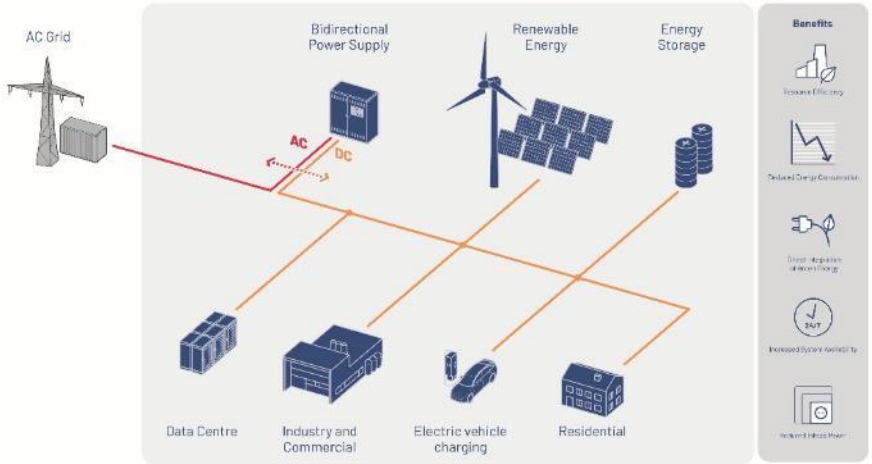
NEFI Technology Talk "DC Industry“: Results of research projects DC-Industry

ODCA direct current by zvei

https://openDCalliance.org



DC-INDUSTRIE
ENERGIEWENDE TRIFFT INDUSTRIE 4.0

https://www.dc-industrie.de

Dr. Hartwig Stammberger, Eaton, Bonn, Germany
Chair of the Board of Open DC Alliance ODCA

EATON
Powering Business Worldwide

NEFI talk: Results of research projects DC-Industry

Dr. Hartwig Stammberger

- **Electrical Engineer**
- **Simulation**
  - Magnetic field for switching devices
  - Short circuit & selectivity
- **Direct current background**
  - 2010 – alternative DC breaker concepts
  - 2016 – Eaton lead for DC-INDUSTRIE
  - 2019 – Coordinator DC-INDUSTRIE2
  - 2022 – Chair Open DC Alliance ODCA

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- DC-INDUSTRIE projects and applications
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- Advantages of DC
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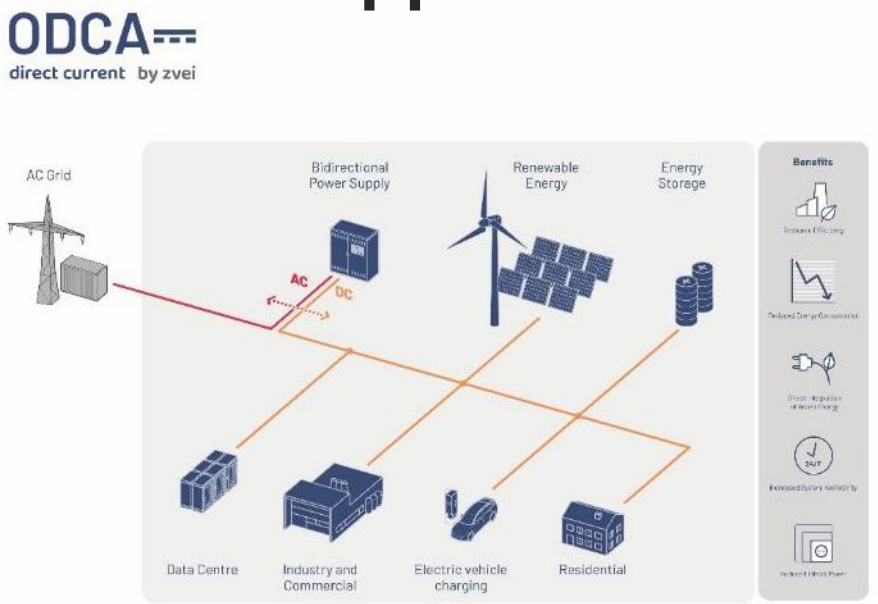

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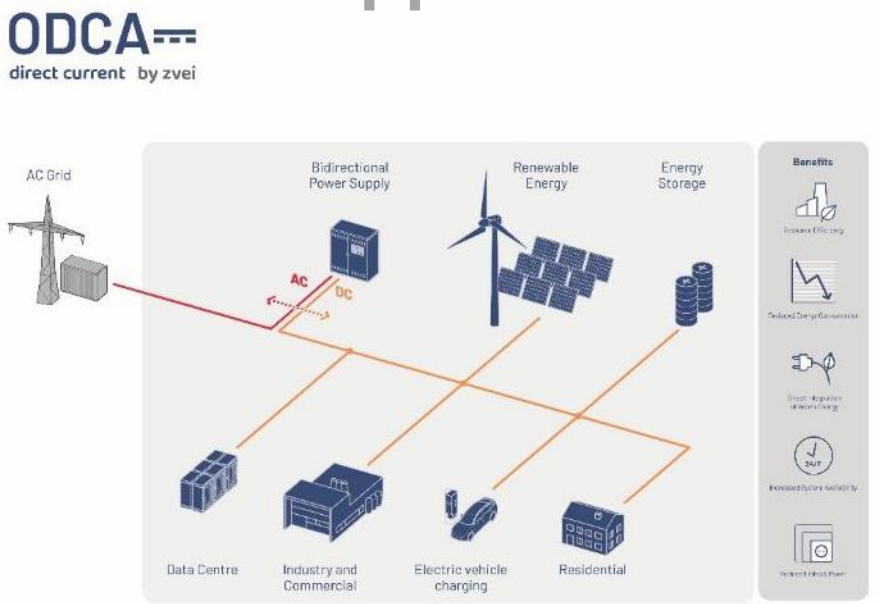

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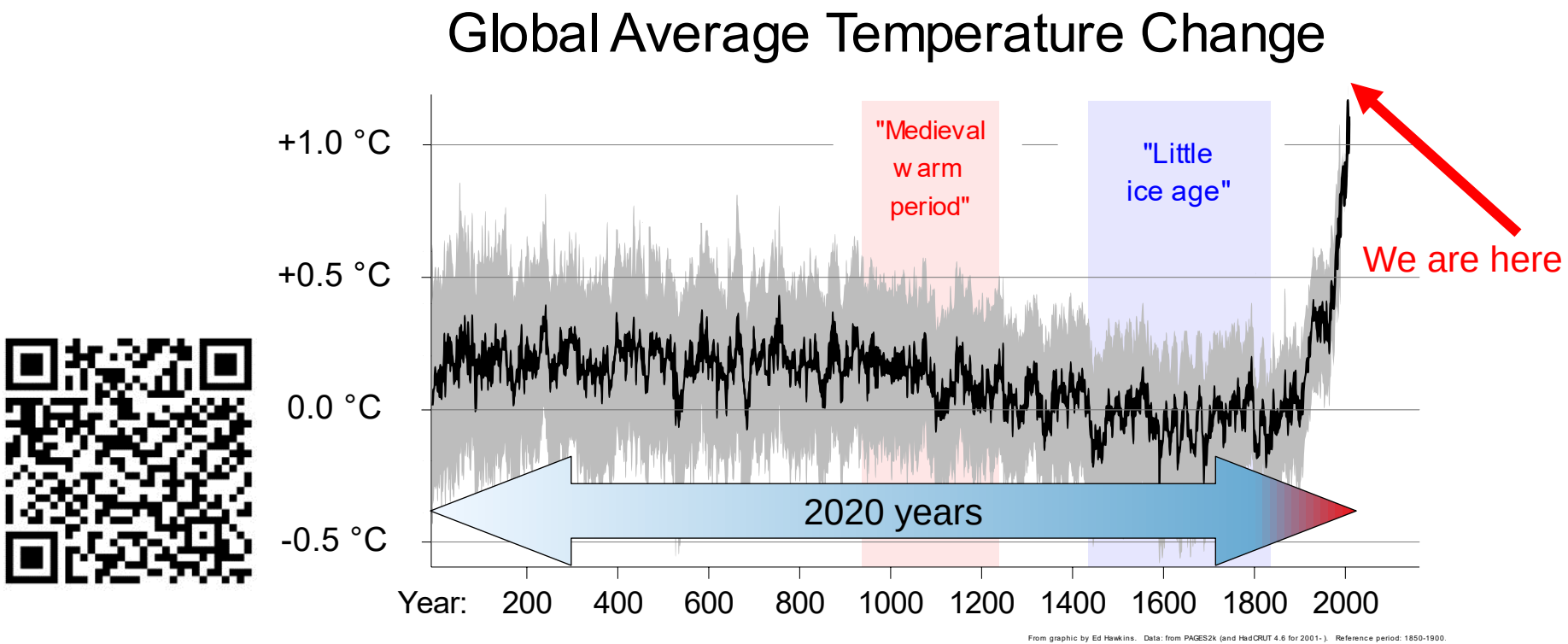
Motivation: global temperature rise



Source:Global temp. Change: By RCraig09 - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=87832845

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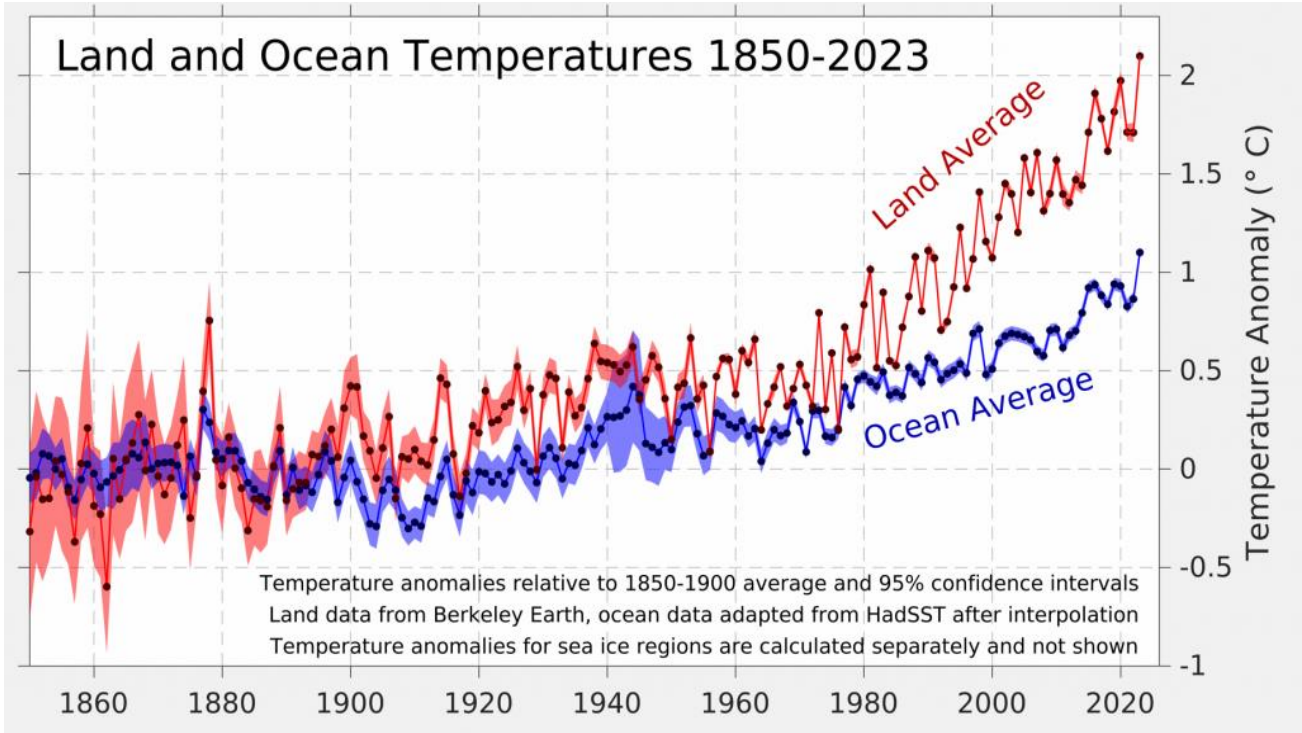
Motivation: Global temperature rise

- **Berkeley Earth**
  - Independent U.S. non-profit organization
  - Focused on environmental data science and analysis.
  - Last 9 years have been the 9 warmest years on record
  - Land mass warms faster than oceans



Source: https://berkeleyearth.org/global-temperature-report-for-2023/

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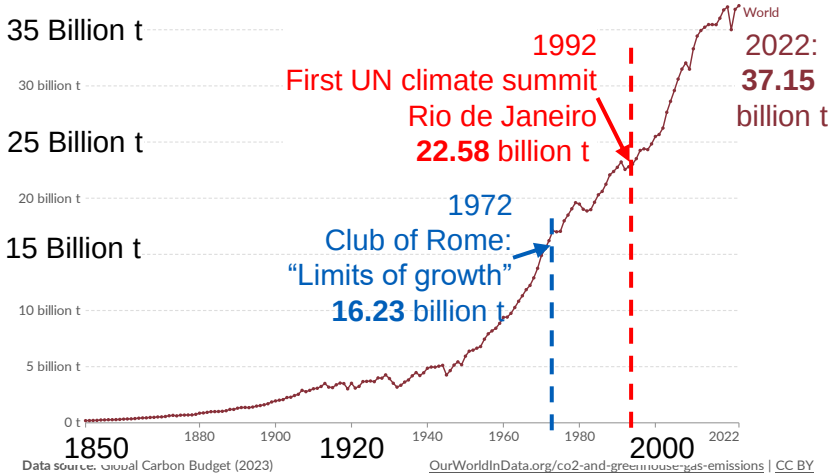
Motivation – CO_2 emissions

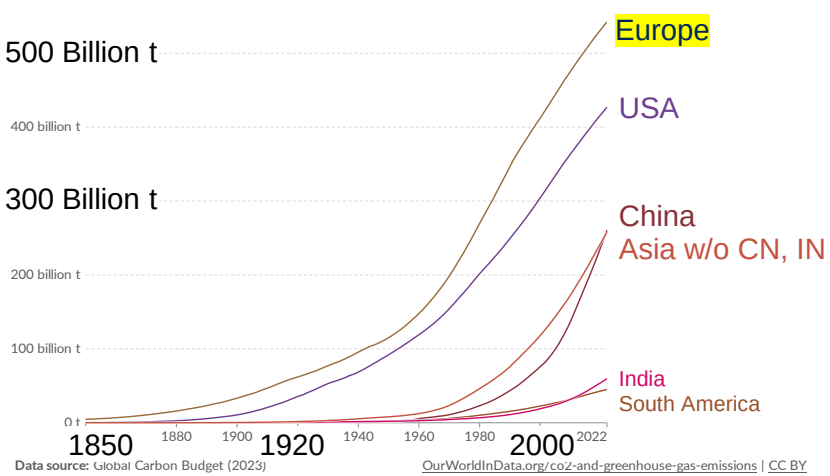
Worldwide annual CO_2 emissions from fossil fuels and industry



1. **Fossil emissions**: Fossil emissions measure the quantity of carbon dioxide (CO_2) emitted from the burning of fossil fuels, and directly from industrial processes such as cement and steel production. Fossil CO_2 includes emissions from coal, oil, gas, flaring, cement, steel, and other industrial processes. Fossil emissions do not include land use change, deforestation, soils, or vegetation.

https://ourworldindata.org/grapher/annual-co2-emissions-per-country

Cumulative CO_2 emissions from fossil fuels and industry since 1750



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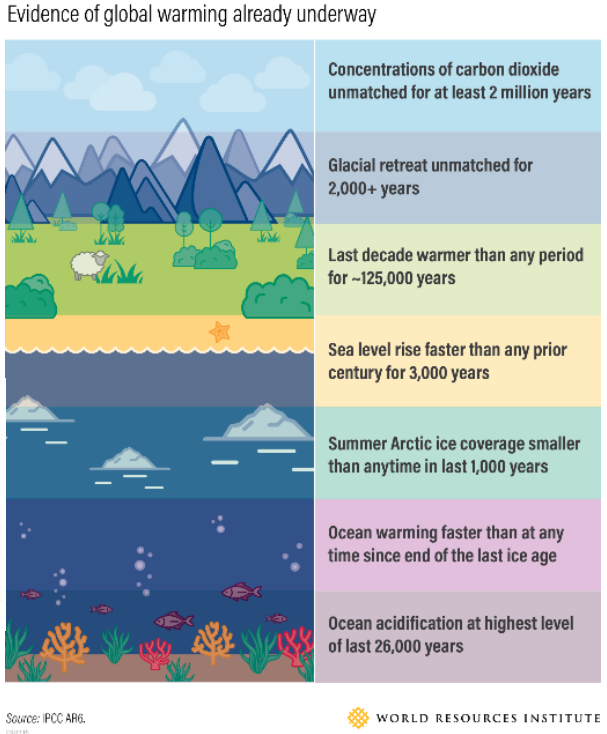
https://ourworldindata.org/grapher/cumulative-co-emissions

What is the IPCC?

- **Intergovernmental Panel on Climate Change**
  - 195 member states, secretariat in Geneva, CH
  - Established in 1988, https://www.ipcc.ch/
  - Reviews relevant scientific literature
  - Does not conduct research on its own
  - Prepares reports for governments and stakeholders
  - Three-stage review process for each report
    1. Expert (peer) review
    2. Review by governments
    3. Government review of the “Summary for Policymakers”
  - Most recent summary published in spring of 2023

Motivation: Consequences

- **IPCC report 2023**
  - Climate change is man-made
  - Climate change impacts people and ecosystems more widespread and more severe than expected
  - It leads to drastic changes
    - Last decade has been the warmest for > 100 000 years!
    - Sea levels rise faster
    - Oceans warm faster
  - But: We have the means to prevent this
    - We need urgent, systemwide transformations to secure a net-zero, climate-resilient future



Source: https://www.wri.org/insights/2023-ipcc-ar6-synthesis-report-climate-change-findings

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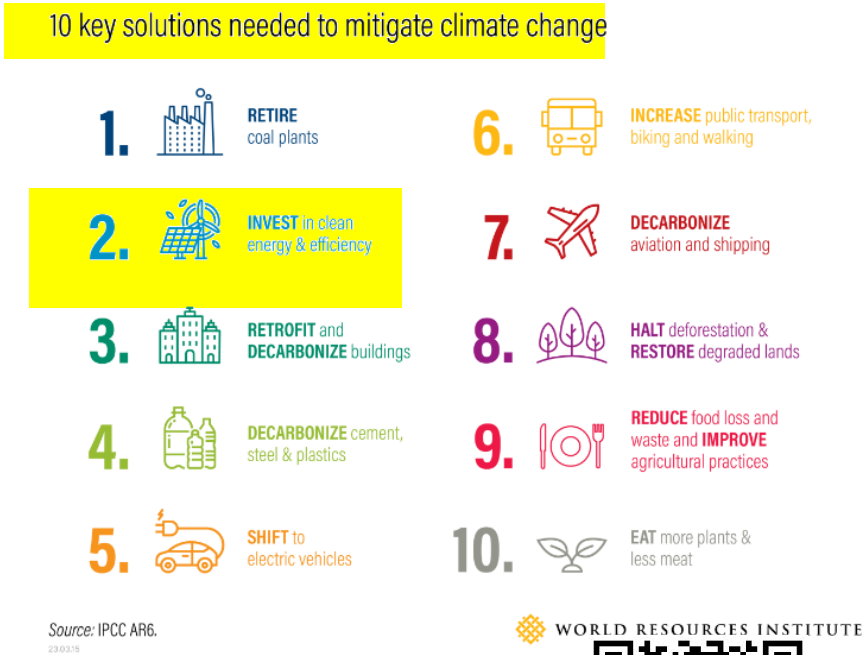
Motivation: Energy efficiency

- **IPCC report 2023**
  - Power generation, buildings, industry, and transport are responsible for close to 80% of global emissions
  - One necessary measure is investment in clean energy & efficiency (2.)
- **DC is part of the solution**



Source: https://www.wri.org/insights/2023-ipcc-ar6-synthesis-report-climate-change-findings and https://www.ipcc.ch/report/ar6/syr/

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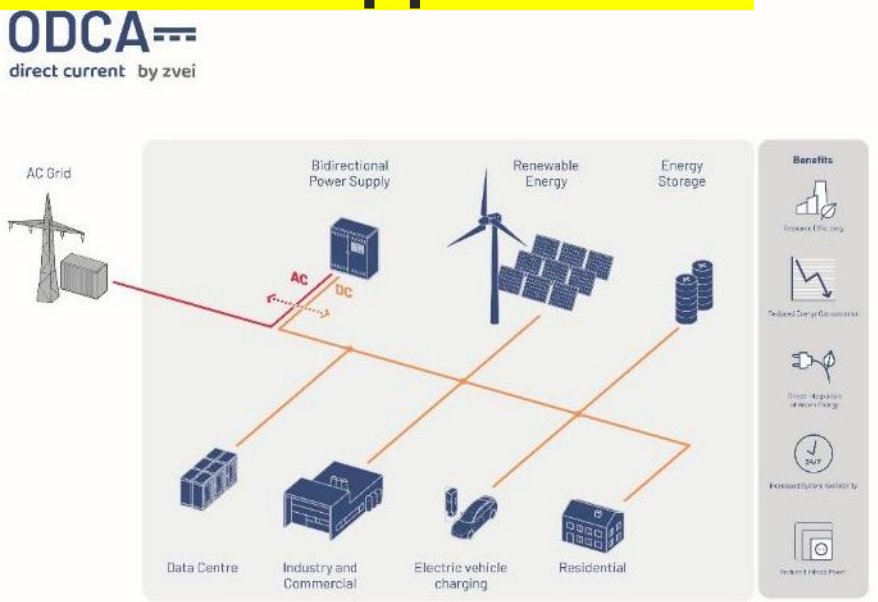
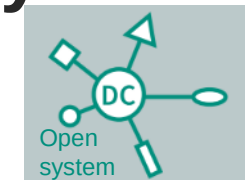


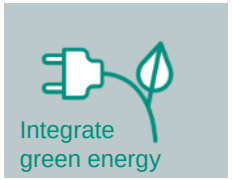
DC-INDUSTRIE projects 2016 - 2023

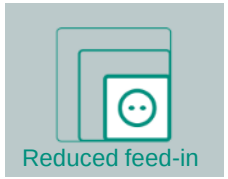
People turn ideas into reality

Kick-off meeting

2019, Lemgo, TH-OWL







Committed, efficient collaboration

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DC-INDUSTRIE project partners

45 corporate & research partners

Funded by German government

150+ engineers & researchers

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DC-INDUSTRIE Highlights

- **Technology proven in 10 model applications**
  - BMW
  - Homag
  - KHS
  - KUKA
  - Mercedes-Benz (with 3 models)
  - Fraunhofer IISB
  - Fraunhofer IPA
  - Ostwestfalen-Lippe University of Applied Sciences (TH OWL)
- **Peak power reduction 40-80%**
- **Recover braking energy**
- **50% less copper in cabling vs. 3~AC**
- **Simple integration of photovoltaics and energy storage**

Model application @ Mercedes-Benz

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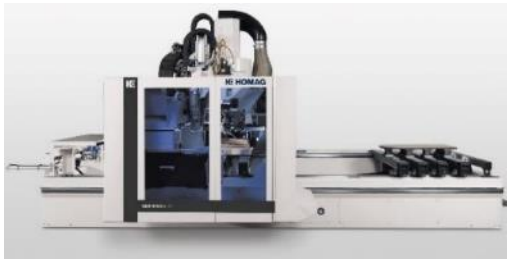
Model applications of DC-INDUSTRIE

- **Mercedes-Benz**
  - Production cell with 4 robots
  - Challenging energy demand (Al-welding)
  - Continued from EU project AREUS

- **Homag**
  - Wood working machines
  - Many loads
  - Sensors & actors
  - Integrated energy storage



- **Mercedes-Benz**
  - Suspension track
  - 5 individual carriers with slip rings
  - Coupling of two applications

- **KHS**
  - Beverage container handling
  - Open concept
  - > 30 drives

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More applications for DC-INDUSTRIE2 1/3

- **BMW**
  - Car body production cell
  - Focus
    - Energy distribution & storage
    - Energy feedback to grid
    - Switching and protection

- **KUKA**
  - Test cell with 4 robots
  - Focus: robot control

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More applications for DC-INDUSTRIE2 2/3

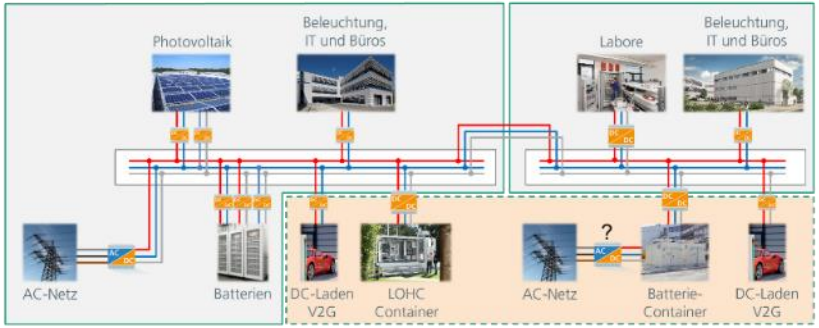
- **Mercedes-Benz Factory 56**
  - Large distances & power
  - 222.000 m2 production area
  - 2 MW DC grid for hall infrastructure
    - 1 MW solar energy, 5.7 MW peak
  - Goal: CO_2-neutral production

- **TH OWL (Lemgo)**
  - Model electro-mechanical loads, up to 11 axes
  - Storage
  - Several infeed rectifiers
  - Focus
    - Model dynamic behavior in real time
    - Test virtual machines in a DC environment
    - Test of multiple failure scenarios

More applications for DC-INDUSTRIE2 3/3

- **Fraunhofer IPA**
  - Industrial power distribution
  - AC-DC transformation
  - Protection concept
  - Parallel operation of AICs

- **Fraunhofer IISB**
  - DC infrastructure in office building
  - Electric car charging



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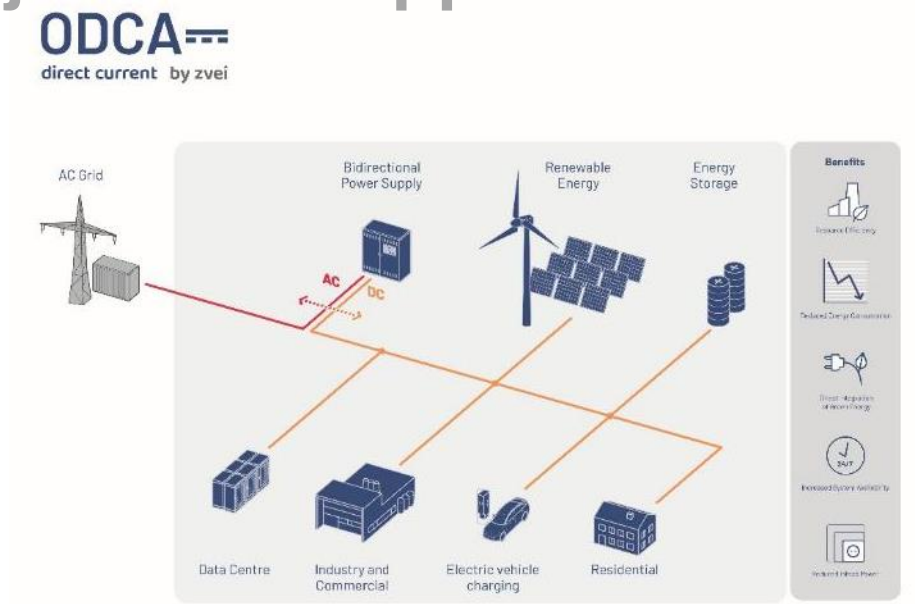

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Results of DC-INDUSTRIE

- **Mercedes-Benz**
  - Production cell with 4 robots
  - Challenging energy demand (Al-welding)
  - Continued from EU project AREUS

- **Hom**
  - Wood working machine
  - Many loa
  - Sensors & actors
  - Integrated energy storage

- **Mercedes-Benz**
  - Suspension track with individual carriers
  - with slip rings
  - Coupling of two application
  - KHS
  - Beverage container handling
  - Open concept
  - > 30 drives

- Devices from all partners collaborate well
- DC system concept confirmed
- No issues found
- All ~100 short-circuit faults cleared w/o failure
- 80% reduction of feed-in power in one unit!

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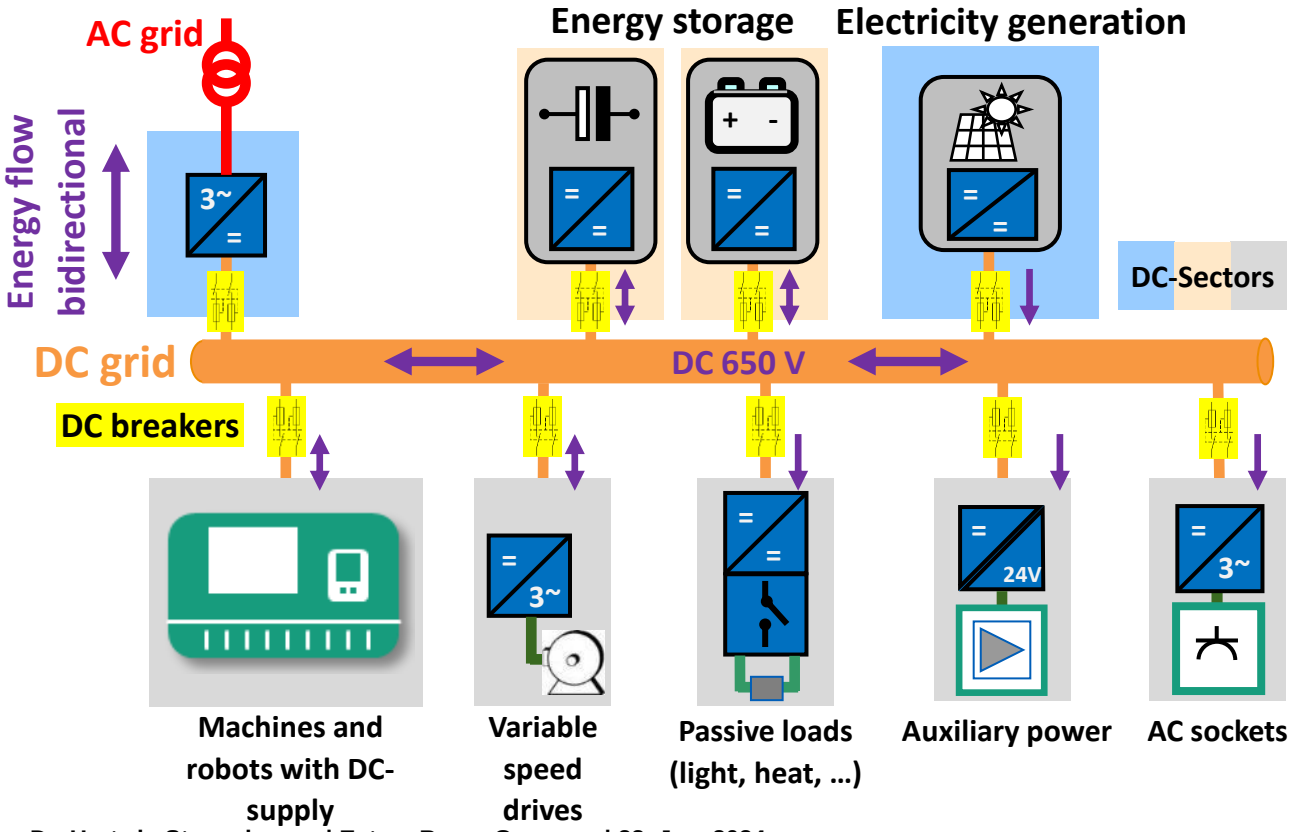
General requirements for protection devices

- **Requirements**
  - Conduct current
  - Detect fault currents
  - Interrupt operational & fault currents
  - Isolate
- **No difference between AC and DC**



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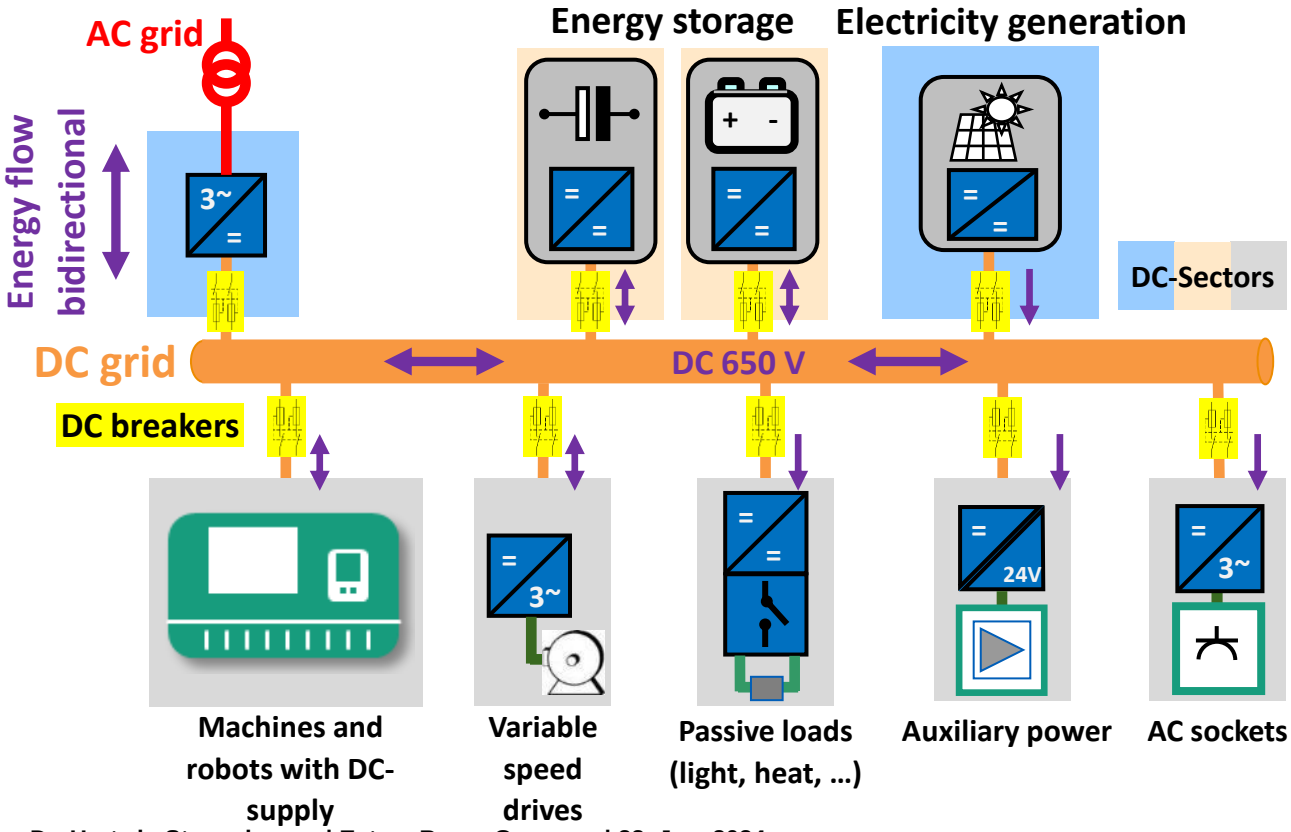
Special DC requirements for protection devices

1. **Inrush current of capacitors**
   - ➔ Limit pre-charge current
2. **Many distributed sources, capacitive grid**
   - ➔ Rapid rise of short-circuit current
   - ➔ Ultrafast operation
3. **No strict “top-down” energy flow**
   - ➔ Detect direction of current for selectivity
4. **No natural current-zero crossing**
   - ➔ Force current to zero



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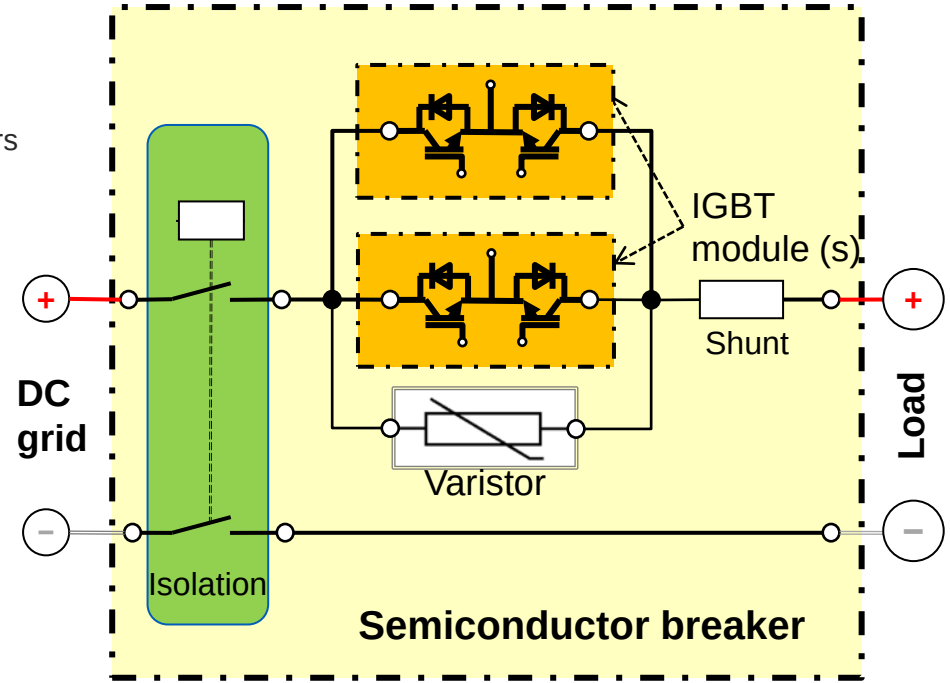
2. Ultrafast operation → semiconductor breaker

- **Rationale for fast operation**
  - Ensure operation of healthy parts of the system
  - Avoid discharging of storage devices
  - Limit short-circuit current to protect semiconductors in the circuit
- **Solution**
  - Power semiconductors
    - Example IGBT + Diode
  - Varistor limits voltage
  - Isolation contacts disconnect w/o current-flow
- **Other functions**
  - Detection of over- & undervoltage
  - Energy measurement
  - Communication
- **Properties**
  - Fast (< 100 µs switch-off time)
  - Low fault energy
    - << 1% of mechanical breaker



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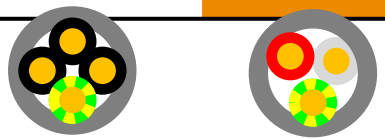
Cabling: Resource- and energy efficiency

- **Inverter-operated 3~motor 7.5 kW**

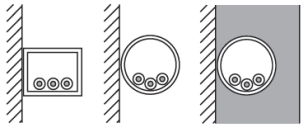
	400 V AC	650 V DC
Current	20 A	14 A
Cable cross section	2.5 mm²	1.5 mm²
Total copper	10 mm²	4.5 mm²
Power loss	8.6 W/m	4.3 W/m



Wiring type	B1	
Number of wires loaded	2	3
Wire cross section in mm²	Max. current in A	
1.5	17.5	15.5
2.5	24	21
4	32	28
6	41	36

Permitted current in A @ 30°C ambient temp. acc. to IEC 60364-5-52

B1



- **50% less copper**
- **50% less power loss**
- **Same insulation requirement**
- **2500 € lower power bill per year per km cable**
  - (2 shift operation, 10 ct/kWh, full load)

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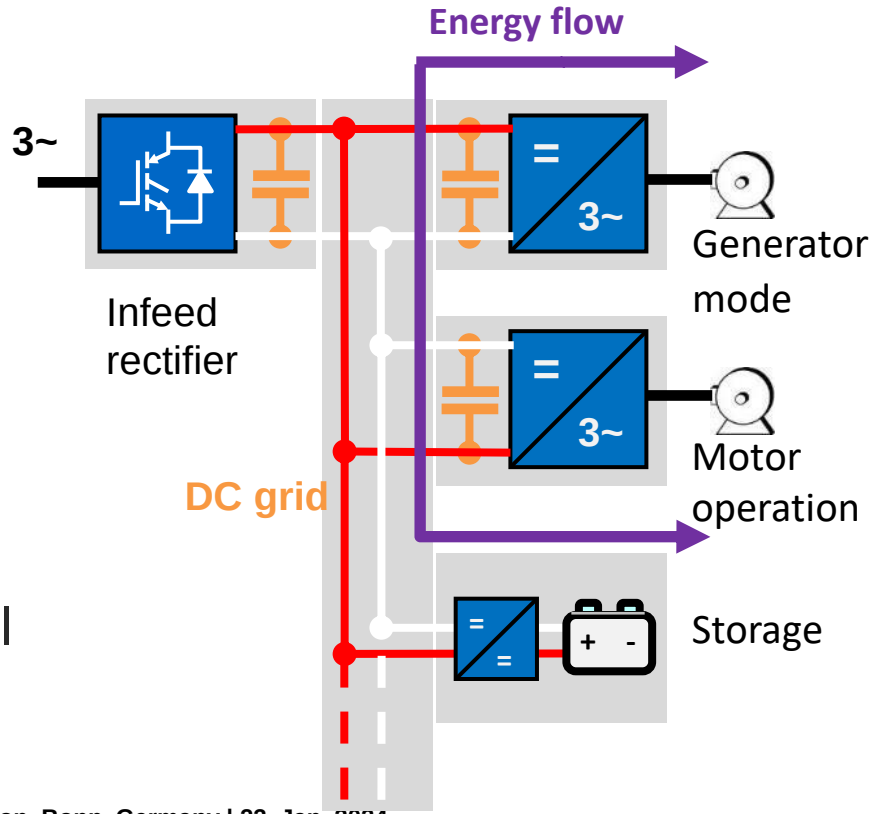
DC benefit: Braking energy is used

- **DC grid**
  - Less effort
    - AC/DC conversion for each drive is redundant
    - Fewer components
  - 100% recuperation of braking energy
    - Into different motor
    - Into storage device
  - No need to “cool-away” the braking energy → additional saving



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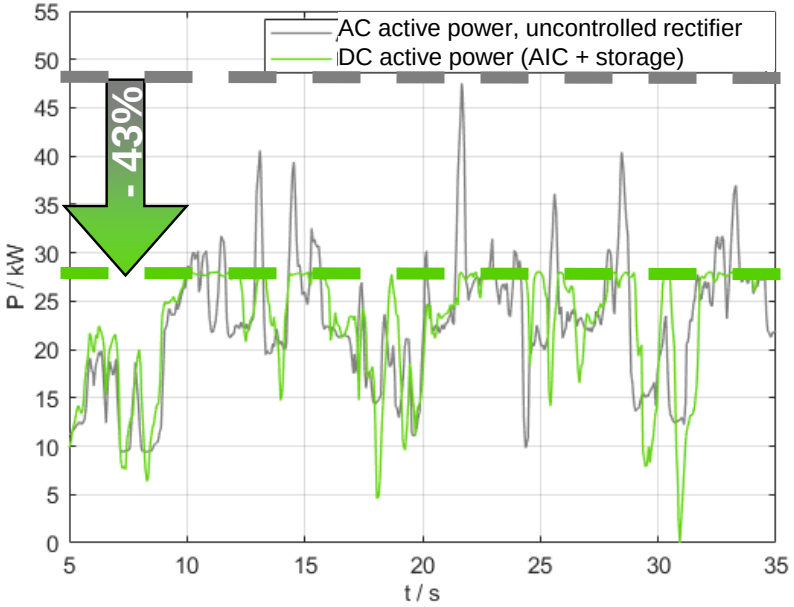
DC Benefit: Mains peak-power reduction

- **AIC + capacitive storage**
- **Reduction peak :**
  - AC: 47 kW peak
  - DC: 27 kW peak
  - **43% reduction**
- **Power factor:**
  - AC: 0,72
  - DC: 0,99
- **Apparent Power (integral over time):**
  - **30% reduction**

HOMAG



Benefits of Direct Current

1. 50% less copper and 50% reduced power loss in cabling
2. Complete recovery of braking energy
3. Significant reduction of peak power demand from AC grid
4. Resilient → simple integration of energy storage & renewables

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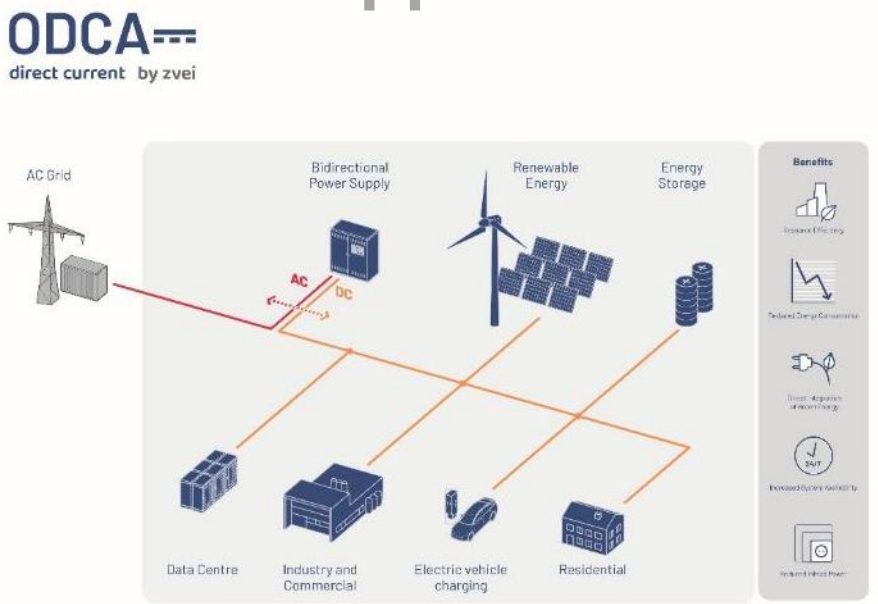

Next steps – outlook

- **Technology is ready**
- **Address hurdles**
  - Regulation, standardization, education
- **EU commission**
  - Strategic Energy Transition Plan for LVDC
- **Provide platforms for collaboration of DC stakeholders**
  - Open DC Alliance ODCA | Current/OS

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Open DC Alliance ODCA

- **International alliance**
  - Founded Nov. 2022
  - 57 partners – up from 33 founding members
- **Vision**
  - DC contributes to a sustainable world
- **Mission**
  - Establish an international DC ecosystem
- **https://openDCalliance.org**

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Sources

- **Systemkonzept DC-INDUSTRIE2: “Abschlussbericht des Projekts”**
  - https://odca.zvei.org/resources/publications/updated-system-concept-for-dc-industrie2-published , Sep. 2023
- **Website Open DC Alliance ODCA**
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Stammberger, Hartwig
I am the author of this document
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