UNIVERSITY OF CAMBRIDGE

Future Energy Needs and Engineering Reality

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Context

The climate science community has convinced many policymakers and politicians of the need to decarbonise the world economy in short order. Their case, and whether it is credible or not, is not the issue in this presentation, but rather some of the lessons of the recent history of technology evolution that should not be lost in the rush.

There are rules concerning the introduction of new technologies, and there are penalties for flouting them. If we are setting out to decarbonise the world economy, we should set out as if we mean to succeed, and not, as now, take actions that will certainly not succeed.

Contents

- Context and History
- Ten lessons
- Three concrete suggestions
- Summary conclusions

Notes

1: I take climate science at the IPCC face value at first but do come back at it.

2: Lack of engineering reality tests cripple most suggested decarbonisations.

3: Nothing here detracts from need to reduce human profligacy

Context and History: Technology / Mankind / Earth

- Thomas Malthus FRS 1798: “The power of population is so superior to the power in the earth to produce subsistence for man, that premature death must in some shape or other visit the human race.”
- 1st Baron Macauley FRS 1830: “On what principle is it that, when we look we see nothing but improvement behind us, we are to expect nothing but deterioration before us?”
- William Stanley Jevons FRS 1868: ‘The Coal Question’ Get off the industrial revolution now as the collapse of society with coal exhaustion is too terrible to contemplate.
- Club of Rome 1970: Multiple mineral exhaustion by 2000
- James Hansen 1988: Continuing temperature rises from CO2 emissions.
- James Hansen 2012: World has used as little as 5% of fossil fuels so far.

Thermodynamics

Work, heat, electricity, hydro- fossil fuels, are all forms of energy

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Three Laws of Thermodynamics:

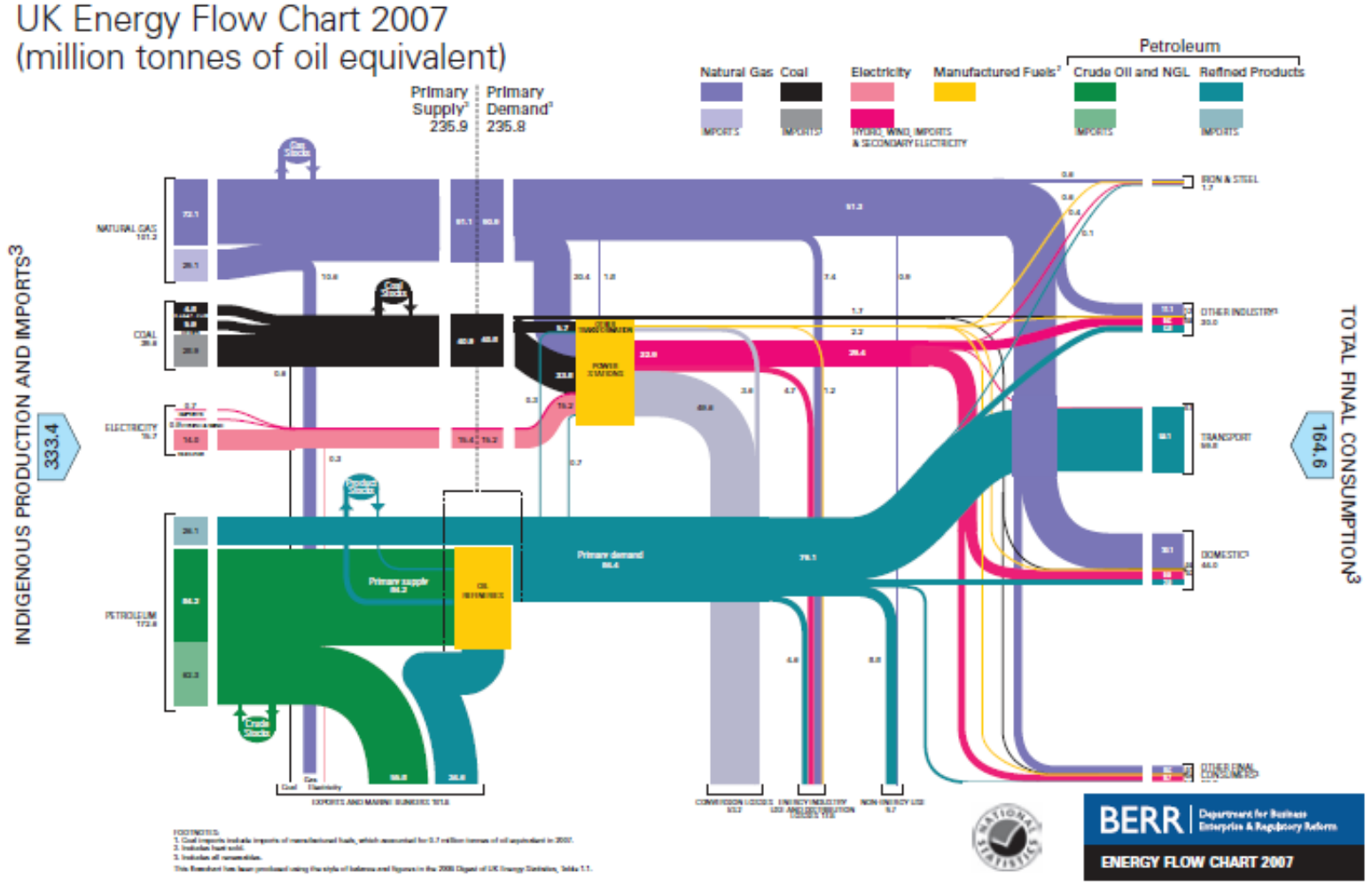
Energy is conserved but downgraded in any process.

Processes go from more ordered to less ordered states unless there is a large input of energy.

Cannot reach absolute zero of temperature.

No free lunch: thermodynamics the miserable part of physics!

UK Energy Flow in 2007: The Sankey Diagram



Ten Lessons from Recent History of Technology

1. Successful new technologies improve the lot of mankind
2. The scale of the decarbonisation problem is unprecedented
3. Tackle megacities first
4. Only deploy new energy technologies when they are mature and economic
5. Salutary lessons from the first round of renewables technologies
6. Subsidies for premature rollout are a recipe for disaster
7. Technology developments are not usually pre-programmable
8. Nothing will happen if the population is not trusting
9. Finance is limited, so actions at scale must be prioritised
10. If the climate imperative weakens, so does the decarbonisation imperative

1. Successful new technologies improve the lot of mankind

- Watt's steam engine – aided agricultural productivity – stopped windmills
- Electricity from steam turbines - lightened the dark, increased productivity
- Jet engines – reduced distance
- Semiconductor technologies – eliminated distance
- Genetic engineering – green revolution – accelerated plant breeding
- Antibiotics – reduced level of infection, but, …
- Smart phone – shrinkage of 20 bulky items of only 20 years ago
- Integrated sensor networks – basis of the future city

Dematerialisation: more for less

This is mainstream business getting more sustainable!

2. The scale of the decarbonisation problem is unprecedented

- 90% of energy used in the world since 1800 is fossil fuel based.
- Today biomass, hydro-, geothermal and nuclear produce 15% of energy
- First generation renewables produce less than 1% of world energy
- I assert: decarbonising by 80% by 2050 is impossible without mass deaths
- UK scale: reduce emissions by 23% by retrofitting all buildings at a cost of £1.7T, with a workforce of over 1M over 40 years. Who pays?
- Chinese emissions have *grown* each year over last 10 years by an amount equal to the whole of UK emissions.
- How would £10T spent over a decade on CO2 emission reduction actually affect future climates?

Retrofit: UK by 2035:

THE SCALE OF THE PROBLEM:

COST to halve domestic energy use:
22M homes, ~£50K for all-round insulation, multiple glazing, draught-proofing, and most energy efficient new appliances
£5K not enough, £500K for complete rebuild! Total Cost>£1T = ~10% of total UK assets today.
Note £23Bpa spent on home improvement.
Equal amount more needed for retrofit.
Note: cutting emissions from today's value means that we cannot count already installed energy efficiency measures.

WORKFORCE just for retrofit:
Cambridge: 44K houses: 1/500 in UK stock.
3000 building workers for 10 years retrofit in Cambridge = 400K in UK for 40 years
Actual no. builders in Cambridge = 1500
i.e. need to double workforce just for retrofit

MATERIALS AND SUPPLY CHAIN
Need 2-fold increase of materials supply for 15 year project in Cambridge and use exclusively on retrofit
Supply chain doubles builder numbers
0.8M employed in retrofit for 20 years.
Comparable with NHS (at 1.3m)
Total retrofit spending = 25% of health – lower technology and simpler jobs all round

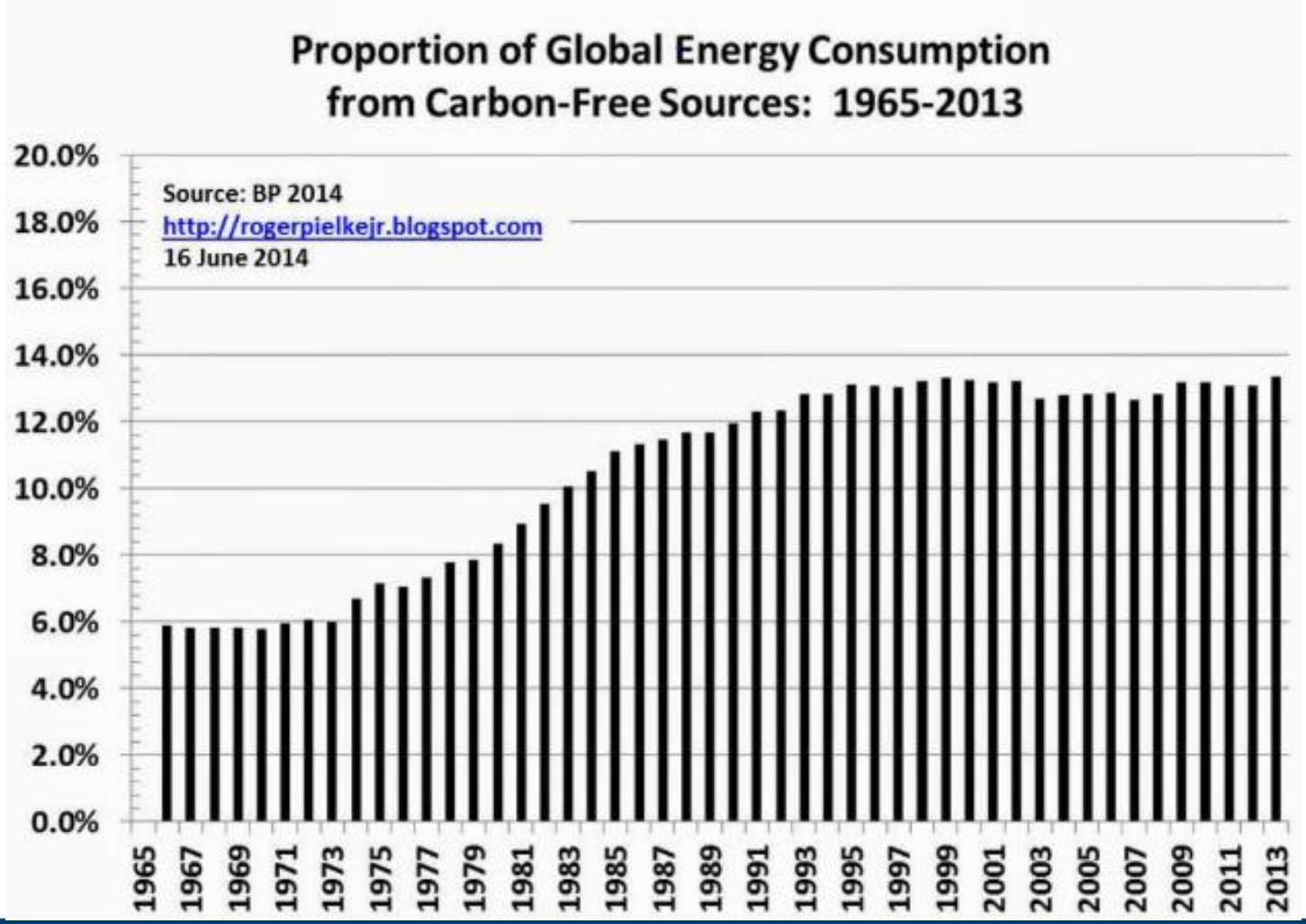
FINANCING
Pay-back on basis of saving energy will be of order 50 years if energy bills go to £2K per household.
Must be justified by asset value growth.
Cost of finance requires <10 years payback: i.e. need energy bills 5 times now with continuing 80% energy inflation per decade this would make sense in 2030.
Only alternative to issue bonds with low returns.
Unattractive for most investors.

EMBEDDED CARBON FOOTPRINT
Insulating materials, glass and appliances, typical of construction materials, and including the waste materials is about 25% of embedded carbon of average house when built, or 200 tonnes.
CO_2 payback time = 30 years.

NON-DOMESTIC BUILDING:
Non-domestic buildings emit 66% of CO_2 of the domestic buildings, excluding any industrial processes. Scale all the above up by 66% to obtain total domestic plus non-domestic costs, labour and materials! Cost £1.7T

CONSEQUENCES
Command economy/taxation essential to get money
Conscription needed to guarantee workforce
>2% of UK GDP tied up for 40 years.
Calculations exclude any effects of new build in terms of cost, carbon budget, manpower etc.

Carbon Free Energy



3. Tackle megacities first

- 1000km^2 of Fenland diverted from food to miscanthus grass would generate under 1GW, while Sizewell B (<0.1km^2) generates 1.3GW (CW)
- Fossil fuel energy density million times denser than gravity fuels and a million times less energy dense than nuclear fuel.
- Shanghai: 22M and 6000km^2 are needs X4 area for wind solar and biofuels for electricity, and X40 area for renewables for all energy, but that land feeds Shanghai!
- The challenge is to power Hong Kong in 2050
- >50% of 9B world population in 2050 will live in megacities.
- Only nuclear and fossil fuels will actually energise 2050 megacities. A science breakthrough tomorrow is too late.
- CCS: Only 20MtCO2 sequestered out of 51000MtCO2 produced yearly.

4. Only deploy new energy technologies when they are mature and economic

- Japanese solar thermal panels
- Spanish solar: EOEIR=2.5!
- Stranded assets
- Batteries not ready
- Abandoned wind and solar farms

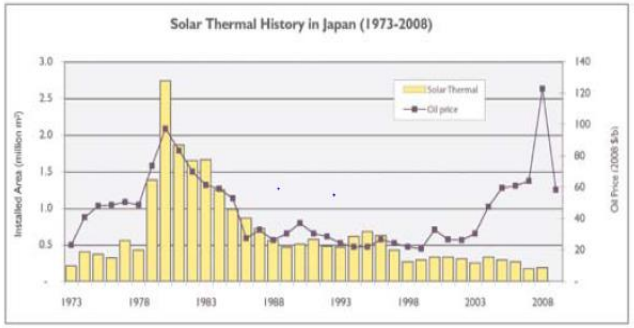
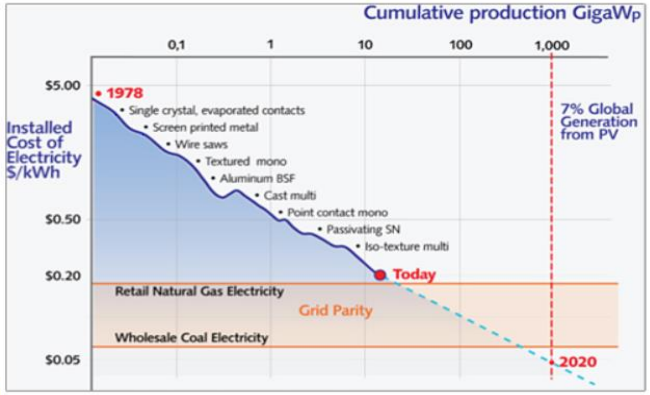
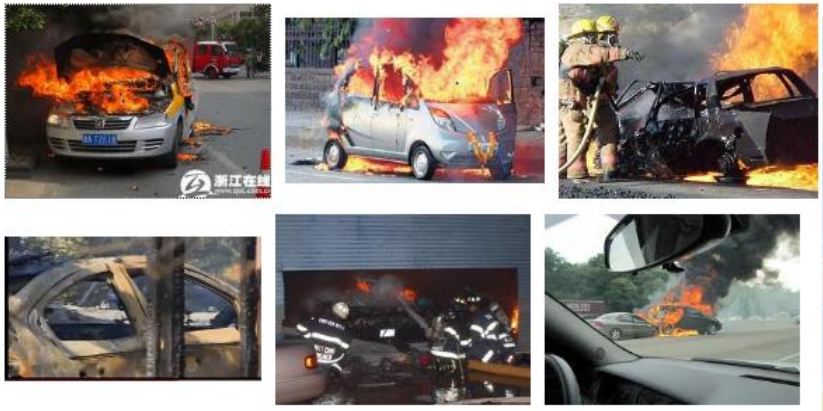
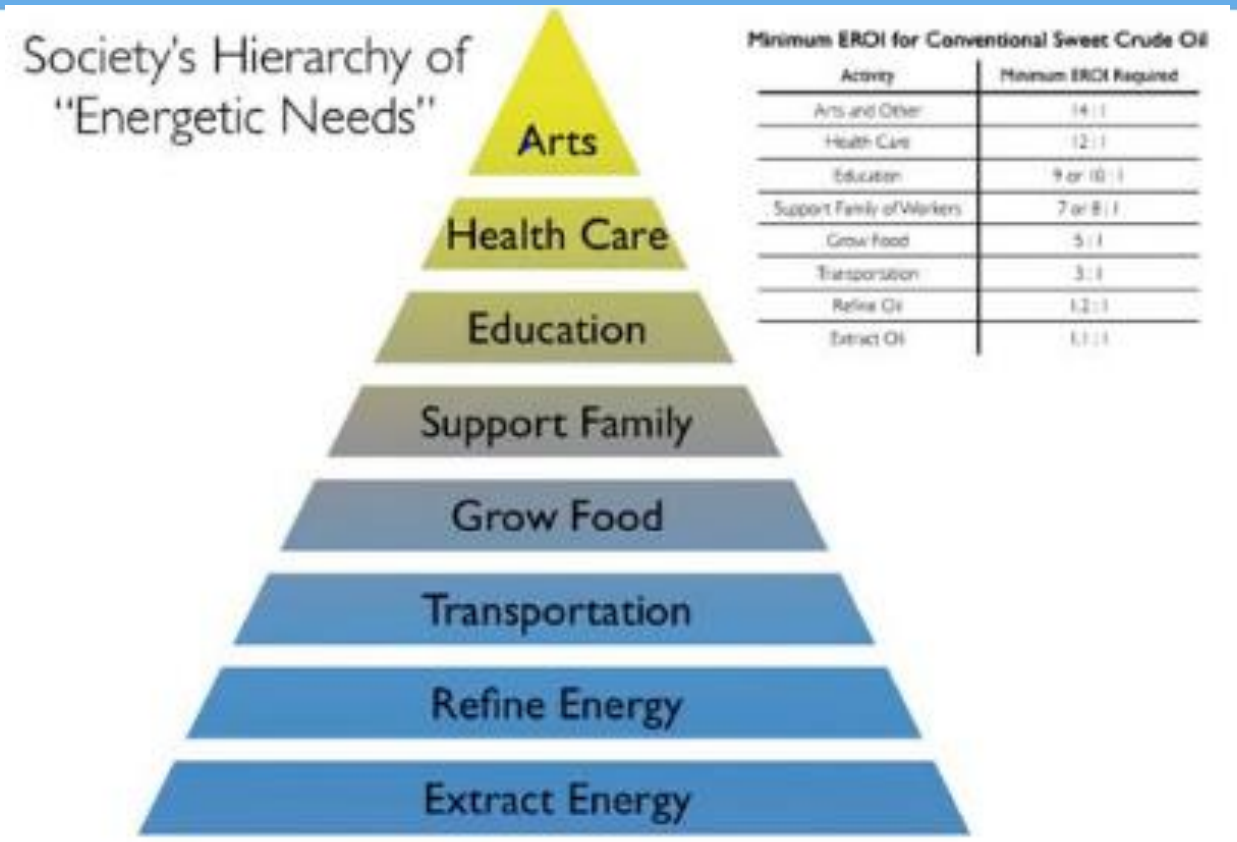


Figure 10: The annually installed capacity (M^2) of solar thermal technology in Japan, charted against oil price. Source: Redrawn from ISEP, 2009.[97]





Energy Return on Investment for Modern Living



Minimum EROI for Conventional Sweet Crude Oil

Activity	Minimum EROI Required
Arts and Other	14 : 1
Health Care	12 : 1
Education	9 or 10 : 1
Support Family of Workers	7 or 8 : 1
Grow Food	5 : 1
Transportation	3 : 1
Refine Oil	1.2 : 1
Extract Oil	1.1 : 1

Fig. 1.3 "Pyramid of energetic needs" representing the minimum EROI required for conventional oil, at the wellhead, to be able to perform various energetic task required for civilization. The *blue* values are published values: the *yellow* values are increasingly speculative (figure adapted from Lambert and Lambert 2012)

Pedro A Prieto and Charles A S Hall: 'Spain's Photovoltaic Revolution: The Energy Return on Investment', Springer 2013, p7

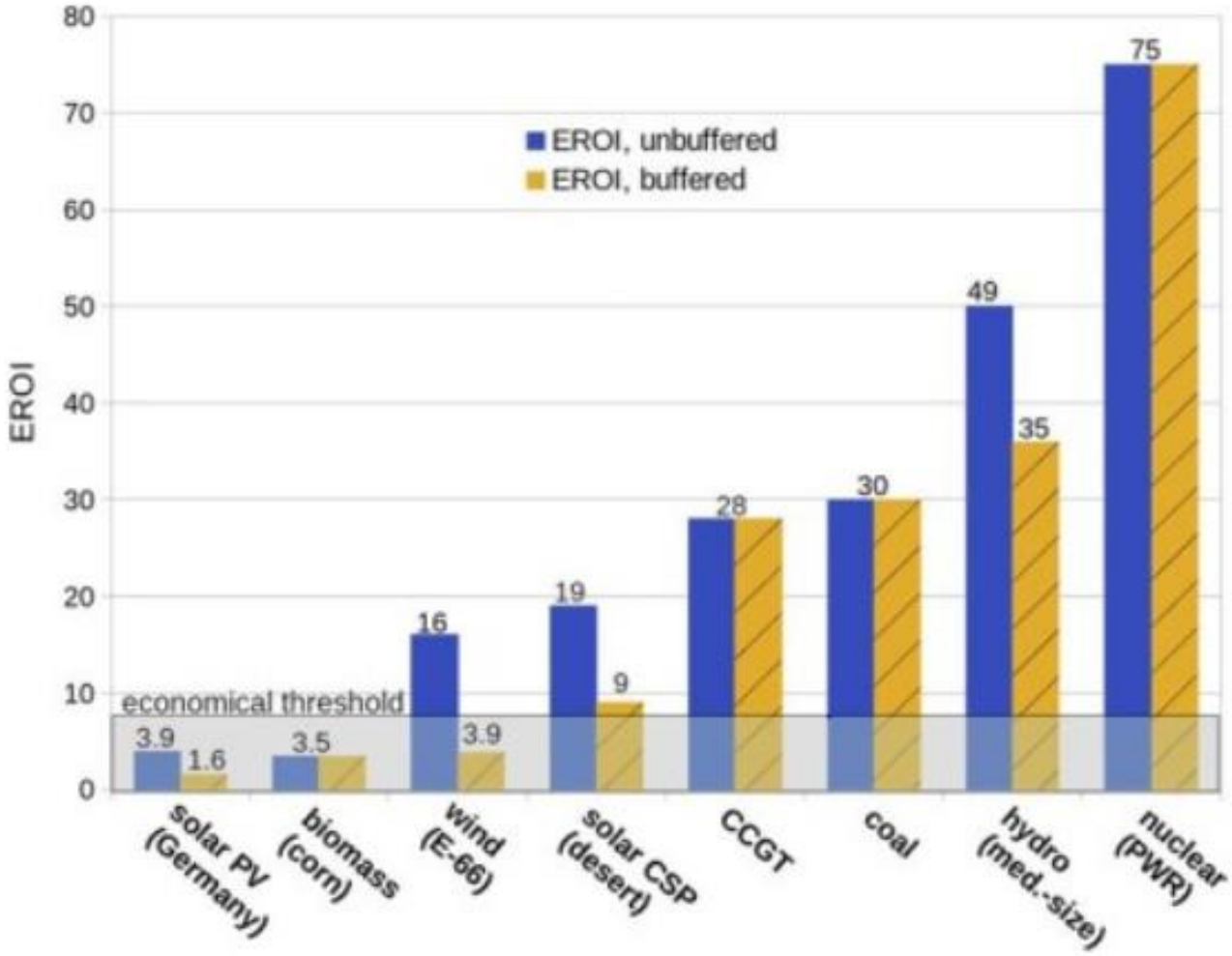
Energy Return on Energy Invested: Spain 2006-9

- Add up all the costs needed to install and deliver electricity
  - permissions, rent, roads, fences, surveillance and security, manufacture, logistics, installation, maintenance.
- Convert cost to energy using ratio of total Spanish energy/Spanish GDP to get to energy in.
- Add up all the metered electricity at the grid entry point and extrapolate to 25 years to get energy out
- Ratio = energy return on investment

Spain's Photovoltaic Revolution: The Energy Return on Investment

- Result: EROI for Spanish solar: 2.5:1 over the 25 year life of the panels
- Poor in energy and economics terms compared with fossil fuels.
- Nowhere enough for civilized living unless supplemented by fossil fuels.
- Other analyses: more focussed on site, less inclusive of costs: 7-11:1
- 7-11 people needed here per MW installed; 2.7 in other energy sectors.
- 3 units of heat energy of coal gives 1 units of electricity now but 3 units of heat to make solar gives 7.35 units of electricity over 25 years.
- Panel manufacture already only 30% of 25-year life-cycle costs
- Other costs scale with the vast land areas covered.
- Solar has serious EROI constraints and materials constraints if scaled up.

Comparative EROI



http://theenergycollective.com/barrybrook/471651/catch-22-energy-storage

5 Salutary lessons from the first round of renewables technologies

Mohave desert ‘green’ wastelands

1. Not a good advertisement:
2. Not enough income to maintain!

6 Subsidies for premature rollout are a recipe for disaster

Subsidies cut because of financial hardship leading to bankruptcies (2012)

- California
- Spain
- USA
- China
- Germany
- UK
- Government & private investments hit: not a place for pension funds!

- SunPower, after receiving $1.5 billion from DOE, is reorganizing, cutting jobs.
- First Solar, after receiving $1.46 billion from DOE, is reorganizing, cutting jobs.
- Solyndra, after receiving $535 million from DOE, filed for bankruptcy protection.
- Ener1, after receiving $118.5 million from DOE, filed for bankruptcy protection.
- Evergreen Solar, after receiving millions of dollars from the state of Massachusetts, filed for bankruptcy protection.
- SpectraWatt, backed by Intel and Goldman Sachs, filed for bankruptcy protection.
- Beacon Power, after receiving $43 million from DOE, filed for bankruptcy protection.
- Abound Solar, after receiving $400 million from DOE, filed for bankruptcy protection.
- Amonix, after receiving $5.9 million from DOE, filed for bankruptcy protection.
- Babcock & Brown (an Australian company), after receiving $178 million from DOE, filed for bankruptcy protection.
- A123 Systems, after receiving $279 million from DOE, shipped some bad batteries and is barely operating. It cut jobs.
- Solar Trust for America, after receiving a $2.1-billion loan guarantee from DOE, filed for bankruptcy protection.
- Nevada Geothermal, after receiving $98.5 million from DOE, warns of potential defaults in new SEC filings.

The RENIXX® (Renewable Energy Industrial Index) World is the first global stock index, which comprises the performance of the world´s 30 largest companies of the renewable energy industry

http://tomnelson.blogspot.co.nz/2012/10/the-green-jobs-debacle.html

7 Technology developments are not usually pre-programmable

- Why did we not get steam power 100 years earlier than we did?
- Why can't we have nuclear fusion tomorrow?
- 40 years is a typical lead timeline for an infrastructure technology
- Remember it is 40 years since the first oil shocks which started the renewables and still <1% of world energy.
- Sequestration unproven at scale for economics and safety: only about 20 Mt CO2/yr sequestered out of a global total of 50,600 Mt CO2/yr.
- What will we have in 2050 at the scale needed to energise the world?
- Only nuclear and fossils fuels will power the world in 2050, and even if there was a scientific breakthrough tomorrow, it takes 40 years to develop and deploy.

8. Nothing will happen if the population is not trusting

Reports from the front line of intervention:

- Saving the planet and reducing energy bills were not enough of a spur
- Cambridge take up of free insulation less than 5%
  - Don’t trust men in white vans
  - Hassle factor
  - No 25 year guarantee against any unintended consequences
- Village near Cambridge: £10M secured to improve insulation:
  - Mailshot: 2 replies from 600 homes
  - Door-to-door: up to 19 expressed some interest: others a firm no!

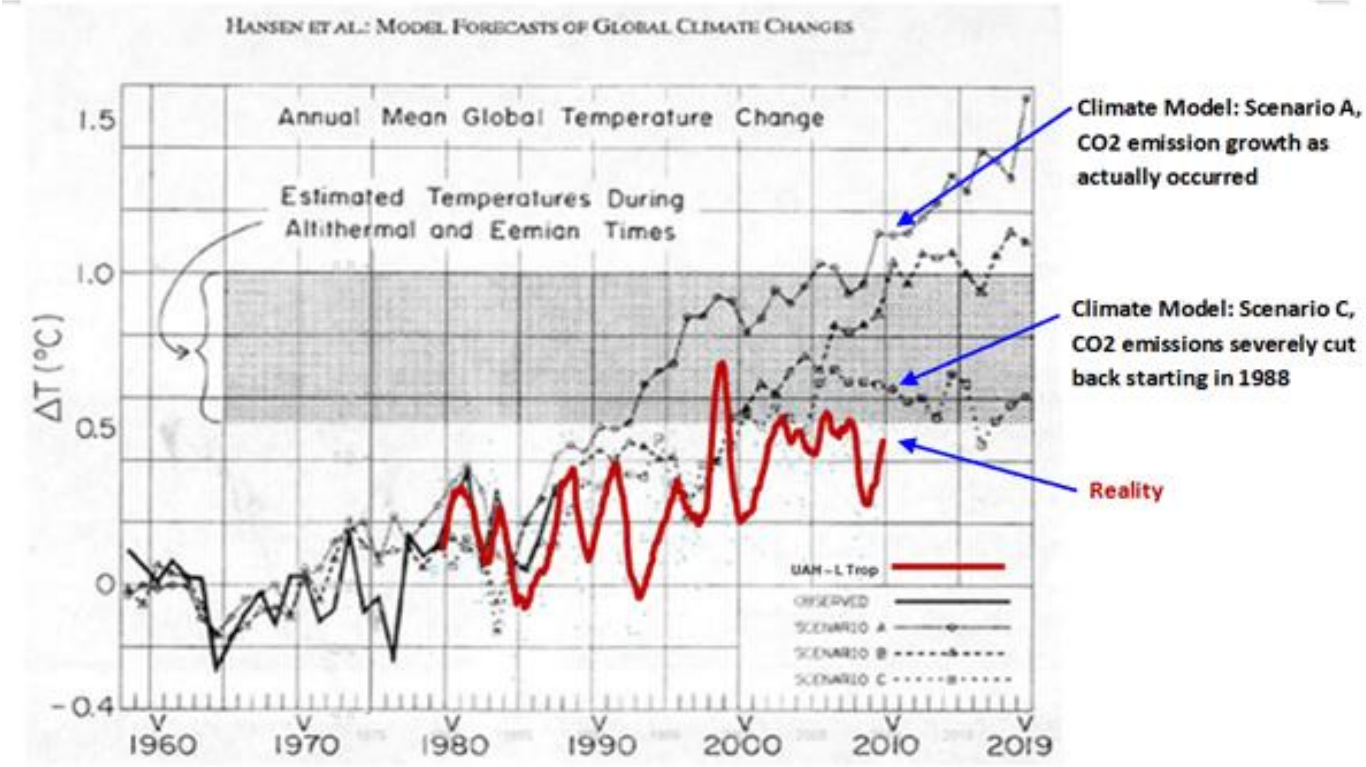
9 Finance is limited, so actions at scale must be prioritised

- Who pays? Taxpayer or consumer – there is no-one else!
- £200B over next decade for UK energy infrastructure renewal
  - raised on the international money market in competition
  - creditworthiness of many nations too low.
- Still need business as usual in terms of food production and manufacturing
- Early adopters in real financial trouble: Spanish energy indebtedness ($100B) is much greater than sum involved in banking crisis ($36B)
- Giving away unneeded peak solar/wind energy disrupts markets.
- Germany CO2 emissions rising with a return to coal. CCGT not designed for load balancing and not economical run that way!

10 If the climate imperative weakens, so too decarbonisation

- 18 years since last global temperature rise during which over 15% increase of overall man-made emissions has occurred.
- Recent IPCC downgraded the rate of predicted temperature rise from that predicted by the models.
- If the sun has been responsible for recent climate change, mitigation is in vain.
- James Hansen's 1988 Scenario C climate model: wrong input, right output!
- We need track-record 20 years of successful prediction of climate change before we use model data as a guide for investing in the global future.
- If other events intervene and temperature rise goes off the agenda, the next decade of infrastructure decisions should have be fossil fuel based.
- No shortage of fossil fuels over next 100-200 years.

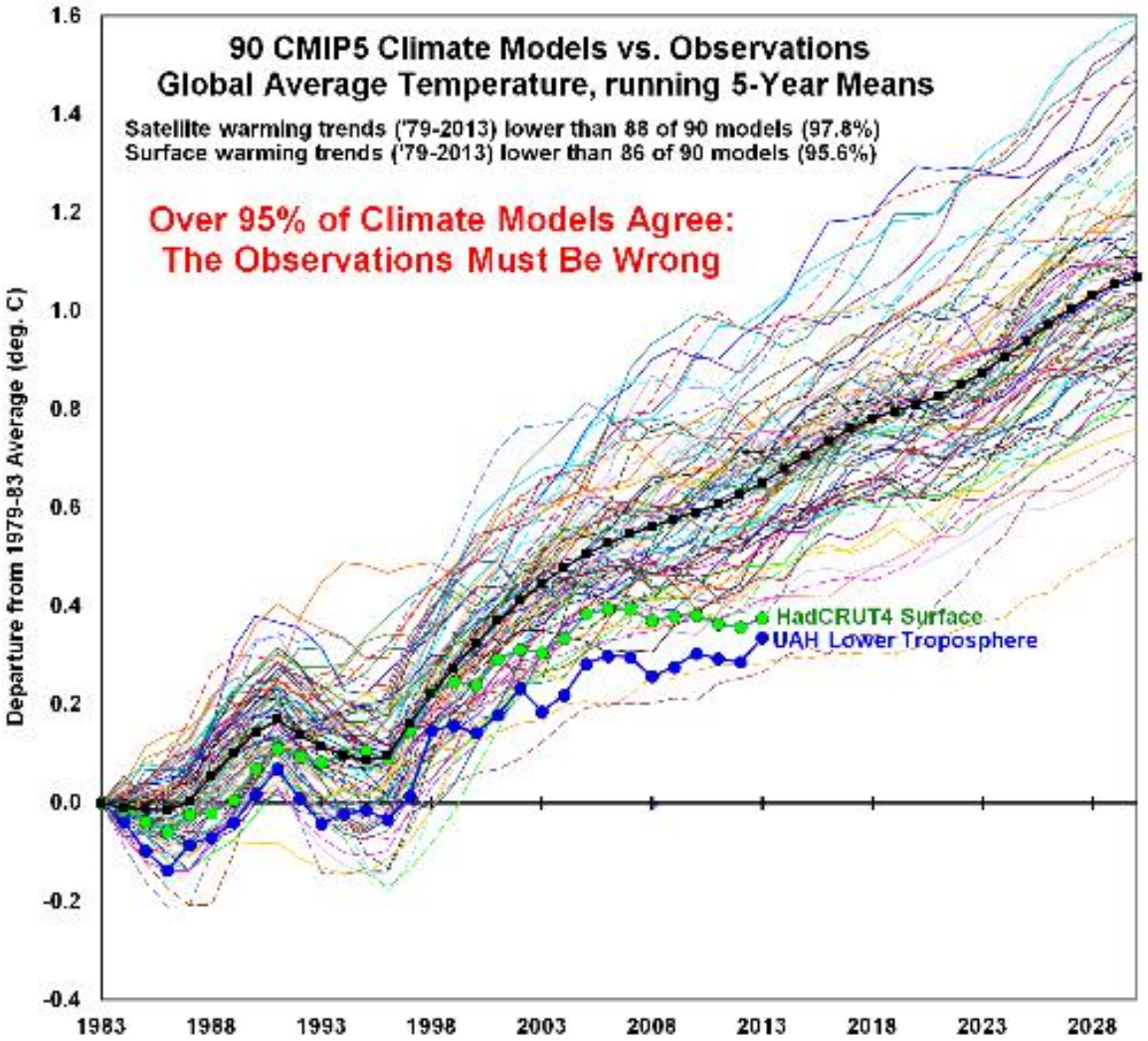
Hansen: Prediction versus data (1b)



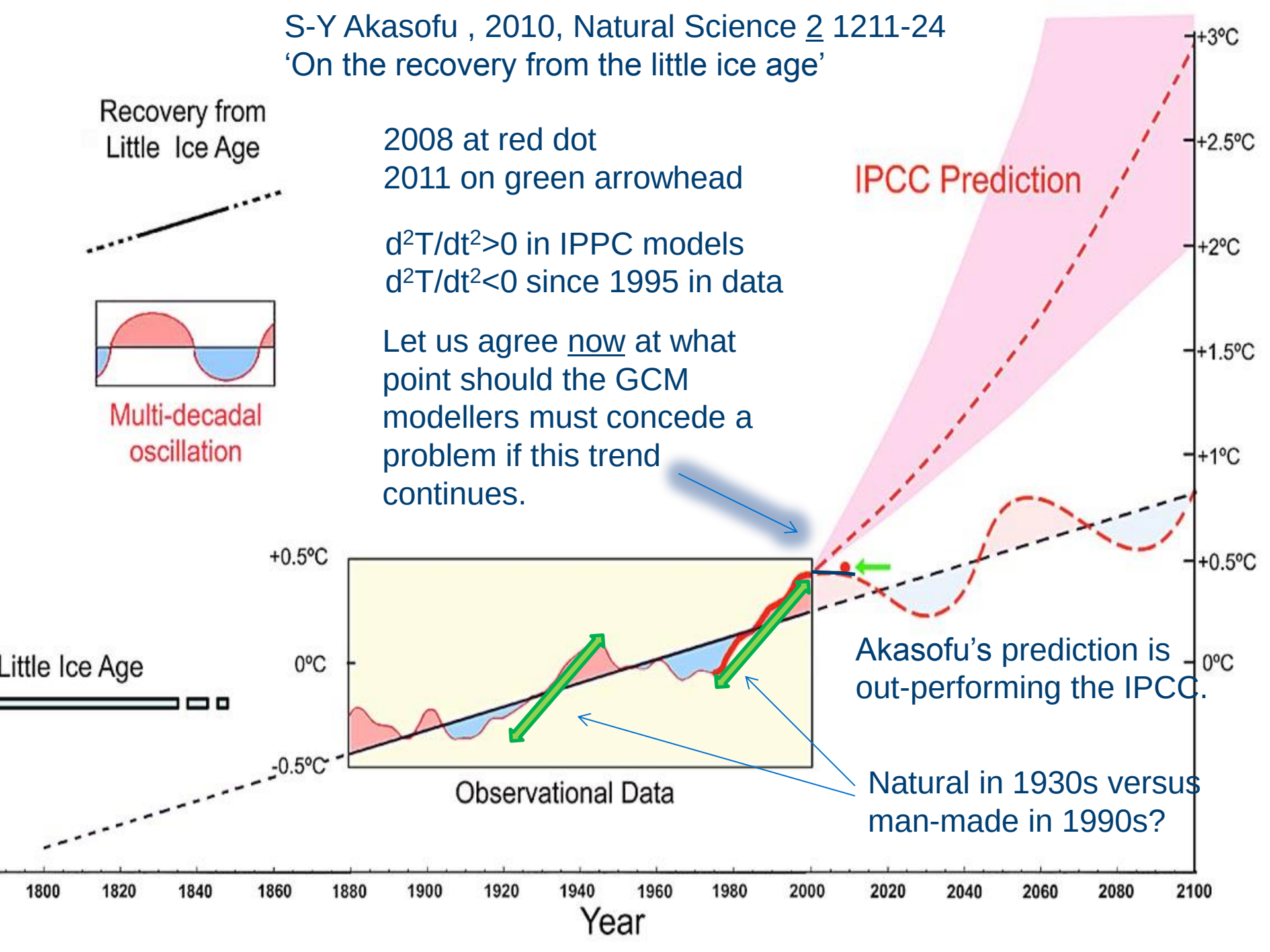
Sources: Hansen Et Al, Journal of Geophysical Research, August 1988, and the University of Alabama Hunstville (UAH) MSU global monthly mean lower troposphere temperature from the NASA Aqua satellite.

JoNova

Models or data?



S-Y Akasofu , 2010, Natural Science 2 1211-24
'On the recovery from the little ice age'



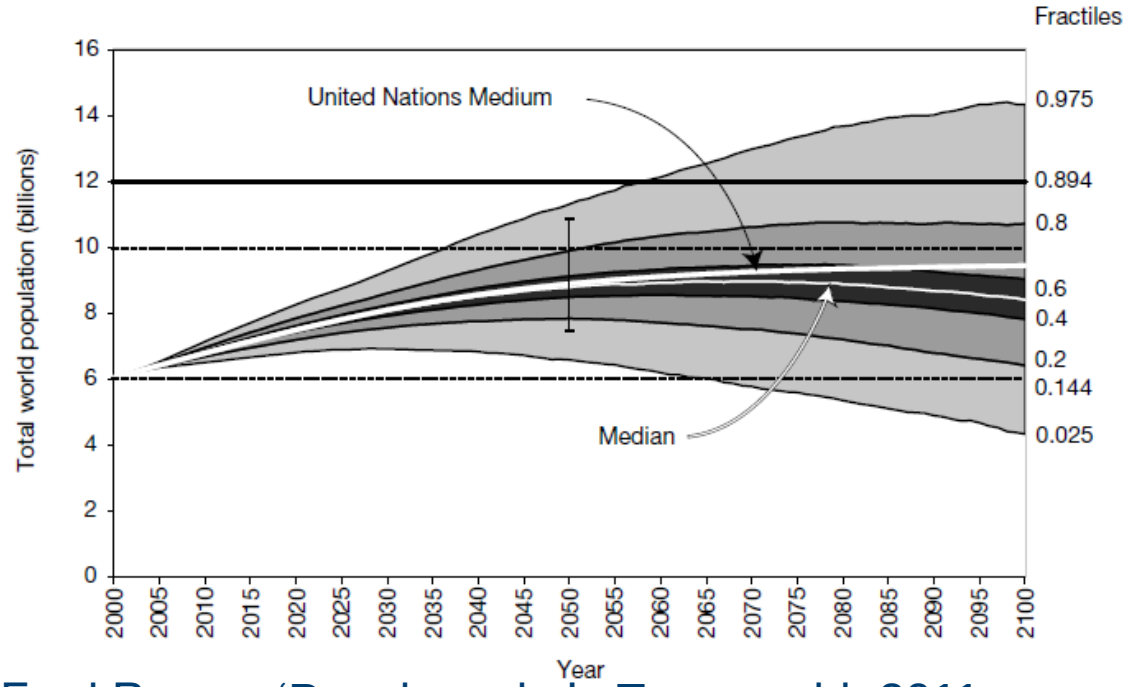
Miscellany

- The poor everywhere are being impoverished by high costs of green energy
- Delaying the development of Africa by denying cheap fossil fuels is immoral.
- Climate change a distraction from more serious and imminent challenges to humanity, such as antibiotic resistance.
- Many measures counter-productive – close aluminium smelters in UK and import from coal-based smelters in China – total madness in CO2 terms.
- Public resentment and mis-investments will grow with public apathy or cognitive exhaustion on climate disasters.
- Do we know we are preparing for the right global disaster?
- Decarbonisation: still no route-map or indicative budget by decades to 2050.
- How will this period be viewed in retrospect in 2050?

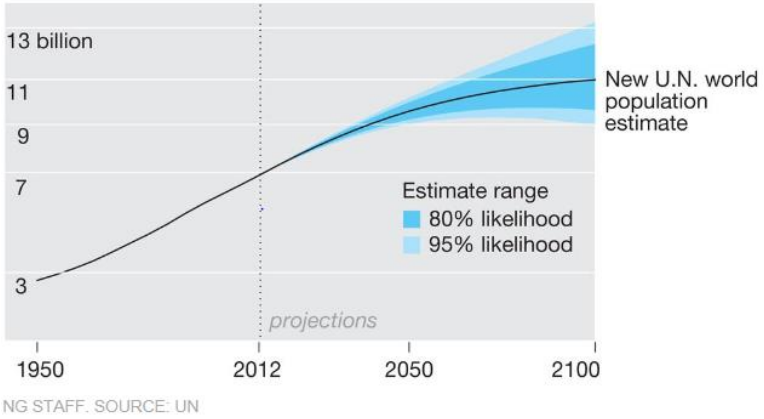
Now for some upsides!

10 minutes to go

Peak Population: The implications



Wolfgang Lutz et al, 'The end of world population growth', Nature 412 543-5 2001



NG STAFF. SOURCE: UN

Fred Pearce 'Peoplequake', Transworld, 2011: p 294

Without change/immigration, by 2100, Italy goes from 58M to 8M, Germany goes to Berlin, Ukraine loses 43%, …..

http://news.nationalgeographic.com/news/2014/09/140918-population-global-united-nations-2100-boom-africa/

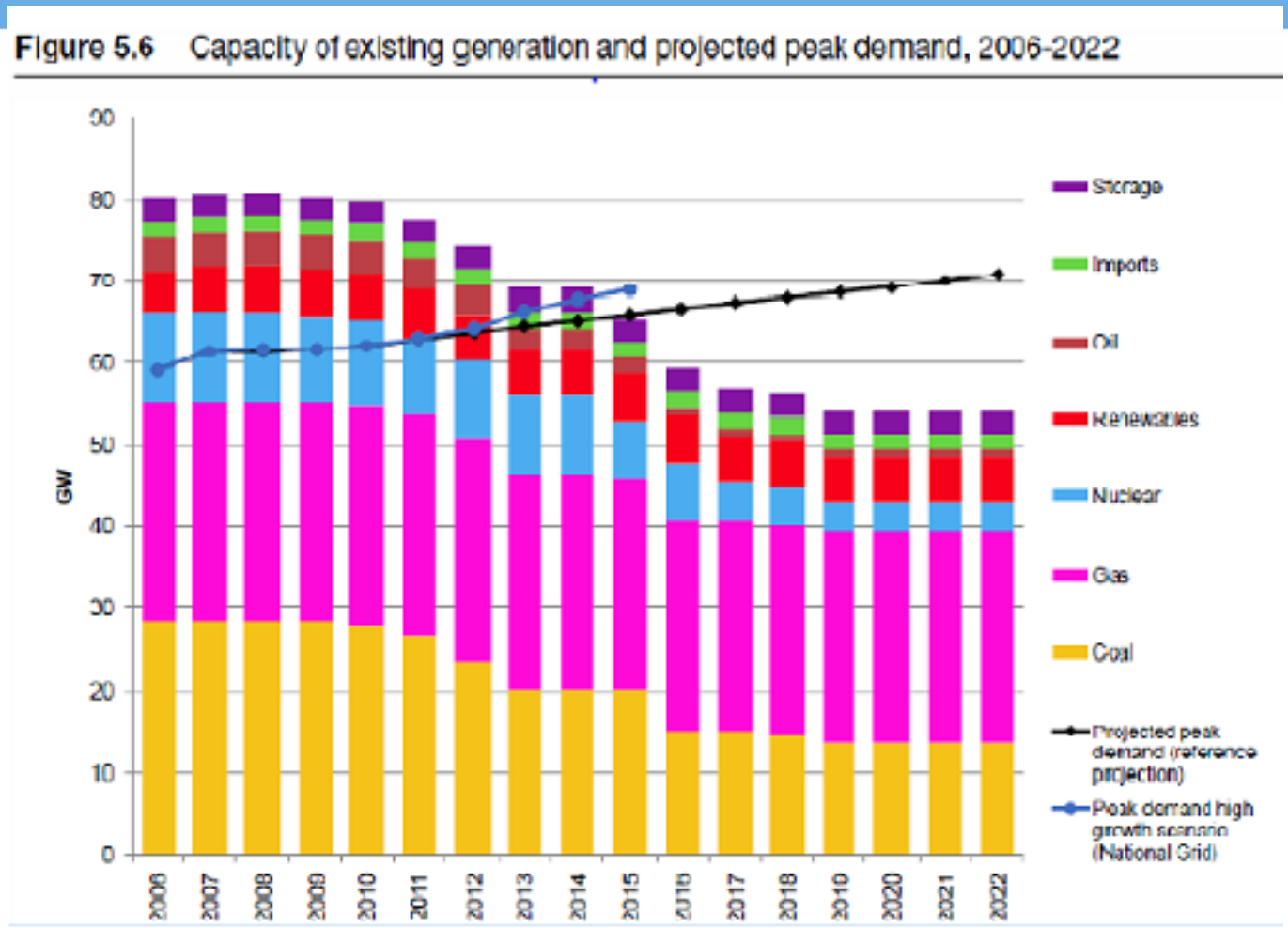
1st Suggestion: STAY WITHIN BUSINESS AS USUAL

- Malthusians over-estimate the problems, and underestimate the ingenuity of humanity to deal with them.
- Business as usual has always had energy and resource efficiency on the agenda – the recent increases in car fuel efficiency a good example.
- New generation of very low power electronics controlling integrated sensor networks will reduce need of much travel and reduce logistical footprints.
- Megacities can be self-sufficient in animal protein and green vegetables from food factories within city boundaries by 2050.
- Too much rose-tinted technological optimism shown by scientists.

2nd Suggestion: DERISK INFRASTRUCTURE PROJECTS

- Infrastructure is very expensive and must make return over life time
- Scarce resources must be husbanded, especially on infrastructure scale
- Abandoned motorways, buildings, windmills and solar farms remain for decades to be mocked
- Grid costs should be bookkept with energy sources (e.g. wind, solar)
- Back-up energy for intermittent sources should be bookkept with source
- Full life costs usually not transparent when governments spent public money on infrastructure projects. Blackmail to complete – c.f. military spending

Warning of UK Blackouts



http://blogs.bsria.co.uk/2013/07/01/when-will-the-lights-go-

3rd Suggestion: PERSONAL BEHAVIOUR AND ATTITUDES

- Changes in personal attitudes and behaviour as exemplified by drink-driving, smoking in public confined spaces.
- If energy and resource profligacy were considered deeply antisocial, demand reduction would make much greater inroads on energy budgets
- We could live a high standard of living with half our per capita use of energy, with less travel, shorter supply chains and lower heating budgets.
- Such an approach immediately effective and economical.
- European actions are penalising EU economy, while China and India forge ahead with much greater use of fossil fuels.
- Faster to implement and greater impact than technology can deliver!

Summary Conclusions

- The current decarbonisation regimes will fail to meet their objectives.
- Malthusians too pessimistic.
- Much mitigation is madness as of today – adaptation as practiced by the Dutch for centuries is the way forward.
- No-one knows the effects on future climates of a crash project to decarbonise the global economy.
- Until now the cure has been worse then the symptoms.
- Noble causes are not helped by poor science or bad engineering.
- Backlash against all science/technology if we get this wrong.

If it really that bad, the advocates must

- Develop a compelling story – not mights or coulds, but wills and woulds.
- Get a much better grip on the problems of scale.
- Put their own capital up as co-lateral to support radical action.
- Preaching to spend other's money gets nowhere.
- Live an exemplary condign lifestyle – minimal use of air travel, supercomputers, internet especially google, cars, …..

Parting Food for Thought

Patrick Allitt: "A climate of crisis: America in the age of environmentalism" Penguin, NY 2014

"The future seemed to them bright so long as environmental pessimism did not lead to the creation of misguided policies" p 178

"It was certainly a good idea – now as always – not to be wasteful or profligate with resources, It was a good idea to continue seeking alternative energy sources and to make existing energy sources more efficient. On the other hand it is not a good idea to devote massive resources to cutting carbon dioxide emissions if, in doing so, other worthwhile ends could no longer be pursued. The great paradox of the 1990s and 2000s was that poor people in developing countries continued to suffer from malnutrition, smoke inhalation, and remediable diseases and to die from drinking contaminated water, while developed nations discussed astronomically expensive carbon dioxide abatement schemes whose benefits were highly conjectural and could only be realised – if at all – in the distant future." p241

"Few people have paused to ask: How would we benefit now if our grandparents and great-grandparents had exercised more self-restraint and self-denial? Would we live better if they had exercised greater prudence and self-control." p241

"The rising carbon dioxide footprint may be troublesome, but it is a side effect of the creation of immense benefits." p242

References

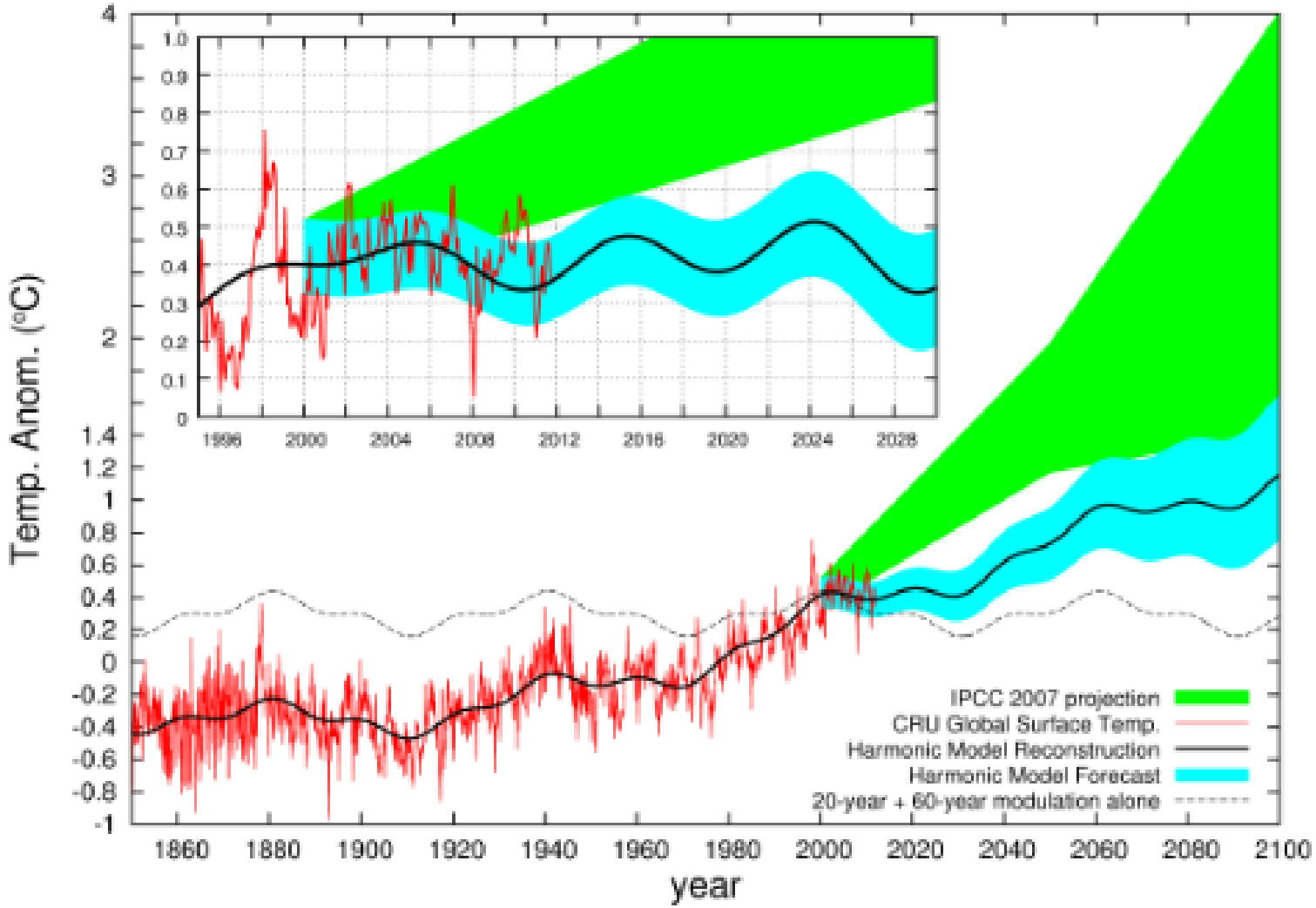
- M J Kelly, 'Energy efficiency, resilience to future climates and long-term sustainability: the role of the built environment', Philosophical Transactions of the Royal Society A 368 1083-9 (2010)
- M J Kelly, 'Why a collapse of global civilization will be avoided: a comment on Ehrlich and Ehrlich', Proc. Roy. Soc. B 280 20131193 (2013)
- Michael J Kelly, 'Technology introductions in the context of decarbonisation: Lessons from recent history', The Global Warming Policy Foundation, GWPF Note 7, 2014, http://www.thegwpf.org/content/uploads/2014/03/Kelly-lessons.pdf
- M J Kelly, "Future Energy Needs and Engineering Reality", Journal of Energy Challenges and Mechanics, 1, #3, 1 (2014) http://www.nscj.co.uk/JECM/PDF/1-3-1-Kelly.pdf

The End

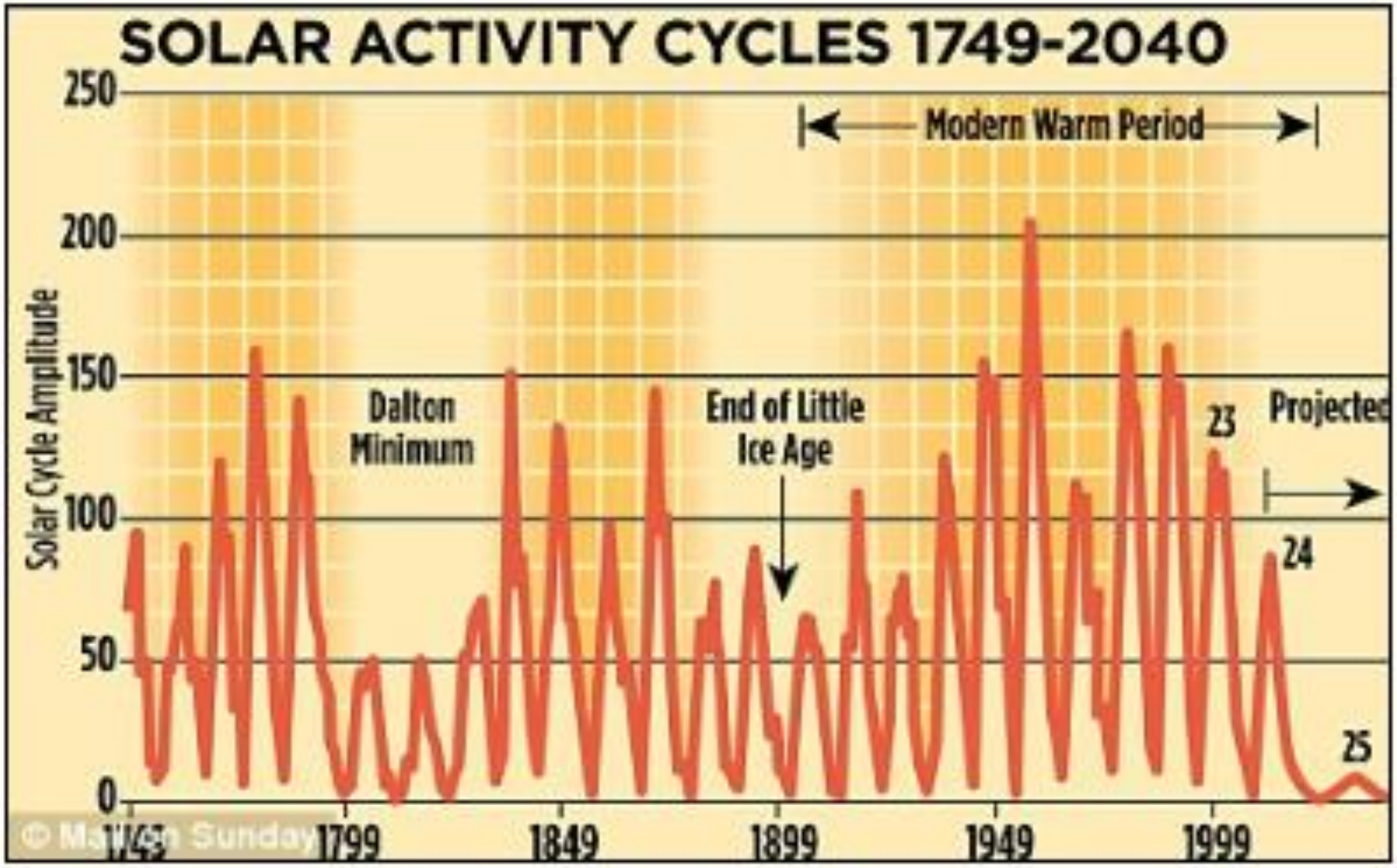
THANK YOU FOR YOUR ATTENTION

Q & A & DEBATE

Scafetta: if future is like the past

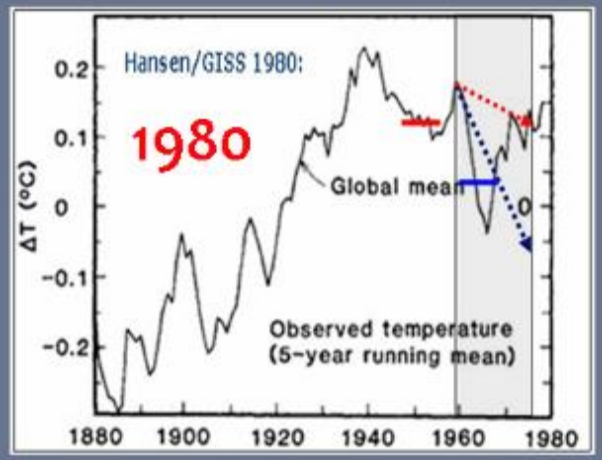


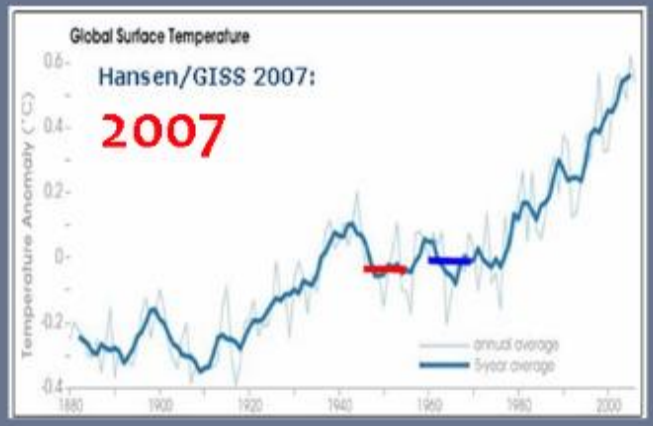
The Sun – the cooling is coming



On-going Adjustments to Raw Data

Watch how the red and blue periods progressively "realign"
as GISS reinterprets the temperature from decades long gone

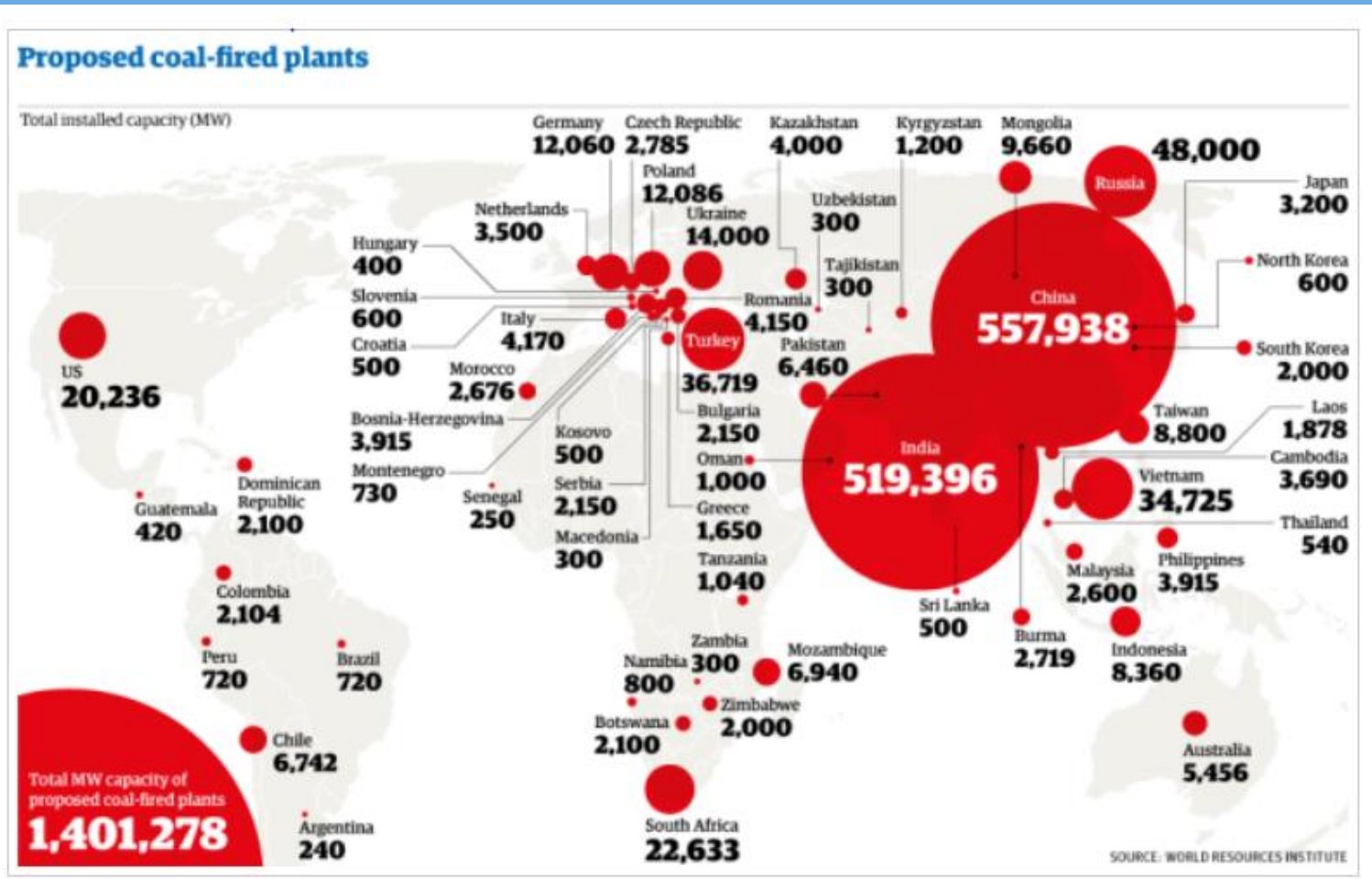




A picture tells a thousand words

http://jonova.s3.amazonaws.com/graphs/giss/hansen-giss-1940-1980.gif

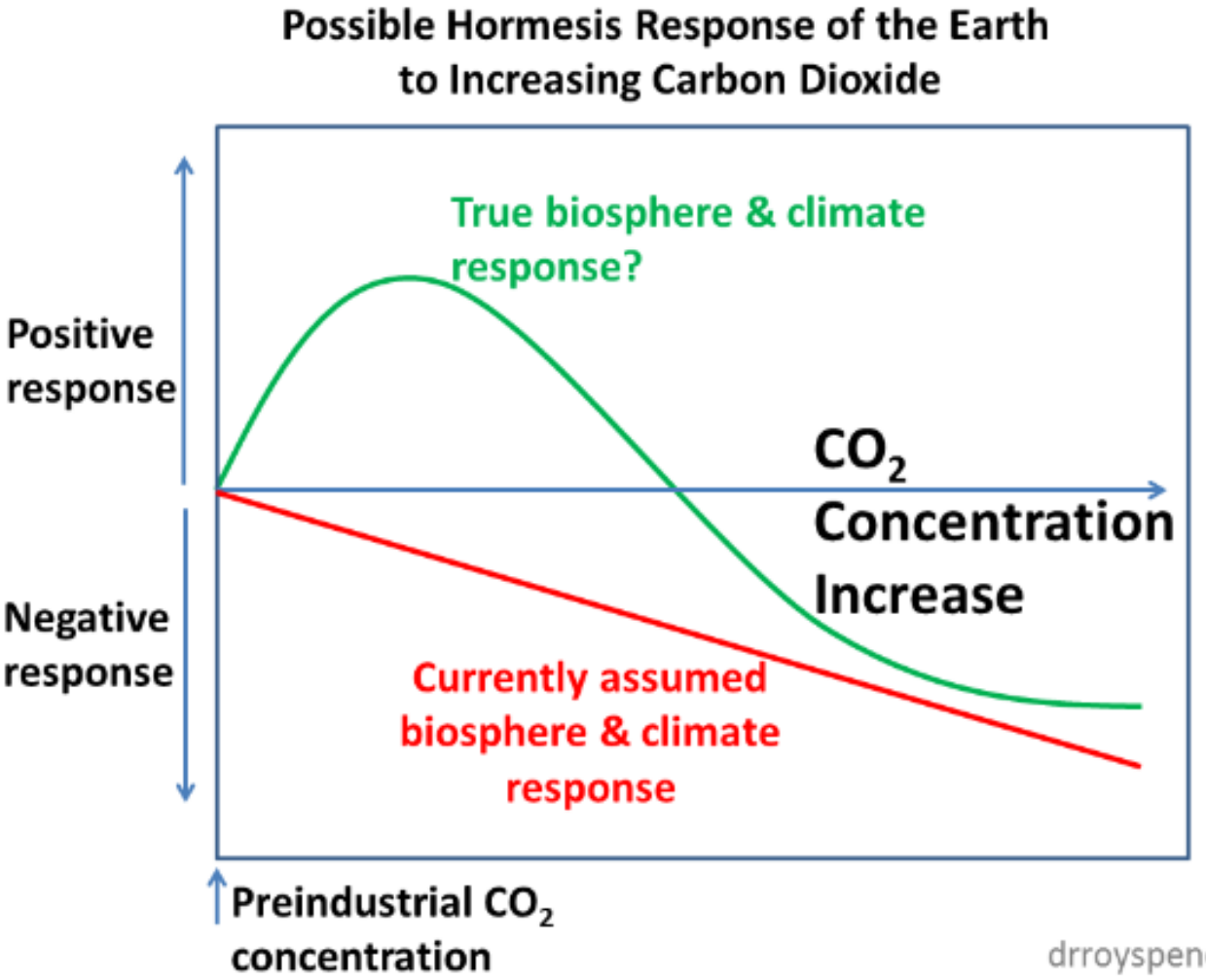
Proposed Coal Fired Plants



http://tomnelson.blogspot.co.nz/2013/01/global-map-of-planned-coal-fired.html

Total UK Coal capacity: 25,000MW

Hormesis

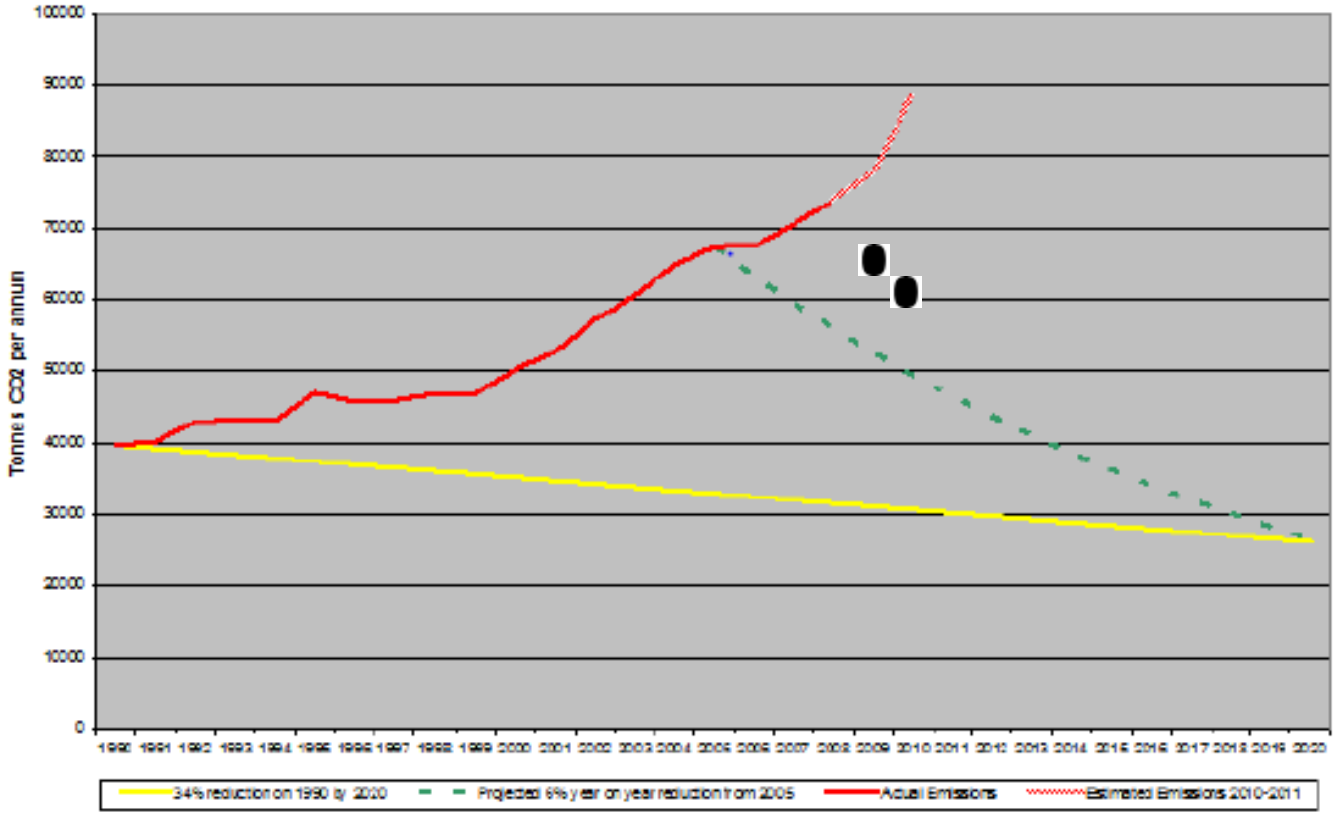


RS/NAS: note the balance of bad and good: Hormesis!

- 17: Are climate changes of a few degrees a cause for concern?
- Yes. Even though an increase of a few degrees in global average temperature does not sound like much, global average temperature during the last ice age was only about 4 to 5 °C (7 to 9 °F) colder than now. Global warming of just a few degrees will be associated with widespread changes in regional and local temperature and precipitation as well as with increases in some types of extreme weather events. These and other changes (such as sea level rise and storm surge) will have serious impacts on human societies and the natural world.
- Both theory and direct observations have confirmed that global warming is associated with greater warming over land than oceans, moistening of the atmosphere, shifts in regional precipitation patterns and increases in extreme weather events, ocean acidification, melting glaciers, and rising sea levels (which increases the risk of coastal inundation and storm surge). Already, record high temperatures are on average significantly outpacing record low temperatures, wet areas are becoming wetter as dry areas are becoming drier, heavy rainstorms have become heavier, and snow packs (an important source of freshwater for many regions) are decreasing.
- These impacts are expected to increase with greater warming and will threaten food production, freshwater supplies, coastal infrastructure, and especially the welfare of the huge population currently living in low-lying areas. Even though certain regions may realise some local benefit from the warming, the long-term consequences overall will be disruptive.

Progress on the home front

Plug load, research led, the main driver of growth: double 1990-2012



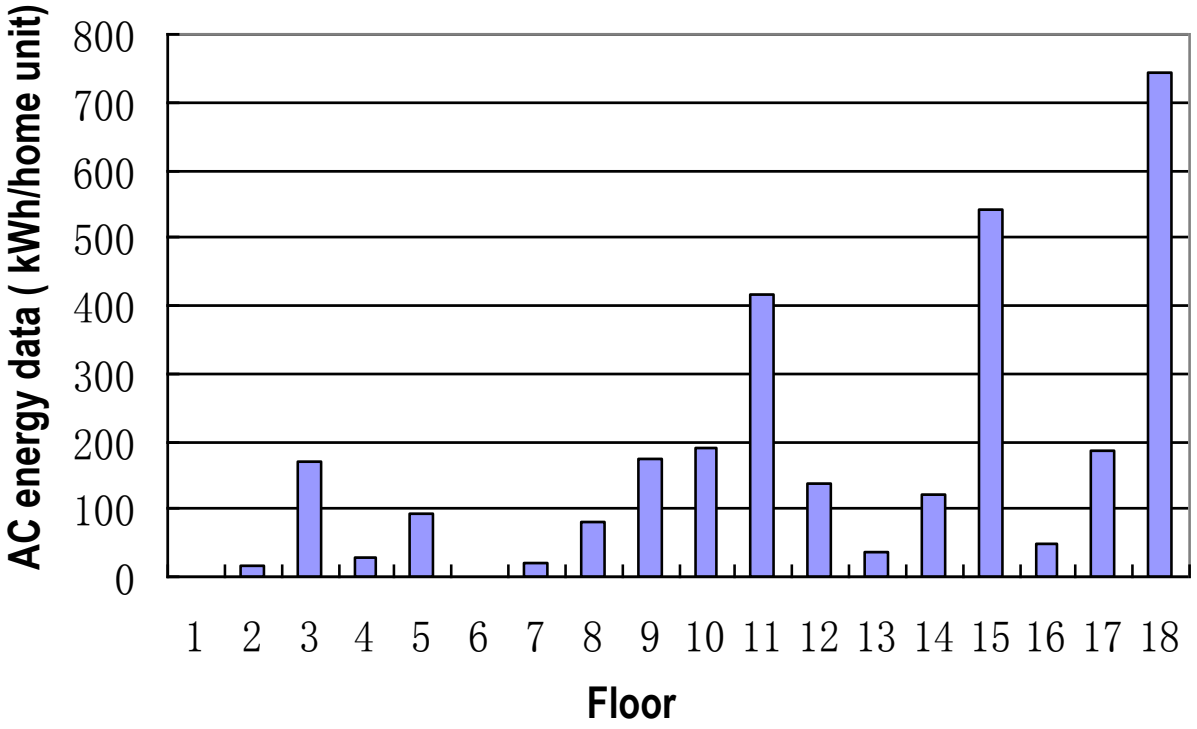
Budget:
1989-90 £179M
(=£315M RPI)
(=£379M HEPPI)
2009-10 £747M

CO2 footprint doubled

Carbon intensity unchanged.

Research:
£38M → £268M

AC energy in building B in Beijing



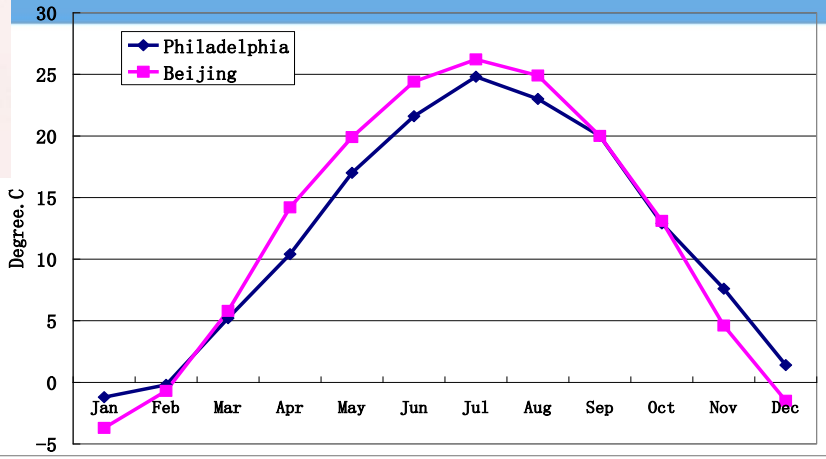
Prof Jiang, Tsinghua

Electricity consumption by AC for home units
at same location but different floors in building B

Lesson: personal behavior can thwart technology

Beijing & Philadelphia

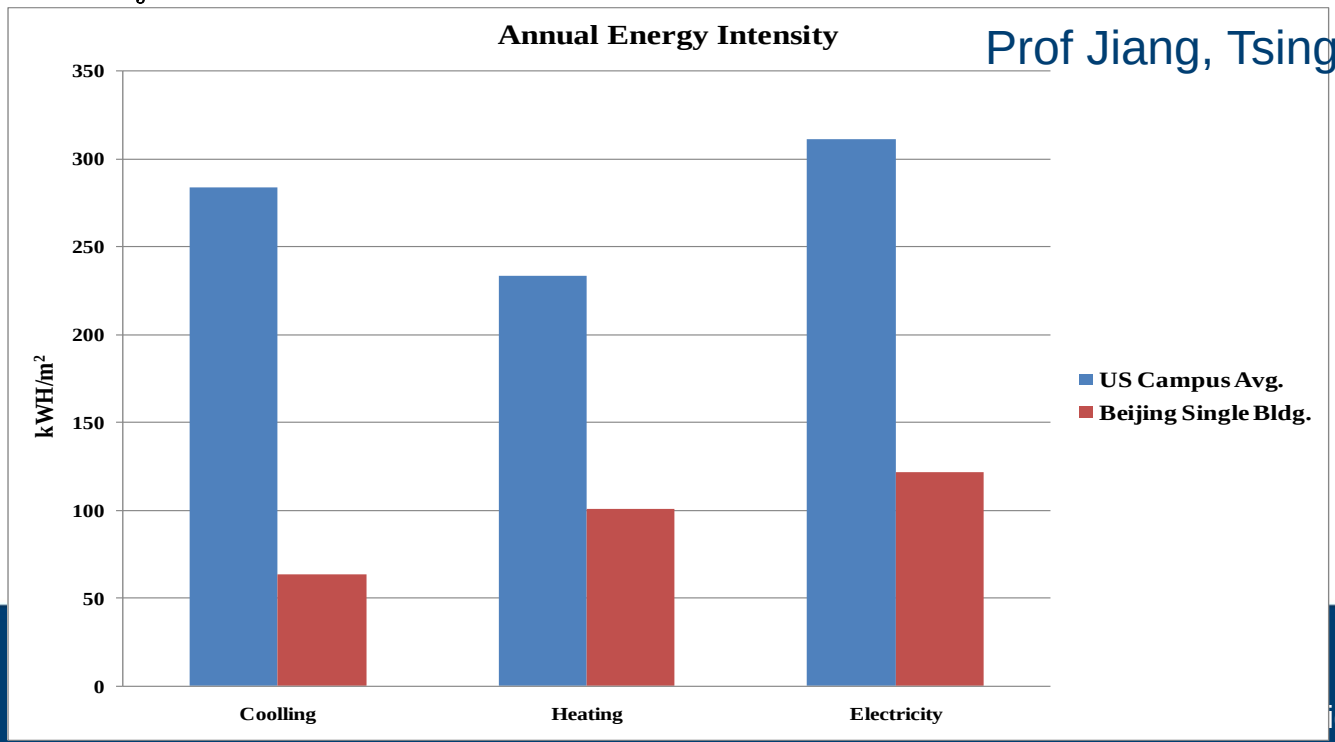
Monthly Mean Temp. in Philadelphia and Beijing



Building in Beijing

Campus building in US

Prof Jiang, Tsinghua



Context and History: Technology / Mankind / Earth

Every age has its peculiar folly; some scheme, project, or phantasy into which it plunges, spurred on either by the love of gain, the necessity of excitement, or the mere force of imitation. Failing in these, it has some madness, to which it is goaded by political or religious causes, or both combined. --Charles MacKay, *Memoirs of Extraordinary Popular Delusions and the Madness of Crowds*, London 1852.