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FRAUNHOFER INSTITUTE FOR SYSTEMS AND INNOVATION RESEARCH ISI

PRODUCT ROADMAP LITHIUM-ION BATTERIES 2030

PREFACE

LITHIUM-ION BATTERIES – THE KEY TO ELECTRIC MOBILITY?

Due to climate change, rising fossil fuel prices as well as the growing capacity of new storage media for electric power, electric mobility represents a future vision for individual mobility on an environmentally-friendly basis. Set against this background are ambitious political aims such as reducing the dependency on oil and cutting CO_2 emissions from road traffic. These aims are important drivers for realising electric mobility in Germany.

The large social and economic significance of this future trend results from the formation of numerous new markets. The "National Platform for Electric Mobility" (NPE) was established in May 2010 and published its second interim report in May 2011. In the report, it documents the great opportunities for Germany which could become reality by implementing electric mobility and emphasizes how important it is that Germany as an industrial nation positions itself as both a lead supplier and lead market for electric mobility. The report contains numerous recommendations directed at the German government for designing its future policies. Also in May 2011, the German government reacted with its "Government Programme in Support of e-Mobility", which contains the planned policy measures based on the interim report. Innovations are very important to the government, which is why supporting the research and development for electric mobility is still essential.

The lithium-ion battery is considered the key technology for future (electric) engine systems. A careful analysis and evaluation of its advantages and disadvantages is therefore indispensable. In order to reach market maturity, not only technology push aspects are important, but also the development of market demand. The significant milestones of market development can be documented in a so-called product roadmap.

PPRODUCT ROADMAP LITHIUM-ION BATTERIES 2030

The product roadmap lithium-ion batteries 2030 is a graphical representation of already realized and potential applications and products, market-related and political framework conditions and the market requirements regarding different properties of the technology from now up to the year 2030. The roadmap provides a wide-ranging orientation concerning the future market development of using lithium-ion batteries with a focus on electric mobility and stationary applications and products. The product roadmap compliments the technology roadmap lithium-ion batteries 2030, which was published in 2010. In the technology roadmap, the scientific and technical developments and challenges surrounding lithium-ion battery technology until the year 2030 were identified and located from the viewpoint of experts in battery research and development.

While the technology roadmap targets the technical development, the product roadmap focuses on the market and documents possible applications for lithium-ion batteries together with the specific market requirements for the technology. However, since the market itself is influenced by changing socio-economic framework conditions, the product roadmap also evaluates the development of broader issues, e.g. regulation and legislation, norms and standards as well as infra-structure and user acceptance. Aspects of all these areas, e.g. statutory and legal challenges or funding instruments and economics play a huge role in market development.

METHODOLOGY AND PROCESS MODEL

The product roadmap lithium-ion batteries 2030 and the accompanying brochure were compiled based on the coordinated combination of qualitative and quantitative research methods, and structured in a process model with four steps:

- Technology and market analyses including the latest publications, market studies, framework conditions, the technology field etc.,
- Expert and company interviews to test qualitative hypotheses and to help prepare the subsequent workshops as well as to obtain feedback for validating the results after the workshops,
- Holding an expert workshop to compile the roadmap,
- Methodologically differentiated elaboration of the roadmap.

The technology and market analyses are used to technically classify lithium-ion batteries in the context of alternative energy storage technologies as well as to prepare development scenarios for the batteries and their applications (especially in electric vehicles) and demand forecasts up to the year 2030. These analyses complement and underline the results of the roadmap.

The expert and company interviews were used as input when constructing the roadmap. Selected expert statements serve to additionally validate and confirm the results. The product roadmap itself was created at an expert workshop organised by Fraunhofer ISI in Frankfurt am Main in 2011. More than fifteen renowned experts from applied research and industry took part in this event. The product roadmap was reviewed afterwards by the workshop participants and their feedback was incorporated.

Selected lithium-ion battery applications and products are positioned and evaluated in this product roadmap together with the specific requirements for the planning period from 2010 until 2030.

Step 1
ANALYSES

Aim
Starting point for constructing the product roadmap: Identification of potential contacts and framework conditions etc.

Approach
Technology- and market analyses

Result
Qualitative hypotheses of LIB market maturity, questionnaire for the interviews

Step 2
EXPERT SURVEY

Aim
Inventory of the expertise regarding market requirements and questions e.g. concerning factors such as infrastructure and economics

Approach
Interviews with experts from different LIB applications

Result
Confirmation of the qualitative hypotheses and preparation of the workshop

Step 3
WORKSHOP

Aim
Construction of the roadmap through interactive discussion and mapping the content and timing of all the objects of consideration in a planning perspective

Approach
Central workshop with users of different LIB applications

Result
First version of the roadmap including all the relevant content

Step 4a
TECHNOLOGY ROADMAP

Aim
Documenting scientific and technical developments and evaluate the properties

Approach
Cooperation with battery developers

Result
Technology roadmap (2010)

Step 4b
PRODUCT ROADMAP

Aim
Documenting battery technology applications and evaluate their requirements

Approach
Cooperation with battery users

Result
Product roadmap (2011)

Step 4c
COMPREHENSIVE ROADMAP

Aim
Combining the technology roadmap and the product roadmap and detecting any gaps

Approach
Cooperation with battery developers and users

Result
Comprehensive roadmap (2012)

Gefördert vom Bundesministerium für Bildung und Forschung — Fraunhofer ISI — LIB 2015 BMBF Innovationsallianz

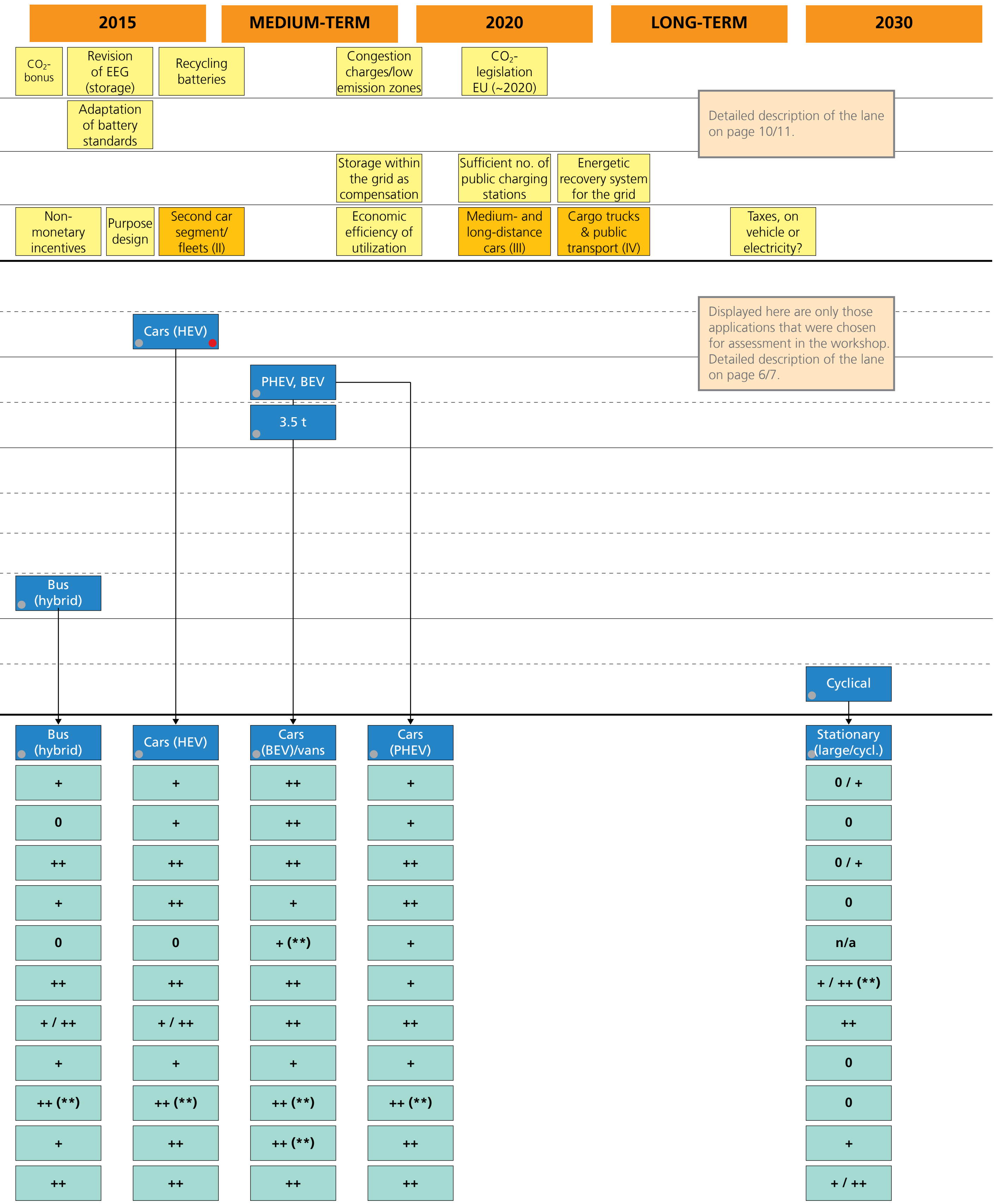
TIME →		< 2010/2011	SHORT-TERM
POLICIES & MARKET	Regulation/legislation	Implementation of low emission zones in cities; New emission norms for various vehicle classes	Regulation of battery trans. & ZEV; Regulations for inland water-way transport
	Norms/standards	Connections vehicle/ charging infrastructure	Charging plug/safety standards; Standard cells for battery modules
	Infrastructure		Promotion of grid expansion; Build-up of charging infrastructure
	Customer acceptance	Funding instruments (e.g. monetary)	Funding of e-vehicles (compare EU); LOHAS/ niches/ commuters (I)

APPLICATIONS & PRODUCTS		< 2010/2011	SHORT-TERM
Electric/mobile #1 (small, <5 kWh)	P/E <10 (traction)	Two-wheeler/ moped	Two-wheeler/ moped
	P/E >10 (hybrid)	Cars (HEV)	
Electric/mobile #2 (medium, between 5 and 25 kWh)	Cars	PHEV, BEV	
	Vans	3.5 t	
Electric/mobile #3 (large, >25 kWh)	Con-struction		
	Agriculture		
	Logistics		
	Public transport	Bus (hybrid)	
Stationary central/decentral (*)	<100 kWh		
	>100 kWh		Cyclical

PRODUCT REQUIREMENTS								
Specific application		Two-wheeler/ moped	Bus (hybrid)	Cars (HEV)	Cars (BEV)/vans	Cars (PHEV)	Two-wheeler/ moped	Stationary (large/cycl.)
Energy density	Gravimetric	0	–	0	++	+	0	0
	Volumetric	0	0	0	++	++	0	0
Power density	Gravimetric	0	++	++	+	++	0	0 / ++
	Volumetric	0	++	++	+	++	0	0 / ++
Charging time		–	–	–	+	–	–	n/a
Lifetime	Cycle life	–	++ (**)	++	++	+	–	++
	Calendar life	+	++ (**)	++	++	++	+	++
Ambient conditions (temperature)		– –	0	0	+	+	– –	–
Safety		+	++ (**)	++	++	++	+	0
Costs	Investment	+	++	+	+	+	+	++
	Operation	+	++	+	0	+	+	++

Timeframe
Comparison of market-related and political framework conditions as well as applications and products for lithium-ion batteries

PRODUCT ROADMAP LITHIUM-ION BATTERIES 2030



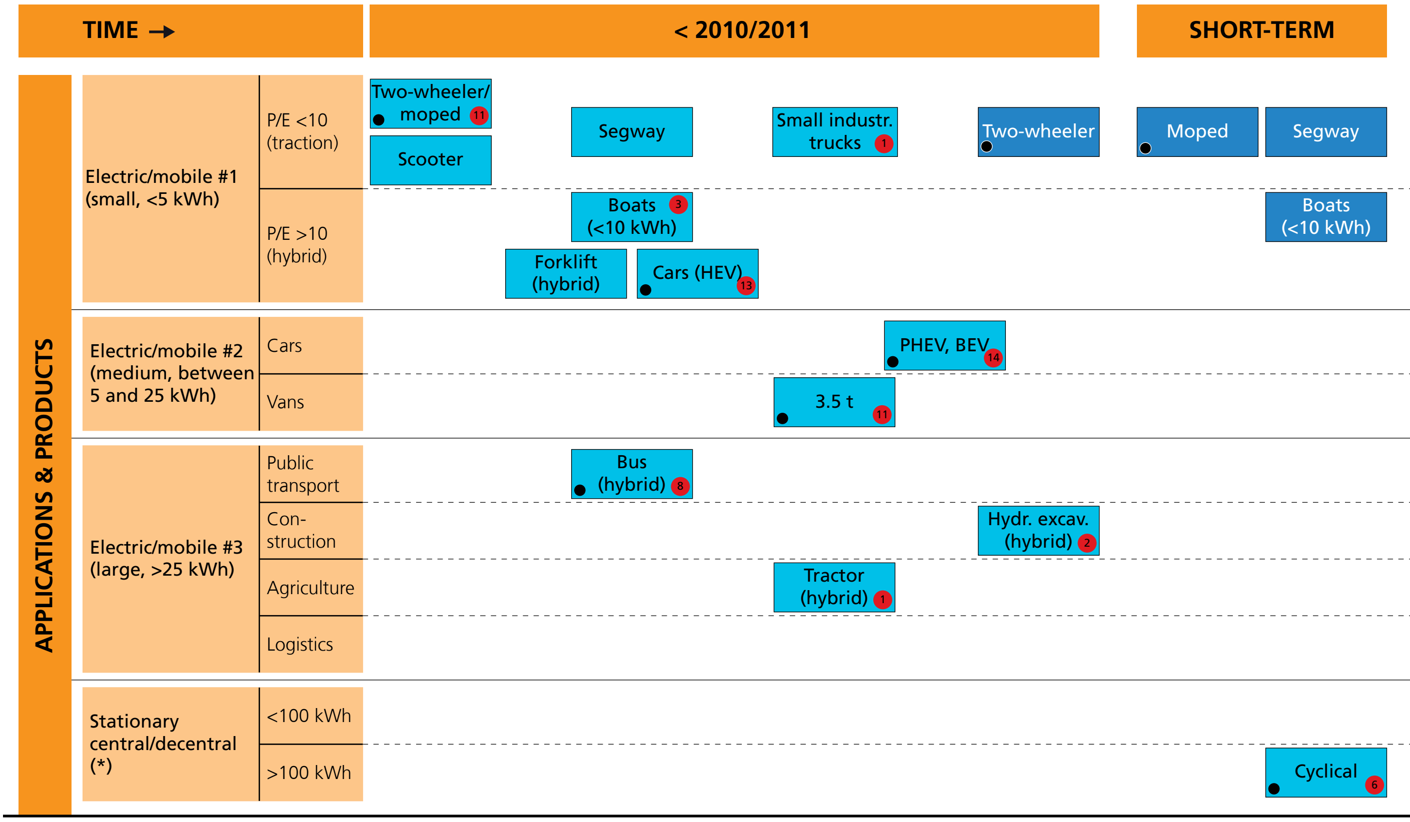
(*) Possible applications:
Load management, emergency back-up power, balancing power, black start
(**) Key parameters

Customer groups
Market entry
Mass production

Assessment of requirements of selected applications regarding particular properties in mutual comparison as well as in relation to other applications at the time of market entry and mass production

0 neutral (corresponds to: Requirement fulfilled)
+ important **++** very important
– less important **– –** unimportant

● Selection of applications to be analyzed
● Assessed in workshop
● Assessed after workshop

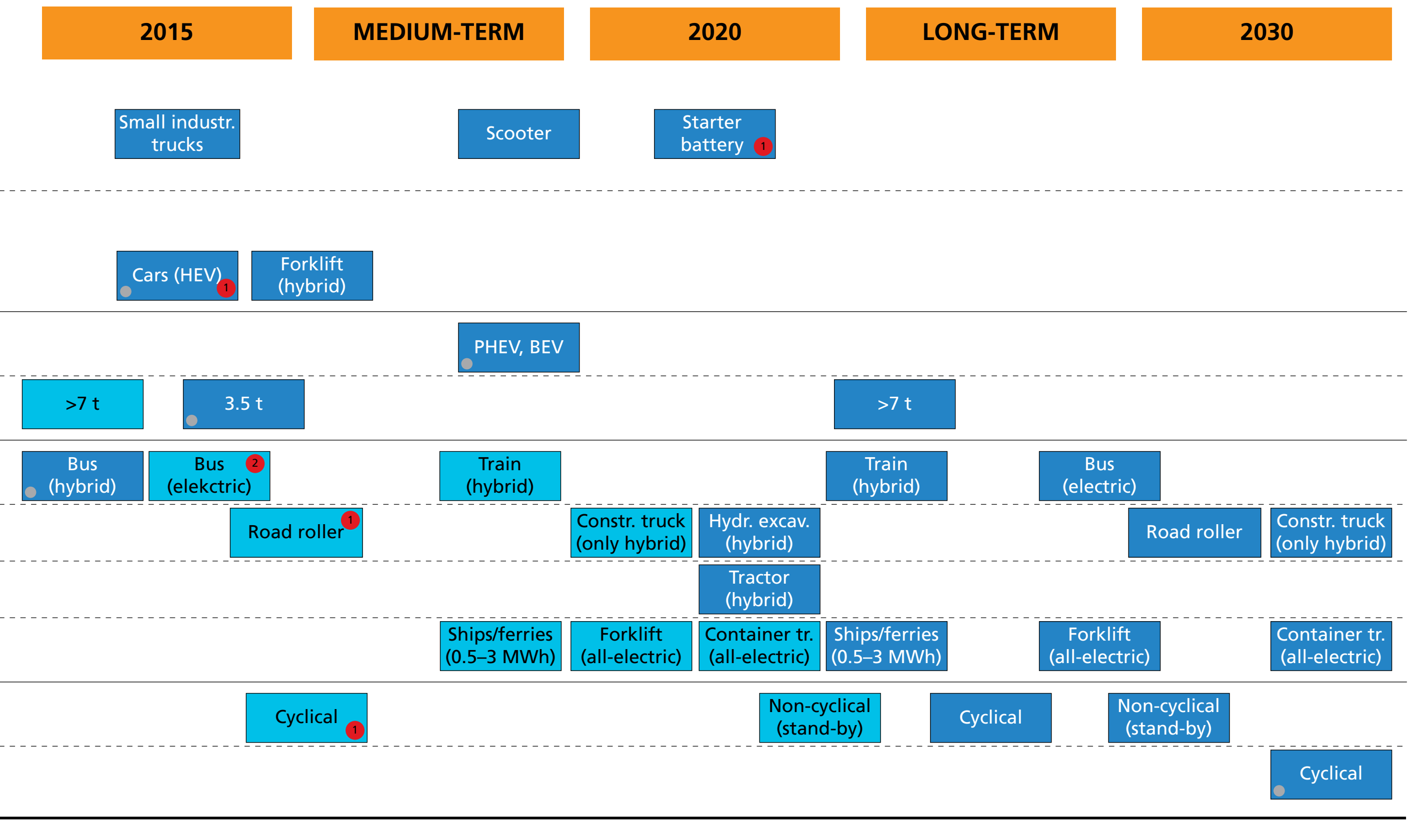


APPLICATIONS AND PRODUCTS

The previously conducted expert interviews and the workshop discussions resulted in a useful and practicable classification of electric mobility applications and products into small, medium and large storage classes. Besides this classification, both centralised and decentralised stationary energy storage are covered in the roadmap. The specification >100kWh is intended to cover energy storage up to a few MWh. The technology roadmap stationary energy storages 2030 due to be published in 2012 contains a more comprehensive classification. How-ever, "size" in this context does not represent the volumetric size of the battery and thus possible vehicle sizes, but only refers to the performance of the battery.

The performance-specific classification in the area of "small" batteries is further refined by the additional criteria of the so-called P/E-ratio. This ratio of performance and energy describes the characteristic of power withdrawal. If the ratio is relatively small, it concerns the high energy sector and is therefore relevant for e.g. purely electric vehicles. If, on the other hand, it is comparatively large, it concerns the high performance sector and is of interest for, e.g. hybrids. This classification makes it possible to discuss which applications will be most common for a battery of a given size. The applications and products are positioned on the roadmap according to two central criteria: The market entry, meaning the date the application becomes commercially available as a product, and the mass market capability, meaning the date when mass production starts. This makes it possible to distinguish the following phases: Market and technology preparation (before market entry), market acceleration (between market entry and mass market) and market diffusion (after reaching the mass market). These phases form the basis for all the applications and products shown in the roadmap on the next double page, where they are classified in the context of their market development. In every case for which sound data was available, the market development was quantified or estimated using the market share (in per cent) or the sales quantity (in units per year). All the observations documented in this brochure refer to Germany.

The most important applications and products of lithium-ion batteries were selected based on the assessment of the experts taking part. By using a simple evaluation system based on awarding points, the following applications were analysed in detail: Two-wheelers/mopeds, HEVs, PHEVs, BEVs/vans, buses (hybrid) as well as stationary (large, cyclical) energy storage. Concrete product requirements are then specified for these applications and products.



(*) Possible applications:
Load management, emergency back-up power, balancing power, black start

- ● Selection of applications to be analyzed by 19 participants (76 rating points in total)
- ● Assessed in workshop
- ● Assessed after workshop

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

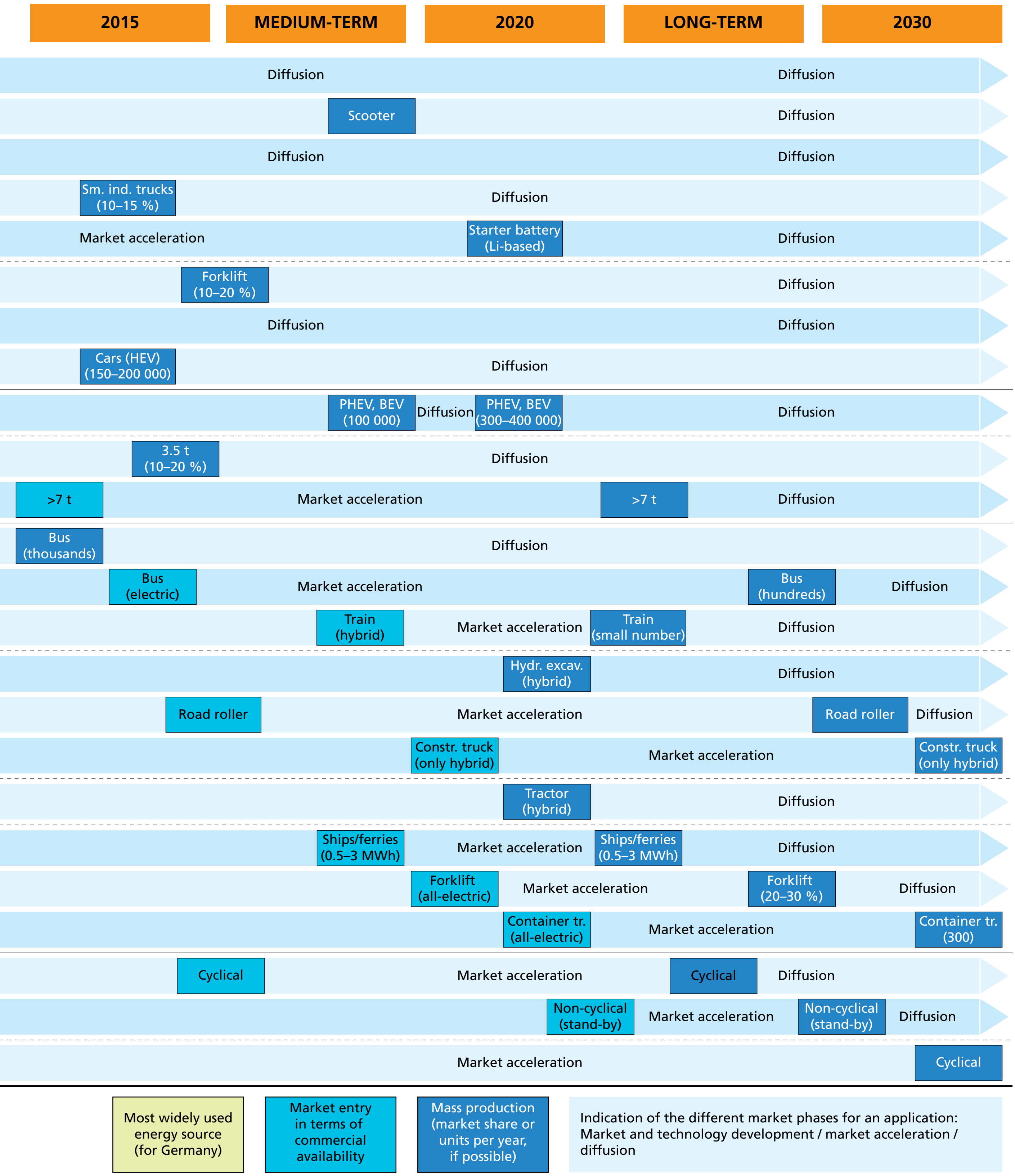
Fraunhofer ISI

LIB 2015
BMBF INNOVATIONSALLIANZ

APPLICATIONS & PRODUCTS	TIME →	STATE OF THE ART	< 2010/2011	SHORT-TERM
Electric/mobile #1 (small, <5 kWh)	P/E <10 (traction)	LIB	Two-wheeler/ moped; Market acceleration; Two-wheeler (350 000)	Moped (100 000)
		Petrol/diesel	Scooter; Market acceleration	Market acceleration
		LIB	Segway; Market acceleration	Segway
		Lead	Market and technology development; Small indust. trucks	Market acceleration
		Lead	Starter battery (lead-acid); Market acceleration	
	P/E >10 (hybrid)	Lead	Forklift (hybrid); Market acceleration	
		Petrol/diesel	Boats (<10 kWh); Market acceleration	Boats (4000–4500)
		Petrol/diesel	Cars (HEV)	Market acceleration
Electric/mobile #2 (medium, between 5 and 25 kWh)	Cars	Petrol/diesel	Market and technology development; PHEV, BEV	Market acceleration
	Vans	Petrol/diesel	Market and technology development; 3.5 t	Market acceleration
		Petrol/diesel	Market and technology development	
Electric/mobile #3 (large, >25 kWh)	Public transport	Petrol/diesel	Bus (hybrid); Market acceleration	
		Petrol/diesel	Market and technology development	
		Petrol/diesel	Market and technology development	
	Con-struction	Petrol/diesel	Market and technology development; Hydr. excav. (hybrid)	Market acceleration
		Petrol/diesel	Market and technology development	
		Petrol/diesel	Market and technology development	
	Agriculture	Petrol/diesel	Market and technology development; Tractor (hybrid)	Market acceleration
	Logistics	Petrol/diesel	Market and technology development	
		Lead	Market and technology development	
		Petrol/diesel	Market and technology development	
Stationary central/decentral (*)	<100 kWh	LIB	Market and technology development	
		Lead	Market and technology development	
	>100 kWh	Redox-Flow	Market and technology development	Cyclical

Time frame
Question of classifying the different applications for lithium-ion batteries chronologically by market entry and mass production

(*) Possible applications:
Load management, emergency back-up power, balancing power, black start


2015
MEDIUM-TERM
2020
LONG-TERM
2030
Diffusion
Diffusion
Scooter
Diffusion
Diffusion
Diffusion
Sm. ind. trucks (10–15 %)
Diffusion
Market acceleration
Starter battery (Li-based)
Diffusion
Forklift (10–20 %)
Diffusion
Diffusion
Diffusion
Cars (HEV) (150–200 000)
Diffusion
PHEV, BEV (100 000)
Diffusion
PHEV, BEV (300–400 000)
Diffusion
3.5 t (10–20 %)
Diffusion
>7 t
Market acceleration
>7 t
Diffusion
Bus (thousands)
Diffusion
Bus (electric)
Market acceleration
Bus (hundreds)
Diffusion
Train (hybrid)
Market acceleration
Train (small number)
Diffusion
Hydr. excav. (hybrid)
Diffusion
Road roller
Market acceleration
Road roller
Diffusion
Constr. truck (only hybrid)
Market acceleration
Constr. truck (only hybrid)
Tractor (hybrid)
Diffusion
Ships/ferries (0.5–3 MWh)
Market acceleration
Ships/ferries (0.5–3 MWh)
Diffusion
Forklift (all-electric)
Market acceleration
Forklift (20–30 %)
Diffusion
Container tr. (all-electric)
Market acceleration
Container tr. (300)
Cyclical
Market acceleration
Cyclical
Diffusion
Non-cyclical (stand-by)
Market acceleration
Non-cyclical (stand-by)
Diffusion
Market acceleration
Cyclical
Most widely used energy source (for Germany)
Market entry in terms of commercial availability
Mass production (market share or units per year, if possible)
Indication of the different market phases for an application: Market and technology development / market acceleration / diffusion

POLICIES & MARKET — TIME →	< 2010/2011	SHORT-TERM	
Regulation/legislation	City centres 30/40 km zone, low emission zone; Euro III for mopeds (up to 125cc); Euro VI for N1 (up to 3.5 t)	Regulations for battery transport on the road; Regulations for inland waterway transport; ZEV laws; Securing electricity from additional renewables; Privileges (e.g. free parking) for PHEV/BEV	CO_2-bonus via controlled charging
Norms/standards	Connections (electr./IT) vehicle/ charging infrastructure	Charging plug/safety standards; Standard cells for HEV/PHEV/ BEV battery modules	
Infrastructure		Promotion of grid expansion/ further development; Build-up of charging infrastructure (privately financed)	
Customer acceptance	Funding instruments (monetary & non-monetary)	Funding of e-vehicles (compare EU) → next legisl. period; LOHAS/ niches/ commuters (<50 km) (I); Non-monetary incentives, e.g. bus lane use, free parking	

POLICY AND MARKET

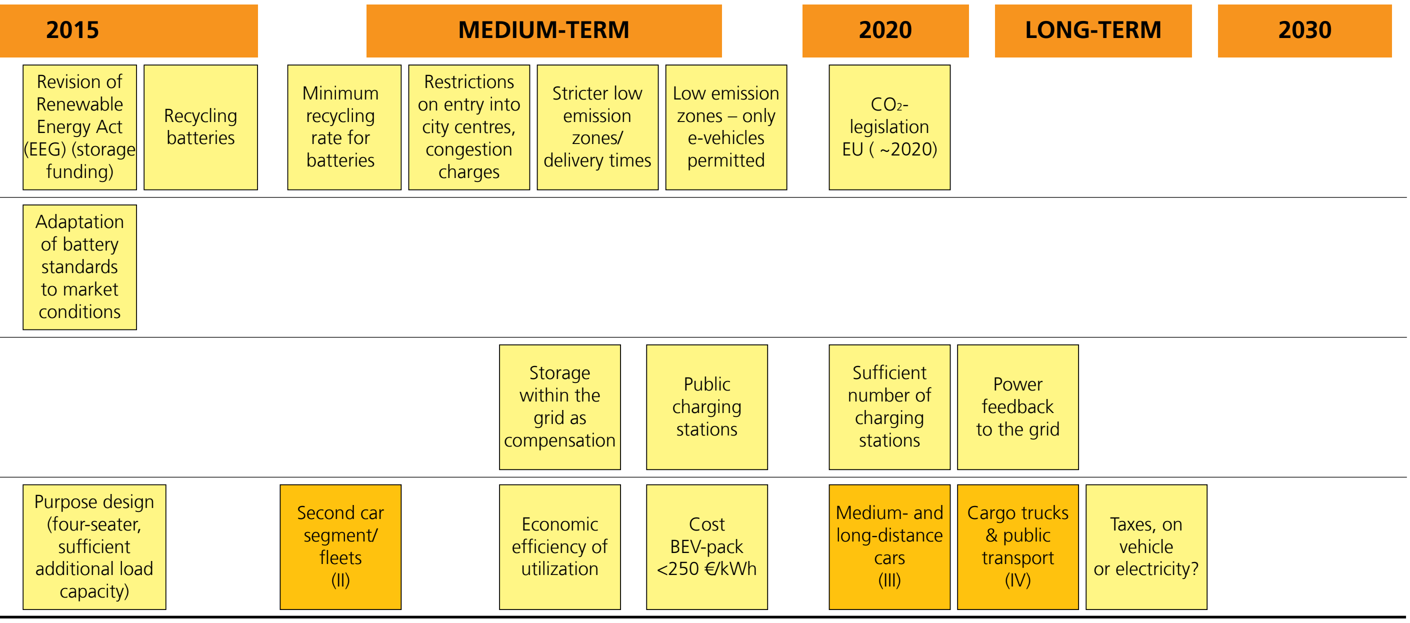
The developments located in the comprehensive overview play a role for both mobile and stationary applications and products and are already expected by the year 2020. Only plausible expectations were estimated for the future.

Several developments discussed in the context of regulation/ legislation affect customer acceptance at the same time: Incentives like using bus lanes and free parking offer potential customer benefits. These regulations can be seen as a programme of incentives for the introduction of electric mobility. Pilot projects are already running in a few large cities, e.g. the introduction of "environmental zones" to reduce speed, emissions and particulates. Stricter exhaust emission standards are expected for certain vehicle classes. In the short term, a number of further measures can be expected, e.g. laws for so-called "zero emission vehicles" (ZEV), which aim to make emission-free driving possible.

Because the aim is to power electric mobility in Germany using (fluctuating) renewable energy, the German Renewable Energies Act (German "Erneuerbare-Energien-Gesetz (EEG)") could be extended and private storage as well as private consumption of energy generated by photovoltaics, for example, could be rewarded. Furthermore, battery recycling is being developed which is oriented more towards sustainability and added value aspects. With regards to norms/standards, German organisations are working mainly on the interfaces between electric vehicles and the charging infrastructure. The development of an overall system for charging batteries has emerged as important in order to give the production companies involved the required planning security.

The design of the electricity grid and the charging infrastructure are key characteristics for developing the infrastructure. Because it is already foreseeable that today's grid will not be able to meet the demand for power up to the year 2020, the EU is thinking about funding the grid and especially how to better integrate renewable energies. Furthermore, it is obvious that the "new" electricity grid has to become more intelligent (keyword: Smart grid). It is expected that the majority of electric vehicles will be charged at home during the market start-up phase, but a large network of public charging stations will be needed with the establishment of a mass market in the medium-term at the latest.

In order to enhance customer acceptance and customer benefits regarding electric vehicles, both monetary and non-monetary support instruments are being discussed politically. There are four main customer groups identified in the roadmap: Ecological premium customers with the so-called "lifestyle of health and sustainability" (LOHAS), company fleets, middle- and long-distance car drivers as well as logistics and public transport companies.



Chronological classification of four potentially significant customer groups for electric mobility (LOHAS = Lifestyle of health and sustainability)

The topic of "taxes" influences economics, too. The costs of operating a car today could be dramatically reduced, e.g. by saving the mineral oil tax and low electricity rates. At the moment, it is not possible to foresee how the German Federal Ministry of Finance will use tax laws to influence this. This question could arise between 2020 and 2030. Germany as an industrial location with an export-based economy is already being indirectly influenced because other countries have already adopted various measures, e.g. regarding regulatory and tax laws to develop the market for electric mobility. For the experts involved, the developments in policies and the market have to be considered always in connection with the energy prices.

An oil price of more than 100 US-dollars per barrel is mandatory to really foster the development of electric mobility. The transition phase until electric mobility can be implemented economically might be managed at lower oil prices by countries with greater financial and investment strengths, like Germany. If the oil price remains below this level for a longer period of time, the development of electric mobility could grind to a halt. In the context of such assessments, other drivers have to be considered such as the political stability regarding raw material supplies. This is one of the reasons why the analytical focus has to be extended to keep an eye on other important world regions, like Asia and especially China.

TIME →		< 2010/2011						SHORT-TERM
PRODUCT REQUIREMENTS Specific application		Two wheeler/ moped	Bus (hybrid)	Cars (HEV)	Cars (BEV)/vans	Cars (PHEV)	Two-wheeler/ moped	Stationary (large/cycl.)
Energy density	Gravimetric	0	–	0	++	+	0	0
	Volumetric	0	0	0	++	++	0	0
Power density	Gravimetric	0	++	++	+	++	0	0 / ++
	Volumetric	0	++	++	+	++	0	0 / ++
Charging time		–	–	–	+	–	–	n/a
Lifetime	Cycle life	–	++ (**)	++	++	+	–	++
	Calendar life	+	++ (**)	++	++	++	+	++
Ambient conditions (temperature)		– –	0	0	+	+	– –	–
Safety		+	++ (**)	++	++	++	+	0
Costs	Investment	+	++	+	+	+	+	++
	Operation	+	++	+	0	+	+	++

PRODUCT REQUIREMENTS

The system boundary was drawn at the module level when assessing the product requirements of single applications and products. The storage system is treated here as a black box, so that an energy storage system can simply be replaced by a second energy storage system. The battery together with a battery management system is treated as a replaceable unit. Cooling modules and energy management systems are not considered.

The experts involved in creating the roadmap rated what they believed to be the most important applications and products of lithium-ion batteries. The results above show the most popular applications and products. Two-wheelers and mopeds were grouped together in one class as were BEV and vans because their profiles are so similar. For the roadmap, the six applications were evaluated regarding their requirements at market entry as well as when a mass market emerges. The rating ranges from not important (--), less important (-) through neutral (0) up to important (+) and very important (++).

For two-wheelers and mopeds, the most important roles are played by calendar life, safety, investment and operating costs because of acceptance and economic reasons. There are no major differences here between market entry and mass market (which already exists).

For HEVs, there are already high requirements at market entry regarding power density, lifetime and safety. For the mass market, only the significance of lower costs is rising. The same picture results for BEVs and vans, although the highest requirements here at market entry concern energy density instead of power density. The cost development is the same for PHEVs, too. Here, the focus is on volumetric energy density, power density, calendar life and safety.

Regarding buses (hybrid), there are especially high requirements at market entry concerning power density and costs. Lifetime and safety are key parameters here. In the case of stationary storage (large, cyclical), it is important which application is being considered. Therefore, a range is given regarding the power density. At the point of market entry, the demands made of lifetime and costs (economics) are especially high. The charging time (hourly, daily, seasonal storage etc.) is not rated as this is not relevant.

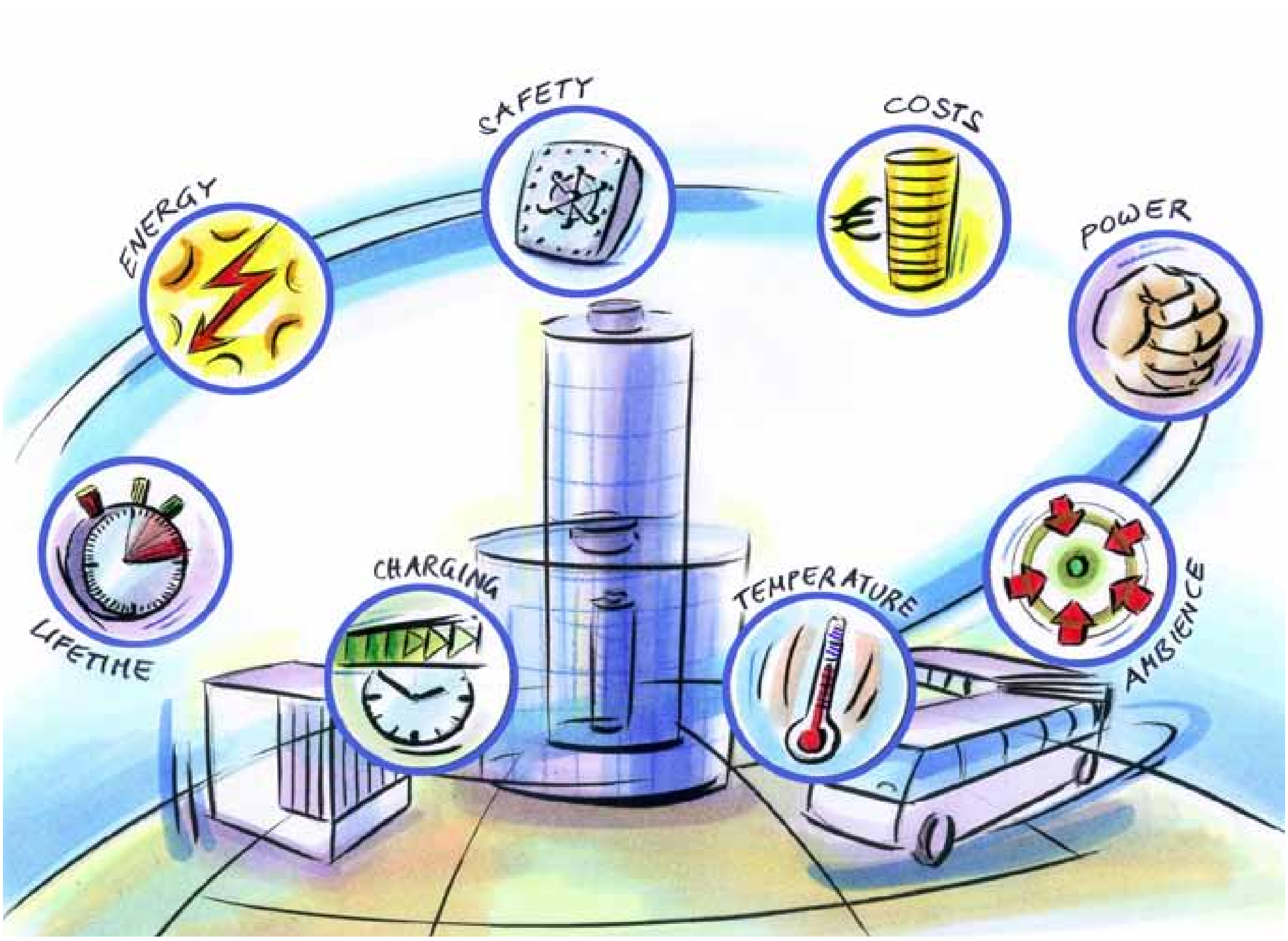
2015 | MEDIUM-TERM | 2020 | LONG-TERM | 2030

Bus (hybrid)	Cars (HEV)	Cars (BEV)/vans	Cars (PHEV)	Stationary (large/cycl.)
+	+	++	+	0 / +
0	+	++	+	0
++	++	++	++	0 / +
+	++	+	++	0
0	0	+ (**)	+	n/a
++	++	++	+	+ / ++ (**)
+ / ++	+ / ++	++	++	++
+	+	+	+	0
++ (**)	++ (**)	++ (**)	++ (**)	0
+	++	++ (**)	++	+
++	++	++	++	+ / ++

(**) Key parameters

Assessment of requirements of selected applications regarding particular properties in mutual comparison as well as in relation to other applications at the time of market entry and mass production

0 neutral (corresponds to: Requirement fulfilled)
+ important **++** very important
– less important **– –** unimportant



CONCLUSION AND OUTLOOK

CONCLUSION

Depending on the scenario and its underlying framework conditions, between 50 and more than 70 percent of lithium-ion batteries are expected to be used in electric mobility applications in the next 10 years, alongside stationary applications and mobile or portable electronic products. Various market forecasts are expecting the global market for rechargeable lithium-ion batteries to triple by 2015 alone.

Battery applications reach from small to large electric vehicles ranging from only a few to more than 25 kilowatt hours, for example mopeds, electric scooters, cars, buses up to diverse machines, as well as small to large centralized/decentralized stationary applications up to the megawatt hour range. Hybrid (high power) and traction (high energy) applications can also be distinguished. In this context, BEV and PHEV developments will also foster other applications, e.g. vans, which is why the markets and market volumes in different applications are interdependent. The battery parameter requirements vary with the applications, as do the material developments to optimise the battery parameters. The product roadmap shows the wide range of applications, their dependencies and framework conditions, and the requirements for lithium-ion batteries.

UPDATING THE ROADMAP ...

The product roadmap lithium-ion batteries 2030 is a work in progress in terms of it being continuously refined and updated. The Fraunhofer ISI has set up a project website, which can be used to comment on the roadmap and make suggestions for its further development. The roadmap can be downloaded at: www.isi.fraunhofer.de/prm-libroad.php.

In late 2012, the current product roadmap was combined with the technology roadmap lithium-ion batteries 2030, which was published in 2010 and updated in 2011, to produce the overall comprehensive roadmap lithium-ion batteries 2030.

... AND THE NEXT STEPS

The envisaged comprehensive roadmap will combine market and technology perspectives complemented by overarching and encompassing developments, for example due to the funding instruments important for a successful market acceleration. Another objective of the comprehensive roadmap is to dovetail market-based and technological aspects with resource aspects and e.g. to include aspects of the life cycle assessment implied by putting the entire lithium-ion battery system in an electric mobility context. In addition, safety aspects and initial production-related issues concerning reliability and availability will be taken into account. These include quality assurance issues from the supplier right up to the vehicle manufacturer.

RELATED PROJECTS ON ELECTRIC MOBILITY

The Fraunhofer ISI is involved in a number of research projects concerning electric mobility, each with a specific area of focus. The spectrum ranges from a systemic approach examining the socio-economic aspects of electric mobility through issues of energy supply, the organisation of charging infrastructures and the development of battery and vehicle concepts right up to new mobility concepts and user acceptance.

PROJECTS

PROJECT	MAIN FOCUS OF FRAUNHOFER ISI	FUNDING
Roadmapping project accompanying the innovation alliance "Lithium ion batteries 2015" (LIB 2015)	Roadmapping regarding the technology- and market-related development possibilities for lithium-ion batteries (LIB)	BMBF
Energy storage monitoring for electric mobility (EMOTOR)	Project with focus on technology monitoring within the priority programme "Key technologies for electric mobility" (STROM)	BMBF
Fraunhofer System Research on Electric Mobility (FSEM)	Socio-economic study accompanying the Forum Electric Mobility	BMBF
Social science study accom-panying the model regions	Setting up a social sciences platform, customer acceptance analyses	BMVBS
Minimum Emission Region Mobile (MeRegioMobil)	Business models, acceptance control, focus on smart homes	BMWi
Fleet trial electric mobility	System integration of renewable energies by electric mobility	BMU
Innovation report "System perspective of electric mobility"	Concepts of electric mobility and their importance for the economy, society and the environment	TAB
Comparison of electricity and hydrogen as CO_2-free final energy sources	Comparison of the final energy sources named for mobile and stationary applications	RWE AG
Regional Eco Mobility (REM) 2030	Development of a concept for and implementation of an efficient regional individual mobility for 2030	FhG, federal state of Baden-Wuerttemberg

GLOSSARY

Balancing power
In the case of unforeseen disturbances in the grid, the provision of balancing power guarantees an uninterruptible power supply, e.g. through short-term performance regulations of adjustable power plants. In the future, stationary energy storage on an electrochemical basis will also contribute to this.

BEV
Abbreviation for "battery electric vehicle": A vehicle which is powered electrically by a rechargeable battery.

Black start
In the case of a black start, a power plant is started independently of the electricity grid. Since the necessary energy for this can neither be provided by the power plant itself nor by the electricity grid, the utilization of large stationary energy storage on an electrochemical basis is recommended.

BMBF
Abbreviation for "Bundesministerium für Bildung und Forschung", the German Federal Ministry of Education and Research. In January 2013, headed by Professor Dr. Annette Schavan (CDU).

BMU
Abbreviation for "Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit", the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. In January 2013, headed by Peter Altmaier (CDU).

BMVBS
Abbreviation for "Bundesministerium für Verkehr, Bau und Stadtentwicklung", the German Federal Ministry of Transport, Building and Urban Development. In January 2013, headed by Dr. Peter Ramsauer (CSU).

BMWi
Abbreviation for "Bundesministerium für Wirtschaft und Technologie", the German Federal Ministry of Economics and Technology. In January 2013, headed by Dr. Philipp Rösler (FDP).

Centralised energy storage
In this case, electricity is generated in large, centralised power plants and then distributed to decentralised consumers. Centralised energy storage usually has to be much larger than decentralised storage since more energy has to be stored if there is no demand at a particular moment in time.

Comprehensive roadmap
A variation of the general term "roadmap", which aims to integrate a technology roadmap and a product roadmap in such a way that the gap between what the technology has to accomplish and what the market is demanding can be determined and the resulting challenges can be identified.

Cyclical energy storage
Energy storage which is charged and discharged in a regular cycle. Its cycle life has to be high, in order to ensure that many charging cycles can be performed. The calendar life should be high, too, similar to non-cyclical energy storage.

Decentralised energy storage
The characteristic feature of decentralised electricity generation is that energy is generated and stored close to the consumer, in both private and industrial utilization. The concept is considered to be modern and sustainable; unneeded surpluses can be fed into the main electricity grid. In comparison to centralised energy storage, decentralised energy storage is usually on a smaller scale.

EEG
Abbreviation of the "Erneuerbare-Energien-Gesetz", the German Renewable Energies Act, which became effective on 1 April 2000 and aims to reduce the dependency on fossil energy sources and nuclear power for electricity generation and to protect the climate by supporting renewable energies.

Emergency back-up power
In order to guarantee the continuous operation of essential facilities or infrastructures in case of a blackout, power units based on combustion are commonly used at present to generate and provide electricity. In the future, the latter can also be done using electrochemical energy storage.

E-vehicles
One of several terms used for vehicles driven by electrical energy.

EU
The European Union (EU) is made up of 27 European countries as of November 2012 with a total population of around 500 million.

Euro III
The Directive 70/220/EEC in the amendment 98/69/EC is an exhaust emission standard applied within the EU. It stipulates for which vehicle and engine types which emission limit values

are permitted for carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (HC) and other particulates (PM). The further tightening of these emission limits should help to protect the environment in the EU and slow down climate change worldwide. At the moment, the older directive Euro II still applies to mopeds, which have only been covered since 1 January 2006.

Euro IV
The directive 70/220/EEC in the amendment 98/69/EC is an exhaust emission standard applied within the EU. It stipulates for which vehicle and engine types which emission value limits are permitted for carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (HC) and other particulates (PM). The further tightening of these emission limits should help to protect the environment in the EU and slow down climate change worldwide.

FhG
The Fraunhofer-Gesellschaft is Europe's largest organization for applied research with more than 22,000 staff, the majority of whom are qualified scientists and engineers. It undertakes applied research of direct utility to private and public enterprises and of wide benefit to society in more than 80 research units throughout Germany, including 66 Fraunhofer Institutes.

HEV
Abbreviation for "hybrid electric vehicle": A vehicle driven by at least one electric motor and one additional energy converter (e.g. a conventional internal combustion engine with petrol or diesel).

IT
Abbreviation for "information technology".

kWh
Abbreviation for the physical unit of kilowatt hours.

Lead
Lead-acid batteries with electrodes of lead and lead oxide and an electrolyte of diluted sulphuric acid.

LIB
Abbreviation for "lithium-ion battery": An electrochemical energy storage technology. It is used for the plural term as well.

LIB 2015
An industrial consortium of BASF, BOSCH, EVONIK, LiTec and VW formed an innovation alliance on 5 November 2007, "Lithium-ion batteries LIB 2015", and pledged to invest 360 million euros in the research and development of lithium-ion batteries. This will be supplemented and complemented by funds from the BMBF to the tune of 60 million euros in the next four years for research in this field.

Load management
Load management aims to calibrate the energy supply as optimally as possible, e.g. of a power plant in relation to the energy demand by temporarily decoupling or storing surplus energy to improve capacity utilization.

LOHAS
Abbreviation for "lifestyle of health and sustainability", the term is used for consumer groups that cultivate lifestyles focusing on health and sustainability.

MWh
Abbreviation for the physical unit of megawatt hours.

Non-cyclical energy storage
Energy storage which is not charged and discharged in regular cycles. Its calendar life has to be as long as that of cyclical energy storage, but not its cycle life.

NPE
Abbreviation for National Platform Electric Mobility. An expert panel which has been advising the German government since May 2010 and making recommendations on how to implement electric mobility in Germany. It is made up of representatives of academia, associations, industry, policy makers and trade unions.

N1
This abbreviation is part of the EU's vehicle classification scheme and, according to EC Directive 70/156/EEC, denotes a vehicle with a gross vehicle weight of not more than 3.5 t and at least four wheels used for transporting goods.

PHEV
Abbreviation for "plug-in hybrid electric vehicle": A vehicle with a hybrid engine whose battery can also be charged externally via the electricity grid. Since it often has a larger built-in battery than a hybrid electric vehicle, it represents a mix between the latter and an entirely electric vehicle.

Product roadmap
A variation of the general term "roadmap", which aims to document the development of market requirements, e.g. for a certain technology.

Roadmap
The term roadmap is generally used for a preparatory project plan in which the steps to be carried out are mapped far into the future. There are 27 different types of roadmaps, e.g. product roadmap or technology roadmap. Their common feature is that creating them reveals dependencies between the individual steps and therefore risks and uncertainties.

RWE
The RWE AG is one of the largest electricity suppliers in Germany. Until 1990, it was called the "Rheinisch-Westfälische Elektrizitätswerk AG" and its head office is located in Essen.

TAB
The Office of Technology Assessment at the German Bundestag (TAB) is an independent scientific institution which advises the German Bundestag and its committees on questions of research and technology change.

Technology roadmap
A variation of the general term "roadmap" which aims to document technological progress.

ZEV
Abbreviation for "zero emission vehicle".

3.5 t
Indicates compact vans up to and including a valid weight of 3.5 tonnes within the roadmap.

7.5 t
Indicates compact vans up to and including a valid weight of 7.5 tonnes within the roadmap.

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