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Thermal Design and Management

Ewa Kolakowska & Torben Andersen

Introduction

- Climate control plagues electrical car manufacturers
  - Keep drivers warm in winter
  - Cool in the summer
- Heating and air-conditioning place high demands on an electrical vehicle's limited power supplies
- The challenge
  - Minimise the drain on the battery from the climate control

Introduction

An example: The HVAC energy need in a Renault Kangoo

Temperature outside [^0C]	Speed [km/h]	Power to drive [kW]	Power to heat [kW]	Power to heat [%]
-15	100	20	3.65	15
-15	80	12	3.10	20
-15	50	5	2.17	30
-15	30	2	1.47	38
-5	100	20	1.86	8
-5	80	12	1.58	11
-5	50	5	1.11	18
-5	30	2	0.75	24
5	100	20	0.67	3
5	80	12	0.57	4
5	50	5	0.40	7
5	30	2	0.27	10

State-of-the-Art

- Simply provided with an electric resistance heater
- Higher efficiency and integral cooling can be obtained with a reversible heat pump (Toyota Prius)
- Auxiliary heating system. For example gasoline-fueled units. (Citroën Berlingo Electrique)
- Cabin cooling can be augmented with solar power

State-of-the-Art

Further ways of heating and cooling:

"Store energy by using the specific heat of materials"

- For heating: Container with heat retentive material (e.g. wax)
- For heating: Keep the heat in. Insulating material
- For cooling: Container with water/ice to store "coldness"
- For cooling: Keep the heat out. Coating of glass

Other idea

- Spot cooling air flow design can reduce thermal loads with 50%

Summary

- Develop an air conditioning system who significantly reduce the energy required by a conventional market-adequate air conditioning system

- Modelling, simulation, control theory and optimization are necessary and powerful tools that need to be understood and mastered

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Control and Optimisation of Energy Flow

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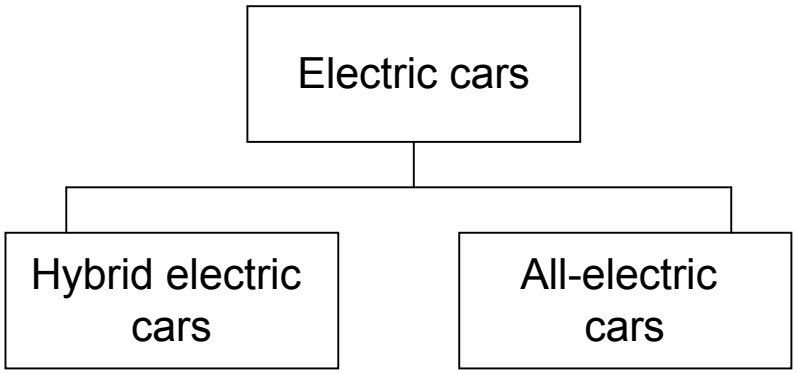
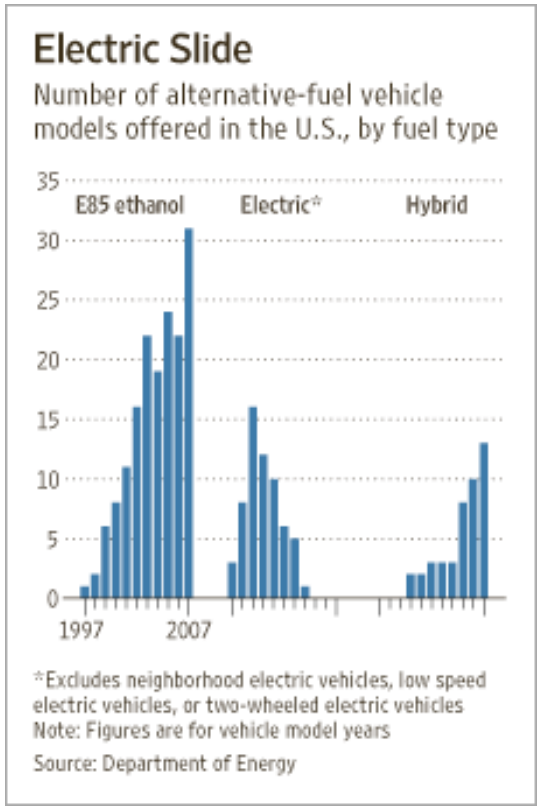
Electric cars



'All-electric vehicles make more sense – environmentally, politically, and economically – than do hybrids, provided there are advances in lithium-ion battery technology.'
Honda President Takeo Fukui 2007



[The Wall Street Journal, October 24, 2007]

All-electric cars on the market

Renault Fluence Z.E. Concept

Reva NXR

Tesla Roadster

Performance

Range: 160km.
Optimizing energy:
- Power from batteries complemented by photovoltaic cells
- Headlights use high- performance electroluminescent diodes
- Triple-zone climate control
- Car's aerodynamics minimizes drag
- Low rolling resistance tires.

Top speed: 104km/h.
Charge: 6h-160km, Fast charge: 15min-40km.
Sun roof – extra km.
Mechanical braking+regenerative braking.
Intelligent Energy Management System with integrated thermal battery management.

Full charge: 3.5h- 393km.
Acceleration.: 0-96kmh in 3.9s.

Energy control and optimization

Climate control.

Regenerative braking.

Control of an electric motor.

Sun cells.

Energy efficient headlights.

Minimization of drag by:

- aerodynamic design,
- low rolling resistance tires.

Regenerative braking

Kinetic and potential energy is converted to electric energy.

Electric energy is stored in an ultracapacitor.

Electric energy is re-used to propel the vehicle during acceleration.

[*Regenerative braking strategy for hybrid electric vehicles*,

F.Wang, B. Zhuo, JAUTO654, 2008]