Wir schaffen Wissen – heute für morgen

Paul Scherrer Institut

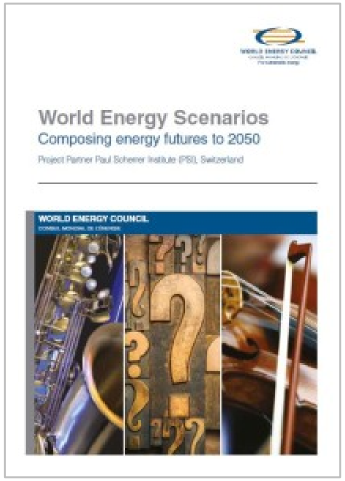
Panos Evangelos, Turton Hal, Densing Martin, Volkart Kathrin

Choosing a tempo to power Sub-Saharan Africa in 2050: Jazz and Symphony scenarios of the World Energy Council

IEW 2014, Beijing

Contents

- Current Situation in Sub-Saharan Africa and Challenges
- Modelling Framework
- Definition and Quantification of WEC‘s Scenarios* for Sub-Saharan Africa
- Results and Conclusions



* World Energy Council: World Energy Scenarios – Composing energy futures to 2050
Project partner Paul Scherrer Institut (PSI) Switzerland
http://www.worldenergy.org/publications/2013/world-energy-scenarios-composing-energy-futures-to-2050/

The Sub-Saharan Africa in 2010 – some facts

POPULATION

857 million (12% of world)

ANNUAL INCOME (per capita in MER)

$1,350 (world: $9,160)

POVERTY (pop. with <$2 in PPP per day)

603 million (25% of world)

URBANISATION RATE (% of population)

36% (world: 52%)

POLICY & INSTITUTION INDEX (1 low, 6 high)

3.18 (Developing Europe & Central Asia: 3.71)

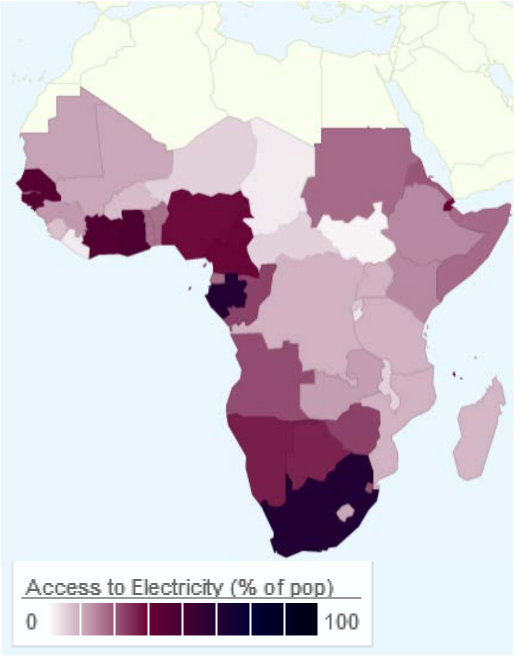
ELECTRICITY GENERATION CAPACITY

92 GW (UK: 94 GW)

ANNUAL ELECTRICITY CONSUMPTION IN RESID.

195 KWh/capita (China: 810) (EU-27: 3,440)

ACCESS TO ELECTRICITY

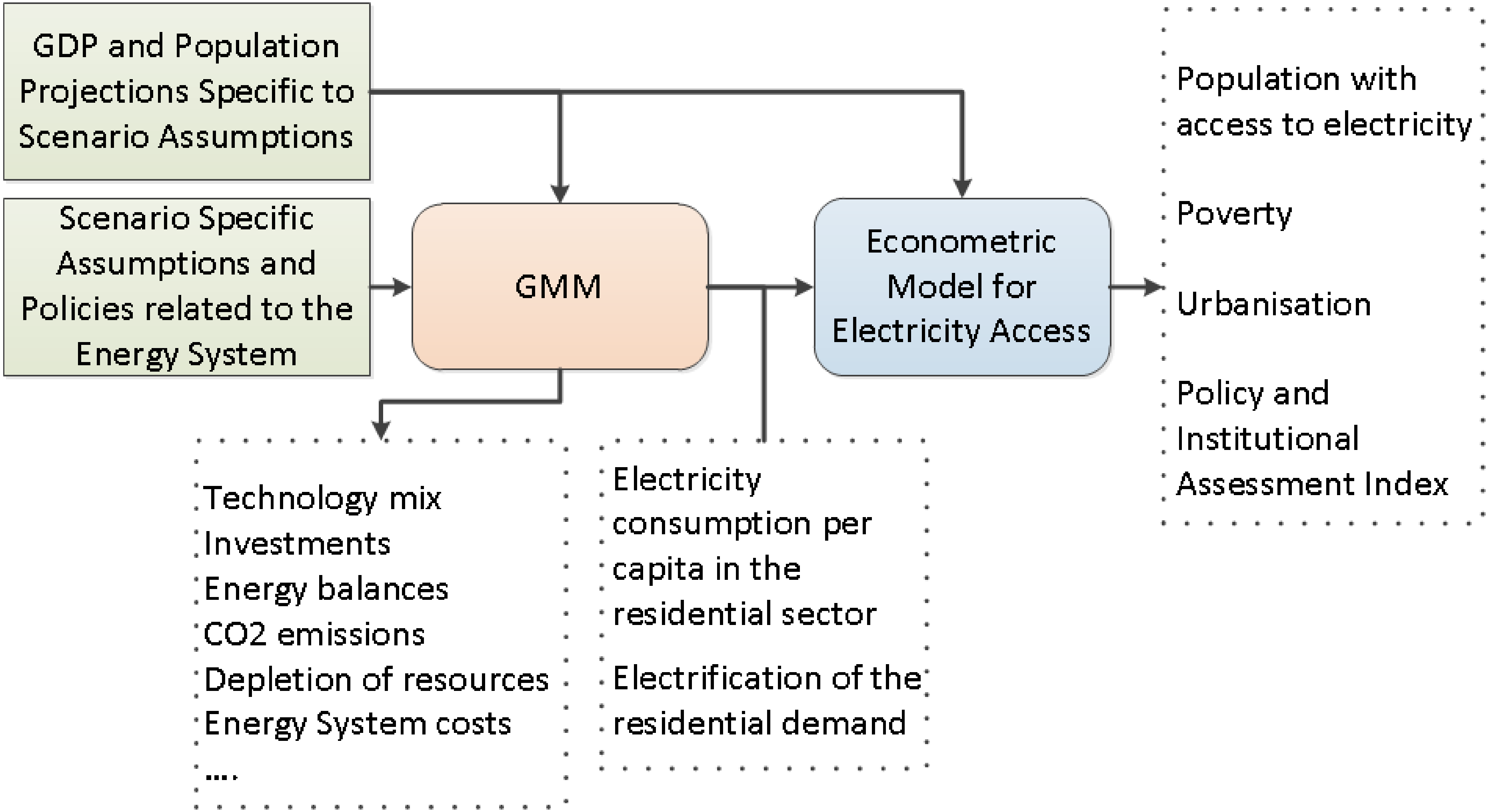


589 million without access to electricity

(46% of world)

Modelling Framework

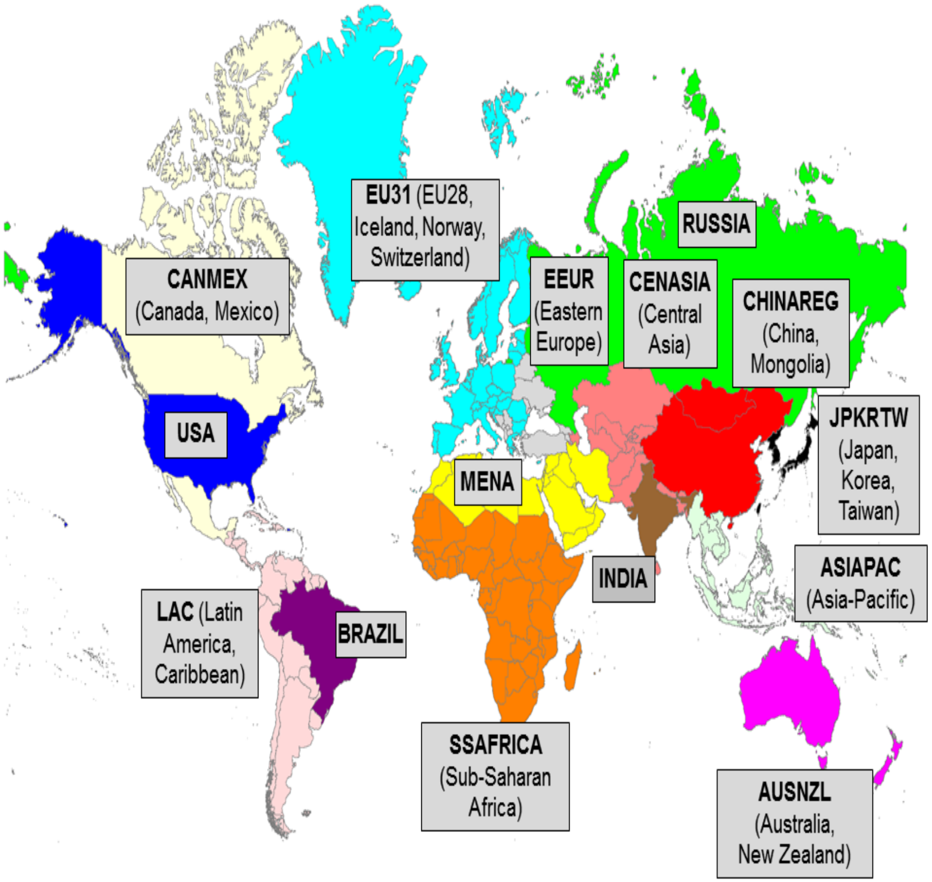
Interfacing PSI's Global Multiregional MARKAL (GMM) model with a reduced-form econometric model

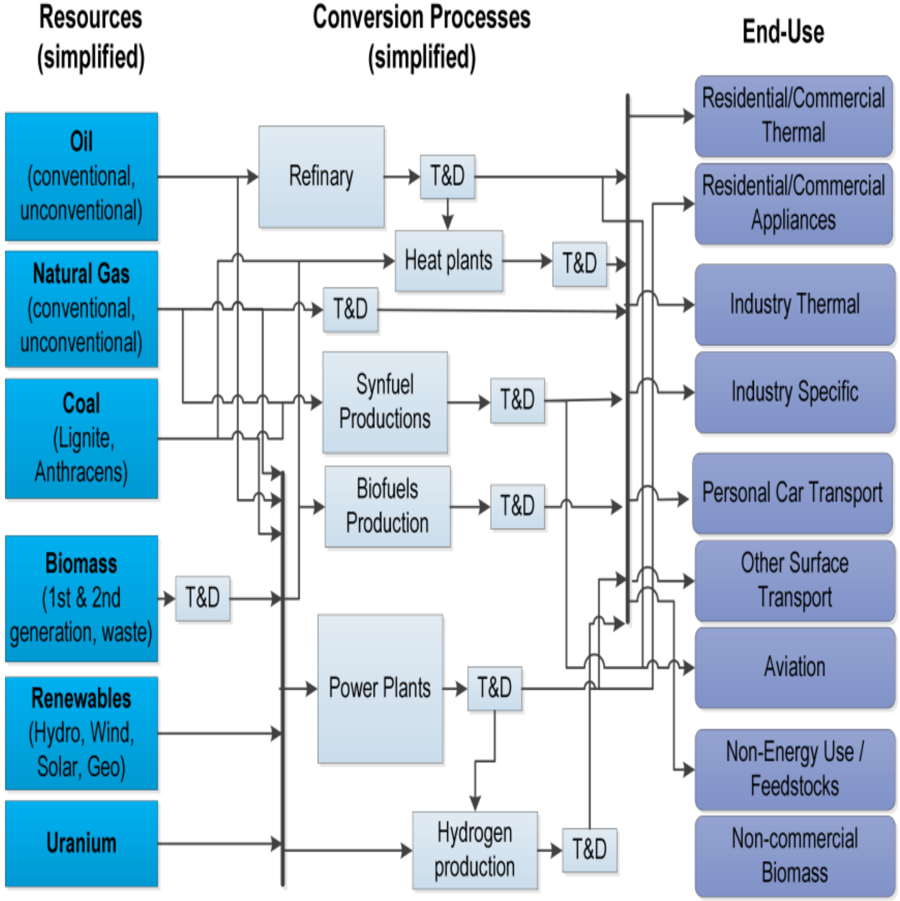


Overview of the GMM Model

Global Multi-regional MARKAL :

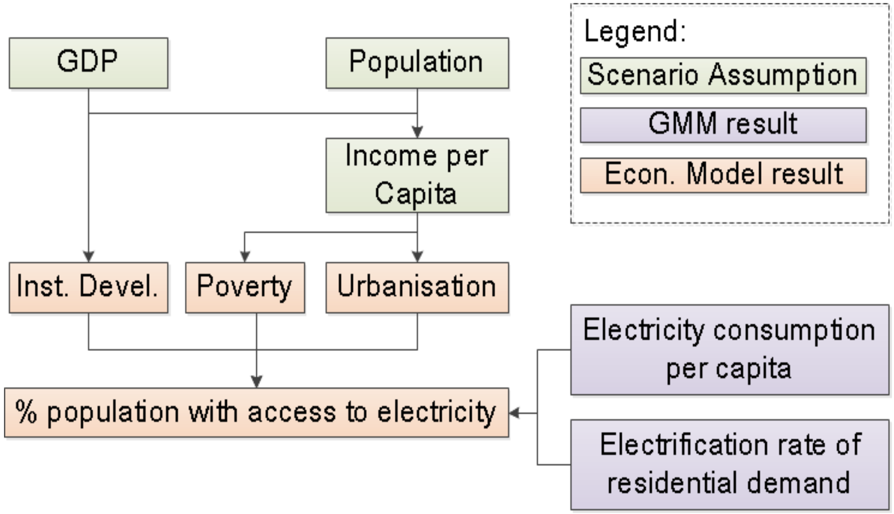
- Cost optimisation of the energy system; perfect foresight; bottom-up model with a detailed representation of resources, technologies, energy flows and technological change
- Non-cost, policy and behavioural assumptions are modelled with side-constraints





Overview of the Econometric Model for Electr. Access

Reduced-form econometric model. Time-series estimation (1970-2010) using Polynomial Distribution Lags



Correlations between model's variables	Income per capita	Urbanisation Rate	Poverty Rate	Institutional development	Electricity per capita	Electrification of demand
Urbanisation Rate	**0.85**					
Poverty Rate	**-1.00**	**-0.85**				
Institutional development	**0.33**	**0.32**	**-0.30**			
Electricity per capita	**0.76**	**0.85**	**-0.73**	**0.39**		
Electrification of demand	**0.66**	**0.79**	**-0.63**	**0.37**	**0.99**	
Electricity access	**0.88**	**0.97**	**-0.87**	**0.29**	**0.85**	**0.79**

$$\ln\left(\frac{poverty_t}{poverty_{t-1}}\right) = \beta_0 + \beta_1 \cdot \sum_{k=0}^{10} \gamma_k \cdot \ln\left(\frac{income_{t-k}}{income_{t-k-1}}\right) + AR(1) + \epsilon_t$$

$$\ln\left(\frac{rural\_migration_t}{1 - rural\_migration_t}\right) = \beta_0 + \beta_1 \cdot income_{t-1} + \epsilon_t$$

$$\ln\left(\frac{cpia_t}{6 - cpia_t}\right) = \beta_0 + \beta_1 \cdot \ln(gdp_{t-1}) + \epsilon_t$$

$$\ln\left(\frac{elc\_access_t}{1 - elc\_access_t}\right) = \beta_0 + \beta_1 \cdot \sum_{k=0}^{7} \gamma_{1k} \cdot poverty_{t-k-1} + \beta_2 \cdot \sum_{k=0}^{3} \gamma_{2k} \cdot elcdem_{t-k-1} + \beta_3 \cdot \sum_{k=0}^{10} \gamma_{3k} \cdot urbanisation_{t-k-2} + \beta_4 \cdot \sum_{k=0}^{1} \gamma_{4k} \cdot cpia_{t-k-2} + \beta_5 \cdot \sum_{k=0}^{4} \gamma_{5k} \cdot elccap_{t-k} + AR(1) + \epsilon_t$$

	β_0	β_1	β_2	β_3	β_4	β_5	ρ	S.E	adj R^2	Akaike	Schwarz
Poverty								0.004	0.743	-8.072	-7.930
estimates		-0.421					0.522				
p-values		0.001					0.008				
Urbanisation								0.008	0.944	-6.620	-6.576
estimates	-5.493	0.216									
p-values	0.000	0.000									
Institutional development								0.004	0.718	-7.763	-7.867
estimates	-0.352	0.063									
p-values	0.078	0.040									
Electricity access								0.005	0.999	-7.461	-7.118
estimates	-9.322	-0.020	3.610	7.843	1.916	0.224	0.464				
p-values	0.001	0.001	0.013	0.000	0.003	0.006	0.044				

The “Jazz” and “Symphony” Scenarios of WEC

WEC – PSI On-going partnership in “Composing Energy Future to 2050”

- WEC: Scenarios definition with the participation of over 3000 organisations from more than 95 countries
- PSI Energy Economics Group: Quantification of the scenarios with the GMM model for 15 world regions

JAZZ

Focus on economic growth via low cost energy and using the best available resources

- Economy liberalisation, opening of upstream energy markets, increased FDI, high economic growth
- Lower fertility driven by higher incomes and education
- Technology choice based on energy markets => limited support for nuclear, CCS, large hydro
- Efficiency is market driven
- Delayed climate policy action

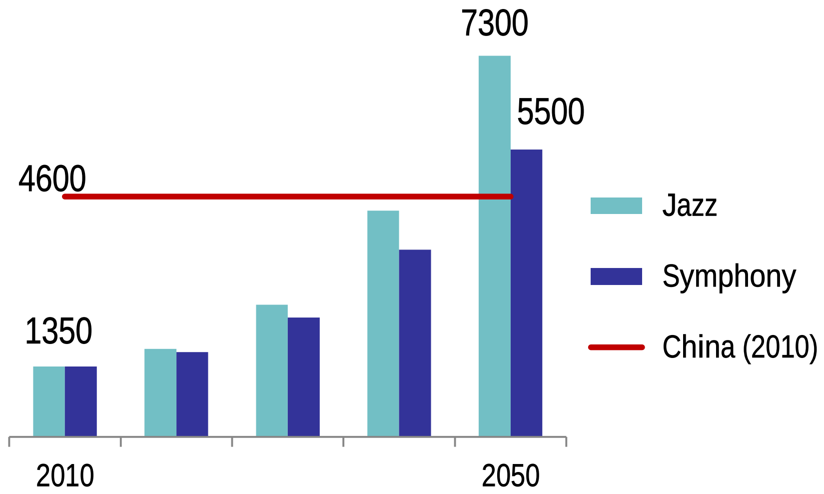
SYMPHONY

Focus on environmental sustainability and energy security

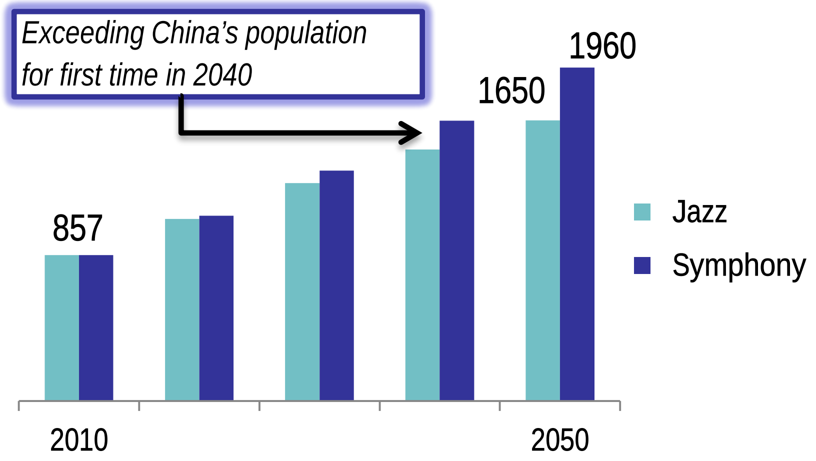
- Market regulation with policies set by governments, regulatory hurdles, limited FDI, lower economic growth than “Jazz”
- Medium fertility inline with UN Population Division
- Government support for low-carbon technologies => CCS, nuclear, hydro, solar, wind
- Efficiency measures by governments
- Strong climate policy with global convergence

Quantification of Key Scenario Assumptions

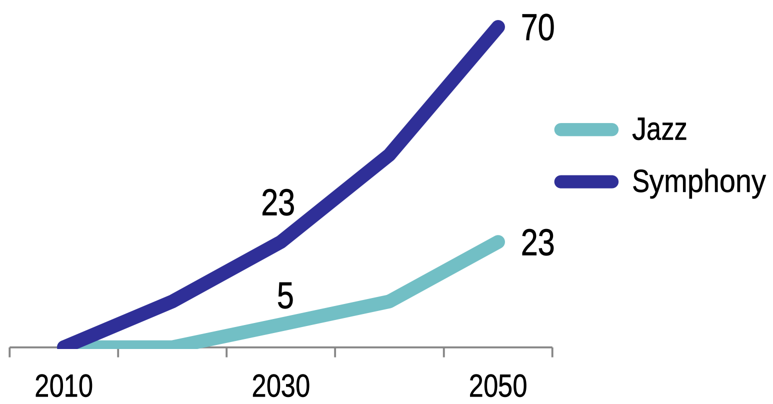
GDP per capita in USD 2010 (MER)



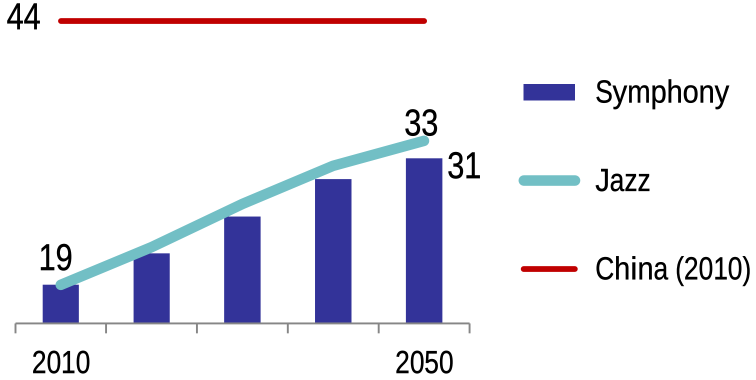
Population in million



CO_2 price in \$/tn CO_2



Cars per thousand capita

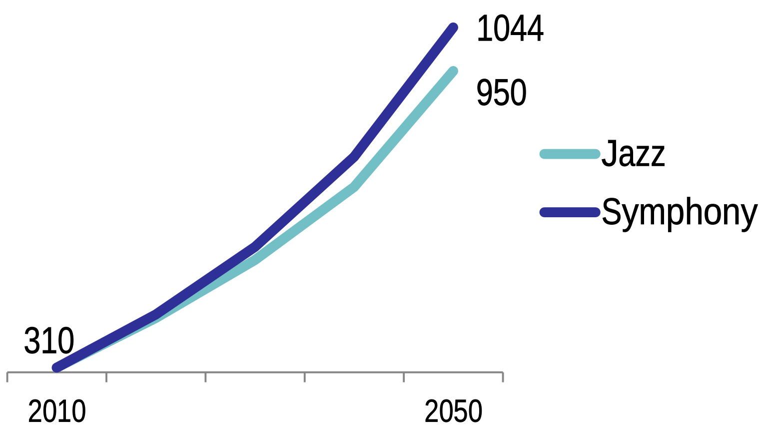


Economic – Demographic Developments

URBANISATION RATE (% of population)

36% **in 2010**
58% **“Jazz” 2050**
53% **“Symphony” 2050**

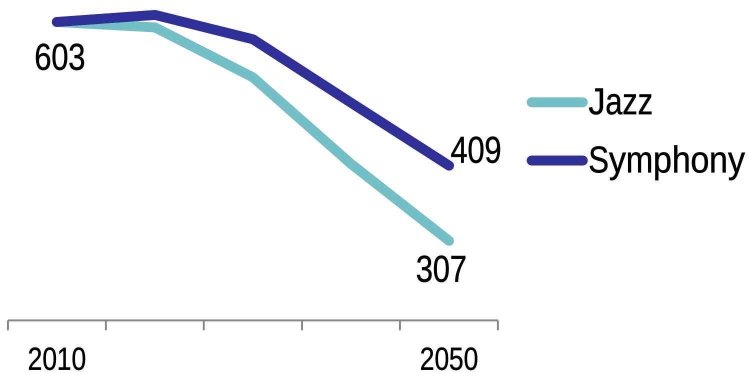
Urban population (million)



POVERTY (% of population)

70% **in 2010**
19% **“Jazz” 2050**
21% **“Symphony” 2050**

Population living with <$2 in PPP per day (million)

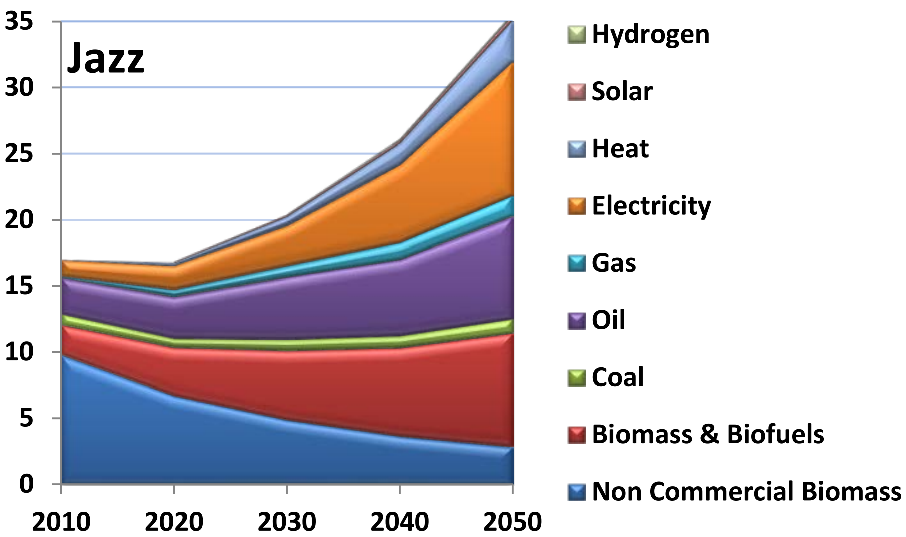


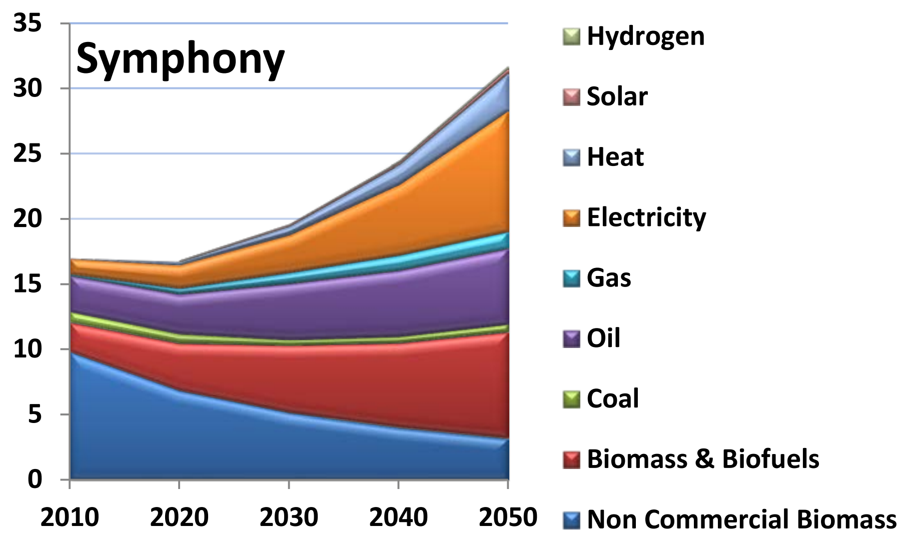
POLICY & INSTITUTIONAL ASSESSMENT INDEX

3.18 **in 2010**
3.41 **“Jazz” 2050**
3.39 **“Symphony” 2050**

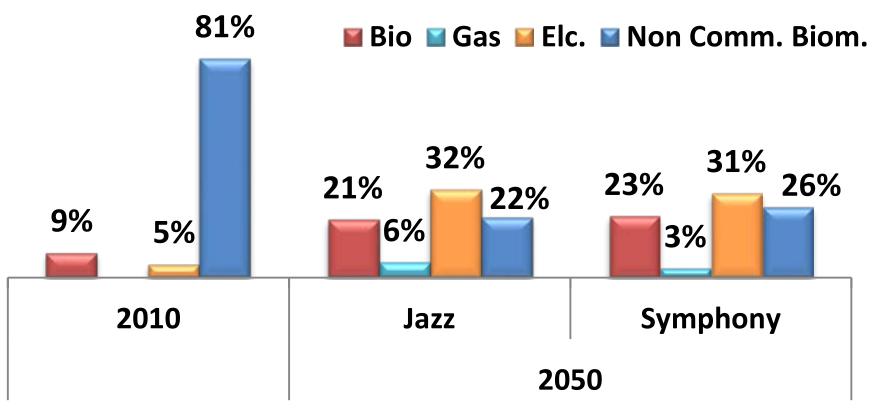
Final Energy Demand Developments

TOTAL FINAL ENERGY CONSUMPTION (EJ)





MODERN ENERGY CARRIERS IN RESIDENTIAL/COMMERCIAL (%)



ELECTRICITY per CAPITA in RESIDENTIAL/COMMERCIAL

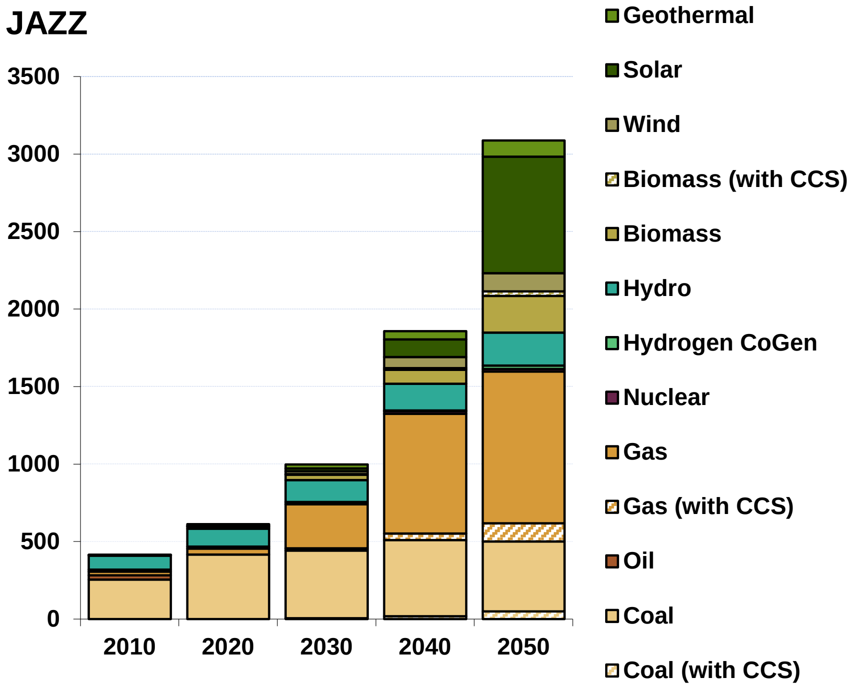
195 KWh in 2010

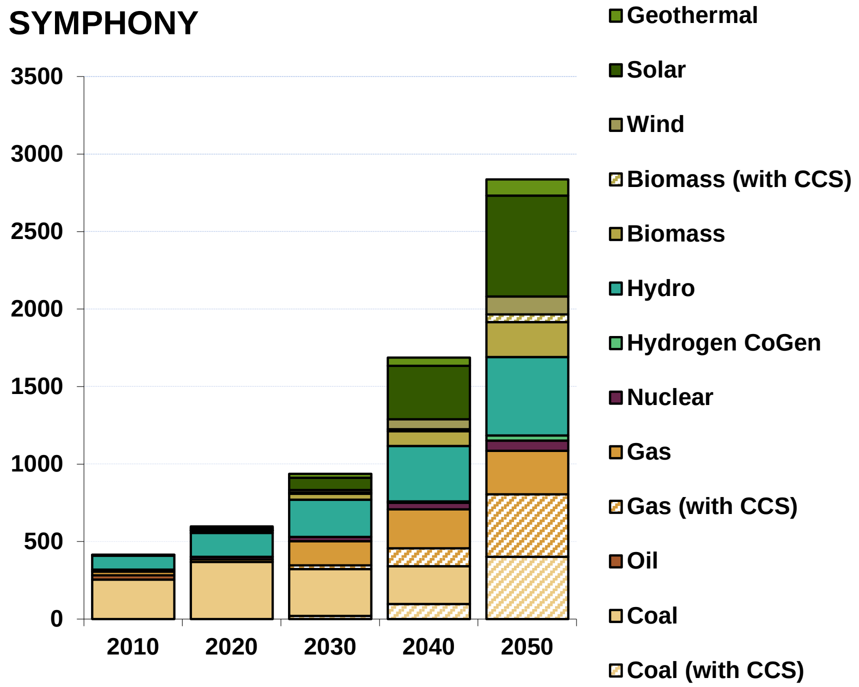
703 KWh "Jazz" 2050

539 KWh "Symphony" 2050

Electricity Generation Sector

ELECTRICITY PRODUCTION (TWh)





NEW CAPACITY INVESTMENTS:
more than 20 GW annually

980 GW “Jazz” in 2011-50
930 GW “Symphony” in 2011-50

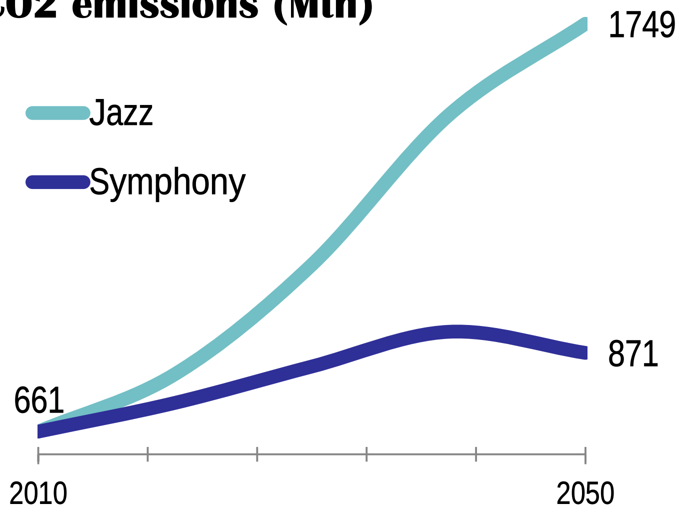
$ 1,264 billion “Jazz” in 2011-50
$ 1,349 billion “Symphony” in 2011-50

ELECTRICITY GRID EXPANSION:
more than $20 billion annually

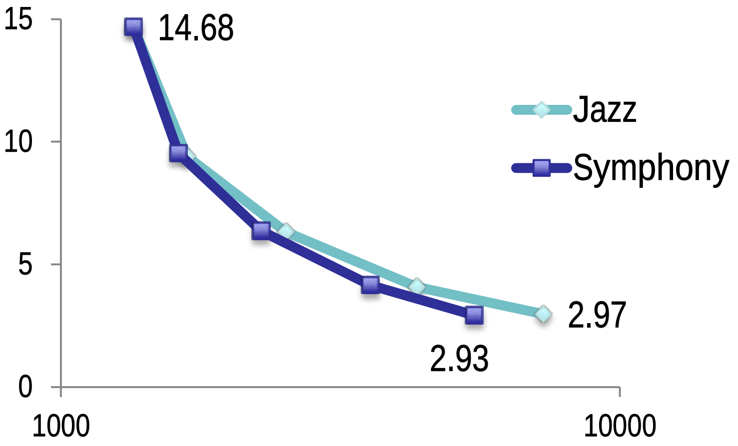
$1,011 billion “Jazz” in 2011-50
$ 964 billion “Symphony” in 2011-50

Emissions, Energy intensity, Costs & Electricity Access

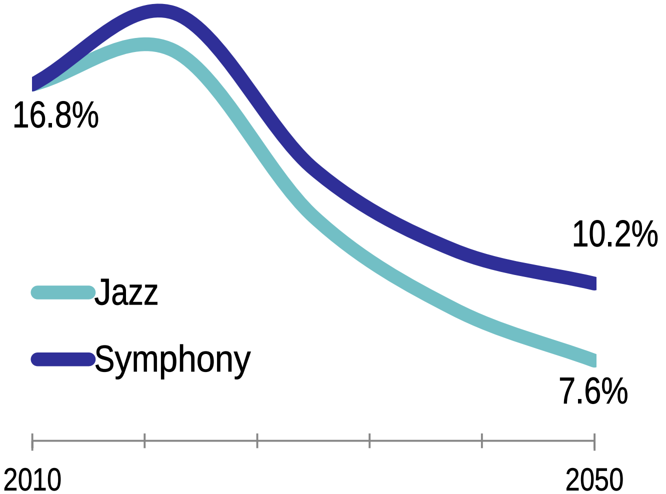
CO2 emissions (Mtn)



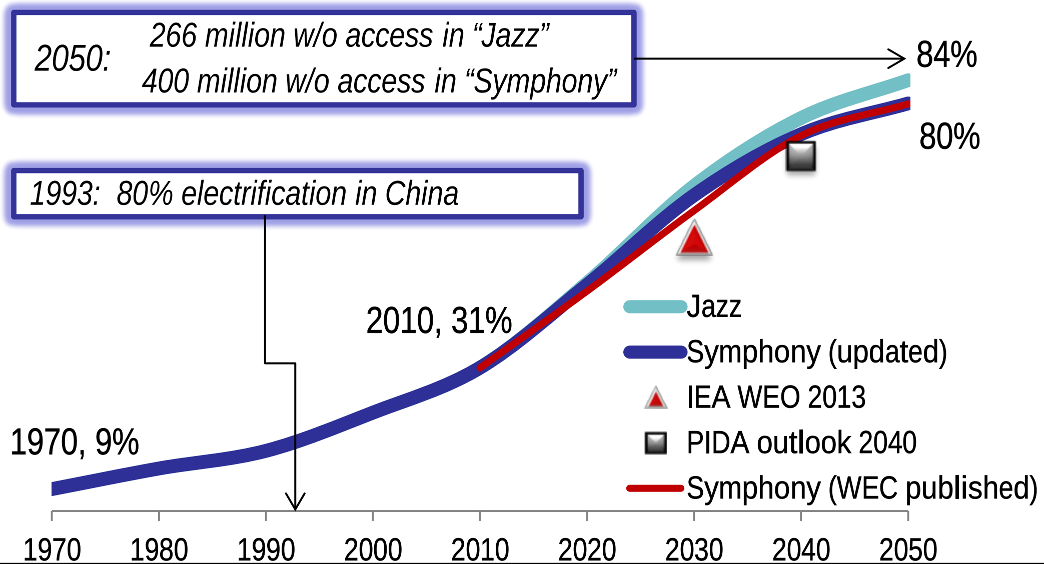
Final Energy Intensity (MJ/$GDP) vs Income per capita



Energy System cost (% of GDP)



Percentage of population with access to electricity



Conclusions

Both scenarios suggest that:

- **Enormous investments** in power infrastructure are required: more than $50 billion annually
- **Access** to electricity improves but the problem is not solved by 2050
- **Biomass** remains an important low cost energy source during the projection period
- **Hydropower** potential is large but not enough to supply the electricity demand alone
- **Solar PV and gas turbines** are among the key options for electricity production
- **Wind** faces strong competition from solar PV in gaining market share in the power generation sector
- **Nuclear** is unlikely to be a game changer in the region (lack of institutional capacity, significant financial resources)

In a "Jazz" world:

- Electrification of demand increases due to high incomes and industrialisation
- Gas penetration in final consumption is constrained mainly by the rate of infrastructure expansion
- Increased urbanisation and access to electricity
- Coal and gas supply half of the electricity in 2050
- CO2 emissions are almost tripled in 2050 compared to 2010 levels

In a "Symphony" world:

- Electricity is important for achieving efficiency
- Lower incomes and lower urbanisation result in lower access to electricity than "Jazz"
- CCS and hydropower supply half of the electricity in 2050
- CO2 emissions remain close to a sustainable path
- Increased system costs due to capital intensive investments and financing of efficiency measures

Some methodological issues:

- **More modelling** is needed for electricity access to capture the complexity of its drivers, including coupling with CGE models
- **Possible deep dives** in SSA, by splitting the region into four power pools and developing specific to the different power pools scenarios, will enhance the analysis

PAUL SCHERRER INSTITUT

Thank you very much for your attention!!

Any Questions?

Paul Scherrer Institut (PSI)
Laboratory for Energy Systems Analysis (LEA)
Energy Economics Group (EEG)

Evangelos Panos, +41563102675, evangelos.panos@psi.ch
Hal Turton, +41563102631, hal.turton@psi.ch
Martin Densing, +41563102598, martin.densing@psi.ch
Kathrin Volkart, +41563105779, kathrin.volkart@psi.ch