INL1-3 SUPPLY UNITS

Introduction

This report evaluates the impact of various heating and cooling supply systems on energy consumption, primary energy usage, and environmental impact (CO_2 emissions). The study uses annual simulations conducted in IDA ICE software, following ISO 52000-1 standards, to assess the performance of these systems for a given building.

Systems Analyzed:

1. Reference System: Boiler (fossil fuel) for heating, liquid chiller for cooling.
2. District Heating and Cooling.
3. Ground Source Heat Pump (GSHP) with Liquid Chiller (variable auxiliary heater size).
4. GSHP with PV Panels.
5. Air Source Heat Pump (ASHP) with Liquid Chiller.

Metrics Evaluated:

- Bought Energy (kWh).
- Primary Energy Used (kWh).
- Environmental Impact (CO_2 emissions, kg).

The supply unit capacities and the discharge capacity of the heat exchangers were adjusted to ensure thermal comfort and permissible PPD values in all the simulations.

Results and Observations

1. Reference System

- **Configuration: <u>Boiler for heating and liquid chiller for cooling.</u>**
    - Bought Energy (el): 38254.4 kWh.
    - Bought Energy (fuel): 54057.4 kWh
    - Overall Primary Energy performance: 140303.1 kWh.
    - Overall CO_2 Emissions: 25474.4 kg.

Delivered Energy: output object in INL1-3 -- Boiler and Liquid chiller-1 (Energy Simulation)

File

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Delivered Energy Report

Project		**Building**	
		Model floor area	2000.0 m^2
Customer		Model volume	6100.0 m^3
Created by	Joachim Claesson	Model ground area	1000.0 m^2
Location	Stockholm (Bromma Airport)_024640 (ASHRAE 2013)	Model envelope area	2780.1 m^2
Climate file	SWE_STOCKHOLM-BROMMA_024640(IW2)	Window/Envelope	11.8 %
Case	INL1-3 -- Boiler and Liquid chiller-1	Average U-value	0.3426 W/(m^2 K)
Simulated	2024-11-25 13:31:23	Envelope area per Volume	0.4557 m^2/m^3

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	1 %
Percentage of hours when operative temperature is above 27°C in average zone	1 %
Percentage of total occupant hours with thermal dissatisfaction	7 %

Overall Energy Performance (ISO 52000-1, Chapter 9.6)

	Total		**Total primary energy**		**Non-renewable primary energy**		**CO2 Emission**	
	kWh	**kWh/m^2**	**kWh**	**kWh/m^2**	**kWh**	**kWh/m^2**	**kg**	**kg/m^2**
Purchased by facility (el)	38245.4	19.1	95613.5	47.8	87964.4	44.0	16063.5	8.0
Exported by facility (el)	-5909.4	-3.0	-14773.5	-7.4	-13591.6	-6.8	-2482.0	-1.2
Total Electricity	32336.0	16.2	80840.0	40.4	74372.8	37.2	13581.5	6.8
Purchased by facility (fuel)	54057.4	27.0	59463.1	29.7	59463.1	29.7	11892.8	5.9
Total Fuel	54057.4	27.0	59463.1	29.7	59463.1	29.7	11892.8	5.9
Overall energy performance			140303.1 (2)	70.2	133835.9 (3)	66.9	25474.4	12.7
RER*			0.046	0.0				
RER on-site**			0.0	0.0				

2. District Heating and Cooling

- **Configuration**: **<u>Heating and cooling provided by district networks.</u>**
    - Bought Energy (el): 28120.2 kWh.
    - Bought Heat Energy (dh): 43344 kWh.
    - Bought Cooling Energy (dc): 51564.9 kWh.
    - Overall Primary Energy performance: 193682.1 kWh.
    - Overall CO_2 Emissions: 36486.6 kg.

Delivered Energy: output object in INL1-3 -- District heating and cooling-1 (Energy Simulation)

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Delivered Energy Report

Project		Building	
		Model floor area	2000.0 m^2
Customer		Model volume	6100.0 m^3
Created by	Joachim Claesson	Model ground area	1000.0 m^2
Location	Stockholm (Bromma Airport)_024640 (ASHRAE 2013)	Model envelope area	2780.1 m^2
Climate file	SWE_STOCKHOLM-BROMMA_024640(IW2)	Window/Envelope	11.8 %
Case	INL1-3 -- District heating and cooling-1	Average U-value	0.3426 W/(m^2 K)
Simulated	2024-11-25 14:14:33	Envelope area per Volume	0.4557 m^2/m^3

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	0 %
Percentage of hours when operative temperature is above 27°C in average zone	0 %
Percentage of total occupant hours with thermal dissatisfaction	7 %

Overall Energy Performance (ISO 52000-1, Chapter 9.6)

	Total		Total primary energy		Non-renewable primary energy		CO2 Emission	
	kWh	kWh/m^2	kWh	kWh/m^2	kWh	kWh/m^2	kg	kg/m^2
Purchased by facility (el)	28120.2	14.1	70300.6	35.1	64676.5	32.3	11809.7	5.9
Total Electricity	28120.2	14.1	70300.6	35.1	64676.5	32.3	11809.7	5.9
Purchased by facility (dh)	43344.0	21.7	56347.1	28.2	56347.1	28.2	11269.8	5.6
Total Heat	43344.0	21.7	56347.1	28.2	56347.1	28.2	11269.8	5.6
Purchased by facility (dc)	51564.9	25.8	67034.4	33.5	67034.4	33.5	13407.1	6.7
Total Cold	51564.9	25.8	67034.4	33.5	67034.4	33.5	13407.1	6.7
Overall energy performance			193682.1 (2)	96.8	188058.1 (3)	94.0	36486.6	18.2
RER*			0.029	0.0				
RER on-site**			0.0	0.0				

3. GSHP and Liquid Chiller

- **Simulation #3**: **<u>Default configuration.</u>**
    - Bought Energy (el): 80976.7 kWh.
    - Primary Energy Used: 202441.7 kWh.
    - CO_2 Emissions: 34009 kg.

Delivered Energy: output object in INL1-3 -- GSHP and Liquid chiller-2 (Energy Simulation)

File

EQUA SIMULATION TECHNOLOGY GROUP

Delivered Energy Report

Project		Building	
		Model floor area	2000.0 m^2
Customer		Model volume	6100.0 m^3
Created by	Joachim Claesson	Model ground area	1000.0 m^2
Location	Stockholm (Bromma Airport)_024640 (ASHRAE 2013)	Model envelope area	2780.1 m^2
Climate file	SWE_STOCKHOLM-BROMMA_024640(IW2)	Window/Envelope	11.8 %
Case	INL1-3 -- GSHP and Liquid chiller-2	Average U-value	0.3426 W/(m^2 K)
Simulated	2024-11-25 14:58:08	Envelope area per Volume	0.4557 m^2/m^3

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	0 %
Percentage of hours when operative temperature is above 27°C in average zone	0 %
Percentage of total occupant hours with thermal dissatisfaction	7 %

Overall Energy Performance (ISO 52000-1, Chapter 9.6)

	Total		Total primary energy		Non-renewable primary energy		CO2 Emission	
	kWh	kWh/m^2	kWh	kWh/m^2	kWh	kWh/m^2	kg	kg/m^2
Purchased by facility (el)	80976.7	40.5	202441.7	101.2	186246.3	93.1	34009.0	17.0
Total Electricity	80976.7	40.5	202441.7	101.2	186246.3	93.1	34009.0	17.0
Overall energy performance			202441.7 (2)	101.2	186246.3 (3)	93.1	34009.0	17.0
RER*			0.08	0.0				
RER on-site**			0.0	0.0				

- **Simulation #4**: **<u>Increased heat pump capacity and reduced top up heaters.</u>**
    - Bought Energy: 80932.9 kWh.
    - Primary Energy Used: 202332.1 kWh.
    - CO_2 Emissions: 33993 kg.

Delivered Energy: output object in INL1-3 -- GSHP and Liquid chiller-2 (Energy Simulation)

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Delivered Energy Report

Project		Building	
		Model floor area	2000.0 m^2
Customer		Model volume	6100.0 m^3
Created by	Joachim Claesson	Model ground area	1000.0 m^2
Location	Stockholm (Bromma Airport)_024640 (ASHRAE 2013)	Model envelope area	2780.1 m^2
Climate file	SWE_STOCKHOLM-BROMMA_024640(IW2)	Window/Envelope	11.8 %
Case	INL1-3 -- GSHP and Liquid chiller-2	Average U-value	0.3426 W/(m^2 K)
Simulated	2024-11-25 15:08:04	Envelope area per Volume	0.4557 m^2/m^3

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	0 %
Percentage of hours when operative temperature is above 27°C in average zone	0 %
Percentage of total occupant hours with thermal dissatisfaction	7 %

Overall Energy Performance (ISO 52000-1, Chapter 9.6)

	Total		Total primary energy		Non-renewable primary energy		CO2 Emission	
	kWh	kWh/m^2	kWh	kWh/m^2	kWh	kWh/m^2	kg	kg/m^2
Purchased by facility (el)	80932.9	40.5	202332.1	101.2	186145.6	93.1	33993.0	17.0
Total Electricity	80932.9	40.5	202332.1	101.2	186145.6	93.1	33993.0	17.0
Overall energy performance			202332.1 (2)	101.2	186145.6 (3)	93.1	33993.0	17.0
RER*			0.08	0.0				
RER on-site**			0.0	0.0				

4. GSHP with PV Panels

- **Simulation #5: Full PV panel size.**
    - Bought Energy (el): 59544.9 kWh.
    - Primary Energy Used: 200421.3 kWh.
    - CO_2 Emissions: 33670.9 kg.

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Delivered Energy Report

Project		Building	
		Model floor area	2000.0 m²
Customer		Model volume	6100.0 m³
Created by	Joachim Claesson	Model ground area	1000.0 m²
Location	Stockholm (Bromma Airport)_024640 (ASHRAE 2013)	Model envelope area	2780.1 m²
Climate file	SWE_STOCKHOLM-BROMMA_024640(IW2)	Window/Envelope	11.8 %
Case	INL1-3 -- GSHP and Liquid chiller - PV panels-2	Average U-value	0.3426 W/(m² K)
Simulated	2024-11-27 12:12:48	Envelope area per Volume	0.4557 m²/m³

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	1 %
Percentage of hours when operative temperature is above 27°C in average zone	0 %
Percentage of total occupant hours with thermal dissatisfaction	7 %

Overall Energy Performance (ISO 52000-1, Chapter 9.6)

	Total		Total primary energy		Non-renewable primary energy		CO2 Emission	
	kWh	kWh/m²	kWh	kWh/m²	kWh	kWh/m²	kg	kg/m²
PV production	23596.4	11.8	58994.3	29.5	54273.4	27.1	9910.9	5.0
Purchased by facility (el)	59544.9	29.8	148862.2	74.4	136953.2	68.5	25009.1	12.5
Exported by facility (el)	-2974.1	-1.5	-7435.2	-3.7	-6840.4	-3.4	-1249.1	-0.6
Total Electricity	80167.2	40.1	200421.3	100.2	184386.2	92.2	33670.9	16.8
Overall energy performance			200421.3 (2)	100.2	184386.2 (3)	92.2	33670.9	16.8
RER*			0.08	0.0				
RER on-site**			0.024	0.0				

- **Simulation #6**: **<u>Half PV panel size.</u>**
    - Bought Energy: 70520.5 kWh.
    - Primary Energy Used: 200546.2 kWh.
    - CO_2 Emissions: 33693.1 kg.

Delivered Energy: output object in INL1-3 -- GSHP and Liquid chiller - PV panels-2 (Energy Simulation)

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Delivered Energy Report

Project		Building	
		Model floor area	2000.0 m^2
Customer		Model volume	6100.0 m^3
Created by	Joachim Claesson	Model ground area	1000.0 m^2
Location	Stockholm (Bromma Airport)_024640 (ASHRAE 2013)	Model envelope area	2780.1 m^2
Climate file	SWE_STOCKHOLM-BROMMA_024640(IW2)	Window/Envelope	11.8 %
Case	INL1-3 -- GSHP and Liquid chiller - PV panels-2	Average U-value	0.3426 W/(m^2 K)
Simulated	2024-11-27 12:20:03	Envelope area per Volume	0.4557 m^2/m^3

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	1 %
Percentage of hours when operative temperature is above 27°C in average zone	1 %
Percentage of total occupant hours with thermal dissatisfaction	7 %

Overall Energy Performance (ISO 52000-1, Chapter 9.6)

	Total		Total primary energy		Non-renewable primary energy		CO2 Emission	
	kWh	kWh/m^2	kWh	kWh/m^2	kWh	kWh/m^2	kg	kg/m^2
PV production	10383.7	5.2	25957.2	13.0	23880.3	11.9	4360.7	2.2
Purchased by facility (el)	70520.5	35.3	176301.2	88.2	162197.1	81.1	29620.0	14.8
Exported by facility (el)	-684.9	-0.3	-1712.2	-0.9	-1575.2	-0.8	-287.7	-0.1
Total Electricity	80219.3	40.1	200546.2	100.3	184502.2	92.3	33693.1	16.9
Overall energy performance			200546.2 (2)	100.3	184502.2 (3)	92.3	33693.1	16.9
RER*			0.08	0.0				
RER on-site**			0.01	0.0				

* [(2) - (3)]/(2)

** Sum(prod*)/(2)

5. ASHP and Liquid Chiller

- **Simulation #7**: **<u>Default configuration.</u>**
    - Bought Energy: 102149.5 kWh.
    - Primary Energy Used: 255737.5 kWh.
    - CO_2 Emissions: 42903 kg.

Delivered Energy: output object in INL1-3 -- ASHP and Liquid chiller-1 (Energy Simulation)

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Delivered Energy Report

Project		Building	
		Model floor area	2000.0 m^2
Customer		Model volume	6100.0 m^3
Created by	Joachim Claesson	Model ground area	1000.0 m^2
Location	Stockholm (Bromma Airport)_024640 (ASHRAE 2013)	Model envelope area	2780.1 m^2
Climate file	SWE_STOCKHOLM-BROMMA_024640(IW2)	Window/Envelope	11.8 %
Case	INL1-3 -- ASHP and Liquid chiller-1	Average U-value	0.3426 W/(m^2 K)
Simulated	2024-11-27 12:54:22	Envelope area per Volume	0.4557 m^2/m^3

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	0 %
Percentage of hours when operative temperature is above 27°C in average zone	0 %
Percentage of total occupant hours with thermal dissatisfaction	7 %

Overall Energy Performance (ISO 52000-1, Chapter 9.6)

	Total		Total primary energy		Non-renewable primary energy		CO2 Emission	
	kWh	kWh/m^2	kWh	kWh/m^2	kWh	kWh/m^2	kg	kg/m^2
Purchased by facility (el)	102149.5	51.1	255373.7	127.7	234943.8	117.5	42903.0	21.4
Total Electricity	102149.5	51.1	255373.7	127.7	234943.8	117.5	42903.0	21.4
Overall energy performance			255373.7 (2)	127.7	234943.8 (3)	117.5	42903.0	21.4
RER*			0.08	0.0				
RER on-site**			0.0	0.0				

* [(2) - (3)]/(2)

** Sum(prod*)/(2)

- **Simulation #8**: **<u>Increased ASHP capacity and reduced auxilary.</u>**
    - Bought Energy: 96128.2 kWh.
    - Primary Energy Used: 240320.4 kWh.
    - CO_2 Emissions: 40374 kg.

Delivered Energy: output object in INL1-3 -- ASHP and Liquid chiller-1 (Energy Simulation)

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Delivered Energy Report

Project		Building	
		Model floor area	2000.0 m^2
Customer		Model volume	6100.0 m^3
Created by	Joachim Claesson	Model ground area	1000.0 m^2
Location	Stockholm (Bromma Airport)_024640 (ASHRAE 2013)	Model envelope area	2780.1 m^2
Climate file	SWE_STOCKHOLM-BROMMA_024640(IW2)	Window/Envelope	11.8 %
Case	INL1-3 -- ASHP and Liquid chiller-1	Average U-value	0.3426 W/(m^2 K)
Simulated	2024-11-27 13:07:13	Envelope area per Volume	0.4557 m^2/m^3

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	0 %
Percentage of hours when operative temperature is above 27°C in average zone	0 %
Percentage of total occupant hours with thermal dissatisfaction	8 %

Overall Energy Performance (ISO 52000-1, Chapter 9.6)

	Total		Total primary energy		Non-renewable primary energy		CO2 Emission	
	kWh	kWh/m^2	kWh	kWh/m^2	kWh	kWh/m^2	kg	kg/m^2
Purchased by facility (el)	96128.2	48.1	240320.4	120.2	221094.8	110.5	40374.0	20.2
Total Electricity	96128.2	48.1	240320.4	120.2	221094.8	110.5	40374.0	20.2
Overall energy performance			240320.4 (2)	120.2	221094.8 (3)	110.5	40374.0	20.2
RER*			0.08	0.0				
RER on-site**			0.0	0.0				

* [(2) - (3)]/(2)

** Sum(prod*)/(2)

Summary

Here is a summary table of Bought Energy, CO_2 Emission, and Primary Energy for all the simulations:

Simulation	**Bought Energy (kWh)**	**Primary Energy (kWh)**	**CO_2 Emissions (kg)**
Reference System	92,311.8 (el + fuel)	140,303.1	25,474.4
District Heating & Cooling	123,029.1 (el + dh + dc)	193,682.1	36,486.6
GSHP + Liquid Chiller	80,976.7	202,441.7	34,009
GSHP + Liquid Chiller (Added heat pump & reduced auxilary)	80,932.9	202,332.1	33,993
GSHP + PV Panels (Full PV)	59,544.9	200,421.3	33,670.9
GSHP + PV Panels (Half PV)	70,520.5	200,546.2	33,693.1
ASHP + Liquid Chiller	102,149.5	255,737.5	42,903
ASHP + Liquid Chiller (Added heat pump & reduced auxilary)	96,128.2	240,320.4	40,374

Among all the systems, the least energy purchased is in case of GHSP with PV panels since the source of power is the sun and less electricity would be required from the grid. The Boiler & Liquid Chiller and District Heating/Cooling cases benefit from their reliance on direct fuel use without much conversion or transmission and high-efficiency centralized systems respectively, thus showing lower primary energy consumption. Apart from the reference system, lowest CO_2 emissions was found to be in case of GHSP with PV panels.

By relying more on highly efficient AHSP/GSHP and less on auxiliary systems keeping the total heating load same, we could notice enhanced energy performance and reduced CO_2 emissions.

With lesser dependence on grid electricity, GSHP with full solar panel shows enhanced energy performance and lesser emissions compared to GSHP with half solar panel case.