects.worldbank.org/P132741/district-heating-energy-efficiency?lang=en&tab=ratings>).

Regulatory framework

State entities dominate oil, gas and electricity provision in Ukraine. The energy market has been designed to maintain state dominance and to subsidise household and public sector energy consumption. The challenge is to design and implement an effective regulatory framework that increases competition, strengthens the efficiency of markets and is attractive to investors. Third-party access, greater market transparency and strong and fair regulatory oversight are key in this regard.

Until July 2019 the electricity market was organised on a single-buyer model. Hydro, nuclear, co-generation and renewables generators were paid fixed prices set by the National Energy and Utilities Regulation Commission, while thermal plants competed for the remaining demand in an energy-only market. The regulator set a cap for the thermal marginal price and generator bids were above the cap for some hours; the regulator then calculated the weighted average price and added transportation and other costs (including the cross-subsidy) to arrive at a final price paid by non-residential customers. Prices paid to generators could also include an “investment component” for NKREKP-approved investment projects. Generator bids were

assessed by the market operator Energorynok for alignment with its estimates of variable costs.

The wholesale price formation mechanism was based on the weighted average price of generation calculated from the competitive marginal price of thermal plants, subsidised prices for households and feed-in tariffs of other technologies.

In April 2017 the parliament adopted the new Electricity Market Law to meet the requirements of the EU Third Energy Package and join ENTSO-E. The law stipulated that the single-buyer model of market operations be replaced by bilateral contracts. Accordingly, the electricity market was divided into a bilateral contracts market, a day-ahead market, an intra-day market, a balancing market and an ancillary services market. The new market model was launched in July 2019, as scheduled under the law. Energorynok was restructured into three companies: a guaranteed buyer (a state-owned trader that buys electricity from producers under feed-in tariffs and sells this electricity on the organised day-ahead and intraday markets), a market operator (responsible for organising trading on the day-ahead and intra-day markets) and Energorynok (responsible for dealing with outstanding debts). The TSO, Ukrenergo, was assigned the roles of commercial metering administrator and settlements administrator.

The wholesale pricing mechanism of the day-ahead market is the marginal price balancing supply and demand; all generators must provide balancing services in volumes of available capacity. The ancillary market is at the developmental stage, and no services have been procured because there are no qualified ancillary service providers registered with the TSO.

The Law on the Natural Gas Market transposing the Third Energy Package was adopted by the parliament in March 2015. This is a major step in reforming Ukraine's gas market and NaftoGaz, and in adopting Third Energy Package regulations.

The only gas price Ukrainian legislation regulates is that of gas used as a commodity supplied to households and used by district heating companies to produce heat; all other commercial and public consumers may buy natural gas directly from any trader. The size of the regulated market in terms of natural gas consumed was 53% of consumption in 2017.

The Law on the Natural Gas Market prescribed full gas market liberalisation, including for households, by 1 April 2017, but this milestone was postponed to 1 May 2020. The

government raised residential natural gas tariffs by 8.4 times and district heating by 4.6 times between 2014 and May 2016 in nominal terms (in real terms the increases are about half as much). Gas price subsidies for households were also phased out in May 2016 after the government aligned regulated prices with import parity; however, residential gas prices were again substantially below import parity (by about 49%) in July 2018 following gas price increases on the European market and further devaluation of Ukraine's national currency. In 2019 Ukraine benefited from price drops in the European market and regulated prices had returned to the full costs of supply by mid-2019.

There is no real market for steam coal. One company, DTEK, owns most coal production and coal-fired power plant capacities; most coal is therefore not traded on the market and the price for steam coal is regulated by NKREKP. The coking coal market differs because there is a scarcity of high-quality coking coal in Ukraine, so Ukrainian steel mills must import it and blend it with domestic coking coal. The price is determined by the market rather than being regulated.

Despite the commitment of the parliament and the government in the coalition agreement of November 2014 to phase out all coal subsidies and close ineffective mines, subsidies for producers increased substantially after the NKREKP adopted the new Rotterdam+ price methodology for steam coal in 2016. The price of steam coal for coal-fired power plants was pegged to the API2 coal index in Rotterdam, and then transportation and freight costs from Rotterdam to Ukrainian ports were added on top; this methodology resulted in a substantial rise in the price of Ukrainian coal. As this is the price that would prevail in a free, competitive market, it must be considered equivalent to a subsidy for coal producers (<http://documents.worldbank.org/curated/en/961661467990086330/pdf/WPS7220.pdf>). According to the regulator, the reference price for steam coal in December 2017 was calculated at an average API2 for 12 months (USD 83.08/t) + freight costs (USD 12.21/t) + port transshipment costs (USD 7.02/t) (http://www.nerc.gov.ua/data/filearch/Materialy_zasidan/2017/gruden/28.12.2017/p30_28-12-17.pdf). Because shipment costs to Black Sea ports and north-western Europe differ by only USD 3-5/t, the transportation cost component of the tariff is the additional rent (about USD 14-16/t) for Ukrainian producers, mostly for the vertically integrated company DTEK that produces most of the steam coal in Ukraine and owns the bulk of coal-fired plants.

In addition, although the NKREKP corrects for the lower calorific value of Ukrainian coal compared with that assumed for API2 index calculations, its very high sulphur (2-2.5%) and ash content (signs of lower quality that make Ukrainian coal illiquid in the European market) remain unaccounted for in the formula. Applying typical discounts for excess ash and sulphur above the API2 benchmark yields an additional discount of USD 8.5/t on the price of Ukrainian steam coal. Thus, the total producer subsidy per tonne of 6 000 kcal/kg steam coal is estimated at USD 22.5-24.5/t, while the annual rent for coal suppliers is estimated at USD 490-533 million.

As a result of inflated thermal coal prices, the price of electricity supplied by coal-fired plants to the wholesale market increased 62.3%, from UAH 978 per megawatt hour (/MWh) in December 2015 to UAH 1 587/MWh in April 2018 (http://www.nerc.gov.ua/data/filearch/Materialy_zasidan/2017/gruden/28.12.2017/p30_28-12-17.pdf). However, state-owned mines under the authority of the Ministry of Energy and Coal Industry remain loss-making even at the new prices and still need state budget support.

Application of the Rotterdam+ formula and the consequent wholesale market price hike made it difficult to eliminate the cross-subsidisation of residential consumers by commercial ones. Despite an average 3.5-times tariff increase for households over three years (February 2014 to March 2017), residential subsidies even increased from UAH 38.1 billion in 2014 to UAH 45.3 billion in 2018 by decree of the NKREKP. Application of the Rotterdam+ formula by the regulator ceased entirely only in July 2019 with introduction of the new, more competitive power market structure.

The SAEE is tasked with the dual role of promoting energy efficiency and deploying renewable energy, and responsibility for energy efficiency was moved from the cabinet of ministers to the Ministry of Economy and Trade. Agency subordination was then shifted to Minregion and was re-shifted to the MEEP. MEEP approves draft legislation developed by the SAEE. In 2017 the parliament approved the important legislation developed by the SAEE and Minregion, in particular the Law on Energy Efficiency in Buildings, the Law on Commercial Metering of Utility Services, and the Law on the Energy Efficiency Fund.

The primary barrier to effective policy design, evaluation and implementation is limited and mismatched data on energy use and economic activity in different sectors and subsectors. Accurate and comprehensive data analysis can provide critical information for decision-making, including for future scenarios, baselines

and indicators that are necessary for tracking progress and monitoring, evaluating and correcting energy efficiency initiatives.

Ukrainian legislation provides very attractive guaranteed feed-in tariffs, known as green tariffs for electricity produced from RESs. The regulator approves feed-in tariff rates on a case-by-case basis upon completion of a power plant, and approved renewables-based generators are shielded from EUR–UAH exchange rate fluctuations because the fixed-minimum green tariff rates are converted into euros at a fixed exchange rate of 10.86 (based on the 1 January 2009 rate). The regulator can apply the exchange rate effective when the green tariff is established only if it is higher than 10.86. In 2014, it also became permissible for households to sell solar photovoltaic (PV) electricity directly to energy suppliers via feed-in tariffs if their installed capacity is lower than 10 kilowatts (kW) (this threshold has been increased to 30 kW).

Regional markets and interconnections

Electricity

Ukraine's electricity network is fully integrated and interconnected with those of its neighbours in the region. The exception is Burshtyn Island in the western part of the country, which is synchronised with Central European grids and facilitates direct exports to Slovakia, Hungary and Romania.

Natural gas

Ukraine is an important transit country for Russian gas exports to Europe, for which it gains substantial transit fees, but Russian transit volumes through Ukraine have fallen progressively since the opening of the Blue Stream pipeline to Turkey in 2006, full commissioning of the Nord Stream pipeline (line 1 in 2011 and line 2 in 2012) and TurkStream in 2019. Russian gas transit through Ukraine therefore fell from 137.1 bcm in 2004 to 90 bcm in 2019.

Furthermore, if the proposed Nord Stream II pipeline is built, Russian gas volumes in transit through Ukraine are likely to drop even more or cease entirely. It is critical that modernisation of Ukraine's pipeline system be tailored to future transit flows and imports to ensure its efficiency.

Oil

Ukraine's oil pipeline system was designed to deliver crude oil supplies from Russia and Kazakhstan to oil refineries in Ukraine, as well as to transit oil to Central and Eastern European countries. The design input capacity is 84 Mt and the output capacity for transit is 36.2 Mt. Russian and Kazakh companies can transit crude oil through Ukraine via three pipelines: the southern branch of the Druzhba pipeline, which enters Ukraine from Belarus (Atyrau-Samara-Unecha-Mozyr-southern Druzhba); the Samara-Lisichansk pipeline; and the Nizhneartovsk-Lisichansk-Kremenchuk-Odessa pipeline. Volumes of oil in transit through Ukraine have been decreasing steadily in recent years – from 56.4 Mt in 2000 to only 13.3 Mt in 2018 and 13.1 Mt in 2019 – as Russian companies diversify their oil transport routes by building pipelines that bypass Ukraine.

Chapter 3. Sustainable development

Renewable energy

Ukraine has made significant renewable energy progress in recent years. RES development is one of the government's priorities because of its potential to reduce natural gas dependency and enhance energy security. The generous guaranteed feed-in tariffs for electricity produced from RES were thus designed to promote this development. In addition, phasing out residential price subsidies for gas and heat makes heat generation from biomass more attractive. In 2017, the SAEE introduced a [map for tracking investment projects in renewables and energy efficiency](#) in Ukraine.

Table 1 Table 1. Ukraine's feed-in tariffs, 2016

RES	Tariff (EUR/MWh)
Solar	160-172.3
Wind	58.1-101.7
Biomass	123.9
Small hydro	104.5-174.4
Geothermal	150.2
Solar in residential sector	190
Wind in residential sector	116.3

Source: SAEE (2017), "Summary of 2016 and tasks for 2017", SAEE presentation.

There were 347 renewable energy projects supplying electricity at feed-in-tariff rates to the wholesale electricity market in Ukraine in 2018. According to the regulator, the number of contracts between energy supply companies and households for solar PV electricity also tripled in 2018. In 2019 the deployment of renewable power projects accelerated further, with total investments amounting to EUR 3.7 billion and total installed capacity increasing more than three times to 6 779 MW (<http://sae.gov.ua/uk/news/3287>). The DTEK Botievska wind power plant (WPP) and the Prymorska WPP are the largest projects so far, with total installed capacity of 200 MW each, and the DTEK Pokrovska solar power plant (SPP) has a

total installed capacity of 240 MW. MEEP projects that the renewables share (without large hydro) will increase to 6.8% (10 284 GWh) in 2020.

Table 2 Ukraine’s renewable energy projects, 2018

	Number of projects	Installed capacity (MW)
Wind	16	532.8
Solar	229	1 388.3
Small hydro	70	98.6
Biomass/biogas	32	97.5
Total	347	2 117.2

Source: NKREKP (2019), “Annual report for 2018”, National Commission for State Energy and Public Utilities Regulation, Kyiv.

Rapid development of energy generation from biomass can be attributed to the phasing out of natural gas price subsidies in the residential sector in 2015-16, which removed numerous distortions and made heat production from biomass fully competitive with heat produced from gas in both the individual and district heating sectors. To remove any remaining legal barriers to biomass-based heat production, the parliament adopted draft Law No. 4334 on Heat from Alternative Sources Production Stimulation, which guarantees biomass heat production developers 90% of the tariff received by natural gas heat producers. The SAEE claims this law will cause up to 3 bcm of natural gas to be replaced with biomass in district heating production. The [Bioenergy Association of Ukraine’s map](#) shows both already-implemented projects and those at the developmental stage.

Energy efficiency

While progress in energy efficiency policies and measures has been made in recent years, a co-ordinated policy framework with a portfolio of programmes to tap into Ukraine’s energy efficiency potential has yet to be established. An effective and balanced policy framework would emphasise market-based prices, regulatory and control mechanisms, fiscal measures and tax incentives, technology development and financial schemes.

The IEA developed [18 key energy efficiency recommendations for Ukraine](#) based on assessment of its situation in 2015. These recommendations aim to inform Ukrainian

stakeholders of the most important short- and medium-term demand-side energy efficiency policy priorities in buildings, appliances, lighting, equipment and industry. They also identify measures such as collecting data on end users, securing financing, and implementing strategies, action plans and procedures for monitoring, verification and enforcement that are crucial for policy success across all sectors.

Following formation of the new parliamentary coalition in April 2016, parliament approved the government's Action Program. Chapter 12, Energy Industry Reform and Energy Independence (<http://zakon5.rada.gov.ua/laws/show/1099-19>), is dedicated to energy industry reforms to enhance energy security and efficiency, and it stipulates:

- Implementation of Third Energy Package commitments.
- Elimination of cross-subsidisation, transparent tariff-setting and commercial metering of energy consumption.
- Energy market transparency to attract private investments to the sector.
- Coal mining industry reforms, including the end of all subsidies and closure of ineffective mines.
- Implementation of an energy efficiency action plan, with provisions for renewable energy incentives, support for energy service contracts, implementation of EU legislation on energy efficiency in buildings, and attracting private investments to improve the energy efficiency of public and communal property.

To implement this programme, the Ukrainian government developed a draft Action Plan to 2020 and presented it to the public in December 2016. The energy efficiency component of the Plan identifies excessive energy consumption in buildings as a major challenge and prescribes measures to tackle it. However, it neglects many other important issues applicable not only to specific sectors (industry, transport, appliances and lighting) but that cut across sectors: improved energy data collection and analysis; refinement of the NEEAP; leveraging of private investments; and policy monitoring, evaluation and enforcement.

It also relies on the outdated goals of the NEEAP to define current government tasks: for example, to reduce total final consumption by 9% in 2020 compared with the average for 2005-09 – even though it was already 30% lower than this target in 2015 due to two severe recessions, the annexation of Crimea by Russia, and the Donbass conflict. Plus, the Plan does not quantify energy consumption savings from proposed policy measures in the residential sector, which means that the government may overestimate potential natural gas savings in the residential sector if current consumption is compared with the EU benchmark of 90 kWh/m² of floor area. Because of climatic differences, the EU average cannot be used as a benchmark for residential

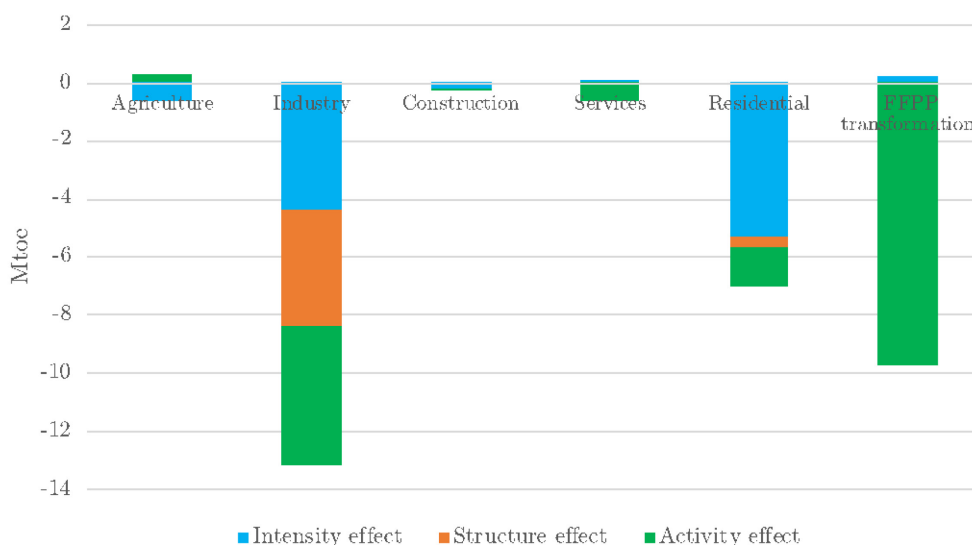
energy efficiency in Ukraine; in fact, ODYSSEE data show that consumption for heating, hot water and lighting per m² is higher even in energy-efficient countries with milder climates such as Denmark (142 kWh/m²) and Germany (186 kWh/m²).

For affordable energy efficiency financing, the government continues to rely solely on its “warm credits” programme that offers households and homeowners partial compensation for energy efficiency improvements. The number of participants as of December 2016 approached 160 000 and total financing had reached UAH 2 727 million (EUR 94 million at the 12 February 2017 exchange rate); of this, the government reimbursed UAH 1 068 million (EUR 37 million). Although the Energy Efficiency Fund was established in 2018, the credit disbursement was negligible by the end of 2019, and even so, the two mechanisms together will be able to meet only a small fraction of energy efficiency investment requirements. The government must instead leverage private financing to tap into Ukraine’s large energy-saving potential.

Total final energy consumption in the agriculture, industry, construction, services and residential sectors, as well as energy transformation at fossil fuel power plants (FFPPs), decreased by 30.9 Mtoe (-36.4%) from 2012 to 2017. However, only one-third of this decline resulted from energy efficiency improvements, with the remaining two-thirds stemming from a drop in activity in 2014-15 and structural changes within sectors (see figure below). The greatest energy efficiency improvements over 2010-17 were recorded in the residential sector (+22.7%) and agriculture (+27.7%), while the energy efficiency index for industry rose by 13.2%. No energy efficiency improvement was recorded for FFPP energy transformation; in fact, it even decreased by 1%. Overall, energy efficiency improved 12.5% during 2012-17.¹

¹ IEA for EU4Energy estimates.

Figure 1 Ukraine energy consumption decomposition, 2012-17



Source: IEA (2019), *Energy Efficiency Indicators 2019*, IEA, Paris, <https://www.iea.org/reports/energy-efficiency-indicators-2019>, IEA for EU4Energy Estimates.

Fuel switching

Numerous strategies, programmes and plans have been proposed for fuel switching, but it is not always clear how they have been developed. The tendency has been to focus on natural gas substitution by coal and biomass in the heating sector because of Russian gas price increases in 2010-14, and the environmental impact has often been ignored or underestimated in cost-benefit analyses of switching from gas to other fuels. Difficulties in accessing financing for such multi-billion-dollar projects, as well as the diminished profitability of coal following the conflict in eastern Ukraine, make the feasibility of these projects uncertain.

In its Energy Strategy for Ukraine through 2035, the Ministry of Energy and Coal Industry predicts several changes in TPES from 2015 to 2035: reduced consumption of coal (from 27 Mtoe to 12 Mtoe) and oil products (10.5 Mtoe to 7 Mtoe); and increased consumption of natural gas (26 Mtoe to 29 Mtoe), nuclear (23 Mtoe to 24 Mtoe), solar and wind (0.1 Mtoe to 10 Mtoe), biomass (2 Mtoe to 11 Mtoe) and hydro (from 0.5 Mtoe to 1 Mtoe).

The government expected biomass to replace 3 bcm of natural gas in district heating, as the parliament adopted legislative amendments in March 2017 guaranteeing

biomass heat producers 90% of the average tariff for heat produced from natural gas. Despite the successful deployment of several renewable heat projects with the assistance of international financial organisations (in particular the construction of a state-of-the-art bio-thermal CHP in Kamianets-Podilskyi as part of the World Bank District Heating Energy Efficiency Project), overall progress towards biomass switching in district heating is very limited and far below the expected 3 bcm of natural gas.

Among the most prominent projects realised in recent years is pulverised coal injection (PCI) in the steel industry, which substitutes coal for natural gas. The technology was successfully introduced at ArcelorMittal Kryvyi Rih and Metinvest Azovstal Iron and Steel Works in 2016, and it has been implemented at all large steel mills in the last five years. Another interesting fuel-switching project at ArcelorMittal Kryvyi Rih substitutes biomass (sunflower seed husks) for natural gas in lime production, an important input for iron- and steelmaking.

Environmental protection

Ukraine has a considerable body of environmental legislation, including extensive rules, regulations and standards for the efficient use of energy resources, energy conservation and renewable energy. Among its approximately 50 national standards are those pertaining to energy efficiency, including method definition; construction and analysis of energy balances; regulation of specific consumption and loss of fuel; energy labelling of household electrical equipment; energy auditing and management; and energy performance standards for certain types of equipment. These standards will have to be successively aligned with EU standards in accordance with the Energy Community Treaty.

Climate change

Ukraine is an Annex I party to the UNFCCC. Under the Kyoto Protocol, Ukraine agreed to keep its GHG emissions at the base year (1990) level during the first commitment period (2008-12). In fact, its GHG emissions in 2018 totalled 344.1 million tonnes of carbon dioxide-equivalent (MtCO₂-eq), which is actually 61.2% lower than in 1990.

Furthermore, Ukraine's energy-related CO₂ emissions totalled 166 Mt in 2017 – 75% less than in 1990 owing to a strong decline after the breakup of the Union of Soviet

Socialist Republics (USSR). Power generation accounted for 50% of these emissions, followed by manufacturing (18.7%), transport (15.1%), households (13.1%), other energy sectors (1.8%) and commercial and other services (1.2%).

In 2016 Ukraine ratified the Paris Agreement on climate change, pledging to reduce its GHG emissions to 60% of the 1990 level by 2030. However, with the economic collapse in the 1990s that followed the dissolution of the USSR, two severe recessions just when the economy was recovering in the 2000s, and loss of sovereignty over part of its territory in 2014-15, Ukraine's current GHG emissions are only 39% of what they were in 1990. Even a strong economic rebound up to 2030 would not be likely to jeopardise Ukraine's compliance with the Paris Agreement.

Ukraine has made significant progress in setting up the necessary legal and institutional frameworks and in implementing two Kyoto Protocol mechanisms: joint implementation (JI) and international emissions trading of assigned amount units (AAUs). It is one of the most active countries in the JI market, but still has considerable GHG emissions abatement potential. The government and industry must make a stronger effort to realise this potential through power sector modernisation and energy efficiency improvements, which will also contribute to energy security.

Carbon capture and storage (CCS) has significant potential in Ukraine. Coal has been exploited for many decades, and the existence of a well-established coal industry and technical expertise are factors that may catalyse future efforts. However, current priorities related to clean coal are focused on technologies for increasing coal-fired plant efficiency and emissions reductions rather than on CCS.

Technology research, development and deployment

Energy-related research and development (R&D) activities in Ukraine are dedicated to the nuclear sector, where a high level of R&D activity is required in areas that are particularly important for safety upgrade programmes and extension plans for nuclear reactors, such as nuclear safety, material science and simulation tools. As R&D requires access to costly experimental facilities such as research reactors, irradiation facilities and hot cells, international collaboration is being encouraged as a means of optimising efforts, offering multinational access to experimental facilities and sharing expertise. The European Commission has considerable experience fostering such activities through co-funded research among EU and other countries under the

Euratom framework programmes. Ukraine is also participating in the International Atomic Energy Agency (IAEA) International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO).

As in other countries that have a long history of nuclear energy use, there is a pertinent need to educate and train skilled workers for employment in the nuclear sector as ageing engineers, scientists and technicians retire. For this purpose, Ukraine has many academic institutions, universities and nuclear research institutions: the Kyiv Polytechnic Institute, the Sevastopol National University of Nuclear Energy and Industry, and the Odessa National Polytechnic University graduate roughly 140 master's students annually in the field of nuclear energy. This may not be enough, however, as newly qualified engineers and technicians may decide to work in other economic sectors or relocate to countries that offer higher salaries. In addition, the National Training Centre for Energoatom Personnel, opened in late 2012 and partially funded by the European Union (EUR 14 million, or one-third of the project's cost), provides training in nuclear maintenance, management and safety.

Numerous research programmes relate to energy technology development under various academic institutions and universities, but state funding in energy technology R&D remains scarce and more efforts in both professional training and research segments of R&D are required.

This publication has been produced with the financial assistance of the European Union and is part of the EU4Energy programme. This publication reflects the views of the International Energy Agency (IEA) Secretariat but does not necessarily reflect those of individual IEA member countries or the European Union. The IEA makes no representation or warranty, express or implied, in respect to the publication's contents (including its completeness or accuracy) and shall not be responsible for any use of, or reliance on, the publication.

EU4Energy is a collaboration between the IEA, the European Union, Focus Countries and other implementing parties, designed to support the aspirations of Focus Countries to implement sustainable energy policies and foster co-operative energy sector development at the regional level.

This publication and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

IEA. All rights reserved.

IEA Publications

International Energy Agency

Website: www.iea.org

Contact information: www.iea.org/about/contact

Typeset in France by IEA - September 2021

Cover design: IEA