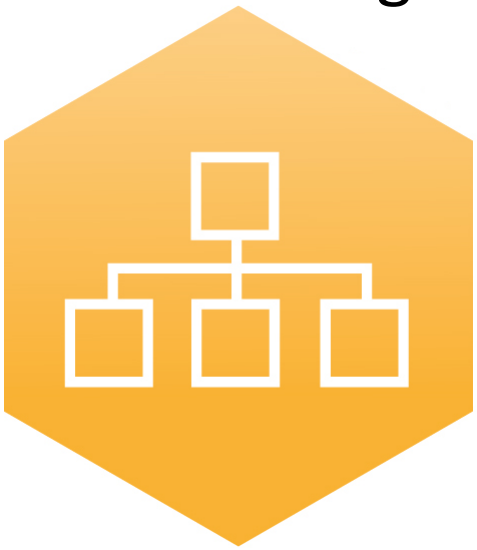
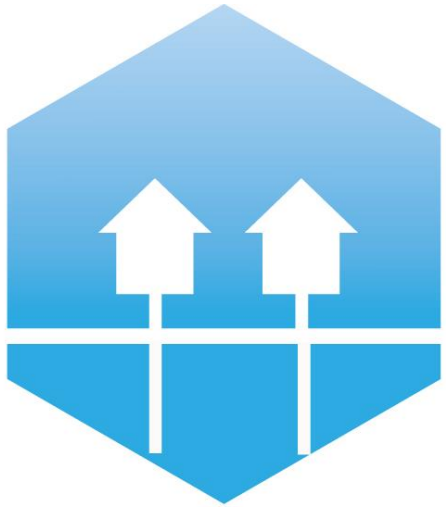
2nd International Conference on Smart Energy Systems and 4th Generation District Heating
Aalborg, 27-28 September 2016

Power-to-Gas and Power-to-Heat interaction in the transition towards Future Smart Energy Systems

Benedetto Nastasi

Gianluigi Lo Basso





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Technologies and Systems

Outline

- **Background**
- **Research Questions**
- **Energy System Model**
- **Power-to-Gas (P2G)**
- **Power-to-Heat (P2H)**
- **Energy Scenarios with 30% - 40% - 50% of RES**
- **Conclusions**

Background

- **Age of buildings entails energy efficiency issues**
- **Low Heating temperature or change production**

✓ ***Energy retrofitting accounting for the constraints***

- **25% is the maximum integrable RES share today**
- **RES intermittency, e.g. PV peak, overcomes 25%**

✓ ***Smart Heating involving RES eletricity excess***

→Power-to-X to meet Heating demand effectively

Research Questions

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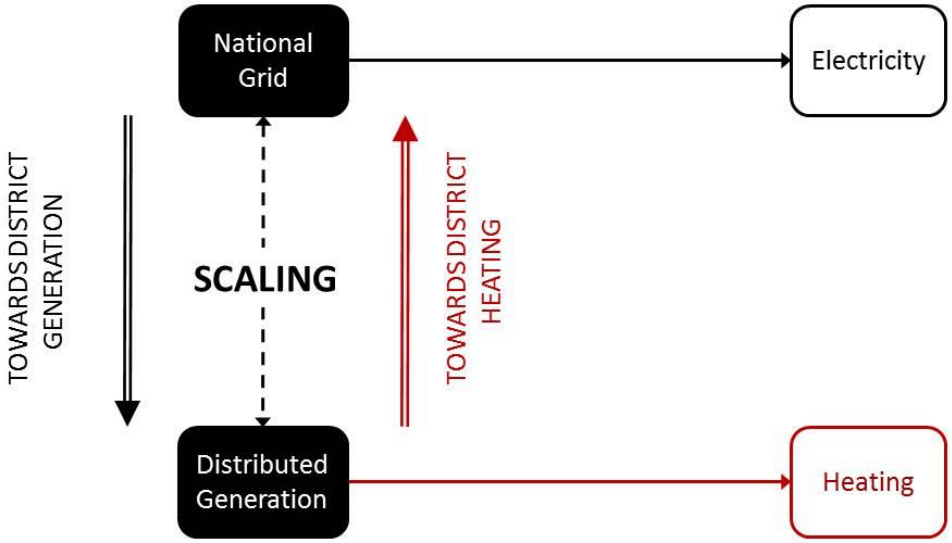
What Heating Technology could be involved in energy efficiency improvement but considering the different temperature levels of energy needs?

Hybrid Systems and Refurbishment opportunities

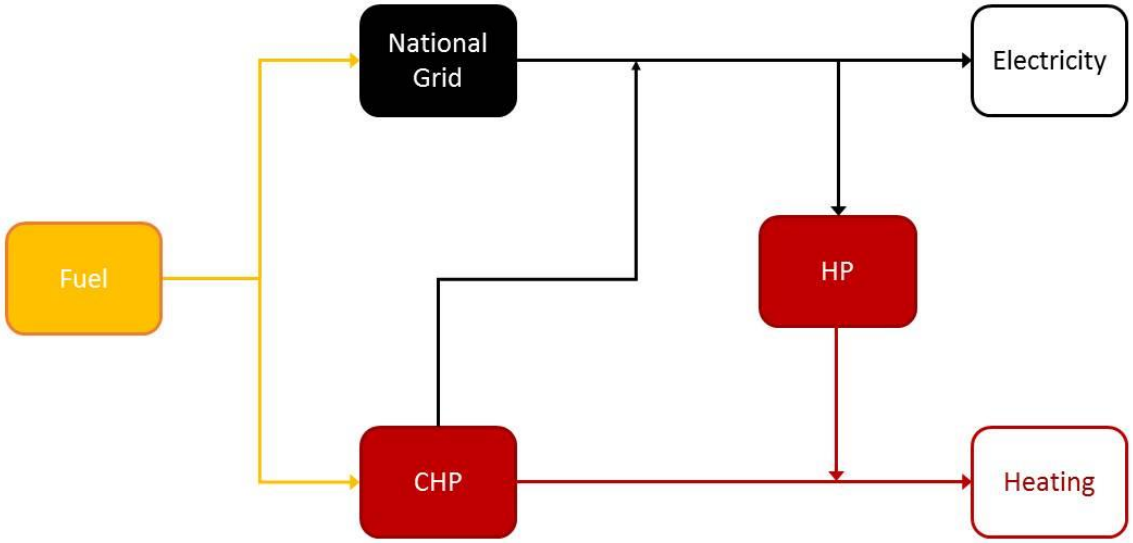
What reduction in Primary Energy and RES excess could be achieved by P2H and P2G technology?

Potential for District Heating & District Generation

Energy System Model



Energy System Model



! Warning about the temperature of supplied heat !

Research Question 1

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What Heating Technology could be involved in energy efficiency improvement but considering the different temperature levels of energy needs?

Conventional Heating supply

- **High Temperature Heating (ca. 85°C)**

✓ **Traditional Boiler → Fuel to Heat**

- **Medium Temperature Heating (ca. 65°C)**

✓ **Condensing Boiler → Fuel to Heat**

- **Low Temperature Heating (ca. 45°C)**

✓ **Electric Heat Pump → Electricity to Heat**

Transition Heating supply

- **High Temperature Heating (ca. 85°C)**

✓ **Traditional Boiler → Cogeneration plant**

- **Medium Temperature Heating (ca. 65°C)**

✓ **Condensing Boiler → Gas Heat Pump**

- **Low Temperature Heating (ca. 45°C)**

✓ **Electric Heat Pump → RES-based Heat Pump**

Transition Heating supply

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- **High Temperature Heating (ca. 85°C)**

✓ **Cogeneration plant → Fuel to Heat and Electricity**

- **Medium Temperature Heating (ca. 65°C)**

✓ **Gas Heat Pump → Fuel to Heat**

- **Low Temperature Heating (ca. 45°C)**

✓ **RES-based Heat Pump → Electricity to Heat**

Future Heating supply

- **High Temperature Heating (ca. 85°C)**

✓ **Cogeneration plant → CO_2 Heat Pump**

- **Medium Temperature Heating (ca. 65°C)**

✓ **Gas Heat Pump → 2-stage Heat Pump**

- **Low Temperature Heating (ca. 45°C)**

✓ **RES-based Heat Pump → Thermal RES**

Future Heating supply

- **High Temperature Heating (ca. 85°C)**

✓ **CO_2 Heat Pump → Electricity to Heat**

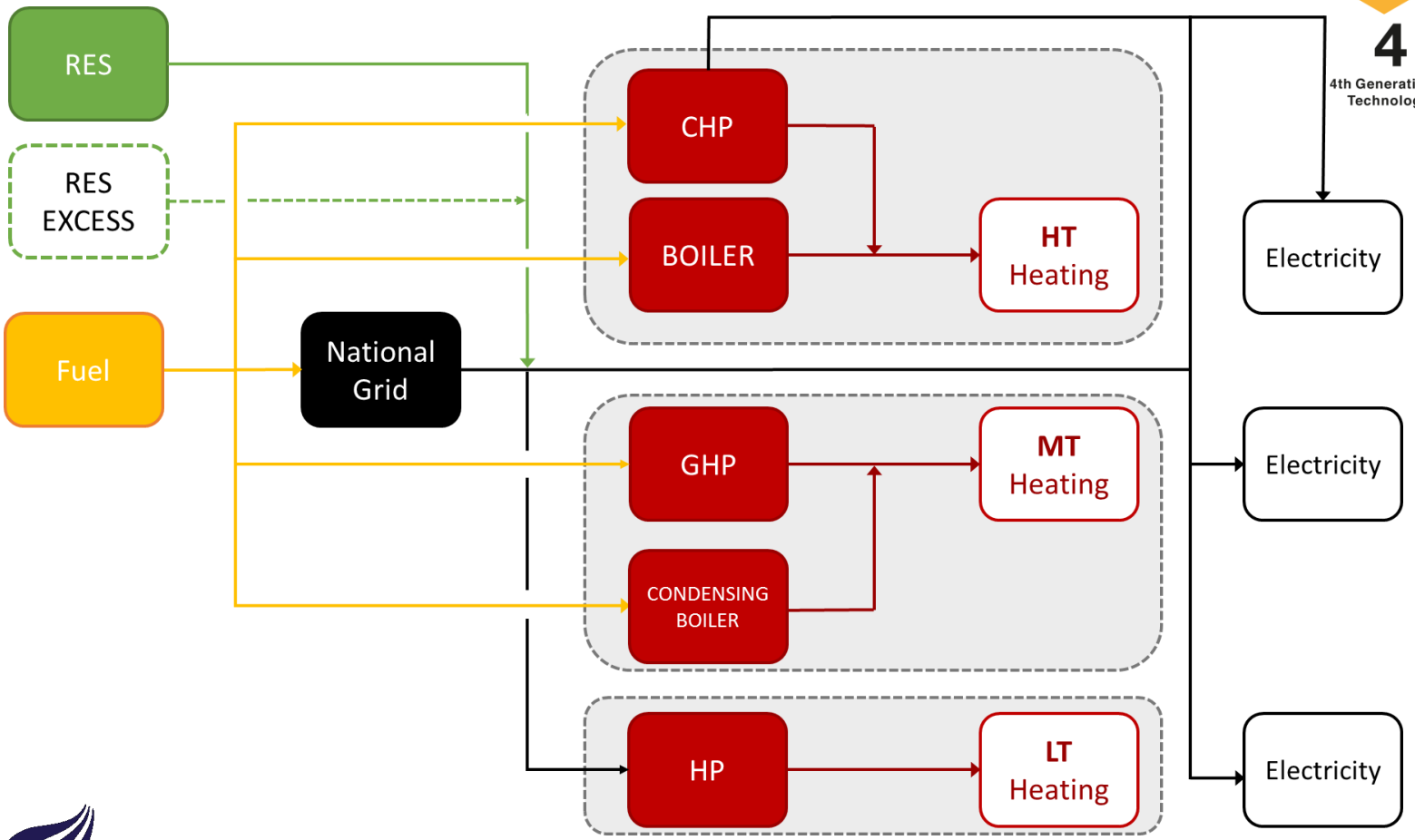
- **Medium Temperature Heating (ca. 65°C)**

✓ **2-stage Heat Pump → Electricity to Heat**

- **Low Temperature Heating (ca. 45°C)**

✓ **Thermal RES → RES to Heat**

Transition Energy System Model



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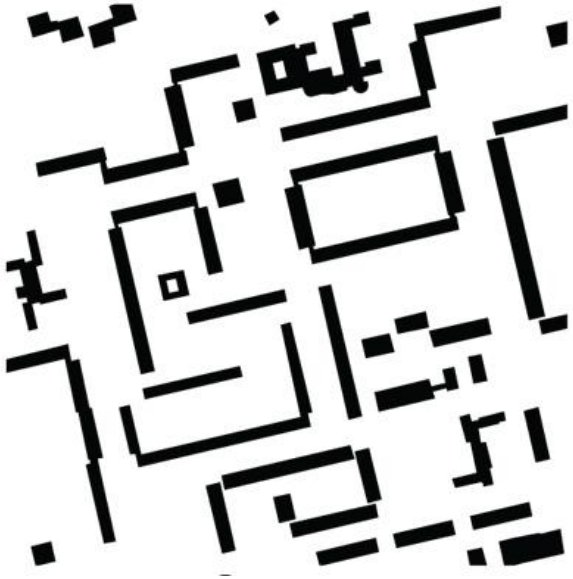
Urban tissue and Heating

HT (City Center)

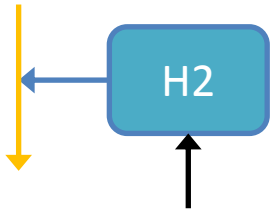


MT (60's Housing)

LT (New areas)

Power-to-Gas (P2G) → H_2NG

Electrolyser efficiency $\eta_{ELY} = \frac{E_{H2}}{E_{el,ELY}}$



Electricity Node $E_{el,GRID} + E_{el,RES} + E_{el,CHP} - E_{el,HP} - \boldsymbol{E_{el,ELY}} = E_{el,D}$

RES fraction $f_{RES} = \frac{E_{el,RES}}{(E_{el,D} + E_{el,HP} + \boldsymbol{E_{el,ELY}})}$

Mixing section $R_{H2NG} = \frac{E_{H2}}{E_{fuel,CHP}}$

Primary Energy $E_{fuel,Sys} = E_{fuel,CHP} \cdot (1 - \boldsymbol{R_{H2NG}}) + \frac{E_{el,GRID}}{\eta_{GRID}}$

Power-to-Gas (P2G)

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Hydrogen to link heat and electricity in the transition towards future Smart Energy Systems

Benedetto Nastasi*, Gianluigi Lo Basso

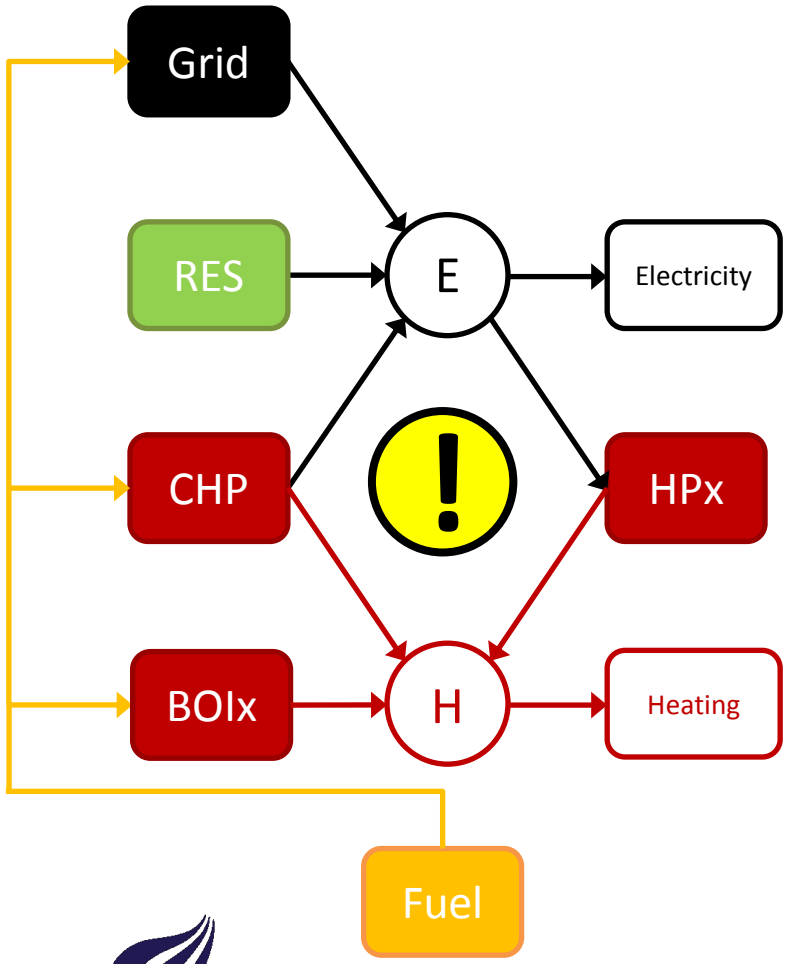
Department of Astronautics, Electrical and Energy Engineering (DIAEE), Sapienza University of Rome, Via Eudossiana 18, 00184, Rome, Italy

* Corresponding author. Tel.: +39 320 8069101; fax: +39 06 49919171.
E-mail addresses: benedetto.nastasi@outlook.com, benedetto.nastasi@uniroma1.it (B. Nastasi), gianluigi.lobasso@uniroma1.it, ing.gianluigi.lobasso@gmail.com (G. Lo Basso).

URL: http://it.linkedin.com/in/benedettonastasi

http://www.sciencedirect.com/science/article/pii/S0360544216303413

Power-to-Heat (P2H)



Electricity Node

$$E_{el,GRID} + E_{el,RES} + E_{el,CHP} - E_{el,HPx} = E_{el,D} \quad (1)$$

Share of RES

$$f_{RES} = \frac{E_{el,RES}}{(E_{el,D}+E_{el,HPx})} \quad (2)$$

Heat Node

$$E_{h,HPx} + E_{h,CHP} + E_{h,BOIx} = E_{h,D} \quad (3)$$

Objective Function

$$E_{fuel,Sys} = E_{fuel,CHP} + E_{fuel,BOIx} + \frac{E_{el,GRID}}{\eta_{GRID}} \quad (4)$$

Reference Urban Energy Systems

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- **Rome – PTHR 0.130 (e.g. 3.3 kWel, 25 kWth)**

✓ **HT 70% MT 20% LT 10%**

- **Berlin – PTHR 0.189**

✓ **HT 40% MT 50% LT 10%**

- **Copenaghen – PTHR 0.283**

✓ **HT 20% MT 40% LT 40%**

Research Question 2

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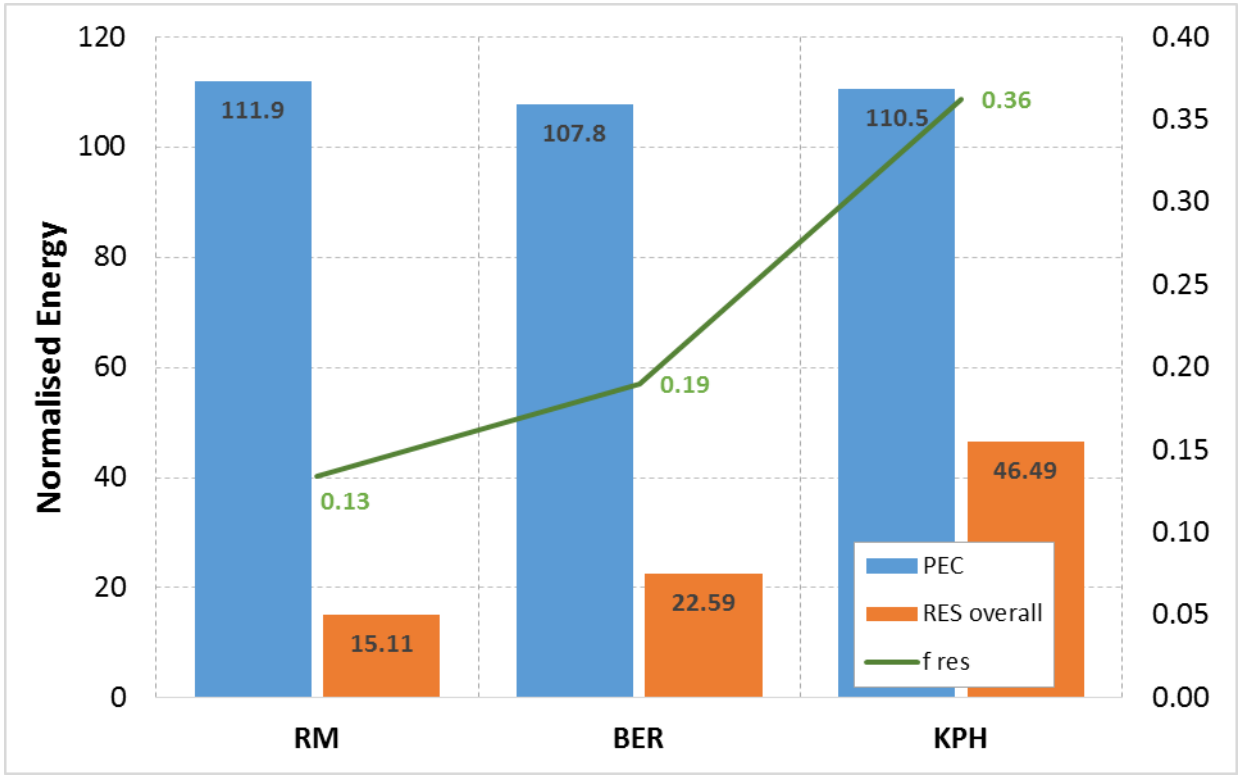
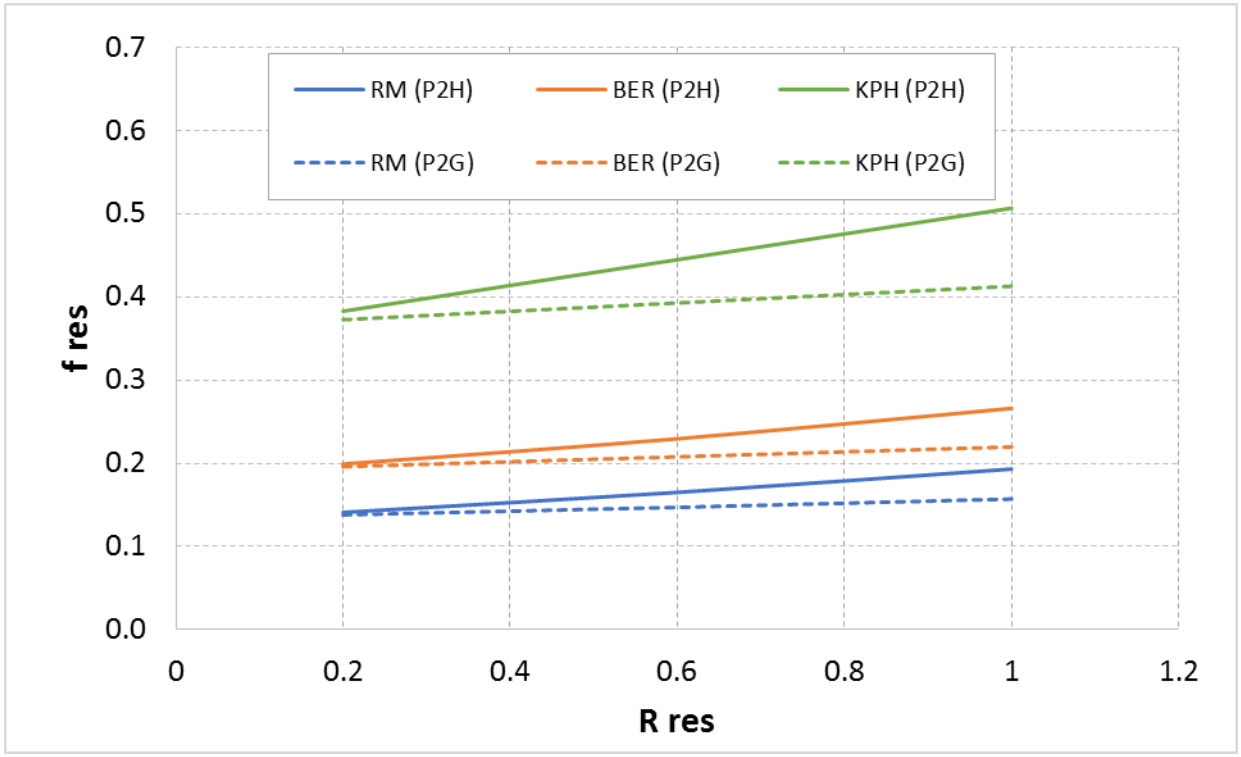
What reduction in Primary Energy and RES excess could be achieved by P2H and P2G technology?

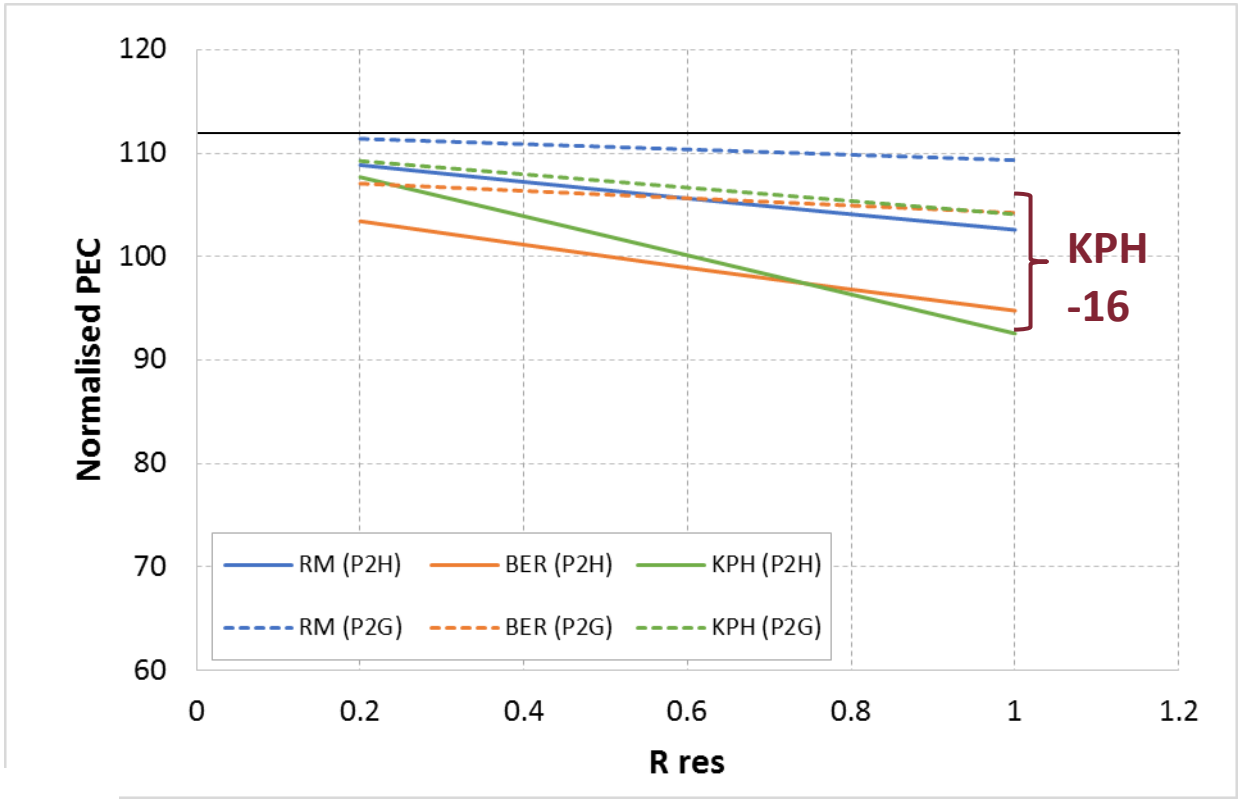
Reference Energy Scenarios



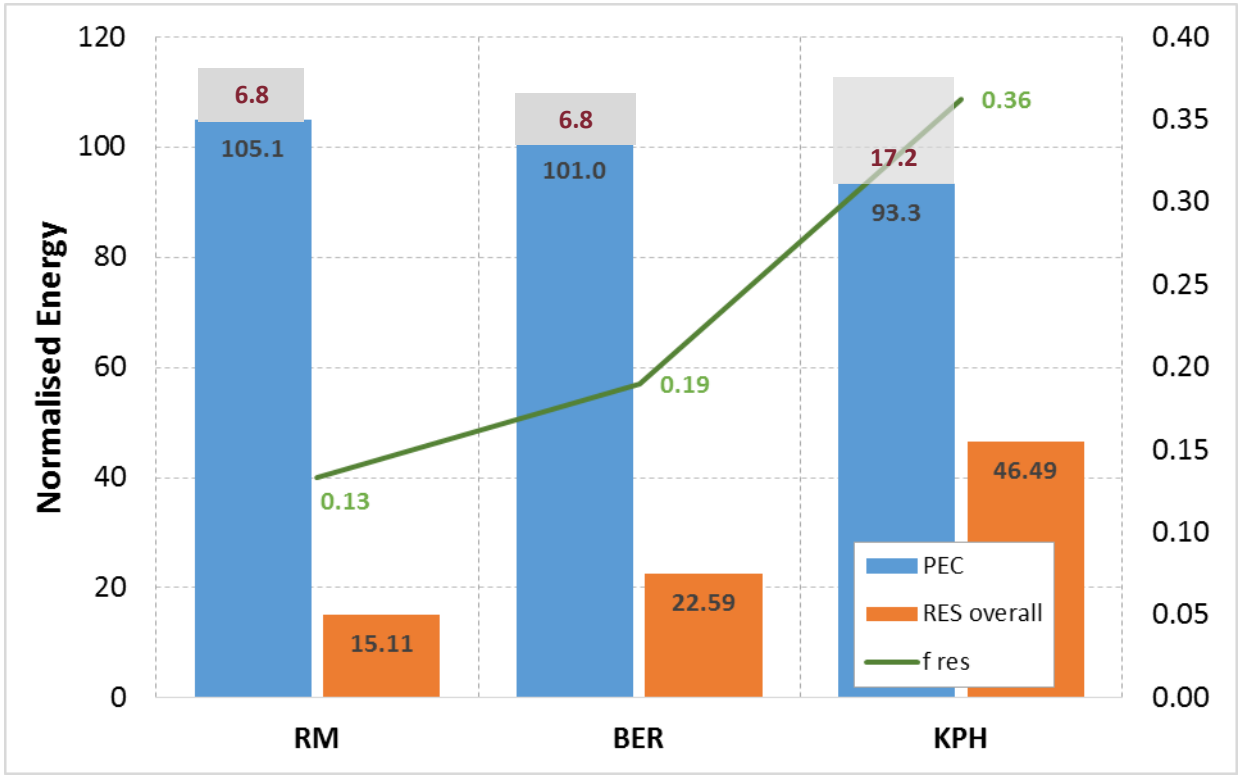
Reference ESs with P2G & P2H



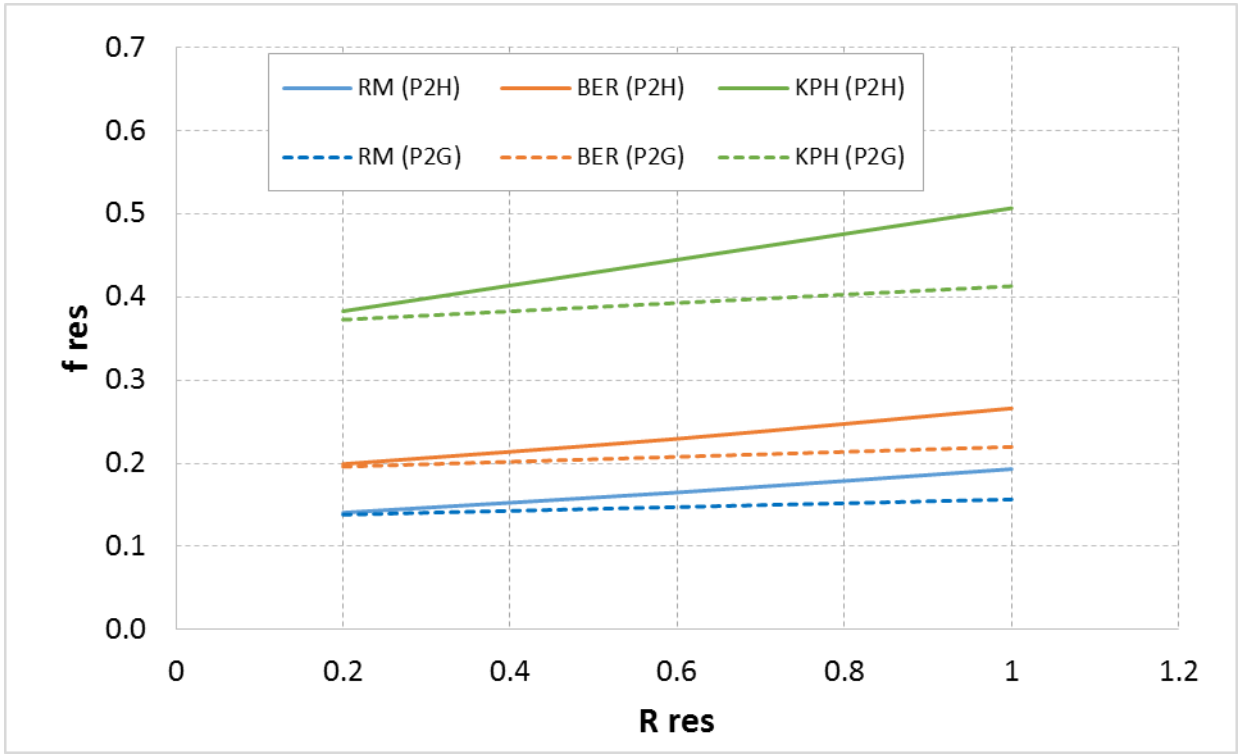
Reference ESs with P2G & P2H



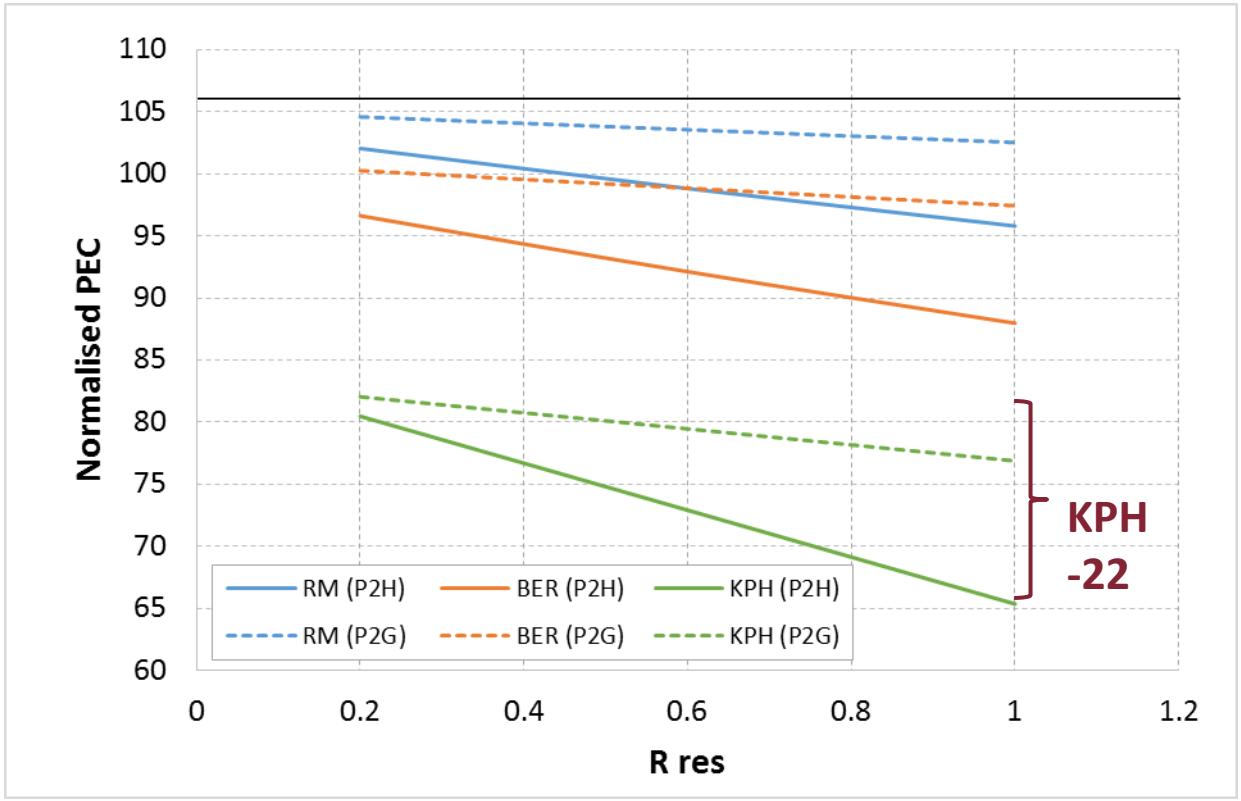
Refurbished Energy Scenarios



Refurbished ESs with P2G & P2H



Refurbished ESs with P2G & P2H



Conclusions

- **Temperature levels are a key technological driver**
- **Power-to-Heat Ratio affects primarily PEC**

✓ ***From "Fuel to Heat" to merging Power and Heat***

- **P2H performs better than P2G in electrification**
- **50% RES share is integrated, leading to -21% PEC**

✓ ***Hybrid solutions improve P2H benefits***

→Energy retrofitting will unlock Smart Heating

Acknowledgement

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Principal Investigator: Benedetto Nastasi.

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Thank you for your attention!

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For any suggestion or further information please contact:

benedetto.nastasi@outlook.com

researchgate.net/profile/Benedetto_Nastasi/

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