Implementing on-site renewables and mini-CHP systems in public buildings and social housing

In a nutshell

SUMMARY
It is best practice to provide public buildings and social housing with low-carbon technologies to meet the energy demand. These can include solar thermal systems for heat generation, on-site photovoltaic panels for electricity generation, or, in case of sufficient heat demand, small-scale combined heat and power (mini-CHP) systems to jointly generate the heat and the electricity at a higher overall efficiency. Mini-CHP systems can run on gas, or have additional environmental benefits if run on biomass where a local source of sustainable biomass is available.
Target group
Local authorities
Applicability
This best practice is applicable to all public administrations. However, the possibility to implement specific solutions may be limited by the local availability of renewable energy sources and the financial investment required.
Environmental performance indicators
• On-site renewable energy generation per unit of floor area (kWh/m^2 year) • Share of total energy use met by on-site renewables (%) • Share of total energy use met by on-site generation of low-carbon energy (%) • Share of total electricity use met by on-site generation of renewable electricity (%) • Percentage of hot water demand met by on-site renewable heat generation (%)
Benchmarks of excellence
• 100 % of the electricity used in a public building is met by on-site generation of renewable electricity • 100 % of the hot water demand in a public building/social housing building is met by on-site renewable heat generation

Description

Public authorities have large portfolios of property and influence over other property e.g. social housing. These properties need heating and electricity, and providing these with low carbon technologies allows to substantially decrease the environmental impact of these buildings.

Electricity is generally provided by a national grid outside the influence of the authority but options for on-site electricity generation are also available. Among them, renewable energy systems like solar photovoltaic panels allow to generate zero carbon electricity, contributing to national targets and local objectives.

As for the heating, this is generally generated on-site, usually with a boiler running on gas or other fuels. Low/zero carbon options include biomass boilers and solar thermal systems. Another option is adopting small scale Combined Heat and

Power systems (mini-CHP) using gas or biomass which allows generating jointly the heat and the electricity at a higher overall efficiency.

0. *Energy Efficiency Measures*

Energy efficiency measures, such as designing an efficient building envelop or retrofitting insulation in existing buildings, reduce energy needs and should always be done first. Behaviour change measures should also be implemented before meeting energy needs by renewable energy is considered. These measures are likely to be more cost-effective, but there is also an important technical reason for doing so – energy efficiency reduces the overall consumption of the building, and, if the renewable energy system is sized to pre-retrofit consumption levels, it will be oversized once the efficiency of the building is improved. This is particularly a problem for heating systems, where operational and maintenance problems can arise if the system is not properly sized (Biomass Energy Centre, 2011).

0. *Renewable Electricity*

The most common renewable energy options available to generate electricity on-site on public authority buildings and houses are:

Solar photovoltaic (PV) panels

Solar PV generates electricity from sunlight. PV panels are ideal for placing on flat or pitched unshaded roofs and can also be mounted on facades or ground-mounted in suitable locations (e.g. gardens, parking lots). Pitched roofs and facades should be broadly south facing to maximise generation. There are also construction elements (e.g. tiles, roofs, glass surfaces) integrating PV elements. These are convenient when integrating renewables while constructing or refurbishing a building. There is a significant difference in generation potential between northern and southern Europe, but it can still be cost-effective to install PV in northern areas, for example a Finnish University recently installed a 220 kW system (LUT, 2013).

Small scale wind turbines

Wind turbines generate electricity from the wind, and can be vertical-axis or horizontal-axis. Building-mounted systems are usually vertical-axis and range up to around 10 kW in capacity.

Geothermal

Electricity generated from naturally occurring geological heat sources can provide significant amounts of renewable energy. Water heated by the heat source (as steam) is used to drive a turbine, generating electricity. Geothermal energy resources are very localised but where available can supply a significant percentage of local energy demand. For example, Siena (Italy) generates 97.6% of its electricity from a geothermal plant (Terre di Siena Green, 2014).

Biomass/biogas

Sustainably sourced biological materials such as wood or gas produced by anaerobic digestion can be burnt to generate electricity. However, these fuels are primarly used for heat production or CHP.

0. *Renewable Heat*

The most common renewable energy options available to provide space heating and hot water to public authority buildings and houses are:

Solar thermal

Solar thermal panels or tubes can be used to generate hot water using heat from the sun. This can then be used for domestic or commercial hot water, in homes, offices or where there is a relatively high heat demand during summer daytimes, e.g. swimming pools or sport centres with large shower rooms. Because heat is not easily stored, solar thermal works best in combination with back-up technologies such as biomass or natural gas hot water systems which can generate heat when the sun is not enough. In locations where there are many sunny hours also when the external temperatures are low, solar thermal can also be used (at least partially) for space heating.

Biomass/biogas

Sustainably sourced biological materials such as wood or gas produced by anaerobic digestion can be burnt to generate heat in a boiler or in a mini-CHP system. The most common systems are biomass boilers that burn wood in the form of logs, chips or pellets to heat water used in a central heating system.

0. *Low Carbon Energy*

When generation of renewable electricity and heat is not technically or economically feasible or can only cover part of the energy needs of a building, low carbon energy options should be considered. The main ones are:

Mini-CHP

CHP involves the production of electricity and useful heat from a single plant, which is more efficient than generating electricity and heat separately[1]. Mini-CHP refers to small scale CHP systems that may power individual buildings or complexes such as hospitals, schools or social housing blocks. CHP can be fuelled using fossil fuels, being a lower carbon system[2], or by renewable fuels such as biomass, where it is zero carbon. Mini-CHP systems should be appropriately sized to match the heating needs of the building. This would usually generate part of the electricity needs. Generating more electricity would often mean reducing the overall efficiency or producing extra heat. The latter only makes sense if this heat can be exported to nearby buildings. In this sense, CHP can be used in combination with a district heating network.

Heat pumps

Heat pumps use electricity to drive a refrigeration cycle to extract heat from the environment (air, water, sea, ground). Although the heat is renewable (it comes indirectly from the sun), heat pumps still need electricity or another fuel to drive the system. However, for every 1 kWh consumed it is possible to get 3 kWh of heat or more. The ratio between the heat which is extracted from the environment and made available and the consumption of the system is called the Coefficient of Performance (CoP). The normal range of CoP is between 2.5 and 5. Heat pumps can be used for space heating and hot water, as well as cooling. Heat pumps are most suitable in well-insulated environments where low temperature heat is required and in climates with mild outdoor temperatures, since the temperature difference between the environment and the heat required lowers the CoP as the difference increases.

0. *Choice of the appropriate technology and appropriate siting*

The choice of the appropriate technology depends on whether it is for an existing building or for newbuilt, on the position and orientation of the building, on the local climate… This also applies to the specific siting chosen (e.g. PV and solar thermal can be placed on the roof, on the parking lot, on the ground around the building…).

From an environmental point of view, zero carbon heat and electricity technologies (including biomass-fuelled mini-CHP) should be preferred to mini-CHP running on gas and heat pumps. Between these two options, heat pumps should be preferred when the carbon intensity of grid electricity is low and mini-CHP when this is high[3].

0. *Project implementation*

1. *Audit*

The first step in implementing a renewable energy or low carbon solution is to understand the current situation of the building(s), in terms of:

- Fuel costs
- Carbon emissions
- Maintenance costs
- Lifespan of current system
- Current and future usage of the building(s)
- Strategic objectives of the public authority
- Potential for (further) reducing the energy needs of the building by implementing energy efficiency measures (such as improving the building envelope performance) or fostering behavioural change[4].
- Potential for / availability of renewable energy sources in the examined area

This will include a physical audit of the building(s), but also a detailed analysis of the results and the strategic and policy context. This audit and analysis may cover multiple buildings with those most suitable being targeted for specific interventions.

A similar exercise can also be carried out when designing a new building. There are a number of key differences however which can lead to different technology choices being made compared to retrofitting an existing building. This can be because there may be additional cost of retrofitting systems compared to incorporating them within the construction plan, or because the design can be altered to accommodate a preferred technology. For example, a ground-source heat pump may not be economically beneficial or practically achievable for an existing building, however if the boreholes/trenches for the pipes are dug during the construction phase this could be the most viable option. Additionally, some technologies, e.g. solar PV roof tiles, may not be cost-effective to retrofit (if the roof is in good condition) but could be cost-effective for new construction if they replace other building materials (i.e. new roof tiles).

2. *Setting of objectives*

The second step is deciding what the public authority wants to achieve. Objectives may span from minimising the life cycle cost of a building (i.e. choosing the option to provide heating and electricity with the lower life cycle cost) to an environmental objective such as achieving carbon neutrality.

3. *Analysis of the different solutions*

Once the objectives for the intervention are established and the current situation and potentials are known, all the solutions should be examined with a thorough cost-benefit analysis and outline business case options.

4. *Business case and Finance*

Once the preferred solutions have been identified, the business case is prepared. This will compare the solutions with the "business as usual" option and will include strategic targets as well as financial considerations.

Renewable energy solutions often require a large up-front capital investment and generate long-term income through sales, savings and subsidies. Financing the capital investment can be achieved from several sources (including a combination of these sources). Each has its own advantages and disadvantages, some of which are outlined in the table below.

Table 1: Advantages and disadvantages of different funding options

Funding option	**Advantages**	**Disadvantages**
Authority investment from own funds	• Low interest rates required by the authority improve business case • Long-term interest in project	• Legal limits to authority lending • Investment competes with other strategic priorities
Private investment via bank or commercial organisation	• No cost to the authority	• Higher interest rates required to service investment, impacts on business case
Community investment	• Usually lower interest than commercial funding • Involves wider municipality in project • Retains financial benefits in local area	• Not suitable for very large investments • Large number of stakeholders

5. *Consultation/stakeholder engagement*

Some projects may require consultation with the public and stakeholders. This could be a planning requirement for major projects, but can be a good way to engage with people about the project and any broader sustainability objectives and schemes. Projects in social housing require serious engagement to reassure residents, particularly if there are changes to their income or environment (e.g. changed heating system and billing).

6. *Procurement, Installation and Monitoring*

Once the project has been approved and financed, the installer will be procured and installation will take place. Where an installation involves disruption to building users or residents, on-going engagement should take place to explain the installation process, notify of disruption and reassure them. Where users or residents have to change their behaviour, a suitable handover should be arranged to explain the new system and how it works.

Post-installation monitoring is an essential part of the process. This should include technical monitoring to ensure the system is working as expected, but should also include ongoing engagement with users or residents. Proper use of the system is a key aspect to ensuring it works as expected and that the environmental benefits are achieved. Poor handover can lead to technical problems with the system as well as additional costs, for example if usage is higher than modelled.

7. *Dissemination*

Public authorities are expected to play a leading role in reducing energy consumption and carbon emissions. One of their responsibilities is to disseminate knowledge on successful and unsuccessful projects so that other people, business and authorities can learn from the experience, replicate the successes and be aware of the potential issues.

[1] This is because during the generation of electricity from fossil fuels heat is also generated. In large power plants, the heat is mostly wasted as there are few large heat users next to the power generation facility. Wasting the heat means that the efficiency of the conversion from fossil fuel to electricity is only around 40%. If that heat can be used, the overall thermal efficiency increases to 70%+ or even more.

[2] Under the assumptions that grid electricity generation is less efficient than local generation of electricity and heat from mini-CHP

[3] Heat pumps usually run on electricity. Although they generate 2.5 to 5 times as much heat as electricity they use, if this electricity is generated from carbon intensive sources and/or very inefficiently, there will be little overall environmental benefit. In those cases, the higher environmental benefit is offered by mini-CHP, which would be more efficient at generating heat and electricity than grid electricity generation.

[4] As explained above, reducing the energy needs of a building should always be preferred and prioritised to implementing renewable energy systems.

Environmental benefits

Renewable energy and low carbon energy systems described in this best practice can significantly reduce CO_2 emissions of buildings. In some cases, renewable energy systems can also produce more than a building requires and export green electricity to the national electricity grid.

Side effects

Renewable energy systems can impact on other environmental pressures by competing for space (e.g. solar PV vs green roofs), or through unsustainably sourced biomass. Below is a table of example negative impacts of building-scale renewable energy technologies. These impacts can usually be mitigated by proper siting choice and design features.

Table 2: Possible Negative Impacts of low carbon technologies

Technology	**Possible negative impacts**
Solar photovoltaic	•

Wind	• Can cause damage to wildlife if sited in bird migration routes or near bat nesting sites
Biomass	• Can impact on deforestation if produced unsustainably • Can cause habitat damage if sourced from a poorly managed site • Generation of particle emissions
Heat pumps	• Ground source can freeze the ground under certain conditions, e.g. if too many heat pumps are located close to each other

Applicability

The suitability for implementing a renewable energy or low carbon system on a particular site depends on numerous factors. However, there should be a solution applicable to most situations. A brief summary of applicability of different technologies is outlined in Table 3.

Table 3: applicability of different on site-renewable and mini-CHP technologies

Technology	Suitable sites	Less suitable sites
Solar photovoltaic	Flat/pitched roofs, ground mounted. Little shading, E-S-W facing.	Shaded areas. Ground-mounted when competes with productive land. Historic buildings.
Wind	Large buildings (vertical axis turbines).	Areas with high natural or heritage value.
Geothermal	Naturally occurring heat, site-specific.	Cannot be used where there is no naturally occurring heat.
Biomass	Rural areas relatively near fuel source.	Highly urban areas (due to transporting fuel). Buildings with limited storage.
Biogas	Feedstock is usually rural, so gas production is generally in rural areas.	Highly urban areas (due to transporting fuel).
Solar thermal	Flat/pitched roofs, ground mounted. Little shading, E-S-W facing.	Shaded areas. Ground-mounted when competes with productive land. Historic buildings. Low hot water requirement.
Mini-CHP	Depends on fuel. Natural gas CHP suitable where gas is available.	Natural gas CHP - Off-grid areas.
Heat pumps	Well insulated buildings requiring low temperature heat	Poorly insulated buildings, high heat requirements,

As described in the next section 'economics' the implementation of on-site renewables and mini-CHP on public buildings and social housing can be subject to relevant and long-term economic investments and public administration, in light of their specific features compared to the private sector, may face some challenges in this respect.

Economics

The technologies mentioned in this best practice are commercially available, but the business case depends heavily on geographical location and national incentives, as well as national energy prices. In general the financial benefits can be calculated using:

- Capital cost (€)
- Incentives for installation (Feed-in Tariffs, grants) (€, €/kWh)
- Estimation of on-site usage (kWh per year)
- If applicable, unit price for exported generated energy (€/kWh)

Compared with:

- Current energy costs (if relevant) (€)
- Current and future fuel prices (natural gas, electricity) (€/kWh)

An example hypothetical calculation for a 33 kWp solar photovoltaic array costing £50,000 is detailed in Table 4. This assumes finance is arranged at 5% over 25 years. Generation is assumed to be 33,000 kWh per year for a UK-based system. Feed-in tariff rates are based on 2014 UK rates. Other countries have different support mechanisms for renewable energy although many are similar in structure.

Table 4: hypothetical calculation of solar photovoltaic system installation

Item	**Income (annual)**	
Loan payment @5% interest over 25 years on £50k capital	-£3,547.62	-€ 4,505.48
Maintenance (including inverter replacement)	-£1,000.00	-€ 1,270.00
FIT @£0.12/kWh	£3,960.00	€ 5,029.20
Export Tariff assuming 50% on-site use @£0.047/kWh	£775.50	€ 984.89
Savings from 50% on-site use assuming grid electricity @£0.10/kWh	£1,650.00	€ 2,095.50
Outgoings	-£4,547.62	-€ 5,775.48
Income	£6,385.50	€ 8,109.59
Net income	**£1,837.88**	**€ 2,334.10**

The FITs ensure viability of the project in this example, giving a small profit for the public authority. In other EU countries, particularly in Southern Europe, the project may be viable without subsidy due to the higher solar irradiation.

Driving forces for implementation

The two main drivers for the implementation of on-site renewable energy generation and low carbon technologies are: lower life cycle costs and environmental considerations.

Indeed, many public administrations are keen in delivering carbon reduction, driven by legislated or voluntary commitments to reduce CO_2 emissions in the municipality.

The price of fossil fuels is on a long-term upwards trajectory and the cost of renewables has reduced significantly over the last 20 years. In some parts of Europe (e.g. Spain, Italy, Germany) electricity from solar PV is now at "grid parity", meaning it is the same cost as or lower than the cost of grid electricity (Eclareon, 2014). Since the price of electricity produced from renewables is fixed once the system is installed (for most technologies), and increases in fossil fuel prices will ensure that grid electricity increases above the rate of inflation, it can be financially beneficial to invest in renewable energy.

Some municipalities benefit from an abundance of natural resources where the fuel (e.g. biomass) is significantly cheaper than the market average, for example Eno (Finland) which has implemented a biomass district heating system using sustainably managed wood from local forests.

Reference organisations

Wierzchos?awice, Poland

Solar PV

Samsø, Denmark

Wind, biomass

Provincia di Siena, Italy

Geothermal

Xanthi, Greece

Hydroelectricity

Ostrava, Czech Republic

Biomass

Woking Borough Council, UK

CHP

Lyon, France

Heat pumps

Literature

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