Sustainable Development for Aerospace Engineers

Feeling for Numbers

Numerical values for 'on the back of a napkin' calculations, based on numerical examples from the Lectures and example calculations.

Human footprint (western society)

Land required per capita:	2 ha (1 ha = 10,000 m^2)		
Surface area Netherlands:	40,000 km^2 ->	4 x 10^6 ha	land available
Inhabitants Netherlands:	16,600,000 p. ->	3.3 x 10^7 ha	land required

Land required for US lifestyle and 6 billion people: 4.3 x Earth

Energy consumption: 4000 kWh/year/household = 0.5 kW/household

Sun and Solar Energy

Energy from Sun:	1367 W/m^2	Diameter Sun:	1.4 x 10^6 km
Effective BB Temp.:	5777 K	Distance Sun:	1.5 x 10^8 km
Atomic mass H:	1.00797 g/mole	1 atomic mass:	1.66 x 10^{-27} kg
Atomic maar He:	4.0026 g/mole	Light speed:	3 x 10^8 m/s

Nuclear fusion energy: 26.7 MeV/mole = 4.277 x 10^{-4} J/mole = 4.24 x 10^{-4} J/g H

Light emission sun:	UV – 6.4% of energy	Wavelength:	< 380 nm
	VIS – 48% of energy	Wavelength:	380 – 780 nm
	IR – 45.6% of energy	Wavelength:	> 780 nm

Photosynthesis: 15.61 M J/kg Glucose required

Earth

Reflection/albedo Earth:	0.3 (30%) ->	960 W/m^2 on surface (~1000 W/m^2)	
Incoming energy on Earth:	1.079 x 10^{10} J/m^2y	Average energy on ground: 342 W/m^2	

Radius Earth: 6371 km

Greenhouse gasses: 390 p.p.m. current 280 p.p.m. previous century

Netherlands

Surface area Netherlands:	40,000 km^2	Length 'Afsluitdijk':	30 km
Inhabitants Netherlands:	16,600,000 p.	Height 'Afsluitdijk':	6 m
Energy consumption:	16 GW		

Cars in Netherlands: 7,000,000

Coastline Netherlands: 300 km

Coastal wind area: 3 x 10^9 m^2 -> 2.5 [kW/m^2] * 3 x 10^9 = 7500 GW wind energy

Investment in innovation: €1,000,000,000. - /year

Electric Cars

Energy consumption:	6 kWh/ 100 km		
Average car usage:	20,000 km/ year	->	20 m^2 P.V. required per car
	50 km/day	->	21 GWh/day for all cars in NL (~1 GW)

Cost of Energy

Price normal energy:	20 cts/kWh	Wind energy:	1 cts/kWh (kites)
Price solar energy:	~17 cts/kWh (35 cts/kWh also)		
EPBT Solar Cells:	2 years	EPBT = Energy Pay Back Time	
EPBT Windturbine:	several months		
Price Solar Wall:	€2000, - /meter	(6 meters height)	
Price Sound Barrier:	€6000, - /meter		

Solar Cells / Solar Energy

Cost solar cells:	2.5 €/Wp	(Wp = W @ 1000 W/m^2 Sun)
EPBT solar cell:	2 years	
Price solar energy:	~ 17 cts/kwh	
Power generation:	1 kW/m^2	

Wind Energy

Kite energy @ 9km:	5 kW/m^2	
Average wind power:	2.5 kW/m^2	See Netherlands for total coastal wind energy

Nuon Solar Team and NUNA

NUNA5 consumption:	2000 W @ 110 km/h	Charge: 1800 W in full sunlight	
	1450 W @ 100 km/h	LiPol specific capacity:	0.2 kWh/kg
	900 W @ 90 km/h	Efficiency solar cells:	35%

Cradle to Cradle

Reduction CO2 when taken elevator instead of stairs:	5 times (!)
Burning rainforest in Indonesia:	7000 tons CO2/ha

Fossil fuels

Global energy production using fossil fuels:	85%	
Part of energy produced from coal:	24%	
Energy efficiency coal:	65% lost in power plant,	10% lost in transport
Energy efficiency gas:	10% loss in conversion to energy	

Hydrogen

Energy conversion:	50 -70% efficient
Worldwide production:	50MT/ year

Waste production average household

Domestic waste:	500 kg p.p. /year	of which:	100 kg p.p. /year GFT (biodegradable waste) 60 kg p.p. /year Paper

CO_2 emission:	12000 kg p.p. /year	->	100 p.p.m. rise of CO_2 in 50 years

Climate change

Temperature rise in 2100: 1.5 – 6 °C

ΔCO_2 of 180 – 280 p.p.m:	ΔT = 8 °C	->	Below 550 p.p.m: ΔT of 2 °C

Ice caps melting

2002 est.:	- 1% /year		
Surface 2005:	5,000,000 km^2		
Surface 2007:	4,000,000 km^2	->	- 10% /year!