EE2022
Electrical Energy Systems

NUS
National University
of Singapore

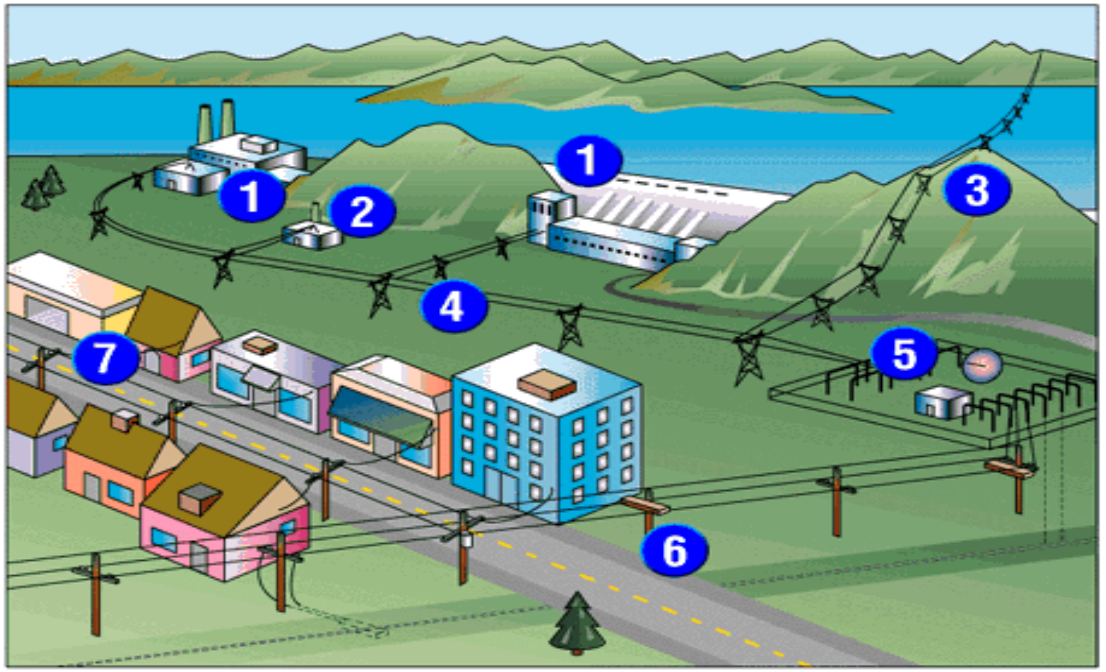
Electrical Energy

Energy is a basic necessity for human activity, and economic and social development.

Energy is used in many forms – e.g. to perform mechanical "work", heating, lighting, etc

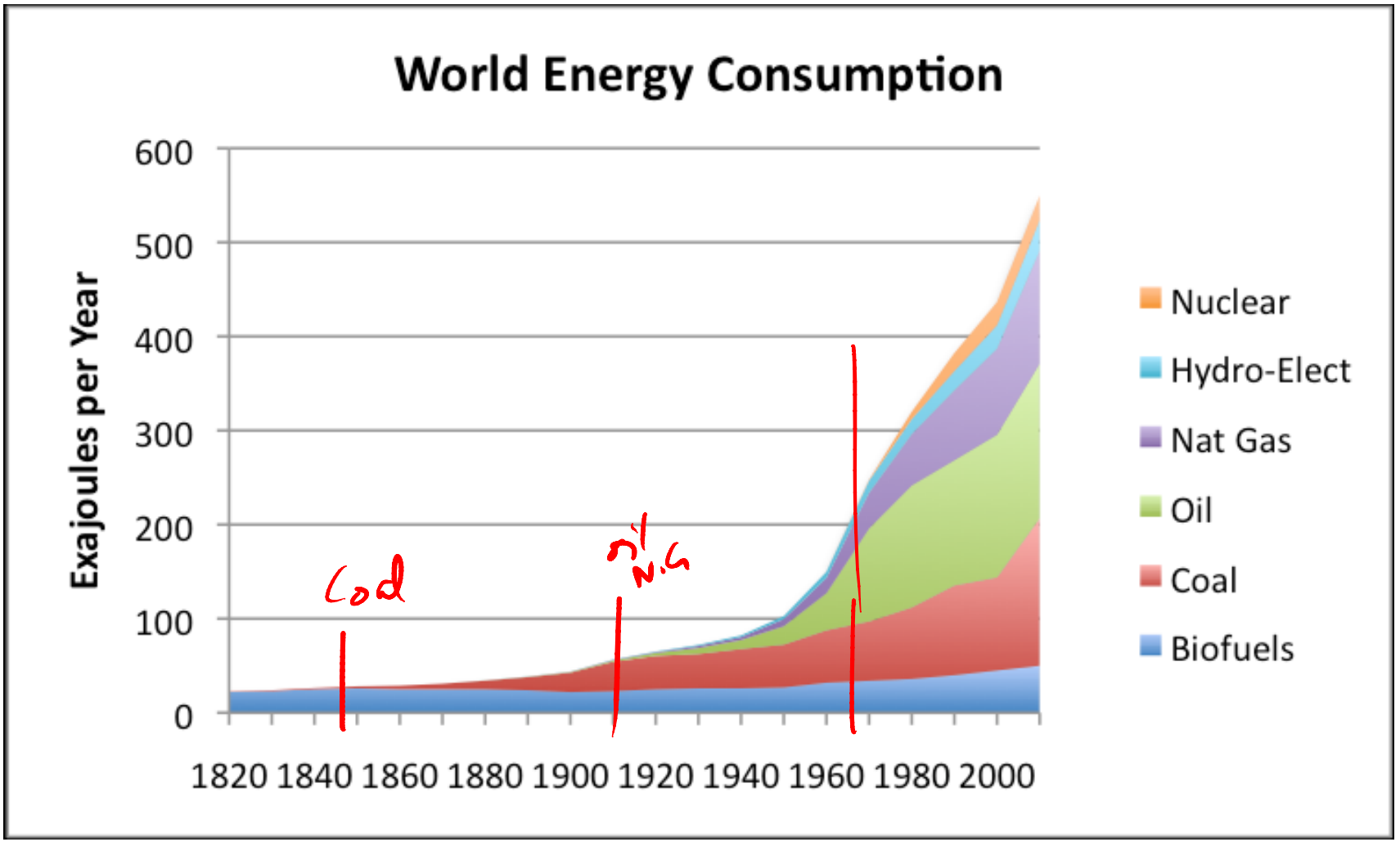
Electrical energy has an important position in the world as it can be easily converted into any form of energy

- **Convenient**
- **Ease of control**
- **Flexibility – easy to transport and distribute**
- **High transmission efficiency**
- **Clean at the point of use**

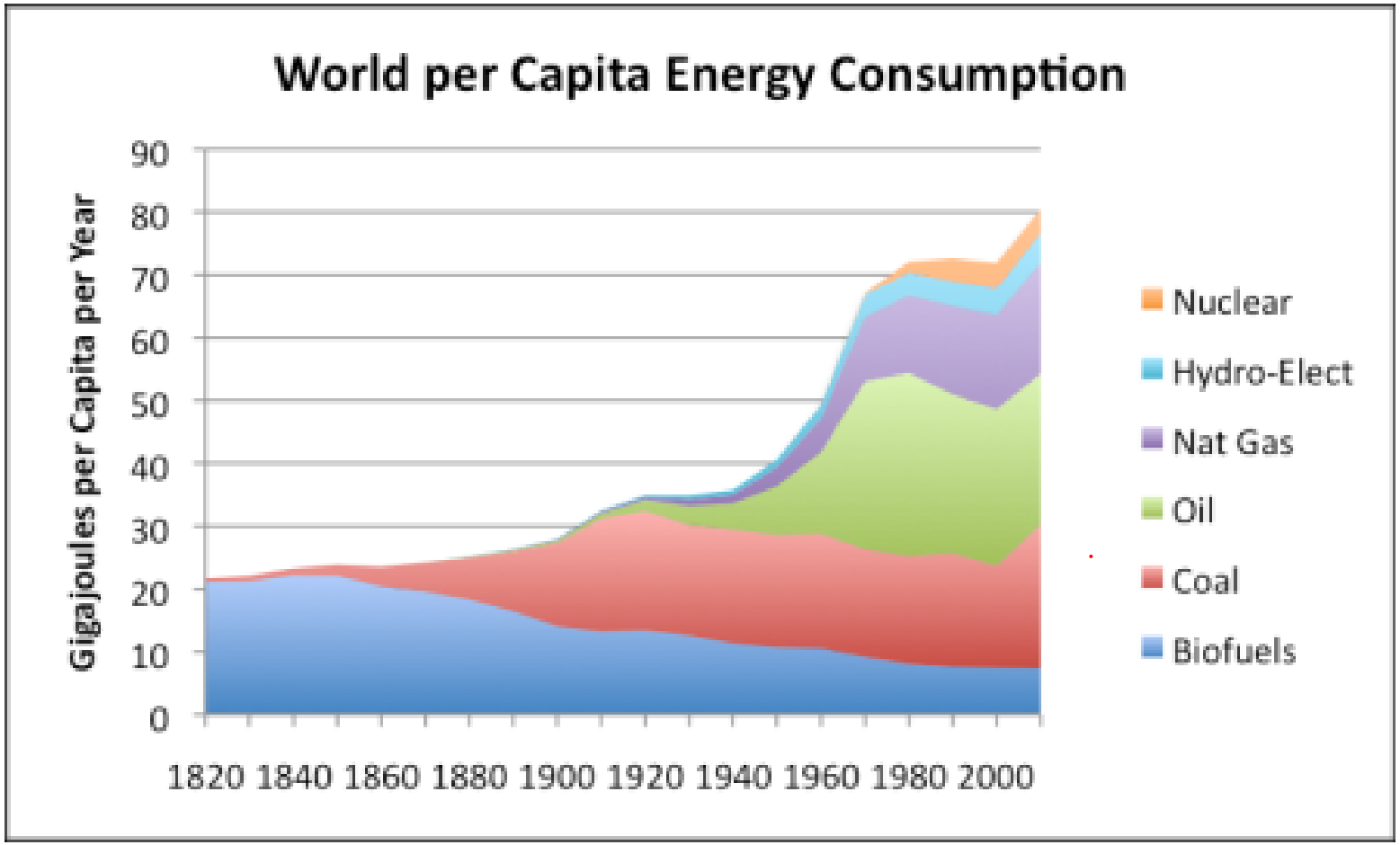


History of Energy Use

https://www.youtube.com/watch?v=EM1IyIyr-Zc

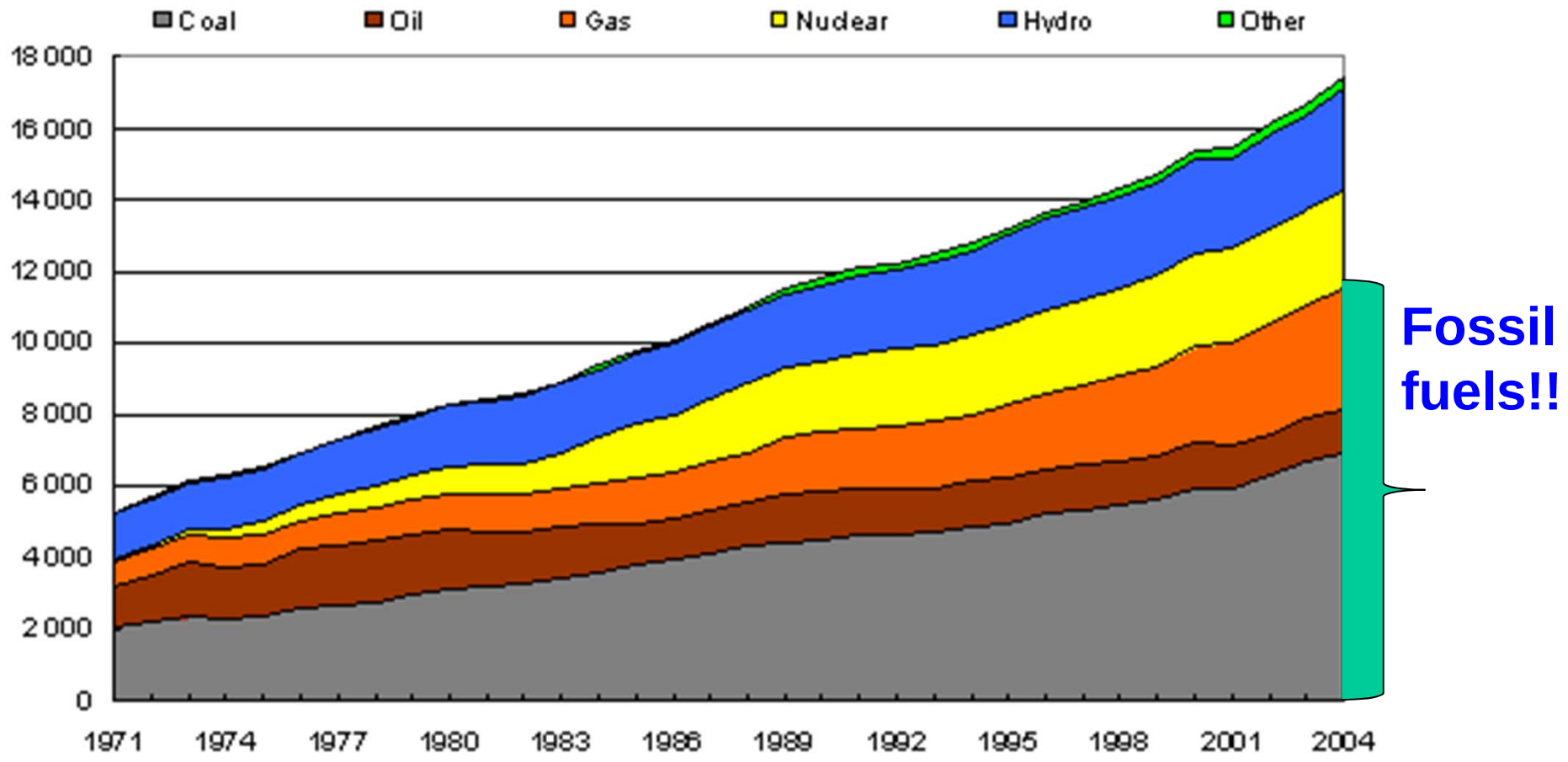


http://ourfiniteworld.com/2012/03/12/world-energy-consumption-since-1820-in-charts/



http://ourfiniteworld.com/2012/03/12/world-energy-consumption-since-1820-in-charts/

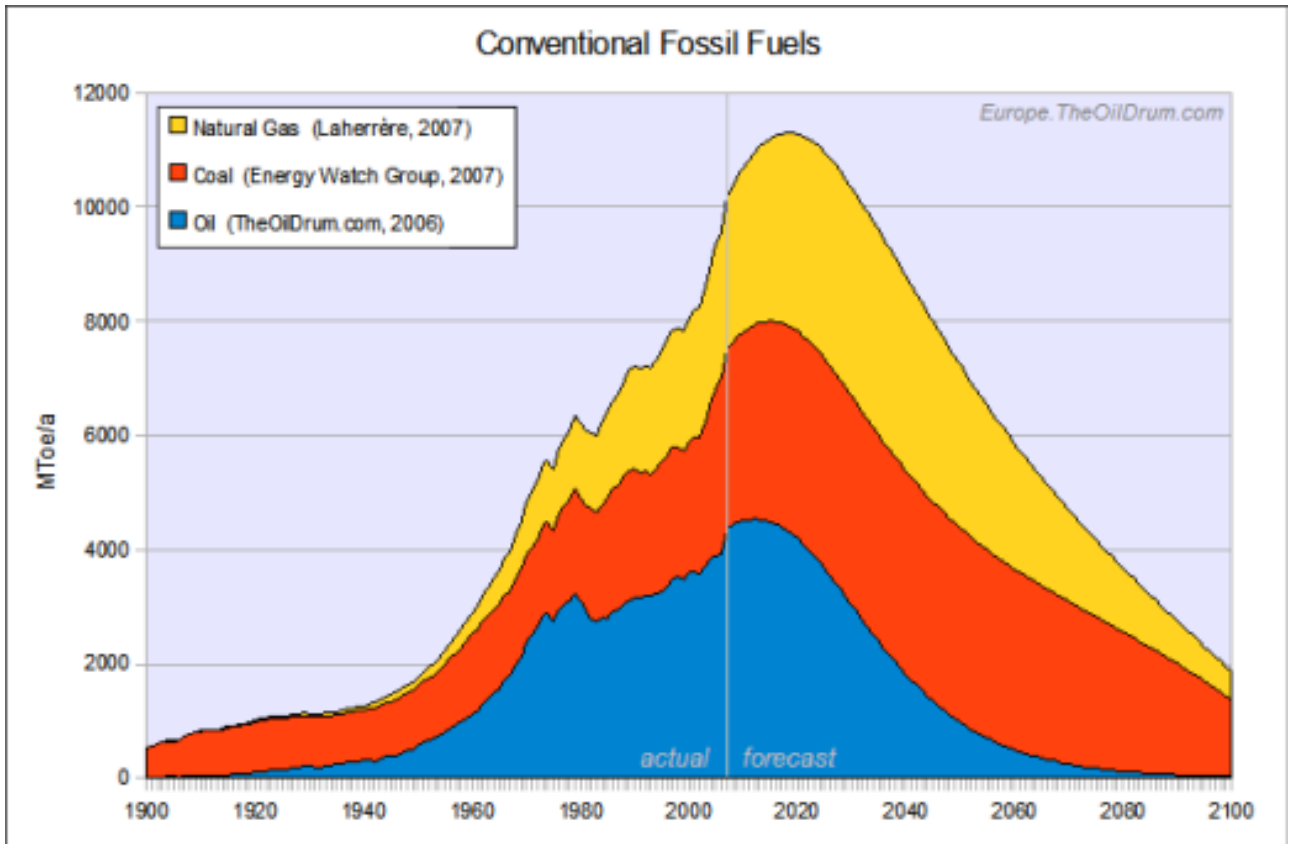
World Electricity Generation by Fuel – Historial data (Terawatt hours - TWh)



Source OECD Factbook 2007

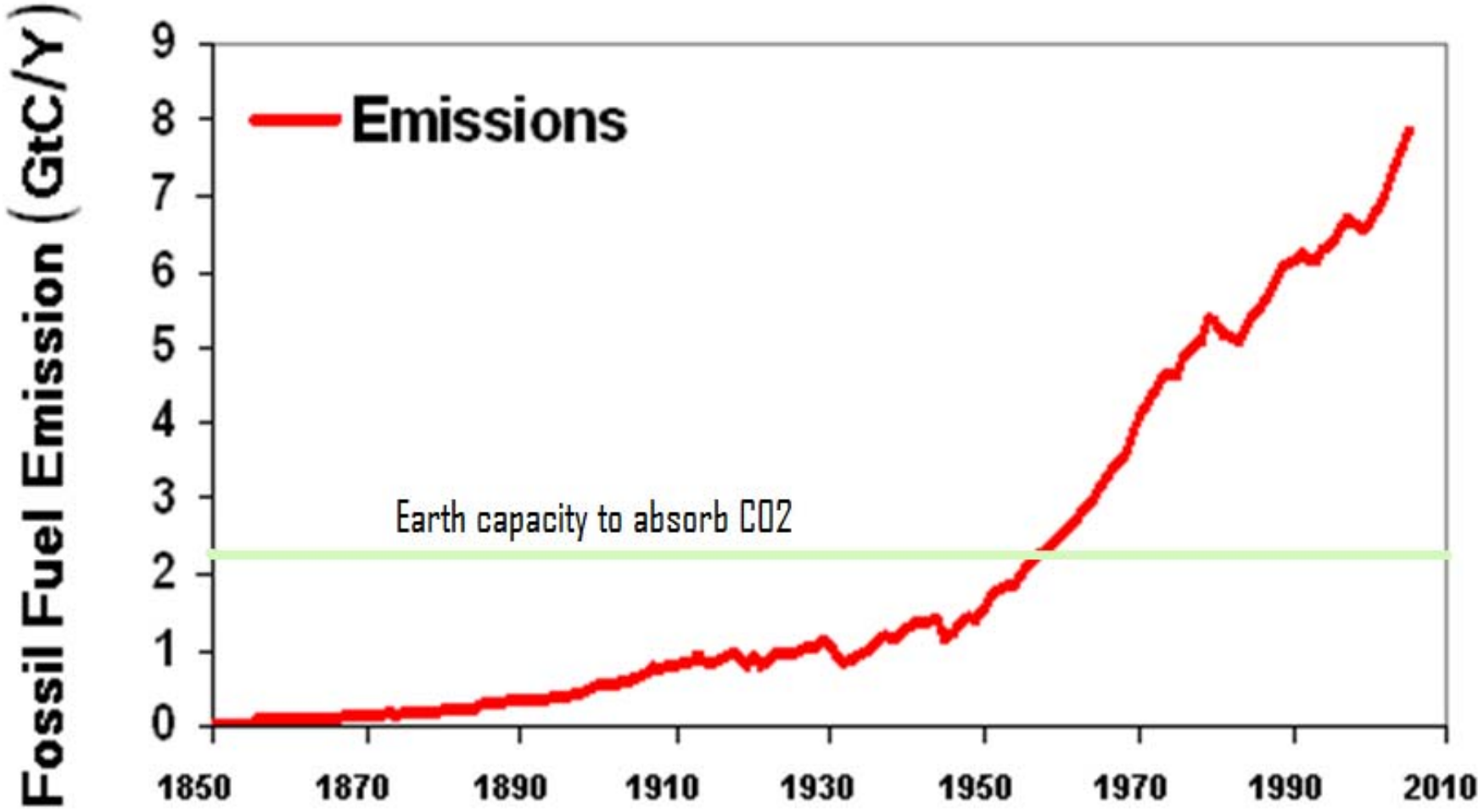
Note that electrical energy consumption has more than tripled from 5,200 to 17,400 TWh in 23 yrs.

Availability of conventional Fossil fuels is expected to decline



Source: Earth Trends, Environmental Information, World Resource Institute

World Co_2 Emissions From Fossil Fuels



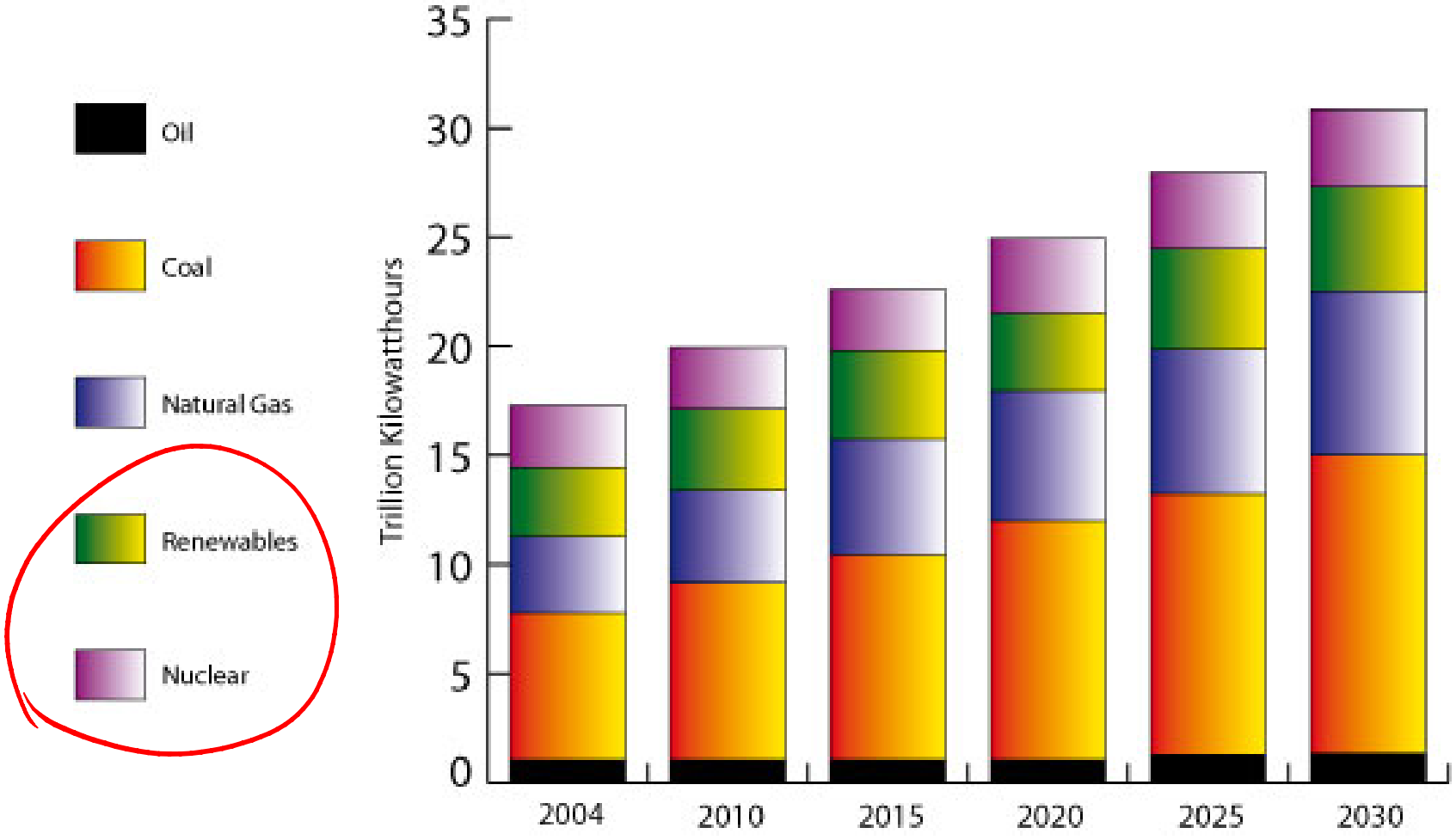
Source: Energy Information Administration (EIA), US Department of Energy

Three hard truths will shape the future of the ecosystem

- **Surge in energy demand**
- **Declining supply of Resources**
- **Rising Environmental stresses**

We are entering an era of revolutionary transitions!

World Net Electricity Generation by Fuel - Projection



Source: Energy Information Administration (EIA), US Department of Energy

How do we achieve the balance between increasing demand for electrical energy and sustainable development?

- **Renewable Energies on a Large Scale:** **Electricity supply mix away from fossil fuels with expanded development of wind, solar, biomass, geothermal, nuclear and energy from the oceans**
- **Expanded focus on energy efficiency**

- **Smart electric power grid: Greater application of IT and communication technologies**

Solution: Renewable Energies on a Large Scale

A combined use of renewable energy sources could meet our current energy needs:

- *Solar energy (photovoltaic and thermal)*
- *Hydroelectric energy*
- *Wind energy*
- *Geothermal energy*
- *Ocean Thermal energy*
- *Ocean wave energy*
- *Tidal and currents energy*

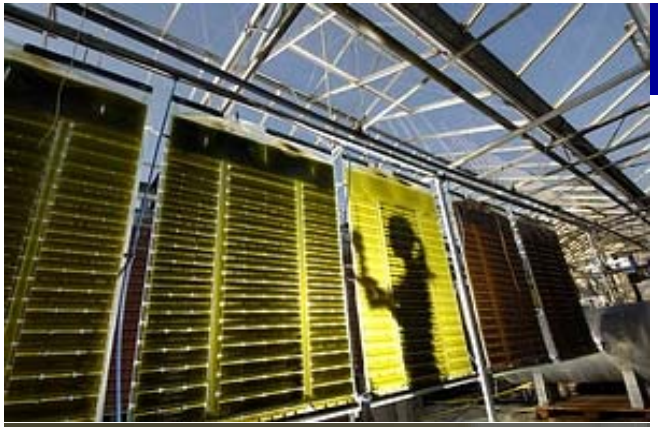
These technologies are available today …

We must however rapidly make the shift going away from fossil fuel based energies

Solution: Sustainable Transportation

- Transportation accounts for almost **one third** of all greenhouse gas emissions
- Improving energy efficiency and emission reducing technologies within transport is a priority

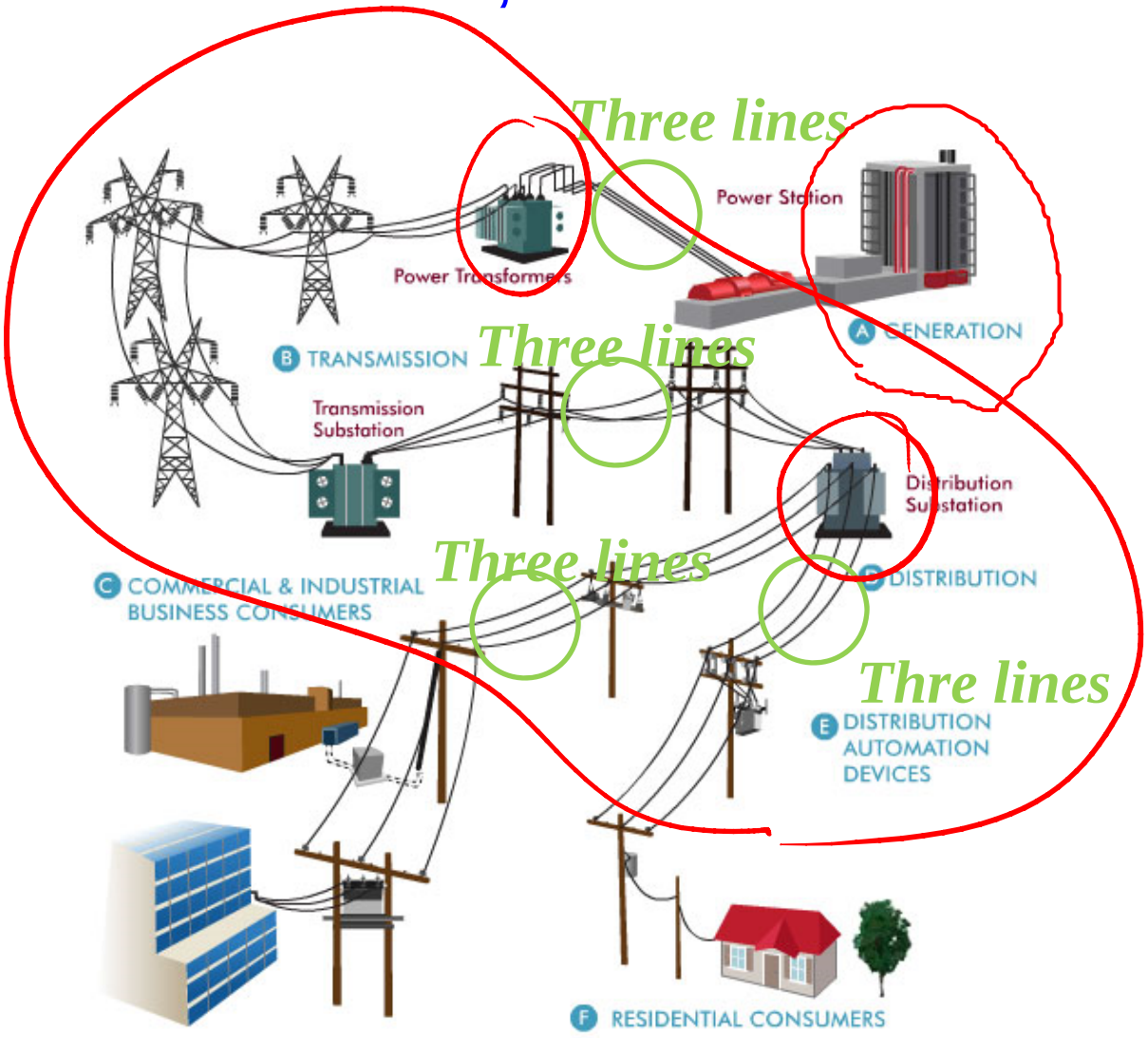
- *Hybrids*
- *Fuel cells*
- *CNG vehicles*
- *Mass public transportation*
- *Human energy vehicles*
- *Solar and wind energy vehicles*



Solution: Biofuel Generation from Algae

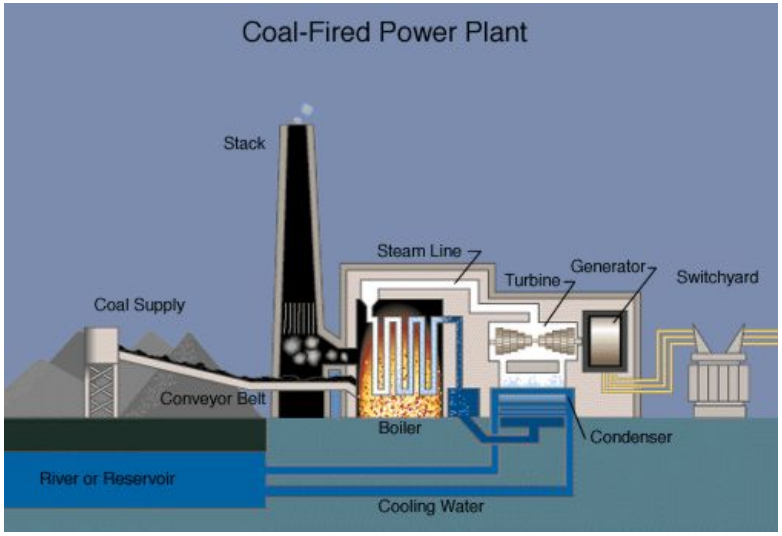
- The current biofuel production process is highly unsustainable (land use, energy requirements) => negative impact on agriculture
- Biofuel generated from algae could solve these issues:
  - *saving in energy*
  - *saving in land use*
  - *high yield*
- Fuel of the future?

Generation, Transmission and Distribution



Source: http://venturebeat.com/2010/10/29/super-grid-introduction/

Power Plants Operation



Source: http://www.tva.gov/power/

Source: http://www.youtube.com/watch?v=Km1M4Hbt-io&feature=related

http://www.worldenergyoutlook.org/media/weowebsite/2014/WEO2014FactSheets.pdf

- In the New Policies Scenario, energy demand grows by 37% to 2040 on planned policies, an average rate of growth of 1.1%.
- Energy efficiency slows energy demand growth, diminishes supply-side investment and reduces international energy prices.
- In the New Policies Scenario, world electricity demand increases by almost 80% over the period 2012-2040.
- Fossil fuels continue to dominate the power sector, although their share of generation declines from 68% in 2012 to 55% in 2040.
- The share of renewables in total power generation rises from 21% in 2012 to 33% in 2040, as they supply nearly half of the growth in global electricity generation.

http://www.worldenergyoutlook.org/media/weowebsite/2014/WEO2014FactSheets.pdf

- Global investment in the power sector amounts to $21 trillion through to 2040, with over 40% in transmission and distribution networks.
- CO2 emissions from the power sector rise from 13.2 gigatonnes (Gt) in 2012 to 15.4 Gt in 2040, retaining a share of around 40% of global emissions over the period.
- In the New Policies Scenario, the share of nuclear power in global electricity generation increases slightly to 12% in 2040. Nuclear generation capacity rises by 60% to 624 GW in 2040.
- Nuclear power's limited exposure to disruptions in international fuel markets and its role as a reliable source of baseload electricity can enhance energy security.

EE2022 Syllabus – Part 1

1. Introduction

Energy and its various forms; Importance of Electrical Energy in secondary form

2. Introduction to Electrical Power

Active, Reactive and Apparent Power; Concept of Power factor, lagging, leading and unity power factor operation

3. Three phase systems

Single- and three-phase power system; Star and Delta connection; Relationship between phase and line quantities; per-unit representation.

4. Generation, Transmission and Distribution Network

Transmission line modelling; Calculation of transmission line parameters;

EE2022 Syllabus – Part 2

4. Generation, Transmission and Distribution Network
Power system structure; Generation, Transmission and Distribution; Complex Transformer;Concept of rotating magnetic field. Principle of operation of synchronous and asynchronous machines; Terminal characteristics; Applications.

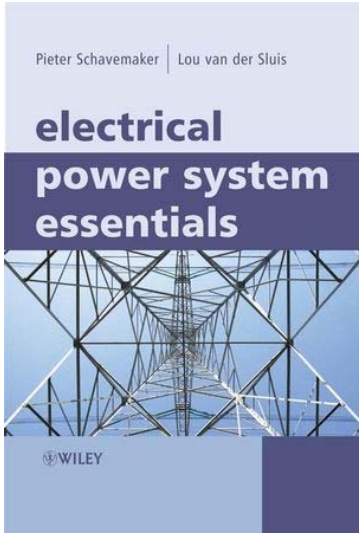
5. Renewable Energy Sources and Distributed Generation
Sustainable and clean energy sources; Solar Photovoltaic, Wind, Hydro, Fuel-cell; Materials consideration;Concept of distributed energy generation and utility interfacing

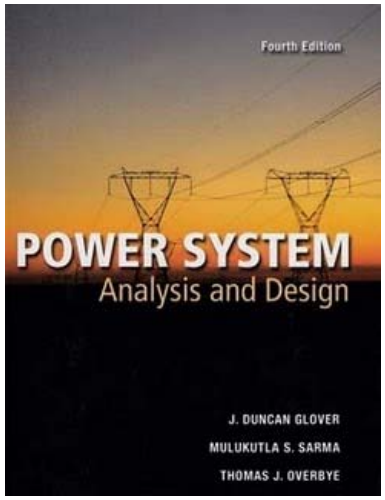
6. Energy Storage
Concept of energy storage; Batteries, Super-capacitors, Fly-wheels

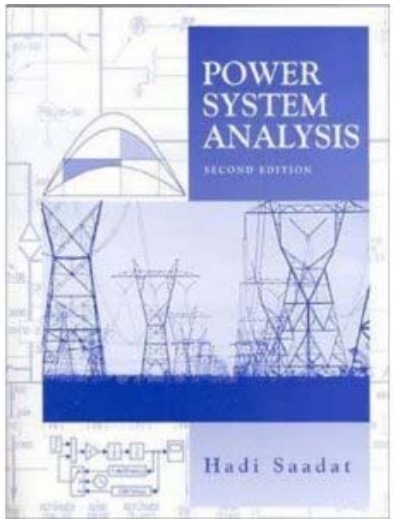
7. Electric energy market operation, Cost of Electricity

References

1. Pieter Schavemaker and Lou Van Der Sluis, “Electrical Power System Essentials”
2. Glover, Sarma, and Overbye, “Power System Analysis and Design”
3. Hadi Saadat, “Power System Analysis”







Schedule Part 1

Week of	Lecture Topics	Tutorial
12th Jan	Introduction, AC systems basics	
19th Jan	AC Power , Power factor correction	Tut 1 AC systems basics
26th Jan	Three-phase circuit analysis	Tut 2 Power, power factor correction
2nd Feb	Transmission lines	Tut 3 Three-phase circuit
9th Feb	Revision of part 1	Tut 4 Transmission lines
16th Feb	Midterm Test 1	Chinese New Year
23 Feb	Midterm break	