Growth opportunities in the next thirty years of climate tech

Trunks, branches, and knots. A view from Energy Impact Partners

Andy Lubershane, SVP Research & Innovation
lubershane@energyimpactpartners.com

Background

- EIP is a **leading global, strategic investment firm** focused on energy & climate.
- We represent the world's **largest, most diverse coalition of strategic energy infrastructure operators** & **representatives from major energy-consuming sectors** – investing collaboratively in the solutions that will define the future of carbon.
- With this presentation, we aim to **share some of the insight** that our in-house research & innovation team has synthesized from our strategic partner coalition and our portfolio companies.

Want to *invest in* the future of energy? **Let's talk.**

Got a transformational company or idea that will *define* the future of energy? **You, too.**

Visualizing growth opportunities in the next thirty years of climate tech

We believe that the global economy will transition towards net-zero (hopefully net-negative) greenhouse gas emissions in roughly the next thirty years.

From where we sit today, some of the outlines of this transition are already clear. We see **three big growth opportunities**, each with the following elements…

Trunk – A core conviction about the future of energy & carbon.

Branches – Second-order beliefs stemming from those trunks.

Knots – Areas of uncertainty which might disrupt the trajectory of those trunks & branches, positively or negatively.

Three big growth opportunities in the next 30 years of climate tech

The tree of abundant, affordable, zero-carbon power

The tree of electrification ascendant

The tree of carbon management
(one species among many, or decarbonization kudzu?)

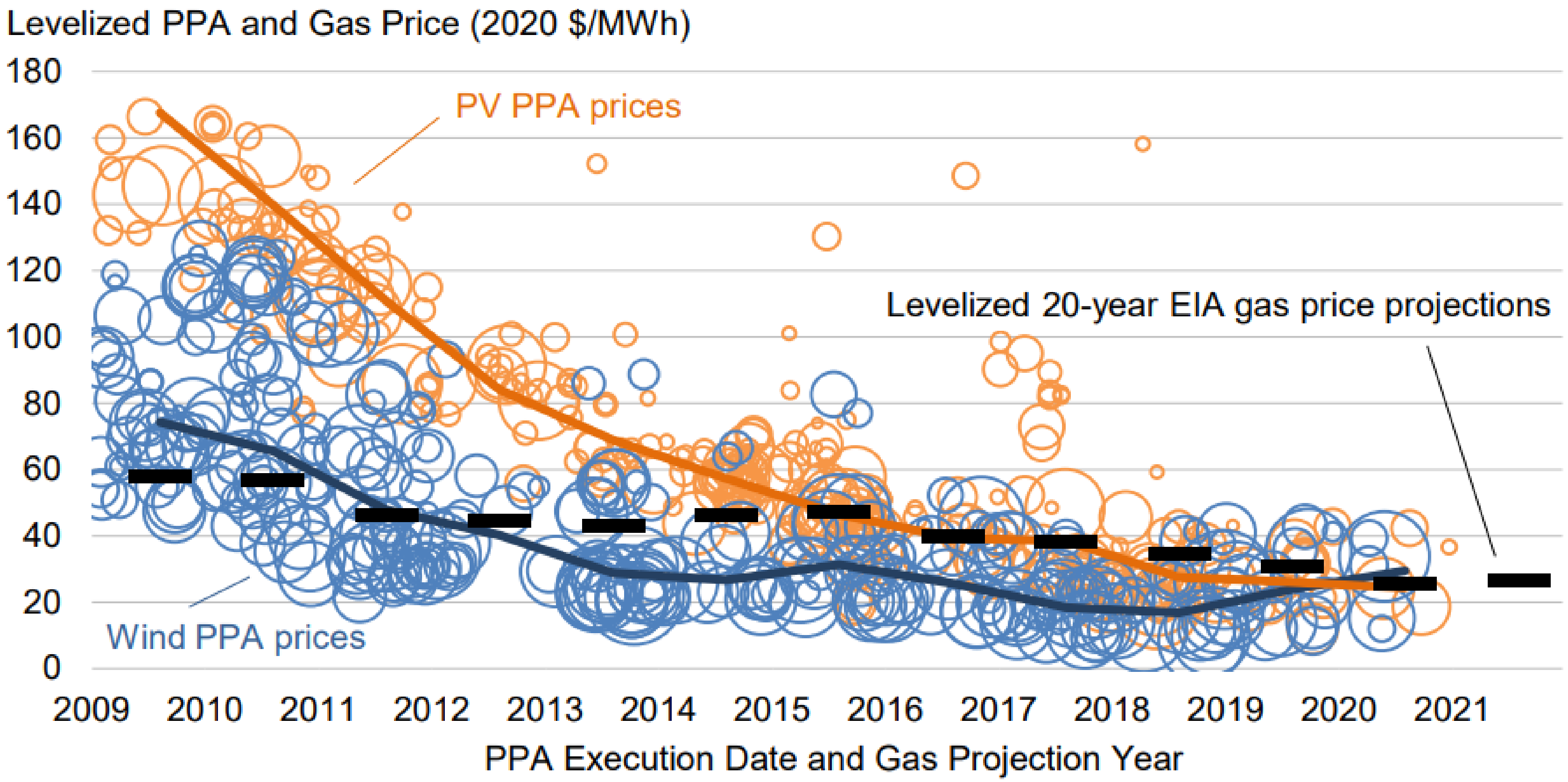
Visualizing growth opportunities in the next thirty years of climate tech

But first…

Roots – The decarbonization story so far, and why we built Energy Impact Partners

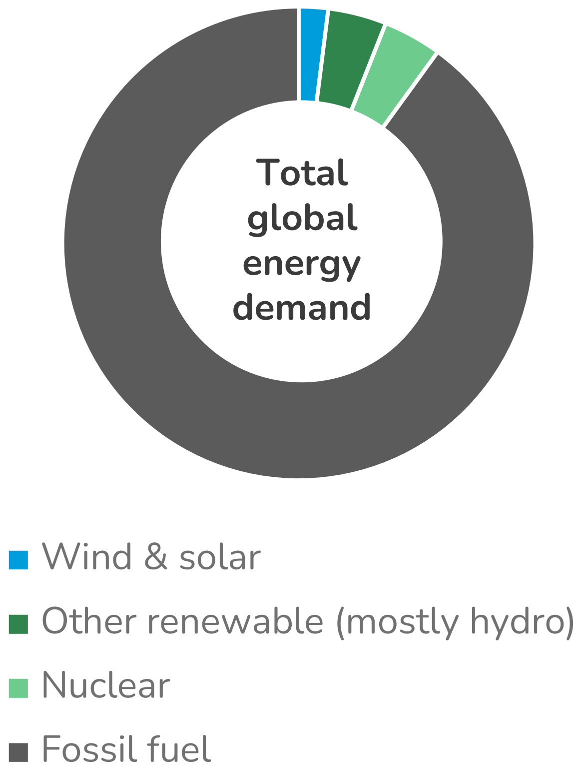
Root #1: Wind & solar are ready to rock…but they're still growing too slowly

Tremendous progress on wind & solar power costs – particularly for large "utility-scale" systems – means we now have two globally-scalable & reasonably affordable sources of zero-carbon energy. **And yet, roughly two decades into the renewable power revolution, wind & solar still only supply about 2% of global energy demand.**



Note: Smallest bubble sizes reflect smallest-volume PPAs (<5 MW), whereas largest reflect largest-volume PPAs (400 MW)

Sources: Berkeley Lab, FERC, EIA

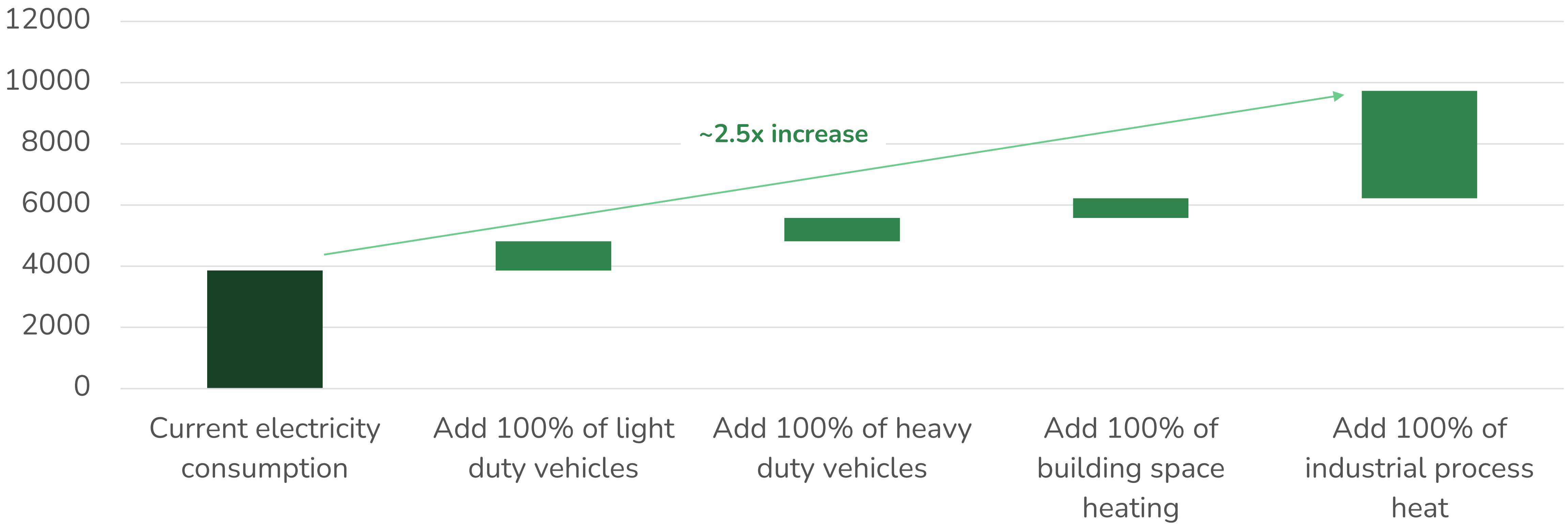


Source: "Land based wind market report: 2021 edition", NREL, Aug 2021

Root #2: Currently, wind & solar can only reach about 20% of total energy demand

Only 20% of energy demand is currently served by electricity. The rest is served mostly by the direct combustion of fossil fuel. That means **our most scalable zero-carbon energy resource – clean wind & solar power – can't solve the majority of our carbon problem**. Direct electrification is the simplest solution…entailing a 2-3X potential increase in demand.

***An illustrative US example*: Impact on electricity demand from direct electrification of major energy end uses (TWh)**



Note: EIP estimates for electrification are based on: 1) Vehicles: US vehicle miles traveled (US census) multiplied by typical electric vehicle mileage metrics; 2) Space heating: Annual residential & commercial building heat demand (EIA Residential/Commercial Building Energy Use Surveys) and typical air-source heat pump efficiency ratios.; 3) Industrial heating demand (based on EIA Annual Energy Outlook data) assuming a 1:1 ratio of thermal energy to electric energy.

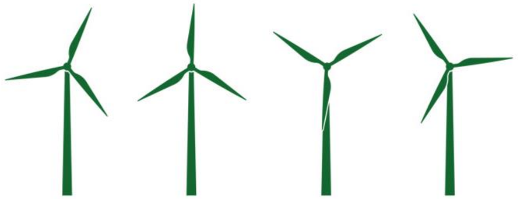
Root #3: Most of the big remaining questions are the types of questions we're used to handing off to "utilities" and other infrastructure owners

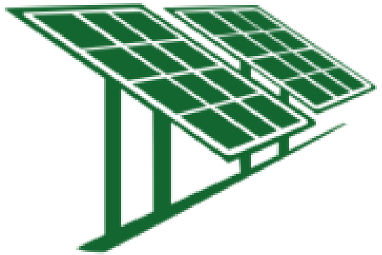
How to transition existing assets?

How to manage intermittency?

How to cost-effectively expand the power grid by 2-3x?

How to maintain reliability through unusual weather conditions?





???

A safe, affordable, reliable, resilient, and fully decarbonized energy system

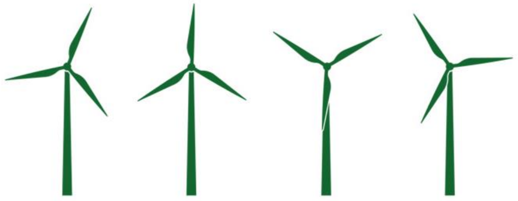
How to uphold the regulatory compact for essential energy service?

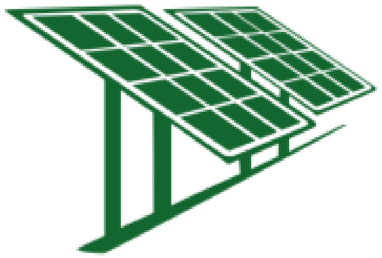
How to coordinate a system of multiple, interconnected fuels (electric, gas, hydrogen, ??) ?

How to preserve social license to operate?

How to finance this generational infrastructure investment?

Utilities are the keystone species of the energy transition. So, we built EIP as a platform for utilities, energy producers, industrial suppliers, and consumers to collaboratively invest in the most promising climate solutions.





The world's largest consortium of utilities, energy producers, industrials, and consumers investing collaboratively in transformational solutions

EIP

- Expertise of >200,000 employees
- Serving >55m customers
- Operating electric transmission & distribution networks >1.5m miles
- Spending >$50b annually on capex

A safe, affordable, reliable, resilient, and fully decarbonized energy system

+ supporting decarbonization beyond energy

(materials, agriculture, etc.)

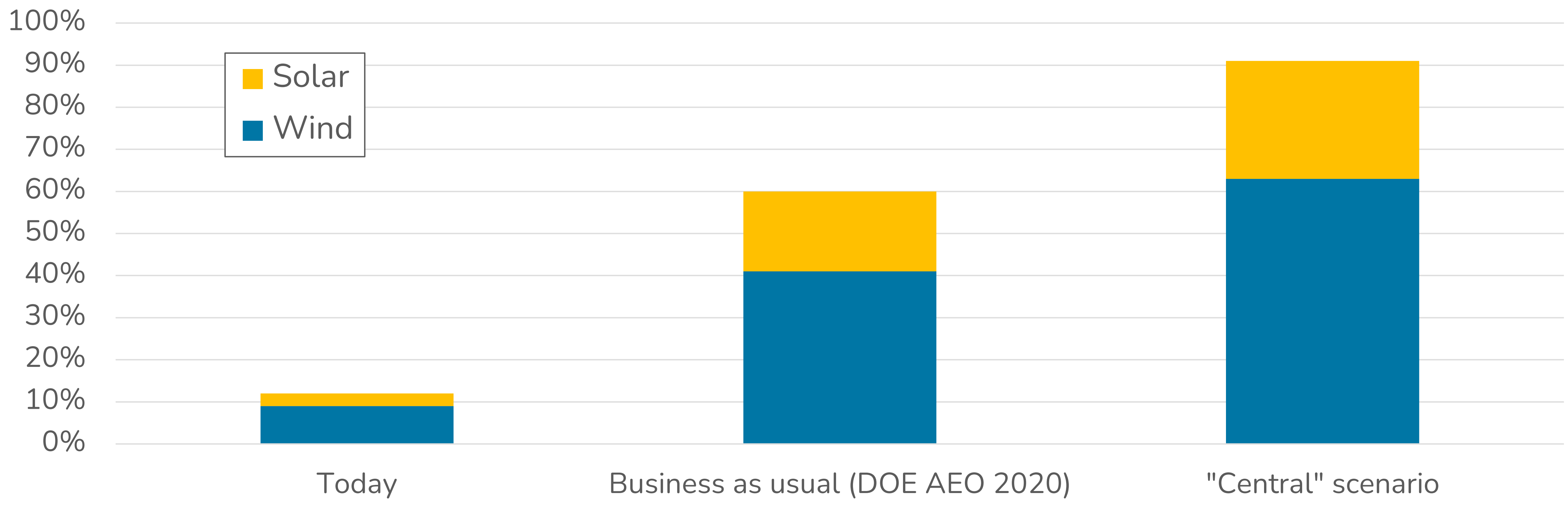
The tree of abundant, affordable, zero-carbon power

Trunk: Wind & solar bonanza

Sophisticated models of the pathway to net-zero tend to ‘select’ a very high level of wind & solar power generation, because wind & solar have become so dang cheap. **Absent constraints on project siting or transmission, renewables end up dominating electricity generation in nearly all net-zero scenarios.**

Percentage of annual US electricity generation from wind & solar by 2050

“Carbon Neutral Pathways for the United States”, Williams et al, 2021



Source: “Carbon Neutral Pathways for the United States”, Williams et al, Jan 2021

Branch: Grid storage will make intermittency manageable

A common perception of wind & solar is that *intermittency* is the biggest constraint on their long-term growth. But we're sufficiently confident in a range of emerging storage technology that we don't believe intermittency will be renewables' Achilles heel. **We see three emerging tranches of storage tech that will keep the cost of intermittency manageable:**

Daily peak shaving & ancillary services
4-6 hours of storage

Daily 'net load' balancing
8-16 hours of storage

Firm multi-day & seasonal capacity
100+ hours of storage

Lithium-ion batteries

Flow batteries
ESS INC
PRIMUS POWER
WattJoule
VANADIS POWER
VOLTSTORAGE

Gravity-based systems
GRAVITY POWER
ENERGY VAULT
Enabling a Renewable World

Zinc-based batteries
e-zinc
URBAN ELECTRIC POWER
eos

High temperature heat
MALTA
RONDO
Antora Energy
KELVIN thermal energy
KRAFT BLOCK
ELEMENT16 TECHNOLOGIES
MGA THERMAL
Joule Hive
Electrified Thermal Solutions

Compressed liquid / gas
Quidnet Energy
Highview Power®
Apex-CAES
ENERGYDOME
GROUND-BREAKING ENERGY STORAGE
HYDROSTOR

form energy

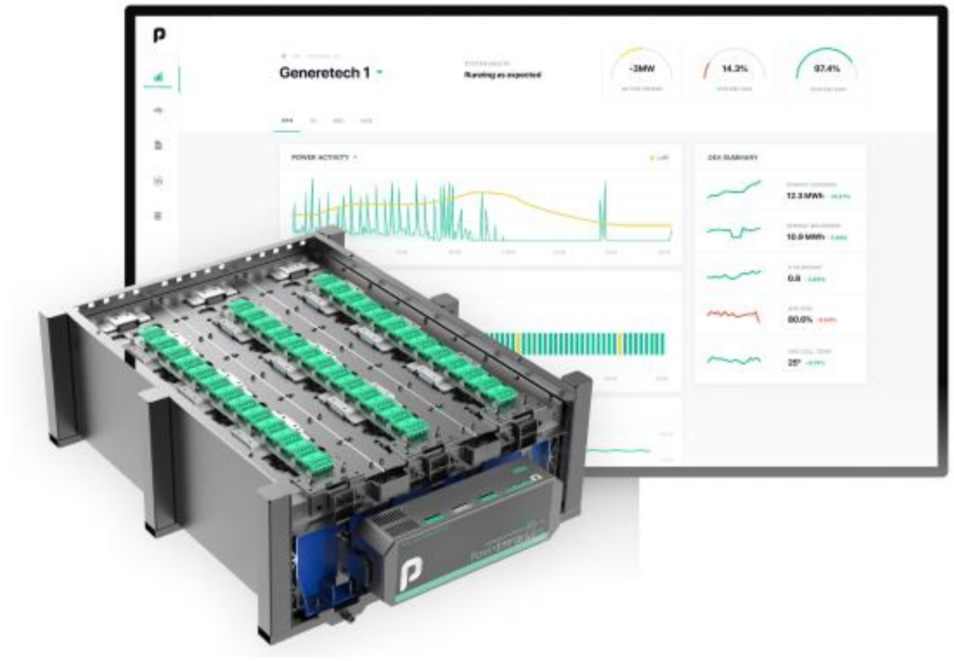
noon ENERGY

Hydrogen

POWIN

EIP portfolio spotlight:

Optimizing grid storage system integration



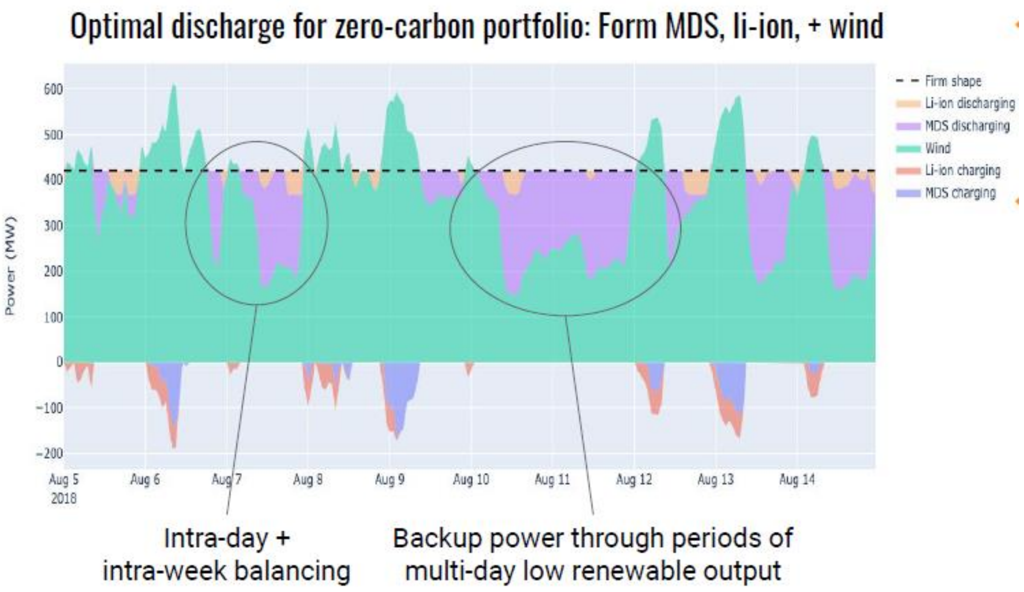
- **Solution:** Powin is a utility-scale grid storage system integrator, which takes third-party battery cells & power electronics, then adds its own proprietary hardware & software components to create fully operational storage systems, ready for grid interconnection. Powin currently utilizes lithium-iron-phosphate batteries, which are now becoming the go-to lithium-ion variant for grid storage. The company just launched its first fully modular system design, the “Centipede Platform”, which is factory-built & pre-integrated in outdoor rated enclosures. Centipede requires less time to procure and deploy, has superior reliability, requires less space on site, and costs less to install than comparable systems.

- **Why it’s interesting:** We’re now well past the first round of grid storage deployment, in which hooking up EV battery packs to the grid was considered advanced. For lithium-ion-based systems, which are already being deployed cost-effectively today, grid storage is now a sophisticated integration game focused on squeezing out margin from every inch of a system. Powin has emerged as one of the most experienced, reliable, and creative system integrators doing just that.

- **EIP perspective:** Even with no major innovation in battery technology, deployment of grid storage using lithium-ion batteries is on track to grow by leaps & bounds over the course of the next 5-10 years. The Powin team has scrapped their way into a leadership position as one of the few trusted, bankable, and innovative vendors in system integration, and is therefore set to grow in this booming market.

EIP portfolio spotlight:

Game-changingly low-cost, multi-day grid storage



- **Solution:** Form is developing a proprietary iron-air battery chemistry for grid storage applications. The company has a clear technical pathway to undercut even the most optimistic projections for total installed lithium-ion storage costs by at least 90%. Form's first product is a 100-hour duration system that, when paired with the right combination of wind & solar, can fully balance load against up to 100% wind & solar generation, at levelized costs that can be very competitive with other firm, zero-carbon power supply options.

- **Why it's interesting:** If Form achieves the techno-economic milestones on its roadmap, then intermittency will no longer be a major limiting factor for the deployment of very high levels of renewables. Moreover, even well below 100% wind & solar, Form's technology can create substantial value by improving the efficiency and reliability of the power system. For example, in remote regions with high wind & solar potential but limited transmission capacity, Form can serve as a kind of 'virtual' transmission that accelerates renewable power deployment. And if deployed near large commercial or industrial building sites, it can also serve as the backbone of an extraordinarily resilient, renewable microgrid.

- **EIP perspective:** Form was EIP's first real investment in 'deep tech' for a reason: it is hands-down the company with the most credible plan to achieve the cost & performance parameters required for multi-day storage, plus the commercial & financial skillset to build a business around the technology. Form is already engaged with several of our utility partners in serious discussion about early commercial projects.

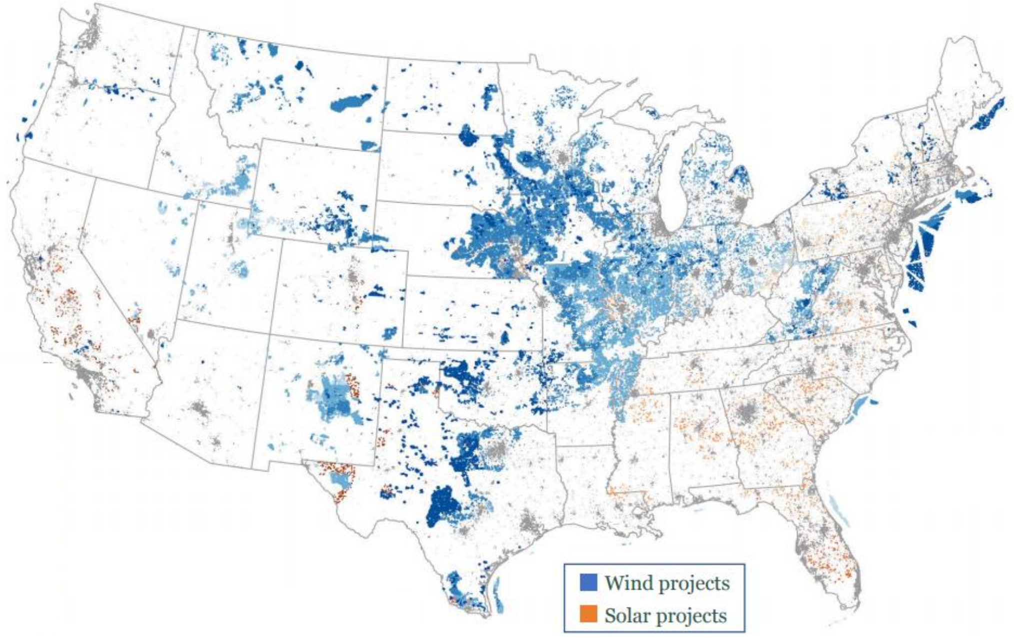
Knot? Siting & permitting for all that wind & solar (and associated transmission)

Net-zero models end up saturated with renewables because they're cheap, and getting cheaper. But wind & solar at true net-zero scale will utterly transform the landscape in some regions – as will the long-distance transmission required to continue building out more capacity. **Public acceptance hurdles are a major, underappreciated risk to the cost & feasibility of renewables.**

Total land area consumed by onshore wind & solar:

7% of total US lower 48

(though the vast majority of that can still be used for agriculture*)



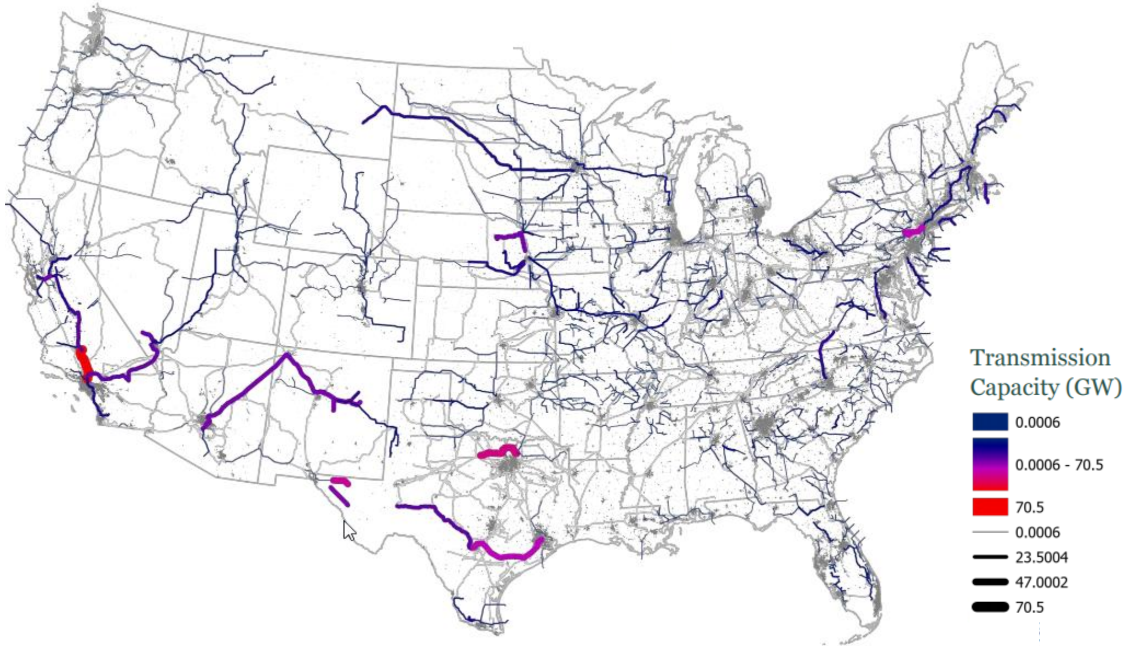
PRINCETON UNIVERSITY

NET-ZERO AMERICA:

Potential Pathways, Infrastructure, and Impacts

Estimated 2050 transmission capacity increase:

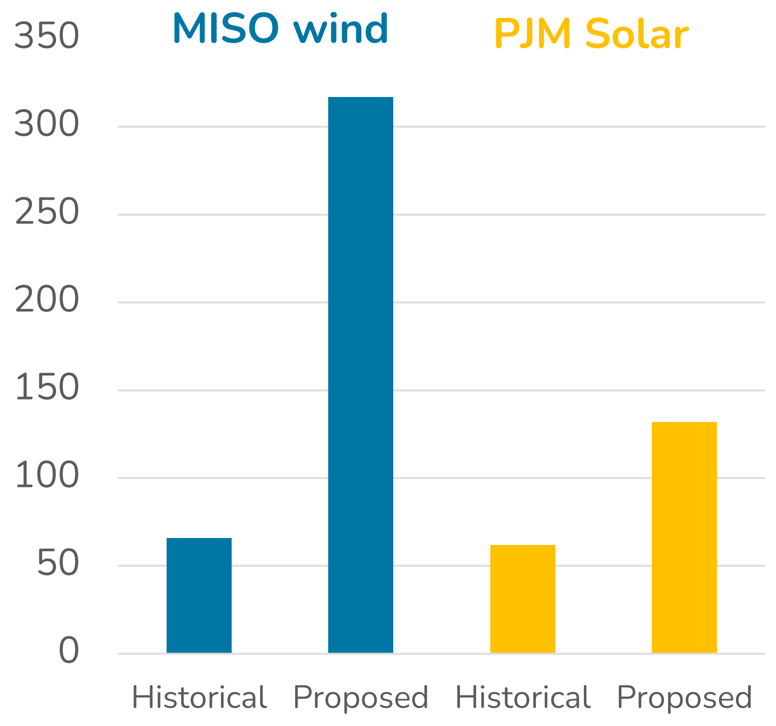
3.2x (majority inter-state)



Source: Princeton University, "Net Zero America: Potential Pathways, Infrastructure, and Impacts", Dec 2020
Note: Represents the "E+" scenario. *Wind turbines only take up about 1% of total site area.

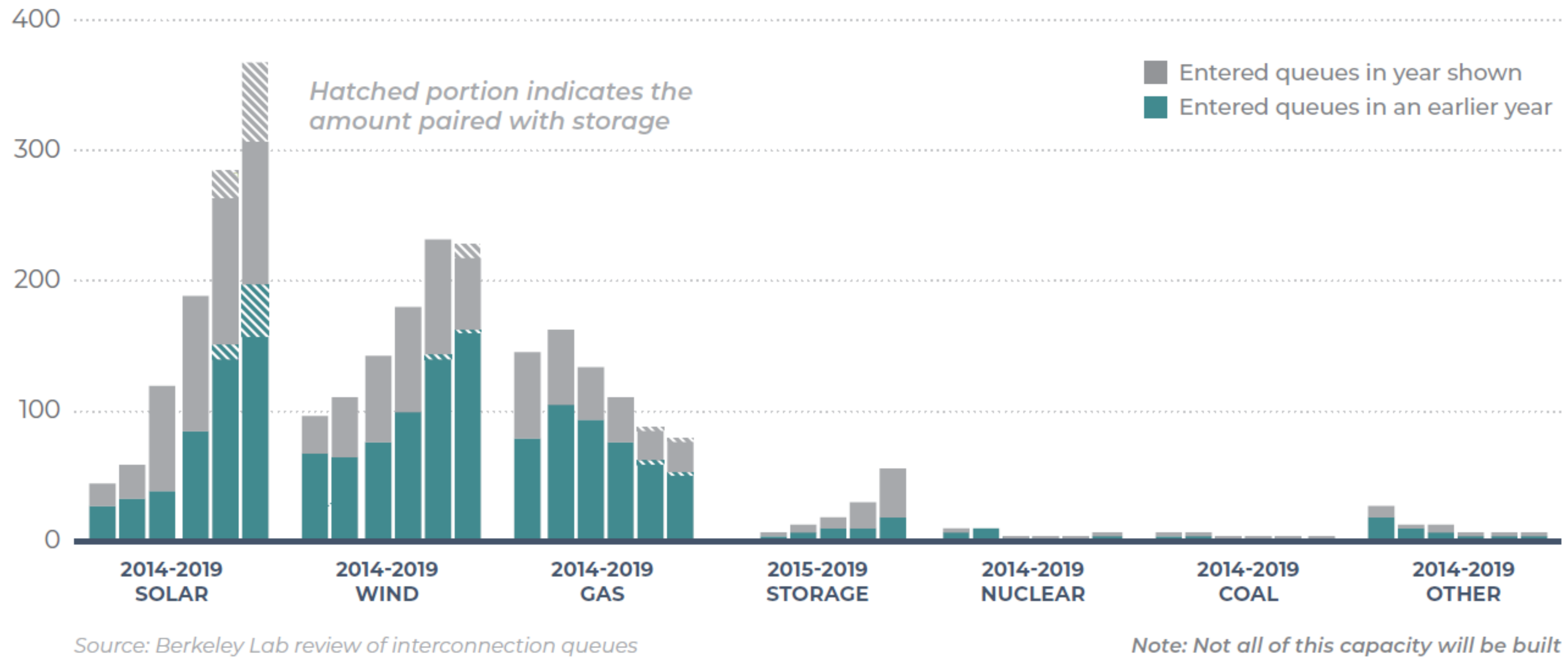
Renewables & transmission go hand-in-hand. Unfortunately, today, transmission constraints are beginning to look like an Achilles' heel...

Interconnection upgrade cost ($/kW)



The cost of upgrading the grid to safely add new wind & solar projects is increasing

Capacity in US interconnection queues, YE 2019



Meanwhile, wind & solar project proposals are getting stuck in long lines – sometimes for many years – to be studied for their impact on the grid.

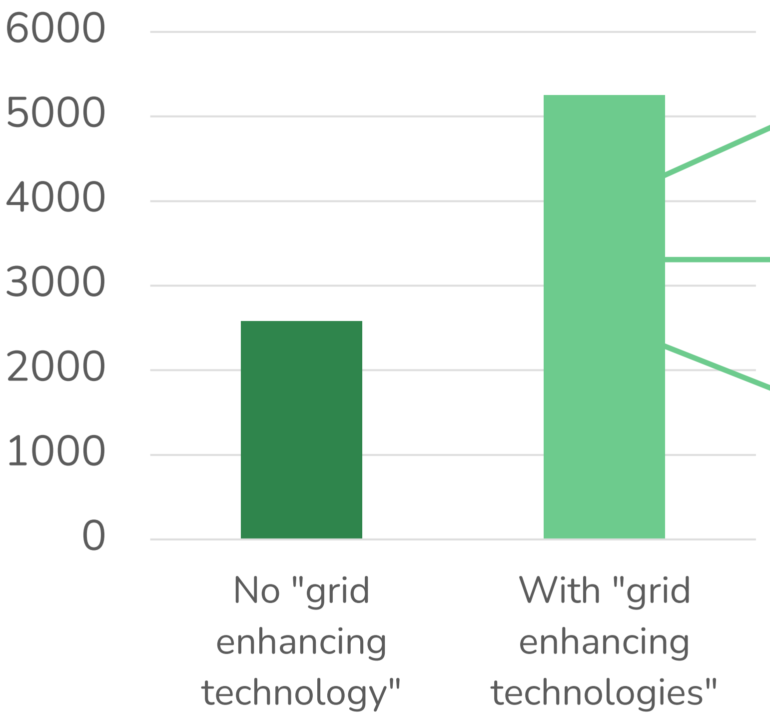
Source: Upgrade cost chart from "Disconnected: The need for a new generator interconnection policy", Grid Strategies & Americans for a Clean Energy Grid, Jan 2021; Capacity chart from "Planning for the Future: FERC's Opportunity to Spur More Cost Effective Transmission Infrastructure", Grid Strategies & Americans for a Clean Energy Grid, Jan 2021 – based on Berkeley Lab review of interconnection queues

Branch: Smarter, nimbler and a lot more electric transmission

There's no doubt we'll need more physical poles & wires to unlock hundreds of gigawatts of wind & solar. But given the daunting hurdles to siting & permitting new high-voltage, inter-regional transmission lines, it will also be crucial to make the most of every line. **New sensing, monitoring, analytics, and control solutions can make a big difference…**

THE Brattle GROUP

MW of additional wind & solar the regional grid operator in the central US (the Southwest Power Pool) can integrate with no additional 'poles & wires' investments



Advanced Power Flow Control: Pushing power from overloaded facilities or pulling power to under-utilized facilities.

SMART WIRES
REIMAGINE THE GRID

Dynamic Line Ratings (DLR): Adjusts thermal ratings based on actual weather conditions and potentially real-time line behavior.

LINEVISION

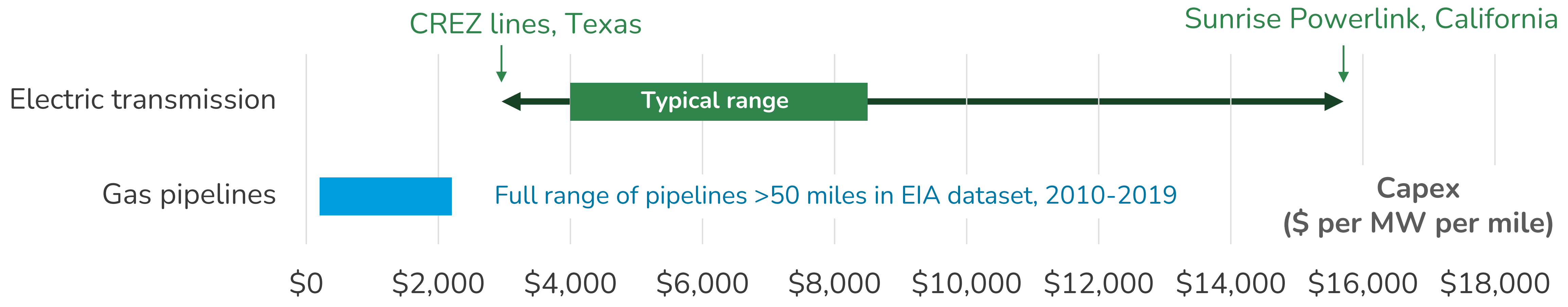
Topology Optimization: Advanced network models to reconfigure the grid to avoid transmission 'congestion'

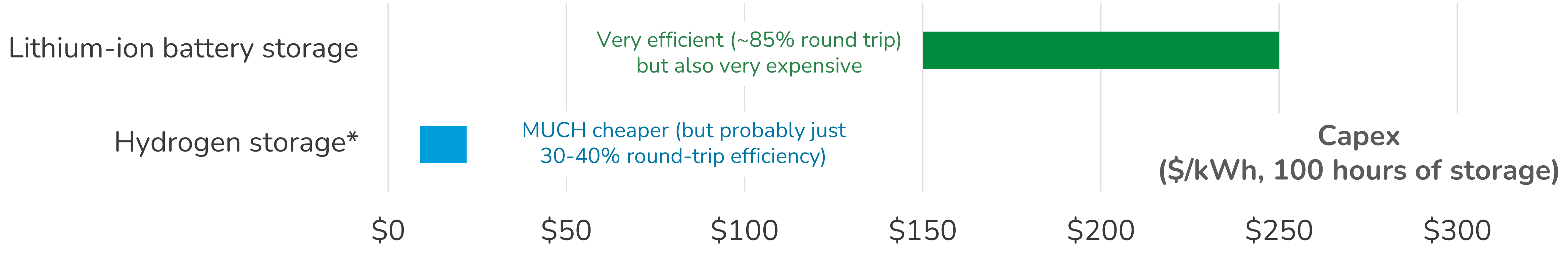
newgrid

Source: "Unlocking the queue with grid-enhancing technologies", Brattle Group, 2021

Branch: 'Green' hydrogen as a combined transmission & storage solution

Green hydrogen – produced from zero-carbon electricity and water – has many potential uses (more on this later). Perhaps its greatest use will be to unlock the very cheapest, remote wind & solar resources – by **substituting a pipeline project for a much more expensive, uncertain transmission project – while also providing an ultra-low-cost form of energy storage.**





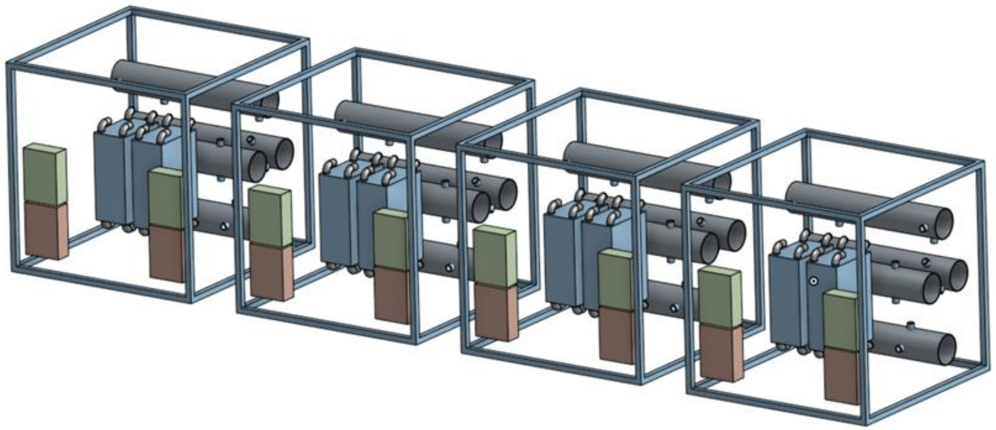
Sources: "Estimation of Transmission Costs for New Generation", University of Texas Austin Energy Institute, 2016 | "Capital Cost for Transmission & Substations", Black & Veatch (prepared for WECC Transmission Expansion Planning), 2012 | EIA "US Natural Gas Pipeline Projects Workbook", Nov 2020
Note: *Includes a cost of $700-1000/kW for electrolysis capacity & existing gas turbine retrofit (conservative future assumption).

EIP portfolio spotlight:

Redesigning electrolysis from the ground up for least-cost H2

ELECTRIC HYDROGEN

- High Throughput Industrial R&D (Fast learning cycles)
- Design for Performance (High current density and efficiency)
- Design for Manufacturing (Cost = (materials + Process) x yield)



Economic < $2/kg, going to $1/kg at scale

Green = Renewable-powered (down to 30%CF Solar)

At-Scale = 100MW-scale units targeting GW-scale plants

Industrialized = Re-imagined for high volume manufacturing

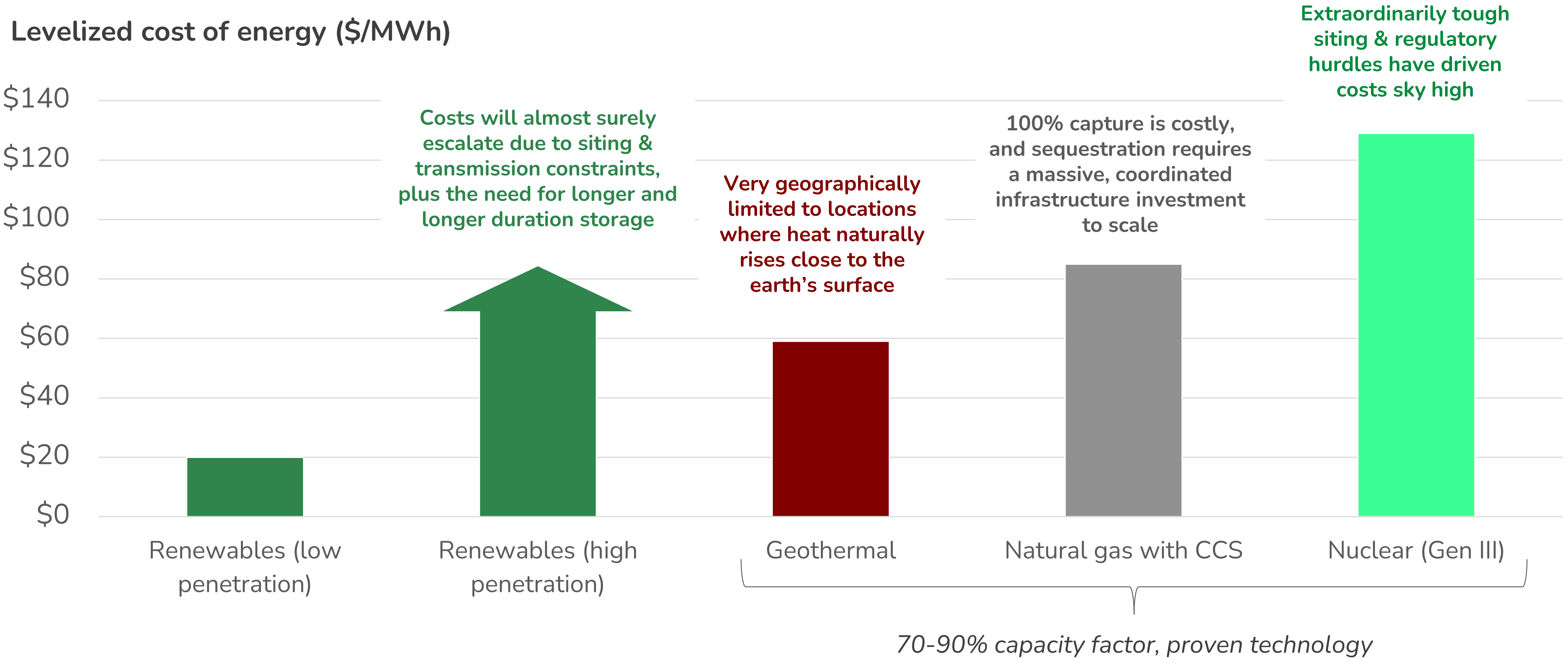
- **Solution:** Electric Hydrogen is building on established electrolysis technology fundamentals, but redesigning their system from the ground up with a singular focus on levelized cost of hydrogen. So far, the team has been able to make radical improvements in electric current density over conventional solutions, which allows for a much smaller total system footprint. EH2 has also identified a pathway to lower utilization of rare metals; and they're designing for both manufacturability & ease of on-site installation. The company's core product is a 100 MW system intended to be paired directly with large wind & solar farms.

- **Why it's interesting:** Current electrolyzer technology has a pathway to very low 'stack' cost (particularly via China-based alkaline technology manufacturers). But that low stack cost does not translate to low total installed cost, or low levelized cost of H2 – because of high balance of system, installation, and O&M expenses. Also, alkaline technology is poorly suited to direct pairing with intermittent renewables, due to its relatively low flexibility. Electric Hydrogen's total installed cost profile and high operational flexibility make its approach extremely attractive for harnessing remote, large-scale renewables.

- **EIP perspective:** It's a tough time to bet on a novel electrolysis technology given the presence of big incumbents in the space, the threat of low-cost Chinese supply, and the flood of venture dollars flowing into startups. However, Electric Hydrogen has an unparalleled team, with a CEO who previously executed a very similar strategy of total cost reduction while CTO of First Solar. We also believe the company's distinctive approach – designing a highly differentiated product based on fundamentally well-understood building blocks – has one of the best chances to scale quickly once the product's cost advantages are realized.

Knot? At least one more scalable, *power-dense* zero-carbon generation option

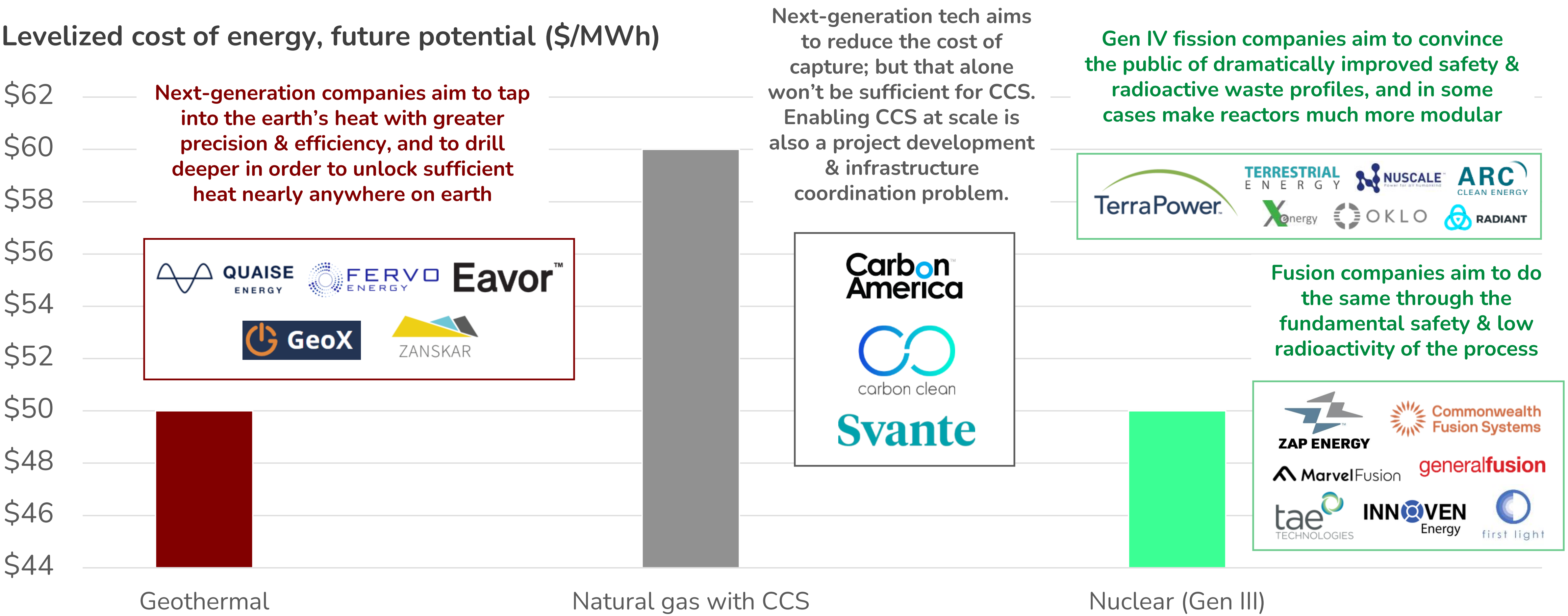
Assuming constraints on wind, solar, and transmission siting, there's most likely a need for **at least one more highly scalable, firm, and most importantly power-dense** zero-carbon electricity generation technology. Nearly all options fall into one of three broad categories: geothermal; gas or coal with carbon capture & sequestration; or some form of nuclear (fission or fusion).



Incremental technology advancement won't do for these solutions; we need to see true game-changers

Game-changers in any one of these three categories would represent the ideal baseload complement to renewables & storage – reducing the land use requirements of the energy transition; making use of existing power plant sites & transmission capacity; maintaining 'inertial response' in the power grid.

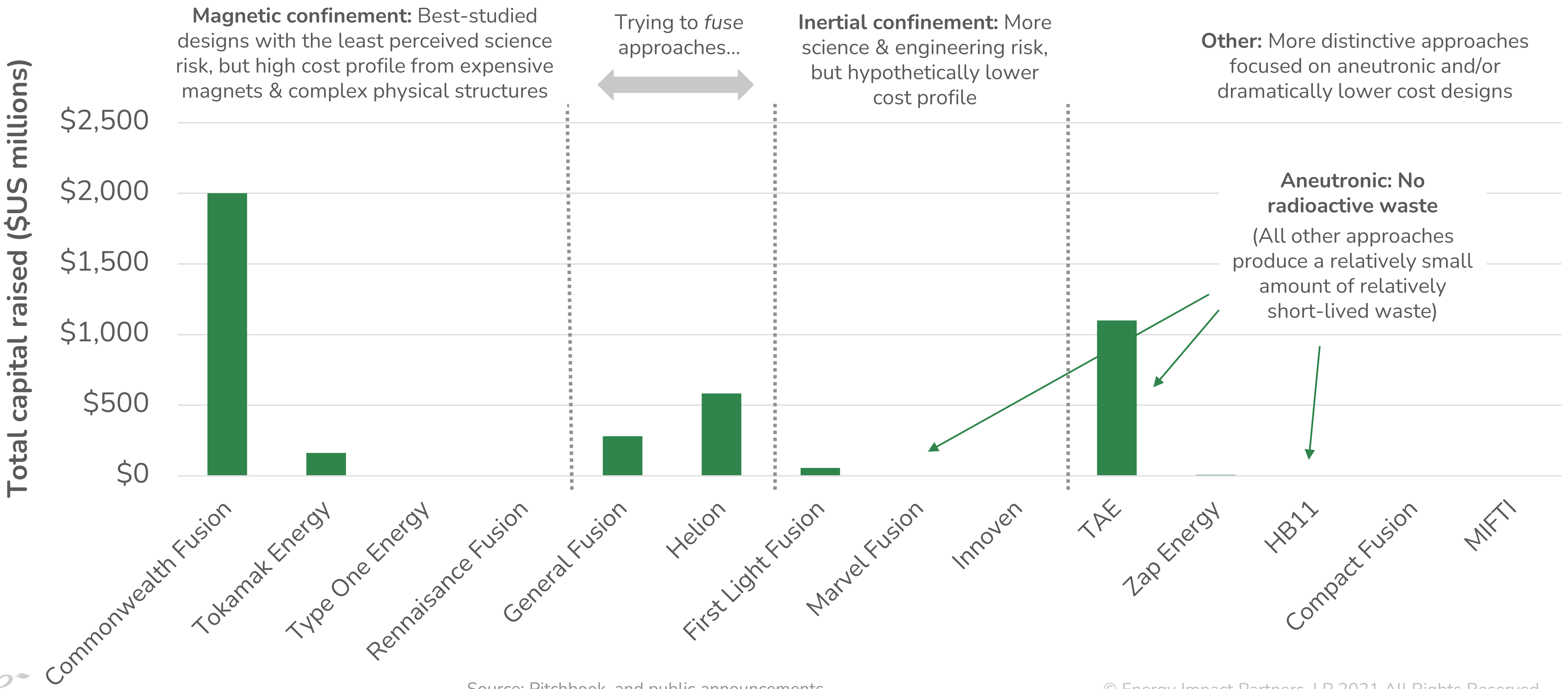
Levelized cost of energy, future potential ($/MWh)



Note: Select representative companies highlighted. Not an exhaustive list.

For example: Nuclear. Freaking. Fusion.

Fusion is famous for having been “twenty years away” for the past fifty+ years. **We think fusion might now actually be ten years away**…at least, ten years from a foundational reactor design that has demonstrated ‘energy break-even’. A surge in private investment in fusion technology is now giving the small but mighty fusion community lots of shots on goal.



Source: Pitchbook, and public announcements.

ZAP ENERGY

EIP portfolio spotlight:

The dark horse game-changer in fusion energy

- **Solution:** ZAP is developing a completely novel approach to nuclear fusion based on truly distinctive 'sheared flow stabilized z-pinch' technology. Unlike 'tokamaks', the most well studied fusion reactor concept, Zap's technology uses no expensive magnetic coils – and its reactor is theoretically much simpler and smaller than any other approaches of which we're aware. The company has made tremendous strides towards proving out the scientific theory behind the technology, and is making rapid progress towards "Q=1", the point at which a fusion reaction produces more energy than it consumes.

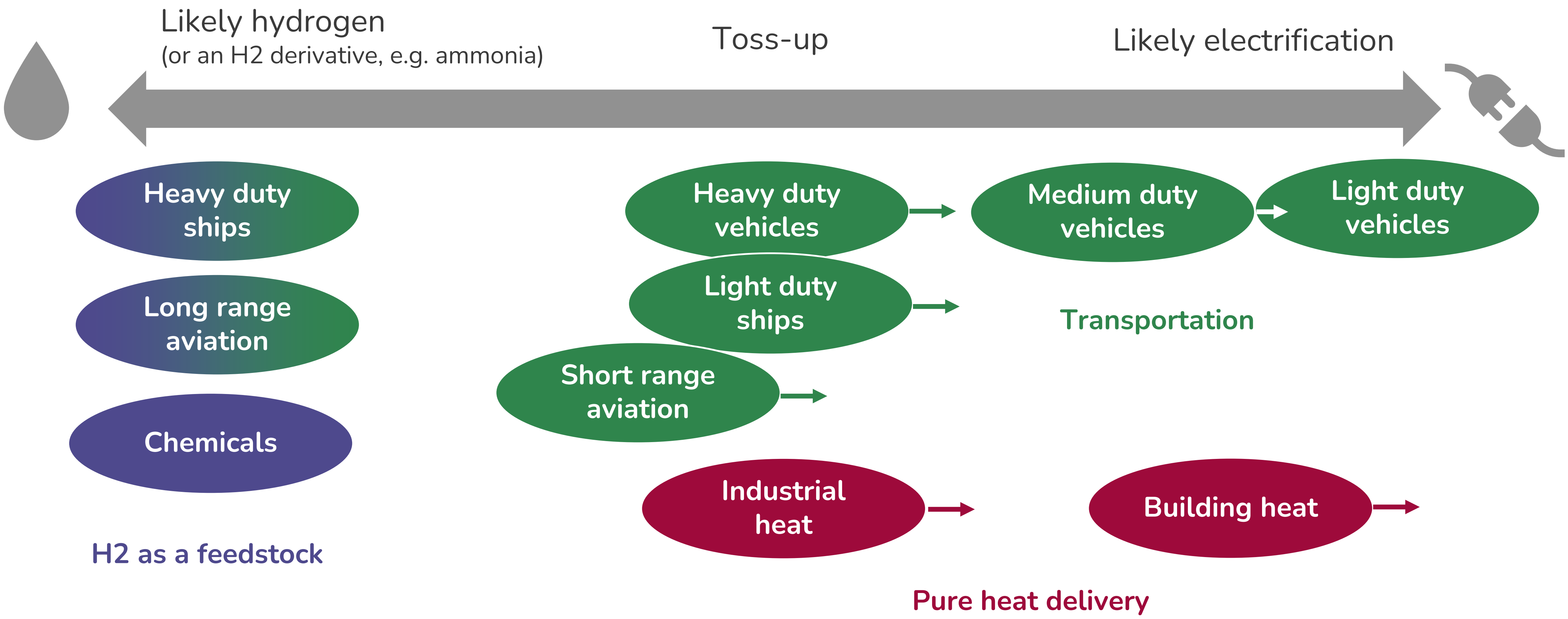
- **Why it's interesting:** Fusion, duh? Actually, that's not enough: While fusion easily captures the imagination ("stellar energy on earth!"), even a successful fusion experiment that achieves the sought-after Q=1 threshold would not necessarily lead to energy system transformation. Net-energy-positive fusion needs to be achieved *cost-effectively* in order to make a difference for the energy industry & the climate. Yet even some of the most advanced fusion players do not have a clear path to affordability. Zap, because of its small physical footprint and lack of reliance on superconducting magnets, has a fundamentally easier road to commercialization than most competitors.

- **EIP perspective:** There is still a daunting amount of both science & engineering risk associated with *all* approaches to nuclear fusion, but we've become convinced that ZAP has a uniquely promising combination of team, technology, capital-intensity, and end-state. ZAP is fairly widely regarded as the 'dark horse' fusion approach with potentially the fastest & cheapest pathway to demonstrating & then commercializing the technology at a price point that would secure its role in the energy transition.

The tree of electrification ascendant

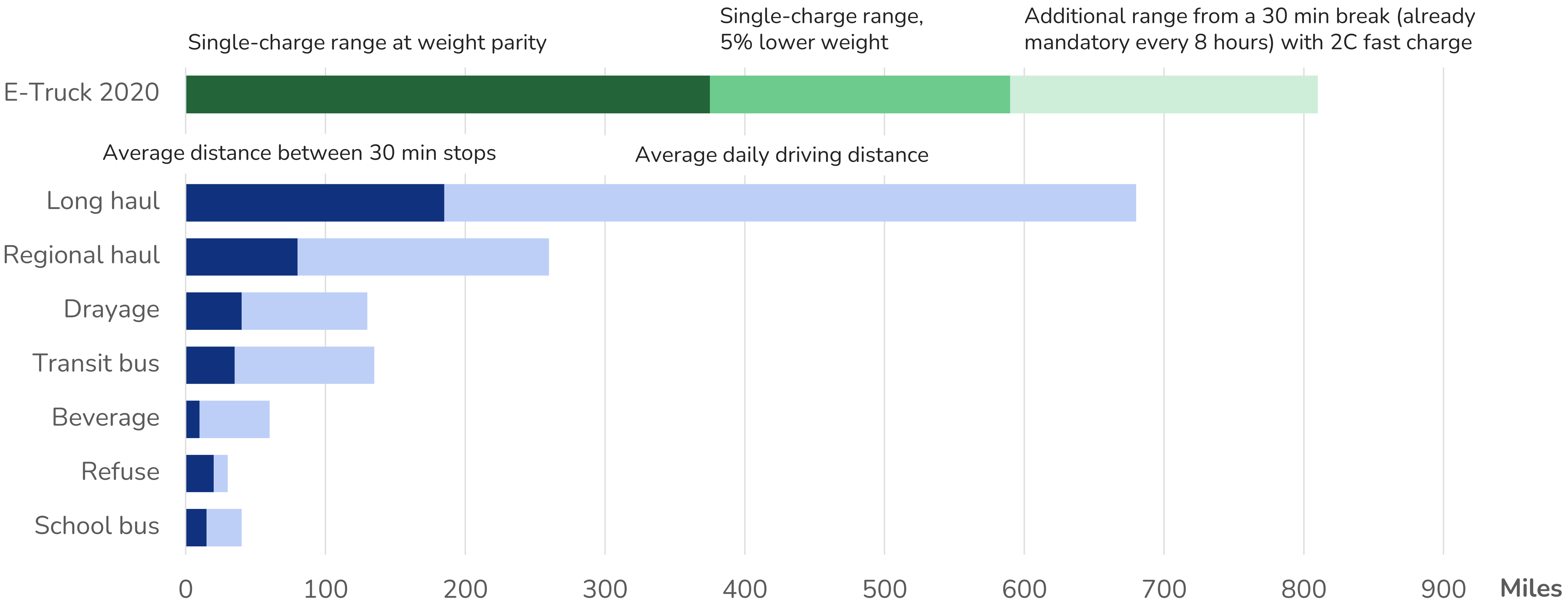
Trunk: Electricity is a formidable contender in nearly every major end use for energy

Affordable zero-carbon power is a great first step toward decarbonization. But electricity currently serves only 20% of end use energy demand. The remaining 80% will probably take one of three routes to net-zero: electrification, CCS, or clean hydrogen. **Currently, we see electricity gaining ground in the competition to decarbonize big end uses, particularly against hydrogen:**



Branch: Electrification of ground transport

Most policymakers & automakers have now accepted that electrification is the presumptive nominee to decarbonize light duty vehicles. What's less well understood is how competitive electricity could become in heavier-duty vehicles, given the evolution of lithium-based battery technology. **Even long-haul trucks are now looking like reasonably viable targets for electrification:**

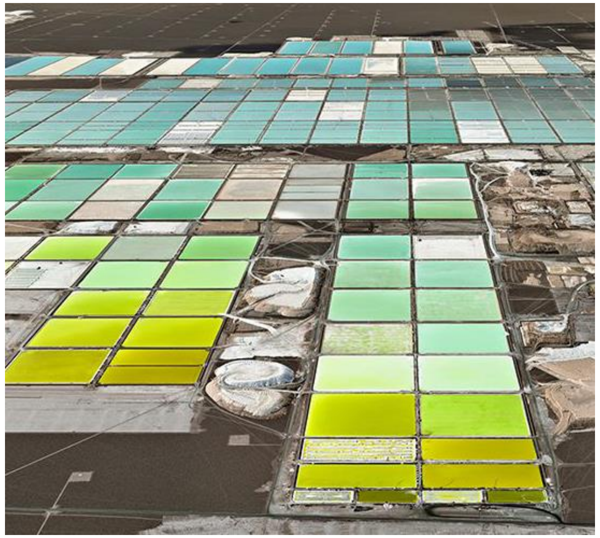


Source: Adapted from "Why Regional and Long-Haul Trucks are Primed for Electrification Now", Lawrence Berkeley Lab, March 2021

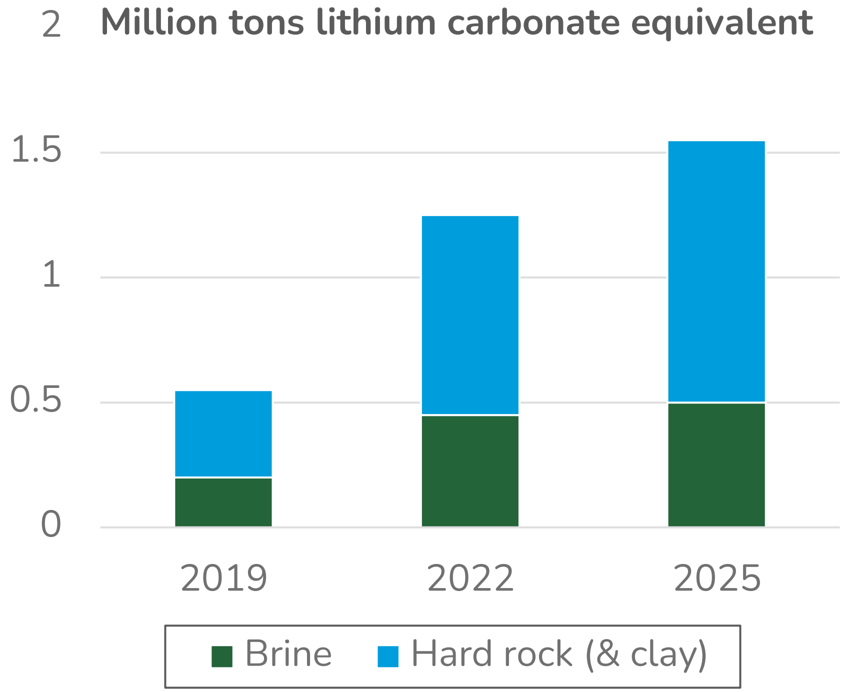
Branch: Soaring demand for lithium-based battery materials

There's theoretically enough lithium in the world to support a global transition to EVs, but we're still in the very early days of tapping into that theoretical resource. While there are several other critical battery metals that the industry needs to focus on as well, **lithium itself could become a bottleneck without new, more efficient & sustainable methods of extraction.**

Today, extraction of lithium from brines relies on high water & land consuming evaporation ponds… which yield <50% of available lithium, and have rapidly become much more difficult to site & permit.



Hence, forecasters (like S&P) expect most of the near-term growth in supply to come from hard rock mines. Yet longer-term, the hard rock resource isn't big enough to keep up with EV demand.



Consequently, the li-ion battery industry will require a step-change in brine extraction technology. "Direct Lithium Extraction" (or DLE) is one family of dramatically more efficient & lower land use alternatives to evaporation ponds.

Lilac solutions

SUMMIT NANOTECH

energyX

Standard LITHIUM

Sources: S&P Global, "Lithium Supply Set to Nearly Triple by 2025", 2019
Summit Nanotech & Lilac Solutions investor presentations

Branch: Lithium battery optimization, from R&D to end of (first) life

Batteries are super complicated & opaque. **Currently, we're still remarkably poor at designing, monitoring, and optimizing one of the world's fastest-growing asset classes.** We need new solutions to answer important questions in nearly every step of the battery life-cycle – whether a battery is destined for an electric vehicle, a grid storage system, or a weed whacker.

A selection of the big uncertainties across the lithium-ion value chain

Battery R&D and manufacturing

- What impact will this variation in battery chemistry (e.g. electrolyte, anode, cathode material) have on key performance metrics at varying temperatures
- What's the health of each battery cell coming off the production line?
- What impact will the initial electrolyte interphase formation process have on battery performance & lifetime?

Battery system design

- How much initial capacity do I need to satisfy an expected duty cycle in various environmental conditions
- What impact will various balance of system changes have on battery performance and cycle life?
- What's the best specific battery chemistry for the application I'm targeting?

Real-time battery operations

- What is the state of charge (SOC) & state of health (SOH) of each cell or module in my battery *right now*? (estimates can be off by as much as 10%)
- Given how I'm operating the battery and the environment, what SOC/SOH can I expect over the next hour or day?
- What early warning signs might help me prevent catastrophic thermal runaway?

Asset management & trading

- How can I maximize the revenue or performance of this battery or fleet?
- Which other markets can I operate in, while also meeting contractual performance obligations?
- Given expected operations, how long until capacity degrades to X%?
- Am I at risk of voiding this battery's warranty, or needing to replace or refurbish it?

Battery end of life / second-life

- What's the SOH of the battery today?
- Is the battery approaching a point of "rollover failure" (non-linear degradation)?
- Can I get the most value out of this battery by recycling it, or by selling it to a second-life buyer?
- How can I cost-effectively select the right battery cells or modules for use in second-life applications?

Lithium battery optimization, from R&D to end of (first) life

R&D & manufacturing

Testing & analytics to accelerate new materials and cell designs (especially electrolyte formulations)

EONIX · MiTRA Chemical Consulting, LLC · CHEMIX · AIONICS

Ultrasonic sensors & analytics for testing cell quality during manufacturing

Feasible

System design

ZITARA · TWAICE · dox · voltaiq · ACCURE Battery Intelligence

Software solutions focused on SOC/SOH estimation, lifetime prediction and safety monitoring across battery fleets

Real-time analytics & operations

Qnovo · GBatteries · BattGenie Inc · iontra

Algorithms to increase charging rate with lower degradation

Battery management systems with better cell/module level optimization

EVchip smart energy · Brill Power · IONENERGY · tae POWER MANAGEMENT · RELECTRIFY MAKING ENERGY STORAGE AFFORDABLE

Ultrasonic sensors + analytics software for high-accuracy SOC/SOH estimation

TITAN ADVANCED ENERGY SOLUTIONS

Asset management & trading

HABITAT ENERGY · ARENKOGROUP · VEST Energy · Origami · open energi · FLUENCE · Flexitricity · Ascend Analytics · cQuant.io · IONENERGY

Automated forecasting, dispatch and risk management software focused on energy storage

End of life / second-life

SNT SPIERS NEW TECHNOLOGIES · ReJoule

Characterizing & sorting EV batteries for either recycling or second-life applications

RELECTRIFY MAKING ENERGY STORAGE AFFORDABLE

TITAN ADVANCED ENERGY SOLUTIONS

EIP portfolio spotlight:

Flexible software for making the most of lithium batteries in any setting

Simulation and Planning

- Pack sizing + cell selection
- Warranty planning
- Lifetime value simulation

Real-Time Operations

- Predictive Safety Shutdown
- Accurate SoC, SoH, SoP
- Lifetime value optimization

	Competitor A	Competitor B	Competitor C	ZITARA
Battery Lab Data Cleaning & Visualization	✓	✓	✗	✓
Field BMS Data Management	✓	✓	✓	✓
Simulation & Planning	✗	✓	✓	✓
Cloud-Enhanced Embedded SoX / Safety	✗	✗	✗	✓
Certified & Qualified Operational Interventions	✗	✗	✗	✓

- **Solution:** Zitara has developed a suite of software-based tools for managing battery assets in nearly every end use sector, from system planning through real-time operations. The software is cloud-based, but can also make use of a hybrid edge/cloud architecture. Its most distinctive feature is a physics-based model for near-real-time state estimation – e.g. “state of charge” and “state of health” (SOC & SOH)

- **Why it’s interesting:** Lithium-ion battery assets are incredibly complex and opaque, whether they’re deployed in electric vehicles or in stationary grid storage systems. Uncertainty around SOC & SOH leads to underutilization both in real-time and over the full battery life cycle. There is still a surprising amount of headway for better analytical tools to make use of existing data to improve battery asset O&M.

- **EIP perspective:** Zitara is one of a handful of very early-stage startups vying to gain a foothold in this space. We view the greatest competition, though, as coming from in-house development by battery asset owners. So far Zitara’s distinctive physics-based approach has proven to be able to win over those customers, earning the company pilots in every key battery market vertical (grid storage, consumer electronics, and transport). As the market hits an inflection point in the next 2-3 years, we believe Zitara is very well positioned as an early leader – enabling the company to add new features and services that will cement its role in the battery O&M tech stack.

Startups & incumbent industrial players alike are beginning to pursue opportunities within the end-of-life / second-life battery value chain

End of first useful life in a vehicle

Characterization & sorting

- TITAN Advanced Energy Solutions
- ReJoule
- RePurpose Energy
- Smartville
- Spiers New Technologies

Logistics & sales

- Battery Solutions
- call2recycle — Leading the charge for recycling.

Second-life in stationary systems

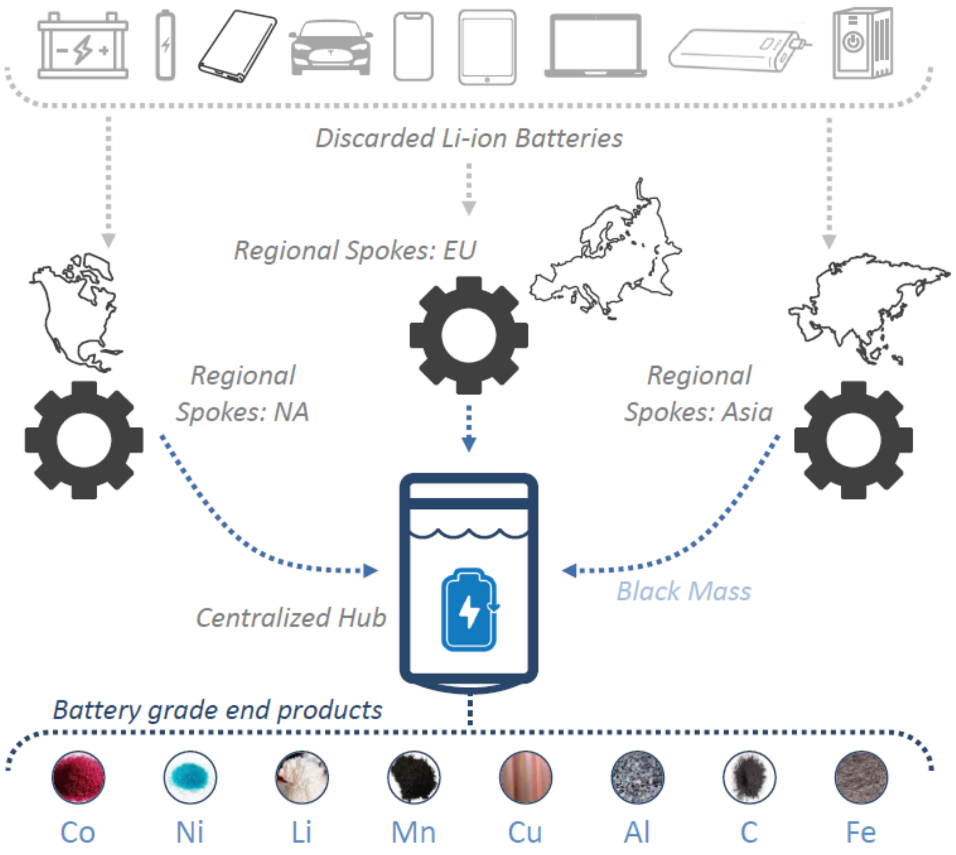
- Relectrify — Making energy storage affordable
- Moment
- betteries
- Brill Power

Recycling & disposal

- Li-Cycle
- Redwood Materials
- American Manganese Inc.
- Battery Resourcers
- Farasis
- fortum
- Primobius — Battery recycling without limits
- northvolt
- Duesenfeld
- umicore

EIP portfolio spotlight*

The leader in ultra-high recovery, environmentally-safe EV battery recycling



- **Solution:** Li-Cycle is already one of the top recyclers of li-ion batteries in North America. The company has developed a proprietary hydrometallurgical process for recycling li-ion batteries with >95% materials recovery. Li-Cycle is now building out multiple 'spoke' facilities across North America (and eventually other regions) that ingest end-of-life batteries at any state of charge and convert them to "black mass" (a mix of materials ready to be separated). This black mass can then be safely transported to a larger, centralized 'hub' for materials recovery. Li-Cycle will then either sell those materials in the commodity market, or provide them directly back to a battery manufacturer/supplier.

- **Why it's interesting:** The value of materials in end-of-life batteries is on track to exceed $20b by the end of this decade, and could account for more than 10% of the critical metal inputs to new li-ion batteries. (And that's assuming a significant amount of second-life utilization of EV batteries.) Waste & scrap from battery manufacturing also represents a large source of materials that need to be recovered. Battery supply chain issues are already a thorn in the EV industry's side, and could become a critical obstacle absent a truly circular economy.

- **EIP perspective:** Li-Cycle does not have the only low-emissions, high-recovery recycling solution; but we're convinced that their approach has several key advantages: notably their hub & spoke model; their ability to process batteries at any state of charge; and their best-in-class recovery rate. Most importantly, we believe the company has timed the market impeccably, being a first-mover with just enough runway to develop commercial relationships and prove their mettle before the first big wave of gigafactories ramps up outside of China, and before the first really big wave of end-of-life EV batteries arrives.

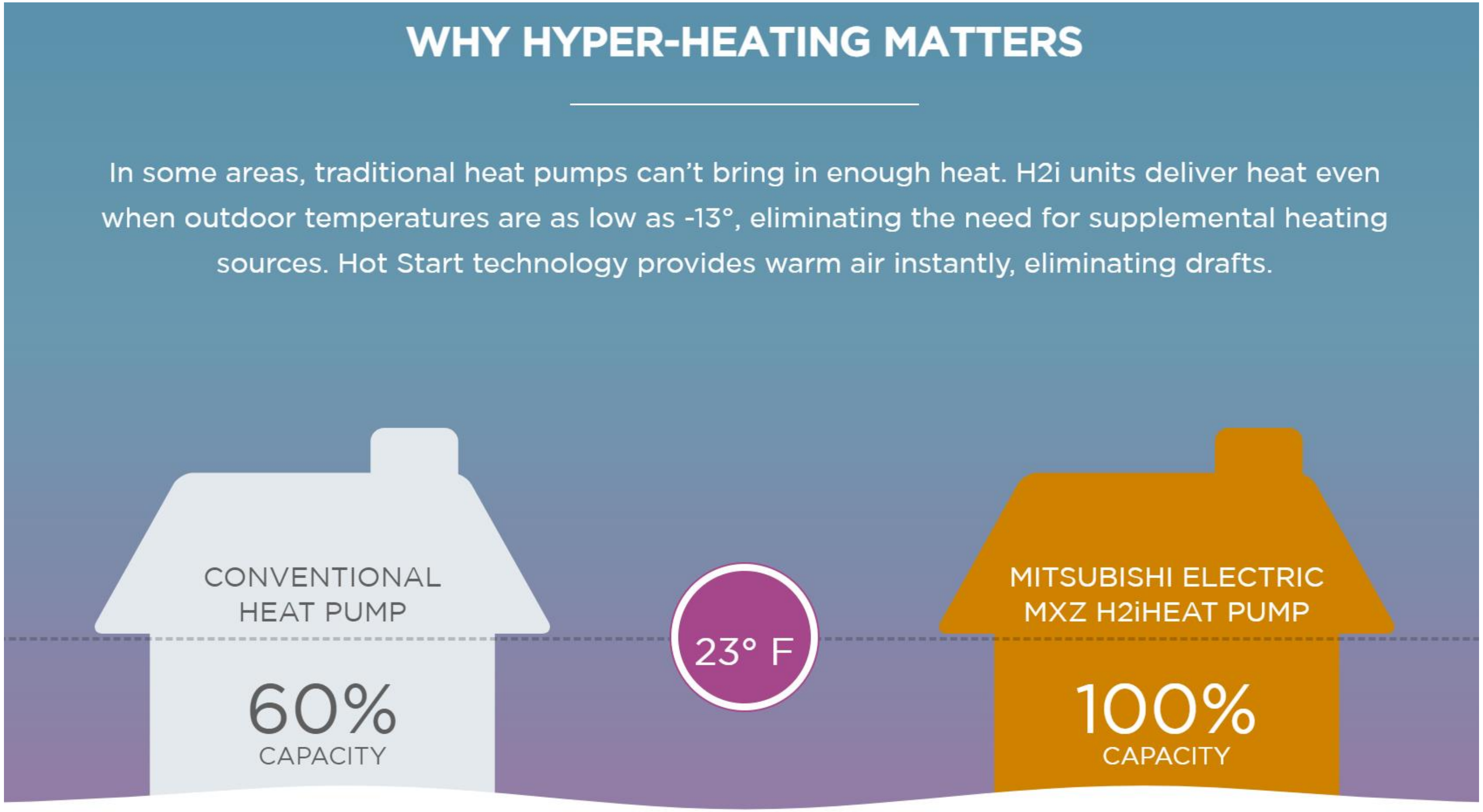
Note: *Now a publicly-traded entity

Branch: Electrification of building heat

Electric heat pumps have been making relatively quiet progress in the past decade – including, recently, even in very cold temperatures. So far, this progress has been driven mostly by large incumbent vendors iterating on established technology.

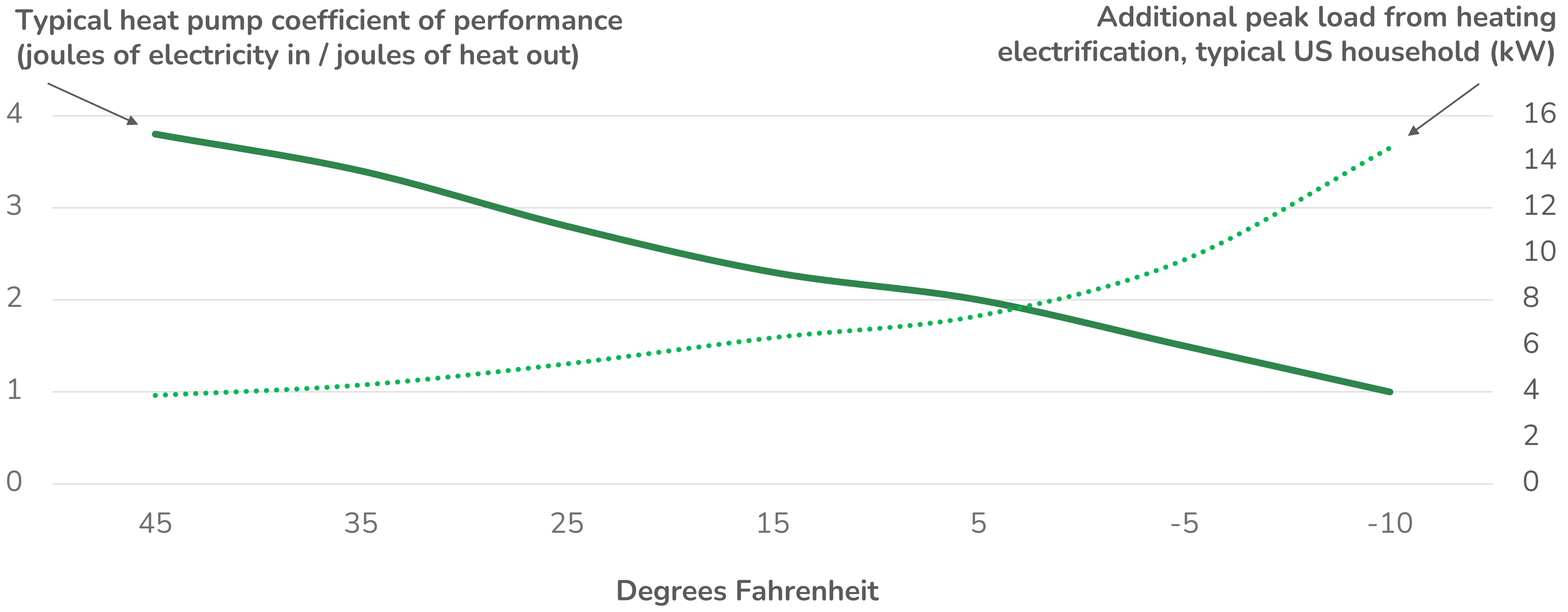
An illustrative example: the Mitsubishi HyperHeat…

MITSUBISHI ELECTRIC
COOLING & HEATING



Knot? The winter night problem for the electricity grid

While heat pumps are magically efficient at turning electricity into heat during *average* heating season conditions, their efficiency advantage is lost during the coldest winter periods. **In northern latitudes, sizing the electricity grid to satisfy 100% heating electrification demand could require upwards of 3x more peak capacity** in generation, transmission, and distribution.



Sources: Northeast Efficiency Coop Cold Climate Air Source Heat Pump List | Nordic Heat Pumps, "How Low Can Nordic Heat Pumps Go?", Jan 2017 | Mitsubishi Hyperheat product specifications

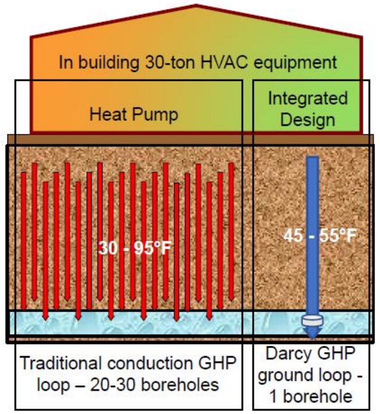
Knot? Heat pump revolution

Game-changers in heat pump efficiency could take the edge off peak load from electrification of heating (and cooling, too) in buildings & light industry. Ground source technology has historically been much too expensive & disruptive, but new solutions & business could flip the script. Much more efficient, higher 'lift' air source heat pumps could are also quite promising.

DANDELION

- The first company to make a serious attempt to scale & standardize the residential ground source heat pump business
- Proprietary low-footprint drilling techniques

DARCY



- Novel approach to utilizing groundwater for geothermal heating & cooling
- Proprietary system design and heat exchanger dramatically reduces drilling requirements and total system footprint

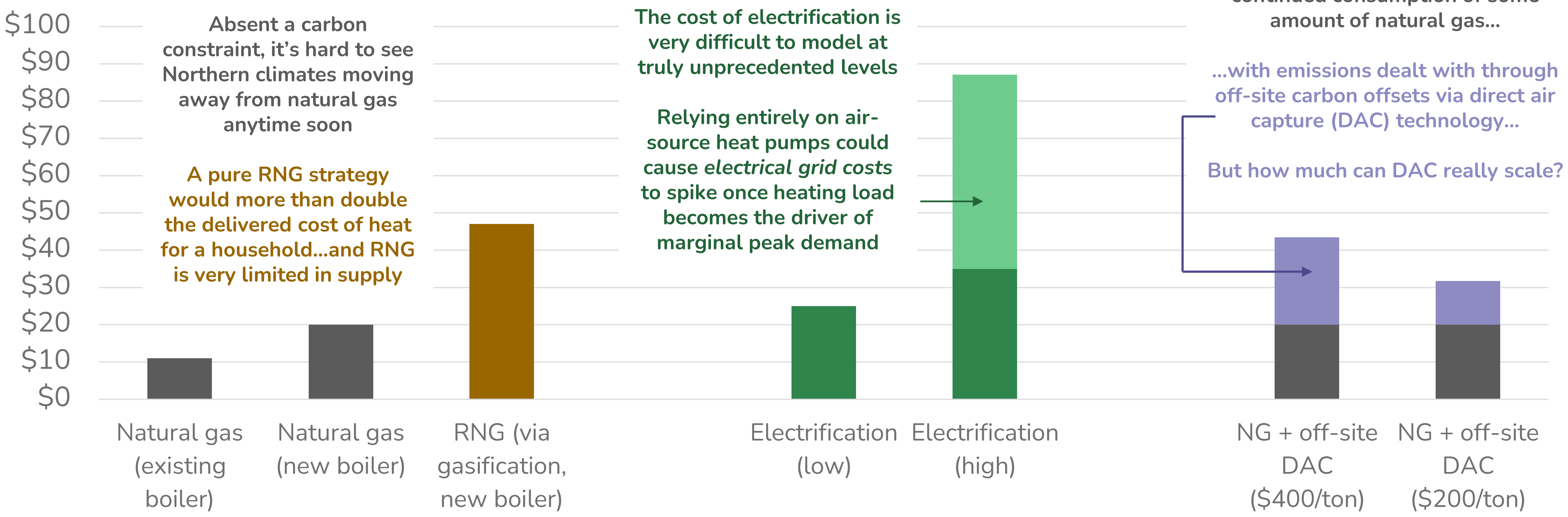
AtmosZero

- The first air source heat pump capable of producing steam even from below freezing temperatures
- Proprietary design & components set to achieve previously unheard of efficiencies for such a high temperature 'lift

Branch: Gas retains a diminished but critical role in heating & resilience

Electricity will undoubtedly make significant inroads in building heat; but **we believe natural gas infrastructure will continue to play a role in cost-effectively serving peak heating demand, and as a source of distributed resilience**. In fact, it may turn out that the cheapest net-zero gas is…natural gas itself – just much less of it, and with emissions offset elsewhere (perhaps via DAC).

Levelized cost of residential heating, cold climate (e.g. US Northeast, $/mmbtu)

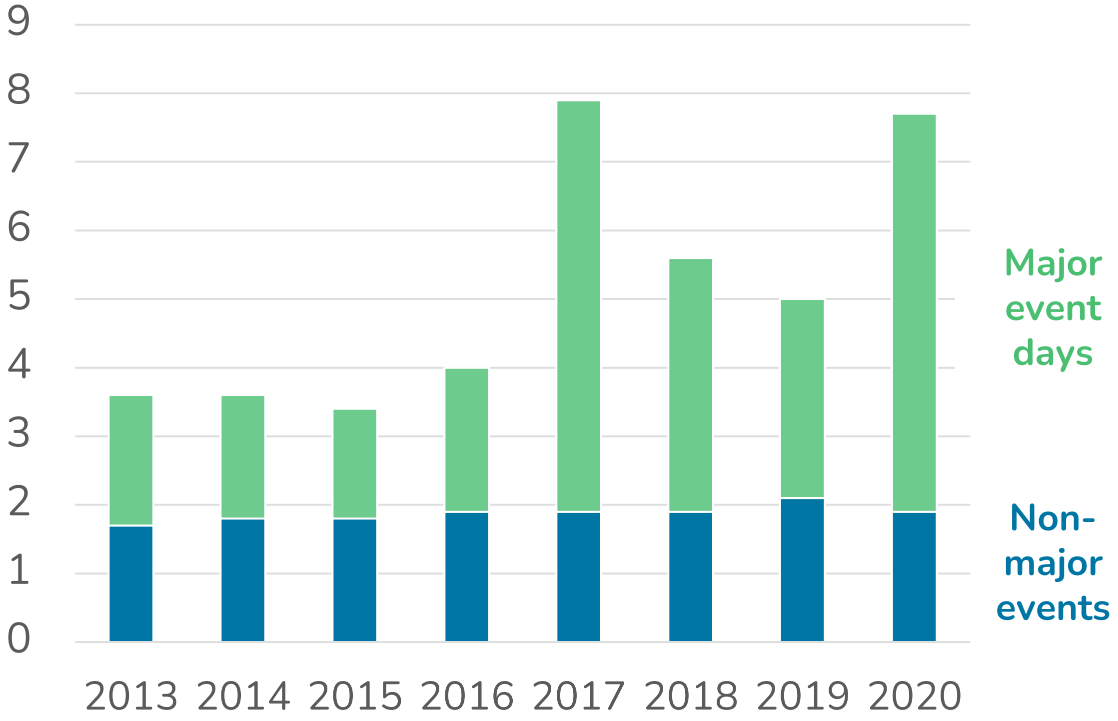


Notes: Basic equipment cost assumptions come from BNEF's Heating Unit Economics Calculator (Oct 2020 version). Assumes an RNG cost of $35/mmbtu at scale (via biomass gasification). Assumes minimal impacts of electric distribution costs from low electrification. High electrification assumes a peak heating load increase per household of 14.6 kW, and a marginal peak cost of $300/kW-year.

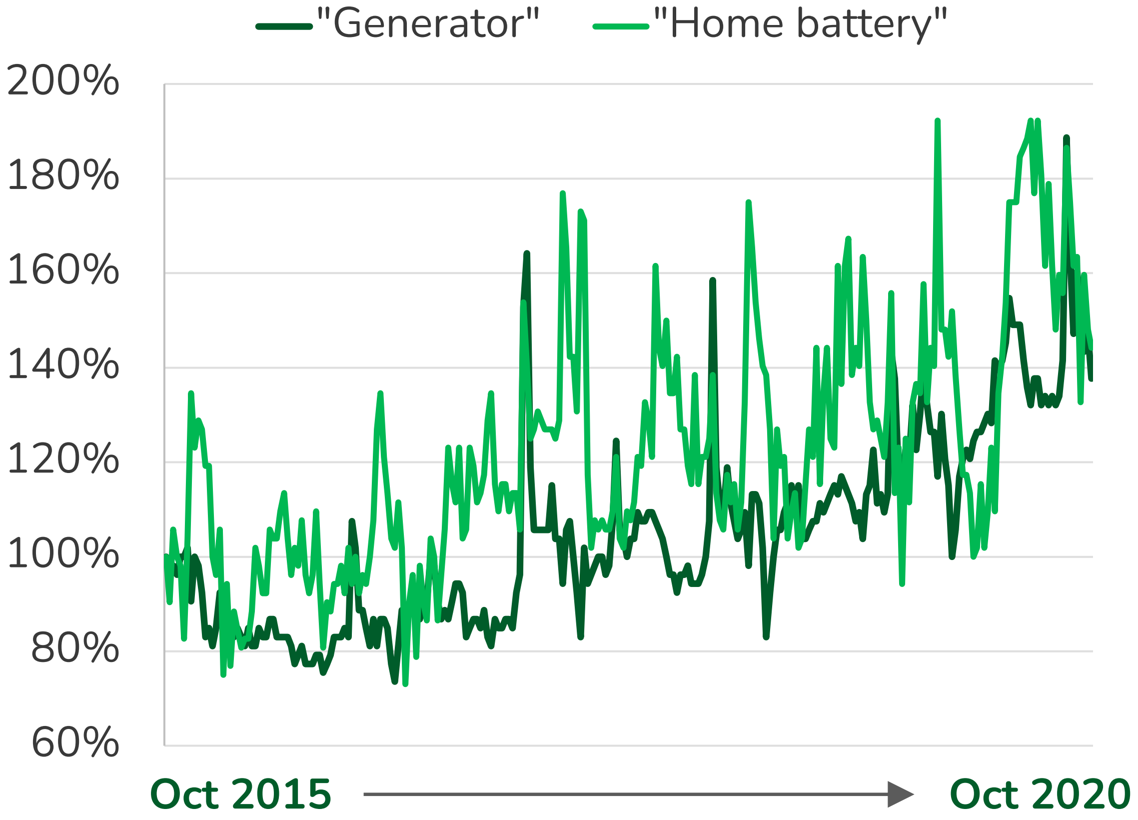
Branch: Grid hardening & resilience to support all this electrification

Utilities are doing an admirable job maintaining reliability through normal conditions. But climate change means there are more 'abnormal conditions': weather events that would challenge even the best system planners. **Consumers are beginning to take notice (as evidenced by their google searches) and are increasingly signaling demand for backup power solutions.**

Average total annual power outage duration (hours per customer, or SAIDI)



Google search frequency index (Google Trends data)



Sources: EIA, "U.S. customers experienced an average of nearly six hours of power interruptions in 2018", June 2020 | EIA Form 861 | Google Trends

ENCHANTED ROCK
The Power is On.

EIP portfolio spotlight:

Flexible gas-based microgrids for renewables integration & resiliency

CANARY MEDIA

How distributed energy can harden the Texas power grid

Natural-gas microgrids and battery-backed solar can hedge against climate change risk — maybe even without major policy changes.

Enchanted Rock started running its microgrids days before the crisis, not to back up customers but to bid their power reduction into the wholesale energy market of Texas grid operator ERCOT, he said. When ERCOT started to call on the state's distribution utilities to black out portions of its grid to prevent a systemwide collapse, it switched over to emergency backup power operations.

7 April 2021

Solution: Enchanted Rock provides commercial-scale customers with microgrids that are differentiated in two aspects: 1) they utilize proprietary, ultra-clean, quiet natural gas gensets alongside other resources (e.g. solar, batteries); and, 2) they own & operate those microgrids on behalf of their customers – effectively providing 'resilience as a service', E-Rock is then able to monetize the grid services that their microgrids can provide given various power market opportunities & utility programs. This revenue enables E-Rock to reduce the total cost of the solution that they offer to customers, leading to an overall cheaper, cleaner, quieter, more compact, and more dependable solution than a diesel genset.

Why it's interesting: E-Rock's solution addresses two of the most critical issues facing grid operators around the world: resiliency, and renewables integration. We believe that the company's brand of distributed, flexible, resilience-critical natural gas generation could end up being the most valuable, least dispensable form of gas-fired power generation over a decades-long march to net zero carbon. Over time, the company's microgrids can also be transitioned to run on zero-carbon resources, such as renewable natural gas, hydrogen, and increasing levels of solar & battery storage.

EIP perspective: The E-Rock team is an execution machine. Since we initially backed the company in 2017, Enchanted Rock has scaled to over 380 MW, and has delivered 99.999% uptime through nearly five hundred utility service outages. They have also written the playbook for microgrid partnerships with electric & gas utilities. As E-Rock continues to expand beyond ERCOT, we believe that the team's strong track record and the urgent need for resilience solutions to guard against extended power outages will position the company for tremendous growth.

Branch: Electrification of industry

Industrial decarbonization is currently viewed as the natural domain of hydrogen or carbon capture & sequestration, rather than electrification. But **new technology is making the formerly "impossible to electrify" not just possible – but possibly preferable given access to cheap wind & solar power, and the ability to store that energy in the form of high temperature heat.**

BOSTON METAL

- Electrification of virgin steel production
- Novel, proprietary inert anode material enables molten oxide electrolysis process previously considered unconceivable

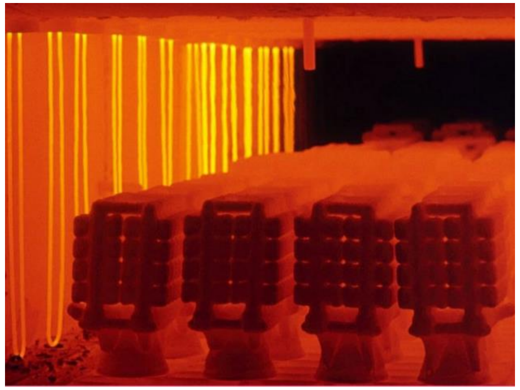
SUBLIME SYSTEMS

- Electrification of lime production – a key, carbon-intensive ingredient in cement manufacturing
- Novel, proprietary electrochemical approach

Nitricity

- Electrification of fertilizer production; modular enough to be paired directly with 'on farm' renewables
- Based on a proprietary plasma arc reactor

RONDO



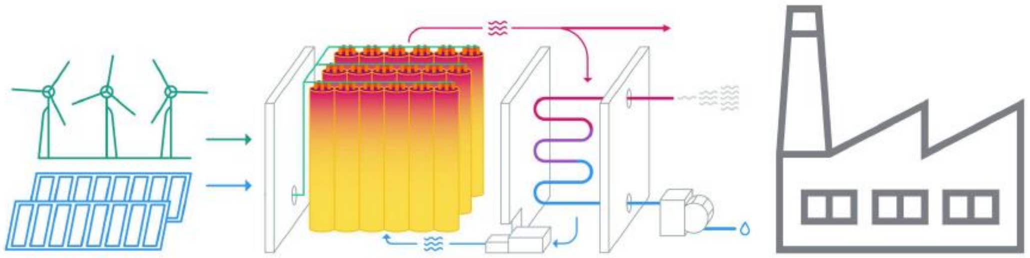
- Electrification of industrial heat for nearly any process, paired with ultra low cost thermal storage
- Proprietary system built on well-established industrial materials

RONDO

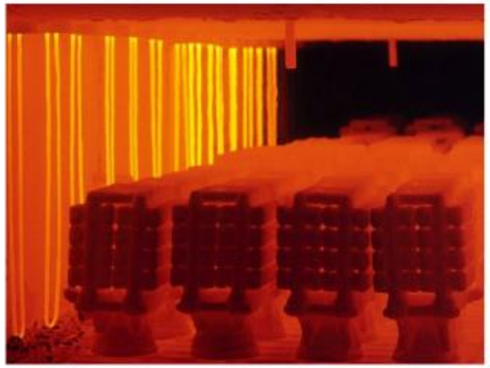
EIP portfolio spotlight:

Proven, ultra-low-cost thermal storage for industrial heat electrification

Rondo replaces fossil fuels with clean electricity and thermal energy storage.



+



$3 per kWh

- **Solution:** Rondo has developed a proprietary system to store electrical energy as high temperature heat (in a globally available, inert, ultra-low-cost material), and then dispatch that heat on-demand. The heat can be used to fuel industrial processes, may be converted back to electricity by running a steam turbine. The total installed cost for a long-duration (12 hour) unit is already well below a third that of grid-scale lithium-ion batteries, and is one of the few storage options with a credible claim to achieve <$20/kWh total cost of storage. Heat-to-heat storage cycles can achieve round-trip efficiencies north of 95%.

- **Why it's interesting:** The prospect of very low-cost storage is, of course, exciting on its own. But the concept of storing this energy as heat, in order to serve industrial heat demand, is perhaps even more compelling – opening up a new world of possibility for industrial electrification via low-cost renewable power.

- **EIP perspective:** Rondo is one of a handful of early-stage companies developing thermal storage technology, and it's not the only one to have caught on to the enormous potential of attaching storage to industrial heat. We've surveyed the landscape and have assessed many competing approaches. We view Rondo as having the best combination of technology, commercial prowess, and execution ability to emerge from the pack. Rondo is also the most commercially advanced among startups, with a customer-funded demonstration project already on the books.

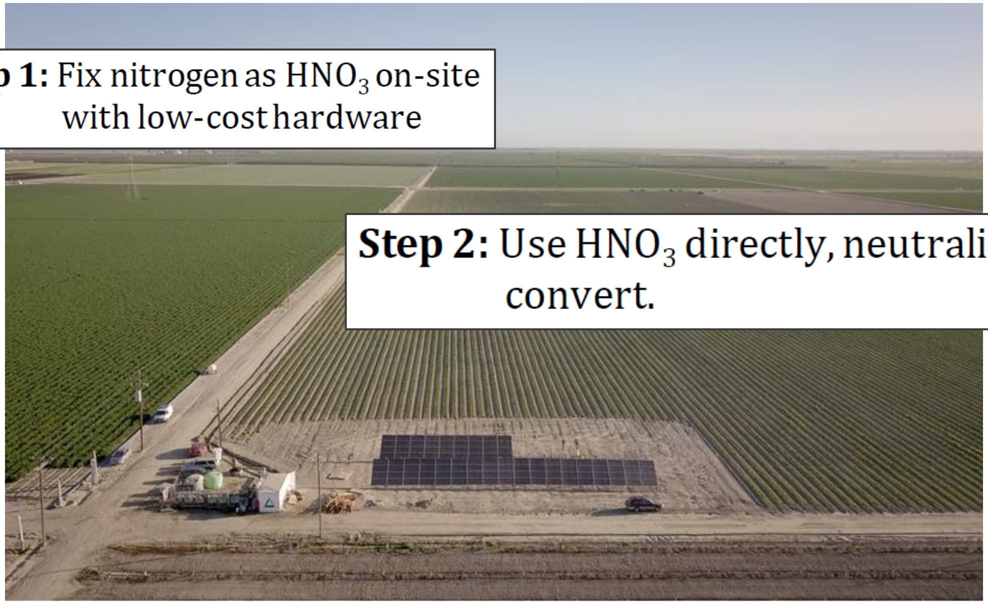
Nitricity

EIP portfolio spotlight:

Electrification of fertilizer production with modular, distributed "lightning"

Step 1: Fix nitrogen as HNO_3 on-site with low-cost hardware

Step 2: Use HNO_3 directly, neutralize, or convert.



- Nitricity installs a system at each irrigation head
- Power is purchased from a utility (or solar is installed)
- Backend financing and management of the fertilizer production assets

*Snapshot of current process

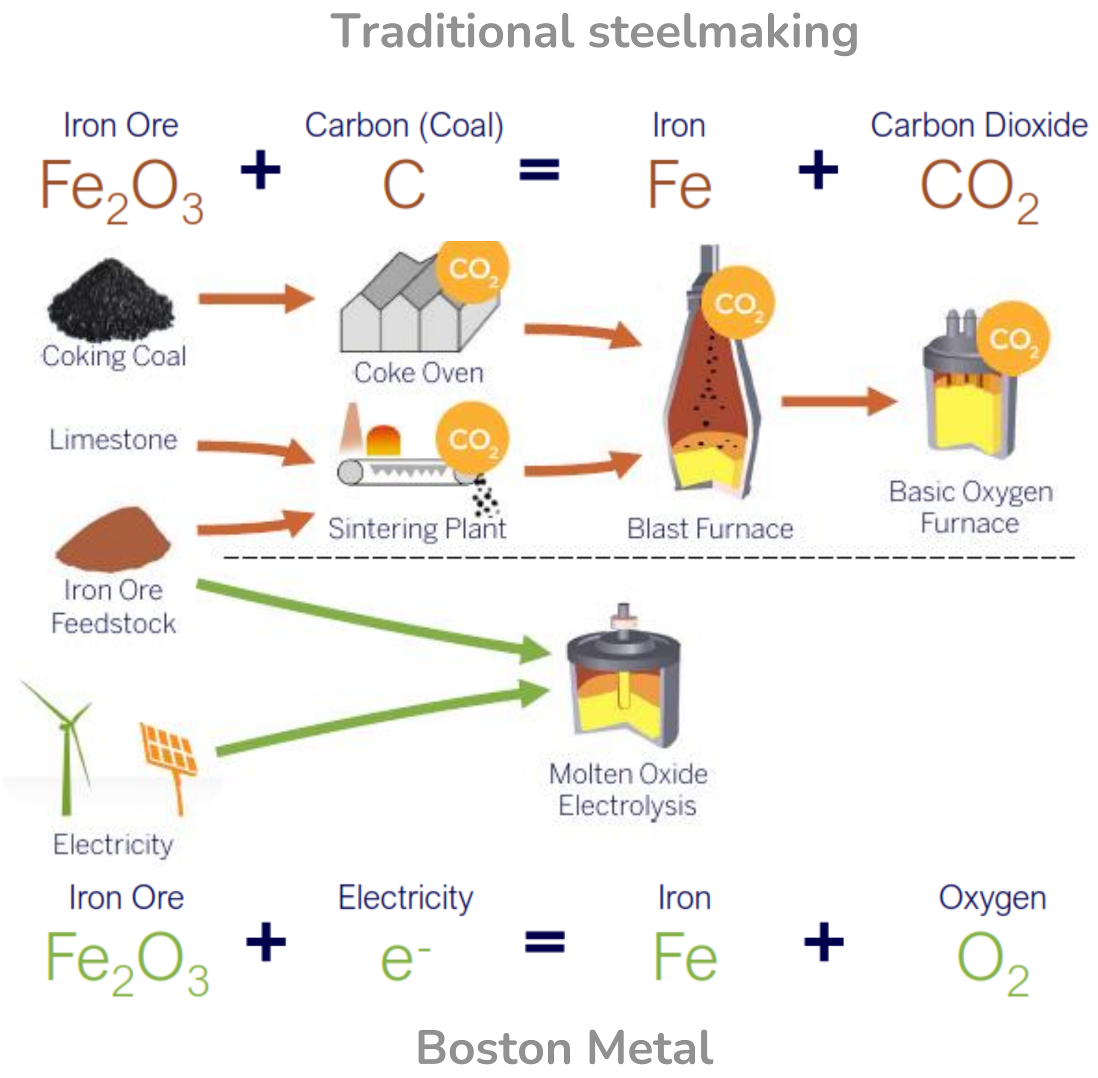
- **Solution:** Nitricity has developed a modular, plasma-based reactor system to produce nitrogen fertilizer on-farm using only air, water and electricity – which can come from either on-site renewables or the grid. This system fixes nitrogen in the form of nitric acid (HNO3). HNO3 can either be applied directly as fertilizer (on alkaline soils) or neutralized with readily available elements. Farms can tailor the recipe to their needs and can fully integrate the process with automatic irrigation systems.

- **Why it's interesting:** Nitrogen fertilizer is one of the world's biggest, most critical commodities, and production today is responsible for more than 1% of total GHG emissions. While there are other means of decarbonizing the roughly 300 global mega-facilities that produce the vast majority of the product today, Nitricity's approach offers several distinct advantages, notably: decentralization & precision application. Reducing fertilizer waste & tailoring fertilizer production on-site to specific soil needs also has great potential for reducing other direct agriculture-related GHG emissions. Because of its low capex profile, Nitricity's system can run relatively cost-effectively even following renewable generation profiles; hence, it represents a new source of potentially highly flexible electric load.

- **EIP perspective:** We led Nitricity's seed round in mid-2021 after witnessing the compelling nature of its value proposition firsthand. One of our utility LPs introduced the company to a significant local specialty fertilizer producer & grower, and within weeks Nitricity was on track for several pilot deployments. The company's modular, on-farm approach is distinctive; and the technology is surprisingly well-proven relative to its transformational potential.

EIP portfolio spotlight:

The only proven process for electrifying virgin steel production



- **Solution:** Conventional virgin steel production is a multi-step, carbon-intensive process, which inherently relies on carbon (in coke, a derivative of coal) as a reducing agent to separate iron and oxygen from iron ore. Boston Metal has developed a novel approach, which instead uses a proprietary electrochemical process involving an inert anode material, to achieve the same feat. Given low zero-carbon electricity prices, the process has a pathway to becoming economically competitive with conventional steel production.

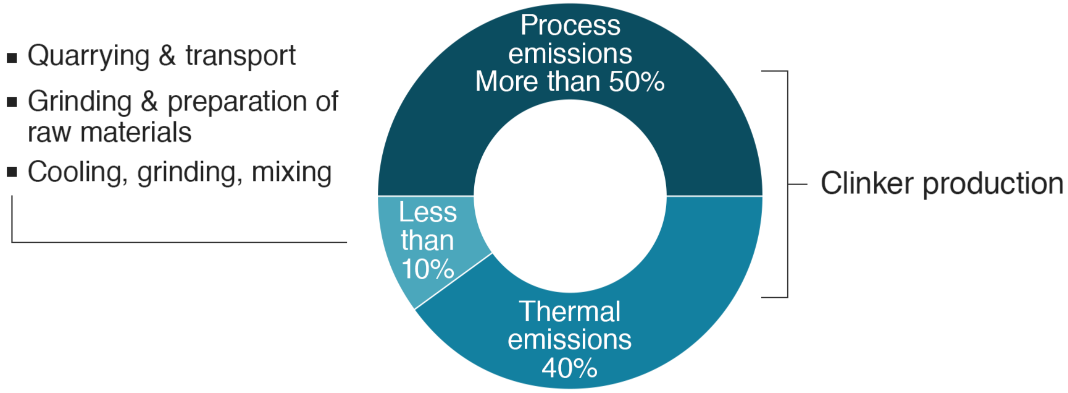
- **Why it's interesting:** In short, there is no other credible pathway for electrifying virgin steel production, and we believe electrification is the most promising pathway to full decarbonization. Other options, such as replacing fossil combustion with hydrogen, do not fully solve the problem of reducing iron ore without generating carbon emissions. The best alternative is most likely to be carbon capture & sequestration; but that inherently adds cost & complexity, while Boston Metal's approach simplifies the process and can be economically competitive.

- **EIP perspective:** EIP invested in Boston Metal in mid-2021 because we believe that the company's single-step, modular approach will be attractive to the steel industry both for decarbonization, and for more mundane economic & business reasons. The company has built an experienced team that has both incredible technical chops and – just as importantly in this sector – deep knowledge and relationships in the steel industry that will be required for success.

EIP portfolio spotlight:

Electrification of lime production for zero-carbon cement

Conventional cement production emissions



8% of global CO_2 is from cement, the most massively consumed man-made material.

Sublime's technology, developed at MIT, makes cement using electricity instead of fossil fuel.

Sublime Cement™ is a low-cost, CO_2-neutral, drop-in replacement for today' cement.

- **Solution:** More than half of the emissions from manufacturing cement are process emissions from the production of lime. Sublime has developed a novel electrochemical process for producing lime either with zero carbon emissions, or with a highly concentrated stream of emissions that's much more easily captured than in a conventional cement manufacturing process. This zero-carbon lime can then be used to produce multiple variants of cement & concrete, with the same performance attributes as today's Ordinary Portland Cement.

  Why it's interesting: If global cement manufacturing were a country, that country would be the world's third largest carbon emitter. There's no other single solution we know of with a credible claim to attacking this enormous problem; all the rest require multiple unproven changes to the cement production process – e.g. kiln conversions to electricity or hydrogen PLUS carbon capture. Sublime can hypothetically decarbonize cement on its own, or integrate with other measures in an existing facility.

- **EIP perspective:** Sublime is an incredibly compelling electrification story, enabling clean electrons to decarbonize one of the toughest sectors, which is typically considered beyond the reach of electricity. The company will undoubtedly bump up against the conservatism of the construction industry, not to mention the cement industry. However, we believe the company's solution is sufficiently attractive to overcome industry inertia; given sufficiently low clean electricity prices, it can be very economically compelling. Hence, we invested in the company in the second half of 2021.

The tree of carbon management

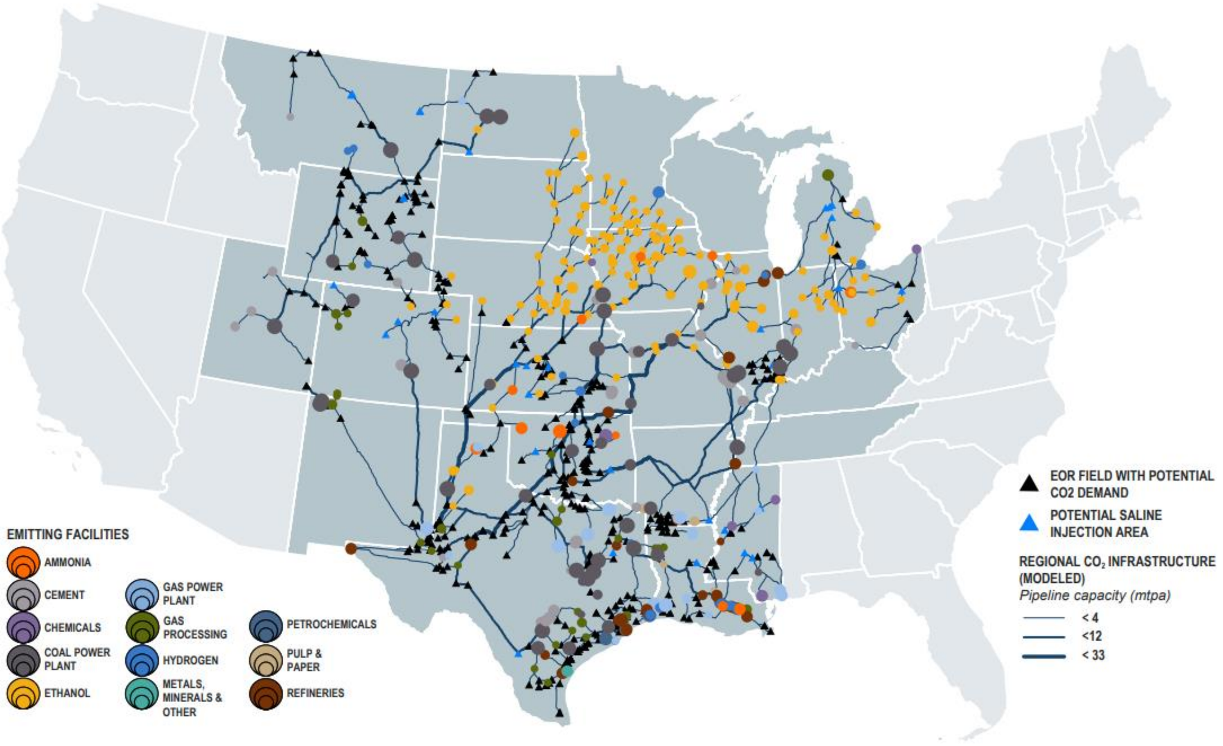
(one species among many, or decarbonization kudzu?)

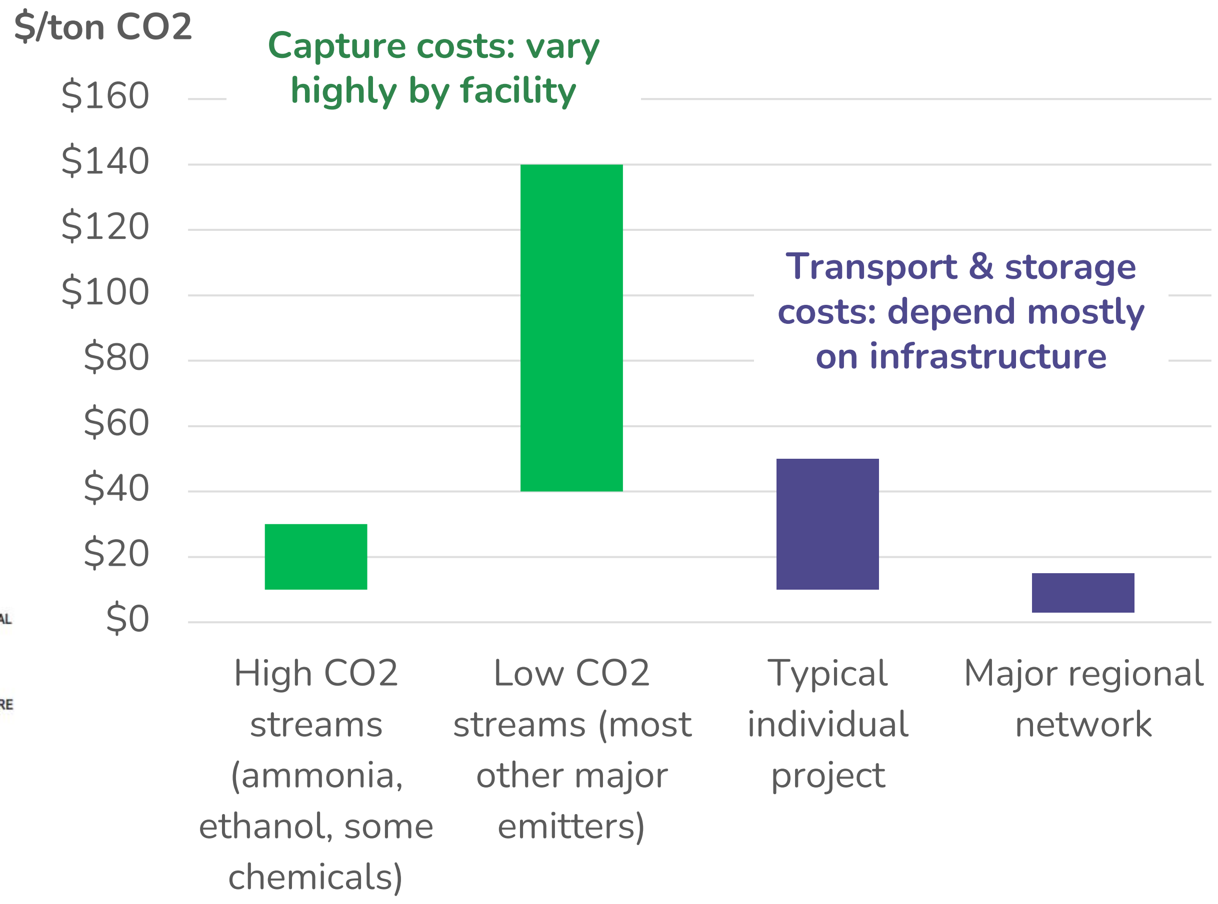
Trunk: *Some* point-source CCS. Knot? Pervasive point-source CCS.

The scope & scale of CCS remains one of the biggest uncertainties of the energy transition. CCS tends to look quite economically attractive on paper, but the devil is in the details for individual plants. **If regional transport & sequestration infrastructure begins to take shape, one can imagine a snowball effect that leads CCS to become the solution to beat for large-scale emitters.**

GREAT PLAINS INSTITUTE

Analysis of an optimal CO_2 transport & sequestration network for the central US ("great plains") region





Source: Great Plains Institute, "Transport Infrastructure for Carbon Capture and Storage: Whitepaper on Regional Infrastructure for Midcentury Decarbonization", June 2020

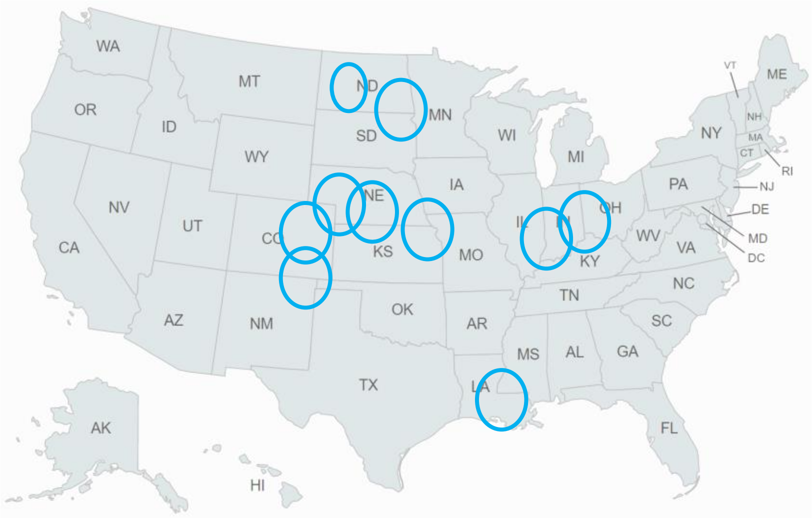
Carbon America

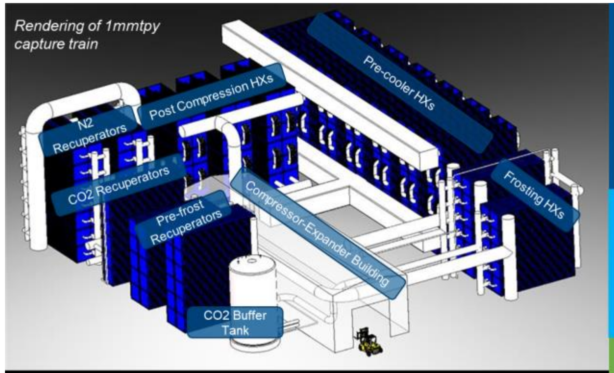
EIP portfolio spotlight:

A leading CCS project developer, *also* developing disruptive capture tech

A leading US-based CCS project developer

…and a proprietary, revolutionary capture technology





Minimal site/host impact
- Off-site construction
- No need for process heat
- Carbon America owns/manages sequester

Extremely low capital costs
- Commodity materials
- Designed for low-cost manufacturing
- Modular, scalable components
- Lower development costs

Captures 99%+ of CO_2
and removes other pollutants (SOx, Hg, NOx, PM 2.5+)

Designed for Scalability
- High volume manufacturing
- High volume commodity materials
- Flexible configuration for different gas compositions
- No chemicals to develop, manufacture, or dispose of

- **Solution:** Carbon America is on the CCS project development frontier, with one of the largest credible pipelines of near-term projects in the US market. The company's first targets are those that are generally considered the 'low hanging fruit' of CCS: i.e. industrial facilities with very high CO2 concentration effluent (such as ethanol plants). Meanwhile, the company is also developing its own proprietary capture technology, which uses cryogenics to tackle effluent with much lower concentration CO2, at 30-50% lower cost than best-in-class established solutions.

- **Why it's interesting:** The 45Q tax credit in the US has already been a game changer for CCS at a rate of $50/ton, and legislators appear likely to increase that subsidy to $85/ton. Nascent project developers are flocking to the market. However, CCS projects are among the most complex in the energy business, requiring highly specialized talent spanning site identification & project scoping all the way to operations. Carbon America – a firm with all the right skills already on-board & advanced project pipeline to show for it – is a rare find.

- **EIP perspective:** The moment is ripe for the creation of a vertically-integrated CCS "super developer", and Carbon America has a better shot than most at growing into the role. This vision prompted our investment in the company in Q4 2021. We're also extremely excited by the prospect of "FrostCC", the company's proprietary capture technology. It has the potential to significantly expand the range of viable effluent streams for CCS, thereby strengthening the company's position as a top project developer, and potentially also representing another enormous business line entirely.

Knot? "Turquoise" hydrogen as a low-touch form of CCS

So-called 'blue' & 'turquoise' hydrogen pathways strip off the carbon atoms from methane as gaseous CO2 (blue) or as solid carbon (turquoise). **The latter pathway could have an especially big impact, because it doesn't require any new pipelines to transport carbon to its ultimate resting place** – it's the closest thing to a pure 'bolt-on' to existing industrial-scale gas infrastructure.

Why blue/turquoise hydrogen?

1. **North American natural gas is wicked cheap (usually):** $10/MWh thermal energy cost

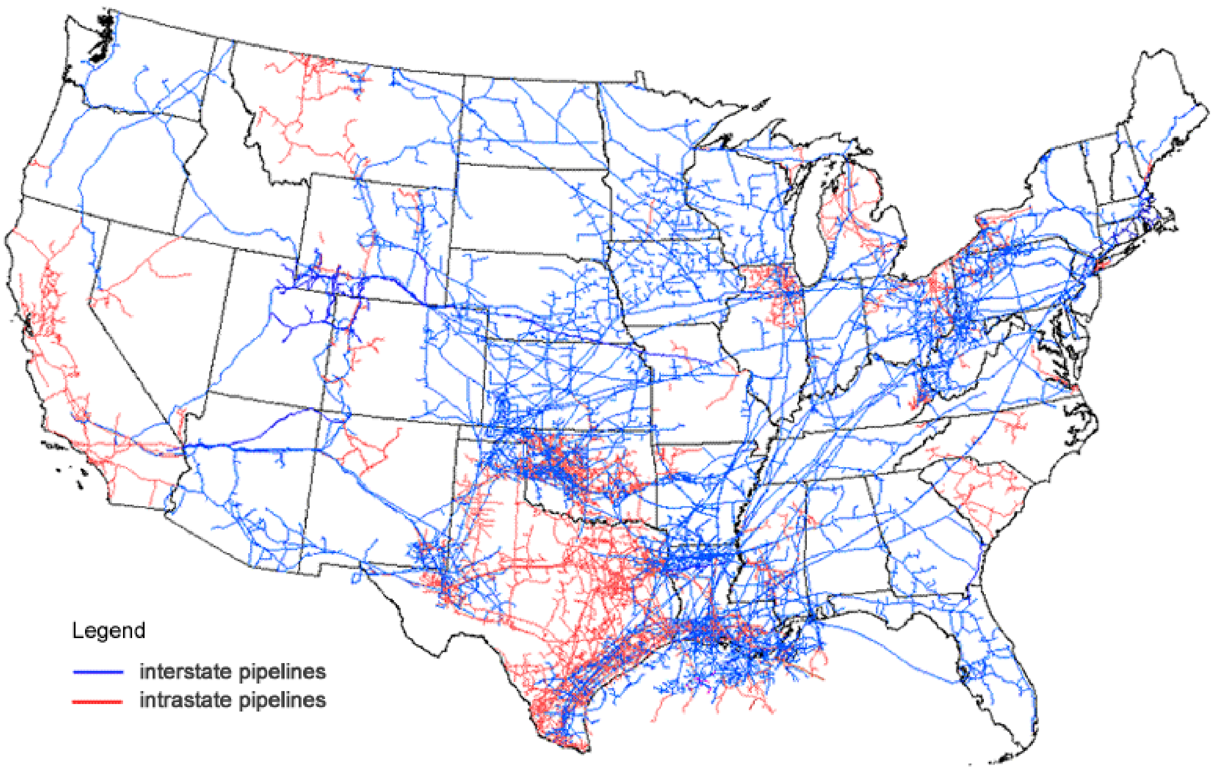
2. **We already have a massive continent-spanning pipeline network** to deliver it everywhere at industrial scale

3. At many industrial facilities, **it's probably easier to retrofit for hydrogen consumption than to retrofit for post-combustion CCS**

4. **In the case of turquoise H2, you don't need any new network infrastructure.** At worst, you need solid carbon waste disposal; at best, you can turn that solid carbon into a profit center. **Example tech developers:**

MONOLITH, BASF We create chemistry, C-ZERO, ETCH, EKONA, HazerGroup, MOLTEN INDUSTRIES

Map of U.S. interstate and intrastate natural gas pipelines

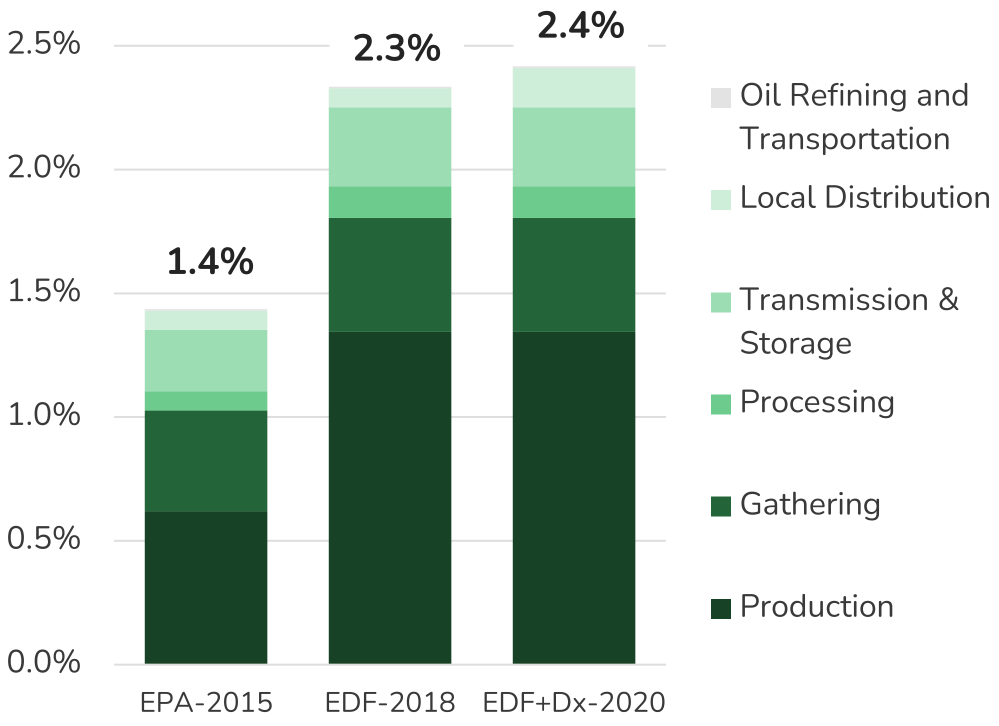


Source: U.S. Energy Information Administration, *About U.S. Natural Gas Pipelines*

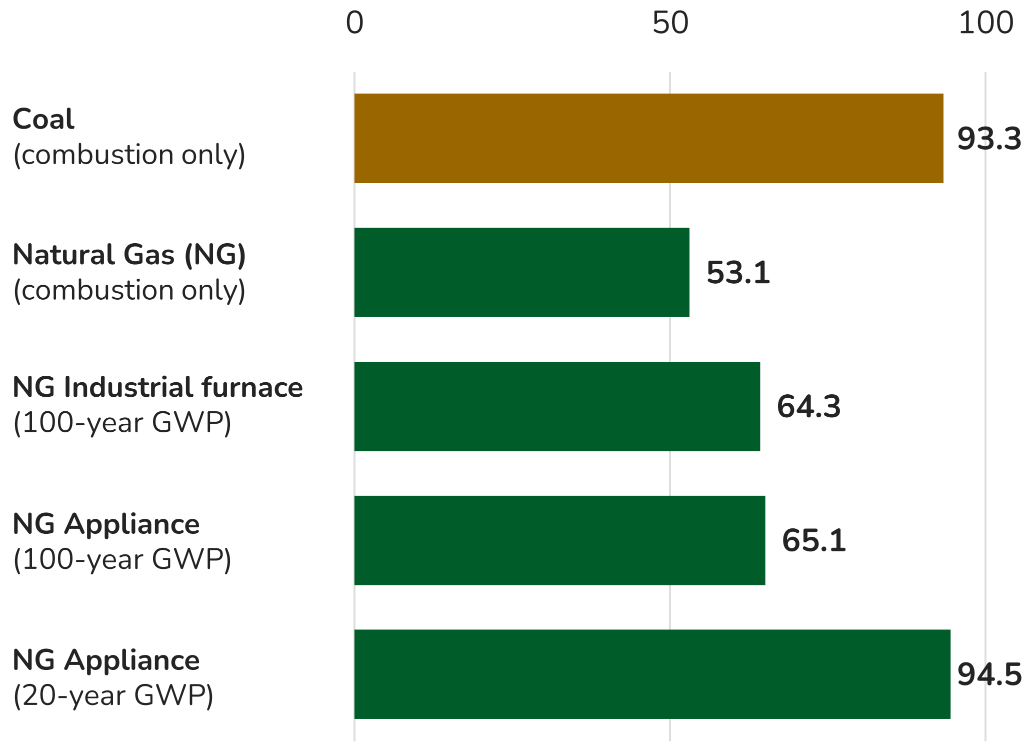
Knot? Methane emissions doom *any* pathway that relies on natural gas

Unless methane 'leaks' are dealt with all the way from wellhead to end use, there's no long-term future for natural gas in a decarbonized energy system. **This is THE existential priority for every link in the natural gas value chain**, and for any decarbonization pathway that aims to capture carbon at the end of the natural gas pipe, whether pre or post-combustion.

Methane leakage rate
(as % of gross annual production)



Carbon intensity of embodied energy
kg CO2e / mmbtu thermal output

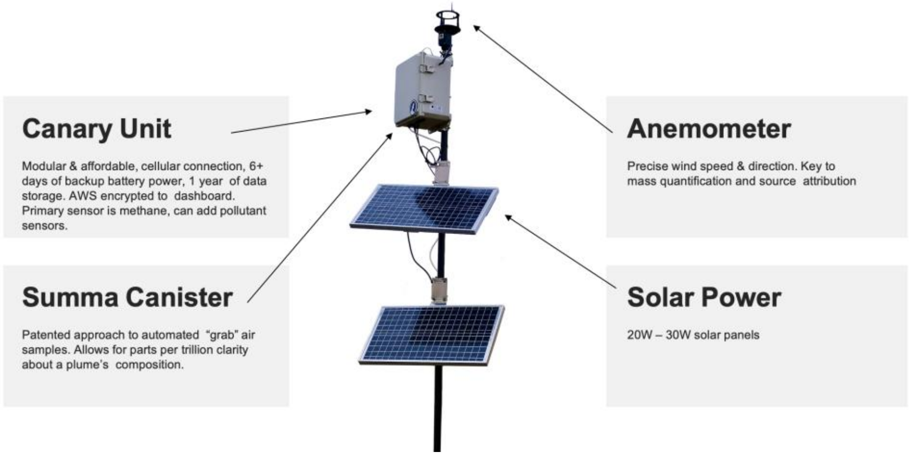


Sources: Assessment of methane emissions from the U.S. oil and gas supply chain (July 2018), AAAS / Science; A National Estimate of Methane Leakage from Pipeline Mains in Natural Gas Local Distribution Systems (June 2020), American Chemical Society; EIA carbon intensity of fuel combustion (lower bound used for coal); lifecycle emissions for coal combustion not shown (generally ~5% increase). Note: "GWP" refers to global warming potential, a measure normalized to carbon dioxide equivalent units.

PROJECT CANARY

EIP portfolio spotlight:

Monitoring, analyzing, and certifying ultra-low-emissions natural gas



Solution: Project Canary provides a software package that ingests data from a variety of sensors to monitor and analyze methane emissions from natural gas infrastructure in real-time. The team has developed their own proprietary ground sensor package, which they prefer to use due to its high resolution, but they do not view themselves as an inherently hardware-focused company. They use this technology package to independently certify methane emissions from gas producers or pipeline owners, and offer gas buyers verified low-emissions (often called "responsible") gas in the most scientifically rigorous and auditable way possible.

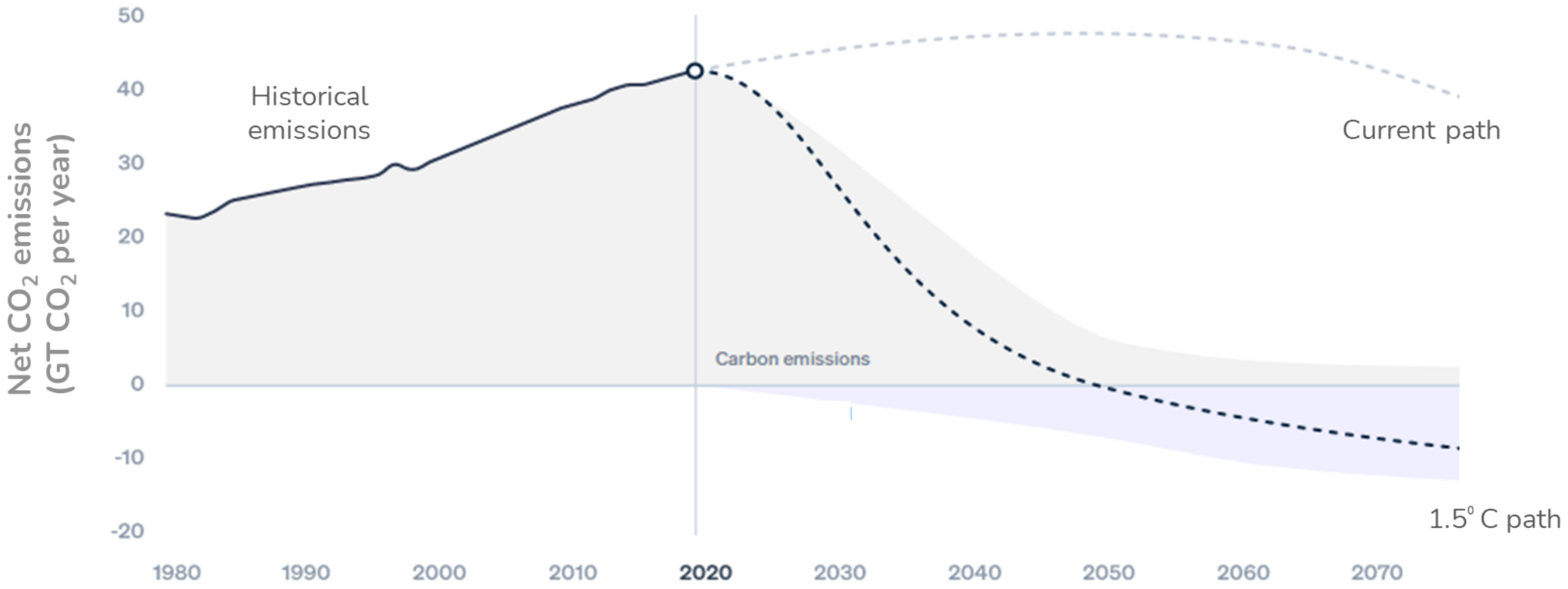
Why it's interesting: Methane emissions – particularly from production & gathering systems – represent an existential risk to the social license to operate of the entire natural gas value chain. Without quickly getting these emissions under control, there is a growing risk that policymakers & regulators will cut off otherwise cost-effective decarbonization pathways for natural gas assets, from pipelines to power plants. Utilities & other large gas buyers need a way to demonstrate to these stakeholders that they are making progress towards best-in-class, low-emissions gas procurement.

EIP perspective: EIP invested in Project Canary in mid-2021 with the thesis that we are at a pivotal point for methane emissions reduction. Our utility partners recognize the critical importance of dealing with fugitive emissions, and are seeking ways to improve both their own operations and to influence upstream decision making. We believe the company is well positioned to help utilities make the case to regulators that rigorous certification is the best way to reduce emissions, at one of the lowest achievable costs per ton of CO2 equivalent.

Trunk: We can't get keep warming to 2⁰ C without *some* carbon removal

The IPCC tried to create scenarios that don't rely on ***net negative*** emissions trajectories in order to confidently stay below 1.5° C. **It's practically impossible.** At some point we're going to have to start removing carbon from the atmosphere to undo the emissions we're unable to mitigate fast enough.

Average of 90 emissions trajectories modeled by the IPCC to achieve a 1.5° C climate pathway

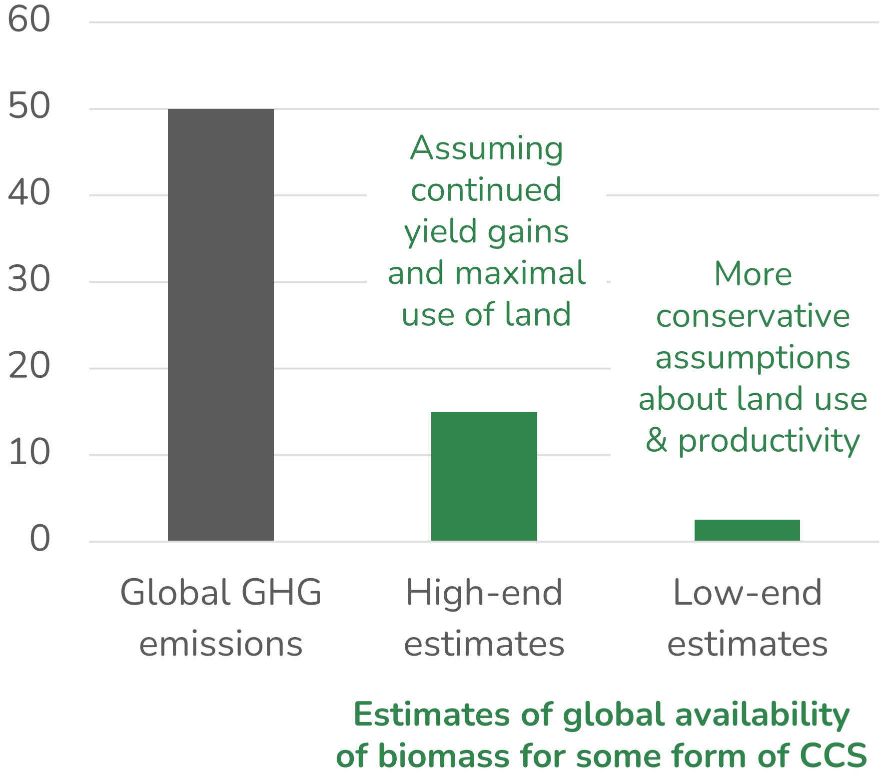


Sources: IPCC; International Energy Agency; Global CCS Institute.

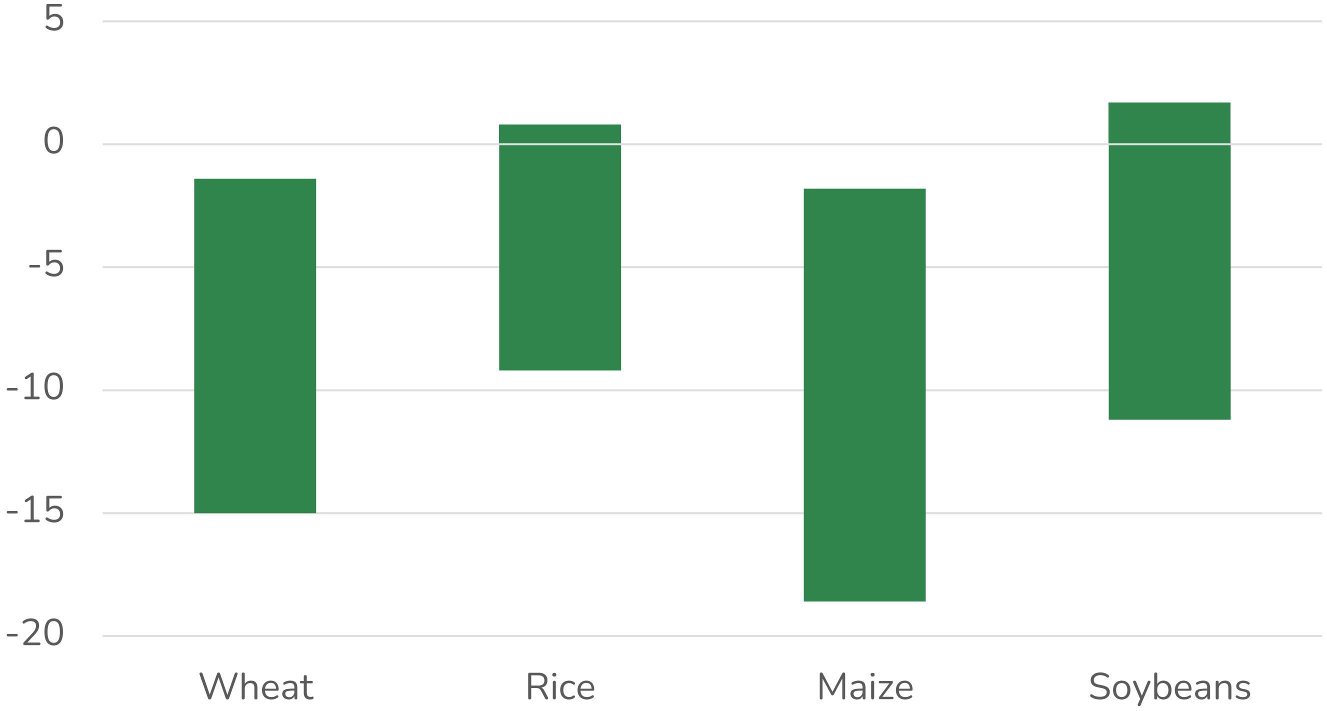
Knot? Biomass-based removal falls short

Many net-zero pathway models end up relying on a dramatic increase in the use of biomass for a combination of energy & permanent carbon sequestration (via processes referred to by the acronyms BECCS and BiCRS). **Given many competing uses for land & biomass, we find it unlikely that these processes live up to their theoretical potential.**

Global CO2e emissions vs. biomass-based carbon removal & storage potential (Gt)



A reason to be cautious… Estimated percentage change in average crop yield by end of century (2.6° C scenario)



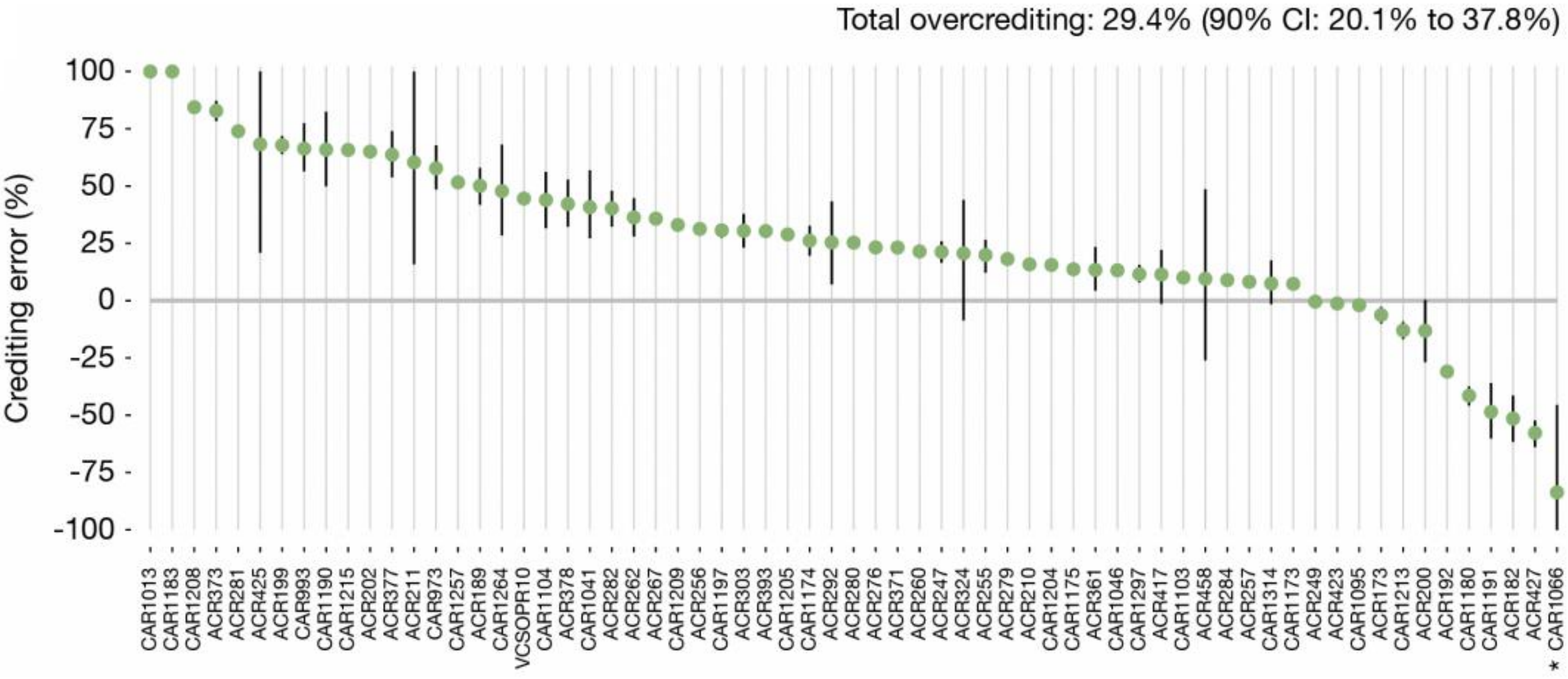
Sources: Innovation for Cool Earth Forum, "Biomass Carbon Removal & Storage (BiCRS) roadmap", Jan 2021 | "Temperature increase reduces global yields of major crops in four independent estimates", Chuang Zhao et al, July 2017. Note: "Biomass-based CCS" refers to processes that capture carbon via photosynthesis in plant mass, and then permanently sequester that carbon outside of the natural carbon cycle (i.e. not stored in living biomass).

Forestry-based carbon removal is also coming under an increasing degree of scrutiny, due to questions about its sustainability, longevity, and even basic measurement

A recent, credible analysis by the non-profit firm CarbonPlan showed that California's forest offset plan – the largest of its kind in existence – over-credited the actual carbon removed from forestry by nearly 30%.

(carbon)plan

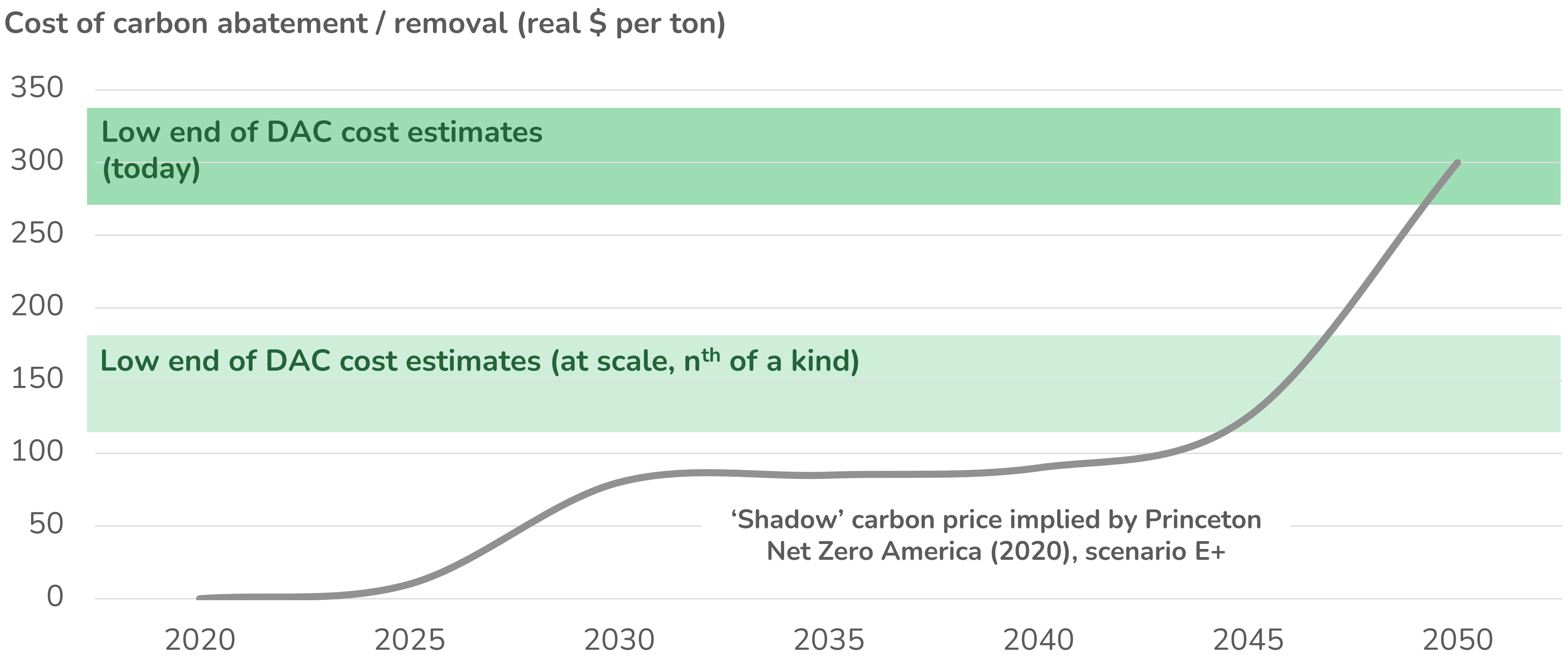
Estimated carbon crediting error by forest offset project analyzed



Source: "Systematic over-crediting of forest offsets", CarbonPlan, 2021

Knot? DAC for days… (DAC wins out over 'direct' decarbonization in several big end uses)

Unlike its big sister point-source CCS, Direct Air Capture (or DAC) tends to look silly on paper until decades from now. But: **never bet against easy.** Continuing to burn fossil fuel while DAC-ing away the emissions might just end up winning the day simply because its *easier* for some big energy end uses. In a few cases – e.g. aviation – DAC might actually be the best long-term solution.



Source: Princeton University, "Net Zero America: Potential Pathways, Infrastructure, and Impacts", Dec 2020

Follow-ups?

- **Entrepreneurs** working on more upsets?
- **Investors** looking for pragmatically optimistic bets?
- **Operators** seeking the most cost-effective pathway to net-zero carbon?

Let's talk.