Shell energy scenarios to 2050

energy

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Acknowledgements

Our thanks go to Shell colleagues and the many external experts who have contributed to the development of these Shell energy scenarios.

Other Shell scenario material can be found at www.shell.com/scenarios

The publications "Shell Global Scenarios to 2025"and "Signposts" are available through this website.

Designed by Peter Grundy

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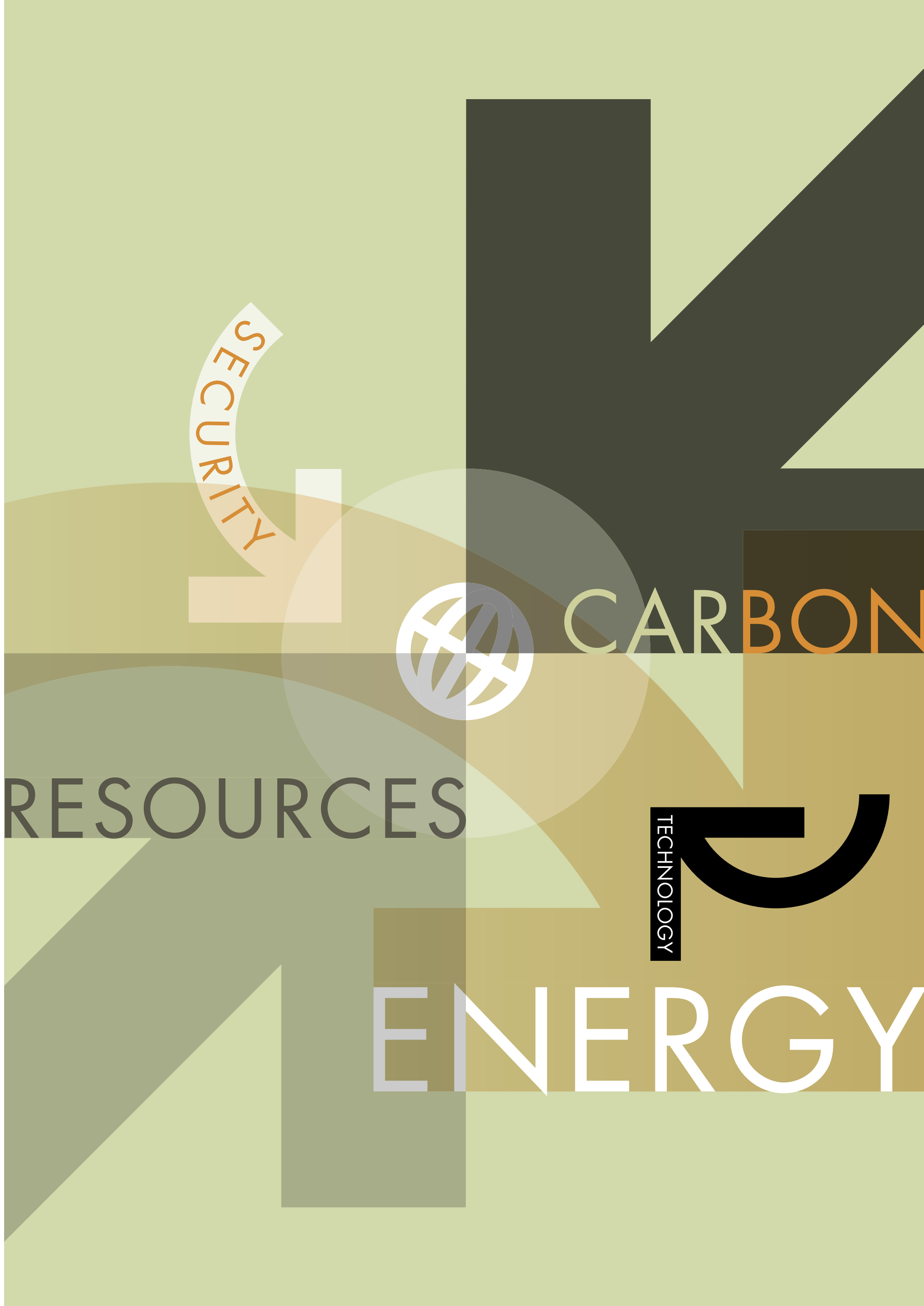
Foreword

Never before has humanity faced such a challenging outlook for energy and the planet. This can be summed up in five words: "more energy, less carbon dioxide".

To help think about the future of energy, we have developed two scenarios that describe alternative ways it may develop. In the first scenario – called **Scramble** – policymakers pay little attention to more efficient energy use until supplies are tight. Likewise, greenhouse gas emissions are not seriously addressed until there are major climate shocks. In the second scenario – **Blueprints** – growing local actions begin to address the challenges of economic development, energy security and environmental pollution. A price is applied to a critical mass of emissions giving a huge stimulus to the development of clean energy technologies, such as carbon dioxide capture and storage, and energy efficiency measures. The result is far lower carbon dioxide emissions.

We are determined to provide energy in responsible ways and serve our customers and investors as effectively as we can. Both these scenarios help us do that by testing our strategy against a range of possible developments over the long-term. However, in our view, the **Blueprints**' outcomes offer the best hope for a sustainable future, whether or not they arise exactly in the way we describe. I am convinced they are possible with the right combination of policy, technology and commitment from governments, industry and society globally. But achieving them will not be easy, and time is short. We urgently need clear thinking, huge investment, and effective leadership. Whatever your role in this, I hope these scenarios will help you understand better the choices you face.

Jeroen van der Veer.
Chief Executive
Royal Dutch Shell plc



Introduction

How can I prepare for, or even shape, the dramatic developments in the global energy system that will emerge in the coming years?

This question should be on the mind of every responsible leader in government, business and civil society. It should be a concern of every citizen.

The global energy system sits at the nexus of some of the deepest dilemmas of our times: the development dilemma – prosperity versus poverty; the trust dilemma – globalisation versus security; and the industrialisation dilemma – growth versus the environment. There have always been tensions in the global energy system, but it is evident today that the strains are becoming more acute.

In the 1990s Shell scenarios introduced us to **TINA** – **T**here **I**s **N**o **A**lternative. The entrenched forces of market liberalisation, globalisation, and technology had created a global economic engine that was already beginning to engage vast populations in Asia. Shell scenarios in the 1990s helped people examine and explore different faces of TINA. Then, in 2005, we published scenarios that explored the geopolitical crises of security and trust that accompany TINA, as foreshadowed in the events of 9/11 and the Enron scandal. Now, as noted in our recent **Signposts** booklet, significant fault lines are developing in the mindsets and behaviour of major energy producing and consuming nations. These intensify the stresses that population growth and economic development are placing on energy supply, energy demand and the environment. All in all, we are entering turbulent times for the energy system.

So how might the tensions and contradictions in the system work out? Well, now is the time to introduce

TAN!A

There Are No Ideal Answers

TINA's natural offspring, **TANIA** – **T**here **A**re **N**o **I**deal **A**nswers.

There is a great deal of inertia in the modern energy system, given its vast complexity and scale. The often lengthy timescales required for planning and constructing new energy infrastructure mean that strains within the system cannot be resolved easily or quickly, if at all. It will be several years before major changes become apparent. But below the surface, the pieces are already shifting. The question is, how to recognise and grapple with these changes.

Scenarios are a tool to help identify such shifts, and consider the plausible interactions between different perspectives and possibilities. They help people to prepare for, shape, and even thrive in the reality that eventually unfolds. This text describes two alternative scenarios, **Scramble** and **Blueprints**, for the development of the energy system over the next fifty years.

These are both challenging outlooks. Neither are ideal worlds, yet both are feasible. They describe an era of transformation. Everyone knows that the energy system a century from now will be very different to that of today. But how will the transitions emerge over the next few decades? These scenarios bring out the impact of critical differences in the pace and shape of political, regulatory and technological change.

I trust you will find them stimulating and instructive. But more than anything, I hope they will help you prepare for, and shape, your responsible participation in a sustainable energy future.

Jeremy B. Bentham
Global Business Environment
Shell International B.V.

1 An era of revolutionary transitions

The world can no longer avoid three hard truths about energy supply and demand.

1: Step-change in energy use

Developing nations, including population giants China and India, are entering their most energy-intensive phase of economic growth as they industrialise, build infrastructure, and increase their use of transportation. Demand pressures will stimulate alternative supply and more efficiency in energy use — but these alone may not be enough to offset growing demand tensions completely. Disappointing the aspirations of millions by adopting policies that may slow economic growth is not an answer either — or not one that is politically feasible.

2: Supply will struggle to keep pace

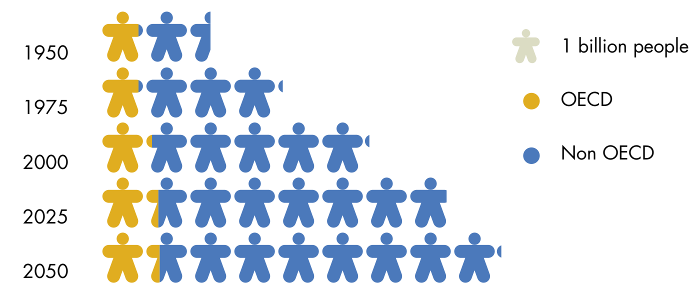
By 2015, growth in the production of easily accessible oil and gas will not match the projected rate of demand growth. While abundant coal exists in many parts of the world, transportation difficulties and environmental degradation ultimately pose limits to its growth. Meanwhile, alternative energy sources such as biofuels may become a much more significant part of the energy mix — but there is no "silver bullet" that will completely resolve supply-demand tensions.

3: Environmental stresses are increasing

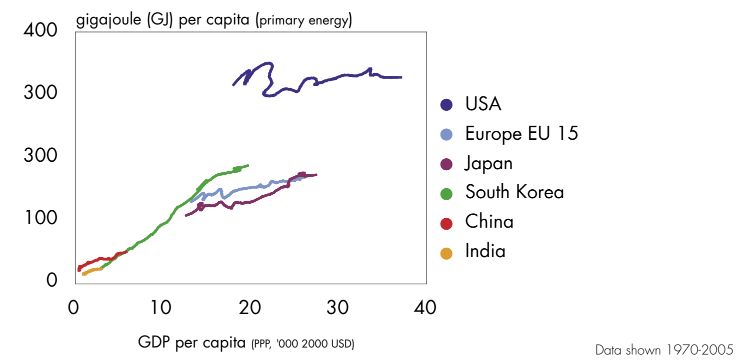
Even if it were possible for fossil fuels to maintain their current share of the energy mix and respond to increased demand, CO_2 emissions would then be on a pathway that could severely threaten human well-being. Even with the moderation of fossil fuel use and effective CO_2 management, the path forward is still highly challenging. Remaining within desirable levels of CO_2 concentration in the atmosphere will become increasingly difficult.

World population has more than doubled since 1950 and is set to increase by 40% by 2050. History has shown that as people become richer they use more energy. Population and GDP will grow strongly in non-OECD countries and China and India are just starting their journey on the energy ladder.

World population[1]



Climbing the energy ladder



Note 1: All data sources for charts and a glossary of abbreviations can be found on pages 44 and 45

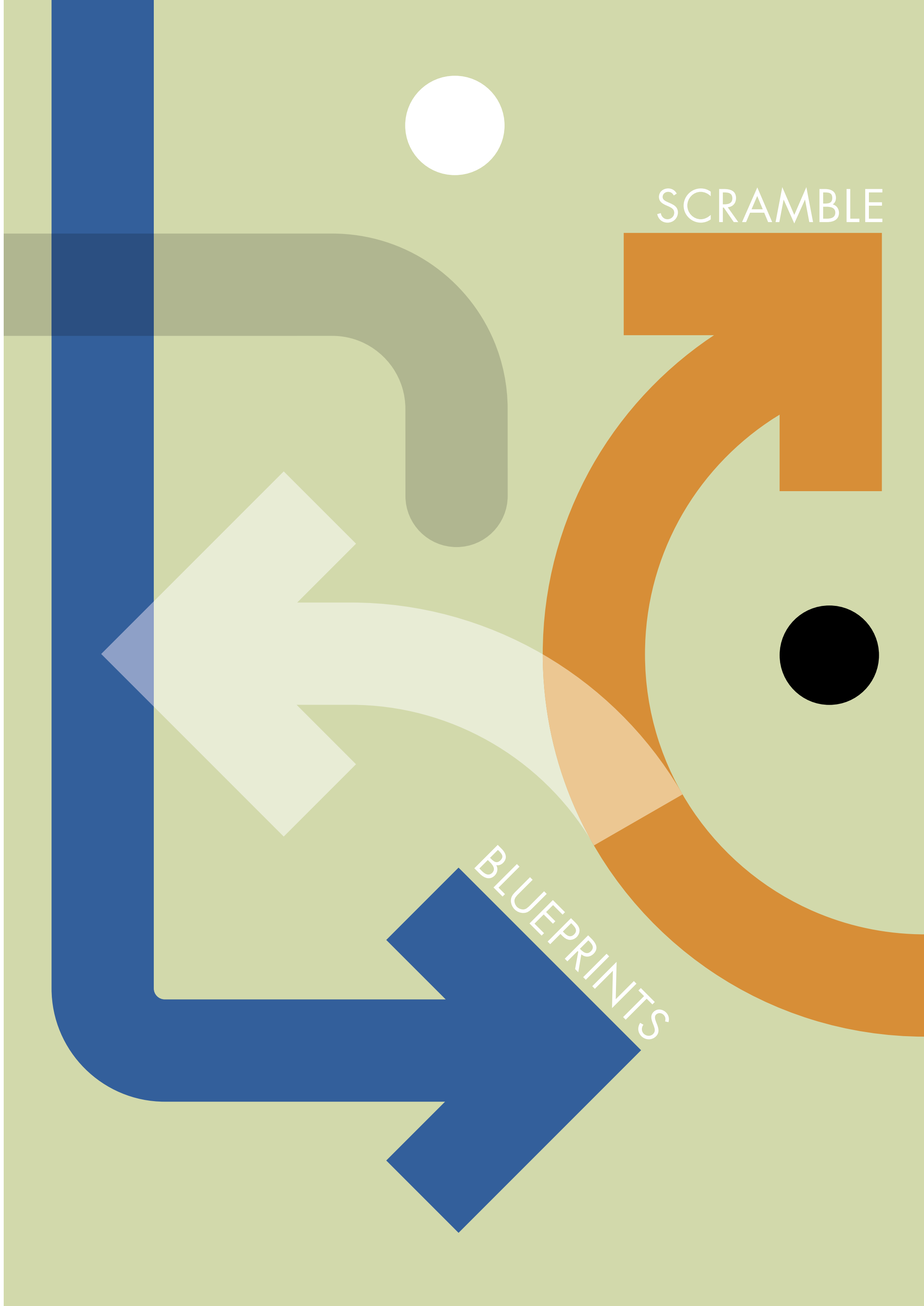
Preparing for the future

When all three of the most powerful drivers of our current energy world — demand, supply, and effects on the environment — are set to undergo significant change, we are facing an era of revolutionary transitions and considerable turbulence. And while prices and technology will drive some of these transitions, political and social choices will be critical. Those choices also depend on how alert we are to the transitions as they happen, especially because for a decade or so we may be distracted by what appears to be healthy development. But underneath this "business-as-usual" world, the transitions are already beginning: governments and companies are positioning for longer-term alternatives; regulatory frameworks are being debated; as there will be no silver bullets, new technology combinations are under development such as intermittent renewable sources being integrated into existing power supply systems; and new infrastructures, such as carbon dioxide capture and storage (CCS), are required and older inefficient ones need to be decommissioned.

People are beginning to realise that energy use can both nourish and threaten what they value most — their health, their community and their environment, the future of their children, and the planet itself. These deeply personal hopes and fears can intensify and interact in ways that have different collective outcomes, and usher in the new energy era in very different ways.

Two possible worlds

Given that profound change is inevitable, how will it happen? Will national governments simply **Scramble** to secure their own energy supplies? Or will new **Blueprints** emerge from coalitions between various levels of societies and government, ranging from the local to the international, that begin to add up to a new energy framework?



2 Scramble

Scramble – overview at a glance

Scramble reflects the dynamics behind energy security. Immediate pressures drive decision-makers, especially the need to secure energy supply in the near future for themselves and their allies. National government attention naturally falls on the supply-side levers readily to hand, including the negotiation of bilateral agreements and incentives for local resource development. Growth in coal and biofuels becomes particularly significant.

Despite increasing rhetoric, action to address climate change and encourage energy efficiency is pushed into the future, leading to largely sequential attention to supply, demand and climate stresses. Demand-side policy is not pursued meaningfully until supply limitations are acute. Likewise, environmental policy is not seriously addressed until major climate events stimulate political responses. Events drive late, but severe, responses to emerging pressures that result in energy price spikes and volatility. This leads to a temporary slowdown within an overall story of strong economic growth.

Although the rate of growth of atmospheric CO_2 has been moderated by the end of the period, the concentration is on a path to a long-term level well above 550 ppmv. An increasing fraction of economic activity and innovation is ultimately directed towards preparing for the impact of climate change.

The unfolding story

2.1 Fear and security

National governments, the principal actors in **Scramble**, focus their energy policies on supply levers because curbing the growth of energy demand – and hence economic growth – is simply too unpopular for politicians to undertake. A lack of international cooperation means that individual countries are unwilling to act unilaterally in a way that will damage their own economic growth. The result is a relatively uncoordinated range of national mandates and incentives for developing indigenous energy supplies where available, including coal, heavy oils, biofuels, and other renewables, which leads to a patchwork of local standards and technologies.

At the international level, **Scramble** is a world of bilateral government deals between energy producers and energy consumers, with national governments competing with each other for favourable terms of supply or for access by their energy companies. There is a strong element of rivalry between consumer governments, but they align with each other where their interests coincide. In this world, national energy companies play key intermediary roles, but themselves become increasingly mired in political machinations. Globalisation exacerbates the tensions within and between nations, and distracts policymakers from the need to take action and build international coalitions to face the energy and climate change challenges.

Although business cycle variations continue, energy prices are generally strong. This is not only because of the intrinsic pressures on supply but also because OPEC has learned from the price increases since 2004 that the world can absorb higher energy prices relatively easily. In the economic interests of its members, therefore, OPEC manages oil supply to minimise any incipient price weakness. With strong prices and lagging supply, "favourable terms" for importing nations increasingly means just some assurance of uninterrupted supply.

In **Scramble**, major resource holders are increasingly the rule makers rather than the rule takers. They use their growing prominence in the world to influence international policies, particularly when it comes to matters they insist are internal such as human rights and democratic governance. Nations who have hammered out "favourable" deals with oil-producing nations do not want to rock the energy boat they have just managed to board, resulting in a world in which international relations are mainly a race to ensure continuing prosperity, not the building of a more sustainable international community.

There are enormous disparities in the economic and energy performance of different countries. Developing nations scramble to procure the energy necessary to climb the economic ladder, while wealthy nations struggle to adapt their energy consumption patterns to maintain their existing lifestyles. Yet, the scramble for energy at the national level is constantly hampered by the unavoidable reality that countries are interdependent. Complex economic and political ties as well as shared transmission structure means that ensuring energy security for one nation requires some cooperation with others. The problems that inevitably arise are dealt with slowly and inefficiently because of the lack of relevant international frameworks and the weakness of multilateral institutions.

With growing stresses in the energy system, news media regularly start to report energy-related crises in one part of the world or another. Ruling regimes under stress in societies that are changing fast easily lose legitimacy in the eyes of their people, and there is dramatic political change in several countries. In a few cases, this is even sparked by misjudged attempts to moderate energy demand through the knee-jerk removal of subsidies. Nevertheless, in spite of the turbulence, the majority of people experience strong material progress during these early years. Overall global economic development continues unabated for the first quarter of the century — in large part because of coal.

2.2 Flight into coal

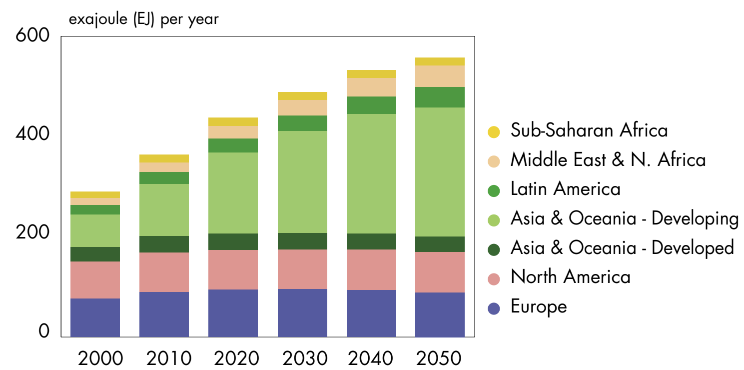
In the face of growing energy concerns, political and market forces favour the development of coal as a widely available, low-cost energy option. Partly in response to public pressures for "energy independence," and partly because coal provides a local source of employment, government policies in several of the largest economies encourage this indigenous resource. Between 2000 and 2025, the global coal industry doubles in size, and by 2050 it is two and a half times at large.

But coal has its own problems, which environmental pressure groups do not hesitate to point out. In the U.S. and other high-income countries, the building of each new coal plant creates a battleground of protest and resistance. In China, local environmental degradation provokes pockets of unrest. And the Chinese railway infrastructure struggles to transport large quantities of coal across the country – necessitating significant and costly improvements to the country's railway infrastructure, as well as coal imports from Australia, Indonesia and elsewhere. Perceived changes in world climate are attributed to the growing coal industry in China and the U.S. Despite widespread protests against coal, governments – fearful of the potential damage to economic growth – are slow to establish meaningful greenhouse gas management schemes through carbon taxation, carbon trading and efficiency mandates.

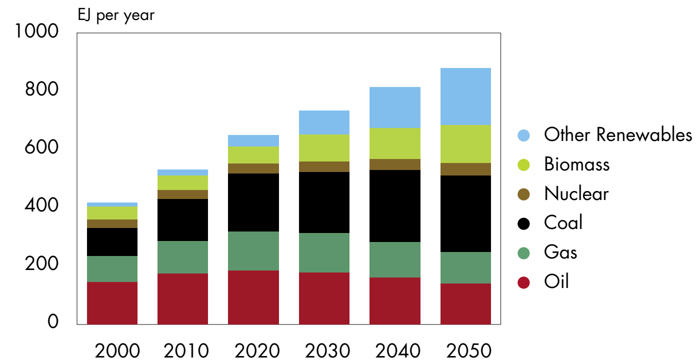
In an attempt to moderate the demand for coal for power generation, several countries conclude that nuclear energy must also grow significantly. In contrast to coal, however, nuclear is one of the more difficult energy sources to expand quickly on a global scale. Building capacity for uranium mining and nuclear power station construction takes time. Add to that the difficulty of disposing of nuclear waste. Even in those countries where nuclear facilities are privately owned and managed, significant government support is necessary before companies will take the enormous, long-term financial risk of building new plants. In addition, the relative reluctance to share nuclear technology with non-friendly states, for fear of contributing to nuclear weapons proliferation, means that the contribution of nuclear power to the energy mix in **Scramble** is much less than its potential might have promised.

First coal, then biofuels followed by renewable energy, are sequential supply responses to the increasing energy demand. But no single or easy solution to the energy challenge exists. Government driven efficiency measures are introduced when stresses become too high for the market to cope with.

Final energy consumption by region



Primary energy by source



Biomass includes traditional renewables such as wood, dung, etc.

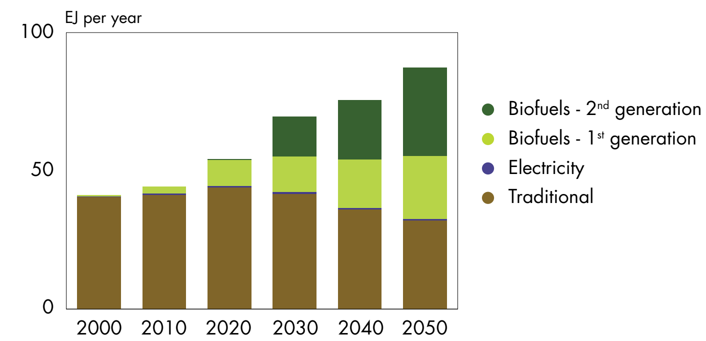
2.3 The next green revolution

Large agricultural lobbies are already powerful in developed nations, and a huge push for biofuels develops early in this scenario. This helps meet the rapid growth in demand for liquid transport fuels, but also leads to unintended consequences. First-generation biofuels compete with food production, driving up world market prices, especially in those countries that use maize as a staple. And regions with insufficient production potential, such as the EU, import the shortfall and so indirectly encourage poorer nations to destroy large sections of rainforests and habitats in order to grow palm oil and sugar cane. The result of these land use changes is that significant quantities of CO_2 stored in the soils are also released.

The reaction to these unintended consequences plays its part in helping to establish second-generation biofuels by 2020 – those that use the woody parts of plants, including waste products such as stalks and leaves from plants grown for food production. Certification systems also emerge to promote sustainability of both first- and second-generation biofuels. A key advantage of second-generation biofuels is that energy yields are a lot higher, particularly outside the tropical regions. Most OECD countries, being in temperate regions, encourage and eagerly embrace economic routes to second-generation biofuels.

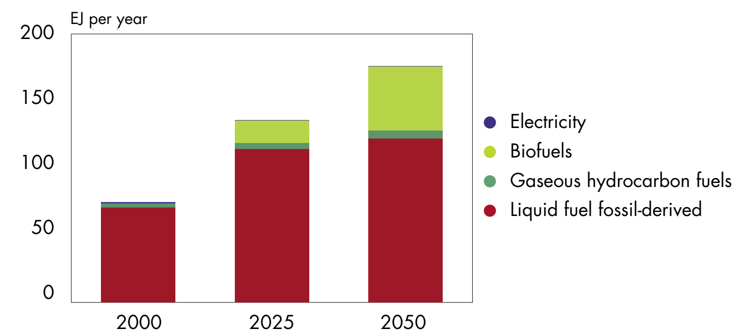
Biomass represents around 15% of primary energy by 2050. Biofuels become a significant part of this, in particular helping to diversify the supply of transport fuel. But with accelerating demand, fossil fuels remain an important part of the energy mix.

Final energy consumption of biomass



Traditional biomass includes wood, dung, etc.

Final energy consumption for transport



2.4 Solutions are rarely without drawbacks

How unconventional oil from oil sands, shale, and coal is developed provides a typical **Scramble** example of solutions being introduced with immediate benefits to energy security but some later negative consequences. Throughout the 2010s, investors pour more and more capital into unconventional oil projects that make an important contribution to addressing supply pressures. Nevertheless, these attract increasing opposition from powerful water and climate lobbies that oppose the environmental footprint of additional developments. This ultimately provokes a political backlash that challenges even the best-managed projects.

As supply-side actions eventually prove insufficient or unpopular in addressing growing demand pressures, governments finally take steps to moderate energy demand. But because pressures have already built up to a critical level, their actions are often ill-considered, politically-driven knee-jerk responses to local pressures, with unintended consequences. For example, the sudden imposition of strict energy efficiency standards for new construction delays new developments while builders and civil servants adapt to the legislation. In some instances this actually slows the trend in overall efficiency improvements.

In **Scramble**, a typical three-step pattern begins to emerge: first, nations deal with signs of tightening supply by a flight into coal and heavier hydrocarbons and biofuels; then, when the growth in coal, oil and gas can no longer be maintained, an overall supply crisis occurs; and finally, governments react with draconian measures — such as steep and sudden domestic price rises or severe restrictions on personal mobility with accompanying disruptions in value chains and significant economic dislocations. By 2020, the repetition of this volatile three-step pattern in many areas of the energy economy results in a temporary global economic slowdown.

2.5 The bumpy road to climate change

The focus on maintaining economic growth, especially in emerging economies, leaves the climate change agenda largely disregarded. Despite increasing protests by campaigners, alarm fatigue afflicts the general public. International discussion on climate change becomes bogged down in an ideological "dialogue of the deaf" between the conflicting positions of rich, industrialised countries versus poorer, developing nations – a paralysis that allows emissions of atmospheric CO_2 to grow relentlessly.

The emerging economic pressures of energy supply and demand tensions make it even more difficult for politicians to act until they are forced to, despite their ongoing rhetoric of concern. Addressing climate change is perceived as an additional economic pressure and, given the type of response required, nobody is prepared to risk being the first to act.

Meanwhile, political pressures become intense in those developing countries where rising aspirations are suddenly disappointed. International relationships come under strain as well. Russia's internal use of its oil stifles expected growth in Eastern Europe and the energy have-nots, such as low-income African nations, struggle for access.

Eventually, this lack of action creates fertile conditions for politically opportunistic blame for extreme weather events and supply crunches — and triggers knee-jerk, politically-driven responses. These are not only late, but often too small to make a difference on the demand side. In some cases they are disruptively over-reactive as when a number of nations enact moratoria on the development of certain high-carbon energy sources.

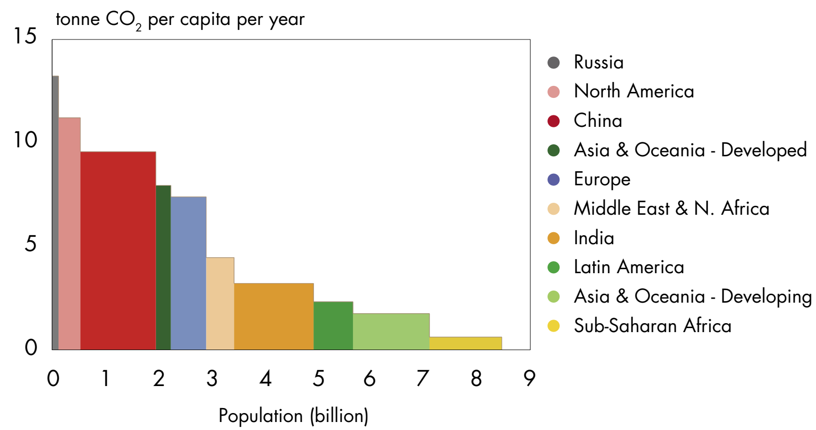
2.6 Necessity – the mother of invention

Although change must and does occur, the turnaround takes a decade because large-scale transformations of the energy system are required. High domestic prices and exceptionally demanding standards imposed by governments provoke significant advances in energy efficiency. Eventually, locally developed alternative supplies – biofuels, wind, and thermal solar – also contribute on a much greater scale than before. By 2030, healthy economic growth is restored, with particular vibrancy in the new energy sector that has received a massive stimulus to innovation through this difficult period.

The declining share of hydrocarbon fuels in the overall energy mix, the growing contribution from alternative energy sources, and greater energy efficiency all moderate the rate of growth of CO_2 in the atmosphere. But the subsequent restoration of economic growth means that vigorous energy consumption resumes with its accompanying rebound in CO_2 emissions – and concentrations are already high. A consensus develops around the need for a new international approach to energy security and climate change mitigation – but the world is twenty years behind where it would have been had it set up such a system by 2015. Economic growth continues to deliver increasing prosperity to many, but market responses to greenhouse gas challenges have been delayed by the absence of regulatory certainty or international agreements. An increasing fraction of economic activity and innovation is ultimately directed towards preparing for the impact of climate change. Having avoided some hard choices early on, nations now recognise they are likely to face expensive consequences beyond 2050.

China is already the largest emitter of CO_2 and by 2035 China's total carbon emissions represent 30% of the world's total.

Direct CO_2 emissions from energy in 2035



Growth of atmospheric carbon dioxide (CO_2)

The release of CO_2 into the atmosphere due to the use of fossil fuels since the start of the industrial revolution, and the large-scale deforestation of the planet that began in the Middle Ages, has changed the carbon balance of the planet. The increasing concentration of CO_2 in the atmosphere – almost universally accepted as responsible for global warming – has risen from 280 parts per million by volume (ppmv) in pre-industrial times to 380 ppmv today and is set to rise rapidly as world economic development accelerates. This trend is not sustainable if climate change is to be moderated.

3 Blueprints

Blueprints – overview at a glance

Blueprints describes the dynamics behind new coalitions of interests. These do not necessarily reflect uniform objectives, but build on a combination of supply concerns, environmental interests, and associated entrepreneurial opportunities. It is a world where broader fears about life style and economic prospects forge new alliances that promote action in both developed and developing nations. This leads to the emergence of a critical mass of parallel responses to supply, demand, and climate stresses, and hence the relative promptness of some of those responses.

This is not driven by global altruism. Initiatives first take root locally as individual cities or regions take the lead. These become progressively linked as national governments are forced to harmonise resulting patchworks of measures and take advantage of the opportunities afforded by these emerging political initiatives. Indeed, even the prospect of a patchwork of different policies drives businesses to lobby for regulatory clarity.

As a result, effective market-driven demand-side efficiency measures emerge more quickly, and market-driven CO_2 management practices spread. Carbon trading markets become more efficient, and CO_2 prices strengthen early. Energy efficiency improvements and the emergence of mass-market electric vehicles are accelerated. The rate of growth of atmospheric CO_2 is constrained so that a long-term sustainable level below 550 ppmv is feasible.

The unfolding story

3.1 Starting at the grassroots

While international bodies argue over what environmental policies should be and which policies are feasible, and many national governments worry about energy security, new coalitions emerge to take action. Some bring together companies from different industries with a common energy interest. Others involve coalitions of cities or regions, which begin to take their destinies into their own hands and create their own blueprints for their energy futures. Individuals effectively begin to delegate responsibility for the complexities of the energy system to a broader range of institutions besides national governments. Cash, votes, and legitimacy reward the successful.

It is a slow process at first, two steps forward and one step back. There is almost as much political opportunism as rational focus in early developments. Many groups try to circumvent, undermine or exploit the new regulations and incentives for alternative energy paths. In places, uncertain regulatory outlooks discourage developments. But as successful ventures emerge, halting progress develops into a larger and larger take-up of cleaner energy such as wind and solar.

As more consumers and investors realise that change is not necessarily painful but can also be attractive, the fear of change is moderated and ever-more substantial actions become politically possible. These actions, including taxes and incentives in relation to energy and CO_2 emissions, are taken early on. The result is that although the world of **Blueprints** has its share of profound transitions and political turbulence, global economic activity remains vigorous and shifts significantly towards a less energy-intensive path.

In the early part of the 21st century, progressive cities across the globe share good practices in efficient infrastructure development, congestion management and integrated heat and power supply. A number of cities invest in green energy as sources for their own needs and energy efficiency. At first, perceptions of local crisis help to drive these changes, such as protests about falling air and water quality. In an increasingly transparent world, high-profile local actors soon influence the national stage. The success of individual initiatives boosts the political credentials of mayors and regional authorities, creating incentives for national and international leaders to follow suit. National and local efforts begin to align with and amplify each other, and this progressively changes the character of international debate.

Perceptions begin to shift about the dilemma that continued economic growth contributes to climate change. Alongside the quest for economic betterment, air quality and local environmental concerns – rather than climate change or green entrepreneurship – initially impel action in countries such as China, India and Indonesia. Gradually, however, people make the connection between irregular local climate behaviour and the broader implications of climate change, including the threats to water supplies and coastal regions. In addition, successful regions in the developing world stimulate their local economy by attracting investments in clean facilities made possible by the clean development provisions of the international treaties that replace the Kyoto Protocol which expires in 2012. These allow industrialised countries to invest in emission-reduction projects in developing countries as an alternative to more costly projects at home.

The key enabler of these energy system blueprints is the introduction of a CO_2 pricing mechanism using a carbon emissions trading scheme that begins in the EU and is progressively adopted by other countries, including the U.S. and, later, China. This trading regime gives a boost to new industries emerging around clean alternative and renewable fuels, and carbon capture and storage. In addition, carbon credits boost income – particularly for those investing in renewable energy – and reduce investment uncertainties.

3.2 Paths to alignment

This critical mass of participation in international frameworks does not stem from an outbreak of global altruism. Instead, the new initiatives at the regional and national levels create incentives for broader change, partly in response to pressure from multinationals. Companies argue strongly for clear, harmonised international policies as a way of avoiding the inefficiencies and uncertainties that result from a patchwork of local and national standards and regulations.

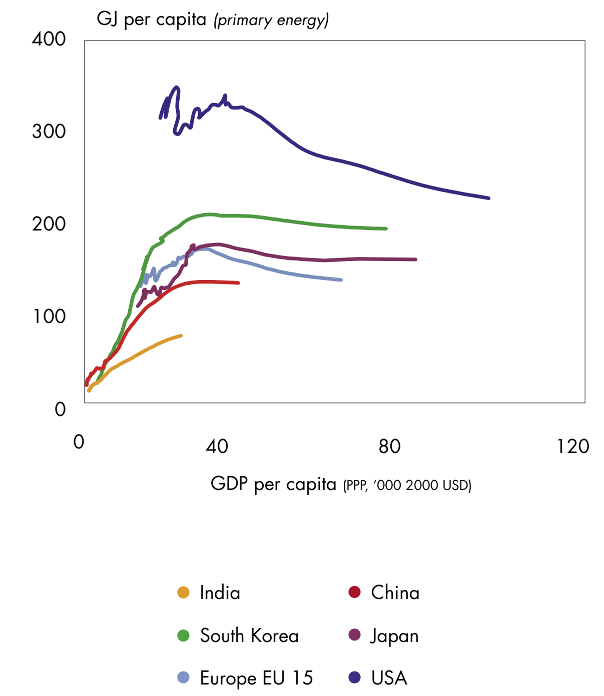
The U.S. responds to both public and industry pressure by taking significant steps to foster greater fuel efficiency through three new initiatives: well-to-wheels carbon assessments of fuels sold; a gradual rise in the U.S. Corporate Average Fuel Economy (CAFE) standards – which lay down minimum fuel economy standards for cars – to reach European levels of 2007 by 2020; and taxes on the sale of less fuel-efficient vehicles to encourage the purchase of more fuel-efficient cars. Europe, meanwhile, imposes stricter CO_2 emission allowances rather than adding to the already significant fuel taxes, and sets aggressive emission reduction targets.

The Chinese and Indian governments attempt to balance the intense political pressures – both domestic and international – to both sustain economic growth and respond to concerns about climate change and energy efficiency. In return for their participation in international frameworks, they secure agreements that will facilitate technology transfer and investment in energy-efficient plants. They also receive assurances that a substantial proportion of the future revenues raised through international auctioning of emission permits will be channelled to nations on a per capita basis. Behind the scenes, all parties anticipate that such agreements will ultimately benefit all, through the increasing openness of China and India to international markets and investment.

These developments bring increasing alignment between the U.S., Chinese, Indian, Japanese, and European approaches to CO_2 management. From 2012, a critical mass of nations participates in meaningful emissions-trading schemes, stimulating innovation and investment in new energy technologies and paving the way to CO_2 capture and underground storage after 2020.

Developing economies climb the energy ladder but overall the journeys of both the developed and developing economies follow less energy intensive paths.

Energy ladders to 2050



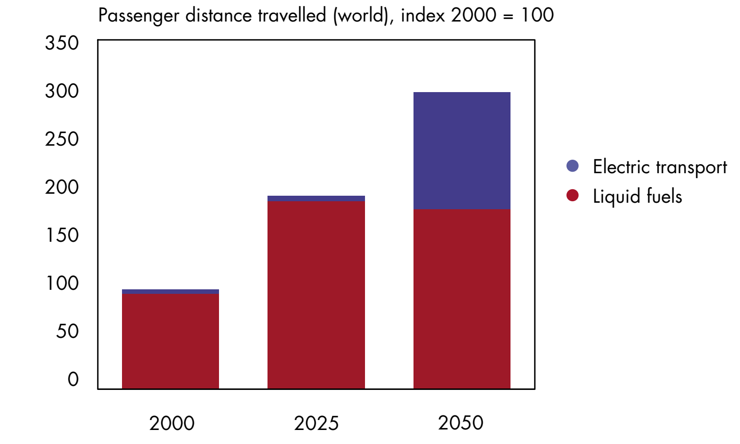
3.3 Developments benefit the energy poor

In **Blueprints**, the disorderly but early development of innovative solutions and adoption of proven practices from the grassroots benefit low-income nations as well. Initially, this stems from the dynamics of the oil market: OPEC raises oil production to maintain lower prices and defer the development of more costly substitutes. Benefits also begin to emerge from accelerated growth in distributed power generation from wind and solar energy. New wind turbines and more cost-effective solar panels are easily exported to rural areas, and in a relatively brief time, many African villages have a wind- or solar-powered energy supply for drawing water from deeper, cleaner wells — and for later development needs. India, too, invests heavily in wind, while China pioneers new developments in solar energy — and these technological developments in both wind and solar are exported back to the west, accelerating the uptake of solar in particular.

Government mandates for vehicles with significantly reduced and zero emissions, fiscal incentives to support the build-up of mass production, and ever-more wind and solar power all stimulate a surge in electric transport – powered by battery, fuel-cell or hybrid technologies. This growth in the use of electric vehicles allows most nations to enter the plateau of oil production without the shocks that they would otherwise have experienced. In **Blueprints**, the more efficient end-use of electricity and the resulting slower growth in primary energy demand mean that the former energy poor enjoy an additional boost in their standard of living made possible by the resulting affordable energy prices.

High overall efficiency of electric cars reduces demand in the transport sector and changes the fuel mix.

Growth of electricity in transport



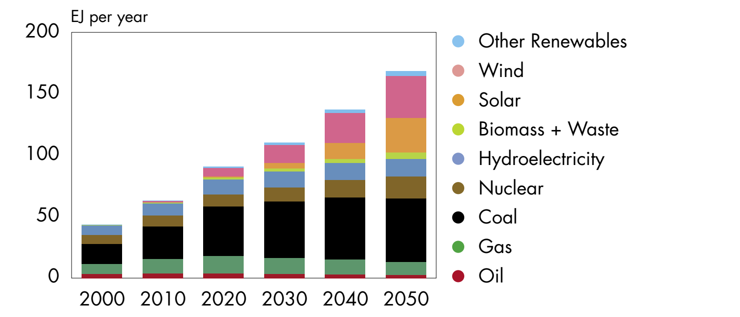
3.4 Both disaggregation and integration

By 2050, one of the key revolutionary transitions observable in **Blueprints** is that economic growth no longer mainly relies on an increase in the use of fossil fuels. It is increasingly a world of electrons rather than molecules. Electric vehicles are becoming the norm in the transport sector because of their attractiveness to consumers and cost-effectiveness once governments have incentivised the build-up to mass production. Power generation from renewable energy sources is growing rapidly, while utilities that still rely on coal and gas are required to implement strict carbon abatement technologies. In the developed world, almost 90% of all coal-fired and gas-fired power stations in the OECD and 50% in the non-OECD world have been equipped with CCS technologies by 2050. This reduces overall CO_2 emissions by 15 to 20% compared to what they would have been without CCS. New financial, insurance, and trading markets are already emerging that help finance the major investments necessary to build this new infrastructure. Europe's lack of indigenous fossil fuels does not place it at a disadvantage, thanks to the emergence of these new renewable technologies. It does well economically in spite of its shrinking population and the fact that capital stock was replaced earlier to meet tightening efficiency requirements.

In **Blueprints**, a second, more profound transition occurs at the political level, where there is increased synergy between national policies and those undertaken at the sub-national and international levels. While details may differ from nation to nation, international organisations – concerned with the environment, global economic health and energy – increasingly agree on what works and what does not. This makes "big-picture" action more possible than ever. Unlikely partnerships begin to form across political divides. Cities across the world continue to share experience and create broader partnerships. The C-40 group of leading cities, which continue to grow in number, identifies best practices in urban development and eventually rural areas begin to join these coalitions – in part to avoid becoming the dumping grounds for old technologies.

Reducing CO_2 emissions through electrification triggers strong growth in the power sector and pulls in renewable energies. By 2050, over 60% of electricity is generated by non-fossil sources. Carbon capture and storage can make an important contribution to reduce emissions but is not a silver bullet.

Final energy consumption of electricity



Carbon dioxide capture and storage (CCS)

There are many technical options for capturing CO_2. Once captured, CO_2 can be stored underground (in aquifers or in certain oil and gas fields), or used in some industrial processes. However, capturing and storing CO_2 is energy intensive and expensive. CCS is technically feasible with today's technologies but has not yet been deployed on a large scale. Its development will require the creation of a substantial CCS infrastructure, incentives for greenhouse gas emission control (e.g. CO_2 pricing or emission intensity targets), and the addressing of regulation, permitting, safety and liability issues.

Given these requirements, large-scale deployment of CCS is not expected to take place until at least 2020. Even then, CCS is not without drawbacks: its use inevitably reduces the efficiency of power stations and so increases the pressure on the energy system. Reaching an annual storage capacity of 6 gigatonnes of CO_2 – a substantial contribution to efforts to lower emissions – would require an enormous transportation and storage site infrastructure twice the scale of today's global natural gas infrastructure. Nevertheless, by 2050 CCS can make an important contribution to CO_2 management.

Closer cross-border cooperation increases the speed of innovation. Because of increased synergy between local, national and international regulations, new technologies become competitive more quickly and are rolled out over the globe more easily.

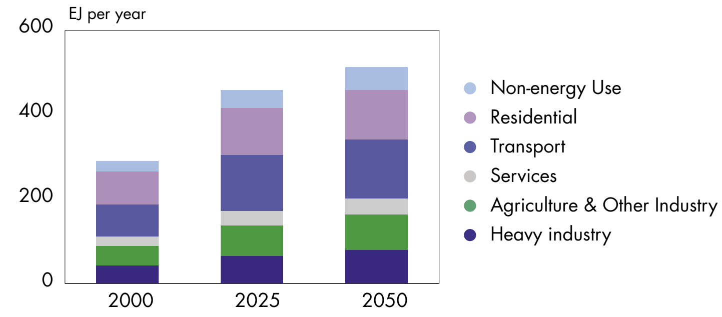
A significant role is played by a kind of strategic self-interest that results in, for example, Russia and the Middle East developing sources of alternative energy for their own use and reserving their conventional fuels for more profitable export. Other nations continue to develop coal, but adopt clean coal technologies and CCS. Increasingly, coal-exporting nations, especially in the OECD, require CO_2 permits on exports, and this extends further the reach of the frameworks for managing greenhouse gas emissions. These developments help reduce CO_2 emissions to a level leading towards a more sustainable atmospheric concentration.

Multinational R&D expenditures, higher transparency and more reliability in energy statistics, effective carbon pricing, and predictable regulation – fostered by new industry-government cooperation – reduce investment uncertainty. This in turn encourages entrepreneurs and investors to invest yet more in R&D and to bring innovations more quickly to market.

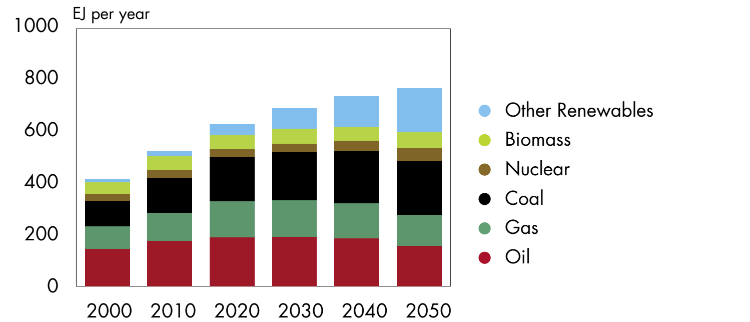
This is a world of steady economic development and global economic integration. Yet the grassroots pressures and growing transparency that characterise **Blueprints** also put relentless pressure on governments to become more accountable in both democratic and authoritarian countries. In some cases this facilitates orderly transitions. However, the accelerated pace of technological and regulatory change in this scenario adds additional stresses, and the more rigid societies and political regimes struggle to adapt. Tensions between urban and rural communities increase and there is dramatic political change in several countries, particularly where governance is poor. Unless they have acted and invested wisely, this affects even the wealthier energy-exporting nations when exports and revenues eventually begin to decline. This is a world of increasing global alignment coupled with ongoing, widely distributed, political turbulence. But this is turbulence that has progressively less impact on the functioning of the global energy system.

Meaningful CO_2 pricing stimulates energy efficiency and electrification of the energy system, reducing the demand on conventional hydrocarbon resources.

Final energy consumption by sector



Primary energy by source



Biomass includes traditional renewables such as wood, dung, etc.

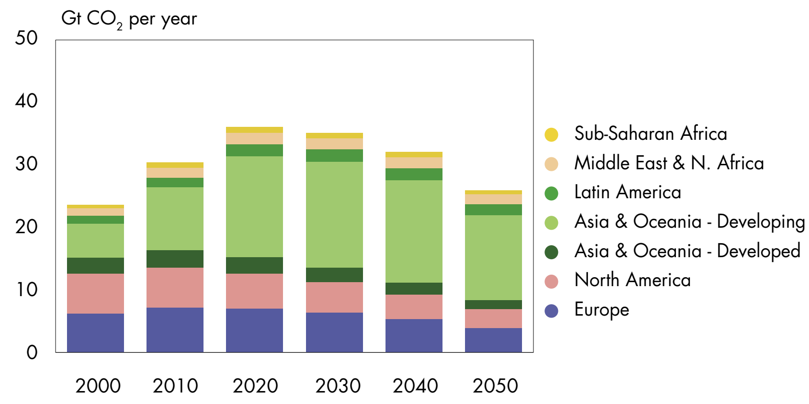
3.5 Blueprints for climate change responses

Agreements on how to address climate concerns are not the result of a miraculous change in the behaviour of political leaders. They reflect the way that grassroots values are now imprinting themselves on political agendas through the media and international pressure groups. They also stem from pressure exerted by industry eager for regulatory clarity and consistency. Such pressure results in breakthroughs in an international architecture for managing energy security concerns in parallel with options for climate change mitigation and adaptation. After the Kyoto Protocol expires in 2012, a meaningful international carbon-trading framework with robust verification and accreditation emerges from the patchwork of regional and city-city schemes. Consistent U.S. policy support for technology investment and deployment pays dividends in providing tangible breakthroughs for effective change. More reliable energy statistics and better informed market analysis allow carbon-trading futures markets to reflect clearer long-term price signals. Because of these frameworks, markets can anticipate tightness in CO_2 emission allocations and plan for them.

By 2055, the U.S. and the EU are using an average of 33% less energy per capita than today. Chinese energy use has also peaked. India is still climbing its energy ladder, but as a relative latecomer, it has to be resourceful in following a lower energy-intensive development path. The political and bureaucratic effort to harmonise and align energy policies is difficult and requires a great deal of up-front investment — but in **Blueprints**, in a critical mass of countries, people support national leaders who promise not only energy security but also a sustainable future. Initial pain has reduced uncertainty and prepared the way for long-term gain.

Concerted global efforts reduce CO_2 emissions but still enable growth in developing economies. Nevertheless, achieving a CO_2 emission pathway of 450 ppmv post 2050 remains a significant challenge.

Direct CO_2 emissions from energy



Reducing the growth of atmospheric carbon dioxide (CO_2)
Limiting the rise of CO_2 levels to 550 ppmv is expected to reduce the probability of dangerous climate change. Reversing the growth in CO_2 emissions requires significant CO_2 pricing and trading, early and widespread implementation of carbon capture and storage, second-generation biofuels and rapid penetration of electric vehicles after 2020. Limiting the CO_2 levels to an even more challenging 450 ppmv – as scientists now recommend – might deliver a world where climate change effects could be more moderate and would involve a virtual world-wide scrapping of the current approach to electricity generation and mobility. It would require a zero-emission power sector by 2050 and a near zero-emission transport sector in the same time period, with remaining energy-related emissions limited to aviation and the production of cement and metals.

4

Scenario timeline

Three hard truths

1
Step-change in energy use

2
Supply will struggle to keep pace

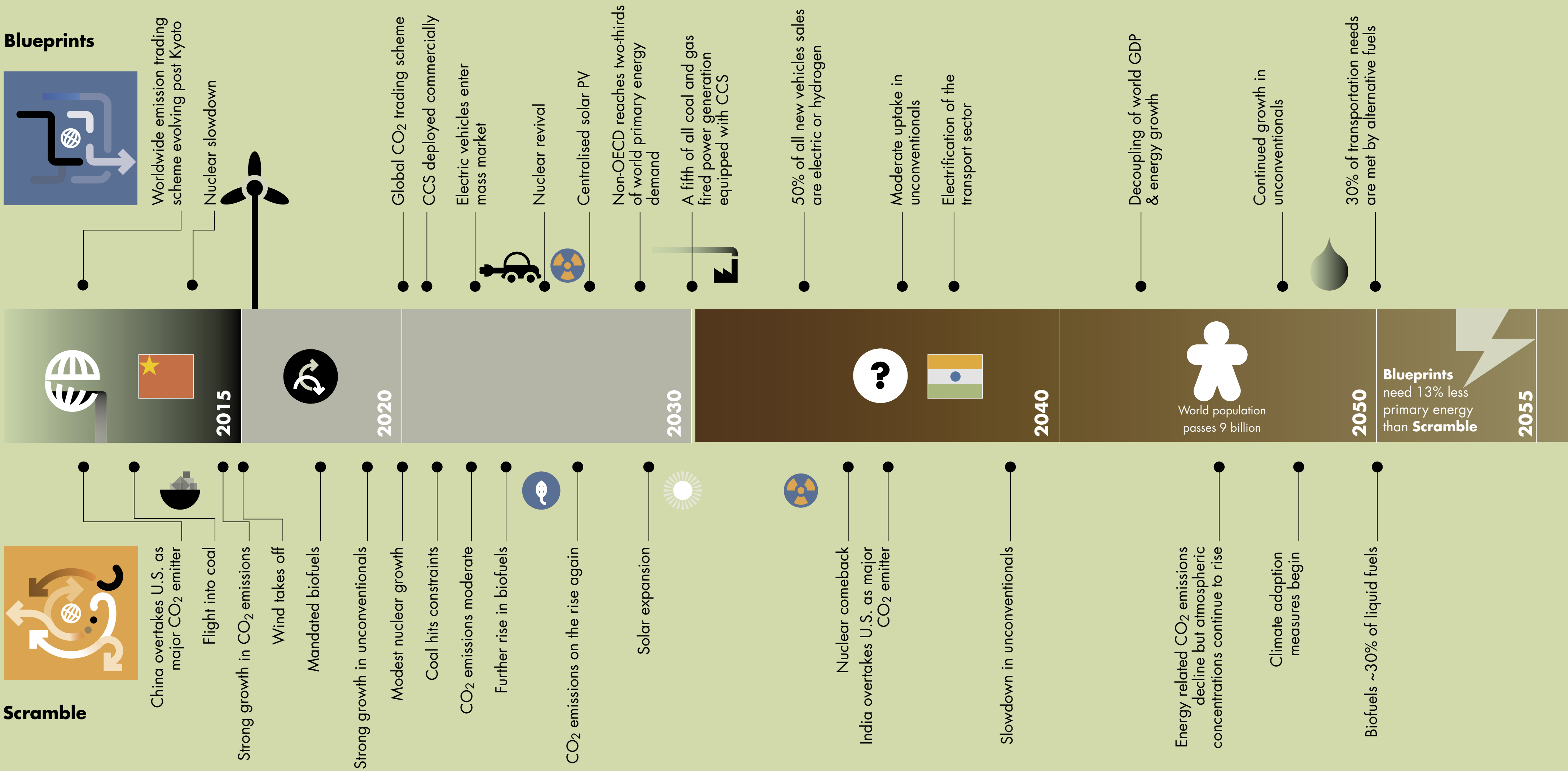
3
Environmental stresses are increasing

What can we expect from the future?

The present
to 2015

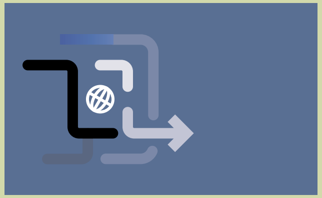
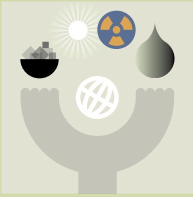
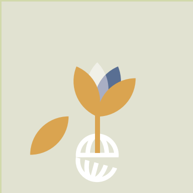
Turbulence
2015-2030

The future
2030-2055



4 Scenario comparisons

What are the energy-related differences between the two scenarios?

	Drivers	Scramble	Blueprints
			
Demand 	Choice Prices Efficiency technology Efficiency behaviour	• Mandates • Externalities not included • Mandates • Necessity	• Market driven but incentivised • Externalities included • Economic incentives & standards • Designed in
Resources 	Oil & gas Coal Nuclear Electric renewables Biomass	• Constrained growth • Flight into coal • Modest uptake • Sequential - wind, solar • Strong growth	• Long plateau • Coal not wanted unless "clean" • Continued growth • Incentivise early stage technologies • Complements alternative fuel mix
Technology 	Innovation Implementation Mobility Power IT	• Strongly guarded • National "docking points" • Hybrids & downsizing • Efficiency • Supply optimisation	• Extensively shared • International "tipping points" • Hybrids & electrification • Carbon capture & storage • Demand load management systems
Environment 	Land use Pollution Climate / Biodiversity Water	• Energy vs. food principle • Important locally • Background global concern • Energy production & climate change impact	• Sustainability principle • Important • Prominent local & global concern • Factored into development frameworks

Shell energy scenarios: concluding remarks

The **Scramble** and **Blueprints** outlooks are both rooted in detailed analyses of energy supply, demand, and technology fundamentals. Of course, it is impossible to condense the full richness of scenarios into a brief overview, but we trust this booklet has given you a good flavour of the main insights of Shell's latest energy scenarios, along with the choices to be faced and their key implications.

Neither of the scenarios is comfortable, which is to be expected given the hard truths we are facing. While both portray successful economic development and the globalisation that accompanies this, both also have branching points that could potentially lead towards escalating geopolitical chaos. They create different legacies for future generations, with both good and disturbing features. Together, however, they sketch the landscape of possibilities, constraints, opportunities and choices for this era of revolutionary transitions in the global energy system.

Some readers may find one scenario preferable to the other, or one more plausible than the other. This should not be surprising as readers will approach these outlooks with their own unique experience and interests. In truth, we have found all possible combinations of reactions to the two storylines as we have developed and discussed the scenario material with specialists and groups from different backgrounds across the globe. This has confirmed to us that both are realistic and both are challenging.

To get the most out of the storylines, we recommend reviewing them with a number of specific questions in mind such as: "what are the potential milestones or events that could particularly affect us?"; "what are the most significant factors that will influence our environment and how could these play out?"; and "what should we do in the next five years to help prepare for, or shape, the turbulent times ahead?"

We are pleased to share our thinking with you. Together, we all face the future of TANIA over the next fifty years. Though there are no ideal answers to the coming challenges we will, however, be required to address many difficult questions. The more clearly we can see the complex dynamics of tomorrow's world, the better we might navigate through the inevitable turbulence. We hope these scenarios will make a modest contribution to helping us all do so.

Jeremy B. Bentham
Shell International B.V.

TAN!A

There Are No Ideal Answers

"If historians now see the turn of the 19th century as the dawn of the industrial revolution, I hope they will see the turn of the 21st century as the dawn of the energy revolution."

Rob Routs
Executive Director
Downstream
Royal Dutch Shell plc
Apeldoorn, June 2007

Glossary

Abbreviations

boe = barrel of oil equivalent
CCS = carbon dioxide capture and storage
CO_2 = carbon dioxide
Gt = gigatonne
kWh = kilowatt hour
mbd = million barrels per day
mt = metric tonne
ppmv = parts per million by volume

International System (SI) of units

MJ = megajoule = 10^6 joule
GJ = gigajoule = 10^9 joule
EJ = exajoule = 10^{18} joule

Conversion between units

1 boe = 5.63 GJ*
1 mbd = 2.05 EJ/year
1 million cubic metre gas = 34 700 GJ*
1 million tonne coal = 25 GJ*
1 kWh = 3.6 MJ

** This is a typical average but the energy content of a particular carrier may vary.*

Glossary

Data sources

The principal data sources used in the development of Shell's scenario analyses and charts in this booklet are:

- World Bank WDI
- Oxford Economics
- UN Population Division
- Energy Balances of OECD Countries © OECD/IEA 2006
- Energy Balances of Non-OECD Countries © OECD/IEA 2006

Summary quantification

Scramble	2000	2010	2020	2030	2040	2050
	EJ per year					
Oil	147	176	186	179	160	141
Gas	88	110	133	134	124	108
Coal	97	144	199	210	246	263
Nuclear	28	31	34	36	38	43
Biomass	44	48	59	92	106	131
Solar	0	0	2	26	62	94
Wind	0	2	9	18	27	36
Other Renewables	13	19	28	38	51	65
Total primary energy	**417**	**531**	**650**	**734**	**815**	**880**

Blueprints	2000	2010	2020	2030	2040	2050
	EJ per year					
Oil	147	177	191	192	187	157
Gas	88	109	139	143	135	122
Coal	97	137	172	186	202	208
Nuclear	28	30	30	34	41	50
Biomass	44	50	52	59	54	57
Solar	0	1	7	22	42	74
Wind	0	1	9	17	28	39
Other Renewables	13	18	29	40	50	62
Total primary energy	**417**	**524**	**628**	**692**	**738**	**769**

Notes

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