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Renewable energy options appraisal

Sustainable Futures, Changeworks, August 2010

This report provides an overview of the opportunities for renewable energy generation in Woodburn Terrace, a typical street in South Edinburgh where stone-built tenement properties predominate. All the main microgeneration systems are explored, together with larger district heat and power schemes. As well as technical appraisals, broader considerations such as planning policies, cost and payback, CO_2 savings and behaviour are considered.

Transition Edinburgh South

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Introduction

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After a brief overview, each microgeneration technology is considered for its applicability to the properties in Woodburn Terrace. The following key aspects are covered: technical, policy & planning, capital costs & payback periods, installation logistics, behaviour, and cost and CO_2 savings.

Detailed guidance on all the microgeneration systems and issues covered in this report is available in Renewable Heritage: A guide to microgeneration in traditional and historic homes (Changeworks, 2009).

Transition Edinburgh South

Transition Edinburgh South (TES) is a grass roots community group, and is part of the Transition Movement. It uses the transition model to inspire and facilitate the work of communities to lower their carbon footprint, and increase their resilience and sustainability to the effects of peak oil and gas and climate change in a creative way. TES exists to enable and support ideas about how to make their community more fit for the future.

More information on TES is available on their website.

Executive summary

Solar water heating and photovoltaics are both viable forms of microgeneration for households in Woodburn Terrace. However, the potential complications of neighbour consents and installation could make any installation a complex process, due to the tenemental nature of the properties. Photovoltaics are probably limited to top-floor properties only, due to the array size needed; solar water heating could potentially be run down the buildings to lower-floor flats but this increases the complexity further.

Ground and air source heat pumps are technically viable, and would require minimal neighbour consents, making them logistically simpler to install. Installing ground source heat pumps is a messy but temporary affair. However, the negligible cost and carbon savings that would be achieved by replacing a gas central heating system with an electric heat pump pose a serious question as to the financial or environmental viability of any such installation.

Biomass too has potential, and would make the greatest CO_2 savings. Unfortunately the restrictions likely to put in place by the Planning and Environmental Health departments may make these significantly harder to install. Installations that do not require formal permission will be considerably simpler, and are perhaps the most viable for Woodburn Terrace (and elsewhere in Edinburgh).

The multi-occupancy and multi-ownership nature of the tenements in Woodburn Terrace could make it more convoluted to install solar systems (SWH or PV), or any communal system. Communal heating or power systems could be put to good use in Woodburn Terrace, but would require considerable time and community working in the early developmental stages of any installation. The ‘hassle factor’ involved in planning and getting consents for any such installations should not be underestimated, and will require a determined approach. This should not be taken negatively, rather it is intended to make householders aware of the significant commitment needed to progress such a project.

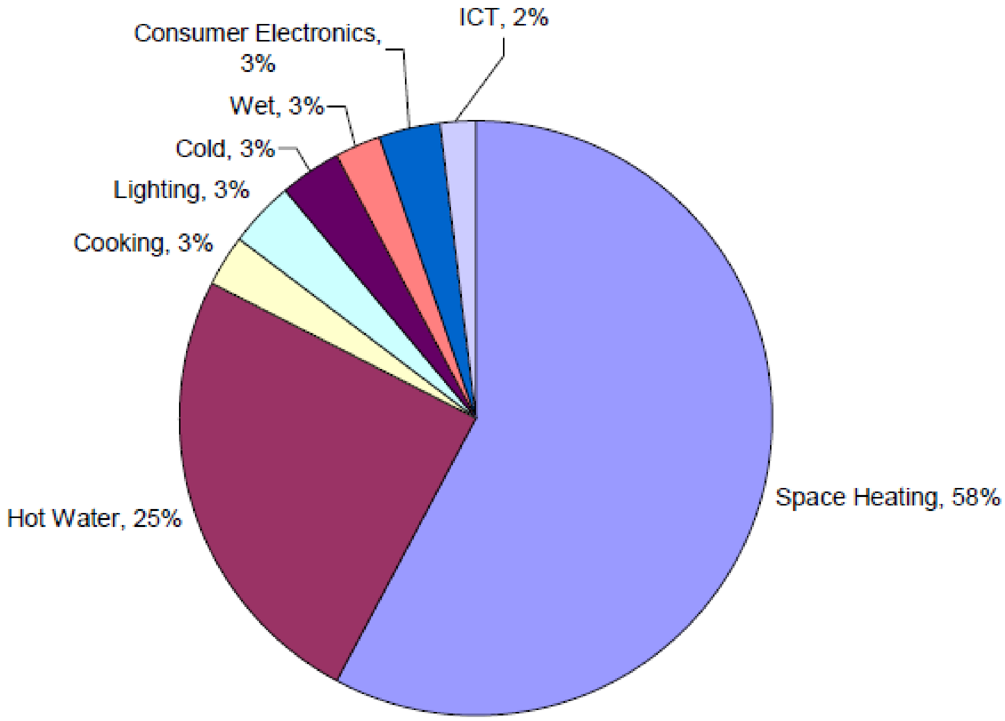
Understanding the installed system is important, to ensure that appropriate behaviours and usage patterns can be adopted to get the most out of the system. Understanding is also important even before this stage, however: knowing the lifestyles, property features and characteristics of the different microgeneration systems will enable householders to identify the system that will work best for them.

Behaviour can make a microgeneration system achieve or exceed its potential, or can lead to significant under-performance. This is a key area for householders to bear in mind: generating one’s own energy requires a fundamental shift of thought compared with our current conventional heat and power systems. This does not necessarily mean more work, but rather a different way of thinking about energy use, and changing some behaviours to allow the system to work to the best of its potential.

Cost and saving predictions are only ever a guideline, and should be treated with some degree of caution. However, in the long term the high capital costs of most microgeneration systems should be more than offset by fuel bill savings, income generation schemes and long-term protection from fossil fuel price rises.

1 Overview

The breakdown of CO_2 emissions from the average UK home is shown in the following chart.



Average UK household CO_2 emissions split by sector (weighted average for all heating fuel types)[1]

Naturally, these proportions will vary in different properties, however they provide a useful guideline for those wishing to reduce their CO_2 emissions through both energy efficiencies and microgeneration. Improvements in all areas will make a difference, but the biggest savings can be achieved by focusing on those areas responsible for the most emissions (space and water heating, for example). If a property uses significant amounts of electricity, however, this could also be a priority as electricity generates significantly higher associated CO_2 emissions than mains gas.

[1] Sources: ECUK 2007 & MTP

1.1 Summary of key considerations

Before choosing a renewable energy system, a number of key questions must be addressed. These will help determine not only which system is best suited to the property, but also which system is best suited to the householders. Answering the following questions will help the householders in Woodburn Terrace in selecting the best systems for them.

Key considerations
What is more important, cost savings or CO_2 savings? Some technologies generate greater cost savings than CO_2 savings; others vice versa. It is important to have a clear understanding of the main reasons for wanting to generate one's own energy.
What type of property is it? Some property types are better suited than others to certain technologies. Being aware of this can ensure that an appropriate system is installed, that can perform as well as possible.
What other works are planned? Certain maintenance or improvement works can be combined with the installation of microgeneration technologies, or selected and installed with future microgeneration in mind. In either case suitable combinations can save time and money on the works.
How hands-on are the householders prepared to be? The manual elements of running a biomass system call for considerable interaction with the system; the opposite is true of a heat pump, for example. It is important to know how much the household likes or dislikes this type of interaction, to help select a system compatible with that household's way of life.
How visible or invisible do the householders want the system to be? Some people may prefer 'invisible' heating systems such as ground source heat pumps, with no obvious controls or focal point. Similarly, some people may wish to show off their solar panels while others may prefer them hidden. These are all important considerations in the planning of any installation.
What is the household size and make-up? Different household sizes clearly have a big impact on energy use. A solar water heating system is not well suited to a one-person household with low hot water usage, but could be ideal for a larger family who use considerably more hot water.
What are the lifestyles of the householders? Related to the other questions, this is critical in identifying the technologies best suited to each individual household. Lifestyle affects people's heat and power use. Being aware of the greatest areas of energy use, levels of technological awareness, and behaviour patterns (see below) of a household will help highlight the systems best suited to them.
How willing are the householders to adapt their behaviour? Some level of behavioural change is fundamental to get the most out of any microgeneration system. This does not mean more work, just a different approach and more consideration before doing certain things. The considerable financial outlay makes it imperative that a system is used to best effect, avoiding behaviours that could reduce its efficiency and impact.

The below matrix provides some insight into the above questions, and other key areas. The answers relate to the properties in Woodburn Terrace, and to those technologies deemed most suitable for this street. All answers are necessarily somewhat generalised, however they provide a basic overview.

	Solar water	Biomass	Heat pump	Photovoltaics
Greater cost or CO_2 savings?	Fairly equal (EST estimates annual savings of £50 / 250kg CO_2)	CO_2	Neither (Replacing gas central heating with an electric heat pump is unlikely to make particular cost or carbon savings)	Fairly equal, although FIT could make cost savings greater (EST estimates annual savings of 1 tonne CO_2 and 40% off bills)
Performance affected by property characteristics?	No (But South-facing roof best)	No	Yes (Well-insulated property vital; could require additional works)	No (But South-facing roof best)
Installation affected by property characteristics?	Yes (Mount panels on angled frames on flat roofs facing South, or evacuated tube systems flat on roofs; flat-plate panels may need crane delivery; lower-floor installations possible but complex)	Yes (Space for fuel store & delivery; running stove flue through other properties' chimneys)	Yes (Space for drilling rig access if borehole in rear gardens;)	Yes (Mount panels on angled frames on flat roofs facing South; flat-plate panels may need crane delivery)
Particular planning issues?	Yes (Neighbour consents & liabilities needed, especially for lower-floor installations)	No, but potential Environmental Health restrictions	No for GSHP Yes for ASHP	Yes (Same as SWH)
Integrate with other works?	Yes (Re-roofing; boiler replacement)	Yes (Heating system replacement)	Yes (Heating system replacement)	Yes (Re-roofing)
Hands-on approach needed?	No	Yes (Topping up & cleaning system)	No	No
Visibility of system?	Low internally Higher externally (Panel visibility dependent on siting)	Low (Higher with stoves)	Low (Higher with ASHP; dependent on siting)	Low internally Higher externally (Panel visibility dependent on siting)
Performance affected by household size & makeup?	Yes (Best suited to larger households where all solar-generated water will be used)	No	No	No

Performance affected by lifestyle?	Yes (Not suited to low hot water use; need to draw off all hot water if possible)	No for boilers Yes for stoves (As below)	Yes (As below)	Yes (Indirectly: greater savings will be made by using electricity during daytime as it is being generated; otherwise it is exported to grid and bought back at higher cost)
Need to adapt behaviour?	Yes (Need to draw off all hot water if possible; need to manage timing of hot water use & boiler top-up; need to plan ahead)	Yes (manual approach needed for topping up / cleaning system; non-automated stoves require considerably more interaction)	Yes (Frequent opening of windows or altering of controls can considerably reduce efficiency of system; lack of heating focal point if combined with under-floor heating can take some getting used to)	Yes (As above; also minimising electricity use will increase impact of system)
Overall suitability to Woodburn Terrace	**High** (Top-floor properties simplest; all floors possible)	**Medium** (potential Environmental Health restrictions)	**High** (Ground- & top-floor properties)	**High** (Top-floor properties)

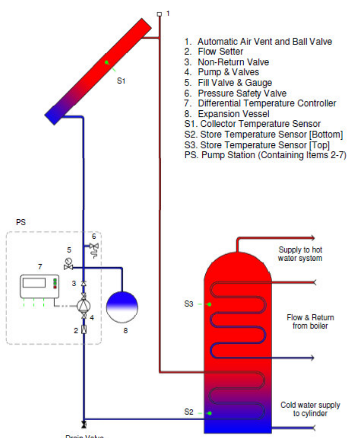
2 Technical considerations

Renewable energy can be used to generate **heat** or **electricity**. The main heat generating options are solar water heating, biomass and heat pumps; the main electricity generating options are photovoltaics, wind and hydro. In addition, communal systems can provide heat and / or power to multiple buildings.

This section explores the technical aspects of each option in relation to Woodburn Terrace.

2.1 Solar water heating

On a technical level, solar water heating (SWH) is well-suited to householders in Woodburn Terrace where they already have a conventional condensing boiler. However, roof-mounted panels would require considerable householder liaison to determine maintenance responsibilities and liabilities, and replacing a combi boiler would add considerably to the cost.



A SWH system is relatively simple: liquid runs through an insulated panel facing into the sun, which heats the liquid before it returns to the hot water cylinder. Here it heats the domestic hot water supply, which can be topped up as required by a conventional boiler or immersion system. A typical panel array might be 3-5m^2, and a common rule of thumb dictates that this should provide around half of a household's annual hot water needs (all in the summer, less in the winter).

There is a wide range of solar panels available. These fall into two main groups, flat-plate panels and evacuated tubes. The former are more common, more robust and cost less, however the latter can be more efficient, take up less space and can sometimes be sited more easily on flat roofs as some tube systems can be laid flat (this also reduces visibility, which can be an important consideration in conservation areas). Panels are generally mounted on roofs, although they can also be recessed into the roof or mounted on the ground on short poles or angled frames.

Due to the considerable shading of the gardens in Woodburn Terrace, the roofs are likely to provide the most suitable siting space. This makes them simplest to fit to serve top-floor properties. However, it is possible to run pipework down through the building so that householders on lower floors (even basement level) can also benefit from solar water heating. Due to the orientation and roof configuration of the tenements in Woodburn Terrace (the tenements face East-West, and most have mansard roofs with flat tops), flat-plate panels would have to be mounted on angled frames facing South, or evacuated tubes could be used and laid flat on the roofs.

The energy surveys (carried out by Changeworks as another part of this project) showed a predominance of combi boilers in the Woodburn Terrace households. While it is sometimes possible to adapt these so they can work with solar water heating systems, this can be difficult and can also invalidate any warranty. It is anticipated that any solar system would also therefore require a new conventional condensing boiler and a relatively tall hot water cylinder, adding considerably to the overall costs. Space would be needed for the cylinder, however in many older tenement flats there are large cupboards etc. that could house such a cylinder.

The major complication arises from the multi-ownership of the building: consents, liabilities and maintenance responsibilities for both the panels and the roof would have to be clarified before proceeding with any works. Changeworks carried out such multiple-system, multi-floor installations with Lister Housing Co-operative at Lauriston Place, under their Renewable Heritage project: a detailed case study is available in Part C of Renewable Heritage: A guide to microgeneration in traditional and historic homes (Changeworks, 2009). However, they key difference in this project was that only one owner was involved (Lister Housing Co-operative owns all the tenements concerned).

2.2 Biomass stoves & boilers

Biomass boilers may be viable options for ground- or basement-floor properties in Woodburn Terrace. Stoves may be viable for lower and upper floors, although the logistics of carrying and storing fuel together with the flue / chimney liner costs could make this complicated. The current views of the Council's Environmental Health department may be an important factor in determining the viability of any biomass system in Edinburgh.

Biomass usually refers to wood, which can be burned in a variety of forms to generate both space heating and hot water. Biomass systems are closed systems, making them far more efficient than open fires (where up to 85% of the heat generated is lost up the chimney).

In domestic situations biomass can be burned either in a small stove or a larger boiler: a stove will commonly heat one room (sometimes more, depending on the internal layout and size of the stove), while a boiler can heat a whole property through a central heating system. Both systems can also provide hot water, although this is more common with boilers. Boilers are often sited outside in an outbuilding, which can then also house the fuel store.

Any biomass system needs a flue. Older properties are ideally suited to biomass stoves in this respect, as they generally have chimneys that can house a flue. However, flues and chimney liners are expensive, potentially prohibitively so for lower-floor properties which would need longer flues (as well as consent to run through upper properties). As boilers are often sited outside, the flue would be sited on the outbuilding.

Stoves could potentially be installed in flats on the upper floors, however the logistics of carrying fuel upstairs on a regular basis could make this problematic for some householders, as well as identifying a suitable space for a fuel store which would probably be needed (e.g. in the shared garden).

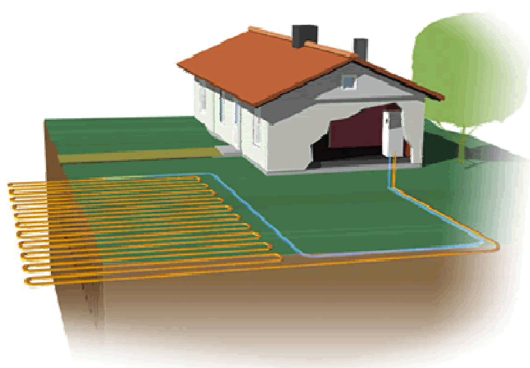
In terms of fuel type, logs or pellets would be the viable options for Woodburn Terrace in view of the typical property sizes. Pellets cost more but are considerably more ‘energy dense’, i.e. less fuel is needed to generate heat. This means that it lasts longer, needs to be topped up less often, requires less storage space and fewer deliveries are needed. However, logs are a cheaper and more basic option. Woodchips are also available, however these are best suited to larger systems, such as a large country house or a communal system heating multiple properties (this would be technically possible in Woodburn Terrace, however environmental health restrictions may limit this; see section 3.3 for more details).

Most biomass systems can be fully automated, so once they are full of fuel they will run by themselves until a top-up is required. Simpler log stoves are often not automated, however, increasing the manual element of these systems.

Any biomass system needs fuel, which needs a covered space to be stored. Garden areas could provide space for fuel storage, however mutual consent would be needed with the other tenement owners if any structure were needed to house the fuel. In the case of fuel being delivered in bulk, access is also a consideration: unless the delivery is manual, a lorry would need to be close enough to blow pellets into the fuel store through a pipe, or to unload 1-tonne bags on pallets.

2.3 Ground & air source heat pumps

Heat pumps may be viable for some properties in Woodburn Terrace, where steps have first been taken to ensure they are well insulated and draughtproofed. Ground and air source heat pumps would be technically viable for ground- and basement-floor properties. Some types of air source heat pump may be viable for top-floor properties where they could be housed in loft spaces.



Heat pumps take the heat from the ground, air or water and convert this into useful heat to provide space and / or water heating. A there is no water source nearby, ground and air source heat pumps are the most viable options for properties in Woodburn Terrace.

Good levels of insulation and airtightness are prerequisites for efficient performance of heat pumps. As such, most of the properties in Woodburn Terrace are likely to require improvements in these areas before considering installing a heat pump.

Ground source heat pumps comprise several elements: a ‘ground loop’ (a length of pipe running underground) which contains a liquid that absorbs heat from the ground; a heat pump which increases the temperature of this liquid before it reaches the home; and a distribution system (i.e. under-floor heating or radiators) to transport the heat around the property. The ground loop can be installed horizontally in shallow trenches, or vertically in boreholes: borehole installations are slightly more efficient as the deeper ground is less subject to seasonal temperature variations, and require less space, however they are generally more expensive to install. Considerable space is required for trench installations, making boreholes a more viable option for Woodburn Terrace. Boreholes could be drilled in garden areas (with mutual consent) assuming there is access space for a drilling rig, or through pavements at the front of properties assuming the required permissions are obtained from the Council.

Air source heat pumps are cheaper than ground source heat pumps, and simpler to install. The external unit comprises a large box housing a fan, similar to an air conditioning unit. This fan extracts heat from the air (which clearly is greater during the warmer seasons), and the heat pump then converts this into a useful space or water heating facility. Some models can be sited in lofts, making them a potential option for the top-floor properties in Woodburn Terrace. Air source heat pumps can be well suited for water heating in the summer months.

Exhaust air heat pumps also exist. These work in harmony with a mechanical ventilation system that extracts ‘stale’ air from a property and draws in fresh air: before the stale air is expelled it passes through a heat exchanger that extracts the heat from the air. Exhaust air heat pumps are best suited to smaller properties, and can often be hard to install in older properties due to ducting required. As such, they are often best suited to properties that already have ventilation ducts or that are being refurbished.

The heat pump itself is contained in a large box (similar to a refrigerator), and is generally sited inside a property. Like many white goods (e.g. refrigerators) and boilers, it does make some noise, however with good design this can be kept to a minimum, and internal suspension should minimise any vibrations. The noise from the external element of an air source heat pump can be more of an issue, as can the draught it creates: these issues make siting an important consideration to ensure they are not intrusive.

Ground source heat pumps are more efficient than air source heat pumps, as they are less subject to daily / seasonal temperature variations. The efficiency of an air source heat pump could drop off significantly in the winter months, making a back-up system (e.g. stove or boiler) a likely requirement.

When providing space heating, heat pumps work most efficiently with under-floor heating (under-floor heating requires a lower water temperature than radiators, and heat pumps become less efficient the hotter they have to heat the water). However, if fitting under-floor heating is considered too disruptive, larger radiators can be fitted that also run at lower temperatures than conventional radiators (however these can take up a considerable amount of room). Some older properties also have micro-bore heating pipework, which would need to be replaced with larger-bore pipework to be compatible with a heat pump.

On a technical level, one or more communal ground source heat pumps may be viable in Woodburn Terrace. These could be installed to serve multiple properties, providing space (and potentially also water) heating. However, as with any communal works the consents and legal responsibilities would need to be put in place, together with the local authority planning requirements that would be needed. (Changeworks developed such a proposal in 2009, to install 2 communal ground source heat pumps to serve a stone tenement comprising 9 flats in central Edinburgh. Full funding was awarded, however the project was unfortunately never taken forward due to subsequent owner complications. Nonetheless, the project proposal did demonstrate the feasibility of such an installation.)

2.4 Photovoltaics

On a technical level, photovoltaics are best suited to the top-floor properties in Woodburn Terrace, and to communal areas (e.g. to power stair or garden lighting).

Photovoltaic (PV) cells generate electricity from sunlight. Although most commonly used in panel form and mounted on roofs (either directly on top or recessed into the roof), they can be erected on short poles or angled frames on the ground, and incorporated into roof slates and glazing as well. A typical household PV array is likely to be at least 12m^2, and a common rule-of-thumb suggests a generation of around a third of annual electricity needs. (PV is one of the easier technologies to predict, i.e. the predicted output is generally fairly close to what is actually achieved.)

An array of reasonable size is needed to generate significant amounts of electricity (a typical domestic system might be around 12m^2 and generate around a third of annual electricity needs, although clearly this is very dependent on individual household energy use). This is therefore an important consideration for households with less siting space. In Woodburn Terrace, this is limited mainly to the roofs (although there is some garden space available, initial inspection suggests that this is largely overshadowed for periods of each day).

Where the electric wiring for a PV system would run through multiple properties or into the communal area of a tenement, appropriate fire-stopping measures would have to be included in the design.

2.5 Wind power

Woodburn Terrace is poorly suited to wind power. The fundamental reason for this is the street's urban setting, however a range of other factors are also outlined below.

Wind power is harnessed most effectively in rural areas, where there is more likely to be unimpeded wind and more space to site turbines. Smooth, unrestricted airflow is critical for good turbine performance, making open spaces such as smooth hills ideal sites. Built-up areas have too many obstacles for wind to pass through without being disrupted, and this turbulence can severely affect turbine performance. Recent research and monitoring[2] are increasingly showing wind turbines to be non-viable for urban environments.

Wind turbines come in many different sizes and styles. As well as the conventional mast-mounted 'horizontal access' turbines (i.e. the wind passes horizontally past the turbine blades), small building-mounted turbines exist, as well as 'vertical axis' turbines that are more cylindrical in shape (the Botanic Gardens in Edinburgh has a vertical-axis turbine on the roof of the new entrance building). Building-mounted turbines are generally too small to be effective, and although vertical-axis turbines are sometimes promoted for urban areas (due to their increased ability to function in turbulent conditions) their performance cannot be guaranteed.

[2] A good example is Location location location: the Energy Saving Trust's field trial report on domestic wind turbines (Energy saving Trust, 2009)

As a rule of thumb, larger turbines are generally more efficient than smaller turbines and generate significantly more power. Again, it can be difficult and often impractical to site large mast-mounted turbines in urban areas.

Turbines need minimum wind speeds to function effectively (5-6 m/s is often cited as the minimum[3]). Although the UK Government's online wind speed estimation tool[4] shows Woodburn Terrace as having an average wind speed of 5.6 m/s (at 10 metres above ground level), this is not a very accurate tool as it only estimates each 1 km^2 (so the estimate for Woodburn Terrace is actually for the entire km^2 that it sits in, despite the considerable geographic and building variations). In addition, wind speeds in urban areas can often be considerably overestimated[5], for the reasons mentioned above.

Finally, wind speed also increases with height, making large turbines on tall masts the most effective option; such turbines are impractical for Woodburn Terrace.

2.6 Hydro power

There is no suitable water source in the area, making hydro power an unsuitable option for Woodburn Terrace.

2.7 Communal / District schemes

Communal heating and power schemes, using a local generation point to provide heat and / or power to a group of buildings, are becoming an area of increasing interest. They can provide high efficiencies and relatively low emissions, and avoid the need for multiple small systems in each household. However, a major retrofit system would be a considerable undertaking, particularly in older multi-ownership properties such as tenements.

A communal heat and / or power system would be most viable when providing a combined service to Woodburn Terrace and adjacent non-domestic buildings, such as the Astley Ainsley hospital which could provide an 'anchor point' for the power load. Installation would be a significant construction process, if each property were to be connected up to a communal system.

Planning such a project would be a major undertaking, requiring community consultation and 'buy in', and working with the Council (who currently have no plans for such an installation in this area of Edinburgh). In the longer term the Astley Ainsley hospital may also be sold off for private development (this has already started, albeit in a small way), which could change the dynamics and applicability of a communal energy scheme.

Such installations are feasible, and potentially highly beneficial, but the scale of such an undertaking may well be overwhelming for what is a busy and relatively small community, unless the Council were to buy into the scheme and lead its development.

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[3] Renewable energy sources in rural environments (Energy Saving Trust, 2004)
[4] www.bwea.com/noabl/index.html
[5] Micro wind turbines in the UK domestic sector (Ahadzi *et al*, 2007)

3 Policy and planning considerations

Microgeneration systems are becoming increasingly widespread, however in many instances the planning and / or building standards departments may need to be involved. This could be through informal meetings and negotiations, or formal permissions may be needed. The main permissions that could be required are planning permission, listed building consent and building warrants.

Consent	Summary	Department to contact
Planning permission	Often needed for work that would affect the appearance of a building or area. **N.B.** Many microgeneration systems are now exempt from planning permission in certain circumstances; see *Permitted Development* below.	Planning
Listed building consent	Generally needed for work that could affect the appearance or fabric of a listed building or its grounds.	Planning
Building warrant	Sometimes needed to ensure that any planned work meets Building Standards, and in particular satisfies health and safety requirements.	Building Control

Whether or not a proposed installation requires formal consent, it is always advisable to contact the local authority planning department and make sure they have no issues with the proposed works. Where formal consent is needed, the Council may also require proof of neighbour notification for the proposed works. More information on the priorities for planning teams can be found in Sustainable energy in the built environment: best practice for Scottish planners (EST, 2010).

Planning permission and building warrants both carry a charge, which could be added to by the need to employ architectural or other technical services to help prepare the applications.

More details on the Council's planning and building control procedures can be found on the relevant page of their website (click here). The Planning department can be contacted on 0131 529 3550; the Building Standards department can be contacted on 0131 529 4655.

3.1 Permitted development

Some microgeneration systems are covered by 'Permitted Development' legislation, meaning that they can be installed without having to apply for planning permission (N.B. other permissions may still be required, however). This can make installations much easier, faster and cheaper. **Permitted development does not apply to listed buildings, but can sometimes apply to buildings in conservation areas.** If in doubt, it is always advisable to check with the planning department.

If a proposed installation is not covered by Permitted Development, this does not mean that permission will not be granted. It does however mean that an application for planning permission must be submitted to the planning department.

The current Permitted Development criteria for all technologies are covered in Scottish Statutory Instrument No. 34 (Scottish Government, 2009), however current consultation may change the extent of these criteria in the near future (see below). Below is a brief summary of Permitted Development for those technologies best suited for Woodburn Terrace:

- **Solar panels** (water and electric) are permitted as long as the panels meet certain criteria (e.g. they must not protrude more than a set amount about a roof). They are permitted in conservation areas (such as Woodburn Terrace) as long as they are not on the principal elevation or visible from the road, and are as discreet as is reasonably possible.

- **Biomass** systems are permitted as long as the flue does not protrude more than 1m above the highest point of the roof, and as long as the flue is not in an Air Quality Management Area (see below). Again, they are permitted in conservation areas as long as the flue is not on the principal elevation or visible from the road.

- **Ground source heat pumps** are permitted with no restrictions.

- **Air source heat pumps** are not covered by permitted development due to concerns over noise levels; however this may change in the near future (see below).

These Permitted Development Rights are currently under consultation, with a view to extending the rights for air source heat pumps and micro wind turbines. This consultation is still underway, however it is likely that these technologies will be judged more on noise levels than distance from other properties.

3.2 Conservation areas / listed buildings

None of the buildings in Woodburn Terrace is listed, however the street does lie in the Morningside conservation area (see map overleaf). This means that the properties may be subject to certain constraints in terms of microgeneration installations. This is mentioned above in relation to solar panels and biomass, however it is always best to confirm with the planning department before proceeding with any works in a conservation area.

Solar panels would be best-sited on the flat roofs. It is doubtful whether these would be visible from surrounding streets of buildings; as such, this should not present a problem from a planning perspective.

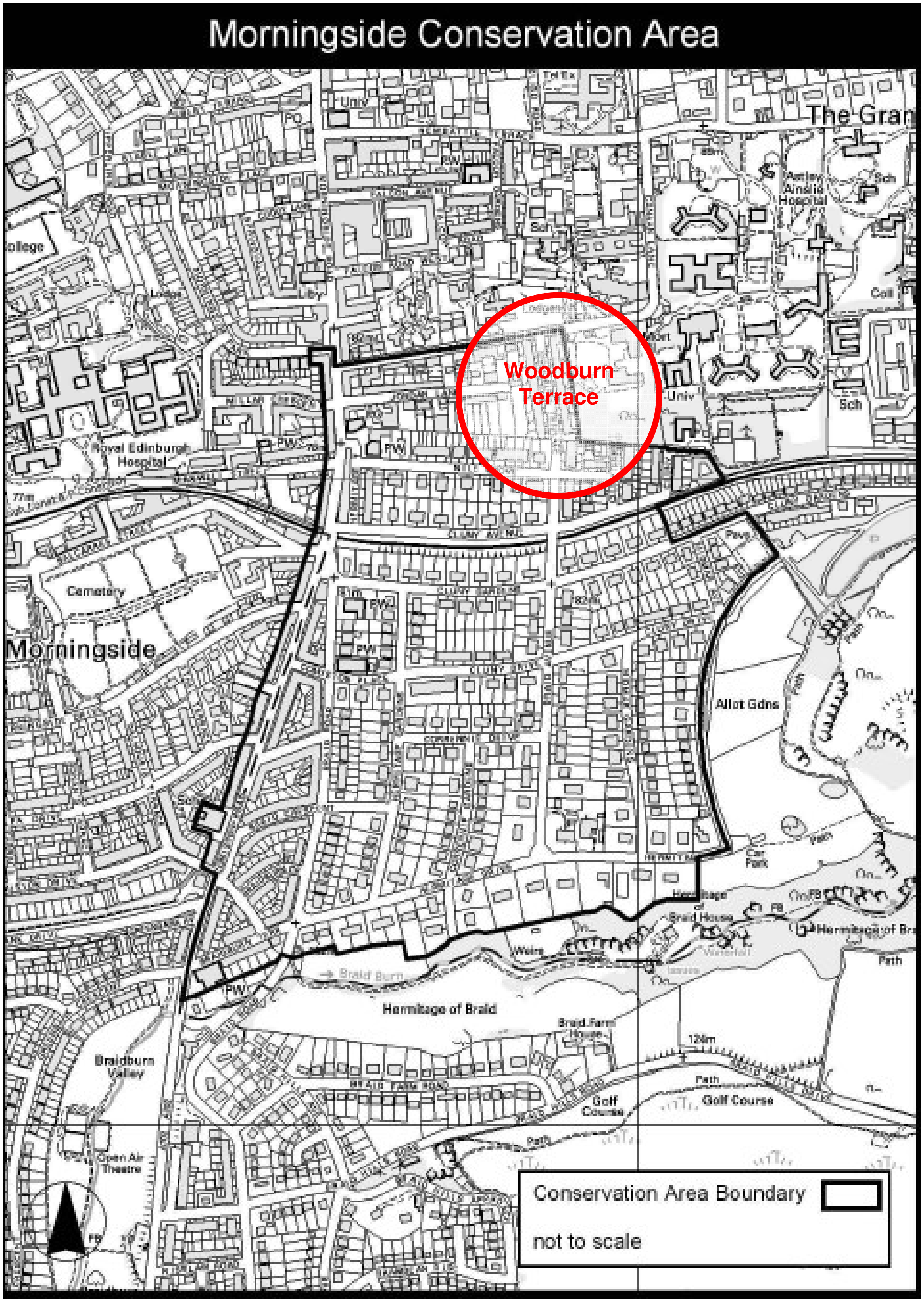


Figure 1 Morningside conservation area boundary (© The City Of Edinburgh Council, 2006)

3.3 Biomass in Edinburgh

Biomass systems can be harder to install in some urban areas. This is due to concerns raised over the potential health risk of certain particulates emitted by burning biomass. Despite recent research into this issue (commissioned by the Scottish Government) that found no particular cause for concern in either Edinburgh or Dundee[6], some local authority Environmental Health departments are unfortunately taking a highly precautionary approach that could largely ban biomass systems in their urban areas.

Currently, air quality is managed in two main ways:

- Biomass systems in Smoke Control Areas (of which Edinburgh is one) must comply with the Clean Air Act. This poses no particular difficulty, as there are many such systems available.

- If an area is designated an Air Quality Management Area (AQMA), local authority Environmental Health departments are likely to advise against biomass installations. **However, these departments can only act on installations that enter the planning system, so if a system does not need any formal consents then it cannot be advised against.**

Currently, there are two AQMAs in Edinburgh, encompassing a very small area of the city. However, it is possible that Edinburgh may follow Dundee's lead and make the whole city an Air Quality Management Area, which would effectively ban domestic biomass systems wherever planning permission would be needed (unless costly abatement technologies could be added into the systems to satisfy the Environmental Health department).

The City Of Edinburgh Council is due to publish a planning policy statement in September that should clarify their position on this matter. This statement is likely to make abatement technologies a requirement for small biomass systems, however these would have to satisfy the Environmental Health department and it is unclear whether they deem current abatement technologies to be sufficient.

The effect of the above is that small biomass systems (e.g. stoves, and possibly boilers in some cases) could still be installed where no formal consents are required. As planning permission is only generally required for new visible flues or outbuildings, in reality the most viable systems will be stoves in older properties where the flue can be housed inside an existing chimney (although this then presents an extra challenge in terms of cost), or boiler systems where the flue or any outbuilding would not need formal permissions.

[6] Measurement and modelling of fine particulate (PM_{10} & PM_{22}) emissions from wood-burning biomass boilers (AEA Energy & Environment, 2008)

4 Installation and usage considerations

This section covers any logistical aspects particular to Woodburn Terrace or the individual technologies.

Multi-occupancy buildings (e.g. tenements) always present more of a challenge than single-occupancy buildings (e.g. houses), and this can be exacerbated where there is also multiple ownership, as in Woodburn Terrace. A whole-building approach or communal heat or power installation can be a more comprehensive approach, however this requires mutual consents and a significant level of communal working.

Timescales for installing renewable energy systems should not be under-estimated, particularly during the planning stages and where the works are dependent on grants or loans. Time spent planning and researching in the early stages is always a good investment, however if negotiations or formal permissions are required these can take some time (c.2 months). The Renewable Heritage multi-floor SWH installations took a year to plan and secure permissions and feasibility studies, and several months to install; individual systems would be significantly quicker, however several months should be allowed.

4.1 Solar water heating

Installation of SHW systems is fairly straightforward in most cases, as it is now a well-established technology in Scotland.

Roof-mounted SHW panels would require consents from the other property owners in the tenement stair, as the roof is part-owned by all owners. Liabilities and maintenance responsibilities would also need to be clarified (e.g. should the roof need re-slating or repairing once the panels are installed, any additional costs or issues would be the responsibility of the panel owners). These would need to be clearly established, to cover future owners in the case of a change in ownership.

Flat-plate panels may need to be craned onto the roofs at Woodburn Terrace, if the loft hatches are too small for them to fit through; alternatively the loft hatch could be enlarged (both options would attract additional costs). Evacuated tube systems are often modular, so these could easily be taken apart and passed through a small loft hatch.

Combi boilers would in all likelihood need to be replaced with conventional condensing boilers. A hot water cylinder would also be needed, which could result in less storage space than previously.

If a SHW system is installed, steps should be taken to maximise its use: a SHW system works most efficiently when the hot water it generates is drained from the tank, and the more solar-heated water is used, the less boiler-heated water is needed. Obvious measures include changing any electric showers to mains-fed showers (a relatively cheap switch), and only using the boiler as a top-up when necessary (changing the timer settings is an easy way to help with this). Hot-feed washing machines and dishwashers could also be considered, although these can be hard to find.

4.2 Biomass

For stoves or boilers installed inside the property, the flue would be best sited within the original chimney. Flues and chimney liners can be very expensive, and the longer the flue the greater the cost will be. Consent and liabilities would also be needed if the flue would pass through other properties.

Adequate ventilation will be needed in the room that houses the stove or boiler.

A covered space would be needed for a fuel store. Any biomass system also requires a manual element: even if it is fully-automated it will need to be topped up with fuel and cleaned of ash periodically. Logs generally require more manual input than pellets, and any system installed on the upper floors would require regular carrying of fuel up the stairs. These factors make biomass systems in Woodburn Terrace best-suited for those who enjoy this manual element.

Any biomass system installed in Woodburn Terrace would have to meet the requirements of the Clean Air Act; a list of approved systems for Scotland can be found on Defra's Smoke Control website (click here). Manufacturers should also be able to advise further on this.

4.3 Heat pumps

If installing a ground source heat pump in a communal garden, again consent would be needed from all owners, although it should be stressed that the disruption is temporary. For borehole installations there would also need to be sufficient space for a drilling rig to access the garden. Boreholes could also be drilled through the pavement at the front of the tenements (this has been done successfully in Edinburgh's New Town), although permission would have to be obtained from the Council beforehand.

Air source heat pumps create some noise and draught, so careful siting is needed to make sure that this would not interfere with anyone using the space nearby. In top-floor properties, some models could be installed in the loft spaces, although the strength of the ceiling would have to be checked first. It may also be possible to install some models on the roofs of the tenements.

If using a heat pump for space heating, the most efficient distribution system is under-floor heating. This is possible with timber floors but requires some temporary upheaval. Larger radiators are also an option, however these would take up more space than conventional radiators.

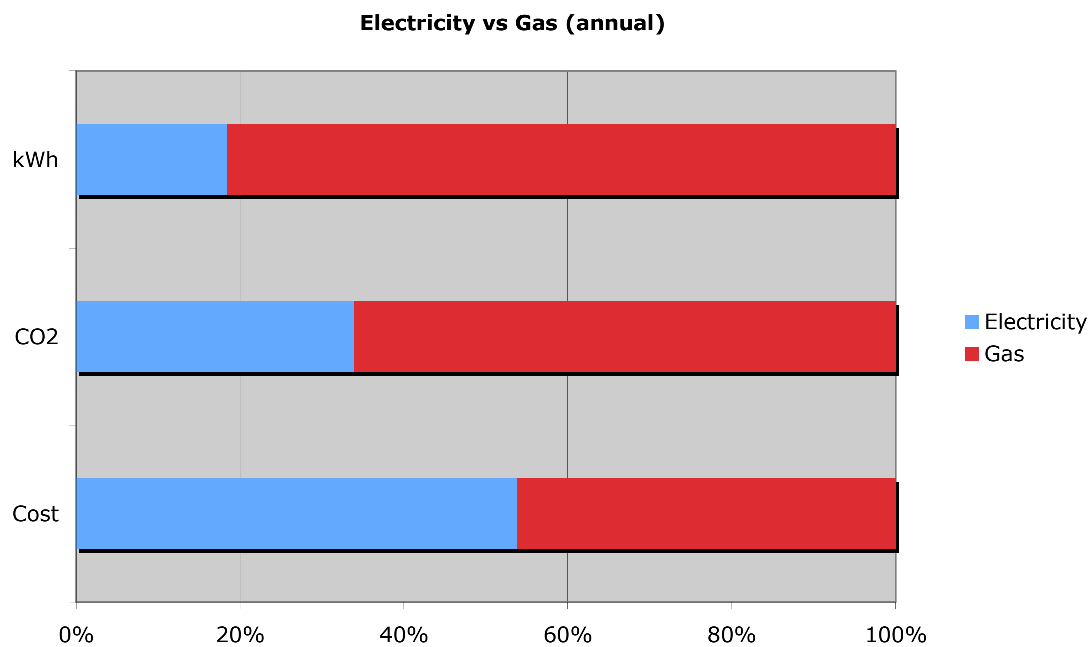
The critical thing for any heat pump installation for space heating is that the property in question should be well-insulate and relatively airtight in order for the heat pump to work efficiently. If this is not ensured, the heat pump will have to work a lot harder than it otherwise would, making it less efficient and more costly to run. The behaviour of the householders can have the same effect: if windows and doors are opened frequently or left open, this negates the insulation and airtightness of the property

Sizing the heat pump correctly is also important, although an installer should be able to do this. Heat pumps should not be over-sized, or again they will create needless additional costs.

4.4 Photovoltaics

Compared with solar water heating, PV panels require far more space (generally 12m^2 or more). As the roofs are the most viable site for PV in Woodburn Terrace, this will limit the number of systems that can be installed. This makes PV best-suited to top-floor properties, although it could also be used to power stair or garden lighting (although negotiations with te Council would be necessary as they currently manage stair lighting). Any roof installations would require the same considerations as solar water heating.

Electricity accounts for around 20% of energy used in a typical property on the gas network. However, its high price and poor environmental credentials mean that it accounts for considerably more in terms of cost and CO_2 emissions. This is illustrated in the below example, taken from the actual energy use and bills[7] of a typical Victorian tenement flat.



	Cost	CO2	kWh
Gas	£ 227	1,292	6,799
Electricity	£ 265	663	1,540

This makes it important to combine any PV installation with a assessment of electricity use in the home, to ensure that as little electricity is used as possible; this will maximise the impact of the PV system. Low-energy lighting and efficient appliances are obvious solutions, and can make a considerable difference to the electricity consumption of a property. As well as CFL lightbulbs, LED spotlights are now available to cater for the current trend for multiple spotlights and use extremely low amounts of energy. Changing from an inefficient plasma screen television to an efficient LCD screen television can save nearly £100 per year in

[7] These electricity costs are slightly higher than average, as the electricity provider provides 100% renewable electricity which currently comes at a premium.

running costs[8]; the most efficient desktop PC can cost just £2 per year to run, the least can cost £77[9]. Savings of a similar proportion can be realised for many other appliances.

Any electricity-generating technology either needs to be connected to the electricity grid or have a storage facility (a battery bank) and back-up generator (e.g. a diesel generator). Woodburn Terrace is connected to the grid, which means that if the electricity generated by the PV system is not used immediately it can be exported to the grid (for which the householder is currently paid 3p per kWh). The household then buys back the electricity when they need it (although they will pay more for this than the supplier paid for their home-grown electricity). To make the most of solar electricity, therefore, it should be used as it generated, i.e. during the daytime. This is not practical for many people as they are out at work during the weekdays, however if washing machines / dishwashers etc. can be run during the day then this will minimise the amount of higher-cost electricity that needs to be purchased from the grid.

4.5 Ongoing logistics

It is always advisable to install a clear, easy-to-understand display in a prominent position in the home once a renewable energy generator has been installed. This shows the occupants how the system is performing, and provides a continual and valuable reminder of any behavioural change that may be needed to get the most out of the system. It also helps promote renewable energy to any visitors.

In the early stages following installation, using the system may require a bit more thought than previously. However, with familiarity no more effort should be involved than when running a gas central heating system (other than the manual element of a biomass system); it is more a question of timing when things are done.

Many people who install microgeneration systems plan them as an investment over time, and will remain in their property for some years to recoup the benefits. However, when moving house, it is important to consider that fact that the new property owner will be inheriting an energy system they may not be familiar with. Leaving copies of all user manuals and other useful guidance will help them become familiar with the new system.

[8] www.sust-it.net
[9] *Ibid*

5 Financial considerations

Fossil fuel costs have been steadily rising in recent years, and the average household now spends well over £1,000 on heating and powering their home. This trend is predicted to continue, with some forecasts of energy bills doubling in a matter of years. These costs are yet another reason to make homes as efficient as they can be.

Regularly updated cost savings, CO_2 savings, and payback periods for all the main renewable energy systems are available from the Energy Saving Trust, although it is important to note that these are generic and constantly changing, and can be drastically affected by different property types and behaviour patterns. However, they provide a useful indicator for anyone considering a range of improvement options.

5.1 Capital costs

Costs for microgeneration systems can vary widely, depending on the individual property and system, and current market forces. The following figures are indicative only.

System	Indicative cost	*Notes*
Solar water heating	£4,000 - £5,000	• *Assuming 3-5m² panel array & replacement hot water cylinder* • *Boiler replacement (combi to conventional) will add to cost*
Biomass stove	£2,500 - £3,000 (stove only); could be up to £6,000 in total	• *Assume 6-12 kW stove* • *(See below note on flue costs)* • *(See below note on fuel costs)*
Biomass boiler	£3,000 - £7,000 (stove only); could be up to £12k total	• *Assume 8-20 kW boiler* • *Flue, plumbing, outbuilding & radiators will add to cost* • *N.B. Longer flues / chimney liners (that could be needed for tenement installations) can be very costly* • *Fuel: typical annual needs are c.4 tonnes for whole-house boiler system; pellets currently cost c.£200 per tonne (delivered)*
Ground source heat pump	£11,000 (trench) £14,000 (borehole)	• *These costs are very variable, and could increase considerably with complex installations* • *Distribution system (under-floor heating or radiators, + possibly pipework) will add to cost if not already present*

Air source heat pump	£7,000 - £10,000	• *Cheaper than ground source heat pump as no groundworks needed*
Photovoltaic array	Min. £9,000	• *Assuming 1.5kWp system (12m^2); many systems are larger than this* • *Larger arrays achieve economies of scale*

Additional costs can also be attracted by planning permission and building warrants, and if professional services are needed (e.g. architect / engineer / renewable energy consultant) these can add considerably to these costs.

5.2 Running costs

Microgeneration systems vary a lot in how much they cost to run, depending on size, efficiency, suitability of the installation, how efficiently they are used, and so on. As such, any predictions of running costs should be regarded as indicative only. Detailed savings predictions are provided in section 6; the following text provides more of an overview into the proportional savings that the different technologies could make.

The majority of energy in a home is used for space heating (around 60%); water heating accounts for around 23% and the rest (17%) is used for lighting and appliances. Woodburn Terrace is on the gas network, so all space and water needs are met by gas at present. Microgeneration systems displace fossil fuel use: the fossil fuel being displaced can make a big difference to the savings made (e.g. electricity is a lot more expensive than gas, so displacing electricity will generate far higher savings). As the Woodburn Terrace flats mainly use gas, their savings will not be as high as, for example, a rural electric-run property.

Solar water heating is estimated to provide around half the annual hot water needs of a household. As such, it may not make a huge saving on annual bills (EST suggests around £50 for a gas property), however when used efficiently this figure could be higher.

Using **biomass** systems may not make particular cost savings, as unlike some other microgeneration systems they still require fuel to run. Biomass fuel costs are currently similar to gas costs, perhaps marginally more. However, prices for both fluctuate regularly, and in the long term fossil fuel prices are set to rise considerably, meaning that biomass systems will start making greater cost savings. (The real benefit of biomass is its environmental savings; see sections 2.2 & 6 for more details).

Heat pumps, like biomass, need energy to run; however, they generate a lot more energy than they use. They run on electricity, which means that they make the greatest cost savings in off-gas properties: replacing a gas-fuelled heating system with an electric heat pump may not make any particular cost (or CO_2) savings, as the lower energy consumption is offset by the higher unit cost (and higher associated CO_2 emissions). However, if the gas heating system is very old and inefficient, and the heat pump system is set up very efficiently (e.g. combined with under-floor heating, not oversized, and installed in a well-insulated property), savings could be made. Larger communal heat pumps could also make greater cost savings if they replace multiple gas-fuelled systems.

The cost of running a heat pump is largely dependent on the cost of the electricity. It is important to use a low-rate tariff with a heat pump (e.g. Economy 10), as they run during the day when peak-rate electricity is very expensive. Another way of reducing the running costs is to use electricity from a free renewable source (i.e. photovoltaics).

Photovoltaics are estimated to provide around a third of a typical home's electricity needs (although clearly this proportion will be higher with larger systems). Al electricity is expensive, this could make a significant saving on electricity bills.

It is important to note that **all the above cost savings can be considerably increased** as a result of recent financial incentive schemes set up by the Government, which pay householders for generating their own energy (see section 5.3.1 for details). Savings will also become greater as fossil fuel prices rise.

5.3 Financial support

Unfortunately many of the long-standing grant support programmes have now come to a close. The Low Carbon Buildings Programme, Home Renewables Grants, and home loans have all been closed (although the UK Government's 'Green Deal' budget proposal would see loans of up to £6,500 extended to up to 14 million households, from later in 2012). Some householders may be eligible for funding through the Energy Assistance Package, which does fund heat pumps, but this is unlikely in an area connected to the gas mains.

For communal systems, Community And Renewable Energy Scotland (CARES) grants are available, although these are becoming harder to access and ongoing funding is uncertain.

This lack of funding for the up-front costs can make installing microgeneration systems more of a challenge, particularly for those on lower incomes. However, the Government has instead introduced schemes that pay home energy generators for the energy they produce, which should enable such householders to more than make back the capital costs over the lifespan of the system. These payback schemes are outlined in the following section.

5.3.1 Feed In Tariff & Renewable Heat Incentive

In April 2010 the Government launched the Feed In Tariff, a scheme which pays any generator of renewable electricity (i.e. photovoltaics, wind or hydro) for all the energy they generate. In April 2011, a similar scheme is planned for renewable heat generation, called the Renewable Heat Incentive (although the Government is still consulting on this).

Full details are available at the above links, however the below tables provide a summary of the key features of each scheme:

Feed In Tariff
• Paid according to how much electricity is generated • A photovoltaic system (>4kW) retrofitted to an existing building will be paid **41.3p** per kWh for 25 years (this rate decreases slightly over the first 3 years, but not significantly) • (The tariffs for hydro and wind systems are not included in this report as they are not viable technologies for Woodburn Terrace) • Any system installed after 15 July 2009 is eligible

Renewable Heat Incentive
• Deemed (i.e. payment is based on predicted rather than actual energy generation) • A solar water heating system (>20kW) will be paid **18p** per kWh for 20 years • A biomass system (>45kW) will be paid **9p** per kWh for 15 years • A ground source heat pump system (>45kW) will be paid **7p** per kWh for 23 years • An air source heat pump system (>45kW) will be paid **7.5p** per kWh for 18 years • Any system installed after 15 July 2009 is eligible • *(The above details are subject to ongoing Government consultation)*

Owners of electricity-generating systems can also sell their electricity to the grid, if they have a grid connection and do not use all the energy they generate (or generate energy at times when they cannot use it). This is known as an Export Tariff; the current rate is **3p** per kWh.

These schemes mean that, if a householder can find the up-front costs to pay for the installation of microgeneration systems, they should more than recoup these costs over the lifetime of the system, and could ultimately save significant amounts of money.

5.4 Payback periods

It is important to note that payback periods are subject to constant change, and as such they should not be relied upon for accurate predictions. Payback periods are affected by many variables including the system's size, suitability, installation, efficiency and lifespan; the fossil fuel being displaced; user behaviour; fossil fuel costs; and financial incentives. The introduction of the Feed In Tariff and Renewable Heat Incentive will make a considerable difference to payback periods.

Savings are greater where a microgeneration system replaces an expensive fossil fuel (e.g. electricity, LPG). Woodburn Terrace is on mains gas, which (fortunately or unfortunately, depending on perspective) is still relatively cheap; this makes it harder to make significant financial or environmental savings when replacing gas with electricity (i.e. heat pump).

The worked example below shows the possible payback period for an SWH system:

SOLAR WATER HEATING PAYBACK		**Replacing gas**	**Replacing electricity**	**Assumptions**
Capital costs	Installation - 30% grant	£5,000 £1,500 £3,500	£5,000 £1,500 £3,500	*4m^2 installation* *Access to EST grant (now stopped)*
Annual saving	Generation (kWh) x unit cost	1,800 £0.04 £72	1,800 £0.07 £126	*Annual generation: 450kWh/m^2/yr* *Gas 4p / electricity 7p (off-peak)*
Annual income	Generation (kWh) x unit income (deemed)	1,800 £0.18 £324	1,800 £0.18 £324	*Renewable Heat Incentive*
Annual payback	Saving + Income	£396	£450	
Payback period	With grant (years)	**8.8 years**	**7.8 years**	*Static fossil fuel costs / static RHI income / average performance*
	Without grant (years	**12.6 years**	**11.1 years**	

As noted previously, these figures are dependent on many variables. Putting up the unit price of gas to 10p, for, example, brings the payback periods down under 10 years even without grant assistance for the capital costs. Carrying out the same process for a photovoltaic system suggests a payback period of 14 years without a grant, but increasing the unit cost again brings this down significantly.

Similar calculations from the Energy Agency[10] (for actual installations) show payback periods of **15 years** for a 8m^2 PV system, **9 years** for an air source heat pump (12 kW), and **8 years** for a communal biomass system (100 kW, serving 20 houses).

Wind and hydro systems can generate even shorter payback periods, however these are not included in this report as they are not deemed viable for Woodburn Terrace.

Bearing in mind that all microgeneration systems should last considerably longer than the payback periods given above, and that payback periods will continue to fall as fossil fuel prices rise, over the lifetime of the system any microgeneration system should save the householder significant amounts of money and actually generate an ongoing income.

[10] *Case studies of FIT-eligible renewable energy systems* presentation at Scottish Heca Officers Network (SHON) Forum, April 2010 (Energy Agency)

6 Cost and CO_2 savings

The microgeneration systems considered feasible for Woodburn Terrace were modelled by Changeworks using NHER software. They do not take account of the additional financial benefits arising from the Feed In Tariff ad Renewable Heat Incentive, which could make a considerable difference to the actual financial savings generated.

It is important to recognise that these figures are only guidelines, and computer-generated modelling will never provide a fully accurate picture of cost or CO_2 savings[11]. The figures should therefore be regarded as indicative rather than specific. (CO_2 savings may to some extent be increased by selecting a credible green tariff or green energy provider for standard gas and electricity, although the credentials need investigation to ensure they are robust.)

Systems were modelled in a range of property types (ground-, mid- and top-floor flats):

- Solar water heating was modelling in all property types, to cater for a Renewable Heritage-style multi-system installation
- Biomass stoves were modelled in all property types, to cater for those willing to carry fuel to upper floors
- Air source heat pumps were modelled in ground- and top-floor flats, on the assumption that a unit could be installed in a loft space
- Photovoltaic arrays were modelled in top-floor flats only, as the array size would be likely to limit the roof space to 1-2 arrays only

Predictions were calculated on the assumption that any microgeneration installation would be combined with other energy efficiency measures. The predictions generated are therefore not as straightforward as standard modelling (that would simply give the predicted impact for a system installed in an otherwise unimproved property). However, best practice dictates that any microgeneration installation should be preceded by improvements in energy efficiency; so these predictions perhaps provide a more realistic and accurate picture of the systems' potential impact.

It should also be made clear that cumulative impacts are always lower than stand-alone impacts: i.e. loft insulation alone would make a greater saving to an unimproved property than if it were added after the installation of (for example) a new boiler, double glazing and wall insulation. As such, some of the predicted impacts below are not as great as might have been imagined (most savings predictions are calculated on a stand-alone basis).

The results are shown below. The first table gives the total impact of the microgeneration systems installed alongside other energy-saving measures; the second table breaks this down to show the impact that the microgeneration system alone makes to this total.

[11] Changeworks has carried out detailed assessments of the accuracy of industry-standard energy modelling tools. Two comprehensive reports are available from Historic Scotland's website: Technical Paper 8: Energy modelling of the Garden Bothy, Dumfries House (2010) and Technical Paper 3: Energy modelling analysis of a traditionally built Scottish tenement flat (2008).

Table 1: Cumulative savings (combined saving made by all improvements)					
System	Property[12]	Installed with:	Predicted savings (cumulative)		
			Running costs (£)	Energy (kWh)	CO_2 (tonnes)
SWH	Ground floor	Boiler + secondary glazing (50%) + floor insulation	£511 (24%)	15,779 (32%)	3.1 (29%)
	Mid floor	Secondary glazing + room thermostat + low-energy lighting	£298 (17%)	7,806 (22%)	1.6 (19%)
	Top floor	Loft insulation + secondary glazing (50%) + door draughtproofing + low-energy lighting	£710 (39%)	20,224 (51%)	4.1 (45%)
Biomass stove	Ground floor	Boiler + secondary glazing (50%) + floor insulation	£558 (27%)	18,946 (39%)	4.1 (38%)
	Mid floor	Secondary glazing + room thermostat + low-energy lighting	£451 (26%)	13,612 (38%)	3.0 (36%)
	Top floor	Loft insulation + secondary glazing (50%) + door draughtproofing + low-energy lighting	£680 (38%)	20,168 (50%)	4.3 (48%)
Biomass boiler	Ground floor	Boiler + secondary glazing (50%) + floor insulation	£241 (12%)	18,724 (38%)	7.9 (74%)
GSHP	Ground floor	Boiler + secondary glazing (50%) + floor insulation	£943 (45%)	35,642 (73%)	5.1 (48%)
ASHP	Ground floor	Boiler + secondary glazing (50%) + floor insulation	£839 (40%)	33,780 (69%)	4.3 (40%)
	Top floor	Loft insulation + secondary glazing (50%) + door draughtproofing + low-energy lighting	£816 (45%)	28,836 (72%)	4.2 (47%)
PV	Top floor	Loft insulation + secondary glazing (50%) + door draughtproofing + low-energy lighting	£847 (54%)	21,252 (62%)	4.6 (59%)

Cumulative savings can be misleading: for example, the greatest cost saving is achieved by the PV system, however this is likely to be largely due to the addition of loft insulation, which has a notoriously high saving potential. The greatest energy savings are made by heat pumps, but these too are combined with high-saving measures such as new boilers, floor insulation and loft insulation. The greatest CO_2 savings are achieved by the biomass boiler, as this provides a fully carbon-neutral heating fuel (the remaining emissions will be generated by the electricity used for lighting and appliances).

The proportional impact of the microgeneration system alone is shown in Table 2 (see below).

[12] The following properties (previously surveyed for TES by Changeworks) were used for modelling the systems: Ground-floor flat = 29 Woodburn Terrace; Mid-floor flat = 36 (2F1) Woodburn Terrace; Top-floor flat = 9 (3F2) Woodburn Terrace.

Table 2: Stand-alone savings (saving made by microgeneration system when installed alongside other improvements)					
System	**Property**	**Installed with:**	**Predicted savings (stand-alone contribution)**		
			Running costs (£)	**Energy (kWh)**	**CO_2 (tonnes)**
SWH	Ground floor	Boiler + secondary glazing (50%) + floor insulation	£19 (1%)	611 (2%)	0.1 (2%)
	Mid floor	Secondary glazing + room thermostat + low-energy lighting	£27 (2%)	833 (3%)	0.2 (2%)
	Top floor	Loft insulation + secondary glazing (50%) + door draughtproofing + low-energy lighting	£20 (2%)	611 (3%)	0.1 (2%)
Biomass stove	Ground floor	Boiler + secondary glazing (50%) + floor insulation	£66 (4%)	3,778 (1%)	1.1 (15%)
	Mid floor	Secondary glazing + room thermostat + low-energy lighting	£180 (12%)	6,639 (23%)	1.5 (22%)
	Top floor	Loft insulation + secondary glazing (50%) + door draughtproofing + low-energy lighting	-£10 (-1%)	556 (3%)	0.3 (7%)
Biomass boiler	Ground floor	Boiler + secondary glazing (50%) + floor insulation	-£251 (-16%)	3,556 (11%)	5.0 (64%)
GSHP	Ground floor	Boiler + secondary glazing (50%) + floor insulation	£451 (28%)	20,474 (61%)	2.1 (28%)
ASHP	Ground floor	Boiler + secondary glazing (50%) + floor insulation	£347 (22%)	18,163 (55%)	1.4 (17%)
	Top floor	Loft insulation + secondary glazing (50%) + door draughtproofing + low-energy lighting	£126 (11%)	9,223 (45%)	0.3 (6%)
PV	Top floor	Loft insulation + secondary glazing (50%) + door draughtproofing + low-energy lighting	£157 (14%)	1,639 (8%)	0.7 (13%)

The heat pumps show the highest predicted running cost savings. However, the accuracy of the NHER assumptions could be questioned, as running costs for a gas central heating system and electric heat pump are unlikely to differ substantially. PV also shows a reasonable cost saving. Biomass is shown to cost more than gas central heating, however again this could be questioned as anecdotal evidence suggests these costs are comparable.

In terms of energy savings, the heat pumps again show the highest predicted saving; this is based on the fact they generate more energy than they use. They also comprise the new boiler, which some of the other modelled systems do not (boilers make a big impact in predicted savings).

The greatest CO_2 savings come from the biomass systems, which reflects their nearly carbon neutral status. The heat pumps also show significant savings, although again these could be questioned, for the same reason as those given above in relation to cost savings. PV shows a reasonable CO_2 saving, although this could be improved or negated in reality by careful or careless electricity use.

Savings from SWH are modest in all cases.

7 Conclusions

Solar water heating and photovoltaics are both viable forms of microgeneration for households in Woodburn Terrace. However, the potential complications of neighbour consents and installation could make any installation a complex process, due to the tenemental nature of the properties. Photovoltaics are probably limited to top-floor properties only, due to the array size needed; solar water heating could potentially be run down the buildings to lower-floor flats but this increases the complexity further.

Ground and air source heat pumps are technically viable, and would require minimal neighbour consents, making them logistically simpler to install. Installing ground source heat pumps is a messy but temporary affair. However, the negligible cost and carbon savings that would be achieved by replacing a gas central heating system with an electric heat pump pose a serious question as to the financial or environmental viability of any such installation.

Biomass too has potential, and would make the greatest CO_2 savings. Unfortunately the restrictions likely to put in place by the Planning and Environmental Health departments may make these significantly harder to install. Installations that do not require formal permission will be considerably simpler, and are perhaps the most viable for Woodburn Terrace (and elsewhere in Edinburgh).

The multi-occupancy and multi-ownership nature of the tenements in Woodburn Terrace could make it more convoluted to install solar systems (SWH or PV), or any communal system. Communal heating or power systems could be put to good use in Woodburn Terrace, but would require considerable time and community working in the early developmental stages of any installation. The ‘hassle factor’ involved in planning and getting consents for any such installations should not be underestimated, and will require a determined approach. This should not be taken negatively, rather it is intended to make householders aware of the significant commitment needed to progress such a project.

Understanding the installed system is important, to ensure that appropriate behaviours and usage patterns can be adopted to get the most out of the system. Understanding is also important even before this stage, however: knowing the lifestyles, property features and characteristics of the different microgeneration systems will enable householders to identify the system that will work best for them.

Behaviour can make a microgeneration system achieve or exceed its potential, or can lead to significant under-performance. This is a key area for householders to bear in mind: generating one’s own energy requires a fundamental shift of thought compared with our current conventional heat and power systems. This does not necessarily mean more work, but rather a different way of thinking about energy use, and changing some behaviours to allow the system to work to the best of its potential.

Cost and saving predictions are only ever a guideline, and should be treated with some degree of caution. However, in the long term the high capital costs of most microgeneration systems should be more than offset by fuel bill savings, income generation schemes and long-term protection from fossil fuel price rises.