# IBPSA-Nordic Seminar 2013

***Selection of micro-cogeneration heat and power achieving Net Zero Energy Building using overall matching index***

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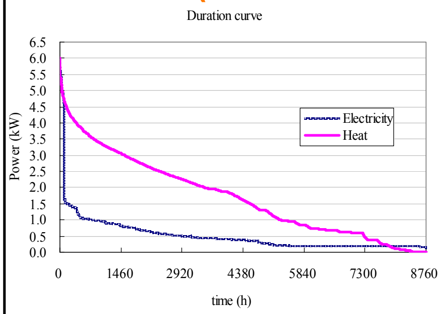
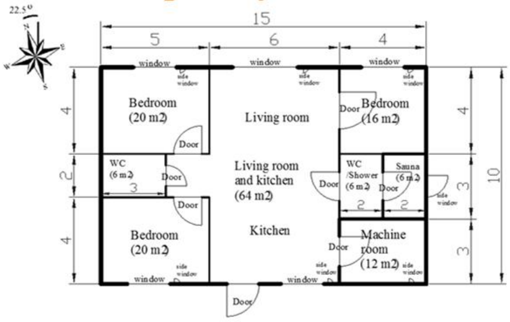
## Objectives

1. Define the overall weighting matching index (WMI)
2. Introduce the two opposite extreme situations for NZEB regarding the matching capability.
3. Create a physical method to calculate the weighting factors of OEF and OEM indices. (Preferences)
4. Formulate mathematical formulas for the weighting factors.
5. Present the applicability of using the annual WMI regarding the matching analysis instead of four annual OEF and OEM indices by simulating an onsite bio-syngas fuelled based micro-cogeneration heat and power (micro-CHP) connected to a single family house in Helsinki, Finland (achieving NZEB) under thermal tracking strategies.

# Simulated single faimly house in Heslinki, Finland (Simulation tool is Trnsys 17)




Plan view of the single family house (all dimensions in meters).

| Heating demands (AHU, space, and DHW heating) | Electrical demands[(a)] (Ventilation fan, lighting, and equipments) | Peak heating demands (AHU, space, and DHW heating) | Peak electrical demands[(a)] (Ventilation fan, lighting, and equipments) |
|---|---|---|---|
| Annual energy (kWh/m ) | | Peak power (kW) | |
| 100.3 | 29.9 | 6.0 | 5.6 |

(a) The electric demands listed exclude the electricity consumption of the circulated pump of the mCHP and auxiliary electric heaters.

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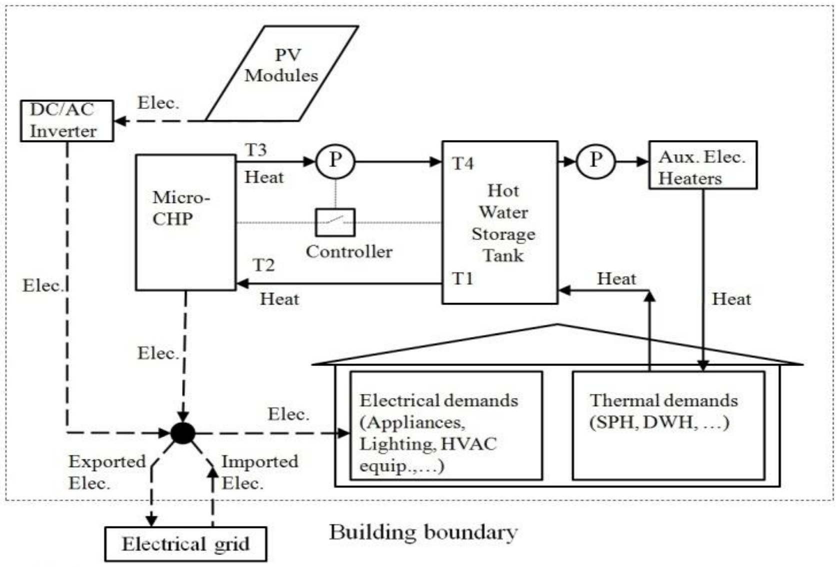
# Bio-syngas fuelled based micro-CHP operates with thermal tracking strategy

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# Basic matching indices OEF & OEM

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

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

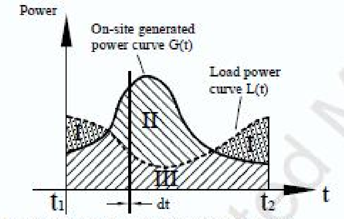


Figure 2. The main principle for the two basic indices.

On-site energy fraction (OEF) indicates the proportion of the load covered by the on-site generated energy, while On-site energy matching (OEM) indicates the proportion of the on-site generated energy that is used in the load rather than being dumped or exported.



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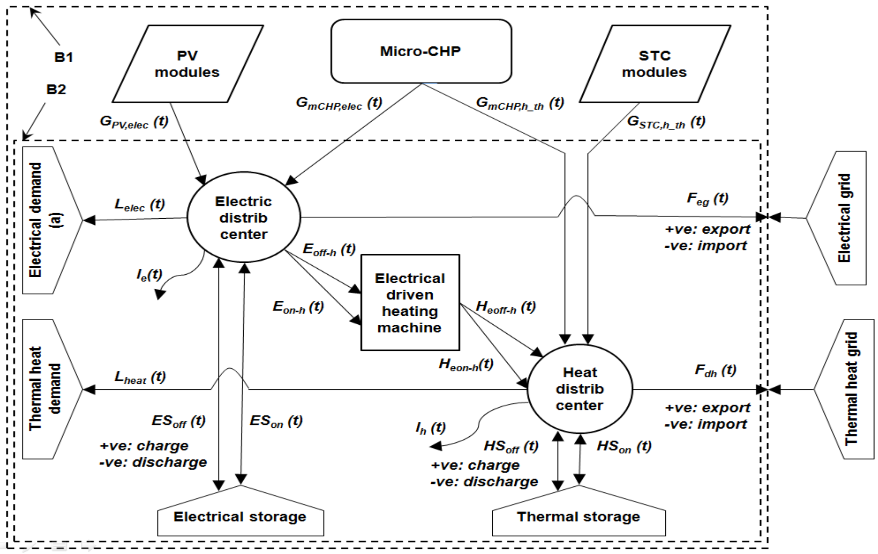
# Extended matching indices topology

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## Extended Matching Indices

$$OEFe = \frac{\int_{t_1}^{t_2} Min\,[G_{mCHP,elec}(t) + G_{PV,elec}(t) - ES_{on}(t) - l_e(t); L_{elec}(t) + E_{off-h}(t) + E_{on-h}(t)]dt}{\int_{t_1}^{t_2}[L_{elec}(t) + E_{off-h}(t) + E_{on-h}(t)]\,dt}, 0 \le OEFe \le 1$$

$$OEFh = \frac{\int_{t_1}^{t_2} Min\,[G_{mCHP,h\_th}(t) + G_{STC,h\_th}(t) + H_{eon-h}(t) - HS_{on}(t) - l_h(t); L_{heat}(t)]dt}{\int_{t_1}^{t_2} L_{heat}(t)\,dt}, 0 \le OEFh \le 1$$

$$OEMe = \frac{\int_{t_1}^{t_2} Min\,[G_{mCHP,elec}(t) + G_{PV,elec}(t)]\,; L_{elec}(t) + E_{on-h}(t) + ES_{on}(t) + l_e(t)]dt}{\int_{t_1}^{t_2}[G_{mCHP,elec}(t) + G_{PV,elec}(t)]\,dt}, 0 \le OEFe \le 1$$

$$OEMh = \frac{\int_{t_1}^{t_2} Min\,[G_{mCHP,h\_th}(t) + G_{STC,h\_th}(t) + H_{eon-h}(t); L_{heat}(t) + HS_{on}(t) + l_h(t)]dt}{\int_{t_1}^{t_2}[G_{mCHP,h\_th}(t) + G_{STC,h\_th}(t) + H_{eon-h}(t)]dt}, 0 \le OEMh \le 1$$



## Weighting matching index WMI

$$\text{WMI}=w_1\text{OEFe}+w_2\text{OEMe}+w_3\text{OEFh}+w_4\text{OEMh},$$

$$\sum_{i=1}^{4} w_i = 1,\;\; 0 \le w_i \le 1,\;\; 0 \le \text{WMI} \le 1$$

- How can the weighting factors be defined?
- **For nearly and net ZEB**, there are two extreme situations regarding the building grid interaction.
- The first extreme situation is **a load matching priority strategy** (maximizing the on-site energy fraction OEF for both electrical and thermal energies).
- The opposite extreme situation is **an export priority strategy** (minimizing the on-site matching index OEM for both electrical and thermal energies as a goal to reach NZEB balance).

# Primary energy approach

Table 1: The crediting factors of energy carriers.

| Weighting system | Unit | Primary energy factors | | | |
|---|---|---|---|---|---|
| | | Electricity | District heating | Bio-syngas | Solar energy |
| Primary energy | $kWh_{pe}/kWh_{end}$ | 2.23 | 0.77 | 0.17 | 0.00 |

- Based on the definition of OEF,
- It shows the proportion of the load covered by the on-site generated energy.
- What does it mean? It means that, by increasing OEF, the portion of the exported energies (Electricity or DH) will decrease and vice versa. Thus, OEFe can be weighted according to grid electricity PE factors and OEFh can be weighted according to the DH PE factor as well. The befits of that are:
  1. OEFe and OEFh will be weighted proportionally based on corresponding energy quality.
  2. The weighting factors are reflecting the first extreme situation mentioned in previous slide.



# Primary energy approach

- Based on the definition of OEM,
- It shows the proportion of the on-site generated energy that is used in the load rather than being exported.
- What does it mean? It means that, by increasing OEM, the portion of the utilized on-site generated energy will increase and vice versa. In this study, the m-CHP fed by bio-SNG is considered as on-site. Thus, any produced electricity and heat are on-site generated energies. Comparing the PF factors of bio-SNG with that of grid electricity and DH, bio-SNG has lowest PE factors. Thus, bio-SNG PE factor can be used to weight both OEMe and OEMh. The befits of that are:
  1. OEMe and OEMh will be weighted proportionally based on corresponding fuel fed to CHP.
  2. The weighting factors are reflecting the second extreme situation mentioned earlier.

## Mathematical model of weighting factors for only CHP

$$w_1 = \frac{f_{ele,grid}}{f_{ele,grid}+f_{h,grid}+f_{CHP,e}+f_{CHP,h}}$$

$$w_2 = \frac{f_{CHP,e}}{f_{ele,grid}+f_{h,grid}+f_{CHP,e}+f_{CHP,h}}$$

$$w_3 = \frac{f_{h,grid}}{f_{ele,grid}+f_{h,grid}+f_{CHP,e}+f_{CHP,h}}$$

$$w_4 = \frac{f_{CHP,h}}{f_{ele,grid}+f_{h,grid}+f_{CHP,e}+f_{CHP,h}}$$

Allocated based on energy content method

$$f_{CHP,e} = \frac{f_F}{\eta_{CHP,overall}}$$

$$f_{CHP,h} = \frac{f_F}{\eta_{CHP,overall}}$$

| | |
|---|---|
| W1 | 0.660 |
| W2 | 0.056 |
| W3 | 0.228 |
| W4 | 0.056 |

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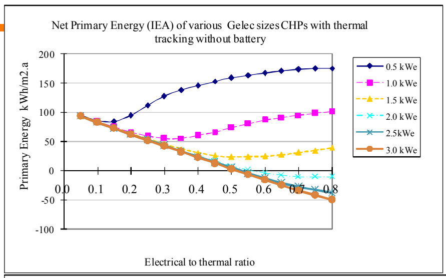
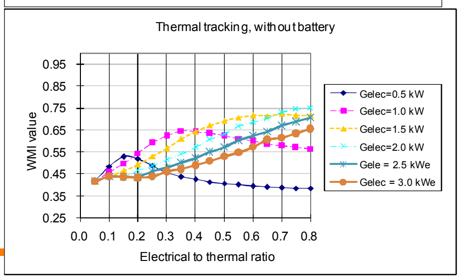
## Results thermal tracking strategy

- M-CHP overall efficiency = 90%




- Without installing PV, the m-CHP with P/H in range 0.7-0.8 and nominal electric capacity of 2.0 kWe achieves the NZEB with higher WMI of 0.75.

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## Mathematical model of weighting factors at several onsite energy systems (CHP, PV and STC)

$$w_1 = \frac{f_{ele,grid}}{f_{ele,grid} + f_{h,grid} + f_{on-site,av,elec} + f_{on-site,av,h\_th}}$$

$$w_2 = \frac{f_{on-site,av,elec}}{f_{ele,grid} + f_{h,grid} + f_{on-site,av,elec} + f_{on-site,av,h\_th}}$$

$$w_3 = \frac{f_{h,grid}}{f_{ele,grid} + f_{h,grid} + f_{on-site,av,elec} + f_{on-site,av,h\_th}}$$

$$w_4 = \frac{f_{on-site,av,h\_th}}{f_{ele,grid} + f_{h,grid} + f_{on-site,av,elec} + f_{on-site,av,h\_th}}$$

$$f_{on-site,av,elec} = \frac{\sum_{i=1}^{n}(f_{i,e} * G_{i,elec})}{\sum_{i=1}^{n} G_{i,elec}}$$

$$f_{on-site,av,h\_th} = \frac{\sum_{i=1}^{n}(f_{i,h\_th} * G_{i,h\_th})}{\sum_{i=1}^{n} G_{i,h\_th}}$$

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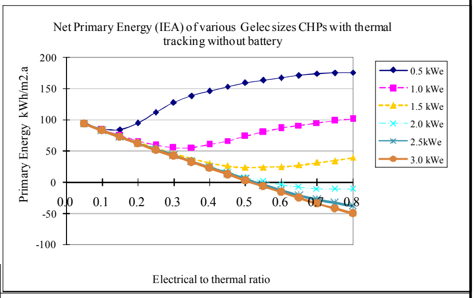
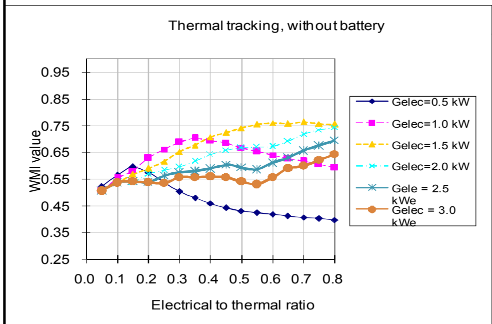
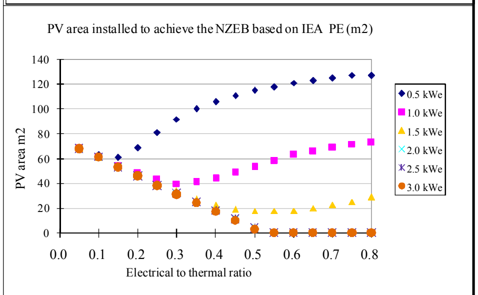
## NZEB achievement by installing the required PV area

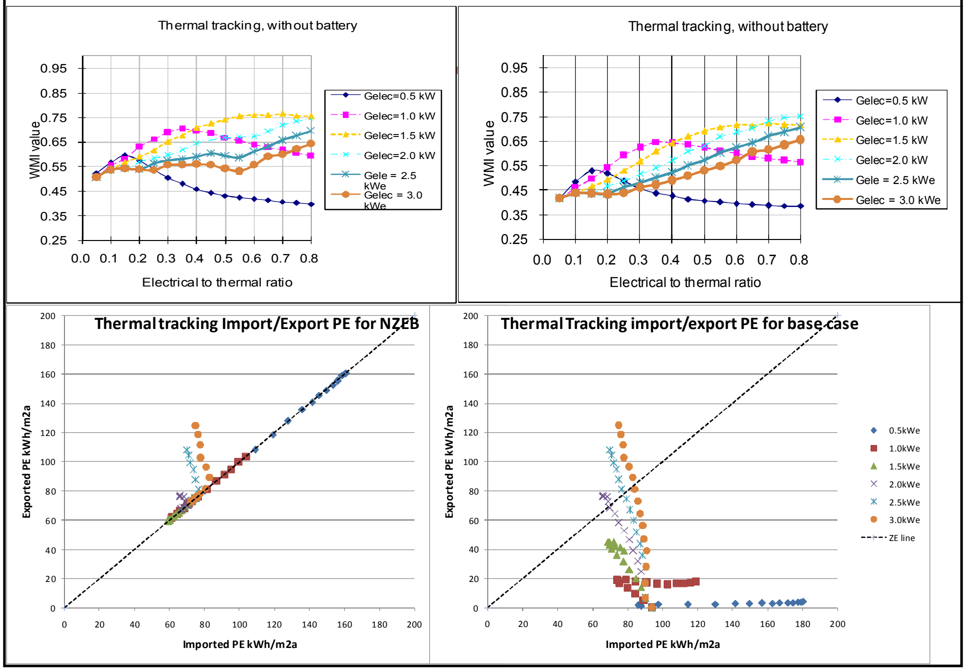
- After installing the required PV to achieve NZEB for all cases, the m-CHP with P/H in range 0.55-0.75 and nominal electric capacity of 1.5 kWe (with around 20 m2 PV) achieve the NZEB with higher WMI of 0.77.



# Import/Export PE for thermal tracking




# Results and Conclusions

1. In case of the single family house, regarding m-CHP operates thermal tracking strategy, the following findings are observed:
- Without installing PV, the m-CHP with P/H in range 0.7-0.8 and nominal electric capacity of 2.0 kWe achieves the NZEB with higher WMI of 0.75.
- After installing the required PV to achieve NZEB for all cases, the m-CHP with P/H in range 0.55-0.75 and nominal electric capacity of 1.5 kWe (with around 20 m2 PV) achieve the NZEB with higher WMI of 0.77.
3. The annual WMI can be applied to be a matching indicator providing a macroscopic view.
4. Using the primary energy factors of the energy carriers crossing the building boundary to calculate the weighting factors is an appropriate way to calculate the weighting factors of WMI regarding the NZEB situations. Also, the mathematical model of weighting factors is created to be applicable with single or hybrid supply systems.
5. The annual WMI can be used as an objective in the net and nearly ZEB optimization problems.

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# Thank you!

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