Revolutionary high performance batteries based on common/cheap materials

BroadBit Batteries Oy

August 2021

Current battery tech limits market

Fossil fuel world = ~1 kg batteries per person
Electric world = ~100 kg batteries per person

~80 B$
Today

Existing batteries:

Expensive (>150 $/kWh)
Harmful (Environment & Users)
Slow to charge (> 2hrs)
Low capacity (< 260 Wh/kg)
Delicate (0C – 40C)
Resource limited (Lithium, Cobalt, Nickel)

>1 T$
2030

BroadBit's core battery innovations

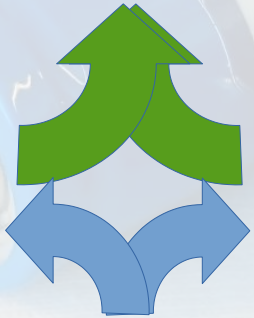
Better Battery Chemistry

Evolutionary (Li-Ion):
Electrolyte: Wide-temp/Hi-Volt
Cathode: Co & Ni Free
(TRL-8, TRL-9 2021)

Revolutionary (Na-Salt):
Anode, Cathode, Electrolyte:
Rare Earth Metal Fee
(TRL-5, TRL-9 2022)

Lower Cost, Higher Performance, Greener, Safer, More Scalable

Evolutionary:
Water-based: Non-Toxic
(TRL-7, TRL-9 2021)



Revolutionary:
Dry: Liquid Free
(TRL-6, TRL-9 2021)

Better Battery Manufacturing

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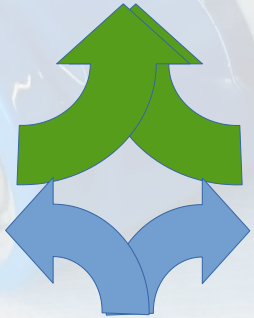

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(TRL-6, TRL-9 2021)

Better Battery Manufacturing

BroadBit's Li-ion Innovation vs. Std. Li-ion

Novel BroadBit Electrolyte (for all Li-ion Chemistries):

- **Safer** (no reaction w/ water creating toxic by-products)
- **10% Higher Voltage Limit** (charging up to 4.5V vs. 4.2V for std. Li-ion)
- **15°C Higher Temperature Limit** (75°C vs. 60°C for std. Li-ion)
- **30% Higher Conductivity** (3.2 mS/cm vs. 2.4 mS/cm for std. Li-ion)
- **2x Cycle Life** (2000 cycles vs. 1000 for std. Li-ion)

Theoretically valid for ALL existing Li-ion cathodes, anodes and separators

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Novel BroadBit Cathode (for Li-ion LFP Replacement):

- **20% Higher Energy** (discharge voltage 3.6V vs. 3.2V for Li-LFP)
- **More scalable and sustainable (Cobalt and Nickel free)**

Areal mass loading (mg/cm^2)	21±5%
Areal capacity (mAh/cm^2)	2,6±5%
Recommended maximum charge voltage	4.2V vs. Li/Li+
Recommended cut-off voltage for discharge	2.5 vs. Li/Li+

BroadBit's Li-ion Innovation vs. Std. Li-ion

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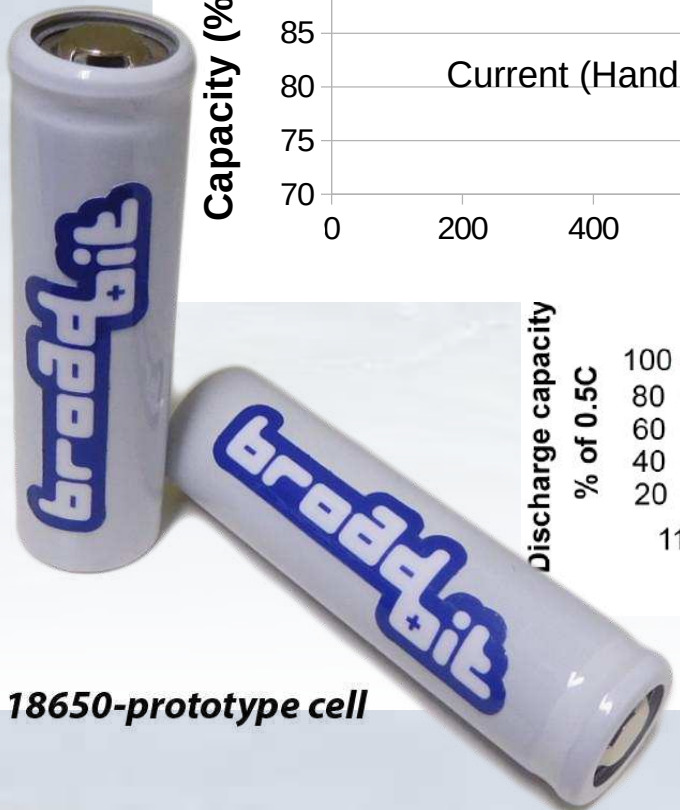
Novel BroadBit Cathode + Electrolyte (for Li-ion LFP Replacement):

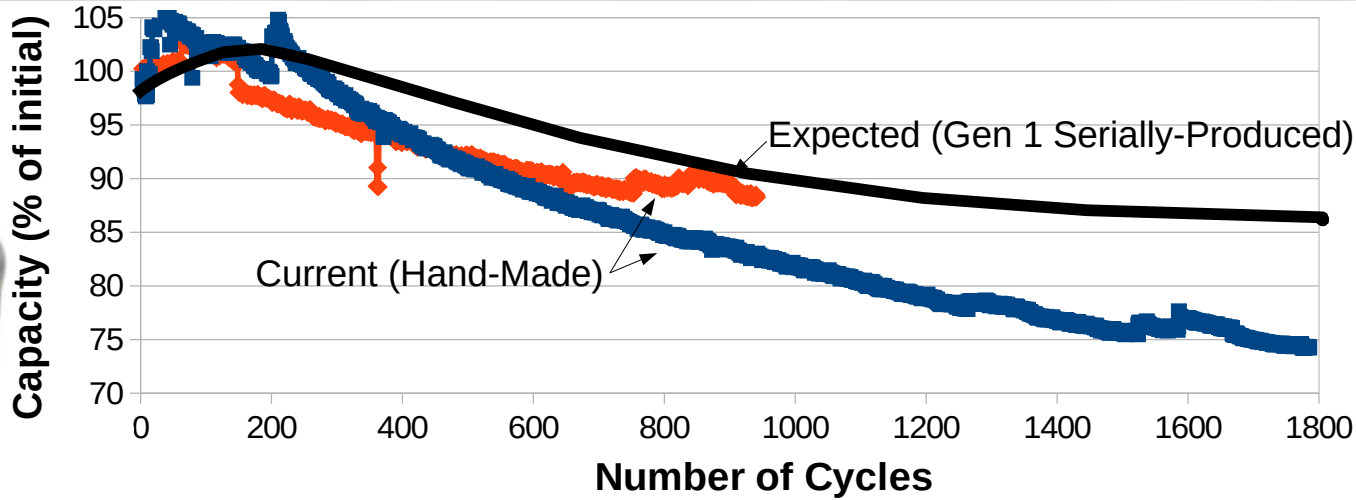
- **Safer, More Robust, Longer Life, Higher Energy**
- **10% lower cell cost / kWh, 25% lower pack cost / kWh**

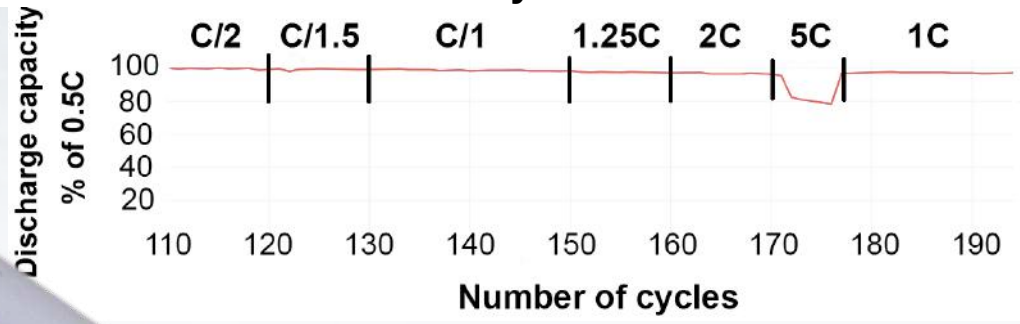
BroadBit's Li-ion LFP replacement chemistry

- Wider temperature range
- Cobalt & nickel free
- Lower flammability
- Faster charging
- Higher power
- Non-toxic
- Longer life
- Lower cost



18650-prototype cell

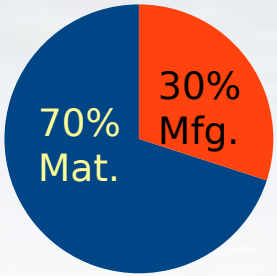




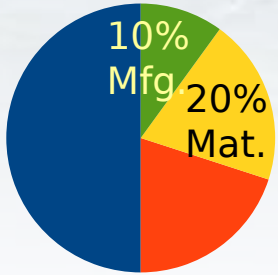
BroadBit beats the competition

KPI	LFP Li-ion	BroadBit Li-ion (Theoretical)
Recharge time	2 hrs to 99%	½ hr to 99% (<10 mins possible)
Energy Capacity	<145 Wh/kg	155 Wh/kg (>175 Wh/kg possible)
Cycle Life	2000 cycles	3000 cycles (>10000 possible)
Temperature Range	0°C to 60°C	-20°C to 75°C (85°C possible)

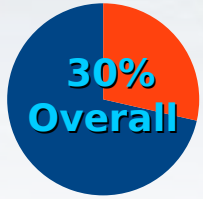
Existing LFP Li-Ion

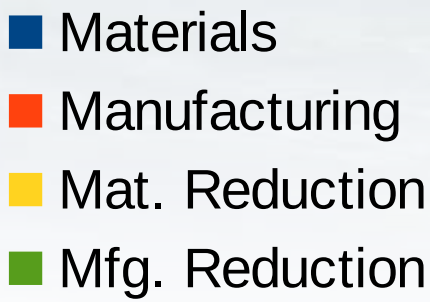


Cost Reduction



BroadBit Li-Ion





Cost

Initial: >70 $/kWh → <50 $/kWh

Levelized: <35 $/MWh → <20 $/MWh

BroadBit's core battery innovations

Better Battery Chemistry

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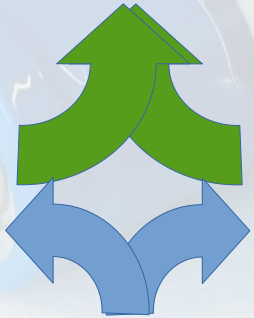


Revolutionary:
Dry: Liquid Free
(TRL-6, TRL-9 2021)

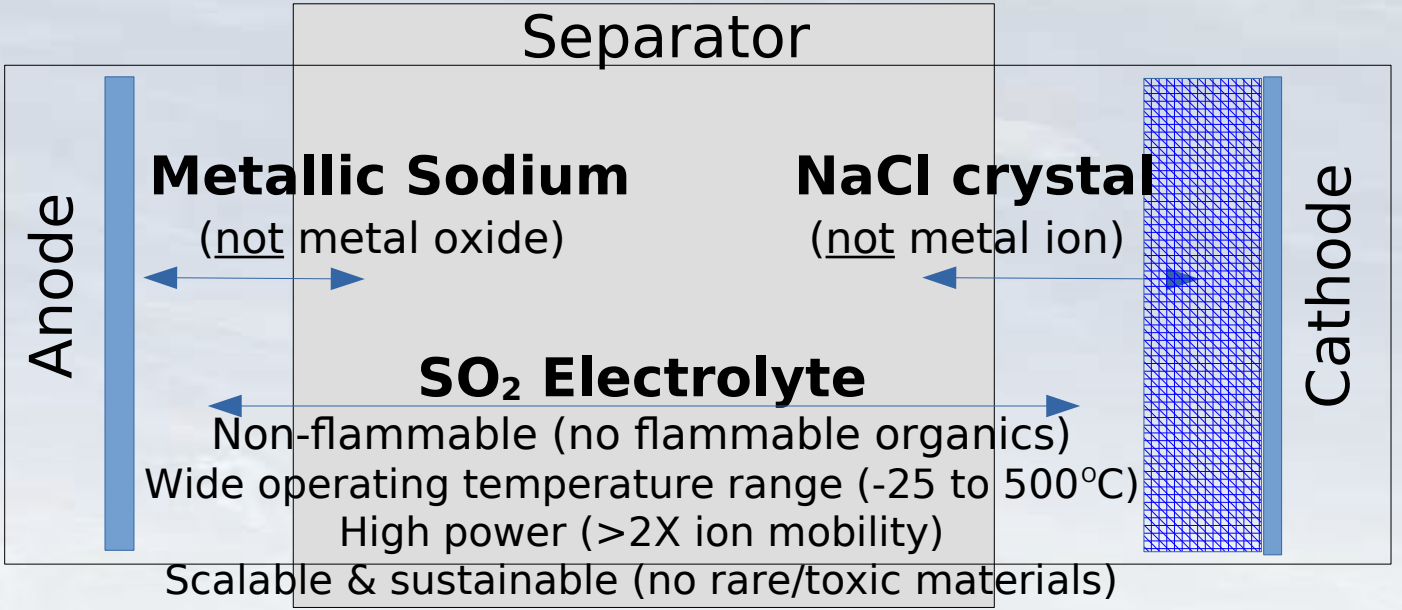
Better Battery Manufacturing

broadbit

BroadBit's unique sodium technology

Unique operating principle

Superior Performance

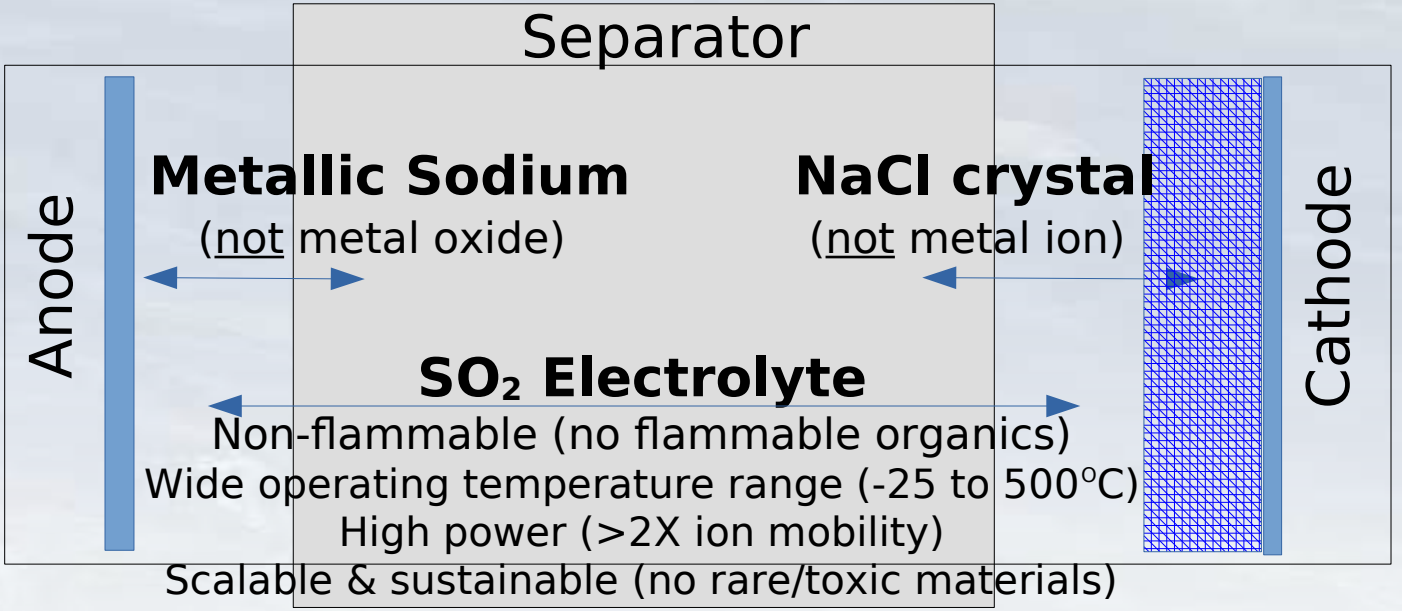


BroadBit's unique sodium technology

Unique operating principle

Superior Performance

Low cost



Salt (NaCl)

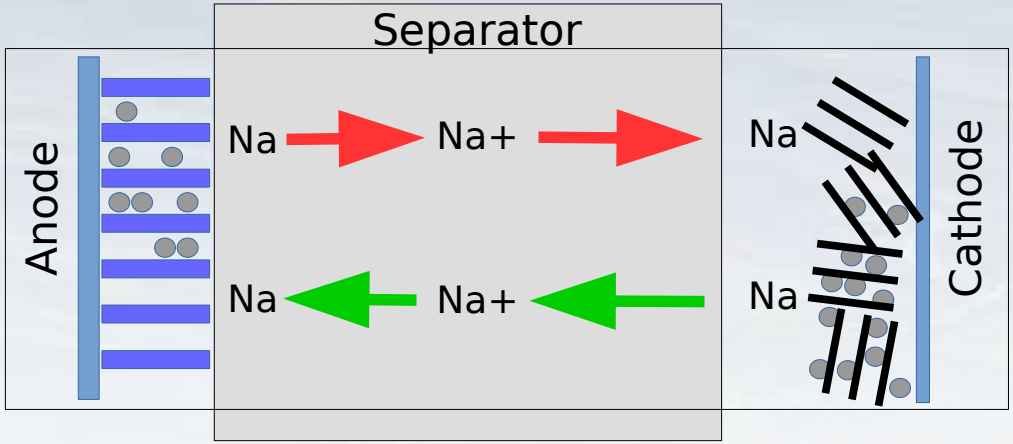
Sand (SiO_2)

Coal (C)

Sulfur (S)

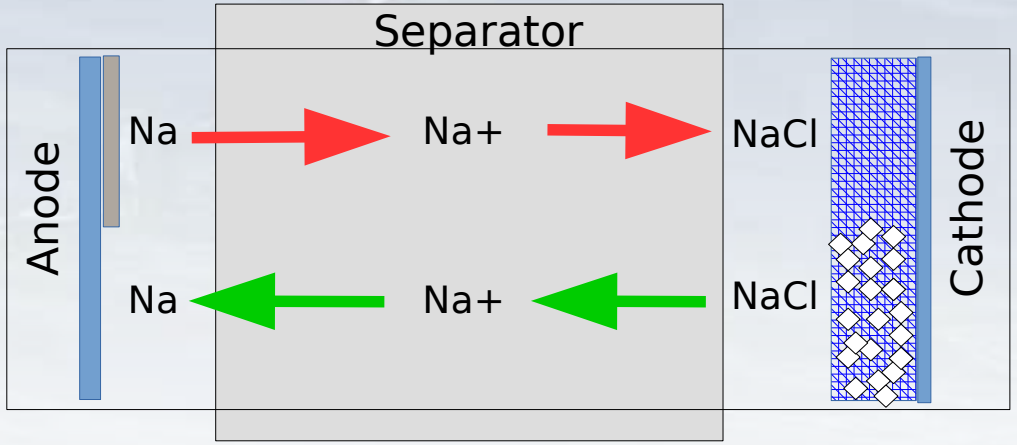
Fundamentally NOT Sodium-Ion

Sodium-ion batteries use intercalation to store charge



~100 Wh/kg
Flammable

BroadBit uses electrodeposition & crystallization to store charge



~300 Wh/kg
Non-Flammable

Na = Elemental (Metallic) Sodium

Na+ = Sodium Ion (in solution)

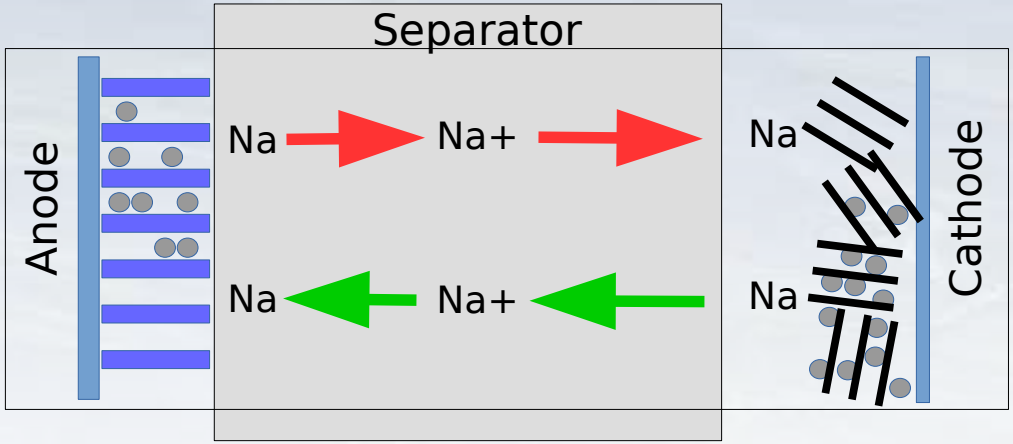
NaCl = Sodium Chloride (crystal)

= Charge

= Discharge

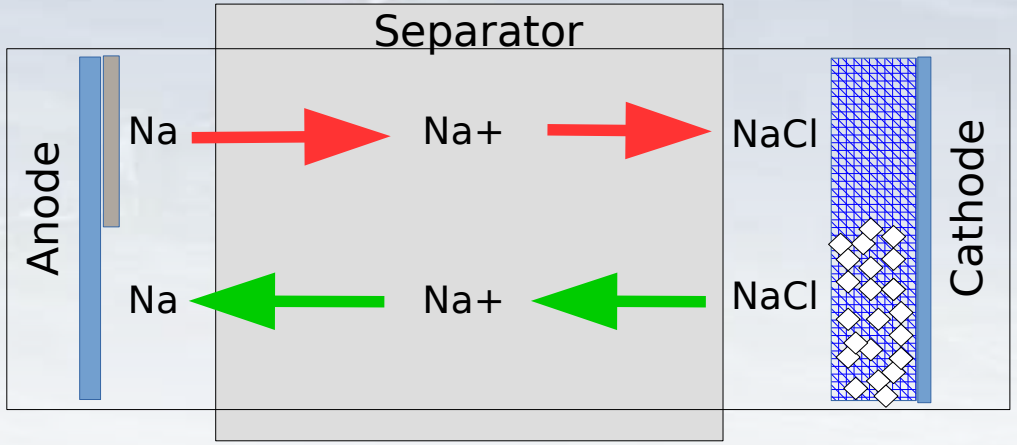
Fundamentally NOT Saltwater

Saltwater batteries use H_2O as the electrolyte solvent



~50 Wh/kg
10 hr to charge

BroadBit uses SO_2 as the electrolyte solvent



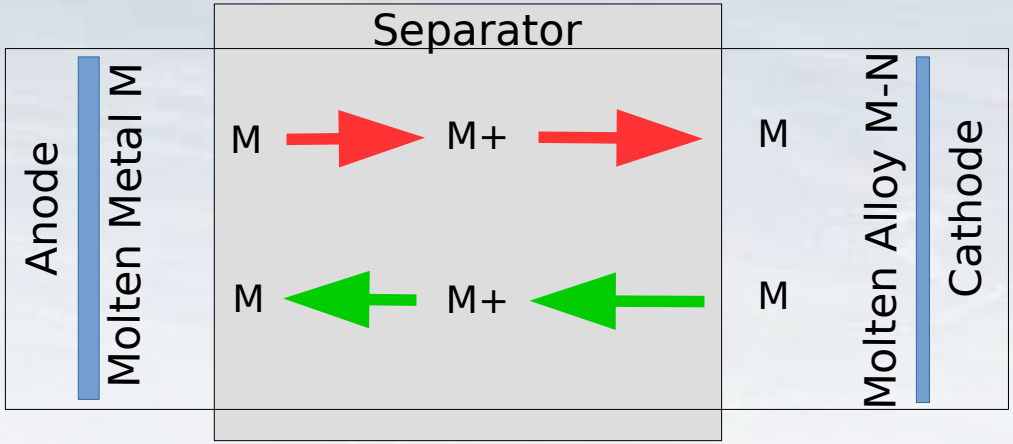
~300 Wh/kg
0.5 hr to charge

Na = Elemental (Metallic) Sodium Na+ = Sodium Ion (in solution) NaCl = Sodium Chloride (crystal)

= Charge = Discharge

Fundamentally NOT Molten Salt

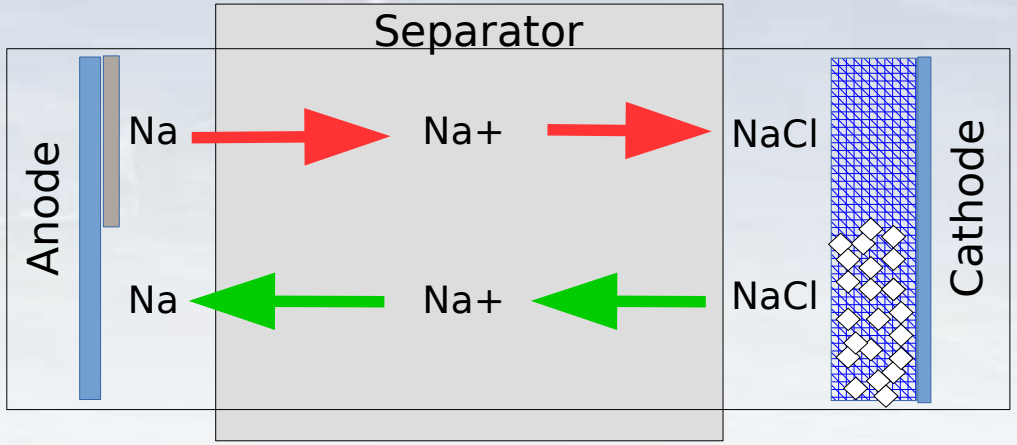
Molten salt batteries use melted salt* as the electrolyte



~300 Wh/kg

>300 C operating range

BroadBit uses table salt (NaCl) as the active material



~300 Wh/kg

-20C - +60C operating range

Na = Elemental (Metallic) Sodium Na+ = Sodium Ion (in solution) NaCl = Sodium Chloride (crystal)

* as in “an ionic compound” = Charge = Discharge

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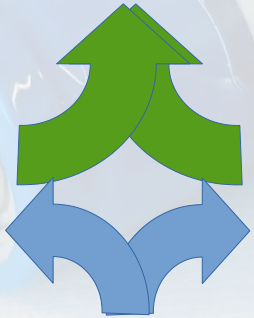
Water-based: Non-Toxic
(TRL-7, TRL-9 2021)



Revolutionary:
Dry: Liquid Free
(TRL-6, TRL-9 2021)

Better Battery Manufacturing

BroadBit's unique H_2O-based mfg. technology

Existing Wet (Toxic Solvent) Process

BroadBit Wet (H_2O-based) Process

CapEx Cost:	3 - 15 M€	→ <2 M€
Energy Cost:	200 - 500 kW	→ < 100 kW
Process Material Cost:	3 - 5 €/L	→ 0.01€/L
Factory Area:	400 – 600 m^2	→ 300 m^2
Health, Safety & Environment:	Flammable/ Toxic	→ Inert

BroadBit's core battery innovations

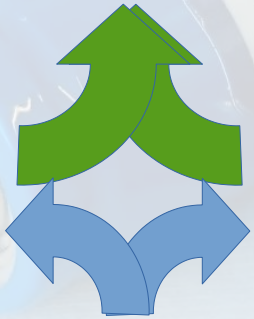
Better Battery Chemistry

Evolutionary:
Li-ion: Cobalt and Nickel Free
(TRL-8, TRL-9 2020)

Revolutionary:
Na-salt: Rare Earth Metal Fee
(TRL-5, TRL-9 2021)

Lower Cost, Higher Performance, Greener, Safer, More Scalable

Evolutionary:
Water-based: Solvent Free
(TRL-7, TRL-9 2021)



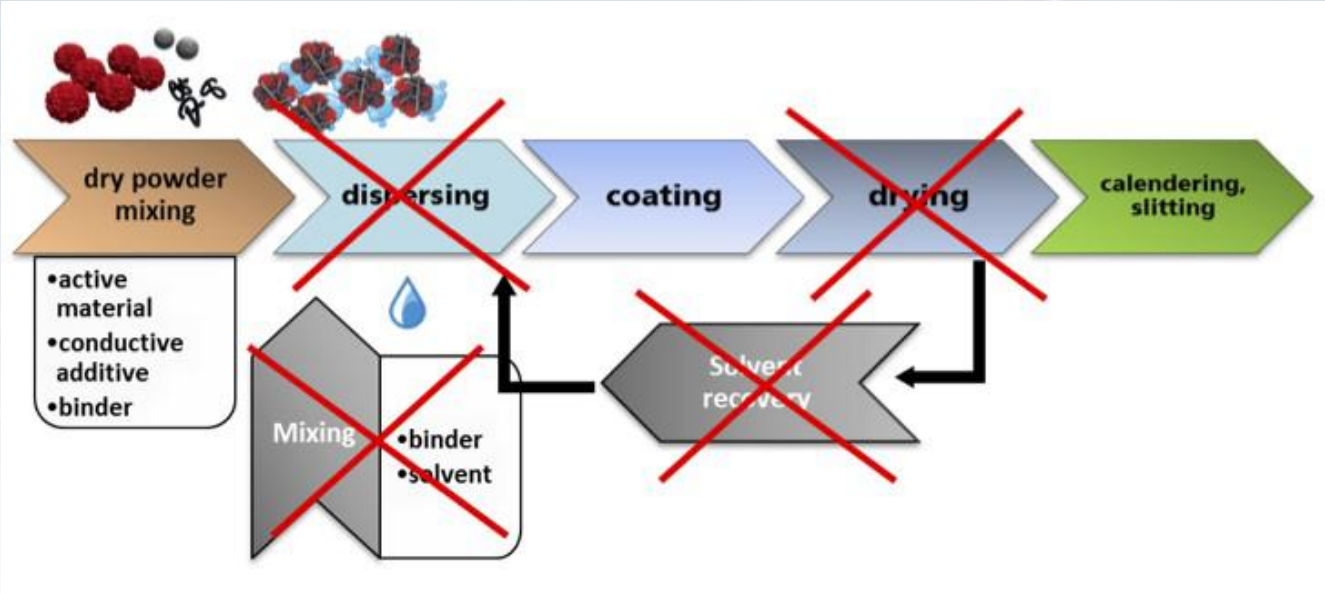
Revolutionary:
Dry: Liquid Free
(TRL-6, TRL-9 2021)

Better Battery Manufacturing

BroadBit has better manufacturing

Cheaper, faster, safer, greener, cathode production

Dry, solvent free, contamination resistant process



Applicable to all of BroadBit's Batteries

BroadBit's unique water-based mfg. tech

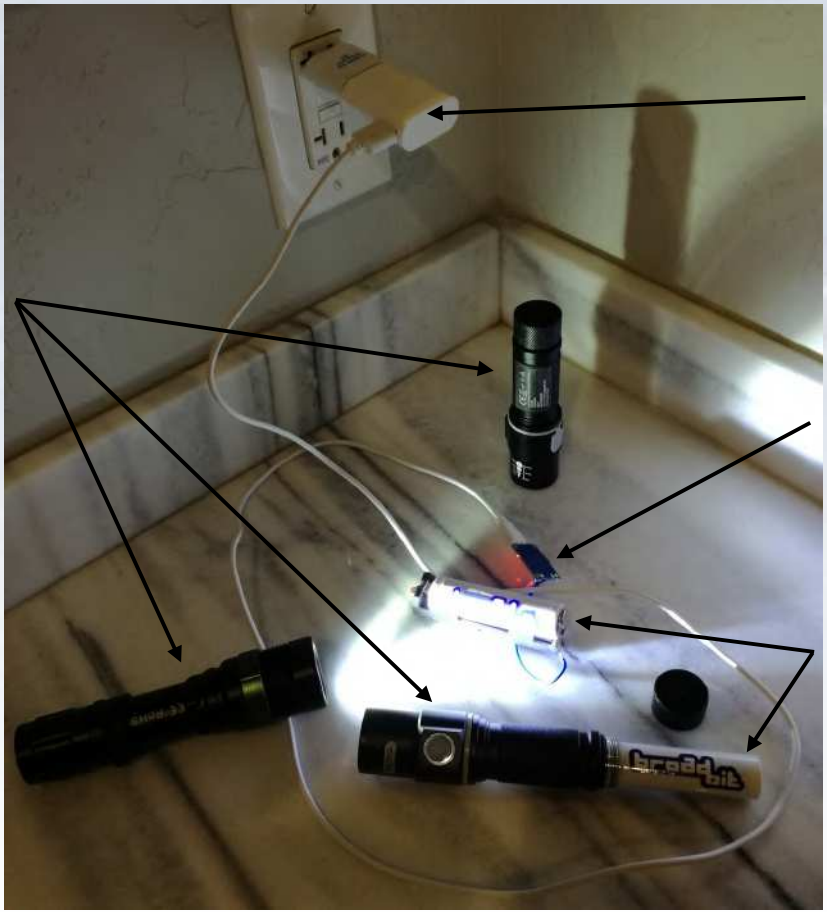
Existing Wet (Toxic Solvent) Process

BroadBit Dry Process

CapEx Cost:	3 - 15 M€	→ 0.1 M€
Energy Cost:	200 - 500 kW	→ 10 kW
Process Material Cost:	3 - 5 €/L	→ 0
Factory Area:	400 – 600 m²	→ 10 m²
Health, Safety & Environment:	Flammable/ Toxic	→ Inert

BroadBit is Plug-and-Replace for Li-Ion

Standard devices



Standard USB power source

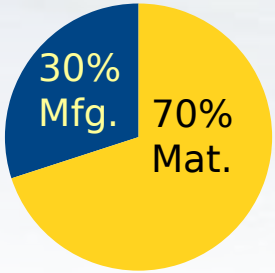
Standard Li-Ion charger chip

Standard cells
(size, voltage, current)

BroadBit outclasses the competition

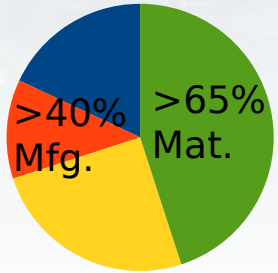
Key Parameter	Li-Ion NCA/NCM	**BroadBit Na-salt** (Theoretical)
Harm: Planet/People	Flammable / Cobalt, Lithium mines	Non-flammable / No rare Earth materials
Recharge time	2 hrs to 99%	30 mins to 99% (5 mins to 99% possible)
Energy Capacity	260 Wh/kg	300 Wh/kg (350 Wh/kg possible)
Temperature Range	0C to 40°C	-20C to 60°C (-30 to 95°C possible)

Existing Li-Ion



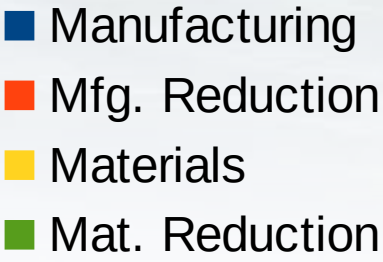
>125 $/kWh

Cost Reduction



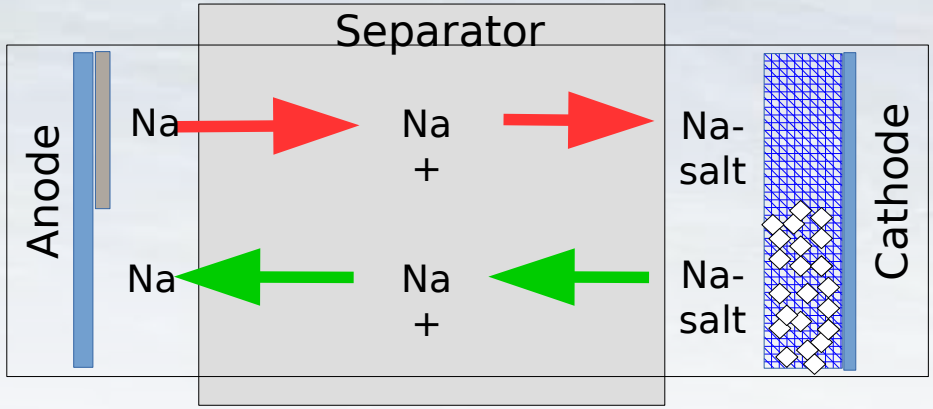
BroadBit Na-Salt

<50 $/kWh



BroadBit sodium batteries are flexible

Using the same core concept, BroadBit's cell chemistry can be optimized for various applications:



High energy density

300 Wh/kg vs. 250 for Li-ion

e.g., electric vehicles

High energy efficiency

95% efficient vs. 90% for Li-ion

e.g., grid storage & stabilization

High power density

5-min charging vs. 30 for Li-ion

e.g., starter, drones & power tools

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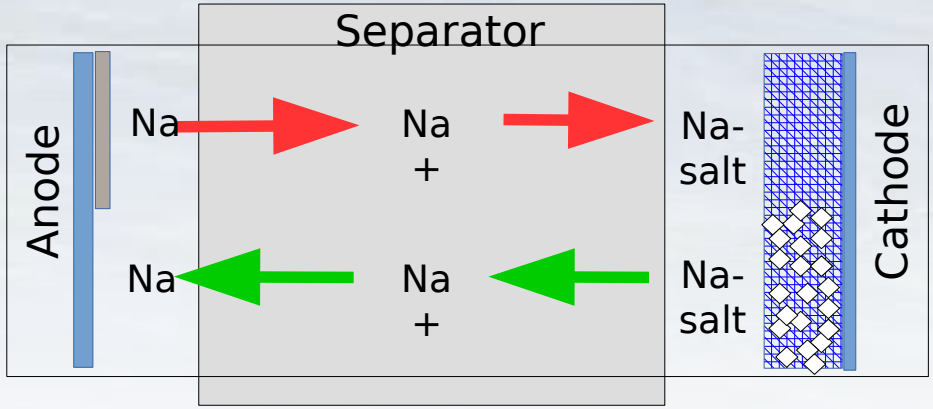

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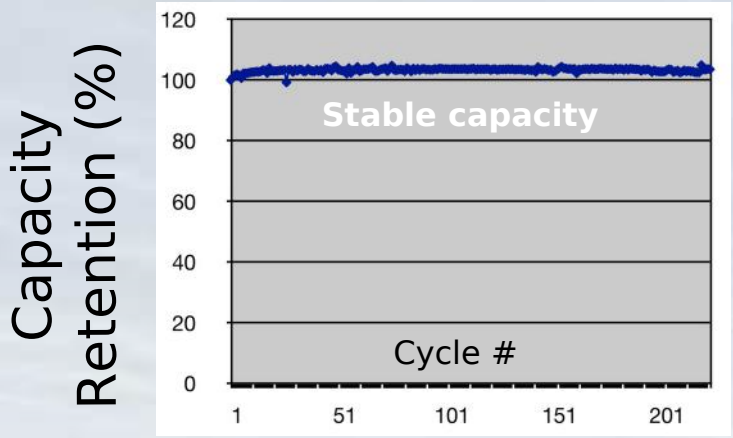
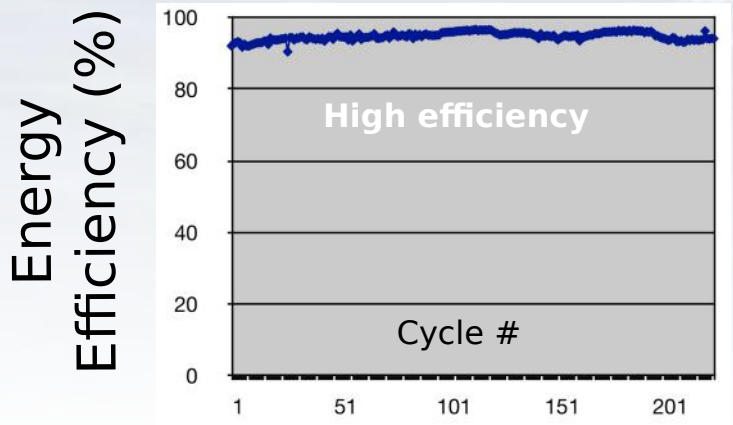
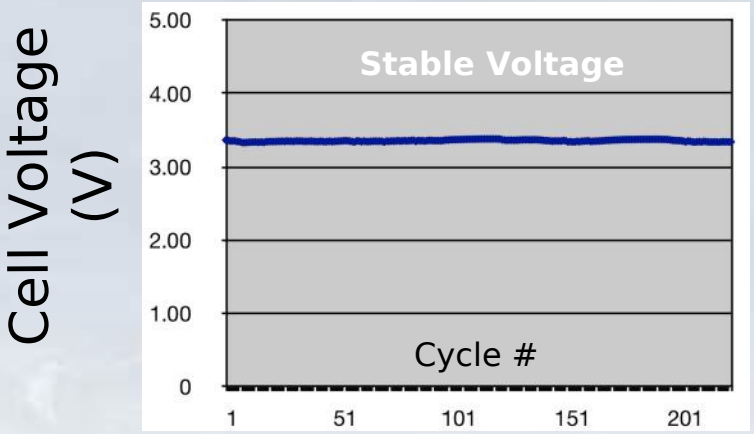
e.g., grid storage & stabilization

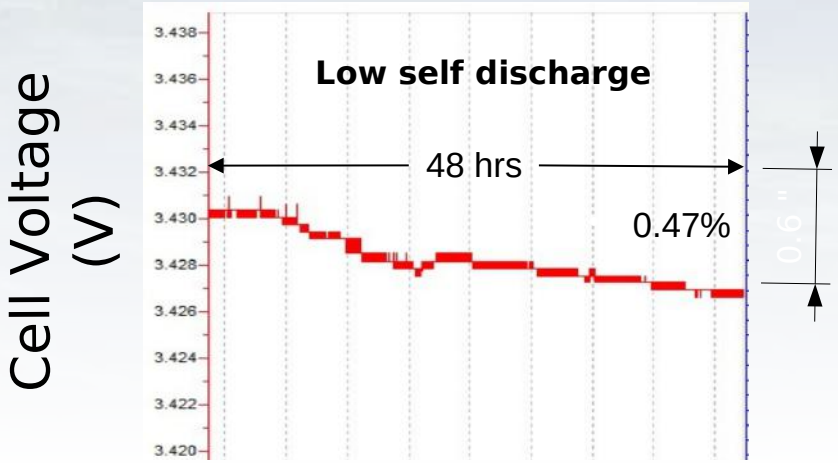
High power density
5-min charging vs. 30 for Li-ion
e.g., starter, drones & power tools

BroadBit's durable/efficient chemistry









Patents Status (1/1)

#	Description	Granted (Recently), Applied in	Priority	WO, PCT Numbers (Our ID)
1 a	ELECTROCHEMICAL SECONDARY CELLS FOR HIGH-POWER BATTERY USE -High power NaCl with NaBF4 or NaBH4	**FIN**	2015.09.30	WO2017/055678A1, PCT/FI2016/050133 (99077LN)
1 b	ELECTROCHEMICAL SECONDARY CELLS FOR HIGH-ENERGY BATTERY USE -Discharge state assembled, high energy sodium / sodium salt	PCT, EUR, USA, JAP, KOR, CHN, CAN, ISR, **RUS**, BRA, IND, TWN	2015.09.30	WO2017/055678A1, PCT/FI2016/050133 (99077LN)
2	RECHARGEABLE SODIUM CELLS FOR HIGH ENERGY DENSITY BATTERY USE -Non-aqueous electrolyte, SO2 additive and SEI forming salt	**FIN**, PCT, EUR, USA, JAP, KOR, CHN, CAN, IND, IND, TWN, ISR, **RUS**, AUS, MEX, BRA, PER	2016.03.04	WO2017/149204, PCT/FI2017/050139 (99096LN)
3	ELECTROLYTE FOR SUPERCAPACITOR AND HIGH-POWER BATTERY USE -NaClO4 electrolyte in nitrile solvent	FIN, PCT, TWN, EUR, USA, JAP, KOR, CHN, IND, ISR, AUS, BRA, CAN, MEX, PER, RUS	2017.03.17	WO2018/167365, PCT/FI2018/050182 (105598LN)
4	IMPROVED ELECTROCHEMICAL CELLS FOR HIGH-ENERGY BATTERY USE -Anode current collector for SO2 solvent with C-coated metal/alloy	FIN, PCT, TWN, USA, EUR, JAP, KOR, CHN, IND, IND, RUS, ISR	2017.08.04	WO2019025663A1, PCT/FI2018/050571 (107989LN)
5	A DISCHARGE STATE ASSEMBLED RECHARGEABLE ELECTROCHEMICAL CELL COMPRIZING METALLIC ELECTRODES -Discharge state assembled metal-metal battery.	FIN, PCT, USA, EUR, JAP, KOR, CHN, IND	2018.09.17	WO2020058572A1, PCT/FI2019/050663 (114412LN)
6	IMPROVED RECHARGEABLE BATTERIES AND PRODUCTION THEREOF -Electrolyte with Carbonate – Nitrile solvent with alkali salt	FIN, PCT, USA, EUR, JAP, KOR, CHN, IND	2018.10.02	WO2020070391A1, PCT/FI2019/050714 (114723KM)
7	IMPROVED ANODE MATERIAL AND ANODE FOR A RECHARGEABLE BATTERY -Composite anode of metal matrix and distributed material	FIN, PCT, USA, EUR, JAP, KOR, CHN, IND	2018.10.10	WO2020084197A1, PCT/FI2019/050759 (114857LN)
8	AN ELECTRODE MATERIAL AND COMPONENTS THEREFROM AND PROCESSES FOR THE MANUFACTURE THEREOF -Dry blends and pastes and manufacturing methods for batteries	FIN, PCT, TWN	2019.08.13	WO PENDING PCT PENDING (119960KM)
9	IMPROVED ELECTROLYTE FOR ELECTROCHEMICAL CELL -An electrolyte comprising a solvent comprising at least two carbonate solvents	FIN, PCT, TWN	2020.06.26	PCT/FI2021/050493 (139177LN)

Applied (recently), Expected to be accepted soon, Accepted, **Granted**

Granted Claims to Date

An electrochemical cell comprising:
a) a cathode comprising a sodium-containing material, and an anode; and
b) an electrolyte comprising a solvent and a sodium salt positioned between the cathode and the anode, wherein the solvent of the electrolyte comprises sulfur dioxide (SO_2) or ammonia (NH_3) and/or an organic amine.

An electrochemical cell, comprising:
a) a cathode and a rechargeable metallic sodium anode; and
b) a non-aqueous electrolyte which comprises an SO_2 additive and at least one electrolyte salt which participates in the anodic SEI (Solid Electrolyte Interface) formation together with the SO_2 additive positioned between the cathode and the anode.

An electrochemical cell, comprising:
a) a cathode and a rechargeable metallic sodium anode; and
b) an electrolyte which comprises a sufficient amount of dissolved SO_2 for a stable SEI (Solid Electrolyte Interface) formation and at least one electrolyte salt which is soluble to at least 1.2 molar concentration positioned between the cathode and anode.

An electrochemical cell comprising:
a) a cathode and an anode ; and
b) an electrolyte positioned between the cathode and anode comprising:
1. one or more nitrogen-containing solvent precursors and
2. at least one salt comprising a sodium cation and a boron, aluminum, phosphorus or a chlorine cored anion or a sulfonyl or sulfonate containing anion.

An electrochemical cell for a secondary battery or supercapacitor, wherein the electrolyte comprises a solution of $NaBF_4$ or $NaBH_4$ salt in ammonia, having approximate formulas of $NaBF_4 \cdot 2.5\ NH_3$ and $NaBH_4 \cdot 1.5\ NH_3$ respectively.

An electrolyte for an electrochemical battery cell comprising:
i. a carbonate : nitrile type solvent mixture based electrolyte, wherein the electrolyte comprises at least one polymer additive; or
ii. a dimethylcarbonate (DMC) : malononitrile (MLN) solvent mixture based electrolyte or a dimethylcarbonate (DMC) : (succinonitrile (SCN) : malononitrile (MLN)) solvent mixture based electrolyte, wherein the electrolyte further comprises an alkali salt and the electrolyte is liquid during electrochemical operation.

An electrochemical cell, wherein the active cathode material comprises partially oxidized Na_2S.

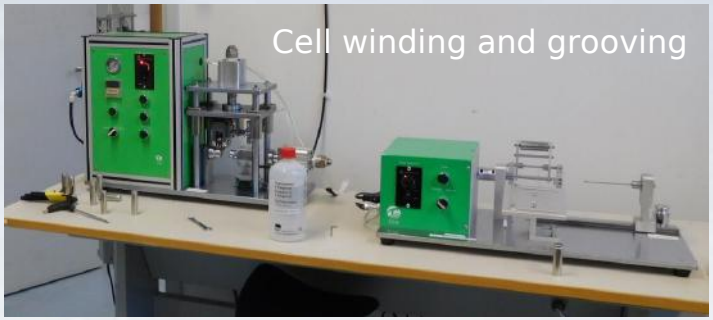
BroadBit opens new markets

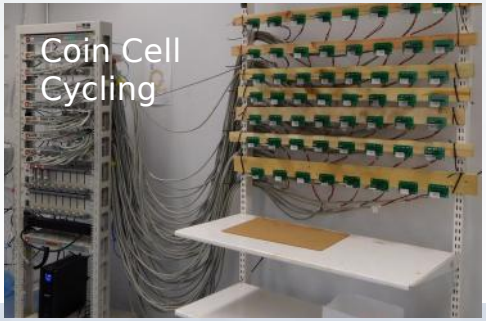
Sufficiently high energy to enable electric airplanes

Sufficiently low-cost to enable grid storage

Sufficiently robust to replace starter batteries

BroadBit Production Facilities





BroadBit's market & introduction plan

Short Term: **Niche and specialty** (>10%/yr growth) **2021**
e.g. OBU, UPS, Drones TAM ~2B$

Mid Term: **Transportation** (>15%/yr growth) **2022**
Bikes, Buses, Trucks, Ships, Cars, Planes TAM ~60B$

Long Term: **Energy and power** (>20%/yr growth) **2023**
Grid storage, Grid stabilization TAM ~60B

BroadBit in-house production **Outsourced production**

Electrolyte → Anodes + Cathodes → Cells → Battery Packs

Components

SAM/SOM: ~0.1B$/0.001B$ (2021) → ~10B$/1B$ (2025)

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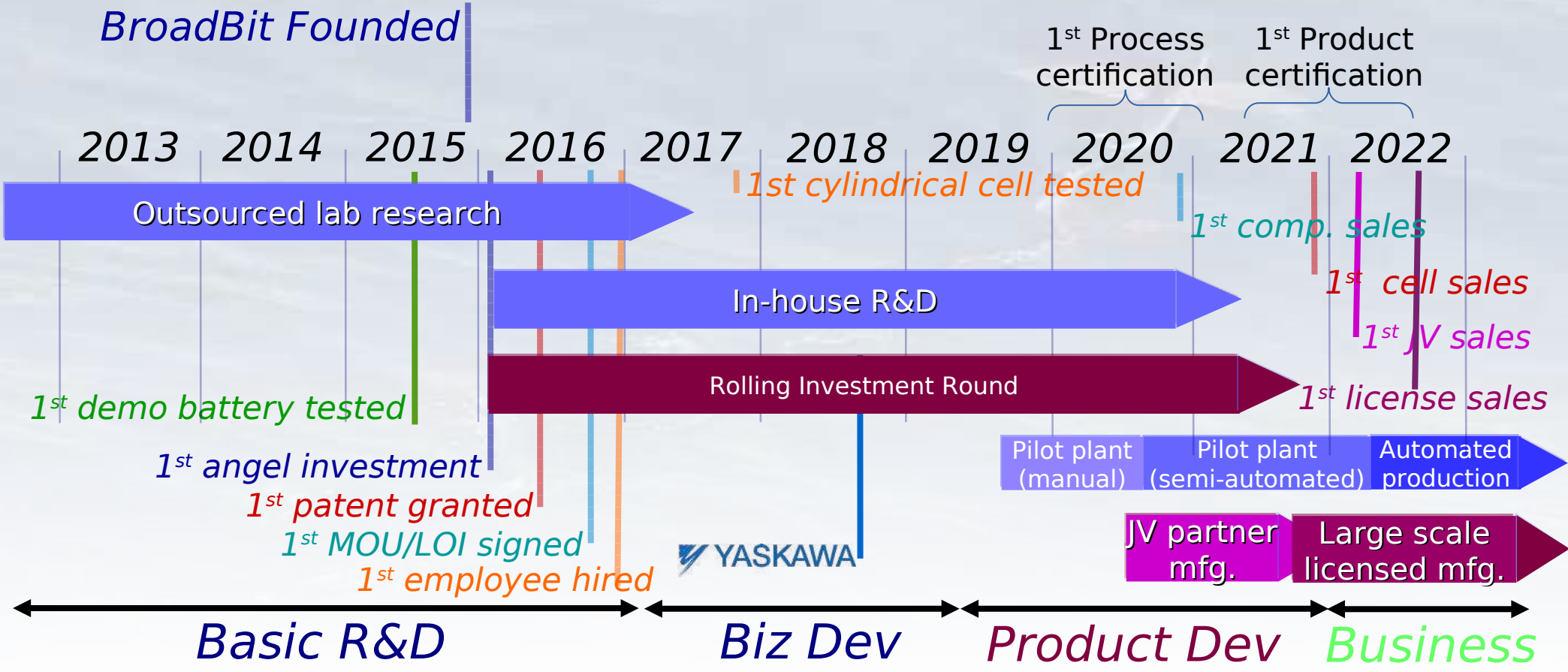
BroadBit commercial roadmap



BroadBit seeks visionary partners

Investments to date:

2000 k€ private

2500 k€ public

YASKAWA

HORIZON 2020

Tekes

BUSINESS FINLAND

Income to date:

350 k€ from samples, demos and PoCs

+ leading battery, automotive and government customers

AIRBUS

kapsch >>> challenging limits

VULCAN

CONFIDENTIAL

Funding goals:

2.0 M€ Q2 2021 (>80M€ Val)

7.5 M€ H2 2021

Purpose:

Purchase assembly for 1st 3 niche LOIs

Scale production for 1st volume app.

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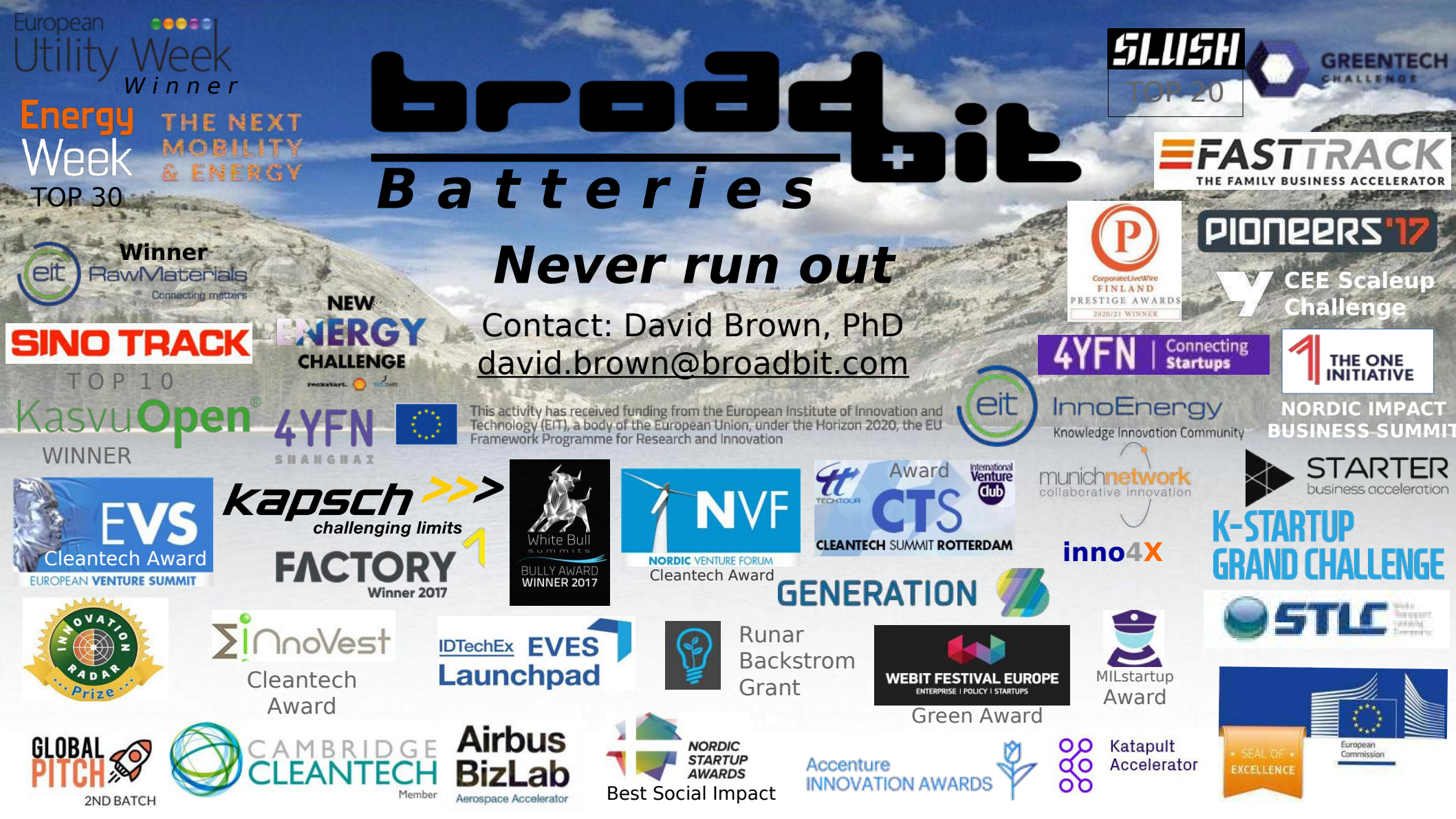
European Utility Week Winner
Energy Week TOP 30
THE NEXT MOBILITY & ENERGY
broadbit Batteries
Never run out
Contact: David Brown, PhD
david.brown@broadbit.com
SLUSH TOP 20
GREENTECH CHALLENGE
FASTTRACK THE FAMILY BUSINESS ACCELERATOR
PIONEERS'17
CEE Scaleup Challenge
Winner RawMaterials Connecting matters
SINO TRACK TOP 10
NEW ENERGY CHALLENGE
CorporateLiveWire FINLAND PRESTIGE AWARDS 2020/21 WINNER
4YFN Connecting Startups
THE ONE INITIATIVE
NORDIC IMPACT BUSINESS SUMMIT
KasvuOpen WINNER
4YFN SHANGHAI
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InnoEnergy Knowledge Innovation Community
munichnetwork collaborative innovation
STARTER business acceleration
EVS Cleantech Award EUROPEAN VENTURE SUMMIT
kapsch challenging limits
FACTORY Winner 2017
White Bull summits BULLY AWARD WINNER 2017
NVF NORDIC VENTURE FORUM Cleantech Award
Award CTS CLEANTECH SUMMIT ROTTERDAM
inno4X
K-STARTUP GRAND CHALLENGE
GENERATION
STLC
INNOVATION RADAR Prize
InnoVest Cleantech Award
IDTechEx EVES Launchpad
Runar Backstrom Grant
WEBIT FESTIVAL EUROPE ENTERPRISE | POLICY | STARTUPS Green Award
MILstartup Award
GLOBAL PITCH 2ND BATCH
CAMBRIDGE CLEANTECH Member
Airbus BizLab Aerospace Accelerator
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