Market study on mitigation potential for heat pump and commercial refrigeration equipment in Ukraine

In the framework of the project "Capacity Building for the Innovative Application of Energy-Efficient and Climate-Safe Technologies RACHP in Ukraine"

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Kurzbeschreibung/ Abstract

This study presents an overview of the situation in Ukraine's market relating to the current market and future demand for heat pumps and commercial refrigeration appliances. Both sectors are cases where significant greenhouse gas savings can be achieved through the transition to low GWP, natural refrigerants and highly energy efficient equipment. The successful transition to low GWP solutions has been successfully deployed in the EU and is equally feasible in Ukraine. This project has established three guidelines based on the best practices in the EU on regulations, refrigerant safety and training of technicians which can be accessed for free under the website of the Ukrainian Refrigeration Association[1].

Diese Studie gibt einen Überblick über die Situation auf dem ukrainischen Markt in Bezug auf den aktuellen Markt und die zukünftige Nachfrage nach Wärmepumpen und gewerblichen Kühlgeräten. Beide Sektoren sind Fälle, in denen durch den Übergang zu natürlichen Kältemitteln mit geringem Treibhausgaspotential und hoch energieeffizienten Geräten erhebliche Treibhausgaseinsparungen erzielt werden können. Der erfolgreiche Übergang zu Lösungen mit niedrigem Treibhausgaspotential wurde in der EU erfolgreich umgesetzt und ist auch in der Ukraine wirtschaftlich und technisch machbar. Im Rahmen dieses Projekts wurden drei Richtlinien auf der Grundlage bewährter Praktiken in der EU zu Vorschriften, Kältemittelsicherheit und Ausbildung von Technikern erstellt, die auf der Website des Ukrainischen Kältetechnikverbandes kostenlos zugänglich sind.

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[1] http://ref.org.ua/projects

1 Introduction

1.1 Country background

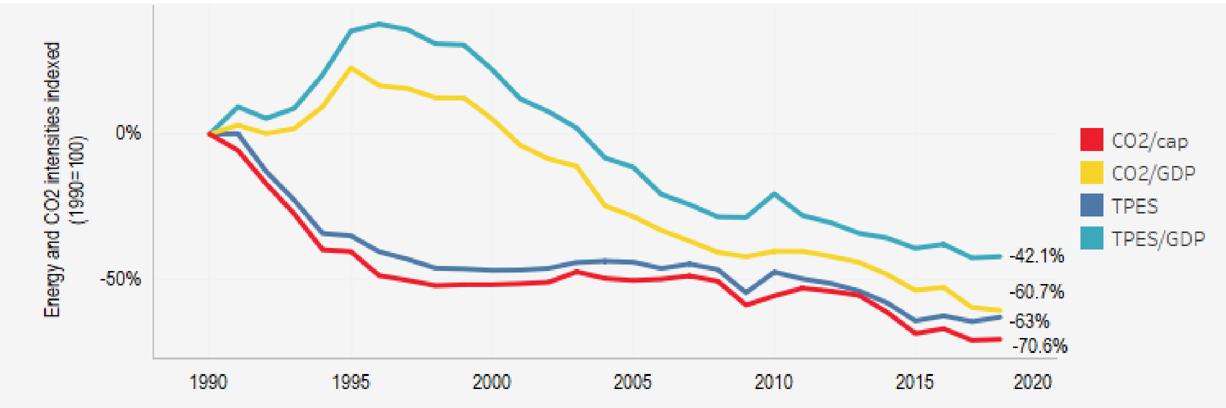
With a population of approx. 42.2 million (2018)[2], Ukraine, a lower middle-income country, is situated in Eastern Europe and bordered by Russia, Belarus, Poland, Slovakia, Hungary, Romania, Moldova, and the Black Sea. Ukraine's gross domestic product (GDP) was 131 billion USD in 2018[2]. Currently, Ukraine is going through a political and an economic transition. The 2014 border conflict between Russia and the Ukraine caused crisis in many areas, leading to an economic decline and to a long-term divide in politics and business within the country and the region. Even though some progress has been recently made and the economy of Ukraine has started to grow again, the country still continues to suffer under high unemployment and inflation rates.

Table 1: Key indicators on Ukraine's economy, 2018

Indicator	Value
Population, million[2]	42.2
Number of households, million[3]	16.3
GDP, US$ billion[2]	131
GDP per capita, US$[2]	2,975
Inflation, percent[2]	9
Employment rate, percent[2]	66.3
CO_2 emissions[4], metric tonnes per capita	4.47

Table 1 presents main indicators of Ukraine's economic performance whereas the trends of indexed energy and CO_2 emission intensity since 1990 are illustrated in Figure 1. As shown, the economy in Ukraine has used its primary energies effectively with declining fuel intensities after the year 2000 and again after 2012. However, despite these decreasing energy intensities in recent years, Ukraine's energy consumption per unit of GDP is almost 3-fold that of the OECD average[5] whereas the intensity of CO_2 emissions per unit of GDP is 3.2-fold the EU average[4].

Figure 1. Intensities of energy and CO_2 emissions in Ukraine indexed vs 1990, 1990-2018) (%)



Source: IEA Data Statistics, EDGAR

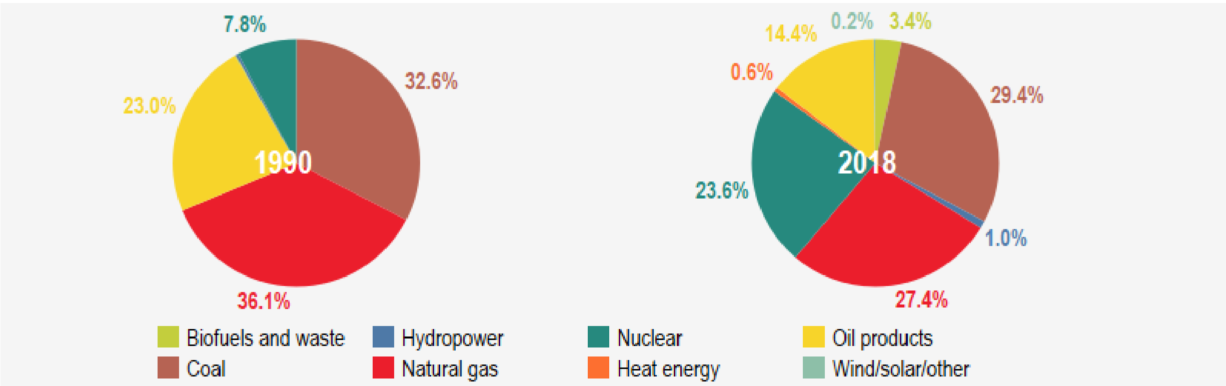
Having ratified the Paris Agreement, Ukraine has committed itself to its mitigation targets and is also a party to the Montreal Protocol. Since the Kigali Amendment entered into force/ was ratified on January 1st 2019, Ukraine has been under obligation to reduce its CO_2-weighted consumption of HFCs by 85% in relation to the baseline by the year 2036[6]. However, the Ukraine is not yet in the list of countries that have ratified the Kigali Amendment[7]. Ukraine submitted its 6th National Communication to the

(2) Trading Economics, World Bank
(3) State statistics Service of Ukraine, average 2.6 persons per household – the number is approximated, since there is no official census
(4) Joint Research Centre, EC, Emissions Database for global Atmospheric Research (EDGAR)
(5) OECD 2019, Snapshot of Ukraine's Energy Sector, https://www.oecd.org/eurasia/competitiveness-programme/eastern-partners/Snapshot-of-Ukraines-Energy-Sector-EN.pdf
(6) The baseline is defined as the average HFC production & consumption between 2011-2013 and 15% of HCFC baseline. Ukraine is a developed country under Article 2 Group 1 of the Kigali Amendment.
(7) https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-2-f&chapter=27&clang=_en#3

UNFCCC in 2012. In 2019 the Ministry of Energy and Environmental Protection of Ukraine prepared the GHG emissions inventory, still exists only as a draft), which covers the period from 1990-2017[8].

Ukraine's economy is dominated by the mining, construction, electricity, and gas industries. In 2018 the Ukraine's total primary energy supply (TPES) was 93.2 Mtoe, 63% less than the supply in 1990 (see Figure 1). Table 1 presents main indicators of Ukraine's economic performance, whereas emissions intensities as of 1990 are illustrated in the trends of indexed energy and CO_2 . As shown, the economy in Ukraine has used its primary energies effectively with declining fuel intensities after the year 2000 and again after 2012. However, despite these decreasing energy intensities in recent years, Ukraine's energy consumption per unit of GDP is almost 3-fold the OECD average, whereas the intensity of CO_2 emissions per unit of GDP is 3.2-fold the EU average.[4] Even though changes have taken place in the structure of the TPES in Ukraine due to the introduction of low-carbon technologies, the primary energy supply is still dominated by fossil fuels that accounted for nearly 71% of the total in 2017 (see Figure 2). The heating sector is largely dependent on the use of fossil fuels. The heat pump market penetration is still at an early stage. In 2017[9] heat pumps accounted for only 1% of energy used for heating purposes.

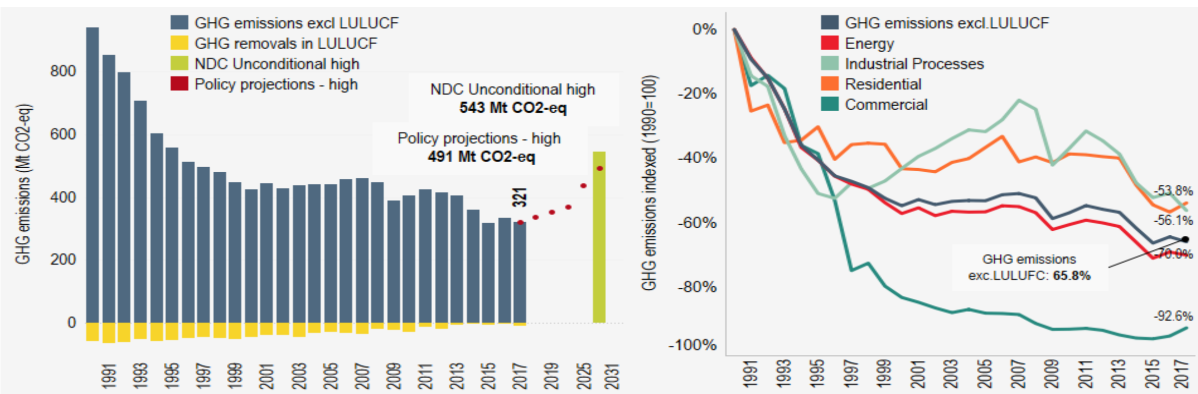
Figure 2. Breakdown of total primary energy supply in Ukraine by sources, 1990 (left) – 2018 (right)



Source: UKRSTAT

By releasing 321 MtCO2-eq of GHG emissions in 2017[10], Ukraine is among the largest greenhouse gas emitters on the European continent. This total amount of GHG emissions was equal to 7.2% of the overall GHG emissions in the in the same year. The energy sector was responsible for 68% of total GHG emissions even though these emissions had a significant decrease of 70% since 1990. Following the heavy-industry collapse post-Soviet Union after 1990, the GHG emissions saw a significant drop up until 2000 (see Figure 3). Overall, Ukraine's GHG emissions decreased by 65.8% between 1990 and 2017. Meanwhile, after the drop in 1996, the emissions from industrial processes increased up until 2007 following a decreasing pace during the crisis period from 2008-2009. After the increase in 2011, these emissions have been decreasing further. In 2017 these emissions were 56% below the level they had been in 1990. GHG emissions from the residential sector, as well as those from natural gas[11], have decreased over the years by more than 53% when compared with 1990.

Figure 3: Ukraine's climate performance from 1990 to 2017 - policy projection (high) and NDC unconditional projection (high) up to 2030



Source: UNFCCC GHG Inventory Data, Climate Action Tracker[12]

(8) Ukraine's GHG emissions inventory (1990-2017), https://menr.gov.ua/files/docs/Zmina_klimaty/kadastr2017/Ukraine_NIR_2019_draft.pdf
(9) Ukraine 3rd Progress Report on renewable energy sources, https://www.energy-community.org/implementation/Ukraine/reporting.html
(10) UNFCCC, https://di.unfccc.int/detailed_data_by_party
(11) Including emissions during exploration, production, processing, transmission, distribution, storage, etc.
(12) Climate Action Tracker, https://climateactiontracker.org/countries/ukraine/

1.2 Objective of the study

The presented study will assess the regulation framework for the transition to energy efficient and climate friendly appliances in the two focus sectors of commercial refrigeration and heat pumps. It will also estimate the current state and projected size of the market to quantify the mitigation, energy saving potential and market potential of climate-friendly and energy efficient appliances in these subsectors. Cooling appliances have a climate impact through their electricity consumption and refrigerant use. However, old energy inefficient equipment is still commonplace and commercial refrigeration equipment often still deploys ozone and climate damaging HCFCs. Regardless of its own natural gas production, Ukraine is heavily dependent on imports to cover the country's needs. The introduction of modern, energy-efficient cooling technology and heat-pumps in combination with climate-friendly refrigerants with a low Global Warming Potential (GWP), renewable energies as well as the required technical training to handle these climate friendly technologies will be required for Ukraine to meet its international obligations, get closer to carbon neutrality and gain energy independence.

In its transition process, Ukraine can strongly benefit from the experience of the EU and the established structure for the transformation of the RACHP sector towards low carbon technologies. This is regulated under the EU F-gas Regulation (EU Reg. No. 517/2014) for the use of low-GWP refrigerant use and energy performance requirements for heat pumps with the relevant Eco design and energy label regulations (EU Reg. No. 814/2013 and EU Reg. No. 812/2013 with the eco-labelling requirements 2007/742/EC, amended in 2011 & 2013) and for commercial refrigeration equipment with the Eco design Regulation (EU Reg. No. 2015/1095) and the Labelling Regulation (EU Reg. 2015/1094). The further stabilization of the country and economic recovery can be greatly supported through international financing and cooperation. Cooperation between European countries and market actors in the area of climate policies and technologies will be economically beneficial and advantageous for the required transition to a low carbon pathway.

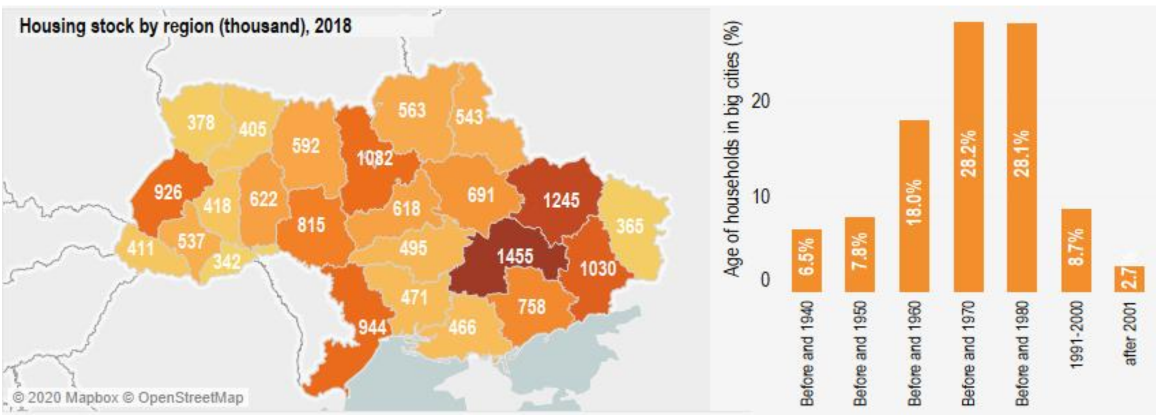
2 Heating/cooling demand drivers and gas usage in Ukraine

2.1 Heating/cooling demand drivers

Ukraine's climate can be characterized as continental, with cold winters and hot summers. The average winter temperature ranges from -8 ° to -12 ° C and in the southern regions it stays around 0 ° C. The average summer temperature ranges from +18 ° to 25 ° C, while in the afternoon it can reach more than +35 ° C[13]. The temperatures in Ukraine are predicted to further increase in the future. Mean annual temperature is projected to rise by 2.6°C by 2050 and number of annual hot days with a temperature above 35°C could rise by 12.8 (days) (RCP 8.5, High Emission)[2].

Urban population in Ukraine dominates with a share of 65%[14], with the biggest cities being Kyiv (capital), Kharkiv, Odessa, Dnipropetrovsk, Donetsk and Lviv. The housing stock in Ukraine was 17.1 million in 2018 with buildings from the 1970s and 80s dominating (see Figure 4)[14]. The heating sector in Ukraine is dominated mainly from space and water heating for residential, commercial, industrial and public buildings. However, it also includes the industrial heat needed for production processes. In 2018 the final heat consumption in Ukraine reached 7.5 Mtoe[14].

Figure 4. Housing stock in Ukraine by region (in thousand) – Age of households in big cities (%) (2018)



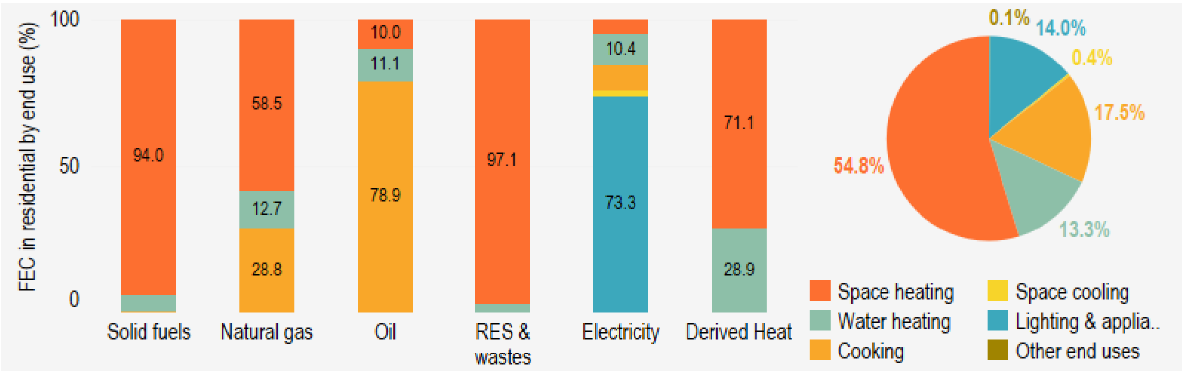
Source: UKRSTAT

([13]) 6th National Communication of Ukraine on Climate Change, 2013

([14]) State Statistical Service of Ukraine, http://www.ukrstat.gov.ua/druk/publicat/kat_u/2018/zb/07/zb_sdhdu2018pdf.pdf

Around 40% of Ukrainian households rely on district heating companies (DHCs) for the provision of hot water and heating[15]. Nearly 55% of final energy consumption in the residential sector is used for space heating. Almost 60% of natural gas in Ukraine and 97% of RES and wastes is consumed for space heating (see Figure 5). Moreover, the DH system in Ukraine was built during Soviet times and approx. 70% of the heating networks are obsolete and their deterioration causes bursts and frequent power outages in cold months. So, this system has a low energy efficiency, high losses, elevated CO_2 emissions and increased energy costs that have an impact on residents and businesses. This implies that the old systems will have to be replaced in the near future.

Figure 5. Distribution of final energy consumption in Ukraine's residential sector by end use in 2018



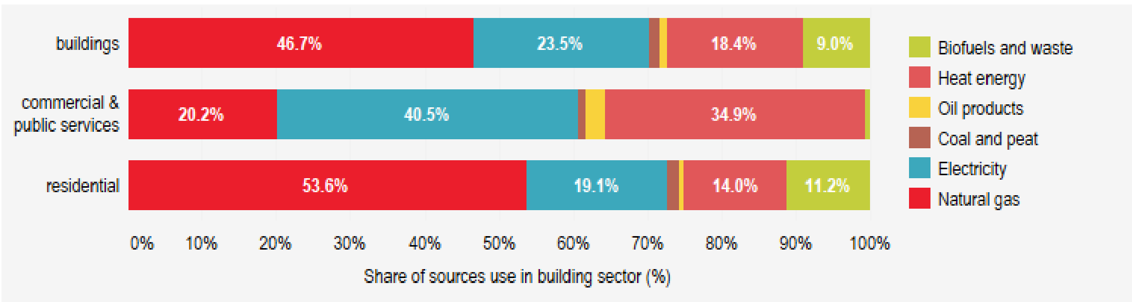
Source: UKRSTAT

2.2 Gas usage

The residential sector accounts for 35% of Ukraine's total final energy consumption[16] and thereby dominates all other sectors, i.e. industry 32% and transport 20%. Within the residential sector about 40% of the total final energy is consumed in district heating and the rest in individual buildings. About 54% of the residential energy supply is generated from natural gas (see

Figure 6). Within the residential sector, 80% of the energy used for district heating originates from natural gas (18 bn m^3 or 620 PJ in 2010). In contrast, the commercial and public sub-sectors source most of their energy, i.e. 41%, from electricity. 80% of housing stock in urban areas is equipped with facilities for gas supply and more than 78% are connected to central heating[14].

Figure 6. Share of fuels and sources used in building sector in Ukraine, 2018



Source: UKRSTAT

From 2015, Ukraine covered its natural gas import requirements with supplies from the European market. Ukraine imported 13.7 billion cubic meters (bcm) of natural gas in 2017, which is more than 60% below the imported level in 2009[17]. In 2018 the total supply of natural gas amounted to 32.3 bcm, whilst it produced 20.9 bcm and imported 10.6 bcm[18]. Gas prices as a commodity for households have increased by 5-times the price they had been in 2014[15]. Ukraine's dependency on imported gas was almost double that of the EU in 1990, at 80%. The import gas dependency in Ukraine has decreased over the years, reaching the level indicated in the EU in 1990, at 45%. [17].

Naftogaz is the largest importer of natural gas in Ukraine and the largest supplier to users. The Naftogaz group of companies are by far the largest corporate players in Ukraine[19]. The transit contract between Naftogaz and Gazprom is set to expire in

(15) The Oxford Institute for Energy Studies, 2016, https://www.oxfordenergy.org/wpcms/wp-content/uploads/2016/07/The-Ukrainian-residential-gas-sector-a-market-untapped-NG-109.pdf
(16) Energy Community Annual Implementation Report, November 2019,
(17) Eurostat
(18) Naftogaz Group Annual Report 2018, Naftogaz Group, http://www.naftogaz.com/files/Zvity/Annual-Report-2018-engl.pdf
(19) See https://annualreport2015.naftogaz.com/en/strategija-ta-reformi/operacijna-efektivnist/ last accessed 05.01.2020

December 2019, after which Ukraine will cease to be the main transit country of Russian gas into the European Union. To reduce its dependency on gas, the Ukrainian government aims at stimulating the substitution of heat supply with alternative sources other than natural gas. The IRENA mitigation REMAP 2030[20] scenario recommends keeping the consumption of natural gas in Ukraine at the level of 2012 and 43 bn m3 by 2030 and thereby 7.6 bn m3 or 16% lower than the reference scenario. The scenario targets to reduce the gas consumption by 50% for district heating and direct gas use in buildings from 16.8 bn m3 in 2015 to 8.4 bn m3 in 2030. These targets can only be achieved through improved energy efficiency and the replacement of gas as a fossil fuel-based heating source.

3 Legal and regulatory framework

3.1 Regulations and status on climate protection

Ukraine has committed to multiple international climate-related agreements. Since 1997, Ukraine is an Annex, I Party to the **UNFCCC** making it an active participant in negotiation processes. Since 2004, it is also an Annex B Party to the **Kyoto Protocol**. By using mechanisms such as the Joint Implementation market and the Green Investment Scheme of the Kyoto protocol, some 47 million Assigned Amount Units (AAU) through industrial mitigation projects were issued during 2008-2012. These investments allowed the government to sell their emission rights and use the revenue to invest in green projects[21]. In 2014 the Ukraine agreed, as part of the EU-Ukraine Association Agreement (2014), to further increase its efforts in climate mitigation.

Ukraine ratified the **Paris Agreement** in September 2016. In its first **Nationally Determined Contribution** (NDC), submitted in 2015, Ukraine declared its intention to reduce GHG emissions by at least **40%** below 1990 levels (including LULUCF) by 2030. Given the fact that the post-Soviet Union heavy industry collapsed after 1990, the carbon emissions fell in parallel. Based on this background, the emission target of a 40% reduction by 2030 compared to 2005 is not considered sufficiently ambitious[22]. Ukraine’s NDC covers energy, industrial processes and product use, agriculture, LULUCF and the waste sector, but does not specify the mitigation contribution of each sector.

In December 2017, Ukraine adopted the Concept for the Implementation of State Policy in the Field of Climate Change to be reached by 2030[16]. As a result of these efforts, Ukraine has established the first frameworks and necessary institutional arrangements to set up and implement GHG mitigation projects. The concept defines the main basis of state policy in the field of climate change, including 49 measures as the development of two national strategic documents: a Low Emission Development Strategy and a National Adaptation Strategy. According to the Low Emission Development Strategy, adopted in July 2018, the indicative GHG emissions target is a 31 - 34% reduction by 2050[16], compared with 1990.

Ukraine has imposed a carbon tax on stationary sources in the industry, power and building sectors, which was increased in 2018 (0.02 to 0.36 USD/tCO_2). It came into effect in January 2019 and further increases are planned. It is still the lowest carbon price rate worldwide[23].

In 2018, Ukraine published its **2050 Low Emission Development Strategy** (LEDS) targeting an emissions reduction by 65% compared to the 1990 emissions levels. The LEDS sets the 2°C temperature target as the reference value for its defined goals. The three objectives described in the LEDS are:

- An energy transition to low-carbon energy sources and increase in energy efficiency and clean transport;
- An increase in carbon absorption through agricultural practices and forestry; and
- A reduction in methane and nitrogen oxide emissions.

Policies and measures for carbon neutrality in the sectors of energy efficiency, renewable energy, modernization and innovation (industry), market mechanisms, the process of extraction, processing, transportation and storage of fossil fuel, waste treatment and agriculture were set in the LEDS. However, the quantitative distribution and the contribution of each sector to these goals are still only vaguely defined.

3.2 Regulations and status on energy efficiency and renewable energy

In general, the policies on energy efficiency and renewable energy are made separately and are not yet well integrated in Ukraine. The most concrete and recent plans on both have been made in the 2050 Low Emission Development Strategy (LEDS). In February 2011 Ukraine joined the Energy Community, an international organization that aims to create an integrated pan-European energy market. As a contract party of the Energy Community, Ukraine has the obligation to implement the EU energy and environment acquis.

(20) IRENA REMAP 2030 Renewable Energy Prospects for Ukraine
(21) Ukraine LEDS https://unfccc.int/sites/default/files/resource/Ukraine_LEDS_en.pdf
(22) See https://climateactiontracker.org/countries/ukraine/
(23) See https://climateactiontracker.org/countries/ukraine/current-policy-projections/

Energy efficiency

As a contract party of the Energy Community, Ukraine is moving towards the transposition of EU acquis in the field of energy efficiency. Currently the implementation of the EU acquis in the energy efficiency sector is well advanced. In the **National Energy Efficiency Action Plan through 2020 (NEEAP)**, energy saving quantitative targets for 2017 and 2020 are determined as 5% and 11% of the average total final energy consumption as compared to the period from 2005-2009. In 2017 the final energy consumption (FEC) in Ukraine has reached 50.7 Mtoe, a drop by 4.2% when compared to the previous year and 8.6% below the 2020 target[24]. The Low Emission Development Strategy targets the following use areas for improvements on **energy efficiency**: (i) **Electricity and heat energy;** (ii) **Buildings;** (iii) **Agroindustry; and (iv) Industry.**

To foster energy efficiency improvements in the Ukrainian residential sector in accordance with European energy efficiency standards, the "iq energy" program was designed by the European Bank for Reconstruction and Development (EBRD) as part of the EU4Energy initiative and is supported by donors in providing technical assistance and incentives. Supported EE projects consist of investments in high performing energy efficiency technologies and measures, which have at least a 20% higher energy performance than the market average. There are two associated databases – the List of Eligible Materials and Equipment (Technology Selector) and the List of Suppliers and Installers (Supplier Selector), which meet the higher standards based on a proven methodology used in many countries. Eligible technologies including windows, insulation, heat pumps, heating systems, boilers, solar, meters, front doors, and heat recovery units are listed on a specialized website[25].

Table 2. Ukraine's 2030 EE targets under different scenarios[26]

Scenarios	SoE35 (in FEC)	EnC 2030 (in FEC)	National EE (in FEC)
2030 EE target	-46%	-32.5%	-31% up to -34%

International financial institutions such as the EBRD, World Bank, NEFCO and EIB have been supporting Ukraine for the implementation of projects enhancing energy efficiency. Ukraine receives international funding for energy efficiency in district heating systems, particularly from Sweden[27] and the World Bank[28]. In 2019 Ukraine drafted the new NEEAP for 2019-2030 which is waiting to be adopted by the Cabinet of Ministers. **Ukraine has adopted almost all energy labelling regulations except those on space heaters**[16].

Renewable energy

The key renewable energy resources in Ukraine are so far **biofuels, waste-to-energy,** and **hydropower**. The current renewable energy share constitutes 6.6% of the gross final energy consumption (GFEC)[24], which is below the planned share of 8.9% for this year as set in the Ukrainian **National Renewable Energy Action Plan (NREAP)**. The progress of the country in the transposing and implementation of EU acquis related to renewable energy is behind the progress it has achieved in the energy efficiency sector. In its **NREAP** (submitted in October 2014) Ukraine aims to increase the renewable share to 11% in 2020. Ukraine has prepared a new NREAP (by June 2018), aiming a lower renewable energy share for 2020. However, the document it is not yet adopted[16]. So far, Ukraine is not on track to reaching the stated renewable energy targets. A major barrier are the highly subsidized gas prices against which renewable energies are hardly competitive. The LEDS specify the following measures in **renewable energies**:

- Increase in output and consumption of electricity produced from renewable sources;
- Environmentally sustainable production and extension in the use of biomass (biofuel);
- Production of biogas and extension in its use for heat energy and electricity production; and
- Development of Ukraine's sectors international integration in the sphere of renewable energy.

A map of current renewable investment projects as well as information on resource potential is provided within the UA MAP project[29]. Electricity generated from renewable energy and used for powering heat pumps will allow the Ukraine to produce heating while achieving carbon neutrality. To eventually meet global climate targets, the electricity supply needs to shift entirely to renewable energy sources. With 100% electricity being supplied through renewable energy sources, electrically powered heat pumps will provide the most climate friendly heat supply, having a lower carbon footprint andoutperforming fossil fuel powered district heating systems.

The projection of RES share in Ukraine in 2030 and beyond has been the subject of several studies.

(24) Energy Community
(25) www.iqenergy.org.ua/technologies
(26) EU-Ukraine Renewable Energy Investment Forum, 2018, https://ec.europa.eu/info/sites/info/files/presentations_res_forum_speakers.pdf
(27) https://www.swedenabroad.se/en/embassies/ukraine-kiev/current/news/sweden-will-scale-up-support-for-the-development-of-district-heating-in-ukraine/
(28) https://www.worldbank.org/en/news/video/2019/03/28/improving-energy-efficiency-and-district-heating-in-ukraine
(29) https://uamap.org.ua/en/

Table 3 illustrates some of the results related to the renewables share in Ukraine for 2030. The deployment of heat-pumps as specific renewable technologies lies far behind what was planned in the Ukraine's NREAP.

Table 3. Ukraine's 2030 RES targets under different scenarios[26]

Scenarios	SoE35 (in GFEC)	TIMES-Ukraine (in GFEC)	EnC 2030 (in GFEC)	Revolutionary Scenario (in FEC)
2030 RES target	27% - 32%	19%	17% – 23%	30%

3.3 Regulations and status on fluorinated gases and refrigerants

Cooling appliances and heat pumps are powered by electricity and use refrigerants. As described above, the electricity in Ukraine is still mainly powered by fossil fuel energy sources. Also, the refrigerants which are used in the refrigeration cycle of cooling appliances and heat pumps are mainly hydrochlorofluorocarbons (HCFCs) or hydrofluorocarbons (HFCs) with a high Greenhouse Gas potential. The carbon footprint of these appliances can be lowered by using highly energy efficient appliances with low GWP refrigerants. The following subchapter describes the current framework of the Ukraine on the use of refrigerants.

Phase out of HCFCs

As a party to the Montreal Protocol under Article 2, Ukraine is obliged to phase out 100% of HCFCs by 01. January 2020. In 2012, Ukraine was found to be **non-compliant** with the Montreal Protocol (Decision XXIV/18) in not following the timely phase out of HCFCs. Following the decision, Ukraine has confirmed its commitment to meet the following compliance schedule for the phase out of HCFCs[30]:

- 86.90 ODP-tons in 2013,
- 51.30 ODP-tons in 2014,
- 16.42 ODP-tons in 2015, 2016, 2017, 2018 and 2019,
- Zero by 1 January 2020, save for consumption restricted to the servicing of refrigeration and air-conditioning equipment between the period 2020 and 2030 as prescribed in the Protocol.

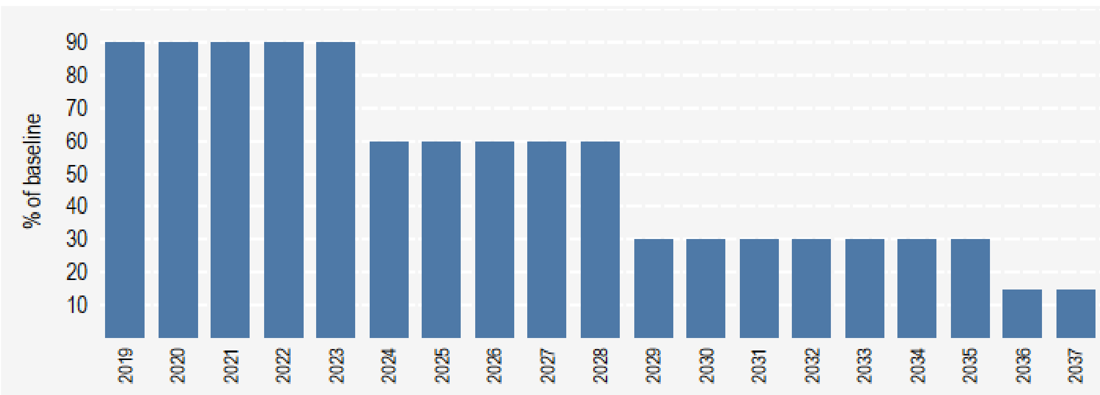
Accordingly, Ukraine must **prove its compliance with fully phasing out HCFCs after 01. January 2020**. The Ministry of Energy and Environmental Protection of Ukraine has made an order on the procedure for the approval of the import and export of ozone-depleting substances and equipment in 2016 which determines that the Ministry of Energy and Environmental Protection requests licenses for import and export of ODP from the Ministry of Ecology and Natural Resources of Ukraine. Otherwise, there is no quota so far on export or import of ODP. The "**Law on protection of atmospheric air**", first released in 1992 and last updated in 2016, sets the general requirement for emission limits and standards, but doesn't specifically mention ODS or HFCs.

Phase out of HFCs

In addition to proving its compliance with the Montreal Protocol for the phase out of HCFCs, Ukraine is facing **ambitious targets** for the phase out of HFCs as an **Article 2 Group 1 country of the Kigali Amendment**.

Figure 7 illustrates the **HFC phase down path** of Ukraine. According to this schedule, the first significant phase down steps must be achieved by 2024, as compared to the baseline (the average HFC consumption in the years 2011-2013 plus 15% of the historical HCFC baseline).

Figure 7 Phase down schedule for Ukraine under the Kigali Amendment



Source: UNEP Ozon Action Fact Sheet Kigali Amendment http://bit.ly/2UitCuR

(30) https://ozone.unep.org/treaties/montreal-protocol/meetings/twenty-fourth-meeting-parties/decisions/decision-xxiv18-non?source=decisions_by_article_topic_relation&args%5B0%5D=137&parent=2261&nextParent=2262

With the draft regulation "Law on ozone-depleting substances and fluorinated greenhouse gases" proposed to the Verkhovna Rada (Parliament/Supreme Council) of Ukraine on the 14th of September 2018, Ukraine started to prepare the phase down of HFCs. The draft law is still under revision. The main elements introduced in the draft law include:

- Preparation of a roadmap for introducing regulations controlling F-gases.
- Introduction of financial incentives for companies to purchase low-GWP refrigerants and the respective equipment, such as tax exemptions.
- Management of disposal, recovery and reuse of refrigerants.

The rapid entry into force of the law and the continuous monitoring, review and verification of its implementation is highly important to ensure compliance with the Kigali Amendment. For the implementation of the HFC phase down, Ukraine can build on the experiences, rules and regulations under the EU F-gas directive or the transposition of the EU F-gas directive, or key elements of it, in neighboring countries such as Turkey. Similarly, the industry in Ukraine can profit from cooperating with European appliance manufacturers in adopting energy efficient and climate friendly F-gas free appliances. In particular, the swift replacement of HCFC equipment with equipment working with low GWP, natural refrigerants would allow Ukraine to directly leapfrog from ozone depleting substances to climate friendly substances.

4 Heat pumps market – current state and projections

With the need to meet carbon neutrality by mid-century or earlier according to the Paris Agreement, Article 2, (UNFCCC, 2017) and IPCC Special Report 1.5°C (IPCC, 2019)), it can be expected that fossil fuel prices will increasingly internalize the costs of carbon and thereby become more expensive. With this, the heating costs for end users particularly in the industrial and residential sectors will increase rapidly.

Heat pumps, powered by electricity from renewable energies, can provide the required heating for buildings with a near zero carbon footprint and are therefore a major alternative to the conventional, fossil fuel powered heating systems. Heat pumps are devices that extract ambient heat energy out of the air, ground and ground waters for heating building spaces or water. A heat pump directs the heat from various sources such as outside air or the ground into the building. Depending on the source, heat pumps are classified into the following types: groundwater, water-water, air-water and air-air. In in industrial processes excess heat from production processes can be used through heat pumps to warm water and for heating purposes.

The energy efficiency of a heat pump is measured by the Coefficient of Performance (COP), the ratio of generated heat energy to the used electrical energy (the higher the better). The different options available for heat pumps depend on their application and the source of energy they use. HPs can be classified in this report based on their heating capacity for **small residential applications** (up to 10 kW heating capacity), **larger residential applications** (up to 10-20 kW) and **commercial use** (over 20 kW) as well as by their heat source, into **ground-source and air-source heat pumps**.

4.1 Heat pumps market in the EU – benchmarking the progress

Half of the EU's energy is consumed in the heating/cooling sector, a consumption that has decreased by 13% since 2004. Meanwhile, the deployment of renewable heat has increased by 65% reaching a share of 19.7% in the 2018 gross final energy consumption (GFEC). Besides the role played by biomass thermal and solar thermal, heat pumps are increasingly becoming a major source of renewable heating. Being supported through investment grants and tax exemption schemes, this contribution has increased from 2.8% of renewable heat in 2004, to 6.5% in 2010 and 11.6% in 2018. Italy and France had the largest contribution in 2018 with nearly 22% each followed by Sweden (12%), Germany (9.6%) and Spain (6.2%).

Table 4. Share of heat from heat pumps in EU countries final renewable heat/cold, 2018[31]

Share in final RES-HC	Less than 5%	5% – 10%	Above 10%
Countries	BE, LT, HR, PL, HU	EE, DE, AT, BG, LU, DK, CZ, FI	MT, PT, CY, IT, EL, FR, SE, UK, ES, IE, NL

Source: Eurostat SHARES Tool[32]

Heat pump sales in the EU have increased by more than 55% since 2010, reaching 1.26 million units in 2018, bringing the total to nearly 12 million[33]. In eleven EU countries heat pump shared more than 10% of the final renewable heat in 2018. The heat pump market is still widely absent in Latvia, Romania, Slovenia and Slovakia

(31) Within each range countries are ranked in the descending order of the relative contribution
(32) Eurostat SHARES Tool, https://ec.europa.eu/eurostat/web/energy/data/shares
(33) EPHA Market Report 2019 https://www.ehpa.org/market-data/market-report/report-2019/

In the overall EU final energy consumption picture, this contribution still remains low at only 1%, whereas in the heating/cooling sector this deployment reaches 2.3%. The EU heat pump market grew with an annual average rate of 10% between 2009 and 2018.

4.2 Heat pumps market in Ukraine – progress and projections

Despite their considerable potential, the usage of heat pumps is not yet widespread in Ukraine. Ukraine has been too ambitious in having planned a 2020 contribution of 600 ktoe from heat pumps in its NREAP, that reflects an installed capacity of 1732 kW. Despite these plans, the introduction of the heat pump market in Ukraine has been characterized by slow progress. In 2017 there were only 25.5 ktoe in the heating/cooling sector coming from heat pumps instead of the 350 ktoe expected. The aerothermal heat pump is the main type covering more than 70% of Ukrainian market in 2017. Geothermal heat pumps covered 18% whereas hydrothermal only 11%. Between 2016 and 2017 the renewable heat from aerothermal heat pumps in Ukraine increased by 15.3%; from geothermal heat pumps by 27.8%; and from hydrothermal heat pumps by 33.3%.

Over the two-year period since 2015, hydrothermal heat pumps have experienced the largest annual increase by 33%. Aerothermal and geothermal heat pumps increased respectively with 15.3% and 27.8% over the same period. Currently **the heat produced from heat pumps in Ukraine cover only 0.05% of the GFEC, 1% of final renewable heat and 0.8% of final consumption of renewables**.

Since January 2019, the building stock area in Ukraine totalled 991.8 million m^2, with nearly 61% of housing space situated in urban areas[14]. Residential area covers 624.4 million m^2. The average dwelling area per person is 24 m^2. The share of one-room apartments of all apartments was 19.5%; two-room apartments was 36.6%; three-room apartments was 32.6% and four-room and larger apartments was 11.3%.

An estimation of the heat pump stock in Ukraine by 2050 is showed in

Table 5. The estimated high scenario has been conservatively developed based on the historic development but, notably, still falls short under an ambition to reach an economy wide carbon neutrality by 2050. Current heat pump market penetration in Ukraine's household fleet as well as the developments in the EU heat market are used as benchmarks. The assumptions included in these projections are related to:

- Low impact of current and planned policies;
- The change in the number of households - number of households is assumed to follow the trend of demographic growth rate with a decrease by 0.6% annually as estimated at the UN report[34] "World Population Prospects 2019",
- Heat pump market penetration in the residential sector - the share of heat pumps market in Ukraine households' fleet is very low, less than 1%,
- Annual growth rates of the heat pump market - following the recent developments in the heat pumps market in the EU, an annual average growth rate of 10% is applied in the deployment of the heat pump market in Ukraine until 2050.

Table 5. Estimated heat pump penetration in the Ukraine household stock

	2018	2020	2030	2040	2050
Number of households	16,000,000	16,000,000	15,760,000	15,523,600	15,290,746
Penetration of HPs -high	1%	2%	4%	8%	16%
Penetration of HPs -low	0.5%	1%	2%	4%	8%
Number HPs - high	150,000	300,000	564,957	1,063,920	2,003,562
Number HPs - low	75,000	150,000	282,478	531,960	1,001,781

The stock of heat pumps estimated by this study ranges between 1 million and 2 million in Ukraine's household market by 2050. Internationally supported projects are being introduced in this sector and it is apparent that subsidies and grants will be indispensable to further spread the heat pump technology with the simultaneous taxing of fossil fuels. This estimation goes in line with the analysis carried out by the UNHPA on the potential market for heat pumps in Ukraine, which can include:

- Public buildings – 38,000 (schools, hospitals, public commercial buildings);
- Residential multi-storey buildings – 200,000 installations.
- Commercial buildings - 250,000 heat pumps.
- Residential/ commercial low-rise buildings - 1 million heat pumps.

Some information on energy-efficient heat pumps currently available in Ukraine can be found on the database of the EBRD project. A total of 1193 appliances eligible for financing through the project are currently registered/listed on the database. Main

(34) UN 2019, World Population Prospects 2019, https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf

manufacturers of heat pumps included in the list include Daikin, Viessmann, Hitachi, Thermia, Kronoterm, Ochsner, Dimplex, Vaillant, IDM, Waterkotte and Climaveneta.

4.3 Climate friendly and conventional heat pumps vs gas boilers

The heat generation efficiency of mostly fossil-fuel powered boilers in Ukraine reach an average of 89%. However, 40% of boilers in use need to be modernised or replaced[35]. Because heat pumps work by absorbing the heat occurring naturally outside of homes and moving it indoors, the efficiency of heat pumps can reach 300% - 500% (COP can range between 3-5). High-performance heat pumps can generate more than 4–5 kWh of useful heat for every 1 kWh of electricity consumed[36].

Comparing heat pumps using natural gas and electricity as their source respectively, it can be observed that the main result of the significant difference between the efficiencies of these appliances is the reduction of CO_2 emissions. Considering an emission value of **0.202 t CO_2-eq/MWh linked to the combustion of natural gas** to produce thermal energy and electricity and comparing it with the **emissions from electricity consumption in Ukraine (0.663 t CO_2-eq/MWh)**[48], there is a 30.4% savings in GHG emissions. This GHG saving yield will further increase in the future with the required transition to renewable powered electricity generation.

Table 6. Electricity and natural gas prices (including taxes) for households' consumers in Ukraine, first half 2019 (€/kWh)

Electricity	Gas	Ratio electricity/gas
0.0442	0.0267	1.66

Annual energy consumption for heating in buildings in Ukraine goes up to 265 kWh/m²/year[46]. In order to calculate the energy generation costs with heat pump technology the annual energy demand for heat in households is needed together with the average energy price for final energy based on fuel type.

The guides to calculate the renewable energy from heat pumps can be found at the Annex VII of RED and at COM (2013) 1082 that defines the default values for the operating hours and Seasonal Performance Factors (SPFs) for both electrically and thermal driven heat pumps under different climate conditions. Table 7 illustrates the default values for heat pump functioning under cold climate conditions.

Table 7. Default values for full load hours and seasonal performance factors under cold climate conditions[37]

Heat pump type	Load hours (H_{HP})	SPF ($SCOP_{net}$)
Aerothermal (electrically driven)	600 - 1970	2.5
Geothermal (electrically driven)	2470	3.2 – 3.5
Hydrothermal (electrically driven)	2470	3.2 – 3.5
Aerothermal (thermally driven)	600 - 1970	1.15
Geothermal (thermally driven)	2470	1.4 – 1.6
Hydrothermal (thermally driven)	2470	1.4 – 1.6

Minimum performance of electric heat pumps is defined by a (SPF) above 1.15* (1/ή) where the power system efficiency (ή) is set at 45.5%. Minimum of SFP for electrically driven heat pumps is 2.5 whereas for thermally driven heat pumps is 1.15. In case a heat pump is used for both heating and cooling, the relationship between the Energy Efficiency Ratio (EER) and COP is set by the following formula:

$$EER = COP * 3.412$$

A comparison between emission savings reached when using conventional and climate friendly heat pumps is presented below. The main factors taken in consideration in the following comparison consist on (i) investment costs and (ii) environmental benefits. The refrigerant (propane R290) used in the climate friendly heat pumps has a very low GWP, only 3 and it is climate friendly, relatively inexpensive, worldwide available and leads to high coefficients of performance. According to a piece of research from Fraunhofer ISE[38] "*the greenhouse gas potential (of EE heat pumps) is about 500 times less than conventional refrigerants and thus extremely low. Another advantage is that the new brine-to-water prototype requires only one fourth of the refrigerant compared to conventional heat pumps available on the market at the same power*".

The comparison is carried out between a geothermal electrically driven conventional heat pump of **15 kW** heat capacity used for **residential or office application** sold on the market in Ukraine and a geothermal electrically driven energy-efficient heat pump on propane with the similar capacity. The performance of a natural gas boiler is also analyzed to bring more information on

(35) KT-Energy LLC , Improving the performance of District Heating Systems in Central and Eastern Europe – District Heating in Ukraine (42 million MWh)
(36) IRENA 2019, Renewable Power-to-Heat, Innovation Landscape Brief, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Power-to-heat_2019.pdf?la=en&hash=524C1BFD59EC03FD44508F8D7CFB84CEC317A299
(37) COM(2013) 1082 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013D0114&from=EN
(38) Fraunhofer ISE, Press Release October 2019, https://www.energie.fraunhofer.de/content/dam/energie/en/documents/01_PDF_PR/Dokumente_PR_2019/191021_ise_2719_ISE_e_PR_Heat%20Pumps_with_Climate_Friendly_Refrigerant.pdf

contemporary appliance use to produce heat. The life-cycle costs were calculated with the current price for electricity of 0.05 USD/kWh. For the calculations, an average heat pump **lifetime of 15 years** is assumed. The COP for the climate friendly heat pump is set at 5.7, meaning that the system will provide 5.7 kW annual heating load for each kW energy supplied. Actual savings are calculated by comparing the final/primary energy consumption from the use of these two appliances. For the heat pump, the SPF values and the operating hours for cold climate are presented in Table 7 whereas for the gas boiler the efficiency is set at 88 % (upper heating value). As noted above, the lifetime emissions of heat pumps will further decline. Therefore, with the required higher share or renewable energy share in the power generation mix, both the conventional HP and the Climate friendly HP will have lower lifetime emissions.

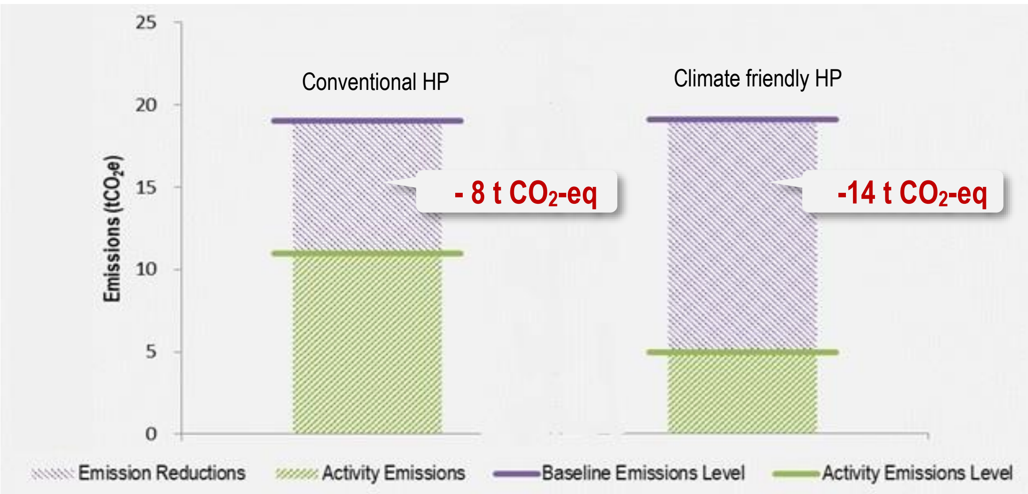
Table 8. Climate and energy performances indicators for a gas boiler, a conventional and a climate friendly heat pump

	Conventional HP (R134A)	Climate friendly HP (R290)	Natural gas boiler
Heating capacity (kW)	15	15	15
Annual heating load (kWh)	37,000	37,000	37,000
Running hours	2,470	2,470	2,470
COP	2.5	5.7	-
Gas boiler efficiency (%)			88
Gas boiler electricity consumption (kWh)			200
Energy consumption (kWh/yr)	14,800	6,500	32,604
Source of energy	Electricity grid	Electricity grid	Electricity grid/On site combustion
Lifetime emissions -15 years (t CO2-eq)	148	65	131
Total investment (USD)	7,220	8,320	2,800
Annual emissions (t CO2-eq)	10.8	4.7	8.7

Due to the drastic increase in energy efficiency, the end life-cycle cost of the R290 installation, adjusted for the discount rate in Ukraine is still lower than for the current conventional heat pump installation. The discount rate of Ukraine's central bank is currently remarkably high, which drives the difference in life cycle costs closer together. From a survey on the heat pumps commercially available in the Ukrainian market, we found that the price for an air-water heat pump with 12 kW heat capacity and 4 kW power capacity goes approximately up to 6,000 USD for a geothermal ground-water heat pump with 12 kW heat capacity and 3 kW power capacity goes approximately up to 4,500 USD for a heat pump with a heat capacity of 15 kW and COP 3.9 goes up to 4,400 USD.

According to our calculations the use of **conventional heat pumps** would imply a **42% reduction** in GHG emissions when compared with baseline emissions, whereas the **reduction can reach up to 74%** in the case of a **climate friendly heat pump.** When comparing the effect of moving from conventional heat pumps towards climate friendly heat pumps, the impact on **GHG emissions reduction can be quantified up to 56%**.

Figure 8. GHG emissions reduction due to the use of a conventional and climate friendly heat pumps

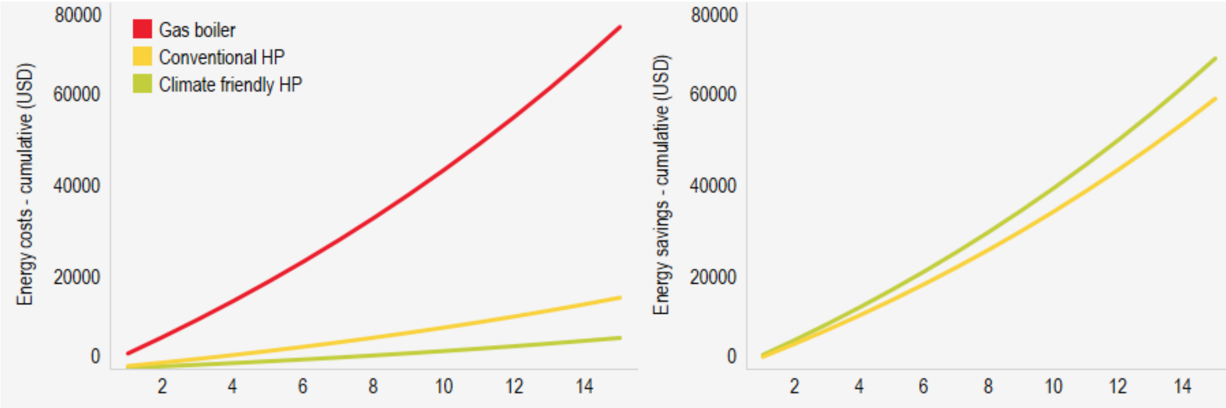


Own calculations[39]

([39]) USAID methodology on mitigation potential of geothermal heat pumps adopted https://www.cleertool.org/Home/Index

Energy costs (cumulative) when using a gas boiler, a conventional and a climate friendly heat pump as well as the energy savings (cumulative) when comparing both heat pumps with a gas boiler are illustrated in Figure 9. Even that the initial cost of conventional and climate friendly heat pumps are higher by a factor of 2.6-3 when compared with the initial costs of a gas boiler, energy savings can range between 60% and 82%. Considering the above-mentioned factors, the payback period for installment of such a climate friendly heat pump would be **2.5 years** with an Internal Rate of Return (IRR) of 17% and a Return of Investment (ROI) rate of 39%.

Figure 9. Performance of gas boiler, a conventional and a climate friendly heat pump for cumulative energy costs and energy savings



Own calculations

5 Commercial refrigeration- current state and projections

5.1 The GHG impact of commercial refrigeration

Retail stores are among the building types with the highest carbon intensity. Within retail stores, food stores have the highest carbon intensity. Refrigeration equipment accounts for over 50% of the energy consumption and carbon emissions (Ferreira et al., 2020) in food retail stores. The carbon emissions of the refrigeration equipment are related to (a) direct emission from the refrigerant leakage during manufacturing, servicing and the appliance's end of life and (b) the indirect emissions through the use of electricity which is mostly generated from fossil fuel sources in Ukraine. Significant emissions reductions can be achieved for refrigeration equipment in supermarkets with the transition to energy efficient appliances and the use of low carbon refrigerants. With the replacement of high carbon refrigerants to low carbon natural refrigerants, a relatively rapid and cost-effective transition to low GWP refrigerants can be achieved. The replacement of older equipment will be cost effective, if the transition to energy efficient appliances is combined with the installation of new and energy efficient equipment.

5.2 Overview commercial refrigeration equipment and refrigerant options

In line with common classifications for commercial refrigeration, the equipment types have been classified here into standalone equipment, condensing units and centralized equipment. The different equipment types and variations are explained as follows:

Standalone equipment. These appliances are plug-in refrigerators and freezers and stand-alone commercial units (Table 9). A typical product contains a factory assembled refrigeration system and contains 50 gr to 250 gr of refrigerant and up to 1 kg for small commercial units. In the EU, natural refrigerants are rapidly becoming the norm for standalone equipment. In Ukraine, HFC equipment is mostly still sold. However, most local manufacturers are starting the shift to natural refrigerants, in line with the EU trend. There is no major barrier for Ukraine to move to energy efficient stand-alone appliances with high energy efficiency along the trend in the EU.

The main replacement options for the current dominant refrigerant in Ukraine, HFC-134a, are:

- **HC-600a** continues to be the main alternative to HFC-134a. Concerns in connection with the high flammability of the refrigerant when introduced in 1994 in Europe no longer exist, particularly as the charges required for domestic refrigeration are well below the allowable charge sizes for flammable refrigerants. While the refrigerant itself is less expensive than HFC-134a, additional investment cost for HC-600a application can arise due to safety requirements such as spark-free electrical components.

- **HFO-1234yf** was originally developed to replace HFC-134a in automotive air conditioning applications. These unsaturated fluorocarbons have been evaluated for domestic refrigeration but are not being pursued with high priority in this sector which is more demanding than automotive applications. Moreover, the prices for HFOs[40] are considerably higher than for HFCs[41].
- **CO_2-R744** is a good option for light commercial equipment. Experience is available from a large number of coolers and vending machines which have been in use since 2004. The additional cost is estimated to be between 5 and 15 percent depending on the equipment's size. So far however, CO_2-R744 has not proven to be as commercially competitive an option for domestic refrigeration when compared to HC-600a.

Table 9: Stand-alone refrigeration equipment

Equipment	Application	Current HFC refrigerants	Abatement options	Temperature range	Cooling capacity in W	HFC refrigerant charge (gr)
Coolers, Freezers, vending machines	Commercial	HFC-404A, HFC-134a	HC-290, HC-600a, CO_2	-20°C to +10°C	50 – 500	50 – 500

Condensing units in commercial refrigeration are typically direct expansion systems with compressors and condensers located externally to the sales area. Refrigerants used today in Ukraine are primarily HFC-404A, HFC-507 and HFC-134a, CO2 and HFOs and have a charge between 4 kg and 8 kg. Most technically feasible abatement options for condensing units include:

- Direct HC-290 or HC-1270 which are an alternative to condensing units with a battery of larger stand-alone units and a water loop circuit. With the amendment of the international safety standard IEC 60335-89, charge sizes up to 500g with hydrocarbons, classified in the A3 flammable risk class, per individual appliance are now possible. Through the advantageous thermal properties of hydrocarbons, the energy consumption of hydrocarbon equipment can be up to 10 percent lower than conventional HFC equipment. The investment cost of direct hydrocarbon systems can be up to 25 percent higher due to safety requirements but compensated by the higher efficiency of the refrigerant.
- Trans critical CO2 has a higher investment cost and lower energy consumption.
- Indirect systems with HC or HFO with liquid secondary refrigerants. Indirect systems with flammable refrigerants in the primary circuit in an unoccupied machinery room, in the open air or a special ventilated enclosure can operate over a much wider range of refrigerating capacities compared to direct systems. This technology would be as energy efficient as a comparable HFC system.

Centralized equipment in commercial refrigeration are installations where usually a number of compressors are mounted on a rack in a machinery room and operated in parallel, also called multiplex systems. The heat transfer typically takes place through glycol-water circuits. Centralized systems are typical refrigeration equipment of larger supermarkets. Refrigerants used today in Ukraine are:

- HCFC-22 (which is in the phase-out process in the Ukraine and no new systems are being installed),
- HFC-404A used for both Medium Temperature (MT) and Low Temperature (LT) systems,
- HFC-134a which is used for MT applications,
- Ammonia-R717 with secondary loop systems.

Refrigeration capacities vary from 20 kW to more than 1 MW and refrigerant charges vary from 40 to 3,000 kg. Details of the most technically feasible abatement options for centralized equipment are as follows:

- Trans critical CO2-R744 system. Two stage (booster) system using CO2 as the only refrigerant throughout the supermarket. The systems are currently designed in a way that the maximum operating pressure inside the shop area is kept below 40 bars. High-pressure lines and components are confined to the machinery room and to the outdoor condenser. R744 systems are considered standard off the shelf solutions by several European manufacturers. Many European supermarket chains have opted for this kind of system for all their new installations. The investment costs are an estimated 20 percent higher than direct HFC-404A systems. In moderate climates, the energy consumption of the CO2 system is up to 10 percent lower. However, the trans critical CO2 system consumes more energy in warmer climates.
- HCs or HFOs, and CO2 pump circulation for MT and CO2-cascade for LT. Cascade refrigeration systems with CO2 show the best climate and energy performance. In this process, CO2 is maintained at relatively low pressures so that standard

[40] https://prom.ua/p1173732551-freon-r1234yf-5kg.html
[41] See here for example the price for HFC-134a https://prom.ua/p555893808-freon-r134a-hladagent.html

refrigeration components can be used. The primary refrigeration circuit can be located in a separate room or outdoor so that occupied spaces are free of flammable refrigerants like HC-290 or HFO-1234yf.

5.3 Commercial refrigeration market in the EU

5.3.1 Benchmarking the progress

1-2% of global GHG emissions stem from food retail; 3-4% of electricity use in Germany, France or Sweden is related to the sector. Stores selling food have a 50% higher energy usage than other commercial buildings. Refrigeration makes up 30-50% of total energy in a store and is therefore the largest contributor to a food retailer's overall environmental impact. Commercial refrigeration is responsible for approx. 1/3 of HFC demand in the EU, with high-GWP refrigerants being responsible for 18-30% of the overall carbon emissions in EU stores. Based on the obtained information, the direct emissions in Ukraine also account similarly for 20-30% of supermarket emissions. Smaller stores with only standalone equipment have a lower share of direct emissions.

5.3.2 EU regulations limiting GHG emissions for refrigeration equipment

In order to limit direct and indirect emissions of commercial refrigeration equipment in the EU, the main regulatory instruments are the EU F-Gas Regelation 517/204, the Ecodesign Directive (EU, 2009) and the Energy Labelling Regulation (EU, 2017).

Control of direct emissions from the use of refrigerants: Under the F-Gas Regulation 517/2014 for commercial refrigeration, from 2022 onwards in commercial refrigeration all standalone and multi-pack system with refrigerants > 150 will be banned and centralized equipment will be regulated through the licensing system of the regulation and will not be allowed to have refrigerants with a GWP above 2500.

Control of indirect emissions from the use of electricity. The EU is regulating the use of energy through the amended Directive 2018/2002 (EU, 2018), as part of the **Clean Energy for All Europeans Package**, obliging EU countries to save on average 4.4% of their annual energy consumption between now and 2030. Under these conditions, the energy efficiency of energy-related products on the EU market is governed through the Ecodesign Directive (EU, 2009), controlling the minimum energy performance of products and the Energy Labelling Regulation (EU, 2017) and governing the energy performance rating systems of products. Professional refrigerated storage cabinets are regulated by the Ecodesign Directive and the Energy Labelling regulation.

5.4 Commercial refrigeration in Ukraine – progress and projections

In line with commonly adopted market structures, food stores have been classified in this report into three categories, small stores, supermarkets and hypermarkets according to the floor areas as illustrated in

Table 10. Overview commercial refrigeration

	Small stores	Supermarkets	Hypermarkets
Size category	Below 1000 m2	1000 -3000 m2	Above 3000 m2
Number of stores	12,000	1,500	160
Types	Kiosks, bakeries, corner stores, small food retail stores	Large groups such as Fozzy Group, ATB Market, Metro	
Mix equipment (typical)	Standalone and condensing units	Standalone and condensing units	Standalone, condensing units and centralized units

Based on the number of stores and the typical equipment per store, the installed number of commercial refrigeration equipment in the Ukraine has been assessed as illustrated in Table 11.

Table 11. Overview of installed commercial refrigeration equipment

	Standalone	Condensing units	Centralized equipment
Number of equipment	30,456	15,920	160

The above assessment is based on the typical installation of standalone units and small condensing units in **small stores**, the installation of several standalone appliances, commercial plug-in fridges and freezers, small- and large-scale condensing units up to 27m length in **supermarkets** and the installation of standalone, condensing units and centralized equipment (chillers) in **hypermarkets**.

Table 12 shows the installed cooling capacity with the typical distribution of equipment in food stores.

Table 12. Typical installed cooling capacity (in kW) in food stores

	Small stores	Supermarket	Hypermarkets
Standalone			
300 liter chest freezer	0,4	4	4
1,8 m3 chest freezer		2,5	2,5
3,6 m3 chest freezer		5,1	5,1
Condensing unit			
2,5 m refrigeration shelf	5		
8 m refrigeration shelf		20,4	20,4
27 m refrigeration shelf		39,5	39,5
Centralized unit			150

Based on the equipment set in each food store type, the current GHG emissions per food store type were calculated (see Figure 10). The detailed underlying assumption for the calculation of direct and indirect emissions are shown in Annex A.4.1 (refrigerants) and Annex A.4.2 (energy efficiencies). Small scale stores deploy mostly standalone equipment with relatively low direct emissions. Standalone appliances use hermetically closed compressors with low service emissions during the operational lifetime of the appliances. Ukraine has no effective recycling mechanisms with a proper extraction and destruction of refrigerants. Accordingly, 100% of end of life emissions were assumed for all equipment types. Supermarkets have the highest share of direct, refrigerant, related emissions compared to other store types with 27% of the total store emissions. Typically, supermarkets deploy direct expansion condensing units with high leakage rates and operating emissions. Hypermarkets deploy condensing units and centralized equipment and tend to service their equipment better.

Figure 10. Typical emissions per type of food stores

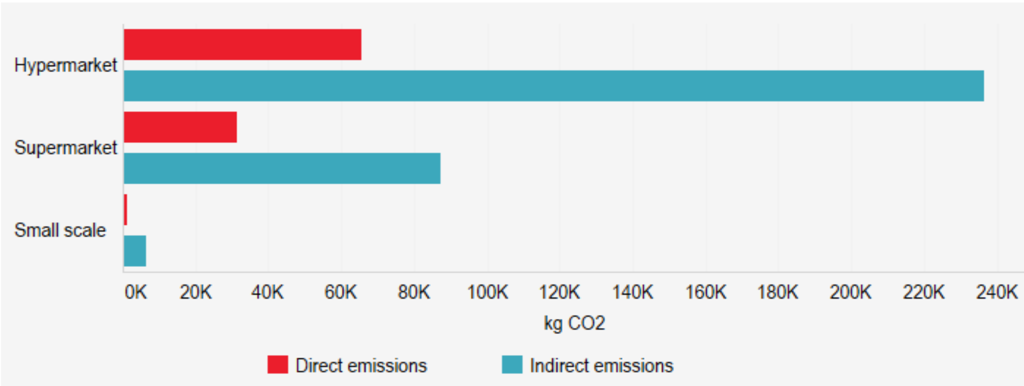
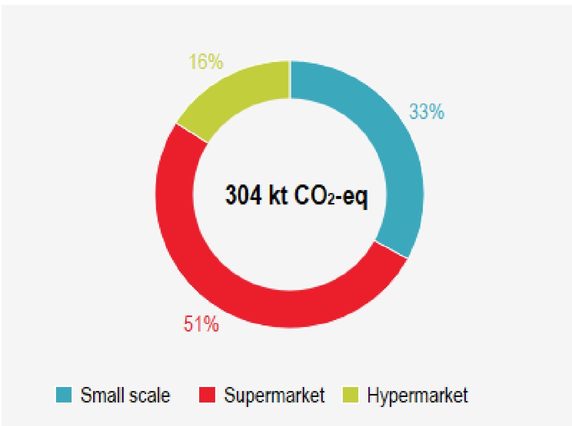


Figure 11 shows current (2020) the GHG emissions of refrigeration appliances in food stores, including small scale stores, supermarkets, and hypermarkets. Supermarkets have more than a 50% share in GHG emissions from commercial refrigeration equipment in Ukraine's food stores. This is followed by a 33% share of small stores and 16% share of hypermarkets. Two thirds of all emissions are related to indirect energy consumption related emissions, and one third is related to direct refrigerant related emissions. The direct emissions are related to the use of mostly HFC based refrigerants with a high GHG emissions potential.

Figure 11. Current (2020) GHG emission in food stores in the Ukraine



6 Mitigation scenarios

Based on the assessment of the current market trends, current and alternative, low GWP technology alternatives, this chapter assesses the future mitigation potential in the heat pump and commercial refrigeration subsectors.

6.1 Emission saving potential with heat pumps

The analysis in the estimated options that accelerate the deployment of renewables in Ukraine in a cost-effective way are presented in several studies/scenarios. However, few studies or scenarios include projections or potential estimations on the heat pump deployment in Ukraine. The projection of heat pump deployment by 2020 is set in the NREAP document where the contribution within the heating/cooling sector could reach more than 10%, in final consumption of renewables nearly 7% and 1.3% in the GFEC. No projections on heat pump deployment by 2030 or 2050 can be found in the series of scenarios as TIMES-Ukraine or Energy Strategy of Ukraine until 2035 (ESU2035). IRENA REMAP 2030[20] projections for Ukraine under the Reference Case scenario sees significant growth in electrification for heating with heat pumps, and partly through other technologies such as electric boilers and resistance heating. The estimated 2030 potential of heat pumps under the IRENA Reference Scenario and REMAP2030 is 1195 ktoe/yr (50 PJ/yr).

A contribution of 4.4% in 2030 supplied energy from renewable sources in the heating/cooling sector, other than biomass (including solar thermal and heat pumps), is estimated in the study carried out by Energy Community on 2030 targets[42] for EE, RES and GHG emissions. Under the Baseline III scenario developed in this study the FEC in Ukraine in 2030 is estimated at 81.7 Mtoe while the FEC cap under the Baseline 32.5 scenario is 55.2 Mtoe. Some estimations on heat pump stocks in South East Europe (SEE) can be found at the SEE 2050 Carbon Calculator Tool[43] according to which **the 2050 heat pumps in SEE will cover 24% of the installed heating devices in the stock**.

For Ukraine the assessment projects a penetration of heat pumps as a percentage **of the installed heating devices in the stock** form currently 1-2% to 8% (low) and 16% (high) by 2050 (see

Table 5). In relation to the current low rate of heat pump deployment in Ukraine, several barriers need to be overcome in order to achieve a higher penetration of heat pumps:

- **Prevailing policies** still support centralized heating lacking the attention to the efficiency of heating and energy systems. Willing to support heat generation from renewable sources, Ukraine has adopted the Law №1959-VIII, 2017 "On amendments to the Law on "On heat supply"", which introduces a simplified procedure of fixing a stimulating tariff for thermal energy from alternative sources. This tariff is fixed at the level of 90% of the acting tariff for thermal energy from gas (1400 UAH/Gcal)[9].
- **Lack of awareness of the advantages of heat pump systems**, absence of a demonstration facility for different types of heat pumps or testing labs as well as lack of government support for research, development and introduction of such technologies. Households and business should show initiative in taking measures for modernization and should depart from the notion that everything is only done and subsidized by the government;
- **Lack of available technologies**. There is a lack of heat pumps systems particularly with natural refrigerants;
- **Lack of financing** - Currently housing and utility subsidies programme have little incentive for the improvement of energy efficiency and switching to more environment and climate-friendly options;
- **Subsidized energy prices, for fossil fuels and electricity generated from fossil fuels.**

The following assessment of emissions saving potential[44] with heat pumps in Ukraine is based **on the fossil fuels displacement principle** within final energy consumption (FEC) in a certain year and having in focus the residential sector. Projections on FEC, GHG emissions and natural gas of scenarios are selected. A short description of selected scenarios can be found in Table 15 (Annex -A2 section). Main parameters of selected scenarios are illustrated in Table 13.

Table 13. Some parameters of selected scenarios for year 203045,46

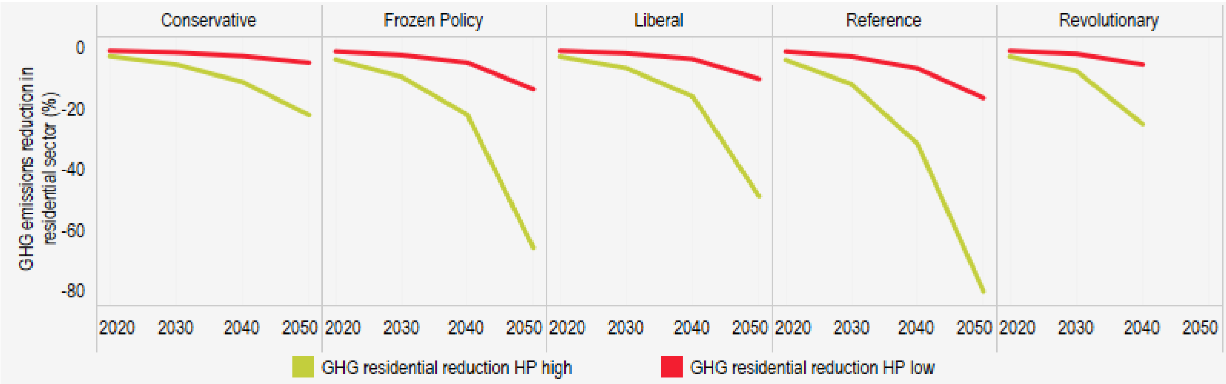
Conservative (S1)	Frozen Policy (S2)	Reference (S3)	Liberal (S4)	Revolutionary (S5)
RES 4.2% in FEC	RES 6% in TPES	RES 21% in TPES	RES 9.9% in FEC	RES 30% in FEC

(42) TU Wien, EEG, REKK, 2019, Study on 2030 overall targets for the Energy Community, https://www.energy-community.org/dam/jcr:b9a77a36-ed7d-4f1c-9228-8bf687b50b99/MC_Annex16a_122017.pdf
(43) South East Europe 2050 Carbon Calculator, https://see2050carboncalculator.net/
(44) Methodology applied and assumptions made can be found in A.3 section of the Annex.
(45) Diachuk, O., Podolets, R., Yukhymets, R., Pekkoiev, V., Balyk, O., & Simonsen, M. B. (2019). Long-term Energy Modelling and Forecasting in Ukraine: Scenarios for the Action Plan of Energy Strategy of Ukraine until 2035.
(46) Diachuk, O., Chepeliev, M., Podolets, R., Trypolska, G., Venger, V., Saprykina, T., & Yukhymets, R. (2018). Transition of Ukraine to the Renewable Energy by 2050. Transition of Ukraine to the Renewable Energy by, 2050.

FEC +35.8% until 2030	FEC +6.2% until 2030	FEC +8.1% until 2030	FEC +6.6% until 2030	FEC -3.4% until 2030

Natural gas is projected to be the main fuel in Ukraine's residential sector in all scenarios apart from in the S5 scenario in which moving towards 2050, the share of natural gas consumption decreases, being almost fully substituted by renewable electricity and renewable heat. In the S4 scenario, the share of natural gas decreases slightly, whereas in S1 scenario it increases.

Figure 12. Estimated GHG emissions reduction in Ukraine's residential sector in 2020, 2030 and 2050 due to heat pumps deployment



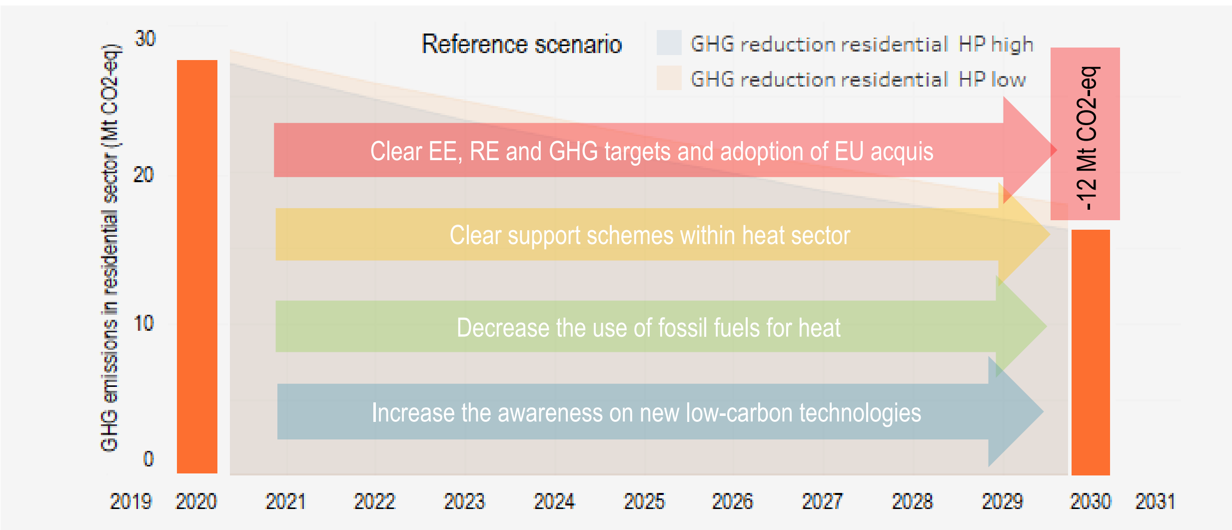
Own calculations based on scenarios selected

Figure 12 illustrates the mitigation potential of heat pumps deployment in Ukraine under different established scenarios. As expected, the main reduction could be reached under the reference scenario which reflects the main policy targets on energy efficiency, renewable energy and GHG emissions.

Under the assumption of high penetration of heat pumps in FEC, a reduction of up to 80% can be reached in the 2050 GHG emissions in the residential sector. Under the low penetration assumption, this reduction can reach up to 16%. The share of heat pumps in final renewables under the reference scenario ranges between 11.6% (low penetrations) and 58% (high penetration).

Under the reference scenario the share of heat production from gas boilers is projected to decrease from 21% in 2020 to 13.8% in 2030 and only by 1% in 2050. A drop by 39.5% is projected in this scenario for the heat production from gas boilers between 2020 and 2030 whereas a decrease by 96.5% compared with 2020 is projected for 2050.

Figure 13. Climate impact of heat pump technology deployment in Ukraine's Reference Scenario



Heat pump deployment is related to the energy policies, regulations and incentives in place for renewables in the heating/cooling sector in Ukraine. Currently the main support for renewables within this sector in Ukraine is given to the use of biomass since the country has a huge domestic potential. However, despite this support the use of biomass was behind by more than 30% in 2017 when compared with expectations. Tariffs for heat energy in Ukraine are torn between the need to cover all expenses of district heating operations and the capacity of clients, particularly individual households, to sustain the prices[35].

6.2 Emission saving with climate friendly commercial refrigeration equipment

Ukraine is currently undergoing a deep restructuring process in the cooling sector. With the currently still pending ratification of the Kigali Amendment and its subsequent implementation, Ukraine faces a massive challenge in changing its cooling infrastructure, which is currently still based on HCFC and HFC refrigerants to low GWP refrigerants, with the target to lower HFCs by 85% from its baseline by 2036. Also, as an Article 2 country under the Montreal Protocol, Ukraine has to practically stop the use of HCFC by 2020. The cooling sector represents a significant opportunity to combine the system change from high GWP refrigerants to low GWP refrigerants with the transition to improved energy efficiencies. The EU has developed an effective set of policy instruments to address both the transition to low GWP refrigerants and improved energy efficiency. These instruments include the F-Gas Regulation (EU Reg. No. 517/2014) for the use of low-GWP refrigerants and, for energy efficiency, the relevant Ecodesign Regulation (EU Reg. No. 2015/1095) and the Labelling Regulation (EU Reg. 2015/1094). For the transition to low GWP solutions for commercial cooling, Ukraine can adopt important elements of the regulations by:

- Banning high GWP refrigerants – as elaborated in Chapter 5 low GWP solutions exist for all commercial cooling applications;
- Adopting and implementing of minimum energy efficiency standards and energy labels, initially for standalone appliances and condensing units.

Energy efficient commercial appliances are to be amortized during their useful operation time, even at current highly subsidized electricity prices. At higher electricity prices the amortization of energy efficient appliances and their payback periods shorten. The current electricity prices in Ukraine are substantially below the European average and it can be expected that electricity prices will increase over time. Figure 14 illustrates the payback of a modern centralized refrigeration system based on a trans critical CO2 system (green line) against the conventional R134a system. The initial costs of the CO2 system are assumed to be 20% higher. The energy savings amortize the incremental capital costs after 13 years (blue line).

Figure 14 Amortisation of energy cost replacing a conventional with a low GWP alternative (accumulated energy costs)

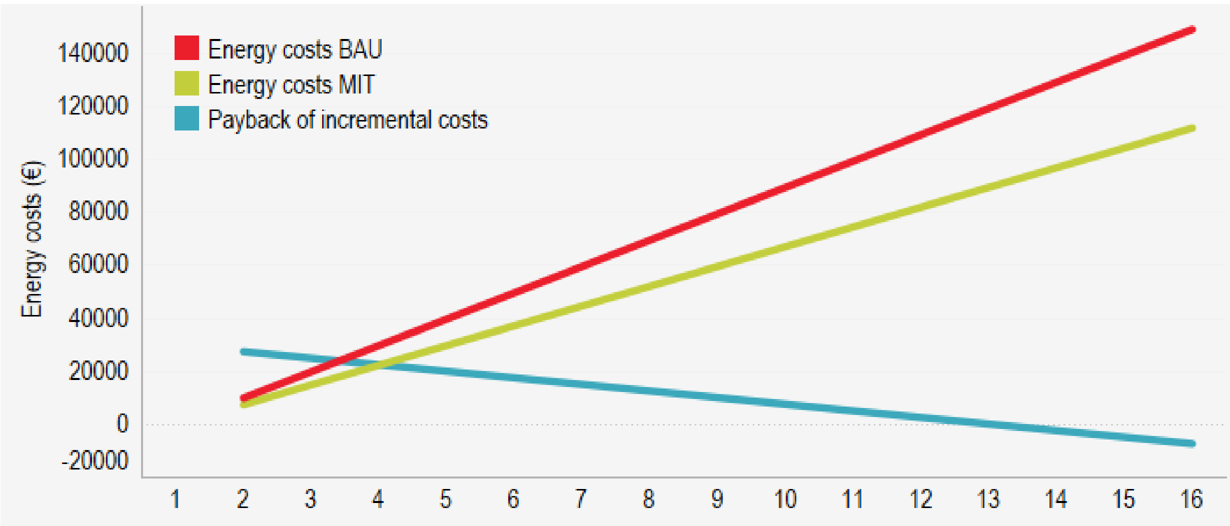


Table 14. illustrates the direct and indirect emissions with a typical equipment set both for small scale stores, supermarkets and hypermarkets both with conventional, HFC-based appliances, and natural refrigerants. The underlying assumptions are explained in Annex A 4.1 and A 4.2.

Table 14 Food store GHG emissions business as usual and mitigation scenario

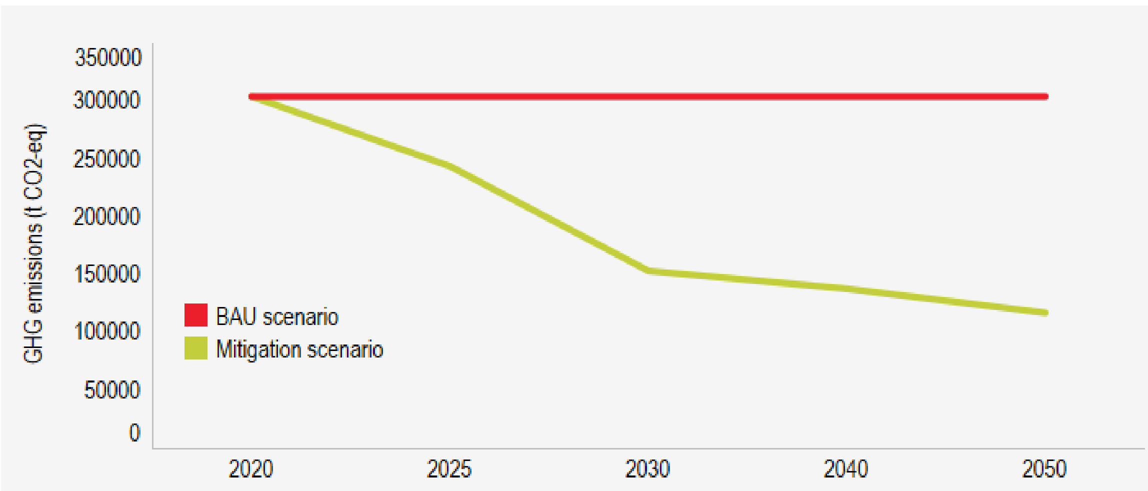
	Small scale	Supermarket	Hypermarket		Small scale	Supermarket	Hypermarket
Emissions in kg CO2eq	**7.833**	**118.787**	**301.996**	**Emissions in kg CO2eq**	**4.128**	**56.228**	**168.141**
Grid emissions factor	0,66			**Grid emissions factor**	0.66		
Indirect	6.509	87.216	236.391	**Indirect**	4.127	56.214	168.095
300 litre chest	542	5.425	5.425	300 litre chest	398	3.978	3.978

1,8 m3 chest		3.390	3.390	1,8 m3 chest freezer		2.486	2.486
3,6 m3 chest		6.916	6.916	3,6 m3 chest freezer		5.072	5.072
Condensing unit				**Condensing unit**			
2,5 m refrig. shelf	5.967			2,5 m refrig. shelf	3.729		
8 m refrig. shelf		24.345	24.345	8 m refrig. shelf		15.216	15.216
27 m refrig. shelf		47.139	47.139	27 m refrig.shelf		29.462	29.462
Centralised unit			149.175	**Centralised unit**			111.881
Direct	1.323	31.572	65.606	**Direct**	1	14	45
300 litre chest	79	786	786	300 litre chest	0	2	2
1,8 m3 chest		471	471	1,8 m3 chest freezer		1	1
3,6 m3 chest		943	943	3,6 m3 chest freezer		2	2
Condensing unit				**Condensing unit**			
2,5 m refrig.shelf	1.245			2,5 m refrig. shelf	0		
8 m refrig. shelf		4.480	4.480	8 m refrige. shelf		1	1
27 m refrig. shelf		24.892	24.892	27 m refrig. shelf		8	8
Centralised unit			34.034	**Centralised unit**			31
CO_2 emissions per m2 in kg/ year	31	48	40	**CO_2 emissions per m2 in kg/ year**	17	22	22

On a national level the projected development of emissions under a BAU and mitigation scenario are illustrated in Figure 15. The projected number of stores have been assumed constant across the projected years, assuming a growing GDP per person and declining population. The distribution of food stores for the different store types has been adopted from the current distribution as shown in
Table 10.

With the transition to low GWP refrigerants and higher energy efficiency standards, the GHG emissions from commercial refrigeration could be cut by half. The underlying assumption are that by 2050 all stores have migrated to low GWP refrigeration and have adopted state of the art energy efficient equipment, which is currently already available. The transition to low GWP refrigerants can be achieved cost-effectively as assessed above. For the mitigation scenario, the grid emission factor was assumed unchanged. With the transition to renewable energy, the grid emission factor will fall and, with the transition to zero carbon refrigerants or near zero carbon refrigerants as in the case of natural refrigerants and to 100% renewable energy for electricity supplies, zero carbon cooling can also be achieved for commercial refrigeration.

Figure 15 Estimated GHG emission reduction potential commercial refrigeration



7 Conclusions

The assessment of this report has shown that climate friendly and energy efficient technologies are available in the EU and the Ukraine market. The rapid penetration of such technologies can lead to emissions reductions over 50% by 2050 for both subsectors.

The rapid penetration of heat pumps is critical for the Ukraine on a meaningful path towards decarbonization. So far, the heating market is dominated by heating through gas. The effective decarbonization of heating for housing can only be meaningfully achieved through the transition to renewable electricity and the supply of electricity to power heat pumps. Through the rapid penetration of heat pumps, GHG emissions could be reduced by up to 12 $MtCO_2$-eq by the year 2030 and thereby contribute significantly to Ukraine's climate targets. The deployment of low GWP, natural refrigerants for heat pumps, such as hydrocarbon, can improve the thermodynamic properties of heat pumps and will further contribute to the environmental sustainability of heat pump technology. This technology has been successfully deployed and tested in the EU.

Commercial refrigeration equipment is the main source of energy consumption in food stores. As an A2 group country under the Montreal Protocol, Ukraine is required to halt the use of HCFCs from 2020. The Ukraine has not yet ratified the Kigali Amendment but with its ratification, Ukraine will be required to reduce HFCs by 85% from its baseline by 2036. Therefore, the transition from HCFCs to HFCs and the deployment of new cooling equipment with HFCs is not an option for the Ukraine. Through the required transition to low GWP refrigerants, there is an opportunity to deploy low carbon technologies with high energy efficiency and low GWP refrigerants. Emissions could be reduced by 150 ktCO2eq p.a. by 2030. Relevant technologies with low GWP natural refrigerants have been introduced and have become mainstream solutions in the EU.

For the transition to low GWP solutions with heat pumps and climate friendly and energy efficient commercial refrigeration equipment, Ukraine can make use of the policy instruments developed in the EU. The project has developed guidelines on the relevant regulations, refrigerant safety standards and the training of technicians in English and Ukrainian. The guidelines can be accessed freely under the website of the Refrigeration Association of the Urkaine[47].

47 http://ref.org.ua/projects/design/rozvytok-kompetentsiy-po-innovatsiynym-zastosuvannyam-energoefektyvnykh-ta-ekologichno-bezpechnykh-t/

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List of abbreviations

DH	District Heating
EER	Energy Efficiency Ration
FEC	Final Energy Consumption
GFEC	Gross Final Energy Consumption
GWP	Global Warming Potential
HC	Hydrocarbons
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
LCC	Life-Cycle-Costs
LULUCF	Land Use, Land Use Change and Forestry
MENR	Ministry Energy and Environmental Protection
NDC	Nationally Determined Contribution
NEEAP	National Energy Efficiency Action Plan
NREAP	National Renewable Energy Action Plan
ODP	Ozone-Depleting Potential
ODS	Ozone-Depleting Substances
PU RAU	Public Union “Refrigerating Association of Ukraine”
RES-HC	Renewable Energy Consumption in Heating/Cooling
TEWI	Total equivalent warming impact
UNHPA	Ukrainian National Heat Pump Association

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Annex

A.1 Market data

Market data acquisition

As outlined in the introduction, the study aims to set a baseline for heating and cooling technologies and their mitigation potential in the future, with a focus on heat pumps and commercial refrigeration equipment. For this purpose, an inventory model was applied estimating the historic, current and future stock of appliances in use. To estimate the current and future GHG impact of the appliances the specific parameters are modelled as listed below:

Refrigerant-related appliance parameters

- Refrigerant charge;
- Refrigerant type;
- Leakage rates (manufacturing leakage rate, operating leakage rate and end of life leakage rates).

Energy-related appliance parameters

- Runtime hours;
- Cooling/ heating capacity;
- Coefficient of performance;

For the purpose of determining the baseline and mitigation scenario, data for the appliances in use (historic, current and future) is collected from primary and secondary data sources. Primary data was requested from key RACHP industry stakeholders. Secondary data was collected from market reports, statistical, customs etc.

The study serves as a preparational step for estimating the baseline and mitigation pathways for the two focus sub-sectors, heat pumps and commercial refrigeration. The establishment of a comprehensive RACHP inventory goes beyond the scope of this study and will help Ukraine to comprehensively understand its GHG baseline emissions and options to effectively transit to low carbon F-gas free alternatives.

Primary data

Primary data is sourced from associations, companies and industry representatives of the RACHP sector.

Main participating stakeholders are:

- Members of the Refrigerating Association of Ukraine including the following companies Tehnohol, Aisberg, Astra Group, Green Frost, RMC manufacturer company, Alternative Technologies, BRG Group, Stor, Eurocool (fruits, vegetables, flower, milk, fish and meat). These companies include suppliers of major supermarkets and retail chains represent ca. 70% of the (commercial) cooling sector.
- The Ukrainian National Heat Pump Association (UNHPA).

Secondary data

Major secondary data sources covering the cooling and heat pump sector were drawn from the following sources:

- Reports published on Ukraine's implementation of the Montreal Protocol from UN implementing agencies, mainly UNDP;
- Customs data from the Customs Office;
- National reporting under UNFCCC (National Communication of Ukraine on Climate Change);
- Sectoral studies carried out by international organisations and market intelligence services, including
    - EBRD
    - Heinrich Boell Stiftung
    - Intelligent services such as BSRIA, JRAIA and Euromonitor.

A.2 Emission savings with heat pumps- Methodology

The approach assumes that renewable energy from heat pumps replaces a set of initial energy carriers (fuels in heating/cooling sectors) that would have been supplied by other energy resources. Emission savings are calculated with regards to an established scenario. Below are the steps followed for this estimation:

- Determine the increasing trend of heat pump penetration in the FEC by 2050. Current progress of heat pumps in Ukraine as well as the progress in the EU are to be used as benchmarks in determining the shares of heat pumps in FEC for each year;
- Determine which is the main fuel to be substituted by considering its emission factor. In the estimations presented in this report, the fossil fuel that will be substituted by heat pumps is natural gas. According to the Natural gas default Life Cycle Assessment approach (LCA) (2008-2015), GHG emission factor[48] of 0.240 t CO_2-eq/MWh has been recorded;
- Selection of scenarios against which to measure the effect of heat pump deployment in heating/cooling sectors;
- Calculation of heat pump deployment affects against the projections of selected scenarios;
- The contribution of emission savings in a year to the GHG emissions in the residential sector for that year is calculated as the ratio of net savings in the year concerned to total hypothetical greenhouse emissions for that year. The total hypothetical emissions in a year are obtained by adding the absolute values of net emissions avoided in a year through use of heat pumps to actual emissions in that year.

Table 15 Description of scenarios selected[49,50]

Conservative (S1)	Frozen Policy (S2)	Reference (S3)	Liberal (S4)	Revolutionary (S5)
Most energy technologies remain unchanged by 2050 compared to 2012 and hence there is almost no increase in efficiency of the use of energy resources and only a very small part of the potential of RES is used.	Considers only those policies, measures and targets that were adopted by 2015 (i.e. no policies, measures and targets from ESU2035 and other strategic documents).	Reflects the conditions and main targets of the Energy Strategy of Ukraine until 2035, maintains the energy consumption at the level of 2015 while simultaneously increasing the use of RE by reducing the consumption of coal and natural gas.	By 2050 the share of RES in the structure of the final energy consumption (FEC) may exceed 30% and the need for energy resources will decrease due to the introduction of energy efficiency measures while the economy will grow.	In energy transition assumptions, the policy target for renewables is implemented as well as energy efficiency and implementation measures.

Under the selected scenarios the assumptions applied are that:

- The contribution of heat pump deployment (high and low) has substituted an identical amount of natural gas consumed in the residential sector;
- The current penetration of the heat pump market in Ukraine and the EU are used as benchmarks to define the initial shares;
- The annual growth factor of heat pumps in the EU is taken as a benchmark (growth by a factor 2 over a period of 10 years) to define the growth of shares in FEC up until 2050.

Table 16.Assumed penetration of heat pumps in Ukraine's final energy consumption in 2020, 2030, 2040 and 2050

	2020	2030	2040	2050
HP penetration in FEC - high	0.5%	1%	2%	4%
HP penetration in FEC - low	0.1%	0,2%	0,4%	0,8%

(48) JRC Report 2017, CoM Default Emission Factors for the Eastern Partner countries

(49) Diachuk, O., Podolets, R., Yukhymets, R., Pekkoiev, V., Balyk, O., & Simonsen, M. B. (2019). Long-term Energy Modelling and Forecasting in Ukraine: Scenarios for the Action Plan of Energy Strategy of Ukraine until 2035.

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A.3 Conventional vs climate friendly heat pumps & refrigerants – input data

A.3.1 Conventional and climate heat pumps vs gas boiler

	Natural gas Boiler	New EE HP R290	Conventional HP R134A
Heating capacity (kW)	15	15	15
Gas boiler efficiency (%)	88		
Gas boiler electricity consumption (kWh)			200
Natural gas low calorific value (kW/m^3)	9.2		
Natural gas volume (calculated for 2470 h)	4570		
Unit price (USD)[52]	1 000	8 000	7 000
Installation price (USD)[53]	1 800	300	200
Maintenance cost (USD/year)[54]	20	20	20
Total investment (USD)	2 820	8 320	7 220
COP		5.7	2.5
GWP (kg CO2 / kg refrigerant)		3	1420
Refrigerant charge (g)[55]		150	1200 – 1350
Annual leakage rate (%)		2	2
Refrigerant loose during demolition (%)		15	15
Grid loss rate (%)	10	10	10
Energy consumption (kWh/year)	32 604	6 500	14 820
Annual electricity cost (USD)	1 815	319	726
Gas price (USD/year)[56]	1.654	-	
Total energy cost (USD/year)	3 470	319	726
LCC (USD)	27 835	10 598	12 440
Emission factor electricity (g CO_2-eq/kWh)	663	663	663
Emission factor natural gas (g CO_2-eq/kWh)	202		
Emission factor energy mix (g CO_2-eq/kWh)[57]	460		
Net calorific value for natural gas (GJ/t)[58]	48.77		
Grid losses (%)	10%	10%	10%
Activity emissions	8.7[59]	4.7	10.8
Additional price (USD)	5 500	4 400	
Discount rate %	5%	5%	
Inflation rate %	5%	5%	
Electricity price (USD/kWh)	0.049	0.049	0.049
Running hours	2 470	2 470	2470
Lifetime (years)	15	15	15
IRR (%)		17%	
Payback period (years)		2.5	

(51) Volume = 15/ (9.2*0.88) = 1.85 cubic m/hour = 4570 m3 for 2470 hours. Average (fluctuating temperatures during the season and average for Ukraine) ¾ of that = 3427 cubic meter per season.
(52) Cost of boiler initial investment: (5 000 to 25 000 UAH, average 590 USD)
(53) Installation costs: (5 000 to 25 000 UAH, average 590 USD)
(54) Cost of boiler maintenance: 300-600 UAH per year, average 18 USD
(55) Upper limit of 150 gr for a climate friendly heat pump used in residential (5-10 kW). For other HP for each kW there are used 80-90 gr of refrigerant
(56) Cost of fuel/unit: average (different in every region) including VAT, delivery costs and supplier margins currently ca. 7000 UAH per 1000 cubic meters = 0.276 USD/cubic meter, likely to increase
(57) Sourced from USAID GHG emissions calculator for Combined Marginal Grid emissions factor for Ukraine.
(58) Ukraine NIR 2017, https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/submissions/national-inventory-submissions-2017
(59) 1m^3 natural gas = 1.9 kg CO_2-eq (IPCC, 2006)

A.3.2 Refrigerant emission factors and charge sizes

Refrigerant		HFC	R290
Manufacturing emission factor	1%		
Disposal emission factor	100%		
Service emission factor standalone	7%		
Service emission factor condensing	25%		
GWP standalone/ centralised		1430[60]	3
GWP condensing		3922[61]	3
Lifetime [years]	15		
Charge standalone cooler 300 liter		0,4	0,06
Charge standalone chest freezer 1,8 m3		2,4	1,2
Charge standalone chest freezer 3,6 m3		4,8	2,4
Charge condensing unit 2,5m [Kg]		1	0,5
Charge condensing unit 8m[Kg]		3,6	2
Charge condensing unit 27 m3 [Kg]		20	12
Charge centralised		75	30

A.3.3 Commercial refrigerant equipment energy efficiency ratios

Equipment COP	BAU	MIT 2030
Stand Alone Equipment		
300 litre	2,2	3
1 unit 1,8 m3 cooling capacity in kW	2,2	3
1 unit m3 cooling capacity in kW	2,2	3
Condensing unit		
2,5 m Refrigeration schelf	2,5	3,5
2 unit 8 m cooling capacity in kW	2,5	3,5
1 unit 27 m cooling capacity in kW	2,5	3,5
Centralised unit	3	4

(60) HFC-134a
(61) HFC-404A

A.4 Stakeholder Map

Key stakeholders in the climate protection, energy efficiency and the RACHP sector in Ukraine are presented in Table 17.

Table 17 Main stakeholders in the sector in Ukraine

Organization & Link	Role
Ministry of Energy and Environmental Protection (MEEP)), http://mpe.kmu.gov.ua/	Central executive authority developing and implementing the state policy on climate change, energy, environmental protection, ozone protection and regulating the use of fluorinated gases. The MEEP is a mergerof the new Ministry from the former Ministries of Energy and Coal Industry and the Ministry of Ecology and Natural Resources.
National Energy and Utilities Regulatory Commission of Ukraine (NERC), www.nerc.gov.ua	State regulator overseeing the energy sector including utilities (electricity, natural gas, heating, cold water and domestic waste).
State Statistics Service of Ukraine, http://www.ukrstat.gov.ua/	Central service for statistical data economical and imports.
State Agency on Energy Efficiency and Energy Saving of Ukraine, http://saee.gov.ua/en	Providing services on energy (e.g. operating the https://uamap.org.ua/en/ website).
Odessa National Academy of Food Technologies, https://www.onaft.edu.ua/en/	Research institution providing information and services on commercial cold applications.
Refrigerating Association of Ukraine (PU RAU), www.ref.org.ua	Promoting energy efficiency and environmentally friendly cooling and heating (heat pumps) technologies; contributing to the development and the implementation of regulatory acts; supporting the development of conditions for professional technical education and knowledge exchange for cooling and heating applications.
Ukrainian National Heat Pump Association (UNHPA), www.unhpa.com.ua	Promoting heat pump technologies, development of the market in Ukraine, development of draft law and roadmap on heat pump technologies.
European-Ukrainian Energy Agency (EUEA), http://euea-energyagency.org/	Promoting policy, technology and finance for effective energy transition, provides latest EE and RE industry insights.
Renewable Energy Agency of Ukraine, www.rea.org.ua/en/contacts-en	Promoting the market development of renewable energy technologies and their enabling framework.

A.4.1 Refrigerants

Refrigerant		**HFC**	**R290**
Manufacturing emission factor	1%		
Disposal emission factor	100%		
Service emission factor standalone	7%		
Service emission factor condensing	25%		
GWP standalone/ centralised		1430	3
GWP condensing		3922	3
	15		
Lifetime [years]			
Charge standalone cooler 300 liter		0,4	0,06
Charge standalone chest freezer 1,8 m3		2,4	1,2
Charge standalone chest freezer 3,6 m3		4,8	2,4
Charge condensing unit 2,5m [Kg]		1	0,5
Charge condensing unit 8m[Kg]		3,6	2
Charge condensing unit 27 m3 [Kg]		20	12
Charge centralised		75	30

Emissions in tCO2eq (annualized lifetime emissions)		BAU	MIT
Direct refrigerant emissions			
Standalone 300 liter		0,08	0,00
Standalone chest freezer 1,8 m3		0,47	0,00
Standalone chest freezer 3,6 m3		0,94	0,01
Condensing unit 2,5m		1,24	0,07
Condensing unit 8m		4,48	0,01
Condensing unit 27 m3		24,89	0,05
Centralised		34,03	0,29

A.4.2 Energy Efficiency

Equipment COP	BAU	MIT 2030
Standalone equipment		
300 litre	2,2	3
1 unit 1,8 m3 cooling capacity in kW	2,2	3
1 unit m3 cooling capacity in kW	2,2	3
Condensing unit		
2,5 m refrigeration shelf	2,5	3,5
2 unit 8 m cooling capacity in kW	2,5	3,5
1 unit 27 m cooling capacity in kW	2,5	3,5
Centralised unit	3	4