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Synthetic fuels potential by Power-To-Gas integration at National level for enhancing energy independency

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4DH 4th Generation District Heating Technologies and Systems

Outline

- **Background**
- **Research Questions**
- **Data**
- **Methodology**
- **Power-to-Gas (P2G)**
- **Results**
- **Conclusions**

Background

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

✓ **Storage & sector coupling to firm RES capacity**

- **Long term contracts signed for fossil fuel supply**
- **Energy security linked to geopolitical issues**

✓ **RES-based energy independency strategies**

→ **Electro-fuel as strategic reserve for security**

Research Questions

What Fuels could be involved in RES-excess based synthesis considering the different sectors and their demand (fuel, heat, power)?

Electrolysers as electricity-based process

What improvements in security and CO_2 emission could be achieved by RES-based reserve fuel?

Potential for blending and pure fuel substitution

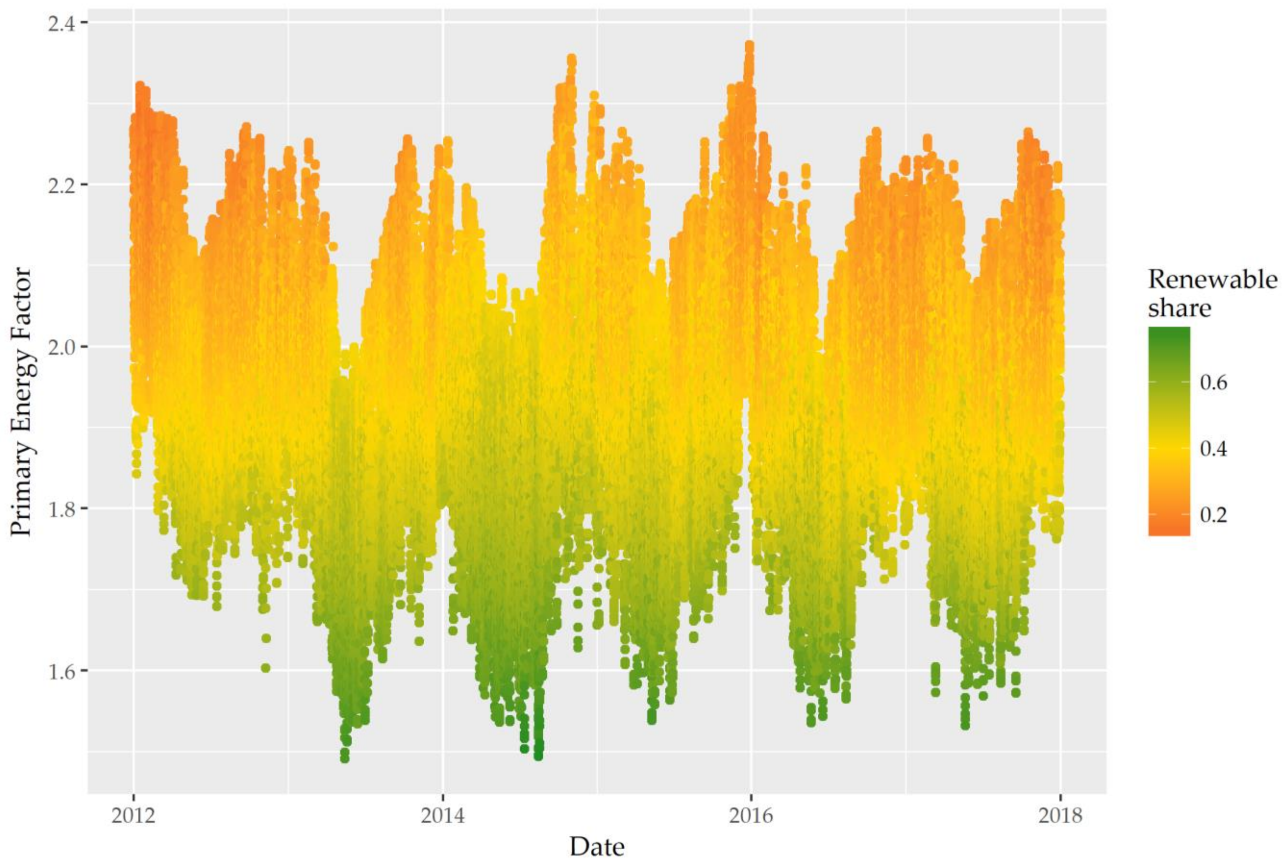
Data – Italy 2012-2017

- **Hourly data of Power Grid**
- **Hourly data of Natural Gas Grid**
- **Solar energy for electricity production**

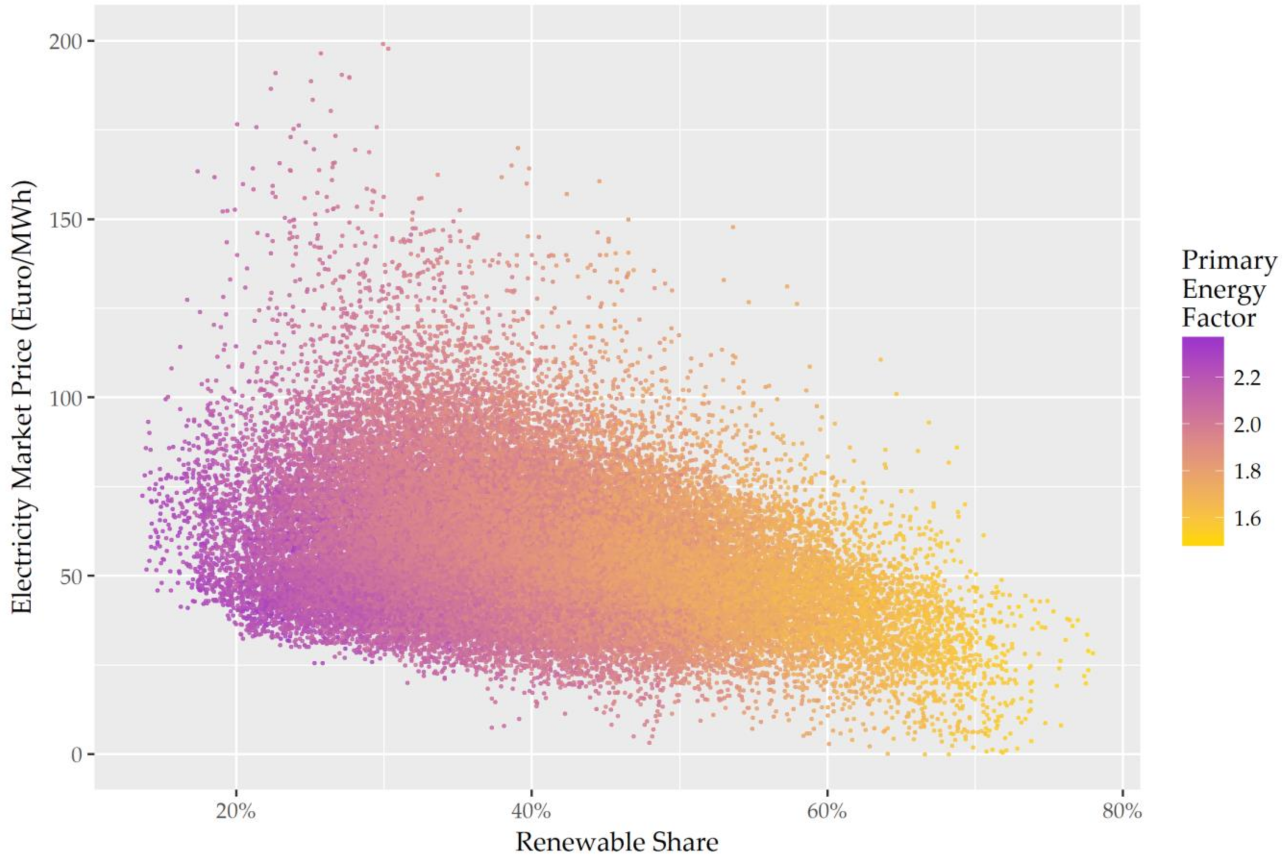
Table. Calculated values for Renewable share, Primary Energy Factor and CO_2 Emissions Factor.

Year	Renewable Share			Primary Energy Factor			CO_2 Emissions Factor (g/kWh)		
	Min	Median	Max	Min	Median	Max	Min	Median	Max
2012	13.6%	33.6%	61.1%	1.603	2.005	2.322	218	372	484
2013	20.7%	40.6%	73.8%	1.491	1.932	2.256	146	330	440
2014	22.9%	46.0%	78.0%	1.494	1.925	2.356	127	310	443
2015	19.1%	40.3%	73.8%	1.539	1.954	2.372	143	325	440
2016	18.9%	38.4%	72.5%	1.535	1.929	2.314	149	334	440
2017	16.4%	36.2%	73.8%	1.532	1.947	2.265	142	346	453

Data – Power Supply Performance



Data – Power Supply Performance



Data

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Article

Performance Indicators of Electricity Generation at Country Level—The Case of Italy

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Research Question 1

What Fuels could be involved in RES-excess based synthesis considering the different sectors and their demand (fuel, heat, power)?

Conventional fuel supply – CH_4

- **Natural Gas Power Plant**

✓ **Combined Cycles → Fuel to Electricity**

- **Natural Gas Heating Systems**

✓ **Boilers → Fuel to Heat**

- **Natural Gas Engines**

✓ **Vehicles & Machines → Fuel to Transport**

Future fuel supply – H_2

- **Hydrogen Power Plant**
- ✓ **Solid Oxide Fuel Cell → Fuel to Electricity**
- **Hydrogen Heating Systems**
- ✓ **Catalytic Converters → Fuel to Heat**
- **Hydrogen Fuel Cell - Engines**
- ✓ **Vehicles & Machines → Fuel to Transport**

Transition fuel supply – H_2NG

- **Hydrogen Enriched Natural Gas Power Plant**

✓ **Combined Cycles → Fuel to Electricity**

- **Hydrogen Enriched Natural Gas Heating Systems**

✓ **Boilers → Fuel to Heat**

- **Hydrogen Enriched Natural Gas Engines**

✓ **Vehicles & Machines → Fuel to Transport**

Transition fuel supply – H_2NG

- **Natural Gas Engines**

✓ **Number of Methane → up to 20% H_2 vol. fraction**

- **Natural Gas Grid**

✓ **Leakage & Corrosion → up to 5% H_2 vol. fraction**

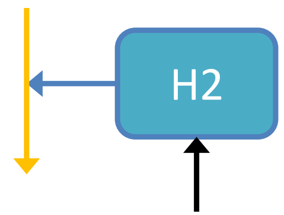
- **Storage facilities**

✓ **Location and Mixing → up to direct injection**

Power-to-Gas (P2G)

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

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

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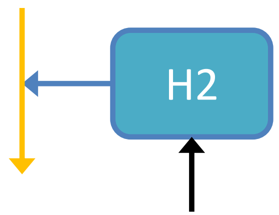
Power-to-Gas (P2G)

Mixing section

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



Primary Energy

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

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Power-to-Gas (P2G)

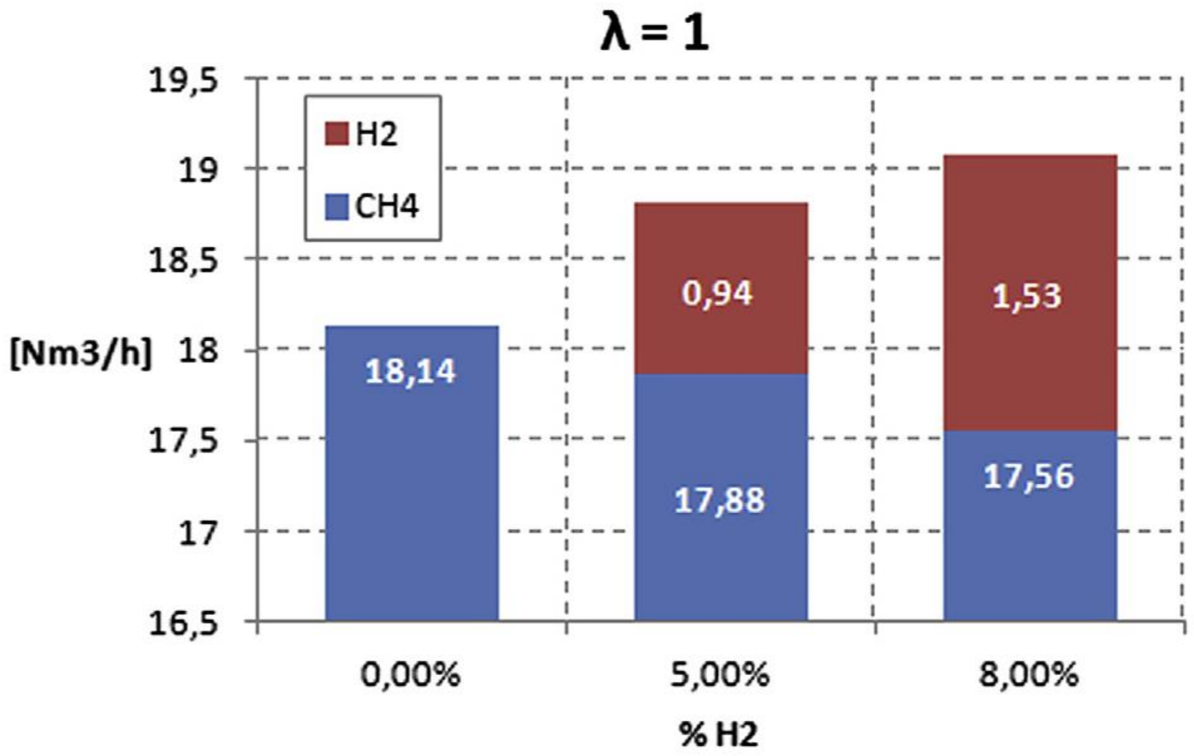
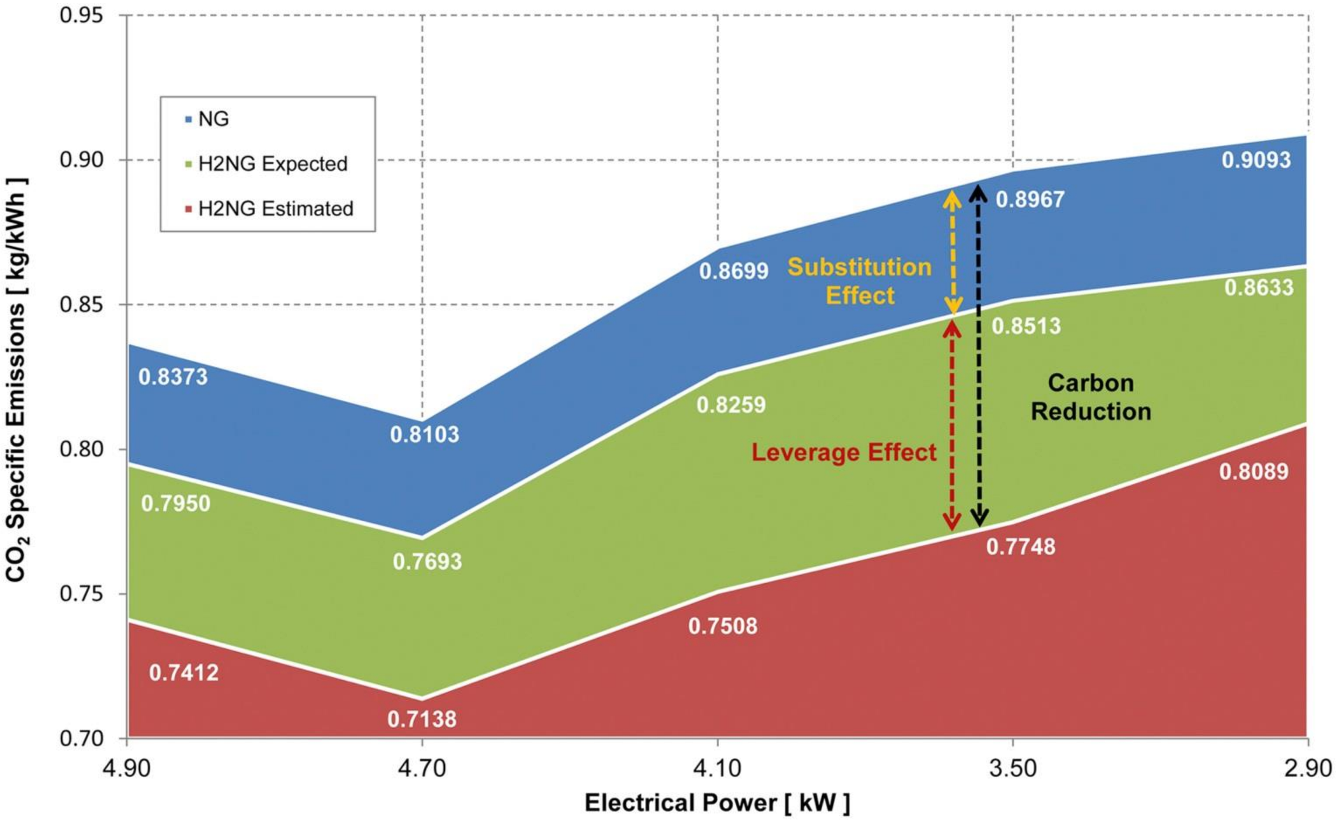


Fig. 5. Blends consumption vs %H_2 (stoichiometric).

Power-to-Gas (P2G)



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Power-to-Gas (P2G)

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

CrossMark

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Research Question 2

What improvements in security and CO_2 emission could be achieved by RES-based reserve fuel?

Objective function

→Energy Security as share of covered reserve

$$ES = \frac{E_{H2}}{E_{Reserve}}$$

→Decarbonization Potential

$$DP = \frac{CO2_{BAU} - CO2_{H2NG}}{CO2_{BAU}}$$

Methodology

- **Current and Transition Energy Scenarios**

✓ **2017 data and 2030 projection**

- **Solar energy-based supply**

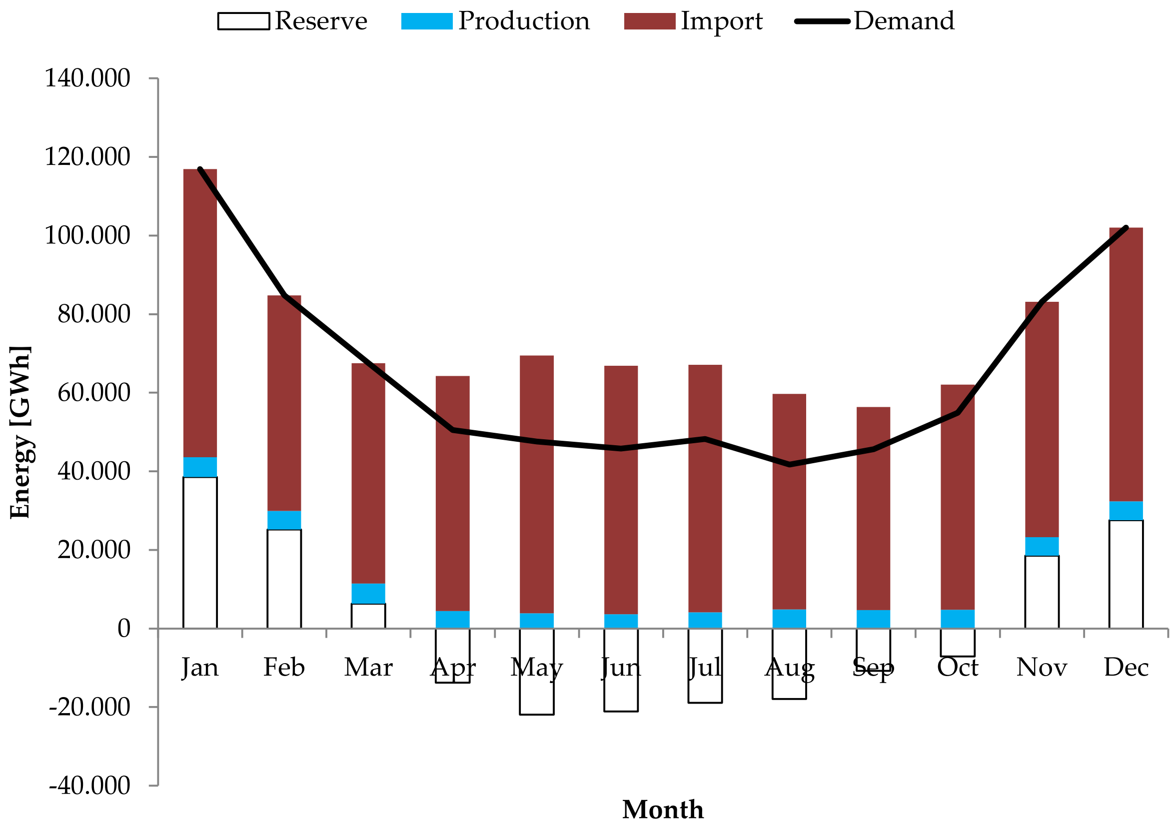
✓ **2017 production and 2030 doubled supply**

- **Strategic Natural Gas reserve**

✓ **Constant value for 2017 and 2030**

→ **Monthly trends comparison**

Natural Gas supply



Current Scenario

- **Natural Gas Demand**

✓ **786,112 GWh ~ 82,835 MNm^3**

- **Yearly PV Production**

✓ **24,811 GWh ~ 17,367 GWh H_2 ~ 4,907 MNm^3**

- **Yearly H_2 volumetric fraction at 5%**

→ **1,858 MNm^3 avoided Natural Gas**

→ **2.2% avoided CO_2 emissions**

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Transition Scenario

- **Natural Gas Demand**

✓ **786,112 GWh ~ 82,835 MNm³**

- **Yearly PV Production**

✓ **49,622 GWh ~ 34,734 GWh H_2 ~ 9,814 MNm³**

- **Yearly H_2 volumetric fraction at 10%**

→**4,307 MNm³ avoided Natural Gas**

→**5.1% avoided CO_2 emissions**

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Energy Security

- **Current Scenario**

✓ **17,632 GWh ~ 1,858 MNm^3**

- **Transition Scenario**

✓ **40,873 GWh ~ 4,307 MNm^3**

- **Reserve capacity equal to 120,000 GWh**

→**14,7% solar H_2-based reserve for 2017 data**

→**34,1% solar H_2-based reserve for 2030 data**

Conclusions

- **Hydrogen plus Natural Gas for the transition**
- **Decarbonization way for all the sectors**

✓ **Partial substitution as ready solution**

- **Solar energy is already enough to H2NG @5%**
- **15% of the NG reserve is achievable today**

✓ **Reserve as fourth sector in the regulation**

→ **Dedicated RES-based electro-fuel for RES security**

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

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Power-to-gas leverage effect on power-to-heat application for urban renewable thermal energy systems

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Data – Special Issue

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