Applicable directives for vehicles

Sound Level
Emissions
Fuel tanks/rear protective device
Rear registration plate space
Steering effort
Door latches and hinges
Audible Warning
Rear visibility

Braking

Masses and dimensions
Safety glass
Tyres
Couplings
Frontal impact
side impact

Parking lamps

Suppression (radio)

Seat belts

Diesel smoke

Forward vision

Interior fittings

Identification of controls

Anti theft and immobiliser

Defrost/demist

Protective steering

Wash/wipe

Seat strength

Heating systems

Exterior projections

Wheel guards

Speedometer and reverse gear

Head restraints

Plates (statutory)

Fuel consumption

Seat belt anchorages

Engine power

Installation of lighting and
Light signalling device

Diesel emissions

Reflex reflectors
Position lamps
Direction indicators
Rear registration plate lamps
Head lamps
Front fog lamps
Towing hooks
Rear fog lamps
Reversing lamps

Figure 1

Applicable directives for vehicles

Sound Level Emissions Fuel tanks/rear protective device Rear registration plate space Steering effort Door latches and hinges Audible Warning Rear visibility

Braking

Suppression (radio)

Diesel smoke

Interior fittings

Anti theft and immobiliser

Protective steering

Seat strength

Exterior projections

Speedometer and reverse gear

Plates (statutory)

Seat belt anchorages

Installation of lighting and
Light signalling device

Masses and dimensions Safety glass Tyres Couplings Frontal impact side impact

Parking lamps

Seat belts

Forward vision

Identification of controls

Defrost/demist

Wash/wipe

Heating systems

Wheel guards

Head restraints

Fuel consumption

Engine power

Diesel emissions

Reflex reflectors Position lamps Direction indicators Rear registration plate lamps Head lamps Front fog lamps Towing hooks Rear fog lamps Reversing lamps

Figure 2

Application for a European Whole Vehicle Type Approval (WVTA)

TÜV for pressure vessels

Approval for high pressure parts and report

TÜV Automotive

Expertise

Application for approval (incl. exemption)

WVTA restricted to 36 month

National approval authority

Report

EU-Commission

CATP

EU-Commission

Decision

National approval authority

Figure 3

Project Partners

Air Liquide S.A., Sassenage, France,

Bayerische Motoren Werke AG, BMW, Munich, Germany,

EC-Joint Research Centre, Ispra, Italy,

Hamburgische Electrcitäts-Werke AG, HEW, Hamburg, Germany,

Hydrogen Systems N.V., Turnhout, Belgium,

Instituto Nacional de Técnica Aeroespacial, INTA, Madrid, Spain,

Ludwig-Boelkow-Systemtechnik GmbH, LBST, Ottobrunn, Germany,

Messer Griesheim GmbH, Krefeld, Germany,

Renault - Direction de la Recherche, Guyancourt cedex, France,

AB Volvo, Göteborg, Sweden

Figure 4

Overall Project Schedule

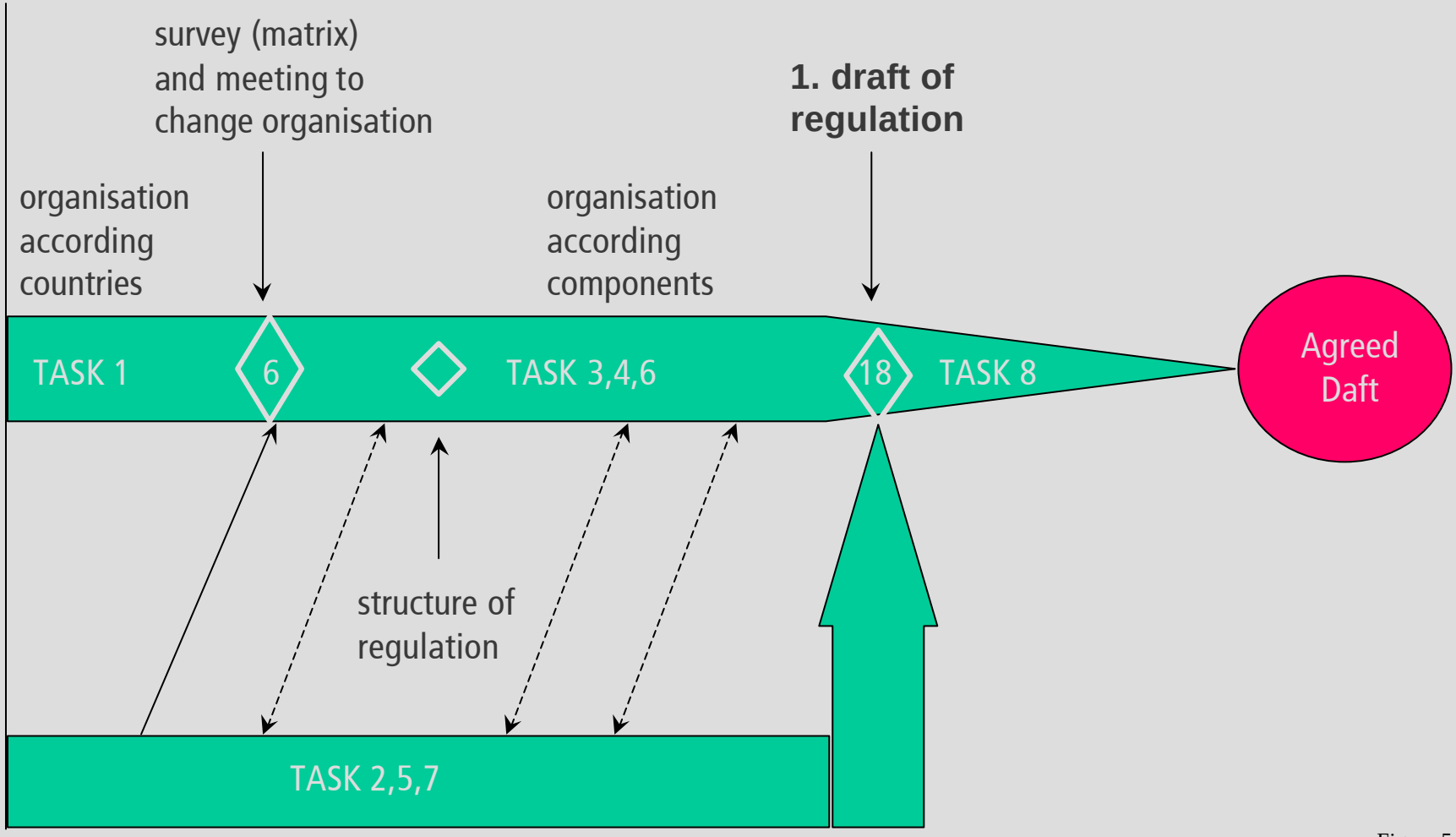

Figure 5

Project Organization in TASKs and Status

The project was subdivided into eight work packages or tasks:

Task 1: Survey/ analysis of rules, regulations and licensing procedures in all participating countries

Task 2: Analysis of existing and planned H_2 safety concepts and technologies

Task 3: Identification of rules and regulations ready for harmonization

Task 4: Identification of deficiencies in rules and regulations

Task 5: Identification of deficiencies in safety concepts and technologies

Task 6: Proposal for investigations to create a basis for standardization

Task 7: Proposal for safety concepts

Task 8: Proposal of Draft for Submission to ECE

Figure 6

Legal Requirements for LNG/LH_2 Vehicles in Germany

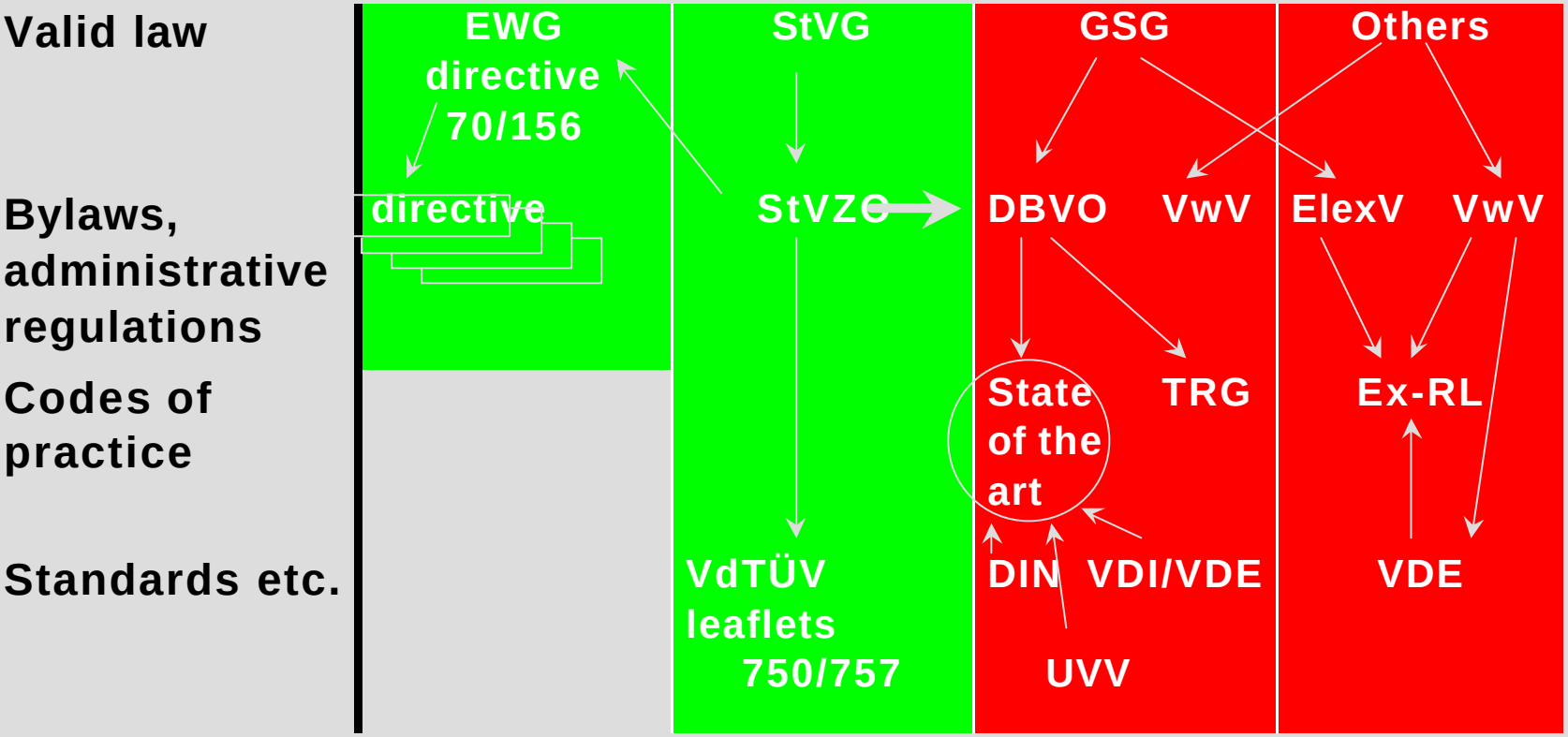

Figure 7

USA Regulations

Figure 8

ECE Draft Proposal Document

LH_2 Vehicle

PROPOSAL FOR A NEW DRAFT REGULATION

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF:

I. SPECIFIC COMPONENTS OF MOTOR VEHICLES USING LIQUID HYDROGEN;

II. VEHICLES WITH REGARD TO THE INSTALLATION OF SPECIFIC COMPONENTS FOR THE USE OF LIQUID HYDROGEN

CGH_2 Vehicle

PROPOSAL FOR A NEW DRAFT REGULATION

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF:

I. SPECIFIC COMPONENTS OF MOTOR VEHICLES USING COMPRESSED GASEOUS HYDROGEN;

II. VEHICLES WITH REGARD TO THE INSTALLATION OF SPECIFIC COMPONENTS FOR THE USE OF COMPRESSED GASEOUS HYDROGEN

Figure 9

ECE Platform for Globally Harmonized Regulation

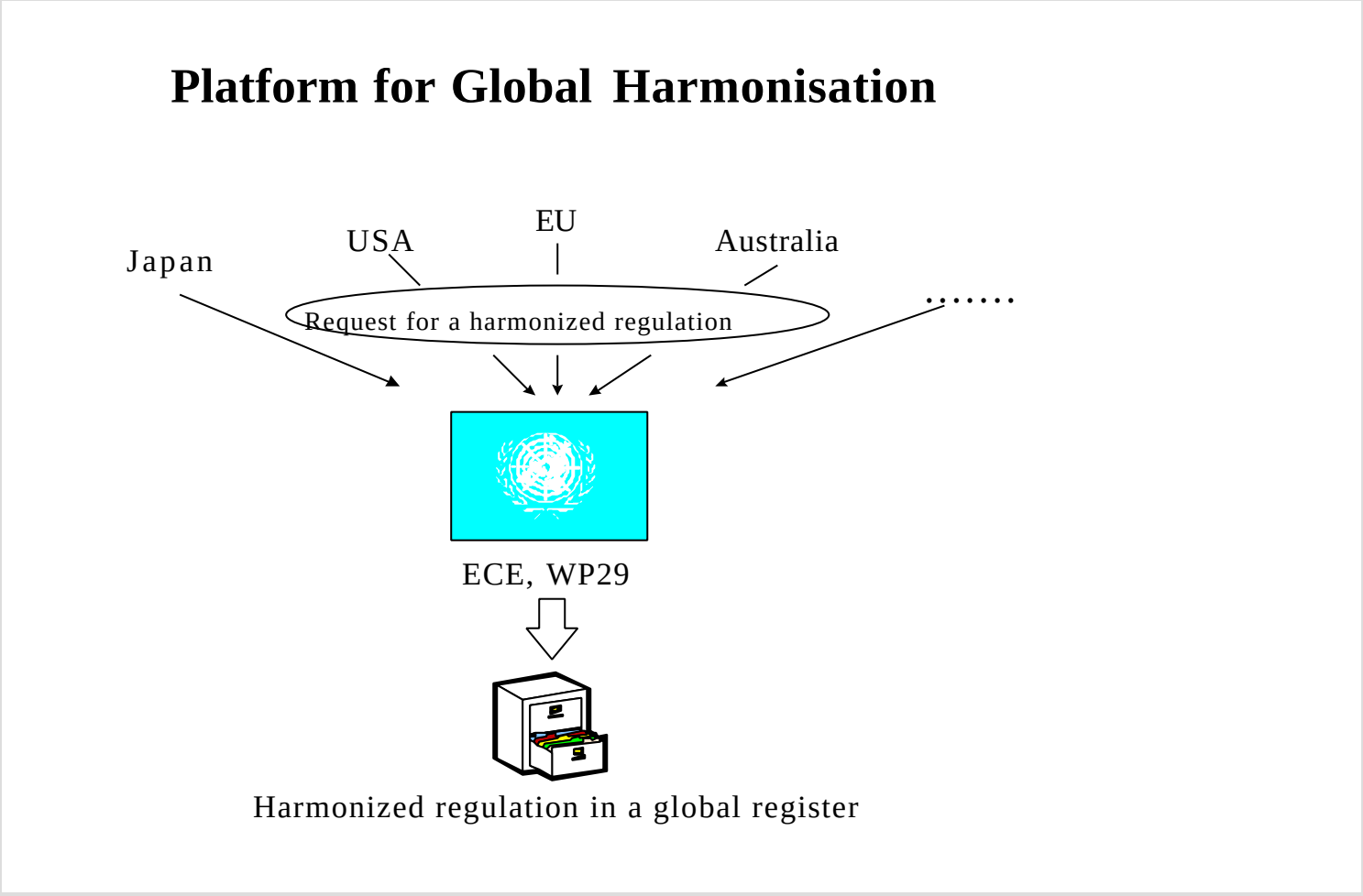

Figure 10

Overall Project Schedule

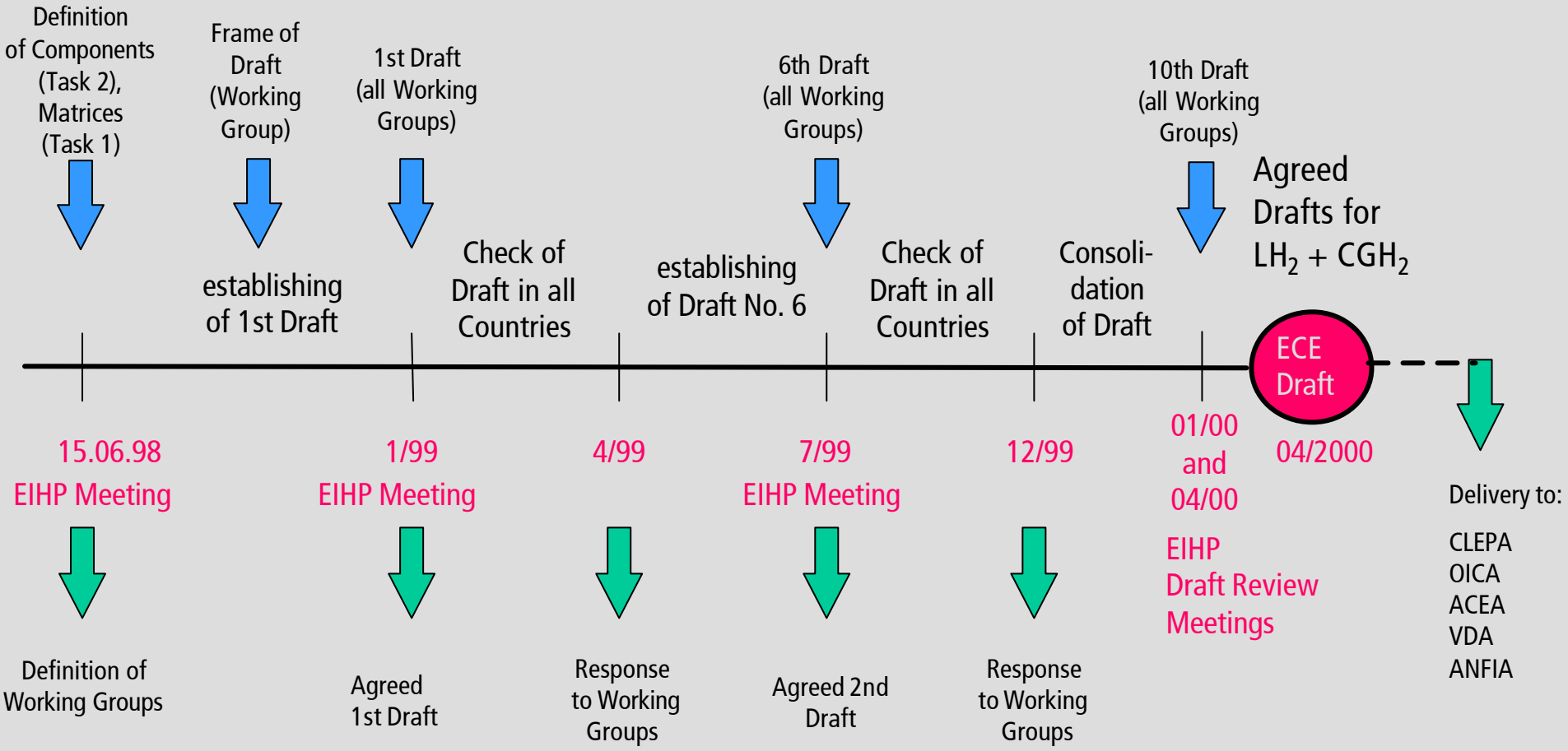

Figure 11

Application Process for a Harmonized Regulation at ECE

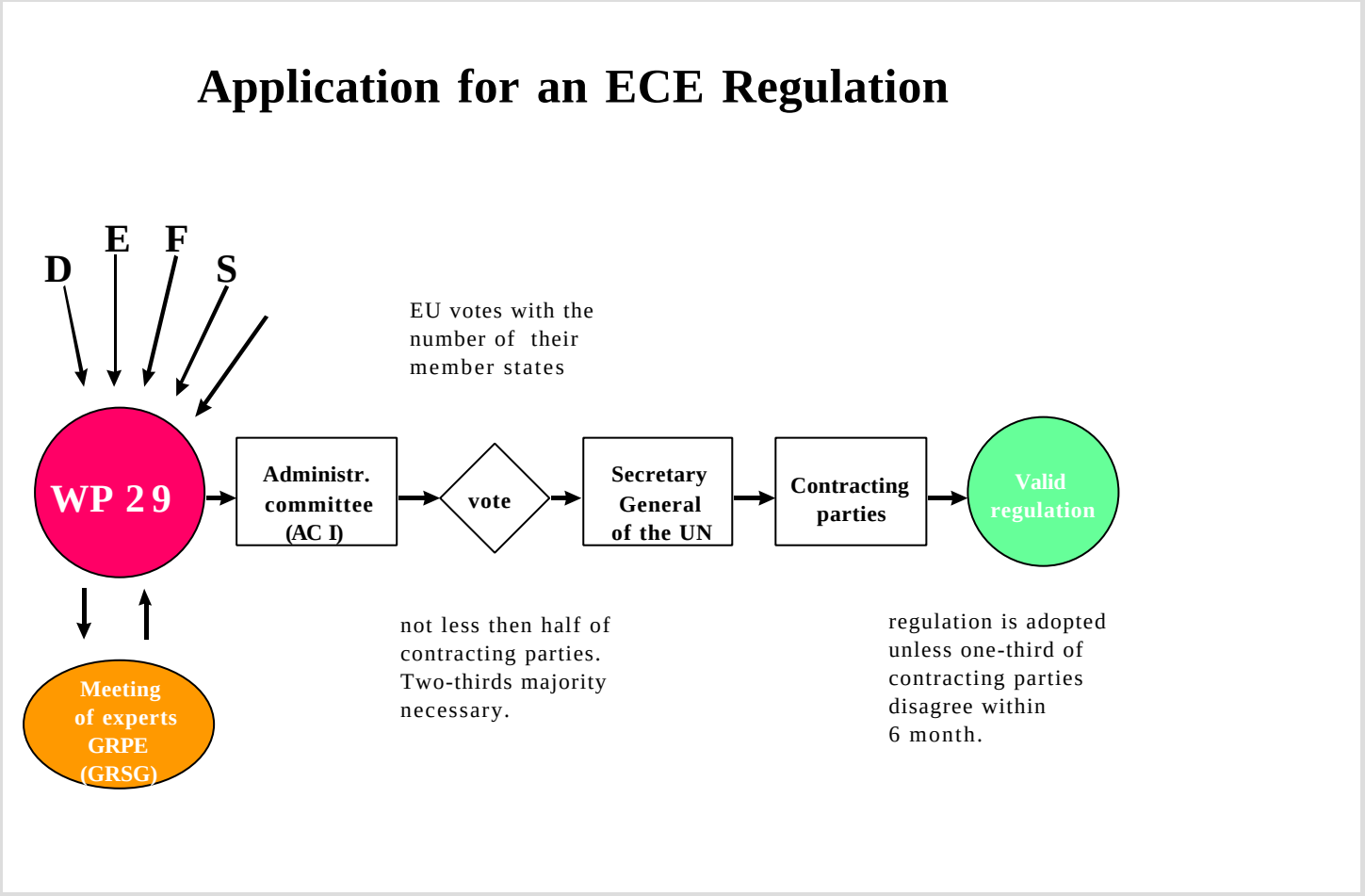

Figure 12

The European Integrated Hydrogen Project (EIHP)

Presented by Dieter Stoll, BMW AG, Munich

1. Motivation for the project

   In order to understand the motivation for the project, let me say only a few words about the approval of vehicles in the European community.
   If you look at figure 1, you will see a vehicle surrounded by all of the EC directives applicable to it. In total these are 47 directives. If a vehicle is tested according to these 47 directives it has to be approved. The result is a Whole Vehicle Type Approval.
   If we look at the same picture for hydrogen vehicles you see some coloured directives (figure 2). Red colour means that a hydrogen vehicle powered by fuel cells cannot be tested according to these directives. In particular these are the directives for emissions, fuel consumption and engine power. The reason is mainly the absence of a standardised reference fuel or the absence of a procedure for testing the engine power.
   The directives, which are marked with yellow colour, can be fulfilled formally, but from the technical point of view they should be revised for hydrogen vehicles.
   If you look at this picture very thoroughly you will notice that some requirements are missing regarding the safety of the hydrogen on board storage system.

   What needs to be done to approve a hydrogen vehicle in Europe? In this case the exception ruling for application of new technologies, as per Article 8(2)c of directive 70/156/EEC, has to be invoked. With respect to this, evidence has to be shown that an equivalent amount of safety and environmental protection is ensured with the vehicles as compared to conventional vehicles.
   The course of this procedure is portrayed in figure 3. Within six months, the commission should make a decision regarding the application.

   When BMW applied for an EC Whole Vehicle Type Approval for CNG vehicles for the very first time the process lasted 1½ years.
   Therefore the weaknesses of the process are as follows:

   - Excessive amount of time required
   and
   - Uncertainty of the outcome of the process up until the very end

   It is evident that such a process cannot be the path for the future for hydrogen fuelled vehicles.

2. Conception of the European Integrated Hydrogen Project

   In order to enhance the safety of hydrogen vehicles and to facilitate the approval of hydrogen vehicles, the European Integrated Hydrogen Project was established.

   The objectives of the project are as follows:

- To create a Pan European database of existing regulations and codes of practice
- To contact other pertinent authorities outside Europe
- To identify weak spots in today's technology
- To define the areas requiring regulation
- To create a basis for an ECE regulation for hydrogen vehicles

The consortium participating in the project comprises some of the most experienced companies and institutions actively involved in the fields of hydrogen vehicle applications, hydrogen infrastructure and hydrogen safety in Europe. Figure 4 shows you the organisations in alphabetic order.

3. Project overview

The project is based on a dual strategy (figure 5):

One part of the project – a top down approach – is focused on the existing hydrogen related vehicle legislation in European countries.
The other part of the project – a bottom up approach – is focused on hydrogen vehicles and technology in Europe including safety issues and infrastructure supply technology.

A continuous exchange of the results between the 2 parts assures the effectiveness of the project. The results of the systematic technology analyses and of the safety studies were integrated into the draft hydrogen regulations.

4. Description of the different tasks of the project

Figure 6 shows the description of the different tasks or work packages.
Task 1,3,4,6 and 8 are dealing with existing laws and with the draft for a new regulation.
The tasks 2,5 and 7 are focused on the evaluation of already existing hydrogen vehicles and components.

5. Top down approach

The first step of the top down approach was the survey and the analysis of existing laws for hydrogen vehicles. The survey was conducted for Belgium, France, Germany, Spain, Sweden and USA. The aim was not only to identify deficiencies but also to define regulations, which were already sufficiently comprehensive to facilitate harmonisation throughout Europe.
In almost every country there are a lot of regulations for hydrogen in different applications but there is almost no regulation for hydrogen vehicles.
Therefore the survey was structured in order to identify the different categories of the regulations and additionally, to subsequently accommodate corresponding surveys of other countries.

We distinguished between 4 categories:

1. Legal requirements.
These are the requirements which are directly applicable

2. Not directly valid regulations and standards etc. which should be applied analogously. An example for this is the ECE regulation R67 for LPG vehicles.

3. Peripheral requirements affecting the vehicle system. For example regulations for the use of garages or tunnels or sea transport by ship etc.

4. Requirements with potentially transferable safety targets. These are mainly standards which are not applicable for hydrogen vehicles or components but from which we can take the safety targets.

Now I would like to give you briefly the results of the survey in Germany and in the USA.

Germany

Figure 7 shows the situation in Germany in a simplified form.
Usually we have all legal requirements for vehicles described in StVG, which is the road transport law, or in the equivalent EC directives. In figure 7 these laws and all the following bylaws, codes of practice standards etc. are in green colour. We know them and we know what to do. In case of hydrogen vehicles however we have a link in the StVZO to the law for pressure vessels. This link brings a lot of other bylaws, codes of practice standards etc. into the game. Of course these requirements are not made for vehicles at all and often they don't meet the demands for a mobile application. This leads to long lasting discussions with the inspectors of the technical services and, depending on individuals, this can end finally in different requirements. Therefore they are in red colour.
One example: When we use the signal "engine speed 0" for switching off the safety valve of the hydrogen supply line, and if we take this signal from the ECU of the engine, the ECU has to be additionally tested, approved and marked according to VDE specifications. And of course for this approval another inspector is responsible than the inspector from the automotive application.

USA

Figure 8 shows you all the relevant requirements for hydrogen applications in the USA beside the usual requirements for road vehicles. This picture is for the demonstration of the amount of different requirements.

A similar picture can be made in almost every country.

It is very clear that it will be also impossible to meet all the requirements of all countries with 1 vehicle.
Example: The automatic shut off valve for the BMW CNG vehicle was placed according to German law at the safest place of the vehicle, which is outside the body but above the rear axle. This was not acceptable for the authorities of the Netherlands. They are requiring the safety valve directly mounted onto the CNG container. A certain requirement for the crash protection of this important safety

valve in the Netherlands however doesn't exist.

6. Bottom up approach

This part of the project focused on existing hydrogen vehicles in Europe. It is focused also on the fuel supply technology.
The different partners conducted systematic analyses such as Fault Tree Analysis (FTA) or Failure Mode and Effect Analysis (FMEA). The work was complemented by detailed studies of worst case scenarios.
Additionally some components were subjected to certain tests developed for the new technology.

Examples:

BMW conducted a complete Failure Mode and Effect Analysis concerning the Hydrogen Technology onboard liquid hydrogen driven passenger cars.
FMEA is a systematic approach to identify possible failures so that they can be avoided. It is a living document reflecting the actual product development phases. The structural format serves as a basis for discussion and documentation. Most of the possible failures can be discovered and avoided through this systematic approach.

Renault undertook a preliminary risk analysis executed on functions, allowing the determination of undesirable functional events, and a preliminary risk analysis executed on components, which allowed the determination of undesirable functional events for components. By the establishment of failure trees, different failures associated with each undesirable functional event were identified and categorised.

Volvo undertook a wide ranging safety study based on a passenger car powered by fuel cells with hydrogen carried on board in the form of a compressed gas at pressures of up to 700 bar. The study investigated the safety of vehicle systems related to the use of hydrogen, and the use of the vehicle in various operational environments, including the vehicle in traffic, refuelling, maintenance and vandalism.

The improvement of the hydrogen related systems started with the critical components of the vehicle. The protection of the LH_2 fuel tank against over-pressurisation has been identified by the EIHP partners as an important matter in the daily use of hydrogen driven vehicles. Consequently the existing safety valve, type approved for cryogenic gases, has been investigated. Its behaviour for the release of cryogenic gases is well known. For safety valves on mobile cryogenic fuel tanks that may be involved in various accidents or incidents, it cannot be ruled out that there are situations where two phase flow conditions prevail, e.g. car turned on its roof. Therefore an experimental test of the valve under two-phase flow conditions was performed and compared with the results of theoretical calculations by Messer.

Safety problems related to the release of cryogenic liquid/gas or pressurised gas were investigated with detailed CFD (computed fluid dynamics) calculations and

simulations of various worst case accident scenarios for garage and tunnel settings. The release and dispersion behaviour of hydrogen gas clouds resulting from the discharge of CGH2 and the evaporation of LH_2 were studied. For tunnels the effects of Hydrogen combustion were investigated. All the calculations were done by the EC - Joint research centre

As mentioned before from all results of the systematic technology analyses and of the safety studies, recommendations were defined and integrated into the draft hydrogen regulations. For example the necessity of boil off management systems, ventilation, flow restrictors, shut off valves etc.

7. The drafts

The EIHP partners finally developed 2 drafts for new ECE regulations (figure 9). One regulation for the use of liquid hydrogen in vehicles and one regulation for the use of compressed gaseous hydrogen in vehicles.
The requirements of the drafts are for hydrogen components as well as for the installation of the hydrogen components in a vehicle. That means part 1 of each regulation is for the component manufacturers and part 2 is for vehicle manufacturers. Whenever it was appropriate, a reference to an international standard is made. Beside the technical requirements, all procedures for granting a type approval are given as usual in ECE Regulations.

8. Why an ECE Regulation

We know that the ECE which is the Economic Commission for Europe under the United Nations, will be the platform for the future global harmonisation for legal requirements for vehicles (figure 10). Therefore we decided to make drafts for new ECE regulations. Members of the ECE are not only European countries. The ECE is free for the accession of countries from other continents. For example Australia was the last country, which has joined ECE on 25.2.2000.

9. Current status of the drafts

The drafts were finished in April 2000. Before finishing the drafts, several consolidations together with authorities, technical services and other companies were conducted. The drafts are currently distributed to different industrial associations (CLEPA, ACEA, OICA, VDA, ANFIA) and we are expecting comments.
The next step will be to deliver the drafts to the relevant ECE bodies in which they will be discussed and finally hopefully released. (Figures 11 and 12)

10. Necessary further steps to promote hydrogen vehicles

<u>Elaboration of a code of practice for refuelling stations</u>
This should allow the installation of H_2 refuelling stations throughout Europe. There is almost the same problem as for vehicles. Different requirements in different countries are asking for a different design of refuelling stations.

<u>Standardisation of the interface between refuelling station and vehicle, including</u>

the refuelling procedure
Currently almost every hydrogen on board storage system requires its own refuelling station

Development of a world wide harmonised and accepted regulation for hydrogen vehicles

All of these further steps are identified and currently a new partnership, called EIHP 2 is drafted.