Енергетичне Партнерство
Energy Partnership
Ukraine – Germany

Ministry of Energy of Ukraine

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Analysis

Quick Fixes for the Restoration of Heat Supply

in the areas of Ukraine affected by war damage

dena
German Energy Agency

Legal information

Publisher:
Deutsche Energie-Agentur GmbH (dena)
German Energy Agency
Chausseestrasse 128 a
10115 Berlin, Germany
Tel: +49 (0)30 66 777-0
Fax: +49 (0)30 66 777-699
E-mail: info@dena.de
Internet: www.dena.de

Authors:
Yannick Severin dos Santos (lead author), Valentyn Bondaruk, Thilo Cunz, Rita Ehrig, Andreas Koch, Lukas Kupfer, Alexander Lorenz, Johanna Meier, Bettina Morgenstern-Kennedy, Stefan Schirmer, Christin Schmidt, Martin Schön-Chanishvili, Klaus Völler, Gustav Weber, Friederike Wenderoth, Thomas Wenzel

Image credits:
Page 8: ©shutterstock/A_Lesik; ©shutterstock/Alexxxey; page 9: ©shutterstock/Maksim Safaniuk; ©Siemens Energy; page 10: ©shutterstock/Zigmunds Dizgalvis; page 11: ©shutterstock/Ronald Rampsch; ©shutterstock/servickuz; page 12: ©shutterstock/Studio Harmony; ©shutterstock/Alexxxey; page 13: ©shutterstock/Chad Robertson Media; page 14: ©shutterstock/New Africa; ©shutterstock/AlexLMX; page 15: ©shutterstock/Aliaksei Charapanau; ©shutterstock/Africa Studio; page 16: ©shutterstock/EvijaF; ©shutterstock/Independent birds; page 17: ©shutterstock/Balser; ©shutterstock/Allmy; page 18: ©shutterstock/Luca Rossatti; page 19: ©Bettina Morgenstern-Kennedy; page 20: ©Bettina Morgenstern-Kennedy

Last updated:
September 2022

Please cite this publication as follows:
Deutsche Energie-Agentur (dena, 2022). Quick Fixes for the Restoration of Heat Supply in the areas of Ukraine affected by war damage

Content

1 Introduction

On 24 February 2022, the Russian Federation launched a full-scale war against Ukraine. Due to numerous attacks and the occupation of some areas, residential districts and critical infrastructure have suffered significant damage. Especially for the 2022-2023 heating season, quick solutions are needed to provide the local population with necessities. Therefore, the main objective of this analysis is to identify and analyse technological solutions that can be used to quickly restore heat supply to large apartment blocks.

1.1 Situation in Ukraine

As a result of the war in Ukraine, the energy infrastructure has been severely damaged. The damage to the electricity and gas infrastructure could, at least, be partially restored. Due to the decrease in electricity demand, Ukraine can even export electricity within the ENTSO-E system.

However, the heating infrastructure for various residential buildings remains severely damaged. Russian shelling has hit thermal power plants and gas-fired boiler plants throughout Ukraine. As heat generation in Ukraine is centralised, the destruction of these plants can bring the heat supply of entire apartment blocks to a standstill.

It is already clear that it will not be possible to rebuild the destroyed CHP plants before the start of the heating season. Therefore, local authorities are discussing applicable solutions to the heating problem. This analysis “quick fixes for the restoration of heat supply” should therefore examine different heating technologies and evaluate under which circumstances they become the preferred option.

1.2 Methodology

This study identifies and describes various technologies to restore heat supply in cities where the heating infrastructure has suffered damage or destruction. To this end, dena engaged a team of its experts, as well as the expertise of the Ministry of Energy of Ukraine and other experts from Ukraine. A series of joint consultations were carried out and the results are presented in this analysis. To provide a better overview, the technologies were rated in five categories:

- **Costs:** What are the average costs of the technology?
- **Availability:** Is the technology available on the international/Ukrainian market and how long would it take to order and to deliver it?
- **Installation:** How long would it take to install the technology? How much expertise is required and is this expertise available in Ukraine? Is the technology scalable?
- **Dependencies and external effects:** Is the technology dependent on fossil fuels (e.g. domestic or imported gas or coal)? Are there external effects, e.g. Power2Heat technologies have a strong impact on the distribution system and might require an expansion of the electricity grid. Also, heat pumps depend on a well-isolated building infrastructure to work efficiently.
- **Environmental impacts:** To what extent is this technology suitable for Ukraine's energy transition goals? Is the technology a short-term solution or can it be used in the long term?

However, the categories are not sufficient to provide a complete and comprehensive overview of the specific use cases of each technology and under which circumstances the heating system should be used. Therefore, a "technology pathway" has been created that provides a simple summary of when and how which particular technology should be used. In addition, there is a short description for each technology.

2 Executive Summary

The project identified 16 different technologies. In addition, the technologies were analysed and evaluated in five different categories (costs, availability, installation, dependency and environmental effects). Due to the heterogeneous conditions in Ukraine they are only a rough estimate. In general, technologies that make use of the existing district heating network are preferable. However, decentralised and flexible technologies like heat pumps can also be a better solution. They are an efficient technology that can also support the decarbonisation of the energy system. In some cases, rapid installation is often not possible due to the limited availability, missing expertise and low electricity connection capacity. Therefore, other options such as decentralised heating systems or one-room solutions must be used to provide some basic heat. To provide a quick understanding, the seven key findings of the analysis are summarised below.

2.1 Build Back Better: Stranded assets should be avoided

Ukraine has ambitious climate plans. Therefore, it is advisable to invest in technologies that are compatible with future energy transition goals, and can integrate low-carbon renewable energy sources (RES). Investments in long-running fossil fuel plants should be avoided to avoid "stranded assets". However, due to the critical timeframe, investments in certain fossil technologies are probably unavoidable.

2.2 The situation in Ukraine is heterogenous: There is no “one size fits all” technology solution

The different situations / needs require individual solutions. However, generally, large-scale heat pumps and combined heat and power plants are the preferred options since they are very efficient and use the existing heating distribution infrastructure. However, the availability of heat pumps on the market is currently limited, which means that it would take too long to deliver and install them in time for the 2022-2023 heating season. If unavoidable, and in order to cover at least the basic demand for heat, second-best solutions such as decentral technologies must therefore also be considered. Decentral technologies, while usually better available, are often not compatible with the Ukrainian energy transition goals, as they often rely on fossil fuels. The use of small-scale efficient heat pumps is thus the preferable decentral option.

2.3 For lack of alternatives, people will buy decentral heating devices

To provide themselves with some basic heat people will purchase decentralised technologies such as fan heaters or solid fuel heaters. However, without preparation, this can put a huge strain on the distribution system and could become a serious fire hazard. Therefore, the government and infrastructure providers should plan for these circumstances and proactively communicate in advance, how they plan to repair the damaged heating infrastructure.

2.4 Winterisation: One-room solutions might be unavoidable

Due to the long installation and delivery times, paired with the ongoing war, it is likely that there are not enough resources to repair all major heating infrastructure. Therefore, it might be necessary to provide the population with temporary one-room solutions. Several technologies can be used (see Technology Path). However, appropriate measures should be taken to better insulate these spaces and avoid potential fire hazards (see chapter 4 – Winterisation).

2.5 Winter can destroy the existing heating infrastructure

In winter, any water-filled pipes could be destroyed when the water freezes. Single-room solutions or disconnection from the heating network, can lead to destruction of the building infrastructure as a result of freezing damage. It is therefore necessary to ensure that at the very least, the system remains heated e.g. with an electric boiler, to keep the water in the circuit. Alternatively, the heating circuit could be drained to avoid frost damage to the pipes. The same problem exists with regard to the drinking water pipes. In addition, the designated warm rooms in each household should ideally be located near the sanitary/kitchen areas where the majority of the water pipes are located.

2.6 Electric heating can place a heavy load on the power grid

Electric heating can put a heavy burden on an inflexible system with a high share of nuclear generation. A good example is France, where almost 80% of electricity is generated by nuclear power. And about 40% of heating (2018) is electric. In winter, at the peak of demand, the required capacity is almost twice as much as in summer. Ukraine has a similar generation infrastructure. Flexibility would likely be provided by relatively flexible coal-fired power plants, which could significantly undermine climate targets. In addition, electric heaters pose a challenge, especially for the lower voltage levels in the distribution grid (see chapter 5 – Distribution system).

2.7 Providing well-insulated pipes is a no-regret option

Buying well-insulated plastic jacket pipes in advance is a safe option, as they are needed to repair damaged infrastructure and can also be used to replace existing and rusty Soviet-era pipes that have often leaked. For lower temperatures and pressures, flexible plastic medium pipes (PMR) are standard components that are cheaper to install and also more flexible (see chapter 3, option 1).

3 Technology Path

The situation in Ukraine is very heterogeneous and reconstruction of the heating infrastructure can depend heavily on local conditions. To better assess which technology should be used, dena has developed a technology path (see figure 1) that shows the preferred technology for each situation. The higher the option in the diagram, the better the technology is in general. However, the technologies are often difficult to obtain on the international market, so alternative options have to be procured.

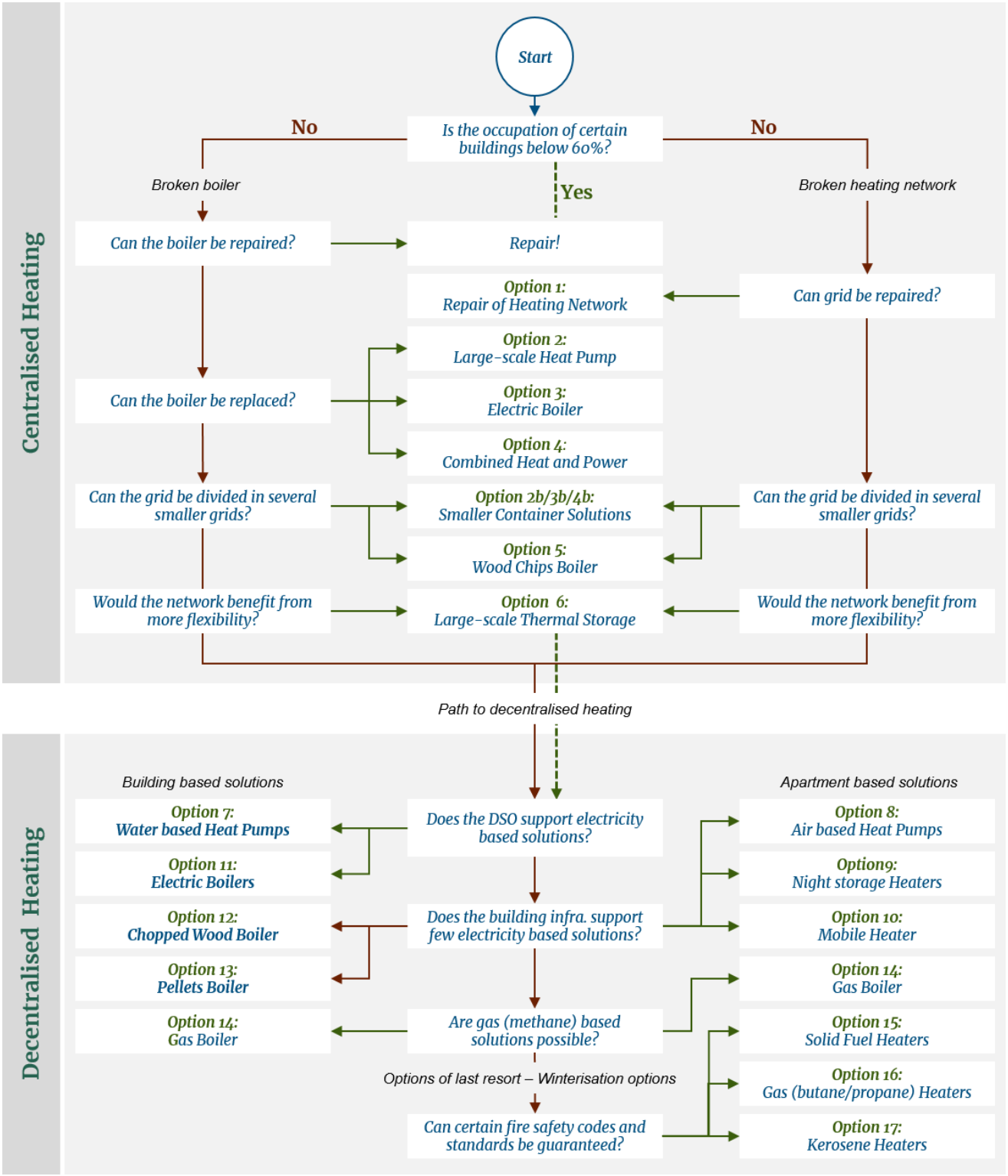


Figure 1. Technology Path

3.1 What is the current occupancy of the building?

The occupancy of a building is an important factor in determining whether it should be connected to the central heating network or if more decentralised technologies should be used. In the majority of Ukrainian buildings, the heating pipes run directly through all flats. Therefore, it is often not possible to disconnect individual flats from the system, and even in a sparsely inhabited buildings, every flat is heated in winter, resulting in high energy losses.

Since many citizens have left their homes due to the war, it is to be expected that many flats in Ukraine will be empty. If the occupancy rate of a building is below 60%, it is recommended that the entire building be disconnected from the heating network in order to save energy and use more decentralised heating techniques.

In the past, , to protect pipes from frost damage, electric heaters were sometimes installed as "frost monitors" (electric heaters with thermostats) in bathrooms in Germany. They ensured that the temperature in the bathroom did not fall below the freezing point. Electricity consumption is lower because the sanitary rooms do not need to be heated to 18°C, rather only to about 5°C. This could all be packaged to ensure the protection of unoccupied but still intact houses, so that plumbers winterise the unoccupied buildings. Alternatively, the heating circuit could be drained to prevent frost damage to the pipes. However, the same problem arises with the fresh water pipes. Therefore, the warm rooms should ideally be located near the sanitary or kitchen areas.

Centralised Heating

The use of central or district heating has various advantages and is often preferable to decentralised solutions. In the best-case scenario, the heat comes from combined heat and power (CHP) or industry, and uses waste heat and renewable energy. The environmental impact is then relatively low. Moreover, since district heating is usually highly efficient, it is often the best option for urban areas. Many European cities are pushing to expand their district heating supply, and Ukraine should try to maintain the existing infrastructure.

Centralised heating infrastructure

Decentralised Heating

The use of decentralised heating technologies may become necessary if all other technologies are not feasible or unavailable. Decentralised heating means that heat is generated either directly in the home or in the basement of the building. Since decentralised technologies are usually electricity-based, they can place a large burden on the distribution grid. Therefore, the use of decentralised heating should be planned by an authorised body in order to avoid a failure of the distribution network, or various fire hazards.

Apartment based / decentralised heating

3.2 Can the infrastructure be repaired?

If the boiler or network is damaged and can be repaired in a reasonable time frame, this should be the preferred strategy. Installing a completely new boiler within a short time frame is very difficult, and spare parts aren't always readily available. Dena cannot provide valuable information on the repair process of large boilers. For the repair of the distribution network, new efficient pipes should be ordered as soon as possible to repair the damaged infrastructure.

Option 1: Heating Network

During the Soviet era, most heating networks in today's Ukraine consisted of steel pipes laid in bonnet ducts. Glass wool or oil-based paper served as insulation for the pipes. Over time however, a large part of the pipes began to rust. As a result, the pipes leaked and the insulation began to rot. For this reason, it is suggested that in the upcoming years the heat networks be gradually replaced with plastic jacket pipes.

Repair of District Heating Network

These pipes are much better insulated and show little signs of corrosion. Installing these pipes requires knowledge of the existing system layout. Depending on the surface, this seems to be a feasible and relatively inexpensive option. For lower temperatures and loads, flexible plastic medium pipes (PMR) are standard components that are cheaper to install and more flexible. According to Fraunhofer Umsicht, the application range for PMR is 130-140°C at 16-25 bar and 85-95°C at 6-10 bar, so the latter range is likely to be considered only for low-temperature branches of DHN or new local networks.

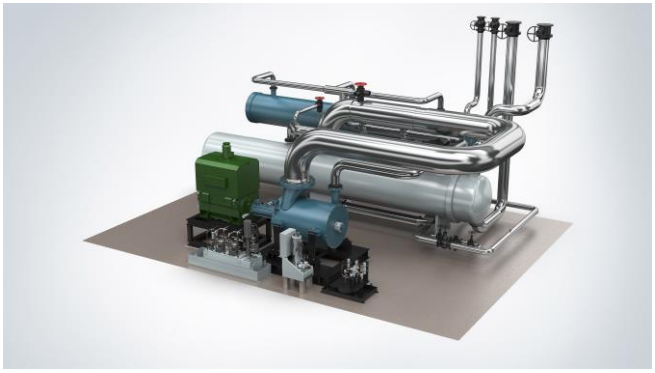
Due to the amount of work and equipment required, the replacement of damaged pipes in winter 2022-2023 may not be possible for all district heating networks. Systems with minor damage and a larger number of habitable buildings (with functioning internal distribution systems) should be prioritised.

3.3 Can the boiler be replaced within a reasonable period of time?

If a boiler is too badly damaged, it can be replaced with new technology. There are various options such as heat pumps, electric boilers or combined heat and power plants. Usually, all these options take several months or years to install, especially on a large scale. Therefore, their procurement should start as soon as possible. If they are not available by the winter of 2022-2023, decentralised transitional solutions could be a suitable short-term solution.

Option 2: Large-scale Heat Pumps

Although heat pumps already set the standard for heat supply in many private households or businesses, a broad market introduction of large-scale and industrial systems with outputs of 100 kW to several MW is currently still under very slow development.



Large-scale Heat Pump by Siemens Energy

A heat pump uses the environmental heat from the ground, groundwater or air. The heat is extracted from the environment and raised to a higher temperature level with the help of a refrigeration circuit. An electricity-driven compressor operates the refrigeration circuit in the heat pump. In this way, heat pumps can be used to heat buildings and to produce hot water.

- **Installation:** Depending on the natural heat source, the installation of large heat pumps can be a very demanding process, and must be carried out by professionals. In addition, the installation depends on the capacity of the distribution system.
- **Dependencies:** As a result of the war, industrial demand has declined, therefore the capacity of the high-voltage lines should be sufficient.
- **Environmental:** The impact of heat pumps depends strongly on the emissions of the electricity. The more renewable or low-emission sources are in the grid mix, the better is the overall impact.
- **Availability:** In larger projects such as a heating network, the plants are usually individually adapted to the project and therefore have significantly higher outputs in the range of >10 MWth.

Option 3: Large-scale Electric Boiler

Electric boilers offer a standardised solution from 0,55 MW to 120 MW and function like giant instantaneous water heaters. In Germany they are used mainly to generate heat during peak load periods. In the future they will also be used to convert wind energy into heat for heating purposes.

- **Costs:** Various sizes are available. Investment costs are low. Operating costs can be higher depending on electricity costs.
- **Installation:** Integration into the heating network and the electricity grid must be planned by experts, and takes more than a year for larger systems.
- **Dependencies:** Electricity is currently the most reliable energy source in Ukraine. In combination with thermal storage, cheap electricity from nuclear power plants can be used at night to generate heat without overloading the grids.
- **Environment:** The best solution compromise would be a central heat pump. If further renewable energies are planned, this could be a good solution to integrate surplus electricity.
- **Availability:** Standardised container solutions up to 6 MW should be available. For larger boilers, customised installations are required.

Option 4: Combined Heat and Power

Combined heat and power (CHP) is a technology for generating electricity and thermal energy that is highly efficient using different technologies and fuels. Losses are minimised when electricity is generated on site. Normally, CHP plants operate heat-led, i.e. the heat demand is the decisive parameter.

Combined Heat and Power Plant

CHP plants can be designed for different requirements. They range from supplying individual residential buildings to supplying entire district heating networks. And can run on various resources such as (bio)gas, oil, petrol, paraffin and biomass. Micro-CHPs usually start with an installation of less than 5 kW_e and can be scaled up to industrial units with a capacity of tens of MW. The cost of a typical gas-fired unit per kW of electrical output is around $577/kW, which is comparable to large centralised power plants.

- **Installation:** Depending on size and performance, installation can take different amounts of time. Permanently installed systems require a longer preparation time and must be individually adapted.
- **Dependencies:** The operation of the CHP unit depends entirely on the availability of the selected fuel (e.g. gas or wood).
- **Environment:** Flexible CHP solutions can be handled very effectively and can be used as a short or long-term option for heat grids.
- **Availability:** Depending on the type of fuel and the thermal output of the plant CHP plants are readily available in common sizes. It is possible to rent mobile units to temporarily support or supplement the existing infrastructure.

3.4 Would it be possible to split the network?

In certain situations, it may not be possible to completely renew or replace the distribution network, or the large boiler house. In these cases, the feasibility of continuing to use the parts of the network with several smaller boilers, should be examined. The technologies proposed for options 2, 3 and 4 are also usually available as smaller container solutions. These can be bought on the international market and are easier to transport to Ukraine and require less installation time. Even if the grid is not destroyed, several smaller boilers can be used to replace one large boiler.

Option 2b/3b/4b: Smaller Containers Solutions

Container solutions of large heat pumps, electric boilers and combined heat and power units can theoretically be ordered and installed quickly. Several energy containers can also be combined so that a larger output is available. In addition, there is the possibility of renting mobile units to temporarily support or supplement the existing infrastructure. However, availability depends heavily on the technology. Large heat pumps are currently very difficult to obtain and might not be available when needed.

Combined Heat and Power Plant Container

Option 5: Wood Chip Boiler

Wood chip stoves are automatically fed biomass stoves. They are used in a wide performance range from approx. 10 kW to the higher double-digit megawatt range. Woodchip heaters are ideal for supplying heat in larger residential buildings or apartment buildings. Also, in heating plants for local municipal heating supply and for commercial heat and process heat supply.

- **Costs:** In addition to the boiler with control, the prices include the peripheral components as well as the storage tank and the installation costs. The comparatively low costs for woodchips are an advantage.
- **Installation:** The planning and construction time for larger plants is 1 to 3 years. Rapid deployment in Ukraine will therefore be difficult.
- **Dependencies:** Wood chips are produced from local waste wood. Possibly in competition with the paper industry, which uses the same source.
- **Environment:** Emissions from woodchip heating plants are generally low because they are highly industrialised and the exhaust gases are processed.
- **Availability:** Larger wood chip plants are available in many different variants. Smaller plants under 30 kW are not very common.

3.5 Does the system require additional flexibility?

The increasing use of renewable energies will increase the importance of energy storage systems. Wind and sun do not always generate as much energy as is consumed. Therefore, it is possible to use the surplus electricity to store heat. Furthermore, it can be advantageous to shift heat generation to times when electricity demand is low. If more electricity is consumed at night, nuclear power plants, for example, can be better utilised. Better utilisation of generation reduces environmental impact as well as the costs.

Option 6: Thermal Energy Storage Tank

One method of coping with peak loads in the district heating supply is to store hot water in insulated large-scale storage tanks. Large thermal storage tanks operate in a wide range of operating temperatures and can have a capacity of up to 7.000 m^3. A plant in Lamarmora (Italy) with a storage of 5.200 m^3 has a heat capacity of 220 MWh. The construction costs were €3 million.[1]

Large-scale Thermal Storage

3.6 What is the electrical capacity of the distribution system?

In the case of defective and irreparable heat grids, and district heating, Ukrainian households can be supplied, to a certain extent, with heat generated from electricity (Power2Heat applications – P2H).

Electrically powered heat applications (P2H) consume a comparatively large amount of electricity at the household level, comparable to a kitchen cooker or kettle with 2.000 to 4.000 W. However, these applications have operating times of up to 24 hours per day when only heat is supplied. In addition, boilers in the basement of a building that supply heat to the entire apartment require significantly more electricity.

Any Power2Heat application that is connected to the public electricity grid therefore has an impact on the electricity distribution grid. As the energy required for heat generation is transported in the form of electricity via the distribution grid to the respective residential units. For more information about the distribution grid, see chapter 5.

Option 7: Heat Pumps

In apartment buildings in Ukraine, the existing hot water heating system can be used and connected to heat pumps. The energy source for water heat pumps is

[1] Euro Heat & Power Magazine (2022): Large Scale Thermal Storage Tanks Provide District Heating in Brescia

renewable environmental heat and always available: Outside air, ground (geothermal energy) or groundwater. The efficiency is higher when the temperature difference between the medium and the flow temperature is lower, so the best COP is achieved with groundwater as the energy source. Heating, cooling and dehumidification are possible.

source	transfer	efficiency	costs
air	water	lower	lower
soil	water	high	high
groundwater	water	higher	higher

Efficiencies of Heat Pumps

In Ukrainian apartment buildings, the installed water heating system is designed vertically, so a water-based system for each flat is not possible. Heat pumps can be installed for an apartment building or a compound of several houses. They can be installed in the basement, boiler houses and container solutions are available.

Medium-sized Heat Pump

The heating capacity is 50-85 kW per medium-sized heat pump, in a cascade of 5 units 280-1.500 kW. This is sufficient for a typical apartment building with approx. 60 flats and a heating load of 200-250 kW.

- **Costs:** The installation of heat pumps can be quite expensive, especially if they use ground or groundwater as an energy source. However, due to the high efficiency, the variable costs should be quite low and depend on the electricity costs.
- **Installation:** The installation must be carried out by professionals. If container solutions are used, concrete foundations and connections to the existing heating system must be prepared. Good thermal insulation of the connecting pipes is important. Professionals may not be available in every city in Ukraine.
- Additional cost-effective measures such as hydraulic balancing of the heating system, lowering the flow temperatures to 45-55 °C for higher heat pump efficiency and sealing all gaps in the building envelope are recommended.
- **Dependencies:** In Ukraine, electricity is usually generated with nuclear power plants. There should be enough electricity available. Problems can arise due to destroyed or insufficient grids. In Ukraine there are also restrictions on noise pollution from a heat pump and restrictions on depth up to 50 metres. In addition, heat pumps work best in well-insulated buildings.

  Environment: The impact of heat pumps depends strongly on the emissions of the electricity. The more renewable or low-emission sources in the grid mix, the better the overall impact. A liquid refrigerant with a low GWP value should be used, e.g. R32, difluoromethane with a GWP value of 675 or less.
- **Availability:** Should be available on the Ukrainian market, but a shortage is likely due to the Corona crisis and the war. There are some manufacturers in Ukraine and international brands.

Option 8: Medium-sized Electric Boiler

Electric boilers are used in heating systems of apartment buildings to heat the water that flows through the system. They can be installed centrally in the basement of an apartment building or decentrally in each flat. Decentralised electric boilers on the scale of a flat only work if the heating pipes run horizontally through the unit to be heated. In many buildings, the heating pipes run vertically from the basement to all the flats. The technology therefore only makes sense for systems in which a gas boiler is already installed, which can then be replaced, or if some conversions are carried out.

Medium-sized Electric Boiler

The technology used by electric boilers is commonly known as a way to heat the water in an apartment. As a heating technology however, they heat the water which remains inside the heating system. An electric boiler typically works with a heating rod with 4 kW (heats up to 50 m^2) to 24 kW (heats 300 m^2).

Another option is to install integrated systems where electric boilers supply central heating as well as warm water. Such systems require a 400V power connection and, depending on size, draw large quantities of electricity (e.g. 4 kW heat combined with 12 kW warm water up to 12 kW heat combined with 21 kW warm water).

- **Costs:** The choice of electric boilers is wide. Small boilers for up to 50 m^2 cost up to €700. Operating

costs depend on electricity prices, which are relatively low in Ukraine.

- **Availability:** Parts produced outside the European Union are mainly electronics, such as control technology. The more modern the electronics are, the more challenges we will encounter in the supply chain. When large quantities are ordered, there can be problems in the supply chain. The war in Ukraine is further affecting production, as some companies manufacture parts in Eastern Europe, where production has slowed down and transport has become more difficult.
- **Installation:** If an intact horizontal central heating system exists, installing a new electric boiler or converting from an oil or gas boiler to an electric boiler is not very difficult. With good guidance, even untrained personnel can install these systems, making them easily an accessible technology. However, these types of systems are almost non-existent in Ukraine, as most building complexes are currently heated with district heating. The actual application of electric boilers in flats is therefore likely to be rather limited.
- **Dependencies:** All electric heating options require a stable power supply. They have a load profile that is relatively difficult to support from a system stability perspective. They are usually all used at the same time, which puts a strain on the power grid.
- **Environmental:** Any heating solution, especially direct electric heating, must be accompanied by extensive efforts to improve the insulation of Ukrainian houses. CO_2 emissions depend on the energy sources used to generate electricity. The technology is generally suitable to decarbonise the energy system, but not as efficient as heat pumps.

3.7 What is the electrical capacity at the apartment level?

If the installation of larger medium-sized heaters in the basement of flats is not possible due to lack of resources, installation or availability, it may be possible to use smaller electricity-based heaters. They can be an option and are already used in several flats to provide extra warmth in winter.

However, these technologies are associated with various disadvantages. They place a large load on the electricity grid, especially on the internal infrastructure of the flats. Most flats in Ukraine are not designed for high loads and have a capacity of 3.000 to 5.000 W. For a more detailed explanation, see chapter 5 – Impact on the electricity distribution network. It is possible that the infrastructure or wiring can temporarily be increased to handle higher loads. If only one or two appliances can be operated, it is best to focus on one-room solutions and avoid frost damage to the existing pipe infrastructure.

Option 9: Small Size Heat Pump (Air)

Air-to-air heat pumps can generally be used to heat or cool indoor air, also known as air conditioners or split systems. They consist of an outdoor unit (evaporator) connected via media hoses to one or more indoor units (compressor, condenser, pressure relief valve and air fan) located in the upper part of the exterior walls in the living spaces.

Small Size Heat Pump

To prevent the outdoor unit from freezing in winter, a defrost system is included by reversing the cooling circuit, which requires additional energy and reduces the efficiency of the system. Wifi and remote control, timer and night mode are normally available. Domestic hot water cannot be heated with this technology. For typical Ukrainian flats, one indoor unit each for living room/bedroom and kitchen should be provided, as well as direct electric heating for the bathroom (e.g. infrared heating), if the electrical infrastructure allows it.

The average heating load in typical Ukrainian apartment buildings is a maximum of about 100 W/m². Single room units have about 1.800-3.000 W for about 15-30 m² and 2.500-6.000 W for about 25-60 m².

Small air-to-air heat pumps have some disadvantages. Each room needs an indoor unit for a comfortable room temperature. They have high power consumption. Uncomfortable room climate due to constantly blowing wind and high sound levels (indoor unit approx. 30-50 dB(A), outdoor unit approx. 50-70 dB(A)). Connection to the existing hot water radiator heating system is not possible. The heating of domestic hot water is also not possible with this technology. Direct electric heating or another heat pump are possible for this.

- **Costs:** A single-room air-conditioning system costs about €300-800 + labour, while a multi-room air-conditioning system costs about €1.000-3.000 + labour. A typical apartment building with 60 flats and 2.225 m² living space, 30 two-bedroom and 30 three-bedroom flats would cost about €150.000. Decentralised systems for apartment buildings are therefore possible, but not economical and not sufficient for climate protection goals. First, the

feasibility of a centralised system using the existing water heating system, needs to be checked.

- **Availability:** Should be available on the Ukrainian market, but a shortage due to the Corona crisis and the war in Ukraine is likely.
- **Installation:** Simply attach the outdoor unit to the wall, e.g. under the window, drill a hole of approx. 100 mm for the media hoses (two hoses for the cooling liquid incl. thermal insulation and electric cables).
- **Dependencies and external effects:** In Ukraine, electricity is usually generated by nuclear power plants. There should be enough electricity available. Problems can arise due to destroyed or insufficient grids.
- **Environmental Impact:** The liquid refrigerant can pollute the environment. In addition, air-to-air heat pumps for space heating are not particularly suitable for Ukraine's energy transition goals due to their lower efficiency. In the short term, however, this is an easy-to-install and inexpensive way to provide heating for the winter of 2022-2023.

Option 10: Mobile Heaters

Mobile heaters allow the user to individually control the temperature in each room. This can be helpful in keeping heating costs down and concentrating heating efforts where they will make the most difference. There are two options for mobile electric heaters, namely convection heaters and infrared heaters.

Convection heaters use electricity to heat a coil, which in turn heats a fluid, e.g. hot air, water or other liquids. Air convection heaters include panel heaters and fan heaters. Fluid heaters include oil radiators and water radiators. The difference lies in the way the heat is distributed in the room and the form in which the heat is stored. Around 50% of homes today use mobile electric heaters to supplement district heating. The technology is therefore already widespread and proven. There are two variants of convection heaters:

Panel Heaters and Fan Heaters: Hot air rises naturally and cool air falls. Panel heaters and fan heaters draw in the cool air and pass it over a hot metal coil to heat it. Because convection heaters heat the air, the heat stays in the room even when the heater is turned off. A panel heater is the basic form of a convection heater that draws in the cool air in the room and releases the warm air back into the room, creating a circulation of warm air. They are mainly used as a fixed system on the wall, but can also be mobile. However, the best-known direct electric heater is the fan heater. The fan heater has an electric fan that directs the air over the heat source, heating the air and warming the surrounding room more quickly.

Heating Fans

Oil and Water Heaters: An oil heater or oil radiator uses electrical energy to heat a special thermal oil, which then releases heat over a large metal surface. The oil acts as a heat accumulator and stores the heat. Similarly, convection heaters, which use water to store heat, use electrical energy to heat water that remains in the radiator and warms the room via its metal surface. Oil and water radiators are among the safest types of portable heaters.

Oil Heater

- **Costs:** Convection heating is one of the cheapest options for providing heat to a person. However, the cost of the system can be higher. Operating costs depend on electricity prices. Intermittent or per-day use can be more cost-effective than heating an entire building, as specific areas can be heated. As electricity prices are relatively low in Ukraine, this could be a cost-effective option.
- **Installation:** Mobile convection heaters are one of the most "plug-and-play" heating options available, and they can simply be placed in a room of your choice and plugged into the wall socket. Convection heaters do not take up much space and can be moved to another location if needed. However, fan heaters in particular are known to be fire hazards and should not be used in damp environments.
- **Dependencies:** All direct electric heating options require a stable power supply. Deployed on a large scale, the heaters themselves have an impact on the

stability of the power system. Direct electric heaters have a load profile that is relatively difficult to support from a system stability perspective. They are usually all used at the same time, which puts a strain not only on the power grid but also on the building's system itself. If too many electrical appliances are used at one time, the fuse will automatically switch off. In cases where a fuse is missing or defective, there is a high risk of cable fires. The problem can be exacerbated by the high proportion of inflexible nuclear power generation in Ukraine.

- **Environment:** Decentralised direct electric heating systems are a short-term solution, as their use is not efficient enough to be compatible with long-term climate goals. They step in when district heating and central heating are not available. Although mobile electric heaters can be a short-term support, they should be phased out in the future and replaced by more efficient heating options. CO_2 emissions depend on the energy sources used to generate electricity.
- **Availability:** Convection heaters are readily available on the European market, but with some limitations. The parts produced outside the European Union are mainly electronics, such as the control technology. The more modern the electronics, the more the problems the production will encounter in the supply chain. Ukraine also produces convection heaters. However, due to the war, production may be reduced.

Option 11: Wood-fired Boiler

Wood boilers and stoves are the most flexible biomass heating systems available, considering the quality requirements for the fuel. They can be fired with wood chips, wood shavings or wood briquettes, or alternatively with coal. They are available as slow-burning stoves or as more efficient wood gasification heaters, the latter also being available as CHP units. Logs can be split and stored without large machines. However, the boiler must be fed manually.

Wood Chip Boiler

- **Costs:** Flexibility in fuels allows the cheapest option to be used.
- **Installation:** Wood boilers are usually easy to install on an existing chimney or with an additional chimney on the outside facade. In addition to the boiler itself, space is needed for wood storage. Wood boilers are highly scalable, from single stoves for heating individual rooms to boiler houses for heating entire building complexes.
- **Dependencies:** Due to the flexibility of the fuel, a wide range of locally produced biomass can be used.
- **Environment:** In particular, burning low-quality wood in old, poorly maintained stoves, and under unfavourable combustion conditions produces unnecessarily harmful emissions that can worsen air quality, especially in urban areas. High-efficiency biomass plants can be used as a cornerstone for a decarbonised heating concept if wood is regionally available. However, various issues such as biodiversity should be carefully considered.
- **Availability:** While slow-burning stoves are widely available and used, wood gasifiers are not so widely available. Both are available within a few weeks.

Option 12: Pellet Stoves / Boilers

Pellet heating systems are used to heat individual rooms or flats through to central heating systems in entire buildings. They are available as pure pellet heating systems and as pellet-chip combination systems. Which can easily be converted to one or the other, as well as to the simultaneous use of both energy sources. The calorific value of wood pellets is about 5 kWh/kg. Two kilograms of pellets can replace 1 litre of heating oil or 1 m^3 of natural gas.

Pellet Boiler

- **Costs:** Pellet stoves (air-led) heat the air in the room where they are installed by convection and radiation. From €2.561 for 6 kW to €6.445 for 11,3 kW. Pellet stoves (water-led) are connected to a central heating system and transfer most of the heat to a central heating buffer tank or to a hot water tank. From €4.310 EUR for 8 kW to €5.040 for 25 kW. Pellet boilers: from €4.463 for 12 kW to €21.241 for 100 kW. Pellet condensing boiler from €10.855 for 10 kW to €18.555 for 64 kW. Split log-pellet combi boiler: from €9.850 for 17,7 kW to €14.890 for 45 kW.

- **Installation:** Pellet heating systems are plug-and-play systems. You can use an existing chimney or install a chimney on the outside facade. In addition to the system itself, space is needed for the pellet store. Pellet heating systems come in all sizes, although lower quality pellets can also be used in larger systems.
- **Dependencies:** Pellet production for the European market is one of Ukraine's main exports. In recent years, the use of pellets for heating has already undergone huge development, with the aim of reducing dependence on natural gas, especially from Russia.
- **Environment:** Wood pellet stoves are one of the most efficient and cleanest biomass heating systems. Pellets are available in high quality standards.
- **Availability:** No shortage, delivery time 3 to 4 weeks.

3.8 Is a natural gas connection available?

If the various technologies are not available or cannot be used, natural gas can be a viable option. However, this depends on the distribution network for the gas. The use of natural gas is only feasible if a close connection already exists. It should also be kept in mind that the use of natural gas can significantly increase dependence on Russia.

Option 13: Gas Boiler

The application for gas boilers is quite similar to that of the medium-sized electric boiler. It is possible to install a boiler in a dwelling that requires a horizontal heating pipe system. If this is not possible, a larger gas boiler can be installed in the basement of the building, and the pipes previously connected to the district heating network can be used. The advantage of gas boilers is that they do not overload the electricity grid. However, a connection to the gas infrastructure is required, and the use of natural gas increases dependence on Russia.

Gas Boiler

- **Costs:** Gas boilers have a wide range, but are generally not very expensive. Small boilers for up to 50 m^2 cost up to €1.000. Operating costs depend on gas prices. However, installation in the existing Ukrainian building infrastructure usually requires further installations and piping.
- **Availability:** The parts should be available on the international market. There is no information about production and availability in Ukraine.
- **Installation:** As the installation requires changes to the gas and water infrastructure, it should be carried out by a professional. However, the skills can be learned in a relatively short time.
- **Dependencies:** The use of gas boilers will increase dependence on methane and thus also on Russia.
- **Environmental:** Natural gas is a fossil fuel, but emissions from its combustion are lower than those from coal or oil. Nevertheless, for a potential decarbonisation of the energy system, electricity-based solutions are preferable to integrate low-carbon technologies.

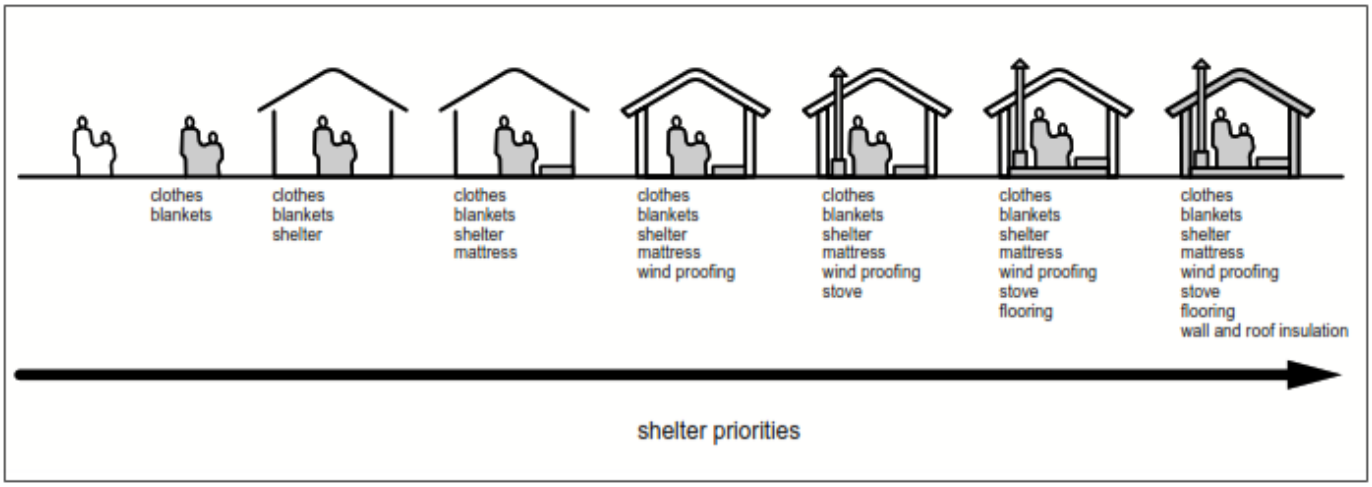
3.9 Can certain fire safety standards and regulations be met? Winterisation concept

Winterisation is a life-saving, critical assistance service, aimed at protecting people from harsh winter conditions. When preparing a winterisation response, time is the key to success. If central heating cannot be restored before the onset of winter, other solutions must be found. Depending on the situation (available resources, capacities, needs, vulnerabilities), the assistance must be flexible and easy to implement. Winterisation is a programme that can be implemented in a short time and on a large scale, to meet the needs of many thousands of families. Examples from other countries in the region have shown that winterisation can be successfully implemented with the help of volunteer teams and short training programmes.

What does winterisation mean?

Winterisation ensures that a wide range of damaged dwellings - flats, family houses or other buildings adapted for human habitation - can be used as life-saving shelter during the cold months. Depending on the implementation of the programme, winterisation can also help revitalise local economies and markets. With the right technical guidance, winterisation can be the first step in a phased approach to rehabilitating houses and restoring a better building fabric.

When many people are forced to leave their homes due to armed conflict, they are displaced, either within their own country (internally displaced persons) or to other countries (refugees). In both cases, they often live in shelters that are only for temporary use and have only a minimum of personal belongings with them. Once the areas are liberated and relative security is restored, many people want to return quickly (returnees). Buildings and infrastructure in these (liberated) areas are often



Shelter priorities in cold climates. Source: Tom Corsellis, Antonella Vitale (2005). Transitional settlement. Displaced populations. Oxfam GB, University of Cambridge

damaged. Knowing the number, and locations, of households in need, will be one of the biggest challenges in Ukraine for this winterisation response.

Winterisation assistance is needed for IDPs and returnees who are in relatively safe areas, but may not be able to fall back on their usual coping strategies (winter clothing, housing, heating, sufficient food ...). In particular, returnees in formerly contested areas often live in damaged buildings, cut off from functioning infrastructure and energy networks. (In areas where the conflict is still ongoing, only a very limited amount of aid can be provided due to security and logistical problems).

Delivery of Convection Kerosene Heaters

In a humanitarian context, winterisation support starts with the provision of personal insulation layers (appropriate winter clothing, blankets), protection from the elements (wind, rain, snow, etc.) and adequate insulation of the shelter, as well as draught reduction to prevent heat loss. The provision of stoves/heaters with the appropriate energy source is an essential part of the winterisation strategy. Modalities include in-kind as well as financial support and technical assistance.

Emergency Fuel Delivery

"One warm room" approach

An effective form of winterisation in many conflict-affected countries, where tens of thousands of people are housed, in makeshift shelters, unfinished and damaged buildings, is the 'warm room' concept, where simple heaters and fuel vouchers are widely distributed and enough simple building materials are provided to seal and basically insulate a space where all people can survive during the coldest season. This approach was first developed in the Balkans in the 1990s. It was then adapted for Georgia in 2008 and more recently used in areas such as northern Iraq and north-eastern Syria. The aim was to provide decent shelter for people affected by the conflict and to protect them from harsh winter conditions. The primary outcome is at least one warm room per household.

Insulation according to the "one warm room" approach

Key activities

1. **Measures to prevent heat loss in this room**, preferably with technical advice. Sealing gaps in the walls, insulating the floor or replacing doors or windows are important. If there are no suitable windows, a double layer of plastic sheeting will help.
2. **Providing the most urgent building materials and tools** (if possible, with local companies/traders) - for example wooden slats, plastic sheets, cement, nails, tools (financial support if markets work). Elaboration of simple technical advice on how to reduce heat loss in damaged buildings, tailored to the different types of dwellings and the relevant situation.
3. **Provision of heating equipment and corresponding energy** (electricity, solid fuels or gas), depending on availability in local markets and people's preferences. Preparing the supply and storage of heating fuels for the duration of the winter/heating season.
4. **Provision of winter clothing, blankets and carpets:** When markets are functioning, cash assistance for those in need is recommended. The overall strategy needs to consider additional support for people who are less able to prepare for winter and buy/carry fuel themselves.

Winterisation heating options

In emergencies, when resources are scarce and people are housed in makeshift shelters, damaged buildings or buildings with damaged infrastructure, it is recommended that at least one warm room per household is established. Basic insulation measures for this room, such as sealing openings/cracks in the outer walls, and the installation of a heater are essential components of the one warm room concept.

The following mobile heaters are temporary solutions that should be considered if the central heating cannot be restarted before the cold season begins. These solutions can only be applied if minimum fire safety standards can be met.

Fire extinguisher in action

Option 14: Solid Fuel Heaters

Wood/charcoal stoves have long been the most widely used technology for heating; therefore, it remains a familiar and generally accepted technical solution. Increasingly, biomass pellets are also being produced in Ukraine, which can also be used in such stoves. Burzhuika stoves (free-standing cast-iron heaters/stoves) are very well known and still used in rural areas, family homes and by the army.

Solid Fuel Heater - Burzhuika

Every stove must be connected to a chimney, or requires a flue pipe to the outside; it may therefore be necessary to knock a hole in an outside wall or connection via a window. A dry storage place for the fuel (wood, coal or pellets) and a safe disposal place for the ashes must be considered. As this is an individual solution, each household may wish to store the fuel in their home - consider the maximum point load.

This poses a major logistical challenge and overwhelms the building regulations for a multi-storey apartment block. The responsibility for implementation depends on the applicable regulations. Permission from the owner/housing association or local authorities may be required as this has implications for the fire safety of the whole block of flats.

- **Costs:** To determine the range of average costs, a market analysis in different regions of Ukraine is necessary. A German brand cooker with all burners costs about €500 incl. VAT, plus transport costs. In

Ukraine and Eastern Europe there are other local brands that are cheaper - prices from €150.

- **Availability:** Burzhuika stoves are manufactured and available in Ukraine, so far demand has been higher in rural areas. Dependence on a functioning market for solid fuels (coal, briquettes, wood, pellets), but in emergencies people can collect and burn available material (although this is not recommended). The availability of coal for private consumption seems to be very limited. Coal available on the Ukrainian market might be limited to factories/industry.
- **Installation:** Relatively easy to install by someone who has basic construction skills. It is important that the flue pipe is properly connected and fixed. It's important to verify if the installation (especially in a multi-storey residential building) requires official approval.
- **Dependencies and external effects:** Under normal circumstances, installation is strictly prohibited, with some exceptions. Since heating for individual homes is absolutely essential during the winter months, we recommend developing technical guidelines for proper installation, fire safety, CO poisoning prevention and insulation improvement tips. Every household needs a dry storage room. Ash disposal must be organised. This should be seen as a last resort.
- **Environmental Impact:** This is a temporary (short to medium term) solution until the central heating network can be reconnected, ideally already in an improved form (sealed and insulated). The temporary use of individual heating devices/technologies should give the necessary time to repair and improve the existing district heating network and provide life-saving heating comfort to the war-affected people during the next winter season.

Option 15: Portable Gas heaters

Butane Heater

Portable gas heaters are used in Ukraine in areas without central heating and for temporary heating of rooms that are not in constant use. The advantages are that gas cylinders are easy to refill and safe to store. Types of gas include propane, butane or a mixture of both (such as liquefied petroleum gas). Gas heaters come in different sizes and shapes. Models that produce radiant heat should be preferred. The responsibility for implementation depends on the applicable regulations. Approval from the owner/housing association or local authorities may be required, as this has implications for the fire safety of the whole block of flats.

- **Costs:** A market assessment in Ukraine and neighbouring countries is required. Information on the cost of the devices is based on online research. Costs range from €100 to €150 per heater. LPG prices range from ₴40-48/l or €1,10-1,30/l.
- **Availability:** Many gas heaters are manufactured in Europe and Asia. The technology is available on the Ukrainian market, through retail chains as well as online - availability of large quantities could be problematic as the technology is not very common. Delivery can take a week to a month for appliances up to 10 kW. Each household needs at least two gas cylinders, one of which is in use and the other needs to be refilled - gas cylinders are available. The availability of large quantities is not known. Gas bottles can be refilled at gas/filling stations in every city in Ukraine, it is also possible to fill up with LPG (Liquified Natural Gas). The gas cylinders have to be refilled regularly; it is not known whether the availability of this gas can be ensured over the entire heating season.
- **Installation:** Easy to operate, no fixings required, the technology is scalable. The room in which the heater is operated should be ventilated to avoid CO poisoning. Mobile heaters take 20 to 60 minutes to install if there is a safe place for installation and ventilation. A prepared technical manual for proper use and installation of such heaters is recommended, as currently only contractors and workshop owners in Ukraine have experience with the use of gas heaters.
- **Dependencies and external effects:** Dependence on a functioning market for the heaters, and refilling possibilities for the gas cylinders. All LPG in Ukraine is supplied by other European countries, prices have increased, and there is currently a slight shortage. There are legal restrictions on the installation of this heating technology, especially for multi-storey apartment blocks. Since heating is absolutely essential during winter, we recommend providing technical guidelines for proper installation, fire safety, CO poisoning prevention and tips for improving insulation. Most portable indoor gas heaters available on the European market are equipped with ODS (oxygen detection safety pilot) technology and automatic shut-off valve - a prerequisite for compliance with DIN EN 14543; heaters without this safety technology are banned for indoor use in Ukraine.

- **Environmental Impact:** It should be seen as a temporary (short-term) solution. The increase in fossil gas consumption is definitely not compatible with the goals of Ukraine's energy transition, but is acceptable in times of emergency. Propane/butane gas can be replaced with biogas.

Option 16: Kerosene Heater

Kerosene is also called lamp oil, as this was a common use. Kerosene heaters were mainly used in rural areas in Ukraine, but have been replaced by more efficient technologies. Portable kerosene heaters are still used in weekend huts, camping, on boats or in emergencies. One advantage is that kerosene is easier and safer to store than petrol, for example.

Kerosene heaters come in different sizes and shapes. Models that offer cooking facilities should be preferred. The responsibility for implementation depends on the applicable regulations. Approval from the owner/housing association or local authorities may be required, as this has implications for the fire safety of the whole block of flats.

Kerosene Heater

- **Costs:** To determine the range of average costs, a market analysis in different regions of Ukraine is necessary. The cost of a small portable heater ranges from €40 to €80, for a slightly larger one about €150. The prices for kerosene - ₴90/l (approx. 3 €/l).
- **Availability:** Most kerosene heaters are manufactured in Asia. Due to current supply chain disruptions, availability in large quantities might be difficult, but 300 to 400 units are immediately available in Ukraine. The technology is also available in other Eastern European countries and in Germany. Oil fuel availability is currently not reliable in Ukraine, kerosene is not a common fuel in the country.
- **Installation:** Easy to use, no fixings required. The room should be ventilated to prevent CO poisoning. The technology is simple and scalable, but most people in Ukraine are not familiar with it.
- **Dependencies and external effects:** Consider any possible legal restrictions, especially for multi-storey dwellings. Since heating is absolutely essential during winter, we recommend providing technical guidance on proper installation, fire safety, CO poisoning prevention and tips on improving insulation. Dependence on a functioning market for the heaters and kerosene. It is very likely that kerosene will have to be imported and there is a lack of large storage facilities for kerosene. Kerosene must be stored in a closed container. Since it is an individual heating solution, each household needs a place to store such a container (preferably outside the living room).

Environmental Impact: This is a temporary (short-term) solution. The increased consumption of fossil oil is definitely not compatible with the goals of Ukraine's energy transition, but is acceptable in times of emergency.

3.10 Conclusion and Technology Overview

The technology path shows the preferred technology for each situation. The higher the option in the diagram, the better the technology is in general.

However, the situation in Ukraine is very heterogeneous and reconstruction of the heating infrastructure can depend heavily on local conditions. The occupancy of a building is an important factor in determining whether it should be connected to the central heating network or if more decentralised technologies should be used. If the boiler or network is damaged and can be repaired in a reasonable time frame, this should be the preferred strategy. If a boiler is too badly damaged, it can be replaced with new technology. There are various options such as heat pumps, electric boilers or combined heat and power plants. Usually, all these options take several months or years to install, especially on a large scale. Therefore, their procurement should start as soon as possible. If they are not available by the winter of 2022-2023, decentralised transitional solutions could be a suitable short-term solution. In emergencies, when resources are scarce and people are housed in makeshift shelters, damaged buildings or buildings with damaged infrastructure, it is recommended that at least one warm room per household is established. Basic insulation measures for this room and the installation of a heater are essential components of the one warm room concept.

Table 1 below provides an overview of all the options presented in this chapter. The technologies were analysed and evaluated in five different categories (costs, availability, installation, dependency and environmental effects). Due to the heterogeneous conditions in Ukraine, they are only a rough estimate.

Technology	Costs	Availability	Installation	Dependencies	Environmental
1. Repair of Heating Network	8	8	7	6	9
2. Large-scale Heat Pumps	4	1	2	8	9
3. Large-scale Electric Boilers	6	4	6	6	7
4. Combined Heat and Power	6	4	6	2	5
5. Wood Chip Boilers	5	3	6	8	6
6. Large-scale Thermal Storage	6	4	7	9	9
7. Water Based Heat Pumps	6	2	3	7	8
8. Air Based Heat Pumps	8	8	9	5	7
9. Portable Heaters	9	10	10	3	6
10. Small-scale Electric Boilers	4	7	7	4	7
11. Wood-fired Boilers	9	9	9	8	3
12. Pellets Boilers	7	7	6	8	8
13. Gas Boilers	4	8	7	8	4
14. Solid Fuel	8	8	9	8	3
15. Portable Gas Heaters	8	6	9	7	2
16. Portable Kerosene Heaters	9	2	9	6	1

Table 1: Technology Overview

4 Limitations of Power Distribution Grids for the use of P2H Technologies

With defective and unrepairable heat grids and district heating, Ukrainian households can be supplied to a certain extent with heat generated from electricity (Power2Heat applications - P2H). P2H applications consume a comparatively large amount of electricity at the household level, comparable to a kitchen cooker or kettle with 2,000 to 4,000W. However, these applications have operating times of up to 24 hours per day when only heat is supplied. Any Power2Heat application that is connected to the public electricity grid therefore has an impact on the electricity distribution grid, as the energy required for heat generation is transported in the form of electricity via the distribution grid to the respective residential unit.

4.1 Introduction

The characteristics of the installed electricity cables and lines, together with its safety concept ("Schutzkonzept"), e.g. the respective overcurrent protection devices, determine the maximum possible amount of electricity (amperage) that can be used and transported at each level of the household and distribution network. Thus, the available electricity can potentially be used for heat supply. The following levels are relevant in this context:

1. **Household level** (individual dwelling unit) (circuit breaker and distributor)
2. **Apartment block** (house connection/service drop)
3. **Main distribution board** and secondary distribution line
4. **Medium voltage level** (primary distribution lines)

With regards to supply, there do not appear to be major constraints on electricity generation, as demand has fallen significantly since the start of the war. Electricity demand is on average 37% lower than before 24 February 2022, primarily due to lower industrial and commercial demand.

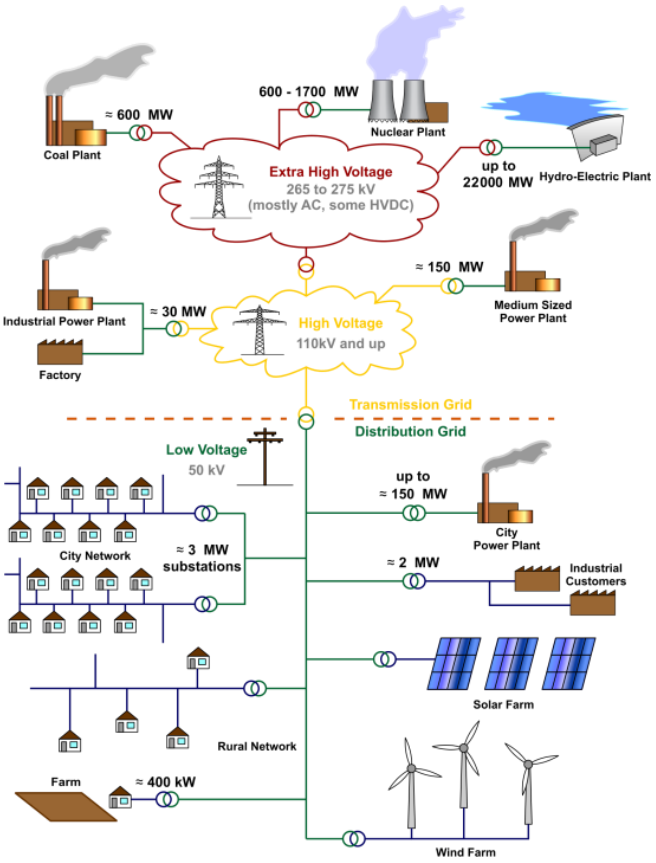
4.2 Overview of relevant aspects

In this context, it is highly relevant to determine how many residential units can be supplied (exclusively) with decentralised and, above all, in-house generated heat and thus the local electricity grid. Furthermore, it is important to determine which (additional) measures are required to keep the local and regional power grid stable, and thus avoid power outages. Therefore, two aspects are considered in the following:

Maximum Load: Determination of the respective maximum load, defined by the underlying safety concept (upper load or amperage limit) of the individual levels of the electricity grid as well as the households.

1. Can an entire building or a whole city district be supplied with direct electric heating?
2. How can overloads of individual circuits be avoided? E.g. caused by a 1-phase consumer (electric heating) at the 3-phase house connection. If by chance all heaters are connected to the same phase, an overload will occur. Action: It is probably not possible to determine the phases of the individual outlets because they are not specifically documented. In the case of a tripped fuse, the problem can be solved by using a different outlet.

Replace or Reinforce: Check whether certain network resources need to be replaced or reinforced in the short term as a preventive measure to avoid overloading the system. E.g. temporary and mobile transformers on site or additional laying of auxiliary cables.



Schematic structure of an electrical grid from distribution to transmission grid. Source: Wikipedia

Monitoring: Where possible and necessary, monitoring of the network status is advisable, e.g. in areas with a high risk of overload. E.g. by retrieving drag indicator ("Schleppzeiger"), if this is already available, or by using mobile measuring devices.

Grid-friendly: (Grid-serving) operation of the Power2Heat units can avoid overloading the existing infrastructure capacities (peak load shaving) Grid-friendly measures when approaching peak load:

1. Identify the standard load profile prior to the start of the war and, if possible, also for the current situation. This is a task for all actors: communicator, DSO, consumers, public authorities.
2. Only use electric heaters outside of peak load times. Also, only when other high-consumption appliances are switched off (such as cooker, kettle, toaster, drill, hair dryer, washing machine, vacuum cleaner, etc.). The responsibility lies with the consumer, communicator.
3. Develop and implement appropriate communication strategies to achieve "grid-friendly" behaviour. The responsibility lies with the communicator (e.g. public authority) and the DSO.

4.3 Network layers

Sub-distribution level

With regards to electricity in older buildings, it appears that the distribution and sub-distribution network only have enough installed capacity to provide a minimum heating capacity of about 3-5 kW per flat. This would be sufficient for one warm room, but not for the whole flat.

In this case, it would be prudent to establish the need to either reinforce, or replace, certain electrical facilities of the internal house network, in the short term in order to increase the electrical heating possibilities and avoid overloading the system. This could be the temporary laying of auxiliary cables and electrical panels.

If this is not possible and only one room can be heated, it is essential to measure and monitor the temperature in the remaining unheated rooms. If the temperature in these rooms falls close to or below 0°C, preventive measures must be taken to avoid severe damage to the building infrastructure (e.g. draining the water pipes to prevent destruction of the pipes by freezing). This may result in flats becoming temporarily uninhabitable due to lack of water.

In apartments with a higher power rating of 7-15 kW, minimal electric heating of half or even the entire apartment may be possible. These are, for example, newer buildings or houses with existing electric boilers.

- **Old houses 60-80s:** The maximum load of the individual flat is approx. 3-5 kW.[2] We assume that the circuit breakers are configured at a similar level in all cases.
- **New houses (with electric stoves):** The maximum load of a single dwelling is approx. 7-15 kW.[3]

Apartment block level

The simultaneity assumption for the load of all dwelling units together is decisive for whether the house connection point is able to supply enough energy for electric heating to the households.

Apartment buildings are often collectively owned by the respective flat owners (often the residents). There is no clear data or overview of which flat blocks or individual flats have been renovated, e.g. insulated or fitted with new electricity cables.

The maximum load of the entire flat block = maximum load of the flat * simultaneity assumption * number of flats. With a simultaneity assumption: approx. 80%.

---

[2] First expert workshop Dena – Ukraine on 24.05.2022. comparable value in Germany is 14,5 kW for first apartment and 3,6 kW for 20 apt. (see DIN 18015-1 without electric boilers for hot water)

[3] First expert workshop dena – Ukraine on 24.05.2022

Street level

The installed network capacity for the secondary distribution lines and the main distribution panel is determined by the maximum load of each connected end consumer and the simultaneity assumption. This is crucial in determining whether the low-voltage grid is capable of supplying enough energy to households for electric heating.

Assumption of simultaneity by the grid operator: This varies depending on the characteristics of the connected households and consumers. On average, 4-5 kW of simultaneous consumption per household is assumed. The maximum load of the low-voltage grid = maximum load of the end consumer * simultaneity assumption * number of end consumers. Overcurrent protection threshold: Appropriate configuration of overcurrent protection is assumed.

Medium voltage level

There do not appear to be any bottlenecks in the medium-voltage grid at present, as the industrial and commercial sectors currently have low demand and the medium-voltage grids tend to be underutilised in this situation.

4.4 Conclusion

It appears that the distribution and sub-distribution network only have enough installed capacity to provide a minimum heating capacity of about 3-5 kW per flat with electricity. This would be sufficient for one warm room, but not for the entire flat.

In this case, it is essential to measure and monitor the temperature in the remaining unheated spaces. If the temperature in these rooms falls close to or below 0°C, preventive measures must be taken to avoid severe damage to the building infrastructure (e.g. draining the water pipes to prevent destruction of the pipes by freezing). This may result in temporarily uninhabitable dwellings due to lack of water.

Heating an entire flat with electricity depends on the specific circumstances (e.g. year of construction, insulation, laid power cables & assumed simultaneity etc.). In the best case, this should be checked individually on site.

If all households constantly use two or more electric heaters or more than 4 kW, the limit of the low-voltage grid may be reached and it may not be able to cope.

In this case, it might be prudent to consider reinforcing or replacing certain grid resources at short notice to prevent the grid from being overloaded. E.g. additional laying of auxiliary cables or temporary and mobile transformers on site.

In addition, it may be advisable to monitor the condition of the network where possible and/or necessary, e.g. in areas with a high risk of congestion. This can be done, for example, by retrieving information from drag indicators or by using mobile measuring devices.

If this is not possible or does not sufficiently relieve the situation in the grid, it is of great importance to use intensive consumption appliances such as electric heaters alone and not at the same time as other large consumption appliances (such as stoves, vacuum cleaners, etc.). In this context, an effective communication strategy is absolutely essential to make residents aware of the possibilities and restrictions of electric heating. In this context, it is also important to introduce "emergency" channels for the electricity grid (e.g. via social media, etc.) so that people can be informed when a critical situation occurs in the grid and there is a need to reduce their electricity consumption for a certain period of time. A dialogue with a German distribution system operator (DSO) like "Westnetz" can be useful to develop specific measures and strategies. However, adapting existing measures or benchmarks to local needs, circumstances and culture is essential.

www.energypartnership-ukraine.org