Annex VII: Hybrid Vehicles
Overview Report 2000

Chapter 5: HEV programmes and projects in the world

Worldwide developments and activities in the field of hybrid road-vehicle technology

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This report

This Overview Report on the status of Hybrid Vehicle Technologies and Programmes is the result of collaborative work carried out in phase I of Annex VII between June 1998 and June 2000. It incorporates the results of both Subtask VII/1 and Subtask VII/2 over this period. The main text is based on the information collected by the participants on the status of hybrid vehicle technology and the R&D and implementation projects and programmes in various countries. As the Topics that have been studied in Subtask VII/2 closely relate to the aspects that are analyzed in the Overview Report resulting from Subtask VII/1, the Topic Reports have been integrated into this report at the appropriate places. Whenever this is the case, authors of the Topic Report are clearly mentioned.

At the end of phase II an updated version of this Overview Report will be published, incorporating the Topic Reports on subjects studied in phase II.

The structure of the report is as follows:

Chapter 2 introduces the various hybrid drivetrain configurations which are being developed and studied by the light duty and heavy duty vehicle manufacturers in the world. Roughly spoken, one can divide hybrid drivetrain configurations using electrical storage devices into series-, parallel and combined hybrids. Furthermore, hybrids making use of a mechanical energy storage device are briefly discussed.

Chapter 3 takes a closer look at some concrete examples of hybrid vehicles that have been developed for different applications (two-wheelers, passenger cars, vans, buses and trucks) and discusses some trends. Different vehicle applications demand different hybrid configurations. On the basis of existing examples the choices made by the R&D community and automotive industry are illustrated.

Subsequently, Chapter 4 deals with the two main components that are specifically developed for hybrid vehicle applications: thermal energy sources and energy storage devices (i.e. batteries, supercapacitors and flywheels). An overview and analysis of the state-of-the-art of these components is presented and some general reflections on the latest developments are given. In a future version of this report more components for hybrid powertrains will be discussed.

Chapter 5 describes large programmes and projects on hybrid vehicles that are being carried out worldwide. These are on the one hand divided into governmental and industrial programmes and on the other hand split up for the three regions Europe, USA and Asia.

Based on the vast amount of data collected in Annex VII Chapter 6 analyses worldwide trends within the field of hybrid vehicle technology in a more statistical manner. Trends in R&D (for instance status of hybrid vehicles, components used within several hybrid vehicle configurations), market introduction and mass production are visualized. Furthermore time paths for the development and introduction of hybrid electric vehicles and fuel cell vehicles are discussed.

Chapter 7 is focused on energy and emission aspects of hybrid vehicles. This chapter is composed of various Topic Reports written by the Annex VII participants. Attention is paid to test methods for HEVs, energy consumption and emissions of hybrids and the perspectives for using alternative motor fuels in hybrid vehicles. As part of the discussion on energy aspects a comparative assessment is presented of different HEV configurations using the simulation tool ADVISOR.

The next chapter (Chapter 8) presents a study of the cost aspects of hybrids, fully based on a Topic Report devoted to this subject.

Chapter 9 concludes the report with some final remarks. A summary of the conclusions from the various chapters of this report can be found in the executive summary.

Finally in Chapter 10 a general overview is given of the information collected on hybrid vehicles (from human powered hybrid two-wheelers up to heavy duty vehicles) which are currently in the R&D or early commercial stage (prototypes, testing vehicles, concept cars). The overview is of course not complete. A selection is made of those vehicles that are attractive or illustrative by virtue of their technical innovation, or that are already in the (pre-) commercial stage. Apart from general vehicle data, some technical information of the driveline configuration is given (whenever available).

Contents

5 HEV programmes and projects in the world

5.1 Introduction

This chapter describes large programmes and projects on hybrid electric vehicles that are carried out worldwide. The programmes can be divided in government sponsored or coordinated programmes and activities performed by the automotive industry.

In order to create an overview of the activities of the automotive industry a large amount of manufacturers have been approached by means of a questionnaire. The response to this questionnaire has been extremely limited, even after contacting all addressees by telephone. Therefore it has not been possible to create an up-to-date overview of industrial HEV projects. Instead we have included in this chapter a table that indicates the various areas of hybrid vehicle R&D for which we know from literature, press releases and web-sites that the various manufacturers are actively involved in.

5.2 Governmental programmes

In the USA, Europe and Japan different "models" are used for setting up government sponsored programmes. The "Partnership for a New Generation of Vehicles" is characterized by a strong programmatic coordination and intensive cooperation between automobile manufacturers, component suppliers, the US government and governmental research centers. Challenging development goals are set collectively.

The big three manufacturers each have their own R&D programmes to meet these goals and work together with the US Government, selecting, reviewing, and advising on the R&D needed to remove barriers to commercialization and advance technologies that are critical to achieving the overall objectives of the PNGV program. Through the involvement of government laboratories the technical achievements of the programme are closely monitored and evaluated.

In Europe, on the other hand, the central European government plays a more detached role. Under so-called Framework Programmes consortia of manufacturers and research organizations can submit proposals for sponsored projects. Although the proposal has to ascertain that the project has environmental and socio-economic benefits at the EU-level, the consortium sets the development goals themselves. Independent testing and validation of technical deliverables (prototype components or vehicles) is generally not foreseen.

The Japanese "model" seems in between these two extremes. The ACE-programme does have some programmatic coordination, but still leaves a lot of freedom for the participating industries. An important aspect in Japan is that the automotive industry takes much more initiative by themselves to develop and market hybrid vehicles.

5.2.1 USA

Two government programmes are described here. One is the "Partnership for a New Generation of Vehicles" which supports the development of clean and fuel efficient passenger cars. More recently the U.S. government has initiated the 21st Century Truck Program in which government and truck industry will work together on developing advanced trucks and buses. Descriptions of relevant projects in the USA are available on http:\\www.uscar.com.

Partnership for a New Generation of Vehicles (PNGV)

The most important government-sponsored programme on hybrids in the USA is the PNGV program. This program is worked out in collaboration with the 'Big Three': GM, Ford and DaimlerChrysler, various component developers and research institutes.

General objectives:

- Improvements in fuel efficiency (so-called '3x': efficiency improvement by a factor of 3)
- Reducing exhaust emissions
- Operating on alternative fuels
- Compete with conventional vehicles in terms of performance, reliability, safety and value
- Make a positive impact on US auto industry competitiveness and industrial productivity
- Curb national dependency on foreign oil

General Motors

Title:
- General Motors Hybrid Propulsion Systems Development Program

Period:
- Starting date: September 1993

Field:
- R&D, Field testing / demonstration

Objectives:
To develop and validate vehicle system technologies which will facilitate the production of competitive, consumer acceptable, automobiles having revolutionary improvements in fuel economy while meeting emission and safety standards and having the capability to use domestically produced alternative fuels.

Activities:
The main thrust of the hybrid propulsion development effort is to support multiple competitive, domestic industry "teams" in developing and demonstrating hybrid propulsion systems that could be commercialized in the 2000 to 2003 time frame.

Participants:
- General Motors Corp.
- Department of Energy (DOE)
- National Renewable Energy Laboratory (NREL)

Examples:
- Several mule prototypes, in the first time frame using a Lumina Sedan (both series and parallel HEV), focused on development of electric motor, generator, transmission, APU, gas turbine, battery, flywheel and the body. At the January 2000 Detroit Auto Show GM unveiled the Precept that nearly achieves 80 miles per gallon through a combination of a small diesel engine and two electric machines in a parallel hybrid configuration. Another version of the Precept is powered by fuel cells.

Budget:
- US$ 128 million

Ford

Title:
- Ford Hybrid Propulsion Systems Development Program

Period:
- Starting date: December 1993

Field:
- R&D, Field testing / demonstration

Objectives:
- To develop and demonstrate a production-feasible hybrid propulsion system in a vehicle that incorporates advanced propulsion, control and energy storage technologies to:
- Achieve fuel efficiency at least twice that of a comparable production vehicle over the Federal Urban Driving Schedule.
- Maintain driving range equivalent to current production vehicles.
- Meet EPA Federal Tier II standards.
- Meet market requirements for cost, safety and performance.

Activities:
As part of the DOE U.S. Hybrid Propulsion Systems Development programme, Ford Motor Company began a five-year program to analyze component trade offs for potential hybrid products; initiate design and development of fundamental enabling technologies; identify configurations and components for concept vehicle build; and build hybrid concept vehicles. Potential deliverable vehicles include a series hybrid vehicle with an internal/external combustion engine, a parallel hybrid vehicle with an internal combustion engine, and a low storage requirement (LSR) hybrid vehicle.

Participants:
- Ford Motor Company
- Department of Energy (DOE)
- National Renewable Energy Laboratory (NREL)

Examples:
- P2000 in several configurations (both series and parallel HEV), focused on (a.o.) development of electric motor, generator, transmission, APU, ICE, gas turbine, battery, flywheel, the total driveline and the body. At the beginning of 2000 the Prodigy Ford unveiled the Prodigy at the Detroit Auto Show. This vehicle is an interim stage between Ford's P2000 research vehicle and it's plan for an affordable, production hybrid.

Budget:
- US$ 100 million

Chrysler

Title:
- Chrysler Hybrid Propulsion Systems Development Program

Period:
- Starting period: march 1996

Field:
- R&D, Field testing / demonstration

Objectives:
To develop, build, test and demonstrate a production-feasible hybrid propulsion system for use in a vehicle that provides a high-energy efficiency and low emissions. This propulsion system will incorporate advanced propulsion, control and energy storage technologies while meeting market requirements for cost, safety, and performance. An additional objective of this program is to develop alternative propulsion systems technologies that would address and contribute to the goals set for the PNGV program.

Activities:
The Chrysler hybrid propulsion system development program began in March of 1996 with the signing of a three-year, nine-month letter subcontract, 50-50% cost shared with the Department of Energy. Chrysler plans to develop a viable hybrid propulsion system with the PNGV goals in mind.

Participants:
- Chrysler Corp.
- Department of Energy (DOE)
- National Renewable Energy Laboratory (NREL)

Examples:
Several ESX prototype mules (both series and parallel HEV), focused on (a.o.) an electric motor, generator, transmission, APU, ICE, battery, the total driveline and a body. In February 2000 Chrysler unveiled the ESX3. The car combines a lithium ion battery, and electric powertrain and a diesel engine to get an average of 72 miles per gallon of fuel.

Budget:
- US$ 35 million

The 21st Century Truck Program

The 21st Century Truck Program is a partnership between the U.S. truck and bus industry and its supporting industries and the federal government for research and development (R&D) of commercially viable technologies that will dramatically cut the fuel use and emissions of commercial trucks and buses, while enhancing their safety and affordability and maintaining or enhancing performance. The innovations resulting from this partnership will reduce U.S. dependence on foreign oil, improve the nation's air quality, and enhance the competitiveness of the U.S. truck and bus industry, while ensuring safe and affordable freight and bus transportation to benefit the U.S. economy. The Program was announced on April 21, 2000, in Romulus, Michigan, at a gathering of the U.S. trucking and supporting industries, concerned environmentalists, and federal agency representatives.

Program goals and research objectives

The program goals and research objectives of the 21st Century Truck Program are described in a "road map" which is part of the "Declaration of Intent - Twenty First Century Trucks" which can be found on http://www.osti.gov/bridge/. In summary the program will develop and demonstrate commercially viable technologies for trucks and buses to:
- improve fuel efficiency, specifically:
  - double the Class 8 line haul truck fuel efficiency by 2010 on a ton-miles per gallon basis,
  - triple the Class 2b and 6 truck (delivery van) fuel efficiency by 2010 on a ton-miles per gallon

basis,
  - and triple the Class 8 transit bus fuel efficiency by 2010 on a ton (passenger)-miles per gallon basis
- reduce emissions to exceed standards for oxides of nitrogen, particulate matter, carbon monoxide, and hydrocarbons for the year 2010.
- enhance safety, specifically to:
  - meet or exceed the motor carrier safety goal of reducing fatalities by half in ten years,
  - improve the crash friendliness of trucks for other road users,
  - conduct operation road tests of truck safety improvement components, and
  - ensure linkages to the Intelligent Vehicle Initiative and the Intelligent Highway System and Infrastructure
- reduce total owning and operating costs, and
- maintain or enhance performance.

A central goal of this initiative is to develop cost-effective, heavy-duty vehicles for truck operators that are fully competitive in prevailing markets. These program goals and research objectives are aggressive, especially as they need to be reached simultaneously, and there is no certainty that they can be achieved. Fully aware of the magnitude of the challenge and the importance of meeting the partnership's objectives, the parties involved commit their best efforts to the achievement of the goals.

The federal government will promote the introduction of innovative truck technologies developed in the initiative through its own purchases of these trucks and buses and will encourage state government and other purchasers to take similar actions.

Participants

R&D of the advanced technology needed to achieve the ambitious goals of the 21st Century Truck Program require a "teaming" effort among truck and bus manufacturers, their suppliers, federal and private research laboratories, and universities.

The U.S. Department of Energy (DOE) leads the partnership's federal component in coordination with the Office of Science and Technology Policy (OSTP). Other federal agencies involved are the Department of Transportation (DOT), the Department of Defense (DOD, represented by the Army), and the Environmental Protection Agency (EPA). The federal government brings to the table R&D resources, including the capabilities resident in government laboratories. Government and industry will coordinate R&D and share the costs. University participation also will be encouraged.

5.2.2 Japan

New Energy and Industrial Technology Development Organisation – Advanced Clean Energy Vehicle Project (NEDO-ACE)

Descriptions of relevant projects and more information on project level is available on http://www.nedo.go.jp/english/index.html

Period:
- 15/10/1997 - 31/03/2004

Field:
- R&D

Objectives:
- Doubling of fuel economy
- Utilization of clean energy (natural gas or synthetic fuels)
- Ultra low emissions

Main sponsors:
- Government (Ministry of International Trade and Industry)

Participants:
- JARI
- Nissan
- Honda
- Isuzu
- Mitsubishi
- Nissan Diesel
- Hino

Examples: several prototypes, including component development on the electric motor, generator, transmission, APU, ICE, fuel cell, reformer, battery, flywheel, supercapacitor, the total driveline and control strategies. Below, examples are given of vehicles developed within NEDO-ACE. In chapter 10 ("Vehicle data"), more extensive information of these vehicles is presented.

Nissan

Status:	prototype
Vehicle type:	small van
System type	series HEV (methanol fuel cell)

Nissan Diesel

Status:	prototype
Vehicle type:	bus
System type	series HEV engine and capacitor

Honda

Status:	prototype
Vehicle type:	passenger car
System type	series HEV ANG engine and flywheel battery

Isuzu

Status:	prototype
Vehicle type:	truck
System type	series HEV engine and capacitor

Mitsubishi

Status:	prototype
Vehicle type:	truck
System type	combined HEV engine and Li-ion battery

Hino

Status:	prototype
Vehicle type:	bus
System type	combined HEV DME engine and supercapacitor

Budget:
- US$ 36 million

5.2.3 Europe

5.2.3.1 Introduction

There are no really large, European Union or partly European Union sponsored programmes which are entirely focused on EVs or HEVs. However, there are EU sponsored programmes that focus on research, development and demonstration projects in the field of innovative energy technologies in general. Some of these programmes cover (H)EV development activities and projects.

In general, the European Union programmes are structured in 'Framework Programmes', containing several sub programmes and lasting several years. In the period 1995 – 1998 the overall programme was called the 'Fourth Framework Programme for Research and Technological Development' and covered a.o. the 'Non-Nuclear Energy Programme (NNE)'. This programme covered two sub programmes 'NNE-Joule' and 'NNE-Thermie'. Other programmes were the Brite-EURAM III and EUREKA programmes.

The Fifth Framework Programme (FP5) sets out the priorities for the European Union's research, technological development and demonstration (RTD) activities for the period 1998-2002.

- 'Fifth (EC) RTD Framework Programme', comprising programmes for implementing research, technological development and demonstration activities;
- 'Fifth (Euratom) Framework Programme', comprising programmes for implementing research and training activities in the nuclear sector.

The Sixth Framework Programme will subsequently succeed the Fifth Framework Programme in 2003, dependent on the progress of the political debate and decision-making processes.

5.2.3.2 Fourth Framework Programme: Non-Nuclear Energy (NNE)

Period:
- 1/1/1995 – 31/12/1998

Budget:
- ECU 1030 million (in total, HEV share unknown)

Central issues:
- improving security of energy supply
- protecting the environment
- encouraging the rational use of energy

Areas:
- energy research and technological development strategy

- rational use of energy
- renewable energy sources
- fossil fuels

5.2.3.3 Joule C (As part of the NNE Programme)

Period:
- 23/11/1994 – 31/12/1998

Type:
- Research and Development

Field:
- Innovative energy technologies

Objectives:
Improve energy security by ensuring durable and reliable energy services at affordable costs and conditions; to reduce the impact of the production and use of energy, in particular the emissions of CO2 and to strengthen the technological basis of the energy industry.

Principal:
- European Union

Budget:
- ECU 460 million (HEV share unknown)

Examples on HEV programs / projects:
- FLEETS ENERGY (Friendly Low Energy Efficient Transport Systems):
  - The Motor Industry Research Association
  - England

- PEAKFLY (Development of Flywheel Motor Generator Unit for Peak Power Application in electrically Propelled Vehicles):
  - Fiat, Ansaldo, Bertin, BMW and other
  - Italy, France, Germany, England, Finland

- Low cost Li polymer battery system:
  - Danionics, Daimler-Benz, Tobias Jensen Production, J.D. Stenqvist
  - Denmark, Germany, Sweden

- Solid state Li polymer batteries:
  - Danionics, University of Southampton, University of St.Andrews, Uppsala University, University of Delft, Sonnenschein Lithium, ARMINES, Alcatel
  - Denmark, England, Sweden, Netherlands, Germany, France

- Development of air metal hydride battery
  - Lyngby University, Kungliga Tekniska Hogskolan, Trondheim University, Ni-Me Hybrid AB, Hoganaes AB, Imatran Voima, norsk Hydro, Helsinky University, GFE Metalle und Materialien, Oy Hydrocell, Kewet Industri
  - Denmark, Sweden, Norway, Finland, Germany

- Safe and high energy density Li battery module for electric vehicle
  - CEA, SADACEM, Fiat, Novexel, Tadrian Batteries, TNO, Centralp Automatismes
  - France, Belgium, Italy, Israel, Netherlands

- Li C liquid electrolyte battery system for electric vehicles: battery module and system development project
  - Saft, Fiat, Solvay, PSA, Volvo, BMW, Ford, Silent Power, Opel, Daimler-Benz, VW, Renault, Varta, Alcatel
  - France, Italy, Belgium, Sweden, Germany

5.2.3.4 Thermie C (As part of the NNE Programme)

Period:
- 23/11/1994 – 31/12/1998

Type:
- Demonstration

Field:
- Innovative energy technologies

Objectives:
Improve energy efficiency, in both demand and supply sectors to promote a wider utilization of renewable energy sources; to encourage a cleaner use of coal and other solid fuels and to optimize the exploitation of the EU's oil and gas resources

Principal:
- European Union

Budget:
- ECU 532 million (HEV share unknown)

Examples on HEV projects / programs:
- ZEUS (Zero and low Emission Vehicles in Urban Society)
  - Purchase and use 1000 zero- and low emission vehicles in eight European cities
  - Sweden, England, Germany, Denmark, Finland, Greece, Luxembourg, Italy

- ENTRANCE (Energy savings in TRANsport through innovations in the Cities of Europe)
  - Demonstration of integrated measures for improving public transport operations and use
  - Germany, Portugal, Spain, France, Italy, Austria, Luxembourg, Netherlands, Denmark, Belgium, Sweden, England

- JUPITER (Joint Urban Project in Transport Energy Reduction)
  - Alternative fuelled vehicles and HEVs
  - England, Denmark, Spain, Italy, Belgium, Greece, Germany, France

- SAGITTAIRE
  - Demonstration of hybrid electric buses in urban public transport
  - Luxembourg, France, Spain, Portugal, Norway, Italy, Greece, Belgium

5.2.3.5 Fourth Framework Programme: Brite-EuRam III (IMT)

Period:
- 27/07/1994 – 31/12/1998

Field:
- production technologies
- materials and technologies for production innovation
- technologies for transport

Objectives:
- stimulate technological innovation
- encourage traditional sectors of industry to incorporate new technologies and processes
- promote multi-sectored and multidisciplinary technologies
- develop scientific and technological collaboration

Principal:
- European Union

Budget:
- ECU 1722 million (HEV share unknown)

Examples:
- HYZEM
  - A sustainable development for efficient zero emission mobility
  - Development of test cycles, simulations and prototype vehicle testing
  - BMW, Fiat, Daimler-Benz, PSA, Renault, Rover, Volvo, VW and 6 institutes
  - Germany, Italy, France, England, Sweden, Greece, Austria, Switzerland

- FLYTECH
  - Research on New Technologies for Flywheel Electromechanical Storage Systems
  - ISI, Ansaldo, BMW, Fiat
  - Italy, France, Germany, England, Finland

- TETLEI (Turbine Electric Taxi for Low Environmental Impact)
  - Rover, Turbo Energy, OPRA, Renault and other
  - England, France, Netherlands, Greece, Germany

- ATES (Advanced Technologies for Supercapacitors)
  - Saft, Danionics, MMM Carbon
  - France, Denmark, Belgium, Germany

- INMOVE (Integrated Modular Electric Propulsion System for Parallel Hybrid Vehicles)
  - PSA, Fichtel und Sachs, Rover, SGS-Thomson Microelectronics
  - Germany, England, Italy, France

5.2.3.6 Fourth Framework Programme: EUREKA

Period:
- 1994 - 1998

Type:
- A Europe-wide network for industrial R&D

Objectives:
- strengthening European competitiveness
- promoting 'market-driven' collaborative RTD
- involving industry and research institutes across Europe
- using advanced technologies
- resulting in cost-effective products, processes and services

Examples:
- ELECTRE (Electric Truck for Environment and Refuse Collection)
  - Development of zero emission and noiseless refuse collection vehicles
  - SITA, Compagnie Generale d'Entreprises Automobiles, Faun
  - France, Germany, Switzerland, Netherlands

- AGATA II (Advanced Gas Turbine for Automobiles)
  - Development of new components for a 60 kW gas turbine
  - PSA, Aerospatiale, ABB Cerama, Volvo Aero
  - France, Sweden

- FLEETS (Friendly Low Energy and Environmental Transport System)
  - Assess the effectiveness of an innovative bus fleet in an urban area
  - MIRA
  - England

5.2.3.7 Fifth Framework Programme (FP5)

The EC Framework Programme comprising four focused Thematic programmes and three more wide-ranging Horizontal programmes whereas the Euratom Framework Programme comprises only one Thematic programme. The thematic programmes cover a series of more or less defined problems whereas the horizontal programmes respond to more common needs across several research areas.

The total budget of the fifth framework programme covers 14,960 million euro, of which 13,700 million euro has been agreed for the implementation of the European Community part of FP5. The remainder of 1,260 million euro has been allocated to the Euratom programme.

Each of the Framework Programmes also contains a specific programme covering the direct RTD actions to be implemented by the European Commission's Joint Research Centre (JRC) which comprise research, scientific and technical support of an institutional nature.

Table 5.1 Thematic programmes

Activity	Programmes
First Activity Research, technological development and demonstration programmes	– Quality of life and management of living resources; – User-friendly information society – Competitive and sustainable growth; – Energy, environment and sustainable development

Table 5.2 Horizontal programmes

Activity	Programmes
Second Activity: Promotion of cooperation in the field of Community RTD with third countries and international organizations	– Confirming the international role of Community research
Third Activity: Dissemination and optimization of the results of activities in Community RTD	– Promotion of innovation and encouragement of participation of small and medium-sized enterprises (SMEs)
Fourth Activity: Stimulation of the training and mobility of researchers in the Community	– Improving human research potential and the socio-economic knowledge base

Direct RTD Actions Joint Research Centre (JRC)	– Research and scientific and technical support activities of an institutional character

In order to get insight in the overlap and interrelations between fourth frame and fifth frame programmes the next table has been set up in which the thematic successors of the fourth frame programmes are given and matched to their predecessors.

Table 5.3 Mapping of FP5 and FP4 Programmes

FP5 Thematic programmes	*FP4 Specific Programmes*
Quality of Life (Improving the quality of life and management of living resources)	– Biotechnology (BIOTECH 2) – Biomedicine & Health (BIOMED 2) – Agriculture & Fisheries (FAIR)
IST (Information Society Technologies)	– Advanced Communications – Technologies and Services (ACTS) – Information Technologies (ESPRIT) – Telematics Applications
GROWTH (Promoting competitive and sustainable growth)	– Industrial and Materials Technologies (BRITE-EURAM 3) – Standards, Measurements and Testing (SMT) – Transport
EESD (Energy, environment and sustainable development)	– Environment and Climate Marine Science and Technologies (MAST 3) – Non-nuclear energies - R&D activities (NNE-JOULE) – Non-nuclear energies - Demonstration activities (NNE-THERMIE)

5.3 Industrial activities

5.3.1 Introduction

This section describes the activities performed by the automotive industry in the field of hybrid vehicles. In order to get insight in the various areas of hybrid vehicle R&D the data presented in the Annex VII vehicle database (Chapter 10) was used. The analysis focuses on the LD passenger cars because this part of the database is most complete. Obviously R&D which is not made public is not taken into account in this analysis. This is however considered being a small amount for LD passenger cars because all major manufacturers have presented HEVs. For this analysis vehicles of which the presentation date is unknown are left out. The resulting data from the database are available in Table 5.4. Because of the recent cooperation between Renault and Nissan they are grouped together, like Mitsubishi and DaimlerChrysler. Main points of interest are the drivetrain configurations (Section 5.3.2) and the types of fuel (Section 5.3.3). The trend from charge sustaining to charge depleting hybrids is dealt with in Section 6.4.

Table 5.4 Selection of LD passenger car HEVs from the Annex VII database

HEV Light Duty	*date of presentation*	*driveline*	*ICE fuel*	*concern*
Audi Duo III	September 1997	parallel HEV	diesel	Volkswagen
BMW 318 ISAD	1999	parallel HEV SA	gasoline	BMW
Chevrolet Triax (Hybrid)	October 1999	parallel HEV	gasoline	GM
Chrysler Citadel	January 1999	parallel HEV	gasoline	DaimlerChrysler
Chrysler Durango	2000	parallel HEV	gasoline	DaimlerChrysler
Citroën Saxo Dynavolt	September 1998	series HEV	gasoline	PSA
Citroën Xsara Dynalto	March 1998	parallel HEV SA	gasoline	PSA
Citroën Xsara Dynactive	March 2000	parallel HEV	gasoline	PSA
CSIRO aXcessaustralia	March 2000	series HEV		CSIRO
Daihatsu Charade Social	October 1996	parallel HEV	gasoline	Toyota
Daimler Chrysler S-class	September 1999	parallel HEV	gasoline	DaimlerChrysler
Dodge Intrepid ESX	January 1996	series HEV	diesel	DaimlerChrysler
Dodge Intrepid ESX2	1998	parallel HEV SA	diesel	DaimlerChrysler
Dodge Intrepid ESX3	1999	parallel HEV SA	diesel	DaimlerChrysler
Dodge PowerBox	2001	parallel HEV	CNG	DaimlerChrysler
ETH-Z Hybrid	July 1996	parallel HEV	gasoline	ETH
Fiat Multipla Ibrida	May 1999	parallel HEV	gasoline	GM
Ford Escape US/Maverick	2000	parallel HEV	gasoline	Ford
Ford Explorer	2001	parallel HEV SA		Ford
Ford P2000 LSR	1999	parallel HEV SA	F T fuel	Ford
Ford Prodigy	2000	parallel HEV SA	diesel	Ford
Ford Synergy 2010	January 1998	series HEV	diesel	Ford
GM EV1 Parallel Hybrid	1998	parallel HEV	diesel	GM
GM Precept	2000	parallel HEV SA	diesel	GM
Holden ECOmmodore	May 2000	parallel HEV	gasoline	GM
Honda Insight	September 1999	parallel HEV SA	gasoline	Honda
Honda Insight Japanese	September 1999	parallel HEV SA CVT	gasoline	Honda
Honda Spocket	1999	parallel HEV		Honda
Hyundai FGV II	May 1999	parallel HEV	gasoline	Hyundai
Mitsubishi Chariot	1995	series HEV	CNG	DaimlerChrysler
Mitsubishi ESR	January 1994	series HEV	gasoline	DaimlerChrysler
Mitsubishi Pistachio	September 1999	parallel HEV SA	gasoline	DaimlerChrysler
Mitsubishi SUW Advance	October 1999	parallel HEV SA	gasoline	DaimlerChrysler
Mitsubishi SUW Compact	September 1999	parallel HEV SA	gasoline	DaimlerChrysler
Nissan Tino Neo Hybrid	2000	parallel HEV	gasoline	Renault-Nissan
Peugeot 406 VERT	1996	series HEV	diesel	PSA
Pininfarina Ethos	1997	parallel HEV SA	gasoline	Pininfarina
Renault Koleos	March 2000	parallel HEV	gasoline	Renault-Nissan
Renault Next	December 1995	parallel HEV	gasoline	Renault-Nissan
Renault Pangea	1997	series HEV	LPG	Renault-Nissan
Renault Scenic Hybrid	September 1998	parallel HEV	gasoline	Renault-Nissan
Renault Vert Monospace	1996	series HEV	diesel	Renault-Nissan
Sachsenring Uni 1	September 1998	parallel HEV	diesel	Sachsenring
Subaru Elten	February 2000	parallel HEV SA CVT	gasoline	GM
Suzuki EV-sport	October 1999	parallel HEV	gasoline	GM
Suzuki Pu3 Commuter	October 1999	parallel HEV	gasoline	GM
Toyota Corona	December 1997	parallel HEV	gasoline	Toyota
Toyota HV-M4	October 1999	parallel HEV	gasoline	Toyota
Toyota Prius	December 1997	combined HEV	gasoline	Toyota
Toyota Prius	2000	combined HEV	gasoline	Toyota
Volvo ECC	1992	series HEV	diesel	Ford

5.3.2 Trends concerning drivetrain configuration

The vehicles available in Chapter 10 are all Hybrid Electric Vehicles. Their main components are Batteries, ICEs and of course an electric motor as can be seen in Section 6.2.2. Remaining question is

in what drivetrain configuration these components are grouped. From the hybrid drivetrain configurations presented in Chapter 2 only four configurations are used for Light Duty passenger cars presented in the Annex VII database. These are combined hybrid electric, series hybrid electric, parallel hybrid electric starter-alternator (mild hybrid) and parallel hybrid electric (conventional). Trends are analyzed per make and year for trend analysis and per concern for recent years in order to evaluate state of the art technology.

5.3.2.1 Trends concerning drivetrain configuration per make

The data from table Table 5.4 are separated into three periods namely before 1999, 1999 and 2000. Because of the small amount of HEVs in the database that is presented in 2001 they are left out of this analysis. HEVs introduced in 1992-1998 are presented in Figure 5.1.

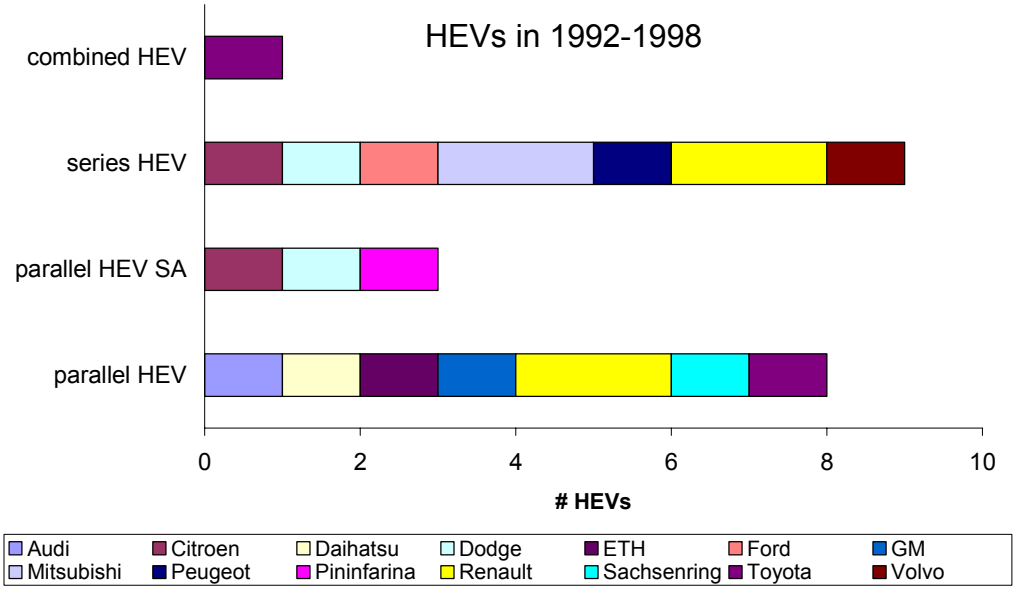

Figure 5.1 HEV drivetrain configurations per make in 1992-1998 (based on number of vehicles), derived from the Annex VII database

From Figure 5.1 it can be seen that most of the presented HEVs in the period 1992-1998 were of the series hybrid type. Renault was the most productive OEM-er, presenting two series hybrids and two parallel hybrids. The only combined HEV in the Figure is the Toyota Prius, introduced in Japan in 1997. HEVs introduced in 1999 are presented in Figure 5.2.

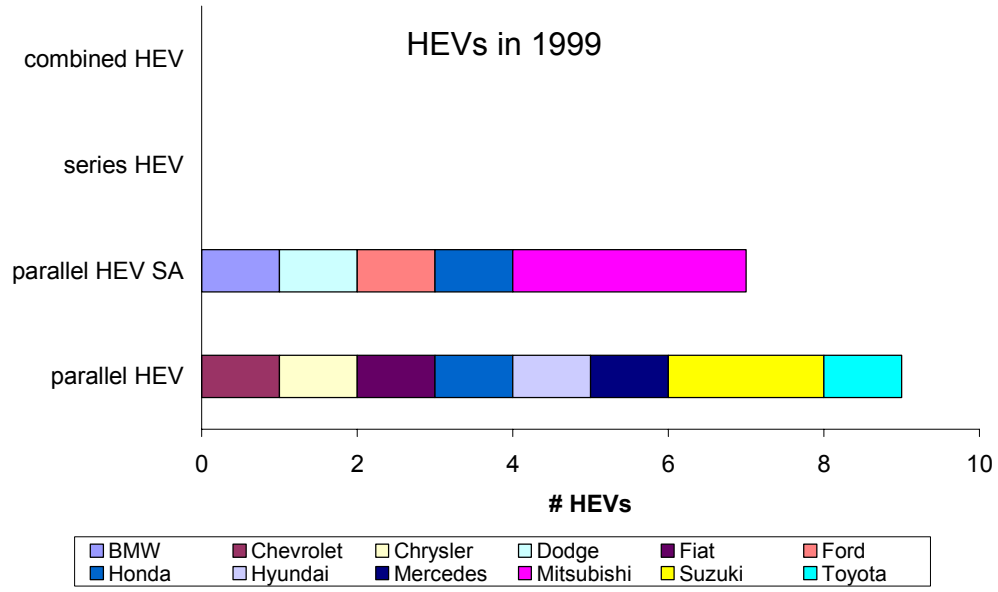

Figure 5.2 HEV drivetrain configurations per make in 1999 (based on number of vehicles), derived from the Annex VII database

What is remarkably in 1999 is the absence of vehicles. No HEVs were introduced with a combined or series hybrid electric drivetrain and no HEVs were presented by Renault. Introduced vehicles were merely parallel hybrids, of which the most were conventional hybrids. Mitsubishi was the most productive, introducing three parallel hybrid starter-alternator vehicles. HEVs introduced in 2000 are presented in Figure 5.3.

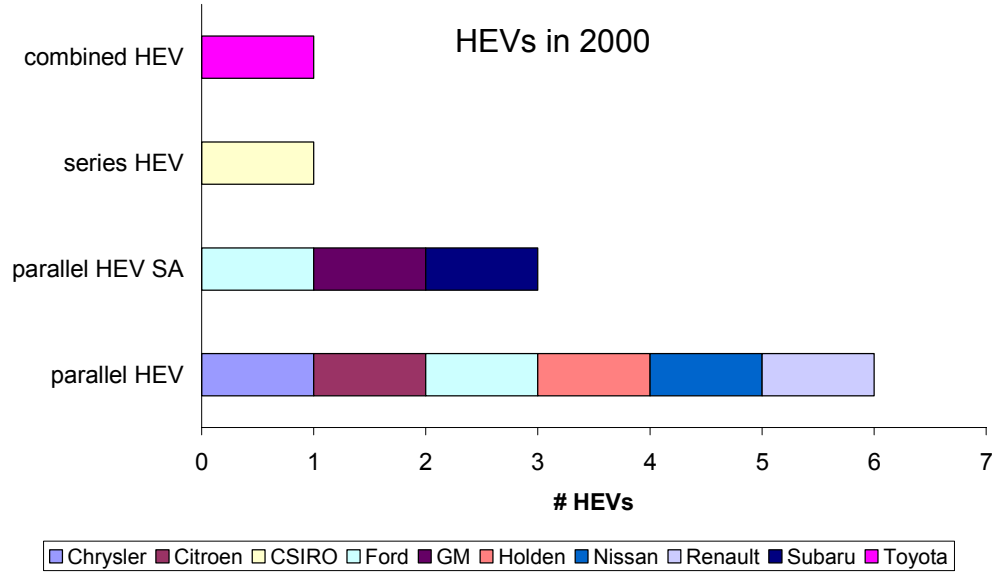

Figure 5.3 HEV drivetrain configurations per make in 2000 (based on number of vehicles), derived from the Annex VII database

2000 shows that parallel HEVs are still the most popular vehicles. There were only two different types of vehicles. These are the Toyota Prius for the North American/European market (combined hybrid) and the CSIRO aXcessaustralia (series hybrid). Ford was the most productive, introducing both a Ford

Escape (parallel hybrid) and the Ford Prodigy (parallel HEV starter-alternator). After one year of absence Renault presented a parallel hybrid Koleos.

5.3.2.2 Trends concerning drivetrain configuration per concern

When all the above mentioned makes are grouped together in the concerns they belong to, it is possible to determine which R&D path the specific automotive concerns are focusing on. In order to get a state of the art view of the R&D activities, only vehicles introduced in 1999 and 2000 are presented in Figure 5.4.

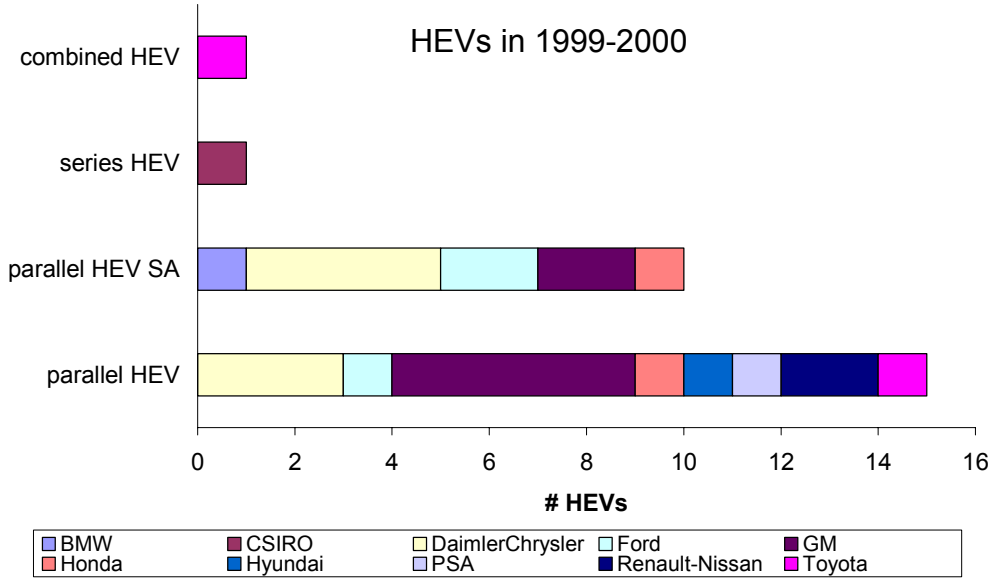

Figure 5.4 HEV drivetrain configurations per concern in 1999-2000 (based on number of vehicles), derived from the Annex VII database

It can be seen clearly that R&D in the field of combined and series HEVs is not state of the art anymore. R&D in the field of hybrid LD passenger vehicles concentrates on parallel hybrid vehicles, of which the most are conventional parallel hybrids. The "Big Three" (DaimlerChrysler, Ford and GM) account for 17 of the 27 hybrid vehicles introduced (63%). No clear focus between conventional (#9) and starter-alternators (#8) can be determined for the "Big Three". However DaimlerChrysler and Ford focus more on starter-alternator hybrids, were GM focuses more on conventional parallel hybrid electric vehicles.

5.3.3 Trends concerning fuel type

When analyzing the fuel type of recently introduced HEVs it is clearly that most of these vehicles are equipped with a gasoline engine. When the number of vehicles per fuel type is separated in years of vehicle introduction (years 1998, 1999 and 2000) this results in Figure 5.5.

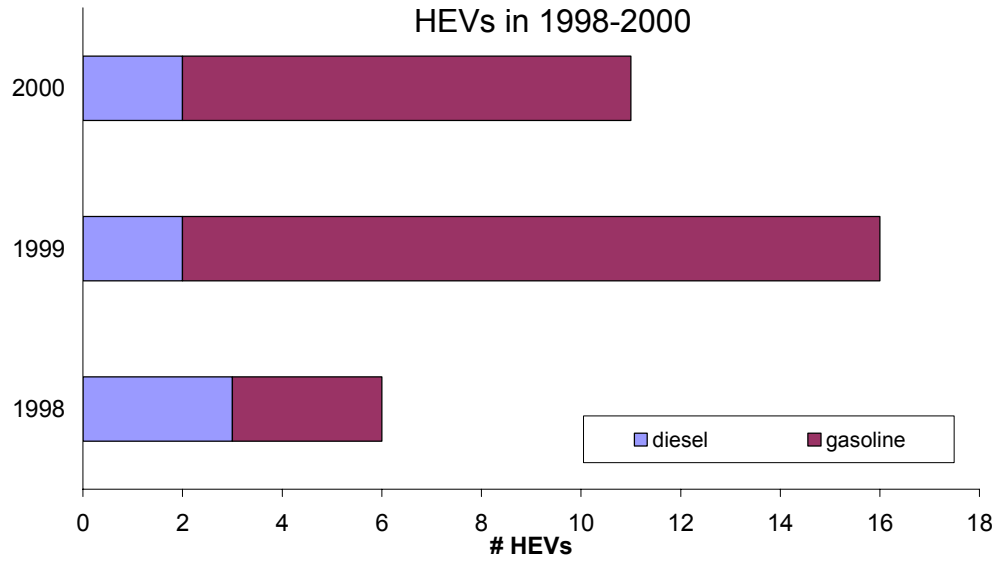

Figure 5.5 HEV fuel type in 1998-2000 (based on number of vehicles), derived from the Annex VII database

The most recently presented HEVs with a diesel engine remain fairly constant over the years. When looking more closely at the figures is becomes clear that all of these vehicles are PNGV vehicles from the "Big Three". In the PNGV project (see Section 3.1.1, Section 5.2.1 and http://www.uscar.com) all three manufacturers targeted 2000 as the year to show test cars that had three times the standard sedan's fuel economy (80 miles per gallon or roughly 3 l/100 km gasoline equivalent) and promises of no compromises in safety, performance or price. In order to achieve this it was apparently necessary to use diesel engines. However with respect to emissions of hybrid passenger cars this seems not to be a fortunate choice.