



Report: Market Analysis “reconfigurable isolated multiport DC-DC converter”

Version 1.9

27. Feb. 2020

Introduction

- market research analysis “reconfigurable isolated multiport DC-DC converter”
 - this specific DC-DC converter was the result of research conducted @ CAU Kiel, Chair of Power Electronics, in the U-HEART and HEART research projects over the last couple of years *
- the intention of this analysis is to provide an overview of the market potential of such solution in the competitive landscape with a focus on the European and in particular the German region
- this report is covering below topics:
 - introduction
 - IP patent analysis & spin-off activities
 - general market overview
 - automotive market segment and applications
 - analysis of automotive market potential
 - competitive overview
 - SWOT analysis
 - conclusions and recommendations

Intellectual Property – Patent Analysis

- IP patent infringement analysis was done on German database DEPATISNET and European database ESPACENET*
- various search terms were applied**
- IP infringement analysis carried out by Dr. Markus Andresen in January 2020, with highest order being closest to Kiel Universities own patent application for a “reconfigurable isolated multiport DC DC converter”

IP Ranking	IP Code	IP Title	IP Owner	Comments
1	US020150183330A1	MODULAR RECONFIGURABLE MEDIUM VOLTAGE TRANSFORMER FOR DATA CENTERS, VOLT/VAR CONTROL, AC AND DC CHARGING, AND VEHICLE-TO-GRID APPLICATIONS	Electric Power Research Institute	search term on ESPACENET „reconfigurable modular DC DC converter” yields 708 hits
2	EP000003125392B1	MULTI-PORT DC-DC CONVERTER AND APPLICATION THEREFOR	Huazhong University	search term on DEPATISNET „multiport solid state transformer” yields 2 hits
3	WO002019212609A1	SYSTEM AND METHOD FOR ADAPTIVELY CONTROLLING A RECONFIGURABLE POWER CONVERTER	Raytheon	search term on DEPATISNET „reconfigurable isolated DC DC converter” yields 2 hits
4	US020140049990A1	SOFT-SWITCHING HIGH VOLTAGE POWER CONVERTER	Rudolf Limpaecher (Technical Director Varentec)	this patent was cited by the German patent office as reference infringement, when rejecting the patent application from Kiel University for "reconfigurable isolated multiport DC DC converter"

Spin-Off Activities @ other Research Hubs

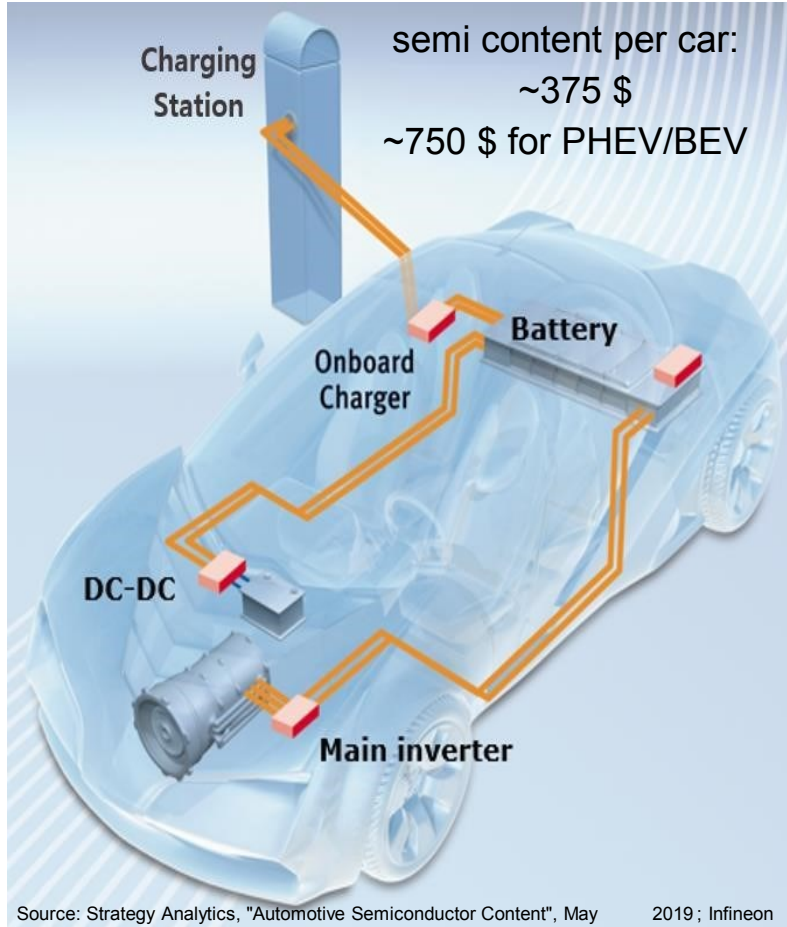
Name of Professor	University/ Research Institute	Name of Company	Weblink of Company	Comments
Prof. Alex Huang + Prof. Subhashish Bhattacharya (FREEDM Systems Center North Carolina State University, NC, US)	https://www.ece.ncsu.edu/people/sbhatta4/	GridBridge Inc. (US)	http://www.grid-bridge.com/	founded in 2012, have licensed three patents from North Carolina State University, in total they have some 10+ patents, since 2017 part of ERMCO Inc. (www.ermco-eci.com). In 1999, ERMCO purchased the General Electric Transformer Components company. Gridbridge will provide their smart transformer solution to LV Engine project to Scottish Power Energy
Prof. Deepak Divan (Georgia Institute of Technology, Atlanta, GA, US)	https://cde.gatech.edu/home/team/deepak-divan/	Soft Switching Technologies Corporation (US)	-	founded some 25 years ago, not in operation anymore
		Smart Wires Inc. (US)	www.smartwires.com	founded in 2008 , received more than USD 100 Mio in VC-funding
		Innovolt Inc. (US)	https://innovolt.com	founded in 2005, acquired by East West Manufacturing (www.ewmfg.com) in 2017
		Varentec Inc.(US)	www.varentec.com	founded in 2002, received funding from Bill Gates and Vinod Khosla (VC-guru) , total VC-funding assumed to be USD +50 Mio
Prof. Johann W. Kolar (ETH Zurich, Switzerland)	https://pes.ee.ethz.ch/	Celeroton AG (Switzerland)	www.celeroton.com	founded in 2008, no VC-funding, focus on e-drives
		Enertronics GmbH (Switzerland)	-	founded in 2008, no VC-funding, company is offering power electronics systems engineering and prototyping, apparently no in operation anymore
		Gecko-Simulations AG (Switzerland)	-	founded in 2013, no VC-funding, company was offering tools for power electronics simulation, not in operation anymore
Prof. Thierry A. Meynard (LAPLACE Lab, University of Toulouse, France)	http://www.laplace.univ-tlse.fr	Power Design Technologies SA (France)	http://www.powerdesign.tech/	founded in 2016, design software for power converters

General Market

- dedicated market reports of several market research agencies* on the specific subject of the “global DC/DC converter market” have projected an average CAGR of some 15% to 18% , with an overall market volume to grow from ~ USD 8bn in 2019 to roughly USD +20bn by 2025
- the majority of this market will be in the low-power segment mainly driven by consumer electronics like smart-phones, tablets/notebooks and other gadgets
- the vertical market with strongest growth perspective is the automotive/transportation segment, however this will be contingent on a successful and fast introduction of BEV, HEV and FCEV**
- from a regional perspective the market will be dominated by Asia, leaving Europe and the Americas behind
- trends nurturing this growth are 5G roll-out, increased adoption of IoT technologies and electrification in the transportation domain

Automotive Market

Automotive Market

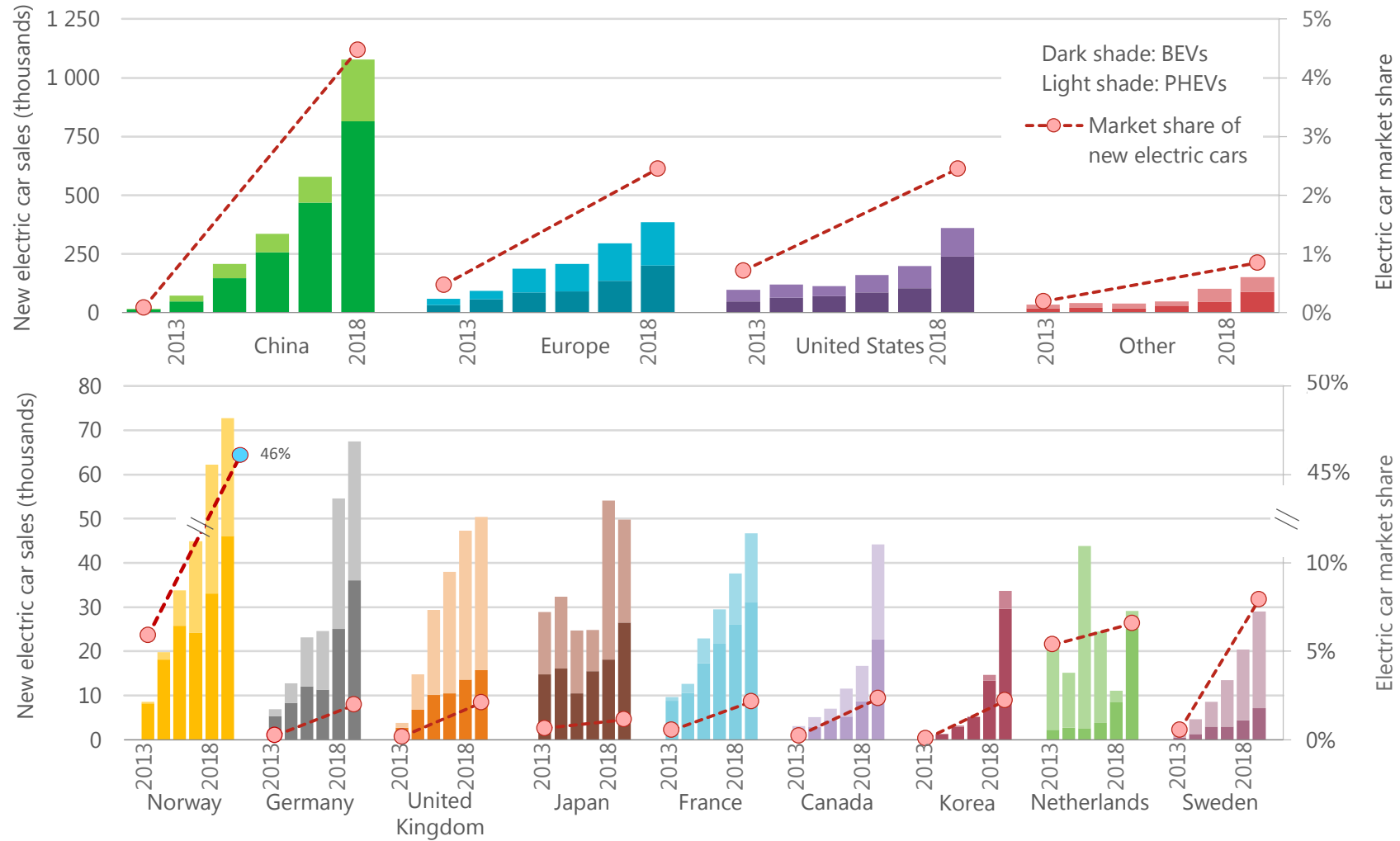


- applications for deployment: in-vehicle for BEV, HEV and FCEV are onboard charger, DC-DC converter as well as charging stations
- what are growth drivers for the e-mobility roll-out:
 - EU policies* for CO2 emissions of cars/light-trucks
 - subsidies: governmental as well as industrial**
 - governmental tax incentives
 - public sentiment towards global warming/climate change, e.g. fridays-for-future movement
 - selective municipal ban of diesel cars***
- potential risks to the e-mobility roll-out:
 - limited BE-range
 - governmental subsidy policy may be subject to change for political reasons****
 - high purchase cost of vehicles and constantly rising electric energy cost (at least in Germany)
 - limited availability of charging points, long charging cycles
 - societal skepticism and hesitation towards technological change



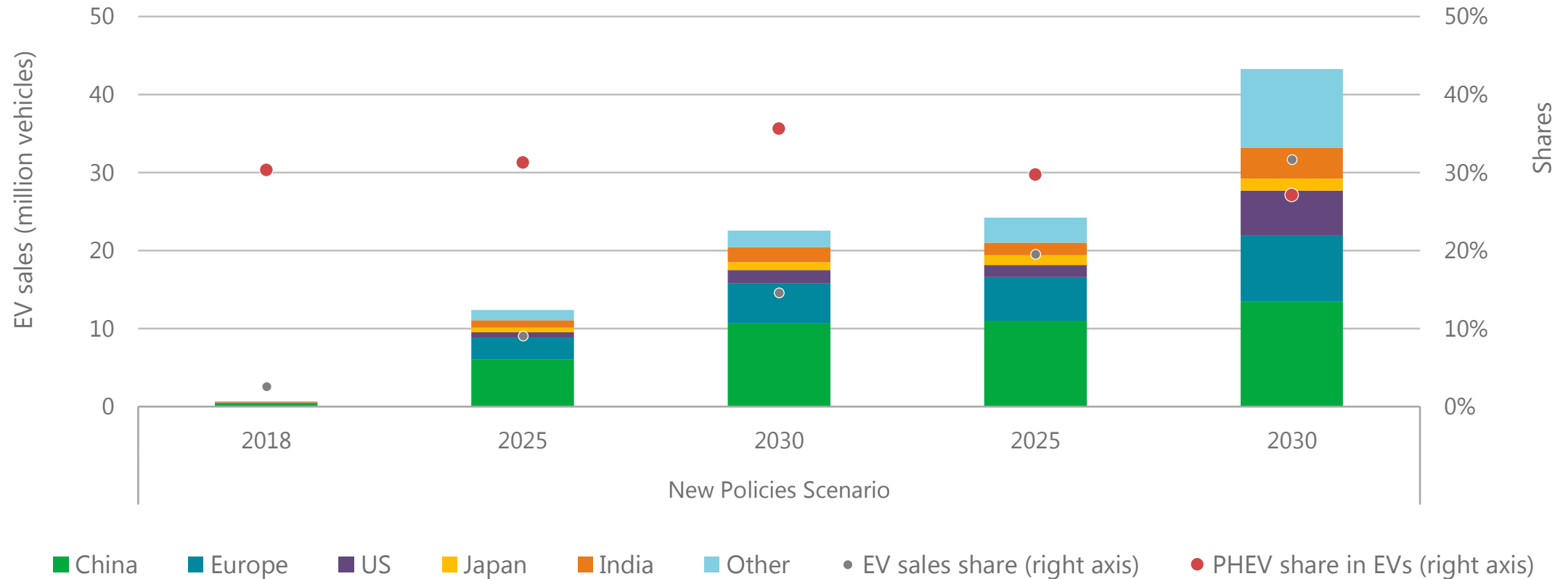
Source: VDE ETG Task Force, standard DC fast charging topology*****

Global EV Automotive Market I



Source: Global EV Outlook Report 2019 www.iea.org

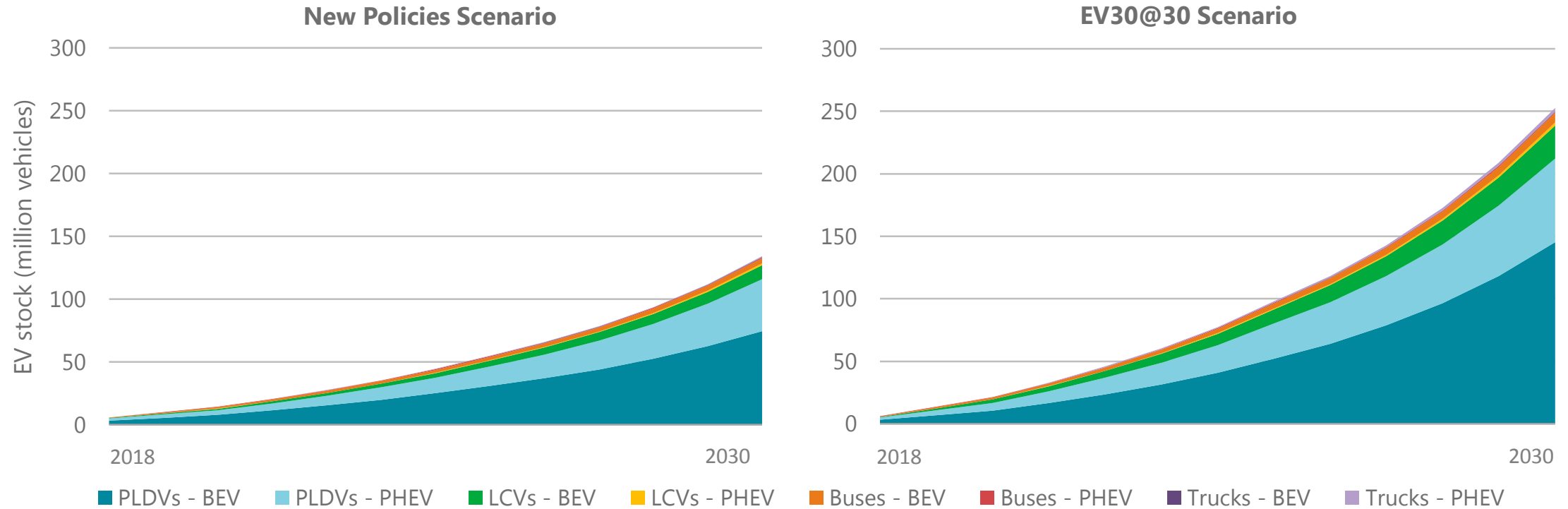
Global EV Automotive Market II



Source: Global EV Outlook Report 2019 www.iea.org

for Europe this yields a CAGR of xEV sales of ~42% for NP-scenario and ~48% for EV30@30 scenario

Global EV Automotive Market III

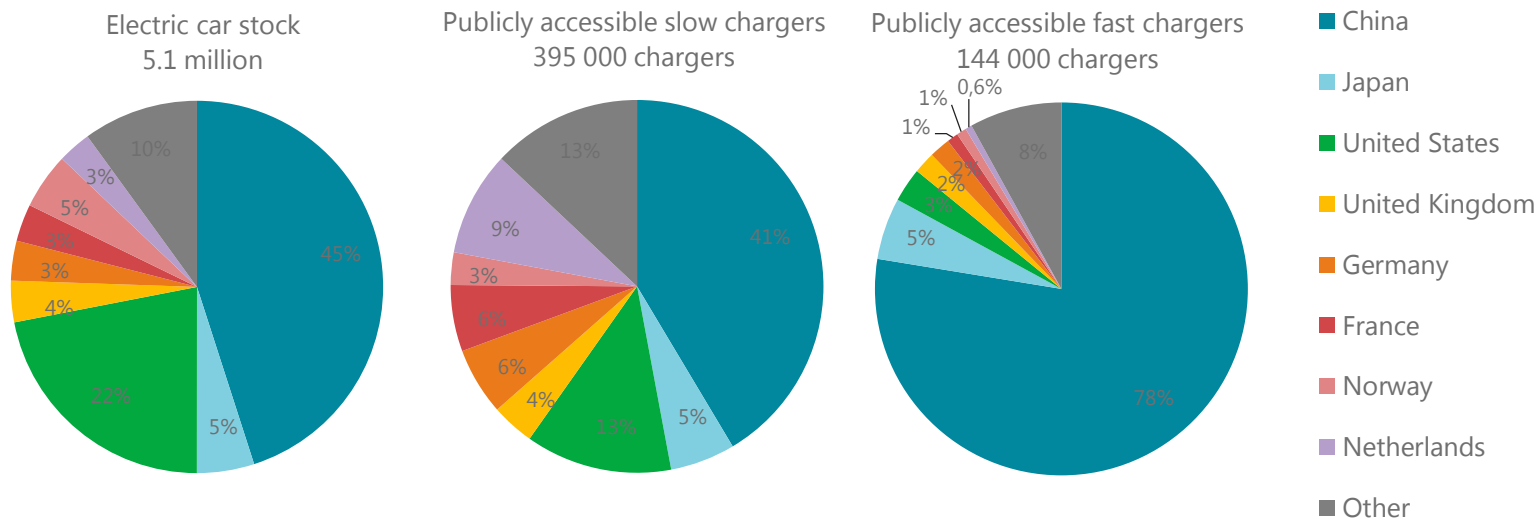


Source: Global EV Outlook Report 2019 www.iea.org

Global EV Automotive Market: Charging Stations 2018

Germany:

- 177k e-cars in stock (~3,5% of global EV market, ~0,37% of registered vehicles in Germany)
- 23k publicly accessible slow chargers (~13% of e-cars in stock)
- 2,6k publicly fast chargers (~1,5% of e-cars in stock)
- 35k private slow chargers (~15% assumption that owners install private wallbox)

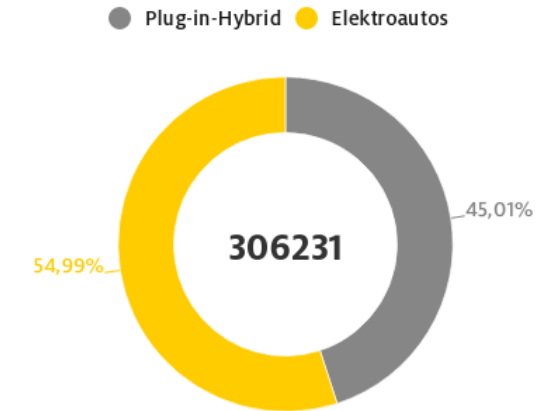


Source: Global EV Outlook Report 2019 www.iea.org

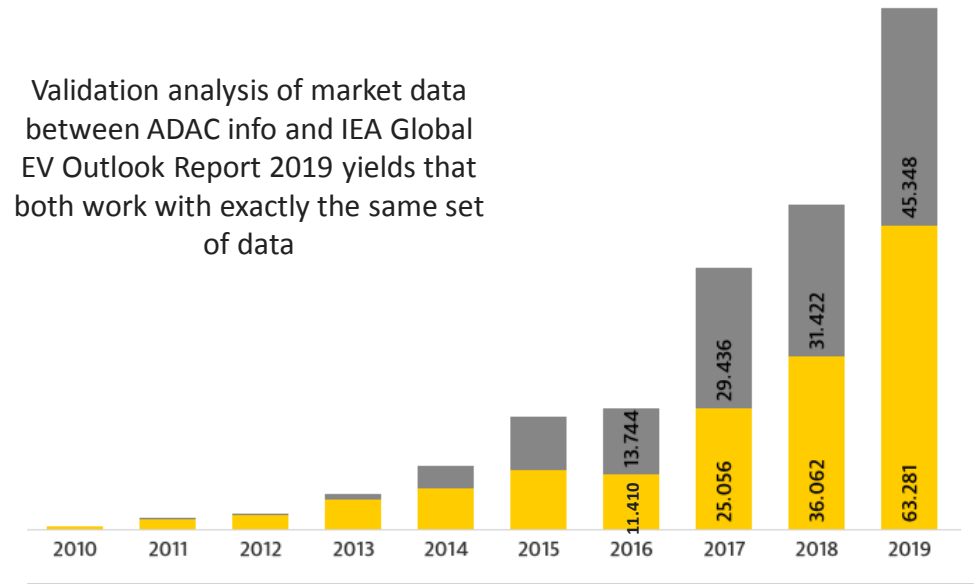
German EV Automotive Market

- total passenger vehicle sales in 2018 were 3,44 Mio units
- the passenger vehicle market is assumed to be saturated with no growth in total volume
- ~2% were xEV vehicles*
- from 2016 onwards new xEV vehicles registration has grown at a CAGR of ~63%
- considering the more moderate CAGR of ~48% in the EV30@30 scenario of the Global EV Outlook Report 2019 of the IEA, it seems to be reasonable to reach a goal of 30% market share by 2030

Neuzulassungen von Elektroautos in Deutschland



Validation analysis of market data between ADAC info and IEA Global EV Outlook Report 2019 yields that both work with exactly the same set of data



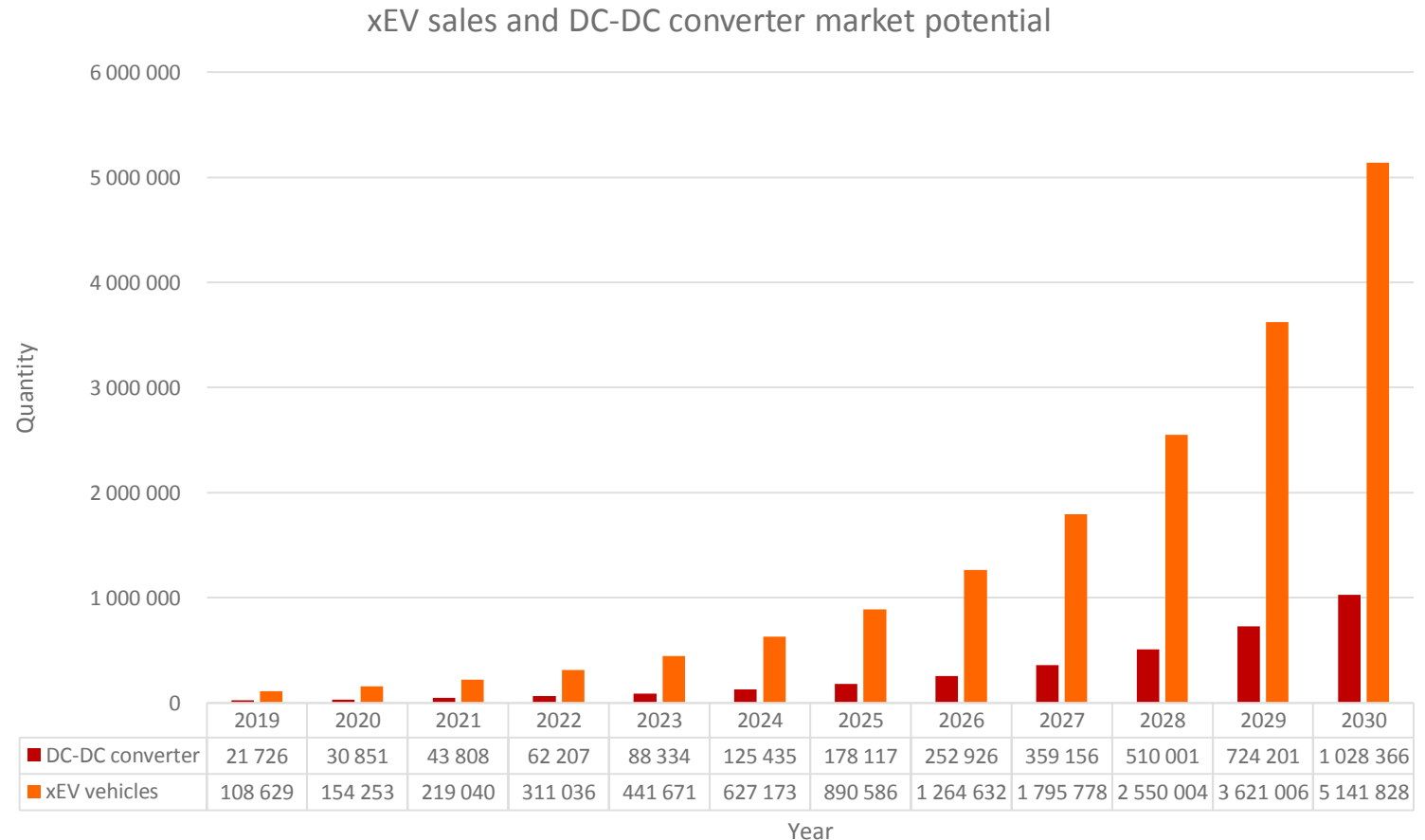
Quelle: KBA, EAFO, VDA

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German market analysis I

assumptions:

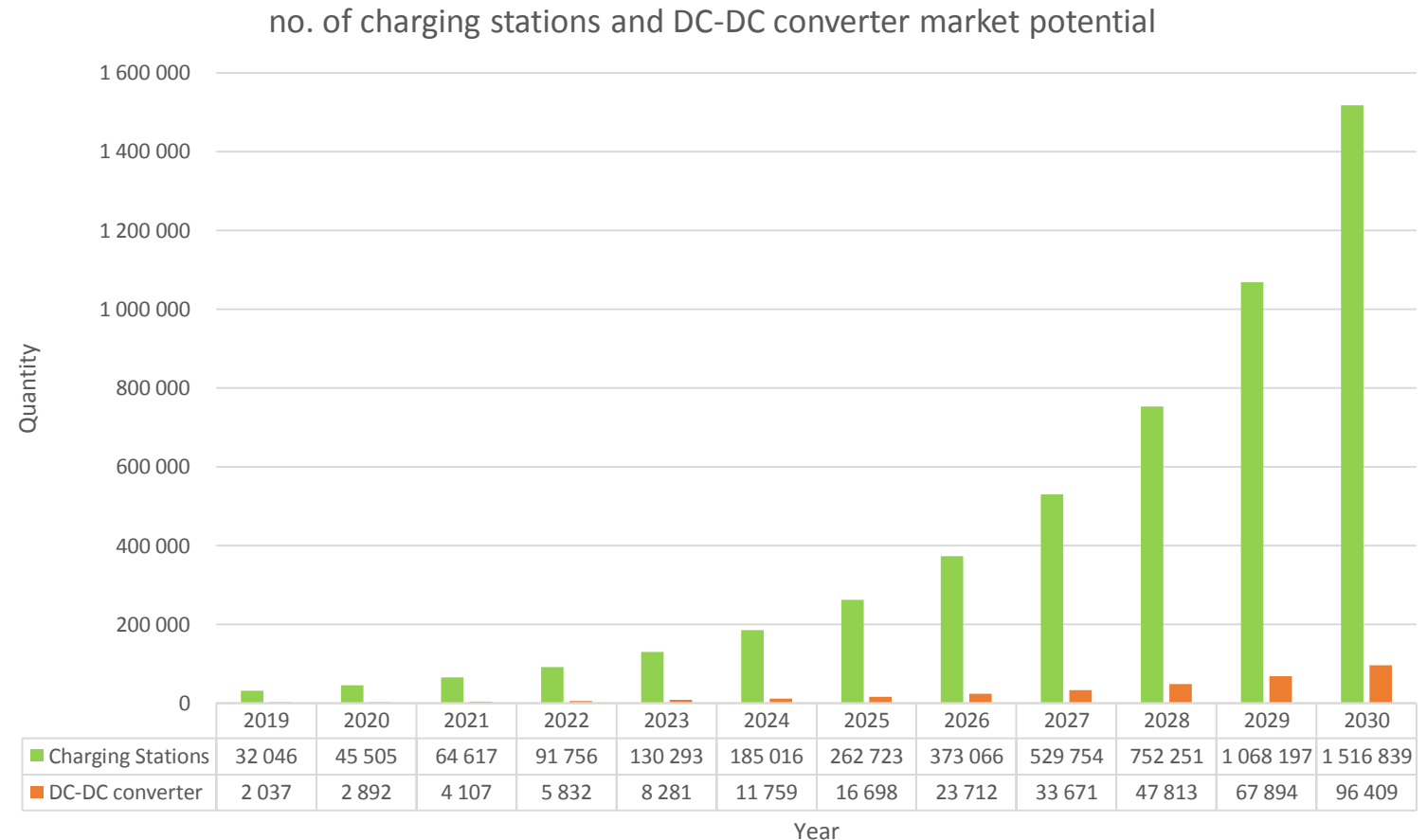
- 42% CAGR applied*
- two DC-DC converter per vehicle
- 10% take-up rate for a sophisticated DC-DC converter design (reconfigurable, isolated, multiport)
- sum of market volume for a sophisticated DC-DC converter design (reconfigurable, isolated, multiport) over 10 year span exceeds 3mio units



German market analysis II

assumptions:

- 42% CAGR applied*
- one DC-DC converter charging station
- 7,5% average take-up rate for a sophisticated DC-DC converter design (reconfigurable, isolated, multiport)**
- sum of market volume for a sophisticated DC-DC converter design (reconfigurable, isolated, multiport) over 10 year span exceeds 300k units

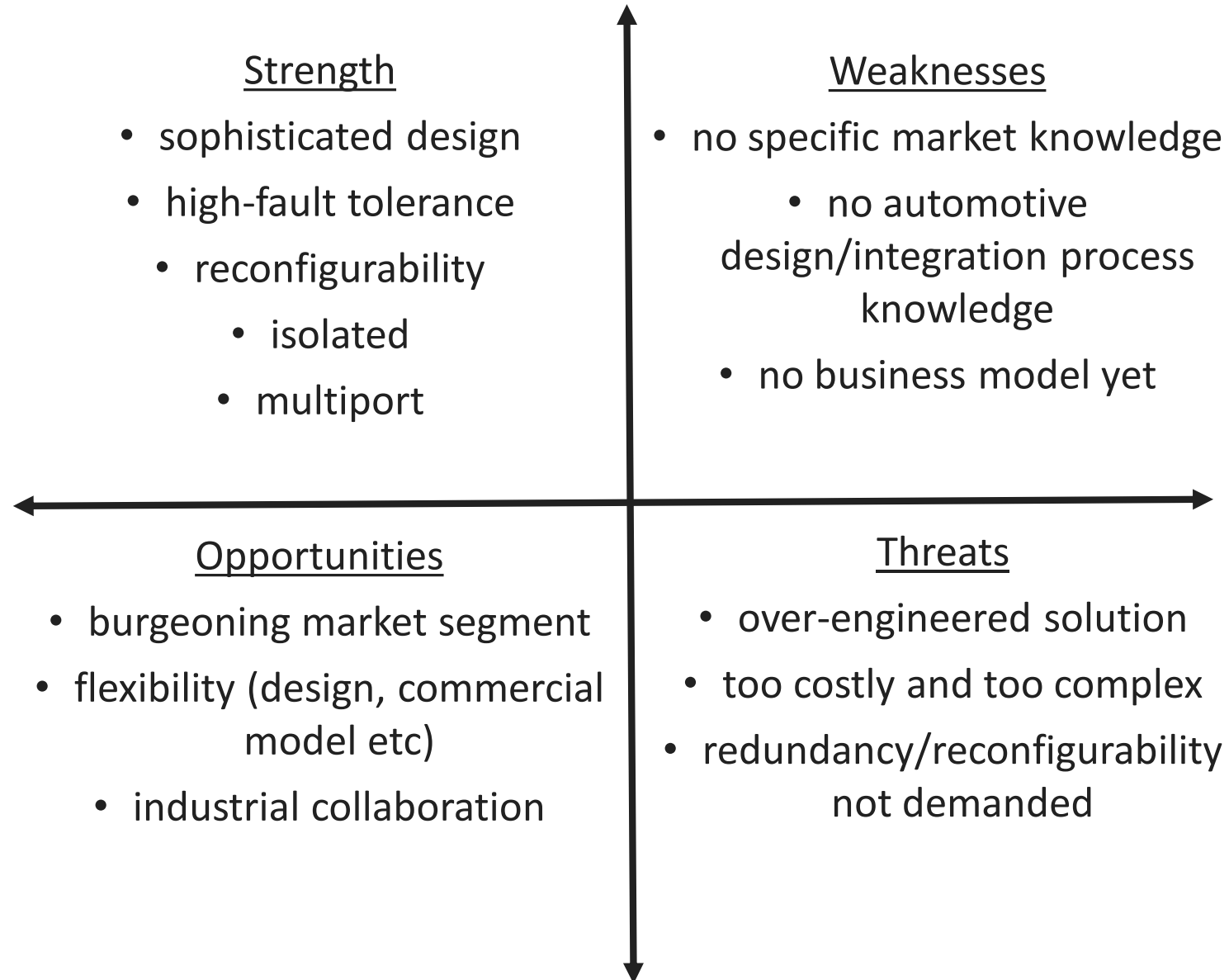


Competitive Landscape Automotive

- no particular design details of competitive products are available nor any sort of reliability or fault tolerance figures
- it is assumed that high-power DC-DC converter have been designed with discrete components e.g. IGBTs
- regarding charging stations it is not clear whether DC-DC converter has been integrated by the vendor itself or whether they have integrated third-party component
- Companies offering competitive solutions could also be potential customers for a sophisticated DC-DC converter design

Name of Company	Webaddress	Comments
Bosch	https://www.bosch-mobility-solutions.de/de/produkte-und-services/pkw-und-leichte-nutzfahrzeuge/antriebssysteme/hochvolt-hybridssysteme/dcdc-wandler/	in-vehicle
Continental	https://www.continental-automotive.com/de-DE/Passenger-Cars/Powertrain/Electrification/Hybrid-Electric-Vehicles/High-Voltage-DC-DC-Converter-4th-Generation	in-vehicle
Hella	https://www.hella.com/microsite-electronics/de/DC-DC-Wandler-155.html	in-vehicle
Denso (Japan)	https://www.denso.com/fr/en/products-and-services/oem/products-for-electric-and-hybrid-vehicles/	in-vehicle
Valeo Siemens (French German)	https://valeo-siemens.com/de/#who-we-are	in-vehicle
ZF	https://www.zf.com/products/de/cars/products_29285.html	in-vehicle
Delphi (US)	https://www.delphi.com/featured-technologies/combined-inverter-and-dcdc-converter	in-vehicle
Lear (US)	https://www.lear.com/Site/Technology/hv-power-control-modules.aspx	in-vehicle
Webasto	https://webasto-charging.com/default/products.html	charging station
Ionoty	https://ionoty.eu/de/design-und-technik.html	charging station, JV (Ford, VW, Daimler, BMW) , charging stations from Australian manufacturer Tritium https://www.tritium.com.au/
Mennekes	https://www.chargeupyourday.de/portfolio/	charging station
Walther Werke	https://www.mennekes.de	charging station
Siemens	https://www.walther-werke.de	charging station
ABB (CH)	https://new.siemens.com/global/de/produkte/energie/niederspannung/komponenten/electric-vehicle--ev--charging.html	charging station
Phoenix Contact	https://new.abb.com/ev-charging	charging station
Enercon	https://www.phoenixcontact.com/online/portal/pi?1dmy&urile=wcm:path:pien/web/main/products/subcategory_pages/Charging_technology_for_e-mobility_P-29/915a6b27-2307-48e1-a398-ecd45f5bfd1a	charging station
Bosch	https://www.enercon.de/fileadmin/Redakteur/Medien-Portal/broschueren/pdf/EC_E-Charger_600_de_042019.pdf	charging station
ABL	https://www.boschevsolutions.com/charging-stations	charging station
Keba (Austria)	https://www.ablmobility.de/de/produkte/ladesaeulen-emc.php	charging station
Schneider Electric (French)	https://www.keba.com/de/emobility/elektromobilitaet	charging station
Volkswagen Group Components	https://www.se.com/de/de/product-subcategory/80408-evlink-ladestationen/	charging station
Efacec (Portugal)	https://www.elektroniknet.de/elektronik-automotive/elektromobilitaet/aufbau-einer-ultraschnellen-ladeinfrastruktur-173424.html	charging station
	https://electricmobility.efacec.com/	charging station

SWOT Analysis Automotive



Conclusions and Recommendations for the Automotive Segment

- the DC/DC automotive market is a vibrant market segment with strong sustainable growth projections
- due to the specific market structure of the automotive market with its multi-tiered set-up this market has certain idiosyncrasies:
 - in essence it's a very complex systems integration business
 - process driven with strong focus on systems integration
 - heavy liability and warranty requirements from car manufacturers
 - high entry barriers w.r.t. to systems architecture, e.g. AUTOSAR in E/E-systems of vehicles
 - many contenders who on the other side could be potential business partners
- because of the complexities and idiosyncrasies of the automotive market any sort of collaboration regarding marketable IP should rather be indirect e.g. through licensing agreement of technology or a tier-2 set-up as component supplier
- no specific recommendation regarding licensing model is given here since the whole bouquet could apply from one-time sale of all IP-rights to any sort of royalty based model

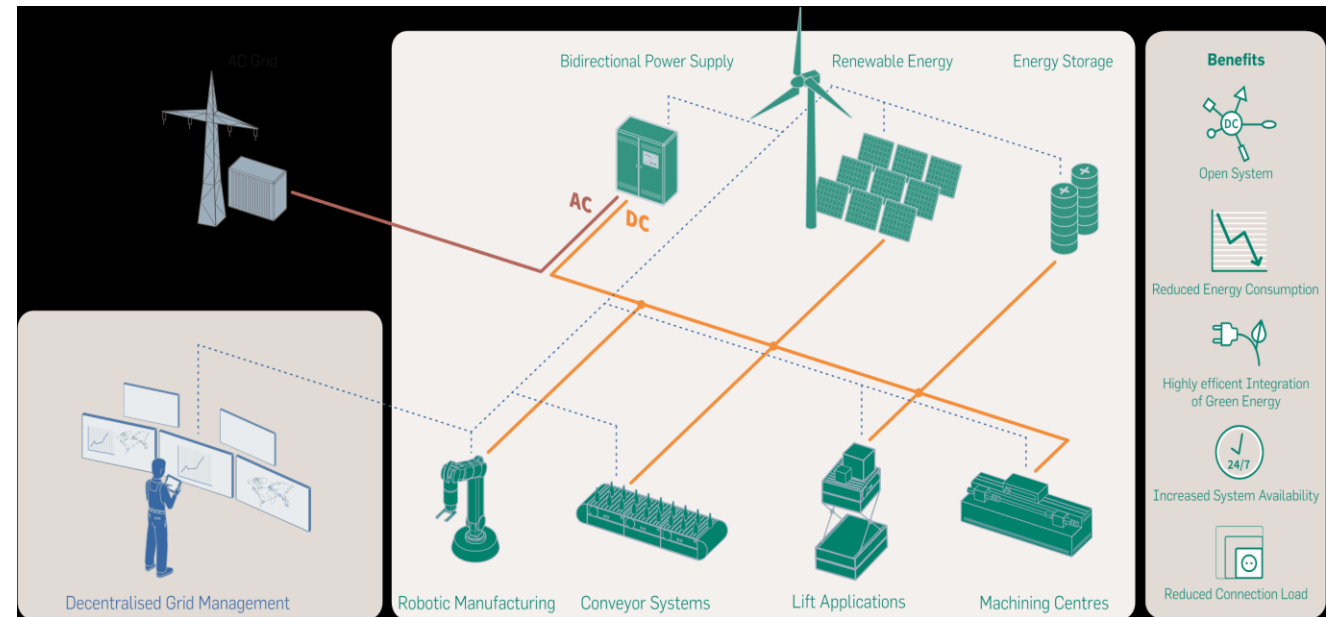
Industrial Market

DC-Industry

- DC-Industrie* is a joint R&D project sponsored by the BMWi**, energy savings of around 15% are projected in phase 1 through:
 - central AC-DC conversion
 - motion control energy recuperation via DC grid
 - simple integration of solar panels and battery storage systems
 - reduced installation effort and less material required, less capital investment, less floor space
 - higher level of grid autarky
 - less harmonic load on MV/LV grid

Comment:

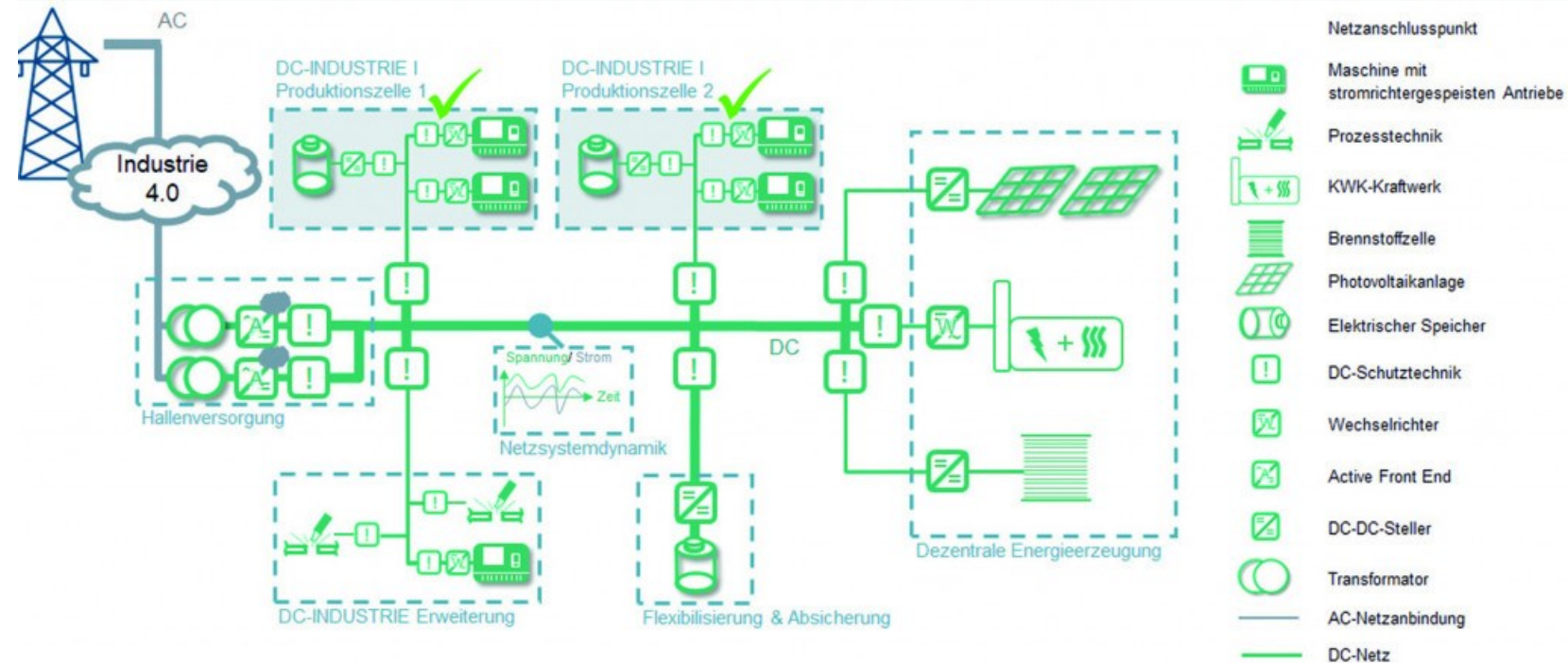
The concept of DC grid is a paradigm shift with centralized AC-DC conversion. This itself will cannibalize the hitherto DC-DC market and thus may spark counterforces...



Source: ZVEI www.zvei.org

DC-Industry targeted scenarios

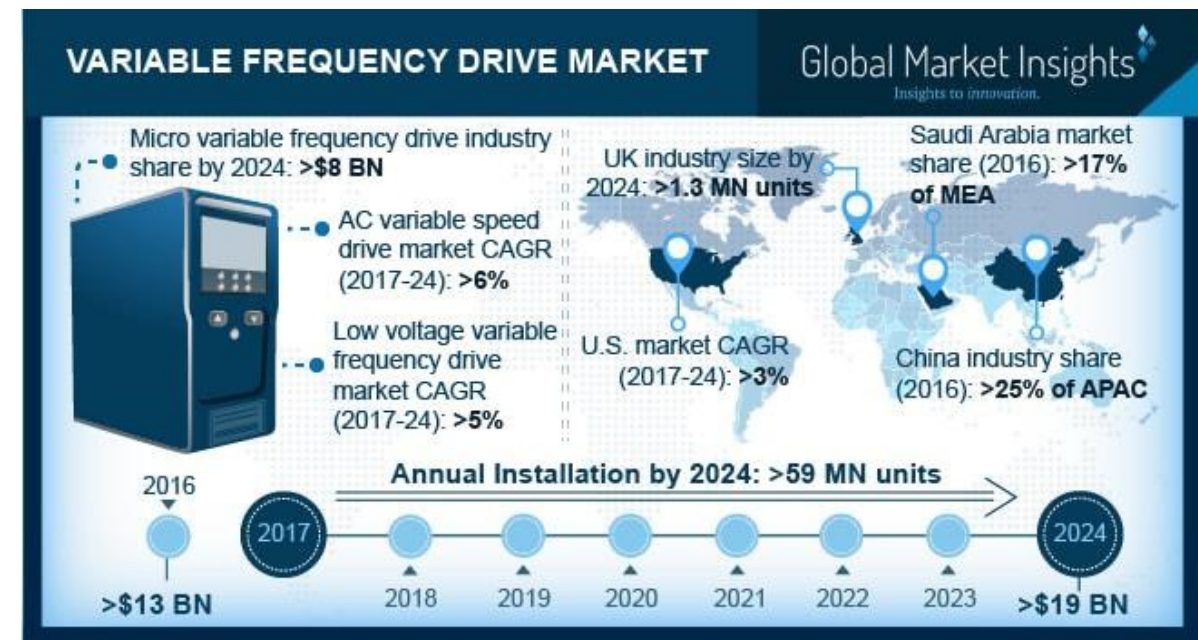
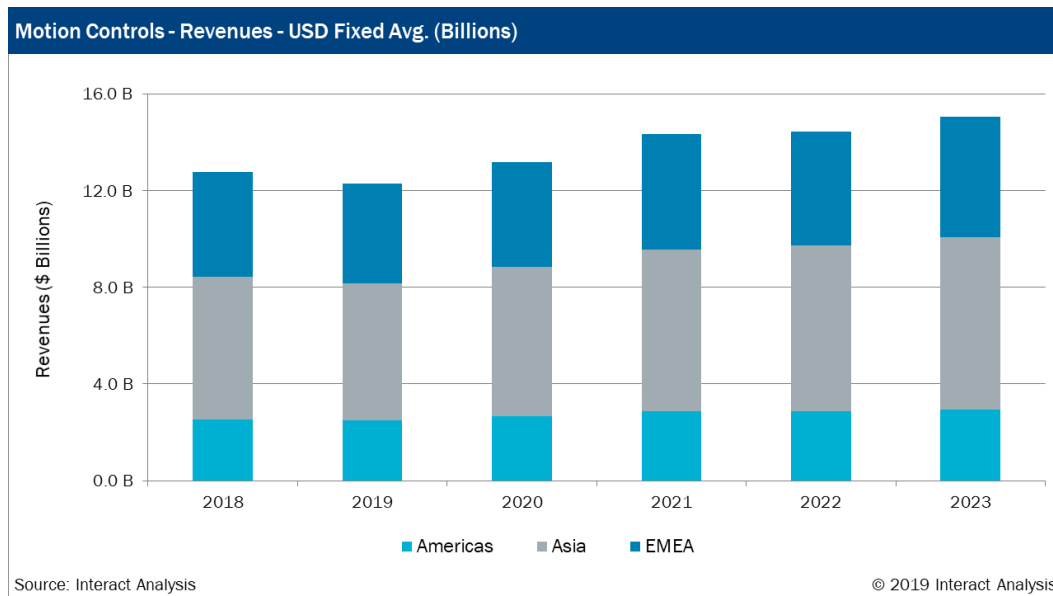
DC-Industrie phase 2
started in October 2019



Source: EEP Universität Stuttgart

Industrial Market

- dedicated market reports of several market research agencies* on the motion control market are forecasting an average CAGR of some 5% , with an overall global market volume in the \$ double digit range
- German motion control market**:
 - 5% CAGR
 - 3,3 Mio systems in 2020



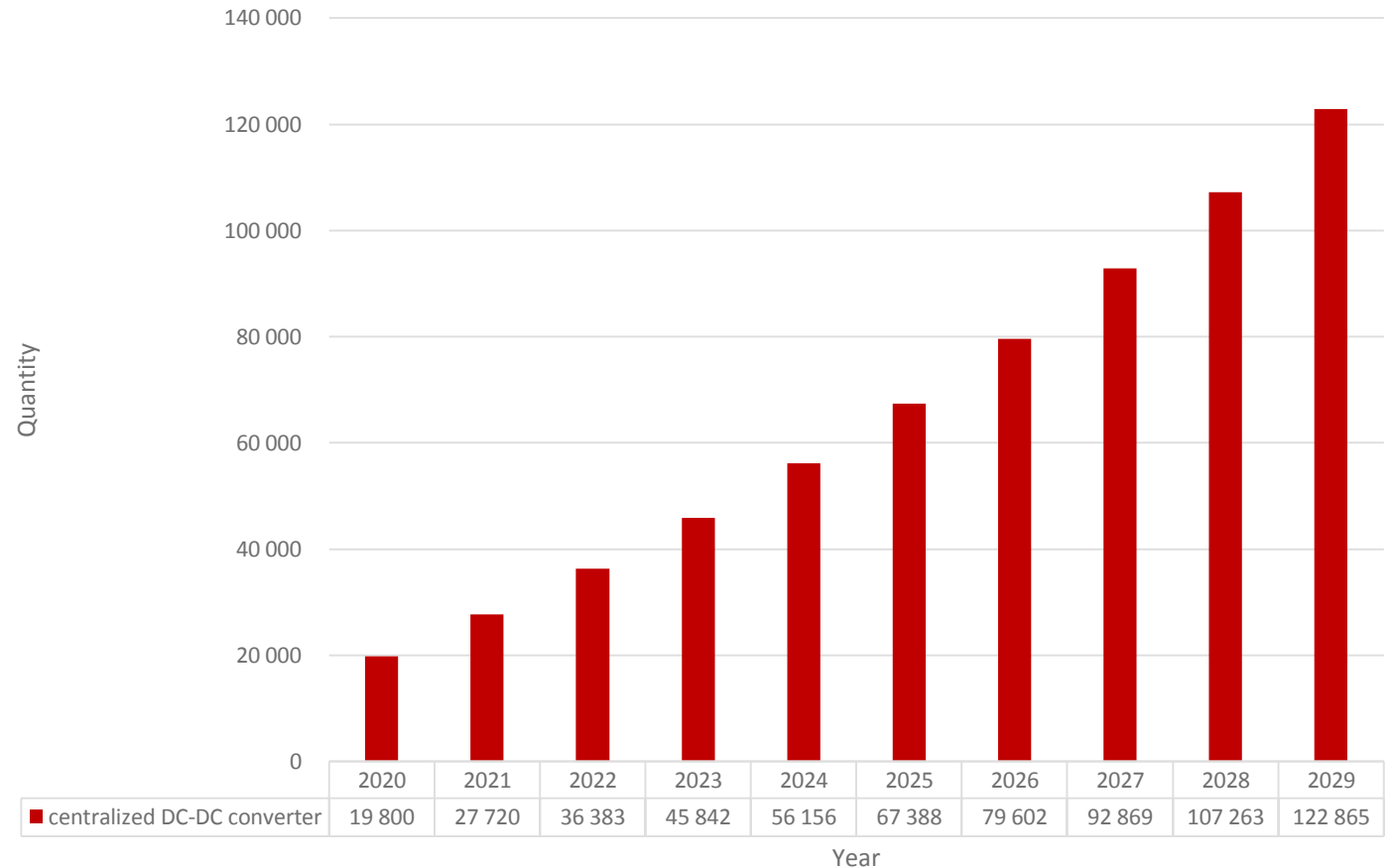
Source: Global Market Insights www.gminsights.com

Industrial Market: Analysis Germany

assumptions:

- 3,3 Mio motion control systems to be installed in 2020
- 5% CAGR applied*
- centralizing AC-DC conversion consolidates the DC-part of 10 motion controller into one DC-DC converter
- 6% take-up rate for a sophisticated DC-DC converter design (reconfigurable, isolated, multiport) rising 2% each year due to increased adoption of DC-Industry approach

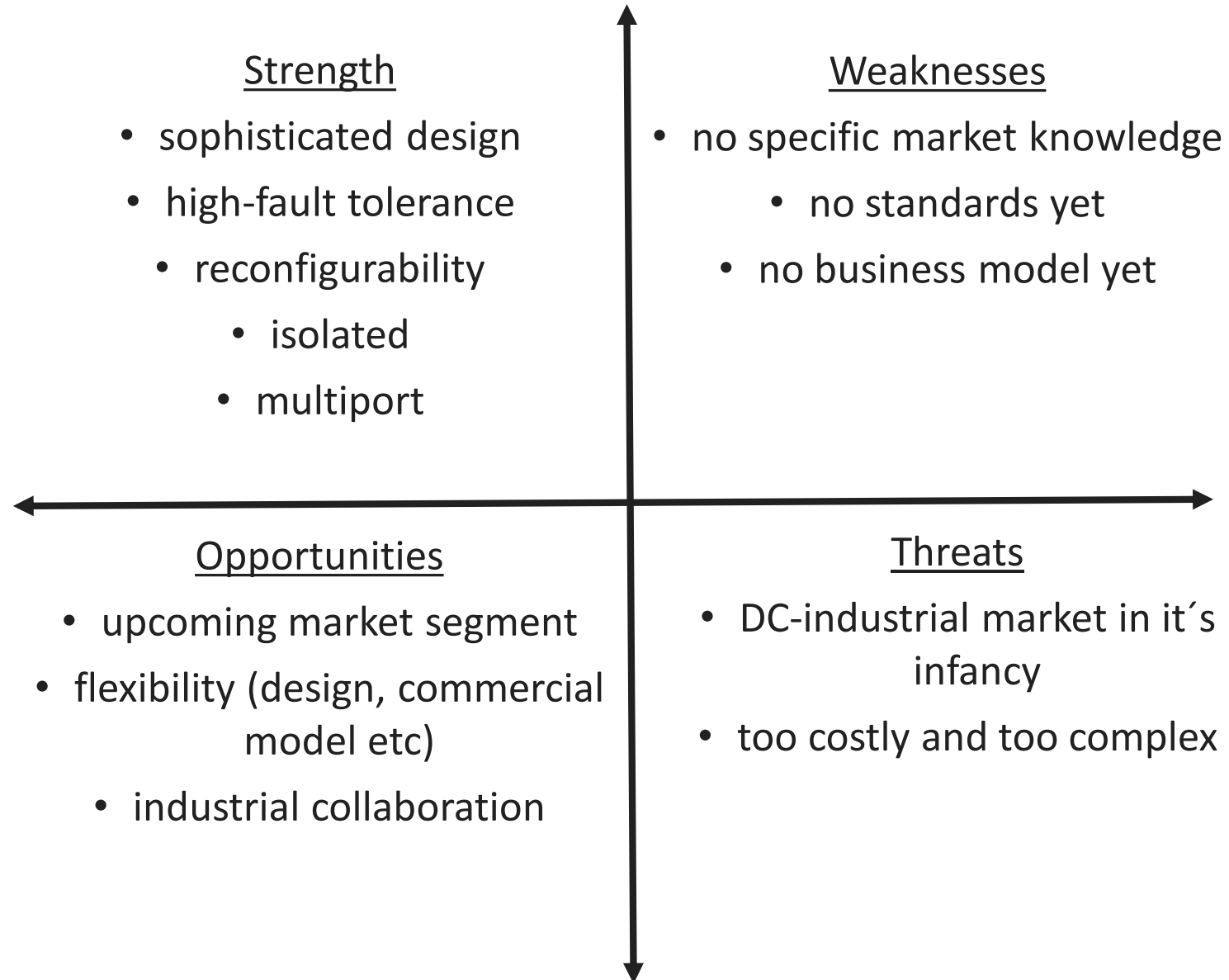
market potential centralized DC-DC converter in motion control



Competitive Landscape Industrial Automation

Name of Company	Webaddress	Comments
Bosch Rexroth	https://www.boschrexroth.com/de/de/produkte/produktgruppen/elektrische-antriebe-und-steuerungen/frequenzumrichter	inverter for e-motor drives
Weidmüller	https://www.weidmueller.de/de/presse/produktmeldungenn/connectpower-dc/connectpower-dc/dc-	
Schneider Electric (French)	https://www.se.com/at/de/product/ABL8DCC12020/dc-dc-wandler-24-w,-24-28,8-vdc,-12-vdc,-2-a/	
Phoenix Contact	https://www.phoenixcontact.com/online/portal/de?1dmy&urile=wcm%3apath%3a/dede/web/main/products/subcategory_pages/Power_supply_units_and_UPS_P-22/50153bdf-c771-4ea3-a528-1e85612526c4	
Siemens	https://new.siemens.com/global/de/produkte/automatisierung/stromversorgung/dc-usv.html	
Eaton (US)	https://www.eaton.com/Eaton/ProductsServices/Electrical/ProductsandServices/Transportationsolutions/PowerConversion/index.htm	
Emerson (US)	https://www.emerson.com/de-de/catalog/solahd-scd-dc-dc-de-de	
Wago	https://www.wago.com/de/c/stromversorgungen?f=%3AProdukthauptfunktion_5200%3ADC%2FDC-Wandler	
SEW Eurodrive	https://www.sew-eurodrive.de/produkte/umrichtertechnik/schaltschrankinstallation/power-and-energy-solutions/power-and-energy-solutions.html#panel-0c7f16e9-d206-4214-a737-4b1fbf49304a-2	
Danfoss (DK)	https://www.danfoss.com/de-de/about-danfoss/our-businesses/drives/	inverter for e-motor drives
Getriebebau Nord	https://www.nord.com/cms/de/product_catalogue/drive_electronics/pgop_drive_electronics.jsp	inverter for e-motor drives
Lenze	https://www.lenze.com/de-de/produkte/umrichter/	inverter for e-motor drives
Baumüller	https://www.baumueller.com/de/produkte/antriebselektrotechnik	inverter for e-motor drives
KEB Automation	https://www.keb.de/news/servosystem-combivert-s6-fuer-ethercat-profinet-und-powerlink	inverter for e-motor drives
KEBA Automation (Austria + Germany)	https://www.keba.com/en/industrial-automation/products/drive-technology/overview/overview	inverter for e-motor drives
WEG Equipamentos Elétricos (Brazil)	www.weg.net	inverter for e-motor drives
ABB (CH)	https://new.abb.com/drives/de/	inverter for e-motor drives
Rockwell (US)	https://ab.rockwellautomation.com/Drives/PowerFlex-700	inverter for e-motor drives
Bonfiglio (Italy)	https://www.bonfiglioli.com/germany/de/produktkategorie-aus/frequenzumrichter-servoantriebe#premium-umrichter	inverter for e-motor drives
Nidec (Japan) + subsidiary Leroy Somer (France)	https://acim.nidec.com/de-de/motors/leroy-somer	inverter for e-motor drives
Beijer Electronics (Sweden)	www.beijerelectronics.de	inverter for e-motor drives

SWOT Analysis Industrial Automation



Conclusions and Recommendations for the Industrial Automation Segment

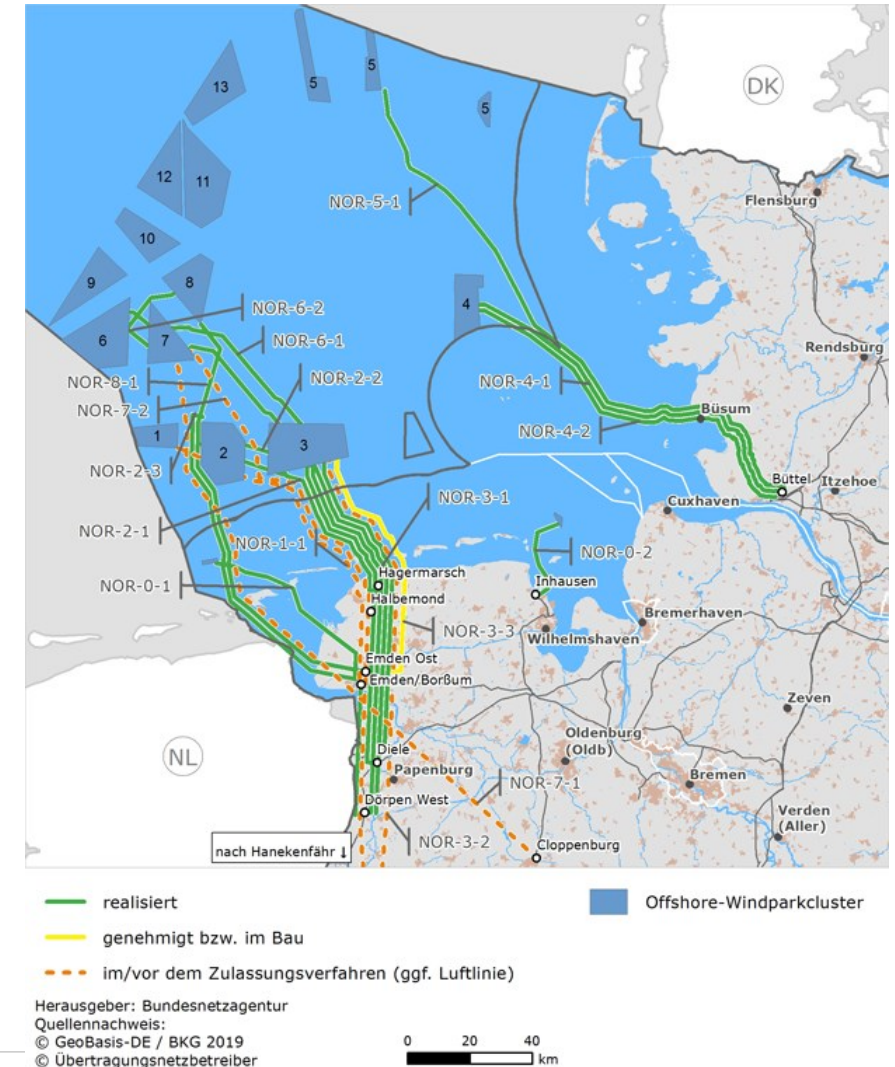
- DC grid in the industrial production environment is still in R&D stage with first field trials in the market thus there is no real market traction yet
- due to multiple benefits of a DC-grid approach in the industrial context, the specific reliability requirements of production environments as well as the sheer market size this market segment is an ideal target for a sophisticated DC-DC converter solution
- because of the complexities of the industrial automation market any sort of collaboration regarding marketable IP should rather be indirect e.g. through licensing agreement of technology or a tier-2 set-up as component supplier
- no specific recommendation regarding licensing model is given here since the whole bouquet could apply from one-time sale of all IP-rights to any sort of royalty based model

other Markets



DC-Link for Offshore Wind Generators to DC-Grid

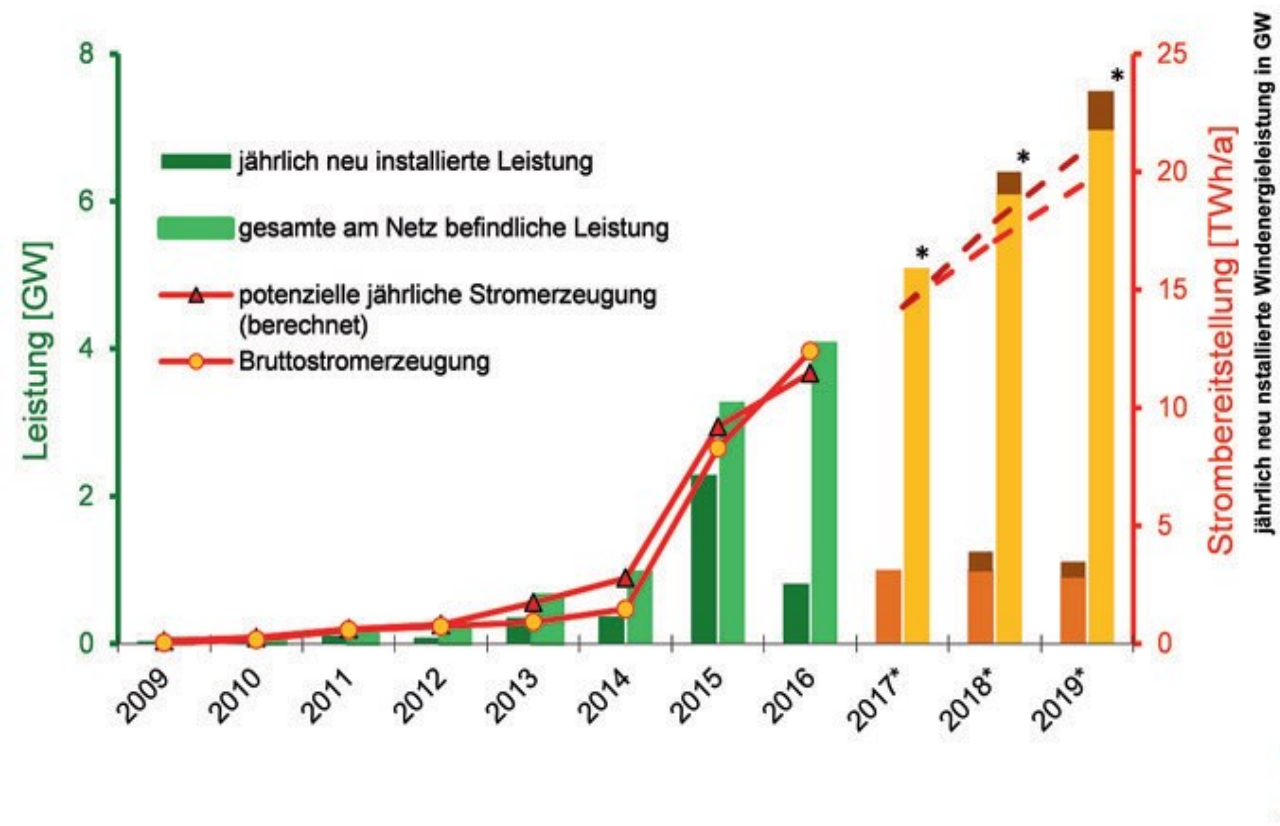
- technological progress is making the direct DC-link of wind generators to a DC-Grid collection network a viable alternative for offshore windparks*
- planned offshore windparks in the Baltic Sea will be linked to the onshore grid via AC-link**
- North Sea windparks planned until 2030 will all be linked to onshore grid via HVDC-link***
- considering the 5 windparks planned until 2030 each with a capacity of 900MW and assuming conventional 5MW windpowered turbines a demand of 900 DC-DC converters each @ 5MW can be anticipated if a DC-grid collection network approach will be applied



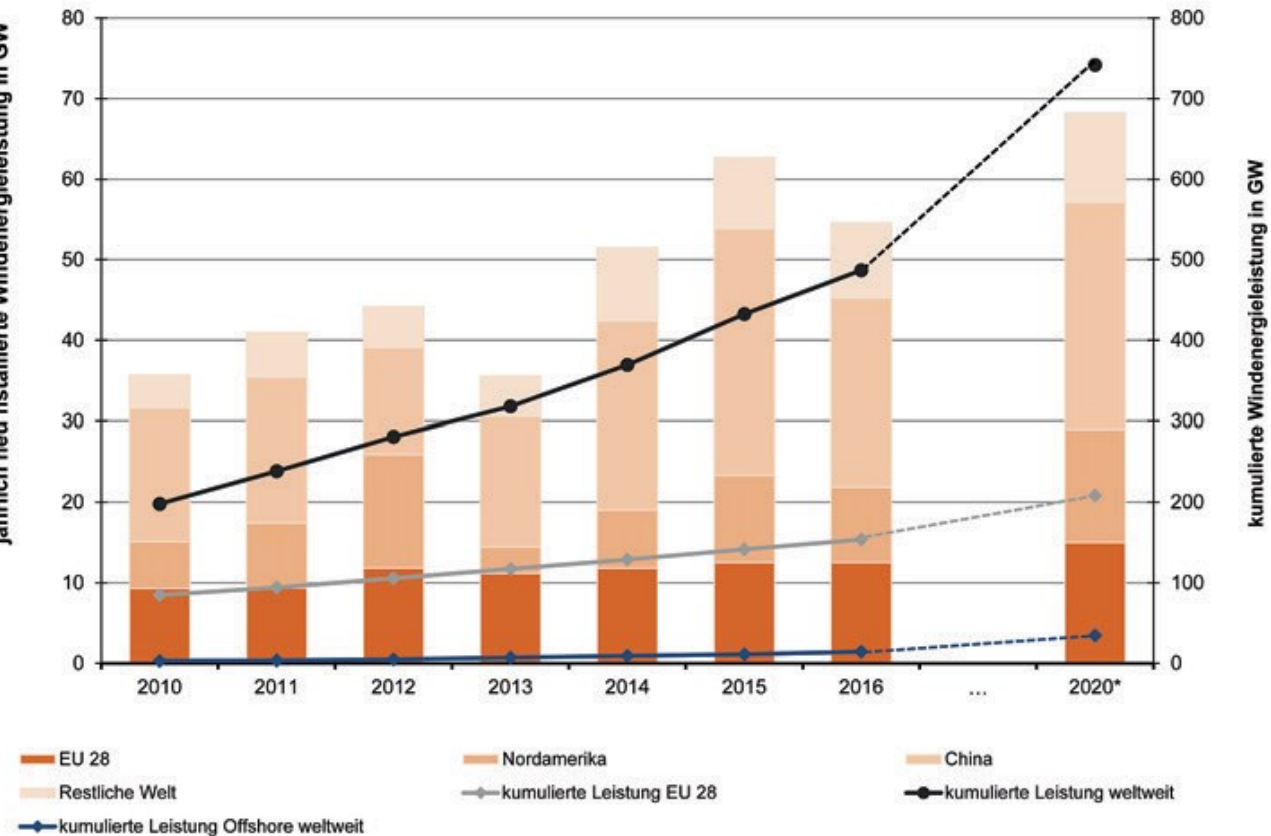
Offshore Wind Market

- globally the offshore wind market is intact with dynamical growth rates, in Germany the situation is currently deferred due to legislative changes in subsidiary policies

Germany: offshore windenergy production capacity



EU/global cumulative annual installed windenergy production capacity, onshore/offshore



Source: VDI Report *

Data center

- DC-grids in data centers is driven by similar logic like DC-Industrie even though benefits are more obvious here and easier to reap, since all servers are essentially DC-driven as well as storage systems etc. , e.g. large datacenters are housing tens of thousands of servers and hardware*
- UPS, an essential element to guarantee high availability as per IEEE terms** could be replaced by battery storage systems
- telecom industry has used 48V DC systems for decades with tremendous results***
- DC grid in data centers yield +10% energy savings****, benefits are:
 - central AC-DC conversion
 - simple integration of solar panels and battery storage systems
 - reduced installation effort, less material required, less capital investment, less floor space
 - higher level of grid autarky
 - less harmonic load on MV/LV grid

Comment:

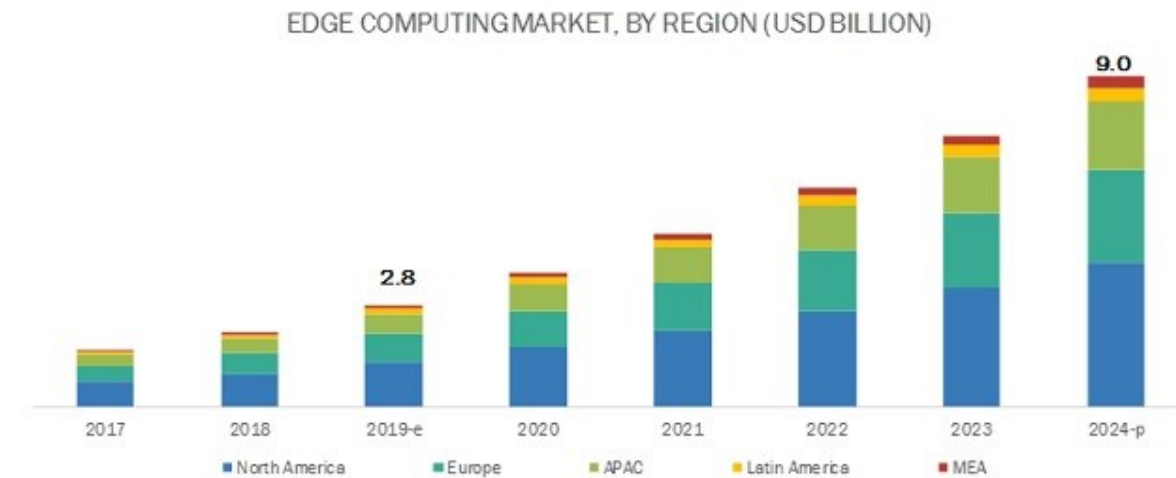
The concept of DC grid is a paradigm shift with centralized AC-DC conversion. This itself will cannibalize the hitherto DC-DC market and thus may spark counterforces...



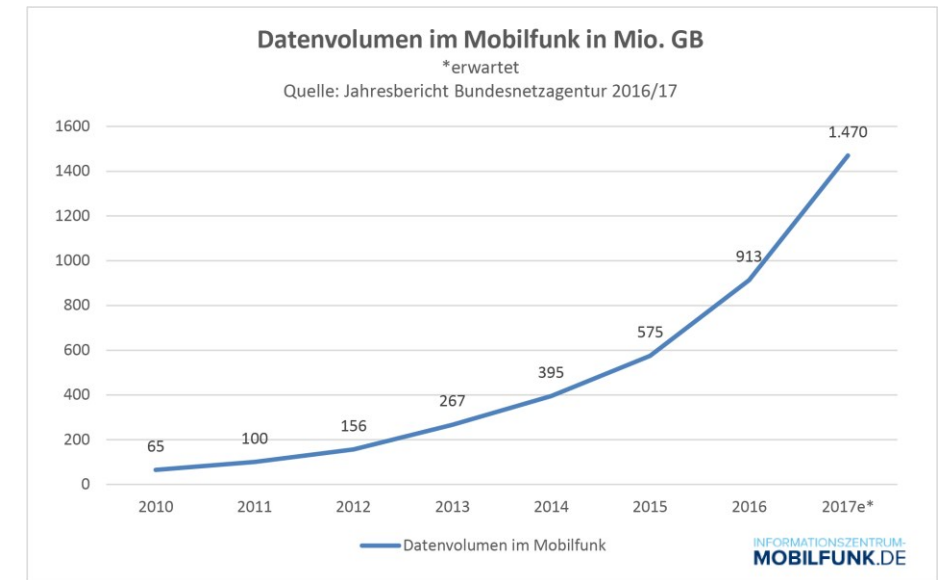
Source: ABB <https://new.abb.com/>

Data center

- data center investments are growing exponential in-line with data load on networks
- IoT, AI and 5G will bring ever more data into networks/clouds while IoT will even drive the demand for more distributed data centers with edge computing in production environments*
- an immediate market opportunity for DC-DC converter is representing the UPS market, however this may shrink and merge into centralized DC-grid scenarios



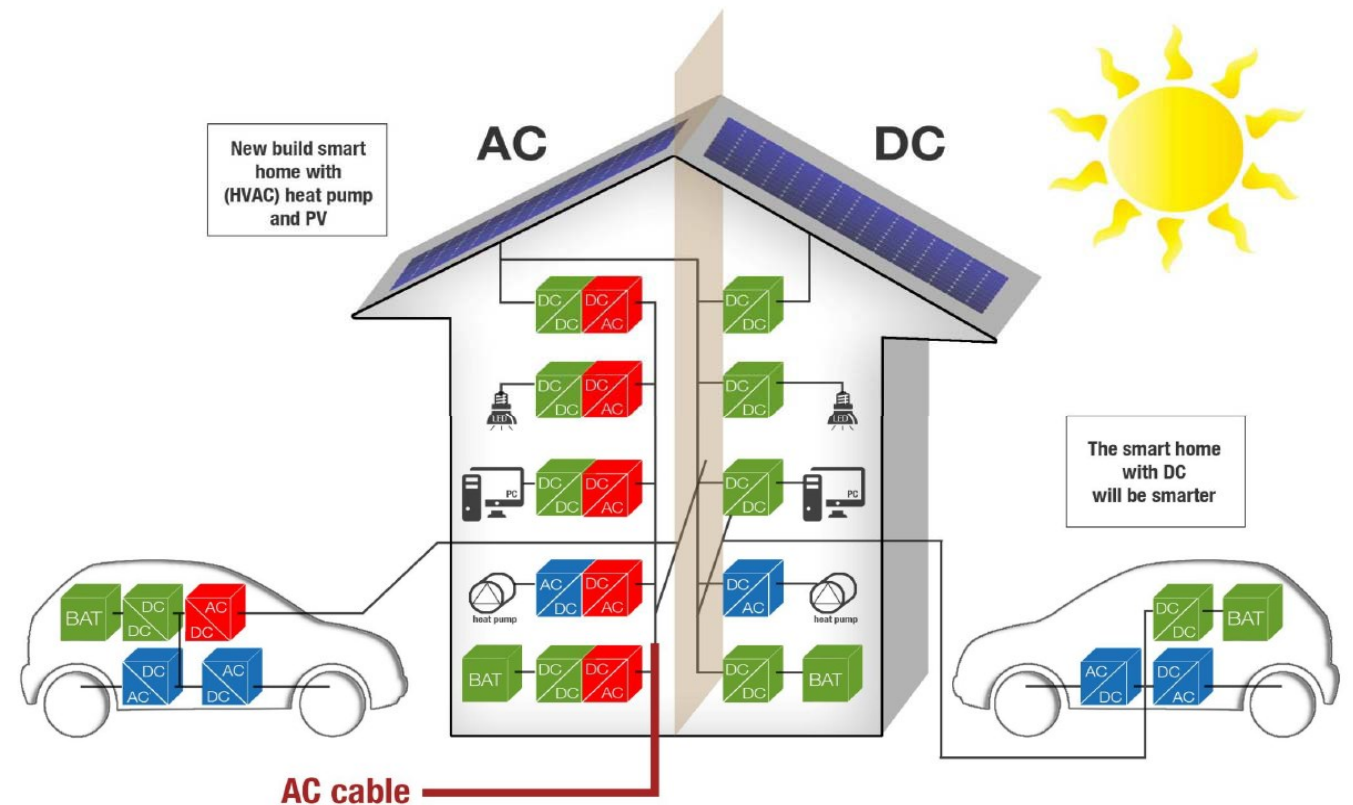
Source: www.marketsandmarkets.com **



Source: www.informationszentrum-mobilfunk.de *** mobile data volume in Germany

Office + Residential DC Grids

- office + residential DC-grids are getting rising interest through increased adoption of LED-lighting technology, DC-driven electronics like servers, PCs, TVs and smartphones as well as simplified integration of solar panels, battery storage and e-vehicle chargers
- some projected benefits are*:
 - 25% reduction in required floor space
 - 15% reduced capital investment
 - 10% energy savings
- since this market is not yet developed and there are no standards for LV-DC-grids like DC-voltage-levelband, arc flash, grounding, connectors etc it is assumed that this market will first get traction in the industrial segment (DC-Industrie, data centers, large office buildings, hospitals etc.) before it is “democratized” into mass-market



Source: VDE ETG Task Force **

Leisure Industry Camping

- a healthy, prosperous and ageing society is the relentless driver for growth in the campervan and caravan business segment
- in 2019 +500k campervans and caravans were registered in Germany*, with +70k new vehicle entrants in 2019** with a +10% CAGR over the last couple of years
- assuming one DC-DC converter per camping vehicle with a take-up rate of 10% for a sophisticated DC-DC converter design (reconfigurable, isolated, multiport), a market potential of +7k DC-DC converter annually can be anticipated for the local market here in Germany
- key players (potential customers) would be manufacturers like Hymer, Hobby, Knaus, Groupe Pilote (France) or suppliers like Votronic***



Source: Messe Düsseldorf GmbH www.caravan-salon.de

Leisure Industry Boating

- there are some estimated 475k boatowners* in Germany nowadays with a small but rising base of e-boats
- in 2016 roughly 1200 e-boats were registered for Lake Starnberg (Bavaria) only**
- in a fairly saturated market and due to the long lifetime of the boats it is assumed that roughly 3k new boats* are entering the German market
- assuming one DC-DC converter per new vessel with a take-up rate of 15% for a sophisticated DC-DC converter design (reconfigurable, isolated, multiport), a market potential of 225 DC-DC converter annually can be anticipated for the local market here in Germany
- key players (potential customers) would be large leisure boat manufacturers like Bavaria, Hanse, Dehler, Beneteau (France), Janneau (France) or suppliers like Torqeedo or Philippi***
- for the professional shipping market the market opportunity in Germany is even smaller with 27 merchant vessels delivered by German shipyards within the year 2019****



Source: BVWW www.bvww.org

Market Players UPS segment

Name of Company	Webaddress	Comments
Rockwell Automation (Allen Bradley, US)	https://ab.rockwellautomation.com/Power-Supplies/Uninterruptible-Power-Supplies	
Siemens	https://new.siemens.com/global/de/produkte/automatisierung/stromversorgung/dc-usv.html	
Phoenix Contact	https://www.phoenixcontact.com/online/portal/de?1dmy&urile=wcm%3apath%3a/dede/web/main/products/subcategory_pages/Power_supply_units_and_UPS_P-22/50153bdf-c771-4ea3-a528-1e85612526c4	
APC (US, belong to Schneider Electric from France)	https://www.apc.com/de/de/#	
Eaton (US)	http://powerquality.eaton.de/Deutschland/Products-services/Backup-Power-USV/default.asp?cx=81	
Emerson (US)	https://www.emerson.com/en-us/catalog/uninterruptible-power-systems?fetchFacets=true#facet:&facetLimit:&productBeginIndex:0&orderBy:&pageView:grid&minPrice:&maxPrice:&pageSize:&	
Numeric (India, belong to Legrand Group from France)	https://www.numericups.com/categories	
Effekta	https://www.effekta.com/unternehmen/	
AEG Power Systems	https://www.aegps.com/de/produkte/3-phasige-usv-systeme/	
Riello Power Systems	https://www.riello-powersystems.de/	
Vertiv (US)	https://www.vertiv.com	
ABB (CH)	https://new.abb.com/ups/de/usv-portfolio-von-abb	jointly marketed with Rittal in their rack-systems; in 2011 ABB has taken a controlling stake in Validus DC Systems (US), a leading provider of integrated DC power infrastructures for datacenters and telecommunication facilities
Salicru (Spain)	www.salicru.com	
Puls GmbH	https://www.pulspower.com/de/produkte/ergaenzungsgeraete/dc-usv-und-puffermodule/	

Market Players Energy segment

Name of Company	Webaddress	Comments
SMA	https://www.sma.de/produkte/dc-technik/sma-dc-dc-converter.html	primary business DC/AC converter
AEG Power Solutions	https://www.aegps.com/de/produkte/dc-module/	
Kostal	https://www.kostal-industrie-elektrik.com/de/produkte/electronics/dc-dc-wandler	fuel-cell application
SFC Energy AG	https://www.efoy-pro.com/efoy-pro/efoy-pro-800/	fuel-cell application
Viessmann	https://www.viessmann.de/de/wohngebaeude/kraft-waerme-kopplung/mikro-kwk-brennstoffzelle/vitovale.html	fuel-cell application
Bosch (with brands Buderus and Junkers)	https://www.buderus.de/de/produkte/catalogue/alle-produkte/108941_brennstoffzelle-bluegen	fuel-cell application
E3DC	https://www.e3dc.com/produkte/s10-e/	battery storage solution private home
ABB (CH)	https://new.abb.com/products/48990001-PM/dc-dc-converter	in 2018 ABB has completed the acquisition/integration of GE Industrial Solutions BU, representing GE's entire electrification business
Kaco New Energy	https://kaco-newenergy.com/de/produkte/	DC/AC converter
Siemens	https://kaco-newenergy.com/de/produkte/Kategorie/string-wechselrichter/	DC/AC converter , in march 2019 Siemens announced to take over the STRING inverter product business of KACO
Fronius (Austria)	https://www.fronius.com	primary business DC/AC converter, also do battery charging
SolarEdge (Israel)	www.solaredge.com	only DC/AC converter
Efacec (Portugal)	https://www.efacec.pt/en/transformers/	transformers, solar inverters, power supply systems
Block GmbH	www.block.eu	transformers, power supply systems
Ingeteam (Spain)	www.ingetteam.com	broad portfolio wrt power electronics systems, inverters, electric motor
Power Electronics (Spain)	https://power-electronics.com	broad portfolio wrt power electronics systems, inverters, electric motor
Traco Electronic (CH)	https://www.tracopower.com/products/browse-by-category/category/dc-dc-converters/	up to 22kw

Market Players Aviation & Rail segment

Name of Company	Webaddress	Comments
GE Aviation (US)	https://www.geaviation.com/sites/default/files/20kW-DC-to-DC-SiC-Converter.pdf	aviation segment
Crane Aerospace (US)	http://www.interpoint.com/products/by_type/type/converters	aviation segment
KID Systeme	https://www.kid-systeme.de/doc/KID_SKYpower_next_gen.pdf	aviation segment, power supply AC and DC
Powertech (Germany)	www.kb-powertech.com	railway and industry segment, sold by Knorr-Bremse to a private equity company in Nov 2019
Kiepe Electric (Germany)	https://www.kiepe.knorr-bremse.com/kiepe-electric-gmbh	part of Knorr-Bremse AG
Ingeteam (Spain)	https://www.ingetteam.com/en-us/sectors/railways/s15_59_p/products.aspx	
Sinepower (Portugal)	http://www.sinepower.com/en/products/civil-and-military-aviation-aeronautical-industry/	

Market Players Robot Transport Systems

Name of Company	Webaddress	Comments
Jungheinrich	https://www.jungheinrich.de/produkte	charging stations, forklift trucks and robot transport systems
Kion Group	www.kiongroup.com	brands: Linde MH, Still, OM, Dematic ; logistics and transport
Kuka Robotics	https://www.kuka.com/de-de/produkte-leistungen/mobilit%C3%A4t/mobile-roboter	robot transport systems
SEW Eurodrive	https://www.sew-eurodrive.de/automatisierung/fabrikautomatisierung/mobile-assistenzsysteme/mobile-assistenzsysteme.html	robot transport systems
Stäubli WFT (CH, Germany)	https://www.wft-gmbh.de/mobile-roboter/	robot transport systems
Comau (Italy)	https://www.comau.com/de/unsere-kompetenzen/robotik/automation-products/agile1500	robot transport systems
MIR mobile industrial robots (DK)	https://www.mobile-industrial-robots.com/en/	robot transport systems

DC-DC component suppliers

Name of Company	Webaddress	Power
Semtech Corp (US)	https://www.semtech.com/products/power-management/femtobuck-dc-dc-regulators-controllers	
Texas Instruments (US)	http://www.ti.com/de-de/power-management/non-isolated-dc-dc-switching-regulators/overview.html	low power
ON Semiconductor (US)	www.onsemi.com	low power
Monolithic Power Systems (US)	www.monolithicpower.com	low power
Maxim Integrated (US)	www.maximintegrated.com	low power
Infineon (Germany)	https://www.infineon.com/cms/de/product/power/dc-dc-converters/	up to 0,6kW
Rohm (Japan)	www.rohm.com	low power
Artesyn (US)	https://www.artesyn.com/power-supplies/cat/26/dc-dc-converters	up to 0,6kW
XP Power (Singapore)	https://www.xppower.com/de/Produkte/dc-dc-wandler	up to 0,6kW
Vicor Corporation (US)	http://www.vicorpower.com	up to 0,6kW
Delta Electronics (Taiwan)	https://www.deltaww.com/Products/CategoryListT1.aspx?CID=01020101&hl=en-US	up to 1,3kW
Murata (Japan)	https://power.murata.com/products/dc-dc-converters/isolated.html	up to 1kW
TDK Electronics (Japan, Germany)	https://product.tdk.com/info/de/products/power/switching-power/dc-dc-converter/index.html	up to 0,6kW
Recom (Austria)	https://recom-power.com/de/index.html?9	

Final Conclusions

- several vertical market segments have been analyzed regarding their opportunities for a “reconfigurable isolated multiport DC-DC converter” with a prime focus on the Central-European region
- the automotive and industrial automation markets have been analyzed in more depth since they are key target markets with the largest market opportunity
- it is not the intention of this report to show the most accurate forecasts but rather to point out some viable and robust business trends solidifying strategic market opportunities
- some market verticals may be smaller but offer a more imminent opportunity, others be larger with a more deferred perspective* and others may even never develop
- a general criticality is to judge the particular market opportunity for a specific “reconfigurable isolated multiport DC-DC converter” solution

Final Recommendations

below the author provides his personal recommendations regarding go-to-market strategies:

- each vertical market needs to be addressed individually taking the specific market idiosyncrasies into consideration
- a solutions approach is highly recommended:
 - means for e.g. DC-grids like DC-Industrie the focus should not be on DC-DC only but rather on a solution comprising centralized AC-DC including central DC-DC, reinforcing the underlying general trend of energy/environmental saving
 - even for application specific DC-grids like DC-Industrie a more holistic solution will eventually come into the perspective also comprising LV AC, MV AC and MV DC, which will give way for a full-blown smart transformer scenario

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Thank You

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