Alternative World Energy Outlook 2005: a possible path towards a sustainable future

Dr. Werner Zittel, L-B-Systemtechnik GmbH, Ottobrunn, Germany
(zittel@lbst.de)

This talk sketches a possible path towards the future energy supply in the light of foreseeable challenges and opportunities. First, the shortcoming of the World Energy Outlook, which is biannually published by the International Energy Agency, is criticised. The deficits of these reports are the reason why a more progressive approach and alternative scenarios are needed. An alternative approach must address both the challenges as well as promising pathways towards a sustainable energy future. Secondly, I will briefly pinpoint the challenges and discuss those non-sustainable approaches which represent today's commonviews in the energy community. Finally, and most important, I will give you an idea about the potential of a relevant renewable energy scenario. My goal is to set your minds towards a more positive direction. We will need all our energies to master the coming challenges and this will be simpler if we know which direction we are heading, not blocking our minds with dead end solutions.

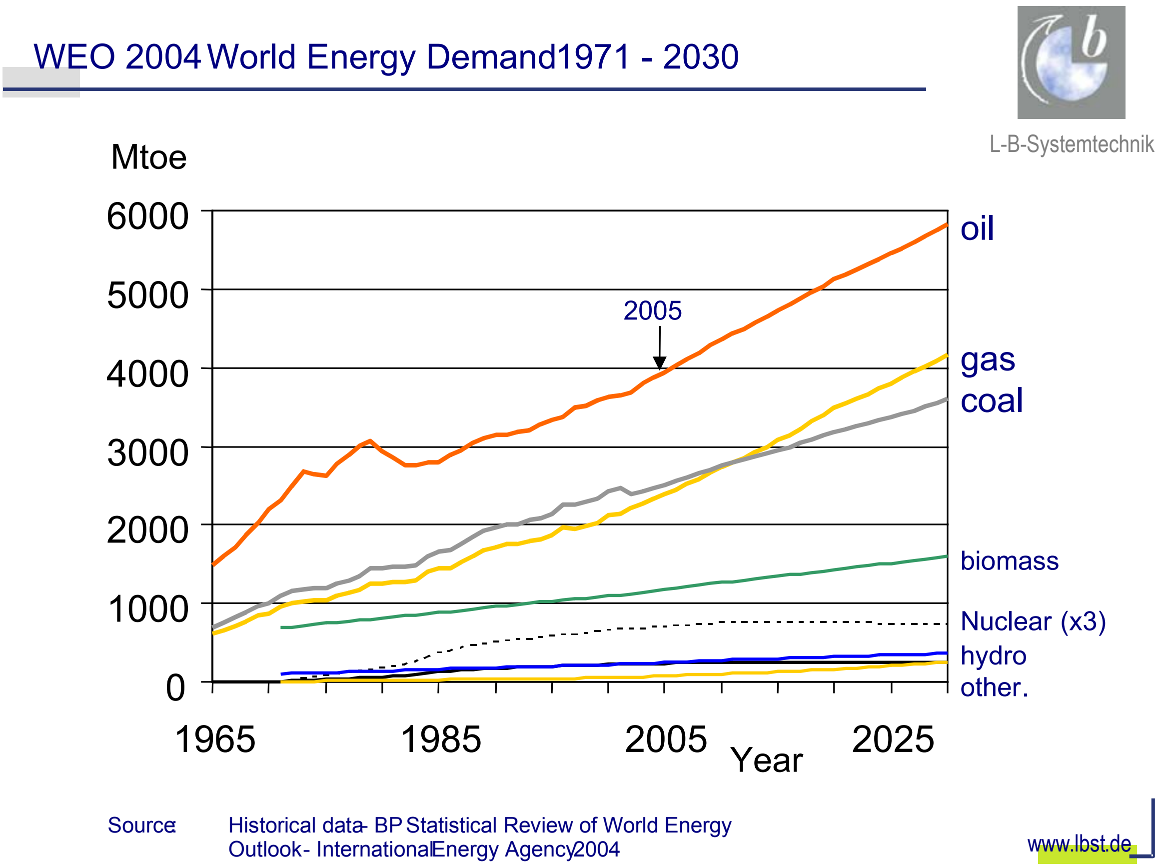

Figure 1: World Energy Outlook 2004 by the International Energy Agency

Figure 1 provides the World Energy Outlook as published by the International Energy Agency in 2004. The figure shows the development of the world energy supply over the last 40 years since 1965 and the forecast for the next 25 years until 2030. The first three curves from top to bottom show the development of the fossil sources oil, coal and natural gas which together provide almost 80 percent of the world energy needs. Oil alone is the most important fuel with a share of almost 40 percent. Next is the use of biomass, mostly in an unsustainable manner for cooking and heating in developing countries. Between 10 – 15 % of the world needs are covered by this source. Nuclear and hydropower produce roughly the same amount of electricity at world level, each with a share of about 18 percent of world electricity production. The exaggeration of the nuclear energy in this figure is due to the counting method which assumes an efficiency of 33% from nuclear fuel to electric power provision and almost 100 percent from hydropower to electricity. Fact is, that both produce almost the same amount of electricity. Finally, the smallest contribution with about 1 percent comes from all other renewables such as wind, direct solar energy, geothermal energy use or wave power.

What does this figure tell us? Oil will remain the most important fuel. Its consumption and production level will increase over the next 25 years by the same amount as it did during the last 40 years. In other words: the production rate will increase almost twice as fast as it did over the last 40 years. The signal to the consumer is: In the next two decades we will see no major changes, don’t worry, go ahead with business as usual, no sign of change becomes apparent. The price for oil is set to rise to 27 $ per barrel of oil until 2030, to 37$ respectively including the annual inflation rate. To remind you of the present situation: Oil has been traded at around 60$ per barrel for several months with no sign of strong recovery.

The next message is that natural gas and coal supply will combat for the second most important position, natural gas supply probably developing more rapidly than coal: The supply of natural gas will more than double over the next 25 years. Again, compared to the last 40 years, this pretends that the annual rate of extraction will more than double. Back to reality: Presently, North America and Europe are the most important natural gas markets absorbing more than half of the world’s natural gas consumption. In both regions natural gas production already has peaked. North America already experiences a decline of its supply which will continue at least for some time as natural gas from foreign sources is hardly imported due to limited import capacities. There is no doubt about that large quantities of natural gas are still in the ground. However it must be doubted that the extraction rate will exceed the past level once the production in North America and Europe is in decline. Any new natural gas supply must first compensate for this deficit before a net increase can be realised. This will become a real challenge!.

Just a few words about the other sources: the increase in the use of biomass will continue as in the past. For nuclear energy the report spends just one out of more than 400 pages, claiming without any further justification that total production will remain almost at present level. Finally, new renewable energies like wind or solar will almost triple their contribution over the next 25 years. This is based on an expected average growth rate of about 3 percent per year. Again back to reality: Over the last 15 years the average growth rate of wind energy was about 30 – 35 percent per year, for solar thermal energy about 10 – 15 percent and for solar electricity production 15 – 20 % with a strong acceleration during the last few years.

Which are the driving forces that influence our present energy supply and probably will even grow in importance in the years to come? Predominantly, I can identify three drivers:

Most prominently, we have learned a lot about the relation between fossil fuel combustion and its role in heating the earth atmosphere during the last 20 years. Understanding the physical principles tells us that, the more we pollute the atmosphere with the combustion product carbon dioxide, the more we change the radiation balance. This must result in heating the earth’s surface temperature with all related effects of increased evaporation and rainfalls. An increase of water vapour in the air is almost synonymous with more energy in the air and consequently must result in stronger rainfalls and storms. This today is beyond any doubt. The remaining uncertainties are: How long can competing effects dampen that rise and how large is the uncertainty range of the natural variability of our climate? How much does the temperature still need to rise until we become convinced that the rise experienced is related to anthropogenic influence.

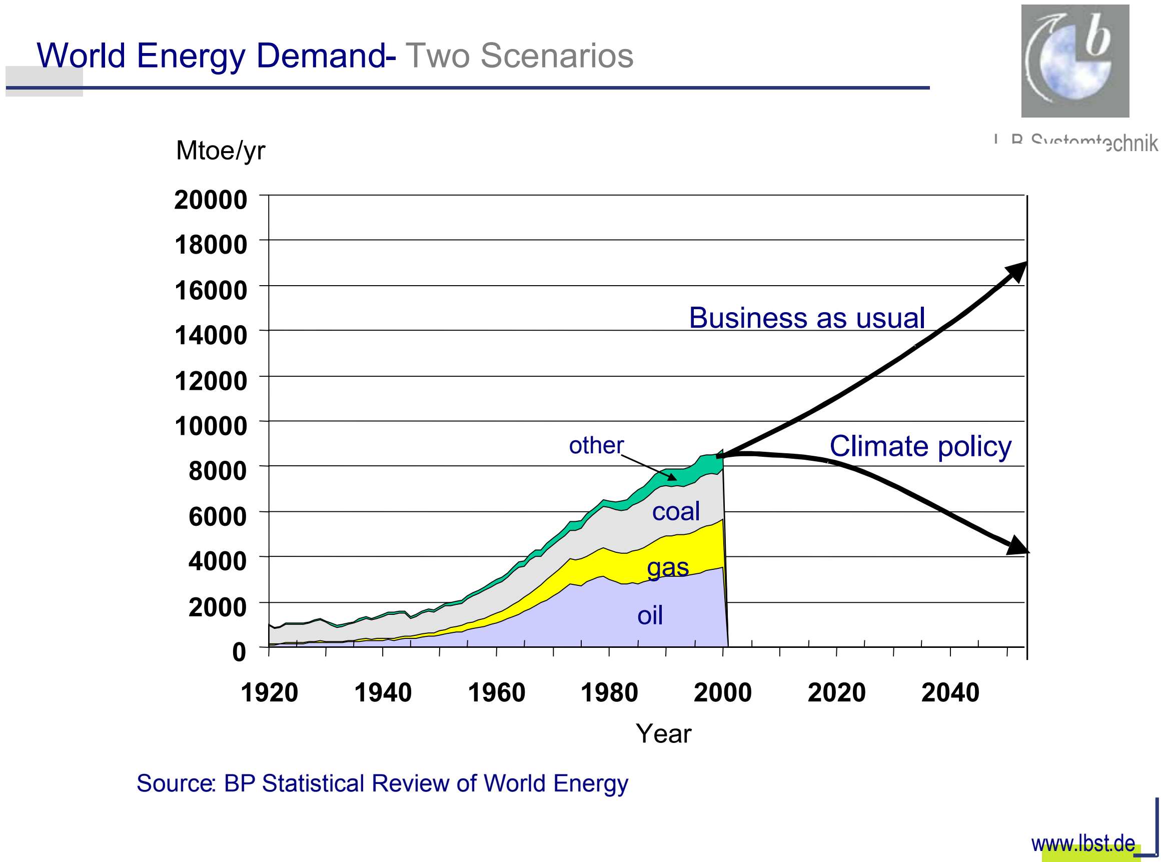

Figure 2: Our basic dilemma – business as usual or climate policy

Figure 2 sketches our dilemma: Our economic principles are constructed in such a way that our economies need to grow each year in order to maintain the required living standard for its inhabitants. All our efforts are directed towards this growth of economic power which is measured by the “gross domestic product”. And of course we all support that the not yet developed countries must concentrate all their forces on the growth of their economic power. But the growth of the economic power is almost completely linked to the growth of materials extraction, which predominantly means rising consumption of raw materials and fossil energy. But at the same time we know from our hearts, that sooner or later this is deemed to fail as an unrestricted growth of limited resources is simply impossible.

The most descriptive way to depict this dilemma is climate change: The figure does not show not the energy consumption as before, but its combustion products carbon dioxide which accumulate in the atmosphere. The past trend is history, the projected trend exhibits this mental “schizophrenia”: On one hand we believe that we need a growing fossil fuel combustion to keep our economies running and to reach welfare – on the other hand we need strongly declining fossil fuel combustion in order to save our planet: Otherwise the ecosystem responds with rising temperatures, raising wind speeds, changing precipitation patterns etc, which all are deemed to worsen our lifestyle at world level.
This is our basic dilemma!

But there is another driving mechanism which we have to accept: This is the natural endowment of our fossil energy resources. I must not talk about details of the imminent production peak of oil supply as this was broadly discussed yesterday by Colin Campbell and is already part of the Rimini Protocol. Oil is the first resource which will decline. Within years or decades it will be followed by the decline of natural gas production and by the geological restrictions of uranium and coal supply.

Let me still mention the third driving mechanism: This time I mean a positive driver, that is our hope, our intuition and our genius for technical inventions. Once we have a positive imagination about where to go and what to do we can realise the impossible, we can move mountains. And we already have a positive intuition. Over the last years we have had lots of improvements and technical innovations in promoting the distribution of renewable power. And this will also set a stimulus how to manage the transition from the present unsustainable to the future sustainable economic behaviour. However, this is not an automatism, how fast we move towards that direction depends on the active players, these are the politicians, the industry leaders, and, of course the consumers and voters, that’s we all.

Some people hope that nuclear energy is a remedy to cure these problems. However, I do not see any justification for that hope. I will not speak about all the environmental, legal or financial problems or problems of acceptance. Just the simple facts make it difficult to believe in that technology as a long term sustainable strategy:

The forecasts of the International Atomic Energy Agency from 1975 and beyond projected nuclear power to rise to more than 1,000 GW of installed power in the year 2000. This proved to be far too optimistic. Even the actual forecast with a growth of between 10 – 30 percent until 2030 will be much too optimistic. Why?

Because installed reactors are ageing. Most of today’s reactors have been build between 1965 – 1985. This was the “golden age” of nuclear energy. In recent years the number of new reactors fell to below five reactors annually. After a period of several years of construction – about 10 in average – most reactors are connected to the grid. **Figure 3** provides the development of the cumulative nuclear power capacity world-wide. From the 510 reactors built world-wide more than 100 have already been decommissioned. On the average, old reactors were decommissioned after less than 25 years of operation. Now, if we assume, that the still operating reactors will be decommissioned after 40 years in average, we soon will experience a rapid decline of nuclear power capacity, declining from 370 GW now to less than 100 GW in 2030. In the upper right part of the figure you see the before mentioned forecast by the International Atomic Energy Agency. The next dotted line below is the projection of the International Energy Agency in its most recent World Energy Outlook. Below you also see a sketch of our LBST-scenario what we believe might be achieved if all efforts are undertaken to start a renaissance of nuclear power – at best we probably could keep the present level. Much more realistically however we will experience a decline of installed capacity.

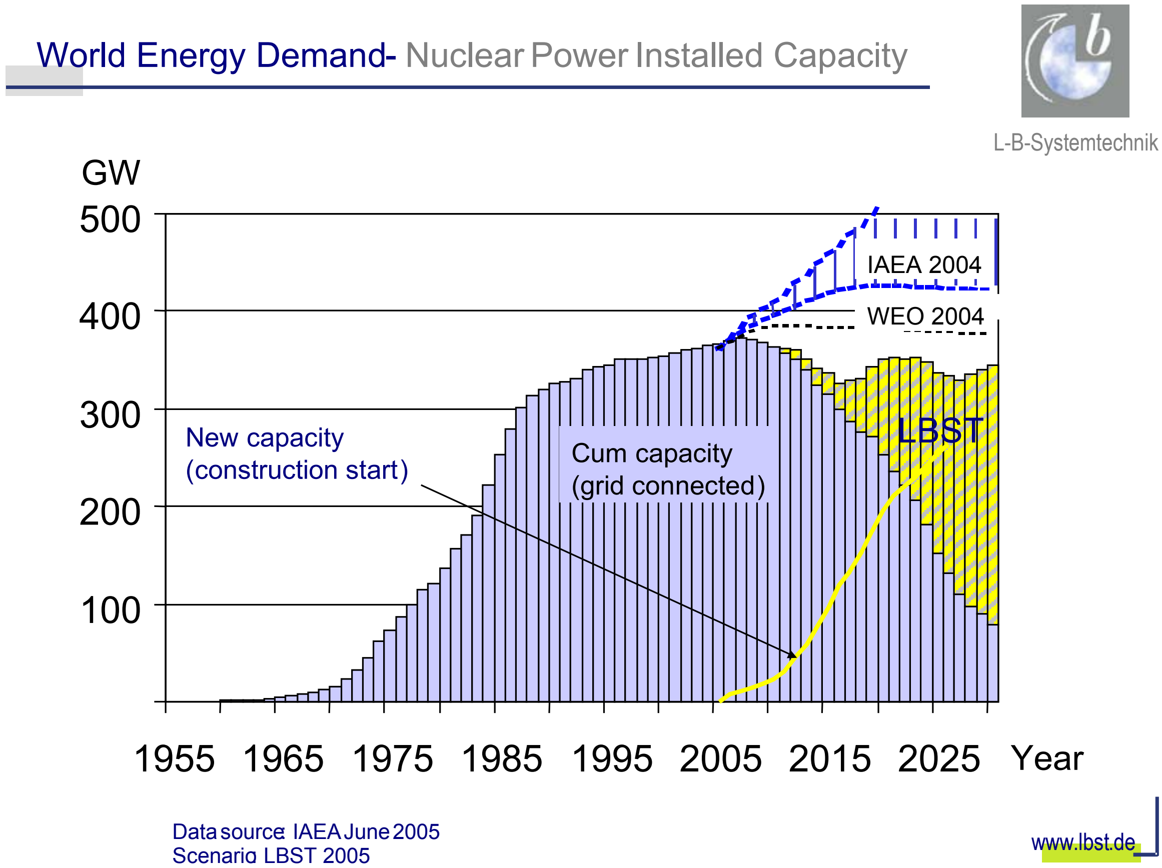

Figure 3: Installed capacity of nuclear power plants and various forecasts

Figure 4 provides an overview of the nuclear fuels resource uranium. The upper part sketches the uranium used for nuclear weapons. Let us assume that this amount will remain constant for the next 25 year. Below you see the amount which is already consumed by the nuclear power plants in operation. If the present capacity will remain constant for the next 25 years we can simply extrapolate the total consumption to 2030. This will use up all our remaining uranium reserves, including the amounts stored from nuclear disarmament and the reprocessing plants. Even if additional uranium resources which are believed to be mined at costs below 130 $ become available, these resources would be exhausted by about 80 percent.

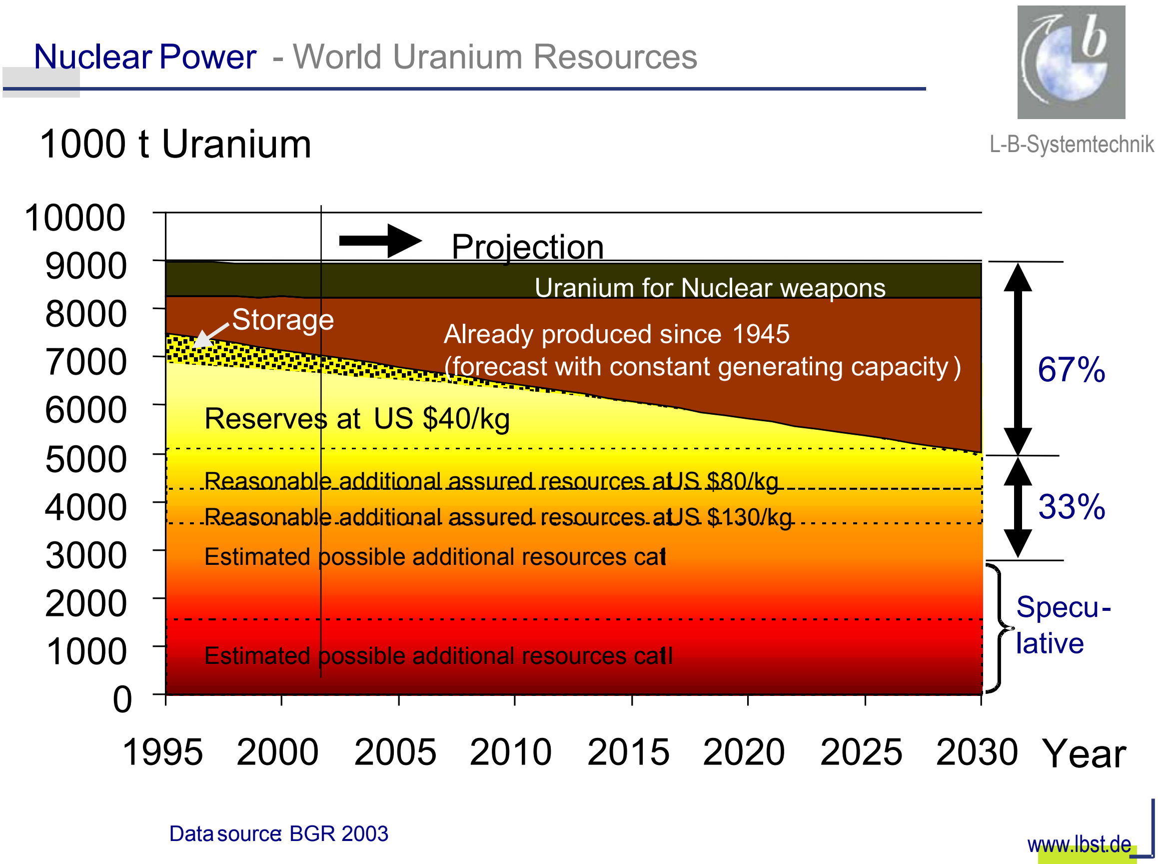

Figure 4: World uranium reserves and cumulative uranium consumption

Further estimated possible additional resources mentioned have a probability of realisation of between 5 – 50%. Most of them are highly speculative and probably will never be extracted. This confronts us with the fact that until 2030 about 2/3 of the uranium will be extracted, if the capacity remains at present level. This makes an increase of nuclear power over the next years almost impossible. Only a fast introduction of nuclear breeding reactors could become a possible loophole. Yet at present, not any change in this direction can be observed, instead, almost all important nations have strongly reduced or even stopped these activities.

There are plenty of coal resources available. At present production level, coal reserves would probably last for another 180 years. If we assume a bell shaped production pattern and adapt this to the reserves and the historical growth rate, we can estimate that coal production will peak around 2050 – 2060, assuming an increase of about 60 – 70 percent over the present production rate. This is sketched in **figure 5**.

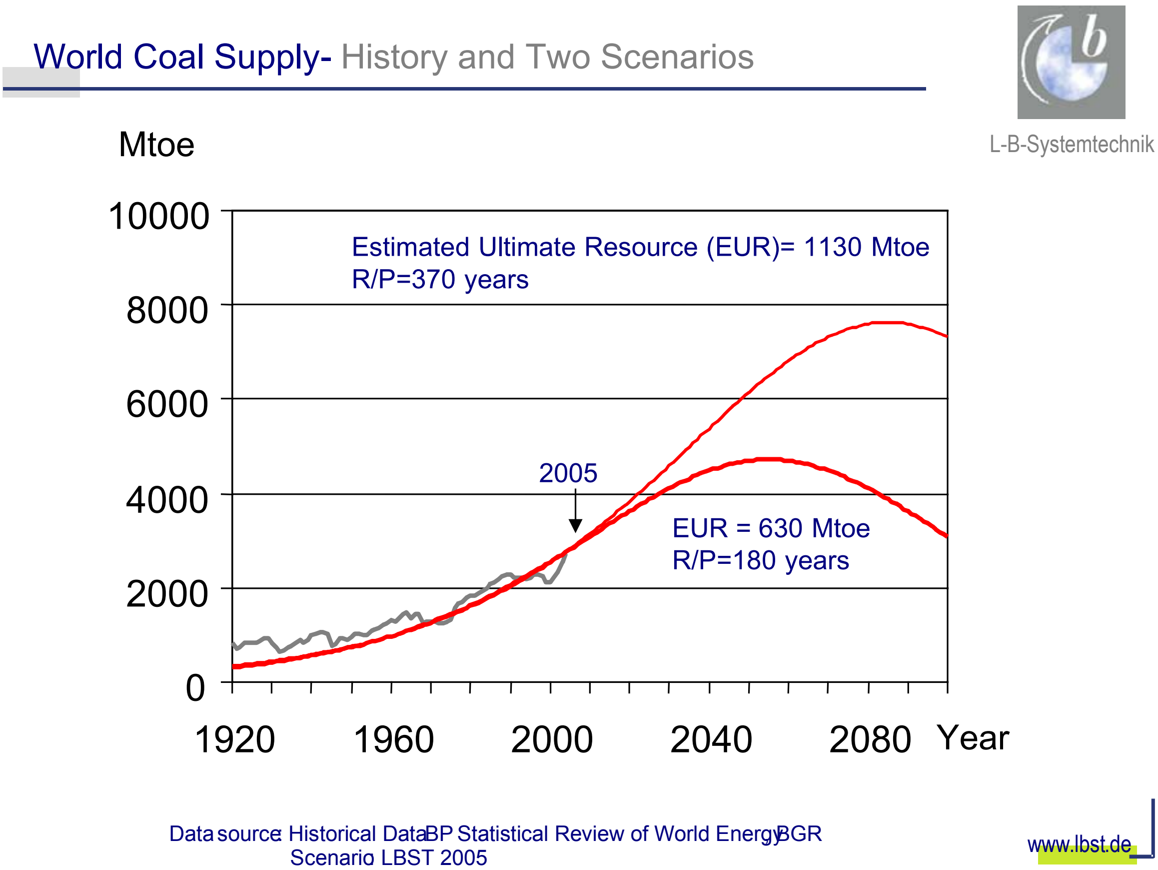

Figure 5: Possible world coal production profiles based on 180 years and 370 years of reserves

If we for the moment assume an unrealistic doubling of present reserves, this production peak could be delayed until 2080 and to higher production levels.

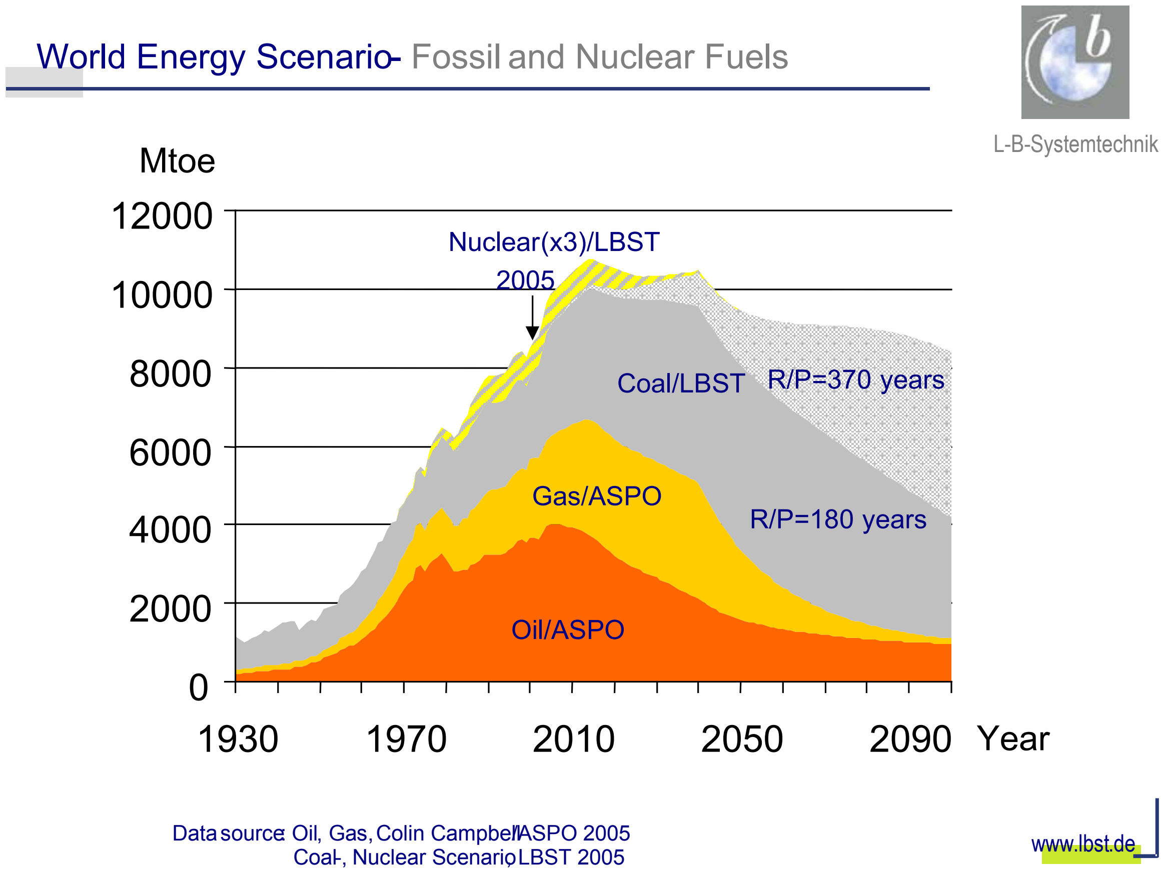

Figure 6: Possible scenario of future production of fossil and nuclear fuels

Figure 6 brings the possible individual developments into perspective. The oil production profile is shown at the bottom as outlined by Colin Campbell and the ASPO group. The natural gas production profile is also taken from their publications. According to these scenarios, oil will peak before 2010, gas will reach a plateau at 2015 which will eventually turn into decline by 2025. The top layer represents the scenarios for coal production and nuclear energy as outlined above. This sketch illustrates the huge gap in energy supply which is created by declining oil and gas production. At best, coal might flatten the decline for a few years, and nuclear energy is almost irrelevant in that context. In addition to this figure, we have to ensure, that any new fuel must substitute the quality of declining oil. In other words 40 – 50 percent will be lost due to transformation to transport fuel, irrelevant if “gas to liquids”, “coal to liquids”, “coal to hydrogen” or “electricity to hydrogen” will be the new fuel technology of choice.

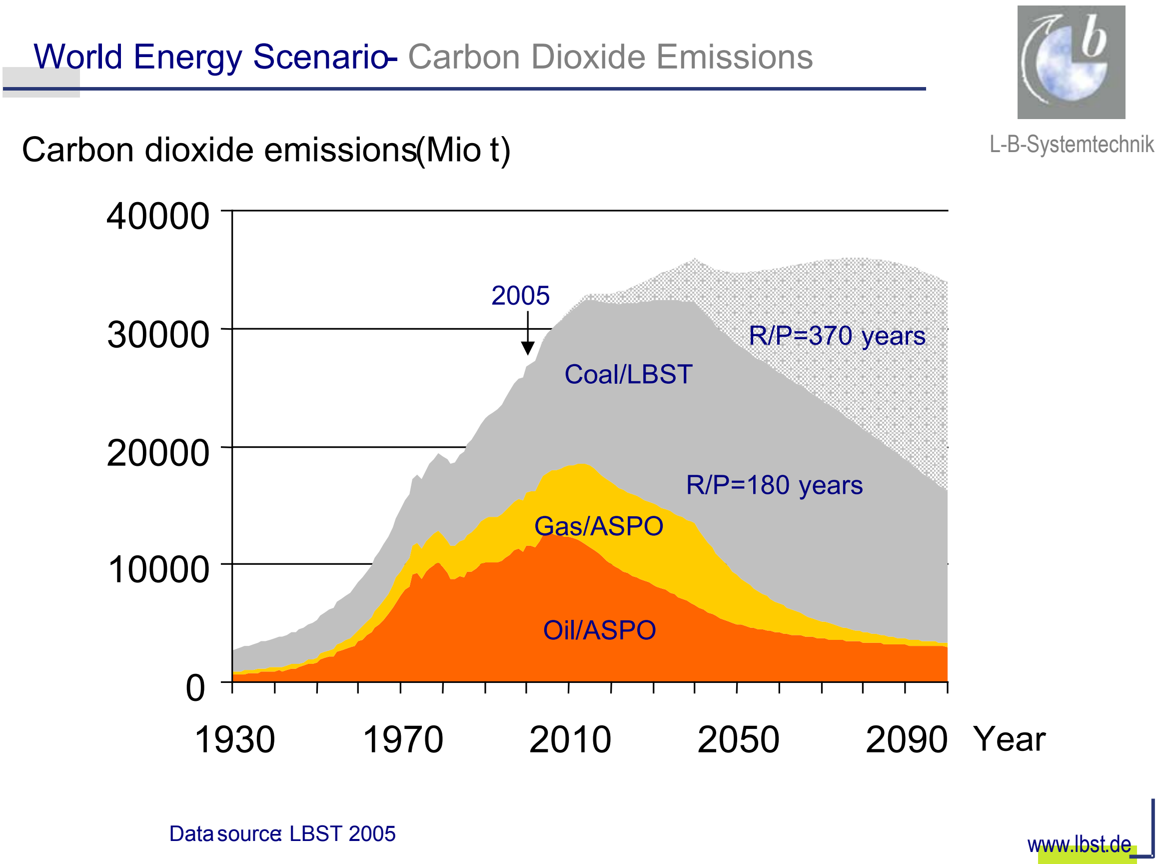

Figure 7: Carbon dioxide emissions according to the production profiles as outlined in figure 6

Figure 7 presents the implication of these scenarios for climate change. Though oil and natural gas are declining over the next decades, the carbon dioxide emissions would remain constant at least until 2030 at present production levels. Sequestration of carbon dioxide cannot be expected to start before 2020 at reasonable amounts – if at all. I have my serious doubts on its large scale realisation in general.

Now let me switch to the final part of my presentation, from problems to solutions. What could be the contribution from renewable energies to remedy these challenges?

For such a scenario we have calculated a growth function for each region and for each technology which starts exponentially, and approaches a saturation level. This is sketched schematically in **figure 8**.

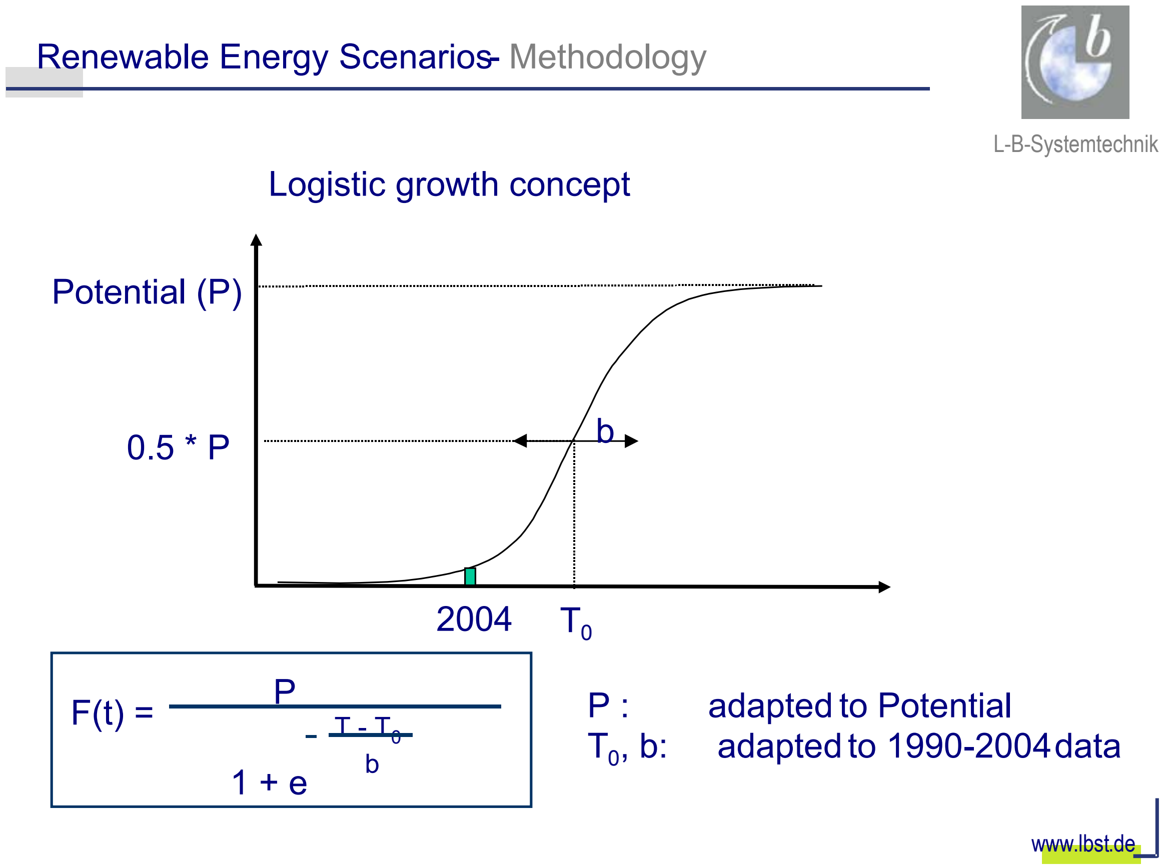

Figure 8: Calculation of the market penetration of renewable energies

The parameters for this simulation are adapted to the historical growth patterns and to the estimated potentials, which are expected to be reached one day. These potentials are based on a detailed analysis of literature and own calculations. All these numbers have a large range of uncertainty. Consequently, lower boundshave been used in all calculations.

Typical examples for these calculations are the development of solar thermal collectors in China (**figure 9**), of photovoltaic applications in OECD Pacific (**figure 10**) or of wind energy in South Asia (**figure 11**).

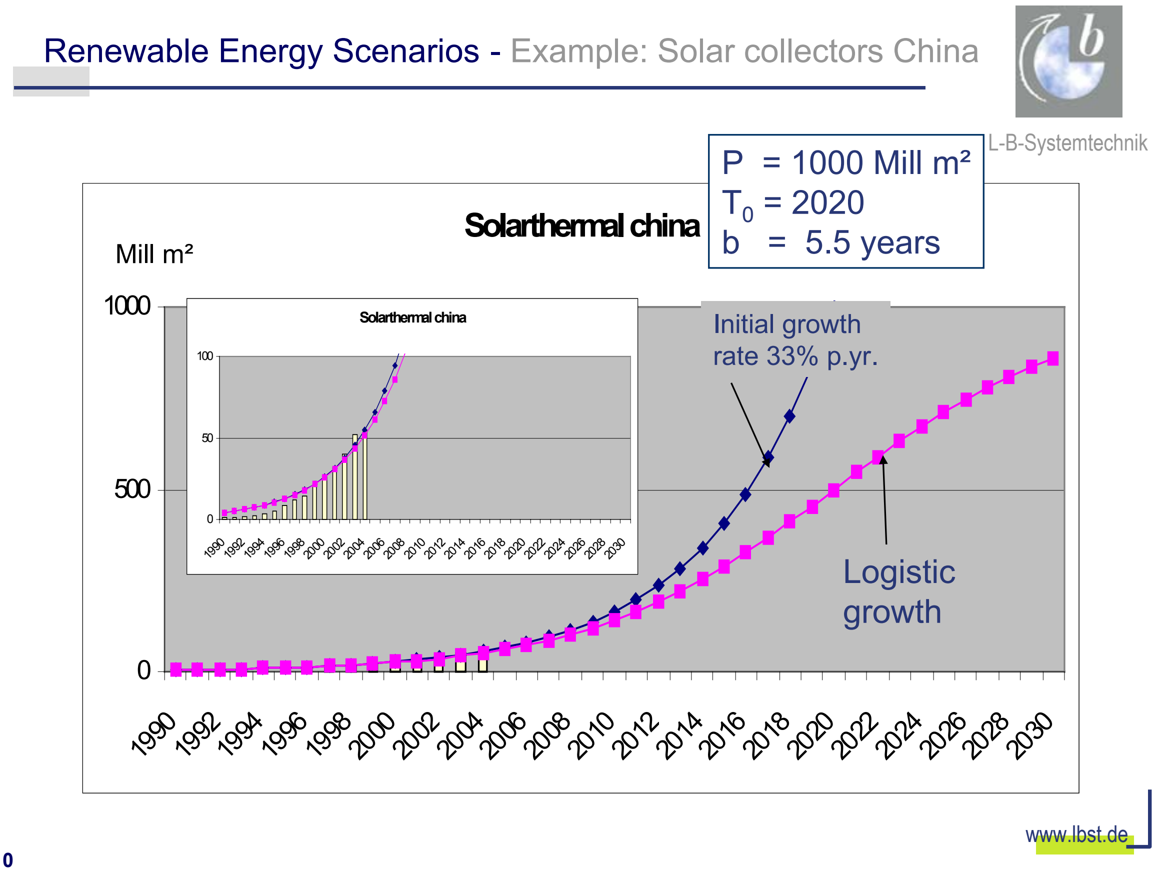

Figure 9: Market penetration of solar thermal collectors in China

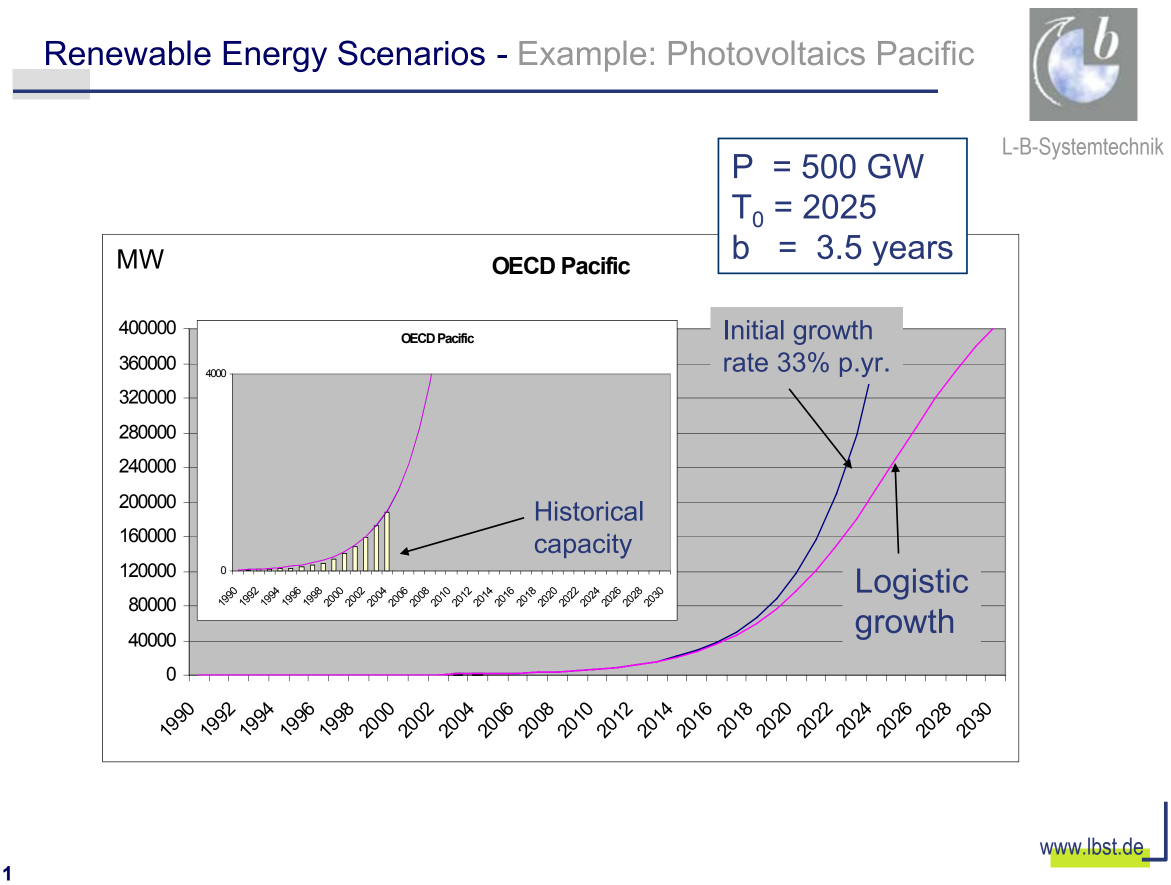

Figure 10: Market penetration of photovoltaic applications in OECD Pacific

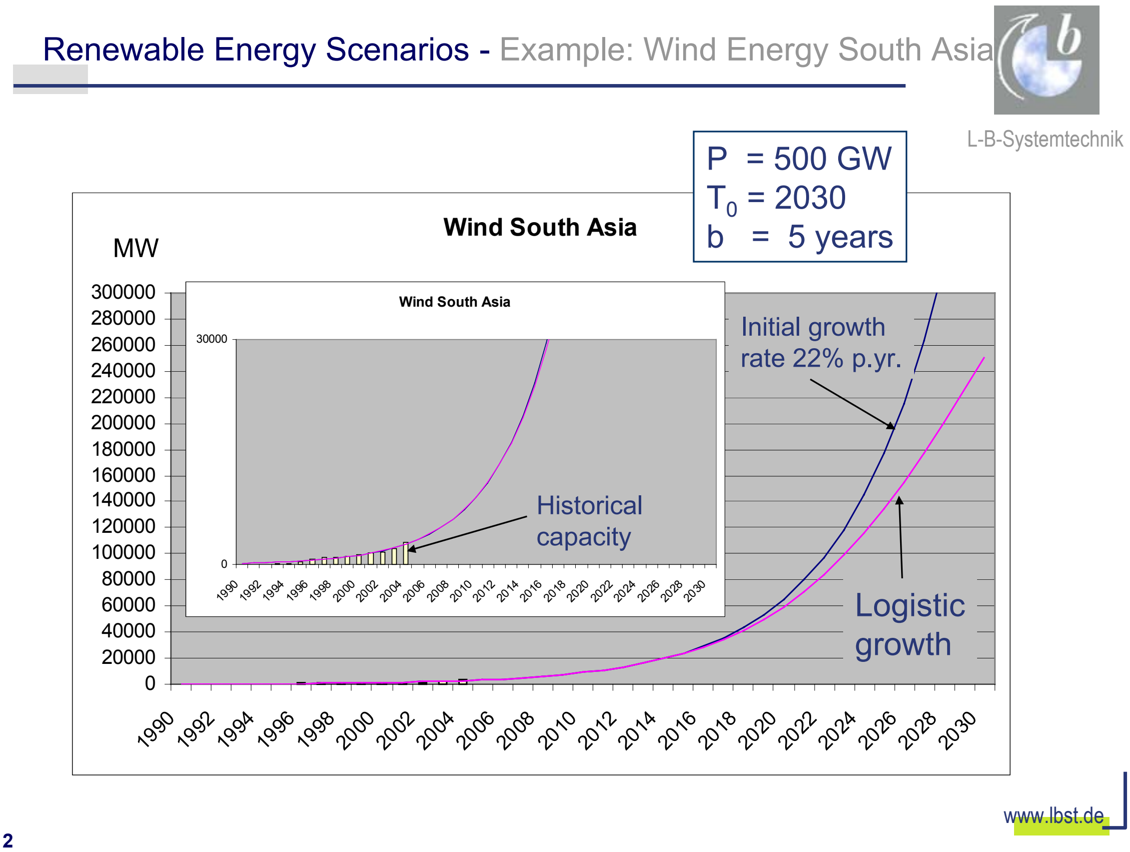

Figure 11: Market penetration of wind energy use in South Asia

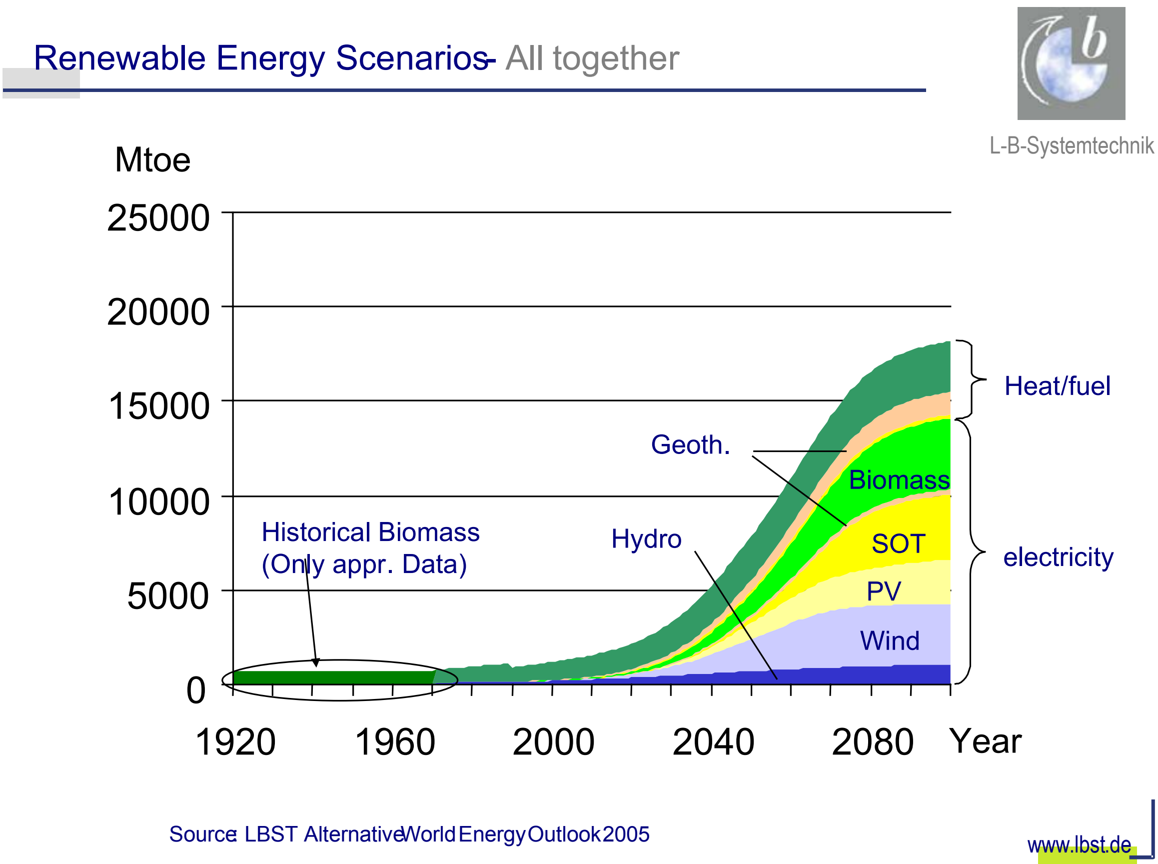

Figure 12: Market penetration of all renewable energy sources

Figure 12 summarises the expected growth of solar energy applications until 2100 in aggregated form. It represents the sum of the development potential for each technology in each world region. In general it is found that in the long run plenty of renewable energy will become available. The capacity increase of renewable energies might eventually reach their maximum around 2050. But most important: renewable energies will supply most energy in form of electricity and not as fuel or heat.

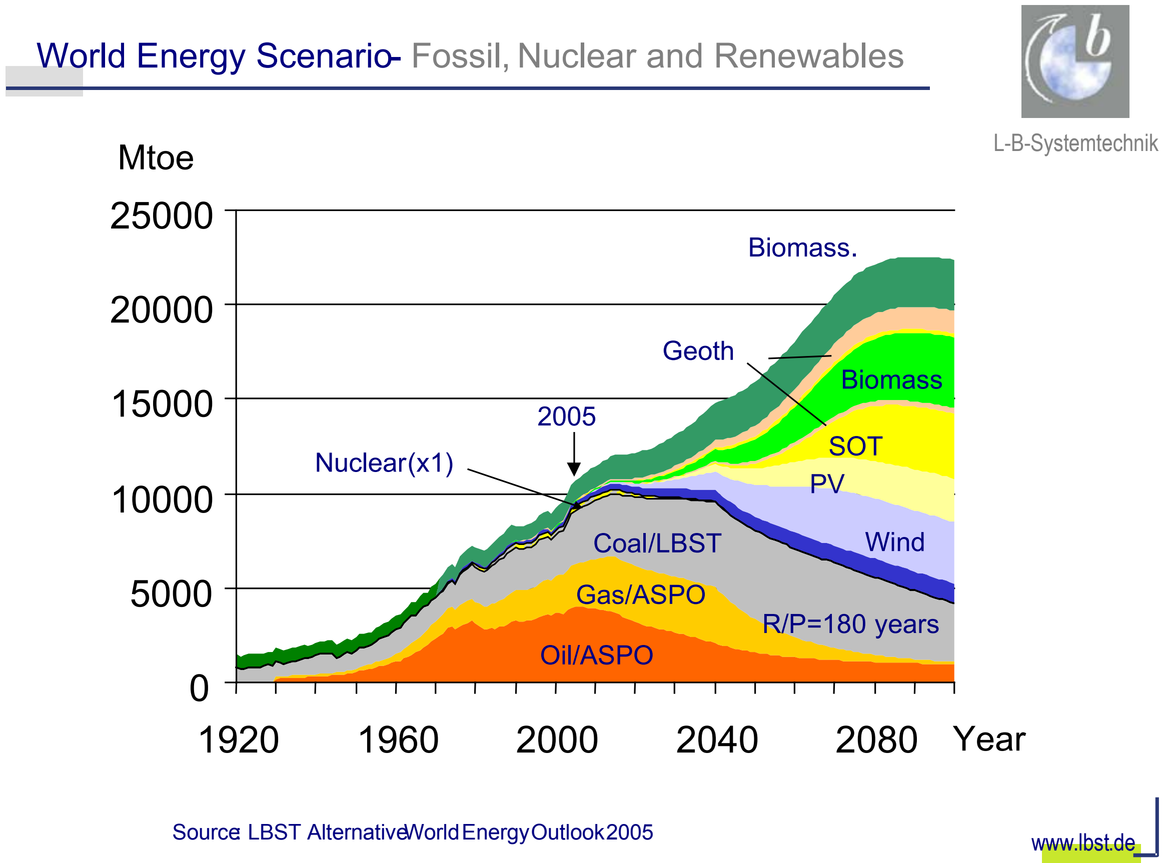

Figure 13: Forecast of an alternative world energy scenario until 2100 – the transiton from fossil fuels to renewable sources

Figure 13 provides an overview of our full Alternative World Energy Scenario including the declining supply of fossil resources at the bottom which is steadily substituted and extended by the growth of renewable energy additions. In this graph, nuclear energy is treated with the same conversion factor as renewables to give evidence of its minor importance. From our analysis we come to the conclusion that a transition from today’s fossil fuel based energy system to a sustainable long term strategy based on renewable energies will be possible. Clearly, the major reason is that no long term alternative is foreseeable. Also, wehave to concentrate on the crucial transition period which we might expect during the first quarter or half of this century.

Let me summarize the basic features of this crucial transition period in my concluding remarks:

We will experience a decline first of oil and later also of natural gas. The remaining energy supply gap can only partly be filled with coal. But this would increase carbon dioxide emissions to unacceptable levels.

Declining oil and natural gas supplies for stationary applications of electricity and heat production are relatively easily substituted by energy efficiency measures and strongly rising contributions from renewable sources. Probably we will have plenty of electricity but much too less fuels for transport. A serious fuels deficit will develop over time which can only partly be compensated by efficiency improvements along the whole transport chain.

Various strategies to produce synthetic fuels arise: Either hydrogen from electricity or hydrogen and synthetic liquids from the remaining coal reserves which could be phased out from the electricity sector. But whatever option we choose, we probably will have a serious change of our economic patterns, because the new technologies are much more complicated. The transport properties of fuel alternatives in terms of handling and energy density are less favourable than oil has been. Therefore the introduction of alternative fuels will be slower and more expensive but will probably be partially compensated by higher energy efficiencies in end-use. Therefore declining oil supply will probably result in declining transport intensity. This will imply declining distribution activities, and therefore declining production levels of goods.

In other words our today’s economic principles are endangered. The challenge will be to master that transition period in a compatible and controllable manner. The path between economic disruptions on one side and ecological disruptions on the other side is very narrow. The later we start to realise the real challenge and necessity for drastic changes the more problems we will face. Instead let us start to think in a positive way how to shape this transition period! Let us build a vision and follow that road.