6 Business Case

6.1 Introduction

1 This section provides an overview of the:

- Net financial benefits the project will provide to existing and future customers;
- Net carbon savings the project expects to deliver;
- Approach and methodology that the project has taken in assessing financial and carbon benefits; and
- Key assumptions that underpin the project's business case.

6.2 Summary

2 On the assumption that the project is successful and the learning is adopted nationally (where the learning is replicable), it is estimated that the project will deliver £16.83bn of net financial benefits, including 43.5MtCO2 benefits, to consumers over the period 2020 – 2050. These benefits are built up from the following high level benefit areas:

- **£6.63bn network capital cost savings** – avoided costs associated with reinforcing the electricity distribution networks to support additional load and increased variability of supply and demand;
- **£2.02bn customer benefit** – payments to customers associated with DSR flexibility;
- **£6.00bn carbon emission savings** – carbon savings relating to acceleration of the connection of LCTs; and
- **£2.18bn generation capital cost savings** – avoided costs associated with reducing peak generation requirements.

This gives a total <u>net</u> benefit of £16.83bn, with an NPV of £6.11bn

3 This analysis currently indicates that the earliest benefit to the network occurs in 2020. We have attempted in the assessment methodology to capture, as far as possible, the effects of geographical clustering of LCTs, most of the previous literature having assumed smooth dispersal across the network as a whole. However, this has only been partially successful in that it does not effectively capture the local nature of clusters nor that some of these clusters are likely to have above average impacts on the network. We have already stated both the conservative nature of the figures used throughout the analysis and that, for the purposes of analysis, numbers in the middle of the range of possibilities have been used. Although the analysis indicates that on average across the network as a whole there are no issues until 2020 this is clearly not going to be the case for the all parts of the network. We are already seeing impacts on the network in some areas due to early LCT clusters.

4 On this basis we conclude that in order to tackle issues that are already arising with respect to LCT clustering and to ensure that there are no general issues that prevent the wide scale take up of such technologies it

is essential that the customer solutions proposed within our project are ready as soon as possible for implementation within the DPCR6 period. Whilst this will generate both carbon and customer benefits we believe that our ability to model the clustering effects of LCT take up is insufficiently sophisticated to provide a credible quantitative assessment of this. In the context of this project we therefore claim carbon and business benefits associated with additional, accelerated LCT technology take up only from 2020 although there are likely to be substantial benefits before this date.

6.3 Enablers

5 The benefits highlighted in section 2 are expected to be delivered through the following enablers:

6.3.1. Demand Side Response learning

6 The project aims to test a range of customer-side strategies (smart meter-based energy tariffs, smart heat pumps, generation, smart appliances) for providing Demand Side Response (DSR). These tests will result in a set of learning outcomes which can be used by the industry to develop operational policies and practices and new commercial arrangements which engage customers and market participants (suppliers, DNOs, generators) to provide effective demand management services.

7 More effective DSR will have a number of benefits. It will allow DNOs to develop planning tools to allow today's network to be adapted faster, and potentially at lower cost, to support the requirements of existing and future LCTs. It will make investments in LCTs more affordable by discovering commercial mechanisms that allow customers to access the value of their contribution to network load management. These benefits will have the knock-on effect that this should accelerate the take up of LCTs, and this will have an associated carbon benefit.[1] DSR can also have a benefit associated with reduced generation costs, if demand is moved from periods of higher to lower generation costs.

6.4 Optimal use of installed network capacity

8 One of the key elements of the project involves trialling network-side technology and methods (voltage control, dynamic thermal rating and storage) at different points along the EHV/HV/LV system. The output of these trials will be used to develop cost-effective network design tools and codes of practice which enable control at the appropriate level of the network hierarchy to allow network elements to operate safely closer to the engineering limits than is allowed by the current conservative

[1] Our quantification of carbon savings is therefore based on accelerating the uptake of LCTs, rather than claiming carbon benefits associated with their implementation, as discussed later in this section.

engineering recommendations. This will create additional headroom on the network without the need for conventional reinforcement. The customer will therefore benefit from lower distribution charges resulting from the difference between the cost of reinforcement and the cost of employing the new network design tools and codes of practice i.e. network capital cost savings. Network capital cost savings will be reflected in lower use of system charges and lower connection costs.

9 We recognise that there are likely to be both increases and decreases of losses, dependent on the combination of new technologies that are applied. At this stage the project has not analysed these in detail and is therefore assuming that there is zero overall carbon impact (i.e. any increases in losses are offset by any decreases).

10 We do not believe there will be any benefits associated with generation capital cost savings from this enabler.

6.5 Benefit Analysis Methodology

11 This subsection provides an overview of the methodologies and approach which has been taken to analyse the net benefits of the project to the consumer.

6.5.1. Network capital cost savings

6.5.1.1. High level approach

12 To determine the network capital cost savings that will be delivered to the consumer, the project has compared the cost of conventional reinforcement with the cost of employing alternative methods (demand side response and network-side technology and methods) to support the roll-out of low carbon technologies (EVs, Heat Pumps, CHP and PV).

13 Standard DNO LV network design software (WinDebut) was used to model the impact of low carbon technology penetration on representative LV networks. This resulted in an understanding of the different levels of low carbon technology penetration that can be achieved before mitigation action is required to overcome network constraints (voltage and thermal constraints).

14 Industry literature was then used to determine likely penetration scenarios for the various low carbon technologies. The total cost of the appropriate conventional reinforcement required to overcome any LV network constraints which would be encountered was calculated using DPCR5 unit costs. These costs were then compared against the anticipated cost of employing the optimal alternative mitigating actions to overcome these constraints.

15 The project has assumed that the same type of network constraint applies at both LV and HV levels. For example, if a thermal constraint is reached

on the LV network, then the increased power flows are likely to result in an HV thermal constraint being reached before an HV voltage constraint is reached.

16 Therefore the mitigating actions which are used at the LV level are used to determine the nature of corresponding HV mitigation action required. To calculate the HV net benefits to customers the same approach is applied as with the LV benefits in that the cost of conventional reinforcement is compared with the cost of mitigating actions.

6.5.1.2. Applicability

17 We estimate that the findings of the project will be applicable to 84% (by length) of GB Rural LV networks and 80% (by length) of GB LV Urban networks. The analysis to support this is as follows:

18 In order to estimate how transferable the learning from the project on CE Electric network will be to other DNOs we have calculated the overall feeder length of each representative network and made estimates as to the proportion of each licence which have networks which are comparable to these representative networks.

19 1) We have calculated the length of the representative Urban and Rural Networks by assuming that on average 10% of the length of Rural Network is Underground.

Therefore the length of the Rural Network for each licence is given by:

$$L_{rural} = L_{ohlv} / 90\%$$

Where L_{ohlv} is the published length[2] of the overhead LV network for the licence area.

And the length of the Urban Network for each licence is given by:

$$L_{urban} = L_{uglv} + L_{ohlv} \times (1 - 1 / 90\%)$$

Where L_{uglv} is the published length[3] of the underground LV network for the licence area.

20 2) We have estimated the percentage of each licence which is comparable to the CE Network as follows:

<u>Urban Network:</u>

- LPN: 0% (Interconnected network)
- SPManweb: 30% (70% interconnected, 30% radial)

[2] Based on 2009 RRP data submitted by DNOs to Ofgem
[3] Based on 2009 RRP data submitted by DNOs to Ofgem

- Others (incl CEE): 90% (there will be a relatively small number of unusual configurations)

Rural Network:

- LPN: 0% (No O/H LV)
- SSEHydro: 50% (due to proportion of particularly long feeders)
- WPDWest: 60% (due to proportion of particularly long feeders)
- WPDSWales: 80% (due to proportion of particularly long feeders)
- Others (incl CEE): 90% (there will be a relatively small number of unusual configurations)

6.5.1.3. Key assumptions

- Penetration levels of LCT at which network constraints occur are correctly predicted by the methodology used.
- LV rural and urban feeders which were modelled are representative of GB LV feeders, to the extent described in section 4.1.2
- Extrapolation to GB LV networks using Ofgem source[4] for number of connections per km of feeder for rural and urban network plus total GB length of overhead and underground LV feeders
- Clustering - Low carbon technologies are unlikely to be dispersed uniformly across the GB network. We have estimated the effect of clustering by assuming that 50% of LCTs will be connected to 20% of the network. As the connections are necessarily assumed to be randomly distributed over this proportion of the network the analysis cannot reflect the impact which might be seen on individual feeders. It is likely that there will be clusters, where a large number of LCTs are connected to a feeder, whilst in other areas of the network very few numbers of LCTs are connected to a feeder. Consequently this analysis is likely to indicate that network issues will arise later than might occur in practice. The project therefore considers its network capital savings to be conservative and shown later than might be seen in practice.

6.5.1.4. Methodology

21 We assume that there is no interaction between the potential solutions which could either increase or decrease the number of installations from simple aggregation of the individual numbers for each potential solution. The methodology comprises two parts:

A) Determine the cost / additional LCT connection of each method and reinforcement option

[4] Based on 2009 RRP data submitted by DNOs to Ofgem

22 The following method was followed for a representative LV network feeder and a representative HV network feeder. Each feeder was modelled using the WinDebut software tool (the LV network design software tool that is used by all GB DNOs).

1) For each type of LCT, we determined the number of installations of the LCT which can be accommodated on the feeder before a network constraint (voltage or thermal) is reached (subsequently referred to as the "headroom") in each of the following cases:
    a. For the feeder "as is" (the "natural" headroom)
    b. after application of the following methods:
        i. Demand Side Response (through use of tariff)
        ii. Demand Side Response (by load control)
        iii. Enhanced Automatic Voltage Control
        iv. Dynamic Thermal Ratings
        v. Electrical Energy Storage
    c. After application of the following circuit reinforcement options
        i. Split feeder at midpoint and run a new underground cable feeder to the mid-point.
        ii. Cable plus higher capacity transformer
        iii. Additional Substation

2) We then selected the method for relieving the constraint on the HV feeder which supplies the LV network using the following table.

LV Method	HV Method
Novel Methods	
DTR	DTR
EAVC	EAVC
Load Control	None required
Load Tariff	None required
Sec SS Storage	None required
Reinforcement Options	
Additional Substation	Reinforce HV Feeder
Cable + Transformer	Reinforce HV Feeder
Cable Replacement	Reinforce HV Feeder

Note that for an urban HV feeder reinforcement we assume that the feeder is split at mid-point and a new HV cable is installed between substation and mid-point with half the length of the original feeder, whereas for a rural HV feeder reinforcement we assume re-conductoring with a higher capacity conductor.

3) We calculated the estimate of cost of each relevant method, using the following sources for costs:
   a. DPCR5 unit costs
   b. CE Electric cost (where a direct DPCR5 unit cost is not available)
   c. Supplier provided information
   d. DSR costs were set to result in a cost / LCT connection which was broadly comparable with the least cost novel network solution.
4) We expressed the cost of each method as a cost per additional LCT Connection
5) We summed the costs of the LV method (or reinforcement option) and the concomitant HV method (or reinforcement option)
6) We expressed the number of LCT Connections which can be accepted on a conventional feeder as a % of maximum connection points on the feeder for each of the methods and reinforcement options (listed in (1) above)

B) Calculate the financial benefit for GB from use of the most economically efficient method, when compared to the conventional reinforcement option

23 The reinforcement option used for this comparison was that which releases the greatest headroom for connection (denoted below as reinforcement).

1) We assumed that clustering of LCT will occur. Specifically we assumed that 50% of LCT connections will be distributed relatively uniformly across 20% of the network, and that 50% of LCT connections will be evenly distributed across the remaining 80% of the network. We also assumed that there is no bias towards urban or rural networks.
2) We summed the numbers of Heat Pumps and Electric Vehicles because each are similar loads and connection of one will reduce the available headroom for the other.
3) We ranked the methods and reinforcement options in order of cost / additional connection of the LCT
4) We calculated the difference between the cost / additional connection of each of the methods and the cost / additional connection of reinforcement
5) We noted the “headroom” for connection of each LCT which results from the application of the method or reinforcement option, expressed as a % of the total number of connection points on the feeder.
6) We calculated the number of LV connection points that represent the “natural” headroom and the headroom for connection of each LCT in both the 20% (clustered) part of the urban and rural GB network,
7) We estimated the numbers of connections of LCT between 2015 and 2050. The section on carbon benefits below describes how these

numbers are determined for each of the individual technologies and the data sources used.

8) We divided the numbers of connections of LCT per year so that 13% are assumed to be connected to rural networks and 87% to urban networks, inline with the proportion of rural and urban LV networks by length[5].
9) We then further divided both urban and rural network numbers into the 50% to be applied to 20% of the network and 50% to be applied to 80% of the network.
10) For each of the following network segments:
    a. 20% Urban Clustered
    b. 20% Rural Clustered
    c. 80% Urban Dispersed
    d. 80% Rural Dispersed

    We calculated the annual financial benefit for each of the LCTs, using the following method:
    a. Check if the number of connections of the LCT is above the "natural" headroom for the LCT. If it is below this headroom, then the LCT can be connected without action and there is therefore no financial benefit. Provided that it is above the "natural" headroom, then
    b. Check if the number of connections of the LCT is below the headroom for the method with the lowest cost per connection. If it is below then multiply the change in % of connections of the LCT over the relevant year by the difference between the cost / additional connection of this method,
    c. If it is above the headroom for this method, then use the difference between the cost / additional connection of the next lowest cost method,
11) We summed the annual financial benefit for each LCT to give the overall annual financial benefit.
12) Finally we multiplied the annual financial benefit by 80%, in order to account for the replicability of the project. Note that Box 1 refers to the replicability of the learning outcomes of our project through GB networks.

6.6 Customer Benefit, Payment For DSR ,participation

24 A further project benefit is generated for supply customers in terms of the payments made to them for their participation in DSR, both tariff and load control.

25 Participation in and take up of DSR opportunities closely follows the business set out above but only on that fraction of the network where the available overhead room for additional connection is potentially exhausted. Estimating this figure, the number of connections involved and the level of payment likely to be made has been estimated on the following basis;

26 The cost of Load Control and Load Tariff DSR which we assumed for the avoided network capital cost financial benefits, were set to make DSR broadly comparable in cost to novel network solutions whilst providing a reasonable incentive to customers. At these costs, Load Control and Load

[5] Based on 2009 RRP data submitted by DNOs to Ofgem.

Tariff DSR are financially attractive (compared with novel network solutions) for dealing with thermal issues but not voltage issues.

27 Our analysis shows that Load Control DSR typically provides 25% of the additional headroom for heat pumps and electric vehicles which is provided by the alternative methods (in place of conventional reinforcement) and Load Tariff DSR typically provides a further 15% of that headroom. Scaling the annual network capital cost financial benefit for connection of heat pumps and electric vehicles by these factors gives the annual quantum of benefit which is derived from each DSR method.

28 For each DSR method, we use the cost per LCT connection, the ratio of the power of the LCT to the power of the flexible load per DSR participant and the annual payment to each participant to calculate the annual payments to new DSR participants. Adding the payment amounts for Load Tariff and Load Control DSR methods gives the total annual payments to new DSR participants. As these payments continue into the future, the total annual payments to DSR participants are the cumulative sum of all years up to and including that year.

29 For Load Tariff we have estimated values of £5 per customer and for Load Control £20 per customer, based on an apportionment of the DUOS saving.

30 This methodology gives an aggregate customer benefit of £2.08bn over the period 2025-2050 at 2010 process.

6.7 Carbon Emissions Savings

6.7.1. High level approach

31 Project success will not in itself bring about the acceptance and use of key carbon reducing technologies. For these the technology trajectories are already established and are likely to be achieved without a successful outcome of the project.

32 The carbon case methodology is based on an assessment of the change in overall carbon emitted as a result of the project outcomes bringing forward the implementation of such technologies such as photovoltaic microgeneration, heat pump installation and replacement of fossil fuelled vehicles with electric vehicles.

33 For each technology for each year a comparison can be made of the number of installations of that technology that would be expected across the whole UK, according to current predictions against the number that would be expected if the take-up curve was bought forward due to successful project delivery.

34 Making this comparison gives a carbon benefit for each year as a result of this accelerated technology take up. Total carbon benefit can then be calculated by aggregating across the individual technologies for each year.

The project benefits would not benefit the whole of the UK network in the same way. To account for this a reducing constant is applied, in this case 80%, representing our calculations of the applicability of the project's learning outcomes. These are stated in the overall project business case.

6.7.2. Qualification

35 Identifying consistent figures, in particular for take up figures for individual technologies is difficult. As a result, the philosophy throughout this analysis has been to make conservative estimates about such figures, and where possible make comparison across more than one source to check for consistency. Such checks may require the comparison of qualitative and quantitative data and as such may not be entirely rigorous.

36 As far as possible the data sources quoted have been from organisations such as DECC, the Environment Agency, DEFRA and the Office For National Statistics (ONS). Figures from pressure groups or trade associations have been found to be consistently optimistic about technology take up.

37 Figures for current emissions have been used as baseline for the analysis. This can have a potential impact on the aggregate emissions impact figures. For instance the current carbon equivalent emission per kWh of generated electricity is likely to change with time as increased renewables displace fossil fuels from the generation mix. This does however mean that the carbon saving for EV and HP is likely to increase under the scenarios outlined here, whilst the benefit from the installation of PV is likely to decrease. Again examination of the figures would indicate that failing to take account of this will lead to understated rather than overstated carbon figures and as such is in line with the stated philosophy of conservatism.

6.7.3. Electric Vehicles

6.7.3.1. Assumptions

6.7.3.2. Electric Vehicle Take Up

38 Data are available describing several scenarios for vehicle take-up, but figures vary greatly. Predictions are influenced by a variety of different issues, taking in tax regime, government subsidy, technology improvement curves, and others. Figures for the years up to 2022 and for 2030 are available from one source[6] which is relatively consistent with other mid range predictions. These have been used as the starting point for the generation of take-up figures.

39 Data are not available for all years. Between 2023 and 2029 it has been assumed that EV take up will be taken up on a linear interpolation.

[6] Market Outlook To 2022 For Battery Electric Vehicles & Plug In Hybrid Electric Vehicles, Report to Committee On climate change, AEA Technology plc, 2009.

40 Beyond 2030 it has been assumed that take up will increase the number of electric vehicles by around 2.5% per annum until the electric vehicle fleet is around 20 million representing about 50% of the total UK vehicular fleet of around 40 million. This figure is consistent with the 2050 Pathways Analysis[7] report.

41 This assumption of the total vehicular fleet size is based on a 0.6% year on year increase in 28.4 million UK vehicles which is the last available count for the end of 2009[8].

6.7.3.3. Current Car Travel

42 Average car travel has been calculated[8]. This is based on average travel per person of 7133 miles pa (11900km). Of this 80% is by car giving an annual per person figure for car travel of 5706miles (9510km). This figure is then further refined to make an allowance for journeys where a car took more than one passenger. This reduces the per car figure by one third to 3880miles (6370km).

43 For the purposes of this study it has been assumed that there will be no change in this figure. Current trends reported by ONS are for a slight reduction in number of trips with a small increase in average trip distance.

6.7.3.4. Current Carbon Emissions[9]

44 Current average emission is 204g CO2 per km for all fossil fuel cars.

45 Again there may be scope for considerable improvement in this figure with the use of improved drive chains, regenerative breaking and other technologies but assessments of both the magnitude and likely availability of these improvements and their precise impact has been ignored.

6.7.3.5. Electric Vehicle Carbon Emissions

46 Current electric vehicles emission, based on fossil fuel generated electricity, sits in a range from 40g CO2 per km to 150g CO2 per km. For the purposes of this analysis a figure of 104g CO2 per km has been selected. This type of value is already available from commercial vehicles in 2010 and approximates to a consumption of 20kWhr/100km[10].

47 Further advances in technology might be expected to improve this figure further, as would the adoption of more renewable/low carbon electricity generation. However, as with estimating fossil fuel vehicle improvements data are difficult to obtain and interpret. It is sufficient to observe that neglecting technology improvements will result in a more conservative estimate of carbon emission improvements.

[7] 2050 Pathways Analysis, DECC, July 2010
[8] Social Trends, No. 40, 2010 Edition, Office For National Statistics

[9] 2010 Guidelines To Defra/DECC's GHG Conversion Factors For Company Reporting, July 2010
[10] Review Of Electric Vehicle Emissions, No Hot Air, D. McKay, 2009, p136

6.7.3.6. Per Vehicle Per Annum Carbon Saving Calculation

48 The above data allows the calculation of a carbon saving associated with additional electric vehicles on the road ahead of when they would otherwise be. This is the difference between the typical fossil fuel emissions per vehicle per year and an electric vehicle, assuming the same mileage and usage pattern.

	Fossil Fuelled Vehicle	Electric Vehicle
Annual travel, km	6370	6370
Emissions, gCO2 per km	204	104
Emissions per year, kgCO2	1299	662
Carbon saving, kgCO2 per vehicle	-	637

49 The average carbon dioxide saving achieved per vehicle per annum is 637kg.

50 This is, therefore, the carbon saving per year for each electric vehicle that is on the road but otherwise, in the absence of the successful outcome of the project, would still be a fossil fuelled car.

6.7.3.7. Project Impact

51 The following table demonstrates the effect of bringing electric vehicles to the road sooner than otherwise. The table shows three scenarios, in which the conversion to an electric vehicle fleet is bought to bear one, two and three years early. These figures are modified to take account of applicability.

52 This gives a range of estimates for carbon saving as follows:

EV roll out acceleration, years	Carbon Saving, t CO2
1 year	9,716,472
2 years	19,516,700
3 years	29,392,808

53 This indicates a considerable absolute saving in carbon emissions as a result of the project plus a contribution to the facilitation of the overall UK Low Carbon Transition Plan with its explicit target of reducing emission from transport by 40% over 2007 levels.

No of Vehicles

Year	Low-Range	Mid-Range	High-Range
2007	0	0	0
2008	0	0	0
2009	0	0	0
2010	0	0	0
2011	0	0	0
2012	0	0	28200
2013	0	0	56400
2014	0	0	105750
2015	70500	133950	373650
2016	169200	274950	599250
2017	225600	408900	860100
2018	289050	564000	1128000
2019	571050	951750	2122050
2020	853050	1325400	3087900
2021	1120950	1670850	3955050
2022	1410000	2044500	5076000
2023		3287833.3	
2024		4531166.7	
2025		5774500	
2026		7017833.3	
2027		8261166.7	
2028		9504500	
2029		10747833	
2030	4100000	12000000	20600000
2031		12307200	
2032		12622264	
2033		12945394	
2034		13276796	
2035		13616682	
2036		13965269	
2037		14322780	
2038		14689444	
2039		15065493	
2040		15451170	
2041		15846720	
2042		16252396	
2043		16668457	
2044		17095170	
2045		17532806	
2046		17981646	
2047		18441976	
2048		18914091	
2049		19398291	
2050		19894888	
		20392260	
		20902066	
		21424618	

Scenarios where a successful project implementation bring forward EV implementation

Scenario 3yrs	Δ EVs	Δ CO2 (tonnes)
3,287,833	1,962,433	1000056
4,531,167	2,860,317	1457617
5,774,500	3,730,000	1900808
7,017,833	3,730,000	1900808
8,261,167	3,730,000	1900808
9,504,500	3,730,000	1900808
10,747,833	3,730,000	1900808
12,000,000	3,738,833	1905309
12,307,200	2,802,700	1428256
12,622,264	1,874,431	955210
12,945,394	945,394	481773
13,276,796	969,596	494106
13,616,682	994,418	506755
13,965,269	1,019,875	519728
14,322,780	1,045,984	533033
14,689,444	1,072,761	546679
15,065,493	1,100,224	560674
15,451,170	1,128,390	575027
15,846,720	1,157,276	589748
16,252,396	1,186,903	604846
16,668,457	1,217,287	620330
17,095,170	1,248,450	636210
17,532,806	1,280,410	652497
17,981,646	1,313,189	669201
18,441,976	1,346,806	686332
18,914,091	1,381,285	703903
19,398,291	1,416,645	721923
19,894,888	1,452,912	740404
20,392,260	1,478,169	753275
20,902,066	1,503,775	766324
21,424,618	1,529,730	779551

Total Saving 29,392,808 t

Scenario 2yrs	Δ EVs	Δ CO2 (tonnes)
2,044,500	719,100	366453
3,287,833	1,616,983	824015
4,531,167	2,486,667	1267205
5,774,500	2,486,667	1267205
7,017,833	2,486,667	1267205
8,261,167	2,486,667	1267205
9,504,500	2,486,667	1267205
10,747,833	2,486,667	1267205
12,000,000	2,495,500	1271707
12,307,200	1,559,367	794653
12,622,264	622,264	317106
12,945,394	638,194	325224
13,276,796	654,532	333550
13,616,682	671,288	342088
13,965,269	688,473	350846
14,322,780	706,098	359828
14,689,444	724,174	369039
15,065,493	742,713	378487
15,451,170	761,726	388176
15,846,720	781,227	398113
16,252,396	801,226	408305
16,668,457	821,737	418757
17,095,170	842,774	429478
17,532,806	864,349	440472
17,981,646	886,476	451748
18,441,976	909,170	463313
18,914,091	932,445	475174
19,398,291	956,315	487338
19,894,888	980,797	499814
20,392,260	993,968	506526
20,902,066	1,007,179	513258

Total Saving 19,516,700 t

Scenario 1yrs	Δ EVs	Δ CO2 (tonnes)
1,670,850	345,450	176041
2,044,500	373,650	190412
3,287,833	1,243,333	633603
4,531,167	1,243,333	633603
5,774,500	1,243,333	633603
7,017,833	1,243,333	633603
8,261,167	1,243,333	633603
9,504,500	1,243,333	633603
10,747,833	1,243,333	633603
12,000,000	1,252,167	638104
12,307,200	307,200	156549
12,622,264	315,064	160557
12,945,394	323,130	164667
13,276,796	331,402	168883
13,616,682	339,886	173206
13,965,269	348,587	177640
14,322,780	357,511	182188
14,689,444	366,663	186852
15,065,493	376,050	191635
15,451,170	385,677	196541
15,846,720	395,550	201572
16,252,396	405,676	206733
16,668,457	416,061	212025
17,095,170	426,713	217453
17,532,806	437,636	223019
17,981,646	448,840	228729
18,441,976	460,330	234584
18,914,091	472,115	240590
19,398,291	484,201	246749
19,894,888	496,596	253065
20,392,260	497,372	253461

Total Saving 9,716,472 t

6.7.4. Heat Pumps

6.7.4.1. Assumptions

6.7.4.2. Heat Pump Take Up

54 Data are available describing several scenarios for heat pump take-up. . Data[11] from the Environment Agency (EA) has been used as the basis for the estimate of take up. High and low bound figures are available for all years up to 2020 and for the purposes of this analysis a figure halfway between the two has been selected.

55 The EA figures are comparable with another estimate and somewhat below the figures from the Ground Source Heat Pump Association.

56 Beyond 2020 it has been assumed that the use of heat pumps will increase at about 10% year on year. Taking this increase out to 2050 gives a prediction of around 13 million installations. This compares with a figure for total UK households in 2009, of 25.6 million and would therefore represent about half of all households, assuming no growth in that time. On this basis the figure would seem to be a reasonable figure to accept given the large degree of uncertainty and would not seem excessive. In addition this figure is in line with several of the middling scenarios presented in the Pathways to 2050 document which indicate 40-60% of UK space heating being from ground or air source heat pumps by 2050.

6.7.4.3. Current Heating Fuel Use

57 Average gas consumption for heating has been has been calculated[8]. This is based on total UK gas consumption for domestic heating of 21,887 thousand tonnes of oil (toe) equivalent, and converting this to kWh using the OECD/IEA standard conversion of one toe equals 11.63MWh, gives a total energy usage of for gas heating of 254.546TWh.

58 ONS reports 25.2m households in the UK in the latest year for which there are figures (2009), giving an average per household per annum usage of 10,101kWh.

59 As a sense test this can be compared with the average UK annual gas consumption per household, which was 16,000kWh[12] in 2007. Again a ratio of 2:1 for heating to other uses of gas would seem to be reasonable.

60 It should be noted that the estimates are very much that. This doesn't take into account households that are not connected to natural gas. As such the mean usage per household is likely to be somewhat underestimated but that will contribute to a conservative estimate of potential carbon savings.

[11] Ground Source Heating & Cooling Pumps– State of Play & Future Trends, Evidence Directorate, Environment Agency, Nov. 2009
[12] BERR, Energy Trends, 2007

6.7.4.4. Current Carbon Emissions[13]

61 Current average emission is 206g CO2 per kWh for natural gas.

62 This allows us to convert current gas usage for heating into an annual total per installation carbon output of 2076kg.

6.7.4.5. Heat Pump Carbon Emissions

63 To calculate heat pump carbon emissions it is necessary to appreciate that we are converting from a predominantly natural gas-fuelled system to one which is predominantly electric.

64 At first sight this gives an increase in CO2 when changing from gas to electric space heating as the aggregate carbon output for electricity is 545g per kWh[13]. However we also need to consider that the key advantage, from a carbon perspective, of adopting heat pumps is the increased efficiency in terms of power consumption to useable heat developed, when compared with gas installations. This efficiency is usually expressed as a coefficient of performance (COP), which is the ratio of the useful the heat produced to the energy input to the system.

65 The value of COP can vary between heat pumps and can also vary throughout the year due to seasonal impacts. A relatively un-ambitious value to choose for the purposed of this estimate is 3.5[14]. Like many of the other figures used here this may prove to be an underestimate as newer technologies have already demonstrated values in the range 4.7-5.0[15] and such technologies are likely to be have an impact at some point in the future.

66 No distinction is made between ground source and air source heat pumps. The former tend to have higher COP values but retro fitting of the latter is much easier and it is suitable for smaller properties or those without gardens. 2050 Pathways Analysis figures indicate a probable mixture of the two technologies. The selected COP figure is relatively representative of both.

67 Combining the carbon output figure for electricity with the COP gives a figure of 156g CO2 per kWh for heat (ie 545/3.5).

68 Changes in the electricity supply mix impact this figure. The use of additional renewables, displacing fossil fuels, or the use of carbon sequestration will reduce the typical carbon emissions from electricity generation. This will increase the carbon benefit of displacing gas with

[13] 2010 Guidelines To Defra/DECC's GHG Conversion Factors For Company Reporting, July 2010
[14] Building a low-carbon economy –the UK's contribution to tackling climate change, DECC, 2008

[15] Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, p398.

electrical heat pump based space heating. This potential additional benefit has been neglected, in line with the policy of conservatism.

6.7.4.6. Per Heat Pump Per Annum Carbon Saving Calculation

69 Comparing gas heating with electric heat pumps gives us a carbon saving ratio of 0.757 (ie 156g/206g).

70 Converting from gas to electric heat pumps gives a carbon saving of 24.3% (1-0.757)

71 The per installed-unit carbon saving can be estimated as 506kg per annum (ie 0.243*10101kWh*206g)

	Gas Heating	Heat Pump
Annual energy consumption, kWh	10101	10101
Emissions, gCO2 per kWh	206	156
Emissions per year, kgCO2	2081	1575
Carbon saving, kgCO2 per HP	-	506

72 The average carbon dioxide saving achieved per heat pump per annum is 506kg.

73 This is, therefore, the carbon saving per year for each heat pump based system which otherwise, in the absence of the successful outcome of the project, would still be fossil fuelled, most likely natural gas.

6.7.4.7. Project Impact

74 The following table demonstrates the effect of bringing electric heat pump space heating installations into use sooner than otherwise. The table shows three scenarios, in which the conversion to an electric heating is bought to bear one, two and three years early. These figures are modified to take account of network applicability.

75 This gives a range of estimates for carbon saving as follows:

HP roll out acceleration, years	Carbon Saving, t CO2
1 year	5,593,028
2 years	11,745,359
3 years	18,512,923

76 This indicates a considerable absolute saving in carbon emissions as a result of the project plus a contribution to the facilitation of the overall UK Low Carbon Transition Plan with its explicit target of reducing emission from all sources by 80% over 2007 levels.

No of HP installations

Year	Low-Range	Mid-Range	High-Range
2007		0	
2008	**8,000**	**8,000**	**8,000**
2009	12,000	**16,000**	20,000
2010	24,000	**37,000**	50,000
2011	50,000	**70,000**	90,000
2012	76,000	**105,500**	135,000
2013	112,000	**146,000**	180,000
2014	129,000	**184,500**	240,000
2015	150,000	**230,000**	310,000
2016	180,000	**290,000**	400,000
2017	210,000	**355,000**	500,000
2018	245,000	**435,000**	625,000
2019	280,000	**540,000**	800,000
2020	**320,000**	**760,000**	**1,200,000**
2021		836000	
2022		919600	
2023		1011560	
2024		1112716	
2025		1223988	
2026		1346386	
2027		1481025	
2028		1629127	
2029		1792040	
2030		1971244	
2031		2168369	
2032		2385206	
2033		2623726	
2034		2886099	
2035		3174709	
2036		3492179	
2037		3841397	
2038		4225537	
2039		4648091	
2040		5112900	
2041		5624190	
2042		6186609	
2043		6805270	
2044		7485797	
2045		8234377	
2046		9057814	
2047		9963596	
2048		10959955	
2049		12055951	
2050		13261546	
		14587700	
		16046470	
		17651117	

Scenarios where a successful project implementation bring forward HP implementation

Scenario 3yrs	Δ HPs	Δ CO2 (tonnes)
1,011,560	251,560	101751
1,112,716	276,716	111926
1,223,988	304,388	123119
1,346,386	334,826	135431
1,481,025	368,309	148974
1,629,127	405,140	163871
1,792,040	445,654	180258
1,971,244	490,219	198284
2,168,369	539,241	218112
2,385,206	593,165	239924
2,623,726	652,482	263916
2,886,099	717,730	290307
3,174,709	789,503	319338
3,492,179	868,453	351272
3,841,397	955,299	386399
4,225,537	1,050,829	425039
4,648,091	1,155,911	467543
5,112,900	1,271,503	514297
5,624,190	1,398,653	565727
6,186,609	1,538,518	622300
6,805,270	1,692,370	684530
7,485,797	1,861,607	752983
8,234,377	2,047,768	828281
9,057,814	2,252,544	911109
9,963,596	2,477,799	1002220
10,959,955	2,725,579	1102442
12,055,951	2,998,136	1212686
13,261,546	3,297,950	1333955
14,587,700	3,627,745	1467350
16,046,470	3,990,520	1614085
17,651,117	4,389,572	1775494

Total Saving 18,512,923 t

Scenario 2yrs	Δ HPs	Δ CO2 (tonnes)
919,600	159,600	64555
1,011,560	175,560	71011
1,112,716	193,116	78112
1,223,988	212,428	85923
1,346,386	233,670	94515
1,481,025	257,037	103966
1,629,127	282,741	114363
1,792,040	311,015	125799
1,971,244	342,117	138379
2,168,369	376,328	152217
2,385,206	413,961	167439
2,623,726	455,357	184183
2,886,099	500,893	202601
3,174,709	550,982	222861
3,492,179	606,081	245148
3,841,397	666,689	269662
4,225,537	733,358	296629
4,648,091	806,693	326291
5,112,900	887,363	358921
5,624,190	976,099	394813
6,186,609	1,073,709	434294
6,805,270	1,181,080	477723
7,485,797	1,299,188	525496
8,234,377	1,429,107	578045
9,057,814	1,572,017	635850
9,963,596	1,729,219	699435
10,959,955	1,902,141	769378
12,055,951	2,092,355	846316
13,261,546	2,301,591	930947
14,587,700	2,531,750	1024042
16,046,470	2,784,925	1126446

Total Saving 11,745,359 t

Scenario 1yrs	Δ HPs	Δ CO2 (tonnes)
836,000	76,000	30740
919,600	83,600	33815
1,011,560	91,960	37196
1,112,716	101,156	40916
1,223,988	111,272	45007
1,346,386	122,399	49508
1,481,025	134,639	54459
1,629,127	148,102	59904
1,792,040	162,913	65895
1,971,244	179,204	72484
2,168,369	197,124	79733
2,385,206	216,837	87706
2,623,726	238,521	96477
2,886,099	262,373	106124
3,174,709	288,610	116737
3,492,179	317,471	128411
3,841,397	349,218	141252
4,225,537	384,140	155377
4,648,091	422,554	170915
5,112,900	464,809	188006
5,624,190	511,290	206807
6,186,609	562,419	227487
6,805,270	618,661	250236
7,485,797	680,527	275260
8,234,377	748,580	302786
9,057,814	823,438	333064
9,963,596	905,781	366370
10,959,955	996,360	403008
12,055,951	1,095,996	443308
13,261,546	1,205,595	487639
14,587,700	1,326,155	536403

Total Saving 5,593,028 t

6.7.5. Photo-Voltaic Microgeneration

77 Compared with the other technologies the carbon impact of photovoltaic microgeneration is relatively easy to determine.

6.7.5.1. PV take up

78 Pathways to 2050[16] outline several scenarios for the installation of PV. A conservative estimate (level 2) suggests an installed capacity of around 70GW peak output by the year 2050. This would give an implied output of a little over 60GWh per annum, based on output of 850kWh per kW of installed capacity per annum.

79 An implied number of installed units has also been developed by taking the assumption that an average installation is 3kW peak output. This is also shown below.

80 Using this target and the other figures presented allows an uptake curve to be developed. It is assumed that the electricity generated by this technology is primarily used locally and that it directly displaces electricity that would be otherwise generate through fossil fuels.

81 Converting the overall electricity generated to carbon using the published conversion figures[9], allows the calculation of a total, per kW installed, carbon benefit.

82 The impact of this benefit alongside any acceleration of uptake, is then calculated in a similar way to the figures for electric vehicles and for heat pumps.

6.7.5.2. Project Impact

83 The following table demonstrates the effect of bringing electric heat pump space heating installations into use sooner than otherwise. The table shows three scenarios, in which the conversion to an electric heating is bought to bear one, two and three years early. These figures are modified to take account of applicability.

84 This gives a range of estimates for carbon saving as follows:

PV roll out acceleration, years	Carbon Saving, t CO2
1 year	28,162,299
2 years	59,959,384
3 years	95,858,514

85 This indicates a considerable absolute saving in carbon emissions as a result of the project plus a contribution to the facilitation of the overall UK

[16] See footnote 2 above

Low Carbon Transition Plan with its explicit target of reducing emission from all sources by 80% over 2007 levels.

	PV installed capacity		TWh	
Year	Low-Range	Mid-Range	High-Range	Installed units
2007				
2008	8,000		8,000	
2009	12,000		20,000	
2010	24,000		50,000	
2011	50,000		90,000	
2012	76,000		135,000	
2013	112,000		180,000	
2014	129,000		240,000	
2015	150,000	0.38	310,000	147,059
2016	180,000	0.45	400,000	176,471
2017	210,000	0.54	500,000	212,418
2018	245,000	0.65	625,000	254,902
2019	280,000	0.78	800,000	305,882
2020	320,000	0.94	1,200,000	367,059
2021		1.12		440,471
2022		1.35		528,565
2023		1.62		634,278
2024		1.94		761,133
2025		2.33		913,360
2026		2.79		1,096,032
2027		3.35		1,315,238
2028		4.02		1,578,286
2029		4.83		1,893,943
2030		5.46		2,140,155
2031		6.17		2,418,376
2032		6.97		2,732,765
2033		7.87		3,088,024
2034		8.90		3,489,467
2035		10.05		3,943,098
2036		11.36		4,455,700
2037		12.84		5,034,942
2038		14.51		5,689,484
2039		16.39		6,429,117
2040		18.53		7,264,902
2041		20.93		8,209,339
2042		23.66		9,276,553
2043		26.73		10,482,505
2044		30.21		11,845,231
2045		34.13		13,385,111
2046		38.57		15,125,175
2047		43.58		17,091,448
2048		49.25		19,313,337
2049		55.65		21,824,070
2050		62.89		24,661,199
		71.06		27,867,155
		80.30		31,489,886
		90.74		35,583,571

Scenarios where a successful project implementation bring forward PV implementation

Scenario 3yrs	Δ TWh	Δ CO2 (tonnes)	Scenario 2yrs	Δ TWh	Δ CO2 (tonnes)	Scenario 1yrs	Δ TWh	Δ CO2 (tonnes)
1.62	0.68	273653	1.35	0.41	165395	1.12	0.19	75180
1.94	0.82	328384	1.62	0.49	198474	1.35	0.22	90215
2.33	0.98	394061	1.94	0.59	238169	1.62	0.27	108259
2.79	1.18	472873	2.33	0.71	285802	1.94	0.32	129910
3.35	1.41	567448	2.79	0.85	342963	2.33	0.39	155892
4.02	1.70	680937	3.35	1.02	411556	2.79	0.47	187071
4.83	2.03	817125	4.02	1.23	493867	3.35	0.56	224485
5.46	2.10	844781	4.83	1.48	592640	4.02	0.67	269382
6.17	2.14	860319	5.46	1.43	575400	4.83	0.80	323258
6.97	2.14	859020	6.17	1.34	537061	5.46	0.63	252141
7.87	2.42	970693	6.97	1.51	606879	6.17	0.71	284920
8.90	2.73	1096883	7.87	1.71	685773	6.97	0.80	321959
10.05	3.09	1239478	8.90	1.93	774924	7.87	0.91	363814
11.36	3.49	1400610	10.05	2.18	875664	8.90	1.02	411110
12.84	3.94	1582690	11.36	2.46	989500	10.05	1.16	464554
14.51	4.45	1788439	12.84	2.78	1118135	11.36	1.31	524946
16.39	5.03	2020936	14.51	3.15	1263493	12.84	1.48	593189
18.53	5.69	2283658	16.39	3.56	1427747	14.51	1.67	670304
20.93	6.43	2580533	18.53	4.02	1613354	16.39	1.89	757443
23.66	7.26	2916003	20.93	4.54	1823090	18.53	2.13	855911
26.73	8.20	3295083	23.66	5.13	2060092	20.93	2.41	967179
30.21	9.27	3723444	26.73	5.80	2327904	23.66	2.72	1092913
34.13	10.48	4207492	30.21	6.55	2630531	26.73	3.08	1234991
38.57	11.84	4754466	34.13	7.40	2972500	30.21	3.47	1395540
43.58	13.38	5372546	38.57	8.36	3358926	34.13	3.93	1576960
49.25	15.12	6070977	43.58	9.45	3795586	38.57	4.44	1781965
55.65	17.08	6860204	49.25	10.68	4289012	43.58	5.01	2013621
62.89	19.30	7752031	55.65	12.07	4846584	49.25	5.67	2275391
71.06	21.81	8759795	62.89	13.64	5476639	55.65	6.40	2571192
80.30	24.65	9898568	71.06	15.41	6188603	62.89	7.23	2905447
90.74	27.85	11185382	80.30	17.41	6993121	71.06	8.18	3283155
	Total Savi	95,858,514 t		Total Savi	59,959,384 t		Total Savi	28,162,299 t

6.7.6. Aggregate Figures.

86 To calculate an aggregate benefit across the technologies used and In keeping with the philosophy of conservatism, the figures for a one year improvement in take up have been chosen for the purposes of this analysis. They have then been modified further through the use of a constant to take account of the overall applicability of the solutions to the UK's installed network, and then been converted into monetary values in accordance with paragraphs 2.9 and 2.10 of the LCNF Governance Document using the 2010 published traded carbon prices.

	Annual Carbon Saving				Carbon Value	
Year	**EV**	**HP**	**PV**	**Total**	**£/tonne**	**Carbon Value £**
2015					£15.1	
2016					£15.4	
2017					£15.6	
2018					£15.8	
2019					£16.1	
2020	176041	30740	75180	**281961**	£16.3	£4,595,970
2021	190412	33815	90215	**314442**	£21.7	£6,823,391
2022	633603	37196	108259	**779057**	£27.1	£21,112,449
2023	633603	40916	129910	**804428**	£32.4	£26,063,482
2024	633603	45007	155892	**834502**	£37.8	£31,544,178
2025	633603	49508	187071	**870181**	£43.2	£37,591,829
2026	633603	54459	224485	**912546**	£48.5	£44,258,488
2027	633603	59904	269382	**962889**	£53.9	£51,899,716
2028	633603	65895	323258	**1022756**	£59.3	£60,649,418
2029	638104	72484	252141	**962730**	£64.6	£62,192,355
2030	156549	79733	284920	**521202**	£70.0	£36,484,123
2031	160557	87706	321959	**570222**	£76.5	£43,622,004
2032	164667	96477	363814	**624958**	£83.0	£51,871,503
2033	168883	106124	411110	**686117**	£89.5	£61,407,457
2034	173206	116737	464554	**754497**	£96.0	£72,431,708
2035	177640	128411	524946	**830997**	£102.5	£85,177,168
2036	182188	141252	593189	**916628**	£109.0	£99,912,497
2037	186852	155377	670304	**1012532**	£115.5	£116,947,466
2038	191635	170915	757443	**1119993**	£122.0	£136,639,116
2039	196541	188006	855911	**1240458**	£128.5	£159,398,812
2040	201572	206807	967179	**1375558**	£135.0	£185,700,349
2041	206733	227487	1092913	**1527132**	£141.5	£216,089,229
2042	212025	250236	1234991	**1697252**	£148.0	£251,193,307
2043	217453	275260	1395540	**1888252**	£154.5	£291,734,992
2044	223019	302786	1576960	**2102765**	£161.0	£338,545,219
2045	228729	333064	1781965	**2343758**	£167.5	£392,579,470
2046	234584	366370	2013621	**2614575**	£174.0	£454,936,114
2047	240590	403008	2275391	**2918988**	£180.5	£526,877,416
2048	246749	443308	2571192	**3261249**	£187.0	£609,853,596
2049	253065	487639	2905447	**3646152**	£193.5	£705,530,365
2050	253461	536403	3283155	**4073019**	£200.0	£814,603,844

Total **43471799** tonnes Total £5,998,267,032

87 Overall, a successful project gives a conservative estimate of the aggregate carbon saving of 43.5Mt of CO2, to 2050, with a value of just under £6bn, before discounting.

6.8 Generation Capital Cost Savings

88 A further customer benefit from increasing the learning associated with providing DSR will come through reduced generation costs. This is because DSR will also be used to move load from higher to lower cost generation periods. This will reduce the costs associated with generation, leading to savings in the cost of generation capital costs over time.

89 We have used Ofgem's analysis contained within its DSR report[17] to provide an estimate of this benefit. We have taken Ofgem's estimate of the range of annual generation capital cost savings for a 5% and 10% shift in peak load[18,] and estimated the proportion of this benefit that could be attributed to domestic customers, using the assumptions that Ofgem has used to build up the DSR estimate[19]. We have then assumed that the increased learning that our project will deliver about how DSR can be fully exploited will deliver an incremental 2.5% increase in DSR. We accept that this figure is subjective, but believe it is a relatively conservative estimate given the scope of our project covers all domestic customer demographics and will seek to develop commercial arrangements across the energy supply chain to maximise the value from DSR.

90 As with the carbon case, we do not attribute any savings until 2020 (by which stage all domestic customers are expected to have smart meters and so will be able to take advantage of a range of DSR opportunities), even though we expect the learning to be implemented before this date. We have also not factored in any change in peak generation costs through to 2050, which is again likely to be a conservative assumption.

91 Taking all of this into account, this produces an annual benefit from generation capital cost savings of £70.4m (in 2010 prices) from 2020 through to 2050, an aggregate saving of £2.18bn over the period.

92 There are further benefits arising from DSR that we have not attempted to quantify, but should be included as a benefit to this project. As Ofgem notes, DSR can also be expected to provide a benefits from facilitating variable generation. As the share of variable generation increases in the generation mix, it is recognised that DSR can replace some of the need for higher cost, and in some cases more carbon intensive, peaking plant that would otherwise be needed to maintain security of supply at times low output. There may also be a carbon saving resulting from this category of load shifting, although this depends on the relative carbon intensity of the replacement, and displaced, generation. We note that Ofgem's Demand

17 "Demand Side Response – A discussion paper", Ofgem (2010).
18 Ofgem (2010) Table 2.1 p17.
19 Ofgem (2010) Table A2.1 p50.

Side Response (2010) paper shows that there can be a carbon saving associated with DSR. However, we have assumed that the net impact of DSR on carbon emissions is zero, given our conservative approach to benefit estimation.