Toolbox 1 & 2: Parameter Estimation and Economics

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LECTURE 5

What do investors care for?

- Money
- To navigate to a sustainable future we need to account for the economic effects of technology policy:
  - How to compare investing between different technologies?
  - How to account for total lifecycle energy flows?

What do policy makers care for?

- Sustainability!
  - (of their electability mostly)

- Effect of policies on:
  - Economy:
    - Attracting investors
  - Environment:
    - Meeting targets
  - Equity:
    - Policy cost to tax-payers – bang for the buck
    - Employment

Calculation of Lifecycle Costs

- Good news: they can be quantified
- Bad news: there are enormous uncertainties
- Why are we interested in them?
  - Evaluate investments
  - Evaluate policies

Values Estimation

- Easiest way:
  - Find reliable sources
  - Crosscheck sources
  - Order of magnitude verification of results
- Hard way:
  - Bottom up calculations

Values Estimation Example

- What is the engine power requirement for an electric vehicle?
- What is the battery size required for a 200km range?
- What is the size of a PV solar field necessary to provide 100km/day?
- How much CO_2 do we save by the EV/PV combo?

EV Estimation Example: Power

- Small Internal Combustion Engine (ICE) vehicle ~
  - Fuel consumption: 6l/100km.
  - Highway driving - speed: 100km/h = 28 m/s.
- Thermal content of fuel = heating value = amount of heat released from combustion
  - Higher heating value (HHV): all products of combustion brought back to normal conditions (condensing vapor). Useful for when condensation practical and there is use for heat at 150C or less
  - Lower heating value (LHV) = HHV – heat of vaporization
  - Gasoline LHV: 32MJ/l (source: http://www.ces.ncsu.edu/forestry/biomass/pubs/WB008.pdf, or alternatively Text Table 8.1, pg. 378 see later)
    - 32MJ x 0.278 kWh/MJ (source: Text p.830) = 8.9 kWh / l
- ICE drivetrain thermal efficiency: ~25%
- Vehicle uses 6 l /h 6 x 8.9 = 53.4 kWh / h or a fuel power of 53.4 kW
- The engine provides a power of 13.4 kW for propulsion with remaining dissipated as heat.

EV Estimation Example: Power II

- Vehicle kinetics - power: $VP = K + AD + RR$
  - Acceleration – deceleration power: K

$$K = \frac{kinetic\_energy}{time\_between\_stops} = \frac{\frac{1}{2} m_v u^2}{d/u} = \frac{m_v u^3}{2 \times d}$$

  - Aerodynamic drag: AD = <u>rate</u> of kinetic energy generation of air mass turbulence

$$AD = \frac{\frac{1}{2} m_{air} u^2}{t} = \frac{\frac{1}{2} r_{air} \times (A_{eff} \times u \times t) \times u^2}{t} = \frac{1}{2} r_{air} \times A \times C_d \times u^3$$

Cd ~ 0.35

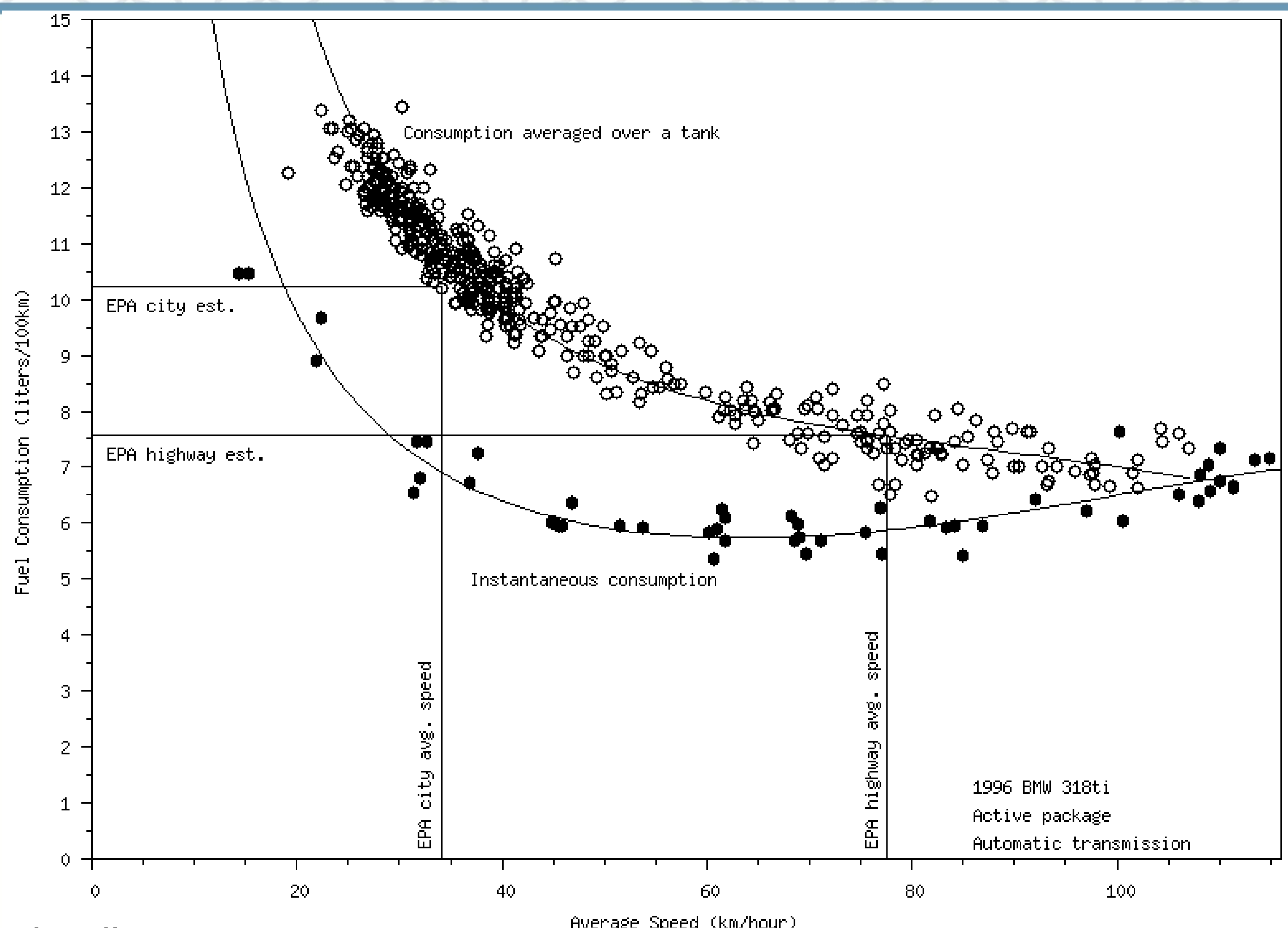
  - Rolling resistance: RR

$$RR = m_v \times C_{rr} \times g \times (d / t)$$

Crr ~ 0.01

- In numbers: $VP = 110 + 14982 + 280 = 15372W$

Some real world data…



Why the dip?

Source: http://www.randomuseless.info/318ti/economy.html

Battery Size (Energy Capacity)

- Desired range 200km
  - Energy required □E=2 x 15kWh = 30 kWh
- Electric Drivetrain efficiency: 0.85
- Battery should provide: Eb=30/0.85 =35kWh

- For Li-Ion ~200Wh/kg

- Battery required will weigh: 35/0.2 = 175kg

Renewable Charging

- 100km / day requirement = 35kWh
  - Charging efficiency 0.85 (combined inverter/charger)
- □Renewable energy required 35/0.85=41kWh

- Our PV panels operate in UAE at 1800 Full Load Hours (FLH)
- In an average day they would provide: 1800/365 ~4.9FLH

- Our panels need to be rated @: 41kWh/4.9h=8.4kW