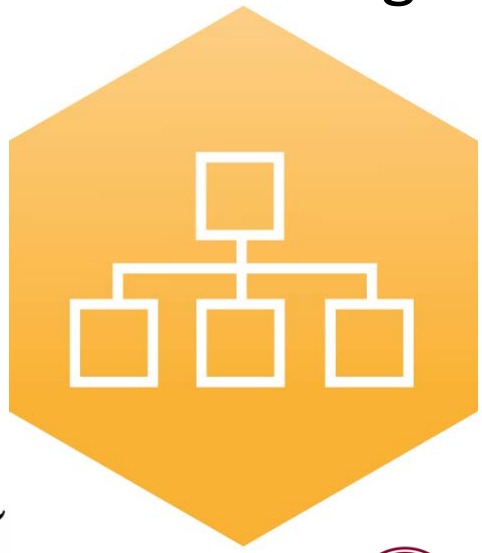
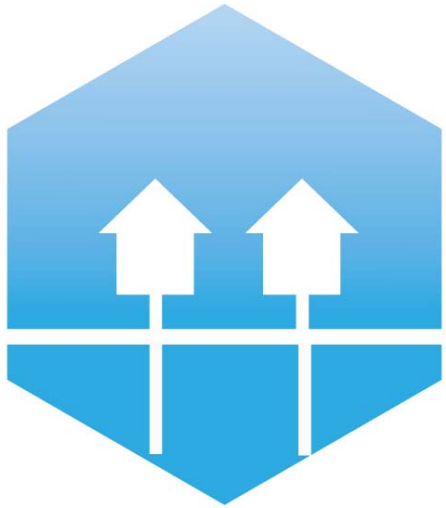
3rd International Conference on Smart Energy Systems and 4th Generation District Heating
Copenhagen, 12-13 September 2017

Smart Heat sharing for high, medium and low temperature Power-To-Heat solutions

Benedetto Nastasi

Gianluigi Lo Basso





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Technologies and Systems

Outline

- **Background**
- **Research Questions**
- **Energy System Model**
- **Power-to-Heat (P2H)**
- **Methodology**
- **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-HP to meet Heating demand effectively

Research Questions

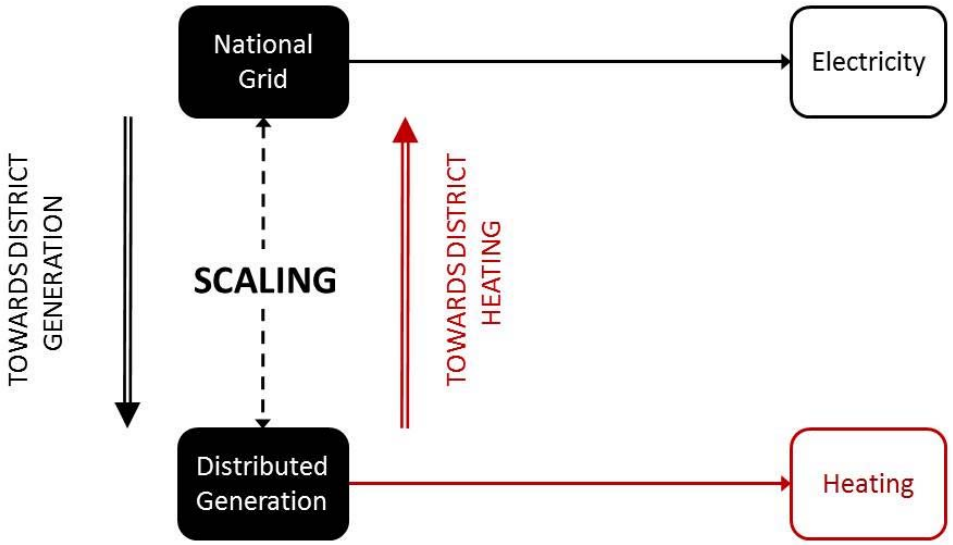
What Heating Technology could be involved in energy efficiency improvement but considering the different temperature levels of energy needs?

Heat Pumps technologies and Refurbishment

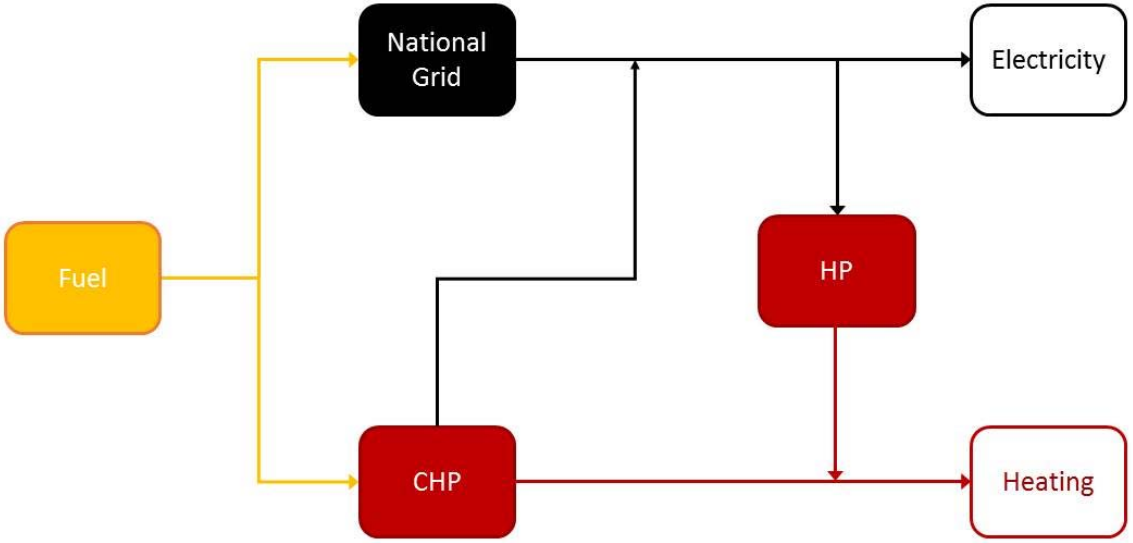
What reduction in Primary Energy and RES excess could be achieved by P2H strategy in Cities?

Potential for District Heating & District Generation

Energy System Model

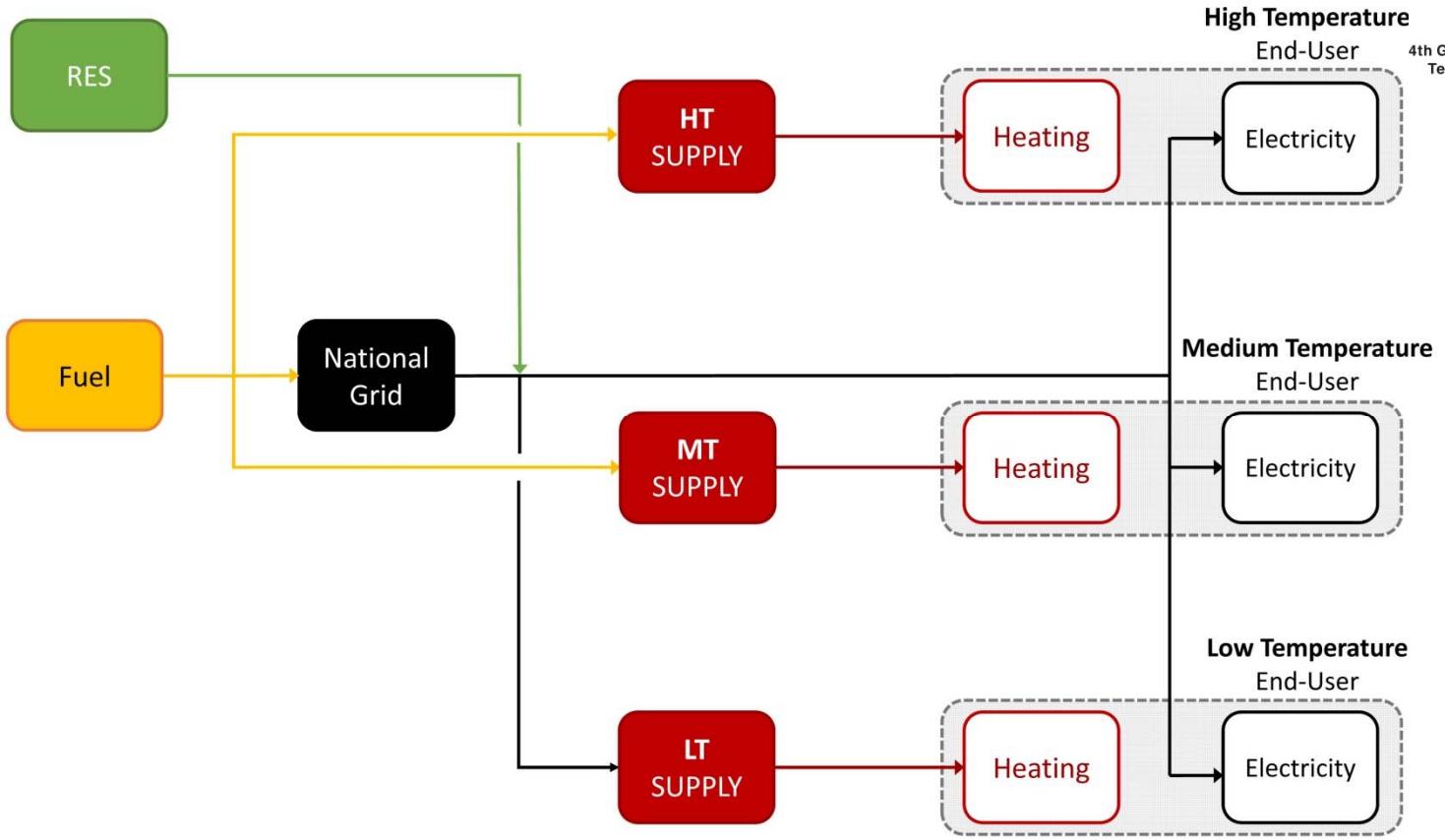


Energy System Model



! Warning about the temperature of supplied heat !

Energy System Model



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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**
- **Medium Temperature Heating (ca. 65°C)**
- ✓ **Condensing Boiler**
- **Low Temperature Heating (ca. 45°C)**
- ✓ **Electric Heat Pump**

Transition Heating supply

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- **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

- **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**

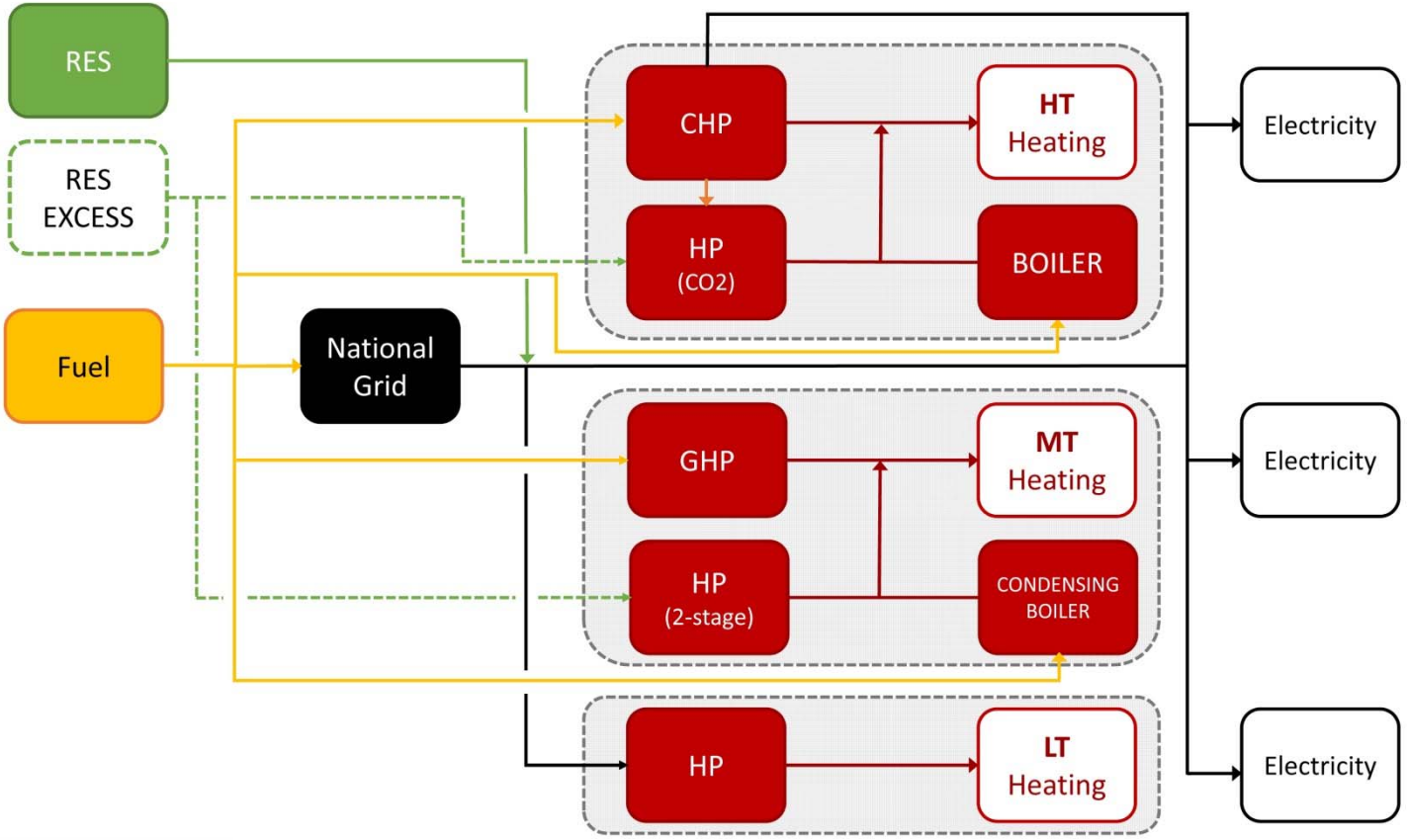
Future Heating supply

- **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**

Energy System Model



Urban tissue and Heating

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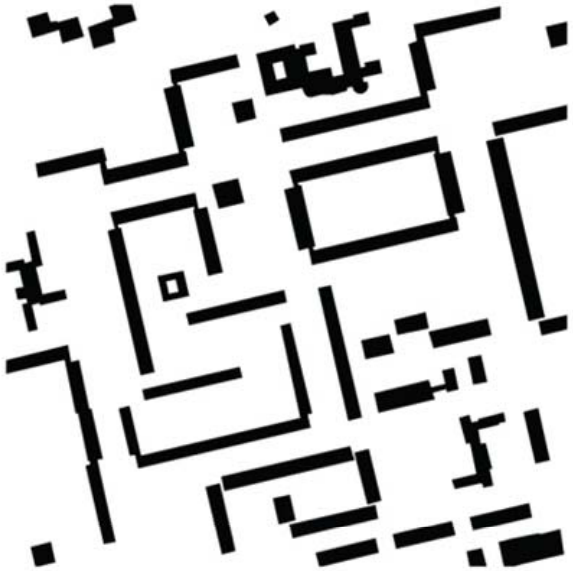

HT (City Center) **MT (60's Housing)** **LT (New areas)**

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Interaction Heat and Electricity

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- **High RES EXCESS but I need a cold heat sink**

✓ **Traditional Boiler → CO2 Heat Pump**

- **Intermittent DHW but I expect low COP**

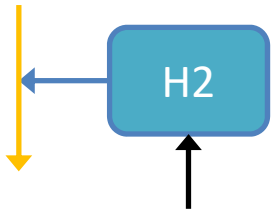
✓ **Condensing Boiler → 2-stage Heat Pump**

- **Radiant floor heating but I need large flows**

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

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

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Power-to-Gas (P2G)

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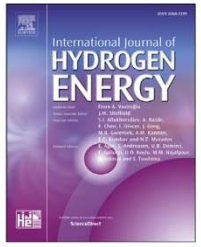

Power-to-Gas integration in the Transition towards Future Urban Energy Systems

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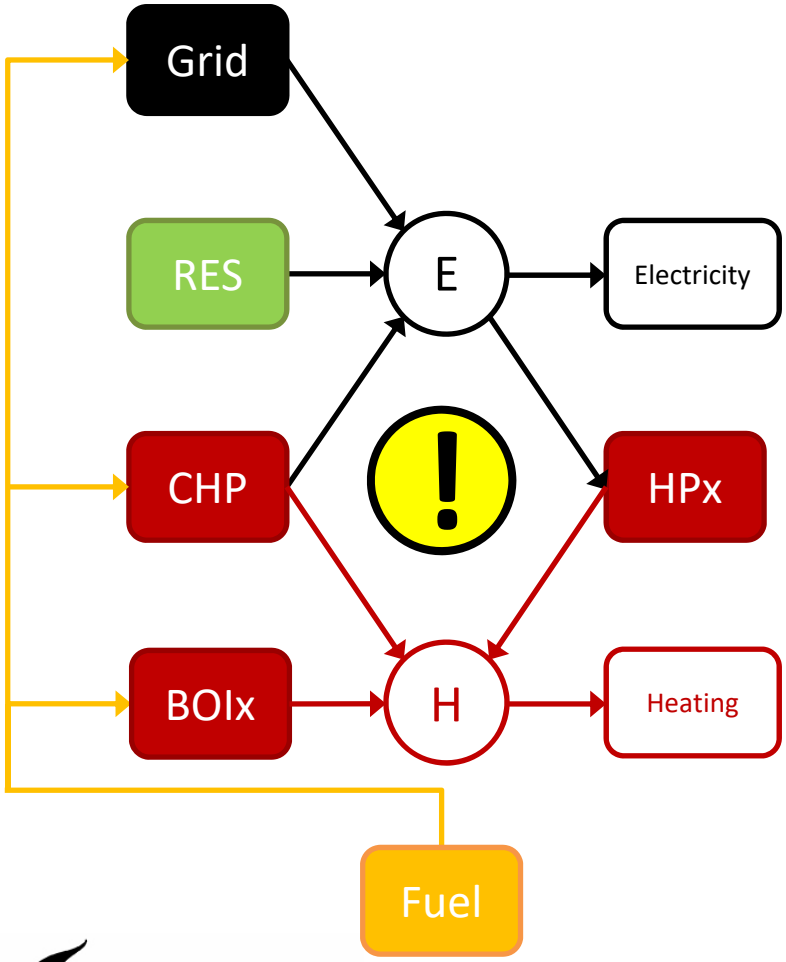
Power-to-Heat (P2H)



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

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

Methodology

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- **Power-To-Heat Ratio as Cities KPI**
- ✓ **Ratio between Electricity and Heating demand**
- **Share of heating demand quality from database**
- ✓ **TABULA/episcope project with climate data**
- **Normalized heating demand to check progress**
- ✓ **HT/MT/LT share to assess readiness for RES**
- **P2H adption by RES excess for substituting supply**

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Reference Urban Energy Systems

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- **Rome**

✓ **HT 70% MT 20% LT 10%**

- **Berlin**

✓ **HT 40% MT 50% LT 10%**

- **Copenaghen**

✓ **HT 20% MT 40% LT 40%**

Source: TABULA/episcope project

Research Question 2

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What reduction in Primary Energy and RES excess could be achieved by P2H strategy in Cities?

How much Renewable is the delivered Heat?

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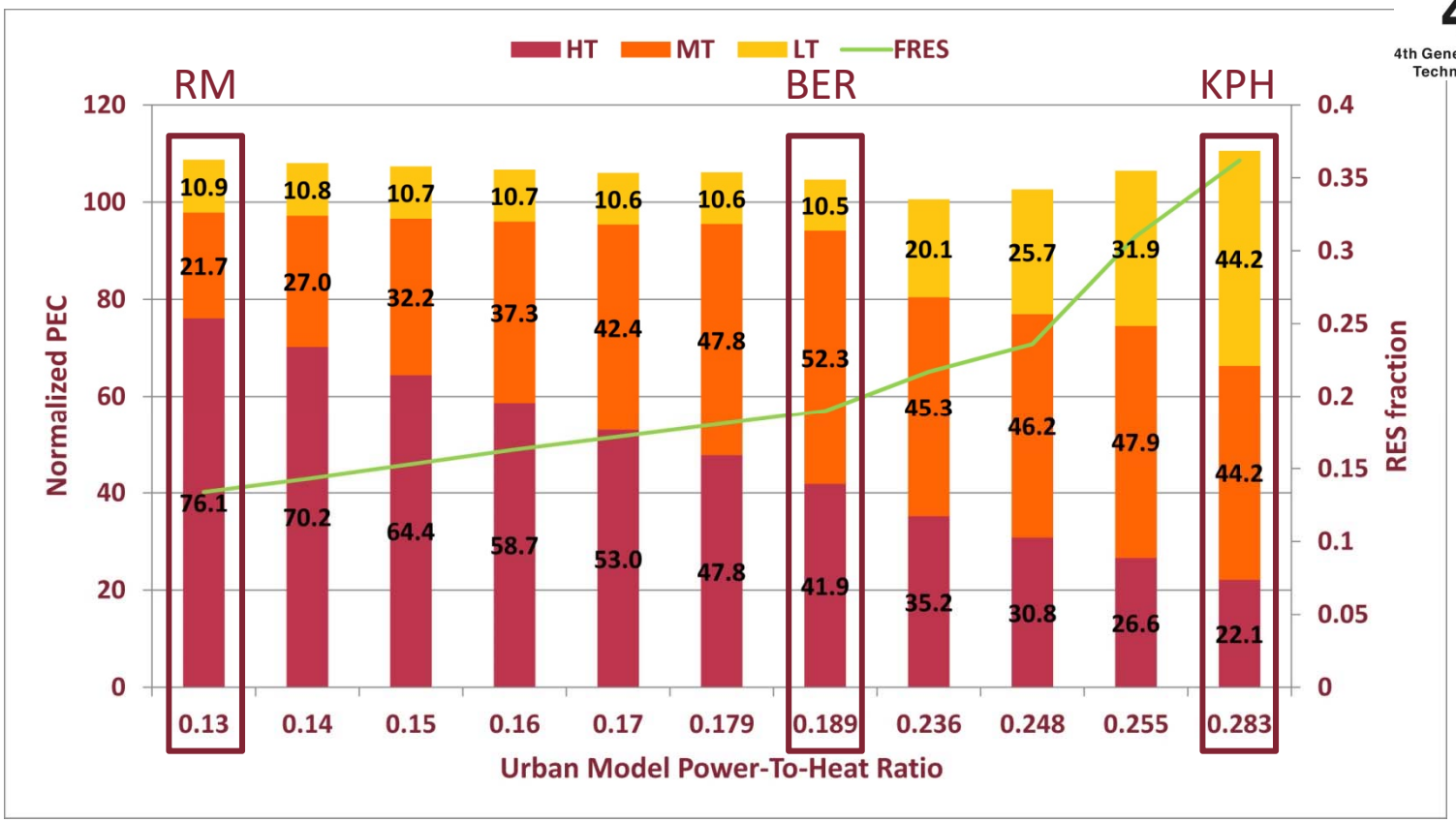
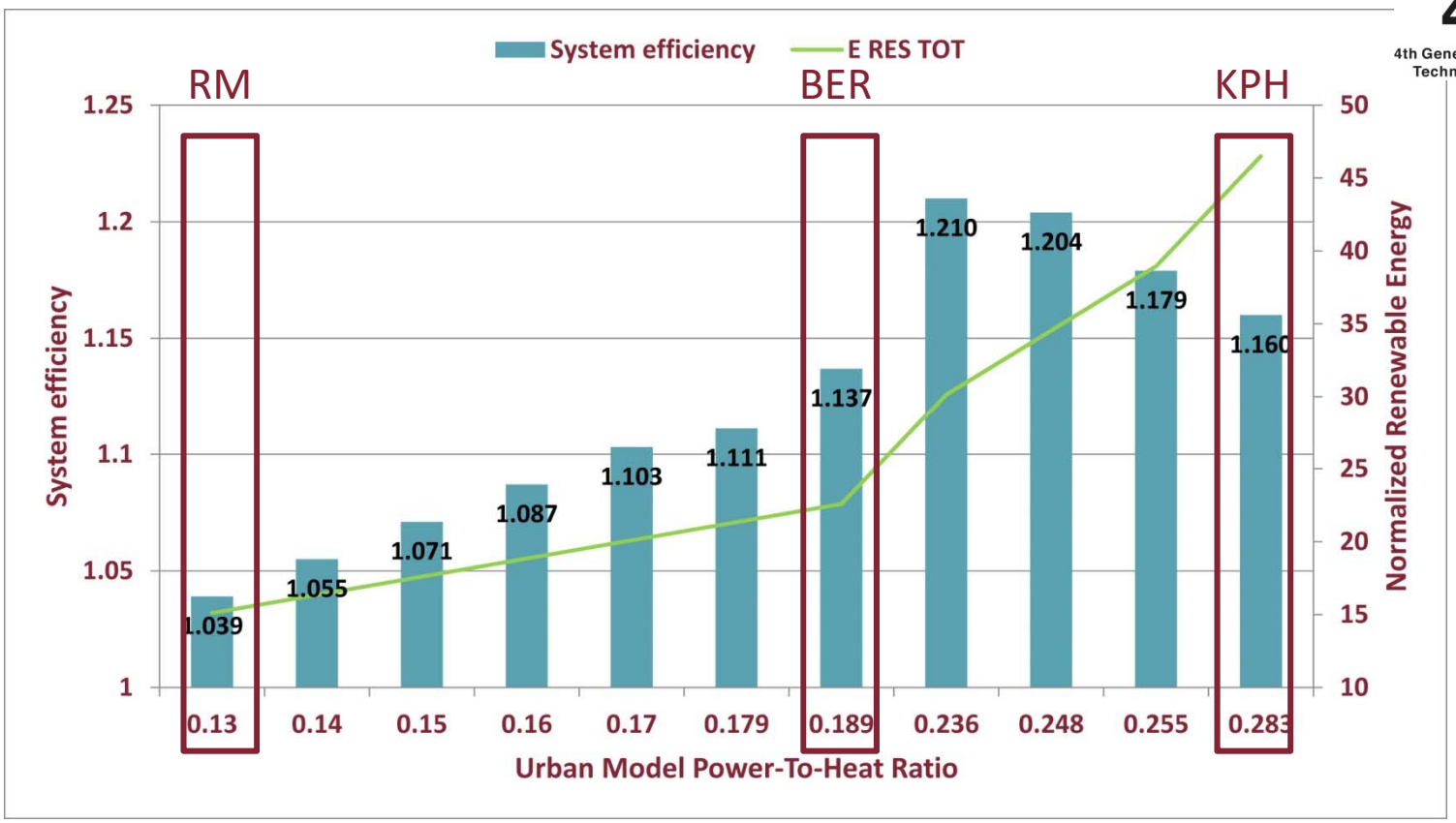
Reference Energy scenarios



Reference Energy scenarios



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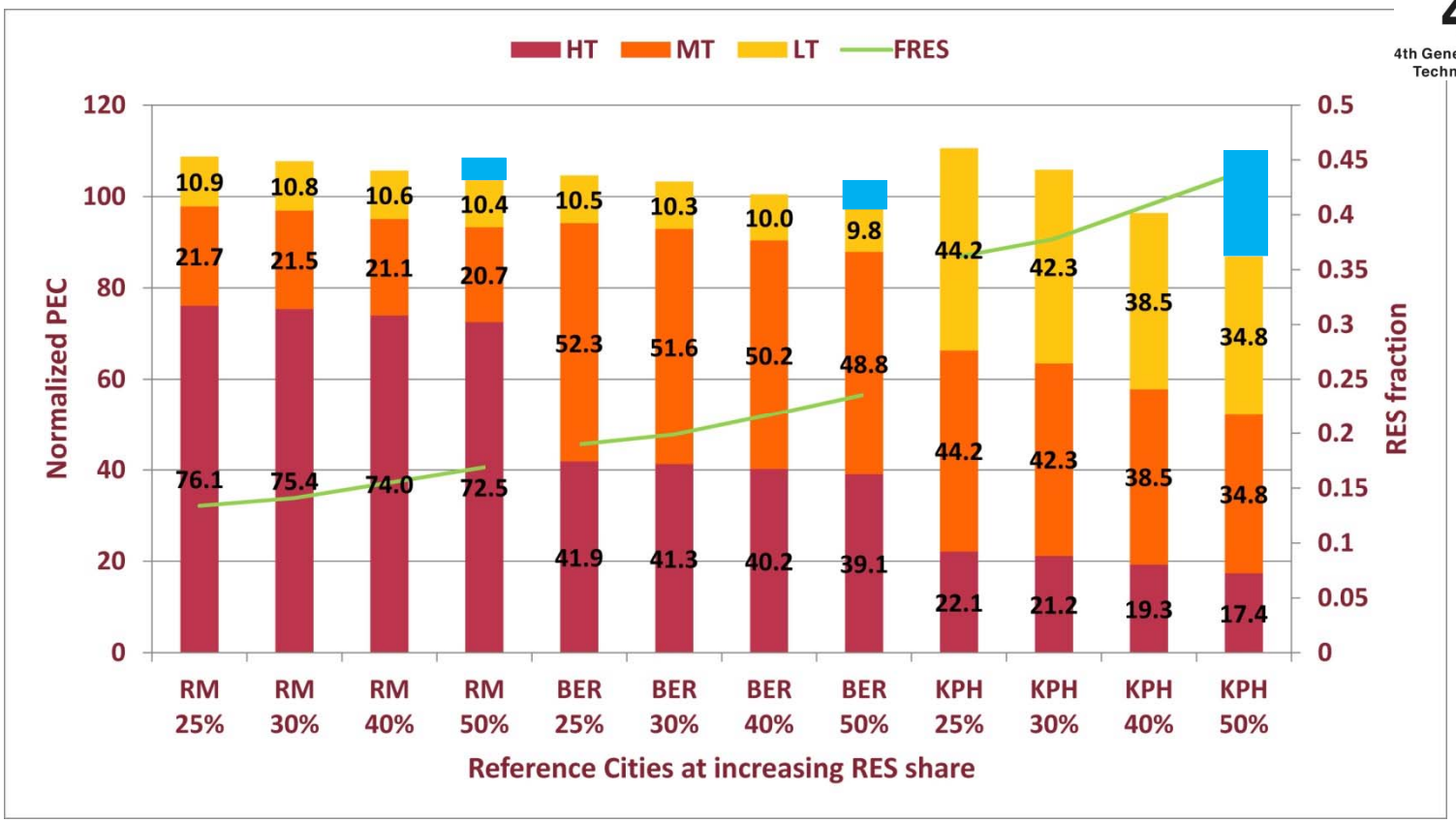
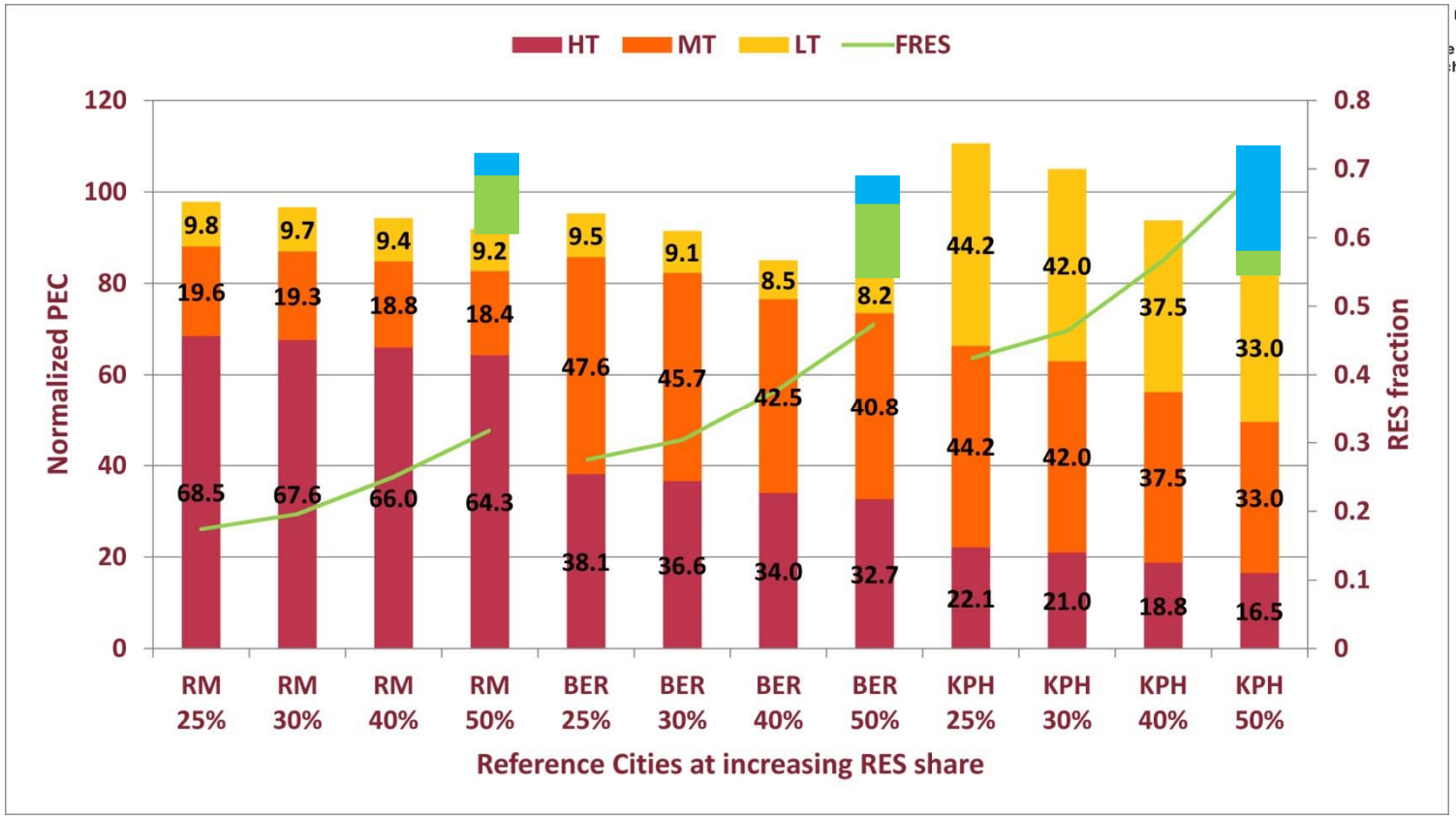
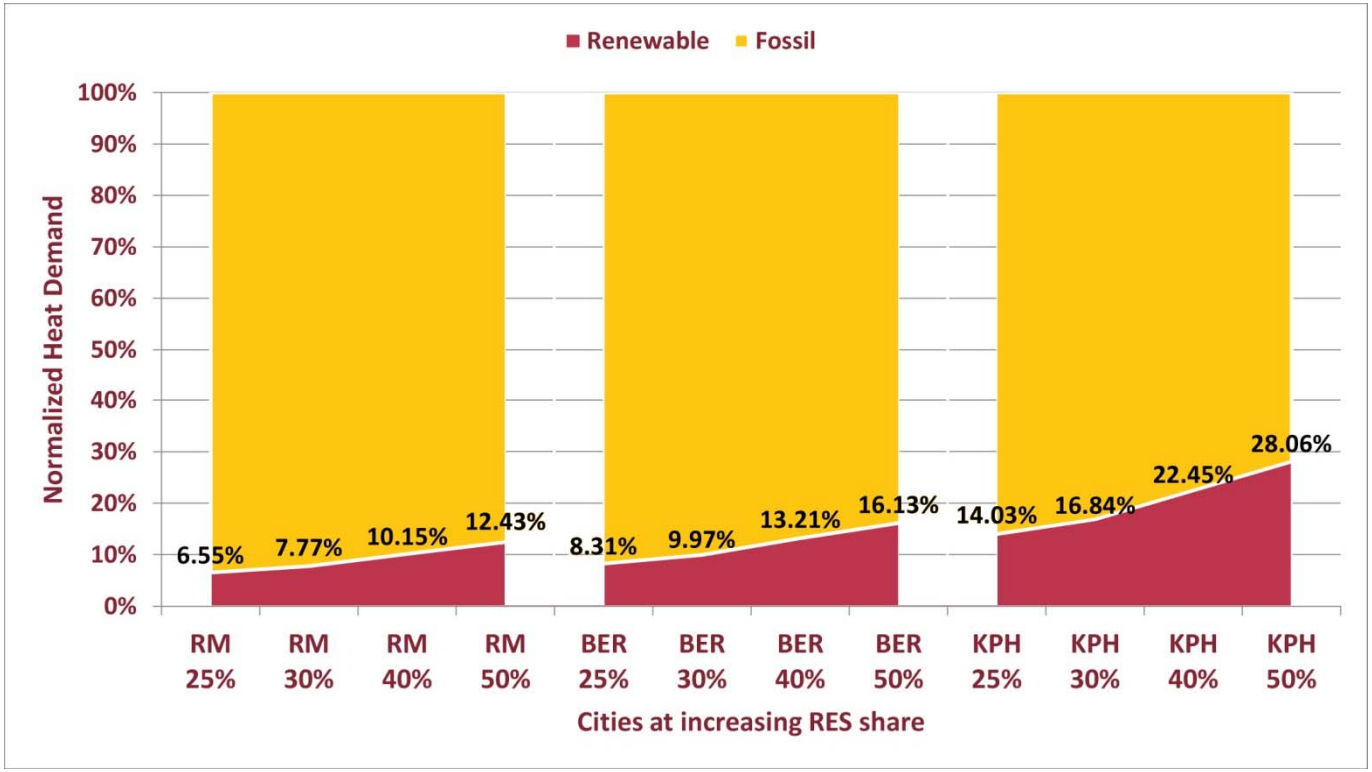
Energy scenarios at increasing RES



P2H scenarios at increasing RES



Energy scenarios at increasing RES



Conclusions

- **Temperature levels are a key technological driver**
- **Grid efficiency affects Heating efficiency**

✓ ***Electrification entails enhancing Grid Power***

- **P2H has high potential if combined with retrofit**
- **High RES situation can be firmed by HP feeding**

✓ ***Smart Heating to share RES excess as benefit***

→District Heating as a temporary cold heat sink

Thank you for your attention!

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