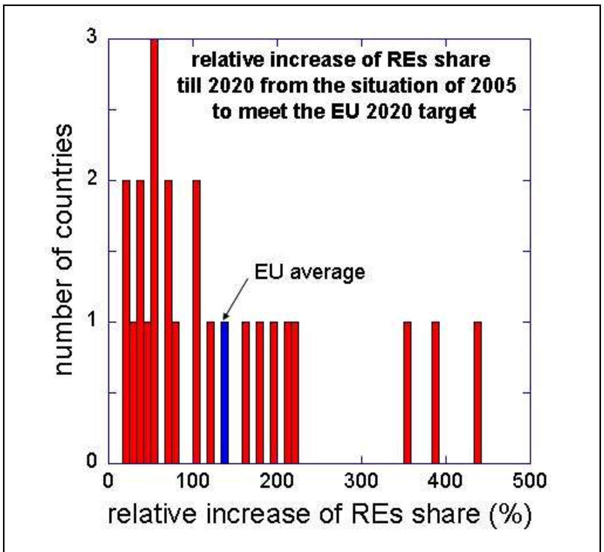
Summary report on the EPS/SIF energy meeting: Energy perspectives in Europe
Varenna, April 7. - 8.2008

One goal of the EPS energy working group (EWG) is to analyse all physics fields with relevance for the technologies of energy production, conversion, transmission and savings for their potential and the need for more research and development to unfold it. For this purpose, topical workshops are organised. Another goal of the EWG is to motivate national physical societies to form energy working groups (if not yet done) to introduce the physics related topics into the national debate. Following the invitation of the Italian Physical Society (SIF) the second meeting of the national EWGs was held in Varenna, April 7th and 8th. The following physical societies were represented and contributed with talks: Belarus, Czech Republic, Denmark, Finland, France, Germany, Italy, Lithuania, Norway, Portugal, Spain, Sweden (Academy), United Kingdom, and Turkey. Besides these presentations more on the local energy situation there was a talk addressing the energy related work done within Chemistry (Th. Lehmann; the talk is based on the position paper: Future Energy Supplies – the contribution of Chemistry- available under http://www.gdch.de/oearbeit/energie_en.pdf), a talk on the energy related activities of the European Academies Science Advisory Council, EASAC (S. Kullander), and summary talks on the previous topically oriented workshops in cooperation with the Condensed Matter Division and the Environmental Division (Th. Hamacher; separate summaries will be published). One talk introduced the scientific background of the EPS position paper: Energy for the future: the nuclear option (H. Freiesleben; http://www.eps.org/highlights/energy-for-the-future/). Programme and copies of the individual presentations can be downloaded from: http://www.sif.it/SIF/it/portal/attivita/energymeeting_it.

The European energy supply situation is very inhomogeneous. There are countries with nearly 100% CO_2-free, others with exclusively fossil-based electricity production. Some countries ban the use or future use of nuclear energy, for others, their electricity production is based on it and they build or plan new power reactors; some export electricity to a large extent other import it; some have used the last years to approach the 2012-Kyoto goals, others have moved away from it; some invest heavily in Renewable Energies (RE), for others, they do not play a major role. Despite this disparity, Europe has specific goals to which Dr. Menna from the European Commission reminded the audience in his introductory talk. The most ambitious ones are the 2020 targets – to increase the share of



REs and the energy efficiency each by 20% and to reduce GHG (greenhouse gas) emissions also by 20%.
In order to meet these goals, all EU-27 countries have to increase their present RE share of 7%. The extent, to which this has to happen shows a wide distribution which again portrays the inhomogeneity of the EU energy supply situation.
Fig. 1 shows in a histogram the relative increase in shares of REs, the different countries have to achieve to meet the EU-2020 20% target. Reference is the 2005 situation. Three countries do not fit onto the plot because they have to increase their RE share by more than 500%.

The implication of the CO_2 emission target was exemplified by the German situation. Germany will meet its Kyoto goals owing to saving measures, the replacement or upgrade of inefficient coal power stations in the former GDR and the reduction of the industrial activities in this region. To achieve the 2020 goal requires, however, a drastic increase of the effectiveness of the measures taken between 1990 and today.

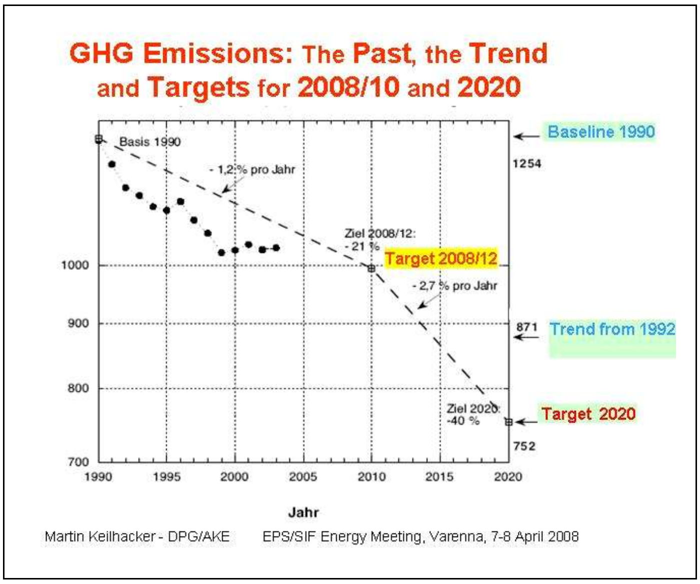


Fig. 2 plots the reduction in GHG emission of Germany from 1990 on (the reference year) along with the projections to the two targets, the Kyoto target for 2012 and the national 2020 target.

Also the energy efficiency has, in all European countries, to be increased clearly beyond the present measures. Between 1971 and 2005, the annual increases in energy intensity were ~ 25 Mtoe/year calculated on the technology basis of 1971, however. For the EU plans, the energy efficiency has to be reduced by 30 Mtoe/y, but now on the basis of the present level of energy intensity and the present technology.

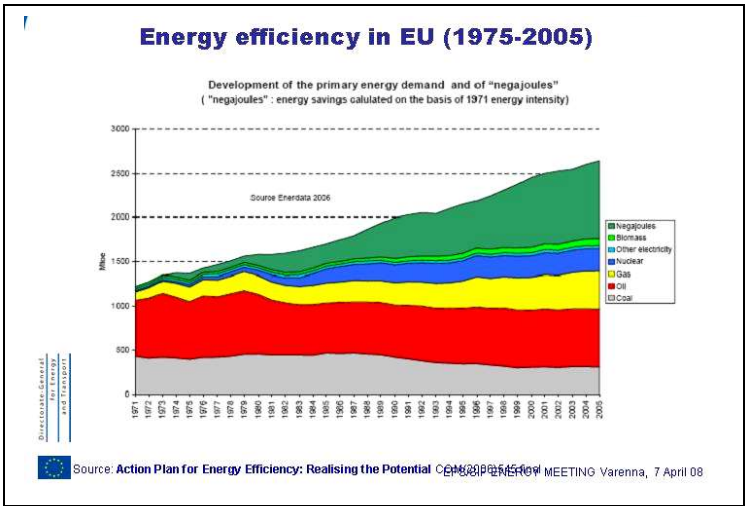


Fig. 3 Plotted is the effect of the energy efficiency on the PE demand over the years based on the energy technology of 1971.

Next, I would like to briefly comment on the reports from the various countries:

Italy (De Sanctis):
A detailed report has been elaborated by SIF within the last year. An executive summary is available in English. The main text will be translated.
Italy uses mostly gas and oil and little coal for electricity production. Gas keeps replacing oil. No nuclear power plant (NPP) exist. ~14% of electricity has to be imported (mostly from French NPPs). The import is at the limit of the transmission lines between these countries. Owing to a large fraction of hydro power, Italy enjoys a large fraction of REs in its electricity production. CO_2 emission has increased over the reference period by about 10% (Kyoto goal: -6.5%). The SIF energy working group recommends for longer term perspectives in CO_2 reduction the implementation of CCS technologies, the building of nuclear power plants and – if sufficiently economic – the use of solar energy.

Sweden (S. Kullander):
The energy studies in Sweden are done by the Royal Swedish Academy of Sciences. General energy issues are addressed in a set of individual studies which go beyond the local Swedish situation. The perspective is 50 years and global. The basic outcome of many studies is:
- New bio-energy should come primarily from forestry and agriculture residues.
- Concentrating-Solar-Power devices will give a steady electricity supply in Southern Europe.
- Nuclear energy is very sustainable even compared with renewable energy forms!
- Keeping nuclear energy is essential for reducing Swedish CO_2 emissions by 20-30 %.
-The political target for building wind power is 10 TWh for the next ten years (presently, 1 TWh).

The Swedish supply side is characterised by large fractions of bio-energy (17%), hydro power (10%) and nuclear power (18%). 27% of Sweden’s primary energy (PE) comes from the RE hydro and biomass; new REs (wind, geothermal, solar) do, however, play a minor role.

Portugal (C. Varandas):
Portugal’s energy supply is characterised by import and a high fossil fraction. The Kyoto target for CO_2 production in 2010 (77.2 Mt) will be considerably surpassed (95,2 Mt) with business as usual. To counteract, the plan is to install more than 5 GW wind power and hydro electricity. Portugal has the most powerful PV system worldwide (88 GWh/y); windpower grew 60% in 2006. The hydro-electricity potential of Portugal is exploited only by about 50% and 10 new hydro-plants are planned. Portugal invests little in energy R&D (less than 0.03% of the GDP). A decision on nuclear energy might only be considered after 2010.

Germany (M. Keilhacker):

Germany makes all efforts to implement REs and fulfill its 2012 and 2020 committments with the additional difficulty to phase out ~20 GW of nuclear power. Under these circumstances, 11-16 GW of electrical power (depending on the demand scenario chosen) are projected to be missing in 2020. The AKE of the DPG makes the following recommendations (see also the report: Climate Protection and Energy Supply in Germany 1990 to 2020, which can be downloaded from the DPG web page):

- The result of 15 years of German climate change policy shows that some of the national reduction goals were unrealistic.
- The German Kyoto gas reduction goal for 2008/12 (“minus 21%”) seems reachable (roughly 30 % of the reduction will be due to CH_4 and NO_2)
- A “minus 40%” goal of German Kyoto gas emissions for 2020 is completely unrealistic even under most favourable circumstances (highest possible efforts in efficiency improvement and in building up of REs, continued operation of nuclear power)
- The phasing out of nuclear power by 2020 cannot be compensated for by any realistic efforts in efficiency improvement or forcing of REs.

Spain (J.A. Tagle):
The Spanish energy supply is heavily toward fossil fuels with about 10% from nuclear. Despite the long coast and the high solar radiation, wind and solar energy harvests are small (1.2% (7.2% in electricity production) and 0.05%). The reserve margin of the thermal power plants in operation will decrease sharply from 2010 on. The state plan is to have about 28 GW new installations as CCGT (combined cycle gas turbine) and based on REs.

France (J. L. Bobin):
France has the advantage of an electricity production which is ~80% CO_2-free. Though new nuclear power stations (EPR) are planned or considered, it is also planned to expand bio-energy, wind- (25 GW at 2020 for 38 MrdEuro) and hydro-electricity.

Finland (J. Keinonen):
Finland has the highest energy R&D expenses in Europe (no EU country matches the Japanese expenses, however!). A specific characteristics of its energy supply is that wood plays a large role as a fuel. 68% of the country is covered by forests. On the other hand the forest and wood industry consumes a larger fraction of the electricity supply. As a consequence, Finland has to import typically 13% of its electricity mostly from Russia. The electricity demand grows constantly at an annual rate of ~1%. With respect to the Kyoto target, Finland is slightly above the limit; with the new EPR under construction Finland will meet its commitment.

Czech Republic (J. Mlynar):
The Czech Republic is presently a net electricity exporter. Electricity is mostly based on coal and nuclear energy. The location of the coal-fired power stations is close to the coal mines, in the north of the country. To balance the grid, the nuclear power stations are located more toward the south. The power supply system will drastically change up to 2020

because power plants will come to their technical and economic end and legislation restricts surface mining. A specific aspect of the Czech Republic is the low potential for RE, wind and solar, owing to geographical circumstances. The share of RE (13%) in the frame of the EU 2020 target will be obtained by an increase in small hydro power stations, by a stong increase in bio-mass and bio-gas and a modest increase in wind power up to 700 MW_{inst}. A major concern is the replacement of old conventional power stations. Till 2020, about 30 TWh have to be replaced. This requires either increased import of energy, extend coal mining or building new nuclear power stations.

Norway (J. Vaagen):
The energy situation of Norway is special. Norway is the world's 4^{th} largest energy exporter (oil, gas). On the other side, Norway produces its electricity nearly CO_2-free. Norway has no nuclear power but considers the potential of its rich Thorium ressorces. Norway has 10 years of experience in CCS technology because the large CO_2-content of its gas ressources demand CO_2 removal; legislation requires that the CO_2 residues are not blown into the air.

United Kingdom (J. Twidell):
The CO_2 emissions could be strongly reduced in the last decades due to the replacement of coal-fired power stations by gas (2004: 40% CCGT). 19% of electricity is nuclear based. The share of “new” REs is small (3.6% in 2004).
As the national ressorces are declining oil and coal are coming back again and fossil-fuel imports are rapidly increasing. This causes less supply security and increased prices. Wind (2007: 2.43 GW_{inst}), small-hydro power stations, the use of bio-fuels and that of waste have strong growth (wind: +30%/y). PV power is small with 9.9 MW_{inst} in 2006.

Denmark (P-A Lindgard):
Denmark has a high fraction of wind electricity (~20%); ~15% of the PE is contributed by RE forms (including bio-mass and waste). But Denmark employs also many coal-fired power stations which make Denmark to a net-electricity exporter and cause a rather substantial CO_2/capita figure. Thermal power is used in combined heat and power mode (CHP; ~50% of electricity is produced in this mode); Denmark owns a well developed district heating system.
A detailed plan (IDA plan) has been elaborated for Denmark to reduce its CO_2 production to 50% in 2030 and to effectively 0% in 2050. This requires that present PE supply decreases in two steps, by ~-25% in 2030 and by -50% in 2050 (from the 2004 level). The ambitious plan for 2050 necessitates a large fraction of bio-fuel (twice of the residual biomass resources including waste of 165 PJ) which would enforce a change in crops and other agricultural measures. The reduction of bio-mass use closer to the agricultural reality (to 200 PJ) would necessitate energy storage (e.g. hydrogen). As a compromise, 270 PJ bio-mass are foreseen and 10 GW_{inst} wind power.

Belarus (S. Filatov):
Belarus has signed the Kyoto treaty. 84% of its energy comes from gas which originates basically from import from Russia. The energy market is strongly state-governed. It is the national plan to produce electricity in the future exclusively inside the country. A 1GW NPP is planned for 2015, another one for 2020. Nuclear waste is seen, however, as a problem for a country the size of Belarus. These measures are accompanied by plans to save energy and by the need of continuous investments into the energy sector to increase the present electrical supply of 65 MW to 350 MW in 2010. The changes in the overall energy system are characterised by a reduction of gas in PE down to 60% in 2020 being replaced by nuclear power (19%) and an increase in the use of wood from presently 7% to 15%. Belarus has a long tradition into hydrogen energy research.

Lithuania (J. Vilemas):
More than 90% of Lithuania's PE is imported from Russia. Supply security is a concern. Per capita energy consumption is low; the growth rates for energy supply start from a low level and are high. It is the intension to become self-sufficient in electricity production on the background of an aging arsenal of existing power stations. Critical is the decision to terminate the Ignalina NP reactor end of 2009. To compensate the losses a CCGT 450 MW unit should go into operation before 2012. It addition, it is planned to increase the electricity transfer capability specifically to Poland and Sweden and finally a new NPP should be built at the Ignalina site together with the Baltic neighbour countries and Poland.

Turkey (S. Oktik):
Turkey is in a dynamic development of its economy. It has not signed the Kyoto protocol whereas the per capita CO_2 production is 2.9 t (in comparison to 8 t as EU average). As bridge between the oil and gas suppliers of the near-East and Europe as a major consumers, Turkey wants to grow into the role of a turntable for these fuels to Europe. To build LNG terminals at the end of major pipe lines (blue stream) is under consideration. 4 new pipe lines are under construction or planned. Turkey's energy consumption is strongly growing; the growth is matched by import. The PE consumption is expected to grow from presently ~ 90 Mtoe at an annual rate of 6% to 220 Mtoe in 2020 with an import of 70%. The share of hydro and wind in the 189 TWh electric power are 19% and 0.2%, respectively. 22 new dams (7.5 GW) are being built to increase the hydro electricity share; the biggest one is the South-eastern Anatolia Project (GAP) along the basin of the Tigris and Euphrates Rivers. The first NPP (1.8 GW) is planned for 2014 at the Black Sea. Thermal solar hot water production is well developed in Turkey with >10 Mill m^2 and an annual growth of ~ 1 Mill m^2. PV development is minor; a feed-in-tariff system does not exist. 120 MW of wind power is presently installed; recently, licences for wind power have been handed-out which – when realised - would contribute with 78 GW_{inst}. 120 Mrd$ will be invested till 2020 to expand and modernize the electric power system.

Next, I would like to summarize a few other topics, which were presented and discussed at the energy meeting.

Social, political and environmental issues
The EU goals are environmental sustainability and the prevention of a possible climate change, the diversification of energy sources and security of supply for Europe, and to allow economic growth and ensure stable employment by strengthening European research capacities. There are, however, many obstacles along this line, which often have to do with the national experience or the national characteristics – whatever this is. I will give a few examples. In the Czech Republic, it is a social issue that electricity is exported whereas the open pit mining is a major public concern. - Though 70% of the population of Belarus is in favour of nuclear energy, the country lost many of the specialists after the Chernobyl catastrophe; the research base, however, survived. - Though nuclear energy is the backbone of electricity production in France ensuring a low per capita CO_2 production, there is strong opposition by the movement "Sortir du nucléaire". But there is another strong movement, "Vent de colère", which turns against wind energy. Like in other EU countries, there is now a controversial debate on the use of bio-mass based on crops and not on agricultural waste.

Research into energy technologies.
In the category "Cooperation" of the 7^{th} Framework programme, the Commission provides 32.4 Mrd Euro whereas "Energy", which is part of this category, gets only 2.35 Mrd Euro. Though Fusion, fission and the JRC nuclear activities are not covered (funded by the Euratom treaty with 2.7 Mrd Euro), the level of this fund does not seem to match the dependence of Europe on the availability of economic energy.

It is not possible to summaries the research activities in the different countries represented in this meeting. Nevertheless, a few – possibly less known – facts and cases should be mentioned.

Nuclear energy:
France in involved in all nuclear technologies, fission and fusion - in ITER, based on magnetic confinement and in LMJ, based on inertial confinement. CEA and CNRS are the major research institutions. - Germany has moved out of publicly funded nuclear energy research (apart from safety and waste) – an awkward position for a country with nuclear energy at a high technical standard (availability) and a long tradition in basic research and industrial application. - In Portugal two State Laboratories - Instituto Tecnológico e Nuclear and Instituto Nacional de Energia e Geologia together with an Associated Laboratory - Instituto de Plasmas e Fusão Nuclear – work in the nuclear field. - In Spain, nuclear technologies are covered by the CIEMAT Institute of Nuclear Technology and EURATOM-CIEMAT Fusion Association. CIEMAT works on transmutation and on plasma vitrification technologies and is involved in ITER as well as in inertial confinement programmes.

In the Czech Republic, two research reactors are operated, LVR-15 in the Nuclear Research Institute Řež near Prague and the training Reactor VR-1 of the Technical University Prague.
The IPP Prague of the Czech Academy just commissioned the Tokamak COMPASS, operated in the EURATOM frame. - The Institute of Physical and Technical Problems of Energetics, founded in 1956 in Kaunas, Lithuania, deals with safety and reliability of nuclear power plants, radwaste management, spent nuclear fuel storage and disposal, and decommisioning of nuclear power plants. With Westinghouse, it cooperates in the development of the small reactor IRIS. For fusion, the institute is engaged in reactor safety analysis. - Turkey also has a nuclear research programme in fission.

Solar energy:
Solar energy research is a wide field where devoted research institutions as well as universities are engaged in. Again, no comprehensive account can be given. Portugal and Spain accommodate large PV installations as well as solar thermal power plants. There are also efforts to integrate solar technologies into Eco-buildings. - Within the framework of the EU project "PV Enlargement", 20 kW power stations for demonstration and education were built in the Czech Republic by several universities.
The Mugla University in Turkey has a strong programme on electricity production from solar energy.

Fossil fuels, conversion and distribution technologies :
Spain, Norway and Turkey are engaged in CCS technologies; Spain is involved in the development of high-temperature superconducting cables, of heat resistant material, of corrosion and cracking problems. Another field are fuel cells, which is also an important research field in Belarus.

Hydrogen technologies:
Activities toward a hydrogen economy exist in Spain and as a programme of emphasis and national programme in Belarus. These activities – about 28 individual projects - are mostly centred in Minsk in the Mass Transfer Institute (HMTI) but include 10 Institutes, 5 Universities and 269 scientists.
The activities embrace all areas – the production of Syngas from biomass, coal and methane, the H_2 production from microbiology reactors, hydrogen storage in metal hydrides, the development of fuel cells (PEM, DM, and SO FCs but also novel nano electrocatalyst for FCs).
The Lithuanian Institute (PTPE) is engaged in the gasification process of biomass and other organic materials, in hydrogen storage in solid state materials, in the synthesis of materials and their stability, and in high temperature fuel cells.
Turkey is involved in fuel cell development for transport, in hydrogen combustion technologies, and in energy storage technologies.

Chemistry:

Chemistry is a key technology and contributes substantially to the generation, conversion, storage and efficient use of energy. Chemistry plays also a role in nuclear energy, specifically in fuel reprocessing.

For hydrogen or new fuels, electrolysis, catalytic water splitting, algae in bioreactors or more generally, new (bio-) catalytic approaches, and – as a final goal - artificial photosynthesis are chemically based techniques. Hydrogen technology involves chemisorption (metal hydrides or other complex hydrides) and physisorption e.g. by metal organic frameworks (MOF)

The efficient production of biomass and more efficient and cheaper solar cells (dye or organic solar cells) involve chemical processes. Fuel Cells will need custom-tailored electrolytes, electrodes and membranes

The conversion of energy requires the synthesis of new materials and thin layer deposition techniques.

For the storage of electricity so called supercaps (double layer capacitors) are developed. They are complementary to batteries and necessitate new materials for electrodes, electrolytes (ionic liquids).

Light: Modern developments involve LEDs and organic LEDs (OLED) based on chemical processes.

Activities of the national energy working groups:
Only a brief overview over the different actions will be given here which might help the newer energy working groups to select and focus on specific activities. It would also be helpful, if those groups with a larger experience would interact with the newer ones. The contacts within the groups may not be restricted to activities initiated by EPS alone.

The general set of activities are the organization of workshops and seminars, specific policy seminars, the preparation and publications of reports and briefing papers, and educational and outreach programmes.

IOP has organized the following policy seminars:
- *Climate Change: Physics for a sustainable world*
- *Fusion: The future of electricity generation*
- *Nuclear power: Keeping the option open*
- *Future nuclear power: Addressing the barriers*

The AKE of the DPG regularly informs itself and the general public about issues related to energy production and climate change. It has since early 1980s publicly expressed its oppinions in form of memoranda (1986/87/95). The AKE organises, twice a year, two-day energy seminars and prepares its own programme of energy lectures at the main annual DPG physics conferences (published as AKE conference proceedings).

The Portugese Physics Society is about to create an energy task force but its future members already in the past educated students on the basic principles for the sustainable development of our society.

The Energy Working Group of the French Physical Society promotes semi popular books (published by EDP-Sciences), e.g. L'énergie Dans le Monde and L'énergie de Demain. It organizes meetings and schools but still is concerned to be sufficiently visible in the energy debate and to be heard as the voice of physics.

The Energy working groups write recommendations and many of them were stated in the meeting. Only a few can be given here; the interested reader may go directly to the presentations.
The EASAC states:
- A European electricity net is needed.
- With respect to bio-fuels: The full picture is complex as different biofuels have widely differing environmental, social and economic impacts. Each biofuel must be assessed on its own merits.
The Swedish Royal Academy says:
- Nuclear energy is essential for reducing CO_2 emissions by 20-30 %.
- Research is recommended on emerging reactor systems.
- World's agricultural products must meet the increasing demands for food rather than being used for bio-fuels.
- It should be possible to double the global bio-energy production, currently 13 000 TWh/y, primarily by using residues from agriculture and forestry.

The French Physical Society warns:
- to write position paper which might be politically incorrect.

The AKE of the DPG suggests:
- Existing nuclear power plants must continue until a substantial substitute for CO_2-free energy is available.
- Solar thermal power plants must be developed in southern lattitudes, e.g. Spain (and later North Africa).

Thoughts on how to continue:
- The groups involved should consolidate themselves in case they are rather new. The groups might organise themselves like divisions or sections of EPS or of national physics societies. The more established groups could help with structures, terms of references, working modes...

- The next meeting like this one should be in 2009; the groups may cooperate in between. The EPS energy working group should keep e-mail contact in-between. One could invite each other to the national EWG meetings and select topics of mutual interest.

- Many of the given reports are near completion and it is highly recommended that the presentations of Finland, Turkey, Spain and the Czech Republic are elaborated to a complete report. The material seems to be available. The report of SIF is complete and printed and will be translated into English. Maybe, each of the reports should culminate in a clear recommendation for national energy policies based on the views and insights of physicists. All these reports, available in English, should be distributed.

- It might be a good joint project to analyse for each country the expected CO_2 emission toward the 2020 goals and again comment it. One could follow the example of the AKE of the DPG in their published analysis (see Fig. 2).

- Another joint project up to the next meeting could be to analyse the various energy techniques where physics in involved for their potential in case more research is invested. This is the ultimate goal of the present exercise and it should lead to an EPS position paper. For this purpose we have to more clearly identify the research fields and scientific strengths in the various countries.

- Participation on the next energy activities: Les Houches, June 2.- 5. 2008 (viewgraphs available at)and ESOF, Barcelona, July 18. 2008 (on fission and fusion; see web-page); contribute to the planned energy exhibition in the European Parliament, Strasbourg. Participation in the next divisional meeting on fission.

- We need a volunteer to organise the follow-up meeting of this one in 2009.

After several workshops it might be time for EPS to consider the establishment of a regular EPS Energy and Environment conference. The idea is to have a conference, which covers all fields so that this forum serves to bring together all scientists in the various energy related areas with the side effect of improving the cooperation between sometimes competing fields. Most important is, however, to attract the scientists active in the field and their students to the conference. Only in this case, EPS justifies its engagement. To achieve this objective, a possible conference structure could be to have plenary sessions with invited speakers from all fields in the morning and several parallel topical sessions in the afternoon (e.g. PV, fission, fusion (there is, however, a very central EPS plasma and fusion conference), energy saving technology, climate issues with physics and other topics where physics plays a role.

If such a model would work, a publisher might be interested to publish the plenary talks from the morning sessions.

As physics alone will not save the energy problem, the effort could be extended to chemistry and materials research. One could think about a combined conference. It might even be worthwhile to have in mind a conference structure, which includes the USA (APS) and Asia (AAPP) and where the conference may come to Europe every third year.

In a first step, it is necessary now that the EPS Energy Working Group consolidates. Those interested to work in this frame my send me an e-mail (fritz.wagner@ipp.mpg.de).

F. Wagner; 11.7.08