MINISTRY OF FOREIGN AFFAIRS
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# Assistance to the Development of the Mykolaiv Masterplan

## Current Situation and Future Trends in District Heating and Power Sectors, Report

## Final

November 2023

COWI

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# List of Abbreviations

| | |
|---|---|
| BAT | Best Available Technology |
| BH | Boiler House |
| CAPEX | Capital Expenditure |
| CBA | Cost benefit analysis |
| CHP | Combined Heat and Power |
| CRM | Customer Relationship Management |
| DH | District Heating |
| DIC | Discounted Investment Cost |
| DSO | Distribution System Operator |
| EIB | European Investment Bank |
| ESAP | Environmental and Social Action Plan |
| EUR | Euro |
| E5P | Eastern Europe Energy Efficiency and Environment Partnership Fund |
| FB | Final Beneficiary |
| FNPV | Financial Net Present Values |
| FPI | Financial Performance Indicators |
| FRoR | Financial Rate of Return on the Investment |
| FS | Feasibility Study |
| HH | Household |
| HTW | Hot Tap Water |
| IHS | Individual Heating Substations |
| IRR | Internal Rate of Return |
| LFO | Light Fuel Oil |
| LTIP | Strategic Long-term Investment Plan |
| MCTIDU | Ministry for Communities, Territories, and Infrastructure Development of Ukraine |
| MD | Micro-district (residential area) |
| MoF | Ministry of Finance |
| MCHPP | Mykolaiv Combined Heat and Power Plant, Private Joint Stock Company |
| MOE | Mykolayivoblenergo, Joint Stock Company |
| MOTE | Mykolayivoblteploenergo, Municipally Owned Heat Supply Company |
| NG | Natural Gas |
| NPV | Net Present Value |
| OPEX | Operation expenditure |

# 1 Introduction

This report has been developed within the framework of the project “Mykolaiv - Denmark partnership – Technical support unit” financed by the Danish Ministry of Foreign Affairs (MFA). The project, which has been entrusted COWI, is a framework contract, which, among others, includes assistance to the Mykolaiv City Administration (MCA) in developing the Mykolaiv Masterplan in close cooperation with an Italian company, One Works.

*Box 1-1 COWI's contribution to Mykolaiv Masterplan in a nutshell*

Mykolaiv Masterplan, which has been requested by the Mayor of Mykolaiv City, has a time horizon till 2050. It provides a compass for actions to be taken by the Mykolaiv City to ensure that it will develop into a thriving city attractive to its citizens and business community.

COWI and One Works assist Mykolaiv City Administration in developing the masterplan. In this work, COWI focuses on three sectors:

- Water and wastewater
- Energy, including power, district heating and renewable energy sources
- Solid waste management.

Mykolaiv City Administration meets every week with COWI and One Works to ensure proper coordination.

COWI has established a project organization consisting of a project management team and three sector teams of professionals, each headed by a Discipline Leader. Three sectoral Focal Points are responsible for monitoring cross-cutting activities, ensuring coordination between the parties and maintaining consistency in the deliverables.

To enhance transparency in the development of the Mykolaiv Masterplan, given its significant public interest and exposure, COWI has established three sector-specific Sounding Boards inviting all potentially interested parties to take part in these.

The principal audience for this report comprises the Mykolaiv City Administration (MCA) and One Works, given their central roles in the realization of this vision.

The report contains a description of the current situation and future trends in the district heating (DH) sector in Mykolaiv. The baseline situation end of 2021 and 2023 has been established through questionnaires and interviews with both utilities in Mykolaiv responsible for generating and distributing heat to end consumers and collecting payments for this service.

Please be advised that the preparation of an analysis of the current situation in the DH and power sectors of Mykolaiv is significantly constrained due to limited access to information regarding the current state, operational statistics, and the consequences of military actions. This limitation is in accordance with the resolution of the National Energy and Utilities Regulatory Commission (NEURC) No. 349 dated March 26, 2022, regarding the protection of information that, under the conditions of a state of war, may be classified as restricted access information, including information related to critical infrastructure objects. This limitation results in incomplete operational data, making it challenging to gather comprehensive information about system performance and generate accurate statistics.

# 2 Background and Context

District Heating is defined as a system for distributing heat generated in a centralized location through a system of insulated pipes for residential and commercial heating requirements such as space heating and hot tap water.

The International Agenda

Globally, cities are facing challenges such as inefficient utilization of resources, air pollution and waste accumulation. In addition, burning of fossil fuels contribute to greenhouse gas emissions. At the same time, the urban population has increasing demands for improved comfort and living conditions, including requirements for good and stable heat supply.

In order to solve these challenges, increasing attention is directed to the potential of district heating (DH) as an important 'hidden backbone' for urban environment, economic development, energy security and comfort. This applies particularly to countries with cold winters - like Ukraine. Therefore, DH is on the international agenda because:

- DH can improve energy security. It enables the use of local energy sources or surplus sources that would be wasted otherwise;
- DH can contribute significantly to decrease greenhouse gas emissions through use of alternative energy sources;

However, to maximize the benefits of DH, attraction of significant investments and a secure customer base are required.

**The Ukranian Challenge**

As for most FSU countries, energy efficiency was not high on the agenda in Ukraine before the break up of the FSU. Besides, Ukraine had a huge heavy industry with a very high energy consumption. As a result, in 1990, Ukraine's total energy consumption per capita had reached 4,9 toe (Tonnes of Oil Equivalents), among the highest in the world.

When the FSU collapsed, Ukraine was suddenly faced with a serious challenge due to its high dependence on imported oil and gas from Russia. Furthermore, the heavy industry, which had produced mainly for export to other members of the FSU, started a steep decline after 1990. As a result, according to Our World in Data, Ukraine's total energy consumption per capita has decreased from 4.9 toe in 1990 to 2.1 toe in 2021. In 2022, due to the war, it dropped an additional 14% to 1.8 toe, which is 40% lower than the average for the EU2.

For many years, Ukraine has been faced with structural challenges to its energy system, both with regards to production and distribution of heat and power. Ukraine's energy intensity per GDP at purchasing power parity (PPP), before the war, was the second highest among EU4Energy countries.

The presently overarching challenge for the Ukrainian government is to become independent from imports of gas, coal, and nuclear fuel from Russia, by embarking on a rapid transition to renewable energy, combined with realizing significant energy efficiency gains.

## Challenge in the DH sector

District heating system capacities across the country are excessive, and 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.

The DH sector in Ukraine is in critical condition at all stages from production, distribution to consumption of heat for space heating and hot tap water. It calls for either decentralization into smaller systems as small gas boilers, or the opposite: to strengthen the centralization and scale up the use of alternatives to natural gas as heat source.

The benefits of decentralization into small gas boilers are obvious as regards stable and reliable heat supply services, reasonable prices, and fair billing. Despite challenges for the local environment and emission of greenhouse gasses, it can in some cases be an attractive solution, when the existing district heating system is in a severe critical condition.

However, recognition of the benefits of DH is growing due to knowledge about international cases of modern systems – especially throughout the front-running countries in Northern Europe that have been able to achieve high share modern and efficient DH systems with high supply security.

Well performing DH systems with high heat supply reliability, increased comfort and affordable heat prices are also achievable in Ukraine. The main benefits of well-planned and well-operated district heating include:

- Increased Energy Efficiency: Modern DH systems can provide substantial energy savings for consumers and cities when compared to alternatives, providing the opportunity to increase the use of cogeneration (combined heat power production) plants that increase the overall energy efficiency considerably;

- Flexibility and Increased Security of Supply: numerous energy sources can connect and supply heat to a DH network including heat from combined heat and power (CHP) production, geothermal heat, surplus heat from industrial processes, energy from waste, solar systems, and heat pumps etc. This allows numerous alternative energy sources to supply a district heating network, and increases the heat supply security should one heat supply source be interrupted;

- Lower Carbon Footprint: DH can supply heat independent of fossil fuels, meaning significantly lower carbon footprint than conventional gas driven heat supply system. Cheap, low carbon base load heat can be obtained by utilizing surplus heat, renewable energy sources, combined District Heating and Cooling (DHC) technology as well as Combined Heat and Power (CHP) technology. DH can improve the efficiency of resource utilization, thus lowering the city’s carbon footprint;

- Reduced Investment for the individual: connection to a DH network saves the building owners from investing and maintaining individual building or apartment boilers.

Such benefits provide sufficient justification for investments in maintaining, and improving existing DH systems to become more environmentally friendly and energy efficient.

**Context in Mykolaiv.**

The description of the current situation is focussed mainly on Mykolaiv City, where the bulk part of DH consumers within Mykolaiv Oblast are located. In contrast, the future development will also include extension of existing or construction of new DH systems in smaller towns and villages throughout the oblast where biomass or geothermal based DH are promising alternatives to existing heat sources.

# 3 General Characteristics

Mykolaiv is located in the southern region of Ukraine and serves as the administrative center for the Mykolaiv region, district, and city community. The city has emerged as one of the major economic hubs in southern Ukraine, primarily due to its shipbuilding industry, which has been pivotal in its growth since its inception. Situated on a peninsula surrounded by the Southern Bug and Inhul rivers, Mykolaiv is positioned 65 kilometers away from the Black Sea. The city encompasses an area spanning 260 square kilometers.

Climatic conditions in Mykolaiv, Ukraine, are indicative of a region characterized by significant seasonal variations in both temperature and humidity. According to DSTU-N B V.1.1-27:2010 "Building Climatology," the average annual temperature in Mykolaiv stands at 10.1°C. The city experiences a humid continental climate with warm summers and no distinct dry season. Throughout the year, the average monthly temperatures typically range from -2.6°C during the colder months to 22.7°C in the warmer months, as illustrated in the table 3-1 below.

*Table 3-1 Average monthly temperatures according to state norms*

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average temperature, ℃ | -2,6 | -1,6 | 2,8 | 10,2 | 16,4 | 20,3 | 22,7 | 22 | 16,8 | 10,4 | 4,2 | -0,4 |

The lowest temperature of the coldest days reaches -26, and the lowest of the five days is -22.

However, actual statistical data, including the period since the development of the aforementioned standard, indicate that real temperatures are even higher, as shown in the figure below.

| | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. Temperature °C (°F) | -1.7 °C (28.9) °F | -0.3 °C (31.4) °F | 4.2 °C (39.6) °F | 10.9 °C (51.6) °F | 17.4 °C (63.3) °F | 21.7 °C (71.1) °F | 24.3 °C (75.7) °F | 24.1 °C (75.4) °F | 18 °C (64.4) °F | 11.1 °C (51.9) °F | 5.5 °C (41.9) °F | 1 °C (33.8) °F |
| Min. Temperature °C (°F) | -4.6 °C (23.7) °F | -3.7 °C (25.3) °F | -0.1 °C (31.9) °F | 5.7 °C (42.2) °F | 11.8 °C (53.3) °F | 16.3 °C (61.3) °F | 18.8 °C (65.9) °F | 18.5 °C (65.3) °F | 13.1 °C (55.6) °F | 7.1 °C (44.8) °F | 2.6 °C (36.7) °F | -1.6 °C (29.1) °F |
| Max. Temperature °C (°F) | 1 °C (33.8) °F | 3.1 °C (37.6) °F | 8.5 °C (47.4) °F | 15.8 °C (60.5) °F | 22.4 °C (72.2) °F | 26.4 °C (79.6) °F | 29.2 °C (84.5) °F | 29.2 °C (84.6) °F | 22.8 °C (73.1) °F | 15.2 °C (59.3) °F | 8.5 °C (47.2) °F | 3.5 °C (38.4) °F |

*Figure 3-1 Statistical data about climatic conditions*

Source: https://en.climate-data.org/

In terms of administration, the city's territory is divided into 4 districts:

- Central: located in the northwestern part of the city. It includes the historical center of the city, the Rocket Area, areas of Soliani, Pivnichny Ternivka, Matviivka, and Varvariivka.

- Zavodskyi: situated in the west and characterized by a significant industrial zone. It also includes residential "bedroom" neighborhoods such as Namiv, Lisky, and the new residential area Lisky-2.

- Inhulskyi (formerly Lenin District until February 19, 2016): located in the east. It encompasses, among other places, the PTZ area (YUTZ), Novyi Vodopii, and Staryi Vodopii. This district is home to the bus and railway stations and a zoo.

- Korabelny: situated in the south and including areas like Shiroka Balka, Bohoiavlenskyi (Vitovka), Balabanivka, and Kulbakine.

# 4 Current situation of district heating in Mykolaiv

The main heat supply for the residents of Mykolaiv is provided by two major suppliers: PJSC Mykolaiv Combined Heat and Power Plant (CHP) and Mykolaivoblteploenergo, municipally owned heat company (MOTE).

The leading heat energy enterprise, MOTE, provides thermal energy to approximately 60% of Mykolaiv's consumers. As of January 1, 2023, the enterprise operates:

- 94 active boiler houses with a total installed capacity of 440,519 Gcal/hour (94 boiler houses are on the enterprise's balance sheet, and 92 boiler houses are in operation).
- 23 CHPs (Centralized Heating Points) and 95 ITPs (Individual Heating Points).
- 33 booster pumping stations.

PJSC Mykolaiv CHP contributes to covering thermal and electrical loads. Its primary equipment includes 4 power boilers, 2 water boilers, and 3 turbogenerators. Most of the heating networks of PJSC Mykolaiv CHP and MOTE were put into operation in the 1960s.

The length of the heating networks of MOTE within the city is almost 255 km, of which 20 km are outdated. 10.2% of the enterprise's heating networks have been in operation for more than 25 years, exceeding the permissible service life specified in regulatory documents.

The length of the heating networks of PJSC Mykolaiv CHP within the city is almost 50 km, including 3 km of emergency sections and 47 km of outdated sections. Approximately 80% of the enterprise's heating networks have been in operation for more than 25 years, exceeding the permissible service life specified in regulatory documents.

## 4.1 Mykolaivoblteploenergo base line situation end of 2021

District heating systems of MOTE operate on the temperature schedule 95 ºC – 70 ºC, including part of the powerful boiler-houses with boilers, designed for the temperature of the coolant up to 150 ºC. The type of fuel used at the majority of boiler houses (BHs) is natural gas, whereas 2 BHs in the city (BHs on 1 Verhnya street and 124 H. Sahaydachnoho (Vatutina) street are using coal.

The traditional (Soviet style) scheme is used for district heating. Thermal energy is generated at district, quarterly and house boiler rooms with a well-developed transportation system. The majority of the DH system operates on the old Soviet principle where the flow rate of the heat transfer fluid in the network is constant, and the regulation of the amount of heat released is achieved by manually changing the temperature of the heat transfer fluid after the boiler. This leads to low efficiency of the heating system’s operation. A few boiler houses have been upgraded to automatic operation and control of the heat release including operation with variable flow.

MOTE has the following legal documents:

- Certificate of state a legal entity registration, Series A00 №590410 dated 29.12.2000 issued by the executive committee of the Mykolayiv City Council; Identity code of the legal entity: 31319242

- The statute of the MOTE (new edition), approved by the decision of Mykolaiv City Council dated December 21, 2017, No. 32/22

- Excerpt from the Unified State Register of Legal Entities, Individuals-Entrepreneurs and Public Formations dated May 10, 2018, No. 1003956175

The main type of economic activity by CES: 35.30 – steam, hot water and air-conditioned air supply. At present, based on the decisions of the Mykolaiv City Council dated September 13, 2017, No. 24/5 and January 21, 2012, No. 32/21, the process of transferring the integral property complex of heat supply to MOTE from the joint ownership of villages, settlements, cities of the region (regional property) to the communal property of the territorial community of Mykolaiv city has been completed.

The structure of the utility includes the following divisions: 8 district heating networks in the city of Mykolaiv, as well as centralized workshops, services, laboratories, departments.

The main activity of MOTE is the production, transportation and sale of heat energy to meet the needs of the population and other consumers in the services of heat supply.

## Heating Networks

The total length of heat networks (two pipe system), is 254,554 km, of which 56,2657 km (about 30%) of above-ground gaskets. They are laid predominantly in impenetrable reinforced concrete channels and made of steel pipes. Thermal insulation is made of mineral wool mats, slag or foam polyurethane, foil insulation, ruberoid, evaluated steel. Repair works on heat networks replacement are carried out mainly by the own forces of the enterprise.

Only 10% of the total heating networks in operation are laid as pre-insulated pipes.

Also, 16,462 km of over-the-ground heat networks has been additionally insulated by adding a polyurethane foam covering on existing pipes.

The length of the networks (two pipe system) by method of laying and age is given in Table 3.1.

*Table 4-1 Length of networks (two pipe system) by method of laying and age*

| Pipelines | | | Lifetime | | | | | |
|---|---|---|---|---|---|---|---|---|
| Method of laying | Length | | < 5 years | | 5-15 years | | >15 years | |
| | km | % | km | % | km | % | km | % |
| Underground | 171,3 | 66,6 | 23,0 | 78,5 | 87,1 | 82,0 | 61,2 | 51,4 |
| Overground | 56,3 | 22,5 | 2,5 | 8,6 | 16,8 | 15,9 | 36,9 | 31,0 |
| In basements | 27,0 | 10,9 | 3,8 | 12,9 | 2,3 | 2,1 | 21,0 | 17,6 |
| Total | 254,6 | 100,0 | 29,2 | 100,0 | 106,3 | 100,0 | 119,0 | 100,0 |

In Mykolaiv city 15,961 km of underground networks are replaced by pre-insulated steel pipes with polyurethane foam insulation in a polyethylene membrane and with a channelless gasket.

About one third of all heating networks have been demolished, whereas about 21.5 km are in a dilapidated and emergency condition.

The main problems during operation and repair of heating networks are i) the flooding of trays of underground networks, both groundwater and leakages from the networks of water supply and sewage installed along with thermal networks, and ii) the insufficient number of sectional shut-off valves and drainage devices.

**Boiler houses and individual boilers**

MOTE is operating a total of 341 boilers installed on own BHs. Besides, Mote is gradually assuming responsibility for the operation of a number of individual household gas boilers and boilers installed on roof tops of buildings.

Most of the thermal energy is produced at district boiler-houses with boilers of the types DE-25, DKVR, PTVM-50, KV-GM-10, KV-G-6,5, TVG-8, KV-G-5,6, on district or building boiler houses, where modernized boilers "NIISTU" and "Universal" are installed.

All operating boiler units of the enterprise are equipped with automatic safety devices. Almost one quarter of the boiler units have exceeded a lifetime of 20 years. The technical condition of the auxiliary equipment is satisfactory, except deaerators, deaerator water containers and salt storage.

32 BHs are installed in residential buildings 30-40 years ago, out of which 2 - in educational institutions – do not meet the requirements of existing normative documents.

Despite the unsatisfactory financial condition of the enterprise in recent years, MOTE has introduced, as far as possible, advanced equipment and measures to reduce the cost of production, transportation and supply of heat energy.

The traditional scheme is used for district heating. The regulation of thermal energy release is done by adjusting the supply pipe temperature according to a schedule in accordance with the temperature of the outside air.

Automatic regulation of the gas-air ratio and weather control is carried out only on 11 roof boiler houses and one furnace. The technical state of a large part of the auxiliary equipment of the BHs is satisfactory, and only a minor part of equipment is physically worn out and technically outdated.

Many boiler houses have constant speed network pumps installed, which results in inefficient operation of pump units and excessive electricity consumption for the transport of coolants, and transport of an excessive amount of heat carriers, which ultimately leads to increased heat loss from the network.

Electricity supply to BHs is carried out from the city electric network with a voltage of 0.4 kV. The electricity supply system of the CHP plant (control equipment, starting equipment, electric motors, lighting system, etc.) is in a satisfactory state. Control and measuring equipment on the CHP plant corresponds is standard for such plants.

In order to ensure introduction of the latest resource-saving technologies to achieve energy savings and reduce the cost of production, transportation and supply of heat energy, it is necessary to take measures for the reconstruction and modernization of existing and construction of new modern facilities with improved functioning, efficiency and reliability.

**IFI funded rehabilitation projects under implementation or completed**

MOTE is a participant in the Ukraine District Heating Energy Efficiency Project (hereafter UDHEEP), which is financed by loans from the International Bank for Reconstruction and Development (IBRD) and the Clean Technology Fund (CTF). The borrower under the project is the Ministry of Finance of Ukraine.

The total amount of the loan is USD 21.78 Mio, including USD 19.39 Mio from the IBRD and USD 1.69 Mio from the CTF.

Under the UDHEEP the following contracts have been completed:

1. Under the contract with "Energoresource-Invest Corporation" (Lviv, Ukraine) dated May 25, 2016, UDHEEP-MYC-ICB-05 "Replacement of thermal insulation of heat networks in Mykolaiv," the work to replace the insulation of 25.4 km of heat networks has been completed in full.

2. Since September 2016, Latvian PJSC "Siltumelektprojekts" has been preparing project and estimate documentation for the reconstruction of heat networks in Mykolaiv.

3. French company "EGIS INTERNATIONAL" has developed project documentation for the "Technical and Economic Calculation" (TER) stage and tender documentation for the reconstruction of boiler houses and central heat points in Mykolaiv.

4. Using the credit funds of the MBRD, 2 (two) cargo-passenger vehicles of the brand Mitsubishi Motors Company, Mitsubishi L200 MT Intense were purchased for emergency response. The contract, dated September 24, 2018, No. UDHEEP-MYK-SH-09.5, is concluded. The vehicles were purchased for credit funds of the International Bank for Reconstruction and Development due to production needs (for the purpose of updating the company's vehicle fleet, as well as for the prompt and timely delivery of specialists to the site of emergency situations). Purchasing such vehicles allows for increased work productivity by reducing the time required for work, extending the intervals between vehicle repairs due to equipment reliability, rational use of working time in performing production tasks at the enterprise, and significant savings in fuel and lubricants and spare parts expenses.

5. In accordance with contract No. UDHEEP-MYK-SH-12 dated October 9, 2019, "Purchase of an Excavator-Loader in Mykolaiv," on November 8, 2019, the equipment was purchased from LLC "Trading House "AL'FATEKh." The contract is concluded. The excavator-loader was purchased using credit funds from the International Bank for Reconstruction and Development due to production needs. The purchase of this special equipment enables the enterprise to carry out repair

work on its own heat networks in a shorter time and at a higher level of qualification, to lay and replace pipelines in emergency areas, and also significantly saves fuel and lubricants and spare parts expenses. In addition, it significantly reduces the need for hiring such special equipment from external sources.

6. Contract No. UDHEE-MYK-ICB-06 dated December 18, 2017, "Installation of Individual Heat Points in Mykolaiv" (Joint Venture Agreement dated November 28, 2016, No. EI-1691128/1 - authorized representative of LLC "ENERGO-INVEST") for the design, manufacture, testing, delivery, installation, commissioning, and commissioning of individual heat points (IHP) in Mykolaiv (a total of 92 IHPs, 3 CHPs, and one heat network from CHP 3). According to the contract, 92 IHPs, 3 CHPs, and heat networks from 3 CHPs have been installed.

7. Contract with LLC "Progress-92" - TOV "Enerhoresurs-montazh" No. UDHEE-MYK-NCB-04 dated December 6, 2018, "Reconstruction of Heat Networks in Mykolaiv."

8. Reconstruction of the heat supply zone with the unification of boiler houses on Sportyvna Street, 1k, Terasna Street, 16, Mykolska Street, 8, Buzkyi Bulvar Street, 9, Mostobudivnykiv Street, 6, Velyka Morska Street, 3, 6, 13, 21, with a total length of 5,735.27 meters of heat networks; and the reconstruction of the heat supply zone with the unification of boiler houses on Samoilovycha Street, 42-a, and Zavodska Ploshcha Street, 1, with a total length of 2,927.71 meters of heat networks..

9. Under Contract No. UDHEE-MYK-NCB-11 dated July 18, 2019, "Installation of Central Heat Points in Mykolaiv" by LLC "ENERGO-INVEST," 12 CHPs have been installed.

Currently, one construction contract is practically being implemented:

10. Contract with the French company ENERTEX No. UDHEE-MYK-ICB-07 dated April 23, 2019, "Reconstruction of Boiler Houses and Central Heat Points in Mykolaiv." The reconstruction of five large district boiler houses, namely, PGU, 72, Sportyvna Street, 1, Bila Street, 71, Samoilovycha Street, 42, and Novozavodska Street, 48, is in the final stage. Training of personnel, commissioning of objects, and the preparation of all required documents are underway. The contract is valid until May 31, 2024.

## 4.2 Mykolaiv Combined Heat and Power Plant base line situation end of 2021

The Private Joint-Stock Company "Mykolaiv CHP" is an energy supply source that participates in covering the thermal and electrical loads of the city of Mykolaiv. It provides approximately 40% of multi-story residential buildings in Mykolaiv with thermal energy and becomes the sole source of electrical generation for the city during power outages.

The main equipment at Mykolaiv CHP includes four power boilers, three water heating boilers, and three turbogenerators. The main characteristics and year of production are shown in the table below.

*Table 4-2 The characteristics and year of production of main assets*

| Name and station number: | Installed capacity | Year of manufacture/year of installation |
|---|---|---|
| Steam boiler TKP-2 (ТКП-2), station No. 1 | 160 tons of steam per hour. | 1938/1949 |
| Steam boiler TKP-2 (ТКП-2), station No. 2 | 160 tons of steam per hour. | 1938/1948 |
| Steam boiler TP-230 (ТП-230), station No. 3 | 230 tons of steam per hour. | 1955/1957 |
| Steam boiler TP-230 (ТП-230), station No. 4 | 230 tons of steam per hour. | 1957/1958 |
| Water heating boiler PTVM-100 (ПТВМ-100), station No. 1 | 116,3 MW | 1972/1973 |
| Water heating boiler PTVM-100 (ПТВМ-100), station No. 2 | 116,3 MW | 1973/1974 |
| Water heating boiler KVGM-100 (КВГМ-100), station No. 3 | 116,3 MW | 1986/1987 |
| Turbine P-15-29/10 (П-15-29/10), station No. 2 | 15 MW | 1951/1951 |
| Turbine VR-25-1 (ВР-25-1), station No. 3 | 15 MW | 1956/1957 |
| Turbine TR-10/29/0.8-1.2 (ТР-10/29/0,8-1,2), station No. 4 | 10 MW | 1958/1959 |
| Generator No. 2 T2-25 | - | 1951 |
| Generator No. 3 TVS-30 (ТВС-30) | - | 1957 |
| Generator No. 4 TVS-30 (ТВС-30) | - | 1959 |

The installed thermal capacity of the CHP is 410 Gcal/h (477 MW), and the connected load is 177 Gcal/h (206 MW). Consumers include 777 multi-apartment buildings, 87 schools and kindergartens, and 19 hospitals, mainly located in the industrial district, as shown on the figure 4-1 below.


*Figure 4-1 Map shoiwng scheme of DH networks of MCHPP*

The heat is transported to consumers through a two-pipe radial-ring network of the city's heat supply system, consisting of two main pipelines with diameters of 700 mm and 600 mm. The key characteristics of the thermal network are provided in the table 4-3 below.

*Table 4-3 Main characteristics of MCHPP network*

| No | Parameter | Length, km |
|---|---|---|
| 1 | The length of the thermal networks, in total, including: | 50,712 |
| | Steam | 3,120 |
| | Hot water | 47,592 |
| | Leased, in total: | 10,965 |
| 2 | Operational life of thermal networks, years: | |
| | Up to 5 | 0,394 |
| | 5 to 10 | 0,180 |
| | 10 to 15 | 0,000 |
| | 15 to 25 | 5,456 |
| | More than 25 | 41,562 |

As can be seen from the tables provided, the main equipment of the station and network has exceeded its standard service life.

## 4.3 Power sector in Mykolaiv base line situation of 2021

Electricity production in the region is carried out by the South Ukrainian Nuclear Power Plant, Oleksandrivska Hydroelectric Power Plant, Tashlytska Hydro Accumulating Power Plant, Mykolayiv Combined Heat and Power Plant, as well as a large number of sources operating on renewable energy, such as wind and solar.

The distribution of electrical energy to consumers in the Mykolayiv region is managed by the Joint Stock Company "Mykolayivoblenergo" (hereinafter referred to as MOE), founded in accordance with the order of the Ministry of Energy and Electrification of Ukraine dated August 31, 1995. 70% of the company's shares are owned by the National Joint-Stock Company "Energy Company of Ukraine."

JSC "Mykolayivoblenergo" is a distribution system operator that conducts licensed activities in the territory of the Mykolayiv region, covering an area of 24.6 thousand $km^2$ and serving a population of over 1,093.4 thousand people. The company is comprised of 20 separate structural divisions (branches) and the management. The electrical networks of JSC "Mykolayivoblenergo" include:

- 25 substations with a voltage of 150 kV;

- 192 substations with a voltage of 35 kV;

- 5835 transformer substations with a voltage of 10(6)/0.4 kV;

- overhead lines with a voltage of 35-150 kV - 4 318,66 km;

- overhead lines with a voltage of 0.4-10 kV – 17 271,66 km;

- 35 kV cable lines – 33 523 km;

- cable lines with a voltage of 0,4-10 kV - 1534.78 km

PJSC "Mykolaivoblenergo" carries out the distribution of electrical energy to consumers in 19 districts of the Mykolaiv region and in the regional centre of Mykolaiv.

As part of its electricity distribution activities, the company:

- provides services for concluding connection agreements to electrical networks, develops and approves project and estimate documentation, and performs electrical installation work for connections;

- carries out capital, current repairs, and technical maintenance of electrical networks and energy facilities;

- constructs new and modernizes existing energy facilities across its licensed territory;

- implements measures for the automation and telemetry of the electricity distribution process;

- conducts training, preparation, retraining, qualification enhancement, and personnel training activities.

The transmission and delivery of electricity to end consumers are carried out through overhead networks with a total length of over 25,000 km and cable networks with a total length of over 1,400 km.

As of 2021, it is possible to determine the actual annual volume of available electrical power of electricity producers located in the territory of the Mykolaiv region and connected to the networks of the JSC "Mykolayivoblenergo". These figures are presented in Table 4-4.

*Table 4-4 Annual electricity production*

| No | Generation Type | Generating capacities connected to the networks of MOTE, MW | | |
|---|---|---|---|---|
| | | 2018 | 2019 | 2020 |
| 1 | CHP and station block | 310,29 | 310,29 | 310,29 |
| 2 | **RE, including:** | **119,989** | **509,192** | **652,37** |
| 2.1 | wind | 70,6 | 98,8 | 152,10 |
| 2.2 | solar | 40,83 | 396,954 | 484,56 |
| 2.3 | small hydro | 2,13 | 1,854 | 4,15 |
| 2.4 | biomass and others. | 6,43 | 11,584 | 11,56 |
| | **Total** | **430,279** | **819,482** | **962,66** |

Source – The development plan of the distribution system of JSC "Mykolayivoblenergo" for 2022-2026.[1]

It is worth noting a significant increase in the installed capacities of wind and solar power stations. This was driven by the introduction of the "green tariff" law in Ukraine, which has significantly stimulated the development of renewable energy, leading to a sharp increase in the installed capacities of solar and wind power stations. The table does not include the capacities of nuclear and hydroelectric power stations because they are not connected to the distribution networks.

The South Ukraine Nuclear Power Plant (NPP) is located on the banks of the Southern Bug River in the city of Yuzhnoukrainsk. Construction of the plant began in spring 1975, and it consists of three power units, each equipped with VVER-1000 type reactors. These reactors are pressurized

1. [1] https://www.energy.mk.ua/wp-content/uploads/data/Plan_rozv_OCR/Plan_rozv_OCR-%202022-2026.pdf

water reactors with an electrical power capacity of 1000 MW each. The total installed electrical capacity of the plant is 3000 MW.[2]

The Oleksandrivska HPP is a hydroelectric power station located near the city of Yuzhnoukrainsk in the Oleksandrivka settlement on the Southern Bug River. The construction of the power station began in 1984 and was completed in March 1999. The station initially had a total capacity of 11.5 MW from two units. In 2017, the hydro units were re-rated, resulting in a reduction of the station's capacity to 9.8 MW.[3]

The Tashlyk Hydroaccumulative Power Station is located near Yuzhnoukrainsk. Construction of the Tashlyk HPP began in 1981, and it was designed to include six reversible (generator/motor) units. The plant's first hydro unit was launched in September 2006, followed by the second unit in July 2007. The initial design projected a total installed capacity of 1900 MW in generating mode and 1350 MW in pumping mode. However, the current configuration consists of six units with a total capacity of 906 MW in turbine mode and 1299 MW in pumping mode [4].

Electricity consumption in the networks of Mykolayivoblenergo is shown in table 4-5.

*Table 4-5 Electricity consumption in the networks of MOE*

| No. | Indicators | Annual electricity consumption, million kWh | | |
|---|---|---|---|---|
| | | **2018** | **2019** | **2020** |
| **1** | Electricity consumption (gross) | **3167,8** | **3131,2** | **3121,5** |
| **1.1** | Electricity consumption (net), including: | **2752,2** | **2722,1** | **2781,7** |
| 1.1.1 | Industrial | 879,5 | 889,0 | 897,3 |
| 1.1.2 | Agriculture | 128,1 | 129,4 | 154,2 |
| 1.1.3 | Transport | 102,4 | 111,0 | 110,4 |
| 1.1.4 | Construction | 10,7 | 8,9 | 9,9 |

2 https://www.uatom.org/ru/obschie-svediniya/deystvuyuschie-aes-ukrainy/yugno-ukrainskaya-aes#:~:text=%D0%AE%D0%B6%D0%BD%D0%BE,%D1%81%D0%BF%D1%83%D1%82%D0%BD%D0%B8%D0%BA%20%D0%90%D0%AD%D0%A1

3 https://ru.wikipedia.org/wiki/%D0%90%D0%BB%D0%B5%D0%BA%D1%81%D0%B0%D0%BD%D0%B4%D1%80%D0%BE%D0%B2%D1%81%D0%BA%D0%B0%D1%8F_%D0%93%D0%AD%D0%A1#:~:text=%D0%90%D0%BB%D0%B5%D0%BA%D1%81%D0%B0%D0%BD%D0%B4%D1%80%D0%BE%D0%B2%D1%81%D0%BA%D0%B0%D1%8F%20%D0%93%D0%AD%D0%A1%20%28%E3%80%9016%E2%80%A0%D1%83%D0%BA%D1%80,%D0%B7%D0%B0%D0%B2%D0%B5%D1%80%D1%88%D0%B5%D0%BD%D0%BE%20%D0%B2%20%D0%BC%D0%B0%D1%80%D1%82%D0%B5%201999%20%D0%B3%D0%BE%D0%B4%D0%B0

4 https://ru.wikipedia.org/wiki/%D0%A2%D0%B0%D1%88%D0%BB%D1%8B%D0%BA%D1%81%D0%BA%D0%B0%D1%8F_%D0%93%D0%90%D0%AD%D0%A1#:~:text=%D0%A2%D0%B0%D1%88%D0%BB%D1%8B%D0%BA%D1%81%D0%BA%D0%B0%D1%8F%20%D0%93%D0%90%D0%AD%D0%A1%20%28%E3%80%9020%E2%80%A0%D1%83%D0%BA%D1%80,29%E2%80%A0%D0%90%D0%BB%D0%B5%D0%BA%D1%81%D0%B0%D0%BD%D0%B4%D1%80%D0%BE%D0%B2%D1%81%D0%BA%D0%B0%D1%8F%20%D0%BC%D0%B0%D0%BB%D0%B0%D1%8F%20%D0%B3%D0%B8%D0%B4%D1%80%D0%BE%D1%8D%D0%BB%D0%B5%D0%BA%D1%82%D1%80%D0%BE%D1%81%D1%82%D0%B0%D0%BD%D1%86%D0%B8%D1%8F%E3%80%91

| | | | | |
|---|---|---|---|---|
| 1.1.5 | Municipal and household consumers | 324,7 | 307,6 | 296,5 |
| 1.1.6 | Other non-industrial consumers | 202,6 | 208,0 | 220,1 |
| 1.1.7 | Population | 1104,3 | 1068,2 | 1093,3 |
| **1.2** | **Electricity consumption for own needs of the DSO** | **7,94** | **6,17** | **5,72** |
| **1.3** | Electricity consumption for its transportation in the DSO networks | 407,6 | 402,9 | 334,1 |
| | as a percentage of electricity inflow to the network | 13,47 | 13,55 | 11,33 |

The two largest electricity consumers in 2020 were the population and industry. The most energy-intensive industrial consumers of JSC "Mykolayivoblenergo" are Limited Liability Company "Mykolayiv Alumina Plant," Private Joint-Stock Company "Dikherhoff Cement Ukraine," State Enterprise "NVO Zorya-Mashproyekt," LLC "ETSK," LLC "Bandurka Oil Extraction Plant," Municipal Enterprise "Mykolayivvodokanal," LLC "Sandora," Regional Municipal Enterprise "MYKOLAYIVOBLTEPLOENERGO," and Limited Liability Company "MARINE SPECIALIZED PORT "NIKA-TERA."

### 4.3.1 Analysis of the technical condition of fixed assets. Power grids.

The technical condition of power transmission lines and their structural and construction part (supports, foundations) is determined by criteria such as the duration of operation, the presence of defects and damages that cannot be repaired. According to the rules of technical operation, the service life of power transmission lines is as follows:

- On metal supports: 30-50 years (provided they are galvanized or regularly painted).
- Reinforced concrete supports with prestressed reinforcement: 30-50 years. Reinforced concrete supports with non-prestressed reinforcement: 25-30 years.

Considering the long service life, maintaining the lines in proper condition requires increasing expenses with each passing year. Some elements, such as metal structures and support foundations, lightning protection cables, and line insulation, require increased attention. Despite repairs and support replacements, a significant number of defective supports remain in operation, which according to regulatory documents need to be replaced with new ones.

As of January 1, 2021, "Mykolayivoblenergo" has 4 971,138 km of overhead lines and 33,523 km of cable lines with nominal voltages of 35-150 kV, including 4 590,555 km of overhead lines 35-150 kV and 1,482 km of cable lines 35 kV, whose service life exceeds 30 years, and 822,446 km of overhead lines 35-150 kV, which require reconstruction and replacement.

"Mykolayivoblenergo" developed and approved a Plan for the Development of Distribution Electric Networks for 2016-2020. According to this Plan, in 2016, the reconstruction of the double-circuit 35 kV power transmission line "Substation Berezan - Substation Tuzly - Substation Koblevo" with a total length of 13.3 km was carried out. In 2017, the construction of the 35 kV cable line "Substation MTEC - Substation Vokzalna" with a total length of 1.345 km was carried out. In 2018, the construction of the 35 kV cable line "Substation Liski - Substation S. Fontan" with a length of 4.538 km and the 35 kV cable line "Substation Sukhyi Fontan - Substation Pisky" with a length of 2.654 km were carried out.

### 4.3.2 Analysis of the technical condition of the main assets. Substations.

The total number of installed transformers in the networks is 6-150 kV is 6412 units (3 555,579 MVA), including 47 transformers at 150 kV (1 358 MVA) and 281 at 35 kV (986,8 MVA).

The main years of commissioning of substations with 35-150 kV voltage levels occurred between the 1960s and 1990s. Therefore, the service life of most substations ranges from 25 to 55 years.

Many substations have air break disconnectors and air and low-oil circuit breakers in the protection circuits of 35-150 kV transformers, which have exceeded their technical lifespan, significantly reducing the reliability of substation operation.

The circuit breakers of the VMT 220 kV type have reached the end of their switching resource and service life. According to the "Technical Description and Operating Instructions" Ibzh.674143.001, the service life of these circuit breakers is 28 years. Additionally, maintaining VMT 220 requires significant operational expenses. According to the operating instructions, a functionality test of the circuit breaker must be conducted every quarter, leading to consumer disconnections and a disruption in power supply reliability.

Isolators and disconnectors are morally and physically outdated. The operation of disconnectors induces additional peak disturbances in the networks, both in terms of current and switching overvoltages. The insulation of 35-150 kV lines with a sufficiently long service life is subjected to additional overload and consumers are disconnected during emergency switching operations. Overall, the reliability of the electrical network decreases, and the quality of electricity worsens. Currently, maintaining these devices is quite costly and ineffective.

As of January 1, 2021, the number of circuit breakers installed on the electrical network objects of "Mykolayivoblenergo" with voltages of 6-150 kV amounted to 4108 units.

Currently, in the operation of "Mykolayivoblenergo" networks, the following equipment is in service:

- 44 power transformers at 150 kV and 271 power transformers at 35 kV, the service life of which exceeds 25 years.
- 458 circuit breakers at 35 kV have reached the end of their switching resource and require replacement.
- 14 current transformers at 35-150 kV, which require replacement.

- 15 voltage transformers at 35-150 kV, which require replacement.
- 15 35-150 kV inputs, which require replacement, but they fail annually.
- 34 disconnectors at 35-150 kV and other substation equipment that require replacement.
- 11,732 RZA (Relay Protection and Automation) devices, including 10,638 simple, 1,015 complex, and 79 highly complex devices. The majority of these devices are electromechanical. More than a third of the operating RZA devices are morally and physically outdated and require replacement.
- 227 150 kV disconnectors, of which 41 require replacement, and 1,618 35 kV disconnectors, of which 300 require replacement.
- 3,367 6/10 kV voltage switches of various modifications, including 2,649 oil switches, which require replacement.
- 1,924 current transformers at 6(10) kV, of which 60 require replacement.
- 334 10 kV voltage transformers, of which 10 require replacement.

The mass aging of electrical network objects and equipment leads to a significant increase in maintenance costs for maintaining the operability of power lines and substations. This results in increased use of machinery, structures, materials, and an increased number of service personnel for conducting planned and unplanned inspections, routine maintenance, and emergency repairs. According to the provided data, 70% of the main high-voltage equipment, including power transformers, have exhausted their service life, which exceeds 25 years.

# 5 Situation end of 2023

The situation has considerably deteriorated with the start of the full-scale war with Russia in February 2022, as Mykolaiv became one of the cities located in the combat zone and the city's defence expenditures increased while its budgetary inflows decreased. Besides the immediate need for rehabilitation of the ageing and warn out structures of the DH system in Mykolaiv there is an immediate need to repair or replace buildings and equipment destroyed due to the war.

In mid-2022 the situation significantly worsened when, according to various estimates, up to 50% of the population left the city. Some began to return in the fourth quarter of 2022 when the situation on the front in the Kharkiv region improved. Still, the population number has not returned to its pre-war levels. It is expected that most of the people who have left due to the war will return once peace has been restored.

## 5.1 Mykolaivoblteploenergo situation end of 2023

To overcome the consequences of hostilities and constant shelling of the city, together with its main activities, MOTE is involved in the following activities: technical maintenance of water pumping stations, provision of services for issuing technical conditions for connection to the centralized heating system, conducting hydraulic tests of heating system pipelines, and providing rental of real estate owned by the communal property of the territorial community of Mykolaiv for the placement of telecommunications equipment of mobile operators.

As a result of the aggressor's actions, the main and backup lines of the Dnipro-Mykolaiv main water pipeline, which supplied water from the Dnipro River to Mykolaiv, were damaged. Starting from April 17, 2022, centralized water supply was unavailable in the city.

Since April 2022, the enterprise has been involved in drilling wells and installing reverse osmosis stations in Mykolaiv. These facilities are used for filling the heating networks and providing purified water to the population. The enterprise has installed and launched 69 water purification units based on reverse osmosis technology with a total capacity of 123 cubic meters per hour to support boiler houses and drinking water needs of the population on a free basis (10 liters per person per day), serving almost 100 000 people. 39 stations operate based on wells.

Since September 2022, the enterprise has been engaged in the collection, purification, and supply of water, including centralized drinking water supply, drinking water supply through drinking water dispensing points (including mobile ones), drinking water supply through individual and collective drinking water treatment facilities.

Furthermore, work has been organized and conducted on the installation of a backup section of a large-diameter pipeline to supply water from the Buzk Lagoon to Mykolaiv for household needs, and repairs of certain damaged sections of the water pipeline in the territory of the Kherson region.

It is therefore necessary to provide immediate support in terms of supply of urgently needed pipes and equipment. Delivery of such equipment by various donor organizations has been initiated based on MOTE’s specification of critically needed items. MOTE will be responsible for installation of the equipment with own staff and resources. Besides, reconstruction and restructuring of heating networks may, at least partly, be realized by MOTE based on such emergency supplies.

As a result of the armed aggression of the Russian Federation since February 24, 2022, the following damages occurred:

- 39 objects (including: boiler houses - 24, CHP plants - 5, pumping stations - 6, other objects - 4). Most of these objects had damaged windows and soft roofing.
- 577.6 meters of district heating networks in single-pipe design (of which 487.6 meters required complete replacement, and 90.0 meters required insulation replacement).

The damaged heating networks have been restored. The damaged windows and glass on the facilities of MOTE have been temporarily covered with chipboard panels until the situation in the city stabilizes.

In the conditions of constant rocket and artillery shelling that occurred throughout 2022, the restoration of all damaged enterprise objects was organized and carried out, and effective preparation of the heat supply system for the start of the heating season 2022/2023 was conducted.

To illustrate the consequences of the hostilities in the city and the extensive work carried out by the MOTE, below are some photographs. Specific locations and names of objects are not provided, as this is classified information concerning critical infrastructure in the context of war.


*Figure 5-1 Consequences of the bombing of one of the boiler houses…*

*Figure 5-2 ... and the restored boiler house before the heating season.*

During the heating season, the capacity of heat generation was ensured by attracting international technical assistance in the supply of 13 modular boilers using alternative fuel, with a total capacity of 6.5 MW, and the company's boiler houses were equipped with a constant power source.

## 5.2 Power sector in Mykolaiv base line situation end of 2023

The city's energy network faces several constraints:

- Inadequate electrical connections across city areas lack the necessary capacity for efficient power distribution.
- The existing 6 kV voltage class of the distribution network is outdated, causing significant capacity limitations and high electrical losses.
- Most of the electrical network equipment is obsolete, surpassing its service life and not meeting the current standards for energy efficiency.
- The network has suffered damage from armed conflict, affecting its integrity and operation.

Energy security issues include:

- Insufficient connection capacity hinders load transfers across the city during outages, posing a high risk of failure.
- Direct power input from Ochakiv district wind farms to the city grid is not possible, resulting in a critical dependency on main substations, which are vulnerable to disruption.

- The lack of operational conventional generation facilities in the city eliminates a stable reference voltage source necessary for grid balance, especially in isolated operation modes.
- A significant portion of substation switching equipment is too old to function in automatic or remote modes.
- There is no automated dispatch control system for managing the electrical networks.

**Improvement Priorities for Energy System**

Key improvements have been identified to enhance the city's energy infrastructure.

- Constructing a 150 kV cable line of approximately 6.5 km to enhance city-wide electrical communication.
- Developing an automated dispatch control system for electrical networks.
- Reconstructing the 150 kV external electrical networks, including integration of wind farm generation from Ochakiv district to the "Lisky" substation.
- Upgrading the distribution network voltage from 6 kV to 20 kV.

**Tariff Collection Efficiency**

As of July 1, 2023, tariff collection stands at 36%. The low payment rate stems from financial difficulties among consumers and suppliers. The utility company enforces non-payment measures according to Retail Market Rules. Actions include disconnecting power for non-payment, excluding the general populace as specified by the Ministry of Energy's order. Additionally, a 3% annual charge on unpaid debts is applied, along with compensation for inflationary losses as allowed by the Civil Code of Ukraine. These measures aim to safeguard the company's financial interests and compensate for material losses, particularly during martial law, excluding the general population from such penalties.

# 6 Future trends for district heating in Mykolaiv

In June 2022 the National Council for the Recovery of Ukraine from the Consequences of the War consisting of 24 working groups have finalised and published Ukraine's National Recovery Plan (cf. Annex J). According to the document the three main objectives – Resilience, Recovery and Modernization and growth shall not just lead to recovery of war-related damages but shall ensure economic growth and improved quality of life for Ukrainians.

## 6.1 Major goals of the sector

According to the National Recovery Plan main strategic goals for the energy sector include:

- ensuring a high level of energy security and Ukraine's integration into the European energy market.
- ensuring the operation of a smart, modernized, and reliable energy system that fully meets the requirements and needs of end consumers.
- ensuring the functioning of free, efficient, and competitive markets.
- increasing the general energy efficiency of the economy and the environmental sustainability of the energy sector, including through significant investments in renewable energy sources e.g. solar, wind and water energy.

National Recovery Plan addresses energy sector in several national programs:

- National program #3, #4a and b: Energy independence and EU Green Deal alignment, strengthening integrated energy system resilience and supporting EU's zero-carbon energy transition.
- National program #10a: Modernization of regions and housing targeting recovery and upgrade of housing with priority focus on Energy Efficiency.
- National program #11: Modernize social infrastructure in accordance with principles of energy efficiency.

Work on the National Recovery Plan was carried out by 24 working groups each focusing on one sector. Materials of the “Energy security” working group seeks answering the question: what kind of energy sector are we building in Ukraine? In the comprehensive report the working group presents objectives, challenges and opportunities of electricity, gas, oil and oil products, and power-to-X sectors and suggest detailed plan of measures targeting recovery and development.

According to the working group recovery will require: “a stable, modern and investment-attractive energy industry that provides Ukrainian consumers with clean, affordable and reliable energy, relies on the responsible development of domestic energy production, and supports the EU in achieving its strategic autonomy”.

The proposed recovery measures planned for three time periods (short-term, midterm and long-term) and are grouped under the following five objectives:

1. European integration and efficient operation of energy markets.

2. Energy security: diversification of energy supply sources, creating reserves, cyber-security.

3. Decarbonisation, optimisation of the energy mix and development of low-carbon generation.

4. Modernisation and development of infrastructure for energy transportation, transmission, distribution, and storage.

5. Improvement of energy efficiency and demand-side management.

Finally, the working group suggest a comprehensive list of legislations needed for the fulfilment of the above objectives. It has not been possible to verify the present status of the readiness of these legal acts.

## 6.2 Energy storage and maneuverable capacities

Revitalizing the power sector in Ukraine requires a strategic focus on decentralizing the energy system, fostering integration with EU energy markets, and promoting the development of renewable energy sources (RES).

An important element of this concept is creating the energy storage capacities. Energy Storage Systems (ESS) represent innovative technologies that enhance the functioning of the electricity market by synchronizing energy consumption and production. They play a vital role in mitigating imbalances arising from weather-dependent green energy generation. ESS contribute by offering reserves during sudden fluctuations in frequency and voltage, preventing a decline in the quality of electricity supply. Additionally, they present an opportunity to save costs by accumulating electricity, particularly during off-peak hours.

In Ukraine, there exists a legislative framework that governs the operations within the electricity market for energy storage systems. A corresponding law5 which came into effect in 2022, establishes the concept of energy storage activity. The licensing requirements[6] for energy storage business activities have been adopted by the National Energy and Utilities Regulatory Commission (NEURC).

Despite having this regulatory foundation, the energy storage systems (ESS) market in Ukraine is still in its early stages of development. The primary ESS currently in operation are pumped hydroelectric energy storage (PHES). The system comprised 101 units before the damage to the Kakhovka Dam. However, the persistent challenge has been the inherent low flexibility of the Unified Energy System (UES) of Ukraine.

In 2021, DTEK, the Energy Holding, in collaboration with Honeywell, initiated a pilot project in Ukraine, introducing the first industrial lithium-ion Energy Storage System (ESS). This 1 MW installation, with a capacity of 2.25 MWh, is currently situated in the occupied territory, specifically

[5] The Law of Ukraine (Law No. 2046-IX) on amendments to certain laws of Ukraine regarding the development of energy storage facilities, https://zakon.rada.gov.ua/laws/show/2046-20#Text
[6] The resolution by NEURC dated July 22, 2022, No. 798.

in the town of Enerhodar, on the premises of the Zaporizhzhia Thermal Power Plant. The primary objective of this system was to investigate the optimal operating models of ESS across different segments of the power market.

Despite the ongoing hostilities in Ukraine, there are efforts to pursue the Energy Storage System (ESS) projects. Ukrhydroenergo has taken the lead in initiating the construction of the largest underground energy storage facility in Europe.

The implementation plan for this ambitious project[7] has received approval from the World Bank, and there are plans to complete the economic and technical feasibility study, along with the construction project decision, by the end of 2023.

The deficiency in maneuverable capacities within the Unified Power System (UPS) of Ukraine, coupled with the insufficient storage capacities, has been a persistent and significant challenge.

In particular, Ukrenergo the Transmission System Operator (TSO) of Ukraine, has reiterated the need to install at least 1 GW of fast start generation capacity and 0.5 GW of energy storages systems by 2031 in its "Report on availability (sufficiency) of generating capacities"8, approved by National Energy and Utilities Regulatory Commission (NEURC).

The last report of NEC Ukrenergo assessing the sufficiency of generating capacity in 2022, although approved by NEURC[9], is currently unable to be made public due to the ongoing martial law.

Thermal generation has served as a manoeuvrable capacity to offset the increasing RES generation. However, due to the hostilities, only about 13.3 GW out of the 21.5 GW of balancing capacities are still operational. By the end of September 2022, approximately 20% of power units have undergone reconstruction. Despite these efforts, the slightly enhanced manoeuverable characteristics fall short of meeting the modern requirements of the UPS of Ukraine.

According to the recent energy damage assessment report by the United Nations Development Programme (UNDP) and the World Bank, which underscores Ukraine's international commitments to the green transition, the recommendation is to prioritize the development of sustainable and highly maneuverable generation facilities[10] as follows:

- Thermal generation from biomass (conversion of existing TPPs and CHPs from fossil fuels to biomass and construction of biomass-fired CHPs instead of fossil fuel boilers).
- Electricity storage systems based on high-capacity batteries that can release the stored energy within a few hours to balance the power system; and

[7] Ukrhydroenergo wants to build the largest underground energy storage facility, https://ecopolitic.com.ua/en/news/ukrgidroenergo-hoche-pobuduvati-najbilshij-v-ievropi-pidzemnij-energonakopichuvach-2/
[8] https://ua.energy/general-news/neurc-has-approved-the-generation-adequacy-report-for-2020/
[9] NEURC Resolution No 664 dated 11 April 2023
[10] Towards the green transition of the energy sector in Ukraine, update to the energy damage assessment, June 2023, UNDP, undp-ua-energy-damage-assessment.pdf

- Hydroelectric storage facilities.

## 6.3 Introduction into district heating development goals

Due to many years of budget constraints faced by the two entities providing DH services in Mykolaiv, their main focus has been on keeping the DH system fully operational, and to avoid major accidents, by replacing old and warn out equipment.

For the same reason, there has been limited focus on upgrading and improving the DH system. Nevertheless, due to their high dedication and professional conduct both DH providers have managed well to keep the heat production and distribution system operational and to satisfy the needs of their customers.

Despite these constraints, both DH providers have managed to gradually reduce the temperature levels in the network without jeopardizing the quality of heat supply. Compared to the originally temperature regime designed for maximum 150 $^{o}$C on the coldest day, the supply temperature has rarely exceeded 95 $^{o}$C in the network during recent years.

During recent years, some technological upgrades have been made or are in the process of implementation, with a major focus on improvement of energy efficiency. Most of these projects have been realized based on loans and grants from international IFIs.  However, only a small fraction of boiler houses and networks have been upgraded or rehabilitated so far, and there is a need for very large investments to reach a full-scale rehabilitation and energy efficiency upgrade.

For the above reasons, the planning horizon of both DH providers has been limited to immediate and short-term needs. The list of projects presented in this section was compiled based on discussions with the mentioned companies or on the basis of specific requests and proposals received from them. Furthermore, in developing these projects, COWI has maintained close contact with the Mykolaiv City Council, Mykolaiv Oblast Administration, as well as relevant professional associations such as the Wind Energy Association of Ukraine (UWEA), the Bioenergy Association of Ukraine (UABIO), and the Solar Energy Association of Ukraine.

## 6.4 Development plans for MOTE

It should be noted that the requests from MOTE and Mykolaiv CHP have worked out a list of short term projects with high priority due to urgency for replacing outdated and warn out equipment with highly efficient, modern equipment, which will both increase the reliability and quality of heat supply, and provide significant savings of natural gas and reductions in CO2 release to the atmosphere. As all short-term projects are sufficiently well specified by MOTE, have either a detailed design or a similar example of a tender dossier in place and do not require a feasibility study.

### 6.4.1 MOTE short-term investments projects

The proposed list of short-term projects is presented below.

- Installation of IHSs in residential buildings supplied from the previously rehabilitated boiler house located at 42 Samoilovicha str (Project requested by MOTE)

- Installation of IHSs in residential buildings supplied from the previously rehabilitated boiler house located at 71 Bila str (Project requested by MOTE)

- Construction of modular boiler house with a total installed capacity of 5 MW at Metalurgiv str, Mykolaiv and decommissioning of an unreliable 530 mm diameter, 630 m in length, district heating pipeline, which is a source of high losses of both heat and water (Project requested by MOTE)

Mote has also proposed one large project for implementation on medium and long term aimed at complex rehabilitation of Rehabilitation of 28 boiler houses in Mykolaiv City before 2030.

The project envisages the reconstruction of about 30% of the total number of boiler houses of the enterprise in order to provide quality district heating services to consumers. Boiler houses are small to medium capacity (with typical capacity of 0,5, 1, 2 or 4 MW) and located in different districts of the city as shown on the map below.

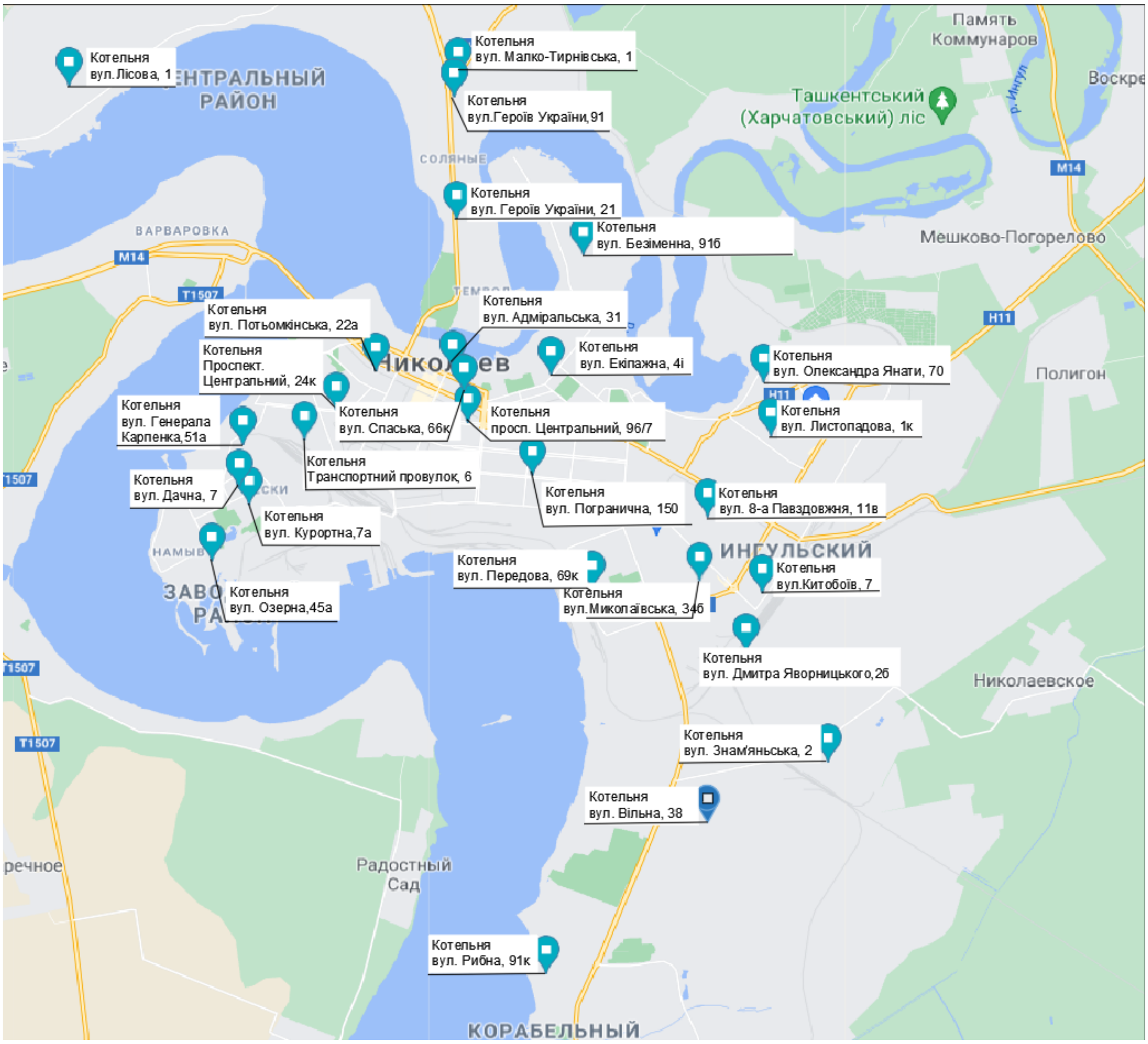


*Figure 6-1 location of 28 small BHs to be reconstructed*

The following measures for the reconstruction of the boiler houses are foreseen:

1. Reconstruction of the existing boiler house building with finishing works of internal and external surfaces and repair of roofing, replacement of technological and drainage pipelines, as well as lighting networks;

2. Installation of energy efficient gas-fired water heating boilers with at least 95% efficiency

3. Installation of modern burners (control range 30% to 100% of rated capacity) and automatic control system for cascade operation of boilers

4. Installation of at least one solid fuel fired hot water boiler with a pellet burner, with a boiler efficiency of at least 90% and an automatic fuel supply system in the boiler house for increasing fault tolerance and decreasing OPEX

5. Installation of at least one electric hot water boiler, which is expected to use surplus power from nuclear or coal fired power plants during night time when there is a reduction factor to the tariff rate. Despite the potentially higher efficiency, we do not propose the use of heat pumps because of the high temperature levels required for heating the existing building stock in Ukraine which renders the efficiency gains through the use of heat pumps to be too low to ensure an acceptable pay back. Throughout Ukraine in-house heating systems (and therefore heating surfaces) are designed for a maximum supply temperature of 95 degrees, and many boiler houses are therefore designed to supply water with a temperature up to 115 degrees and above

6. Equipment for cascade operation of the boilers to be installed

7. Installation of systems for automatic regulation of the coolant temperature at the boilers' outlet depending on the outdoor temperature, specified temperature schedule and time of day

8. Installation of a new modern water treatment system

9. Replacement of the existing pumping equipment with installation of low-power network pumping stations equipped with frequency converters, shut-off and control cabinets

10. Establishment of a dispatching and visualization system with the possibility of remote control with GSM communication and access to the automated control system of technological processes, enterprise server, etc.

11. Equipment for boiler house operation in automatic mode, without the constant presence of service personnel

The project will lead to:

- natural gas savings will amount to 2.400 (19.2 Mio UAH) thousand m3 per year which is approx. 4,5% of total gas consumption of the enterprise

- Reduction of emissions of pollutants into the environment in the amount of 6, 228.5 tons/year, namely:

  - carbon monoxide (CO) – 1 640 tons/year

  - carbon dioxide ($CO_2$) – 4 582 tons/year

  - nitrogen oxides ($NO_x$) – 6 tons/year

  - hydrocarbons – 0.5 tons/year

### 6.4.2 MOTE medium-term investments projects

As mentioned before, Ukraine seeks to modernize and decarbonize its energy sector, and the government has set ambitious targets for the development of renewable energy sources and energy efficiency measures. The implementation of these policies will require significant investments and collaboration between the public and private sectors but will ultimately lead to a more sustainable and resilient energy system for the country.

The war in Ukraine has had a devastating impact on the country's infrastructure, particularly the energy sector. Power plants and transmission lines have been damaged or destroyed, leading to power outages and disruptions in energy supply. As a result, reducing Ukraine's reliance on fossil fuels, particularly coal and gas, has become even more urgent. Developing renewable local energy sources, such as wind, solar, and biomass, is necessary to ensure a more reliable and resilient energy supply. However, transitioning to a decentralized energy system that relies more on distributed generation poses challenges in managing and balancing the system, requiring new approaches and technologies to address. Despite these challenges, Ukraine will have to move towards a more sustainable and resilient energy system to meet the needs of its citizens and ensure long-term energy security.

In line with this, the Energy Strategy of Ukraine until 2035 has set ambitious goals for the country's energy sector, including generating at least 25% of electricity from renewable sources by 2035. This will require significant investments in renewable energy projects and the development of supportive policies and regulations to encourage their growth.

The proposed projects and activities in the development plan for Mykolaiv aim to promote sustainable development while taking advantage of local resources and opportunities for renewable energy.

In accordance with these objectives, two main areas of interest can be identified for DH utilities, where they see potential for the development of their companies aiming to promote sustainable development while taking advantage of local resources and opportunities for renewable energy. These areas are the use of Biomass energy and Solar Energy.

**Biomass Energy**

The Mykolaiv Oblast is facing a challenge in meeting its energy demand due to a lack of access to traditional sources of biomass, such as forests. This limits the options for biomass-based heat production to agricultural waste, specifically straw and slurry. Utilizing straw as a fuel source for heat production presents its own set of challenges, such as transportation and storage logistics, and the need for appropriate technology and infrastructure for processing and combustion.

The military conflict in Ukraine, particularly in the regions of Mykolaiv and Kherson, has rendered a significant portion of agricultural land unsuitable for crop cultivation. The lack of current data and long-term industry development projections may hinder potential investments. The City and Oblast must address these challenges in order to effectively utilize biomass as a source of heat and meet its energy needs in a sustainable and cost-effective manner and one of the most promising and requested by DH utilities option is a Direct Heat production in boilers and cogeneration plant on biomass.

In accordance with these objectives, several areas of interest for DH utilities or potential projects can be identified, where they see possible development of their companies aimed at promoting sustainable development while taking advantage of local resources and opportunities for renewable energy. Primarily, these include the use of Biomass energy, municipal solid waste and Solar Energy.

The list below presents a range of projects that are in various stages of development and in which both DH utilities are extremely interested.

1. Direct combustion in boilers for heat production: The straw is burned in a boiler to produce steam that is used to generate electricity or heat. This option is cost-effective and has low capital requirements. As per UABIO, the cost per unit of constructing a solid fuel boiler house plant is estimated to range from EUR 90 to EUR 200 per kW of installed capacity, varying depending on the manufacturers of the equipment and type of solid fuel.

2. Co-firing with other fuels: Straw can be mixed with other fuels, such as coal, wood, peat or municipal solid waste and burned in power plants to generate electricity. This option reduces the amount of fossil fuels needed and provides a renewable energy source.

It is worth noting separately that MOTE is highly interested in constructing several Biomass Combined Heat and Power (CHP) plants, typically with electrical capacities ranging from 2 to 6 MW, in various areas of the city. The company has already conducted preliminary surveys, identified a list of consumers, and made a preliminary selection of industrial sites in the city where the installation and operation of such CHP plants are possible. The list of facilities includes the following:

1. Boiler house at 1-K Sportivna Street ("Stadion") - with a total capacity of 5 MW.

2. Boiler house at 71 Bila Street - with a total capacity of 4 MW.

3. Boiler house at 48 Novozavodska Street - with a total capacity of 2 MW.

4. Boiler house at 42 Samoilovycha Street - with a total capacity of 6 MW.

5. Boiler house at 2-K Znamyanska Street - with a total capacity of 3 MW.

6. The building of the decommissioned boiler house at 36 Vodopiyna Street - with a total capacity of 4.2 MW.

7. Boiler house at 1 Malko-Tyrnivska Street ("MTB") - with a total capacity of 2 MW.

These locations are shown on the map in the figure below.

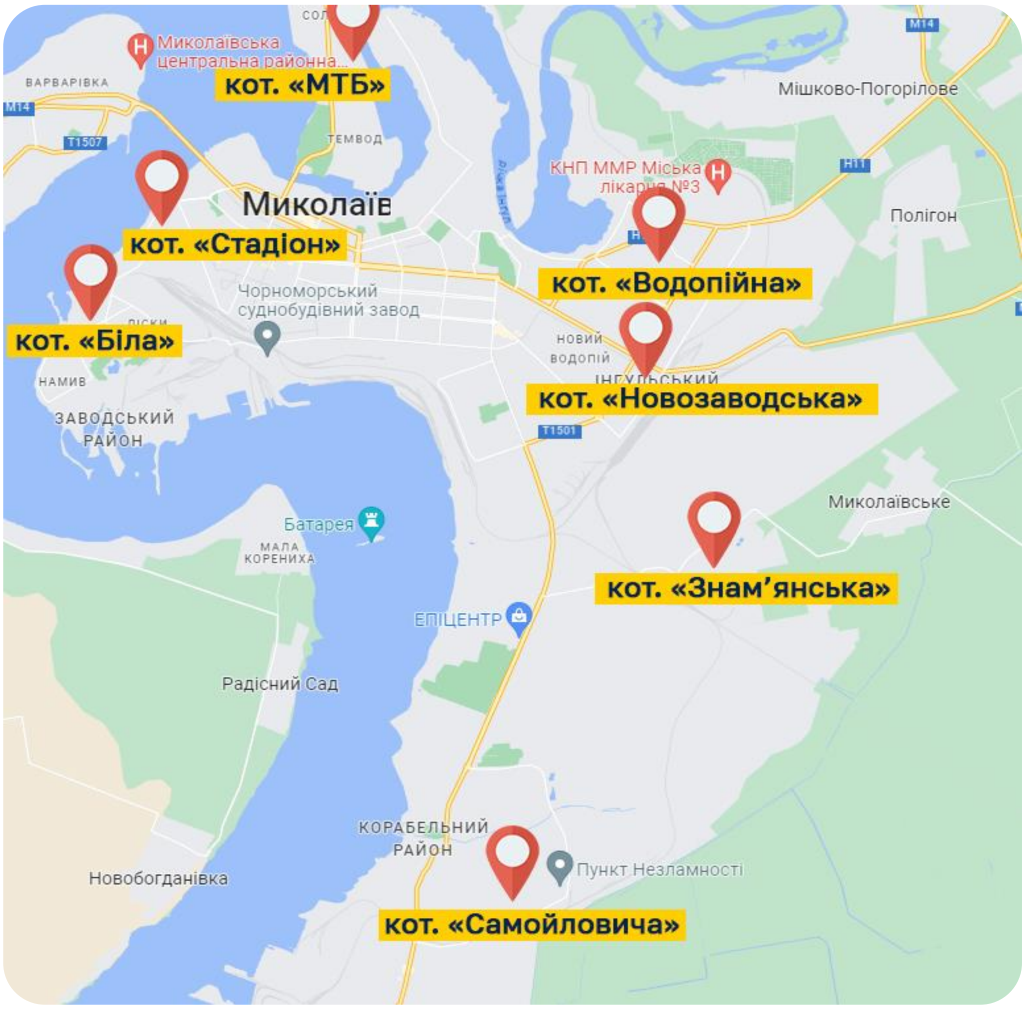


*Figure 6-2 The map representing the proposed location of the CHP*

## 6.5 Development plans for Mykolaiv CHP

Based on the development strategy for Mykolaiv CHP for 2023-2028, several priority projects can be identified. Part of these projects can be characterized as "putting things in order" and relate precisely to maintaining or enhancing the operability of existing infrastructure, as mentioned in chapter 6.2. Among them are the following:

### 6.5.1 Mykolaiv CHP short term investment projects

#### Replacement of Turbogenerator No. 2

The Mykolaiv CHP facility has prioritized the replacement of its economically inefficient Turbogenerator No. 2 (TG-2), which has reached the end of its modernization potential. Financially, a major repair would not be cost-effective nor would it enhance the unit's economic performance.

The objective of this project is to install a new 15 MW turbogenerator that promises to serve as a dependable source of electrical energy, featuring high performance indicators. This modernization is anticipated to result in a 35% cost reduction in power generation, enabling Mykolaiv CHP to compete more effectively in the electricity market.

The estimated investment for the new turbogenerator is 60 million UAH. This project is a critical component of the strategic plan to enhance the operational efficiency and competitive position of the Mykolaiv CHP in the energy market.

*Figure 6-3 An illustration of a general view of turbogenerator*

### Installation of condensing economizers

This project aims to boost fuel efficiency at the by equipping each boiler with a condensing economizer.

The goal is to optimize fuel usage during the CHP's operations by recovering and utilizing heat from boiler exhaust gases. The installation of condensing economizers will enable this process, capturing waste heat to preheat the boiler feedwater, which reduces fuel requirements and boosts boiler efficiency.

The strategic use of condensing economizers is expected to yield significant fuel savings and lower greenhouse gas emissions, contributing to both economic benefits and environmental sustainability.

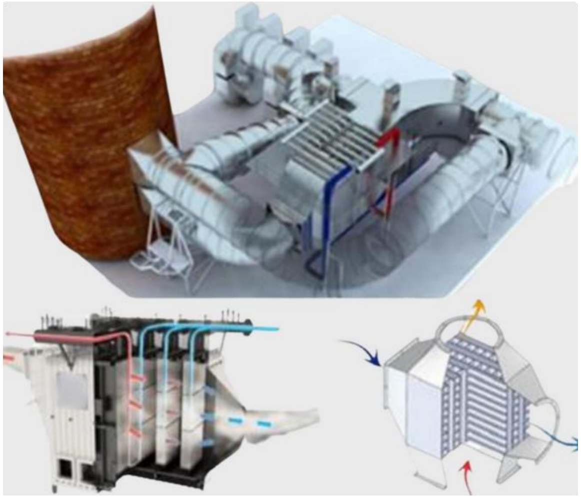

*Figure 6-4 An illustration of a general view of condensing economizer*

Implementing these economizers will likely lead to improved operational efficiency and a smaller carbon footprint for the plant's energy output. While the document does not specify the cost, the investment is anticipated to be offset by the fuel efficiency savings.

### Installation of frequency converters

The installation of frequency converters is expected to provide significant energy savings and process improvements, which include a more stable and efficient operation of the heating network and better fuel utilization in boilers.

This project represents a strategic step towards modernizing the electrical infrastructure of the CHP plant, optimizing energy use, and enhancing the safety and reliability of the heating supply system.

The purpose of this project is to install frequency converters on the electric motors of network pumps, the electric motors of smoke exhausts and fans for the first and second boilers. This initiative targets the reduction of electricity consumption for powering electric motors by 30%.

By controlling the speed of the electric motors, the frequency converters will allow for a reduction in electrical energy consumption, contributing to overall energy efficiency.

The project will also help in maintaining constant pressure within the heating network, thus preventing emergency situations. This will also optimize combustion processes in the boilers, leading to more efficient gas burning and, consequently, reduced gas consumption.

The cost of implementing the frequency converters is estimated at 12 million UAH.

**Increase of thermal load of the CHP**

The main goal is to increase the thermal load on the CHP plant. This involves reconfiguring connections to transfer customers from the MOTE to the plant's capacities.

The project is a critical step in enhancing the efficiency of the CHP plant. It is also expected to improve the heating system's reliability and meet the increased demand from consumers transferred from the regional utility.

This project is part of a strategic move to optimize the energy production of the CHP plant, ensuring it can meet the city's growing energy needs while also leveraging the plant's existing capacities more effectively.

*Figure 6-5 Part of the map of Mykolaiv indicating 16 BHs are to be decommissioned*

The project is planned in coordination with the Mykolaiv city administration. The plan includes modernizing the city's heat consumption infrastructure. Part of this modernization involves reconnecting consumers from 16 boiler houses of MOTE, which cannot be modernized, to the CHP plant.

By increasing the thermal load, the CHP plant will receive approximately an additional 10 GCal/h (11,6 MW) of load, allowing it to generate extra profit from the sale of thermal energy.

**Additional initiatives.**

In addition to the projects already mentioned, the document also proposes a series of other initiatives. These include:

1. The reconstruction of the boiler-turbine department of the CHP by replacing the existing burner devices on steam boilers TKP-2 stations No. 1 and No. 2 with energy-efficient burner devices. The reconstruction aims to significantly reduce fuel (gas) consumption by up to 3%, increase the working regulation coefficient of the burners, stabilize the combustion process, and reduce emissions of pollutants (NOx). This will bring them in line

with the requirements of Directive 2010/75/EU of November 24, 2010, on industrial emissions. The cost of implementing this project is estimated at 50 million UAH.

2. The replacement of emergency sections of the network, with a cost of 150 million UAH, is aimed at reconstructing 14.7 km of main network sections with diameters ranging from 250 to 720 mm over five years.

3. The implementation of an automated system for managing technological processes will ensure the efficient operation of the CHP's technological equipment in an energy-saving mode. The cost of implementation is estimated at 12 million UAH.

4. The installation of individual heating substations at consumer sites, costing 600 million UAH, as well as the introduction of an accounting and dispatching system, will allow for the most efficient management of heat transmission and consumption in an automated mode.

### 6.5.2 Mykolaiv CHP strategical view. Medium and long-term projects.

In the beginning of 2022 the document “Dynamic District Heating Concept” outlines an advanced strategy for the development of the Mykolaiv. Wärtsilä, an established energy solutions provider, has developed a comprehensive plan to modernize the Mykolaiv CHP, turning it into a pilot project for Naftogaz's broader ambitions.

Wärtsilä uses PLEXOS software to model the most profitable configuration of power plants, taking into account different market conditions and aiming to minimize production costs while maximizing revenue.

The primary objectives are to ensure a reliable, stable, and accessible heat supply for consumers, make the business profitable, reduce gas consumption, minimize $CO_2$ emissions, and maximize the efficiency of investments.

The proposed optimal combination includes wind turbines, heat pumps, electric and gas-fired boilers, and gas piston units (GPUs) with a thermal accumulator. The GPUs are particularly highlighted for their ability to switch to renewable fuels in the future, supporting the transition to a more sustainable energy system.

The modernized CHP is expected to produce thermal energy up to 135 MWth (historical 10-year consumption peak) and electrical energy up to 80 MWe (double the current capacity). The document stresses the profitability of the optimized configuration due to lower variable costs and increased flexibility in electricity and auxiliary services markets.

Below are the details of some projects for implementing the main elements of reconstruction in accordance with the developed strategy.

## Installation of energy storage


Figure 6-6 An example of industrial energy storage

The project aims to enhance the energy efficiency and reliability of the CHP plant by adding a significant electric energy storage capacity, thus enabling better energy management and support for the city's energy needs during regular operations and emergency conditions.

The main goal is to compensate for the negative imbalances in electric energy, which currently amount to an average of UAH 1,200.000 per year. In the self-consumption mode, the ESS will allow maintaining consumption within the necessary balance, leading to additional savings of UAH 3,000.000.

In the event of a blackout accompanied by massive consumer disconnections and the CHP plant operating in island mode, the ESS will enable the station to start from zero. It will provide not only for the station's own needs but also supply critically important city facilities.

The estimated cost of implementing the electric energy storage project is UAH 50 million.

## Installation of gas piston generators.

The goal is to establish a complex of gas piston generators with waste-heat boilers, having a total capacity of 80 MW, to actively participate in the balancing electricity market. The complex will allow covering morning and evening peak loads within its capacity at high price positions in the balancing market. The waste-heat boiler provides the opportunity to save thermal energy, reducing station losses and enabling quick load changes within 10-15 minutes.

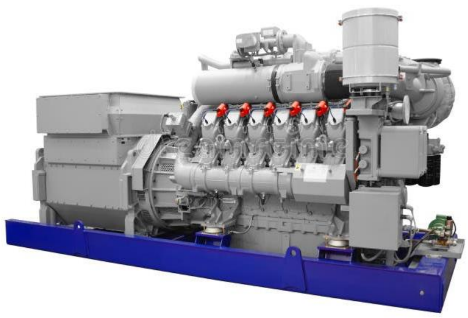
Figure 6-7 An example of gas piston generator

The complex will consist of gas piston generators paired with waste-heat boilers, divided into two stages:

1. The first stage, feeding into the 6 kV grid, will have a capacity of 40 MW.

2. The second stage will supply the 35 kV grid through a coupling transformer, also with a capacity of 40 MW.

Each gas piston generator is planned to be equipped with a synchronization system to the electric grid. A sectional switch will connect the first and second stages, allowing for load adjustments between them.

In addition, the waste-heat boilers are designed to collect thermal energy in storage tanks with a volume of 4000 m³. This energy will then be evenly distributed to heat water in the heating network.

The installation cost of the complex is estimated at 150 million UAH with a payback period of 7 years.

**Installation of waste processing complex**

The project aims to create a complex capable of processing and incinerating household waste to generate thermal energy of 10 MW and electrical energy of 3.3 MW which will have the capacity to process up to 35,000 tons of waste annually.

For the implementation, it is necessary to build a production complex with an area of 10,000 m², which includes a sorting facility, a weight disinfection warehouse for municipal solid waste, drying rooms, a boiler room, and auxiliary workshops.

The estimated cost of the project is approximately €30 million, with a payback period of seven years.

By utilizing alternative fuels, it is expected to reduce the tariff for heat for the population by 10% due to the savings in primary fuel (gas).

**Installation of heat pumps.**

The Mykolaiv CHP plant is initiating a project to establish a thermal pump complex with a capacity of 25 Gcal. The system will utilize the thermal energy of the Buzkyi Liman by channeling water through a dedicated coastal pumping station to a heat pump located in the CHP's turbine department.

For sufficient electricity generation, a stable base power source of at least 10 MW, potentially provided by the existing TG-4 turbogenerator, will be employed. Additionally, the project involves substantial modernization work on the coastal pumping station, which includes a major overhaul, replacement of the circulation pumps, updates to the electrical equipment, new feed cables, and restoration of three DU1200 circulation water pipelines that extend from the station to the CHP.

This comprehensive upgrade, with an investment of 1.2 billion UAH, aims to reduce the plant's fuel costs by 20% and to fully activate the station's normal thermal operating scheme.

## 6.6 Development plans for MOE

In the development of this chapter, materials from the Development Plan of the Distribution System Operator were used. This plan was developed based on the technical assignment provided by "Mykolayivoblenergo" and in accordance with the requirements of Section III of the Distribution System Code, approved by the NEURC Resolution No. 310 dated March 14, 2018, and the Procedure for the Development and Submission for Approval of Development Plans of Distribution Systems and Investment Programs of Distribution System Operators, approved by NEURC Resolution No. 955 dated September 4, 2018.

The development planning of the distribution system is carried out with the following objectives:

1) Timely provision of the necessary throughput capacity of the distribution system in accordance with the existing and forecasted needs of Users and Customers (regarding electricity consumption and injection into the network).

2) Ensuring sufficient throughput capacity of the distribution system for the needs of Users of developing energy hubs (regarding electricity consumption and injection into the network).

3) Ensuring the reliable, safe, and efficient operation of the distribution system, in compliance with the quality of electricity supply requirements.

4) Reducing technological losses of electricity in distribution system elements and commercial losses of electricity in the distribution system.

### 6.6.1 Reactive power compensation

The project aims to enhance the efficiency and stability of the electrical grid by installing reactive power compensation devices. The goal is to reduce the consumption of reactive power, which does not contribute to productive work but is a factor in electricity costs due to its role in creating electromagnetic fields. By implementing compensation devices such as capacitor banks, synchronous motors, and compensators, the project seeks to improve the technical and economic indicators of electricity supply, reduce losses, and thereby lower the reactive power portion of electricity bills.

The project focuses on the installation of static reactive power compensation devices at the "Koblevo" and "Morporth" substations. Based on the technical-economic justification, it is deemed economically viable to install capacitor banks with a capacity of up to 700 kvar on the 10 kV side of the "Koblevo" substation. This initiative is expected to have a payback period on the 8th year of operation when equipment is installed on the 1st and 2nd busbar sections, and within the 10th year if all three sections are equipped, considering a 30-year service life of the equipment.

The installation of these reactive power compensation devices (RPCD) is projected not only to compensate for reactive power but also to improve the voltage level in the 35 kV network by 12 – 36%, depending on the network mode and the number of RPCD units switched on. This also allows voltage deviations during maintenance schemes to meet the requirements of the power quality standards GOST 13109-97.

For the 10 kV network, the capacity of capacitor banks that can be installed without additional reactors to prevent resonances with the network should be within 600-700 kvar. The addition of reactors significantly increases the cost of equipment and leads to additional losses in the reactors, which substantially extends the payback period.

The implementation of this measure is anticipated to cost a total of 3,04 million UAH as planned by "Mikolaivoblenergo" for the development plan of 2022. Furthermore, for the continuous implementation of reactive power compensation devices on the 35-150 kV substations in Mykolaiv, "Mikolaivoblenergo" has included the development of a technical-economic justification for the "Morporth" substation in 2021, with design and further implementation planned for 2023. The implementation for this particular substation is estimated at 35 million UAH, scheduled for 2023.

Additionally, the installation of controlled shunt reactors with a capacity of 33 Mvar on the busbars of specific substations during 2023-2030 is planned to normalize the voltage mode in the 35 kV network during summer load reduction periods with maximum renewable energy generation.

### 6.6.2 Installation of smart metering

The smart electricity metering system project aims to modernize the energy sector by implementing automated data collection systems in multi-storey residential buildings. The initiative involves the use of Power Line Communication (PLC) technology-equipped meters for automated billing, supply management, remote data collection, information archiving, and integration with broader information systems. This upgrade is directed towards boosting efficiency and curtailing energy wastage.

An Automated Data Reading System (ADRS) has been successfully installed at 34,234 metering points, in line with the National Commission's regulations for state energy and utilities. Meters from "Telecommunication Technologies" and "NICK Electronics" have been deployed, leveraging PLC technology's suitability for apartment complexes.

The technology underpinning this system, PowerLine, utilizes frequency division of signals to manage high-speed data transmission by splitting it into multiple slower streams across different carrier frequencies before reassembling it into a single data flow. This approach has proven to be effective and meets the comprehensive requirements for household metering devices, facilitating variable tariff rates and immediate detection of electricity theft.

For households, the system offers the ability to switch to more advantageous tariff plans, especially if their previous meters were not tariff-based. It also enables network organizations to diminish losses through remote meter readings and controls, including the capability to disconnect services for non-payment without physically accessing the meters.

The project further includes the integration of LoRa technology for private sector consumers, providing a cost-effective alternative to PowerLine technology for certain contexts. A comparative analysis demonstrates LoRa technology's efficiency in data reading results for the private sector.

An implementation schedule has been established, detailing the annual installation of single-phase and three-phase metering points, as well as routers.

To address electricity theft, the plan involves the installation of external meter cabinets to prevent unauthorized access and minimize non-technical losses. These cabinets are strategically placed, particularly in areas that are difficult to access or remote, where manual meter readings are impractical and where theft is more prevalent.

The initiative is set to continue evolving, with the objective of achieving precise and efficient energy distribution and billing through the advancement and deployment of these automated systems.