Vehicle Propulsion Systems
Lecture 1
Course Introduction & Energy System Overview

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Outline

Vehicle Propulsion Systems

Vehicles as a hot topic is everlasting

- Brings freedom to the user
- Have a direct influence on the environment
- Consume resources that are limited
- Have different appeal to different persons

Vehicle Propulsion Systems

A diversity of powertrain configurations is appearing

- Conventional Internal Combustion Engine (ICE) powertrain. Diesel, Gasoline, New concepts
- Hybrid powertrains – Parallel/Series/Complex configurations
- Fuel cell electric vehicles
- Electric vehicles

Course goal:

- Introduction to powertrain configuration and optimization problems
- Mathematical models and . . .
- . . . methods for
  - Analyzing powertrain performance
  - Optimizing the powertrain energy consumption

Top Priorities in Vehicle Development

- Improve the fuel economy of vehicles (Better cars are our best oil-wells)
- Reduce costs
- Drivability
- Safety
- Emissions
  - Exhaust emissions
  - Road dust
  - Noise
  - Legislations

All issues are important but the first item is the main topic here.

Vehicle properties

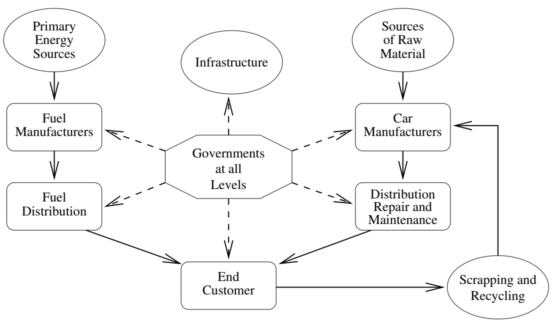
The vehicle in focus is passenger cars. (In the book.)
–What characterizes passenger cars?

- Autonomous and do not depend on fixed power grid.
- Have refueling time negligible compared to the driving time between two refuelings.
- Transport two to six persons and some payload.
- Accelerate from 0 to 100 km/h in 10-15 seconds, or drive uphill a 5% ramp at legal top speed.

Methods and tools are also applicable to trucks and other transportation systems.

- Numerical values differ
- Demands are different
- Principles are the same but solutions differ

Life Cycle of a Vehicle



Many things are important!
–Focus is on energy path and in-vehicle energy conversion

Outline

Examination – 3 (5) Hand-In Assignments

Hand-In assignments done individually.
Compendium for Hand-In assignments.

1. Fuel consumption requirement of a driving mission.
   Methods and tools for estimating the fuel consumption.
   –Mandatory and optional tasks.
2. Optimal control of series and hybrid concepts.
   Tools for investigating the best possible driving schedule.
   –Mandatory and optional tasks.
3. ECMS based on-line control of a parallel hybrid.
   Standard optimal control based controller.
   –Mandatory and optional tasks.
4. Three concepts for short term energy storage.
   Very open ended problems.
   –Optional tasks.
5. Fuel cell vehicle.
   –Optional tasks.

Examination – Grading system

1. Pass – Grade 3.
   All mandatory tasks must be completed.
   Handed in, examined, returned (corrected, handed in again, until pass).
   Written report needed but not enough for pass, must be able to explain your solution orally.
2. Higher grades.
   Each task handed in once, graded by us (like an exam), returned.
   Point system connected to extra tasks.
   - Grade 3 – 0-13 p
   - Grade 4 – 14-? p
   - Grade 5 – 24-? p
3. More details are found in the project PM.
   Deadlines given on the home page and Lisam.

Resources

- Computer tools are necessary, to be able to solve interesting problems.
  –Matlab and Simulink with extra packages.
- If you have your own computer, we encourage you to use it.
- 3 computer rooms booked on 2 occasions per week
  Tue 13–17, and Thursday 8–10 (Wed 17–21).
- See it as support opportunity.
  – Lab room assistant, answers questions.
  – Collect your questions and come to us.

Preparations for hand-in – Refresh your knowledge

Matlab and Simulink programming experience.

Course Outline

- Let's have a look at LISAM!
- Let's have a look at the course home page!

- You will of-course make all deadlines...
  - Flow and pace of the course.
  - Efficiency for teachers corrections.
- If you don't make a deadline make a first empty hand-in, important!
  - Within the system.
  - Lower priority in corrections.

Outline

About the Course

More Course Details

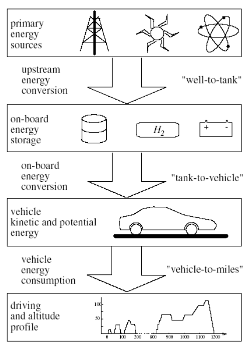
Analyzing Energy Demand for a Vehicle

Energy System Overview
- Different Links in the Energy Chain
- Why liquid hydrocarbons?

A Well-to-Miles Analysis
- Some Energy Paths
- Conventional, Electric and Fuel Cell Vehicles
- Pathways to Better Fuel Economy

Other Demands on Vehicles
- Performance and Driveability

Energy System Overview



Primary sources

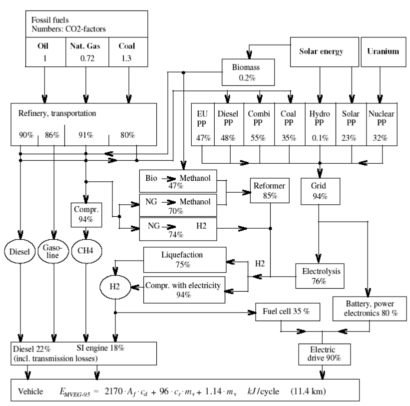
Different options for on-board energy storage

Powertrain energy conversion during driving

Cut at the wheel!

Driving mission has a minimum energy requirement.

Example of Some Energy Paths – W2M



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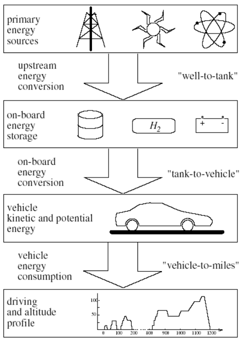

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Primary Energy Sources

Few sources – But many options

- Oil, Natural Gas, Coal
  - Oil wells as we know them will be depleted
  - Still much usable carbon in the ground
  - Cost will increase
- Nuclear power
  - Fission material available
  - Fusion material available
- Solar power
  - Hydro, wind, wave power
  - Solar cell electricity
  - Crop, forest, waste
  - Bacteria

Energy Carriers for On-Board Storage

Energy carriers – Many possibilities

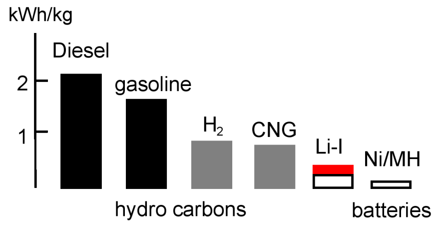
- Diesel, Gasoline, Naphtha, ...
- CH4, Compressed Natural Gas (CNG), Liquefied Petr. Gas (LPG), ...
- CH3OH, C2H5OH, C4H9OH, DME, ...
- H2
- Batteries

–What are the desirable properties?

- High energy density – Long range
- High refueling power – Fast refueling
- Simple refueling
- Low environmental impact (health aspects)
- Infrastructure

Why (Liquid) Hydrocarbons?

- Excellent energy density
- High refueling power
- Good Well-to-Tank efficiency



(including average engine/motor efficiencies)

Why (Liquid) Hydrocarbons?

Think of the fuel molecules as a wire that pulls the vehicle forward.

- –How thick is the fuel wire?
- 1 500 kg car needs 6 liters per 100 km.
  Area = 0.006/100000 = 6e-8 m^2
  $D = \sqrt{6e-8*4/pi} \approx 0.3$ mm
- A 40 000 kg truck needs 30 liters per 100 km.
  Area = 0.03/100000 = 3e-7 m^2
  $D = \sqrt{3e-7*4/pi} \approx 0.6$ mm

–Chemical bonds are strong!

Why (Liquid) Hydrocarbons?

- Filling a car at the gas station.
  - filling the tank with 55 [dm^3] of gasoline
  - takes about 1 minute and 55 seconds
- What is the power?
  The heating value for isooctane is $q_{LHV} = 44.3$ [MJ/kg], and the density is $\rho = 0.69$ [kg/dm^3]. Gives the power

  $$\dot{Q} = \frac{44.3 \cdot 0.69 \cdot 55\ MJ}{115\ s} = 14.6\ [\text{MW}]$$

  (Perspective: Worlds biggest wind turbine is 7.58 MW.
  Enercon E-126, rated capacity 7.58 MW, height 198 m (650 ft), diameter 126 m.)
- What is the current?
  For a single line 240 V system this would mean 60 000 A!
  (Perspectives: 0.2 A kills a human.
  Residential house, 3*16 A.)

We have a challenge in finding a replacement for the fuel!

Upstream Energy Conversion

- Manufacturing (pumping, crop, ...).
- Transport to refinery
- Refining
- Transport to filling station
- Filling of Vehicle

Ongoing intense research
–Investigating energy paths and improving all processes.

Energy Conversion in Vehicles

Many paths in the vehicle

- Energy storage(s) (tank, battery, super caps)
- Energy refiner (reformer)
- Energy converter(s)
- Power (force) to/from transportation mission

This important topic will be covered later in the course

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Other Demands on Vehicles
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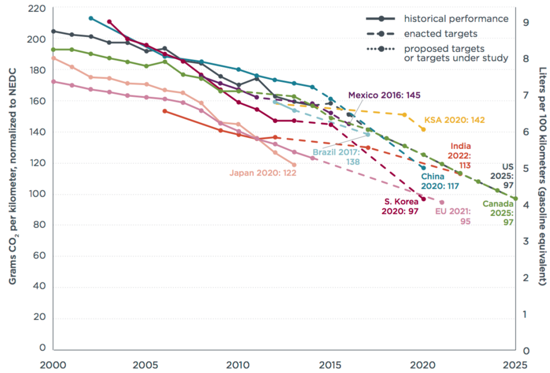
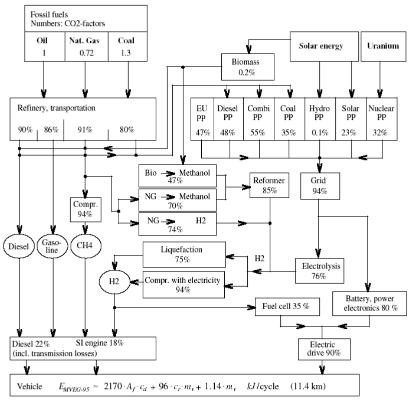
Environmental Concern – CO_2 as technology driver

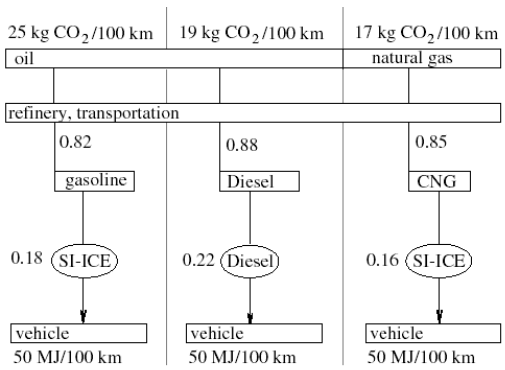


W2M – Energy Paths

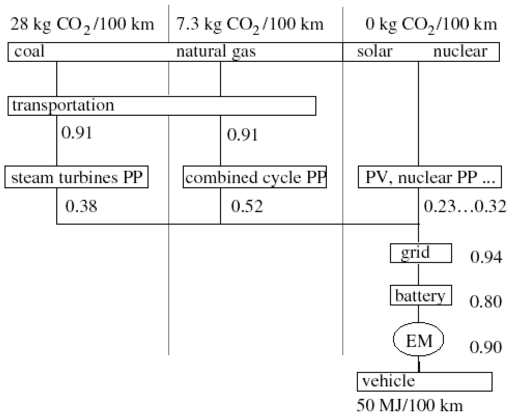


Environmental Concern – Coal+Sulphur, Beijing 2013

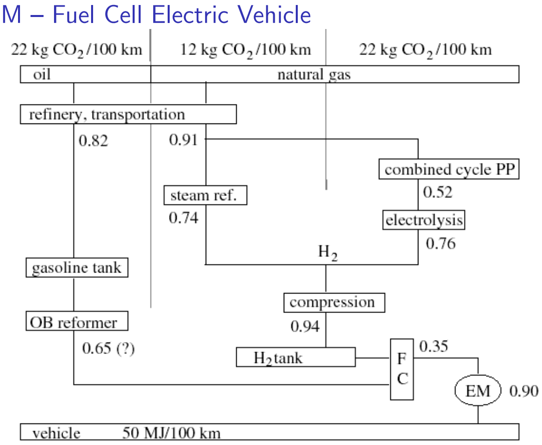
W2M – Conventional Powertrains



W2M – Electric Vehicle



W2M – Fuel Cell Electric Vehicle

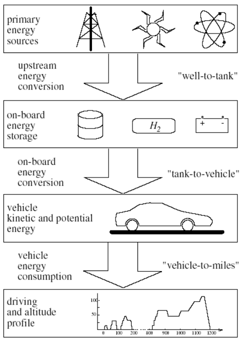


Pathways to Better Fuel Economy

Improvements on the big scale
- Well-to-tank (Upstream)
- Wheel-to-miles (Car parameters: mass, rolling, aerodynamics)
- Tank-to-wheel

Improvements in Tank-to-wheel efficiencies
- Peak efficiency of the components
- Part load efficiency
- Recuperate energy
- Optimize structure
- Realize supervisory control algorithms that utilize the advantages offered in the complex systems

Energy System Overview



Primary sources

Different options for on-board energy storage

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Outline

Performance and driveability

- Important factors for customers
- Not easy to define and quantify
- For passenger cars:
  - Top speed
  - Maximum grade for which a fully loaded car reaches top speed
  - Acceleration time from standstill to a reference speed (100 km/h or 60 miles/h are often used)

More about this on Lecture 2-3