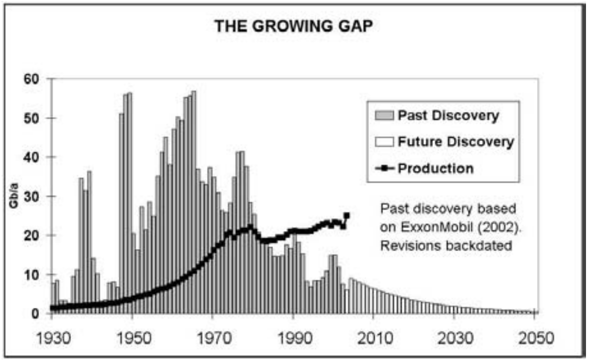
The Coming Energy Winter and the Role of Fusion

Brendan McNamara
Leabrook Computing, Bournemouth   brendan@leabrook.co.uk

The Decline of Conventional Oil

The Association for the Study of Peak Oil (ASPO), a 700 strong group of geologists and other scientists, has closely examined the history of oil discovery and production, on a country by country basis. Fig. 1 below shows that production now substantially exceeds discovery despite a truly global effort to explore all likely rock formations. There is now little prospect of finding any new oil fields on the scale of Saudi Arabia, and their future projections simply fade away.


THE GROWING GAP

Past discovery based on ExxonMobil (2002). Revisions backdated

As a consequence, the history and projections of oil production now show a peak in 2008 followed by a 3-5% decline to the end of ‘conventional’, or cheap easily accessed, oil – Fig. 2 – and a peak in gas supplies only a decade later. With a global economy based on perpetual growth, an exponentiating population, and rising demands and expectations, this can only lead to a coming Energy Winter. The peak of supplies is the crucial point at which vast economic changes must be made

Fig. 1 Production has exceeded discovery for 20 years. (ASPO)

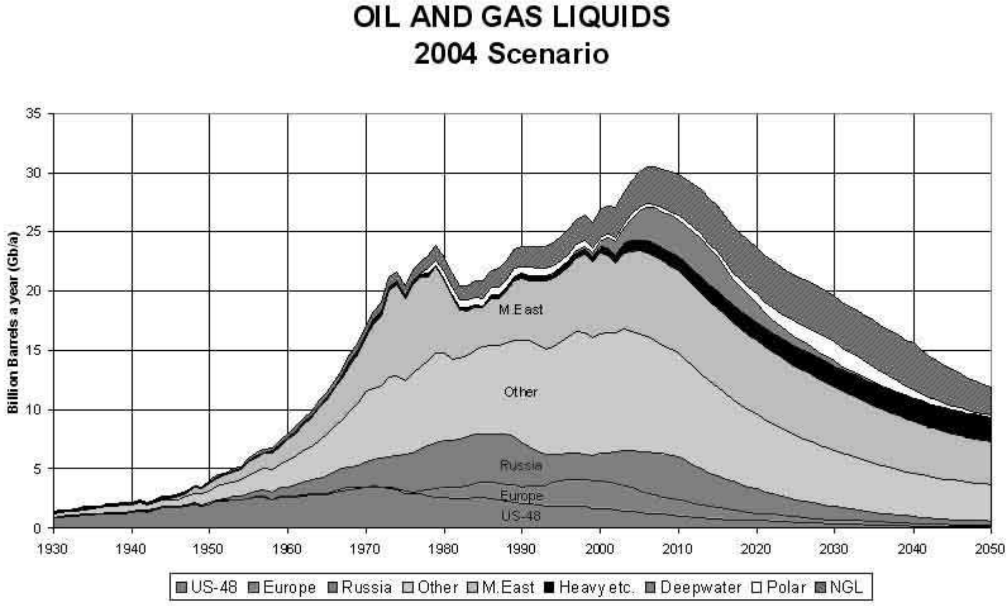

OIL AND GAS LIQUIDS
2004 Scenario

Fig. 2 The peak of conventional oil supply is now predicted to be at 2008. The US, EU, Indonesia, and many others will be out of oil by 2020. (ASPO)

The US Geological Survey 2000 report projects continued growth till about 2035 based on the hopes of substantial new discovery and large increases over the average 40% total extraction from oil fields thanks to new technologies. It is common knowledge that the actual results since 2000 have been a remorseless decline in discovery and little improvement in recovery in the best engineered oil fields in the world, the USA. The oil industry has been highly creative, with horizontal drilling, 3D seismology, and submarine extraction, and more, but few believe something dramatic may be invented to raise world extraction by 30%. Such hopes are no substitute for planning.

Recently, the USGS and derivative agencies have claimed the huge deposits of tar sands, oil shale, and methyl hydrates as a solution to the oil decline – implicitly agreeing with ASPO on the fate of conventional oil. Tar is oil that has been partially consumed by bacteria and requires expensive processing to manufacture usable crude. Processing tar sands is about the same as digging up highways to make oil, and consumes 1 barrel for every 3 produced – Q=3. Oil shale contains no oil but only the kerogen pre-cursor to oil. Estonia has been processing shale for 50 years, but it is a Q=2 process. No methyl hydrates have yet been recovered successfully in any commercial quantity. Human ingenuity and stunning investment - $ Trillions – could produce 50 million barrels/day by 2035 from these sources, but still too late to avoid the drop into an Energy Winter.

Getting through the Winter.

The effects of political instability are clearly seen in the historical parts of Fig 2. The supply and economic variations in decline will be far more extreme without a huge political effort.

Conservation is the only way to reduce the impact of the decline and extend supplies while new energy systems are put in place. Transport policies must recognise the Energy Winter: Cancel all new roads and airports, stop production of SUVs and their spares, encourage virtual travel by internet wherever possible, electrify all railways, and eliminate non-essential world trade in favour of local independence. ….

Alternative Energies.

Wind and Solar Energy systems will soon be cheaper than oil and gas for electricity generation and will always be cheaper than tar, shale, or hydrate systems. However, renewables will probably never sustain a 10 billion population at a European level. Only nuclear energy, by fission or fusion, can meet our electricity needs.

Current fission reactor designs are much cleaner, safer, and more efficient than existing nuclear plants and can therefore be deployed rapidly. Molten Thorium salt reactors offer a safe, high breeder option to allow fission an ongoing role throughout the century. While the EU and America are still squeamish about nuclear power, the US is making strong efforts to sell new nuclear stations to China.

The Role of Fusion

Fusion is the ultimate energy source for our civilisation and could have been ready to deploy now. It could still be ready in 20 years. It is now urgent to bring Fusion to fruition.

The world programmes to develop fusion energy have been stalled for twenty years, running on a third of the peak budgets of 1985. This reflects a failure by the Fusion program to maintain any kind of public understanding of the progress and achievements. The current plans to develop a full scale demonstration reactor are still constrained to run at the half the pace of earlier. The world magnetic fusion project, ITER, is not planned with a strong, explicit underpinning of continuing research using the existing global facilities and their upgrades, nor for a large enhancement of computing support. Laser fusion prospects are focussed on a single facility, NIF, at Lawrence Livermore because no other country has developed lasers on such a scale, though there are many excellent physics support facilities.

The US MFE program was forced to close its principal tokamak, TFTR, in 1998 in favour of small scale, advanced designs with little previous history. The US also withdrew from the ITER project which was then redesigned on a smaller, cheaper basis. The latest US plans from the FESAC committee, in obeisance to long term budget constraints, plan to almost drop out of MFE if the laser fusion option looks really viable by 2020.

To see how far off the pace the present programs are consider the Jet project. In 1969 a Culham team verified that the Russian T-3 Tokamak had indeed reached plasma temperatures of 1 kev. This was taken as a complete proof of principle. The machine had a major radius of 1m and a minor radius of 12cm. Bas Pease of Culham immediately started a push for European collaboration on a large Tokamak. Within 4 years a European group had negotiated funds to design JET, a huge leap into fusion engineering and physics, under a team lead by P.H. Rebut. The Fusion Director for the European Commission, D. Palumbo, ran the politics of the project with great skill. The design of a Tokamak with R=3.5m and r=1m took 2 years till 1975. Construction started in 1979 and the first plasma in this huge device was fired in 1983. Fusion conditions were reached by 1988 but DT experiments were put off till 1997. From conception to meeting the goals was only 20 years, or 10 years from the start of construction. Although JET produced 16MW of fusion power the DT experiments were curtailed by Health & Safety from the licensed level of 10^{24} neutrons to the 10^{20} produced. This reflected the stalled funding but at least leaves JET able to do many more physics experiments.

The project benefited greatly from international cooperation and key results from ASDEX, Alcator, DIII-D, and many Tokamaks that followed, and from the neutral beam technology created by the US Mirror program. New diagnostics have unravelled a range of Tokamak operating scenarios which can be refined as a portfolio for ITER machines as they are built.

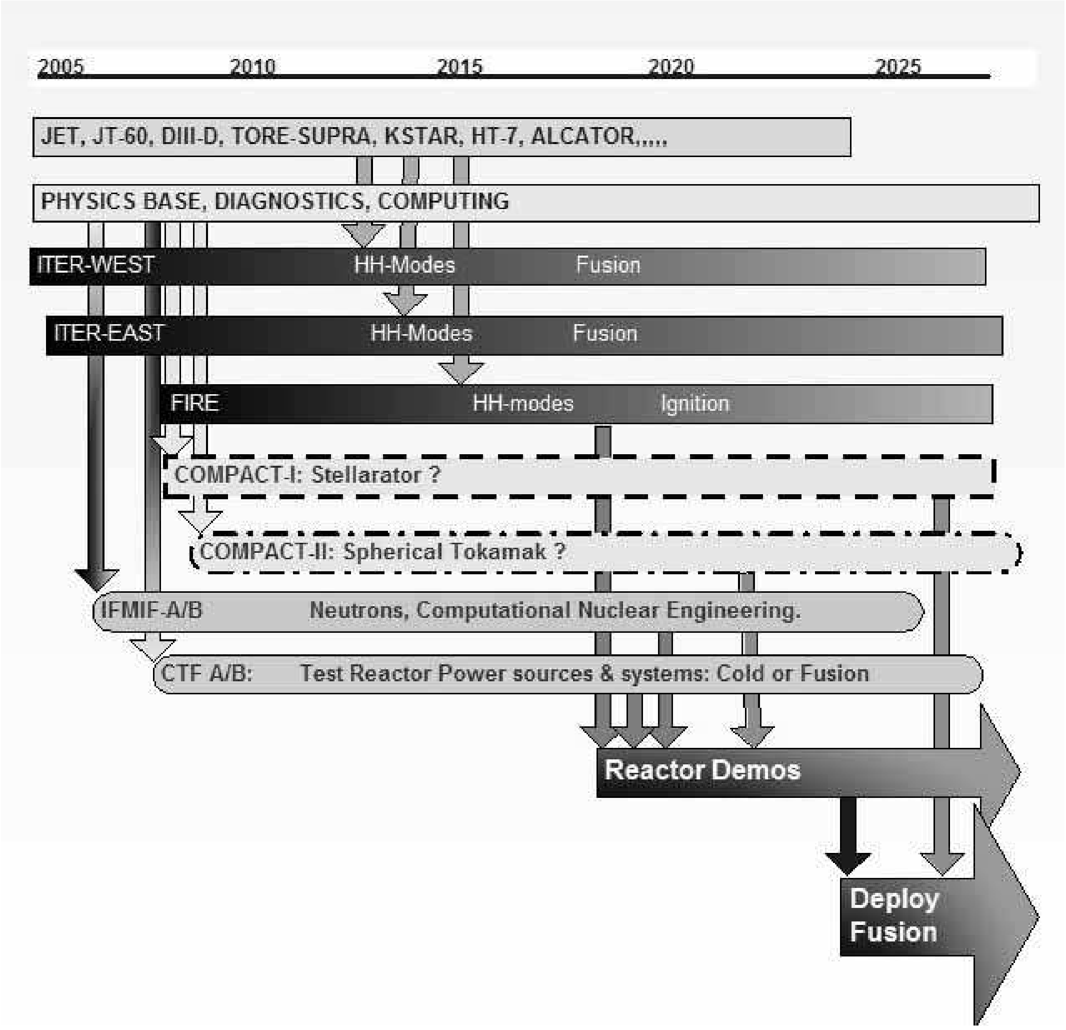
A vital contribution has been made by the US Computational Physics efforts which, in the last 5 years, have produced a tremendous breakthrough of 4 orders of magnitude improvement in the modelling of energy transport in the Tokamak. Computing is set to play a huge role in the plasma physics and nuclear engineering of fusion reactors.

Compare this with ITER which is only about double the size of JET: Design and re-design time of 12 years, 5+ years for site selection, 3 years for licences, 10 years for construction (the 42 story London ‘gherkin’ office tower took 4 years), and 8 years before burning plasmas are generated, a project pace of 35 years. This is far below the capabilities of Japanese, European, or US laboratories. The construction and operation of other key facilities like IFMIF and CTX start later at a similar pace. FESAC gives 6 years for the construction of a Demo Reactor for an independent US program.

The diagram below shows what the Fusion community is really capable of. It is important that more than one ITER class device be built. There are options A/B to the existing IFMIF accelerator system and to the Component Test Facility – a Gas Dynamic Trap, for example. Some cold testing of robotics, blankets, and other components can be undertaken early at modest expense. Compact versions of the Tokamak could show a scalable $n\tau_E T_i$ to match conventional ones - a much higher level ‘proof of principle’ than T-3 had to meet. Advanced computing, with the excellent understanding of the physics, can allow a compact Tokamak to be built on a JET scale or even as a CTF, with confidence. The initial round of commercial reactors deployed could then be a Mark II version rather than Mark I.

Japan can lead the Asian countries – China, Korea, India – in an independent development of an ITER machine. The EU and the FSU is able to build ITER alone. The USA plans a separate program based on FIRE and NIF and also of other compact alternatives. The EU and Japan have fallen significantly behind the US in the application of computing to Fusion and this should be remedied with dedicated resources and significantly larger teams.

Fig. 3 Fast Fusion: Ongoing support, Multiple paths, Compact upgrades, early engineering, and multiple reactor demo designs done in a 20 year period.



A critical task for Fusion is to raise its public image and engage political support wherever it can be found. The cost of an accelerated Fusion program is minute on the scale of total energy expenditure. Our politicians should be made aware of what has been dropped from a full program and the attendant risks.

It is too late for Fusion to help with the Coming Energy Winter but Fusion can be brought up for the high summer of our energy future.

A full account of all the issues raised here is available on request to brendan@leabrook.co.uk You are recommended to browse the ASPO website, www.peakoil.net which concentrates on the oil issues without analysis of energy alternatives.

Acknowledgements

This paper is based on extensive recent discussions with Roger Bentley, Secretary of ASPO, and with many people at Lawrence Livermore, JET, Culham, R.A.L., and F.O.M.

Author

Brendan McNamara worked on Fusion Theory with AEA Technology, Culham (1961-71) and at the Lawrence Livermore National Labs in California (1971-85). He also ran a series of Plasma Colleges at ICTP, Trieste, 1974-84. He was V.P. of a Supercomputer Center in Princeton (1985-88) and now operates Leabrook Computing as a Consultancy.