



The Coming Energy Winter

- **Every Westerner born this century can expect to see the end of conventional oil.**
- **Worse: The peak of global oil is NOW.**
- **New Energy Technologies must be accelerated hard.**
- **Social change is inevitable and good.**
- **We need a True Economics for a finite world.**



Energy-Gap



- **Brendan McNamara**

Career Background:

Theory and Computing in Magnetic Fusion Energy – UKAEA and Lawrence Livermore Labs, California. 1961 –1985

Director of Plasma Colleges, Trieste. 1975-85.

Exec. V.P. John von Neumann Supercomputer Center, Princeton 1985-89

Managing Director: Leabrook Computing Ltd., UK. 1989-

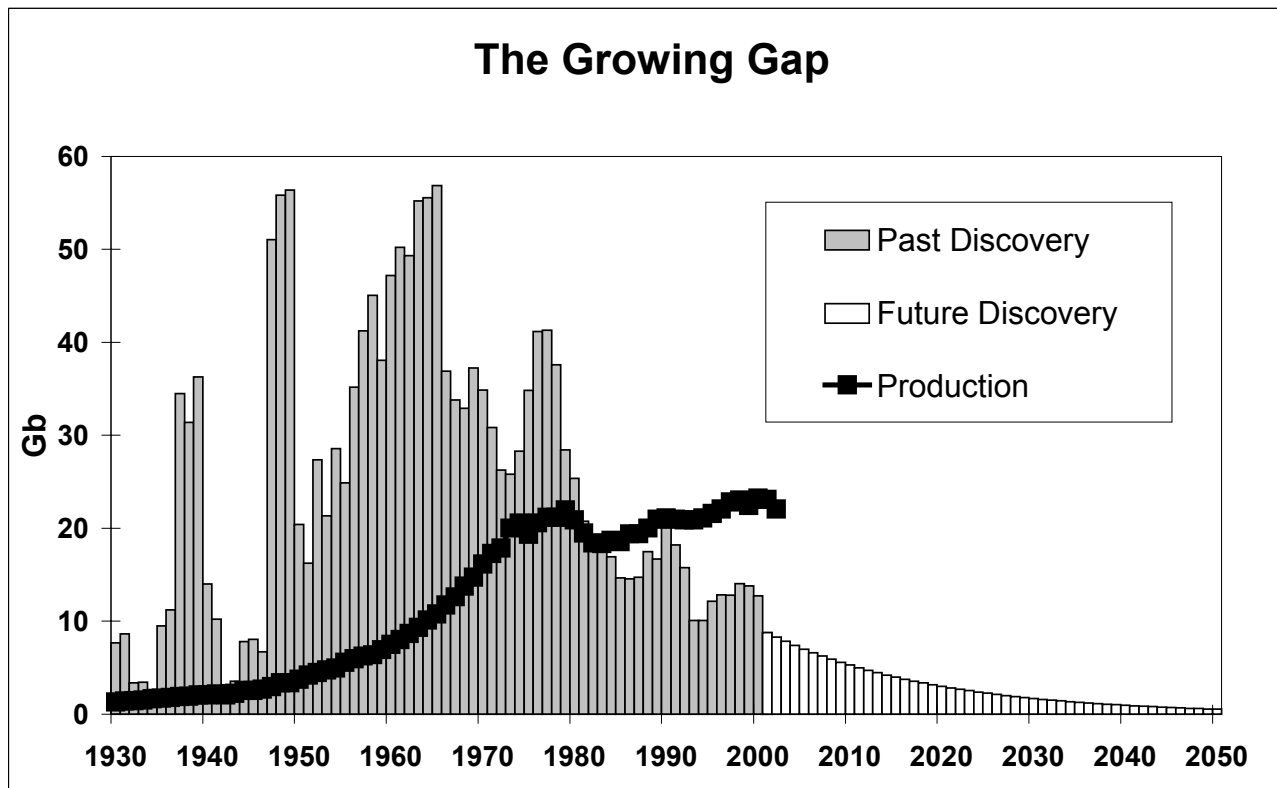
Now seeking to carry out the *Energy-Gap* mission.

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Decline of Discovery

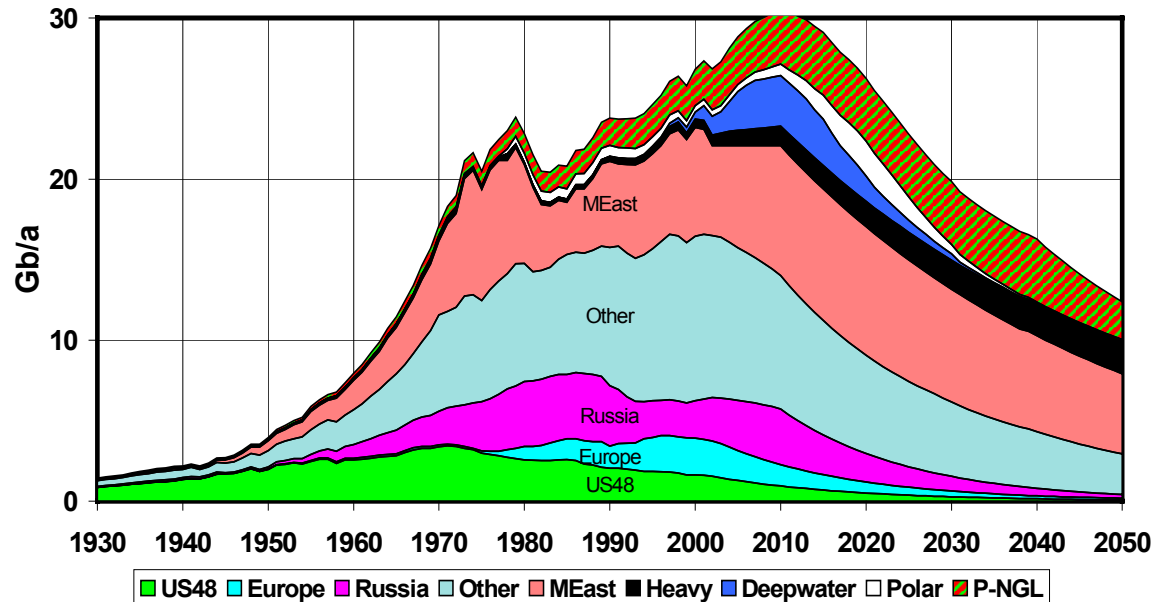


- Use original discovery dates, not 'reserve growth' profiles.



ASPO: The Peak of Oil.

Regular Oil & Natural Gas Liquids
2003 Base Case Scenario



Jagged political history.
Smooth predictions.

30 Mb/day below peak by 2030.



Oil Production Peak: 2010

Association for the Study of Peak Oil –

www.asponews.org

ASPO - 2010

- ***Lord Browne, Chairman BP – 2010***
World Energy Forum, Davos, 2001
- ***Volkswagen – 2010***
- ***BP Statistical Review 2002 – 2010+***
- ***US Geological Survey – 2036***

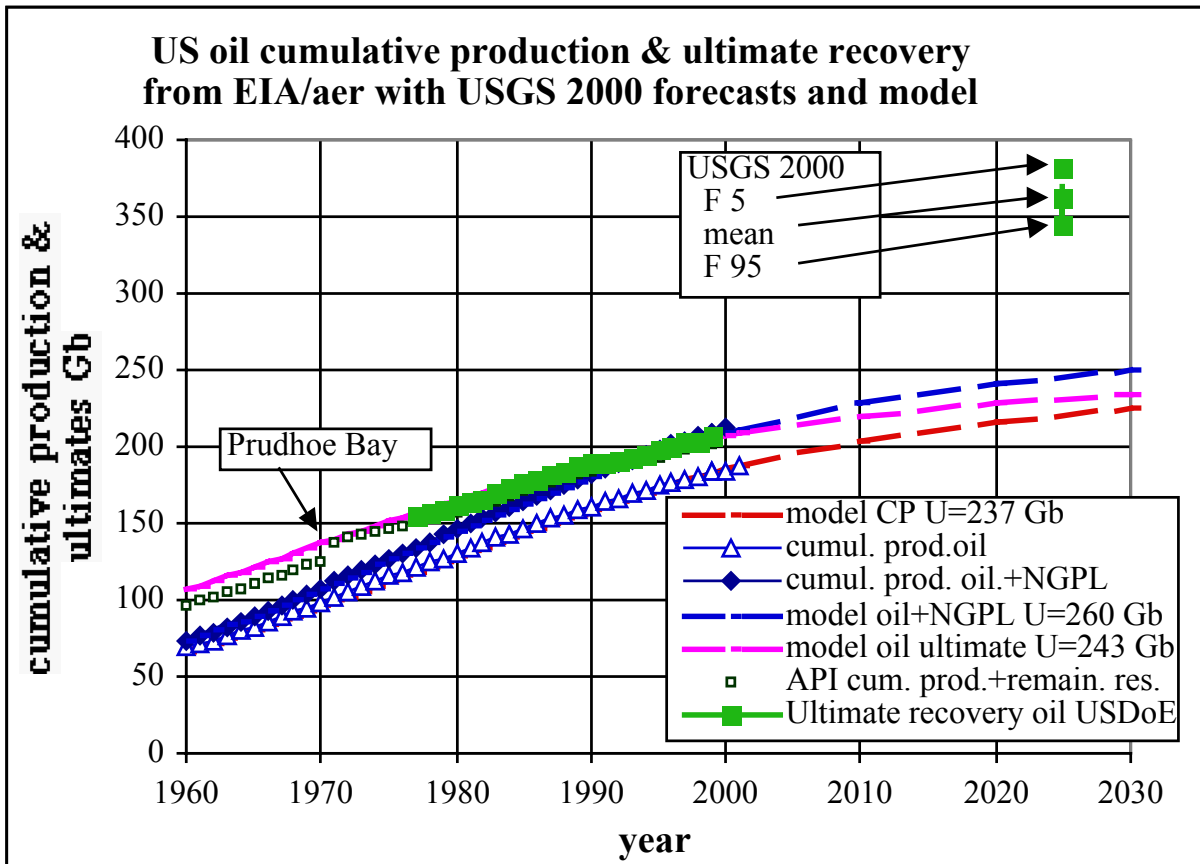


How did this happen?

- LIFE Science Library: Energy 1963 'Enough to last a century and a half'
- 1972: US Oil Production began to decline.
- Stock Markets: Good news only.
- Institute Predictions always positive.
- **Failure by other scientists to audit predictions**
- The story continues.....



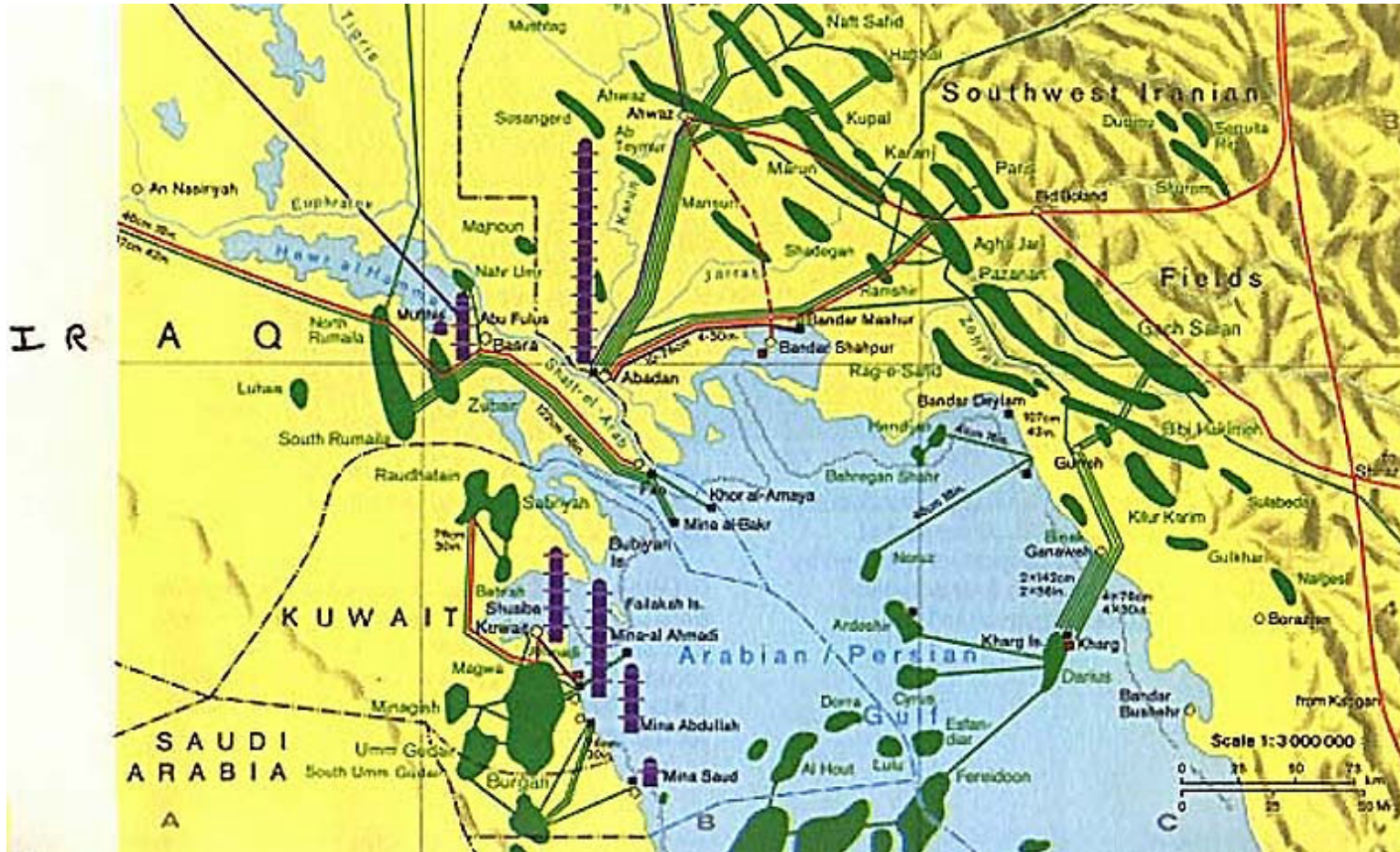
USGS 2000 Optimism



- 'Enhanced Recovery' - the big hope. Can it be this high? What will it cost?
- Computational Seismology in 3D+T offers better oil field management.



Gulf Oil Fields



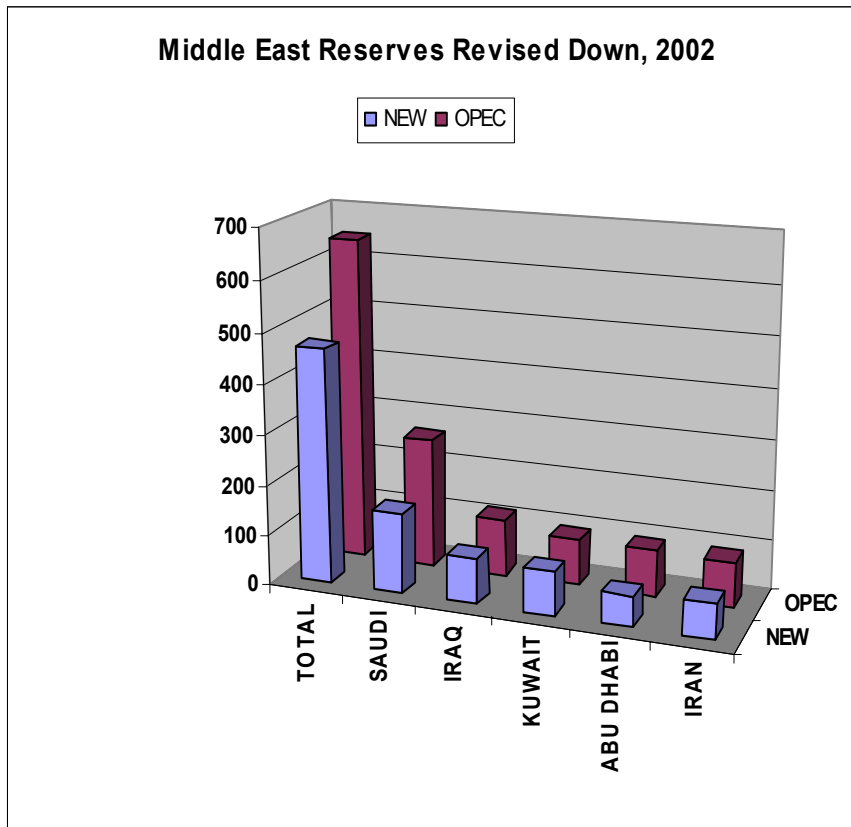
20-80% Recovery.

7MB/d seawater pumped into Ghawar to maintain pressure!

Re-Survey M.E. oilfields?



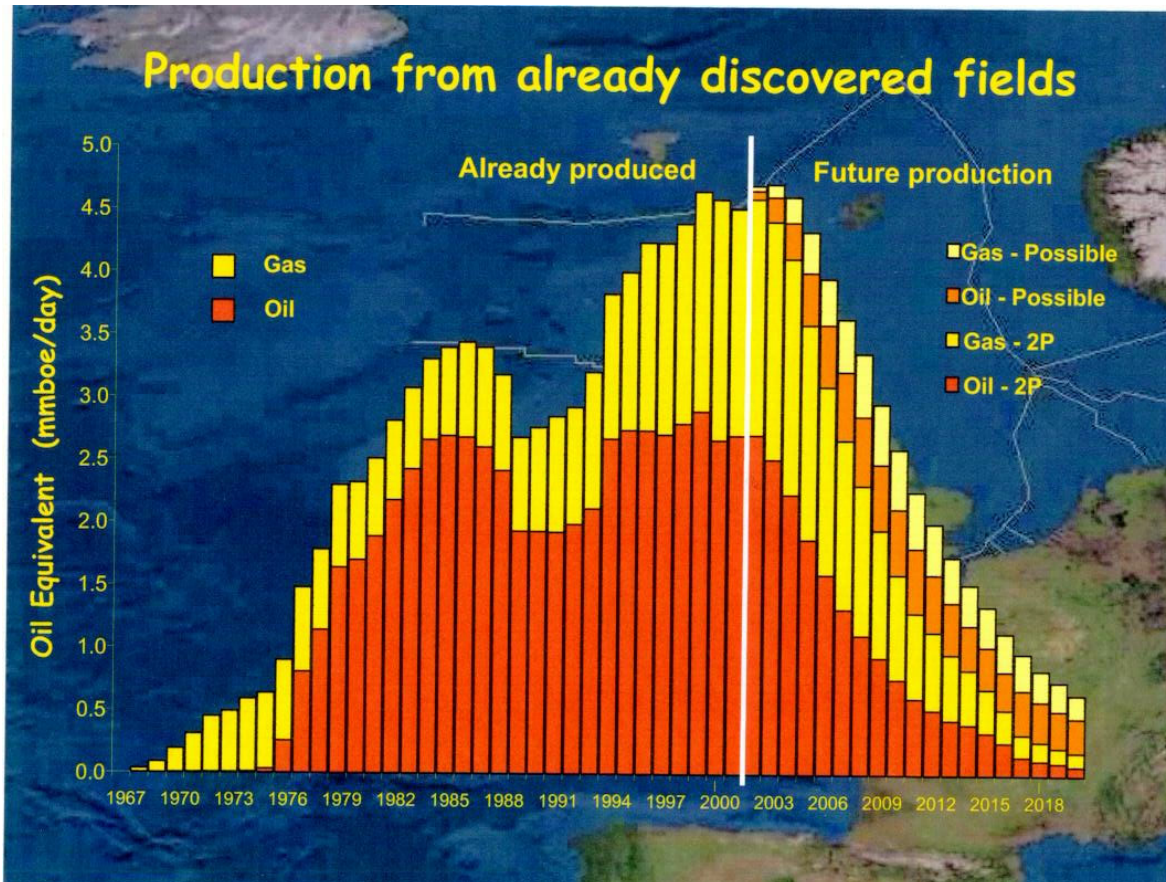
Middle East Reserves Revised Down: 2002



- The OPEC countries arbitrarily increased their quoted reserves in 1989 to adjust market shares.
- The true picture is 180GB lower. Oil n Gas Journal, May 2002
- Could ME Reserves be even lower?



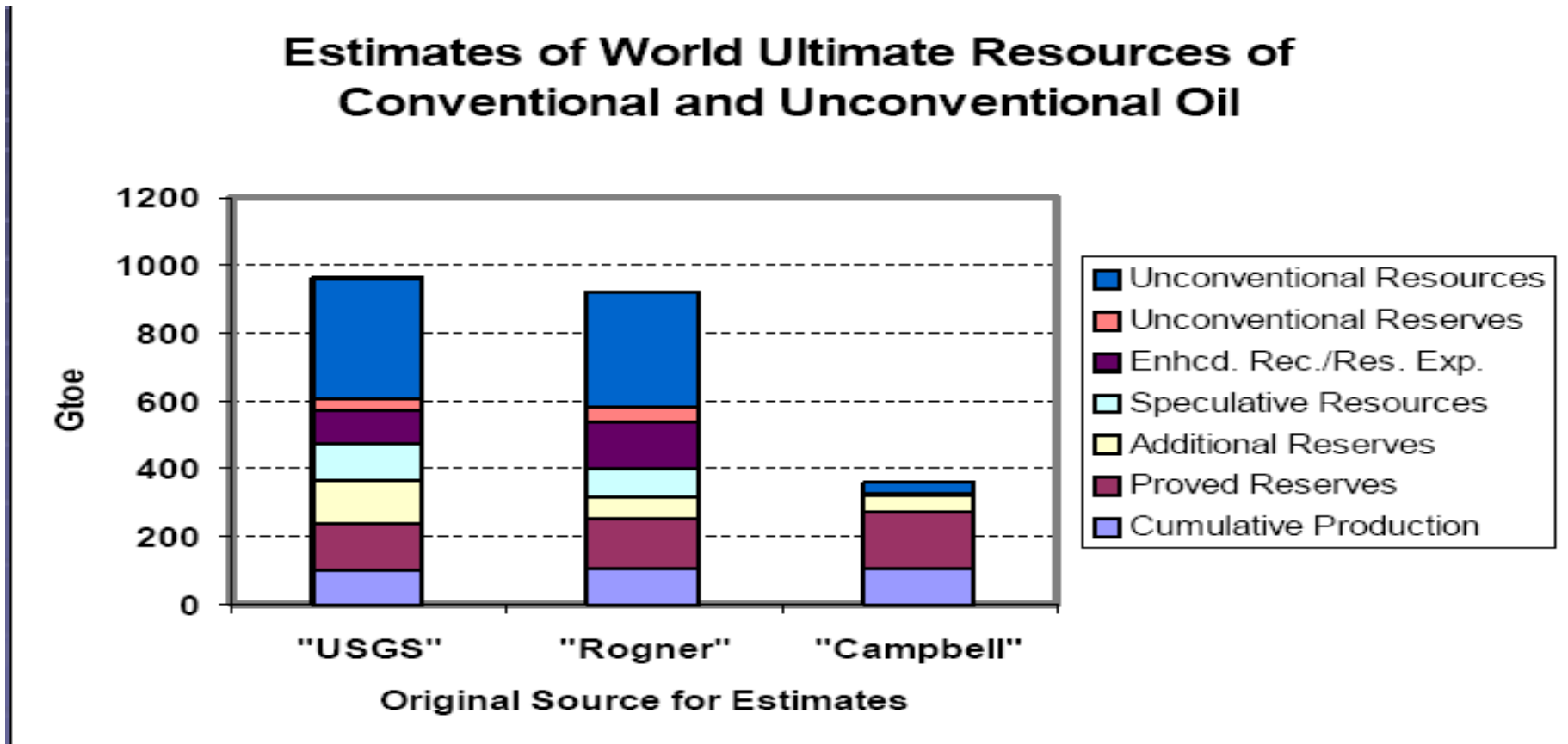
North Sea Decline - Official



- UK DTI chart to stimulate exploration.
- How secure are long distance pipelines?

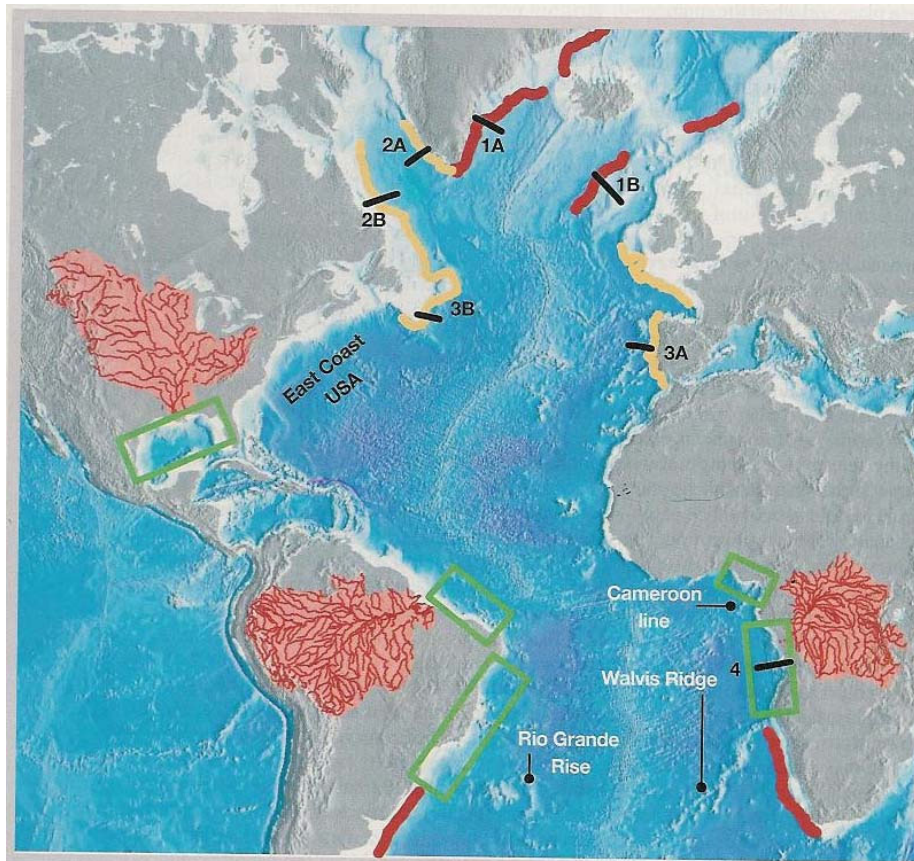


ORNL Views USGS vs ASPO





Atlantic Exploration



- USGS predict 50Gb off NE Greenland.
- Difficult 'Hot Margin' w km. thick magma flows.
- White et al., Nature 426, p. 336, 2003.



Syncrude: The Alberta Tarsands



- Biodegraded oil in sandstone.
- 350 Gboe recoverable from 1000Gb Total
- Only 35 GB in surface mines.
- 315 GB in deep deposits.



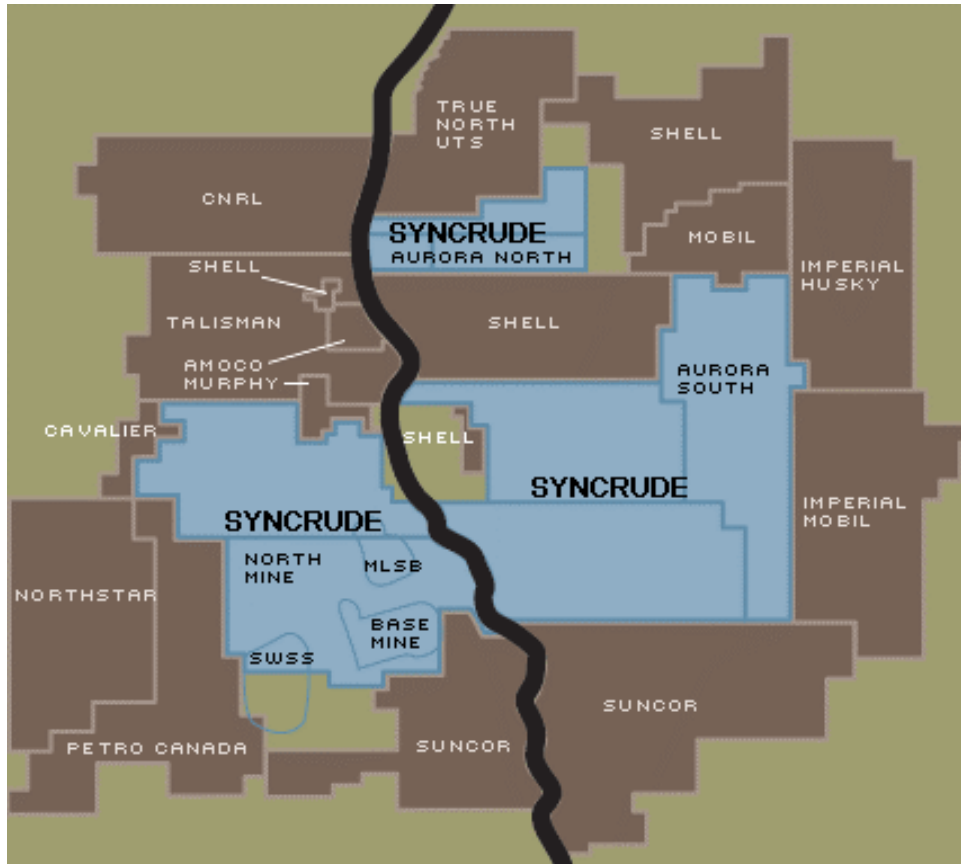
Bitumen Extraction



- Boiling water
- Huge amounts
- Vast lakes of waste.
- $Q = 3$
- Extraction costs \$15/b vs \$3/b for conventional oil.



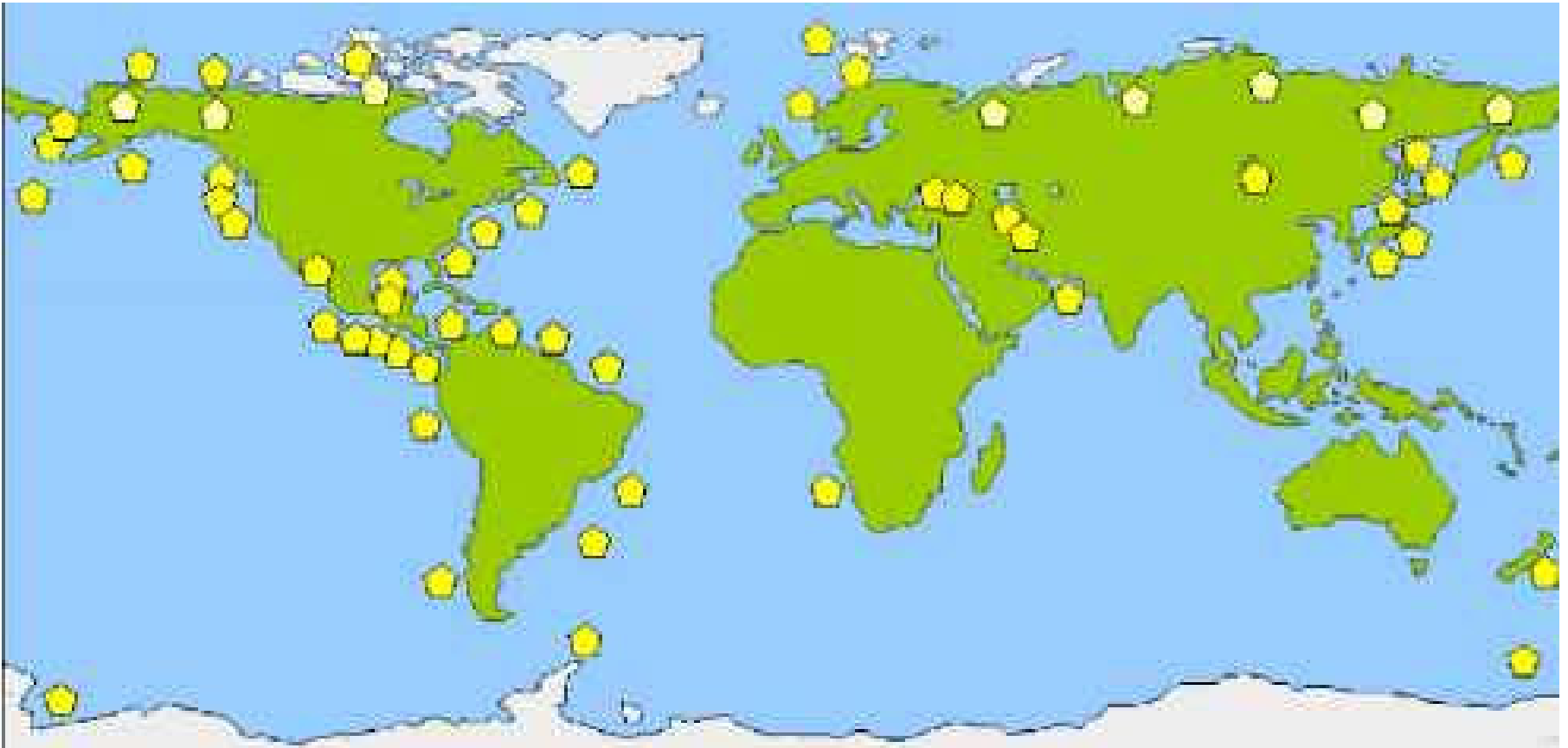
Global Contractors



- 800 Kb/d
- 2.5 Mb/d by 2020
- New catalytic processes – Ophus?
- Deep mining and in situ extraction much more expensive.
- $Q \sim 2?$

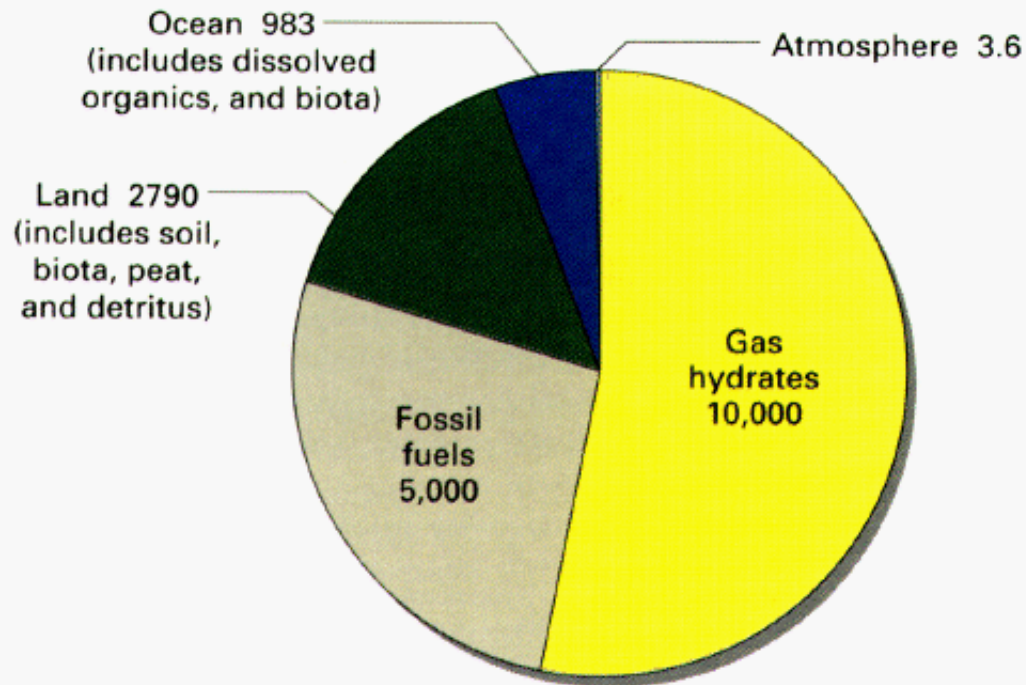


Methane Hydrate Resource Map





USGS Global Guesstimate



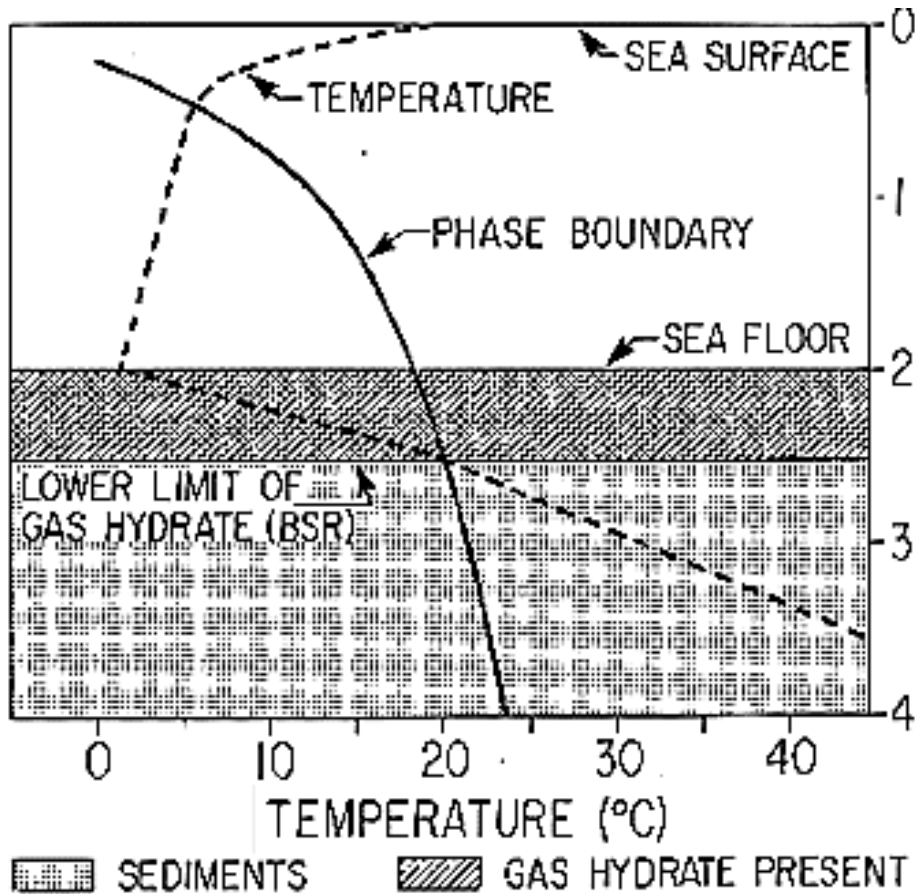
Distribution of organic carbon in Earth reservoirs (excluding dispersed carbon in rocks and sediments, which equals nearly 1,000 times this total amount). Numbers in gigatons (10^{15} tons) of carbon.

Shell analysts estimate 20 times less!

If it can be mined, should it be burned?



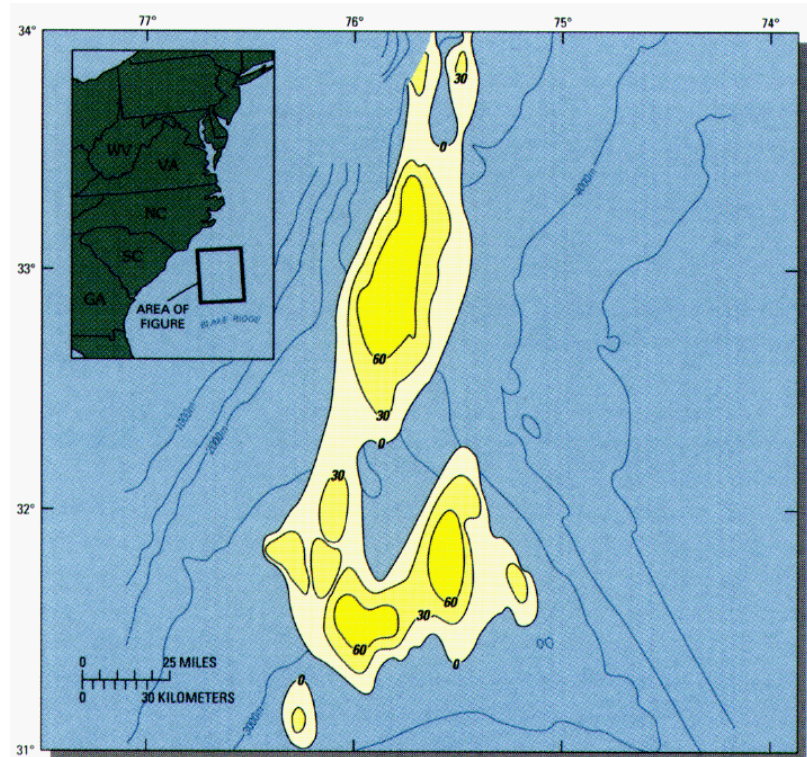
Methyl Hydrate Phase Diagram



- Methane trapped in water 'cage' at high pressure and low temperature.



North Carolina Hydrate Deposits



Map showing location and inferred thickness (in meters) of hydrates within sediments in the high concentration area off North Carolina and South Carolina.



USGS Blake Ridge Data

Location	Cores amples	H2O depth.	Sed. Depth	Description
Blake Ridge (Southeastern USA)				
DSDP				
Leg 76 Site 533 ODP	1 Samp.	3191	238	Fragments in mud.
Leg 164 Site 994	2 cores	2799	260	Fragments in clay.
ODP Leg 164 Site 996	5 cores	2170	0-66	Nodules, veins in mud
ODP Leg 164 Site 997	1 samp.	2770	331	Massive 30cm. Core.

Human ingenuity will find a way. – Micawberism?

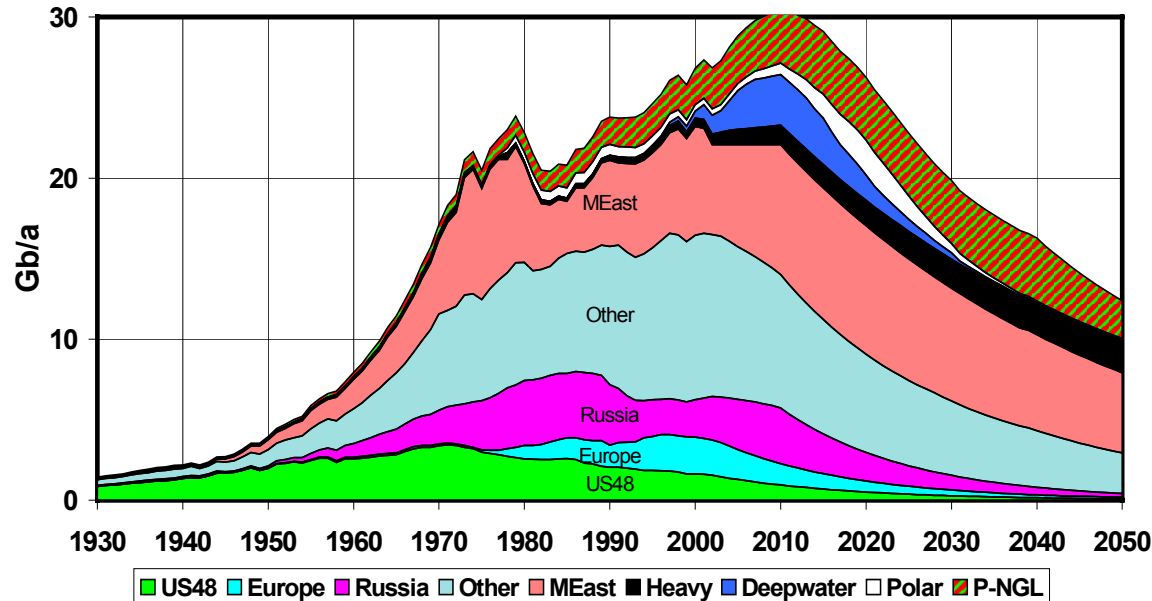
Robotic deep ocean mining and gas recovery?

Equivalent to \$100/b oil?

Could "Heavy Oil" restore supply?



Regular Oil & Natural Gas Liquids
2003 Base Case Scenario



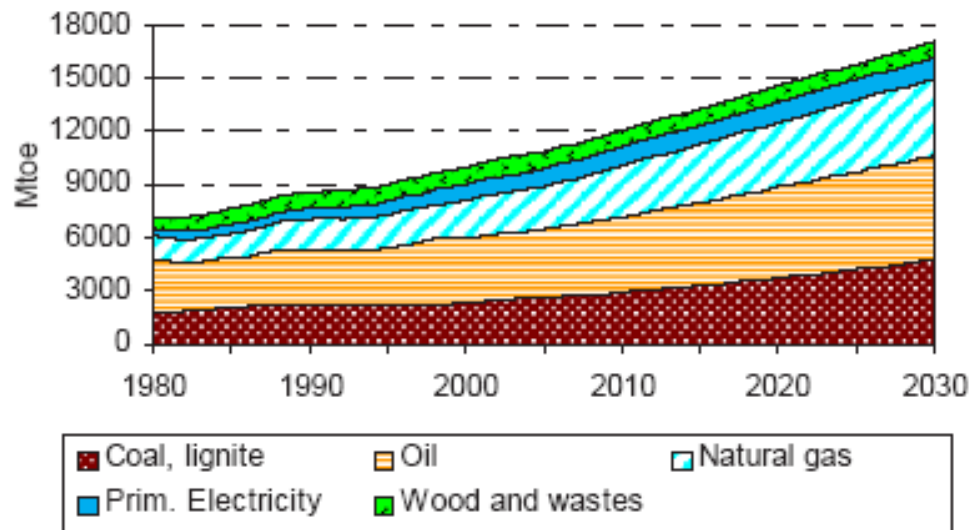
Black strip to expand by 10?

Why have Oil companies not declared 40% enhanced recovery reserves?



EEC WETO Projections of USGS Survey

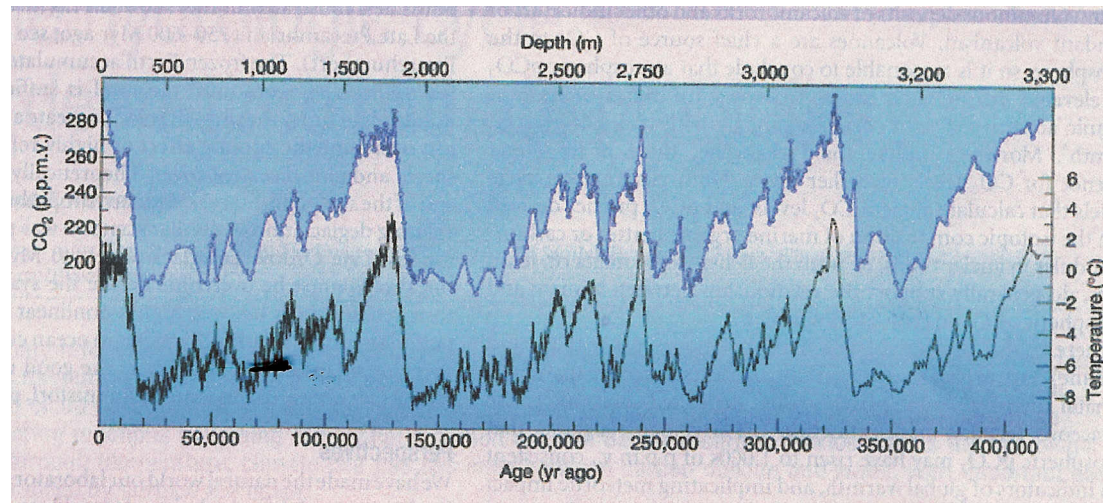
Figure 2.7: World energy consumption



- Energy use and CO₂ emissions double by 2030.
- Oil prices below \$25.
- 30% \$ devaluation now has oil at a new low.



CO₂ & GLOBAL WARMING



Lee R. Kump, Nature, V149, No. 12, 2002

A comparison of CO levels and global temperatures over the last 400,000 years as measured in the geological record.

Complete utilisation of the world's coal reserves in the next 250 years would raise the level to 2000 ppm.



Risk Analysis

Win Win	Heads wins a TV	Tails wins a VCR
Game Show	Heads wins a TV	Tails loses winnings
Hobson	Heads you die by fire.	Tails you jump.
Corporate Gamble	Heads wins £100Bn	Tails means bankruptcy.

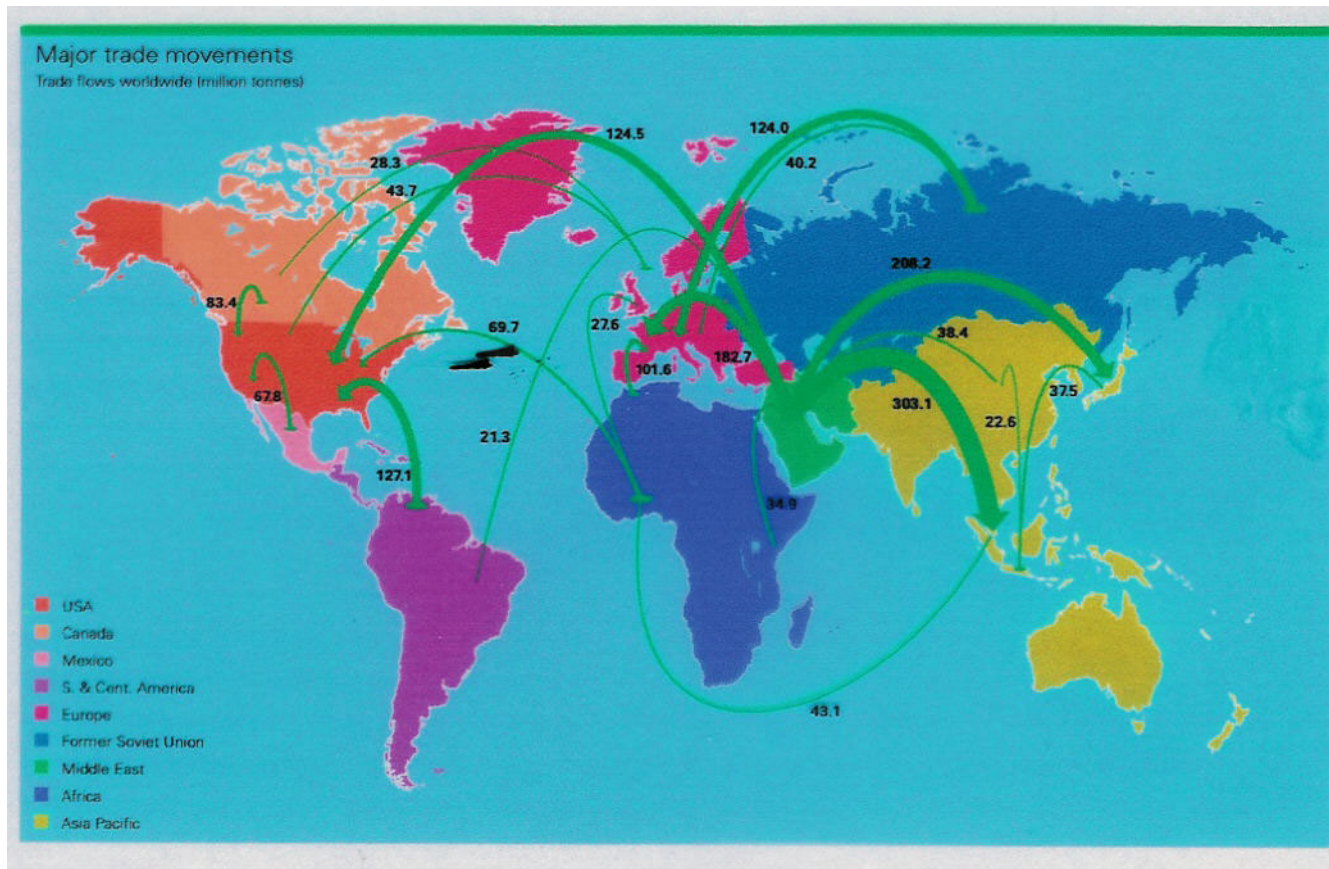


Conventional vs Expensive Oil

- Are ASPO and USGS both right?
- Do they agree that Conventional is now peaking?
- 30/50 Mb/d shortfall by 2030.
- Expensive oil will appear over 20-50 years.
- Global Warming might make this moot!
- Lucky strikes vs. Economic Failure.
- Bet the curves, not the hopes.



Global Oil Trade 2000



- Middle East to:
- US 124
- EU 182
- Japan 208
- Asia Pacific 303



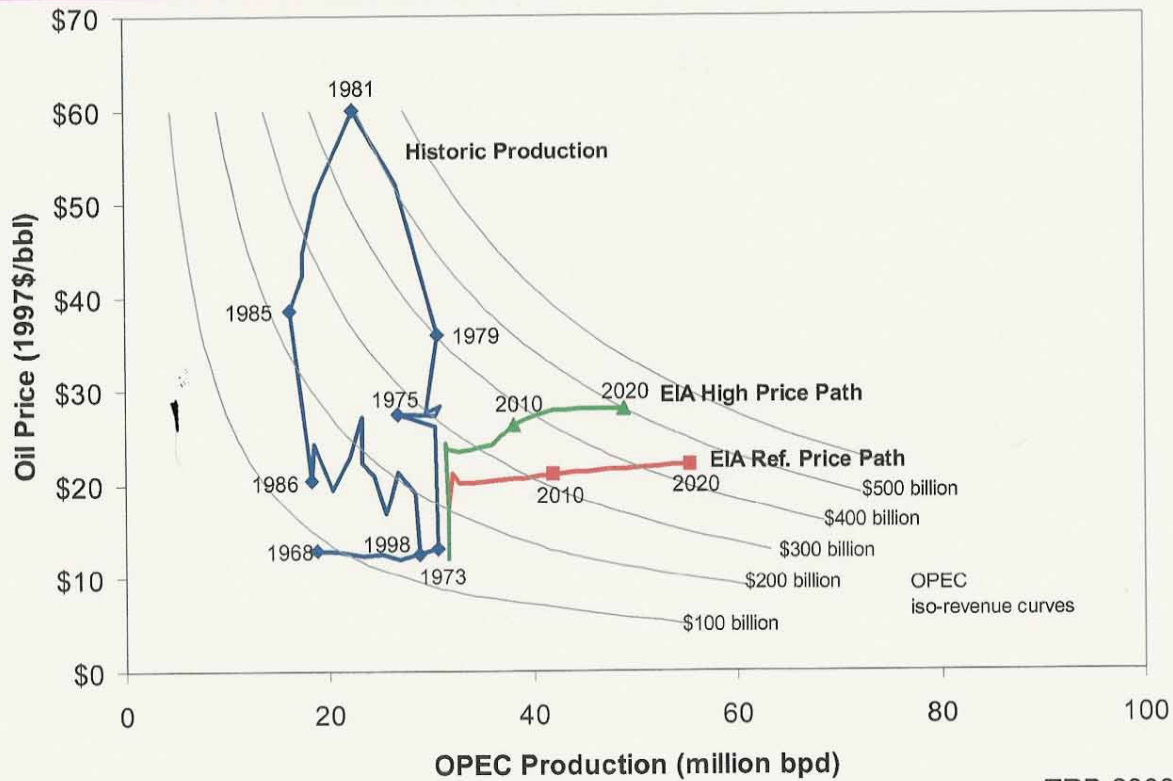
Problems with Energy Economics

Oil Prices, OPEC Production and Revenue



Double ME production by 2020 @ \$22/b.

Really?



TRB 2000 - 9



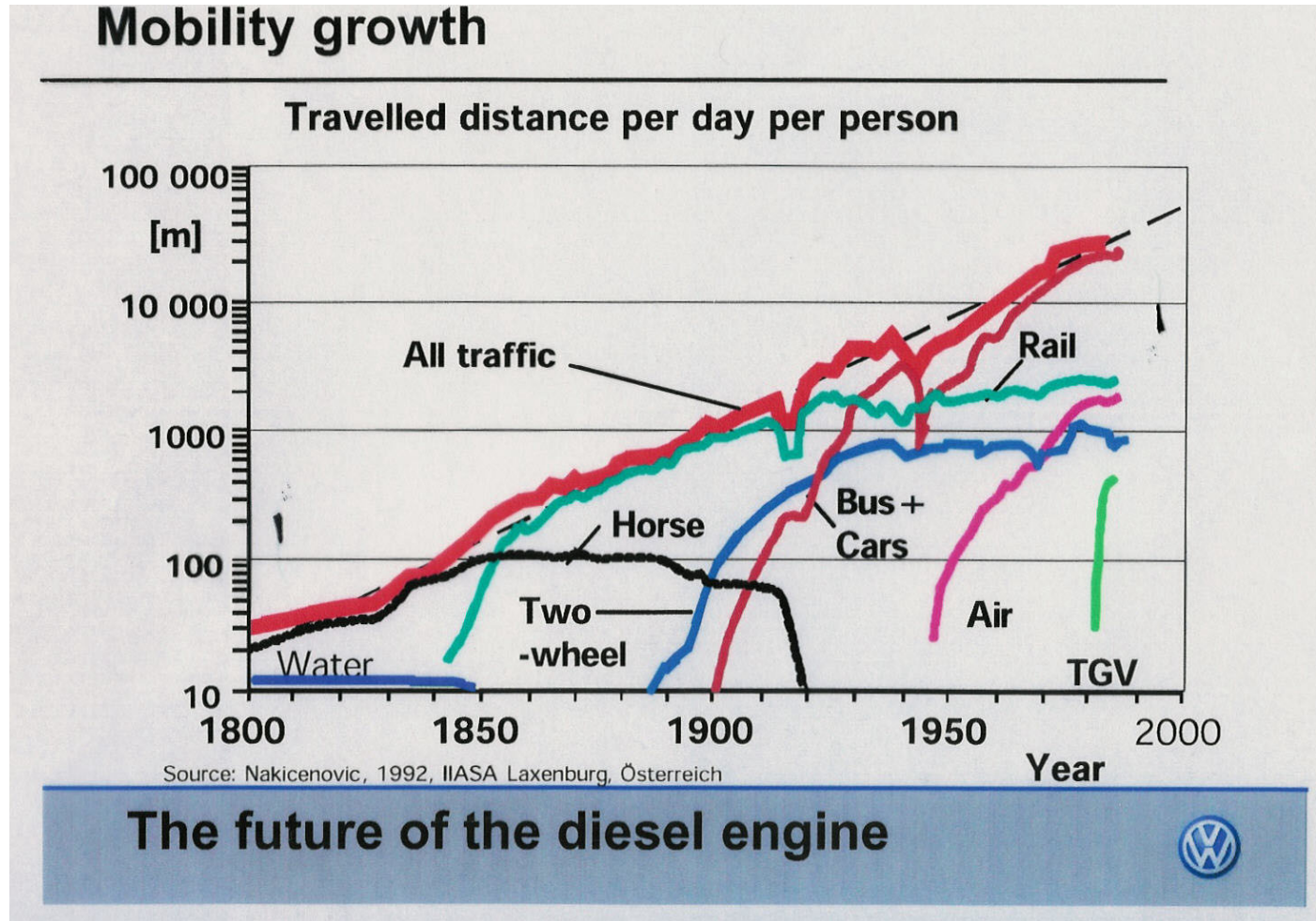
CONSEQUENCES TRANSPORT MUST CHANGE



Too much, Too far, Too wasteful, Too tiring.



Transport Growth





VW Diesels at 80 mpg

The first 3L vehicle in production

VW Lupo 3L TDI

- **1.2 l TDI engine with unit injection**
- **45 kW (61 PS)**
- **2,99 l/100 km**
- **Euro 4 limits**

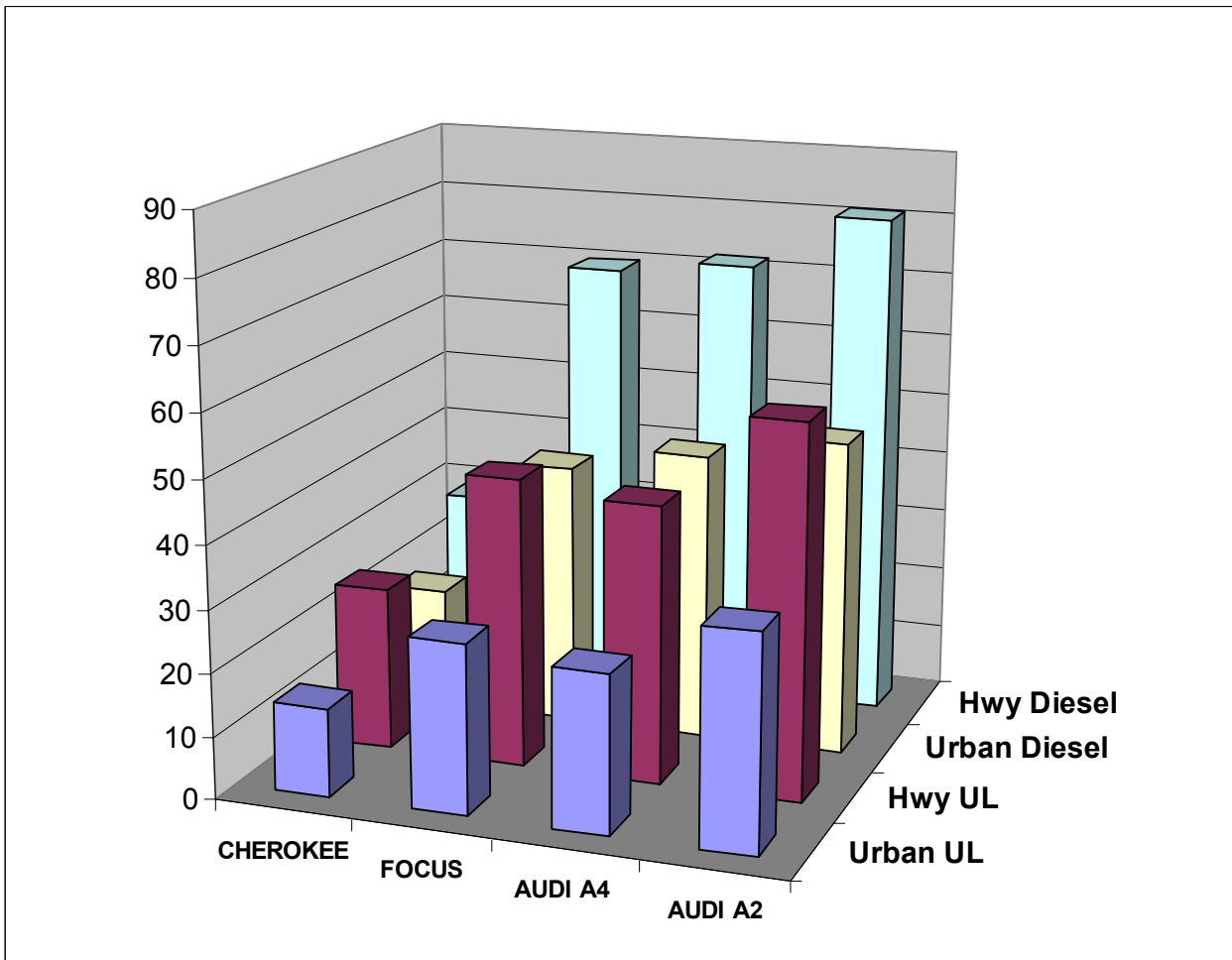


The future of the diesel engine





MPG for UL & Diesel Cars, 2003



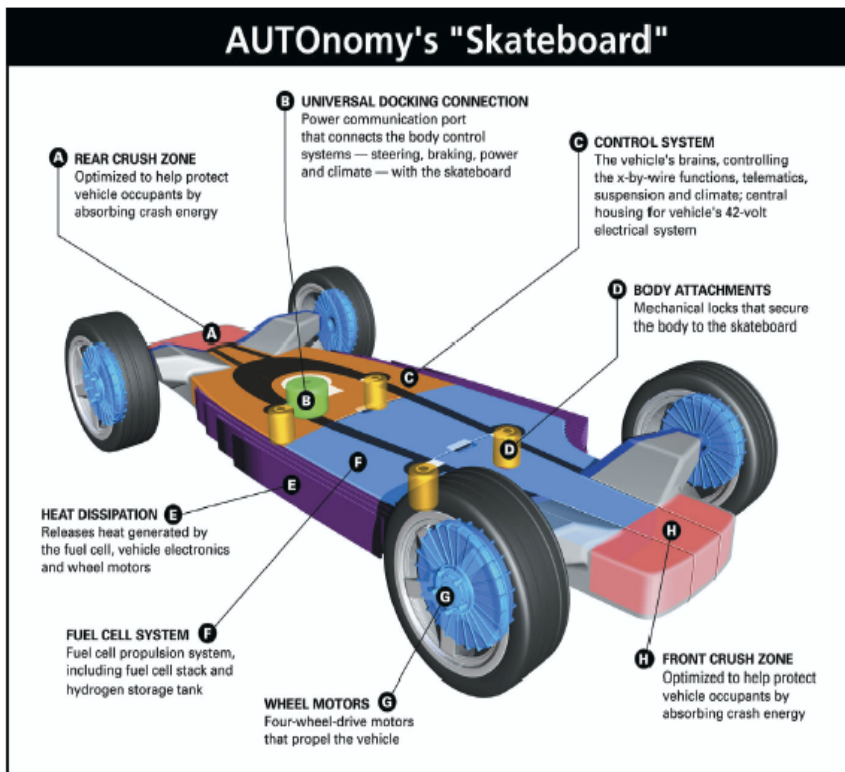
US DoE predicts most families will have an SUV by 2020

No legislation to limit consumption.

Will Diesel help the EU?



GM Fuel Cell Cars



The main conduit for AUTOmy's electrical system is a universal docking port at the center of the chassis that connects all of the body systems to the rolling chassis.

- 4 wheel drive
- 100kw output
- Compact skateboard platform
- Electronic control: X-drive-by-wire



General Motors H₂ Fuel Cell Hywire



- Starting the 'Hydrogen Economy'
- 4 wheel drive motors
- All electronic steering and braking.
- How much is Hydrogen? What will the system cost?

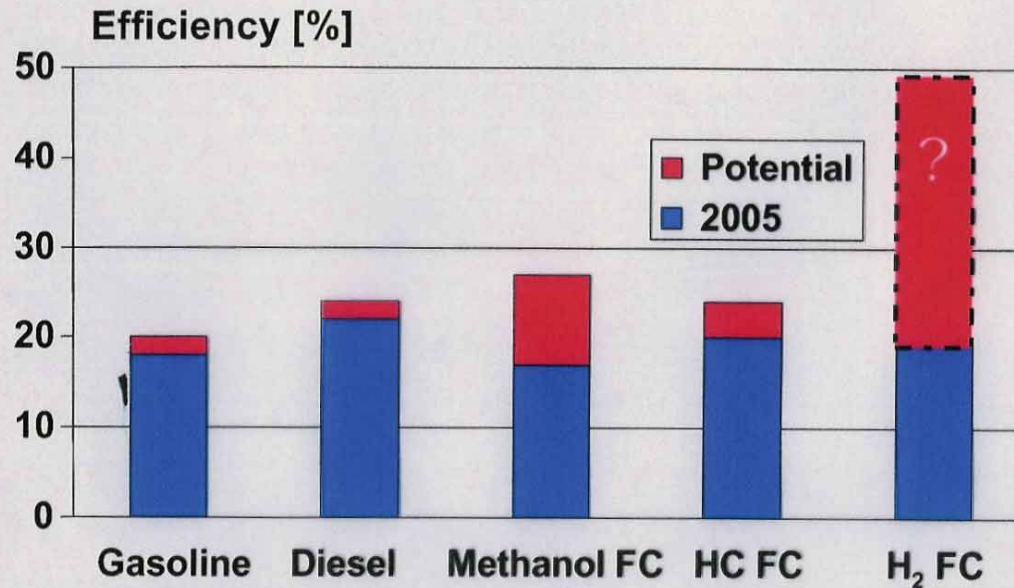


Engine Comparisons



Comparison of modern propulsion concepts

Total efficiency incl. fuel production, transport and vehicle operation



The future of the diesel engine





FIFTEEN MINUTE RULE

- If you can walk, bike, drive, train, helicopter, fly, or rocket to it in fifteen minutes it is part of your life. Any further and it can only be a necessity like work or mother-in-law. When choosing a place to live check out your 15 minute zone.
-
- **Corollary for after the Oil Peak:**
- If you have to take transport there it is not part of your life.



Coal



- Huge supplies – 250 years - of Carbon
- → High CO₂ burden.
- Air pollution: Sulphur, Arsenic, soot, ...
- 'Clean Coal' Power Stations?
- Chemicals and Fuel source?



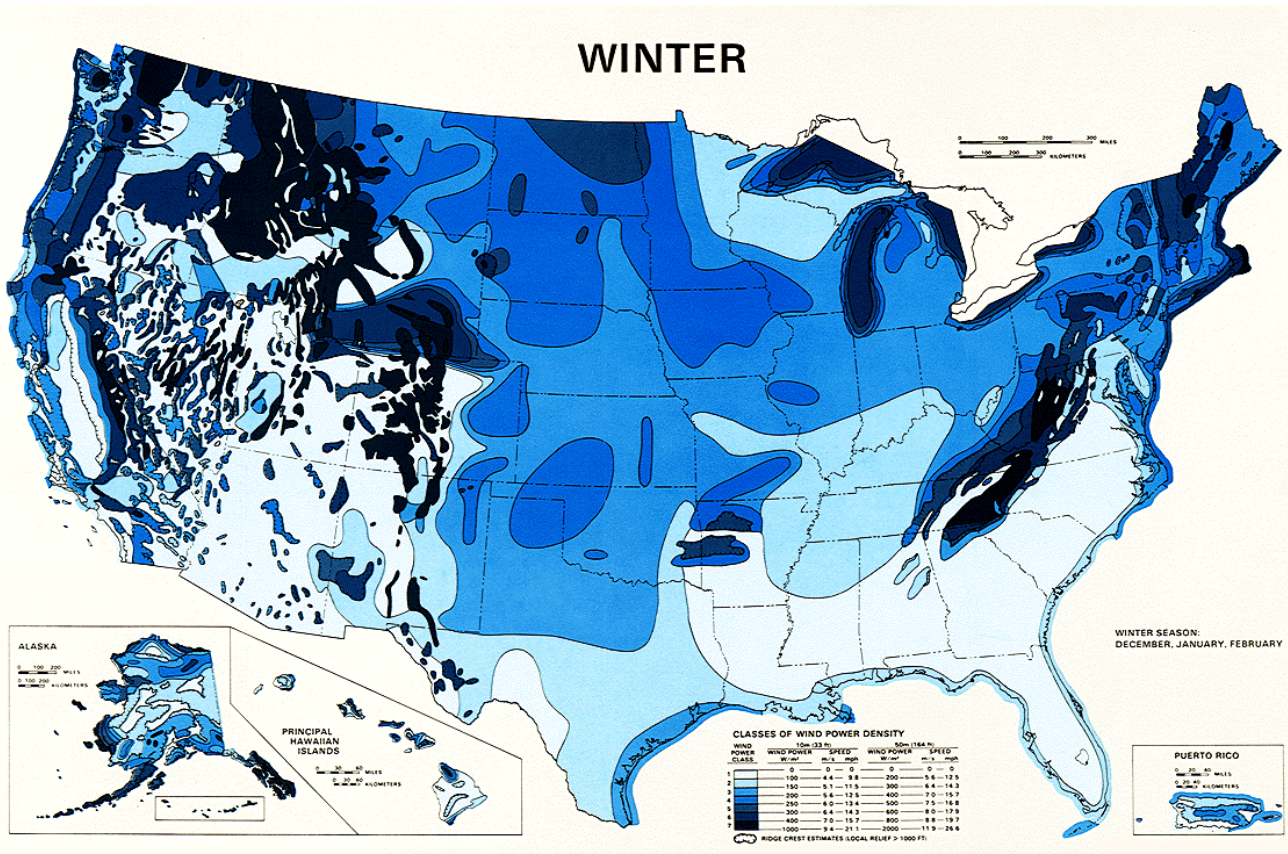
Wind Energy

- **EU investing EU10Bn by 2010**
- **Gives 10GW peak, delivers 2.5GW. Needs 140,000 acres.**
- **Useful, working, competitive, limited.**
- **Needs 5m/sec. average wind – coastal and mountain locations.**
- **Costs 5-10 c /Kwh**

©AMEC Border Wind



AVG Winter Winds

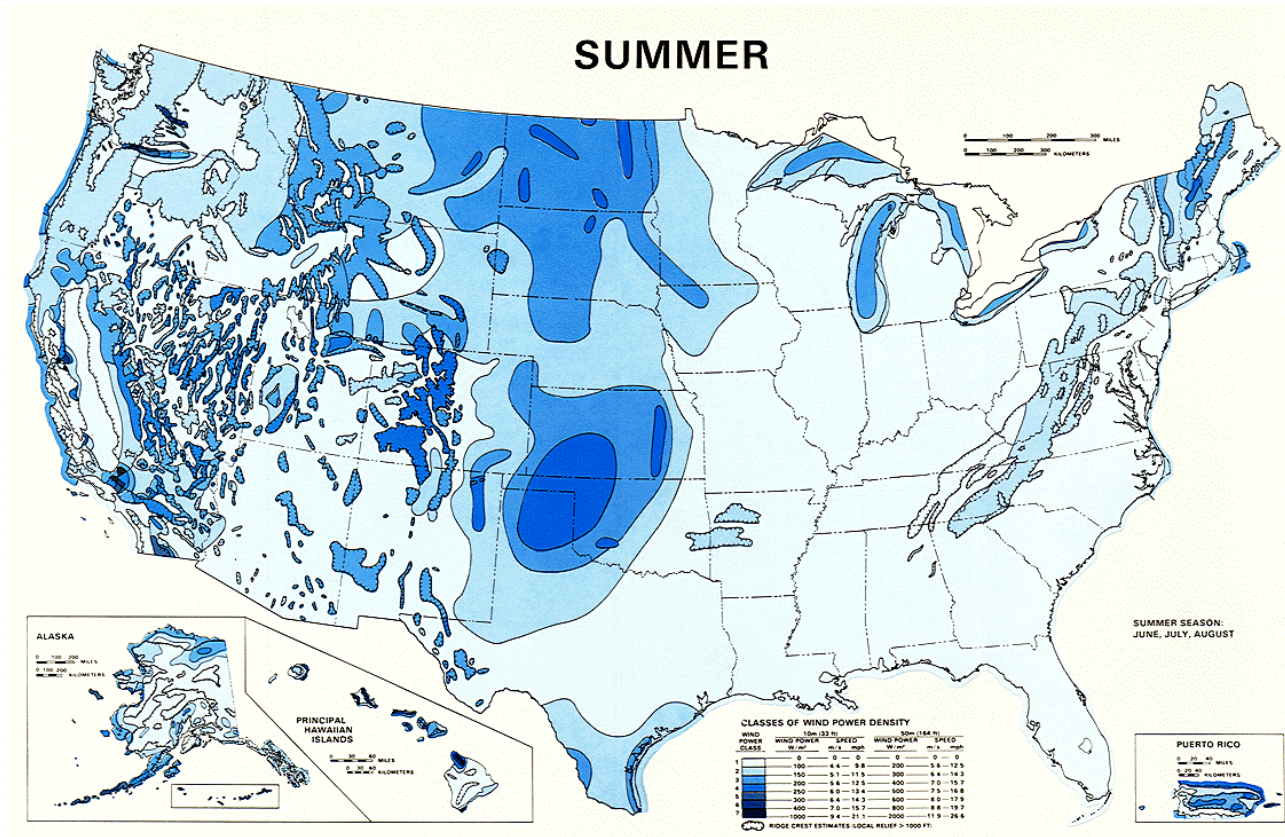


- Central US OK for wind power
- Mountain winds strong.



AVG Summer Winds

- Central US OK for wind power





Meeting Renewables Obligations

- RO: 10% UK Electricity by 2010
- Targets unlikely to be met. High capital costs
- Slow build due to Finance and Windmill technology upgrades.
- All technical problems solvable.
- Expensive oil could enhance prospects.



Solar Power

- Excellent for low power applications.
- Lighting, radio, TV, computing.
- 4 acres/MW.
- Commercial deployment still weak.
- £10,000 for 2-3KW-pk Home Solar.
- Unlikely source for central power.



$$E = m c^2$$

- All our energy sources ultimately derive from nuclear processes in the Sun which convert mass into energy.
- ($F = GmM/d^2$)
- The Gravitational force of the mass of the moon drive tidal power sources.)



Nuclear Fission

The main interim solution





Nuclear Fission



- Nuclear Waste still a problem. Use oil field salt domes. No CO₂ burden.
- Japan + China + other Developing Countries building new nukes - slowly.
- US: Generation IV Designs: Safer, high burnup, cheaper, less waste. Deploy and control? Just a concession to bureaucracy?
- Major US/EU source. Is another round required now?
- Current US Nukes output at 1.17 c/kwh.



Generation IV Reactors



Office of Nuclear Energy, Science and Technology



Generation IV - An International Initiative

DOE is leading the Generation IV International Forum

- Formal, chartered organization of Governments
- Developing GEN IV Technology Roadmap
- Conduct collaborative nuclear R&D to leverage U.S. Funding



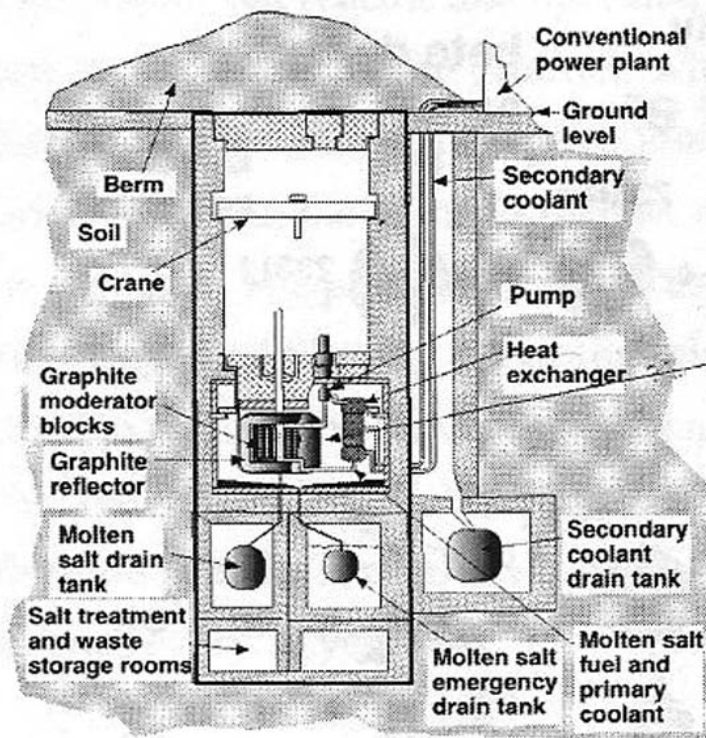
The Generation IV Technology Roadmap will:

- Identify 6 to 8 most promising technologies
- Establish clear R&D plans
- Enable deployment of GEN IV systems after 2010 but before 2030





Molten Thorium Salt Breeder



7/16/2003

- Li, Be, Th, U Fluoride salts.
- Non fissile fuel.
- -ve Temp. Coeff.
- 80-100% breeding.
- Low weapons material production
- Moir & Teller, 2003



UK DROPS FISSION



- Following the UK Energy White Paper, Patricia Hewitt, Dti Secretary avoids issues:
- “New nuclear build would destroy incentives we’ve set up for renewables and energy efficiency”
- What is needed to persuade people differently?



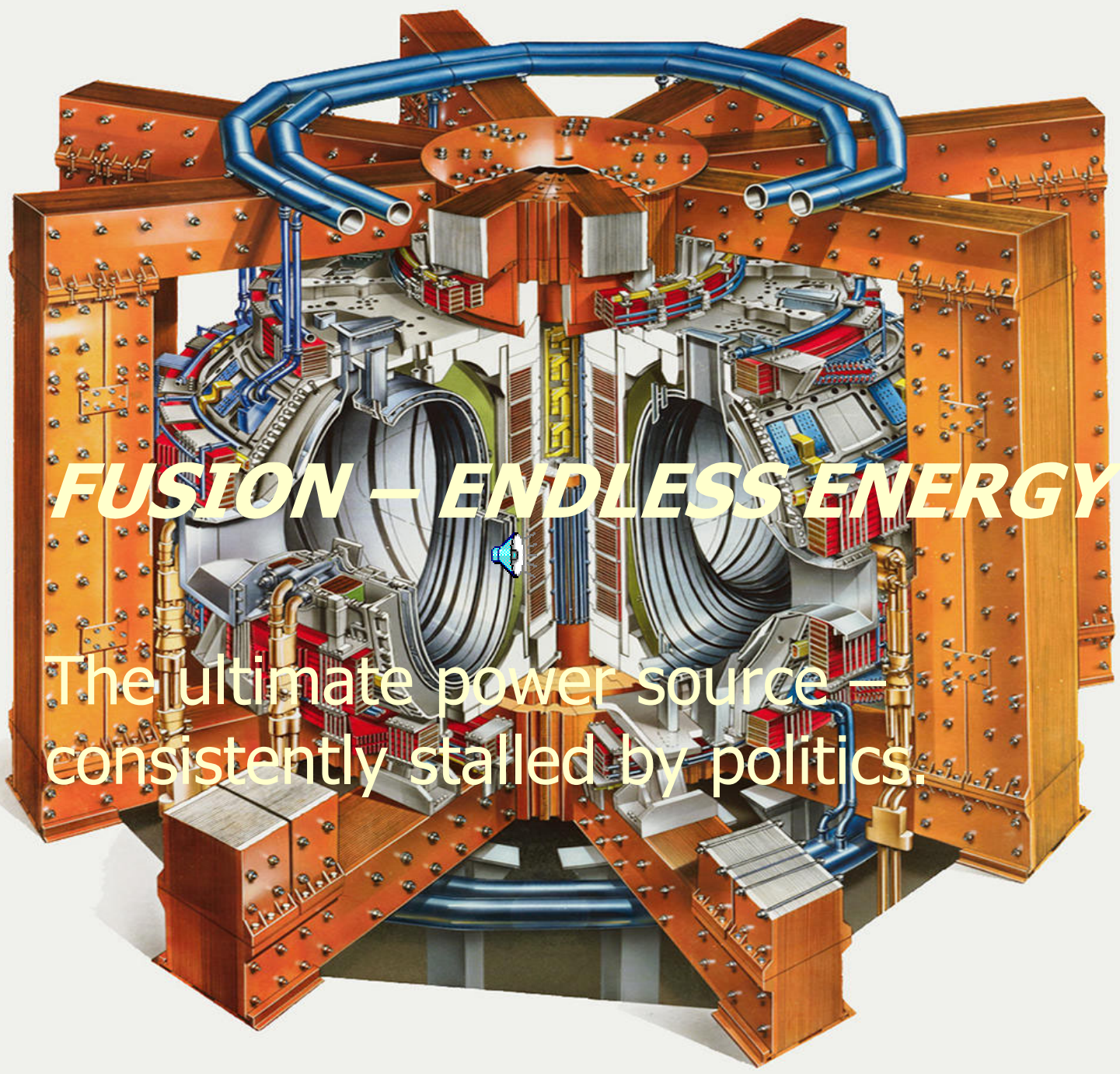
German Greens to close all nukes

- Germany derives 30% of its electricity from 19 nuclear stations.
- Green Party condition for coalition support is the closure of all 19.
- They have no clear plans for energy substitution.
- Regime change?



Nuclear Accidents

- Three Mile Island and Chernobyl used to kill nuclear power.
- Both events due to human folly, not engineering failure.
- Bored workers created BNFL and Tokai incidents.
- No significant French nuclear accidents.
- **Can these events can be engineered out?**



FUSION – ENDLESS ENERGY

The ultimate power source –
consistently stalled by politics.

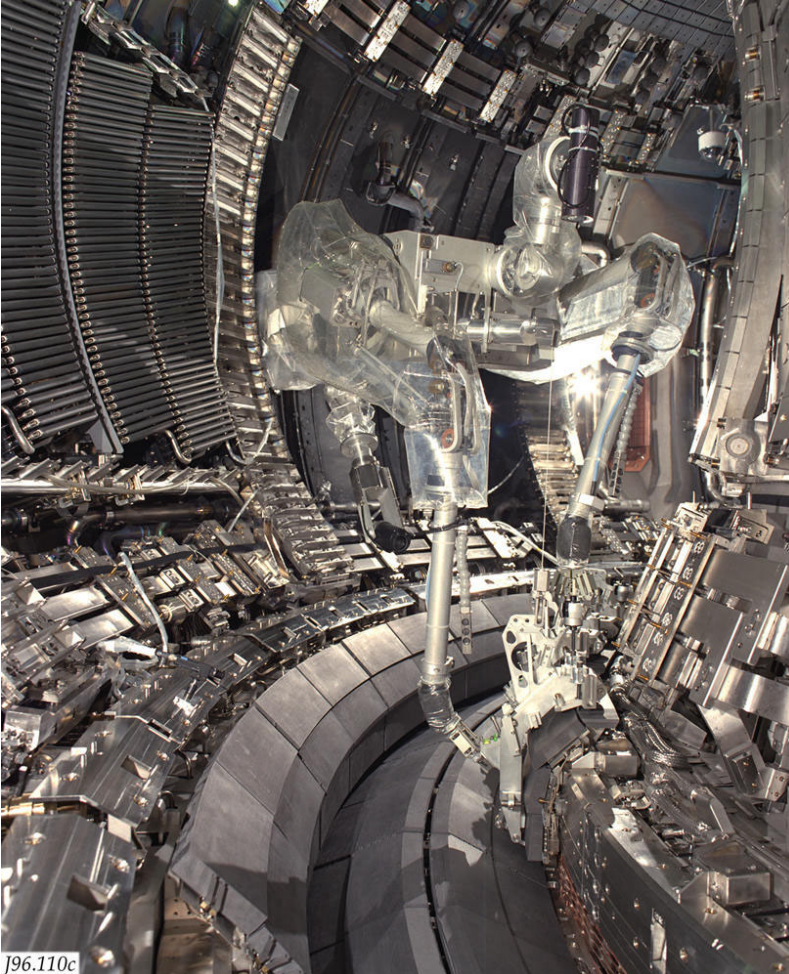


But Fusion image is poor...

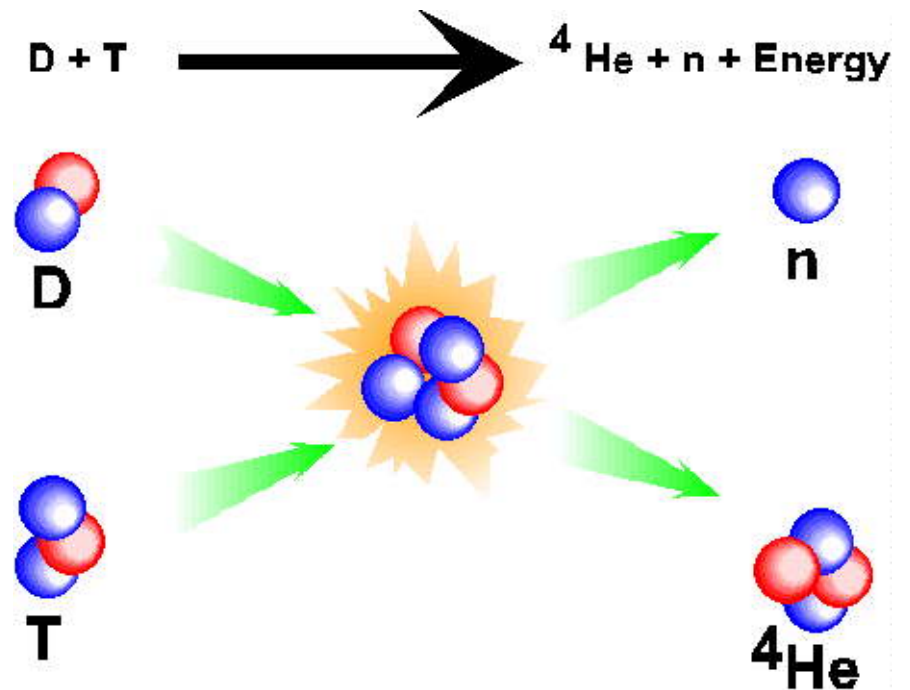
- Manchester Guardian, 13.11.03
- ... Science Scams...
- Cars that run on water and fusion machines that generate more energy than they use are staples of inventors' fantasies.
- Fusion ignored by WEC, IEA, etc.
- How can Fusion change its image?



JET Man-in-Loop Maintenance Robot



J96.110c
Brendan@leabrook.co.uk





Magnetic Fusion Energy

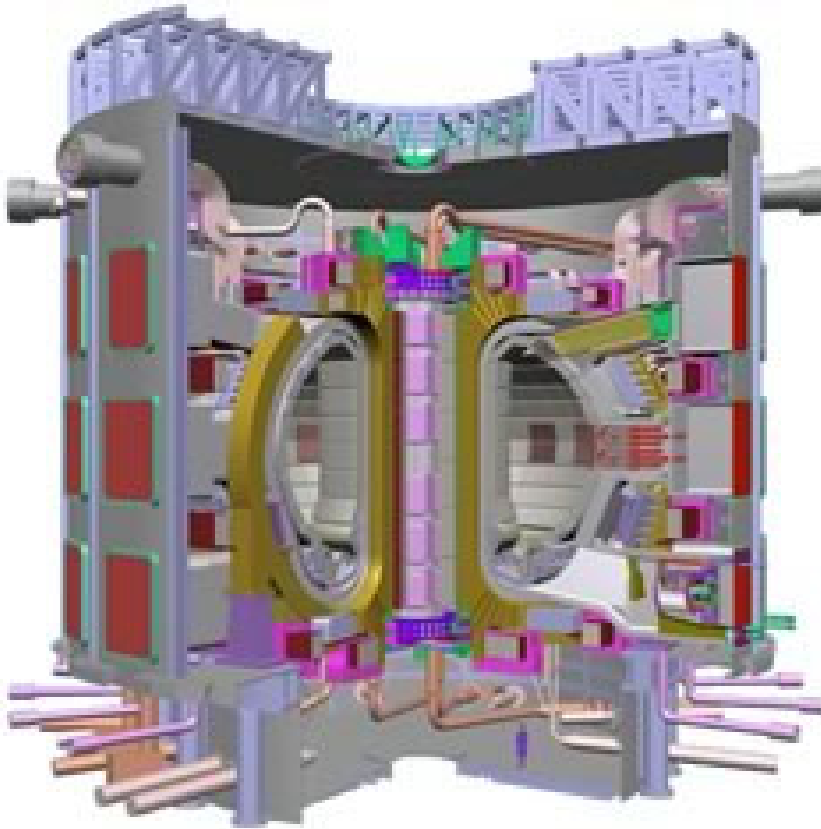
Programme lost 20 years to politics.

JET Completed thanks to the Bader-Meinhof gang.

- ITER: International Tokamak in design mode for 15 years + 10 to build & 10 to run = 35 years.
Can this be shortened?
- IFMIF: Irradiated Materials Testing pushed by UK
- Large Component Test Facility in design.
- Are these needed in parallel with ITER?



ITER – International Torus



- **Main parameters and dimensions:**

Total fusion power: **500 MW**

Fusion power/auxiliary heating power: **10**

Average (14 MeV) neutron wall loading: **0.57 MW/m²**

Plasma major radius: **6.2 m**

Plasma minor radius: **2.0 m**

Plasma current: **15 MA**

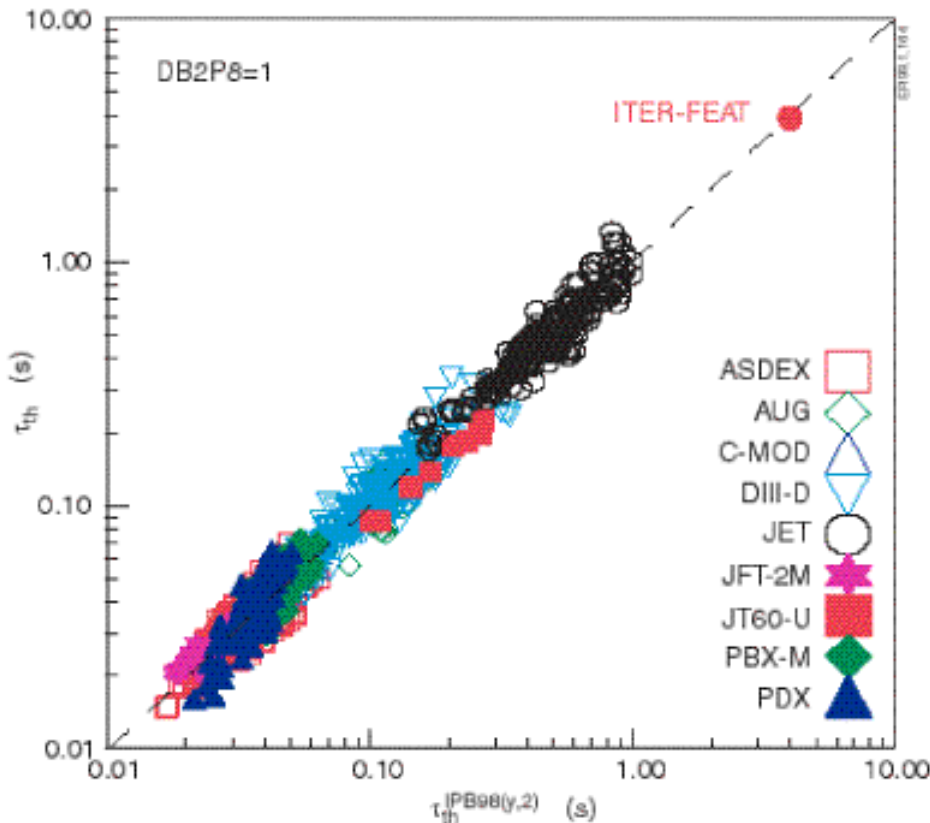
Toroidal field at 6.2 m radius: **5.3 T**

Plasma volume: **837 m³**

Auxiliary heating and current drive power: **73 MW**



Design by Empirical Scaling



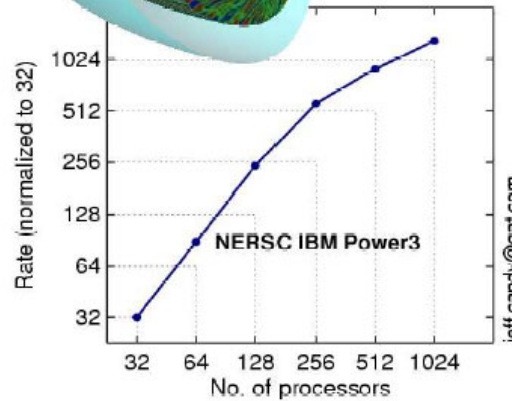
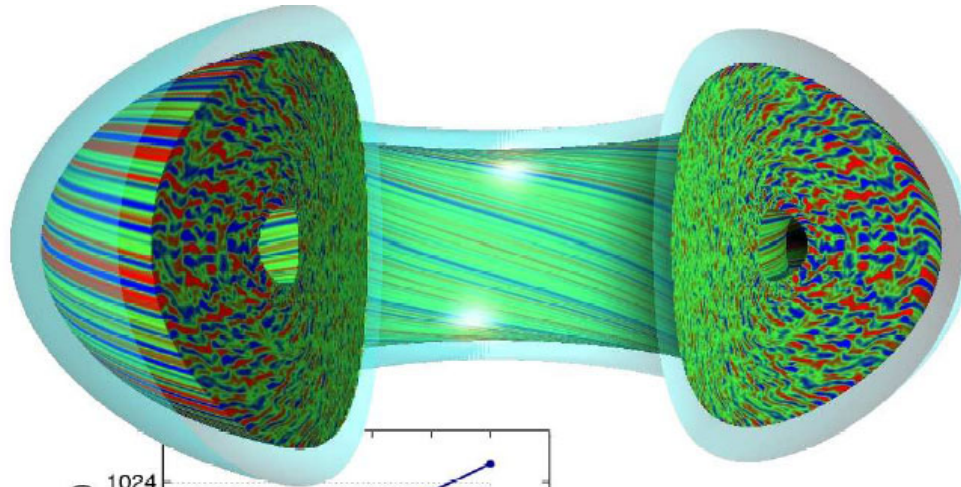
$$\tau_{E,th} = 0.0562 I_p^{0.93} B_T^{0.15} P^{-0.69} n_e^{0.41} M^{0.19} R^{1.97} \varepsilon^{0.58} \kappa_a^{0.78}$$

Transport scaling theory out by 1000 times in 1980s. New diagnostics revealed the mechanisms.

Massive numerical models now within 10%. This breakthrough is unrecognised.



Tokamak Weather Simulation



GYRO gives superlinear scaling up to 1024 processors on FIXED problem size.



Candy and Waltz, JCP 2003, subm. to PRL.



Plasma Heating

- Ohmic heating, & ECRH, & ICRH, & Lower Hybrid heating.
- Neutral Beams are the primary source – invented at UC Berkeley for LLNL Mirror program.
- Is this confusion or is it a set of methods to explore the best operating conditions?
- Why is ITER insistently described as 'an experiment'? Is it not the final test bed for a family of commercial fusion reactors?

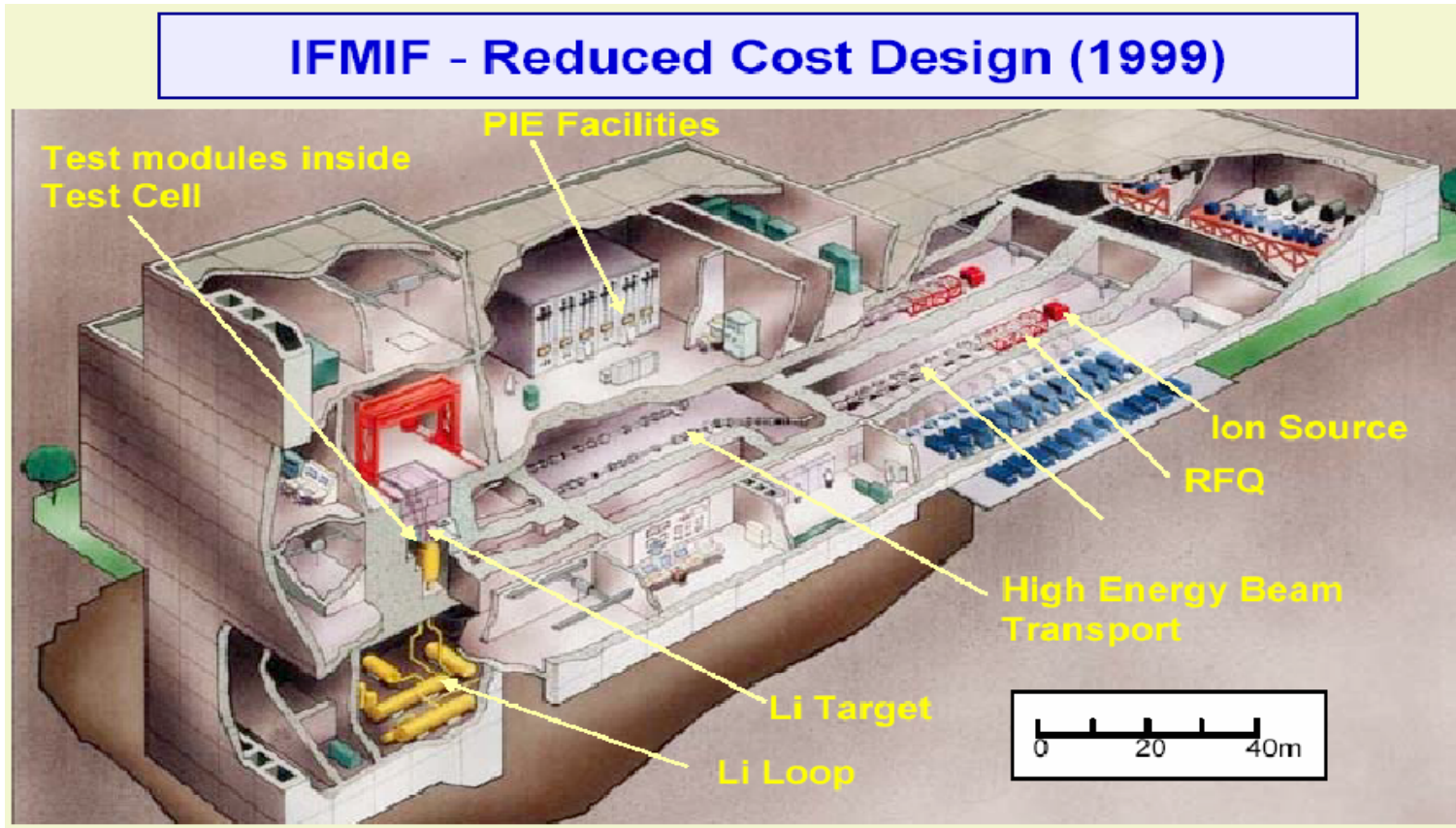


The ITER Site

- Rokkasho is the main Japanese site for nuclear fuel reprocessing and Plutonium storage.
- Will Fusion be damaged by association with these controversial activities?



IFMIF: Test volume=500cc.





Fusion materials testing: 20 years

IFMIF Road Map

IFMIF-Plan	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22
KEP	█																				
Transition phase		█	█																		
New IEA-agreement			█	█	█	█	█	█													
EVEDA			█	█	█	█	█	█													
Procurement packages							█	█	█												
Reference site					█	█	█	█													
IFMIF agreement for constr.						█	█	█													
Licensing for operation								█	█	█	█										
Construction and commiss.								█	█	█	█	█	█	█							
Testing accel. module											█	█	█								
Operaton Phase 1 (125 mA)														█	█	█					
2nd accelerator Phase															█	█	█				
Operation phase 2 (250 mA)																		█	█	█	█

Almost 10 years of Admin before construction.

Does not compare with normal DoE projects.

Materials physics augmented by massive computer simulations.



An Aggressive Fusion Programme

- Will ITER drain funds from existing, weakened Fusion research? Is JET and the reduced Culham group a model of the future?
- Jet benefited widely from existing programmes – Tore Supra, ASDEX, DIII-D, JT-60. Why should these stop?
- Constructive competition from Spherical Tokamaks, Spheromaks, Stellarators. Should they be enhanced?
- Alternates in Heavy Ion fusion and Z-pinches still have much to contribute.
- Laser Fusion, with massive defense support is also a competitor.



The Future of JET

- Should JET continue for another 15 years?
- Only real intermediate between 2nd generation Tokamaks and ITER.
- Edge physics, ELMS, electron heat transport.
- Heating and plasma control. JET has all the systems.
- All could shorten time to burning plasma trials in ITER



ITER II

- Is one ITER sufficient? Where is the competition, oversight?
- What happens if ITER-I has a major breakdown? Could it be a write-off?
- Other facilities like FIRE or IGNITOR should be funded to accelerate progress.
- The US, with only a 10% ITER commitment may well make its own way.



Alternate Fusion Concepts

- An aggressive Fusion program would support a range of devices at the JET/TFTR level – fusion quality plasmas, long pulse lengths, full diagnostics, full theory and computer simulation efforts.
- Another Tandem Mirror? Easy to repair. Materials testing.
- Advanced Concepts: D-D, Heavy Ion, etc.
- These do not imply uncertainty, only the further opportunities for improvement and invention.
- Cf: Petrol, Diesel, Wankel, multi-valve, Hydrogen, fuel-cell, catalytic, electric, ...

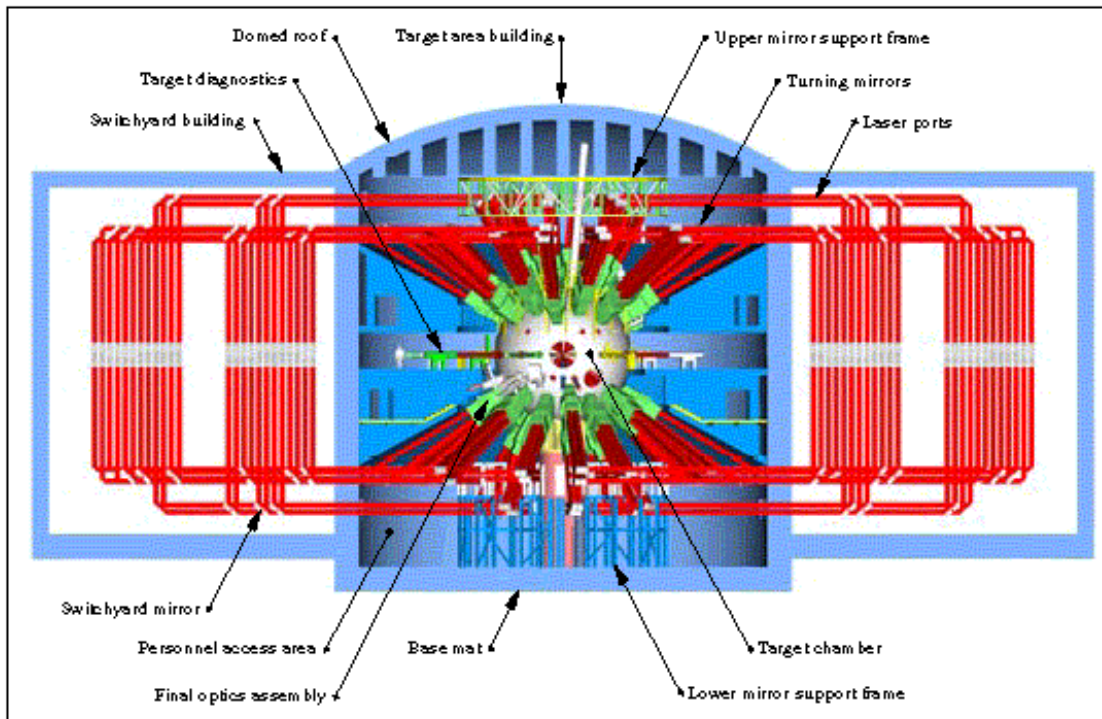


Toroidal Fusion Alternates

- US best placed for Ultrascale Computational Design of Alternates at fusion temperatures.
- Build one or more Compact Torus experiments at Generation II level.
- Strengthen other teams to get value from other concepts.



Laser Fusion - NIF



- Need $Q > 100$ from pellet fusion.
- 5 cycles/sec lasers.
- Smoothed beams avoid Rayleigh Taylor.
- Computational target design.
- NIF could demonstrate by 2012.
- Technology/materials problems shared with Magnetic.
- DoD funding.



Fusion Economics

- Most recent FOM study of fusion Economics flawed:
- Assumes \$25 oil + 3% GNP growth rates forever.
- 3% discount rate inappropriate for falling economies.
- No coupling to global economics



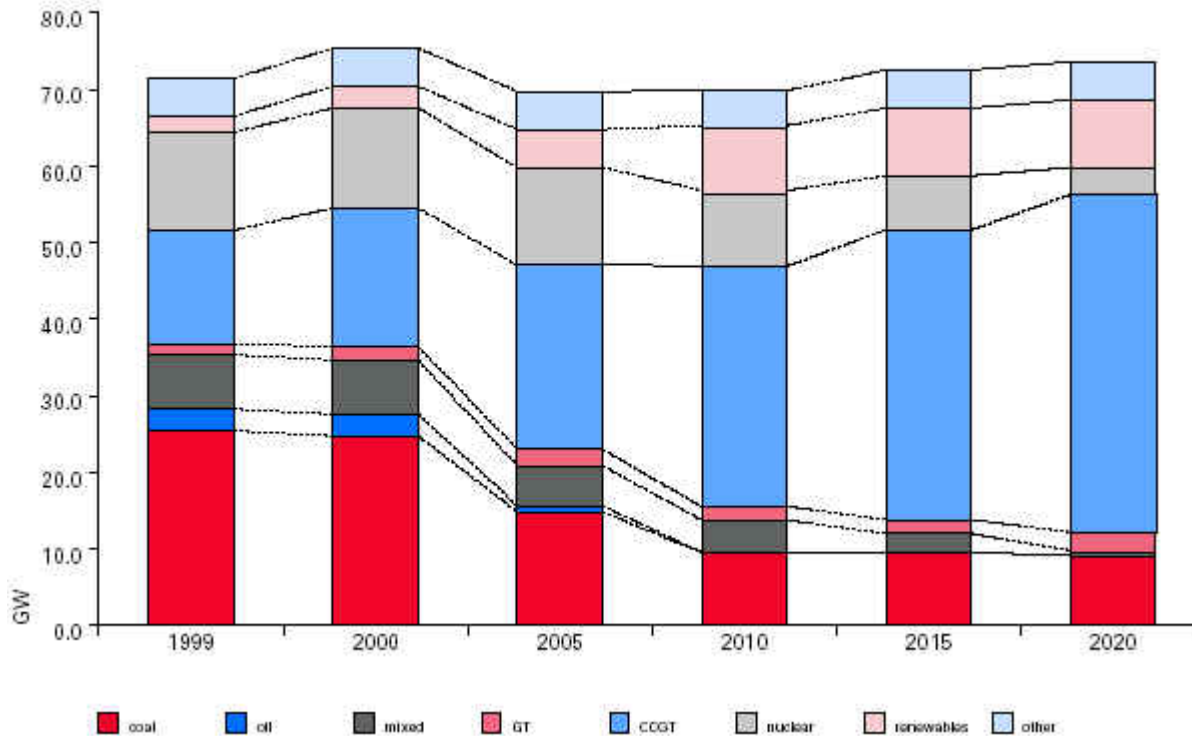
'The Fusion Quest', T.K.Fowler, 1996

- ... barring a visible environmental collapse of global proportions one is hard pressed to prove the urgency of fusion as the solution to an environmental crisis.
- The 'Coming Energy Winter' is that crisis.



UK PROJECTIONS

Chart 5.3: UK Generating Capacity, GW, CH⁷



- Hydro static.
- Wave n Wind
- Drop Nuclear
- All Gas (Russian?)
- Drop Coal
- No Energy R&D
- Ref: Policy Pete, 2002



UK ENERGY WHITE PAPER 2003



- Can 50-70% of energy demand be met by Renewables by 2050?
- Models ignore Energy Winter. Will GDP grow at 2.5% till 2050?
- Why is there no reference to transport policy?
- **Policy:** Price Signals , market fundamentalism, advice, targets, standards. Should government be more involved?
- 'Incentivise innovation via economic instruments.' What?
- All modeling based on Nuclear Closure. Energy security?
- UK Universities Research Budget 2003 =£466M. Bournemouth City Budget =£500M. Should we have a DoE with support for Energy Research?



Positive Energy Economics

- Politicians find Physics hard to follow.
- Everyone is an expert on Economics.
- Building a new energy future can be a great economic stimulus, not a loss leader.



Concluding Remarks

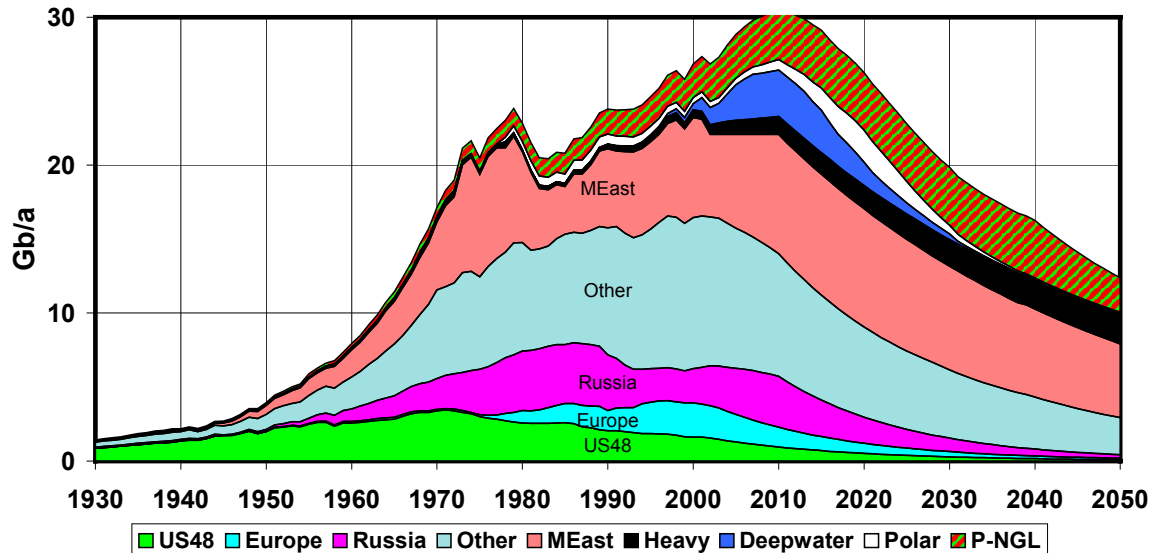
- An Energy Winter is coming.
- The world needs an Agency for an Oil & Gas audit.
- ALL the alternatives need to be developed.
- ALL energy teams need to cooperate.
- Economic modelling must become more realistic
- Society must embrace energy conservation.
- ASPO 3rd Workshop: Berlin, May 25-26.
- brendan@leabrook.co.uk



ASPO: The Peak of Oil.




Regular Oil & Natural Gas Liquids
2003 Base Case Scenario



Jagged
political
history.
Smooth
predictions.



The Old Economics

- The Economics of Market Forces is failing. Unable to handle large or sudden changes.
- Markets cannot handle  long term problems without government intervention.
- Markets are not just a government revenue source.



True Economics



- New Lifestyles
- More Expensive energy, less transport.
- High growth for new technologies.
- Durability vs Throwaway
- Reduce spurious 'Value Added' goods and services.
- A Legislated process of collaboration.



Government Regulation

- Energy markets are distorted by Regulation. British Energy ->bankruptcy.
- US Transport experiments use compulsion on public bodies and agencies.
- Multiple energy/transport options supported.
- **No acknowledgement in US/EU of coming oil peak.**



Modelling Energy Economics

- Collaborate & Compare with current models
- Explore non-standard scenarios
- Physics models match experiments, weather prediction is good, Telecoms and Banking handle millions of players, but Economics needs an upgrade.
- Need Market Response models, real time, dynamic international links



The Energy-Gap Contribution

- High level Seminars and Conferences on a mix of Energy Technology solutions.
- Cards on the table from every Energy Technology
- Include Media, Environmentalists, Politicians.
- Create Sponsor groups for key problems.
- Stimulate the True Economics Micro-Models.



Energy-Gap Global Headquarters – a website.

- Continuous online discussion.
- Interactive Forums on every issue.
- Voting mechanisms.
- An online Energy Library
- Online Conferences + Real Meetings
- Global Work Groups



Energy Economics

- International Collaboration on Economic Modelling of the Energy Transition.
- Models of Energy Economics: IEA, World Bank, IMF, Netherlands, BP-Amoco, RITE (Japan)
- Technical data from Energy-Gap Panels.



Social Understanding

- Science and Technology need...
- Publicly Accepted products
- Funding
- Marketing
- Industrial deployment

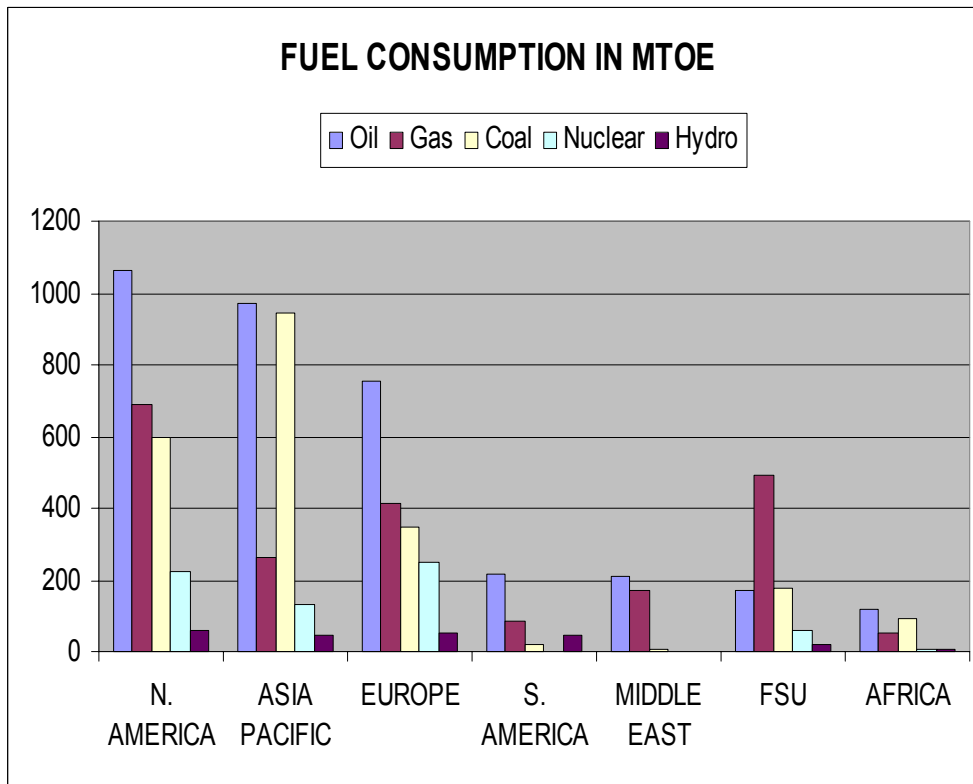


Energy-Gap Objectives

- To promote understanding of 21st. Century Energy Technologies
- To promote the transfer of 21st. Century Energy Technologies to Developing Countries



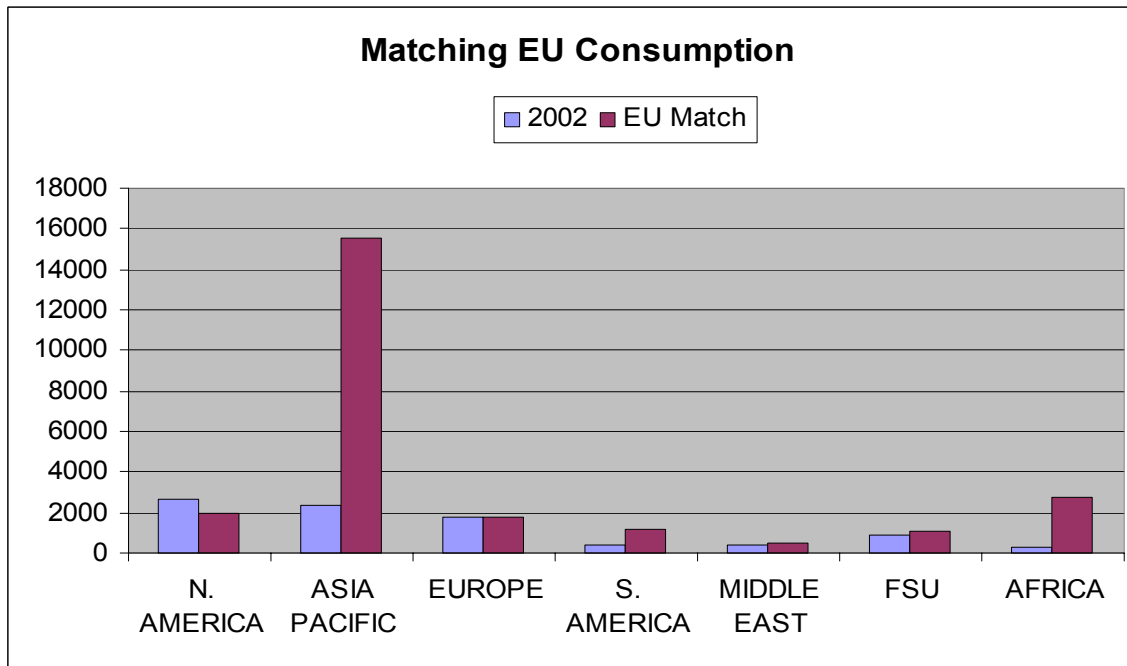
Regional Consumption



- US: Highest Oil n Gas
- China: Coal
- EU: Nuclear
- FSU: Gas
- Africa: Lowest.



Matching EU per person triples energy consumption



- US down 700
- Asia Pacific: 3 Bn people
- S. America up 800
- Africa up 2400



Wind vs Fusion



- ITER 500MW Reactor to scale with a 1MW wind turbine.