Programme Area: Distributed Energy

Project: Micro DE

Title: Micro DE Technology Interviews

Abstract:

Please note this report was produced in 2010/2011 and its contents may be out of date. This deliverable is number 4 of 7 in Work Package 3. It is in 3 parts:
3.4.1 Roadmap for Micro DE Technologies. This report summarises the views of the consortium regarding future performance of micro DE technologies
3.4.2 Micro DE Technology Comparisons. This report provides a comparison of the performance capabilities of different micro DE technologies in 2010 and 2040, based on analysis carried out in the model developed as part of the project
3.4.3 Micro DE Technology Case Studies.
This report provides 3 case studies around the potential deployment of micro DE technologies in properties in the 2010 / 2020 / 2040 timeframes, aligning with the scenario analysis carried out in report 3.5The findings from these reports have been included in report D3.7 : Final project report together with outputs from other deliverables within Work Package 3.

Context:

The project was a scoping and feasibility study to identify opportunities for micro-generation storage and control technology development at an individual dwelling level in the UK. The study investigated the potential for reducing energy consumption and CO2 emissions through Distributed Energy (DE) technologies. This was achieved through the development of a segmented model of the UK housing stock supplemented with detailed, real-time supply and demand energy-usage gathered from field trials of micro distributed generation and storage technology in conjunction with building control systems. The outputs of this project now feed into the Smart Systems and Heat programme.

WP 3.4.2 Micro DE Technology Comparisons

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1 Introduction

1.1 Context

Housing energy use is responsible for approximately 20% of UK CO_2 emissions and so has an important role to play in achieving the 80% reduction target by the year 2050. The ETI micro Decentralized Energy (DE) project seeks to focus on the different DE technologies available that could be combined to reduce the energy consumption and CO_2 emission per dwelling to reach the target of 80% reduction.

The DE technologies analysed or monitored (mainly renewable ones) in this project are the following:

- Biomass
- Condensing gas boiler
- Micro-CHP system
- Heat-pump (Air source heat pump and ground source heat pump)
- Solar PV
- Solar thermal
- Small wind turbine (P < 5 kW).

A fact sheet per technology with a general description, the current products available on the market, the technology maturity, CO_2, energy savings and existing or future subsidies has been completed as part of Work Package 1 of the project.

To reduce energy consumption or CO_2 emissions, the next interesting deliverable is to choose a representative dwelling in a geographical region with an occupant scenario, to know which combined DE technologies are most efficient.

As the current annual UK new-build rates equate to less than 1% of the total housing stock (estimated 27 millions of dwellings), the majority of the CO_2 emissions will come from the existing UK housing stock. Moreover, UCL has already carried out a study of new dwellings to compare the energy consumption savings and CO_2 emission savings. So, here we focus on an existing dwelling with an old non-condensing gas boiler heating system, which is representative of the UK housing stock, and calculate the CO_2 emission and energy consumption for different combined DE technologies cases to identify the most efficient one.

1.2 Purpose of the deliverable

The purpose of this deliverable is:

- To present a methodology to rank the different results of combinations of DE technologies installed in an existing dwelling with either CO_2 emission, energy consumption or investment cost key rankings
- To analyse the ranking results to know if they are relevant

The house modelling tool chosen to calculate, for each case, the energy consumption and CO_2 emissions is the alpha version model produced by BRE and UCL.

The aim of this work is to compare the ranked micro-DE solutions results for 2 scenarios:

- a 2010 scenario,
- a 2030 scenario, with updated parameters for efficiencies of the DE technologies installed, CO_2 intensities and average kWh cost per energy.

The purpose of this document is clearly to propose **a <u>methodology</u> to compare combinations of DE technologies** to provide energy for different uses. The results ranking is highly correlated with the alpha version of the model tool calculation and to the different parameters and inputs captured in the tool before running it.

1.3 Prior DE Comparative Studies

Comprehensive comparisons across all micro DE technologies are relatively rare. The DTI commissioned a review of the potential for micro-generation, published in 2005, from a consortium including the Energy Saving Trust (DTI, 2005). The report concluded that subsidies, for example an *Export Energy Equivalence*, were crucial to unlocking the potential of micro-generation – especially of micro-CHP systems such as Stirling Engines and Fuel Cells in the 2030 timeframe and small wind turbines in 2050.

The Energy Saving Trust provides a "home energy generation selector" on its website at http://www.energysavingtrust.org.uk/renewableselector/start/ . This tool gathers some basic building parameters and constraints and then computes the most suitable micro DE technologies.

2 Description of the Approach and Comparison Parameters

2.1 Scope of the study

All the calculations have been done by UCL with the alpha version of the model.

To have an idea of the potential offered by the tool analysis proposed in this Micro-DE comparison study, we suggest a representative type of dwelling and to compare the results of different DE technologies and their combination for this representative case. This methodology should be extended to the 20 Archetype Building types, within the Work Package 2 of the ETI Optimising Thermal Efficiency of Existing Dwellings.

Later, the aim of the study is to analyse the results of all the possible combinations:

- either the results per DE technology chosen as space heating system only,
- or the results with a combination of **two** DE technologies (space heating and another DE technology to produce domestic hot water or to provide electricity)

2.2 Reference dwelling chosen

i. Description of the dwelling

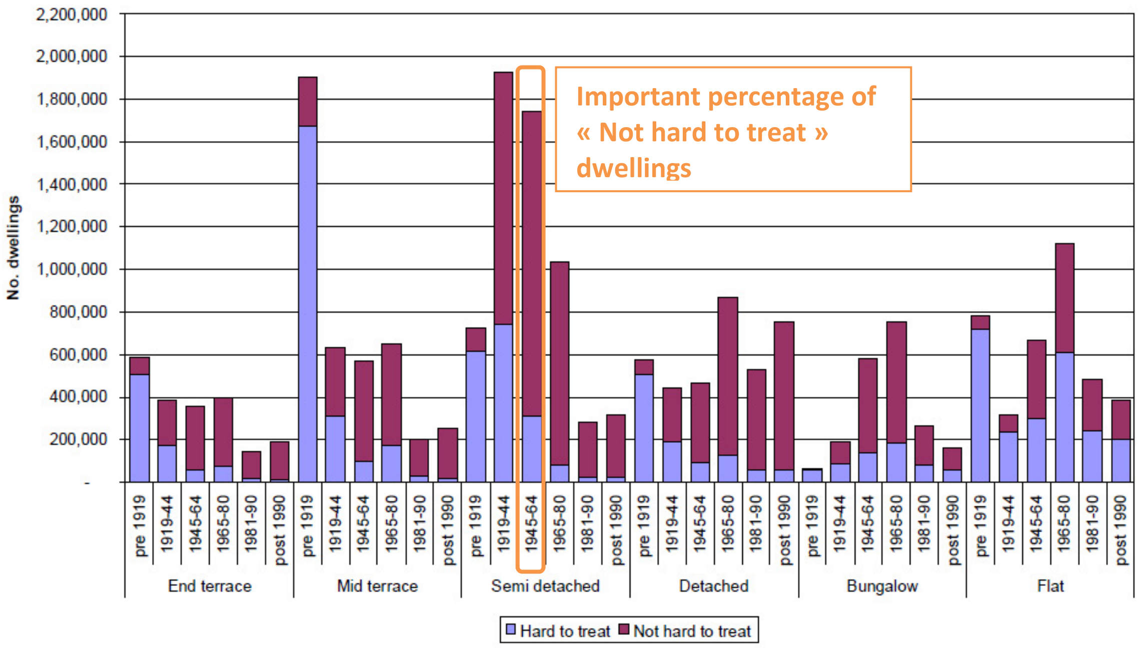
The alpha model version of the tool makes calculations for 20 different dwellings. To collect results from the tool quickly, we decided to choose one of these for comparison of the results in terms of energy consumption and CO_2 emission for this reference dwelling.

According to BRE and UCL (WP1.2 Segmentation of the UK Housing Stock), the subdivision of the stock results in 20 archetypes listed in Table 1. Considering the limited impact of building type on micro-DE technologies, this segmentation will give an optimum level of description for the purposes of this project. However, it will be developed further in the ETI Optimising Thermal Efficiency of Existing Dwellings project.

Case No	Build Type	Building Age	Estimated number of dwellings in England (2007 EHS data)	Weight
1	Semi & end terrace	Pre 1919	1 385 000	6,24%
2	Semi & end terrace	1919-1944	2 337 000	10,53%
3	**Semi & end terrace**	**1944-1965**	**2 448 000**	**11,03%**
4	Semi & end terrace	1965-1980	1 669 000	7,52%
5	Semi & end terrace	1980+	1 128 000	5,08%
6	Mid terrace	Pre 1919	1 917 000	8,64%
7	Mid terrace	1919-1944	651 000	2,93%
8	Mid terrace	1944-1965	525 000	2,37%
9	Mid terrace	1965-1980	712 000	3,21%
10	Mid terrace	1980+	519 000	2,34%
11	Flat	Pre 1919	854 000	3,85%
12	Flat	1919-1944	315 000	1,42%
13	Flat	1944-1965	645 000	2,91%
14	Flat	1965-1980	1 094 000	4,93%
15	Flat	1980+	860 000	3,88%
16	Detached	Pre 1919	606 000	2,73%
17	Detached	1919-1944	568 000	2,56%
18	Detached	1944-1965	736 000	3,32%
19	Detached	1965-1980	1 336 000	6,02%
20	Detached	1980+	1 881 000	8,48%
	Total		**22 189 000**	**100,00%**

Table 1 - Suggested segmentation for the micro-DE project *(Deliverable WP1.2 Segmentation of the UK Housing Stock)*

BRE has also carried out an analysis, identifying, in the English housing stock, the dwellings “Hard to treat” and “Not hard to treat”. To do this BRE analysed and combined both the English House Survey (EHS) data from 2003 to 2005 and retrofitting dwelling actions (insulation for walls, loft, glazing, heating system and fuel) and identifying dwellings as "Hard to treat" and "Not Hard to treat" (***ETI Thermal Efficiency Project – Deliverable WP6.1 Impact of Policy and Building Regulations***).



Graph 1 - Occurrence of "hard to treat" dwellings in the English stock broken down by dwelling age and type

So, combining these two parameters, we selected, as a representative reference dwelling for the DE technologies comparison:

- a semi-detached (1945 – 1964) dwelling (11% of the dwelling stock with 2,448,000 dwellings) with an area of 89 m² occupied by 3 people
- located in the region of Manchester
- with an old non-condensing gas boiler as the primary space heating system (η = 80% - tank volume= 50L)

ii. Energy Consumption and CO_2 emissions of the reference dwelling

The results for energy consumption and CO_2 emissions have been calculated with the alpha version tool:

Energy consumption: 25 323 kWh / year
CO_2 emission: 6 209 kg CO_2 / year

All the calculations for the combination of DE technologies will be compared to this reference energy consumption and CO_2 emissions in order to assess the energy and CO_2 savings related to each micro-DE technology.

2.3 List of DE Technologies studied for the 2010 and 2030 scenario

The best way to identify the impact of a technology on energy and CO_2 savings is to compare them for the same use: space heating, production of domestic hot water and production of electricity.

Space heating system	Domestic Hot water	Production of renewable electricity (auto-prod or export on the grid)
• Old gas boiler • Condensing gas boiler • Micro-CHP • Biomass • Heat Pump (Air Source or Ground Source)	• Double uses (space heating + DHW) : Gas boilers / Heat pumps • Electric immersion • Solar thermal	• Solar PV • Small wind turbine(SWT)

Table 2 - List of micro-DE Technologies

In order to evaluate the performance of each DE technology in terms of energy consumption and CO_2 emissions, we propose to analyse the following test cases with combinations of different DE technologies dedicated to different needs (space heating, DHW and electricity production).

Scenario 2010 – 16 cases calculated:

Works or changes	Comments	Number of cases
DE technologies combinations	- Biomass - Biomass + Solar Thermal - Biomass + Solar PV - Biomass + Small Wind Turbine - Gas condensing boiler - Gas condensing boiler + Solar Thermal - Gas condensing boiler + Solar PV - Gas condensing boiler + Small Wind Turbine - Microgen - Air Source Heat Pump - ASHP + Solar Thermal - ASHP + Solar PV - ASHP + Small Wind Turbine - Ground Source Heat Pump - GSHP + Solar PV - GSHP + Small Wind Turbine	**16 cases**

Table 3 - Test cases for Scenario 2010

Scenario 2030 - 16 cases calculated:

For the scenario 2030, we would have liked to assess the impact of an increase in the efficiency of the DE technologies, and of insulation work.

However, at this stage of development, the alpha-model tool (version 4) does not allow changes to these parameters.

Consequently, we focused our scenario 2030 on changing the following parameters:

- Investment costs (ETI Micro-DE Project – Deliverable WP1.1 Review and roadmaps of each DE Technology)
- Average kWh costs per energy
- CO_2 intensities per energy (with an decrease in CO_2 intensity for electricity in order to be compliant with the Government aim to decarbonise the UK electricity mix production)

Parameters chosen for the 2 scenario

The parameters chosen for each DE technology per scenario depend on the list of choices allowed by the alpha version of the tool under development.

We suggest selecting the following parameters, to be compliant with the data mentioned in the fact sheets and the road-map per technology:

DE technologies	Scenario 2010 Efficiency suggested for the calculation	Scenario 2030 Efficiency suggested for the calculation**	Other parameters unchanged
Old Non-Condensing gas boiler (reference case)	80% (HHV)	80% (HHV)	DHW tank : 50L
Condensing gas boiler	95% (HHV)	97% (HHV)	DHW tank : 50L
Micro- CHP (Microgen)	Efficiency : 90% Maximal nominal heat output : 25 kW / unit Peak electric power : 1 kWe Heating regime : 24	Efficiency : 95% Maximal nominal heat output max : 25 kW / unit Peak electric power: 1 kWe Heating regime : 24	DHW tank : 50L
Biomass (with wood chip / pellet)	Efficiency : 75% *60% in winter and summer (impossible to capture in the actual BREDEM tool)* Responsiveness of 0.75 Secondary heating : 10% of direct electricity	Efficiency : 85% Responsiveness of 0.75 Secondary heating : 10% of direct electricity	DHW tank : 500L
Heat pump	ASHP : 290% GSHP : 400%	ASHP : 440% GSHP : 480%	DHW tank : 250L
Solar thermal			4 m² Flat plates, Oriented SE / SW Tilt of 30° DHW tank: 200 L

Solar PV	Parameters allowed by the alpha version tool – No change between 2010 and 2030 for the efficiency	4 m^2 Flat plates Peak power : 3 kWp Oriented SE / SW Tilt of 30°
SWT		1 turbine Power : 3 kW Rotor diameter : 4m *Hub height : 12 m (10 m maximum allowed in the actual BREDEM tool)* Low rise urban

Table 4 - Efficiencies and parameters of each Micro-DE Technology

***The efficiencies suggested in the column of the scenario 2030 are indicative since, as explained previously, the alpha-model tool (version 4) does not allow changes to this parameter. Consequently, the calculations were run with the values for the 2010 scenario and the results in terms of energy consumption will be the same for both scenarios (2010 and 2030).*

2.4 Other assumptions

i. CO_2 intensities of energies

The aim of the UK Government is to reduce, by about 80%, the emissions of CO_2 by the year 2050. To compare the micro-DE technologies in terms of CO_2 emissions, we need to focus on the CO_2 intensities of energies:

CO_2 Intensities	Gas	Wood	Electricity
Scenario 2010 (g/ kWh)	198	28	517
Scenario 2030 *assumption* (g/ kWh)	194	25	150

Table 5 - CO_2 intensities of energies (2010 & 2030)

The values given for 2010 are extracted from SAP 2009. The assumptions made for 2030 are consistent with the UK Government's aim to decarbonise the electricity mix production.

ii. Investment costs of DE technologies

The fact sheets and roadmap for each micro DE technology (ETI Micro-DE Project – Deliverable WP1.1 Review and roadmaps of each DE Technology) give the order of magnitude in terms of investment costs regarding the 2010 and 2030 scenarios:

DE technology	Investment costs £ Scenario 2010	Investment costs £ Scenario 2030
Condensing gas boiler	2,500	2,000
Micro- CHP (Microgen)	9,000	7,000
Biomass (with wood chip / pellet)	9,000	7,000

Air Source Heat Pump	8,000	6,500
Ground Source Heat Pump	17,000	14,000
Solar thermal	7,500	3,000
Solar PV (4 m²)	3,000	2,000
Small Wind Turbine	12,000	9,000

Table 6 – Scenario 2010 and 2030: Investment costs for each DE Technology

iii. Average retail energy prices for London

Fuel prices per kWh inc. VAT	Gas	Wood pellets	Electricity
Scenario 2010	3.10p	3.9p	11.46p
Scenario 2030 *assumption*	6.2p	5.9p	22.9p

Table 7 - Average retail energy prices

The values given for scenario 2010 are extracted from SAP 2009 for Electricity and gas and from ***ETI Micro-DE Project Deliverable WP1.1 Review and roadmaps of technologies: Biomass*** for Wood pellets. For 2030, we assume that prices of electricity and gas double (same hypothesis as mentioned in ***Deliverable WP1.1 Review and roadmaps of technologies: Micro-CHP***).

3 Calculation Approach

3.1 Limits of BREDEM alpha version tool

The different calculations have been made using the Alpha version model v4.stock, delivered on 6th May 2011. Some additional functionality has been included and some of the bugs detected have been fixed. Nevertheless, the results extracted from this version still require additional confirmation. Once the final tested version of the model has been developed, new results and analysis of the results ranking could be incorporated into the comparison DE analysis. For this report, the results used are those carried out by UCL on the 14th June 2011.

3.2 Analysis tool

In order to compare the cases simulated on the Alpha version model tool, we created a specific analysis Excel tool allowing us to choose a ranking criterion:

- Either : Energy efficiency (energy savings regarding the reference initial case)
- Or Environmental impact (CO_2 emissions savings regarding the reference initial case)
- Or Economic criterion (investment cost or Energy bill)

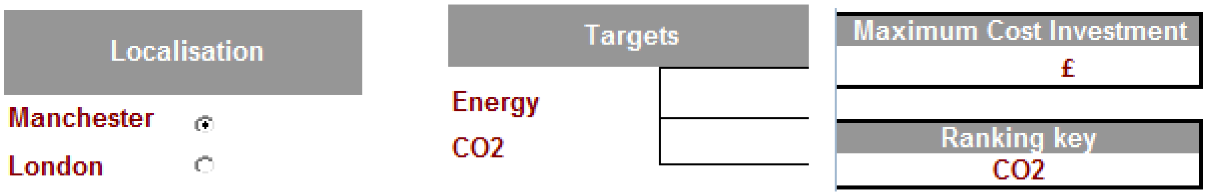
This tool acts as an interface between the user and the database built with the results of the version v4 alpha model calculations. In practical terms, it allows the user to sort and rank easily a database, which can be very large, by choosing different parameters, targets or ranking criteria.

With this Excel tool, we have the **opportunity to choose:**

- **The context** (2010 or 2030 – different databases in terms of investment costs, energy prices and

CO_2 intensities)

- **The location** (for this study we were only interested in Manchester, but we could try other regions)
- **The targets** to reach in terms of energy consumption or CO_2 emissions
- **The maximum investment cost**
- **The ranking key** (CO_2 emissions, Energy consumption, Investment cost and energy bill)



The Excel tool analyses the resulting databases (all the calculations have been made previously with the alpha version v4 model tool) according to the targets and choices made in the interface. The result of this tool is a list of the ten best solutions (depending on the ranking criteria chosen).
For instance, the table below ranks the best solutions in terms of energy bill. With a 39% of savings on the energy bill, the solution “Gas condensing boiler + PV” is the one that implies the lowest energy bill.

The 10 best retrofitting solutions									
	Retrofitting solution	Energy consumption* kWh/an	*Energy savings %*	CO2 emissions kgCO2/an	*CO2 savings %*	Energy bill £	*Bill savings%*	Investment £	£ invested / kgCO2 saved
	Reference case : Old gas boiler	25 323		6 209		**1 098**			
1	Condensing_boiler_PV	17 941	*29%*	3 991	*36%*	671	*39%*	5 500.00	*2*
2	Condensing_boiler_SWT	19 155	*24%*	4 619	*26%*	810	*26%*	14 500.00	*9*
3	Condensing_boiler_ST	18 935	*25%*	4 944	*20%*	900	*18%*	10 000.00	*8*
4	Condensing_boiler	20 077	*21%*	5 170	*17%*	936	*15%*	2 500.00	*2*
5	GSHP_PV	8 758	*65%*	4 282	*31%*	939	*14%*	20 000.00	*10*
6	GSHP_SWT	9 971	*61%*	4 909	*21%*	1 078	*2%*	29 000.00	*22*
7	Microgen	27 895	*-10%*	6 472	*-4%*	1 113	*-1%*	9 000.00	*- 34*
8	GSHP	11 127	*56%*	5 507	*11%*	1 211	*-10%*	17 000.00	*24*
9	ASHP_PV	11 515	*55%*	5 708	*8%*	1 255	*-14%*	11 000.00	*22*
10	Biomass_PV	24 569	*3%*	2 881	*54%*	1 271	*-16%*	12 000.00	*4*

Table understanding: Analysis of the 2010 Scenario - Ranking key = Energy bill

In this table, we can read, for each solution:

- The **total Energy Consumption** and the percentage of savings compared to the reference case (Old non-condensing gas boiler)

  *The total Energy Consumption is calculated by summing the consumptions of electricity, gas and solid. The unit is a **final energy**.*
- The **total CO_2 emissions** and the percentage of savings compared to the reference case

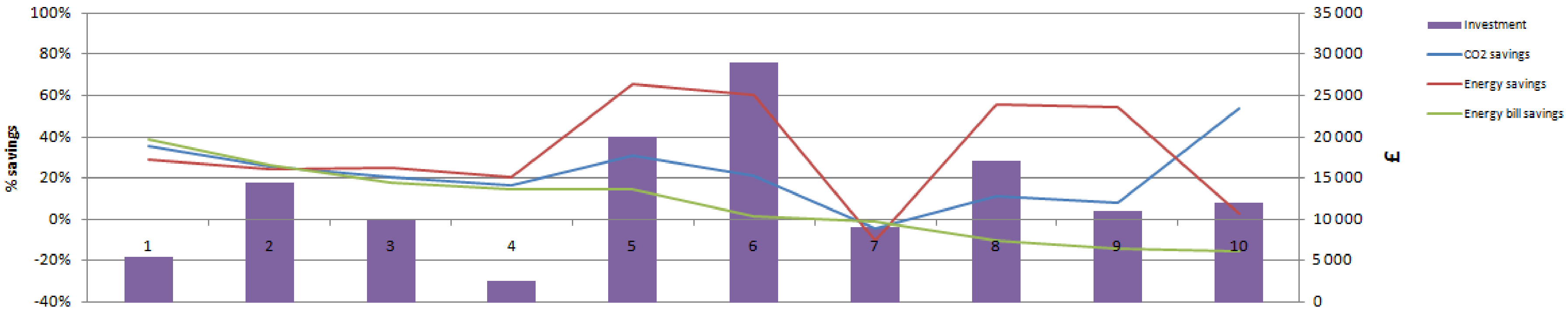
  The total CO_2 emissions is calculated by multiplying energy consumptions (electricity, gas and solid) by the CO_2 intensity corresponding.
- The **total Energy bill** and the percentage of savings compared to the reference case

The total Energy bill is calculated by multiplying energy consumptions (electricity, gas and solid fuel) by the corresponding average kWh cost . The sale of the electricity production (from PV or small wind turbine) and the possible incentives are not considered. We decided to calculate the Energy bill ***without taking account of the existing or future incentives*** *that are very different from one DE technology to another. We suggest that the incentives through the Feed In tariff, the Renewable Heating Incentive or the future Green Deal should promote the DE technologies that allow a maximum CO_2 saving, if the main driver is the CO_2 emission reduction.*

- The **total Investment cost of the retrofitting** solution

  The total investment cost of the retrofitting solution is calculated by summing the investment cost of each DE technology considered in the retrofit.

- The **cost invested to save one kg of CO_2 emissions** (investment cost divided by CO_2 savings). This parameter is essential if we aim to reduce the CO_2 emissions and also to take into account the cost investment and the energy bills of the best DE technologies.



Graph understanding: Analysis of the 2010 Scenario

1: Condensing boiler + PV, 2: Condensing boiler + SWT, 3: Condensing boiler + ST, 4: Condensing boiler, 5: GSHP + PV, 6: GSHP + SWT, 7: Microgen, 8: GSHP, 9: ASHP + PV, 10: Biomass + PV

On this graph, the blue curve refers to the CO_2 savings, the red to the energy savings and the green to the energy bill savings. The purple histogram refers to the investment cost.

We can note that the solutions with Electricity as energy for space heating have essentially **negative Energy bill savings, except for GSHP (with a COP of 4) combined with Solar PV or SWT**. Even if these solutions drive a **significant energy saving (up to 65%)**, the electricity price (that is more than three times higher than the gas one) makes the energy bill higher than solutions with gas condensing boiler or even classic boiler. The solutions with gas condensing boilers as space heating systems show reductions of the energy bill of up to 39% with condensing boiler and PV.

To promote the best technologies regarding the CO_2 criterion up to 2030, the Government **should introduce public subsidies in order to reduce the cost investment or the Energy bill, by increasing for example the Feed In Tariff per kWh produced or the RHI incentive**.

Once the final tested version of the alpha model tool is available, the ranking results per segmentation of dwellings (including different incentives scenario per DE technologies) should be used to drive energy new policies and scheme mechanisms as the FIT, RHI or the future Green Deal.

4 Analysis of the 2010 Scenario: Ranking key = CO_2 emissions

The 10 best retrofitting solutions

	Retrofitting solution	Energy consumption* kWh/an	Energy savings %	CO2 emissions kgCO2/an	CO2 savings %	Energy bill £	Bill savings%	Investment £	£ invested / kgCO2 saved
	Reference case : Old gas boiler	25 323		6 209		1 098			
1	Biomass_PV	24 569	3%	2 881	54%	1 271	-16%	12 000.00	4
2	Biomass_SWT	25 783	-2%	3 509	43%	1 410	-28%	21 000.00	8
3	Biomass_ST	25 301	0%	3 740	40%	1 429	-30%	16 500.00	7
4	Condensing_boiler_PV	17 941	29%	3 991	36%	671	39%	5 500.00	2
5	Biomass	26 939	-6%	4 107	34%	1 542	-40%	9 000.00	4
6	GSHP_PV	8 758	65%	4 282	31%	939	14%	20 000.00	10
7	Condensing_boiler_SWT	19 155	24%	4 619	26%	810	26%	14 500.00	9
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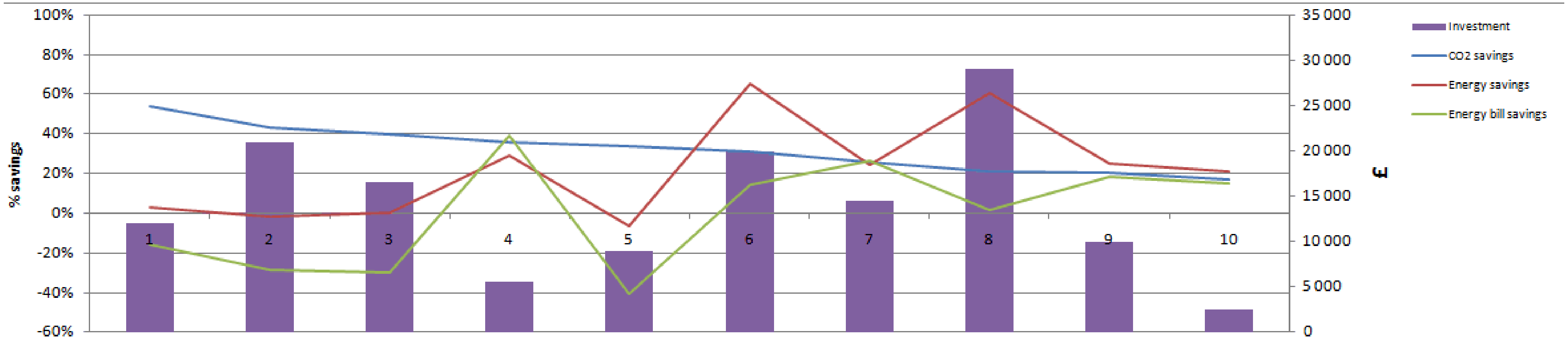

1: Biomass + PV, 2 : Biomass +SWT, 3: Biomass + ST, 4: Condensing boiler + PV , 5 : Biomass, 6 : GSHP + PV, 7: Condensing boiler + SWT, 8 : GSHP + SWT, 9 : Condensing boiler + ST , 10 : Condensing boiler

Regarding the **CO_2 emissions savings**, the best solutions are the cases with **Biomass** used as energy for space heating, followed by **gas condensing boilers and Ground Source Heat Pumps**. Among the 10 best ones, there **is no solution with Air Source Heat Pump (COP of 2.9)**. Microgen solution is also not ranked in the top ten.

In terms of **Energy Bill savings**, the Biomass solutions are the most expensive, followed by GSHP. The gas solutions are the most cost competitive.

Regarding the **cost invested by kilogram of CO_2 saved**, we observe a wide range of values between the best solutions and the worst. The solutions with **GSHP combined with Solar PV or SWT have a high cost investment per CO_2 saved (£10 and £22 /kgCO_2 saved). Meanwhile, the Biomass solutions combined with Solar PV or SWT have a lower cost investment per CO_2 saved (4 and 8 £/kgCO_2 saved).**

For the scenario 2010, the ranking of solutions by CO_2 emissions savings, is actually highly dependent on the **CO_2 intensities** per energy (28g CO_2/kWh for wood pellets, 198 for gas and **517 for electricity**).

The **best solutions** are clearly the DE solutions for **space heating using the energy with the lowest CO_2 intensity** (i.e. wood, then gas then electricity). In the context of 2010, a **Heat Pump,** combined with either a renewable production of domestic hot water or a renewable production of electricity, **does not reach as significant CO_2 savings** as Biomass or gas condensing boiler. Hence, **the Heat Pumps (even with a COP of 4) are not competitive in terms of CO_2 savings**.

The right argument to promote Heat Pumps should be **the Energy Consumption Savings**.

The next section, presents two different means to promote Heat Pumps in two different contexts:

- In 2010, by financial incentives
- And, in 2030, by the evolution of the CO_2 intensity for electricity (decarbonisation of the electricity grid over the next 20 years)

5 Analysis of the 2010 Scenario: Ranking key = Cost investment

The 10 best retrofitting solutions									
	Retrofitting solution	Energy consumption* kWh/an	*Energy savings %*	CO2 emissions kgCO2/an	*CO2 savings %*	Energy bill £	Bill *savings%*	Investment £	£ invested / kgCO2 saved
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2	Condensing_boiler_PV	17 941	*29%*	3 991	*36%*	671	*39%*	5 500.00	*2*
3	ASHP	13 885	*45%*	6 933	*-12%*	1 527	*-39%*	8 000.00	- *11*
4	Biomass	26 939	*-6%*	4 107	*34%*	1 542	*-40%*	9 000.00	*4*
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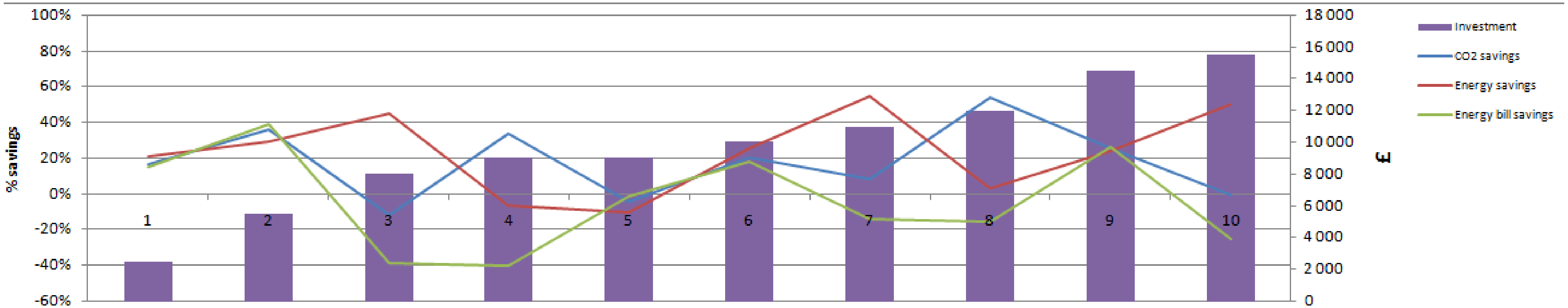
10	ASHP_ST	12 541	*50%*	6 238	*0%*	1 373	*-25%*	15 500.00	- *530*



1: Condensing boiler, 2: Condensing boiler + PV , 3: ASHP, 4: Biomass, 5: Microgen, 6: Condensing boiler + ST, 7: ASHP + PV, 8: Biomass + PV, 9: Condensing boiler + SWT, 10: ASHP + ST

In terms of investment cost, the lowest cost solutions are the ones with condensing boiler, followed by Air Source Heat Pump, Biomass and Microgen.

The solution with **ASHP** (COP of 2.9) is particularly interesting in terms of **Energy Consumption Savings**: 45**% compared** to the reference case. But, due to a high CO_2 intensity value and a high price for electricity, this solution is less competitive than the condensing gas boiler (Energy bill 39% higher than the reference case).

In order **to replace gas boilers, from 2011 up to 2030**, by **Air Source Heat Pumps**, two kinds of incentives are essential:
V

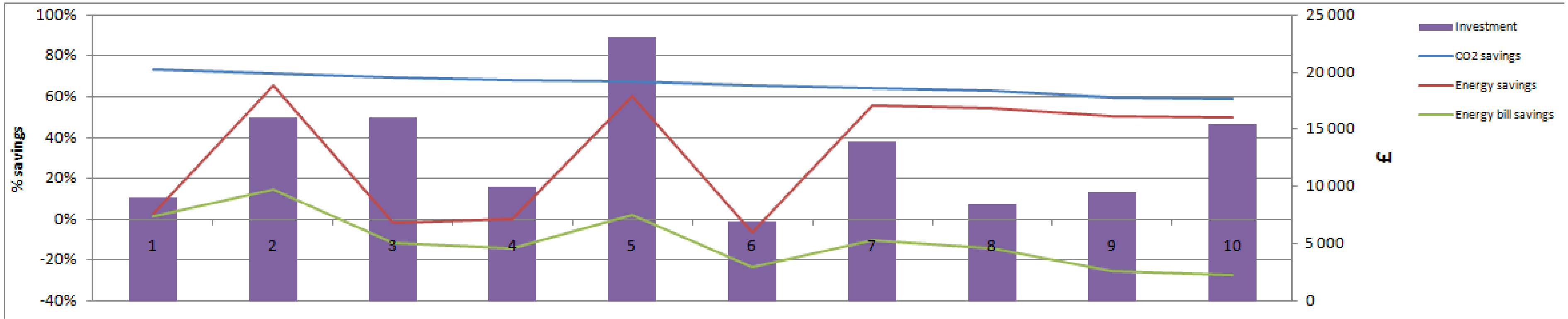
- An incentive on the cost investment (at least **£5,500** to be competitive with the gas boiler solution)
- **And/or** an incentive on the electricity price (lower than **8.4p/kWh** instead of **11.5p/kWh** to be competitive with the gas boiler solution)

6 Analysis of the 2030 Scenario: Ranking key = CO_2 emissions

For the 2030 scenario, we have used the 2010 results (in terms of energy consumptions) and updated the values of CO_2 intensities, energy prices and investment costs. With the version 4.0 of the alpha model tool, it is not possible to change the values of efficiency per technology for the 2030 scenario. So, we chose to keep the values used in the 2010 scenario. Once the final version of the alpha model tool has been developed, new results should be run and incorporated in this analysis.

The 2010 results updated give the ranking below:

The 10 best retrofitting solutions									
	Retrofitting solution	Energy consumption* kWh/an	*Energy savings %*	CO2 emissions kgCO2/an	*CO2 savings %*	Energy bill £	Bill *savings%*	Investment £	£ invested / kgCO2 saved
	Reference case : Old gas boiler	25 323		4 748		2 196			
1	Biomass_PV	24 569	*3%*	1 272	*73%*	2 169	*1%*	9 000.00	*3*
2	GSHP_PV	8 758	*65%*	1 348	*72%*	1 877	*15%*	16 000.00	*5*
3	Biomass_SWT	25 783	*-2%*	1 454	*69%*	2 447	*-11%*	16 000.00	*5*
4	Biomass_ST	25 301	*0%*	1 504	*68%*	2 503	*-14%*	10 000.00	*3*
5	GSHP_SWT	9 971	*61%*	1 530	*68%*	2 155	*2%*	23 000.00	*7*
6	Biomass	26 939	*-6%*	1 627	*66%*	2 712	*-24%*	7 000.00	*2*
7	GSHP	11 127	*56%*	1 703	*64%*	2 420	*-10%*	14 000.00	*5*
8	ASHP_PV	11 515	*55%*	1 761	*63%*	2 508	*-14%*	8 500.00	*3*
9	ASHP_ST	12 541	*50%*	1 915	*60%*	2 743	*-25%*	9 500.00	*3*
10	ASHP_SWT	12 729	*50%*	1 943	*59%*	2 786	*-27%*	15 500.00	*6*



1 : Biomass + PV, 2 : GSHP + PV, 3 : Biomass + SWT, 4 : Biomass + ST, 5 : GSHP + SWT, 6 : Biomass, 7 : GSHP, 8 : ASHP + PV, 9 : ASHP + ST, 10 : ASHP + SWT

For the scenario 2030, with the CO_2 intensities per energy updated (**25g CO_2/kWh for wood pellets, 194 for gas and 150 for electricity**), the best solution remains the **one with Biomass for space heating.**

Contrary to what we observed in the 2010 scenario, the condensing gas boiler solutions are no longer ranked in the 10 best solutions.

Nevertheless, the electricity solutions (GSHP or ASHP combined with Solar PV, Small wind turbine or Solar thermal) are more promising than in the 2010 scenario to reduce CO_2 emissions. The solutions combining Air Source Heat Pump (with a COP of 2.9) and Solar PV, Solar Thermal or SWT are particularly interesting in terms of CO_2 emissions savings and cost invested per kg of CO_2 saved (from £3-6 invested per kg CO_2 saved). However, due to the **high price of electricity** (four times higher than the wood price), the **energy bills of these solutions are higher** than the Biomass ones.

7 Conclusions and Future work

This analysis should be considered as provisional since the final tested version of the alpha model is still under development. The results and analysis presented in this deliverable are only indicative and not representative. An updated version of this analysis should be carried out once the final version of this tool has been delivered.

Nevertheless, this deliverable presents a **methodological approach and a mapping decision tool to rank the different DE technologies solutions for the 2010 and 2030 scenario. This decision approach should be used to decide the level of new incentives scheme to promote DE technologies, in terms of cost investment or energy bill incentives.**

The 2010 scenario analysis indicates that the electrical solutions for space heating are **less competitive in terms of CO_2 emission savings**, investment cost, and cost invested per kilogram of CO_2 saved **than the Biomass solutions or the gas condensing boiler**. Nevertheless, a GSHP with a COP of 4 combined with either Solar PV or Small Wind Turbine remains competitive in reducing CO_2 emissions.

Actually the best solutions providing CO_2 emission savings, , are highly dependent on the CO_2 intensity of the energy chosen for space heating (which represents the greatest part of total energy consumption in an existing residential dwelling)**.**

By the year 2030, the best solutions, ranked by CO_2 emissions savings, are:

- **biomass solutions** alone or combined with renewable DE technologies such as Solar Thermal, Small Wind Turbine or Solar PV ,
- Followed by the **electrical solutions with heat pumps** (first, GSHP with a COP of 4 then ASHP with a COP of 2.9) combined with Solar PV, Small Wind Turbine or Solar Thermal.
- The gas solutions are not ranked in the 10 best solutions.

If the **policy aim is to reduce the CO_2 emissions over the next 20 years**, the best solutions for space heating systems are Biomass or Heap pumps (with a minimum COP of 2.9 for ASHP and 4 for GSHP). However, these technologies are **more expensive** (in terms of cost investment but also for the energy bill) than the gas condensing boilers.

To bridge the gap in cost (investment cost and energy bill) and to encourage the **development of these technologies** up to 2030**, it is essential to launch incentives scheme** (for both: investment cost and electricity tariff with the FIT, RHI or the future Green Deal).
As the electricity solutions become more interesting by the 2030, probably before the decarbonisation of the electricity production, and with the decreasing investment costs of heat pumps, the Renewable Heat Incentive Scheme should be updated between 2010 and 2030.

Moreover, once the **best space heating technology has been identified**, **installing renewable production of electricity (Solar PV or Small Wind Turbine)** and/or **renewable production of domestic hot water (Solar Thermal)** will increase CO_2 emission savings.

8 References

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