Tyndall Centre
for Climate Change Research

Towards a 2℃ future: emission reduction scenarios for Wales

A research report by The Tyndall Centre, University of Manchester

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Report commissioned by the Climate change Commission of the Welsh Assembly Government

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Executive Summary

Introduction

The Welsh Assembly Government is already demonstrating strong leadership on sustainable development, putting associated principles at the heart of the Assembly Government vision for the future. Climate change is a central issue within the recently published *One Wales: One Planet, The Sustainable Development Scheme of the Welsh Assembly Government*, as is the desire to respond to its challenges in a meaningful way. A more detailed programme of action for dealing with climate impacts is being prepared and the *Climate Change Strategy* is due for publication before the end of 2009. This current work, Commissioned by the Climate Change Commission for Wales working with the Welsh Assembly Government, will contribute to its development.

The research explored the implications of annual emissions reductions beyond the 3% by 2011 already pledged, and informed by wide academic debate on the need to limit temperature rise to a maximum 2^{o}C to avoid 'dangerous' climate change.

The primary objectives of the project were to:

- gain a better understanding of the implications of different emission reduction scenarios for people, communities and organisations in Wales
- identify, for key sectors, the broad practical impact of these different scenarios and the type and scope of policy interventions, regulation and financial incentives and penalties that would be required
- assess current Welsh proposals against the demands accompanying a 2℃ commitment, including whether they "lock-out" even greater reductions in key areas in the future
- undertake a provisional appraisal of the barriers, challenges, opportunities and costs in each key area

Approach

The analysis is based on a 'backcasting' methodology used as a means of achieving a preselected endpoint target and accompanying pathway. For this project, the targets are the politically and scientifically-derived annual rates of decarbonisation (3% and 9% respectively) and an intermediate, mid-way rate (6%). Tasks included: a review of key documents, a focus on business, transport, agriculture, residential, public and waste management sectors; determination of baselines; identification of actions (existing and proposed) to bridge the gap between the baseline target pathways; grouping of actions to develop the Tyndall–WAG 'core' scenario; alternative scenarios; analysis using social and economic criteria e.g. job creation, costs; and a stakeholder workshop. A number of key limitations and assumptions were identified:

- Wales was considered as an 'island' with no buyout or offsetting of emissions, no emissions allowance obtained through trading in the EU ETS and consumption rather than source-based data on electricity emissions used.

- Both core and alternative scenarios assume successful implementation of the *Renewable Energy Route Map.*
- Biological sequestration is excluded.
- Actions to reduce international aviation and shipping emissions are excluded.

Analysis

A detailed analysis of the opportunities for emissions reductions and associated impacts, resulting from existing and proposed specific actions for the residential, transport, business and agriculture sectors, provides the basis for the core scenario and alternative scenarios for 2025 (relative to 2010). The results are presented both textually and visually.

Key conclusions

Wales as an exemplar for 2℃ mitigation

- Whilst in the longer term, research, development and deployment of *new* low-carbon technologies are a prerequisite of sustaining reduction rates, Wales has the capacity and wherewithal to begin the transition to a 2℃ emission reduction pathway as early as 2011.
- The financial implications will be substantial, however, there will be significant and relatively early economic returns arising from increased resilience to high energy prices, tax revenue from increased employment and lower adaptation costs.
- The analysis within this report is supported by broader Tyndall and other research suggesting significant medium and long-term economic dividends to those nations making an early transition to a low-carbon society. Wales is, in many respects, well placed politically and geographically to provide an evidence-based exemplar of a nation successfully transitioning to a 2℃ future.

Achieving the 9% pathway: headline conclusions by sector

- **Residential**: With reductions equivalent to 14.5% p.a. the residential sector's contribution is significant. Substantial investment and innovative programmes are required to ensure implementation with minimum disruption to people's lives. All new homes built from 2011 are zero-carbon and around 60% of existing homes in Wales are fitted with heat pump technology, meeting all heating and 50% of hot water needs, while a further 20% will have solar hot water heating. Houses are well insulated and thermostats are set lower. The measures are not particularly new or innovative but need to be applied sympathetically and often in novel ways to mitigate objectives and maximise 'buy-in across the sector. The result is a dramatic improvement in housing standards with people living in more comfortable houses, using less energy and potentially having lower bills.
- **Transport**: Measures to reduce emissions ensure that the target 9% p.a. is achieved. Improvements in technology are central to this change, with optimistic estimates for what can be achieved in this timeframe being realised. Making this

happen in Wales, without equally significant change elsewhere, is difficult and innovative approaches to incentivising consumer choice are needed. In addition, a significant reduction in demand, with vehicle kilometres reduced by over 40% compared to 2010 levels, is required. This calls for a major shift in the way that people get around and the investment to make this happen. Rail and bus travel is the mode of choice for inter-city travel and there is progress in changing the towns and cities of Wales to 'design out' car trips for daily tasks. Personal mobility is not compromised, but it is likely that certain trips come to be seen as unnecessary. An increase in cycling and walking brings important health benefits.

- **Business**: 9% annual reductions are theoretically attainable but difficult to achieve in practice. Pushing well recognised measures to their limit still leaves a significant shortfall compared to the reductions required. Bridging this gap calls for two new approaches. Firstly, process-based carbon capture and storage plays a significant role and, while this is not a 'new' technology, the current rate of deployment suggests this is an optimistic assumption. Secondly, industrial fossil fuel use is replaced by electricity drawn from the zero-carbon grid. This results in additional demand and will entail an expansion of current plans for renewable energy. Although the challenges of achieving these emission reductions are clear, there are no significant structural changes imposed on the business sector in Wales.
- **Agriculture**: The reductions achieved for agriculture are lower than for any other sector due to its fundamentally different nature. The role that livestock play in Welsh agriculture makes emissions reductions difficult and means that a significant fall in livestock numbers is inevitable, along with changes in the way remaining livestock are managed. However, this is only achieved through parallel action on consumption, with replacement of meat and dairy in the diet with other lower impact food. The 30% of food that ends up as waste is cut drastically and the volume of consumption further reduced through improved diets. Compared with other sectors, there is greater uncertainty in assessing potential emission reductions, making investment in research into all possibilities for low-carbon farming a necessity.
- **Waste**: By implementing a zero-waste policy for 2025, emissions from the waste sector are reduced beyond the 9% target. Policies to achieve this have already been set out in the consultation document *Towards Zero Waste*, albeit over a longer timescale. This earlier target has been considered in appraisals of *Towards Zero Waste* but identified to be too difficult to achieve. Efforts to follow a 9% pathway will require implementation of existing waste strategy to be accelerated.
- **Public**: By going zero-carbon, the contribution of the public sector is well beyond 9% p.a. reductions. Although the public sector makes a minor contribution to overall emissions, this leadership role is a vital signal of intent.

Issues for policymakers

- A short-term and narrow financial assessment suggests delivering 3% mitigation now (as the least cost option), whilst an economic assessment of revisiting

sectors in the future to implement higher mitigation rates would likely favour an early adoption of higher rates.

- There is a high probability that the price of energy will rise significantly over the coming decade and beyond. Moreover, with increasing demand for reducing reserves of finite fossil fuels, price volatility is also projected to increase. Consequently an indirect benefit of an early transition to a low-carbon Wales, in line with the 9% scenarios and based on highly efficient industry and indigenous energy production, would be to insulate Wales from the otherwise significant implications of such changes.
- A more strategic benefit of an early transition to high mitigation rates could be an accompanying transition of Wales' industrial and manufacturing capacity towards low-carbon demand and supply technologies. In this regard, a domestic Welsh market for such technologies, supported by strong Welsh Assembly Government regulation, could offer sufficient security of demand to incentivise the private sector to invest in indigenous production capacity.
- The near-term costs of implementing radical emissions reductions within Wales have the potential to contribute to triggering wider international mitigation responses and thereby help avoid the extreme social and economic repercussions of high global temperatures.
- There are clearly important changes to the Welsh energy system necessary to achieve the higher emissions reduction levels (6% to 9% p.a.). However, where alternatives exist, it is generally preferable to initiate changes in relation to energy demand rather than supply, as the former maintains flexibility in the system whilst the latter typically involves greater technology lock-in.
- The level of ambition reflected in current policy developments puts Wales at the forefront of action on climate change. That this is not enough to meet the Sustainable Wales vision is not a criticism of current action, but rather recognition that the basis for this action has rapidly being overtaken by the evidence for more urgent and radical change. This report is an early assessment of what would be necessary for Wales to meet this new challenge.

Further work

- A programme of research to explore the potential for long-term biological sequestration – particularly given the barriers to the 9% scenario for agriculture and land use. This exploration must be systems based, relating the science underpinning sequestration to different emissions and temperature scenarios with different social and land-use responses.
- A detailed analysis of the social, environmental and economic costs of the Tyndall–WAG scenarios is necessary for both strategic budgeting and to tailor support to those individuals and communities negatively impacted by the accompanying measures. This assessment must extend well beyond conventional 'financial' approaches and consider issues of system interdependencies and complexity, as well as relative impacts to the more vulnerable communities and threatened eco-systems.
- A system level exploration of agriculture, linked to energy production, material production, local tourism and food production, identifying synergies/conflicts.

1. Introduction

"Our Vision of a Sustainable Wales is one where Wales:

> *lives within its environmental limits, using only its fair share of the earth's resources so that our ecological footprint is reduced to the global average availability of resources, and we are resilient to the impacts of climate change*"
>
> One Wales: One Planet p.17 - 2009

1.1 Climate change from long-term targets to emission pathways

The European Union (EU) regularly reiterates its commitment, collectively and within individual member states, to make a 'fair' contribution to 'avoiding dangerous climate change.' In the absence of a global consensus on an appropriate metric for delineating dangerous from acceptable climate change, European leaders have committed to mitigate emissions in line with ensuring that *"global average temperature increases do not exceed pre-industrial levels by more than 2℃"* .[1]

Within the EU, the United Kingdom (UK) has taken a particularly strong stance on climate change. The publication of the Royal Commission for Environmental Pollution's report '*Energy—the changing climate*' (RCEP 2000) initiated a series of Government sponsored assessments of the UK's contribution to the 2℃ threshold. Amongst others, the Performance and Innovation Unit's analysis and the modelling work of the Intergovernmental Analysts Group, led ultimately to the 2003 Energy White Paper's explicit correlation between a 60% reduction in UK emissions, stabilisation at 550ppmv and keeping temperature rise to below 2℃. [2]

Despite further reports and improvements in the scientific understanding of climate change, the target to reduce UK emissions by 60% by 2050 remained the centre piece of UK climate policy until the Climate Change Act of 2008. The Act established the Committee on Climate Change (CCC) to provide independent advice to Government on achieving its greenhouse gas emissions (GHG) reduction targets. In its first report, the CCC not only recommended increasing the 2050 target from 60% to 80%, but more significantly expressly considered the crucial importance of cumulative emissions, proposing a series of carbon budgets for the UK to 2022. Both the 80% target and the CCC's 'intermediate' budgets have subsequently been enshrined in legislation.

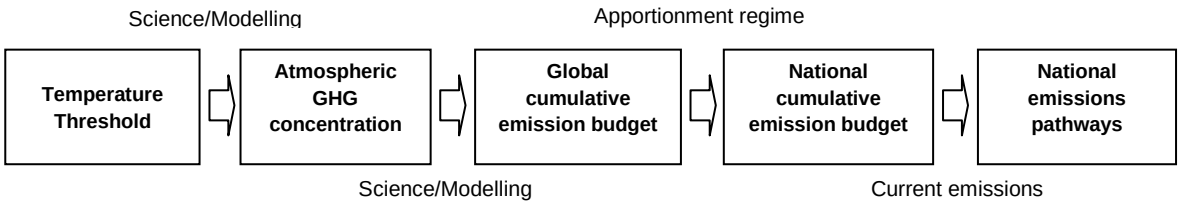
1.2 2℃ and setting emissions pathways

The publication in summer 2009 of the government's *Low Carbon Transition Plan* reinforced the UK's strong position and leadership on climate change. In particular the Plan made clear the UK's unambiguous commitment to the integrity of the 2℃ threshold when stating "...to avoid the most dangerous impacts of climate change,

[1] European Commission 2007.
[2] DTI 2003, pp 28-29.

average global temperatures *must* rise no more than 2℃"[3]. This position was subsequently reiterated by Ed Miliband, the Secretary of State for Energy and Climate Change, when, in reference to the forthcoming Copenhagen meeting, he stated, "we should limit climate change to a *maximum* of two degrees"[4]; a stance that reflects the European position that "the EU must adopt the necessary domestic measures … to *ensure* that global average temperature increases *do not* exceed pre-industrial levels by more than 2℃" [5] (emphasis added).

Figure 1.1: The 'correlation trail' for setting emission pathways



Source: adapted from Anderson & Bows, 2007

The analysis outlined in this report reflects the explicit commitment of both the UK Government and the EU to the integrity of 2℃. In this regard at least it departs from the UK CCC's analysis, premised, as it is, on around a 60% chance of exceeding 2℃. Whilst the CCC's analysis corresponds with UK annual emission reduction rates of around 3% per annum (p.a.) from 2008, applying the same analytical logic to the probabilities implied in the Government's statements[6], raises the emission reduction rates to at least 9% annually.

Figure 1.1 shows the logical correlation trail from a desired temperature threshold (in this case 2℃) to a national emissions pathway. The analysis in this report proceeds from a global cumulative emissions budget based on the range of global emissions budgets within IPCC AR4 associated with 450ppmvCO2e stabilisation (IPCC 2007)[7]. The appropriate national emissions budget is allocated according to a modified version of contraction and convergence (Bows and Anderson 2008). and corresponds closely with the apportionment regimes used within UK Government documents from the

[3] DECC 2009b, p.5.
[4] DECC 2009a
[5] European Commission 2007
[6] The following statement is taken from Tyndall Briefing Note 40: "Whilst the language often used in Government statements evidently suggests a zero to low probability of exceeding 2℃, the Government is not explicit in quantifying what probabilities underpin their statements. In the absence of such quantification, probabilities can be inferred based on the approach developed for the IPCC's reports on climate change, whereby a correlation is made between the language of likelihood and quantified probabilities. Following this logic even a conservative judgement would suggest that Government statements could reasonably be quantified as representing a 5% to 33% chance of exceeding 2℃." (Anderson et al, 2009).
[7] The full range is used, from approximately 1400–2200GtCO2e for 2000-2100, but only those that *include* carbon cycle feedbacks, which, on average, reduce the values by about 27% from those *without* feedbacks (Anderson and Bows 2008).

Royal Commission on Environmental Pollution's 22nd report (Energy - the changing climate; 2000) through to more recent Committee on Climate Change reports

The implications of the different probabilities of 2℃ are difficult to exaggerate. Applying the CCC's probabilities gives 2020 and 2050 emission reductions of around 40% and 80% respectively, relative to 1990. By contrast, extrapolating the Government's oft-cited stance on not exceeding 2℃ has reduction levels rising to almost 70% by 2020 and virtually 100% by 2050, again relative to 1990. This latter scale of reductions corresponds with rates proposed in earlier Tyndall research for emissions from all sectors[8].

1.3 The context of this report: why 3%, 6% & 9%?

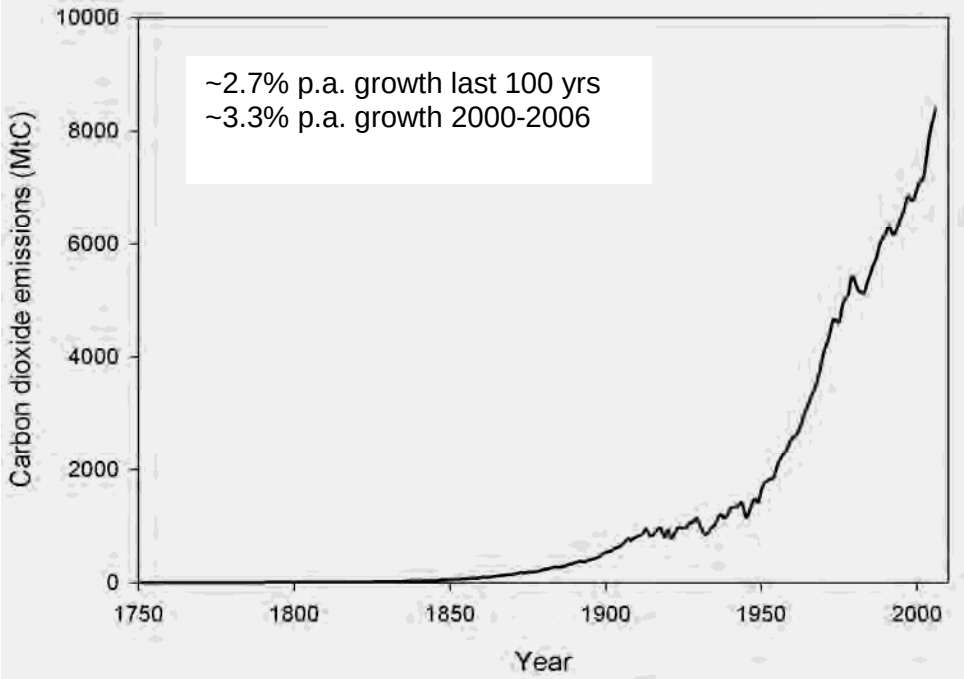
Notwithstanding the high national and international profile of climate change and increasing dialogue on emissions targets and policies, global GHG emissions continue to rise. Moreover, the rate of global emission growth since 2000 is well above that of the previous 100-year average (figure 1.2). So, despite climate change rising up the political agenda, not only have emissions continued to grow but the rate of growth has also increased. Extreme events have periodically moderated such growth, for example, the economic decline associated with the events of the 11th September 2001 and the more prolonged implications of the 2009 global economic downturn. The challenge is to build on emission reductions, not through ad-hoc recessions but through coherent, comprehensive and strategic mitigation and adaptation policies. Only with an urgent and stringent framework that addresses cumulative emissions from all sectors will the more severe implications of climate change be avoided. The UK Climate Change Act and the subsequent report from the CCC are important landmarks in acknowledging the scale of the challenge, but nonetheless they fall far short of what is necessary to meet the UK and EU's commitment to 'not exceeding the 2℃' threshold.

With specific focus on Wales and recognising the shortfall in the 2℃ framing of existing UK and EU climate change policy, this report provides a high-level assessment of how Wales may be able to achieve:

i. the Welsh Assembly Government's politically-derived 3% p.a. emissions reductions
ii. scientifically-informed 9% p.a. emissions reductions
iii. a mid-way (6% p.a.) reduction rate

[8] Anderson and Bows 2008; Anderson et al, 2008

Figure 1.2: Global emission growth of carbon dioxide from pre-industrial times to the present day



2. The approach

This section gives an overview of the report team's approach to assessing how Wales may be able to achieve 3%, 6% and 9% p.a. emissions reductions.

2.1 Scope

Following the brief, the key objectives of the project are to:

- gain a better understanding of the implications of different emission reduction scenarios for people, communities and organisations in Wales
- for key sectors, identify the broad themes around the practical impact these different scenarios and the type and scope of policy interventions, regulation and financial incentives and penalties that would be required
- test out current proposals against this, in particular that current proposals do not shut the door on even greater reductions in key areas in the future
- get a sense of the costs, barriers, challenges and opportunities in each key area

The project developed scenarios for the implications of annual emission reductions of 3%, 6% and 9% p.a., exploring the following questions:

i. What would the world look like under the different scenarios?
ii. What would need to happen to achieve them?
iii. What are the implications of these scenarios?
iv. How do the current proposals for action to reduce emissions map onto the actions implied by these scenarios?

Thus, the Tyndall–WAG project is a high level scenario generation and comparison exercise, intended to assess the broad technical, social and economic feasibility of meeting demanding emissions reductions objectives. It should be noted that the guiding objective of devising the scenarios is to represent possible versions of Wales in which the desired reductions occur, while keeping social, environmental and economic disbenefits to a minimum. However, it is not within the scope of this work to advance strategies for smoothing the transition to the full implementation of any given scenario. It is inevitable that in some cases, the extremely challenging task of decarbonising certain sectors will give rise to conflicts with public acceptance and sustainability criteria in the short-term.

2.2 Method

The analysis is based on a 'backcasting' methodology, a useful technique for assessing possible means of achieving an endpoint target that has been preselected according to normative values. For this project, the relevant targets are the politically and scientifically-derived rates of decarbonisation (3% and 9% respectively) and an intermediate, mid-way rate (6%).

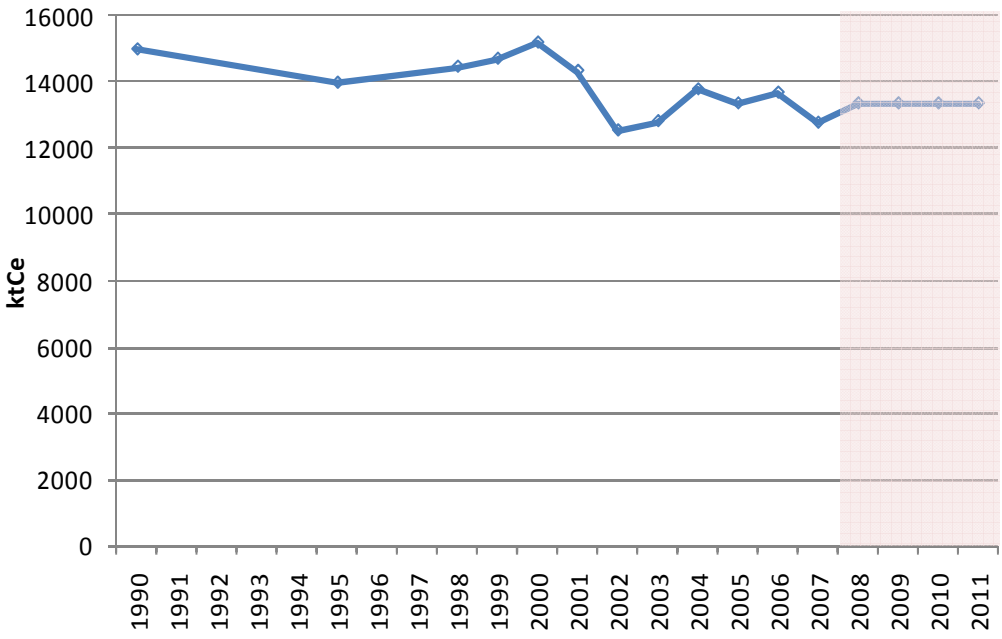
2.2.1 Data review

A number of key documents relating to Wales were identified, reviewed and summarised as a basis for the developing project. The emphasis was on the identification of primary emissions datasets for specific sectors, and estimated or known emissions reductions associated with specific actions or policy options.

2.2.2 Determining baselines

Baseline data for GHG emissions were collated and plotted as a series of graphs to reflect trends for sectors included in the study, anomalies and relative proportions contributing to emissions from Wales to date (see figures 2.1 and 2.2). For consistency, the report uses 2010 throughout as its 'start' year; the end of 2010 / start of 2011 being considered the earliest possible commencement of any system-wide programme of emissions reduction.

Figure 2.1: Total basket of six GHG emissions for Wales (producer-based, with projection from 2007)



Historical data from NAEI (AEA 2009), projection based on AEA 2008.

National and sectoral emissions in 2010, and for the period to 2025, are based on AEA's emissions projections for Wales, which are in turn disaggregated from the UK

energy projections in BERR's 2007 Energy White Paper and UEP30, among other sources (AEA 2008)[9].

Primary emissions from electricity generation were removed from the national total, with emissions from electricity production added to the projected 2010 individual sectoral emissions in proportion to projected sectoral electricity consumption (table 2.1). Other assumptions relating to emissions from electricity generation are discussed further in section 2.3.2.

Table 2.1: Composition of 2010 emissions baseline[10]

	Direct emissions	Emissions from electricity	Total emissions
Residential	1050	850	1900
Business	4400	1020	5420
Public	105	140	245
Agriculture	1550		1550
Transport	1840		1840
Waste	380		380
2010 baseline	9325	2010	**11335**

2.2.3 Treatment of sectors

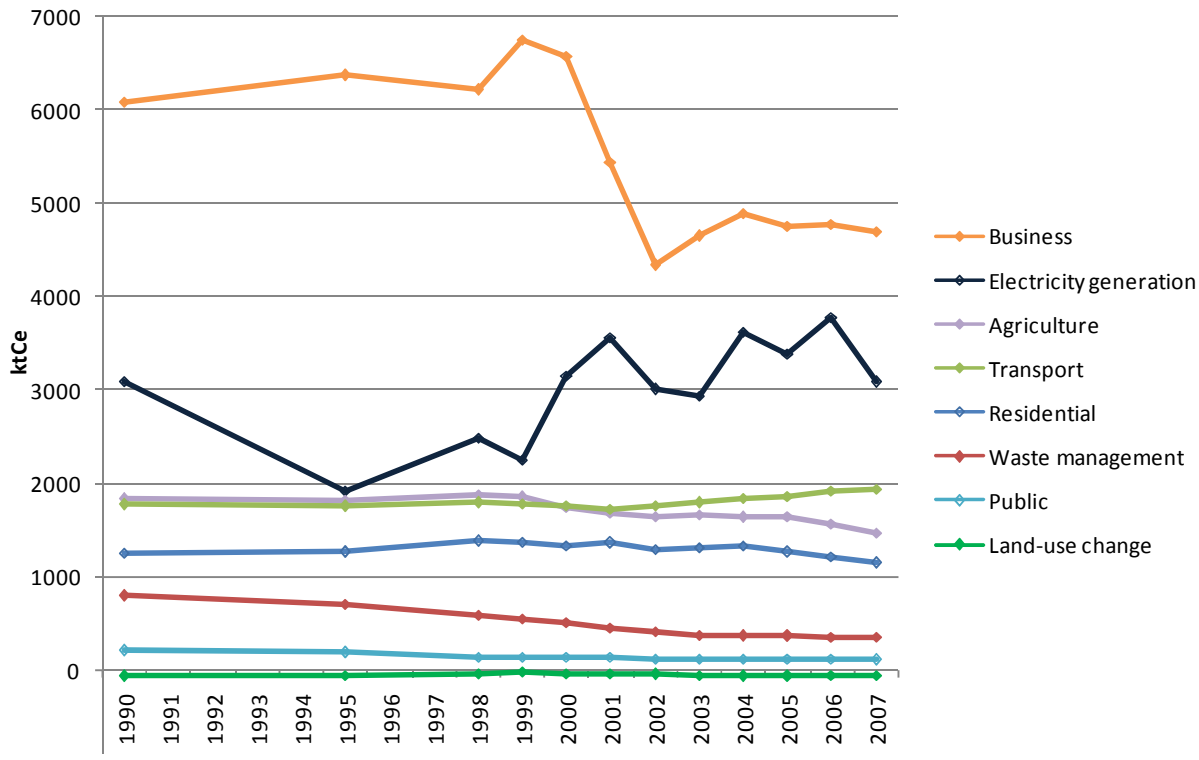
As shown in figure 2.2, the two biggest emitting sectors in Wales, by a considerable margin, are business and electricity generation. Emissions from electricity are dealt with by the *Renewable Energy Route Map*, full implementation of which will result in Wales' entire national electricity demand being fulfilled by zero-carbon generation by 2025. Additional abatement measures applying to power generation have not been sought in the scenarios for this report; concentrating instead on identifying opportunities to reduce energy demand in each sector.

At the other end of the scale, the public sector is the smallest emitter but has the potential to significantly influence other sectors by demonstrating emission-reduction good-practice and leadership. This important role was recognised within the report through an anticipation that public sector institutions would decarbonise by 2025.

Given the above the primary analysis therefore focused on the remaining sectors, namely: business, transport, agriculture, residential and waste management (in descending order of emissions).

[9] It is understood that the Welsh Assembly Government intends to use the mean emissions values for 2003 to 2007 as the formal baseline for the 3% annual decrement. At the national level, the 2010 projections selected for use in this report are closely aligned to the 2005-2007 mean value.
[10] Source: AEA 2008

Figure 2.2: Historical GHG emissions for Wales by sector



Source: NAEI (AEA 2009)

2.2.4 Timescales

Major emissions reductions are required as a matter of urgency from wealthy, industrialised ('Annex 1') countries. The current project has been guided by the need to achieve the bulk of emissions reductions in the short to medium-term (by 2025). Longer-term reductions will require a 'ratchet down' to more or less complete decarbonisation (excluding food production) by between 2030 and 2050[11].

2.2.5 Gap analysis

A notional emissions 'baseline' for 2025 was obtained for Wales and for each of the key sectors by subtracting the emissions reductions associated with existing mitigation policies from projected emissions trends for 2010-2025 (based on AEA 2008, see section 2.2.2). This enabled detailed analysis of the potential impacts of additional actions in the near-term. Emissions reduction figures already within the public realm were used wherever possible[12].

[11] The exact decarbonisation date and emission profile will be determined by population, economic and other characteristics of the nation in question relative to the Annex 1 'average' (New et al, 2009).
[12] Calculations available on request.

A variety of potential further actions (with associated emissions savings), beyond existing 'firm and funded' policies, was also explored within the literature. A comprehensive list of existing and suggested actions, and their associated emissions reductions, was compiled for each sector and reviewed, with overlapping activities identified and accounted for where possible. The data were subsequently used to build a framework on which to base decarbonisation pathways based on 3%, 6% and 9% p.a. targets, for each of the defined sectors and for Wales as a whole.

Numerous additional actions were researched and developed in order make up shortfalls and bridge the gap between the emissions savings delivered by the proposed actions and the target pathways. These new actions were linked to the intensification of already proposed actions, increasing penetration of renewable electricity and greater behaviour change.

2.2.6 The core scenario

All the actions identified within the research or newly defined were subsequently combined into packages of measures for each sector, which, taken together, constitute a scenario where Wales achieves 3%, 6% and 9% p.a. emissions reductions between 2011 and 2025. This is referred to as the Tyndall–WAG core scenario (hereafter the core scenario).

The core scenario is premised on a concerted push to realise the maximum possible efficiency of all existing technology, in parallel with a complementary reduction in energy demand and / or consumption across all sectors. It is essentially accumulative, insofar as it draws on a variety of abatement opportunities and does not rely on the introduction of any particular new, as yet unproven, technology to achieve the requisite emissions savings. The second key feature of the core scenario is its additive approach to meeting the increasing challenges of 3%, 6% and 9%, whereby, successive pathways build on each preceding 'package' of measures.

The selection of specific actions to make up the core scenario was dependent on the availability of data, likelihood of implementation (based on the judgement of other authors as well as the report team), the scale of potential reductions and workshop discussions (see below). The possible positive and negative implications of actions, synergies and potential interactions between individual actions and sectors also informed the overall package. Whilst preference was given to the quickest, most effective and efficient measures, 'win–win' measures alone were not sufficient for any of the sectors, even for the 3% pathway. This led to the need to push some sectors harder than others and beyond their apparent 'fair share'. The relative carbon reduction for each reflected in the core scenario therefore varies considerably and emissions for sectors are not proportionally reduced. For example, the residential and public sectors contribute savings above the mean rate of reduction, whereas agriculture and business contribute below the mean (figure 2.3).

The scenarios presented in sections 3 and 4 of this report are not prescribed, nor are they likely to occur without strenuous effort from the government, private sector, individual citizens and NGOs. Therefore, to avoid overtones of 'what ought to happen'

or 'what will happen', the scenarios are discussed in the present tense – as if the 3%, 6% or 9% pathway has been adopted and the changes and actions have actually occurred.

2.2.7 The alternative scenarios

Alternative scenarios to the core scenario are presented in brief for comparison. They are provided in recognition that there are other alternative futures that could reach the 3%, 6% and 9% targets. These alternative approaches were defined with the particular characteristics of each sector in mind. Common themes include innovation and technology acceleration, greater sharing of resources such as transport and housing, and a higher degree of economic and social restructuring than presented in the core scenario.

2.2.8 Analysis criteria

The core and alternative scenarios are analysed in terms of a number of key criteria, as compared to the current situation in Wales (the reference case). The following criteria form the basis of the analysis, and permit comparison between scenarios.

Job creation	Considers opportunities for new employment. Possible job losses are also included in this category.
Capital expenditure	Captures the up-front costs entailed in the scenario, in terms of new infrastructure, plant, technology and skills.
Running costs	Estimates the ongoing operational costs in a given scenario, again in terms of new infrastructure, plant, technology and skills.
New skills requirement	Indicates the gap between the skills currently available within Wales' workforce and those required to implement the scenario.
Degree of speculation	Describes the level of uncertainty involved in the scenario in terms of reliance on new, as yet unproven technologies (specifically not behaviour change).
Embedded emissions	Assesses emissions for the scenario as a whole, including emissions arising from consumption of goods and services produced outside of Wales.
Aesthetics	Gives an impression of changes to the visual appearance of Wales in the scenario (NB this criterion is not given a positive or negative value as an advantage or disadvantage).
Living standards	Considers the effects of the scenario on the welfare and comfort of individual citizens.

2.2.9 The workshop

The workshop held at the Welsh Assembly Government offices in Cardiff on 19th October 2009, with policymakers and other stakeholders, provided a mechanism for presenting the draft scenarios, gathering additional information and refinement of the approach and scenarios. Feedback from this event is reported here as Appendix 1.

2.3 Limitations and assumptions

2.3.1 Island Wales

For the purpose of the study, a case was made for considering Wales as an 'island'. In practical terms for the core and alternative scenarios, this means that:

- there is no buyout or offsetting of emissions
- no emissions allowance is obtained through trading in the EU ETS
- consumption rather than source-based data on electricity emissions are used

However, additional emissions arising from any increases in domestic agricultural production are not considered in the scenarios presented. It is possible that additional production will be required to offset potential productivity declines elsewhere in Europe or the global food supply chain.

This 'Island Wales meta-scenario' means that in achieving its abatement obligation indigenously, Wales dispenses with relying on other countries to make an effort on its behalf, the implication being that Wales leads the world in climate change mitigation.

2.3.2 Zero-carbon grid

The key policy document addressing emissions from electricity production is the *Renewable Energy Route Map*, the primary goal of which is to produce Wales' entire electricity requirement from renewable sources by 2025. Both core and alternative scenarios assume successful implementation of the *Renewable Energy Route Map*. Thus, provided Wales generates its domestic requirement of electricity from renewable sources, then it can be reasonably claimed that the Welsh electricity supply is zero-carbon by 2025. It is of course recognised that, in reality, Wales will still be receiving electricity through the grid and that there will be emissions associated with it. However, by following the *Route Map*, Wales would be generating more renewable electricity than it consumes in 2025, and while it would also be generating some non-renewable power, the view was taken that in essence this could be seen as supplying the rest of the UK. In principle at least, Welsh electricity consumption would be virtually carbon-free by 2025 and hence have zero carbon intensity. It is therefore a political argument for Wales to make the claim of being zero-carbon.

It is also acknowledged that there are potentially serious impediments to achieving the full extent of the emissions savings set out in the *Route Map*. However, the scale of

emissions reduction required by the UK and EU 'commitment' to avoiding 2℃ is such that, more or less, complete decarbonisation of the energy system is the foremost priority. As such the report team commend the Welsh Assembly Government's *Route Map*, while noting that it will not be accomplished without some considerable effort.

Based on these assumptions, the following approach was taken:

i. Projected 2010 electricity emissions were added to source-based emissions values for each sector in proportion to projected sectoral electricity demand
ii. Electricity-based emissions were subtracted from projected 2025 sectoral emissions (as per full implementation of the *Route Map*), giving the notional 2025 'baselines' against which emissions savings from the various actions were calculated for each sector.
iii. The sum of all emissions from all sectors (including emissions from their electricity consumption) in 2010 becomes the 'baseline'.

The analysis in this report could be re-run assuming the *Route Map* was not achieved – but this would be to question the commitment to the *Route Map* and for this report that was not considered appropriate. Furthermore, if Wales is to meet the target reduction pathways considered, it will need to ensure that the full potential of the *Route Map is* met, if not exceeded, so that additional energy demands can be switched to low- / zero-carbon electricity (for example transport and heat).

2.3.3 Other key assumptions and limitations

The core scenario also assumes:

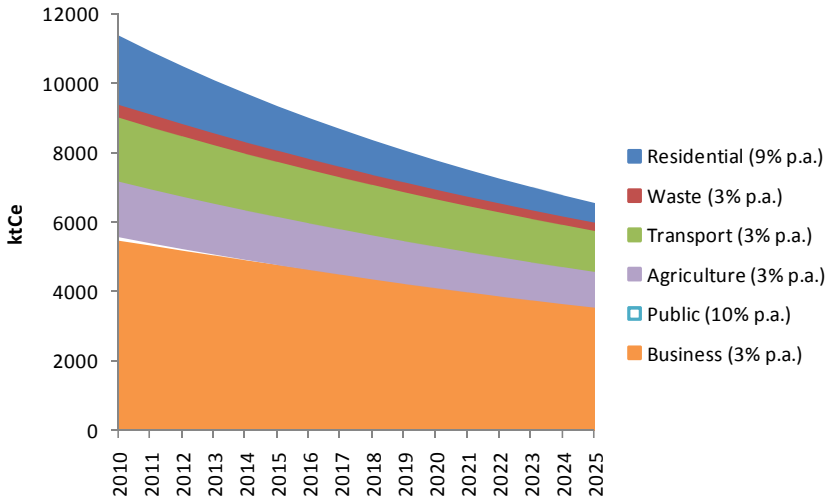
- there is no biological sequestration
- actions to reduce *international* aviation and shipping emissions are excluded[13]

[13] This is at the request of the Welsh Assembly Government. Early assessments put all international and domestic aviation and shipping at around 4% of total emissions from Wales. This is likely to be an underestimate as emissions from shipping are based on international bunker fuel sales, which, as previous Tyndall work has demonstrated, estimates shipping emissions at much lower levels than the emissions associated with imported goods.

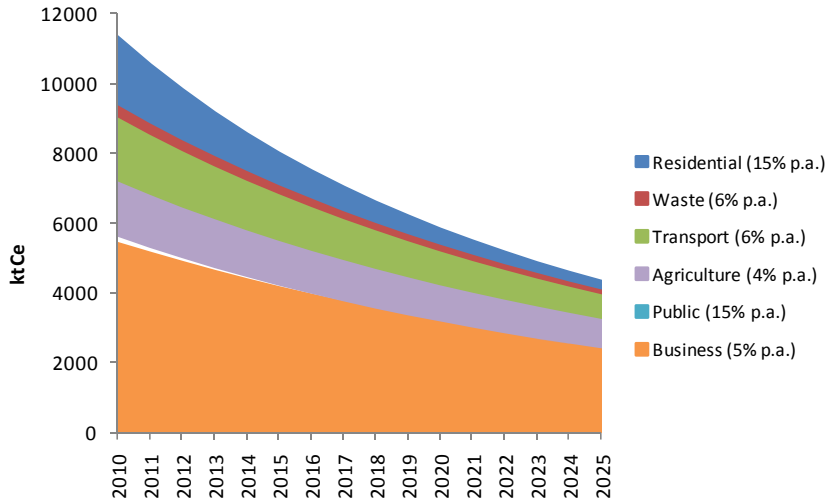
Figure 2.3: Sectoral contributions to the core scenario emissions reductions in 3%, 6% and 9% p.a. pathways

2.3.4

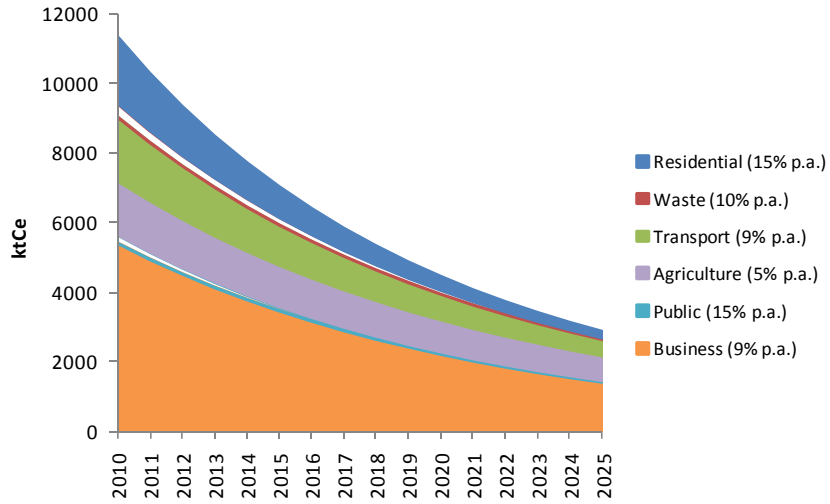
3%



6%



9%



3. Analysis

This section presents analysis of the measures available to Wales to reduce emissions at a rate consistent with the three pathways of the core scenario (3% p.a., 6% p.a. and 9% p.a.), along with alternative 9% scenarios for comparison.

3.1 3%, 6% and 9% reduction pathways

Assuming Wales commences a programme of measures on 1st of January 2011, figure 3.1 illustrates the rapidly diverging emissions savings returned by 3%, 6% and 9% pathways. This is made clearer still in table 3.1 and figure 3.2. The main body of the analysis focuses on the near term to 2025, seeking opportunities to make rapid cuts and capitalise on the cumulative emissions savings delivered by early action. Mid and long-term reductions are also considered on the basis that the largest cuts should be made immediately. The analysis, and subsequent level of detail, is guided by recognition that even a 'reasonable' chance of avoiding 'dangerous' climate change demands that the higher 9% rate of decarbonisation is observed.

Figure 3.1: Comparison of the annual rate carbon reduction required for 3%, 6% and 9% p.a. pathways

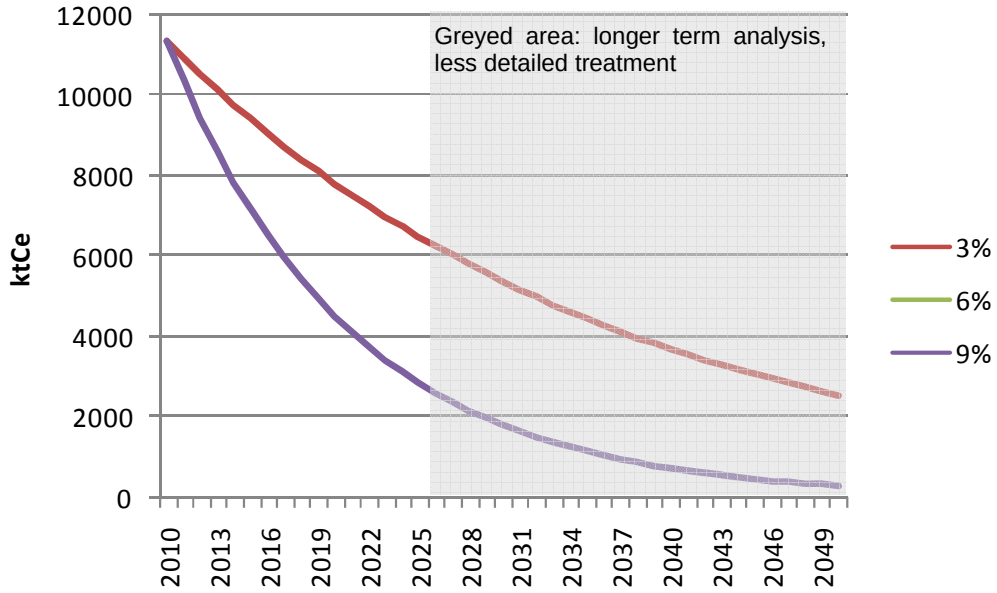


Table 3.1: Approximate % emissions reductions after each decade for 3%, 6% and 9% p.a. pathways			
	3% p.a.	**6% p.a.**	**9% p.a.**
2020	30	50	60
2030	50	70	90
2040	60	80	94
2050	70	90	97

Each of the proposed pathways for Wales (3% p.a., 6% p.a. or 9% p.a.) is significantly more demanding than for the 'intended budget' of the UK CCC[14], which delivers 1.7% 'equal annual reductions' to 2025[15]. Full implementation of the measures included within Wales' *Climate Change Strategy – Programme of Action Consultation,* at maximum technical potential and including current measures detailed in EU and UK policy, gives around 2.33% p.a. reductions, although the final strategy will most likely include measures that should achieve 3% p.a. reductions.[16]

Figure 3.2: Emissions reductions for Wales on proposed 3%, 6%, 9% pathways for 2025 relative to 2010

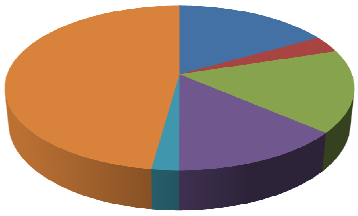
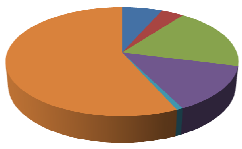
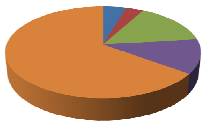
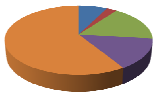
2010 emissions	2025 3%	2025 6%	2025 9%
			
11300 ktCe *(100%)*	6500 ktCe *(57%)*	4300 ktCe *(38%)*	2800 ktCe *(25%)*

Figure 3.2 shows the diminishing 'carbon footprint' of the three core scenario pathways (3%, 6% and 9% p.a.) relative to emissions at the 2010 baseline (see section 2.2.3).

[14] Enacted in UK law by the Carbon Budgets Order 2009.
[15] CCC 2008, p.38.
[16] Personal communication with Matt Sayer at the Welsh Assembly Government.

3.2 Residential

The projected emissions from the residential sector for 2010 represent around 17% of the total. Wales has a higher proportion of 'hard to treat' homes than the UK average, with 37% of properties having solid walls (compared to 27% in England) and 37% being off the gas network (compared to 15% in England)[17]. This means that the potential for emission savings are likely to be proportionally greater in Wales but these will come at a higher cost.

Table 3.2: Residential sector summary

	Total sectoral emissions (ktCe)	% of total emissions	Annual % reduction for this sector	Absolute % reduction vs. 2010
2010 emissions	1900	17%		
2025 emissions (3%)	472	7%	9%	75%
2025 emissions (6%)	182	4%	14%	90%
2025 emissions (9%)	182	6%	14%	90%

Table 3.2 shows that the residential sector is being pushed particularly hard to achieve reductions in emissions. It is recognised that this sector presents significant opportunities for improvement through the implementation of measures that will also result in improved housing stock, reduced energy bills and elimination of fuel poverty. The measures selected as part of the core scenario are shown in figure 3.3. It is assumed that current demolition and new build rates are maintained.

3.2.1 Achieving the reductions from the residential sector in the core scenario

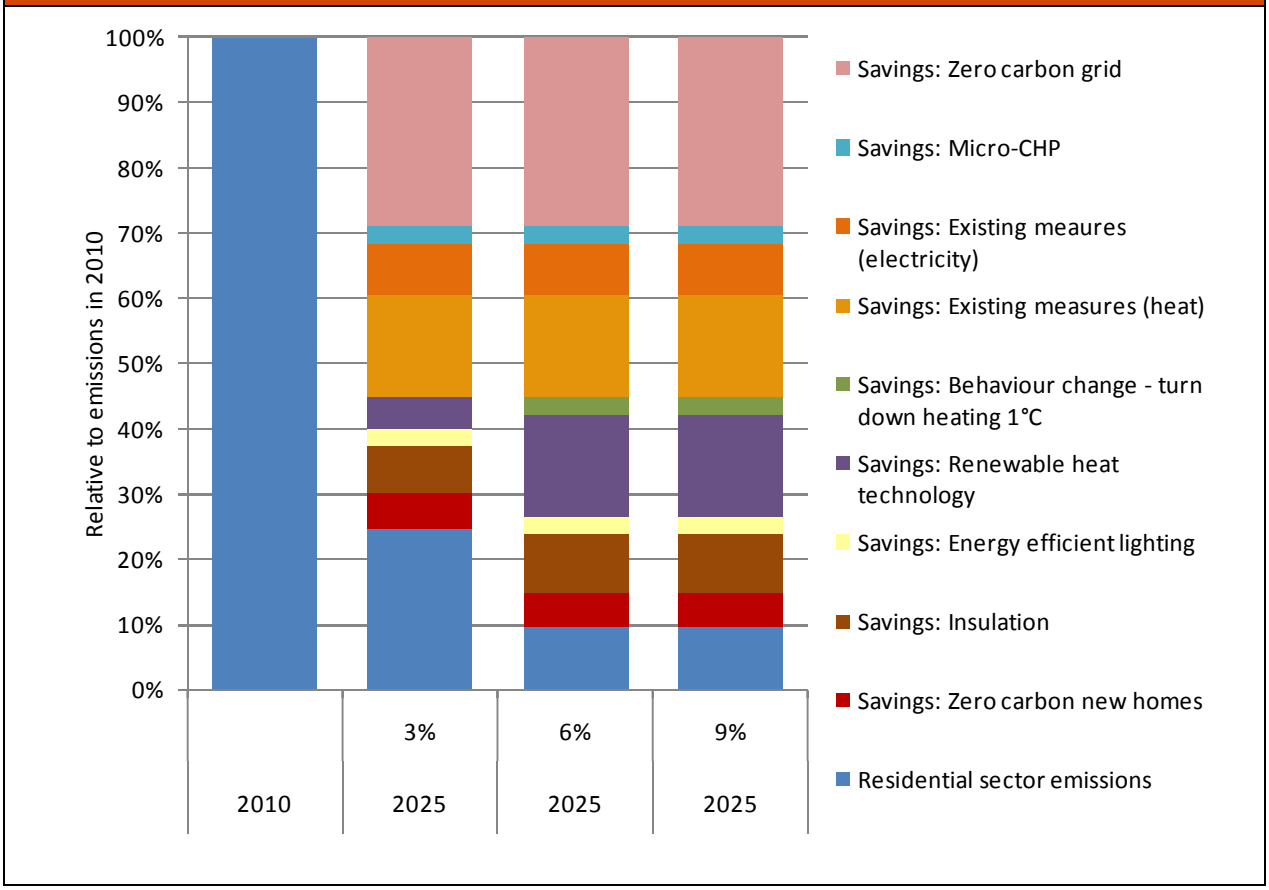
It is clear from figure 3.3 that a significant proportion of reductions are achieved through policies that are already in place. In particular, tightening of building regulations, obligations on suppliers to reduce emissions, fuel poverty programmes, enhancement of efficiency of consumer goods and a roll-out of smart metering all play an important role[18]. A key priority is to ensure that these existing measures are implemented fully to attain maximum benefit.

There are a substantial number of feasible additional options that enable the residential sector to contribute more than its 'fair share'. As indicated in table 3.2, these opportunities mean that even for the 3% pathway, the actual reductions equate to nearly 9% per annum. A major programme of insulating homes is central to achieving this reduction. Simpler insulation measures, such as cavity wall and loft insulation, are practically universal across Wales and significant effort is made to deal with the 'hard to treat' homes through external and internal wall cladding. In addition, there is major penetration of renewable heat technologies with, for example, an estimated 30% of homes being fitted with a solar thermal heating system, and another 15% with heat

[17] AEA (2008), p.68.
[18] AEA (2008), p.65.

pumps[19]. The aspiration for all new homes to be zero-carbon by 2011 has been realised.

Figure 3.3: Illustrative emissions savings from the residential sector on 3%, 6% and 9% pathways* in the core scenario



* In this and subsequent charts showing sources of emissions savings, the columns represent the 3%, 6% and 9% *pathways*; the individual sectors may achieve more or less than this mean rate of emissions reduction. See summary tables at the start of each sector for the actual rate of sectoral emissions reduction (e.g. table 3.2 for residential).

Under the 6% pathway total emissions from the residential sector are reduced by around 90% compared with 2010 levels. To achieve this, nearly all properties are insulated to a high standard, with a particular focus on 'hard to treat' homes. As significant effort was made for 3% the change in savings is limited with marginal costs increasing. The use of renewable heat technologies is widespread, encompassing an estimated 80% of homes. In particular, heat pumps are extensively used (on 60% of homes) addressing space heating and hot water needs. Solar thermal heating systems are used on 20% of homes. Additional emission reductions are met through

[19] The type of heat pump used (e.g. air source, ground source, water source) has not been specified and would depend on the local conditions. Heat pumps do require electricity and, assuming that this was met from the grid rather than a local renewable source, this would result in increased demand and emissions. For the 6% and 9% pathways this would mean approximately an extra 3TWh p.a. (assuming heat demand of 15000kWh per house and a coefficient of performance of 3.5).

behavioural intervention. For example, 50% of households encouraged to turn down thermostats by 1℃. Under the 6% pathway the contri bution to overall emissions from the residential sector falls from 17% in 2010 to only 5% in 2025.

The substantive emissions savings achieved for the 6% pathway leave little room for further change and no additional measures are proposed for the 9% pathway.

In line with a primary assumption in the core scenario, electricity emissions in the residential sector decline to zero by 2025.

3.2.2 What does the core scenario mean for Wales' residential sector?

Jobs creation and new skills required

The extensive insulation and renewable programmes proposed demand greater employment within these areas. This requires investment in skills and training to ensure a quality service is provided and maintained. Initiatives such as the Green Skills Centre in Tredegar are expanded across the country. A significant emphasis is placed on overcoming cultural barriers and widely held beliefs in the construction industry. Demonstration of practical examples and engagement on the benefits of new approaches assists with this process. Nurturing attitudinal change is central to realising synergies between construction and carbon sequestration, for example, through the use of local sustainable timber in construction or application of wool products for insulation. Consideration of the impacts of one technique on another has also been explored. For example, using a particular type of insulation and installation technique might impact negatively on air flow and moisture content. With this in mind, significant discord and resistance across the sector is avoided. Innovative approaches, as well as new ways of engagement mean that maximum benefits are achieved. Business connected to the construction sector has also grown and leads the way on new and integrated low-carbon approaches that are subsequently exported.

Aesthetics

The use of external wall cladding on 'hard to treat' homes alters appearance and affects traditional character, particularly with the 6% and 9% pathways. There is some resistance to this, although this is tempered to some degree through wide engagement. Although effort is made to reach necessary standards in unobtrusive ways, compromise is necessary to achieve results. Timber housing, other alternative designs and micro-generation choices also influence the visual appearance of homes. Early and wide consultation limits difficulties in this area and planning regulations adapt to take account of these issues.

Capital expenditure

Significant capital outlay is necessary to implement the required action. As with current programmes aimed at fuel poverty, subsidised services are targeted at those people with the least ability to pay and that have homes with the greatest need for improvements. For others, a mixture of incentives and regulations is employed, for example, linking Council Tax to the energy performance of homes. The introduction of the Renewable Heat Incentive in the UK in 2011 provides some impetus for home owners to purchase renewable heat technologies. This encouragement is bolstered in

Wales with the introduction of Pay as You Save (PAYS) schemes in parallel with low or no interest loans to cover all or part of the up-front capital costs. These schemes are offered via Council departments, Residential Social Landlords (RSLs) or other partners. Special care is necessary to avoid penalising people in 'hard to treat' homes. RSLs play a key role in implementation and high standards of performance are expected, with support provided to them at an early stage.

Living standards and running costs

Disruption to people's lives as a result of refurbishment of homes is inevitable. However, the end result is homes that are low-carbon, warmer, healthier and cheaper to run. Fuel poverty is greatly reduced and there is greater resilience to higher energy prices. Behaviour change initiatives, accelerated and supported at the community level, mean people have a wide understanding of the way they use energy and of its impacts at the local and global scale, helping to avoid major rebound effects[20].

Embedded emissions

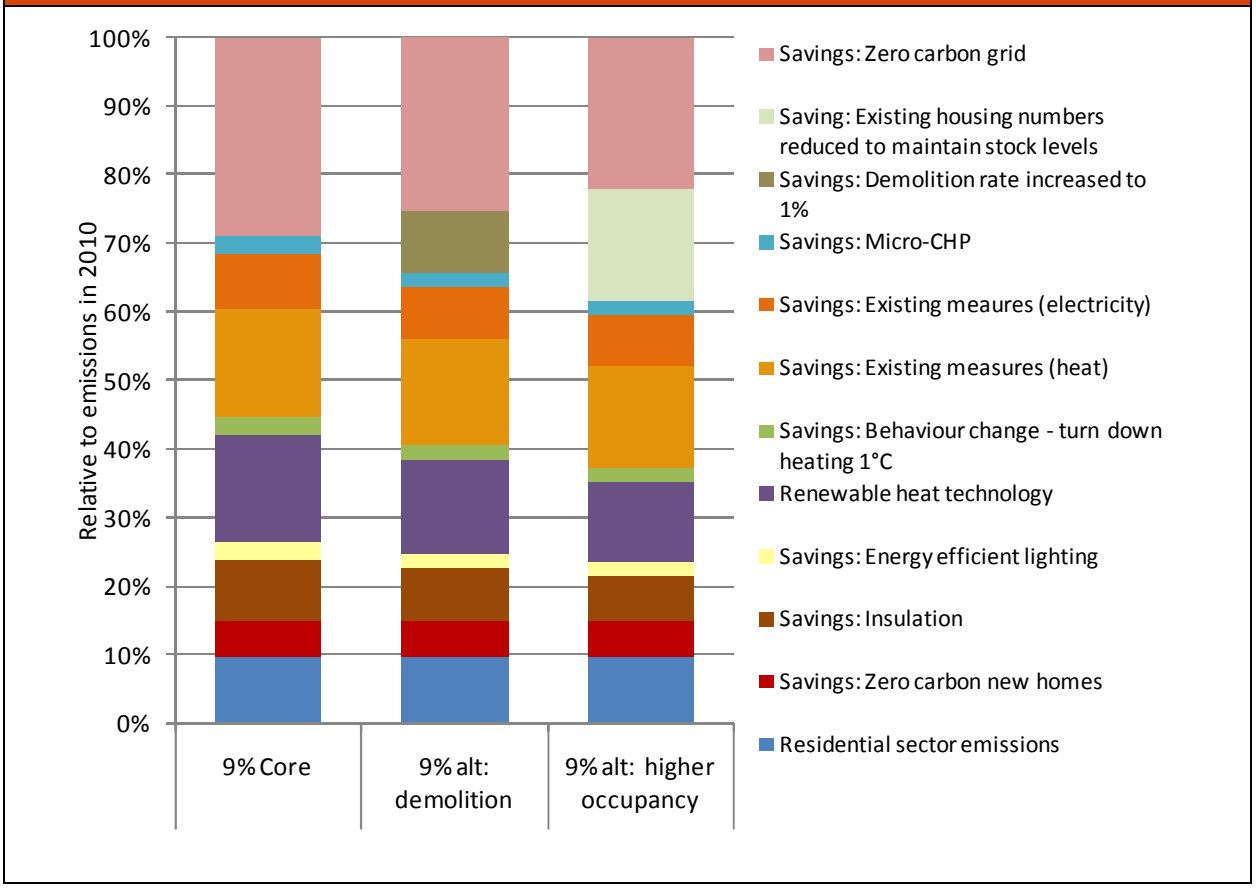
In line with efforts to reduce the ecological footprint of Wales, materials used in proposed refurbishment and new build programmes have as low an impact as possible. For example, carbon sequestered in trees is then locked-up by using the timber in construction.

[20] Rebound effects in this context refer to any negative carbon related consequences of improvements in energy efficiency. For example, a better insulated home leads to the occupier keeping the heating on for the same time as before but at a higher temperature, or money saved through reduced energy use is spent on high-carbon choices such as flying.

3.2.3 Alternative residential scenarios

Two alternative scenarios to the 9% core scenario are also presented in brief below to demonstrate that there are different mechanisms for achieving the same end goal.

Figure 3.4: Illustrative residential emissions savings in 2025 on the 9% pathway in the alternative scenarios



"Demolition"

There is no change in the number of houses in Wales compared to the core scenario. The main difference is that demolition rates in Wales are increased twenty fold, from 0.05% up to 1%. This means that, in the first instance, 12,000 homes will be demolished each year, declining to around 10,000 homes by 2025. By 2025 a total of 168,000 homes will have been demolished and replaced, accounting for 14% of the current housing stock. As in the core scenario, all new homes are zero-carbon. Demolition is targeted on the lowest quality housing that is hardest to bring up to the required standards for energy efficiency. This lowers the overall cost of treating the housing stock that remains. The capital cost is significant and, as new homes are for residents of demolished homes and these costs are unlikely to be met privately. This high level of demolition and replacement only amounts to 10% of the overall savings required in the 9% pathway. Additional measures similar to the core scenario achieve the remaining reductions. However, the lower number of homes to treat and

replacement of 'hard to treat' houses, means that the costs of these measures are reduced.

"Increased Occupancy"

This scenario is built on the idea of slowing down and reversing the trend to lower occupancy levels in housing in Wales and there is little change in physical structures overall. Unlike the core and "demolition" scenarios it is assumed that while population may increase, the total number of homes in Wales will remain at the current level. The number of new homes that are required to meet current household projections are built to zero-carbon standards and replace existing homes, the latter of which are then demolished. Occupancy increases are met in a variety of ways, for example, communal living housing projects for those in support of this approach, leaving others to continue the trend towards more single person households. Emissions savings resulting from large-scale replacement of existing homes account for 18% of the total required to meet the overall savings in the 9% pathway. Costs associated with other measures defined within the core scenario are reduced as there are fewer homes to treat and 'hard to treat' homes are targeted first.

Box 3.1: Comparison of alternative 9% p.a. scenarios for the residential sector

Advantage
Neutral
Disadvantage

Criterion	"Tyndall–WAG Core"	"Demolition"	"Increased occupancy"
	All commercially available technology pushed to limit	All new homes are zero carbon	Average household size increases
Job creation	HIGH	HIGH	MED
Capital expenditure	HIGH	HIGH	MED
Running costs	LOW	LOW	LOW
New skills requirement	HIGH	HIGH	MED
Living standards	HIGH	HIGH	MED
Degree of speculation	LOW	LOW	LOW
Embedded emissions	MED	MED	LOW

"Demolition"

The number of houses in Wales remains the same as the core scenario but the demolition rate is increased to 1%. As a result, by 2025 nearly 170,000 homes have been demolished and replaced by new zero-carbon homes. By targeting 'hard to treat' homes the cost per house of bringing remaining houses up to the required standards is lowered.

"Increased Occupancy"

Action is taken to maintain occupancy rates at current levels resulting in the number of homes in Wales being kept steady. While the same number of new zero-carbon homes built is as in the core scenario, these replace existing homes, which are then demolished.

3.3 Transport

Transport is responsible for 16% of total emissions in Wales[21]. Transport emissions in Wales disaggregate in broadly similar proportions to those from the UK transport sector as a whole, with road transport dominating and private cars being responsible for approximately 63% of emissions from road[22]. Therefore effort has been concentrated on road transport generally, and private vehicles in particular.

Table 3.3: Transport sector summary

	Total sectoral emissions (ktCe)	% of total emissions	Annual % reduction for this sector	Absolute % reduction vs. 2010
2010 emissions	1840	16%		
2025 emissions (3%)	1165	18%	3%	37%
2025 emissions (6%)	727	16%	6%	60%
2025 emissions (9%)	447	16%	9%	76%

As shown in figure 2.2, in the core scenario transport decarbonises in line with the mean reduction rate for each pathway (i.e. it achieves 3% p.a. in the 3% pathway...). Table 3.3 shows that, as a result, transport continues to emit in proportion to its 2010 contribution to the Wales total, remaining more or less constant at 16% of total emissions (the increase to 18% of total emissions in the 3% pathway being due to variance in the contribution of other sectors rather than a deviation from trend in transport).

3.3.1 Achieving the reductions from transport in the core scenario

In the core scenario, emissions reductions in the transport sector come from increasing deployment of existing technological improvements to the fleet, roll-out of electric vehicles and varying degrees of demand reduction, specifically with respect to demand for private vehicle kilometres (figure 3.5).

For the 3% p.a. pathway, the core scenario adopts the emissions reduction measures set out in the 'extended ambition' (central) scenario from the UK CCC (table 3.4). The only deviation from this package of measures is that the national speed limit is additionally reduced to 60mph. Although this belongs to the more challenging CCC 'stretch ambition' scenario, it is deemed sufficiently feasible to implement to contribute emissions savings for the 3% pathway.

[21] WAG 2008a, p.5. This is significantly less than transport's 24% share of emissions from the UK as a whole (CCC 2008 p.253), although this is largely due to the relative shares of other sectors. Transport emissions in Wales represent around 5% of the UK total, consistent with Wales' population being around 5% of the UK total (WAG 2008a).

[22] WAG 2008a, p. 16. This proportion is slightly more than for the UK as a whole, of which around 58% of emissions are from private cars (DfT 2009, citing NAEI 2007 data). Wales has a bigger rural population than the UK average, which may account for this divergence.

Table 3.4: UK CCC measures to reduce transport emissions

Extended ambition	Stretch ambition
Biofuels	Biofuels
Car - powertrain - plug-in hybrid and electric	Car - powertrain - plug-in hybrid and electric
Car - non-powertrain	Car - non-powertrain
Van – powertrain - stop start	Van - non-powertrain
Van - non-powertrain	Rail - efficiency measures
HGV – powertrain - hybrid	Demand - Smarter Choices
HGV - non-powertrain	Demand - Eco driving - HGVs
Rail- efficiency measures	Van-powertrain - plug-in hybrid and electric
Demand - Smarter Choices	HGV - powertrain - plug-in and electric
Demand - Eco driving - cars	Speed reduction and enforcement at 60mph
Demand - Eco driving - vans	Eco-driving cars - far reaching
Demand - Eco driving - HGVs	Eco-driving vans - far reaching
	HGV: non-powertrain, inc. aero and weight reduction

Thus, emissions savings are from three main sources, roughly in equal shares:

- Improvements to the vehicle 'powertrain', comprising engine, transmission and driveshaft, in the form of hybrid vehicle technology, stop-start technology, and plug-in hybrid (PHEVs) and fully electric vehicles (battery electric vehicles, EVs).
- 'Driver behaviour', including eco-driving (reducing rapid acceleration and heavy braking, maintaining correct tyre pressures, removing unnecessary vehicle weight), 'Smarter Choices' (journey planning, car sharing, workplace and school travel plans, modal and shift) and enforcement of a countrywide 60mph speed limit.
- Jointly from the use of biofuels and efficiency improvements from non-powertrain vehicle components (aerodynamics, weight, rolling resistance of tyres, gear-shift indicators etc). Biofuels are restricted to use in proportion to the current renewable transport fuel obligation, in view of the current problems surrounding sustainability of feedstocks.

For 3% p.a. there is a small decrease in total vehicle kilometres travelled (4% on 2005), which is a departure from the 29% growth in vehicle kilometres predicted between 2003 and 2025 for Wales[23].

With respect to the 3% and 6% p.a. pathways, a significant proportion (10–20%) of intercity car journeys is transferred to the existing rail network, with minimal additions to existing rail infrastructure and therefore minimal capital costs.

[23] DfT 2008, Annex 2, Summary Results for Wales, central forecast.

The 6% p.a. pathway involves implementation of all measures from the UK CCC's 'stretch ambition' scenario, plus demand reduction approximately equivalent to a reduction in the total number of vehicle kilometres by around 27%, i.e. reversing the predicted 28% increase on 2003 levels by 2025. Demand reduction in the core scenario refers exclusively to demand for private vehicle kilometres, entailing no constraint on passenger kilometres or, concomitantly, on personal mobility. Reductions in demand for private vehicle kilometres are delivered by:

- increasing the occupancy rate (average load factor) of private vehicles and / or
- substituting private car journeys to zero-carbon modes of transport and / or
- removing the need to make some trips altogether (net reduction in passenger kilometres).

The 9% p.a. pathway includes all of the UK CCC measures above, plus demand reduction equivalent to a 43% reduction on 2010 levels by 2025. With greater penetration of zero-carbon electricity into the rail network, rail travel replaces many intercity car journeys, reducing emissions without curtailing personal mobility. Thus, public transport between Wales' main urban centres is much more important. Additionally, organised car share schemes and priority high-occupancy vehicle lanes lead to an increase from the current private vehicle occupancy rate of 1·39.[24] There is a notable programme of investment in rail, with new routes created and the number / capacity of train carriages increased to absorb the passengers displaced from car journeys. Beyond this, the 9% pathway is based on a society and infrastructure where the need to make private vehicle trips for many daily tasks is 'designed out'. Land use planning considerations come to the fore with a central role for Sustainable Travel Towns. Also, alternative, more flexible patterns of working are the norm, spreading the rush hour and dissipating peak time commuting bottlenecks on public transport systems. Well-planned delivery-based supply networks replace many car trips to out of town shopping centres.

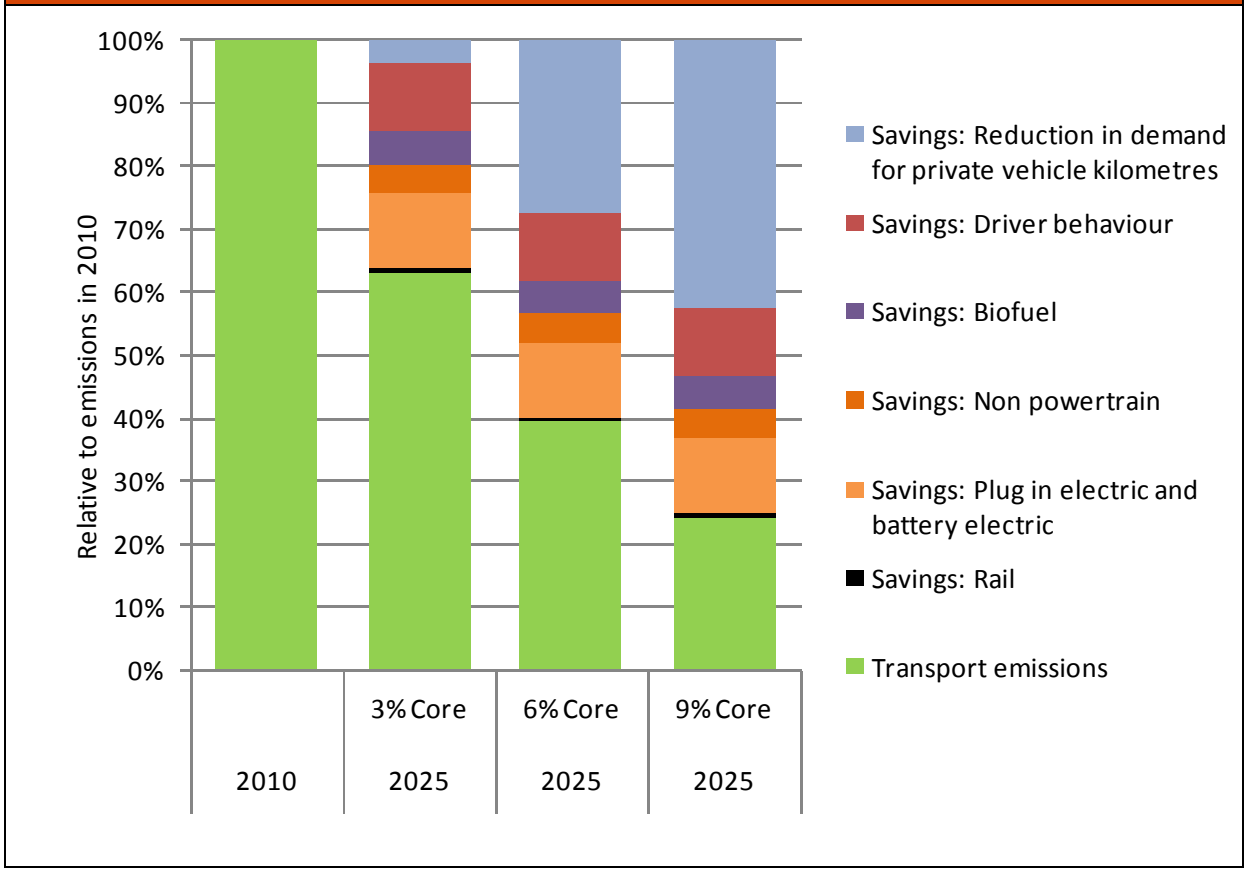
3.3.2 What does the core scenario mean for Wales' transport sector?

Job creation

On the 9% pathway, substantial job creation comes from civil construction projects for new routes for rail and tram and from the deployment of new fuelling / charging infrastructure associated with increasing penetration of electric vehicles. The engineering and construction sectors in particular see growth. Conversely, reduced dependence on private cars mean there are fewer vehicles on the road, hence job losses occur in the automotive manufacturing and servicing industries.

[24] Based on total passenger kilometres divided by total personal transport vehicle kilometres in Wales, as reported in Welsh Transport Statistics (WAG 2008b).

Figure 3.5: Illustrative transport emissions savings on 3%, 6% and 9% pathways in the core scenario



Capital expenditure

Investment is required to create the necessary infrastructure for electric vehicles, as well as to promote them and offer price support (subsidies) for early adopters[25]. The 9% pathway sees significant investment in the rail network to enable modal shift-based demand reduction in private vehicle kilometres. In contrast, major road building has ceased in order to avoid the 'own goal' of increased emissions from induced traffic demand, thus releasing capital to other public transport projects.

Running costs

Revenue generated from fuel taxes diminishes as vehicle kilometres are curtailed which means that, in the short term at least, running costs are significant. Ongoing support for public transport facilitates the shifting of passengers from cars to lower-carbon forms of transport.

New skills requirement

Emissions savings in the core scenario come from actions that do not require a major change in Wales' employment profile, and skills are not a barrier to implementation.

[25] The UK Government announced in April 2009 that it will offer subsidies up to £5000 to purchasers of electric vehicles (CCC 2009, p.210).

Degree of speculation

As savings are derived from tried and tested measures, the core scenario is relatively predictable in terms of the emissions savings that it can deliver.

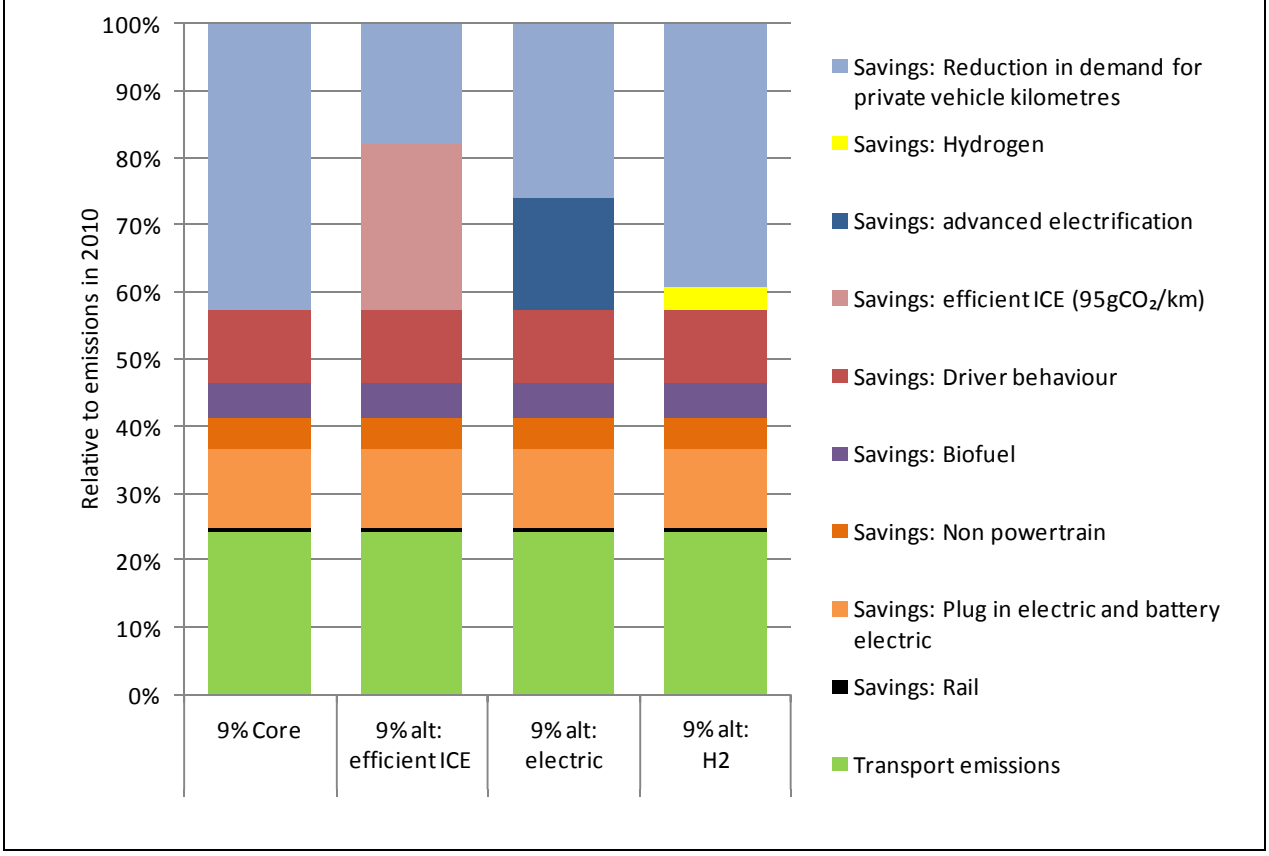
Embedded emissions

Achievement of the 9% pathway is largely premised on a shift away from the private car (especially away from so-called 'drive alone trips') and, as a result, the link between status and vehicle ownership has started to erode. Car sharing and community and city car clubs are commonplace. New infrastructure enables use of electric vehicles and trains but, on balance, embedded emissions in the 9% core scenario are markedly reduced from present levels.

3.3.3 Alternative transport scenarios

Two alternative scenarios to the 9% core scenario are also presented in brief below to demonstrate that there are different mechanisms for achieving the same end goal.

Figure 3.6: Illustrative transport emissions savings in 2025 on 9% pathway in alternative scenarios



"Low emission ICE"

This scenario builds on the measures in the core scenario, but emphasises regulation to set minimum vehicle emissions standards for Wales over demand reduction. EU legislation adopted in April 2009 will require vehicle manufacturers to achieve sales weighted fleet average emissions for new cars of 130g CO_2/km by 2015, falling to 95g CO_2/km by 2020. However, internal combustion engine (ICE) vehicles meeting the 2020 target of 95g CO_2/km could be made commercially available immediately – for example the Audi A4 or Citroen C3 are both currently rated at 99g CO_2/km. Mild hybrids can achieve even lower emissions per kilometre. However, on the European Continent the Audi A2 '3 litre' emits around 80g CO_2/km, has been available since 1999 and in reality is little more than an ICE vehicle with a specific design emphasis on fuel economy.

Thus the 'low emission ICE' scenario encourages a push for rapid deployment of such low emissions vehicles by legislating from 2010/11 that every new vehicle to be kept in Wales must emit no more than 95gCO_2/km. Policy mechanisms to regulate this include linking council tax records to vehicle registrations, MOT certification and / or vehicle excise duty payments. At current renewal rates this scenario has the potential to reduce emissions from the Welsh car fleet by around 25% of 2005 levels by 2025. The approach taken in this alternative scenario has the advantage that it uses only the most efficient internal combustion vehicle technology currently on the market, and does not rely on particular innovations being perfected and made available at some future date. It does however require new powers for Wales to regulate purchasing and registering of new vehicles, as well as working with manufacturers to ensure availability of low emissions vehicles to Welsh consumers.

"Electric"

In this scenario, deployment of fuelling infrastructure for electric vehicles is rapidly accelerated, and measures put in place to create incentives for individuals to choose electric vehicles when purchasing new cars (and strong disincentives to choosing petroleum-fuelled cars). Financial support enables early adoption of electric vehicles. This results in annual increase of 2% of all private vehicle kilometres being travelled in electric vehicles – thus 30% of all vehicle kilometres are electric by 2025 – giving emissions savings of around 15% of 2005 levels by 2025. Wales' electricity demand increases by around a third compared to consumption in 2009. The additional demand burden from electric vehicles is (conservatively) equivalent to an additional 1200 2MW onshore wind turbines. This scenario goes well beyond the penetration rates suggested by the UK CCC and demonstrates a concerted and sustained push for electrification in Wales. Even so, reduction in demand for private vehicle kilometres is a necessary component and plays a significantly greater role in overall emissions reduction than electrification.

"H_2"

The hydrogen future scenario envisages uptake of hydrogen-fuelled combustion engine vehicles with an additional 1% p.a. of total vehicle kilometres being transferred to hydrogen power from 2020. Given the late inception of this strategy and the relatively low rate of penetration, savings from hydrogen vehicles are modest in comparison to other interventions (around 3% in 2025). Hydrogen vehicles are used

most effectively for local public transport (buses) and short, intra-city car journeys (city car clubs). This serves as a demonstration of hydrogen vehicles for 2025 to 2050.

Box 3.2: Comparison of alternative 9% p.a. scenarios for transport

Advantage
Neutral
Disadvantage

Criterion	"Tyndall–WAG Core"	"Low emission ICE"	"Electric"	"H_2"
	Push existing technology and demand reduction	Existing technology pushed to limit of efficiency	Widespread electrification of fleet	Uptake of hydrogen fuel cell technology from 2020
Job creation	MED	MED	HIGH	HIGH
Capital expenditure	MED	LOW	HIGH	HIGH
Running costs	MED	MED	MED	HIGH
New skills requirement	LOW	LOW	MED	HIGH
Degree of speculation	LOW	LOW	MED	HIGH
Embedded emissions	LOW	MED	MED	MED

"Low emission ICE" (internal combustion engine)

The most efficient existing internal combustion engine technology is the legal requirement for all new cars in Wales. The vehicle replacement rate is ten years, the same as for 2009. All core scenario measures are included, but the need to reduce demand for private vehicle kilometres is the lowest of all 9% p.a. decarbonisation scenarios.

"Electric"

Extensive deployment of electric vehicle charging infrastructure and incentives to choose electric cars has occurred. Early adoption of new battery electric vehicles is encouraged with financial support. Core scenario measures and significantly reduced demand for private vehicle kilometres are still required.

"H_2" (hydrogen)

Hydrogen is used as fuel in combustion engines for city-based journeys and local public transport. Hydrogen is associated with limited emissions reduction to 2025 but serves as a demonstration of potential for longer-term measures.

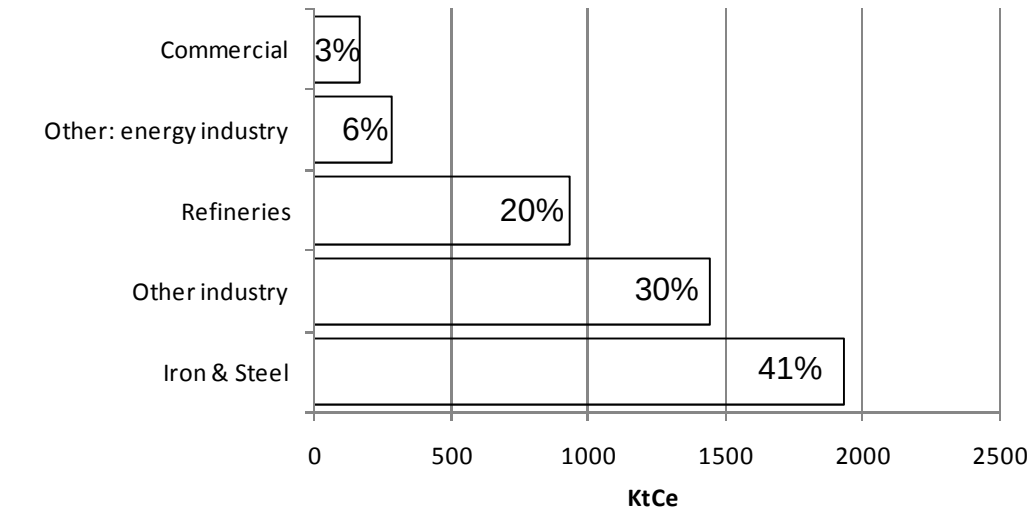
3.4 Business

Table 3.5: Business sector summary

	Total sectoral emissions (ktCe)	% of total emissions	Annual % reduction for this sector	Absolute % reduction vs. 2010
2010 emissions	5420	48%		
2025 emissions (3%)	3592	55%	3%	34%
2025 emissions (6%)	2420	56%	5%	55%
2025 emissions (9%)	1420	50%	9%	74%

Table 3.5 shows that the business sector decarbonises at (or very nearly at) the mean average for all sectors in each pathway, but this belies how resistant many aspects of the sector are to emissions reduction[26]. For example, the bulk of business sector emissions come from a handful of large plants making iron and steel, which despite being among the most efficient plant of their kind worldwide, produce a sizeable proportion of their emissions from the coking stage of the steelmaking process. The business sector as a whole is presently responsible for nearly half of Wales' emissions and decarbonisation at around the mean rate is imperative if Wales is to achieve the emissions reductions required for the steeper 6% and 9% p.a. pathways, particularly as contributions from agriculture and food production are relatively low.

Figure 3.7: Breakdown of 2005 business emissions by sub-sector, with percentage of total business emissions



Source: AEA 2008

[26] Note that, as in other sectors, emissions from electricity are not included here, as one of the key assumptions in the Tyndall-WAG scenarios is the decarbonisation of the grid via successful implementation of the *Renewable Energy Route Map*.

The business sector comprises all commercial, industrial and service activity in Wales outside the public sector, and excluding electricity generation. The bulk of emissions arise from installations in the steel and refineries sectors, with the commercial and services sector contributing only 3% of total emissions (figure 3.7). To address this, the core scenario has concentrated efforts on the heavy industry sector, where significant emissions savings can be achieved by targeting specific sites. It is acknowledged that Wales has a disproportionally large micro-SME sector, in which very small scale businesses operate in a way more comparable to domestic households. In this sub-sector bespoke measures may achieve further savings from the business sector as a whole.

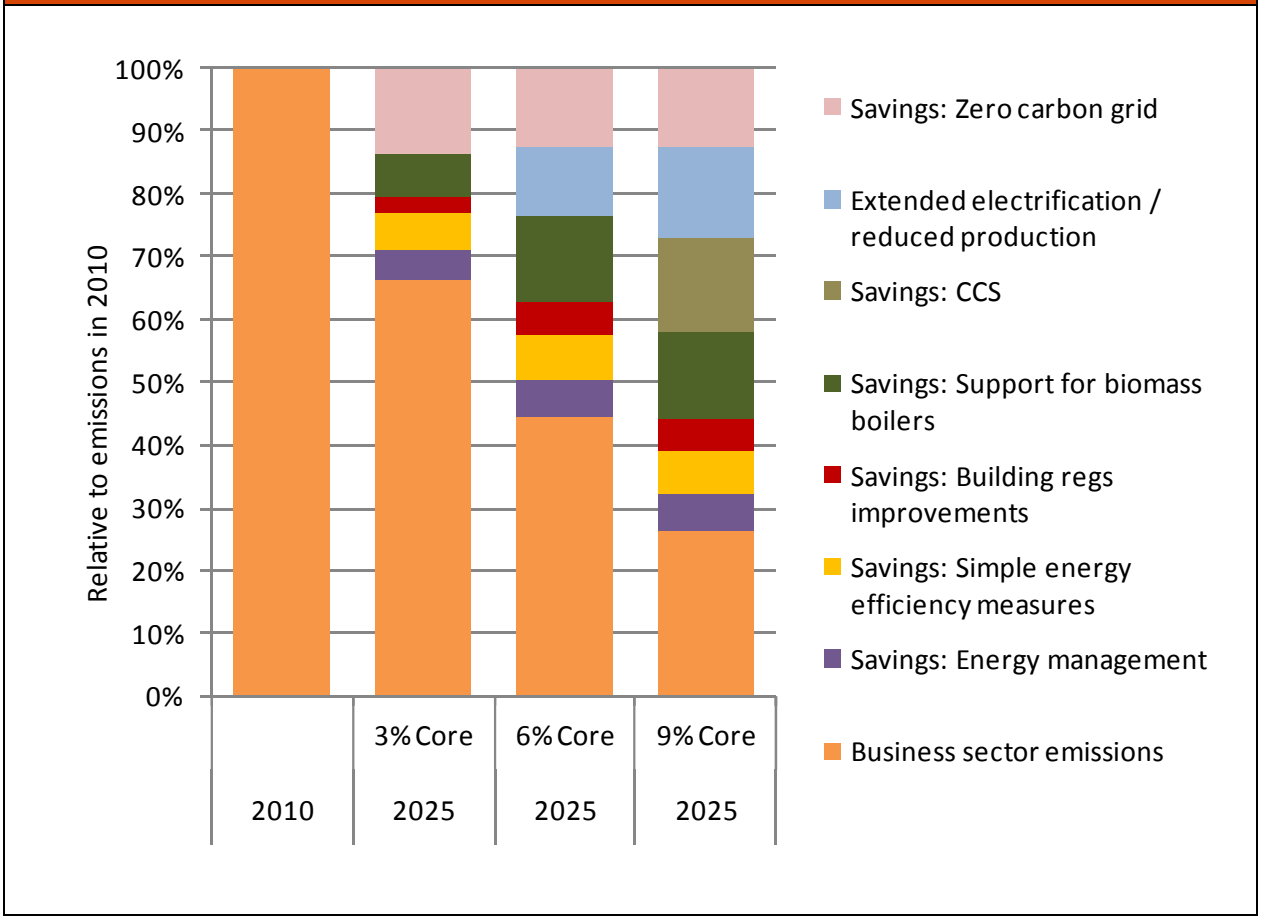
3.4.1 Achieving the reductions from business in the core scenario

For 3% p.a. reductions, existing incremental measures are pushed as far as possible for heavy industry, with an intensification of established efficiency and energy management measures, and significant uptake of biomass boilers for onsite heating requirements.

For the 6% p.a. pathway much more stringent building regulations and a twofold increase in the rollout of biomass boilers for industrial sites occurs. Even pushed to their 'feasible limit', these measures do not achieve reductions from the business sector at the mean Wales reduction rate, (i.e. the business sector reduces at only 4% with these measures alone). It is therefore necessary to implement systematic electrification of heating and motive industrial processes. Where electrification is not possible, for example, with coking, production is restricted to make up the shortfall in savings.

The 9% p.a. pathway is achieved through all of the above measures plus deployment of process-based carbon capture and storage (CCS) technology, much increased penetration of (renewable) electricity and the direct combustion of biomass for onsite heat requirements. The inclusion of process-based CCS in this pathway reflects the need to utilise every possible means to reduce emissions at a challenging rate of change. CCS is not included in the 3% or 6% pathway scenarios because other, simpler means conceivably deliver reductions at desired rates.

Figure 3.8: Illustrative business sector emissions savings on 3%, 6% and 9% pathways in the core scenario



3.4.2 What does the core scenario mean for Wales' business sector?

Job creation

The changes result in additional job creation centred around manufacture, installation and maintenance of new biomass plant within larger industrial sites, and construction and maintenance of CCS for agglomerations of heavy industrial sites, for example, in the Milford Haven area. Jobs supporting businesses to implement energy management and efficiency schemes also increase. However, with reduced production in the 9% pathway, there are some associated job losses.

Capital expenditure and running costs

Although additional capital outlay is required to bring businesses in Wales up to the energy efficiency standards required by this pathway, no alterations are being made to the overall structure of the business sector. Thus there is no decommissioning of plant or replacement with new types of industry. Because measures focus on efficiency, operating costs are much lower than in 2009, making the core scenario potentially the least cost of the scenarios considered.

New skills requirement

The 'new ways of doing things' require new skills to enable the rollout of biomass plant and construction of CCS facilities. However, the body of trained engineering, construction and maintenance expertise created enables Wales to export skills to other countries seeking a similar path.

Degree of speculation

Achieving the 9% pathway relies on deployment of CCS technology for process-based emissions from small groups of industrial plant. Although this technology is relatively new, in terms of commercial use, it is not unproven. In 2009 a suitable repository for CO_2 gas captured from Welsh industrial sites remains to be addressed, making the economics of transportation indeterminate. However, in comparison with alternative scenarios, the increased efficiencies of the core scenario are reliant on proven technology and business models.

Embedded emissions

The penetration of electricity into business is widespread, effectively decarbonising the sector bar process emissions arising from coking, refinery and cement manufacture. The additional burden on the supply of renewable electricity is considerable, even once efficiency savings from the business, residential and public sectors is taken into account. Fabrication and installation of the requisite renewable energy infrastructure to supply this extra demand from industry comes at the cost of additional embedded emissions.

3.4.3 Alternative business scenarios

Two alternative scenarios to the 9% core scenario are also presented in brief below to demonstrate that there are different mechanisms for achieving the same end goal. Due to the relatively large uncertainties involved in the emissions savings that could be achieved, comparison charts are not possible for the alternative business sector scenarios.

"Service economy"

In this scenario, heavy industry and manufacturing is completely replaced by service-based businesses, such as insurance, business and IT consultancies, contact / call-centres for customer support in the financial services, travel and utilities sectors. Lightweight value-added assembly of low-carbon goods such as electronics, and lightweight manufacturing of bio-medical and pharmaceutical goods also feature. Tourism is expanded across rural Wales by creation of new centres and facilities for visitors. There is a substantial shift away from polluting heavy industrial plant leading to a proportionate reduction in domestic emissions but this is associated with a significant increase in 'exported emissions' embedded in the products that Wales consumes but no longer makes. Capital costs arise from refurbishment and retraining, whereas operating / running costs are lower for non-mechanised businesses compared to the heavy industry they replace. A net increase in jobs occurs, replacing automated industrial plant with service-based business centres, although the type of employment and skills required are markedly different.

"Green manufacturing"

In the core scenario, it was not possible to completely decarbonise the steel industry while continuing to run large-scale integrated steel works of the type currently found in Wales. The alternative green manufacturing scenario sees Wales taking advantage of its existing industrial skills base by switching from volume production of steel to smaller quantities of value-added renewable energy infrastructure components. This scenario does not imply industrial transformation to such an extent as 'service economy', but it does involve a comprehensive re-directing of the industrial sector towards low-carbon products and processes. Thus, aspects of the steel industry and manufacturing base are preserved to enable fabrication of renewable energy infrastructure within Wales. This strikes a balance between retaining some industrial production in Wales, where the sector is tightly regulated, and taking responsibility removing emissions arising from the rest of business. Capital costs associated with re-tooling and re-skilling are higher than in other scenarios, but new employment opportunities abound and skills can be exported to other countries seeking to embark on decarbonising energy supplies.

Box 3.3: Comparison of alternative 9% p.a. scenarios for business

Advantage
Neutral
Disadvantage

Criterion	"Tyndall–WAG Core"	"Service economy"	"Green manufacturing"
	All available technology & practices pushed to limit	Swap services & low carbon hi-tech for industry	Switch to making low carbon energy, products and processes
Job creation	MED	HIGH	HIGH
Capital expenditure	MED	MED	HIGH
Running costs	LOW	LOW	MED
New skills requirement	MED	HIGH	HIGH
Degree of speculation	LOW	LOW	MED
Embedded emissions	MED	HIGH	MED

"Service Economy"

Wales replaces its heaviest industries with an expanded services sector (insurance, call centre, etc) and low-carbon manufacturing (lightweight hi-tech and pharma). Significant retraining and changes in employment patterns occur in the industrial south. Expansion of tourism and online retail is seen throughout Wales.

"Green Manufacturing"

Wales re-skills and re-tools its heaviest industries, replacing iron and steel and refinery with a manufacturing base producing low-carbon (ultimately zero-carbon) energy infrastructure (generation and transmission), low-carbon goods and services, as well as R&D into low and zero-carbon industrial processes.

3.5 Agriculture

This section looks at emissions reduction scenarios for land use, principally in the form of agriculture, although forestry and land use change are also covered to a limited extent[27]. Projected emissions for the agriculture sector for 2010 represent around 14% of total emissions. The majority of the agriculture emissions in Wales are associated with livestock farming. This means, that unlike other sectors, the vast majority of these emissions do not arise from carbon dioxide, but from methane (CH_4) and nitrous oxide (N_2O).

Table 3.6: Agriculture sector summary

	Total sectoral emissions (ktCe)	% of total emissions	Annual % reduction for this sector	Absolute % reduction vs. 2010
2010 emissions	1550	14%[28]		
2025 emissions (3%)	985	15%	3%	37
2025 emissions (6%)	825	19%	4%	47
2025 emissions (9%)	730	26%	5%	53

As table 3.6 shows, emissions reduction in the land use sector prove particularly difficult to achieve and, for the 6% and 9% pathways, falls below the mean rate of reduction. There is considerable uncertainty around the degree of reductions that can be achieved through the various measures proposed for the sector and a best estimate, based on the evidence reviewed, is provided. Also, biological sequestration is not included as a means of reducing emissions as it is difficult to guarantee that carbon remains sequestered for a considerable time (see section 3.5.1). This limits the options that are often discussed for reducing emissions from agriculture. For example, the IPCC's Fourth Assessment Report states, "soil carbon sequestration (enhanced sinks) is the mechanism responsible for most of the mitigation potential [in agriculture]"[29].

3.5.1 Biological sequestration

It is acknowledged that there is much 'potential' for biological sequestration both in relation to biomass (forestry etc) and soils, but although it is regularly touted as the new 'silver bullet' (as have nuclear power, CCS and geo-engineering), effectiveness hinges on the precise conditions and context of implementation as well as attitude towards risk. For example, whilst CO_2 fertilisation may have short term sequestration

[27] The vast majority of emissions from 'land use' are from agriculture (see figure 2.2), hence effort has been targeted at addressing agriculture emissions in the scenarios.
[28] This differs from other estimates of the *share* of emissions from agriculture due to differences between the 'Island Wales – zero-carbon grid' baseline of approx.11MtCe (see figure 3.1) and baselines used elsewhere.
[29] Smith et al, 2007, p.499.

potential, beyond a critical CO_2ppmv threshold such additional sequestration ceases and overall CO_2 uptake may begin to reduce.[30]

A more particular concern regarding sequestration (including biomass) is their stability (ecologically and socially) at high atmospheric CO_2 concentrations – and hence levels of climate change. There is now little evidence for more than an 'outside chance' of restricting cumulative emissions to a level commensurate with 2℃ average temperature increase. In the absence of a global sea change in the economic orthodoxy and a rethinking of equity and distribution between the northern and southern hemispheres, cumulative emissions commensurate with global average temperature increase of 4℃ are likely to be surpas sed well before the end of the 21st century. The Hadley Centre suggest a 4℃ increase b y 2060-70 is associated with relatively high emission scenarios and climate sensitivity[31] – both of which appear to be increasingly likely. Regional variations associated with a 4℃ global mean (~5 to 5.5℃ land mean) may range as high as 10-15℃, and the implications of such temperature ranges for sea level, rain fall, irrigation water, upland fires, etc are simply not well understood. A further complication arises from possible migration issues at 4℃, with Wales facing additional pressures on land use from the arrival of migrants (climate change 'refugees'), with further repercussions for the stability of soil and biochar sequestration.

As it stands robust data are not currently available on the stability of biochar and soils under these possible variations and combinations. Consequently the large uncertainties regarding the make-up of high temperature futures leave biological sequestration insufficiently robust and resilient as a carbon sink to be included in this analysis. More research on biochar and soils in a 4–6℃ warming world, with regional modelling disaggregated to the Welsh level, is needed to enable appropriate inclusion of biological sequestration in emission scenarios, beyond physically 'locking-up' carbon into other 'structures'.

3.5.2 Achieving the reductions from agriculture in the core scenario[32]

The core scenario sees a shift in the approach to agriculture for Wales. The production and consumption of food is more closely aligned with an express desire to focus on 'feeding Wales'. This is not about Wales becoming self-sufficient – trade will still have an important role to play – but becoming more self-reliant in its food production. To help address significant uncertainties around the most appropriate low-carbon approaches to agriculture Wales is a global centre of excellence in the research and practice of low-carbon food production, focussing on both high-tech solutions and also alternative approaches to food production, for example, permaculture, agro-forestry and small-scale / garden, hydroponics. Impacts on wider ecosystem services are central to these considerations.

[30] Bows and Anderson, 2008; and Friedlingstein et al, 2006.
[31] New et al, 2009.
[32] The scenarios presented here are based on an assessment of numerous documents. However, it is recognised that much of the evidence is often contradictory and it is difficult to draw firm conclusions. These scenarios represent one interpretation of this evidence but further discussion and development is required.

In the 3% pathway, emission reductions arise from a variety of measures and their relative contributions are detailed in figure 3.9. Primarily they are driven by a reduction in livestock numbers and a corresponding reduction in meat and dairy consumption. Recognising the important role that ruminants can play in utilising land unfit for the production of other foodstuffs, a key aspect to reducing livestock numbers is an assessment of land use, leaving lower value marginal land (unsuitable for other foodstuffs or potentially biomass) to be used for livestock rearing[33]. As meat and dairy consumption in Wales is reduced it is replaced by other food, which itself has emissions associated with production[34]. The higher value land freed up from livestock rearing is used to produce as much of this food as possible, utilising methods that result in the lowest possible GHG emissions to best maintain the carbon currently held in soils. This is complemented with increased small-scale production in urban areas. Reductions in livestock are further enabled by an increase in 'nose to tail' consumption, with each animal being more productive. There is also a corresponding increase in the use of mutton adding value to sheep stocks. Substitution of red meat by white meat plays a limited role as increases in pig and chicken numbers have to be achieved in ways that avoid significant impacts on emissions along the supply chain[35]. Fertility of grazing land is maintained through alternative approaches to the application of artificial fertilizers. The majority of sheep that remain are reared organically[36] while the growing divide between beef and dairy herds is reversed,[37]. The trend towards higher yields but lower fertility in the dairy herd is also reversed resulting in longer and more productive life for animals and the need for fewer replacement calves[38]. The amount of food waste is drastically cut and diets improved to align more closely with recommended intake for a healthy life[39]. The overall level of food consumption is subsequently reduced.

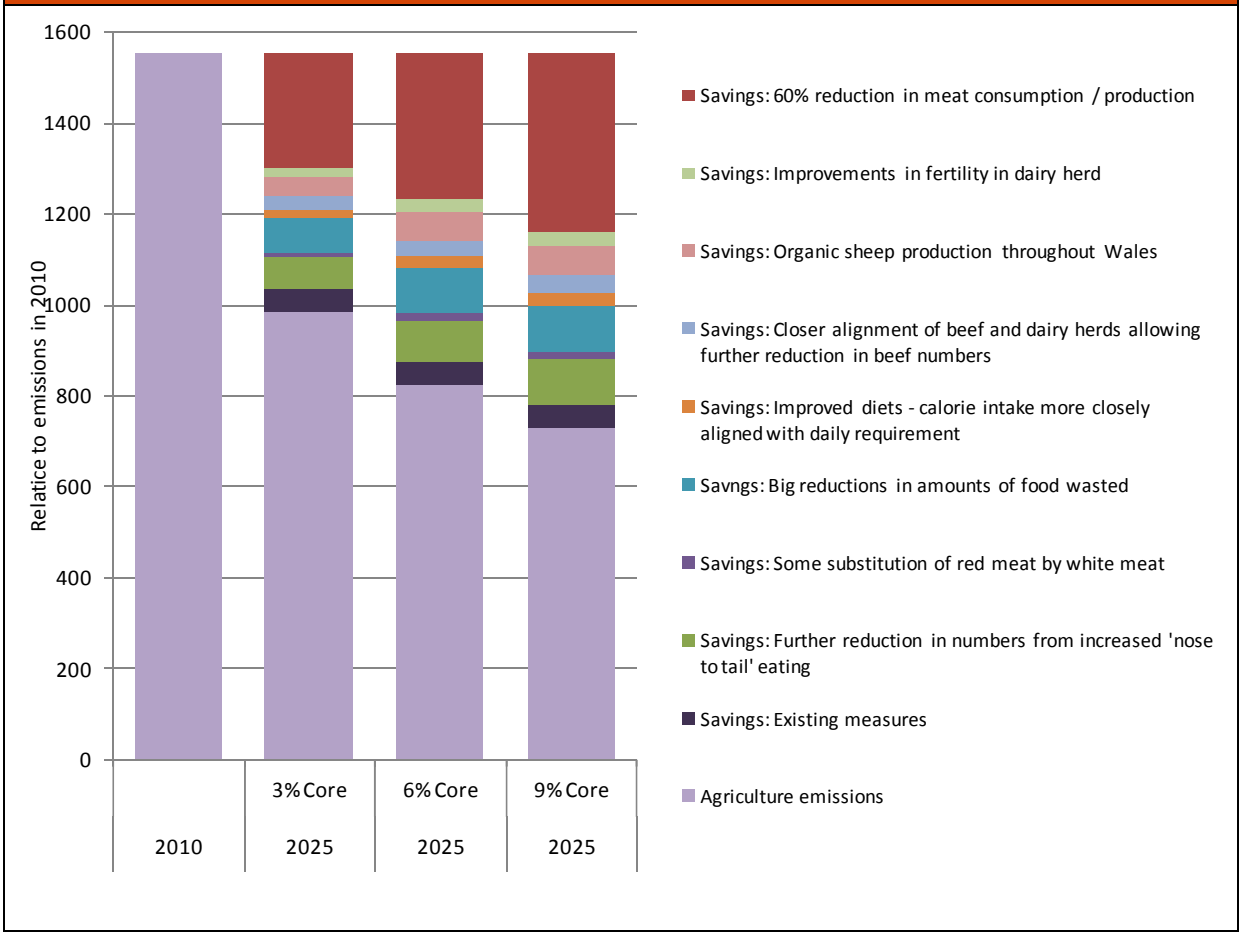
Both 6% and 9% pathways involve extending the measures outlined above. For the 9% pathway it is assumed that livestock numbers and consumption of meat are reduced by around 60% and that all sheep farming is organic. The latter is also the case for 6%.

[33] Garnett 2007, p165, refers to this as "marginal livestock rearing". It is recognised that such an assessment should not be limited to Wales and that consideration at EU or other levels may suggest lesser or greater reductions for Wales than those assumed here.
[34] This substitution effect limits the reductions that can be achieved from reducing livestock numbers alone. See Audsley et al, 2009. In short, it means that stopping eating meat entirely would only result in a 20% reduction in emissions. More optimistic figures for reductions have been assumed based on the fact that most additional food would be produced in Wales using low emission techniques.
[35] For example, the potential impact on land use change in other countries from producing feed (Garnett 2009).
[36] Williams et al, 2006 suggest that emissions per tonne of meat from sheep are 40% lower for organic systems. Analysis showed that , for both dairy and beef, organic rearing led to greater emissions (a 15% increase).
[37] Garnett 2007, pp.136-137, suggests that closer alignment between beef and dairy herds could reduce the number of cattle raised purely for beef and hence further reduce emissions.
[38] Quoting other research, Garnett 2007, p.138, notes that "efforts to restore fertility to 1995 levels could reduce methane emissions by 10-11% while further improvements still could reduce methane emission by up to 24%".
[39] Currently about one third of food bought is thrown away (WRAP 2009)

Consideration of land use beyond agriculture within this report is limited. While additional biological sequestration has not been considered as a mitigation option, it is important that the levels of carbon that are already 'locked up' in soils, forests, etc, are maintained. With this in mind it is a concern that current predictions see forestry as being a net emitter of GHGs by 2025[40], highlighting some of the issues that biological sequestration presents.

3.5.3 What does the core scenario mean for Wales' agriculture sector?

Figure 3.9: Illustrative emissions savings from agriculture on 3%, 6% and 9% in the core scenario



[40] AEA 2008, p.85. This draws on the work of the Centre for Ecology and Hydrology which can be accessed at http://www.edinburgh.ceh.ac.uk/ukcarbon/reports.htm.

Jobs creation and new skills requirement

Given the cultural and historical importance that livestock farming has in rural Wales there is a profound shift in approach. Low-emissions farming necessitates an increase in people working in agriculture, depending upon the approaches adopted, and the potential to reinvigorate the rural economy. The use of low-carbon techniques, along with a reduction in livestock numbers and switch to alternative production (either food or other crops), requires training for agricultural workers. The value of existing livestock is enhanced by ensuring there are markets for products such as wool. This links, for example, to the insulation required for refurbishing homes. Tourism plays an increased role, reflecting a desire (both as a result of cost and changes in values) of people to holiday closer to home. Growth in small-scale / urban food production is driven by skills sharing, and supported encouragement will catalyse action. New ways to encourage healthy eating are utilised.

Aesthetics

The Welsh countryside changes with the impact (positive or negative) subject to chosen management approaches and perception. Impacts on biodiversity are an important aspect of decisions regarding the targeting of livestock reductions. The reduction in livestock numbers and greater arable production in lowland Wales, provided it is managed in an environmentally sensitive manner, contributes to biodiversity conservation. This is a particularly sensitive issue for the large areas of Welsh countryside under statutory protection.

Capital expenditure

Given the rapid change envisaged it is necessary to provide financial assistance to enable farmers to make the required adjustments, and to ensure that food production is not compromised. Early investment in research into low emission farming helps to build an evidence base. Improved health and better diets reduce medical costs.

Living standards

The upheaval experienced by farmers demands support for those affected. However, by changing the focus of policy and placing greater emphasis on the food system and its importance, greater value is placed on those working on the land. While eating less meat is initially perceived as detrimental to lifestyles, the overall health benefits[41] and greater physical activity, associated with cycling and walking for example, results in a drop in obesity rates.

Embedded emissions

The changes outlined have a positive impact on embedded emissions by, for example, reducing the levels of animal feed required. An important component of the core scenario is that where meat is replaced by other food in the diet, it is sourced, wherever possible, from within Wales to avoid exporting emissions.

[41] The recent report from the Sustainable Development Commission, *Setting the Table* (Ready et al, 2009), highlights the health benefits from a diet lower in meat and dairy products.

3.5.4 Alternative agriculture scenarios

Two alternative scenarios to the 9% core scenario are also presented in brief below to demonstrate that there are different mechanisms for achieving the same end goal. Due to the relatively large uncertainties involved in the emissions savings that could be achieved, comparison charts are not possible for the alternative agriculture sector scenarios.

"High-Tech"

Significant emissions reductions are achieved through a combination of high-tech approaches to food production. Through genetic manipulation of the animals directly, and the food that they eat, the levels of methane emitted by livestock is greatly reduced. Efforts to produce animal feed in chemical processes, negating the need to use land for growing crops for animal consumption, are coming to fruition. In many cases, animal husbandry is changed beyond recognition. Cattle are increasingly kept indoors with the methane they emit captured (along with the manure) and used as an energy source. Early experiments to farm pigs in 'pig towers' powered by manure lead to widespread adoption of this approach[42]. Fruit and vegetables are grown all year round in large greenhouses that cover the countryside, heated by anaerobic digestion processes with the CO_2 generated used to aid growth. Yields are improved dramatically and, with an abundant water supply, Wales looks to displace drought-stricken Spain as a major supplier of fruit and vegetables.

"Sequestration"

The long-term sequestration potential of locking up carbon in timber is recognised and Wales plays an important role in providing timber to the construction industry. Timber is increasingly the material of choice in house building and Wales leads the way in demonstrating its role in zero-carbon homes and other buildings. Appropriate areas of previously agricultural land are turned over to forestry with coexistence of the sectors in the mixed use of land. The trees selected for planting are those that are of particular value as timber in construction. The carbon sequestered by trees enables the agriculture and land use sectors to claim considerable reductions in emissions but at the expense of significant changes in land use.

[42] See http://www.mvrdv.nl/#/projects/urbanism/181pigcity

Box 3.4: Comparison of alternative 9% p.a. scenarios for agriculture

Advantage
Neutral
Disadvantage

Criterion	"Tyndall–WAG Core"	"High tech"	"Sequestration"
	All available technology & practices pushed to limit	Widespread GM and intensive farming techniques	Switch from agricultural land use to forestry
Job creation	LOW	LOW	LOW
Capital expenditure	MED	HIGH	LOW
New skills requirement	HIGH	HIGH	LOW
Degree of speculation	LOW	HIGH	MED
Embedded emissions	MED	MED	LOW

"High Tech"

Advances in high-tech food production have changed agriculture. Measures such as the genetic manipulation of crops and livestock are accepted and widely practiced; while huge zero-carbon glasshouses are used for fruit and vegetable production. Livestock is increasingly kept in ways that enable methane and waste products to be captured and used.

"Sequestration"

By ensuring that trees that are planted are used in construction, Wales has found a robust way of ensuring that carbon sequestered by the trees is locked-up for a significant period of time. The value of land for forestry has grown, with areas of agricultural land turned over to trees.

3.6 Waste

Emissions from waste currently account for 3% of the total for Wales. Although this appears relatively small, addressing waste offers a way of tackling the difficult issue of excessive consumption and high levels of 'imported' embedded emissions.

Table 3.7: Waste sector summary

	Total sectoral emissions (ktCe)	% of total emissions	Annual % reduction for this sector	Absolute % reduction vs. 2010
2010 emissions	380	3%		
2025 emissions (3%)	231	4%	3%	39%
2025 emissions (6%)	154	4%	6%	60%
2025 emissions (9%)	77	3%	10%	80%

Proposed reductions expected from the waste sector broadly follow the 3%, 6% and 9% pathways shown in table 3.7. Current discussions on waste reduction are largely framed in terms of reducing its ecological footprint. It is recognised that GHG emissions account for around half of the ecological footprint and it has been assumed in the core scenario that a reduction in this will see a corresponding reduction in GHGs[43].

3.6.1 Achieving the reductions from waste in the core scenario

For the 3% pathway, the core scenario envisages implementation of the strategy set out in *Towards Zero Waste*. Option two from the strategy is adopted resulting in annual reductions in ecological footprint (and GHGs) of 3.2% compared to the previous year. The 6% and 9% pathways necessitate more rapid implementation of the strategy, with the 9% pathway assuming a zero waste Wales by 2025 (as opposed to 2050)[44]. The 6% pathway falls between the 3% and 9% pathways in terms of the effort required.

3.6.2 What does the core scenario mean for Wales' waste management sector?

As emphasised in *Towards Zero Waste*:

> "There are lots of opportunities in waste management to build a sustainable future – by helping our society and economy as well as the environment. By designing products differently – so they are more easily recyclable and reusable and use more sustainable and lesser quantities of materials and cleaner production methods – we can create higher value jobs, and marketable products. If businesses become more efficient with their resources, they can become more competitive and profitable. There are also lots of possibilities for innovation in new, greener, technologies. By recycling more, we create more jobs, and if we

[43] See WAG 2009c, p.11.
[44] This reflects the 'Option 5' of zero waste by 2025 identified in the Sustainability Appraisal of the Wales Waste Strategy (ERM UK 2009).

> engage our communities more in these activities we can increase employment, skill levels and people's well-being even further"[45].

Moving beyond the 3% pathway presents significant challenges and involves costs to both public and private sector. Investment in infrastructure and skills development is significant. However, setting out on this path places Wales in a stronger position to realise the benefits outlined above, and enables export of expertise.

[45] WAG 2009c, p.15.

3.7 Public

Emissions from the public sector account for only 2% of total emission in Wales, however, action plays an important symbolic and leadership role.

Table 3.8: Public sector summary

	Total sectoral emissions (ktCe)	% of total emissions	Annual % reduction for this sector	Absolute % reduction vs. 2010
2010 emissions	245	2%		
2025 emissions (3%)	49	1%	10%	80%
2025 emissions (6%)	0	0%	34%	100%
2025 emissions (9%)	0	0%	34%	100%

The core scenario envisages major reductions for the sector (see table 3.8) with effectively zero emissions for both the 6% and 9% pathways[46].

3.7.1 Achieving the reductions from the public sector in the core scenario

Nearly half of the emissions reductions observed in the 3% pathway arise from policies and actions already in place in 2009. This includes EU and UK legislation such as the Energy Performance in Buildings Directive and the Carbon Reduction Commitment respectively, as well as action proposed by the Welsh Assembly Government. Additional savings are achieved from improved carbon management via support programmes offered by the Carbon Trust, the tightening of building regulations, and the expansion of revolving funds to take account of longer payback periods. There is extensive use of renewable heat technologies, with choice reflecting local feasibility.

3.7.2 What does the core scenario mean for Wales' public sector?

The relatively low levels of emissions from the public sector mean that changes, in isolation, have a limited impact. The exemplary and educational role played by town halls, schools, hospitals and other public buildings does, however, helps to catalyse action across other sectors.

[46] There will be residual emissions to parts associated with the public sector supply chain that cannot be eliminated within the scenario timeframe.

4. Discussion and conclusions

4.1 Wales as an exemplar for 2℃ mitigation

This report demonstrates that the GHGs necessary for a 2℃ future are compatible with the existing or slightly modified structures, technologies and societal framing of Wales today. Whilst in the longer run, research, development and deployment of *new* low-carbon technologies are a prerequisite of sustaining reduction rates, Wales has the capacity and wherewithal to begin the transition to a 2℃ emission reduction pathway as early as 2011. However, the political will necessary to put the theory into practice should not be underestimated, and a significant increase in the influence of the Welsh Assembly Government on all areas of Welsh society will be inevitable. In addition, early in the next decade it will be necessary for further powers to be devolved to the Assembly if it is to maintain a 2℃ pathway across all sectors and ensure a coherent and strategic policy framework fostering synergies and avoiding conflicts between sectors.

There is no escaping that the financial implications of a 2℃ pathway will be substantial, particularly in terms of upfront capital costs. However, with strategic vision and direction there will be significant and relatively early economic returns arising from increased resilience to high energy prices, tax revenue from increased employment and, in the medium-term, lower adaptation costs.

The analysis within this report is supported by broader Tyndall and other research suggesting significant medium and long-term economic dividends to those nations making an early transition to a low-carbon society. With increasing international momentum for stringent caps to be placed on emissions from industrialised nations, and with Copenhagen 2009 likely to catalyse international action, making the necessary transition now is certainly preferable to delay and further lock-in to high-carbon growth. Acknowledgement by the Welsh Assembly Government of the need for early and rapid reductions places Wales amongst the lead nations on climate change. Translating this acknowledgement into meaningful action will demand strong and courageous leadership alongside cross-party support. Nevertheless, Wales is in many respects well placed politically and geographically to provide an evidence-based exemplar of a nation successfully transitioning to a 2℃ future.

Box 4.1: Headline conclusions for the 3% p.a. core scenario

Figure 4.1: 3% pathway by sector

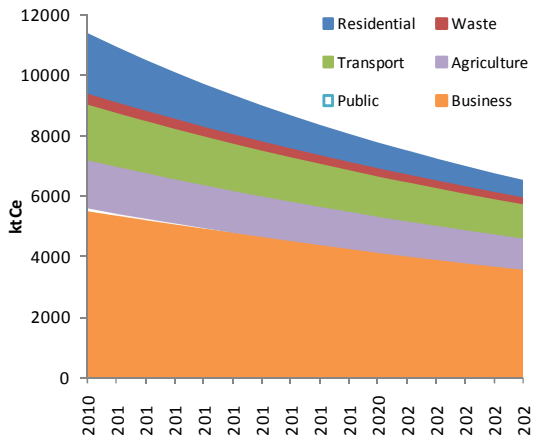


Table 4.1: emission reductions in 3% pathway

	Absolute % reduction vs. 2010	Annual % reduction
Residential	75%	9%
Transport	37%	3%
Business		

The GHG reduction measures necessary for a 3% p.a. pathway present significant challenges but the scale of change can be incorporated into the current framing of Welsh society and economy.

The **residential** sector is pushed relatively hard to achieve reductions in excess of 3% p.a. with widespread recognition that there are considerable benefits beyond carbon savings resulting from the upgrading of housing stock. Stringent building standards, zero-carbon homes, a major programme of insulation and roll-out of renewable heat technology in homes where it will have the greatest benefit all combine to reduce energy bills, help greatly reduce fuel poverty and enhance standards of living.

Within the **transport** sector a range of technology changes, along with eco-driving skills and some substitution of car journeys by other zero-carbon transport (e.g. trains or buses powered from a zero-carbon grid) are able to deliver 3% p.a. reductions.

The **business** sector in Wales presents significant challenges in terms of emission reductions as the sector has a number of high emitting heavy industry sites. Ensuring that the savings from energy management and energy efficiency are maximised, along with improvement in building regulations and the adoption of more biomass systems is, however, sufficient to bring about 3% p.a. reductions in emissions.

Agriculture differs from the other sectors as the 3% p.a. carbon reductions demand significant changes to existing farming practices. Appreciably lower levels of production and consumption of meat and dairy are central to the core scenario, along with efforts to maximise the value of remaining livestock and minimise emissions directly associated with them. This entails a significant cultural shift in agriculture in Wales. It is assumed that the food needed to replace meat in diets is grown in Wales wherever possible and utilising low-carbon techniques. The waste associated with consumption is also greatly reduced and people's diets improved.

Continues...

Box 4.1 continued

Efforts to reduce the impacts of **waste** are already underway and 3% p.a. reductions is achieved through the implementation of existing policy measure. Finally, the **public** sector plays an important leadership role reducing emissions by the equivalent of 10% p.a.

While these changes will test Wales and its people, there are benefits to exploit. New and changing employment across all sectors demands training and skills to maximise the potential. The knowledge required to understand and implement low-carbon approaches is to be widely shared, particularly in relation to agriculture where Wales could become a centre of expertise. A Wales that achieves 3% p.a. reductions is, outside of the agriculture sector, unlikely to change markedly. There is a small shift in the way people take car journeys, but again it is limited. Changes in the appearance of many homes are a feature of this pathway, with external insulating cladding and domestic renewable heating and hot water systems commonplace. In general, higher quality, lower cost homes prevail. The level of waste is reducing, with new habits around recycling forming and minimal packaging an expectation. Evolving diets are initially hard for some to accept but a combination of price incentives and clearly presented health benefits mitigate against opposition. Rural Wales undergoes greater change than is immediately evident within towns and cities, and an eye on this situation enhances or at least sustains a vibrant and resilient rural economy.

Box 4.2: Headline conclusions for the 9% p.a. core scenario

Figure 4.2: 9% pathway by sector

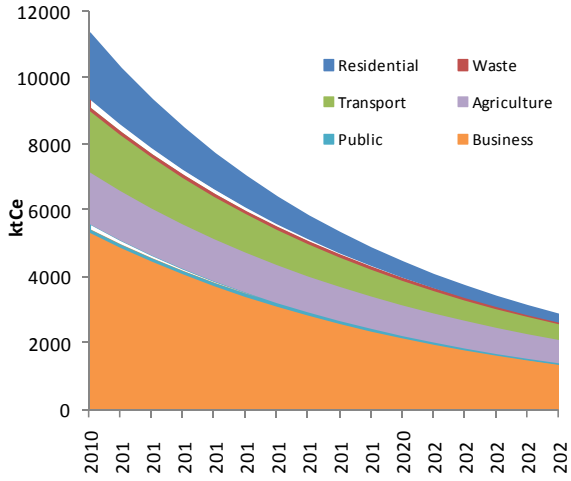


Table 4.2: emission reductions in 9% pathway

	Absolute % reduction vs. 2010	Annual % reduction
Residential	90%	15%
Transport	76%	9%
Business		

Achieving the changes necessary to bring about the equivalent of a 9% p.a. reduction in total carbon emissions involves a rapid escalation of measures introduced under the 3% p.a. pathway. However, while these measures may not be new, the degree to which they have to be extended to achieve 9% has significant if not fundamental implications for Welsh society.

For **residential** four out of five houses have renewable heat technology fitted and a high level of insulation is standard throughout the housing stock. Significant changes in individual behaviour are occurring, particularly in relation to the level of domestic heating considered appropriate for a comfortable living style, with a shift away from uniform temperatures throughout households. The reductions resulting from these measures in the residential sector, in conjunction with a shift to low-carbon electricity, are well above the 9% target.

Technology measures are pushed hard in **transport** but fall short of the target. A considerable reduction in overall vehicle kilometres demands an increase in journey load factors (such as people sharing lifts, or a significant modal shift to alternative forms of transport. The latter challenges the existing design of the towns and cities of Wales.

In the **business** sector energy efficiency and some demand reduction bring significant challenges and site-specific CCS is introduced to heavy industry. The shortfall of these interventions is met through the substitution of fossil fuels by zero-carbon electricity.

Continues...

Box 4.2 continued

For **agriculture**, measures used to achieve the 3% pathway are extended as far as reasonably possible but still fall far short of what is necessary for 9%. Even with a drop of at least 60% in the production and consumption of meat and dairy, it is hard to achieve savings of greater than 5% p.a. Even at this level the cultural changes are major. Whilst biological sequestration of carbon is not considered sufficiently robust to be included in the scenarios, the use of timber-frame housing is a viable route for locking-up those emissions from land use not amenable to alternative reduction approaches.

Measures that are implemented to achieve a target of zero waste by 2025 contribute significantly to a rapid reduction in emissions from the **waste** sector. In the **public** sector leadership is central with an exemplar programme of refurbishment and adoption of renewable heat technologies leading to extremely low to zero emissions by 2025.

The Wales outlined in this scenario is, in many respects, a markedly different place from that of today. Nevertheless, it retains similar organisational structures, family, work and social arrangements. However, it does demand reduced expectations in terms of economic growth, at least in the short-medium term. And although many of the measures suggested to achieve the 9% p.a. target are relatively conventional, the degree to which they are implemented will result in significant changes. This is a long way from tweaking 'business as usual', and brings with it significant opportunities and risks. Following a 9% pathway sees Wales leading the world and potentially exporting expertise globally. The infrastructure of Wales is, in most regards, vastly improved, with better quality homes and public transport, along with improved facilities for walking and cycling. Changes to diets and increased exercise bring improved health and lower associated costs for the health service. If managed well, the changes to rural Wales result in more people working on the land, revitalising rural communities.

There are, of course, significant implications, both financial and social. Sourcing the capital to implement the scale of changes outlined is a challenge requiring new ways of viewing the problem. A radical adjustment to ways of thinking about value in the economy will put well-being and ecological value alongside more traditional economic approaches. The greatest challenge is the effort required to build political consensus amongst the people of Wales to support this scale of change. It demands enduring leadership, considerable engagement and a revitalisation of citizenship around common environmental goals.

4.2 Achieving the 9% pathway: headline conclusions by sector

4.2.1 Residential

With reductions equivalent to 14.5% p.a., the residential sector's contribution is significant. Substantial investment and innovative programmes are required to ensure implementation with minimum disruption to people's lives. All new homes built from 2011 are zero-carbon and around 60% of existing homes in Wales are fitted with heat pump technology, meeting all heating and 50% of hot water needs, while a further 20% will have solar hot water heating. Houses are well insulated and thermostats are set lower. The measures are not particularly new or innovative but need to be applied sympathetically and often in novel ways to mitigate objectives and maximise 'buy-in across the sector. The result is a dramatic improvement in housing standards with people living in more comfortable houses, using less energy and potentially having lower bills.

4.2.2 Transport

Measures to reduce emissions ensure that the target 9% p.a. is achieved. Improvements in technology are central to this change, with optimistic estimates for what can be achieved in this timeframe being realised. Making this happen in Wales, without equally significant change elsewhere, is difficult and innovative approaches to incentivising consumer choice are needed. In addition, a significant reduction in demand, with vehicle kilometres reduced by over 40% compared to 2010 levels, is required. This calls for a major shift in the way that people get around and the investment to make this happen. Rail and bus travel is the mode of choice for inter-city travel and there is progress in changing the towns and cities of Wales to 'design out' car trips for daily tasks. Personal mobility is not compromised, but it is likely that certain trips come to be seen as unnecessary. An increase in cycling and walking brings important health benefits.

4.2.3 Business

9% annual reductions are theoretically attainable but difficult to achieve in practice. Pushing well recognised measures to their limit still leaves a significant shortfall compared to the reductions required. Bridging this gap calls for two new approaches. Firstly, process-based carbon capture and storage plays a significant role and, while this is not a 'new' technology, the current rate of deployment suggests this is an optimistic assumption. Secondly, industrial fossil fuel use is replaced by electricity drawn from the zero-carbon grid. This results in additional demand and will entail an expansion of current plans for renewable energy. Although the challenges of achieving these emission reductions are clear, there are no significant structural changes imposed on the business sector in Wales.

4.2.4 Agriculture

The reductions achieved for agriculture are lower than for any other sector due to its fundamentally different nature. The role that livestock play in Welsh agriculture makes

emissions reductions difficult and means that a significant fall in livestock numbers is inevitable, along with changes in the way remaining livestock are managed. However, this is only achieved through parallel action on consumption, with replacement of meat and dairy in the diet with other lower impact food. The 30% of food that ends up as waste is cut drastically and the volume of consumption further reduced through improved diets. Compared with other sectors, there is greater uncertainty in assessing potential emission reductions, making investment in research into all possibilities for low-carbon farming a necessity.

4.2.5 Waste

By implementing a zero-waste policy for 2025, emissions from the waste sector are reduced beyond the 9% target. Policies to achieve this have already been set out in the consultation document *Towards Zero Waste*, albeit over a longer timescale. This earlier target has been considered in appraisals of *Towards Zero Waste* but identified to be too difficult to achieve. Efforts to follow a 9% pathway will require implementation of existing waste strategy to be accelerated.

4.2.6 Public

By going zero-carbon, the contribution of the public sector is well beyond 9% p.a. reductions. Although the public sector makes a minor contribution to overall emissions, this leadership role is a vital signal of intent.

4.3 Issues for policymakers

4.3.1 Finance for 3% versus the economics of 9%

The transition to a moderately low emission society, as described by the 3% p.a. reduction scenarios, incurs relatively low mitigation costs in the short-term, but at the risk of much higher mitigation and adaptation costs in the medium to long-term.

Given that the scale of mitigation accompanying any reasonable characterisation of dangerous climate change demands annual reductions in the order of 9% p.a., the reduction rates for Wales will need to be ramped up much further in the near to medium-term if 2℃ is to remain a Wales and UK goal . The analysis conducted here suggests that, in light of the 6% and 9% p.a. rates being (in many respects) an in-depth extension of the 3% measures, there is substantial economic benefit to be had from making the necessary changes earlier rather than later. In brief, a short-term and narrow *financial* assessment suggests delivering 3% mitigation now (as the least cost option), whilst an *economic* assessment of revisiting sectors in the future to implement higher mitigation rates would likely favour an early adoption of higher rates.

4.3.2 Resilience to energy price rises and volatility

There is a high probability that the price of energy will rise significantly over the coming decade and beyond. Moreover, as there is increasing demand for reducing reserves of

finite fossil fuels price volatility is also projected to increase. Consequently an indirect benefit of an early transition to a low-carbon Wales, in line with the 9% scenarios and based on highly efficient industry and indigenous energy production, would be to insulate Wales from the otherwise significant implications of such changes. This is particularly relevant to the Welsh economy if, as is assumed in the core scenario, it maintains a competitive and resilient industrial sector.

4.3.3 A modern take on the manufacturing history of Wales

A more strategic benefit of an early transition to high mitigation rates could be an accompanying transition of Wales' industrial and manufacturing capacity towards low-carbon demand and supply technologies. In this regard, a domestic Welsh market for such technologies, supported by strong Welsh Assembly Government regulation, could offer sufficient security of demand to incentivise the private sector to invest in indigenous production capacity. Given both the climate change agenda and the probability of higher energy prices, the development of significant low-carbon manufacturing and knowledge sectors in Wales would likely have significant export potential.

4.3.4 Catalysing mitigation saves on adaptation

Amongst the industrialised (Annex 1) nations the UK is currently the leading advocate of implementing measures necessary to 'avoid dangerous climate change'. Within the UK, the Welsh Assembly Government is at the forefront of meeting this challenge through the development of strategic and coherent mitigation policies, and to this end is a potentially important driver of international responses to climate change. Consequently, whilst the implications of Wales' lead on mitigating emissions are inevitably speculative, they have, in conjunction with others, the potential to catalyse major international efforts to reduce emissions and thereby avoid the more severe implications associated with adaptation. In brief, the near-term costs of implementing radical emissions reductions within Wales have the potential to contribute to triggering wider international mitigation responses and thereby help avoid the extreme social and economic repercussions of high global temperatures. The impacts of climate change should be considered when designing mitigation actions, for example the effects of a changing climate on the design and siting of new homes.

4.3.5 Strategic planning avoids the risk of lock-in

There are clearly important changes to the Welsh energy *system* necessary to achieve the higher emissions reduction levels (6% to 9% p.a.). However, where alternatives exist, it is generally preferable to initiate changes in relation to energy demand rather than supply, as the former maintains flexibility in the system whilst the latter typically involves greater technology lock-in. Whilst some white goods have mean lifecycles of as little as two years, others, such as refrigerators, are higher at around 8 years, with domestic heating boilers and cars nearer to 8-12 years. By contrast the lifecycle of energy supply technologies is almost an order of magnitude higher, with wind turbines, 15-25 years, gas turbines 25-30 years, nuclear and coal power stations 35-50 years and large hydro schemes (including tidal) typically 60+ years. Consequently, the very

high capital outlay associated with large-scale supply options has a strong tendency to lock-out alternative approaches for many decades to come. Alternatively, a transition to much more efficient end-use technologies could either be reversed or complemented within a decade or often considerably less. However, as reduction rates increase from 3% to 9% p.a., so there is increasing need to instigate rapid changes to both the consumption of energy (i.e. reduce energy demand) *and* the transition to the low-carbon energy supply. Nevertheless, lock-in remains an important issue, as, for example, establishing large centralised power stations can inadvertently reduce opportunities for more localised small-scale renewables unless issues of grid stability, etc, are considered well in advance. Similarly an extensive biomass programme would likely have significant implications for land-use, with concurrent risk of locking-out, or at least constraining, alternative agricultural practices.

Extending the issue of lock-in to others sectors demonstrates the need for considerable forethought and strategic planning if 'inappropriate' routes to a low-carbon future are to be avoided. For example, in relation to agriculture, the construction of a substantial network of large-scale anaerobic digesters suggests an industry dominated by intensively reared livestock, essentially locking out a transition to low intensity farming. Similarly, in relation to transport, constructing major infrastructure of car charging points, with, accompanying distribution network, would reduce the viability of a transition to a hydrogen alternative. In this regard, using a stringent regulatory regime to make a rapid transition to more efficient internal combustion engine cars would achieve significant short-term reductions without necessarily locking-out either future electric or hydrogen options.

4.4 Further work

The project has highlighted several key areas for further research to enable the Welsh Assembly Government to move to a strategic implementation programme.

- A programme of further research to explore the potential for long-term biological sequestration is an important issue given the barriers to the present 9% scenario for agriculture and land use. This exploration must be systems based, relating the science underpinning sequestration to different future emissions and temperature scenarios with different social and landuse responses - national and internationally.
- A system level exploration of agriculture, linked to energy production, material production, local tourism and food production, identifying synergies and conflicts
- A detailed analysis of the social, environmental and economic costs of the Tyndall–WAG scenarios is necessary for both strategic budgeting and to tailor support to those individuals and communities negatively impacted by the accompanying measures. This assessment must extend well beyond conventional 'financial' approaches and consider issues of system interdependencies and complexity, as well as relative impacts to the more vulnerable communities and threatened eco-systems.

- There is considerable scope for undertaking a detailed piece of academic research based on the approach outlined and analysis undertaken in this report. Such research would likely be of a two-to-three year duration, involve a range of partners, including one or more of the research councils, and engage, at a high level, with a wide range of stakeholders.

4.5 Returning to the 'Vision of a Sustainable Wales'

In light of the EU and UK's characterisation of 2℃ as delineating acceptable from dangerous climate change, ensuring Wales *"lives within environmental limits"* and uses *"only its fair share"* of resources demands urgent and radical reductions commensurate with a minimum 9% p.a. emission-reduction pathway. At the same time, it is recognised that sustainability encompasses more than just climate change and in addressing this one issue consideration must be given to the impact on others. Such analysis is, however, beyond the scope of this report.

The level of ambition reflected in current policy developments puts Wales at the forefront of action on climate change. That this is not enough to meet the Sustainable Wales vision is not a criticism of current action, but rather recognition that the basis for this action has rapidly being overtaken by the evidence for more urgent and radical change. This report is an early assessment of what would be necessary for Wales to meet this new challenge.

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APPENDIX: Workshop Feedback

Comments and alternative actions proposed from Welsh Assembly Government – Tyndall Workshop, Cardiff, 19 October 2009. Separate sessions were delivered for each of four sectors – residential, transport, business and agriculture.

I. RESIDENTIAL

Session Attendees	Organisation
Alexa Spence	University of Cardiff
Michelle Aitchison	Sustain Wales
Jon Westlake	Forestry Commission, Wales
Havard Prosser	WAG
Roger Wade	Environment Agency Wales
Steven Glynn	Association for Sustainable Change
Fiona Nicholls	Association for Sustainable Change

Actions in core scenario	Comments
New housing: building regs 100% reduction in CO_2 from 2010	• Assumption that low impact housing will remain low impact e.g. people replace energy efficient light fittings, low flow shower heads • Costs of building vs. existing housing • Building industry – difficult to change culture and build up skills
Existing housing: Regulation to promote energy efficient lighting	• Potential health scares • Acknowledge and address shortcomings of introduction • Technical aspects improved • Better to have improved natural lighting homes • Focus on reduced demand for lighting
Existing housing: Insulation (this is as suggested by AEA)	• Planning and conservation hurdles • Changes distinctive character of Welsh homes • Tax varying according to efficiency of building
Existing housing: 30% SHW; 50% heat pumps	• High cost of installation • Lower running costs • Public acceptability of new technology and lack of understanding of the costs • Planning and regulation issues for heat pumps • Information campaigns • Low/no interest loans to overcome capital funding of larger scale energy efficiency improvements/renewables • Heat pumps reduce urban heat island effect

Existing housing: micro CHP	• Demand for heat and electricity can be out of phase with demand
Turning heating down by 1℃ in 50% of homes	• General lack of understanding of the costs vs. benefits

Alternative actions	Comments
Biomass domestic heating as alternative to micro	
Greater behavioural change	• What options are there? Different ways of promoting behavioural change: carrots (financial or value based) and regulation. Regulation often unpopular but difficult to predict the impacts that carrots will actually have.
Demolish and rebuild and replace existing housing by 2050	• What is an acceptable demolition rate?
Lower impact of embedded materials e.g. storing C in timber	• Duel benefits of using greater timber build in new housing – very different Wales but could be a positive rebranding. This would require a rethink in planning as these would be very different houses in character.
Advanced white goods to include monitoring of energy use screens	
Population constraint	• Unclear of assumptions about population growth within the scenarios. Current trends to single occupancy reflect a disintegration of the family unit. Can this be reversed? What benefits would there be in this?
Reduce property and space size and co-housing with centralised facilities	
Water use reduction through grey water and rainwater recycling	• Lots of energy within water delivery process
Energy pricing cap and trade	
Smart metering to include useful and clear information in accessible place in the home	• Possible rebound as savings are used to fund other higher impact activities

Other general comments

- Linking funding opportunities to awareness programmes and policy i.e. co-ordination, is key to getting awareness, behaviour change and action
- Four key barriers were identified:
    - **Skills shortage and culture within industry** – there is clearly a shortage of skills at the current time to undertake the kind of programmes envisaged in the scenario. There would therefore need to be a significant investment in training. However, it is not as simple as this as there are also cultural barriers that would need to be overcome – "we've always done it this way so why should we change". This could be a likely response to, for example, any efforts to move towards timber frame housing. Efforts to address skills issues are already underway with a 'green skills college' recently being established. The flip side of the skills shortage is the potential job creation possibilities that these programmes would necessitate. The key question here is how to ensure that you developed these jobs in Wales and, beyond Wales, realise opportunities to expand into other markets. It may be a case of identifying niches where particular specialism could be developed (e.g. in addressing hard to treat homes). Another issue is in trying to ensure that skills can be accessed reasonably locally to avoid significant amounts of additional travel around the country.
    - **Costs** – There is the issue of costs related to public funds but also the costs to citizens. For example could low/no interest loans be used to help overcome issues of high up front costs for renewable energy technologies and insulation measures. The equity issues of how you deal with the fact that some homes will cost a lot more treat than others were raised. Issues around the costs of energy were also highlighted and it was suggested that there is an assumption that energy costs will always be cheap and a cultural shift was needed to break this so that people would see the longer term savings. The possibility of using council tax (one of the few tax raising powers available) as an incentive to action was mentioned e.g. linking Council tax to energy ratings for houses.
    - **Awareness** – In general it was felt that there was too little awareness of the issues and it would be challenge to instigate programmes on the scale proposed without addressing this. For example it was said that there is very little awareness about what heat pumps are. Lack of awareness of energy use was blamed in part on direct debit payments as this distances the consumer from their energy use. Smart meters were seen as having an important role to play in bringing back this connection with energy use.
    - **Civil liberties** – It was recognised that the level of intervention required would have potential civil liberty issues. For example would everyone be happy about having their homes changed? What do you do if they aren't?
- A theme running through the discussion was the need for more joined up policy/thinking to ensure that any measures were introduced in a clear and complementary way.

II. TRANSPORT

Workshop Attendees	Organisation
Claire Bennett	WAG
Bernie George	WAG
Clive Walmsley	Countryside Council for Wales
Martin Kemp	Centre for Alternative Technology
Louise Haines	WAG
Peter Randerson	University of Cardiff
Simon Brindle	WAG
Dave Proctor	
Morgan Parry	Sustain Wales
Kevin Anderson	Tyndall Centre
Dan Calverley	Tyndall Centre

Actions in core scenario	Comments
Car- powertrain- hybrid	
Biofuels	
Car- powertrain- plug-in hybrid and electric	• Suggestion the potential for using electric vehicles to reduce emissions has been underestimated in this scenario.
Car- non powertrain- all cars	
Demand: 'Smarter Choices'	• Question: why are some people so determined to stay in their cars? The main reasons are time budgets; identity and status (which resist price / disincentives); and strong habit formation (which is especially strong in the personal transport sector). • Need to think about the reasons for travel: observation that the school run is a big contributor. What additional actions are possible to reduce the need to drive to make this trip? Change the system of school place allocation? • Is it possible to change people's perceptions of 'danger'? i.e. the risk to children of traffic injury and threat from strangers. Can informational campaigns change this by pointing out the self-defeating nature of driving on the school run to protect from traffic dangers? What if these threats were compared to the risks to children of a lifetime of car dependency and risk of obesity?

Speed reduction and enforcement at 60mph	• This is quite a high speed limit for much of the Welsh road network – a lower limit would be more effective.
Demand reduction (car vehicle km) e.g. modal shift, increased load factor, forgoing journeys	• Emissions saved at UK level cannot be scaled directly to Wales as the split of urban to rural populations is different. • Observation that the main criteria affecting choice of mode are convenience and time constraints. Any intervention aiming to bring about modal switching must recognise this. • Problem with demand reduction is its link with prosperity and social mobility. People nowadays have dispersed social networks; if you remove access to that network you reduce social and economic mobility. • This was countered with the question of what proportion of Wales' population is really that mobile. Furthermore, in less rural parts of Wales public transport allows for perfectly good mobility and these areas are ripe for encouragement of further modal shift away from the private car. • Rural areas may be significantly disadvantaged by a blanket demand reduction policy, but also acknowledgement that policies can be buttressed and include compensatory measures. • Also, acknowledgement that the reduction in vehicle km (e.g. 22% by 2025) is for the whole of Wales, so some regions may be able to reduce by less if others do more. • Wide support for the positive sustainability implications of demand reduction, and lower emissions from the lifecycle of vehicles from manufacture to disposal. • Rural communities may benefit from increased community cohesion as a result but their economies may suffer. • Appreciation of the greater social interaction and social inclusion offered by slower, public modes. • Concern that the time required to achieve a significant change in behaviour may be much more than is assumed (it may require people to relocate home and work etc). • Constraint on personal flexibility, going against the grain of strong habits and overcoming short-sighted 'rational self-interest' were commonly seen as the main barriers.

Alternative actions	Comments
Further emissions reductions from freight	• Supposition that freight was a significant contributor to total transport emissions based on observation. Investment in rail suggested to enable modal shift for freight. • Noted possibility for potential unintended effect of reduced congestion leading to more private vehicles using the roads and transport emissions increasing.
50mph speed limit	• Much of the Welsh road network does not permit average speeds in excess of 60mph anyway. Also suggestion that electric vehicles might be allowed a higher speed limit to incentivise their use.
Congestion charging in urban areas, and generally more 'punitive' measures required to discourage certain travel behaviours	• All speeding fines revenue to be used by WAG climate change fund.
Investment in integrated transport	
Modification of road network: convert two or three lane motorways / carriageways into three or four lanes respectively.	• Reduces congestion but also forces significant reduction in speed.
Park and ride schemes	• Perhaps these should be devised to be the opposite of current P&R schemes, whereby people drive most of the distance, then take public transport for the last short leg of the journey into urban areas. Wouldn't it be better to have a reliable and fast train network that could substitute for the driving section, i.e. short drive at the start of the journey to train station, train straight to destination?
Expansion of commercial 'car clubs' (e.g. City Car Club)	• Shorter journeys within cities are especially amenable to electrification.

Other general comments
• More consideration should be given to costs – CBA of the various measures to compare the 'value for money' they represent • There are currently no incentives for business people to use public transport, for instance, there are no power points on trains in Wales for laptop use (although there are none in cars either). • Need to remove conflicts of interest between business and consumers by aligning their priorities. For instance, by facilitating a shift away from car ownership to rental / pay-per-mile, the higher marginal private transport costs for consumers encourages use of public transport. Other examples include supply chain pressures arising from bigger companies' 'green' marketing images and harnessing the influence of individual employees by incentivising selection of low-carbon means of business travel. To realise the full benefit, regulation would be needed to level the playing field for companies that try to reduce their transport carbon emissions, or perhaps even give them an advantage. • Need to disaggregate this sector by reason for trip: issues vary according to trip purpose.
Discussion of alternative scenarios
• Suggestion that technology-driven scenarios have the advantage of avoiding behaviour change barriers by maintaining current levels of convenience. However, this notion was challenged by pointing out the behavioural changes that must occur in people's choices before technological change can happen. This has to come on top of a step change in infrastructure, so the technology scenario has a behavioural element anyway. • Suggestion that the barriers to switching to a different type of private vehicle are lower than those presented by modal switch or reducing private vehicle km. • Alternative view: in fact construction of new infrastructure is the bigger barrier. • Comment that behavioural change is also a necessary antecedent of technological change, as manufacturers will not move towards providing new vehicles and infrastructure unless there is visible demand. • Question of whether a vocal minority (the 'Clarkson brigade') could give rise to differences in performance (acceleration and top speed) between conventional and electric cars becoming a real barrier to uptake, thus making technology scenarios more akin to demand reduction scenarios anyway. • Further, could perceptions about the 'safety' or 'health risks' that will inevitably be linked to new technologies (induction charging point causes radiation! H_2 fuelling station explosion risk) present similar behaviour-related barriers to uptake? • Suggested advantage of the technology-driven scenario is the opportunity to attract inward investment and business development for Welsh companies. • Broad support for a combined strategy of demand reduction and improvement / pushing existing technology, with consideration to spatial relevance (demand reduction more appropriate to urban areas, technology in rural areas).

III. BUSINESS

Workshop Attendees	Organisation
Claire Bennett	WAG
Bernie George	WAG
Martin Kemp	Centre for Alternative Technology
Louise Haines	WAG
Dave Proctor	
Morgan Parry	Sustain Wales
Ram Ramachander	Greenstone Carbon Management Ltd
Lorraine Whitmarsh	University of Cardiff
Kevin Anderson	Tyndall Centre
Dan Calverley	Tyndall Centre

Actions in core scenario	Comments
Energy management e.g. building energy management systems	• Are there data available on benchmarks for how many businesses have so far embraced energy efficiency measures? (Carbon Trust has some info). • Big businesses have already gone a long way towards efficiency improvements, should smaller businesses be the focus? • About 5 $MtCO_2$ comes from businesses that are not covered by the EU ETS in Wales.
Simple energy efficiency measures, e.g. more efficient lighting	• Efficiency measures do not guarantee emissions reduction; they may just make production more efficient and profitable. • New Welsh guidance on how businesses report emissions, as well as the inclusion of 'green' electricity, is likely to become law soon
Building regs, low-carbon building refurbishment improvements of 50%	
Biomass boilers for large industrial and other sites	• Question re the best use of biomass? (use for fuel is considered poor value, better to combust, CHP being best of all). • Observation that the new Port Talbot biomass-fired plant will effectively consume all of Wales' Forestry Commission biomass (although it will not be supplied from domestic sources of biomass), the point being that the limited availability of biomass means that it is better put to use in smaller scale installations. • Moreover, issues about reliability of long term supply of biomass mean use for large-scale industrial uses is not appropriate.

Significant drop in emissions from key intervention, e.g. industrial CCS and / or higher use of renewable electricity for heat	• CCS for Corus steel may prove to be an extremely costly way to save carbon, as it would most likely involve shipping or piping CO_2 from the site to the Liverpool oilfield. Uncertainty surrounds use of coalfields for sequestration. • Regarding greater use of electricity in heavy industry, despite a lack of detailed understanding of the steel industry, it was agreed that this implies a different kind of steel works (arc-furnaces are used in smaller manufacturers, for specific kinds of steel, but not possible for huge integrated works like Corus, where process emissions from coking are a necessary evil).
Energy management, e.g. building energy management systems	
Simple energy efficiency measures, e.g. more efficient lighting	

Alternative actions	Comments
Algal CCS sequestration	
Support / push construction of new kinds of business, especially those necessary to building sustainable infrastructure	
Consider using alternative materials that Wales can supply sustainably in industry – greater use of wood in construction.	• Are there other *ways* of making the things that Wales needs?
Focus on non-ETS business	• The biggest emitters, Corus et al, are already covered by EU ETS.
Gather data and consider measures for SMEs	• Disaggregate business sector: large, SMEs, micro-SMEs (95% Welsh businesses <10 people).
Energy tariffs that increase marginal costs with greater consumption (rather than vice versa, as is currently the case)	• SMEs may be more susceptible to energy price increases.
Rewards for businesses that achieve better efficiency / emissions savings than the benchmark	• Danger that this becomes a time-consuming and empty exercise – every case is special and everyone has an angle to argue. • General suspicion about the value of benchmarking.

Better use of location-specific targeting of micro-SMEs, using local authority liaison	• Micro-businesses operate more like household economies, currently they fall between the advice offered by EST and CT. They need specific not generic advice.
Consider ways of changing the behaviours of individuals (employees)	• Many actions are common to the various business sectors. • Habits and lifestyle have a part to play in reducing emissions in business too, as in some industries energy costs are only a relatively small proportion of a company's expenditure, making a change in practices difficult to bring about without a shift in the perceptions of individual employees. For example, lighting in the hospitality, services and public sectors.
Supply chain pressures	• Could an accreditation scheme like Green Dragon be adapted to include energy efficiency / energy consumption? • Make more of standard accreditation schemes to confer promotional advantages for business that make the effort. • This should be led by the public sector, requiring accreditation for all procurement.
New energy efficiency standards for procurement	• Many of the high volume consumables and lower volume pieces of equipment in the health sector (for example) have no standard for energy efficiency. By extension, is this the case for other areas of business? If so, then could a certification scheme be deployed in such a way that it would become a criterion for product selection during procurement?
Greater use of onsite renewables	• Technical Advice Note 8 includes provision for promotion of renewables in local development plan documents. • Interest free loans from the Carbon Trust?
Greater use of feed in tariffs	• From next year, market incentives ought to be more favourable
District heating schemes	• Care must be taken that cost burdens are not placed on SMEs. • Heat efficiency has been poorly dealt with in previous initiatives – focus has been strongly on power (ROCs etc).

Other general comments
• As this project specifically deals with measures for Wales, the 3% scenario should show emissions from the business sector minus the emissions covered under the EU ETS. • It was noted that the Anglesey aluminium smelting works has recently announced imminent closure. • Observation that problems revolve around (i) power generation (which accounts for 50% of traded sector emissions), therefore much greater support for and promotion of renewables is required; (ii) steel - a difficult sector to improve efficiency, Corus is already one of the most efficient steelworks in the world, do we risk forcing it to relocate to somewhere where there is less stringent regulation?; and (iii) oil refineries – how much of Welsh oil is used for feedstocks and how much for fuel? Comment that if electric vehicles come to dominate then need for these refineries may decline. Aviation fuel is among the main end products from Welsh refineries. • Consensus that Wales should maintain its manufacturing base, but become as energy efficient as possible. No support for closing businesses. • Observation that the construction of new gas-fired power stations in Wales is at odds with the Renewable Energy Routemap, but highlights that the future energy generation mix in Wales will not be renewables only. • Some concern that by not taking an ecological footprint / consumption approach, in addition to excluding coal and gas power from the Island Wales scenario calculations, that we are at risk of trying to massage the numbers. Acknowledgement that eco-footprint approach is fraught by depending on the policies of other countries. • Comment that nevertheless, by taking out the choices of individuals of the equation, we are treating business as a distinct sector differently to, say, transport. Suggestion that individual changes in behaviour can have a big impact on what business does, whereas that is omitted from this approach. Response that data on supply chain / eco footprint are notoriously unreliable. However, keeping business as a distinct sector separate from individual behaviour constrains how you conceive of responses and the ability to mitigate emissions.

IV. AGRICULTURE

Workshop Attendees	Organisation
Alexa Spence	University of Cardiff
Michelle Aitchison	Sustain Wales
Jon Westlake	Forestry Commission, Wales
Peter Randerson	University of Cardiff
Havard Prosser	WAG
Clive Walmsley	Countryside Council for Wales
Steven Glynn	Association for Sustainable Change
Fiona Nicholls	Association for Sustainable Change

Actions in core scenario	Comments
Dietary change	
Reduce numbers of animals reduction of 70% sheep; 70% beef; 70% dairy	• Can't just reduce animals without thinking about land use change. • Does this mean having the same amount of land for livestock but less intensively used or a smaller amount of land? • Key issue of locations in Wales in terms of type of land available – most land is pasture land rather than arable • Culture based on livestock farming. • Real conflict between CC and wider sustainability issues in rural areas. • Could make some change to cereal crops but the trend is for global increase in animal consumption – where will this be met from? • Not linked to CAP reform (CAP no longer linked to animal numbers). • Sheep stock significantly dropped and real rural livelihood and sustainability issues present already. • Wales has a role to play in global context in provision of food as result of good pasture land. • Such reductions will lead to a very different countryside - few large farms, loss of family farms, under-grazing on the uplands, loss of jobs but possible diversification to timber, renewables, tourism, horticulture, high intensity dairy...leaving livestock on areas where conservation is key. • Some concern that alternative vegetarian diet is harmful as people lack key nutrients but recognition that there are opportunities to align with obesity issues when considering alongside need to reduce demand.

	• Much of the meat finishing processes are over the border in English lowlands which employs many (transport emissions high?). • Reducing livestock would see changes such as extensive grazing limited to the uplands and more intensive dairy production. You would have an intensive dairy sector; uplands used for some grazing but managed to conserve carbon; and a horticultural sector.
Increase in dairy productivity	
Reduction in grazing	
Major improvement in fertiliser efficiency	
Major use of nitrification inhibitors with fertilisers	• Nitrogen inhibitors as an option is questionable as evidenced in recent research.
Major inroads for anaerobic digestion	

Alternative actions	Comments
Organic nitrate fixing	• Reduces fertiliser impacts. • Reduced yield?
Change in crops (for animal feed and other?) to GM e.g. nitrogen fixing cereals	• GM crops for animal feed and biomass more acceptable to people than inclusion in direct foodstuffs.
GM animals	• Not currently acceptable to people.
Preserve the C in soil/land/biomass e.g. Myscanthus and also increase opportunities	• Need to recognise that there is a primary role for agriculture/land management in preserving existing stocks of carbon in the soil. • Enhances biodiversity. • This limits the type of uses that land can be put to as you need to be careful that changes in land use do not result in release of more C on currently unused/organic land.
Expand forestry	• To stop it going into positive. • Traditional conflict between forestry and farming • Possibility for doing this on some but not all pasture land.
Change in livestock to pigs and poultry	• Demand for cereals, which have emissions impact.
Substitute dairy for soya, other?	• Need to go vegan.

Vegetarian one day per week	• Possibility to encourage this through behaviour change but beyond this is too difficult.
Lower intensity farming	• Will provide more realistic reductions.
Higher intensity dairy and capture of methane?	
Change type of beef consumed to e.g. veal	• Veal is associated with the dairy industry so you could reduce overall numbers of livestock.
Reduce tillage	
Local, more self-sufficient model with expansion of horticultural practices	• Some vulnerability as if failure at home then will need global back up.
Need to reduce consumption and link to waste	• 30% of food currently wasted so there is a huge opportunity to reduce overall consumption if this could be addressed. • Problem of potential 'lock in' if investment in large organic waste facilities coupled with reduction in organic waste feed stock.
Diversification	• Shifts/changes in land practices driven in the past by financial incentives – farmer follow the money. Changes to new practices would need major cost drivers.
Expand biomass growth	• Few options for biomass as only 600,000 hectares available - study showed this is the maximum technical potential). • Substantial incentives or significant change in market demand needed. • Will take 3-4 years to establish harvest, which is possibly out of phase with demand – some god examples of this on a small scale. • Links to other sectors with regards to whether biomass can be supplied from within Wales.
Pyrolysis	• Emerging improvements e.g. demonstration of small-scale bio oil generation for transport in Belgium. • Possible problems of large scale biomass burning as limited potential capacity of biomass to feed them.
Substitute steel etc in buildings for wood	
Co-digestion with farm anaerobic digestion (AD) taking in municipal waste	• Problems include waste licensing issues for AD manager, acceptability to rural community, planning issues, resistance from farmers who don't want to do it, transport.

Make use of whole animal and change diets as in the past	• May be opportunity to change behaviour / diet and lead to significant reduction in emissions • In Wales much less of the animal is consumed when compared with NZ. • Can capitalise on people being into eating at the moment, evidenced by TV chefs, for example.
Decrease food intake per person	• Will reduce emissions and can be aligned with obesity problems and vegetarian diets.
Laboratory meat	• Low acceptability within the timeframe of scenarios to 2025.
Breeding animals using traditional genetic means	• If could start again on 'design' of animals we wouldn't do it the same way – could establish more efficient digestion systems by using different breeds.
Biochemically produced milk	
Back to local	• Need to overcome public desire for all year round food stuffs increases emissions.

Other general comments
• Concern over treating Wales as an island as a reduction in animals will not reduce consumption elsewhere – Wales is a net exporter by x%? Part of a global market and land in Wales is well suited to livestock rearing. • Very market driven so can you approach this from the other end and change consumer behaviour? • A Welsh branded approach to meat products and consumption could be good, with a focus on quality, all animal use, etc – how to get people engaged though? Estimated that about 50% of a lamb is currently treated as waste but this needn't be the case. Could link to idea of less intensive farming. • Peak oil issues must be considered – agriculture needs to be resilient to changes in supply of oil – fertiliser costs are growing issues and phosphate supplies are limited – key drivers for change. • Farmers will follow the money so possibilities of influencing what they do but expensive.