Autumn School Flow Battery

Barcelona – 12th-13th of November 2018

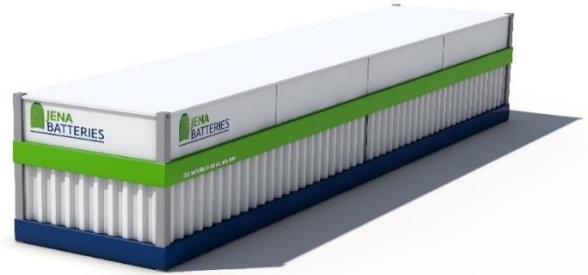
LEITAT managing technologies

IREC Institut de Recerca en Energia de Catalunya
Catalonia Institute for Energy Research

UAB Universitat Autònoma de Barcelona

Universitat de Barcelona

JENA BATTERIES



A BATTERY TECHNOLOGY STARTUP

FROM IDEAS TO PRODUCTS

JenaBatteries GmbH
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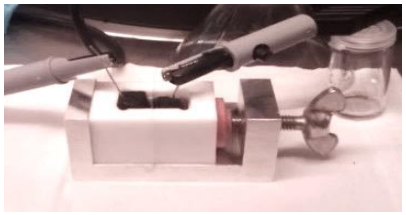
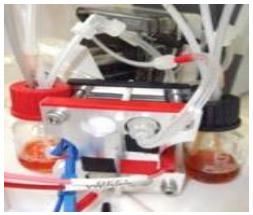
EFRE EUROPE FOR THURINGIA
EUROPEAN REGIONAL DEVELOPMENT FUND
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag
ZIM Zentrales Innovationsprogramm Mittelstand
Thüringer Aufbaubank

Introduction

JenaBatteries GmbH

Laboratory and prototype facility:


Pilot projects:

PV application

Microgrid

Tailored solutions

JenaBatteries GmbH

- Founded in 2012, JB holds global patents for organic redox-flow batteries.
- In August 2016 we welcomed two new investors with outstanding expertise in R&D, Engineering and Business Development. This speeds up the transformation towards an economically successful company.
- JB is an innovative company that produces and develops large-scale energy storage systems from 100 kWh upwards.
- We are currently building a global partner network with project developers/technology partners and we are delivering selected pilot plants.
- Our award-winning Batteries avoid heavy metals and aggressive materials like sulphuric acid.
- JB is currently supported by:

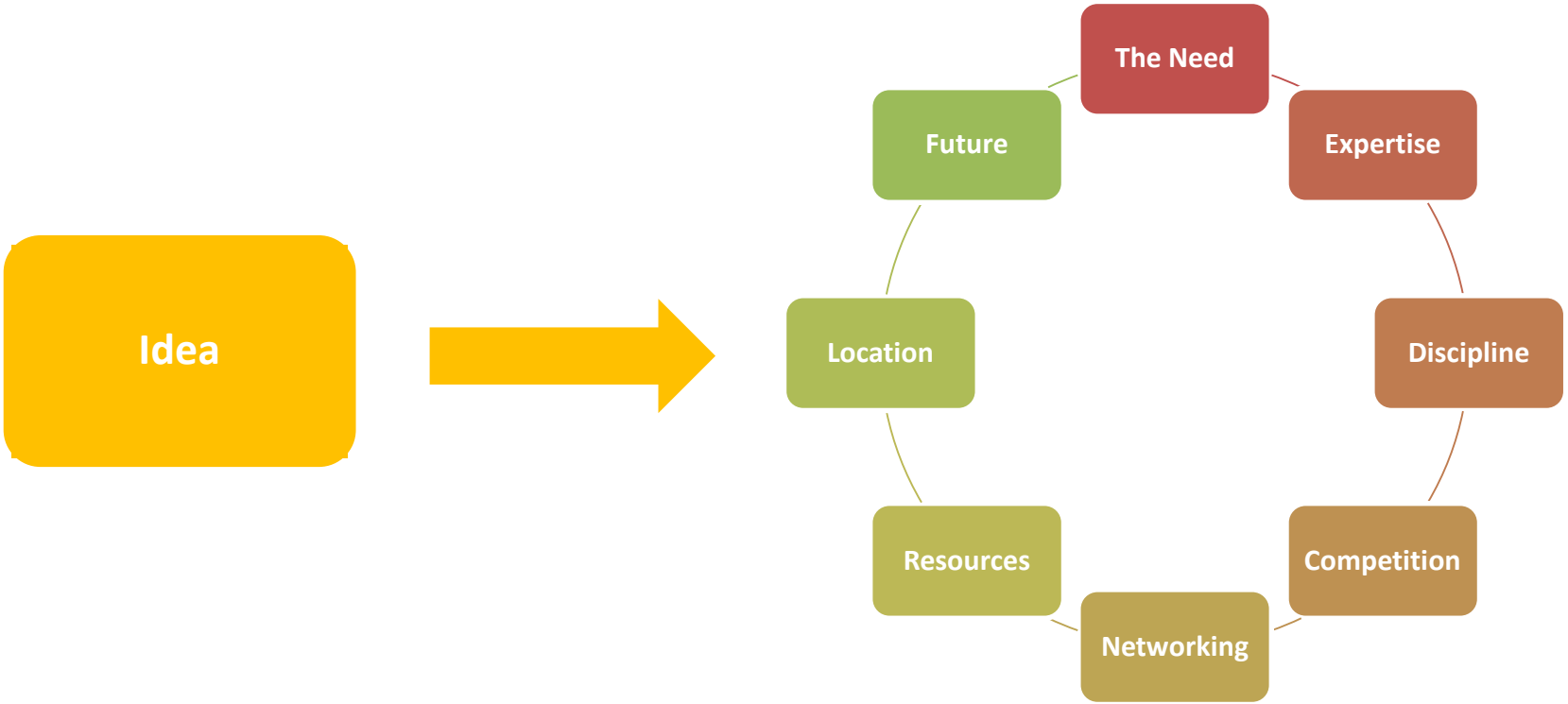
- www.jenabatteries.com

Idea

A great idea …

… can loose you a lot of money!

First things first



Organic radical batteries

- high capacity
- long-life
- high power
- cobalt free
- mobile applications

Li-ORB

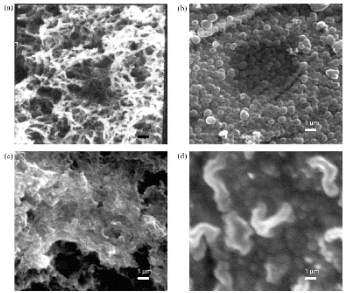
ultrafast chargeable

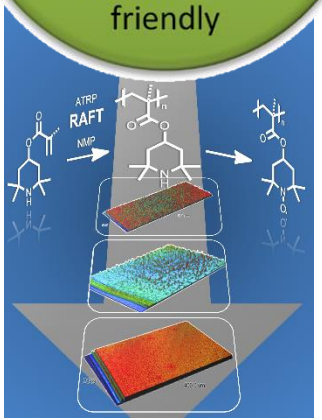
ORB

environmentally friendly

org-ORB

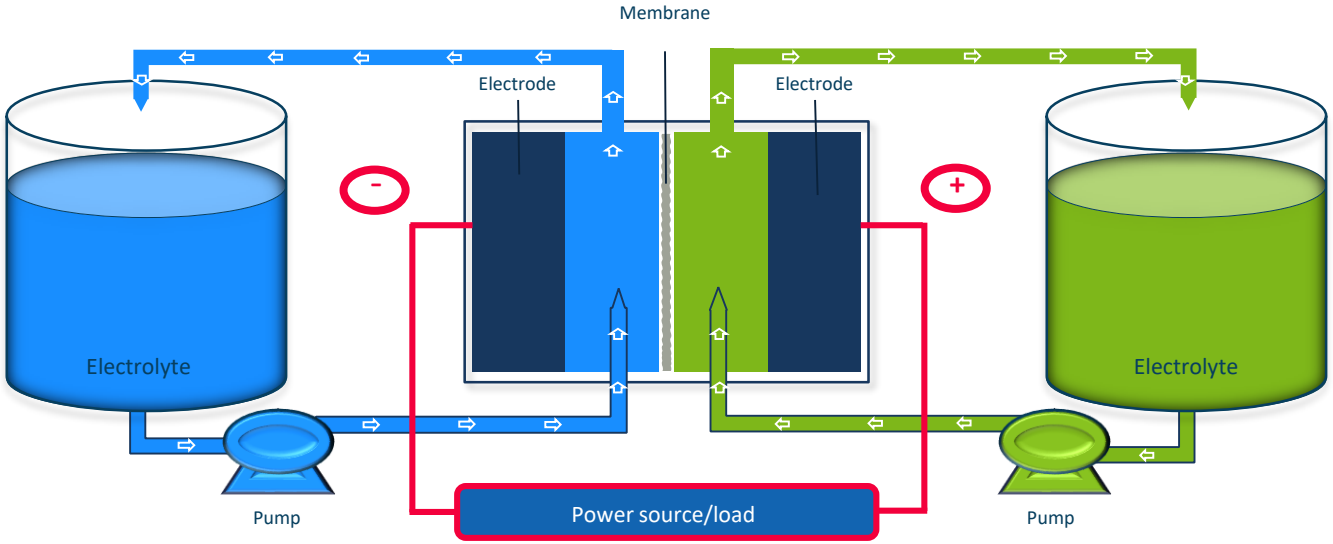
- lower capacity
- tailor-made
- disposable
- printed electronics





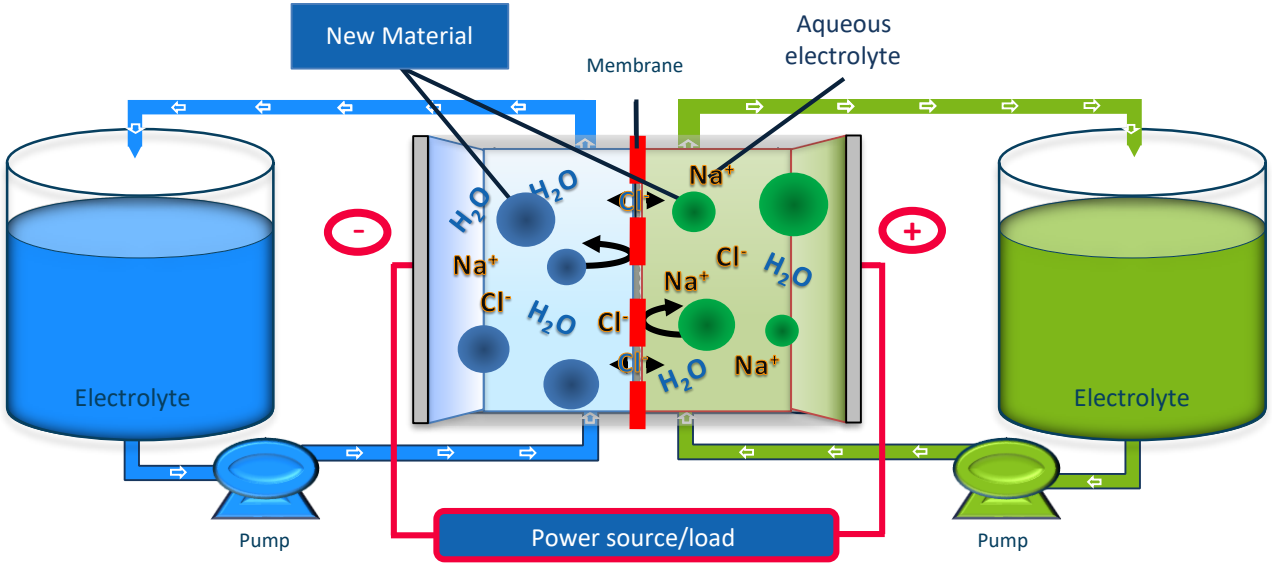
Conventional RFB

- A solid mature foundation -



Vanadium, iron, chromium, bromine, …

JenaBatteries' metal free aqueous RFB



Sustainable and easy-to-handle:

A water-based electrolyte replaces highly corrosive, acidic, vanadium-based electrolytes.

Resources

Energy need in 2040: 110 TWh per day

→ Need for 55.000 GWh storage

(plus batteries for electric vehicles)

Lithium

- Estimated reserves ca. 16 Mio. t
- Annual production ca. 0,1 Mio. t
- 55.000 GWh storage require
  - 5,3 Mio. t Li
  - 1/3 of known reserves
  - plus Co, Ni, etc. for cathode

Organic RFB

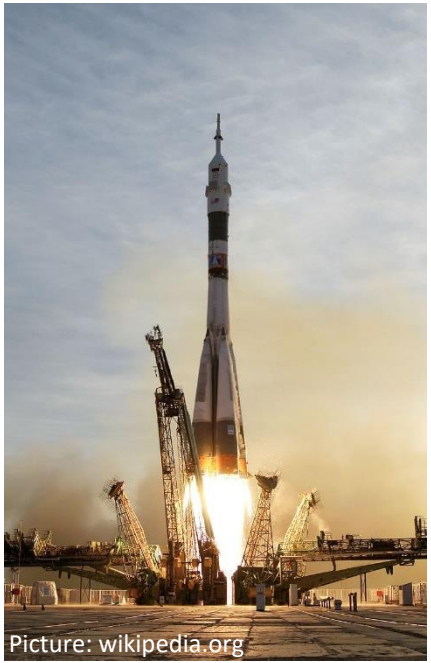
- Estimated reserves ca. 240.000 Mio. t
- 4.400 Mio. t oil in 2016
- 55.000 GWh storage require
  - 1.000 Mio. t oil
  - 23% of one year‘s production
  - Including cathode and anode

International Energy Agency, wikipedia.de, 2018; pictures: wikipedia.org.

Metal-free RFB stands for …

- **Safe & easy**
  - Free and independent scalability of power and capacity
  - Non-flammable and non-explosive
  - Turnkey energy storage system
- **Clean energy**
  - No heavy metals or aggressive acids
  - Resource-efficient
  - Near-neutral pH
- **Economical**
  - Inexpensive raw materials without raw material bottleneck
  - Low maintenance and excellent stability > 10.000 cycles
  - Flexible and sustainable investment

Requirements for Success


Picture: wikipedia.org

To determine whether your idea meets the basic requirements for a successful business, you must answer at least one of the following questions with a “Yes!”

- Does the business address an **underserved need**?
- Does the business serve an existing **market** in which demand exceeds supply?
- Does the business have a significant **advantage** over competitors (price, location, etc.)?

Major Flaws

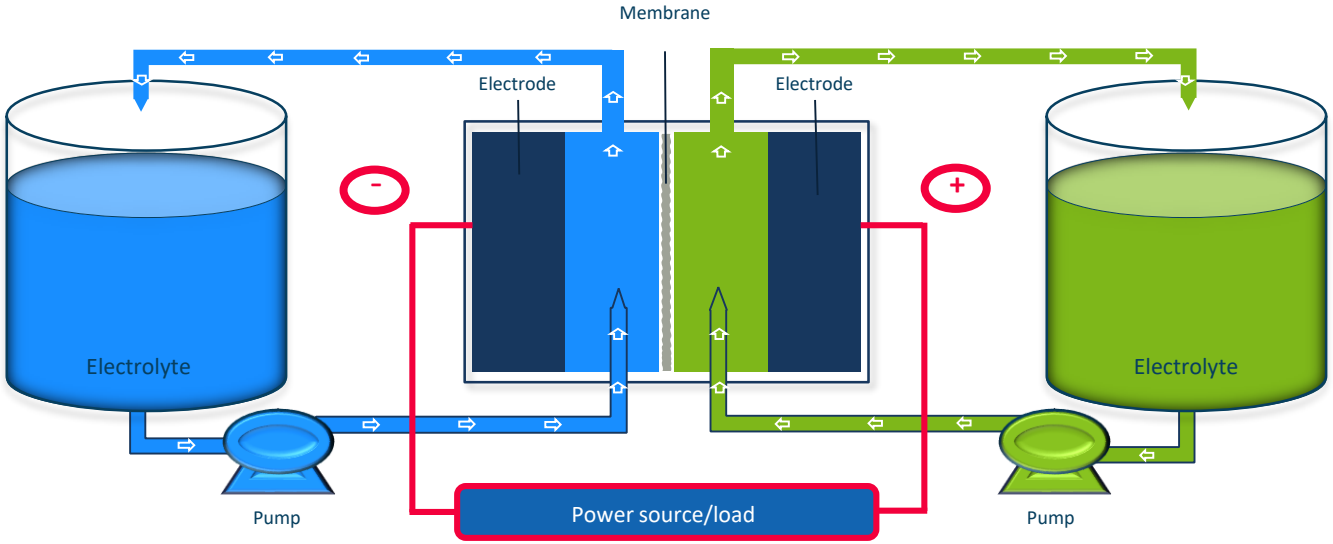
A “yes” response to any of these questions means your idea has little chance for success:

- Are **capital requirements** for entry or continued operation excessive?
- Are there factors that would make **financing hard** to obtain?
- Are there potential detrimental **environmental effects**?
- Are there factors that prevent **effective marketing**?
- Are there zoning, **licensing**, or other **restrictions**?
- Are there factors that **restrict** the availability of **resources** (raw materials, skilled personnel, etc.)?

Market & need

Conventional RFB

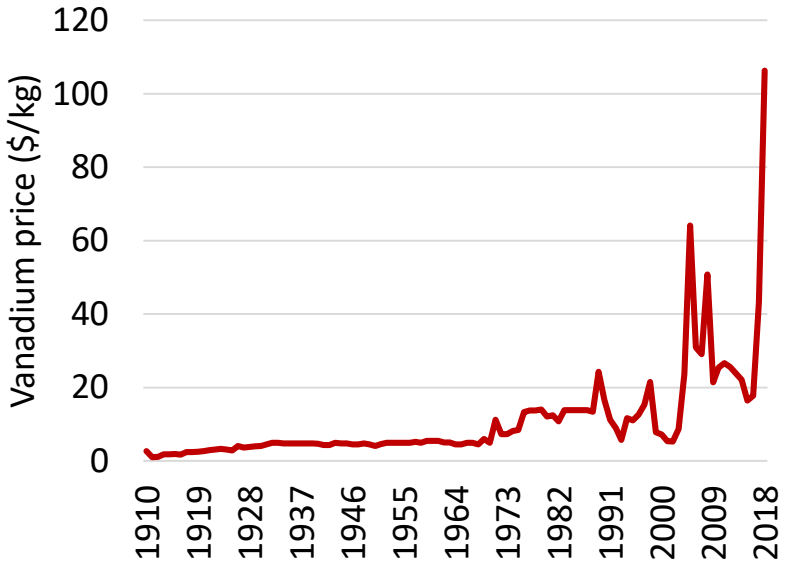
- A solid mature foundation -



Vanadium, iron, chromium, bromine, …

Vanadium-RFB

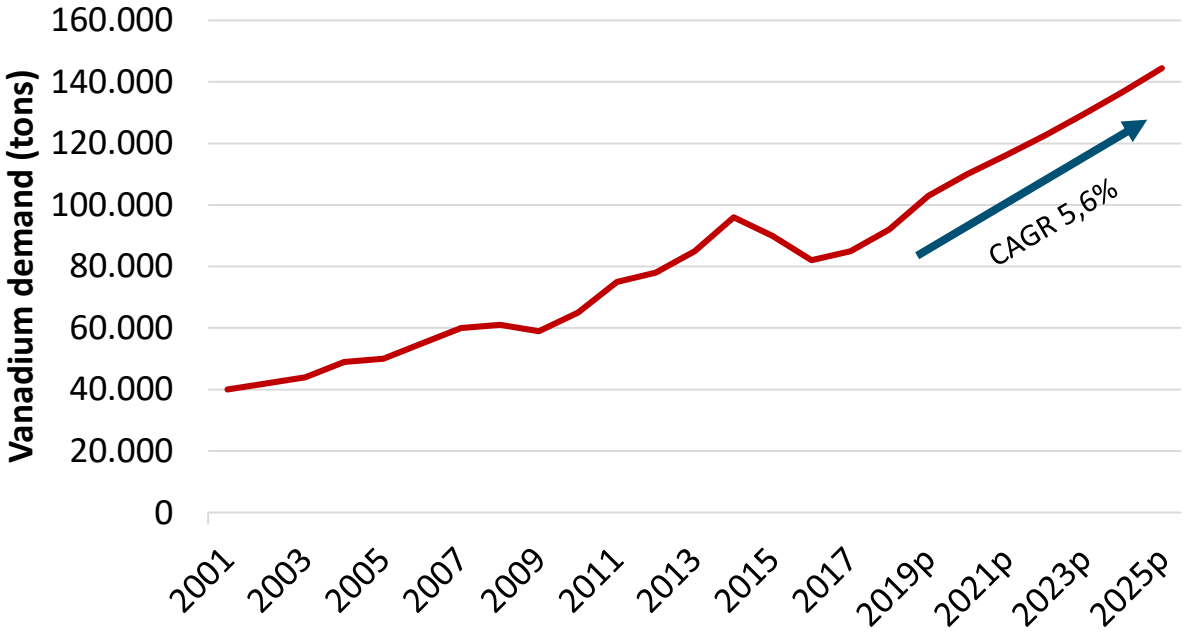
- An unpredictably expensive system -



U.S. Geological Survey; www.vanadiumprice.com.

- Demand exceeds supply (80,000 t vs. 75,000 t, 2016)
- China and South Africa are closing down polluting mines
- China introduces stricter standards for structural steel (higher V share) from November 2018
- High cost of extraction as by-product from coal, …

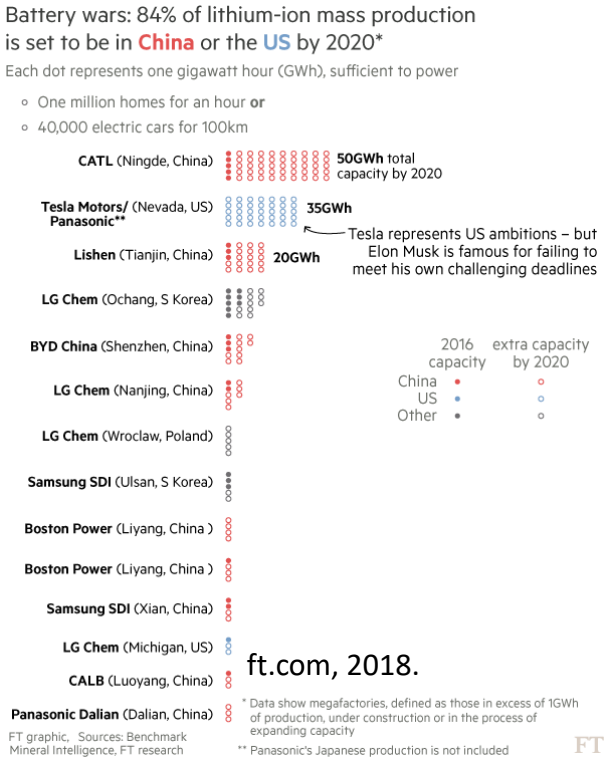
Vanadium demand



3.400 t per 1 GWh

IFBF, 2018.

Production of Li-ion batteries



ft.com, 2018.

174 GWh

The Big Read Batteries + Add to myFT

Electric cars: China's battle for the battery market

Beijing invests billions to try to squeeze out Japanese and South Korean rivals

Save

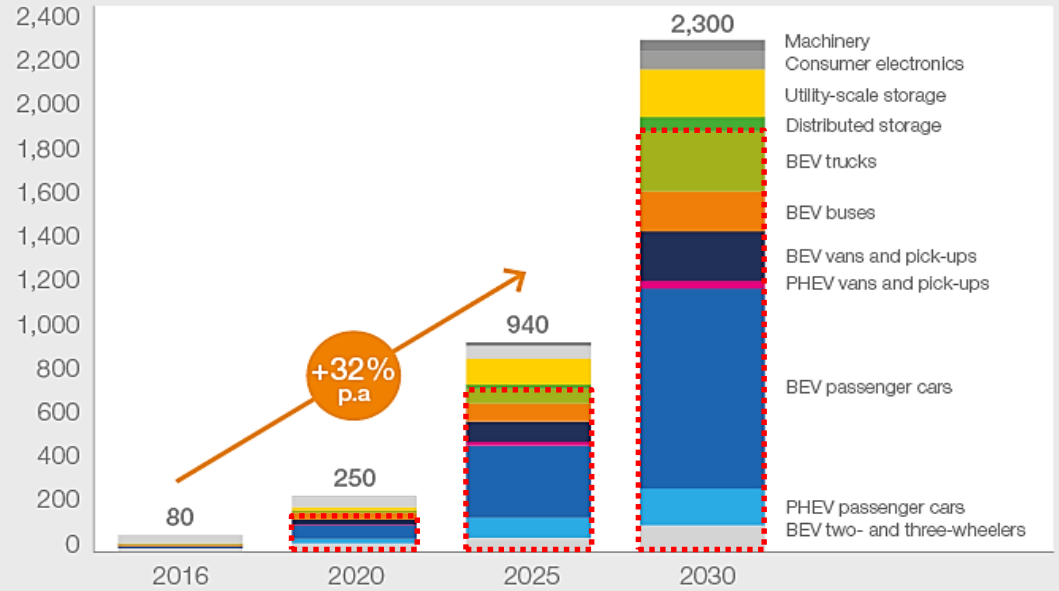
Henry Sanderson, Tom Hancock and Leo Lewis MARCH 5, 2017

77

The headquarters of CATL, China's fastest growing battery maker, lie on the edge of the city of Ningde, a stone's throw from ponds where farmers raise carp and a street of cheap noodle restaurants and vehicle repair shops frequented by

Li-ion batteries – They are for cars!

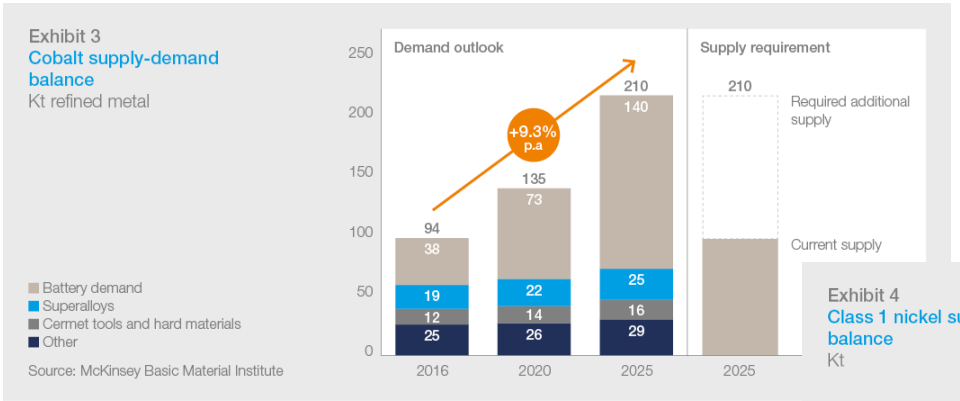
Exhibit 1
Annual battery demand: electric mobility segments, stationary battery storage, consumer electronics, and machinery
GWh/yr



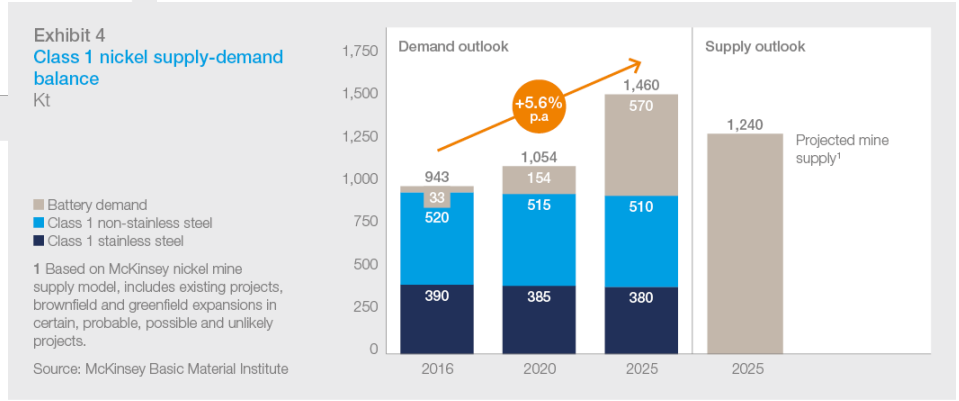
Source: McKinsey Energy Insights' Global Energy Perspective (March 2018), Avicenne

Li-ion batteries

Cobalt from Congo and substitute **nickel**: A bottleneck



McKinsey, 2018.



Diverging markets

DEEP DIVE

Electric vehicle and stationary storage batteries begin to diverge as performance priorities evolve

Separate markets could evolve as EVs push for batteries with higher density and stationary storage seeks higher cycling capability

AUTHOR
Peter Maloney
@TopFloorPower

PUBLISHED
Aug. 1, 2018

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For the past 10 to 15 years, electric vehicles (EV) have been the driving force behind the falling costs of lithium-ion (li-ion) batteries. But the markets for EV and stationary storage batteries are beginning to diverge, which could result in separate cost trajectories and changes in their respective supply chains.

Analysts say that about 90% of the market for stationary energy storage is served by li-ion batteries. Most of those batteries have been the same as those used in EVs because the performance metrics required for both applications are compatible, but that is changing.

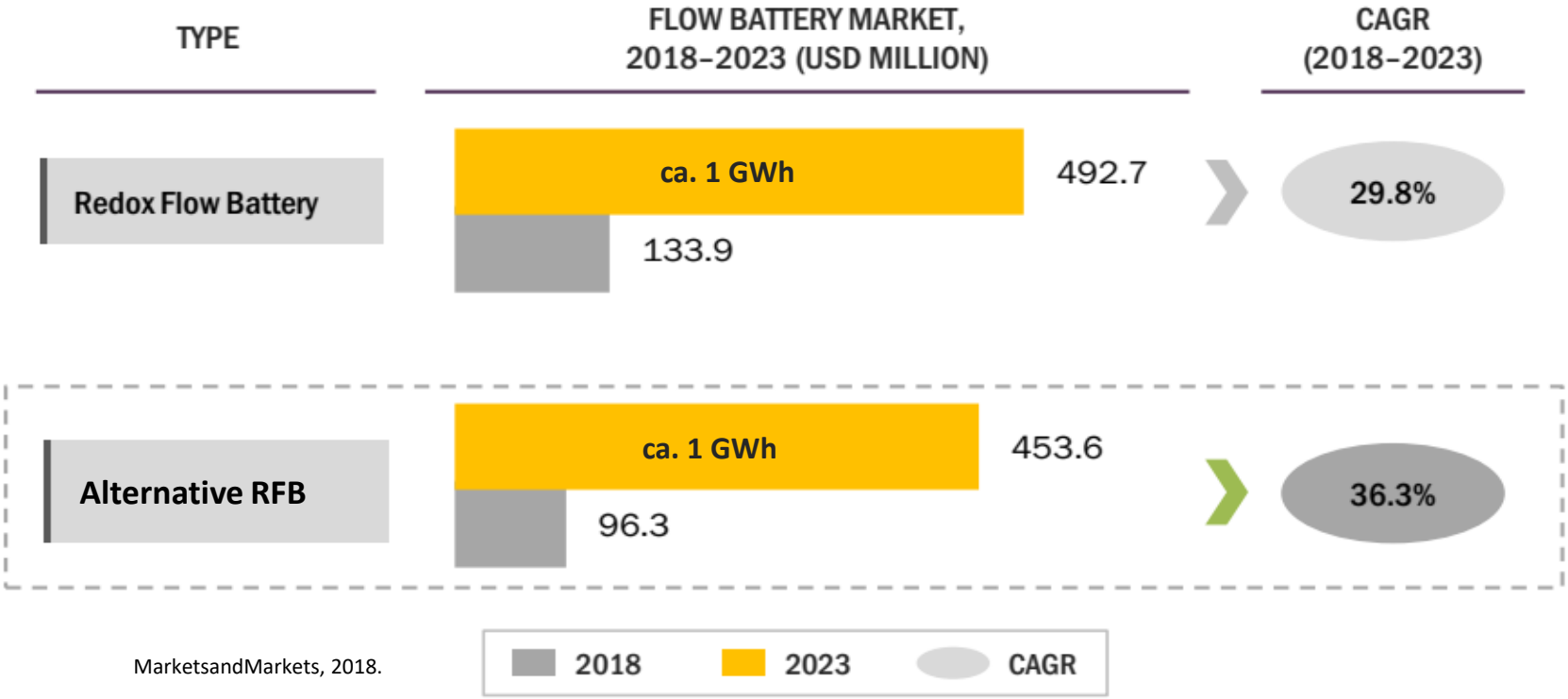
"We expect that this split is already occurring due to high cobalt prices, and the move to increase EV ranges in China," James Frith, energy storage analyst at Bloomberg New Energy Finance, told Utility Dive via email. "The impact on the market isn't clear yet but it is likely to mean that manufacturers will have to make a clear decision on which market or markets they want to serve."

https://www.utilitydive.com/news/batteries-for-electric-vehicles-and-stationary-storage-are-showing-signs-of/528848/

Mobile	Stationary
• Energy density • Co-based, but low Co-content (NMC 811) • <2000 cycles	• Cycle life • No Co • LFP, LMO • Lower energy density

The **divergence** that appears to be occurring **between the EV and stationary** battery markets is **similar to** the divergence that occurred in the past between batteries for **consumer electronics**, such as phones and laptops, **and EVs**, according to Christopher Robinson, an analyst with Lux Research.

RFB market



MarketsandMarkets, 2018.

Organic flow battery companies

- Country: Italy
- Materials: Bromine + quinones
- Status: First small prototype presented

- Country: France
- Materials: Organic
- Status: 10 kW prototype presented

- Country: USA
- Materials: Metal-organic
- Status: 250 kW/500 kWh prototype presented

- Country: Canada
- Materials: Quinones
- Status: Early stage

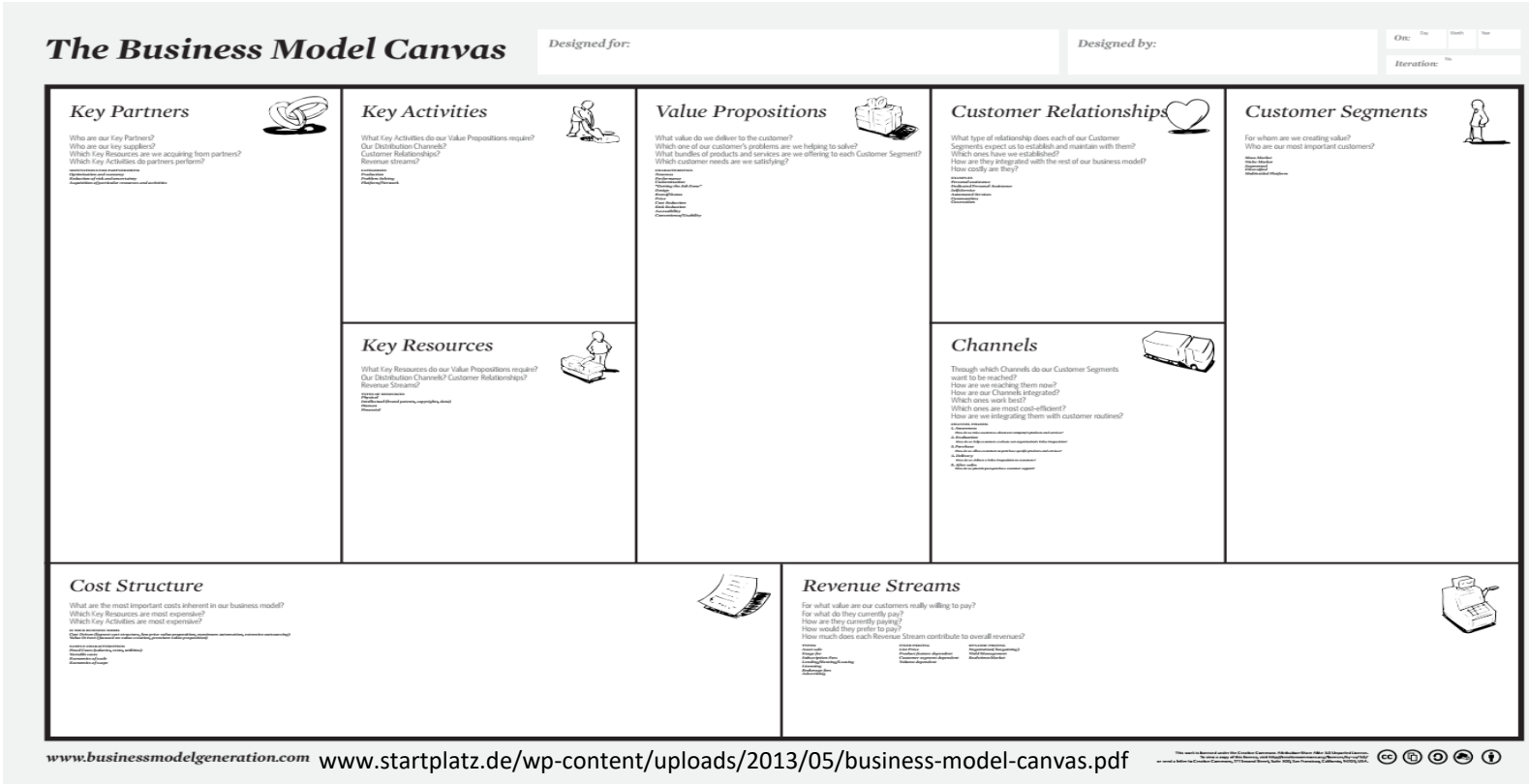
Business plan

Business plan

https://questfusion.com/how-to-create-a-startup-business-plan/

Business model

business-model-canvas.pdf



www.startplatz.de/wp-content/uploads/2013/05/business-model-canvas.pdf

Value Propositions

What value do we deliver to the customer?
Which one of our customer's problems are we helping to solve?
What bundles of products and services are we offering to each Customer Segment?
Which customer needs are we satisfying?

CHARACTERISTICS
Newness
Performance
Customization
"Getting the Job Done"
Design
Brand/Status
Price
Cost Reduction
Risk Reduction
Accessibility
Convenience/Usability

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Metal-free RFB stands for …

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  - Free and independent scalability of power and capacity
  - Non-flammable and non-explosive
  - Turnkey energy storage system
- **Clean energy**
  - No heavy metals or aggressive acids
  - Resource-efficient
  - Near-neutral pH
- **Economical**
  - Inexpensive raw materials without raw material bottleneck
  - Low maintenance and excellent stability > 10.000 cycles
  - Flexible and sustainable investment

The European answer to lithium

Li (cobalt) battery

+ Advantages

- High energy density
- High efficiency

- Disadvantages

- Intensive battery management for durability and safety
- Limited resources (lithium, cobalt, nickel) with increased price sensitivity
- State of charge from 20-80%
- Fire hazard

Organic RFB

+ Advantages

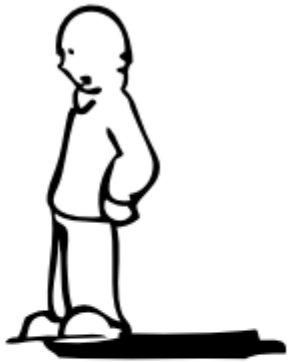
- Independent scalability of power & capacity
- Avoids heavy metals and aggressive acids
- All battery components can be made in EU
- Non-flammable and non-explosive
- Long lifetime
- Wide SOC window

- Disadvantages

- Lower energy density
- Average efficiency

Both battery systems have their advantages and which one to use depends ultimately on the application and environmental situation such as operational temperature, availability of space, power vs. capacity requirements etc.

Customer Segments



For whom are we creating value?
Who are our most important customers?

Mass Market
Niche Market
Segmented
Diversified
Multi-sided Platform

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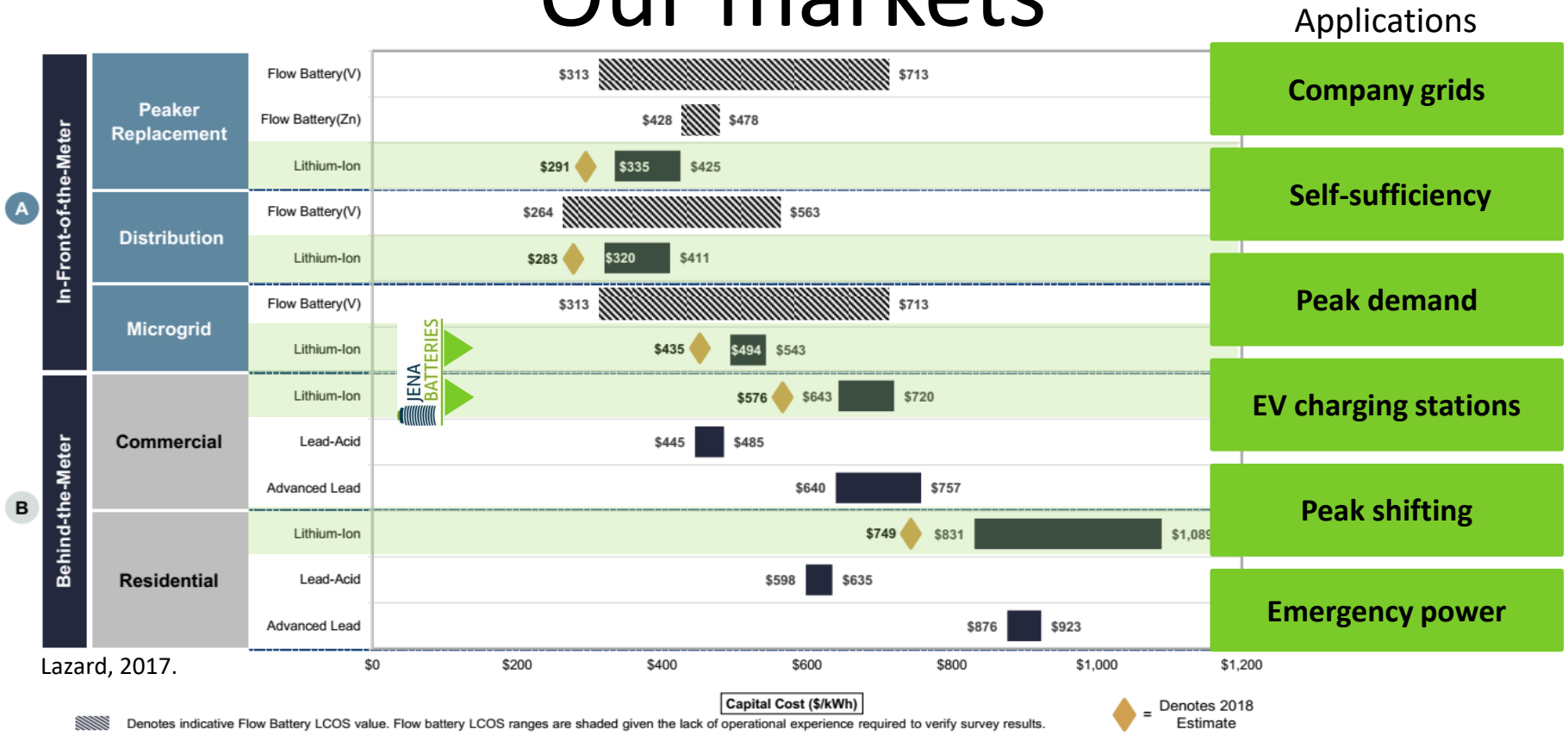
Our markets

		Project Life (Years)	MW[1]	MWh of Capacity[2]	100% DOD Cycles/Day[3]	Days/ Year[4]	Annual MWh	Project MWh
In-Front-of-the-Meter	1 Peaker Replacement	20	100	400	1	350	140,000	2,800,000
	2 Distribution	20	10	60	1	350	21,000	420,000
	3 Microgrid	10	1	4	2	350	2,800	28,000
Behind-the-Meter	4 Commercial	10	0.125	0.25	1	250	62.5	625
	5 Residential	10	0.005	0.01	1	250	2.5	25

Lazard, 2017.

Our markets



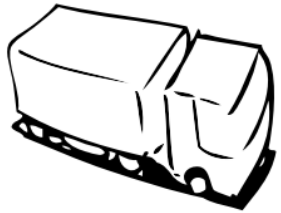
Lazard, 2017.

Customer Relationships

What type of relationship does each of our Customer Segments expect us to establish and maintain with them?
Which ones have we established?
How are they integrated with the rest of our business model?
How costly are they?

EXAMPLES
Personal assistance
Dedicated Personal Assistance
Self-Service
Automated Services
Communities
Co-creation

Channels



Through which Channels do our Customer Segments want to be reached?
How are we reaching them now?
How are our Channels integrated?
Which ones work best?
Which ones are most cost-efficient?
How are we integrating them with customer routines?

CHANNEL PHASES:
1. *Awareness*
   How do we raise awareness about our company's products and services?
2. *Evaluation*
   How do we help customers evaluate our organization's Value Proposition?
3. *Purchase*
   How do we allow customers to purchase specific products and services?
4. *Delivery*
   How do we deliver a Value Proposition to customers?
5. *After sales*
   How do we provide post-purchase customer support?

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Revenue Streams

For what value are our customers really willing to pay?
For what do they currently pay?
How are they currently paying?
How would they prefer to pay?
How much does each Revenue Stream contribute to overall revenues?

TYPES:
Asset sale
Usage fee
Subscription Fees
Lending/Renting/Leasing
Licensing
Brokerage fees
Advertising

FIXED PRICING
List Price
Product feature dependent
Customer segment dependent
Volume dependent

DYNAMIC PRICING
Negotiation(bargaining)
Yield Management
Real-time-Market

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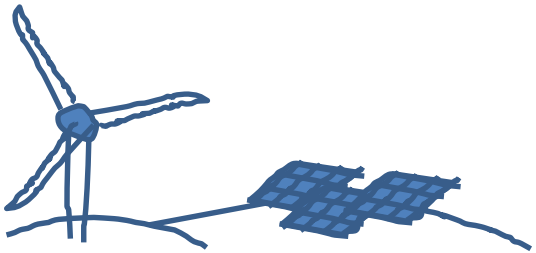
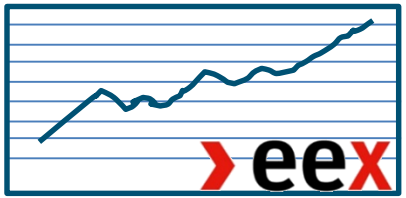
Customers: Project developer



Energy provider



Energy exchange

JENA BATTERIES

Electricity

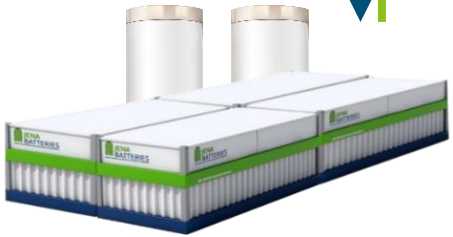
remuneration

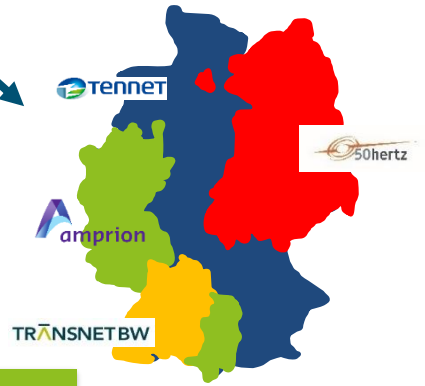
Electricity

Market price

Elec-

tricity





Management fee

Utility/service company

System operator

Cost Structure

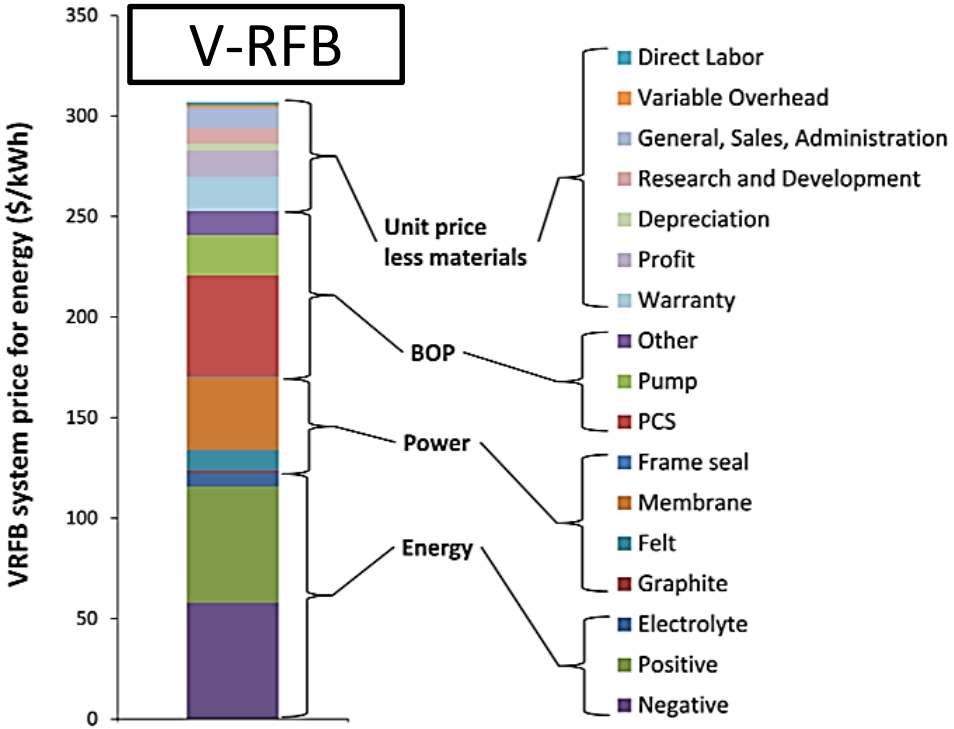
What are the most important costs inherent in our business model?
Which Key Resources are most expensive?
Which Key Activities are most expensive?

IS YOUR BUSINESS MORE:
Cost Driven (leanest cost structure, low price value proposition, maximum automation, extensive outsourcing)
Value Driven (focused on value creation, premium value proposition)

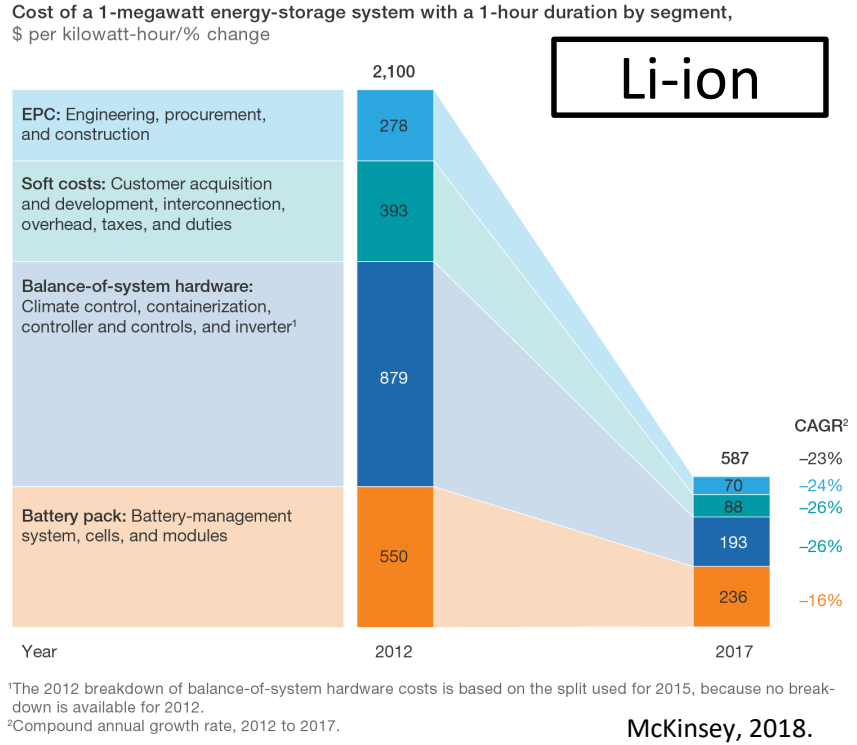
SAMPLE CHARACTERISTICS:
Fixed Costs (salaries, rents, utilities)
Variable costs
Economies of scale
Economies of scope

www.startplatz.de/wp-content/uploads/2013/05/business-model-canvas.pdf

System price breakdown



https://www.jcesr.org/estimating-the-system-price-of-redox-flow-batteries-for-grid-storage/



McKinsey, 2018.

Key Activities

What Key Activities do our Value Propositions require?
Our Distribution Channels?
Customer Relationships?
Revenue streams?

CATEGORIES
Production
Problem Solving
Platform/Network

Key Partners

Key Resources

What Key Resources do our Value Propositions require?
Our Distribution Channels? Customer Relationships?
Revenue Streams?

TYPES OF RESOURCES
Physical
Intellectual (brand patents, copyrights, data)
Human
Financial

Who are our Key Partners?
Who are our key suppliers?
Which Key Resources are we acquiring from partners?
Which Key Activities do partners perform?

MOTIVATIONS FOR PARTNERSHIPS:
Optimization and economy
Reduction of risk and uncertainty
Acquisition of particular resources and activities

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Next steps

Legal structure

- Important decision!
- Defines taxes
- Amount of paperwork
- Personal liability
- Ability to raise money

Legal structure

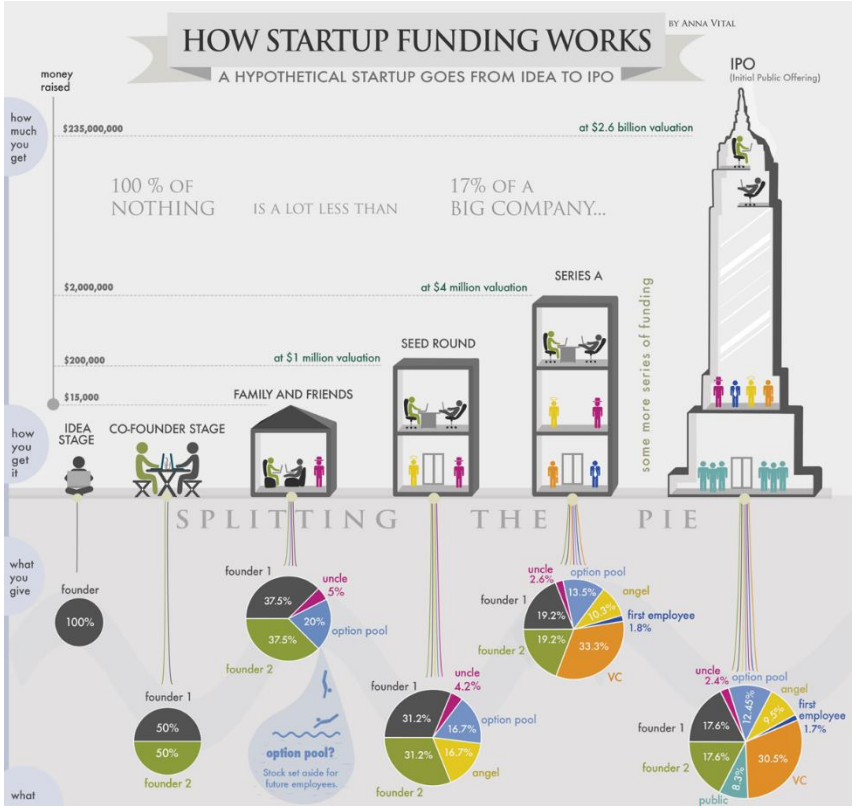
GmbH	S.L.	Ldt. (UK)
• Gesellschaft mit beschränkter Haftung • Min. capital stock 25 TEUR • Limited personal liability • No shelf company	• Sociedad de responsabilidad limitada • Min. capital stock 3 TEUR • Shelf company possible and fast	• Limited Company • Limited by shares • Limited by guarantee • No min. capital stock • Fast (24 h)

Funding

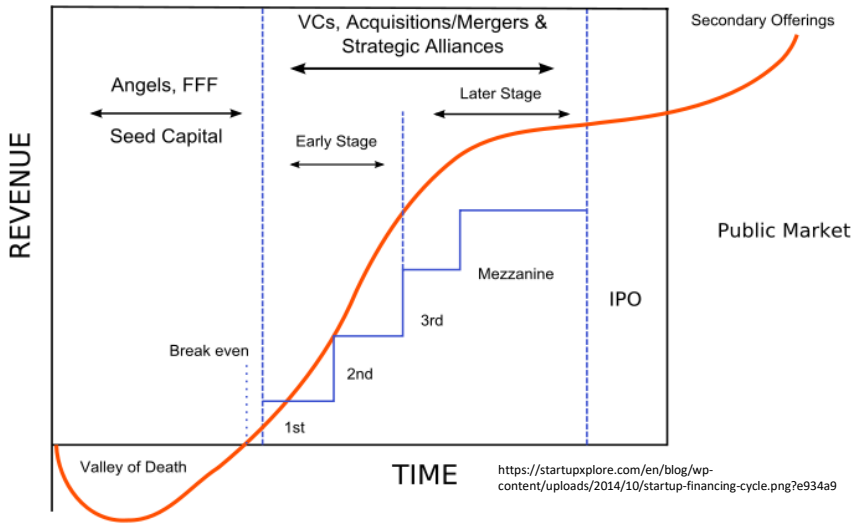
- You
- Friends and family
- Loans (banks, microlenders, government-guaranteed)
- Private / angel investors
- Venture capital firms
- Public grants
- Crowdfunding

Picture: wikipedia.org

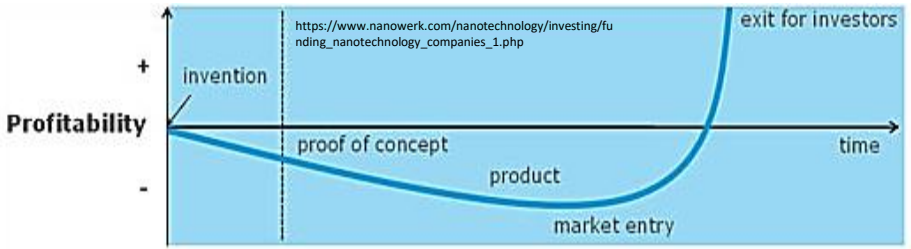
Financing cycle



https://blog.adioma.com/how-funding-works-splitting-equity-infographic/



https://startupxplore.com/en/blog/wp-content/uploads/2014/10/startup-financing-cycle.png?e934a9



Financing cycle – first steps

Founding partners

Public funding of R&D projects

Public funding of R&D

EFRE
EUROPA FÜR THÜRINGEN
EUROPÄISCHER FONDS FÜR REGIONALE ENTWICKLUNG
Thüringer Aufbaubank

1,75 Mio. € - Basic research on organic RFB

1,1 Mio. € - RFB/Smart Grid

EUROPÄISCHE UNION

Bundesministerium
für Wirtschaft
und Energie

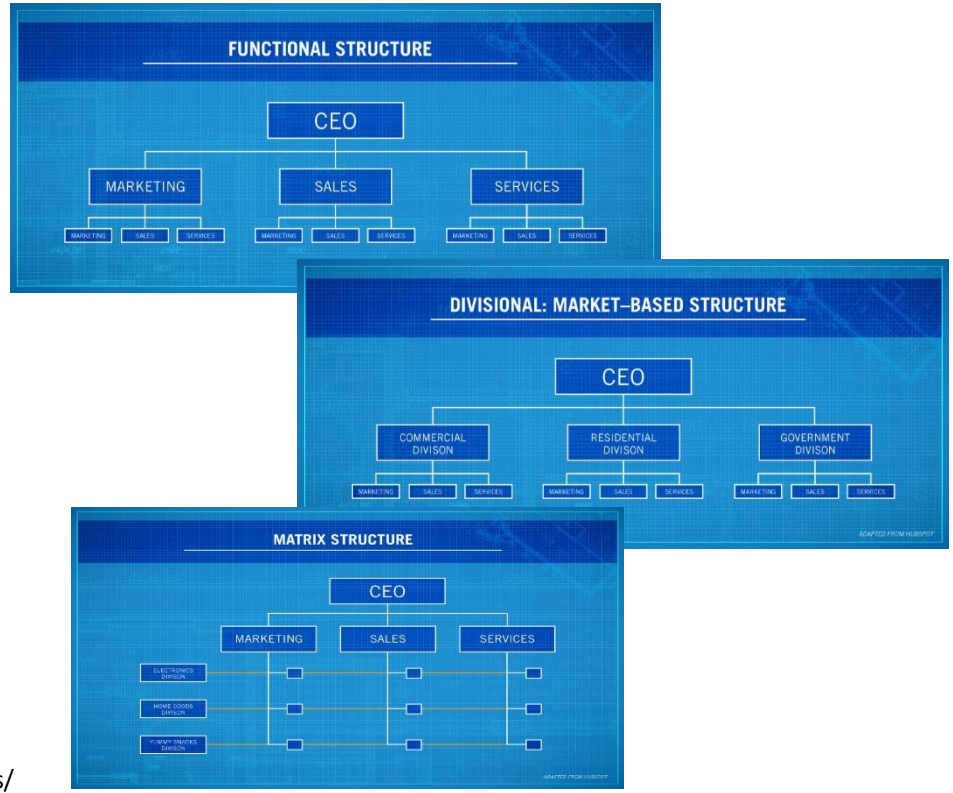
340 T€ - photo-electrochemical RFB

140 T€ - innovative materials

ZIM
Zentrales
Innovationsprogramm
Mittelstand

Organizational structure

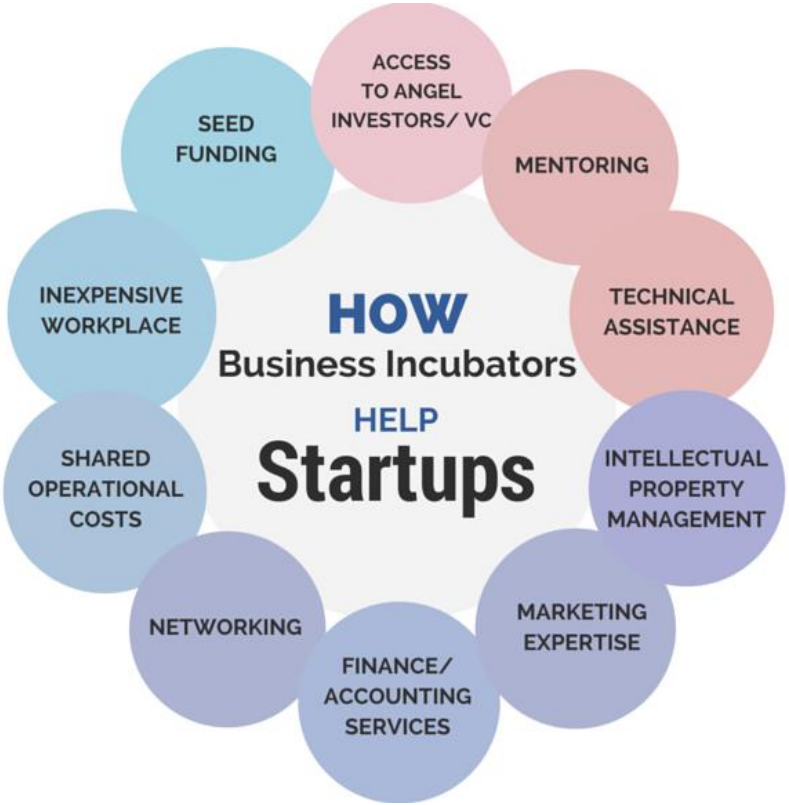
- What expertise do we need?
- How many people? – Avoid being a one-person team, recruit talent
- Cost? – Running costs add up fast!
- Is working at a start-up company attractive?
- How much formalism is needed? When to change?
- Leadership skills – Do we need an experienced manager?
- Conflicts!



https://online.pointpark.edu/business/types-of-organizational-structures/

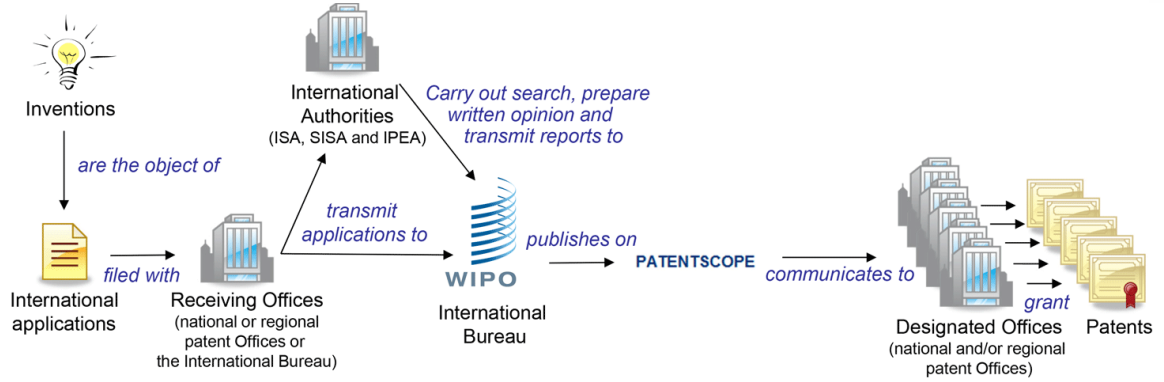
Infrastructure

- Offices & labs, collaborative spaces, …
  → business incubator
- Professional accounting
- Legal counselling
- Avoid heavy investments at an early stage



https://www.hindiapost.com/what-are-incubators/

Intellectual property



http://www.wipo.int/pct/en/faqs/faqs.html

Make yourself known

IQ Innovation award 2015

TV: 3sat - nano

luxresearch

This is a **preview** of an

COMPANY PROFILE

JenaBatteries

Flow battery developer using small organic molecule electrolyte

Content Programs:
Owning the Energy Transition

Coverage Areas:
Energy Storage

Categories:
Flow batteries

JENA BATTERIES

Market reports: Lux Research

- Pivoted from longer chain polymer electrolytes due to viscosity issues; retains original stack design permitting low pressure drop operation
- Demonstrated full systems at 10 kW-scale as part of a publicly-funded program; starting another publicly-funded 30 kW/100 kWh microgrid project funded by Horizon 2020

STAGE OF DEVELOPMENT

Introduction

Clients should view JenaBatteries as the leading player in organic molecule flow battery commercialization, but look for continued technology development before engaging for next generation energy storage solutions

JenaBatteries:

The battery of the future

We all know that we need to change some things if we want to preserve our planet. Unfortunately, the average stationary battery system is relying heavily on mining and refining in sensitive habitats and is anything but green. JenaBatteries creates revolutionary organic redox-flow-batteries based on metal-free energy storage materials salt and water, which reduce the environmental impact and can be manufactured

grid applications, micro-grid solutions, island grids, storage of renewable energy, load shifting and peak shaving, emergency and uninterrupted power supply, for e-mobility, charging solutions and many

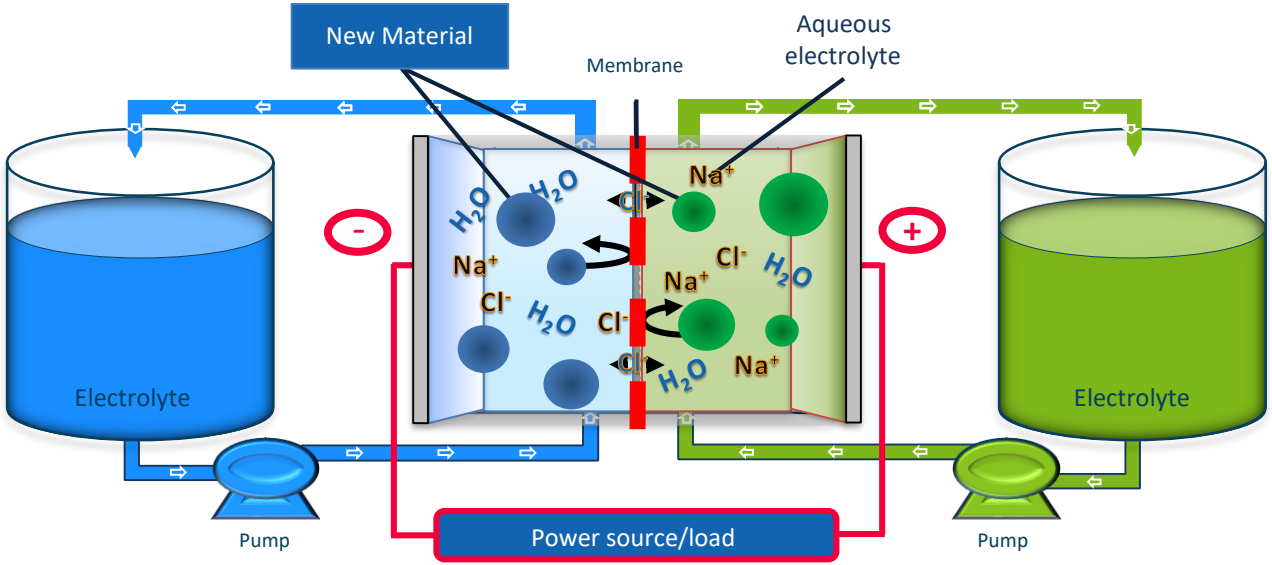
TEXT: MARLENA STRACKI

Inflight Magazin „Discover Germany“

Clients should view JenaBatteries as the leading player in organic molecule flow battery commercialization […]

Development

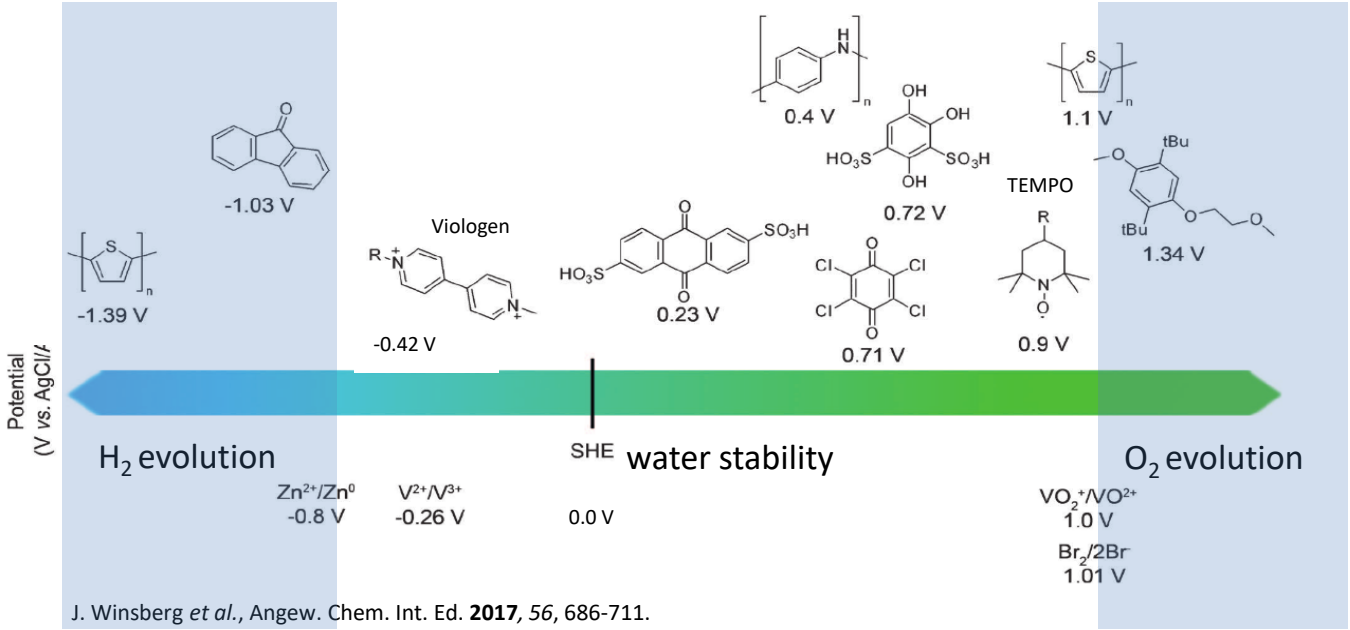
JenaBatteries' metal free aqueous RFB



Sustainable and easy-to-handle:

A water-based electrolyte replaces highly corrosive, acidic, vanadium-based electrolytes.

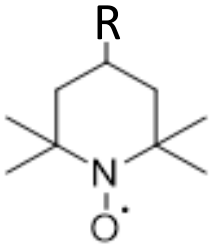
Organic active materials



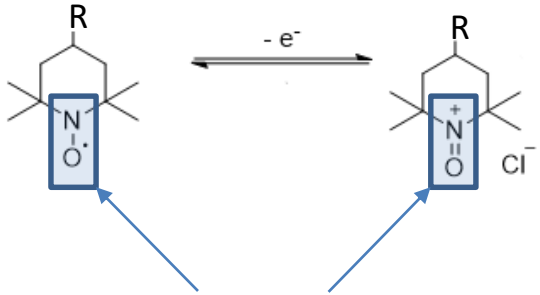
J. Winsberg *et al.*, Angew. Chem. Int. Ed. **2017**, *56*, 686-711.

- Aqueous solutions are favored due to cost, safety and conductivity
- TEMPO/viologen-system uses a great part of water stability window

How to chose organic active materials



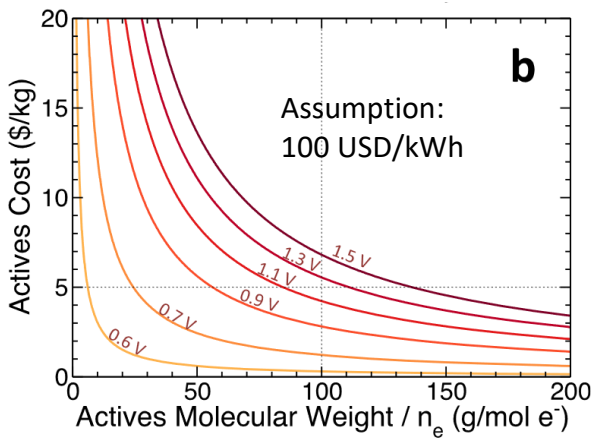
- 2,2,6,6-Tetramethylpiperidinyloxyl (TEMPO) derivatives
- Persistent radicals
- Cheap educts (acetone und ammonia)
- Simple synthesis routs for various R-groups



Active part

Molar mass N-O: 30 g/mol

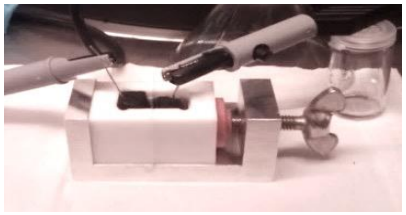
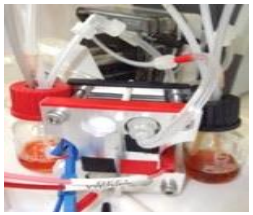
Molar mass TEMPO: 156 g/mol



R. Dmello *et al.*, *J. Power Sources* **2016**, *333*, 261-272.

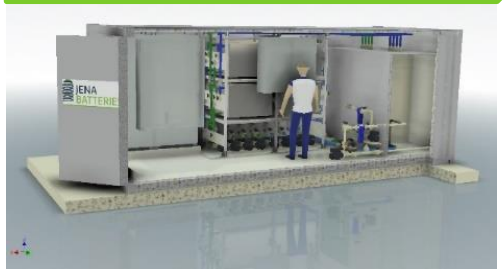
Development

Laboratory and prototype facility:


Pilot projects:

PV application



Microgrid

Tailored solutions

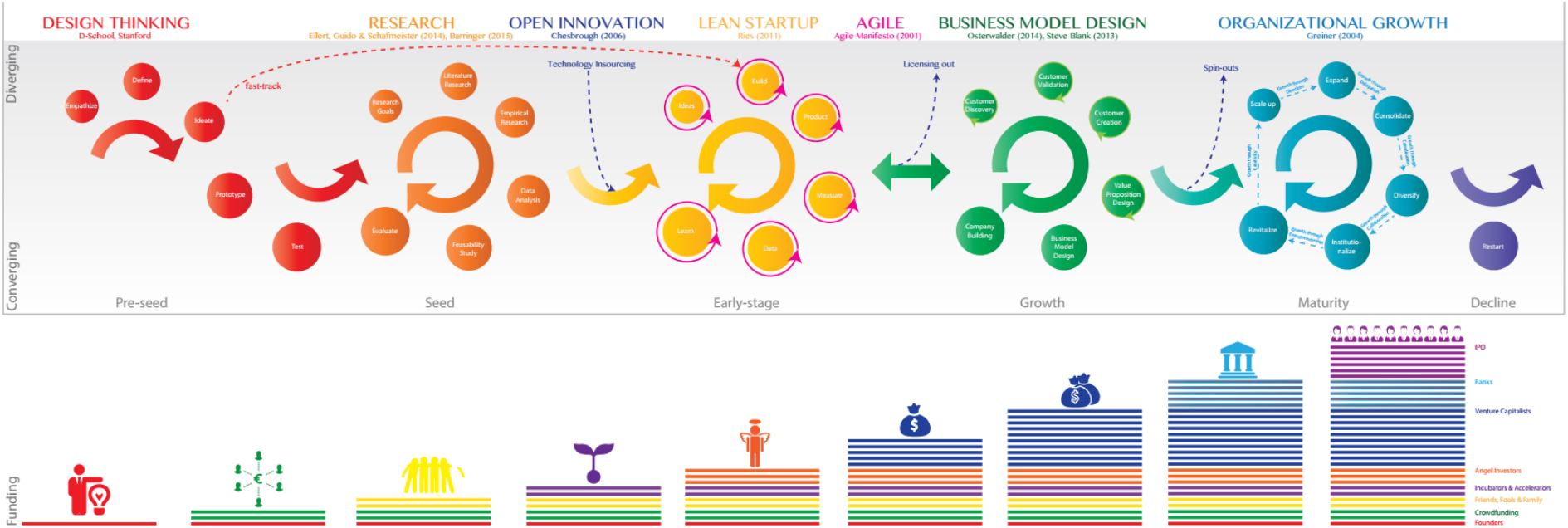
Go and sell! – Testing the market

If you are not embarrassed about the first version of your product when talking to potential customers, you have launched to late!

Organizational growth & scale up

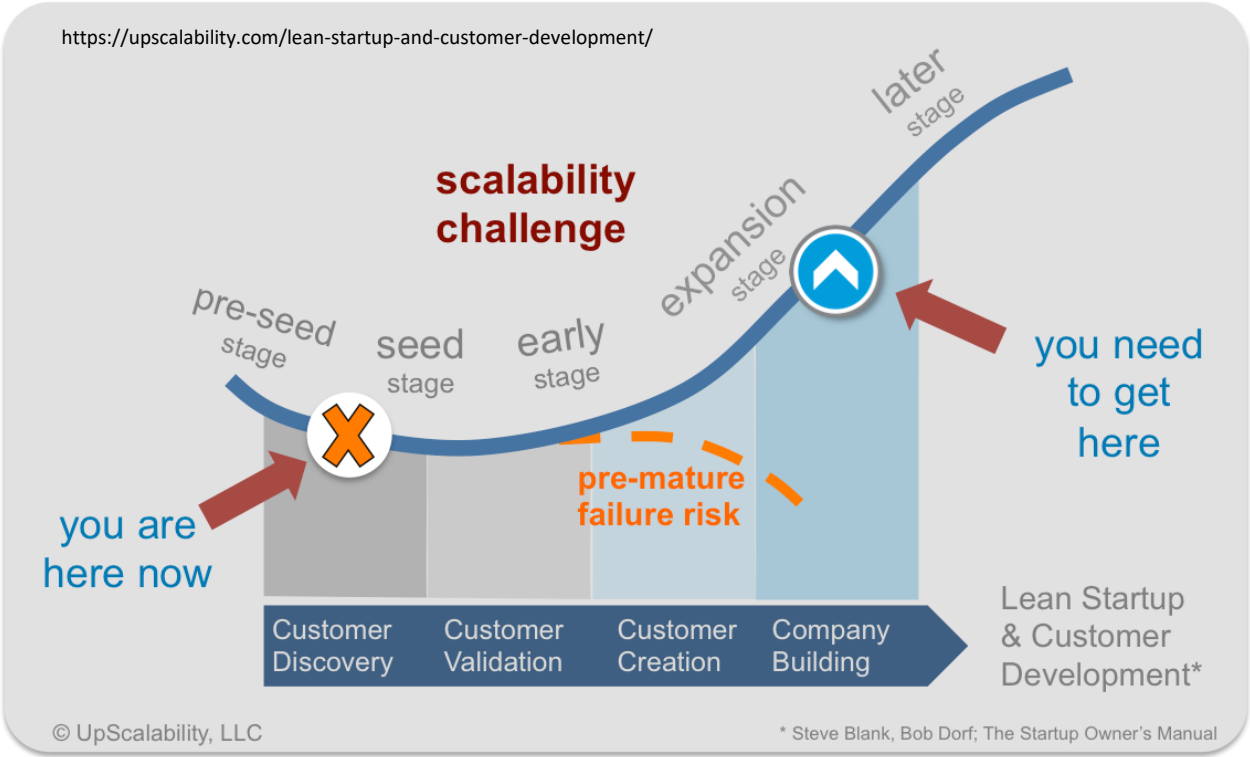
Lean Scale-Up: Innovation & Entrepreneurship for New Ventures

Innovative Dutch serious games for serious professionals

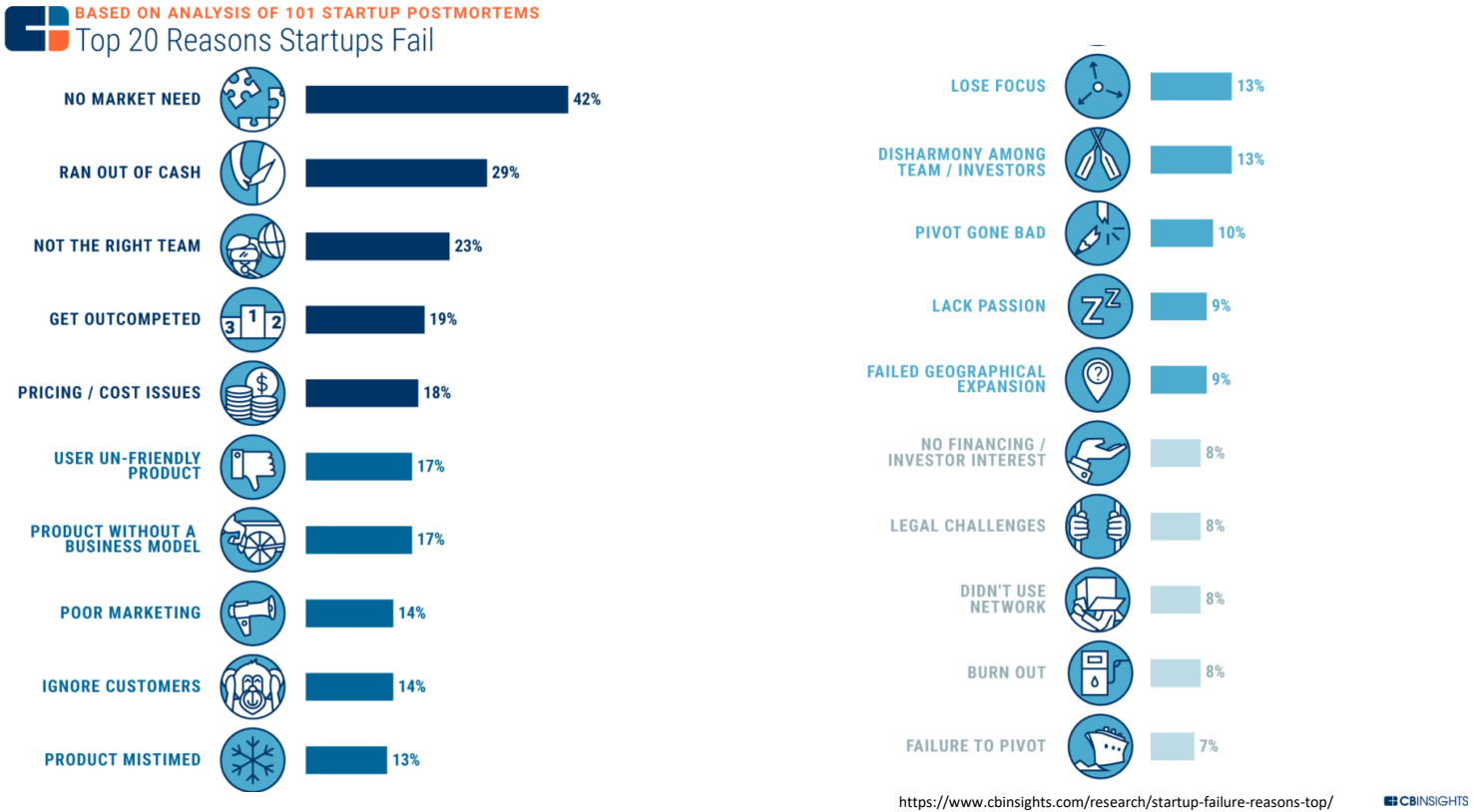


https://www.innovativedutch.com/the-lean-scale-up-innovation-entrepreneurship-for-new-ventures-infographic/

Organizational growth & scale up



Failure


BASED ON ANALYSIS OF 101 STARTUP POSTMORTEMS
Top 20 Reasons Startups Fail
NO MARKET NEED 42%
RAN OUT OF CASH 29%
NOT THE RIGHT TEAM 23%
GET OUTCOMPETED 19%
PRICING / COST ISSUES 18%
USER UN-FRIENDLY PRODUCT 17%
PRODUCT WITHOUT A BUSINESS MODEL 17%
POOR MARKETING 14%
IGNORE CUSTOMERS 14%
PRODUCT MISTIMED 13%
LOSE FOCUS 13%
DISHARMONY AMONG TEAM / INVESTORS 13%
PIVOT GONE BAD 10%
LACK PASSION 9%
FAILED GEOGRAPHICAL EXPANSION 9%
NO FINANCING / INVESTOR INTEREST 8%
LEGAL CHALLENGES 8%
DIDN'T USE NETWORK 8%
BURN OUT 8%
FAILURE TO PIVOT 7%
https://www.cbinsights.com/research/startup-failure-reasons-top/
CBINSIGHTS

Don’t be afraid!

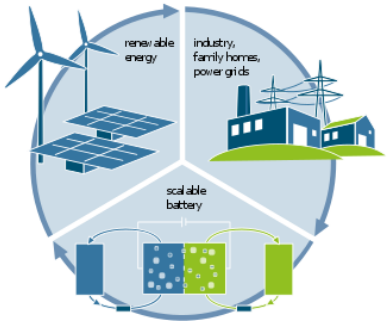
https://yourstory.com/wp-content/uploads/2014/12/fundersandfounders_18-Mistakes-That-Kill-Startups.png

Don’t be afraid of failure.
If you don’t start, who else will?
If necessary, launch again!

Summary

Summary

- Metal-free, aqueous RFBs as safe, non-flammable alternative for lithium-ion batteries in stationary storage
- Organic molecules provide "unlimited" raw material availability
- Predictable costs allow for projectability, bankability, insurability
- JenaBatteries offers metal-free, aqueous RFBs starting at 100 kW for industrial customers



JENA BATTERIES

Autumn School Flow Battery

Barcelona – 12th-13th of November 2018

LEITAT managing technologies

IREC Institut de Recerca en Energia de Catalunya
Catalonia Institute for Energy Research

UAB Universitat Autònoma de Barcelona

Universitat de Barcelona

JENA BATTERIES