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CONSEIL MONDIAL DE L'ÉNERGIE
For sustainable energy.

World Energy Scenarios

Composing energy futures to 2050

Project Partner Paul Scherrer Institute (PSI), Switzerland

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World Energy Scenarios

World Energy Council's unique approach to composing energy futures to 2050

The WEC's approach

Scenarios are alternative views of the future which can be used to explore the implications of different sets of assumptions and to determine the degree of robustness of possible future developments. While most widely known scenarios are normative, the WEC has adopted a different, exploratory approach. 'Normative' in this context means that the scenarios are being used to drive the world towards a specific objective such as a particular atmospheric CO_2 level. In contrast, the WEC with its exploratory scenarios Jazz and Symphony, attempts to provide decision makers with a neutral fact-based tool that they will be able to use to measure the potential impact of their choices in the future.

Rather than telling policymakers and senior energy leaders what to do, in order to achieve a specific policy goal, the WEC's World Energy Scenarios to 2050 will allow them to test the key assumptions that they decide to make to shape the energy of tomorrow. Investors can use this tool to assess which are likely to be the most dynamic areas and real game-changers of tomorrow.

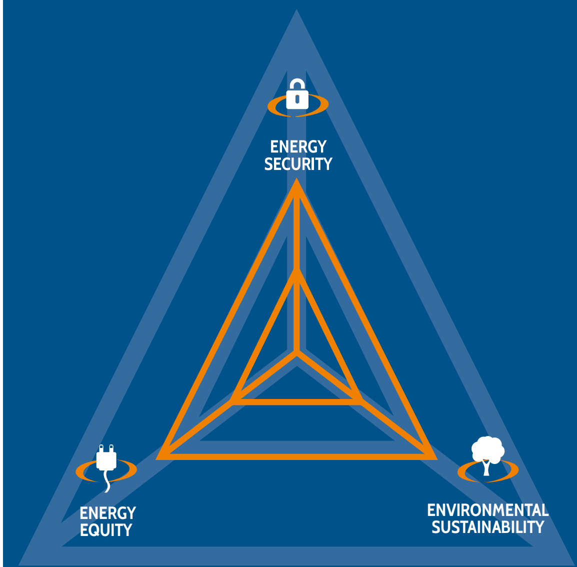
These scenarios are therefore likely to change the way energy decision makers consider the choices they make in understanding the real impact of their actions in the long term.

This approach can only be done successfully by a network like the WEC's with its impartial and inclusive membership structure. Over 60 experts from more than 28 countries have contributed to the WEC's scenario building process over a period of three years.

Assessing the energy trilemma

These scenarios are designed to help a range of stakeholders address the 'energy trilemma' of achieving **environmental sustainability**, **energy security**, and **energy equity** and hence putting forward different policy options.

Clearly, each policy option has some cost associated with it. The cost of one scenario versus the other must not only be considered in terms of necessary capital investments and the impact on and of gross domestic product (GDP) growth; the overall environmental benefits and avoided climate change adaptation costs also need to be taken into account. This means that one scenario is not necessarily better than the other and should not be judged as such. Instead, a wider view needs to be adopted when assessing the overall implications of each of the scenarios.



World Energy Scenarios 10 key messages

1	Energy system complexity will increase by 2050.
2	Energy efficiency is crucial in dealing with demand outstripping supply.
3	The energy mix in 2050 will mainly be fossil based.
4	Regional priorities differ: there is no 'one-size-fits-all' solution to the energy trilemma.
5	The global economy will be challenged to meet the 450ppm target without unacceptable carbon prices.
6	A low-carbon future is not only linked to renewables: carbon capture, utilisation and storage (CC(U)S) is important and consumer behaviour needs changing.
7	CC(U)S technology, solar energy and energy storage are the key uncertainties up to 2050.
8	Balancing the energy trilemma means making difficult choices.
9	Functioning energy markets require investments and regional integration to deliver benefits to all consumers.
10	Energy policy should ensure that energy and carbon markets deliver.

Composing Energy Futures to 2050

The WEC has built two scenarios typified by characteristics, which, each from their own perspective, may comprehensively describe large parts of the world in 2050. In this scenario exercise, the elements of the two scenarios are generalised as being applicable to the (albeit imaginary) whole world: the more consumer-driven Jazz scenario and the more voter-driven Symphony scenario. While the scenarios are 'music based', they are completely different in nature.

JAZZ

As an energy scenario, Jazz has a focus on energy equity with priority given to achieving individual access and affordability of energy through economic growth.

Jazz *is a style of music, characterised by a strong but flexible rhythmic structure with solo and ensemble improvisations on basic tunes and chord patterns. In Jazz, musicians have freedom to take the lead and improvise; others in the band will often follow.*

SYMPHONY

As an energy scenario, Symphony has a focus on achieving environmental sustainability through internationally coordinated policies and practices.

A ***Symphony*** *is a complex piece of music with a fixed structure composed to be played by a symphony orchestra. The orchestra will have a conductor and 80 or so orchestra members will each have a specific role to play and score to follow.*

The WEC's scenarios at a glance

The stories behind Jazz and Symphony

JAZZ

World where there is a consumer focus on achieving energy access, affordability, and quality of supply with the use of best available energy sources.

Free-trade strategies lead to increased exports.

Renewable and low-carbon energy grows in line with market selection.

Energy sources compete on basis of price and availability.

SYMPHONY

World where there is a voter consensus on driving environmental sustainability and energy security through corresponding practices and policies.

Nationalistic strategies result in reduced exports/ imports.

Certain types of renewable and low-carbon energy actively promoted by governments.

Selected energy sources are subsidised and incentivised by governments.

JAZZ

In the absence of international agreed commitments carbon market grows more slowly from bottom up based on regional, national and local initiatives.

Higher GDP growth

Due to faster convergence across countries, higher international competition, and low environmental constraints.

Main players are multi-national companies, banks, venture capitalists, and price-conscious consumers.

Technologies are chosen in competitive markets.

SYMPHONY

Carbon market is top down based on an international agreement, with commitments and allocations.

Lower GDP growth

Due to less convergence, more environmental constraints and a more capital-intensive growth pathway.

Main players are governments, public sector and private companies, NGOs, and environmentally-minded voters.

Governments pick technology winners.

Source: World Energy Council (2013)

The WEC's scenarios findings

Composing energy futures

Energy landscape in 2050

The energy landscape we expect to see in 2050 will be quite different from how it looks today. Meeting future energy demand will be a key challenge. The world's population will increase from approximately 7 billion in 2013 to approximately 8.7 billion in the Jazz scenario and approximately 9.4 billion in the Symphony scenario in 2050, which is equal to a 26% increase (36% respectively). The GDP per capita will also increase from slightly more than 9,000 US$2010 on average globally (US$2010 MER) in 2010 to approximately 23,000 US$2010 in Jazz and about 18,000 US$2010 in Symphony in 2050. This represents an increase by 153% and 100%, respectively. Mobility will also increase, with car ownership in terms of cars per 1000 people increasing from 124 in 2010 to 244 in 2050 in Jazz and 193 in Symphony. This equates to an increase by 98% and 57% respectively.

The WEC's view on global economic growth up to 2050

Source: World Energy Council (2013)

GDP growth, compound annual growth rate (CAGR) % market exchange rate (MER) (%PPP)						
	1990–2000	2000–2010	2010–2020	2020–2030	2030–2040	2040–2050
JAZZ	2.9 (3.2)	2.8 (3.5)	3.2 (3.9)	3.1 (3.8)	2.9 (3.5)	2.6 (3.1)
SYMPHONY			2.8 (3.3)	2.6 (3.2)	2.5 (3.0)	2.2 (2.7)

'This is a time of unprecedented uncertainty for the energy sector. Energy demand will continue to increase. The pressure and challenge to develop and transform the energy system is immense.'

What Jazz and Symphony can offer

Many key messages arise from the Jazz and Symphony scenarios. One of these is that more international cooperation, including internationally harmonised politics and trust in market mechanisms, is essential for achieving environmental goals, energy security and energy equity. Jazz and Symphony can contribute towards enhancing the debate on how these goals can best be achieved, taking into account a wide range of policy options. The WEC's World Energy Scenarios to 2050 will help strengthen the debate on how collaboration among all relevant stakeholders in the energy field can effectively be implemented.

'Neither scenario relies on a "magic wand" to radically change the future. Rather, both scenarios are exploratory and show the multiplicity of possible choices regarding the energy trilemma.'

From stories to figures

The WEC's scenario story quantification assumptions

The WEC's scenario stories were quantified into the following figures which acted as constraints in the two models.

	JAZZ 2050	SYMPHONY 2050
GDP growth (CAGR, PPP)	3.54%	3.06%
Population (billion)	8.7	9.3
Technology support	Limited; energy choice based on free markets – only limited nuclear, CC(U)S, large hydro	Government support for nuclear, large hydro, CC(U)S and renewables
Climate policy	Limited (and more diverse)	Stronger (with global convergance)
Resources	Better access to unconventional resources (esp. gas)	More expensive unconventionals (less competition, regulation, water)
Technology innovation	Further development of CCGT, decentralised power (SPV), wind, gas vehicles, EVs	Focused R&D programmes, esp. CC(U)S demonstration, nuclear, solar photo voltaic (SPV)
Efficiency	Increasing	Increasing more strongly

Source: World Energy Council (2013)

Key message

Energy system complexity will increase by 2050.

Total primary energy supply

The WEC estimates that **total primary energy supply** (equal to consumption) will increase globally from 546 EJ (152 PWh) in 2010 to 879 EJ (144 PWh) in the Jazz scenario and 696 EJ (193 PWh) in the Symphony scenario in 2050. This corresponds to an increase of 61% in Jazz and 27% in Symphony. Just to compare: from 1990 to 2010 – which is roughly half the time span covered in this scenario study – total global primary energy consumption rose by approximately 45%. It is expected that global primary energy consumption will continue to rise, but at a much lower rate than in previous decades. Meeting both global and regional energy demand will be a challenge. There is no one global solution to the energy supply issue. Instead, each of the individual parts of the challenge must be worked out to reach the global goal of sustainable, affordable and secure energy supply for all.

+61%
in the Jazz scenario in 2050

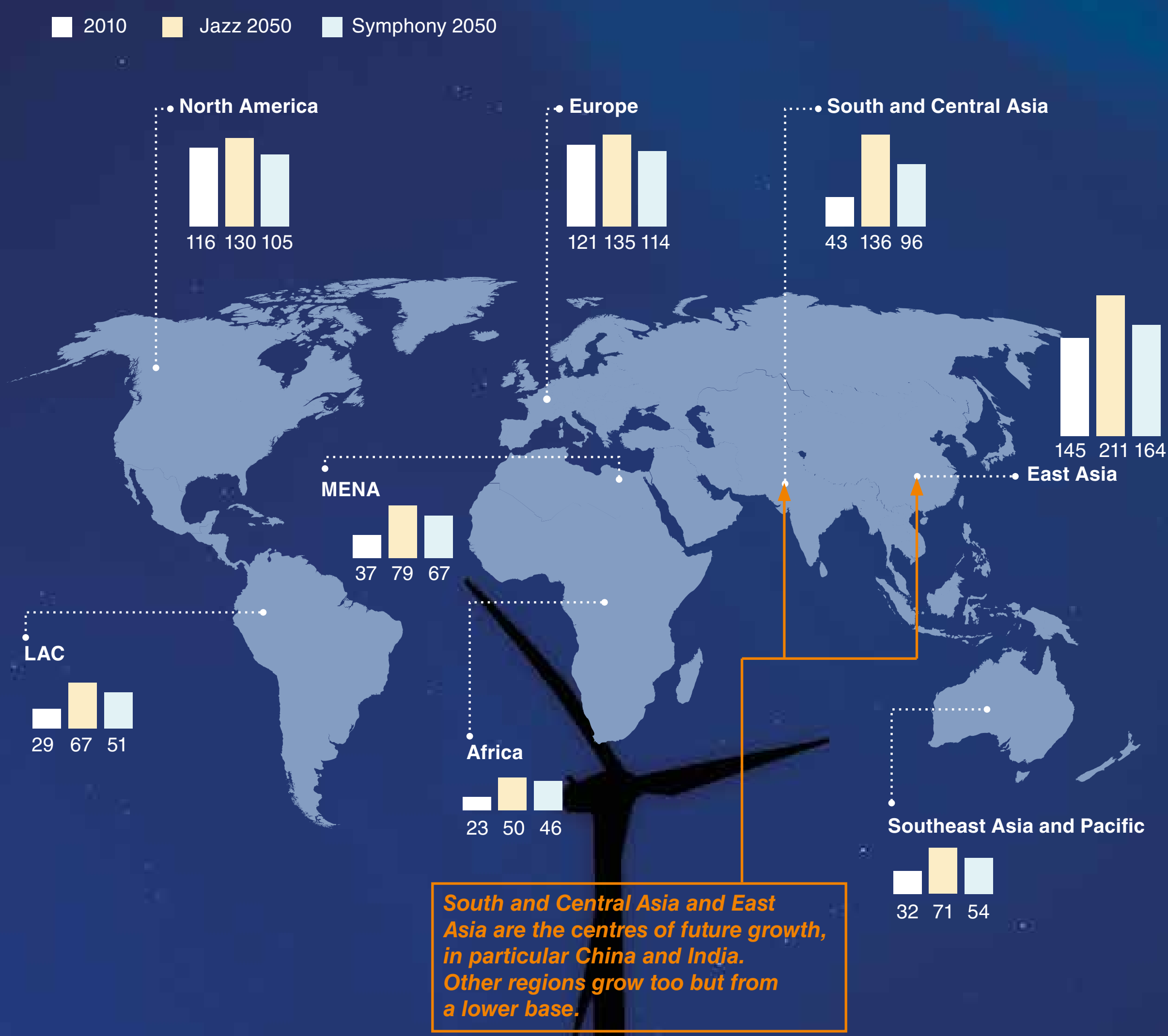
+27%
in the Symphony scenario in 2050

Estimated increase globally of total primary energy supply (equal to consumption)

Share of net imports in primary energy supply (%) (for aggregated world regions)

Source: World Energy Council
Note: The share of net imports in primary energy supply is defined as the sum of net imports of those aggregated world regions which are net importers, divided by the total global primary energy supply.

Total primary energy supply by region (Units: EJ/y)



Key message

Energy efficiency is crucial in dealing with demand outstripping supply.

Energy efficiency

Energy efficiency will increase significantly in both scenarios: primary energy intensity as measured in energy use per unit of GDP created will decrease by 50% and 53% in Jazz and Symphony respectively by 2050. Hence when comparing primary energy consumption to GDP produced, only half the amount of energy is needed until 2050 to produce the same output. This is true for both scenarios although primary energy consumption is higher in 2050 in the Jazz scenario than it is in the Symphony scenario. WEC World Energy Scenarios to 2050 show that energy efficiency and energy conservation are absolutely crucial in dealing with demand outstripping supply – both require a change in consumer priorities and have cost implications across industries – and hence capital is required to finance energy-efficiency measures in terms of an initial investment before it can pay off.

Energy intensity will change by

-50%
in the Jazz scenario by 2050

-53%
in the Symphony scenario by 2050

Primary energy intensity (MJ/USD2010 MER)

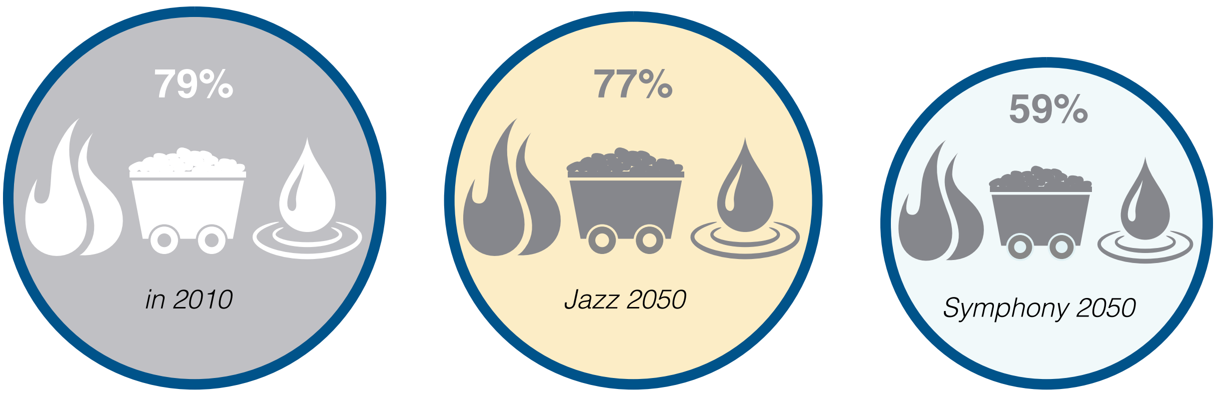
Source: World Energy Council (2013)

The energy mix in 2050 will mainly be fossil based.

Future primary energy mix

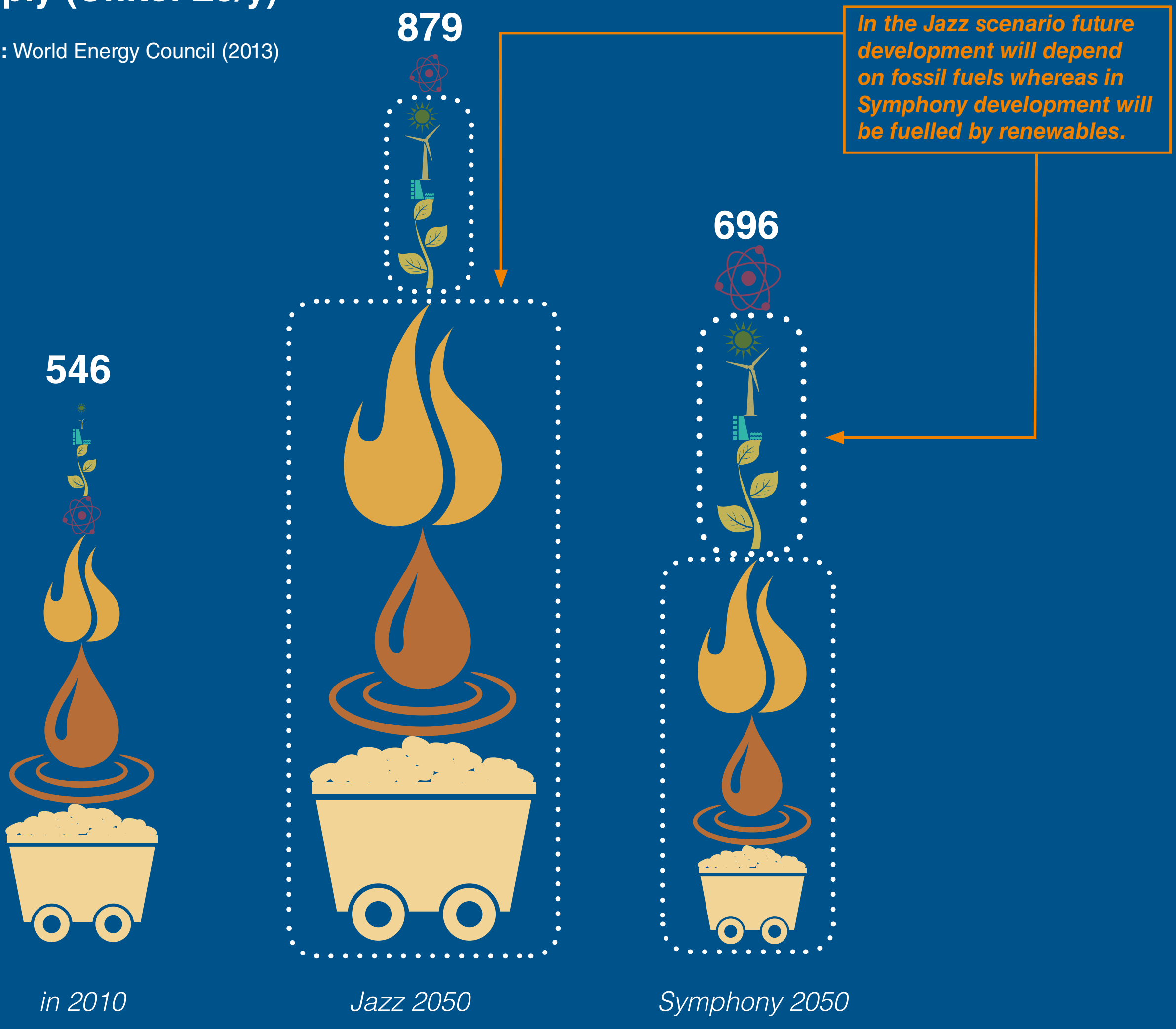
The **future primary energy mix** in 2050 shows that growth rates will be highest for renewable energy sources. In absolute terms, fossil fuels (coal, oil, gas) will remain dominant, up to and including 2050. The share of fossil fuels will be 77% in the Jazz scenario and 59% in the Symphony scenario – compared to 79% in 2010. The share of renewable energy sources will increase from around 15% in 2010 to almost 20% in Jazz in 2050 and almost 30% in Symphony in 2050. Nuclear energy will contribute approximately 4% of total primary energy supply in Jazz in 2050 and 11% in Symphony globally – compared to 6% in 2010.

Fossil fuels will remain dominant up to 2050 (share of fossil fuels)



Total Primary Energy Supply (Units: EJ/y)

Source: World Energy Council (2013)



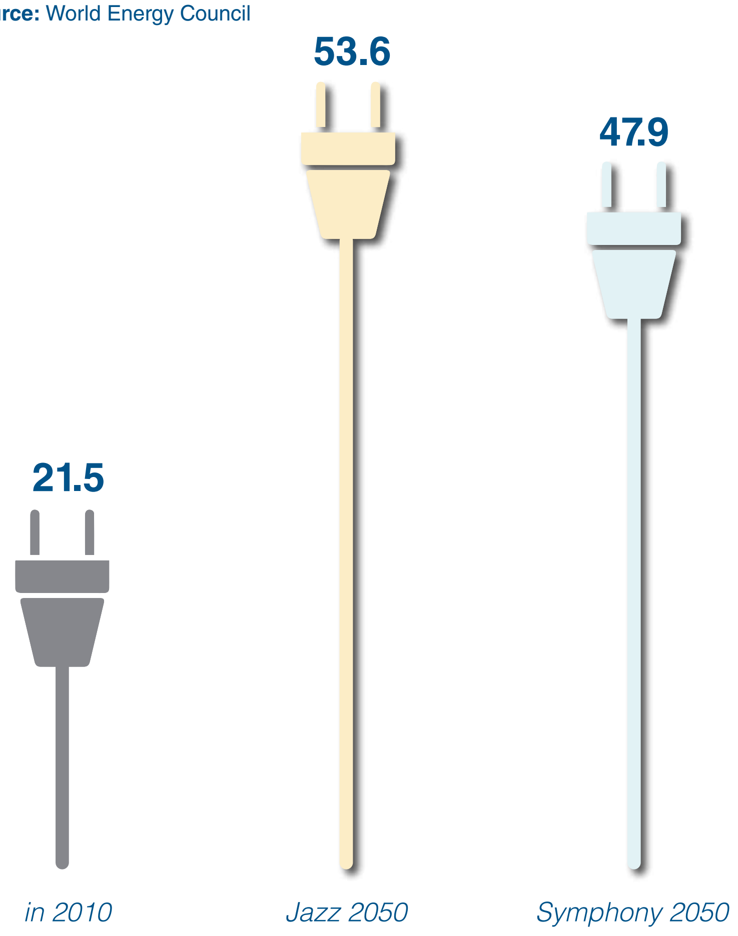
Global electricity generation will increase between 123% and 150% by 2050.

Global electricity generation

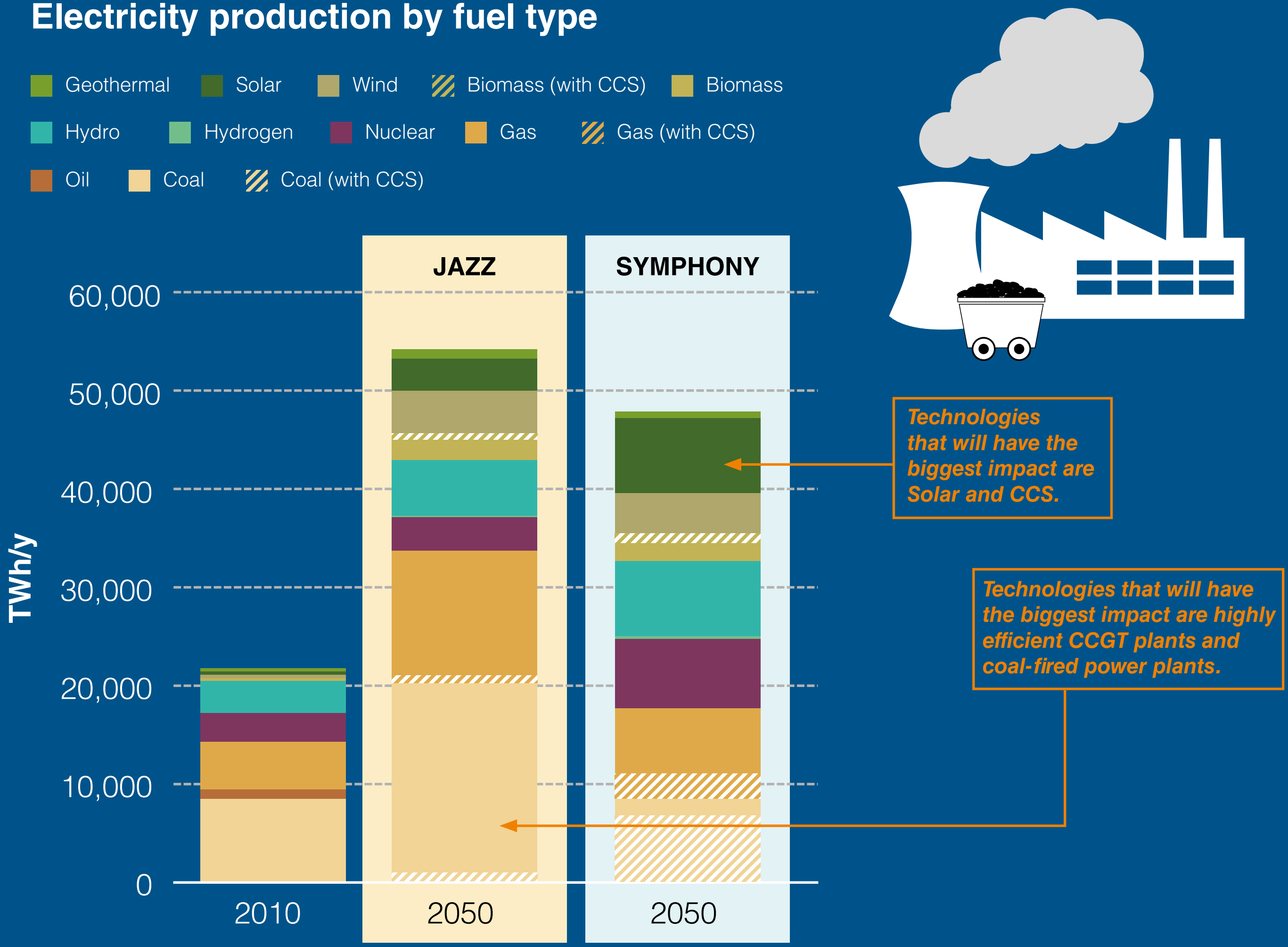
Global electricity generation will increase between now and 2050: In 2010, global electricity production was 21.5 billion MWh globally. In Jazz, this is expected to increase by 150% to 53.6 billion MWh by 2050. In Symphony, the increase is about 123% to 47.9 billion MWh by 2050. Simply due to the sheer increase in electricity production that is needed to meet future demand, the **future electricity generation mix** will be subject to tremendous changes up to 2050.

Global electricity generation (billion MWh)

Source: World Energy Council



Electricity production by fuel type



Investment needs in electricity generation will be between $19 trillion and $26 trillion worldwide up to 2050.

Future investment needs in electricity generation

Huge **investment in electricity generation** is needed to meet future electricity demand. The WEC estimates that total investment needed will range from US$19 trillion in Jazz to US$26 trillion in Symphony (in 2010 terms) – in terms of cumulative investment in electricity generation in both scenarios (2010–2050, undiscounted). Depending on each scenario, a share of 46% in Jazz and almost 70% in Symphony of this is to be invested in renewable electricity generation. Major investment requirements are in solar PV, hydro and wind electricity generation capacity. The WEC's work clearly highlights that the availability of funds for investment is one of the key clusters in scenario building terms that will shape the energy landscape until 2050.

Share of investment in renewable electricity generation

46%	70%
in the Jazz scenario by 2050	in the Symphony scenario by 2050

Investment requirements in electricity generation (2010–2050, billion US$2010, undiscounted)

Source: World Energy Council (2013)

The overall degree of energy access will increase. Africa faces great challenges to increase access to electricity.

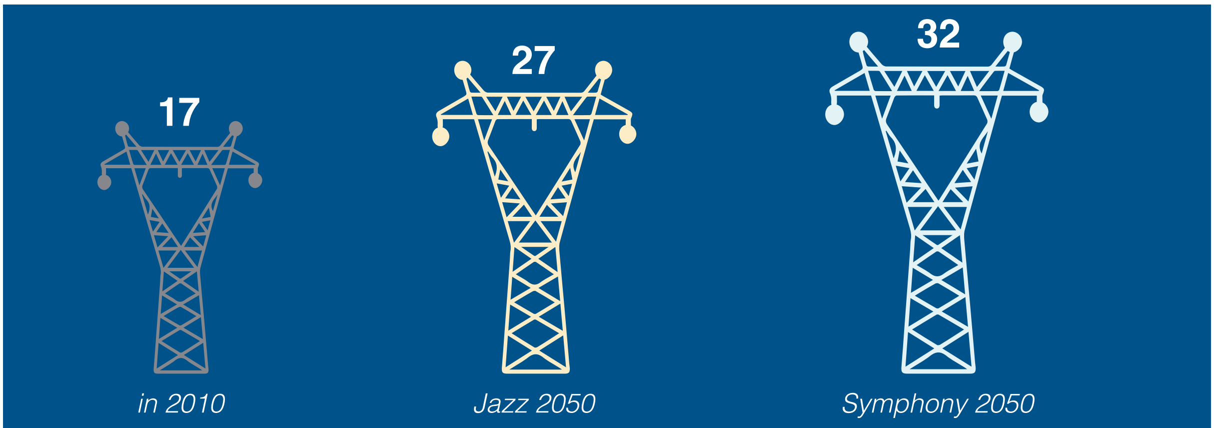
Access to energy

The **degree of electrification** measured in terms of the share of electric energy on the final energy mix, increases up to 2050 significantly. In Jazz, the degree of electrification will be almost 30% in 2050, in Symphony this will even be slightly more than 30% in 2050 – as compared to 17% in 2010.

Electricity consumption per capita increases globally by 111% in Jazz and 78% in Symphony in 2050.

Electricity access, measured as the share of population connected to the electricity grid will increase in both scenarios: energy access will hence improve.[1] While in 2010, 1.267 billion people were without access to electricity globally, this reduces to 319 million in Jazz and 530 million in the Symphony scenario in 2050.

Electrification (in terms of the share of electricity in final energy consumption) (%)

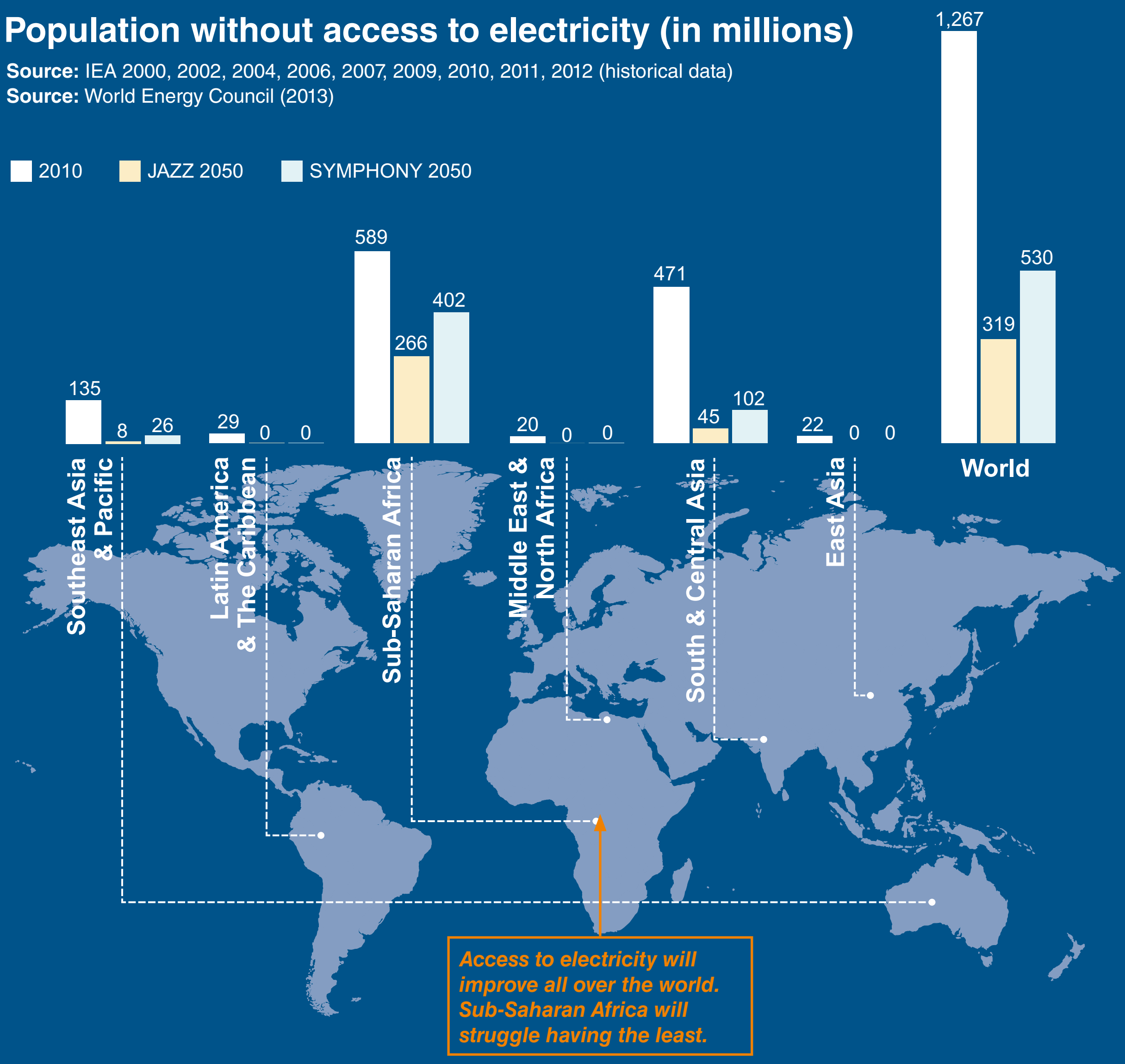


Source: World Energy Council (2013)

1 The estimate of 1.267 billion people without access to electricity for 2010 differs from that of the World Bank of 1.2 billion people due to 'differences in a relatively small number of countries, including Pakistan, Indonesia, South Africa, Thailand, and Gabon, where the International Energy Agency (IEA) uses government data (which typically report more people without access) while the World Bank uses estimates derived from various types of surveys'. (World Bank, 2013).

Population without access to electricity (in millions)

Source: IEA 2000, 2002, 2004, 2006, 2007, 2009, 2010, 2011, 2012 (historical data)
Source: World Energy Council (2013)



Key message

Regional priorities differ: there is no 'one-size-fits-all' solution to the energy trilemma.

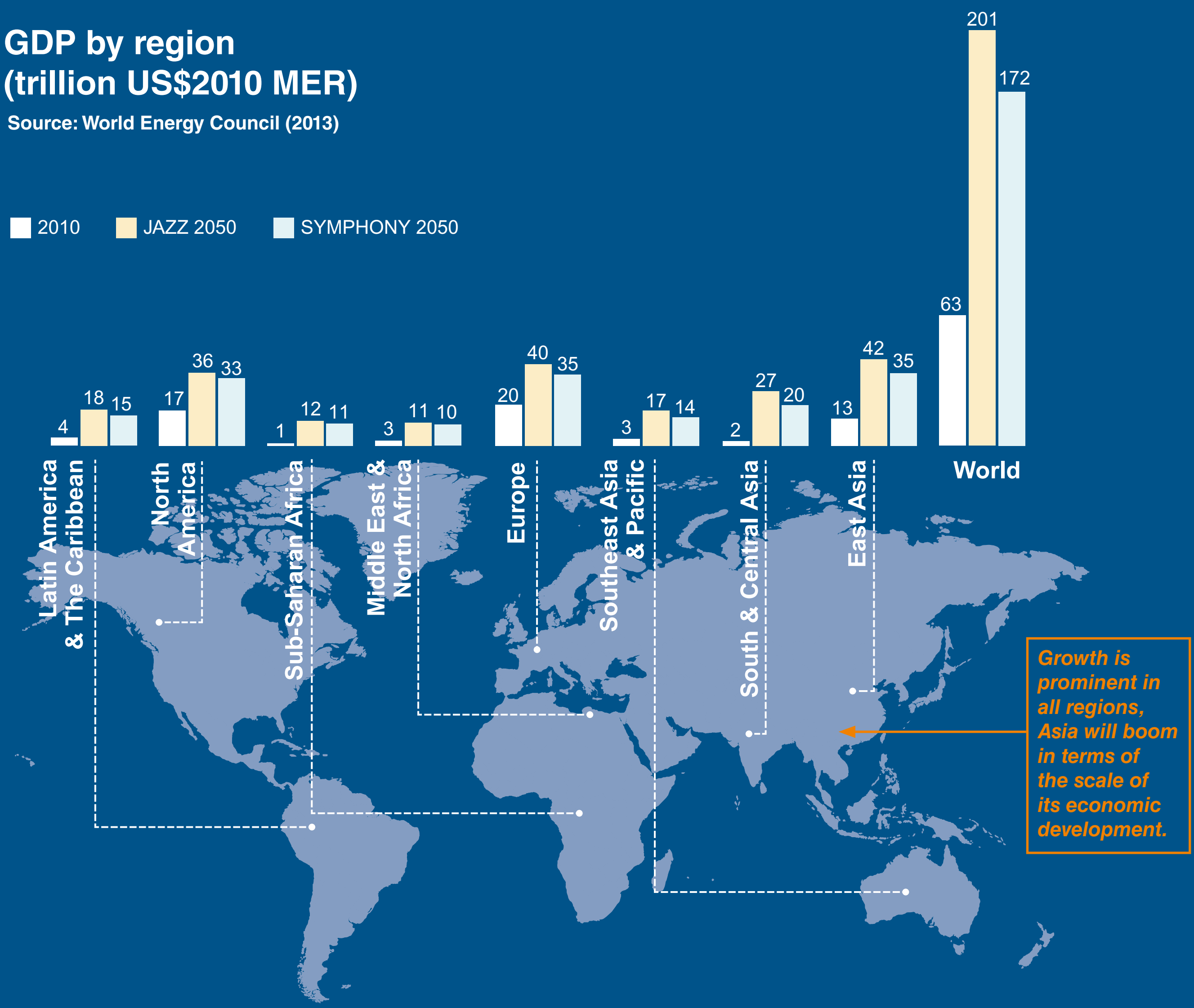
Regional developments

Future economic growth shifts from developed countries to developing and transition economies, in particular in Asia. Of all the eight regions considered in this scenario study, Asia will be characterised by highest economic growth both in relative and absolute terms. By 2050, nearly half of all economic growth (measured in terms of production of GDP) will happen in Asia and its three sub-regions: Central and South Asia, East Asia and Southeast Asia and Pacific both for Jazz and Symphony. This means that the share of Asia on total primary energy consumption will increase from 40% in 2010 to 48% in Jazz and 45% in Symphony. To compare: by 2050, Europe and North America (including Mexico) will make up for about 30% of total global primary energy consumption in Jazz and 31% in Symphony (2010: 44%). Africa, including the middle East will account for 15% (Jazz) and 16% in Symphony (2010: 11%) and Latin America and The Caribbean 8% in Jazz and 7% in Symphony (2010: 5%).

GDP per capita (US$2010 MER)

Source: World Energy Council

GDP by region
(trillion US$2010 MER)
Source: World Energy Council (2013)



Key message

The global economy will be challenged to meet the 450ppm target without unacceptable carbon prices.

Implications for climate

The WEC has analysed where the Jazz and Symphony scenarios might lead in terms of climate change. The WEC has also assessed the potential impact of Jazz and Symphony scenarios on the climate with reference to the work of the Intergovernmental Panel on Climate Change (IPCC).

Jazz scenario

In Jazz, an assumption is made that the negotiations on climate change and emissions targets are not finalised. In the absence of international agreed commitments, regions, countries, states and municipalities take their own sustainable development initiatives and pathways. An international carbon market grows slowly from the bottom up based on regional, national and local initiatives, which coalesce to achieve greater market efficiencies and liquidity. Commercially viable innovative low-carbon technologies (solar, wind, and city gas/waste to energy) experience growth, major reductions in CO_2 emissions come from growth in natural gas, in preference to oil and coal for purely economic reasons.

Symphony scenario

In Symphony, countries pass through the Doha Gateway and successfully negotiate a global treaty because all countries are prepared to accept commitments and concessions. Climate change has more focus along with international initiatives on climate change. Low-carbon technologies are promoted despite lacking commercial viability at initial stages.

The carbon market is top-down based on an international agreement, with commitments

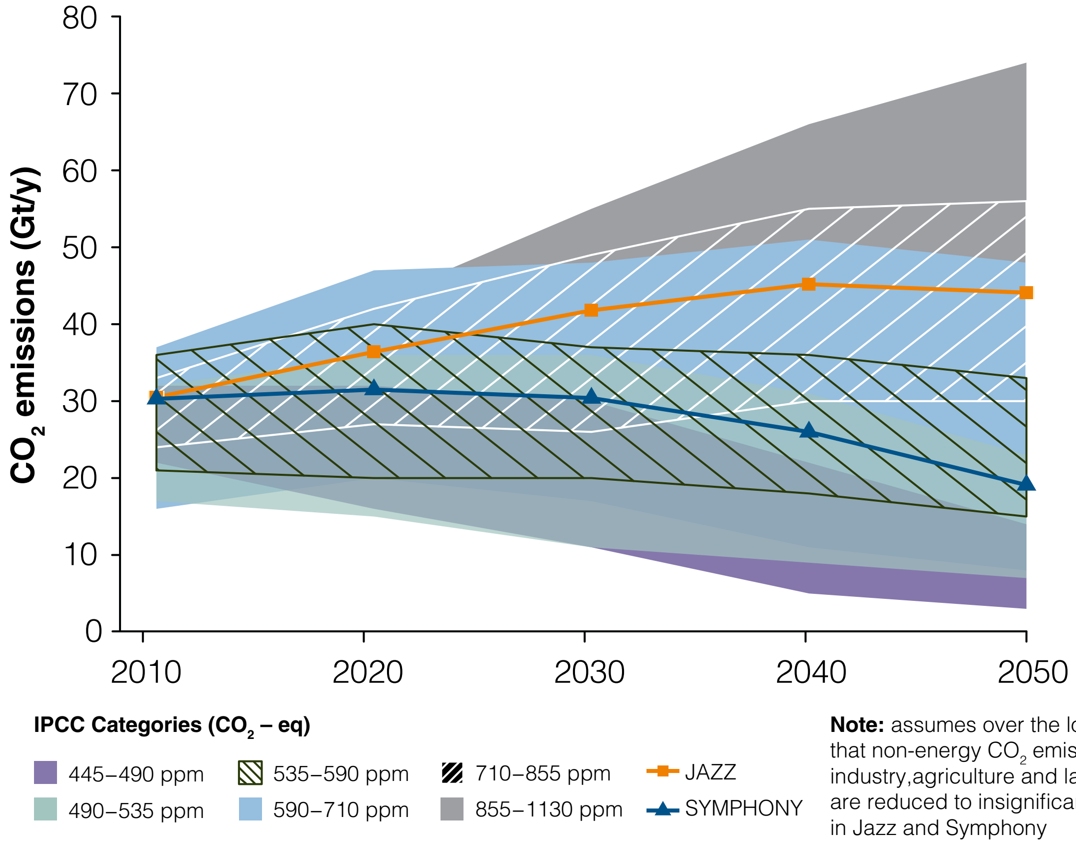
The WEC's commitment to climate change

At the COP 15 (Conference of Parties) meeting, the 15th session of the United Nations (UN) Framework Convention on Climate Change, the 'Copenhagen Agreement' or 'Copenhagen Accord' was ratified by delegates and they endorsed the continuation of the Kyoto Protocol. Specific emissions-reduction targets for 2020 were submitted by individual countries. At subsequent COP meetings, this was reinforced, in particular at the COP18 meeting in Doha when the 'Doha Climate Gateway' was developed – a package of deals that set out a work programme through which both rich and developing countries can deliver a new international climate agreement. The Doha Climate Gateway includes a timetable for a 2015 global climate change agreement and for increasing ambitions before 2020. At Doha, countries agreed a course for negotiating the Durban Platform for Enhanced Action, a new climate deal for all countries to be agreed by 2015 and to take effect in 2020 – the Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP).

To establish a clear link between energy use and climate change objectives, the WEC has included the Doha Climate Gateway as a key differentiator between its two scenarios. The WEC assumes that in the Symphony scenario, countries pass through the Gateway and successfully negotiate a global treaty. In the Jazz scenario, these negotiations fail, and regions, countries, states and municipalities take their own sustainable development pathways.

Emissions trajectories for atmospheric GHG concentrations

Source: World Energy Council (2013) based on the IPCC's 4th assessment report (AR4) (2007)



Note: assumes over the long term that non-energy CO_2 emissions from industry,agriculture and land use are reduced to insignificant levels in Jazz and Symphony

JAZZ	SYMPHONY
CO_2 emissions in the Jazz scenario follow a trajectory consistent with a long-term atmospheric concentration of all GHGs of between 590 and 710 parts per million CO_2 equivalent.	Symphony is on track for 490-535 ppm CO_2 equivalent.

and allocations. In the early part of the scenario period, national initiatives to meet treaty obligations to reduce emissions emerge (developed and developing countries). These national initiatives are linked to form regional markets with exchange of Clean Development Mechanism (CDM) and other emission units. The final part of the scenario period sees global action on climate change with the market instrument emission trading as the leading mechanism for meeting CO_2 emission obligations.

The WEC's scenarios and climate implications

The above chart shows the potential implications of the emissions trajectories for Jazz and Symphony for atmospheric GHG concentrations (and hence climate) based on the IPCC's 4th Assessment Report:

Although Jazz includes a stronger emphasis on adaptation and Symphony mitigation, in both scenarios additional action is expected over the longer term (beyond 2050), further reducing the impact on climate. The implications of these changes to atmospheric GHG concentrations for surface temperature change, sea-level rise, changes in precipitation, incidence of extreme events and other impacts remain uncertain.

Pressure for climate action will change over the period, the WEC recognises that the climate forcing of CO_2 is considered now to be lower in some of the scientific literature in 2013. There is also increasing awareness of severe weather events that could be linked to climate forcing.

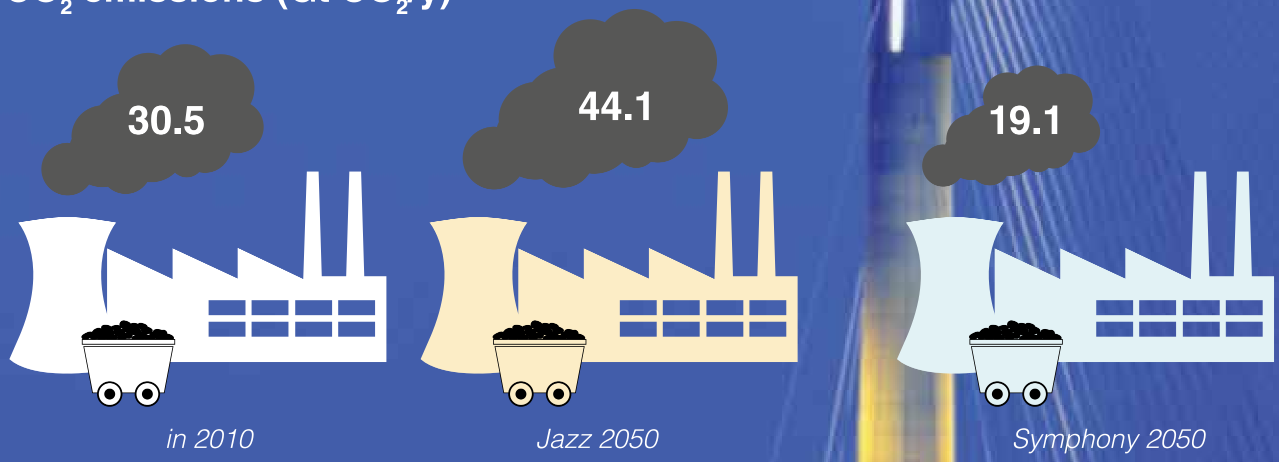
Key message

A low-carbon future is not only linked to renewables: CC(U)S is important and consumer behaviour needs changing.

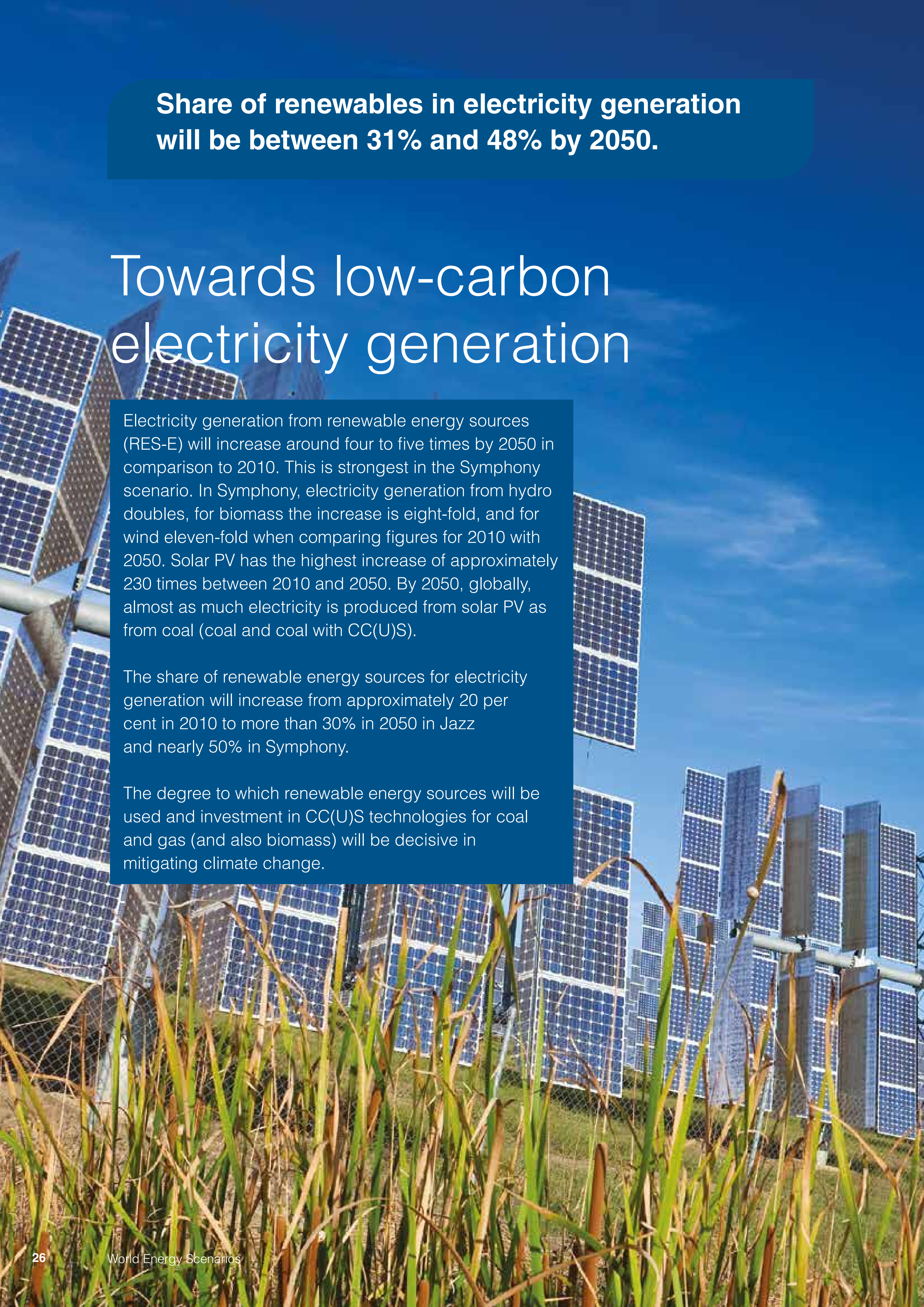
CO_2 emissions and climate change

CO_2 emissions will increase in both scenarios in the first half of the scenario period. In the Symphony scenario, where, by assumption, greater emphasis is placed on climate change mitigation and adaptation, a turning point will be reached by 2020. In the Jazz scenario, the turning point is only reached by 2040. As far as the total amount of CO_2 emissions are concerned, both scenarios differ substantially. In the Jazz scenario, CO_2 emissions will be more than 44 billion tonnes per annum in 2050 which is 45% higher than in 2010. In the Symphony scenario, CO_2 emissions reach 19 billion tonnes per annum which is nearly 40% lower than in 2010. The WEC's World Energy Scenarios to 2050 underline that a reduction of greenhouse gas emissions is possible in the second half of the scenario period with global agreements and the implementation of cost-efficient measures like emissions trading within a cap and trade system (assumed in Symphony).

CO_2 emissions (Gt CO_2/y)



Source: World Energy Council (2013) (CO_2 emissions only, not CO_2 equivalents)



Share of renewables in electricity generation will be between 31% and 48% by 2050.

Towards low-carbon electricity generation

Electricity generation from renewable energy sources (RES-E) will increase around four to five times by 2050 in comparison to 2010. This is strongest in the Symphony scenario. In Symphony, electricity generation from hydro doubles, for biomass the increase is eight-fold, and for wind eleven-fold when comparing figures for 2010 with 2050. Solar PV has the highest increase of approximately 230 times between 2010 and 2050. By 2050, globally, almost as much electricity is produced from solar PV as from coal (coal and coal with CC(U)S).

The share of renewable energy sources for electricity generation will increase from approximately 20 per cent in 2010 to more than 30% in 2050 in Jazz and nearly 50% in Symphony.

The degree to which renewable energy sources will be used and investment in CC(U)S technologies for coal and gas (and also biomass) will be decisive in mitigating climate change.

Solar power will increase from 34.4 (TWh/y) to

2,980 in the Jazz scenario by 2050

7,740 in the Symphony scenario by 2050

Renewable Electricity Production (Units: TWh/y)

Hydro

3,490 *in 2010*

5,790 *Jazz 2050*

7,700 *Symphony 2050*

Geothermal

70 *in 2010*

950 *Jazz 2050*

650 *Symphony 2050*

Wind

360 *in 2010*

4,510 *Jazz 2050*

4,000 *Symphony 2050*

Solar

35 *in 2010*

2,980 *Jazz 2050*

7,740 *Symphony 2050*

Biomass

340 *in 2010*

1,920 *Jazz 2050*

1,910 *Symphony 2050*

Biomass (with CCS)

0 *in 2010*

440 *Jazz 2050*

800 *Symphony 2050*

Key message

CC(U)S technology, solar energy and energy storage are the key uncertainties up to 2050.

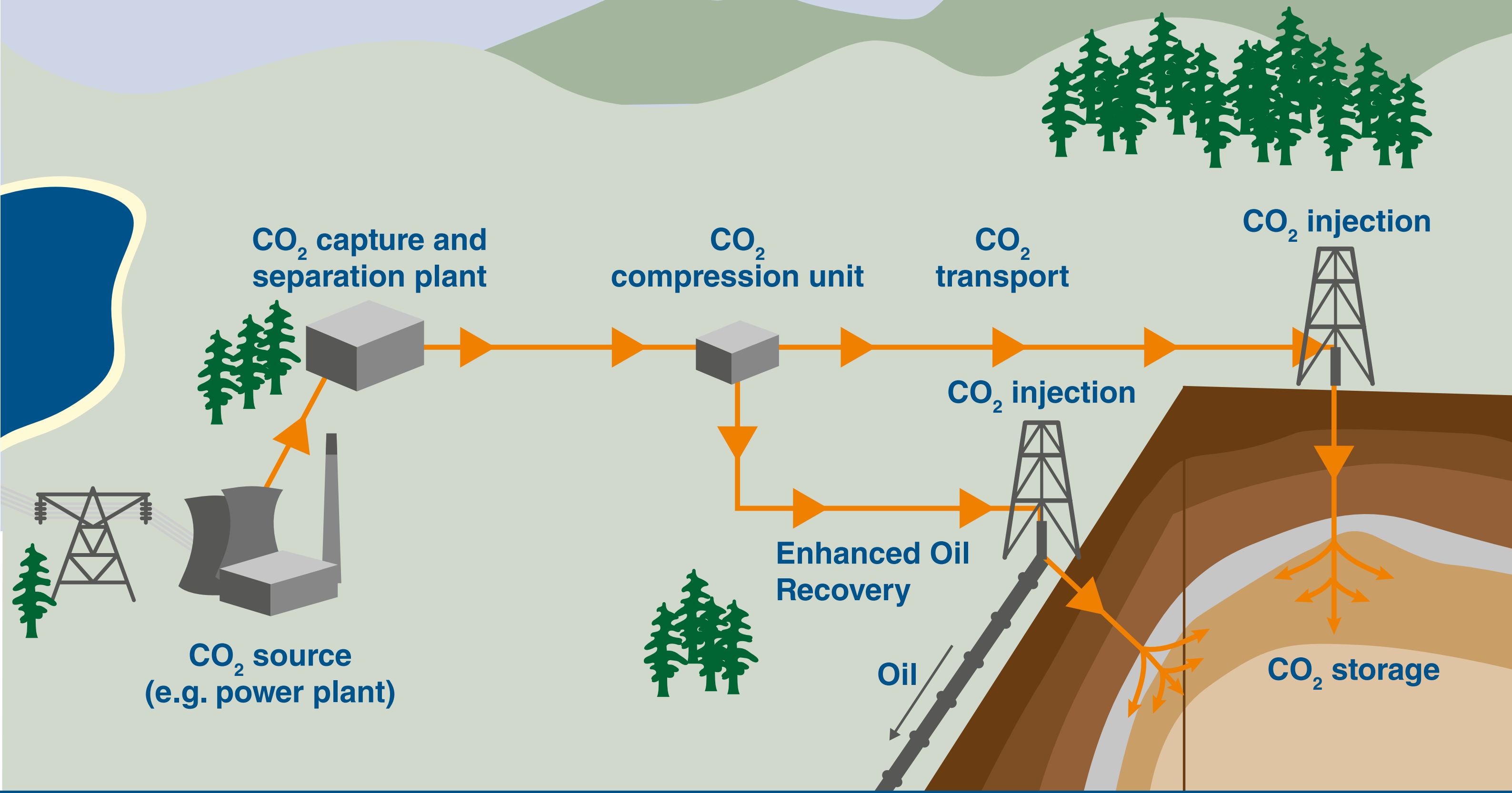
Carbon capture, utilisation and storage

Carbon capture utilisation and storage (CC(U)S) technologies are widely employed in Symphony and hence subject to higher growth rates in the Symphony scenario than in the Jazz scenario. Half of the total electricity generated based on fossil fuels will be in conjunction with CC(U)S in 2050 in Symphony. Combining nuclear and CC(U)S for gas, coal and biomass, more than 80% of all electricity generated in 2050 will be from low-carbon sources in the Symphony scenario, compared to 40% in the Jazz scenario. To compare: In 2010, only one-third of global electricity generation was CO_2 from low-carbon sources.

The WEC believes that CC(U)S technology, solar energy and energy storage are the key uncertainties moving forward up to 2050. For CC(U)S to work, clear legislative frameworks are needed – combined with infrastructure investment and the right incentives. A low-carbon future is not only linked to renewables: CC(U)S is important and consumer behaviour needs changing. Changes in consumption habits can be an effective way to decarbonise the energy system. Voters need to balance local and global issues.

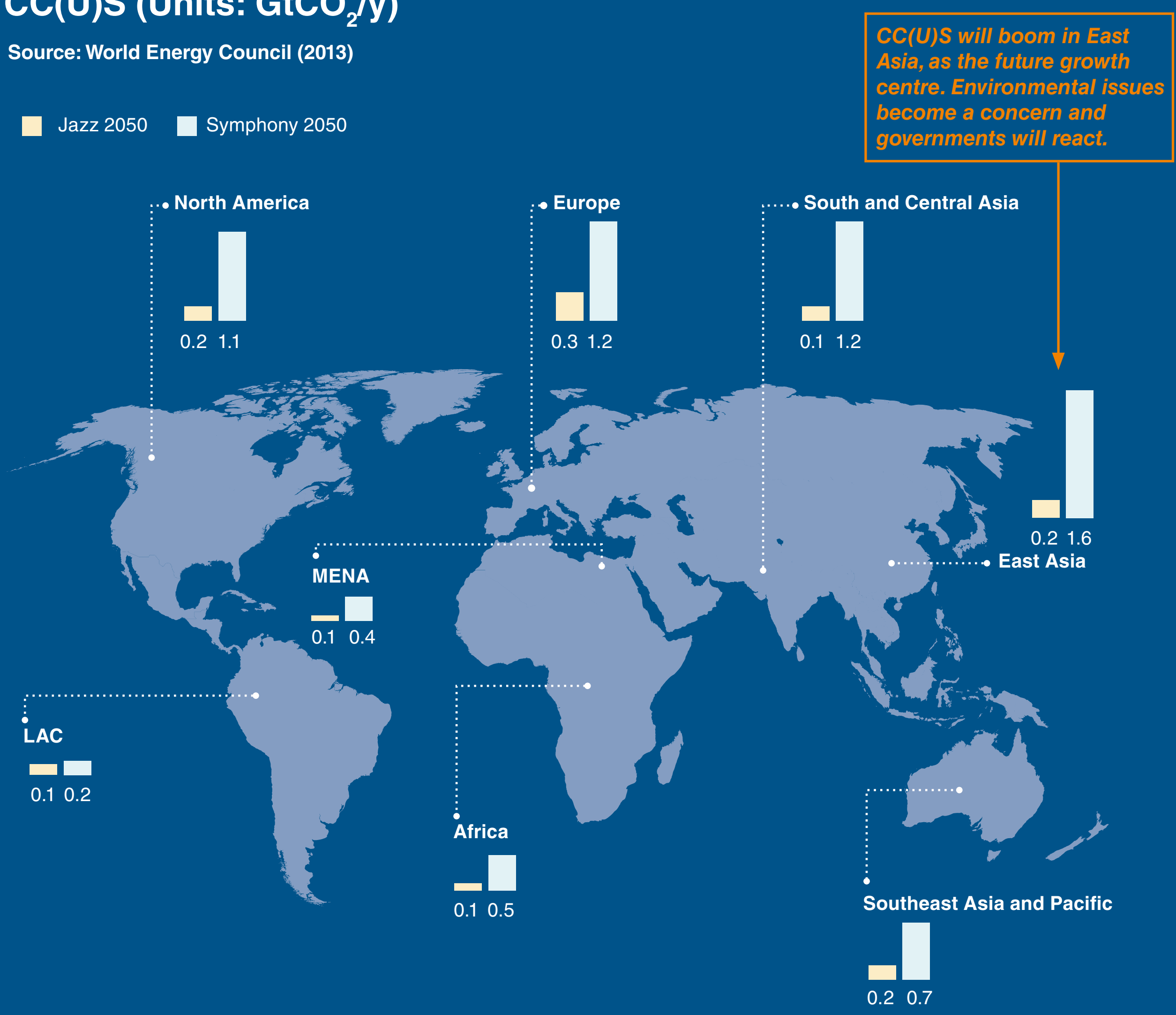
'For decarbonisation to be more effective, citizens play a crucial role, as consumers in Jazz, and voters in Symphony.'

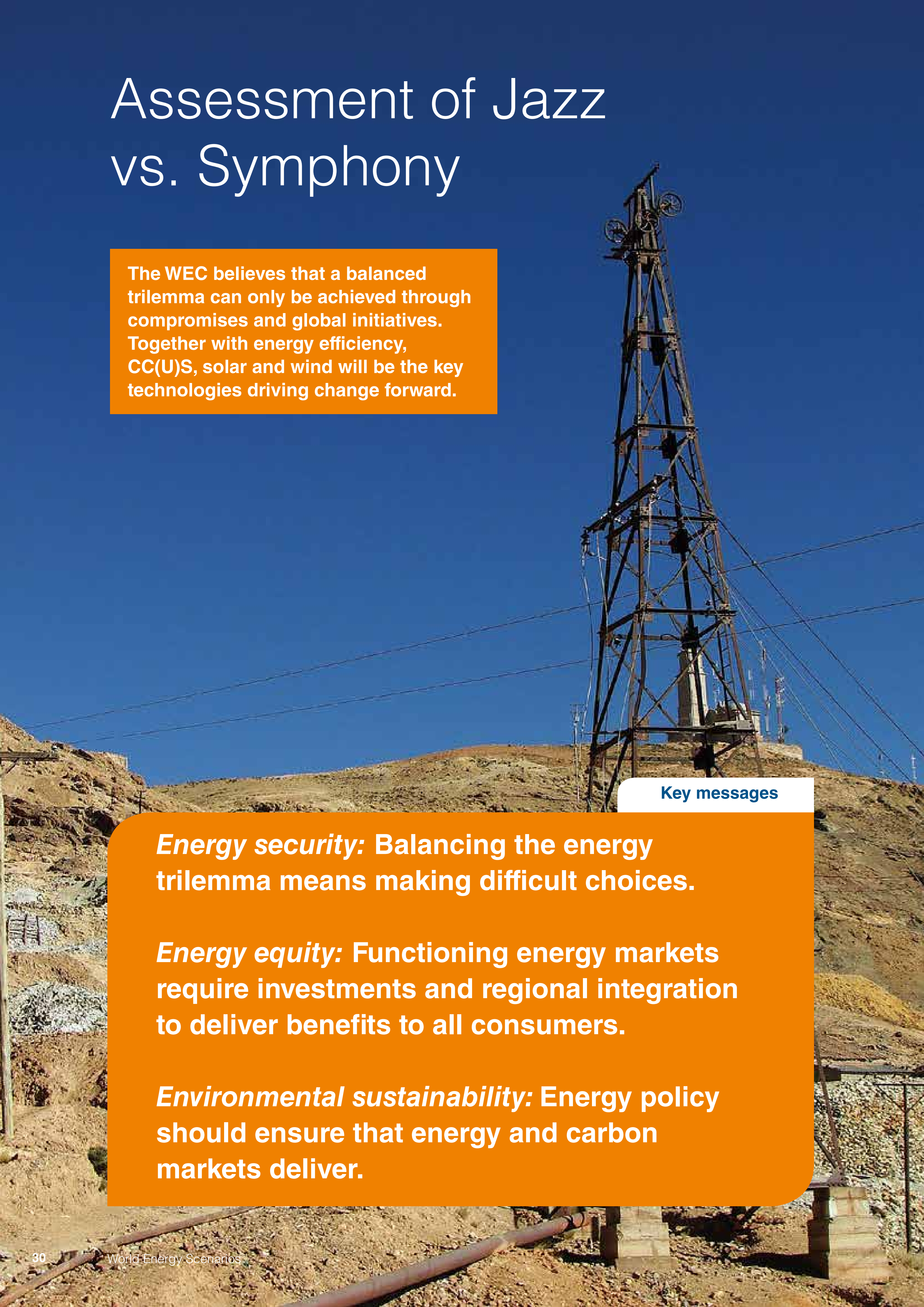
Carbon capture, utilisation and storage



CC(U)S (Units: $GtCO_2/y$)

Source: World Energy Council (2013)





Assessment of Jazz vs. Symphony

The WEC believes that a balanced trilemma can only be achieved through compromises and global initiatives. Together with energy efficiency, CC(U)S, solar and wind will be the key technologies driving change forward.

Key messages

***Energy security:* Balancing the energy trilemma means making difficult choices.**

***Energy equity:* Functioning energy markets require investments and regional integration to deliver benefits to all consumers.**

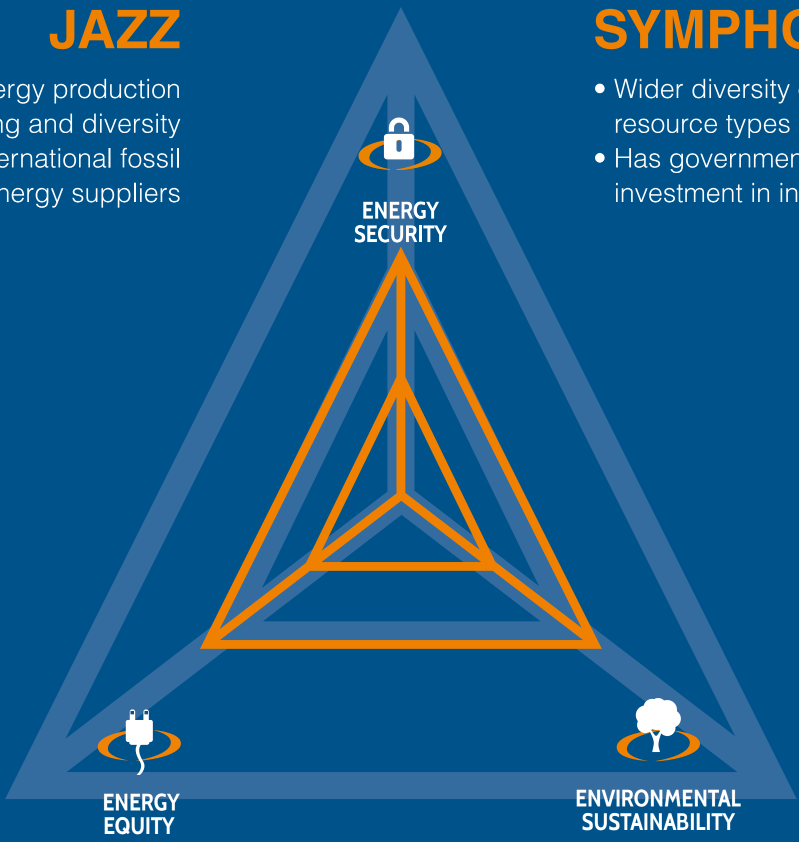
***Environmental sustainability:* Energy policy should ensure that energy and carbon markets deliver.**

JAZZ

- Higher energy production
- Greater trading and diversity of international fossil energy suppliers

SYMPHONY

- Wider diversity of energy resource types
- Has government-promoted investment in infrastructure



JAZZ

- On average, energy equity progresses better
- More people are able to afford more energy because the global market leads to higher GDP growth

SYMPHONY

- Energy equity is less because there are inevitably interventions restricting GDP growth
- Funds directed into low-carbon initiatives would actually start diverting funds from other government priorities such as health care and other programmes
- Financial resources are not limitless
- Governments have to set spending priorities
- Wise choice of policies as identified in the WEC World Energy Trilemma Report could avoid this drop, as countries strive to score well on the WEC's trilemma index

JAZZ

- Emissions don't drop until after 2040
- Performance improves markedly if a bottom-up carbon market develops early in the scenario, but the higher GDP growth still means higher emissions
- Puts more emphasis on adaptation

SYMPHONY

- Scores well on environmental impact mitigation particularly CO_2 emission reduction, with emissions dropping after 2020
- Externalities are more effectively internalised: this is primarily because countries adopt a range of mechanisms to meet treaty obligations on CO_2
- Higher carbon prices would achieve higher emission reduction
- The market instrument emission trading is assumed as the leading mechanism for meeting CO_2 emission obligations in the second part of the scenario period

The WEC's scenario building methodology

The WEC's World Energy Scenarios to 2050 are designed to glimpse what the future might look like in a plausible and maybe challenging manner – yet they are not meant to be exact or precise forecasts.

Predicting the future is not possible. As we move on, the range of possible future outcomes becomes greater – especially since uncertainty increases. As trends and innovations pick up speed and gain momentum, their impact increases.

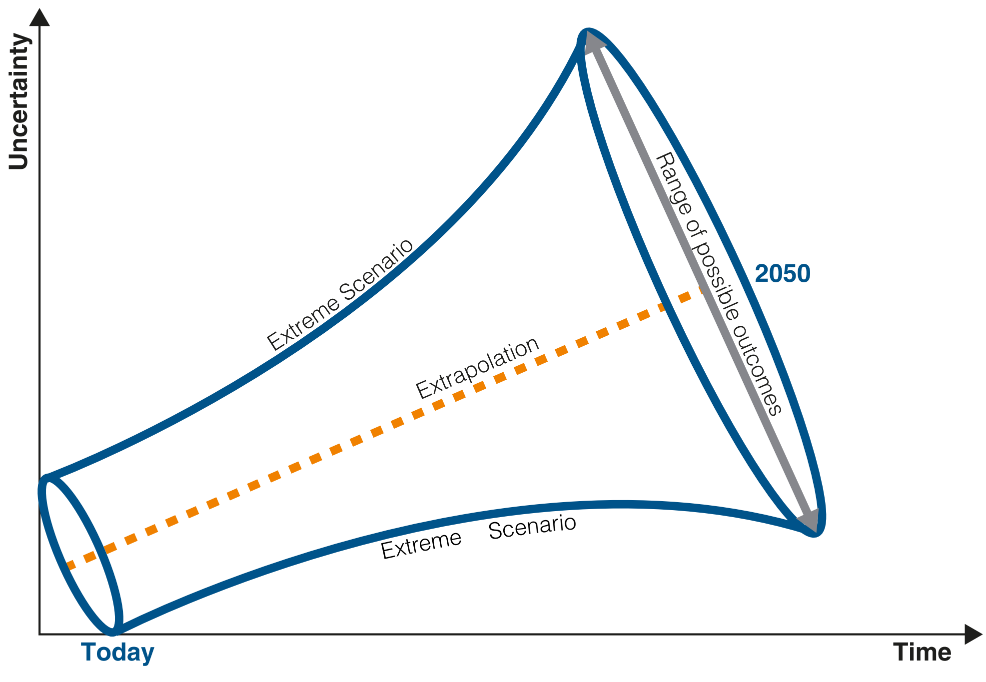
The signals we observe today can be distilled into drivers, critical uncertainties, and pre-determined elements that form the future. It is of strategic importance that governments and companies who seek to make investments and take decisions in the energy sector undertake some sort of long-term planning exercise.

In order to aid senior decision makers and policymakers in this endeavour the WEC began its newest scenario building exercise in 2010.

To develop a view of how the energy landscape might look in 2050, the WEC started by looking at the critical drivers of the energy system from the broadest possible viewpoint by adopting a systemic approach. The WEC structured its analysis by first identifying 116 drivers that will affect the energy landscape globally up to 2050. These drivers were narrowed down to 29 key issues that will have an impact on the energy landscape up to 2050, and 15 key clusters where identified that were then used to derive the two future spaces or scenarios.

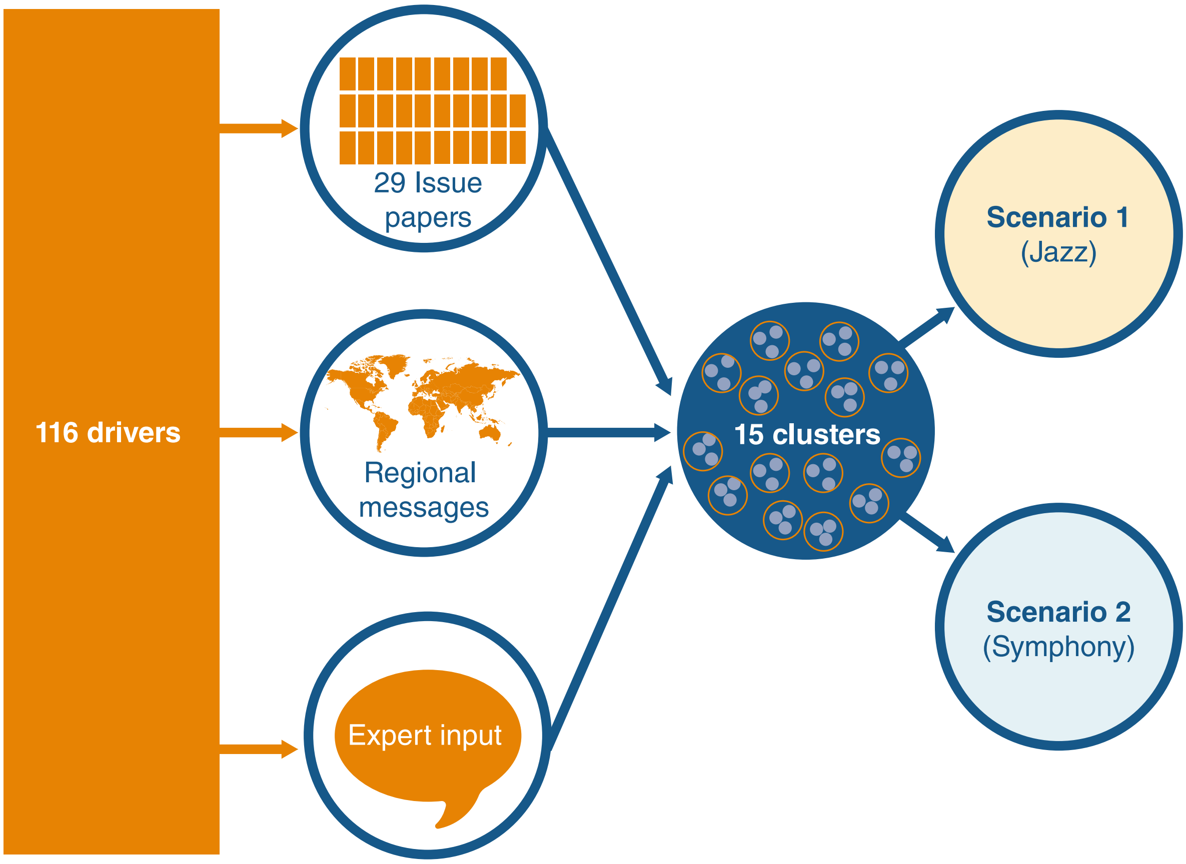
The scenario funnel: As uncertainty increases, the funnel widens

Source: World Energy Council (2013)



The WEC's scenarios: Two future spaces

Source: World Energy Council (2013)



These 15 key clusters are:

1. Government and the role of state
2. Availability of funds: investment
3. Mitigation of CO_2
4. Equality, energy access and poverty
5. Global economics
6. Energy prices
7. Consumer/citizen acceptance
8. Energy efficiency
9. Technology developments
10. Security of supply
11. China and India
12. Energy poverty
13. Energy sources
14. Competition for resources
15. Skills shortages

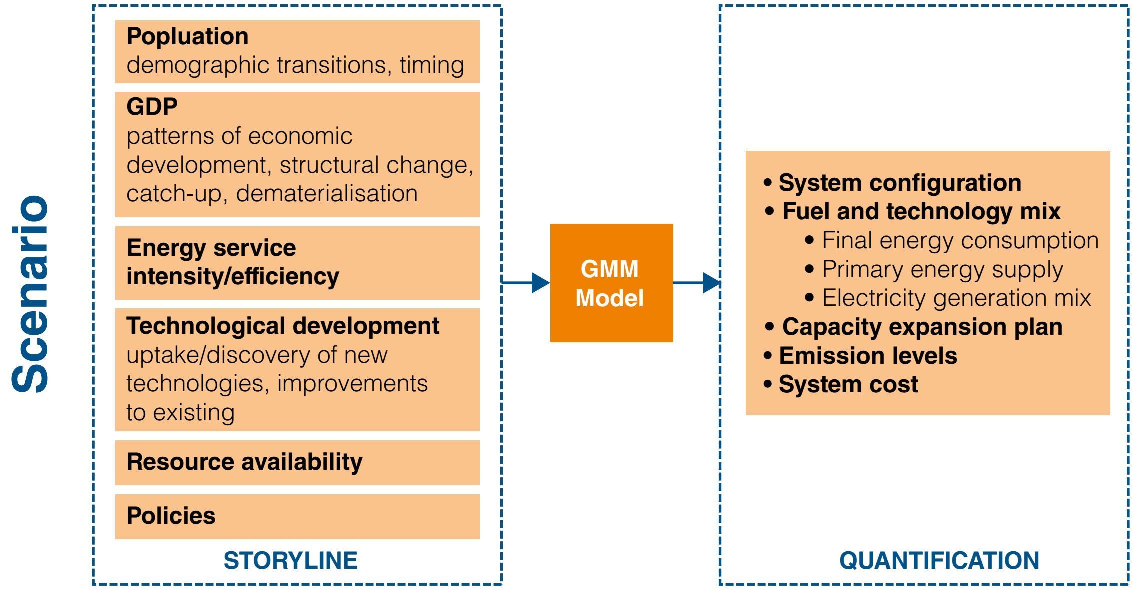
In WEC's view, the future development in these 15 key clusters will determine how the 'energy landscape' might look in 2050. All clusters are therefore equally important, none of them is more important than another.

The WEC has used these key clusters and bundled them to form two separate future spaces, depending on the exact assumptions made that ultimately represent two different views of the world and hence two possible future 'scenarios'. The two scenarios stories that were developed on these methodological bases are therefore exploratory and not normative, equally probable but differentiated – rather than just good and bad.

To obtain the best possible input from energy experts worldwide, the WEC has adopted an open, inclusive and transparent process with input from constituents into the scenario stories a scenarios study group, expert participation and interviews, and a series of regional workshops in New Delhi, Johannesburg, London, Beijing, Cancun, and Washington.

The WEC scenarios quantification: Use of a global multi-regional MARKAL (GMM) model

Source: World Energy Council (2013)



WEC's quantification of the scenario stories

To model and quantify each scenario, the drivers from the clusters were grouped and then translated into quantified inputs such as energy demands, technology characteristics and deployment/availability, energy resource availability and extraction costs, CO_2 prices and others. Policy measures and behavioural aspects of the scenario assumptions were translated into additional modelling constraints and parameters, for example, assumptions on unconventional fossil resources, biofuels, and climate policy. The storyline development and quantification steps sought to account for the interdependence between different drivers and input assumptions (e.g. energy demand, which depends on GDP, structural developments and energy efficiency, which in turn relies on policy and other factors).

The scenario drivers are used as input to an energy system model, which: (i) models the structure of the underlying energy system; (ii) is based on numerical data and time series; (iii) follows a specific mathematical structure; (iv) includes information on boundaries and constraints based on user-defined relationships; and (v) can accommodate different scenarios and strategies.

The energy system model employed by the WEC to quantify its scenario stories is based on the well-established MARKAL (MARket ALlocation) framework.[2] More specifically, the WEC uses the global multi-regional MARKAL (GMM) model maintained by the Paul Scherrer Institute (PSI). GMM is a cost-optimisation model that yields least-cost solutions for the global energy system under a given set of scenario assumptions and constraints. It is a dynamic partial-equilibrium model; the shares of technologies and of energy carriers used for extraction and for conversion as well as the final energy demands are determined endogenously by the model, whereas the demands of useful energy (services) are scenario inputs.

The GMM model allows the world to be subdivided into different regions so that different regional splits can be analysed. The model also considers a long-term horizon (to 2050 and potentially beyond) allowing the analysis of future energy issues of resource depletion, climate change policy, economic development and technology learning.

GMM is a bottom-up model that reflects the WEC's decentralised approach towards developing the scenario stories; the model contains a detailed representation of resources, technologies, energy flows, and assumptions

2 The MARKAL modelling framework is widely used in over 250 institutions in approximately 70 countries; the framework is part of IEA's Energy Technology Systems Analysis Program (ETSAP).

regarding technological change, learning, cost and efficiency improvements over time.

Wild cards and critical uncertainties

The WEC believes that CC(U)S technology, changing demand patterns and energy storage are the key uncertainties moving forward to 2050.

CC(U)S technology is already available and is potentially one of the lower-cost deep decarbonisation options, but it will always be an added cost and will require major pipeline and other infrastructures. For CC(U)S to work, clear legislative frameworks are needed, combined with infrastructure investment and the right incentives. The carbon price signals that need to be developed in the coming years to allow the emergence of CC(U)S will also improve renewable learning curves and scalability (i.e. digression of capital cost over time). CC(U)S might only be feasible in geographical regions of the world with the right geology. The WEC assumes that it is most likely that in Symphony initial CC(U)S projects will involve aquifer storage in Europe under the North Sea, and major enhanced oil recovery (EOR) projects in gas and oil reservoirs in the US driven by US Environmental Protection Agency restrictions on CO_2 emissions from power generation. The WEC assumes that, in the Jazz Scenario, without government interventions the market will be slow to optimise on CO_2 due to the high initial infrastructure costs involved, unless there are commercial drivers such as EOR.

As far as energy storage technologies are concerned, pump storage is a well-developed and widely applied technology, with its use limited by site limitations. Power-to-gas (hydrogen or methane) could be an early option given it could use existing gas pipeline infrastructures. Other new and emerging energy storage technologies, such as batteries and hydrogen, still need more R&D before they become commercially viable. Investment in R&D is therefore needed to promote these technologies which could play a key role up to 2050 especially to overcome the problem of intermittency of renewables.

The WEC's World Energy Scenarios to 2050

Key signal messages for policymakers and energy leaders from Jazz and Symphony

1 Energy system complexity will increase by 2050

The energy landscape we expect to see in 2050 will be quite different from how it looks today. Meeting energy supply and demand will gain complexity. Energy systems will remain complex – there are substantial system integration costs especially when a large proportion of renewables are involved due to increased network expansion costs in both transmission and distribution systems (especially in the Symphony scenario). To better understand and ultimately cope better with this increasing complexity, integrated system modelling will deserve more attention in the future to provide a more holistic view and lead to a better understanding of complex energy systems.

2 Energy efficiency is crucial in dealing with demand outstripping supply

The WEC's World Energy Scenarios to 2050 show that energy efficiency and energy conservation are absolutely crucial in dealing with demand outstripping supply – both require a change in consumer priorities and have cost implications across industries – and hence capital is required to finance energy-efficiency measures in terms of an initial investment before it can pay off. Both in the Jazz and Symphony scenarios, electric mobility comes later than originally expected – at the earliest after 2030. Policymakers and industry need to undertake even greater effort to promote the share of renewables in electricity production which is not increasing enough to ensure environmental sustainability in the long run up to 2050 and beyond.

3 The energy mix in 2050 will mainly be fossil based

The WEC's World Energy Scenarios to 2050 show that, in 2050, fossil fuels will still play a crucial role for both power generation and transport, this is particularly so in Jazz. Coal is going to play an important role in the long run, especially for power generation in China and India, the two most rapidly growing demand centres up to 2050. Natural gas, especially from unconventional sources, will play an increasing role and gain more importance in the energy share. An example is the transport sector where heavy transport will depend on fossil fuels for decades to come.

Oil will continue to remain dominant for transport, an increase in importance of unconventional sources – in particular oil sands, and oil shale – is expected. No renaissance of nuclear energy is anticipated. Nuclear energy is not a game-changer – with limited impact also because of restrictions in economics. In the Symphony scenario, the WEC anticipates a large increase in the share of renewables – mainly in solar PV, hydro and wind globally.

4 Regional priorities differ: there is no 'one-size-fits-all' solution to the energy trilemma

There is no global solution to the energy supply issue. Instead, reaching a solution relies on solving each of the individual parts to reach the global goal of sustainable, affordable and secure energy supply for all. Critical uncertainties remain, especially with regard to CC(U)S and the future development of energy storage technologies that are scalable in economic terms.

In this complex world, governments play a crucial role in determining and establishing frameworks for markets to function in both scenarios. Industries and markets need to provide efficient solutions. Up to 2050, the reality will lie somewhere between the Jazz and Symphony scenarios in terms of energy supply, energy demand increases, and GDP growth – or it might even go beyond the levels indicated here.

5 The global economy will be challenged to meet the 450ppm target without unacceptable carbon prices

World Energy Scenarios to 2050 underline that a reduction of greenhouse gas (GHG) emissions is possible in the second half of the scenario period if it comes to global agreements and the implementation of cost-efficient market instruments like emissions trading within a cap and trade system (assumed in Symphony). Carbon capture and storage (CC(U)S) as a cost-efficient CO_2 mitigation option can play an important role after 2030 – dependent on the assumed CO_2 price. Such a price for CO_2 has to be high enough to create right signals to provide an adequate incentive for CO_2 reduction.

The WEC's World Energy Scenarios to 2050 indicate that these large reductions in CO_2 are possible when governments are acting and industry players and markets are given right incentives to provide suitable technological solutions to achieve this. However, current signals indicate that the global economy is not on track to meet the 450ppm target (in terms of the emission pathway) without unacceptable carbon prices. In the Symphony scenario, CO_2 emissions begin to drop from 2030, but fall short of the 450ppm target. In the Jazz Scenario, lower carbon prices emissions do not plateau until around 2050.

6 A low-carbon future is not only linked to renewables: CC(U)S is important and consumer behaviour needs changing

Carbon capture, use and storage (CC(U)S) is a suitable technology (In addition to renewable electricity generation) to reduce CO_2 emissions. Given a CO_2 price signal CC(U)S can play an important role after 2030 as a cost efficient CO_2 mitigation option.

Such a price for CO_2 has to be high enough to create the right signals to provide an adequate incentive for CO_2 reduction. Issues remain such as technical feasibility at a large scale, public resistance and the upfront infrastructure cost. These are addressed more in Symphony where CC(U)S and solar contribute equally to the decarbonisation of energy systems by 2050.

For the decarbonisation to be more effective, citizens play a crucial role, as consumers in Jazz, and voters in Symphony. Changes in consumption habits can be an effective way to decarbonise the energy system. Voters need to balance local and global issues.

7 CC(U)S technology, solar energy and energy storage are the key uncertainties moving forward up to 2050

The WEC believes that CC(U)S technology, solar energy and energy storage are the key uncertainties moving forward up to 2050. CC(U)S technology is already available and is potentially one of the lower-cost, deep decarbonisation options, but it will always be an added cost and will require major pipeline and other infrastructures. For CC(U)S to work, clear legislative frameworks are needed – combined with infrastructure investment and the right incentives.

The WEC assumes that solar technologies, in particular solar PV, will take off promoted by feed-in electricity tariffs, subsidies and net pricing in Europe, and solar technology prices tumbling. The technologies then make major inroads, and used in India, Africa and other countries to bring power to rural and off-grid communities. Subsidies are needed for solar to be economic and to create an incentive for investment to happen. Subsidies for solar are higher in Symphony than they are in Jazz, which leads to a higher trajectory of uptake of solar PV in Symphony.

As far as energy-storage technologies are concerned, pump storage is a well-developed and widely applied technology, its use is limited. Other new and emerging energy storage technologies, batteries, hydrogen, power to gas (hydrogen or methane), still need more research and development (R&D) before they become commercially viable. Investment in R&D is therefore needed to promote these technologies which could play a key role up to 2050 especially to overcome the problem of intermittency of high levels of renewables in Symphony.

8 Balancing the energy trilemma means making difficult choices

Citizens face a choice between affordable energy with higher economic growth in Jazz, or more expensive energy prices and less impact on the environment in Symphony. This underlines that a holistic long-term view on the energy sector is required to address these energy trilemma issues up to 2050 and beyond.

For politicians, the time of short-termism is over: clear and stable legislative frameworks are needed to ensure financial predictability, for markets to develop and for industry to provide solutions to rising global energy needs.

9 Functioning energy markets require investments and regional integration to deliver benefits to all consumers

The availability of funds for investment is one of the key clusters in scenario building terms that will shape the energy landscape until 2050. The WEC has assessed the investment implications for electricity generation both for the Jazz and the Symphony scenarios at the global and regional level. Long-term investment decisions are needed to meet future energy demand.

The investment costs for electricity generation associated with each scenario are in the region of approximately US$265 trillion (US$2010) in the Jazz scenario and approximately US$19 trillion (US$2010) in the Symphony scenario for electricity-generating capacity only.

For an investment in this region to be taken, clear signals are needed, together with high financial predictability, stable regulatory frameworks with low regulatory risk and functioning markets to ensure that energy can be delivered to all consumers who need it and to the greater benefit all.

10 Energy policy should ensure that energy and carbon markets deliver

The WEC firmly believes that energy policy should ensure that energy and carbon markets deliver investments, promote regional integration and hence provide benefits to consumers. In Symphony, an agreed 2030 decarbonisation target could provide the right signals to investors of incentivising investment in different technologies.

In Symphony, governments should be aware that promoting new technologies through subsidies such as feed-in tariffs can also lead to 'energy market bubbles'. In the Jazz scenario, governments can facilitate the growth of national and regional markets by cutting the red tape, and the promotion of regional integration and greater cooperation. This will lead to better market integration and the creation of regional markets with greater benefits for all consumers.

Data annex

Jazz

Symphony

TOTAL PRIMARY ENERGY SUPPLY BY FUEL TYPE (Units: EJ/y)

Primary energy	2010	2020 (Jazz)	2030 (Jazz)	2040 (Jazz)	2050 (Jazz)	2020 (Symphony)	2030 (Symphony)	2040 (Symphony)	2050 (Symphony)
Coal	148	181	200	224	223	146	125	101	106
Oil	172	193	225	231	216	177	185	170	141
Gas	114	151	189	216	234	141	160	170	166
Nuclear	30	36	37	37	37	40	52	66	79
Biomass	66	60	59	71	97	62	66	79	111
Hydro	13	14	16	19	21	16	19	24	28
Renewables	2	7	14	28	51	10	23	45	65
Total	**545**	**642**	**740**	**826**	**879**	**592**	**630**	**655**	**696**

TOTAL PRIMARY ENERGY SUPPLY BY REGION (Units: EJ/y)

Region	2010	2020 (Jazz)	2030 (Jazz)	2040 (Jazz)	2050 (Jazz)	2020 (Symphony)	2030 (Symphony)	2040 (Symphony)	2050 (Symphony)
Sub-Saharan Africa	23	24	29	38	50	23	27	35	46
Southeast Asia, Pacific	32	44	56	66	71	40	46	50	54
North America	116	128	135	136	130	118	114	108	105
Middle East and North Africa	37	44	55	67	79	43	52	59	67
Latin America and The Caribbean	29	38	49	58	67	35	43	47	51
Europe	121	127	133	136	135	119	117	114	114
East Asia	145	187	215	222	211	167	174	166	164
South and Central Asia	43	52	69	102	136	47	57	75	96
Total	**546**	**644**	**741**	**825**	**879**	**592**	**630**	**654**	**697**

TOTAL ELECTRICITY GENERATION (Units: TWh/y)

Region	2010	2020 (Jazz)	2030 (Jazz)	2040 (Jazz)	2050 (Jazz)	2020 (Symphony)	2030 (Symphony)	2040 (Symphony)	2050 (Symphony)
Sub-Saharan Africa	414	612	996	1,857	3,087	597	936	1,687	2,836
Southeast Asia, Pacific	996	1,549	2,106	3,123	4,024	1,409	2,045	2,699	3,398
North America	5,214	6,152	6,903	7,728	8,024	6,100	6,733	7,695	8,057
Middle East and North Africa	1,150	1,445	1,951	2,693	3,644	1,485	1,911	2,476	3,314
Latin America and The Caribbean	1,147	1,648	2,422	3,131	3,701	1,571	2,209	2,750	3,221
Europe	5,104	5,932	6,869	7,803	8,439	5,656	6,363	7,037	7,961
East Asia	6,121	8,761	11,070	13,064	14,298	7,749	9,223	10,916	12,571
South and Central Asia	1,331	1,861	2,881	5,055	8,429	1,749	2,476	4,339	6,560
Total	**21477**	**27960**	**35198**	**44,454**	**53,646**	**26316**	**31896**	**39,599**	**47,918**

CARBON PRICE ($US\$2010/tCO_2$)

Region	2020 (Jazz)	2030 (Jazz)	2040 (Jazz)	2050 (Jazz)	2020 (Symphony)	2030 (Symphony)	2040 (Symphony)	2050 (Symphony)
Sub-Saharan Africa	0	5	10	23	10	23	42	70
Middle East and North Africa	0	5	10	23	10	23	42	70
Latin America and The Caribbean	0	5	10	23	10	23	42	70
North America	8	15	21	28	21	28	55	70
Europe	0–8	5–15	10–30	23–45	10–30	23–40	50–60	75–80
South and Central Asia	0	5	10	23	10	23	50	75
East Asia	0–6	5–12	10–24	23–38	10–24	23–38	50–60	75
Southeast Asia, Pacific	0–6	5–12	10–24	23–38	10–24	23–38	50–60	75

CO_2 – EMISSIONS BY REGION (Units: $GtCO_2/y$)

Region	2010	2020	2030	2040	2050	2020	2030	2040	2050
Sub-Saharan Africa	0.7	0.8	1.1	1.5	1.7	0.7	0.8	0.9	0.9
Southeast Asia, Pacific	1.7	2.5	3.2	3.8	3.7	2.1	2.3	2.1	1.7
North America	6.5	7.2	7.3	7.2	6.7	6.2	5.4	4.4	3.1
Middle East and North Africa	2.1	2.3	2.7	3.1	3.5	2.2	2.5	2.4	2.3
Latin America and The Caribbean	1.2	1.5	2.0	2.2	2.1	1.3	1.5	1.3	0.8
Europe	6.2	6.4	6.7	6.4	5.6	5.6	5.0	3.9	2.5
East Asia	9.8	12.7	14.7	14.7	12.3	10.8	10.1	7.8	5.1
South and Central Asia	2.3	3.0	4.1	6.3	8.4	2.5	2.8	3.1	2.7
Total	**30.5**	**36.4**	**41.8**	**45.2**	**44.0**	**31.4**	**30.4**	**25.9**	**19.1**

CARBON CAPTURE, UTILISATION AND STORAGE BY REGION (Units: $GtCO_2/y$)

Primary energy	2010	2020	2030	2040	2050	2020	2030	2040	2050
Sub-Saharan Africa	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.5
Southeast Asia, Pacific	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.2	0.7
North America	0.0	0.0	0.0	0.1	0.2	0.0	0.1	0.3	1.1
Middle East and North Africa	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.4
Latin America and The Caribbean	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.2
Europe	0.0	0.0	0.0	0.1	0.3	0.0	0.1	0.3	1.2
East Asia	0.0	0.0	0.0	0.1	0.2	0.0	0.1	0.4	1.6
South and Central Asia	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	1.2
Total	**0.0**	**0.0**	**0.0**	**0.4**	**1.3**	**0.0**	**0.3**	**1.7**	**6.9**

GLOBAL ELECTRICITY PRODUCTION BY FUEL TYPE (Units: TWh/y)

Primary energy	2010	2020	2030	2040	2050	2020	2030	2040	2050
Coal (with CCS)	0	10	87	346	1,007	41	301	1,587	7,100
Coal	8,666	11,920	14,792	18,565	19,272	9,289	7,949	5,280	1,383
Oil	980	0	0	0	0	0	0	0	0
Gas (with CCS)	0	2	31	140	558	11	113	789	2,505
Gas	4,777	7,232	9,734	11,427	12,869	6,609	8,127	9,049	7,012
Nuclear	2,763	3,255	3,430	3,395	3,279	3,651	4,706	5,888	6,950
Hydrogen	0	0	2	12	69	0	5	32	155
Hydro	3,491	4,003	4,550	5,146	5,789	4,337	5,408	6,530	7,701
Biomass	337	287	390	884	1,923	362	535	1,056	1,913
Biomass (with CCS)	0	8	28	160	441	16	100	295	800
Wind	358	818	1,435	3,142	4,513	1,386	2,418	2,994	4,003
Solar	34	302	462	732	2,979	519	2,054	5,752	7,741
Geothermal	69	125	257	504	949	94	182	346	654
Total	**21,475**	**27,962**	**35,198**	**44,453**	**53,648**	**26,315**	**31,898**	**39,598**	**47,917**

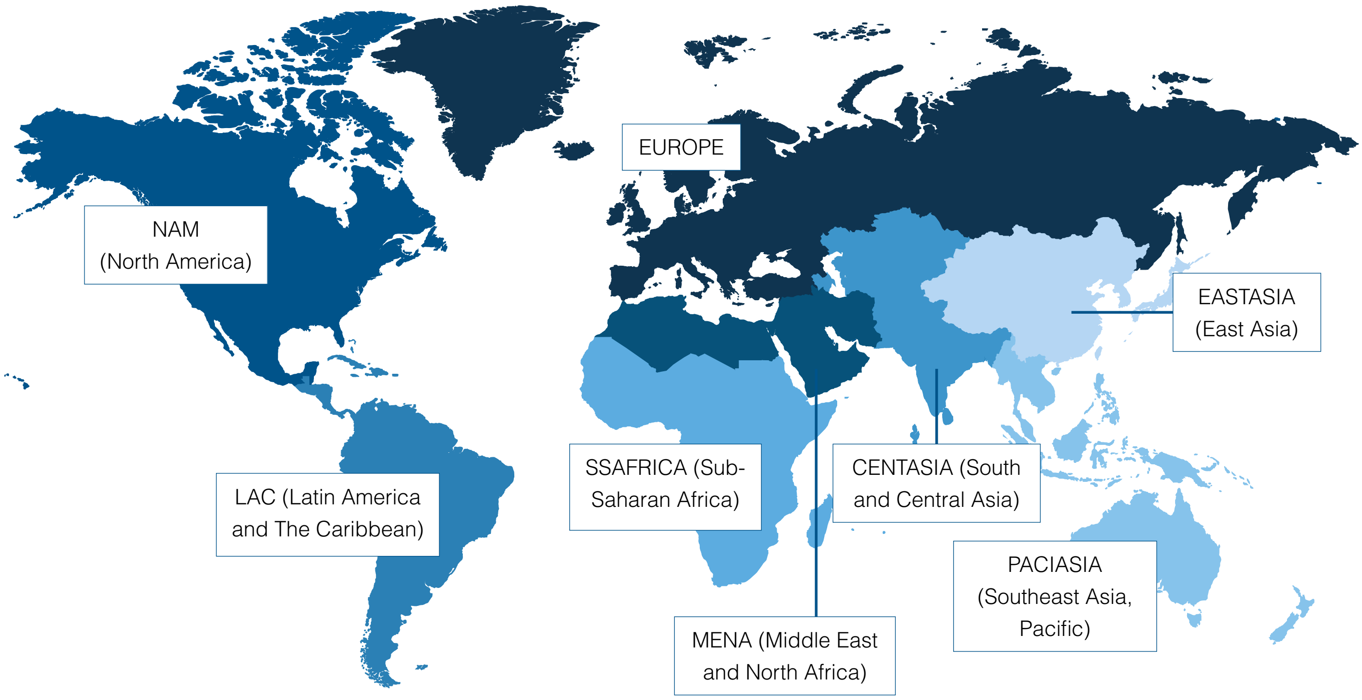
GLOBAL INSTALLED ELECTRICITY GENERATION CAPACITY BY FUEL TYPE (Units: TWh/y)

Technology	2010	2020	2030	2040	2050	2020	2030	2040	2050
Coal (with CCS)	0	2	14	49	141	9	47	226	1,006
Coal	1,606	2,084	2,503	3,038	3,003	1,610	1,352	1,003	484
Oil	426	289	168	86	41	289	168	86	41
Gas (with CCS)	0	4	20	63	178	8	40	206	603
Gas	1,412	1,657	1,674	1,851	2,353	1,589	1,691	2,198	2,036
Nuclear	373	417	438	434	421	468	603	751	884
Hydrogen	0	0	0	3	15	0	2	10	39
Hydro	1,026	1,136	1,267	1,414	1,575	1,223	1,505	1,854	2,161
Biomass	71	62	65	124	256	73	87	156	292
Biomass (with CCS)	0	2	9	28	78	5	18	52	141
Wind	191	404	621	1,290	1,824	667	1,059	1,274	1,654
Solar	39	255	326	445	1,654	437	1,451	3,585	4,439
Geothermal	11	19	38	75	141	14	28	54	102
Total	**5,156**	**6,330**	**7,142**	**8,899**	**11,680**	**6,392**	**8,049**	**11,454**	**13,881**

CUMULATIVE INVESTMENT IN ELECTRICITY GENERATION (2010–2050, billion US$2010, undiscounted)

Primary energy	South and Central Asia	East Asia	Europe	Latin America and The Caribbean	Middle East and North Africa	North America	Southeast Asia and Pacific	Sub-Saharan Africa	World
Coal (with CCS)	20	40	50	20	10	30	30	10	200
Coal	2,260	2,540	750	90	30	580	510	180	6,950
Oil	0	20	20	10	10	30	0	0	90
Gas (with CCS)	30	50	0	0	30	0	10	30	140
Gas	100	320	440	190	340	320	190	160	2,050
Nuclear	30	380	370	10	50	160	0	10	1,010
Hydrogen	20	0	0	0	0	0	0	10	30
Hydropower	230	560	370	310	10	290	100	80	1,950
Biomass	20	20	90	70	0	30	10	20	260
Biomass (with CCS)	10	20	80	30	10	40	30	10	240
Wind	160	370	770	170	10	990	160	100	2,720
Solar	160	710	270	380	150	150	540	580	2,950
Geothermal	40	70	50	80	20	150	240	70	720
Total	**3,080**	**5,100**	**3,260**	**1,360**	**670**	**2,770**	**1,820**	**1,260**	**19,310**
Coal (with CCS)	310	400	290	30	50	290	170	90	1,620
Coal	330	820	240	10	10	110	80	50	1,660
Oil	0	20	20	10	10	30	0	0	90
Gas (with CCS)	80	120	30	10	90	10	50	90	490
Gas	140	470	400	120	270	320	190	70	1,980
Nuclear	130	830	550	30	100	300	60	20	2,020
Hydrogen	60	0	0	10	0	0	10	20	100
Hydropower	540	1,020	510	480	0	490	230	260	3,520
Biomass	50	20	100	120	10	30	10	10	340
Biomass (with CCS)	70	90	90	40	20	70	40	20	440
Wind	580	420	1,020	110	0	990	70	80	3,280
Solar	1,110	3,160	1,120	360	840	1,600	860	600	9,660
Geothermal	60	30	30	0	10	210	100	70	520
Total	**3,460**	**7,400**	**4,390**	**1,330**	**1,410**	**4,450**	**1,870**	**1,380**	**25,720**

Regions



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World Energy Council
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