Lecture 1A 1B & 1C

Energy Resources, Economics and Environment

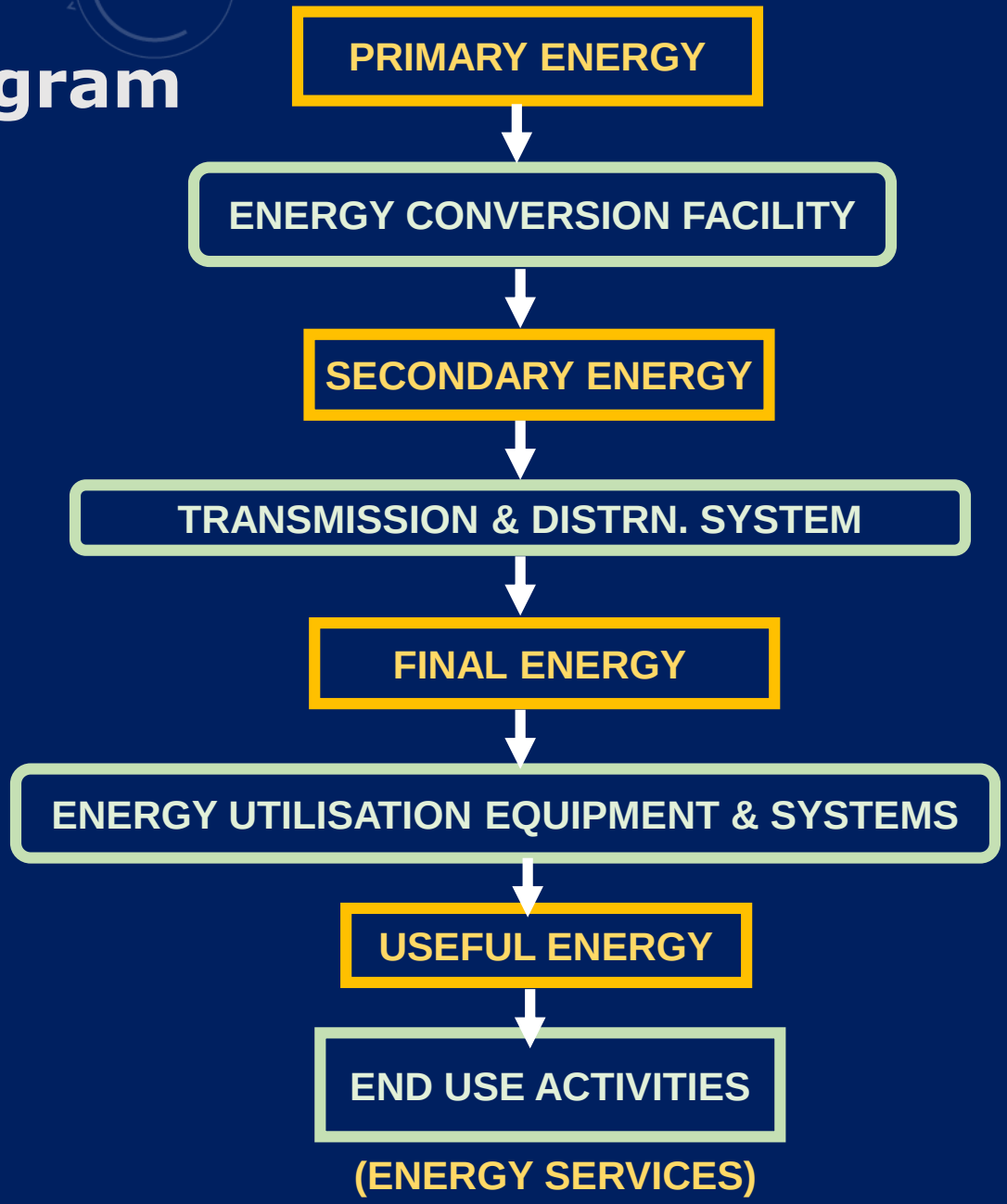
Lecture 1 Introduction

Rangan Banerjee
Forbes Marshal Chair Professor
Department of Energy Science and Engineering

IIT Bombay

Energy Flow Diagram

Energy Flow Diagram



COAL, OIL, SOLAR, GAS

POWER PLANT, REFINERIES

REFINED OIL, ELECTRICITY

RAILWAYS, TRUCKS, PIPELINES

WHAT CONSUMERS BUY DELIVERED ENERGY

AUTOMOBILE, LAMP, MOTOR, STOVE

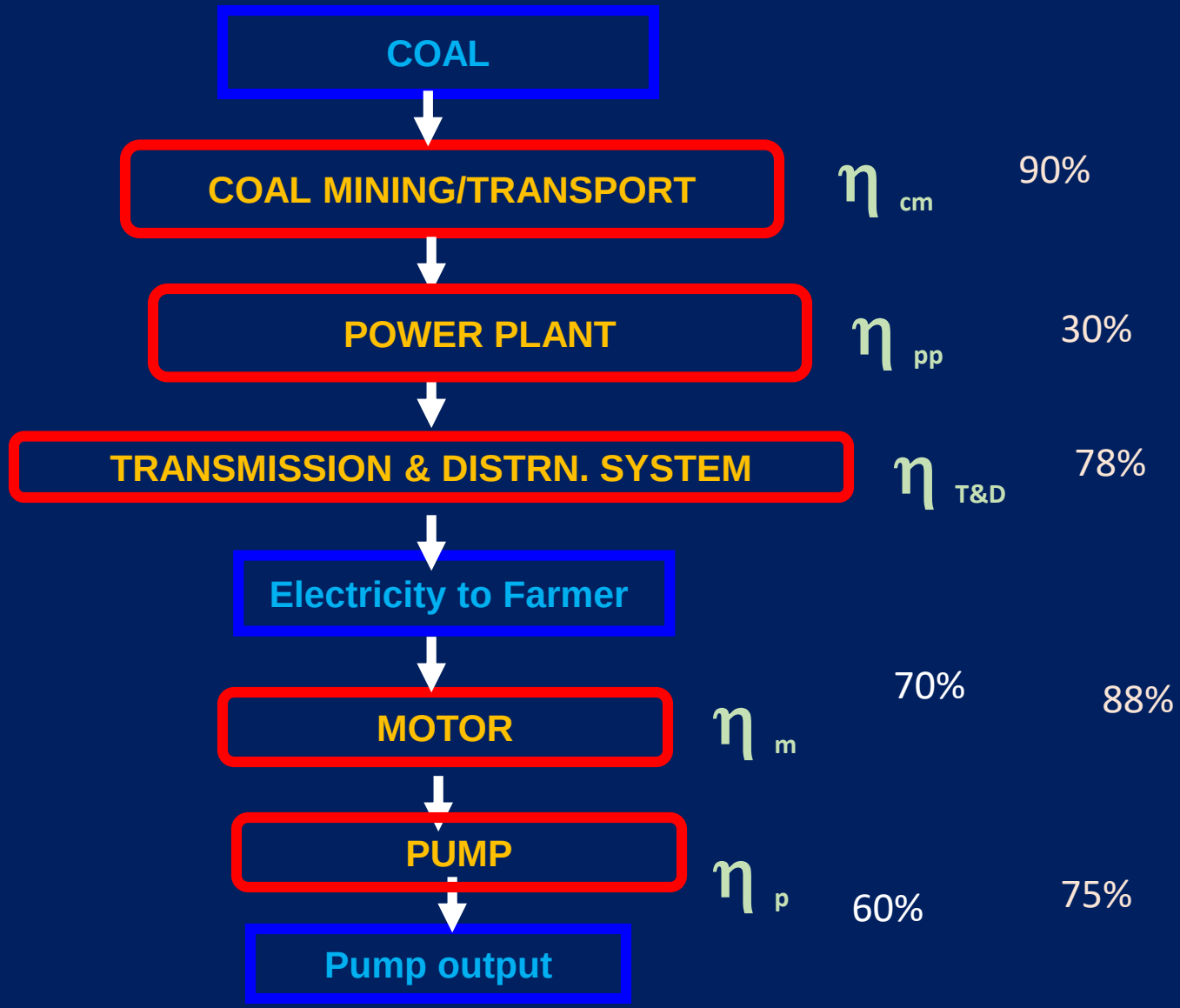
MOTIVE POWER RADIANT ENERGY

DISTANCE TRAVELLED, ILLUMINATION,COOKED FOOD etc..

Energy End Uses

End Use	Energy Service	Device
Cooking	Food Cooked	Chullah, stove
Lighting	Illumination	Incandescent Fluorescent, CFL
Transport	Distance travelled	Cycle, car, train, motorcycle, bus
Motive Power	Shaft work	Motors
Cooling	Space Cooled	Fans, AC, Refrigerator
Heating	Fluid heated	Boiler, Geyser

Electric Motor-Pump



Terms

- Primary Energy
- Secondary Energy
- Final Energy (Delivered Energy)
- Useful Energy
- Energy Service
- End Use
- Sector
- Aggregation/Dis-aggregation

Units

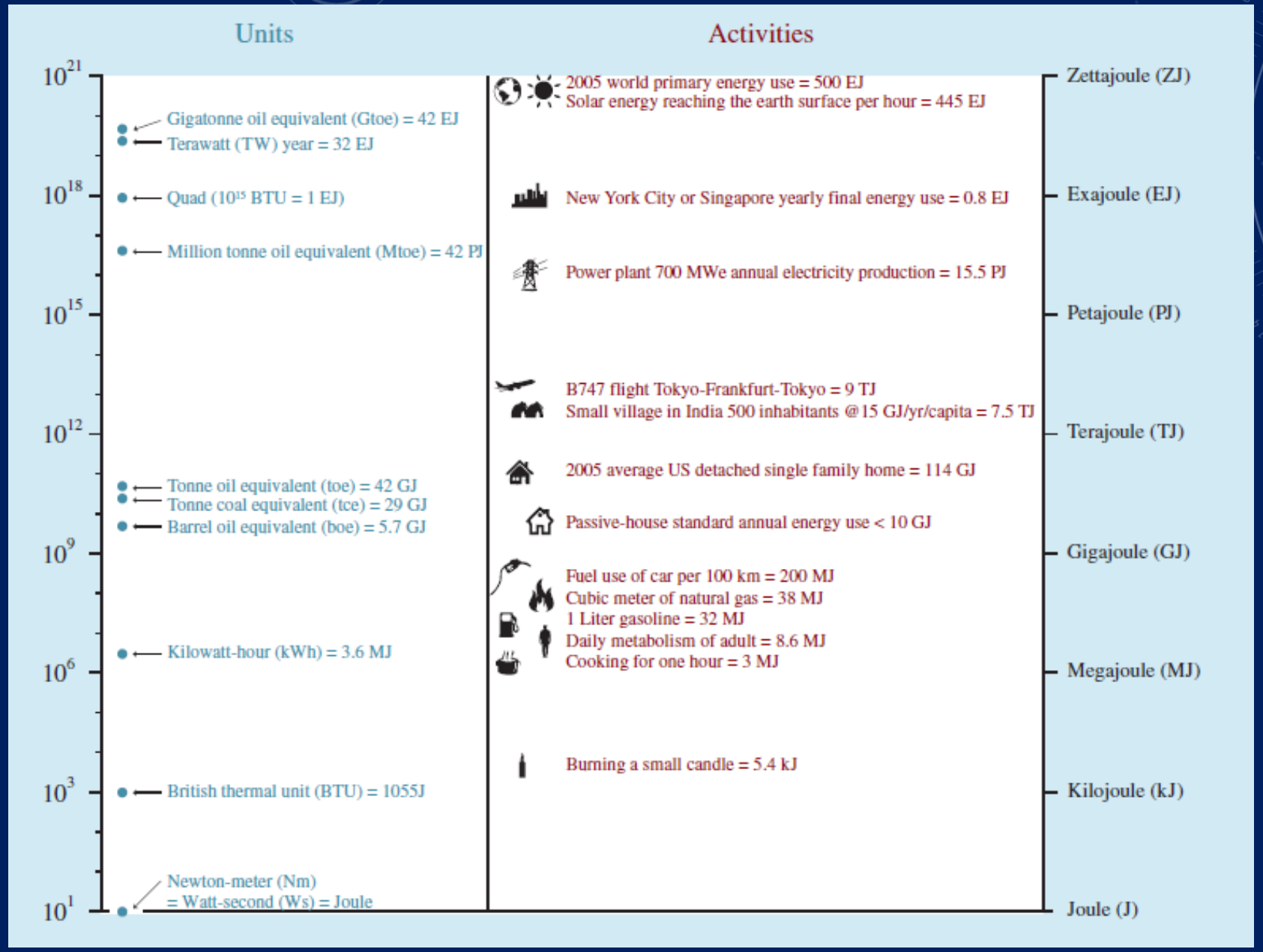
- J, calorie, BTU, Quad, kWh
- Energy and Power
- W, hp
- Kilo, Mega, Giga,Tera, Peta, Exa,
- Mtoe, ktoe, Mtce, ktce

Insert in order of decreasing energy

1. Energy use of average US detached house annually
2. Burning a candle
3. World Energy use annually
4. Boeing 747 Tokyo-Frankfurt-Tokyo
5. One litre of gasoline
6. Energy use of Indian village (500 people)
7. New York city annual energy use
8. Solar Energy reaching the earth in an hour
9. Power plant 700 MW annual electricity production
10. Daily metabolism of an adult

Insert in order of decreasing energy

1.	World Energy use annually	500 EJ
2.	Solar Energy reaching the earth in an hour	445 EJ
3.	New York city annual energy use	0.8 EJ
4.	Power plant 700 MW annual electricity production	15.5PJ
5.	Boeing 747 Tokyo-Frankfurt-Tokyo	9TJ
6.	Energy use of Indian village (500 people)	7.5 TJ
7.	Energy use of average US detached house annually	114 GJ
8.	One litre of gasoline	32 MJ
9.	Daily metabolism of an adult	8.6 MJ
10.	Burning a candle	5.4 kJ



Source: GEA, 2012

What is the total amount of primary energy used by the world?

What is the trend or variation of this energy use over the years?

Global Energy Use

What is the total amount of primary energy used by the world?

What is the trend or variation of this energy use over the years?

International Energy Agency – Detailed Statistics

https://www.iea.org/statistics/kwes/

https://www.iea.org/statistics/kwes/balances/

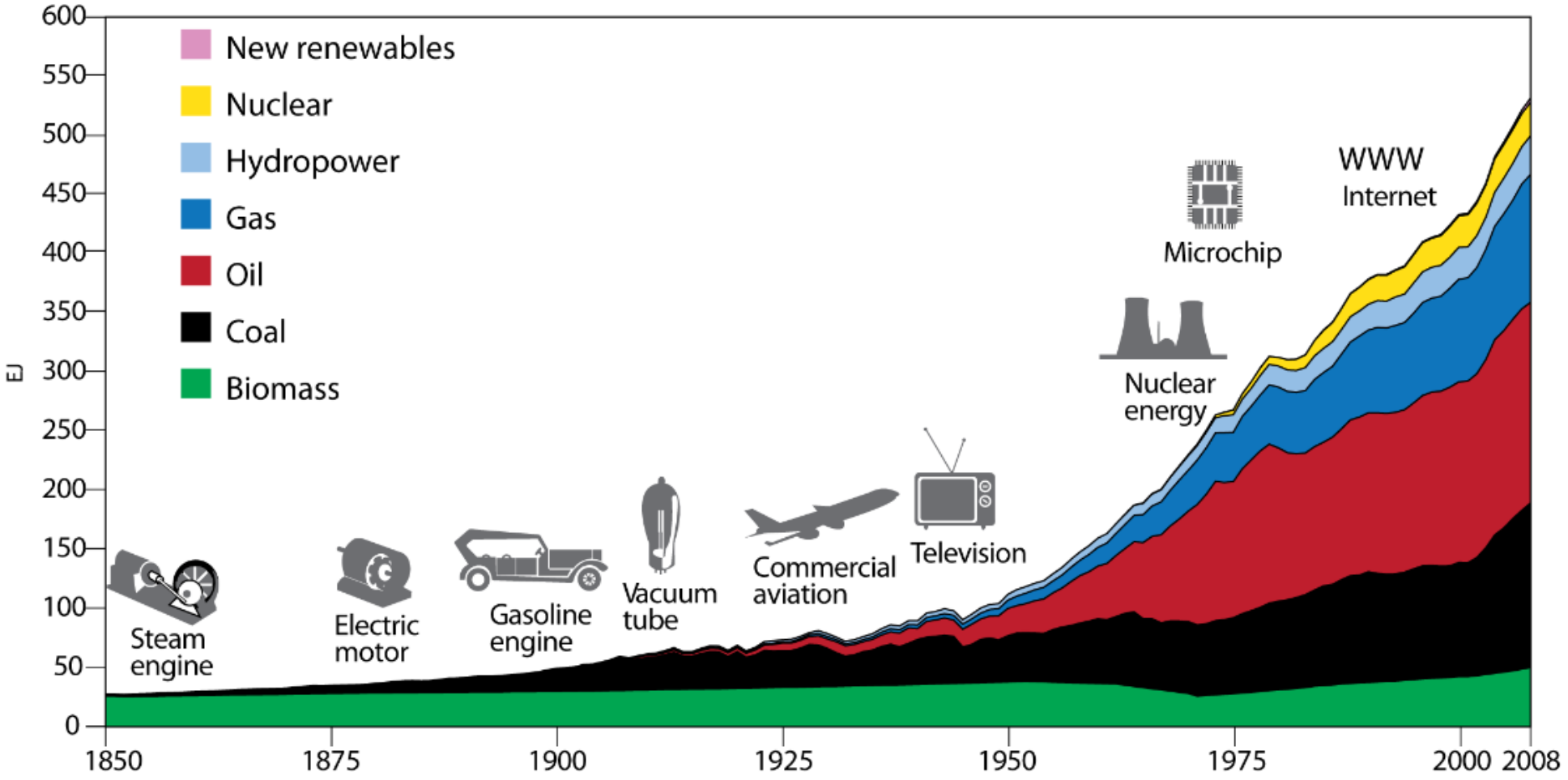
Energy Information Administration US DOE

https://www.eia.gov/

Statistical Review of World Energy - BP

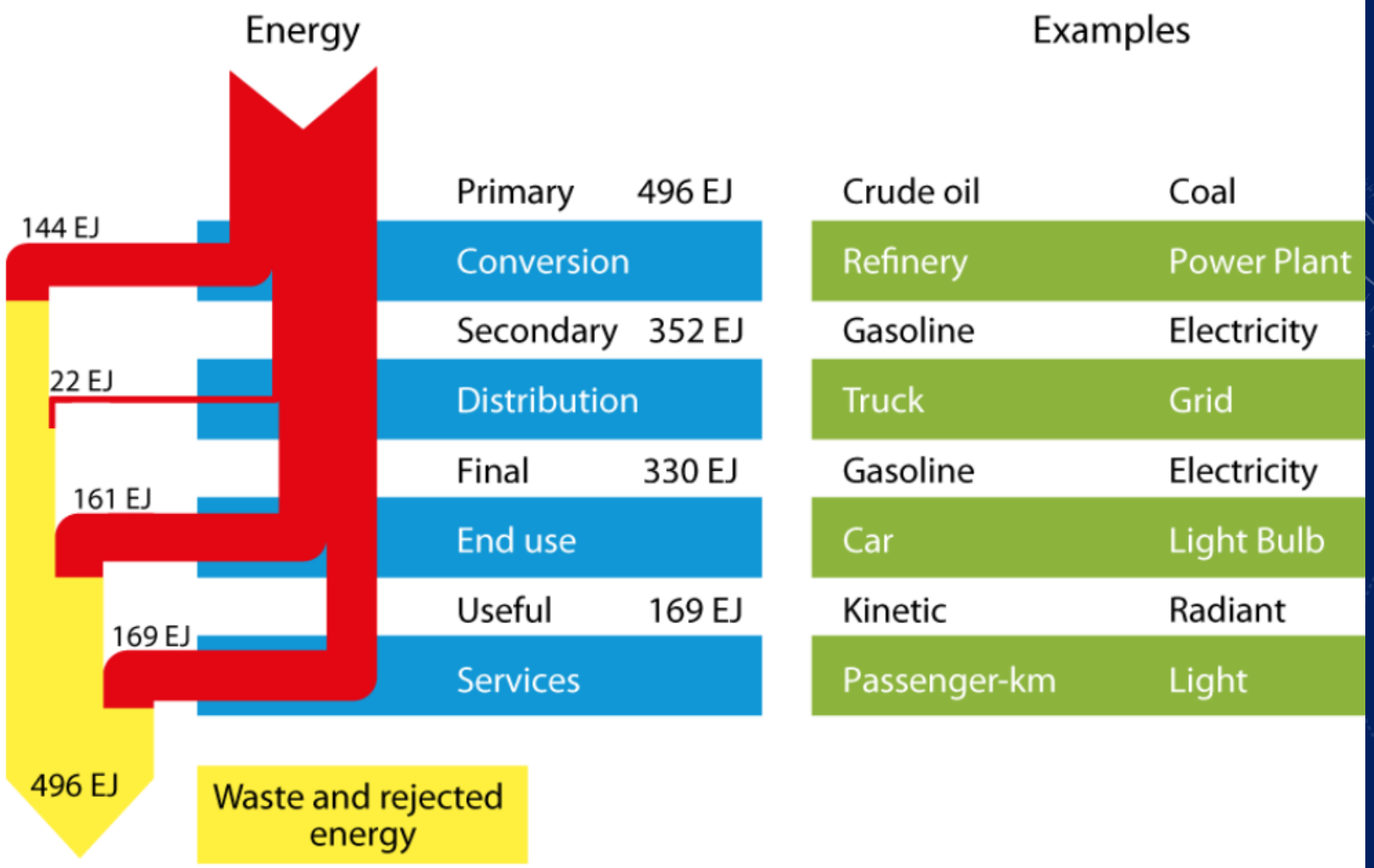
https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

History of World Primary Energy Use



www.globalenergyassessment.org

Global Energy Flows



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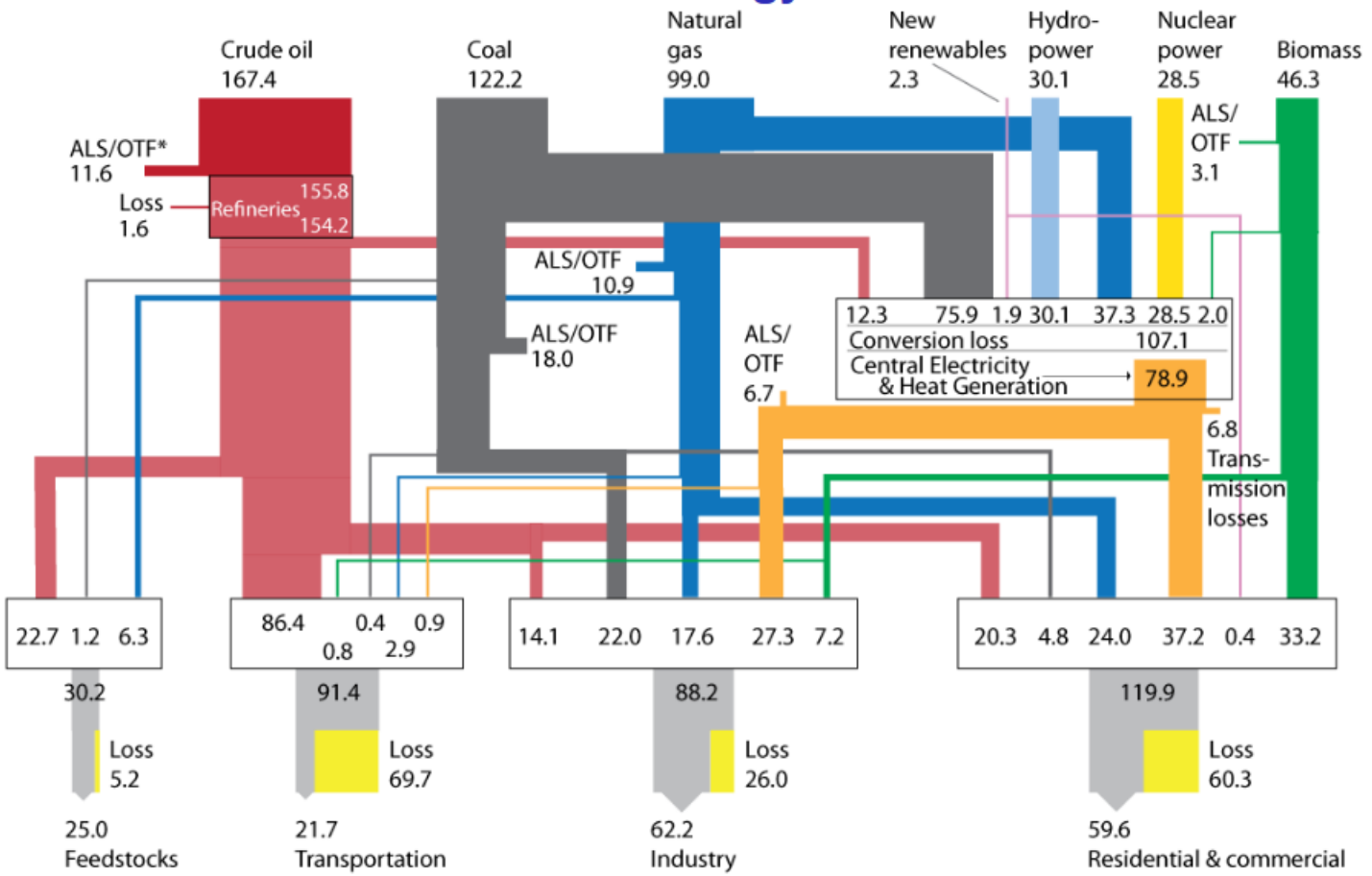
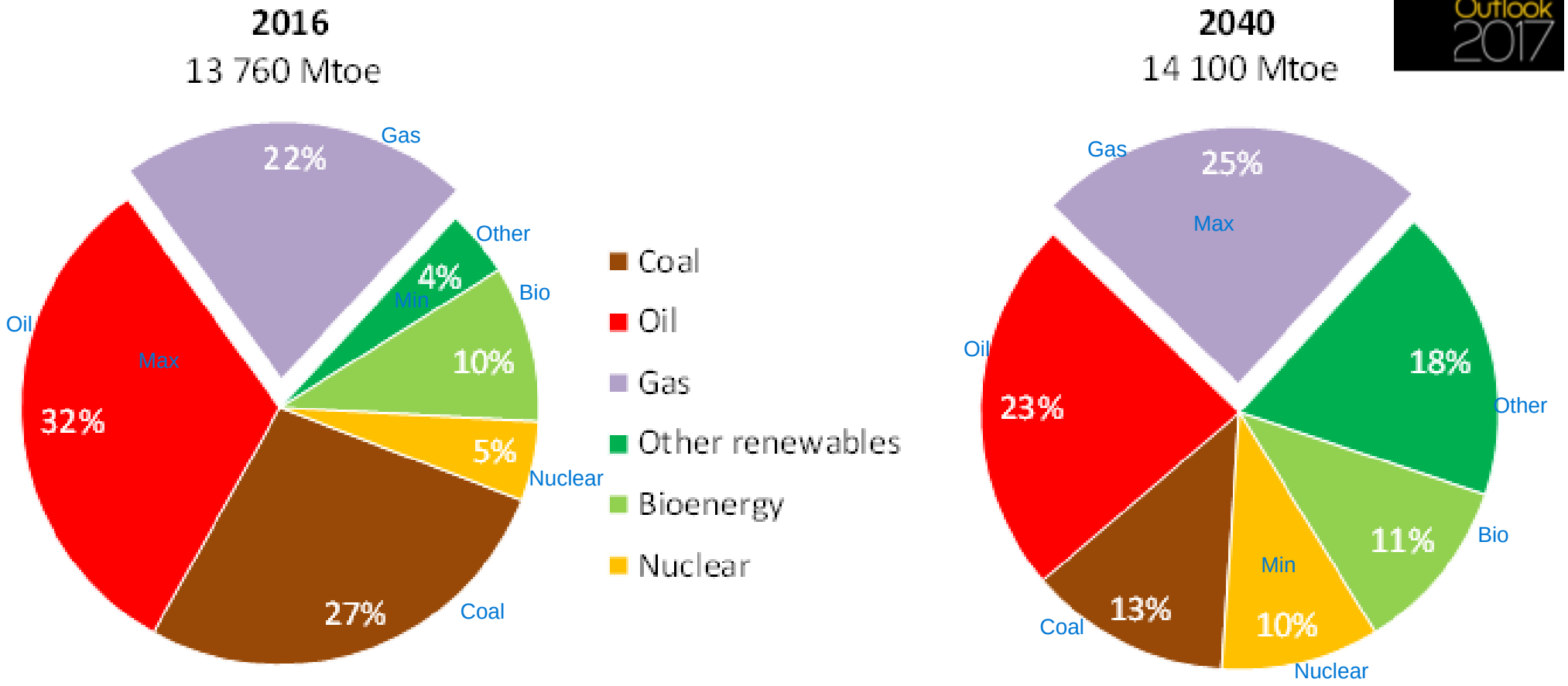
Global Energy Flows



Chapter 1, #5 www.globalenergyassessment.org © GEA 2012

World Energy Outlook



Source: https://www.iea.org/weo2017/

What does the Energy use of a region depend on?

- Country
- State
- City

Parameters affecting Energy Use

What does the Energy use of a region depend on?

- Country
- State
- City

Exponential growth

$$\frac{dP}{dt} \propto P$$

$$P = P_0 e^{kt}$$

Compound annual growth rate(CAGR)

$P_T = P_0 \ (1+g)^T$ where g is the compound annual growth rate during the period 0 to T

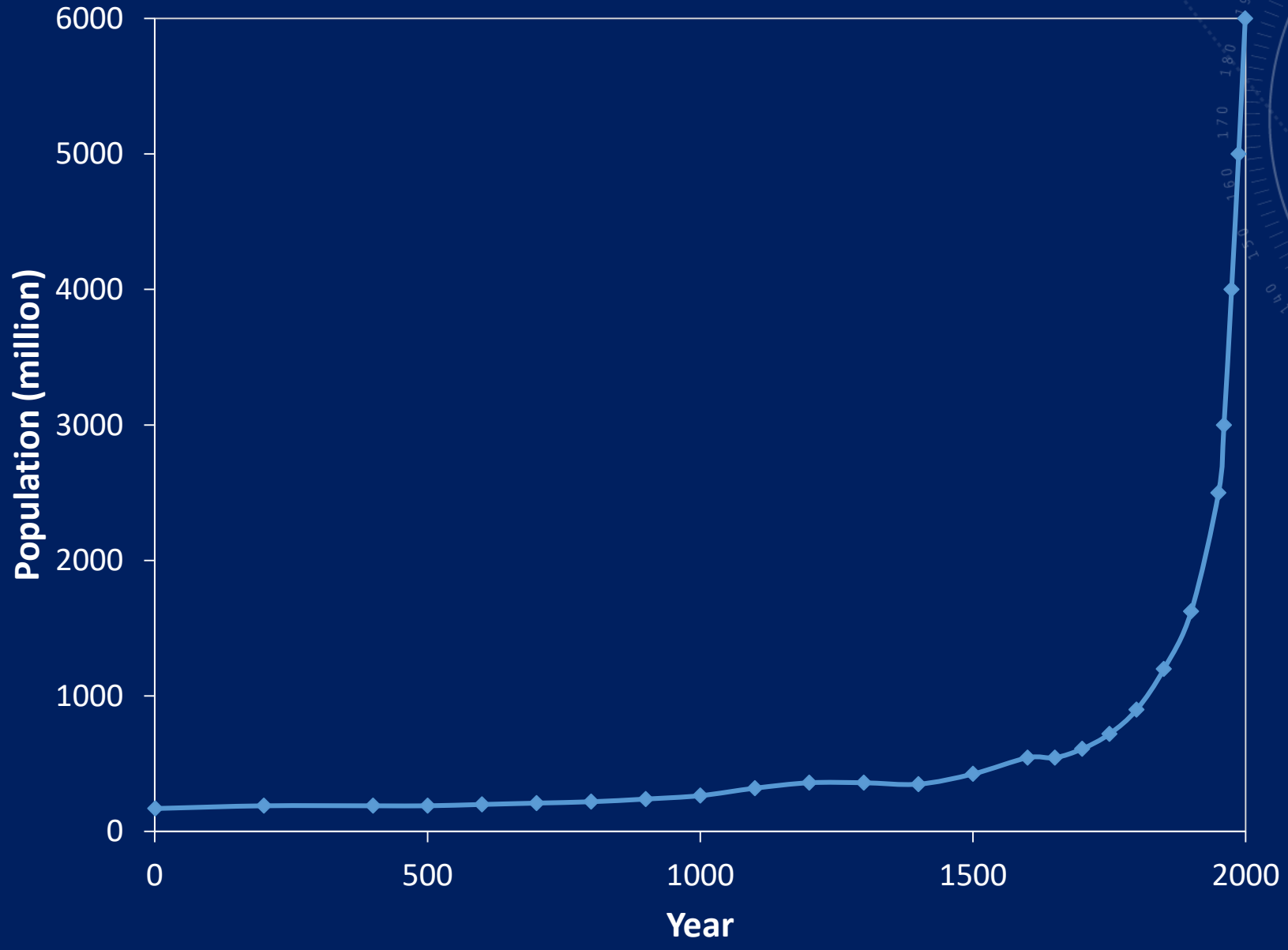
Energy and Population growth

The trend of world population versus time for the last two thousand years would show :

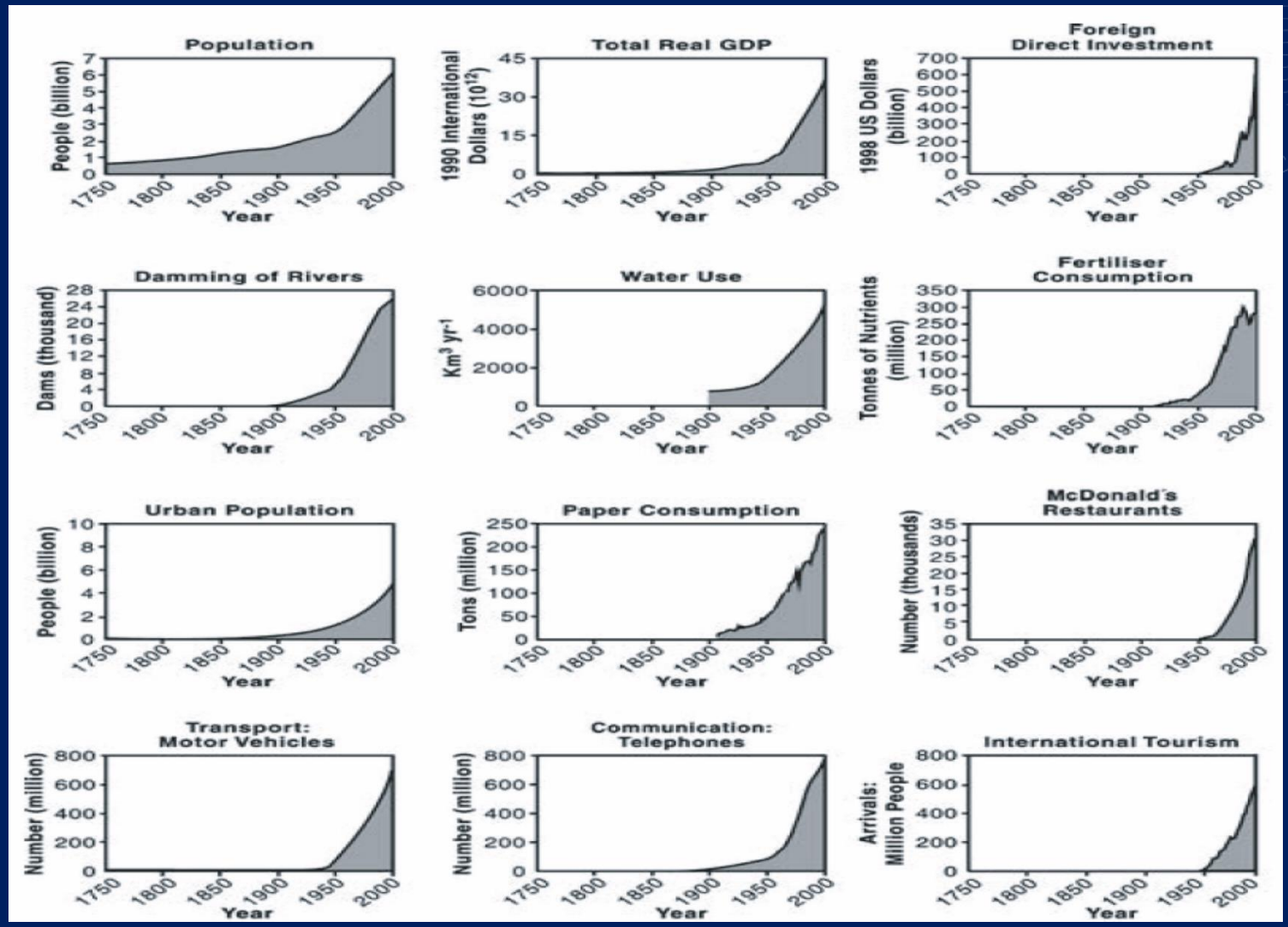
i) Significant crests and troughs corresponding to periods of global stability and recession
ii) Monotonic linear growth
iii) Monotonic exponential growth
iv) Monotonic growth of the form

$$P(T) = a + bT + CT^2$$

v) None of the above


6000
5000
4000
3000
2000
1000
0
Population (million)
0
500
1000
1500
2000
Year

Global Trends – Unbounded Growth?



World Energy trend

The trend of world energy use for the last two thousand years would show :

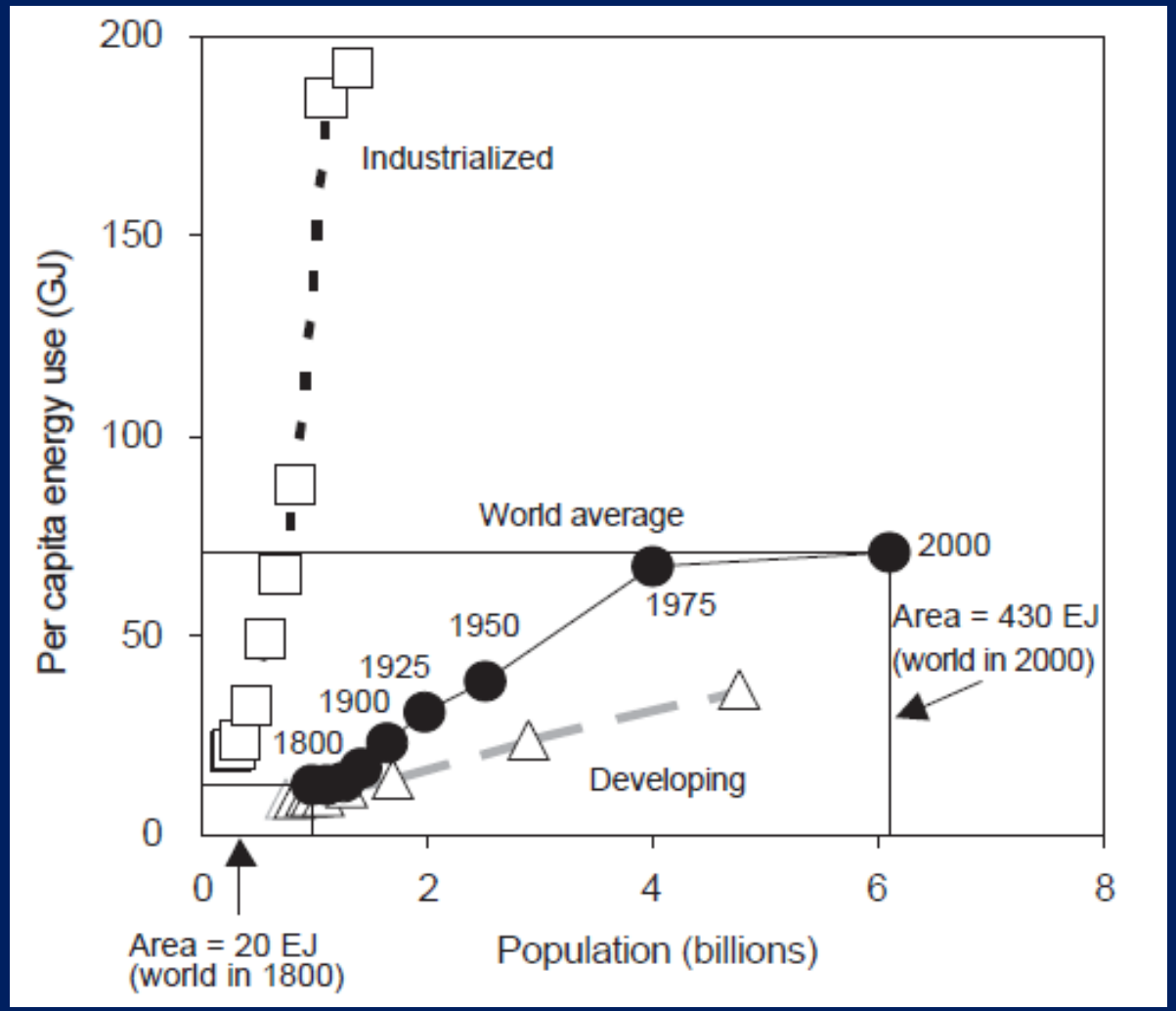
i) Exponential growth similar to the population growth
ii) Exponential growth with a growth rate less than the population growth
iii) Monotonic growth that initially followed the population growth but a reversal of growth seen after 1970's.
iv) Exponential growth with a growth rate higher than the population growth
v) None of the above

Transitions in Energy Use

World Primary Energy use and World Population				
	1800	1900	2000	2100
World primary energy (EJ)	20	50	430	500-2700
"South" (percentage)	70	45	41	66-75
World "modern" energy (EJ)	<1	20	390	500-2700
"South" (percentage)	0	2	34	66-75
World Population (billions)	1.0	1.6	6.1	7-15
"South" (percentage)	75	66	78	80-90

Grubler 2004

Transitions in Energy Use

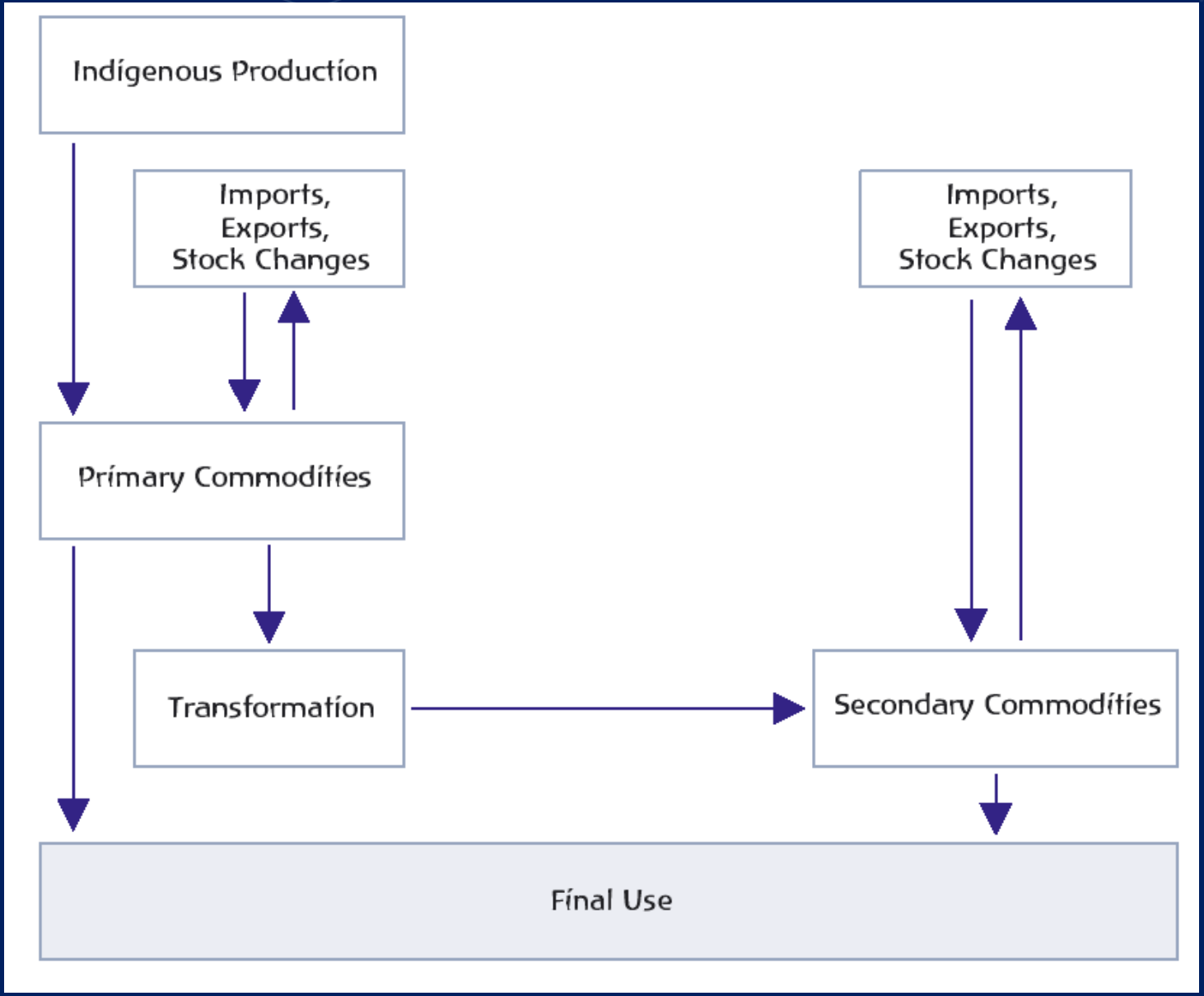


Grubler 2004

Energy in India

How does India compare with the World ?

What are the expected growth rates?



Source : Energy Statistics Manual, IEA

Units

- Physical Quantities –Coal, Oil (Tonnes)Oil- Barrels
- Natural Gas- m^3 often expressed as Nm^3 ,sm^3
- Electricity kWh , MUs (Million units)
- Gross Calorific Value(GCV/HHV), Net Calorific Value (NCV/LHV) – based on fuel composition
- Coal Equivalent/ Oil Equivalent – In terms of energy equivalents of Coal or oil

Energy Content

- Average Calorific Value of Indian Coal 4500kcal/kg (18.8 MJ/kg)
- Average Calorific Value of Oil 10000kcal/kg (41.8 MJ/kg)
- Natural Gas 9300 kcal/m^3 (38.9 MJ/m^3)
- Nuclear, Hydro – Work backwards from generation based on plant efficiencies
- Hydro 85%, Nuclear 25%

Some terms

- Plant load factor – Actual generation of a power plant
  (PLF) ----------
  Maximum generation if operated continuously at rated/ design value

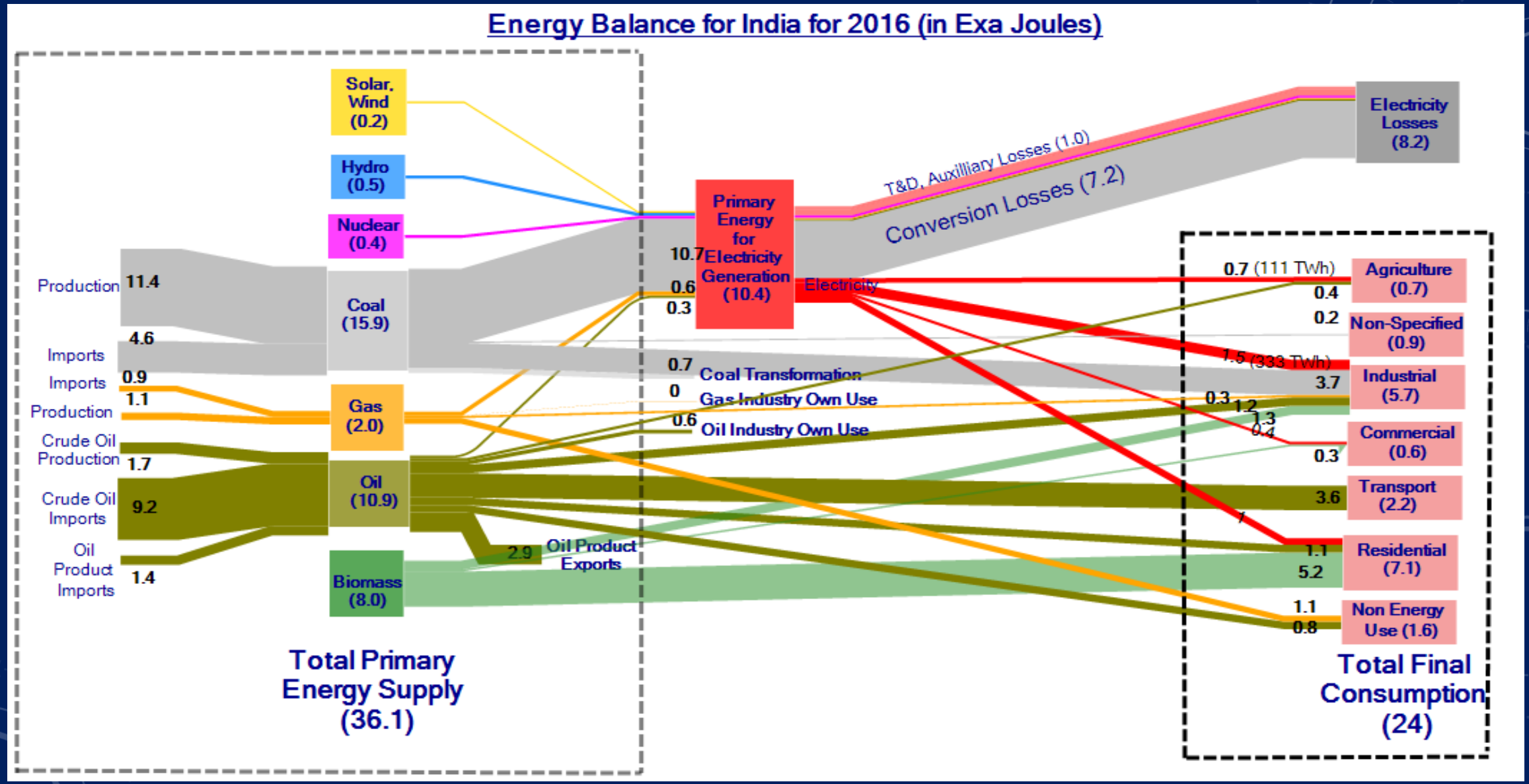
Daily, monthly, annual PLF

- Auxilary consumption – power consumed within the plant itself
- Gross Power Output- Auxilary consumption = Net Power Output
- Auxilary % = Auxilary consumption*100/ Net Power output

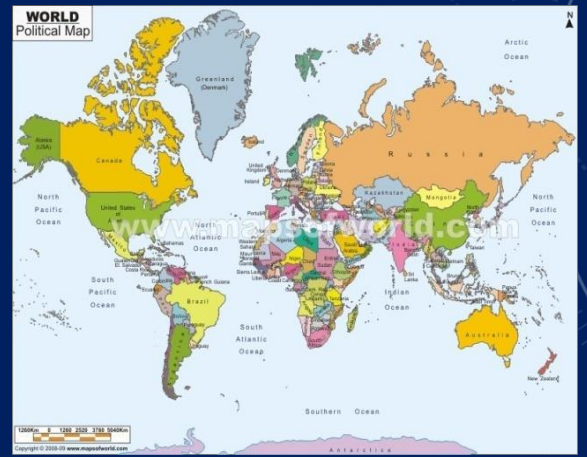
Power plant calculation

- A thermal power plant is rated at 500 MW (gross), has 9% auxiliary consumption, has an annual PLF of 80%. Calculate the annual generation in MWh and Million units and in GJ.
- If the plant has an efficiency of 38% calculate the amount of input energy supplied to the plant. If the input energy used is coal (NCV 4500 kcal/kg) calculate the annual amount pf coal used

Energy Balance – India 2016 (in Exa Joules)



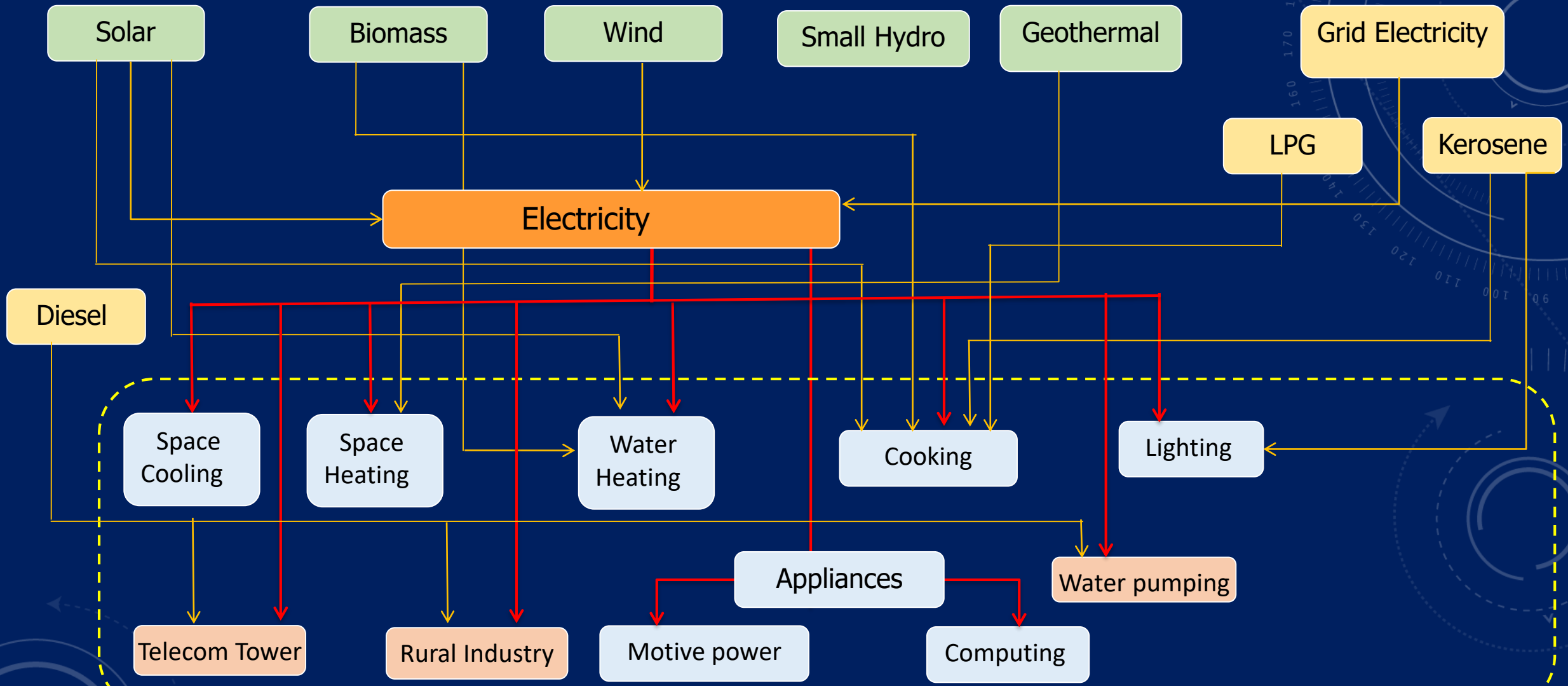
India and World (Selected Indicators for 2016)



Population	1324 million	7429 million
GDP (PPP)	7905 Billion 2010 US$ (5970 $/person)	109 231 Billion 2010 US$ (14703 $/person)
Primary Energy	36 EJ	576 EJ
Energy/person	27.2 GJ/person/year	77.5 GJ/person/year
Electricity/person	920 kWh/capita/year	3000 kWh/capita/year
CO_2 emissions	2077 Million tonnes	32 316 Million tonnes
CO_2/Per population	1.57 tonnes /capita/year	4.0 tonnes /capita/year
CO_2/GDP	0.84 kg /2010US$	0.30 kg /2010US$

Source: IEA, Key World Energy Statistics 2018

Pathways for End Uses



Summing up

- Energy flow diagram
- Energy balance diagram for a region
- Units – Power, Energy- conversions
- Exponential, unbounded growth
- Developed, Developing
- Drawing up aggregate energy balances –physical, energy units
- Use the energy balances and trends to develop insights on energy systems
- What are the drivers for energy systems?

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Email: rangan@iitb.ac.in

Thank you