Energy Analysis Toolbox

# Units and Conversions

* Energy = Power x Time
* 1 watt (W) = 1 J/sec = 3.6 kJ/h, 1 horsepower (hp) = 0.764 kilowatts (kW)
* 1 kWh = 3.6 x 106 J =3.6MJ, 1 Btu = 1055 J, 1 cal = 4.18 J
* Prefixes: 103 kilo (k), 106 mega (M), 109 giga (G), 1012 tera (T)

# Energy consumption trends

* US primary energy: Electricity: 39%, Transportation 28%, Heating, 33%
  + 25% of US energy is imported, 70% of imports are oil, 71% of oil is used in transportation, 39% of electricity in US is from coal
* Global energy challenges: Dependence on oil from politically volatile regions, 80% of global energy use is from fossil fuels (climate change), 1.4 billion lack access to electricity

# Thermodynamics

* 87% of our electricity comes from thermal power plants. 60% of our primary energy ends up as heat!
* Energy must be conserved (Total energy = heat energy + work energy). Heat can’t be 100% transformed into mechanical work (2nd Law).
* ηI = Wnet/Qin , or What you want out / What you put in
* Carnot Efficienty: ηc = 1 – Tlow/Thigh, (temperature is in Kelvin). This is the maximum theoretical efficieny of a heat engine operating between a cold and hot temperature reservoir.
* Ideal combustion: Fuel + O2 🡪 CO2 + H20 + light + heat
* Molar Mass: C 12 g/mol, H 1 g/mol , N 14 g/mol, O 16 g/mol
* Molar mass of CO2: 1 x 12g/mol + 2 x 16 g/mol = 44 g/mol
* Kg CO2 emissions per kWh (electric – depends on power plant efficiency and fuel source):
  + Coal:0.79-1.02, Nat Gas: 0.36 – 0.58
  + Emissions per kWh electric from PNM (2013): 0.66 kg CO2/kWh

# Power Plants

(Data is from 2012 EIA report on generation technology)



# Energy economics

1. If you want to make a quick, simple calculation of a new technology investment that will result in energy (and money) savings, you can calculate the simple payback: 
2. Calculating the annualized power plant costs: Total cost ($/yr) = capital cost ($/yr) + fixed O&M ($/yr) + variable O&M ($/yr)
   1. Convert capital cost to annualized cost using , where P is present value, r is discount rate, and n is project lifetime.
   2. Calculate fixed O&M based on planned plant capacity.
   3. Calculate variable O&M based on expected energy production (Nameplate x Capacity factor x 8760 hrs/yr).
3. If you want to find lifetime cost of energy, then you can use your annualized total cost divided by expected annual energy production:



1. If you want to find the cost for reducing CO2, for switching from a dirtier to a cleaner technology, you can calculate it as:

# Transportation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Fuel | Emissions (kg CO2/gallon) | Emissions (kg CO2/liter) | Energy density (kWh/liter LHV ) | Emissions (kg CO2/kWh) |
| gasoline | 8.887 | 2.348 | 8.7 | 0.27 |
| diesel | 10.18 | 2.690 | 10 | 0.27 |

* Average miles/year/person : 13,000 miles
* Average ownership of cars: 11.4 yrs (2012)
* Ave passengers/car: 1.55, average daily travel time: 22-25 min.
* VMT – vehicle miles travelled
  + MPG – tells us vehicle efficiency (1 MPG = 0.4 km/l)
* BTU per passenger mile tells us efficiency in moving **people** (what we want!)
  + 1 kWh per p-km = 5459.68 BTU per p-mi

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Transport mode** | **Ave passengers per vehicle** | **BTU per passenger-mile** | **kWh per passenger-km** | **kWh per 100 passenger-km** |
|
| Rail (Intercity Amtrak) | 20.9 | 2,435 | 0.45 | 45 |
| Motorcycles | 1.16 | 2,460 | 0.45 | 45 |
| Rail (Transit Light & Heavy) | 24.5 | 2,516 | 0.46 | 46 |
| Rail (Commuter) | 32.7 | 2,812 | 0.52 | 52 |
| Air | 99.3 | 2,826 | 0.52 | 52 |
| Cars | 1.55 | 3,538 | 0.65 | 65 |
| Personal Trucks | 1.84 | 3,663 | 0.67 | 67 |
| Buses (Transit) | 9.2 | 4,242 | 0.78 | 78 |
| Taxi | 1.55 | 15,645 | 2.87 | 287 |

Source: Transportation Energy Data Book, Edition 33, 2014 (stats from 2012)

# Buildings

* The average annual US household energy intensity in 2009 ranged from 40,000-70,000 BTU/ft^2 (130-220 kWh/m^2)
* About 39% of US GHG emissions, and 38% of total energy use
  + 21% of energy use in residential (32% goes to heating),18% commercial (28% to lighting)
* Interventions: consumer information (energy star ratings), builder information (architecture 2030 pallette), performance ratings (energy star, passive house), design phase ratings (LEED)

# Climate Change

1. Long term observational evidence of climate change: global ave temperature, change in sea level, and melting of land/sea ice
2. Clear correlation between drastic increases in atmospheric CO2 concentrations and human made emissions (fossil fuels primarily, and land use change) since industrial revolution
3. No other explanations explain observational evidence (#1) in models if CO2 increases are removed…

* Scientist believe that if ave global warming rises above 4 C (relative to 1880) – we are now at 1 C – we may cross thresholds for tipping points, such as complete melting of the ice caps, that can put Earth’s climate into an irreversible, new climate, with drastic consequences…
* If atmospheric concentrations remain below 450 ppm (currently we are at 400 ppm) global average warming may remain between 2-3 C warming…
  + This will require reducing net emissions down to zero by 2050-2080…

# Energy policy tools

* Levers that impact market transformation, leading individuals and societies to make different choices about how they produce/utilize energy
* Technical/economic solutions – renewable energy technologies, energy efficiency, tax credits, carbon tax
* Policy solutions – regulations (renewable portfolio standards, banning incandescent, CAFE standards)
* Social solutions – green movements – biking, car pooling, eating less meat, etc.
* Good policy tools – simple to understand/conceptualize, and useful for setting achieving goals
  + Marginal abatement cost curves - show both cost and abatement potential (relative to a baseline) from available mitigation projects in a city or country
  + Wedge analysis – shows how a group of technical solutions can group together to reduce emissions within a given time-frame
* Shortcomings – Too Simple – don’t show how abatement projects impact different social classes or have other environmental co-benefits. Need tools that reveal the triple-bottom line impact (social, economic, environment) of policies