The Future of Direct Air Capture

Research, intelligence, and insights on DAC technology, costs, applications, and implementation

Multi-Client Study Prospectus

ADI Analytics
OIL & GAS • ENERGY • CHEMICALS

440 COBIA DR • STE 1704
HOUSTON • TEXAS 77494
+1 (281) 506-8234
INFO@ADI-ANALYTICS.COM
WWW.ADI-ANALYTICS.COM

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Outline

- **Study Prospectus**
- About ADI

ADI's new study will analyze the current state of Direct Air Capture (DAC) and its future projections

Multi-client study drivers

- The latest IPCC estimates that that we must remove up to 660 billion tonnes of CO_2 to limit global warming.
- Direct air capture (DAC) will be an important component of achieving carbon targets as other solutions alone will not be enough.
- The recently-passed Inflation Reduction Act (IRA) provides new incentives through enhanced 45Q tax credits to promote advancements in DAC.
- Numerous companies are entering the space and advancing technologies to reduce the costs and energy needs currently associated with DAC.

Strategic questions for the ADI study

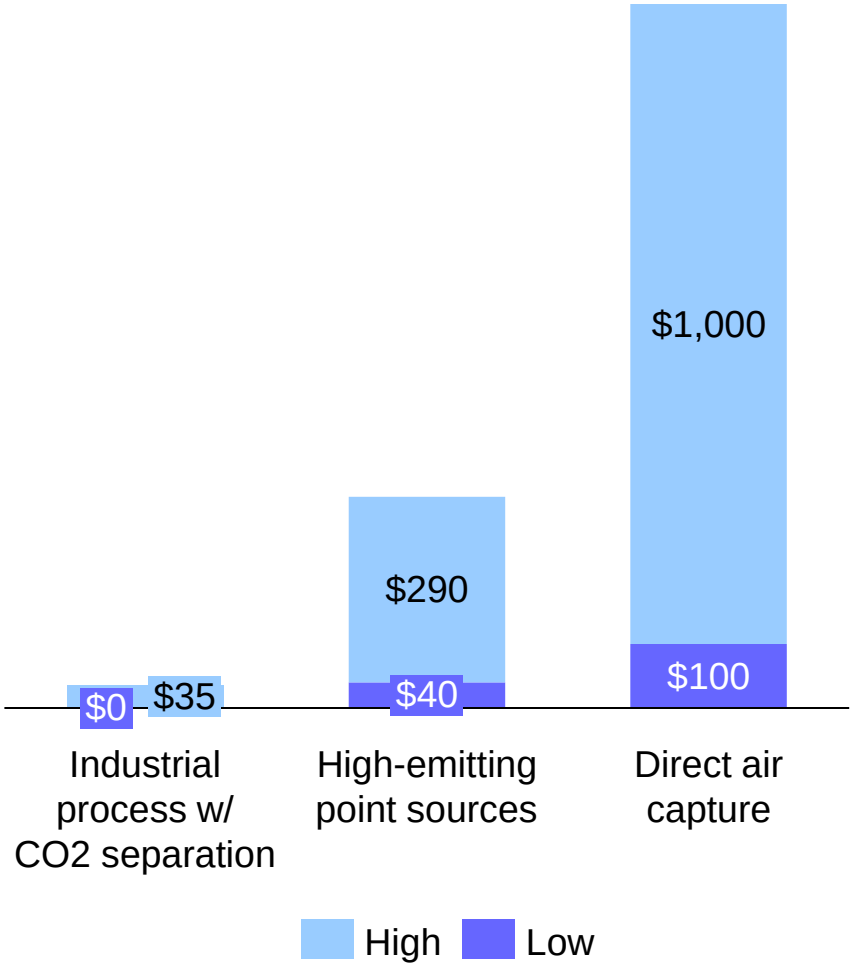
- What is the state of the DAC industry?
- What advances are being made in technology, and how are these advanced improving costs?
- What longer term challenges remain?
- Who is playing in this space, both developing technology and implementing projects?
- What DAC projects are being developed, and what challenges are they facing?
- What environmental and regulatory challenges are affecting the industry?
- Where is DAC headed over the next decade, and what share of CO_2 can it get?
- What are the strategic implications and associated risks and uncertainties for current and new participants?

DAC today is very expensive and has the highest CO_2 capture costs of all carbon capture technologies

Discussion

- DAC costs between $100 and $1,000 per tonne of CO_2 compared to costs well below $50 per tonne for industrial process and high-emitting sources
- Globally there is limited DAC capacity today, with 27 facilities worldwide removing around 10,000 kilotonnes of CO_2 annually
- Globally, numerous DAC projects are underway, some having 1+ $MtCO_2$ capacity
- Numerous companies and startups are developing innovative DAC technology to increase efficiency and reduce costs
- Carbon management and DAC have incredible federal and growing private support right now promoting rapid innovation

Carbon capture costs
($ per ton CO_2)



Numerous federal incentives are promoting the advancement and implementation of DAC technology

DAC Incentives in Inflation Reduction Act

	Pre IRA 45Q credits ($ / tCO_2)	IRA 45Q credits ($ / tCO_2)	Increase
Industrial carbon – non-EOR	$50	$85	70%
Industrial carbon – EOR/utilized	$35	$60	71%
DAC carbon – non-EOR	$50	$180	260%
DAC carbon – EOR/utilized	$35	$130	271%

- Requirement for qualified DAC facilities reduces from 100,000 to 1,000 tCO_2 annually
- Direct pay provision for 45Q credits makes them easier to monetize
- Construction deadline extend from 2026 to 2033

Discussion

- The 2022 Inflation Reduction Act (IRA) provided numerous benefits to promote carbon management
- Prior to the IRA, DAC CO_2 and industrial CO_2 were valued the same, providing little incentive to target expensive DAC technology
- The IRA increased 45Q credits for DAC at least 260%; making DAC credits worth more than twice that of industrial captured CO_2
- IRA made it easier for DAC facilities to qualify for 45Q
- The Infrastructure Investment and Jobs Act of 2022 (IIJA) also provided significant funding for DAC
  - $3.5 billion for regional DAC hubs
  - $3.5 billion for carbon capture demonstration and pilot programs
  - $115 million for DAC prizes

International governments are funding and promoting DAC advancement as well

Publicly funded programs and strategies outside the U.S.

Canada	European Union	United Kingdom	Japan
▪ Greenhouse Gas Offset Credit System ▪ Climate Action and Awareness Fund ▪ Net Zero Accelerator ▪ Clean Fuel Standard ▪ 2022 Canadian Federal Budget	▪ Horizon Europe ▪ Innovation Fund ▪ Communication on Sustainable Carbon Cycles	▪ Spring Budget 2023 ▪ DAC and GHG removal competition ▪ Net Zero Strategy	▪ Moonshot Research and Development Program: Goal 4

Countries with DAC projects in development					
Australia	Canada	Chile	Norway	U.S.	U.K.

The private sector is also providing unprecedented funding to fight climate change through DAC and carbon capture

Growing investments

UNITED

BlackRock

Multi-million-dollar commitment to 1PointFive DAC facility in Texas

Alphabet

shopify

stripe

Meta

McKinsey & Company

- $925 million advanced market commitment (AMC), known as Frontier, for carbon removal
- Additional companies anticipated to join over time
- 60% of first accepted proposal were for DAC

Growing customer support

- Amazon, TD Bank Group, Houston Astros, ANA, and Airbus have invested millions of dollars in CDR credits from 1PointFive
- Record fund raise for carbon capture in 2022, with venture capital up to $13.8 billion
  - Largest investment was $650 million for Climeworks series F fundraising
  - Climeworks is the largest DAC company in the world
- Breakthrough Energy Ventures – led by Bill Gates – working to advance carbon capture
- Chan Zuckerburg Initiative – led by Priscilla Chan and Mark Zuckerburg – donated $21 million for carbon removal technologies
- The Musk Foundation and X-Prize partnered for a $100 million carbon removal challenge

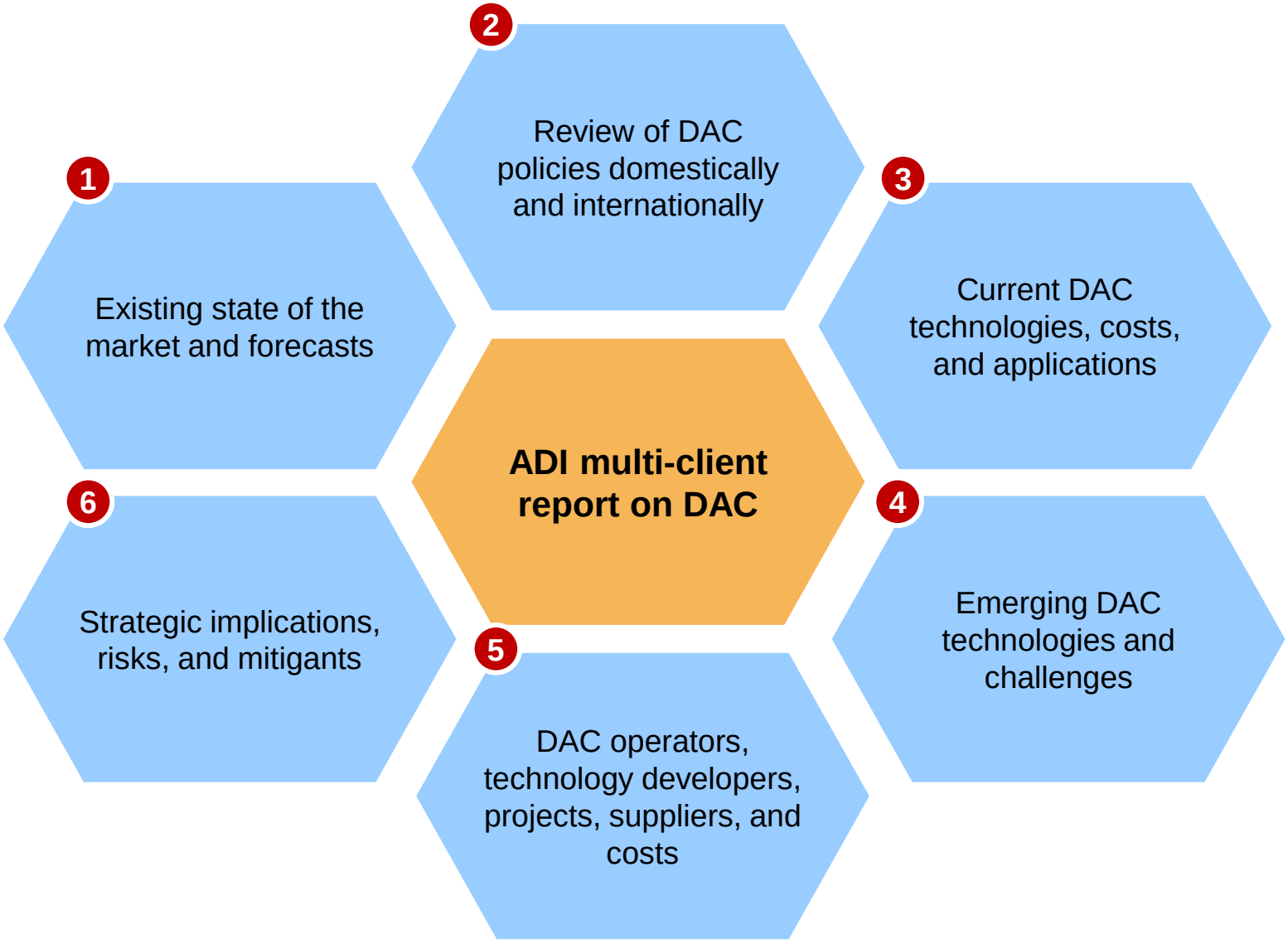
Currently there are limited types of DAC technologies, but emerging technologies look to improve efficiency

Current Technology		
	S-DAC	**L-DAC**
CO_2 separation	Solid sorbent	Liquid solvent
Energy consumption (kWh / tCO_2)	Up to 2,783	Up to 1,825
Temperature	50-120°C	900°C
Water requirements (tH_2O / tCO_2)	-2 to 2	0 to 50
Land requirement ($km^2 / MtCO_2$)	1.2 – 1.7	0.4
Levelized cost of capture (USD / tCO_2)	Up to 1000	Up to 340

Emerging Technologies

- Electro-swing adsorption (ESA)
  - Based on electrochemical cell
  - Absorbs CO_2 when negatively charged and releases when positive charged
  - Tested with efficiency ~90%
- Membrane-based DAC (m-DAC)
  - Technology in infancy
  - Requires expensive compression of large amounts of ambient air
- Artificial leaf utilizing capturing CO_2 across electrically charged membrane
  - Lab tested concept
  - Flux rate 100x better than other systems
  - Cost estimated at 145 per tCO_2

The ADI study will be an in-depth review of DAC policies, technologies, costs, incentives, innovation, projects, and players



ADI's proposed study contents is detailed and comprehensive but can be shaped and refined further by subscribers

1	**Executive summary** *Key conclusions, findings, and strategic implications with a review workshop and data spreadsheet*	7	**Challenges for DAC** *Analysis of challenges in DAC including in technical advances and implementation*
2	**Introduction to DAC** *Background and introductory information on existing DAC technology and projects*	8	**DAC projects in progress** *Details on DAC projects in planning or development and review of companies operating in this space*
3	**DAC market and forecasts** *Review of DAC projects, investors, and forecasts and drivers for DAC growth*	9	**DAC costs and economics** *Breakdown of costs and economics for DAC technology and facilities*
4	**U.S. policies and incentives** *Review of local and federal policies and regulations promoting and financing DAC*	10	**Risks and mitigants** *Review of risks for DAC implementation and mitigants available*
5	**Global policies and incentives** *Review of international policies and regulations promoting and financing DAC*	11	**Market and strategic implications** *Analysis of implications for various technical, structural, and regulatory changes for DAC*
6	**Innovations in DAC** *Analysis of emerging technologies, innovations and players in this space*	12	**Conclusions and recommendations** *Key findings and major conclusions*

ADI's "The Future of Direct Air Capture" study offers subscribers a number of benefits

	Outcomes	Deliverables
1	In-depth coverage of DAC space	~100-page report
2	Extensive review of existing and emerging global policy and initiatives	~20-page executive summary deck
3	Review of DAC projects, technology, players, and stakeholders	Spreadsheet data package
4	DAC costs and breakdown by technology type and cost improvement opportunities	Review workshop and analyst access
5	Key commercial insights and strategic implications	Quarterly subscription option to stay updated

Contact Uday Turaga, +1.281.506.8234 or info@adi-analytics.com to purchase this study.

Outline

- Study Prospectus
- **About ADI**

ADI is a consulting firm serving oil & gas, energy, chemicals, and industrial clients with expertise, rigor, and passion

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Petrochemicals


Basic Chemicals


Polymers & Plastics


Specialty Chemicals


Power generation


Renewables


Transmission


Energy Transition


Transportation

Markets | **Operations** | **Technology** | **Commercial** | **Policy**

Over 300 clients - Fortune 500 brands, mid-sized firms, start-ups, and investors have engaged ADI to shape decisions

Our value proposition – expertise, experience, analytics, and thought leadership – is designed to help clients succeed

Deep, frontline **industry expertise**

Over **600 projects** for **300+ clients** since 2009

Differentiated **thought leadership**

Proprietary analytics- and **data-driven**

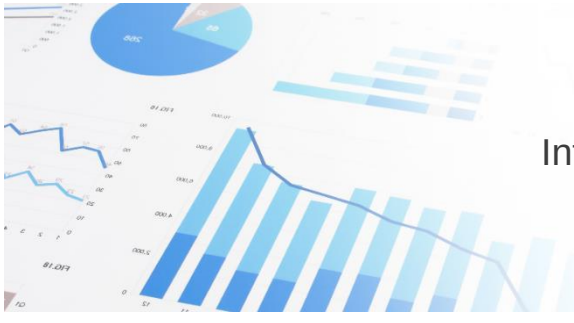
Clients accelerate priorities with ADI's consulting services, subscription research, data analytics, and conferences

Consulting

Discover and capture opportunities, solve problems, and help businesses thrive amid uncertainty with ADI's market research and management consulting services

Research

Track markets with ADI's subscription research



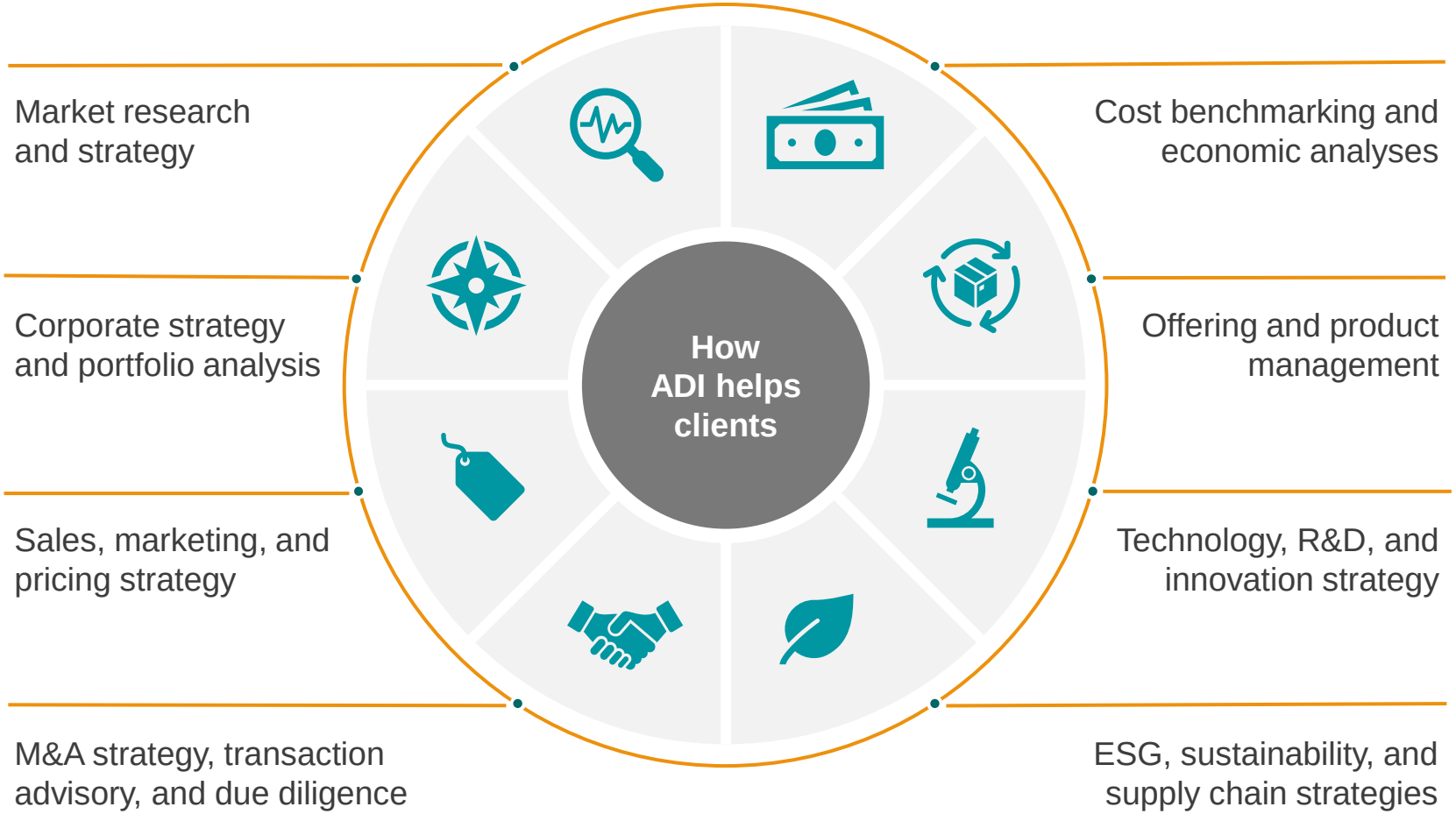
Analytics

Inform workflows with ADI data, models, and analytics

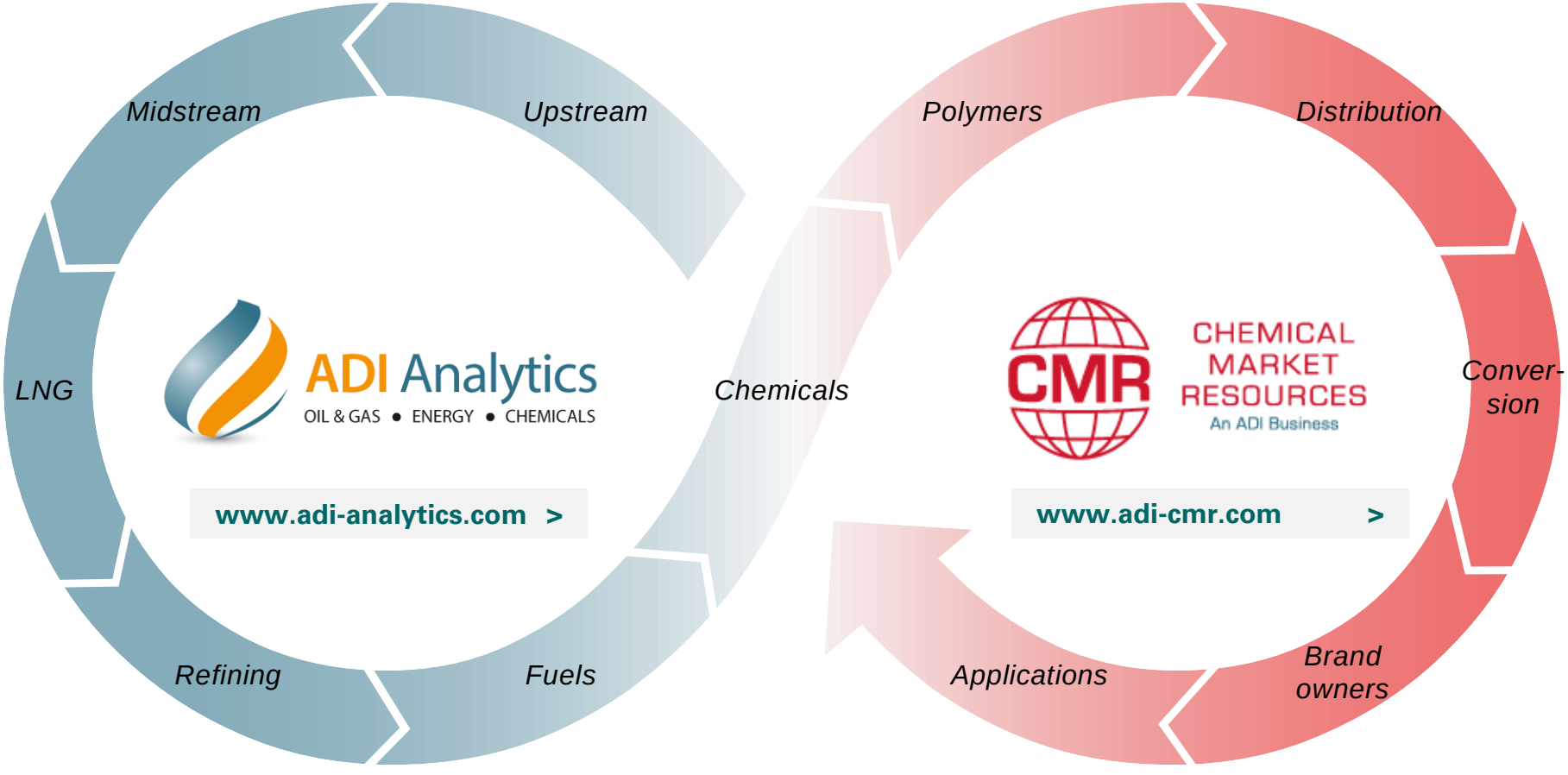
Forum

Build a strategic view and network at our conference

Clients shape strategy, grow sales, refine costs, drive deals, and build competencies with ADI's consulting services



After acquiring Chemical Market Resources, ADI's expertise has grown and now spans the entire hydrocarbon value chain



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Refueling North America with LNG

Latin America refined product exports

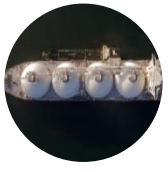
ADI multi-client reports >>

The future of direct air capture

Natural climate solutions

Sustainable aviation fuel (SAF)

Alternative marine fuels market study

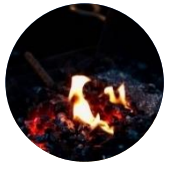


Global / NA small-scale LNG

U.S. gasoline and octane outlook

Assessing opportunities in bio-based chemicals

Benchmarking shale gas monetization options



Critical minerals and energy transition

Access research and reports >>

ADI enjoys a stellar reputation for exceptional project delivery and client service and satisfaction

"Work directly with firm partners … high-quality work products."

– Alex Rozenfeld, *VP, Ventures, Shell*

"The best about ADI is their ability to drill into a specialized area."

– Johanna Schmidtke, *Director, Saudi Aramco*

"They've been outstanding. ADI is very thorough, very professional. They deliver a lot of good insights right out of the gate."

– Randy Benson, *VP, Sales, Harsco*

"ADI did a great job to help us think and advance in making our investments."

– Meghan Leggett, *Principal, White Deer*

"Lots of oil & gas expertise. Very analytically driven. Better customer service."

– Vikki Dunn, *CMO, GE Oil & Gas*

"Very diligent, very detailed … went the extra mile."

– Elliott Smith, *VP, Strategy, Voith*

"The thoroughness of ADI's research is phenomenal."

– Steve Woodward, *SVP, Antero Resources*

"ADI has very deep market knowledge and access to the right experts and delivered very successful projects."

- Brian Orkin, *Partner, Arsenal Capital Partners*

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Upstream, midstream, natural gas, LNG, refining, and fuels

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OIL & GAS • ENERGY • CHEMICALS

440 COBIA DR • STE 1704 • HOUSTON • TEXAS 77494
+1 (281) 506-8234 • INFO@ADI-ANALYTICS.COM
WWW.ADI-ANALYTICS.COM

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