Electromobility and Employment

ELAB
Elektromobilität und Beschäftigung

ELAB-study:
Impact of the Electrification of Power trains on Employment

Electromobility – impact on employment

IndustriALL Automotive Working Group Meeting

2012-09-12 / St. Petersburg

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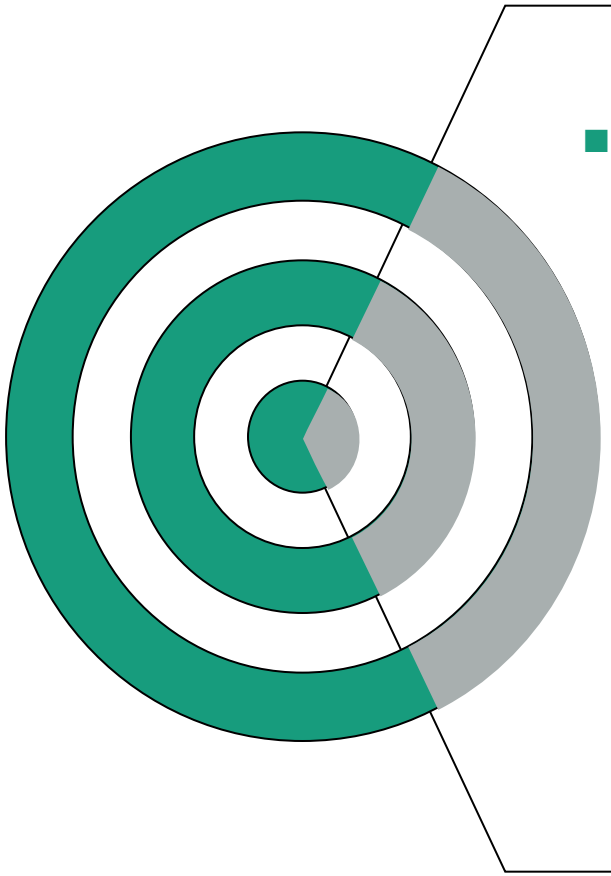
Fraunhofer IAO

Agenda

- Overview: the ELAB research project
- Concepts of power trains and scenarios
- Manufacturing processes and staff requirement
- Quantitative effect analysis
- Qualitative effect analysis
- Summary

Questions of the research project ELAB



- **Central question:**
  What are the effects on employment resulting from the electrification of the drive train?

  - *How much work is connected to the production of the various propulsion concepts?*
    Quantitative employment effects

  - *How do changes in power trains affect contents and skill requirements?*
    Qualitative employment effects

Approach of the research project

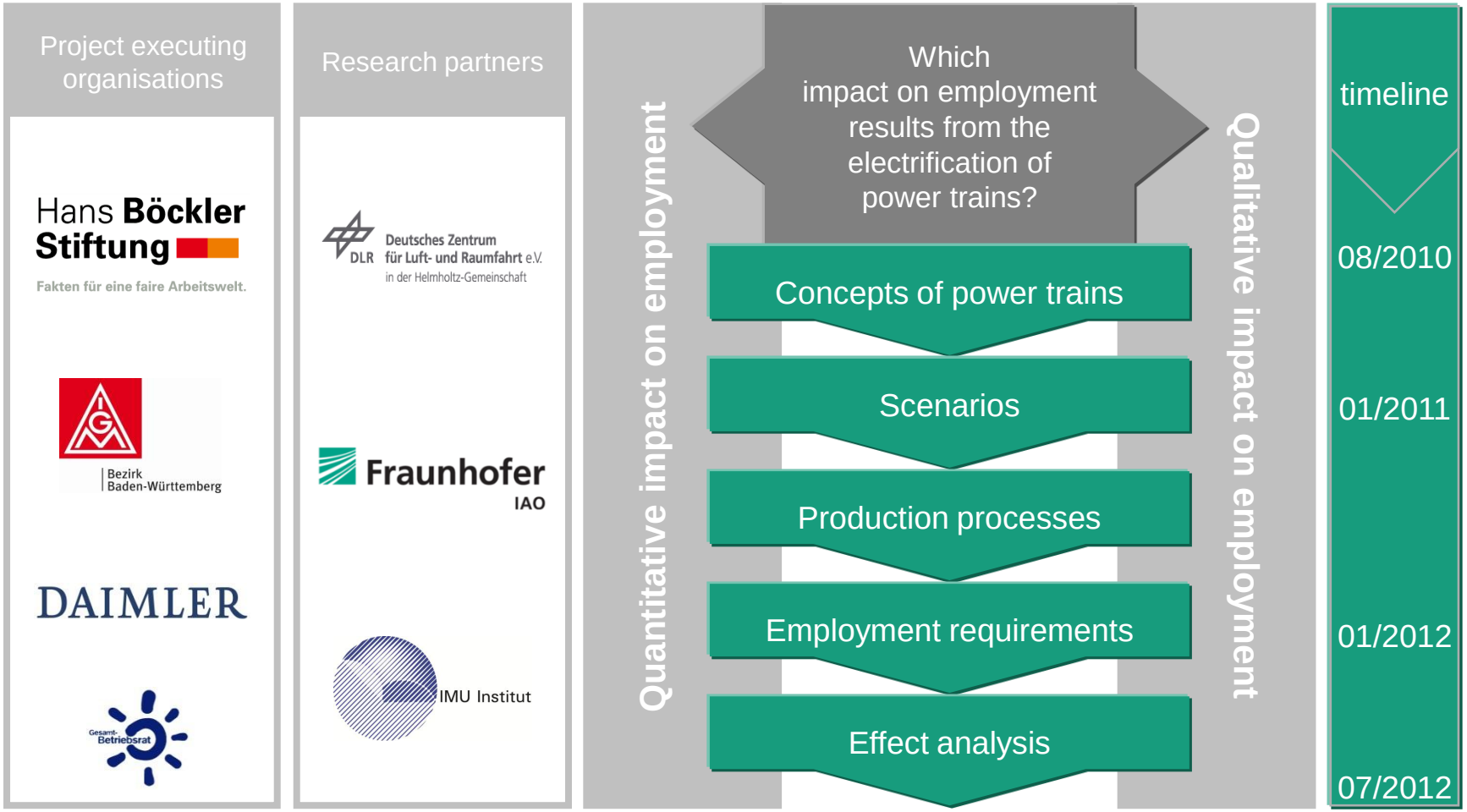
For editing the project task the multilayered contexts were divided into three main areas of investigation:

1. **Characterization of power train concepts** and their transformation by electrification on the component level

2. **Modeling of the production processes** of power train components in terms of manufacturing steps, plant technology, value added contributions and required staff

3. **Effect analysis** of production, added value and occupation based on scenarios for diffusion of alternative drives

Project structure



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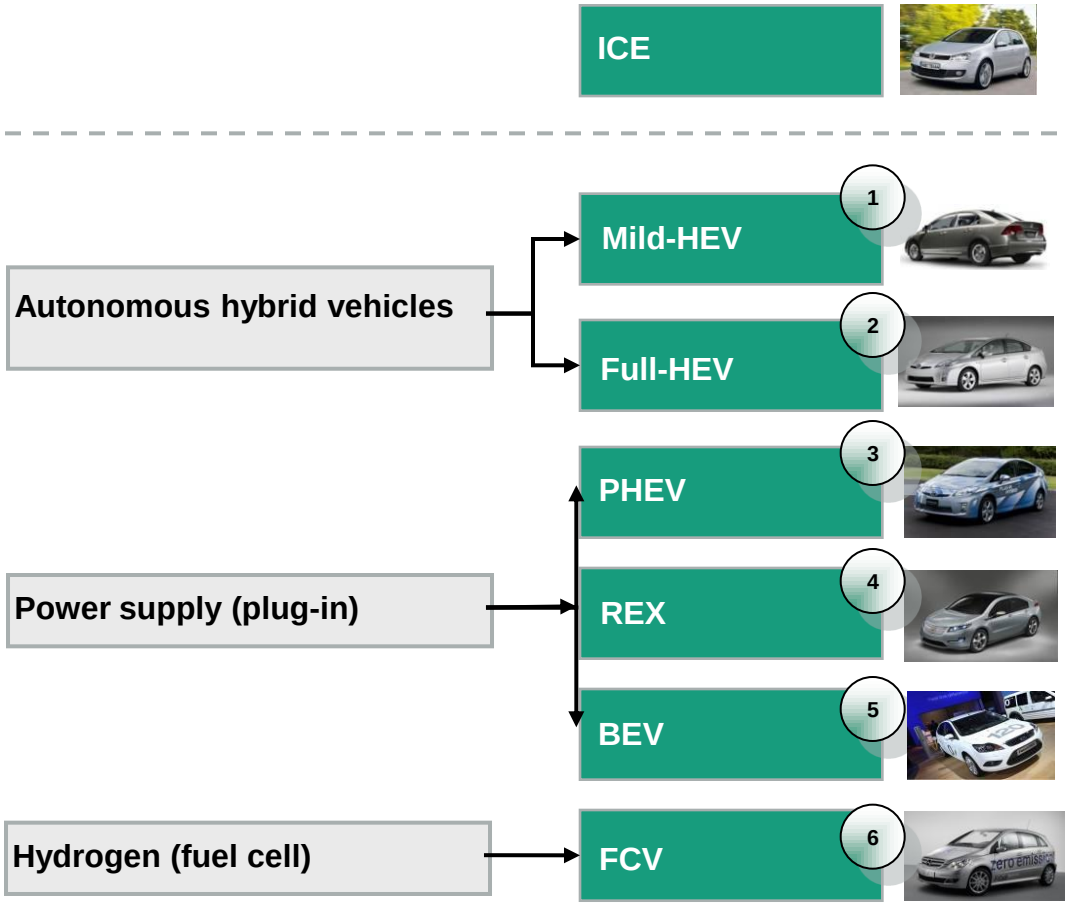
ELAB drive concepts

- **6 alternative power train concepts** were considered
- Each concept was based on a **reference power train**
- Each power train is defined by characteristic **systems**
- Systems consist of **subsystems, components** and **product components**
- Product components were analyzed regarding **materials** and **manufacturing categories**
- New, modified or no longer needed components will be identified for each reference drive train



BEV: Batterieelektrisches Fahrzeug (Battery Electric Vehicle), FCV: Brennstoffzellenfahrzeug (Fuel Cell Vehicle), HEV: Hybridfahrzeug (Hybrid Electric Vehicle), PHEV: Hybridfahrzeug mit Aufladeмöglichkeit (Plug-in Hybrid Electric Vehicle), ICE: Verbrennungsmotorbasiertes Fahrzeug (Internal Combustion Engine), REX: Elektrofahrzeug mit Reichweitenverlängerung (Range-extended Electric Vehicle)

ELAB analysis of components

ELAB-related systems were analyzed to the component level and used for reference drive concepts.

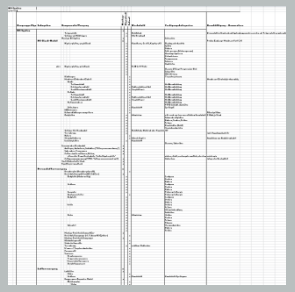
Element analysis:

- System **combustion engine**
- System **automatic transmission**
- System **hybrid transmission**
- System **electrical machine**
- System **power electronics**
- System **battery “pouch-cell”**
- System **fuel cell**
- System **hydrogen pressure tank**

Comparative analysis:

- System **Two-Mode transmission**
- System **battery “round cell"**

Excel databases built, input for analysis of production processes



ELAB analysis of components

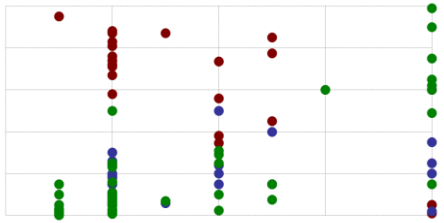
Excerpt and summary of new / modified systems by 2030

Components \ Concepts of vehicles	ICE	Mild-HEV	HEV	REX	BEV	FCV
	Veränderungen der Systeme bis 2030					
International combustion engine	modified	modified	modified	modified	dropped	dropped
Starter & generator	modified	modified	modified	modified	dropped	dropped
Exhaust gas system	modified	modified	modified	modified	dropped	modified
Fuel supply	modified	modified	modified	modified	dropped	modified
Transmission	modified	modified	modified	modified/ dropped	modified/ dropped	modified/ dropped
Electrical machine		new	new	new	new	new
Battery system		new	new	new	new	new
Power electronics		new	new	new	new	new
Fuel cell system						new

ELAB market scenarios

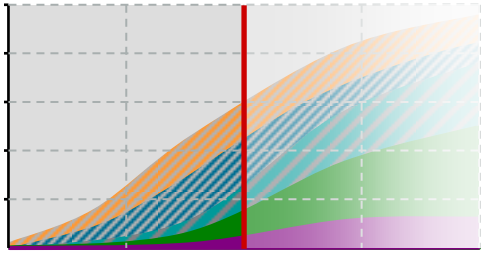
Methodology: Based on a comprehensive meta analysis a reference scenario and three sensitivity scenarios were defined

Meta analysis



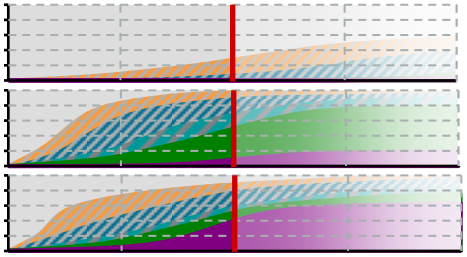
- Analysis of different published scenarios
  - Politics
  - Research facilities
  - Industry
- International orientation

Reference scenario



- Based on the summary of the studies reviewed
- Relevant period of time: 2030
- 6 types of drive trains were analyzed

Alternative scenarios



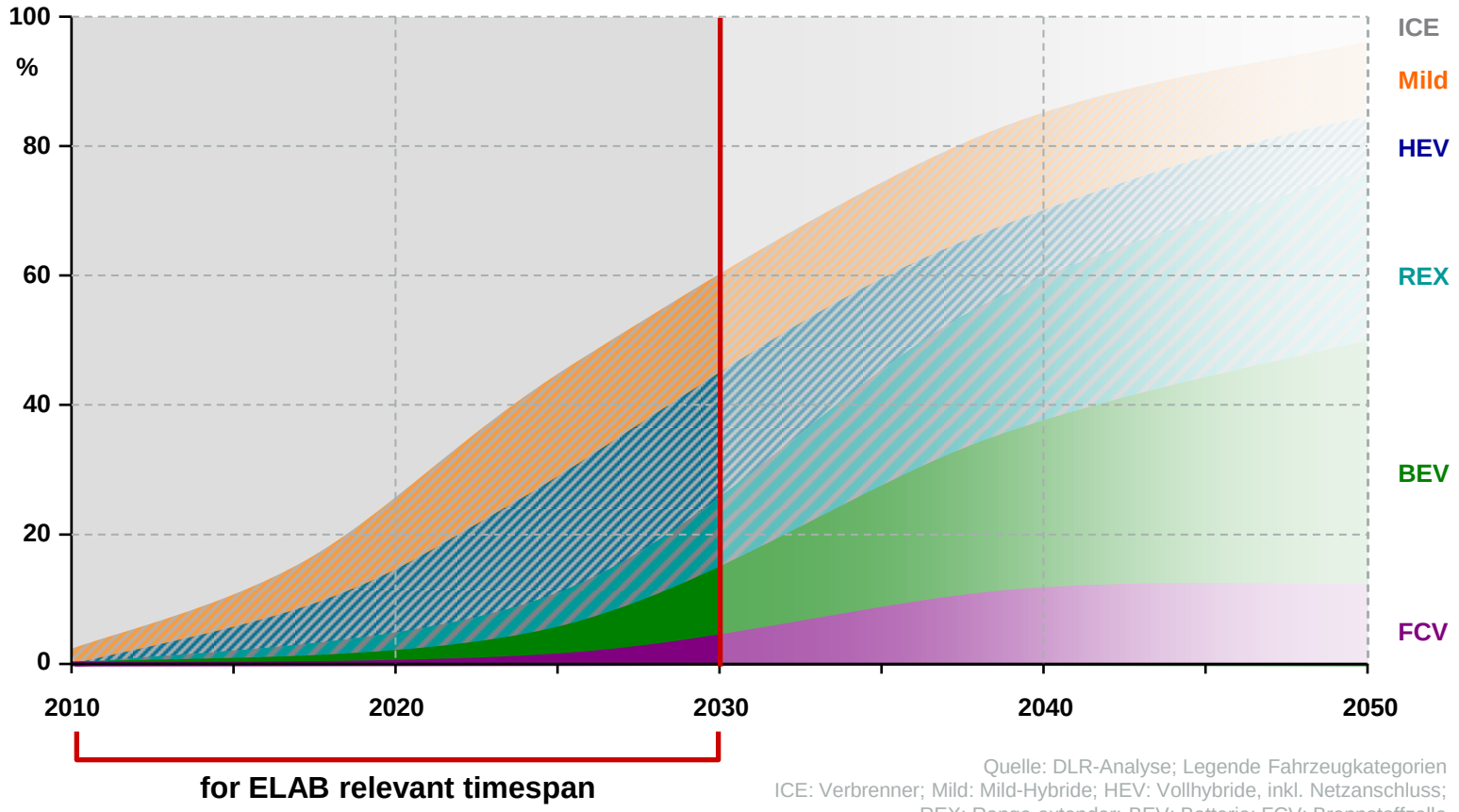
- Definition of 3 ‚what-if' scenarios
  1. Conservative: ICE
  2. Progressive: BEV
  3. Progressive: FCV
- Extreme scenarios for conduction of consequences

ELAB reference scenario

The ELAB reference scenario is based on a summary of the reviewed studies

2030	[%]
ICE	40
Mild	15
HEV	20
REX	10
BEV	10
FCV	5

Market shares of ELAB reference scenario [%] (market for new cars, worldwide)

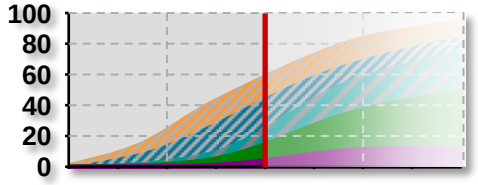


Quelle: DLR-Analyse; Legende Fahrzeugkategorien
ICE: Verbrenner; Mild: Mild-Hybride; HEV: Vollhybride, inkl. Netzanschluss;
REX: Range-extender; BEV: Batterie; FCV: Brennstoffzelle

ELAB alternative scenarios

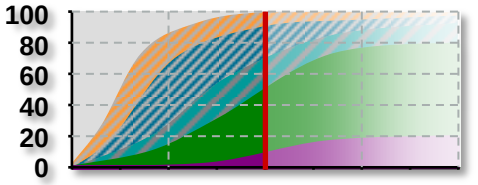
The three ‚what-if' scenarios are used to estimate the consequences and reflect future extreme developments

Reference



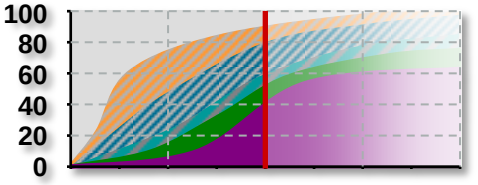
- The scenario, as a summary of the studies reviewed, represents a 'best-guess' scenario.
- The assumed development meets the political objectives and is realistically possible.

BEV



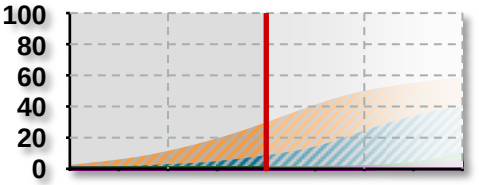
- The first extreme assumes a dominance of battery electric vehicles (BEV).
- Under dramatically increased conditions, particularly by the oil price and the CO_2 legislation, this scenario is conceivable.

FCV



- Dominance of fuel cell vehicles (FCV) represents an extreme case, imaginable only under very special conditions.
- Especially H_2-infrastructure and high vehicle costs currently represent a barrier.

ICE



- ICE scenario (internal combustion engine) represents a conservative extreme case.
- Currently it cannot be assumed that until 2030 **no** all-electric vehicles enter the market.

Quelle: DLR-Analyse

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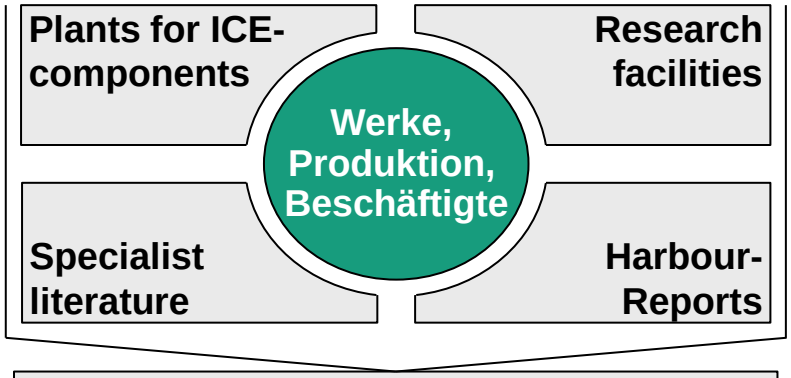
Procedure for inquiry of personnel requirements in drive train production

conventional components:

Personnel requirement for a large number of items is known

Data was able to be collected and further processed

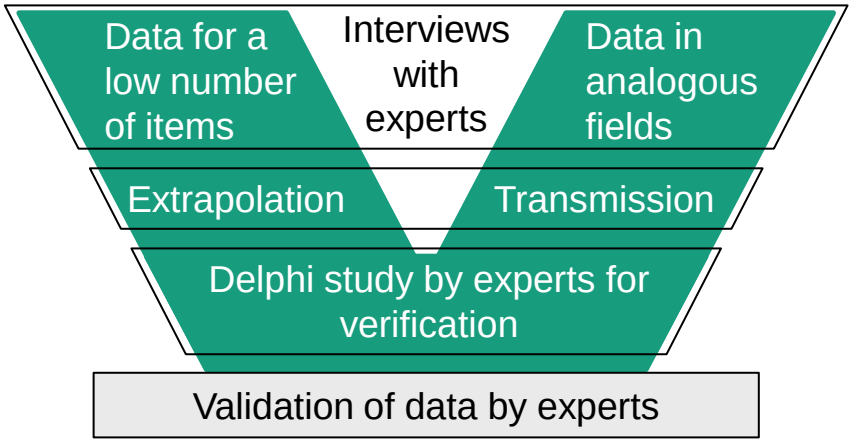


Reuniting of received data and validation by experts

New components:

Personnel requirements only known for low numbers of items or from other sectors

Data was collected for a low number of items and extrapolated or collected in analogous fields and transferred



Validation of data by experts

Number of employees (direct / indirectly close to production/ indirect) on component level

Results: Net personnel requirement

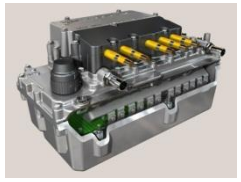
Personnel requirements of various components at different production volumes

Personnel total demand (net)	Value based In-house rate	Production volume				
		30.000	100.000	250.000	500.000	1.000.000
International combustion engine 100kW	20%			**438**		**1.577**
Automatic transmission 8-gear	45%			**714**		**2.541**
Hybrid transmission 8-gear (ohne Fertigung E-Maschine)	40%			**679**		**2.416**
Electrical machine (distributed winding) 100kW	50%		**110**		**328**	
Electrical machine hybrid transmission 30kW	45%		**63**		**144**	
Power electronics (inverters, converters) 100kW	55%		**117**		**216**	
High performance battery system (round cell) 5kWh	30%	**35**	**76**			
High energy battery system (pouch cell) 20kWh	25%	**37**	**84**			
Fuel cell system (PEM) 100kW	50%	**109**	**224**			
Hydrogen pressure tank 2kg	60%	**64**	**79**			







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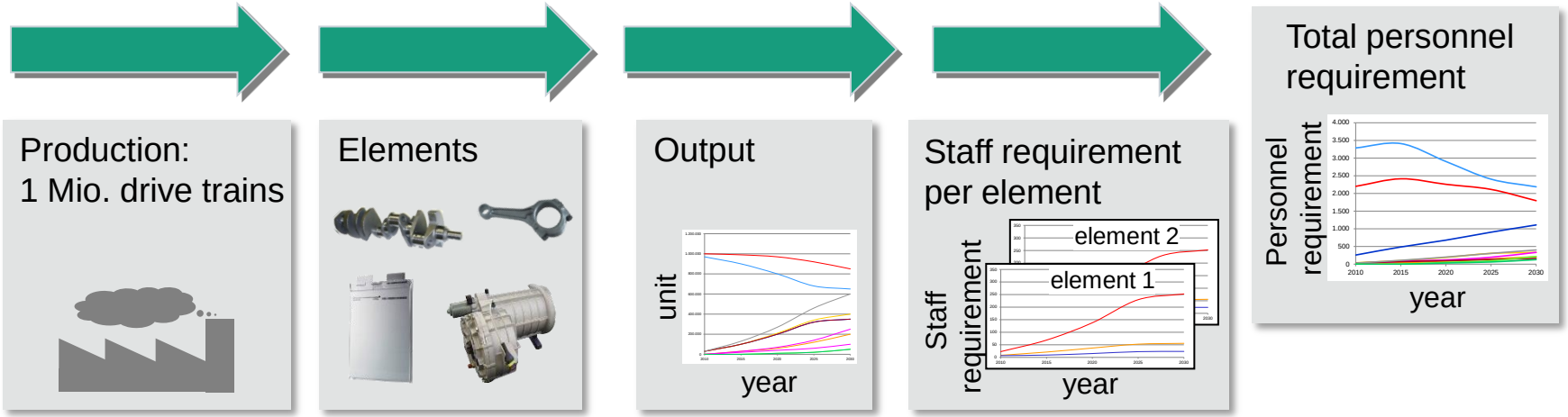
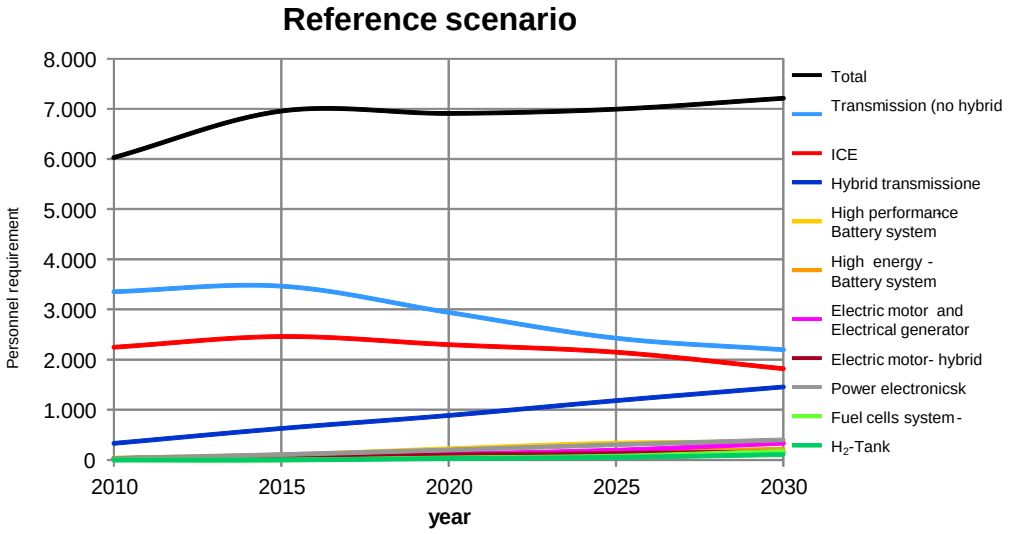
Determination of the total personnel requirements

- Assumption: Fixed production capacity of 1,000,000 drive trains.
- Components of defined reference drive trains are considered.
- The production volume of components depends on diffusion scenarios.
- The production of a drive train component requires a certain personnel requirement.
- The sum of the required staff for production of components results in the total personnel requirement.



Quintessence: reference scenario

Total personnel requirement for reference scenario



Reference scenario: old and new elements in total lead to an increase in personnel requirements in the idealized drive train production.

Total personnel requirement increases.

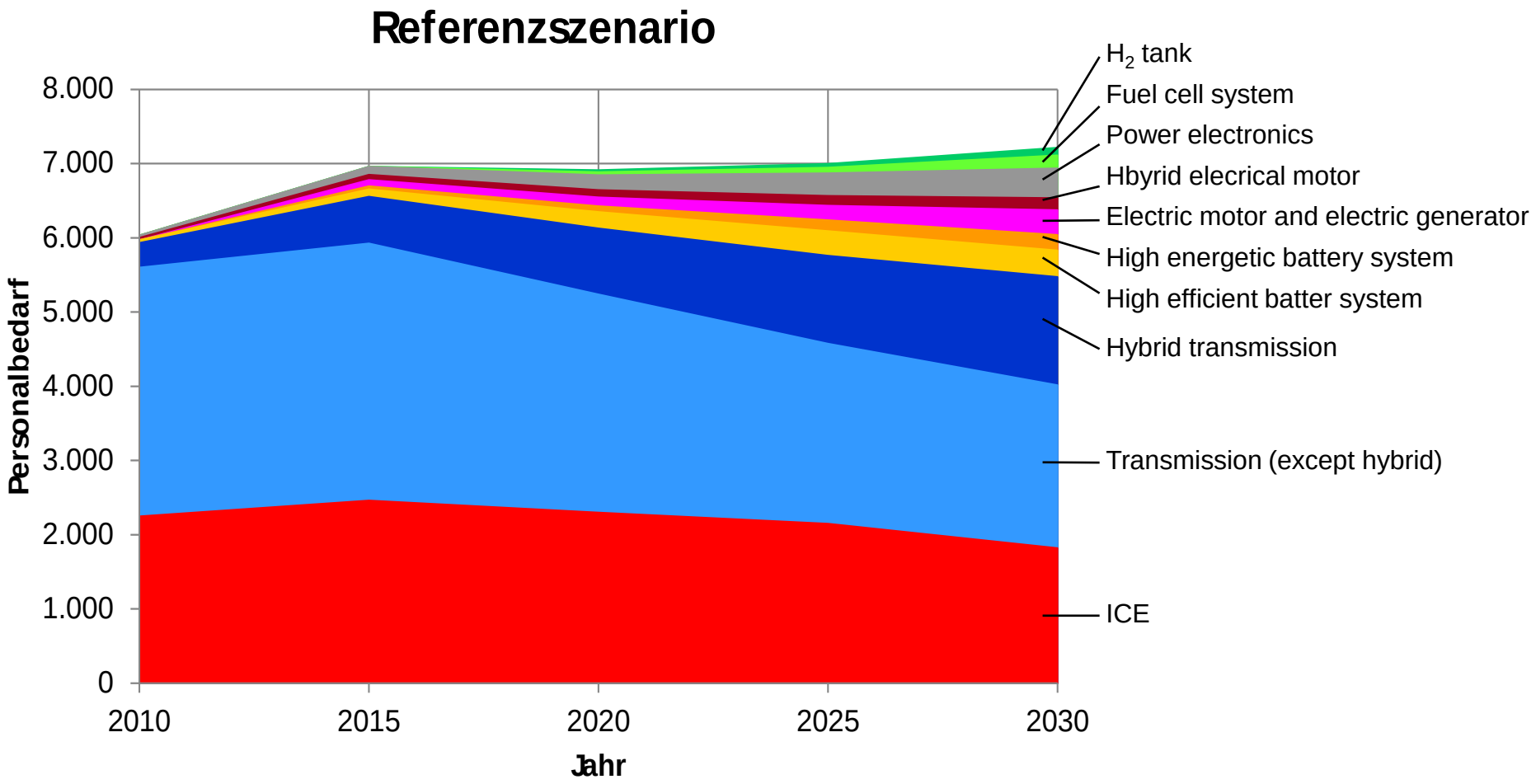
In this scenario the total number of staff required ranges from 6.000 to 7.200.

3 phases can be determined in the reference scenario:

- The first phase (2010 to 2015) shows a strong increase of the total demand. Requirements for conventional transmission components (except hybrids) and ICE increase slightly, while adding new components. The increase in manpower requirements arise due to the fact that production figures for ICE, Mild and HEV are supplemented by the ICE of REX and the transmission of REX and BEV. For this purpose new lines are built. Therefore, the personnel requirements increases, despite the very small market share of the concepts BEV and REX (together 3% in 2015).
- From 2015 to 2020 requirements of new components will continue to increase, but there is a decrease in the conventional components (except hybrid transmission). The total demand falls slightly..
- In the third phase (2020 to 2030) the element of hybrid transmission will experience an increase, compensating the loss of the automatic transmission. All other new components increase slightly stronger. This leads to a slight increase in the overall staffing requirements.

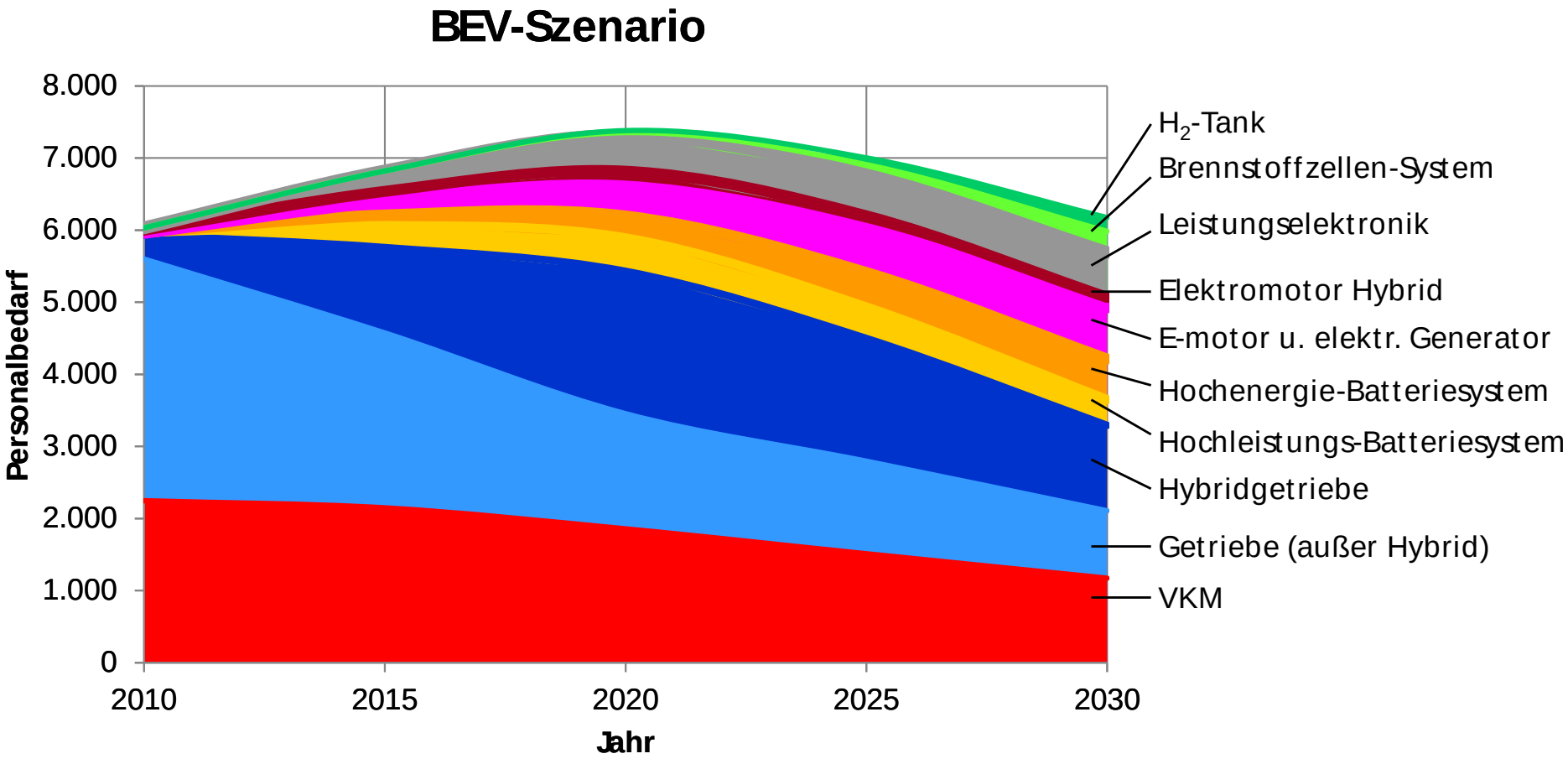
Total staffing requirements for all components

in an idealized drive train production in the reference scenario



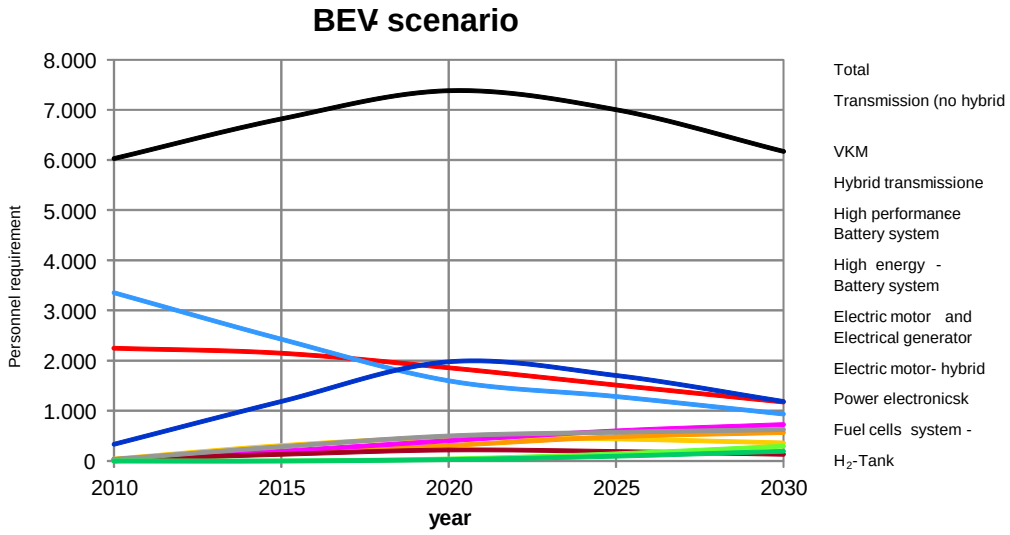
Quintessence: BEV-scenario

Total personnel requirements for the BEV scenario



Quintessence: BEV-scenario

Total personnel requirements for the BEV scenario



BEV scenario: reduced personnel requirements in an ideal-typical drive train production following a significant rise back to the initial state.

Total demand for employees remains static.

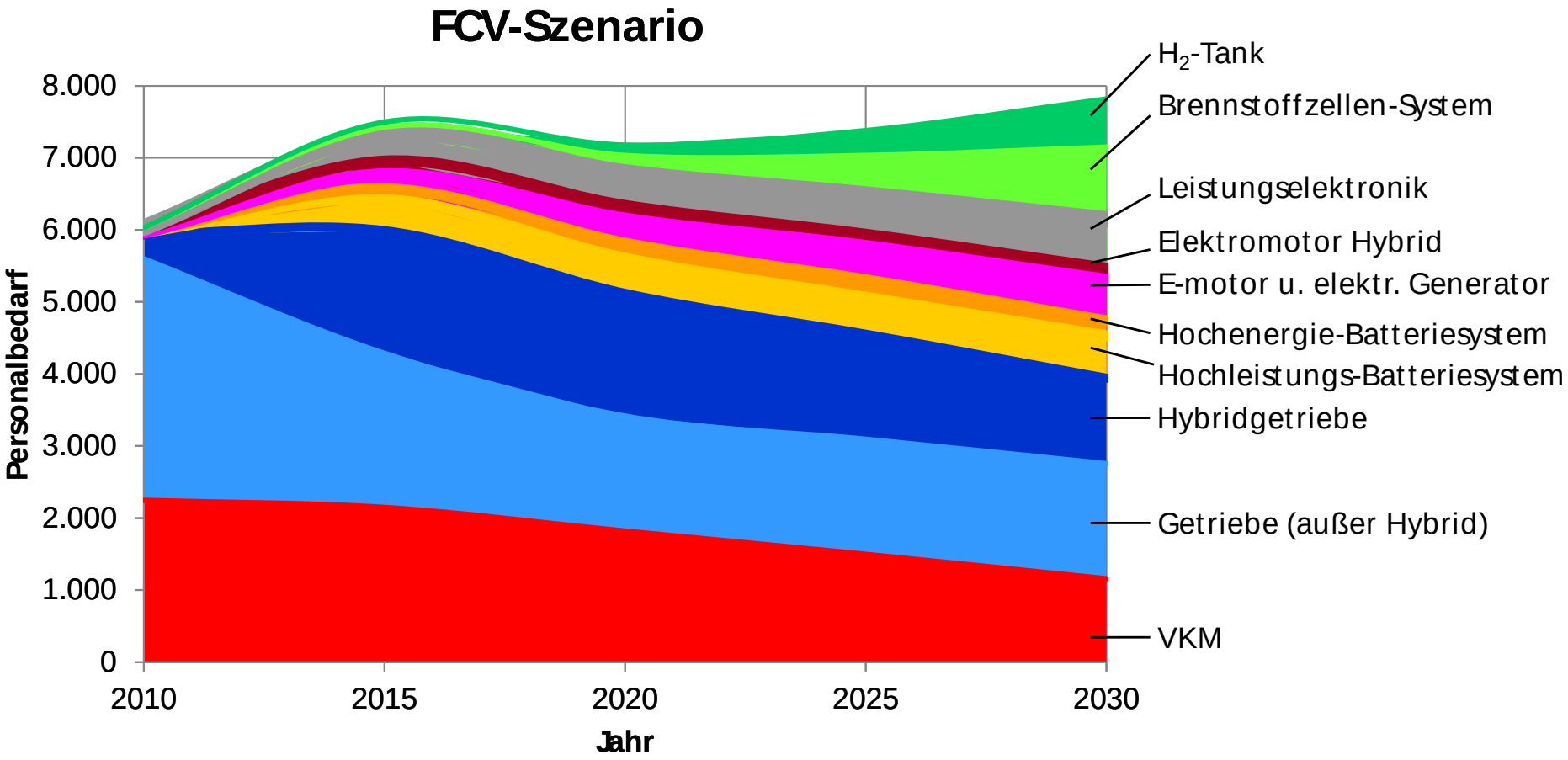
In this scenario the total number of staff required ranges 6.000 to 7.400.

In the BEV scenario, a drastic decline in the ICE drivetrain concept is expected. Two phases are apparent:

- From 2010 to 2020 the total staffing need increases as the component hybrid transmission and the new components compensate the decrease of the transmission component (except hybrids). By 2020, the internal combustion engine component falls only slightly.
- From 2020 the needs of the hybrid transmission elements also decrease, as the proportions of the drive train concepts with hybrid drive (HEV and Mild) decreases, too, in favor for the concept of BEV. Moreover, the demand for the component of the internal combustion engine will be higher than before. The total personnel requirements decrease for these reasons, which is not compensated by the fact that the personnel requirements increases for all new components except the high-performance battery and electric motor hybrid system.

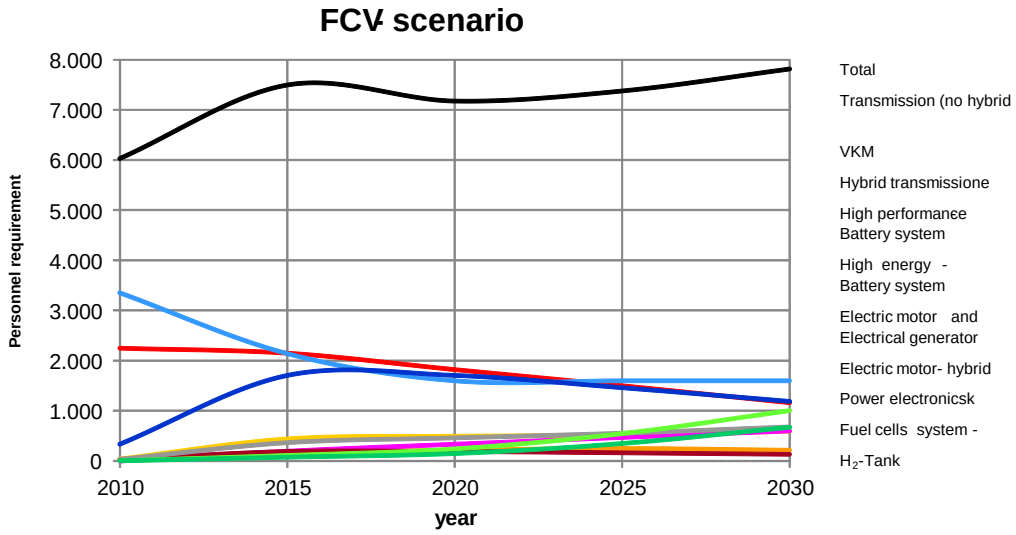
Quintessence: FCV-Scenario

Total personnel requirement for the FCV scenario



Quintessence: FCV-scenario

Total personnel requirement for the FCV scenario



FCV scenario: the personnel requirements increases in an idealized drive train production significantly above the initial level.

In this scenario the total employee requirement varies but increases greatly.

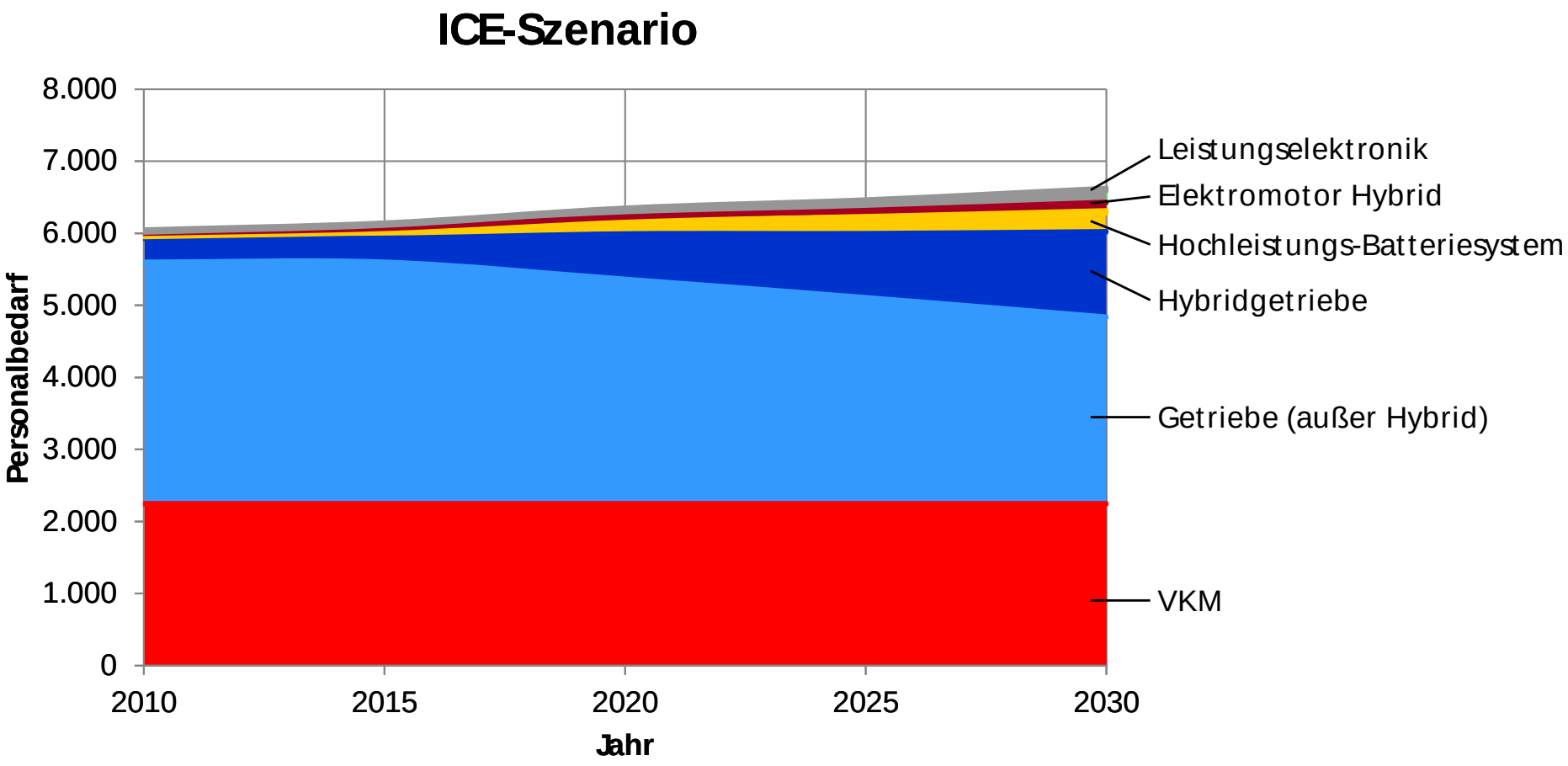
In this scenario the total number of staff required ranges from 6.000 to 7.800.

In the FCV scenario 3 phases occur:

- From 2010 to 2015 the overall staffing needs increase, because the reduction of the transmission component (excluding hybrid) is compensated by an increase in the hybrid transmission component (compare production figures of vehicle concepts in ELAB scenarios). In particular, increases in the power electronics component and high power battery system component lead to an increase in the overall staffing requirements.
- From 2015 to 2020 total staffing requirements decrease, as the needs for the hybrid transmission component and power electronics component decrease now.
- From 2020, requirements for the components of fuel cell system and hydrogen tank system arise noticeably stronger than before, which outweighs the other declines.

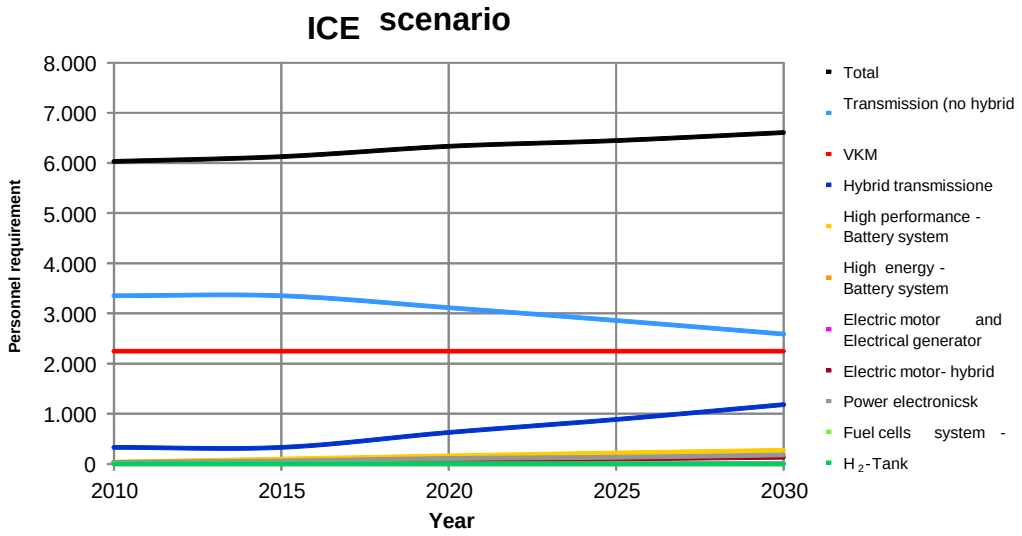
Quintessence: ICE-scenario

Total personnel requirement for ICE scenario



Quintessence: ICE-scenario

Total personnel requirement for ICE scenario



ICE scenario: in an ideal type of drive train production, staff requirements increase slightly above the initial level.

The total demand is rising slowly but steadily.

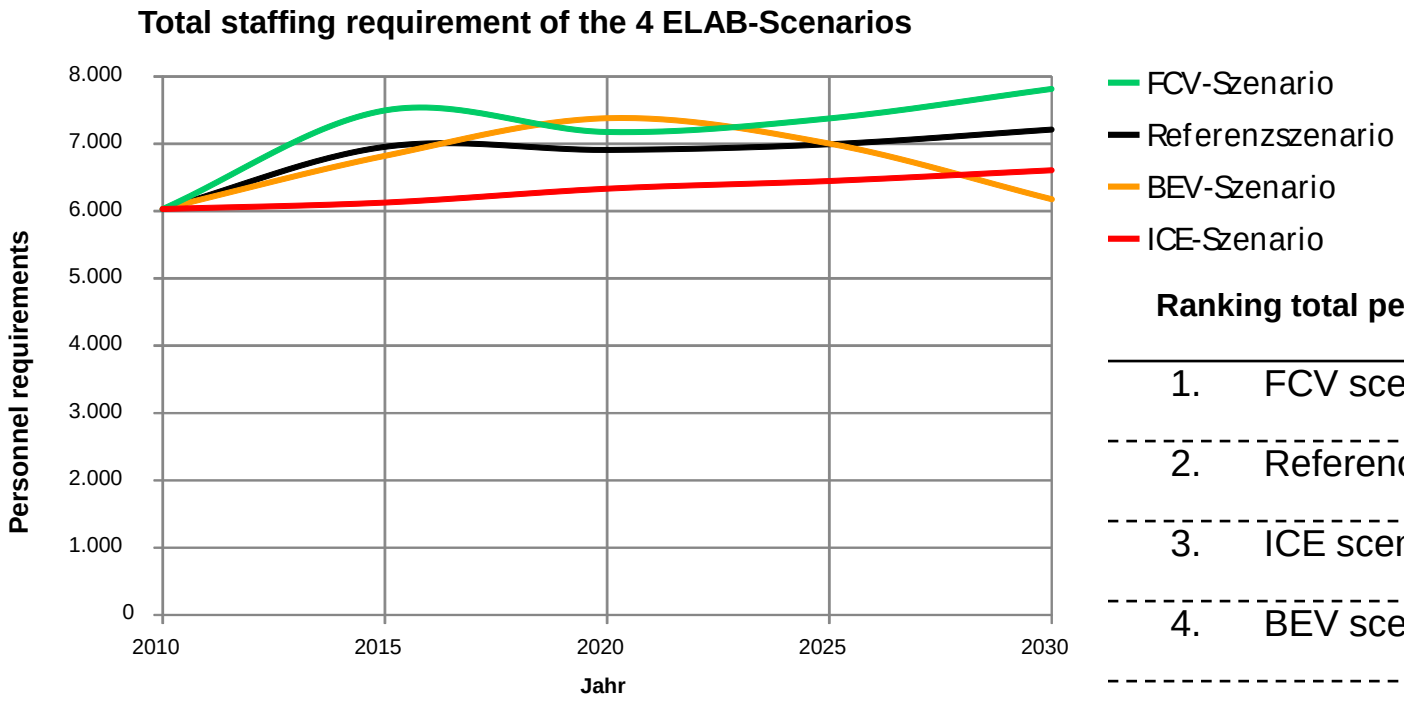
In this scenario the total number of staff required ranges from 6.000 to 6.600.

The ICE scenario shows a steady increase in the total staff requirement, since the vehicle concepts BEV, FCV and REX are attributed with little relevance and hybrid vehicles experienced a slight increase at the expense of the ICE concept.

Still, two phases can be distinguished:

- From 2010 to 2015 little change is seen in the requirements.
- From 2015 stronger hybridization occurs, leading to an increase in demand of the component of hybrid transmission. This outweighs the decrease in the transmission component (except Hybrid). The requirements of the new components increase slightly, with them the total staffing requirements.

Essences: Comparison of 4 scenarios



Ranking total personnel requirements 2030

1.	FCV scenario	7.816 Emp
2.	Reference scenario	7.213 Emp
3.	ICE scenario	6.607 Emp
4.	BEV scenario	6.173 Emp

The mix of power train variants results for all scenarios rising personal needs by 2030.

The FCV scenario is the most labor-intensive scenario, while the BEV scenario is the least labor-intensive in the long run.

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Qualitative effect analysis:

Procedure

Research questions „Competence requirements and qualifications“:

- How do competence requirements and the technological change modify?
- What qualifications of employees are necessary for the production of new drive trains?
- How can institutes of the site environment support technological change through out improving location factors?
- What impacts the labor market and influences demographic change?

Research question „industry environment“:

- How influences technological change the supplier structure in the industrial environment, what challenges are suppliers faced with?

Qualitative effects analysis and demand analysis – mixed methods:

1. Deduction of competence request and qualification requirements from the ELAB analysis of manufacturing processes.
2. Expert discussion with participants of companies (OEM, supplier), of research institutes and other institutes.
3. Secondary analysis of literature and additional documents.

Competence requirements and qualifications:
Initial hypothesis

Thesis:

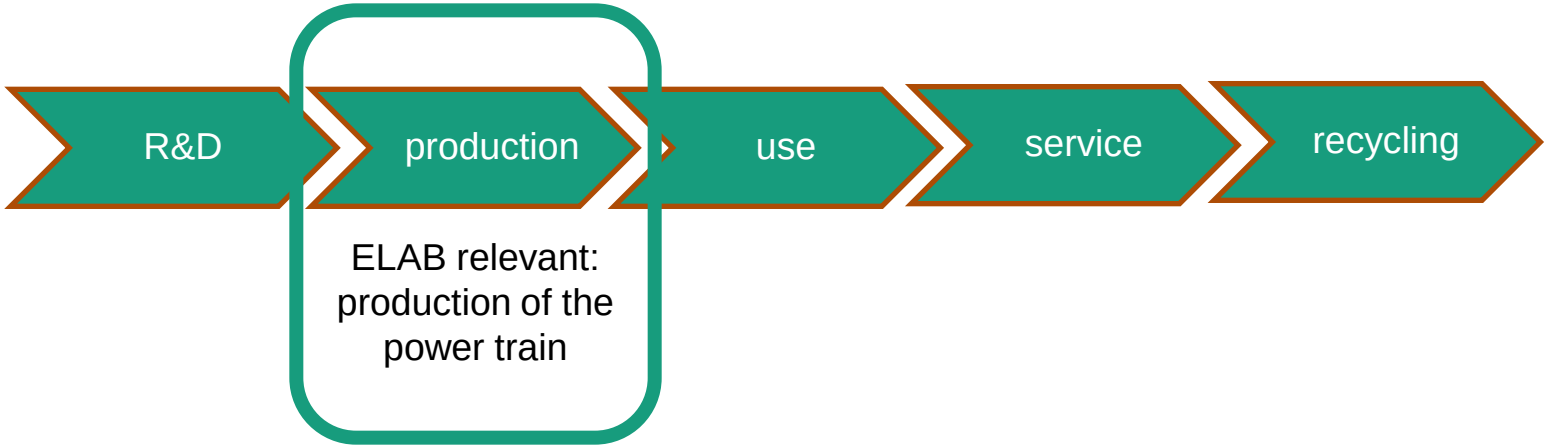
Electrification of the drive train

modifies **requirements of competence,**

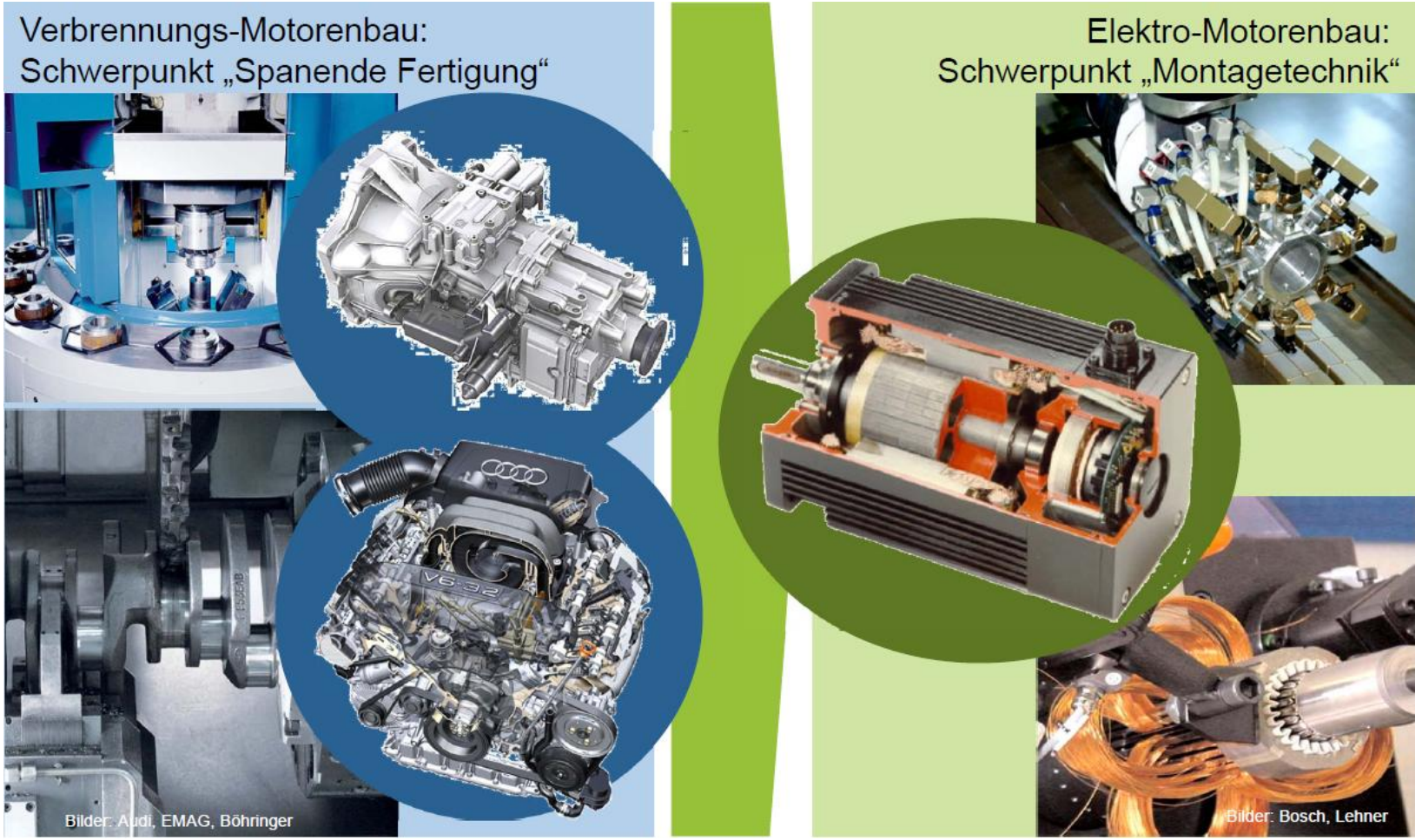
displaces **qualification profiles** and

generates **training needs**

along the process chain



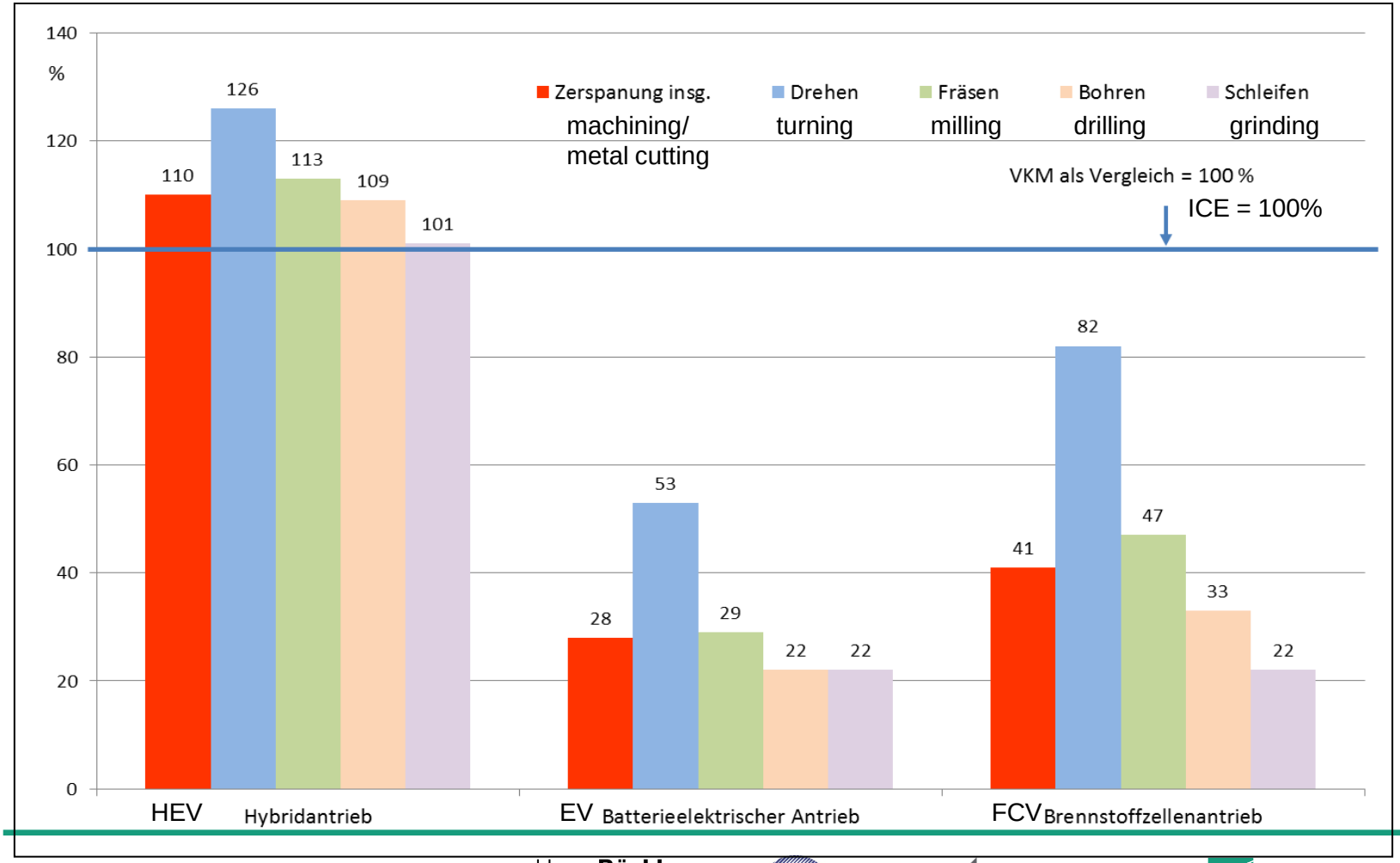
Thesis: Manufacture of electrical drives requires new processes, systems and skills



Quelle: Franke 2011

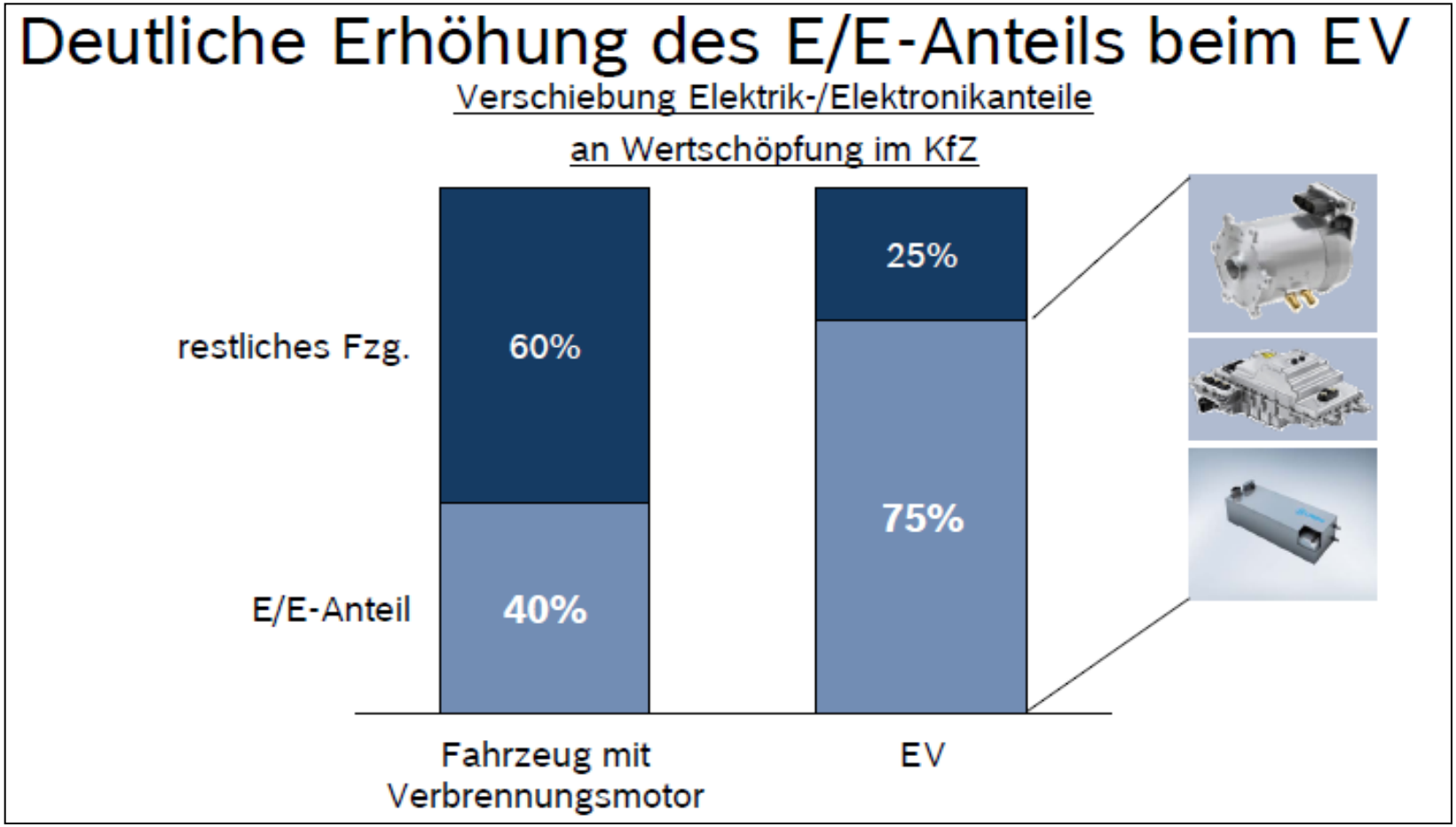
Digression: effects of technological change

Quantitative dimension, proposing a qualitative impact assessment (competence requirements) - Comparison machining times of major drive train components (in %):



Digression: effects of technological change

Verschiebung von Wertschöpfungsanteilen:



Quelle: Bosch 2010

Competence requirements and qualifications

results / essences (1)

- Increasing importance of **electrics/electronics** compared to mechanics.
- Increasing importance of **assembly activities.** Displacement of machining processes by assembly processes.
- Assembly work can‘t be equate with „easy work“, but becomes more complex, flexible, challenging.“Shift of qualification“ towards **professional skills and process skills; „practical knowledge“**
- **Handling of high voltage systems** as central new qualification requirement of employees in production and assembly.
- Advanced competence requirements by optimizing conventional components (clean room, care) as well as lightweight construction and new construction materials.
- **Apprenticeship:** Integration of specific electromobility qualification contents into existing job profiles (e.g. handling of high voltage systems as a module).
- **A Change in the mix of apprenticeship vocations** will continue through electrification. (Increase of mechatronical vocations and industrial electrical vocations).

Competence requirements and qualifications

results / essences (2)

- **Advanced vocational training:** greater demand for qualification in handling high voltage systems („Elektrofachkraft“).
- **Health and safety at work:** handling of traction batteries as largest potential source of danger – electric tension (high voltage!) and hazardous materials (as e.g. lithium).
- **New drive train components:**
  Competence requirements through essential higher automation in future as well as securing a high, consistant quality.
  Further component specific qualification requirements:
  - **Battery system:** Connection method / joining technology (high voltage), quality control, check, tests (electrics, compactness).
  - **Electric motors:** Assembly, quality control, check, tests.
  - **Fuel cell systems:**
    Technical competences (e.g. electrochemical coating) and quality control, diligence, purity.
    Specific knowledge in hydrogen tanks (high pressure, lightweight construction).

Competence requirements and qualifications

Analysis of the educational infrastructure

- **Vocational training at regional level :** In regions of automotive industry educational establishments are mostly geared to the classic metal and mechanical sector. Electro-mobility-specific qualification contents (competence in electrics/elec-tronics, handling high voltage systems) should be more integrated into the existing training opportunities.
- **Coordination** and **standardization** of training opportunities (especially with additional qualifications „handling high voltage systems“).
- **Regional labour market management, including relevant actors:** Creation of a platform or network of all actors of vocational and academic education, to achieve consistent approaches regarding future actions and a coordinated, transparent implementation. Initiation of a regional labour market management as a designing and control tool for regional labour markets and qualification systems.

Competence requirements and qualifications

Contextual analysis: Labor market and demographic change

- **Demographic change:** going to have large influence on the future working environment in the auto industry (with or without e-mobility).
- **Highly declining labour force potential** till 2030 (and longer) and the lasting trend towards academization of the working environment could lead to a shortage at the for drive train production essential labour market.
- As a result it is necessary to bail out labour force potencial better and to improve **opportunities for participation for all**! (Adapting working conditions to the needs of an aging workforce, the balance between family and work, equality and integration).
- Excellent **technology base** for electric vehicles also draws its strength from synergy, feedback processes and mutual learning effects with the simultaneously exsiting **production site**. This is also why the **industrialization of electric mobility** is an important goal!

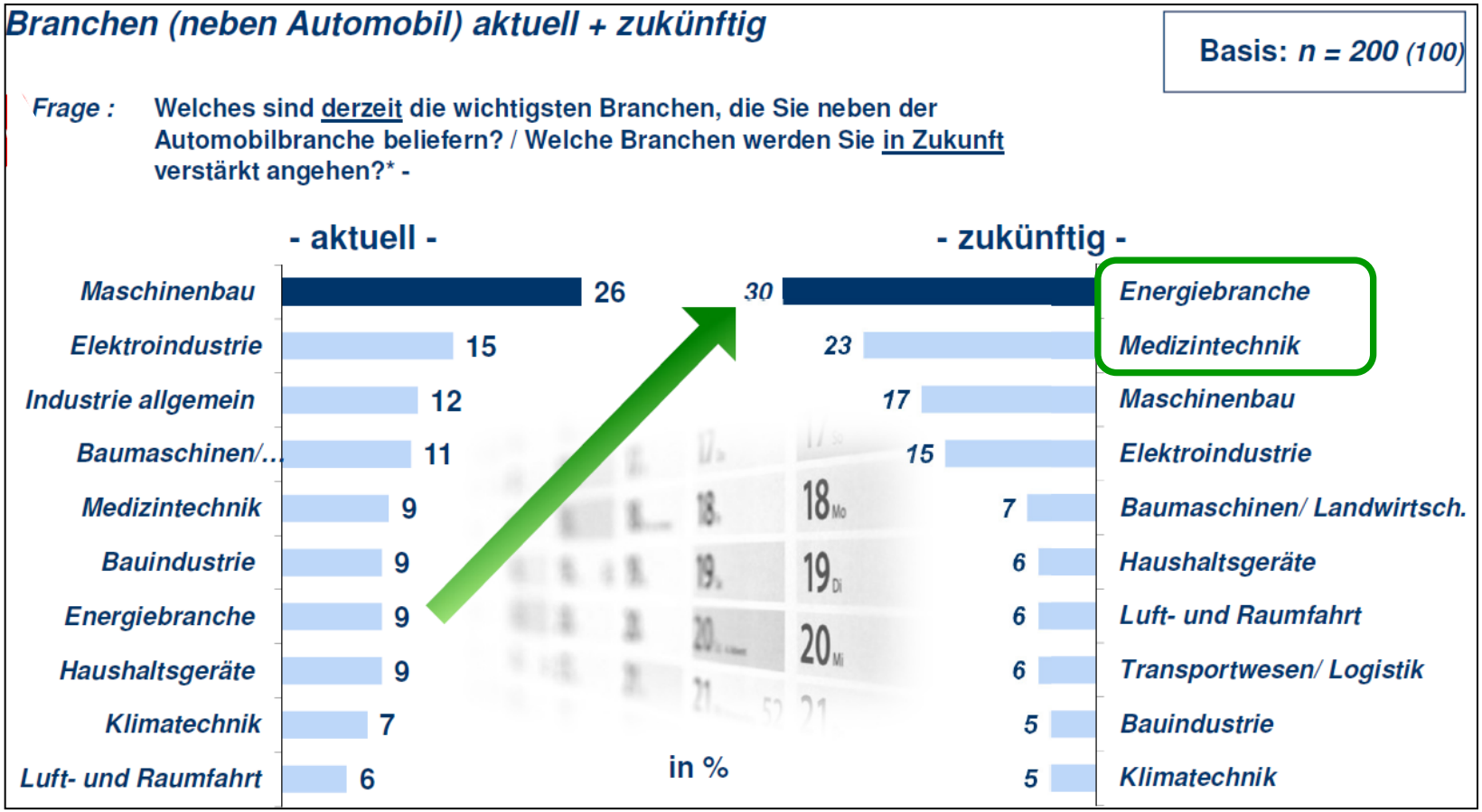
Essences „ industry environment“:

(esp. Structure of suppliers/value chain in Baden-Wurttemberg)

- **Reorganization of the value chain** with readjustment of value shares (competition of established and new suppliers).
- Change to electro mobility with **enormous impacts for the "Autoland Baden-Württemberg"** (with its strong technological orientation to the drive train).
- Handling the change is a major challenge, especially for small and medium corporations (SMEs) – **SME- suppliers** so far have been little prepared for technology change (technological viability of many automotive suppliers in alternative drive concepts is critical to assess).
- **Shortages of SME- suppliers:**
  (1) general innovation deficits;
  (2) technological focus on internal combustion engines;
  (3) lack of awareness of the challenges of electric mobility.
- **Strategy options:** active action in technological change (product innovation, manufacturing expertise) / diversification / cooperations and strategic alliances

Reorganization of the value chain – Corporate strategy: diversification

Diversification is more and more important for suppliers:



Quelle: Puls Marktforschung 2011

Reorganization of the value chain –
Corporate strategy: cooperations and strategic alliances

Examples for cooperations in new technology fields (Snapshot June 2012):

- **Herstellerkooperationen (Auto-OEM):**
  - Daimler & Renault-Nissan / Daimler & BYD / Daimler & Tesla
  - BMW & PSA („BMW Peugeot Citroen Electrification“) / BMW & Toyota
- **Kooperationen OEM-EVU:**
  - BMW & Vattenfall / Volkswagen & E.ON / Daimler & RWE
- **Batterie:**
  - Bosch & Samsung (SB LiMotive)
  - Daimler & Evonik („Strategische Allianz zur Elektrifizierung des Autos“:
    - Li-Tec Battery, Deutsche Accumotive)
  - Volkswagen & Toshiba
- **Elektromotor:**
  - Daimler & Bosch (EM-motive)
  - Volvo & Siemens
  - Brose & SEW-Eurodrive
- **Leichtbau (CFK – carbonfaserverstärkte Kunststoffe):**
  - Daimler & Toray
  - BMW & SGL Carbon
  - Audi & Voith

Agenda

- Overview: the ELAB research project
- Concepts of power trains and scenarios
- Manufacturing process and staff requirement
- Quantitative effect analysis
- Qualitative effect analysis
- Summary

Summary

- Based on the **market scenario** a **mix of various drive train concepts** is expected for **2030.**
- The **production of electric drive train components** requires skills of not been used manufacturing procedures in the automotive industry.
- Drive train producers will **keep their level of personnel requirements** or even increase it, if they add production **components of the electric drive train** to the conventional components.
- There can be massive **dispacements** within the value chain, especially in **supplier companies.**
- Electric mobility includes a **change in working environments**, with changing standards of competence and qualification of employees.
- An adjustment of **occupational training and further education** as well as standardization of training contents and degrees is necessary.

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