FlyGrid – Sustainable energy storage for EV fast charging stations and grid stabilization

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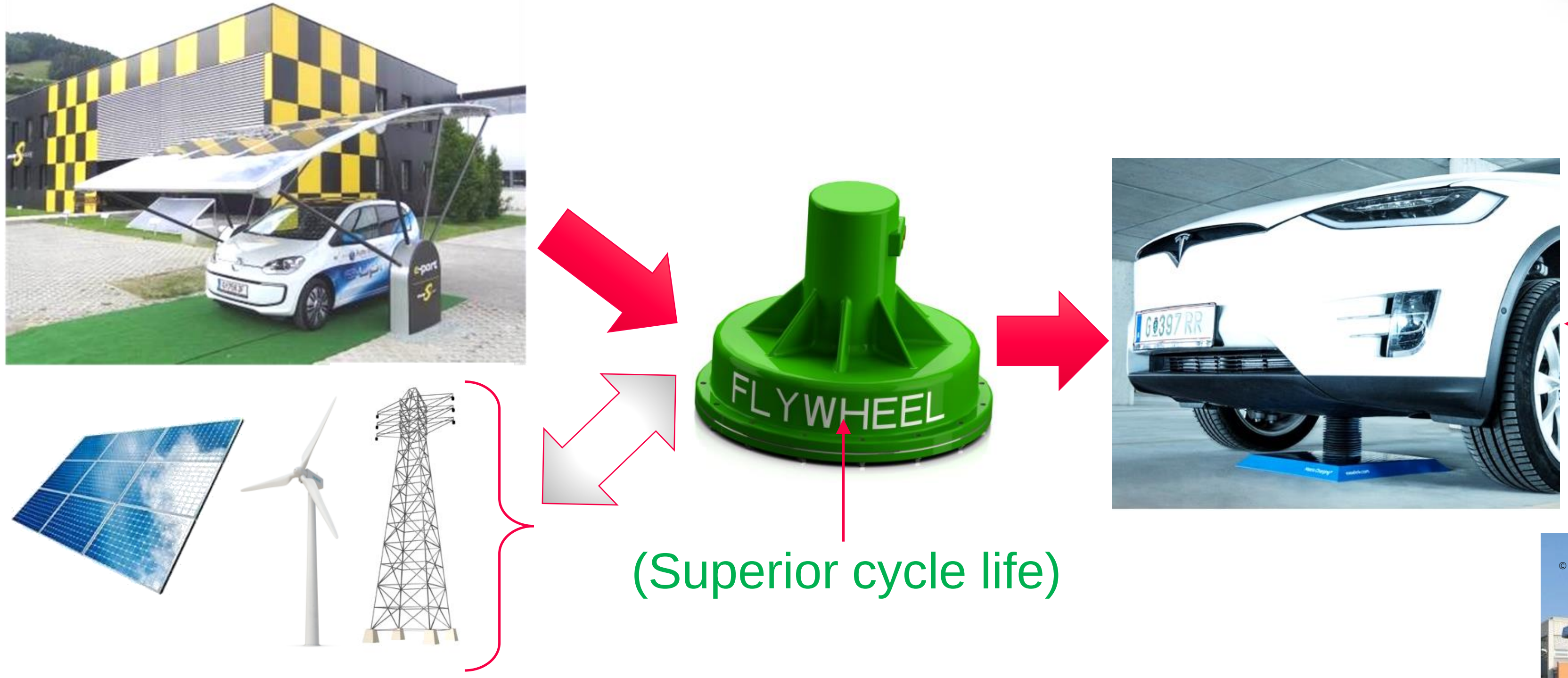
TECHNIK
LEIDENSCHAFT

https://www.tugraz.at/en/institutes/ems/home/

„Peak shaving“ for fast charging applications:

→ Avoid costly modification of existing electricity grid
→ Make use of local renewable sources such as wind / solar
→ Increase grid stability and power quality

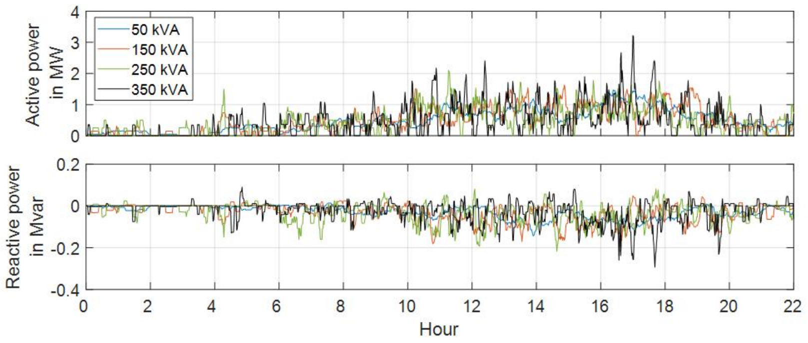


Public
Private
Enterprise

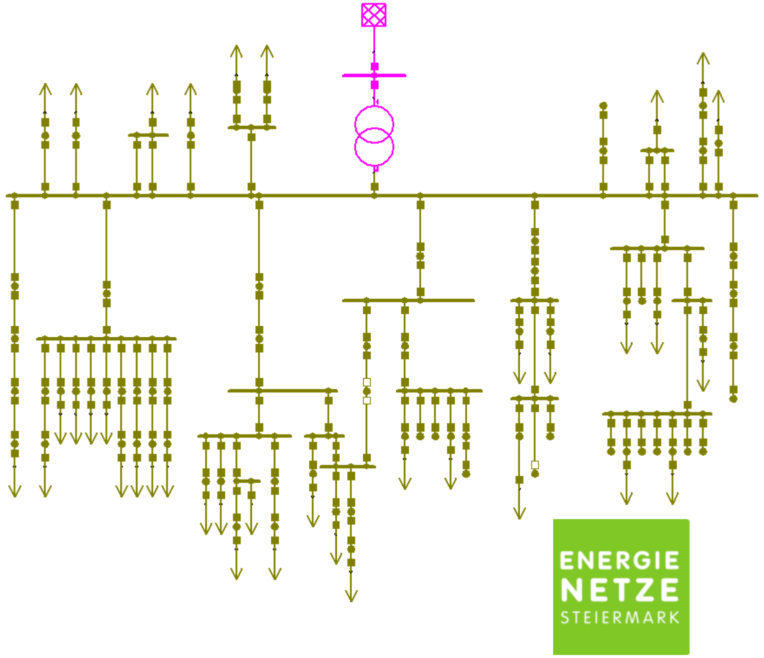
→ *FlyGrid* is a sustainable energy storage solution that can be manufactured in central Europe!

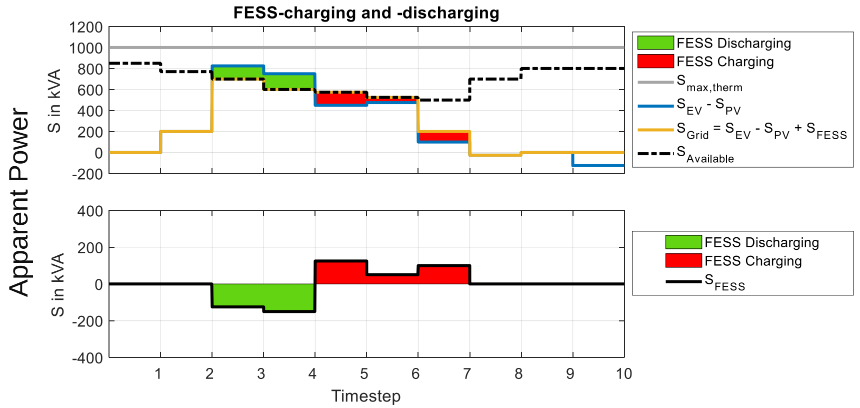
Methodology to Determine FESS Properties

1. Modeling of time-resolved EV charging patterns → **2. Identification of potential grid overloads** → **3. Determination of FESS target properties**



	EV Use Case	Charging power (kVA)
1	Charging at public parking lots	3.7 – 100.0
2	EV car sharing	3.7 – 100.0
3	Highway fast charging	50.0 – 350.0
4	Public charging at shopping centers	3.7 – 100.0
5	Electrified busses	100.0 – 600.0
6	Electrified taxies	3.7 – 100.0
7	Electrified last-mile delivery trucks	100.0 – 350.0



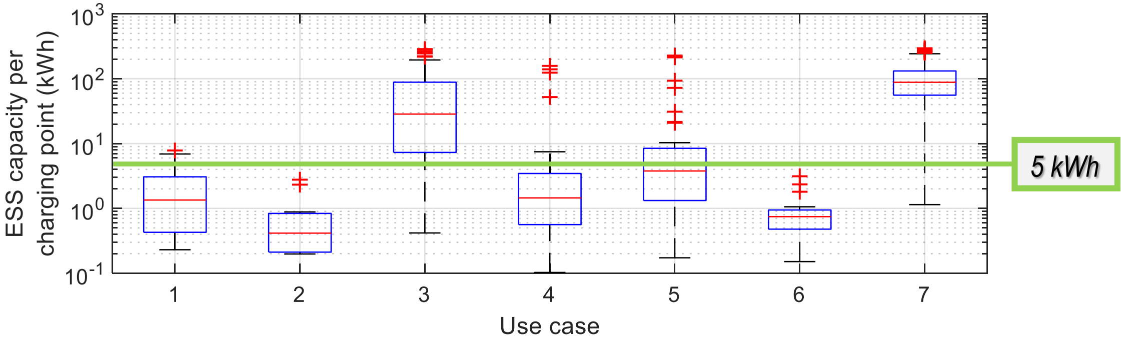


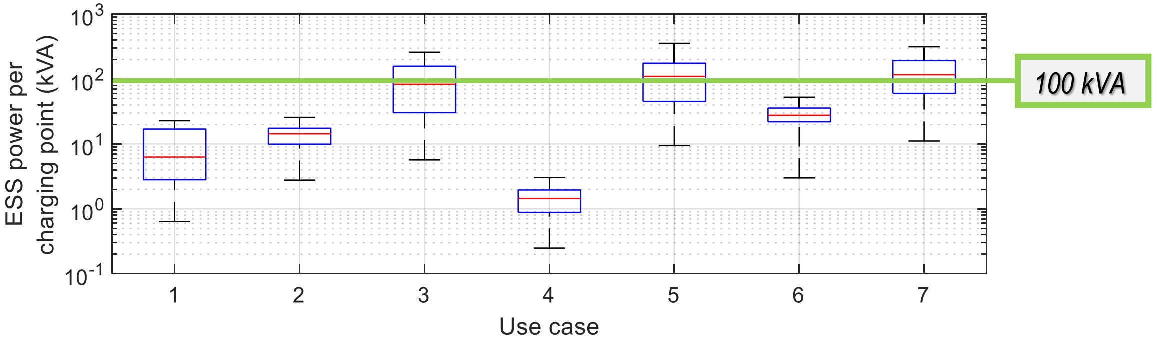
FESS parameter per module	Value
Efficiency: FESS charging	90 %
Efficiency: FESS discharging	90 %
Max. Idling losses	0.5 kW
Cos(ϕ): FESS charging	1.0

Methodology to Determine FESS Properties

FESS Target Requirements

Research question:
What are the desired FESS specifications in order to allow proper peak shaving in EV fast charging applications?





	EV Use Case
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4	Public charging at shopping centers
5	Electrified busses
6	Electrified taxies
7	Electrified last-mile delivery trucks

- ***2/3 of the current EV applications require:***
  < 5 kWh
  < 100 kVA
- *Remaining applications can be covered by a modular expansion of FESS*
- *Not all EV applications allow grid load mitigation via FESS*

Chemical Battery vs. Flywheel

Li-Ion Battery *(Tesvolt TS HV 70)*

- Roundtrip efficiency < 94 %
- 76 kWh
- 75 kW (1C), 4C short term
- 6,000 cycles (1C, 70% EoL, 100 % DoD)
- 30 years
- ~ 550 €/kWh
- **LCOS → 0.10 €/kWh**
- 860 kg

www.tesvolt.com

Flywheel *(Chakratec KPB)*

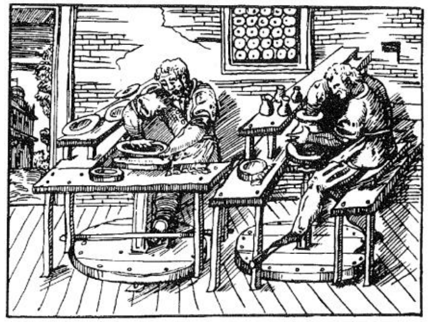
- Roundtrip efficiency < 90 %*
- 10 x 3 kWh
- 100 kW (50 kW nominal)
- 20 years / > 200,000 cycles
- ~ 2500 €/kWh
- **LCOS → 0.015 €/kWh**
- 10,000 kg

www.chakratec.com

* No manufacturer data available. Value taken from *www.stornetic.com*

Why a New FESS Development?

a. Chr. - 1550



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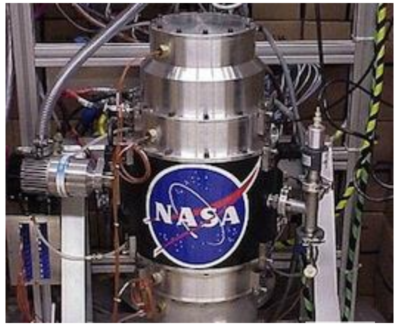

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2011

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2020

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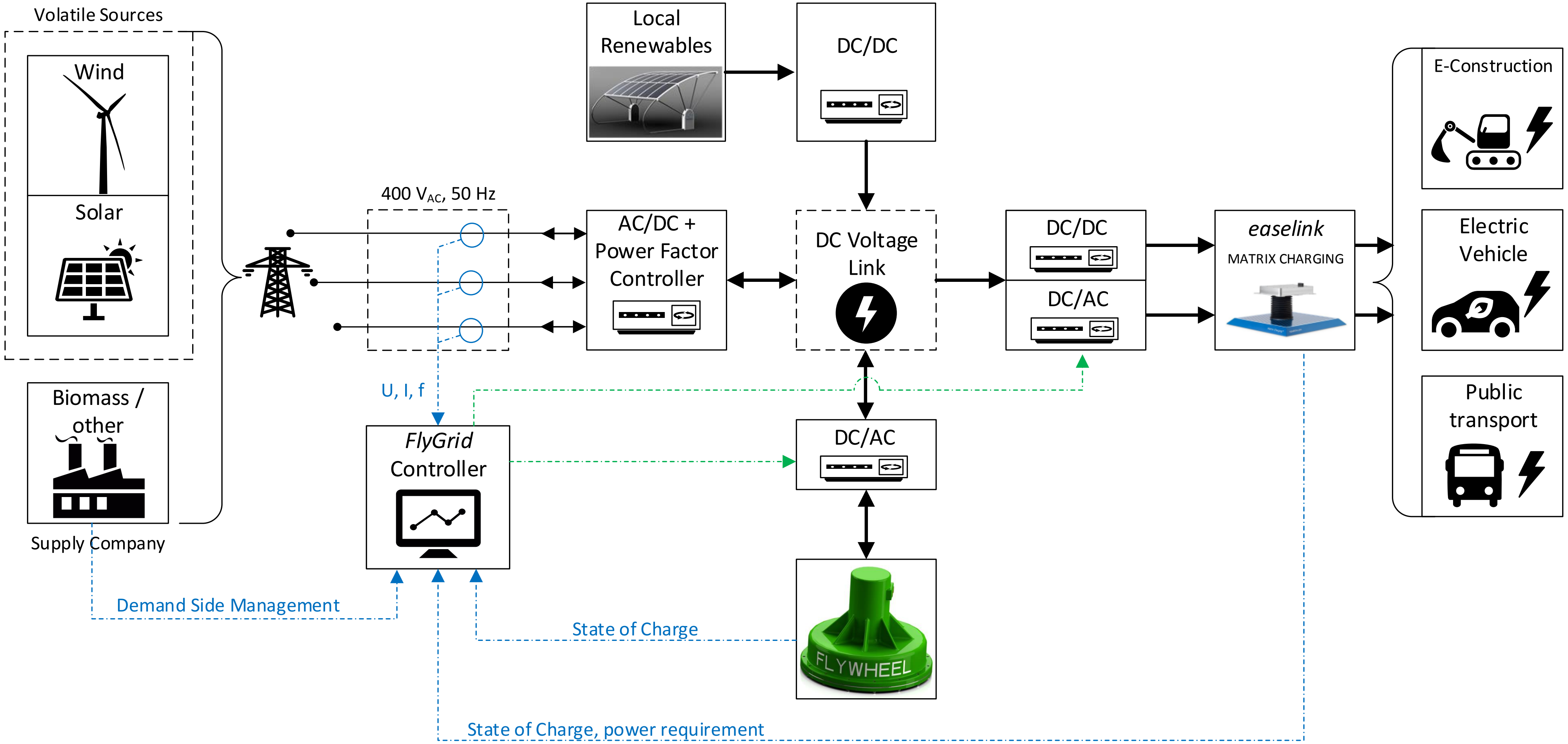
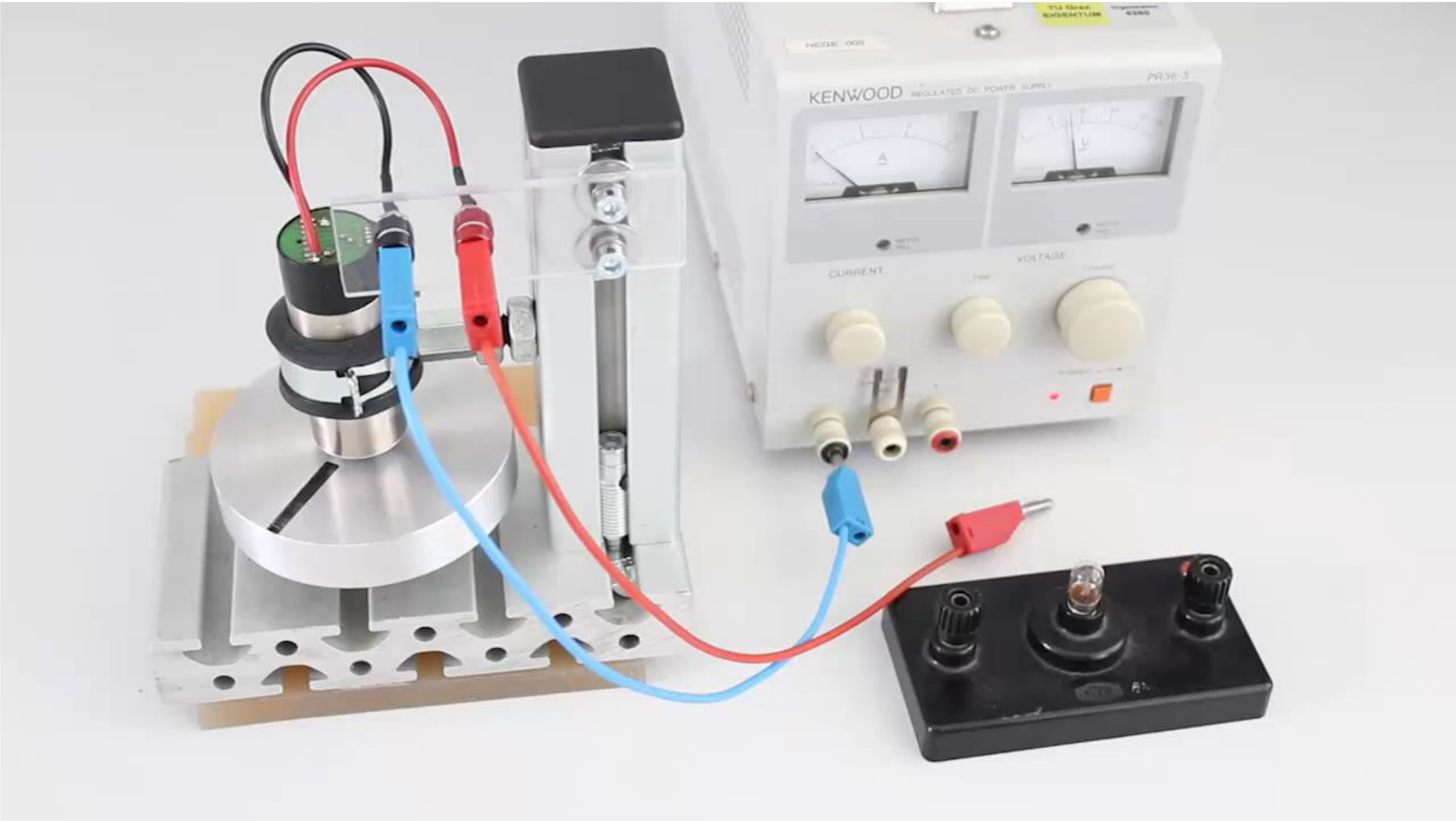
- Technological advantages and potential compared to batteries
- Goal is an improvements beyond state of the art and cost reduction
- Sustainable energy storage will play a major role also in other sectors
- *FlyGrid* does not only develop the FESS, but has a bigger scope
- Bringing technology and know-how to Austria

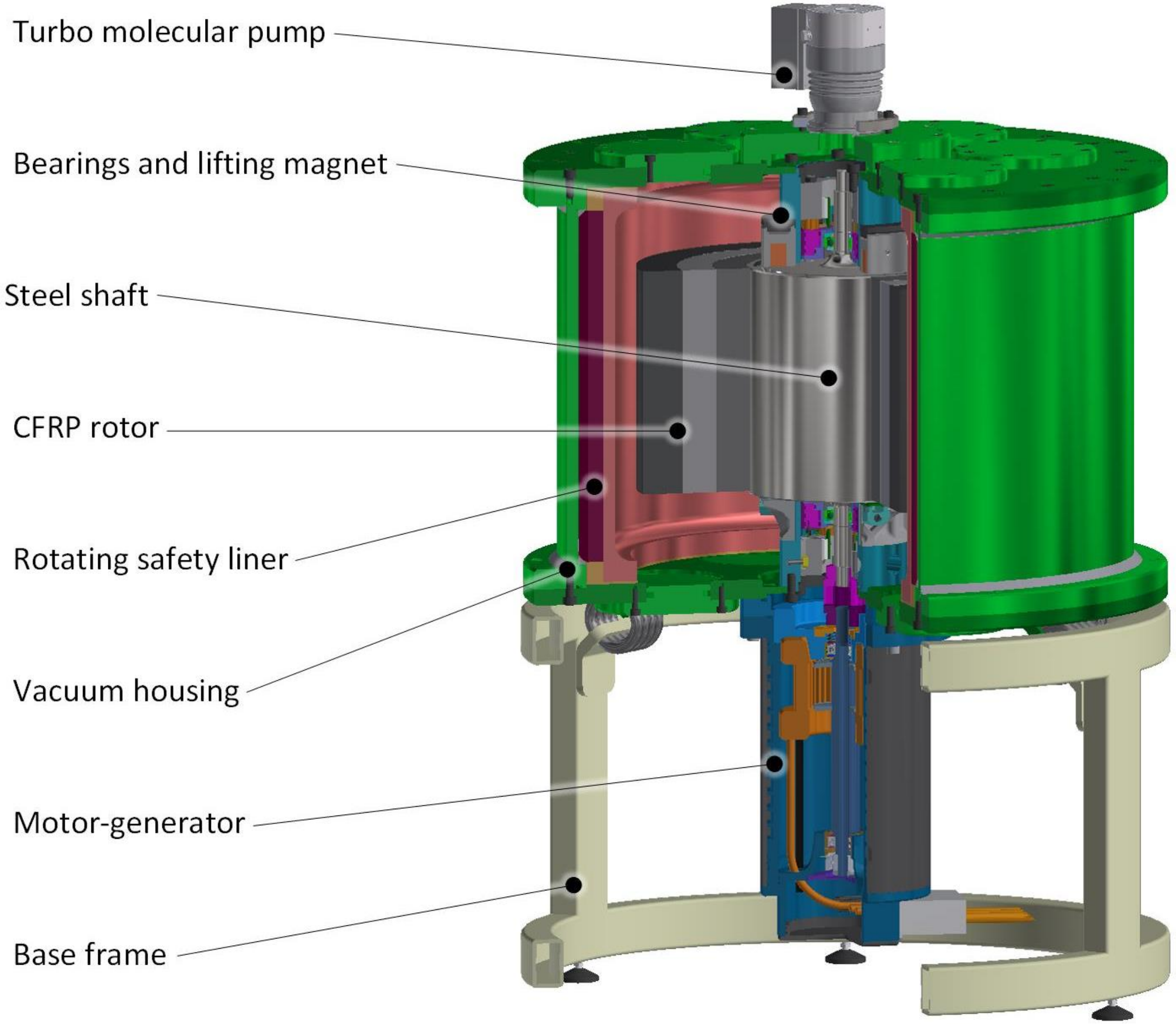
Implementation of FESS



FESS Basics



Modular and Flexible High-Performance FESS Design

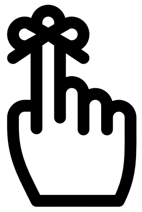


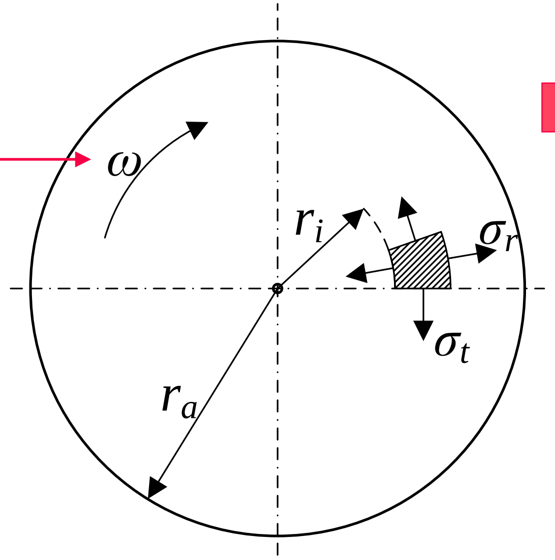
Rotor:
Determines Energy

Generator:
Determines Power

Pre-selection of materials & Rotor topology

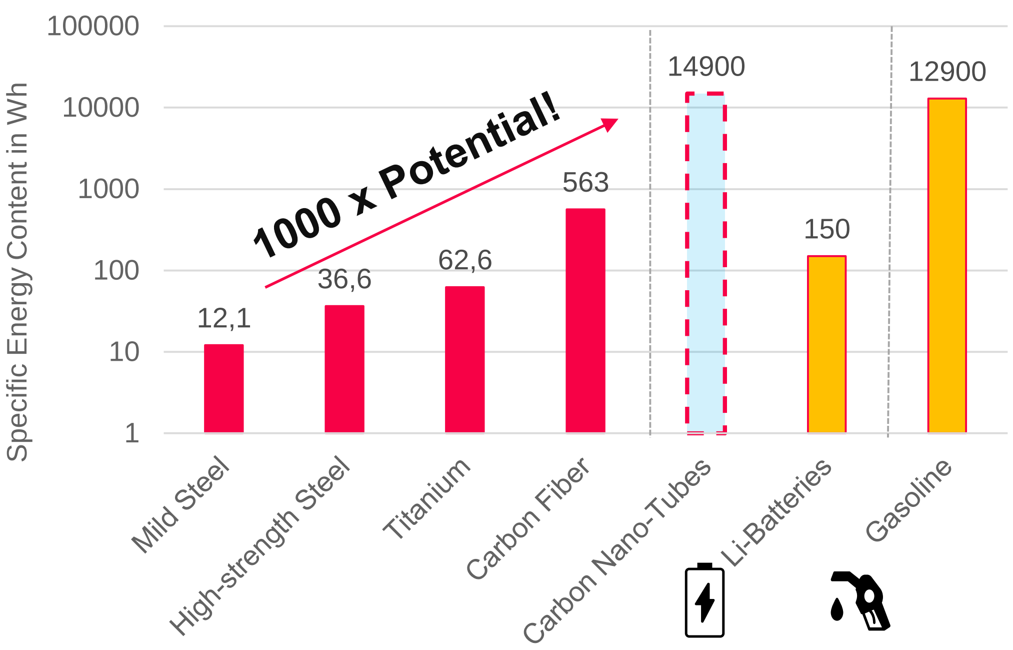
$$E_{kin} = \frac{1}{2} I\omega^2$$





$$\sigma_{t\,max} = \rho\omega^2 r_a^2 \frac{3+\mu}{8}\left[2 + \left(\frac{r_i}{r_a}\right)^2 \left(1 - \frac{1+3\mu}{3+\mu}\right)\right]$$

$$\frac{E_{kin}}{m} = K_{shape} \cdot \frac{\sigma_u}{\rho} \qquad (K_{shape} = \text{empiric})$$



Axial press-fitting of hoops

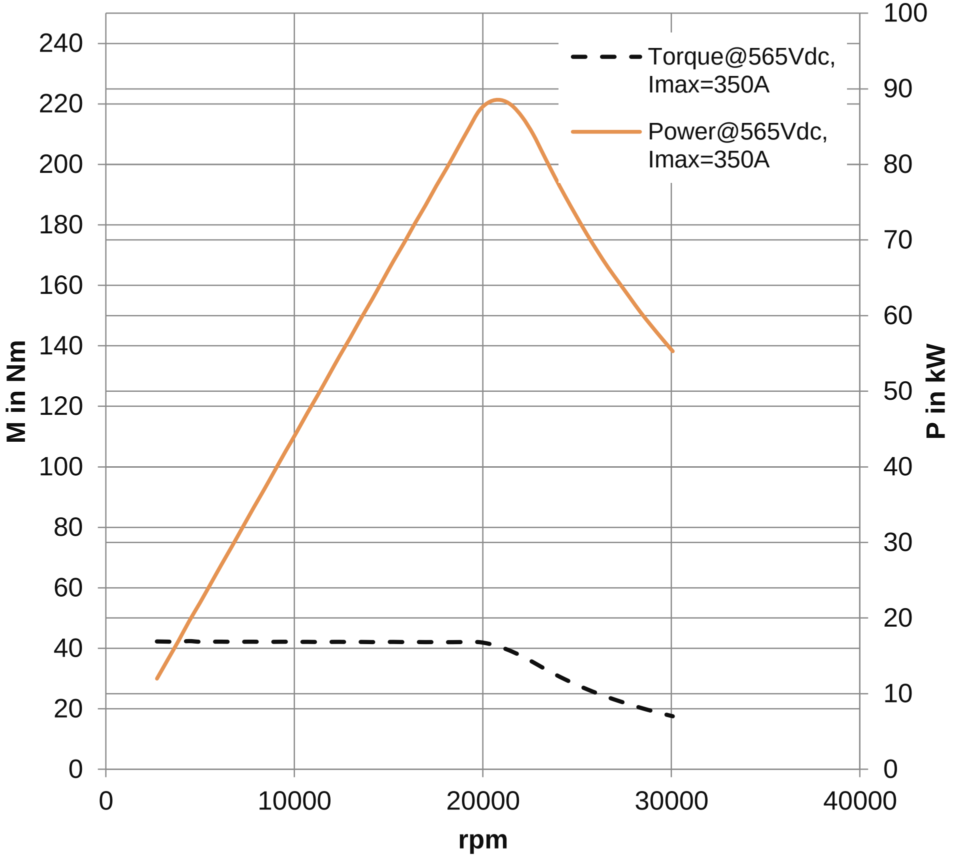
High strength in fiber direction → Ideal to withstand tangential stresses!

Power-Unit: Synchronous Reluctance Machine

- **Low losses in rotor**
  → No current-carrying parts (important in vacuum)
- **High efficiencies** for standard applications (IE4)
- **No magnets / rare earths needed**
  → Easy to recycle
- **No cogging torque**
  → Ideal for FESS with low idling losses

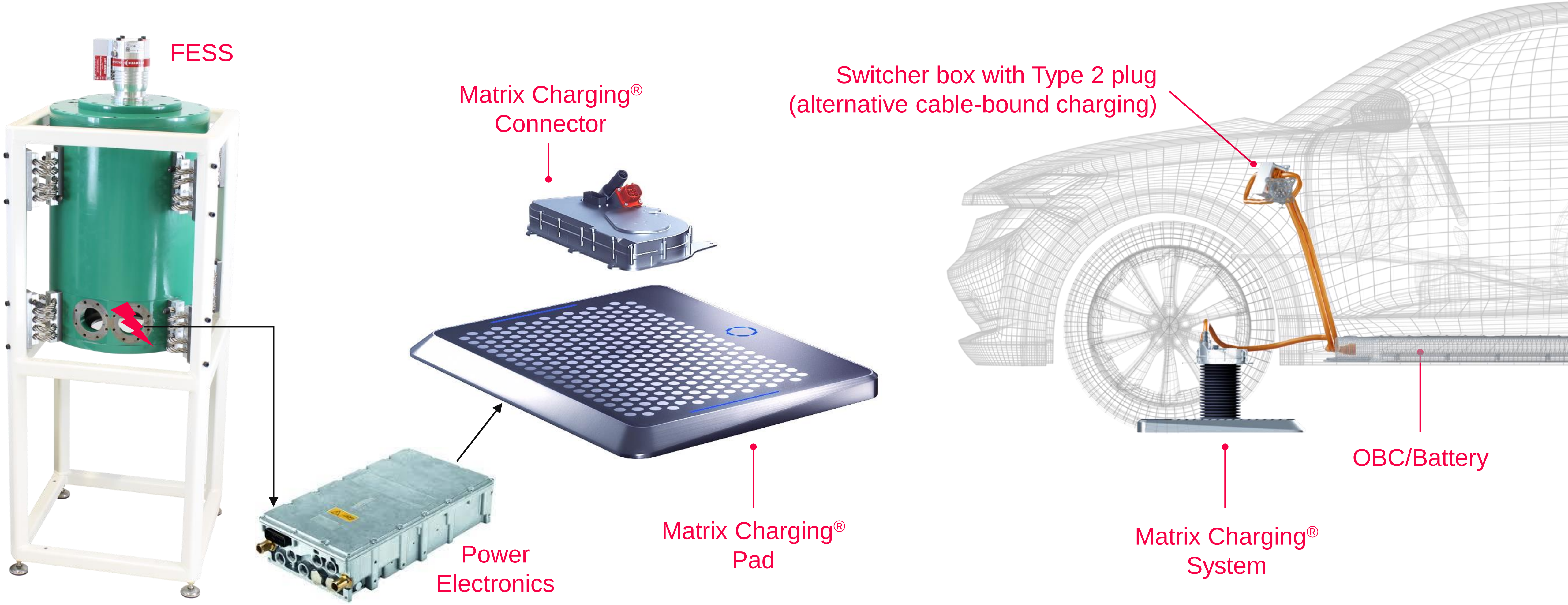
P_{max} and M_{max} at IFU_{max}= 600 A_{rms}

(without thermal consideration)



Automatic Conductive Underbody Charging

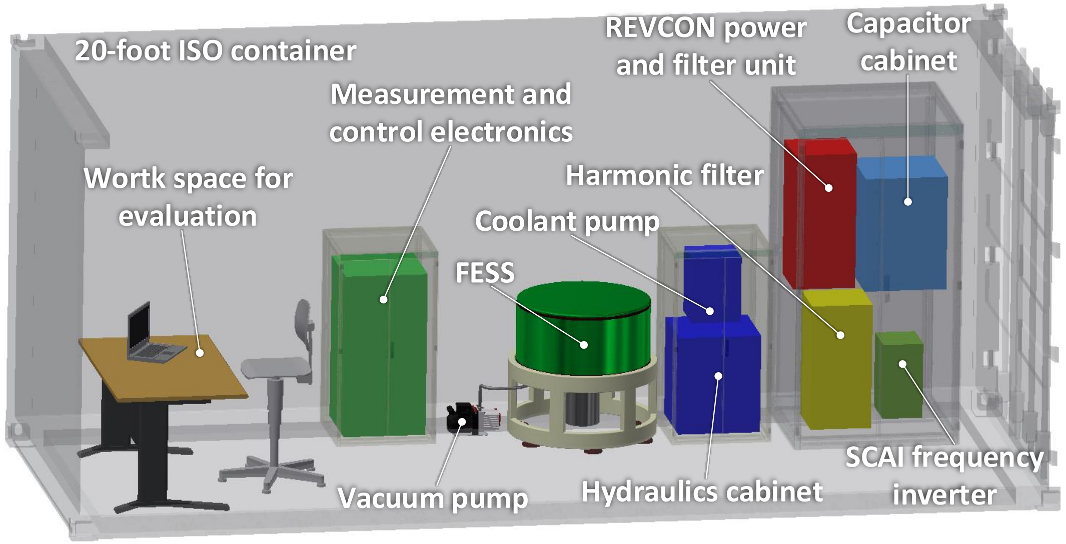
Optimization and Integration of Innovative Charge Point



Summary and Outlook

- User behavior and grid analyses show that frequent charging events of 5 kWh dominate
- FESS can provide moderate energy, but high power and offer supreme cycle life
- There are many energy storage applications outside fast charging
- Rotor design and material strength determine energy content of FESS
- Smart design offers economy of scale factors and recyclability

    - Outlook: Demonstrator facility will be operational in Fall 2022



Thank you for your attention!

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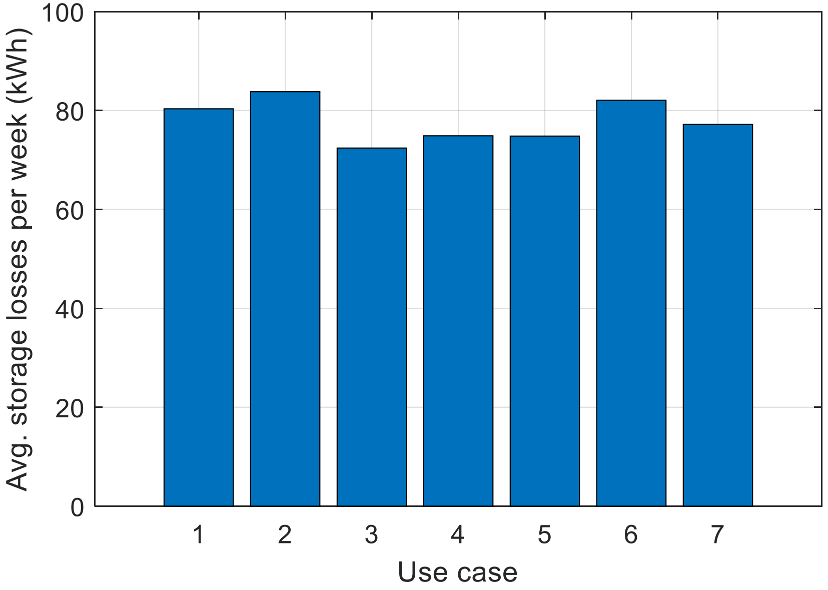
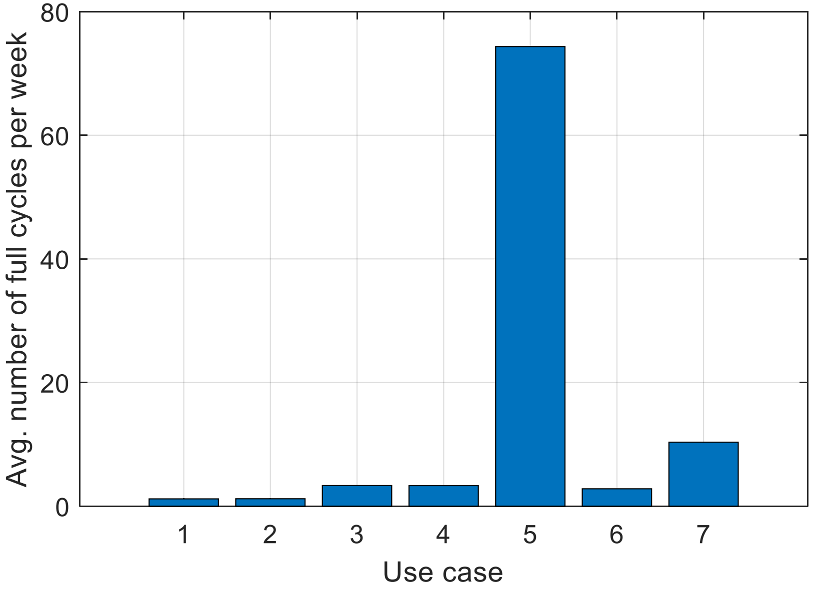
Methodology to Determine FESS Properties

Suitability of the investigated use-cases for FESS application

- **Battery electric busses** and fast charging at **shopping centers or highway stations** allow **lowest FESS idling losses** during operation due to high level of utilization
- **Battery electric busses** require **highest number of daily charge/discharge cycles** resulting in optimal exploitation of the FESS‘s specific properties





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Energy Storage Options

Company / Name	Type of Storage	Energy content	Power	Ref.
Chakratech	FESS	10 x 3 kWh	100 kW	[9]
GRIDSERVE's Electric Forecourts	Battery	> 60 kWh	60/120 kW (installed)	[10]
Powerstar	Battery	n.a.	50 kW DC 11 kW AC	[11]
Tesla Supercharger V3	Battery	n.a.	250 kW	[12]
ENEA labs	Li-Poly battery	16 kWh	50 kW DC 22 kW AC	[13]
Kreisel Electric: Chimero 360	Li-Ion battery	184 kWh	22 kW AC 180 kW DC	[14]
E.On Drive Booster	Battery	193,5 kWh	150 kW	[15]
Porsche Super Charger Truck	Battery	total 2.1 MWh	tot. 3,2 MW	[16]
eCAMION	Li-Ion battery	250 kWh	Up to 400 kW	[17]
Fastned and Tesla	Battery	tot. 2 MWh	300 kW	[18]

Why another FESS Design for FlyGrid ?

- Modular Design of FESS Units
  - Interchangeable Power Modules → adaptable power ratings
  - Modular stackable Energy Modules → scalable energy content

  Independent sizing
- High power (100 – 140 kW) can be supplied already@ relatively low energy (5 kWh) → high number of cycles → stable high round-trip efficiency
- Optimized system components of the current FlyGrid FESS:
  - Roller bearings with supercritical operation (resiliently suspended)
  - Economic carbon material for rotor mass
  - Synchronous Reluctance Motor (no magnets)