Marmara University

Faculty of Engineering

Combine Heat Pump Analysis

Ecem Çisem Tunca

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KEY ACRONYMS AND ABBREVIATIONS

HVAC : Heating, Ventilation and Air Conditioning

GSHP : Ground Source Heat Pump

WSHP : Water Source Heat Pump

COP : Coefficient Of Performance

Comp : Compressor

Cond : Condenser

Evap : Evaparator

Exp : Expansion Valve

AHRI : Air-Conditioning, Heating, and Refrigeration Institute

IEA : International Energy Agency

ASHRAE : American Society of Heating, Refrigerating and Air-Conditioning Engineers.

NPV : Net Present Value

1. INTRODUCTION

1.1. ABSTRACT

Performance of heat pump depends on the temperature differences, different source temperature directly affects efficiency. In this thesis, the calculation will be compared in four different cities with same hybrid system with boiler- heat pump which has same specifications. That is purely theoretical and simplified due to the real- time difficulties will be discussed further.

The simulation will be performed in open studio and energy plus, both of them have open source license. That gives broad aspect of specification, with plug-ins and libraries. That creates a bit of complexity, for borders of research, assumptions, and simulation. Also, that will be discussed further along the thesis.

The four cities chosed for to emphasize aspects of the system.

1.2. Brief History

Heat pump is firstly demonstrated by William Cullen in 1748. Essentially the purpose is refrigerations systems. Then, Lord Kelvin describe scientific concept in 1852. Also he emphasized as the system can also work opposite which is heating. Around 1856, Peter von Riddinger built and develop heat pump. The first safe and functional ammonia-refrigerating machine was built by Carl von Linde in 1876. This marked the start of the combined use of cold and heat.

1.3. Whats Heat Pump

A heat pump is a device used to pumping heat from a cold medium to a lower medium using the refrigeration cycle, with additional energy. Heat pump can work opposite way which is warming the medium.

Heat pump has indirect effect of the clean energy. Heat pump can save waste heat and provides correct use of energy resources. Reducing primary energy comsumption is possible. For this example the addition of heat pump to a boiler shows the effect of. Heat pumps can recover lowquality waste heat by requalifying it at higher temperatures, significantly improving energy efficiency compared to traditional heat production methods (primarily fossil fuel boilers).

[1] https://energyplus.net/licensing

Heat pumps are efficient energy conversion machines that reduce primary energy consumption by utilizing heat recovery (Jung et al., 2000, Gaigalis et al. 2016)

While, on the other hand, they are producing sustainable energy since the same input power for heat pump generates much more useful energy compared to a traditional heating system. (Rudonja,et al.,2020)

Heat pump provides wide options to built it. In every requirements heat pump can combine, can cascade or can work with extreme temperatures. The sink can change according to the usage or facility. For example cost comparison shows savings by heat pump over regular heating oil boilers of 80% efficiency in Alaska. (Garber-Slaught and et al.,2019)

According to the second law of thermodynamics, the heat does not spontaneously flow from a sink at a lower temperature to a source a at higher temperature source. Heat pump supplies this energy by using the electrical energy (mechanical heat pump) or heat energy (thermal heat pumps) Heat pumps are used in the areas of heating, refrigerating and air conditioning. Furthermore, they are used for meeting the hot water needs. Heat pumps differ from each other in terms of the source that they used (air, water, soil, etc.) and the heat that they conduct(Tamdemir et al.,2015).

The heat pump prototypes operate under three main modes.The heating mode produces hot water using heat available in the ambient air. The cooling mode produces cold water and rejects heat to the ambient air. (Byrne et al.,2019)

On the basis of this estimation, it can be concluded that the household sector offers huge possibilities for the implementation of energy savings measures. It can be observed that a relevant part of household energy consumption is due to winter heating purposes. Therefore, the utilization of more effective methodologies for buildings heating may result in primary energy savings and in a decreased environmental impact. (Bianco et al.,2018)

Single stage heat pumps are not able to satisfy these temperature demands resulting in low system performance. Hybrid system can achieve cost efficiency and durability to extreme temperatures.

It is more expensive to get both cooling and heating effects from the two systems independently (i.e. heat pump and refrigerator) since one must buy the two (with each having individual compressor) at the same time in order to usage of the two effects.

Single-stage heat pumps are unreliable at low ambient temperature conditions and over high pressure ratios, resulting in deteriorated heating capacity and low COP. This makes them unpopular for use in the generation of hot water, especially above 65°C, for both domestic and industrial use. For purposes of reliability and maximum system performance, the cascade heat pump is preferred to single stage heat pumps. The cascade heat pump has higher heating capacity, higher hot water temperature and much stable water heating capacity than single stage heat pumps. They also have lower compressor discharge temperature, lower evaporating temperature, lower compression ratio and higher compressor volumetric efficiency than single stage refrigeration systems at the same cooling capacity .System responds to the optimum

COP of the system. The performance of the cascade heat pump decreases when the HS (High Side) is operating at overcharge or undercharge conditions.

Heating capacity decreases at HS refrigerant undercharge conditions and total power consumption increases at HS overcharge conditions. These causes a reduction in the COP of the system at both HS overcharge and undercharge conditions(Boahen et al.,2016)

Heat pumps does not directly emit any pollutions to the atmosphere, but indirect emissions are done during generation of power necessary for their operation (Sewastianik et al.,2020)

Locational availabilities or locational resources limited by availability of resources, best way is energy reducing. Heat pump is a efficient and economical way to reducing energy. Especially residential heating holds significant share for energy demands. Residential heat pump systems common by time. Heat pump cover important share for energy demand.

Domestic hot water, cooling and heating demand can taken care by one system, including one type of resource which is electricity and it can come from renewable energy resources.

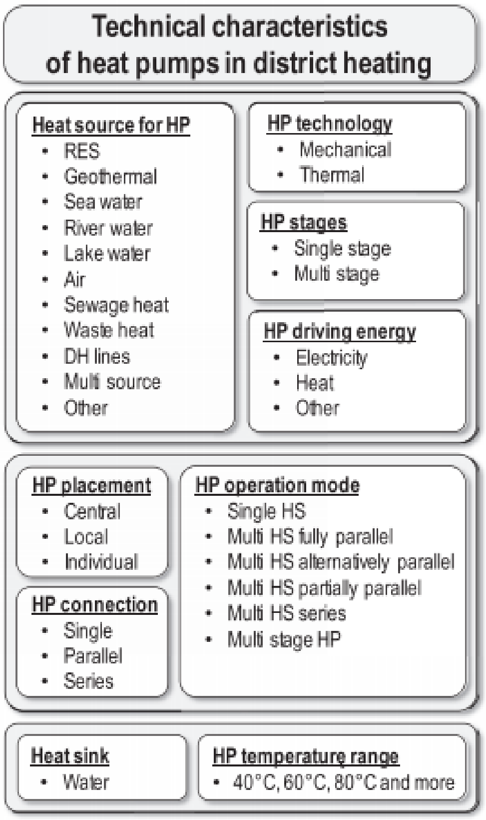


Table 1 Heat pump placement, connection and operational modes in European(Sayegh et al.,2018)

▲ high ▼ low ▬ medium

Type of Heat Source	Temperature	Stability/Security	Proximity to Urban Areas
Sewage water	▲	▲	▲
Ambient water	▬	▲	▲
Industrial waste heat	▲	▼	▬
Geothermal water	▲	▲	▼
Flue gas	▲	▬	▬
District cooling	▼	▬	▲
Solar heat storage	▲	▲	▬

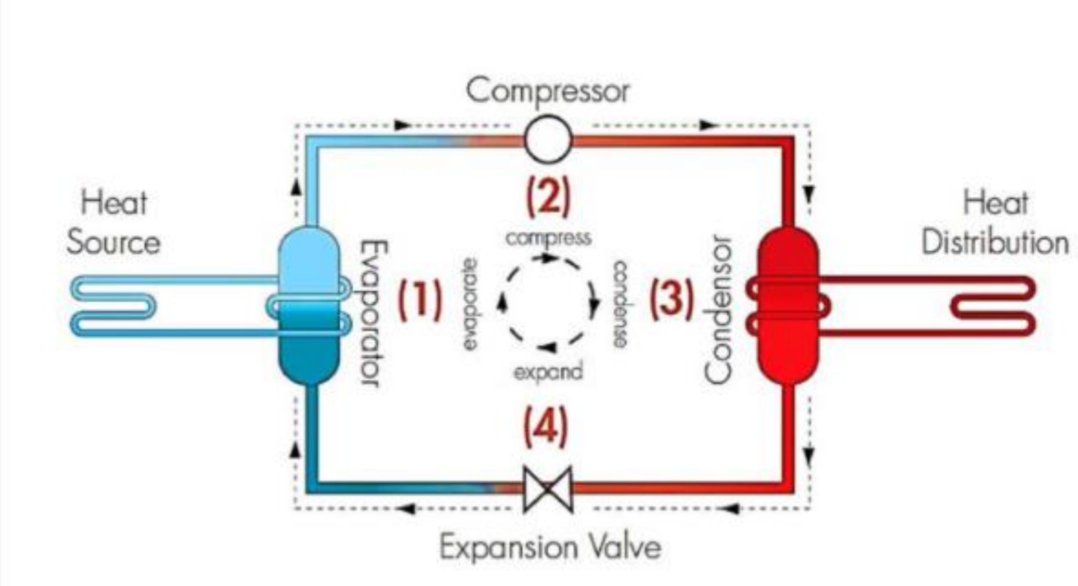
Table 2 Characteristics of the Heat Sources (David et al., 2017)

Type of Heat Source	Capacity (MW)	Percentage of Total Capacity	Number of Units	Average Capacity Per Unit (MW)	Temperature Range (°C)
Sewage water	891	56%	54	17	10–20
Ambient water	390	24%	34	11	2–15
Industrial waste heat	129	8%	28	5	12–46
Geothermal heat	97	4%	19	5	9–55
Flue gas	40	2%	7	6	34–60
District cooling	30	<2%	4	7	0–9
Solar heat storage	4	<1%	3	1	10–35
Total	1580		149		0–60

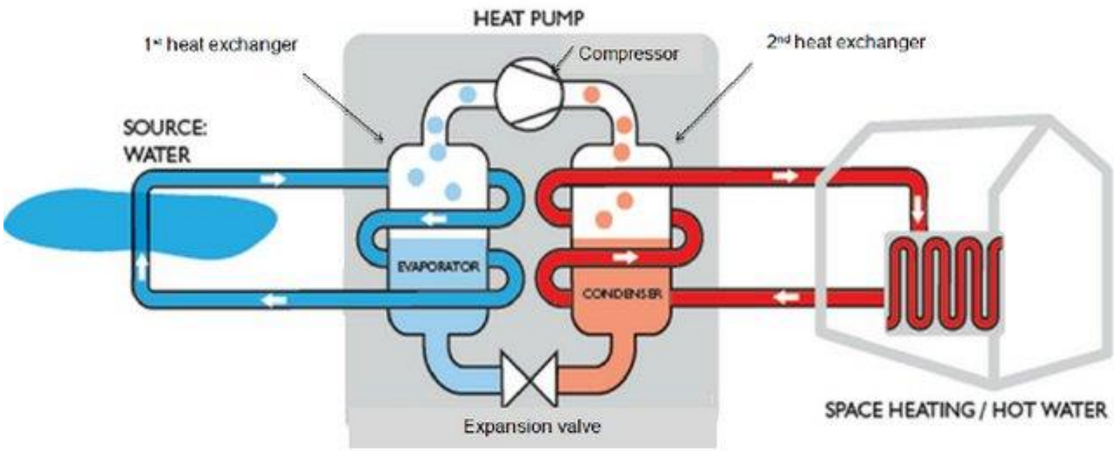
Table 3 Heat Sources for the Heat Pumps (David et al., 2017

1.4. Schematic

The basic units as shown below; the parts shown in red represent the hot refrigerant flows while the blue color represent the cold refrigerant flow.



Pic. 1 The general representation of heat pump (Gamage)

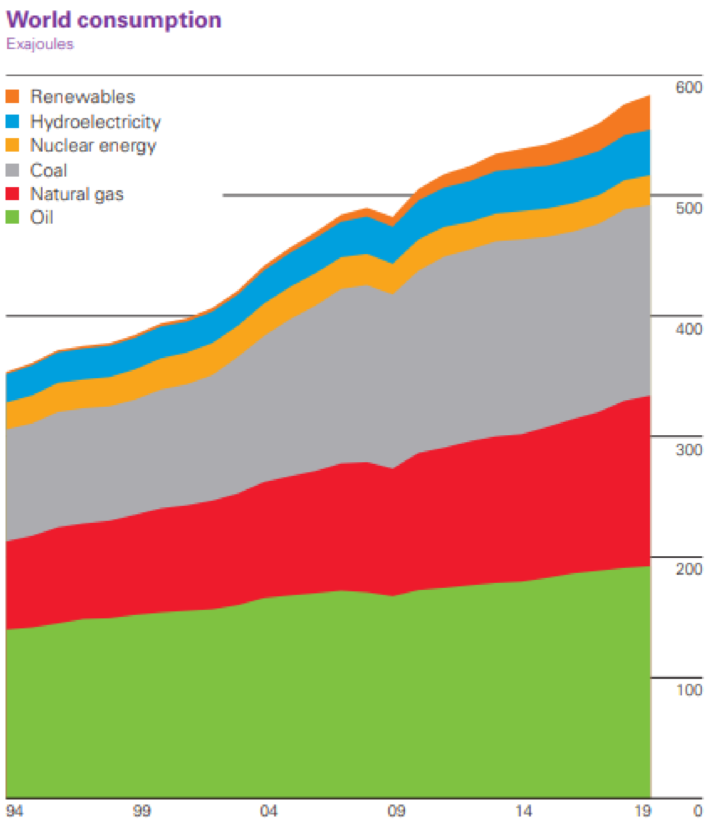


Pic. 2 water source type heat pump units (url1)

2. Usage Areas

Energy demands increasing rapidly due to the developments of technology, population growth and several types of need. Energy saving is more important to reduce energy consumption.

Approximately 40% of end-use carbon dioxide emissions, and 40% of total energy consumption are attributable to buildings (Carrol et al.,2020)



Graph 1 BP reports for energy consumption

Primary energy consumption rose by 1.3% last year, less than half its rate in 2018 (2.8%). Growth was driven by renewables (3.2 EJ) and natural gas (2.8 EJ), which together contributed three quarters of the increase. All fuels grew at a slower rate than their 10-year averages, apart from nuclear, with coal consumption falling for the fourth time in six years (-0.9 EJ). By region, consumption fell in North America, Europe and CIS and growth was below average in South & Central America. In the other regions, growth was roughly in line with historical averages. China was the biggest individual driver of primary energy growth, accounting for more than three quarters of net global growth. (bp Reports)

2.1. Turkey

In Turkey, heat pump is not common. There are some papers about specific types of heat pump especially ground source type. The companies are generally import whole system without further analysis, and most of the time the commercial buildings prefer this type of investment. Turkey experience wide temperature ranges and climate conditions. Colder climates prefarably can chose boiler -heat pump hybrid system.

2.2. In World

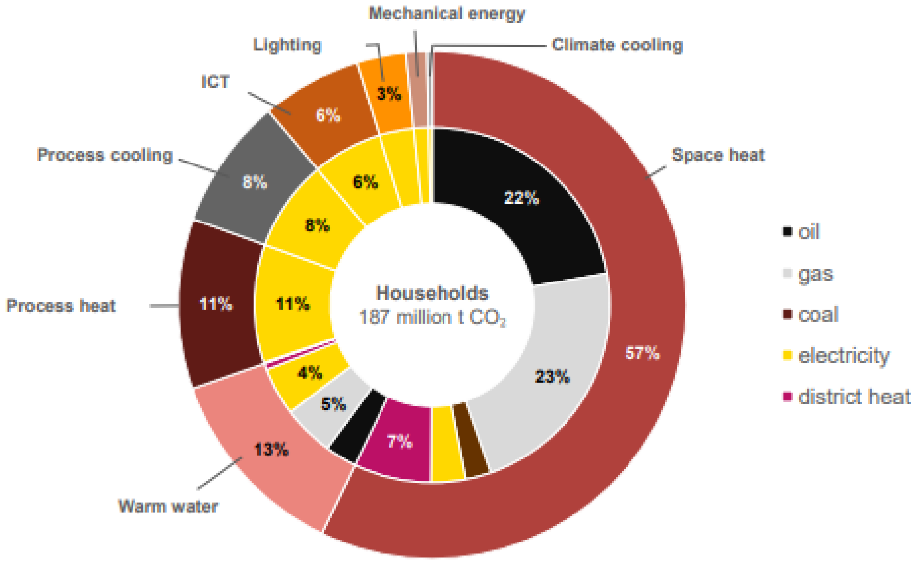
The main problems of central heating system in China are as follows: low efficiency, inadequate regulation function, serious thermal imbalance and excessive heating. These problems result in a high energy consumption in residential building, about three times in developed countries, so it is time to reinforce central heating energy-saving work. Based on statistic data, there are 30% heat loss on average [1], while this in developed European countries is 6-15%. The proper operation strategy of heating system can reduce the heat loss caused by hydraulic imbalance and leakage in the transmission and distribution network(Fang et al.,2018).

Global sales of air-towater heat pumps account for more than 1.8 million units. The volume of the world market for HP of all types in value terms is estimated at more than $ 10 billion. In Russia, the forecast of the market for steam-compressor heat pumps (SCHP) for 2030 is the end of the implementation of the current “Energy Strategy” – 11,000–15,000 units. (500–700 MW). (Malyshev et al.,2019)

In cold regions, like Fairbanks, Alaska the buildings need to be heated for about 8 months of the year. (Garber-Slaght et al.,2019)

Approximately one quarter of energy-related emissions in Germany are caused by the domestic sector. At 81%, the largest share of these emissions is due to heat supply.

With the adoption of the Paris Climate Agreement in 2015, almost the entire world community committed itself to a significant reduction in greenhouse gas emissions, thus creating additional momentum for German efforts. (Conrad et al., 2019)



Graph 2 Emissions sharing in Germany

In 2017, the final energy consumption by households in European Union was 27.2%, while 64.1% of that energy was used for heating (Rudonja et al.,2020)

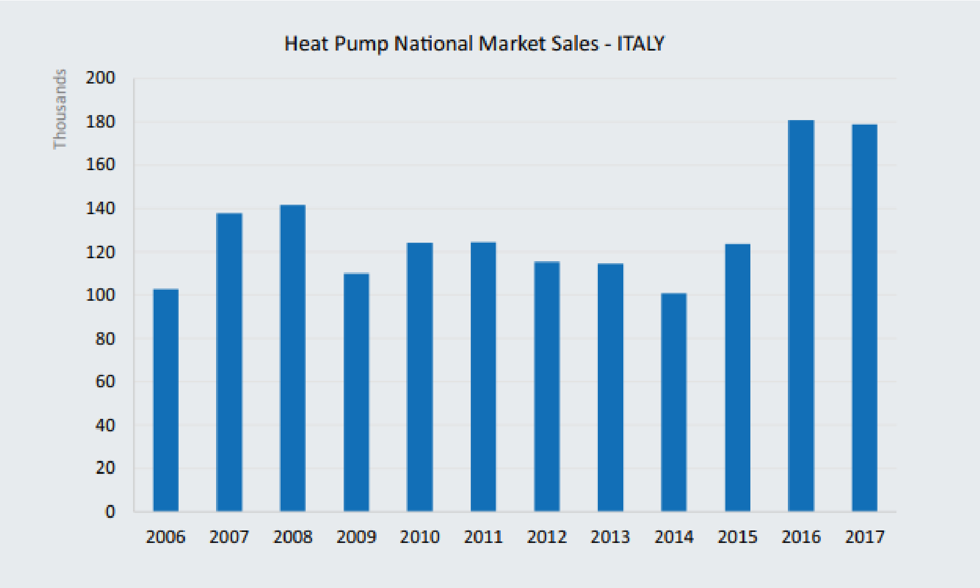
Almost every country, doing the research of heat pump analysis for several reasons. For cost analysis; Cost of Heating Pump Systems in Russia(Lopatin)

For seasonal effect on heat pump; (Sewastianik at all)

For extreme temperatures; (Garber-Slaught and et al.,2019)

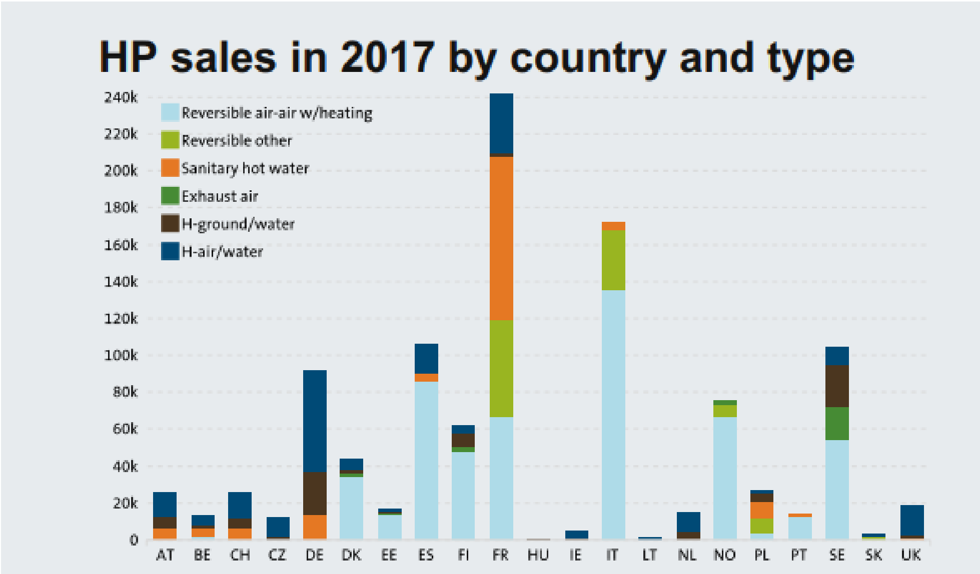
For load profile; (Conrad et al., 2019)

Heat pump usage is increasing in time. And the researches shows us that area promising for future.



Graph 3 (Pieve et al., 2018).

Over the last 10 years average annual sales of heat pumps in Italy were around 130,000, peaking in the last two years up to about 180,000 units. In 2015 and 2016 overall sales increased by 23 % and 46 % respectively compared with the previous year, as shown in Graph 3 (Pieve et al., 2018).



Graph 4 (Pieve et al., 2018).

A positive trend can be seen for hybrid systems which combine a gas boiler and a traditional heat pump (smaller than usual) in a unique integrated system that guarantees best performance relative to climatic conditions. Although this is a recent technology, the increase in its spread is promising, with sales doubling in 2017 compared with 2015. Otherwise, domestic hot water production by means of a heat pump is still not a widespread technology, presumably for cost reasons: currently, a heat pump for domestic hot water production can be as much as eight times more expensive than a traditional electric boiler, depending on size and specific features. Finally, the market for ground-source heat pumps has been largely flat over the last 10 years, with average annual sales of less than 1,000 units [4] – despite the fact that Italy is in the top 10 countries in the world when it comes to exploiting geothermal heat for electricity and is one of the top in the EU for direct heat consumption from geothermal energy.

The leading sector remains air-to-air reversible domestic applications, which historically caught on as summer cooling machines, particular in view of Italy's warm climatic conditions in recent years. A promising trend can be seen for systems that are not air-to-air machines, with sales volumes having tripled over the last 10 years.

For heating element, the subsidy 25% is less than 30% because the operating cost in producing hot water from heating elements is higher than boilers. It has higher rate of return or shorter payback period by itself compared to boiler. (Techato, K., (2012),

According to national statistics, up to the end of 2016 over 22000 GSHP projects were completed with a building floor space of more than 487 million m2 in China. (Diao et al., 2019)

2.2.1. European Green Deal

Heat pumps play a crucial role in achieving the objectives of the European Green Deal, which aims to make the EU climate-neutral by 2050. As highly efficient, low-carbon heating and cooling technologies, heat pumps help reduce greenhouse gas emissions by replacing fossil fuel-based systems in buildings and industry. By utilizing ambient energy from the air, ground, or water, they offer a sustainable alternative that aligns with the EU's goals for energy efficiency, renewable energy integration, and reduced dependence on imported fuels. Their widespread adoption is supported by EU policies and funding mechanisms, recognizing heat pumps as a key solution in the transition to a clean and resilient energy system.

3. Types of Heat Pumps

3.1. Air to Air

In summer, cooling demand increasing, and the solution is air conditining. The common type of heat pump generally used for air conditining with reversing pump it can work either heating or cooling in needed.

In heating, the gas leaves compressor with high pressure and temperature. Reverse valve directs to the indoor heat exchanger. When temperature leaves, the refrigerant condense to the high pressure and cooler liquid. Expansion valve directs to the outdoor exchanger. In expansion valve the liquid expanse in volume and becomes mixture. After outdoor exchanger the refrigerant becomes superheated vapour. Reversing valve orient to compressor then cycles can repeat again.

In cooling the refrigerant leaves from compressor high pressure and temperature. This time refrigerant goes to outdoor heat exchanger. After that, the refrigerant still high pressure but, slightly cooler liquid. Expansion valve causes to drop temperature and pressure. After dropping by indoor heay exchanger, the refrigerant slightly superheated with low temperature and pressure. When refrigerant comes to compressor the cycle can be repeat.

3.2. Ground Source

The design of a Ground Source Heat Pump (GSHP) system is critical because design choices affect the system's energy performance and operating conditions. If the thermal load profile on the ground side is unbalanced the ground temperature will change throughout the time and, consequently, also the energy efficiency of the heat pump. This phenomenon is known as "ground thermal drift". A possible solution to avoid this inconvenience is the adoption of a hybrid system.

The main disadvantage of GSHP systems, compared to conventional ones, is surely the higher initial costs due to drilling for ground heat exchangers or groundwater wells

The ground temperature drift which is practically unavoidable when a building exhibits an appreciable unbalance between heating and cooling requirements (Zarrella et al., 2018)

4. Heat Pump Components

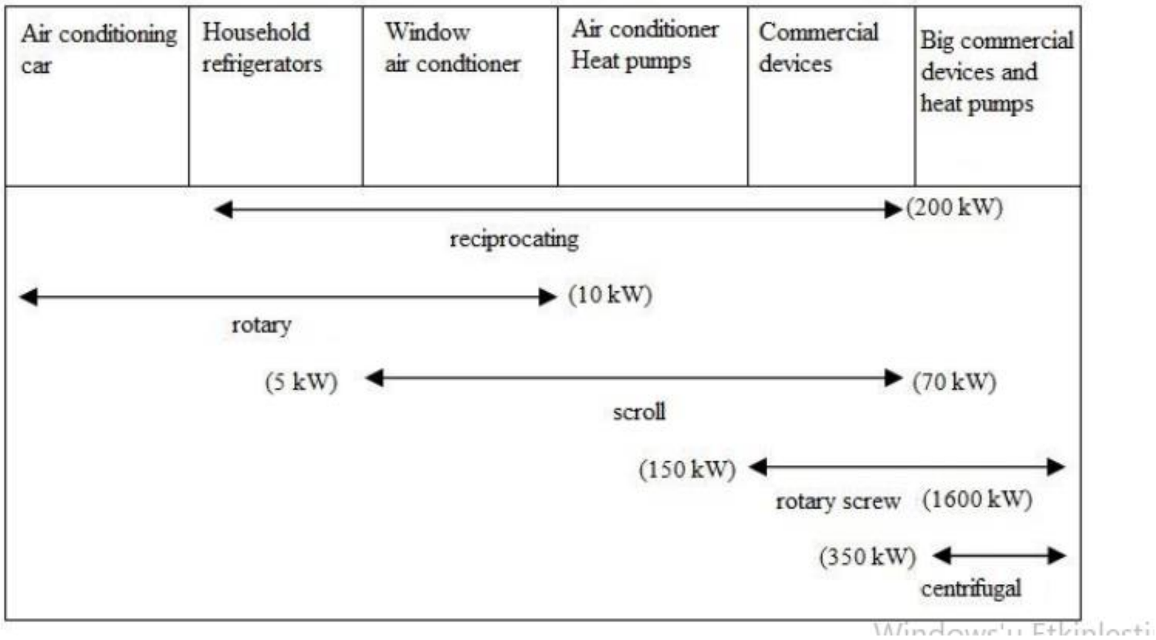
4.1. Expansion Valve

Expansion valves stand between the condenser and the evaporator in the cycle. It controls the refrigerant flow. Expansion valve can save money and energy. It has fair cost according to other components. For further cost analysis (Üçok, H. 2024)

4.2. Compressor

Compressor mainly circulates the refrigerant through the cycle. Compressor shows more temperature due to friction, the real temperature of cycle fluid can be seen after 20-25 cm. [2]A compressor circulates refrigerant between the indoor evaporator and outdoor condensing units. Technical details of compressor can be accessed in Bitzer software with limited data.

[2] According to the meeting at RES energy, during the visiting.



Graph 5 Types and the General Usage is Shown (Guzda et al., 2015)

4.3. Heat Exchangers

In the literature, many thermodynamic models used to assess the HT-HPs performance are fundamental and do not consider many practical aspects such as different values of temperature lift, and pinch point and pressure drop inside heat exchangers.

4.3.1. Evaporator

Definition of evaporator is as it can be seen from the evaporation root, the part of a system which the refrigerant absorbs heat and phase changes from a liquid to a gas. For the cooling purposes, the evaporator takes away the heat from the room or cooling intend space.

4.3.2. Condenser

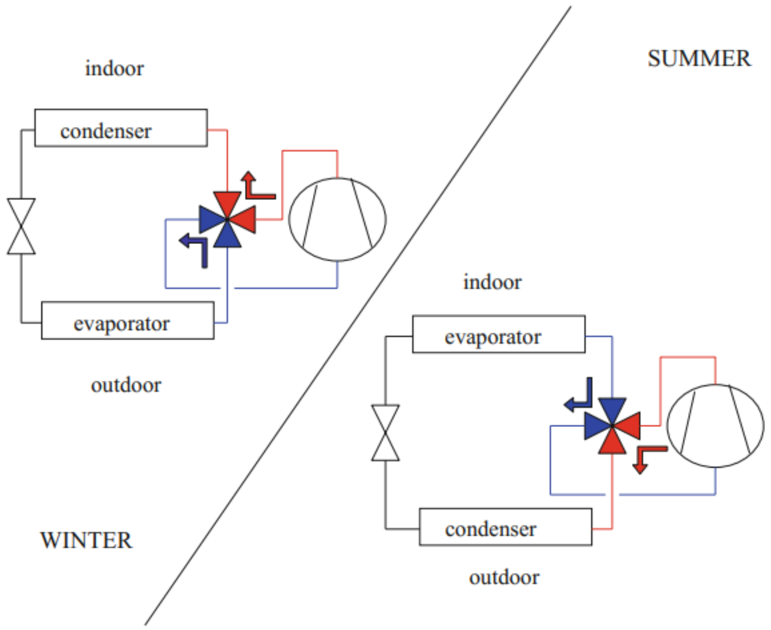
Condenser is simply heat rejector. The heat is rejected to sink which can be air or desired to the heat of the space.

4.4. Refrigerant

Ammonia (NH3)—Ammonia refrigerant generally used in medium and large-scale applications. It can work to temperatures up to 90 _C, such as at the Drammen heat pump plant (Norway), with a COP over 3. Its efficiency is comparable with the one of the synthetic refrigerants analysed in this survey, and it is moderately flammable and toxic, so it requires specific safety precautions [25]. Due to its corrosive properties and different working temperature and pressure, ammonia cannot be used to retrofit the heat pumps using synthetic refrigerants, such as R-22 and R-134a. The heat pumps using NH3 account for 26 units with a total heating capacity of 51 MW, with the oldest units in the survey operating in Laussane (Switzerland) since 1986.Carbon dioxide (CO2)—Carbon dioxide is a non-toxic, non-flammable and non-corrosive refrigerant, which is generally obtained as a waste product, making it as one of the low-cost refrigerants [25]. It is also a transcritical fluid, meaning that temperature and pressure can be controlled individually, unlike other condensing (subcritical) refrigerants. It’s heating COP is 25–150% better than R-134a, and is suitable for high temperature lifts, as the lower the temperature in the inlet is, the better overall efficiency it has [26]. A drawback of this refrigerant is the high pressures it must work under, making it less suitable for large-scale applications (larger than 1–2 MW). There is only one example of a large-scale heat pump using CO2 refrigerant in the survey, in the Marstal DH network in Denmark, with a heating capacity of 1.5 MW. R-134a—It is the most used HFC in the survey, and serves as refrigerant for 110 heat pumps in the survey, with a capacity over 1450 MW. It has zero ODP as it does not contain the chlorine atom, and good heat transfer properties by providing a wide temperature gap. It is also non-flammable, non-toxic and it was regarded as the most suitable option for retrofitting old heat pumps using R-12 and R-22 [28]. The refrigerant has a GWP potential of 1300, which has caused it to be prohibited already in countries such as Denmark and Switzerland. R-152a—It is a HFC which has a GWP of 124 and similar thermodynamic properties as R134a, even yielding a higher COP. Generally, this refrigerant is used in blends with other refrigerants due to its very high flammability, and in the survey two heat pumps use it [29]. R-245fa—A HFC, generally used in high temperature applications. It has a GWP of 950 and a moderate toxicity with a critical temperature of approximately 150 ℃, but it works at a pressure similar to R134a.

5. WORKING PRINCIPLE

A heat pump cycle absorbs heat from a source and transfers the heat to a sink in a cycle of series of activities involving the evaporator, refrigerant, compressor, condenser and the expansion valve. An evaporator extracts the heat from the source by transferring the heat to a refrigerant. The heat transferred to the refrigerant causes it to change from liquid to gas phase (i.e. evaporate). The evaporated refrigerant gas pressure and temperature is raised utilising a compressor and transferred to the condenser. Similarly, heat transfer to the sink causes the high pressure refrigerant gas to condense to a liquid state within the condenser. An expansion valve lowers the pressure of the liquid refrigerant and this expansion process also causes a drop in the liquid refrigerant temperature as the refrigerant enters the evaporator restarting the cycle. All refrigeration equipment (i.e. air-conditioners, chillers etc.) can be classified as heat pumps.(Nwaigwe K. N., 2019)



Winter

$$COP_W = \frac{Q_C}{L} = \frac{1}{1 - \frac{Q_F}{|Q_C|}} = \frac{1}{1 - \frac{T_F}{T_C}\left(1 - \frac{T_C S_g}{|Q_C|}\right)}$$

Summer

$$COP_S = \frac{Q_F}{|L|} = \frac{1}{\frac{|Q_C|}{Q_F} - 1} = \frac{1}{\frac{T_C}{T_E}\left(1 + \frac{T_F S_g}{Q_F}\right) - 1}$$

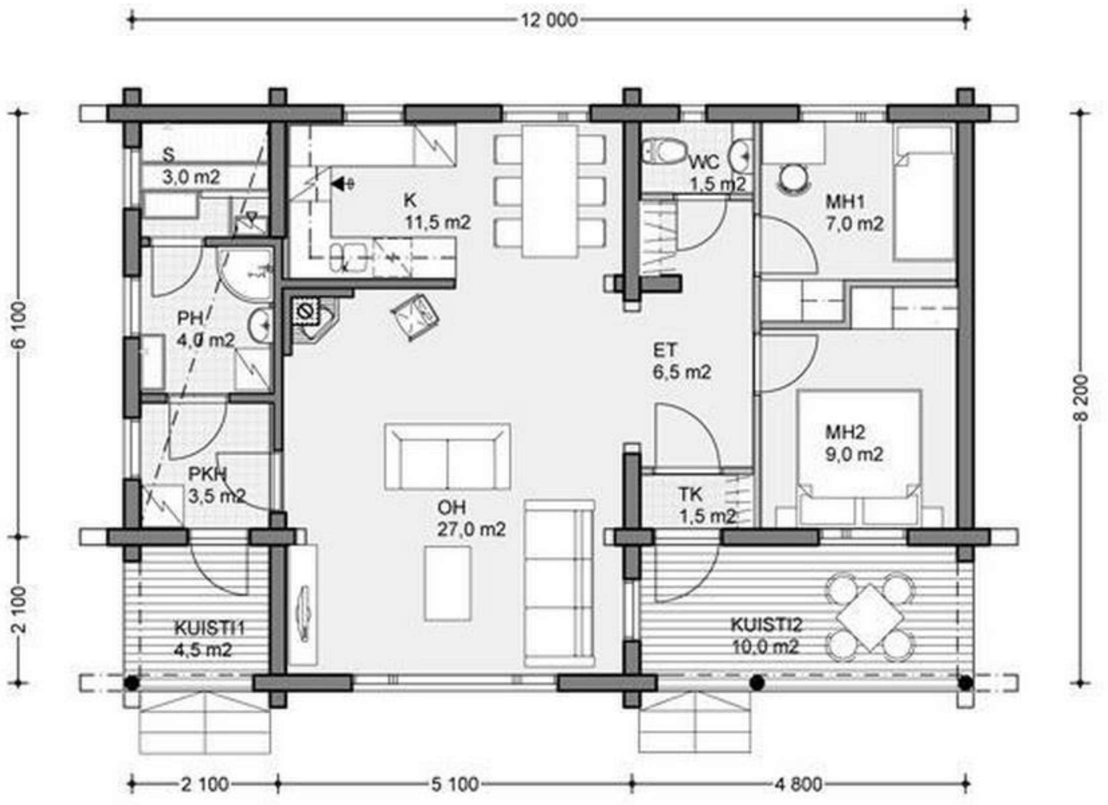
6. MODELLING

6.1. The Parameters

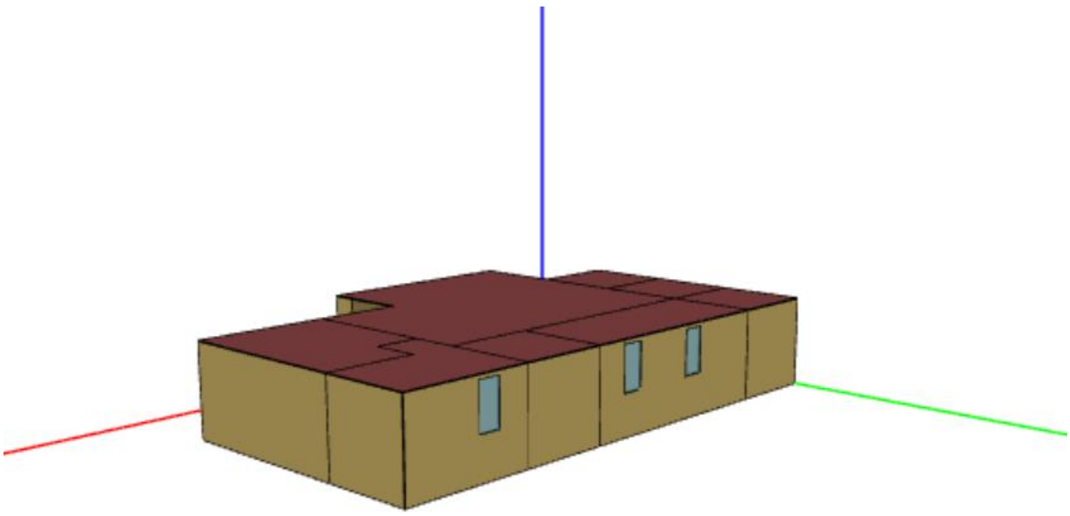
In this study, load accuracy was prioritized over zone thermal comfort, aiming to realistically capture energy demands rather than simulate perfect indoor conditions. The overall optimization focused on balancing construction specifications, insulation levels, weather file accuracy, and heating/cooling load estimations.

6.2. The Sketch

For convience the model choose 100 m^2 however in the end the balcony part accepted as outside zone and does not account for load. The total load area will be 82 m^2. The sketch does not involve balcony, and the outside porch for that reason.



Sketch 1 The sketch of the Unit/Flat



Sketch 2 3D model Floor to Celing Height is 2m

Sketch 3 The footprint with Thermal Zones.

There is a 3 m^2 place at the left-upper corner. That place used for heat pump equipment zone. Also does not involved in conditioning.

Table 4 The Area Ratios

Building Area

	Area [m2]
Total Building Area	82.00
Net Conditioned Building Area	78.00
Unconditioned Building Area	4.00

Table 5 The Ratios of the Flat

Window-to-Wall and Skylight-to-Roof area Ratios

Description	Total (%)	North (%)	East (%)	South (%)	West (%)
Gross Window-Wall Ratio	5.62	6.25	0.0	6.25	9.38
Gross Window-Wall Ratio (Conditioned)	5.56	7.5	0.0	6.25	8.33
Skylight-Roof Ratio	0.0				

6.1. Spaces

All sections are connected each other. That section summarize us the conditions of the buildings, stories, space types, thermal zones, construction sets, schedule sets, and people loads. That conditions are detailed further. For that instance, there is one building, that unit represents one flat between 1-8 floors. Its possible to choose Office building or workplaces. Offices are default but any other types should be imported from any other sources.

6.2. Thermal Zones

There are six thermal zones. That flat can be modeled as one single thermal zone. However, every room has different angles and shading. The outside walls, the number of windows effect the requirements for conditioning. For accuracy there are six different zones, which all of them using one air loop for cooling and heating.

Table 6 Thermal zones And Thermostat Schedules

Zones	Heating Thermostat Schedule	Cooling Thermostat Schedule
TZ_bathroom	Heating Schedule(13-19)	Cooling Schedule (23-25)
TZ_bedroom	Heating Schedule(13-19)	Cooling Schedule (23-25)
TZ_Entry	Heating Schedule(13-19)	Cooling Schedule (23-25)
TZ_heat_pump	Heating Schedule(13-19)	Cooling Schedule (23-25)
TZ_kitchen	Heating Schedule(13-19)	Cooling Schedule (23-25)
TZ_saloon	Heating Schedule(13-19)	Cooling Schedule (23-25)

The deadband will be 4 degree for zones.

6.3. Climate Conditions

6.3.1. Ankara

Weather Summary

	Value
Weather File	ANKARA - TUR IWEC Data WMO#=171280
Latitude	40.12
Longitude	32.98
Elevation	949 m
Time Zone	2.00
North Axis Angle	0.00
ASHRAE Climate Zone	3B

Sizing Period Design Days

	Maximum Dry Bulb (C)	Daily Temperature Range (K)	Humidity Value	Humidity Type	Wind Speed (m/s)	Wind Direction
ANKARA ANN CLG .4% CONDNS DB=>MWB	33.0	15.4	17.6	Wetbulb [C]	4.0	230.0
ANKARA ANN CLG .4% CONDNS DP=>MDB	23.6	15.4	15.2	Dewpoint [C]	4.0	230.0
ANKARA ANN CLG .4% CONDNS ENTH=>MDB	29.1	15.4	59000.0	Enthalpy [J/kg]	4.0	230.0
ANKARA ANN CLG .4% CONDNS WB=>MDB	29.4	15.4	19.2	Wetbulb [C]	4.0	230.0
ANKARA ANN HTG 99.6% CONDNS DB	-15.7	0.0	-15.7	Wetbulb [C]	0.5	100.0
ANKARA ANN HTG WIND 99.6% CONDNS WS=>MCDB	3.4	0.0	3.4	Wetbulb [C]	10.1	100.0
ANKARA ANN HUM_N 99.6% CONDNS DP=>MCDB	-14.8	0.0	-18.3	Dewpoint [C]	0.5	100.0

6.3.2. İzmir

Weather Summary

	Value
Weather File	IZMIR - TUR IWEC Data WMO#=172180
Latitude	38.50
Longitude	27.02
Elevation	5 m
Time Zone	2.00
North Axis Angle	0.00
ASHRAE Climate Zone	3B

6.3.3. İstanbul

Weather Summary

	Value
Weather File	ISTANBUL - TUR IWEC Data WMO#=170600
Latitude	40.97
Longitude	28.82
Elevation	37 m
Time Zone	2.00
North Axis Angle	0.00
ASHRAE Climate Zone	3B

6.3.4. Kars

Weather Summary

	Value
Weather File	Kars.AP KA TUR Custom-170980 WMO#=170980
Latitude	40.56
Longitude	43.12
Elevation	1795 m
Time Zone	3.00
North Axis Angle	0.00
ASHRAE Climate Zone	3B

6.3.5. Erzurum

Weather Summary

	Value
Weather File	Erzurum.AP EM TUR SRC-TMYx WMO#=170960
Latitude	39.95
Longitude	41.19
Elevation	1757 m
Time Zone	3.00
North Axis Angle	0.00
ASHRAE Climate Zone	3B

6.4. Construction Sets

This selections are made for simple flat attributes.

Exterior Roof.	ASHRAE 189.1-2009 Climate Zone 2-5
Exterior Wall	ASHRAE 189.1-2009 Climate Zone 4
Exterior Window	ASHRAE 189.1-2009 Climate Zone 4
Interior Window	Default
Interior Wall	Default
Interior Door	Default

6.5. Schedules-Setpoints

That part is fairly complicated. There are types of schedules:

Schedules	Type	Effects on System
Availability schedules	On/off)	Seasonal behaviour
Cooling-Heating Thermostat schedules	Temperature	Zone Temperature Range
Setpoint Manager Schedules	Loop Control Temperature	Temperature control of loop

6.5.1. Availability Schedules

That schedule determine the seasonal behavior of loops, cooling supply only deliver on summer days. That can be achieved with temperature levels, trigger can be created to kick of cooling supply to zones. However if system overheats for some reason, it can trigger the upper limit of cooling load. The thermostat force the system to balanced with cooling and heating at the same time. That can kick of both system to cool down itself with cooling loop also heating up with heating loop which creates unnecessary load/ energy waste. Thats the reason the calender constructed like this;

Cooling period, heating period without boiler backup, and heating with boiler backup

JANUARY						
M	T	W	T	F	S	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

FEBRUARY						
M	T	W	T	F	S	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28		

MARCH						
M	T	W	T	F	S	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

APRIL						
M	T	W	T	F	S	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

MAY						
M	T	W	T	F	S	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

JUNE						
M	T	W	T	F	S	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

JULY						
M	T	W	T	F	S	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

AUGUST						
M	T	W	T	F	S	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

SEPTEMBER						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

OCTOBER						
M	T	W	T	F	S	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

NOVEMBER						
M	T	W	T	F	S	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

DECEMBER						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

6.5.2. Cooling-Heating Thermostat schedules

That allows to control zones maximum and minimum temperatures. Its possible to autosized air flow rate, heating capacity or cooling capacity, if its not hard sized that helps to optimize this values. The deadbands and thresholds provides reasonable comfort temperature ranges for zones. The schedules are designed like this;

6.5.3. Setpoint Manager Schedules

That manager setup can create conflict and thats the main reason the loop setup are organized three loops instead of two loops. Every loop needs setpoint manager at the end of it. That setpoint manager controls the loop behaviour according to restricted/designed schedules. When availability schedule assigned to a loop it effects whole system, so that makes impossible to implement one loop to zones. Two zones considered as one heat pump loop together, and one boiler loop setup. That allows to optimize boiler and heating DX loops for loads.

6.6. The Hvac System

There are three loops for seasonal schedule, the availability schedules affect whole system, if cooling and heating DX shares same loop the availability schedule can not determine to which unit will be work for.

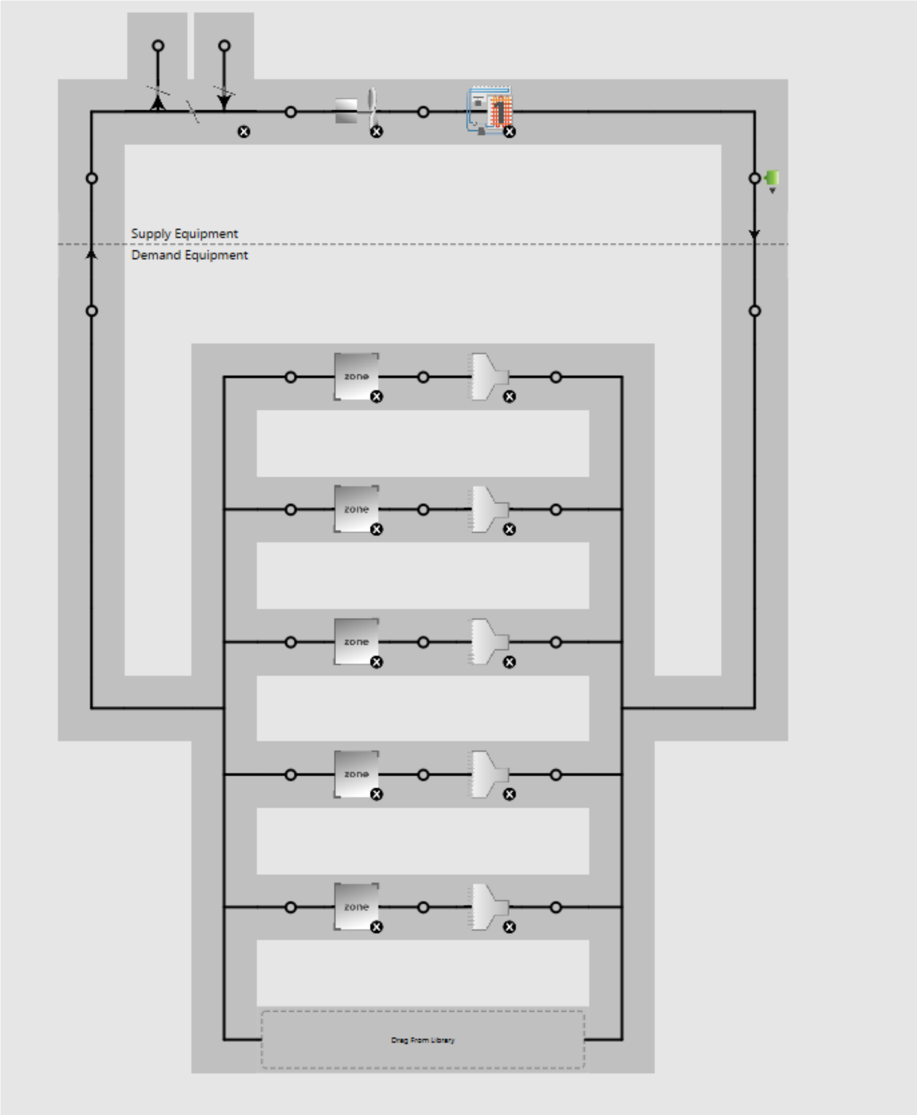


Diagram 1Packaged Rooftop Heat Pump Heating Loop

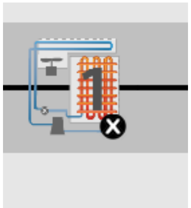


Figure 1 Coil Heating DX Single Speed 2

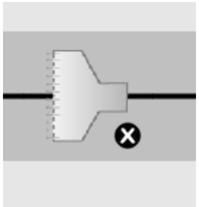


Figure 2 Diffusers

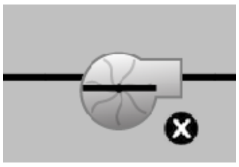


Figure 3 Constant Speed Pump

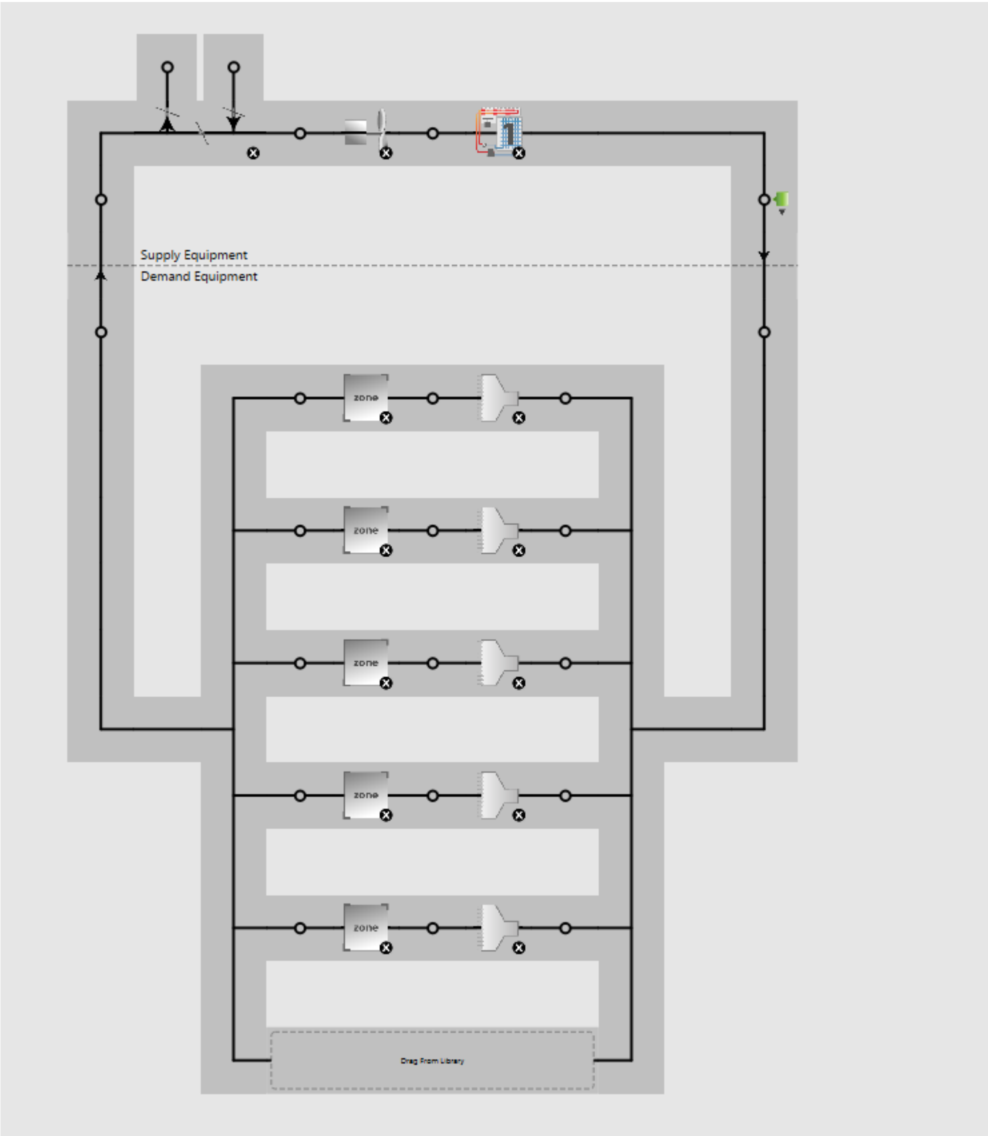


Diagram 2 Heat Pump Cooling Loop

The breakdown of the diagram 2;

- The zones are listed above at Table 4
- There are diffusers for air flow-for distribution system needs diffusers for each zone.
- Fan

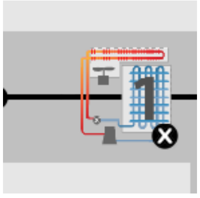


Figure 4Coil Cooling DX Single Speed 2

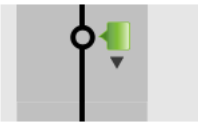


Figure 5 Setpoint Manager:Scheduled

Coil Type	**Represents**	**Acts As**	**Location**
Coil:Cooling:DX	The evaporator in cooling mode	Absorbs heat from indoor air	**Indoors**
Coil:Heating:DX	The condenser in heating mode	Releases heat to indoor air	**Indoors**

Open Studio simplifies the evaporator and condenser as Coil Cooling/Heating Units.

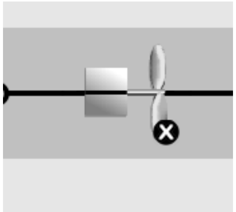


Figure 6 Fan

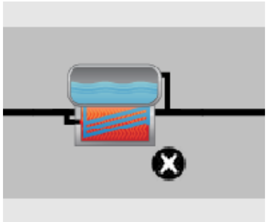


Figure 7 The Boiler Unit

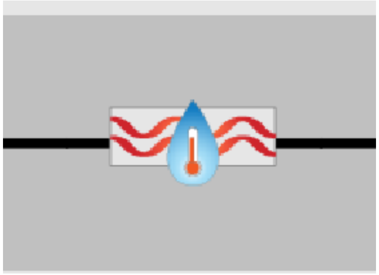


Figure 8 Baseboard HW Htg Coil

Baseboard HW Htg Coil used for to conduct the heat from boiler to zones.

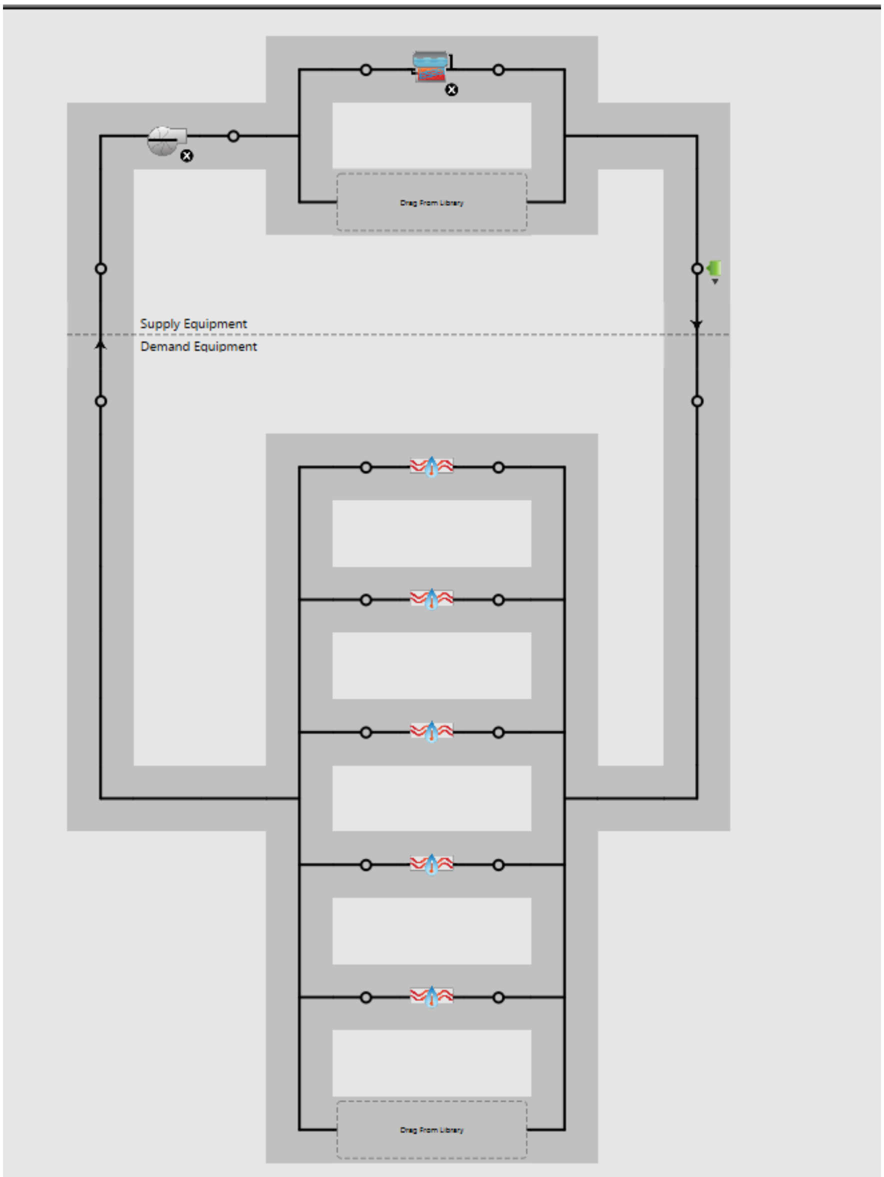


Diagram 3 Boiler Loop

6.7. Loads

For the simulation integrity system needs people load. For this instance light, electrical or any other gas loads did not consider. Its possible to add electrical devices such printer, coffee maker, or any other machines that can be used in office or house. For gas, its possible to add stove etc. People definition has three type occupancy;

People for Daytime occ	This includes daily activities
People For min	This includes minimum spending time/energy zones for entry/bathroom
People for Night	This is for bedroom with sleeping occupancy.

Table 7 People Load for every zone.

Average and Minimum Outdoor Air During Occupied Hours

	Average Number of Occupants	Nominal Number of Occupants	Zone Volume (m^3)	Avg. Mechanical Ventilation (ach)	Min. Mechanical Ventilation (ach)	Avg. Infiltration (ach)	Min. Infiltration (ach)	Avg. Simple Ventilation (ach)	Min. Simple Ventilation (ach)
TZ_BATHROOM	166.67	500.0	30	0.0	0.0	0.0	0.0	0.0	0.0
TZ_BEDROOM	275.0	275.0	22	0.0	0.0	0.0	0.0	0.0	0.0
TZ_ENTRY	133.33	133.33	8	0.0	0.0	0.0	0.0	0.0	0.0
TZ_KITCHEN	200.0	200.0	20	0.0	0.0	0.0	0.0	0.0	0.0
TZ_SALOON	760.0	760.0	76	0.0	0.0	0.0	0.0	0.0	0.0

Heating and Cooling loads will be discussed at conclusion.

6.8. Output Variables

These section used fort o determine which output variables appears in results. That creates data tables for each zone.

For this study, these variables was choosen;

Output Variables	Definition
Zone Air System Sensible Heating Rate	This output variable represents the sensible heating rate in Watts that is actually supplied by the system to that zone for the timestep reported.
Zone Air Temperature	This is very similar to the mean air temperature in the last field. The “well stirred” model for the zone is the basis, but this temperature is also available at the “detailed” system timestep.
Zone Mean Air Temperature	the zone mean air temperature is the average temperature of the air temperatures at the system timestep
Zone Thermostat Cooling Setpoint Temperature	The schedule defines a temperature setpoint for the control type.
Zone Thermostat Heating Setpoint Temperature	The schedule defines a temperature setpoint for the control type.

6.9. Open Studio Measures

The BCL libraries provides the result options.

ViewModel	OpenStudio Measures	Visualize an OpenStudio model in a web based viewer
Set Output Tablet o Sı units v2	Energy Plus Measures	This measure keeps the output table in SI units and the sql file remains in SI units to allow generation of OpenStudio Results in SI units.
Add Output Diagnostics	Energy Plus Measures	Often the eplusout.err file may request output diagnostics. This measure can be used to add this to the IDF file. Re-run your project to see the requested output.
Openstudio Results	Reporting Measures	This measure creates high level tables and charts pulling both from model inputs and EnergyPlus results. It has building level information as well as detail on space types, thermal zones, HVAC systems, envelope characteristics, and economics. Click the heading above a chart to view a table of the chart data.
ViewData	Reporting Measures	Visualize energy simulation data plotted on an OpenStudio model in a web based viewer
ExportSchedule CSV	Reporting Measures	This script exports a CSV file containing values for each schedule in the model at a specified interval.
Create CSV Output	Reporting Measures	Create CSV output for output variables in SQL file

There are several options for lightning, construction, equipment and people. But they are disregarded for the simplicity.

7. SIMULATION RESULTS

7.1. Ankara

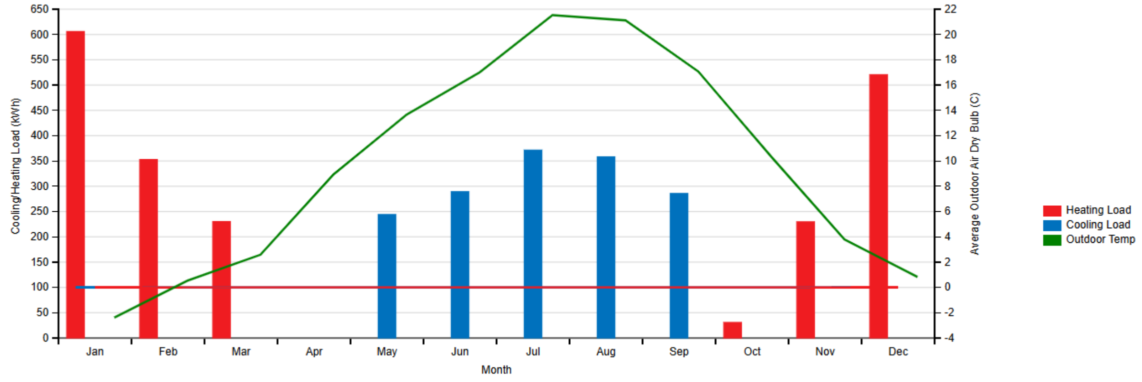
Building Summary

Data	Value
Building Name	Building 1
Total Site Energy	29,239 kWh
Net Site Energy	22,456 kWh
Total Building Area	82 m^2
Total Site EUI	356.57 kWh/m^2
Net Site EUI	273.85 kWh/m^2
OpenStudio Standards Building Type	n/a

7.1.1. Loads

HVAC Load Profiles

Monthly Load Profiles - view table



7.1.2. Zone Condition

Zone Conditions

Temperature (Table values represent hours spent in each temperature range)

Zone	Unmet Htg (hr)	Unmet Htg - Occ (hr)	< 13 (C)	13-16 (C)	16-18 (C)	18-20 (C)	20-21 (C)	21-22 (C)	22-23 (C)	23-24 (C)	24-26 (C)	26-28 (C)	28-30 (C)	>= 30 (C)	Unmet Clg (hr)	Unmet Clg - Occ (hr)	Mean Temp (C)
TZ_BATHROOM	416	416	0	0	1517	2313	197	478	3361	360	493	41	0	0	651	651	20.6 (C)
TZ_BEDROOM	182	182	0	0	118	3355	1062	2708	653	392	435	37	0	0	632	632	20.8 (C)
TZ_ENTRY	1445	1445	0	0	375	3463	844	2684	602	335	417	40	0	0	549	549	20.6 (C)
TZ_HEAT_PUMP	0	0	25	653	1906	1293	666	709	747	824	1525	406	6	0	0	0	20.7 (C)
TZ_KITCHEN	371	371	0	0	212	3969	3029	774	356	292	128	0	0	0	176	176	20.2 (C)
TZ_SALOON	118	118	0	0	41	3266	1141	2856	651	406	372	27	0	0	575	575	20.8 (C)

7.1.3. End Uses

End Uses

	Electricity [GJ]	Natural Gas [GJ]	Gasoline [GJ]	Diesel [GJ]	Coal [GJ]	Fuel Oil No 1 [GJ]	Fuel Oil No 2 [GJ]	Propane [GJ]	Other Fuel 1 [GJ]	Other Fuel 2 [GJ]	District Cooling [GJ]	District Heating Water [GJ]	District Heating Steam [GJ]	Water [m3]
Heating	7.04	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	5.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

7.2. Erzurum

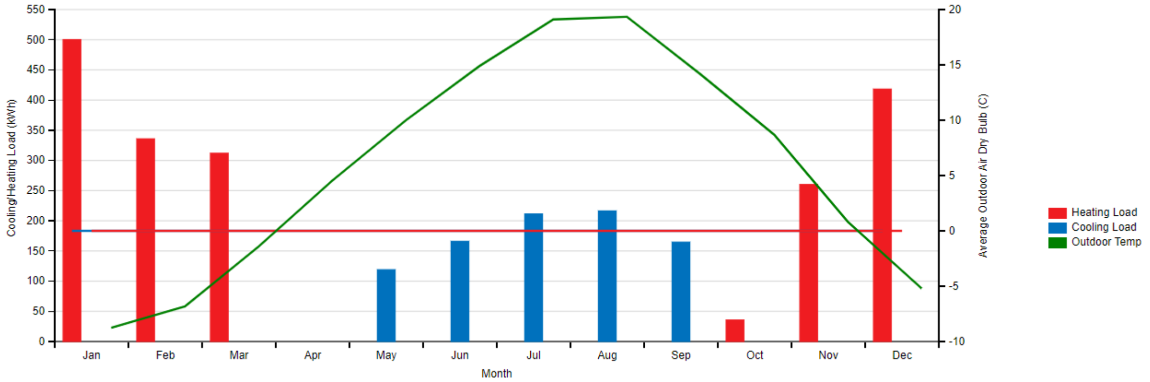
Building Summary

Data	Value
Building Name	Building 1
Total Site Energy	26,922 kWh
Net Site Energy	22,872 kWh
Total Building Area	82 m^2
Total Site EUI	328.32 kWh/m^2
Net Site EUI	278.93 kWh/m^2
OpenStudio Standards Building Type	n/a

7.2.1. Loads

HVAC Load Profiles

Monthly Load Profiles - view table



7.2.2. Zone Condition

Zone Conditions

Temperature (Table values represent hours spent in each temperature range)

Zone	Unmet Htg (hr)	Unmet Htg - Occ (hr)	< 13 (C)	13-16 (C)	16-18 (C)	18-20 (C)	20-21 (C)	21-22 (C)	22-23 (C)	23-24 (C)	24-26 (C)	26-28 (C)	28-30 (C)	>= 30 (C)	Unmet Clg (hr)	Unmet Clg - Occ (hr)	Mean Temp (C)
TZ_BATHROOM	737	737	0	0	1308	3828	822	2192	396	80	134	0	0	0	177	177	19.8 (C)
TZ_BEDROOM	529	529	0	0	990	2993	2527	1613	370	105	162	0	0	0	227	227	20.1 (C)
TZ_ENTRY	1594	1594	0	52	435	4075	2250	1261	433	105	137	12	0	0	218	218	20.2 (C)
TZ_HEAT_PUMP	0	0	619	1505	1590	1398	702	646	658	619	798	221	4	0	0	0	19.0 (C)
TZ_KITCHEN	1195	1195	0	76	2011	4758	1391	380	80	64	0	0	0	0	38	38	19.0 (C)
TZ_SALOON	373	373	0	0	707	2601	3095	1867	258	96	136	0	0	0	198	198	20.2 (C)

7.2.3. End Uses

End Uses

	Electricity [GJ]	Natural Gas [GJ]	Gasoline [GJ]	Diesel [GJ]	Coal [GJ]	Fuel Oil No 1 [GJ]	Fuel Oil No 2 [GJ]	Propane [GJ]	Other Fuel 1 [GJ]	Other Fuel 2 [GJ]	District Cooling [GJ]	District Heating Water [GJ]	District Heating Steam [GJ]	Water [m3]
Heating	5.15	1.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	3.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

7.3. İstanbul

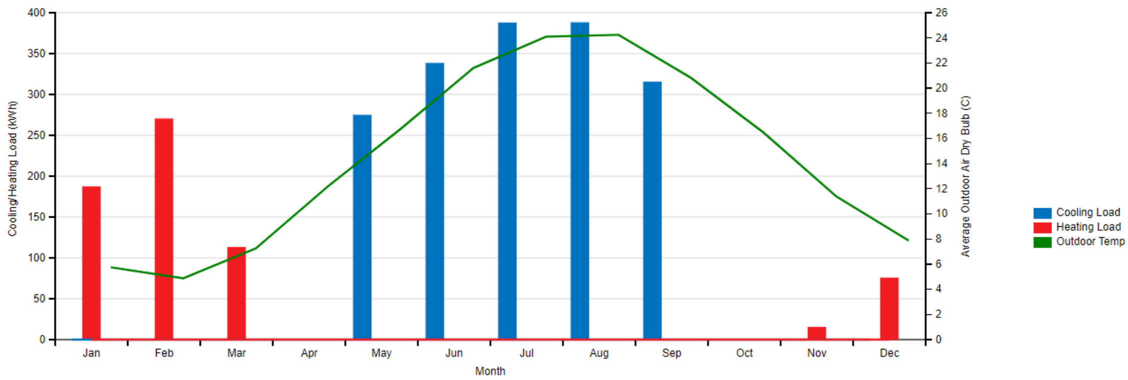
Building Summary

Data	Value
Building Name	Building 1
Total Site Energy	27,889 kWh
Net Site Energy	22,444 kWh
Total Building Area	82 m^2
Total Site EUI	340.11 kWh/m^2
Net Site EUI	273.71 kWh/m^2
OpenStudio Standards Building Type	n/a

7.3.1. Loads

HVAC Load Profiles

Monthly Load Profiles - view table



7.3.2. Zone Condition

Zone Conditions

Temperature (Table values represent hours spent in each temperature range)

Zone	Unmet Htg (hr)	Unmet Htg - Occ (hr)	< 13 (C)	13-16 (C)	16-18 (C)	18-20 (C)	20-21 (C)	21-22 (C)	22-23 (C)	23-24 (C)	24-26 (C)	26-28 (C)	28-30 (C)	>= 30 (C)	Unmet Clg (hr)	Unmet Clg - Occ (hr)	Mean Temp (C)
TZ_BATHROOM	228	228	0	0	981	2725	48	148	2423	821	1080	514	20	0	1474	1474	21.3 (C)
TZ_BEDROOM	91	91	0	0	28	3328	526	1589	1194	601	1023	455	16	0	1412	1412	21.6 (C)
TZ_ENTRY	759	759	0	0	90	3504	340	1655	1118	580	970	486	17	0	1355	1355	21.4 (C)
TZ_HEAT_PUMP	0	0	0	118	654	1561	741	505	708	1048	2651	772	2	0	0	0	22.4 (C)
TZ_KITCHEN	134	134	0	0	35	3205	1596	1624	847	558	738	157	0	0	1047	1047	21.1 (C)
TZ_SALOON	59	59	0	0	0	3051	768	1508	1373	649	1074	328	9	0	1354	1354	21.6 (C)

7.3.3. End Uses

End Uses

	Electricity [GJ]	Natural Gas [GJ]	Gasoline [GJ]	Diesel [GJ]	Coal [GJ]	Fuel Oil No 1 [GJ]	Fuel Oil No 2 [GJ]	Propane [GJ]	Other Fuel 1 [GJ]	Other Fuel 2 [GJ]	District Cooling [GJ]	District Heating Water [GJ]	District Heating Steam [GJ]	Water [m3]
Heating	2.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	6.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

7.4. İzmir

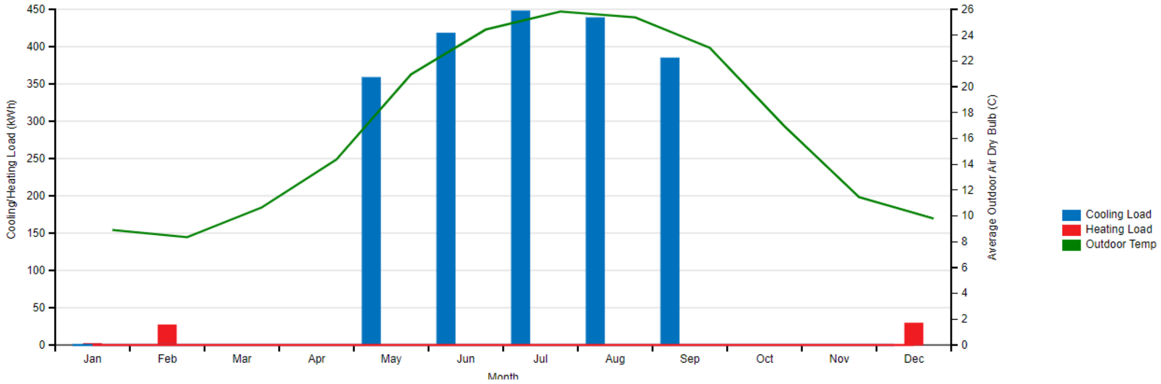
Building Summary

Data	Value
Building Name	Building 1
Total Site Energy	27,956 kWh
Net Site Energy	22,444 kWh
Total Building Area	82 m^2
Total Site EUI	340.92 kWh/m^2
Net Site EUI	273.71 kWh/m^2
OpenStudio Standards Building Type	n/a

7.4.1. Loads

HVAC Load Profiles

Monthly Load Profiles - view table



7.4.2. Zone Condition

Zone Conditions

Temperature (Table values represent hours spent in each temperature range)

Zone	Unmet Htg (hr)	Unmet Htg - Occ (hr)	< 13 (C)	13-16 (C)	16-18 (C)	18-20 (C)	20-21 (C)	21-22 (C)	22-23 (C)	23-24 (C)	24-26 (C)	26-28 (C)	28-30 (C)	>= 30 (C)	Unmet Clg (hr)	Unmet Clg - Occ (hr)	Mean Temp (C)
TZ_BATHROOM	60	60	0	0	784	2888	1	26	669	1218	2069	964	141	0	2371	2371	22.0 (C)
TZ_BEDROOM	0	0	0	0	0	2865	807	186	935	1258	1632	1008	69	0	2303	2303	22.4 (C)
TZ_ENTRY	236	236	0	0	3	3336	349	272	883	1214	1601	964	138	0	2182	2182	22.3 (C)
TZ_HEAT_PUMP	0	0	0	0	43	693	875	914	899	645	2806	1718	167	0	0	0	23.8 (C)
TZ_KITCHEN	6	6	0	0	0	3208	511	799	1233	1207	1292	492	18	0	1561	1561	21.9 (C)
TZ_SALOON	0	0	0	0	0	2518	1154	160	986	1346	1752	801	43	0	2246	2246	22.4 (C)

7.4.3. End Uses

End Uses

	Electricity [GJ]	Natural Gas [GJ]	Gasoline [GJ]	Diesel [GJ]	Coal [GJ]	Fuel Oil No 1 [GJ]	Fuel Oil No 2 [GJ]	Propane [GJ]	Other Fuel 1 [GJ]	Other Fuel 2 [GJ]	District Cooling [GJ]	District Heating Water [GJ]	District Heating Steam [GJ]	Water [m3]
Heating	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	7.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

7.5. Kars

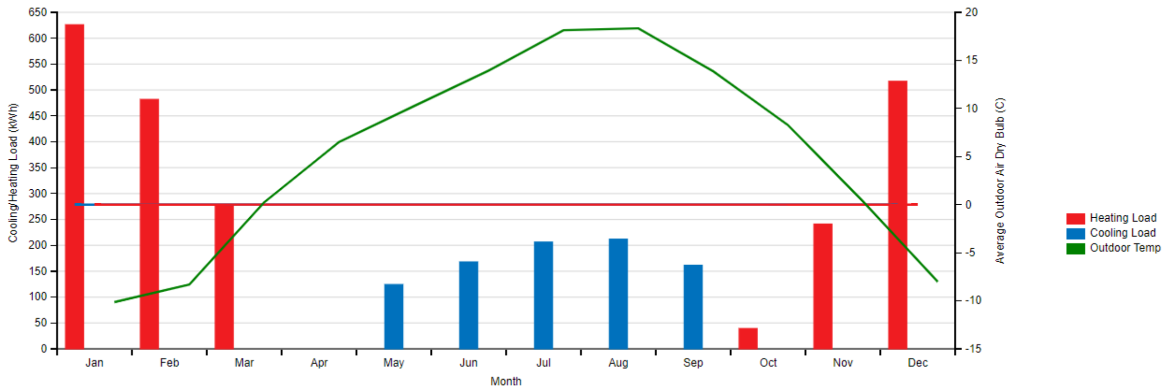
Building Summary

Data	Value
Building Name	Building 1
Total Site Energy	27,211 kWh
Net Site Energy	23,275 kWh
Total Building Area	82 m^2
Total Site EUI	331.84 kWh/m^2
Net Site EUI	283.84 kWh/m^2
OpenStudio Standards Building Type	n/a

7.5.1. Loads

HVAC Load Profiles

Monthly Load Profiles - view table



7.5.2. Zone Condition

Zone Conditions

Temperature (Table values represent hours spent in each temperature range)

Zone	Unmet Htg (hr)	Unmet Htg - Occ (hr)	< 13 (C)	13-16 (C)	16-18 (C)	18-20 (C)	20-21 (C)	21-22 (C)	22-23 (C)	23-24 (C)	24-26 (C)	26-28 (C)	28-30 (C)	>= 30 (C)	Unmet Clg (hr)	Unmet Clg - Occ (hr)	Mean Temp (C)
TZ_BATHROOM	653	653	0	40	1585	3776	696	1769	603	167	118	6	0	0	181	181	19.6 (C)
TZ_BEDROOM	572	572	0	99	1509	2464	2322	1578	465	175	123	25	0	0	224	224	19.9 (C)
TZ_ENTRY	1550	1550	0	156	476	4330	1940	1182	387	173	87	29	0	0	184	184	20.1 (C)
TZ_HEAT_PUMP	0	0	1066	1301	1497	1147	631	685	781	682	826	144	0	0	0	0	18.7 (C)
TZ_KITCHEN	799	799	0	217	2111	3793	1819	616	152	46	6	0	0	0	21	21	19.1 (C)
TZ_SALOON	474	474	0	26	1283	2212	2830	1704	414	183	108	0	0	0	185	185	20.1 (C)

7.5.3. End Uses

End Uses

	Electricity [GJ]	Natural Gas [GJ]	Gasoline [GJ]	Diesel [GJ]	Coal [GJ]	Fuel Oil No 1 [GJ]	Fuel Oil No 2 [GJ]	Propane [GJ]	Other Fuel 1 [GJ]	Other Fuel 2 [GJ]	District Cooling [GJ]	District Heating Water [GJ]	District Heating Steam [GJ]	Water [m3]
Heating	4.86	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	3.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

8. CONCLUSION

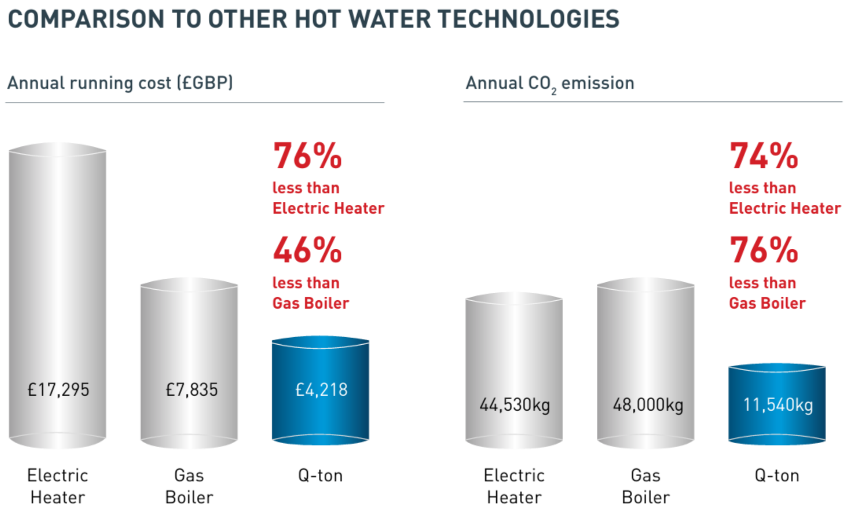
When choosing the heat pump and boiler system, these are the variables that considered for; cost and extreme weather conditions. For warm climates heat pump can answer the needs (air conditining) without boiler. Heat pump system cost, so, with boiler the need of heating can be diminished. The perfect conditions are, commercials, or more than one units, with little cooling requirements and larger heating demand. The warmest climates like İstanbul and İzmir which rarely hits under 0 degrees, for that reason hybrid system cause longer depreciation period.

Daikin EWYT-B HP values are:

Parameter	**Value (@7 °C outdoor)**
Heating capacity	84.9 kW — covers large portion of building demand
Heating power input	25.9 kW
Heating COP	3.28 (rated)
Seasonal COP (SCOP)	3.66 (EN14825)
Cooling capacity	75.1 kW @ 12/7 °C water
Cooling power input	28.0 kW
Cooling EER	2.68 (rated)
Cooling SEER	3.90 (EN14825)
Water-side design temperatures	Supply 40 °C / Return 45 °C (heating loop)
Seasonal operating range (heating)	Down to –10 °C outdoor

Table 8 Mitsubishi Technical Data Table

Model			ESA30EH-25
Power source		-	3 phase 380V +- 5%, 400V +- 5%, 415V +- 5%, 50/60 Hz
Operation to top up (In intermediate season)*1	Heating capacity	kW	30.0
	Water amount	L/min	8.97
	Power consumption	kW	6.98
	COP	-	4.30
Operation to top up (In cold season)*2	Heating capacity	kW	30.0
	Water amount	L/min	5.06
	Power consumption	kW	10.73
	COP	-	2.80



Graph 6 Comparison to other hot water Technologies (not verified in this study-from technical sheet of Mitsubishi Heavy Industries Q-Ton Series)

Mitsubishi Heavy Industries Q-Ton Series: only heating- there is no cooling unit. (30 kw)

Daikin EWYT-B series: Cooling included, however the capacity way beyond (85 kw)

The building needs approximately 30 kw heating load (without boiler) and lesser cooling load. Cooling load added to see seasonally adjusted datas

For boiler +heat pump hybrid system							
Cities	Cooling(GJ)	Annual heating load (GJ)	End uses		Calculated COP	Heating share	
			Electricity (heat pump) (GJ)	Gas (boiler) (GJ)		Boiler contribution	Heating dx
Ankara	5.57	7.09	7.04	0.05	1,9	%1	99%
İstanbul	6.13	2.37	2.37	0	2,13	%0	100%
İzmir	3.14	0.21	0.21	0	2,4	%0	%100
Erzurum	3.16	5.70	5.15	1.55	1,5	%10	%90
Kars	5.57	7.09	7.04	0.05	1,3	%28	%62

The table shows, when heating demand increase the boiler share increase too. For warmest climates boiler almost never triggered. (The value was critically low, one or two days boiler triggered). The system is suitable for moderate cooling loads and greater heating loads.

The simulation results demonstrate that the performance of the hybrid boiler + heat pump system is highly climate-dependent across Turkish cities. In milder regions like İzmir and İstanbul, the heat pump alone successfully covers 100% of the heating demand, achieving seasonal COP values above 2.0, and eliminating the need for boiler backup. However, in colder climates such as Erzurum and Kars, the heat pump's efficiency significantly drops, with COP values declining to 1.5 and 1.3 respectively. Consequently, the boiler supplements a larger share of the heating demand in these cities (10% in Erzurum and 28% in Kars). This performance variation underlines the importance of designing region-specific hybrid systems: while standalone heat pumps may be optimal for temperate zones, hybrid systems become essential in harsher climates to ensure reliability and efficiency. These findings support a strategic approach to decarbonizing residential heating by prioritizing hybrid configurations in colder regions and standalone heat pumps in milder zones.

8.1. COST ANALYSİS

Component	Q-Ton ESA30E	Daikin Solutions
Heat Pump Unit	€15,000-20,000	€12,000-25,000
Additional Cooling System	€8,000-12,000	Included
Installation	€3,000-5,000	€4,000-7,000
Controls & Accessories	€2,000-3,000	€2,000-4,000
Total Initial Cost	€28,000-40,000	€18,000-36,000

Daikin EWYT-B HP was recommended when price considered.

For further NPV and detailed cost analysis see Üçok, H. (2024).

City	Electricity (GJ)	Gas (GJ)	Electricity Cost (TL)	Gas Cost (TL)	Total Heating Cost (TL)
Ankara	7.04	0.05	7,821 TL	5 TL	**7,826 TL**
İstanbul	2.37	0	2,635 TL	0 TL	**2,635 TL**
İzmir	0.21	0	233 TL	0 TL	**233 TL**
Erzurum	5.15	1.55	5,721 TL	140 TL	**5,861 TL**
Kars	7.04	0.05	7,821 TL	5 TL	**7,826 TL**

- **Electricity Cost = Electricity (GJ) × 1,111.1 TL**
- **Gas Cost = Gas (GJ) × 90 TL**

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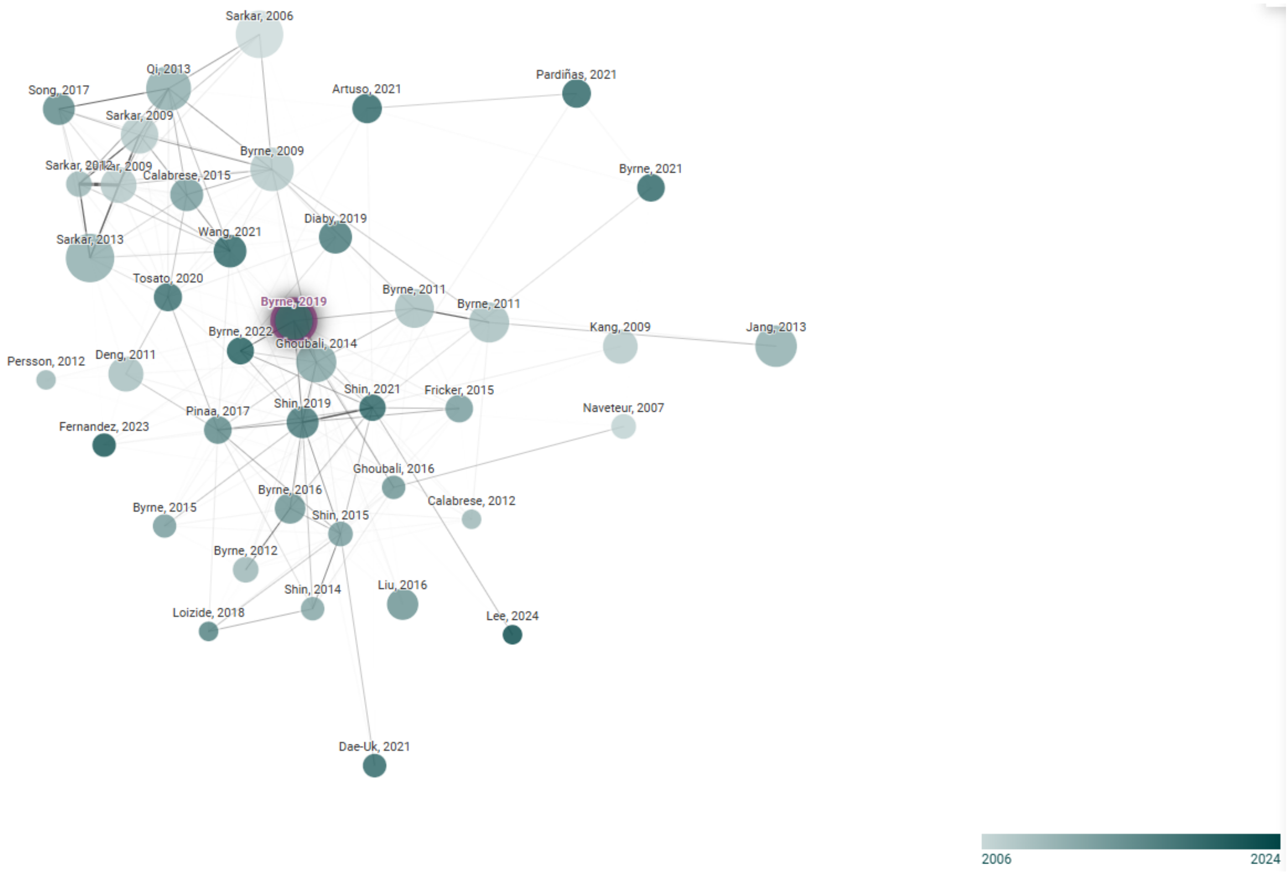

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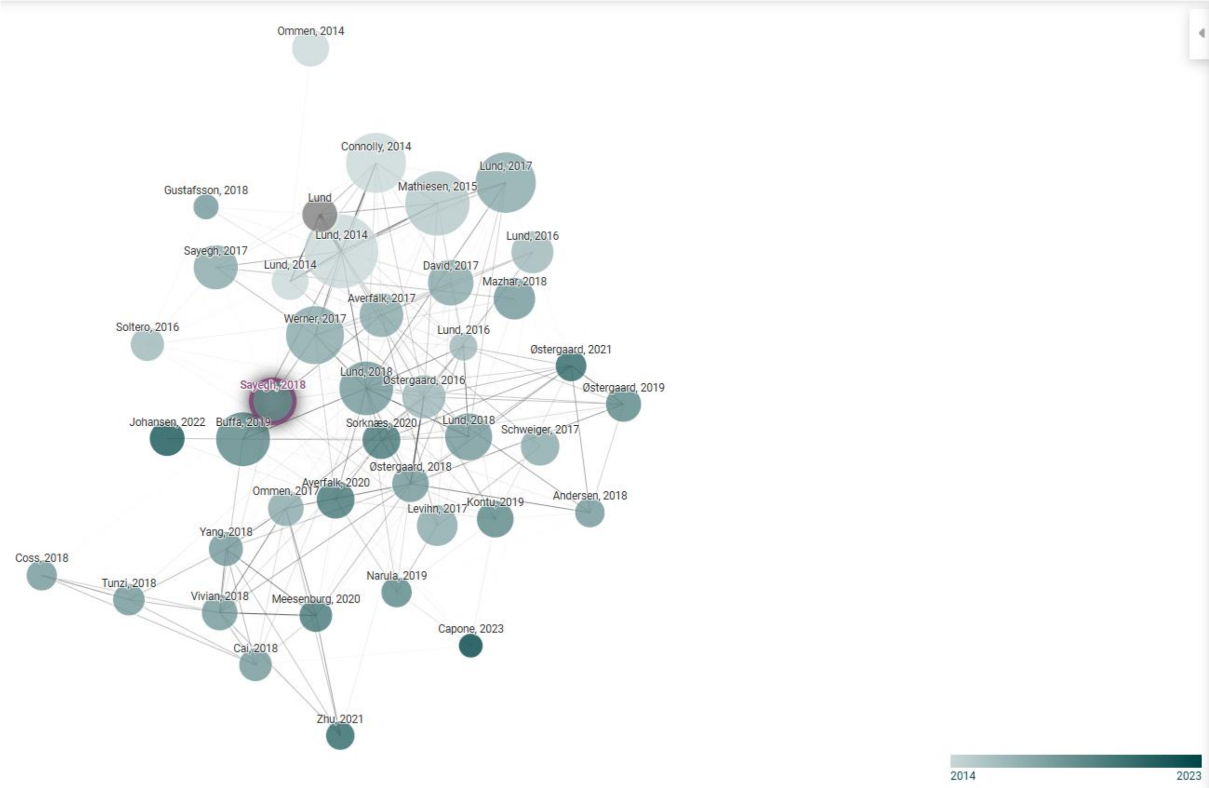

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