Business from technology

Energy Matching in Net-Zero Energy Buildings

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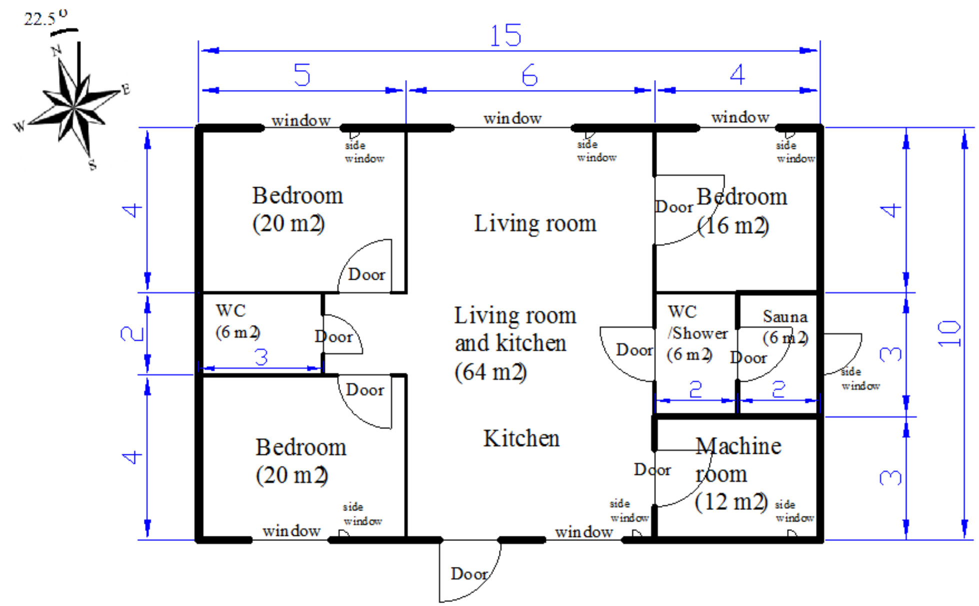
- A single family house,150 m2, Helsinki, Finland.
- A standard house (D3/D5 Finnish Building Code 2012)
- Heating and electrical loads
- Simulation software: TRNBluid and Trnsys17



Energy Supply Systems

Four conventional heating systems

- Electric heating (EH)
- District heating (DH)
- Ground source Heat Pump (GSHP)
- Wood pellet boiler (PB)

Seven bio-mass based mCHP systems

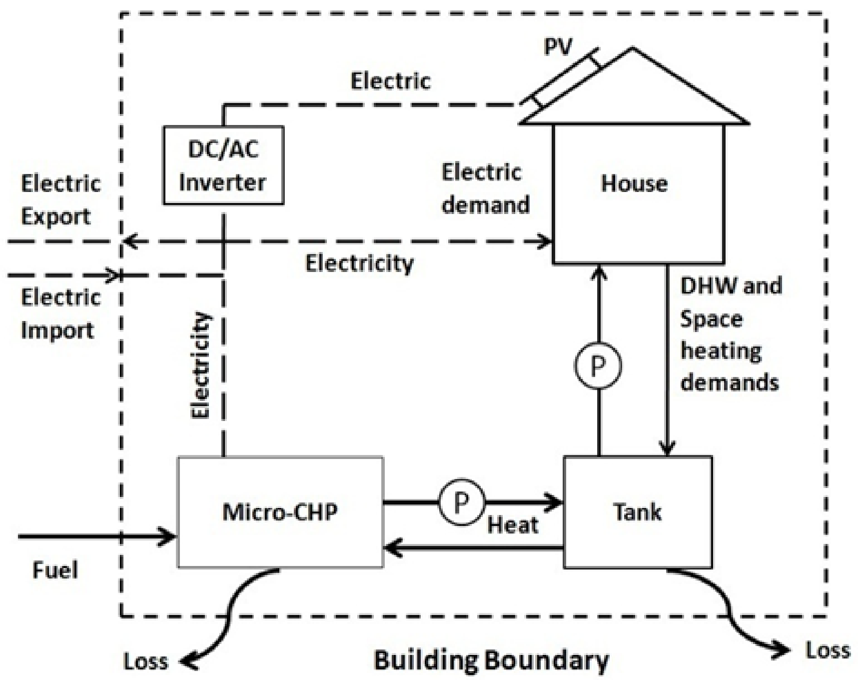
- Domestic-scale Standalone1.4 kWe wood pellet Stirling engine (S-SE)
- Shared 35 kWe direct combustion, Stirling Engine SE (Direct SE)
- Shared 35 kWe updraft gasifier, Stirling Engine SE (Updraft-SE)
- Shared 100 kWe direct combustion, Indirect Fired Gas Turbine (IFGT)
- Shared 30 kWe gasifier internal combustion engine (ICE)
- Shared 0.86 kWe biomass fired Organic Rankine Cycle (ORC)
- Domestic-scale PEM Fuel Cell (H2 produced via shared wood gasification) (PEMFC)

Specifications of the Biomass mCHP Systems

Description	Number of houses	Electric output P_e (kW)	Thermal output H_{th} (kW)	Electrical effeicency η_e%	Thermal effeicency η_{th}%	Overall efficiency η_{tot}%	Power / Heat P_e/H_{th}
1.4 kWe wood pellet SE	1	1.4	5.4	14.3	57.8	72.1	0.256
35 kWe direct combustion SE	44	35	215	12.0	74.0	86.0	0.16
35 kWe updraft gasifier SE	30	35	145	18.0	72.0	90.0	0.24
100 kWe direct combustion IFGT	41	100	200	28.0	56.0	84.0	0.5
30 kWe gasifier ICE	16	30	80	23.0	61.0	84.0	0.377
0.86 kWe biomass fired ORC	9	0.86	47.3	1.4	78.7	80.1	0.0184
The hydrogen based PEMFC	1	2.7/1.8	4.8/3.2	15.3	27.3	42.6	0.56

mCHP Operation

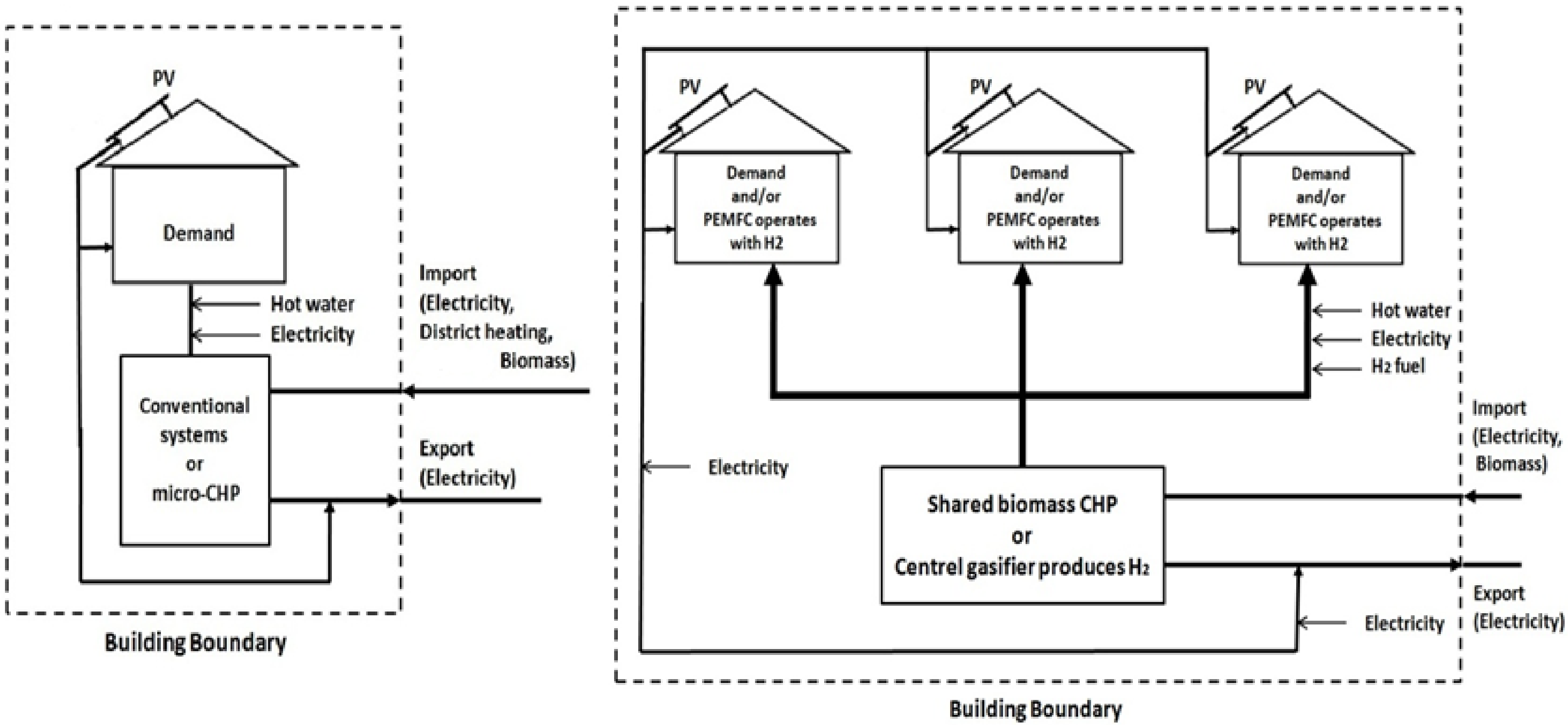
- **mCHP fuel:** Wood pellet/chips
- **Control**: Thermal tracking via hot water storage tank temperature control
- **Back-up**: 1 kW electric heater
- **Energy export**: Electricity



Objective

- To achieve the Net-Zero Energy Building (NZEB) balance for the studied building connected to the different energy generation systems with different credit factors (site-energy, primary-energy and CO2 emissions).
- To find the energy matching characteristics of the studied building with the energy generation systems.

NZEB Balance



It is to achieve the annual NZEB balance for the different types of energy and fuel crossing the boundary of the building.

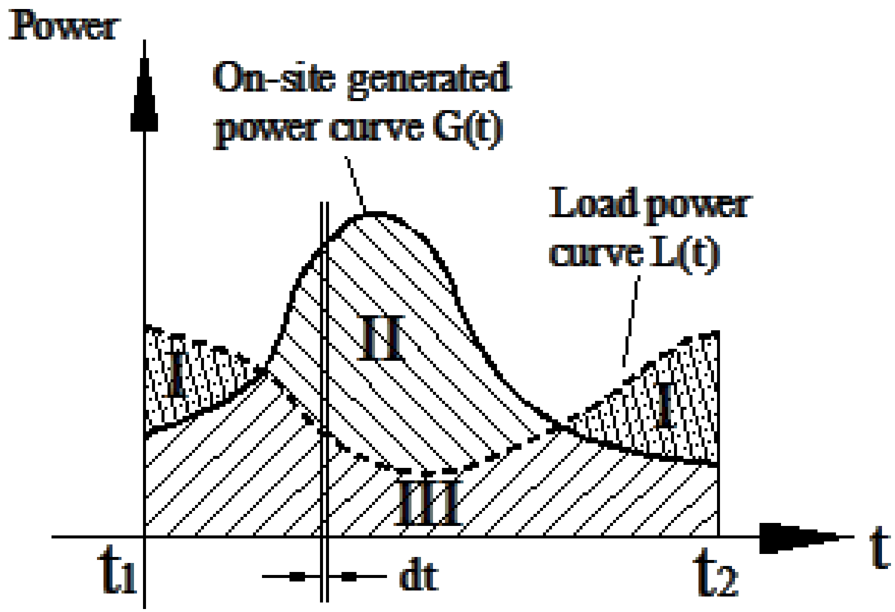
Credit factors

NZEB balance	unit	Credit factors			
		Electricity	District Heating	Imported bio-mass fuel (wood pellet)	Local renewable source (Solar)
NZEB-Site Energy	kWh/kWh_{end}	1	1	1	0
NZEB-Primary Energy	kWh/kWh_{end}	1.7	0.7	0.5	0
NZEB-CO_2 Emission	g_{co2} / kWh_{end}	456	226	18	0

When needed, on-site supplementary PV area is added to bring each case to the NZEB balance

	Module Characteristics	Performance
PV system	Area = 1 m2 Slop = 45 deg Azimuth angle = 0 deg (faced to equator) Inverter efficiency = 0.78	Annual DC electricity production = 120 kWh/a Annual AC electricity production = 93.6 kWh/a

Energy Matching



$$OEF = \frac{\int_{t_1}^{t_2} Min[G(t); L(t)]dt}{\int_{t_1}^{t_2} L(t)dt} \; ; \quad 0 \le OEF \le 1 \qquad (1)$$

OEF On-site Energy Fraction

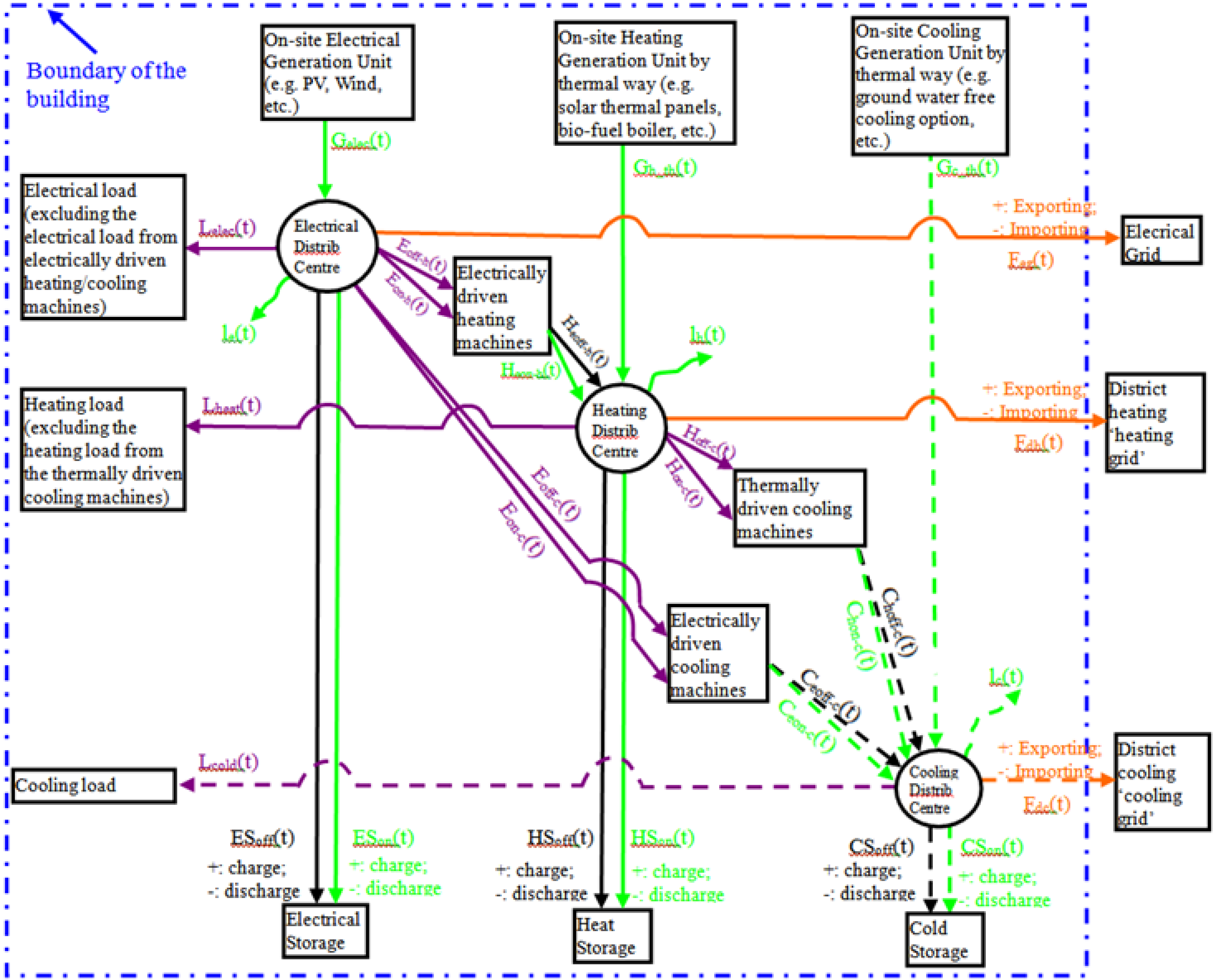
$$OEM = \frac{\int_{t_1}^{t_2} Min[G(t); L(t)]dt}{\int_{t_1}^{t_2} G(t)dt} \; ; \quad 0 \le OEM \le 1 \qquad (2)$$

OEM On-site Energy Matching

$OEF_{electricity}$, $OEM_{electricity}$, $OEF_{heating}$, $OEM_{heating}$, $OEF_{cooling}$, $OEM_{cooling}$

Cao. S, Hasan A, Siren K. On-site energy matching indices for buildings with energy conversion, storage and hybrid grid connections, Energy and Buildings, Volume 64, September 2013, Pages 423–438

Topology for the energy matching analysis

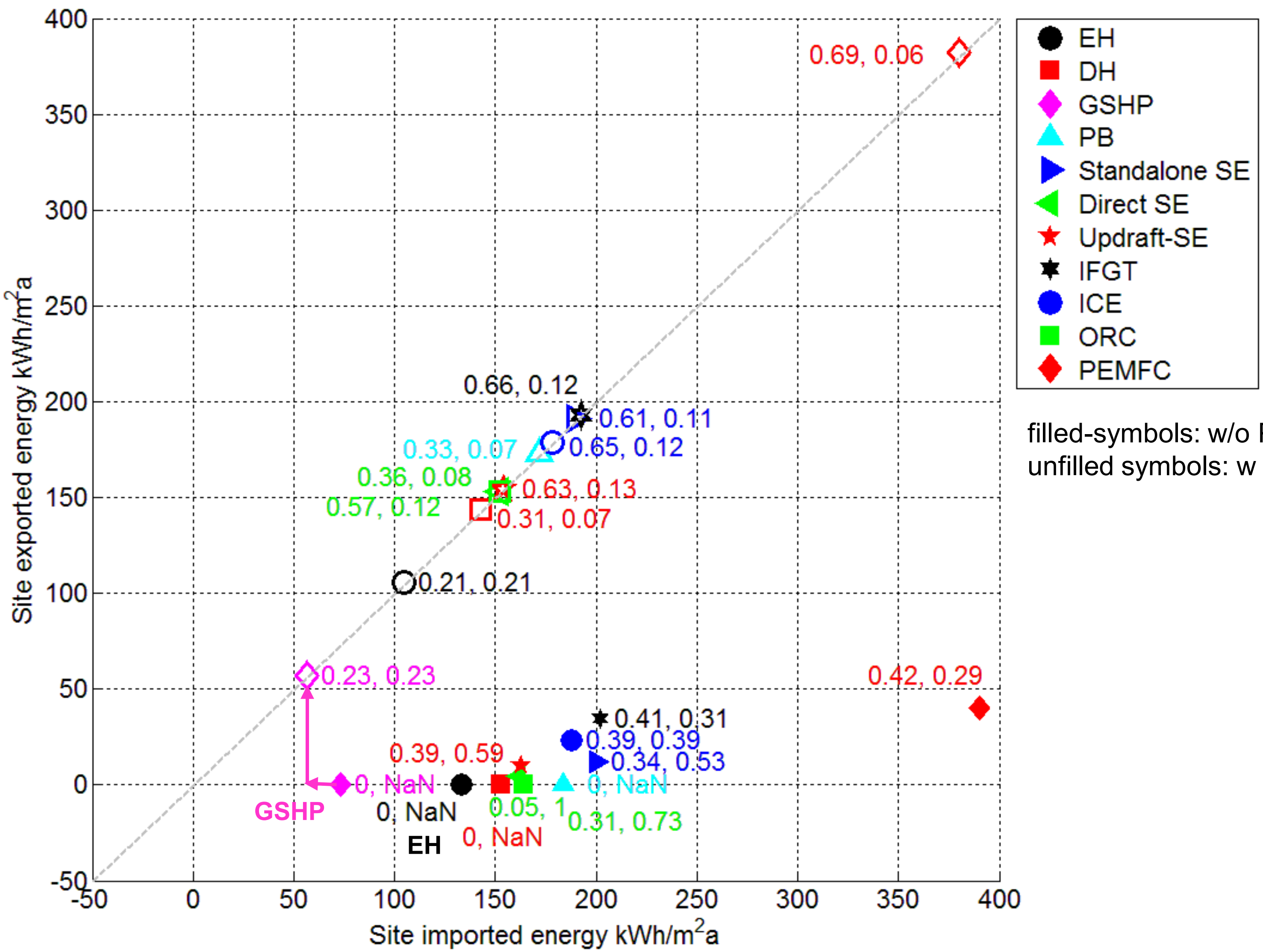


Results

Since the systems run according to heating-tracking operation with enough heating capacity, therefore OEFh=1 and OEMh=1 for all systems.

Next we are looking at the NZEB balance and the electrical matching characteristics in terms of OEFe and OEMe.

NZEB- Site Energy balance and electrical matching (OEFe, OEMe values) for the investigated energy systems



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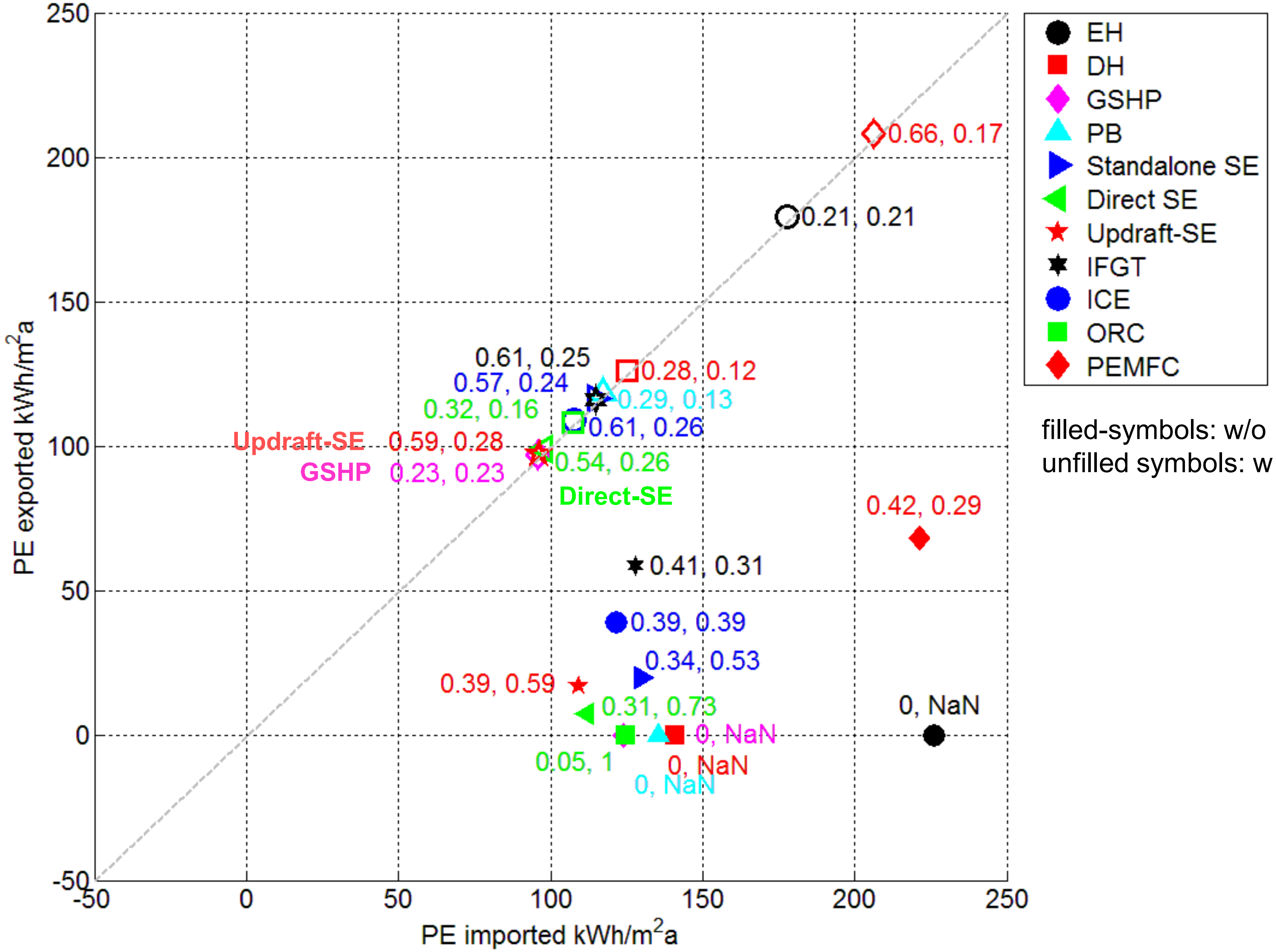
NZEB- Primary Energy balance and electrical matching (OEFe, OEMe values) for the investigated energy systems



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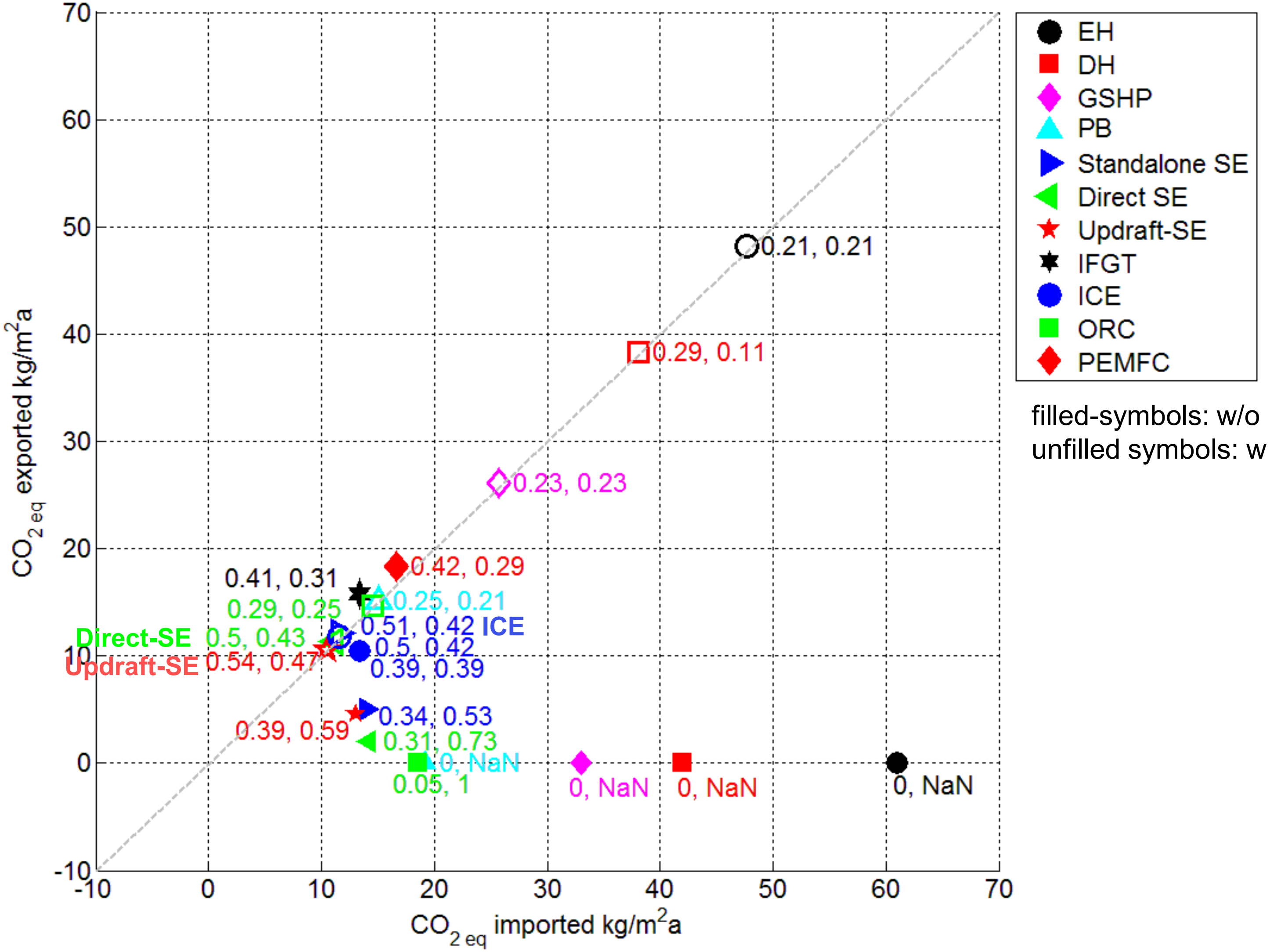
NZEB- CO_2 Emission balance and electrical matching (OEFe, OEMe values) for the investigated energy systems



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Conclusion

In achieving NZEB balance, it is important to include the characteristics of the energy matching in the selection of the on-site energy generation. Otherwise, we will be just pushing the temporal energy imbalance problem to the grid.

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