Energy Projections

Energy options for the Future

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Summary

Energy demand, due to population increase and need to raise standards of living in developing and transitional countries, will require new energy technologies on a massive scale.

Climate change considerations make this need more acute.

The extensive deployment in the transitional and developing countries will require global development in each case.

ITER is an interesting model for how such ventures might be undertaken.

All energy sources will be required to meet the varying needs of the different countries and to enhance the security of each one against the kind of energy crises that have occurred in the past.

New facilities will be required both to meet the increased demand and also to replace outdated equipment (notably electricity).

IMPORTANT CONSIDERATIONS

The global energy situation and demand.

Emphasis given to handling global warming.

The availability of coal, gas, and oil.

The extent of energy efficiency improvements.

The availability of renewable energies.

Opportunities for nuclear (fission and fusion) power

Energy and geopolitics in Asia in the 21st Century.

World Population and Energy Demand-1

Over the 21st century world's population will rise from 6 billion to around 11 (8-14) billion people.

An increase in per capita energy use will be needed to raise the standard of living in the countries of the developing and transitional parts of the world.

During the last two centuries:

Population has increased 6 times,

Life expectancy 2 times, and

Energy use (mainly carbon based) 35 times.

Carbon (grams per MegaJoule) decreased by about 2 times, because of the transition from wood to coal to oil to gas.

Also, the energy intensity (MJ/$) has decreased substantially in the developed world.

World Population and Energy Demand-2

In 2000, the IPCC issued a special report on "Emission Scenarios“. Modelling groups, using different tools worked out 40 different scenarios of the possible future development (SRES, 2000). These studies cover a wide range of assumptions about driving forces and key relationships, encompassing:
an **economic emphasis (category A)** to
an **environmental emphasis (category B)**.

Driving forces are population, economy, technology, energy, and agriculture (land-use).

An important conclusion is that the bulk of the increase in energy demand will be in the non-OECD[1] countries. In the period from 2003 to 2030, IEA studies suggest that 70% of demand growth will be in non-OECD countries, including 20% in China alone. This change has started with the shift of Mid-East oil delivery from being predominantly to Europe and the USA to being 60% to Asia.

New and carbon-free energy sources, respectively, will be important. For both extremes of a very high increase in energy demand and a lower increase in demand but with carbon emission restrictions. This is significant for a new "carbon- free" energy source such as fusion.

A second important fact is that in most (all?) scenarios a substantial increase in electricity demand is expected.

[1] OECD stands for Organisation for Economic Co-operation and Development. Member states are all EU states, the US, Canada, New Zealand, Turkey, Mexico, South-Korea, Japan, Australia, Czech Republic, Hungary, Poland and Slovakia.

Fossil Fuels

The global resources of fossil fuels are immense and will not run out during the 21st century, even with a significant increase in use.

There are ample resources of liquid fuels, from conventional and unconventional oil, gas, coal, and bio-mass.

Technologies exist for removal of carbon dioxide from fossil fuels or conversion. Too early to define the extent of the role of sequestration over the next century.

Financial Investments - IEA

The IEA estimate of needed energy investment for the period **2001** to **2030** is **16 trillion dollars**. Credit ratings a concern.

In China and India more than **85%** of the investment will be in the **electricity area**.

Energy Efficiency

It is commonly assumed, consistent with past experience and including estimates of potential improvements, that energy intensity (E/GDP) will decline at around 1 % per year over the next century.

As an example of past achievements, the annual energy use for a 20 cu. ft. unit was 1800 kWh/y in 1975 and the latest standard is the 2001 standard at 467 kWh/y. It uses CFC free insulation and the refrigerant is CFC free.

Renewable Energies

Renewable energies have always played a major role - today about 15% of global energy use a lot poorly used biomass.

Improving technologies across the board and decreasing unit costs will increase their ability to contribute e.g., more efficient use of biomass residuals and crops; solar and wind power.

Fission Energy

Studies by the Global Energy Technology Strategy Project (GTSP) found that stabilising CO_2 will require revolutionary technology in all areas e.g., advanced reactor systems and fuel cycles and fusion.

The **deployment of the massive amounts of fission energy,** that would meet a significant portion of the needs of the 21st century, is **not possible with current technology**.

Specifically, a global integrated system encompassing the complete fuel cycle, waste management, and fissile fuel breeding is necessary.

Climate Change Driven Scenarios

The requirement to reduce carbon emissions to prevent undesirable changes in the global climate will have a major impact on the deployment of energy sources and technologies. To achieve a limit on atmospheric carbon dioxide concentration in the range 550 to 650 ppm requires that emission's must start decreasing in the period between 2030 to 2080. The exact pattern of the emission curve does not matter, only the cumulative emissions matter.

It is important to remember that there are other significant greenhouse gases such as methane, to contend with.

The alternatives for energy supply include: fossil fuels with carbon sequestration; nuclear energy, and renewable energies. Hopefully, fusion will provide a part of the nuclear resource.

In the IIASA studies, high-technology plays a most important role in reducing carbon emissions. One possibility is a shift to a hydrogen economy adding non-fossil sources (nuclear and renewables) opportunities for fusion energy would be similar to those for fission.

On the one hand, the issue of investments made it clear that the projected large increases in the use of fossil fuel (or energy in general) were uncertain. On the other hand, Chinese and Indian energy scenarios foresee a massive increase in the use of coal.

Geo-political considerations

The dependence on energy imports has been a major concern for many countries since the so-called oil crises in the early and late seventies. After these oil crises countries looked intensively for new energy sources and intensified energy R&D efforts. One result was the development of the North Sea oil, which is till today one of the major oil sources for Europe.

Especially in the case of conventional oil the diversification of oil sources, which reduced the fraction of OPEC oil considerable, will find an end in the next 10-20 years and lead again to a strong dependence of the world conventional oil market on OPEC oil.

In the case of Europe the growing concern about energy imports has lead to a political initiative of the European Commission.

While a country like South-Korea imports 97 % of its primary energy, it is questionable whether countries as big as the US, Europe as a whole, China, or India would accept such a policy.

Dynamics of the Introduction of Technology

Two other important factors that bear on the introduction of technologies: are the limited knowledge of their feasibility and the cost and the improvements that normally occur as a function of accumulated experience (learning curve)..

The advantage of a collaborative world approach to RD&D includes not just the obvious one of cost-sharing but also that it would bring capabilities for sharing in the manufacturing to the collaborators.

It would be hard to conceive of a country deploying hundreds of gigawatts of power plants that were not produced mainly in that country.

Previous energy disruptions were caused by a lack of short-term elasticity in the market and perceptions of problems. Prevention will require diversity of energy supply, the thoughtful deployment of all energy sources, and for each energy-importing country to have a wide choice of suppliers.

Energy in China-1

Chima's population will rise to 1.6-2.0 billion people by 2050, with expected substantial economic growth and rise in standard of living.

Per capita annual energy consumption will approach found in the developed countries; roughly, 2-3 STCE (standard tonnes of coal equivalent) per person per annum.

Annual energy use in China would rise to 4-5 billion STCE. Much of this energy is will come from coal; up to 3 billion STCE/a.
This choice is because there are the large coal resources in China, and limited oil, gas, and capability to increase hydro.
An oil use of 500 Mtoe/a is foreseen, mainly for transportation.

It is projected that electricity capacity will have to increase from today's 300 GW_e, to 600 GW_e in 2020 and to at least 900 GW_e in 2050 and 1300 GW_e in 2100 depending on the population growth. It would be desirable to have about 1 kW_e per person.

Such a large increase means that a technology capable of not more than 100 GW_e does not solve the problem. On the other hand, providing 100's of GW_e by any one source will be a challenge.

To put this in perspective, imagine that the fission capacity in China were raised to 400 GW_e. This would equal total world nuclear power today!

Energy in China-2

China will have to deploy Gen-1V power plants in an integrated nuclear system. To realise multi-hundred MWs of capacity will power plants must be built in China (see Korean example).

Nuclear energy development, like fusion, needs a world collaborative effort so that countries like China can install systems that are sustainable. Particularly acute issue if the low emissions scenarios are to be realised.

The Chinese believe that it will be important to have a broad portfolio of non-fossil energy sources to meet the needs of their country. **In this context, fusion energy is viewed as having an important role in the latter half of this century**.

Initially, their fusion research emphasised fusion-fission hybrid and use of indigenous uranium resources. Good collaboration between their fission and fusion programs continues. During this work they came to realise that it would be very difficult for them to develop fusion energy independently. Hence interest in expanding international collaboration and ITER.

Energy in India

Steady growth in energy use in India for decades. Fossil fuels, particularly coal a major part of commercial energy, because of large coal resources in India. Substantial bio-mass energy is used, but only a part is viewed as commercial.

Future energy demand modelled using the full range of energy sources, production and end-use, technologies, and energy and emissions databases, considering environment, climate change, human health impacts and policy interventions.

For the **A2** case, the population of India is projected to rise to 1,650 million by 2100,
GDP will rise by 62 times, and primary energy will increase from 20 EJ in 2000 to 110 EJ (**3750 Gtce**) in 2100.
The electricity generating capacity will rise from around 100 GW_e to over 900 GW_e by 2100.
Carbon emissions will increase 5 times between to 2100, but 1 ton/a/year less than many developed countries.

For CO_2 stabilisation, there would be a decrease in the use of fossil fuels for electricity production and an increase in the use of renewable energies and nuclear energy, **including fusion**.

Nuclear energy development in Korea-1

Owing to a lack of domestic energy resources, Korea imports 97% of its energy.

The cost of energy imports, $37B in 2000 (24% of total imports) was larger than the export value of both memory chips and automobiles.

80% of energy imports are oil from the Middle East.

The growth rate of electricity averaged 10.3% annually from 1980 to 1999.

The anticipated annual growth rate through 2015 is 4.9%. Such an increase takes place in a situation in which Korea's total CO_2 emissions rank 10-th in the world and are the highest per unit area.

If it becomes necessary to impose a CO_2 tax it is feared that exports will become uncompetitive. In these circumstances, the increasing use of nuclear energy is attractive.

Fission is the approach today and for the many decades, and **fusion is seen as an important complementary source when it is developed.**

There is close collaboration on R&D within the nuclear community. This collaboration has been enhanced by the involvement of Korea in the ITER project.

Nuclear energy development in Korea-2

In Korea, the first commercial nuclear power plant, Kori Unit 1, started operation in 1978.

Currently there are 14 PWR's and 4 CANDU's operating; with 6 of the PWR's being Korean Standard Nuclear Plants.

These power plants amount to 28.5% of installed capacity and provide 38.9% of electricity. It is planned that there will be 28 plants by 2015.

Today, Korea is involved in many of the aspects of nuclear power development, including the international Gen-IV collaborations.

Korea has gone from no nuclear power, to importing technologies, to having in-house capability for modern PWR's, and to be working at the forefront of research within 30-years. One area in which there remains reliance on foreign capabilities is the provision of fuel.

Conclusions

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ITER is a model for how such ventures can be undertaken.

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In fact, fusion energy is viewed as an important potential option in the latter half of this century for transitional and developing countries including China, India and Korea – more than a third of the world's population.

Units

	KJ	kWh	kgoe	kgCe	m^3 NG
KJ	1	$2.78x10^{-4}$	$0.24x10^{-4}$	$0.34x10^{-4}$	$0.32x10^{-4}$
KWh	3600	1	0.086	0.123	0.113
Kgoe	41.868	11.63	1	1,428	1.319
Kgce	29.308	8.14	0.7	1	0.923
m^3 NG	31.736	8.816	0.758	1.083	1

1 barrel (bbl) = 159 l oil

7.3 bbl = 1 t oil