



ZERO CARBON HUB

**Carbon Compliance Standard
Technical Working Group**

**SUMMARY OF OUTPUTS:
Technical Feasibility Matrix**





Items to note

Technical Work Group discussions have led to the following recommendations for the Task Group:

- For houses, decision on level should be based on having technically feasible individual technology options available
- For apartment blocks, decision on level could be based on having technically feasible individual or shared technology options available
- Apartment blocks above 4-storey could be seen as exceptional cases

In the context of this paper, the cut-off for technical feasibility is defined as requiring maximum PV panel area of 40% ground floor area of dwelling* (i.e. prior to requiring solar design). 40% was considered a practical limit for PV within a policy that describes a minimum performance standard applicable to every new home.

* PV figures have been updated to take into account output from SE/SW facing panels at 45deg pitch (rather than S facing at 30deg pitch)



Core technology options modelled

Individual

- Instantaneous electric
- Gas combi boiler
- Gas boiler
- Gas boiler + SHW
- ASHP

Communal

- GSHP
- Biomass boiler
- Gas CHP + Gas boiler

Tech options on which to base decision

Individual

- Gas boiler
- Gas boiler + SHW
- ASHP
- ASHP + SHW

Communal

- [none]

Why?

- Level must work at individual house development scale (availability of comm. solutions are 'upside')
- Inst. elec not feasible in most cases
- Therefore makes sense to focus on two gas options and two elec options (one with & one without SHW)
- Noting indiv. biomass boiler always another option



Core technology options modelled

Individual

- Instantaneous electric
- Gas combi boiler
- Gas boiler
- Gas boiler + SHW
- ASHP

Communal

- GSHP
- Biomass boiler
- Gas CHP + Gas boiler

Tech options on which to base decision

Individual

- Gas combi boiler
- Gas boiler + SHW
- ASHP
- ASHP + SHW

Shared

- GSHP
- Biomass boiler
- Gas CHP + Gas boiler

Apartment blocks

Why?

- Level must work at an apartment block scale, therefore individual and/or 'shared' in-block solutions OK as part of this
- Inst. elec not feasible in most cases
- Therefore makes sense to focus on same individual solutions as houses, but with the additional possibility of 'shared' solutions

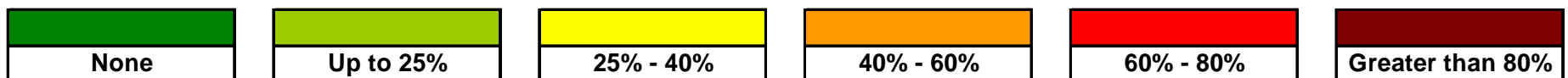


Houses (East Pennines)

| | | Carbon Target = 14 kgCO _{2(e)} /m ² /yr | | | | | | |
|-------------------|--------|---|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| Detached House | FEES | 6.2 | 1.6 | 7.8 | 1.3 | | | |
| | Spec C | -1.9 | -6.6 | 0.5 | -6.1 | | | |
| End Terrace House | FEES | 7.6 | 3.4 | 9.4 | 3.5 | | | |
| | Spec C | 1.0 | -3.4 | 3.3 | -2.7 | | | |
| Mid Terrace House | FEES | 5.7 | 1.5 | 7.6 | 1.7 | | | |
| | Spec C | -0.2 | -4.6 | 2.2 | -3.8 | | | |

- Technically feasible gas and electric options available for all house types at FEES and Spec C
- No PV required for many standard individual technology combinations with Spec C

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):



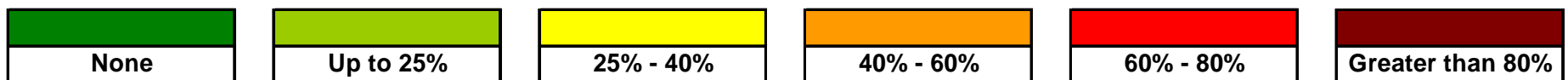


Houses (East Pennines)

| | | Carbon Target = 12 kgCO _{2(e)} /m ² /yr | | | | | | |
|-------------------|--------|---|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| Detached House | FEES | 10.1 | 5.5 | 11.6 | 5.1 | | | |
| | Spec C | 2.0 | -2.8 | 4.3 | -2.2 | | | |
| End Terrace House | FEES | 10.1 | 5.9 | 11.9 | 6.0 | | | |
| | Spec C | 3.5 | -0.9 | 5.8 | -0.2 | | | |
| Mid Terrace House | FEES | 8.2 | 4.0 | 10.1 | 4.2 | | | |
| | Spec C | 2.3 | -2.1 | 4.7 | -1.3 | | | |

- Technically feasible gas and electric options available for all house types at FEES and Spec C
- No PV required for some standard individual technology combinations with Spec C

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):



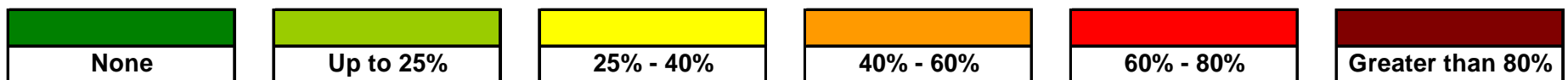


Houses (East Pennines)

| | | Carbon Target = 10 kgCO _{2(e)} /m ² /yr | | | | | | |
|-------------------|--------|---|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| Detached House | FEES | 14.0 | 9.3 | 15.5 | 9.0 | | | |
| | Spec C | 5.9 | 1.1 | 8.2 | 1.6 | | | |
| End Terrace House | FEES | 12.6 | 8.4 | 14.4 | 8.5 | | | |
| | Spec C | 6.0 | 1.6 | 8.3 | 2.3 | | | |
| Mid Terrace House | FEES | 10.7 | 6.5 | 12.6 | 6.7 | | | |
| | Spec C | 4.8 | 0.4 | 7.2 | 1.2 | | | |

- Technically feasible gas and electric options available for all house types at FEES and Spec C
- Some PV required for all standard individual technology combinations

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):



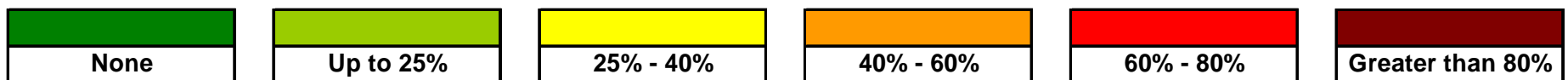


Houses (East Pennines)

| | | Carbon Target = 8 kgCO _{2(e)} /m ² /yr | | | | | | |
|-------------------|--------|--|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| Detached House | FEES | 17.8 | 13.2 | 19.4 | 12.9 | | | |
| | Spec C | 9.7 | 5.0 | 12.1 | 5.5 | | | |
| End Terrace House | FEES | 15.1 | 10.9 | 16.9 | 11.0 | | | |
| | Spec C | 8.5 | 4.1 | 10.8 | 4.8 | | | |
| Mid Terrace House | FEES | 13.2 | 9.0 | 15.1 | 9.2 | | | |
| | Spec C | 7.3 | 2.9 | 9.7 | 3.7 | | | |

- Technically feasible gas and electric options available for all house types
- Starting to see restrictions on electric options on FEES end of terrace house
- Some PV required for all standard individual technology combinations

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):



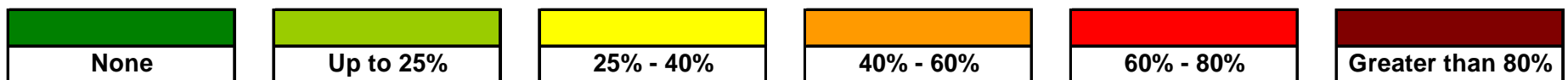


Houses (East Pennines)

| | | Carbon Target = 6 kgCO _{2(e)} /m ² /yr | | | | | | |
|-------------------|--------|--|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| Detached House | FEES | 21.7 | 17.1 | 23.2 | 16.7 | | | |
| | Spec C | 13.6 | 8.8 | 15.9 | 9.4 | | | |
| End Terrace House | FEES | 17.6 | 13.4 | 19.4 | 13.5 | | | |
| | Spec C | 11.0 | 6.6 | 13.3 | 7.3 | | | |
| Mid Terrace House | FEES | 15.7 | 11.5 | 17.6 | 11.7 | | | |
| | Spec C | 9.8 | 5.4 | 12.2 | 6.2 | | | |

- Technically feasible gas and electric options available for all house types at Spec C
- No standard individual technology options feasible at FEES for end and mid terrace houses without assuming solar design (i.e. PV area >40%)

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):



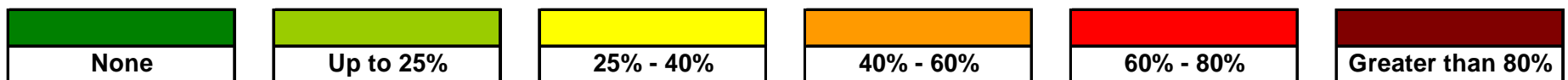


Houses (East Pennines)

| | | Carbon Target = 4 kgCO _{2(e)} /m ² /yr | | | | | | |
|-------------------|--------|--|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| Detached House | FEES | 25.6 | 20.9 | 27.1 | 20.6 | | | |
| | Spec C | 17.5 | 12.7 | 19.8 | 13.2 | | | |
| End Terrace House | FEES | 20.1 | 15.9 | 21.9 | 16.0 | | | |
| | Spec C | 13.5 | 9.1 | 15.8 | 9.8 | | | |
| Mid Terrace House | FEES | 18.2 | 14.0 | 20.1 | 14.2 | | | |
| | Spec C | 12.3 | 7.9 | 14.7 | 8.7 | | | |

- Technically feasible gas and electric options available for all house types at Spec C
- No standard individual technology options feasible at FEES for any house types without assuming solar design

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):



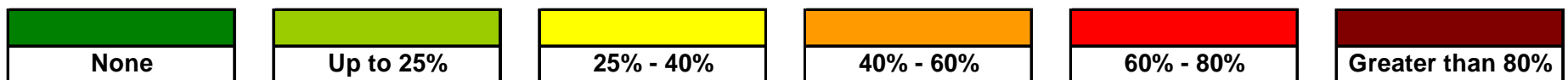


Houses (East Pennines)

| | | Carbon Target = 2 kgCO _{2(e)} /m ² /yr | | | | | | |
|-------------------|--------|--|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| Detached House | FEES | 29.4 | 24.8 | 31.0 | 24.4 | | | |
| | Spec C | 21.3 | 16.6 | 23.7 | 17.1 | | | |
| End Terrace House | FEES | 22.6 | 18.5 | 24.4 | 18.5 | | | |
| | Spec C | 16.0 | 11.6 | 18.3 | 12.3 | | | |
| Mid Terrace House | FEES | 20.7 | 16.5 | 22.6 | 16.7 | | | |
| | Spec C | 14.8 | 10.4 | 17.2 | 11.2 | | | |

- Severe restrictions on feasible standard individual technology options
- No standard individual technology options feasible at FEES for any house types without assuming solar design
- No standard individual technology options feasible for end terrace house without assuming solar design

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):



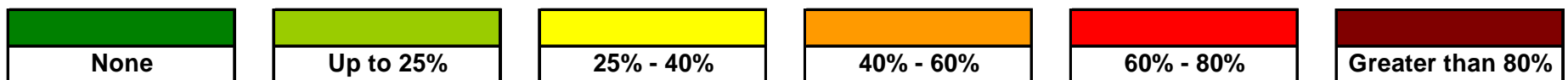


Houses (East Pennines)

| | | Carbon Target = 0 kgCO _{2(e)} /m ² /yr | | | | | | |
|-------------------|--------|--|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| Detached House | FEES | 33.3 | 28.7 | 34.8 | 28.3 | | | |
| | Spec C | 25.2 | 20.4 | 27.5 | 21.0 | | | |
| End Terrace House | FEES | 25.1 | 21.0 | 26.9 | 21.0 | | | |
| | Spec C | 18.5 | 14.1 | 20.8 | 14.8 | | | |
| Mid Terrace House | FEES | 23.2 | 19.0 | 25.1 | 19.2 | | | |
| | Spec C | 17.3 | 12.9 | 19.7 | 13.7 | | | |

- No standard individual technology options feasible at FEES or Spec C for any house types without assuming solar design

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):





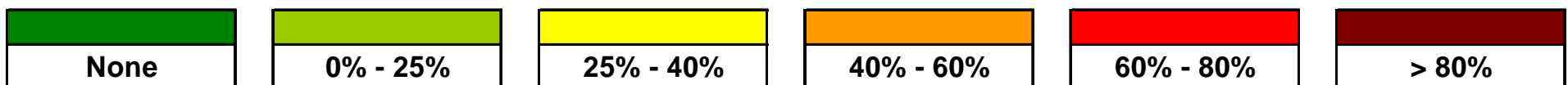
Apartment blocks (East Pennines)

| | | Carbon Target = 14 kgCO _{2(e)} /m ² /yr | | | | | | |
|---------------------|--------|---|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas combi boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| 4-Storey Apt Block | FEES | 157 | 51 | 219 | 68 | -5 | -282 | -40 |
| | Spec C | 33 | -68 | 105 | -41 | -96 | -268 | -191 |
| 8-Storey Apt Block | FEES | 281 | | 414 | | -37 | -567 | -120 |
| | Spec C | 44 | | 192 | | -209 | -539 | -406 |
| 20-Storey Apt Block | FEES | 652 | | 999 | | -132 | -1424 | -362 |
| | Spec C | 76 | | 453 | | -548 | -1351 | -1052 |

- Technically feasible individual gas and electric options available for 4-storey block at FEES and Spec C
- Severe restrictions on standard individual technically feasible options for 8 and 20-storey blocks
- For all blocks, shared solutions are technically feasible and those listed do not require PV

Key

Area of PV required, as percentage of Ground Floor area:



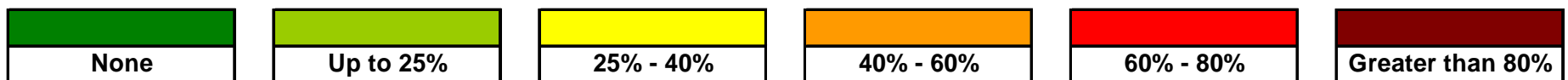


Apartment blocks (East Pennines)

| | | Carbon Target = 12 kgCO _{2(e)} /m ² /yr | | | | | | |
|---------------------|--------|---|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas combi boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| 4-Storey Apt Block | FEES | 215 | 109 | 276 | 125 | 52 | -224 | 17 |
| | Spec C | 90 | -11 | 162 | 17 | -39 | -211 | -134 |
| 8-Storey Apt Block | FEES | 395 | | 528 | | 78 | -453 | -6 |
| | Spec C | 158 | | 306 | | -95 | -425 | -292 |
| 20-Storey Apt Block | FEES | 938 | | 1286 | | 154 | -1138 | -75 |
| | Spec C | 363 | | 739 | | -261 | -1065 | -765 |

- Technically feasible gas and electric options available for 4-storey block at Spec C without assuming solar design
- Severe restrictions on standard individual technically feasible options for 8-storey blocks
- No technically feasible standard individual options available for 20-storey blocks without assuming solar design / façade PV
- For all blocks, shared solutions are technically feasible and many listed do not require PV

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):



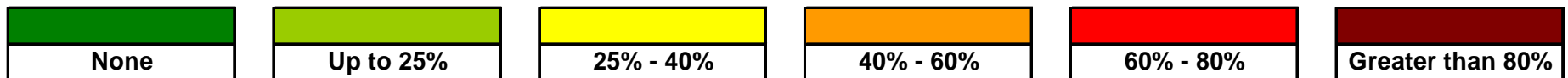


Apartment blocks (East Pennines)

| | | Carbon Target = 10 kgCO _{2(e)} /m ² /yr | | | | | | |
|---------------------|--------|---|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas combi boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| 4-Storey Apt Block | FEES | 272 | 166 | 333 | 182 | 109 | -167 | 74 |
| | Spec C | 147 | 47 | 219 | 74 | 18 | -154 | -76 |
| 8-Storey Apt Block | FEES | 510 | | 643 | | 192 | -338 | 109 |
| | Spec C | 273 | | 421 | | 20 | -310 | -177 |
| 20-Storey Apt Block | FEES | 1224 | | 1572 | | 440 | -852 | 211 |
| | Spec C | 649 | | 1026 | | 25 | -779 | -479 |

- Technically feasible gas and electric options available for 4-storey block, but at Spec C only without assuming solar design
- No technically feasible standard individual options available for 8 and 20-storey blocks without assuming solar design / façade PV
- For all blocks, most shared solutions are technically feasible and some do not require PV

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):



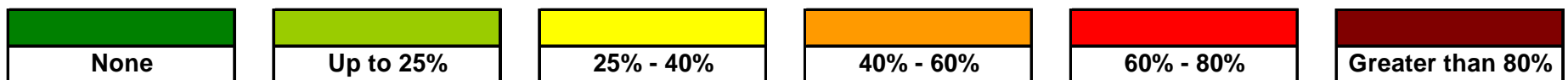


Apartment blocks (East Pennines)

| | | Carbon Target = 8 kgCO _{2(e)} /m ² /yr | | | | | | |
|---------------------|--------|--|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas combi boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| 4-Storey Apt Block | FEES | 329 | 223 | 390 | 240 | 167 | -110 | 132 |
| | Spec C | 205 | 104 | 277 | 131 | 76 | -96 | -19 |
| 8-Storey Apt Block | FEES | 624 | | 757 | | 307 | -224 | 223 |
| | Spec C | 387 | | 535 | | 134 | -195 | -62 |
| 20-Storey Apt Block | FEES | 1511 | | 1858 | | 727 | -565 | 497 |
| | Spec C | 935 | | 1312 | | 311 | -492 | -193 |

- Severe restrictions on technically feasible standard individual options for 4-storey block without assuming solar design
- No technically feasible standard individual options available for 8 and 20-storey blocks without assuming solar design / façade PV
- All listed shared solutions technically feasible for 4-storey block at FEES and Spec C
- For 8+ storey blocks, shared solutions are becoming restricted but some still do not require PV

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):



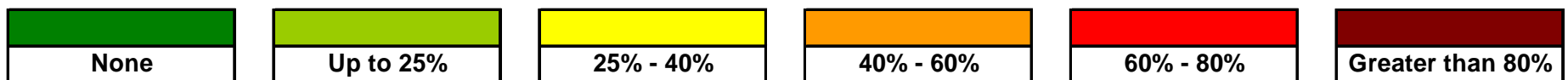


Apartment blocks (East Pennines)

| | | Carbon Target = 6 kgCO _{2(e)} /m ² /yr | | | | | | |
|---------------------|--------|--|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas combi boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| 4-Storey Apt Block | FEES | 386 | 280 | 448 | 297 | 224 | -53 | 189 |
| | Spec C | 262 | 161 | 334 | 188 | 133 | -39 | 38 |
| 8-Storey Apt Block | FEES | 739 | | 872 | | 421 | -109 | 338 |
| | Spec C | 502 | | 650 | | 249 | -81 | 52 |
| 20-Storey Apt Block | FEES | 1797 | | 2145 | | 1013 | -279 | 783 |
| | Spec C | 1222 | | 1598 | | 597 | -206 | 94 |

- No technically feasible standard individual options available for any blocks without assuming solar design / façade PV
- For 4-storey blocks, restrictions seen for listed shared solutions at FEES without assuming solar design, but all shared options available at Spec C
- For 8+ storey blocks, shared solutions are severely restricted (without assuming solar design / façade PV), but biomass still a solution without the need for PV

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):



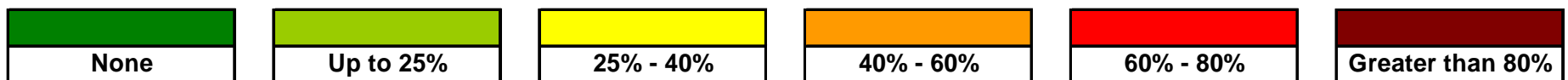


Apartment blocks (East Pennines)

| | | Carbon Target = 4 kgCO _{2(e)} /m ² /yr | | | | | | |
|---------------------|--------|--|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas combi boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| 4-Storey Apt Block | FEES | 444 | 338 | 505 | 354 | 281 | 5 | 246 |
| | Spec C | 319 | 218 | 391 | 246 | 190 | 18 | 95 |
| 8-Storey Apt Block | FEES | 854 | | 986 | | 536 | 5 | 452 |
| | Spec C | 616 | | 764 | | 363 | 34 | 167 |
| 20-Storey Apt Block | FEES | 2083 | | 2431 | | 1299 | 7 | 1070 |
| | Spec C | 1508 | | 1884 | | 884 | 80 | 380 |

- No technically feasible standard individual options available for any blocks
- For all blocks, shared solutions are mainly restricted to only biomass (without assuming solar design / façade PV), and even then require the addition of PV

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):



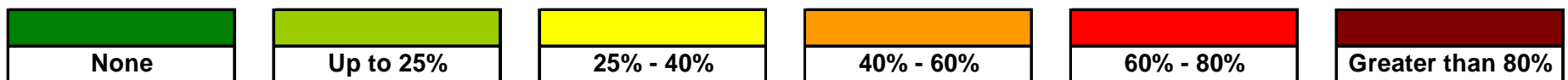


Apartment blocks (East Pennines)

| | | Carbon Target = 2 kgCO _{2(e)} /m ² /yr | | | | | | |
|---------------------|--------|--|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas combi boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| 4-Storey Apt Block | FEES | 501 | 395 | 562 | 411 | 338 | 62 | 304 |
| | Spec C | 376 | 276 | 448 | 303 | 247 | 75 | 153 |
| 8-Storey Apt Block | FEES | 968 | | 1101 | | 650 | 120 | 567 |
| | Spec C | 731 | | 879 | | 478 | 148 | 281 |
| 20-Storey Apt Block | FEES | 2370 | | 2717 | | 1586 | 293 | 1356 |
| | Spec C | 1794 | | 2171 | | 1170 | 366 | 666 |

- No technically feasible standard individual options available for any blocks
- For 4 and 8-storey blocks, shared solutions are mainly restricted to only biomass (without assuming solar design / façade PV), and even then require the addition of PV
- No technically feasible standard solutions available for 20-storey block

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):





Apartment blocks (East Pennines)

| | | Carbon Target = 0 kgCO _{2(e)} /m ² /yr | | | | | | |
|---------------------|--------|--|------------------|------|------------|------------------|----------------|---------|
| | | Individual solutions | | | | Shared solutions | | |
| | | Gas combi boiler | Gas boiler + SHW | ASHP | ASHP + SHW | GSHP | Biomass boiler | Gas CHP |
| 4-Storey Apt Block | FEES | 558 | 452 | 619 | 469 | 396 | 119 | 361 |
| | Spec C | 434 | 333 | 506 | 360 | 305 | 133 | 210 |
| 8-Storey Apt Block | FEES | 1083 | | 1215 | | 765 | 234 | 681 |
| | Spec C | 845 | | 994 | | 593 | 263 | 396 |
| 20-Storey Apt Block | FEES | 2656 | | 3003 | | 1872 | 580 | 1642 |
| | Spec C | 2080 | | 2457 | | 1456 | 653 | 953 |

- No technically feasible standard individual options available for any blocks
- For 4-storey blocks, shared solutions are restricted to only biomass, and even then require the addition of PV
- No technically feasible standard solutions available for 8+ storey blocks

Key: Area of PV required, as percentage of Ground Floor area (SE/SW facing, 45deg pitch, none/ v. little overshadowing):

