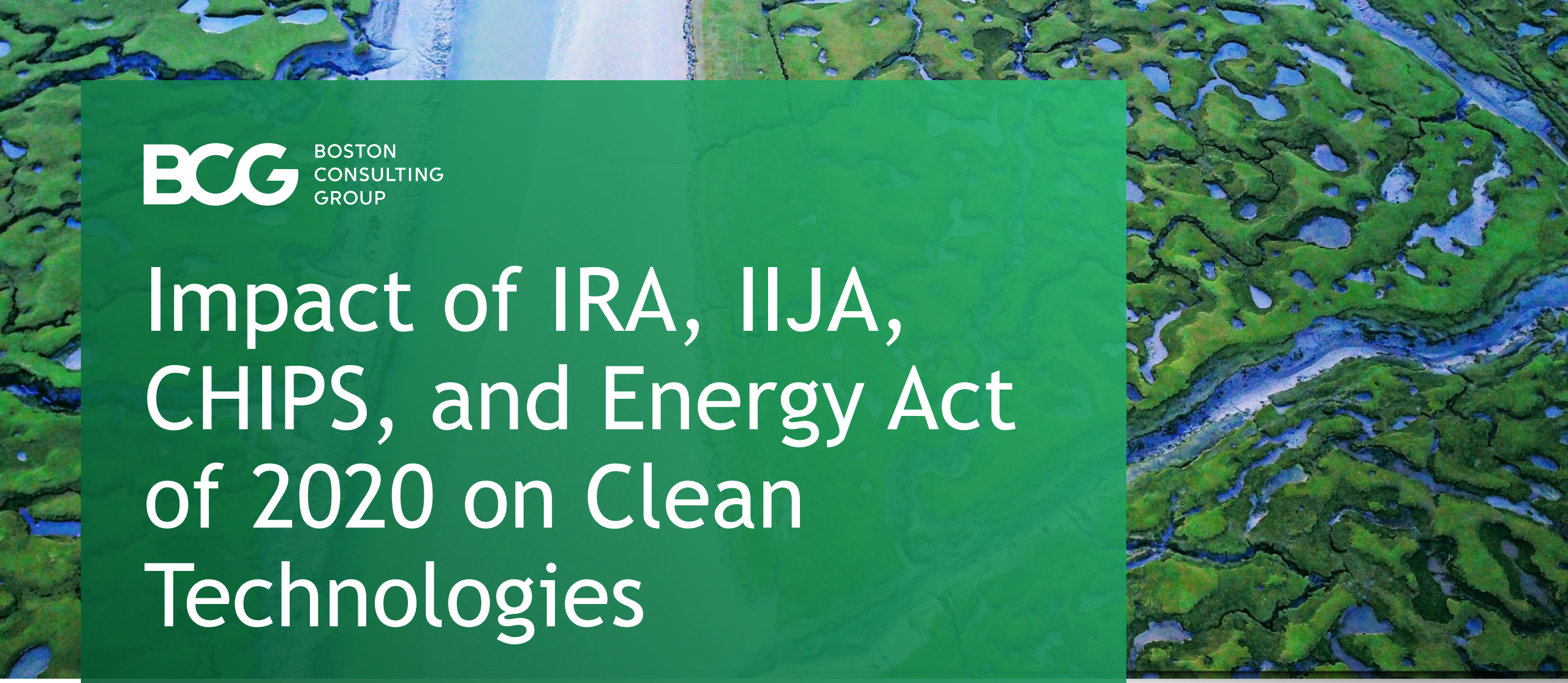


BOSTON CONSULTING GROUP

Impact of IRA, IIJA, CHIPS, and Energy Act of 2020 on Clean Technologies

Deep Dive | Direct Air Capture

APRIL 2023

Background | Objectives and context of this work

Objective

- Explore impacts of recent legislation[1] on U.S. opportunity and remaining challenges for emerging clean technology deployment

Stakeholders involved

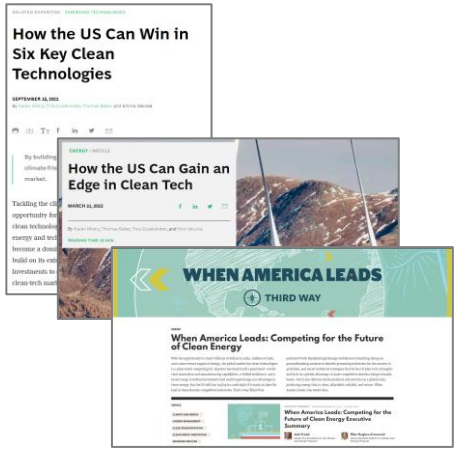
- Analysis was commissioned by Breakthrough Energy and Third Way, with input from stakeholders across the public and private sectors

Breakthrough Energy

THIRD WAY

Related publications

- BCG report | How the US Can Win in Six Key Clean Technologies
- BCG report | How the US Can Gain an Edge in Clean Tech
- Third Way publication | When America Leads: Competing for the Future of Clean Energy



1. Legislation assessed here includes Inflation Reduction Act (IRA), Infrastructure Investment and Jobs Act, CHIPS and Science Act, and the Energy Act of 2020
Source: BCG analysis

~1,900 Mtpa
Annual global abatement potential in 2050

$2-2.5T
Cumulative U.S. domestic market '20-'50

$150-250B
Cumulative US exports '20-'50

~400k[2]
Cumulative job creation through 2050

Direct Air Capture (DAC) | Executive Summary

- Direct funding from the IIJA and expanded tax credits from the IRA will drive ~5-15 Mtpa in DAC deployments by 2030 and make the US the most attractive location for future DAC projects, with the $180/$tCO_2$e value from the IRA higher than any other scheme for monetizing carbon removals[1]
- These deployments will be kickstarted by $3.5B in funding from the IIJA for an initial 4+ Mtpa of US DAC deployments across 4 DAC hubs (up from <0.1 Mtpa today) with a further ~$5B to support buildout of CO_2 transport / storage infrastructure
- Subsidized prices for high quality carbon removals will also stimulate demand, allowing the US to invest in domestic manufacturing capabilities and rapidly commercialize novel tech (e.g., metal organic frameworks), driving down costs from ~$600/tCO2e today to ~$300/tCO_2e in 2030
- These policies and the U.S.'s leadership in DAC will drive ~$0.2B in additional exports through 2030 ($0.3B in 2030 vs $0.1B without policy support) as costs decline and create up ~1,000 new jobs through 2030, primarily from domestic DAC deployments leveraging novel tech selling into global CO_2 removal credit markets
- To support U.S. competitiveness, future policies should focus on further driving DAC down the cost curve via continued RD&D and commercialization funding, targeting <$100 / tCO_2e at which point significant global demand is expected to be unlocked
- Additionally, alignment with international standards for carbon removals will open access to export markets and streamlined permitting & direct government procurement of DAC removals will allow project developers to de-risk projects and build robust pipelines

1. EU ETS near peak value of ~$100/$tCO_2$e but not applicable for carbon removals as of 2022 2. Total number of positions created through 2050; incremental new jobs calculated as the sum of all non-negative one-year differences in # job-years (e.g., 2021 job-years minus 2020 job-years gives 2021 new jobs); incremental new jobs added to sum from prior period for cumulative calculation
Note: All numbers on lefthand side are based on projections from the IEA's 2021 Announced Pledges (APS) scenario and are cumulative from 2020-50 for all value chain segments
Source: DOE; IEA; BCG Analysis

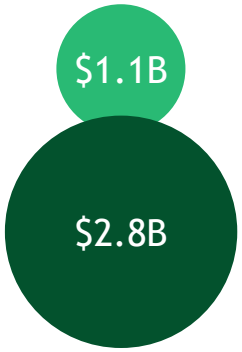
Recent policies have resulted in significant increases in size of US market, exports, and jobs within DAC although market remains small through 2030

Impact of recent US policies (incl. IRA, IIJA) on cumulative market & job creation from 2020-2030

US domestic market

US cumulative domestic market through 2030 increased from $1.1B to $2.8B after IRA/IIJA due to increased domestic deployments

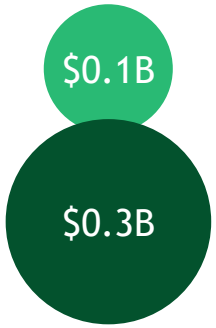
$B in market size



US exports

US cumulative exports through 2030 increased from $0.1B to $0.3B after IRA/IIJA due to expanded domestic manufacturing

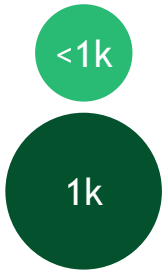
$B in exports



US job creation

New job creation in US DAC industry ('20-'30) increased to ~1,000 after IRA/IIJA due primarily to increased domestic deployments

Number of jobs

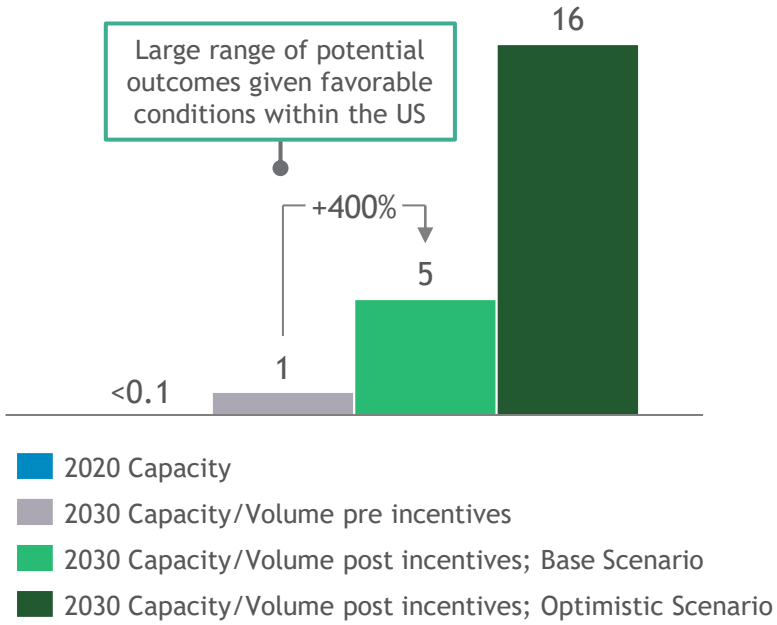


Note: All numbers based on IEA WEO STEPS scenario pre- and post-IRA based on change over timeframe from 2020-2030
Source: BCG analysis

Legislation impact | IRA & IIJA support of DAC expected to drive a ~4x increase in DAC deployments by 2030 and drive down net costs by ~50%

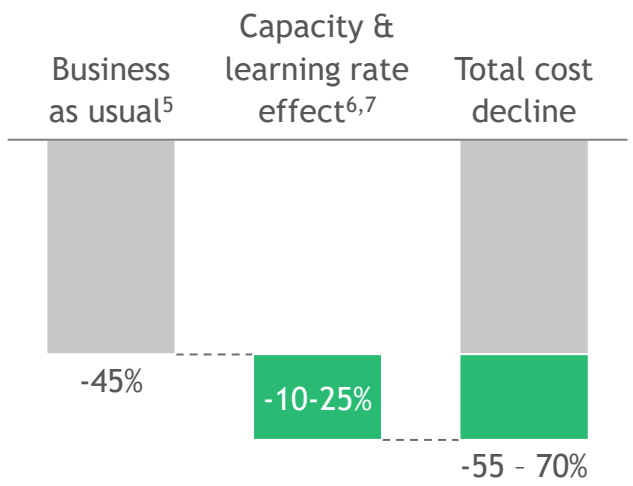
DAC deployed capacity expected to increase ~400% by 2030 …

DAC Capacity (Mt CO2/yr)



… unit costs expected to reduce an additional 10-25% by 2030 from IRA…

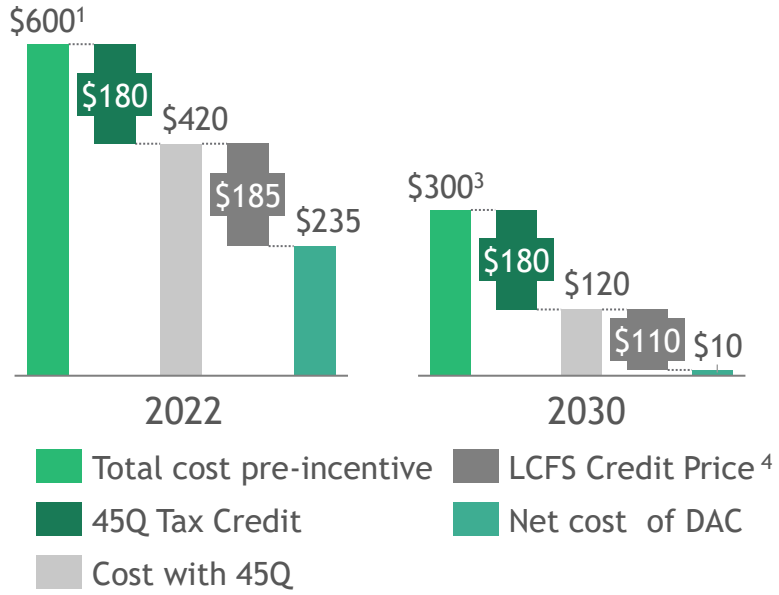
Incremental % change of unit cost in 2030 relative to 2022



… and technology costs expected to fall ~50% relative to 2022

Projected cost of DAC ($/tCO2) inclusive of new tax credits, 2022 vs. 2030[2]

Illustrative

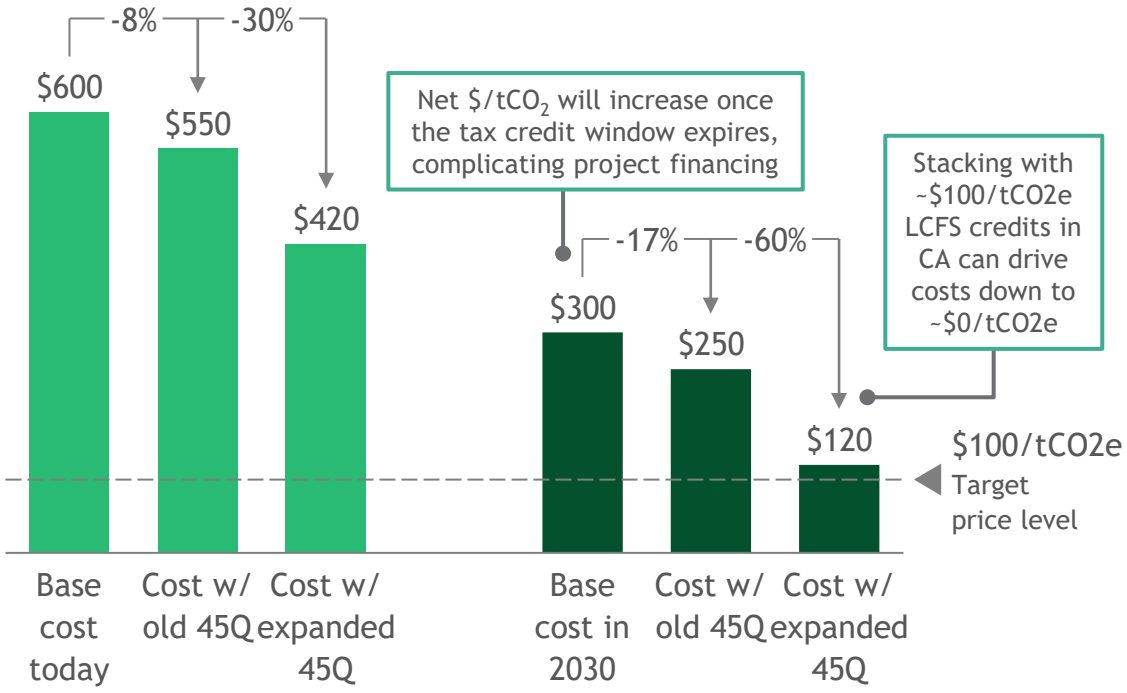


1. Projected cost of DAC today, 2. Net $/tCO2 will increase once the tax credit window expires, complicating project financing, 3. Projected cost of Liquid solvent DAC 4. 2022 LCFS price based upon the Q3 2021 LCFS average price of $185/t. 2030 LCFS price decline is due to expected surplus of available LCFS credits from renewable diesel expansion 5. Business as usual: 2030 capacity projection pre-IRA based on IEA stated policy (STEPS) scenario 6. Capacity effect: incremental cost reduction due to added US capacity and additional global deployment (assumed 3x US increase) 7. Learning rate effect: incremental cost reduction due to de-risked commercialization (US moving early) and innovation (improved learning rates)
Note: 2030 pre incentives and 2030 post incentives (Base Scenario) based on IEA STEPS projections
Source: IEA, CARB, Stillwater Associates; BCG analysis

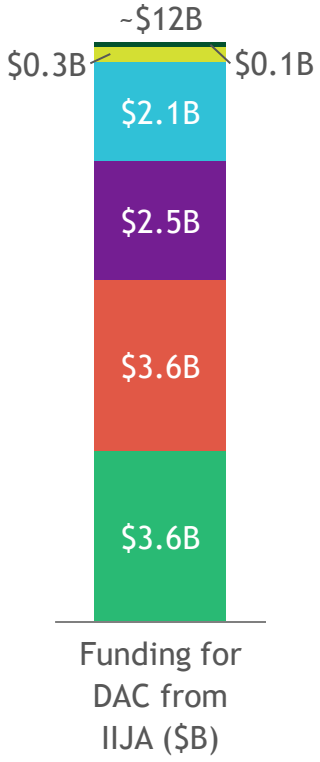
Key incentives | Expanded 45Q tax credits from the IRA and ~$12B in funding from the IIJA are the key drivers of this market expansion

Major IRA 45Q expansion significantly decrease projected costs of DAC

Prior 45Q credit of $35-50/tCO2e increased to $130-180/tCO2e, bringing costs down to ~$100/tCO2e level where significant demand is unlocked



~$12B in funding from IIJA supports early commercial deployments and lays groundwork for future growth



Secure Geologic Storage Permitting:
Grants for states to establish well permitting programs

Carbon Utilization & Procurement:
Grants for state/local gov't to procure products made from captured CO_2

Carbon Dioxide Transportation Infrastructure:
Low-interest loans for large CO2 pipeline projects

Carbon Storage, Validation, and Testing:
Funding for commercial large-scale carbon sequestration projects

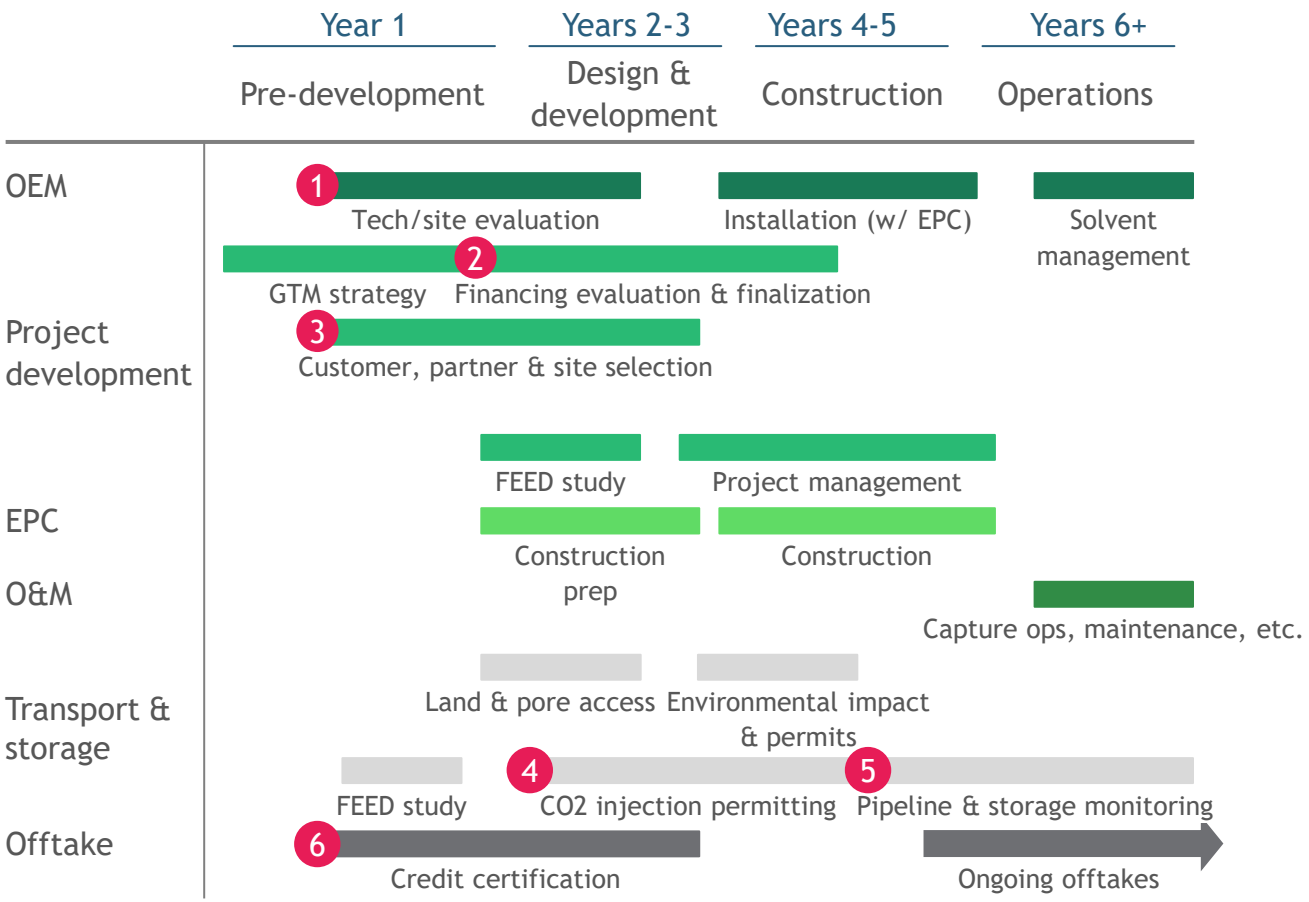
Carbon Removal:
Funding for 4 DAC hubs and pre-commercial demos. Includes $3.5B for DAC hubs and $115M in prizes for demos

Carbon Capture Technology Program (CCUS):
Funding for R&D, pilots, and large-scale commercial CCUS projects (not DAC but strong synergies). Includes $3.5B for pilots and demos & $100M for FEED program on CO_2 infra

1. IIJA appropriated funds for an existing program created by Energy Act of 2020
Source: IIJA; IEA; BCG Analysis

Pre-legislation challenges | DAC deployment dependent on financial support to de-risk projects and enable infrastructure buildout

Illustrative project timeline



Key pre-IRA gaps to be addressed

1. Most DAC technology remains too expensive to economically remove significant amounts of CO_2
2. Limited regulations around CO2 emissions and lack of monetization mechanisms today limit widespread deployment of DAC
3. Insufficient renewables infrastructure available to fully power DAC facilities
4. Long permitting timelines and limited clarity on long-term storage and monitoring liability slows down project development
5. Insufficient infrastructure currently built out with few permitted wells for CO2 storage
6. Few & inconsistent standards around carbon removals limits demand for high quality DAC credits

Source: ADB; International CCS Knowledge Center; BCG analysis

Remaining challenges | Additional policy intervention is needed to provide long-term clarity and certainty for continued DAC investment

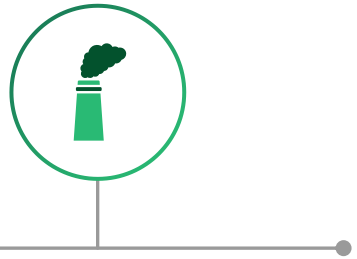
	Pre-legislation priority challenges	Changes from recent legislation (IRA, IIJA, CHIPS, and EA 2020)	Remaining areas to target with future policies
OEM	1 High cost of DAC tech	• RD&D funding for novel & modular techs to drive down cost • ~$4B in direct funding for DAC Hubs from IIJA	☆ Continued support needed for commercialization of US-developed technological breakthroughs to support R&D to project pipeline
Project development	2 Limited regulations around CO2 emissions & lack of monetization mechanisms	• Expanded $130-180/tCO2e tax credit from 45Q in IRA	☆ Limited demand for developing new DAC projects without permanent mechanism for pricing CO2 (by-sector or economy-wide)
	3 Insufficient renewables infrastructure to power DAC facilities with challenges around permitting and transmission	• Various ITCs and PTC for renewable energy and funding for transmission and storage buildout	• Continued need for baseload renewables (e.g., geothermal, storage) / transmission near DAC facilities & CO2 storage sites
Transport & Storage	4 Long permitting timelines and limited clarity on CO2 storage liability	• ~$100M for states to establish well permitting programs in IIJA	☆ Limited clarity on long-term storage & monitoring processes & liabilities at the federal level
	5 Insufficient CO2 transport & Storage infrastructure	• ~$2.1B for financing CO2 pipelines in IIJA • ~$2.5B for large-scale carbon sequestration projects	• Need for further analysis of sub-surface capacity in US and other countries where US companies could develop projects
Offtake	6 Lack of standards around carbon removals		☆ Need to work with international community to define standards for high quality removals

☆ Priority areas

Source: C2ES; DOE; IIJA; IEA; BCG Analysis

Summary | Actions to further boost U.S. competitiveness

Key levers that will enable the US to win the DAC market

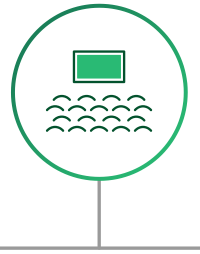


RD&D and commercialization support

Support for early commercial DAC deployments and follow-on funding for initial manufacturing hubs to drive costs down to <$100/tCO2e

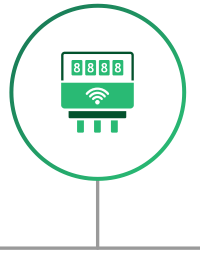
Regulations & long-term monetization opportunities

Permanent monetization opportunities (e.g., LCFS in CA, direct gov't procurement) for DAC projects to replace 45Q after it expires and/or regulations mandating CO2 reductions



Alignment with international standards

Establish quality and verification standards for DAC credits (e.g., permanence) and align on standards with key export partners to ensure offtake and de-risk market for buyers



Processes & infra. for long-term storage

Streamline federal rules for storage and monitoring (e.g., length of liability), define clear permitting processes, and invest in necessary infrastructure to allow OEMs to deploy their tech at scale

Source: BCG analysis

Backup | New legislation provides incentives for Direct Air Capture (I/II)

Unique to DAC

Overlap with CCUS

	Provision	Summary	Type	Total investment
1	IRA Section 13104	Increases tax credit 45Q for sequestration and utilization to a maximum of $180/t for sequestration and $130/t for use with additional prevailing wage and apprenticeship requirements	Production Tax Credit (PTC)	$3.22B to 2033
2	IIJA DAC Hubs	Authorizes program for projects that contribute to development of 4 regional DAC hubs. Facilities must capture min of 1M MtCO2e and be located in regions with fossil fuel industry	Grant Funding	$3.5 billion to 2026
3	IIJA/Energy Act[2] DAC Technologies Prize Competitions	Prize competition to qualified[1] DAC facilities of metric tons of qualified CO2 & verified disposal/utilization. Facilities must capture >50k tCO2/yr	Grant Funding	$115 million to 2025
4	IIJA Sec. 40302/Energy Act[3] Carbon Utilization Program	State/local government grants to procure products derived from captured carbon. Expands DOE's Carbon Utilization program to include standards & certifications for commercialization of CO_2 products	Grant Funding	$310 million to 2026
5	IIJA Sec. 40303 / Energy Act[3] Carbon Capture Technology Program	Expands DOE's Carbon Capture Technology program to include front-end engineering & design for CO_2 transport infrastructure	Grant Funding	$100 million
6	IIJA Sec. 40304 CO^2 Transportation Infrastructure Finance & Innovation	Establishes CO^2 Infrastructure Finance and Innovation Act, providing flexible, low-interest loans for CO_2 transport infrastructure projects & grants.	Loan Authority / Market Enabler	$2.1 billion • $600M for 2022-2023 • $300M for 2024-2026

1. Must capture carbon directly from ambient air, must capture more than 50,000 metric tons of qualified CO2 annually 2. DAC Tech Prize Competitions was originally approved in the Energy Act of 2020 and funded in the IIJA 3. Originally approved in Energy Act of 2020; Source: DOE, IRA, IIJA, BCG Analysis

Backup | New legislation provides incentives for Direct Air Capture (II/II)

Overlap with CCUS

	Provision	Summary	Type	Total investment
7	IIJA Sec. 40305 / Energy Act[1] Carbon Storage Validation & Testing	Expands DOE's Carbon Storage Validation & Testing program to include large-scale commercialization of new/expanded sequestration projects & transport infrastructure	Grant Funding	$2.5 billion to 2026
8	IIJA Sec. 40306 Secure Geologic Storage Permitting	Funding for permitting of wells for geologic sequestration of CO2 & creates grant program for states to establish Class VI permitting programs	Grant Funding	$75 million
9	IIJA Sec. 40307 Geologic Carbon Sequestration	Allows DOI to permit carbon sequestration on outer Continental Shelf	Market Enabler	N/A
10	IRA Section 13501: 48C Advanced Energy Manufacturing Project Tax Credit	Extension of the advanced energy manufacturing project credit. Base rate of 6% and 30% tax credit if wage and apprentice requirements are satisfied	Manufacturing Tax Credit	$10B
11	CHIPS Sec. 10102	Establishes a “Carbon Sequestration Research and Geologic Computational Science Initiative" and at least two carbon storage research and geologic computational science centers	Market Enabler	$250M through 2027

1. Originally approved in Energy Act of 2020
Source: DOE, IRA, IIJA, BCG Analysis

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