Innovation in the renewable heat sector in the UK:

Markets, opportunities and barriers.

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Innovation in the renewable heat sector in the UK – markets, opportunities and barriers

ICEPT report for the DTI Renewable Innovation Review

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Context

DTI are currently undertaking a review of support for innovation of new and renewable energy technologies, to ensure that policies are well integrated and coherent, and are providing appropriate support to the full range of technologies. ICEPT was asked by DTI to provide a review of *'UK innovation systems for new and renewable energy'* undertaken by ICEPT and E4Tech in Spring 2003. This paper on the renewable heat sector is a standalone evaluation but should be viewed in comparison with the other 6 renewable energy sub-sectors (wave, wind, solar PV, biomass, hydrogen and district & micro CHP) evaluated in the above-mentioned review and which were focussed on the production of electricity.

1. Introduction

In 2001, heating[1] accounted for one quarter (24%) of total UK energy consumption. Domestic heating alone accounted for nearly 1/5th (17%) of the energy consumed and possibly up to 14% of total UK GHG emissions. Demand for heat is likely to fall as building energy efficiency regulations are tightened and older housing stock is replaced or renovated – however, this process of renewal is relatively slow, and thus heating will remain an important contributor to emissions for a long time to come. Furthermore, a relatively new and growing sector is the demand for cooling services and innovation in renewable heat systems should also be targeted at the provision of cooling.

Technical scope

This evaluation of the potential for innovation within the renewable heat market in the UK does not include technologies that are overtly designed to improve energy efficiency or those concerned predominantly with CHP, which have both been addressed in associated studies. The thee main technology groups assessed are as follows:

- biomass (wood chip, pellet and straw <1 MWth),
- solar water heating (SWH), and;
- heat pumps (HP).

Success derived from innovation is likely to be focussed on very different areas for each of the three main renewable heat supply technologies considered here e.g. biomass, solar water heating (SWH) and heat pumps (HP). This is because, whilst for biomass the installed capital costs (between £50 to 500 / kWth) and fuel costs may be broadly comparable to natural gas systems[2], for solar and heat pumps fuel costs are zero or minimal but the capital costs are high (£1000/kWth or more). Secondly, only the biomass technologies are able to provide heat of sufficient temperatures to drive 'processes' other than space and water heating and also potentially produce electricity. Therefore, for biomass the challenge is to provide heat with the convenience and cost of fossil alternatives i.e. the fuel supply chain is critical. Uniquely for biomass, the potential market for small-scale domestic CHP may also prove lucrative if key conversion technologies can be successfully developed. For SWH and Heat Pumps the main challenge is to reduce or justify high capital costs whilst improving usability.

Despite the very substantial market for heat in the UK, renewable heat presently accounts for only about 0.1% of heat energy consumption and is provided almost exclusively from the use of wood, predominantly in the domestic sector using mature conventional small-scale combustion systems (e.g. solid fuel stoves/burners). The Clear Skies capital grants initiative, combined with general improvements in technologies and packaged systems, has sparked renewed activity, particularly for small to medium scale automated wood chip and pellet combustion systems and for solar water heating (SWH). However, even with large increases in installation rates the overall impact on fossil fuel consumption for heat provision is likely to be extremely limited unless there is a substantial and sustained step change in activity, both conventional and innovative.

[1] Heating here is defined as the use of energy for space or water heating. Cooking and 'low and high temperature processes' are excluded. Energy consumption for heat (2001) is calculated by the author using data supplied by DTI (2003). Total energy consumption for heat is estimated at 2.39 EJ but the source data is incomplete and in some cases inconsistent.

[2] Typical condensing gas boiler (25kWth) installed for £1300 = £50/kWth. Natural Gas domestic supply price (1.85p/kWh) = £5/GJ.

Resource/potential

In 2001, total UK energy consumption for heat was 2.4 EJ of which only 0.013 EJ came from renewable resources. However, the small size of the current renewable heat industry does not mean that there is not a large relatively 'un-tapped' resource base available to supply heat renewably should enabling conditions emerge. Such enabling conditions could arise from sustained increases or high volatility in the price of conventional heat sources e.g. natural gas and oil, or innovations in renewable systems which significantly reduce perceived costs (particularly capital costs) or which raise reliability and usability and thus acceptability.
Because the current renewable heat industry and installation base is so small and the market for innovative renewable heat technologies is so immature, detailed and reliable techno-economic evaluations of the resource base are not yet available. Therefore, the evaluation of the potential resources provided below for each of the three technologies should be considered preliminary:

- *Biomass*- A study by Woods and Bauen (2003), estimated that the potential energy that could reasonably be recovered from all renewable energy feedstocks in the UK was between 1.1 and 2.0 EJ/yr. When only biomass resources (including energy crops) were considered, the recoverable resource was estimated to be between 0.84 and 0.96 EJ. The capital grant schemes appear to have sparked particular interest in automated wood chip and pellet stoves with the pellets being produced both indigenously and being imported from Europe. The wood chip and pellet resource is in practice limited only by cost-factors and not by the size of the physical resource. However, the use of the wood resource in this way may impact on alternative uses, such as for electricity or liquid fuel production.
  Estimating the size of the potential market is difficult. However, should 10% of the heat market (0.24 EJ) be supplied by biomass it would generate a 14 Mt/yr biomass fuel supply industry with a turnover of over £700 million per year, assuming delivered biomass (wood chip) costs £50/t with an energy content of 16GJ/t[3]. Calculating the scale of the associated installation industry is not possible but might be of a similar value to the SWH and Heat Pump industries provided below. Overall, the biomass heat industry could have a turnover of about £1 billion per year.
- *Solar Water Heating*- Estimates of the gross resource are derived from ETSU (1998). Assuming that by 2011 50% of UK housing stock is fitted with SWH, approximately 0.056 EJ of heat would be supplied annually. According to the industry, the market is expected to expand rapidly from the current installation rate of about 10 000 units (panels) per year to about 15 000 next year, with a long term market of between 150 000 to 300 000 units/yr in 5 years and beyond. A market of this scale (150 000 units) would generate an industry with a turnover of about £450 million[4]. Even at this scale (150 000 units/yr) the installed capacity would only be increasing by 0.00054EJ or 0.02% per year of the current UK heat demand. It is also unlikely that current conditions would support such an expansion of installation rates, and thus the scenario above seems optimistic.
- *Heat pumps* – Despite the historical market for heat pumps being based on the non-domestic sector, dwellings are seen by the UK Heat Pump Network (UKHPN) as the main market of the future. UKHPN estimates an eventual market potential of about 100 000 installations per year of which 40 000 would come from new housing outside gas

[3] Costs for wood pellets are currently higher than wood chips (which are often locally or self-produced; £2-4/GJ). Recent delivered costs for imported pellets (bulk) have been quoted at £10.4/GJ but are expected to fall to £5.3/GJ early next year when production facilities in Devon and S. Wales come on-line.
[4] An average installation cost of £3000 is assumed per unit (4m2 flat plate panel). In practice, installation costs are likely to be significantly lower, particularly when installed into new housing.

supply areas that are projected to be heated electrically. A further 65 000 would arise from the estimated 1.3 million households which are currently outside gas supply areas and are heated by electrical systems which are due for renewal. A market of 100 000 installations per year would generate an installation industry with a £550 million/yr turnover[5] saving approximately 0.0025 EJ of gas-equivalent supplied heat. In addition, about 1,550 potential sites for 'large' industrial heat pumps in the UK were identified[6], each with an average unit size of 800 kW. However, these projected markets must be compared with the current UK installation rate of dedicated HPs of a few hundred per year and a total installation rate of about 70 000 per year in Europe as a whole.

Clearly, without significant gains in building energy efficiency it is highly unlikely that renewables will supply a major share of consumption in the UK in the near to medium term. However, the industry will not be constrained by the lack of physical resources and needs to concentrate on improving acceptability, reliability and usability and decreasing costs.

2. The Renewable Heat Sector

Innovation is occurring in all three of the renewable heat sectors evaluated here with IP being generated and patents filed by UK industry. The innovation is being driven almost entirely by the private sector with SME's being particularly active.

Status

The existing market for renewable heat is small. It is dominated by the conventional use of wood logs for burning in open and closed fires in domestic households. Despite this small scale there are a number of established industry players who are carrying out R&D activities albeit under difficult economic circumstances. Many of the technologies seem to be stuck in a cycle where the return on investment is too small to generate sufficient revenue to fund R&D and so the potential for cost reduction and step-change technological innovation remains out of reach.

In England, Wales and Northern Ireland, biomass, SWH, and HP are now benefiting from the Clear Skies capital grant scheme (www.clear-skies.org) which is aimed directly at the domestic and community markets, but the impacts of the grants is yet to be fully assessed. Scotland, which is not covered under Clear Skies has developed its own capital grants scheme (Scottish householders and not-for-profit community organisations can apply grants from the Scottish Community and Household Renewables Initiative). Despite Wales being covered under Clear Skies, the Welsh Assembly has announced its own capital grant scheme reflecting the importance of the heat sector in Wales. The importance of renewable heat in Wales has also very recently been underlined by the announcement that the debating chamber in the new Welsh Assembly will be heated by a 360 kW wood-fired system provided by the UK-based company Renewable Heat and Power Ltd. (RHPL). Many of the companies interviewed stated that there is renewed interest in, and orders for, renewable heating systems, but that the bulk of these systems are sourced from abroad. The dominance of non-UK manufacturers is particularly acute for the biomass and SWH sectors. See Figure 1 for the linkage between the capital grant schemes and the renewable heat sector.

Whilst both biomass and SWH might be considered mature technologies, there is real scope for innovation and cost reduction in both these sub-sectors. Much of the innovation pathway ahead

[5] Capital costs of £4500 for a ground sourced heat pump are provided by http://www.heatpumpnet.org.uk . An installation cost of £1000 is estimated.

[6] See 'HEAT PUMPS IN THE UK: CURRENT STATUS AND ACTIVITIES. General Information Report 67.' ETSU, 2002.

for both biomass and SWH may be strikingly similar to the PV sector where building integration and advanced 'smart' control systems play the dominant role in cost reductions and improving reliability and acceptability. Novel technologies may still emerge, particularly in the biomass sector where the development of gasification and the application to micro-turbines could result in sufficiently improved efficiencies and reliability to allow for significant cost reductions, particularly for smaller scale applications.

There are around ten manufacturers of biomass conversion equipment but only one dedicated SWH system manufacturer (Filsol Ltd). Although the number of suppliers/installers is significantly greater than manufacturers, many of them import the bulk of their systems. Installers will play a significant role in the successful development of the renewable heat sector, particularly plumbers, and it is instructive that the only renewable heat sector that has an accredited installer scheme is the SWH sector which is heavily dependent on plumbing skills. The importance of customer trust in the installation is being recognised in the other two sub-sectors (HP and biomass), and partially as a result of the clear-skies programme accredited installer schemes are now being developed.

HP is also a relatively mature technology and the market in the UK has been very small and virtually stagnant. The capital grants from the Clear Skies programme only apply to Ground Sourced Heat Pumps and it may be necessary to broaden the scope to air-sourced heat pumps in order to avoid the costs associated with installing an underground pipe network. Only two manufacturers of heat pumps (Calorex and Kensa Engineering) exist in the UK but about 70% of all heat pumps installed in Europe contain Copeland (based in Northern Ireland) compressors. Copeland has just released a dedicated heat-pump compressor which will raise overall efficiencies by 8-12% but perhaps more importantly increase the range of conditions under which heat pumps can function effectively (i.e. keep a COP > 3) and at the same time produce hot enough water to meet the current UK regulations on Legionnaires Disease.

Heat Supply Technologies

Biomass:

Data on UK wood heat supply technologies were obtained from a number of sources and through interviews. A good review source for England, Wales and Scotland is www.logpile.co.uk.

- Automated wood chip and wood pellet (e.g. RHPL and others). These boiler systems are dominated by imports from Sweden, Demark, Finland and Italy. Only two UK companies appear to be manufacturing domestic scale systems (50 kWth or lower).
- Conventional Combustion e.g. Talbotts, medium to large scale (50 kW to 4 MWth); numerous domestic small scale (50kWth or less).
- Gasification- Biomass Engineering Ltd. appears to be the sole commercial supplier of gasification equipment in the UK with their systems based on the production of CHP at scales of 75kWe or higher requiring a 300kWth (or higher) input of biomass feedstock. Gasifiers also offer the potential to utilise otherwise difficult to manage waste/residue feedstocks for both process heat and electricity production. However, it appears that only recently earlier problems with sufficiently clean (low tar and particulate) gas for use in internal combustion engines or boilers have been overcome.
- Fuel supply- new supply chains for chips and pellets are developing, however, imports (particularly of wood pellets) dominate, originating from France, Sweden, the former Soviet Union (Latvia, Estonia, etc) and USA. Potential for other energy supply sources e.g. energy crops and straw, compressed sawdust briquettes etc. are also being developed see e.g. www.biorenewables.co.uk; Thames Valley Energy (www.tvef.org.uk) or Coppice Resources Ltd (IFBN news article; 21/10/03).

SWH:
Solar thermal systems are already highly efficient at converting solar radiation into thermal energy. A series of side-by-side tests of the leading SWH technologies carried out by ETSU (Martin and Watson; 2001) showed that technically over 70% of annual domestic hot water demand can be met by a range of solar thermal technologies. The tests also showed high instantaneous conversion efficiencies, even on cloudy days, but also a worrying lack of reliability in some systems. Despite the high instantaneous efficiencies, the relatively high capital costs and low rates of energy recovery result in long payback times, particularly for retrofits. Therefore, future innovation is likely to concentrate on lowering costs, raising reliability and integrating systems and not on novel conversion technologies aimed at raising instantaneous conversion efficiencies.

- Flat Plate Technologies- novel coatings allow use of direct and indirect radiation raising efficiencies above 80%. Innovations aimed at raising reliability and safety include; 'drain back' and 'smart control systems'. In colder climates (e.g. northern UK or Scotland) heat loss from the panels or the costs of improving insulation may allow evacuated tube systems to be more competitive (see below). Current efforts on improving market penetration have focused on new build markets where the costs of retro-fitting including replacing equipment (i.e. existing single coil water cylinders with twin coil solar ones) can be avoided, pools and recreational facilities. More high profile ground breaking demonstration installations are required e.g., Tomkyns House (Themba Technology and Lambeth Council). Innovative work on integration with existing systems is also required to broaden the possible applications such as, providing pre-heat and coupling to combi-boilers. See also, Filsol Solar Ltd.; www.filsol.co.uk)
- Evacuated Tubes- heat pipe, solar tracking etc. By using vacuum tubes to surround the radiation absorbing mechanism thermal heat losses are minimised even in cold/freezing conditions. However, the vacuum tubing adds to capital costs. The two main suppliers of evacuated tube systems in the UK are Riomay (uses Japanese tubes) and Thermomax (uses its own patented tubes manufactured in Canada).

HP:
Innovation is occurring in the Heat Pump sector and the UK may prove to be a world leader. International collaboration is occurring as is evident on the IEA's Heat Pump Task web site (www.heatpumpcentre.org). The four main technology sub-sectors are briefly described below:

- Ground, water and air source heat pumps. Heat is transferred from the low temperature medium, either directly for water and air sourced systems or via a network of buried tubing (using water as the heat transfer fluid) via high efficiency heat exchangers to the working fluid. This working fluid or gas is passed through a compressor and some form of secondary heat exchanger inside the building to provide space and now possibly water, heating. Ground sources systems must ensure that the heat recovery pipe network is sufficiently diffuse that the heat is not mined from the soil, they are therefore generally quite extensive and cheaper plastic pipe networks have been developed e.g. Kensa Engineering. In addition, innovation is occurring in other areas, most notably the compressors where a UK company is a world leader (Copeland Corporation Ltd. UK).
- Air conditioning (reversible). Because heat pumps are based on the same principle as refrigeration or air conditioning equipment when reversible valves are used heat can be transferred into buildings in winter and out of them in summer.
- Dehumidifiers (domestic and larger): Dehumidifiers are essentially heat pumps which by recovering the latent heat of evaporation, provide heating at the same time as removing water from the atmosphere. e.g. Calorex

- Sorption cycle HPs (larger scales). These systems provide the possibility of using heat directly to create the phase change in the working fluid and so can use heat sources to provide cooling (as with gas powered fridges). Currently they only seem to be economic at scales greater than are feasible for domestic markets.

Innovations in heat supply

Most of the innovative focus in the renewable heat sector centres around two foci:

1. Novel technologies (or technology combinations) for the production of electricity and heat (CHP) at the small to medium scale. This foci is particularly applicable to biomass energy technologies with both Biomass Engineering (Gasification) and Talbotts (combining advanced conventional combustion with novel electricity generating technology) developing prototype and pre-commercial applications. The development of relatively cheap pre-insulated piping is also assisting with cost reductions and reliability issues for the development of mini community district heating schemes. Exciting developments in UK manufacturing of the compressors used in heat pumps may also prove important in both broadening the application of HP and reducing heat supply costs.
2. Using smart technologies to integrate with existing or novel fossil-based heat supply systems and maximise efficiencies. Examples of this type of innovation include solar-thermal pre-heat systems for combi-boilers, single smart controllers for SWH and un-vented central heating systems. Reversible heat pumps that provide heat in the winter and cooling in the summer.

Leading countries

The countries playing leading roles in the development of the renewable heat sector include:

- Sweden
- The Netherlands (Zen)
- Germany (Siemens)
- Austria
- Finland
- UK and Switzerland (Heat Pumps)
- India

UK actors

Despite its small size and apparent lack of commercial viability outside niche markets, a surprisingly numerous and broad range of actors from applied research, through SMEs to large manufacturing industries are involved in the renewable heat sector. A short list includes:

- Nottingham University
- Bristol University
- University of Bangor
- Talbotts Engineering (www.talbotts.co.uk)
- Filsol Ltd. (www.filsol.co.uk)
- Themba Technology Ltd. (www.thembatech.com)
- Riomay Ltd. (www.riomay.com)
- Thermomax Ltd. (www.thermomax.com)
- Renewable Heat and Power Ltd. (www.rhpl.co.uk)
- Welsh Biofuels (www.welsh-biofuels.co.uk)

- BG Technology (HP)
- Kensa Engineering (One of two UK HP manufacturers; www.kensaengineering.com)
- Calorex (main UK HP manufacturer- predominantly dehumidifying HPs for swimming pools)
- Copeland Ltd. (dominant manufacturer of compressors for heat pumps)
- Sheffield University (Novel HP)
- Cambridge University (Novel HP)
- Warwick University (Novel HP)

3. Drivers of innovation

Capital grants

- Clear Skies (England, Wales and NI; managed by BRE), Scottish Community Renewables Initiative (managed by EST). This grant scheme provides limited capital grants, paid directly to home owners, or larger grants (up to £100 000) for community schemes.
- New Opportunities Fund?

Green markets

Green consumer markets are the main driver for the renewable heat sector outside areas where the delivery of conventional fuels (e.g. mains gas, LPG, oil and coal) is problematic or overly expensive. The green consumer (and installer) is particularly important for the domestic SWH and HP markets where the relatively high capital costs and long payback periods force the consumer to make an 'irrational economic' decision in favour of these technologies. For biomass, where the capital and running costs are comparable with conventional alternatives (including mains supplied natural gas), reliability and convenience of use are the main obstacles to future development although they are being address by using fully automated systems and ESCOs. Although only one heat supply ESCO was mentioned during interviews with manufacturers and suppliers (a biomass heat ESCO provided by RHPL), ESCOs should be better suited to the HP and SWH which have higher up front capital costs but lower / zero fuel costs.

Overseas pull

The UK's leading role in combating climate change and its relatively large, although highly seasonal, heat market must require a new impetus to the development of the renewable heat sector in the UK. It is clear that there is a significant research but more importantly, industrial base in the UK which could be developed to take a leading role globally if incentives are correctly developed.

4. Knowledge creation and diffusion

A surprising amount of innovative activity is occurring in all three of the renewable heat provision sectors evaluated here. A number of SMEs are active and apparently taking the lead in creating knowledge and in trying to increase market share, however, conditions remain difficult in the UK whilst conventional fossil fuel heat systems remain so cheap. However, it is clear that there is a manufacturing, installation and research base in the UK which could be the basis for a world leading sector given sufficient support.

As much of the activity is in the private sector knowledge diffusion is really only occurring through commercial channels and appears limited in scope. Understanding and acceptance of renewable heat technologies by potential consumers, and perhaps more importantly installers (e.g. plumbers, builders, architects, etc) is poor and represents a major obstacle to the development of the sector. In general renewable heat systems suffer from a legacy of memories of open fires e.g. they are dirty, time consuming and highly variable / unreliable in heat output. For HP and SWH ignorance and the high capital costs are significant barriers.

5. Partnerships

As highlighted 4 above, basic understanding of renewable heat technologies is poor and apart from SWH, the conversion equipment installed may be complex and require specialist manufacturers and installers. Where complex components are involved e.g. compressors in heat pumps, partnerships between SMEs (or small scale producer/suppliers of plant, may need to form partnerships (which protect IP) for the development of the equipment. The recent partnership being developed between Copeland Ltd (dominant compressor manufacturer), Kensa Engineering (consultancy and small scale producer and supplier), and Marstair (formerly a large scale manufacturer of air conditioning systems) which now intends to develop the market for HP and the large scale production of heat pumps in the UK provides a good example (Freebourne, 2003). Building partnerships is particularly important for biomass because the development of reliable fuel supply chains is intrinsic to the successful deployment of the market. An innovative example of this has been the development of a wood fuel supply cooperative called 'South West Wood Fuels' which is primarily a cooperative of farmers and foresters who share equipment and produce wood chips to a uniform quality standard.
There do not appear to be any significant partnerships between private sector technology developers and academic R&D.

6. IP

IP is currently being generated with instances of recent patents being filed noted in all three renewable heat supply sectors. Individual interviews appear to suggest that patents are regarded as an important mechanism for protecting and therefore developing IP. As noted above, partnerships are important for all three renewable heat sub-sectors but major technology developments may not generate new markets unless they are compatible with the whole production, installation and fuel supply chain.

7. Globalisation

There is a good potential for UK firms to build on their existing global markets, however, significant increase in global activity will only result from a step-change in manufacturing and installation activity in the UK market in to produce sufficient cost reductions to remain competitive globally. Good global networks exist for all three sectors for information exchange with the International Energy Agency providing good fora. The development of renewable cooling systems in conjunction is likely to prove critical to the long term success of the sector.

8. Other system influences

The dominant system influence on the renewable heat sector is the relatively cheap cost of fossil-based alternatives and their ease of supply and use. Because there is no mechanism to reward the use of renewable heat outside the capital grants scheme the sector feels at a disadvantage compared to the other renewable energy sectors which can benefit from the Renewables Obligation and the Climate Change Levy. Mechanisms that reward both competitive development and lowering carbon intensity in the renewable sector would be welcomed.

9. Innovation system map

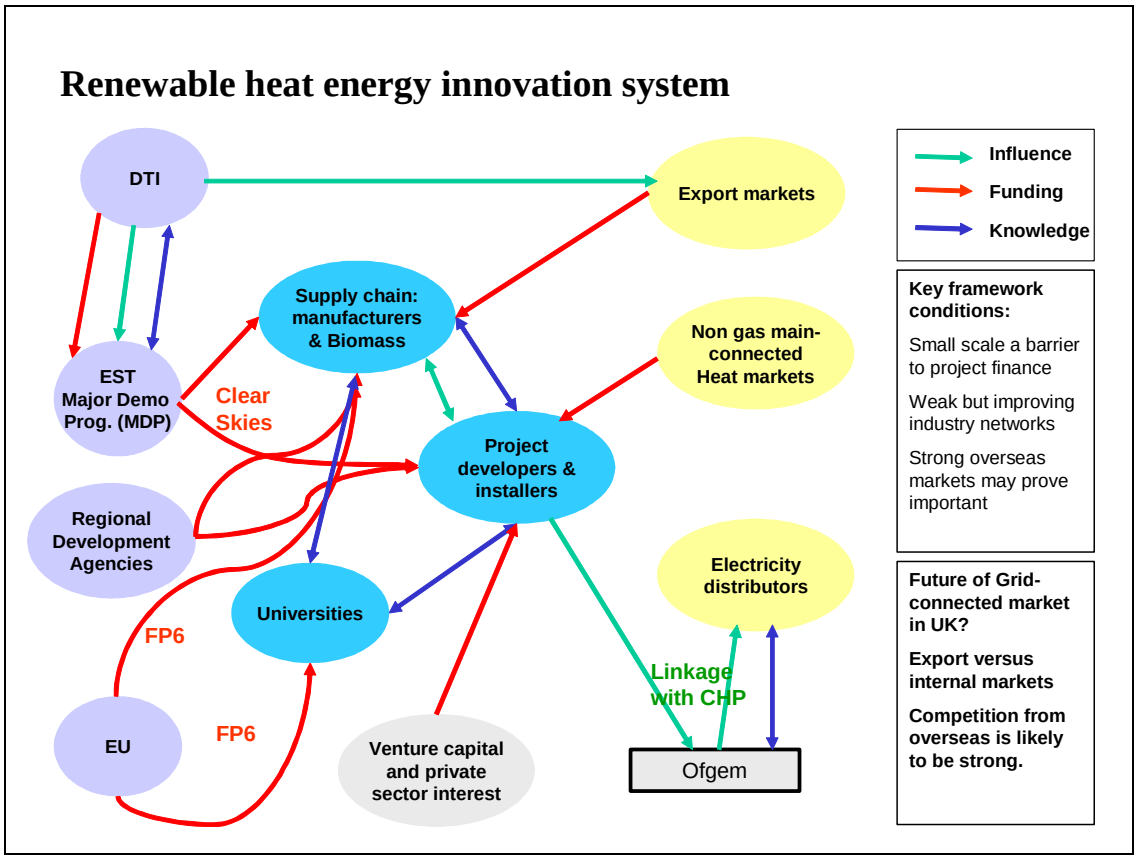

Figure 1

Please note that similar innovation system maps have been produced for the other renewable energy sectors (ICEPT, 2003)