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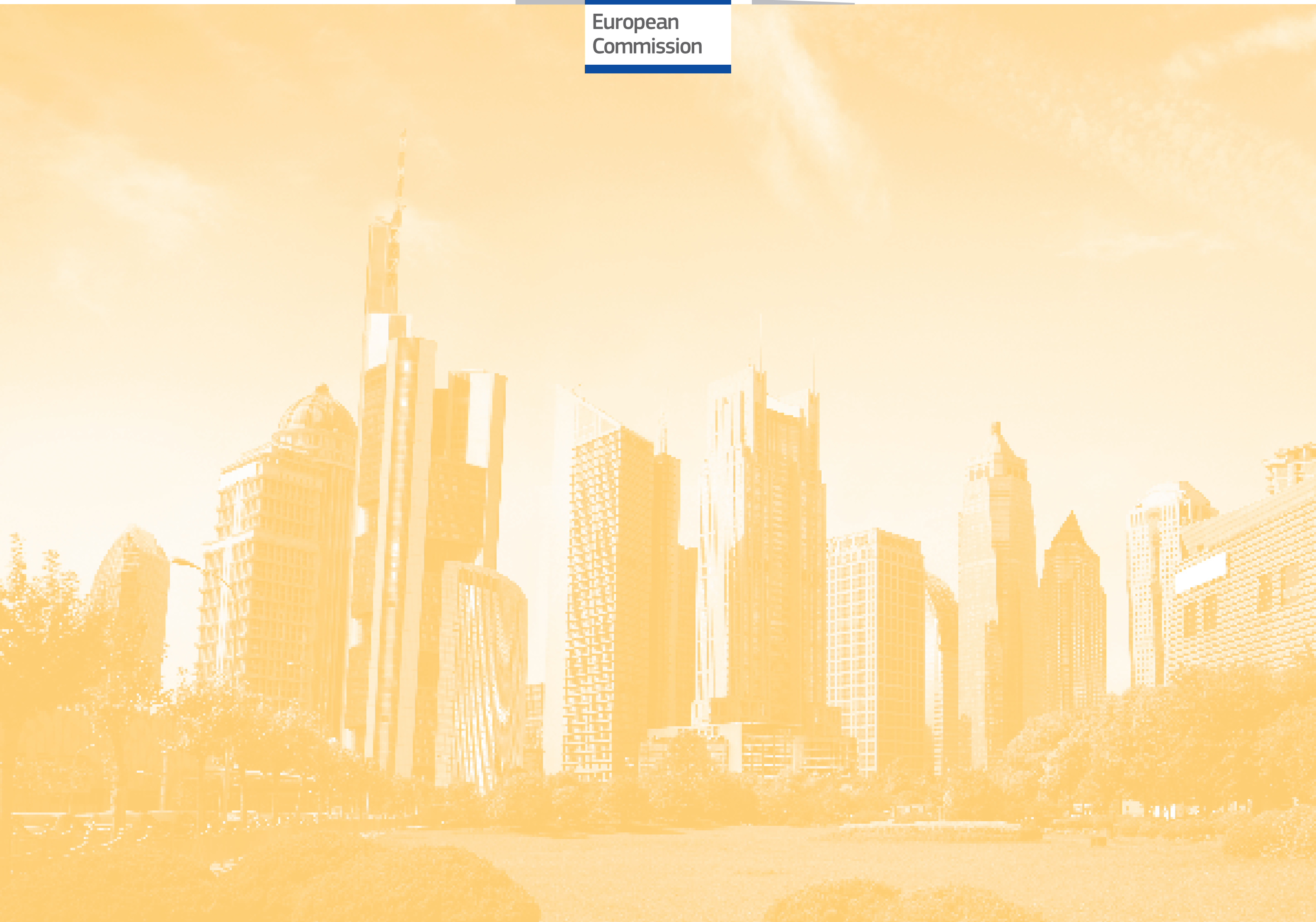

Smart Cities
Stakeholder Platform

Heat Pump and Micro-CHP as complementary boiler alternatives

Key to Innovation Integrated Solution

Heat pump and micro-CHP as complementary boiler alternatives

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INTRODUCTION

The Key Innovations (KIs) are a key output of the Smart Cities Stakeholder Platform. The Platform promotes innovation and is part of the Smart Cities and Communities European Innovation Partnership of the European Union. It aims to accelerate the development and market deployment of energy efficiency and low-carbon technology applications in the urban environment. The main focus: technology integration for European cities. Emphasis will be on their integration, which is a key challenge particularly for Smart Cities' technologies. The Platform aims to bring together technology providers, financiers and specialists in implementing smart city strategies at local level.

The expert Working Groups of the Platform on Energy Efficiency and Buildings, Energy Supply and Networks and Mobility and Transport select from the spectrum of Solution Proposals (SPs) submitted by stakeholders[1] the *most promising and fundamental* solutions to accelerate the development of smart cities. The focus in on specific key innovations, considered pillars or technical leapfrogs for integrated solutions in smart cities, thus promising, but standalone solutions, will not be development into key innovation files and toolkits. Unselected solution proposals are published in the Platform. The Platform is not an evaluation body and is open to all relevant smart solutions, large or small scale for cities and their inhabitants.

The aim is to promote through the preparation of a detailed document, a guide for cities on the performance of the innovation, its technical requirement, as well as prerequisite required in terms of existing infrastructures, technical expertise, regulatory requirements and financial costs involved. The document aims to help promote the adoption of the key technology and to help identify and remove barriers to deployment. It presents the technology provider and a number of financial sources by the EU and other bodies which have supplied information to the platform.

Key Innovations will be an integral part of the recommendations of the Smart City Roadmap the Platform will draft for the European Commission. Recommendations on necessary action at European level required to promote the adoption of key innovations, such as the removal of regulatory barriers or the recommendations on the focus of the Horizon 2020 support will be drafted based on information in the Key Innovation files.

It is important to stress that this document is not a technical proposal or full evaluation of the innovation, but developed to help cities identify potential solutions. It does not exempt or substitute a detailed cost/benefit analysis and implementation plan cities that wish to introduce the innovation. The Stakeholder Platform cannot take any responsibility for inaccuracies or missing information or specific problems in the implementation in a city of the proposed Key Innovations or other Solution Proposals.

[1] Solution proposals are published on the web site: www.eu-smartcities.eu/solution-proposals

Description of a Key Innovation

A key objective of the Smart Cities Stakeholder Platform is to identify Key Innovations for the development of Smart Cities. The selection of an SP as KI is based on the following criteria: **applicability, simplicity, affordability**, the extent to which it addresses technology integration and if the potential impact is significant. Selected SPs will then be enhanced by the Platform's technical Working Groups (WGs) to develop KIs, adding the following aspects:

- Premises for the technology development and up-take (e.g. problems, what the technology is intended to achieve, other unforeseen benefits for the smart cities);
- Potential integration with other technologies and sectors, including use of ICT;
- If necessary, enhancing the information from the SP on the urban environment in which the technology can be applied;
- Key pre-requisites for the applicability of the key innovation, such as the required enabling environment;
- Instruments and market conditions needed to reach commercial viability.[2]

Completed KIs by the technical WGs will be sent to the Finance WG. This group will analyse the financial needs of the KI as well as their financial viability and bankability. The members of the WG will provide information on funding sources. The result will be published as a Key Innovation Toolkit.

The Toolkits thus provide practical solutions that can create an enabling environment for the application and replication of key innovations in a smart city.

[2] This includes a description of the main EU support instruments, such as the Risk Sharing Financing Facility

1. PRESENTATION OF THE KEY INNOVATION

This key innovation is based on the following solution proposal(s):

a. Heat Pump Cities project Etten-Leur (The Netherlands)
b. Micro-CHP options

Submitted to the platform at date: a. 28 October 2012 / b. 26 October 2012

Body(ies) submitting the proposal(s):

a. European Heat Pump Association (EHPA)
b. Gasnatural-Fenosa
c. Mondragon

Type of innovation: Alternatives for heat from boilers

IP right holders:

a. Groenholland BV, Gemeente Etten Leur
b. No

Maturity of innovation:

a. Best Practice
b. Varying per type of micro-CHP

Parties or stakeholders involved: Utilities, RTD and Government.

1.1 Description of the innovation and rationale for selection

1.1.1 Boiler alternatives

Boilers for the production of heat for space heating and hot water have become much more efficient in past years. However, a further increase in conversion efficiency can hardly be expected as the newest types retrieve almost all energy from the burning of fuel, mostly gas.

For new dwellings the goal is to have Near Zero Emission dwellings, using a combination of substantially reducing heating needs and (almost) emission free supply. One option is supply on the basis of own renewable sources which in practice comes down on a large exchange of electricity through the grid. However, this solution is not (economically) viable for existing dwellings as the heat demand can only be reduced to a limited extent and large scale application and grid integration of renewable sources is more difficult. For buildings the same reasoning is valid, except that seasonal heat/cold storage is possible for new buildings, but normally not for existing buildings

Therefore, a radical step is needed as follow up of heat production with condensing boilers, which should lead to substantial lower primary energy consumption, moderate extra costs and a limited burden on the electricity grid. This future system for (existing) dwellings or buildings could be a mix of the following main options:

a. Centralized heat provision through a heating grid
b. Electric heat pumps
c. Micro-CHP.

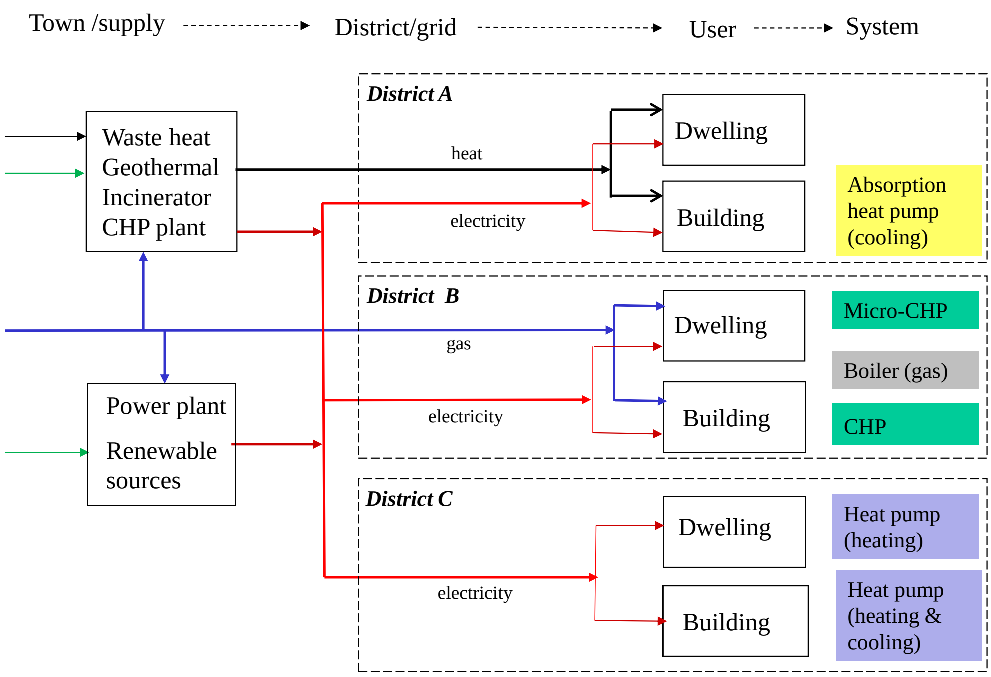
1.1.2 City level alternatives and grids

The choice between these options is not made by the user/owner of the dwelling or building alone as it is closely connected to choices about construction of grids for electricity, gas or heat (see Figure 1). The choices about the grids can be made per district of a town. Three grid cases have been selected:

- Electricity and heat (District A)
- Electricity and gas (District B)
- Only electricity (District C).

In all cases it is assumed that an electricity grid is present. In district A with centralized heat provision no investments into a gas grid are necessary. The same is true for district C with electric heat pumps. However, for micro-CHP in district B a gas grid is needed as is the case for the currently applied gas boiler.

Figure 1: Boiler alternatives in conjunction with available grids



1.1.3 Integrated assessment of grids and options

Because available grids define the choice of systems the decision on grids to be constructed should proceed the decision on systems to be installed in individual dwellings and buildings. The grid choice is by nature made at the city level, while the system choice is normally made by the user/owner. In order to make the optimal grid choice there is a need for an integrated analysis of the combination of grids and systems, i.e. grid supplied heat and cooling, electric heat pumps and (possibly) adapted electricity grid, and finally the gas grid and micro-CHP.

The integrated analysis is part of this key innovation because the choice of systems in dwellings and buildings cannot be made without the partaking of the city as main stakeholder. In the following the set-up of the city level integrated assessment is described, based on[3].

The assessment regards the different levels of:
- buildings/dwellings and systems,
- district with grids,
- town with supply options.

The energy demand of the dwellings/buildings is given; therefore, no trade-off between further demand reduction and supply options is looked at. In addition to heat demand, it is possible to take into account a cooling demand, which can be provided by conventional air-conditioning systems but also by alternatives, such as absorption heat pumps (see Figure 1, district A). In [ANL, 2013] various renewable energy options are taken into account (biomass, geothermal heat, etc.) but they are left out here for reasons of clarity.

[3] Guidelines for municipal assessment and choice of heat supply options at specific locations (in Dutch), ANL, 2013

The selection of options takes place in three steps:

- Skipping of options based on (not) available (heat) supply options and the characteristics of the dwellings and buildings per district (size of district, type of dwellings and buildings, heat demand per m^2, available central heat sources and distance to the sources, possible extraction medium for heat pumps, etc.).
- Rating of the selected options from the first step as to a number of criteria (costs, emission reduction, acceptance, etc.)
- Zooming in on the remaining options from the ambitions (energy neutral), barriers (electric cooking in case of grid supplied heat) and the interests of all stakeholders (e.g. no increase in overall living expenses for rented dwellings).

In all cases the same boundaries for the assessment are defined, in order to have a fair comparison of choices. Energy consumption is expressed in primary terms in order to take account of the energy conversion losses in providing external heat and electricity.

The assessment tool is interactive in nature; it asks input from the applier and provides in return information about the interesting options. This sequence is repeated several times.

The following inputs are needed for the assessment:

- Characteristics of the district: number of new or renovated existing dwellings or buildings, total size of the district and average heat load (GJ/ha)
- Specification of number and type of dwellings and floor area for education, offices, health care and shops
- Possibility to connect existing dwellings or buildings to a heat grid
- Availability of a heat grid nearby (< 5 kilometer)
- Introduction of a town heating system possible?.
- Other heat sources from industry or power plants
- For heat pumps the availability of suitable ground sources, alternative sources such as sewage and all electric heating
- Political choice such a dependence on one grid only or a combination of at least two grids (freedom of choice for citizens), provision of cooling to dwellings and buildings, etc.

1.1.4 Alternatives in dwellings and buildings

In case no choice is made for heat grids, the remaining alternatives are restricted to electric heat pumps and micro-CHP. Both systems are applied for heating cases where they function best, given energy demand and technology characteristics. Both can provide heat as well as cold, and micro-CHP electricity as well (tri-generation), maximizing efficiency and minimizing the consumption from the mains.

In the following, these two options for dwellings/buildings are presented separately but their interaction is accounted for at the city level. For instance the peak demand of heat pumps during cold spells can be covered by the excess electricity from the (fully running) micro-CHP at that moments. At the town and electricity grid level other interactions are possible. Electric boilers and large heat pumps together with thermal storages can absorb critical excess electricity generation, while combined heat and power plants can actively support the electricity supply system during power deficits. Combination of different electricity load balancing options is possible, depending on the climate conditions, available fuels, city morphology and networks.

The two options are rated as to various impacts, such as energy savings, reduction of CO2-emissions, costs and benefits and wider benefits for the city. These impacts should be calculated with respects to the larger picture for the city, with heat grids and central electricity production options taken into account.

1.2 Level of deployment

1.2.1 Level of deployment of heat pumps

Systems

A heat pump uses low-grade heat from the ambient, e.g. from the ground or outside air, and converts it into usable heat for space or domestic water heating. The operating principle is easiest described as a refrigerator in reverse. As the electrical energy needed to drive the heat pump is only a fraction of the thermal energy exchanged, heat pumps can contribute significantly to the reduction of primary energy use.

Heat pumps can play an important role in the necessary conversion of the European heating markets. Although the existing variety of heat pump technologies is already vast, it will increase even more in the future. Apart from different heat sources (ground, water, air, exhaust air, etc.), different driving energy sources (electricity, thermal energy) can be distinguished. Furthermore, different demand types (e.g. space heating, domestic hot water (DHW) and cooling) in all possible combinations as well as hybrid systems such as solar thermal collectors, peak load boilers or PV-panels can be distinguished.

Heat pump projects are feasible when the design takes into account proper design conditions. When clear goals are set, and specifications concerning the thermal performance as well as mechanical installation quality are defined, an environmentally friendly and sustainable use of the ground can be made for heating and cooling applications. In addition to achieving significant savings on primary energy use and greenhouse gas emissions, these systems will provide a high level of comfort and are expected to last for a long time into the future.

Deployment

Heat pump systems are quite successful, as is shown by the numbers of installed units in the USA (more than 900,000 units installed), Sweden (± 275,000 heat pumps installed for residential houses), Germany (over 50,000 units), Switzerland (more than 40,000 units installed) and for instance Austria (over 35,000 units). In the Netherlands, heat pumps for heating and domestic hot water production are currently gaining wider acceptance. Although the total number of heat pumps sold each year is still far less than in e.g. Austria or Sweden, the projects realized are often of a considerable size. Projects of 50 - 100 dwellings, all in a compact space, are becoming more and more common and a number of projects comprising 200 - 300 houses have been realized as well.

The project "Schoenmakershoek" realized in the municipality of Etten-Leur in The Netherlands has now been running for five years. It has been awarded the Heat Pump City of the Year 2012 by the European Heat Pump Association (EHPA). The project is the first to apply heat pumps on a very large scale (1,400 dwellings) and is part of the energy ambition of its municipality, which aims to have only fully energy balanced (zero energy) new dwellings by 2020. The municipality from the onset of the project developed an Energy Vision, in which heat pumps are an integral part of an integrative energy-neutral concept. Within the framework of this long term policy the municipality attained 40% energy neutral housing projects by 2010.

1.2.2 Level of deployment of micro-CHP

Systems

Combined heat and power production (CHP) can take place at different scales, with different outputs and in different sectors. For instance, in industry it regards gas turbines of 2-50 MW_e with a boiler which uses the exhaust heat to produce steam. In buildings, it regards micro-CHP for the provision of space heating and/or hot water and (part of) electricity demand in dwellings and (smaller) buildings. (Micro-CHP is defined by the EC as being of less than 50 kW electrical power output)

Because the ratio between heat demand and electricity demand has a large range, various types of micro-CHP systems have been developed. For all applications the main focus has been on covering the heat consumption.

The following types of micro-CHP can be distinguished:

- Internal combustion engines: this technology is available in a large power range. In some cases the engines come from the car sector. In general they have relatively large emissions.
- Stirling (external combustion) engines: suitable for heat applications with mainly electric self-consumption and in domestic applications, due to low power range available on the market
- Micro turbines: suitable for many applications where electricity is needed, such as a stationary power generator. Micro turbines are also used in hybrid electric vehicles as a low-emission battery charger. In addition, micro-turbines can be used to improve power capacity, quality, or reliability in weak grids.

Some devices used for stand-by power and to reduce electricity demands during peak periods.
- Fuel cells: this technology is still under development. It is capable of operating in applications with a large power range and different kinds of fuel cells.

Deployment
Within the field of micro power generation technologies with lower power than 50 kWe the most common are internal combustion engines, then external combustion engines (generally Stirling) and finally micro turbines.

Regarding the existing facilities:
- Spain: according Eclareon in 2010 were cataloged 150 facilities across the country.
- Japan: is the leader country in installation of micro, having approximately 90% of the total facilities worldwide. Between 2005 and 2010 more than 100,000 units were installed in this country
- Europe: Germany is the first country in number of facilities, with approximately 20,000 units. The second one is UK with approximately 3,000 installed units. Between 2006 and 2010 the number of units sold was between 20,000 and 25,000 units, exceeding this value in 2011

Until 2008, internal combustion engines were the dominant technology. The Japanese market is dominated by Honda with its EcoWill model. In 2009, with the release of Japanese Ene-Farm equipment (Panasonic, Toshiba, Kyocera) of PEM fuel cell, the installation of this technology increased, displacing the internal combustion engines in 2011. In 2012, in Japan new models of Ene-Farm, in this case with SOFC, entered in the market.

In Europe, the most commonly installed equipment is Senertec Dachs' (Baxi) internal combustion engine, with approximately 30,000 units sold. But there is a growing number of installed units based on Stirling engine like WhisperGen of EHE or Thermea BDR, both with distributors in Germany, Holland, Belgium and UK.

Although all technologies are available in the market, a distinction can be made into two types of implementation: the short and medium term. In the short term, the leading technologies will be Stirling engines in the range of low power (<5 kWe) and MACIs and micro turbines for higher powers. In the medium to long term, probably, fuel cells will appear in the market and they will increase its market share in line with the cost reduction of these equipment.

1.3 Impacts

1.3.1 Impacts of heat pumps

The total installed base of heat pumps within Europe exceeds 6 million installations, amounting to a total thermal capacity of nearly 36 MWth. Combined, they 59.9 TWh of useful energy per annum, of which 41 TWh is renewable. In 2012 alone, over 750.000 new heat pump systems were installed in Europe.

1.3.2 Impacts of micro-CHP

With more than 6,200 MW installed in early 2009, CHP covers 12% of the total electricity demand in Spain and represents 6.5% of electricity generation capacity. This represents 1,300 GWh/year of avoided losses since the cogeneration system is connected to the distribution level.
Today, three out of five of Europe's top boiler manufacturers currently have a micro-CHP product on the market. A homeowner in Germany, looking for a 1 kWe micro-CHP system, has the choice of five or more different products. After Delta-ee Annual Subscriber Roundtable Discussion 2012, the estimates from previous roundtable events for future micro-CHP product sales in Europe are:

Year	Lower estimate	Upper estimate
2012	3,000	10,000
2013	6,000	20,000

Participants at Delta's Fifth Annual "Micro-CHP in Europe" Summit – held in June 2010 – had a range of views about how the market would emerge. Estimates for the European annual market size in 2015 ranged from less than 50000 to more than 150000 units per year.

CHP can play a key role in European and in national energy strategies:

- it is a key instrument for energy efficiency and reducing GHG emissions, with significant cost savings
- it is driving investment, innovation, economic development and jobs generation.
- It is fundamental to ensure security of supply and reduce energy dependence.

1.4 Technical feasibility and viability

1.4.1 Technical feasibility and viability of heat pumps

In a study performed by Ecofys under commission of EHPA, the boundary conditions for application of heat pumps was given, based on an investigation in eight key European heat pump markets. It was found that for nearly all types of buildings, excluding buildings situated in extreme climates like Sweden, water source heat pumps are economically and ecologically the heat pump type of choice. However, the restrictions of this technology, given by geological circumstances, legislation and space limitations are considerable. Also for ground collectors source solutions strong restrictions due to limited space have to be considered.

Very efficient systems have chances at markets with high energy prices and also high energy demands like in Germany and Sweden. To increase the trust to switch to a heat pump system in those countries integrated monitoring systems insuring the required efficiency would be beneficial. On the other hand in countries, with low energy prices and low energy demands like Italy, UK, Spain and France, the investment costs are the crucial factors.

Gas heat pumps have actually only very low market shares and product varieties. But this technology is expected to have good chances, at least as bridge technology, especially in the renovation sector exchanging existing gas boilers in countries with comparably low gas prices as it is the case in Germany, Belgium and UK. The potentials strongly depend on system costs compared to those of the less efficient gas condensing boilers, especially for the single-family house sector. In the EHPA study, very high prices for small gas heat pumps have been assumed to consider necessity of further developments. Considering already existing technologies, the gas heat pump is among the most economical solutions for office buildings in most countries. Due to the high CO2-eq emission factors for electricity in UK and Germany the gas heat pump still can also ecologically compete with electrical solutions which themselves have the potential to improve automatically with decarbonisation of the electricity production. It should also be mentioned that thermal driven heat pumps have the potential of operating (nearly) climate neutral when using biomass.

The necessary heating system sizes for single-family houses in this study range from 5 to 10 kW. With regard to tightened regulations it can be expected that those sizes will further decrease.

Hybrid systems with gas boiler and electric air heat pump will have good market chances for renovation of multi-family houses in Germany, where the energy price structure (high el./gas price ratio) and the climate (cold continental winters) are advantageous. Because of the strong increasing share of renewable electricity production, also intelligent controls to use heat pumps as grid storage will surely be needed. Hybrid systems with PV will have good perspectives in the southern countries with high cooling demands, like Italy, Spain, southern France and probably also Austria, preferably in non-residential buildings but also in multi-family houses, where additionally also a major part of the domestic hot water demand can be covered by the system. In the same countries and for the same reasons as mentioned before reversible systems are promising solutions. But also in moderate climates such as in Germany or northern France reversible systems using the cooling demand to heat the domestic hot water in residential buildings or integrated direct cooling systems using the cold of the ground will be interesting regarding economic and ecological aspects.

Besides the mentioned integrated systems for heating, domestic hot water and cooling, it is expected that also solely domestic hot water solutions will improve their market relevance. The main technology will be the exhaust air heat pump, which requires a mechanical ventilation system. Those systems can be observed in multi-family houses of all ages and in all countries. Also in single-family houses, especially in the northern and middle European countries like Sweden, Germany and Austria nearly all new buildings are expected to have mechanical ventilation systems in the future.

1.4.2 Technical feasibility and viability of micro-CHP

Internal combustion engines

Being a very mature technology and reliable, internal combustion engines have a long life of about 40,000 hours, and can reach up to 80,000 hours in some cases. This is particularly relevant for the proper maintenance of equipment among which stands out: oil and air filter change, and strap distribution. Lack of maintenance or improper maintenance (intervals greater than specified by the manufacturer) will shorten the life of the equipment and provokes the premature appearance of faults in different parts.

Micro turbines

Its main disadvantage is its high sensitivity to environmental conditions:
• Inlet Air Temperature: an increase of the intake air temperature causes a decrease of its density. This represents a decrease in efficiency up to 30%.
• Height: the greater height the air contains a lower percentage of oxygen, and therefore in the power output shaft can be lowered to 40%.

Stirling engines

Stirling engines allow high flexibility in terms of fuel and may exploit residual heat even of other machines or processes. Note that the configuration of the piston engines, to require the sealing of the gas contained within it, are maintenance free during its operating life except for possible gas refills needed to cover leaks. Theoretically, the life of this kind of engines is longer, because the fuel is burned outside, and the maintenance is simple (only the burner).

Stirling engines are among the most efficient ones, theoretically matching the efficiency of the Carnot Cycle; very high efficiencies have been achieved in real solutions in the market. They could be adapted to different kinds of thermal energy, but they usually burn gaz. Also, they produce much less noise, and less NOx, without the use of silencer and catalyst.

With the use of an external heat water tank, the efficiency of the installation increases, and the operation of the engine improves.

Fuel cells

These devices are characterized by the absence of moving parts, which implies lower maintenance as well as the absence of noise in operation. As they are electrochemical devices they can achieve efficiencies higher than the other technologies. Fuel cells mostly consume hydrogen, but also methanol. Regarding its supply, typically it is carried in bottles or refill reservoirs in stationary by truck. To avoid the problem of hydrogen availability, most manufacturers use a natural gas reformer to obtain hydrogen from the natural gas. If the fuel is hydrogen, the emissions of these devices are void.

Because of the electricity production by these equipment will not only be necessary to check the existing heat distribution system, but the availability of electrical wiring of the building. Most equipment need a three-phase low voltage, at which be connected and protected as a generator, and not consumers, being necessary to adapt or install electrical components necessary for this task. The European standard for connecting the micro-CHP to the mains is the EN 50438, while in Germany is VDE 4105. However, in Spain, RD 1699/2011 makes easier the network connection for devices with power lower than 100kWe.

Except for the internal combustion engines and micro turbines, that are highly proven and established technology for decades, the other technologies were introduced recently in the market and, therefore, disregard for the life of the main components of the generator. It is especially critical in the case of fuel cells. This means that demonstration projects are necessary to ensure the technologies.

Likewise, for the micro-CHP life is reduced with increasing number of start and stop cycles. Therefore you should avoid starting and stopping continuous through proper sizing of the plant, which also means to increase the operation hours of the equipment and therefore its electricity production.

Generally speaking, the large number of manufacturers and equipment on the market, allow reliably cover a wide range of power, both electrical and thermal. As average, to achieve the viability of the facility (of course, depends on the technology used) the number of operating hours must be between 4,000 and 6,500 hours per year. This determines the power of the equipment to install as well as the need to use a buffer tank to can increase the number of operation hours.

1.5 Financial viability

Please see section 2.2.

2. EXPECTED IMPACTS

2.1 Energy supplied or savings expected

2.1.1 Energy savings expected for heat pumps

Heat pumps are emission-free at the point of operation. When using green electricity or thermal energy from renewable sources, heat pump systems provide a 100% renewable solution for heating and cooling of buildings. In systems where auxiliary energy is provided from conventional (fossil) sources, the renewable energy used is the difference between the total final energy demand and the amount of auxiliary energy input.

The comparison of heat pumps systems using air or ground as energy sources in residential buildings with a gas condensing boiler reveals a possible savings of between 20-49% in primary energy, 67-79% in final energy, and 49-68% in carbon emissions. Heat pumps use between 65-78% of renewable energy to meet their total final energy demand.

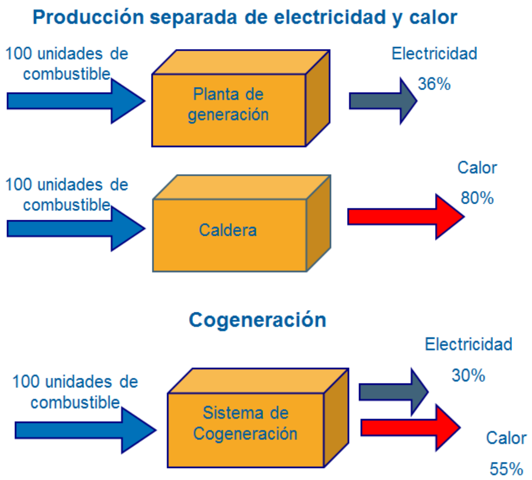
The higher the system's efficiency, the lower the energy demand and operation costs and relative emissions. The primary energy efficiency is largely influenced by the emission value of the electricity of fuel used. Electrical heat pumps will profit from future improvements in efficiency of the European power mix, while thermal units benefit from a larger share of renewable fuels. In all cases, heat pump technology has the lowest emission among heating technologies, and will reduce the carbon footprint of the heating sector.

State-of-the-art electric heat pumps can reach efficiencies of 3–5, which means that one unit of electricity is transformed into three to five units of heat. This relation is called the coefficient of performance (COP) when determined on the unit level, or the seasonal performance factor (SPF) when determined for one complete heating season. Depending on the primary energy conversion factor, this translates into a primary energy efficiency of roughly 1 to 5. Heat pumps using thermal energy can reach efficiencies (gas utilization) of around 1.3 units of heat per unit of primary energy input.

2.1.2 Energy supplied by micro-CHP

The main reason for the micro-CHP sustainability is the primary energy savings. With the traditional power generation, for example in Spain, for every 100 units of fuel used to produce electrical energy or heating only 36 and 80, respectively, are useful. For CHP from the 100 units of fuel used more than 85 are used as thermal or electrical energy, so that the performance is clearly superior. Generating electricity and heat with fewer natural resources means that CO_2 emissions decrease and you get economic savings.

The following images show how, regardless of the technology used in the cogeneration process, the higher efficiency / savings compared to traditional energy production is evident.



2.2 Financial cost/benefit analysis

2.2.1 Financial cost/benefit analysis for heat pumps

The financial viability of a heat pump system depends on a number of variables. First of all, the installation of a geothermal heating and cooling system is more complex and expensive than the installation of an air source heating system. It involves drilling, digging and laying pipes, all of which are expensive and time consuming. On the other hand, the benefits are greater. The type of system that can be installed depends on local conditions, such as the hydrological, geological, spatial characteristics of the land, and how much space is available around the building. Second, heat pumps are more easily implemented in new buildings than in retrofit applications, especially in the case of under-floor heating.

2.2.2 Financial cost/benefit analysis for micro-CHP

Within the scope of the micro-CHP, the equipment costs depend largely on the type of technology employed. In this aspect, internal combustion engines are cheaper compared to fuel cells that, at present, are the most expensive. Furthermore, the higher the power the lower the investment cost.

Tecnology	cost (€/kWe)
internal combustion engines	1.000(50kWe) - 3.000 (5kWe)
Microturbine	1.000(60kWe) - 2.500 (30kWe)
Stirling	4.000 (3kWe) – 8.000(1kWe)
Fuel Cell	4.500(>20kWe) – 25.000(1kWe)

Table 1: Costs per unit of power as technology

Moreover the investment cost of the equipments, we need to take into account the prices of consumed fuel and the produced electricity:

Ratio Price electricity:fuel	Viability
1:1	No
2:1	Unlikely
3:1	Possible
4:1	Viable
5:1	Viable

Table 1.- Feasibility of the project depending on the cost of energy used

Finally, the annual operation hours are very important:

Operation hours	Feasibility
2.000	No
3.000	Improbable
4.000	Possible
5.000	Yes
6.000	Yes

2.3 Impact on GHG emissions

2.3.1 Impact on GHG emissions of heat pumps

Heat pumps are emission-free at the point of operation. When using green electricity or thermal energy from renewable sources, heat pump systems provide a 100% renewable solution for heating and cooling of buildings. In systems where auxiliary energy is provided from conventional (fossil) sources, the renewable energy used is the difference between the total final energy demand and the amount of auxiliary energy input.

The higher the system's efficiency, the lower the energy demand and operation costs and relative emissions. The primary energy efficiency is largely influenced by the emission value of the electricity of fuel used. Electrical heat pumps will profit from future improvements in efficiency of the European power mix, while thermal units benefit from a larger share of renewable fuels. In all cases, heat pump technology has the lowest emission among heating technologies, and will reduce the carbon footprint of the heating sector.

2.3.2 Impact on GHG emissions of micro-CHP

The main reduction in CO2 emissions using micro-CHP is associated with the increase of the efficiency compared to traditional power system.

Taking into account the emission value of 204g CO2/kWh, associated to the combustion of natural gas to produce thermal and electrical energy in micro-CHP, and compare it with the electricity emission value of 270g CO2/kWh (IDAE, Spain 2011), this means 24,4% of savings in CO2 emissions. This means significant CO2 emission savings of 1 Tm CO2/year per appliance.

Moreover if the micro-CHP technology is PEMFC the emission of CO2 is totally avoid, as H2 is used as fuel.

2.4 Interfaces

2.4.1 Interfaces heat pumps and micro-CHP

At the local (street) level there is a strong interaction with the grid, in order to exchange electricity between dwellings/buildings with heat pumps and that with micro-CHP.

The integration of heat pumps and micro-CHP is much recommended, they can collaborate in many ways, and at any time. Together they can provide trigeneration (heat, cold, and electricity), maximizing efficiency and minimizing the consumption from the mains.

2.4.2 Interfaces heat pumps with other technologies

Heat pumps can be combined with heat recovery units in the central ventilation shaft. There is also the option of applying thermal solar panels to generate heat for recharging.

Heat pumps are a key player in smart grids, where all the state of the art technology in terms of energy efficiency and a reliable renewable energy source system are interlinked.

2.4.3 Interfaces micro-CHP with other technologies

Micro-CHP are small cogeneration units that could be fully controllable, in spite of meteorological incidents (clouds, lack of wind, etc.). Also, it is possible to switch on or off the unit at any time, when heat or electricity is needed.

Using alternative energy sources, like solar, wind, and geo-thermal power, the need for automatic or on-demand switching to the most appropriate energy source depending on current energy requirements, time of day, environmental conditions and costs becomes of paramount importance. The need for an effective and supportive environment within which the new Embedded Networked Systems can reduce energy consumption, improve efficiency, and promote maximum supply reliability in case of any incident in the mains. It is by it shelf a key player in the new smart grid networks.

2.5 Wider potential benefits for cities

2.5.1 Wider potential benefits for cities of heat pumps

Particularly for ground source heat pumps, feasibility and technical studies have shown that very large scale and high density (in total about 2500 heat exchangers will be installed) ground source heat pump projects are feasible when correct design conditions are taken into account. Important in this respect is the realization of sufficient recharge or regenerative heat production during summer to offset winter extraction and prevent any trend of long term cooling. Experience has shown that using the underfloor heating system for passive cooling during summer is very effective. In addition heat recovery units can be installed in the central ventilation shaft. Finally, there is an option of applying thermal solar panels to generate heat for recharging. To successfully realize such a large scale, high density ground source heat pump project, it is paramount to pay special attention to the feasibility, performance, long-term sustainability and installation quality. The conditions for the design and implementation of individual heat pump systems (typically consisting of 50 - 100 units each) within the total plan project need to be well defined.

2.5.2 Wider potential benefits for cities of micro-CHP

In many cases, micro-CHP is used to generate not only heat and power in normal situations, but also to generate electricity in case of any natural disaster (see the recent hurricane Sandy in the USA). Thus, its benefits are interesting for both normal and emergency situations.

The installation of one micro-CHP is similar to a standard boiler, with a thermal storage recommended, and an electrical meter to measure the energy generated and injected in the mains. And external controller could be useful if we need a improved control of the installation with more sensors (including measure of external temperature). It integrates directly at home with smart metering, smart grids, smart appliances, etc., and at superior levels with the smart city.

The electricity generated at home is consumed directly at home, as a Virtual Power Plant (VPP), with an efficiency of almost 100%. This is in contrast with the electricity that we buy to the utilities with efficiency about 45%, because of all the losses in the process and transport. The more electricity produced in house the better for the electrical networks.

Another benefit of micro-CHP is that it will reduce the emissions of NOx in virtually all situations.

2.6 Other expected impacts

2.6.1 Other expected impacts of heat pumps

Today’s power grids are based on central electricity production, and one-way delivery of energy to the final consumer. With the ongoing increase in decentralized, renewable electricity generation, this is changing to a system where decentralized generation from photovoltaics and wind will become more dominant. Since these sources cannot be modified to follow demand, demand has to be adjusted to match with the supply at any given point in time. This requires effective load management.

Heat pumps can play an important role in this: they are a demand-side technology that can bridge demand and supply patterns between electricity and thermal grids. Excess electricity can be stored in heat pump systems to be kept in the form of stored thermal energy, either in a dedicated heat store or in the building mass. A heat pump system thus serves as a thermal battery that can be used to overcome times of low electricity supply.

2.6.2 Other expected impacts of micro-CHP

It will lead to a change in the role of consumers by converting them into "Prosumers" with an active involvement and interest in energy efficiency issues.

Advantages of distributed generation as to the electricity system:

- Fit demand curve
- Reduction in energy demand, mainly in peak hours
- Elimination of losses in transmission and distribution lines.
- Less use of electrical grid, meaning improvements in reliability and quality of electricity supply in the area.
- Guaranty the electricity and thermal supply in remote areas
- Greater dispersion of electricity production, therefore the failure of one facility has limited consequences.
- Allows integration of more distributed RES because of manageable generation.

3. ADDITIONAL REQUIREMENTS ON DEPLOYMENT

3.1 Governance and regulation

3.1.1 Governance and regulation for heat pumps

Municipalities can play a major role in the definition of new developments, especially with regard to policies of climate change, energy savings and sustainable project-development. The municipality of Etten-Leur (Netherlands) was among the first to define very ambitious goals for energy consumption. In fact, the goal set by the municipality is to achieve fully energy-balanced new developments by 2020. Already in 2010 40% of all new construction needs to be energy-balanced. From the onset of the project an Energy Vision was developed by the municipality, and heat pumps are an integral part of this "all electric" energy-neutral vision.

3.1.2 Governance and regulation for micro-CHP

In Spain the RITE (Regulation of Thermal Installations and Buildings) and CTE (Technical Building Code) require that the new housing developments include compulsory minimum factor of 60% of solar thermal energy for hot water; this requirement change with the region.

In buildings where the minimum solar contribution is not possible, the inclusion of alternative measures or elements that save thermal energy or reduce carbon dioxide emissions equivalent to the energy saving and emission reduction levels that would be obtained by the corresponding thermal solar system, shall be justified with respect to the basic regulations of the legislation in force, by obtaining improvements in the thermal insulation and energy efficiency of the equipment. In this case the use of micro-CHP is permitted, but many associations are asking to fully comply as soon as possible with the European Directives.

NOx emission standards

The Energy related Products Directive, ErP Directive, is a mandatory piece of legislation, proposed by the European Union, which aims to bring in minimum standards for heating and hot water systems.

The Directive, under Lot 1, proposes a number of new standards including NOx limits and efficiencies for oil-fired boilers, new system & product labelling requirements and differing efficiency points for different controls. As mentioned, the NOx emissions of boilers have been one of the most controversial. The first draft of the ErP Directive called for boilers to achieve NOx emissions of an extremely low value.

The proposal for NOx limits in the latest Commission text proposes a limit on NOX emission for micro-CHP of 120 mg/kWh (natural gas) and 200 mg/kWh (liquid fuel), these to apply first after the fifth year following the publication of the implementing measures. The higher levels proposed for micro -CHP compared to boilers already acknowledge a difference between these two products types.

COGEN Europe proposes that the single 120 mg/kWh limit approach for NOx emission for micro-CHP is not appropriate. COGEN Europe proposes that instead the Commission consider an approach which relates the NOx emission limit both to the energy efficiency of the product and to the capability of the product technology regarding NOx. For example, COGEN Europe therefore proposes a methodology for setting emission limits which is technology neutral and drives improvement across all technologies.

3.2 Suitable local conditions

3.2.1 Suitable local conditions for heat pumps

There are no appropriate characteristics of the urban area needed to fully exploit the potential benefits of the innovation, such as urban density, social demographic and energy mix apart from its geology. Deep geologic studies are necessary to evaluate the conditions for sustainable use of the ground for heating, allowing a clearly defined design conditions in terms of minimum temperature levels that must not be exceeded as well as thermal balance that need to be achieved. Ground source heat pump projects are feasible when the design takes into account proper design conditions. When clear goals are set, and specifications concerning the thermal performance as well as mechanical installation quality are defined, an environmentally friendly and sustainable use of the ground can be made for heating and cooling applications.

3.2.2 Suitable local conditions for micro-CHP

Micro-CHP fits well in all kind of buildings, with different sizes and fuel supply, due to the availability of different types and capacities. They fit very well in cities with mainly existing dwellings and buildings where it is difficult to realise near-zero net energy use and emissions that are foreseen for new dwellings and buildings. In many buildings they could be operated with natural gas, but in others they could be operated with biomass or biogas.

Depending of the different legislation of the countries, the installation could be designed to operate with a focus on heating or a focus on electricity, depending on the different local legislations as to exporting electricity. In some countries the electricity exported to the network could also be treated as a temporal storage for “Net Balance”.

3.3 Stakeholders to involve

In some countries the gas and electricity utilities are promoting themselves the introduction of micro-CHP technology, offering better prices or conditions. Also, through subsidiaries, they may offer ESCO type services.

ESCOs are another player to involve. They can offer all kind of services, with the required solutions, prices, comfort, and maintenance.

The different governments must play an important role, with laws that facilitate the introduction of the micro-CHP in new and refurbishment of buildings.

Finally, other players could offer new solutions as the smart-lift plus some kind of energy generation and storage.

3.4 Supporting infrastructure required

There are clearly a number of barriers that restrict the growth, implementation and use of micro-CHP technologies. These issues include in some cases:
- manufacturing capacity;
- installation capacity;
- consumer acceptance and buy-in;
- costs;
- shortage of financial incentives
- ESCOs to develop a range of energy services agreements possessing a transparent, fair formula of payment to end-users.
- Legislation not appropriate.

4. FINANCIAL REQUIREMENTS AND POTENTIAL FUNDING SOURCES

The Finance Group of the Stakeholder Platform has prepared documents on funding models and the use of EU Funding instruments, either from the EU budget or from the European Investment Bank. The documents are freely downloadable from the Stakeholder Platform's website.

- For funding models please refer to the **"Financing models for Smart Cities"** guidance document.
- For EU supported funding instruments please refer to the guidance document on **"Using EU Funding mechanisms for Smart Cities"**.

This section presents specific recommendations for financing models and potential sources suitable for this KI.

4.1 Specific sources of funding for the KI

This KI proposes to combine micro CHP and heat pumps in dwellings. Both technologies have been successfully introduced separately and this KI proposes a combined approach. This means that a number of different funding sources may be appropriate. For innovative combinations demonstration financing by Horizon 2020 and support by the EU's Risk Sharing Financing Facility (RSFF) may be possible, but in many cases other existing approached to energy efficiency funding may be approriate.

Projects that have already funded such technology:

PANER 2011-2020.

PAEE 2011-2020

European Projects: FC-DISTRICT, EURECA, DIGESPO, PRIMOLYZER, REFORCELL, SOFT-PACT, R-D-SBES-R, H2OME, LOTUS, ASTERIX 3, LOLIPEM

The technology can also e combined with other energy efficiency actions. For larger energy efficiency projects, municipalities can operate through ESCOs and requiring EU assistance, for example from the Intelligent Energy Europe IEE ELENA.

For support from the IEE the country contacts can be found at:

http://ec.europa.eu/energy/intelligent/contact/national-contact/index_en.htm

The IEE programme will no longer exist in the present form after 2014, but the new mechanisms are not yet published.

For individual dwellings, some member states have specific support programmes. The KfW guarantee scheme for energy efficiency for example or the CDC's 'éco-prêt logement'.

KfW information:

https://www.kfw.de/inlandsfoerderung/Privatpersonen/Bestandsimmobilien/Energetische-Sanierung/

CDC information:

http://portail-actus.caissedesdepots.fr/spip.php?article1394

Smart Cities and Communities

Smart Cities Stakeholder Platform

...brings together people, industry and authorities from across Europe to make our cities more energy efficient, better to live in and growth-friendly.

...is about developing concrete innovative solutions for cities through tailored innovations.

...facilitates the exchange of knowledge and best solutions across smart cities in Europe.