

# aluminum

Aluminum — Industry of the Future



Collaborative RD&D efforts are transforming the way aluminum is made and boosting U.S. competitiveness.



Office of Industrial Technologies



Office of Energy Efficiency and Renewable Energy  
U.S. Department of Energy



# partnership

## Consensus on priorities launches revolutionary RD&D agenda

### Partnership works

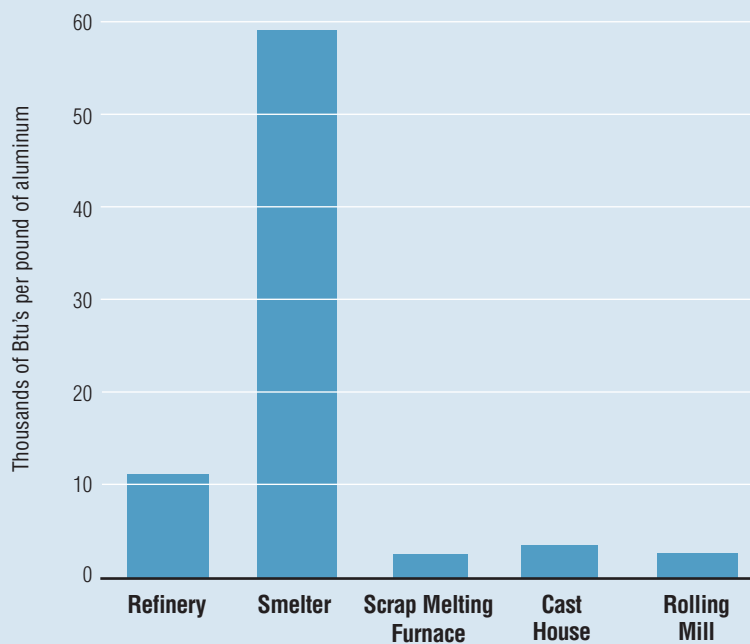
Through participation in the Industries of the Future process, the U.S. aluminum industry now enjoys

- Clearly defined research and development (R&D) priorities
- A common ground for collaboration
- Expanded resources for R&D
- Progress toward major breakthroughs in smelting technology
- New technologies and processes to lower costs and boost productivity

The U.S. aluminum industry is the largest in the world, annually producing more than 22 billion pounds of metal worth nearly \$40 billion. Aluminum's light weight, resistance to corrosion, high strength, and recyclability have made it an essential material for modern economies.

As foreign producers vie for a larger share of the aluminum market, U.S. producers are seeking ways to lower costs, reduce waste, and enhance product quality. Energy represents a key aspect of this competitiveness, contributing roughly a third or more to the cost of producing aluminum from raw materials. In 1996, representatives of the U.S. aluminum industry pledged to work toward shared goals in partnership with the U.S. Department of Energy's Office of Industrial Technologies (OIT) through the **Industries of the Future** process. This partnership is feeding the technology pipeline so that U.S. aluminum producers will get the technologies they need to achieve their economic, energy, and environmental goals in the decades ahead.

### Energy Use in Aluminum Production



Smelting is the most energy-intensive step in primary aluminum production.

Source: Based on data from Nolan Richards, 1997.



## Local communities and the nation benefit

- Reduced energy use
- Reduced waste
- Reduced greenhouse gas emissions

## Industry sets ambitious goals and establishes priorities

Through OIT's Industries of the Future process, the aluminum industry developed its own goals and priorities for reducing energy use, improving environmental performance, and increasing productivity. The industry has produced five complementary documents that establish its framework for success.

### Vision

Under the leadership of The Aluminum Association, the industry reached consensus on broad goals for the future and established the unified research agenda *Partnerships for the Future* to guide collaborative research, development, and demonstration (RD&D).

### Industry Roadmap

In 1997 the industry mapped out its pathway for achieving its vision in the *Aluminum Industry Technology Roadmap*. This landmark document describes priorities, key milestones, and performance targets for collaborative RD&D. Focus is placed on significant improvements in smelting technologies by 2020, including development of a nonconsumable anode to eliminate carbon emissions and a cell that uses only 11 kWh per kilogram of aluminum produced.

### Focused Roadmaps

Recognizing the potential to significantly reduce greenhouse gas emissions, the industry worked through The Aluminum Association with support from OIT to prepare a separate *Inert Anode Roadmap* (1998). The document defines the characteristics sought in an inert anode and identifies the necessary steps and benchmarks in development.

Industry representatives obtained support from DOE's Office of Transportation Technologies to develop the *Aluminum Industry Roadmap for the Automotive Market* (1999). It outlines the R&D needed to facilitate increased aluminum use in the automobile industry, including advances in casting, forming, joining, and recycling of aluminum components.

In February 2000, The Aluminum Association published the *Bauxite Residue Technology Roadmap*, which focuses on one of the key environmental priorities of the aluminum industry—the handling of bauxite residue from primary production. The roadmap identifies R&D needs for some of the most promising options for residue treatment, disposal, and use.



## A critical challenge

Industry-wide consensus on R&D priorities has helped to focus public and private investment on solving the industry's most critical technical problems.

Smelting is a priority area both because of its high energy use (15 kWh per kilogram of aluminum produced) and undesirable by-products (carbon dioxide and other carbon-based gases

implicated in climate change). Achievement of industry's 2020 goals for primary aluminum production will

- Increase the energy efficiency of smelting by 25% to 30%.
- Reduce operating costs by as much as 10%.
- Eventually reduce greenhouse gas emissions by up to 8 million metric tons (carbon equivalent) assuming full market penetration.



# results

## Collaborative teams accelerate progress on innovative technologies

Aluminum manufacturers are working in partnership with DOE's Office of Industrial Technologies to revolutionize the way aluminum is made.

Sharing the costs and risks of RD&D through partnership has made it possible for researchers to simultaneously pursue several promising routes to transform smelting technology. Long-term projects are developing various concepts for an advanced aluminum cell (see below). By 2020 or earlier, these advanced cells should revolutionize primary production, reducing energy use by 25 percent or more and completely eliminating anode-based carbon emissions.

### Revolutionary Cell Technologies for Primary Production of Aluminum

	innovation	partners	benefits
Near- to Mid-Term	<b>Retrofit Technology</b> While the long-term solution is the advanced cell, which incorporates both the inert anode and wettable cathode, separate implementation of these breakthrough technologies is anticipated in the near term.	<ul style="list-style-type: none"> <li>Independent industry efforts</li> </ul>	<ul style="list-style-type: none"> <li>Reduce emissions</li> <li>Save energy</li> </ul>
	<b>Wettable, Drained Cathode</b> A ceramic-based wettable cathode and the necessary engineering packages are being developed as a means to improve the performance of existing Hall-Heroult cells. The candidate materials and drained cathode design are being tested in retrofitted 70 kA prebake cells.	<ul style="list-style-type: none"> <li>Reynolds Metals Company</li> <li>Kaiser Aluminum &amp; Chemical Corporation</li> <li>Advanced Refractory Technologies</li> </ul>	<ul style="list-style-type: none"> <li>Reduce energy requirement by 13% to 20% (<b>13 kWh/kg</b>)</li> </ul>
Mid- to Long-Term	<b>Advanced Aluminum Cells</b> One project design features a vertical electrode slurry cell using a nonconsumable metal alloy anode, a wetted cathode, and an electrolytic bath that is kept saturated with alumina at the relatively low temperature of 750°C. Another project will demonstrate the commercial viability of a cell design using a cathode material that is wetted by aluminum and a cermet anode that produces oxygen rather than carbon. A third project features a nonconsumable anode made up of a thin, oxide-ion-conducting membrane with an electrocatalytic porous internal anode where reformed natural gas is electrochemically oxidized.	<ul style="list-style-type: none"> <li>Northwest Aluminum Technologies</li> <li>Brooks Rand, Ltd.</li> <li>Oregon State University</li> <li>Electrochemical Technology Corporation</li> <li>Alcoa, Incorporated</li> <li>Eltron Research</li> <li>Ohio State University</li> <li>Kaiser Aluminum</li> <li>Gas Research Institute</li> <li>Siemens-Westinghouse</li> <li>TDA Research</li> </ul>	<ul style="list-style-type: none"> <li>Reduce energy requirement by 25% or more (<b>11 kWh/kg</b>)</li> <li>Reduce operating costs 10%</li> <li>Reduce greenhouse gas emissions by 7 million metric tons</li> </ul>
	<b>Aluminum Carbothermic Technology</b> A true departure from electrolytic reduction, this advanced reactor process involves a multi-step, high-temperature chemical reaction that produces aluminum by reduction of alumina with carbon.	<ul style="list-style-type: none"> <li>Alcoa, Incorporated</li> <li>Carnegie Mellon University</li> <li>Elkem ASA Research</li> </ul>	<ul style="list-style-type: none"> <li>Reduce energy requirement by 30% (<b>8.5 kWh/kg</b>)</li> <li>Lower capital costs by 50%</li> <li>Eliminate fluoride emissions, VOC fumes, and spent pollining solid waste</li> </ul>

For more information on these and other OIT-supported projects, please contact the OIT Clearinghouse at (800) 862-2086, or visit the Web site at [www.oit.doe.gov/aluminum](http://www.oit.doe.gov/aluminum)

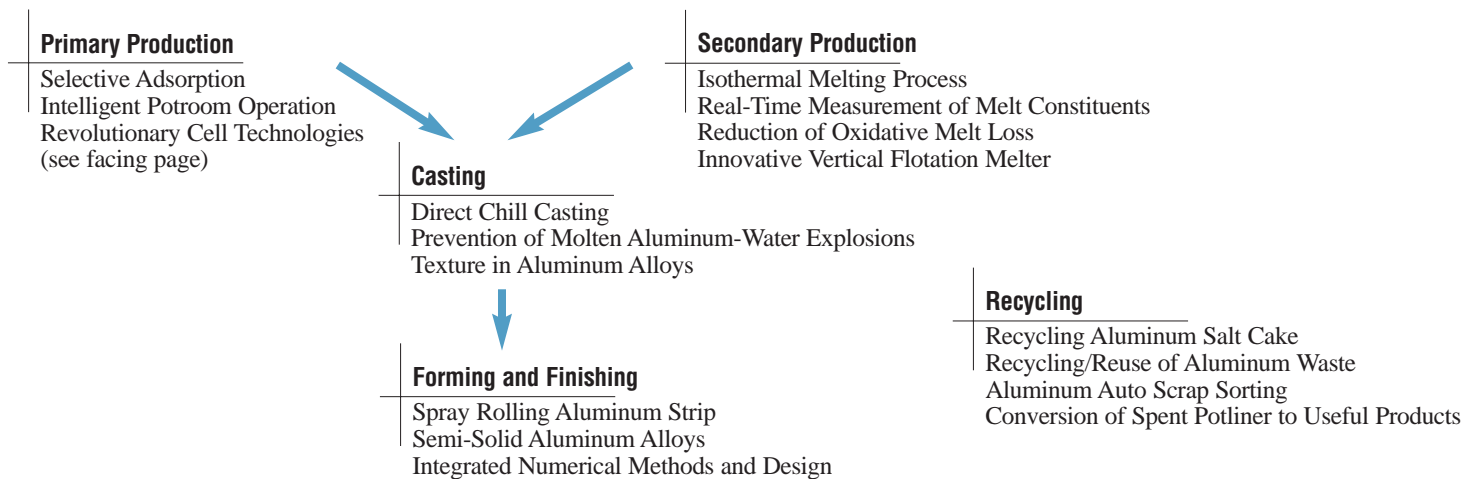


The 25 aluminum projects currently in OIT's aluminum portfolio are worth a total of \$68.5 million in cost-shared funding. Another 23 active OIT projects that are likely to yield benefits to the aluminum industry represent an additional \$18.5 million in combined funding.

## Balanced portfolio based on industry priorities

Guided by industry-defined priorities, OIT provides cost-shared support to a balanced portfolio of RD&D projects that yield useful results in the near-, mid-, and long-term. The projects extend beyond primary aluminum production to solve precompetitive problems in secondary production as well as casting, forming and finishing, and recycling.

## Selected Projects in the Aluminum Industry of the Future Portfolio



## Secondary Production

### Oxygen-Enhanced Combustion for Low-NOx Aluminum Melting

Researchers have combined a high-efficiency, high-capacity combustion system with an innovative oxygen generation system to increase aluminum melting productivity. With the oxygen concentration at 35% to 50%, productivity is increased by 30%, energy use is cut by 40%, and NOx emissions are significantly reduced. The technology can be easily retrofit to existing reverberatory furnaces.

#### Partners

- Air Products & Chemicals, Inc.
- Argonne National Laboratory
- Brigham Young University
- Wabash Alloys, L.L.C.

### Innovative Aluminum Scrap Decoater

The NICE<sup>3</sup> program and Energy Research Company cost-shared a demonstration of a technology to decoat metal using indirect-fired, controlled-atmosphere (IDEX™) kilns.

The metal is first decoated in a rotating kiln by exposing it to a high-temperature, low-O<sub>2</sub> gas, which removes the waste oils without combustion or oxidation. The oil-laden gas is then combusted in an afterburner, apart from the scrap, to destroy the volatile organic compounds (VOCs). The heat released during the oil combustion is then used to drive the decoating process.

#### Benefits

- Energy savings of 56% compared to conventional kiln decoating
- Reduced air emissions, including greenhouse gases, to levels well below permitted allowances
- Improved product quality
- Reduced solid waste disposal (dross and oxidized product)
- Lower operating costs compared to conventional kilns



# resources

## Boosting productivity today and tomorrow

OIT's Aluminum Team provides cost-shared funding to support precompetitive R&D that addresses industry-identified needs and helps achieve national goals for energy and the environment. All R&D awards are based on a competitive solicitation process open to collaborative teams, including aluminum manufacturers and suppliers, universities, national laboratories, and other organizations.

The Aluminum Industry of the Future supplements its R&D budget by coordinating activities with other OIT programs that can help advance aluminum industry goals. OIT's Sensors and Controls program, for example, has funded the development of a process for *in-situ*, real-time measurement of melt constituents, which could increase productivity in aluminum plants. OIT's Metal Casting Team also funds R&D that can offer carryover benefits for aluminum casting. Over the last few years, OIT's Inventions and Innovation program has helped over 20 individual inventors and small businesses develop their concepts for energy-saving aluminum technologies. Similarly, emerging aluminum technologies gain credibility through plant demonstrations funded under OIT's NICE<sup>3</sup> (National Industrial Competitiveness through Energy, Environment, and Economics) program.



### Enabling Technologies

OIT's **Industrial Materials of the Future** program works with industry, the national laboratories, academia, and others to develop and commercialize new and improved materials and coatings that can improve aluminum production, casting, rolling, and extrusion and enhance product quality. The **Combustion** program seeks to improve energy efficiency, reduce emissions, and enhance fuel flexibility by working with the combustion community to develop cost-effective technologies. The **Sensors and Controls** program is working to provide the aluminum industry with integrated measurement systems for operator-independent control of plant processes. Research is extending sensor reach and accuracy in harsh environments and improving the integration and processing of sensor data to enable on-line, automated assessment and adjustment of system parameters.



### Plant-wide assessment at Alcoa plant

A plant-wide assessment of manufacturing processes at Alcoa's aluminum extrusion plant in Lafayette, Indiana, identified eight areas with high energy savings potential. Improvements in these manufacturing processes could save the plant more than \$1.9 million annually, with capital investment costs returned in about 14 months. Energy savings opportunities included improvements in compressed air systems, cooling water recirculation, pumps, and furnace heat recovery, as well as development of process energy use targets.



## BestPractices

OIT offers resources to help aluminum manufacturing companies save energy, reduce costs, and cut waste with existing technologies. OIT provides funding, tools, training, advice, and information.

The program offers **plant-wide assessments** to help large aluminum plants develop a comprehensive strategy for increasing efficiency, reducing emissions, and boosting productivity. Grants of up to \$100,000 in matching funds are awarded through a competitive solicitation process, and a case study helps spread the word on attainable benefits. Alternatively, small to mid-sized manufacturers can take advantage of the **Industrial Assessment Centers**, which provide no-charge assessments through a network of engineering universities.

## Financial Assistance

OIT offers targeted financial assistance to accelerate technology development and adoption. The **Inventions and Innovation** program awards grants of up to \$200,000 to inventors of energy-efficient technologies. Grants are used to establish technical performance, conduct early development, and initiate commercialization activities. The second program, **NICE<sup>3</sup>**, provides cost-shared grants of up to \$500,000 to industry-state partnerships for demonstrations of clean and energy-efficient technologies.

## State-Level Industries of the Future

Programs are starting up in a number of states to bring the energy, environmental, and economic benefits of industrial partnerships to the local level. The state-level program in aluminum has been particularly active in Kentucky, where aluminum producers have formed Secat, a public-private partnership that leverages capabilities and resources to support the industry through technical research and education. West Virginia aluminum manufacturers have also been active in the state-level effort, and a number of projects are in progress there.

**For more information on these and other resources, please contact the OIT Clearinghouse at (800) 862-2086.**

## How to get involved

*Through Industries of the Future partnerships, U.S. aluminum companies can reap the competitive advantages of more efficient and productive technologies and, in turn, contribute to our nation's energy efficiency and environmental quality.*

*To participate:*

- *Monitor the OIT Aluminum Team's Web site for news and announcements of R&D solicitations, meetings and conferences, and research projects ([www.oit.doe.gov/aluminum](http://www.oit.doe.gov/aluminum)).*
- *Team with other organizations and respond to solicitations for cost-shared research.*
- *Begin saving energy, reducing costs, and cutting pollution today by participating in any of the BestPractices programs.*
- *Take advantage of OIT's extensive information resources, including fact sheets and case studies, training, software decision tools, searchable CDs, newsletters, and publications catalog.*
- *Attend the biennial Industrial Energy Efficiency Symposium and Expo.*

[www.oit.doe.gov/aluminum](http://www.oit.doe.gov/aluminum)



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Please send any comments, questions, or suggestions to [webmaster.oit@ee.doe.gov](mailto:webmaster.oit@ee.doe.gov)



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