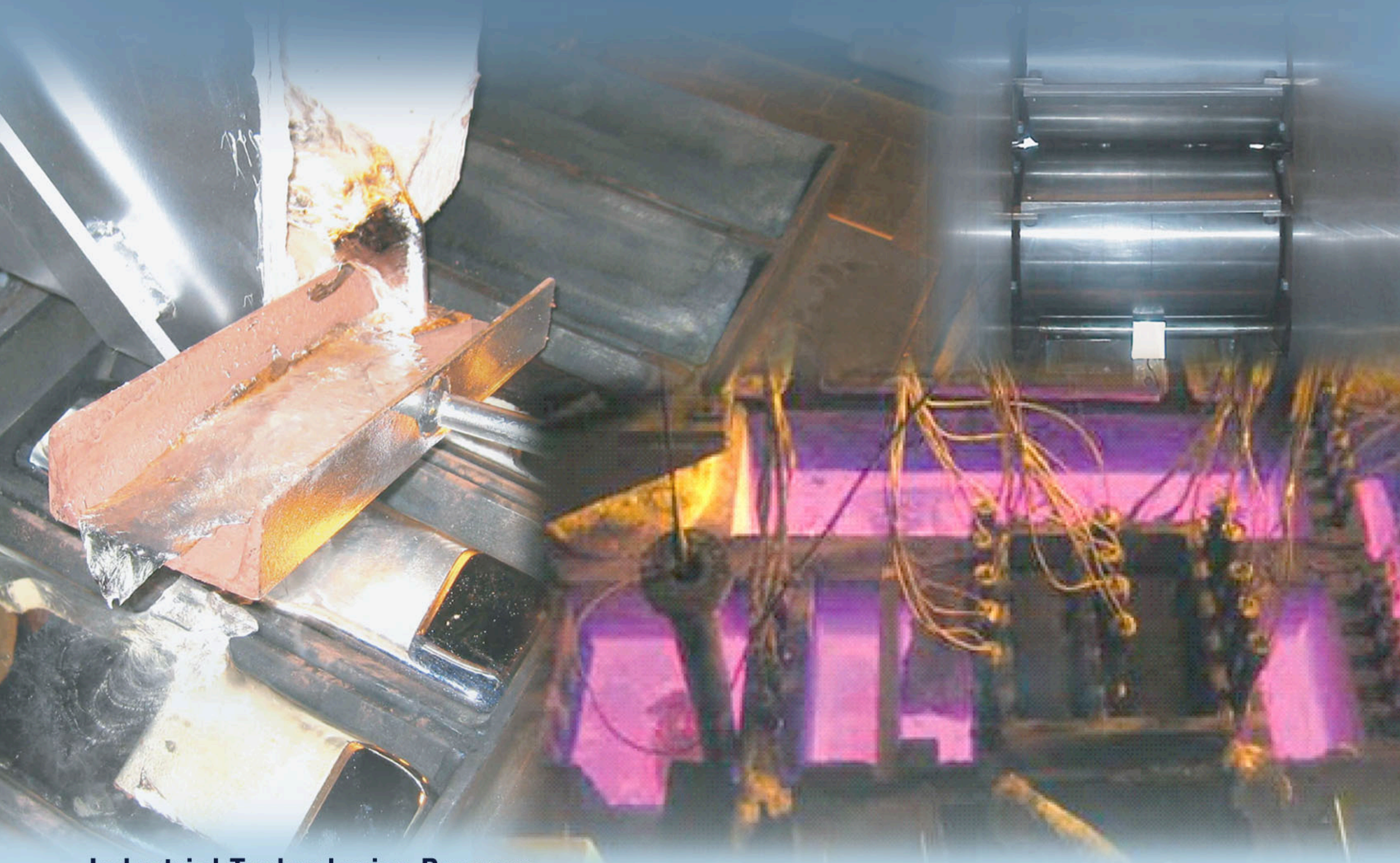
Aluminum

Industry of the Future

Fiscal Year 2004 Annual Report



Industrial Technologies Program

Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

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

Industrial Technologies Program — Boosting the Productivity and Competitiveness of U.S. Industry

Industry consumes 33 percent of all energy used in the United States. By developing and adopting more energy efficiency technologies, U.S. industry can boost its productivity and competitiveness while strengthening national energy security, improving the environment, and reducing emissions linked to global climate change.

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) works in partnership with U.S. industry to increase the efficiency of energy and materials use, both now and in the future. EERE's Industrial Technologies Program (ITP) is working to build the Industries of the Future through a coordinated program of research and development (R&D), validation, and dissemination of energy efficiency technologies and operating practices to reduce energy intensity in the industrial sector. ITP develops, manages, and implements a balanced portfolio that addresses industry requirements throughout the technology development cycle. The primary long-term strategy is to invest in high-risk, high-return R&D. Investments are focused on technologies and practices that provide clear public benefit but for which market barriers prevent adequate private sector investment.

ITP focuses its resources on a small number of energy-intensive materials and process industries that account for over 55 percent of industrial energy consumption.

- Aluminum
- Chemicals
- Forest Products
- Glass
- Metal Casting
- Mining
- Steel

ITP uses a leveraging strategy that maximizes the energy and environmental benefits of its process-specific technology investments by coordinating and cooperating with energy-intensive industries. By working closely with the private sector, ITP is able to effectively plan and implement comprehensive R&D agendas and help disseminate and share best energy management practices throughout the United States. ITP public-private partnerships also facilitate voluntary efforts, such as the President's Climate VISION initiative, to encourage industry and government to reduce greenhouse gas emissions.

ITP also conducts R&D projects on enabling technologies that are common to many industrial processes such as industrial energy systems, combustion, materials, and sensors and process control systems. In addition, ITP funds technical assistance activities to stimulate near-term adoption of best energy-saving technologies and practices within industry. These activities include plant assessments, tool development and training, information dissemination, and showcase demonstrations.

New technologies that use energy efficiently also lower emissions and improve productivity. By leveraging technical and financial resources of industry and government, the ITP partnerships have generated significant energy and environmental improvements that benefit the nation and America's businesses. Energy-intensive industries face enormous competitive pressures that make it difficult to make the necessary R&D investments in technology to ensure future efficiency gains. Without a sustained commitment by the private and public sectors to invest in new technology R&D and deployment, the ability to close the gap between U.S. energy supply and demand will be severely compromised.

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EXECUTIVE SUMMARY

Aluminum is an indispensable metal to modern manufacturing. Its low density, corrosion resistance, and ease of processing make aluminum the metal of choice for many manufactured products ranging from spacecraft components to beverage cans. The aluminum industry consumed nearly 909 trillion Btu (TBtu) in 2002 and produced over $40 billion in products that are vital to U.S. manufacturing. The aluminum industry is responsible for approximately 2.8 percent of the total manufacturing energy consumed in the United States and 1.6 percent of all U.S. electricity consumption. Energy-intensive operations consist of the primary aluminum production from ore, secondary aluminum production from scrap, shape casting, rolling, and extrusion. ITP's Aluminum portfolio cost shares pre-competitive transformational research and development (R&D) to improve the energy efficiency of these operations. It fosters research partnerships and has been credited as the driving force behind many significant technical advances, with the goal of lower energy consumption by an estimated 59 TBtu in 2010.

ITP's Aluminum portfolio conducts its R&D activities to promote partnerships among industry, suppliers, academia, and national laboratories. These partnerships recognize that no single organization is likely to allocate the resources (knowledge, staff, facilities and capital) to pursue high-risk, energy efficiency R&D. R&D partnerships, which include industrial end-users, are established around cost-shared projects to ensure that the developments are of commercial value to the industry. This approach accelerates the rate of development and of new product diffusion. It garners energy efficiency benefits earlier in the product life cycle. These multi-team partnerships also introduce many university and graduate students to the aluminum industry. This enables a well-educated and well-trained workforce, which is imperative for the aluminum industry to remain innovative and competitive in the global economy. The aluminum industry stakeholders developed a vision that they updated in 2001 establishing long-term goals and technology roadmaps that chart the R&D pathways to achieve these goals. These documents, in conjunction with other DOE conducted analyses, have formed the basis for open and competitive R&D solicitations that address the energy efficiency goals outlined in the National Energy Policy, as well as the aluminum industry's research priorities.

This successful industry-supplier-academic-government collaboration continues to focus on transformational research projects to make revolutionary improvements in energy efficiency in the aluminum industry. The following summarizes major highlights and accomplishments of the Aluminum portfolio during FY 2004 and provides a snapshot of the Aluminum portfolio research.

A Successful Strategy with Industry

DOE's Office of Energy Efficiency and Renewable Energy leads federal development of advanced energy-efficient and environmentally-friendly industrial technologies. Aluminum industry R&D is a component of the overall EERE strategy, contributing to a reduction in energy intensity of industry, a goal outlined in the National Energy Policy.

EERE/ITP is working to build the Industries of the Future through a strategy that is based on multi-year planning, industry involvement and input during the planning process, and careful analysis and data based decision making. This strategy not only takes into consideration the interests of the industry as described in their R&D Technology Roadmaps, but also consists of an agenda of analytical studies that provide the basis for decision making. For instance, the *Aluminum Industry Technology Roadmap*, published in 1997 and revised in November 2001, has provided the basis for focusing the R&D by identifying industry research interests. The *Aluminum Energy and Environmental Profile*, Bandwidth study, and Footprint study were developed using both government and industry data and information, and industry expertise to provide the next level of prioritization for the portfolio. By using these studies, the portfolio is able to design a multi-year R&D plan based on the focus area, barrier, and pathway approach. In this approach, a limited number of critical technology focus areas are identified along with the technical barriers preventing their successful implementation. A multi-year plan (called a "Pathway") is then developed that will guide the R&D activities leading to a successful development of the focus area technology. The "Pathways" are then the basis for solicitations of pre-competitive R&D that addresses both energy efficiency goals outlined in the National Energy Policy and aluminum industry research priorities. This successful strategy has now evolved to a point where it provides focus on potentially high-impact research to make revolutionary improvements in aluminum production.

Research Portfolio

ITP manages a diverse Aluminum portfolio of research focused on primary metal production, melting/thermal, and forming operations. Production of primary aluminum from ore is the area with the most opportunities for improving energy efficiency. Approximately 36 percent of Aluminum portfolio funding is directed toward lowering primary metal energy consumption. Essentially, all secondary metal and most imported metal are initially melted to be processed into aluminum products. In addition, molten primary metal is held in furnaces for purification and alloy adjustment. These melting and thermal operations provide large opportunities for energy efficiency improvement. Nearly 47 percent of the Aluminum portfolio funding is directed at melting/thermal operations. Forming aluminum by itself is not a relatively high consumer of energy. However, remelting, trimming, scrap, and off-spec products are energy-intensive. The remaining 17 percent of Aluminum portfolio funding is directed at developing methods and techniques to minimize forming losses.

The FY 2004 ITP Aluminum portfolio consists of 27 projects. These involve over 52 partners from industry, suppliers, academia, and national laboratories working in 20 states to improve the energy efficiency of the industry. These projects typically last from two to four years and will expend over $48 million federal and industry cost-shared funds to address the research priorities identified by the industry in their vision and roadmap documents. The involvement of the industry at the inception of project development accelerates technology transfer and dissemination of research results.

Industrial experts review the Aluminum portfolio annually. These experts provide the Aluminum portfolio with information concerning the performance of each project, the portfolio's technology distribution and potential risk/reward. It is estimated that the activities of ITP's Aluminum portfolio will produce energy savings of over 59 TBtu in 2010.

Aluminum Portfolio Accomplishments

The Aluminum portfolio performed various outreach activities to disseminate R&D results and accelerate adoption of developed technologies during the 2004 fiscal year. Nine documents by the Aluminum portfolio and its partners were presented at the 2004 Minerals, Metals, and Materials Society's (TMS) 133rd annual meeting. The Aluminum USA 2003 Exposition provided the Aluminum portfolio with the opportunity to interact with many of the aluminum industry stakeholders. The Aluminum portfolio worked with the DOE's Midwest Regional Office to coordinate booth activities and to develop a presentation on the Aluminum portfolio and EERE's R&D activities. Students participating in EERE's Industrial Assessment Centers (IAC) in the Chicago area were also invited to attend and participate in the exposition.

The ITP's Aluminum portfolio actively promoted a success story of Alcoa's involvement with DOE's Plant-Wide Assessment (PWA) program, which was instrumental in the development of the Alcoa Energy Services' Energy Efficiency program. The initial 2000 DOE cost-shared PWA at Alcoa's Lafayette, IN, facility identified over $2 million in potential energy savings. The savings opportunities identified by the PWA and the methods used to categorize potential savings opportunities became a key part of Alcoa's Energy Efficiency program. Building on the Lafayette assessment, Alcoa's Energy Efficiency Network has identified over $60 million in potential energy savings that could result in over 6,500,000 million cubic feet of natural gas and 60,000,000 kWh of electricity savings annually. To date, over $15 million of this energy savings potential has been realized.

Current R&D and Project Successes

Researchers at Alcoa, Inc., Elkem, Inc., and Carnegie Mellon University are modeling and pilot testing subsystems of a carbothermic reduction reactor for primary aluminum production. This technology could revolutionize the aluminum industry in the same way that the "mini-mill" changed the steel industry. Researchers have identified and overcome substantial engineering challenges related to materials-of-construction for high-temperature reactors, recovery of aluminum vapor, and process controls for complex multi-stage chemical reactions. The models and test results are providing the technical, economic, and environmental data to evaluate the viability of the carbothermic reduction process. ITP estimates that this new technology will save about 20 TBtu and $108.3 million annually in operating costs by 2020.

The Laser Induced Breakdown Spectroscopy (LIBS) system developed with ITP and Energy Research Company (ERCo) is operational and undergoing field evaluation at Commonwealth Aluminum in Uhrichsville, Ohio. The installed system is intended to be permanent with continued operation by Commonwealth personnel following the initial testing/evaluation. The LIBS system provides real-time molten metal compositional data, enabling the user to adjust concentrations of various elements while manufacturing different aluminum alloys. The system will be commercially useful to production in various industries, including glass, steel, and other metals. A cumulative reduction of 55 TBtu to 83 TBtu per year across the aluminum industry is achievable using this technology.

The "Energy Efficient Isothermal Melting" project utilizes a novel immersion heater concept with the potential to revolutionize melting/thermal capabilities of the aluminum industry. The completely submerged melting tube and real-time controls maintain the temperature of molten aluminum in a furnace system at a constant temperature under various thermal melting loads. Energy efficiencies of over 95 percent have been demonstrated by limiting the energy input to only what is required and not the excessive energy required for heating fuel gases and refractories. This technology is applicable to every segment of the aluminum industry. It will enhance the United States' capability to meet domestic demand for aluminum. The method is also adaptable to other metals and to glass melting.

INDUSTRY OVERVIEW

Even after 100 years, the demand for aluminum continues to increase as it finds new uses and replaces other materials. Its low density, corrosion resistance, and easy processing possibilities, coupled with its ease and value for recycling, strengthen its position as the material of choice in many applications. Aluminum demand has grown at an annual rate of 3.6 percent over the past 10 years. The U.S. per capita consumption in 2002 was 65 pounds. U.S. aluminum manufacturing operations are performed in more than 400 plants in 41 states and employ over 145,000 people. More recently, demand for aluminum is accelerating due to the need for lightweight materials in the transportation sector. Measured in either mass-produced or economic value, aluminum's application exceeds that of any other metal, except iron. Exhibit 1 illustrates the wide use of aluminum and major North American industrial markets for aluminum components.

Exhibit 1
North American Aluminum Major Markets in 2002

Markets	Metric tonnes	Percent
Transportation	3,409,000	**31.8%**
Containers & Packaging	2,258,000	21.1%
Building & Construction	1,564,000	14.6%
Consumer Durables	722,000	6.8%
Electrical	677,000	6.3%
Machinery & Equipment	616,000	5.8%
Other Shipments	390,000	3.6%
Exports	1,069,000	10.0%
TOTAL	**10,705,000**	**100%**

Source: *Aluminum Statistical Review for 2002.* The Aluminum Association, page 27.

Aluminum Industry in Brief

Aluminum metal is made from two sources: primary metal produced from bauxite ore and secondary metal produced from scrap. The aluminum forming industry, consisting of over 300 U.S. facilities, transforms both primary and secondary metals into plate, sheet, foil, extrusions, castings and other components used throughout the U.S. manufacturing industries. The U.S. demand for aluminum metal is met by both domestic production of primary and secondary metals and by imports.

Production of aluminum metal from ore requires very large facilities (capacity over 400,000 tonnes/year) to obtain viable economies-of-scale. The large-scale and high-capital cost requirements ($4,000/annual tonne) limit market entry. Only 11 producers maintain 23 U.S. plants. These plants produced more than 2,705,100 tonnes of primary metal in 2002.[1] Since the inception of the industry in 1886 until 2001, the United States was the world's largest producer of primary aluminum. During the summer of 2001, the majority of the aluminum smelting capacity in the Pacific Northwest – approximately 43 percent of all U.S. primary capacity – was shut down due to four key factors: an extensive heat wave in the western United States, historically low water levels in the Pacific Northwest, a downturn in U.S. economic growth, and significant increases in electricity costs. Energy represents 25 to 35 percent of the costs of producing primary metal. The Pacific Northwest plants have remained idle due to continued high regional costs of electricity and global competition. China, Russia, and Canada have now surpassed the United States in primary aluminum production. In order to compete internationally, the U.S. primary industry is in critical need of new technologies that reduce energy consumption.

Secondary aluminum is produced by melting and purifying scrap or recycled aluminum. The growth of secondary metal production from recycled aluminum products represents the greatest change in the structure of the U.S. aluminum industry. Secondary metal, which accounted for only 18 percent of U.S. aluminum metal production in 1960, accounted for 52 percent in 2002. Recovering aluminum from scrap consumes less than 6 percent of the energy required to produce primary aluminum and capital costs are roughly one tenth the cost of production in a primary plant. The economies-of-scale and barriers to market entry for secondary producers are less significant than in primary production, and the United States has more than 136 plants in 35 states that produced over 2,920,000 tonnes of metal in 2002. The U.S. secondary market will continue its steady growth (4.3 percent annually) and be a major contributor to the industry's energy savings.[3] However, the growth of the secondary industry is limited by the supply of scrap in the Unities States[4]. Intense global competition from countries that recognize the limited supply and economic benefits of producing secondary metal domestically has contributed to a tight international scrap supply market.

1 *Aluminum Statistical Review for 2002*, The Aluminum Association Inc., 2003, p 10.
2 *"Light Metal Age"* Secondary Aluminum Smelters of the United States, Aug 2003 p 8-9.
3 *Aluminum statistical review for 2002*, The Aluminum Association Inc., 2003, p 10.
4 "*Modeling the Impact of Secondary Recovery (Recycling) on U. S. Aluminum Supply and Nominal Energy Requirements,"* William T. Choate, John A.S. Green, TMS 2003.

Shipments and Trade

Exhibit 2 illustrates the changing U.S. primary and secondary production, along with total U.S. shipments (primary, secondary and imports) from 1998 to 2002.

Global restructuring of the primary aluminum industry began in the late 1970s and continues to this day. Energy costs account for 25 to 35 percent of the total cost of primary aluminum production, and nearly 53 percent of the energy used worldwide for primary aluminum comes from hydroelectric power. For this reason, many companies have moved production from sites close to their customers to sites with lower electricity costs. Countries with low energy costs are emerging as primary producers: Brazil, Norway, and Venezuela with hydroelectric power, Iceland with geothermal power and countries in the Persian Gulf with excess fossil fuels. Primary aluminum production is viewed as an effective means of converting a local energy resource into an export that provides hard currency. Exhibit 3 illustrates the decline of U.S. market share as a percentage of world primary production. It is important to note that many U.S. aluminum companies maintain production facilities in other countries around the world. Global primary aluminum production has been growing at a rate of 2.2 percent annually over the last 10 years.

Exhibit 2
U.S. Aluminum Production

Year	U.S. Primary Metal Production metric tonnes	U.S. Secondary Metal Production metric tonnes	U.S. total Supply, metric tonnes
1988	3,712,700	3,442,000	10,419,000
1999	3,778,600	3,695,000	11,154,000
2000	3,668,400	3,450,000	10,699,000
2001	2,636,500	2,970,000	9,093,000
2002	2,705,100	2,920,000	9,500,000

Source: *Aluminum Statistical Review for 2002*, The Aluminum Association, page 7.

Exhibit 3
World Primary Production

Year	Global Primary Metal Production, metric tonnes	U.S. Global Market Share %
1998	22,608,000	16.4%
1999	23,641,000	16.0%
2000	24,395,000	15.0%
2001	24,281,000	10.8%
2002	25,915,000	10.4%

Source: *Aluminum Statistical Review for 2002*, The Aluminum Association, page 46.

Secondary aluminum production accounts for roughly one-quarter of the total aluminum production worldwide, and more than half of the United States' domestically produced aluminum is made from recycled scrap. Recycling has historically been concentrated in the countries where the scrap is generated, with the exception of a few Asian countries, particularly China, that import scrap to supply demand from their automobile industries. The international market for aluminum scrap is changing as developing countries realize that scrap aluminum provides reasonable economies-of-scale for local production to meet local demand. For this reason, scrap exportation from the United States continues to grow and is beginning to exert pressure on the supply of metal to U.S. secondary aluminum producers. Detailed world secondary aluminum production numbers are not available.

Imported aluminum supplies the U.S. demand for metal not met by domestic primary and secondary production. Imports are used to produce nearly one-third of the aluminum products manufactured in the United States. Exhibit 4 lists the five countries that provide most of the U.S. imported aluminum. Imports typically originate from countries with large hydroelectric capacity and low-cost electricity. Canada, which operates 100 percent of its primary production on hydroelectric power, is the largest exporter to the United States.

Exhibit 4
U.S. Imports by Country 2002

Country	Metric tonnes	Percent of Imports
Canada	2,554,000	58%
Russia	752,300	17%
Venezuela	235,300	5%
Australia	97,200	2%
Germany	97,600	2%

Source: *Aluminum Statistical Review for 2002*, The Aluminum Association, page 40.

Energy Use and Emissions in Aluminum Production

The aluminum industry consumed more than 909 TBtu in 2002. This includes an estimated 494 TBtu lost in off-site power generation and distribution losses.[5] The aluminum industry is responsible for about 2.8 percent of all energy consumed by the U.S. industrial sector, with 85 percent of the energy consumption attributable to electric power use. The amount of electricity consumed by an average primary facility is equivalent to that of 300,000 residential homes in the United States.[6] Energy costs the industry over $2 billion each year, or 5.2 percent of the value of products produced in 2000.[7] Exhibit 5 shows the industry's energy use by energy source. While more than 50 percent (218 TBtu/yr) of the on-site energy used is supplied by electric power, the remainder (196 TBtu/yr) is provided by fossil fuels (60 percent natural gas, 14 percent coke and pitch, 20 percent fuel oil, and 6 percent other fuel sources).[8]

More specifically, primary aluminum is one of the most energy-intensive materials produced in large quantities in the United States. Only paper, gasoline, steel, and ethylene manufacturing consume more energy for manufacturing in the United States. During 2002, primary aluminum production was the largest U.S. electric energy consumer, using 57.6×10^9 kWh of electricity, or 1.5 percent of all the electricity consumed by the residential, commercial, and industrial sectors of the U.S. economy. Electricity represents 25 to 35 percent of the costs to produce primary metal.[9] Primary metal production contributes 40 percent, or 7.4 million tonnes annually of the non-combustion CO_2 generated by U.S. industry. This is a by-product of the consumable anodes used for electrolysis. In addition, nearly 28.6 million tonnes/year of CO_2 can be attributed to the electricity needed for the primary reduction reaction.

The melting and purification of scrap to produce secondary aluminum consumes less than 6 percent of the energy required to produce primary aluminum. Hence, recycling in the United States saved more than 788 TBtu of energy in 2002. Fifty-two percent of U.S.-produced metal during that year was made from recycled material. The growth of the secondary metal market is due in large part to its economic benefits.[10] Approximately 2 million tonnes/year of CO_2 are associated with the production of secondary aluminum.

The major aluminum-forming operations, consisting of rolling, extrusion, and shape casting, consume about 40 TBtu annually and emit about 2.8 million tonnes/year of CO_2.

5 These values include energy generation, transmission losses, and feedstock energy. The values assume 9,780 BTU/kWh for tacit electrical energy conversion.

6 Based on the U.S. Department of Energy, Energy Information Administration, *Residential Energy Consumption Survey,* average energy consumption in a year per house ratioed to the average Btu consumption by a primary aluminum facility.

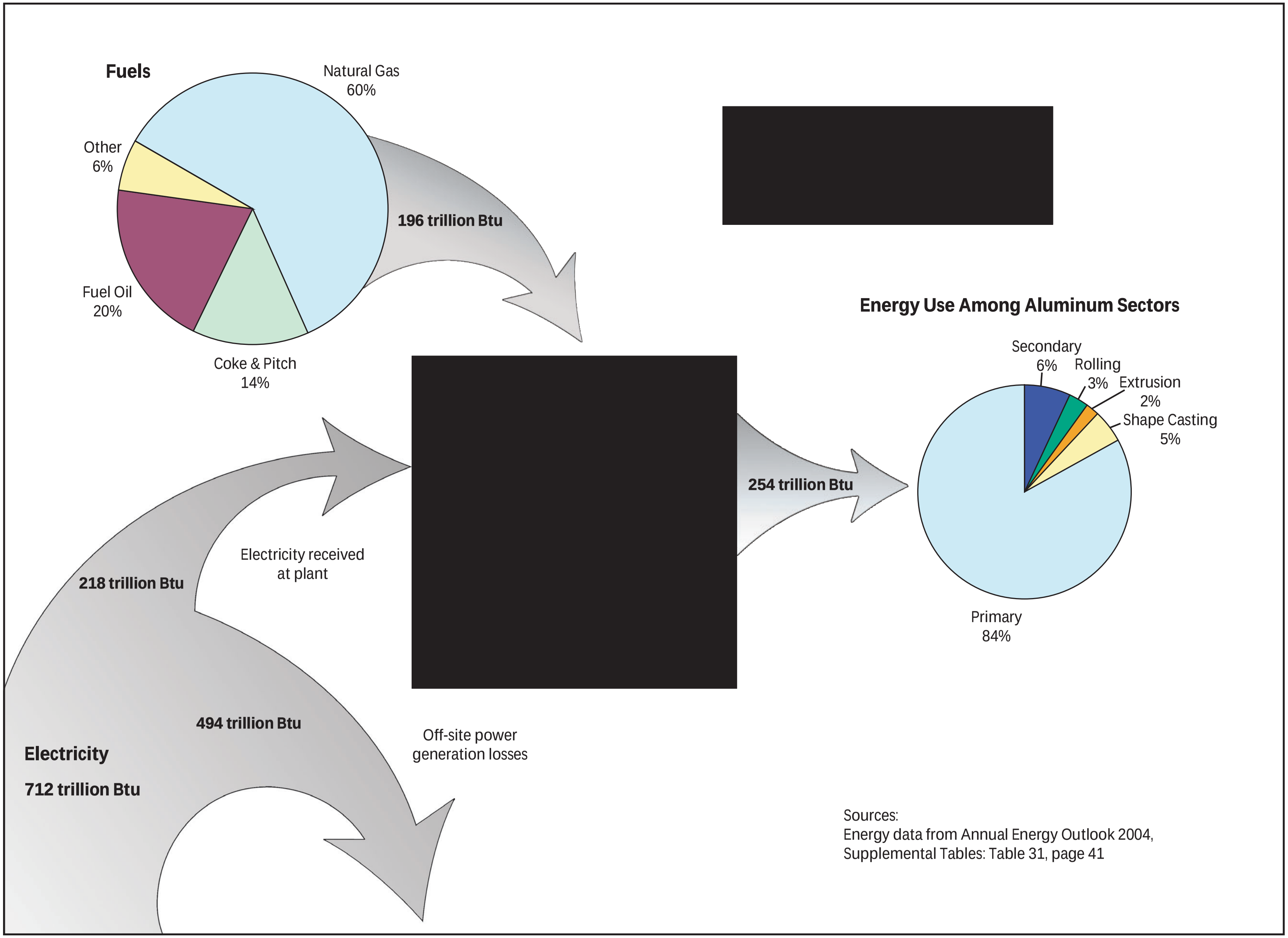
7 Aluminum Industry of the Future http://www.eere.energy.gov/industry/aluminum/profile.html

8 Choate, William T. and John A.S. Green, PhD, *U.S. Energy Requirements for Aluminum Production: Historical Perspective, Theoretical Limits, and New Opportunities*, November 2002, Appendix F, Table F-7.

9 Ibid, Table F-7.

10 Ibid, pg. 59.

Exhibit 5
Energy Use in the Aluminum Sector



Sources:
Energy data from Annual Energy Outlook 2004,
Supplemental Tables: Table 31, page 41

THE CHALLENGE

The U.S. aluminum industry has reduced its energy intensity by 58 percent over the past 40 years: 21 percent as a result of technical progress and 37 percent with the growth of recycling. Secondary aluminum's strong growth rate (4.3 percent annually) will continue to contribute substantially in lowering the total energy demand of the industry. Secondary aluminum is also changing the structure of the industry; its inherently low-energy intensity (6 percent of primary metal) and lower capital requirements have made secondary metal the largest production segment for aluminum in the United States.

All commercial primary aluminum (aluminum from ore) is produced using one process: Hall-Héroult electrolytic reduction of alumina. This process – developed, patented, and commercialized in 1886 – is still in use, and consists of a reaction cell with a single pair of electrodes. The process fundamentals remain unchanged despite vast engineering improvements in efficiency and scale. The Hall-Héroult process is energy-intensive, with electricity accounting for 25 to 35 percent of the total production costs. Significant engineering changes in cell design and operation have occurred as a result of increased attention to energy efficiency, but technical progress of late has been slow and incremental. The last significant energy efficiency process improvement was made in the 1970s as use of new equipment and techniques for smaller and more frequent alumina additions began.

The 777 TBtu consumed in 2002 by the U.S. primary aluminum industry (85 percent of the energy consumed by the entire aluminum industry) was over three times greater than the theoretical minimum requirement. This large difference indicates the technical potential to reduce energy intensity through R&D activities. Although the theoretical ideal may not be achieved, large gains in efficiency and savings appear attainable. Examination of the energy consumption and theoretical requirements of individual processes point to pathways where valuable R&D resources should be focused to provide the greatest reduction of energy intensity. Further efforts to improve the Hall-Héroult process require high-risk and high-cost research. The primary market is mature and in decline in the United States, and like other mature industries, this market focuses their limited resources on product application and use instead of primary metal production. The Aluminum portfolio has selected and funded primary production projects in partnership with industry that could revolutionize the production of aluminum. These projects are high-risk with a potential to provide significant increases in energy efficiency, yet they are endeavors that mature, risk-adverse industries are hesitant to pursue.

All primary metal is placed in holding furnaces to be purified and alloyed. All secondary metal is produced by melting scrap aluminum, purifying, and alloying. A large portion of imported primary and secondary aluminum ingots are remelted for many processing reasons. Nearly every segment of the aluminum industry uses melting/thermal technology to maintain a vast pool of molten metal (over 25 billion lbs/year is a tenable number). The energy required to melt, maintain temperature, and process molten metal was about 118 TBtu in 2002. The average energy efficiency of melting/thermal process is less than 30 percent. This low efficiency provides a significant opportunity for new technologies to save energy.

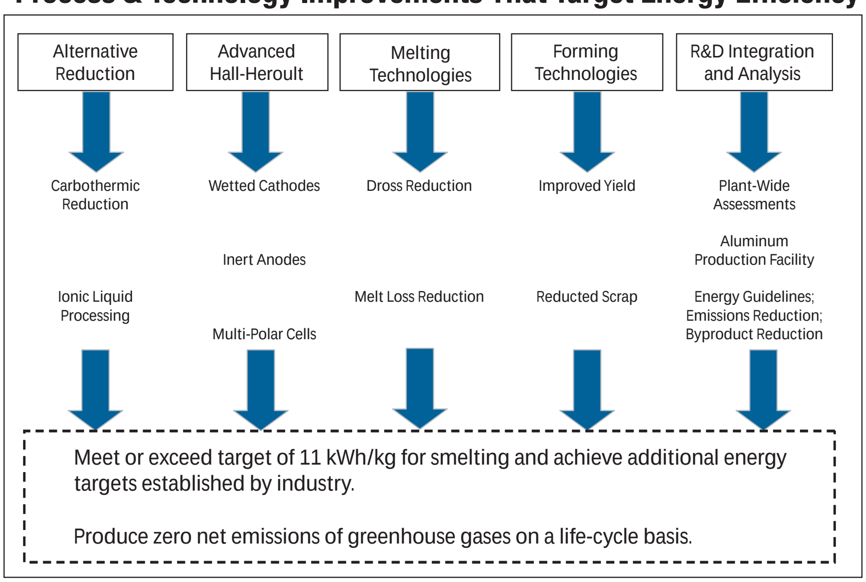
Recovering one pound of secondary aluminum saves 10 times the energy required to produce the same pound of metal with primary processing. The secondary metal industry is dominated by small companies lacking resources to focus on R&D, such as high-risk melting/thermal technologies. The technologies that aid in the recovery of aluminum (e.g., the identification and sorting of scrap), or the reduction of metal lost to oxidation or metal entrained in dross saves nearly all the energy consumed to produce the primary metal. ITP's Aluminum portfolio has therefore selected and funded secondary production projects in partnership with secondary industry members and equipment suppliers. Especially considering the current trend of more and more aluminum ingot being imported, this approach brings together more resources to accelerate development of secondary metal technologies. Furthermore, R&D funding used to improve yield in the forming markets saves significant energy by avoiding the need to remelt scrap with its resultant oxidation and dross losses of aluminum.

Research Categories of the Aluminum Portfolio

The success of ITP's Aluminum portfolio is rooted in a strong alliance between the aluminum industry, its suppliers, academia, national laboratories, and EERE. This collaborative partnership directs its efforts at high-impact, revolutionary research to improve energy efficiency and lower emissions. The research is grouped into five categories:

- **Alternative Reduction Systems:** Research to develop non-Hall-Hèroult reduction techniques that have the ability to revolutionize the aluminum industry.
- **Advanced Hall-Hèroult Cells:** Research to develop materials and engineering designs needed to dramatically reduce unproductive heat-generating cell resistances, eliminate cell-side CO_2 emissions with inert anode materials, and provide more efficient control of cell fluid flows.
- **Melting/Thermal Technologies:** Research focusing on the entire melting/thermal system and involving multiple technologies that minimize melt oxidation, dross formation, and remelting requirements. Improvements in the melting process can significantly impact energy consumption and costs.
- **Forming:** Research to improve product quality, performance, and scrap generation lowers energy by reducing the amount of scrap generated requiring remelting, thereby reducing heat treatment requirements.
- **R&D Integration and System Analysis:** Integration of applicable ITP technologies to improve energy efficiency and reduce emissions in aluminum manufacturing practices. This includes other ITP portfolios and ITP's BestPractices programs for energy demand management.

Exhibit 6
Process & Technology Improvements That Target Energy Efficiency

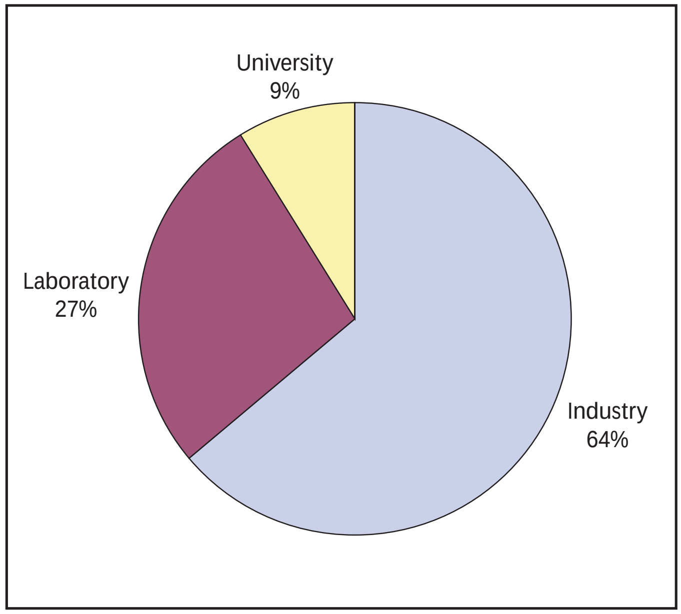


FY 2004 HIGHLIGHTS & ACCOMPLISHMENTS

ITP's Aluminum portfolio supports a diverse and balanced R&D portfolio of cost-shared, pre-competitive projects to realize national goals regarding energy, economy, and the environment. The 27 active projects within the FY 2004 portfolio have a total budget of $48 million, $24 million in ITP funding and $24 million in cost-share funding from the project partners.

All R&D projects are selected through a competitive solicitation process. Official solicitation notices can be found on the ITP's Aluminum Web site, *Commerce Business Daily*, and/or *FedBizOpps*. Projects are chosen based on energy efficiency, environmental improvements, and their ability to meet industry needs identified in vision and roadmap documents. Awarded projects are researched by multi-team partnerships; these partnerships typically include at least one aluminum company or industry equipment supplier in order to boost the market introduction phase of commercial development. Annual R&D portfolio reviews are conducted by industry experts who assess the current status of projects in terms of energy savings and industry impact. These authorities recommend project modifications to the Aluminum portfolio and principal investigators to ensure that milestones are reached and goals are achieved. The Aluminum Association plays an active role in supporting, monitoring, and disseminating project results and Aluminum portfolio activities.

Exhibit 7
ITP Aluminum Funding By Performing Organization

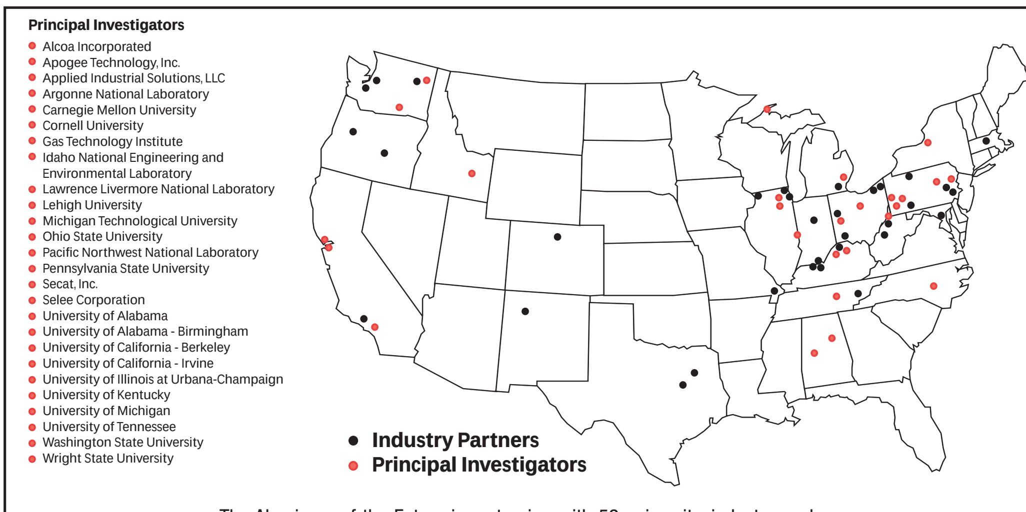


Broad Industry Partnership

The Aluminum portfolio facilitates R&D collaboration among industry, suppliers, universities, and national laboratory participants. Partnerships spread the cost and risk of R&D to promote innovation and progress on projects too complex, costly, or time-consuming for companies to undertake individually. Technical expertise, practical experience, and state-of-the-art resources and facilities are brought together to dramatically accelerate advances in critical challenge areas.

The FY 2004 Aluminum portfolio funded 27 active projects with 52 industry, laboratory, and university partners in 20 states. Exhibit 7 illustrates the distribution of ITP Aluminum funding by performing organization. Industry received 64 percent, national laboratories 27 percent, and universities 9 percent of the Aluminum project funding. The geographic reach of

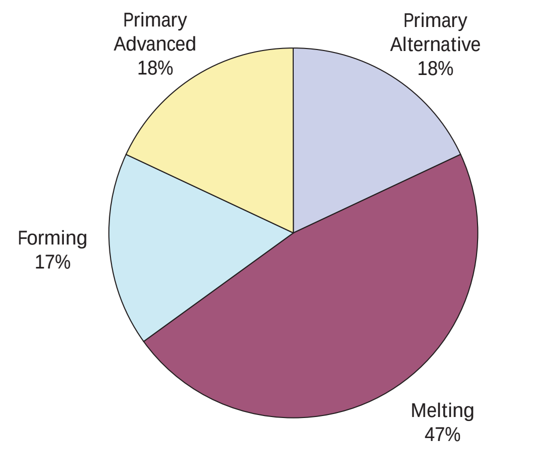
Exhibit 8
Industry Partnership – Aluminum Research Performers and Project Partners



The Aluminum of the Future is partnering with 52 university, industry, and laboratory partners in 20 states across the U.S.

the Aluminum portfolio partnership is illustrated in Exhibit 8 and includes suppliers, designers, manufacturers, end-users, and national laboratories. The portfolio also enables the industry to expose students to opportunities in the aluminum industry by involving universities in various research projects.

Exhibit 9
Research Funding by Roadmap Category



A Diverse Research Portfolio

Exhibit 9 illustrates Aluminum portfolio funding by research category. The portfolio addresses the diversity of the industry with research in melting/thermal, forming, and primary operations. The largest opportunities for improving energy efficiency are in the primary production sector and a significant portion (36 percent) of the funding goes to research in this area. This proportion of funding recognizes the high risks involved and the decline of the primary sector in the United States. The research focuses on technologies that, in addition to reducing energy usage, will help to sustain the industry in the United States. A list of the current portfolio of aluminum projects along with performing organizations organized by research categories is shown in Exhibit 10.

Exhibit 10
Aluminum Portfolio by Primary Category and Project Leadership

(Fact sheets are available at http:/www.eere.energy.gov/industry/aluminum/portfolio.html)

Primary

Advanced Hall-Héroult

- Inert Metal Anodes for Primary Aluminum Production *(Argonne National Laboratory) 1644*
- Microwave-Assisted Electrolyte Cell with Inert Anode and Wetted Cathode for Primary Aluminum Production *(Michigan Technological University) 1850*
- Numerical Modeling of Transient Melt Flows and Interface Instability in Aluminum Reduction Cells *(University of Michigan) 1853*

Alternative Reduction Technologies

- Aluminum Carbothermic Technology *(Alcoa Incorporated) 1273*
- Low-Temperature Reduction of Alumina Using Fluorine-Containing Ionic Liquids *(University of Alabama) 1854*

Melting

- Energy-Efficient Isothermal Melting (ITM) of Aluminum *(Apogee Technology, Incorporated) 1646*
- Spray Rolling Aluminum Strip *(University of California-Irvine) 1079*
- High-Efficiency Low-Dross Combustion System for Reverberatory Furnaces *(Gas Technology Institute) 1274*
- Molten Aluminum Treatment by Salt Fluxing with Low Environmental Emission *(Ohio State University) 1855*
- Improving Energy Efficiency in Aluminum Melting *(Secat, Incorporated) 1645*
- Modeling Optimization of Direct Chill Casting to Reduce Ingot Cracking *(Secat, Incorporated) 1276*
- Reduction of Oxidative Melt Loss *(Secat, Incorporated) 1277*
- Selective Adsorption *(Selee Corporation) 1272*
- Gas Fluxing of Aluminum *(University of California Berkeley) 1753*
- Degassing of Aluminum Alloys Using Ultrasonic Vibrations *(University of Tennessee) 1852*

Forming

- Combined Experimental and Computational Approach for the Design of Mold Surface Topography *(Cornell University) 1844*
- Coolant Characteristic and Control in Direct Chill Casting Aluminum *(Idaho National Engineering and Environmental Laboratory) 1684*
- Development of a Rolling Process Design Tool for Use in Improving Hot Roll Slab Recovery *(Lawrence Livermore National Laboratory) 1683*
- Surface Behavior of Aluminum Alloys Deformed Under Various Processing Conditions *(Lehigh University) 1752*
- Effects of Impurities on the Processing of Aluminum Alloys *(Pennsylvania State University) 1856*
- Evaluation & Characterization of In-Lined Annealed Continuous Cast Aluminum Sheet *(Secat, Incorporated) 1686*
- Effects of Casting Conditions and Composition on Microstructural Gradients in Roll Cast Aluminum Alloys *(University of Alabama-Birmingham) 1851*
- Reduction of Annealing Times for Energy Conservation in Aluminum Processing *(Carnegie Mellon University) 1755*
- Two-Phase Model for the Hot Deformation of High-Alloyed Aluminum *(University of Illinois-Urbana) 1754*
- Structural Factors Affecting Formability of Continuous Cast Aluminum Alloys *(University of Kentucky) 1760*
- Development of Integrated Methodology for Thermo-Mechanical Processing of Aluminum Alloys *(Washington State University) 1756*
- Continuous Severe Plastic Deformation Processing of Aluminum Alloys *(Wright State University) 1687*

Integrated Technical Assistance for the Aluminum Industry

ITP and other EERE portfolios have specifically supported and promoted programs that contribute to enhancing the viability of the aluminum industry. ITP has designed its organizational structure to provide every industry with a strategic and integrated array of assistance programs for saving energy. Approximately $25 million in funding and research relevant to the aluminum industry was provided in 2004 through the combined investments of the EERE NICE[3], EERE Inventions & Innovation, and ITP's Steel, Metal Casting, Sensors and Controls, and Supporting Industries portfolios.

Exhibit 11
Examples of EERE Technical and Financial Assistance

- **I&I:** Inventions and Innovation (I&I) provides financial assistance for conducting early development and establishing technical performance of innovative, energy-saving ideas and inventions.
- **IAC:** Industrial Assessment Centers enable eligible small and medium-sized manufacturers to have comprehensive industrial assessments performed at no cost to the manufacturer.
- **State EERE Partnerships:** State EERE Partnerships deliver the accomplishments of the national Industries of the Future strategy to the local level to expand the opportunities to a larger number of partners and reach smaller businesses and manufacturers that were not initially involved in EERE's efforts.

EERE's technical and financial resources extend beyond support of ITP's Aluminum portfolio to improve energy efficiency and increase competitiveness in the aluminum industry. Several examples of EERE assistance are shown in Exhibit 11. Exhibit 12 specifically lists examples of recent related research activities conducted concurrently with those funded through the Aluminum portfolio. EERE provides research on leading-edge enabling technologies, including Sensors &

Exhibit 12
Examples of EERE and ITP Research Related to Aluminum

EERE Financial Assistance
- Aluminum Bridge Decking
- Aluminum Scrap Decoater
- Demonstration of a High-Temperature Corrosion-Resistant Recuperator for the Metals Industry
- Energy Conserving Tool for Combustion Dependent Industries
- Increasing Productivity and Reducing Emissions Through the Enhanced Application Control Die
- Casting Lubricants
- Microsmooth Process on Aluminum Wheels
- Rapid Heat Treatment of Cast Aluminum Components
- Recycling of Aluminum Dross/Saltcake
- Advanced Intermetallic Alloy Development
- Lightweight, Cost-Effective Cast Aluminum Diesel Engine Head with Localized Reinforcement
- CFCC Immersion Tubes
- Nickel Aluminide Heat Trays and Furnace Fixtures
- Brazing and Spot Welding Innovations for Joining Aluminum Compounds
- Development of a Composite-Reinforced Aluminum Conductor
- Development of an Innovative, Energy-Efficient, High-Temperature Natural-Gas-Fired Furnace
- Development of Inert Anode for Primary Aluminum Industry
- Energy-Saving Lightweight Refractory
- Filtering Molten Metal
- Innovative System Blows Away Sorting Problems for Recyclers
- Monolithic Refractory Material
- Nickel-Based Superalloy with Improved Oxidation Resistance
- Novel Ceramic Composition for Hall-Héroult Cell Anode Technologies
- Viable Inert Cathode for Smelting Primary Aluminum
- Novel Technique for Increasing Corrosion Resistance
- Reflective Aluminum Chips
- Titanium Matrix Composites Tooling Material for Enhanced Manufacture of Aluminum Die Castings
- Viable Inert Cathode for Smelting Primary Aluminum

ITP Crosscutting Applications
- Forced Internal Reticulation (FIR) Burner (Combustion)
- Dynamic Expert System Controls for Optimum Oxyfuel Melter Performance (Glass)
- Advanced Lost Foam Casting Technology (Metal Casting)
- Development of Natural Aging Aluminum Alloy (Metal Casting)
- Die Materials for Critical Applications and Increased Production Rates (Metal Casting)
- Gating of Aluminum Permanent Mold Castings (Metal Casting)
- Heat Transfer at the Mold/Metal Interface in Permanent Mold Castings of Aluminum Alloys (MetalCasting)
- Metallic Reinforcement of Direct Squeeze Die Cast Aluminum Alloys for Improved Strength and Fracture (Metal Casting)
- Optimization of the Squeeze Casting Process for Aluminum Alloy Parts (Metal Casting)
- Sensors for Die Casting (Metal Casting)
- Effects of Applied Pressure During Feeding on the Fatigue Properties of Cast Aluminum Alloys (Metal Casting)
- Rotary Burner Demonstration (Petroleum)
- Centrifugally-Cast Nickel Aluminide Transfer Rolls for Steel (Steel)
- Laser Ultrasonics for On-line Measurement of Tube Wall and Eccentricity (Steel)
- Measurements of Melt Constituents with LIBS (Steel)
- No_x Emissions Reduction by Oscillating Combustion (Steel)
- Intelligent Extruder (Sensors and Controls)
- Thermal Imaging Control of Furnaces and Combusters (Sensors & Controls)
- Enhancement of Aluminum Alloy Forging (Supporting Industries)
- Materials and Process Design for High-Temperature Carburizing (Supporting Industries)
- Innovative Die Material and Lubrication Strategies for Forging Technologies (Supporting Industries)
- Integrated Heat Treatment Model for Aluminum Castings (Supporting Industries)

Technical Assistance
- ITP BestPractices – Plant Assessments and Hands-On Technical Assistance
  - Alcoa
  - Amcast
  - Alumax
  - Metlab
- Industrial Assessments
- Over $20 million in annual energy-saving recommendations implemented in the aluminum industry since 1992.

Controls, Industrial Materials, Combustion, Forging, and others. Consistent with ITP, all these portfolios permit risk sharing for the advancement of industry-specific, pre-competitive, long-term, high-impact research. EERE provides financial assistance for small businesses through Small Business Innovative Research (SBIR) grants.

The Aluminum portfolio is also working with Allied Partners to help deploy the results of aluminum research and improve energy efficiency in the industry. Allied Partners are manufacturers, trade associations, industrial service and equipment providers, utilities, and other organizations committed to promoting increased energy efficiency and industry productivity. The Aluminum portfolio has two Allied Partners - Secat, Incorporated and The Aluminum Association Inc. These Allied Partners are working with ITP to disseminate the results of its research programs and technical assistance.

The Aluminum Industry of the Future achieved a number of important accomplishments in FY 2004 with energy efficiency improvements being applied to the aluminum industry. The following describes successes in several key areas:

- Applying R&D Results
- Disseminating Research Results

Applying R&D Results

The aluminum industry is using ITP's Aluminum portfolio research results to improve energy efficiency and lower costs. The Aluminum portfolio reviews its portfolio to identify those technologies that are emerging as potential commercial successes or are currently experiencing commercial success. "Emerging" technologies are those that have achieved laboratory or pilot-scale successes and are ready to be deployed on a commercial scale. ITP "commercial" technologies are those currently being used in the commercial industry as a result of funding. The following list provides examples of these commercial and emerging technologies.

Current R&D with Promising Results

Aluminum Carbothermic Technology (#1273): The carbothermic process is a complex, high-temperature (>2,000°C), three-stage thermodynamic reaction system for producing primary aluminum. Researchers led by Alcoa, Incorporated are demonstrating the technical, economic, and environmental viability of this industry-changing alternative to Hall-Héroult technology. This technology is estimated to reduce energy use by 35 percent, capital costs by 65 percent, and the environmental costs of producing aluminum. This research on the individual reaction stages will be completed in early FY 2005. ITP estimates an energy savings of 10.0 TBtu and an energy cost savings of $56.4 million in 2020 for this project. To learn more, please visit: http://www.eere.energy.gov/industry/aluminum/pdfs/act-arp.pdf

Inert Metal Anodes for Primary Aluminum Production (#1644): A multipolar pilot cell utilizing inert anodes and wettable cathodes has demonstrated a 17 percent reduction in electrical energy use over 50 hours of continuous operation. This pilot cell will be modified in the first quarter of FY 2005 to allow 1,000-hour continuous runs. These longer runs will evaluate and optimize the long-term stability of the electrodes and electrolyte system. This technology will result not only in lower electrical energy costs, but will lower thermal energy losses, have smaller economies-of-scale than Hall-Héroult and eliminate CO_2 emissions from the reduction reaction. To learn more, please visit: http://www.eere.energy.gov/industry/aluminum/pdfs/dyninertmetanodes.pdf

Energy-Efficient Isothermal Melting (ITM) of Aluminum (#1646): The ITM process achieves many of the goals outlined in the aluminum industry roadmaps, including: operates at well under half of the energy consumption required for conventional melting, decreases melt loss (1 percent versus 6 percent), reduces dross generation, produces no in-plant emissions, is practical for large-scale aluminum operations, future versions can be used in retrofit applications for existing furnaces, derivative heaters can be applied to energy-efficient heating and holding applications, and requires less than 25 percent of the floor space, as compared to conventional melting furnaces. The isothermal melting system has demonstrated success at 300 lb/hr, and in the third quarter of FY 2005, a new system will be installed into a 5,000 lb/hr melting bay of an exiting reverberatory furnace in order to evaluate and optimize the system under industrial conditions. To learn more, please visit: http://www.eere.energy.gov/industry/aluminum/pdfs/itm.pdf

Emerging Technologies

Emerging Technologies are projects that are no longer receiving ITP funding but are anticipated to be commercialized within the next three years.

Laser-Induced Breakdown Spectroscopic (LIBS): LIBS is a in-situ, real-time technique to measure the constituents of molten metal in a process furnace. Currently, constituent or elemental analysis is conducted by periodically extracting a molten metal sample from a furnace and taking it to a control laboratory for analyses. This is labor intensive and time consuming, and it does not allow real-time control. In-situ, real-time measurement of melt constituents will improve product quality by reducing defects, increasing furnace cycle times leading to continuous and semi-continuous operations, increasing furnace life by diagnosing the state of the furnace, and providing necessary data to develop and validate computer modeling and simulation leading to increased automation and efficiency of furnace operations.

Commercial Technologies

The Vertical Flotation Melter (VFM): Energy Research Company and other industrial partners designed, built, tested, produced, and marketed an innovative Vertical Flotation Melter (VFM) for processing scrap aluminum. The VFM can decoat aluminum scrap for feeding into a conventional furnace, or it can simultaneously decoat and melt scrap, which is a unique accomplishment. The thermal efficiency of the integrated decoat/melt process is estimated to be over 75 percent. The emissions of NO_X, SO_2, CO, and VOCs from the VFM process have been measured to be well below allowable limits. The VFM has demonstrated a 58 percent thermal efficiency melting. It is estimated to provide potential U.S. energy savings of 17 trillion Btu. To date, 15 VFM decoaters have been installed in the United States. To learn more about this project, please view the final report at: http://www.eere.energy.gov/industry/aluminum/pdfs/floatation.pdf

Disseminating Research Results

ITP's Aluminum portfolio performs outreach activities to disseminate R&D results, advance emerging technologies and promote involvement in activities such as conferences, seminars, and trade shows. The following outreach activities were conducted during FY 2003:

The Minerals, Metals, and Materials Society (TMS) Annual Meetings: In February, 2004, TMS hosted its 133rd Annual Meeting and Exhibition in Charlotte, North Carolina. This annual event is the largest gathering of aluminum technologists in the United States. The Aluminum projects were well represented with nine documents directly related to the portfolio presented.

Aluminum USA 2003 Exhibition: The Aluminum USA 2003 Exposition provided the Aluminum portfolio with the opportunity to interact with many of the aluminum industry stakeholders. The Aluminum portfolio worked with DOE's Midwest regional office to coordinate booth activities and to develop a presentation on the Aluminum portfolio and EERE's R&D activities. Students participating in EERE's Industrial Assessment Centers (IAC) in the Chicago area were also invited to attend and participate in the exposition.

TOOLS, PUBLICATIONS, AND RESOURCES AVAILABLE

A large variety of Best Practice software tools, publications, and other resources are provided to the industry by the Aluminum portfolio and its partners. These items promote energy-efficient practices, provide information on new technologies, and inform the industry of activities provided by EERE.

The tools available from the Aluminum portfolio include:

Vision and Roadmaps: The industry's unified vision outlines broad goals for the aluminum industry's future. The roadmaps establish the aluminum industry's R&D priorities, performance targets, and milestones for attaining the visions goals. The roadmaps for the Aluminum portfolio are:

- *Aluminum Technology Roadmap (2003)*
- *Alumina Technology Roadmap*
- *Inert Anode Roadmap*
- *Aluminum Automotive Roadmap*

Energy and Environmental Profile of the Aluminum Industry: This report benchmarks the energy and environmental characteristics of the key technologies used in the major processes of the aluminum industry.

U.S. Energy Requirements for Aluminum Production: Historical Perspective, Theoretical Limits, and New Opportunities: This report (2003) provides detailed appendices, statistical data, and descriptions of the fundamental chemistry, as well as practical aspects of aluminum production processes. It compares current usage levels to theoretical minimum energy requirements to demonstrate that large energy-saving opportunities exist.

Inert Anode Report: This American Society of Mechanical Engineers report provides a broad assessment of open literature and patents that exist in the area of inert anodes and their related cathode systems and cell designs, technologies that are relevant for the advanced smelting of aluminum. The report also discusses the opportunities, barriers, and issues associated with these technologies from a technical, environmental, and economic viewpoint.

Efficient Process Heating in the Aluminum Industry: This report (2003) provides suggestions for enhancing the energy efficiency of melters and furnaces to cut process-heating costs by 10 to 30 percent.

To view these documents and applications, please visit: http://www.eere.energy.gov/industry/aluminum/analysis.html

Fact Sheets

ITP's Aluminum portfolio disseminates information on current and past projects through project fact sheets. The information provided in each fact sheet includes the objective, accomplishments, benefits, principal investigator, and project partners. All aluminum fact sheets are available on-line at: http://www.eere.energy.gov/industry/aluminum/portfolio.html.

HOW TO GET INVOLVED AND CONTACT INFORMATION

Partnership Information

Public-private partnerships are the foundation of ITP's technology delivery strategy. ITP includes its partners in every phase of the technology development process to focus scarce resources where they can have the greatest impact on industrial energy efficiency. To learn more, please visit our Web site at http://www.eere.energy.gov/industry.

- Collaborative, cost-shared research and development projects are a central part of ITP's strategy. Annual solicitations provide technology development opportunities in a variety of energy-intensive industries.

- Industries of the Future partnerships increase energy efficiency in the most energy-intensive industries. In addition to cost-shared research and development projects, industry partners participate in the development of vision and roadmap documents that define long-term goals, technology challenges, and research priorities.

- Allied Partnerships provide an opportunity for ITP to reach a broad audience of potential customers by allying with corporations, trade associations, equipment manufacturers, utilities, and other stakeholders to distribute industrial energy efficiency products and services. By becoming an Allied Partner, an organization can increase its value to clients by helping them achieve plant efficiencies.

- State energy organizations work with ITP in applying technology to assist their local industries. ITP assists states in developing partnerships to mobilize local industries and other stakeholders to improve energy efficiency through best practices, energy assessments, and collaborative research and development.

- EERE's technical programs (ITP is one of 11) give manufacturers access to a diverse portfolio of energy efficiency and renewable energy technologies and bring advanced manufacturing technology to the renewable energy community. For more information, access the EERE home page at http://www.eere.energy.gov.

- The President's Climate VISION (Voluntary Innovative Sector Initiatives: Opportunities Now) effort also offers opportunities for manufacturers to pursue cost-effective actions that will reduce greenhouse gas emissions. See www.climatevision.gov for details.

Access to Resources and Expertise

The Industrial Technologies Program provides manufacturers with a wide variety of industrial energy efficiency resources to help your company reduce energy expending right away. Visit our Web site at: http://www.eere.energy.gov/industry or call the EERE Information Center at 877-337-3463 to access these resources and to get more information.

- ITP offers energy management best practices to improve energy efficiency throughout plant operations. Improvements to industrial systems such as compressed air, motors, process heat, and steam can yield enormous savings with little or no capital investment.

- Our suite of powerful system optimization software tools can help plants identify and analyze energy-saving opportunities in a variety of systems.

- Training sessions are held several times per year at sites across the country for companies interested in implementing energy-saving projects in their facilities. DOE software tools are used as part of the training sessions.

- ITP's qualified industrial energy specialists will work with your plant personnel to identify savings opportunities and train staff in the use of ITP software tools.

- Our extensive library of publications gives companies the resources they need to achieve immediate energy savings.

- Plant-wide energy assessments are available to manufacturers of all sizes interested in cutting their energy use. Cost-shared solicitations are available each year for plant-wide energy assessments. In addition, no-cost, targeted assessments are provided to eligible facilities by teams of engineering faculty and students from 26 university-based Industrial Assessment Centers around the country.

- The DOE Regional Offices provide a nationwide network of capabilities for implementing ITP's technology delivery strategy. Regional Offices are located in the Southeast, Northeast, Midwest, Central, Mid-Atlantic, and Western regions. Visit http://www.eere.energy.gov/rso.html for more information.

Where to Go to Get More Information

Visit our Web site: http://www.eere.energy.gov/industry/aluminum

Learn about all EERE programs: http://www.eere.energy.gov

EERE Information Center answers questions on EERE's products, services and 11 technology programs, refers callers to the most appropriate EERE resources, and refers qualified callers to the appropriate expert networks. You may contact the EERE Information Center by calling 1-877-EERE-INF (1-877-337-3463) or by completing the form at this site: http://www.eere.energy.gov/informationcenter. A customer service specialist or energy expert at the EERE Information Center will respond to your inquiry.

For print copies of DOE, EERE and ITP Publications, contact the
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A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and great energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America's energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as a vital new "energy carrier"

The Opportunities

Biomass Program
Using domestic, plant-derived resources to meet our fuel, power, and chemical needs

Building Technologies Program
Homes, schools, and businesses that use less energy, cost less to operate, and ultimately, generate as much power as they use

Distributed Energy & Electric Reliability Program
A more reliable energy infrastructure and reduced need for new power plants

Federal Energy Management Program
Leading by example, saving energy and taxpayer dollars in federal facilities

FreedomCAR & Vehicle Technologies Program
Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

Geothermal Technologies Program
Tapping the Earth's energy to meet our heat and power needs

Hydrogen, Fuel Cells & Infrastructure Technologies Program
Paving the way toward a hydrogen economy and net-zero carbon energy future

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

Solar Energy Technology Program
Utilizing the sun's natural energy to generate electricity and provide water and space heating

Weatherization & Intergovernmental Program
Accelerating the use of today's best energy-efficient and renewable technologies in homes, communities, and business

Wind & Hydropower Technologies Program
Harnessing America's abundant natural resources for clean power generation

To learn more, visit www.eere.energy.gov

Aluminum Industry of the Future

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry

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

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