



Breaking through with flow

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Purpose of these Slides:

- *Offer learnings from 35 years of productizing flow batteries*

Contents:

- 60 years later
- A clear-eyed view
- Challenges
- Clear customer value
- Goldilocks applications
- Design for commercialization

60 years and \$10B have delivered us a lot!



1960's Dr Phil Symons invented the ZnCl flow battery (US#3713888) with EPRI funding

1970's Dr Larry Thaller invented the FeCr flow battery at NASA

1980's Prof Maria Skyllas-Kazacos invented the vanadium flow battery (VFB) at UNSW

1990's Mitsubishi deploys 800kWh substation VFB

2000's Powercell deployed the first production flow battery, 100kWh_{AC} ZnBr PowerBlock®

2012 Sumitomo breaks the MWh threshold

2010's Dr Gary Yang & Dr Liyu Li invent mixed-acid VFB at PNNL - today's leading chemistry

2025 Rongke Power breaks the GWh threshold



We get to stand on the shoulders of giants

We must be clear-eyed on where we are, to understand where to go

Our own myths hurt us

“Flow batteries beat lithium above 6-8h”

- X Li CapEx <€200/kWh_{AC} at MW scale and >10h duration is <1cyc/day

“Vanadium is too expensive”

- X V₂O₅@\$5/lb costs <0.7c/kWh at 2 cycles/day over 25 years

“Hydro is cheaper than flow”

- X Not in daily cycling; few hydro sites left

“Lithium is too dangerous & short-lived”

- X Li is 95% of the market ... we tolerate nuclear meltdowns; severe climate change; the ozone hole

Hard data

- Molecules to MW takes 10 years
- Flow batteries have a poor track record in the field
- Field staff cost US\$2,000 per day
- Li CapEx is half Flow CapEx

We have commercialization challenges

- ⇒ *Poor field reliability*
 - *Customers can't finance projects without excellent working examples*
 - *Even if we put systems on our own balance sheets like AES did for 100MW's of Li*
- ⇒ *High CapEx*
 - *We must be extremely careful and critical of the supply chains. Pumps are terribly unreliable; materials have extremely variable compositions; industry adjacent parts are rarely compatible and typically have a fraction of our required longevity*
- ⇒ *Customer focus on CapEx vs TCO*
 - *Customers want low TCO but rarely can prioritize it over CapEx. This is in large part because it's hard to believe 25-year life with a poor track record in the field. Li is also driving the narrative that OpEx is low.*
- ⇒ *Unknowns*
 - *When attempting to commercialize a breakthrough technology into an intricate and rapidly changing marketplace, it is impossible to see all the hurdles & dead ends ahead.*
 - *Unknowns must be conquered by a team of experts with a full constellation of skill sets*

*There are 2 types of people: those who can work with incomplete datasets ...
which type are you?*

Clear strengths to deliver customer value

1. Flow batteries *love continuous cycling*
2. Are made from *globally abundant materials*
3. Have *slow, linear failure modes*
4. Are **Safe**, even in densely populated areas
5. Have *high intrinsic value* to support free recycling
6. Deliver *low project risk*
 - Extreme flexibility can adapt to the rapidly changing energy industry environment without voiding warranties

Our goldilocks applications

The customer is always right, but is not always the right customer!

Flow batteries are compelling in heavy use applications:

- ⇒ 6 to 10-hour applications with continuous daily cycling, benefiting from flow durability and low cost added energy capacity
 - lithium batteries are conspicuously absent from wind applications
- ⇒ high power ripple cycling – light rail stations to AI loads
- ⇒ extreme temperature, rigorous safety, or strict recycling needs

Net, net: please use your expensive battery 24/7 for 25 years to reduce TCO

Thoughts on flow battery commercialization

We are all striving to achieve compelling performance, quality and cost.

Too often, fundamentals are skipped:

- ⇒ **MTBF** design to go from 90% to 5x9's availability
 - Eg. 2x better pumps cost 10x more, but don't substantially improve availability
- ⇒ **MTTR** design to limit onsite staff and manage TCO
 - MTBF + MTTR work together to define ideal module size for a technology
 - Further reduction thru: hot-swapping modules; without tools; by a local technician.
- ⇒ **Common Module Design** support integrating component breakthroughs
 - Ideally, each subsystem has a clear specification and generous assigned space
 - Eg. analogue controllers, AC canned motor pumps, interdigitated stacks, and bus converters
- ⇒ **Boutique Mass Production** to enable a mature supply chain
 - a product strategy to build batteries that can be combined in various ways to meet diverse customer needs *without changing the supply chain*.
 - Engineers can then focus on significantly improving quality, performance and cost