Carbon Trust Options Appraisal for building decarbonisation: Summary of results

2nd November 2021

Author: Ruth Tewungwa

Reviewed by: Will Rivers

Summary of current building

51 MORDAUNT STREET SW99RD

Domestic	1 Units
Floorspace (m2)	99
EPC Rating	D

Space heating consumption (kWh)	13,141
Cooling consumption (kWh)	0
Water heating consumption (kWh)	1,980
Other electricity use (kWh)	3,168
Annual total fuel bill	£1,273

Thermal Energy Demand Intensity (kWh per m2 pa)	106
Energy Use Intensity (kWh per m2 pa)	185

Age of construction	1900 - 1929
Windows	Single glazed windows
Wall	Solid brick, as built, no insulation (assumed)
Roof	Pitched roof with insulation at joists
Floor	Insulation unknown or as-built
Primary heating	Existing - condensing gas boiler
Air tightness (ACH @ ambient pressure)	Poor performing airtightness (10 n50)
Radiators / emitters	Existing radiators - single panel single convector

Description of Options for Appraisal

Thermal fabric measures:
Whilst this home has a good level of loft insulation, the single glazed windows and un-insulated solid walls mean that thermal energy demand intensity is still relatively high at 106 kWh per m2. Therefore, in scenarios 3 & 4 we look at the potential impact of loft insulation, floor insulation and high performance double glazing alongside electric heating systems.

Heating system:
The high level of heat loss in the property means that, even with upgraded radiators, a high temperature heat pump would be required to meet winter peak demand. Therefore, scenario considers a high temperature heat pump with radiators upgraded to we double panel double convector radiators. We assume that the distribution pipework can support the additional flow rates and velocities that would be required although a roper hydronic system assessment would be necessary to establish this.

In scenario 3. due to the reduced heat loss, peak flow temperatures have reduced to around 45C when combined with upgraded double panel double convector radiators. This enables a lower temperature heat pump to be installed with higher efficiency.

In scenario, the kW peak loss has reduced to the extent that it may be possible to meet heating requirements with an electric storage boiler, partnered with a very low 'super off-peak' overnight electricity tariff. This may have the

Summary of options appraisal measures, costs & CO_2 emissions

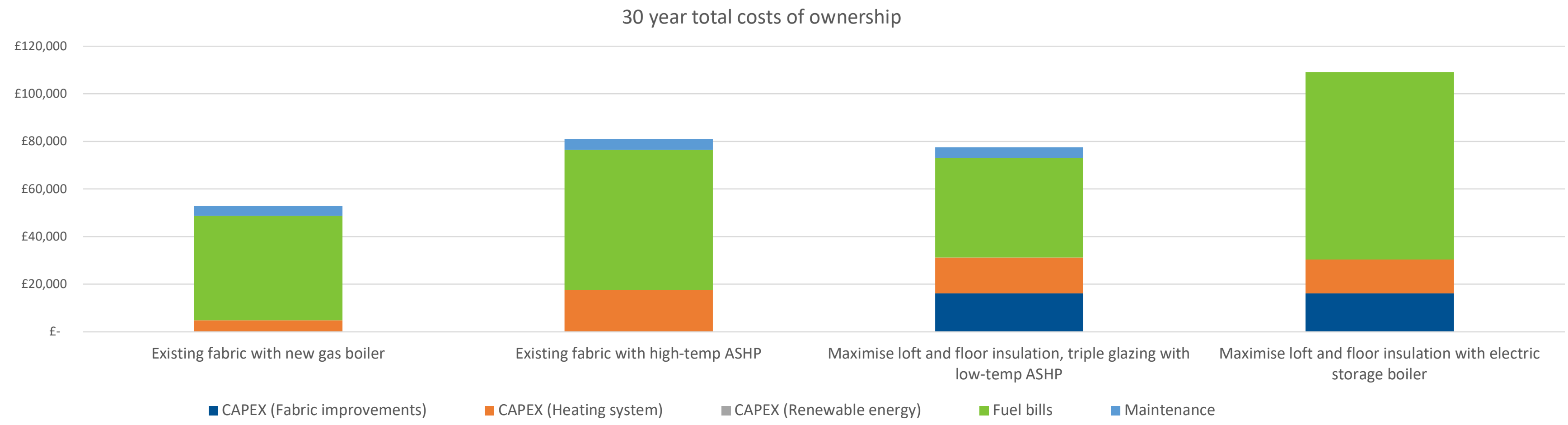
	Existing fabric with new gas boiler	Existing fabric with high-temp ASHP	Maximise loft and floor insulation, triple glazing with low-temp ASHP	Maximise loft and floor insulation with electric storage boiler
HVAC system	1kW New Condensing gas boiler, 0, 0, hot water from main system (gas), combi-boiler, 0	4kW New Hi-temp ASHP Air to water >55°C, 0, 0, hot water from main system (electric), Hot water cylinder and associated pipework	2kW New ASHP Air to water <55°C, 0, 0, hot water from main system (electric), Hot water cylinder and associated pipework	1kW New electric storage boiler (e.g. Tepeo) , 0, 0, hot water from main system (electric), Hot water cylinder and associated pipework
	£2,400	**£8,750**	**£7,750**	**£7,750**
Heat emitter and distribution	Existing pipework, Existing radiators - single panel single convector	Existing pipework, New - Double panel double convector radiators	Existing pipework, New - Double panel double convector radiators	Existing pipework, Existing radiators - single panel single convector
	£0	**£0**	**£0**	**£0**
Thermal fabric measures installed	, , ,	, , ,	, Loft insulation (Joists) 0 - 270mm, Double Glazing (Wooden sash) , Insulate Suspended floor (difficult access)	, Loft insulation (Joists) 0 - 270mm, Double Glazing (Wooden sash) , Insulate Suspended floor (difficult access)
	£0	**£0**	**£15,642**	**£15,642**
Air tightness	Natural ventilation , Poor performing airtightness (10 n50)	Natural ventilation , Poor performing airtightness (10 n50)	MEV, Building regs airtightness (5 n50)	MEV, Building regs airtightness (5 n50)
	£0	**£0**	**£495**	**£495**

Total CAPEX	**£2,400**	**£8,750**	**£23,887**	**£23,887**
Clean Heat Grant	£0	£5,000	£5,000	£0
Net CAPEX	**£2,400**	**£3,750**	**£18,887**	**£23,887**

Electricity tariff	Treasury Green Book Central Domestic Tariff	Treasury Green Book Central Domestic Tariff	Treasury Green Book Central Domestic Tariff	Domestic low overnight Tariff 01:30 - 06:30
Annual fuel bills	**£1,273**	**£1,819**	**£1,287**	**£2,433**
Annual OPEX (maintenance)	£129	£148	£148	£0
30 year total cost of ownership (excluding grant)	**£52,831**	**£81,085**	**£77,542**	**£109,233**

Annual tCO_2 emissions (2021)	**3.7**	**2.4**	**1.8**	**3.3**
Predicted annual tCO_2 emissions (2030)	**3.2**	**1.1**	**0.8**	**1.5**
Predicted annual tCO_2 emissions (2050)	**2.8**	**0.1**	**0.0**	**0.1**

30 year total costs of ownership

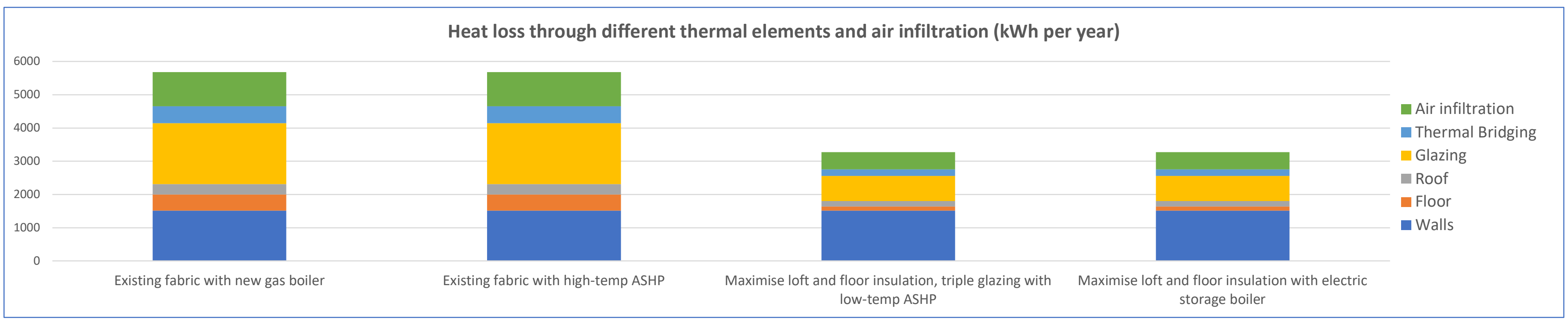


CAPEX
Al options involve significant additional CAPEX over BAU. Particularly in scenarios 3 & 4 where wooden casement double glazed windows carry a cost premium.

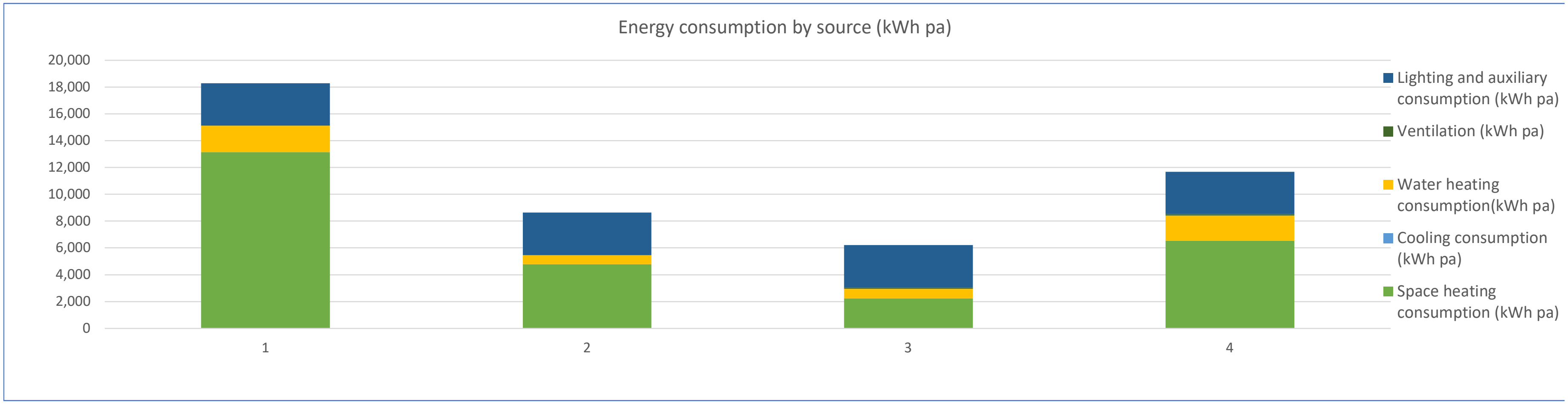
Fuel bills
Fuel bills increase significantly in scenario 2 with a high temperature heat pump. However, in scenario 3, fuel bills are only marginally higher than BAU, due to lower heat demand and higher system efficiency. in scenario 4, fuel bills are higher than BAU, despite benefitting from a very low overnight tariff of approx. £0.06 per kWh. This is due to the relatively poor system efficiency of the storage boiler relative to the heat pumps.

30 year cost of ownership
Of scenarios 2 - 4, scenario 3 has the lowest total costs of ownership, suggesting that the investment in thermal fabric efficiency has a positive payback in lower fuel bills.

Heat loss through thermal elements



Energy Consumption kWh pa



Heat demand and heating system efficiency

	Existing fabric with new gas boiler	Existing fabric with high-temp ASHP	Maximise loft and floor insulation, triple glazing with low-temp ASHP	Maximise loft and floor insulation with electric storage boiler
Space heating demand (kWh pa)	10,513	10,513	6,051	6,051
Space heating peak demand (kW)	5.7	5.7	3.3	3.3
Space heating peak demand per flat (kW)	5.7	5.7	3.3	3.3
Peak electricity load @ 6:00pm	0.8	3.3	2.0	0.8
Required flow temperatures °C	70	63	45	52
Space heating consumption (kWh pa)	13,141	4,779	2,241	6,542
Cooling consumption (kWh pa)	0	0	0	0
Water heating consumption(kWh pa)	1980	679	693	1873
Ventilation (kWh pa)	0	0	99	99
Lighting and auxiliary consumption (kWh pa)	3168	3168	3168	3168
Assumed heating system Seasonal Performance Factor (SPF)	**80%**	**220%**	**270%**	**93%**
Assumed distribution losses	**0%**	**0%**	**0%**	**0%**
Space heating Thermal Energy Demand Intensity (kwh per m2 pa)	**106**	**106**	**61**	**61**
Energy Use Intensity - all energy use (kWh per m2 pa)	**185**	**87**	**63**	**118**

Heat demand and system efficiency
The heat loss graph illustrates the high level of heat loss in the single glazed building and the high impact of high performance glazing scenarios 3 & 4. This impact is re-enforced by assumed lower levels of air infiltration in to the building.

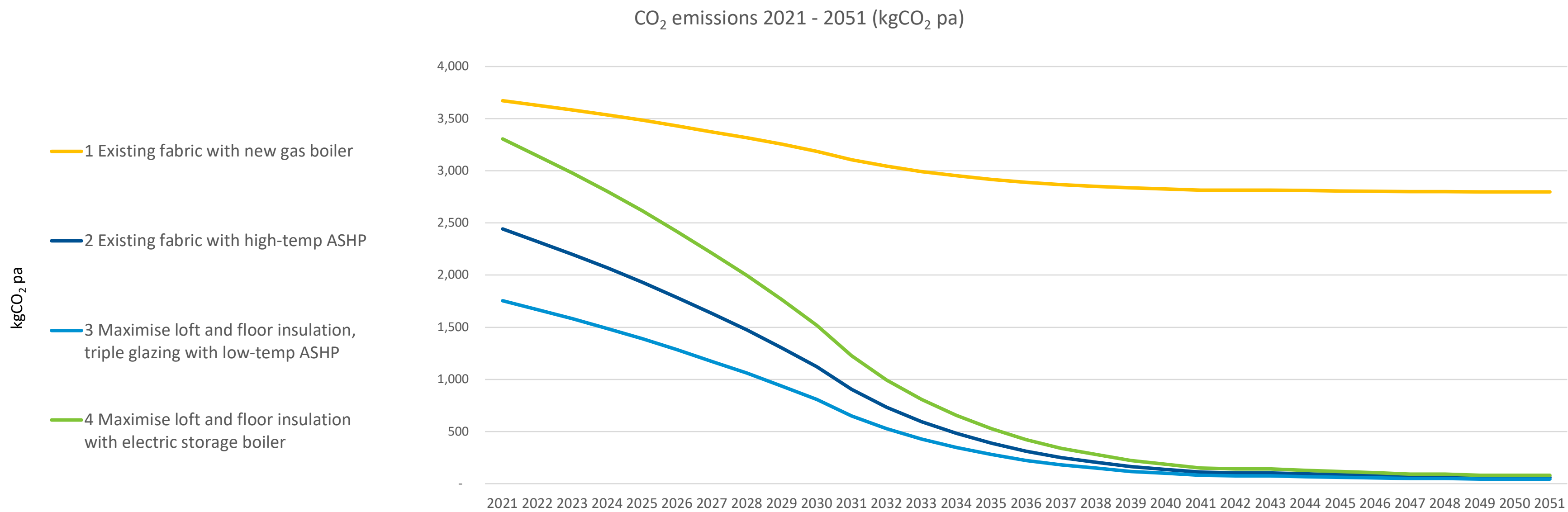
The system efficiency of scenario 2 (high temperature heat pump) is modelled to be significantly lower than the efficiency of scenario 3 (standard temperature heat pump alongside thermal fabric improvements). Whilst Energy Use Intensity for scenario 4 remains high, the 06:00pm peak load is lowest in this scenario, which brings Signiant wider benefits in the context of a net zero carbon energy system.

Retrofit package CO_2 emissions

tCO_2 in 2021	4	2	2	3
Predicted annual tCO_2 emissions (2030)	3.2	1.1	0.8	1.5
tCO^2 in 2050	2.8	0.1	0.0	0.1
tCO^2 cumulative 2021 - 2050	92	23	17	32
tCO_2 saved relative to BAU (30 year cumulative)	0	-69	-75	-60
CO_2 saving relative to baseline (30 year cumulative)	0%	75%	82%	66%
Additional cost over BAU scenario (30 years)	£0	£28,254	£24,711	£56,402
£ per tonne of CO_2 reduction (30 year cumulative)	NA	£412	£329	£936

* negative figures indicate a negative cost of carbon reduction. i.e. the packages of measures reduce 30 year costs and reduce CO2.

30 year predicted CO_2 emissions



CO_2 emissions reductions are greatest in scenario 3 where fabric efficiency is combined with a relatively efficient heat pump operating at lower flow temperatures. In the longer term, the reduction in grid carbon intensity means that CO_2 emissions from all electric scenarios converge toward zero.

Potential impact of Solar PV on all scenarios

	Existing fabric with new gas boiler	Existing fabric with high-temp ASHP	Maximise loft and floor insulation, triple glazing with low-temp ASHP	Maximise loft and floor insulation with electric storage boiler
Included in package? (Y/N)	N	N	N	N
System size kW Peak	2.5	2.5	2.5	2.5
System generation kWh pa	2,409	2,409	2,409	2,409
Utilisation on site kWh pa	1232	1547	1445	1232
Utilisation on site kWh pa	51%	64%	60%	51%
Exported to grid kWh pa	1177	862	964	1177
Assumed system cost £	3750	3750	3750	3750
Net impact on fuel bills £ pa	-£ 307	-£ 361	-£ 343	-£ 308

Renewable energy:
The impact of solar PV was modelled separately for each of scenarios. Results are shown in the table above. The relatively low rate of utilisation on -site reflects the lower demand for electricity in summer when solar PV generation is highest.

Impact of Solar PV on Scenario 2 - typical summer and winter days