Reliable Power Electronics

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Reliable power electronics

- Kempower introduction
- Issues effecting to lifetime
    - Environmental conditions
    - Equipment layout / construction
    - Component dimensioning / selecting
- Application example EV fast charcing
    - Operation cycles at charging
- Passive components
- Active components

Strong growth & geographical expansion

In 2022, we reached EUR 209 million worth of order intake and EUR 104 million of revenue, representing 279% year-on-year growth.

Revenue growth
279%

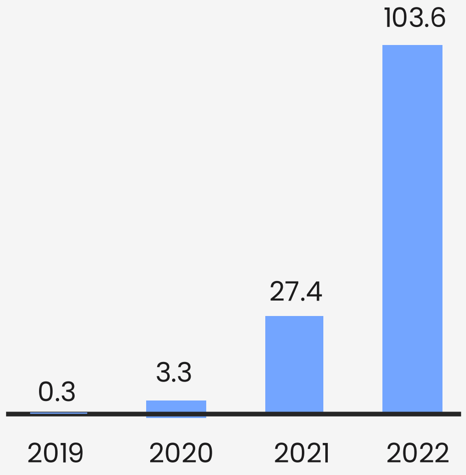
Gross margin
46%

Headcount end of period
375

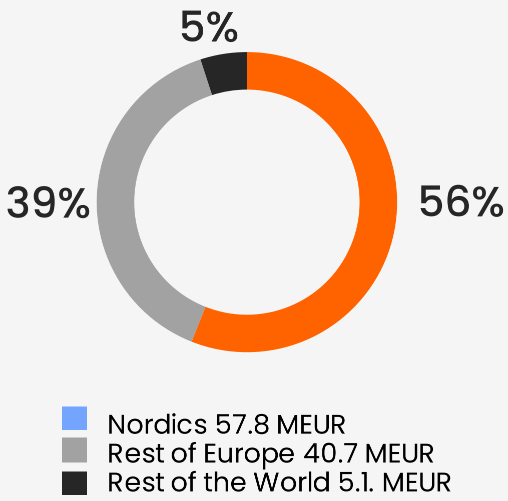
Operative EBIT margin
6%

Revenue

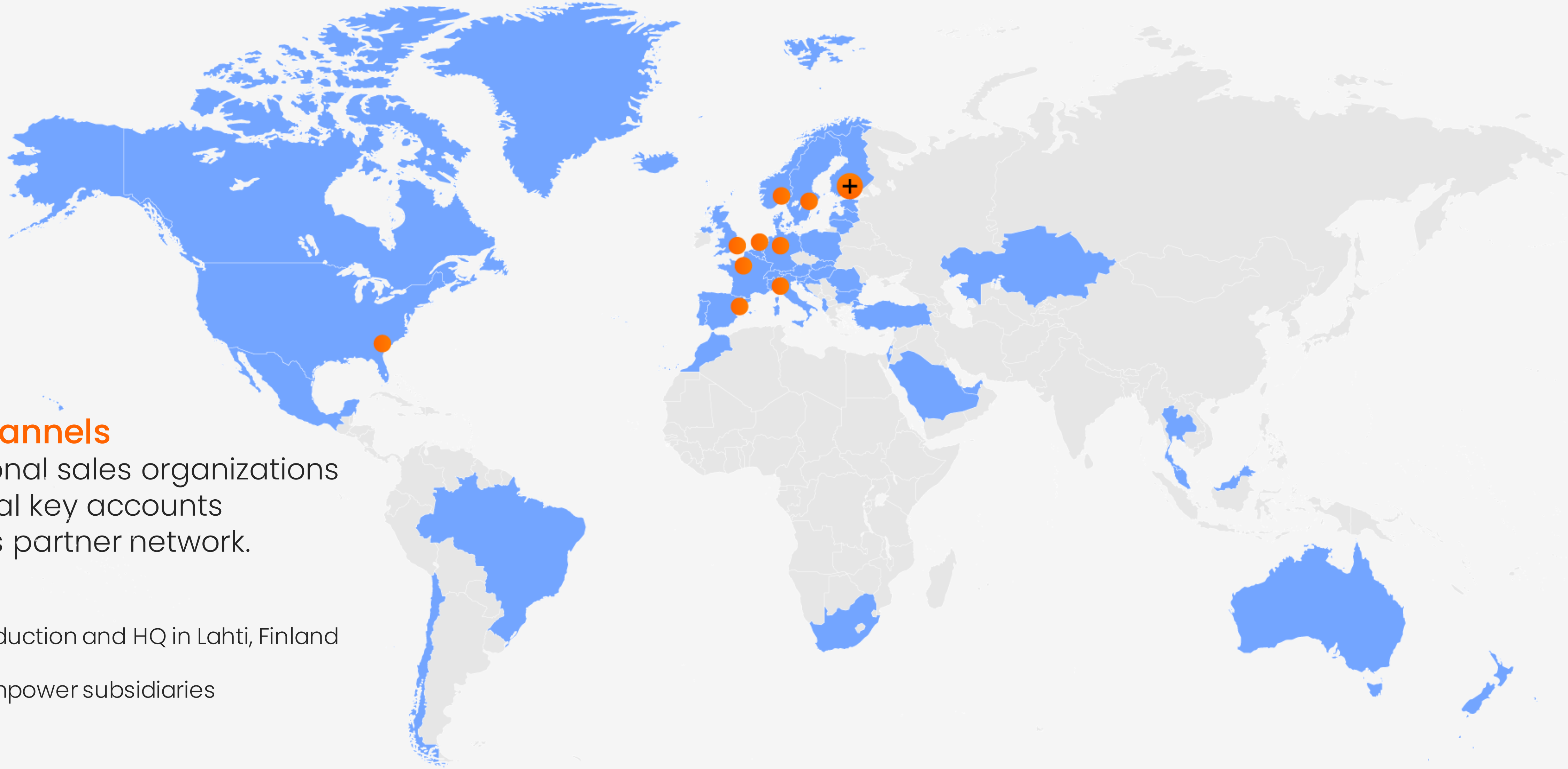
MEUR



Revenue by geographic region 2022



Charging solutions delivered to more than 40 countries worldwide



Our channels

- regional sales organizations
- global key accounts
- sales partner network.

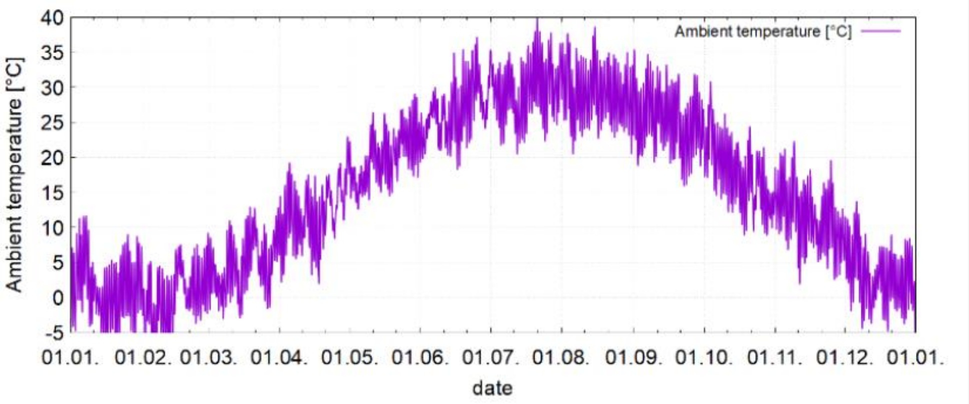
Production and HQ in Lahti, Finland

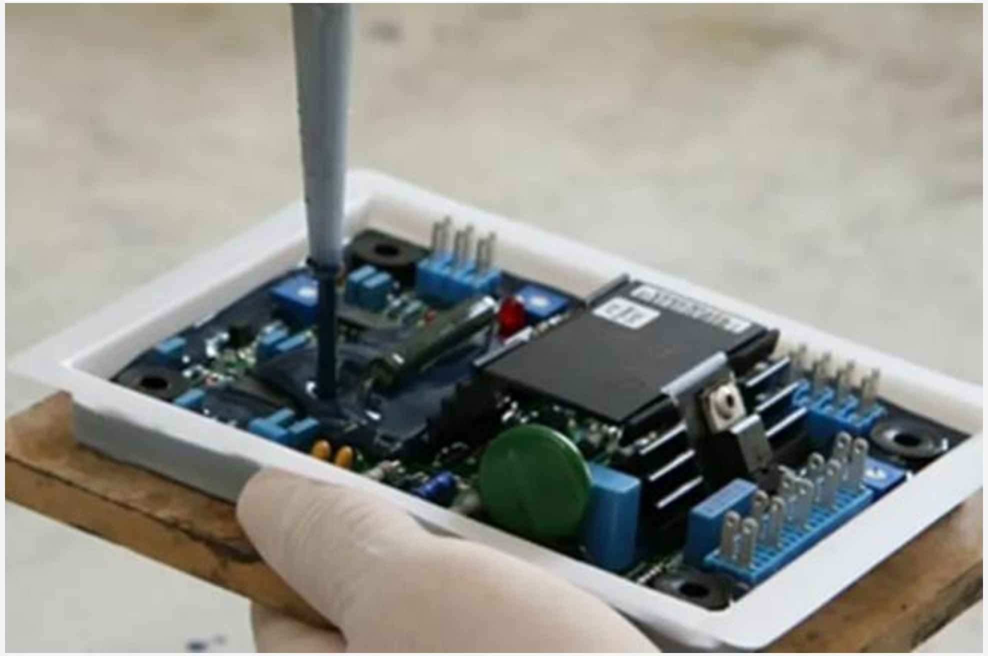
Kempower subsidiaries

Issues effecting to lifetime

Environmental conditions

- **Humidity, condensing water**
  - Condensing water handling by controlled way
  - Sensitive component locations inside the device
  - Conformal coating, potting
- **Temperature variations**
  - Min/Max ambient temperatures



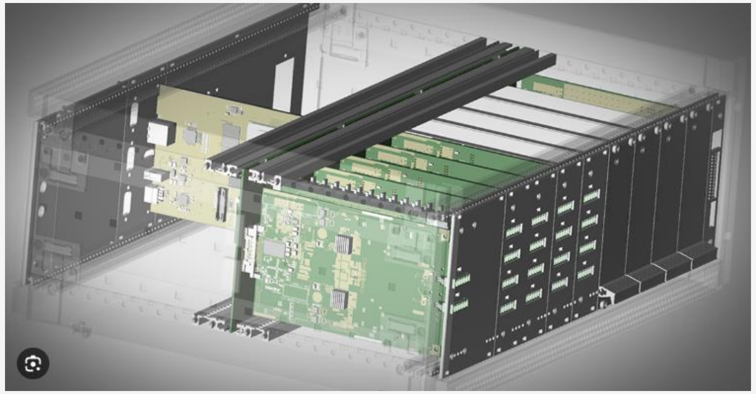


Issues effecting to lifetime

Device construction

- **Indoor / Outdoor use**
    - Mechanical protection
        - IK class for mechanicl impacts (vandal proof)
        - No door/covers which can be opened

- Vertical electronics

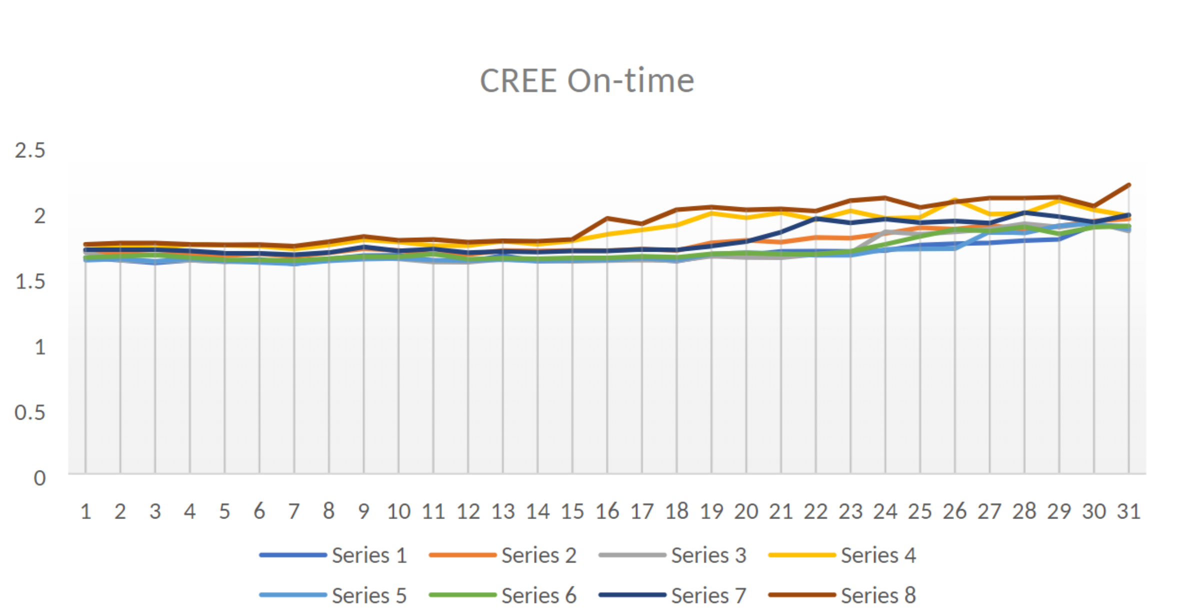


Issues effecting to lifetime

Component dimensioning

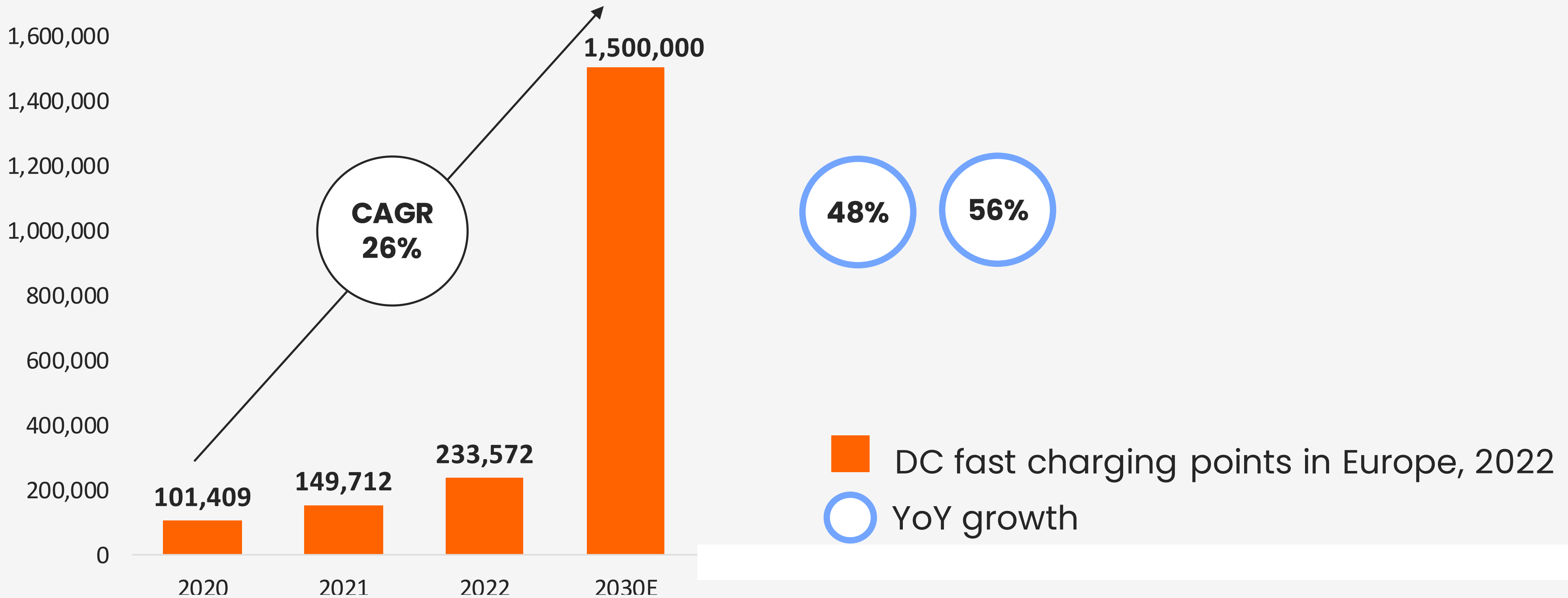
- Component max ambient / operation temperature
- Heat cycles

Example diode heat cycle: 4 min heating, 4 min cooling, max, Case temp. 110°C, ΔT_{case} = 70 °C in the begining of test (TO-247)



Application example: EV fast charging

Up to 6.8 million public charging points required in Europe by 2030



Source: EAFO; EU EV Master plan

Charcing cycles

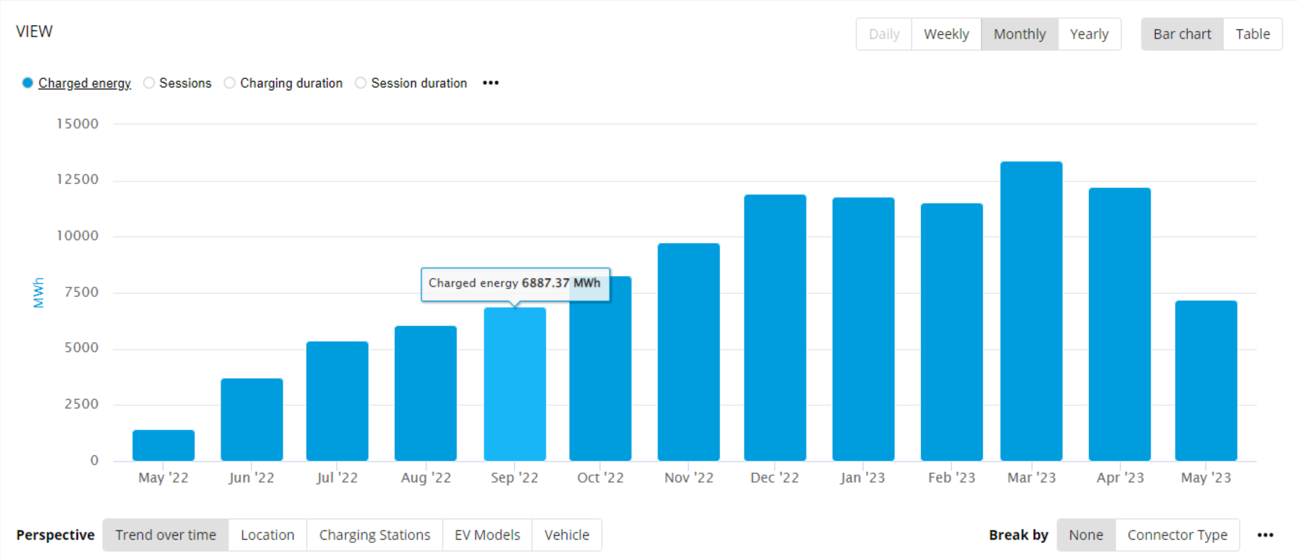
DC Fast charcing is a cyclic in nature

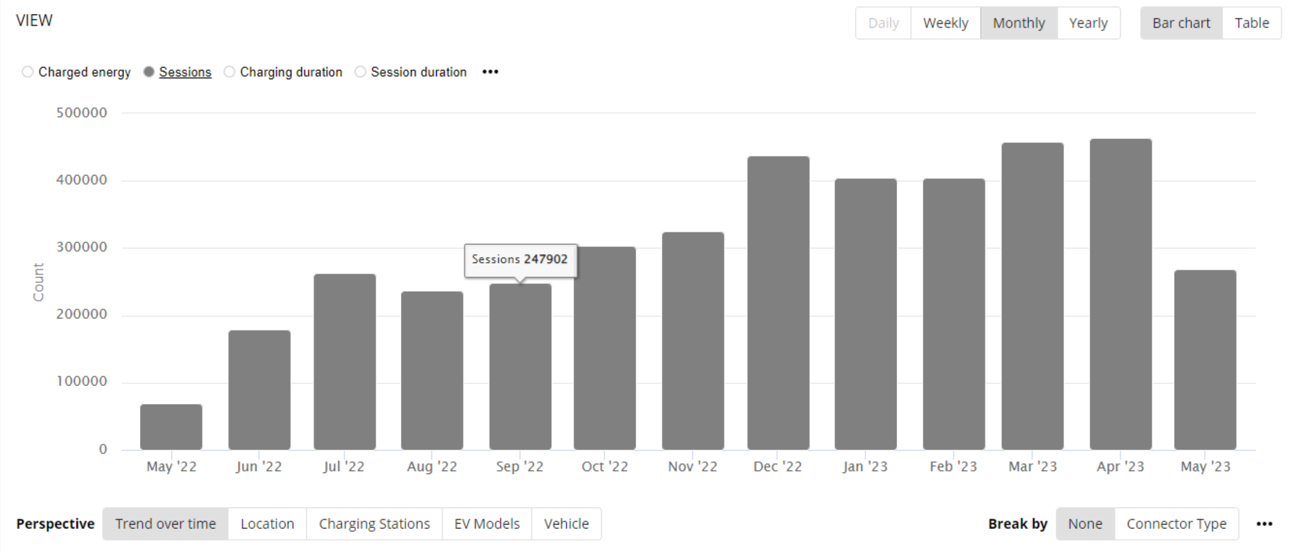
- Average passenger car charging time is 21 min
- Popular charging sites have more than 20 charges / day
- Bus over night charging each charge up to 4 hours

What is required lifetime?

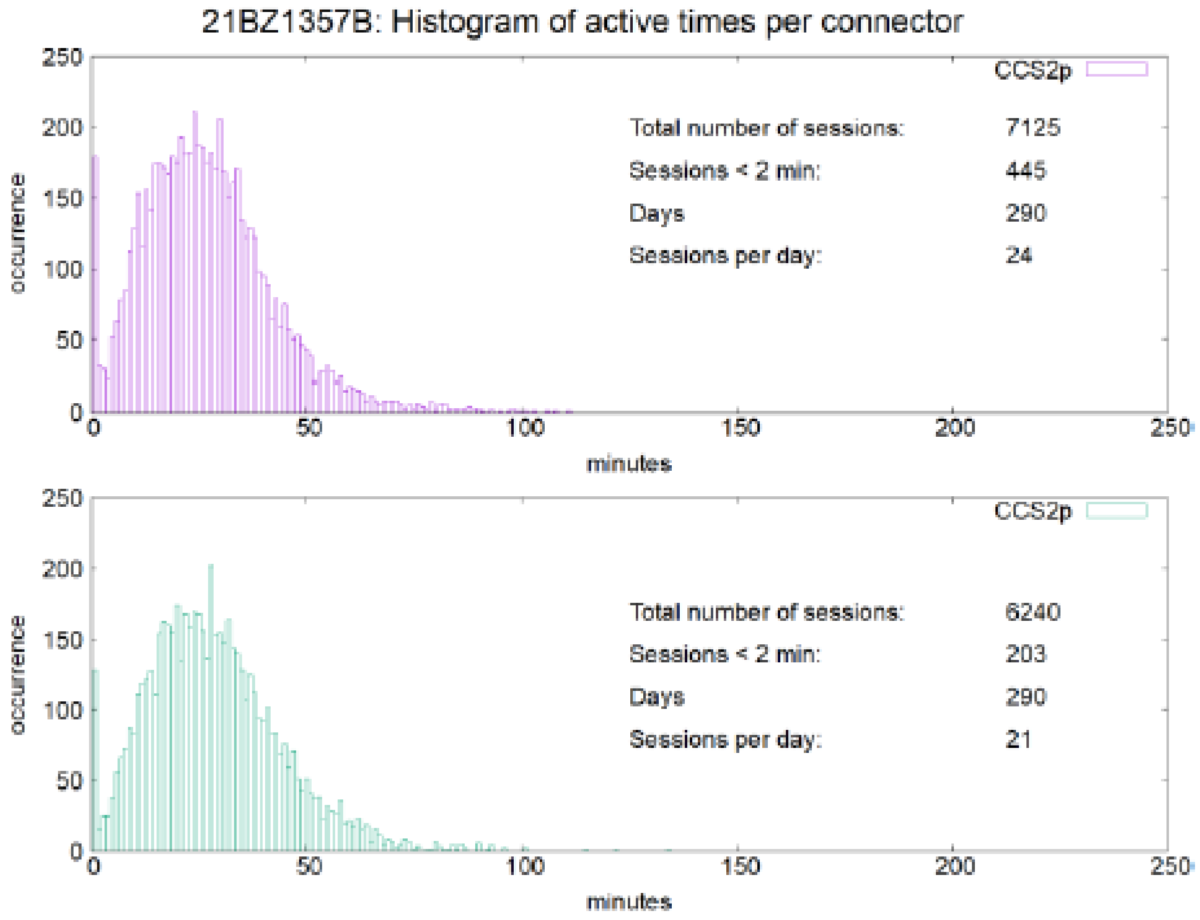
10 years at use at popular passenger car site means:

50- 70 k charcing cycles
15 k operation hours



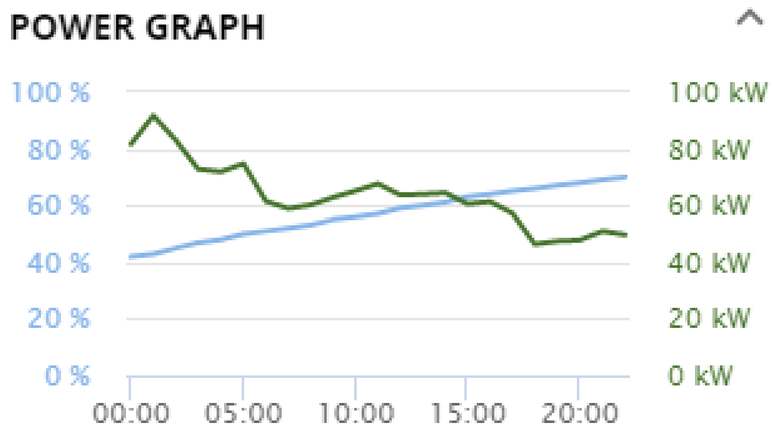


Charging time histogram

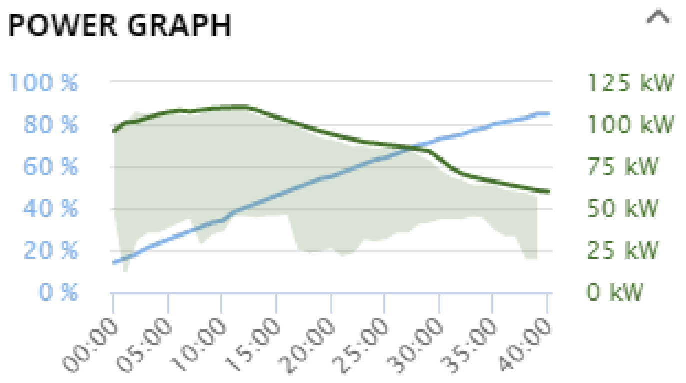


Examples of different vehicle model charing curves

Volvo R40 Recharge



MB EQC



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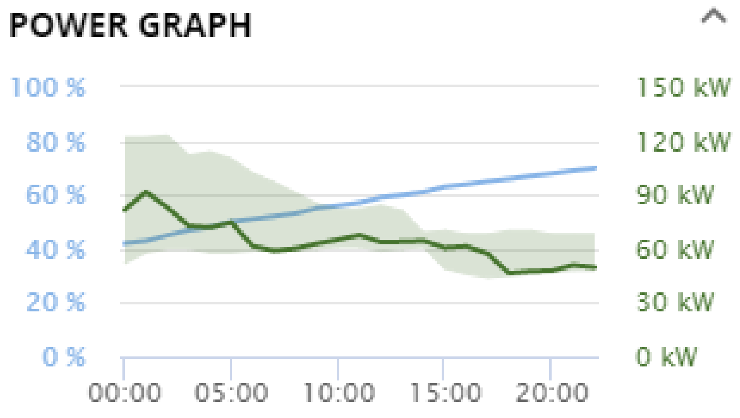
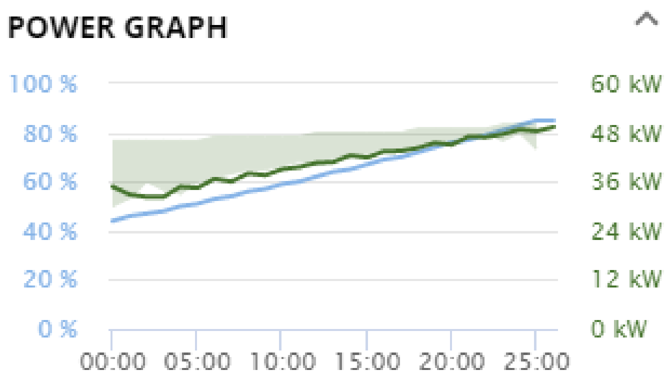


BMW i3



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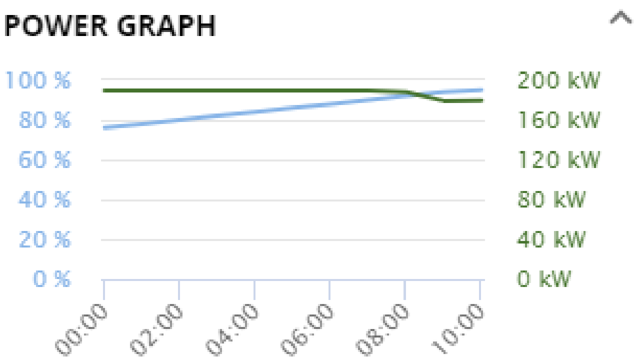
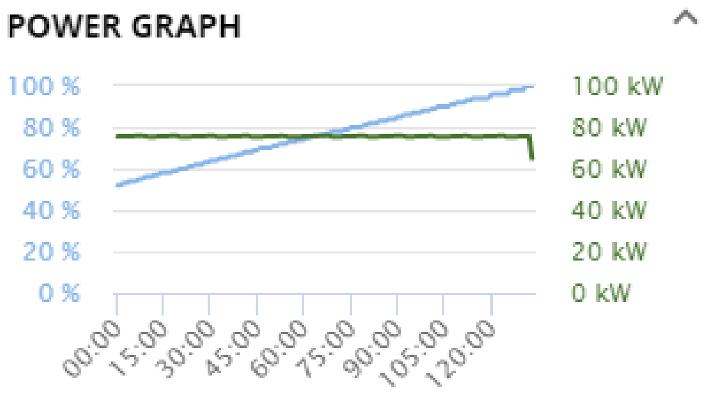
Examples of different vehicle model charing curves

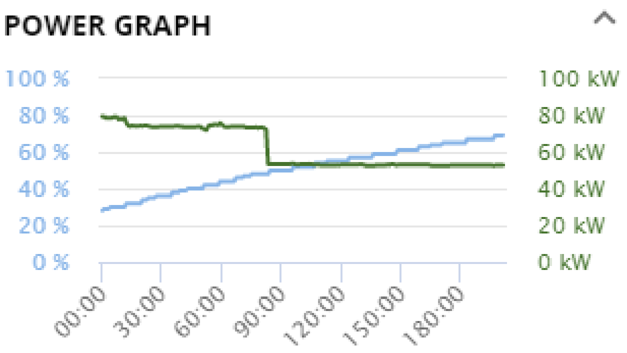
BEV Bus (I) pantograph



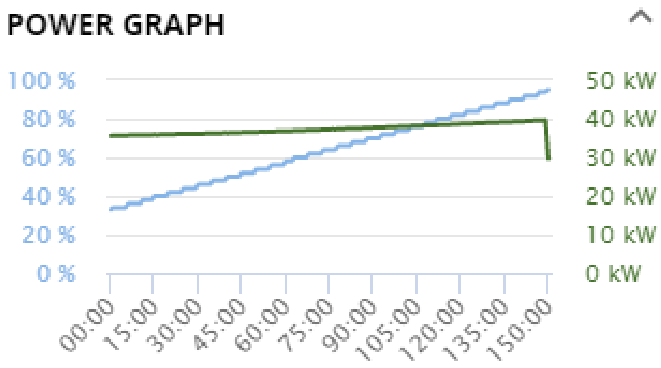
BEV Bus (I) plug



Heavy mining vehicle



BEV Bus (II) plug



Passive component lifetime

Most critical (lifetime point of view) passive components in power circuits are electrolytic capacitors

- Manufacturers rarely promise more than 8000h at 105°C
  - Datasheet value are nominal conditions ➔ correction multibliers
  - Lifetime heavily depends on max. Temperature (see formula)
  - Voltage dependace: rool of thump -50% from nominal voltage will double the lifetime
  - Ripple current
    - Dissipation factor (tanφ) Increses over the time ➔ ESR will increse, too.
  - Law of Arhenius

Useful life[1)] 105 °C; V_R; $I_{AC,R}$	> 8000 h	Requirements: $\lvert\Delta C/C\rvert$ ≤ 20% of initial value tan δ ≤ 2 times initial specified limit I_{leak} ≤ initial specified limit
Voltage endurance test 105 °C; V_R	3000 h	Post test requirements: $\lvert\Delta C/C\rvert$ ≤ 10% of initial value tan δ ≤ 1.3 times initial specified limit I_{leak} ≤ initial specified limit

$$L = L_0 \times 2^{\left(\frac{T_{max} - T_a}{10}\right)}$$

L : Estimated life (Hr)
L_0 : Life at rated temperature (Hr)
T_{max} : Rated Temperature (°C)
T_a : Ambient Temperature (°C)

Semiconductor lifetime

Assumption of linear model:

Cycle i is performed with certain conditions. Number of cycles that could be performed under qual conditions:

$$N_i = f(\Delta T_i, T_i^{max}, \dots)$$

The fraction of total lifetime consumed by cycle i is then given by:

$$\frac{1}{N_i} = \frac{1}{f(\Delta T_i, T_i^{max}, \dots)}$$

Total lifetime is consumed when:

$$\sum_i \frac{1}{N_i} = \sum_i \frac{1}{f(\Delta T_i, T_i^{max}, \dots)} = 1$$

Lifetime estimation: Number of possible cycles derived from i = 1 … n representative load cycles:

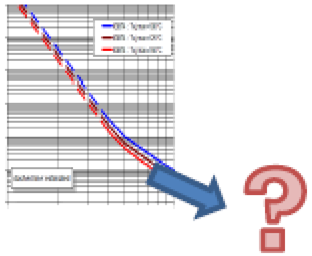
$$N = \frac{n}{\sum_i^n \frac{1}{N_i}}$$

Worst case scenario

- Ambient temp +30°C, Load cycle with max. Charging power until max. Temperature reach

- Max. Heat sink temp 100 °C ➔ T_{max} chip = 125 °C
- ΔT_{hs}= 70 °C ➔ ΔT_{chip} = 95 °C

Module datasheet has to be extrapolated:



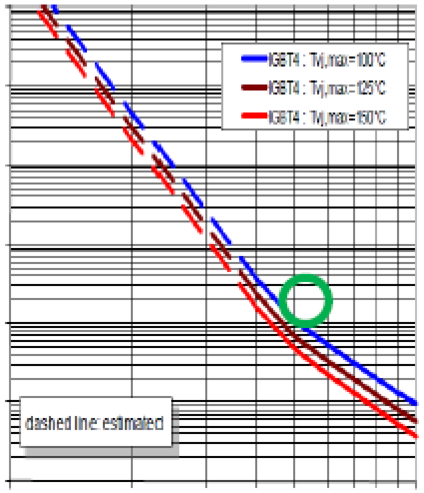
$$N_i = 28280$$

Is this enough?

Light load scenario

- Ambient temp +20°C, Load cycle with average charging power

- Heat sink temp 70 °C ➔ Max. Chip temp 90 °C
- ΔT_{hs}= 50 °C ➔ ΔT_{chip} = 70 °C



N_i= 5,9 x10^5

What that mean in practice?

Assuming 20% cases are ”worst” case senarios and 80 % light load scenarios

”worst case” charge consumes 1/ 28280 part of the lifetime ➔

during 10 years 20%*70k*1/28280 = 49,5% of lifetime used

”Light case” charge consumes 80%*70k*1/5,9x10^5= 9,4% of lifetime

”Worst case” scenarios consumes most of the lifetime, but occurance is low.

Calculated lifetime is long enough

Lifetime calculation vs. experiments

- SiC is extremely promising technology, but challenging:
  - Overcurrent protection
  - “small modules”: Manage thermal inertia, cooling
  - Deal with higher temperatures
- Lifetime aspects are still partially open:
  - Little/limited field experience, especially long term data
  - Acceleration parameters unknown
- Lifetime modelling as promising approach:
  - Get an idea of what one can expect
  - Identify boundary conditions with high leverage

Summary

Many different aspects have effect to the reliability

- Good environment proof design
- Mechanical protection of sensitive components
- Critical component dimensioning according to required lifetime, not rated values

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Questions?

Thank You.