WORLD HYDROGEN ENERGY SUMMIT

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Convention Centre-NDCC,
Parliament Street, New Delhi

GALAXY FCT H_2 in SOLID

DASSAULT SYSTEMES 3DEXPERIENCE® Lab
A Dassault Systèmes 3DS Accelerator Company

"Green Hydrogen towards Net Zero Pathways"

Optimizing Green Hydrogen Ecosystems with SOLID H_2 Logistics

James P. W. Khong
Co-Founder & COO, Galaxy FCT

16th October 2023
www.galaxyfct.com

Solid H_2 Logistics

Empowering H_2 to Transcend the Barriers of TIME and SPACE

Unresolved Climate Pain Points:

- Decarbonization the world where Infrastructure "does not work"
- Long Duration Clean Energy Storage without Hydrocarbons

Solid H_2 Logistics

Solid H2 Logistics Making H_2 …

"Cheap to Store"

"Easy to Move"

"Safe to Handle"

&

Infrastructure LIGHT across the supply chain

Solid H_2 Logistics … the Perfect Complement to the Green Electron Network

Introducing Solid H2 Logistics

CONCEPT & the Ecosystem

CLICK HERE to See Full Article on Solid H2 Logistics in CHT Technical Journal (May 2023)
(Published my Ministry of Petroleum India)

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CONCEPT Overview: H_2 in SOLID

Production of Green Energy and H2 in the most productive Locations globally

"Packaging" of H2 into the form of Solid H2 (Sodium Borohydride/NaBH4)

All Storage/Logistics carried out in the form of Solid H2

H2 Gas is released at user location "on demand" only when required.

Bypassing the need to "fight the physics" of H2 Gas throughout the length of the supply chain

Galaxy FCT:
Patented Process for rapid and efficient H2 Release from SOLID

Sodium Borohydride ($NaBH_4$) Properties

- High Energy Density (126 kg H2/m3)
- Non-Flammable & Non-Explosive
- Ambient Temperature & No Pressure

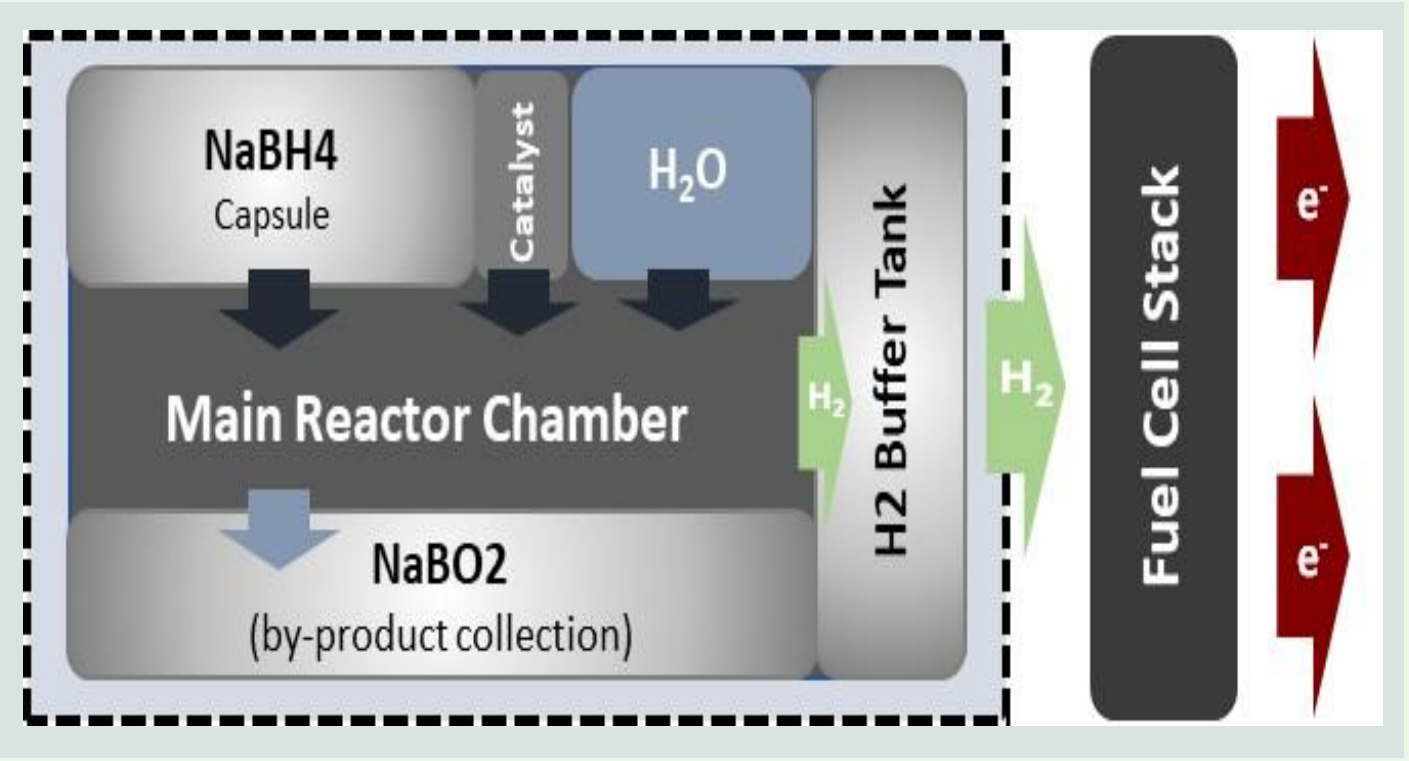
Safe, Simple and Efficient Logistics

Exothermic Reaction – External energy input NOT required at "last mile"

Compressed Gas @ 700 bar	42 kg H_2/m3
Liquid Organic H2 Carrier (LOHC)	57 kg H_2/m3
Liquid Hydrogen (-253C)	71 kg H_2/m3
Sodium Borohydride (NaBH4)	126 kg H_2/m3

Galaxy FCT & Solid H2 Logistics

A Patented Process which is Foundational for the Emerging Ecosystem



RAPID and EFFICIENT release of H2 gas "on-demand" from solid feedstock provides a robust foundation for evolution & paradigm shift towards a Solid H2 Logistics Ecosystem

Galaxy FCT is a Hydrogen Technology Company with a patented process which has resolved the technical difficulties with RAPID and EFFICIENT release of H2 gas from solid chemical feedstock (NaBH4).

Patents Issued in United States of America, India, China, Japan, South Korea, Africa (ARIPO), Australia, Philippines, South Africa, Nigeria, Indonesia, Saudi Arabia, Brazil, Chile, Malaysia and worldwide pending.

Click here for Patent Details

Sodium Borohydride Production Costs

It SHOULD Cost a Lot Less than where prices are TODAY …

Sodium Borohydride

Key Raw Materials

- NaCl (for Sodium)
- Borax (recyclable)
- Water (for H2)

Energy & Process Costs

(very high energy consumption both for processes as well as for drying, distillation and wastewater treatment)

Techno-economic assessment of green hydrogen supply with sodium borohydride as solid carrier

Student: João Miguel Pinheiro Petraglia Margutti
Supervisor TUM: Prof. Dr.-Ing. Kai-Olaf Hinrichsen
Supervisor External: Prof. Nilay Shah FREng
Date of Submission: May 27, 2022

Department of Chemical Engineering
Faculty of Engineering
Imperial College London

[Currently Under Peer Review]

With the Brown-Schlesinger, we estimate the full ENERGY requirements to produce 4.75 kg of NaBH4 (amount of Solid H2 required to release 1 kg of H2 gas) to range between 200 kWh to 250 kWh. This can be executed today, without waiting for any new or further technology breakthrough.

… and production costs can be brought down much lower.

HyperScaling NaBH4 Production

A Unique Opportunity to Accelerate the Solid H2 Logistics Ecosystem

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“Hyper-Scaling” Integrated NaBH4 Production

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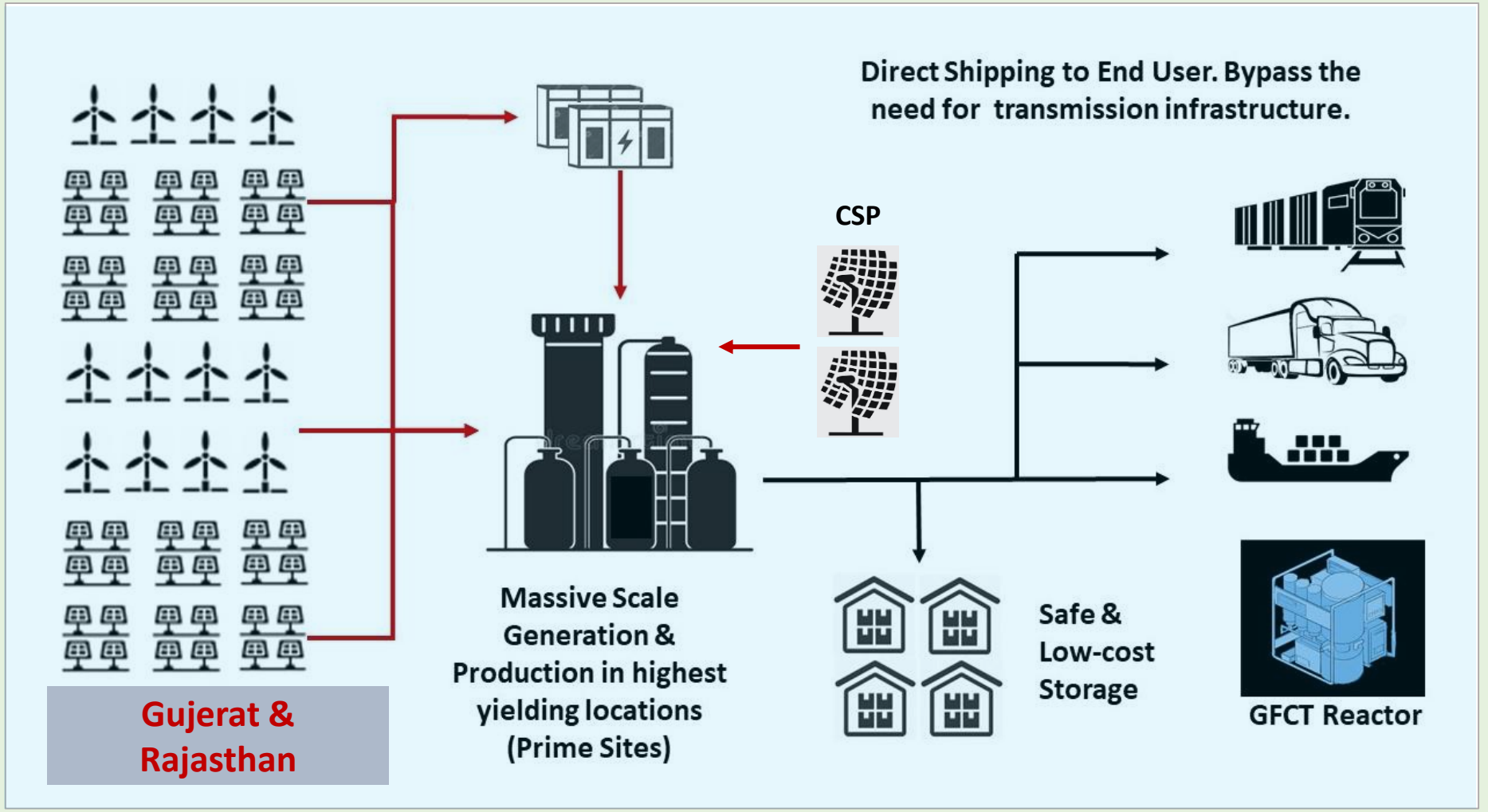
Leveraging the most productive Renewable Energy locations (the “PRIME SITEs”)



Same CAPEX Deployed here produces much more Energy

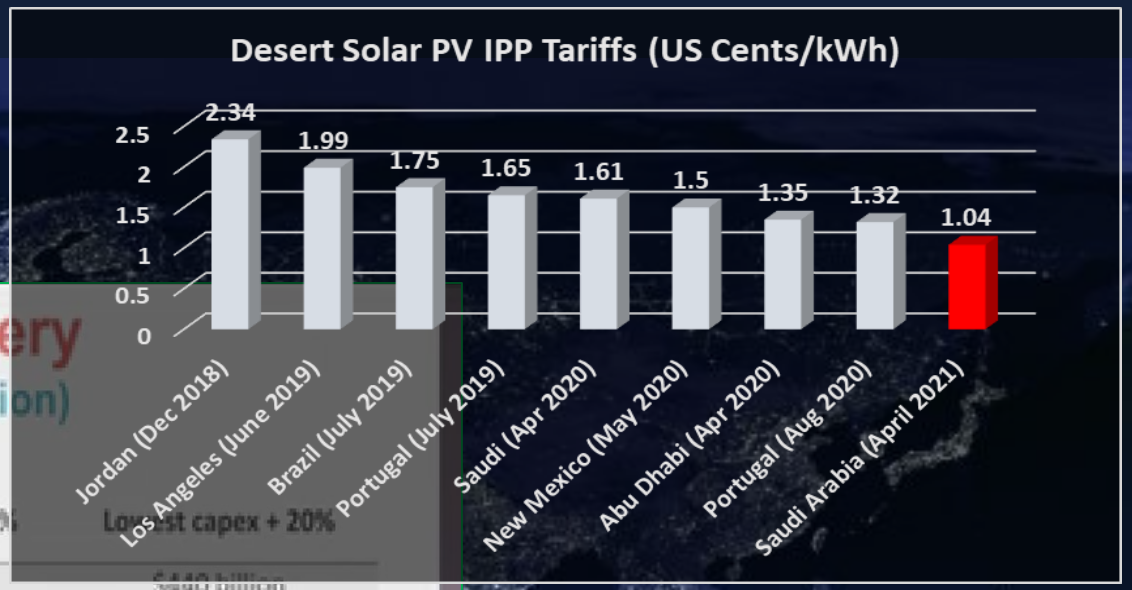
Abundance of Land with No Competing Usage

No Transmission Infrastructure Required

“Unlimited” SCALE & “Shovel Ready” … Off-take not required

Ability to store Solid H2 cheaply and to ship direct removes dependency on transmission infrastructure and allows immediate and large-scale harnessing of the most productive RE locations even if they are remote …

Fully Leveraging Lowest Cost Renewable Energy



2030 Whole System Projection (Rethink Energy)

India – 100% Solar, Wind and Battery

(based on one round of Dynamic System Simulation)

INDIA SWB100	Lowest capex	Lowest capex + 10%	Lowest capex + 20%
Capital cost	$365 billion	$403 billion	$440 billion
Solar PV capacity	810 gigawatts	950 gigawatts	1,070 gigawatts
Wind capacity	70 gigawatts	70 gigawatts	70 gigawatts
Generation capacity	4.8x	5.6x	6.2x
Battery capacity	2,263 gigawatt-hours	2,098 gigawatt-hours	2,073 gigawatt-hours
Battery average demand hours	21 hours	14 hours	14 hours
Annual super power	365 terawatt-hours	623 terawatt-hours	852 terawatt-hours
Fraction of days with super power	97%	99%	99%
Electricity cost (100% of super power utilized)	$0.01/kWh	$0.01/kWh	$0.01/kWh

Based on two years of hourly demand data for India (starting Jan 2018) & solar and wind generation. Regional simulations might return different results. © 2020 RethinkX

'Wright's Law' Points to 'Insanely Cheap' Solar Prices (Ramez Naam)

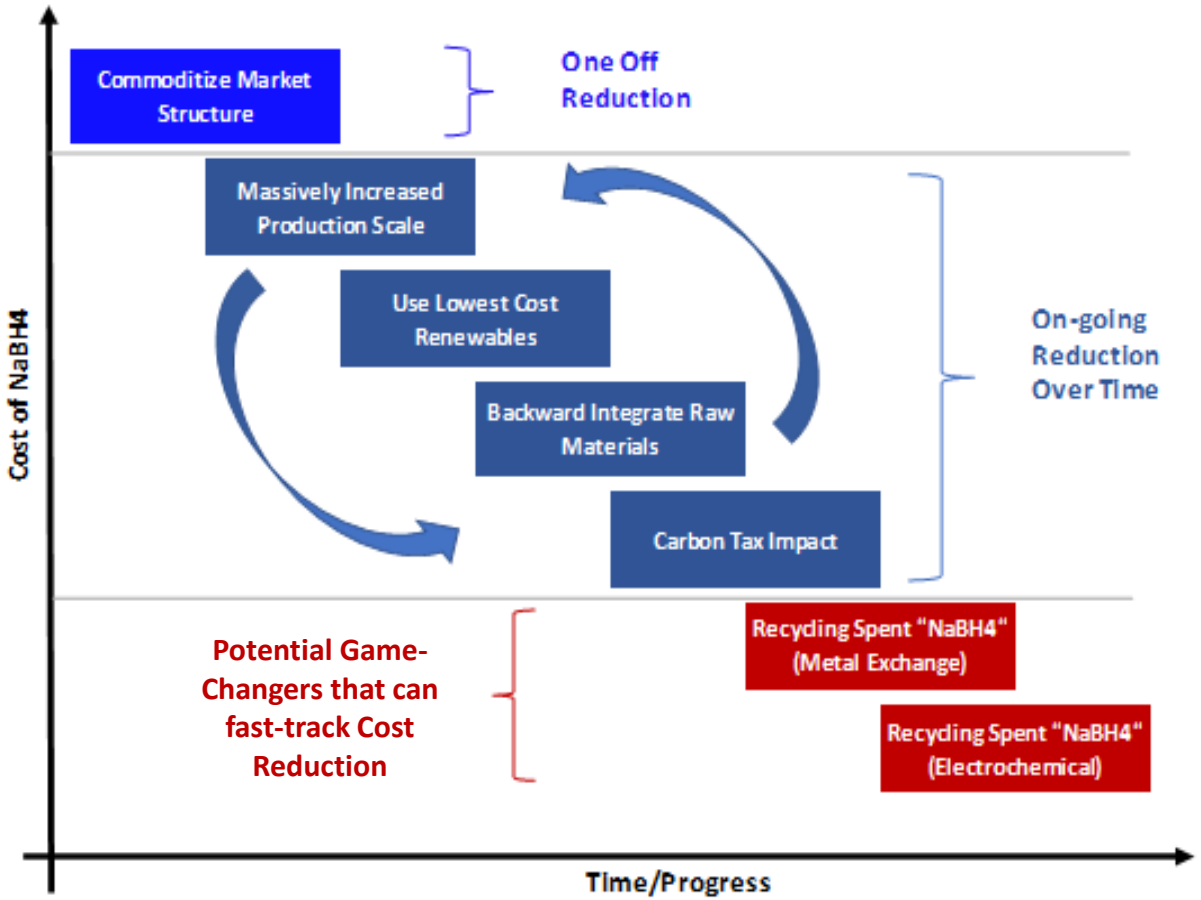
See: "The Great Transformation [Part 3] Disruption of Energy" @ YouTube (Tony Seba 2022)
See Min 15.:42 on India Analysis

Harnessing "Super-Power" from its deserts in Gujerat/Rajasthan and integrating with Hyperscaled NaBH4 Production will fast track India's path towards long term clean energy security …

Roadmap towards Lower NaBH4 Production Costs

Recent Research Suggests Exciting Possibilities ahead

Roadmap towards Future Cost Reduction



Sustainable Energy & Fuels

ROYAL SOCIETY OF CHEMISTRY

Received 27th September 2022
Accepted 30th January 2023

Chemical compression and transport of hydrogen using sodium borohydride

Ainee Ibrahim, Mark Paskevicius * and Craig E. Buckley

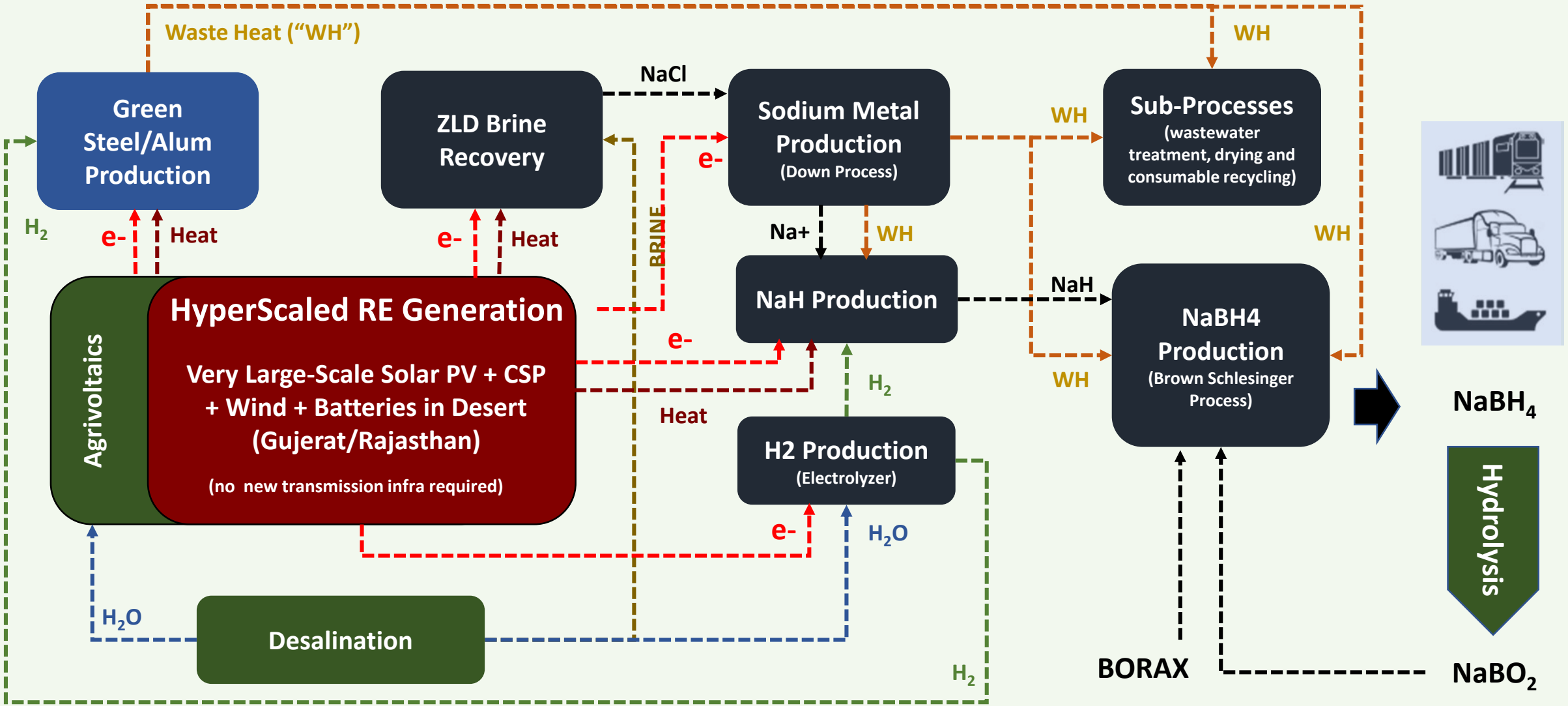
Conclusions

Web-Link

"The potential of NaBH4 as a hydrogen carrier opens up new avenues for the production, storage and compression of green hydrogen. The ability to compress hydrogen using the hydrolysis and methanolysis of NaBH4 to over 1000 bar can be utilised at hydrogen refuelling stations to compress hydrogen on-site. Cost predictions for the electrochemical production of NaBH4 could enable hydrogen to be exported at a cost of **$4.44 USD per kg H2**, at costs much lower than competing technologies, especially if electricity costs are lowered in the future using renewable energy. However, to make NaBH4 competitive for hydrogen storage and export, green methods of regeneration must be proven at scale and optimised. This could ultimately change the future of the global hydrogen economy"

Taking Hyper-Scaling to the Next level

Incorporating Symbiotic Green & Sustainable Industry Clusters …

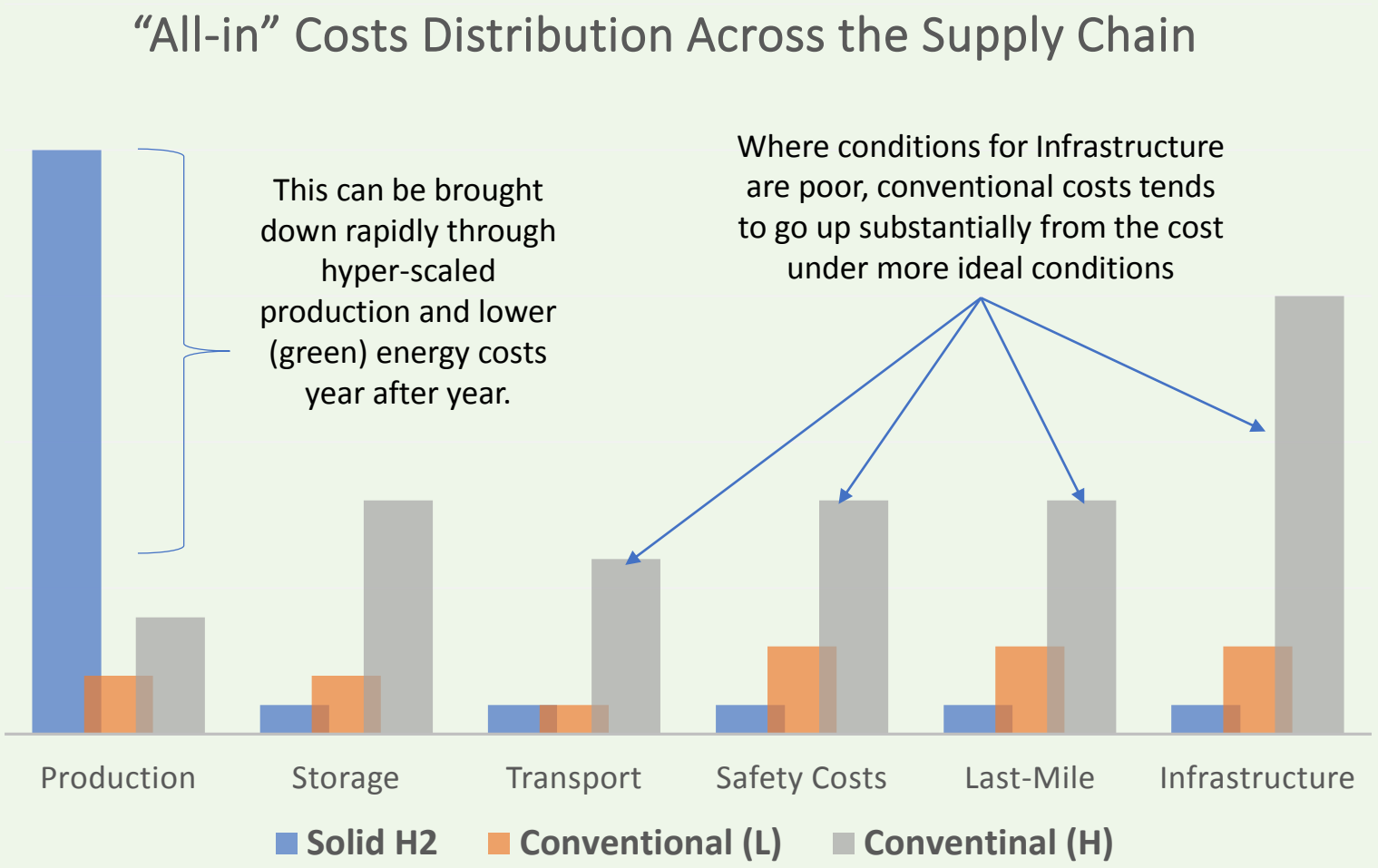


Optimizing Direct Heat (CSP) & Waste Heat to reduce Energy & Process Costs together with Desalination, Green Steel & Agrivoltaics

Ecosystem Level Benefits

Symbiotically Incorporating the Solid H2 Logistics into the Ecosystem

The “Strategic Exchange” Underpinning Solid H2 Logistics



The Strategic “Exchange” underpinning Solid H2 Logistics essentially accepts high production costs today (mostly energy/ process) in EXCHANGE for much lower costs across the entire supply chain (which are harder to bring down significantly). Its about strategically selecting what is perceived to be the more “winnable” battle in the near and immediate future.

Solid H2 Logistics – SHIFTING the battle away from areas where we are WEAK towards the domain where we are STRONG and rapidly getting STRONGER …

Ecosystem Optimization - PRIORITIZE Infrastructure where it Really Counts

"Solid H_2 Logistics for the Rest"

Green Electron Network (Grid & Batteries, "GEN")

Conventional H_2 Logistics

Solid H_2 Logistics

Medium/Long Duration Energy Storage

Required at various segments of the Supply Chain

- Long Distance Supply Chain
- Complex Supply Chains
- Low Volume Users
- Highly Dispersed Users
- Intermittent Usage
- Unpredictable demand fluctuations

Cross-border Inter-dependent infrastructure

No/Limited Existing Usable Infrastructure

Political Instability & Multipolar Geopolitics

High Level of Land Rights/NIMBY/Legal Issues

High/Rising Interest Rates

SHORT time horizon to Decarbonize

IDEAL Conditions for INFRA

SEMI- IDEAL Conditions for INFRA

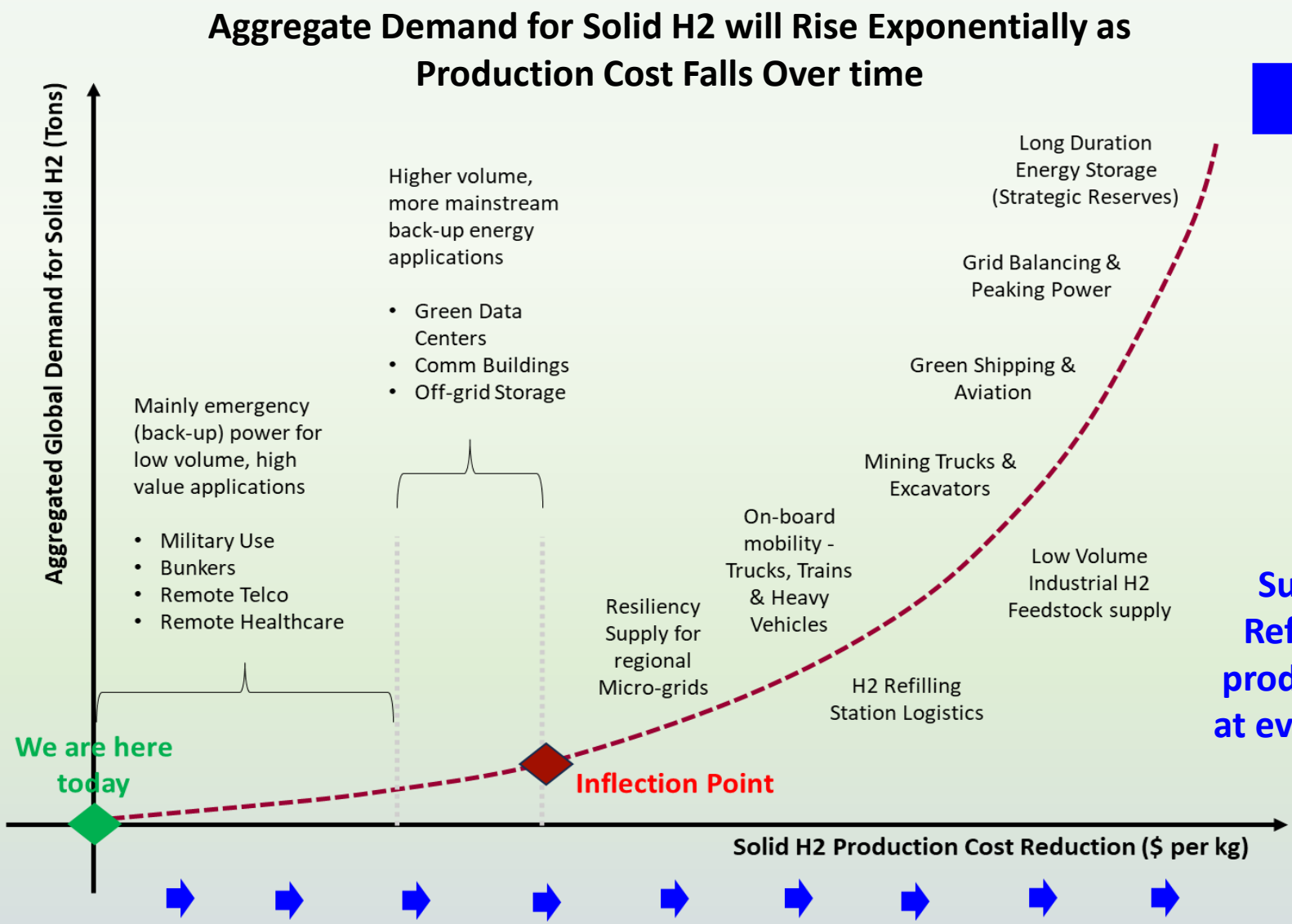
Increasingly POOR to ADVERSE CONDITIONS for INFRASTRUCTURE

10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Attractive for INFRA | Increasingly Unattractive | Highly Problematic | Economically Disastrous

A "Virtuous Cycle" that could Accelerate ALL Associated Renewables

As Solid H2 Applications Increase with lower Feedstock (NaBH4) Costs



Demand for even greater scale production of Solid H2 (more "Sunlight Refineries")

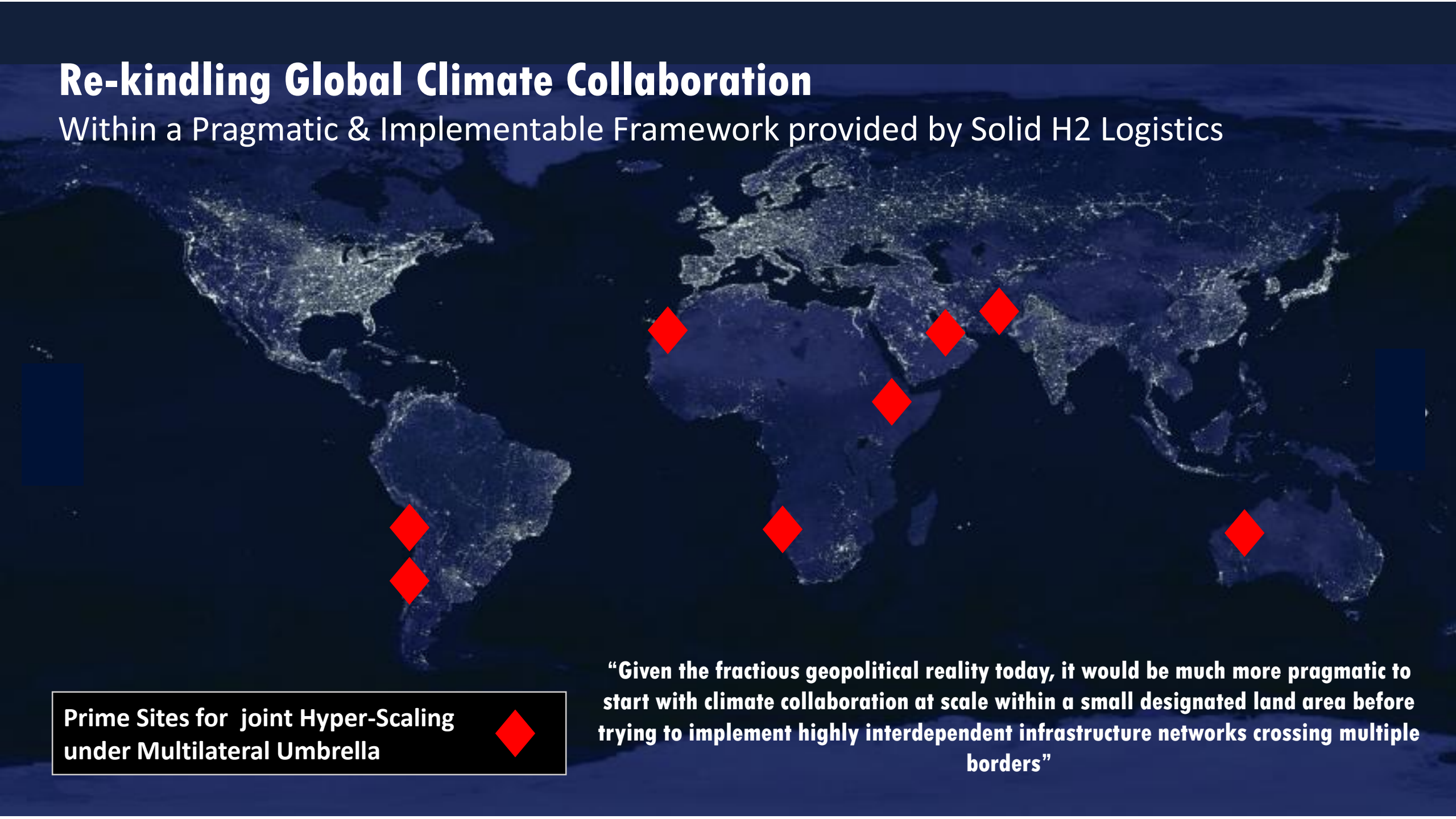
Much greater demand for "associated renewables" and lower component/ consumable prices

Lower cost of energy and greater logistical scale economies

Sunlight Refineries produce SH2 at even lower cost

Re-kindling Global Climate Collaboration

Within a Pragmatic & Implementable Framework provided by Solid H2 Logistics



Prime Sites for joint Hyper-Scaling under Multilateral Umbrella

"Given the fractious geopolitical reality today, it would be much more pragmatic to start with climate collaboration at scale within a small designated land area before trying to implement highly interdependent infrastructure networks crossing multiple borders"

Global Climate Collaboration …

Could we start with just "One Small Step"?

Common Hyper-Scaled Solid H2 Production at "Prime Sites"

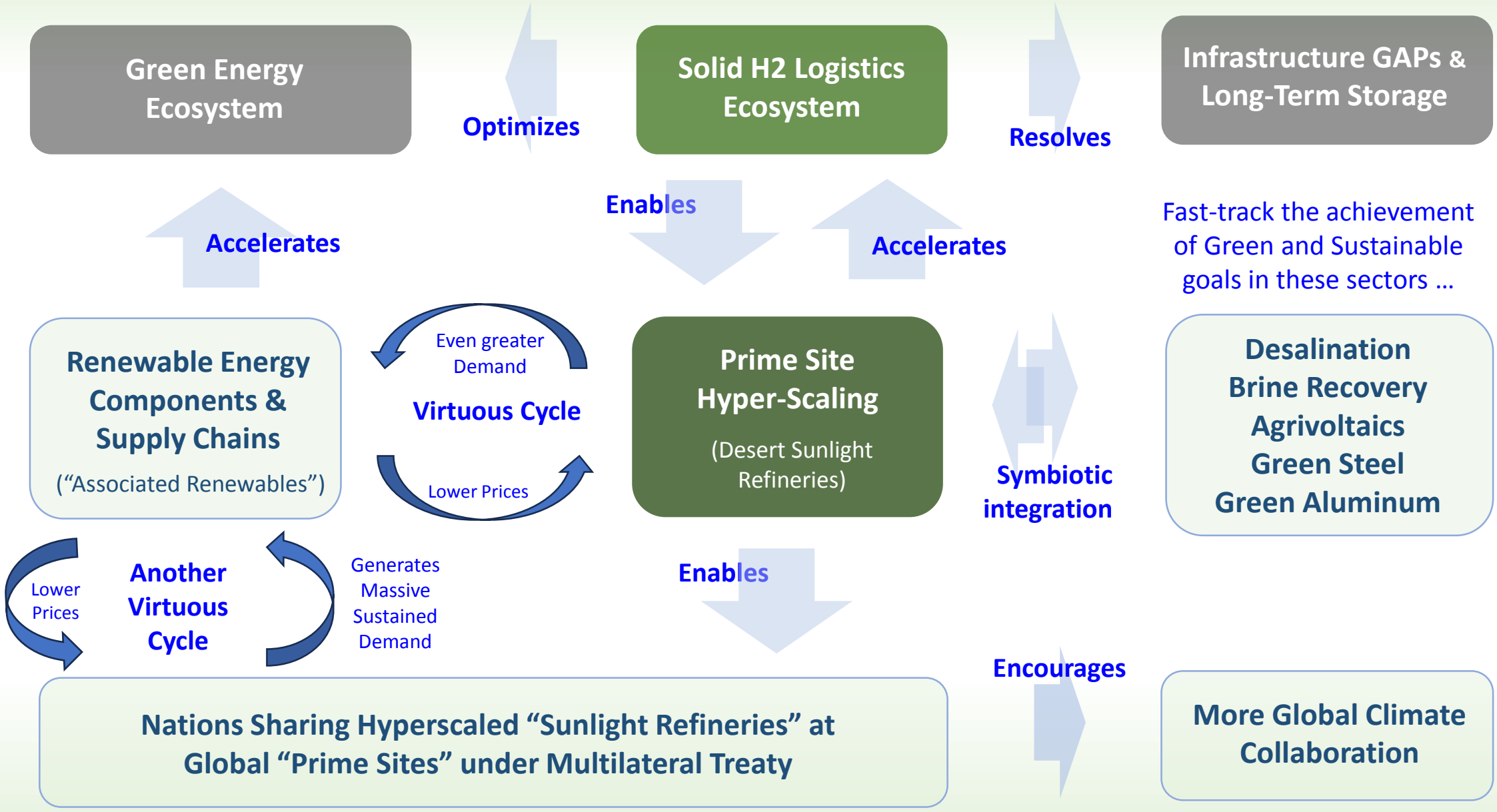
Hyper-Scaled production of Solid H2 at nominated Prime Site(s) under aegis of Multilateral Security Umbrella/Admin where all countries share in the "Sunlight Refinery" and ship their share of Solid H2 back to own country once produced.

- Unprecedented Scale & Efficiency
- More Geopolitically "Acceptable"
- Mitigates Political Risk – lower funding cost
- No in-country transmission/Infrastructure needed
- Framework to benefit Poorer/"Innocent" Countries
- Much Shorter "lead time" to Execution
- Accelerate "lower-price" Global RE Supply Chains

Much easier for nations to start genuine collaboration over a small defined area … and share the benefits of unprecedentedly large scale Solid H2 production in the most productive locations on the planet.

Final Thoughts

Optimizing the TOTAL ECOSYSTEM - Putting it All Together …

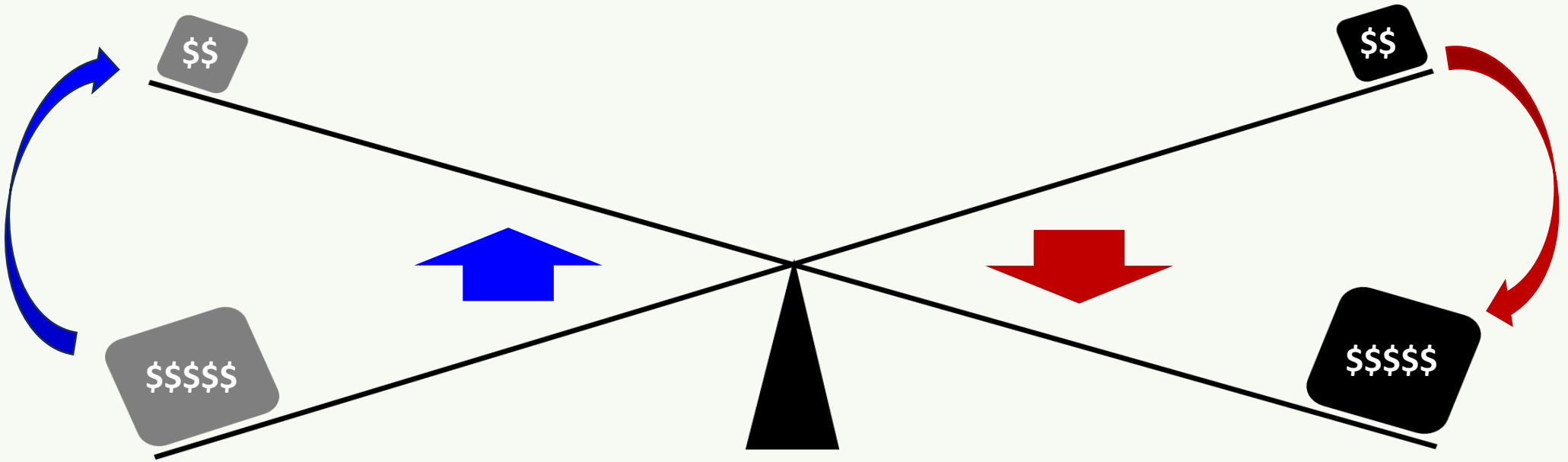


Two Systematic Forecasting "Blind Spots"

And Why the Tipping Point is Closer than We Think …

NaBH4 Production Costs per Unit

Infrastructure Costs per Unit



The true Power of "S-Curves" in Production is consistently and grossly

UNDER-estimated

AND …

Our ability to deploy infrastructure on-spec, on-time & on-cost is persistently

OVER-estimated

Concluding Thoughts …

- There is compelling circumstantial evidence showing that the tipping point for a Solid H2 Logistics Ecosystem is near
- Current Assessment metrics do not fully appreciate the massive "Ecosystem Benefits" that Solid H2 Logistics can bring to the larger overall Ecosystem by filling the gaps/cracks and making it much more flexible, efficient and resilient. It's perhaps time that we revisit this.
- India has all the IDEAL Conditions to make HyperScaled Production Work and well placed to be "first mover"
- Galaxy FCT is looking forward to work with strategic partners and stakeholders to fast track the development of the Solid H2 Logistics Ecosystem in India and Beyond …

Solid H2 Logistics

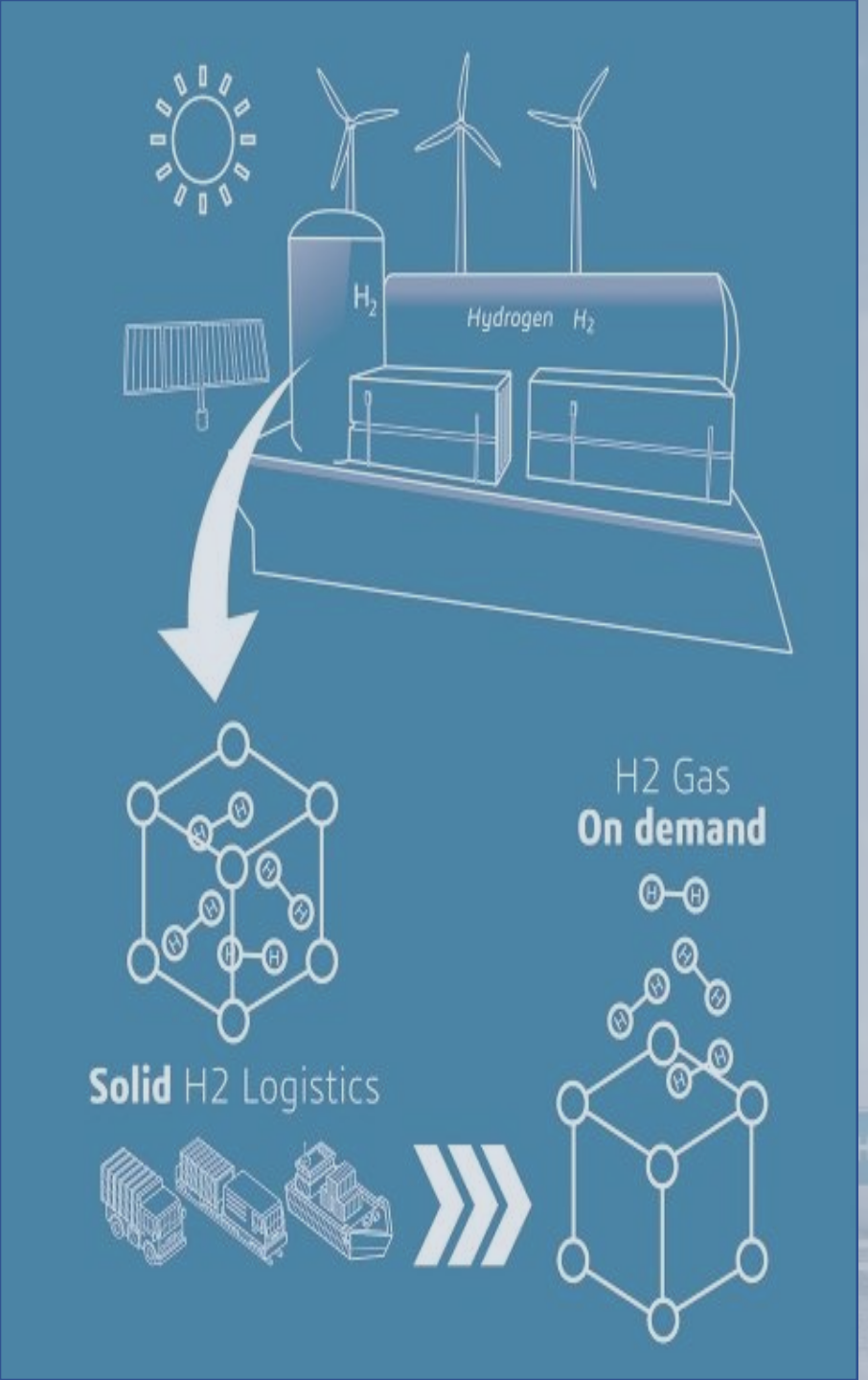
Making H2

"Cheap to Store,
Easy to Move,
Safe to Handle"

And

Infrastructure LIGHT

with an
Efficient & Low-cost "Last Mile"



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Thank You

jpw.gfct@gmail.com
jameskhong@galaxyfct.com