Electrifying Chemicals Production:

Inside RMI's Applied Innovation Roadmap

Welcome! The webinar will begin shortly.

February 2026

Agenda

- Welcome
- Chemicals emissions challenge
- Contents and purpose of the AIR
- Technology overviews
- Technology deep dive – resistive heating
- Key takeaways
- What's next?

RECORDING AND POST-EVENT RESOURCES WILL BE AVAILABLE WITHIN 24HRS

Speakers

MODERATOR

Brianne Cangelose

Initiative Lead

Anisha Krishnakumar

Senior Associate

Emily Albergo

Associate

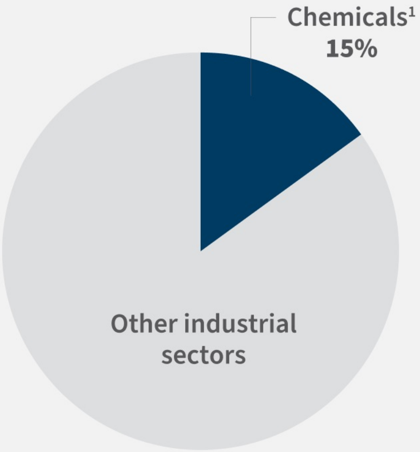
Catherine Huyett

Senior Associate

The chemicals sector accounts for 15 percent of global industrial emissions, driven by the production of materials essential to modern life and health

Global emissions from heavy industry

Share of total carbon dioxide (CO_2) equivalent



Six primary chemicals are transformed into chemical products essential for human life and health

Hydrogen

Methanol

Solvent, paints, coatings

Ammonia

Fertilizer, nylon, foam

Benzene

Dyes, lubricants, detergents

Propylene

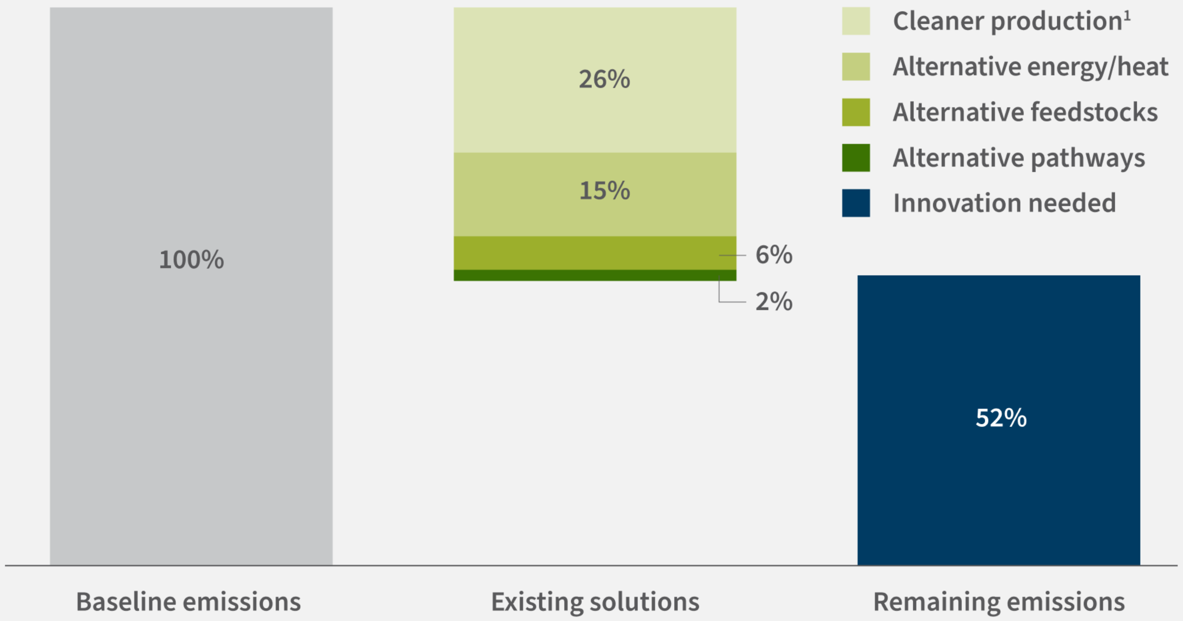
Hard plastics, coolants

Ethylene

Soft plastics, fibers

Notes and sources: 1. Chemicals production emissions include extraction and production emissions. They do not include end of life or use. *Chemistry in Transition: Charting solutions for a low-emissions chemical industry*, RMI, 2025.

Only half of chemicals sector emissions can be addressed with technologies available at scale today



🟩 **Existing solutions** ready for deployment at commercial scale.

🟦 **Remaining emissions** for which innovation is needed to develop solutions for novel technologies, new pathways and products, efficiency, and demand reduction.

Incremental improvements aren't enough

Deploying existing solutions is essential for cutting emissions in half, but new technologies are needed to decarbonize core industrial processes such as cracking, reforming, and distillation.

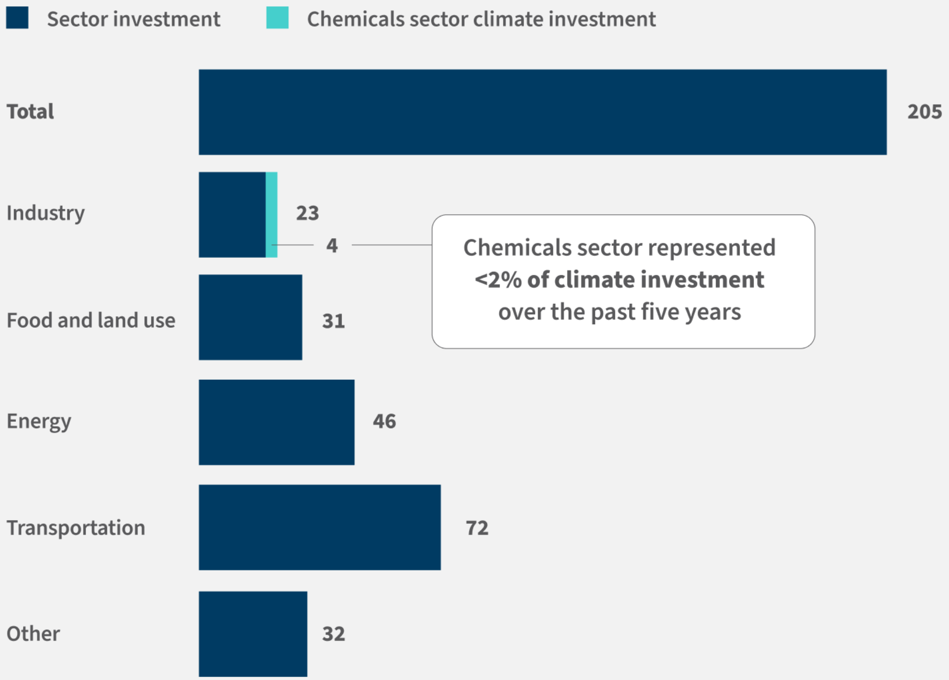
Innovation unlocks new pathways

Breakthroughs in electrification, new production pathways, and CO_2 utilization can cut emissions while preserving competitiveness and reliability. Achieving these breakthroughs requires ongoing support for research, development, and deployment (RD&D) of new technologies.

Notes and sources: 1. Cleaner production includes high purity carbon capture, methane leak mitigation and efficiency measures. *Chemistry in Transition*, RMI, 2025. This analysis does not include circularity/end of life.

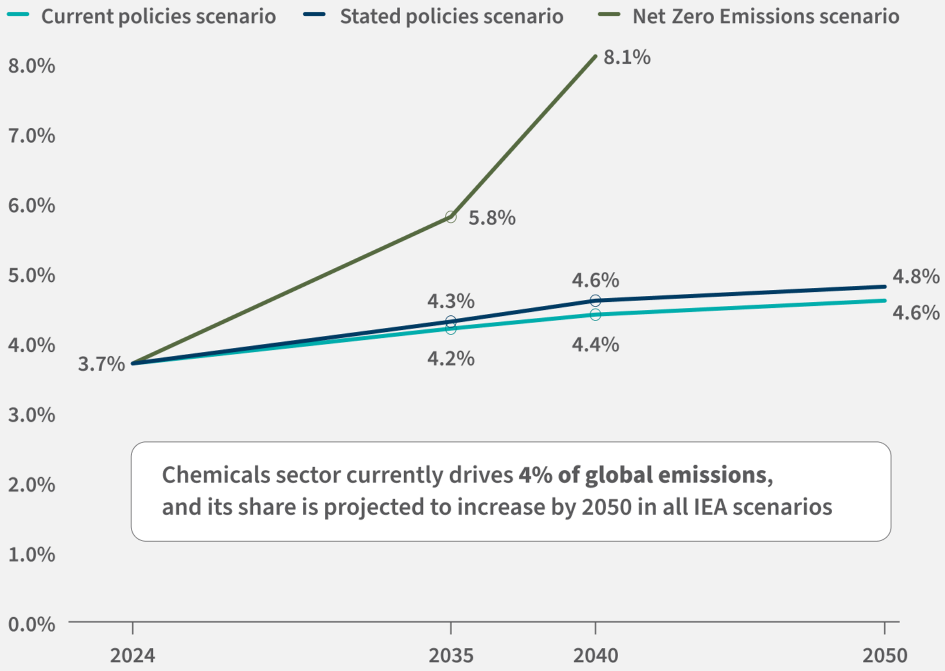
Investment in cutting emissions from the chemicals sector lags far behind its share of global emissions

Climate investment by sector, 2020–25 ($ billion)[1]



Chemicals sector represented **<2% of climate investment** over the past five years

Chemicals share of global emissions by International Energy Agency (IEA) scenario[2]



Chemicals sector currently drives **4% of global emissions,** and its share is projected to increase by 2050 in all IEA scenarios

Notes and sources: 1. *H1 2025 climate tech investment: Capital stacking up for energy security & resilience,* Sightline Climate, 2025. 2. *World Energy Outlook 2025*, IEA, 2025. In 2050 Net Zero Emissions scenario, IEA projects the chemicals sector to account for some emissions, but projects global emissions to be net zero because of emissions reduction and removals in other sectors.

Who and what this roadmap is for

Purpose of this work

To offer an objective and action-oriented perspective on how to advance the deployment of emerging technologies in the chemicals sector, with a focus on electrification solutions, with the intent to expand to other solution sets in future volumes

Audience

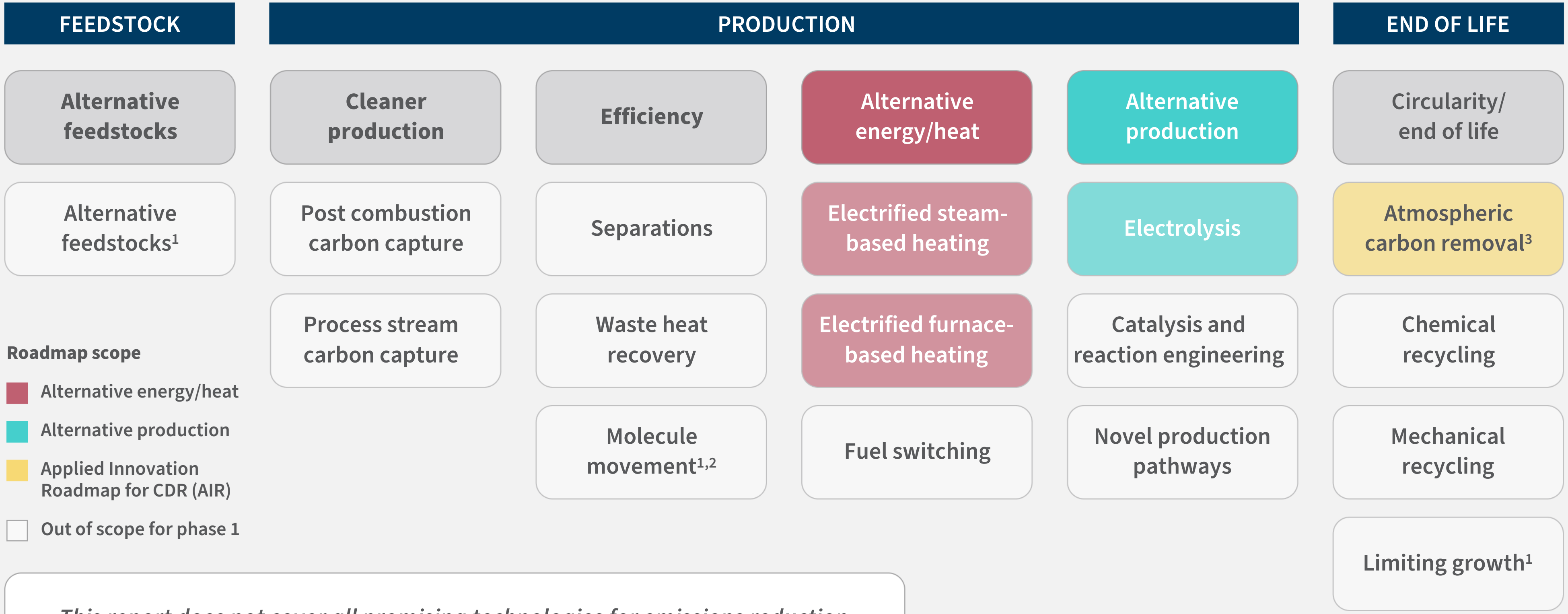
Anyone in a position to help advance the deployment of new technologies to reduce emissions in the chemicals sector. This includes:

- Startups and technology developers
- Chemicals producers and product manufacturers
- Government funding agencies, private donors, and venture capitalists
- Academics, researchers, and educators
- Policymakers
- Nongovernmental organizations and community groups

Intended impact

1. Improve global visibility into research, development, and deployment (RD&D) underway in the chemicals sector and what more is needed
2. Increased, coordinated funding and policy for RD&D gaps in chemicals and critical path activities identified in the applied innovation roadmap (AIR)

Electrification is one of several innovations required to comprehensively reduce chemicals sector emissions at scale



FEEDSTOCK	PRODUCTION				END OF LIFE
Alternative feedstocks	**Cleaner production**	**Efficiency**	**Alternative energy/heat**	**Alternative production**	**Circularity/ end of life**
Alternative feedstocks[1]	Post combustion carbon capture	Separations	Electrified steam-based heating	Electrolysis	Atmospheric carbon removal[3]
	Process stream carbon capture	Waste heat recovery	Electrified furnace-based heating	Catalysis and reaction engineering	Chemical recycling
		Molecule movement[1,2]	Fuel switching	Novel production pathways	Mechanical recycling
					Limiting growth[1]

Roadmap scope

- 🟥 Alternative energy/heat
- 🟦 Alternative production
- 🟨 Applied Innovation Roadmap for CDR (AIR)
- ☐ Out of scope for phase 1

This report does not cover all promising technologies for emissions reduction in the chemicals sector. Further analyses will explore other essential levers.

Notes and sources: 1. Currently considered out of scope of future AIRs. 2. Out of scope due to industry pioneering advancement (e.g., pumps, compressors). 3. *The Applied Innovation Roadmap for CDR*, RMI, 2023.

Each technology is analyzed through nine assessments of potential impact

TECHNOLOGIES COVERED[1]

Alternative energy/heat

1.1 **Induction heating** (steam methane reforming [SMR])

1.2 **Resistive heating** (steam cracking)

1.3 **Shockwave heating** (steam cracking)

1.4 **Air-source heat pumps** [ASHPs] (steam)

1.5 **Thermal energy storage** [TES] (steam)

Alternative production

2.1 **CO_2 electrolysis** (methanol, ethylene)

AIR ANALYSIS

CONTENT FOR EACH TECHNOLOGY

State of play

1. **Technology description** outlining how technology works and its role in chemicals production
2. **Current state** of the market, highlighting companies working toward deployment
3. **Technology readiness level (TRL) and adoption readiness level (ARL)** scoring reflecting readiness of the technology for scaled deployment
4. **CO_2 emissions impact** comparing emissions with incumbents based on electric supply
5. **Human health impact** comparing non-climate health hazards within and beyond chemical plant boundaries
6. **Risk assessment** of potential challenges to scalability and adaptability
7. **Cost improvement potential** of technology with scaled deployment

Pathways to scale

8. **Roadmap to deployment at scale** with stage-gate assessments analyzing investment needed for fundamental technological challenges and research and development needs, as well as for deployment specifically within the chemicals industry
9. **Success story** of what could happen in a best-case global scenario with optimistic projections of deployment scale and cost improvements

Additional detail on the state of play and pathway to scale assessments and how to interpret each page can be found in the *Appendix*.

Notes and sources: 1. Additional technologies may be covered in a future phase of this AIR.

Technology Highlights

Induction Heating

The costly but efficient challenger for hydrogen process heat

- **Highly efficient** compared to fossil-fired heaters
- Can eliminate **40%+ of scope 1 emissions from an SMR facility**
- Challenged by **alternative hydrogen production** and retrofit capability

Resistive Heating

The promising quiet disruptor for steam cracking

- **Simple components,** with **high retrofit potential** enable compatibility with existing units
- Can eliminate **15%+ of scope 1 emissions from a steam cracking facility**
- Challenged by balance of plant considerations and stacking requirement for deep emissions reductions

Shockwave Heating

The smaller-scale specialist for steam cracking

- **Compact** solution compared to conventional heaters and **modular solution**
- Can eliminate **15%+ of scope 1 emissions from a steam cracking facility**
- Challenged by **complex material requirements** and **scale-up challenges** with reliability

Air-Source Heat Pumps

The reliable, low emissions workhorse for steam generation

- **Proven technology** presenting a **drop-in replacement** for conventional steam generation
- Can eliminate **100% of emissions from steam production**
- Challenged by **ability to reach high temperatures** for chemical processes, and **scale-up**

Thermal Energy Storage

The backbone technology for electrification of process heat

- **Mitigates renewable intermittency and cost fluctuations** and provides **a simple solution**
- Can eliminate **100% of emissions from steam production**
- Challenged by **land use** requirements to meet industrial loads and **integration with existing steam systems**

CO_2 Electrolysis

The improbable moonshot with potential to revolutionize chemicals

- Can achieve **complete defossilization** with biogenic or DAC CO2 and 100% low carbon power
- Can eliminate **100% of emissions from ethylene or methanol production**
- Challenged by **high energy use, feedstock availability and scale-up**

Resistive Heating

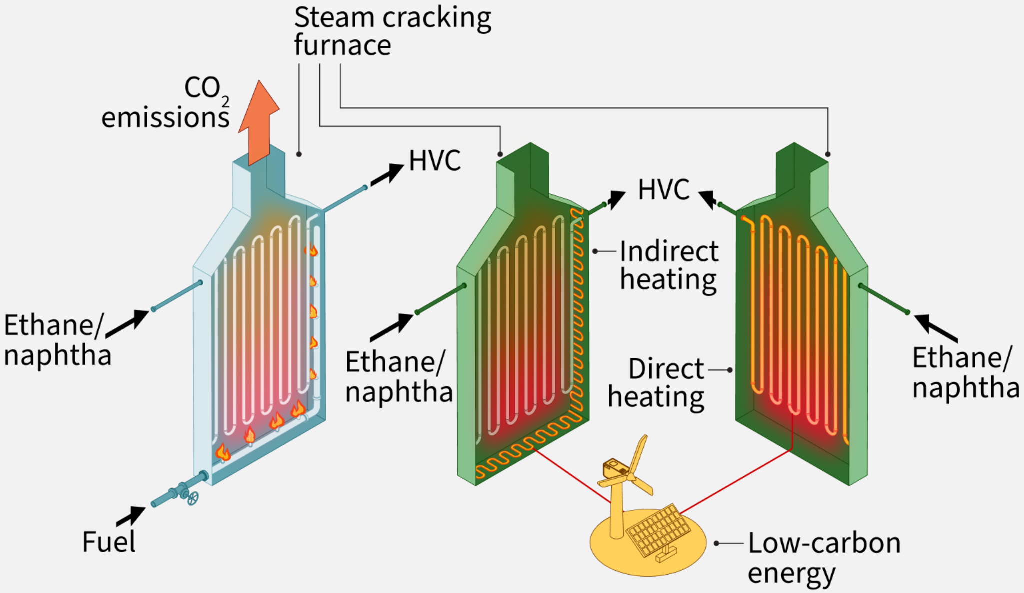
THE APPLIED INNOVATION ROADMAP FOR CHEMICALS:
ELECTRIFICATION TECHNOLOGIES

EMISSIONS REDUCTION CATEGORY	**Alternative energy/heat**
TECHNOLOGY	**Resistive heating**
CHEMICALS PROCESS	**Steam cracking** (ethylene, propylene, benzene)[1]
TEMPERATURE RANGE	**750°C–950°C**[2]

Notes and sources: 1. Resistive heating can be applied to thermal batteries, benzene, toluene and xylene production, H_2 production, and additional downstream processes. This analysis focuses on steam cracking specifically due to the large potential emissions impact. 2. 750°C–950°C is the steam cracking reaction temperature, while steam cracker furnace temperature is typically higher (1,100°C–1,200°C). Temperatures for other applications are projected to be able to exceed these temperatures.

Technology description

Resistive heating can lower chemicals production emissions by replacing natural gas firing with electric coil-based heating



Conventional steam cracking furnace (left), and electric steam cracker furnace with indirect (middle) and direct (right) resistive heating technology

COMPARISON WITH INCUMBENT TECHNOLOGY

Steam crackers convert short-chain hydrocarbons into olefins (chemicals and plastic precursors) using high-temperature heat from fossil fuel–fired furnaces. Resistive heating coils can replace fossil fuel combustion and electrify the heat generation.

HOW THE TECHNOLOGY WORKS

1. Superheated steam and preheated hydrocarbon feedstock (ethane, naphtha) are inputs to the process. The chemical reaction takes place inside heated tubular reactors.
2. An electric current heats resistive elements that heat the cracker's furnaces. At a reaction temperature of 750°C–950°C, the feedstock breaks down into ethylene, propylene, and other high-value products.[1]
3. The products are rapidly cooled to prevent further reaction, and they are separated, compressed, cleaned, and dried.

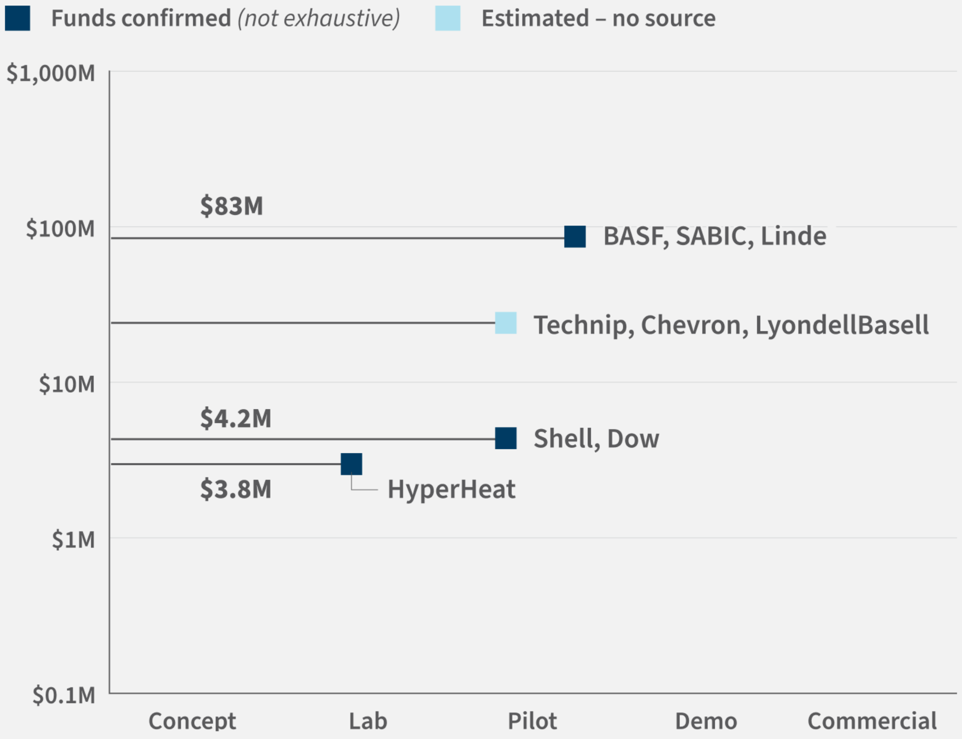
SUBTYPES OF THE TECHNOLOGY

1. **Indirect heating:** Resistive heating elements are installed at furnace walls, and heat is transferred to the coils by radiation.
2. **Direct heating:** Electric current is passed through the reactor tubes, and directly generates heat inside the tubes and facilitates the cracking reaction.

Notes and sources: 1. H_2 and methane coproducts that are typically reused as fuel gas can potentially be managed by routing them to clean H_2 production (ATR or SMR equipped with carbon capture and sequestration).

Current state

Large, multinational companies are leading innovation and have deployed significant capital



NOTABLE COMPANIES/PROJECTS	DETAILS AND DEVELOPMENTS
BASF, SABIC, Linde (Germany): Linde's cracker furnaces under name "STARBRIDGE".[2]	• **April 2024:** Joint project to pilot two electric crackers (3 megawatts [MW] each) at BASF's site in Germany with $15 million via government funding.
Technip, Chevron, LyondellBasell (US): Technip Energies' e-furnace by T.EN for electric steam cracking.[3]	• **June 2023:** Announced Memorandum of Understanding (MOU) for joint design, construction, and operation of electric steam cracking furnace in Texas. • Planned joint development agreement by end of 2023, but no updates since MOU.[4]
Shell, Dow (the Netherlands): e-cracker Furnace[5]	• **June 2022:** Experimental unit operational in Amsterdam with planned multi-MW pilot for 2025 (no updates since 2022).
HyperHeat (Germany): Industrial heat up to 2,000°C using oxide ceramic wires	• Lab-scale technology employing separate heating elements (not process tubes) and oxide ceramic electrical wires to mitigate the major degenerative problems in typical electrical heaters.[6]

Other companies: Cracking of the Future Consortium[7]

STATE OF THE MARKET

- Large, multinational companies are deploying significant capital as part of joint projects to use this technology in industrial applications at the pilot scale.
- Electricity and gas prices, which vary across regions, have an influence on economics and adoption.
- Progress has not been linear; some projects appear to be stalled or on delayed timelines due in part to factors including rising electricity costs, infrastructure bottlenecks, and/or integration complexity. More validation at the pilot scale will be necessary before resistive heating can scale up to the demonstration scale and beyond.

Notes and sources: 1. Funds provided by German government, total project cost estimated at $83 million ("BASF starts the World's First Electric Cracker Furnace," Industry Decarbonization Newsletter, 2024). 2. "BASF, SABIC, and Linde Celebrate the Start-Up of the World's First Large-Scale Electrically Heated Steam Cracking Furnace," Linde, 2024. 3. "Technip Energies, LyondellBasell and Chevron Phillips Chemical Sign MOU for Electric Cracking Ethylene Furnace," Technip Energies, 2023; European chemical consortium evaluating technology opportunities for electric cracking technologies, assumed to include resistive heating ("Accelerating electrification with the 'Cracker of the Future' Consortium," Borealis, 2021). 4. Estimated funding as an average of other announced e-cracking projects by multinational companies. Early-stage pilot due to only MOU announced so far. 5. "Shell and Dow start up e-cracking furnace experimental unit," Shell, 2022. 6. "HyperHeat," Amadeus Capital Partners. 7. Consortium locations based on announced project location, startup location based on headquarters.

Roadmap to deployment at scale

Targeted focus on heater durability and retrofit capability can unlock near-term commercial readiness for electrified steam cracking

RISK TO DEPLOYMENT — HIGHEST → LOWEST

Technology acceleration

$40M–$120M

10–20 years

TRL: 4–6

Challenge	**High-temperature heater durability** Elements need to operate >1,000°C and high current density for multiple years	**Thermal uniformity and control** Even temperature distribution is needed to prevent hot spots and coking or improve selectivity	**Scalable module design** Transition from pilot-scale to commercial multifurnace unit with competitive capital expenses (CAPEX) cost	**Coking and product selectivity** Maintain product yields and run length compared with gas-fired furnaces
Focus actions	• Develop advanced materials with coking resistance • Test long-duration heater performance	• Optimize heater geometry, coil placement, and insulation design • Develop control and monitoring systems for power modulation and temperature balancing	• Develop modular heater blocks for both retrofit and greenfield builds • Validate manufacturability and installation logistics	• Benchmark ethylene selectivity and coil run length • Refine cracking kinetics models with electrical heating instead of gas heating
Investment	**$2M to $20M**	**$10M to $20M**	**$20M to $40M**	**$10M to $40M**
Timeline	**3–5 years**	**4–6 years**	**4–6 years**	**4–8 years**

Deployment acceleration

$100M–$420M

10-20 years

ARL: 4

Challenge	**Retrofit integration** Existing furnaces differ in coil geometry, space, and controls	**Electricity access and cost** High electricity demand increases infrastructure needs	**Supply chain and manufacture** Heater fabrication, controls, and suppliers are limited	**Operational and workforce safety** Operators unfamiliar with high-voltage systems	**Commercial confidence** Investors require proof of reliability, cost, and emissions reductions
Focus actions	• Develop retrofit kit template • Create installation guidelines • Demonstrate retrofit for various feedstocks	• Plan electrical upgrades on site (transformers, interconnects) • Collaborate with utilities to obtain required electrical power	• Qualify vendors for heating elements, power components • Partner with EPCs and furnace OEMs • Develop QA/QC standards	• Create workforce training programs • Update process safety standards for electrical hazards • Publish best practices	• Develop TEA benchmarks and LCA tools • Secure third-party performance certification • Couple with thermal batteries
Investment	**$20M to $170M**	**$50M to $150M**	**$20M to $60M**	**$10M to $25M**	**$1M to $5M**
Timeline	**4–8 years**	**2–6 years**	**2–5 years**	**3–5 years**	**2-4 years**

Notes and sources: Ordered based on relative risk to technology acceleration or deployment acceleration. Total cost and timeline based on assumptions dictating which activities can be pursued in parallel. Approximately 1/3 reduction in time due to parallel execution. Investment represents total global investment needed in multiple projects to address the identified challenge. Cost estimates are ranges and estimated based on publicly available data and expert reviewer feedback.

Alternative energy/heat | Resistive heating | Steam cracking

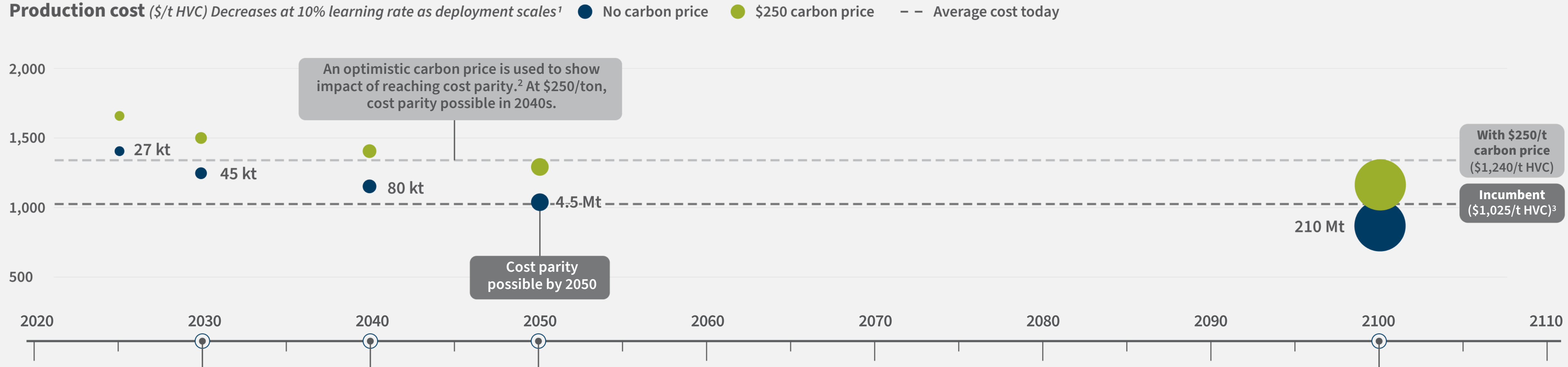
Success story

What is a success story?

- ✓ Optimistic deployment projections
- ✓ What *could* happen in a best-case scenario
- ✓ Independent analysis from roadmap costs and timelines
- ⊖ Expected deployment projections
- ⊖ What *will* happen in any scenario
- ⊖ Based on achieving roadmap actions

Europe leads deployment until cost parity is met by 2050; afterward, all new HVC is electrified

Production cost *($/t HVC) Decreases at 10% learning rate as deployment scales*[1]



An optimistic carbon price is used to show impact of reaching cost parity.[2] At $250/ton, cost parity possible in 2040s.

Cost parity possible by 2050

With $250/t carbon price ($1,240/t HVC)

Incumbent ($1,025/t HVC)[3]

2030
Announced pilots are operational[4]

2040
First commercial-scale furnace is operational

2050
EU leads transition. Facilities transition one furnace at a time between 2040 and 2050. Approximately 22% of EU production capacity by 2050

2100
All new HVC production since 2050 is via electrified steam cracking. Electrified steam cracking is ~40% of global production capacity[5]

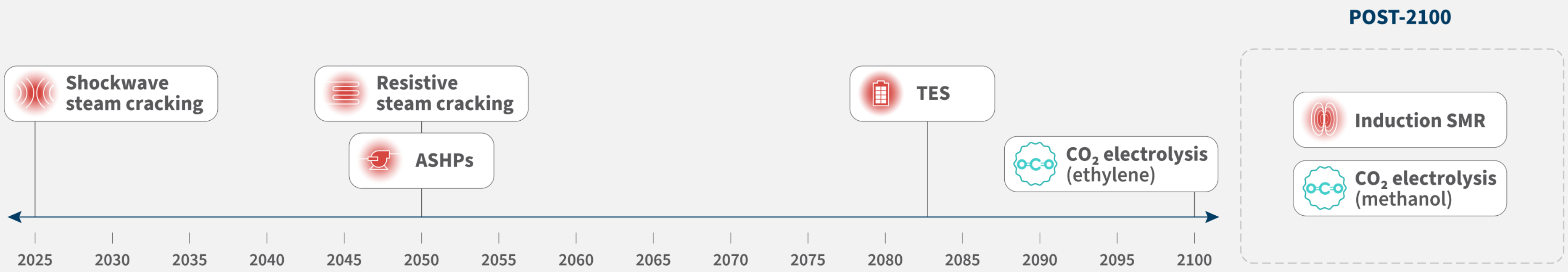
Notes and sources: 1. Production cost only impacted by learning rate as an optimistic, best-case driver for cost improvement. Starting cost based on available data via literature review; actual costs will vary by region and energy costs. 2. Based on the carbon price set in Net Zero by 2050 scenario. Represents potential earlier cost parity point and does not impact deployment in this analysis. (*World Energy Outlook 2024*, IEA, October 16, 2024). 3. Conventional production cost in 2025 used as a benchmark. Although production costs vary by region and over time, a single cost was selected for comparison. 4. Current and announced projects (2025 and 2030) have an applied geographic adjustment factor to account for projects not publicly disclosed or not announced in English. 5. Assumes global HVC production continues to grow, but slower than historic rates to account for slower plastics demand growth.

Key Takeaways

THE APPLIED INNOVATION
ROADMAP FOR CHEMICALS:
ELECTRIFICATION TECHNOLOGIES

Even in optimistic scenarios, many technologies anticipated to reach cost parity after 2050, so accelerating RD&D now is essential to avoid delays

Success stories' cost parity date with incumbent technologies[1]



Shockwave steam cracking

Resistive steam cracking

ASHPs

TES

CO_2 electrolysis (ethylene)

POST-2100

Induction SMR

CO_2 electrolysis (methanol)

KEY TAKEAWAYS

- **Best-case outlook:** Many technologies could reach cost parity in the second half of the century after commercial-scale deployments accelerates in the 2040s.
- **At-scale validation needed:** Further testing and cost verification are needed, especially for low-TRL technologies or those with few operating pilot or demonstration projects.
- **Competing pathways:** CO_2 electrolysis (methanol) and induction SMR face competition from other alternative pathways and may not reach parity before 2100.
- **Regional and temporal factors: Individual** projects' cost parity potential will depend on future local energy prices and policies.

What is a success story?	A success story is not:
✓ Optimistic deployment projections	⊖ Expected deployment projections
✓ What could happen in a best-case scenario	⊖ What will happen in any scenario
✓ Independent analysis from roadmap costs and timelines	⊖ Based on achieving roadmap actions

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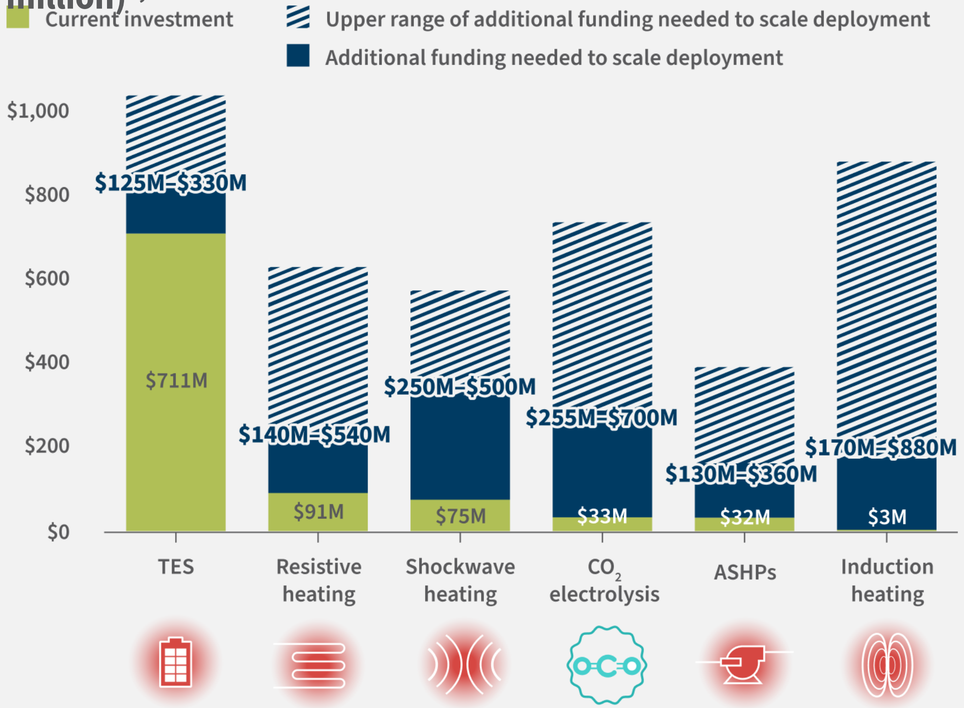
Notes and sources: 1. Production cost is affected only by learning rate as an optimistic, best-case driver for cost improvement. Starting cost is based on available data via literature review; actual costs will vary by region and energy costs. Conventional production cost in 2025 was used as a benchmark. Although production costs vary by region and over time, a single cost was selected for comparison.

Depending on technology focus and cost efficiencies, $100 million to $900 million may be needed to scale RD&D for each technology

Current investment versus additional funding needed to deploy technologies at scale in chemicals industry ($ million)[1,2]



KEY TAKEAWAYS

- **TES is currently leading in RD&D investment.** A key driver is demand for low-emissions steam and power in adjacent industrial sectors. An additional investment **of $125 million to $330 million with a focus on improving material performance and retrofit integration** can scale TES for chemicals.
- Similarly, **ASHPs present a high-impact pathway to decarbonize steam-based heating.** A $130 million to $360 million investment in advanced system design, efficiency, and integration can de-risk deployment for <200°C steam in the chemicals sector.
- **Furnace-based heating technologies** (resistive, shockwave, induction) **and electrochemical production pathways** (CO_2 electrolysis) **represent 75% of the funding needed to scale chemicals electrification RD&D.** These are in earlier stages of deployment. Near-term investment can accelerate pilot and demonstration projects and improve technical performance at scale.

Notes and sources: 1. Funding needed to scale deployment is derived from roadmap calculations outlined for each technology in this report. Shaded bars represent a range of additional investment needed due to uncertainty in technology and deployment acceleration activities. 2. Current funding is based on capital raised by startups; this is not an exhaustive list.

Beyond technology-specific hurdles, electrification projects face broader system-wide challenges that stakeholders must address

INFRASTRUCTURE

Increased industrial electricity demand could put stress on existing infrastructure and may be met with material availability constraints

- New build-out of low-carbon energy generation and transmission will be needed[1]
- On-site facility upgrades will also be needed to serve the new, larger electricity load

RELIABILITY

Transitioning to intermittent low-carbon energy introduces operational risks for facilities

- Continuous 24/7 operations will require energy storage technologies, technology oversizing, or extra low-carbon energy procurement
- Facilities may face competition with other large-demand sources, like data centers, for available low-carbon energy

COST

Transitioning from fossil fuels to electricity will change operating costs for facilities

- Operating costs may increase due to spark gap, the cost differential between electricity and natural gas or coal[2]
- Regional differences in energy prices and grid carbon intensity will affect project economics and emissions impact

COMMUNITY IMPACT[3]

Electrification offers community benefits but requires managing potential risks across the value chain

- Largest opportunities include improved air quality for fenceline communities and job creation across the value chain
- Potential risks include rate impacts for residential customers, construction pollution, and increased e-waste

Notes and sources: 1. Renewable, nuclear, hydro, and geothermal energy sources. 2. See *Appendix* for regional industrial fuel prices. 3. See *Appendix* for broader list of risks and opportunities.

You can help accelerate innovation in the chemicals sector

How to get involved:

- **Information**

  Help RMI stay informed and up to date about new projects, findings, and project outcomes

- **Collaboration**

  Help advance projects on the roadmap by enabling information sharing, or coordination across projects

- **Feedback**

  Offer constructive feedback on the AIR and influence future iterations

To engage, please contact:

Chemicals Initiative at RMI, chemicals@rmi.org

Momentum is building for cleaner chemicals; now is the time to scale for impact in 2026 and beyond

GLOBAL EMISSIONS VISIBILITY & ROADMAPS

Capacity-building with data, clear narratives, accountability, and shared goals. Extend US work to a global model for emissions visibility and reduction across the chemicals sector.

MARKET ACTIVATION

Developing a market-based mechanism that aggregates demand across chemicals value chains and enables customers to claim emissions reductions from verified upstream projects.

REGIONAL POLICY TOOLS

Leveraging techno-economics, emissions, and health impact analysis to identify priority solutions and regional-specific opportunities with actionable policy recommendations.

ACCELERATING INNOVATION

Building Applied Innovation Roadmaps to improve global visibility into RD&D opportunities and increase coordinated funding for RD&D gaps and critical path projects.

Thank You

Please reach out! chemicals@rmi.org

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