Pathways to a zero-carbon economy:

Learning from large scale de-carbonisation strategies

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Executive Summary

This paper provides an overview of key features of the most promising and innovative large scale low-carbon economy transition plans and strategies. The paper draws on and updates findings from the Post Carbon Pathways project which has reviewed a diverse range of ambitious large scale de-carbonisation strategies, augmented by in depth interviews with leading climate and energy transition researchers and policy makers. The study identifies a range of strategies authored by governments, including those of the EU, UK, Wales, Scotland, Denmark, California and Germany, designed to achieve 2050 emissions reduction targets of between 80 and 100%. The study also identifies a range of strategies developed by non-government research organisations in the UK, Germany, Norway, Australia and the US that demonstrate the technological feasibility of achieving close to 100% emissions reduction in the period 2020–2050.

Key findings

1. The probability and risks of global warming of four degrees or more are rapidly increasing. This is an argument for visionary leadership and decisive action rather than for political paralysis and buck-passing.

2. The overall suite of actions required to drive a rapid transition to a zero-carbon economy is now widely understood:
   - Rapid replacement of fossil fuels by renewable energy
   - Rapid reduction in energy consumption through improved efficiency and reduced demand
   - Reducing land use emissions and improving the role of land use in carbon sequestration.

3. While significant technological and financial challenges remain, the most significant roadblocks preventing rapid de-carbonisation are social and political:
   - Denial of the necessity and urgency of action
   - The power and influence of the fossil fuel industry and other vested interests
   - Political paralysis and “short-termism”
   - The dominant economic paradigm of unconstrained and unsustainable consumption
   - Social, economic and technological path dependencies
   - Financial, governance and implementation constraints.

4. Critical factors most likely to trigger the transformational change needed to drive a rapid transition to a just and resilient zero-carbon future include:
   - Evidence and education that strengthen understanding of the necessity and possibility of an emergency-speed reduction in greenhouse gas emissions
   - Creative and disruptive technological, social and economic innovation
   - Visionary leadership, courageous advocacy and skilful implementation by communities, business and government
   - Decisive action at critical moments of ecological, economic and social crisis.

Introduction

As the probability and risks of catastrophic climate change continue to grow, so too does the urgency of a swift transition to a just and resilient zero-carbon economy. The aim of this paper is to provide an overview of the most promising and innovative large scale low-carbon economy transition plans and strategies. The paper draws on and updates findings from the Post Carbon Pathways research project [1, 2].

The Post Carbon Pathways project involved i) a critical review of the most ambitious large scale low-carbon economy transition strategies, from both government and non-government sources and ii) interviews with leading policy makers, researchers and activists working in the field of low-carbon economy transitions.

The study identified a range of strategies authored by governments, including those of the EU, UK, Wales, Scotland, Denmark, California and Germany, designed to achieve 2050 emissions reduction targets of between 80 and 100%. The study also identified a range of strategies developed by non-government research organisations in the UK, Germany, Norway, Australia and the US that demonstrate the technological feasibility of achieving close to 100% emissions reductions in the period 2020–2050.

Table 1 provides an overview of the strategies reviewed, including energy and emissions targets, priorities and recommendations. Table 2 outlines the estimated costs of implementing these strategies. Table 3 summarises the main technological and policy priorities common to many of the strategies reviewed. Table 4 summarises the theories of social and political change that inform the strategies. A list of interviewees is included at Appendix A.

Key findings from the Post Carbon Pathways project are discussed in more detail later. In brief, they are:

1. The probability and risks of global warming of four degrees or more are rapidly increasing. A rapid transition to a zero-carbon economy is a fundamental precondition for reducing the likelihood of this outcome.

2. The overall suite of actions required to drive a rapid transition to a zero-carbon economy is now widely understood.

3. While significant technological and financial challenges remain, the most significant roadblocks to rapid implementation of post carbon roadmaps are social and political.

4. The transformational social and political changes needed to drive a rapid transition to a just and resilient zero-carbon future will require a sustained and integrated combination of skilfully communicated evidence; creative and disruptive innovation; visionary and courageous leadership and advocacy; and decisive action at moments of ecological and economic crisis.

1. The probability and risks of global warming of four degrees or more are rapidly increasing.

The most up to date and robust scientific evidence continues to confirm that the gateway to a world in which there is a reasonable chance of preventing catastrophic climate change is rapidly closing. This conclusion is an argument for visionary leadership and decisive, emergency speed action rather than for political paralysis, buck passing and despair.

Recent analysis of emissions pathways consistent with a reasonable probability of preventing catastrophic climate change remains consistent with the assessment published by Rogelj et al in Nature Climate Change in 2011 [3]: “We find that in the set of scenarios with a “likely” (greater than 66 per cent) chance of staying below 2C, emissions peak between 2010 and 2020 and fall to a median level of 44 Gigatonnes of CO2 equivalent [GtCO2e] in 2020.” Between 2020 and 2050 a rapid decline to close to zero emissions combined with carbon sequestration would be needed in order to achieve the goal of returning atmospheric CO2e to 350 ppm or below.

A quick glance at Table 1 highlights the ongoing gap between timetables consistent with the climate science physics and the actual commitments being made in even the most ambitious strategies. This gap has been observed in other recent systematic analyses of national emission reduction pledges [4]. While a number of the strategies developed by non-government auspices and authors include targets that are closer in speed and scale of emissions reduction to what is needed, the challenge of achieving political support for the rapid implementation of these policies remains formidable.

As Ian Dunlop, member of the Club of Rome, Chair of Safe Climate Australia and former CEO of the Australian Coal Association usefully reminds us, “We are running out of both time and options because we are not being honest about what has to be done. The solutions exist, but unless you are honest about the problem, they will never be adopted.”[1]

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1. Unless otherwise specified, all quotes are from J. Wiseman, T. Edwards and K. Luckins, Post Carbon Pathways, Towards a Just and Resilient Post Carbon Future [2].

Table 1: Low-carbon economy transition strategies: Summary of targets, key priorities and recommendations [2]

Strategy	Energy and emissions targets	Key priorities and recommendations
Government authored strategies		
European Commission: Low Carbon Roadmap 2050 [5]	Reduce EU GHG emissions by 20% by 2020 and 80–95% by 2050 (on 1990 levels)	• Support price on carbon by other policy measures (e.g. energy taxes, subsidies, and enforcement of energy performance standards) • Accelerate investment in research, development and demonstration of low-carbon technologies • Improve fuel efficiency and efficiency of built environment • Electrification of transport and heating • Scale up range of renewables • Deploy CCS after 2035
Government of the United Kingdom: Carbon Plan [6]	Reduce UK GHG emissions by 34% by 2020 and 80% by 2050 (on 1990 levels)	• Continue involvement in EU Emissions Trading Scheme • Major energy efficiency improvements necessary and possible • Cost-effectiveness a key principle • Open to various energy mixes and solutions including nuclear, CCS, gas, and biofuels • Establish "green investment bank" to support efficiency improvements and transition to renewables • Critical role of technological innovation in reducing costs • Transition will require significant public funding
Government of Scotland: Low Carbon Scotland (2nd Report) [7]	42% GHG emissions reduction by 2020 compared to 1990–95 baseline. Electricity "largely decarbonised" by 2030	• Decarbonise electricity by shifting to renewables and utilising CCS • Decarbonise transport with electric vehicles and trains, increase public transport, and more active transport • Retrofit houses for energy efficiency • Recycle 70% of waste by 2025
Government of Wales: Energy Wales: A Low Carbon Transition [8]	Affirms European Council goal of 80–95% reduction in GHG emissions by 2050 compared to 1990	• A whole systems approach essential: including integrated solutions for electricity, heating and transport • Integrated mix of renewable and low-carbon energy sources: wind, tidal, solar, biomass, hydro and existing nuclear • Focus on opportunities in the transition to create jobs and export energy • Energy efficiency vital • Greater electrification of overall energy consumption • Gas a key transitional fuel

2. More detailed summaries of strategy priorities can be found in Wiseman, J. and Edwards, T. (2012) Post Carbon Pathways: Reviewing Post Carbon Economy Transition Strategies. Table includes summaries of several additional large scale low-carbon transition strategies not included in the original Post Carbon Pathways report. This includes low-carbon transition strategies published by the governments of Scotland, Wales and Denmark as well as the Garnaut Review Update 2011; the updated Zero Carbon Britain strategy; and Mark Z Jacobson et al, 100% Wind, Water, Sunlight: All-Sector Energy Plans for the 50 United States.

Government of Germany: Energy Concept [9]	Reduce German GHG emissions by 40% by 2020 and at least 80% by 2050 (on 1990 levels)	• Emphasise huge innovation potential associated with transforming Germany's energy supply structure • Focus on cost-effective expansion of renewable energy sources and efficiency improvements • Target energy efficiency measures for households, industry and public sector • Make nuclear energy part of the solution (although note current government has moved decisively away from nuclear) • Continue strong support for solar PV and expansion of other renewable sources • Terminate subsidies for domestic coal • Promote electric vehicles
Government of Denmark: Our Future Energy (and updated report Towards a Low Carbon Society) [10]	GHG reductions of 40% by 2020 compared with 1990; electricity and transport to be based on 100% renewable energy by 2050	• Taxes and tariffs to incentivise low-carbon development and behaviour • Accelerate investment in low carbon technology innovation • Energy efficiency and reduction in energy demand • Wind to meet half of electricity demand, supported by other renewables • Coal and oil burners to be phased out • Electrify transport, supported by some biofuels • Promote biogas
Government of Australia: Clean Energy Future [11]	Reduce Australian GHG emissions by 5% by 2020 and 80% by 2050 (on 2000 levels)	• Carbon pricing • Strong emphasis on encouraging investment in technological innovation, research and development • Energy efficiency • Renewable energy • Low-carbon land use • Financing mechanisms to support transition, including fund to facilitate closure of coal plants
Government of California: Scoping Plan & Clean Energy Future Plan [12]	Reduce GHG emissions to 1990 levels by 2020 and 80% of 1990 levels by 2050; 33% of electricity from renewable energy by 2020	• Wide range of market-based mechanisms (including cap-and-trade scheme), regulatory measures, consumer and business incentives, and feed-in tariffs • Energy efficiency highest priority • Electrification of transport • Accelerate proportion of electricity generation sourced from renewables

Government of South Korea: Green Growth Strategy [13]	Reduce Korean GHG emissions by 30% below projected 2020 levels (equivalent to 4% reduction on 2005 levels)	• Introduce carbon trading scheme • Development of green technologies crucial • Focus on energy efficiency, including tax incentives • Integrated mix of renewable energy sources • Increase public transport and support hybrids and bicycling • Develop smart grid • Strong emphasis on public awareness campaign to change energy consumption attitudes and behaviour
Government of People's Republic of China: 12th Five-Year Plan & Climate Change White Paper [14]	Reduce Chinese CO2 emissions per unit of GDP by 40–45% by 2020 (on 2005 levels)	• Establish carbon emissions trading scheme • Rapid scaling up of renewables • Nuclear and gas remain significant part of low carbon strategy • Promote clean energy vehicles through R&D • Develop resource-efficient "circular" economy • Enhance capacity of carbon sinks • Continue closures of inefficient power and industrial facilities • Build capacity to adapt to climate change
Government of India: National Action Plan & Low Carbon Growth Report [15]	Reduce India's emissions intensity of GDP by 20–25% by 2020 (on 2005 levels)	• Strong emphasis on energy efficiency to help manage impact of high economic growth targets • Increase share of train freight in transport and improved fuel efficiency • Broad mix of energy supply, including renewables, fossil fuels, and nuclear • CCS noted as potentially important • Diverse mix of market and regulatory approaches

Non government authored strategies		
German Advisory Council on Global Change: World in Transition [16]	Decarbonise global energy system by 2050	• Massive extension of renewables and associated infrastructure • Nuclear rejected, existing capacity to be phased out • CSS not ruled out, but range of limitations noted • Carbon pricing crucial (preference for cap-and-trade) • Phasing out of fossil fuel subsidies • Technology specific funding and tax incentives to stimulate innovation • Feed-in tariffs to encourage expansion of renewables
Lester R. Brown and Earth Policy Institute: World on the Edge [17]	Cut global CO2 emissions by 80% by 2020 (on 2006 levels)	• Energy efficient measures required to offset projected growth • 90% of fossil fuel energy to be replaced with renewables by 2020 • Key priorities: wind, solar, geothermal • Nuclear and CSS rejected • Tax carbon emissions while lowing income tax • Importance of stabilising population at no more than 8 billion by 2040 • De-emphasise GDP as a measure of progress • Reallocate fiscal priorities to protect against ecological security threats
Al Gore, Our Choice [18]	Rapid reduction to 350ppm atmospheric CO2 concentration	• Strong support for pricing carbon as well as a range of other regulations, incentives, national standards, and tax credit schemes • Efficiency improvements highlighted as a particularly cost-effective path • Range of renewable technologies advocated • Development of “super grids” • Replace GDP measure and targets with Genuine Progress Indicator
Paul Gilding and Jurgen Randers: One Degree War Plan [19]	Cut global GHG emissions to zero over 15 years; negative emissions for rest of century	• Robust carbon tax plus strong regulatory measures • Rapid acceleration of energy efficiency • Erect wind turbine or solar plant in every town of more than 1000 people and larger scale projects in suitable areas • Cut deforestation and logging by 50% • Close 1000 coal power plants in 5 years • Retrofit 1000 coal power plants with CCS • Reduce consumption through social marketing (e.g. “shop less / live more”)

Mark Z. Jacobson and Mark A. Delucchi: Powering a Green Planet [20–22]	Switch global energy system to 100% renewable energy (wind, water, solar) by 2030	• Massive expansion of wind, water, solar (among other renewable sources) to replace fossil fuels • Feed in tariffs to drive transition • Nuclear, CCS, biofuels, and natural gas not included in energy mix • Subsidies for “best bet” renewables • Carbon taxes • Elimination of fossil fuel subsidies • Electrification of heating and transport sectors
Mark Z. Jacobson et al: 100% Wind, Water, Sunlight: All-Sector Energy Plans for the 50 United States (Draft) [20, 22]	All new energy to be powered with WWS by 2020; 80–85% of existing energy to be replaced by WWS by 2030, and 100% replaced by 2050	• Electrification plus efficiency improvements to reduce demand • Primary focus on wind, water (hydro, wave, tidal), and solar energy solutions • Electrolytic hydrogen part of the energy solution • Focus on long-term employment and financial benefits of WWS transition
WWF International: The Energy Report [23]	Peak and decline global GHG emissions within five years, reduce by 80% by 2050 (on 1990 levels); 100% renewable energy by 2050	• Global emissions cap-and-trade with wide variety of other market and policy tools • Minimise energy demand • Energy efficiency and increased electrification essential • Renewables transition claimed to be consistent with continued economic growth, due to efficiency assumptions • Move to renewable sources, privileging local sources • Provide remaining energy demand with traditional sources as cleanly as possible • CCS and nuclear rejected
Centre for Alternative Technology UK: Zero Carbon Britain 2030 [24]	Reduce net UK GHG emissions to zero by 2030	• Technological solutions necessary, but not sufficient – behaviour change needed too (e.g. reduced meat consumption) • Emphasis on need for strong policy drivers and business models to facilitate behaviour change • Advocates a range of renewable sources • Advocates using existing nuclear plants, but not commissioning new nuclear plants • Huge potential for efficiency and electrification • Emphasis on socially just outcomes • Shift emphasis from GDP to broader indicators of progress

ClimateWorks Australia: Low Carbon Growth Plan for Australia [25]	Reduce Australian GHG emissions by 25% by 2020	• Huge potential for onshore wind and solar • Advocates shift from coal to gas • CSS considered critical technology in coal-intensive Australia • Various low-carbon strategies considered related to power, forestry, industry, agriculture, buildings, and transport • Government to create incentives for necessary technologies • Lifestyle change not emphasised
The Garnaut Review Update 2011: Australia in the Global Response to Climate Change (26)	In May 2013 Professor Garnaut proposed an Australian emissions reduction target of minus 17% by 2020 (from 2005 levels)	• Key emphasis on market based mechanisms including robust price on carbon • Market based incentives and governance improvements driving innovation and commercialization in renewable energy and energy efficiency technologies and systems • Increased investment and improvements in interstate grid connectivity • Ongoing exploration of potential for cost effective expansion in use of biofuels • Reducing deforestation and promotion of forest regrowth
Beyond Zero Emissions: Zero Carbon Australia Stationary Energy Plan [27]	Reduce net Australian GHG emissions to zero by 2020; 100% of stationary energy from renewables by 2020	• Focus on wind, solar PV, and solar thermal • Hydro and biomass difficult to scale up, but important to support other renewables • Nuclear and CSS unlikely to be implemented in 10 year time frame, and wave, tidal, and enhanced geothermal not yet demonstrated at appropriate scale • Reject “transition fuels” (e.g. gas) and “transition technologies” (e.g. more efficient petrol-cars) due to diverting resources away from renewables and electrification of transport • Efficiency improvements can halve energy demand compared with “business as usual” projections • National grid to flatten demand peaks • Social equity during the transition emphasised

Table 2: Estimated costs of implementing low-carbon transition strategies

Strategy	Estimated costs
European Commission: Low Carbon Roadmap 2050 [5]	Approx. €270 billion p.a. over 40 years (approx 1.5% of EU GDP p.a. above 2009 investment levels). Savings between €175–320 billion p.a. (not including savings on social costs)
Government of the United Kingdom: Carbon Plan [6]	Total net present cost over lifetime of policies in past carbon budget periods approx £9 billion. Average cost approx 0.4% of UK GDP p.a. in period 2008–22 and 0.6% of UK GDP per year over 2023–27
Government of Scotland: Low Carbon Scotland (2nd Report) [7]	£1.6 billion per annum (or 1% of GDP). Average benefits estimated AT £1.2 billion (2011 prices) per annum.
Government of Wales: Energy Wales: A Low Carbon Transition [8]	Does not include detailed costings
Government of Germany: Energy Concept [9]	Additional investment €20 billion p.a., offset by energy cost savings
Government of Denmark: Our Future Energy [10]	Cost to 2020 approx DKK 5.6 billion (US$952 million). Immediate net costs of < 0.25% GDP in 2020. Average additional costs to Danish households approx DKK 1,700 (US$289) in 2020
Government of Australia: Clean Energy Future [11]	Carbon price and related measures to raise approx AUD$25.5 billion in the period 2011–15. Further $3.9 billion public funds to augment.
Government of California: Scoping Plan & Clean Energy Future Plan [12]	Ongoing costs approx US$36 million p.a. Benefits by 2020 (compared to BAU) include increases in economic production of US$33 billion and overall gross state product of US$7 billion
Government of South Korea: Green Growth Strategy [13]	Total investment announced as part of Five-Year Plan (2009–13) US$83.6 billion
Government of People's Republic of China: 12th Five-Year Plan & Climate Change White Paper [14]	Total investment (public and private) in "new energy" of approx RMB5 trillion (US$760 billion) over next 10 years
Government of India: National Action Plan & Low Carbon Growth Report [15]	Does not include detailed costings

German Advisory Council on Global Change: World in Transition [16]	Additional net investment of between US$200 and $1000 billion p.a. by 2030
Lester R. Brown and Earth Policy Institute: World on the Edge [17]	Net cost US $200 billion p.a.
Al Gore, Our Choice [18]	Does not include detailed costings
Paul Gilding and Jurgen Randers: One Degree War Plan [19]	Carbon tax expected to generate US$2500 billion p.a. by year 5 to spend on transition
Mark Z. Jacobson and Mark A. Delucchi: Powering a Green Planet [20–22]	Approx. US $100 trillion over 20 years to construct global renewable energy systems. BAU will cost approx. US$10 trillion (not including mounting social costs)
WWF International: The Energy Report [23]	Total cost of approx €1 trillion p.a. Investment expected to have paid itself off by around 2040 at latest
Centre for Alternative Technology UK: Zero Carbon Britain 2030 [24]	Approx. £50 billion p.a. required for initial investment program
ClimateWorks Australia: Low Carbon Growth Plan for Australia [25]	AU$1.8 billion p.a. Strong emphasis on net savings to business.
The Garnaut Review Update 2011: Australia in the Global Response to Climate Change [26]	Approx. AU$2.5 billion p.a. net cost
Beyond Zero Emissions: Zero Carbon Australia Stationary Energy Plan [27]	AU$37 billion p.a. for ten-year period, or approx 3% of Australian GDP. Net present costs over longer time period (2010–40) roughly equivalent to BAU (not including transport savings).

2. The overall suite of actions required to drive a rapid transition to a zero-carbon economy is now widely understood

The end goal of zero emissions is achievable but not if we continue with our current policies….

- *A lack of strong, consistent carbon pricing signals.*
- *Lack of action on fossil fuel subsidy reform.*
- *Mixed messages and stop-go policies when it comes to supporting renewable energy.*
- *Failure to tackle regulatory and market rigidities that favour fossil fuel incumbency and undermine demand-side options that could empower consumers to choose clean energy.*

Angel Gurria, Secretary General, OECD [28]

As the evidence summarised in Tables 1, 2 and 3 demonstrates, the overall suite of technological and policy priorities needed to achieve a just and sustainable zero-carbon economy is now widely understood: rapid replacement of fossil fuels by renewable energy; rapid reduction in energy consumption (through improved efficiency and reduced demand); significant reduction of emissions from agricultural activity and improvement in role of land use in carbon sequestration.

Rapid replacement of fossil fuels by renewable energy

All of the strategies reviewed emphasise the need to promote a rapid shift from fossil fuels to renewable energy, with technological priorities commonly including significant expansion of innovation, investment and deployment in the following energy sources: solar (concentrated and photovoltaic; wind (on- and off-shore); wave and tidal; hydroelectricity; geothermal (directly to heat buildings and at high temperatures for electricity generation); bioenergy (traditional biomass; sustainable residues and waste; sustainable energy crops; and sustainable algae); the use of spare wind, water and solar energy to produce electrolytic hydrogen; and liquefied hydrogen combustion for aircraft.

The policy settings and infrastructure required to drive a rapid switch in investment from fossil fuels to renewables are likely to include a robust carbon price, feed in tariffs and supportive regulatory initiatives; a rapid phase out of tax breaks and subsidies to fossil fuel intensive industries; and large scale investment in both smart grid infrastructure and local distributed energy networks.

Rapid reduction in energy consumption through improved efficiency and altered consumption practices

Energy efficiency priorities in relation to the building sector include: retrofitting and insulating existing buildings; a wide roll-out of passive solar, combined heat and power and decentralised heating and cooling systems; and improving efficiency of all heating, cooling, lighting and appliances. In the industry sector, common priorities include: upgrading inefficient industrial processes; reducing fugitive methane emissions from mining; and improving recycling and abatement technologies for non-CO2 emissions.

For transport, common priorities include: reducing carbon intensity of transportation fuels; replacing fossil fuel cars with electric and plug-in hybrid vehicles; upgrading inefficient electric motors; expanding the use of second-generation biofuels (e.g. algal biodiesel and lingo-cellulosic ethanol) and hydrogen (from renewable electricity) to be used for some shipping. Large gains in the transport sector can also be achieved by reducing travel distances by means including smarter urban planning, traffic congestion taxes and the increased use of video conferencing.

There is an increasingly important debate about the extent to which energy consumption reductions at the required speed and scale will require significant reductions in energy demand as well as increased energy efficiency [29]. Significant reductions in energy demand would necessitate a broad public debate about the behavioural, lifestyle, incentive and regulatory changes needed to achieve a lasting reduction in household and industry consumption patterns.

Reducing land use emissions and improving the role of land use in carbon sequestration

Common technological priorities for reducing land use emissions and improving the role of land use in carbon sequestration included the following initiatives: reducing and reversing deforestation; reducing cropland soil emissions through reducing tillage, improving fertiliser and nutrient management, and restoring degraded farmland; cropland carbon sequestration; improving pasture and grassland management through optimising grazing intensity, expanding planting of deep-rooted perennial grasses, and improving fire management; reducing livestock emissions through active livestock feeding, anti-methanogenic treatments, and improved manure management; and bio-gasification of organic manure through capture or burning of agricultural methane.

Table 3: Technological and policy priorities for achieving a rapid transition to a post carbon economy, informed by Post Carbon Pathways review of transition strategies

Goal	Technological and policy priorities

Rapid replacement of fossil fuels by renewable energy	• Robust carbon price at level required to drive rapid shift from fossil fuels to renewables
	• Complementary taxation, subsidy and regulatory policies driving rapid electrification and swift phase out of fossil fuel energy in all industry sectors. Key initial priorities include transport (e.g. cars, aviation and shipping) and fossil fuel-intensive industries (e.g. aluminium, cement, iron and plastics).
	• Tax incentives, low interest loans, loan guarantees, feed in tariffs, public sector investment and community based initiatives driving innovation and deployment of renewable energy sources including:
	  • solar: concentrated and photovoltaic
	  • wind: on- and off-shore
	  • wave and tidal
	  • hydroelectricity
	  • geothermal: directly to heat buildings and at high temperatures for electricity generation
	  • bioenergy: traditional biomass; sustainable residues and waste; sustainable energy crops; and sustainable algae
	  • use of spare wind, water and solar energy to produce electrolytic hydrogen
	  • liquefied hydrogen combustion for aircraft
	• Designing and building interconnected “smart” grids and other network infrastructure required for replacement of fossil fuels by renewable energy sources
	• Strengthening investment and innovation in decentralised renewable energy supply systems

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Rapid improvements in energy consumption through improved energy efficiency and reduced energy demand	• Zero waste economy and “cradle to cradle” product design systems
	• Energy efficient buildings and planning
	  • retrofit existing buildings to maximise energy efficiency
	  • zero emissions standards for new buildings
	  • maximise insulation
	  • wide rollout of passive solar, combined heat and power and decentralised heating and cooling systems
	  • improve efficiency of all heating, cooling, lighting and appliances
	  • integrated land use, housing and transportation planning to reduce distances travelled and facilitate the shift to energy efficient transport
	• Energy efficient industry
	  • invest in resource- and energy-efficient industrial processes and equipment
	  • reduce impact of energy intensive industries (e.g. aluminium, cement, iron, plastics)
	  • upgrade inefficient electric motors, lighting and heating systems
	  • recycle heat energy from electricity generation through co-generation
	  • reduce fugitive methane emissions from mining
	  • improve recycling and abatement technologies for non-CO2 emissions.
	• Energy efficient transport
	  • set and achieve higher vehicle fuel economy standards
	  • reduce carbon intensity of transportation fuels
	  • reduce distances travelled through urban planning, traffic congestion taxes, and increased use of video conferencing etc.
	  • replace fossil fuel cars with electric and plug-in hybrid vehicles
	  • improve access to electric vehicle charging stations
	  • encourage shift from private cars to public transport, high-speed rail, bicycles and walking
	  • expand use of second-generation biofuels (e.g. algal biodiesel and lingo-cellulosic ethanol)
	  • use hydrogen (from renewable electricity) for some shipping
	  • significantly reduce airline travel
	• Behavioural, lifestyle, incentive and regulatory changes leading to a lasting reduction in household and industry consumption patterns

Reducing land use emissions and improving the role of land use in carbon sequestration	• Reduce livestock production and consumption; use on-farm energy and fuel more efficiently • Increase local food production and distribution • Reduce cropland soil emissions: reduce tillage; improve fertiliser and nutrient management; restore degraded farmland • Improve pasture and grassland management: optimise grazing intensity; expand planting of deep-rooted perennial grasses; • Improve fire management • Reduce livestock emissions: active livestock feeding; anti-methanogenic treatments; improve manure management • Bio-gasification of organic manure; capture or burning of agricultural methane • Cropland carbon sequestration • End and reverse deforestation • Improve forest management (weed and pest control)

The overall findings of the Post Carbon Pathways report on the technical feasibility of large scale de-carbonisation are largely consistent with and supported by the conclusions of a number of other recently published reviews of low carbon economy transition strategies.

The 2013 Trottier Energy Futures report, Low-Carbon Energy Futures: A Review of National Scenarios, reviewed eight recent low-carbon energy scenarios focusing on wealthy industrialised nations (Australia, the US, Canada, Finland, France, Germany, Sweden, and the UK) [30]. All the reviewed studies concluded, with varying degrees of certainty, that deep reductions in GHG emissions are technically feasible and that the net costs are affordable. Other common findings included the importance of efficiency, electrification, decarbonisation through renewables and biomass, as well as the level of energy demand needed to provide for energy services. The studies from France, Sweden, the UK, and the US include scenario variations with a continued role for nuclear, with some scenarios also including CSS and hydrogen, although uncertainties and limitations with these technologies are generally noted.

The 2013 Ecofys report, Feasibility of GHG emissions phase-out by mid-century, argues that it is technically and economically feasible to phase out net GHG emissions by roughly 90% by mid-century [31]. It concludes that for roughly 10% of global emissions, technological options are not yet available – leading to a strong argument for further significant investment in technological and social innovation as well as for further exploration of the potential to achieve reductions in energy demand through lifestyle and behavioural changes. The cost of these low-emissions scenarios is estimated as less than 5% of GDP until 2050. The report also notes that ongoing controversy remains about the role of nuclear power and CSS.

The 2013 CICERO report, National Climate Policy Ambitiousness: A Comparative Study of Denmark, France, Germany, Norway, and the UK [31], explores the level of ambition of these countries in relation to emissions-reduction targets; emissions regulations; renewable energy policies; and energy efficiency policies. While noting significant differences in strategic priorities the report also highlights the importance of an integrated, system wide approach in achieving rapid emissions reduction – along with the need to employ a broad mix of market based and regulatory policies.

The LCS-RNet report, Achieving a Low Carbon Society: Sharing Knowledge to Meet a Common Challenge [33], brings together insights from climate and energy transition policy makers and researchers from a diverse mix of primarily industrialised economies. The report highlights the potential of “green growth” policies to facilitate economic recovery and enhance the transition to a low-carbon society, noting the key challenge of mobilising private capital. However, the report also notes the evidence that de-carbonising energy supply will not in itself be sufficient to meet ambitious emission reduction goals. Efficiency improvements, lifestyle change, technological development, policy design, and demand reduction will also be essential.

3. The biggest obstacles preventing rapid implementation of large scale de-carbonisation strategies are political and social

Meeting 100 per cent of global energy demands through renewable energy is technically and economically feasible. The main problems are political and social.

Professor Mark Jacobson, Director of Atmosphere and Energy, Stanford University and co-author, Powering a Green Planet

While significant technological challenges remain there is increasingly widespread recognition that, as Rogelj et al. noted in January 2012, "despite all of the uncertainty in the geophysical, social and technological aspects, our analysis indicates that the dominant factor affecting the likelihood and costs of achieving the 2C objective is politics." [4]

- Key political roadblocks preventing rapid implementation of post carbon economy transition strategies include the following:
- Denial of the necessity and urgency of action
- The power and influence of fossil fuel industry and its allies
- Political paralysis and "short-termism"
- The dominant economic paradigm of unconstrained and unsustainable consumption
- Technological, social and economic path dependencies and lock ins
- Financial, governance and implementation constraints

The researchers and policy makers interviewed for the Post Carbon Pathways project highlighted six priority actions that need to be taken in order to remove the key political roadblocks.

i) Overcoming climate science denial and deepening understanding of the necessity and urgency of action

It's crucial to make climate change as real to people as possible in their everyday ordinary lives. It's not this theoretical thing that will happen in the future; it's happening now. The emissions have gone up now, the climate's changing, the impacts are happening. Severe weather is probably the best example of that impact and the way to make the connections.

Kevin Curtis, Chief Program and Advocacy Officer, The Climate Reality Project

Clear and effective communication of the most robust scientific evidence of climate change trends, causes and risks remains the essential foundation for overcoming climate change denial and strengthening understanding of the necessity and urgency of action. Evidence of the ways in which climate change is increasing the frequency and severity of extreme weather events will be particularly important in enabling individuals to join the dots between personal experience and broader climate change trends and patterns.

The evaluation and interpretation of climate science messages is, however, profoundly influenced by pre-existing value frameworks and political perspectives. The core messages of climate science therefore need to be augmented by action to expose and overcome climate denial disinformation campaigns and by framing and communicating strategies in ways that reach and appeal to a variety of audiences.

For some audiences an ethical concern about the consequences of catastrophic climate change for the most vulnerable people and species now and in the future will be a sufficient motive for action. For others recognition of more immediate and personal risks to their own families and communities will be crucial. Others again may be most influenced by imagining and understanding the potential social and economic opportunities and co-benefits of a healthy and sustainable post carbon future.

And, as Ian Dunlop reminds us, the task here extends well beyond refuting the more delusional assertions of the flat earth school of climate denial:

Denial is interesting, politically and corporately, because the moment you accept that you have a problem, and the seriousness of it, then you have to do something about it. For example, corporate directors have a fiduciary responsibility to objectively assess the critical risks to which their companies are exposed, and take action to ensure these risks are adequately managed. But if they acknowledge climate change as a serious risk, they are bound to act, which requires a radical redirection of Australian business away from our addiction to high-carbon coal and gas.

ii) Overcoming the power and influence of the fossil fuel industry and its allies

The biggest barriers to solving the climate crisis are the vested interests of big oil and big coal and the influence they have. They put a lot of money in political campaigns and now there are no limits on what they can put in so they're just buying everything in sight.

Lester Brown, President, Earth Policy Institute and author, Plan B and World on the Edge

Exposing and countering the lobbying and disinformation tactics employed by the fossil fuel lobby and its allies in the media and finance industries is clearly an essential priority. However, as Mark Ogge from Beyond Zero Emissions notes, the reduction of greenhouse gases at the necessary scale and speed cannot be achieved without a swift end to the mining of fossil fuels:

We actually have to beat the fossil fuel lobby. It has to be more painful for our electoral representatives to ignore us than it is for them to ignore the fossil fuel industry. That's the basic equation. Until you reach that point, we don't win.

The most effective strategies for overcoming the influence of the fossil fuel lobby and ending the mining of fossil fuels include ceasing public subsidisation of fossil fuel industries; a concerted campaign to encourage private sector disinvestment in fossil fuel corporations; a sufficiently robust carbon price; and legislation and regulation driving a rapid shift in investment from fossil fuels to renewables.

Equitable structural adjustment programs for communities and households affected by the phase out of fossil fuel industries and employment will also be vital, both for ethical reasons and to maintain community and electoral support for the implementation of tough political decisions.

iii) Overcoming political paralysis and strengthening the determination of communities, governments and businesses to take decisive action

Courageous moral leadership – at multiple levels and in many sectors – is an essential precondition for rapid implementation of post carbon economy transition strategies. In addition to the corrosive influence of denial campaigns and the lobbying of vested interests, other obstacles standing in the way of decisive climate change leadership include competing and more immediate economic and political demands, the pressure not to seem politically naïve or unrealistic; and the sense that the transformational change required is simply not possible.

As Alex Kazaglis from the UK Climate Change Commission notes, climate protection and de-carbonisation legislative targets with progress reviewed by independent monitoring agencies provide one important mechanism for maintaining clear priorities and focus.

One of the lessons from the UK is that having a Climate Change Act which sets things out in law, where there's [legal] implications for government if they don't continue on the track that's set out in that Act, and an independent watchdog overseeing progress … those things help to bind the politics to the long-term targets … so when other factors come up, it doesn't completely knock it off course.

The imagination and communication of parallel narratives visualising a desirable post carbon future combined with "living laboratories" demonstrating what life in such an alternative future might be like can also provide a valuable foundation for sustaining the belief that transformational change is indeed socially and politically feasible. In addition, as Mark Jacobsen reminds us, "showing that it can be done is crucial because people are often afraid to change or don't know what it takes to change. So the more avenues they see their neighbours doing it, the more likely they are to do it."

Mark Ogge also emphasises the importance of employing alternative visions of the future in the development and implementation of shorter term strategies designed to prevent the expansion of fossil fuel industries:

You need the kind of thing we (Beyond Zero Emissions) are doing – creating a positive vision. You also need to stop projects. You need to actually empower people in all those communities across Australia who are being directly impacted by the massive expansion of fossil fuels and [gas] power plants. That will take community organising on a large scale. You have got to community-organise in support of a positive vision and to fight against the kind of negative business as usual thing.

Image: © Paul Mak 2011

iv) Developing an economic paradigm focused on wellbeing and resilience rather than unsustainable consumption of energy and resources

The question about the extent to which we can achieve a sufficiently rapid reduction in greenhouse gases without a significant shift in rates of economic growth was the issue on which there were the greatest differences among strategic perspectives. Strategies concerned with developing countries such as China, India and South Korea, all understandably advocate strongly for continued economic growth in order to meet key human development goals. These strategies tend to highlight concepts of green growth and low carbon growth.

Some authors, such as Amory Lovins, who focus on developed economy policy priorities also argue that we can achieve emissions reduction targets without compromising economic prosperity through a fundamental reconsideration of the way we use and produce energy. Others, such as Kevin Anderson, Deputy Director, Tyndall Centre for Climate Change Research, take the view that

> *for the relatively developed, wealthy countries, [there isn't] any option for our first move other than to reduce our consumption. I'm not saying that because I think that's an easy thing to do politically or that it's something that I might agree with for another set of reasons. I'm simply saying we cannot get off the emissions curve fast enough through technology. We have to change what it is we consume.*

One way to approach a possible reconciliation between these conflicting economic growth perspectives might be to begin a conversation which reframes the debate from growth versus de-growth towards a shift in priorities from limitless growth in the consumption of energy and resources to growth and improvement in important social and ecological priorities. In Prosperity without growth: Economics for a finite planet, UK economist Tim Jackson [29], for example, makes a compelling argument that our ability to decouple conventional economic growth from ecological destruction is highly questionable and that our focus must be on a redefinition of prosperity – a vision "in which it is possible for human beings to flourish, to achieve greater social cohesion, to find higher levels of wellbeing and yet still to reduce their material impact on the environment".

v) Overcoming technological and social path dependencies and driving social, economic and technological innovation

> *It is vital to integrate all the energy-using sectors and all the four kinds of innovation: in technology, policy, design and strategy. The sum of the parts is a lot smaller than what you actually get, and there are some deeply disruptive business opportunities that emerge only when you look at that whole picture.*
>
> Amory Lovins, Chairman and Chief Scientist, Rocky Mountain Institute, and author of Reinventing Fire

The crucial role of individual and organisational change agents, social entrepreneurs and demonstration projects in opening up niche spaces, challenging path dependent thinking and imagining and communicating disruptive ideas and technologies is now widely understood. However, many researchers and policy makers also note the importance of a proactive role for government in setting long policy directions and in mobilising the investment required to drive the rapid, scaled up commercialisation and deployment of game changing social and technological innovations.

John Schellnhuber, Chair of the German Advisory Council on Global Change, reflecting on the speed with which renewable energy is replacing fossil fuels in Germany, offered the following observation:

> *Public will, individual psychology, and technological innovation come together to create tremendous innovation dynamics, tremendous substitution dynamics. In a few years renewable energy has already overtaken, at least in installed capacity, the nuclear power industry in Germany. So this is "proof of concept" – that yes we can create big transitions.*

Several of the non-government transition strategies analysed provide useful demonstrations of the potential of open-source policy making and innovation, drawing on the energy and creativity of a diverse coalition of volunteer researchers, writers and designers. Most importantly, they can reframe political discourse by breaking open the assumption that alternative, scaled-up energy pathways and systems are simply not feasible. As Westley et al. [35] note, innovative networks of activists and academics can catalyse public participation to levels which push policy debates towards experimentation with alternatives and bridge the gap between intention and action. Such approaches highlight the important role of shadow networks – informal networks that work both outside and within the dominant system to develop alternatives that can potentially replace the dominant regime if and when the right opportunities occur.

vi) Strengthening the financial and governance capabilities needed to drive swift implementation of large scale de-carbonisation.

The cost estimates of the post carbon economy strategies summarised in Table 2 are broadly consistent with the conclusions of the 2012 Climate Tracker Update:

> *The cost of staying below 2°C can be less than 1% of global GDP, when investments are spread over time ... Coordinated early action (ie, starting now, well before 2020) will deliver the least cost way of staying below 2°C. The longer the delay, the higher the cost and the bigger the technological challenges. [36, italics in original]*

Strategies for mobilising the required investment funds will need to include a robust carbon tax, a "Tobin tax" on international financial transactions as well as resources arising from the end of subsidies and tax concessions to fossil fuel industries.

An equitable strategy for redistributing the financial burdens and costs of the transition policies will need to include global, national and regional structural adjustment assistance to support workers and communities as they shift away from fossil fuel based employment as well as the embedding of renewable energy and climate change resilience investment resources in all international aid and development programs.

The achievement of global commitments to an internationally verifiable de-carbonisation road map; a shared approach to carbon pricing and a strengthened role for international governance institutions such as the International Energy Agency and International Renewable Energy Agency remain important goals. However, the urgency of the timetable for emissions reduction and the lack of any likelihood of progress towards binding global treaties in the next few years mean that in the short term the main focus needs to be on alliances and collaborations between nation states, sub-national regions, provinces and cities.

There will also be an important and increasing role for local government and local community organisations in exploring and implementing innovative post carbon economy transition solutions and in extending of opportunities for citizen participation, including legislative obligation for governments to provide citizens with opportunities to participate in informed debate.

Finally it will be important to continue to strengthen the labour market skills and policy making capabilities through capacity building and training programs in renewable technology and energy efficiency and through transformation and transition studies as core discipline and program in all universities and research institutes. Alex Kazaglis from the UK Climate Commission highlights the importance of getting implementation right:

> *It's an all too common story. You speak to people who've tried to install solar panels on their roof and they tell you how difficult it was and the guy that they dealt with didn't seem to know all the different options and had his own agenda. So, there's a whole raft of issues there that are very difficult to overcome and I think they're not the glamorous part of the policy. Once you've announced the policy, the implementation side gets forgotten a little bit. Whereas, actually, in terms of success, it's critical.*

4. Conclusion: Towards a theory and practice of transformational change

In the end, the most challenging question remains: How might the transition to a just and resilient post carbon future actually occur? What theories – and practices – of social and political change could plausibly deliver this transformation at sufficient speed and scale? Table 4 provides an overview of the variety of theories of social and political change informing the de-carbonisation strategies reviewed in the Post Carbon Pathways project.

Table 4: Theories of social and political change informing large scale de-carbonisation strategies

Strategy (Government authored)	Theory of social and political change
European Commission: Low Carbon Roadmap 2050	• Political and social change drivers not covered in detail • Notes importance of policy innovation, public education and behaviour change
Government of the United Kingdom: Carbon Plan	Importance of UK Government, industry and citizens "pulling in the same direction" in order to achieve low carbon transition
Government of Scotland: Low Carbon Scotland (2nd Report)	• Strategic assessment of external factors driving pace of change • Embedding achievement of low carbon transition targets • Ensuring access to range of funding and financing mechanisms • Understanding the role of behaviour and decision making in achieving the targets and influencing accordingly • Recognising the long term role of the planning system
Government of Wales: Energy Wales: A Low Carbon Transition	Strong role for government leadership including through: setting clear targets and policy priorities; establishing appropriate market and regulatory mechanisms; improving access to finance; engaging and supporting businesses and working to ensure costs of reform do not fall disproportionately on poor households
Government of Australia: Clean Energy Future	• Carbon price as central driver of change. • Strong emphasis on limited impact of policy measures on Australian economy and lifestyles
Government of Germany: Energy Concept	Importance of public understanding and support for transition. Emphasises importance of accessible information, transparent decision making and opportunities for public dialogue
Government of Denmark: Our Future Energy	Assumes strong ongoing role for government in encouraging innovation and community education
Government of India: National Action Plan & Low Carbon Growth Report	Notes need for final report to include discussion of ways of overcoming barriers to policy implementation and adoption by communities, business and governments

Government of California: Scoping Plan & Clean Energy Future Plan	• Active public participation essential • Emphasis on role for market forces and growing environmental awareness to shift individual choices and attitudes • Targeted public outreach, marketing and education programs.
German Advisory Council on Global Change: World in Transition	Knowledge-based, shared visions of desirable future; strong and effective change agents and champions; social and economic shocks; proactive state; supportive global governance structures
Lester R. Brown and Earth Policy Institute: World on the Edge	Three social change models: • "Pearl Harbor": Dramatic event leads to fundamental change • "Berlin Wall": Social tipping point reached after gradual change in thinking and attitudes • "Sandwich": Grassroots movement strongly supported by political leadership
Al Gore, Our Choice	• Visionary leadership combined with broad community mobilisation. • Need to hold self-interested corporations to account and ensure higher standards in media
Paul Gilding and Jurgen Randers: One Degree War Plan	One or more critical ecological, economic or social tipping point events leading to shift in public support for action required.
Mark Z. Jacobson and Mark A. Delucchi: Powering a Green Planet	Strong political and policy leadership and regulation to overcome path dependencies and avoid dominance of industry preferred technologies.
WWF International: The Energy Report	Human ingenuity, technological innovation and behaviour change as key drivers of transition
Centre for Alternative Technology UK: Zero Carbon Britain 2030	• Importance of sudden, unexpected events as political tipping points in driving dramatic political shifts • Importance of behaviour change plus promotion of wider societal dialogue on values, structures and processes that have led to overconsumption, climate change and resource depletion
ClimateWorks Australia: Low Carbon Growth Plan for Australia	Build support from key industry sectors as a basis for achieving and maintaining broader social and political support
The Garnaut Review Update 2011: Australia in the Global Response to Climate Change	Key role for carbon price and related market mechanisms in driving rapid shift in investment and innovation priorities
Beyond Zero Emissions: Zero Carbon Australia Stationary Energy Plan	• Clarify debate on technical feasibility of 100% renewable energy in Australia to enable social and political changes to occur • Need for decisive leadership from government, business, academia and wider community to implement the plan

Reflections from these diverse examples of ambitious de-carbonisation strategies highlight four interconnected and interlinked drivers of transformational change.

i) Evidence and education which broadens and deepens understanding of the necessity and possibility of an emergency speed reduction in greenhouse gas emissions

Reflecting on the campaigns which overcame the threat of ozone depletion or the power of the tobacco corporations might lead us to imagine an emissions reduction scenario driven primarily by scientific evidence, persuasion and regulation. The key question which remains is whether the speed at which climate tipping points are approaching will allow us the time for such incremental strategies.

ii) Creative and disruptive technological, social and economic innovation

The speed and spread of game-changing technologies like the printing press, the steam engine or the silicon chip provide a second, plausible narrative of swift and transformational change. The speed with which renewable energy technologies and systems are improving in efficiency and falling in cost is certainly impressive, although it is also increasingly clear that social as well as technological innovation will need to be a central part of any real solution to climate change.

iii) Visionary leadership, courageous advocacy and skilful implementation by communities, business and government

A third pathway might be created though the kind of visionary leadership and community mobilisation that led to the achievement of women's rights and the overthrow of apartheid – combined with the highly co-ordinated logistical and implementation achievements of the kind demonstrated by the Roosevelt government in driving the transition from a domestic to a war economy in the period following the attack on Pearl Harbor.

iv) Decisive action at critical moments of ecological, economic and social crisis

It appears increasingly likely that it will also take a devastating series of crises on and above the scale of Hurricane Katrina and Hurricane Sandy to create the kind of "Pearl Harbor" political tipping points in which visionary political leadership, community mobilisation, technological innovation and social creativity can be brought into the alignment needed to drive transformational change at the necessary scale and speed.

The rapidly approaching perfect storm of climatic and ecological tipping points, deeply entrenched inequalities of power and resources and the remarkable capacity for human beings to demonstrate short sightedness and self delusion provides strong ammunition for those who regard the goal of avoiding runaway climate change as an impossibility. An honest assessment of the size and scale of the political obstacles standing in the way of an adequate and timely response to the climate crisis is certainly an essential guard against wishful thinking.

However, while his role in formulating and driving the neo-liberal economic agenda makes his advice deeply ironic, Milton Friedman also provides us with a valuable reminder of the powerful role alternative visions of the future can play in driving transformational change, particularly at moments of economic, social and ecological crisis [37]:

> *Only a crisis—actual or perceived—produces real change. When the crisis occurs, the actions that are taken depend on the ideas that are lying around. That, I believe, is our basic function: to develop alternatives to existing policies, to keep them alive and available until the politically impossible becomes politically inevitable.*

Image © Buro North 2007

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Appendix A: Climate and energy transition policy makers, researchers and activists interviewed for Post Carbon Pathways Research Project

Name	Position
Kevin Anderson	Deputy Director, Tyndall Centre for Climate Change Research and Professor of Energy and Climate Change, University of Manchester
Lester Brown	President, Earth Policy Institute and author, Plan B and World on the Edge
Jenny Clad	Former Executive Director, The Climate Project
Kevin Curtis	Chief Program and Advocacy Officer, The Climate Reality Project
Mark Delucchi	Research Scientist, Institute for Transportation Studies, UC Davis and co-author, Powering a Green Planet
Jean-Philippe Denruyter	Manager, Global Renewable Energy Policy, WWF International and co-author, The Energy Report
Ian Dunlop	Member, Club of Rome, Chair, Safe Climate Australia and Deputy Convenor, Australian Association for the Study of Peak Oil
Ottmar Edenhofer	Deputy Director and Chief Economist, Potsdam Institute for Climate Impact Research and co-Chair, IPCC Working Group III
Adrian Gault	Chief Economist, UK Committee on Climate Change
Paul Gilding	Author, The Great Disruption and co-author, One Degree War Plan

Name	Position
James Goldstene	Former CEO, California Air Resource Board
Peter Harper	Head of Research and Innovation, Centre for Alternative Technology, Wales, and co-author, Zero Carbon Britain 2030
Mark Jacobson	Director of Atmosphere and Energy, Stanford University and co-author, Powering a Green Planet
Alex Kazaglis	Senior Policy Analyst, UK Committee on Climate Change
Amory Lovins	Chairman and Chief Scientist, Rocky Mountain Institute and author of Reinventing Fire
Roy Neel	Former chief of staff to Vice President Al Gore and Adjunct Professor, Vanderbilt University
Mark Ogge	Co-founder, Zero Carbon Australia 2020 project
Jørgen Randers	Professor of Climate Strategy, Norwegian Business School, co-author of Limits to Growth, One Degree War Plan and 2052
John Schellnhuber	Director, Potsdam Institute for Climate Impact Research and Chair, German Advisory Council on Global Change
Anna Skarbek	Executive Director, ClimateWorks Australia