World Energy Scenarios

Composing Energy Futures to 2050

WORLD ENERGY COUNCIL
CONSEIL MONDIAL DE L'ÉNERGIE
For sustainable energy.

BusinessNZ Energy Council
December 2013

Rob Whitney
Executive Chair

BusinessNZ Energy Council
WORLD ENERGY COUNCIL *Member of the World Energy Council*

Jazz and symphony: Rob Whitney and Karl Rose at WEC 2013

Balancing the "Energy Trilemma"

"promoting an affordable, stable and environmentally sensitive energy system for the greatest benefit of all"

Energy security

The effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of energy companies to meet current and future demand.

No power cuts or queues for petrol

Environmental impact mitigation

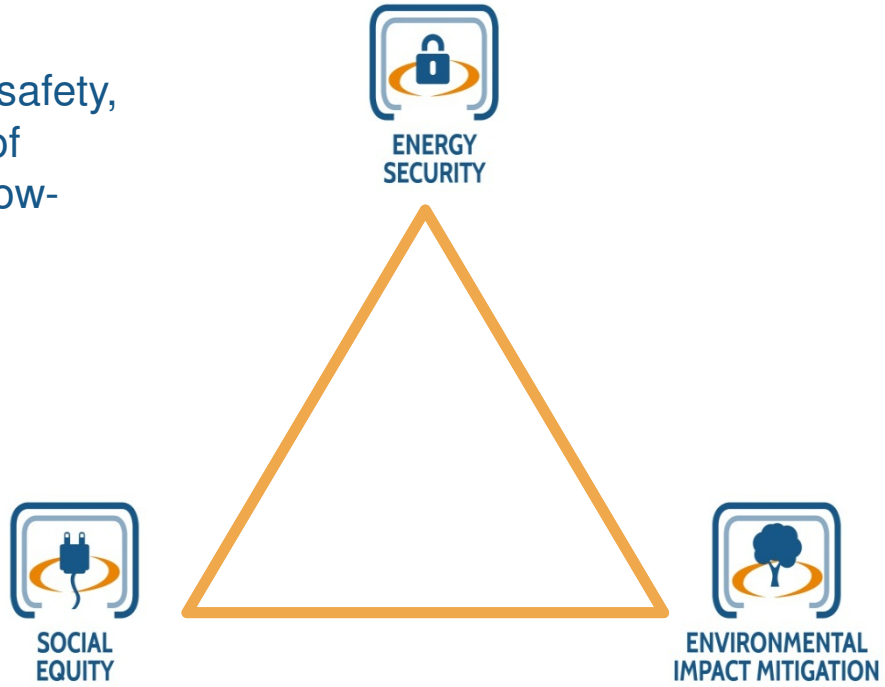
CO_2 emissions, Water, Land use, nuclear safety, Energy efficiencies and the development of energy supply from renewable and other low-carbon sources

UNFCCC 2° C 450ppm CO_2

Social equity

Accessibility and affordability of energy supply across the population.
1.2 billion without access to electricity, energy poverty.

UNSE4ALL by 2030



What are scenarios?

- Plausible, pertinent, alternative stories of the future which:

- portray a range of conceivable outcomes and aid the understanding of how different factors can interact and shape the future.

- identify robust trends; ‘what-if’ assumptions about future. Scenarios are not forecast.

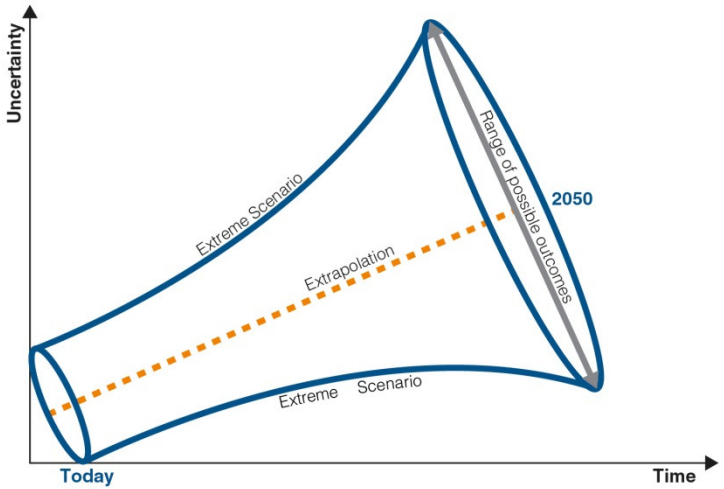


Figure: The uncertainty funnel: WEC Scenarios are explorative, rather than normative

Why scenarios?

- Inform debate regarding the future energy landscape
- Inform company investment decisions & government policies

"We use scenarios to explore possible developments in the future and to test our strategies against those potential developments."

– Royal Dutch Shell

How do scenarios inform decisions?

- Explore the implications of assumptions
- Determine the robustness of possible future developments

→ **Identify robust trends; 'what-if' assumptions about future – not forecast**

World Energy Scenarios: Building on track record & success

WEC Cooperates with businesses, governments, international organisations, member committees

WEC has more than two decades of scenarios expertise:

- Global Energy Perspectives 2000–2020 (1989)
- Energy for Tomorrow's World (1993)
- Global Energy Perspectives to 2050 and Beyond (1995)
- Global Energy Perspectives (WEC–IIASA, 1998)
- Energy for Tomorrow's World – Acting Now (2000)
- Drivers of the Energy Scene (2003)
- Deciding the Future: Energy Policy Scenarios to 2050 (2007)
- White paper on scenarios (2010)
- Global Transport Scenarios 2050 report (2011)

WEC's scenarios study:

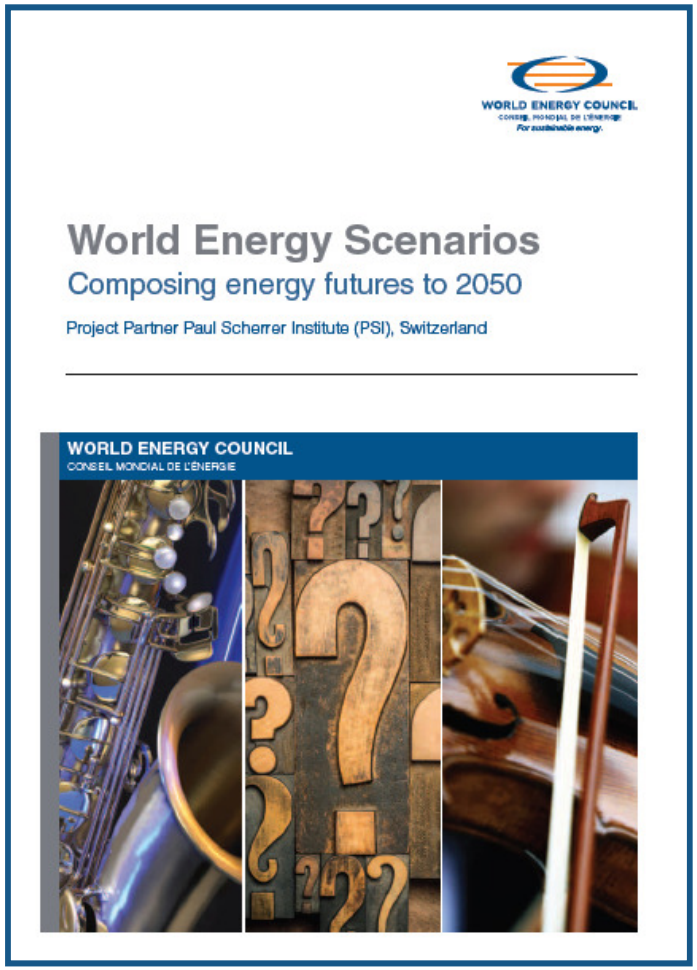
Comprises of two scenarios

The scenarios are designed to help a range of stakeholders to address the "energy trilemma" – of achieving environmental sustainability, energy security and energy equity.

Explorative – not normative

Bottom up – a cast thousands

Stories quantified by Paul Scherrer Institute (project partner)

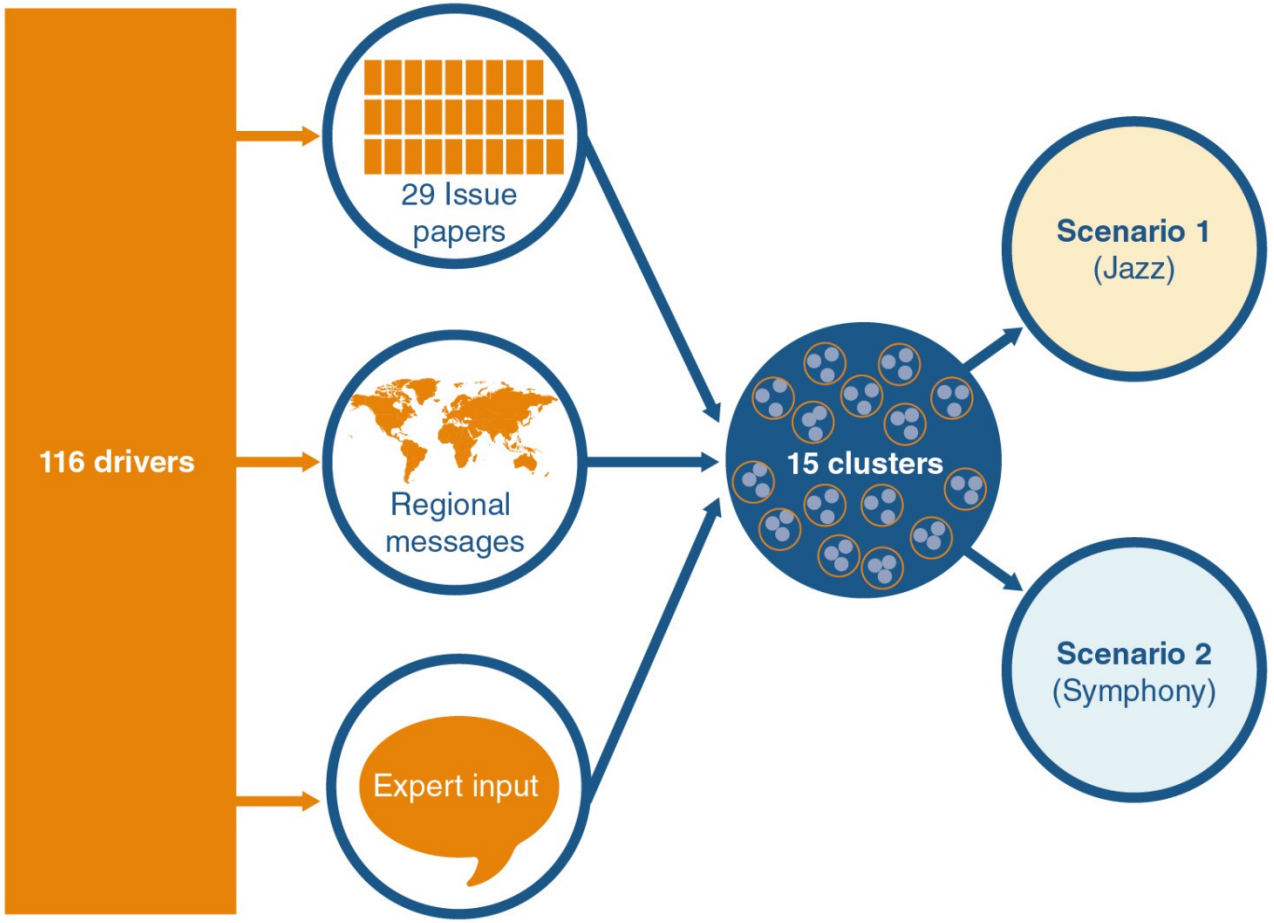


WEC Scenarios
Deriving the scenario stories

Two Scenarios stories, exploratory, different and equally feasible rather than good and bad

- **Jazz:**
  Trade based, consumer driven, focussed on access and affordability, achieving growth through low cost energy. Governments facilitate GHG actions by businesses.
- **Symphony:**
  Government led, voter driven, focussed on environmental goals and energy security, national and regional measures to increase share of renewables in energy mix. Binding international agreement on GHG emissions

Scenario Building Process

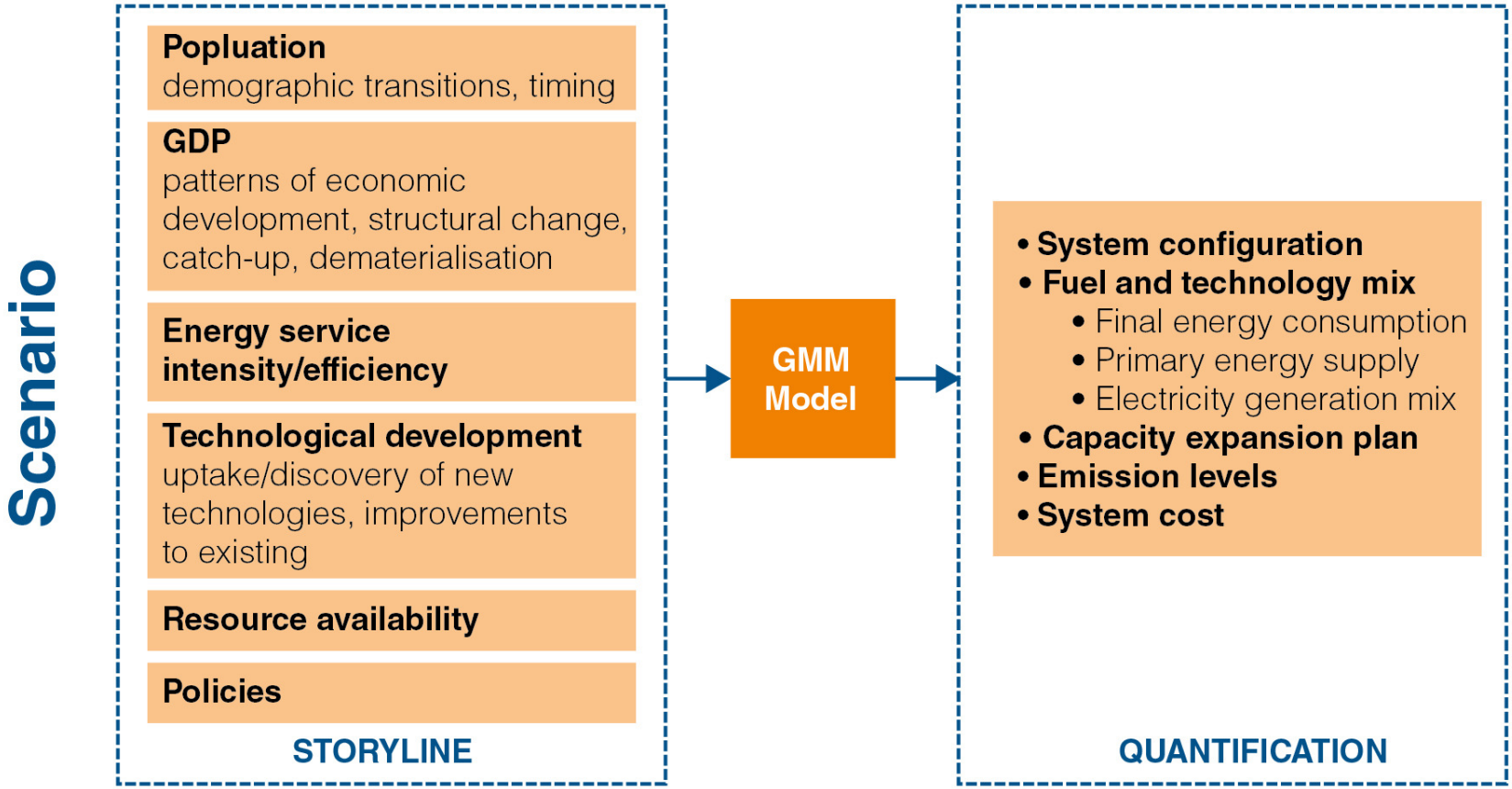


Key Clusters

1. Role of State
2. Availability of Funds
3. Mitigation of CO_2
4. Equality
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

Key scenario drivers

- Evolutions of key scenario drivers are expressed in a **coherent storyline** of future economic and social developments
- Some drivers are **interdependent**, e.g. energy intensity
- Drivers must be **translated into quantified inputs** for the energy system models



Quantification of scenario stories

- Modelling partner: **Paul Scherrer Institut**, Switzerland (PSI)
- Model used: GMM (**Global Multi-regional MARKAL** model)
- Model features: MARKAL (MARKet Allocation)
  Bottom-up, perfect foresight cost-optimization models
  Least-cost solutions
  Endogenous technological learning (ETL)
  8 Demand Sectors (detailed transport sector)
  Time horizon: 100 years, 10-year intervals
  Discount rate: 5% p.a. across all technologies
- Model has been disaggregated to reflect **8 WEC Regions**: Sub-Saharan Africa, MENA, LAC, NAM, Europe, South & Central Asia, East Asia, and SE Asia & Pacific.

Brief outline of Global Scenario Stories

Jazz	Symphony
World where there is a consumer focus on achieving energy access, affordability, and individual energy security with the use of best available energy sources.	World where there is a voter consensus on driving environmental sustainability and national energy security through corresponding practices and policies.
Main players are multi-national companies, banks, venture capitalists, and price-conscious consumers	Main players are governments, international agencies, local public-sector companies, NGOs and environmentally-minded voters
Technologies are chosen in competitive markets	Governments pick technology winners
Energy sources compete on basis of price & availability	Select energy sources are subsidised and incentivised by governments

Brief outline of Global Scenario Stories

Jazz	Symphony
Higher GDP growth due to optimised (efficient) market practices.	Lower GDP due to non-optimal economic policies
Free-trade strategies lead to increased exports	Nationalistic strategies result in reduced exports/imports
Renewable and low carbon energy grows in line with market selection	Certain types of renewable and low carbon energy actively promoted by governments
In the absence of international agreed commitments Carbon market grows more slowly from bottom up based on regional, national and local initiatives.	Carbon market is top down based on an international agreement, with commitments and allocations. There is International Climate Change agreement by 2015

Storyline and quantification assumptions

	Jazz	Symphony
GDP growth	**Higher** (3.54% pa CAGR, PPP)	**Lower** (3.06% pa CAGR, PPP)
Population	**Lower** (2050 = 8.7 billion)	**Higher** (2050 = 9.3 billion)
Efficiency/ Intensity	**Increasing** (-2.29% pa (primary, PPP))	**Increasing more strongly** (-2.44% pa (primary, PPP))
Climate policy	**Limited** Prices (2050): 23-45 USD/tCO_2	**Stronger** Prices (2050): 75-80 USD/tCO_2
Resources	Better access to **unconventional** resources	More expensive unconventionals
Technology support	Limited; energy choice based on free markets	support for **nuclear**, **large hydro**, **CCS** and **renewables**
Technology innovation	Further development of CCGT decentralized power (SPV)	Focused R&D programs (esp. CC(U)S, solar PV)

Highlighted results:

The **share of fossils fuels** in the total primary energy supply:

- In Jazz in 2050: **77%**
- In Symphony in 2050: **59%**

(cf. share of fossils in 2010: 80%)

Global **final energy demand**:

- Jazz 2050: **629 EJ**
- Symphony 2050: **491 EJ**

(cf. the demand in 2010: 373 EJ)

Per capita **electricity consumption** will roughly double:

- In Jazz by 2050: **5440kWh/y**
- In Symphony by 2050: **4600kWh/y**

(cf. consumption in 2010: 2580kWh/y)

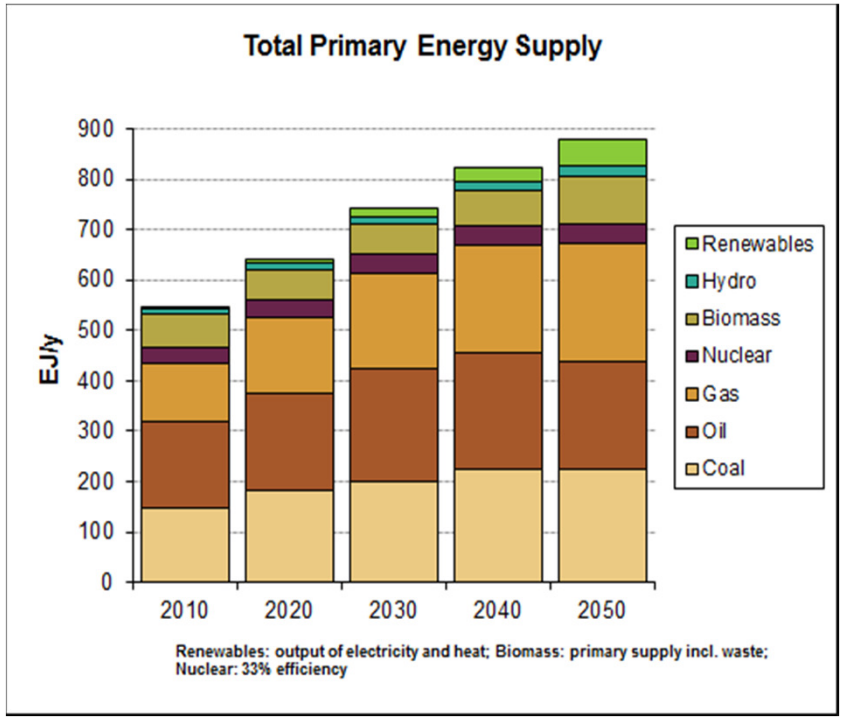
Jazz

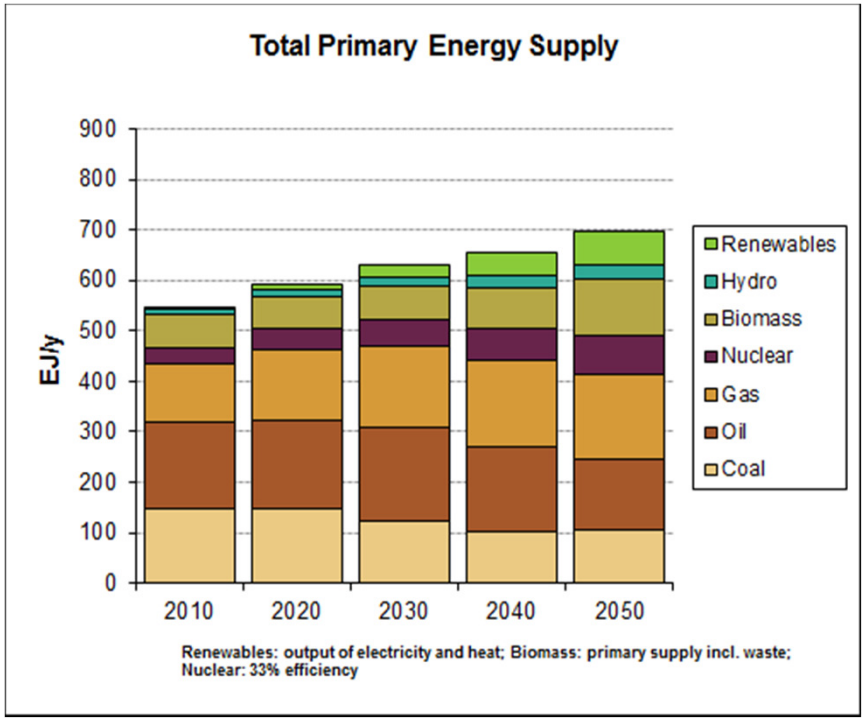
The **cumulative CO_2 emissions** are for 2010 to 2050:

- Jazz: **2000Gt**
- Symphony: **1400Gt**

(cf. roughly 1000Gt from the period 1900-2004, source: www.wri.org)

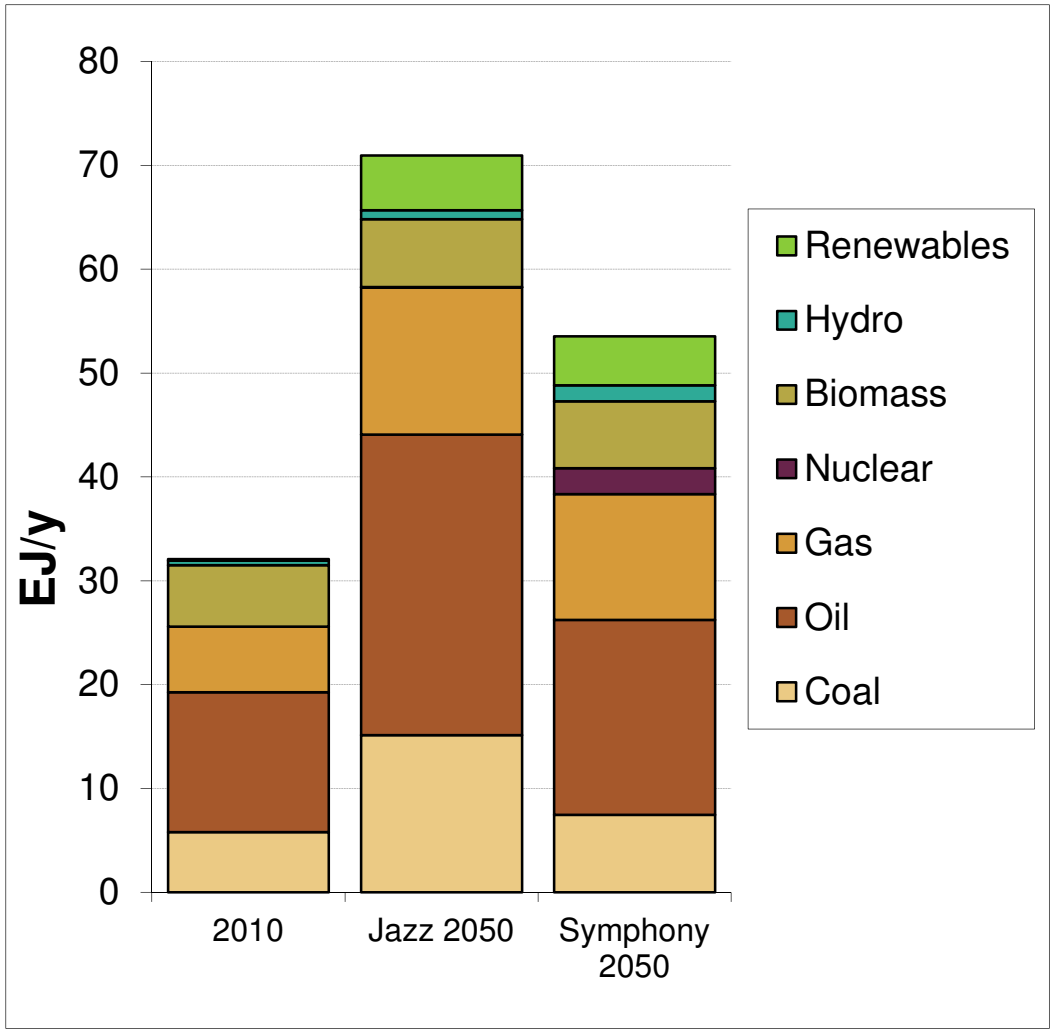
Global total primary energy supply





Jazz	Symphony
Upstream liberalized; technology development, supply surge/more producers Coal remains dominant in some regions	Tighter supply (lower E&P) Higher infrastructure costs Energy security drives reduced fossil use

Total primary energy supply: Southeast Asia & The Pacific



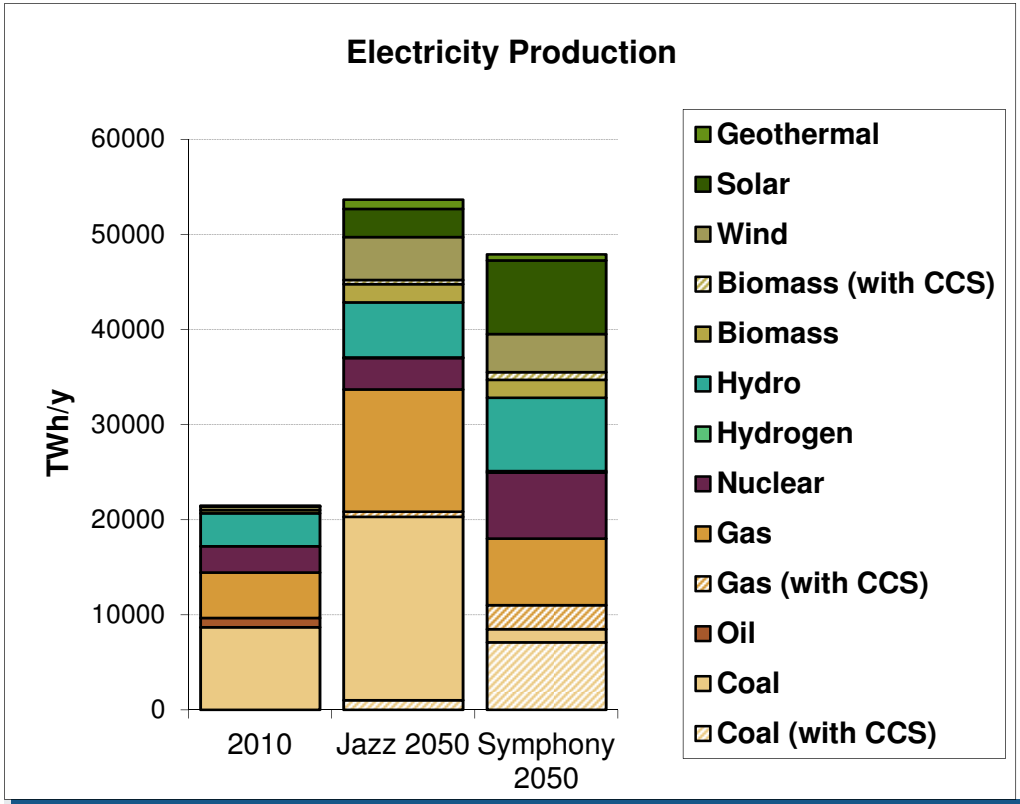
JAZZ:

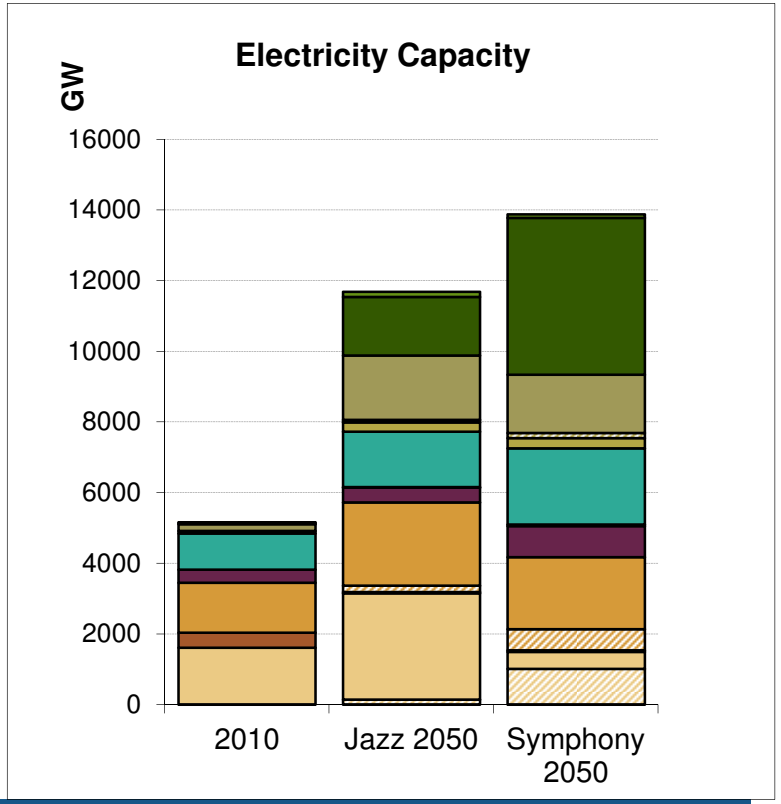
- The share of fossil fuels increases from 80% in 2010 to 82% in 2050
- largest increase in oil use.
- Growth in total energy use starts to slow after 2040

SYMPHONY:

- The share of fossil fuels decreases to 72%
- renewable energy is roughly equal in both scenarios (5 EJ/y).
- Nuclear energy provides 5% of the total energy

Electricity production and capacity





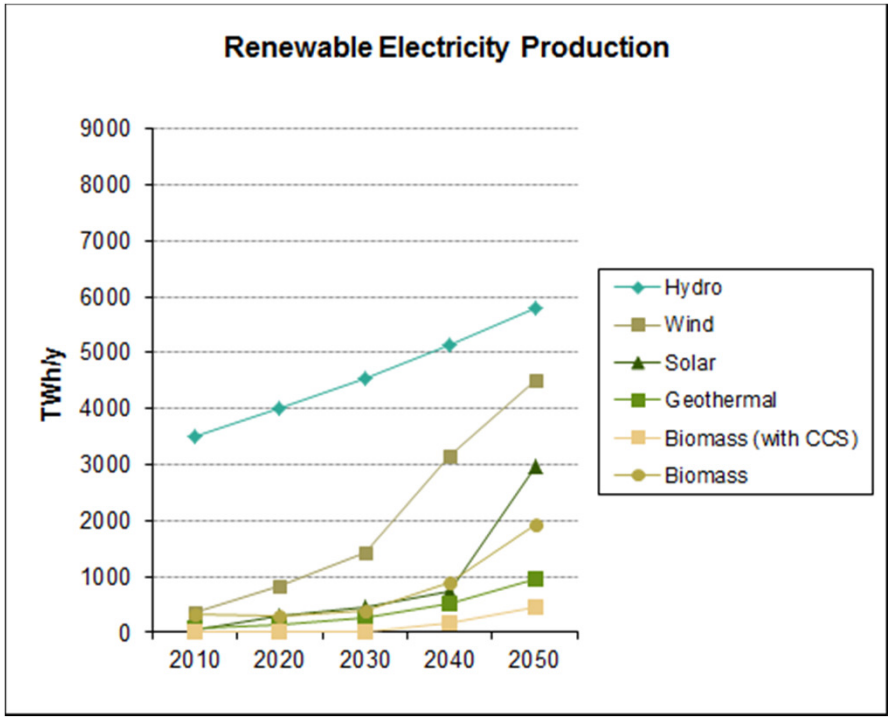
Jazz

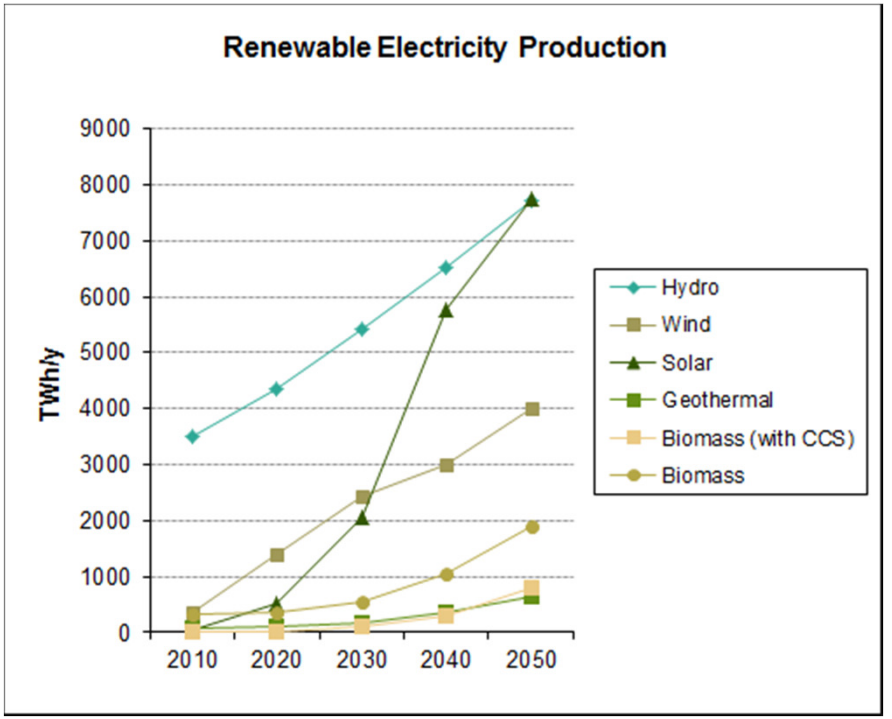
Coal: expected to remain dominant
Gas: share increases (esp. N. America),
Nuclear: mainly non-OECD

Symphony

Coal: share drops, CCS increasingly required
Nuclear: increasing; led by governments
More stable & quicker transition to renewables

Renewable electricity production





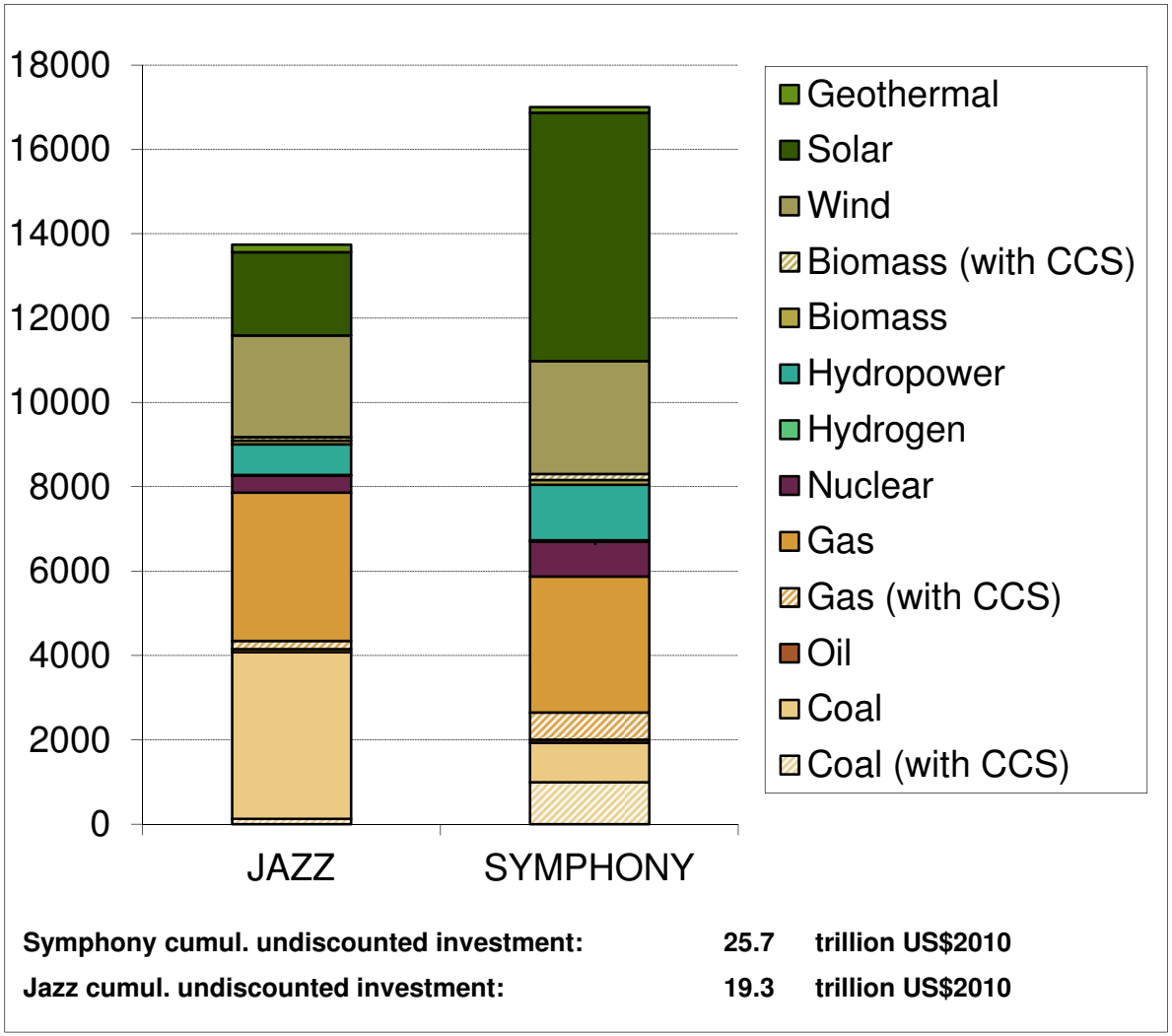
Jazz

Hydro and wind electricity are competitive. Renewables account for roughly 30% of total electricity generation by 2050.

Symphony

Renewables undergo rapid development, accounting for almost 50% of total electricity generation in 2050 (cf. 20% in 2010)

Global investment in Electricity Generation Cumulative 2010-2050 in GW



Symphony cumul. undiscounted investment:	**25.7**	**trillion US$2010**
Jazz cumul. undiscounted investment:	**19.3**	**trillion US$2010**

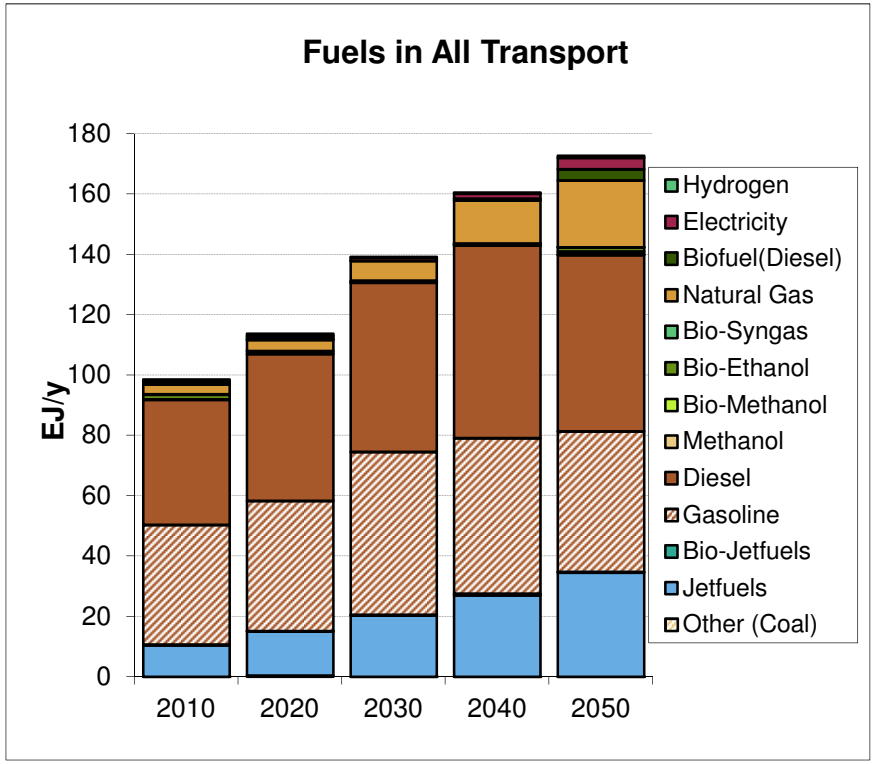
JAZZ:

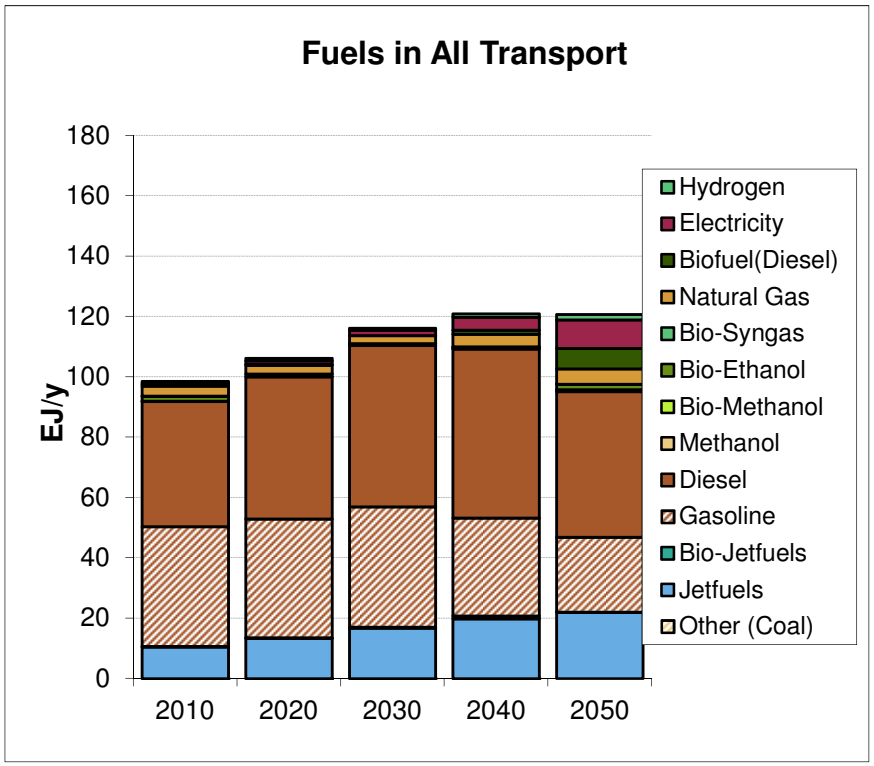
Approximately US$19.3 trillion (US$2010)

SYMPHONY:

Approximately US$25.7 trillion (US$2010)

Fuels in All Transport





Jazz

Economic growth leads to higher consumption

improved access to energy.

Demand increases by 75%

Switch to natural gas

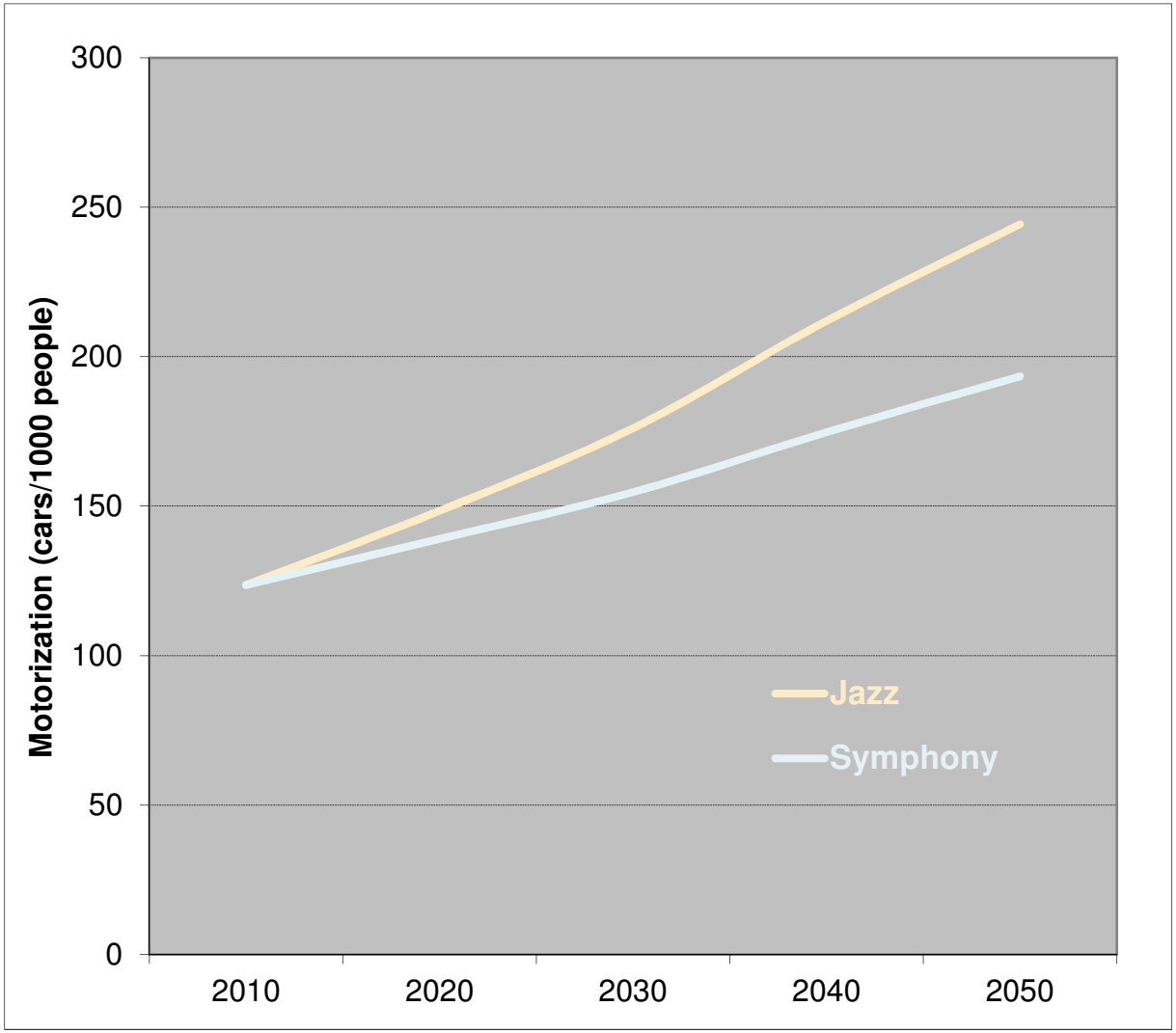
Symphony

Lower consumption, high impact of energy saving and lower growth

Demand increases by 22%

Switch away from fossil fuels which peak in 2030

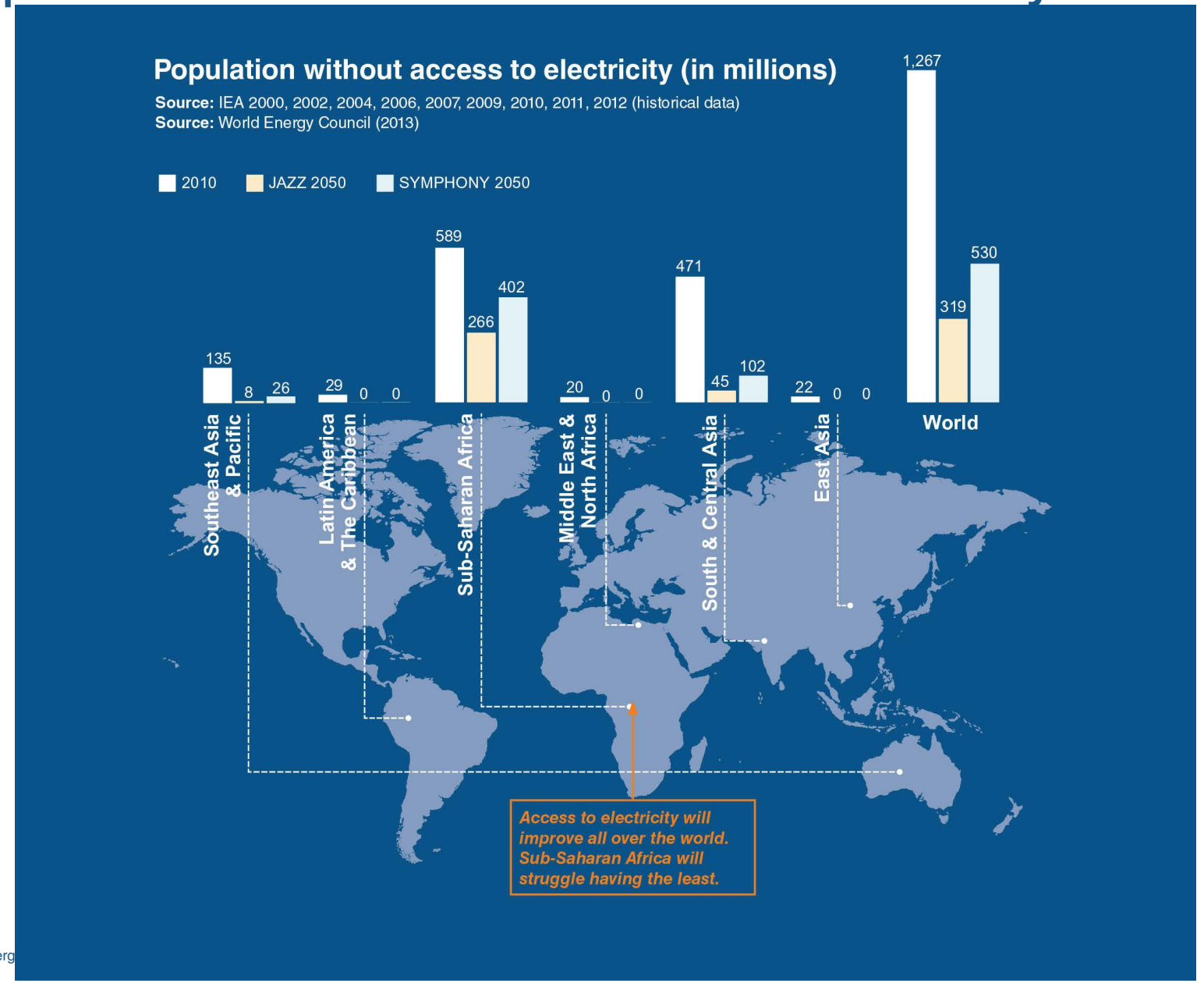
Car ownership (cars/1000 people)



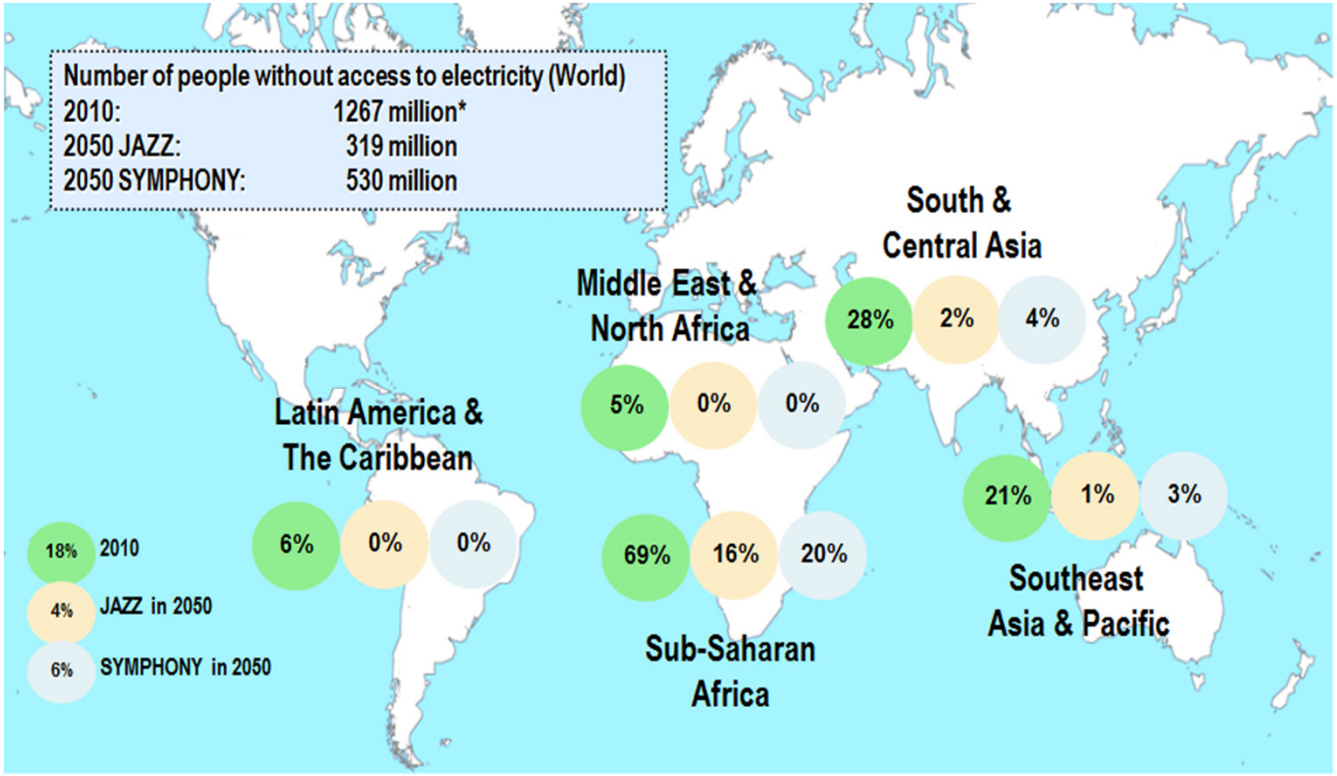
JAZZ:

SYMPHONY:

Population without access to electricity

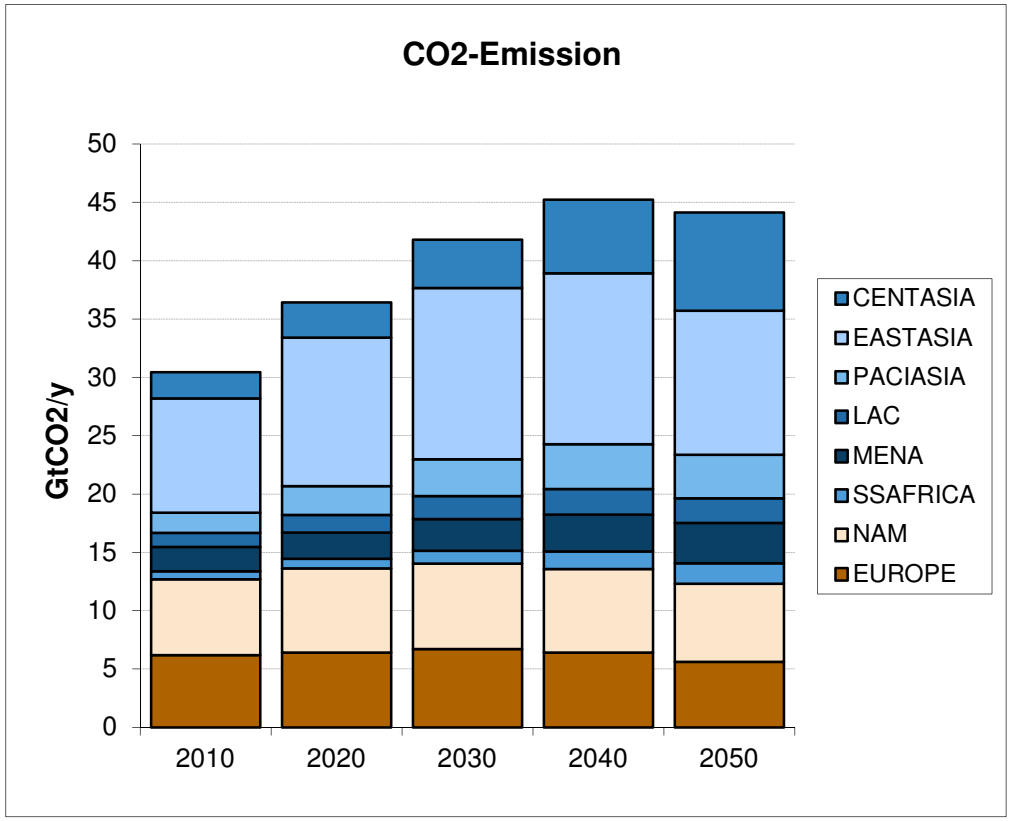


Population without access to electricity



Jazz: **Increase in energy access**	**Symphony:** **Moderate increase in energy access**
Good economic situation; high levels of urbanization, but problem is not solved due to limited government role in infrastructure spending	Government financing of infrastructure projects, but access is limited due to government budgetary constraints

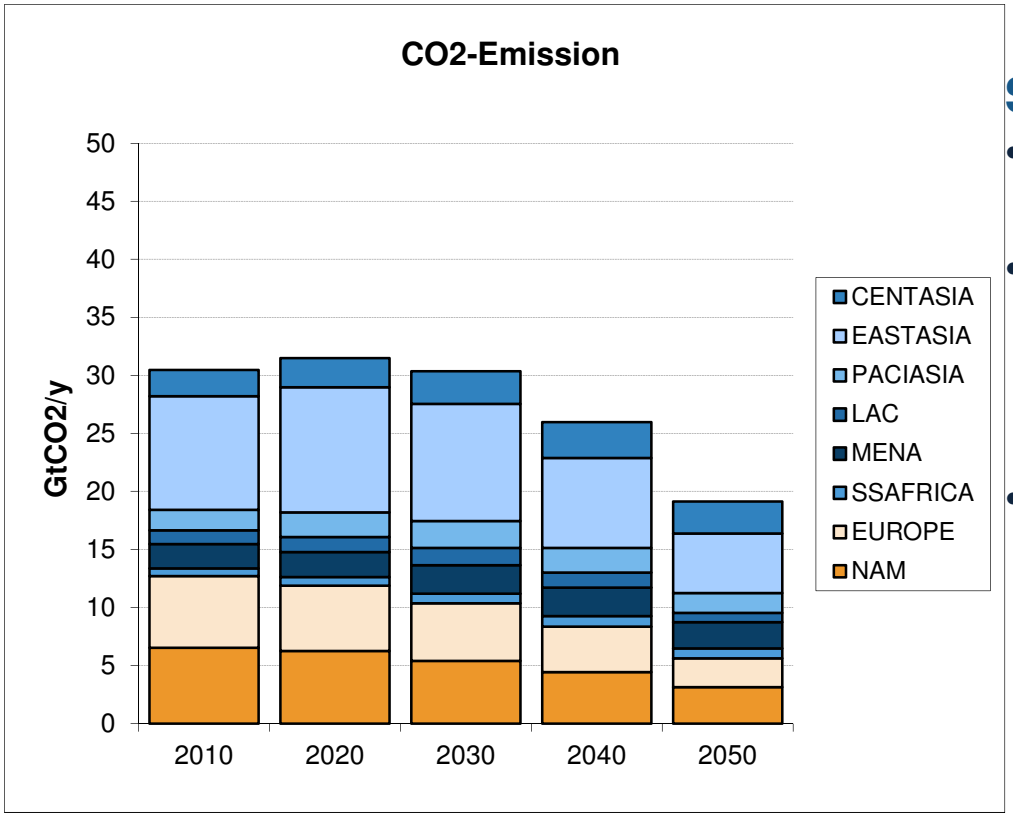
CO_2 emissions by region -Jazz



JAZZ:

- Energy choice based on free markets
- limited regulations supporting low-carbon energy (but regional diversity)
- consequently: carbon pricing only after significant income growth

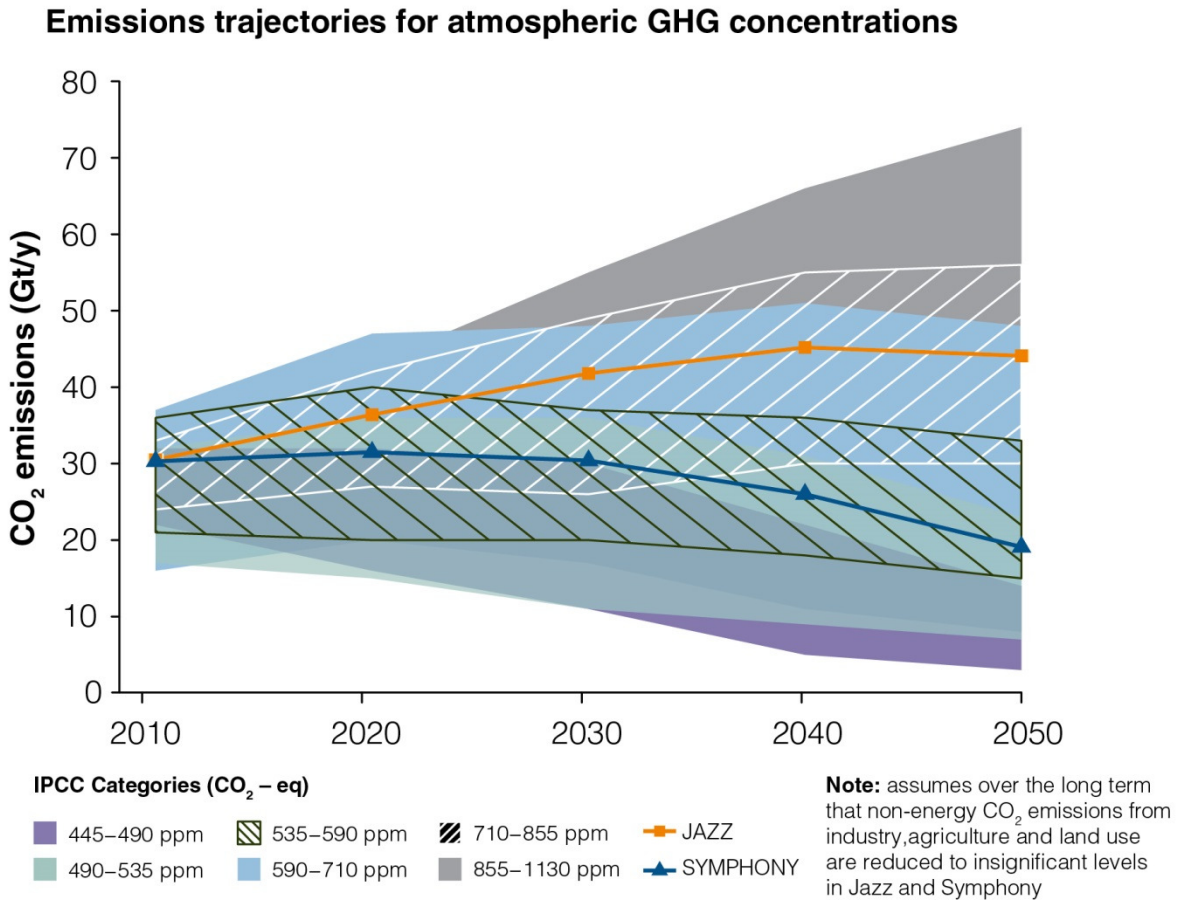
CO_2 emissions by region -Symphony



SYMPHONY:

- Priority to environmental sustainability
- CO2 reduction obligations, carbon taxes, CC(U)S mandates, renewable energy subsidies
- consequently: global carbon price emerges

Resulting CO_2 emissions (black lines)



The global economy will be challenged to meet the 450 ppm target without enormous economic costs

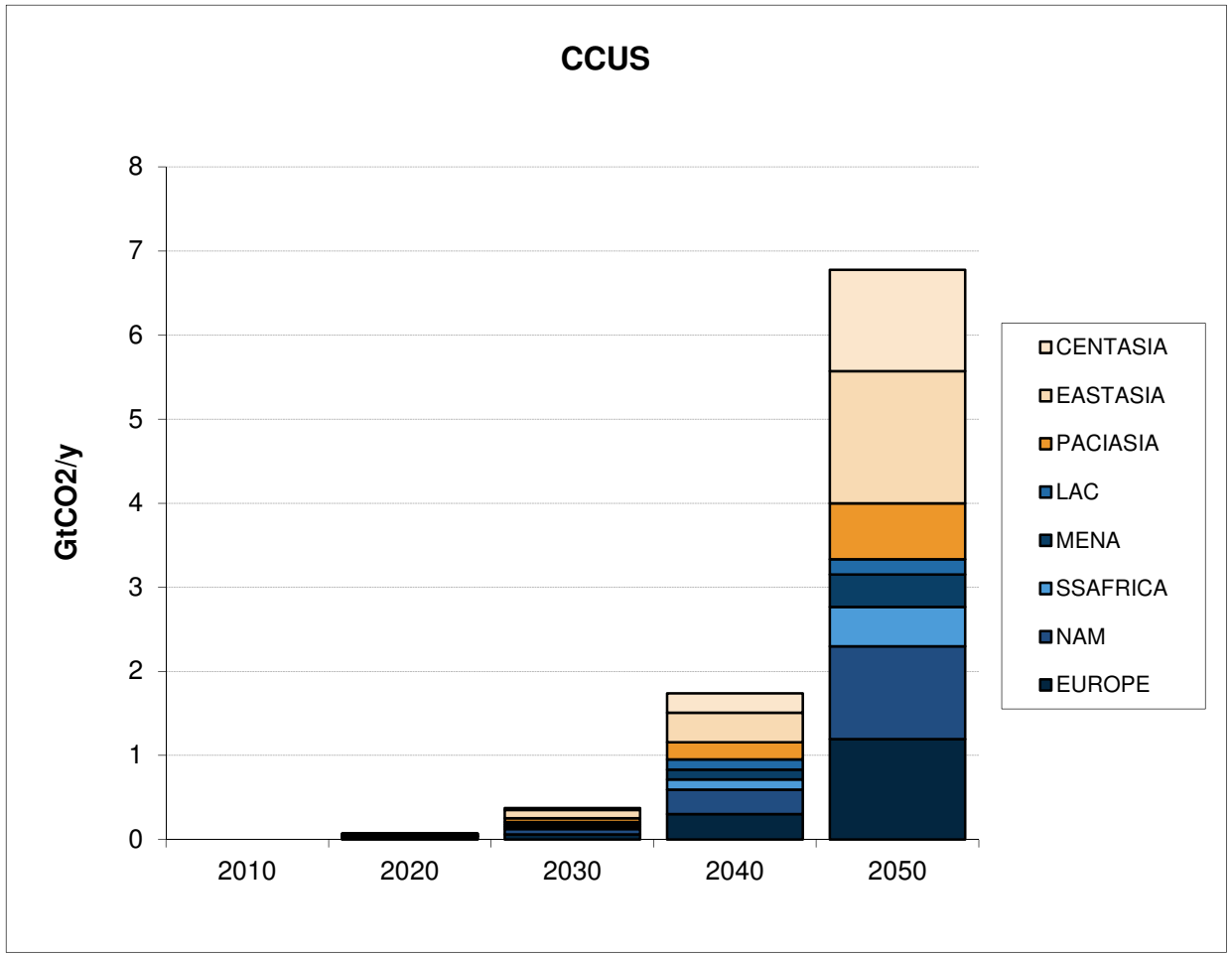
Quantification assumption: CO_2 prices up to 2050

Carbon price (USD2010/tCO_2)

	Jazz			
	2020	**2030**	**2040**	**2050**
Sub-Saharan Africa	0	5	10	23
Middle East & North Africa	0	5	10	23
Latin America & the Caribbean	0	5	10	23
North America	8	15	21	28
Europe	0 - 8	5 - 15	10 - 30	23 - 45
South & Central Asia	0	5	10	23
East Asia	0 - 6	5 - 12	10 - 24	23 - 38
Southeast Asia & Pacific	0 - 6	5 - 12	10 - 24	23 - 38

	Symphony			
	2020	**2030**	**2040**	**2050**
Sub-Saharan Africa	10	23	42	70
Middle East & North Africa	10	23	42	70
Latin America & the Caribbean	10	23	42	70
North America	21	28	55	70
Europe	10 - 30	23 - 40	50 - 60	75 - 80
South & Central Asia	10	23	50	75
East Asia	10 - 24	23 - 38	50 - 60	75
Southeast Asia & Pacific	10 - 24	23 - 38	50 - 60	75

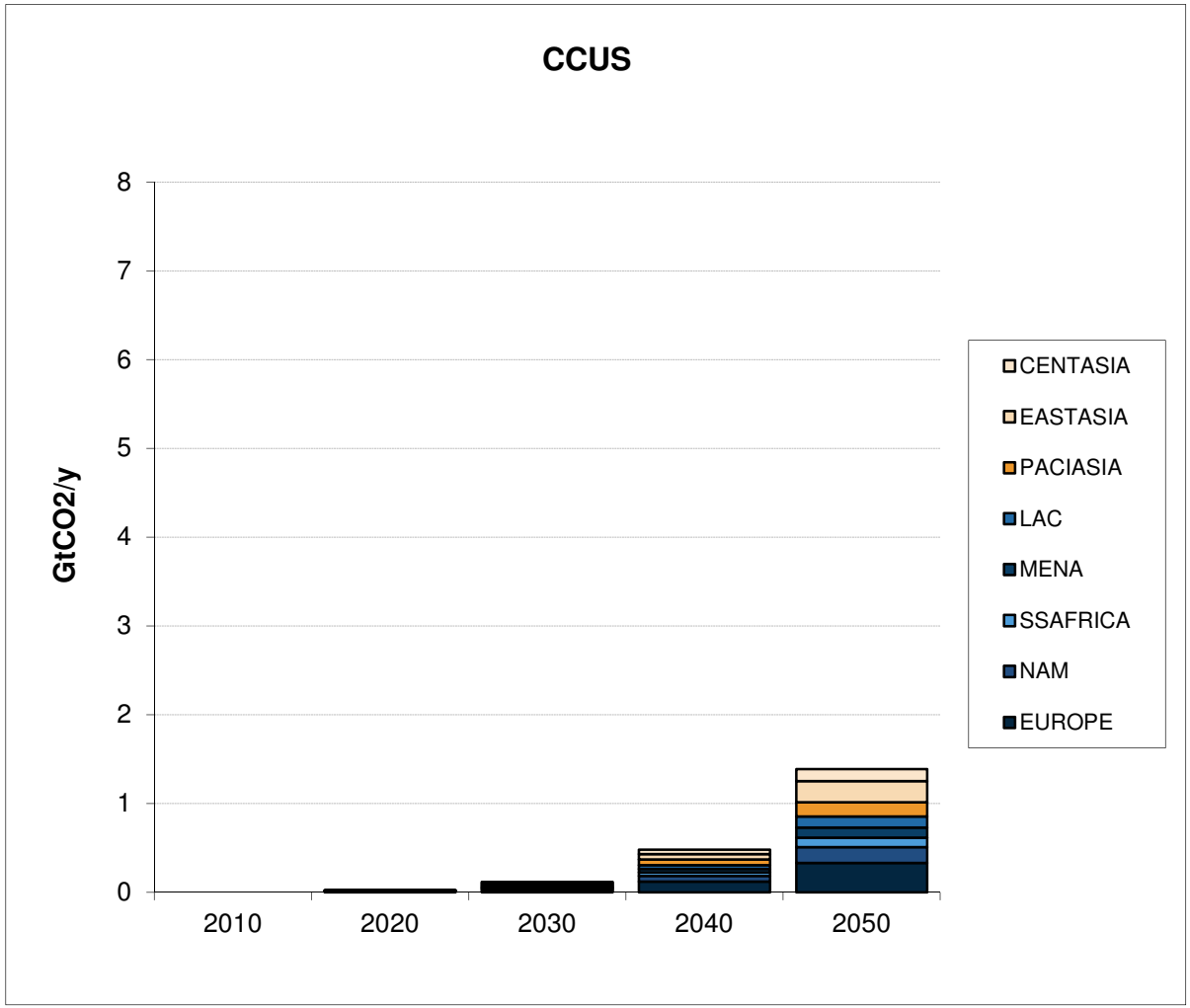
Carbon Capture, Utilization and Storage



SYMPHONY:

- Entry of CC(U)S earlier due to govt. intervention; govt. promotion
- CC(U)S increasingly required on coal new build
- CC(U)S in enhanced oil recovery

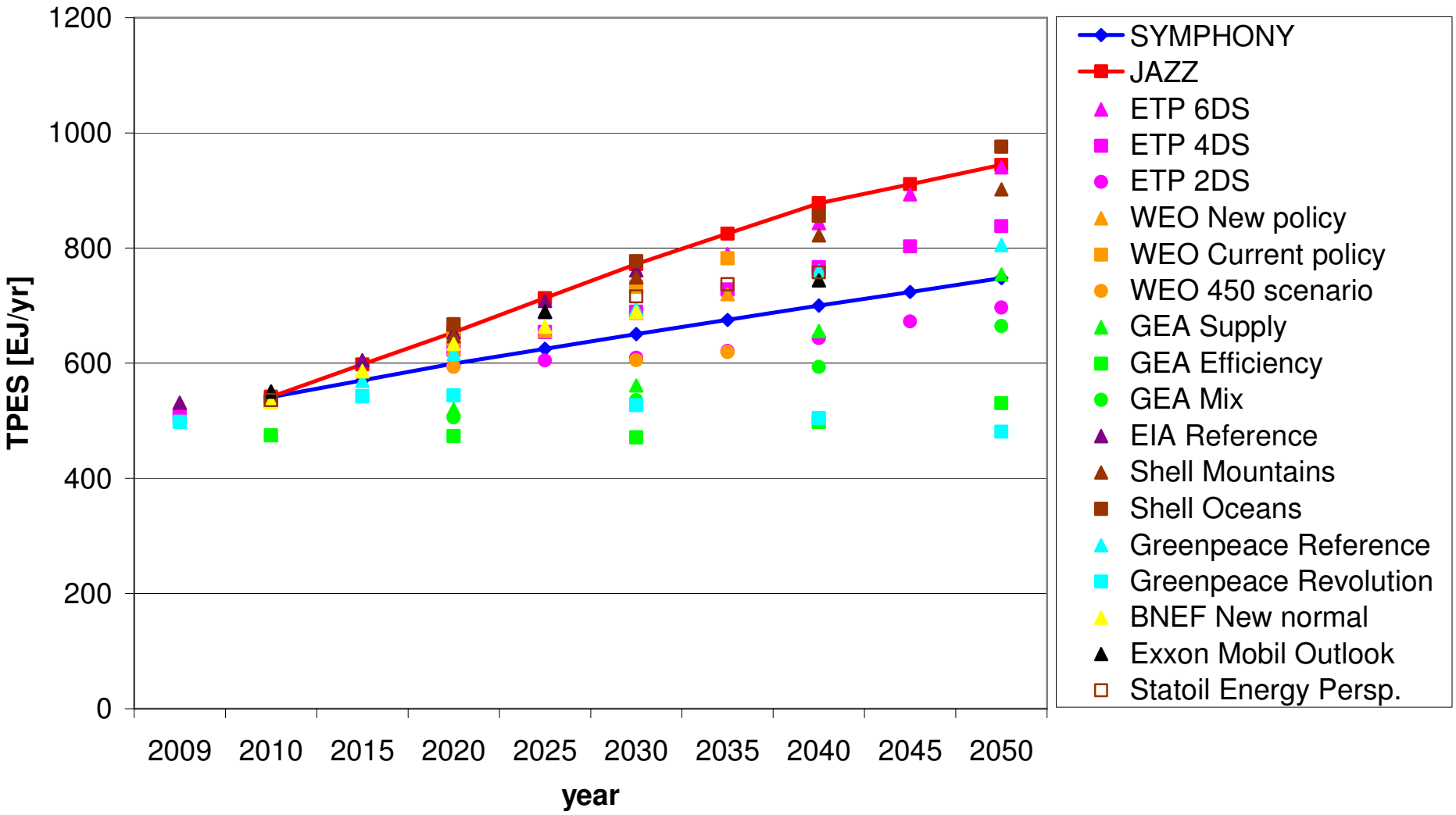
Carbon Capture, Utilization and Storage



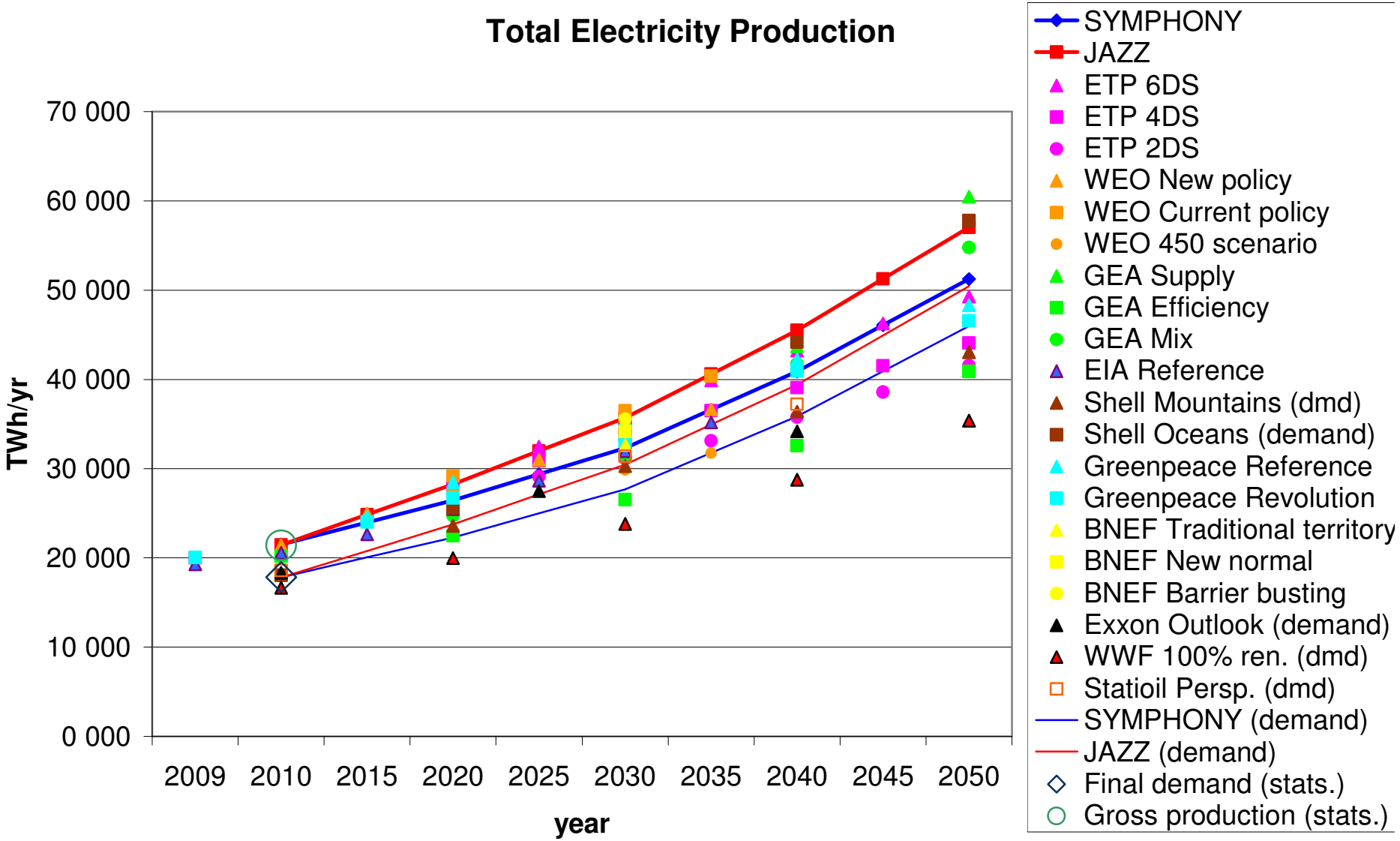
JAZZ:

- Possibly ready at commercial scale 2035
- CC(U)S not adopted initially due to high costs/low carbon price
- Commercial use in enhanced oil recovery
- Wider adoption post 2040

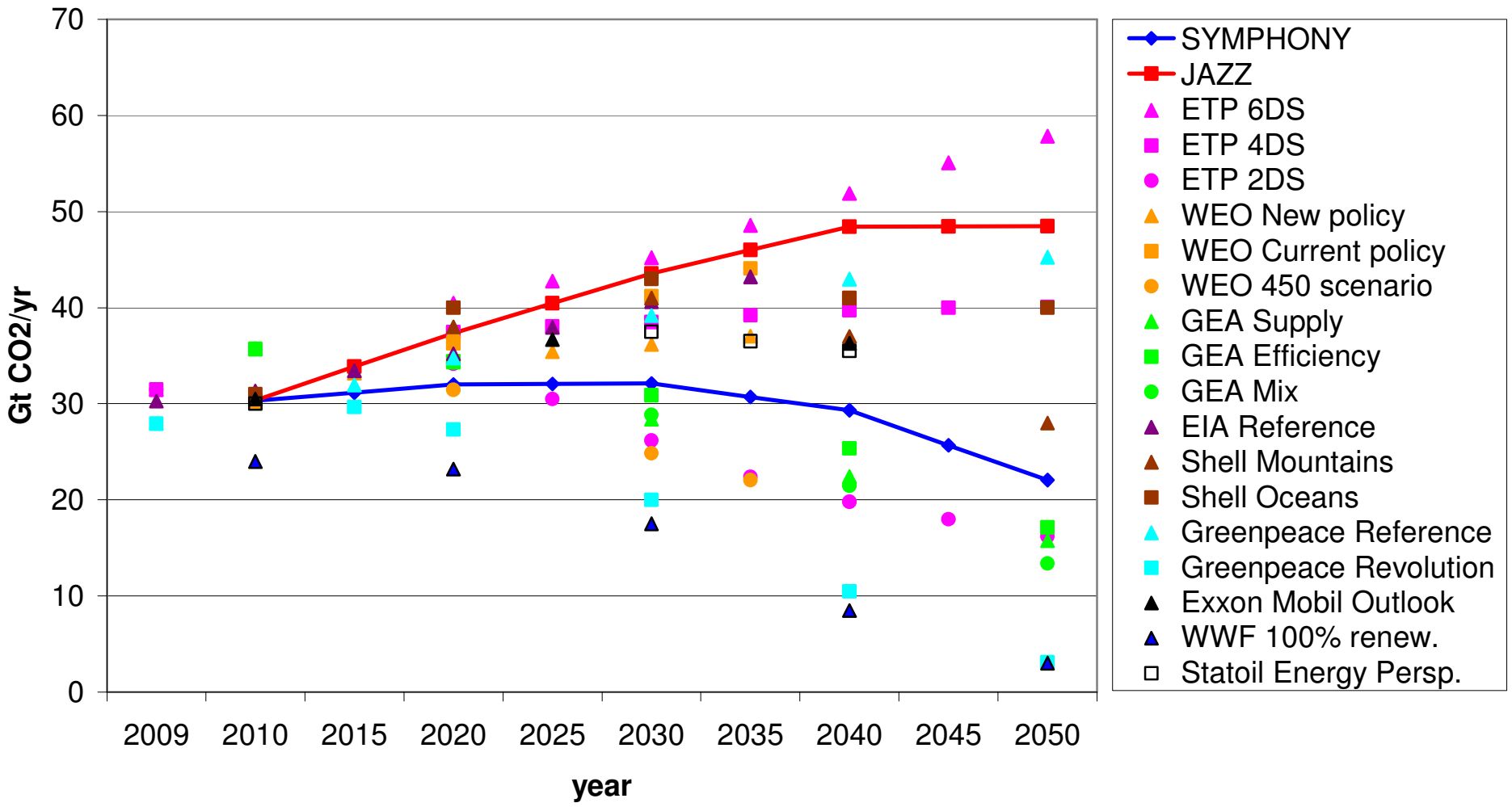
Total Primary Energy Supply (TPES)



Total Electricity Production



CO_2 emissions



WEC and IPCC in context

- Of the 1000 GtC budget of the IPCC (associated with a 2/3rds chance of keeping warming below 2 degrees), 531 GtC has already been used up by 2011. So, only about 470 Gt remains. In addition, non-CO_2 forcings would reduce this to 270 GtC.
- Emissions from Jazz for the 40 years from 2010-2050 would be about 440 GtC; and from Symphony about 310 GtC.
- Jazz is well above the budget by 2050, and will continue to overshoot for some time thereafter since it is very unlikely that emissions would fall from 44 Gt CO_2 in 2050 to zero soon after.
- Symphony would also just exceed the budget by 2050, and emissions would continue afterwards. However, if the declining output of emissions continues, this scenario may still be able to achieve 2 degrees, albeit not with the 2/3rds probability associated with the 1000 Gt budget.

Balancing the "Energy Trilemma"

"promoting an affordable, stable and environmentally sensitive energy system for the greatest benefit of all"

Energy security

The effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of energy companies to meet current and future demand.

No power cuts or queues for petrol

Environmental impact mitigation

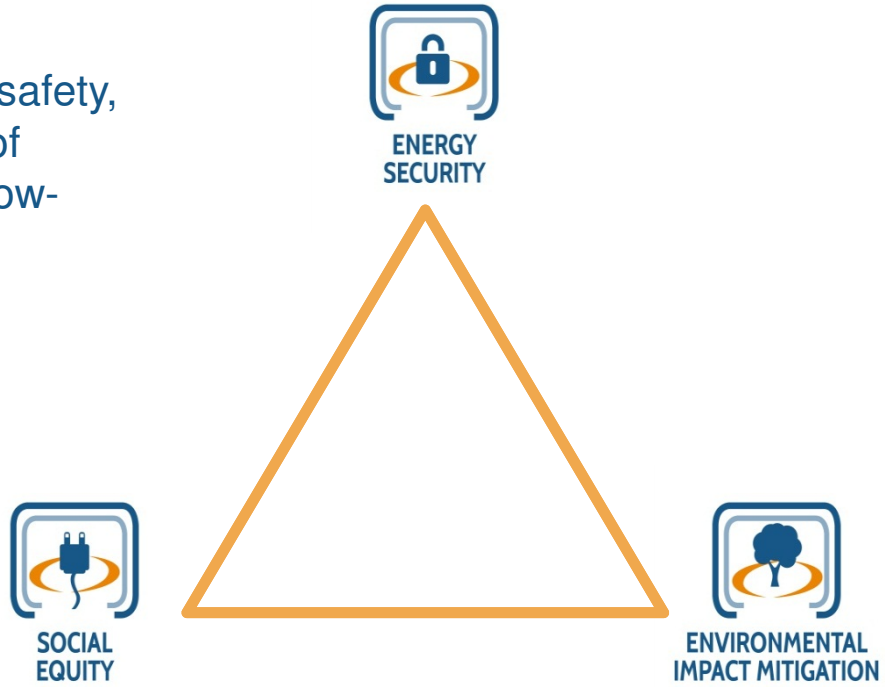
CO_2 emissions, Water, Land use, nuclear safety, Energy efficiencies and the development of energy supply from renewable and other low-carbon sources

UNFCCC 2° C 450ppm CO_2

Social equity

Accessibility and affordability of energy supply across the population.
1.2 billion without access to electricity, energy poverty.

UNSE4ALL by 2030



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 conundrum
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: CC(U)S is important, and consumer behaviour needs changing.
7. CC(U)S technology, solar energy and energy storage are the key uncertainties moving forward up to 2050
8. Balancing the energy trilemma means making hard 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

Energy mix in 2050

- **Energy efficiency** is absolutely crucial in dealing with demand outstripping supply in both Scenarios
- **Coal** remains a dominant fuel (especially in China and India), CCS is critical to coal in Symphony.
- **Natural gas** will gain more importance in the energy share especially in Jazz
- **Oil** will continue to be the dominant fuel in transport with growth in natural gas in Jazz and Biofuels and electricity in Symphony
- **Nuclear** is not a game changer but is important in Symphony
- **Hydro**: great economic potential of hydro electricity generation especially in SSA and LAC
- Share of **renewables** increases in Symphony. Solar takes off.

Conclusions

- Jazz is better for Social Equity
- Symphony is better for Climate change
- Both fall short of the goals set out by the United Nations
- What can achieve with the best of both worlds? Governments doing what only governments can do and consumers and business factoring in environmental costs
- What happens if we get the worst of both worlds? Nimby-ism, inefficient and self interested governments, And corruption

We are in a challenging place

- Demand is not evening out
- Universal electricity access is far from becoming a reality
- The contribution of energy efficiency is not up to expectations
- Current institutions cannot solve the issues
- It is not easy to get funding

What is the way forward?

1. Much of the solution will come from more management in the demand while leaving the market play its role within robust and predictable frameworks.
2. National policy frameworks have to be balanced in order to attract investment
3. International governance in specific areas (eg. trade rules) needs strengthening
4. Focussed RDD efforts (especially in storage and CCUS) are needed