Homes of today for tomorrow

Decarbonising Welsh Housing between 2020 and 2050

STAGE 2:
Exploring the potential of the Welsh housing stock to meet 2050 decarbonisation targets

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Homes of Today for Tomorrow STAGE 2:

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1. executive summary

This piece of work was the second ‘stage’ of research in support of Welsh Government’s Housing Decarbonisation programme. For the Stage 1 scoping review see hyperlink: http://orca.cf.ac.uk/115442/

The primary aim of this study was to understand the degree to which the nature of the existing Welsh housing stock could inform the development of a pathway to decarbonisation, while also giving due consideration to energy costs and affordable warmth.

Fourteen recurrent dwelling ‘types’ were used to explore the effect of key retrofit actions upon the Welsh housing stock, by modelling each dwelling type in 1990, in 2018 and in 2050. The impact of key retrofit actions is explained in terms of capital cost, carbon emissions, ongoing energy costs and overheating. Capital costs are also compared with likely ongoing maintenance costs. Consideration was also given to changes in the energy supply network, because of the current uncertainty around decarbonisation of energy supply, and the impact this could have on decision making.

If targets for decarbonisation are to go beyond 80%, in line with the CCC's recent directive that Wales should target a 95% reduction in carbon emissions by 2050 relative to 1990 levels, this reinforces the importance of aspiring to net zero carbon throughout the existing housing stock. Key recommendations are that:

- UK Government must be lobbied to ensure that energy supplied by the national grid exceeds 60% clean energy by 2050.
- This will inevitably increase the cost of energy. Action must be taken to protect vulnerable households, to ensure that a further consequence is not an increase in fuel poverty.
- There should be no distinction between performance standards for retrofit and newbuild. Similarly, there should be no distinction between standards based on tenure or housing type.
- Some houses have constraints around retrofit, mostly related to character and historic features. However the justification for ‘acceptable fails’ must be carefully defined so as not to jeopardise decarbonisation targets.
- All other housing must be retrofitted beyond SAP90, to achieve an EPC A rating.
- Retrofit must overcome the performance gap (ie. the results should be measured as delivered, not as predicted).
- Retrofit standards are easier to enforce for social housing and the PRS sectors. Work must be undertaken exploring how to initiate this level of retrofit in the owner occupied sector.
- A flexible approach that pushes all housing to achieve appropriate performance standards by 2050 is the only way to anticipate achieving 90%+ decarbonisation under assumed energy supply scenarios.

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This work was funded by Welsh Government's Homes and Places division. The full Stage 1 report can be downloaded at http://orca.cf.ac.uk/115442/

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3. introduction

This piece of work was conceived as the second 'stage' of research in support of Welsh Government's Housing Decarbonisation programme. It built on the learning collected within the previously completed Stage 1 scoping review (ref. Green, Lannon, Patterson and Variale: *Homes of Today for Tomorrow - stage 1 report*, 2018 hyperlink: http://orca.cf.ac.uk/115442/).

The primary aim of this study was to understand the degree to which the nature* of the existing Welsh housing stock could / should inform the development of a pathway to decarbonisation, while also giving due consideration to energy costs and affordable warmth.

A representative taxonomy of recurring dwelling 'types' was developed for the Welsh housing stock, using multiple data sources. These types were then used to explore the effect of key retrofit actions upon the Welsh housing stock, drawn from the Stage 1 work, by modelling each dwelling type in 1990, in 2018 and in 2050. The impact of these retrofit actions is explained in terms of capital cost, carbon emissions, ongoing energy costs and overheating. Capital costs are also compared with likely ongoing maintenance costs. Consideration was also given to changes in the energy supply network, because of the current uncertainty around further decarbonisation of energy supply, and the impact this could have on decision making.

Findings are observed in relation to the degree to which different levels of retrofit could deliver decarbonisation across the Welsh housing stock as a whole. Findings establish the degree to which key metrics such as dwelling type and physical characteristics influence both the retrofit strategy adopted and its effectiveness, and highlight other influential factors – notably tenure, character and primary energy source.

Recommendations are made in terms of the level of retrofit likely to be needed, to meet targets for decarbonisation by 2050 while also giving due consideration to affordable warmth. Links are established between the nature* of the existing housing stock and reasonable targets for retrofit. These recommendations are intended to inform decision making around an appropriate pathway for decarbonisation of the Welsh housing stock.

*The *nature* of the existing housing stock is deemed to include dwelling type, tenure, physical characteristics, age and condition (including pre-existing retrofit actions).

4. Methodology

The Stage 2 work consisted of the following interlinked exercises:

4.1 Developing a taxonomy of 'types' to represent the Welsh housing stock.

4.2 Modelling how each dwelling type performs.

4.3 Comparing the modelling results to identify trends and inconsistencies.

4.4 Exploring the impact of cleaner energy supply on decarbonisation.

4.5 Making recommendations regarding pathways to decarbonisation.

4.1 Developing a taxonomy of 'types' to represent the Welsh housing stock

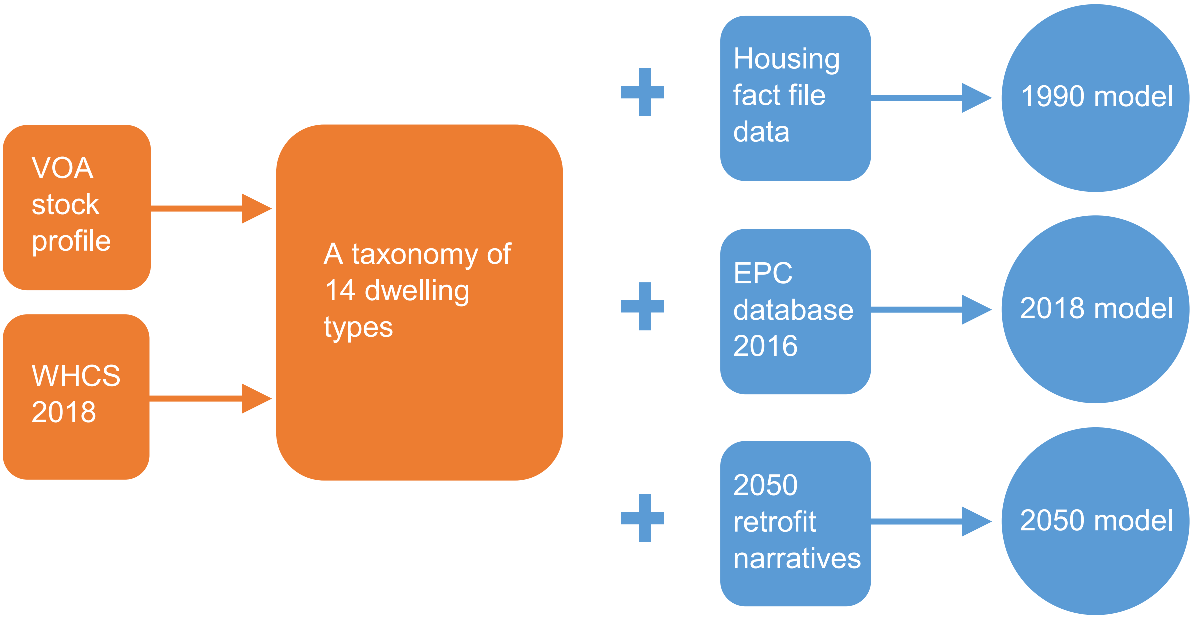
This represented a considerable challenge for the project team. The taxonomy of types needed to be broad enough to provide confidence in findings, but sufficiently constrained that results are legible. Individual dwelling 'types' needed to be sufficiently detailed to allow modelling using SAP, but sufficiently simplified that they capture a range of dwellings rather than a specific single dwelling. Two data sets were used to create the taxonomy of dwelling types. A large, low level detail dataset from the Valuation Office Agency (VOA) was combined with a smaller, high detail dataset from the Welsh Housing Condition Survey (WHCS), related to circa 2,500 dwellings within the Welsh housing stock (collected 2016-2018). From this work, a taxonomy of the existing housing stock was produced, composed of representative dwelling 'types', supported by an understanding of the relative proportion of each type as outlined below:

	HOUSE End terrace	HOUSE Mid terrace	HOUSE Semi-	HOUSE Detached	FLAT (Purpose blt)	Total
pre 1919	type 1, 3%	type 2, 9%	type 3, 4%	type 4, 7%		23%
1919- 1944			type 5, 5%			5%
1945- 1964			type 6, 10%			10%
1965 - 1990	type 7, 4%	type 8, 6%	type 9, 10%	type 10, 9%	type 11, 4%	33%
Post 1990			type 12, 5%	type 13, 7%	type 14, 1%	13%
Total	7%	15%	34%	23%	5%	84%

In addition to the physical characteristics underpinning each ‘type’ (which are considered to be constant over time), further information was needed to model the condition of each dwelling ‘type’ at three points in time – in 1990, in 2018 and in 2050. The data needed to develop these three distinct models came from three sources:

Historic data for the 1990 ‘baseline’ condition came from the Housing Fact File database. Data for the current condition (2016) came from the EPC data for Wales (2016), which represents circa 60% of the total Welsh housing stock (collected over a 9 year period). See Appendix B for details of assumptions made for 1990 and 2018 models.

To develop a model for 2050, four retrofit narratives were developed. Each narrative was designed to represent a viable approach for part, or all, of the Welsh housing stock, and includes a specification detailing the level of retrofit.



The four retrofit narratives can be described as follows:

good practice Within this narrative, actions are driven by best value – in terms of affordability, cost effectiveness, and availability of the necessary skills and resources in the current marketplace. Indicative SAP rating of 88.

best practice This narrative assumes an aspirational client or owner occupier, likely to be more concerned with long term quality than short term cost. Environmental impact is a priority. Indicative SAP rating of 90.

heritage Under this narrative, actions are constrained, e.g. as a result of listed building status or within a conservation area. Impact on exterior appearance is assumed to be problematic. Indicative SAP rating of 71.

rural For this narrative, geographic location is assumed to dictate off-grid energy solutions. As a result the focus is on energy conservation and use of locally viable renewables. Indicative SAP rating of 90.

4.2 Modelling the retrofit of each dwelling type

The digital models developed for each dwelling 'type' (see 4.1) were used to explore how the performance of the dwellings might change over time: from 1990 to 2018 and on to 2050.

To translate retrofit actions explored within the Stage 1 scoping report into the 2050 models, a retrofit specification was developed for each narrative. See Appendix C for details. The fourteen dwelling models were then used to evaluate the impact of the retrofit described by each narrative, by comparing the performance of each dwelling as it was in 1990, as it currently performs, and as it might perform in 2050, based on the retrofit actions contained within each of the four narratives.

The retrofit of each of the fourteen dwelling types was explored in terms of capital costs, and its impact on energy demand, fuel costs, and carbon emissions. Overheating was also investigated.

The capital cost data associated with each retrofit action were provided by cost consultant Lee Wakemans. Predicted costs are based on current cost data and recent, relevant case studies. Some costs are assumed to vary with dwelling size, and others are assumed to be static. These cost assumptions are outlined in appendix C.

The modelling techniques used in this report are based on the Government's Standard Assessment Procedure for Energy Rating of Dwellings (SAP). The models predict the energy required for space heating, water heating, lighting and contributions from renewable technologies. This energy requirement is then used to predict the fuel (primary energy) cost and associated carbon emissions. A Microsoft Excel spreadsheet model of the SAP 2012 9.92 worksheet has been developed by the WSA and tested against approved software (Stroma FSAP 2012). This version of the SAP model allows for different fuel costs and emissions rates, which is critical to understanding the differences between the 1990, 2020 and 2050 narratives, and the three energy supply scenarios. The energy cost and emissions rate assumptions are also listed in appendix C.

4.3 Exploring the impact of cleaner energy supply

To date, emissions from the housing sector are estimated to have reduced by more than 40% from baseline 1990 levels. Three quarters of this improvement comes from cleaner primary energy supply (from changes to the mains gas and mains electricity grid) rather than changes to the housing stock itself.

The degree to which energy supply continues to decarbonise will significantly affect decarbonisation of the housing stock, and could influence the selection and effectiveness of dwelling-based retrofit actions. For this reason, it was deemed necessary to consider decarbonisation of energy supply within this piece of work.

Three distinct energy supply scenarios were allowed to influence the models, to explore the impact of potential future changes to energy supply on decarbonisation of the existing housing stock, as follows:

Scenario 1 – minor future improvements to the national grid (40% clean energy supply)

Scenario 2 – significant future improvements to the national grid (60% clean energy supply)

Scenario 3 – transformational change to the national grid (80% clean energy supply).

4.4 Understanding decarbonisation of the housing stock as a whole

By combining the results arising from each individual dwelling type in their representative proportions, it was possible to illustrate the degree to which potential modifications to the Welsh housing stock could achieve carbon emission reductions, along with associated impacts on energy use and capital cost.

In order to recombine the results of the fourteen dwelling models into a single Welsh housing stock model, it was necessary to make assumptions around the standard of retrofit that would be undertaken. These assumptions draw from the results of the individual dwelling models, and are explained in section 5: Findings.

The results of this work enabled a discussion around realistic limits to the level of decarbonisation we can anticipate achieving. This discussion also explored the significance of each of the three energy supply scenarios in informing the development of a route map towards decarbonisation, in the context of uncertainty around future changes to clean energy supply.

4.5 Making recommendations regarding pathways to decarbonisation

Two summary sheets record the results of the modelling and associated cost calculations for each dwelling type – one for energy supply scenario 1 and another for energy supply scenario 2. These sheets are contained in Appendix A. Energy supply scenario 3 was not modelled in detail because this level of improvement in clean energy supply would obviate the need for physical retrofit to decarbonise the housing stock.

Results were then compared across the fourteen housing types, to identify trends and inconsistencies. Key findings are discussed in Section 5.

The understanding that was gained around the size and shape of the housing stock, combined with the findings that came from the modelling process, enabled us to make recommendations regarding possible pathways to decarbonisation. In particular, key identifying characteristics of the housing stock – character, tenure and location – were used to establish reasonable limits to decarbonisation, in the context of anticipated changes to clean energy supply. These recommendations are described in Section 6.

5. Findings

5.1 Energy supply

The three energy supply scenarios deliver very different results in terms of the overall impact of retrofit actions on carbon emissions for each dwelling type. However, the results are generally consistent across the fourteen different dwelling types, as follows:

Under scenario 1 (minor further improvements in clean energy supply) ‘best practice’ and ‘rural’ narratives deliver in excess of 80% carbon savings, whereas the ‘good practice’ narrative typically delivers around 70% carbon reduction and the ‘heritage’ narrative often delivers only 60% carbon reduction.

Under scenario 2 (significant further improvements in clean energy supply) ‘best practice’ and ‘rural’ narratives consistently deliver in excess of 80% carbon savings. ‘Good practice’ and ‘heritage’ narratives deliver around 80% carbon reduction. These approaches are therefore viable only if the entire occupied housing stock is improved to the same standard, and leave no tolerance for poorly performing or harder-to-reach stock.

Under Scenario 3 (transformational change) more than 80% carbon savings result from changes to energy supply alone. This leaves limited scope for discussion of further impact of dwelling-based retrofit actions. However, such changes to energy supply are not under the control of WG and go beyond the expectations of some experts, certainly in the short to medium term. For these reasons, scenario 3 is not explored at the level of individual dwelling types.

These results are combined in the diagrams overleaf, to assess the impact of these different clean energy supply scenarios on decarbonisation of the housing stock as a whole. As can be seen, the impact of changes to energy supply on the decarbonisation of the housing stock is considerable:

Under scenario 1 (minor further improvements in clean energy supply) it is not currently tenable for the existing housing stock to achieve greater than 90% decarbonisation using established retrofit good practice.

Under scenario 2 (significant further improvements in clean energy supply) 90% decarbonisation is only achieved when the existing housing stock is retrofitted beyond current Building Regulations, with a transition to electricity as a source of heat.

UK Government must therefore be lobbied to ensure that energy supplied by the national grid exceeds 60% clean energy by 2050.

Under Scenario 3 (transformational change) decarbonisation is achieved through improvements in energy supply and services alone. In this context, the significance of retrofit of the existing housing stock relates less to decarbonisation targets and more to the need to avoid increases in fuel bills for occupants, and a consequent increase in fuel poverty.

Figure 5.1 and 5.2: The impact of three energy supply scenarios on decarbonisation

Blue scenario – transformative further improvement (80% clean energy from grid)
Yellow scenario – significant further improvement (60% clean energy from grid)
Red scenario – minor further improvement (40% clean energy from grid)

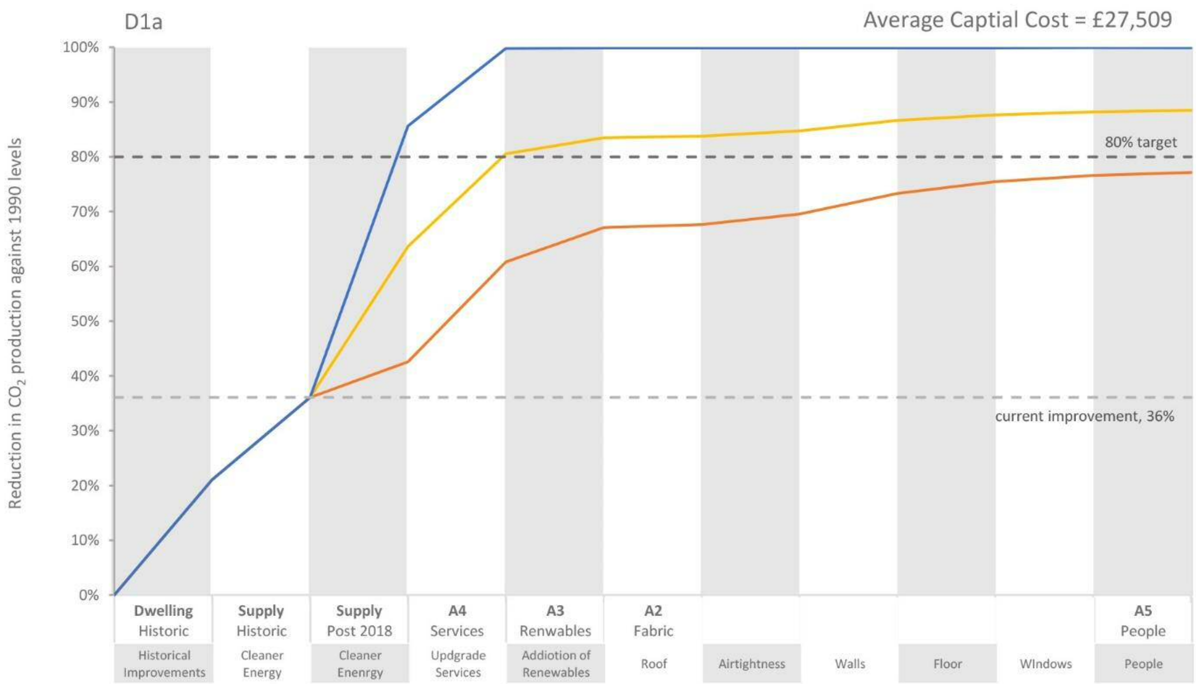


Figure 5.1: 10% of the housing stock is assumed to have limited retrofit. Social housing and PRS sectors are retrofitted beyond current Building Reg.s and transition to heat from electricity (not gas), along with 10% in fuel poverty. The remaining 30% (owner occupied) are retrofitted to current Building Reg.s only, and remain on mains gas.

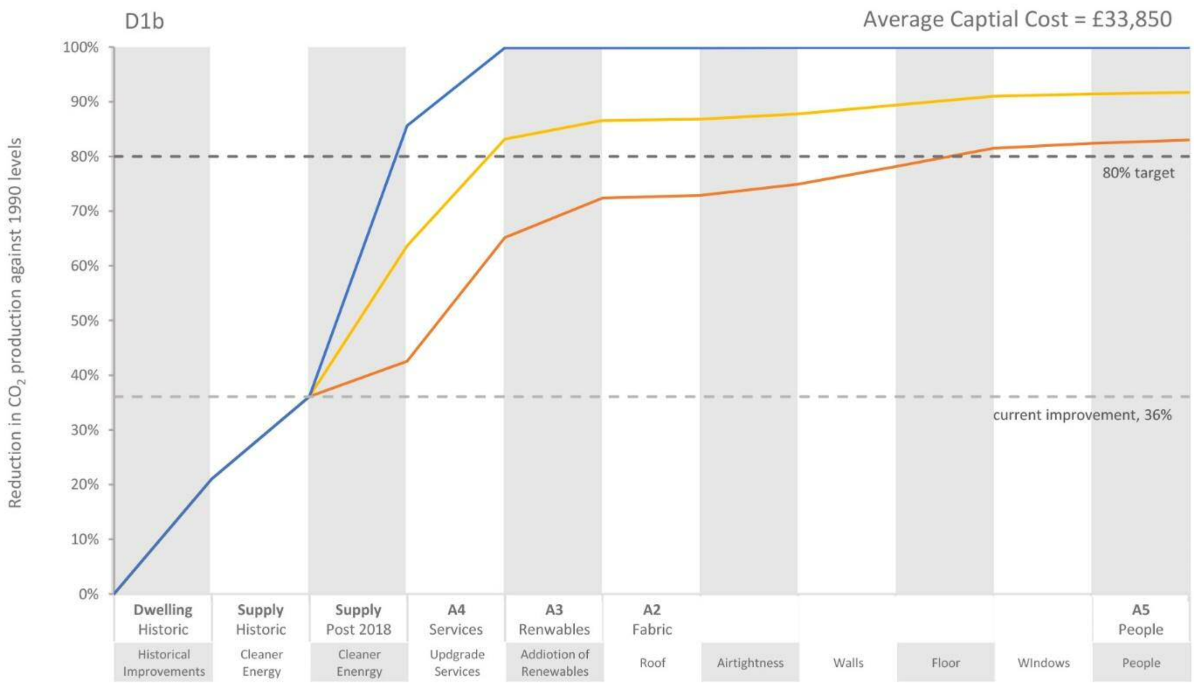


Figure 5.2: 10% of the housing stock is assumed to have limited retrofit. The remaining 90% is all retrofitted beyond current Building Regulations, and transitions to heat from electricity (not gas).

5.2 Retrofit actions and individual dwellings

Building on the work conducted for the Stage 1 scoping review, there is considerable scope to develop appropriate retrofit strategies for the housing stock by employing actions that are well understood, and skills and products that are widely available.

Retrofit actions affecting dwelling fabric are best understood, as the effectiveness of renewables and systems-based actions is more influenced by innovation and emerging technologies. People represent the least understood aspect of retrofit, and introduce the greatest levels of uncertainty around effectiveness, making future work around lifestyle choices and behaviour change particularly important.

The physical size and shape of a dwelling are not necessarily factors that change the approach taken to retrofit, apart from purpose built flats which are prone to overheating (see 5.4) and require a different approach. However, the physical size and shape of a dwelling do have considerable impact on capital cost and energy costs (see 5.6 – 5.8).

The selection of 'appropriate' retrofit actions is most likely to be informed by the current condition and character of the dwelling (and surrounding neighbourhood), by any retrofit actions that have previously been undertaken, and to a certain extent by the personal choice of the occupant / owner.

5.3 Retrofit narratives and the housing stock

The more effective retrofit narratives demand actions that will be difficult or prohibitively expensive to deliver in some dwellings. However, there is scope to establish targets that allow for differences within the housing stock, while prescribing an overall standard of retrofit that achieves the level of decarbonisation deemed necessary, subject to improvements in energy supplied by the national grid. These standards were explored using the retrofit narratives:

- Rural Narrative: 15% of the housing stock are currently thought to be off-gas, most of which are in isolated locations. This narrative demands improvement of dwelling fabric beyond current (new-build) Building Regulations, and a focus on heat from renewable, off grid energy (electricity) – achieving a notional SAP rating of 90.
- Heritage Narrative: based on a minimum standard for dwellings built before 1919. This might be applicable to 20% of the housing stock, based on 60% of the 32% of dwellings built pre-1919. While the resulting reduction in carbon emissions would not meet decarbonisation targets, carbon reduction can still be achieved without impacting unduly on historic character and such work would help to reduce increased fuel costs and consequently fuel poverty. Dwellings built before 1919 whose exterior appearance does not contribute to a locally distinctive character should be taken beyond this standard, which achieves a SAP rating of 71.
- 'Good practice' narrative: based on Building Regulations compliance, with continued reliance on mains gas wet central heating, this might be seen as a softer option for the housing sector, particularly for reluctant owner occupiers. Achieves a SAP rating of 88.
- 'Best practice' narrative: based on best practice retrofit this establishes a tenable but challenging limit for much of the housing stock. Fabric is upgraded beyond current Building Regulations, and the primary energy source transitions from mains gas to mains electricity. Achieves a SAP rating of 90.

To model the housing stock as a whole in 2050, it was assumed that 15% of homes must be retrofitted to the ‘heritage’ standard, and 10% of homes must be retrofitted to the ‘rural’ narrative. It was assumed that the social housing and private rented sectors (30% of the housing stock, with clear mechanisms for implementing retrofit) are retrofitted to ‘best practice’. It was assumed that a further 15% of the housing stock, deemed to be in fuel poverty and outside of the other groupings, are also targeted for retrofit to this standard, to mitigate against the real risk that decarbonisation can increase fuel poverty.

The remaining 30% of the housing stock is likely to be made up of owner occupied homes. They will need to be improved to a standard between ‘good practice’ and ‘best practice’, depending on the level of improvement made in clean energy supply and the level of decarbonisation needed.

5.4 Decarbonisation

As identified in section 5.1 (energy supply), it is critical that that energy supplied by the national grid exceeds 60% clean energy by 2050. In our modelling, this context is represented by Scenario 2.

Within scenario 2, the narratives that exceed Building Regulations and transition from mains gas energy to electrical sources of heat (i.e. the best practice and rural narratives) consistently deliver 90% - 95% carbon savings. This equates to exceeding a SAP rating of 90, or achieving an EPC A rating.

Within scenario 2, ‘good practice’ and ‘heritage’ narratives deliver around 80% carbon savings, constraining the level of decarbonisation that can realistically be achieved.

In the context of 60% clean energy supply, 95% decarbonisation of the housing stock is tenable, but requires retrofit that goes beyond current building regulations (SAP90) throughout the housing stock. This is best represented by achieving an EPC A rating.

It will be necessary for some of the housing stock to achieve net zero carbon, to offset the (typically historic) stock that cannot be retrofitted to meet these standards.

5.4 Overheating

Following implementation of the four retrofit narratives, the majority of the housing stock (circa 86%) experience an acceptable risk of overheating (a slight to medium risk, during peak summer months only).

7% of the housing stock (mid terraced dwellings built 1965-1990) experience an elevated risk of overheating for best practice and rural narratives. This risk would need to be ameliorated, for example through improved ventilation or cooling.

7% of the housing stock (representing flats built post 1965) experience untenable levels of overheating (severe risk throughout peak summer months). This overheating would need to be dealt with through adoption of an appropriate retrofit strategy, such as electric heating / cooling via a heat pump or air conditioning package.

5.5 Capital costs

Capital costs are reasonably stable for most of the actions included in the four retrofit narratives. However, the detailed specification of individual retrofit actions can have a considerable impact on cost – particularly decisions around the use of materials or products that are ethically sourced, environmentally sustainable or have related health benefits.

Capital costs are consistently lowest for older mid terraced properties and approximately doubled for older detached dwellings – the difference being a product of overall size and proportion of external envelope. Costs for the four narratives fall within the following ranges:

Good practice narrative	£17k to £32k
Best practice narrative	£33.5k to £63.3k
Heritage narrative	£10.8k to £25.5k
Rural narrative	£39.4k to £66.8k

Anticipated maintenance and repairs across 30 years fall in the range £11.1k to £19.8k.

Capital costs in the models assume retrofits are coordinated by the homeowner. Involvement of a contractor is likely to add circa 15% to costs. However, by delivering retrofit in packages of around 50 dwellings or more, these costs could be offset by economies of scale.

5.6 Payback periods

Payback period can be a useful outcome to consider the feasibility of the pathways. The payback when considering the capital costs as additional costs to the home owner the pay back periods for scenario 1 are:

Good practice narrative	average of 33 years (26 to 42 years)
Best practice narrative	average of 62 years (43 to 91 years)
Heritage narrative	average of 56 years (31 to 76 years)
Rural narrative	average of 39 years (17 to 69 years)

If the expected maintenance that will occur during the next thirty years is considered, the payback becomes more reasonable

Good practice narrative	average of 13 years (8 to 16 years)
Best practice narrative	average of 42 years (27 to 61 years)
Heritage narrative	average of 6 years (0 to 13 years)
Rural narrative	average of 28 years (12 to 47 years)

The payback periods for Scenario 2 (which assumes an increase of 50% in energy tariff) are slightly higher for all narratives apart from heritage which cannot payback as the costs for the energy used are mostly higher than those at current levels.

5.7 Energy costs

The rural narrative tends to predict very high current energy costs, around double that of the other three narratives, when heating systems are assumed to be Economy 7 electric storage heaters.

For the ‘good practice’, ‘best practice’ and ‘heritage’ narratives, energy costs are predicted to rise by between 30% and 50% when only systems-based retrofits are employed. The increase in energy costs for the best practice narrative are as follows:

Scenario 1 (assumes no increase in energy tariff) average increase 47% (26% to 59%)

Scenario 2 (assumes a 50% increase in energy tariff) average increase 120% (89 to 138%)

It is therefore reasonable to suppose that strategies focussing on cleaner energy supply and systems retrofit alone will impact negatively on domestic energy bills in the short to medium term.

When the holistic retrofit strategy is implemented, the percentage reduction of energy cost compared to the current costs for Scenario 1 are as follows:

Good practice narrative	average of 33% (14 to 49%)
Best practice narrative	average of 29% (20 to 42%)
Heritage narrative	average of 71% (58 to 78%)
Rural narrative	average of 11% (1 to 28%)

The reduction for Scenario 2 (which assumes an increase of 50% in energy tariff) are slightly higher for all narratives apart from heritage where the costs for the energy used are mostly higher than those at current levels.

In the likely event that the costs associated with cleaner energy supply are passed on to households, there could be considerable increases in householder energy costs, and corresponding increases in fuel poverty.

In this event, the rural narrative would deliver greatest robustness against increases in energy tariffs. For ‘good practice’ and ‘best practice’ narratives, energy costs vary by around 10-20% over a 50% increase in energy tariff. For the heritage narrative, energy costs vary by around 40%-50%. This suggests that a low level of fabric retrofit leaves occupants highly vulnerable to changes in energy tariffs.

6. Recommendations

If targets for decarbonisation are to go beyond 80%, in line with the CCC's recent directive that Wales should target a 95% reduction in carbon emissions by 2050 relative to 1990 levels, this reinforces the importance of aspiring to net zero carbon throughout the existing housing stock.

In line with this aspiration, our key recommendations are as follows:

- Cleaner primary energy supply from the national grid is an essential part of any decarbonisation route map, and cannot be ignored. UK Government must be lobbied to ensure that energy supplied by the national grid exceeds 60% clean energy by 2050. Smaller scale generation of clean energy at a local or regional level must also be encouraged.
- Cleaner primary energy supply will inevitably increase energy tariffs. Action must be taken to reduce household primary energy use, to protect vulnerable households and monitor future trends in fuel poverty, to ensure that a consequence of cleaner primary energy supply is not an acute increase in fuel poverty.
- Retrofit strategies that upgrade services must also uplift dwelling fabric to an acceptable standard, to diminish increases in energy costs and fuel poverty
- There should be no distinction between performance standards for retrofit and newbuild, which are confusing and divisive. Similarly, there should be no distinction between performance standards based on tenure or housing type.
- Some housing stock has constraints around retrofit, notably pre-1919 housing with an established character or identity that would be diminished by extensive retrofit. However the justification for 'acceptable fails' must be carefully defined so as not to jeopardise decarbonisation targets
- All other housing must be retrofitted beyond SAP90, which equates to current Building Regulations performance standards. The most straightforward way to achieve this is to insist that all housing targets an EPC A rating.
- Phased targets for retrofit of the entire housing stock (in line with carbon budgets) may appear to offer stepping stones for decarbonisation. However, for many of the fabric-based actions, retrofit will be more cost effective if only undertaken once. Other options, such as boiler replacement, are likely to be undertaken more than once before 2050. There is a real risk that phased targets will diminish, or obviate, the benefit of work carried out in early phases. In any case, actions that avoid lock-in should be utilised, and economies of scale should be explored.
- A more prescriptive performance target risks diminishing opportunities for sensitive retrofit and reducing effectiveness.
- To meet stringent decarbonisation targets, retrofit actions must overcome the performance gap (ie. the results should be measured as delivered, not as predicted). A skilled, trained supply chain is needed to ensure that retrofit is appropriately conceived and properly implemented.

- Retrofit standards are easier to enforce for social housing and the PRS sectors. Work must be undertaken exploring how to initiate this level of retrofit in the owner occupied sector. Point of sale represents a clear opportunity to drive new performance standards.
- It is difficult to forecast how the cost of innovation will change over time. (As an example, the cost of an installed photovoltaic system has reduced by 50% over the past 10 years, as a result of improvements in technology, manufacturing and increased sales.) Cost models should include a 5% annual reduction in capital costs for a maximum of 10 years.
- With continued innovation in technology, current sustainable renewable energy solutions will be replaced by new ones. Again, the impact on cost is difficult to assess, but we advise that future technologies are costed at current rates for similar solutions and then on the same reducing cost of 5% per annum for 10 years, after which the cycle is assumed to repeat.
- The impact of people on retrofit remains the least understood part of the process, and the one most likely to impact (positively or negatively) on the effectiveness of any retrofit strategies. It is essential that users participate in the retrofit process and understand the actions being undertaken, if the anticipated carbon savings are to be realised.

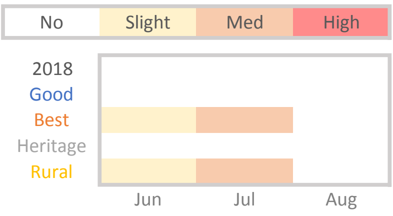
A flexible approach that pushes all housing to achieve appropriate performance standards by 2050 is the only way to anticipate achieving 90%+ decarbonisation under assumed energy supply scenarios.

appendix A: datasheets
fourteen dwelling types, two scenarios

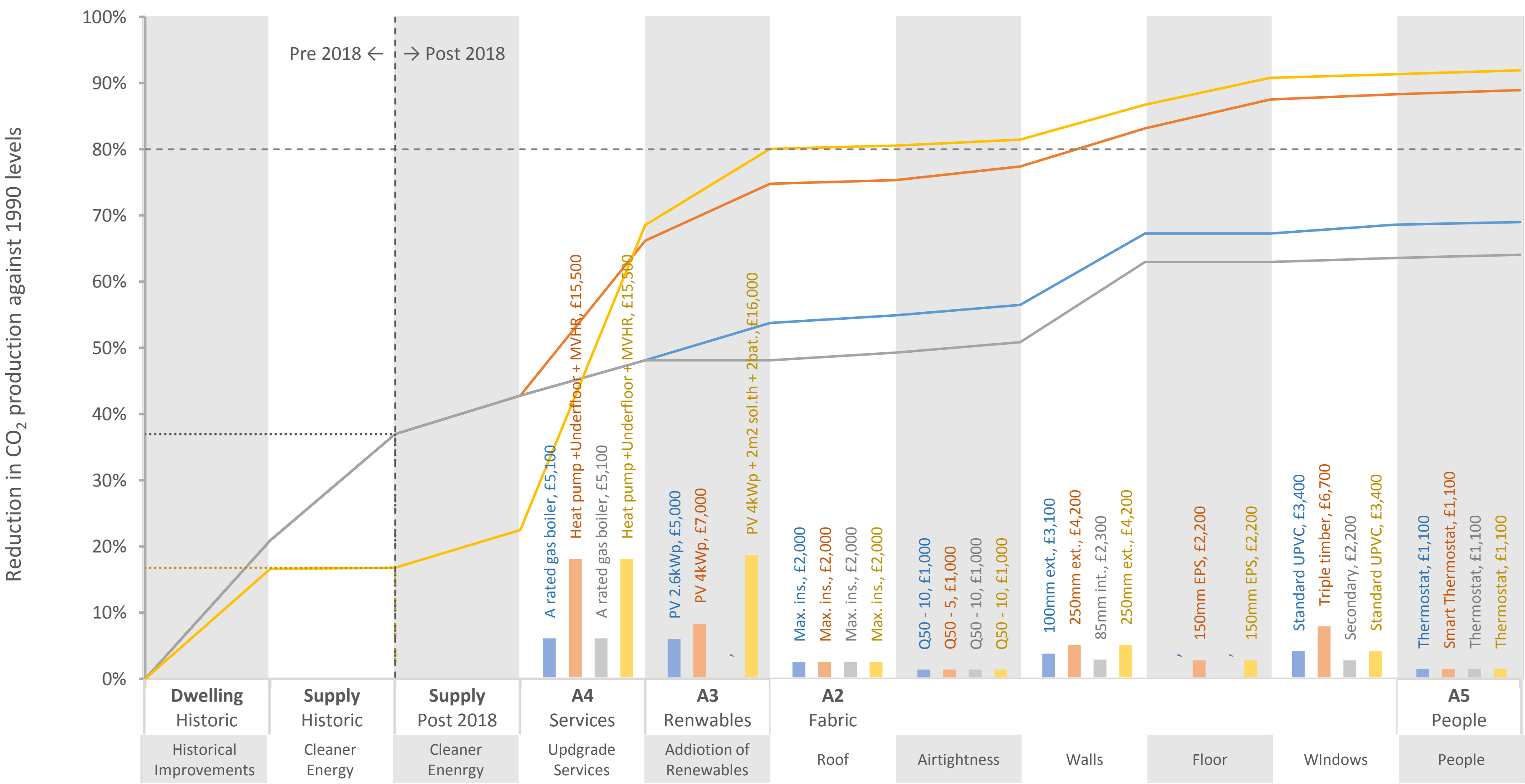
Dwelling type 1: End terrace pre 1919

Scenario 1

Overheating Risk

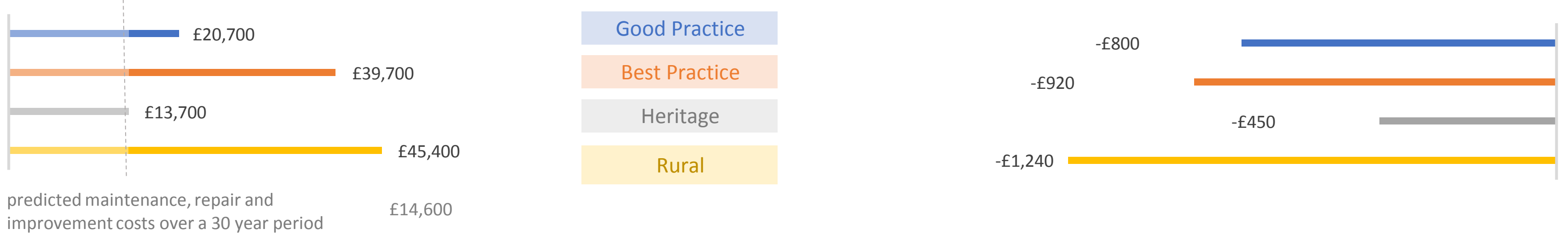


Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



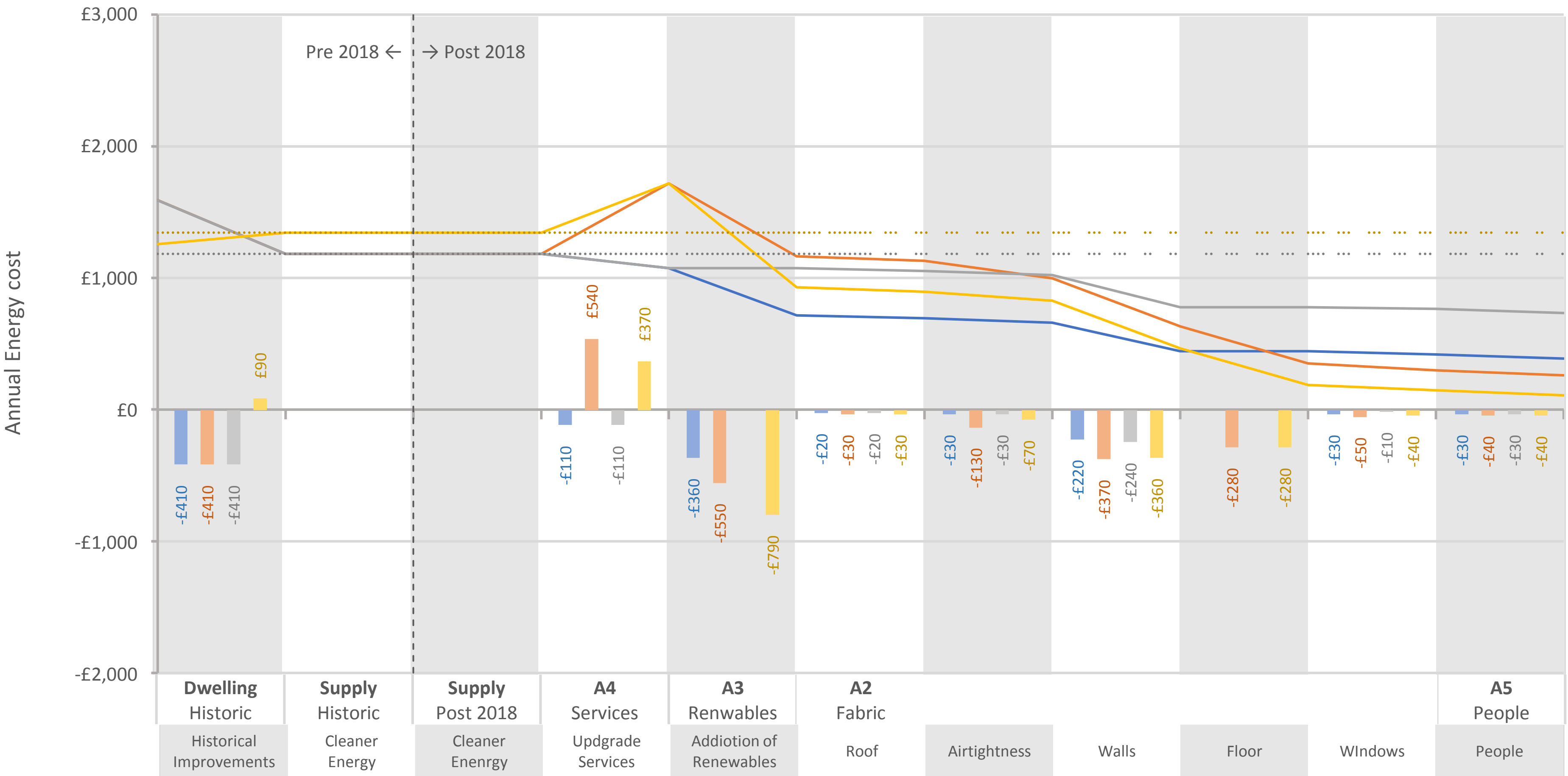
Total capital cost by narrative

Total reduction in annual energy cost by narrative



Impact on annual energy cost of four distinct retrofit narratives

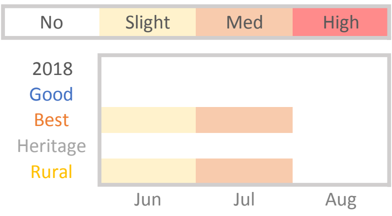
Scenario 1 assumes
no change in energy costs



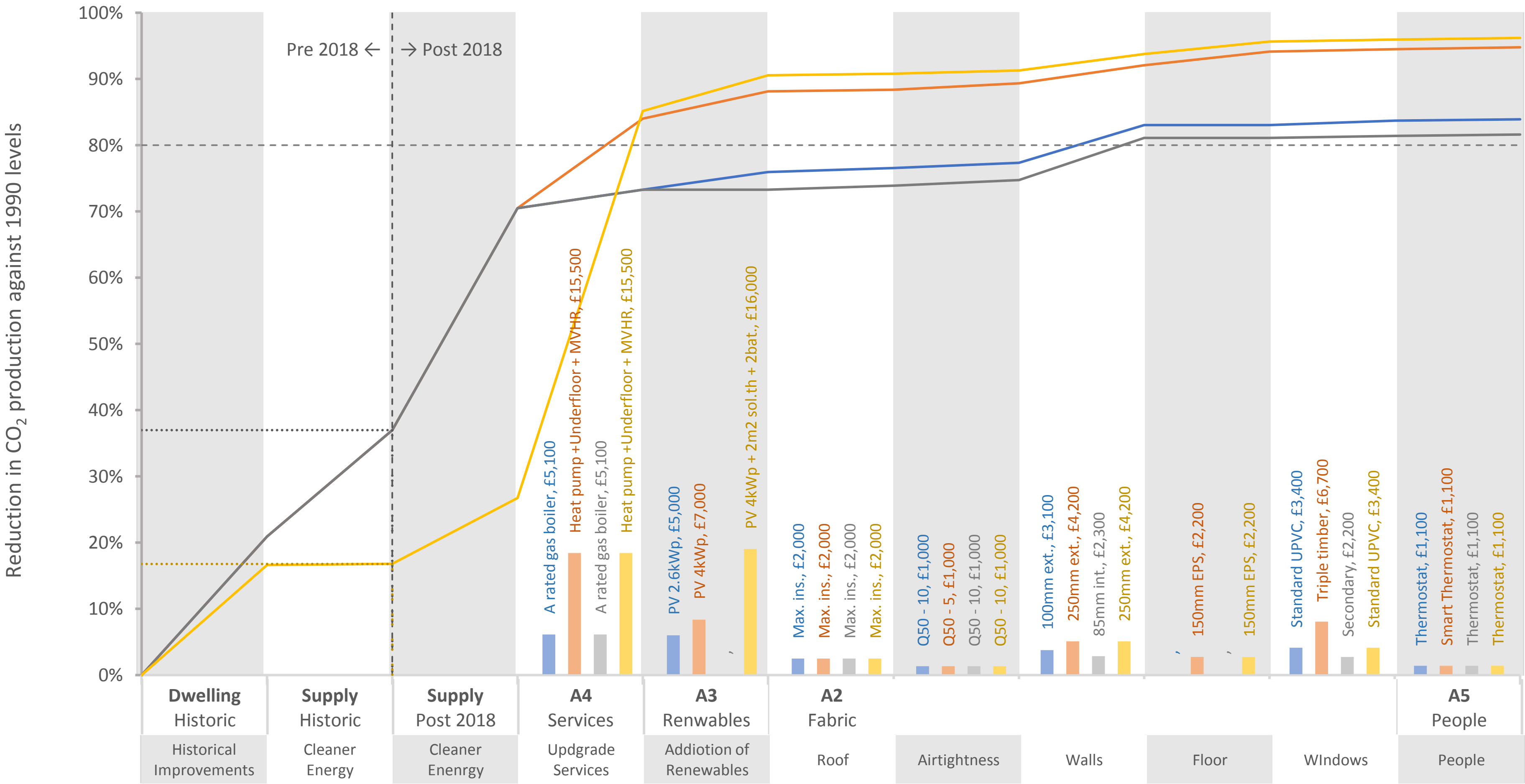
Dwelling type 1: End terrace pre 1919

Scenario 2

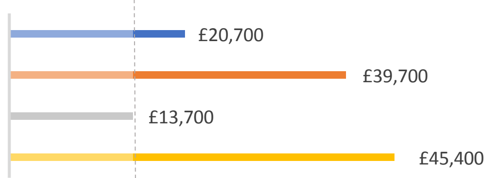
Overheating Risk



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions

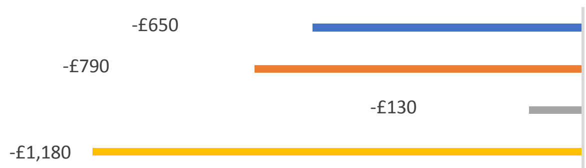


Total capital cost by narrative



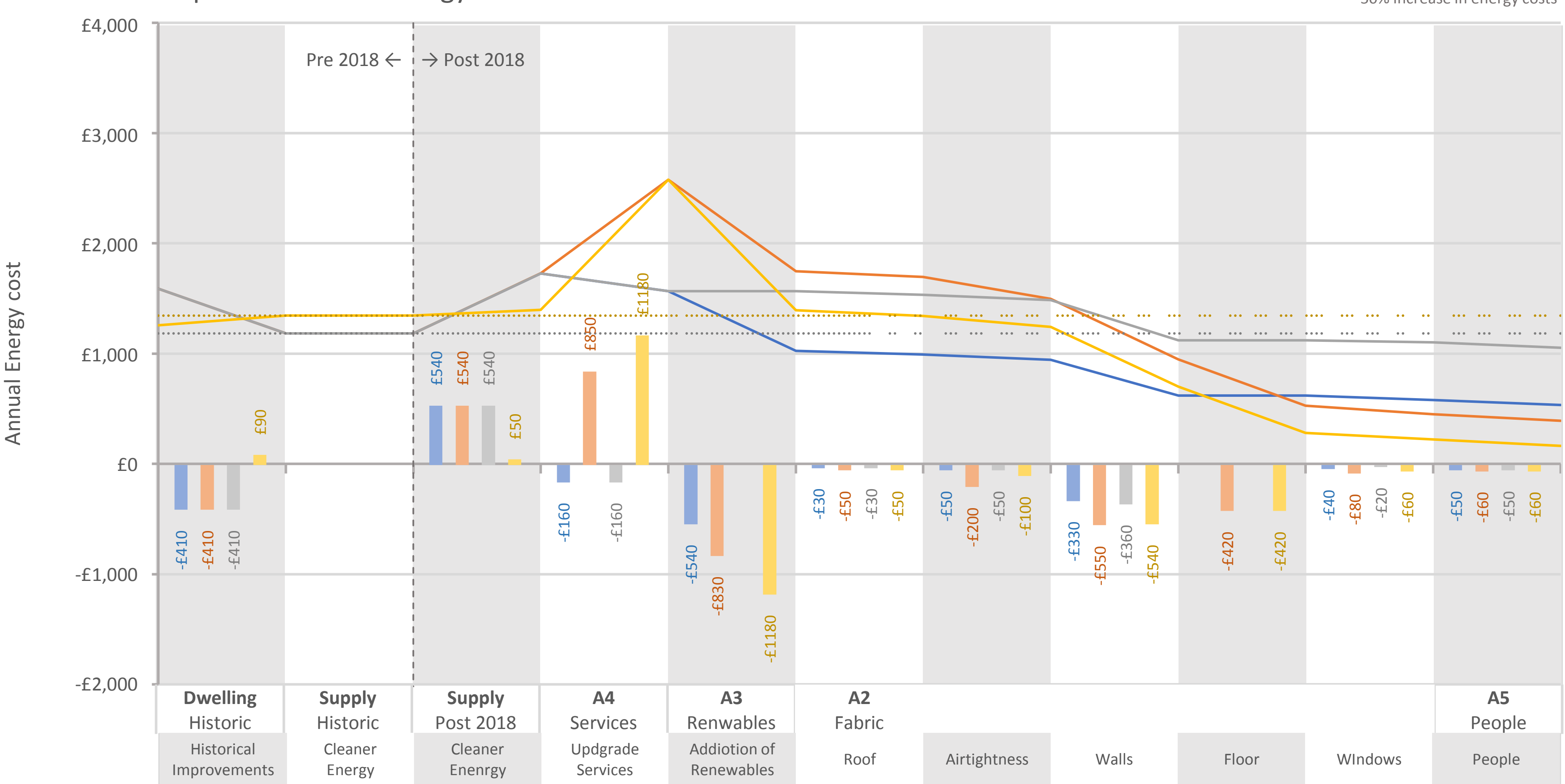
predicted maintenance, repair and improvement costs over a 30 year period

Total reduction in annual energy cost by narrative

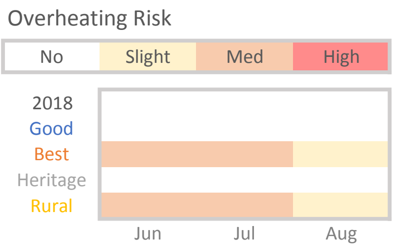


Impact on annual energy cost of four distinct retrofit narratives

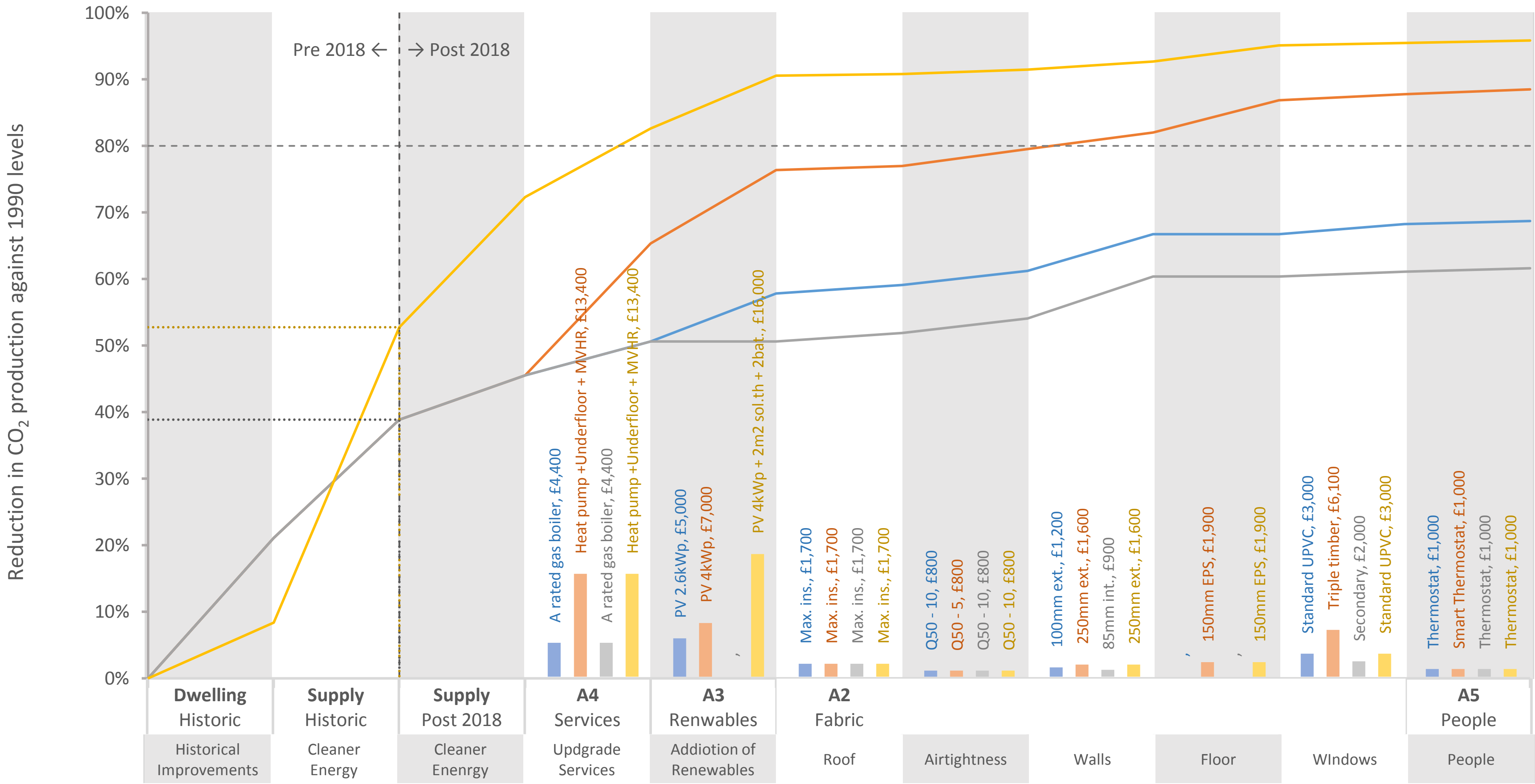
Scenario 2 assumes 50% increase in energy costs



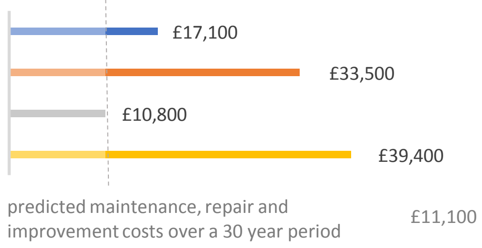
Dwelling type 2: Mid terrace pre 1919
Scenario 1



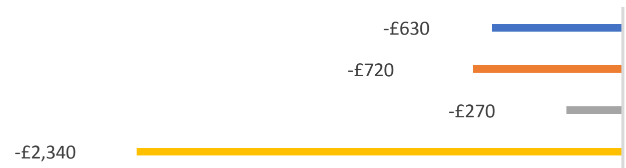
Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative

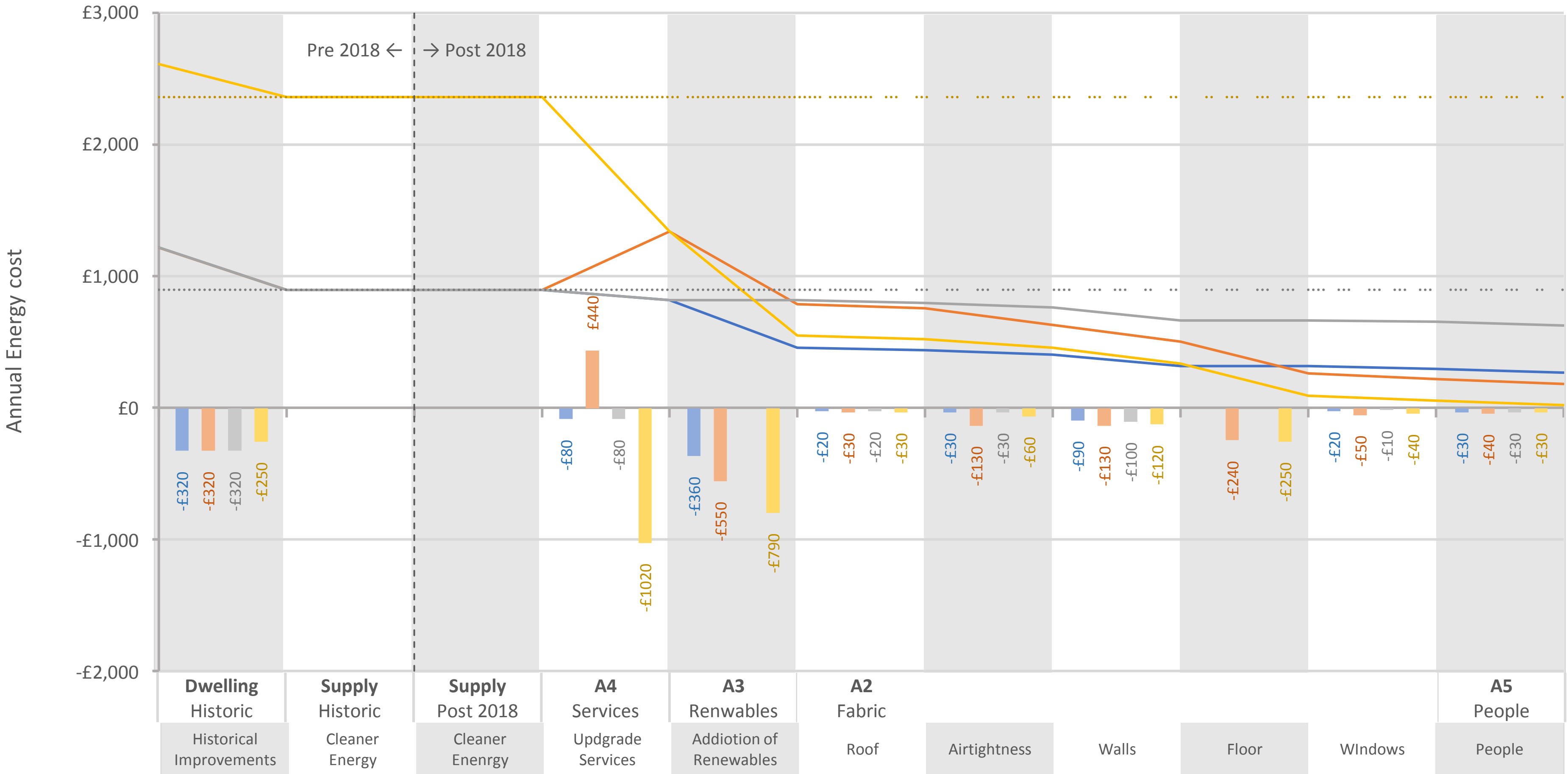


Total reduction in annual energy cost by narrative



Impact on annual energy cost of four distinct retrofit narratives

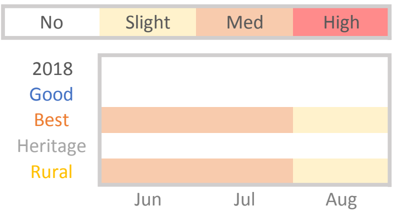
Scenario 1 assumes no change in energy costs



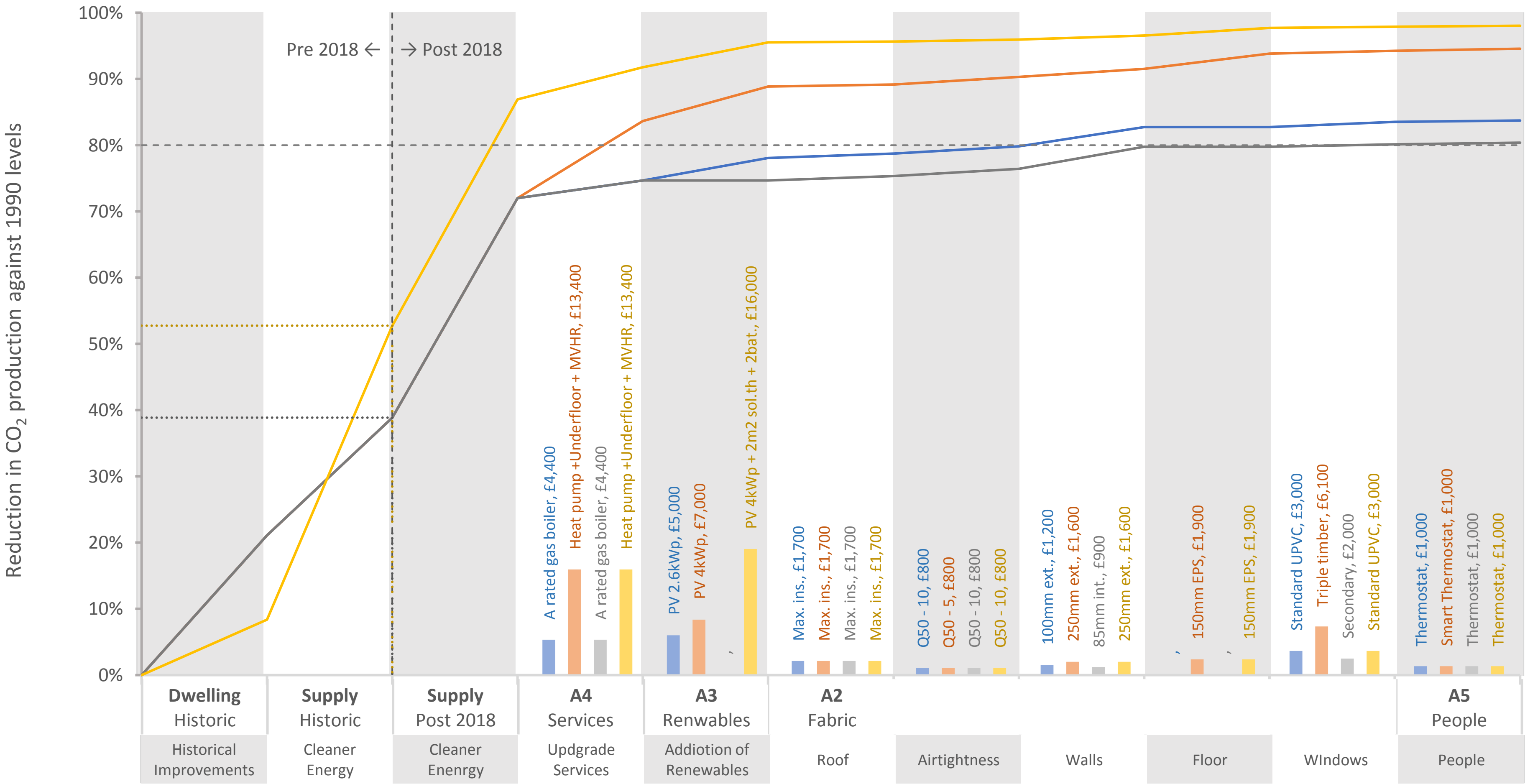
Dwelling type 2: Mid terrace pre 1919

Scenario 2

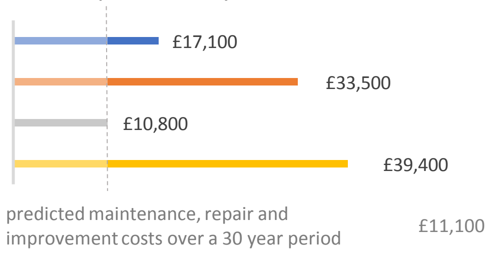
Overheating Risk



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative



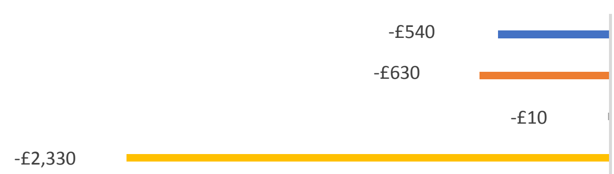
Good Practice

Best Practice

Heritage

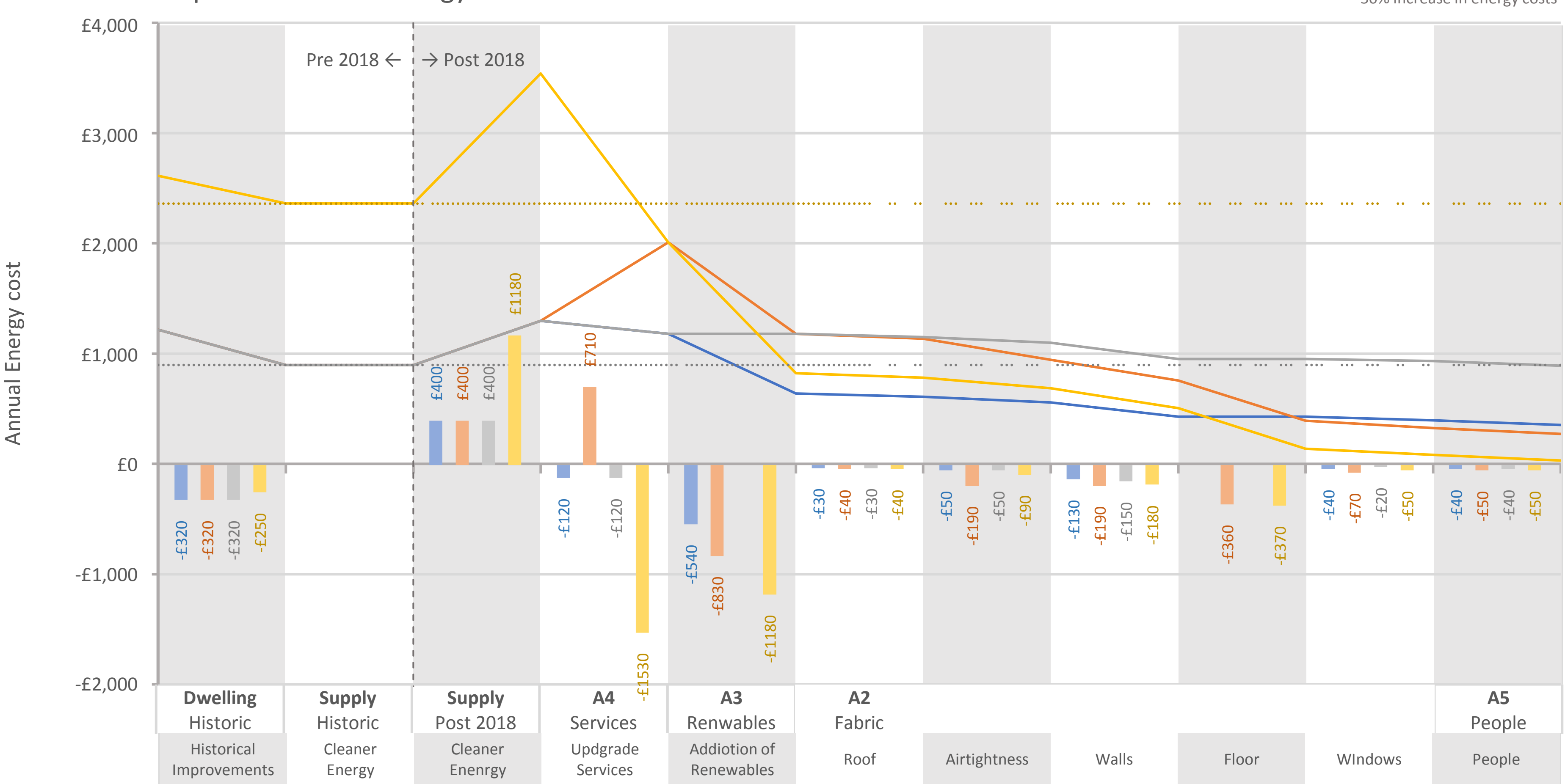
Rural

Total reduction in annual energy cost by narrative



Impact on annual energy cost of four distinct retrofit narratives

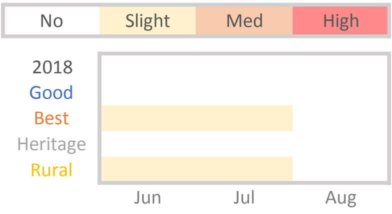
Scenario 2 assumes 50% increase in energy costs



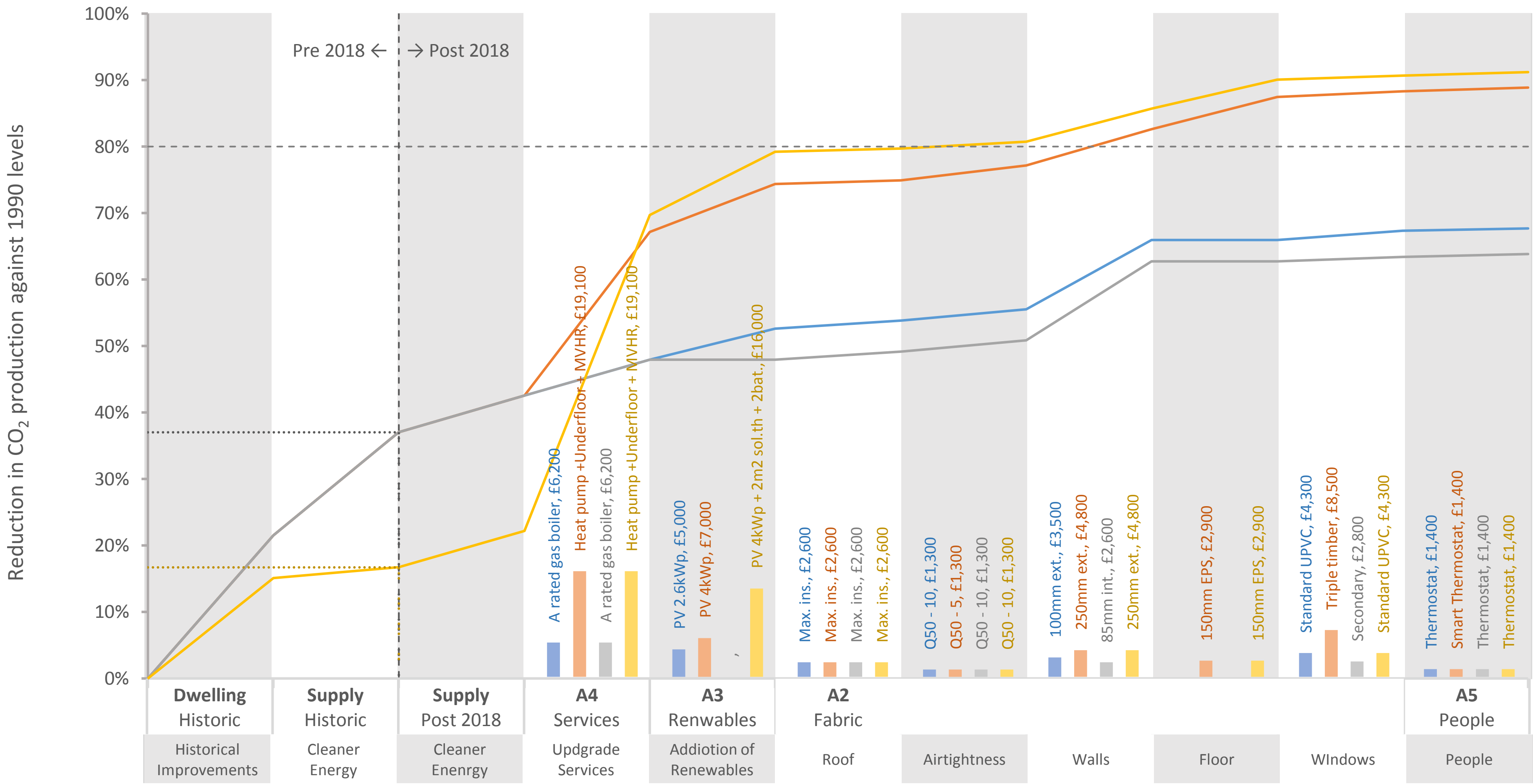
Dwelling type 3: Semi-detached pre 1919

Scenario 1

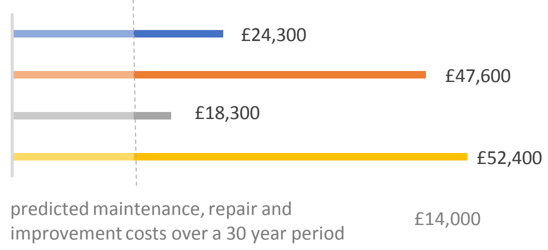
Overheating Risk



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions

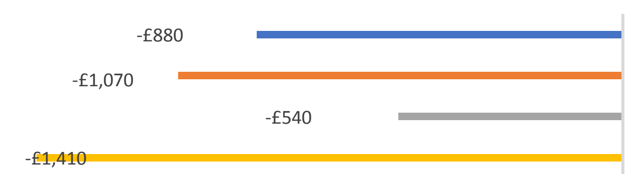


Total capital cost by narrative



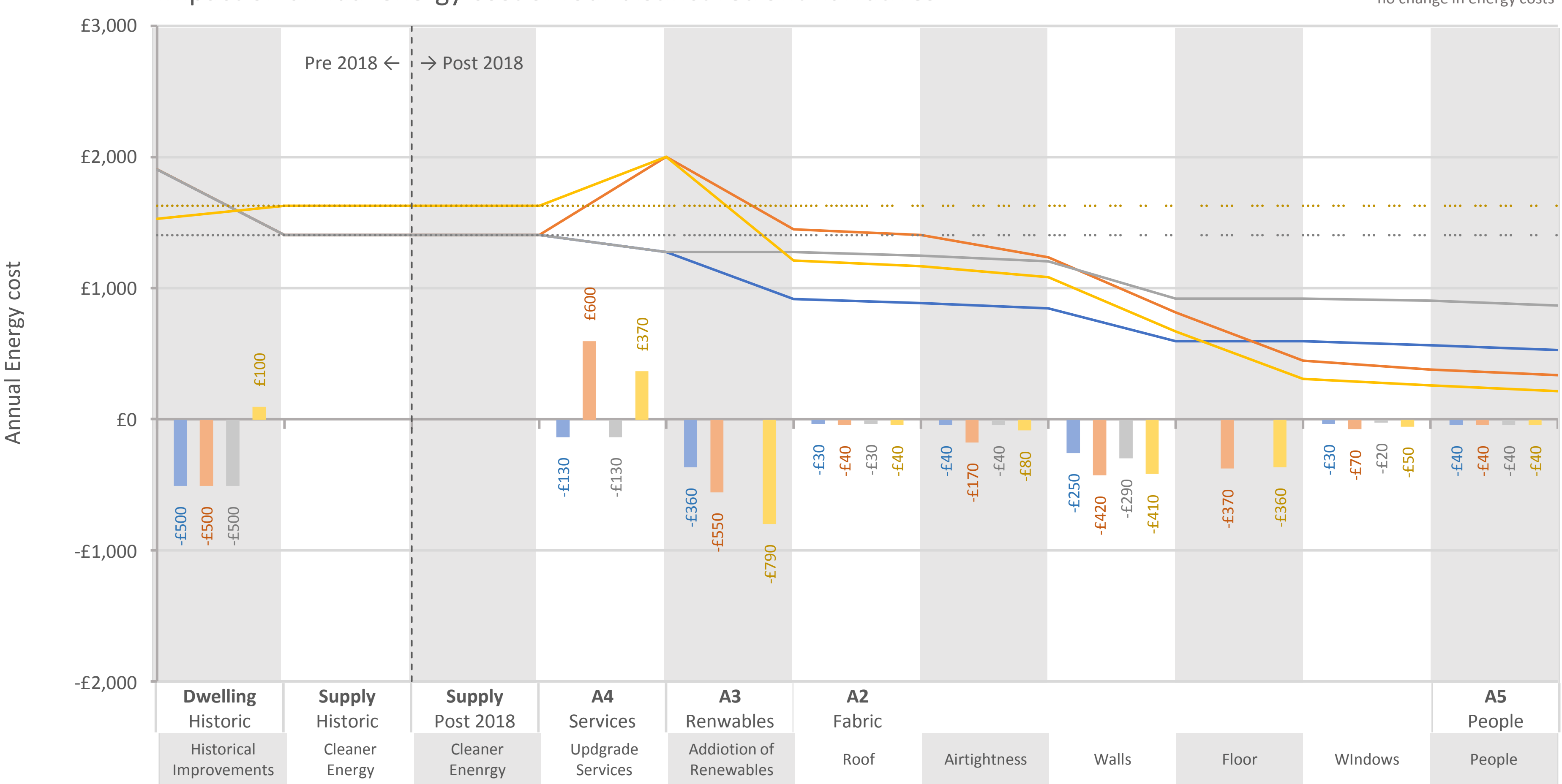
Good Practice
Best Practice
Heritage
Rural

Total reduction in annual energy cost by narrative



Impact on annual energy cost of four distinct retrofit narratives

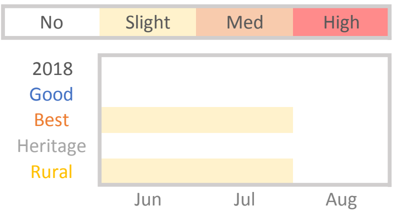
Scenario 1 assumes
no change in energy costs



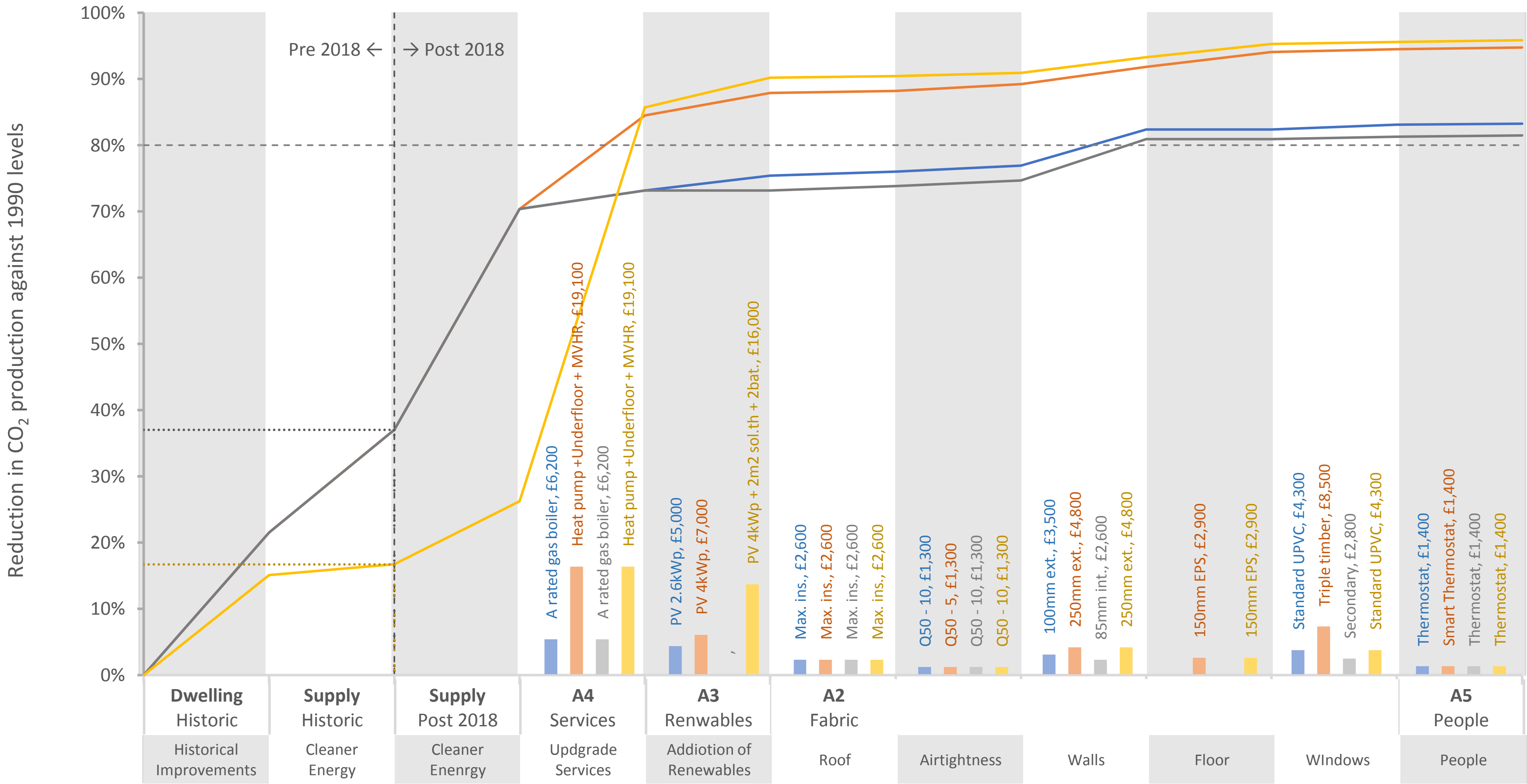
Dwelling type 3: Semi-detached pre 1919

Scenario 2

Overheating Risk



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions

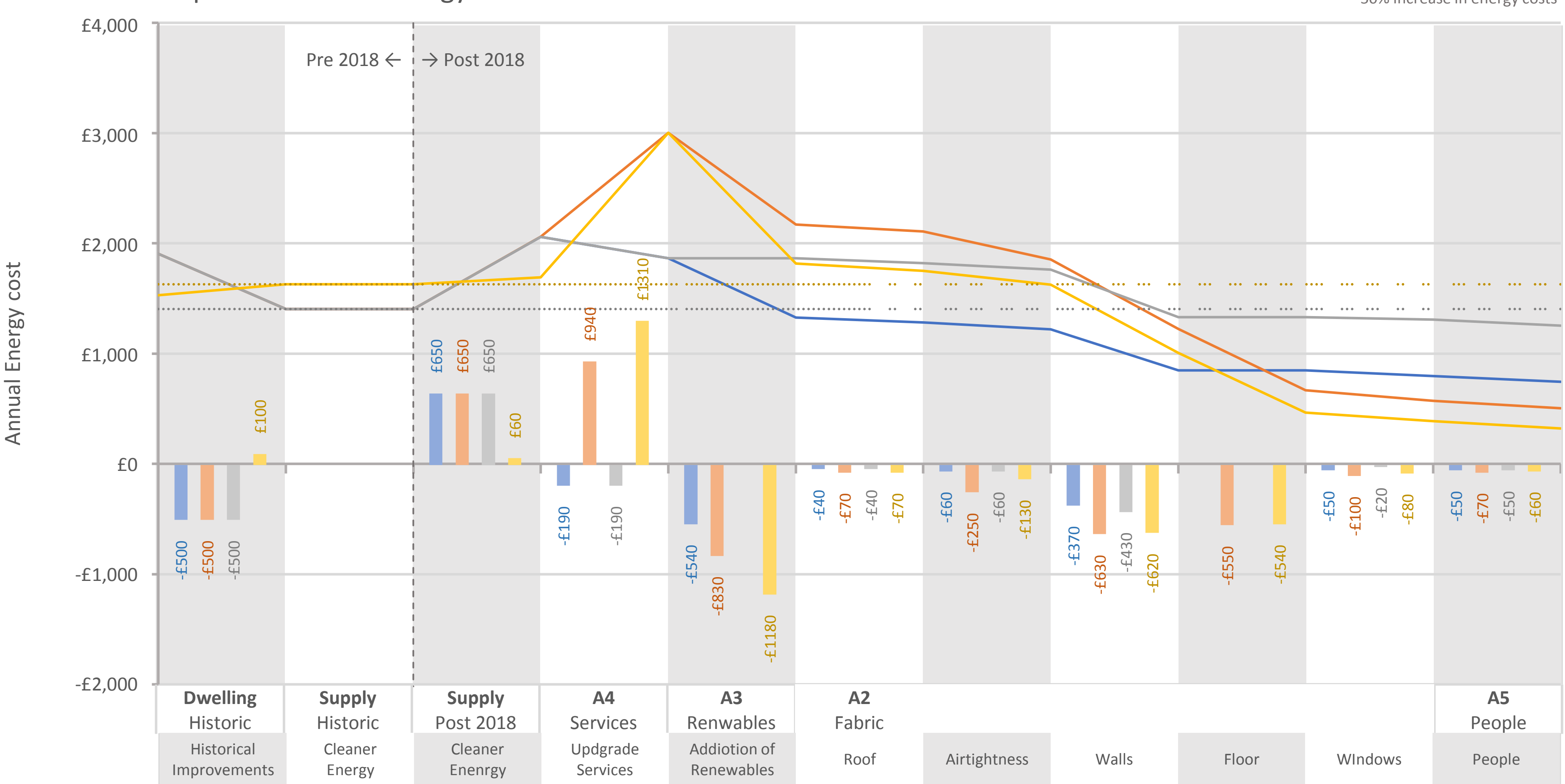


Total capital cost by narrative

Total reduction in annual energy cost by narrative

Impact on annual energy cost of four distinct retrofit narratives

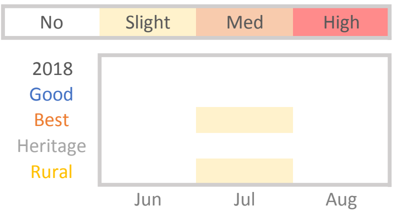
Scenario 2 assumes
50% increase in energy costs



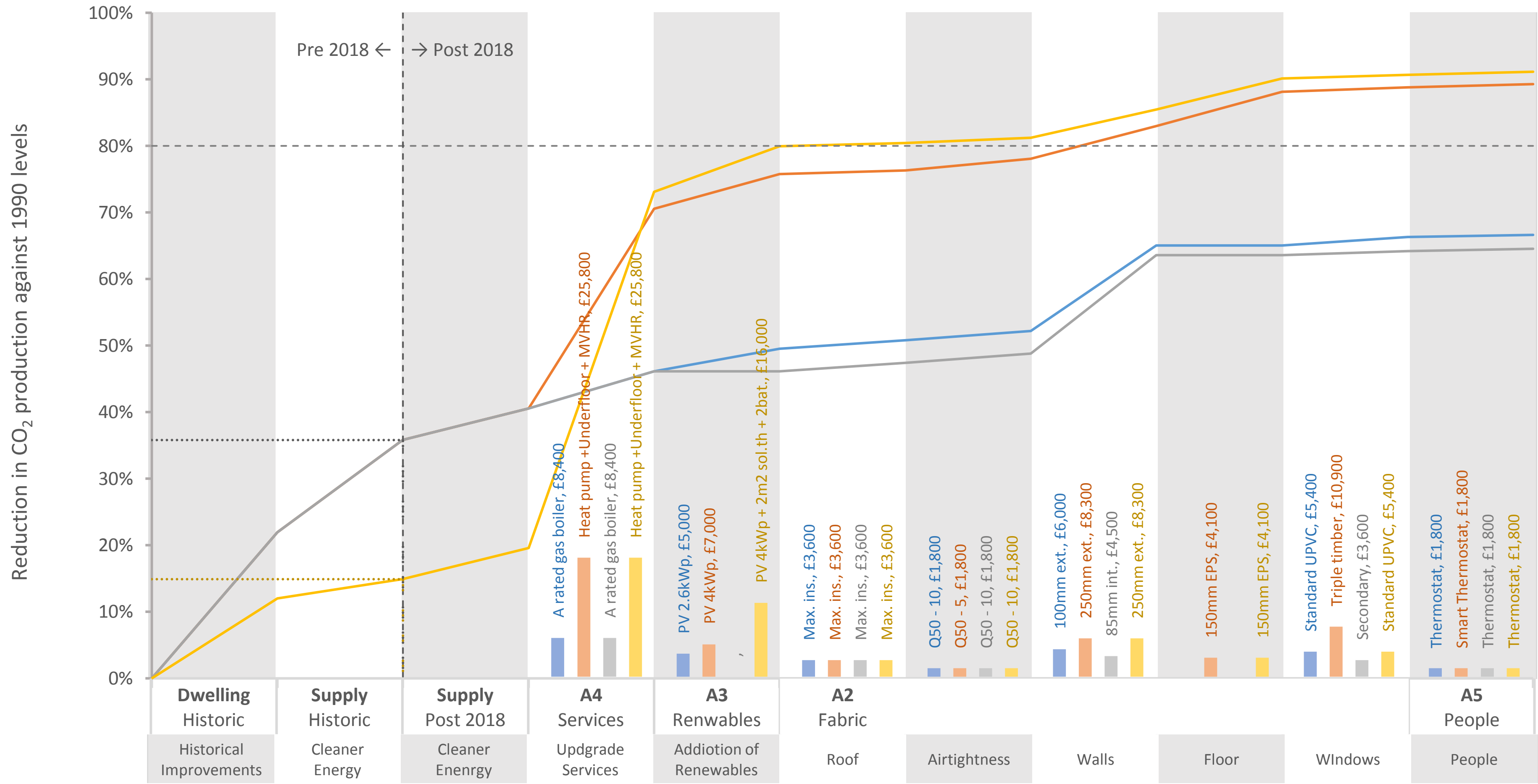
Dwelling type 4: Detached pre 1919

Scenario 1

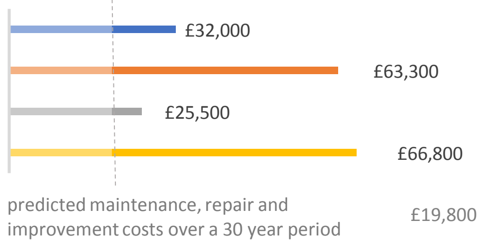
Overheating Risk



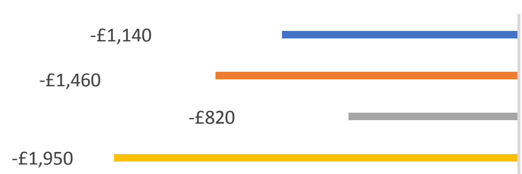
Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative

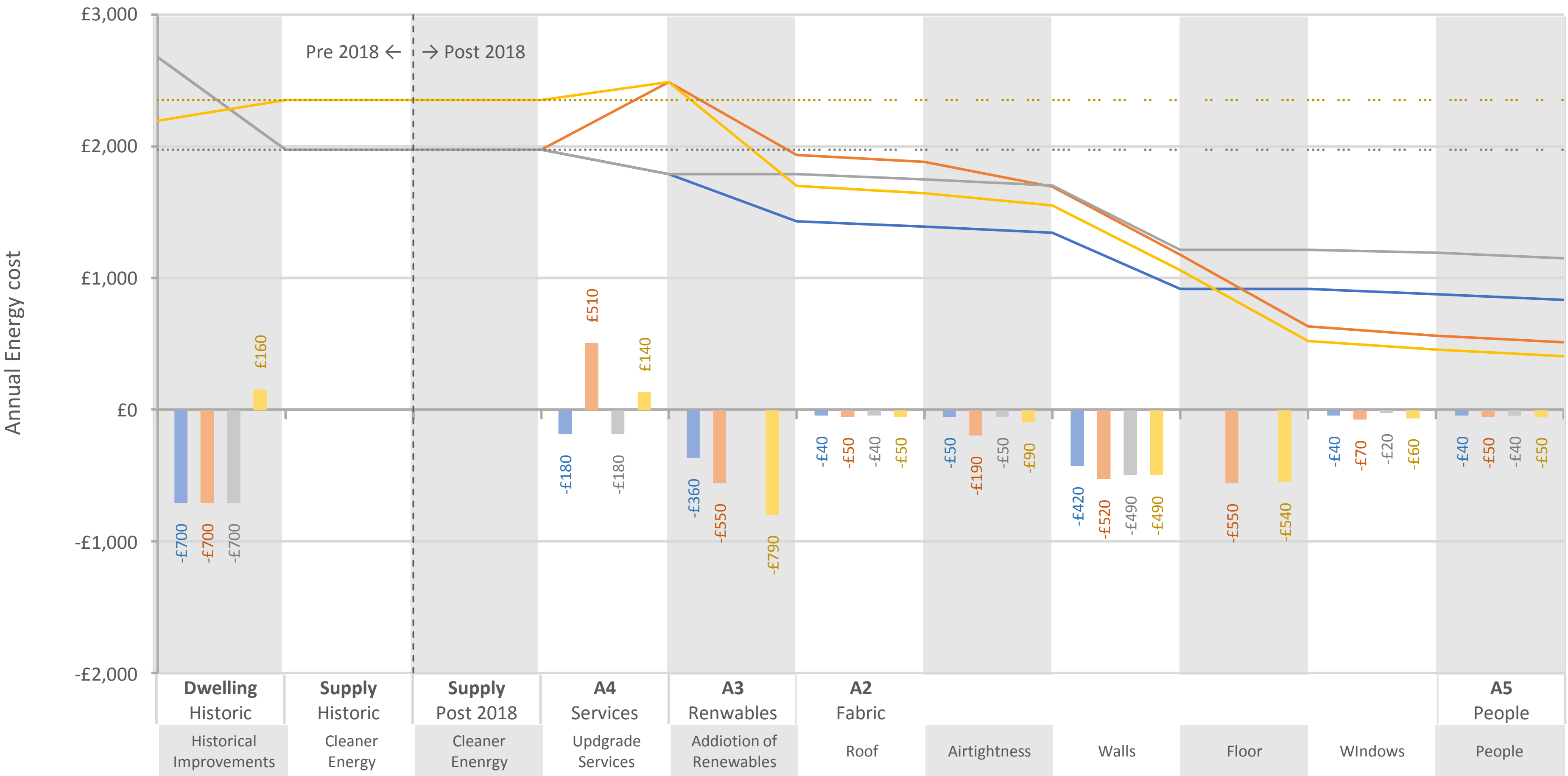


Total reduction in annual energy cost by narrative



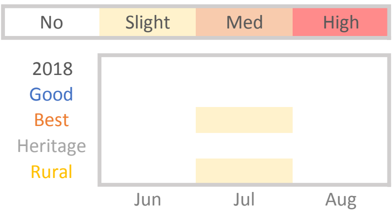
Impact on annual energy cost of four distinct retrofit narratives

Scenario 1 assumes no change in energy costs

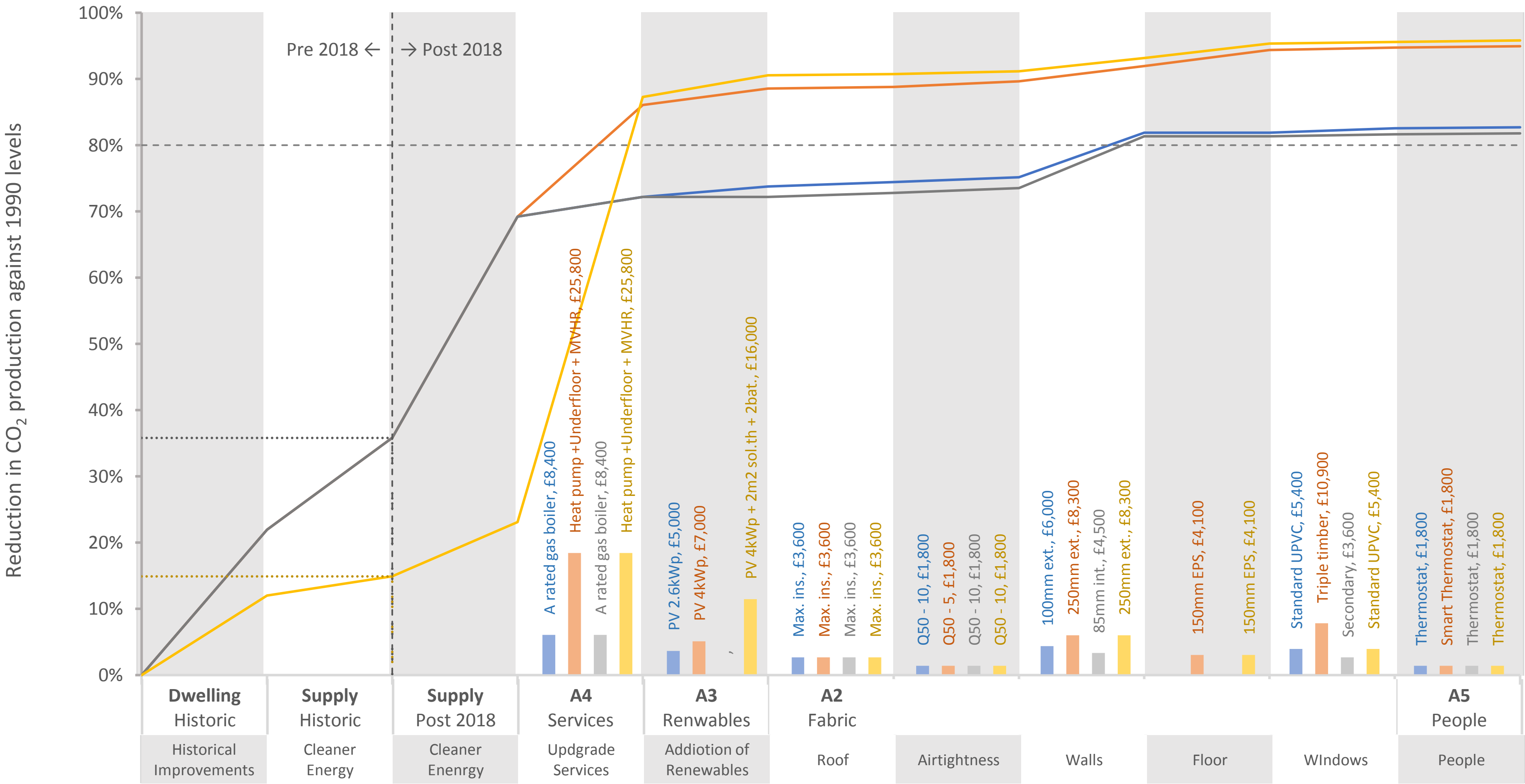


Dwelling type 4: Detached pre 1919
Scenario 2

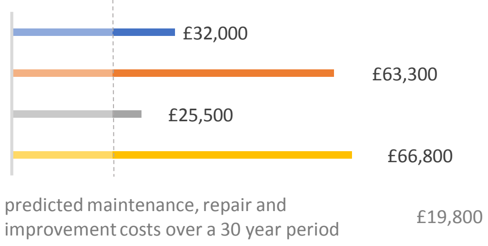
Overheating Risk



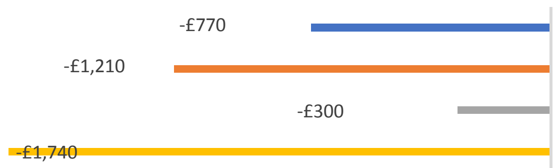
Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative

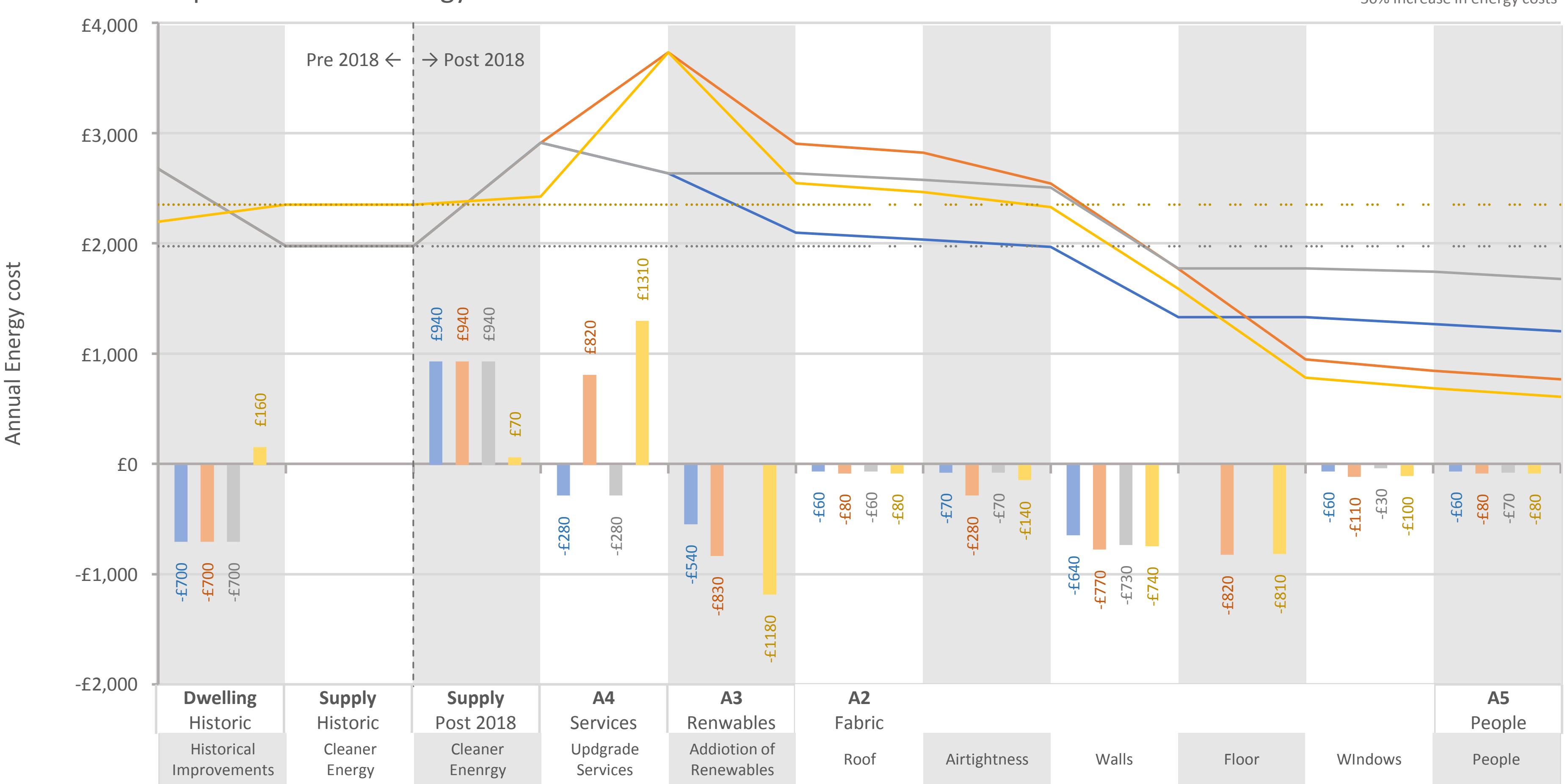


Total reduction in annual energy cost by narrative

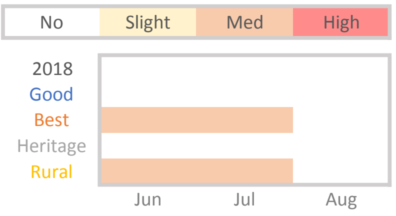


Impact on annual energy cost of four distinct retrofit narratives

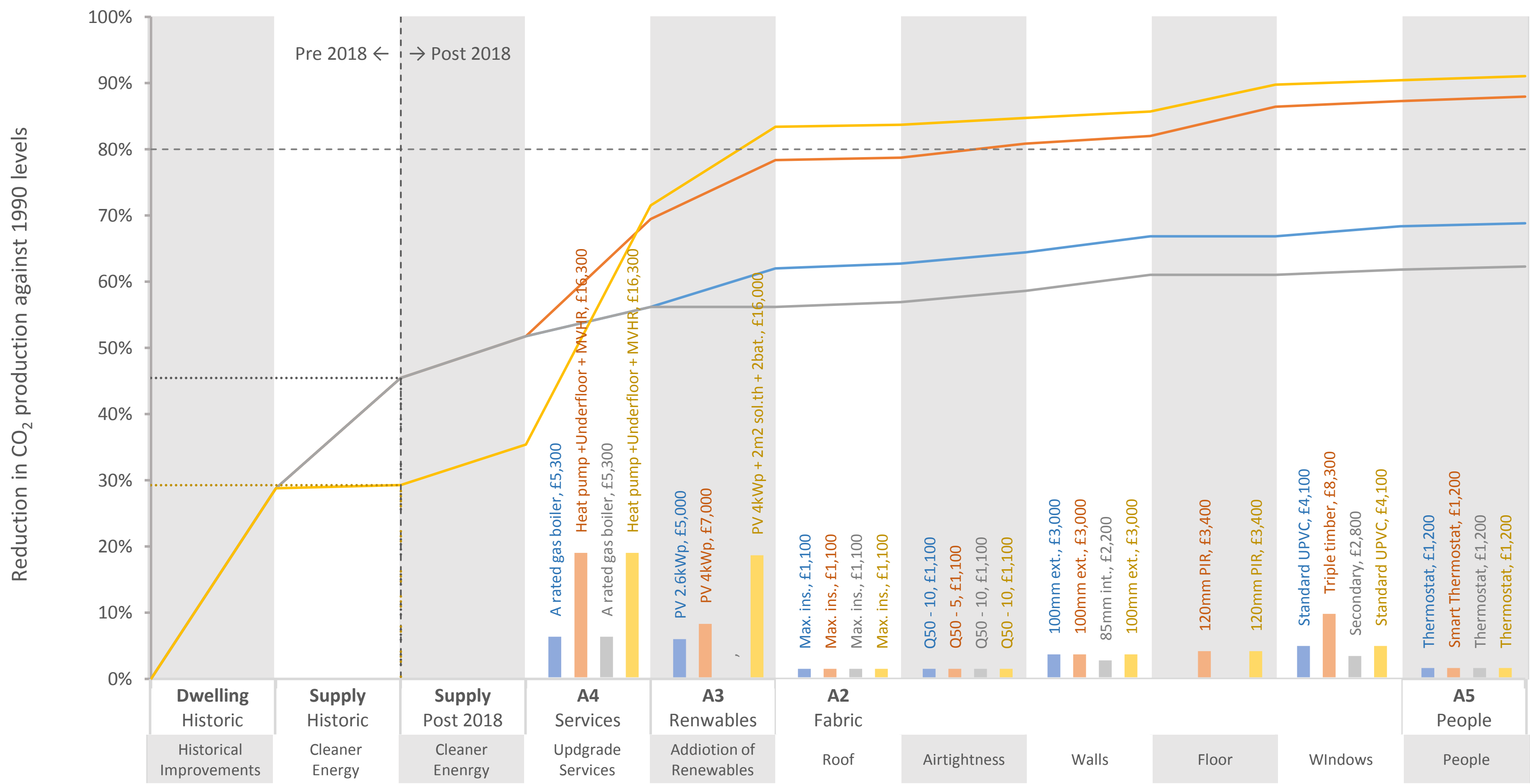
Scenario 2 assumes 50% increase in energy costs



Dwelling type 5: Semi-detached 1919-1944
Scenario 1



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions

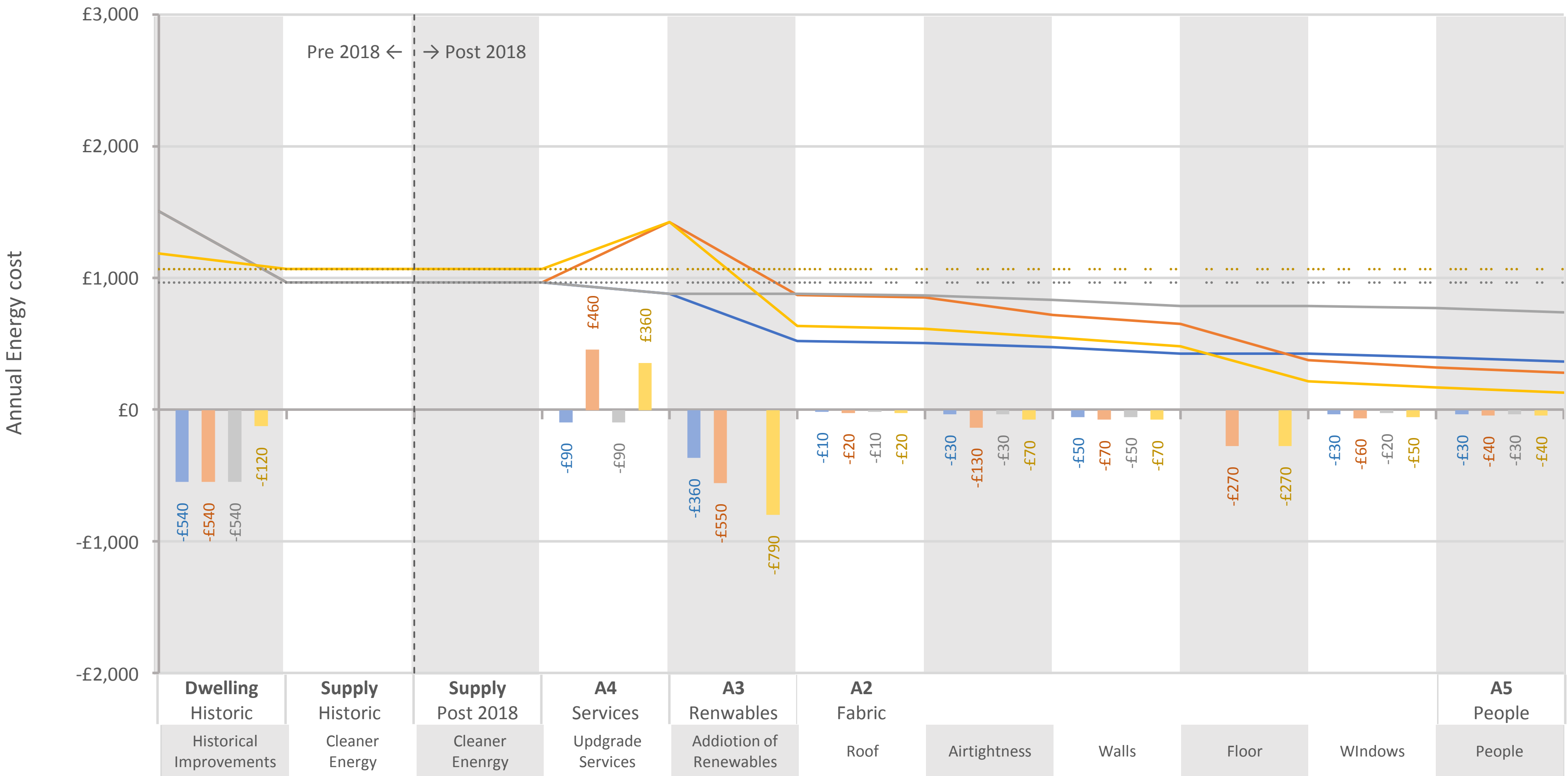


Total capital cost by narrative

Total reduction in annual energy cost by narrative

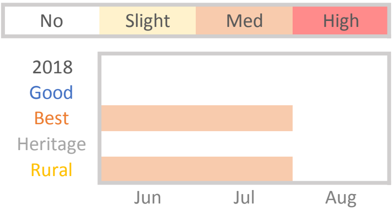
Impact on annual energy cost of four distinct retrofit narratives

Scenario 1 assumes no change in energy costs

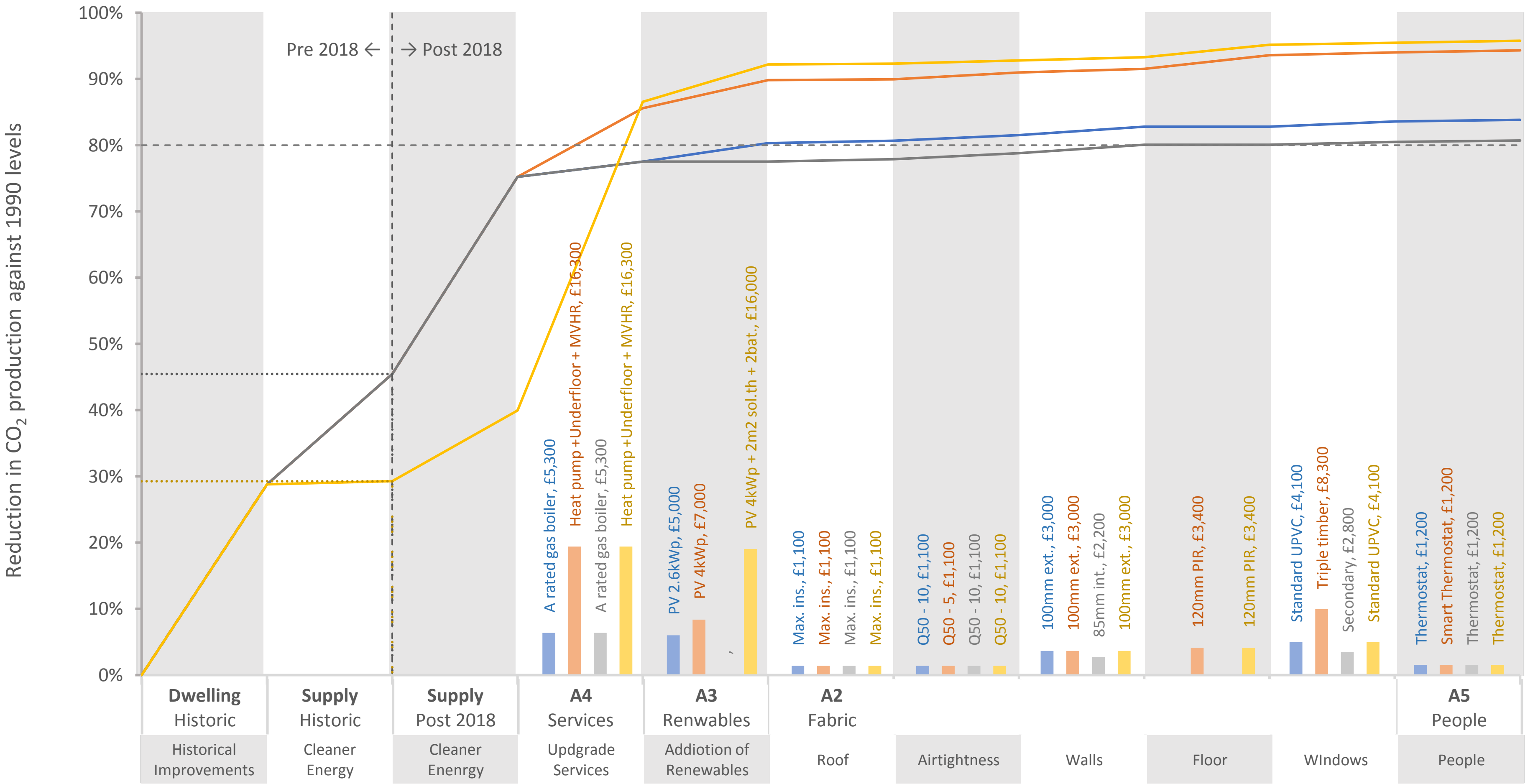


Dwelling type 5: Semi-detached 1919-1944
Scenario 2

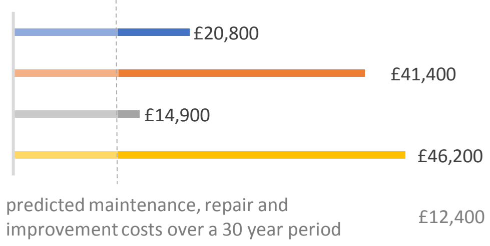
Overheating Risk



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions

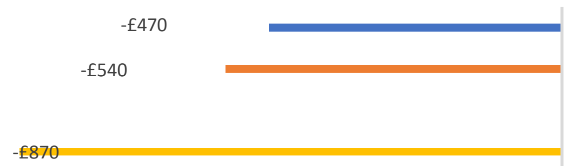


Total capital cost by narrative



Good Practice
Best Practice
Heritage
Rural

Total reduction in annual energy cost by narrative

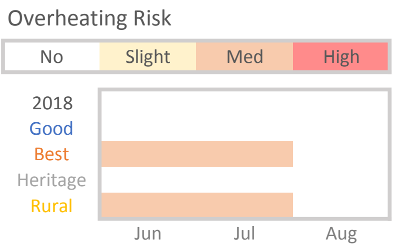


Impact on annual energy cost of four distinct retrofit narratives

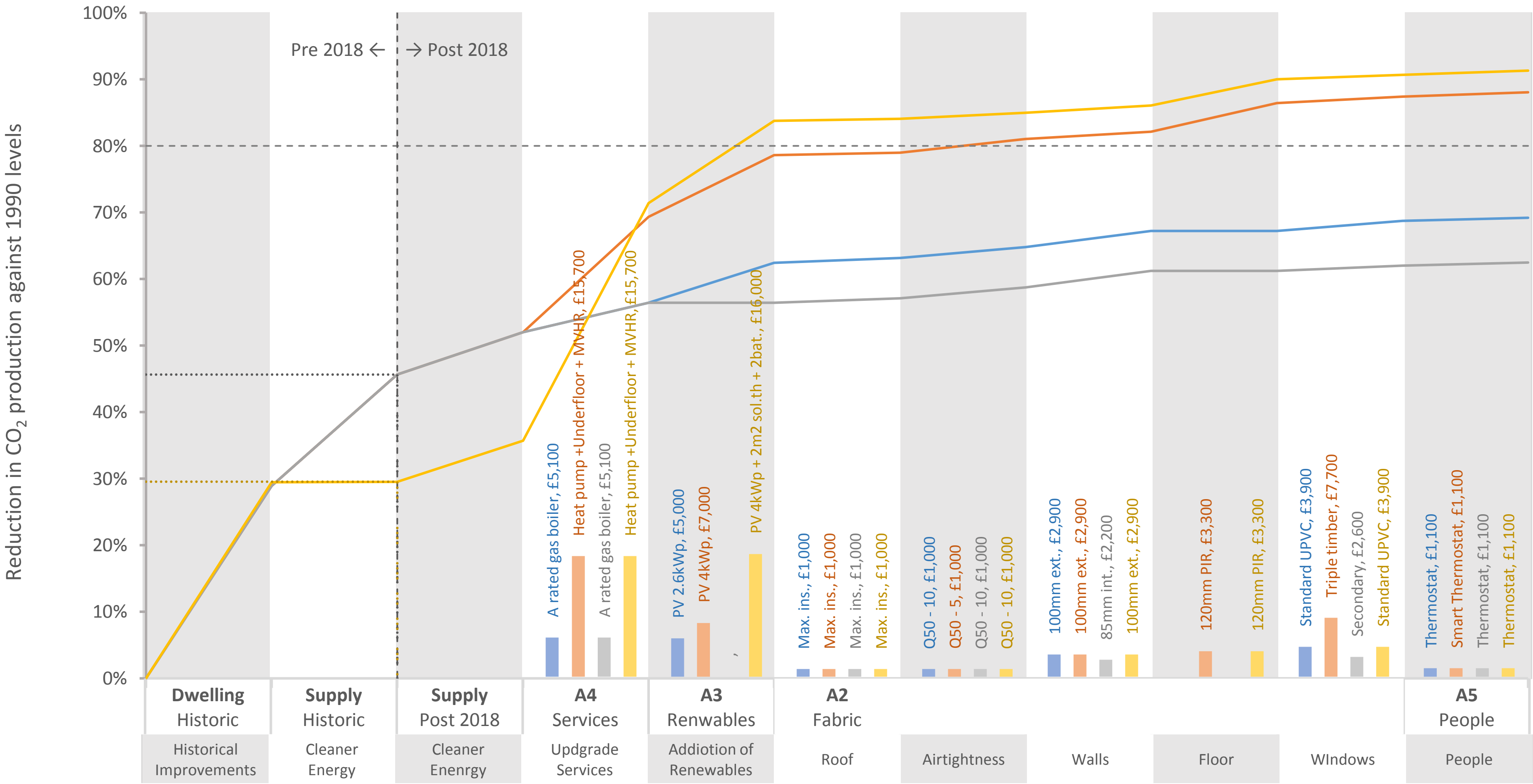
Scenario 2 assumes
50% increase in energy costs

Dwelling type 6: Semi-detached 1945-1964

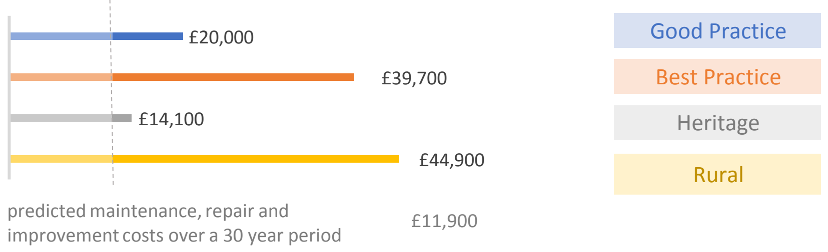
Scenario 1



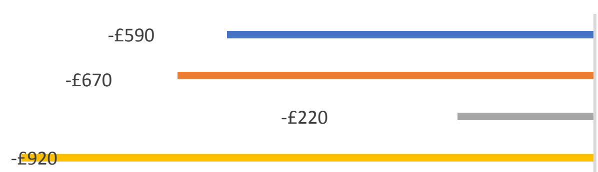
Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative

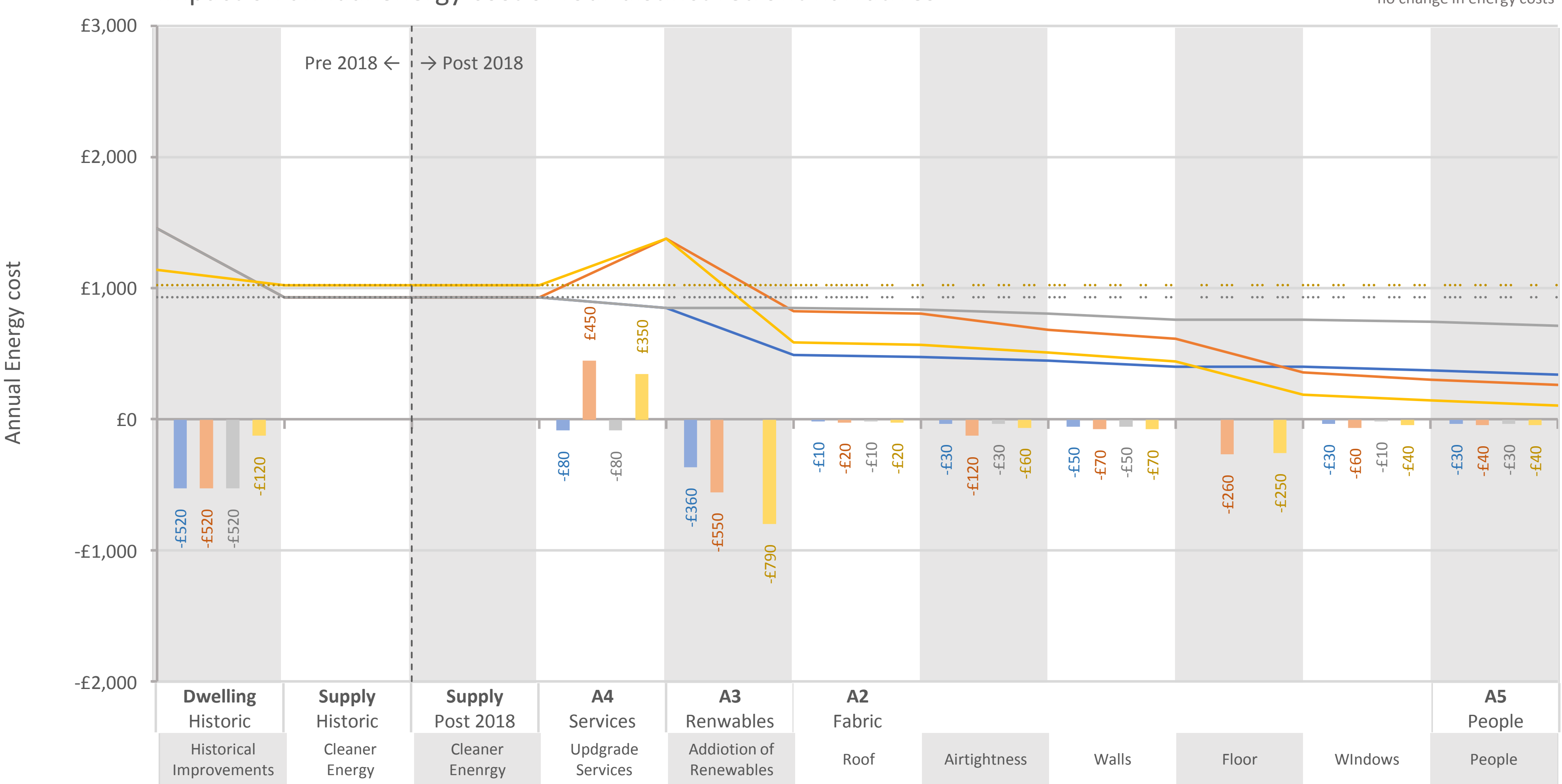


Total reduction in annual energy cost by narrative

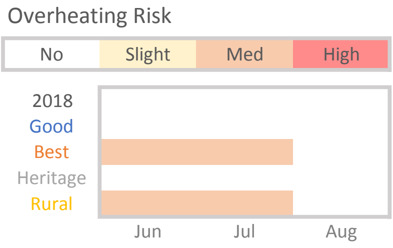


Impact on annual energy cost of four distinct retrofit narratives

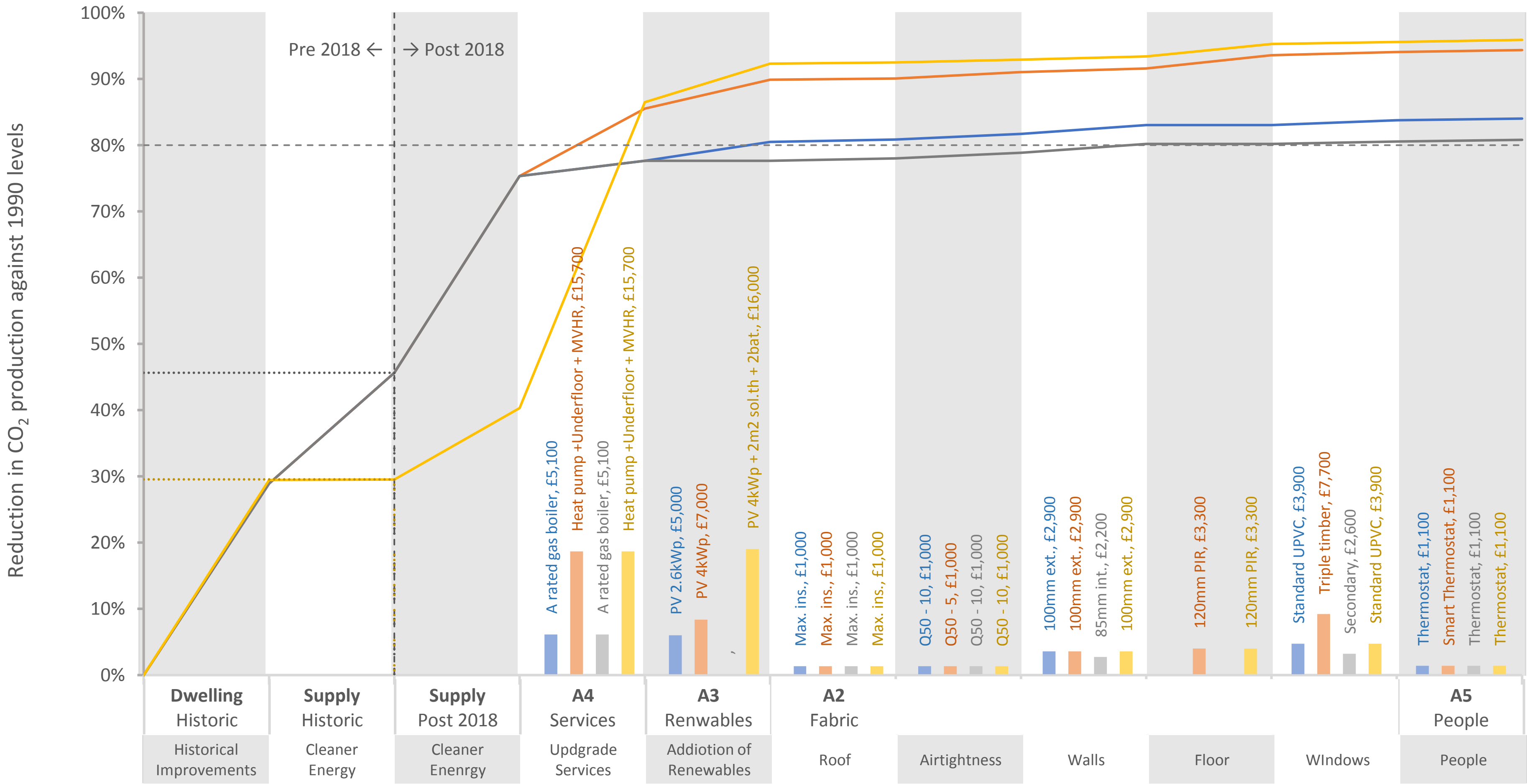
Scenario 1 assumes no change in energy costs



Dwelling type 6: Semi-detached 1945-1964
Scenario 2

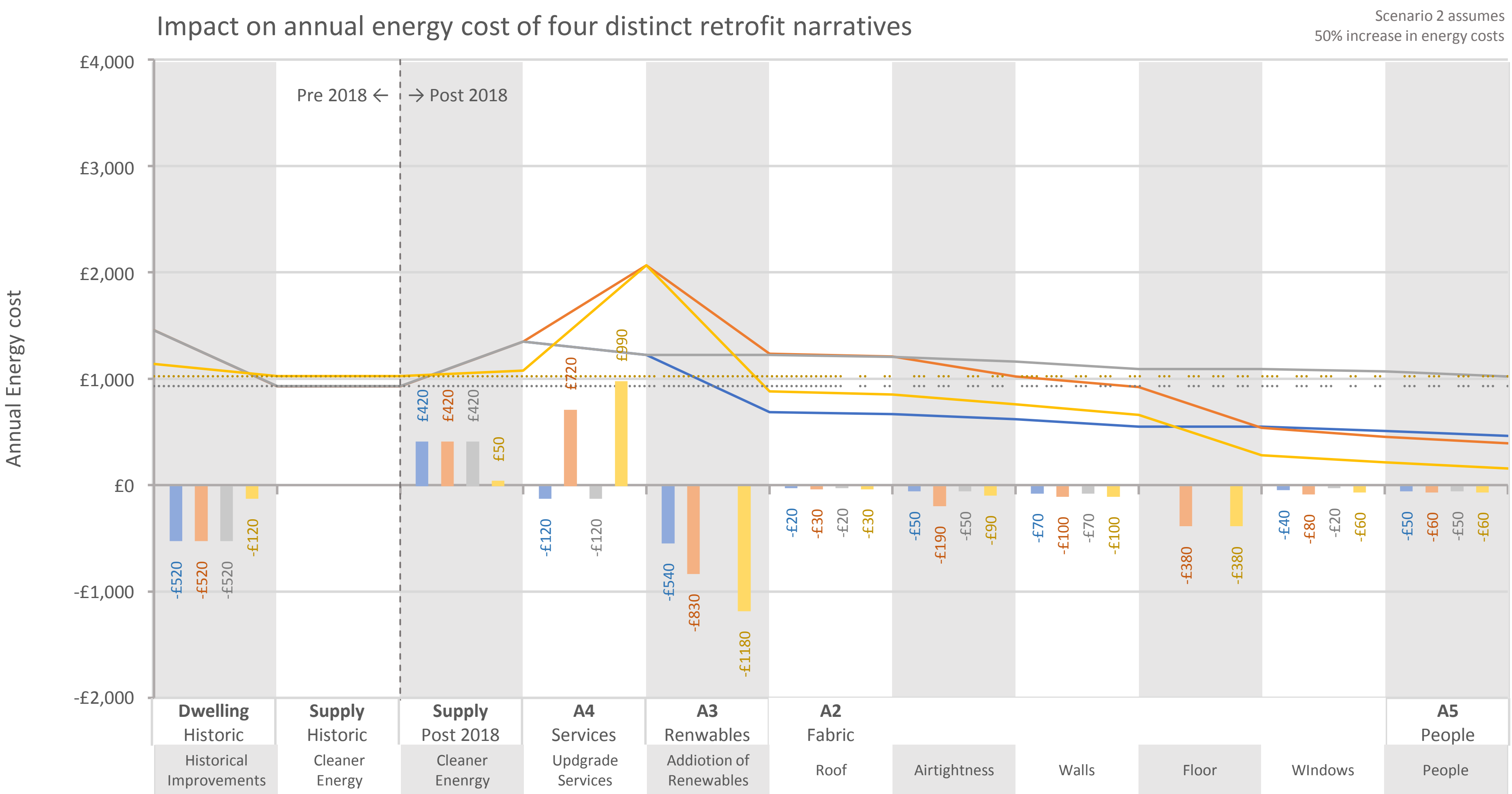


Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



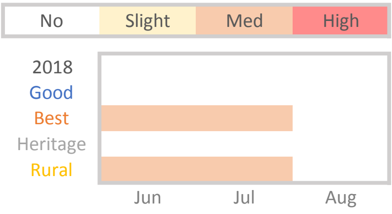
Impact on annual energy cost of four distinct retrofit narratives

Scenario 2 assumes 50% increase in energy costs

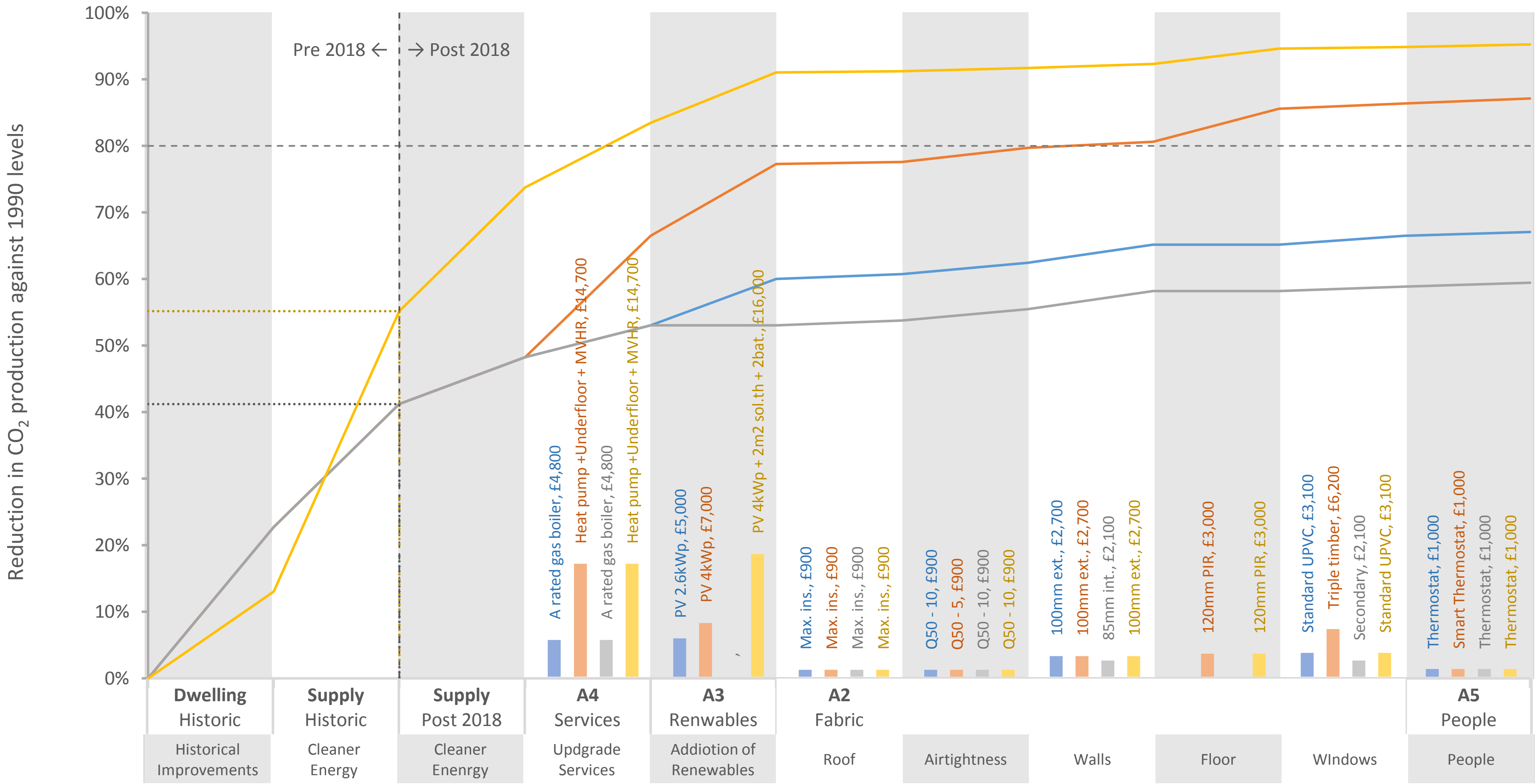


Dwelling type 7: End terrace 1965 - 1990
Scenario 1

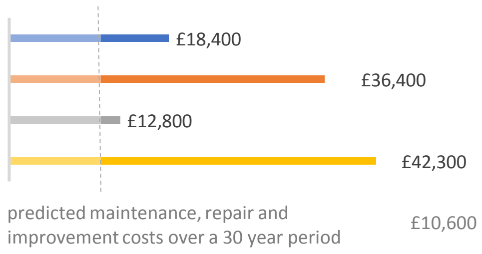
Overheating Risk



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions

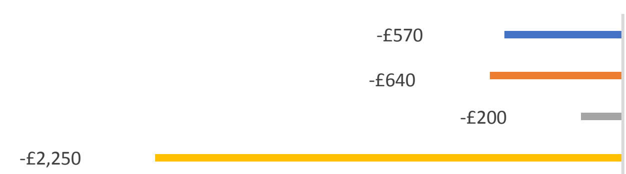


Total capital cost by narrative



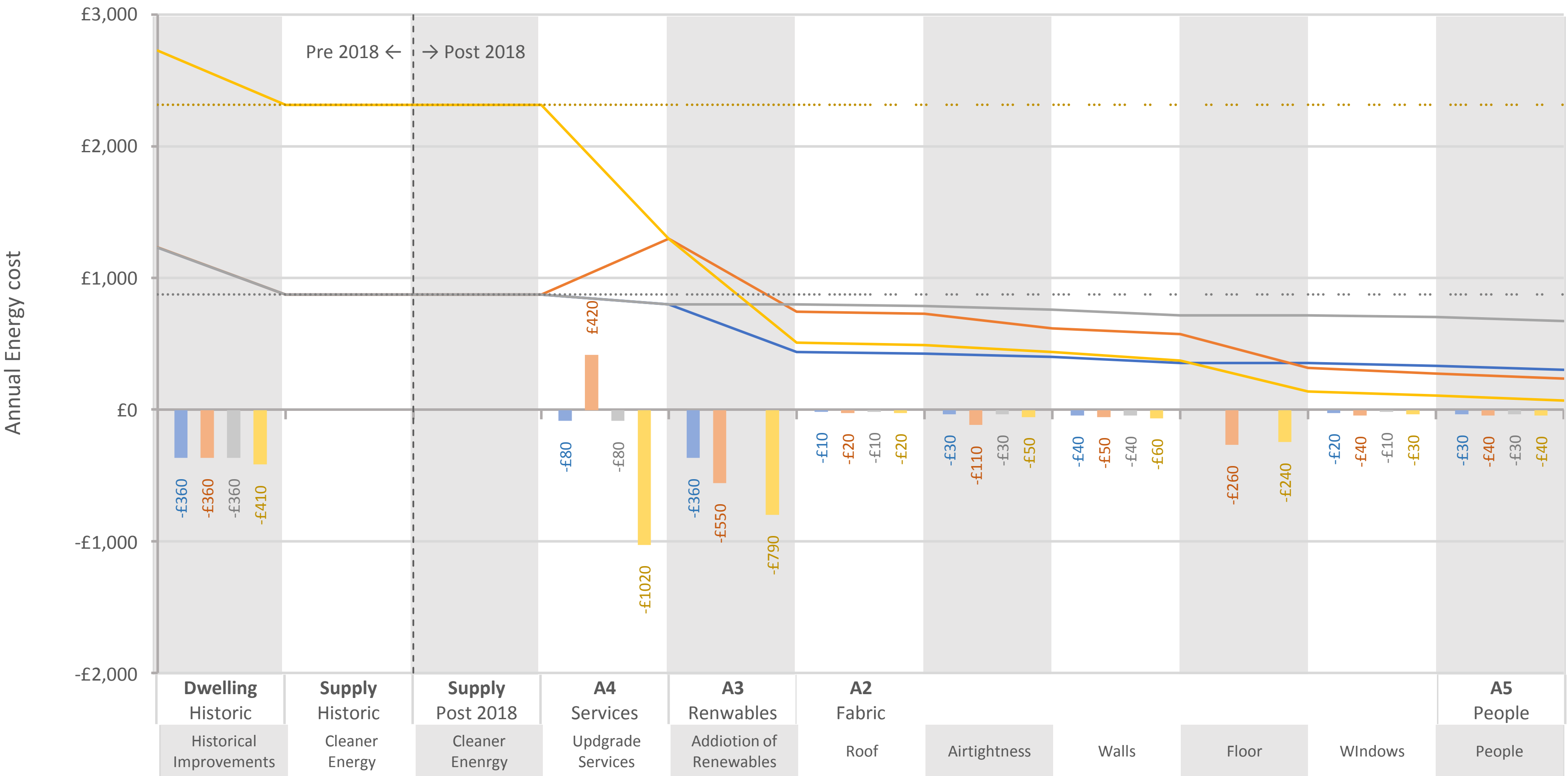
Good Practice
Best Practice
Heritage
Rural

Total reduction in annual energy cost by narrative



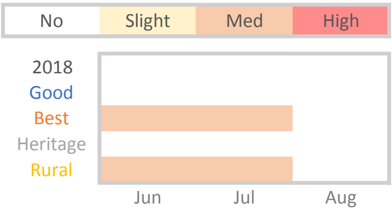
Impact on annual energy cost of four distinct retrofit narratives

Scenario 1 assumes no change in energy costs

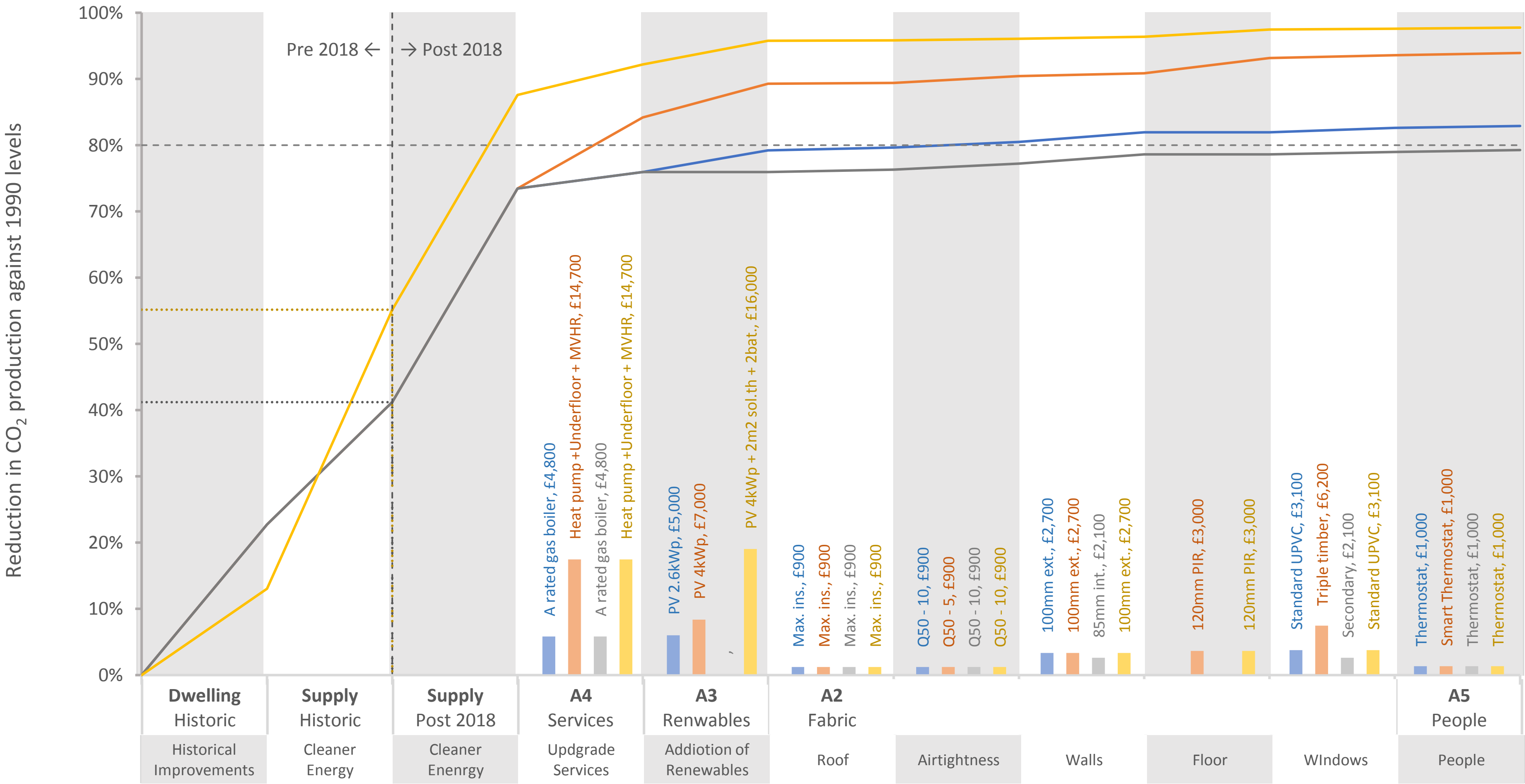


Dwelling type 7: End terrace 1965 - 1990
Scenario 2

Overheating Risk

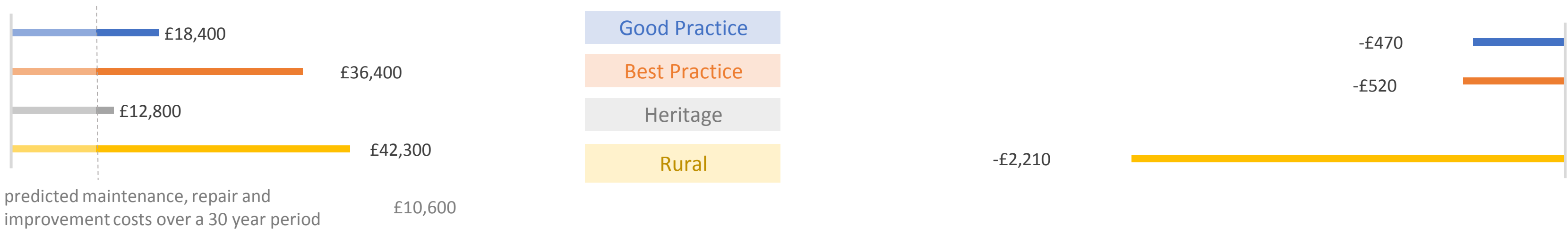


Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



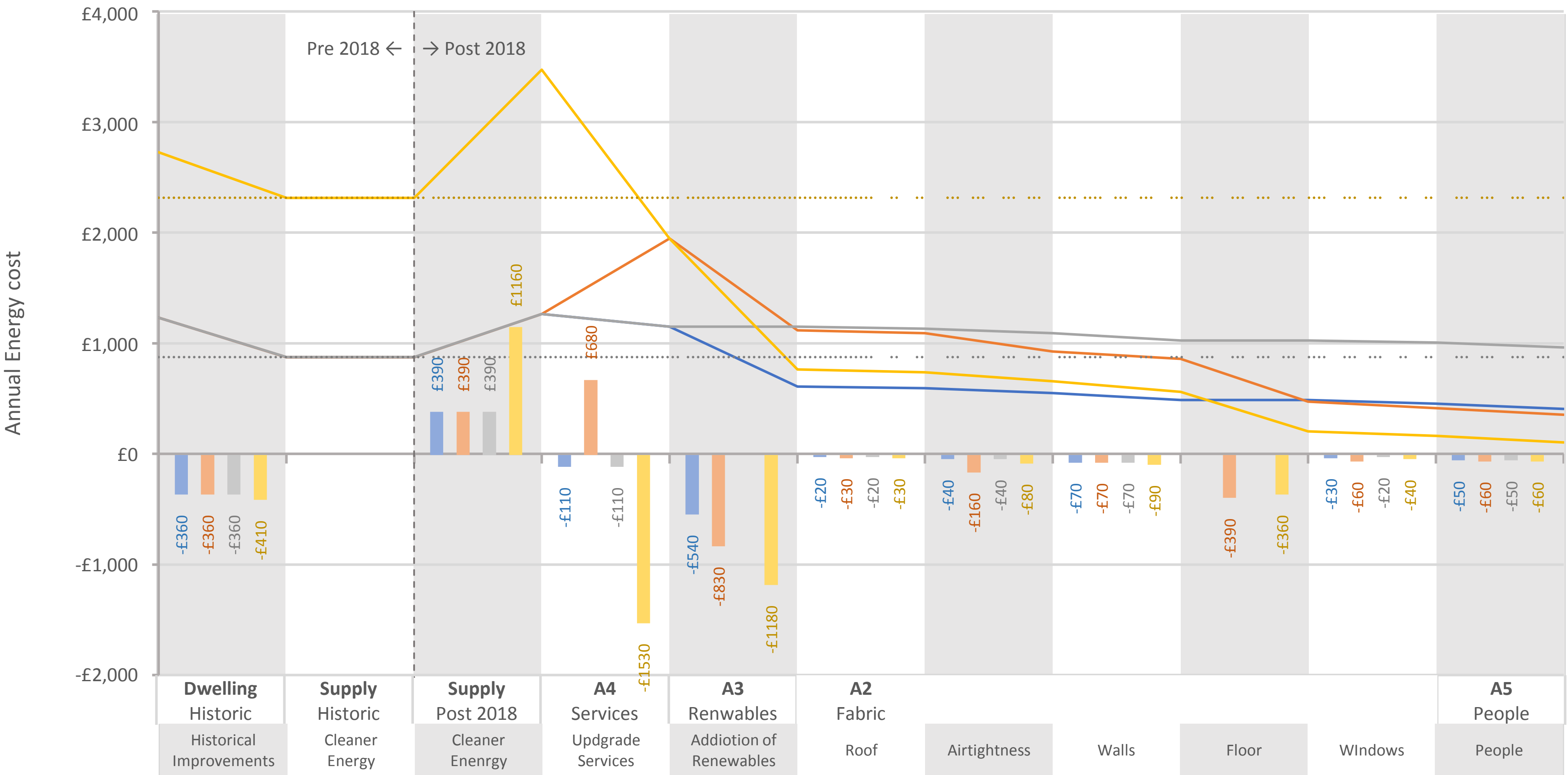
Total capital cost by narrative

Total reduction in annual energy cost by narrative



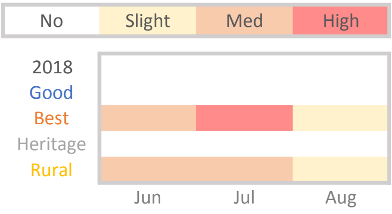
Impact on annual energy cost of four distinct retrofit narratives

Scenario 2 assumes
50% increase in energy costs

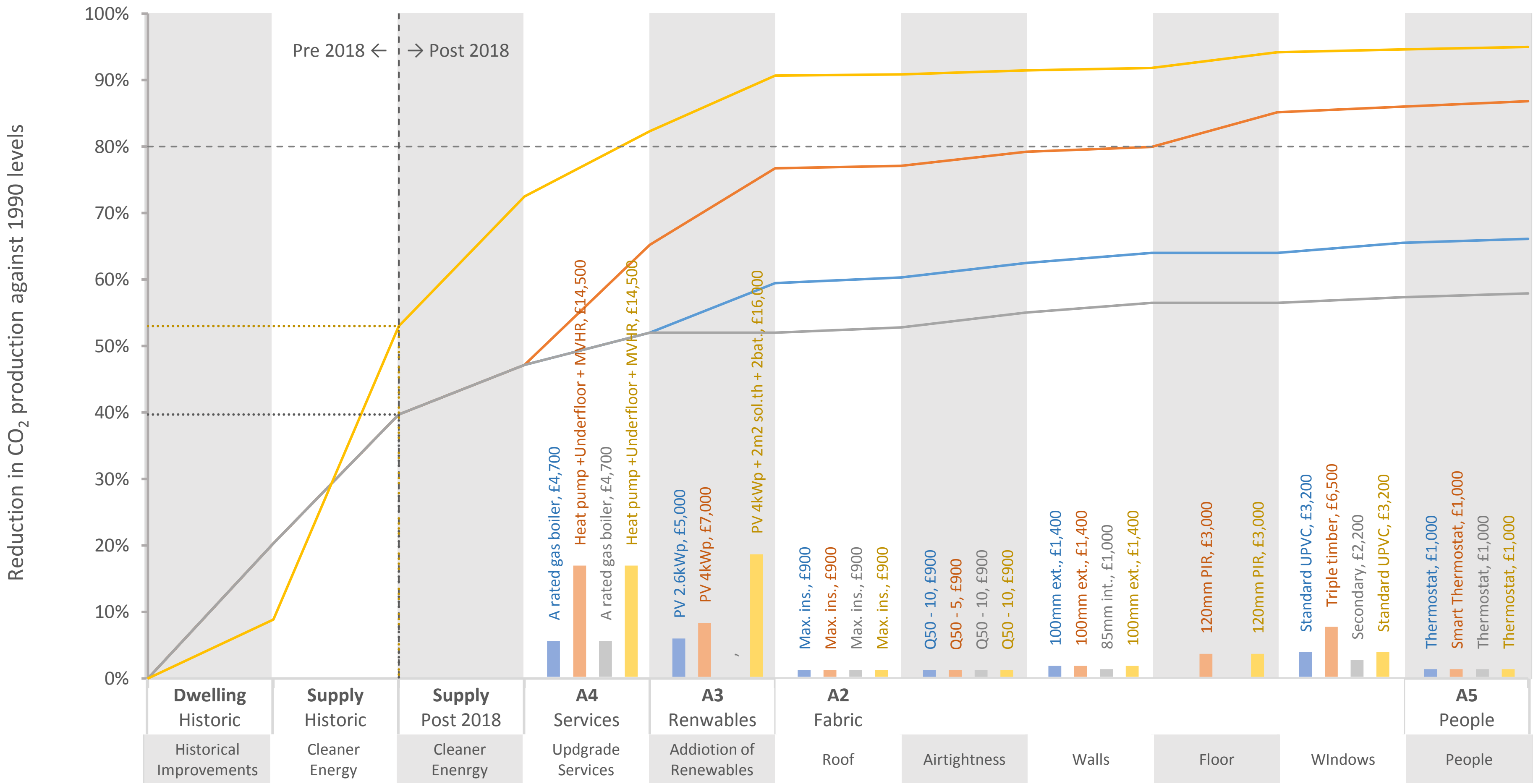


Dwelling type 8: Mid terrace 1965 - 1990
Scenario 1

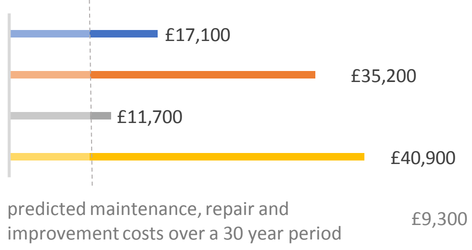
Overheating Risk



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative



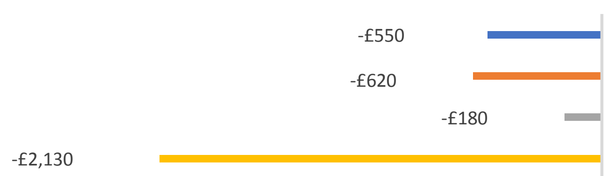
Good Practice

Best Practice

Heritage

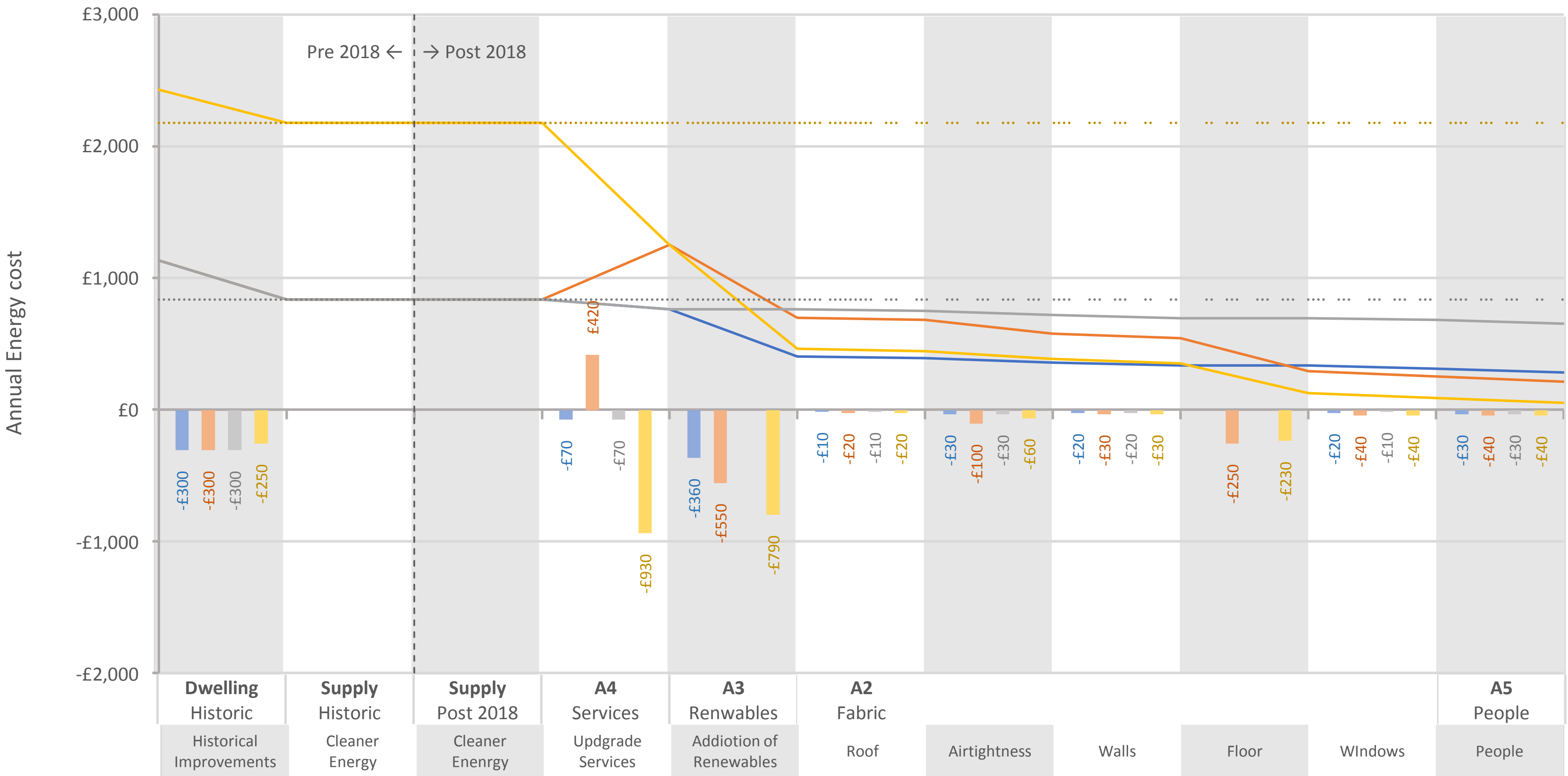
Rural

Total reduction in annual energy cost by narrative



Impact on annual energy cost of four distinct retrofit narratives

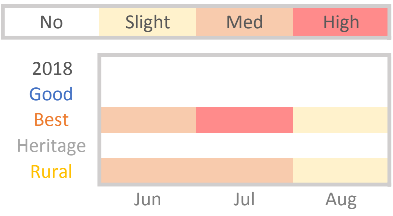
Scenario 1 assumes no change in energy costs



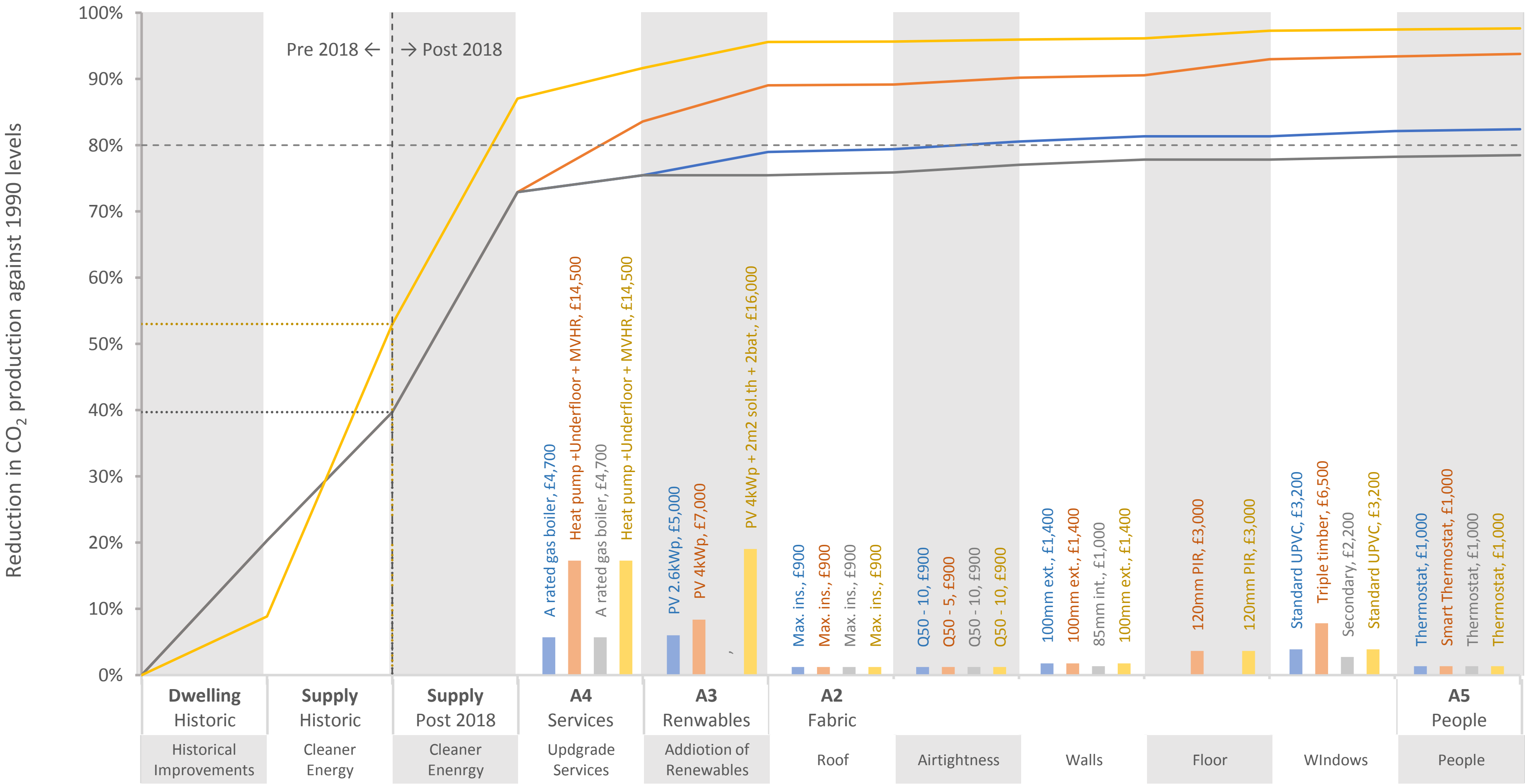
Dwelling type 8: Mid terrace 1965 - 1990

Scenario 2

Overheating Risk

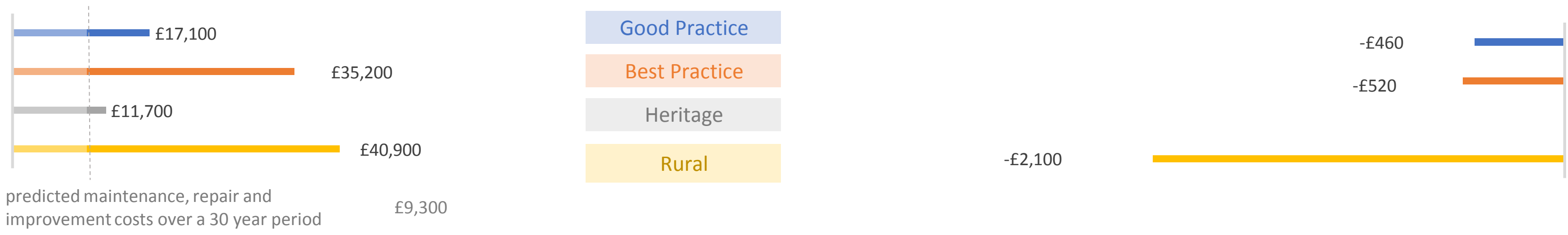


Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative

Total reduction in annual energy cost by narrative

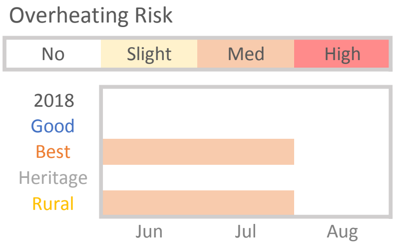


Impact on annual energy cost of four distinct retrofit narratives

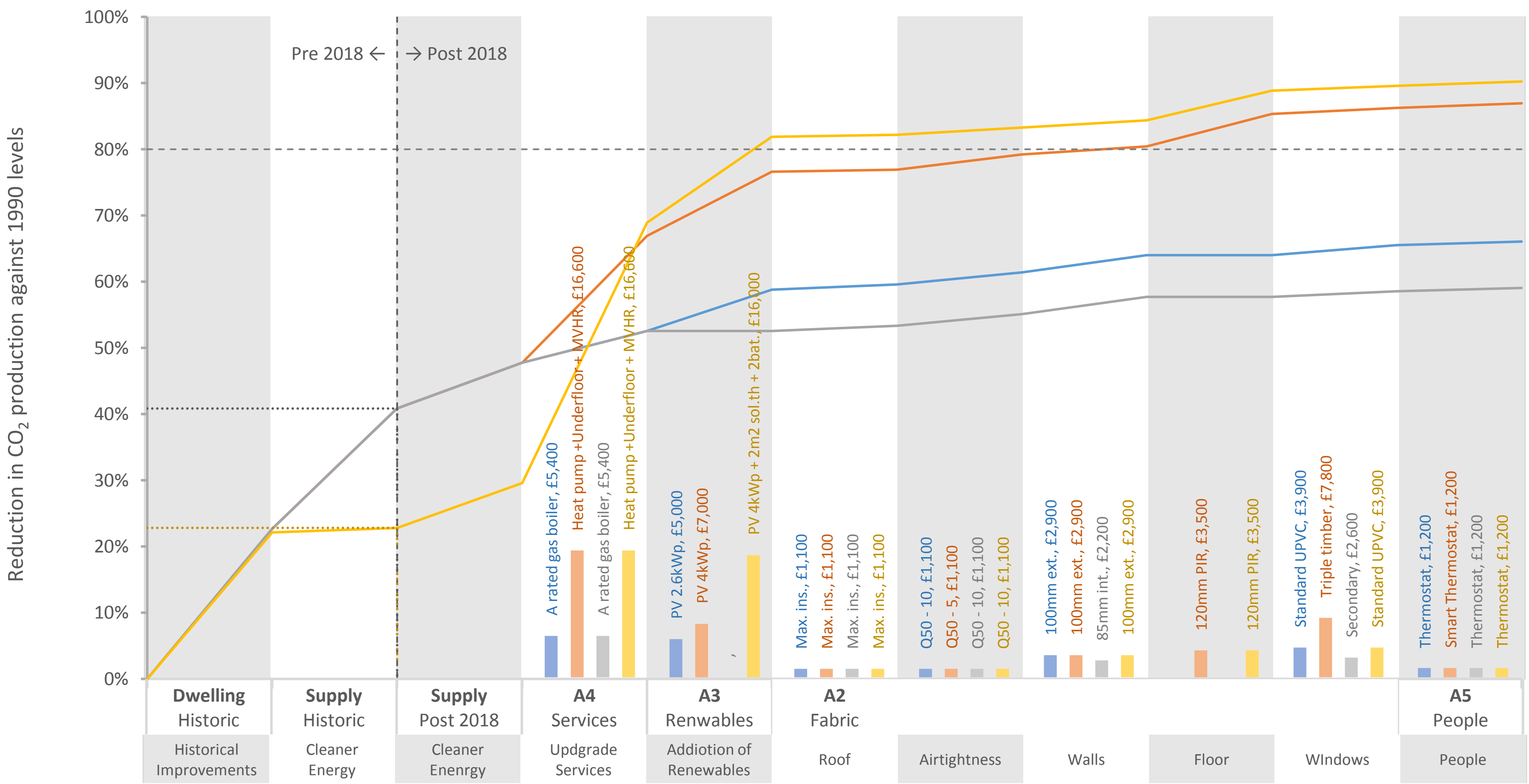
Scenario 2 assumes 50% increase in energy costs

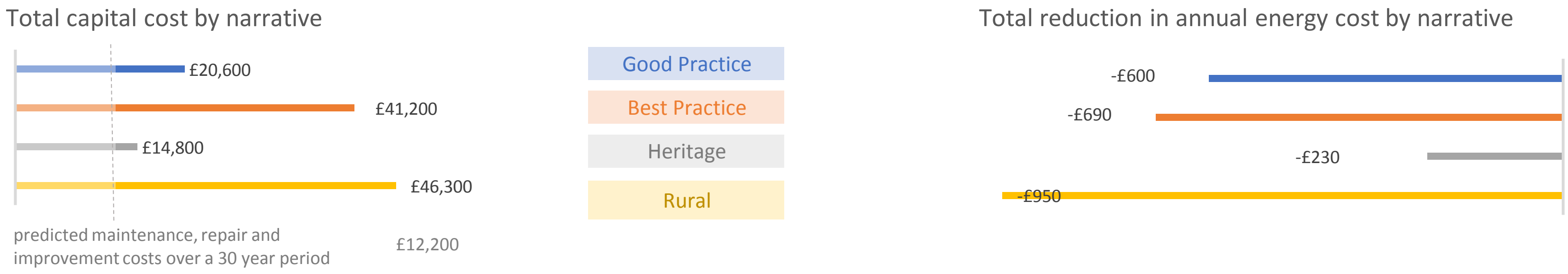
Dwelling type 9: Semi-detached 1965 - 1990

Scenario 1



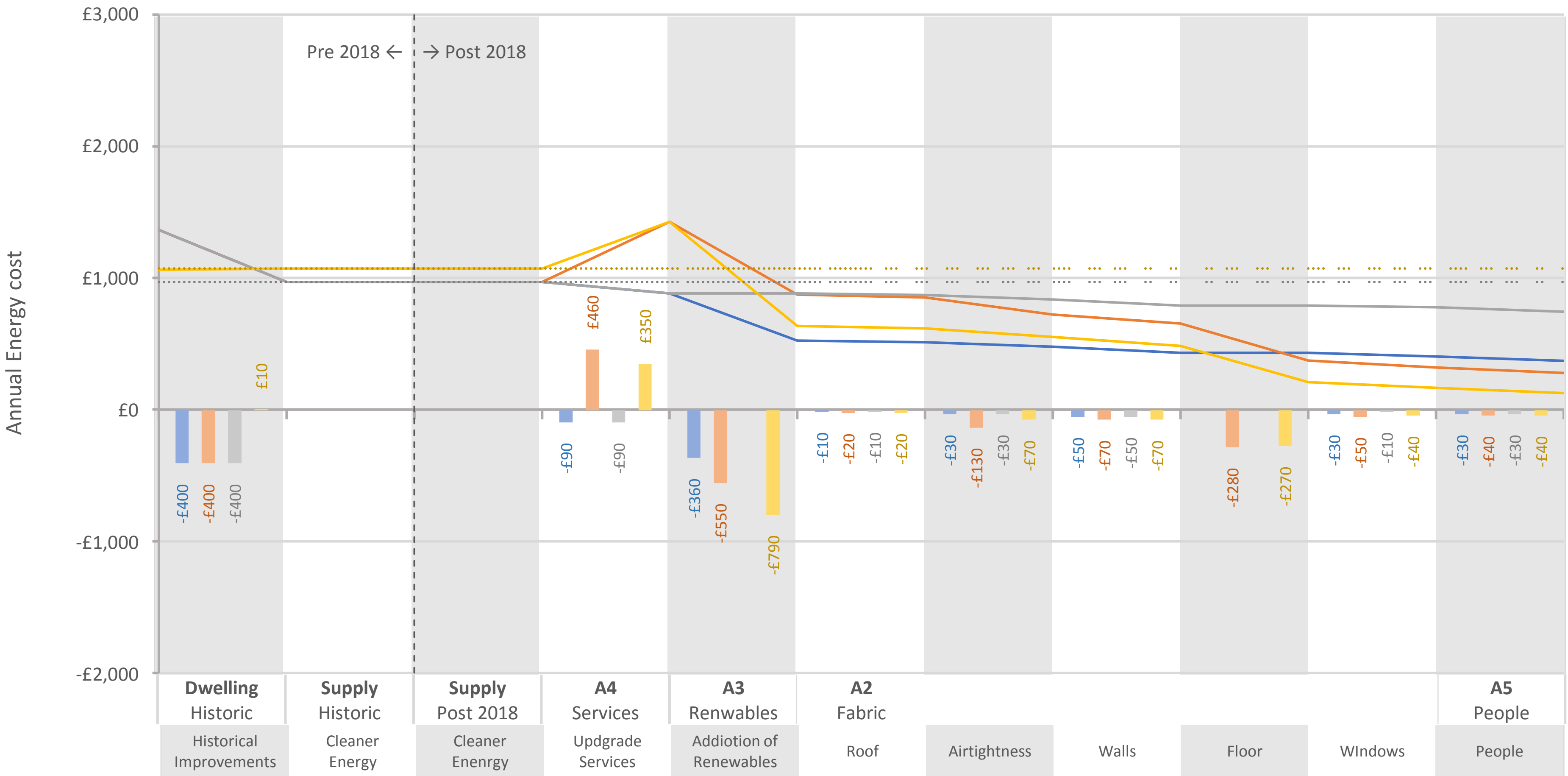
Impact on carbon emissions of four distinct retrofit narratives, each with costed actions





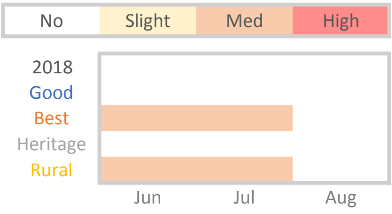
Impact on annual energy cost of four distinct retrofit narratives

Scenario 1 assumes no change in energy costs

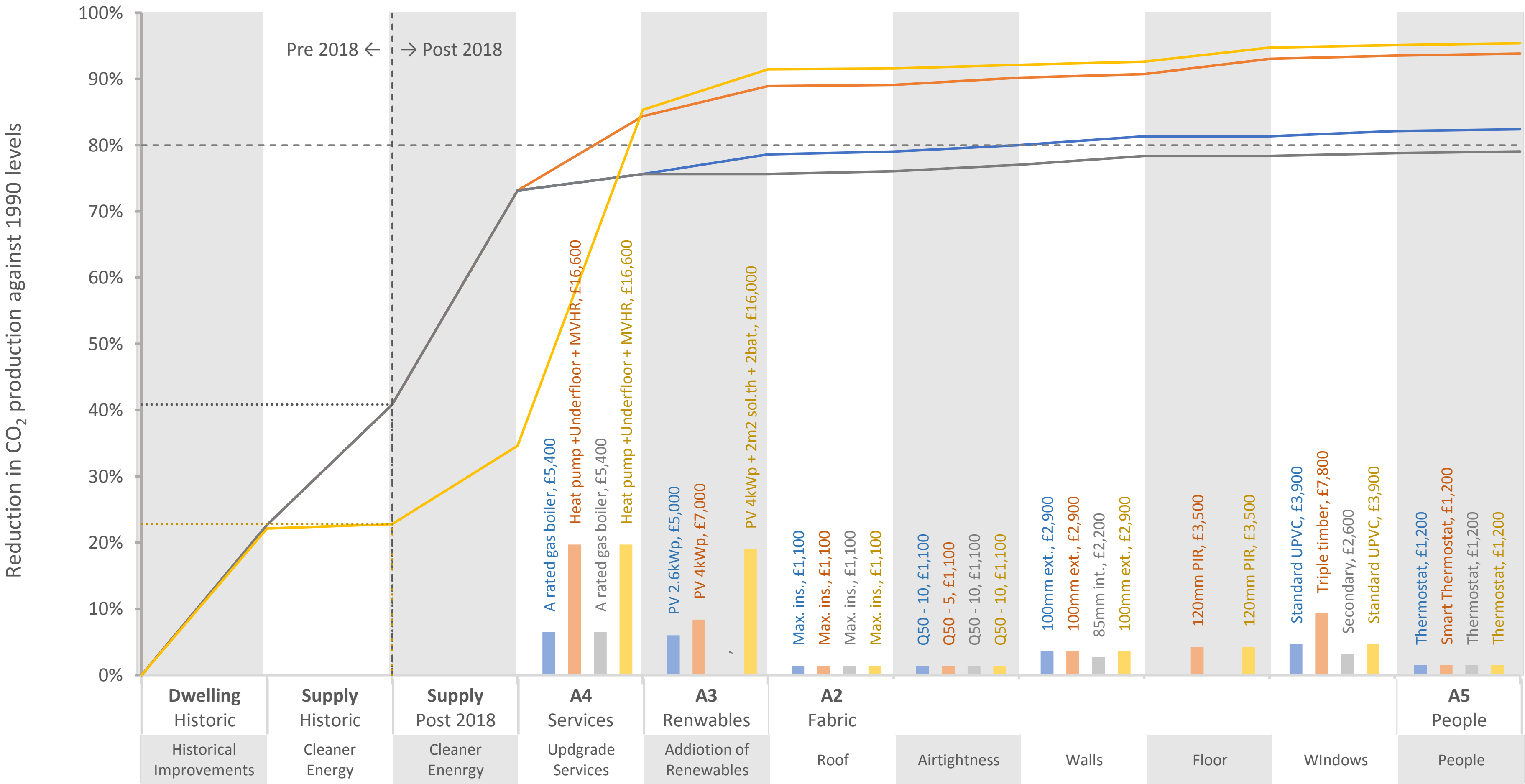


Dwelling type 9: Semi-detached 1965 - 1990
Scenario 2

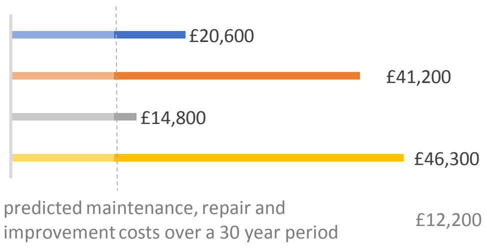
Overheating Risk



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative



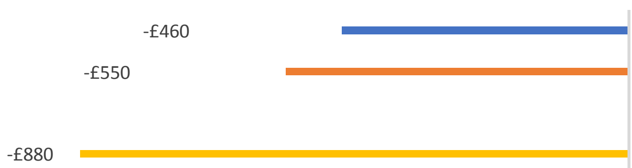
Good Practice

Best Practice

Heritage

Rural

Total reduction in annual energy cost by narrative

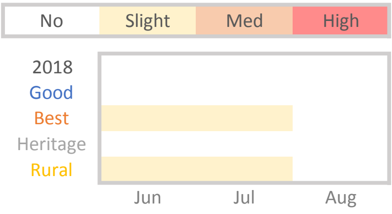


Impact on annual energy cost of four distinct retrofit narratives

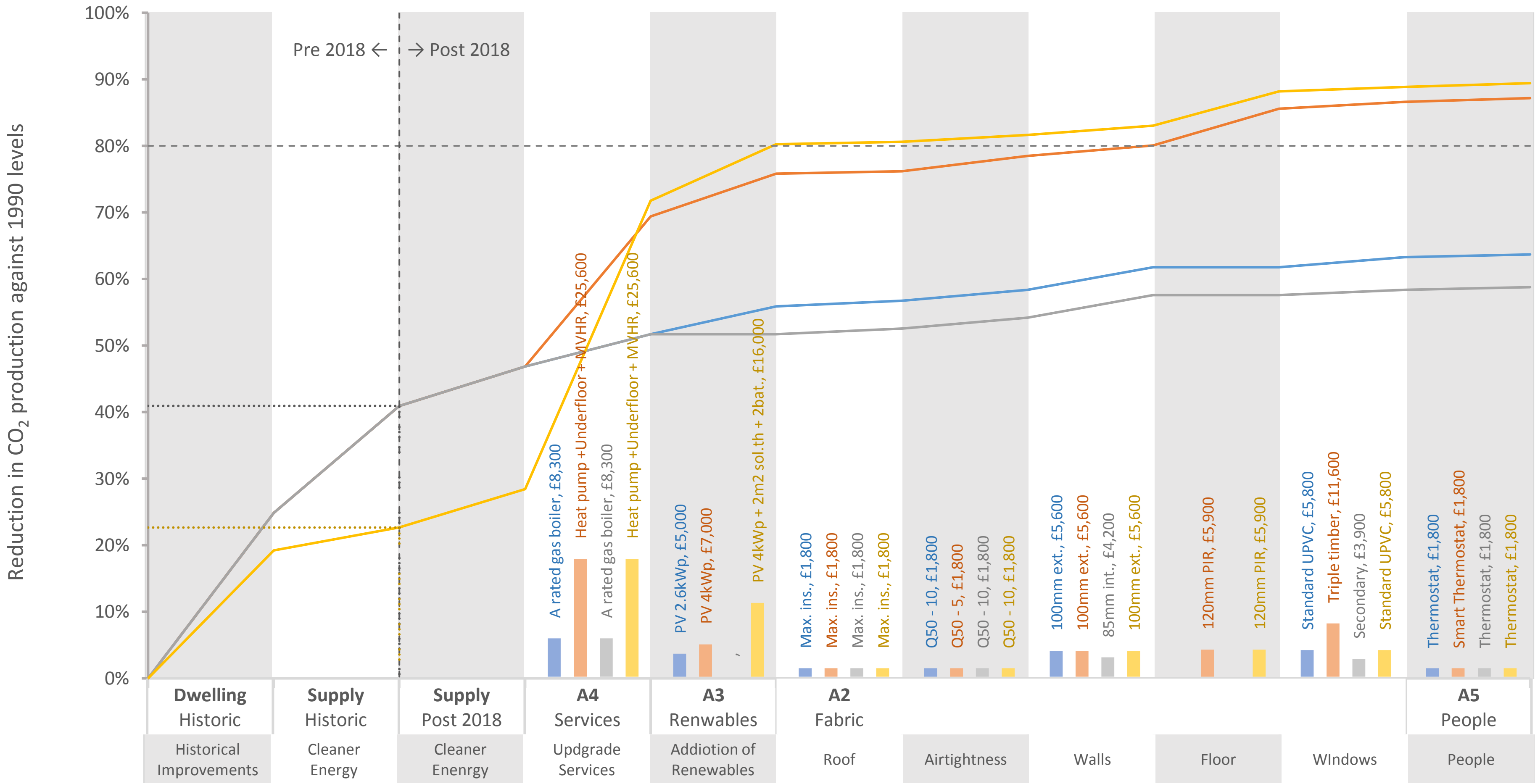
Scenario 2 assumes 50% increase in energy costs

Dwelling type 10: Detached 1965 - 1990
Scenario 1

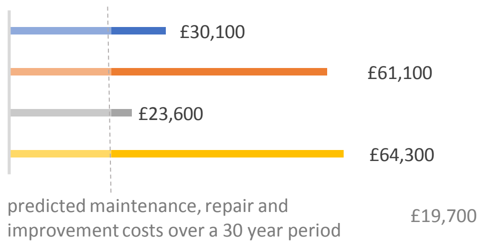
Overheating Risk



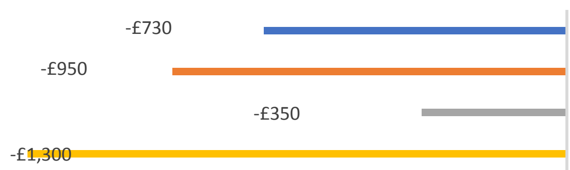
Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative

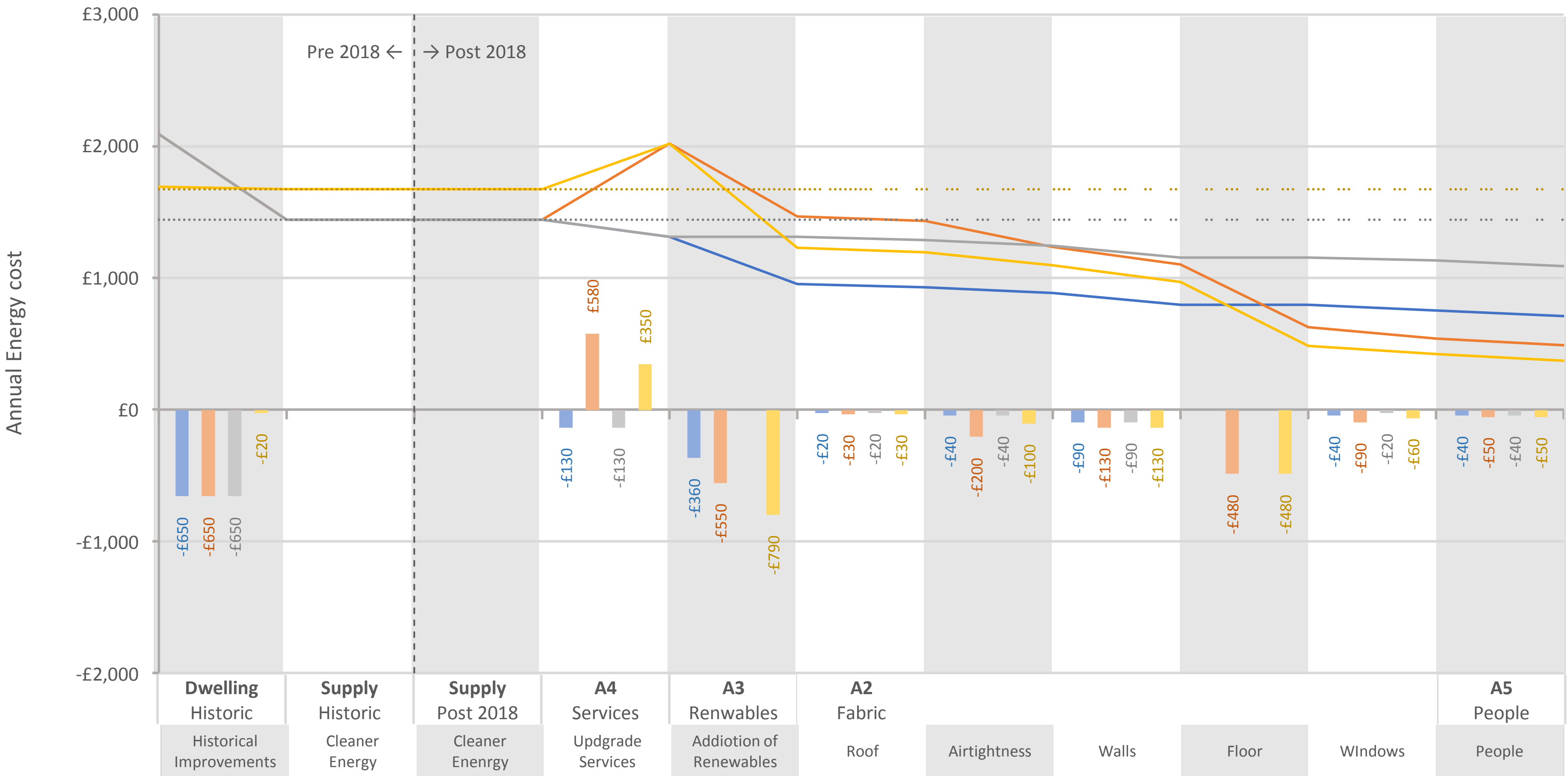


Total reduction in annual energy cost by narrative



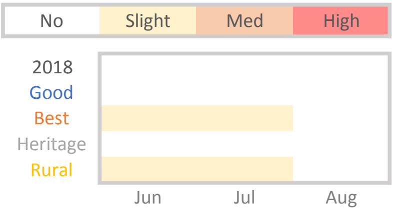
Impact on annual energy cost of four distinct retrofit narratives

Scenario 1 assumes no change in energy costs

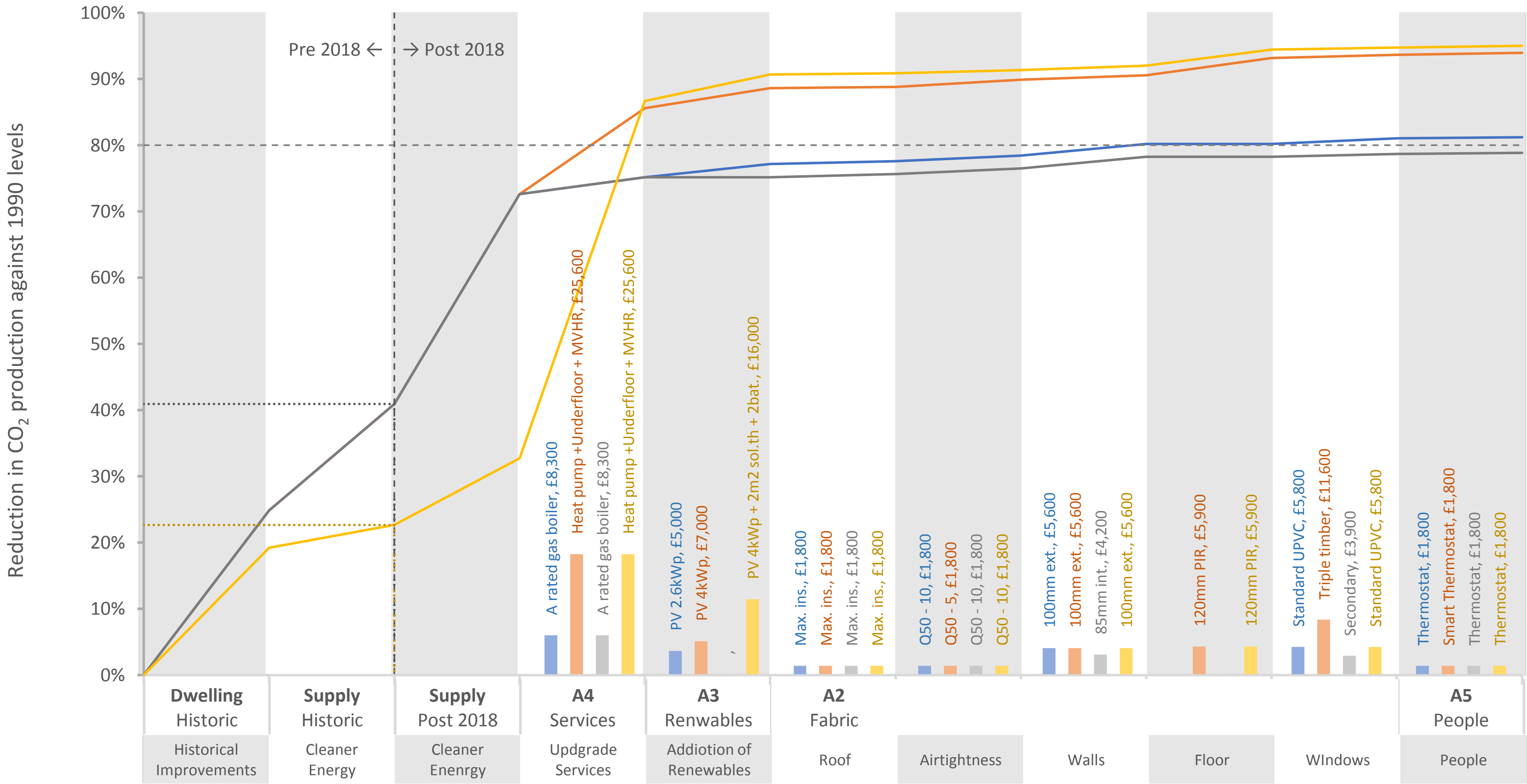


Dwelling type 10: Detached 1965 - 1990
Scenario 2

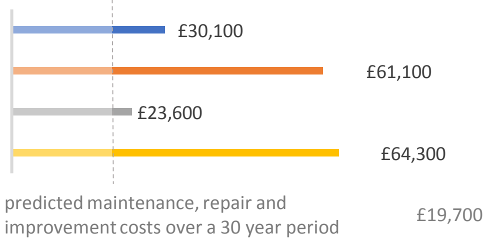
Overheating Risk



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative



Good Practice

Best Practice

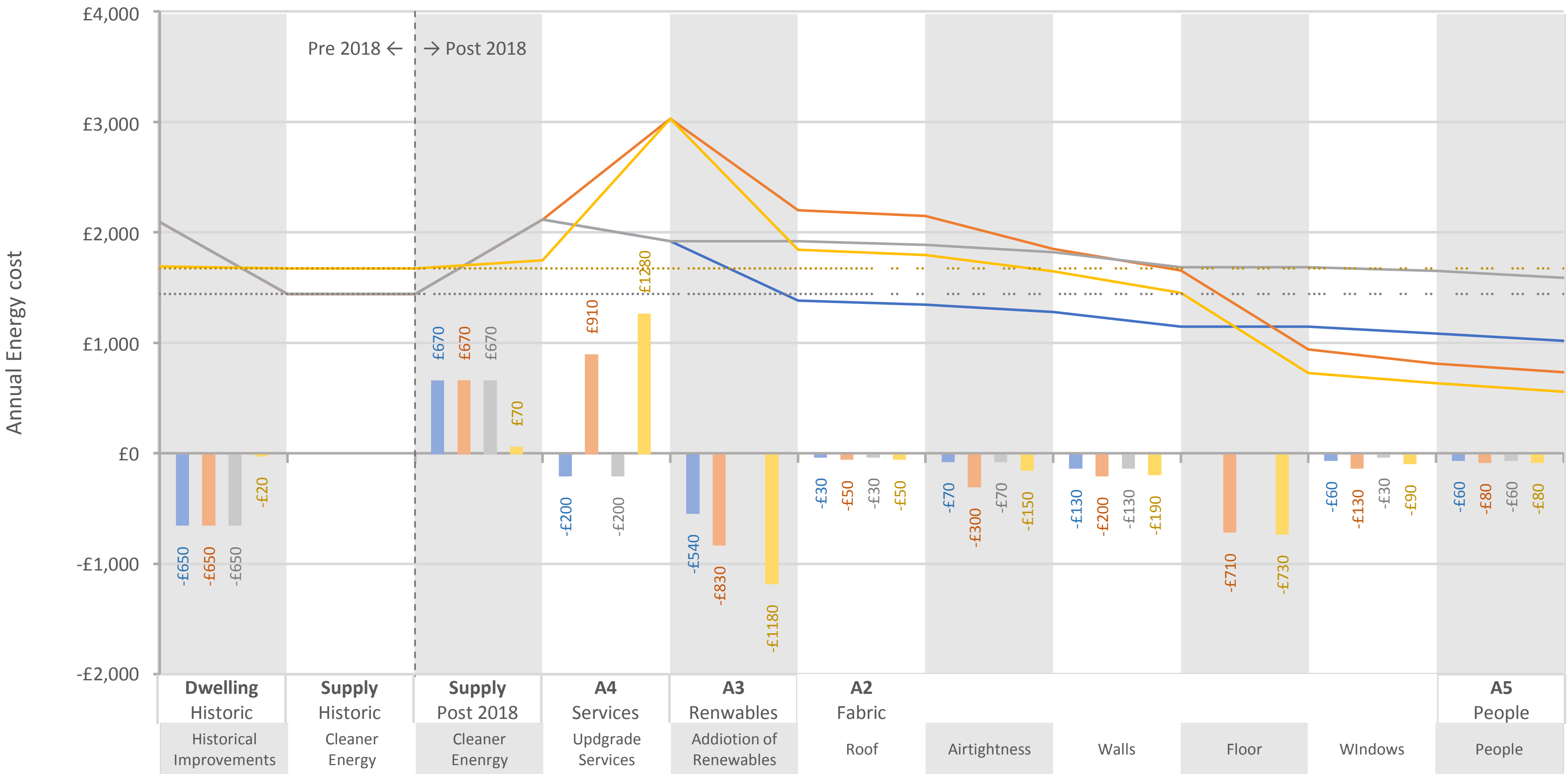
Heritage

Rural

Total reduction in annual energy cost by narrative

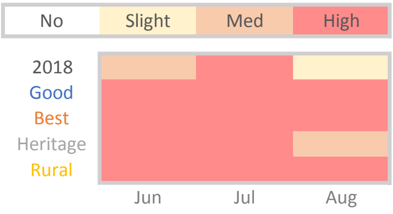
Impact on annual energy cost of four distinct retrofit narratives

Scenario 2 assumes
50% increase in energy costs

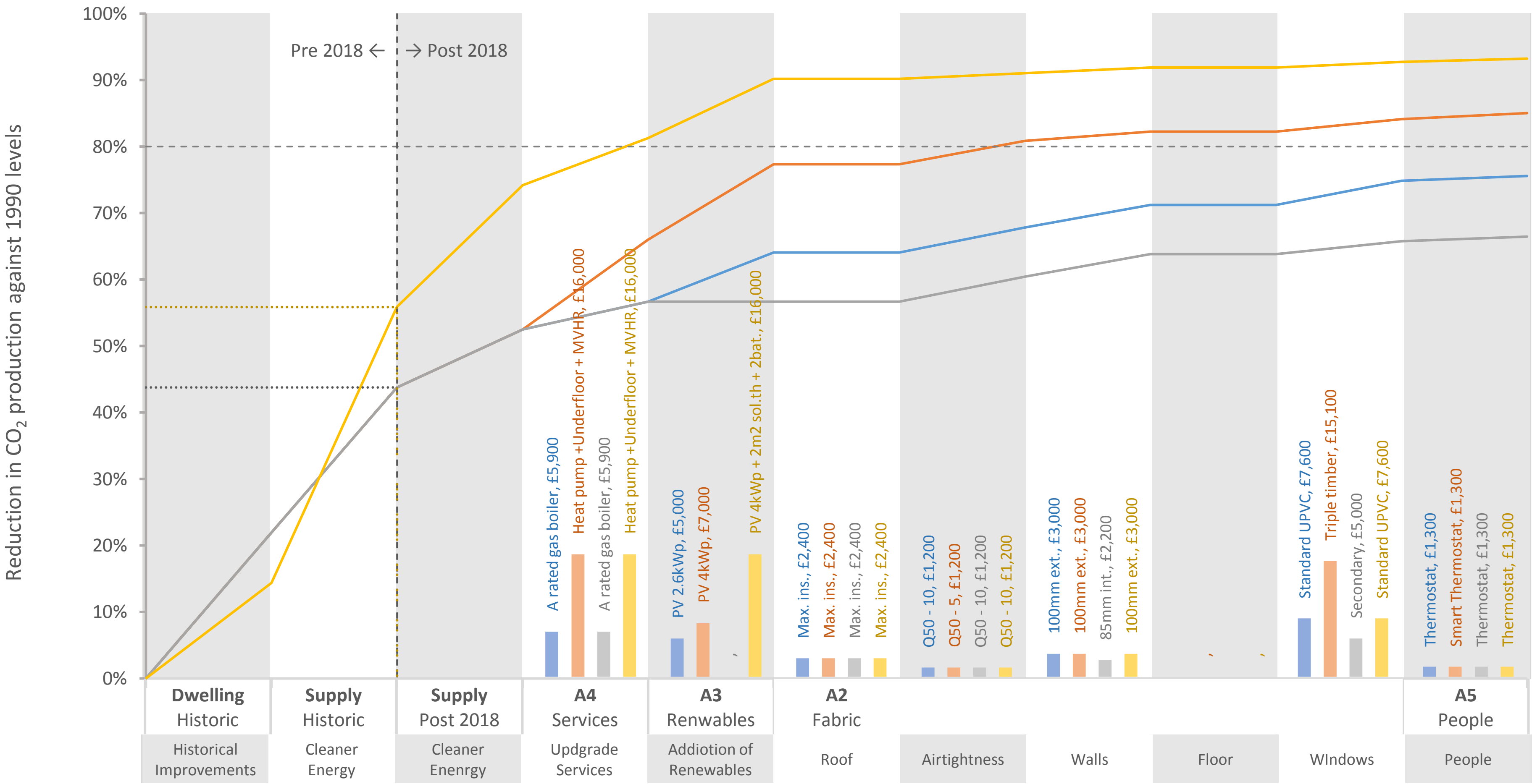


Dwelling type 11: Flat 1965 - 1990
Scenario 1

Overheating Risk



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions

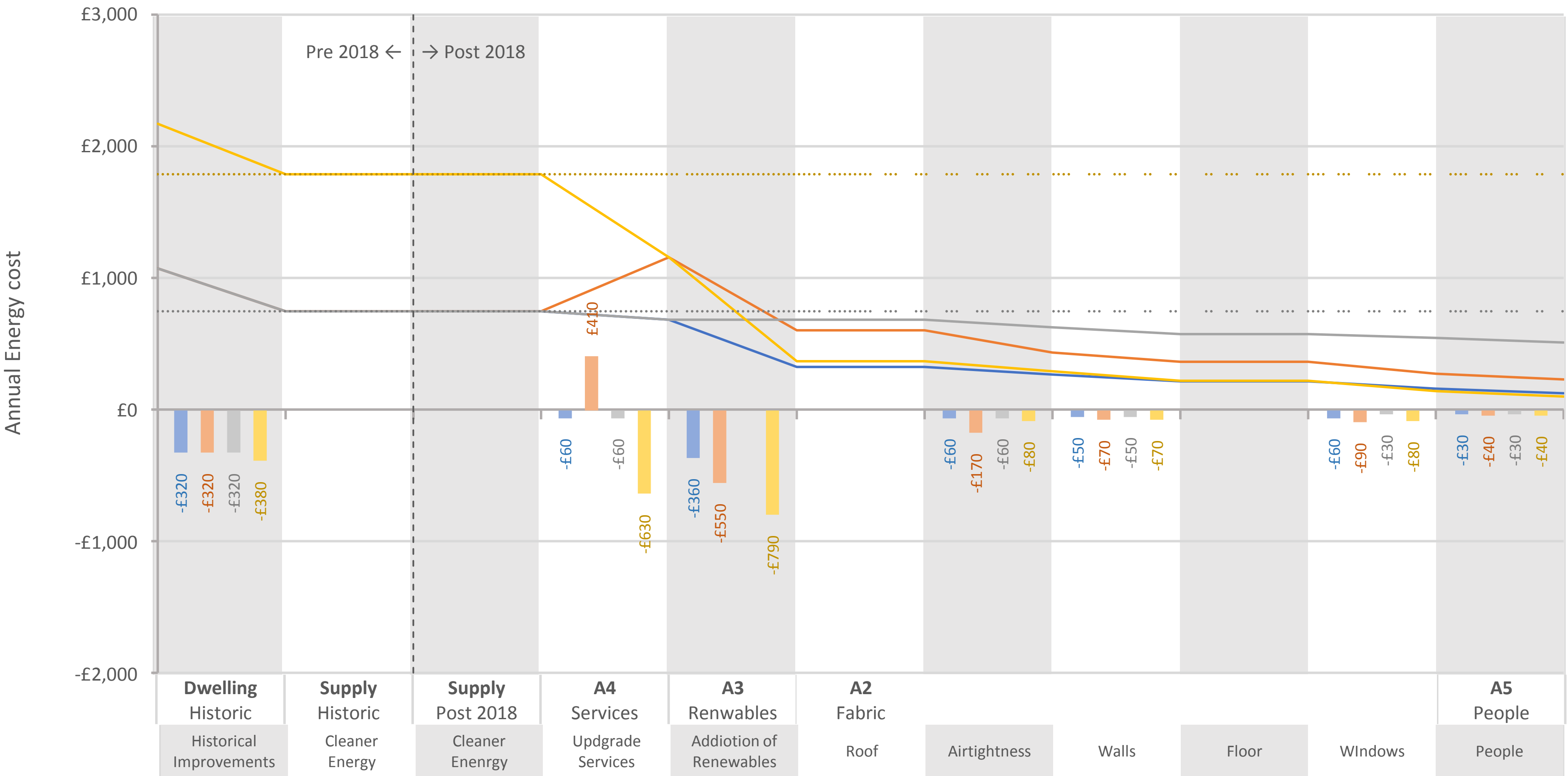


Total capital cost by narrative

Total reduction in annual energy cost by narrative

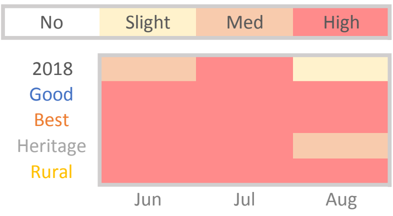
Impact on annual energy cost of four distinct retrofit narratives

Scenario 1 assumes
no change in energy costs

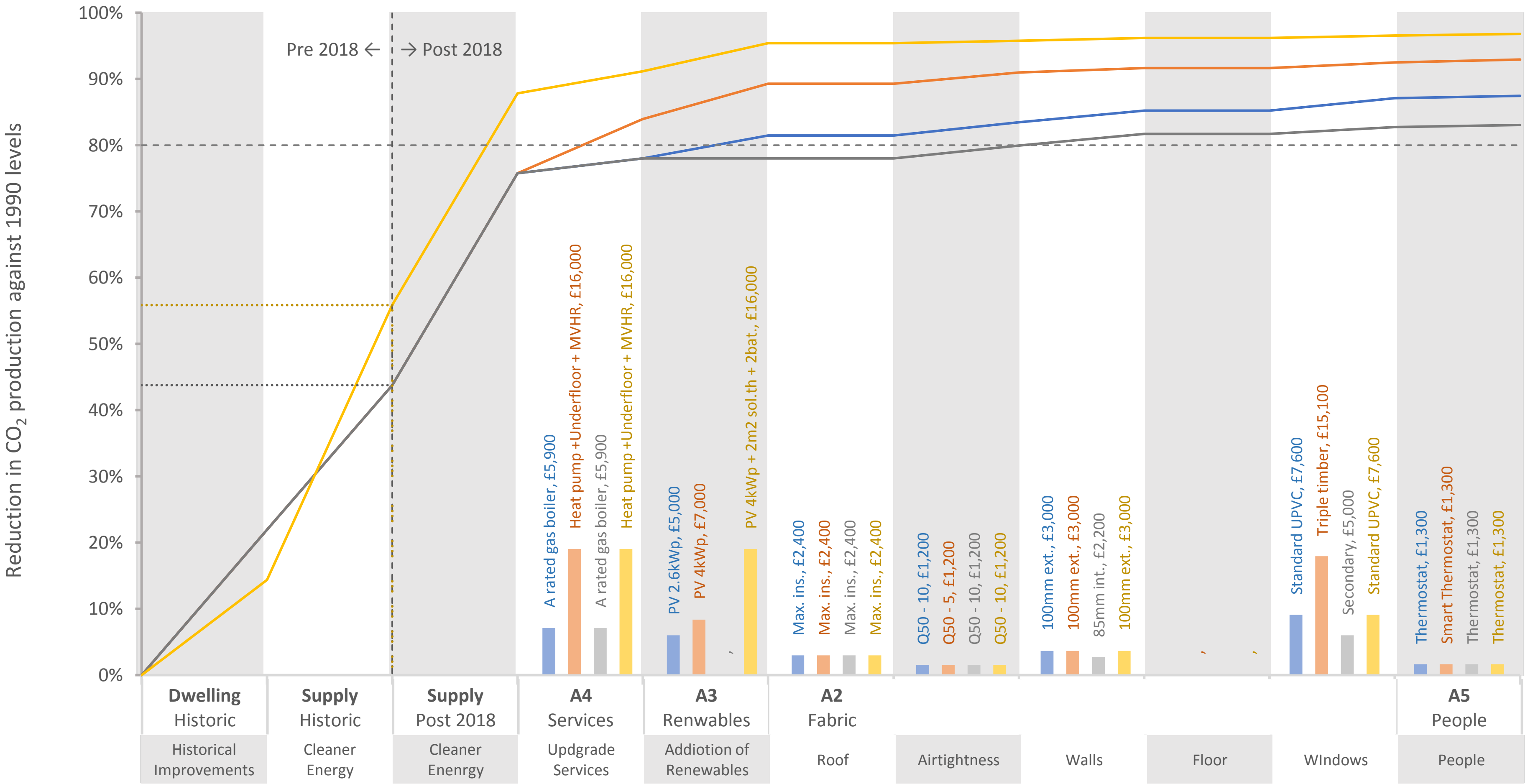


Dwelling type 11: Flat 1965 - 1990
Scenario 2

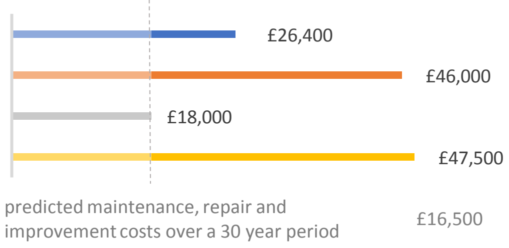
Overheating Risk



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative



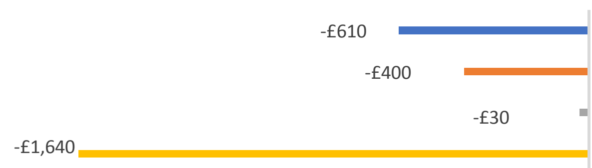
Good Practice

Best Practice

Heritage

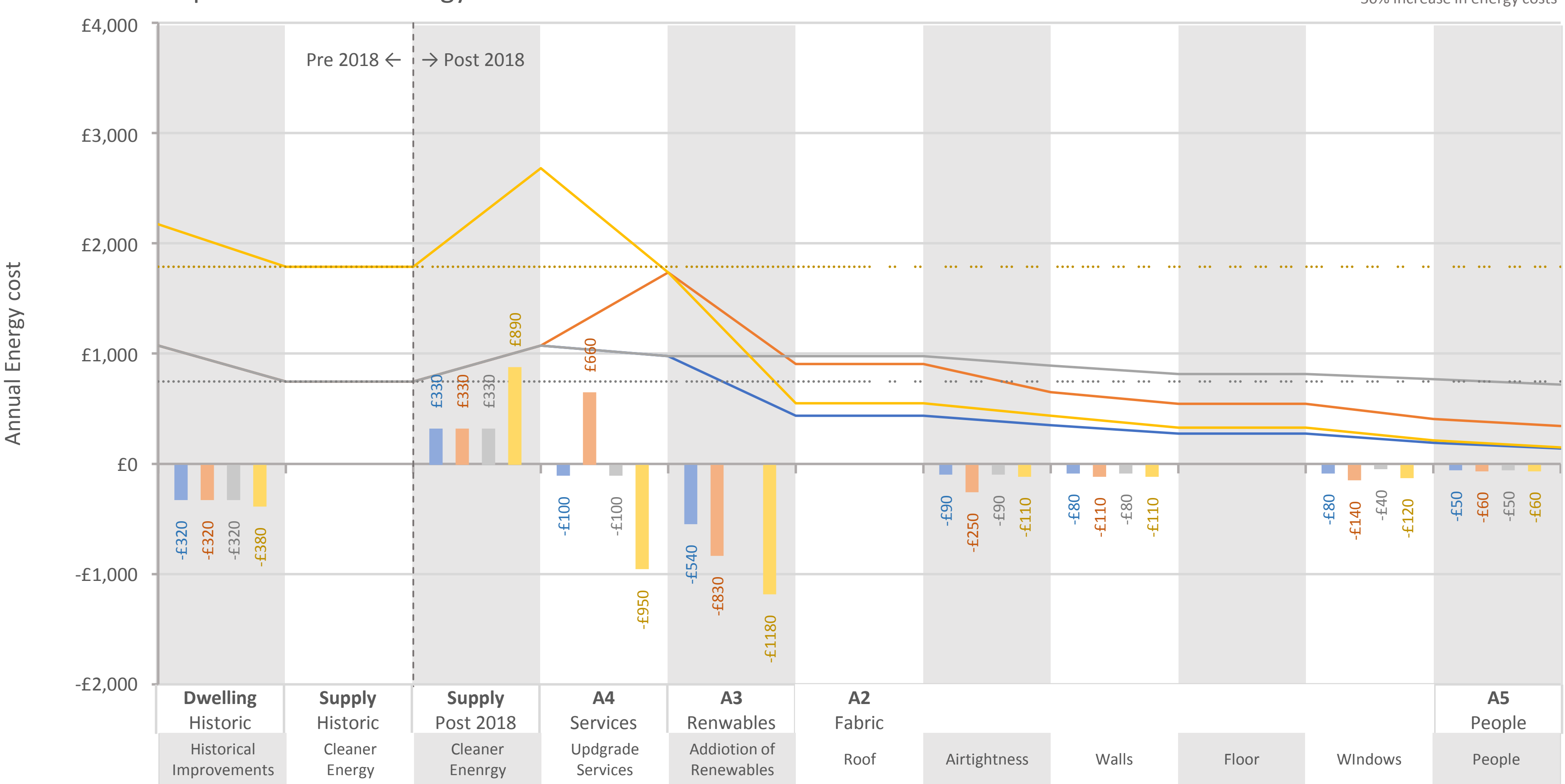
Rural

Total reduction in annual energy cost by narrative

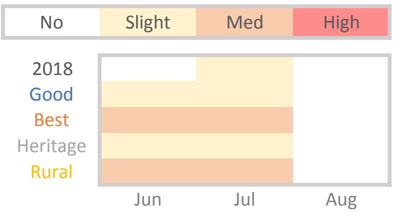


Impact on annual energy cost of four distinct retrofit narratives

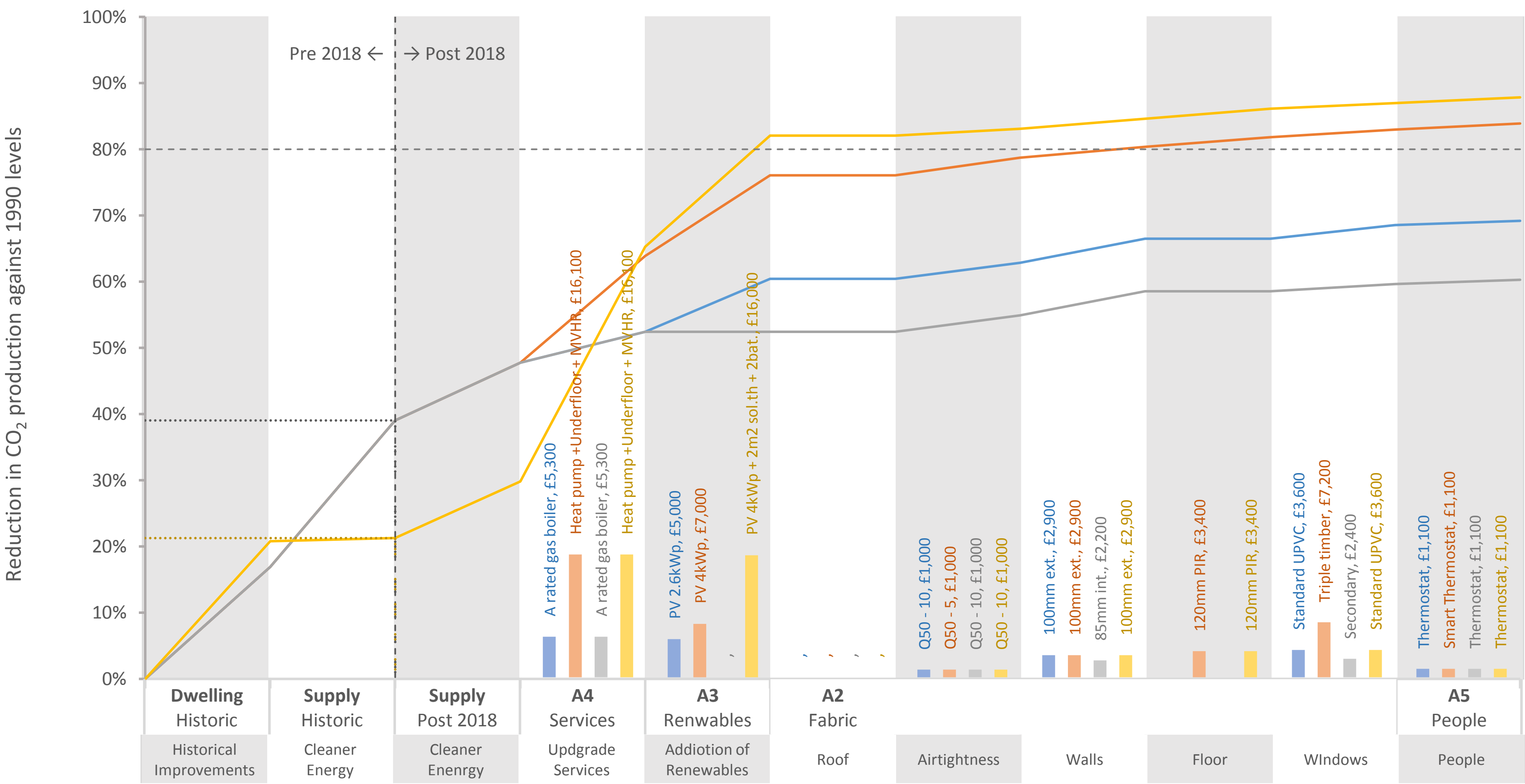
Scenario 2 assumes
50% increase in energy costs



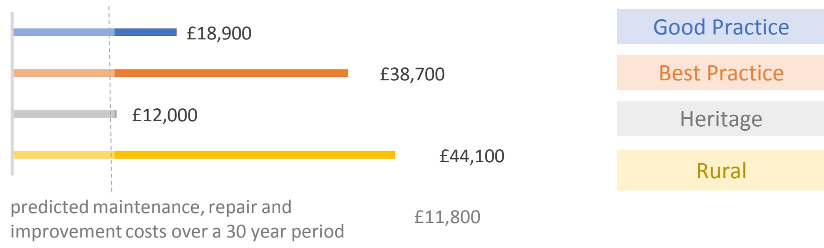
Dwelling type 12: Semi-detached post 1990
Scenario 1



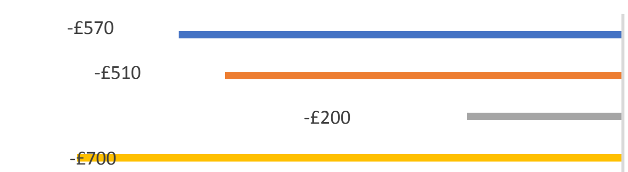
Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative

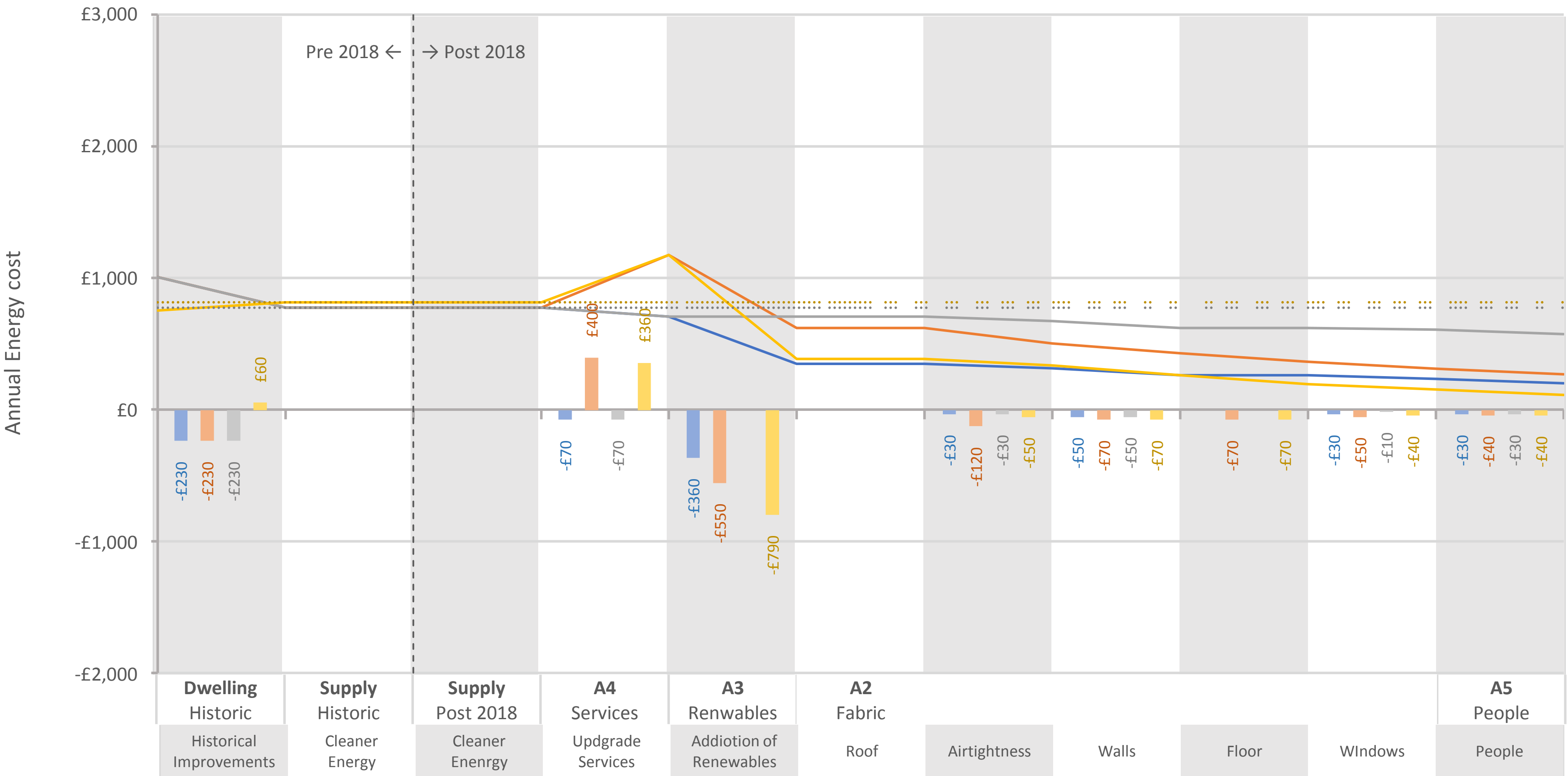


Total reduction in annual energy cost by narrative



Impact on annual energy cost of four distinct retrofit narratives

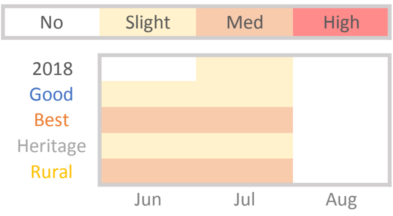
Scenario 1 assumes
no change in energy costs



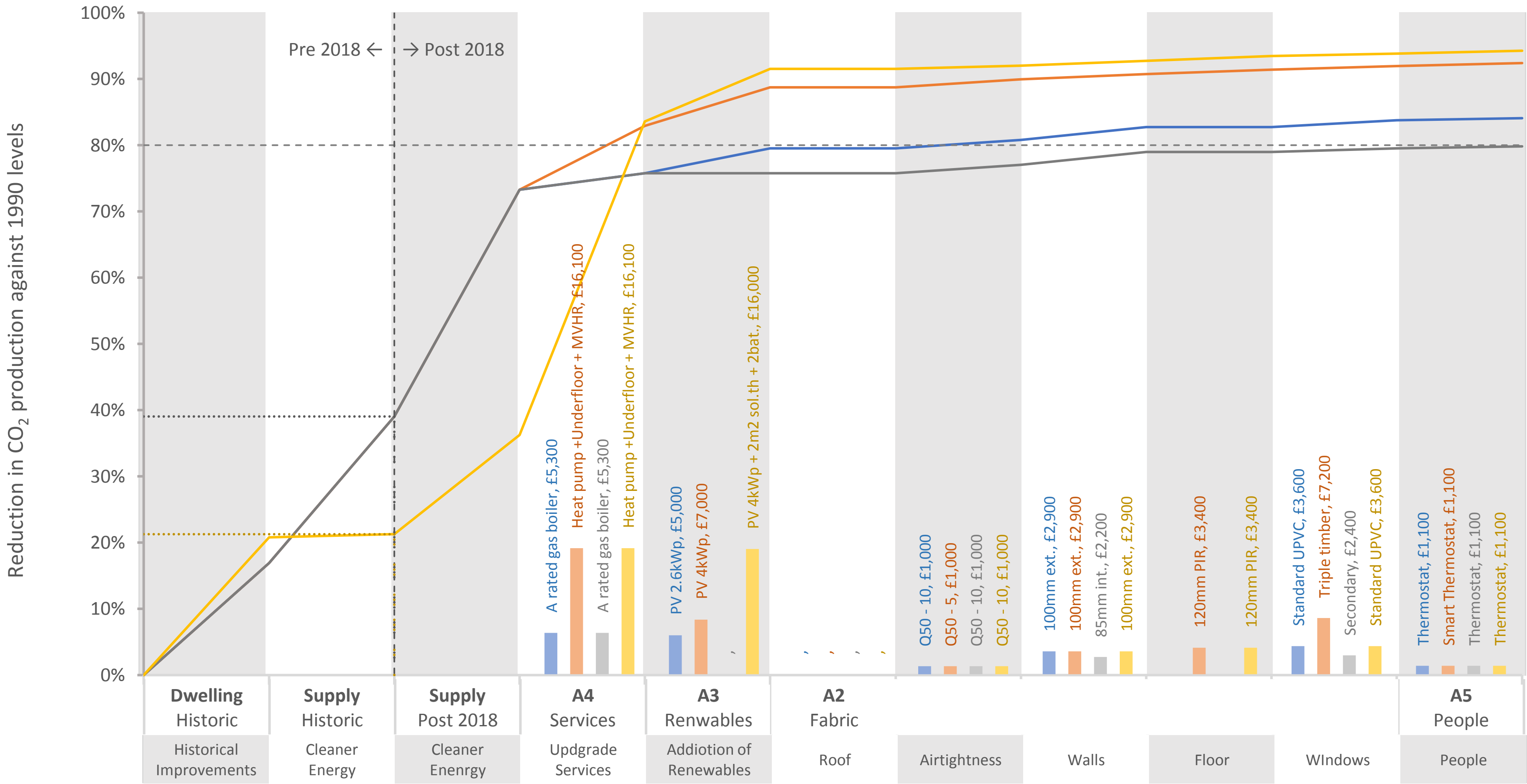
Dwelling type 12: Semi-detached post 1990

Scenario 2

Overheating Risk

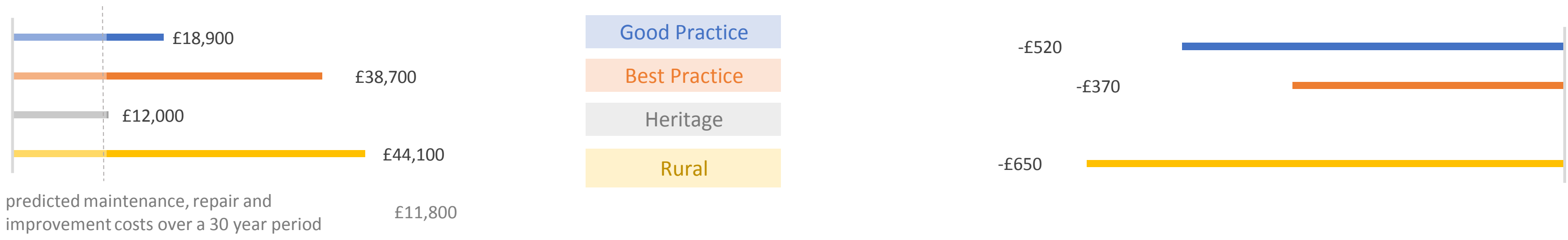


Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



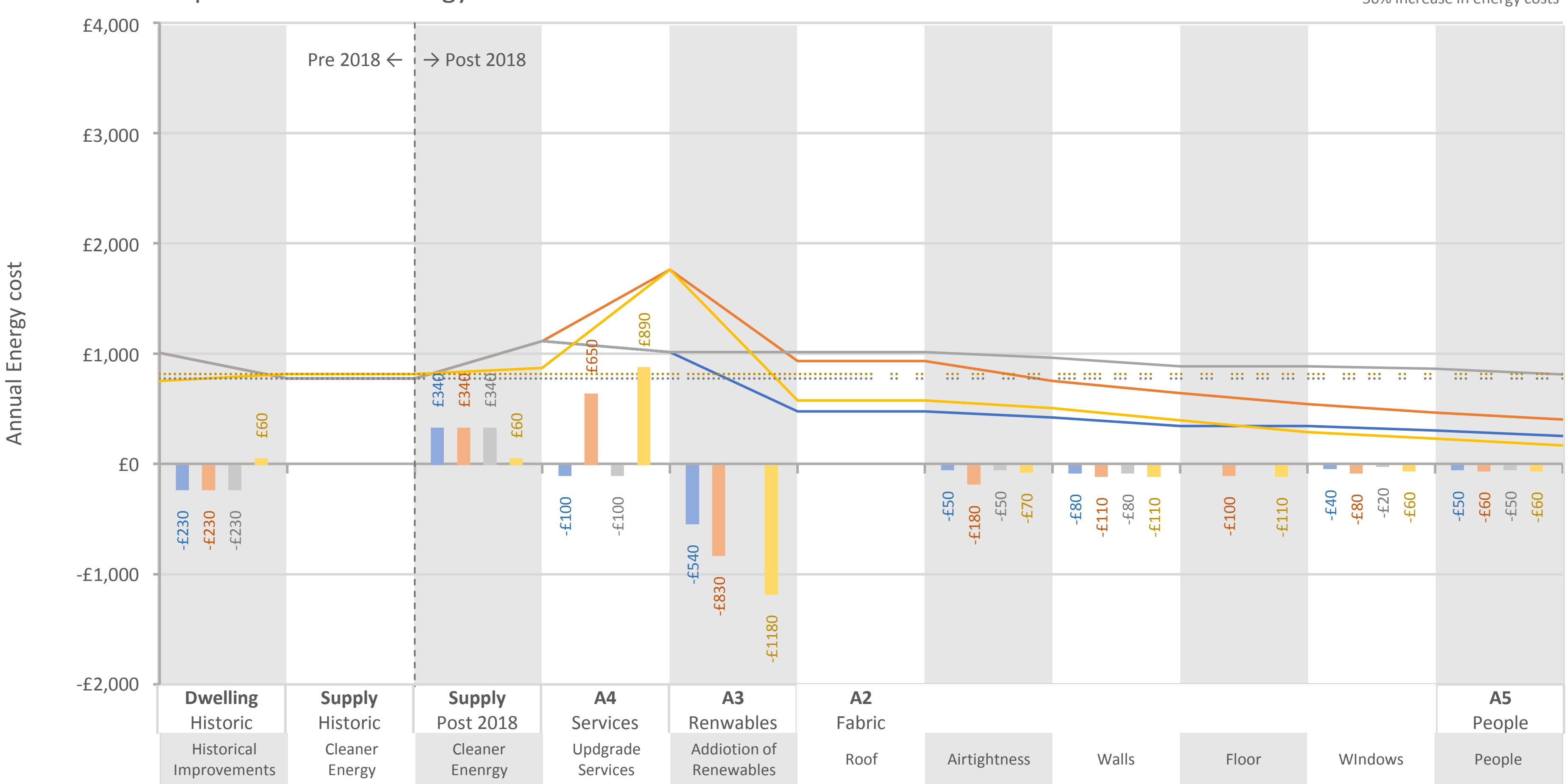
Total capital cost by narrative

Total reduction in annual energy cost by narrative

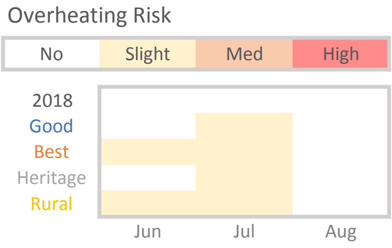


Impact on annual energy cost of four distinct retrofit narratives

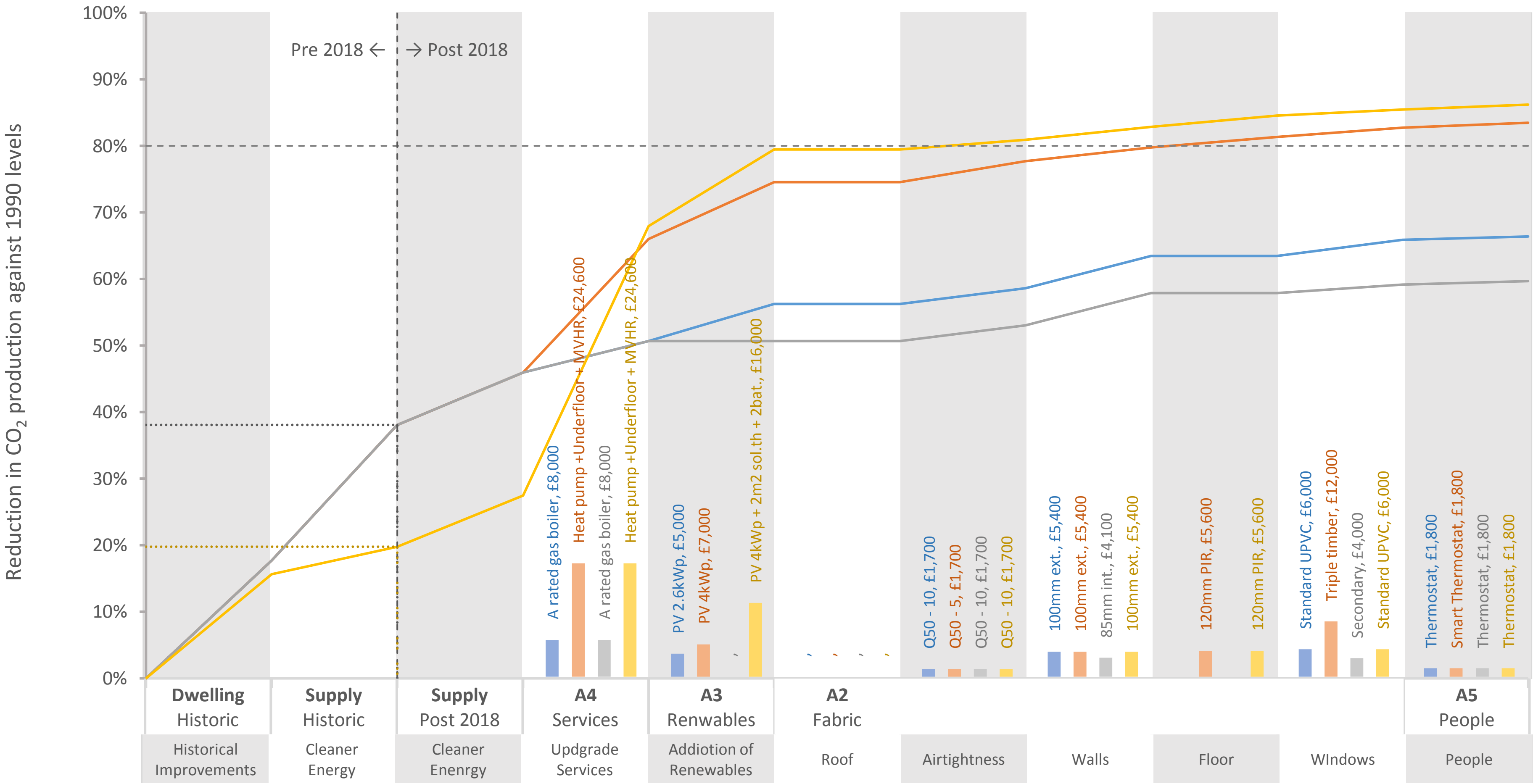
Scenario 2 assumes
50% increase in energy costs

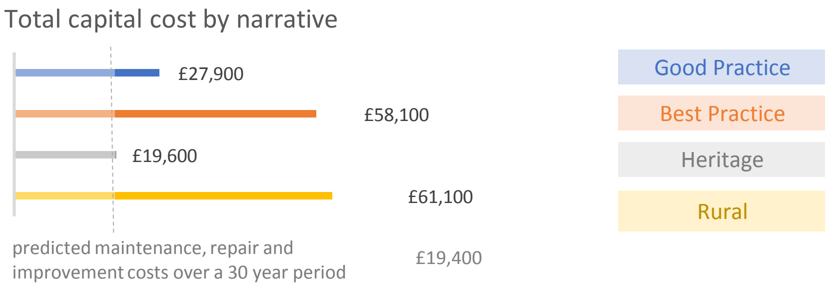


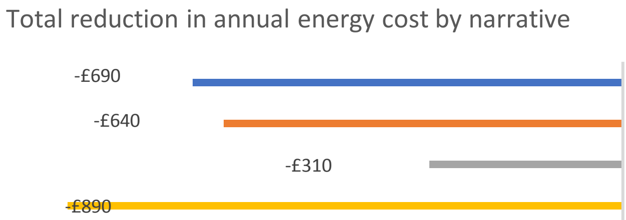
Dwelling type 13: Detached post 1990
Scenario 1



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions

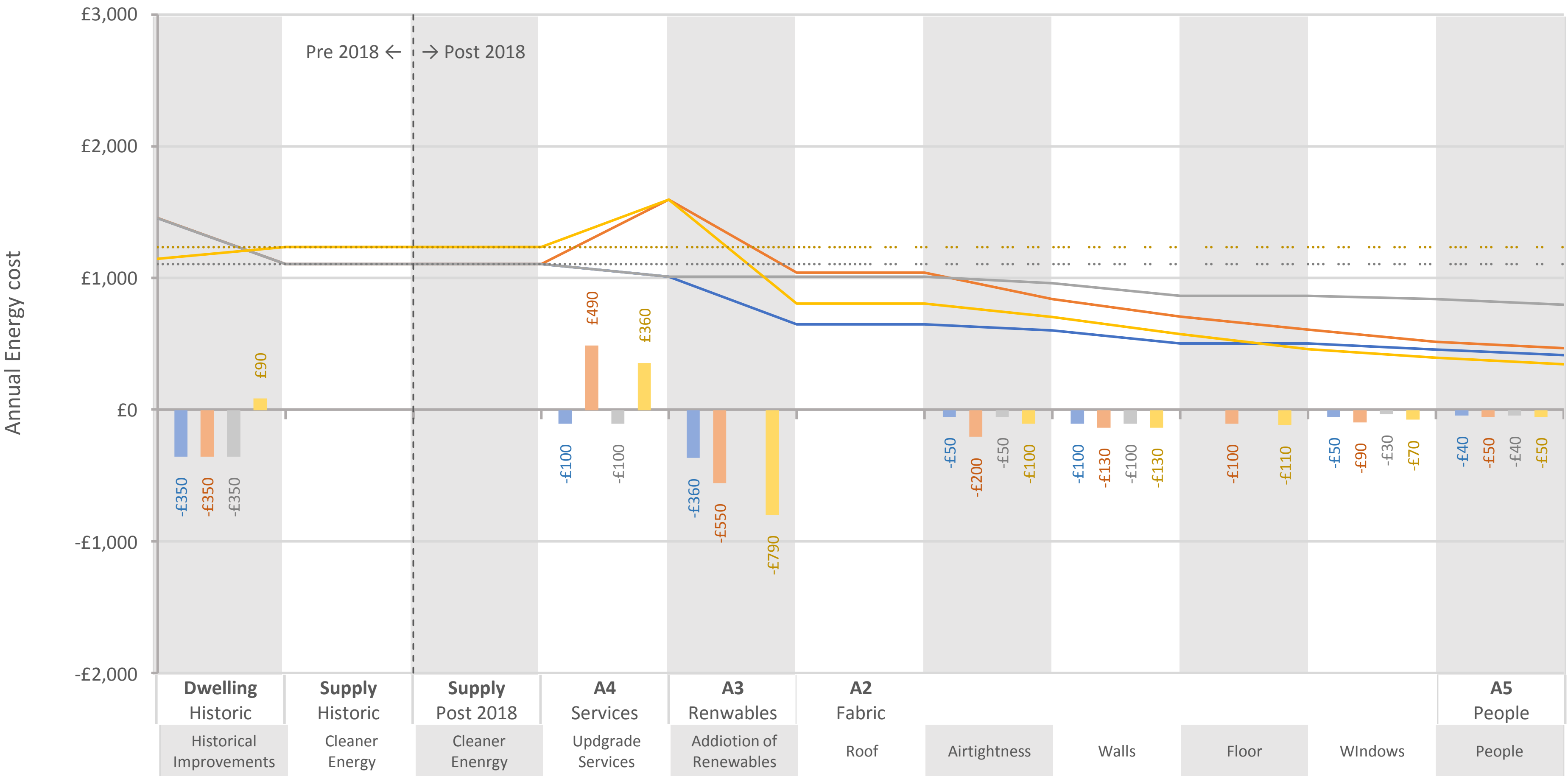






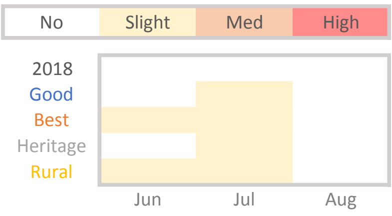
Impact on annual energy cost of four distinct retrofit narratives

Scenario 1 assumes no change in energy costs

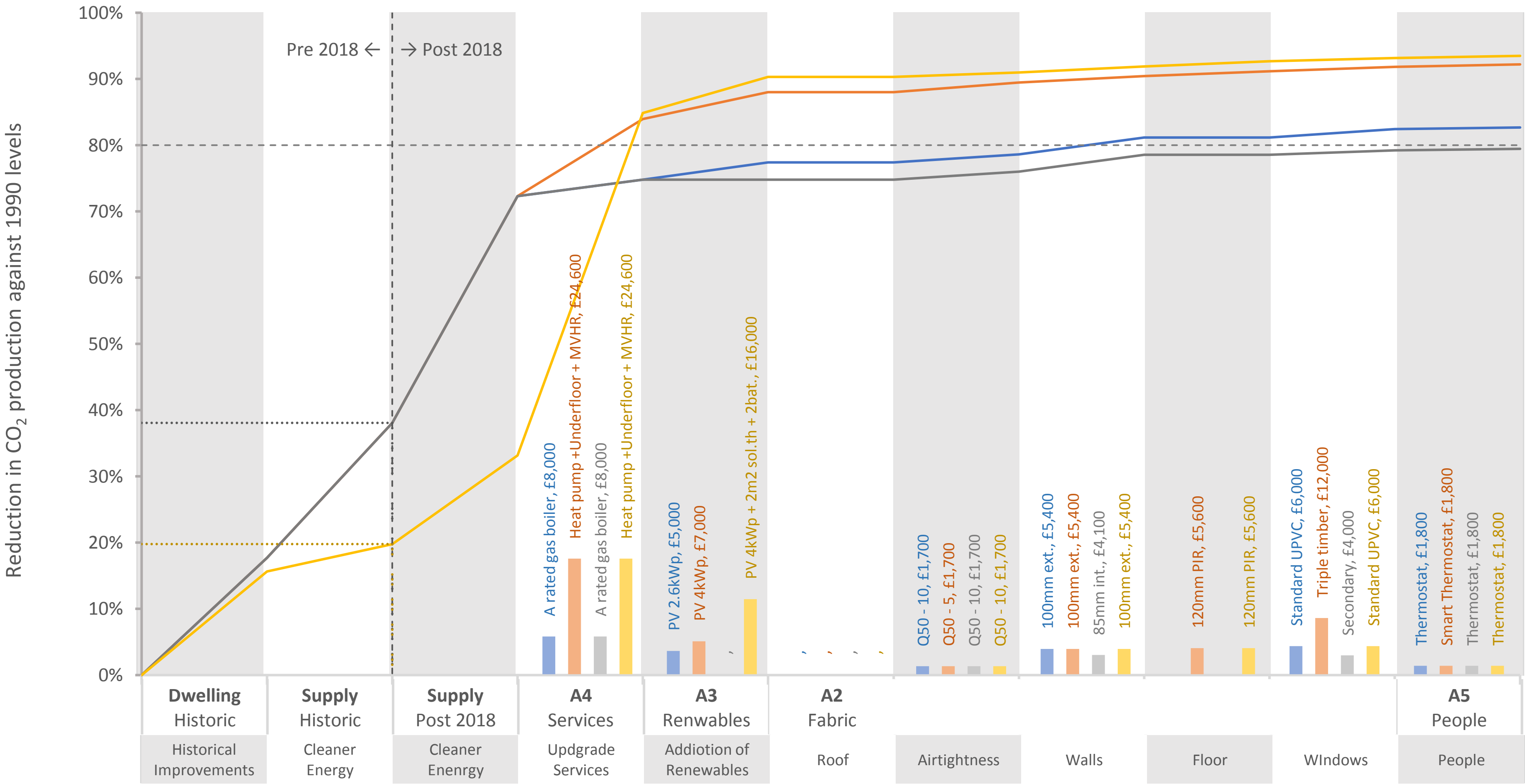


Dwelling type 13: Detached post 1990
Scenario 2

Overheating Risk

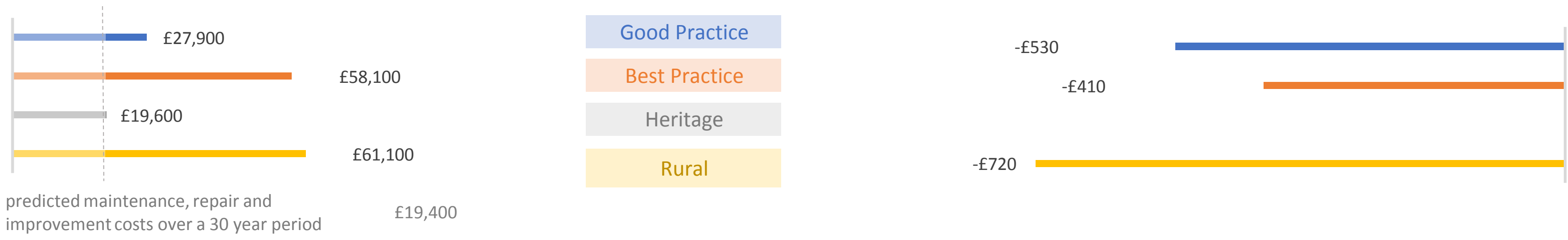


Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



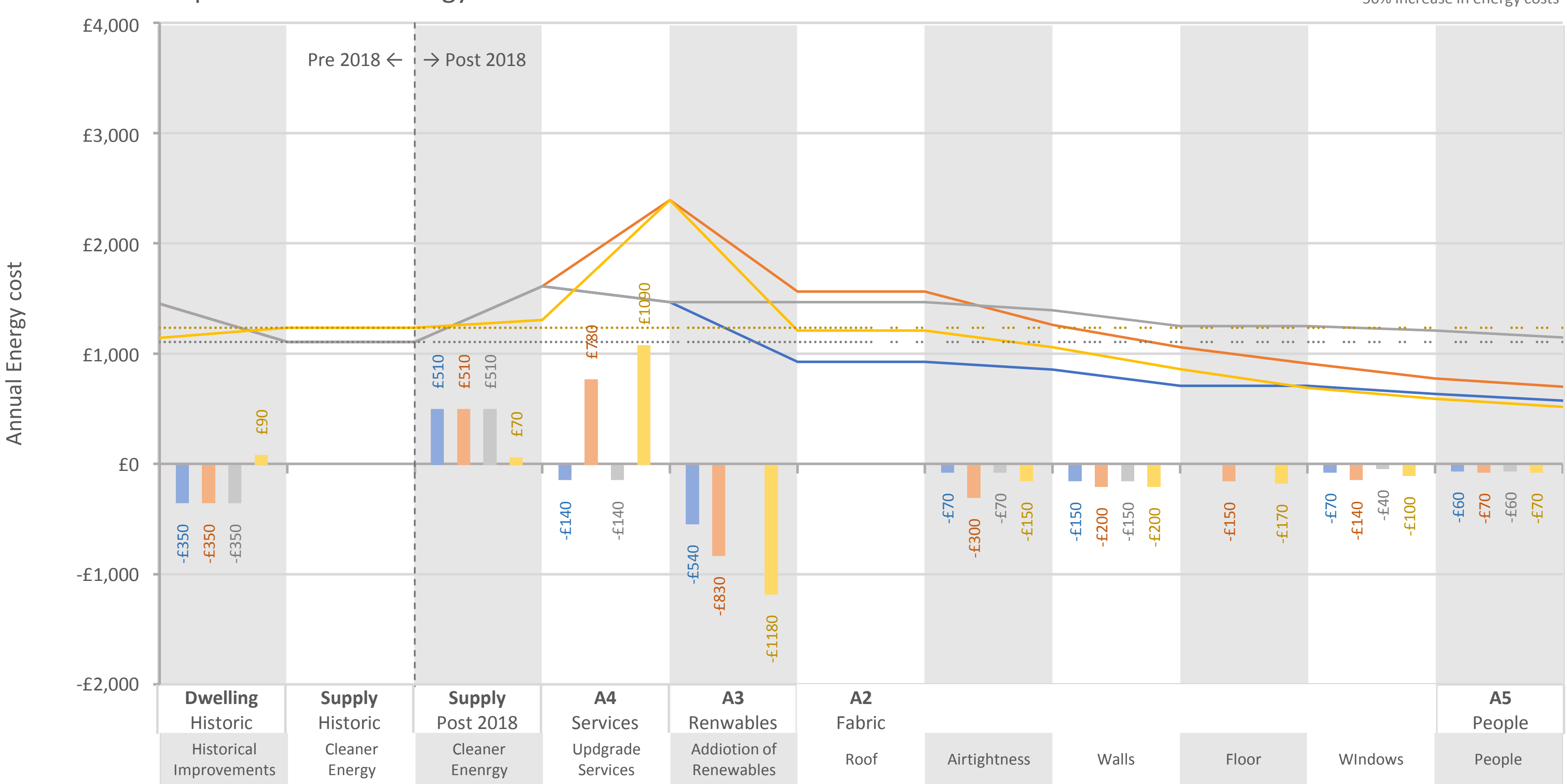
Total capital cost by narrative

Total reduction in annual energy cost by narrative



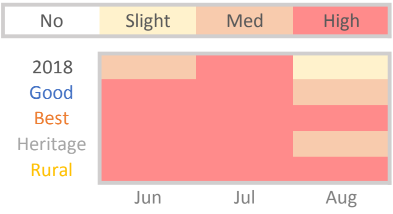
Impact on annual energy cost of four distinct retrofit narratives

Scenario 2 assumes
50% increase in energy costs

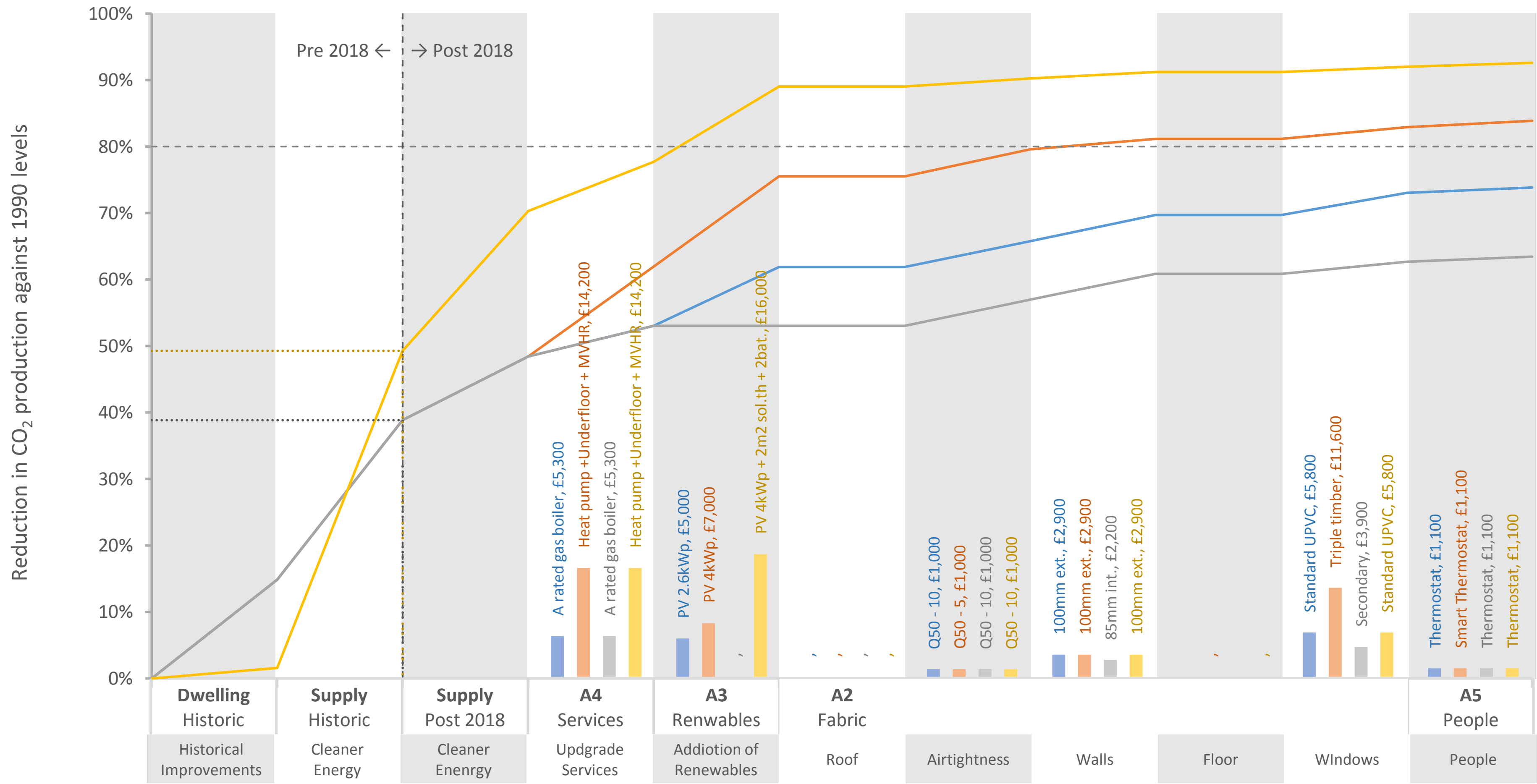


Dwelling type 14: Flat post 1990
Scenario 1

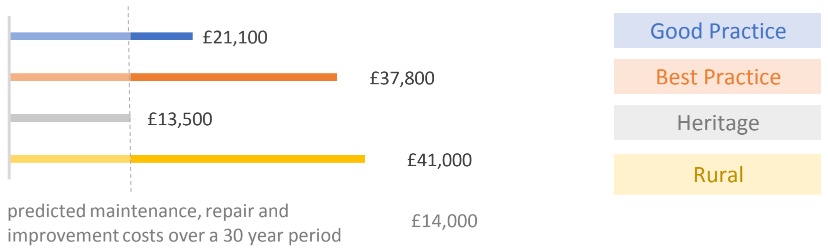
Overheating Risk



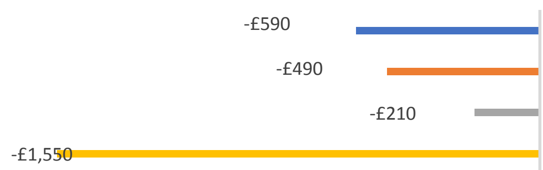
Impact on carbon emissions of four distinct retrofit narratives, each with costed actions



Total capital cost by narrative

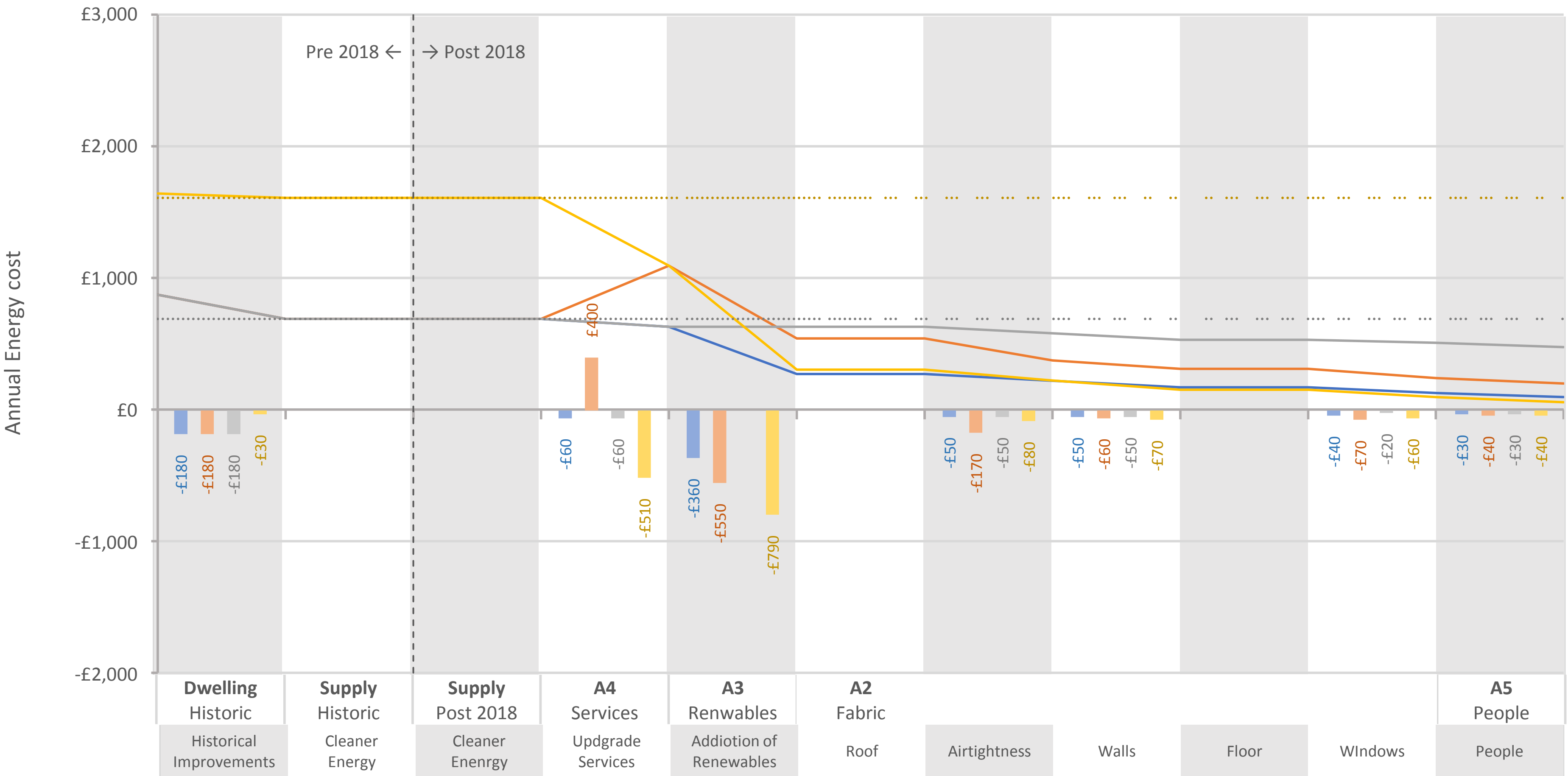


Total reduction in annual energy cost by narrative



Impact on annual energy cost of four distinct retrofit narratives

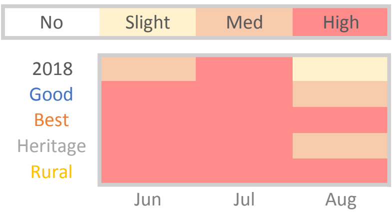
Scenario 1 assumes
no change in energy costs



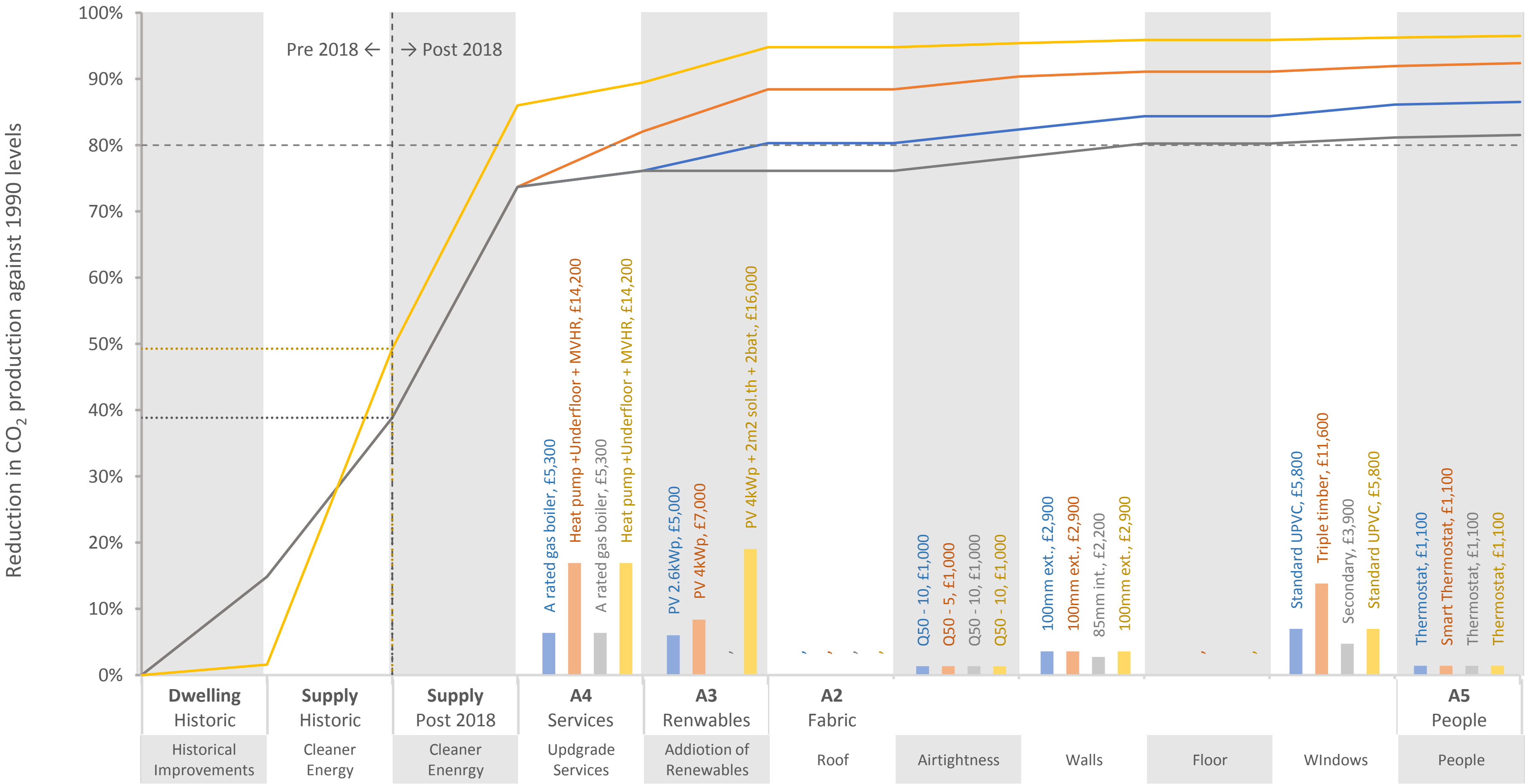
Dwelling type 14: Flat post 1990

Scenario 2

Overheating Risk



Impact on carbon emissions of four distinct retrofit narratives, each with costed actions

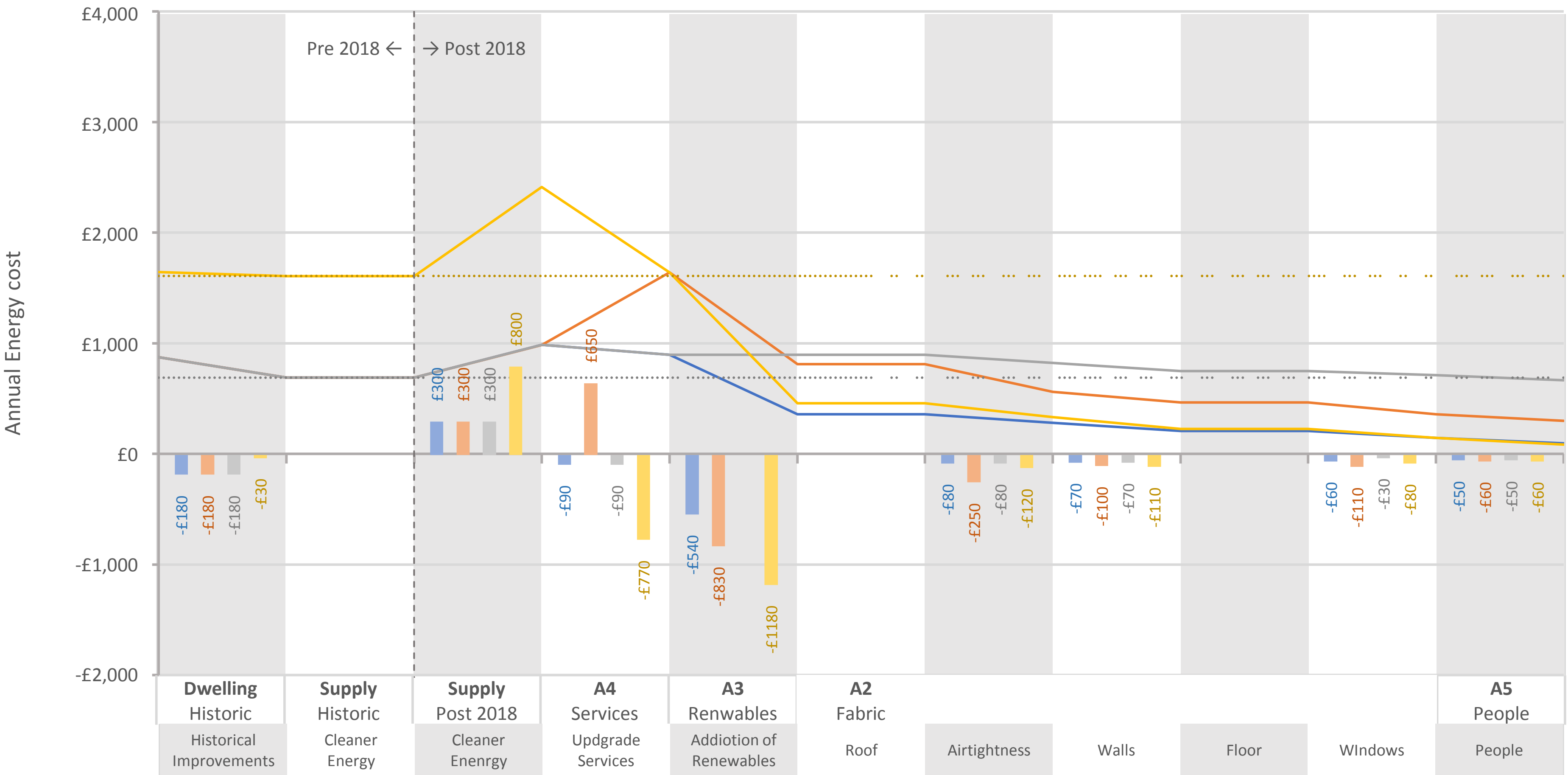


Total capital cost by narrative

Total reduction in annual energy cost by narrative

Impact on annual energy cost of four distinct retrofit narratives

Scenario 2 assumes 50% increase in energy costs



appendix B: mapping WFGA goals

"National and international legislation require that greenhouse gas emissions, specifically carbon dioxide, produced across Wales be reduced by at least 80% of 1990 levels, by 2050. Decarbonisation at this scale represents a huge national challenge, but also provides opportunities, particularly in the context of the Wellbeing of Future Generations (Wales) Act. The housing sector produces around a fifth of all carbon emissions, and has a key part to play in achieving decarbonisation." Stage 1 report: *Homes of Today for Tomorrow*

The Well-being of Future Generations (Wales) Act 2015 (WFGA) demands a focus on long term gains over short term expedience. The seven goals of the Act go further, establishing an imperative for housing that is sustainable, resilient, healthy, equitable, cohesive, culturally aware and responsible:

A globally responsible Wales	Setting higher standards – reducing carbon emissions.
A prosperous Wales	An integrated Welsh supply chain – using local resources, creating sustainable economies.
A resilient Wales	Future proofing with long term flexibility – adaptability, resilience against climate change.
A healthier Wales	Healthier homes promoting physical and mental wellbeing – reducing pressure on the health service.
A more equal Wales	Eliminating household poverty – affordable warmth for all.
A Wales of cohesive communities	Improved neighbourhoods – cohesive communities where people want to live.
A Wales of thriving culture and language	Maintaining sense of place and identity – through Wales' unique heritage and landscape

"Responsible government is not just about delivery in the here and now, vital though it is. It's also about looking towards the end of the decade and beyond, with a vision of the Wales we want for the future." Rt Hon Carwyn Jones AM, First Minister of Wales

The table below maps out the potential benefits associated with each of the seven WFGA goals in more detail, by expressing them as short term aims that might be achieved during construction, as medium term aims that would impact on the dwelling during occupation and as longer term aims that might benefit the wider community or deliver benefits at a regional or even a national scale.

	Short term aim (during retrofit)	**Medium term aim** (the occupied dwelling)	**Long term aim** (the wider community)
>80% carbon reduction	Low embodied CO2 Locking in carbon	Reduced CO2 emissions	Decarbonising Wales meeting international trgts
Welsh supply chain	Delivering good value Using local resources	More affordable housing Welsh supply chain	Stronger local economies Skills / community building
Climate resilience	Lower maintenance Adaptable by the user	Mitigating overheating Resilient to climate change	Reduced pressure on local infrastructure
Healthier homes	Natural resource use Breathable construction	Healthy internal environment Reduced env, impact	Healthier communities Less pressure on NHS
Affordable warmth	More efficient systems Lower embodied energy	Reducing heating bills Reducing fuel poverty	Affordable warmth for all Energy positive communities
Community led change	More flexible layouts Changes by community	More vibrant communities Different procurement paths	Meeting housing need Flexible high quality homes
Maintaining identity	Preserving heritage Sensitivity to context	Maintaining and enhancing local character	Supporting people, communities and distinctive places

"The WFGA requires that commissioners of housing cease thinking purely in terms of capital costs, and encourage the industry to replace construction that drains resources with buildings that generate them – that are energy positive and carbon negative. This perspective shift requires a fundamental step change in Welsh housing standards and existing / established patterns of housing procurement."

More | Better, Green with Forster (2017) http://orca.cf.ac.uk/id/eprint/98055

appendix C: assumptions

Appendix C details the assumptions that have been made in order to model the housing stock condition at three different points in time (1990, 2018 and 2050) in terms of dwelling fabric and heating systems, and for three distinct future narratives (good practice, best practice, heritage and rural narratives). It also details the assumptions that have been made around energy costs and carbon emissions factors, to model three distinct energy supply scenarios, and finally around the capital costs associated with different retrofit actions.

Dwelling fabric

Three data sources were used to make assumptions about the fabric of dwellings types. SAP 2012 document data was used to determine the ‘as built’ parameters for fabric elements.

For the base (1990) models, these ‘as built’ values were updated with data from the housing fact file which allowed an approximation to be made on the likelihood of improvements to fabric up to this date, based on whole UK housing stock statistics.

For the current (2018) models, EPC data was used in a similar manner, to approximate the improvements likely to have been made up to the current date. The EPCs were processed and broken down into 3 age groups and 5 typologies. Statistics on fabric characteristics were used to approximate the current condition of fabric elements for the 14 dwelling types, based on their age and dwelling type.

Fabric EPC data (Wales)

Type	Age	Wall U value W/m2/K					Floor U value W/m²/K				Window U value W/m²/K				Roof U value W/m²/K							
		1.7	0.45	1.6	1	0.45	0.35	0.6	1.2	2	2	2.2	3	3.1	0.12	0.16	0.4	0.6	1	1.5	2	None
F	pre 1919	84%	16%	0%	0%	0%	3%	0%	0%	96%	0%	4%	33%	48%	14%	4%	7%	3%	2%	1%	20%	49%
F	1919-1983	0%	0%	25%	6%	69%	0%	0%	0%	100%	1%	8%	40%	47%	23%	5%	7%	3%	2%	1%	5%	55%
F	post 1983	0%	0%	0%	1%	99%	63%	1%	36%	0%	0%	10%	62%	28%	14%	1%	2%	0%	0%	0%	0%	83%
D	pre 1919	89%	11%	0%	0%	0%	7%	0%	1%	92%	0%	5%	31%	54%	41%	8%	13%	6%	4%	2%	25%	0%
D	1919-1983	0%	0%	29%	8%	63%	0%	0%	1%	98%	0%	6%	35%	57%	47%	11%	18%	7%	5%	2%	9%	0%
D	post 1983	0%	0%	1%	2%	97%	50%	2%	48%	0%	1%	12%	55%	31%	75%	15%	7%	0%	1%	0%	0%	0%
ET	pre 1919	94%	6%	0%	0%	0%	2%	0%	0%	97%	1%	7%	30%	58%	35%	9%	15%	5%	6%	2%	27%	1%
ET	1919-1983	0%	1%	29%	7%	63%	0%	0%	0%	100%	1%	10%	34%	52%	49%	11%	17%	6%	6%	2%	9%	0%
ET	post 1983	0%	0%	0%	1%	98%	52%	1%	46%	0%	1%	11%	56%	32%	72%	16%	9%	1%	1%	0%	0%	1%
MT	pre 1919	96%	3%	0%	0%	0%	1%	0%	0%	99%	1%	7%	29%	58%	33%	9%	15%	5%	7%	2%	28%	0%
MT	1919-1983	0%	1%	37%	7%	56%	0%	0%	0%	100%	1%	8%	33%	54%	45%	11%	17%	7%	6%	2%	12%	0%
MT	post 1983	0%	0%	0%	1%	99%	51%	1%	48%	0%	1%	10%	57%	33%	69%	17%	11%	0%	1%	0%	0%	1%
SD	pre 1919	91%	9%	0%	0%	0%	4%	0%	1%	96%	0%	5%	32%	56%	38%	9%	15%	6%	5%	2%	25%	0%
SD	1919-1983	0%	1%	38%	4%	57%	0%	0%	0%	100%	1%	8%	33%	56%	46%	11%	16%	7%	6%	3%	11%	0%
SD	post 1983	0%	0%	0%	2%	97%	43%	2%	55%	0%	1%	10%	50%	39%	69%	18%	10%	1%	1%	0%	0%	1%

For the 2050 models, the four retrofit narratives (good practice, best practice, heritage and rural) were each developed into a dwelling fabric specification that anticipates a particular retrofit strategy, as detailed below:

		Narrative:	**good practice**	**best practice**	**heritage**	**rural**
		Application:	In line with current Building Reg.s, heat from gas	Exceeds current Building Reg.s, electric heat	Retrofit limited by historic character, heat from gas	Exceeds current Building Reg.s, off grid electric
A2 fabric	insulation	Roof	0.16 W/m^2°C	0.16 W/m^2°C	0.16 W/m^2°C	0.16 W/m^2°C
		Wall internal			0.25 W/m^2°C	
		Wall external	0.30 W/m^2°C	0.12 W/m^2°C		0.12 W/m^2°C
		floor - solid		0.16 W/m^2°C		0.16 W/m^2°C
		floor - suspended		0.16 W/m^2°C		0.16 W/m^2°C
	windows	New	1.80 W/m^2°C	1.40 W/m^2°C		1.80 W/m^2°C
		Secondary			2.40 W/m^2°C	
		Shading				
		Airtightness (Q_{50})	10	5	10	10
A3 renewables	lower carbon sources	Air source heat pump				
		CHP				
		PV	2.6kwp	4kwp		4kwp
		Electric battery				battery storage
		Wind				
		Solar thermal				2 sqm
		Transpired solar Collector				
A4 services	heating	Gas central heating	A-rated boiler		A-rated boiler	
		Underfloor		Heat pump		Heat pump
		Storage				
		Warm air				
		Hot water	combi boiler	heat pump	combi boiler	solar hot water
		ventilation	natural	MVHR	Natural	MVHR
		Simple controls	Thermostat		Thermostat	Thermostat
		Smart meters and homes		Smart thermostat		
		Indicative SAP rating	**88**	**90**	**71**	**90**

Heating systems

The following section explains the assumptions that were made in order to model dwelling systems for the 1990 and 2018 models. Each dwelling type has a mains gas connected and a non-connected heating system specification. The mains gas system is the basis for the 'good practice', 'best practice' and 'heritage' narratives whilst off-gas heating is the basis for the 'rural' narrative.

For approximating the likely heating system types within dwellings currently and in 1990, EPC data was used to determine the most common heating system within age and typology groups giving an approximation of current heating systems within dwelling types. The Housing Fact file was used to approximate the most likely systems in 1990 based on the changes from 1990 statistics to more recent statistics on heating systems.

Mains gas systems

For the mains gas connected narratives, it was assumed that each dwelling type had regular gas boilers in 1990 and a combi gas boiler of 80% efficiency in 2018 as:

- The mode (most common) system for mains gas EPCs was boiler of 80% efficiency
- In 2011, 47% of dwellings had combi gas or oil boilers and 38% had condensing gas or oil boilers (86%) (HFF UK)
- In 1990, 60% of dwellings had gas central heating and 13% had non centrally heated gas heating
- In 1990, only 10.5% of gas or oil boilers were condensing or combi boilers

Mains gas EPC data (Wales)

Type	Age	mains gas Boiler (73% eff.)	mains gas Boiler (80% eff.)	mains gas Boiler (85% eff.)
F	pre 1919	4.4%	88.0%	7.6%
F	1919-1983	8.4%	82.3%	9.3%
F	post 1983	0.9%	81.0%	18.1%
D	pre 1919	7.2%	86.9%	5.9%
D	1919-1983	8.6%	86.1%	5.2%
D	post 1983	0.7%	90.1%	9.2%
ET	pre 1919	6.1%	89.9%	4.0%
ET	1919-1983	9.0%	85.7%	5.3%
ET	post 1983	0.7%	85.3%	13.9%
MT	pre 1919	6.4%	89.8%	3.7%
MT	1919-1983	9.8%	85.2%	5.1%
MT	post 1983	1.2%	84.4%	14.4%
SD	pre 1919	7.1%	88.4%	4.5%
SD	1919-1983	8.0%	87.7%	4.3%
SD	post 1983	1.2%	89.0%	9.8%
	OVERALL	**7.2%**	**87.1%**	**5.7%**

Off gas systems

For the off gas (rural) narrative, the most common heating system for 2018 models was assumed to be oil-based combi boilers. Due to the higher proportion of solid fuel use in 1990, these dwelling types were assumed to use the most common solid fuel heating system in 1990 – solid fuel central heating.

Due to the constant presence of electric storage heaters in dwellings between 1990 and 2011, dwelling types identified as using electric storage heaters in 2018 were assumed to have had the same heating in 1990:

- The most common system for non mains gas EPCs is either electric storage heaters or oil boilers with efficiency of 77% - see boxed entries in the table above.
- In 2011, 47% of dwellings had combi gas or oil boilers and 38% had condensing gas or oil boilers (86%) (HFF UK)
- In 1990, 5.8% of all dwellings had solid fuel central heating and 2.4% used non centrally heated solid fuel heating. 2011, 0.7% of all dwellings had solid fuel central heating and 0.1% used non centrally heated solid fuel heating.
- In 1990, 2.5% of all dwellings had oil-based central heating and oil-based non central heating was negligible.
- In 2011, 3.9% had oil-based central heating and oil-based non central heating was negligible
- The % of dwellings with electric heating dropped from 12.3% in 1990 to 9.3% in 2011. Electric storage heaters were the most common type of electric heating in 1990 (7.4% of properties) and in 2011 (7.0% of dwellings)

EPC data: non mains gas (specific to Wales)

Type	Age	electric_Air source heat	electric_Boiler_0.85	electric_Boiler_1	electric_Ground source heat	electric_Ground source heat	electric_Storage heaters_0	electric_Storage heaters_1	LPG_Boiler_0	LPG_Boiler_0.64	LPG_Boiler_0.73	LPG_Boiler_0.8	LPG_Boiler_0.85	LPG_Community_0.8	oil_Boiler_0.73	oil_Boiler_0.77	oil_Boiler_0.8	oil_Boiler_0.85	biomass_Community_0.8	no system_No system_1	solid_Boiler_0.64	wood_Boiler_0.52	wood_Boiler_0.64	wood_Boiler_0.73	mains gas_Boiler_0	mains gas_Community_0.8	biomass_Community_0	solid_Boiler_0.52	wood_Boiler_0	(blank)_Boiler_0	electric_Ground source heat	oil_Boiler_0	solid_Boiler_0	0_Boiler_0.64	bioethanol_Boiler_0.52
F	pre 1919	0%	5%	1%	0%	0%	0%	67%	0%	1%	3%	0%	0%	0%	0%	4%	1%	0%	10%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
F	1919-1983	0%	1%	0%	0%	0%	0%	62%	0%	0%	1%	0%	0%	0%	0%	1%	0%	0%	29%	2%	1%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
F	post 1983	2%	4%	1%	0%	0%	0%	75%	0%	0%	2%	0%	0%	0%	0%	1%	0%	0%	13%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
D	pre 1919	1%	0%	0%	0%	1%	0%	8%	0%	3%	9%	0%	0%	0%	7%	48%	10%	0%	0%	1%	3%	0%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
D	1919-1983	1%	0%	0%	0%	0%	0%	14%	0%	3%	10%	0%	0%	0%	6%	49%	10%	0%	0%	1%	2%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
D	post 1983	4%	1%	0%	1%	3%	0%	4%	0%	2%	11%	0%	0%	0%	1%	56%	13%	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
ET	pre 1919	1%	1%	0%	0%	0%	0%	25%	0%	5%	10%	0%	0%	0%	2%	29%	6%	0%	0%	7%	7%	0%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
ET	1919-1983	2%	1%	0%	0%	0%	0%	44%	0%	3%	8%	0%	0%	0%	1%	22%	4%	0%	2%	3%	7%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
ET	post 1983	2%	5%	1%	0%	1%	0%	33%	0%	2%	17%	0%	0%	0%	0%	25%	4%	0%	7%	1%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MT	pre 1919	1%	2%	0%	0%	0%	0%	35%	0%	3%	7%	0%	0%	0%	1%	19%	3%	0%	1%	10%	10%	0%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MT	1919-1983	1%	1%	0%	0%	0%	0%	41%	0%	3%	6%	0%	0%	0%	1%	17%	3%	0%	14%	4%	7%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MT	post 1983	2%	5%	1%	0%	0%	0%	42%	0%	2%	15%	1%	0%	0%	0%	22%	6%	0%	2%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
SD	pre 1919	1%	1%	0%	0%	0%	0%	16%	0%	4%	10%	0%	0%	0%	4%	41%	9%	0%	1%	3%	6%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
SD	1919-1983	3%	0%	0%	0%	0%	0%	24%	0%	3%	7%	0%	0%	0%	3%	35%	7%	0%	1%	3%	11%	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
SD	post 1983	3%	3%	0%	1%	1%	0%	23%	0%	3%	15%	0%	0%	0%	1%	36%	10%	0%	1%	1%	1%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	OVERALL	1%	1%	0%	0%	0%	0%	28%	0%	2%	7%	0%	0%	0%	3%	32%	7%	0%	6%	3%	4%	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Example Assumptions for 1990 and 2018 models

(dwelling type 1: Pre 1919 End Terrace)

WELSH HOUSING STOCK	Dwelling type 1
Building Type	End terrace
Construction Age	pre 1919
Stock representation	3.23%
DIMENSIONS	
Average of Storeys	1.99
Average of Width	6.52
Average of Depth	7.66
Average of Gnd floor height	2.42
Average of first floor height	2.52
Average of Front Glazing Ratio	25.8%
Average of Back Glazing Ratio	18.2%
Ground floor area	49.9
First floor area	49.9
Number of exposed sides	3
External wall area front (net)	19.90
External wall area back (net)	19.40
External wall area sides (net)	37.80
Solid door area front	4
Front Glazing area (East)	6.90
Back Glazing area (East)	4.30

SERVICES (+ HOT WATER, CONTROLS, VENT.)	1990 (gas connected)	2018 (gas connected)	1990 (off gas)	2018 (off gas)
Fuel	Gas	Gas	Solid	Oil
SAP main heating	Gas oil boiler	Gas oil boiler	Solid fuel boiler	Gas oil boiler
Main heating description	Mains gas regular boiler	Mains gas combi boiler	solid fuel independent boiler	oil combi boiler
Efficiency	65%	80.3%	77.7%	78.3%
Manufactured date	up to 1990	2002 to current	1984 to current	1996 to current
Index	98	9549	700029	2035
Heat emitter	systems with radiators	systems with radiators	systems with radiators	systems with radiators
Hot water description	From main heating system	From main heating system	From main heating system	From main heating system
Hot water storage (litres)	300	0	300	0
Ventilation description	natural ventilation	natural ventilation	natural ventilation	natural ventilation
Ventilation index				
Heating control	No time or thermostatic control of room temperature	Programmer, TRVs and bypass	No time or thermostatic control of room temperature	Programmer, TRVs and bypass

RENEWABLES	1990	2018
PV (kWp)		
Solar Thermal (m2)		
Electric Battery		
FABRIC	1990	2018
Wall Description	Solid Uninsulated	Solid Uninsulated
Wall U value	1.7	1.7
Wall thermal mass	450	450
Floor description	suspended timber no insulation	suspended timber no insulation
Floor U value	2	2
Roof description	50mm insulation	100mm insulation
Roof U value	0.68	0.4
Glazing description	Single glazing	Double glazing pre 2002
Glazing U value	4.8	3.1
Infiltration (Q50)	15	15
PEOPLE	1990	2018
Lights	0%	50%
Internal temperature setpoint	18	20
Controls (see services)		
Target water	no	no
OVERHEATING	1990	2018
n - effective air change rate	1	1
z (blinds)	0.7	0.7
z (overhangs)	0.8	0.8

The Excel version of the SAP model adopted for the modelling process allows for different energy costs and emissions factors. This is critical to understand the outcomes for the dwelling models at different points in time (1990, 2018 and 2050) and for the three distinct energy supply scenarios.

Assumptions regarding energy costs and emissions factors are as follows:

EMISSION FACTORS (kg CO_2 per kWh)		**Gas**	**Oil**	**Solid**	**Electricity**
1990	(based on SAP 2012 data)	0.216	0.298	0.298	0.772
2018	(based on SAP 2012 data)	0.208	0.298	0.298	0.398
Scenario 1	minor further improvements in clean energy supply	0.21	0.298	0.298	0.233
Scenario 2	significant further improvements in clean energy supply	0.11	0.298	0.298	0.11
Scenario 3	transformational change in energy supply	0.001	0.298	0.298	0.001

ENERGY COSTS (p per kWh)		**Gas**	**Oil**	**Solid**	**Electricity**
1990	2018 energy costs (SAP 2012)	4.32	5.06	4.42	15.32
2018	2018 energy costs (SAP 2012)	4.32	5.06	4.42	15.32
Scenario 1	Assumes no change in energy costs	4.32	5.06	4.42	15.32
Scenario 2	Assumes 50% increase in energy costs	6.48	7.59	6.63	22.98
Scenario 3	Assumes 100% increase in energy costs	8.64	10.12	10.12	30.64

Capital costs

Assumptions made by Lee Wakeman cost consultants are as detailed below:

		Application:	Smaller: GFA 31sqm TFA 62sqm	Larger: GFA 50sqm TFA 100sqm	Notes:
A2 fabric	insulation	Roof	£620	£1,000	Rate of £20/sqm ground floor area (GFA)
		Wall internal	£1,230	£1,230	Rate of £30/sqm external wall
		Wall external – B Regs	£1,640	£1,640	Rate of £40/sqm external wall
		Wall external – B regs+	£2,255	£2,255	Rate of £55/sqm external wall
		floor - solid	£1,550	£2,500	Rate of £50/sqm GFA
		floor - suspended	£1,395	£2,250	Rate of £45/sqm GFA
	windows	New - UPVC	£4,500	£4,500	provisional sum of £300/m2 glazing
		New - timber	£6,750	£6,750	provisional sum of £450/m2 glazing
		New – triple, composite	£9,000	£9,000	provisional sum of £600/m2 glazing
		Secondary	£3,000	£3,000	provisional sum of £200/m2 glazing
		Shading	£1,125	£1,125	provisional sum of £75/m2 glazing
		Airtightness (Q_{50})	£620	£1,000	allowance of £10/sqm total floor area (TFA)
A3 renewables	lower carbon sources	Air source heat pump	£8,180	£11,600	cost at 62sqm dwelling: 5KW ASHP and HWC & immediate controls: £4,650, 7 radiators & valves: £700, Pipes, fittings & all other materials: £650, Labour: £1,400, Electrical works £550
		PV – 2.6 kWp	£5,000	£5,000	£3,500 PV panels and £1,500 builder's work
		PV – 4 kWp	£7,000	£7,000	Pro rata as above
		Electric battery	£5,000	£5,000	Provisional sum
		Solar thermal	£3,000	£3,000	£2,000 for the system, £1,000 for builder's work
		Transpired solar Collect.	£8,000	£8,000	5sqm prototype system - better data in due course.
A4 services	heating	Gas central heating	£3,580	£5,100	provisional sum: £3,000 boiler + £500 builder's work
		Oil central heating	£4,090	£5,800	£3,500 for the boiler and £500 for builder's work
		Biomass	£7,670	£10,900	£5,000 for the boiler and £2,500 for builder's work
		Underfloor	£1,085	£1,085	pipes in insulated GF floor or in screed over slab
		Storage	£1,535	£2,200	£1,000 for the storage and £500 for builder's work
		Warm air	£7,670	£10,900	£5,000 for the system and £2,500 for builder's work
		Hot water	£1,025	£1,500	£2,000 for the system and £1,000 for builder's work
		MVHR	£1,535	£2,200	Base of £1,000 for the MVHR units and ducting and £500 builder's work, pro rata for size of dwelling.
A5	people	Occupants remain in situ	£3,080	£4,600	
		Simple controls	£768	£1,110	£750 for controls and builder's work, pro rata for size
		Smart meters and homes	£768	£1,110	Pro rata as above

Summary of Potential Capital Costs (exlcuding VAT)

leewakemans management

V2 - 28 June 2019
V2 to increase the 14 house types totalling 85% of the housing stock, up to 100%

Report used for information:	**2019 06 06 DECARB stage 2 report SL EG FINAL V2**
Wales Housing Stock	**1,400,000**

	HOUSE End terrace	HOUSE Mid terrace	HOUSE Semi-	HOUSE Detached	FLAT (Purpose blt)	Total
pre 1919	type 1, 3%	type 2, 9%	type 3, 4%	type 4, 7%		23%
1919- 1944			type 5, 5%			5%
1945- 1964			type 6, 10%			10%
1965 - 1990	type 7, 4%	type 8, 6%	type 9, 10%	type 10, 9%	type 11, 4%	33%
Post 1990			type 12, 5%	type 13, 7%	type 14, 1%	13%
Total	7%	15%	34%	23%	5%	84%

Type 1
End Terrace Pre 1919
Percentage of Housing Type: **3.00%**

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	6,300	£ 45,400	£ 14,600	£ 30,800	£ 194,040,000	£ 6,468,000
Heritage	20%	8,400	£ 13,700	£ 14,600	-£ 900	-£ 7,560,000	-£ 252,000
Best	65%	27,300	£ 39,700	£ 14,600	£ 25,100	£ 685,230,000	£ 22,841,000
		42,000				£ 871,710,000	£ 29,057,000

Type 2
Mid Terrace Pre 1919
Percentage of Housing Type: **9.00%**

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	18,900	£ 39,400	£ 11,100	£ 28,300	£ 534,870,000	£ 17,829,000
Heritage	20%	25,200	£ 10,800	£ 11,100	-£ 300	-£ 7,560,000	-£ 252,000
Best	65%	81,900	£ 33,500	£ 11,100	£ 22,400	£ 1,834,560,000	£ 61,152,000
		126,000				£ 2,361,870,000	£ 78,729,000

Type 3
Semi-detached Pre 1919
Percentage of Housing Type: **4.00%**

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	8,400	£ 52,400	£ 14,000	£ 38,400	£ 322,560,000	£ 10,752,000
Heritage	20%	11,200	£ 18,300	£ 14,000	£ 4,300	£ 48,160,000	£ 1,605,333
Best	65%	36,400	£ 47,600	£ 14,000	£ 33,600	£ 1,223,040,000	£ 40,768,000
		56,000				£ 1,593,760,000	£ 53,125,333

Type 4
Detached Pre 1919
Percentage of Housing Type: **7.00%**

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	14,700	£ 66,800	£ 19,800	£ 47,000	£ 690,900,000	£ 23,030,000
Heritage	20%	19,600	£ 25,500	£ 19,800	£ 5,700	£ 111,720,000	£ 3,724,000
Best	65%	63,700	£ 63,300	£ 19,800	£ 43,500	£ 2,770,950,000	£ 92,365,000
		98,000				£ 3,573,570,000	£ 119,119,000

Type 5
Semi-detached 1919-1944
Percentage of Housing Type: 5.00%

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	10,500	£ 46,200	£ 12,400	£ 33,800	£ 354,900,000	£ 11,830,000
Heritage	20%	14,000	£ 14,900	£ 12,400	£ 2,500	£ 35,000,000	£ 1,166,667
Best	65%	45,500	£ 41,400	£ 12,400	£ 29,000	£ 1,319,500,000	£ 43,983,333
		70,000				£ 1,709,400,000	£ 56,980,000

Type 6
Semi-detached 1945-1964
Percentage of Housing Type: 10.00%

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	21,000	£ 44,900	£ 11,900	£ 33,000	£ 693,000,000	£ 23,100,000
Heritage	20%	28,000	£ 14,100	£ 11,900	£ 2,200	£ 61,600,000	£ 2,053,333
Best	65%	91,000	£ 39,700	£ 11,900	£ 27,800	£ 2,529,800,000	£ 84,326,667
		140,000				£ 3,284,400,000	£ 109,480,000

Type 7
End Terrace 1965-1990
Percentage of Housing Type: 4.00%

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	8,400	£ 42,300	£ 10,600	£ 31,700	£ 266,280,000	£ 8,876,000
Heritage	20%	11,200	£ 12,800	£ 10,600	£ 2,200	£ 24,640,000	£ 821,333
Best	65%	36,400	£ 36,400	£ 10,600	£ 25,800	£ 939,120,000	£ 31,304,000
		56,000				£ 1,230,040,000	£ 41,001,333

Type 8
Mid Terrace Pre 1965-1990
Percentage of Housing Type: 6.00%

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	12,600	£ 40,900	£ 9,300	£ 31,600	£ 398,160,000	£ 13,272,000
Heritage	20%	16,800	£ 11,700	£ 9,300	£ 2,400	£ 40,320,000	£ 1,344,000
Best	65%	54,600	£ 35,200	£ 9,300	£ 25,900	£ 1,414,140,000	£ 47,138,000
		84,000				£ 1,852,620,000	£ 61,754,000

Type 9
Semi-detached 1965-1990
Percentage of Housing Type: 10.00%

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	21,000	£ 46,300	£ 12,200	£ 34,100	£ 716,100,000	£ 23,870,000
Heritage	20%	28,000	£ 14,800	£ 12,200	£ 2,600	£ 72,800,000	£ 2,426,667
Best	65%	91,000	£ 41,200	£ 12,200	£ 29,000	£ 2,639,000,000	£ 87,966,667
		140,000				£ 3,427,900,000	£ 114,263,333

Type 10
Detached 1965-1990
Percentage of Housing Type: 9.00%

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	18,900	£ 64,300	£ 19,700	£ 44,600	£ 842,940,000	£ 28,098,000
Heritage	20%	25,200	£ 23,600	£ 19,700	£ 3,900	£ 98,280,000	£ 3,276,000
Best	65%	81,900	£ 61,100	£ 19,700	£ 41,400	£ 3,390,660,000	£ 113,022,000
		126,000				£ 4,331,880,000	£ 144,396,000

Type 11
Flat 1965-1990
Percentage of Housing Type: 4.00%

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	8,400	£ 47,500	£ 16,500	£ 31,000	£ 260,400,000	£ 8,680,000
Heritage	20%	11,200	£ 18,000	£ 16,500	£ 1,500	£ 16,800,000	£ 560,000
Best	65%	36,400	£ 46,000	£ 16,500	£ 29,500	£ 1,073,800,000	£ 35,793,333
		56,000				£ 1,351,000,000	£ 45,033,333

Type 12
Semi-detatched post 1990
Percentage of Housing Type: 5.00%

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	10,500	£ 44,100	£ 11,800	£ 32,300	£ 339,150,000	£ 11,305,000
Heritage	20%	14,000	£ 12,000	£ 11,800	£ 200	£ 2,800,000	£ 93,333
Best	65%	45,500	£ 38,700	£ 11,800	£ 26,900	£ 1,223,950,000	£ 40,798,333
		70,000				£ 1,565,900,000	£ 52,196,667

Type 13
Detatched post 1990
Percentage of Housing Type: 7.00%

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	14,700	£ 61,100	£ 19,400	£ 41,700	£ 612,990,000	£ 20,433,000
Heritage	20%	19,600	£ 19,600	£ 19,400	£ 200	£ 3,920,000	£ 130,667
Best	65%	63,700	£ 58,100	£ 19,400	£ 38,700	£ 2,465,190,000	£ 82,173,000
		98,000				£ 3,082,100,000	£ 102,736,667

Type 14
Flat post 1990
Percentage of Housing Type: 1.00%

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	2,100	£ 41,000	£ 14,000	£ 27,000	£ 56,700,000	£ 1,890,000
Heritage	20%	2,800	£ 13,500	£ 14,000	-£ 500	-£ 1,400,000	-£ 46,667
Best	65%	9,100	£ 37,800	£ 14,000	£ 23,800	£ 216,580,000	£ 7,219,333
		14,000				£ 271,880,000	£ 9,062,667

Remining 16% of unallocated housing stock
Assumed to be in same proportion as House Tyes 1 to 14
Percentage of Housing Type: 16.00%

WSA narrative	*Assumed % to meet 95%*	*Total number of homes*	*Estimate of Capital Costs*	*Minus average Predicted Maintenance, repair and improvement costs over a 30yr period.*	*Projected costs*	*Total costs*	*Cost per year for 30 years*
Rural	15%	33,600	£ 48,757	£ 14,000	£ 34,757	£ 1,167,840,000	£ 38,928,000
Heritage	20%	44,800	£ 15,950	£ 14,000	£ 1,950	£ 87,360,000	£ 2,912,000
Best	65%	145,600	£ 44,264	£ 14,000	£ 30,264	£ 4,406,480,000	£ 146,882,667
		224,000				£ 5,661,680,000	£ 188,722,667

Totals of Housing Stock	**Percentage**	**100.00%**		
	Number	**1,400,000**	***Total costs***	***Cost per year for 30 years***
			£ 36,169,710,000	**£ 1,205,657,000**