Strategies for Sustainable Energy

Lecture 1. Motivations

CBE 652
Sustainable Technology through Advanced Interdisciplinary Research (STAIR)

University of Tennessee, Knoxville
Spring, 2013

Prof. David Keffer

Course Information

Class Meeting Location and Times

- 2:10 PM - 3:25 PM Tuesday & Thursday
- Tuesday & Thursday2:10-3:25 PM

Course Website

- http://utkstair.org/clausius/docs/cbe652/index.html

Course Textbook

- Sustainable Energy without the Hot Air by David J.C. MacKay
- full text available free online at
- http://www.withouthotair.com/

Instructor Information

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- Office telephone: 974-5322
- email: dkeffer@utk.edu

Objective

The objective of this portion of the course is to educate the student with regards to strategies for identifying and developing a coherent plan for sustainable energy on a national scale.

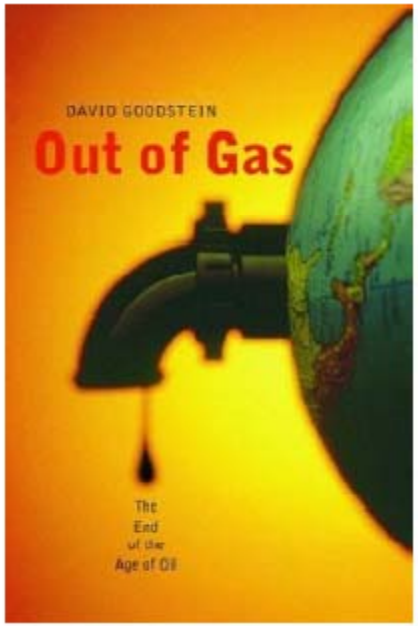
The course is organized into four parts:

- Background and Motivation
- Sources of Energy Consumption
- Sources of Sustainable Energy Production
- Strategies for Sustainable Energy

Instructor: Prof. Keffer

chemical engineer, molecular-level process and materials modeler

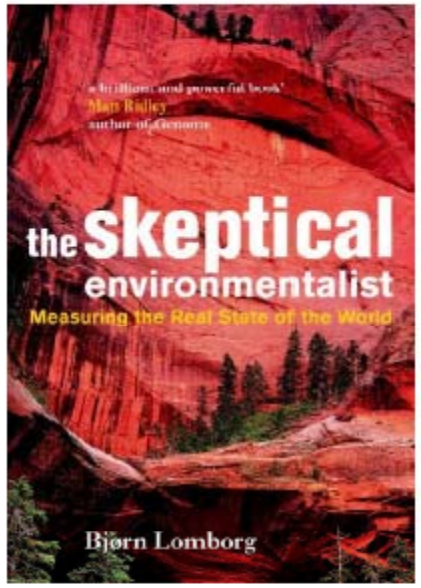
1. Motivations



David Goodstein's *Out of Gas* (2004).

In *Out of Gas,* Caltech physicist David Goodstein describes an impending energy crisis brought on by The End of the Age of Oil. This crisis is coming soon, he predicts: the crisis will bite, not when the last drop of oil is extracted, but when oil extraction can't meet demand – perhaps as soon as 2015 or 2025. Moreover, even if we magically switched all our energy guzzling to nuclear power right away, Goodstein says, the oil crisis would simply be replaced by a *nuclear crisis in just twenty years or so, as uranium* reserves also became depleted.

In The Skeptical Environmentalist, Bjørn Lomborg paints a completely different picture. "Everything is fine." Indeed, "everything is getting better." Furthermore, "we are not headed for a major energy crisis," and "there is plenty of energy."



Bjørn Lomborg's *The Skeptical Environmentalist* (2001).

How could two smart people come to such different conclusions?

1. Motivations

The discussion of an energy crisis requires numbers, not adjectives.

The numbers will be big because the problem is global.

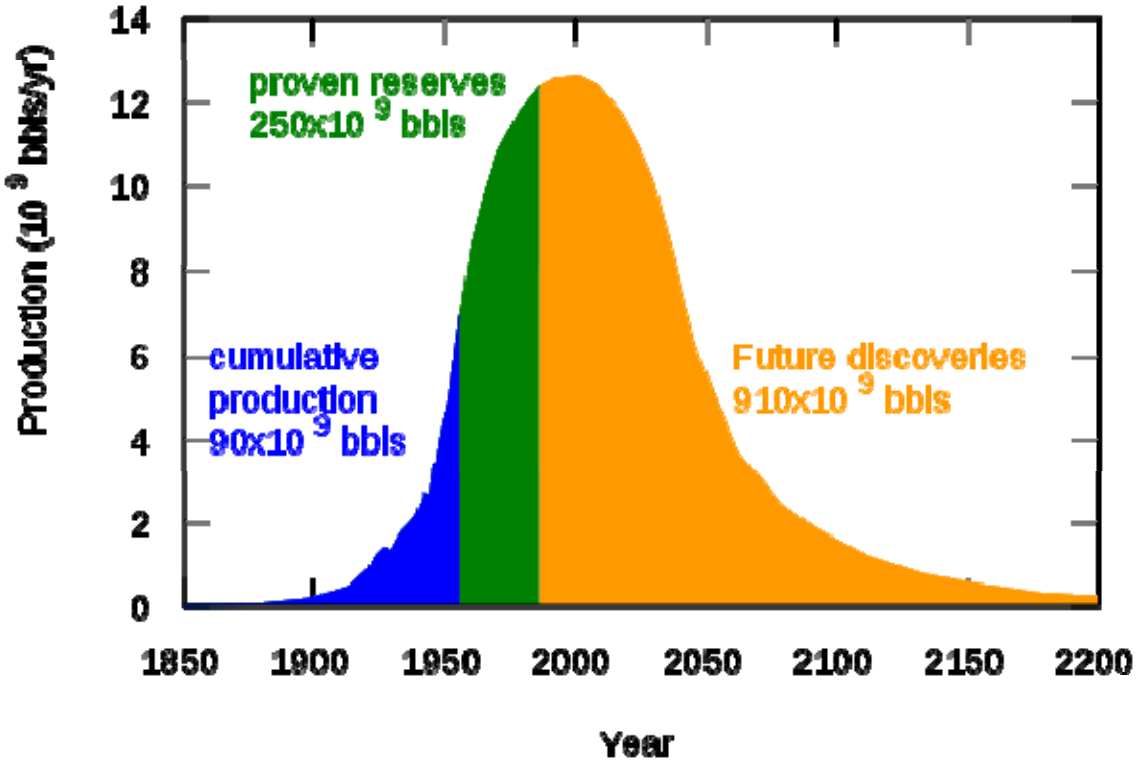
If everyone does a little, we will achieve only a little.

What is required are country-sized changes in energy usage.

Motivations

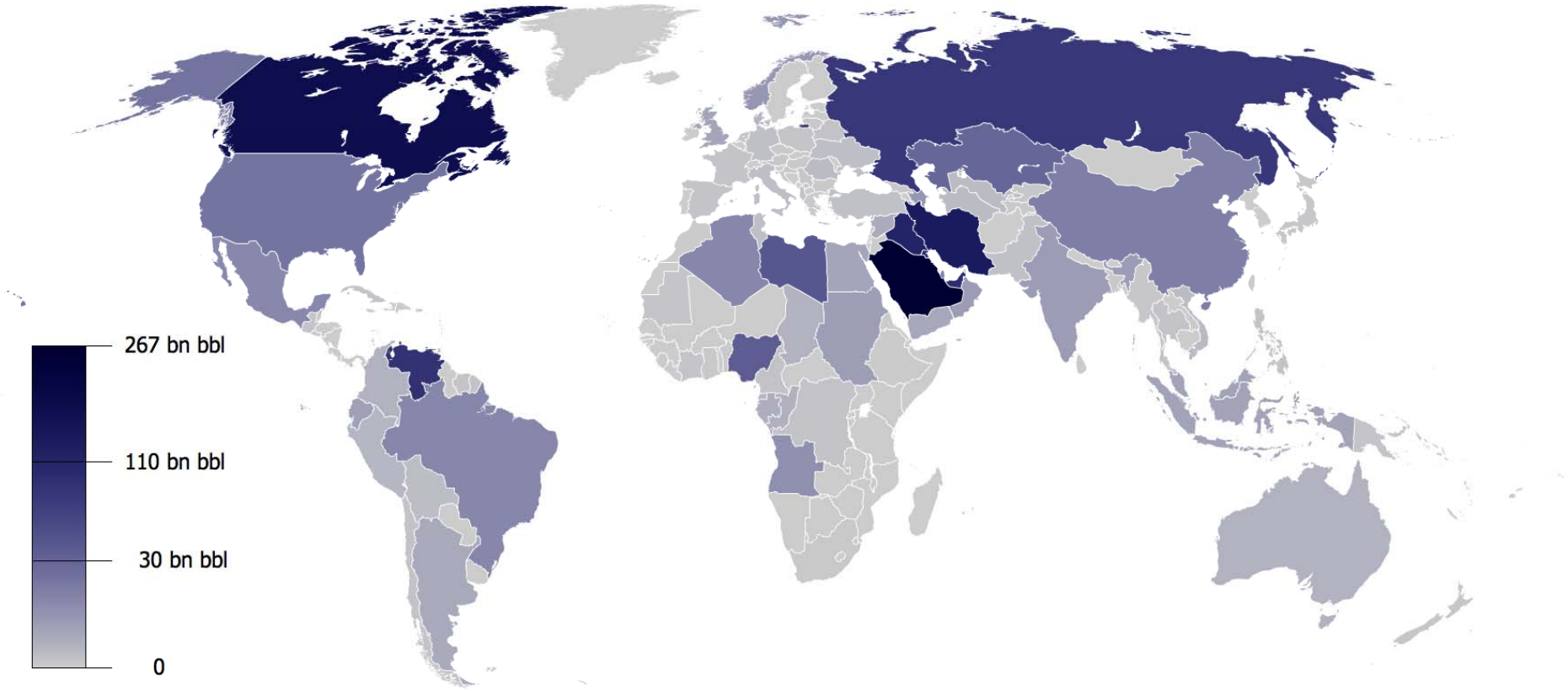
- fossil fuels are a finite resource
- energy security (many fossil fuels are located in politically unstable regions of the world, like the Middle East)
- fossil fuels probably cause climate change

1. Motivations



1. Fossil fuels are a finite resource: Peak Oil
http://en.wikipedia.org/wiki/Peak_oil

1. Motivations



2. Energy Security

http://en.wikipedia.org/wiki/Peak_oil

1. Motivations

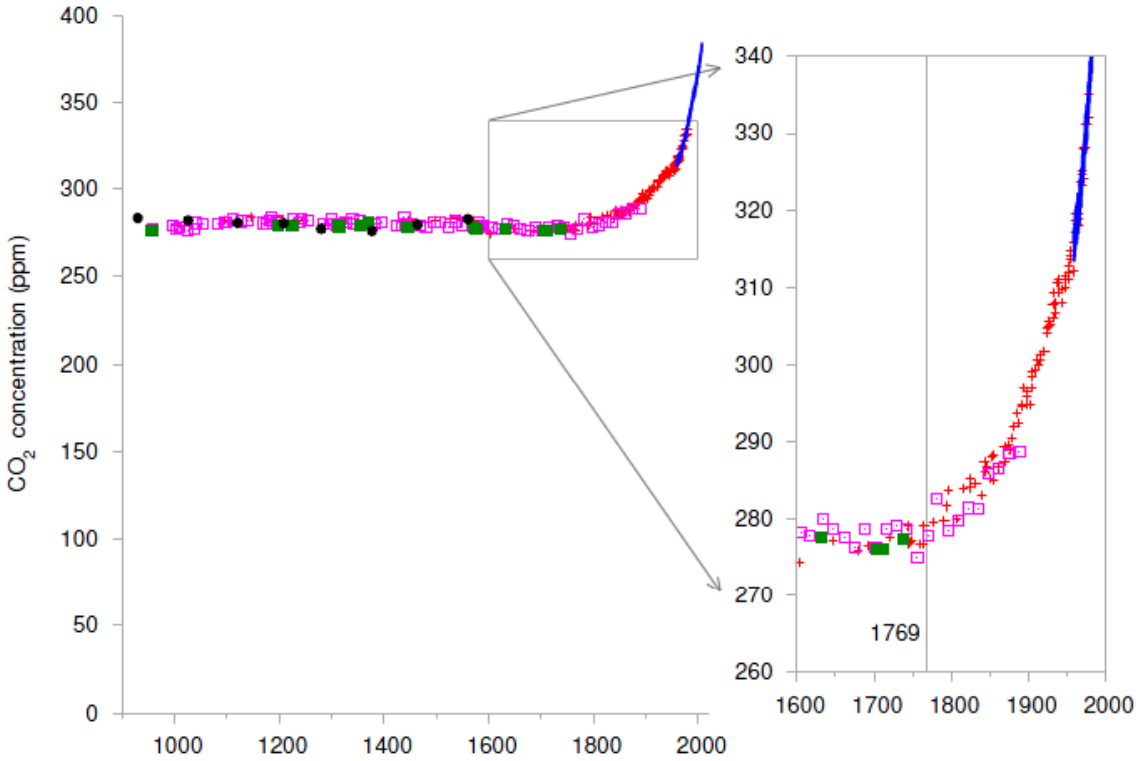


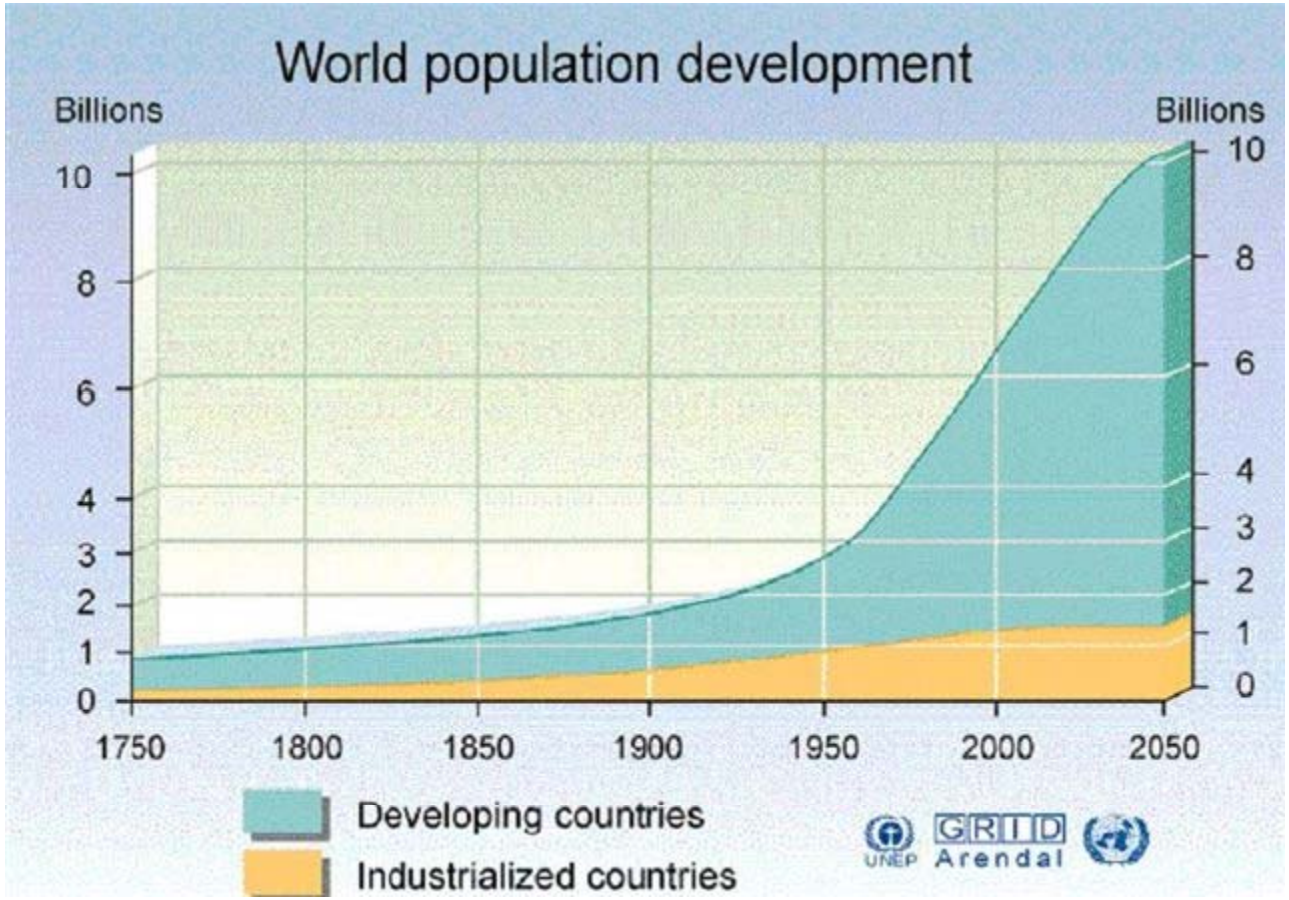
Figure 1.4. Carbon dioxide (CO_2) concentrations (in parts per million) for the last 1100 years, measured from air trapped in ice cores (up to 1977) and directly in Hawaii (from 1958 onwards).

I think something new may have happened between 1800 AD and 2000 AD. I've marked the year 1769, in which James Watt patented his steam engine. (The first practical steam engine was invented 70 years earlier in 1698, but Watt's was much more efficient.)

3. Climate Change

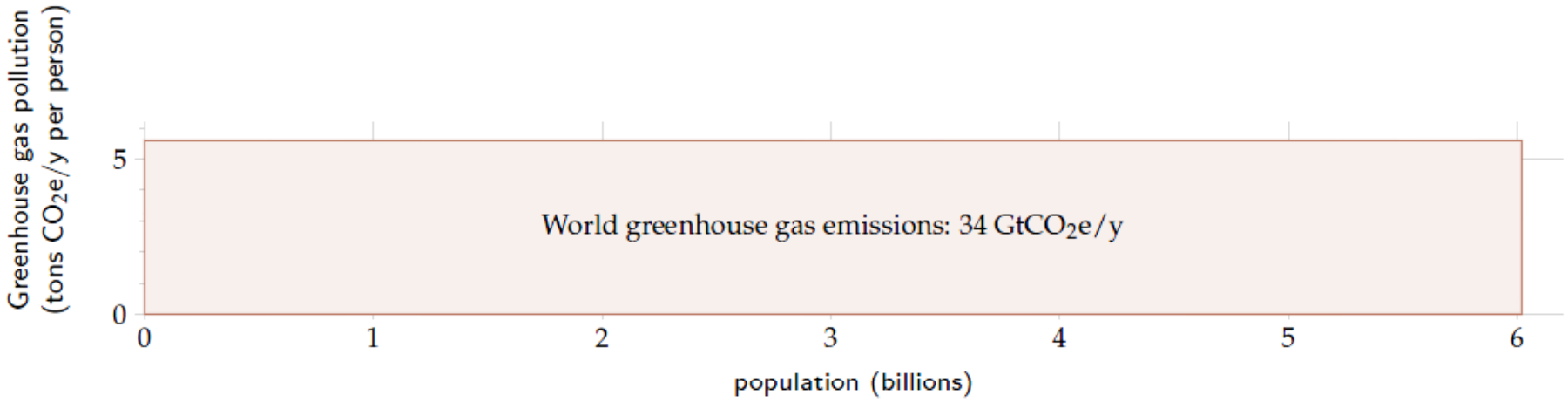
Atmospheric carbon dioxide concentrations over the past 1100 years.

1. Motivations



Primary Cause: World population from 1750 to 2050.

1. Motivations

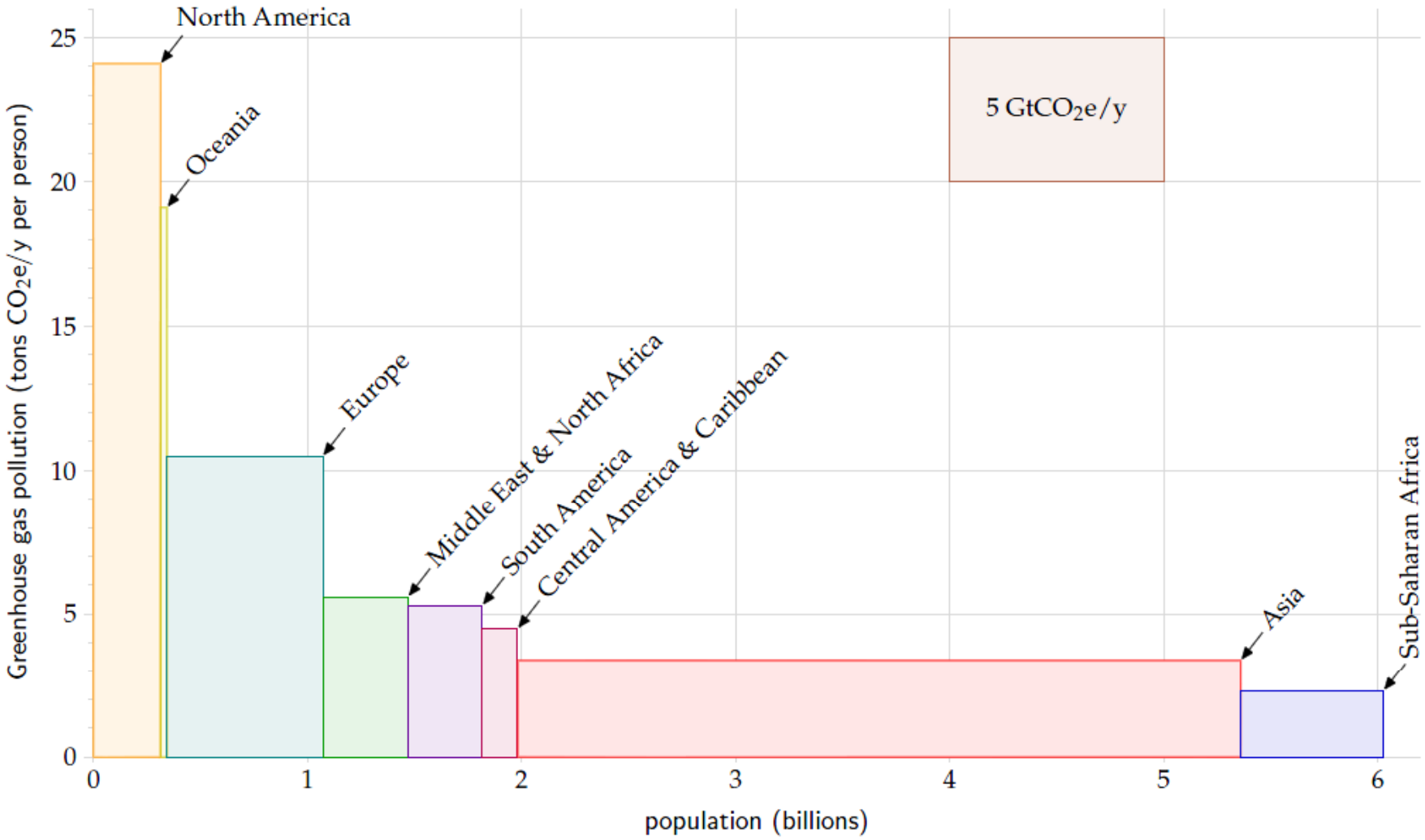


Global Greenhouse gas pollution

34 Gigatons of CO_2 equivalent per year

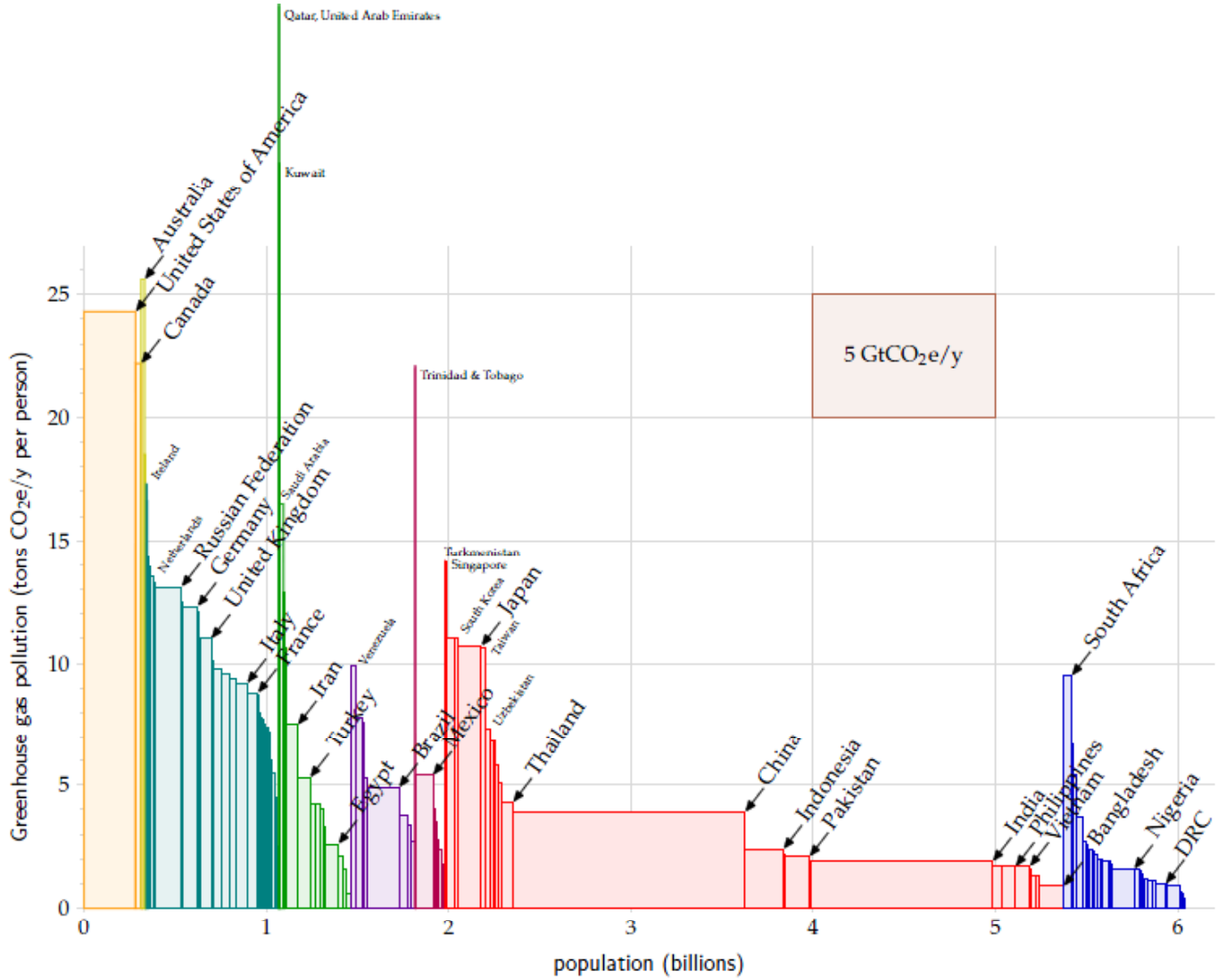
Hypothetically spread uniformly over the global population.

1. Motivations



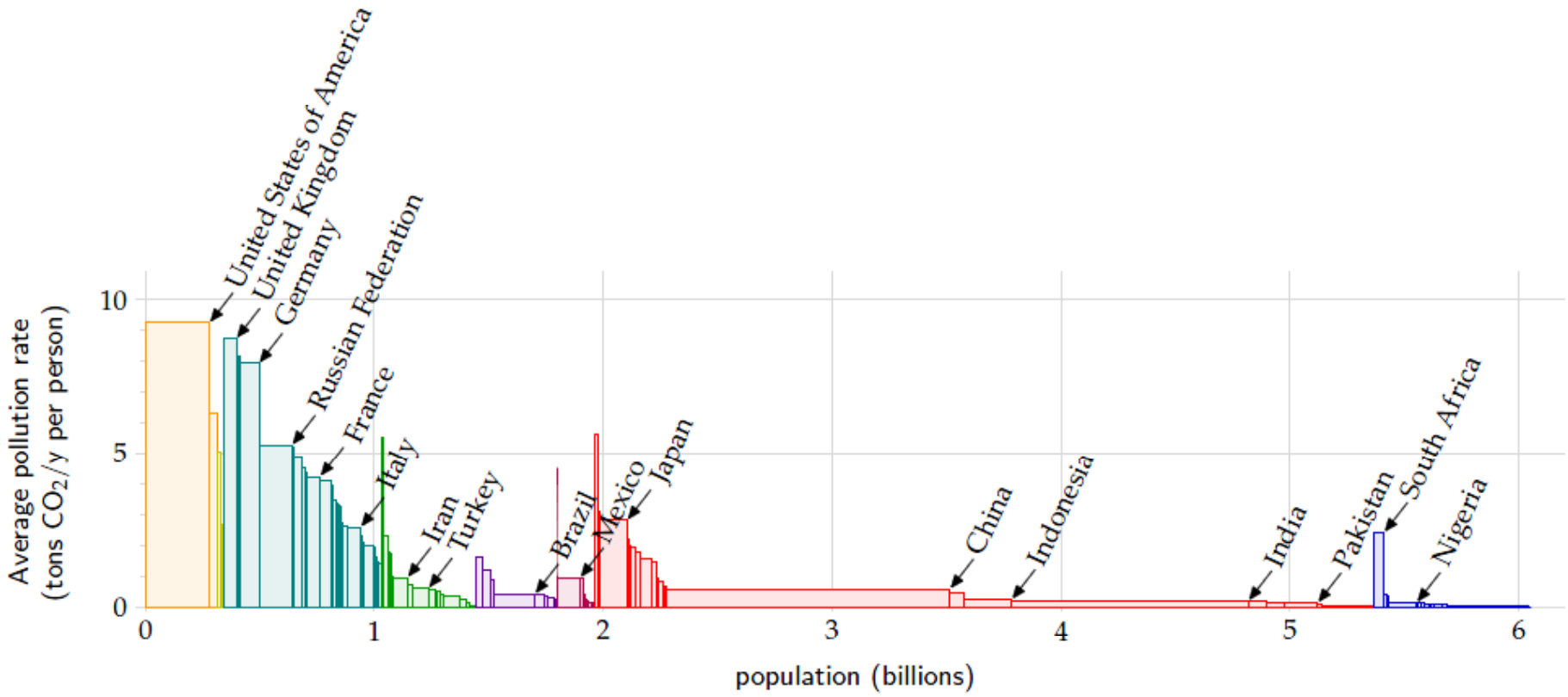
Greenhouse gas pollution by region.

1. Motivations



Greenhouse gas pollution by country.

1. Motivations



Cumulative Greenhouse gas pollution by country from 1880-2004.

1. Motivations

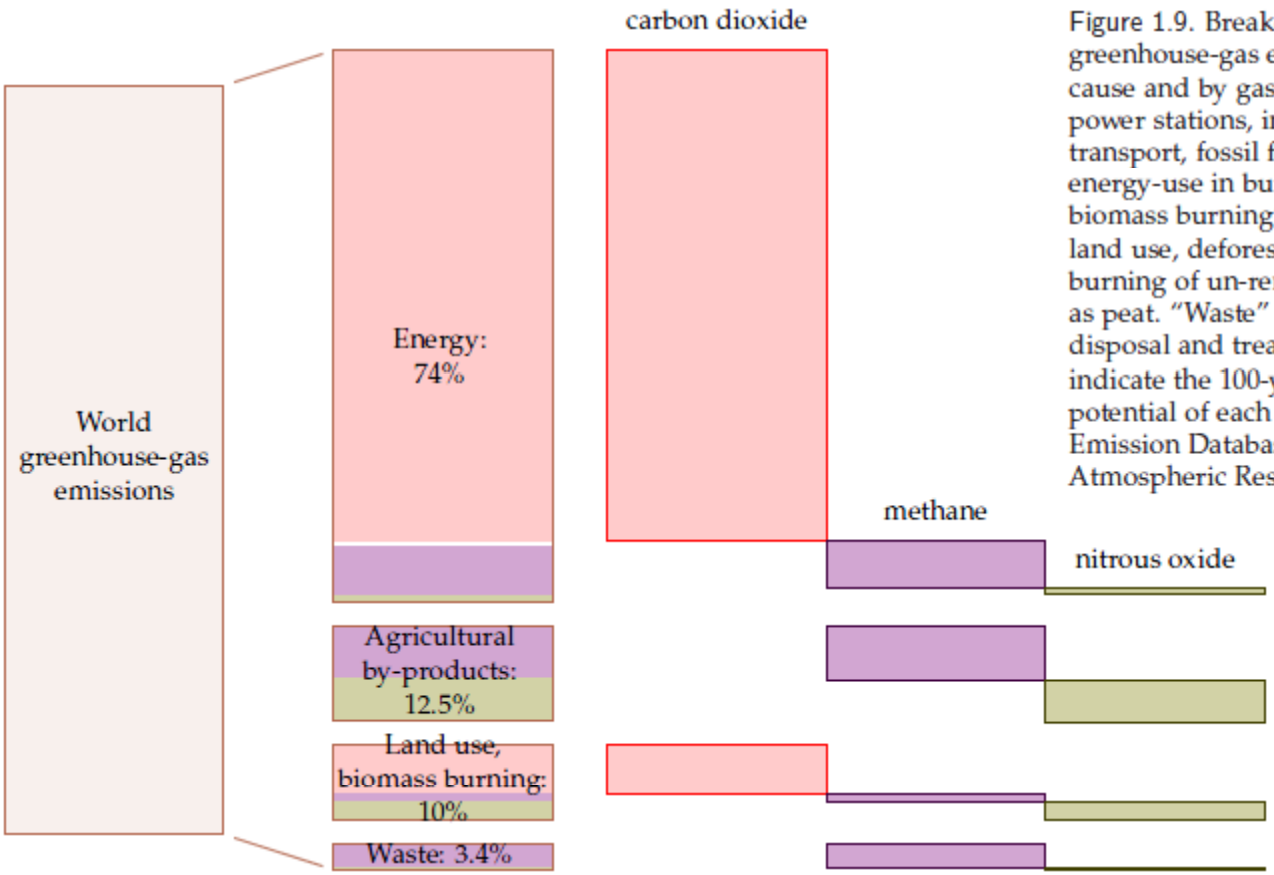


Figure 1.9. Breakdown of world greenhouse-gas emissions (2000) by cause and by gas. "Energy" includes power stations, industrial processes, transport, fossil fuel processing, and energy-use in buildings. "Land use, biomass burning" means changes in land use, deforestation, and the burning of un-renewed biomass such as peat. "Waste" includes waste disposal and treatment. The sizes indicate the 100-year global warming potential of each source. Source: Emission Database for Global Atmospheric Research.

Breakdown of Greenhouse gas pollution by cause and species.

2. The Balance Sheet

consumption

Some key forms of consumption for the left-hand stack will be:

- transport
  - cars, planes, freight
- heating and cooling
- lighting
- information systems and other gadgets
- food
- manufacturing

production

In the right-hand sustainable-production stack, our main categories will be:

- wind
- solar
  - photovoltaics, thermal, biomass
- hydroelectric
- wave
- tide
- geothermal
- nuclear? (with a question-mark, because it's not clear whether nuclear power counts as "sustainable")

Assemble two lists: one of energy consumption, one of conceivable production to answer the question:

Can we conceivably live on sustainable energy?

2. The Balance Sheet

Units of Energy and Power

This book uses the unit of energy

kilowatt-hour (kWh)

1 Watt = Joule/second (J/s)

1 kWh = 1000 W/kW * 1 J/s/W * 3600 s/h = 3.6×10^6 J = 3.6 MJ

Power

power is the rate of energy usage

energy = power * time

This book uses the unit of power

kilowatt-hour per day (kWh/d)

1 kWh/d = 3.6×10^6 J/d = 3.6×10^6 J/d * 1/24 d/h * 1/3600 h/s

= 41.67 J/s = 41.67 Watts

A 40 Watt light-bulb uses energy at about a rate of 1 kWh/d.

2. The Balance Sheet

This book frequently reports power per person
Why?

In the UK, waste incineration (burning garbage) generates 7 TWh per year.
In Denmark, waste incineration (burning garbage) generates 10 TWh per year.

However on a per person basis
In the UK, waste incineration (burning garbage) generates 0.3 TWh per day per person.
In Denmark, waste incineration (burning garbage) generates 5 TWh per day per person.
Danes burn 13 times as much garbage per person as the English.

2. The Balance Sheet

Types of Energy

1. **Electrical Energy**
   - electricity
2. **Thermal Energy**
   - steam
3. **Chemical Energy**
   - gasoline
   - natural gas

Other types

4. **Gravitational Energy**
   - water falls

Types of energy vary in terms of entropy (disorder).

Energy can be converted from one type to another

Coal-fired power plants convert fossil fuels to electricity (efficiency about 40%)

Aluminum plants convert electrical energy to chemical energy (aluminum) (efficiency about 30%)

Hydroelectric plants in dams convert gravitational energy to electrical energy (efficiency about 90%)

2. The Balance Sheet

Some people argue

● 1 kWh of electricity is equivalent to 2.5 kWh of oil, because if we put that much oil into a standard power station it would deliver 40% of 2.5 kWh, which is 1 kWh of electricity."

Hoewever in this class, we use a one-to-one conversion rate when comparing different forms of energy.

● It is *not the case that 2.5 kWh of oil is inescapably equivalent to 1 kWh of* electricity; that just happens to be the perceived exchange rate in a worldview where oil is used to make electricity.

● In an alternative world (perhaps not far-off) with relatively plentiful electricity and little oil, we might use electricity to make liquid fuels; in that world we would surely not use the same exchange rate – each kWh of gasoline would then cost us something like 3 kWh of electricity!

What is sustainability?

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

from The U.N. Report of the Brundtland Commission, *Our Common Future, 1987.*

Full text of the Brudtland Report available at
http://worldinbalance.net/agreements/1987-brundtland.php

What is sustainability?

"Sustainability is the art of living well within ecological limits."

- Tim Jackson, Prof. of Sustainable Development, University of Surrey

"Sustainability is a 21st century business imperative."

- Edward G. Madzy, Director of Product Regulations and Product Stewardship, BASF Corporation

"Sustainability should be viewed as both a responsibility and an opportunity."

- Len Sauers, Vice President for Global Sustainability, Procter & Gamble

What is sustainability?