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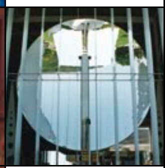

No. 17 / NOVEMBER 2006

ENERGIE-SPIEGEL

FACTS FOR THE ENERGY DECISIONS OF TOMORROW

Clean Energy for China

Energy is key to prosperity, but its use is often strongly opposed to sustainable development. So the current economic boom in China is accompanied by major environmental problems. The worst damage is due to air pollution from burning coal, China's number one energy source. Through the China Energy Technology Program (CETP), PSI and its research partners searched for ways to reduce these emissions.

China is growing wildly and unstoppably. In 2004 the world's most populous country already consumed 55% of the cement and 36% of the steel produced globally. Since 2001 China's highway network has more than doubled, and is now the second largest in the world after the USA. Since 2000 the number of personal autos has climbed from 6 to about 20 million. And China is not alone. India is also exhibiting significant economic growth. If such growth continues, China will exceed the USA's economy in gross domestic product (GDP) by 2050. And India will replace Germany in third place, even though the GDP per capita of both countries will lie far below the American level.

At the same time an alarming gap exists between the rich and poor. 380 million Indians live on less than one dollar per day. Half of the children suffer from malnutrition. Two things must be recognized: the energy hunger of these populous countries is far from satiated. And their energy policy decisions will have very large global consequences for energy use and the climate.

China's energy future can be designed to be more sustainable. The results of the CETP show that the necessary investments will repay themselves many times over. And reducing regional air pollution by replacing coal power plants with gas plants, nuclear energy and renewable energy systems will also reduce CO_2 emissions – which is important for the world as a whole.

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Coal – China's blessing and curse

Bild: bab.ch/photonostop

China's economic boom is built on coal. It provides two thirds of China's primary energy supply, and will remain the number one fuel for the foreseeable future. Half of this coal is burned in power plants and supplies three quarters of China's electricity needs, which have climbed steeply in the last years – along with petroleum consumption. China already uses more coal than the USA, Europe and Japan together – with annual growth rates of 14 % in 2004 and 2005 alone.

Every week a new coal power plant goes into operation in China, delivering electricity to hundreds of thousands of households. The emissions from innumerable smokestacks burden the air, water and soil, causing enormous health

> The USA and China together are responsible for about 40% of global CO_2 emissions

damage, and shortening the life expectancy of the population. Ecosystems are acidified and harvests reduced; costs for medicine and hospitalization climb. Together with labor and income losses, these damage costs are a great burden to economy – representing about 6 to 7 percent of GDP. Air pollution in China is especially serious because the population density in industrial areas is significantly higher than in Switzerland and more people are directly affected.

The global dimension: CO_2

The consequences of these emissions are not just regional. China causes about a fifth of global air pollution from sulfur, contributing to mostly local health damages. But by its burning of fossil fuels China also produces around 17 % of global CO_2 emissions, contributing essentially to climate change. The USA and China together are responsible for about 40 % of global CO_2 emissions. Today the USA leads the emissions list. With about 20 tonnes of CO_2 per capita per year, every American is responsible for about 6 times more CO_2 emissions than each Chinese. According to current trends total US emissions will climb by a third in the next 20 years, while China's will double. The United Nations Framework Convention on Climate Change warns that "waiting for certainty before taking action, or precautionary measures, runs the risk of being too late to avert the worst impacts." Limiting the already visible damage to current levels is urgently needed, but reversing this damage may not be possible. And further, "sustainable economic growth and development are essential ingredients of successful policies to tackle climate change." The signers of the UN convention, industrialized as well as developing countries, share this view. But the relative emphases within different possible sustainability strategies are a matter of opinion.

Particulates: Tiny particles (smaller than 2.5 µm) are more dangerous than larger ones (PM_{10}); primary particles direct from the emission source are distinguished from secondary particles (sulfates, nitrates and organic compounds) created in the atmosphere from SO_2, NO_X and unburned hydrocarbons.

Sulfur dioxide (SO_2): As the precursor to sulfates, SO_2 is a major cause of chronic and acute respiratory disease; it also causes crop and ecosystem damage through soil acidification.

Nitrous oxide (NO_X): The precursor to nitrates; NO_x also promotes the development of surface ozone, causing plant and respiratory damage.

Ammonia: Plays a central role in the development of dangerous secondary particulates (ammonium nitrate and sulfate).

Greenhouse gases (CO_2, CH_4, N_2O, etc.): Responsible for the greenhouse effect and climate change.

Different Priorities

The greenhouse effect is a very serious global problem, and must be tackled as such. The developing countries are right in pointing out that the industrialized countries have contributed far more to creating this problem, and they have more means to contribute to its remedy. The industrialized countries see environmental protection as an integral part of general development goals. Developmental and sustainable aspects should be reviewed with equal emphasis. But in countries like China and India, the local and regional problems are given increased attention – the pollution of air, water and soil and their detrimental consequences cannot be overlooked. Far less priority is given to global environmental protections, global warming and climate change – exactly the concerns that stand at the top of the energy agenda for us.

	Unit	Year	CH	EU25	USA	China	India	World
Total area	Million km^2		0.04	4	9.3	9.6	3.3	149
Population	Million	2006	7.5	461	298	1'314	1'095	6'600
Gross domestic product (GDP)	Billion US $	2005	364	13'927	12'439	2'279	749	44'168
GDP/capita	US $/capita	2005	48'845	30'473	41'917	1'411	678	6'851
Economic growth	%/year	2004	2.3	2.4	4.4	9.5	6.5	4.8
Primary energy demand	Mio. t oil-eq	2004	29	1'719	2'332	1'386	376	10'224
Primary energy demand per capita	GJ/capita & year	2004	162	158	333	44.7	14.8	67.2
Primary energy demand, coal	Mio. t oil-eq	2004	0.1	307	564	957	205	2778
Share of coal in primary energy demand	%	2004	0.3	17.9	24.2	69	54.5	27.2
Installed generation capacity	GW_{el}	2004	17.4	660	942	391	131	3'736
Electricity produced	TWh/year	2004	63.5	2'980	3'979	2'080	631	16'599
Growth in electricity use	%/year	2004	1.9	1.7	1.6	15.2	5.3	4.3
CO_2 emissions, total	Mio. t/year	2004	41	3'789	5'912	4'707	1'113	27'044
CO_2 emissions/capita	t/capita & year	2004	5.5	8.3	20.2	3.6	1	4.2
SO_2 emissions total	Mio. t/year	2000	0.019	8.7	16.5	20	5	98
SO_2 emissions/capita	kg/capita & year	2000	2.6	19.2	58.5	15.8	5	16.1

Dimensions and Shares: Industrialized and developing countries in comparison.

Urgently needed investments

The one-sided electric sector in China can be transformed so that it is significantly more climate friendly, supports economic growth and at the same time improves the environment. What do more sustainable electricity supply strategies cost? The research results of PSI for the province of Shandong show that these costs are significantly less than the cost of damages without such remedial measures.

It is already possible to significantly reduce SO_2 emissions with modest investments in filters and modern coal technologies, as well as through the use of coal with low sulfur content. New, more efficient coal plants save coal, and thereby automatically reduce CO_2 emissions. CO_2 can also be reduced at an economically bearable price with investments in natural gas plants, and even more by using nuclear energy and hydro power. These technologies also simultaneously reduce emissions of SO_2, NO_x and particulates. The savings in health costs alone achieved through the secondary benefits of such climate-friendly policies would exceed the direct costs of all the above measures.

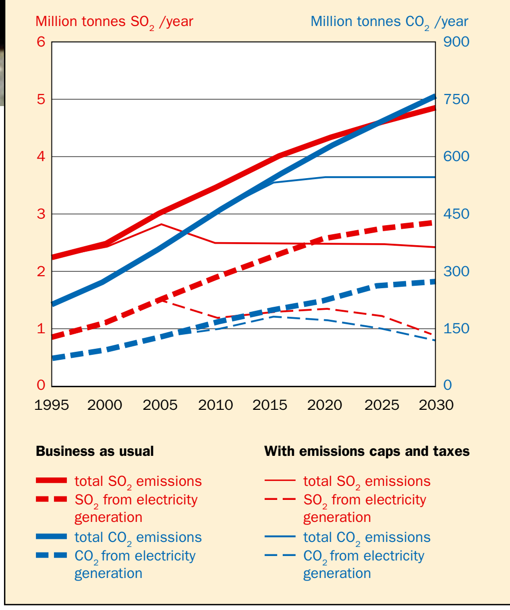
Together with China's Stakeholders

These and many other results were obtained from the China Energy Technology Program (CETP, see insert page). Stakeholders from industry, science and local and national government interests investigated together for the first time how China's energy supply could be designed to be at the same time economically, ecologically and socially sustainable. The detailed modeling of future electricity supply scenarios was concentrated on the province of Shandong – with a population of about 90 million in a geographic area of 160,000 km^2 one of the most highly industrialized and energy-intensive regions of China. Shandong's electricity supply is based almost entirely on coal. The potential for the development of hydropower in Shandong is basically non-existent, the potential of wind power is limited, and the conditions for photovoltaic power or electricity from biomass are unfavorable.

> Environmental damages always cost more than clean energy

A sad inventory

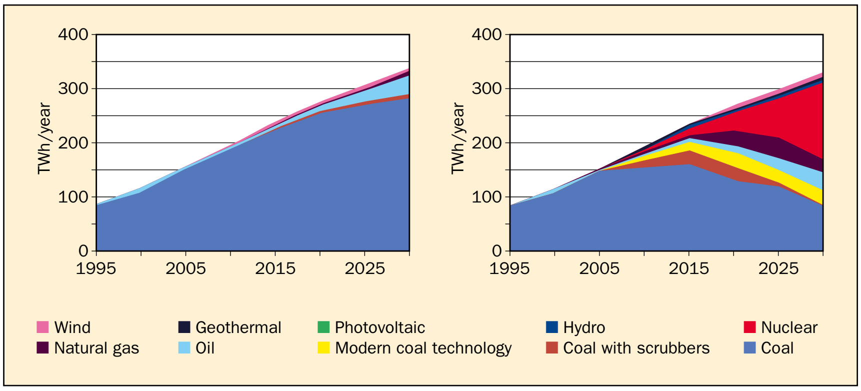
It was first necessary to inventory the current emissions of the coal economy. Then the spread and chemical transformation of these emissions were simulated and the health burdens on the population were estimated. The sad picture that emerges is this: every year in China about 9 million years of life are lost because people become sick and die more early from illnesses related to air pollution. If the electricity sector and its emission continue to grow, the consequences will be even more drastic (see insert page).



CO_2 and SO_2 emissions in Shandong: Same conditions as figure below. (Source: PSI, Kypreos et al.)

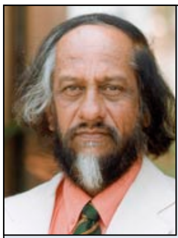
Avoiding emissions is cheaper

The decision-makers in the electricity sector have the power to avoid these grave consequences. Politically responsible measures would be to set and enforce low emissions caps, as well as raising taxes on fuels. This would promote the diversification of generation technologies. For Shandong that would mean that in addition to the current coal mix there would be not only modern coal technologies, but also more natural gas, nuclear energy and wind, and for China in general also more hydropower. Interest rates and fuel prices determine when and how much of the generation can be assumed by different "new" technologies. Low interest rates favor capital intensive technologies like nuclear energy and hydropower, while high rates favor natural gas. Emissions limits and taxes on greenhouse gases and sulfur dioxide are combined in the model with various scenarios for the development of load growth, fuel costs and capital costs. In this way the most cost effective solutions were found for each scenario and its assumptions. In all cases the total costs for cleaner energy in China were much lower than the environmental costs would otherwise have been.



Electricity supply scenarios for Shandong: Both assume a weakly growing energy demand (for China) of 5%/year and stable prices for fossil fuels. The left graph shows development with "Business as Usual". The right graph shows development with emissions caps and taxes on CO_2 and SO_2, significantly promoting diversification into cleaner technologies. (Source: PSI, Kypreos et al.)

"High time for firm action against global warming"



Dr. Rajendra K. Pachauri is Chairman of the Intergovernmental Panel on Climate Change (IPCC) and General Director of The Energy and Resources Institute (TERI) in India. He was active for many years in academic research and teaching, and as an advisor to the Indian government on energy issues. He is committed to promoting sustainable development as a member of advisory boards in the national and international energy economy, as well as for NGO's in the energy and environment sector.

What are the major reasons to take global warming very seriously from a global point of view?

The scientific evidence of human interference with the earth's climate system has now become so strong that human activities need to be altered. The impacts of climate change are becoming apparent already and have a wide range of adverse effects that may affect human welfare and all forms of life on earth adversely. Mitigating climate change and adapting to inevitable impacts also serves the objectives of sustainable development – a path human society has to move along, or else this generation as well as those yet to come would find it very difficult to meet their very basic needs.

And from the point of view of a country like Switzerland?

Apart from the points already mentioned the disruption in the water cycle as a result of climate change and the rapid melting of snows on the mountains would not only have economic implications, but also affect the ecology in a manner that could have serious impacts on the natural systems.

For years science has been warning against CO_2 emissions and global warming. However the general public reacts rather passively. Why?

This attitude is changing. In several parts of the world there is now a willingness to take firm action to meet the threat of global warming. A good example is the recent decisions taken by the State of California, which would curb the emissions of greenhouse gases (GHGs) far beyond recent expectations. We also need leadership to guide the public, which unfortunately has been lacking in several parts of the globe.

Can CO_2 reductions and the necessary investments possibly be a topic in a country where 20% of the population suffers from malnutrition?

CO_2 reductions and matching investments in a country like India would be acceptable only if the developed countries take firm actions to reduce CO_2 emissions – unfortunately this has not been the case thus far. Also, technology transfer should be facilitated from the developed to developing countries, so that a number of measures could be implemented without additional cost and with local environmental benefits.

> We are likely to see a major energy transition worldwide in the next 20–25 years

Would you agree that from the perspective of developing countries the secondary benefits of climate policies may be more important than the primary ones?

Absolutely. In a number of developing countries the secondary or co-benefits of climate policy may be even more appealing than reduction of GHG emissions. For this reason developed countries should help them reduce general air pollution rather than put pressure on the developing countries to reduce GHG emissions. GHG reduction would then be an incidental benefit serving a global purpose.

How can developed and emerging nations co-operate in reduction and climate issues?

Co-operation will work only if the developed nations take firm and adequate action to reduce GHGs, of which there is as yet inadequate evidence. Also, helping the emerging countries would greatly increase their credibility.

May climate change be not only a threat but also an opportunity?

Absolutely. Actions to mitigate climate change could be used for addressing sustainable development, e.g. shifting from fossil fuels to renewable energy would be desirable.

What role for renewable and nuclear energies do you foresee in the struggle against the global climate change? In industrialized countries? In the developing world including India?

I think the role of renewable and nuclear energy technologies is bound to grow. In the industrialized countries they are likely to provide a greater share. The larger developing countries will certainly increase their share of nuclear as well as renewable energy, but most developing countries will not have access to nuclear energy solutions. Overall, we are likely to see a major energy transition worldwide in the next 20–25 years.

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.

GaBE works together with:
ETH Zürich; EPF Lausanne; EMPA; Massachusetts Institute of Technology (MIT); University of Tokyo; European Union (EU); International Energy Agency (IEA); Organisation für Economic Cooperaton and Development (OECD); United Nations Organization (UNO)

Air pollution with dramatic consequences

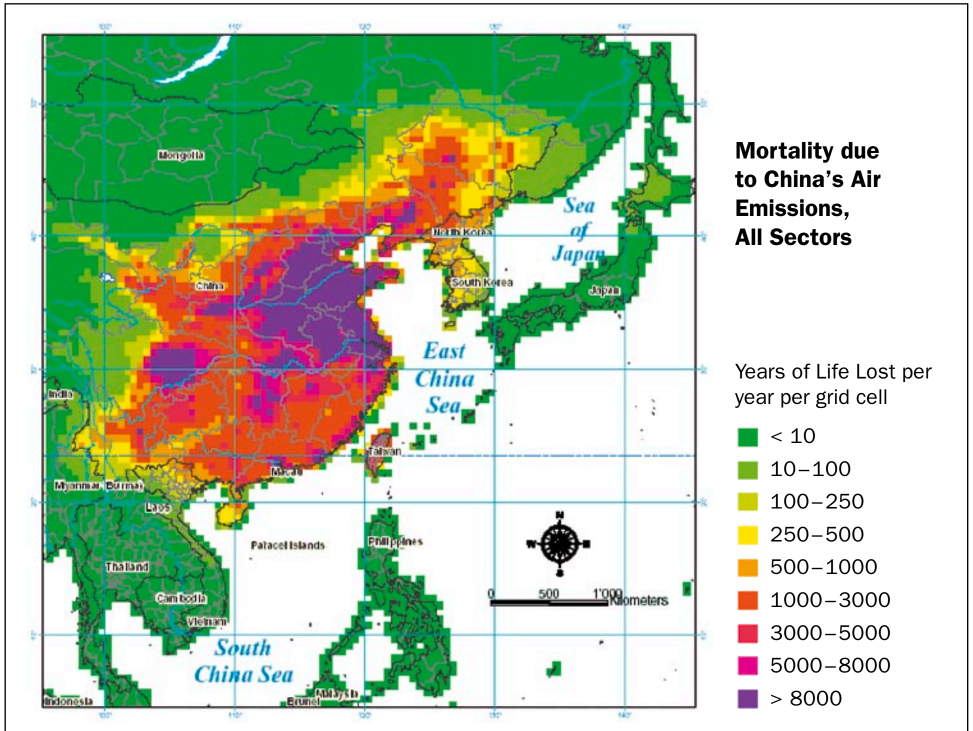
High concentrations of air pollutants can be a deadly burden for the heart and lungs. They predominantly cause chronic illnesses like bronchitis and asthma, but can also cause cancer. They irreparably reduce the proper growth of children's lungs, and the life expectancy of the whole population.

The health damage that may be ascribed to the Chinese electricity generation sector alone costs 7.3 US cents/kWh – about double the average generation cost. The figure on the left below shows the annual years of life lost in China due to air pollution (all emissions from all sectors). Each grid cell represents about 2500 km^2. In Shandong the annual years of life lost (YOLL, see box) can reach over 8000 per cell; in large parts of China it can be 1000 to 5000 YOLL per cell. For all of Shandong this represents about 1.1 million YOLL every year, i.e. 12 % of the China's total loss of about 9 million YOLL per year.

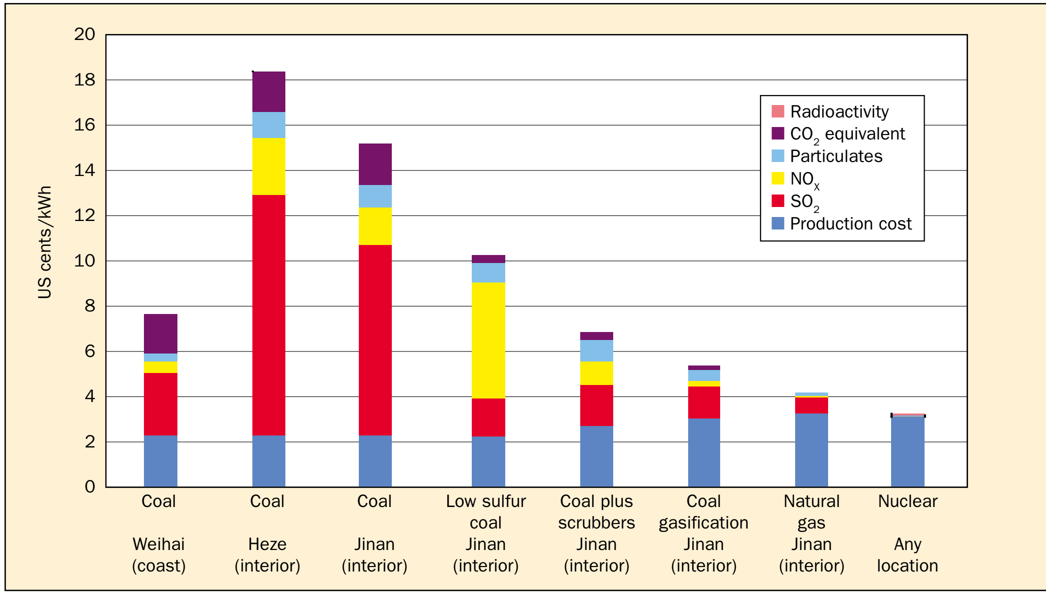
Internal and external electricity costs

Depending upon where a coal power plant is located, the external costs due to health and environmental damage can be up to 7 times higher than the production costs (internal costs, see figure on the right below). The city of Heze lies in the interior and has a high population density. In contrast, Weihai lies on the coast, where only a portion of the emissions are a burden to the population. If the plants in the interior provincial capital of Jinan were to burn low sulfur coal the external costs would sink. Flue gas desulfurization would further improve the situation. The most environmentally friendly and economic solution for coal is via gasification. Still further reductions in total cost can be achieved by substituting natural gas for coal, and the lowest health damage costs are caused by nuclear energy. Environmentally friendly solutions raise production costs very little in comparison to total costs.

How are health impacts measured?
One of the most important indicators for human health is life expectancy. The measure of Years of Life Lost (YOLL) is used to measure health damages. Many victims die prematurely due to acutely high concentrations of air pollutants. But the major share of years of life lost is due to chronic illness caused by less severe burdens over many years. The reduction in life expectancy for individuals is summed to the total YOLL for the entire population.

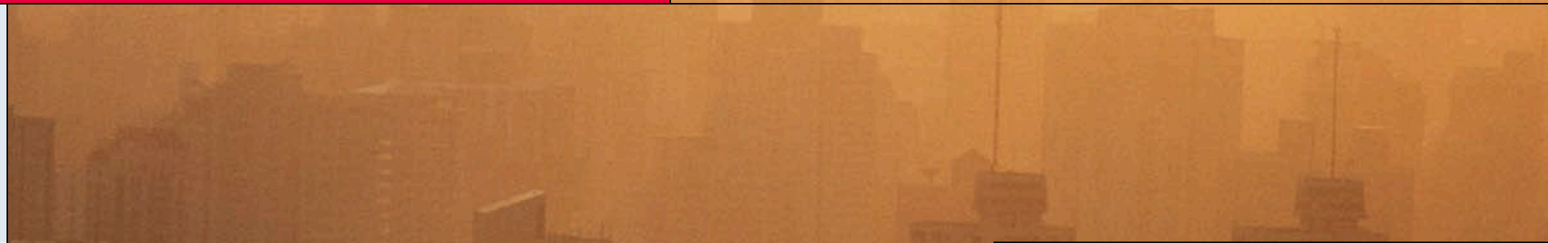


Current Mortality due to China's air emissions, all sectors. (Source: PSI, Hirschberg et al.)



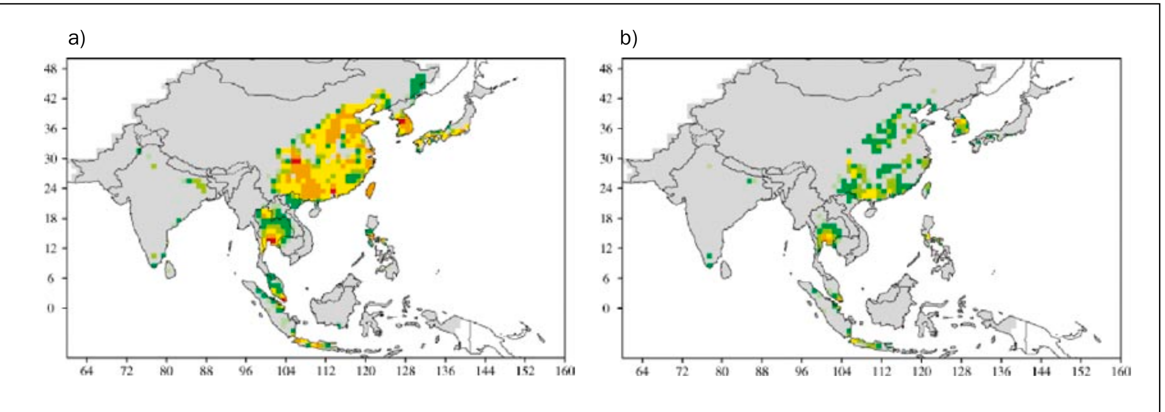
Total Electricity Costs by technology and city. (Source: PSI, Hirschberg et al.)

Sulfur dioxide: Making nature sour



SO_2 emissions are absorbed by water droplets in the air, and fall back to the earth as acid rain. This rain erodes building facades, can reduce crop harvests and leads to the death of forests and fish.

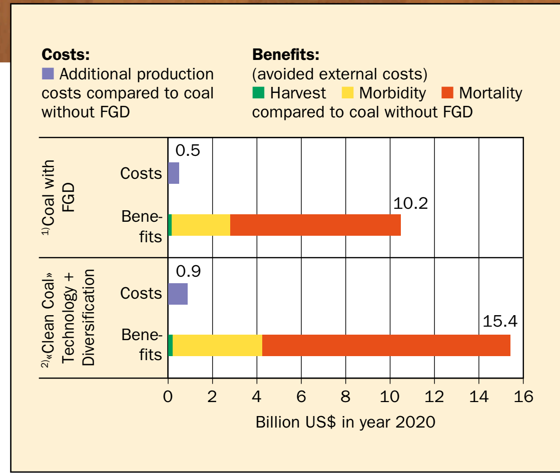
An ecosystem can bear the load of increasingly acid precipitation up to a critical point. If this is reached, then the acidification can cause significant destruction. Currently 25 % of China is designated as at risk due to acidification. Without any additional measures this endangered area will increase to 40 % by 2030, but with strong SO_2 control mechanisms the area might be reduced to 15 %, despite the forecast strong economic growth. High control levels on emissions would cost 13 billion US$ in additional costs per year for all of China in comparison to "Business as Usual."



Acidification scenarios for China, 2020: Regions with above critical sulfur loads are shown a) with minimal control measures, and b) with high control measures. Gray and light green regions suffer under lower loads, dark red under very high loads. (Source: PSI, Hirschberg, et al.)

Moderate costs, higher benefits

The comparison of additional production costs with the benefits through avoided external costs speaks very clearly for the use of cleaner electricity generation technologies. Power plants with desulfurized coal or combined cycle plants with integrated coal gasification may produce electricity somewhat more expensive (internal cost) than conventional power plants that run on pulverized coal. But the benefit of environmentally friendly "Clean Coal" plants is more than ten times larger than the additional cost in production over the usual cheap but dirty technologies. Illness and premature deaths decrease, and harvests rise. In Switzerland there are barely any external costs from the power sector that can be avoided, but these externalities do exist, caused instead by the transportation and heating sectors! With an environmentally friendly energy supply these costs could be reduced by an annual value of about 400 million Swiss francs (see also Energiespiegel 10).



Cost-benefit analysis (excluding CO_2 damages!) for two energy supply scenarios in Shandong (2020), in comparison to a scenario based on the continued use of coal without flue gas desulfurization (FGD). The clean scenarios are: 1) conventional coal with FGD, 2) retrofit/renewal of the current generation of power plants through retirement of old plants and retrofitting of FGD together with "Clean-Coal" technologies, use of nuclear energy and natural gas. (Source: PSI, Hirschberg et al.)

Interdisciplinary and international partnership The CETP was made possible by financing from ABB Corporate Research. The PSI study was performed within the framework of the Alliance for Global Sustainability in cooperation with: ETH Zürich and Lausanne, the Energy Research Institute and Tsinghua University in Beijing, the University of Tokyo, ABB China in Beijing and Jinan, as well as the Massachusetts Institute of Technology in Cambridge.

Stakeholder participation The participation of the most important stakeholders in China was of central significance. They included in Beijing the Chinese Academy of Sciences, the Development Research Center of the State Council, the Ministry of Science and Technology, the State Environmental Protection Administration, the State Power Corporation, and the Administrative Center for China's Agenda 21, and in Jinan the Shandong Economic and Trade Commission, Shandong Electric Power Group Corporation, and the Shandong Environmental Protection Bureau.

Literature references Integrated Assessment of Sustainable Energy Systems in China – The Energy Technology Program (2003). A. Eliasson & Y.Y. Lee (ed.); Kluwer Dordrecht, Boston, London, ISBN 1-4020-1198-9, with *interactive CD and Film* (see also http://gabe.web.psi.ch/projects/cetp/index.html)