



**Library of price and  
performance data of domestic  
and commercial technologies  
for low-carbon energy systems**

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**CEP**

**Andreas V. Olympios, Matthias Mersch,  
Paul Sapin, Antonio Marco Pantaleo,  
Christos N. Markides\***

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*Clean Energy Processes (CEP) Laboratory and Centre for  
Process Systems Engineering (CPSE), Department of  
Chemical Engineering, Imperial College London, SW7  
2AZ, London, UK*

*\* e-mail: [c.markides@imperial.ac.uk](mailto:c.markides@imperial.ac.uk)*

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## Library of price and performance data of domestic and commercial technologies for low-carbon energy systems

Andreas V. Olympios, Matthias Mersch, Paul Sapin, Antonio Marco Pantaleo, Christos N. Markides\*

*Clean Energy Processes (CEP) Laboratory and Centre for Process Systems Engineering (CPSE), Department of Chemical Engineering, Imperial College London, SW7 2AZ, London, UK*

\* e-mail: [c.markides@imperial.ac.uk](mailto:c.markides@imperial.ac.uk)

### 1. Introduction

This library consists of extensive price and performance data of commercially available technologies for low-carbon energy systems on the UK market, including domestic and commercial applications. All information is obtained from published manufacturer datasheets and pricelists. The library contains useful information for *energy-system and technology modellers* in their efforts to capture the techno-economic characteristics of different technology options, minimise uncertainties and suggest reliable system- and technology-design strategies.

The data analysis shows how technology characteristics vary with *component choice, technology size* and to capture the *spread* of values found between different suppliers, which can be used to determine uncertainty bounds on key performance indicators. Fitting techniques can be used to determine relationships arising from the collected data, infer values for which data are not available and quantify the related variability in technology characteristics.

This work was conducted by members of the [Clean Energy Processes \(CEP\) Laboratory](#) and is part of Project 2 of the Integrated Development of Low-Carbon Energy Systems ([IDLES](#)) project. IDLES brings together researchers across Imperial College London and partner organisations and companies to provide the evidence needed to facilitate a cost-effective and secure transition to a low-carbon future. The overarching aim of Project 2 is: (i) to characterise current and new/future technologies in terms of cost and performance to provide evidence for whole-energy system modelling; and (ii) to extend the capabilities of whole-energy-system models so that they can, apart from optimising energy network infrastructures, provide information to manufacturers about the optimal choice of materials, components and the design of key technologies.

The library will be updated regularly as more data regarding existing and new technologies are collected.

### 2. Library description

The library is divided into three main sections.

#### 2.1. Price and performance of technologies (from manufacturers/retailers/projects)

This is the main section of the library, which contains information related to:

- domestic- and commercial-scale electric air- and ground-source heat pumps;
- hot-water cylinders;
- gas- and electricity-driven boilers;
- combined heat and power systems (driven by internal combustion engines, fuel cells or others);

- solar-thermal collectors (evacuated-tube and flat-plate collectors);
- monocrystalline silicon, polycrystalline silicon, and other photovoltaic systems;
- photovoltaic-thermal systems.

All capital expenditure (CAPEX) data exclude additional costs related to installation.

## 2.2. Prices of compressors and heat exchangers (from manufacturers)

This section includes information regarding the price and characteristics of various types of small-scale (< 70 kW) compressors (reciprocating, scroll and other volumetric devices) and heat exchangers. This information is more targeted towards technology modellers.

## 2.3. Heat pumps: off-design heat pump performance (from manufacturers)

The performance of heat pumps largely depends on operating conditions. This section aims to show the relationship between the performance of small-scale electric heat pumps and weather conditions for different heat sources (air, ground) and applications (heating, cooling).

## 3. User guide

The main sheet of the library (Figure 1) allows the user to navigate to the different pages to obtain performance and price information for technologies of interest.

<b>1. Cost and performance of technologies (from manufacturers/retailers/projects)</b>	
Heat pumps (domestic, air-water)	<a href="#">HP (domestic, air-water)!A1</a>
Heat pumps (domestic/commercial, ground-water)	<a href="#">HP (domestic&amp;commercial,ground)!A1</a>
Heat pumps (large-scale)	<a href="#">HP (large-scale)!A1</a>
Cylinders (domestic, heat-pump compatible)	<a href="#">Cylinders (domestic)!A1</a>
Boilers (domestic, gas)	<a href="#">Boilers (domestic, gas)!A1</a>
Boilers (domestic, electric)	<a href="#">Boilers (domestic, electric)!A1</a>
Boilers (large-scale, gas)	<a href="#">Boilers (large-scale, gas)!A1</a>
CHP systems (domestic/commercial, ICE)	<a href="#">CHP (domestic&amp;commercial, ICE)!A1</a>
CHP systems (domestic/commercial, fuel cell)	<a href="#">CHP (domestic, fuel cell)!A1</a>
CHP systems (biogas, Stirling, microturbine)	<a href="#">CHP (biogas,stirling,turbine)!A1</a>
Solar thermal (domestic, evacuated tube)	<a href="#">Solar thermal (domestic, ET)!A1</a>
Solar thermal (domestic, flat plate)	<a href="#">Solar thermal (domestic, FP)!A1</a>
PV (domestic, monocrystalline)	<a href="#">PV (monocrystalline)!A1</a>
PV (domestic, polycrystalline)	<a href="#">PV (polycrystalline silicon)!A1</a>
PV (domestic, CdTe, CIGS, a-Si)	<a href="#">PV (CdTe, CIGS, a-Si)!A1</a>
PVT (domestic)	<a href="#">Photovoltaic-Thermal (PVT)!A1</a>
<b>2. Costs of compressors and heat exchangers (from manufacturers)</b>	
Refrigeration compressors	<a href="#">Refrigeration compressors!A1</a>
Air compressors	<a href="#">Air compressors!A1</a>
Brazed-plate heat exchangers	<a href="#">Brazed-plate HEXs!A1</a>
<b>3. Heat pumps: off-design heat pump performance (from manufacturers)</b>	
HP air-water (Heating)	<a href="#">Air-water (Heating)!A1</a>
HP ground-water (Heating)	<a href="#">Water-water (Heating)!A1</a>
HP air-water (Cooling)	<a href="#">Air-Water (Cooling)!A1</a>
HP air-air (Heating&Cooling)	<a href="#">Air-Air (Heating&amp;Cooling)!A1</a>

**Figure 1.** Main page of the library, from which users can navigate to the pages of interest.

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Whenever sufficient data are available, simple statistical analysis (average and standard-deviation values of price and efficiency) is provided at the bottom of each page in Section 1 for different technology sizes and useful graphs and relationships for energy-system modelers are provided. Furthermore, whenever possible, information regarding each technology's components (e.g., refrigerant, type of compressor, material) is provided.

### *3.1. HP (domestic, air-water)*

This page includes price and performance information for domestic-scale (3 to 20 kW<sub>th</sub>) low-temperature ( $\leq 60$  °C), air-source (air-to-water) heat pumps collected from 12 different manufacturers.

These technologies are driven by electricity and move heat from the outside air to hot water. Monobloc heat pumps refer to “single-block” systems, where all heat pump components are located outside the house. Bi-bloc (split) heat pumps refer to heat pump systems with two units (outside and internal). The performance is measured using the coefficient of performance (COP), defined as the ratio of the system's heat flow output to the electrical power required.

Manufacturers often report heat-pump performance at specified heat-source (air) and heat-sink (hot water) conditions. For example, the information provided for the A7/W55 operating condition refers to a system operated in an outside air temperature of 7 °C and delivering hot water at 55 °C.

### *3.2. HP (domestic & commercial, ground)*

This page includes price and performance information for domestic- and commercial-scale (3 to 150 kW<sub>th</sub>) ground-source (brine-to-water) heat pumps from 10 different manufacturers. These electrically driven technologies collect heat from the ground and upgrade it to the desired hot-water temperature. In most cases, frost-protected brine is used as the heat-transfer medium. Information is provided for different heat-source (ground) and heat-sink (hot water) conditions in a similar manner as in the case of air-source heat pumps. For example, the B10/W55 condition refers to a brine temperature of 10 °C and a hot-water delivery temperature of 55 °C. SCOP refers to the seasonal COP, defined as the average COP the technology over the full heating season.

### *3.3. HP (large-scale)*

In this page, some examples of large-scale heat pump projects are provided. The objective here is to provide a sense of the possible sizes that these systems can have, however information regarding the price of these options is limited.

### *3.4. Cylinders (domestic)*

This page includes information for various domestic-scale (125 to 500 L) hot-water cylinders, which are advertised to be coupled to domestic air- or ground-source heat pumps, from 7 different manufacturers. Data includes specific price and daily heat loss.

### *3.5. Boilers (domestic, gas) - Boilers (domestic, electric)*

These pages include information for the price and performance of domestic-scale (4 to 50 kW<sub>th</sub>) gas-driven combination boilers and electric (resistance-heating) boilers from 12 and 6 different manufacturers, respectively. The efficiency of electricity-driven boilers is not reported since this is always close to 100%.

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### 3.6. Boilers (large-scale, gas)

This page includes information for the price of large-scale (50 to 2900 kW<sub>th</sub>) gas-driven boilers.

### 3.7. CHP (domestic & commercial, ICE)

This page includes information for the price and performance of domestic- and commercial-scale (1 to 500 kW<sub>e</sub>) combined heat and power systems based on a gas-driven internal-combustion engine prime mover, as obtained from 8 different manufacturers. These technologies use natural gas to drive an internal-combustion engine and produce electricity, while at the same time recovering heat for the provision of hot water. Information includes the performance of various systems when operated at part-load conditions (below nominal output). Heat-to-power ratio (HTPR) is defined as the ratio of the heat output to the electrical output of the system.

### 3.8. CHP (domestic, fuel cell) - CHP (biogas, Stirling, turbine)

In these pages, information regarding the performance and price (when available) of combined heat and power systems based on other prime movers (fuel cell, biogas internal combustion engine, Stirling engine, microturbine) is provided.

### 3.9. Solar thermal (domestic, ET) – Solar thermal (domestic, FP)

The solar-thermal collector data set includes information such as collector areas, recommended flowrates, efficiency parameters and incidence angle modifiers for a range of different evacuated-tube and flat-plate collectors. Price information is available for roughly half of the collectors. It should be noted that most of the price data are based on values from retailers operating on the German market. Since collector prices have been volatile, the reference year is also provided.

### 3.10. PV (monocrystalline silicon) – PV (polycrystalline silicon) - PV (CdTe, CIGS, a-Si)

Standard testing conditions efficiency and temperature coefficients as well as price data are available for a range of different mono- and polycrystalline silicon PV modules. Prices per power output are calculated and all values are colour coded.

Only limited information is available for alternative PV modules, but the library also includes some information on cadmium telluride (CdTe), copper indium gallium selenide (CIGS) and amorphous silicon PV systems.

### 3.11. Photovoltaic-Thermal (PVT)

The PVT data include electrical and thermal efficiencies, as well as sizes and nominal powers for different PVT modules. Price data were unfortunately unavailable for the systems included in the library.

### 3.12. Refrigeration compressors

This page includes information related to the price and characteristics (displacement, revolutions per minute, etc.) of various types (scroll, piston, rotary) of small- and medium-scale (0 to 70 kW) refrigeration compressors from 10 different manufacturers.

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### 3.13. Brazed-plate heat exchangers

This page includes information related to the price and characteristics (surface area, number of plates) of small-scale (0 to 6 m<sup>2</sup>) brazed-plate heat exchangers from 1 manufacturer. These heat exchangers are used in liquid-liquid or liquid-air applications.

### 3.14. Air compressors

This page includes information related to the price and characteristics (e.g., pressure, revolutions per minute, etc.) of various types (reciprocating, screw, scroll) of small-scale (0 to 15 kW) air compressors.

### 3.15. HP air-water (Heating)

In this page, the relationship between the performance (heat capacity and COP) of domestic-scale (5 to 20 kW<sub>th</sub>) air-source heat pumps and the outdoor air temperature is captured using information from 6 different manufacturers. The information is based on two different hot-water delivery temperatures (45 °C and 55 °C).

### 3.16. HP water-water (Heating)

In this page, the relationship between the performance (heat capacity and COP) of domestic- and commercial-scale (5 to 45 kW<sub>th</sub>) ground-source heat pumps and ground temperature is captured using data from 7 different manufacturers. The information is based on two different hot-water delivery temperatures (45 °C and 55 °C).

### 3.17. HP air-water (Cooling)

This page includes information on the relationship between the performance (cooling capacity and COP) of domestic-scale (5 to 11 kW<sub>th</sub>) air-source heat pumps and air temperatures, based on 3 different manufacturers, when they are used for cooling instead of heating the domestic water.

### 3.18. HP air-air (Heating & Cooling)

This page includes information on the relationship between the performance (heating capacity, cooling capacity and COP) of domestic-scale (5 to 30 kW<sub>th</sub>) air-air heat pumps (air-conditioning units) and outside air temperatures, based on 2 different manufacturers. These systems can be used for space heating or cooling (but not to heat water).

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