Lux Research

Carbon Capture: System vs. Material Innovation for Cost Reduction

A note about this e-book

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This e-book is an abridged version of our popular webinar "Carbon Capture: System Versus Material Innovation for Cost Reduction."

For the full webinar, which provides more research and context, visit our website here.

Key takeaways

01

Target carbon capture as the primary lever for reducing CCS* costs.

Demand from data centers and new business models with biogenic CO_2 will spur innovation and technology-application tailoring.

02

Explore system benefits for the near term and monitor technologies with different first principles.

Emitters will opt for established solvent providers because of demonstrated market credibility. Novel materials with incremental benefits will face challenges in the long term.

03

Connect the dots: systems, materials, regulations, and byproducts.

Stacking secondary revenues from byproducts and policy will help build a business case around carbon capture.

*CCS, carbon capture and storage

Carbon Capture: System vs. Material Innovation for Cost Reduction

Carbon capture is becoming the critical cost-reduction frontier as transport and storage infrastructure matures.

PRODUCT DESIGN & INNOVATION

Combine proven capture materials with system improvements before taking a technology risk.

MARKET PRESENCE

Established market credibility will increasingly influence which capture technologies win commercial projects.

SUPPLY CHAIN & OPERATIONS

New materials may require investment in manufacturing capacity and entirely new supply chains.

GROWTH POTENTIAL

Cement, natural gas power, and biogenic CO_2 sources represent major growth markets for carbon capture.

Carbon capture is approaching a new innovation cycle

Key takeaway: *As storage infrastructure advances to first injections, industry attention will shift back to the cost and scalability of capturing CO_2.*

Progress in transport and storage is removing one bottleneck from the CCS value chain, but it is exposing another: Point-source carbon capture remains expensive. At the same time, companies are becoming less willing to adopt unproven technologies without a clear path to scale.

Executives should focus on three priorities:

1. Improve near-term carbon capture economics through system-level innovation and proven solvents.
2. Reserve higher-risk material bets for technologies capable of fundamentally changing capture processes.
3. Combine technology, infrastructure, policy, and potential revenue streams when evaluating the business case.

The next phase of carbon capture will reward commercially differentiated solutions, not innovation for its own sake.

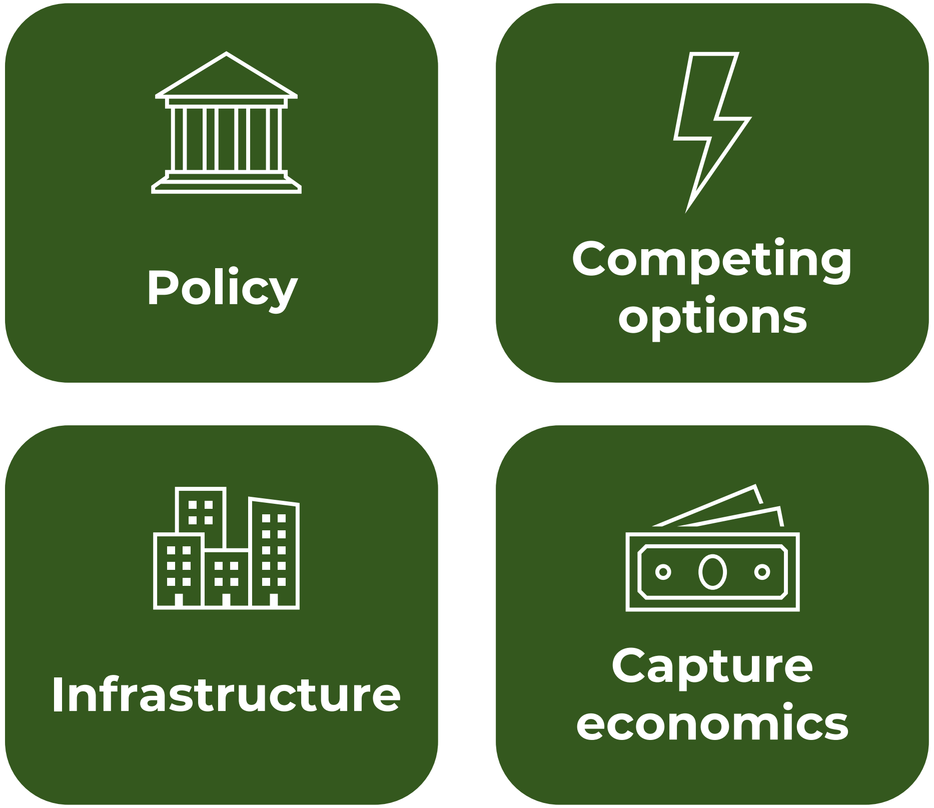
4 forces are shaping carbon capture strategy

***Key takeaway:** CCS adoption depends on more than technology performance. Policy, alternatives, infrastructure, and capture economics must align.*

Four factors determine the success of CCS in a region and its path forward:

1. **Policy:** Carbon pricing and incentives like 45Q in the U.S. can materially affect project viability.
2. **Competing options:** Electrification, fuel switching, and other decarbonization pathways can displace CCS.
3. **Infrastructure:** CO_2 transport and storage must be both available and accessible.
4. **Capture economics:** Capture remains the most expensive part of the CCS value chain, and costs must fall.

As storage infrastructure expands, the economics of point-source capture will increasingly determine whether capacity gets built.



WHERE DEMAND WILL GROW

3 industries will lead the next wave of capture deployment

Key takeaway: *Innovation should target industries where carbon capture is structurally necessary or capable of creating additional value.*

Not every emitter will become a major CCS customer. Lux identifies three sectors with especially strong adoption drivers over the next 10 to 15 years.

1. **Cement:** Process emissions make complete decarbonization through fuel switching difficult.
2. **Natural gas power:** Data center growth could increase demand for low-carbon, dispatchable electricity.
3. **Biogenic CO_2:** Waste-to-energy, bioethanol, and biogas can potentially generate valuable carbon-removal credits.

Together, cement, power and heat, and biogenic CO_2 represent approximately 200 million tonne of announced capacity over the coming decade.

The challenge is that each sector has different flue gas characteristics, operating scales, and capture economics.

Current carbon capture economics leave little room for incrementalism

Key takeaway: *Baseline capture costs remain high, particularly at smaller facilities and in processes with limited access to suitable heat.*

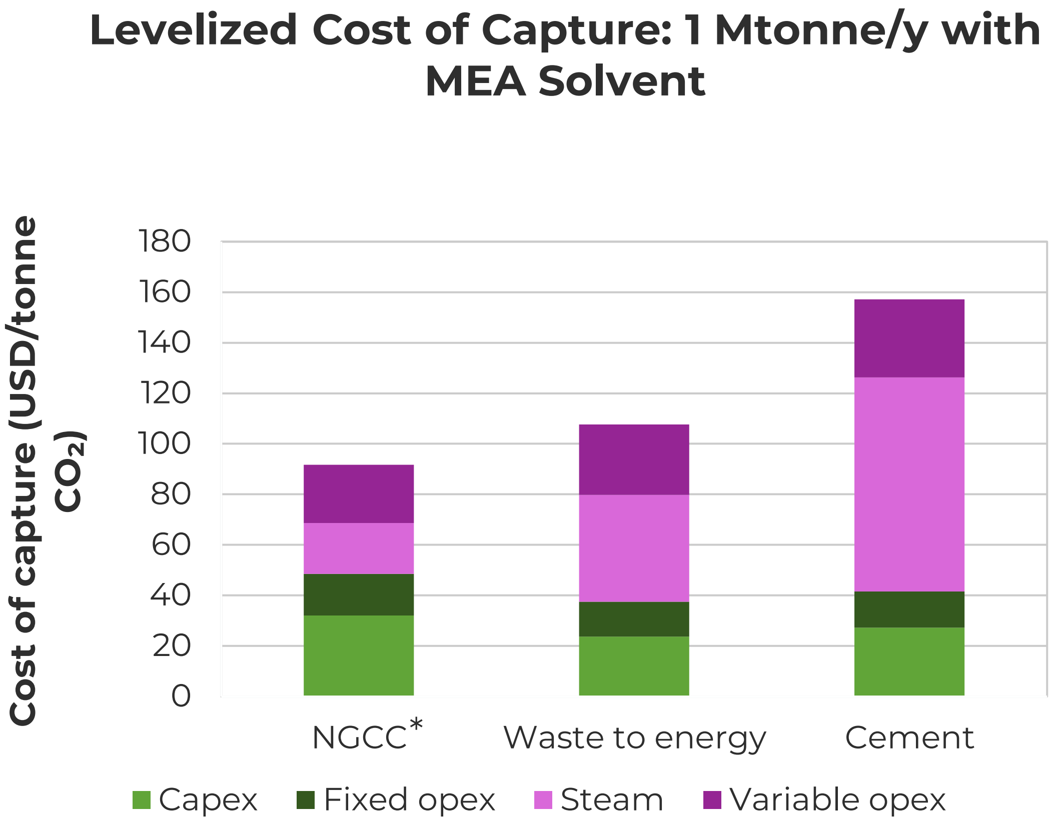
Monoethanolamine (MEA) remains the benchmark for point-source capture. At a 1 million-tonne/y facility, Lux estimates capture costs at approximately USD 90 to USD 160 per tonne of CO_2, depending on the application.

Scale matters significantly. At roughly 300,000 tonne per year, costs rise to approximately:

- Natural gas combined cycle: USD 122/tonne
- Waste-to-energy: USD 131/tonne
- Cement: USD 183/tonne

Advanced amines already reduce energy requirements and can trim costs by roughly 10% to 15%, but costs generally remain above USD 100/tonne.

That leaves companies with two paths: Improve the system or fundamentally improve the capture material.



* NGCC, natural gas combined cycle

Advanced amines improve economics but not enough

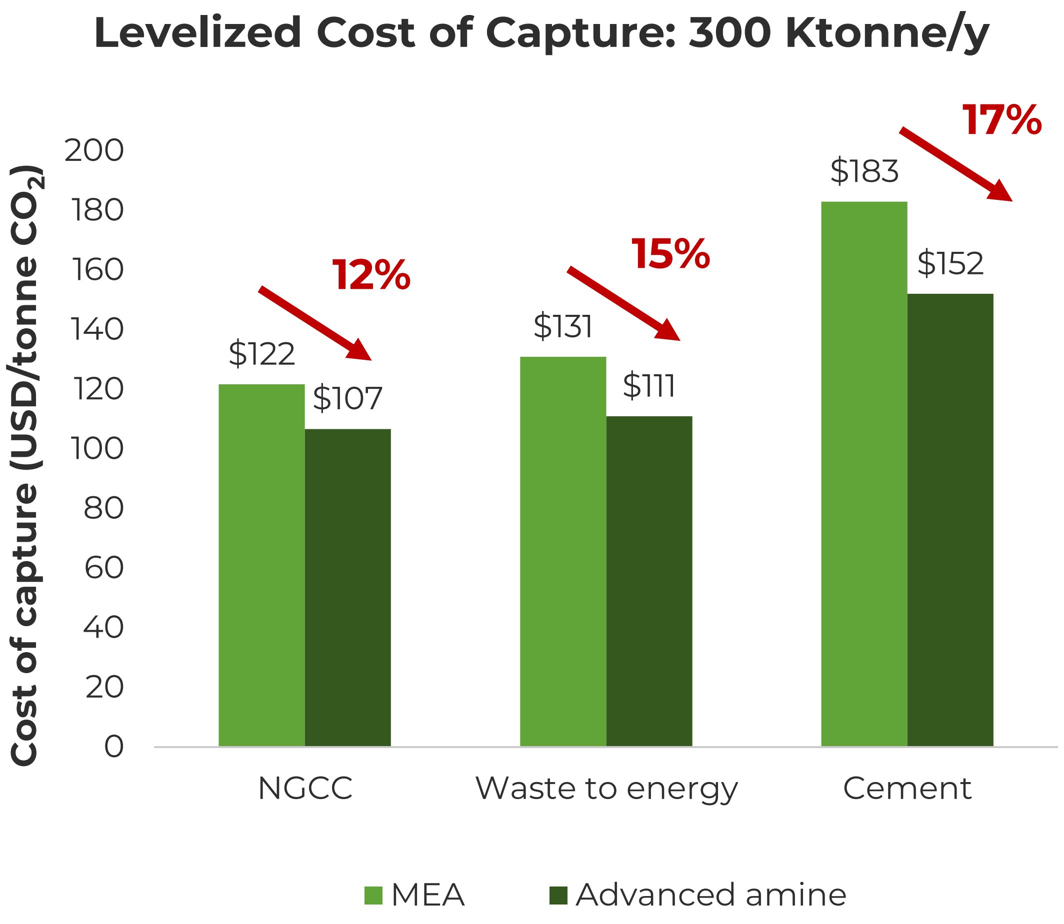
***Key takeaway:** Novel amine solvents can reduce capture costs, but incremental material improvements alone are unlikely to transform project economics.*

Advanced amines are already reaching commercial readiness, with some solutions operating at approximately 2.7 GJ/tonne of CO_2. Compared with baseline MEA, that lower energy requirement can reduce capture costs by roughly 12% to 17%.

At a 300-ktonne/y facility, Lux estimates costs can fall from:

- USD 122 to USD 107/tonne for NGCC
- USD 131 to USD 111/tonne for waste to energy
- USD 183 to USD 152/tonne for cement

The improvement is meaningful, but costs remain high, particularly for cement. For companies seeking larger reductions, the next question is whether to continue improving the material or pair proven solvents with system-level innovation.



Process intensification offers a practical near-term route to lower costs

Key takeaway: *For projects approaching commercialization, system improvements can deliver meaningful savings without requiring a new capture material.*

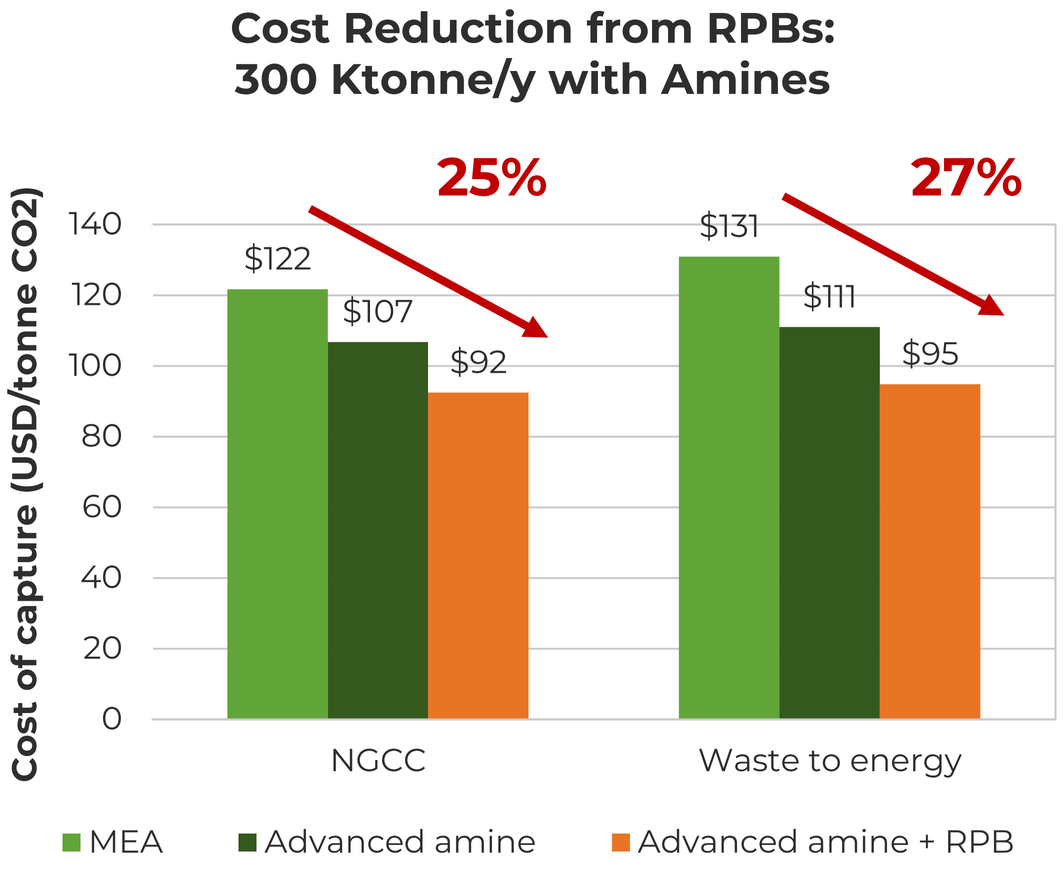
Rotating packed beds (RPBs) illustrate the opportunity. By using centrifugal forces to improve contact between flue gas and solvent, they can reduce equipment size, land requirements, and operating costs.

Lux estimates that RPBs can:

- Reduce the capture unit's capital cost by approximately 50%
- Shrink the physical footprint
- Improve resource utilization
- Lower overall capture costs by approximately 25% to 30%

At 300,000 tonne per year, combining advanced amines with process intensification can push natural gas and waste-to-energy capture below USD 100/tonne.

For projects before 2030, this matters more than theoretical long-term performance of early-stage materials.



Better thermal management can rival material innovation

Key takeaway: *Optimizing heat integration can reduce one of the largest operating costs in solvent-based carbon capture.*

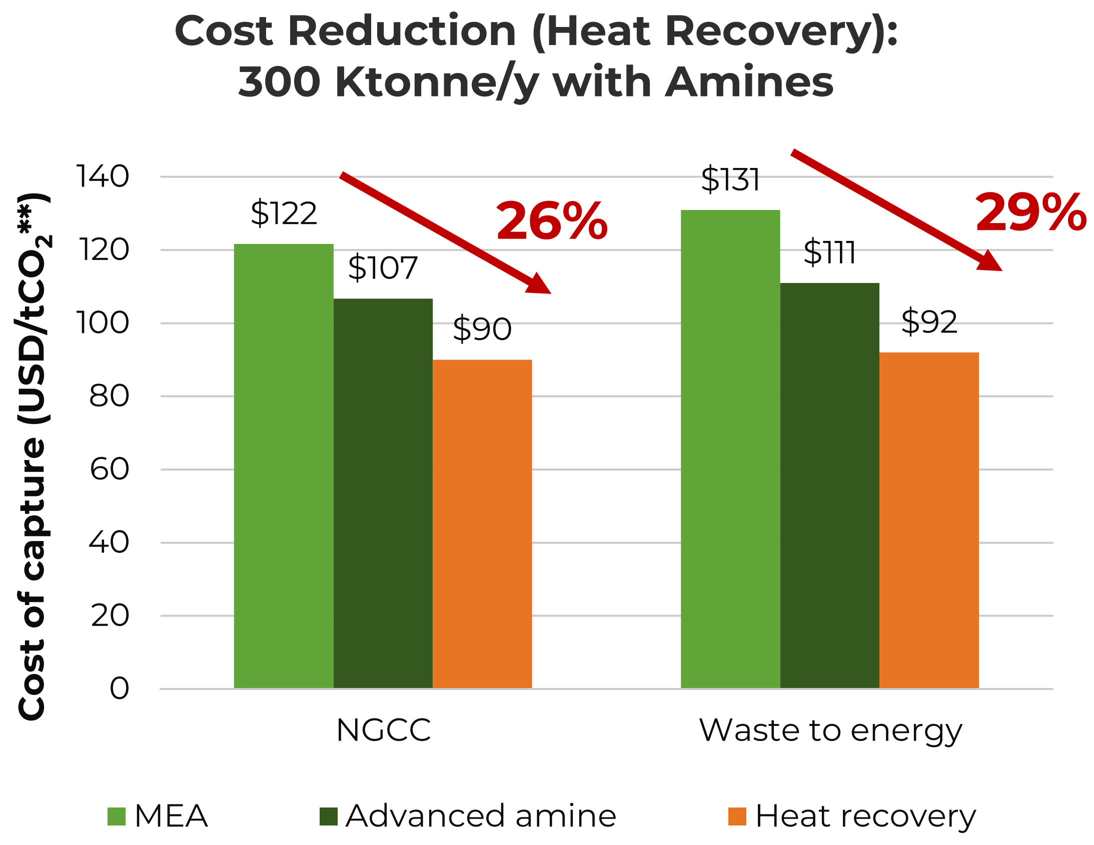
Solvent regeneration is energy intensive, making steam one of the largest contributors to capture cost. Integrated heat recovery can capture otherwise wasted thermal energy and use it to reduce external steam requirements.

Lux's analysis shows that better heat recovery can deliver approximately 20% to 30% cost reduction, with particularly significant benefits where steam costs are high.

The opportunity is application specific:

- Waste heat must be available at the appropriate temperature.
- Additional heat exchangers add infrastructure costs.
- Solutions must integrate into broader engineering and EPC* offerings.

System innovation therefore becomes most valuable when delivered as part of a comprehensive capture solution rather than as another stand-alone technology.



*EPC, engineering, procurement, construction; **tCO_2, tonne of CO_2

New materials must beat the system-improvement benchmark

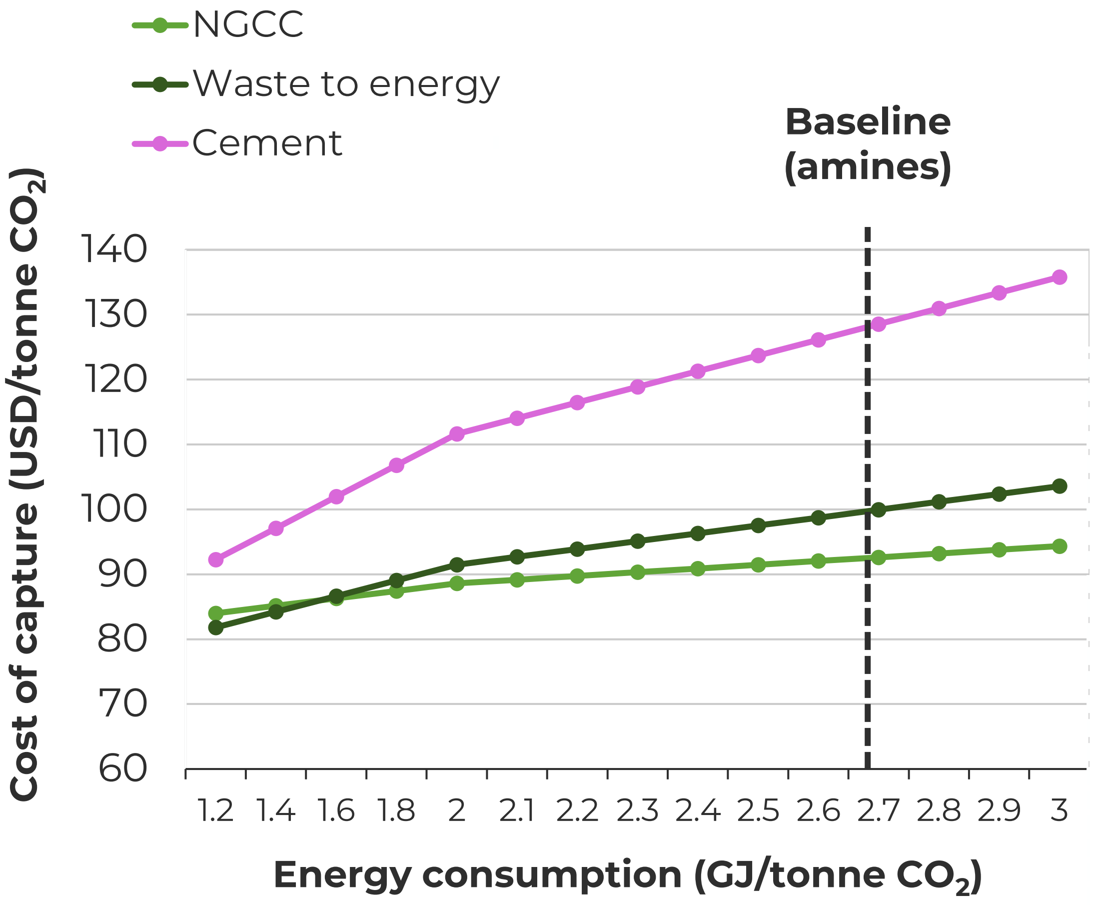
***Key takeaway:** Incrementally better materials may struggle commercially if system improvements can deliver comparable savings with less technology risk.*

System innovations can reduce levelized capture costs to approximately USD 90 to USD 100 per tonne in favorable cases. That creates an important benchmark for new materials.

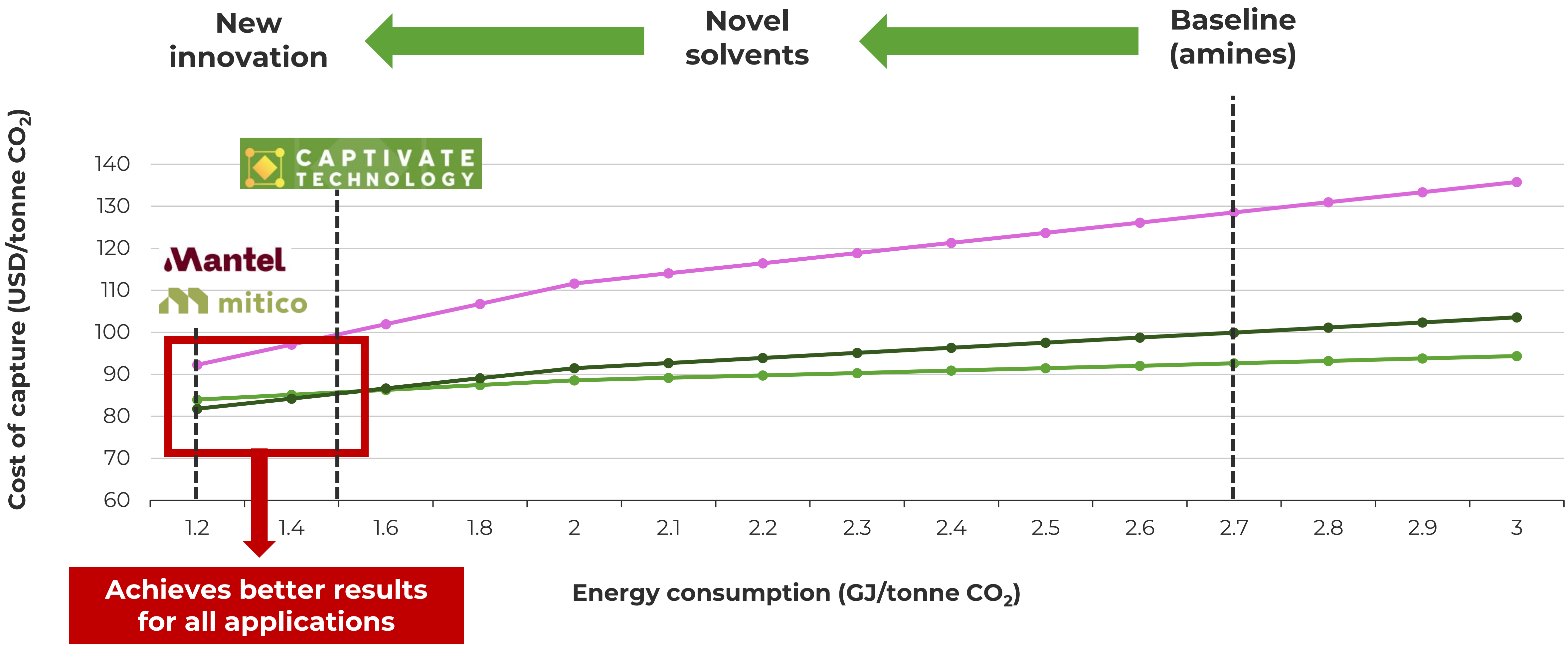
Novel solvents operating around 2.0 to 2.7 GJ per tonne of CO_2 can improve economics but often only marginally compared with proven amines paired with system improvements.

For less-established developers, that creates a difficult proposition: asking an operator to accept additional technology and commercialization risk for perhaps only USD 5 to USD 10 per tonne in additional savings.

The stronger long-term opportunity lies with technologies built on differentiated first principles, particularly those targeting energy consumption below roughly 2 GJ per tonne.



Breakthrough capture technologies must deliver step-change economics



Connect the levers to build the carbon capture business case

Key takeaway: *The winning strategy will combine system innovation, differentiated materials, policy support, and new sources of economic value.*

Reducing technology cost is only one way to improve carbon capture economics. Some emerging approaches can create valuable byproducts or participate in new carbon-removal markets.

For executives, the implication is clear:

- Prioritize system benefits for near-term projects.
- Monitor differentiated, first-principles technologies for longer-term disruption.
- Leverage established market positions and credibility.
- Stack policy, byproduct, and carbon-credit value where applicable.

The strongest CCS strategies will connect these levers rather than evaluating technologies in isolation.

About Lux

Lux Research fuels innovators to not only imagine what's possible in the future but also operationalize innovation success in the near term. We deliver research and advisory services to inspire, illuminate, and ignite innovative thinking that reshapes and grows businesses. Using quality data derived from primary research, fact-based analysis, and opinions that challenge traditional thinking, our experts focus on finding truly disruptive innovations that are also realistic and make good business sense.

The "Lux Take" is trusted by innovation leaders around the world, many of whom seek our advice directly before placing a bet on a startup or partner — our clients rely on Lux insights to make decisions that generate fantastic business outcomes. We pride ourselves on taking a rigorous, scientific approach to avoid the hype and generate unique perspectives and insights that innovation leaders can't live without.

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