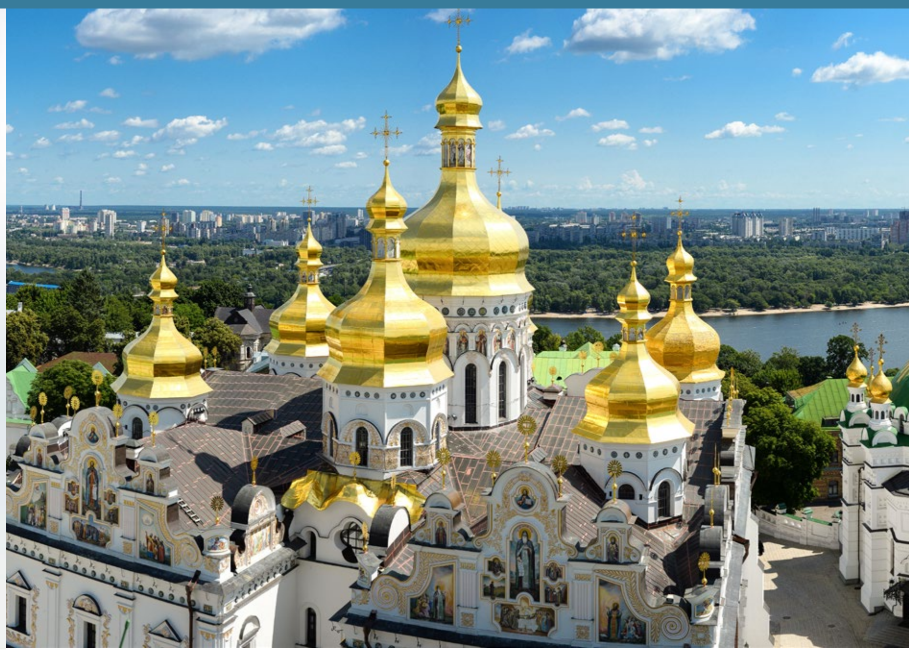
Economic and Social Commission for Western Asia



UNITED NATIONS

الاسكوا

ESCWA

United Nations Development Account project on promoting renewable energy investments for climate change mitigation and sustainable development

Case Study on Policy Reforms to Promote Renewable Energy in Ukraine

E/ESCWA/SDPD/2017/CP.13

Economic and Social Commission for Western Asia

United Nations Development Account project on promoting renewable energy investments for climate change mitigation and sustainable development

Case Study on Policy Reforms to Promote Renewable Energy in Ukraine

UNITED NATIONS
Beirut

United Nations publication issued by ESCWA, United Nations House,
Riad El Solh Square, P.O. Box: 11-8575, Beirut, Lebanon.

Website: www.unescwa.org.

Cover photo credits:

Solar panel, by stevanovicigor
Wind energy, by Satura
Panorama of Assumption Church, Kiev, Ukraine, by esvetleishaya

Preface

This case-study report was prepared for the Sustainable Energy Division, United Nations Economic Commission for Europe (UNECE) within the framework of the United Nations Development Account (UNDA) project Promoting Renewable Energy Investments for Climate Change Mitigation and Sustainable Development. The project focused on capacity-building for policymakers and project developers in order to promote investments in renewable projects. The project was led by UN ESCWA and implemented in partnership with the UNECE.

The UNDA project included case studies of the experience of renewable energy policy reforms in selected countries from each of the two regional commissions. Four countries were selected from each regional commission: Jordan, Lebanon, Morocco and the United Arab Emirates from UN ESCWA Member States; and Georgia, Kazakhstan, Serbia and Ukraine from UN-ECE Member States.

The present report covers the case study for Ukraine, and was prepared by Ms Galyna Trypolska (PhD), Senior Researcher at the Ukrainian National Academy of Sciences. Since 2008 she has been specializing in renewable energy market analysis with particular focus on policies for renewables implementation in Ukraine, market formation, institutional structure of renewables market. Mr. Viktor Badaker, Regional Adviser, Sustainable Energy Division (UNECE), helped review and finalize the document.

Table of Content

List of figures

List of tables

List of abbreviations

BFSRA	Bioenergy and Food Security Rapid Appraisal
CES	constant elasticity of substitution
CGE	computable general equilibrium
CGEM	omputable general equilibrium model
CHP	combined heat and power
CH_4	methane
CO_2eq	CO_2 equivalent
EBRD	European Bank for Reconstruction and Development
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FIT	feed-in tariff
GDP	gross domestic product
GHG	greenhouse gas
GWh	gigawatt-hour
HPP	hydropower plant
IFC	International Financial Corporation
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
JSC	joint-stock company
kW	kilowatt
kton	kilotons (thousand tons)
LCR	local content requirement
Mt	megatons (million tons)
Mm3	million cubic metres
MW	megawatt
OECD	Organization for Economic Cooperation and Development
PP	power plant
RE	renewable energy
RES	renewable energy sources
ROM (coal)	run-of-mine (coal)
SAEEESU	State Agency on Energy Efficiency and Energy Saving of Ukraine
SAM	Social Accounting Matrix
SEC "Biomass"	Scientific Engineering Centre "Biomass"
SPP	solar power plant
toe	ton of oil equivalent
TPP	thermal power plant
UAH	Ukrainian Hryvnia (currency)
USELF	Ukraine Sustainable Energy Lending Facility
VAT	value-added tax
WPP	wind power plant

I. Ukrainian energy sector characteristics

National energy policy serves as one of the key factors of economic development in Ukraine, representing both risks and potential for further improvements. Energy accounts for 8.3% of household expenditure (with a potential to double, considering current tariff reforms), 22.5% of intermediate consumption and 30% of imports. In addition, the sector's enterprises are responsible for over 77% (309 million tons (Mt) of carbon dioxide equivalent (CO_2eq) in 2012) of total greenhouse gas (GHG) emissions. At the same time, onward development of energy policy faces several key challenges, including:

- Poor efficiency and high energy intensity (three times higher than in member countries of the Organization for Economic Cooperation and Development and three to four times higher than in European Union (EU) countries. For instance, to heat one square metre (1m^2) of a residence, more than twice as much natural gas is needed in Ukraine than in the EU);
- One of the highest carbon intensities in the world (Ukraine currently holds seventh place among more than 160 countries);
- High dependence on energy import and declining domestic fossil-fuel production;
- Ineffective market regulatory framework and poor investment climate;
- Low level of local energy security and risk of energy-system collapse.

In order to solve these issues, a wide range of robust energy, social and economic policies have to be designed and implemented. In this context, renewable energy (RE) development holds one of the most crucial positions with a potential to contribute fruitfully to most of the highlighted policy issues.

Until recently, the Ukrainian energy sector was highly dependent on energy imports. In 2015, imports of natural gas became the lowest during Ukraine's entire period of independence, reaching 16.5 billion cubic metres (m^3) (compared to 52.6 billion m^3 in 2008). Only 37% of imported natural gas in 2015 came from the Russian Federation, and the remainder from EU countries via a reversing mechanism. Although Ukraine possesses a natural gas transportation system, the volumes of the gas transported are decreasing slowly for economic and political reasons (with the exception of 2015, when volumes of gas transportation from the Russian Federation to Europe increased slightly as per the increased tariff). Domestic natural gas consumption is decreasing, reaching 33.7 billion m^3 in 2015 (including consumption in the regions of Donetsk and Luhansk). That became possible for several reasons: the economic recession and tremendous drop of industrial output and partly because of governmental measures aimed at substituting natural gas with other types of fuel. Internal natural-gas-mining also decreased due to strict fiscal policy (such as the introduction of 55%–70% bid rent).

Output of oil is also decreasing due to the depletion of oil deposits. Out of six existing oil-processing plants, only two are operational, producing no more than 20% of oil products consumed in Ukraine. Oil products are mostly imported but quality control thereof requires significant improvement. In 2015, petrol consumption decreased by 26%; diesel fuel consumption decreased by 13% due to a fall in industrial output, reduction of the country's territory and fuel price spikes. Biodiesel production in Ukraine is low (up to 20,000 tons (t) annually); insufficient bioethanol production (65,000 t) almost ceased in 2015.

Until 2013, Ukraine mined up to 80 million t of run-of-mine (ROM) coal annually; that was used mainly for combined heat and power (CHP) plants and thermal power plants (TPPs). Military actions in eastern Ukraine led to an almost two-fold loss of mining. For instance, in 2015: coal-mining decreased by 38.8% compared to 2014; coking-coal output decreased by 49.8%; and steam-coal output by 35.3%. Due to declining domestic coal-mining, Ukraine had to import coal, mainly from the Russian Federation (56%), USA, Kazakhstan and South Africa. The coal mines were inherited by Ukraine during the Soviet era and were exploited for more than 70 years. About 90% of CHP units were built in the 1960s and 1970s; 60% of boiler houses and TPPs were built between the 1930s and the 1970s.

Main electricity producers are thermal, heat and power plants, as well as nuclear power plants (Table 1). The installed capacities of 15 units in all four nuclear power plants in Ukraine are 13.835 GW. Since 2011, Ukraine has been fully dependent on the Russian Federation for primary nuclear technology but has been working to overcome the dependence by cooperating with Westinghouse (USA), Skoda (Czech Republic, with informal affiliation to Russian companies).

The entire energy infrastructure is obsolete. In 2013, power losses were as much as 20.7 TWh, which is about half of total household consumption[1]. Despite the share of renewables in the electricity balance remaining unchanged over the years 2014 and 2015, actual output declined in 2015 (1,482.4 million kWh, compared to 1,665.1 million kWh in 2014). Overall electricity output in 2015 fell by 13.6% compared to the previous year due to a decline in industrial output (especially in metallurgy and heavy machine building); decreased household demand; insufficient reserves of steam coal; and a relatively warm winter. Overall efficiency of power plants in Ukraine is 35.2% whereas, in EU countries, efficiency is 43.6%.

Electricity consumption in 2015 also fell by 11.3% (including technological line losses) due to decreased industrial consumption (–17.8%), as well as decreased consumption by the municipal sector (–8.7), households (–7.2%) and others (–9.2%).

In 2015, electricity output from wind-power plants (WPPs) contributed a 30% share of all electricity from renewable energy sources (RES). Solar input was 53%, the remainder were biomass (7%) and small hydro (10%). Since the beginning of 2015, installed capacities in Ukraine have been 513.893 MW (megawatts) for WPP; 817.203 MW for ground solar power plants (SPPs); 1.75 MW for rooftop SPP; 80.3 MW for small hydro; and 40 MW for biomass and biogas. At the beginning of 2016, installed capacities were: 426 MW for WPP; 453 MW for SPP; and 31 MW for biomass-fired PPs. Overall installed capacities of renewable energy sector by the end of 2015 was 1.03 GW, producing 1,347.4 GWh (gigawatt-hour) of electricity. 2015 was a year of stagnation for renewables due to hostilities and minor regulation deficiencies. For instance, only 19.5 MW of new renewable capacities were installed (10.9 MW of SPP, 5.2 MW of small hydro and 3.3 MW of biomass-fired PP), whereas, during previous years, about 300 MW of new capacities were installed annually. Biomass use for heat production increased, substituting 3 billion cubic metres (m^3) of natural gas annually. By the beginning of 2015, a total of 4,581 MW of biomass-fired heat-producing equipment had been installed.

Table 1: Shares of electricity produced in 2014 and 2015 by plant types

	2014	2015
Nuclear power plant	48.6	55.7
Combined heat and power plant	37.6	31.5
Thermal power plant	3.6	3.6
Small hydropower plant	4.5	3.3
Hydro pump storage plant	0.5	1
Isolated power plant	4.3	3.9
Renewables	0.9	0.9

Source: Markevych, K., 2015: Results of the energy sector of Ukraine, Razumkov Centre

Ukraine is now implementing numerous reforms in the energy sector, aimed at reducing natural-gas consumption and increasing energy efficiency. Nevertheless, the country continues to be dependent on imported natural gas, nuclear fuel and steam coal, primarily from the Russian Federation. Its own possibilities to mine steam and coking coal are severely limited by the fact that mines are located on territories that are currently not controlled by the Ukrainian Government or are being destroyed due to hostilities in the east.

In 2015, the energy sector, particularly electricity, heat supply and air conditioning, produced 7,2250.6 thousand tons (kt) of CO_2, which comprised 52% of all the country's CO_2 emissions. The transport sector accounted for 1.8% of all CO_2 emissions (2419.1 kt). Agriculture contributed 0.8% (1,110.4 kt) of all CO_2 emissions. Methane emissions in 2015 were 514,122.2 t (88.6% of the 2014 level); CO_2 emissions were 138,932.1 kt (83.2% of the 2014 level); sulfur-dioxide emissions were 830,252.2 t (73.3% of the 2014 level).

II. Current policy for renewable energy investments

Ukraine has signed several strategic international documents defining national development paths and elaborated respective internal legislation. Strategic documents include the Treaty Establishing the Energy Community (signed by Ukraine in 2005); the Association Agreement between Ukraine, on the one hand, and the European Union, the European Atomic Energy Community and their Member States, on the other hand (2014); the Energy Strategy of Ukraine until 2030 (2013); the National Renewable Energy Action Plan (2014) and the Strategy for Sustainable Development of Ukraine until 2020 (2015).

There are several laws, adopted in early 2000 with further amendments, such as those "On Alternative Fuels", "On alternative energy sources". They define types of fuels, as well as social and economic implications of RES use in Ukraine – but no economic mechanisms of RES use.

The Law of Ukraine "On Combined Heat and Power (Cogeneration) and Waste Energy Potential" defines the legal basis for improving fuel efficiency in the processes of energy production or other industrial processes, development and application of technologies of combined production of electricity and heat, improving reliability and security of supply at the regional level and attracting investment in the construction of cogeneration plants.

The Law "On the Electric Power Industry" defines the legal, economic and organizational basis for activities in energy and regulates relations associated with the production, transmission, distribution, supply and use of energy, to ensure the energy security of Ukraine. It defines the feed-in tariff (FIT) since 2009, its rates and the list of entities that are not qualified for FIT (such as those using cogeneration, blast furnaces, coke gas and large hydropower plants). After 2019 and 2024, these FIT rates will be reduced from the baseline value of 20% and 30%, respectively. FIT have spurred RES market development and the number of entities benefiting from them has grown sharply, especially solar farms and small hydropower plants. High rates of FIT have contributed more than other policy measures to the renewable electricity market expansion in Ukraine. Legislation regarding FIT underwent several major changes regarding local content requirements (LCR). Initially, until mid-2015, there was one which was re-designed several times. Market participants complained that it was almost unrealistic to achieve in all spheres except photovoltaics. The LCR norm was a hindrance for small investors to enter the market.

The tax code of Ukraine and subsequent laws stipulate that electricity generated by RES is not subject to excise duty; the supply of equipment, machinery and equipment – production and reconstruction of vehicles that are not produced in Ukraine and operate on biofuels, including agricultural machines – are exempt from value-added tax (VAT) until 2019, in accordance with the Law of Ukraine "On Alternative Fuels".

Other important laws include the Law "On Amendments to the Law of Ukraine "On Electric Energy Industry" to promote electricity production from alternative energy sources" (2012), "On Alternative Types of Fuels" (2000 with amendments); "On Amendments to Several Laws of Ukraine Regarding Promotion of Production and Use of Biologic Types of Fuels" (2009). These laws defined the terms "biomass", "biofuel producer" and "wastes", as well as the financial preconditions of using biomass for energy purposes. Biomass "producers" and "processors" are obliged to keep records of biomass in the manner prescribed by the Cabinet of Ministers of Ukraine. The list of codes in the Ukrainian qualification of foreign goods was defined so that certain types of bioenergy equipment could have privileges for import to Ukraine. This equipment included boilers, gas generators, burners, ovens and other devices, but did not include internal combustion engines modified for biogas use and their parts.

In 2014 and 2015, all electricity-generating plants with capacity of more than 200 kW were attributed the category of complexity of nuclear power plants, and thus required licensing. This provision has now been abolished and biogas producers do not need a license. Heat output and transportation still require licensing, however.

There were deficiencies and different interpretations of the term “biomass” in various laws (it excluded types of biomass such as cattle manure and other animal waste, sewage sludge and organic parts of municipal solid waste and included only biomass of plant/vegetable origin); biogas plants operating on cattle manure could therefore not obtain FIT for several years.

The Order of the Cabinet of Ministers of Ukraine No. 791-r dated 9 September 2014 “On Approval of the Action Plan for the Implementation of the European Parliament and Council Directive 2009/28/EC of 23 April 2009 on the Promotion of the Use of Energy Produced from Renewable Energy Sources and That Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC” officially implemented the European Directive on renewables in Ukraine.

Order of the Cabinet of Ministers of Ukraine No. 1014-r dated 16 October 2014 "On Approval of a Plan of Short- and Medium-Term Measures of Natural Gas Consumption Reduction Until 2017" endorsed substitution of natural gas with any other types of fuels (including biogas) in Ukraine.

In accordance with its National Renewable Energy Action Plan, Ukraine is obliged to obtain 11% of energy from renewables in the energy balance by 2020. To reach this target, about 700 MW of new energy-generating capacities need to be installed annually (compared to 19.5 MW in 2015).

The system of financial incentives to promote RES use, other than FIT, includes reduced taxes for renewable energy companies; exemption from income tax; and exemption from import duties when importing certain types of equipment for RES.

The Law of Ukraine “On Amendments to the Law of Ukraine “On Electric Energy Industry” to promote electricity production from alternative energy sources” (2012) introduced a guarantee of origin of electricity (as a document confirming that the electricity is produced from renewables).

The Law of Ukraine “On Amendments to Certain Laws of Ukraine to Ensure Competitive Conditions of Electricity Production Using Alternative Energy Sources” (2015) amends laws of Ukraine “On Alternative Fuels”, “On Electric Power Industry” and “On Basics of Functioning Electricity Market of Energy of Ukraine”. It stipulates that FIT for electricity produced from biomass is 12.39 eurocents/kWh; previously existing LCR is eliminated and a premium to FIT for using Ukrainian components in the construction of energy facilities is introduced.

In accordance with Law No. 287-VIII “On Animal By-products Not Intended for Human Consumption”, the disposal of waste of animal origin is carried out exclusively by specialized companies which use such waste and may not be carried out by companies whose products of animal origin are intended for human consumption. Dung/manure and uninfected animal residues belong to the second class of side products of animal origin, and they have to be:

- Converted to organic fertilizer after treatment by compulsory sterilization under pressure;
- Composted or transformed into biogas after processing by sterilization under pressure.

Processing capacities of by-products of animal origin must be located separately from enterprises which process food products or goods of animal origin; they should be provided with technical equipment, which guarantees processing. The companies involved in waste utilization are the market operators. Market operators who carry out disposal or removal of animal by-products and food processing in a manner other than that provided by law (i.e. without sterilization under pressure or without processing into biogas under pressure after sterilization) are subject to a fine. For legal entities, this is 23–30 times the minimum wage[2] (33,350–43,500 Ukrainian Hryvnia (UAH)); for individual entrepreneurs, it is 8–15 times the minimum wage (11,600-21,750 UAH). These are minor penalties: sometimes it is easier to pay a fine and not implement any additional measures. However, large agribusinesses undergo inspections by the Ministry of Health, Public Prosecution Office, Sanitation Centre and Environmental Inspectorate. In some cases, biogas plants with Ukrainian equipment are feasible even to cover the costs of waste utilization.

Since April 2015, natural-gas tariffs for households grew almost six-fold (due to increased transportation costs and national currency depreciation). Overall, the natural-gas tariff increase for households during 2015 was 285%; the heat tariff increased by 67%; the hot water tariff increased by 60%. Natural gas price for utilities grew more than two-fold, reaching 2,934 UAH/1,000 m^3. Growing utility bills make all possibilities of decreasing bills for heat more attractive even for households. High utility prices are the way to optimize utility services, to boost energy-saving measures and to increase the share of renewables in the energy balance.

III. Biogas potential and an assessment of the CO_2 emission reductions possible from the envisaged increased share of renewable energy

Biomass and biogas use have a significant potential for heat and electricity production due to abundant residues in agriculture, favourable climatic conditions, availability of agricultural land, relatively inexpensive labour power and abundant untreated solid-waste landfills. Biomass can substitute about 10–20 billion m^3 of natural gas annually. According to the Bioenergy Association of Ukraine, new bioenergy capacities installed in 2015 substituted about 500 million m^3 of natural gas. The overall rate of substitution of natural gas by bioenergy at the end of 2015 was 3 billion m^3 of natural gas per year.

The most promising now are the projects of cogeneration and biomass-fired CHPs, especially those related to sugar-refineries, farms and sunflower-processing plants, where biogas is a result of methane (CH_4) digestion. Other important biogas sources are waste landfills, but the processing thereof is in its infancy. While biomass potential is far from been deployed, the situation may change for the better with the upcoming unbundling in the municipal sector (so that heat from biomass can access heat networks). Biogas output does not depend on the weather, being less dependent on climatic conditions than intermittent renewables. Biogas can be used to substitute natural gas to generate heat and electricity or to power vehicles, which requires its further refinement.

The largest potential to produce biogas is located in the regions of Dnipro, Donetsk and Kiev, at 150 ktoe/year. Although cattle stock declined six times in 2015 compared to 2000, pig and chicken livestock is growing (from 2000 to 2013, it grew five-fold).

According to the State Agency on Energy Efficiency and Energy Saving of Ukraine (SAEEESU) estimates, economically justified bioenergy potential is more than 800 petajoules (PJ)/year – which is equal to a quarter of the total energy consumption in Ukraine (Table 2). Half the potential energy accounts for energy production from agricultural waste and wood biomass. The other half is energy derived from energy crops and biogas.

According to other assessments (Scientific Engineering Centre (SEC) "Biomass"), the potential of biogas derived from agricultural residues, food industry, landfills and sewage waters of industrial enterprises is significantly higher – as much as 3.2 billion m^3 CH_4 annually[4]. An additional 3.3 billion m^3 of CH_4 could be obtained by planting corn or other energy crops for biogas purposes. In our further calculations, we will focus on the indicators of biogas potential listed in Table 3.

The potential of biogas is only about to be used. For instance, there are only seven large biogas plants in Ukraine, whereas Germany, which has a significantly smaller area of arable lands, had 8,700 biogas plants in 2012 of which 7,515 were in agribusinesses. The International Renewable Energy Agency (IRENA) has estimated that less than 5% of agribusiness-derived biogas potential is used in Ukraine. In 2013, 22.3 Mm^3 of biogas from agricultural wastes and 31.2 Mm^3 of biogas from landfill were produced and used[5]. In 2014, these figures were 49.5 Mm^3 and 33 Mm^3 respectively.

Table 2: Energy potential of biomass in Ukraine[3]

Type of biomass	Theoretical potential (Mt)	Economically feasible potential (Mtoe)	Economic potential (PJ)
Cereal straw	30.6	4.54	131
Rape straw	4.2	0.84	25
Corn production waste (stalks, shanks)	40.2	4.39	129
Sunflower production waste (stalks, receptacles)	21	1.72	50
Secondary agricultural wastes (husk, pulp)	6.9	1.13	33
Woody biomass (wood, felling residues, waste wood)	4.2	1.77	52
Biodiesel (from rapeseed)	-	0.47	14
Bioethanol (from corn and sugar beet)	-	0.99	30
Biogas from waste and by-products of agro-industrial complex	1.6 billion m^3 CH_4	0.97	29
Landfill	0.6 billion m^3 CH_4	0.26	8
Biogas from wastewater (industrial and municipal)	1 billion m^3 CH_4	0.27	8
Willow, poplar, miscanthus	11.5 billion m^3 CH_4	6.28	184
Corn (biogas)	3.3 billion m^3 CH_4	3.68	108
Peat	-	0.40	12
Total	-	27.71	813

Source: State Agency on Energy Efficiency and Energy Saving of Ukraine

Table 3: Estimated biogas output potential in Ukraine (economically feasibe potential)

Enterprise type	Main types of waste	Dry matter content	Number of companies	Total waste generated (Mt/year)	Potential for biogas production (Mm^3/year)
Cattle farms	Manure	10–12%	5,734	20.5	719
Pig farms	Manure	7–10%	6,515	4.7	180
Poultry farms	Litter	25–30%	861	2.9	326
Breweries	Spent grain	20–25%	50	1.4	171
Sugar factories	Beet pulp	10–1 %	184	6.5	216
Ethanol plants	Distillery stillage	6–8%	82	4.5	180
Milk processing/ cheese production	Sewage Milk whey	6-7%	300	0.9 2.5	90
Energy plantations	Corn silage	20-35%	842,000 ha (18% of available area)		1,610
Total				43.9	3,492

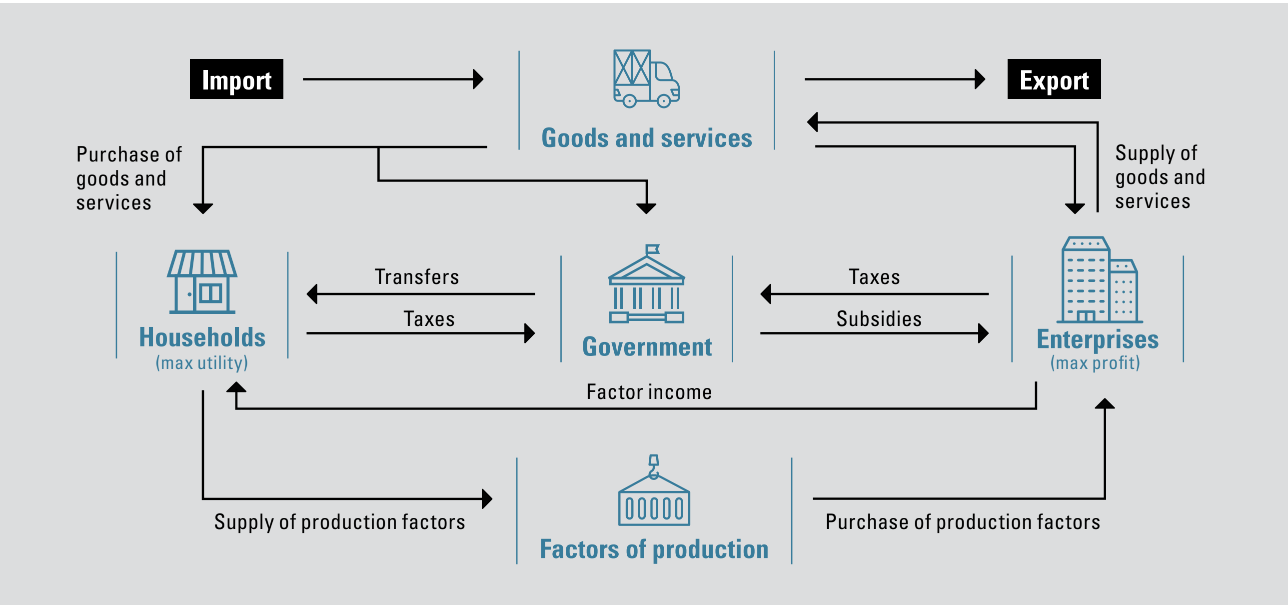
Source: G.G. Geletukha, 2011: Possibilities of natural gas substitution in Ukraine by solid biomass and biogas. Open meeting of Q-club: Alternatives of problematic Russian gas: are they real in Ukraine? Ukrainian House, Kiev

IV. Model used to assess the potential energy production impacts

An employed computable general equilibrium model (CGEM) was developed in the Institute for Economics and Forecasting, Ukrainian National Academy of Sciences (NAS), as part of the research project "Energy markets regulation in the context of Ukraine's international obligations" (Figure 1).

Within CGE methodology, producers are assumed to maximize profits, while households maximize utility. Enterprises are producing goods and providing services, employing capital, labour and intermediate products. The latter may be either produced by national manufacturers or imported. Domestic producers sell to the internal market or export goods. In the domestic market, final goods and services are purchased by households (including non-profit institutions serving households), the Government or contribute to gross capital formation. Households receive labour and capital payments as money transfers, including retirement benefits and educational scholarships. The Government earns revenue and receives tax payments.

Figure 1: Flowchart of Ukraine's computable general equilibrium model



Source: developed by Maxym Chepeliev

Tax rates on production and import, aggregate trade deficit level and marginal propensity to save stay constant, while tax revenues, foreign exchange rates and gross capital formation volumes are endogenous.

Ukraine's CGEM utilizes constant elasticity of substitution[6] (CES) production functions, within which special cases are Cobb-Douglas (substitution elasticity equals "1") and Leontief (substitution elasticity equals "0") production functions. In order to ensure a flexible representation of substitution processes for different product groups, Ukraine's CGEM incorporates multi-nested CES.

Ukraine's CGEM equilibrium is characterized by three types of conditions:

- Zero profit[7];
- Market clearance[8];
- Income balance.

Key input data used for CGEM calibration are represented via the Social Accounting Matrix (SAM) – an extended version of the input-output (IO) table that incorporates additional information regarding transfers between economic agents. Apart from the IO table, it includes disaggregated fiscal revenue structure, sectoral investment distribution and detailed household consumption structure, depending on income level, and pension fund and social security fund transfers. Key input data for SAM derive from 2013 and were updated to 2015, based on the latest data from national accounts.

Functions used in the model are homogeneous of zero degree on prices (multiplication of prices for some positive constant does not change the output): in this context, it is important not in absolute, but in relative value prices. As a rule, therefore, the product price of a particular sector is fixed (considered to equal one), and the results are regarded as price changes relative to price of the selected product type. In Ukraine's CGEM, the economy exchange rate was chosen for fixation.

Ukraine's CGEM is a dynamic, recursive model that is retrospective in nature. In this approach, events of future periods will not affect characteristics of previous years' equilibrium. This means that the model trajectory could be built gradually through finding equilibrium positions, year after year, instead of solving the system of equations for finding equilibrium states at the same time.

The connection between successive periods of the model (years) is taken into account by changes in volume of fixed assets, number of employees and efficient use of resources. In particular, the dynamics of change of the value of capital and labour is described by corresponding equations:

$$\mathbf{KD_{i,t+1} = (1-\delta)KD_{i,t} + Ind_{i,t};}$$

$$\mathbf{LS_{t+1} = (1 + ng)LS_t,}$$

where

$KD_{i,t+1}$ is the amount of fixed assets at the beginning of the period t+1 in sector i, δ - depreciation rate,
$Ind_{i,t}$ - amount invested in sector i during the year t,
LS_t - number of people employed in year t,
ng - growth rate of labour force.

After the baseline model calibration, each scenario is defined by changes in exogenous variables (e.g. tax rates, technological parameters, etc.). Under the new values of exogenous variables, initial equilibrium conditions do not hold. In order to find a new equilibrium path, a system of non-linear equations, which describes the behaviour of economic agents, is solved. The difference between initial and new equilibrium paths represents the effects of studied policies.

V. Evaluation of greenhouse gas emission reduction

The assessment of GHG emission reduction was conducted using the TIMES-Ukraine economic and mathematical model[9], which was designed by the State Institution Institute for Economics and Forecasting, NAS of Ukraine, to provide research into energy and environmental policies and the development of national energy system scenarios. It is an optimization model for all Ukraine's major energy flows. The object of study of the model of energy flows and energy balance is the entire energy system of Ukraine (Figure 1).

In the TIMES-Ukraine model, Ukraine's energy system is represented by the only region consisting of seven sectors: energy supply; electricity and heat production; industry; households; service sector; transport sector; and agriculture.

The industrial sector is represented by the manufacturing industry only, because the energy-extraction industry and electric-power industry are included in the model's energy sector according to the energy balance block diagram; fuel consumption for own needs and transportation losses are not included to the calculation of final consumption.

Industries in the model are divided into two categories by the level of energy intensity. Energy-intensive industries are described in the context of production technologies of the main products types (steel, aluminum, ammonia, cement, lime, paper, glass, etc.). The category of energy-intensive industries includes metallurgy, chemical industry, production of non-metallic minerals, cellulose and paper. For other industries, the structure of energy flows is standard and consists of four types of conventional technologies which meet the needs of technological heat, machine drive, electrochemical and other processes.

The transport sector in the TIMES-Ukraine model is represented by road, rail, pipeline, air and water. Transportation of passengers and cargo are the energy services provided by road and rail transport technologies. Rail transport is divided into cargo and passenger and includes subway.

Energy consumption by households is determined by the most energy-intensive categories of energy services, such as heating and air-conditioning facilities, water-heating, lighting, cooking, cooling devices (refrigerators, etc.), laundry, ironing, dish-washing and other needs which require energy and/or the use of other fuels.

The model structure is designed taking into account existing statistical classifications on the basis of primary statistical information from the State Statistics Service of Ukraine. For model disaggregation, energy-technology production and cost parameters, estimated statistic data of ministries, State committees and industrial enterprises are used. The model database contains information about output volumes and seasonal fluctuations of energy demand, expressed in the form of requirements by energy-system sectors and regions; price, volume and seasonal availability of various types of energy and fuel on the international and domestic markets; and the cost and volume of domestic mining of primary energy resources, technical and economical characteristics of energy technologies, power-consumption graphics, etc.

The TIMES-Ukraine model includes more than 1,600 technologies, amount of energy resources, materials, demands, etc. There are more than 730 elements that are either input or output for the respective technologies; the number of restrictions setting conditions for the mathematical model calculations is about 300; the number of non-zero values in the mathematical model, which are the parameters of any of its elements, is 1–4 million, depending on the forecast period. Although the structure of the TIMES-Ukraine model was focused on the formation of the forecast energy balance in forms of the International Energy Agency or Eurostat, taking into account respective methodical recommendations of the International Panel on Climate Change (IPCC), the model topology allows an adequate calculation of GHG emissions by sector.

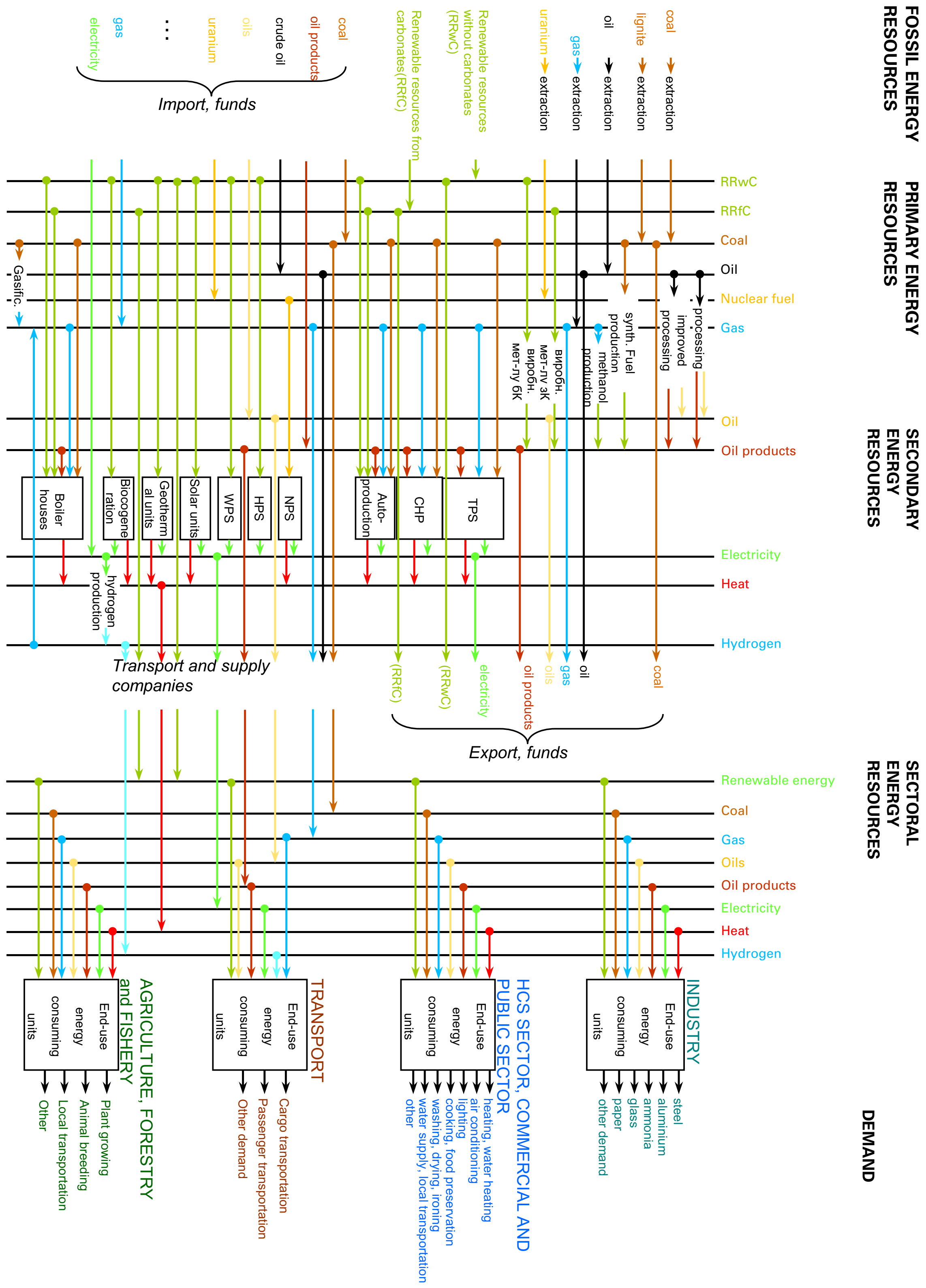
The TIMES-Ukraine model is used for scenario studies of possible changes in the energy sector.

For investigation of the effect of exogenous assumptions changes (for example, substituting natural gas with biogas, change of demand of energy end users, the technical characteristics of energy technologies, etc.), additional (to the baseline) scenarios are developed, which allow the main factors influencing the stability of the power system to be identified and to conduct the appropriate sensitivity analysis. Additional restrictions are imposed on general conditions of the energy industry existing in the model (for example, setting of target indicators), allowing analysis of alternative scenarios of specific policies (set of regulatory measures). For all the scenarios, the lowest overall cost (or maximum utility) is calculated on the designated trajectory of system development: respective assessments of the supply structure and energy use by industries and fuel types, GHG emissions by consumer categories, the optimal technological structure of energy producers and consumers, etc., are conducted.

Greenhouse gases emission reduction resulting in biogas substitution of fossil energy sources (coal, gas) in cogeneration units was carried out according to the procedure used in the national inventory of GHG emissions. Emission factors of GHGs listed in the national inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases for 1990–2014[10], which correspond to the IPCC Guidelines for National Greenhouse Gas Inventories (2006)[11], were used. Respective biogas potential output is given in Table.4.

Source: Power plant chimneys, by stone36.

Figure 2: Reference energy system in TIMES-Ukraine model



Source: "Transition of Ukraine to the Renewable Energy by 2050" / ODiachuk, OChepeliev, R. Podolets,G. Trypolska and oth. ; edited by Y. Oharenko and O. Aliieva // Heinrich Boell Foundation RegionalOffice in Ukriane. – Kyiv : Publishing house "Art Book" Ltd., 2017. –88p.

Table 4: Annual cost-efficient potential for biogas use in Ukraine

Year	Million cubic metres (Mm³)	Terajoule (TJ)	Million tons of oil equivalent (Mtoe)
2016	0	0	0
2017	207	4,547	0.1086
2018	413	9,094	0.2172
2019	620	13,642	0.3258
2020	827	18,189	0.4344
2021	1,033	22,736	0.5431
2022	1,240	27,283	0.6516
2023	1,447	31,831	0.7603
2024	1,654	36,378	0.8689
2025	1,860	40,925	0.9775
2026	2,067	45,472	1.0861
2027	2,274	50,020	1.1947
2028	2,480	54,567	1.3033
2029	2,687	59,114	1.4119
TOTAL	**18,809**	**413,798**	**9.8834**

The six GHGs, regulated by the Kyoto Protocol are: CO_2, CH_4, nitrous oxide (N_2O), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs). According to the national inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases in Ukraine for 1990–2014, the average share of CO_2, CH_4 and N_2O emissions in the overall structure amounted to 99.75%, in particular CO_2 – 68.9%, CH_4 – 20.3 % and N_2O – 10.5%. The other three factors of GHG emissions thus amount to about 0.25%.

The assessment of GHG emission reduction due to electricity and heat output (using biogas instead of fossil fuels) considers CO_2, CH_4 and N_2O.

There are given emission factors of respective GHG emissions for burning 1 TJ of energy resources (fuel) in stationary installations in various sectors expressed in tons of carbon dioxide equivalent (tCO2-eq/TJ). For example, to calculate the GHG emission reductions from biogas substitution of natural gas in cogeneration units we consider that, during the combustion of 1 TJ of natural gas, 55,350 kg of CO_2, 1 kg of CH_4 and 0,1 kg of N_2O will be released. The expression of different types of GHG emissions in CO_2 equivalent should take into account their global warming potential (GWP). The lifetime of CO_2 in the atmosphere is about 100 years, so GWP is 1.25 years for CH_4, and 298 years for N_2O.

Taking into account data from Table 4 and Table 5, with the use of 413,798 TJ (or 9.884 million tons of oil equivalent (Mtoe) of natural gas in cogeneration units, 11.463 Mt of GHG emission in CO_2eq (Table 6) would be released: that is to say, in the use of 1 TJ of natural gas in a cogeneration unit, 55.405 tCO_2eq would be released.

Similar calculations are displayed for the use of coal in cogeneration units (Table 7) according to which, during the use of 1 TJ of coal in cogeneration units, 92.152 tCO2eq will be released.

Table 5: Lifetime and global warming potential of greenhouse gases (IPCC, 2007)

Gas	Lifetime (years)	Global warming potential for period		
		20 years	100 years	500 years
Carbon dioxide	~ 100	1	1	1
Methane	12	72	25	7,6
Nitrous oxide	114	289	298	153

Table 6: Greenhouse-gas emissions from natural gas use in cogeneration units

Year	Natural gas				
	TJ	N_2O (kg)	CH_4 (kg)	CO_2, kg	CO_2eq (Mt)
2016	0	0	0	0	0
2017	2,274	227	2,274	125,844,612	0.126
2018	4,547	455	4,547	251,689,223	0.252
2019	6,821	682	6,821	377,533,835	0.378
2020	9,094	909	9,094	503,378,446	0.504
2021	11,368	1,137	11,368	629,223,058	0.630
2022	13,642	1,364	13,642	755,067,669	0.756
2023	15,915	1,592	15,915	880,912,281	0.882
2024	18,189	1,819	18,189	1,006,756,892	1.008
2025	20,463	2,046	20,463	1,132,601,504	1.134
2026	22,736	2,274	22,736	1,258,446,115	1.260
2027	25,010	2,501	25,010	1,384,290,727	1.386
2028	27,283	2,728	27,283	1,510,135,338	1.512
2029	29,557	2,956	29,557	1,635,979,950	1.638
TOTAL	**206,899**	**20,690**	**206,899**	**11,451,859,650**	**11.463**

Source: Industrial buildings and solar panels, by chombosan.

Table 7: Greenhouse-gas emissions from coal use in cogeneration units

Year	Coal				
	TJ	N_2O (kg)	CH_4 (kg)	CO_2 (kg)	CO_2eq (Mt)
2016	0	0	0	0	0.000
2017	2,274	2,274	3,410	208,445,058	0.210
2018	4,547	4,547	6,821	416,890,117	0.419
2019	6,821	6,821	10,231	625,335,175	0.629
2020	9,094	9,094	13,642	833,780,234	0.838
2021	11,368	11,368	17,052	1,042,225,292	1.048
2022	13,642	13,642	20,463	1,250,670,351	1.257
2023	15,915	15,915	23,873	1,459,115,409	1.467
2024	18,189	18,189	27,283	1,667,560,468	1.676
2025	20,463	20,463	30,694	1,876,005,526	1.886
2026	22,736	22,736	34,104	2,084,450,585	2.095
2027	25,010	25,010	37,515	2,292,895,643	2.305
2028	27,283	27,283	40,925	2,501,340,702	2.514
2029	29,557	29,557	44,336	2,709,785,760	2.724
TOTAL	**206,899**	**206,899**	**310,349**	**18,968,500,320**	**19.066**

VI. Economic, environmental and policy analysis of the policy measures introduced

After a 10% drop of GDP in 2015 in Ukraine, the International Monetary Fund forecast an annual economic growth of 2%. The anticipated growth assumes increased consumption of energy, thus Ukraine, as well other countries, faces a challenge of decoupling. Promotion of renewable energy is one of the ways to achieve this and to minimize the adverse effect of economic growth on the environment.

Source: Bio fuel plant, by loraks.

The Food and Agricultural Organization of the United Nations (FAO) states that economic growth in developing and less developed countries is no less important than the source of growth. Growth originating in agriculture and agriculture-related industry is at least twice as effective in benefiting the poor as growth in non-agricultural sectors (FAO, 2014). This is particularly the case of Ukraine, where people living in rural areas and small towns are poorer than those residing in cities (where there are more jobs and salaries are higher than those for similar jobs in rural areas).

Biogas can be used for cogeneration, or used as automobile fuel or biomethane can be sent to the grid. In this paper, we advocate biogas use for further electricity and heat production by agribusiness companies with further sale of heat to neighbouring households. The option of biogas use is the most favourable in the existing economic and legislative conditions in Ukraine. Our main policy proposal is to create more favourable conditions for existing and new agribusinesses to use biogas in the form of waste-management policies, according to which organic wastes cannot be sent to landfill. Organic wastes are gasified or treated in anaerobic digesters.

We consider potential energy output and potential CO_2 reductions based on the data publicly available on the project aimed at the reconstruction of the existing sugar-refinery in the Kiev region.

VII. Rokytne sugar refinery demonstration project

The Rokytne sugar refinery was built in 1972, and the latest renovation and biogas plant construction started in 2013. The biogas plant produces heat and electricity. The latter is used partially to satisfy the refinery's own needs and the remainder is sold to the grid against the FIT. The heat obtained is used for internal needs (to heat fermenter, 15%–30% of all the biogas energy produced, which is valid for climatic conditions in Ukraine) and is also sold to neighbouring boiler houses and the community (800 households) at prices 5% lower than those offered by the centralized heating supplier. Overall capacity of the plant is expected to be 20 MW. The capacity of the first unit, launched in late 2015, is 2.25 MW_h and 2.16 MW_{el}. Yearly feedstock output is 106.7 kt, yearly biogas output is 9.3 Mm^3. Annual net electricity output is expected to be 16,900 MWh, and it would be sold against the FIT. The first unit's annual electricity net output is 2.25 MWh, with an annual net heat output of 2.22 MWh. There are three types of feedstock – pressurized sugar-beet bagasse (57,600 t/year), cow manure (35,040 t/year) and chicken droppings (14,053 t/year). By-products include fermented solid and liquid organic remainder, which could be used as organic fertilizer. The investments required are about 210 million. The overall investments to build and launch the first energy producing unit were 10 million.

Biogas plants have numerous advantages, such as:

- Energy production from renewables;
- Combination of waste of seasonally operating companies (e.g. sugar refineries) with waste from farms allows energy output throughout the entire year;
- New jobs or annual income possibilities for people employed at sugar refineries (in Ukraine, sugar refineries are located mostly in small towns, where they are the major employer);
- Utilization of a very wide range of agricultural residues;
- Production of organic fertilizers that could be used for organic farming (another way to increase the competitiveness of Ukraine's agriculture);
- Possibilities for proper manure management (which is good for odour reduction, soil renovation and saving potential arable land that otherwise would be used for agricultural waste pits);
- Possibility to produce energy close to the places where agricultural residues originate (which does not require long-distance transportation of fuel);
- Possibility to cover peak load in the network and to fill in gaps of load created by intermittent renewables[12];
- Gradual transition toward the model of decentralized energy supply for the local community.

Factors related to increased GHG emissions are biogas-plant construction work and vehicles delivering feedstock operation. Decreased emissions derive from decreased use of fossil fuels, lower methane and nitrogen emissions from manure pits or other means of storage, substitution of chemical fertilizers with organic ones (the time when fertilizers are needed, however, is limited by natural reasons).

Increased use of biogas, obtained from sugar-producing and farming residue can contribute to fulfilling Ukraine's commitments in terms of share of 11% RES in energy balance by 2020. Agriculture-derived emissions in Ukraine are growing: in 2014 agriculture, forestry and fishing contributed 2.4% of overall GHG emissions, whereas, in 2015, agriculture contributed 2.7% of overall emissions by country (as much as the transport sector). Among all gases that are the largest pollutants, IPCC distinguishes CO_2, N_2O and CH_4. CO_2 is the least potent, while N_2O is 310 times more potent than CO_2 (to cause a certain level of harm) and CH_4 is 23 times more potent than CO_2. In Ukraine, agriculture, forestry and fishing are responsible for 0.5% of country overall CO_2 emissions, which is about 110 times less than CO_2 emissions derived from electricity, heat and vapour supply and air conditioning. The level of other emissions from agriculture, such as N_2O and CH_4, if measured, is not given in official statistics. As CH_4 is mostly emitted by cattle manure, transforming it into energy is a good way to reduce this kind of pollutant. Numerous studies (from Europe and the Islamic Republic of Iran) show that proper manure management, combined with energy production, brings very good results in terms of emission reduction and energy output, even by micro-biogas plants.

For further analysis, the following assumption were used:

- The modelling horizon used was 2016–2030 because FIT is available until 2030. Investments can be distributed evenly among these years. There are some limitations of regulatory policy, but also an attractive FIT, so a significant boom in investment is possible in the next few years;

- Biogas made of a mixture of feedstock types (various animal wastes and corn) is used, with a methane content of about 60%; heating value of the biogas is about 22 MJ/m^3;

- For biogas output, only silage corn is used (both stalks and cobs are used for ensilage and further methanization). Intermediate corn consumption would grow. The average yield of silage is 33,000 kg/ha. Growing corn on 421,000 ha (9% of vacant space) can produce 33,000 kg/ha (421 000 ha = 13.9 Mt of silage).

Based on the data of Table 3 on potential, we assume that biogas will be used on large farms, in sugar factories, ethanol plants and on dedicated corn plantations. In the case that half of the corn potential for biogas is used, we consider that in total we have 2,687 Mm^3 of biogas annually. The first Rokytne biogas-plant unit produces 9.3 Mm^3 of biogas annually. If the annual economically feasible potential of biogas is 2.687 billion m^3, this equals 59.114 million MJ of energy or 1.424 Mtoe (1 MJ = 0.0000241 toe).

- The heating value of natural gas is 35 MJ/m^3 and that of coal is 30 MJ/m^3.

- The overall efficiency of biogas plants (producing electricity and heat with available heat consumers) is 75%–80%. The model of biogas output and processing, where different types of feedstock (sugar beet and animal residues in the case of Ukraine) are processed to obtain biogas, which can be further used for heat and electricity output, is a common model for biogas plants all over the world. The average efficiency of electricity output (without heat) is 34.6%, whereas heat and electricity production efficiency at cogeneration plants is 76.4%.

- Average investments are €3,111/kWh, or €7 million/2.25 MW. In order to employ 2,687 million m^3 of biogas, about €3.8 billion are needed.

- Only a few agribusiness companies (poultry farms, sugar and ethanol refineries) could run large biogas plants with a yield of 100 m^3/h using only their own feedstock and residues. In order to achieve economy of scale and to use large biogas plants, smaller producers may want to use the shared digestion of residues of several companies.

Source: Biogas plant, by buhanovskiy.

VIII. Modelling and evaluation of socioeconomic effects of biogas projects: implementation in Ukraine

When modelling the socioeconomic effects of biogas projects implemented in Ukraine, we assume that, as result of implementing such projects, a partial substitution of the capacity of electricity and heat generation will be achieved.

In particular, considering that the estimated annual economically achievable biogas potential is 2,687 Mm^3 (or 59,114 million MJ of energy), we assume that it will be distributed in the ratio of 50/50 between electricity and heat generation, because heat and electricity output are approximately equal.

We also assume that the potential will be entirely implemented by 2029, and from 2016 it will be evenly increased as of 2016. Taking into account that 1 MJ = 0.0000241 toe, we assume that there will be a replacement of 59.114/ 2 * 0.0000241 = 0.000712 Mtoe of natural gas, provided that the full potential was achieved in 2029 (we assume that the amount of natural gas replacement increases from 0 billion m3 in 2016 to 0.000712 Mtoe in 2029 due to insignificant biogas use). We assume also that coal would be partially substituted for electricity production. In particular, in 2029, 59.114 / 2 * 0.0000241 = 0.000712 Mtoe of coal would be replaced. As in the case of natural gas, such potential of replacement will be achieved in 2029 with a uniform (linear) increase starting in 2016. Thus, during 2016–2029 in both cases (heat and electricity generation) 0.000712 * 14 = 0.00997 Mtoe of energy would be substituted.

We assume that natural gas and coal will be substituted with mainly animal wastes that are other industrial by-products and that therefore there will be no growth in intermediate consumption in the production process. Thus, in the context of technological processes at the aggregate industry level as a result of implementing biogas projects, consumption of natural gas and coal will be reduced. This is considered a technological improvement within Ukraine's adapted dynamic CGEM.

The substitution of natural gas and coal is assumed to take place using corn silage and therefore, in the context of technological processes at the aggregate industry level, as the result of biogas projects implementation, it will reduce consumption of natural gas and coal and increase agricultural production (corn silage). According to preliminary estimates for implementing respective potential of biogas projects in Ukraine, additional consumption of corn silage could reach 13.9 Mt. As in the case of natural gas and coal reduction, it was assumed that such a level of silage consumption would be fully achieved in 2029 and that, starting in 2016, would increase proportionally, starting at 0 Mt.

To implement the above-mentioned projects in the electricity and heat-production industries, 3.8 billion needs to be invested. Investments are assumed to be evenly distributed between heat and electricity output (1.9 billion for each), and the volume of investments will increase in proportion to the GDP growth rate in 2016–2029.

During assessment of the socioeconomic effects of biogas-project implementation, a number of assumptions about macroeconomic indicators were made. With the CGEM used in this study, the conventional approach to developing the baseline scenario is to make assumptions about changes in time values of exogenous parameters of the model, usually the number of employees (labour), depreciation and coefficient of performance (labour, capital, intermediate consumption, etc.)[13]. Thus, indicators such as production volumes, GDP, investment and consumption volumes are the endogenous variables and are calculated/determined by the model. During model calibration, the average annual growth rate of the labour force was assumed to be equal to the average annual change in population, which is a standard approach within CGEM methodology. For building a demographic forecast, data from the Institute of Demography and Social Studies were used, in particular the baseline forecast assumptions of average fertility rates, life expectancy and net migration[14].

The depreciation rate was assumed to remain unchanged throughout the simulation interval.

Its value was assigned as equal to 3%, which corresponds to the average depreciation rate for the period 2000–2012[15] and to an assumption of this index value within the study[16].

In the short and medium term, growth will be in light industry, food and pharmaceutical industries. One can expect recovery of positive dynamics in the production of building materials. In machine building, positive dynamics will be demonstrated by computer, electronic and optical products production. With favourable weather conditions, the agricultural sector might expect recovery of positive dynamics. Recovery of the overall positive dynamics in the Ukraine economy started in 2017.

In 2020–2025, Ukraine's economy will grow quite rapidly. Extractive industry will concede the growth rate to the processing industry and metallurgical industry and will gradually reduce its share in GDP. This trend is likely to continue until 2030. Overall, the average rate of real GDP growth during the period analysed will be about 4%, which is quite realistic compared to retrospective data from other countries.

IX. Socioeconomic consequences

This section presents estimates of socioeconomic effects of biogas-project implementation in Ukraine. Results are obtained using a dynamic CGEM of Ukraine with an extended power block. All the estimates presented in this section are displayed in comparison to estimates of the baseline scenario (described above). That is, any changes in macroeconomic, sectoral or other indicators should be interpreted as a deviation relative to the baseline scenario of the corresponding year. The baseline scenario incorporates macroeconomic scenario GDP growth rates, but does not include implementation of the actions of biogas-project development. The social and economic effects described measure the impact of biogas-project development in Ukraine on macroeconomic, sectoral, social and other indicators on other equal conditions (current fiscal and monetary policies are kept, there are no alternative sector reforms, etc.). In this context, negative values of resulting indicators do not mean a decrease in their absolute values within the target energy scenario, and, in most cases, reflect the slowdown in the growth rates of respective indicators.

X. Macroeconomic consequences

Implementation of biogas-project development in Ukraine generally leads to positive macroeconomic effects, fully apparent in the medium and long term, starting in 2018–2019. The determining factor of such effects is, in particular, the investment process: during the first years of significant growth in gross fixed capital formation in the background, there is a gradual increase of energy efficiency and reduction of production costs, especially for energy-intensive industries. The complete effect of investments is realized in the medium term; there is a predominance of positive effects of energy consumption reduction and substitution of some resources by others over expenditure for the effects achieved.

Considering specifics of the investment processes and the nature of their impact on the reduction of specific volumes of energy resources consumption on the macroeconomic level, the cumulative nature of effects is observed – deviations from the baseline scenario in the positive direction increase with time. Thus, in 2025–2029, additional GDP growth and production may reach 0.3%.

The nature of the macroeconomic effects also depends on assumptions about the distribution of sectoral rates of energy-efficient technology implementation over time. In the study, we have assumed that a reduction in the consumption of energy resources will occur at a constant rate throughout the period analysed. Such a reduction is in accordance with the parameters of the target energy scenario of re-allocated investments over time.

During the modelling, companies' own funds were assumed to be the key source of investments. Thus, the observed nature of economic effects is also caused by the intensive growth of production costs in the first years of investment compared to subsequent periods when rising costs of implementing biogas projects are offset by savings in energy consumption and replacement of energy resources.

XI. Consequences for households

Although domestic consumers are not directly involved in investment processes, the overall economic effects associated with a general increase in the efficiency of electricity and heat-energy production, the substitution of some resources by others and the intensification of investment processes, indirectly influence the level of real household income (Table 8).

As in the case of macroeconomic indicators, moderate negative consequences of implemented measures are observed in the short term for household consumers. Given the scale of the projects analysed at the aggregate level, however, these effects are not significant and represent less than 0.1% of the total income of residential customers. Overall, in the medium and long term, all household groups will experience a moderate positive impact on the real income level (Table 8).

Source: Kläranlage - Faulturm, by Jürgen Fälchle.

Table 8: The impact of biogas-project implementation on household income, real income deviation from baseline scenario (%)

Indicator/scenario	Target energy industry development scenario						
	2016	2017	2018	2019	2020	2025	2029
Aggregate income	0.0	–0.1	-0.1	0.0	0.0	0.3	0.2
I decile group[17]	0.0	–0.1	-0.1	0.0	0.0	0.3	0.3
II	0.0	–0.1	-0.1	0.0	0.0	0.3	0.3
III	0.0	–0.1	-0.1	0.0	0.0	0.3	0.3
IV	0.0	–0.1	-0.1	0.0	0.0	0.3	0.3
V	0.0	–0.1	-0.1	0.0	0.0	0.3	0.3
VI	0.0	–0.1	-0.1	0.0	0.0	0.3	0.3
VII	0.0	–0.1	-0.1	0.0	0.0	0.3	0.3
VIII	0.0	–0.1	-0.1	0.0	0.0	0.3	0.3
IX	0.0	–0.1	0.0	0.0	0.0	0.3	0.3
X (the highest group)	0.0	–0.1	-0.1	0.0	0.0	0.1	0.1

XII. Sectoral effects

In terms of economic activity types, implementation of biogas-project measures in Ukraine will lead to moderate structural changes (Table 9). As in the case of aggregated indicators, additional growth rate in terms of economic activity is accelerated relative to the baseline scenario over time. In 2017, the number of industries that were characterized by a moderate slowdown in output growth rate was 11; in 2029 there were only three such industries.

Table 9: Sectoral effects of biogas-project development in Ukraine: deviation of output from baseline scenario (%)

Industry	Target energy industry development scenario					
	2017	2018	2019	2020	2025	2029
Agriculture, hunting and related service activities; Forestry, logging and related service activities; Fishing, fish farming and related service activities	0.0	0.0	0.0	0.0	0.2	0.3
Mining of coal, lignite and peat Mining of uranium and thorium ores	–0.6	–0.9	–1.2	–1.5	–3.2	-4.7
Extraction of crude petroleum and natural gas and related service activities	–0.1	–0.1	–0.1	–0.1	0.0	–0.1
Other mining and quarrying (except for fossil fuels)	0.0	0.1	0.1	0.1	0.4	0.4
Manufacture of food products, beverages and tobacco products	–0.1	–0.1	0.0	0.0	0.2	0.1
Manufacture of textiles, clothing, leather and related products	0.0	0.0	0.0	–0.1	0.0	0.0
Manufacture of wood, paper, printing and reproduction	0.0	0.0	0.0	0.0	0.2	0.1
Manufacture of coke	0.1	0.1	0.2	0.2	0.4	0.4
Manufacture of refined petroleum products	0.0	0.0	0.0	0.0	0.1	0.1
Manufacture of chemicals and chemical products	0.0	0.1	0.1	0.1	0.4	0.5
Manufacture of basic pharmaceutical products and pharmaceutical preparations	–0.1	–0.1	–0.1	–0.1	0.0	0.0
Manufacture of rubber and plastic products Manufacture of other non-metallic mineral products	0.2	0.2	0.2	0.2	0.4	0.4
Manufacture of basic metals Manufacture of metal products, except machinery and equipment	0.1	0.2	0.3	0.4	0.8	1.0
Manufacture of computer, electronic and optical products	0.3	0.3	0.2	0.2	0.1	0.0
Manufacture of electrical equipment	0.2	0.2	0.2	0.3	0.3	0.4

Manufacture of machinery and equipment	0.5	0.5	0.5	0.5	0.5	0.6
Manufacture of motor vehicles, trailers and semi-trailers Manufacture of other transport equipment	0.3	0.3	0.3	0.3	0.2	0.3
Manufacture of furniture, jewelry, musical instruments and toys Repair and installation of machinery and equipment	0.0	0.0	0.0	0.0	0.1	0.1
Production and distribution of electricity	–0.3	0.1	0.4	0.7	1.8	2.2
Production and distribution of gas	0.0	0.2	0.3	0.5	1.5	1.9
Steam and hot water supply	–1.3	–1.0	–0.8	–0.7	–0.1	–0.4
Water supply, sewerage, waste management and remediation activities	–0.1	–0.1	0.0	0.1	0.4	0.5
Construction	0.9	0.9	0.9	0.9	0.9	0.9
Wholesale and retail trade, repair of motor vehicles and motorcycles	0.0	0.0	0.0	0.0	0.2	0.2
Transport, warehousing Postal and courier activities	0.0	0.0	0.0	0.1	0.2	0.2
Accommodation and food service activities	0.0	0.0	0.0	0.0	0.1	0.1
Publishing, motion picture, video, television programme production, sound recording, programming and broadcasting activities	0.0	0.0	0.0	0.0	0.1	0.1
Telecommunications	0.0	0.0	0.0	0.0	0.2	0.2
Computer programming, consultancy and information service activities	0.1	0.0	0.0	0.0	0.0	0.0
Financial and insurance activities	0.0	0.0	0.0	0.0	0.1	0.1
Real estate activities	0.0	0.0	0.0	0.0	0.3	0.3
Legal and accounting activities, activities of head offices, management consultancy activities, architectural and engineering activities, technical testing and research	0.1	0.1	0.1	0.1	0.1	0.1
Scientific research and development	0.2	0.2	0.2	0.2	0.2	0.2
Advertising and market research, other professional, scientific and technical activities, veterinary activities	0.0	0.0	0.0	0.0	0.1	0.1
Administrative and support service activities	0.0	0.0	0.1	0.1	0.2	0.2
Public administration and defence, compulsory social security	–0.1	–0.1	–0.1	–0.1	0.1	0.1
Education	–0.2	–0.2	–0.1	–0.1	0.1	0.0
Human health activities, residential care activities and social work activities without accommodation	–0.2	–0.1	–0.1	–0.1	0.1	0.1
Arts, entertainment and recreation	–0.1	–0.1	–0.1	0.0	0.1	0.1
Other service activities	0.0	0.0	0.0	0.0	0.1	0.1

Moderate growth in demand for investment products is accompanied by an increase in volumes of investments in certain industries, including engineering and construction. The biggest slowdown in growth is observed in the case of coal, the demand for which is declining due to its substitution by solid and gaseous biofuels. In general, the main impact of biogas-project implementation is on the real sector of the Ukraine economy, while structural changes in the services sector almost do not happen. Although the nature of perceived industrial effects is relatively small at the general macroeconomic level, the vast majority of such positive effects are characterized by qualitative changes.

As mentioned earlier, Ukraine has a good potential for biogas technologies and extended capacity to estimate the existing feedstock flows, to make the feedstock grow by means of increasing livestock breeding and plant processing in the case of growing demand for agricultural commodities in domestic and international markets.

At a first glance, based on the resource base of sugar-beet bagasse, there might be competition between feedstock and bioethanol producers. However, bioethanol production in Ukraine on the industrial scale has not yet started. Ukraine is obliged to obey its international obligations, including European directives that define the types of feedstock for biofuel production and their GHG emission savings. In due course, commercialization of second-generation biofuels will bring new types of feedstock, so that sugar beet and its residue would become acceptable biogas feedstock.

Since April 2016, the price of natural gas for centralized heat producers (teplocomunenergo) has been 75% of its commercial price (UAH 5,500/1,000 m3). Heat produced from natural gas costs more than UAH 1,200/GCal (twice more than before). If biogas or biomass-derived heat is even 10% cheaper for households, these biogas projects become commercially competitive and payback time shorter. Households pay less for heat; Ukraine purchases less natural gas from abroad, paying local enterprises instead, which makes for a win-win situation for households (cheaper energy), enterprises (jobs, less payback time) and country (taxes, less natural gas to import, waste management, reduction of methane).

Obstacles to the proposed biogas reform implementation:

- Although FIT is set until 2030, its future is uncertain. By the above-mentioned Law of Ukraine “On Electricity Market”, purchase of electricity produced from RES is expected through the mechanism of public service obligations, although the amounts and sources of funding are not clearly defined. A scheme whereby a special duty is imposed on the transmission system operator to compensate the guaranteed buyer (payment covers the difference between the FIT and the cost of electricity prevailing in the market a day ahead, and also the cost of settling imbalances), the size of which is determined by the regulator, creates additional risks for the market organizational structure, which, in turn, reduces the investment attractiveness of the sector.

- Land allocation and acquisition for renewable energy facilities need further simplification. To that end, draft law No. 2529a provides placing such facilities on all categories of land without changing their purpose. All potential biogas projects are now required to be included in the detailed plan of territory development but these plans do not always exist and are not always available.

- Lists of items of equipment specified in Article 17-3 of the Law of Ukraine “On Electric Power Industry” do not match the names of the Ukrainian classification of goods for foreign economic activity, which can significantly complicate the process of obtaining certificates of origin, required for receiving surcharges.

- The monopoly of joint stock company (JSC) Naftogaz of Ukraine as natural gas supplier and local heat suppliers (teplokomunenergo), which do not have financial incentives to employ renewables and use less natural gas and households cannot choose their heat supplier. One of the significant drivers to decrease natural gas consumption for heating purposes is its high price. As utility bills are growing, payment discipline is worsening. The Government of Ukraine has launched a UAH 24 billion subsidy programme, aimed at 5.2 million households. By the end of 2015, only UAH 2 billion had been spent; the remainder was used to subsidize JSC Naftogaz of Ukraine and teplokomunenergo.

- Other restrictive factors for wider use of biogas are the insufficient infrastructure to supply feedstock for bioenergy projects; a negligent attitude to biomass residues; the low capacity of domestically produced biogas plants; and imported equipment is expensive due to inflation and currency depreciation.

XIII. Policy design considerations

Given that energy demand in Ukraine is significant and expected to grow and that prices for natural gas and electricity are becoming ever higher, increased use of biogas is a good opportunity to diversify the sources of energy supply. Soaring prices for natural gas, coupled with high energy demand in the agrifood sector, make biogas projects viable.

Before considering the implications of outcomes of regulatory policy measures, one should bear in mind a range of obstacles that hinder biogas projects development in particular and the wider use of renewables in general.

General barriers include:

- High upfront investment costs. This challenge might be partially overcome with the help of international financial organizations having programmes aimed at increasing energy efficiency and RES, such as the International Financial Corporation (which provide loans to small and medium business through Ukrainian banks with lower interest rates than those available on the market), or the European Bank for Reconstruction and Development (EBRD), which provides loans to agribusiness in Ukraine. In 2016, EBRD, together with EU, launched the programme EU4Business, aimed at small and medium-size businesses in Ukraine to make their products and services competitive in the EU market;

- High cost of capital. High interest on bank loans (10% in US$), lack of working capital and investments and Ukrainian currency depreciation (43.3% in 2015) make imported equipment even more expensive; non-transparent conditions and business practices, such as informal payments in order to facilitate local authorities' decisions;

- Poor information dissemination and lack of nation-wide information campaigns regarding use of renewables in the agrifood sector. Emerging agricultural holdings are looking for ways of being more competitive, energy-wise, whereas many existing agrifood companies are the legacy of Soviet times with lack of experience, information about possibilities of RES use and diversification of energy sources. In all, there is a vicious circle of obsolete energy-intensive equipment, high energy expenditure, uncompetitive products, lack of working capital and investments and financial unattractiveness.

As mentioned earlier, biogas projects can be afforded nowadays mostly by large agricultural holdings. Involving small farmers to cooperate in order to use biogas in microscale projects is a challenge even in EU countries with better financing opportunities[18]. In order to make biogas projects affordable for smaller and medium-size businesses in Ukraine, further mechanisms need to be elaborated and implemented, such as governmental internal and external guarantees of loans; interest rates on loans should be lowered via the cooperation of Ukrainian banks with international financial institutions, such as the Global Environment Facility, EBRD and the Clean Technology Fund. The latter launched the Ukraine Sustainable Energy Lending Facility (USELF), which aims to produce more than 200 GWh of energy from RES using the mechanisms of commercial financing, concessional grant co-financing and technical assistance. USELF is currently developing seven projects, but there could be more during the next phases of its operation.

The overall sum of financial assistance of the aforementioned organizations is €107 million for the first phase and €70 million for the second phase. Technical support for the projects will be provided by the Swedish International Development Cooperation Agency. Another important element is the inclusion not only of international financial institutions to provide loans for biogas projects but also of large domestic banks and to create viable and bankable projects for renewables in general.

Grid-connection requirements and procedures need to be clarified. For biogas projects, we suggest prioritizing grid connection. Also, smaller biogas plants (with capacity up to 500 kW) should not require authorization documents.

As mentioned earlier, biogas production implies greater land-use efficiency and better waste management. Current land-use and land-ownership issues and existing legislation on the subject require further improvements. Large agribusinesses have extended possibilities to ensure long-term use of land, whereas this can be an issue for small businesses. After the collapse of the Soviet Union and consequent land reform, agricultural lands were distributed between people formerly employed in kolkhozes (collective farms) or their relatives. Afterwards, the land plots were let by owners, allowing formation of agricultural holdings (IRENA, 2015).

Increased use of biogas and electricity output requires transport infrastructure changes, such as new roads for delivering the feedstock (cattle manure or vegetable residues, etc.). Long-term contracts between feedstock suppliers and processors are needed in the case of small and medium-size projects, when different types of feedstock are provided by different producers.

One of the medium-term implications of widespread agriculture-derived biogas projects can be a potentially growing interest in the landfill gas-utilization projects. This is a pivotal issue in Ukraine, where solid household wastes are almost unprocessed, causing ecological disasters and even human deaths.

Expanded use of biogas projects with locally consumed heat and sale of electricity to the grid would require significant modernization of the existing energy grids and infrastructure. In accordance with the draft Plan of development of Energy System of Ukraine for 2017–2026, the anticipated installed capacities of renewables would grow from 1,168 MW in 2015 to 4,420 MW by 2027. According to the above-mentioned draft, WPP capacities would reach 1,790 MW, SPP 1,790 MW and bioenergy-based plants 840 MW. Connection of new RES power plants above the mentioned threshold would require their participation in regulating the daily load curve. The existing grid requires modernization aiming at increased flexibility in order to maintain different shares of electricity from RES. Unlike variable and intermittent RES, such as wind and solar, output of biogas electricity is more predictable, providing possibilities of energy-system balancing.

Arable lands are available in the majority of regions; livestock breeding is available in the central part (Kiev, Cherkasy, Vinnytsya), the eastern part (Donetsk, Dnipro) and the western part (Lviv, Khmelnytsky), thus biogas projects could be located all over Ukraine. This may result in new jobs and a decrease in official and unofficial labour migration from Ukraine. Additionally, eastern Ukraine requires jobs in order to restore the region after military actions.

Another important implication of new regulatory policy is the potential production of large-capacity biogas digesters in Ukraine, with new jobs in manufacturing, engineering and education.

Legal provisions regarding animal residues/dung sterilization under pressure should be abolished in the case of biogas output. The existing fines for improper agricultural waste management should be raised.

Our further policy proposal, that can be adopted only in the long run, is the mandatory use of biogas. This can be done by introducing new national construction standards when agribusiness companies dealing with waste (farms, breweries, etc.) require mandatory measures to decrease CH_4 and CO_2 emissions, such as by the construction of biogas plants and units. This national standard could be developed by the Ministry of Agrarian Policy and Food in cooperation with the Ministry of Regional Development, Construction and Utilities. We understand that at present this policy proposal is premature, as is the biogas market in Ukraine per se.

XIV. Conclusions and recommendations for future policy development nationally and implications for adoption of a similar approach in neighbouring countries

In accordance with REN21 Renewables 2016 Global Status Report, nearly all Ukraine's neighbours have chosen their own paths in terms of renewable energy potential deployment and have already developed an extensive set of policies and legislative measures. For instance, the Republic of Moldova has national RE targets and FIT, but not renewable heat obligation output, reduction in sales or VAT taxes. Belarus has gone further than Ukraine, with national renewable targets, FIT, electric utility quotas, tax exemptions and reductions but no renewable heat obligation yet. Belarus has especially good prospects for biogas output due to extensive dairy production and available arable lands. Romania does not have FIT, but has renewable electricity obligations and tradable certificates, but no tax exemptions or rebates. EU member countries such as Hungary and Poland have their own obligations and achievements in terms of renewables. Poland has FIT, renewable electricity and heat obligations and fiscal mechanisms. Hungary has FIT and good financial mechanisms to start new renewable projects. The Russian Federation has FIT, renewable electricity and heat obligations, capital grants, subsidies or rebates, but not tax exemptions.

In our opinion, strict environmental policy, coupled with renewable electricity and heat obligations offer good prospects to biogas projects in many countries, including, potentially, Ukraine. Ukraine needs to address several issues, such as taking measures to guarantee lower upfront investment costs and lower capital costs, to promote the dissemination of information about biogas advantages, to guarantee stable and predictable legislation for FIT, prioritized grid connection for biogas projects, modernization of grids and infrastructure, and, in the long run, mandatory use of biogas by agribusinesses.

Bibliography

Markevych, K., 2015: Results of the energy sector of Ukraine. Razumkov Centre.

Savitsky, O., 2016 Towards the Energy Transition in Ukraine. Finding pathways to energy independence and carbon-neutral power sector. Marion Doenhoff Working Paper.

Geletukha G.G., P.P. Kucheruk and Y.B. Matveyeyev, 2013: Prospects of the production and use of biogas in Ukraine. Position Paper No. 4, Bioenergy Association of Ukraine.

Geletukha., G.G., P.P. Kucheruk and Y. B. Matvyeyev, 2014: Prospects of production and use of biomethane in Ukraine. Position Paper No. 11, Bioenergy Association of Ukraine

IRENA, 2015: REmap 2030 Prospects for the development of renewable energy in Ukraine, IRENA, Abu Dhabi.

IFC, 2015: Market conditions for the implementation of biomass energy production projects in Ukraine.

FAO, 2014: Bioenergy and Food Security Rapid Appraisal (BEFS RA). User Manual Introduction. FAO, Rome.

Geletukha, G.G., 2011: Possibilities of natural gas substitution in Ukraine by solid biomass and biogas. Open meeting of Q-club: Alternatives of problematic Russian gas: are they real in Ukraine? Ukrainian House, Kiev, 15 December 2011.

REN21 Renewables 2016: Global Status Report: http://www.ren21.net/status-of-renewables/global-status-report/

Findeisen, C., 2015: Biogas - trends on the german and the international market. German Biogas Association: http://www.eclareon.com/sites/default/files/clemens_findeisen_-_biogas_-_trends_on_the_german_and_international_market.pdf.http://www.eclareon.com/sites/default/files/clemens_findeisen_-_biogas_-_trends_on_the_german_and_international_market.pdf

Draft Project of Development of Energy System of Ukraine in 2017–2026: https://ua.energy/wp-content/uploads/2016/12/Proekt-Planu-rozvytku-OES-Ukrayiny-na-2017-2026-roky.pdf

Podolets R.Z. and O.A. Dyachuk, 2011: Strategic planning in the fuel and energy complex based on TIMES-Ukraine model: scientific presentation. Institute of Economics and Forecasting, NAS, Kiev, Ukraine, 150 pp.

National Greenhouse gas emissions inventory: http://unfccc.int/files/national_reports/annex_i_ghg_inventories/national_inventories_submissions/application/zip/ukr-2016-nir-18jul16.zip

IPCC, 2006: Guidelines for National Greenhouse Gas Inventories, S. Igglesston, L. Buendia, K. Miwa, T. Ngara, K. Tanabe (eds.), Japan. ISBN 92-9169-420-7 https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/0_Overview/V0_0_Cover.pdf

Annabi, N.A., J. Cockburn and B. Decaluwe, 2004: Sequential Dynamic CGE Model for Poverty Analysis. Advanced MPIA Training Workshop in Dakar, Senegal, 10-14, June 2004: http://www.researchgate.net/publication/259486097_A_Sequential_Dynamic_CGE_Model_for_Poverty_Analysis

Kinnunen, J., 2007: Dynamic version of the RegFin regional model – Practical documentation. Ruralia Institute, Finland, 17 pp: http://www.helsinki.fi/ruralia/research/pdf/regfindyn.pdf

Demographic forecast for Ukraine for 2014-2061 years. Institute of Demography and Social Studies, NAS, Ukraine: http://www.idss.org.ua/monografii/popforecast2014.rar

State Statistics Service of Ukraine, 2012: Fixed assets of Ukraine for 2000–2010 years (Statistical digest), Kiev, 293 pp.

State Statistics Service of Ukraine, 2013: The balance of fixed assets of Ukraine for 2011 (Statistical digest), Kiev, 25 pp.

State Statistics Service of Ukraine, Kiev , 2013: The balance of fixed assets of Ukraine for 2012 (Statistical digest), 25 pp.

Hosseini, H.M. and S. Kaneko, 2012: A general equilibrium analysis of the inflationary impact of energy subsidies reform in Iran. IDEC DP Series, 2, No. 8, 35 pp: http://ir.lib.hiroshima-u.ac.jp/metadb/up/ZZT00001/IDEC-DP2_02-8.pdf

BioEnergy Farm: http://www.bioenergyfarm.eu/en/

References

[1] Savitsky, O., 2016: Towards the Energy Transition in Ukraine. Finding pathways to energy independence and carbon-neutral power sector. Marion Doenhoff Working Paper.

[2] Until 1 December 2016, the minimum wage was 1,450 UAH per month; starting 1 December 2016, the minimum wage is 1,550 UAH per month.

[3] Harvesting losses were taken into account.

[4] Geletukha, G.G., P.P. Kucheruk and Y.B. Matvyeyev, 2014: Prospects of production and use of biomethane in Ukraine. Position Paper No. 11, Bioenergy Association of Ukraine

[5] IRENA, 2015: REmap 2030 – Prospects for the development of renewable energy in Ukraine, IRENA, Abu Dhabi, p.10.

[6] Elasticity of substitution indicates changes in consumption quantities resulting from the corresponding relative price changes.

[7] No producer earns an "excess" profit, i.e. unit cost of production must not be lower than unit revenue. At the same time, production costs include capital earnings, so this condition does not ignore positive gross profit.

[8] Market demand should not exceed market supply (for every commodity).

[9] Podolets, R.Z. and O.A. Dyachuk, 2011: Strategic planning in the fuel and energy complex based on TIMES-Ukraine model: scientific presentation. Institute of Economics and Forecasting, NAS, Ukraine, 150 pp.

[10] United Nations Framework Convention on Climate Change (2016) Ukraine's greenhouse gas inventory 1990-2014. http://unfccc.int/files/national_reports/annex_i_ghg_inventories/national_inventories_submissions/application/zip/ukr-2016-nir-18jul16.zip

[11] IPCC, 2006: Guidelines for National Greenhouse Gas Inventories, S. Igglesston, L. Buendia, K. Miwa, T. Ngara, K. Tanabe (eds.), Japan. ISBN 92-9169-420-7 https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/0_Overview/V0_0_Cover.pdf

[12] Findeisen, C., 2015: Biogas - trends on the German and the international market. German Biogas Association. http://www.eclareon.com/sites/default/files/clemens_findeisen_-_biogas_-_trends_on_the_german_and_international_market.pdfhttp://www.eclareon.com/sites/default/files/clemens_findeisen_-_biogas_-_trends_on_the_german_and_international_market.pdf

[13] Annabi, N., J. Cockburn and B. Decaluwe, 2004: A Sequential Dynamic CGE Model for Poverty Analysis. Advanced MPIA Training Workshop, Dakar, Senegal, 10-14 June 2004. http://www.researchgate.net/publication/259486097_A_Sequential_Dynamic_CGE_Model_for_Poverty_Analysis

[14] Kinnunen, J., 2007: Dynamic version of the RegFin regional model – Practical documentation. Ruralia Institute, Finland. 17 pp. http://www.helsinki.fi/ruralia/research/pdf/regfindyn.pdf

[15] Demographic forecast for Ukraine for 2014–2061 years. Institute of Demography and Social Studies, NAS, Ukraine. http://www.idss.org.ua/monografii/popforecast2014.rar

[16] The balance of fixed assets of Ukraine for 2012 (Statistical digest), State Statistics Service of Ukraine, Kiev, 2013. 25 pp.

[17] The balance of fixed assets of Ukraine for 2011 (Statistical digest). State Statistics Service of Ukraine. Kiev, 2013. 25 pp.

[18] Fixed assets Ukraine for 2000-2010 years (Statistical digest). State Statistics Service of Ukraine, Kiev, 2012. 293 pp.

[19] Hosseini, H.M. and S. Kaneko, 2012: A general equilibrium analysis of the inflationary impact of energy subsidies reform in Iran. IDEC DP Series, 2, No. 8, 35 pp. http://ir.lib.hiroshima-u.ac.jp/metadb/up/ZZT00001/IDEC-DP2_02-8.pdf

[20] Households are divided into decile groups in terms of average per capita income.

[21] BioEnergy Farm: http://www.bioenergyfarm.eu/en/

17-00751