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LIFE CYCLE ASSESSMENT OF A CONDENSING GAS BOILER AND COMPARE WITH AN AIR SOURCE HEAT PUMP IN A RESIDENTIAL BUILDING

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Abstract. This study presents a comprehensive life cycle assessment (LCA) comparing the environmental impact of a Condensing Gas Boiler (CGB) and an Air Source Heat Pump (ASHP) within the context of a residential building. As the demand for sustainable and energy-efficient heating solutions rises, evaluating the environmental performance of these technologies becomes crucial for informed decision-making. The assessment encompasses the entire life cycle of both heating systems, including raw materials, production, transportation, installation, operation, and with deep focus on end-of-life disposal through recycling, landfill, and incineration. The environmental indicators considered in the analysis include greenhouse gas emissions, energy consumption, and other relevant impact categories. This study has been conducted using SimaPro 9.4.0 program database with IMPACT 2002+ method and findings from this research aim to guide homeowners, policymakers, and industry stakeholders in making informed decisions regarding the adoption of heating technologies in residential buildings. By shedding light on the environmental implications of CGBs and ASHPs, this LCA contributes valuable insights toward the transition to sustainable and energy-efficient residential heating solutions and destruction methodologies for better environmental gain.

Keywords: life cycle analysis, condensing gas boiler, air source heat pump, ground source heat pump, water source heat pump, greenhouse gas, domestic hot water.

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1. Introduction

The case is with a building which was built recently in the old town of Vilnius city. It can be assumed that the lifetime of the building is 100 years from now. It is a two storied building with an antique traditional heating system with a fireplace as a part of family heritage and has no connection with the district heating system. At this moment, the government has no plan to extend their district heating network in that area due to some unavoidable reason and, therefore, it is not possible to connect the building with the district heating system. This two storied rectangular shaped building is 10 meters long and 7.5 meters wide. The building has a lawn in front of it and some adjacent space which can be used to install a dedicated heating system of choice. From that planning point of view, the indoor part of the heating has been installed completely, i.e., the hot-water and cold-water pipes, required radiators, and necessary power connections are adequately present there. It was planned to bring a gas connection as well but could not be finished for some reason, it yet needs 200 meters of pipeline to be installed for a low-pressure natural gas connection to be used in heating.

At this situation, a complete technical evaluation of two heating systems is made and after a careful evaluation, it is planned to finalize one of between two systems – a) condensing gas boiler (CGB) and b) air source heat pump (ASHP). According to that evaluation, both systems are technically perfect and from the cost point of view can be accepted happily along with the services by the suppliers of these two systems. It is now decided to evaluate these two systems in terms of possible impact on the environment in their entire lifetime. So, it is decided to perform a life cycle analysis (LCA) of these two systems.

As a part of previous studies, it is found that in the year 2022 Naumann et al. (2022) did a rigorous comparative analysis to determine the environmental impacts through the life cycle assessment between the gas boiler and the heat pump. According to this study, it is found that the gas boiler is beneficial in 8 out of 11 impact categories, however, the impact was the most during operation which altered the result with a 70% lower impact for the air-source-heat pump than the gas-boiler. In this analysis, they focused on the methodology of LCA performed and compared the results between attributional and consequential life cycle analysis. Greening and Azapagic (2012)

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did an LCA for ASHP, GSHP and WSHP and compared the results with gas-boiler and he found that ASHP has 82% higher and GSHP and WSHP have 73% higher impact than the gas-boiler due to electricity consumption. According to this analysis, ASHP has higher impact due to low efficiency and higher material requirements. Rey-Martínez et al. (2004) also did an LCA of heat pump which leads to environmental impact as well as external environmental cost analysis. Sevindik et al. (2021) did this analysis in three main scenarios as circular economy (CE), resource efficiency (RE) and limited growth (LG) along with three alternative scenarios as transport (SK), 50% Hybrid and 75% Hybrid. A few other previous studies can be mentioned here (Greening & Azapagic, 2012; Sevindik et al., 2021; Abusoglu & Sedeeq, 2013; Saner et al., 2010; Vignali, 2017; Famiglietti et al., 2020) which have been performed by different authors with different focuses.

In the current analysis, the authors have focused not only on the gas boiler but also required pipeline to feed the gas and for the ASHP part a storage tank for DHW which enriched the analysis by covering the composite requirement because the remaining part like distribution and electricity supply are same for the both. Moreover, a detailed focus has been given on the destruction part which contributes the second most in the impact categories on environment and thus this study differs from other studies.

2. Methodology

The LCA method is used to assess the environmental impacts of two different heat sources, i.e., the ASHP and the CGB. The life cycle phases consist of components to destruction including energy consumption during operational phases and is described in brief in Figure 1. The list of used materials which are referred to as components, along with respective lifespans and weights in kg are collected from the vendors and their Environmental impact are calculated using SimaPro 9.4.0 program database with the IMPACT 2002+ method. Manufacturing (which is referred to as production) related electricity and natural gas consumption is also collected from the vendors in MJ for both and environmental impact are calculated using the SimaPro program. Vendors also provided their destruction procedure. Similarly, transportation related emissions and other impacts are also calculated in every stage for both the systems. Natural gas is required for the CGB system and connection of Natural Gas to the building is also considered in the LCA. The lifespan of the pipeline of household natural gas connection is considered as 40 years. According to the pre-set technical specifications and load analysis, electrical energy, and natural gas consumption for both the systems are known and accordingly environmental impact for energy and gas are also calculated using the SimaPro program. After getting all the emissions, a cumulative scenario is found for both systems and the comparison is done accordingly for the overall life cycle phases. The interpretation of LCA results of these two systems are compared. This is to be noted that, as this is a comparative analysis, emissions by the factories for production purposes are considered identical for the two systems except the production related energy consumptions.

3. Goal and scope of the study

Two systems from two different vendors have been selected. The vendor of CGB has their factory and production set-up in Klaipeda which is 309.6 km far from his home. And the vendor of ASHP has their factory and production set-up in Kaunas which is 105.5 km far from his home. The goal of this study is to understand the environmental impact of a CGB of demanded capacity by performing LCA and compare the environmental impact of an ASHP of demanded capacity by performing LCA in this existing setup. While performing the LCA, the author has considered the following stages for each system:

- Component and Manufacturing / Production of the systems;
- Transportation from the factory to the place of installation;
- Usage over the lifespan of the building (required replacement);
- Transportation to map the usage;
- Destruction of the systems (recycling, landfill and/or incineration);
- Transportation for destruction;
- Electricity consumption during the period of usage;
- Regular maintenance and replacements of consumables and spares.

According to the selected vendors, the CGB will have a life of 20 years and the ASHP will have a life of 25 years. Considering the building lifetime of one hundred years, after the first installation the CGB has to be replaced four (04) times and has to be destroyed five (05) times in total. But their ABS will have a life of 50 years and as a result,

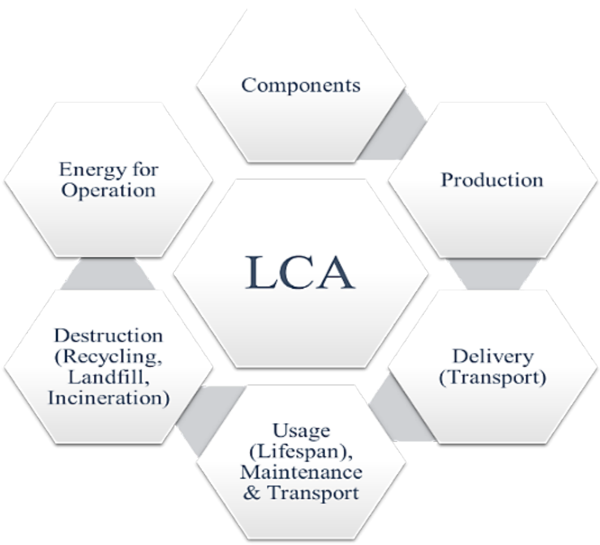

Figure 1. Life cycle phases

it will need replacement once and destruction twice after the first installation. They also said their controller will need 4% of maintenance over their lifespan including spare parts and the rest parts are completely maintenance free over the period of their lifespan.

Similarly, after the first installation, the ASHP has to be replaced three (03) times and has to be destroyed four (04) times in total. According to them, 3% of refrigerant and lubricant are to be refilled annually while the rest of the parts are maintenance free for the period of their lifespans. For the sake of simplicity, materials used in production are considered to be inside the scope of LCA including electricity and natural gas consumption. Raw material processing, product assembling, finished product packaging, etc. related Environmental impact for using different facilities inside the factory including machineries set-up, workforce, office furniture, heating and cooling systems, etc. are assumed nearly identical for both the vendors and kept out of scope of the study. One point is to be noted here, for both the systems, electricity connection is needed and hence lifespan of electricity connection of the building is excluded from the LCA study.

4. System design validation and assumptions

According to the provided data, the following calculations show how the specifications of both the systems were derived along with electricity and natural gas consumption followed by the heat demand calculations. The following table (Table 1) summarizes the settings, calculations, and assumptions of the building, CGB and ASHP.

The following Table 2 summarizes the above information, i.e., energy consumption of CGB and ASHP including assumptions and facts. This is to be noted that around 21.9 kW of electricity is required for the ignition system and controller of the CGB which is a regular and standard consumption.

5. Inventory analysis

According to the information provided by the vendors, the following tables (Table 3 and Table 4) represent the list and quantity of materials used and energy consumed along respective units to produce one set of both the systems. Let's have a glimpse of what vendor noted in their specifications along with some reference (Naumann et al., 2022) where both are identical.

Condensing Gas Boiler (CGB):

The vendor said they use ABS (EU-27) for piping, fresh Aluminium primary ingot from market (EU-27), Brass, rich Copper, electronics for control unit, EPDM (rubber seals), low-alloyed steel, PVC, Silicone, and cabling. Electricity and natural gas consumptions are also associated. This is to note that CGB will require 79.9 MJ and 116.6 MJ of electricity and natural gas respectively during the production phase.

In the destruction stage, they use the current recycling rate of EU-28 (Ciacci et al., 2018). They only recycle Aluminium, Copper, and Steel materials according to (Table 3) mentioned ratio and they follow landfilling for rest of the metals. They incinerate the other plastic materials at the end-of-life stage. This is to be mentioned that, during the transportation stage, a light commercial vehicle is used

Table 1. Settings, calculations, and assumptions of the building, CGB and ASHP for heat demand calculations

Settings, calculations, and assumptions	
General: ▪ Heating area = 150 m^2 ▪ Set room temperature = 20 °C ▪ U-Factor consideration as per A++ standard ▪ Space heating demand per year = 39.15 kWh/m^2 ▪ DHW demand per year = 3,477.64 kWh/m^2	CGB: ▪ Heating value of natural gas = 11.2 kWh/m^3 ▪ Considered system efficiency of CGB = 88.7% ▪ Annual electricity consumption for ignition, controller ASHP: ▪ Considered SCOP = 3.25

Table 2. Annual energy consumption (electricity and natural gas) of the designed CGB and ASHP at the calculated heat load for that particular building

Energy consumption	CGB (1.7-14 kW)	AHSP (5 kW)
Electricity consumption (kWh/y)	21.9	2,877.07
Natural gas consumption (m^3/y)	941.22	0
Considerations in system designs: a) For natural gas, a higher heating value of 11.2 kWh/m^3 is assumed. b) For the CGB, efficiency is found 98.2% using higher heating value of natural gas but with respect to the entire heating system efficiency is considered as 88.7% in the calculation. Usually in CGB, electricity is used to ignition system, control, circular pump, electronic safety features which is not associated to produce heat directly. c) For the AHSP system, SCOP is 3.5 but considered overall system losses and losses due to hot-water tank and distribution system, 3.25 is considered in the calculation. d) 1 kWh = 3.60 MJ e) Natural gas, 1 m^3 = 11.2 kWh = 40.32 MJ		

Table 3. Materials used for CGB manufacturing

Material (CGB: 1-set)	Quantity	Unit	Lifespan (Years)	Maintenance (Yearly)	Destruction method
ABS	1.171	kg	50	Free	Incineration
Aluminium	1.905	kg	20	Free	69% recycling, balance landfill
Brass (67% Cu)	3.215	kg	20	Free	40.87% Copper recycling, balance landfill
Copper	2.29	kg	20	Free	61% recycling, balance landfill
Electronics	0.248	kg	20	4%	Electronics waste transformation
EPDM	0.064	kg	20	Free	Incineration
Low alloyed steel	22.879	kg	20	Free	75% recycling, balance landfill
Gas pipeline	465.2	kg	40	Free	75% recycling, balance landfill
PVC	0.005	kg	20	Free	Incineration
Silicone	0.115	kg	20	Free	Landfill
Stainless steel	6.736	kg	20	Free	75% recycling, balance landfill
Cabling	0.372	kg	20	Free	30.5% recycling, rest landfill & incineration
Total	504.2	kg			

and for gas connection a 200-meter low-pressure domestic pipeline (cast-iron) is considered to be installed. The lifespan of a low-pressure natural gas connection pipeline is 40 years and hence it will need replacement twice and destruction thrice in 100 years. One point is to be noted here, Silicone is considered as a metal during destruction phase as it is often called as metalloid as it has properties like metal. It is also considered that cabling contains 50% insulation materials and the balance 50% is copper.

Air Source Heat Pump (ASHP):

The vendor said they use rich Copper, elastomer, HDPE, low-alloyed Steel, lubricating oil, PVC, refrigerant R-134a, reinforcing Steel and a hot-water tank of 600 litres which is made of Steel. Required electricity and natural gas consumption are also associated. In the destruction stage, they use the current recycling rate of EU-28. They only recycle Copper, and Steel materials according to (Table 4) mentioned ratio and they follow landfilling for the rest of the metals. They incinerate the other materials at the end-of-life stage. ASHP will require 504 MJ and 1,400 MJ of electricity and natural gas respectively during production.

For destruction, both the vendors use same facilities they have in Lithuania and nearest to the waste material collection site. Both vendors preferred the recycling, landfilling and incineration location respectively 6.9 km, 15.8 km, and 14.3 km far from the building. Materials which need more than one type of waste-treatment will proportionately carry waste materials to respective distance for the required number of destruction.

6. Data collection and comparison through data interpretation

Data of different stages for both the systems is collected through SimaPro 9.4.0 program. The following tables will represent collected data. Collected dataset are named as follows:

- Ozone Layer Depletion (OLD) – kg CFC-11 eq
- Aquatic Acidification (AA) – kg SO2 eq
- Aquatic Eutrophication (AE) – kg PO4 P-lim
- Global Warming (GW) – kg CO2 eq
- Non-Renewable Energy (N-RE) – MJ

Table 4. Materials used for ASHP manufacturing

Material (ASHP: 1-set)	Quantity	Unit	Lifespan (Years)	Maintenance (Yearly)	Destruction method
Copper	36	kg	25	Free	61% recycling, balance landfill
Elastomer	16	kg	25	Free	Incineration
HDPE	0.5	kg	25	Free	Incineration
Low alloyed steel	32	kg	25	Free	75% recycling, balance landfill
Lubricating oil	2.7	kg	25	3%	Incineration
PVC	1.6	kg	25	Free	Incineration
R-134a	4.9	kg	25	3%	Incineration
Reinforcing steel	120	kg	25	Free	75% recycling, balance landfill
Hot-water tank	125	kg	20	Free	75% recycling, balance landfill
Total	339.3	kg			

For the above listed materials (in Table 3 and Table 4) for both the systems, production related emissions, transportation from production facility to operational site (the building) related emissions, required replacement related production caused emissions during 100 years of considered operational period, replacement related transportation caused emissions, required destruction related emissions and destruction related transportation caused emissions are captured. Electricity and natural gas consumption related emissions are also covered. For the annual maintenance part, all the emissions are considered for the stages of manufacturing, transportation (manufacturing), destruction and transportation (destruction) throughout the lifespan of operation.

The following illustrations (graphs) will represent the Environmental impact for both CGB and ASHP throughout the lifespan. Every layer is separately mapped here. Table 5 represents the Ozone Layer Depletion impact category information for different life cycle stages for CGB and ASHP. The value is represented by kg CFC-11 eq which clearly shows that the energy consumption takes the key stake of overall impact. It can be understood that the overall impact is comparatively less significant considering other impact categories.

If we see the next impact category which is represented by kg SO2 eq, i.e., the Aquatic Acidification in Table 6, we find that impact is also likely to less significant comparing with other categories but slightly higher than ozone layer depletion and similarly energy is the largest contributor. In this category, there is some gain during the destruction phase.

The Aquatic Eutrophication impact category which is expressed by kg PO4 P-lim is represented in the Table 7 below. The impact is also less significant compared to other impact categories, however, here also energy is the highest contributor.

Next, we will see the Global Warming category impact which is expressed by kg CO2 eq and represented in Table 8 below. This table clearly shows that the Global Warming category has a significant impact on the environment compared to other impact categories and like other categories energy is the top contributor. Interestingly, gain from destruction is the second contributor in terms of value. If we keep energy away, ASHP has more negative impact on environment but considering energy, i.e., the total impact of CGB is higher than ASHP.

Lastly, if we see the Non-Renewable Energy impact category (Table 9) which is expressed by MJ, we will find that more than 95% of total impact is in this category and energy is the top contributor. ASHP has higher energy consumption during production and as a result it has higher energy consumption during usage phase as well, but the next contributor is destruction. Except energy consumption, ASHP has the most contribution in environmental impact, but CGB has significantly higher impact due to its high volume of natural gas burning.

Table 5. Ozone Layer Depletion for different life cycle stages of CGB and ASHP

Impact Category	kg CFC-11 eq	
Row Labels	**Sum of CGB**	**Sum of ASHP**
1. Production	0.0000062	0.0048358
1A. Transport (Production)	0.0000050	0.0000111
2. Usage (Replacement)	0.0000248	0.0145233
2A. Transport (Usage)	0.0000171	0.0000374
3. Maintenance	0.0000028	0.0143093
4. Destruction	0.0000007	0.0000006
4A. Transport (Destruction)	0.0000045	0.0000044
5. Energy	0.0265909	0.0033949
Grand Total	**0.03**	**0.04**

Table 6. Aquatic Acidification for different life cycle stages of CGB and ASHP

Impact Category	kg SO2 eq	
Row Labels	**Sum of CGB**	**Sum of ASHP**
1. Production	2.3751572	14.5265960
1A. Transport (Production)	0.2129222	0.3276702
2. Usage (Replacement)	9.4708738	44.2960380
2A. Transport (Usage)	0.6373155	1.1039401
3. Maintenance	0.2410018	0.4912767
4. Destruction	(18.1431956)	(16.3114439)
4A. Transport (Destruction)	0.1336189	0.1303478
5. Energy	165.4974974	154.2107836
Grand Total	**160.43**	**198.78**

Table 7. Aquatic Eutrophication for different life cycle stages of CGB and ASHP

Impact Category	kg PO4 P-lim	
Row Labels	**Sum of CGB**	**Sum of ASHP**
1. Production	0.0398450	0.2098532
1A. Transport (Production)	0.0050745	0.0069679
2. Usage (Replacement)	0.1592011	0.6509346
2A. Transport (Usage)	0.0146459	0.0234753
3. Maintenance	0.0175724	0.0137272
4. Destruction	0.0003911	0.0003031
4A. Transport (Destruction)	0.0028414	0.0027718
5. Energy	1.1930291	5.6678217
Grand Total	**1.43**	**6.58**

Table 8. Global Warming for different life cycle stages of CGB and ASHP

Impact Category	kg CO2 eq	
Row Labels	**Sum of CGB**	**Sum of ASHP**
1. Production	93	766
1A. Transport (Production)	37	65
2. Usage (Replacement)	362	2,431
2A. Transport (Usage)	116	219
3. Maintenance	35	247
4. Destruction	(1,445)	(1,388)
4A. Transport (Destruction)	27	26

The above tables (Table 5 to Table 9) have been formed using the pivot program of Microsoft Excel which sorts alphabetically and hence to sort according to our choice a numbering is done which is shown in front of each life cycle stage's name. Since the destruction phase of life cycle stages has remarkable environmental impact than the production phases, further details of destruction phases have been analyzed. Destruction has been done through recycling, landfill, and incineration.

From Table 10 we can summarize that both CGB and ASHP have identical emissions for Ozone Layer Depletion and Aquatic Eutrophication. In both the cases of Aquatic Acidification and Global Warming impact category, CGB has gained more than ASHP but in Non-Renewable Energy impact category ASHP is less impactful than CGB.

All impact categories of all life cycle stages are plotted in percentage in Table 11. It shows ASHP has an overall higher impact in production, usage and relevant transportation stages including maintenance. But environmental impact in destruction and relevant transportation faced more from CGB. Finally, the energy consumption in the Non-Renewable Energy part is the game-changer, and it clearly keeps ASHP ahead of CGB as a low-impacting heating solution. Therefore, from this life cycle analysis we can comment that condensing gas boiler is found more vulnerable to environment in comparison to air-source-heat-pump in the analyzed context and environment along with the conditions faced.

The following figures express the above information (Table 11) smartly. Figure 2 represents the impact categories during the first production where ASHP is clearly found to be impactful and same goes for other lifespan stages (Figure 3). But in Energy consumption, ASHP is found more environmentally friendly than CGB in Figure 4 and as a result overall impact (Figure 5) on environment is more influenced negatively by CGB than ASHP.

From the above illustrations, it is understandable that CGB has much higher Environmental impact in comparison with ASHP. In the manufacturing part, CGB is more environmentally friendly than ASHP, but CGB consumes around five times energy consumption of ASHP (Figure 6). For precise emission data, practiced destruction methods have been followed and following illustrations have been produced. As elaborated in Figure 7, around 375 kg of materials of

Table 9. Non-Renewable Energy for different life cycle stages of CGB and ASHP

Impact Category	MJ

Row Labels	Sum of CGB	Sum of ASHP
1. Production	1,414	12,530
1A. Transport (Production)	601	1,051
2. Usage (Replacement)	5,364	39,565
2A. Transport (Usage)	1,880	3,539
3. Maintenance	457	1,755
4. Destruction	15,037	7,552
4A. Transport (Destruction)	428	418
5. Energy	3,679,082	725,021
Grand Total	**3,704,264.71**	**791,430.62**

Table 10. Different destruction methodologies for CGB and ASHP during their life cycle phases

Category	Emission	CGB	ASHP
Destruction (Recycling)	kg CFC-11 eq	0.000000	-
	kg SO2 eq	(18.166917)	(14.614713)
	kg PO4 P-lim	0.000012	-
	kg CO2 eq	(1,456.464164)	(1,291.992300)
	MJ	14,962.052619	10,599.714000
Destruction (Landfill)	kg CFC-11 eq	0.000001	0.000001
	kg SO2 eq	0.021245	0.025032
	kg PO4 P-lim	0.000325	0.000221
	kg CO2 eq	2.899416	4.565484
	MJ	71.772243	83.474100
Destruction (Incineration)	kg CFC-11 eq	0.000000	0.000000
	kg SO2 eq	0.002476	(1.721763)
	kg PO4 P-lim	0.000054	0.000082
	kg CO2 eq	8.642480	(100.840000)
	MJ	3.475941	(3,131.344800)
Destruction (Total)	kg CFC-11 eq	0.000001	0.000001
	kg SO2 eq	(18.143196)	(16.311444)
	kg PO4 P-lim	0.000391	0.000303
	kg CO2 eq	(1,444.922268)	(1,388.266816)
	MJ	15,037.300803	7,551.843300

Table 11. All impact categories for CGB and ASHP during their life cycle phases (in %)

			CGB	ASHP
Production	kg CFC-11 eq	OLD	0.13%	100.00%
	kg SO2 eq	AA	16.35%	100.00%
	kg PO4 P-lim	AE	18.99%	100.00%
	kg CO2 eq	GW	12.16%	100.00%
	MJ	NRE	11.29%	100.00%
Transport (Production)	kg CFC-11 eq	OLD	44.71%	100.00%
	kg SO2 eq	AA	64.98%	100.00%
	kg PO4 P-lim	AE	72.83%	100.00%
	kg CO2 eq	GW	56.73%	100.00%
	MJ	NRE	57.21%	100.00%
Usage (Replacement)	kg CFC-11 eq	OLD	0.17%	100.00%
	kg SO2 eq	AA	21.38%	100.00%
	kg PO4 P-lim	AE	24.46%	100.00%
	kg CO2 eq	GW	14.90%	100.00%
	MJ	NRE	13.56%	100.00%
Transport (Usage)	kg CFC-11 eq	OLD	45.70%	100.00%
	kg SO2 eq	AA	57.73%	100.00%
	kg PO4 P-lim	AE	62.39%	100.00%
	kg CO2 eq	GW	52.83%	100.00%
	MJ	NRE	53.12%	100.00%
Maintenance (Overall)	kg CFC-11 eq	OLD	0.02%	100.00%
	kg SO2 eq	AA	49.06%	100.00%
	kg PO4 P-lim	AE	100.00%	78.12%
	kg CO2 eq	GW	14.31%	100.00%
	MJ	NRE	26.05%	100.00%
Destruction (Total)	kg CFC-11 eq	OLD	100.00%	82.65%
	kg SO2 eq	AA	111.23%	100.00%
	kg PO4 P-lim	AE	100.00%	77.49%
	kg CO2 eq	GW	104.08%	100.00%
	MJ	NRE	100.00%	50.22%
Transport (Destruction)	kg CFC-11 eq	OLD	100.00%	97.55%
	kg SO2 eq	AA	100.00%	97.55%
	kg PO4 P-lim	AE	100.00%	97.55%
	kg CO2 eq	GW	100.00%	97.55%
	MJ	NRE	100.00%	97.55%
Energy (Operational)	kg CFC-11 eq	OLD	100.00%	12.77%
	kg SO2 eq	AA	100.00%	93.18%
	kg PO4 P-lim	AE	21.05%	100.00%
	kg CO2 eq	GW	100.00%	19.31%
	MJ	NRE	100.00%	19.71%
Total	kg CFC-11 eq	OLD	71.81%	100.00%
	kg SO2 eq	AA	80.71%	100.00%
	kg PO4 P-lim	AE	21.79%	100.00%
	kg CO2 eq	GW	100.00%	20.67%
	MJ	NRE	100.00%	21.37%

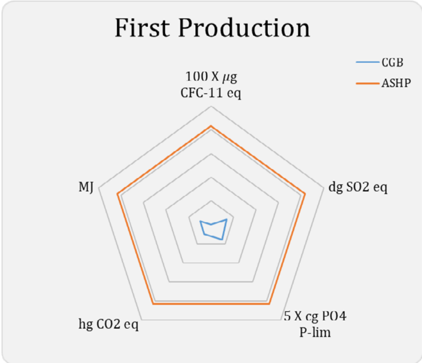

Figure 2. Environmental impact during the first production

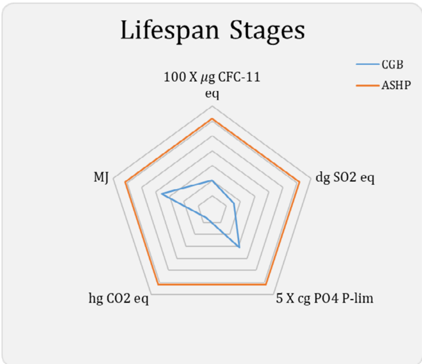

Figure 3. Environmental impact during the other lifespan stages except the first production

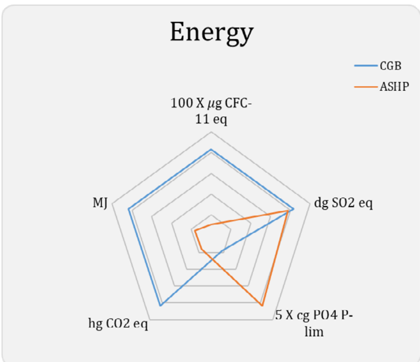

Figure 4. Environmental impact on energy consumption

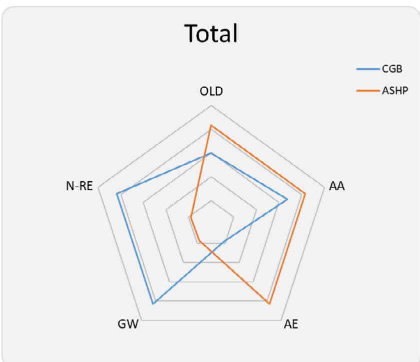

Figure 5. Overall Environmental impact for the whole lifespan of CGB and ASHP

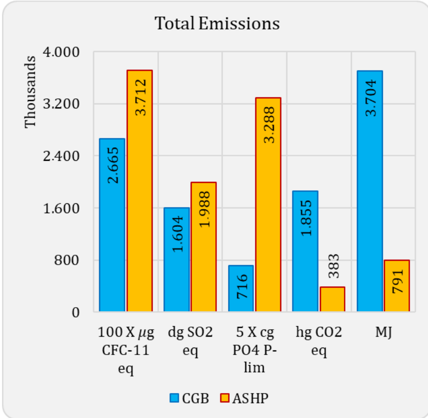

Figure 6. Overall Environmental impact for the whole lifespan of CGB and ASHP

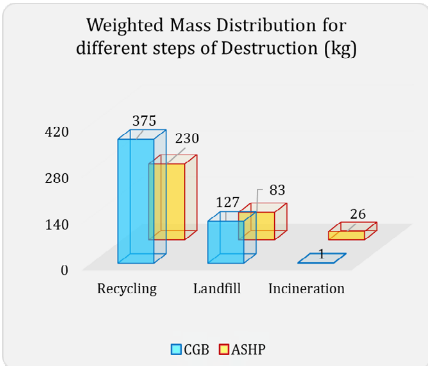

Figure 7. Types of destruction used for CGB and ASHP and weight

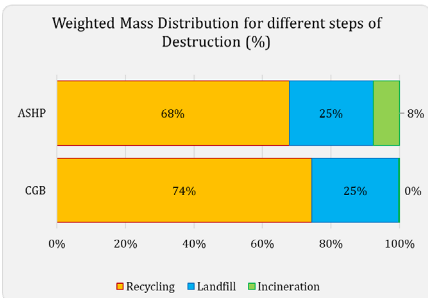

Figure 8. Ratio wise distribution of destruction methodologies for CGB and ASHP

CGB is recycled during destruction whereas 230 kg is for ASHP. The heat pump (ASHP) has 83 kg of landfill against 127 kg of CGB and ASHP has 26 kg of incineration against 1 kg of CGB.

If we deeply observe the destruction emission data (without taking the calculations for destruction related transportation), we will see that incineration saves Environmental impact and ASHP has 8% (Figure 8) of its weighted mass for incineration. Moreover, the recycling and landfill increases Environmental impact and as a result the overall Environmental impact for ASHP is less than CGB.

7. Conclusions

The above life cycle analysis was presented along with an in-detailed database. The most important findings of this study are the destruction part. The recycling part is giving more benefit to environment from CGB than ASHP, on the other hand incineration is clearly an environment-friendly option for destruction of ASHP. Besides, two dominant factors in the production part have been identified. One is at CGB end, and it is the pipeline for domestic natural gas connectivity. This dominates emissions figures in CGB's production. Another is the hot-water tank of ASHP which carries a sizable portion of ASHP's production related emissions. Therefore, throughout this study, a decision was made that ASHP is much more environmentally friendly than CGB for identical heat demand. Further such research and study can play a role to precise the destruction ratio and recycling rate of EU-28 and may bring more interesting outcomes in such comparative scenarios of life cycle analysis.

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GYVENAMOJO PASTATO KONDENSACINIO DUJŲ KATILO GYVAVIMO CIKLO VERTINIMAS IR PALYGINIMAS SU ORO ŠILUMOS SIURBLIU

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Santrauka

Šiame tyrime pateikiamas išsamus gyvavimo ciklo vertinimas, kai lyginamas kondensacinio dujinio katilo (KDK) ir oro šilumos siurblio (OŠS) poveikis aplinkai gyvenamajame pastate. Didėjant tvarių ir efektyviai energiją vartojančių šildymo sprendimų paklausai, šių technologijų aplinkosauginio veiksmingumo vertinimas tampa labai svarbus priimant pagrįstus sprendimus. Vertinamas visas abiejų šildymo sistemų gyvavimo ciklas, įskaitant žaliavas, gamybą, transportavimą, įrengimą, eksploatavimą ir atliekų tvarkymą perdirbant, laidojant sąvartynuose ir deginant. Analizės metu nagrinėjami ekologiniai rodikliai apima šiltnamio efektą sukeliančių dujų išmetimą, energijos suvartojimą ir kitas aplinkos poveikio kategorijas. Šis tyrimas atliktas naudojant SimaPro 9.4.0 duomenų bazę taikant IMPACT 2002+ metodą, o šio tyrimo išvados skirtos padėti būsto savininkams, politikos formuotojams ir pramonės suinteresuotiesiems subjektams priimti pagrįstus sprendimus dėl šildymo technologijų diegimo gyvenamuosiuose pastatuose. Išryškindama KDK ir OŠS poveikį aplinkai, ši gyvavimo ciklo analizė (GCA) prisideda prie vertingų įžvalgų pereinant prie tvarių ir efektyviai energiją vartojančių gyvenamųjų namų šildymo sprendimų ir energijos vartojimo mažinimo metodikų, kad būtų sumažinta žala aplinkai.

Reikšminiai žodžiai: gyvavimo ciklo analizė, kondensacinis dujinis katilas, oro šilumos siurblys, gruntinis šilumos siurblys, vandens šilumos siurblys, šiltnamio efektą sukeliančios dujos, karštas vanduo.