Ankeron:
A DAC Hub Study in the Pacific NW

To advance carbon storage in basalts, direct air capture, and an equitable energy transition

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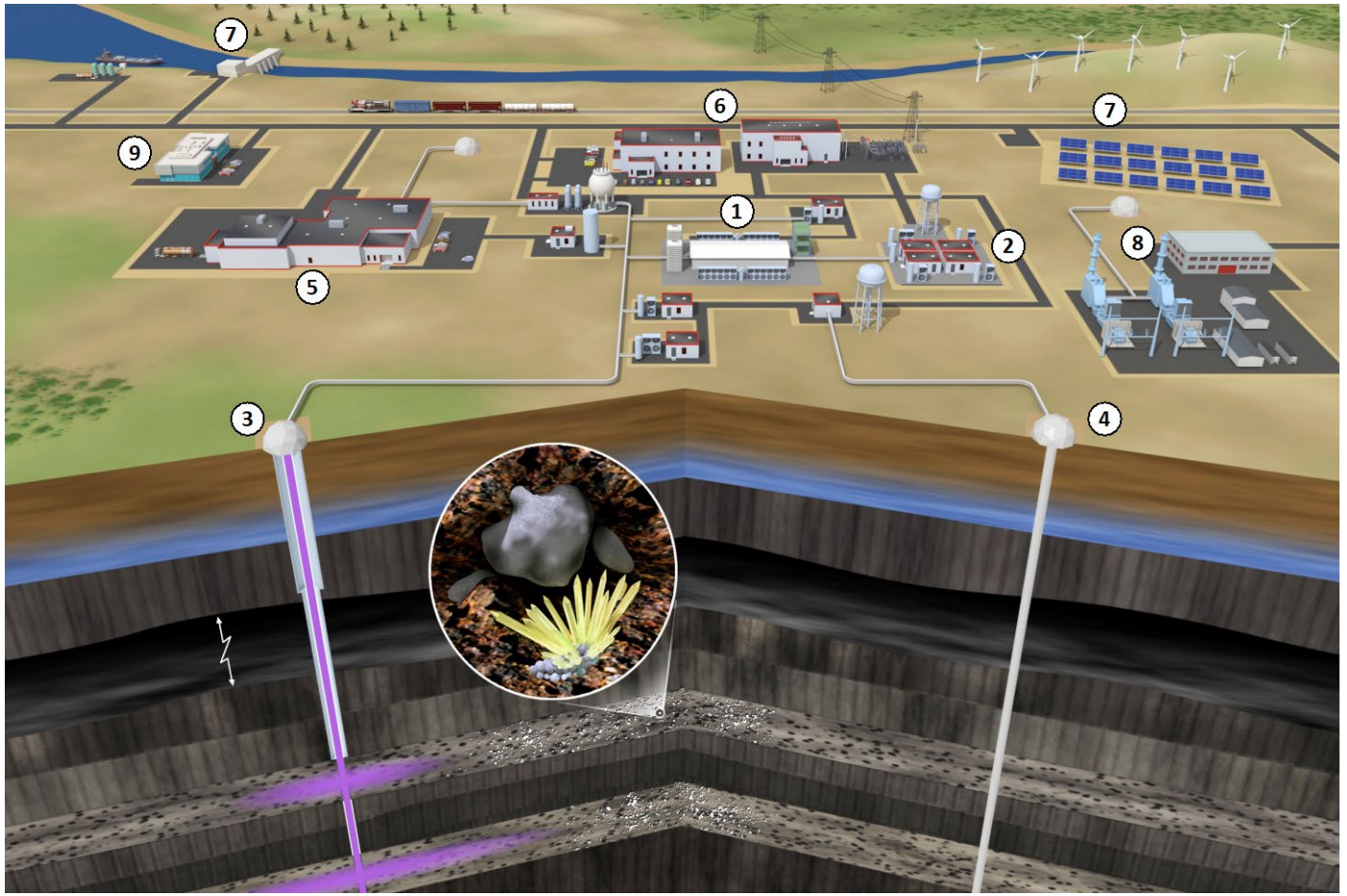
FE-0032377

Project overview

Federal Funds: $2,999,754
Non-federal Cost Share: $1,134,999
Total Project Cost : $4,134,753

Study the feasibility of a regional direct air capture and carbon management hub in the Pacific Northwest that demonstrates a commercial scale-up potential and a viable pathway to the DOE Carbon Negative Shot target of <$100/ton of durable CO_2 removals by 2032.

Duration: 2 years, *currently in award negotiations*



CORE TEAM

RMI ENERGY. TRANSFORMED. · Carbfix · Pacific Northwest NATIONAL LABORATORY

TECHNOLOGY PARTNERS

Heirloom · Sustæra · REMOVR Carbon Removal Solutions · twelve · LanzaTech · Blue Planet · FLUOR

STAKEHOLDER ENGAGEMENT

WASHINGTON STATE UNIVERSITY TRI-CITIES · WASHINGTON STATE DEPT OF NATURAL RESOURCES

Vision

A regional Direct Air Capture hub in the Pacific Northwest that:

Catalyzes the development of Direct Air Capture (DAC) and carbon management technologies, moving them to higher Technology Readiness Levels using clean power.

Unlocks the >10,000 Gt storage capacity of basalts in the United States, facilitating a path to successful EPA Class VI permitting for mineral storage.

Ensures best-in-class outcomes for people – across workforce, equity and justice – leveraging deep engagement, innovative institutional design, and local expertise.

Leadership team

Carbfix

Is alone in having done commercial-scale mineral storage and demonstrating the **DAC+ mineral storage** value chain and has unique data and IP from this.

Pacific Northwest NATIONAL LABORATORY

The sole other entity to have successfully completed a mineral storage pilot and has a uniquely relevant knowledge base, research and lab capabilities, and regional expertise.

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Experience and expertise conducting techno-economic analysis of CDR technology and supporting the development of industrial hubs, including in the Pacific NW.

World-class *and* regional expertise.

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Storage in basalts

Basic mechanics

- Two methods tested:
  a. By Carbfix: requires water
  b. By PNNL: requires supercritical or liquid CO2

- In both methods:
  - The carbon is trapped within stable carbonate minerals
  - The carbon is permanently fixed and there is negligible risk of it returning to the atmosphere

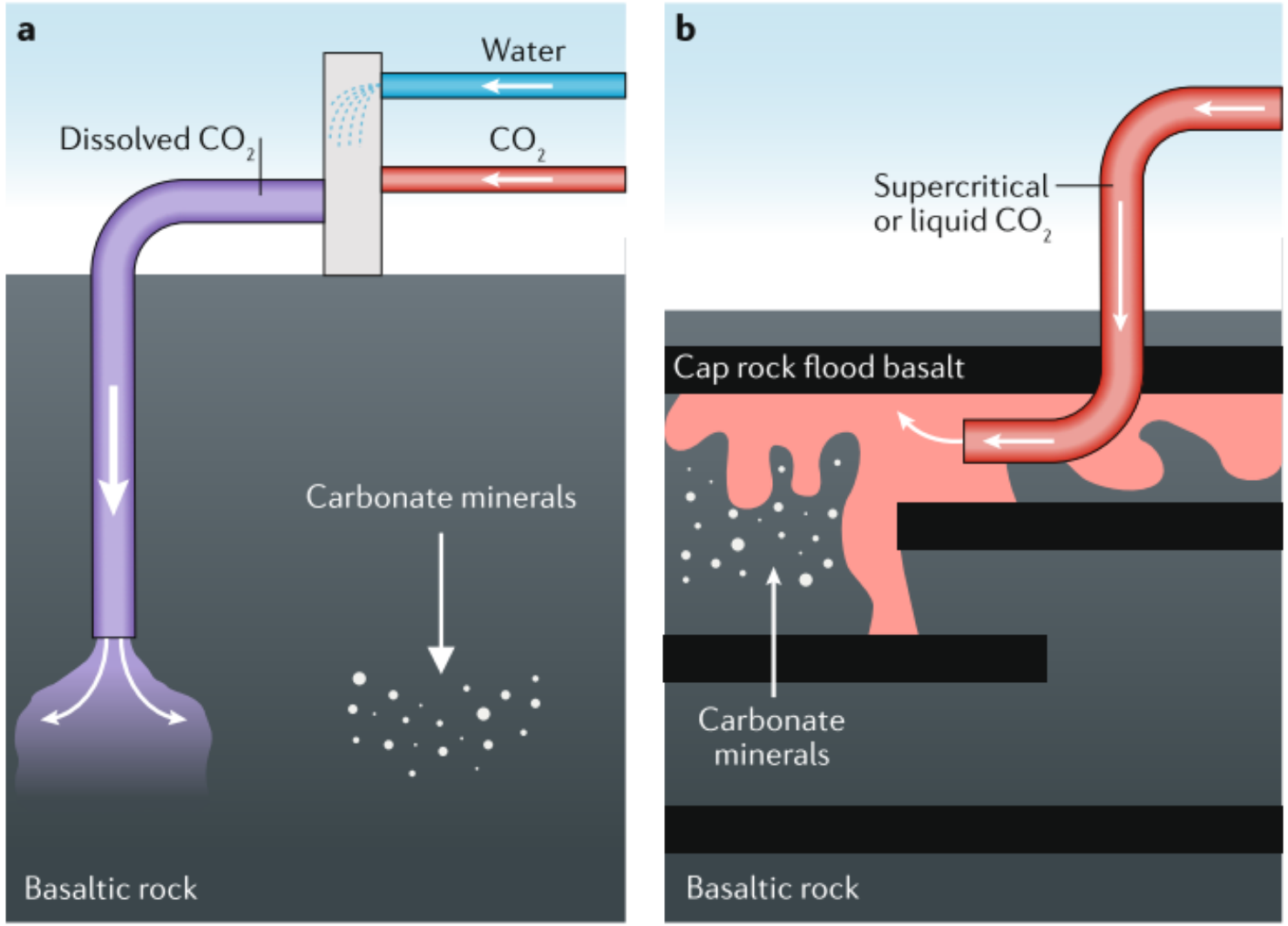

Fig. 4 | **Comparison of carbon-injection methods. a** | The CarbFix method involves the dissolution of CO_2 in water during injection into a basaltic reservoir. **b** | During the Wallula basalt pilot project, pressurized liquid CO_2 was injected into basalts. The figure is not to scale.

Image courtesy of Carbfix (2020)

Results from prior testing

2006: Laboratory testing at PNNL confirmed rapid carbonation.

2012: Carbfix experiment in Hellisheidi, Iceland showed 95% carbonation within two years.

2013: PNNL's Wallula experiment showcased significant carbonation in two years.

2014-2020: Upscaled Hellisheidi project stores >12,000 tonnes annually, with 65% carbonation within two months – with no sign of decreasing permeability or carbonation.

Source: Sandra Ó Snaebjörnsdóttir, Bergur Sigfússon, Chiara Marieni, David Goldberg, Sigurður R Gíslason, et al.. Carbon dioxide storage through mineral carbonation. Nature Reviews Earth & Environment, 2020, 1 (2), pp.90-102.

The permanence offered by these methods could translate into valuable benefits

- Public acceptance
- Lower monitoring costs
- Lower long-term discounts or liabilities from carbon returning to the atmosphere

Source: Sandra Ó Snaebjörnsdóttir, Bergur Sigfússon, Chiara Marieni, David Goldberg, Sigurður R Gíslason, et al.. Carbon dioxide storage through mineral carbonation. Nature Reviews Earth & Environment, 2020, 1 (2), pp.90-102.

Risks that may need to be managed

- Induced seismicity (with method a., because of water volumes)
- Groundwater contamination (from the mobilization of metals)

Source: Sandra Ó Snaebjörnsdóttir, Bergur Sigfússon, Chiara Marieni, David Goldberg, Sigurður R Gíslason, et al.. Carbon dioxide storage through mineral carbonation. Nature Reviews Earth & Environment, 2020, 1 (2), pp.90-102.

The path to permitting these methods in the US is unclear

- Process for meeting EPA standards for **Class VI Well permits** remains unclear - current regulation is specifically designed for storage in deep saline aquifers.

- This project presents **opportunities to set precedent** and gain permitting clarity from DOE and EPA.

- **Potential aids for EPA decision-making** that this project *may* support over time:
  - Regional geologic characterization.
  - Adequate subsurface characterization, including saline mapping for groundwater analysis.
  - New seismic and magnetic surveys, including leveraging emerging technologies.

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The Pacific NW

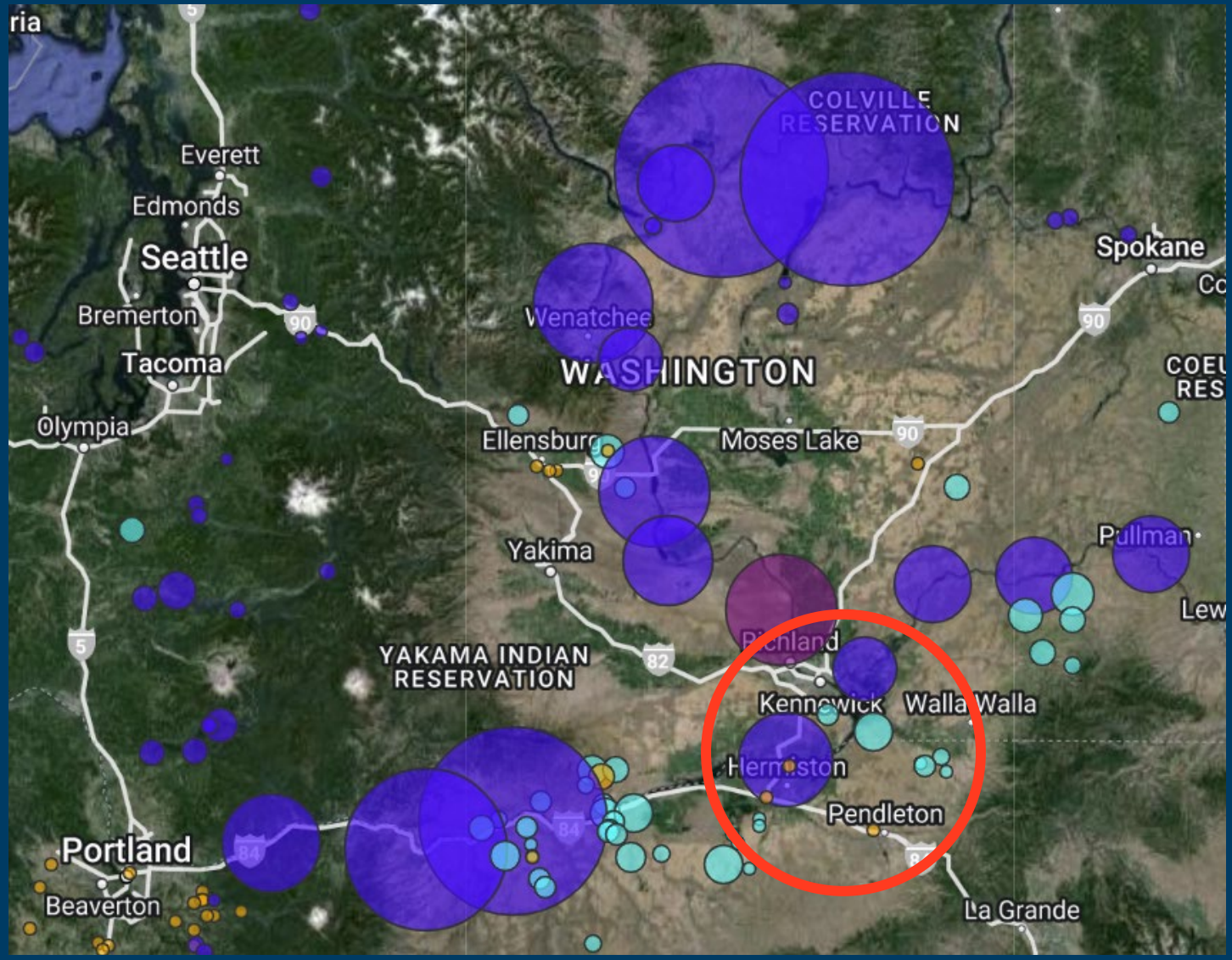
Ideal geology for storage in basalts

- Home to the Columbia River Basalt Group
  - Age ~ 6-17 million years
  - Area span ~ 210,000^2 km
- Minimum storage potential of Eastern WA and OR ≥181 Gt CO_2
- Significant research conducted on mineralization efficacy locally (PNNL)

Map courtesy of Trista Thornberry-Ehrlich and Michael Barthelmes (Colorado State University) with information from Alt and Hyndman (1995, accessed 2013). Base map by Tom Patterson (NPS, 2019)

Strong investment in low-carbon energy

Across hydro, solar, and wind



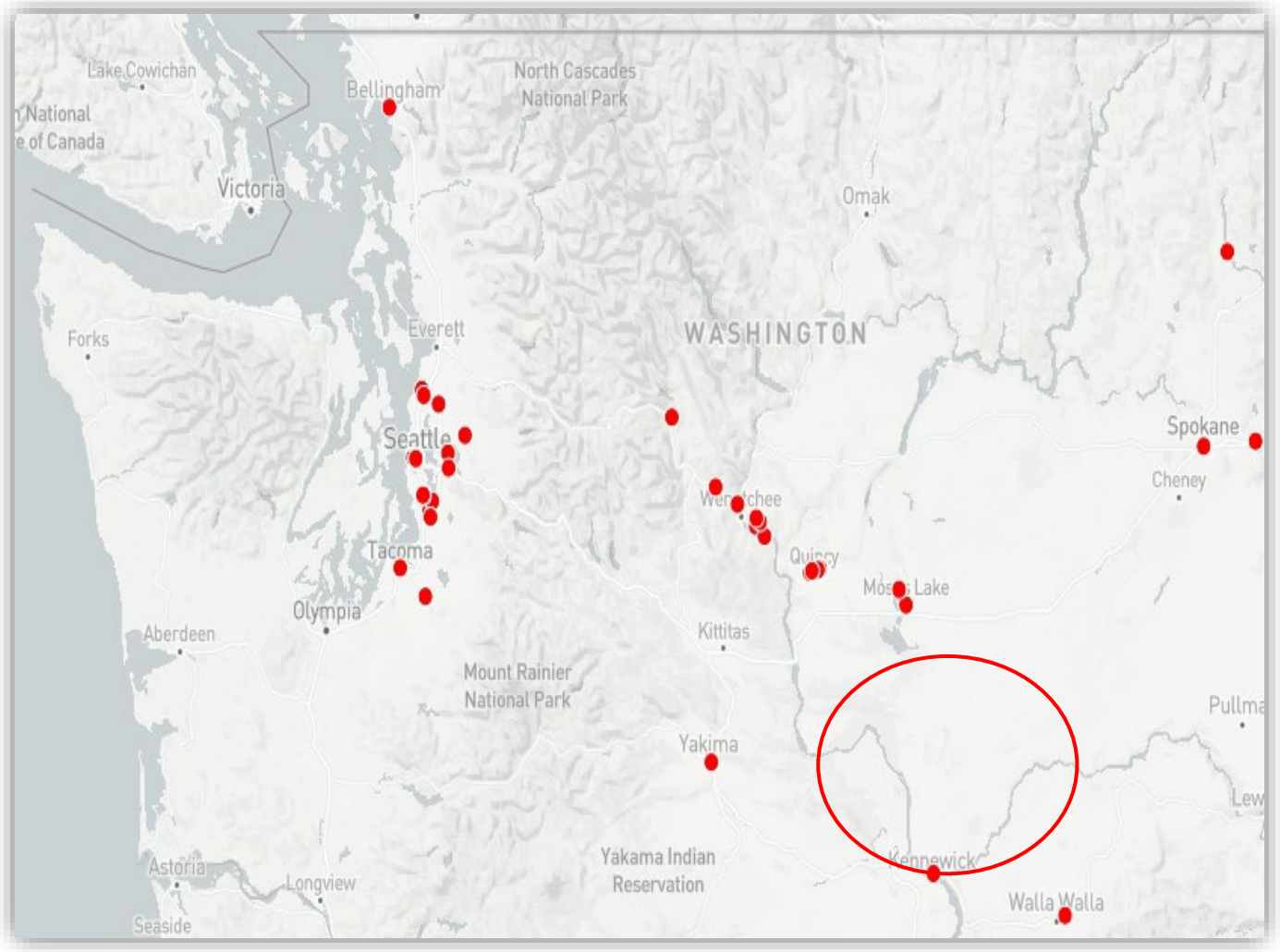
Map courtesy of Northwest Power & Conservation Council online energy mapping tool (2024)

Blue Circle: - Hydropower

Teal Circle: - Wind Farm

Yellow Circle: - Solar Generation

A growing number of data centers



Data center map courtesy of Baxtel Data center locator (2024)

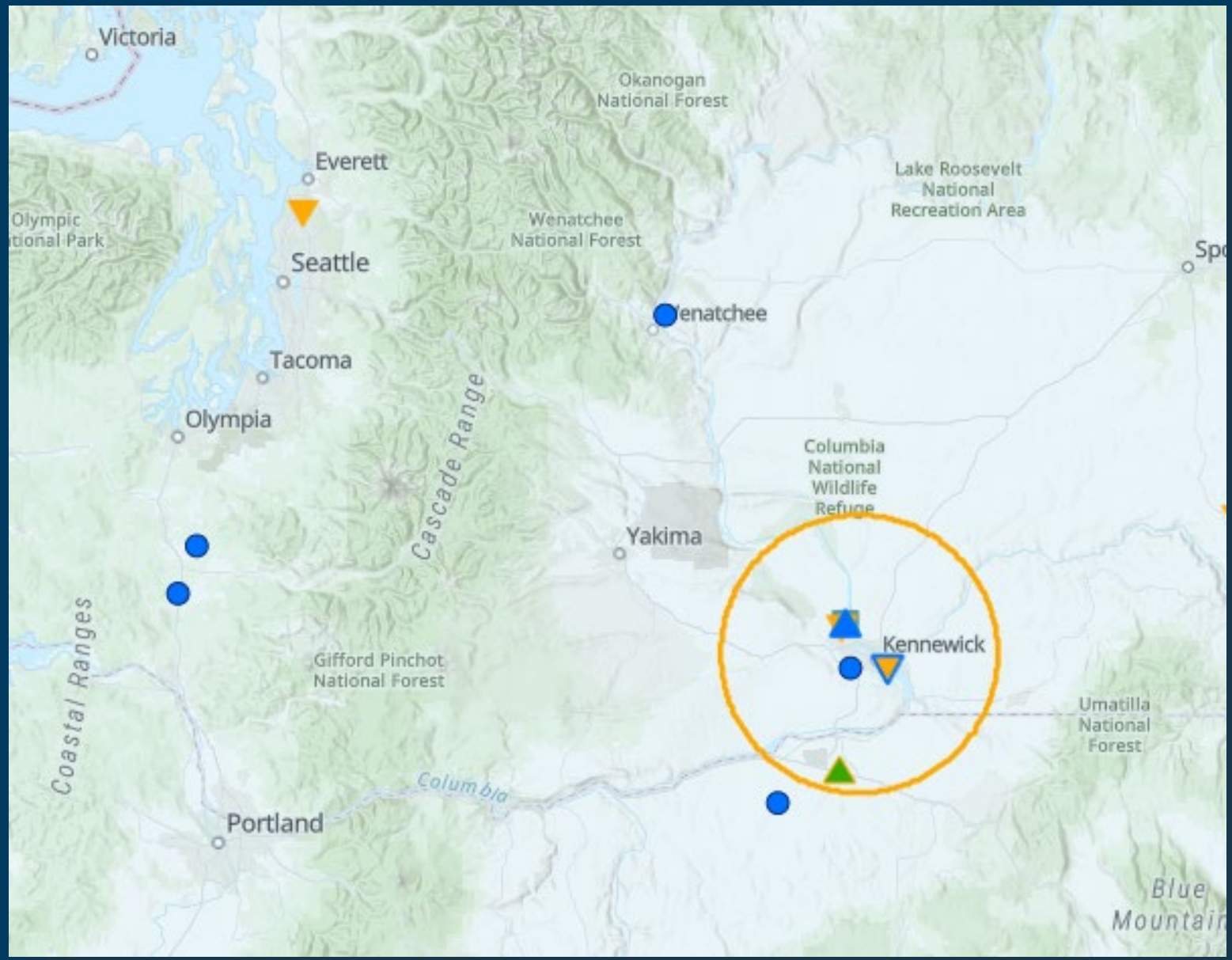
Red dots = Data Center Location

Additional compelling factors for a DAC Hub in the PNW

- Semi-arid conditions = favorable to diverse DAC and conversion technologies
- Railway & barge transportation along the Columbia River = a useful channel
- Research clusters and industries = strong technical workforce

Site selection is pending

We will examine feasibility at sites across the region, from a "home-base" in the Tri-Cities



Carbon removal and storage hub locations in PNW.
Image courtesy of the Department of Energy's Carbon Management Toolkit (2024)

DAC and utilization tech suited to the region

Photo of Heirloom's proprietary limestone CDR methodology. Image courtesy of Heirloom & EnergyTech (2023)

Core technology partners

Heirloom	**TRL 8**	Accelerated weathering using low-cost sorbent and passive air contacting
Sustaera	**TRL 5**	Sorbent with rapid, low-temperature regeneration & selective integrated heating
REMOVR Carbon Removal Solutions	**TRL 5**	Low-cost zeolite sorbent with low regeneration energy requirement and novel water removal technique
twelve	**TRL 7**	Producing jet fuel from CO_2, water, and electricity using a novel electrolysis technology

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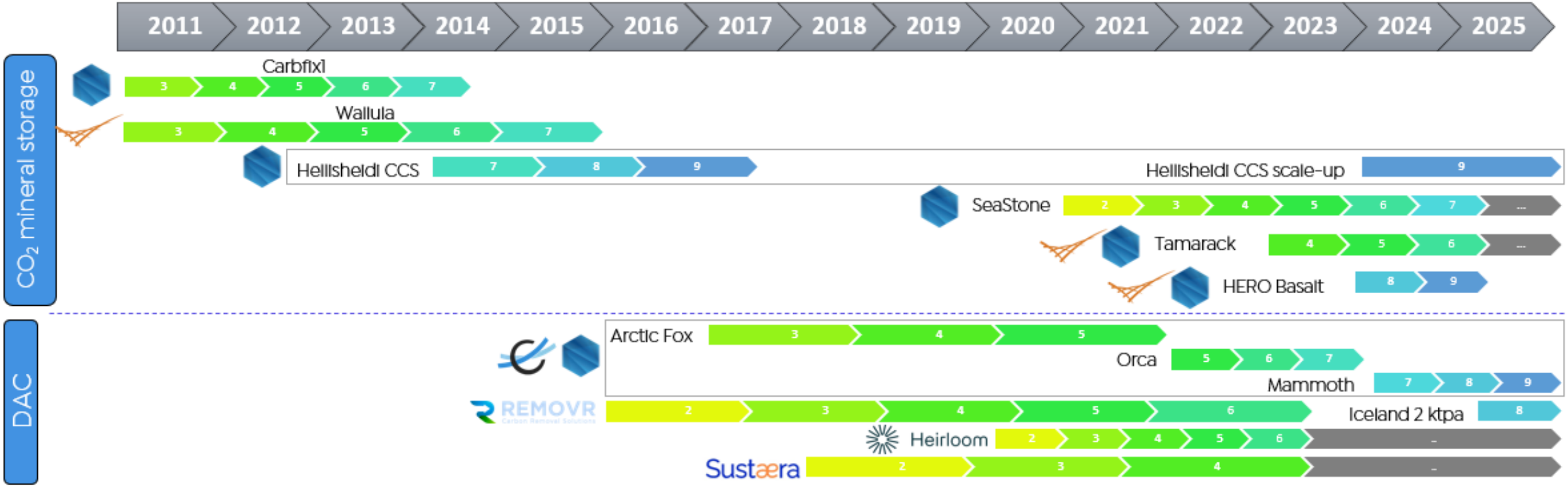
Ankeron partners are leading innovative DAC projects outside of the hub consortium



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Our plan and current status

Project goals are designed to maximize sustainability while reducing cost and barriers to scale-up

Goal 1 – *Commercial Scale-up:*	• Validate potential of a mineralization-based DAC Hub in the PNW region, catalyze market lift-off, and demonstrate a viable pathway towards the Carbon Negative shot goal of <$100/tonne of CDR.
Goal 2 – *Infrastructure:*	• Determine needs for the Hub to sustainably build-out diverse DAC and utilization technologies towards 1 MTA capacity with potential for expansion.
Goal 3 – *Climate Impact:*	• Select DAC technologies that maximize climate impacts with respect to performance, energy sources and lifecycle emissions while minimizing resource usage and environmental impact.
Goal 4 – *Responsible Demonstrations*:	• Develop business models and CBPs that maximize Justice40 benefits to communities, minimize negative impacts, Invest in the American Workforce, advance DEIA, and promote community engagement.

Project scope and technical components for budget period 1

Key deliverables during budget period #1
Initial Hub Business Plan
Financial plan outlining financing for hub
Technology Maturation plan & Technology selections for DAC & Conversion
Community Benefits Plan Proposal
Regional analysis & site selection for storage / hub location
Preliminary LCAs and DAC Hub Data Tables
Hub governance structure

Key milestones completed by FECM Review 2025
Permitting workflow for injection and storage
Submission & subsequent decision on the down selection continuation application
Regional networking & initial community agreement for site(s) location(s)
Conceptual design for the initial DAC Hub capacity (minimum 50 KTA CO2) integrated with required CO2 storage and/or CO2 conversion

Ankeron consortium is committed to early and ongoing engagement with a wide variety of regional stakeholders

Dedicated to investing in regional workforce

Training programs via local universities (WSU)

Competitive wage commitment

Potential for ~200 permanent jobs at Mt scale

Establishing early communications with a wide array of stakeholders:

- Tribal Nations
- Workforce & Labor Unions
- Community Development and Higher Education
- Large Landowners, AHJ's and Local Governments

RMI and Ankeron team have begun laying the foundations in the region for responsible CDR deployment

The PNW CDR community gathered in Seattle on April 18th, 2024 for presentations and discussions on responsible regional CDR deployment.

The event was co-hosted by RMI & the Carbon Business Council, with PNNL & WSU attending.

We envision a hub that is a boon for states and communities in the Pacific NW, and for the CDR field

WORLD-LEADING INNOVATION

STORAGE RD&D

- Carbfix (world leader in CM*)
- Pacific NW National Lab (PNNL) provides research and testing

DAC RD&D

- Leading companies demonstrate multiple approaches and cross the chasm to commercial viability

ECONOMIC SUSTAINABILITY AND COMPETITIVENESS

CDR MONETIZATION

- 45Q
- State & local govt. procurement
- Voluntary corporate purchases

COST COMPETITIVENESS

- Low-cost low-carbon energy and water = sustainable cost advantage
- Economies of scale and learning

OWNERSHIP AND VALUE FOR COMMUNITIES

COMMUNITY ENGAGEMENT

- Marginalized and under-represented communities
- Local and state governments
- Community organizations

EQUITY, JOBS, AND JUSTICE

- Robust environmental protections
- Training and jobs
- Innovative models of ownership and governance

Notes: *Carbon Mineralization.