Carbon Trust Options Appraisal for building decarbonisation: Summary of results

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Summary of current building

SunnyHill Primary School Main (Old) Building

Office with natural ventilation and cooling	1 Units
Floorspace (m2)	1456
EPC Rating	G

Occupied space heating consumption (kWh)	359,657
Cooling consumption (kWh)	0
Water heating consumption (kWh)	19,968
Occupied area electricity use (kWh)	80,080
Annual total fuel bill	£23,269
Annual fuel bill per flat (including share of communal areas)	£23,269

Occupied area Thermal Energy Demand Intensity (kWh per m2 pa)	198
Occupied area Energy Use Intensity (kWh per m2 pa)	316

Age of construction	1900 - 1929
Windows	Single glazed windows
Wall	Cavity as built
Roof	Pitched roof with insulation at rafters
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 - double panel, double convector

Description of Options for Appraisal

Thermal fabric
This school building has very high levels of heat loss due to solid walls, single glazing, assumed minimal loft insulation and assumed very poor levels of air tightness / high air changes per hour. In scenario 2 we assume that the fabric remains un-improved. In scenario 2 we consider the installation of roof insulation, high performance glazing and under floor insulation. In scenario 4 we also add internal wall insulation.

Energy systems
The building is currently heated by a gas boiler. In scenario 1 we assume this is replaced with a new condensing gas boiler. In scenario 2 we assess the installation of a high temperature air source heat pump. Due to the high flow temperatures required, system efficiency is assumed to be relatively poor with a COP of approximately 2.

In scenarios 3 and 4 we assess the installation of standard air source heat pumps. Scenarios 2, 3 and 4 all consider the replacement of current radiators with high capacity triple panel triple convector radiators.

Summary of options appraisal measures, costs & CO_2 emissions

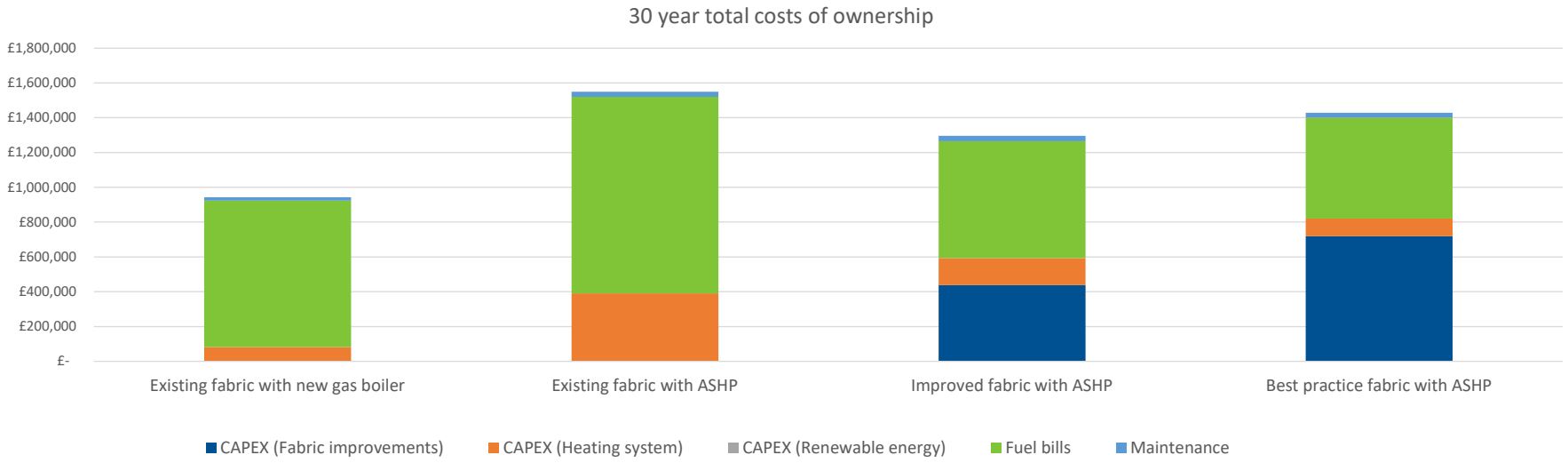
	Existing fabric with new gas boiler	Existing fabric with ASHP	Improved fabric with ASHP	Best practice fabric with ASHP
HVAC system	165kW New Condensing gas boiler, 0, 0, hot water from main system (gas), Communal thermal store, 0	165kW New Hi-temp ASHP Air to water >55°C, 0, 0, hot water from main system (electric), Communal thermal store	79kW New ASHP Air to water <55°C, 0, 0, hot water from main system (electric), Communal thermal store	52kW New ASHP Air to water <55°C, 0, 0, hot water from main system (electric), Communal thermal store
	£41,250	**£173,250**	**£67,150**	**£44,200**
Heat emitter and distribution	Existing pipework, Existing radiators - double panel, double convector	Existing pipework, New - triple panel triple convector radiators	Existing pipework, New - triple panel triple convector radiators	Existing pipework, New - triple panel triple convector radiators
	£0	**£43,725**	**£20,935**	**£13,780**
Thermal fabric measures installed	, , ,	, , ,	, Loft insulation (Rafters) (room in roof), high performance triple glazing , Insulate Suspended floor (difficult access)	Internal wall insulation (High price - complex interior), Loft insulation (Rafters) (room in roof), high performance triple glazing , Insulate Suspended floor (difficult access)
	£0	**£0**	**£437,984**	**£719,281**
Air tightness	Natural ventilation , Poor performing airtightness (10 n50)	Natural ventilation , Poor performing airtightness (10 n50)	Natural ventilation , Average air tightness (7.5 n50)	Natural ventilation , Building regs airtightness (5 n50)
	£0	**£0**	**£0**	**£0**

Total CAPEX	**£41,250**	**£216,975**	**£526,069**	**£777,261**
Clean Heat Grant	£0	£0	£0	£0
Net CAPEX	**£41,250**	**£216,975**	**£526,069**	**£777,261**

Electricity tariff	Treasury Green Book Central Commercial Tariff	Treasury Green Book Central Commercial Tariff	Treasury Green Book Central Commercial Tariff	Treasury Green Book Central Commercial Tariff
Annual fuel bills	**£23,269**	**£34,878**	**£20,754**	**£17,852**
Annual OPEX (maintenance)	£650	£950	£950	£950
30 year total cost of ownership (excluding grant)	**£943,265**	**£1,549,887**	**£1,295,200**	**£1,429,392**

Annual tCO_2 emissions (2021)	**92.3**	**65.7**	**39.1**	**33.6**
Predicted annual tCO_2 emissions (2030)	**80.1**	**30.2**	**18.0**	**15.5**
Predicted annual tCO_2 emissions (2050)	**70.2**	**1.6**	**1.0**	**0.8**

30 year total costs of ownership



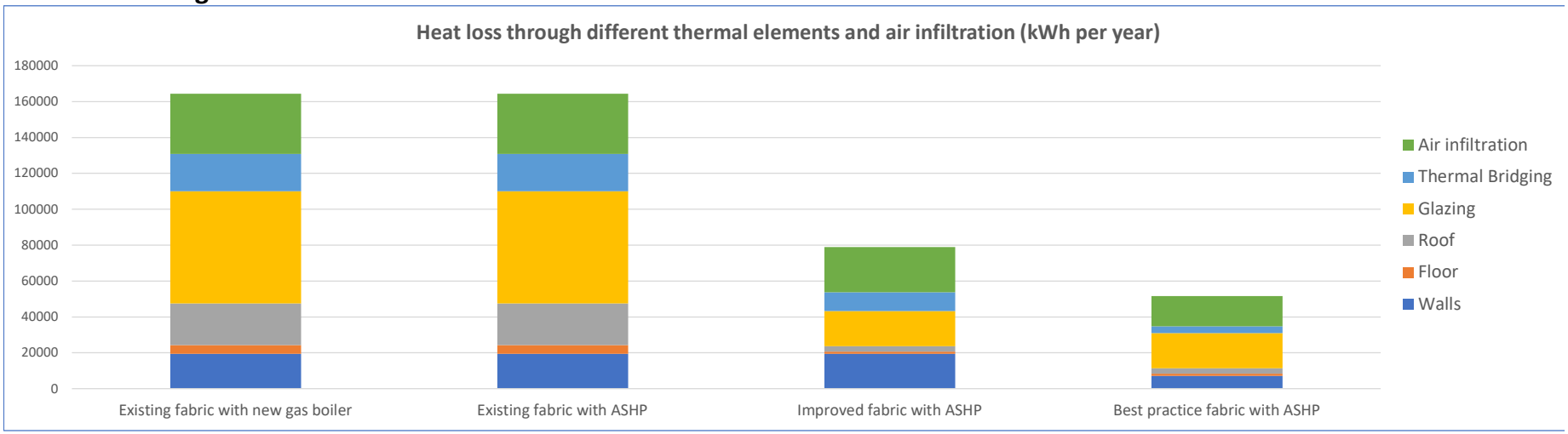
CAPEX
CAPEX increases significantly in scenarios 2, 3 and 4. The highest increases in CAPEX are associated with the installation of the heat pump, high performance glazing (due to the very high proportion of the building envelope that is glazed) and internal wall insulation.

Fuel bills
Fuel bills increase significantly in scenario 2. This is due to the very high flow temperatures that are likely to be required form the heat pump in the absence of any improvements to the thermal of the building. However, in scenario 3, fuel bills are broadly equivalent to scenario 1. This is due to the significantly reduced heat loss due to loft insulation and glazing. In scenario 4, fuel bills are assumed to be lower than in scenario 1 due to lower heat demand and improved heat pump efficiency.

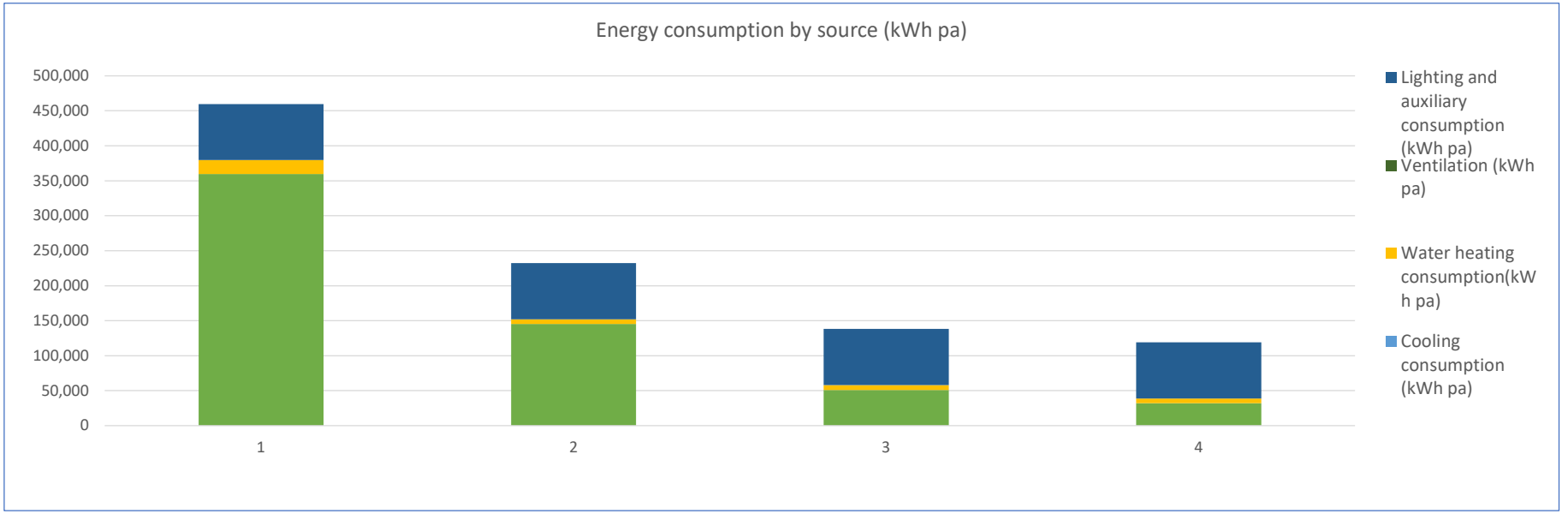
30 **year costs of ownership**
Of the electrification options, scenario 3 provides the lowest costs of ownership. This suggests that investment to improve the very poor elements of the fabric (loft insulation and glazing) have a financial payback. However, in this analysis, the additional cost of internal wall insulation (scenario 4) does not result in a positive return on investment.

Scenario 2 has the highest 30 year costs of ownerships. The very high fuel bills due to poor heat pump efficiency outweigh the lower initial CAPEX.

Heat loss through thermal elements



Energy Consumption kWh pa



Heat demand and heating system efficiency

	Existing fabric with new gas boiler	Existing fabric with ASHP	Improved fabric with ASHP	Best practice fabric with ASHP
Space heating demand (kWh pa)	287,726	287,726	138,051	90,322
Space heating peak demand (kW)	164.4	164.4	78.9	51.6
Peak electricity load @ 6:00pm	19.3	75.4	39.1	31.6
Required flow temperatures °C	70	67	45	38
Space heating consumption (kWh pa)	359,657	145,316	51,130	31,804
Cooling consumption (kWh pa)	0	0	0	0
Water heating consumption(kWh pa)	19968	6852	6989	6989
Ventilation (kWh pa)	0	0	0	0
Lighting and auxiliary consumption (kWh pa)	80080	80080	80080	80080
Assumed heating system Seasonal Performance Factor (SPF)	**80%**	**198%**	**270%**	**284%**
Assumed distribution losses	**0%**	**0%**	**0%**	**0%**
Space heating Thermal Energy Demand Intensity (kwh per m2 pa)	**198**	**198**	**95**	**62**
Energy Use Intensity - all energy use (kWh per m2 pa)	**316**	**160**	**95**	**82**

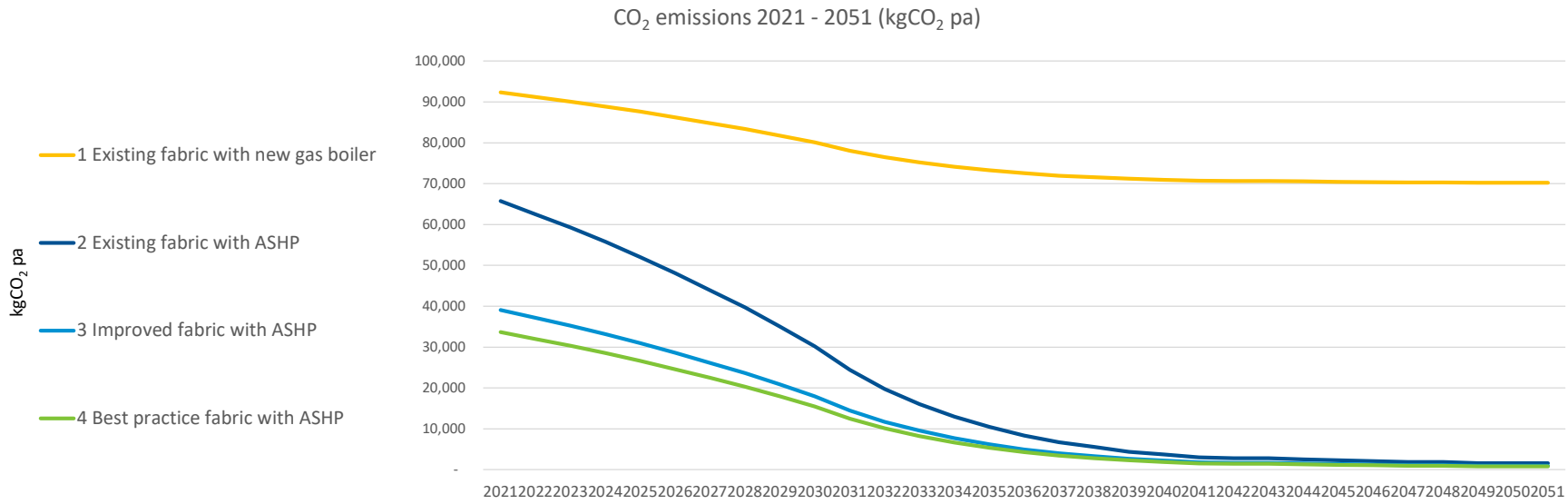
System efficiency
System efficiency is assumed to be very low in scenario 2 due to assumed very high flow temperatures of 67°C. System efficiency increases significantly in scenarios 3 and 4.

Retrofit package CO_2 emissions

tCO_2 in 2021	92	66	39	34
Predicted annual tCO_2 emissions (2030)	80.1	30.2	18.0	15.5
Predicted annual tCO_2 emissions (2050)	70.2	1.6	1.0	0.8
tCO2 cumulative 2021 - 2050	2306	627	373	321
tCO_2 saved relative to BAU (30 year cumulative)	0	-1679	-1933	-1985
CO_2 saving relative to baseline (30 year cumulative)	0%	73%	84%	86%
Additional cost over BAU scenario (30 years)	£0	£606,621	£351,935	£486,127
£ per tonne of CO_2 reduction (30 year cumulative)	NA	£361	£182	£245

* 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
CO_2 emissions reduce significant in all electrification scenarios (2 - 4). The greatest emissions reductions are achieved in scenarios 3 and scenario 4.

Scenario 3 provides carbon reduction at the lowest cost of carbon.

Potential impact of Solar PV on all scenarios

	Existing fabric with new gas boiler	Existing fabric with ASHP	Improved fabric with ASHP	Best practice fabric with ASHP
Included in package? (Y/N)	N	N	N	N
System size kW Peak	25.0	25.0	25.0	25.0
System generation kWh pa	24,090	24,090	24,090	24,090
Utilisation on site kWh pa	22115	23880	23762	23661
Utilisation on site kWh pa	92%	99%	99%	98%
Exported to grid kWh pa	1975	210	328	429
Assumed system cost £	37500	37500	37500	37500
Net impact on fuel bills £ pa	-£ 3,400	-£ 3,595	-£ 3,582	-£ 3,570

We modelled the impact of a 25kW PV array for each of the scenarios. On-site utilisation of solar PV was assumed to be high although the model assumes that there is a level of building occupancy all year round. In practice, if the building is unoccupied for summer holidays, on-site utilisation would be lower.

Impact of Solar PV on Scenario 3 - typical summer and winter days