Sustainable Energy

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Part A: MIT IAP 2007 Two Week Course

Lis Drake, January 16, 2007

Energy Sustainability issues

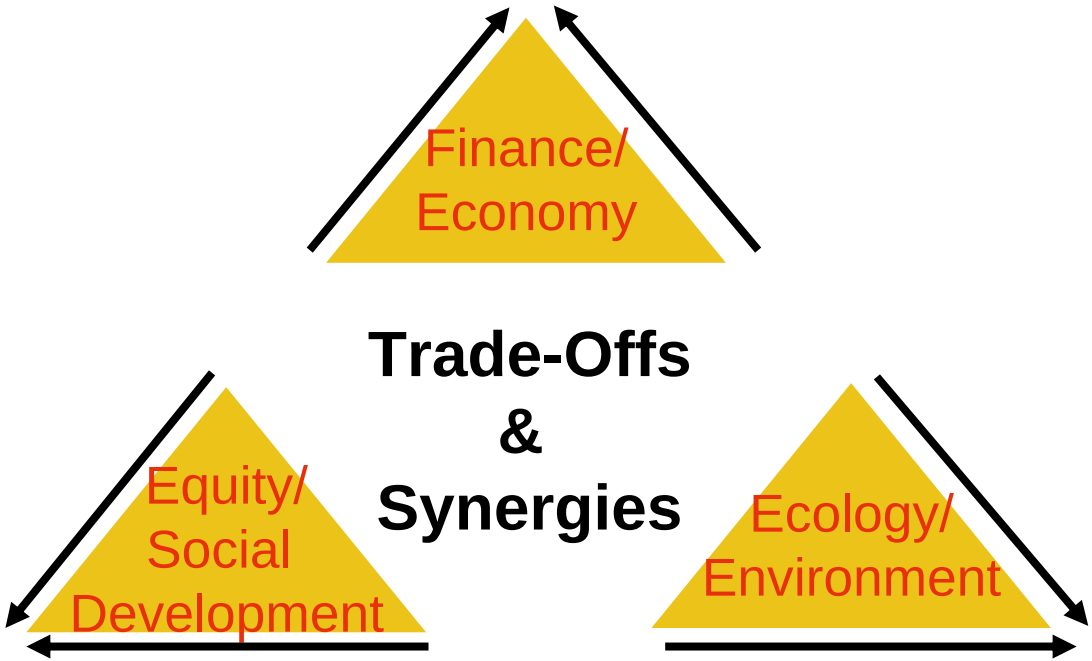
- **What is "sustainability?"**
- **How does energy use impact sustainability?**
- **What are the problems with present energy use?**
- **What are global challenges for the future of energy use?**

What is Sustainability?

- **The ability of humanity to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. [Bruntland, 1987]***
- **Preservation of productive capacity for the foreseeable future. [Solow, 1992]**
- **Biophysical sustainability means maintaining or improving the integrity of the life support system of earth. [Fuwa, 1995]**
- **A dynamic harmony between the equitable availability of energy-intensive goods and services to all people and the preservation of the earth for future generations [Tester, et al. 2005]**

***Full references are given in: Tester et al., *Sustainable Energy: Choosing Among Options*, The MIT Press, Cambridge MA, 2005**

The Three Dimensions of Sustainabilty



Derived from World Bank (1996)

How does energy use impact sustainability?

- **Some Benefits**
  - **Energy is critical to human survival and development**
  - **Fossil fuels are plentiful and convenient to use**
  - **Energy is key to industrialization and transportation**
  - **Energy facilitates economic growth and globalization**
- **Some Problems**
  - **Rapid growth in fossil fuel use raises concerns about:**
    - **Security of supply (over-dependence?)**
    - **Environmental impacts**
    - **Societal conflicts over inequitable distribution of resources**
    - **Depletion of critical resources**

What are the problems with present energy use?

- **Global Energy consumption is growing because:**
  - **Population is growing**
  - **Energy use per capita is growing – especially in developing countries**
- **Growing megacities need concentrated energy sources**
- **Transportation systems depend largely on petroleum fuels**
- **Major fossil energy sources have problems**
  - **Security of supply/price stability (esp. petroleum)**
  - **Depletion**
  - **Climate impacts from greenhouse gas emissions**
- **Energy access is unequally distributed**
- **Global economy is significantly dependent on present fossil energy prices and availability – changes to include "externality" costs may slow economic growth (or at least cause major short-term disruptions in the economy)**

Intragenerational Principles

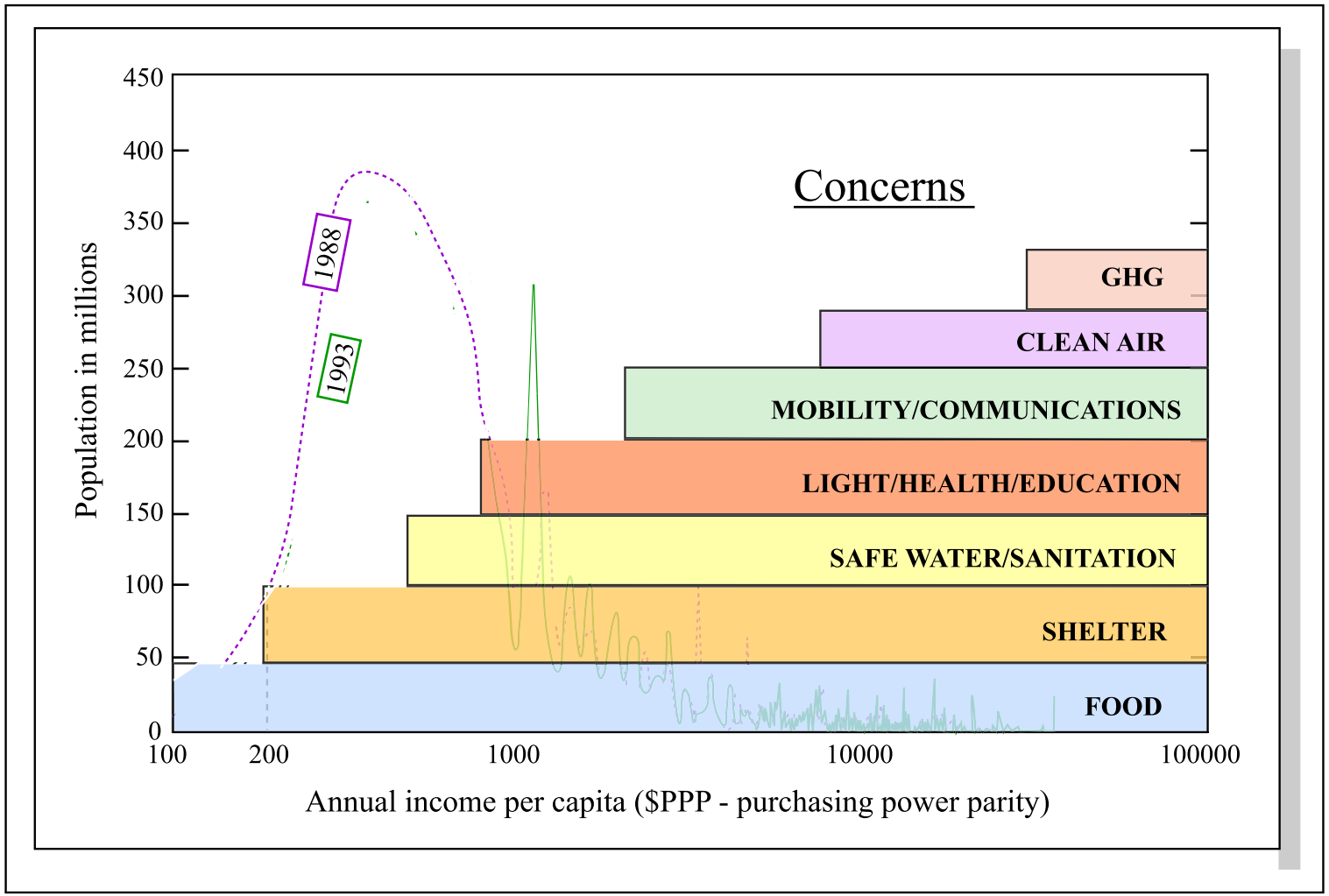
- **Reduce gross inequities between the poorest and wealthiest both nationally and globally**
  - **Meet the basic needs of the poorest with food, shelter, health care, clean water, access to electricity, education, opportunity for work, etc.**
  - **Avoid exploitation of poorer country/region resources and labor to create even greater wealth for the richest**
- **Provide ways to protect the common good (social, environmental, economic) locally and globally through national and international governance/cooperation**
  - **Preserve natural ecosystems against unconstrained development**
  - **Avoid interference with natural balances in the atmosphere, the oceans, and the arctic regions**
  - **Maintain stable institutions that protect human rights, adjudicate conflicts, and allow responsible trade and market economy activities**

Intergenerational Principles

What are our obligations to future generations?

- **Trustee: Every generation has an obligation to protect the interests of future generations**
- **Chain of obligation: Primary obligation is to provide for the needs of the living and succeeding generations. Near term concrete hazards have priority over long term hypothetical hazards**
- **Precautionary Principle: Do not pursue actions that pose a realistic threat of irreversible harm or catastrophic consequences unless there is some compelling or countervailing need to benefit either current or future generations**

World Income Distribution in 1988 and 1993
(in millions of persons, bandwidth = 0.005) – Milanovic, World Bank 2000*
and Concerns at Different Income Levels



Curves from Milanovic, B. "True World Income Distribution, 1988 and 1993: First Calculation Based Onhousehold Surveys Alone." World Bank, 2000. (PDF)

Are There Limits to Growth?

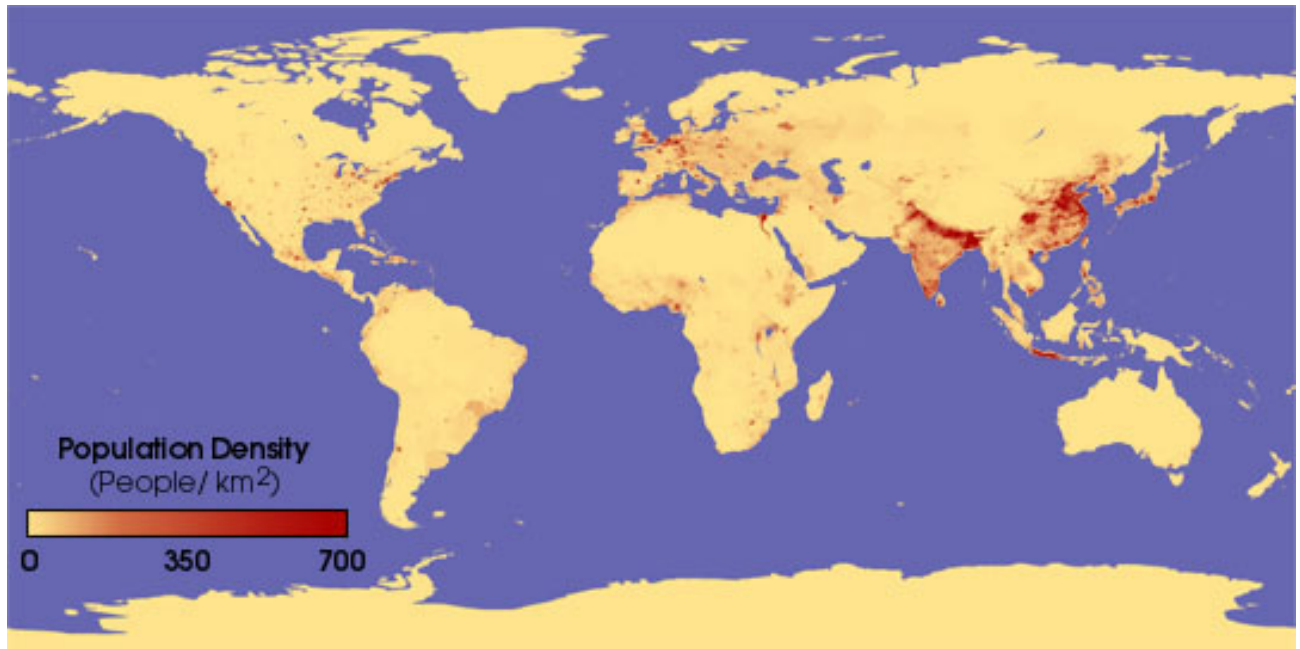
- **Malthus – 1798* – Population grows exponentially; food production grows linearly. Population growth ceases when incremental person doesn't have resources to survive**
- **Hardin – 1968 – Tragedy of the Commons**
- **Ehrlichs – 1968 – Overpopulation is the problem, depleting soils and disrupting natural life support ecosystems**
- **Forrester – 1972 – Limits to Growth – potential for disaster within 100 years**
- **Meadows – 1992 – Beyond the Limits – overshoot but human ingenuity could prevent collapse**
- **Cohen – 1995 – How many people can Earth support? (maybe a trillion, more likely around 16 billion)**

***Full references are given in: Tester et al., *Sustainable Energy: Choosing Among Options*, The MIT Press Cambridge MA, 2005**

Global Population Density Distribution

World Population

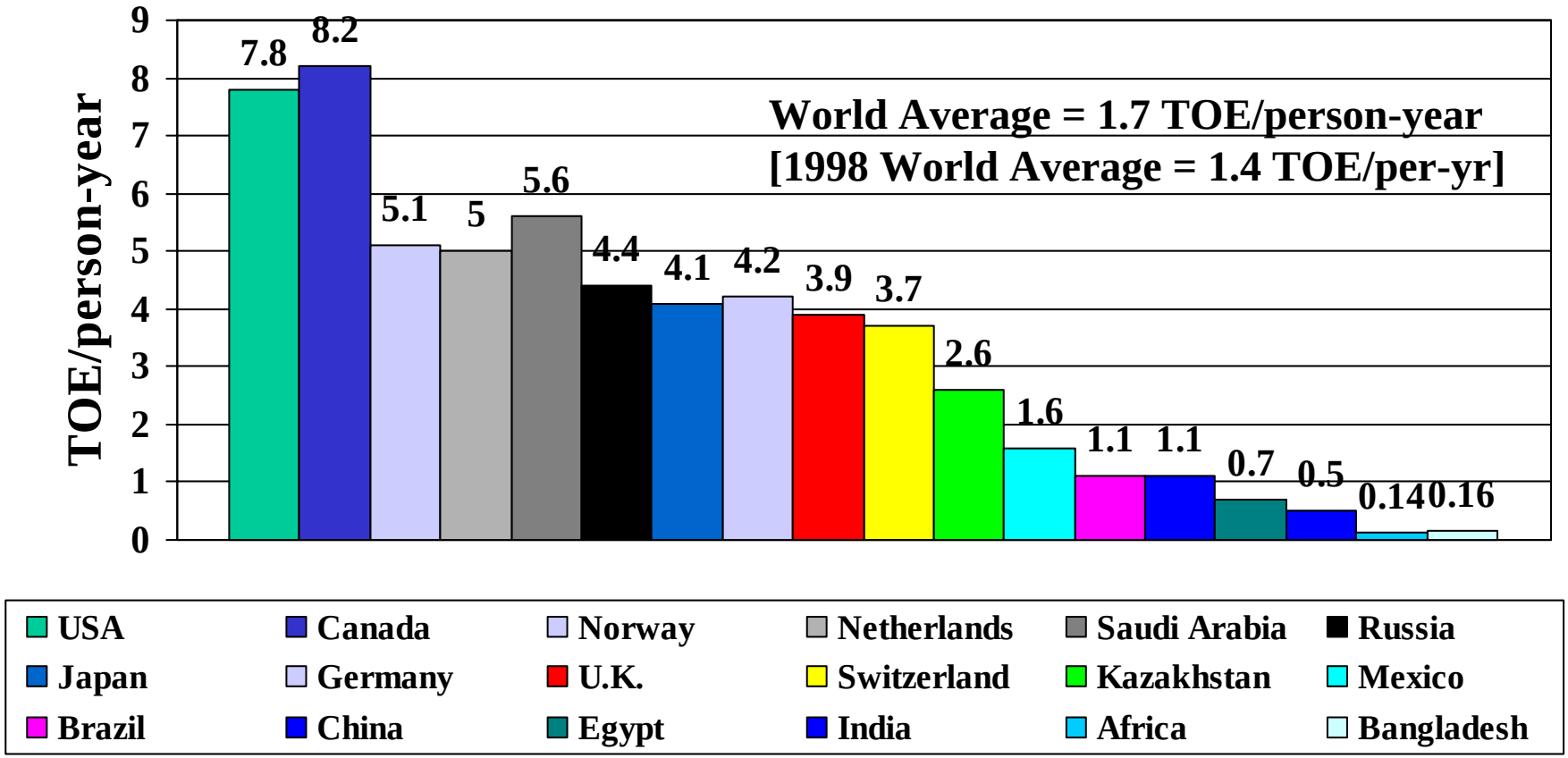
1650	**550 million**
1750	**725 million**
1850	**1.2 billion**
1900	**1.6 billion**
1950	**2.6 billion**
1980	**4.5 billion**
2000	**6.1 billion**



From NASA: http://visibleearth.nasa.gov/view_detail.php?id=116

2006 Per Capita Average Energy Use for Selected Countries

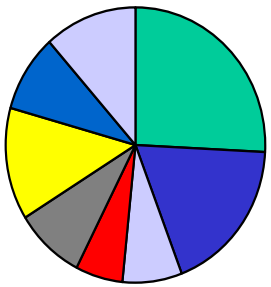
Tonnes of Oil Equivalent per person per year

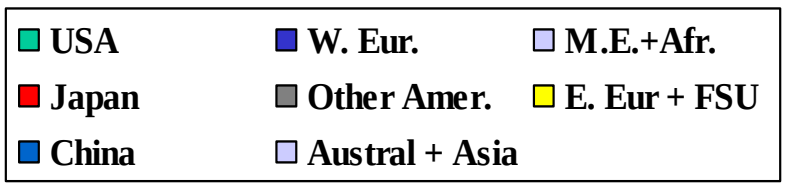


From: Pocket World in Figures 2007, The Economist, London

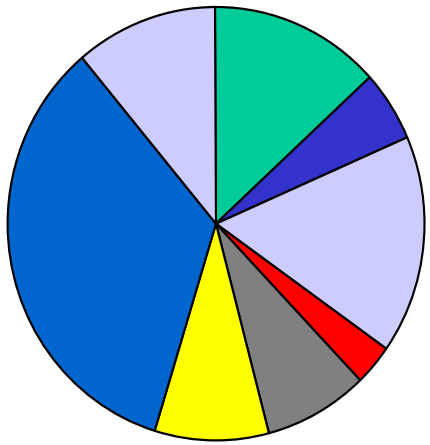
World Commercial Primary Energy Use – Now and Projected (Edmonds, BAU)

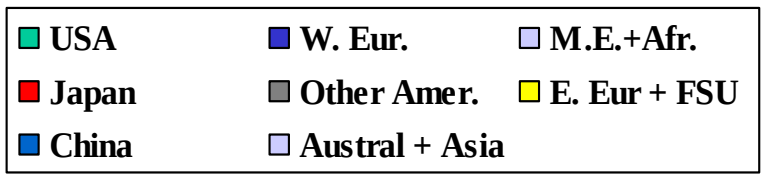
BP data, 1999, 8.5 bTOE





Edmonds, 2095, 30+ bTOE?





From: BP Statistical Review of World Energy, 2000 and Edmonds, J., *Energy Policy*, 23:4-5, 1995

Energy Use by Sector

- **Typical Wealthy Country**
  - **25% primary energy to electricity**
  - **1/3 to transportation**
  - **1/3 to industry**
  - **1/3 to buildings (about half the electricity)**
- **Poorer Countries**
  - **Buildings and industries (rural) predominate, but industry and transportation grow with development**
- **Worldwide**
  - **18% primary energy to electricity**

Percentage shares of world population, world GDP, and world commercial energy consumption for selected countries.

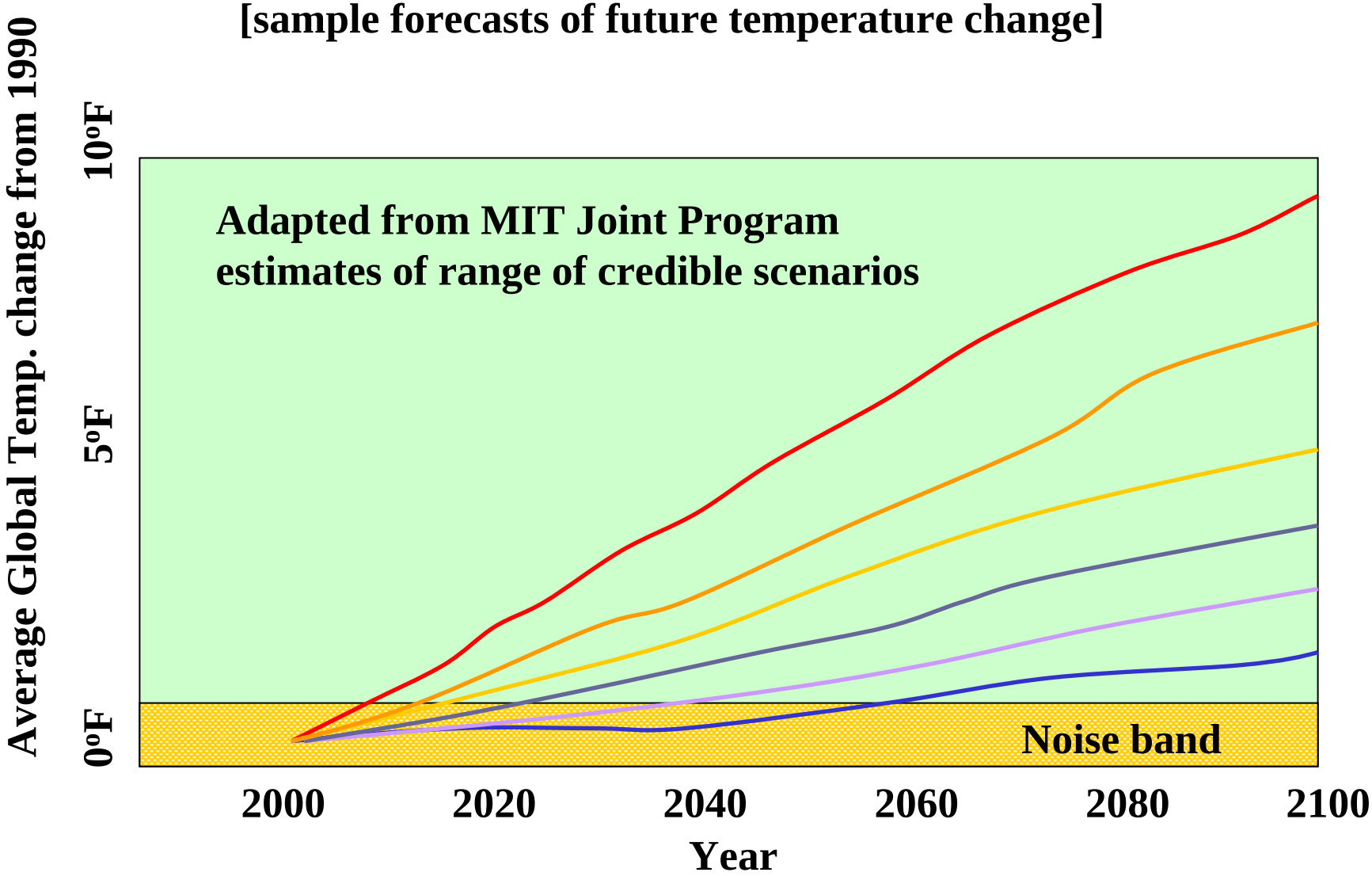
Country	% of World Population 2006	% of World GDP 2006	% of World Energy Consumption 2006
United States	4.6%	28.4%	22%
Japan	2.0%	11.2%	5%
France	0.9%	5.0%	3%
Germany	1.3%	6.6%	3.3%
United Kingdom	0.9%	5.1%	2.2%
China	20.6%	4.7%	13.4%
India	17%	1.7%	5.2%

Climate Change Concerns

- **Global energy demand is growing and is over 80% of primary energy is supplied by fossil fuel today**
- **Combustion of fossil fuel generates greenhouse gases – predominately CO_2 – that can lead to global warming and associated impacts (melting of glaciers and polar ice, sea level rise, changes in local rainfall and climates, increases in storm severity, impacts on biosphere and agriculture, changes in ocean circulation, etc.)**
- **Methane, CH_4, is also a GHG and reaches the atmosphere through agricultural activities and leakage**
- **There is no "silver bullet" replacement for fossil fuels**

The Greenhouse Gamble

[sample forecasts of future temperature change]



Other Energy Sources all have pros and cons

- **Nuclear: can provide concentrated power, but there are concerns about waste management and proliferation**
- **Solar-based Renewables (solar, wind, hydro, biomass): require large land areas for collection because of the lower energy intensity of sunlight**
- **Geothermal: Deep access is needed in most areas to reach high enough temperatures for efficient power production**
- **Fossil with carbon capture and sequestration: energy penalty for processing and concerns about long-term CO_2 storage integrity**

Energy Sources, Conversions and Use

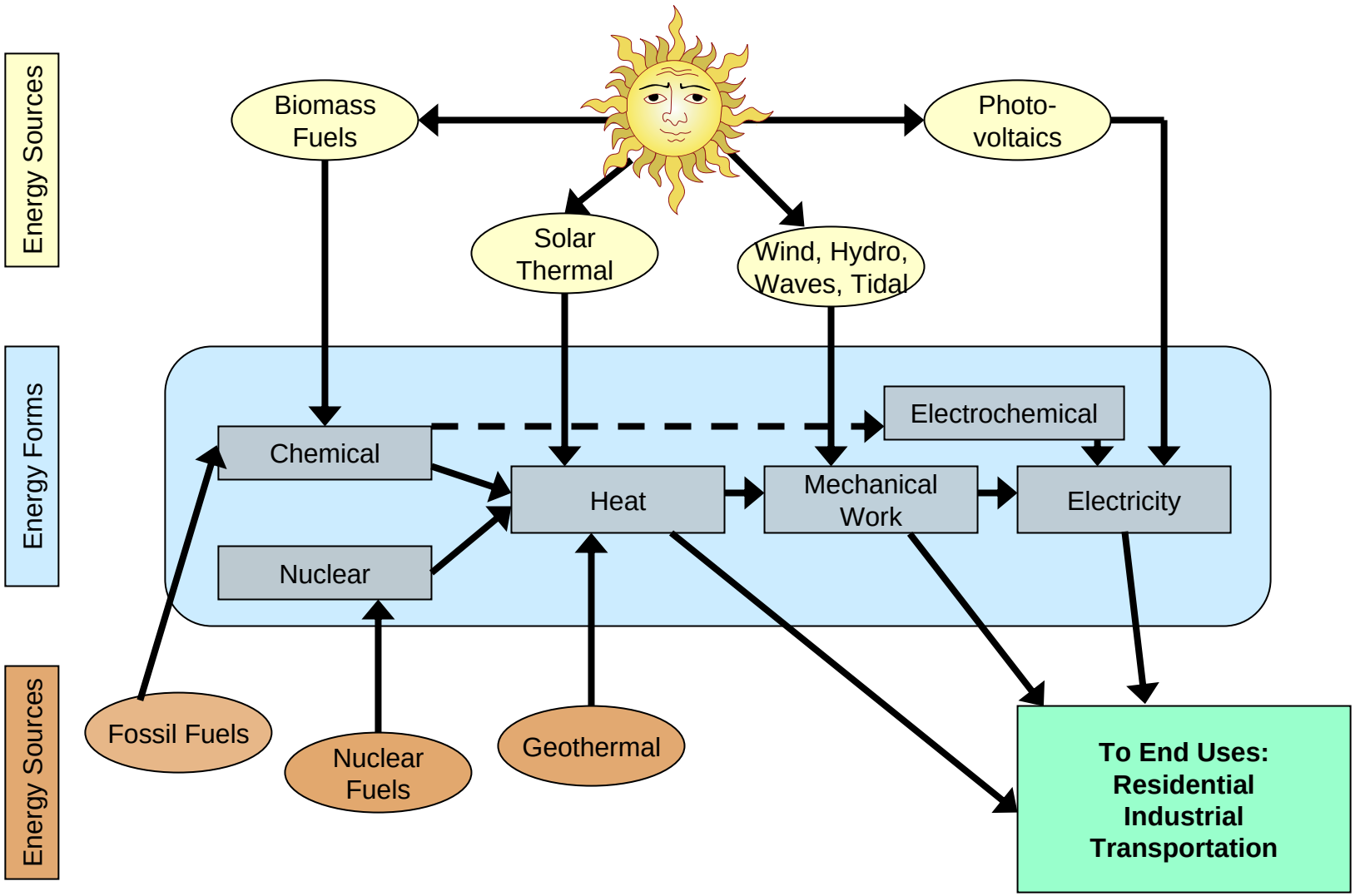


Image of sun by MIT OpenCourseWare.

Trends and Issues

- **Population growth still increasing though slowing. Some OECD countries may actually see a populations decline without immigration**
- **Increasing electrification in all sectors except transportation – which remains oil dependent**
- **Existing energy technology infrastructure is in place; this is a barrier to competition from new sources**
- **Growing concerns about "externalities:"**
  - **Global climate change**
  - **Economic and societal instabilities**
  - **Resource depletion**
  - **Land impacts**
- **Worldwide dependence on low cost fossil fuels makes it difficult to raise prices over a short time span – could change trade patterns significantly**
- **China's rapid growth and motorization are creating growing demands for new petroleum production and refining**

Economic Impacts and Costs

- **From: UK Economic Service Assessment:**

  "Stern Review Report on the Economics of Climate Change" (October 2006)

  - **Costs associated with unabated climate change are estimated to be at least 5% of GDP/year**
  - **Other impacts such as economic effects on human life and the environment and differential impacts on the poor could raise estimates to 20% of GDP per year or more.**
  - **Each tonne of CO_2 emitted now causes damage worth at least $85**
  - **Many emissions reduction opportunities cost less than $25/TCO_2$**
  - **Tackling climate change soon is a long term growth path – the status quo will ultimately undermine economic growth**

Policy Changes for Effective Response

From: UK Economic Service Assessment:

"Stern Review Report on the Economics of Climate Change" (October 2006)

Progress will require:

- **Carbon pricing (taxation, emission trading, regulation) to build a common global carbon price that includes full social costs of use**
- **Technology policy to drive the development and large-scale deployment at scale of low-carbon and high-efficiency products**
- **Policies that remove barriers to energy efficiency and inform, educate, and persuade individuals about what they can do to facilitate the transition**

Need consistent global policy, guided by understanding of long-term goals, with strong frameworks for international cooperation.

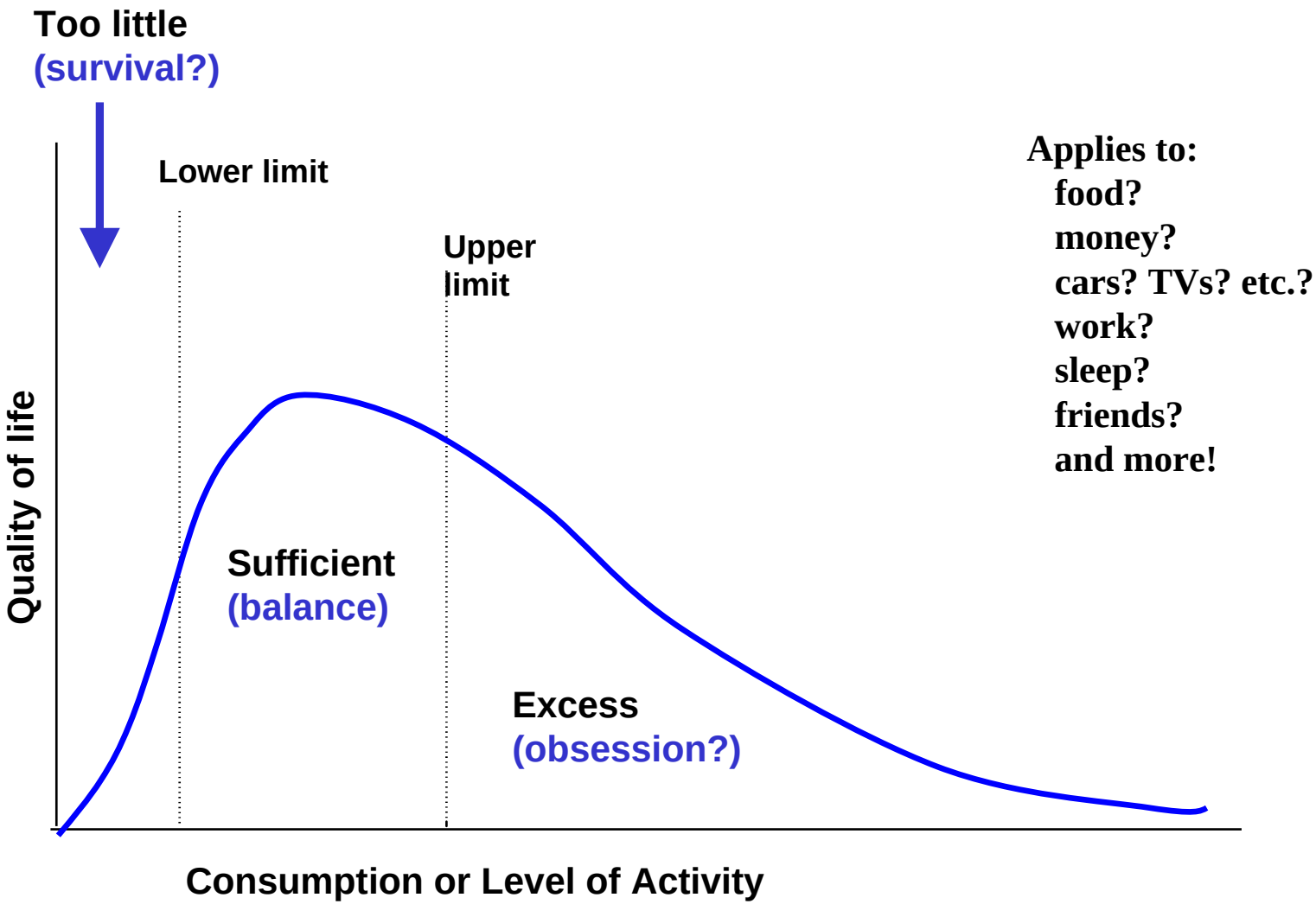
The Energy Challenge

- **If we have to change our energy technologies over a relatively short period of time, where are the best alternatives?**
- **How should we invest in developing better alternatives?**
- **What are the drivers that will encourage timely development and market penetration of these technologies?**

- **Do we also have to change behaviors?**

Thring's Sufficiency Concept

(slightly modified)



Applies to:

- **food?**
- **money?**
- **cars? TVs? etc.?**
- **work?**
- **sleep?**
- **friends?**
- **and more!**

Some Barriers

- **Most people don't like change unless it will improve their life now**
- **Changing energy sources will entail additional costs, will upset present economic balances, will create winners and losers, and may slow economic growth in the short term**
- **Most people have a preference for short over long term gain, especially if the long term gain is intangible**
- **We have trouble assessing the value of "externalities" – and the value may not be uniform among nations or regions**
- **Moving to more expensive energy sources will force us to use less energy and perhaps to forgo some habits we have come to like (e.g., SUVs in the US) – and will differentially impact the poor**
- **Our leaders are reluctant to do anything that may hurt major industries or the economy – unless there is a compelling reason to do so**
- **Most Americans are unaware of the rapid industrialization and growth of China - and its competition in global markets for petroleum and other resources**

Mitigating Climate Change: Progress - How Far and How Fast?

- **Gaming – Wait for the "other guy:"**
  - **Developed countries go first; Kyoto modest start**
  - **Each country wishes to preserve or improve economic status**
  - **US administration backed away from the Kyoto Protocol and looks to a variety of voluntary initiatives**
- **Result – INACTION!**
- **BUT: Evidence of climate change is increasing and public awareness is rising, even in the US**

Addressing Poverty: How Far and How Fast?

- **Gaps between rich and poor still widening**
- **Cultural and religious values influence attitudes**
- **Energy/electricity access help improve life of the poorest**
- **Selfishness and denial**
  - **Developed world (especially the U.S.) – view that poverty is self-inflicted, limited social services aimed at reacting to problems rather than to correcting them, unwillingness to share enough domestically, much less internationally**
  - **Developing countries – desire for better quality of life among both the richer and the poorer, graft and corruption, acceptance of large inequities, inadequate resources (human and financial) for much change, anger at the "haves" – who are even more visible now thanks to modern communications**

Consequences of Inaction

- **Climate change**
  - **Shifting regional weather patterns impacting ecosystems, agriculture, water, storms, floods, etc.**
  - **Impacts of warming about double the average at the poles**
  - **Most human impact on the poor – wealthy countries can better afford mitigation**
- **Poverty**
  - **Subhuman living conditions for many; ill-health, addiction, crime, mass migration, etc.**
  - **Loss of human capital and environmental degradation**
- **Major societal inequities**
  - **Economic conflicts and disruptions**
  - **Institutional instabilities**
  - **“Fortress World” for the rich? Terrorism? Wars?**

Some considerations…

- **There is no right or wrong – it is a matter of balance**
- **Each one may contribute in a different way**
- **Selfishness and materialism are OK in moderation, but may block other rewarding human values like being of service to others, feeling part of a community, self respect, love, and compassion**
- **We can only control our behavior – not other people's (though it is possible to be an example)**

Rewards of Action

- **Perhaps a better quality of life with enough to meet our needs – not our wants!**
- **A different business paradigm – not mass production, but life cycle service production with careful regard for externalities**
- **Greatly reduced social inequity and improved societal stability**
- **Appreciation and care for nature and diversity, both human and environmental**
- **A balance between self-care and the good feeling from giving our share as part of a healthy community and world**

What can we do?

- **In our daily living?**
- **In choosing careers?**
- **In our professional lives?**
- **As private citizens?**
- **As national citizens?**
- **As global citizens?**

How much are we willing to do?

Some references

- **US DOE Energy Information Administration**

  http://www.eia.doe.gov/
- **BP Statistical Review of World Energy 2005.**

  http://www.bp.com/statisticalreview [links to latest year version]
- **IEA World Energy Statistics 2006.**
  http://www.iea.org/Textbase/stats/index.asp
- **Sir Nicholas Stern, Review Report on the Economics of Climate Change (October 2006) http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm**

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