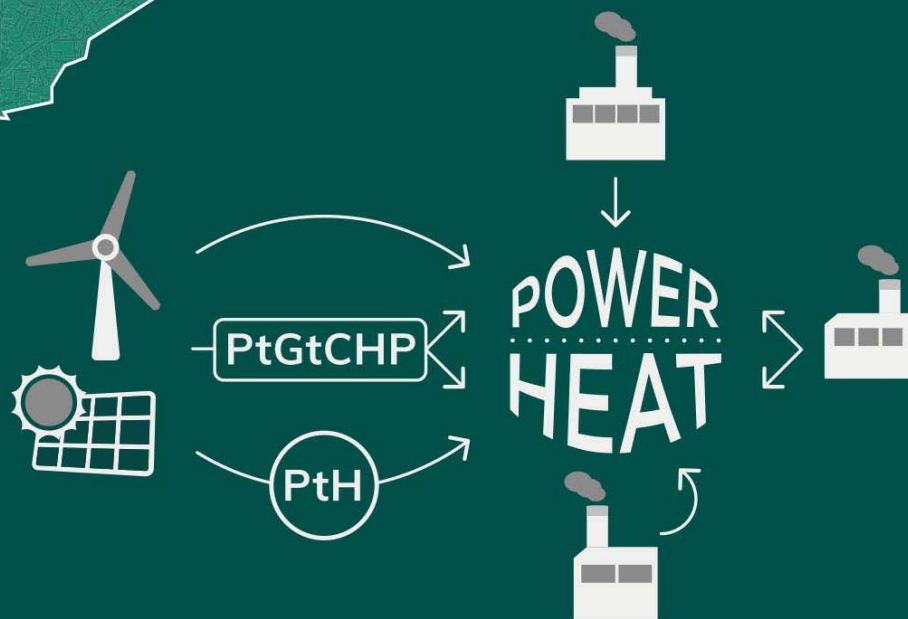


# Analysis of renewable energy integration options in urban energy systems with centralized energy parks





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# **Analysis of renewable energy integration options in urban energy systems with centralized energy parks**

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Technischen Universität Hamburg-Harburg  
zur Erlangung des akademischen Grades

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Ricardo Peniche Garcia





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## ABBREVIATIONS AND SYMBOLS

### *Abbreviations*

|             |                                             |
|-------------|---------------------------------------------|
| CHP         | Combined Heat and Power                     |
| DHG         | District Heating Grid                       |
| DSO         | Distribution System Operator                |
| EEG         | Renewable Energy Sources Act                |
| EG          | Electric Grid                               |
| EnWG        | Energy Industry Act                         |
| CCGT        | Combined Cycle Power Plants                 |
| GG          | Gas Grid                                    |
| GHI         | Global Horizontal Irradiance                |
| GT          | Gas Turbine                                 |
| HRSG        | Heat Recovery Steam Generator               |
| IO          | Input / Output                              |
| O&M         | Operation and Maintenance                   |
| PEM         | Polymer Electrolyte Membrane                |
| PtG         | Power to Gas                                |
| PtGtCHP     | Power to Gas to Combined Heat and Power     |
| PtH         | Power to Heat                               |
| PV          | Photovoltaic                                |
| RE          | Renewable Energy                            |
| RE share DH | Share of RE in District Heating Consumption |
| RH          | Renewable Hydrogen                          |
| ST          | Steam Turbine                               |
| STOR        | Storage                                     |
| TSO         | Transmission System Operator                |

### *Chemical Symbols*

|                 |                     |
|-----------------|---------------------|
| CO <sub>2</sub> | Carbon dioxide      |
| H <sub>2</sub>  | Hydrogen            |
| KOH             | Potassium hydroxide |



### ***Latin Symbols***

|             |                                    |                                    |
|-------------|------------------------------------|------------------------------------|
| $c$         | Specific costs                     | €/MW, €/MWh, €/m, €/m <sup>3</sup> |
| $e$         | Specific CO <sub>2</sub> emissions | kg/MWh                             |
| $E$         | Electric energy                    | MWh                                |
| $HHV_{H_2}$ | Higher heating value of hydro-     | MJ/kg                              |
| $LHV_{H_2}$ | Lower heating value of hydro-      | MJ/kg                              |
| $\dot{m}$   | Mass flow                          | kg/s                               |
| $M$         | Mass                               | kg                                 |
| $P$         | Electric power                     | MW <sub>el</sub>                   |
| $\dot{Q}$   | Heat flow                          | MW <sub>th</sub>                   |
| $Q$         | Heat                               | MJ                                 |
| $T$         | Temperature                        | °C                                 |
| $t$         | Time                               | s, h                               |

### ***Greek***

|          |                             |
|----------|-----------------------------|
| $\eta$   | Efficiency                  |
| $\sigma$ | CHP coefficient             |
| $\zeta$  | Fuel utilization efficiency |

### ***Indices***

|                |                                  |
|----------------|----------------------------------|
| cons           | Consumption                      |
| el             | Electrical                       |
| ELY            | Electrolyzer                     |
| <i>fuel</i>    | fuel                             |
| H <sub>2</sub> | Hydrogen                         |
| HP             | Heating Plant                    |
| in             | Input                            |
| out            | Output                           |
| PtP            | Power to Power                   |
| PtH            | Power to Heat                    |
| PtCHP          | Power to Combined Heat and Power |
| th             | Thermal                          |

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