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Facts for the energy decisions of tomorrow

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FACTS FOR THE ENERGY DECISIONS OF TOMORROW

A Glimpse into the Future

The global population in the year 2050 will be around nine billion people. And global economic production will be at a minimum twice as high as today. China and India are likely to replace Europe and North America as the largest economic spheres, while the population will grow fastest in Africa. What this means for the world in the areas of energy supply, CO_2 emissions and energy resources has been investigated by PSI together with the World Energy Council.*

Even though the economic development of the last years has been none too rosy in Europe and the USA, and has stumbled in some transition countries – this should not be an enduring condition. The longer-term projections for global economic growth are 3% per year, or above. Today's developing and emerging economies will grow above this average.

How the energy demand, the use of different energy carriers, the related CO_2 emissions and access to the supply of electricity will develop depends on the political boundary conditions. If one counts on market forces, the economy will grow more strongly. This will help supply power to a large fraction of the almost 1.3 billion people that today have no access to electricity.

The other side of the coin is a stronger use of coal, gas and oil, with the consequence of significantly higher CO_2 emissions. Only an internationally coordinated climate policy with appropriate guidelines can help renewable energies achieve a rapid breakthrough. The same is true for carbon capture and storage. And a rapid increase in energy efficiency will only be reached with political support and investment in research and development.

A range of diverse interests must be considered. For today's less developed countries a fast-growing economy will have priority. Countries with greater prosperity today can already afford to promote environmentally friendly technologies, and to support poorer countries on the path to sustainable development.

* The complete study can be downloaded as a report from the World Energy Council site (www.worldenergy.org/publications/).

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Markets or regulation?

The year 2050 is still far away. And no one knows how the world will be supplied with energy then. But a glimpse into the future is worthwhile: How can development look that will benefit the most people possible?

To answer this question, PSI has designed two scenarios in partnership with the World Energy Council (Table 1). These calculate how different development goals and boundary conditions can affect the global energy system up to 2050. The framework of the first scenario "Jazz" is market oriented: economic growth and an affordable access to energy are in the foreground globally. In contrast, the second scenario "Symphony" contains coordinated policy measures and increased regulation by governments and international organizations, with the goals of guaranteeing secure access to energy and avoiding environmental damage. This includes an international price for CO_2 emissions, and the simultaneous promotion of energy efficiency and renewable energy. Higher environmental standards also make unconventional fossil energy resources like shale gas and oil sands less attractive.

Population and economy will grow

The economy grows faster in the "Jazz" scenario without regulatory measures. Higher incomes mean that the population grows less strongly. Regional differences are striking (Figure 1). While the per capita income in Europe and North America doubles by 2050 in the best case, it grows in other regions like Central and South Asia to almost ten times today's level. But the level of prosperity in Europe and North America will still remain the highest. The situation is worst in southern Africa (Sub-Saharan).

The economy also grows there, but at the same time the population increases from 860 million in 2010 to 1.6 billion ("Jazz") or to 2 billion ("Symphony").

The differences between the two scenarios are greater in the developing countries than in North America and the EU. Measured by per capita income, the developing countries benefit more strongly from international open markets in the first scenario. This should also contribute to these regions being able to afford adaptations to climate change and other environmental damages.

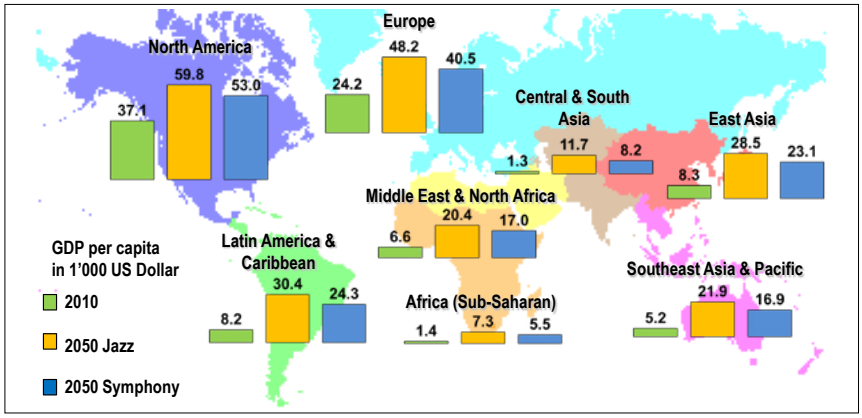

Figure 1: Economic development by 2050, measured by per capita Gross Domestic Product (GDP).

	Scenario "Jazz": Market-Oriented Future	Scenario "Symphony": Regulation-Oriented Future
Goals	• Affordable access to energy through free markets • High income ➔ Mainly adaptation to environmental damages	• Secure access to energy • Targeted regulation through states and international organizations ➔ Mainly avoidance of environmental damages
Economic Growth (Gross Domestic Product, GDP)	**GDP growth has priority** (3.5% annual average to 2050)	**Less GDP growth** (3.1% annual average to 2050)
Population	**Increase** (8.7 billion in 2050)	**Stronger increase** (9.3 billion in 2050)
Climate Policy	**CO_2 markets develop slowly** (CO_2 price in 2050: 23–45 \$/tCO_2)	**Rapid state controls** (CO_2 price in 2050: 70–80 \$/tCO_2)
Energy Efficiency / Intensity	**Efficiency increases based on economic criteria**	**State promotion of measures for efficiency and energy savings**
Unconventional Resources (Shale oil/gas, oil sands)	Expanded **opening of markets**. High incentives for use due to high energy demand.	**Regulation** (regarding water use, market access). Less incentives due to lower demand.
Renewable Energy	**Limited promotion.** "The market" selects the technologies.	**Selective state promotion**
Non-renewable Energy	**Limited support:** • CCS market driven, pilot plants by 2030 • Nuclear plants under construction partially not in operation	**State support:** • CCS available from 2020 • Nuclear energy, large hydro power

Table 1: Comparison of both Scenarios. CCS: „Carbon Capture and Storage"

Climate goals: still achievable?

Growing prosperity has until now always been connected to increasing energy consumption. Even if energy would be used more efficiently in the future, global energy consumption will climb further. What is decisive is which energy carriers and technologies we will use.

In the market driven scenario "Jazz", one uses the cheapest energy carrier in each region: primarily oil, coal and natural gas – according to what is available most economically in the market. The share of these fossil energy carriers in the overall energy supply in 2050 remains almost unchanged from today, at about 80 %. The regulatory and climate protection measures in the "Symphony" scenario mean that this share declines to almost 60 %. Transportation remains dependent on oil in both scenarios, but in contrast there are large differences in the power generation (page 5).

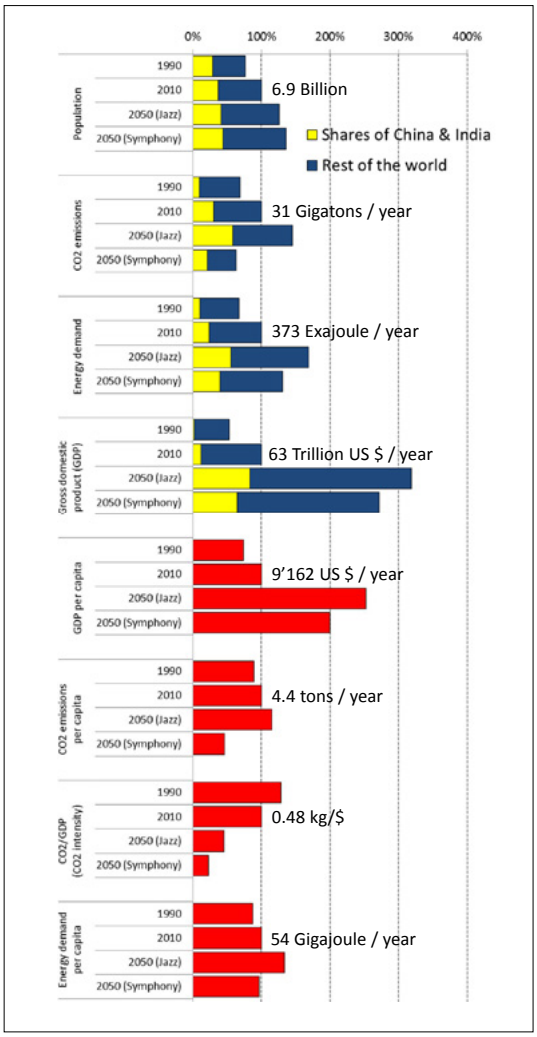

Figure 2: Changes in different indicators from 1990 to 2050 in both scenarios.

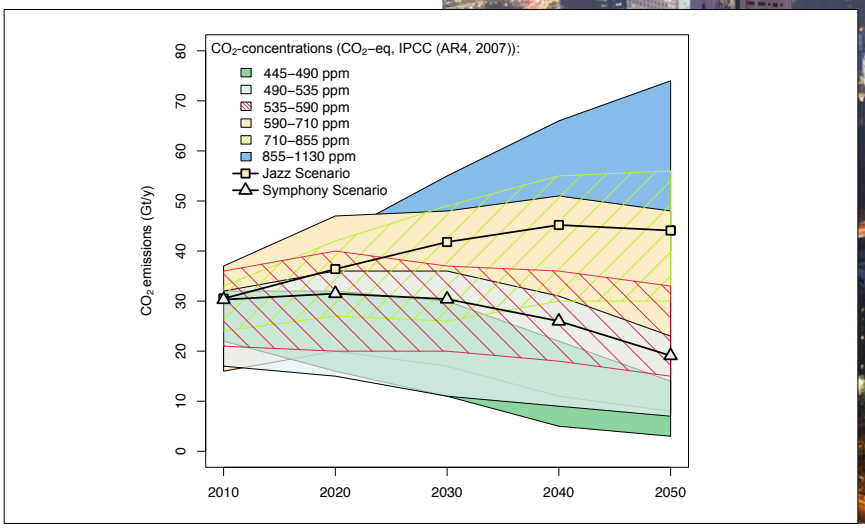

Figure 3: Trajectory of CO_2 emissions in both scenarios until 2050, compared to the ranges of the long-term CO_2 concentration in the atmosphere resulting from emission scenarios according to IPCC. How to read: emissions in the "Jazz" scenario are about in the middle of the green shaded area; this results in a CO_2 concentration of 710–855 ppm. A concentration of 800 ppm corresponds to a global temperature increase of 2.0–3.7 °C at the end of this century according to the latest findings of the IPCC.

Energy efficiency alone is not enough

World energy demand will increase (Figure 2). Even if the past trend towards higher energy efficiency continues, or if it could be further strengthened as in the regulation oriented scenario. This increase results from the growing economy and from the growing world population. However, the regulatory measures in the "Symphony" scenario do have an effect: the per capita energy consumption is slightly reduced in comparison to today, while in the market driven scenario it increases by a third by 2050. If one compares the development in the industrialized countries of today with that of the developing and emerging countries, it becomes clear how much global weights will be shifted towards Asia and Africa. Internationally coordinated policies therefore become ever more important.

Consequences for the climate

The differences in CO_2 emissions between the two scenarios are large. In the market driven scenario the emissions are almost 50 % higher in 2050 than today. An effective climate policy in the regulation oriented scenario reduces the emissions in 2050 by 40 % compared to today. Per capita CO_2 emissions increase in the first scenario by 15 %, while they decrease by almost half in the second scenario. This positive outcome is due to a much stronger use of "CO_2 free" technologies, and the deployment of carbon capture and storage (CCS) in the generation of electricity. Additionally, this is also due to a weaker increase in energy use.

There are corresponding consequences for the climate. Figure 3 shows the trajectory of the CO_2 emissions for both scenarios and the long-term CO_2 concentrations in the atmosphere as a consequence of various emission scenarios according to the Intergovernmental Panel on Climate Change (IPCC). In the market driven "Jazz" scenario it is unlikely that the goal of not exceeding a 2 °C temperature increase will be met at the end of this century. With the climate protection policy in the "Symphony" scenario one is more on track to reach this goal according to the latest findings of the IPCC.

«The scenarios reveal some myths in the energy sector»

What are the most important conclusions of the new energy scenarios of PSI and the World Energy Council for you personally?
The scenarios reveal and expose some myths in the energy area. First is the myth that the demand for fossil fuels will decrease. The scenarios clearly show that this is not the case. Second, the world will not achieve the climate goal of halving greenhouse gas emissions from their 1990 levels by the year 2050. Measured against this goal, the emissions in the WEC-scenarios are larger by factors of two and four, respectively. And thirdly, we will not succeed in eliminating energy poverty by 2050.

Where do you see the greatest uncertainties in the future energy supply?
The scenarios underestimate the influence of disruptive innovations that could fundamentally alter the energy field. This includes energy storage, and the area of CO_2 capture, use and storage. Breakthroughs in both of these areas would have great consequences for the energy system.

There are already many energy scenarios, from quite different organizations. What differentiates the WEC scenarios from these?
With 3000 member organizations in 100 different countries, the WEC has unique access to signals of developing changes. With these, we design exploratory, "bottom-up" scenarios. That means, we ask: where do we stand today, and what are the plausible ways that could lead us into the future? This is a contrast to other scenarios that work with a top-down approach, or roadmaps that ask how one gets from A to B. Second, the PSI-WEC model is based on a unique "open-source" philosophy. The model for the scenario calculations is available for use by others. And third, regarding the results: these are similar to the results of other organizations regarding the technology mix. We are however somewhat less optimistic regarding energy efficiency. This is based on the observations of the last 20 years: the efficiency gains were higher in the 1990's than in the first decade since the year 2000.

> CO_2 emissions must have a price

If you could choose how the world would develop – what would be your preference: the market-oriented "Jazz" scenario or the regulation-oriented "Symphony" scenario?
In the "Jazz" scenario the decisions are made in a distributed or decentralized fashion – in the "Symphony" scenario orchestrated decisions lie in the foreground. Both sides have strengths and weaknesses. The example of shale gas shows significantly the strength of a "Jazz" environment in fostering a massive innovation breakthrough. On the other hand, it has been possible with an orchestrated "Symphony" approach to strongly reduce poverty, e.g. in China. We must learn from both worlds and ask ourselves, which goals can best be reached with which methods.

> The demand for fossil fuels will increase

How should one deal with external costs, which are not included in the scenarios, e.g. the possible costs of climate change or the public health costs as a consequence of pollution?
Every form of market distortion in the energy area – and this includes external costs, but also subsidies – leads to a waste of energy. It is therefore important to remove existing subsidies. However, this is politically difficult if these were introduced to limit poverty. It is just as important to consider external costs: CO_2 emissions must provide a price signal. Both together must lead to higher energy and resource efficiency.

Dr. Christoph Frei is Secretary General of the World Energy Council (WEC), the global impartial network of energy leaders and practitioners representing the entire energy spectrum. Before joining the WEC, Frei was Senior Director of Energy Industries and Policy at the World Economic Forum (WEF) and a member of the WEF Executive Council (2001-2009). He received his PhD in electrical engineering and econometrics from the Swiss Federal Institute of Technology in 2001.

Will the World Energy Council continue to pursue this kind of scenario analysis? What emphases will be set in this effort?
Yes, certainly. We are proud of the cooperation with PSI: the WEC brings its unique network to this cooperation, and PSI brings a very strong research team. New questions always continue to surface. For example, what would breakthroughs in the areas of energy storage and CCS mean? We would also like to improve the model in the areas of water and food. We are facing a really exciting future of scenario analysis.

Entire interview:
www.psi.ch/info/energie-spiegel

Impressum

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Energy systems analysis at PSI: The goal of energy systems analysis at the Paul Scherrer Institute in Villigen is to analyze present and future energy systems in a comprehensive and detailed way, considering in particular health, environmental and economic criteria. On the basis of Life Cycle Assessment (LCA), energy-economic models, risk analysis, pollution transport models and finally multi-criteria decision analysis, it is possible to compare different energy scenarios to create a basis for political decision-making.

In cooperation with:
ETH Zurich; EPF Lausanne; EMPA; Swiss Federal Office of Energy (SFOE), swisselectric research; World Energy Council (WEC); Massachusetts Institute of Technology (MIT); European Union (EU); International Energy Agency (IEA); Organization for Economic Cooperation and Development (OECD).

Electricity: a key to CO_2 reduction

Switzerland is in the fortunate position of producing a lot of its electricity with hydro power. In many other places this is not the case. On the contrary, electricity generation is usually fired with coal and natural gas – with corresponding pollution and negative climate consequences.

How electricity will be generated in the future (Figure 4) will depend strongly on the political guidelines. In the market driven scenario „Jazz“, the production costs are decisive, and should be as low as possible. Financial risks are avoided, so large-scale projects like new nuclear and hydro plants have a difficult time. The strongly increasing electricity demand in Asia, Africa and the Middle East will be covered above all with coal and natural gas. Renewables are only used where they are competitive without subsidies, i.e. solar power in the Middle East, in Africa and South Asia, and wind power in Europe and North America.

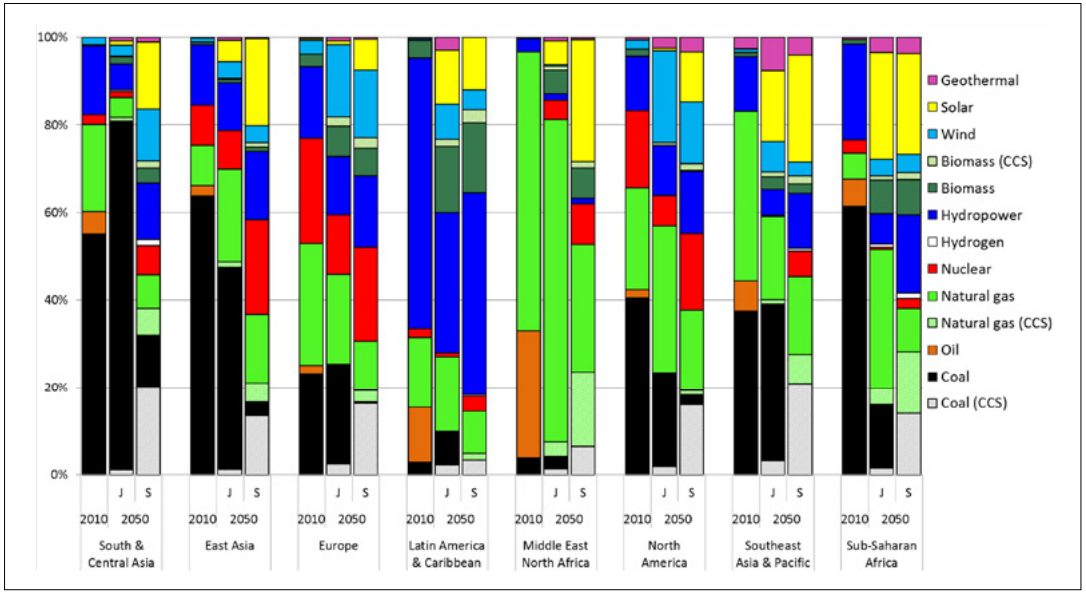

Figure 4: Electricity generation in 2010 and 2050 by regions of the world for both scenarios, showing contributions by energy carriers. “J“ indicates the market driven scenario “Jazz,“ and “S“ the regulation oriented scenario “Symphony.“

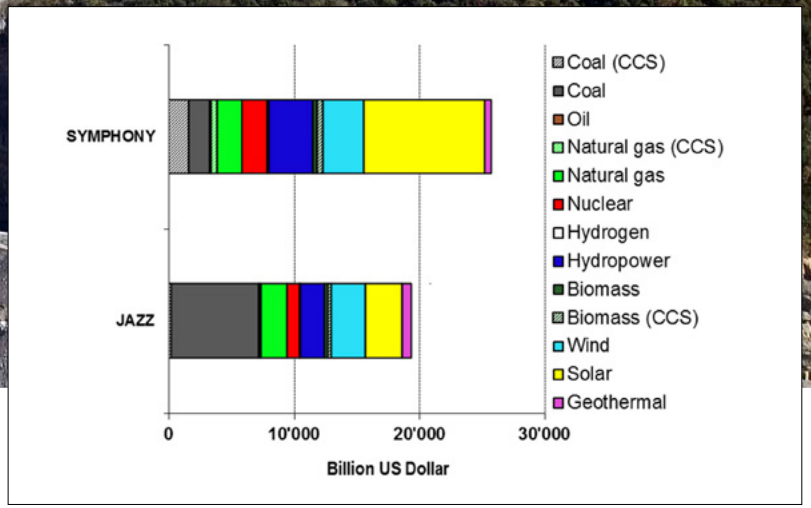

Figure 5: Investment in global generation capacity by 2050 in billions of US dollars; shown by energy carrier.

Renewables need support

With international climate and environmental policies, other factors come into play in addition to costs, including lower CO_2 emissions and less dependence on imported energy carriers. To reach these goals, renewables are financially subsidized in the “Symphony” scenario. The risks of large investments in hydro and nuclear plants are taken over by the state. At the same time, a framework will be created so that carbon capture and storage (CSS) will be implemented. The result is in many regions a cleaner electricity mix with significantly more solar energy, wind, hydro and nuclear energy. The global share of coal, oil and natural gas is reduced from almost 70 % today to less than 40 %. Coal power plants will hardly be operated without CSS.

For such a conversion however a great deal of money must be invested. The electricity sector will in any case need high investment in the coming decades. In the „Symphony“ scenario with climate policies however a third more investment will be required, even though the electricity demand will be about 10 % lower by 2050. The additional investment is spent above all in solar, nuclear and hydro plants. In all, new power plants must be built by 2050 with a total capacity of almost 17’000 Gigawatts and 14’000 Gigawatts for the scenarios „Symphony“ and „Jazz,“ respectively.

Enough energy for all?

For us in the West unimaginable, but for 1.3 billion people – almost every fifth person – it is daily experience: a life without electricity. Often this is a result of the poverty in which these people live, often the necessary infrastructure is lacking.

In southern Africa today, a large share of the population must live without electricity (Figure 6). And this is also a reality for many in Asia. These people must mostly cook with wood or dried dung. The consequences are poor air quality in their houses, leading to serious health problems. The key to improving this situation is increasing prosperity and stable social conditions.

The number of people without access to electricity by 2050 will be noticeably reduced. In the market driven scenario this reduction is stronger – to about 300 million. This is above all thanks to the quicker increase in prosperity and the increasing urbanization. In the "Symphony" scenario more than 500 million people still remain without electricity. Although the governments may strive to put the necessary infrastructure in place, the money is partially lacking.

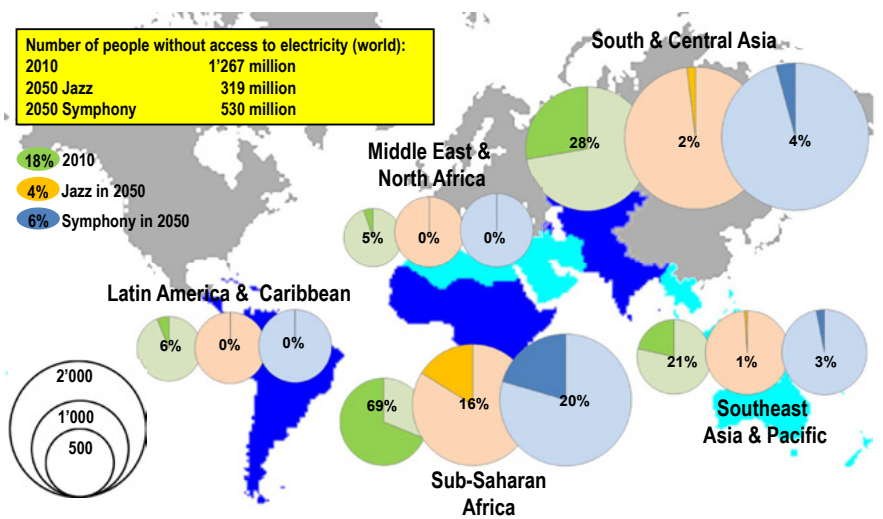

Figure 6: Share of population without access to electricity in the different regions, 2010 and in both of the scenarios for 2050. The size of the circles is proportional to the respective populations.

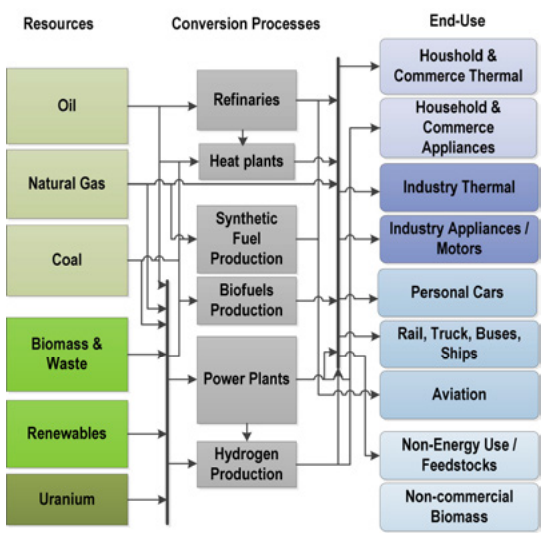

Figure 7: Schematic diagram of the "MARKAL" model used to analyze the energy scenarios.

The **Scenario Analysis** was carried out by PSI using a global **"MARKAL" model**. This optimization tool calculates the least cost composition of the energy supply in 15 world regions under specific boundary conditions. These conditions are different for the two scenarios "Jazz" and "Symphony." For the projected energy demand the model chooses the optimal combination of around 400 different energy technologies (e.g. power plants, heating devices, vehicles, etc.) in each region. The separate demands for the industrial, transport and housing sectors are considered (see Figure 7). The results depend above all on how much energy technologies and fuels cost, and when they are available, as well how the population and economy develop. Future advances in technologies are considered, for example in the form of increasing efficiencies for power plants. The expected cost trajectories for power plants, coal, oil and natural gas extraction are also included. The costs of CO_2 emissions and the differing regional potentials for the use of renewable energies are also part of the calculation. The scenarios are not forecasts, but rather "If-Then" answers.

PSI will further develop the scenario model together with the World Energy Council. The model will be available to the over 3000 members of the WEC, guaranteeing full transparency.