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

ITP

Industrial Technologies Program

Multi Year Program Plan

Version
May 2008

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

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

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Executive Summary and Outlook

The Industrial Technologies Program (ITP) is actively working to address the enormous energy challenges now facing American industry. While all sectors of the U.S. economy are feeling the pinch of high energy prices, impacts on industry are especially acute. Reducing industrial energy intensity is also a quick, reliable solution for addressing national climate change and energy security issues.

ITP is the lead federal agency responsible for improving energy efficiency in the largest energy-using sector of the country. Together with our industry partners, we strive to:

- Accelerate adoption of the many energy-efficient technologies and practices available today
- Conduct vigorous technology innovation to radically improve future energy diversity, resource efficiency, and carbon mitigation
- Promote a corporate culture of energy efficiency and carbon management

> *"Industrial efficiency is important. Everything the U.S. can do to increase industrial energy efficiency or divert consumption and production from petroleum-based feedstocks helps enhance energy security."*
>
> *Samuel Bodman*
> *Secretary, U.S. Department of Energy*

ITP's successful partnership with industry has thrived for decades. Together we have developed hundreds of advanced technologies that have been commercialized and are saving energy *today*. We work closely with our partners to industry's top energy technology priorities. In addition to our traditional energy-intensive industry partners, we are reaching out to an even broader range of industries and service providers throughout the supply chain. We also collaborate with state energy offices, utilities, industry associations, the financial community, and other organizations with a stake in industrial energy efficiency to spur investment in new technology throughout this highly diverse sector.

Our partnership with industry is taking a giant leap forward in FY08 with the launch of a voluntary program to reduce energy intensity. ITP has established an ambitious goal to help lower the energy intensity of U.S. industry 25% by 2017 in accord with the *Energy Policy Act of 2005*. Industrial companies voluntarily pledge to meet this goal; ITP supports them by delivering resources to help boost their energy efficiency—whatever their current level of energy performance.

All indicators point to U.S. industry as a pivotal player in meeting national energy, environmental, and economic goals. While providing clear economic benefits, industry consumes more energy than any other single sector of the economy and is a major contributor to U.S. greenhouse gas emissions. Recent studies by both McKinsey and the International Energy Agency establish a strong role for industrial energy efficiency in cost-effectively reducing carbon emissions in the near term.

Industry: Critical to U.S. Energy Security and Economic Health

- Largest energy-consuming sector
- Highest contribution to U.S. GDP
- Responsible for >2/3 of U.S. exports
- 13 million direct jobs

Conducting energy efficiency R&D is a cornerstone of ITP's strategy. The Program develops and demonstrates cost-effective technology solutions to save energy and reduce carbon emissions in a broad manufacturing base. We also coordinate with other DOE programs – and other federal agencies—to turn scientific discoveries into next-generation solutions and promote distributed generation and fuel and feedstock flexibility. In defining our R&D investment strategy, we consider:

- Impacts on energy use throughout the manufacturing value chain
- Evolving business patterns and structural shifts
- Volatility in supply and price of fuels and feedstocks
- U.S. technological leadership in global markets
- Climate change mitigation

In addition to maintaining a pipeline of innovative technology R&D, ITP has a robust technology delivery program to help plants access new technologies and best energy management practices. We work closely with industry to help elevate energy efficiency as a priority within its traditional focus on production and product development.

How well our industries address energy and climate change challenges will determine our nation's economic growth and energy security. ITP is not resting on past successes, but is undertaking bold new initiatives to support meet the challenges of today and tomorrow head on. We will continue to build on our strengths, expand into new areas, and boost program impacts to support national goals. We are proud to be serving our industrial sector and our country.

The detailed plans outlined in this ITP Multi-Year Program Plan are linked to the policies and priorities described in the National Energy Policy by the EERE and ITP Strategic Plans. Those plans describe the EERE and ITP missions and visions, and outline long-term strategies for achieving dramatic improvements in the energy and environmental performance of energy-intensive industries. This MYPP builds on the EERE Strategic Plan by providing specific strategies for achieving EERE's nine goals, particularly Goal 6 (*Increase the Energy Efficiency of Industry*).

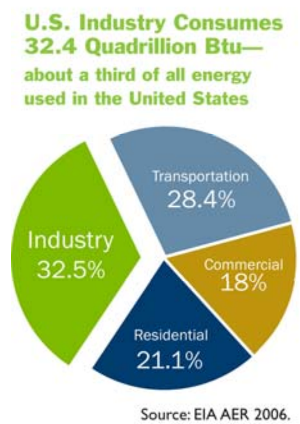
All of us in ITP look forward to working with EERE in executing this Multi-Year Plan and engaging industry to explore opportunities to boost energy efficiency and reduce carbon intensity.

ITP Delivers Results

Our most recent documented achievements include:

- Over 760 trillion Btu in savings in 2004-2005 (equivalent to 130 large tankers filled with crude oil)
- CO_2 reductions of 14.2 MMTCe in 2004-2005 (equivalent to taking 12 million mid-sized cars off the road for an entire year)
- 11 prestigious *R&D 100 Awards* in 2006-2007 (and a total of 42 since 1990)
- 450 industrial plants assessed in 2006-2007
- 14 new technologies commercialized in 2006 alone

Since the 1980s, ITP has saved 5 quads (10^{15} Btu) of energy, representing cost savings of $30 billion.



ITP's Portfolio Addresses Opportunities throughout Industry

Industry-Specific Applications

- Aluminum
- Chemicals
- Forest Products
- Metal Casting
- Steel
- Information Technologies

Crosscutting Technologies

- Energy-Intensive Process R&D
- Nanomanufacturing and Other Interagency Manufacturing R&D
- Fuel and Feedstock Flexibility
- Industrial Distributed Energy
  - Advanced Reciprocating Engines
  - Combined Heat and Power
- Industrial Materials
- Combustion
- Sensors and Automation
- Industrial Technical Assistance
  - Best Practices
  - Industrial Assessment Centers
- International Activities

Goals for Industrial Energy Efficiency

National Energy Policy
- Modernize conservation
- Modernize our energy infrastructure
- Accelerate the protection and improvement of the environment

DOE Strategic Plan
- Energy use and greenhouse gas emissions versus the Gross Domestic Product (GDP) are reduced by 40% by 2025 compared to 2000 and the growth versus the U.S. population stops by 2025.

EERE Strategic Plan
- Increase the energy efficiency of industry (Goal 6)
- Dramatically reduce, or even end, dependence on foreign oil (Goal 1)

ITP Strategic Plan
- Drive a 25% reduction in U.S. industrial energy intensity by 2017 in support of the Energy Policy Act of 2005 (EPAct 2005)
- Contribute to an 18% reduction in U.S. carbon intensity by 2012 as established by the Administration's "National Goal to Reduce Emissions Intensity"

ITP MYPP
- Specific and Crosscutting goals for FY'08 – FY'12 that result in implementation of goals in the Industrial Technologies Strategic Plan

1 Program Overview

The Industrial Technologies Program (ITP) leads the national effort to reduce energy use and carbon emissions in industry. To carry out our mission of transforming the way U.S. industry uses energy, ITP develops and promotes new technologies and practices that improve industrial energy efficiency both today and tomorrow. To this end, we support cost-shared research and development (R&D) to address the top energy challenges facing industry while fostering the adoption of today's advanced technologies and best energy management practices. We want energy-efficient technology to be the first choice when industry replaces equipment or constructs new facilities. To achieve this, the Program:

- Conducts R&D on efficient new technologies
- Promotes distributed generation and fuel and feedstock flexibility
- Supports the commercialization of emerging technologies
- Helps plants access and use proven technologies, energy assessments, software tools, and other resources
- Promotes a culture of energy efficiency and carbon management in industry

> *ITP's Vision*
>
> *U.S. industry leads the world in energy efficiency and productivity*

> *"25 in 10" Goal for Industry*
>
> *Achieving a 25% reduction in industrial energy intensity by 2017 will save an amount of energy equal to that consumed in California (all sectors)—8.4 quads each year.*

At its most basic level, this strategy seeks to condition the market, invest strategically in technology R&D, and deliver highly efficient technologies and practices to a receptive industrial stakeholder base.

In line with our mission and vision, ITP has embraced an overarching goal of driving a 25% reduction in industrial energy intensity by 2017, in accord with the Energy Policy Act of 2005. This Save Energy Now "25 in 10" initiative delivers resources to help *all* companies improve their energy performance, no matter where they lie on the efficiency continuum.

Partnering with industry is the keystone of our strategy. ITP engages diverse segments of the industrial sector to tackle some of the toughest technological challenges facing the nation. Together we develop and deliver technology solutions with large potential impacts and build awareness of the many benefits of energy efficiency.

1.1 Market Overview and Federal Role

1.1.1 Overview of the Industrial Sector

The U.S. industrial sector consists of both manufacturing and non-manufacturing industries. Non-manufacturing industries are agriculture, mining (including the oil and gas extraction industries), and construction. Manufacturing industries include major process industries (e.g., chemicals, steel) and final fabrication industries that produce both durable and non-durable goods (e.g., auto manufacturing).

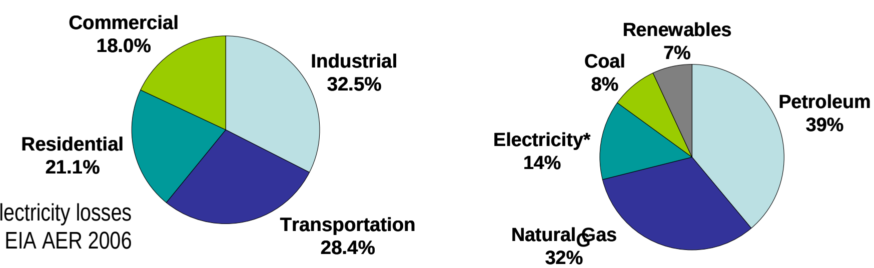
Industrial Energy Consumption

The industrial sector is the largest energy-consuming sector in the United States (Figure 1-a). In 2006, industry:

Figure 1-a. U.S Energy Consumption (2006)

Consumption by Sector* (Total = 100 Quads)

Industrial Consumption by Fuel Type (Total = 25 Quads)



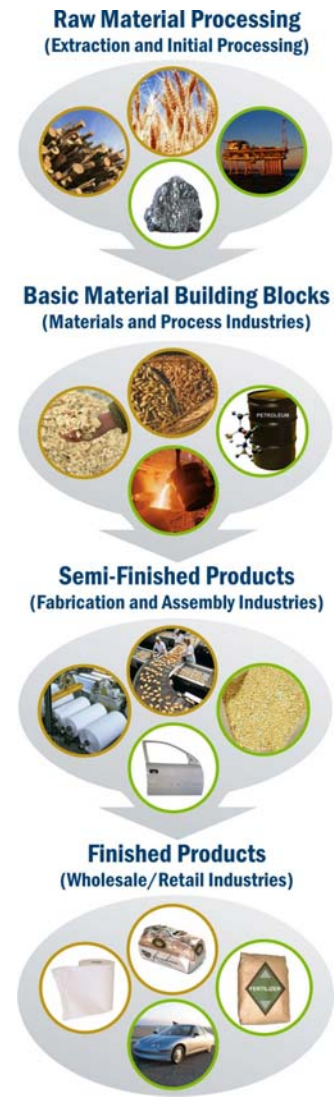
*Includes electricity losses
Source: EIA AER 2006

- Consumed over 32 quadrillion Btu (quads), or about one-third of the 100 quads consumed in this country
- Lost nearly 22% of the energy input during the generation, transmission, and distribution of electricity to industrial facilities
- Used ~18 quads to meet heat and power demands of U.S. factories, farms, and mining and construction operations
- Used about 7 quads of fossil fuels as feedstock to produce materials and products such as chemicals and plastics
- Spent nearly $104 billion in the manufacturing sector alone for purchased fuels and electricity

The industrial sector is also the most diverse energy-consuming sector in terms of both the types of energy services required and the mix of energy sources used to provide those services. Several crosscutting types of energy services are particularly important in this sector, most notably motor-driven equipment (representing nearly two-thirds of industrial electricity use), steam systems, and compressed air equipment. Beyond these crosscutting areas, industrial energy consumption tends to be process-specific. The industrial sector is also the most diverse energy-consuming sector in terms of both the types of energy services required and the mix of energy sources used to provide those services.

As shown in Figure 1-a, petroleum and natural gas account for the largest portion of primary industrial energy use at 39% and 32%, respectively. Electricity consumed at the point of use represents 14%, with coal and renewable energy sources accounting for the remainder of industrial energy consumption at 8% and 7%, respectively. In 2006, industry used over 3.3 quads of energy in generating its own electricity and process heat in combined heat and power systems. Figure 1-b shows trends (both historical and projected) in industrial energy use by fuel type. As shown in this figure, total industrial energy use is predicted to continue rising as industrial output grows between now and 2030. This trend highlights the need for getting more efficient technologies and practices in place *today* in order to curb total energy use and carbon emissions.

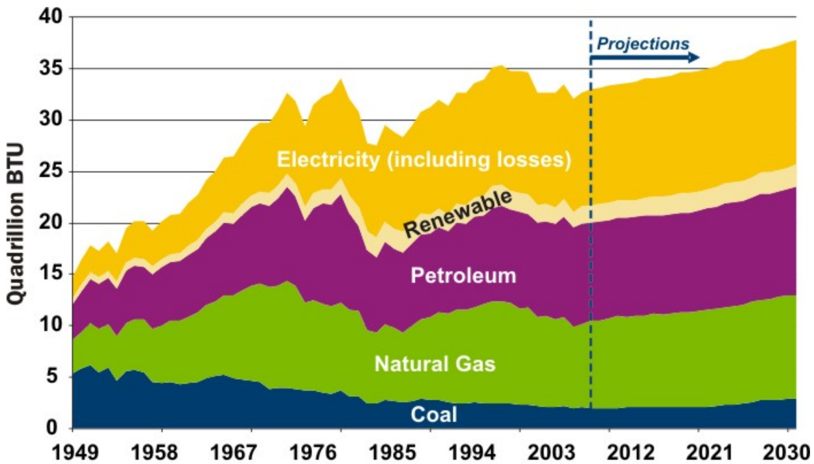
Figure 1-c. The Manufacturing Value Chain



Industry and Energy Intensity

Energy use varies significantly from industry to industry. The majority of industrial energy use is concentrated in a small number of "heavy" manufacturing industries that transform raw materials into higher-value industrial materials and end products (see Figure 1-c). These industries also tend to be very energy-intensive, using large amounts of energy per dollar of product output.

While downstream fabrication and assembly industries such as automotive and aerospace may not be as energy-intensive as the major materials and process industries, these industries use materials with significant quantities of "embedded" energy. And fast-

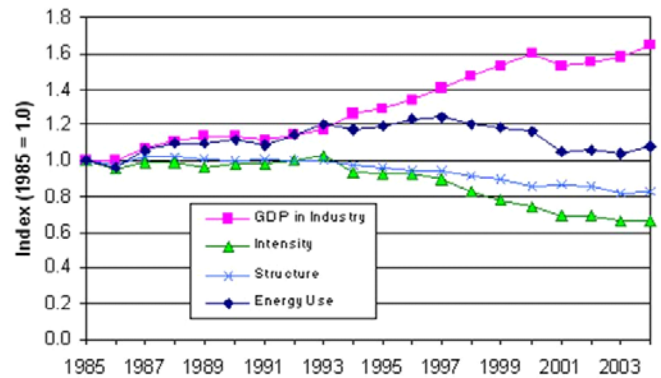


Source: EIA-AER2006, AEO2007

growing industries such as computers and electronic equipment, data centers, and ethanol producers are consuming a greater proportion of industrial energy use. This diversity inhibits a “one-size-fits-all” approach to energy efficiency.

Despite considerable efficiency gains over the past 50 years, many industries continue to use far more energy than the theoretical minimum required for key processes, a gap that can be addressed by the development of new technologies and processes as alternatives to existing inefficient ones. In addition, large opportunities exist in industry to help our nation achieve energy and carbon reduction goals using currently available, state-of-the-art technologies and operating practices. In fact, a recent analysis by McKinsey identified an untapped pool of approximately 3.9 quadrillion Btu in industrial energy savings that are economically attractive (internal rates of return above 10%). The Industrial Technologies Program helps industry take advantage of *both* types of opportunities.

Figure 1-d. Industrial Sector Energy Intensity Has Dropped Steadily Over the Past 20 Years



Industrial Energy Use Trends

Over the past 20 years, many factors have influenced industrial energy use -- increased utilization of recycled materials, availability of raw materials, stricter environmental standards, availability of more efficient technology, and shifts in product demand. In 2006, the U.S. economy posted its lowest energy intensity in 50 years (8,750 Btu/dollar of GDP - constant chained 2000). This ~50% drop from 1970 reflects the willingness of private industry to respond to economic signals and adopt energy-efficient technology. In fact, the DOE Policy Office determined that more efficient manufacturing was the largest component of total U.S. energy savings from 1970 to 1988.

Although manufacturing output surged in the late 1990s, energy use did not keep pace, despite relatively low energy prices. This ability to increase output without a corresponding increase in energy use is a major strength of U.S. industry (Figure 1-d).

The industrial sector is expected to continue to provide one of the biggest opportunities to increase energy efficiency in the United States and worldwide (Figure 1-e). Industrial energy intensity is projected to decline as companies become more energy efficient and the composition of the industrial sector continues to shift. Industrial energy consumption is projected to increase by only 19% between 2005 and 2030, whereas the value of shipments is expected to increase by 65%. Figure 1-f depicts expected changes in value of shipments for several key industries.

Figure 1-e. Industry Presents the Biggest Opportunity to Increase Energy Efficiency Worldwide

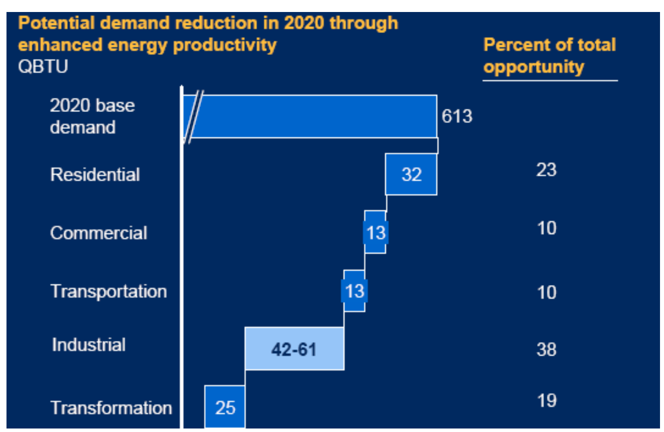


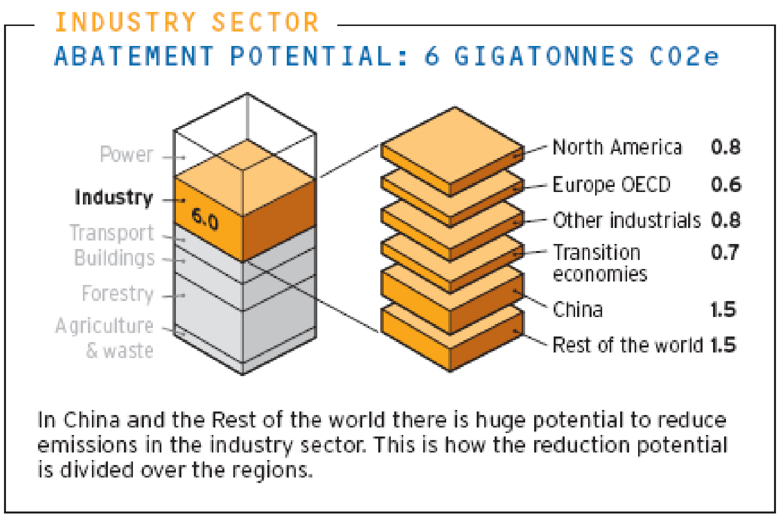
Figure 1-f. Many Industries Are Expected to Experience Strong Growth

Industry	Projected Increase in Value of Shipments, 2005-2030
Food Products	53%
Paper	37%
Petroleum Refining	33%
Chemicals	70%
Primary Metals	44%
Computers and Electronics	206%
Transportation Equipment	79%
Total Manufacturing	77%
Total Industrial Sector	65%

Source: EPA 2006

Energy use projections indicate that industry will continue to be a major source of future U.S. energy efficiency gains.

Figure 1-g. Global Opportunity to Reduce GHG Emissions from Industry Is Large (2030)



Industry, the Environment, and Carbon

Industry accounts for nearly a third of U.S. CO_2 emissions. The majority of industrial carbon emissions are related to combustion processes, including the generation of electricity. In addition, industry is responsible for about two-thirds of domestic non-CO_2 greenhouse gas emissions – particularly methane, nitrous oxide, HFCs, PFCs, and SF_6.

Analysis shows that *the cheapest and most available source of new energy for the industrial sector is the energy that is wasted every day*, which is why industry has led all other economic sectors in reducing its energy intensity. Higher efficiency and lower carbon intensity also translate into higher productivity. *In short, industrial energy efficiency presents a compelling opportunity for reducing national carbon emissions and energy intensity while increasing productivity*.

As the world's leading economy and largest consumer of energy, the United States is under increasing pressure to take more aggressive action regarding climate change. At the same time, China, India, and other developing countries are undergoing considerable economic growth, significantly expanding their manufacturing infrastructure in the coming years. Much of this expansion is occurring in basic industries such as steel, cement, and chemicals that have high energy consumption and carbon emissions. As a result, much of the opportunity to reduce industrial greenhouse gas emissions exists outside of North America. A recent Vattenfall report projects only 13% of the industrial opportunity by 2030 is represented by the United States and Canada (Figure 1-g).

Manufacturing industries also generate substantial quantities of hazardous and toxic wastes. Even with significant increases in production, manufacturers have significantly cut their generation and release of these wastes over the past decade. Environmental and climate change factors are playing an increasingly important role in corporate decision-making.

Economic Significance of Industry

U.S. manufacturers – comprising the largest portion of the industrial sector - shipped $5 trillion worth of products in 2006. Manufacturing industries employ nearly 13 million workers, about 12% of the Nation's total non-farm, private-sector employment. Beyond direct jobs, manufacturing industries indirectly support many other workers in supplier, repair, sales, finance, and other industries. Manufacturing alone represents about $1.5 trillion in GDP, or 12% of U.S. total GDP. Key economic statistics for U.S. manufacturing are shown in Figure 1-h.

The most energy-intensive manufacturing industries spend a significant portion of operating costs on energy, presenting major market opportunities for energy-efficient technologies, as shown in Figure 1-i. Other industries are also good strategic targets for efficiency improvement because of their significant contribution to the U.S. economy (Figure 1-j).

Industrial Markets and Competitive Landscape

U.S. manufacturers face intense competitive pressures. Strong cost competition from foreign producers and alternative products, as well as shareholder expectations of near-term profits, are squeezing corporate expenditures. In today's global economy, U.S. firms often find themselves at a cost disadvantage for labor, materials, energy, and environmental compliance. Unable to significantly differentiate their product from foreign sources in many cases, and with reduced trade barriers, increased trade deficits have occurred for most manufacturing industries. In addition, many products are pursuing the same markets. For example, steel, aluminum, glass, and plastics all target the food and beverage container market, as well as many automotive applications.

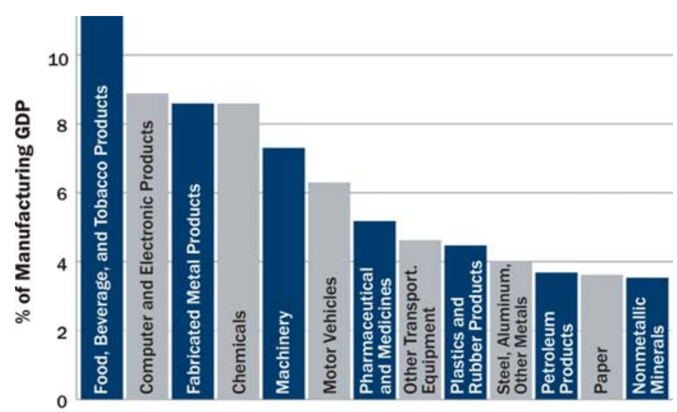
Figure 1-h. Salient Economic Statistics for U.S. Manufacturing Industries, 2006

Manufacturing Sector	Value of Shipments (billion)	Value Added (billion)	Employment (thousands)	Payroll (billion)	Capital Expenditures (billion)	Current Cost Net Capital Stock (billion)	Total Trade (billion)	Trade Balance (billion)
Durable Goods	$2,561	$1,216	8,120	$387	$70	$1,155	$1,606	$-471
Energy-Intensive Sectors (primary metals, nonmetallic minerals, wood products)	$471	$200	1,432	$60	$15	$232	$181	$-82
Other Sectors	$2,090	$1,016	6,688	$327	$55	$923	$1,425	$-389
Nondurable Goods	$2,459	$1,090	4,870	$205	$66	$882	$727	$-220
Energy-Intensive Sectors (paper, chemicals, petroleum refining)	$1,377	$565	1,263	$75	$37	$483	$437	$-90
Other Sectors	$1,082	$525	3,608	$131	$29	$399	$290	$-131
Total Manufacturing	$5,020	$2,306	12,990	$592	$136	$2,037	$2,333	$-692

To combat these competitive pressures, companies have cut costs and mitigated risk through mergers and acquisitions (both domestically and globally), leveraging R&D funds with private and public partners, globalizing and integrating R&D, and outsourcing technical components.

The critical role of many upstream manufacturing industries in the economy is often overlooked by the national media, and misunderstood by the public. Because the basic material building blocks – commodity materials -- these industries produce largely lose their identity when converted into usable consumer products, mass media advertising is not widely practiced by these industries. As a consequence, firms in these industries often are not widely recognized. In addition, these firms often cannot significantly differentiate their product in the marketplace from competitors. Many manufacturers in these industries have come to rely on superior production technology to increase productivity and throughput in order to capture a cost advantage. Another approach taken by

Figure 1-j. Industries that Contribute Heavily to U.S. GDP Are Strategic Targets (2005)



Source: U.S. Department of Commerce, 2005.

Figure 1-i. Market Data for Select Industrial Sectors[a]

Sector	2002 Energy Use (Quads)	2020 Energy Use (Quads)[b]	% of Operating Costs for Energy	Major Market Opportunities for New Technologies	2020 Deployment Potential/ Savings (Quads)[d]
Pulp and Paper	2.3	2.5	20-30	Improved drying, enhanced steam systems, efficient motor systems, combined heat and power (CHP)	0.6
Iron and Steel	1.4	1.4	5-15	Blast furnace/BOF and EAF applications, heat recovery (across all process steps), CHP, improved process controls, and new processes such as thin slab casting	0.3
Chemicals	6.5	6.6	2-7[c]	Process improvements (e.g., membrane separation techniques, new catalysts for petrochemicals, CHP	0.3
Petroleum Refining	3.5	4.7	~40	Process improvements, increased steam efficiency, higher furnace efficiency, CHP	0.3

a Based on McKinsey 2007 report “The Untapped Energy Efficiency Opportunity in the U.S. Industrial Sector”
b Projected by Energy Information Administration.
c Excludes feedstock expenditures.
d Potential above business-as-usual case through implementation of financially attractive (>10% IRR) energy-saving technologies.

some vertically integrated companies is to enhance or upgrade their products, leading to greater brand recognition and higher profits.

This approach results in a significantly different business environment than exists for downstream high technology, aerospace, or service industries. In downstream industries, brand recognition and product differentiation is more prominent. Companies gain advantages by using copyrights, ensuring significant product development lead times by adding new features and functionality, holding dominant market positions, and owning technology standards.

1.1.2 Overview of State, Local and International Political Environment

Federal Environment

The Federal government does not have a unified voice regarding industrial issues; objectives and priorities within different Federal agencies are dependent on their individual missions. Manufacturing has received increased emphasis within the Bush Administration, culminating with the Department of Commerce publication entitled *Manufacturing in America: A Comprehensive Strategy to Address the Challenges to U.S. Manufacturers*. The report recommended several actions the government should take to enhance government’s focus on manufacturing competitiveness.

Many of the benefits of saving energy in industry accrue to society rather than within the organization that makes the investment. These social benefits include enhanced energy security, reduced dependence on foreign energy sources, and avoided emissions of NOx, CO_2, and other pollutants. Companies have less incentive to invest in energy-efficient technologies because they cannot capture all the benefits.

Governmental programs can play a supporting role in helping companies deal with their own inefficiencies and more consistently pursue economically viable projects. To do this, the government can focus on removing internal barriers, including informational and motivational programs to disseminate "best practices"; targeted capital programs to push select investments past the tipping point; and removal of external regulatory barriers that hold companies back from capitalizing on energy efficiency.

Increasing concern throughout the Federal government on climate change is reshaping the Federal environment. To date, efforts have centered on voluntary commitments from industries to reduce carbon emissions, and on R&D activities to develop the next generation of low-carbon technologies.

Two bills of particular importance have been enacted in the past few years that affect ITP:

- *Section 106 of the Energy Policy Act of 2005* allows the Secretary of Energy to enter into voluntary agreements with industrial entities that consume significant quantities of energy. The goal of each agreement is an energy intensity reduction of at least 2.5% annually between 2007 and 2016 by the participating entity.
- *Section 452 of the Energy Independence and Security Act of 2007* directs the Secretary of Energy to establish a program under which the Secretary, in cooperation with energy-intensive industries and national industry trade associations representing the energy-intensive industries, shall support, research, develop, and promote the use of new materials processes, technologies, and techniques to optimize energy efficiency and the economic competitiveness of the United States' industrial and commercial sectors. Energy-intensive industries defined in the Act include:
  - Information technology, including data centers containing electrical equipment used in processing, storing, and transmitting digital information
  - Consumer product manufacturing
  - Food processing
  - Materials manufacturers, including aluminum, chemicals, forest and paper products, metal casting, glass, petroleum refining, mining, and steel
  - Other energy-intensive industries, as determined by the Secretary

  The Act also authorizes funds to be appropriated to conduct this program in the amounts of: $184 million for fiscal year 2008; $190 million for fiscal year 2009; $196 million for fiscal year 2010; $202 million for fiscal year 2011; $208 million for fiscal year 2012; and such sums as are necessary for fiscal year 2013 and each fiscal year thereafter.

State/Local Needs

ITP's implementation of state activities is conducted through the Golden Field Office and the National Energy Technology Laboratory. Emphasis has been placed on working with the largest energy-using plants throughout the Nation to help them access ITP's resources. These results will be included in the overall ITP metrics.

The Office of Energy Efficiency and Renewable Energy has created a Federal State Partnership known as the State/Federal Collaborative Pilot Program (STAC). This is collaboration between the Department of Energy, the National Association for State Energy Officials (NASEO), and the Association for State Energy Research and Technology Transfer Institutes (ASERTTI). The STAC program is run through competitive solicitations requesting proposals through six committee areas, one of which is the industrial sector. Once a decision is made regarding specific technology areas for each committee, a solicitation will be widely disseminated. Proposals will be funded with a minimum 50% cost-share from States and companies.

International Environment

Internationally, governments are generally supportive of the industrial sector. Developing countries are very interested in expanding their technological base and creating manufacturing jobs. In addition, some foreign governments provide significant subsidies to industry, resulting in a lower cost of capital. For example, companies operating in China are estimated to have a cost of capital closer to 5% as a result of government subsidies.

For the last twenty years, there have been significant efforts throughout the world to reduce emissions of greenhouse gases. The Intergovernmental Panel on Climate Change (IPCC) has produced a number of reports on the potential impact of global warming, science, and mitigation, resulting in a dramatic increase in awareness and concern about climate change. The 4th Assessment Report from the IPCC indicated a much higher probability of human influence on the climate. As the world's leading economy and largest consumer of energy, the United States is under increasing pressure to take more aggressive action regarding climate change.

1.1.3 Competing Technologies and Technology Environment

Energy-efficient technologies compete with less-efficient alternatives for market share. Often, initial equipment price is the primary factor considered instead of a life-cycle approach. This leads to the installation of technology that not only is less energy-efficient, but in the end, costs more.

Technology development is performed both by companies in particular industries and also equipment vendors. Industrial research and development is discussed further in the following sections.

Industrial R&D

Energy-intensive industries are severely constrained in their ability to invest in R&D due to their low profit margins and inability to fully appropriate R&D benefits to their companies. In recent years, R&D investments in the energy-intensive industries have not kept pace with the rest of the economy. From 1994 to 2003, R&D investments for the energy-intensive industries grew by only 1.3% per year, compared to 4.4% per year for all of manufacturing. As a result, the portion of total manufacturing R&D contributed by the energy-intensive industries fell from 13% to 10%.

Process technologies that use less energy per unit of output are logical investment opportunities for energy-intensive industries, but energy-intensive manufacturers are often unable to invest in energy-related process R&D without government assistance. Companies in these industries are unable to accept the costs and risks associated with undertaking complex, capital-intensive technology development and implementation for highly efficient, next-generation process technologies. These technologies are seen as too expensive and risky, and unlikely to provide adequate long-term return to the firm, potentially resulting in lost production. In fact, the risk of lost production often overshadows all other factors in the decision not to invest in energy-efficient technologies.

As a result of perceived risks, most manufacturers favor R&D investments that incrementally improve existing technology platforms, rather than exploring transformational technologies. While this "optimize and extend" strategy carries less risk and produces near-term returns, it also prevents companies from investing in the very technologies that can help ensure their long-term competitive advantage.

R&D risks that are often cited by industry include:

- Technology development risk
- Increased risk with larger project size and complexity
- Changing market conditions

- Regulatory risk
- Internal management, culture, and resources

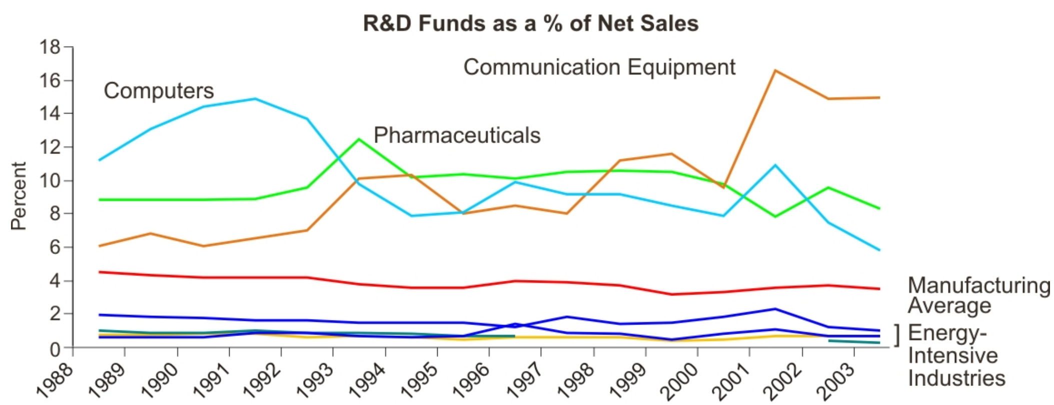
The cost of technology failure in mature industries can be extremely high. While a significant invention may lead to a temporary cost advantage for individual firms, it seldom leads to a long-term competitive advantage in the marketplace.

R&D Investment Comparison

Mounting evidence indicates that industry is severely underinvested in R&D for technologies that can improve energy efficiency. If this underinvestment is caused by market failures, the Federal government has a valid role in trying to correct the failure.

The energy-intensive industries have the lowest R&D investment rate in the entire industrial sector, with R&D spending at a rate of only 1% of sales. This compares with an average of R&D spending of about 4% of sales for all of industry (Figure 1-i).

Figure 1-i. Energy-Intensive Industries Have Lowest R&D Investment



Alternative stimulants to technology development such as tax incentives and R&D tax credits are generally inappropriate for developing energy-efficient process technologies. These incentives are blunt policy instruments that increase all types of R&D investment, and may subsidize R&D that would occur without public support.

Average Cost of Capital

With relatively low profit margins, many companies in the manufacturing sector face higher than average financing costs. On average, the cost of capital in these industries is about 10%. Many companies in these industries have seen their credit downgraded by rating agencies as foreign competition, along with high legacy costs for employee health care and pension plans, and asbestos litigation settlements, which have severely impacted profitability. Several well-known companies in these industries have filed for bankruptcy protection over the past few years, including Bethlehem Steel, Owens Corning, Kaiser Aluminum, and W.R. Grace. A sample of current credit ratings for leading companies in various manufacturing industries is shown in Figure 1-j. Other companies in these industries with less-stellar financial results would have substantially lower ratings.

Furthermore, within companies in manufacturing industries, capital resources must be prioritized and investment in energy efficiency and process R&D generally receives a low priority.

Options for Expanding Production

There are three main avenues in which manufacturing firms can expand their domestic production: greenfield development, retrofit expansions, and acquisitions. Little greenfield development has occurred in most heavy manufacturing industries over the past twenty years for virgin material production. These industries are cyclical in nature, and significant overseas expansion led to global overcapacity. Advances in technology, however, have led to the development of new facilities that use recycled materials, such as scrap-based steel mills, newspaper recycling plants, and aluminum remelting facilities. While states often compete vigorously by providing significant tax incentives for new fabrication facilities, such as automobile assembly plants, this is rarely the case for facilities in the energy-intensive industries. The very nature of these industries, which often are highly automated and perceived to have undesirable qualities, limits their attractiveness. In addition, the approval and permitting process for new facilities, especially in states with more stringent environmental requirements, can take years, and result in significant costs before construction even begins. As an example, even though consumption of petroleum has grown 20% over the last twenty years, the last new petroleum refinery was commissioned in 1983.

The majority of actual production expansion in heavy manufacturing industries comes from investments at existing facilities. Some of this expansion is the direct result of improvements in productivity, which allow for increased throughput of existing equipment. Space permitting, additional unit operations can be added to increase capacity. Unfortunately, there are inherent disadvantages to retrofitting existing plants, in particular as they relate to energy efficiency. More modern designs, improved space utilization, and newer equipment would make a new plant much more efficient than retrofitting an existing plant on a piece-meal basis.

Figure 1-j. Bond Ratings of Various Industrial Firms

Industry	Company	Rating (S&P)
Paper and Wood Products	Weyerhaeuser MeadWestvaco	BBB BBB
Petroleum	ExxonMobil Valero Energy	AAA BBB
Chemicals	Dow Chemical Praxair	A- A
Computers and Electronics	Intel Hewlett-Packard	A+ A
Primary Metals	Nucor Alcoa	AA- BBB+
Transportation Equipment	General Motors Boeing	B A+
Diversified Manufacturing	General Electric United Technologies	AAA A

Companies in heavy manufacturing and mining industries have often decided that acquisitions or mergers are more suitable than greenfield development to expand market share. One popular reason for this strategy is the speed of an acquisition compared to the time for permitting and building a new facility. The acquired firm also brings existing customers for the plant's output. In addition, the technologies, expert management, research results, and innovation of the acquired company become the property of the acquiring firm. With less stringent anti-trust rules, this has led to significant consolidation in many manufacturing industries over the past 20 years.

As a result, in December 2006, crude processing had much higher capacity utilization rates than primary and semifinished processing and finished processing, as depicted in Figure 1-k.

On the other hand, the high-tech manufacturing sector has experienced phenomenal growth during this decade. Capacity has more than doubled in this area, which includes computers, semiconductors, and communications equipment.

Capital Expenditures and Stock Turnover

The manufacturing sector accounted for about $2.037 trillion in current-cost net capital stock of fixed assets in 2006. Capital expenditures by manufacturing firms were $136 billion in 2006, about 3% of sales. A significant portion of industry's capital investments is required to meet environmental standards, further limiting opportunities for replacing production equipment with more efficient technology or building new facilities.

Because manufacturing industries are already relatively energy-efficient, opportunities for further improving efficiency are closely interlinked with the industrial process or production system itself. Technological innovations are strongly influenced by considerations other than energy efficiency. Without major improvements in technology in these industries, capital productivity has stagnated, resulting in low investment returns and low capital stock turnover.

Furthermore, energy-intensive industries remain conservative where the risk is significant and the savings associated with installing a new technology are not guaranteed. The cost of lost production due to plant shutdowns can far outweigh minor cost savings. Other potential risks include:

- Negative effect on product quality
- Unexpected process impacts
- Higher-than-expected initial and/or operational costs

Figure 1-k. Industrial Capacity and Utilization

Category	Change in Capacity, 2000-2006	Utilization, December 2006
Overall Manufacturing	8.8%	80.3%
Crude Processing	-1.5%	89.6%
Primary and Semifinished Processing	7.7%	81.7%
Finished Processing	10.4%	79.0%
Mining (excluding oil & gas)	1.6%	85.5%
High-Tech Manufacturing (computers, semiconductors, communications equipment)	128.8%	79.4%

The larger the size of plants and production capabilities, the more hesitant companies are to implement innovations that involve technical and economic risks.

Companies are reluctant to be the first adopter of a new technology, even one whose performance has been demonstrated and validated. The cost of failure could be fatal to the company or their competitive position. Many corporate managers in risk-averse industries declare they want to be "the first to be second" in deploying new technology. Often the third, fourth, or fifth installation of a technology can be at least 30% less expensive than the first because of increased knowledge and experience gained from prior installations.

As with all manufacturing industries, investment decisions are affected by implied return on investment. Companies employ a variety of methods to evaluate investment opportunities, including net present value, internal rate of return, and payback period. The results from these methods are also linked with Federal tax policy. In particular, the tax treatment for depreciating equipment purchases can significantly influence investment decisions.

1.1.4 Market Barriers

U.S. industrial firms have a large potential to profitably implement energy efficiency technology and processes, but a number of market barriers prevent companies from capturing these opportunities. Some of these barriers lie within companies and are present at the senior executive level or on the ground with line managers. Other times, government regulations present barriers to companies. This includes, but is not limited to, the uncertainty of future legislation and existing regulatory restrictions, both of which impose hurdles to successful energy efficiency investment.

Within a company, barriers to pursuing energy efficiency opportunities take two forms. First, energy efficiency decisions may not make it to the senior executive's agenda and thus are delegated to line managers. Second, these line managers who are responsible for making decisions face many obstacles. They often have incomplete information, a lack necessary personal incentives to drive energy efficiency, and a competition for capital with other company projects that are either mandatory or much larger.

Energy-efficient technologies compete with less-efficient alternatives for market share. "First cost" is often the primary factor considered in these decisions rather than life-cycle cost, which leads to the installation of technology that not only is less energy-efficient, but ends up costing more over the life of the equipment.

Other market barriers to technology development and deployment include:

- *Globalization and consolidation* of companies in energy-intensive industries. In some cases, ownership of U.S. based facilities is being transferred to foreign owners.
- *Reduced R&D staff* within industry, limiting R&D efforts to improve energy efficiency.
- *Difficulty obtaining venture capital for process development* in the more mature energy-intensive industries.
- *Low profitability* together with high capital intensity, high environmental compliance costs, and high energy prices, resulting in low investment returns.
- *Insufficient information for decision-makers* to help them choose energy-efficient technologies.
- *Corporate preference for incremental changes* such as low-risk process improvements over transformational technologies.
- *Environmental regulations* that often act as a significant barrier to the testing, evaluation, and commercialization of new improved technologies.

1.1.5 Program History and Major Accomplishments

Program History

The Industrial Energy Conservation Program began in 1975 under the mandate of the Federal Non-Nuclear Energy Research and Development Act of 1974. This Act directed that a comprehensive program be conducted to improve the efficiency of energy use in the industrial sector through R&D of high-risk, innovative technologies. The program was further shaped with the passage of the Department of Energy Organization Act of 1977, effectively merging all Federal Energy Agency and Energy Research and Development Administration programs. This led to the creation of the Office of Industrial Processes (OIP), ITP's organizational predecessor.

As OIP's experience and success in energy efficiency RD&D projects grew, the Program began responding to the changing needs and priorities of its principal customers. Competitive threats to U.S. industries arising in the 1980s led OIP to emphasize productivity, capital efficiency, and quality in addition to energy efficiency. Industrial waste reduction and pollution prevention also became critical elements of the Program's RD&D

Figure 1-I. Impacts of ITP (and Predecessor Organizations)

Metric	Results
Technologies Commercialized	190+
Energy Savings	
2005	402 trillion Btu
Cumulative	5,130 trillion Btu
Environmental Benefits (Cumulative)	
Carbon	103.0 million tons
SOx	1.62 million tons
NOx	810 thousand tons
VOCs	28.1 thousand tons
Particulates	25.2 thousand tons
R&D 100 Awards	42

portfolio. The passage of the Steel Initiative in the mid-1980s (and later the Metals Initiative) led to increased program investment in new steel and aluminum process technologies.

Around 1990, OIP was reorganized into the Office of Industrial Technologies (OIT). By 1994, OIT had changed its program strategy and adopted an innovative, industry-driven approach known as *Industries of the Future* to be more responsive to customer needs. Key components of OIT's strategy included:

- Focusing investments on the most energy-intensive industries
- Using collaborative partnerships among industry, government, and the research community to optimize intellectual and financial resources
- Encouraging industry to identify and cost-share pre-competitive technology priorities critical to future success

This approach responded to industry's need to leverage investments for high priority, pre-competitive technologies where the expected risks and returns did not warrant private investment. Technology transfer aspects of OIT were consolidated into the Best Practices program. In addition, the OIP-initiated Energy Analysis and Diagnostic Center (EADC) program - a university-based program to provide plant energy audits - broadened its focus to include productivity and environmental aspects, and was renamed the Industrial Assessment Center program.

In 2002, as part of a broader EERE reorganization, OIT was renamed the *Industrial Technologies Program (ITP)*. Since this time, ITP has faced declining budgets, but increased its analytical activities and refocused its research on crosscutting, high-impact R&D. Figure 1-l highlights the Program's success over the past several decades.

Major Accomplishments

Since its inception, ITP and its predecessors have had great success in supporting the development and implementation of energy-efficient technology:

- Total cumulative energy savings of more than 5 quads, representing production cost savings of nearly $30 billion
- Around 85 commercialized technologies currently being used throughout industry.
- 42 prestigious R&D 100 Awards

Figure 1-m. 200 *Save Energy Now* Assessments Were Completed in 2006

The Industrial Assessment Center (IAC) program has been successfully generating energy savings for over 28 years. Currently, twenty-six IACs located within engineering departments of U.S. universities conduct comprehensive energy assessments for small- and medium-sized manufacturers and train the future workforce of energy engineers. Recommendations from industrial assessments have averaged more than $58,000 in implemented annual cost savings per plant. Since 1980, 13,500+ audits have been completed by the EADC/IAC programs.

ITP's Best Practices activity works with industry to identify plant-wide opportunities for energy savings and process efficiency. Through the implementation of new technologies and systems improvements, companies across the United States are achieving immediate savings results. Over 16,000 U.S. manufacturing plants have been impacted by Best Practices; many of these plants have implemented new technologies and practices to achieve immediate savings results.

Best Practices launched the *Save Energy Now* initiative in 2005 to help companies respond to the natural gas crunch. Under this initiative, ITP cost-shares intensive three-day assessment s with companies, providing energy experts who work closely with the Plant Lead and other key personnel to identify target opportunities.

The centerpiece of the *Save Energy Now* initiative in 2006 was the delivery of 200 energy savings assessments to large manufacturing plants (Figure 1-m). DOE completed these assessments and results highlight the potential for significant energy savings in U.S. industry:

> *"Save Energy Now has helped us find creative ways to save energy and reduce carbon emissions in our manufacturing processes -- all while delivering the same great products our consumers love."*
> *-- Dick Frohmader, Program Manager for Global Energy, Kraft Foods*

- The typical large plant can cut its energy bill by 10% or more each year (over $2.5 million per plant, on average).
- New energy savings opportunities were identified in most plants—even plants with in-house energy teams.
- The three-day assessments prompted most of the participating plants to undertake or seriously consider implementing the recommendations—demonstrating that even relatively quick assessments can identify feasible, worthwhile projects

1.1.6 Program Justification & Federal Role

National Need Addressed by Program

Reliable, affordable, and environmentally sound energy for America's future is the cornerstone of the National Energy Policy (NEP). Yet an expanding economy, growing population, and rising standard of living create growing demands for energy. Modernizing energy conservation is one of five national goals included in the NEP. Further, "the best way of meeting this goal is to increase energy efficiency by applying new technology – raising productivity, reducing wastes, and trimming costs." Accordingly, ITP's strategy and implementation plan is critical to the successful implementation of the NEP, since the industrial sector uses a third of the Nation's energy.

Need for Government Involvement

Many of the highly energy- and carbon-intensive industries manufacture basic materials and industrial commodities such as steel, cement, glass, aluminum, and chemicals. In the United States, these are typically mature industries that operate on small margins, providing little opportunity for large capital investment in new technology that will increase energy and material efficiency. Since the mid-1970s, these energy- and material-intensive manufacturers have adopted many energy-efficient technologies and practices, particularly in large plants. However, additional opportunities to adopt smart energy and waste reduction practices exist in non-energy-intensive industries and in all small- to medium-size facilities.

To capture these opportunities, companies require the appropriate information, assessment tools, and specialized expertise to identify cost-effective measures. Manufacturers can then justify costs and make appropriate investments in technologies and practices.

The introduction of more advanced manufacturing technology is difficult for many industries because of the technical and operational risk of developing and implementing a promising, but unproven, technology. Round-the clock operations combined with small margins renders even a small risk of technical glitches too costly for many companies. In such cases, the government has an appropriate role to help demonstrate and cost-share the first application of promising carbon reduction technologies.

Perhaps the biggest opportunity to reduce industry's energy and carbon intensity is to develop next-generation manufacturing concepts and technologies that break with traditional production strategies. Certain opportunities are limited by constraints in the existing manufacturing infrastructure, which represents hundreds of billions of dollars in cumulative capital investment over many decades. Many of the basic processes used to make aluminum, glass, and other materials have changed little over the past 100 years. However, entirely new manufacturing platforms, alternative chemical processing routes, nanomanufacturing, and integrated energy, heat, and material systems have the potential to deliver very low energy and carbon footprints for new manufacturing facilities.

Development of radically new industrial technologies requires significant investment in fundamental sciences, technology development, engineering, and demonstration. Such resource requirements are beyond the reach of even the largest companies—and often entire industries—without government facilitation and support. The diverse technical and financial resources required for these complex technology platforms create significant technical and economic barriers. The government has a clear role both in supporting the fundamental science that can lead to innovation and in providing early-stage technology research and development that can accelerate technology concepts to the point at which they can attract private investment for commercial development.

Unique and Critical Program Aspects

The Industrial Technologies Program has several unique and critical aspects:

- *ITP is the sole government program focused on reducing energy demand in and costs to industry*, which benefits U.S. energy security, competitiveness and the environment.
- *The U.S. government's investment in energy efficiency technologies is small compared with competitors*, Japan invested over 5 times as much in 2003 ($300 million) as the current ITP funding request, with an economy half the size.
- *ITP invests in "pre-competitive" R&D* with academics, national labs, and many small entrepreneurial businesses - addressing a growing gap between basic research and the marketplace and grooming U.S. technology vendors with exportable products.
- *ITP catalyzes R&D investment within and across industry*, supporting large R&D projects that could not be funded by industry itself. Many companies praise ITP's role in putting together collaborative R&D partnerships, developing technologies they would not be able to bring to market alone, and catalyzing industrial investment in both technology development and near-term savings opportunities.

Complimentary Federal Programs

ITP coordinates with other Federal agencies such as NIST, NSF, and DOD to organize research efforts in common areas and on key manufacturing technology issues. Within DOE, ITP has numerous relationships with other EERE programs, coordinating with:

- FEMP on the application of CHP in federal facilities.
- Solar Energy Technologies program on glass manufacturing for photovoltaic systems.
- DOE's Office of Science on translating discoveries in basic science (e.g., nanoscience) into technologies applicable in industrial processes (nanotechnology and nanomanufacturing efforts are coordinated by the National Nanotechnology Initiative, with participation from many Federal agencies)
- NIST on advanced manufacturing technologies
- EPA on pollution prevention and climate change activities aimed at industry

Context of Program within EERE

ITP has numerous relationships with other EERE programs (including FEMP and the Solar Technologies Program, as just described). Manufactured products are used extensively in the transportation and buildings sectors, and research activities and interests sometimes overlap.

1.2 Program Vision

ITP's vision is that U.S. industry leads the world in energy efficiency and productivity.

1.3 Program Mission

The Industrial Technologies Program (ITP) leads the national effort to reduce energy use and carbon emissions in industry. To carry out our mission of transforming the way U.S. industry uses energy, ITP develops and promotes new technologies and practices that improve industrial energy efficiency both today and tomorrow. To this end, we support cost-shared research and development (R&D) to address the top energy challenges facing industry while fostering the adoption of today's advanced technologies and best energy management practices. We want energy-efficient technology to be the first choice when industry replaces equipment or constructs new facilities. Transforming the way industry uses energy requires a strategic, concerted effort led by the federal government. Meaningful progress in reducing industrial energy intensity requires accelerated adoption of the many energy-efficient technologies and practices available today, as well as vigorous technological innovation to radically improve future energy diversity, resources efficiency, and carbon mitigation.

ITP's three-part strategy is designed to deliver results (Figure 1-n). We:

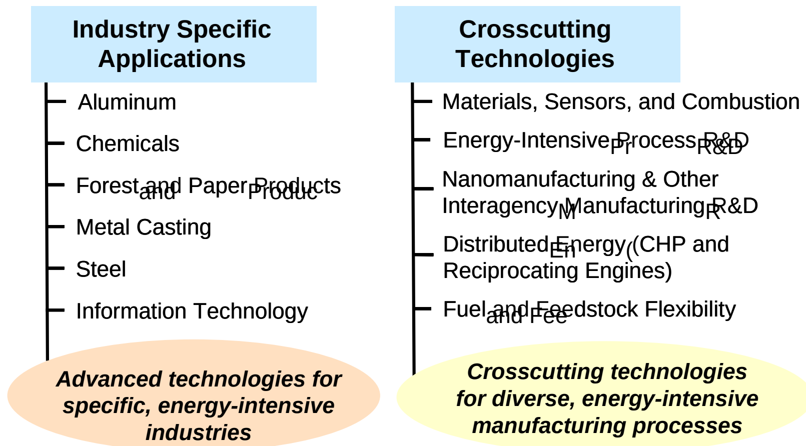
- Sponsor research, development, and demonstration (RD&D) of technologies to reduce energy and carbon intensity
  - Industry specific applications
  - Crosscutting technologies
- Conduct technology delivery activities to help plants access today's technology and management practices
- Promote a corporate culture of energy efficiency and carbon management within industry

At its most basic level, this strategy seeks to condition the market, invest strategically in technology R&D, and deliver highly efficient technologies and practices to a receptive industrial stakeholder base.

In line with our mission and vision, ITP has embraced an overarching goal of driving a 25% reduction in industrial energy intensity by 2017, in accord with the *Energy Policy Act of 2005*. This Save Energy Now - "25 in 10" - initiative delivers resources to help all companies nationwide boost their energy efficiency—whatever their current level of energy performance.

Figure 1-n. ITP's Three-Part Strategy

Figure 1-p. Structure of ITP's R&D Activity



1.4 Program Design

1.4.1 Program Structure

ITP strives to accelerate the development of energy-efficient technologies ready to enter the market in the near term, while conducting groundbreaking research on revolutionary technologies for the future. Our applied R&D focus effectively turns knowledge and concepts initiated by others into real-world energy solutions. With our industry partners, we support research, development, and demonstration activities in both industry-specific and crosscutting areas (see Figure 1-p).

We identify the best opportunities for energy savings through comprehensive technical and market-based analysis and planning. Our industry-specific activities seek to improve the performance of America's most energy- and carbon-intensive industries. The broader initiatives in our crosscutting area focus on high-impact R&D with applications throughout the industrial sector. Once they reach the later stages of development, technologies supported in our crosscutting area are typically demonstrated in one or more specific industrial applications, often in the energy-intensive industries. This dual approach dramatically improves the energy efficiency and environmental performance of the most energy-intensive industrial processes.

R&D Activities

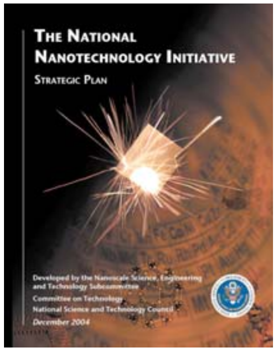
Industry-Specific R&D

ITP engages key energy-intensive industries to develop solutions to the most challenging process-specific priorities. We work closely with its industry partners – often through industry trade and technical associations – to identify these priorities and potential pathways for addressing them. The Program has received strong praise from industry for its role in bringing together companies within an industry to address common technical issues. Our strategy has been to focus scarce resources on high-risk, high-payoff R&D by selecting the best opportunities, leveraging intellectual and financial resources, condensing technology development cycles, and accelerating commercialization and deployment. Currently, the Program is conducting industry-specific R&D in five industries (as shown in Figure 1-r).

Crosscutting R&D

ITP's main R&D focus is on cross-cutting activities that could achieve large energy benefits throughout the manufacturing supply chain. In our crosscutting activities, we work with industrial partners and equipment suppliers to conduct cost-shared research, development, and demonstration on technologies that have potential applications across many segments of industry. Our Energy Intensive Process (EIP) activity – which is structured along "platforms" of technological focus that provide the framework for cost-shared projects -- is the largest component of our crosscutting R&D area. Currently, we are:

- Initiating R&D in four EIP technology platforms
  - Waste Heat Minimization and Recovery
  - Industrial Reactions and Separations
  - High-Temperature Processing
  - Sustainable Manufacturing
- Completing key projects in Sensors and Automation (new sensors projects are being conducted under the EIP activity)



DOE is one of 25 Federal agencies working together to develop next-generation nanotechnologies.

- Continuing R&D in Industrial Materials of the Future and Combustion R&D (complemented by R&D in the EIP platforms)

ITP is also exploring innovative new approaches to expand efficiency throughout the industrial sector. We strive to maintain a full "R&D pipeline" of technologies that could revolutionize manufacturing in the future. We also support industrial applications of existing technologies that will transform the market for combined heat and power and other distributed generation systems, and promote industrial fuel and feedstock flexibility. Specific activities include:

- *Nanomanufacturing and Other Interagency Manufacturing R&D*: We coordinate with other government agencies on next-generation research, focusing initially on processes for the mass production and application of nano-scale materials, structures, devices, and systems for industrial applications.
- *Distributed Generation*: We promote widespread deployment of Combined Heat and Power (CHP) and Advanced Reciprocating Engine Systems (ARES) throughout the United States.
- *Fuel and Feedstock Flexibility* activities: We support the development and deployment of alternative fuel and feedstock technologies to replace natural gas and oil. This targeted, deployment-focused initiative links industrial users with advanced fuel development activities taking place throughout DOE (e.g., EERE's Biomass Program, the Fossil Energy office, etc.) and the National Laboratories.

> *"While [Dow] has long been a leader in energy efficiency, with DOE's help we found yet more cost-effective opportunities to save energy."*
>
> *-John Dearborn*
> *Global Business VP for Energy*
> *Dow Chemical Company*

Technology Delivery

To capture the energy-savings opportunities presented by both new technologies and existing best energy management practices, companies require the appropriate information, assessment tools, and specialized expertise to identify cost-effective measures. Manufacturers can then justify costs and make appropriate investments in technologies and practices.

The dissemination of energy-efficient technologies and operating practices is at the core of ITP's strategy. Through our outreach efforts—voluntary pledge agreement, tools, training, plant assessments, technology demonstrations, website, and other resources—we are able to help companies access resources to save energy today.

ITP's *Save Energy Now Leader* initiative will encourage leading industrial companies, plants, and supply chains to pledge to reduce their energy intensity by 25% over a 10 year period. As part of this initiative, ITP provides resources and incentives to help companies implement energy- and carbon-reducing technology solutions. We work directly with companies who sign the pledge, and help other companies either directly or indirectly through state, utility, and other partners. The Program continues to provide industrial process application tools relevant to major energy systems – including steam, pumping, process heating, and compressed air systems -- emphasizing system-level improvements.

Save Energy Now Leaders – Meeting the "25-in-10" Goal

Save Energy Now is a national initiative to drive a 25% reduction in industrial energy intensity in ten years. It delivers resources to help all companies boost their energy efficiency—no matter where they stand along the energy performance continuum.

Save Energy Now is about action. The initiative reinforces energy efficiency as a profitable business model. It makes available a broad range of resources to help industry identify and implement cost-effective options for energy savings. The portfolio of resources will be expanded over time to fill existing gaps, paving the way for free enterprise to affirm America's leadership in energy technology.

We invite industrial companies and plants to make a bold Pledge to reduce their energy intensity and associated carbon emissions as part of their cost-reduction strategy. Companies and plants are encouraged to make a Pledge that is ambitious yet achievable for their operations. Taking the Pledge demonstrates that they are dedicated to:

- Using energy-efficient processes, technology, and practices
- Fostering industrial energy efficiency and using materials and products made with energy-efficient processes
- Making continuous investments in energy efficiency and carbon reduction as part of their business strategy

Building off the success of 450 completed Energy Savings Assessments (ESAs) in 2006 and 2007, ITP continues performing plant energy assessments, sending energy experts to the Nation's most energy-intensive manufacturing facilities to identify immediate opportunities for saving energy and money. The Industrial Assessment Centers program continues to enable eligible small and medium-sized manufacturers to have comprehensive industrial assessments performed at no cost to the manufacturer.

Corporate Culture of Energy Efficiency

ITP is cultivating a corporate culture of energy efficiency and environmental stewardship throughout U.S. industry. Energy efficiency is a sound business strategy that yields huge benefits. ITP is spearheading major efforts to raise awareness of opportunities and encourage investments in energy efficiency throughout the public and private sectors. The Program is developing and implementing a comprehensive strategy that clearly defines key messages, products, channels, partners, and events necessary to transform the way industry thinks about and uses energy.

To elevate energy efficiency as a priority within industry, ITP will:

- *Serve as the federal resource for industrial energy efficiency* by providing unbiased, reliable information
- *Shape the direction of the industrial market relative to energy efficiency* in collaboration with individual corporate leaders, the National Association of Manufacturers, the Business Roundtable, and other high-level business organizations
- *Foster voluntary corporate commitments* to reduce industrial energy intensity
- *Support third-party certification of plant energy efficiency* to create a standard of excellence and guide investments
- *Encourage energy efficiency up and down supply chains* by providing guidelines to help companies develop and implement policies and protocols
- *Provide energy analysis and management resources* to help diverse industry segments establish energy use baselines
- *Provide flexible energy planning resources to corporations* to encourage programs and goals for energy efficiency

Organization

The current ITP structure has been instituted to provide a balance between various program elements, budget, management/staff ratio, and responsibilities. This structure responds to the variety of opportunities to improve industrial energy efficiency (Figure 1-q).

The ITP organization is designed to achieve ITP and EERE missions, operate efficiently within the EERE organization, and encourage dynamic staff interaction. Our Headquarters organization in Washington, DC is responsible for developing, managing, and evaluating technology portfolios that best achieve ITP goals and strategies. The Golden Field Office and National Energy Technology Laboratory are responsible for initiating, managing, and monitoring all ITP projects. Additionally, they are responsible for delivering technologies to our many partners.

ITP strives to operate under the following principles:

- Foster an environment where individual initiative and accomplishments are valued in a team setting.
- Allocate resources to those technologies that offer the best investment relative to the potential energy savings.
- Use competitive solicitations to select and support proposals that offer the most technically and commercially feasible solutions.
- Contribute to the value and balance of the overall EERE portfolio by supporting industrial R&D, validation, and dissemination activities.
- Provide strategic leadership and program management from EERE headquarters, and rely on field Project Managers to oversee individual projects.

- Seek opportunities to work with all other EERE programs to collectively contribute to the success of the entire EERE team.
- Serve as good stewards of public resources appropriated to carry out the mission.
- Engage industry, states, national laboratories, universities, other federal agencies, and other nations to jointly achieve the EERE and ITP missions, and leverage resources for mutual benefit.

Figure 1-q. Industrial Energy Use and Opportunities

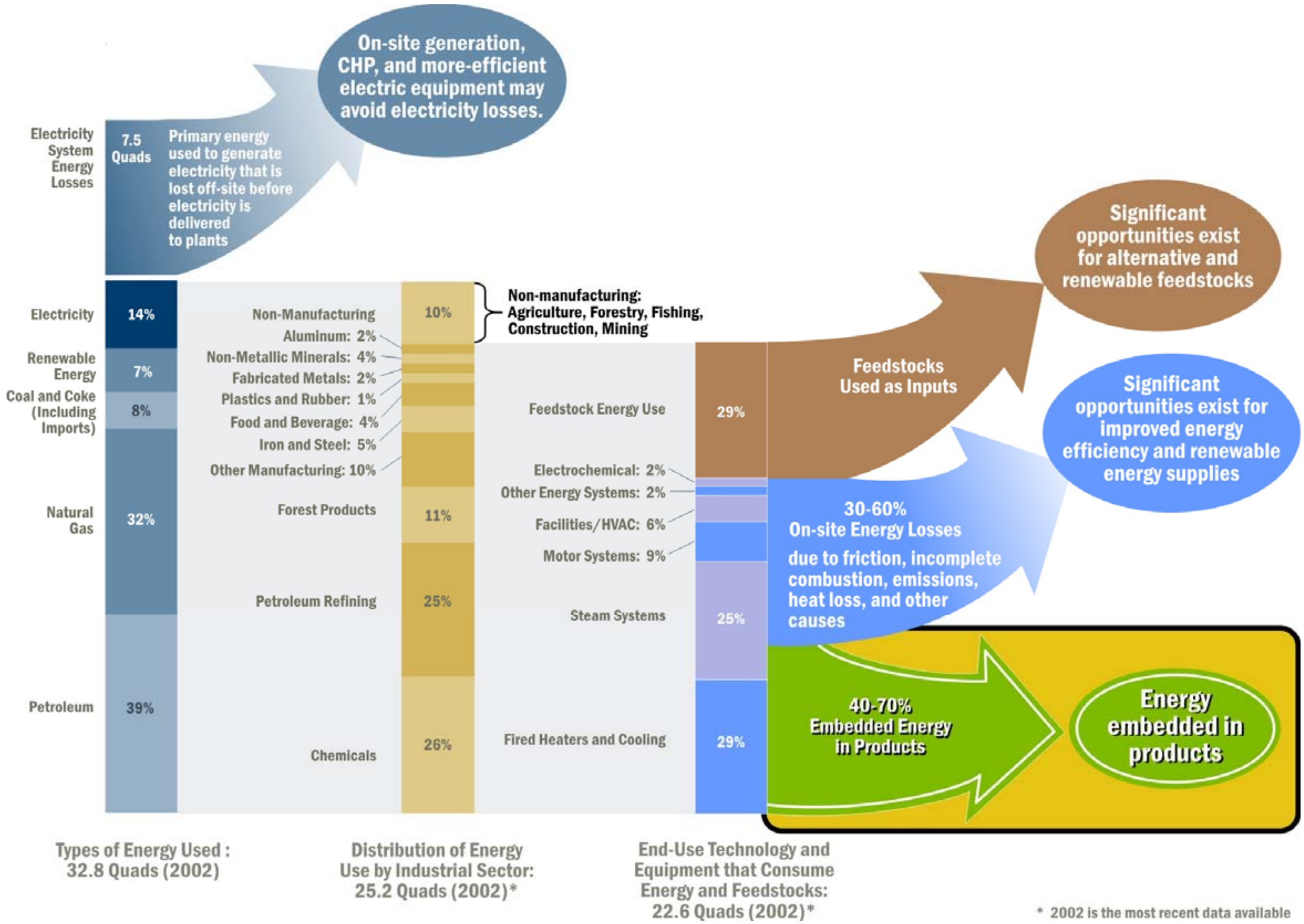
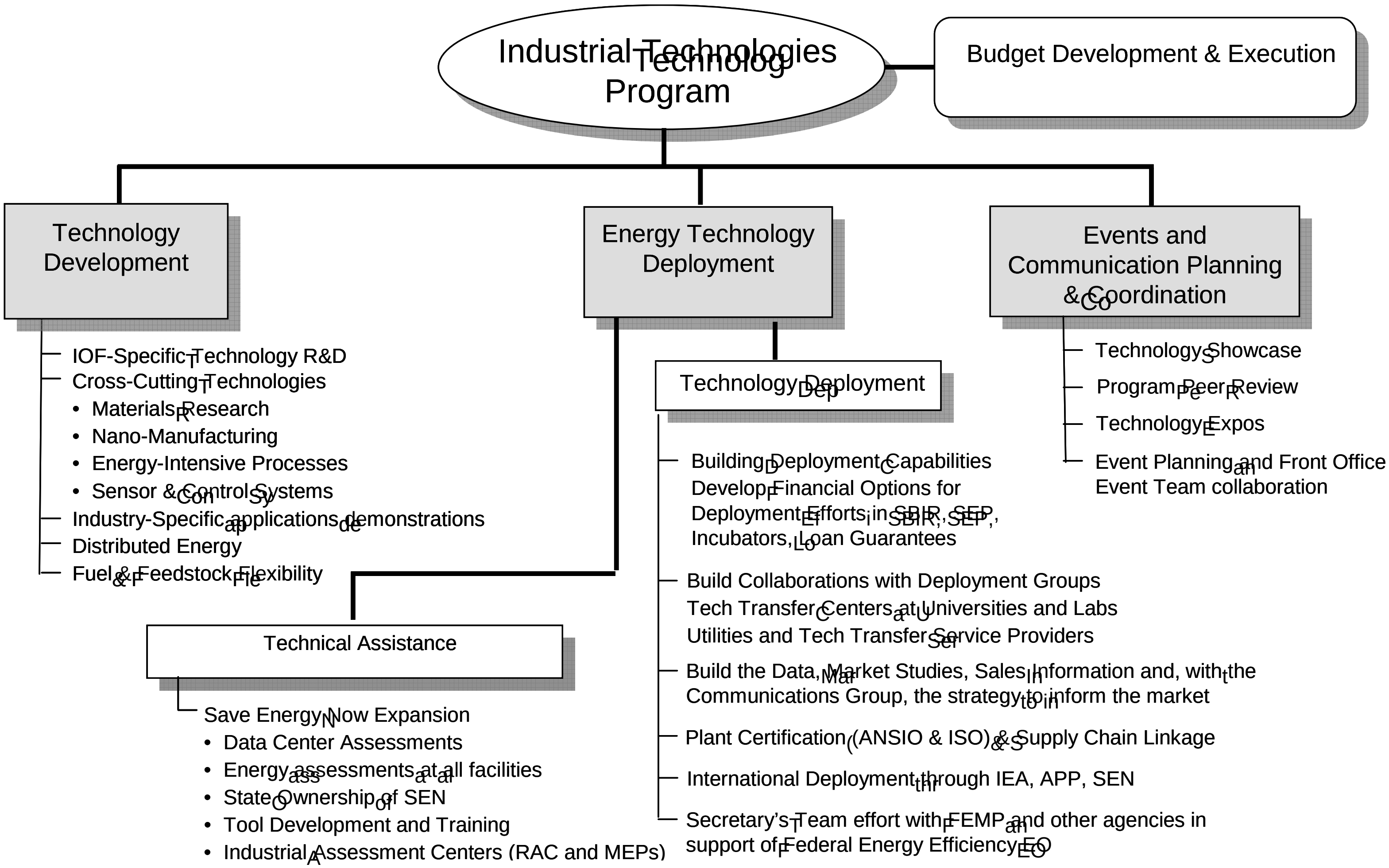


Figure 1-r. ITP Organization Chart



1.4.2 Program Logic

ITP's logic model is displayed in Figure 1-s.

The Industrial Technologies Program has evolved over time into a well-managed and effective program. Its strategy is consistent with higher-level plans of the nation and the Department of Energy, and its management and decision-making processes are solidly based. The program's scope and depth of analysis and reporting are impressive. The ITP significantly leverages its resources through a large and growing number of partnerships with industry, industry associations, and academic institutions. Project portfolios are in place to achieve subprogram goals and, presumably, overall program goals. Current ITP leadership is strong, and the enthusiasm, dedication, and knowledge of subprogram managers are noteworthy. As an overall assessment, it is clear that the ITP team works well together and that a working environment has been established that has made and will continue to make the subprograms succeed.

ITP's STRATEGIC ELEMENTS		
Promote a corporate culture of efficiency in industry	Develop real world energy solutions for industry	Expand the use of proven technologies
Serve as the Federal resource for industrial energy and carbon management • Shape the direction of the industrial market • Foster voluntary corporate commitments to reduce industrial energy intensity • Encourage energy efficiency up and down supply chains • Foster third-party certification for plant energy efficiency • Provide energy analysis and management resources Help Federal agencies reduce energy intensity and carbon emissions	Conduct energy efficiency R&D • Develop advanced technologies for energy-intensive industries • Meet the energy technology needs of a broad manufacturing base • Turn scientific discoveries into next-generation solutions • Investigate industrial carbon reduction strategies Promote fuel and feedstock flexibility • Conduct process integration R&D • Support technology analysis and education • Validate technologies Support commercialization of emerging technologies	Help plants access today's technology and management practices • Assessments • Software tools, training, and outreach • Incentives and recognition • Activities to address market barriers Foster strategic partnerships to expand investment, innovation, and outreach

1.4.3 Relationship to Other Federal Programs

In carrying out the program's mission, Industrial Technologies Program (ITP) performs the following collaborative activities:

- ITP works with DOE's Basic Energy Sciences Program to coordinate research in areas such as nanotechnology.
- ITP coordinates with other Federal agencies, including the National Aeronautics and Space Administration, the National Science Foundation, the National Institute of Standards and Technology, EPA, and the Departments of Defense, Commerce, Agriculture, and Interior to organize research efforts in common areas.
- On manufacturing technology issues, ITP collaborates through the National Science and Technology Council inter-agency working group on manufacturing (IWG) with many of the participating agencies.

There are many examples of projects where ITP has worked with other government programs; examples of ITP's collaboration with other EERE programs are described in Section 1.1.6.

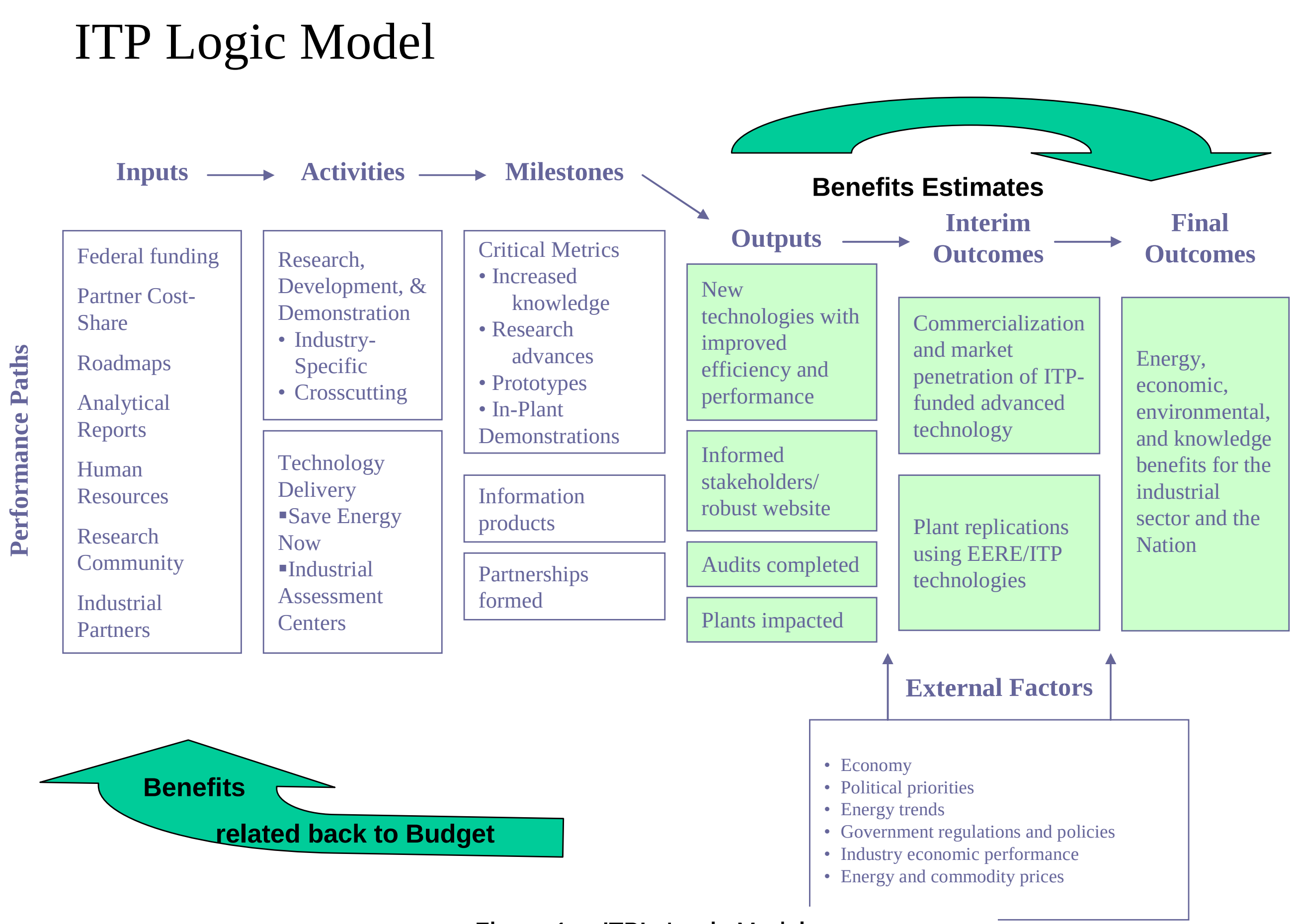


Figure 1-s. ITP's Logic Model

1.5 Program Goals and Multiyear Targets

1.5.1 Goal Cascade

1.5.2 Program Strategic Goals

ITP seeks to reduce the energy and carbon intensity of the U.S. industrial sector through a balanced portfolio of collaborative technology investments, validation, and dissemination of information on energy-efficiency technologies and best energy management and operating practices that are used and replicated. This reduction in energy intensity reduces carbon emissions and improves national energy security, climate and environment, and economic competitiveness. Program objectives are to:

- Provide national leadership in energy efficiency through collaborative R&D and best energy management practices
- Promote the use of proven energy management methods and advanced technologies throughout industry
- Spur national investment in energy efficiency through strategic partnerships with states, utilities, business, the financial community, and others

ITP maintains its position on the cutting edge of new technologies for industry. We continue to work with our traditional industry partners, while identifying game-changing new industries where we can impact efficiency at the ground level. We are also expanding our reach to even more companies through a robust network of state energy offices, utility companies, industry associations, and non-governmental organizations who have a stake in industrial energy efficiency.

Our partnership with industry is taking a giant leap forward in FY08 with the launch of a voluntary program to reduce energy intensity. ITP has established an ambitious goal to help lower the energy intensity of U.S. industry 25% by 2017 in accord with the *Energy Policy Act of 2005*. Industrial companies will voluntarily pledge to meet this goal; ITP will support them by delivering resources to help boost their energy efficiency—whatever their current level of energy performance.

1.5.3 Program Performance Goals

Our R&D and Technology Delivery activities are designed to help industry achieve the goal of a 25% reduction in energy intensity by 2017, as well as a similar decrease in carbon intensity. Our priorities include accelerating the deployment of emerging technologies such as the ultra-efficient superboiler into the market to achieve benefits as quickly as possible – an estimated 300 trillion Btu/year by 2030. Other innovative technologies in the pipeline will be commercialized in the next five years:

- *An alternative ironmaking process* that is 30% less energy intensive (saving 4.7 million Btu/ton of iron produced) than the conventional coke oven/blast furnace route

- *An aluminum melting technology* that reduces melting energy intensity by 70% (saving 2 million Btu/ton of aluminum produced)
- *A high-efficiency pulping process* that is at least 20% less energy-intensive than today's Kraft pulping (saving 2.2 million Btu/ton of pulp produced)
- *A microchannel reactor* for on-site, concentrated hydrogen peroxide production (saving 11 Btu/lb of H_2O_2 produced)
- *A wireless motor monitoring system* to detect poor-performing motors that will save at least $3,000 in energy costs per year for a single 200 hp motor
- *Advanced catalysts* that have 40% higher reaction yields than conventional systems (saving nearly 3,000 Btu/lb of ethylene produced)

ITP's Technology Delivery contributes to the energy intensity reduction goal by giving plants the tools, training, information, and motivation they need to adopt today's more energy-efficient technologies and practices with full confidence in their performance.

1.5.4 Program Multi-Year Targets

Key programmatic outputs and outcomes in the 2008-2012 timeframe are described below.

ITP's Activities Will Have a Significant Impact on Industry

In FY08, we will:

- Launch the Save Energy Now Leaders partnership and sign up 60 companies
- Complete 300 Energy Saving Assessments
- Commercialize 3 new technologies
- Achieve annual savings of 100 trillion Btu through Program activities

Over the five-year period FY08-FY13, we will:

- Sign up 240 companies for the Save Energy Now Leaders partnership
- Complete 1,500 Energy Savings Assessments
- Launch ANSI-accredited plant energy-efficiency certification process and certify 1,500 plants
- Commercialize 15 new technologies
- Achieve cumulative 5-year savings of 500 trillion Btu through Program activities

Programmatic Outputs in 2008-2012 Timeframe

Program outputs are key measures of progress towards reaching program goals.

FY08:

- Commercialize 3 new technologies in partnership with the most energy-intensive industries that improve energy efficiency of an industrial process or product by at least 10%.
- An estimated 100 trillion Btu saved by an additional 800 energy intensive U.S. plants applying EERE technologies and services.

FY09:

- Commercialize 3 new technologies in partnership with the most energy-intensive industries that improve energy efficiency of an industrial process or product by at least 10%.
- An estimated 100 trillion Btu saved by an additional 600 energy intensive U.S. plants applying EERE technologies and services.

Key outputs for FY10-FY12 have not been determined at this time.

Key FY08-FY12 technical milestones for potential technologies that will help meet program goals are included in Section 2.

Programmatic Outcomes in 2008-2012 Timeframe
Programmatic outcomes are key indicators of realizing the program vision.

FY08:

- Annual energy savings from ITP activities in partnership with industry: 180 trillion Btu
- Annual energy savings from ITP technical assistance activities: 200 trillion Btu
- Energy intensity change from 2002: -7.2%

FY09:

- Annual energy savings from ITP activities in partnership with industry: 180 trillion Btu
- Annual energy savings from ITP technical assistance activities: 200 trillion Btu
- Energy intensity change from 2002: -8.3%

Key outcomes for FY10-FY12 have not been determined at this time.

2 Technology Research and Deployment Plan

ITP includes 14 program elements with appropriated funding in FY08. Each of these program elements will be described in more detail below. For each program element, the MYPP presents an overview, followed by a current snapshot of the milestone chart. Accompanying the chart is a table that enumerates barriers, pathways and metrics for each technology focus area. Additionally, where applicable, the energy footprint, roadmap summary, and bandwidth study are included.

Standardized wording for certain focus areas appears on most milestone charts. Those areas are:

- Cross-EERE Activities
- BP Integration / Technology Delivery
- Studies & Analysis

Stage Gate Process

ITP has drafted a document defining its stage gate process, entitled *Stage Gate Innovation Management Guidelines*. The ITP portfolio management guidelines are based on Stage Gate™ principles (a registered trademark of R.G. Cooper & Associates), a methodology which has been successfully applied throughout industry and government (Cooper 2002, Cooper 1998, GRI 1995). Stage Gate is a phased project development approach that produces fact-based funding decisions based on a set of defined evaluation criteria. The ITP Stage Gate process builds upon the guidelines for the methodology contained in the *EERE RDD&D Decision Process – Standard Model*.

Specifically, Stage Gate will be used by ITP to:

- Provide consistent program and project management guidelines
- Characterize projects in terms of scope, quality, performance, and program integration
- Evaluate and monitor project progress against milestones and metrics
- Assess viability of technology commercialization
- Guide decisions on project funding (e.g., go forward, stop, hold, return)

Commercialization Track Stages

Stage 1 – Preliminary Investigation and Analysis: Scoping studies to identify research topics; technical and market assessments; idea generation.

Stage 2 – Concept Definition: early stage research to explore and define technical concept or to answer a specific technical question; laboratory scale research.

Stage 3 – Concept Development: development and testing of prototype technology or process; development of models and informational databases; predictive modeling or simulation of process or equipment performance; evaluation of scalability and end-user acceptability; demonstration of concept feasibility at the prototype or bench scale.

Stage 4 – Technology Development and Information Validation: pilot scale development of technology or process; technology field test and validation of economic potential; verification and documentation of information.

Stage 5 – Information Dissemination and Commercialization: all activities necessary for information delivery and commercial launch (production scale technology manufacture and installation; development of market infrastructure; demonstrated commercial operation).

A key tenant of the Stage Gate model is that funding commitments for projects are initially low, and will increase as work progresses and confidence in a successful outcome rises. Early focus is placed on exploring the most uncertain and risky technical elements, to minimize spending in the long-term. Conducting a thorough background study of the potential for the technology and its expected economics in the initial stages provides important information for making judgments about the project along the way. The expectation is that projects with serious technical or other issues will be identified early-on, enabling greater investment in the projects with the greatest probability for success.

For projects that are expected to produce a commercial process or technology product, stages and gates are designed to facilitate the development of new technology and enable industrial partners to take it forward to commercial launch. Projects that focus on information generation, which may range from fundamental scientific research to the dissemination of information about technology developments, similarly use the stage-gate process to ensure outcomes are valuable to end-users.

Stage and gate criteria have been developed that are uniquely suited to the type of projects funded by ITP. More details, including stage descriptions and gate review criteria, can be found in the stage gate document.

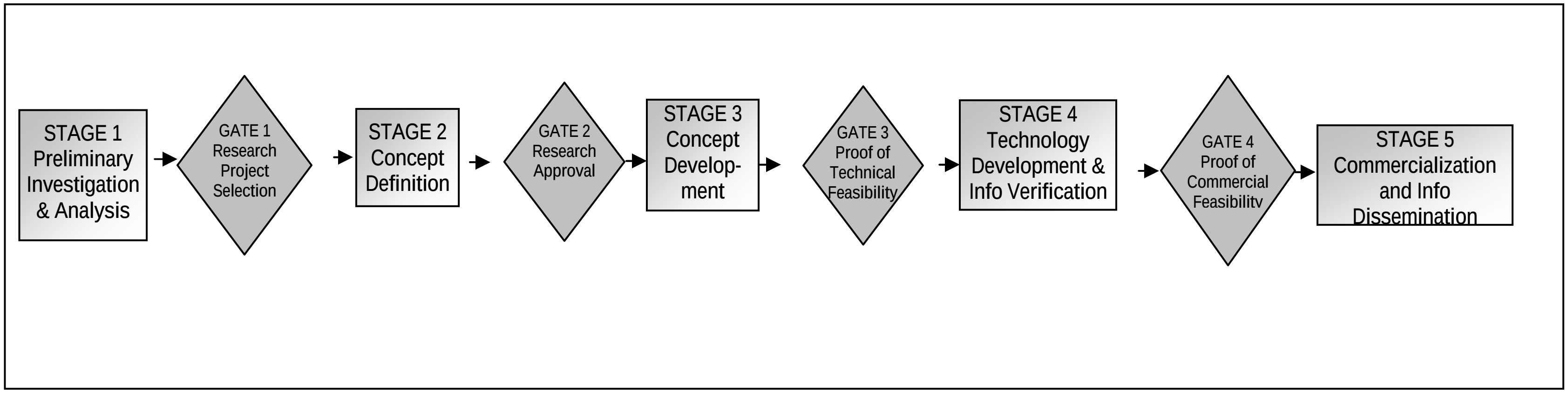


Figure 2-a. ITP Stage Gate Project Decision-Making Process

Corporate Milestones

In the summer of 2002, ITP initiated a formalized process to track and maintain program milestones. These program milestones have been identified at junctures along the critical path toward the program objectives and goals. They mark key decision points for determining, as early as practical, whether the program is on track to meet its objectives. The purpose is to facilitate timely adjustments to the program strategies, if necessary. The milestone charts that have resulted from this process are reviewed quarterly, with updates published. In conjunction with the charts, an overview of the key technology barriers and proposed pathways are included, along with metrics that focus on the key measurements of ITP success: energy savings; cost savings; environmental impact; and commercialization potential.

In this Multi-Year Program Plan, each of the planning units, or sub-programs, has identified key milestones within major focus areas. These milestones are represented in the individual planning unit charts that follow in section 3 of this document. These key milestones are selected because progress against them is indicative of the health of the technical focus area they represent. Progress on the most important of these milestones can be indicative of the health of the whole planning unit and are, therefore, of interest at the corporate level.

What follows is a chart of the nominated milestones, by year, as submitted by each planning unit.

PROGRAM MILESTONES 2008-2012

Program Area	Milestone/Deliverable	Completion Date
Industry-Specific Applications	Establish 'best practice' in melting with 10% energy savings in producing die castings	Q4-FY08
	Complete microchannel reactor system optimization, integration and evaluation for catalytic hydrogenation with 90% reduction in energy	Q4-FY08
	Create completely safe, energy-efficient reheat system that significantly minimizes or eliminates scale formation during steel reheating	Q1-FY09
	Complete scale-up and field tests of highly selective oxidation catalysts to achieve conversion efficiency >80% and selectivities >90%	Q3-FY09
	Complete mill trial of directed green liquor utilization (D-GLU) pulping process with 20% energy reduction	Q2-FY10
	Demonstrate energy- efficient production of high quality iron that is equivalent in quality to blast furnace pig iron and can be used directly by electric steelmaking processes	Q2-FY10
	Begin efforts to scale up the ITM capacity to 150,000 lb/hr with 70% energy savings potential	Q1-FY11
	Develop innovative casting process with 20% improvement in productivity and energy efficiency	Q4-FY12
Crosscutting Technologies	Complete installation of gas composition microanalyzer at operating field sites resulting in energy savings of 1-5% depending on the application	Q3-FY08
	Commission 4.6 MW CHP system at food processing plant to recover waste heat for process use, increasing overall efficiency	Q4-FY08
	Extend maximum use temperature of aerogel insulation to 1200 F and reduce production cost by about 10%	Q4-FY08
	Demonstrate Transport Membrane Condenser (TMC) in a retrofitted conventional boiler to recover waste heat and improve efficiency towards 94% goal	Q4-FY09
	Conclude first field trial of >94% efficiency watertube boilers capable of 1,500 F and 1,500 psi steam	Q3-FY10
	Conduct demonstration of solid-state steel welding in plant operations with >15% energy savings	Q4-FY10
	Complete design of modified burners to run on gas with Btu content of less than 500 Btu/scf	Q4-FY10
	Complete development of two non-destructive quality control methods to enable nanomaterial manufacturing	Q4-FY11
	Demonstrate a non-thermal dewatering technology that reduces energy requirements by at least 20%	Q4-FY11
	Manufacture prototype transient processing systems and successfully demonstrate commercial viability in plant trials with energy savings in excess of 20%	Q1-FY12
Technology Delivery	Conduct 300 assessments by the end of the calendar year	Q1-FY08, 09, 10, 11
	Train 200 engineering students in energy efficiency through IACs	Q4-FY08, 09, 10, 11
	Award 25% of plants receiving IAC assessments Energy Saver Plant or Energy Champion status for previous calendar year	Q2-FY08, 09, 10, 11
	Train/mentor 26 local MEPs in energy efficiency tools, resources and practices	Q4-FY08, 09, 10, 11
	Get companies to sign Save Energy Now Leaders pledge - 60 by FY09	Q4-FY08, 09, 10, 11

Program Area	Milestone/Deliverable	Completion Date
	- 200 by FY10 - 240 by FY11	
	Complete 4 online issues of *Energy Matters;* complete 12 monthly issues of *E-Bulletin*	Q4-FY08, 09, 10, 11
	Present annual awards; hold SEN Champion Awards Event and Leader Awards Event	Q4-FY08, 09, 10, 11
	Award 16 or more states state-level Save Energy Now awards	FY09, 10

2.1.1 Aluminum

Background

The United States aluminum industry is the world's second largest, processing 9.6 million metric tons of metal and producing about $40 billion in products and exports in 2003. U.S. per capita consumption was 29.5 kilograms. The industry operates more than 400 plants in 41 states and employs more than 145,000 people. Aluminum impacts every community and person in the country, through either its use and recycling or the economic benefits of manufacturing facilities.

Energy reduction in the U.S. aluminum industry is the result of technical progress and the growth of recycling. These two factors have contributed 22% and 39% respectively to the total 61% energy reduction achieved over the past 40 years. However, this strategic metal whose light-weight characteristics are essential in transportation and aerospace among other applications, remains one of the most energy-intensive materials to produce. Even with large reductions in energy intensity, the industry consumes nearly three times the theoretical minimum energy required. In addition, there are concerns about the continuous decrease in domestic primary aluminum production capacity due to increased energy and alumina costs. Domestic smelters only operated at about 63% of rated or engineered capacity in 2004.

Major energy-consuming processes for aluminum are smelting and thermal processing, which includes melting, molten metal holding, purifying, alloying, and product heat treating. Smelting is the most energy-intensive of these processes requiring 46% of the total energy consumed in the U.S. manufacturing of aluminum. This area represents the largest single energy savings opportunity. However, the Aluminum portfolio's limited resources preclude major work in primary smelting since the scale and scope of this work requires very significant long-term investment. In addition, smelting is used only by the primary aluminum industry, a subsector that has shrunk dramatically in this country and is predicted to continue moving offshore to countries with low electricity costs. Current R&D efforts are focused on other (non-primary) areas where resources spent will yield energy savings in the near-term. DOE supports two functional areas, advanced melting and innovative forming.

The second largest energy consuming operation is thermal processing and DOE is supporting R&D in this area. It accounts for 27% of the total energy consumed in manufacturing of aluminum and over 52 trillion Btu/year of the energy consumed in the United States. *ITP's analysis shows that 40-50% energy savings are possible in melting, hot rolling, and other thermal processing operations.* The results of the R&D efforts in melting technologies are applicable to many U.S. industries that utilize furnaces, ovens, kilns, refractory and high-temperature technologies. The advanced melting work could lead potentially to a paradigm shift in the industry by eliminating melting and holding furnaces at the casting cell and moving to centralized, off-site facilities. This work is being performed by Apogee Technologies and other partners. The second area supported by DOE is innovative forming and seeks to save energy by minimizing the planned or incidental scrap in the hot rolling of aluminum ingot. The scrap has to be re-melted which wastes an enormous amount of energy. This work is being conducted at the University of Illinois - Urbana Champaign and others.

Strategy

The Aluminum portfolio strategy is to continue improvements in melting – heat loss reduction, heat recovery and reduction of oxidation losses – where improved energy efficiency and product quality can be realized. Forming technologies are relatively small energy consumers compared to melting but will be supported in cases where improvements in yield avoid remelting or where energy savings can be obtained by expanding proven technologies (i.e., continuous casting of sheet products).

Funding activities will be distributed among university, national laboratory and industry-based researchers. Their activities will address the high priority melting and forming research needs described in the Vision and Roadmap documents: Advanced Melting Technologies, and Innovative Forming Technologies. Melting activities are aimed at improving the thermal efficiency of the melting processes and technologies and with geographically optimized central melting operations. Forming activities are aimed at reducing scrap and losses, especially at the edges of rolled aluminum products. Since these processes and technologies can be readily integrated into current production practices, they can have a significant impact on energy savings in the aluminum industry.

End States

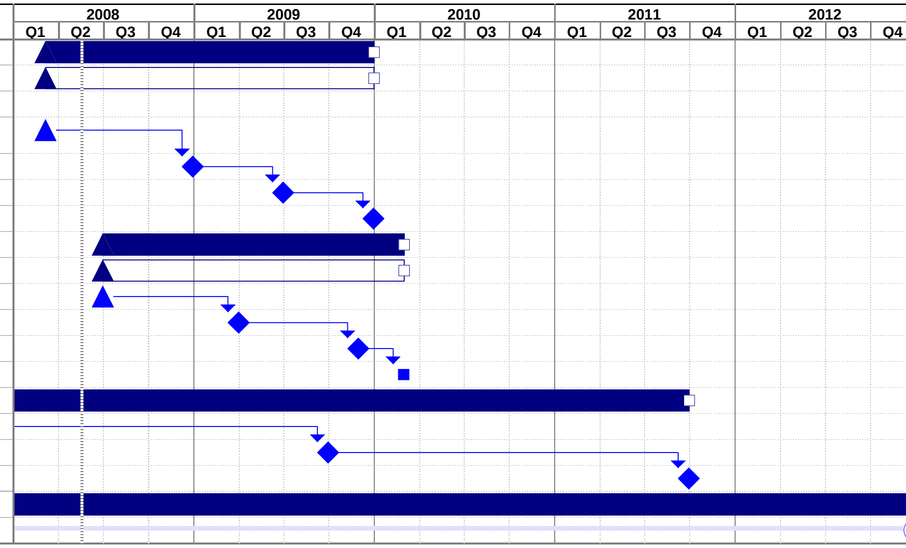
The end state is defined as the time when the federal government can step out of the process of technology research and development, and further development is picked up and continued by industry. This is, in many cases, difficult to forecast but should be considered in formulation of strategy and funding plans. For the focus areas of the Aluminum portfolio, the end states, at this time are considered to be:

Advanced Melting. The end state will be successful demonstration that theoretical practical minimum energy use can be obtained using technologies developed with federal funding. This will, of necessity, require integration with product manufacturing, reduction of lost heat, reduction of oxidative melt losses and recovery of energy from the melting process.

Innovative Forming. The end state will be reached when virtually no additional benefit can be derived from further increasing yield, reducing scrap rates, avoiding remelt and when the limitations on continuous casting alloy have been reduced as much as possible.

Last updated: 5/5/2008

ID	Name
1	Advanced Melting
2	Energy Efficient Melting Technologies
3	
4	Implement Active Temperature Control at Aleris Casting Line
5	Complete the final design of a 6,000 lb/hr production ITM
6	Install and Start-Up TeL Delivery-Dispension Vessels
7	Integrate ITM/TEL and Conductive Trough
8	Innovative Forming
9	Computational Model for Hot Rolling
10	Characterize Microstructures of Selected Aluminum Alloys
11	Develop Fracture/Failure Criteria
12	Validate 3D Simulation Results
13	Tech Delivery
14	BP Interaction /Technology Delivery
15	Portfolio Review
16	Portfolio Review
17	Portfolio Review
18	Cross-EERE Activities
19	For Future Development

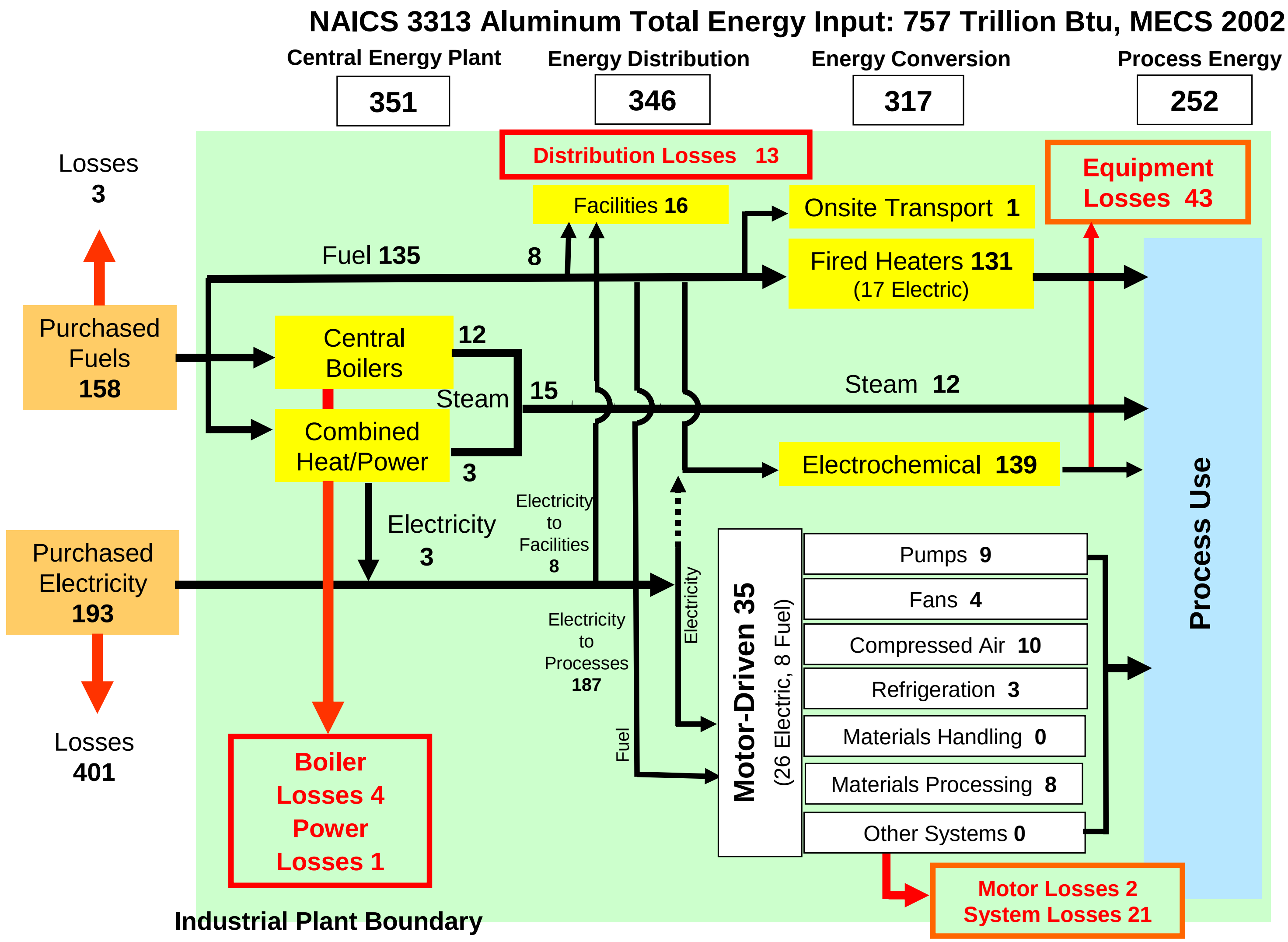


R&D Strategy Focus Area	Barriers	Pathways	Metrics
Advanced Melting (1) <u>Objective</u> Develop melting systems that reduce metal oxidation and energy consumption	• The aggressive nature of molten aluminum and aluminum purifying processes (e.g., gas fluxing with Cl_2) limits heat conservation or recovery by modifications to furnace refractory, recuperator and other system materials (2) • Aluminum oxidizes readily, resulting in metal lost to oxidation (2-8%) during the melting and holding operations (2)	Efficient Melting Technologies pathways will provide the aluminum industry with advanced melting technologies that could potentially use immersed electric heaters to melt metal by heat conduction and convection. In FY2008, the conductive trough will be installed and started up and the final design for a 7,000 lb/hr ITM will be completed. The Apogee Technology project plans to construct and commission the IsoThermal Melter (ITM) and routinely operate it to measure performance. It also plans to build, test and validate the turboelectric ladle (TeL) design and develop, install and successfully operate the TeL fill docking station at IMCO. In FY2009, the TeL will be installed and the ITM, TeL and CT will be fully integrated. In FY2010, the ITM system will supply fully processed high quality molten aluminum directly to the casting lines, using an off-site melter with high energy efficiency, to support one foam casting line at General Motors with a nominal throughput of 6,000 lb/hr. In FY2011, the project team will begin efforts in scaling up the ITM capacity to 150,000 lb/hr with 50% energy savings potential.	Demonstrate melting operation at less than 1% melt loss (compared to current 2-3% loss) and 70% reduction in energy intensity (from current thermal efficiency level of less than 30%). *Total potential savings = 20 trillion Btu/year*
Innovative Forming (2) <u>Objective</u> Reduce scrap and energy consumption by developing predictive models that relate alloy microstructure and properties to specific forming processes	• Lack of models capable of relating structural properties to manufacturing process and the materials employed (1) • Lack of accurate materials data, including elemental data by alloy type (1) • Lack of accurate process design data and integrated process models (1) • Lack of models that allow reverse engineering (1)	The Computer Modeling for Hot Rolling Scrap Reduction pathway will improve the total rolling-plant recovery of aluminum process from ingot to final products. This will be done through: 1) linking microstructure to macroscopic properties of aluminum and rolling process parameters; 2) predicting history of deformation and damage revolution in hot rolling; 3) optimizing processing parameters to reduce scrap in hot rolling and validate the integrated models; 4) demonstrating the predictive ability of the integrated model as a process optimization tool for hot rolling; and 5) using the integrated models to significantly reduce both planned and incidental scraps in hot rolling.] In FY2008, the microstructures of selected aluminum alloys will be characterized and the criteria for fracture/failure will be developed. In FY2009, the 3D simulation results will be validated.	Significantly reduce both planned and unplanned scrap in hot rolling, and improve the rolling process recovery by at least 10%. *Total potential savings = 1 trillion Btu/year*

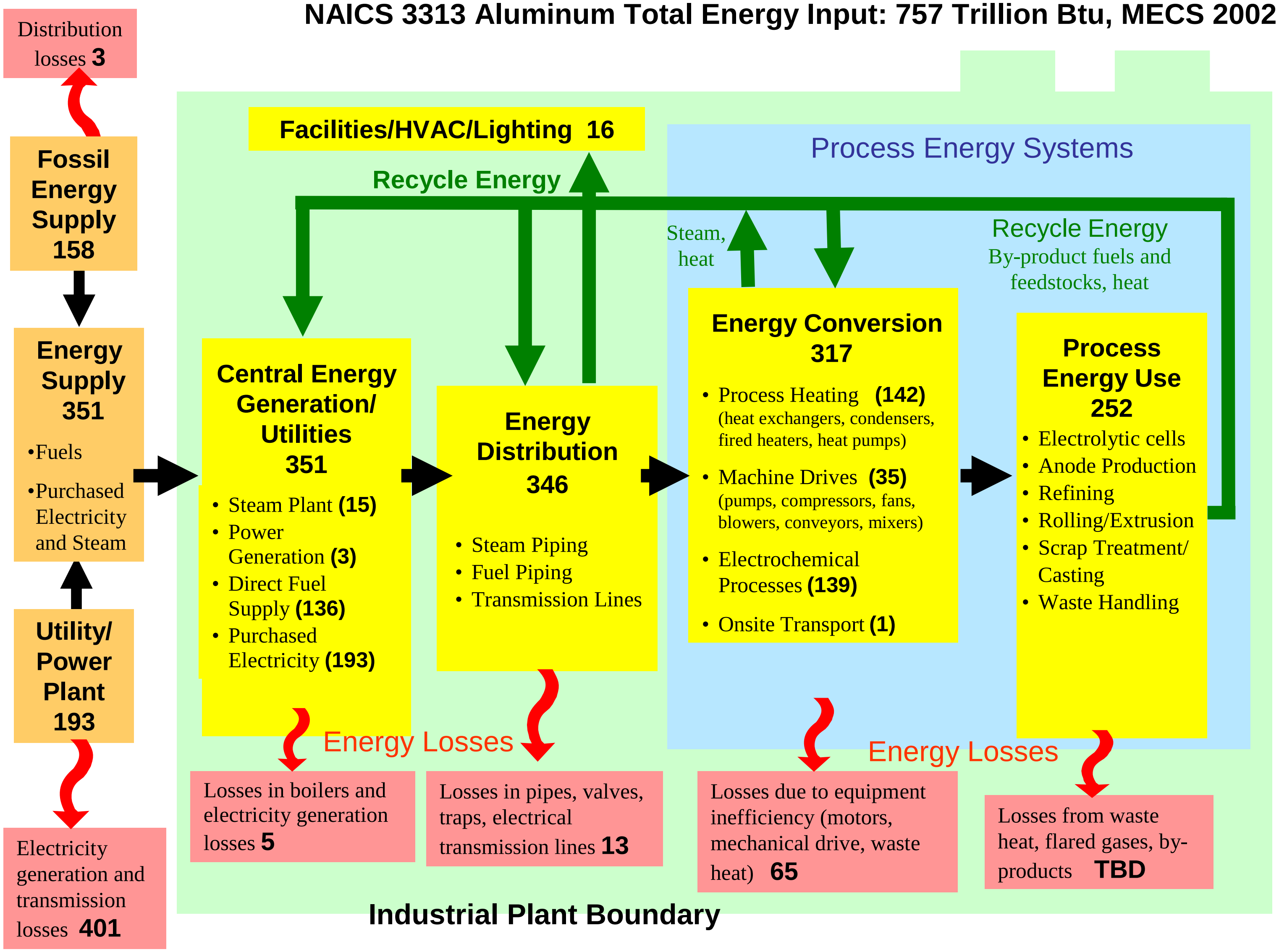
Sources:

(1) U.S. Department of Energy, Energy Efficiency and Renewable Energy, Industrial Technologies Program, Aluminum Industry of the Future, *Aluminum Industry Technology Roadmap,* Washington D.C., February 2003.
(2) U.S. Department of Energy, Energy Efficiency and Renewable Energy, Industrial Technologies Program, Aluminum Industry of the Future, *U.S. Energy Requirements for Aluminum Production; Historical Perspective, Theoretical Limits and New Opportunities,* Washington D.C., February 2003.

2.1.1.1 Aluminum Footprint

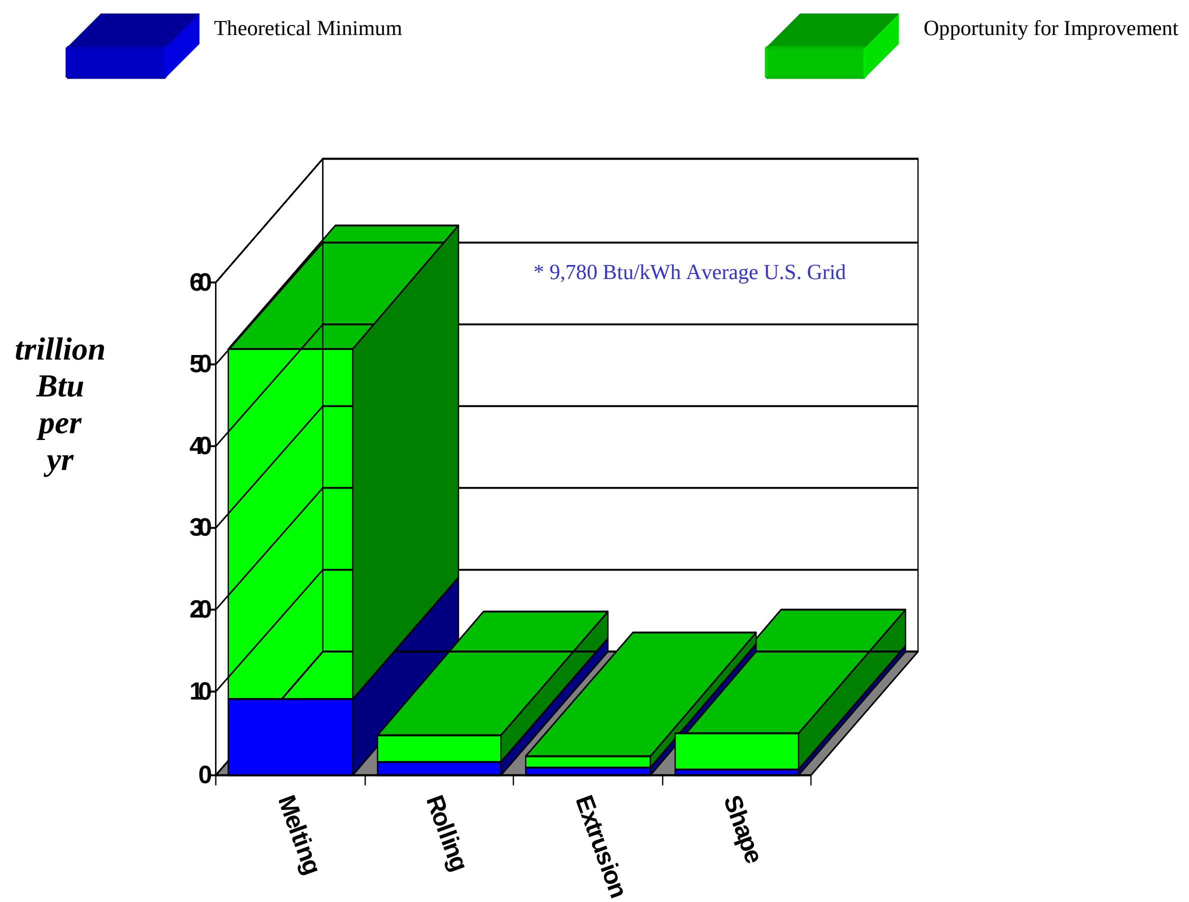


NAICS 3313 Aluminum Total Energy Input: 757 Trillion Btu, MECS 2002



2.1.1.2 Aluminum Bandwidth Analysis

U.S. Annual Tacit Energy Consumption by Process, 2003



2.1.2 Chemicals

Background

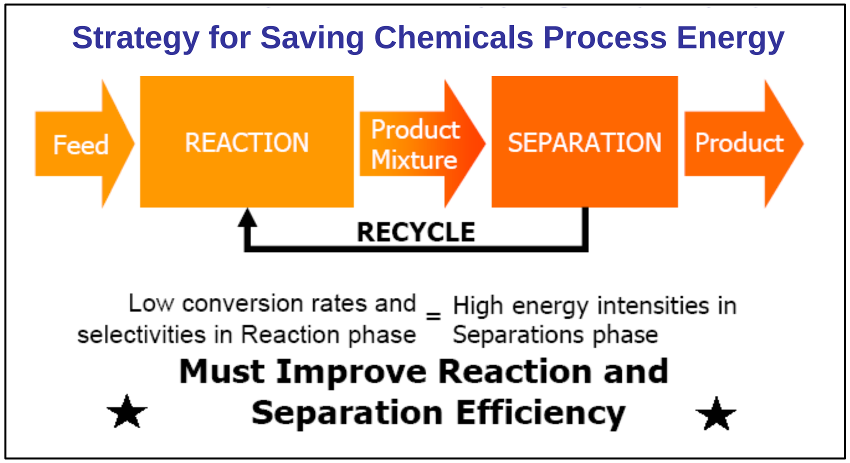
The Chemical Industry is a keystone of the U.S. economy, converting raw materials (oil, natural gas, air water, metals, and minerals) into more than 70,000 different products. Few goods are manufactured without some input from the chemical industry. Chemicals are used to make a wide variety of consumer goods, as well as thousands of products that are essential input to agriculture, manufacturing, construction, and service industries. The chemical industry itself consumes 26 percent of its output. Major industrial customers include rubber and plastic products, textiles, apparel, petroleum refining, pulp and paper, and primary metals.

Chemicals are nearly a $1.5 trillion global enterprise, and the U.S. chemical industry is the world's largest producer. There are 170 chemical companies with more than 2,800 facilities abroad and 1,700 foreign subsidiaries or affiliates operating in the United States. According to the Energy Information Administration, the chemical industry records large trade surpluses and employs more than a million people in the United States alone. The chemical industry is also the second largest consumer of energy in manufacturing and spends over $5 billion annually on pollution abatement.

The U.S. Department of Energy's Industrial Technologies Program has formed a partnership with the U.S. chemical industry to accelerate the development of technologies and processes that will improve the industry's energy efficiency and environmental performance. ITP's analysis of the top 40 chemicals (by volume) shows that energy savings of 67% are possible through the development and use of new technologies and processes.

Strategy Statement

The Chemicals Subprogram overall strategy is illustrated in the figure to the right.



Most chemical processes begin with a reaction and are followed by a separation of the product mixture into desired product, unreacted feedstock, and unwanted by-products. The unreacted feedstock and unwanted by-products are recycled back to the reactor. Since most industrial reactions have typically low conversions and selectivities, the separation train is usually both energy and capital intensive. Similarly, the recycle loop is usually large, resulting in large electrical energy required to pump the liquids or compress the gases in order to move the fluids around. The equipment sizes in the recycle loop are also large, again translating into large capital.

Therefore the chemicals strategy is to focus on improving the reaction conversion and selectivities, while also looking at ways to improve the efficiency of separation processes.

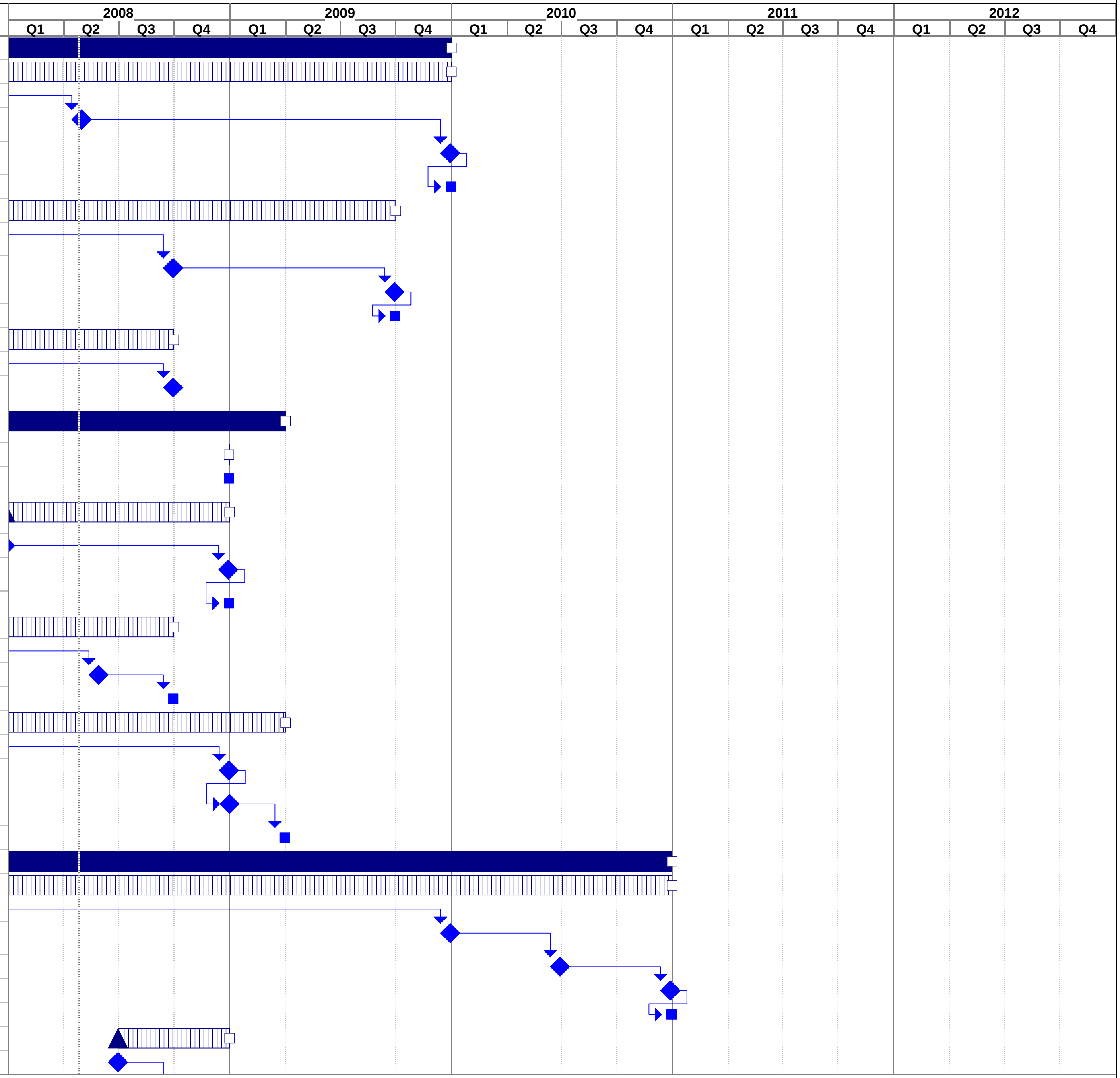
The following are strategies for each focus area in the Chemicals subprogram:

1. Strategy for Oxidation Reactions Focus Area: This focus area represents about 80% of industrial reactions; hence any breakthrough in this area will have huge impact on the majority of industrial reactions. Emphasis will be on the development of high conversion and selectivity oxidation catalysts, that operate at moderate temperatures and pressures; improvement of better catalyst design and characterization methods; and establishment of better procedures for the operation of laboratory, pilot and plant reactors.
2. Strategy for Micro Reactors Focus Area: Development of micro reactors enables the practice of process intensification. Process intensification is new buzzword for processes which minimize feedstock and energy usages, leading to higher product yield, smaller size equipment and inherently safer environment because quantity of materials is below explosive limits. A microchannel reactor is a new concept that has the potential to impact the entire industrial reactions if successful. Therefore research in this area should focus on micro-channel reactors and process intensification to obtain high reactor yield with less feedstock, and better heat transfer and material mixing characteristics.

3. Strategy for Alternative Processes Focus Area: Our bandwidth studies revealed some old chemical products' manufacturing technologies which are very energy intensive. The strategy here is to explore new process chemistry and chemical process synthesis to replace these archaic chemical product processes like ethylene and ammonia that are on top of the list for most 50 energy intensive processes.
4. Strategy for Distillation & Hybrids Focus Area: The Separations area focuses on hybrid distillation technologies like distillation-adsorption, distillation-membranes, distillation-crystallization, extractive distillation, azeotropic distillation, and reactive distillation. Distillation equipment accounts for over 90% of the separations equipment deployed in the chemical and petroleum industry and yet it is very energy intensive. Therefore any slight improvement of its efficiency should translate to significant energy savings. Recent thermodynamic analysis shows that theoretically 40% energy savings is possible with improvements in the current designs. Yet design improvements in existing equipment to date have yielded only marginal efficiency, hence hybridizing it with other separation technologies may give much better efficiencies and reduce the energy usage in distillations, since the feed into the columns must have already been pre-concentrated before entering the distillation columns. A second area to focus on is reactive separations. Taking one component out while the reaction is proceeding has been one way of driving equilibrium reactions to completion and is therefore an important area to focus on. Any major breakthrough in membranes for separation of hydrocarbons will have huge impact in the whole manufacturing industry because of prolific applications. Membranes could replace distillations if they are developed to be technically efficient and economically attractive. One major problem with inorganic membranes in separating hydrocarbons is lack of understanding of the phenomenon at the interface as well as the prohibitive cost of commercial membrane modules. The R&D effort in this area will focus on solving these two main problems first.

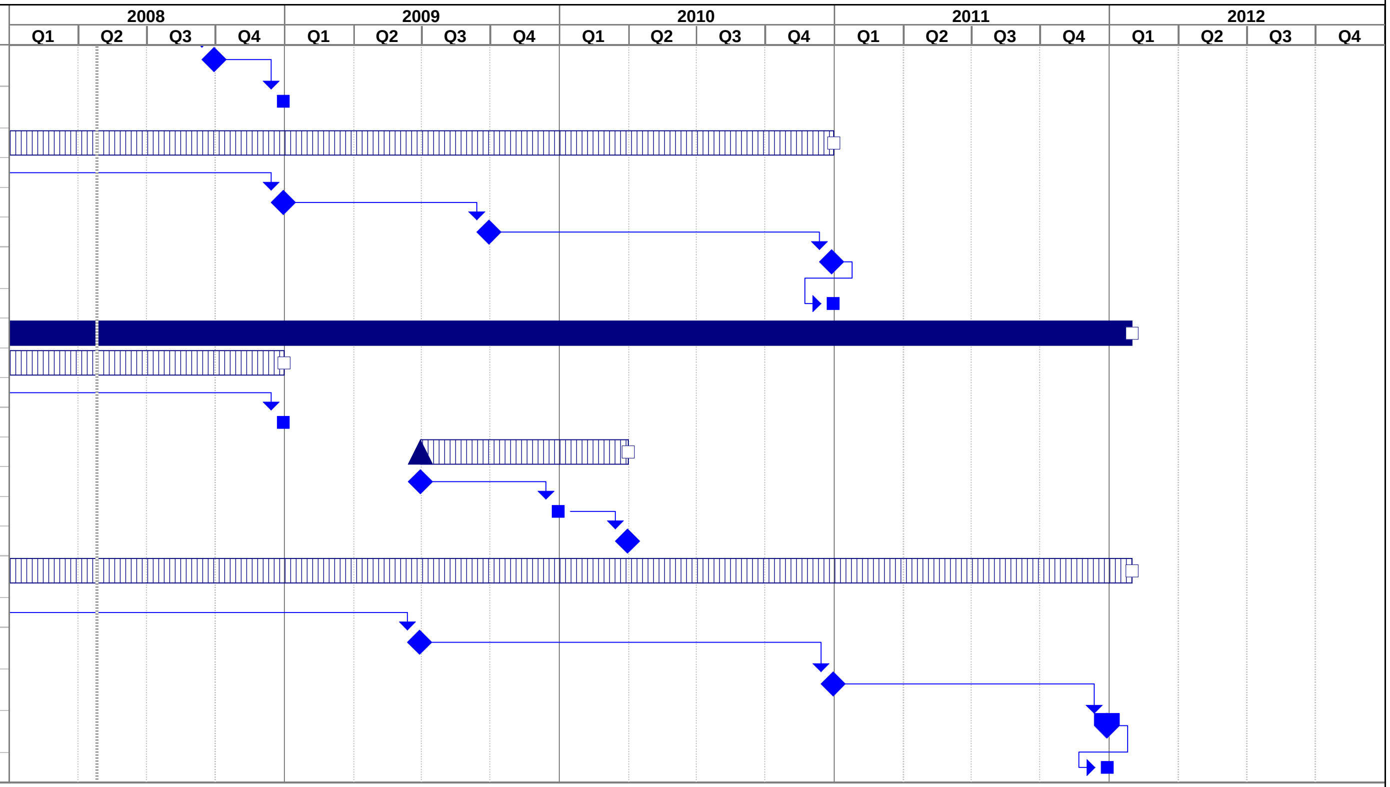
Chemicals

ID	Task Name
1	(1) Oxidation Reactions
2	Millisecond Oxidation
3	Catalyst Performance Targets Met
4	1st Target Met Over Current Technology
5	2nd Target Met Over Current Technology
6	Establish Minimum Catalyst Life
7	Highly Selective Oxidation Catalysts
8	Develop ALD Processes (Transition Metals)
9	Evaluate Catalysts
10	Catalysis Modeling
11	Complete Scale-Up Tests
12	Ionic Liquids
13	Develop Virtual Rapid Prototyping
14	Demonstrate Process for direct methane to methanol conversion
15	(2) Micro Reactors (Microchannel Technologies)
16	Microchannel Reactor for H2O2
17	Reactor System Optimization, Integration & Evaluation
18	Microchannel Reactor for Catalytic Hydrogenation
19	Lab Reactor Optimization
20	Reactor System Optimization, Integration & Evaluation
21	End of Task
22	Olefins by High-Intensity Oxidation
23	Optimize Reactor Design
24	Comparative Economics
25	Sensitivity Studies & Flowsheet
26	Multifunctional Reactor
27	Construct Pilot Scale Experiment
28	Implement Advanced diagnostics on pilot scale
29	Model & Validate Pilot scale Experiment
30	Commercial Transition
31	(3) Alternative Processes
32	Ammonia By PSA
33	Proof of concept completion
34	Setup and Demo Integrated Prototype
35	Complete Economic Evaluation
36	Scaleable Design to Industry
37	End of Task
38	Low Cost Chemical Feedstock
39	Construct Pilot Scale Unit



Chemicals

ID	Task Name
40	Perform Theoretical & Experimental Study
41	Develop & Complete Commercialization Package
42	Catalytic Membrane Reactors
43	Proof of Concept
44	Build Pilot Unit for Demo & Validation
45	Scale up membrane module system
46	Build Skid Mounted Unit for Commercialization
47	End of Task
48	(4) Distillation & Hybrids
49	Advanced Distillation
50	MPT Bench-Scale Design
51	Validate Scalable Distillation Design
52	Advanced Membranes
53	Fabricate Demo System
54	Test Demo System
55	Evaluate Energy Benefits
56	Optimal Configuration for Multiple Distillation Columns
57	Proof of Concept
58	Develop Algorithm for Optimum Distillation Configurations
59	Develop Algorithm for Optimum Thermally-coupled Distillation Column
60	Apply Algorithm to 3 high impact industrial processes
61	End of Task

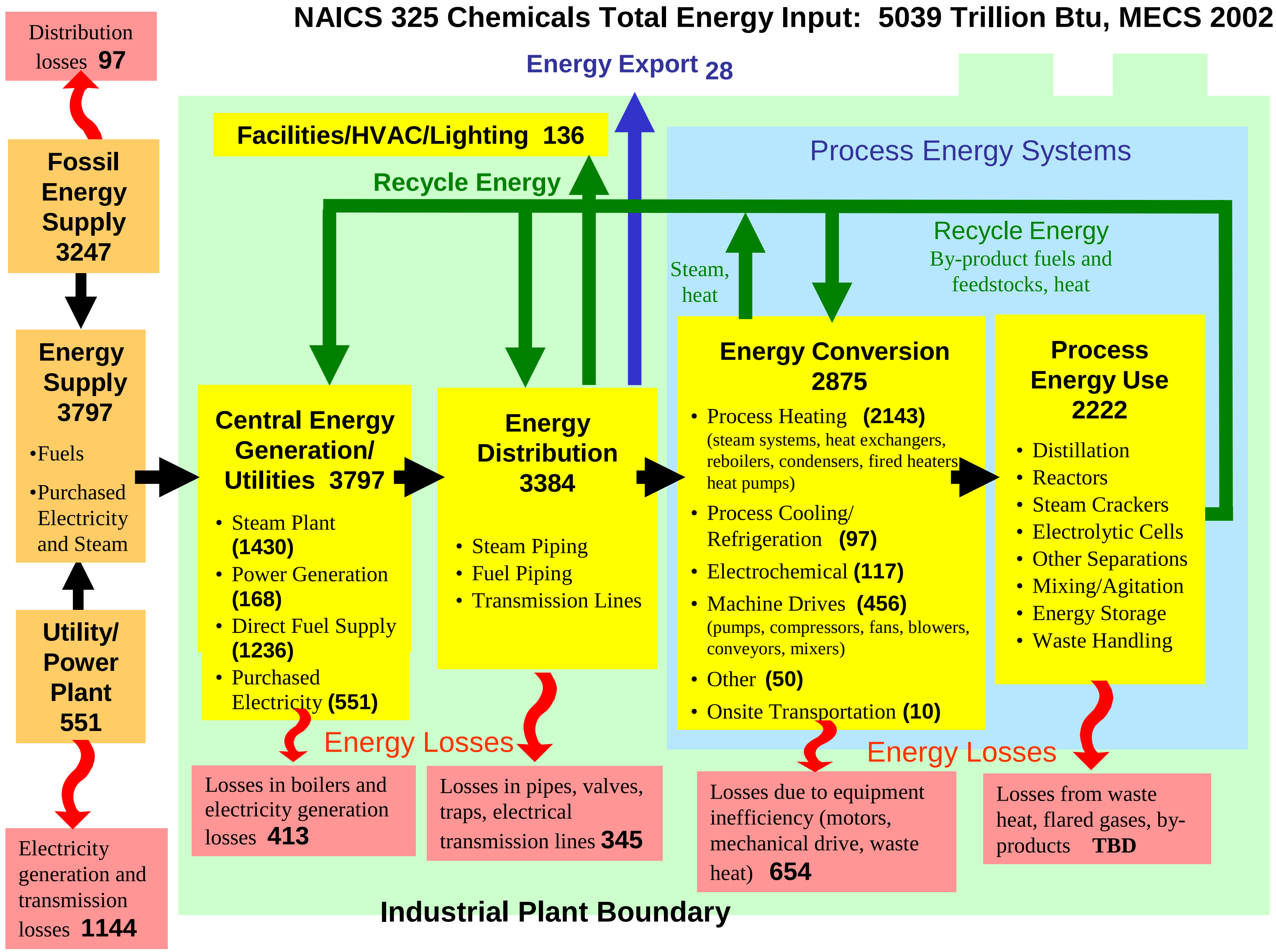


R&D Strategy Focus Area	Barriers	Pathways	Metrics
Oxidation Reactions <u>Objective</u> Develop technologies that will increase conversions > 60% and selectivities > 70% for oxidation reactions.	1. Catalysts operate at high temperatures (> 250 deg. C) and pressure (> 1 atm)	1. Develop catalysts that operate at moderate temperatures (<100 deg. C) and pressures (1 atm.), for homogeneous or heterogeneous catalyzed processes. Focus on selective oxidation, alkane activation, selective synthesis, and alkylation. Meet 1st catalyst performance target by Q2 of FY08. Meet 2nd catalyst performance target by Q4 of FY09. Establish minimum catalyst life by Q4 of Fy09. *[Millisecond Oxidation – Rohm & Haas]*	1. Demonstrate catalysts with 60% conversions and 70% selectivities operating at 1 atm pressure and temperatures < 100 C. *Total potential savings = 20 trillion Btu/year*
	2. Poor catalyst designs	2. Develop new catalyst design through combined experimental, mechanistic understanding, and improved computational modeling of catalytic processes. Complete catalyst modeling by Q3 of FY08. Complete catalyst evaluation by Q3 of FY09. Complete scale up and field tests by Q3 of FY09. *[Highly Selective Oxidation Catalysts – ANL]*	2. Demonstrate catalysts with conversions > 80% and selectivities > 90%. *Total potential savings = 25 trillion Btu/year*
	3. Lack of optimal reaction media	3. Develop and evaluate ionic liquids as alternative reaction media Completed virtual rapid prototyping in FY07. Demonstrate optimized solvent by Q3 of FY08. Complete demonstration of process for direct methane to methanol conversion also by Q3 of FY08. *[Ionic Liquids - California Institute of Technology] Combination of Ionic Liquids and Microchannel reactors to reduce energy consumption for both reactions and separation simultaneously will be addressed in FY08 solicitation]*	3. Demonstrate reaction in ionic liquids with conversion >60% and selectivity > 70%, and non-thermal separation method that will take advantage of the presence of ions (membranes, adsorption, and ion-exchange) *Total potential savings = 5 trillion Btu/year*

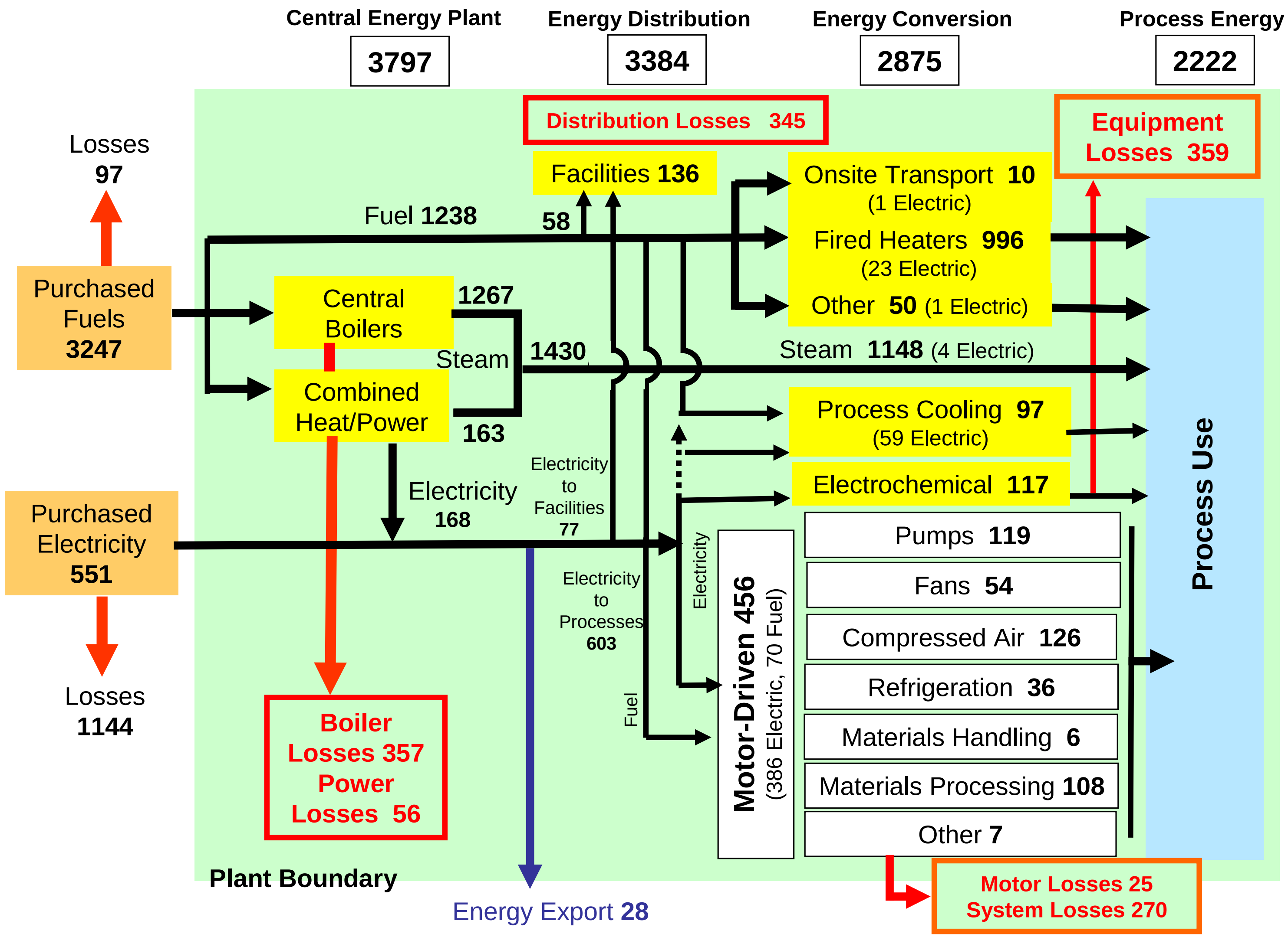
Micro-Reactors <u>Objective</u> Develop micro reactor technologies that will reduce reaction feedstock by 20%, increase reaction yield by 20% and increase reactor safety by eliminating potential for explosion.	1. Conventional reactors cannot handle mixing of reactants and uniform heat transfer very well and sometimes have "hot spots" due to poor mixing 2. Catalyst's inefficiency leads to high use of feedstock 3. High use of feedstock poses risk of explosion during oxidations and hydrogenations	1. Develop novel and/or non-standard reactors coupled with Process Intensification like micro-channel reactors where amount of reactants stay below explosive limits and reactor design ensures high yield with less feedstock and better heat transfer and material mixing.	
		a. Complete Reactor System Optimization, Integration and Evaluation by Q4 of FY08. *[Mircrchannel Reactor for H_2O_2 Production. – Stevens & FMC]*	a. Demonstrate microchannel reactor pilot unit producing 1-5 wt% H_2O_2 *Total potential savings = 24 trillion Btu/year*
		b. Completed laboratory reactor optimization by Q4 of FY07. Complete Reactor System Optimization, Integration and Evaluation by Q4 of FY08. *[Microchannel Reactor for Catalytic Hydrogenation – Stevens Inst.]*	b. Demonstrate a continuous microchannel hydrogenation reactor pilot unit with ~ 100% conversion and 90% reduction in energy. *Total potential savings = 64 trillion Btu/year*
		c. Completed Reactor Design Optimization by Q4 of FY07. Complete comparative economics by Q2 of FY08. Complete sensitivity studies and flowsheet development by Q3 of FY08. *[Olefins by high intensity Oxidation – Velocys]*	c. Demonstrate micro reactor technology with savings in feedstock about 20% than conventional. *Total potential savings = 22 trillion Btu/year*
		d. Completed pilot scale unit construction/experimentation in Q4 of FY07. Implement advanced diagnostics on pilot scale by Q4 of FY08. Complete modeling and validation of pilot scale experiment by Q4 of FY08. Complete commercial transition by Q1 of FY09. *[Multifunctional Reactor – SNL]*	d. Demonstrate a microchannel reactor that can be used for different reactions with little adaptation. *Total potential savings = 22 trillion Btu/year*

Alternative Processes <u>Objective</u> Develop new technologies with new chemistry and process synthesis to replace very old and high energy intensive processes.	1. Many old industrial processes plagued by reactions with high temperatures (> 300 deg. C) and pressure (> 2 atm.). 2. Current processes are equilibrium limiting	1. Develop entirely new processes using process synthesis techniques based on complete new chemistry and new routes for manufacture of these energy intensive commodity chemicals – ethylene, ammonia, etc. *a.* Proof of concept completed in Q4 of FY07. Complete set up and demonstrate integrated prototype by Q4 of FY09. Complete economic evaluation by Q2 of FY10. Complete Scalable design and industrial testing by Q4 of FY10. *[Ammonia production by PSA—Smart Koncept]* b. Pilot scale unit construction started in FY07 will be completed by Q2 of FY08. Performance of experimental study will be completed by Q3 of FY08. Development of completes commercialization packages will be completed by Q4 of FY08. *[Low Cost Chemical Feedstock (Ethylene) – ANL]* 2. Develop membrane reactors, reactive separation technologies to shift equilibrium to favorable directions. Proof of concept completed in Q4 of FY07. Complete building pilot unit for demonstration and validation by Q4 of FY08. Complete scaling up membrane module system by Q3 of FY09. Complete building a skid mounted unit for commercialization purposes in Q4 of FY10. *[Catalytic Membrane Reactors - Compact Membrane Systems]*	1. Demonstrate novel process with new chemistry and chemical synthesis route for one of the top 5 most energy intensive processes (Ethylene, Ammonia, Ethylene Oxide, Terephthalic Acid (TPA) and with a shut down economics such that pay back time <5 years and ROI up to 50%. *Total potential savings = 12 trillion Btu/year* 2. Demonstrate a membrane reactor technology where more than 90% of water produced in the reaction is removed simultaneously through the membrane walls, thus driving the reaction conversion to nearly 100% and selectivity to about 90%. *Total potential savings = 4 trillion Btu/year*

Distillation and Hybrids <u>Objective</u> Develop technologies to increase the efficiency of distillation columns by 40% (100 to 2,000 Btu/lb, depending on the product being separated) in order to impact the nearly 900 trillion Btu used in the U.S. each year for distillation.	1. Conventional distillation technology has many physical fundamentals that are not well understood, including transport phenomena such as fluid flow, poor heat and mass transfer characteristics, poor mixing associated with multi-phase flow processes occurring within trayed or packed distillation columns, et cetera. 2. Conventional Distillation columns consumes too much energy when not hybridized with other separation unit operations. 3. Currently, no method exists for determining the optimal arrangement of multiple distillation columns for multi-component distillation columns. Distillation – lack of physical fundamentals including accurate real stage efficiency calculation, mixing characterization, understanding of distillation phenomena, vapor liquid imaging techniques, ability to measure and understand multi-phase flow; and inability to see inside distillation columns, lack of effective sensors, modeling capabilities to predict and optimize equipment performance.	1. Develop and evaluate the efficiency alternative non-conventional distillation technology like the application of micro-channel technology to a horizontal distillation column and compare results with conventional distillation technology and decide on the next steps. MPT Bench Scale Design was completed in Q4 of 2007. Complete Validation of Scalable Distillation Design by Q4 of FY08. *[Advanced Distillation – Velocys]* 2. Develop other separation technologies (membranes, adsorption, etc) that can be used as hybrids with conventional technologies that will improve column efficiencies upwards to 40%. Complete the fabrication of membrane demonstration system by Q2 of FY09. Complete testing the demo system by Q4 of FY09. Complete the evaluation of energy benefits by Q1 of FY10. *[Advanced Membranes – Air Products]* 3. Develop an algorithm that will lead to software for designing the optimal columns configuration for multi column, multi component distillation columns. Completed proof of concept in Q4 of FY07. Complete development of algorithm for optimum distillation columns configurations by Q2 of FY09. Complete development of algorithm for thermally coupled optimum distillation columns configurations by Q4 of FY10. Complete applying algorithm to 3 high impact industrial processes by Q4 of FY11. *[Optimal Configuration for Multi Component Multi Distillation Columns – Purdue University]*	1. Demonstrate a micro-channel, horizontal distillation technology and obtain engineering data from the scaled up unit for analysis to determine if this configuration has any advantages over conventional distillation columns. *Total potential savings = 14 trillion Btu/year* 2. Demonstrate a good membrane system that will serve as a pre-concentrator to a distillation column such that the efficiency of the distillation column is close to 40%. *Total potential savings = 19 trillion Btu/year* 3. Demonstrate an algorithm and computer software for evaluating different arrangements for multiple distillation columns for separating multiple components such that the optimal arrangement will give overall efficiency of the system close to 40%. *Total potential savings = 14 trillion Btu/year*


NAICS 325 Chemicals Total Energy Input: 5039 Trillion Btu, MECS 2002
Distribution losses 97
Fossil Energy Supply 3247
Energy Supply 3797
•Fuels
•Purchased Electricity and Steam
Utility/ Power Plant 551
Electricity generation and transmission losses 1144
Energy Export 28
Facilities/HVAC/Lighting 136
Recycle Energy
Process Energy Systems
Recycle Energy
By-product fuels and feedstocks, heat
Steam, heat
Central Energy Generation/ Utilities 3797
• Steam Plant (1430)
• Power Generation (168)
• Direct Fuel Supply (1236)
• Purchased Electricity (551)
Energy Distribution 3384
• Steam Piping
• Fuel Piping
• Transmission Lines
Energy Conversion 2875
• Process Heating (2143)
(steam systems, heat exchangers, reboilers, condensers, fired heaters, heat pumps)
• Process Cooling/ Refrigeration (97)
• Electrochemical (117)
• Machine Drives (456)
(pumps, compressors, fans, blowers, conveyors, mixers)
• Other (50)
• Onsite Transportation (10)
Process Energy Use 2222
• Distillation
• Reactors
• Steam Crackers
• Electrolytic Cells
• Other Separations
• Mixing/Agitation
• Energy Storage
• Waste Handling
Energy Losses
Energy Losses
Losses in boilers and electricity generation losses 413
Losses in pipes, valves, traps, electrical transmission lines 345
Losses due to equipment inefficiency (motors, mechanical drive, waste heat) 654
Losses from waste heat, flared gases, by-products TBD
Industrial Plant Boundary

NAICS 325 Chemicals Total Energy Input: 5039 Trillion Btu, MECS 2002



Chemical Industry Vision 2020 Roadmaps

Catalysis

- Catalysis Applications: Lower energy requirements via higher selectivity, more moderate temperature or pressure, and reduced number of unit operations for the homogeneous or heterogeneous catalyzed processes: selective oxidation, alkane activation, by product and waste minimization, selective synthesis, alkylation, olefin polymerization, alternative and renewable feedstocks
- Enabling Science: New catalyst design through combined experimental, mechanistic understanding, and improved computational modeling of catalytic processes. Development of techniques for high throughput synthesis of catalysts and clever new assays for rapid testing of small quantities of catalysts on diverse processes, and reduction of analytical cycle time by parallel operation and automation. Better techniques for catalyst characterization under actual operating conditions, particularly at high temperature and pressure (>1 atm). New methods to synthesize stable, high productivity catalysts with control of active-site architecture.
- Reactor System Design and Scale-up: Establish better procedures for characterizing the operation of lab, pilot and plant reactors and cross correlating their behavior. Develop more efficient methods to obtain physical, chemical, and transport property data for input into and verification of models.
- Novel Reactors and Process Intensification: Development of nonstandard reactors is dependent on advances in fundamental research and enabling technologies. Research areas include intensified reactors, rapid heating and cooling techniques, structured contacting, external field-assisted and photochemical reactions, and reactors for extreme conditions. Enabling technologies include new materials development, systems integration, micro-scale properties and phenomena determination, multistage design capabilities, and self-assembling reactor development
- Computations Develop powerful computational models that can accurately simulate the product yields and process dynamics in real life systems.
- Cross-cutting technologies: See below (*).

Separations

- Adsorbents: New materials with improved selectivity and stability and more favorable geometries, tools to predict adsorbent performance and aid in process design, and demonstration of commercial feasibility.
- Crystallization: Physical property data and molecular modeling capability for solid/liquid equilibrium and crystal growth mechanisms, and instruments to measure degree of super-saturation.
- Distillation: Improved understanding of physical phenomena, better in situ sampling, analytical and flow-visualization methods, and better predictive modeling tools.
- Extraction: New solvents, a better understanding of the fundamental physical processes, and an enhanced physical property database.
- Membranes: Economic evaluations to direct research efforts, membrane system development to enhance operability and robustness, new membrane materials, increasing surface area at lower cost, and predictive models.
- Separative Reactors: New materials, economic evaluations to prioritize applications for separative reactors, and improved design capabilities.
- Ion Exchange: New materials with greater selectivity, improved regeneration methods, lower cost materials, innovative ion exchange equipment, and hybrid systems.
- Bioseparations: Development of robust biocatalysts; development of better separations technologies with emphasis on membranes, extractants, adsorbents, and hybrid systems; obtaining physical properties data; extending predictive models; pursuing in vitro synthesis; and development of closed-loop fermentation processes.

• Materials: Develop improved cost-effective materials that have improved physical properties as well have improved thermal and chemical stabilities in harsh and corrosive environments. 1. Sensors and Controls: Develop systems that integrate sensor data to allow for the optimization of systems on a real-time basis. • Dilute Solutions: Improved understanding of physical phenomena and intermolecular chemistry, enhanced physical properties databases, better predictive modeling tools, and improved separations technologies including hybrid systems. • Cross-cutting technologies: See below (*).
Alternative Feedstocks TBD
*Cross-cutting technologies: Major research needs that cut across several or all of the technical areas fall into four technical categories: experimental tools, modeling and property estimation, sensors, and system integration. Improved experimental tools are needed to design and operate reaction engineering systems more efficiently and to provide input data for models. These include better designs for laboratory-scale reactors and better experimental techniques for screening of synthesis methods and for developing a fundamental understanding of plant system operations. Fundamentals-based models are needed to support design and operation of reaction engineering systems. Thermophysical, thermo-chemical, and transport data that describe complex systems are needed for input into and validation of these models. Fast, precise, robust, online sensors are needed for data collection, monitoring, and process control. Integration of all these research capabilities into a systems approach is required to develop viable production reactors for industry. There is a need for better integration of models and experimental data gathering as well as models which couple process chemistry with process modeling. Ultimately, design and optimization tools are needed which will link process conditions to product properties at the micro-, meso-, and macro-scales. and new products to market, Develop capability to determine application enabling properties (modeling, synthesis, characterization & functional testing)

Chemicals Bandwidth Analysis

The Chemicals subprogram has completed the analysis of 50 top commodity chemicals that have the largest production, and the report has been published on the Chemicals website.

2.1.3 Forest Products

Background

The forest products industry is based on wood as a renewable and sustainable raw material. The industry produces thousands of products from renewable raw materials that are essential for everyday needs in communication, education, packaging, construction, shelter, sanitation, and protection. The U.S. forest products industry is made up of two major categories: Paper Manufacturing (NAICS 322) and Wood Product Manufacturing (NAICS 321). These industries are grouped together because they both rely on the nation's vast forest resources for raw materials and many companies that produce paper also produce lumber and wood products in integrated operations. The United States is the world's leading producer, consumer and exporter of pulp, paper and paperboard products. In 2003, it produced 90 million tons of paper and paperboard (25% of world production), which is equivalent to over 700 pounds for every man, woman, and child in the United States. The U.S. is also the leading producer of lumber and wood products used in residential construction and in commercial wood products such as furniture and containers. With total shipments valued at about $283 billion a year, the industry directly employs nearly one million people in over 44,000 facilities. The industry is especially important in many rural economies where the local paper or lumber mill can be the area's largest employer.

The forest products industry consumes about 12% of domestic manufacturing energy use (Pulp and Paper 2.36 quads, Wood Products 0.38 quad (MECS 2002)), and ranks behind only chemicals and petroleum in its energy consumption. Although the industry self-generates more than half of its energy need by burning wood residuals and spent pulping liquor (black liquor) to generate steam and power, is still the third largest user of fossil energy in the U.S. manufacturing sector. The forest products industry also generates more than 2 billion tons of waste each year – mostly in the form of non-hazardous waste water and sludge. The industry practices recovery and recycling in its operations and its forests help the global carbon balance by sequestering carbon dioxide from the atmosphere. The industry also contributes to land management and natural resource conservation.

ITP's pulp and paper energy bandwidth analysis reveals opportunities for savings (compared to today's best available technologies) of 57% for paper drying and 27% for liquor evaporation during chemical pulping.

The U.S. Department of Energy's Industrial Technologies Program (ITP) formed a partnership with the U.S. forest products industry to support collaborative, innovative R&D on forest products technologies, promote deployment of promising technologies, and encourage the implementation of best practices and state-of-the-art technologies that will help the forest products industry cut energy use, minimize environmental impacts and improve productivity.

Strategy

The program is focusing most of its R&D effort on reducing natural gas consumption because of industry's reliance on this increasingly scarce and expensive fuel. The Forest Products subprogram supports ITP's and EERE's goals by targeting the development of technologies which will reduce steam demand in a state-of-the-art pulp and paper mill by 15% by 2015. In non-integrated paper mills, steam is typically produced in natural gas-fired boilers; so reducing steam demand reduces natural gas use. In integrated mills, steam is primarily produced in black liquor fired Tomlinson boilers while the remainder is generated in biomass or natural gas-fired power boilers. Thus, reducing steam demand in integrated mills saves natural gas and reduces black liquor requirements.

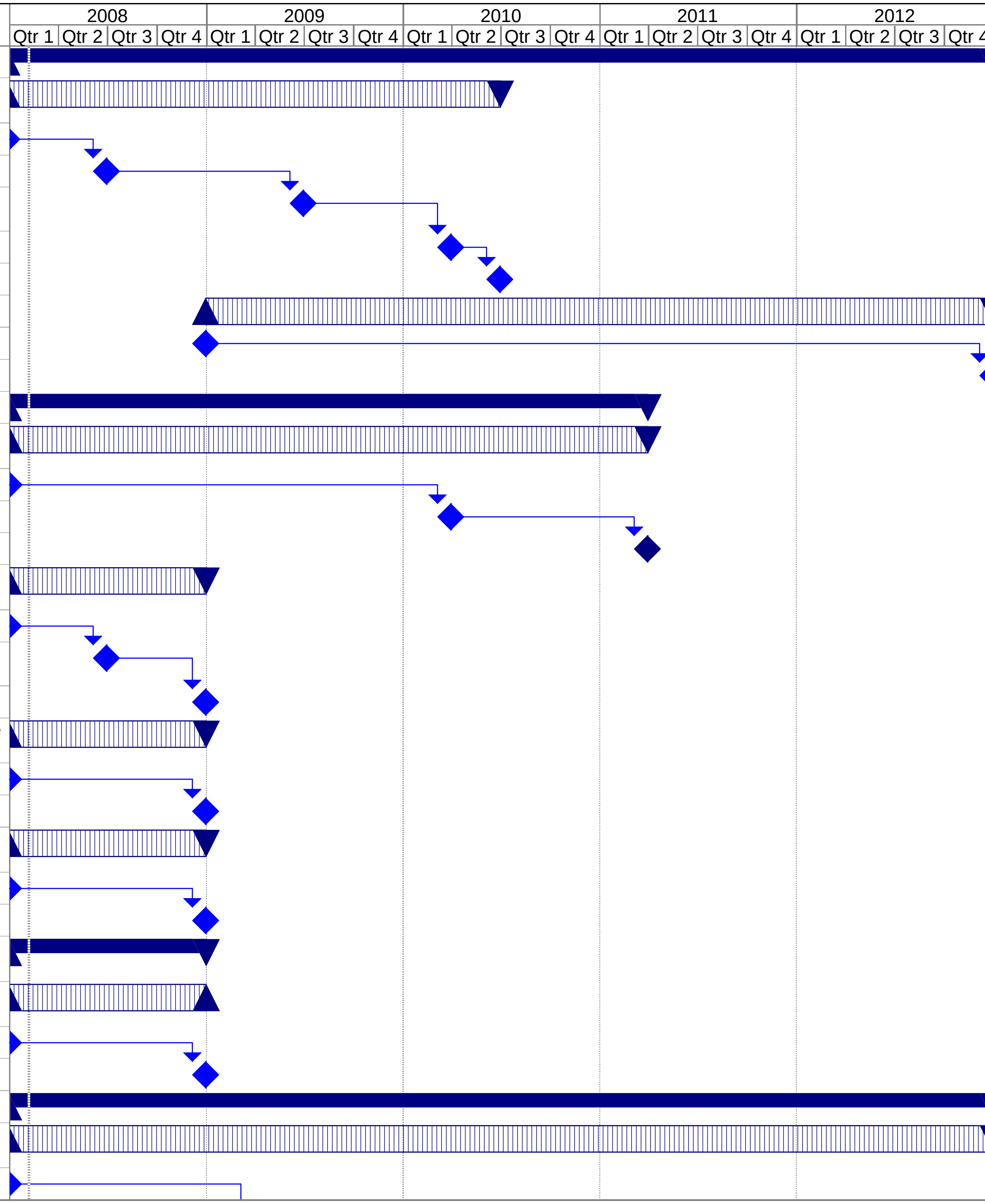
Last updated: 5/5/2008

Developing black liquor gasification and biorefinery technologies are both EERE and industry priorities which become more economically attractive when less black liquor is required for steam generation. Reducing steam demand helps enable black liquor gasification because gasifiers typically produce 65% more electricity but 15% less steam than Tomlinson boilers. As a result, a mill that uses black liquor gasification must satisfy its steam requirements by reducing steam demand or by increasing its inputs of wood or other energy sources. Likewise, reducing steam demand makes the biorefinery concept more economically attractive because black liquor components (e.g. hemicelluloses), which are no longer needed to produce the steam, can be used as a feedstock for the biorefinery for no or low incremental cost. Thus, while ITP doesn't pursue direct R&D in the areas of gasification and the biorefinery, R&D investment in technologies to reduce steam demand will help enable these technologies.

ITP is currently funding projects that target significant technical barriers in the following four focus areas, but will concentrate most of its future effort in Advanced Water Removal and High Efficiency Pulping:

- Advanced Water Removal: This focus area aims to develop non-evaporative water removal technologies that will reduce the steam load for pulp and paper mills. Water removal through evaporation in the Forest Products Industry occurs in extremely energy intensive processes that consume over 600 trillion Btu/year of steam energy. Non-evaporative water removal technologies have the potential for being much less energy intensive.
- High Efficiency Pulping: This focus area targets the development of technologies that will reduce the energy intensity of chemical pulping. The Kraft chemical process is currently the dominant pulping process and uses approximately 725 trillion Btu/year (pulping and chemical recovery). This process uses heat and alkaline chemicals to remove the lignin that binds the cellulose fibers in wood. Wood chips are cooked in a digester and then the spent chemicals and lignin are washed from the pulp. This wash water or weak black liquor is then processed to generate steam and electricity and recover the pulping chemicals for reuse.
- Innovative Wood Drying and Curing: This focus area seeks to develop drying, curing, and VOC mitigation technologies that will reduce the energy intensity of the wood products sector. Energy is the highest wood processing cost and wood drying accounts for 50-80% of the wood products total manufacturing energy costs.
- Improved Fiber Recycling: This focus area targets the development of technologies that will increase the amount of fiber that can be recovered from waste paper. Recovered paper provides approximately 27% by weight of the fiber used for U.S. paper and paperboard production. Rising wood prices and land fill costs demand efficient processes for waste paper recycling.

ID	Task Name
1	**Advanced Water Removal**
2	**11425 Steam Cycle Washer for Unbleached pulp (GO14304)**
3	Ongoing Project
4	Demonstrate Fabrication
5	Initiative Field Tests for commercial -scale steam cycle
6	Complete Field Tests
7	Commercial Introduction
8	**FY08 Solicitation - Non-Evaporative Technology**
9	Initiate Awards
10	Complete Awards
11	**High Efficiency Pulping**
12	**11550 Highly Energy Efficient Directed Green Liquor Utilization (D-GLU) Pulping (GO14308)**
13	Initiate D-GLU Mill Trials
14	Complete D-GLU Mill Trials
15	Commercial Introduction
16	**11440 - Integrated Forest Products Refinery - Extraction and Redeposition of Hemicellulose (GO14306)**
17	Ongoing Project
18	Demonstrate Feasibility of Hemi Extraction Technology
19	Demonstrate Feasibility of Mill Integration
20	**15720 - Integration of the Mini-Sulfide Sulfite Anthracquinone (MSS-AQ) Pulping Process and Black Liquor Gasification**
21	Project is Ongoing
22	Initiate Prototype Development
23	**17521 Direct Causticization for Black Liquor Gasification in a Circulating Fluidized Bed (GO16042)**
24	Project is Ongoing
25	Initiative Prototype Development
26	**Innovative Wood Drying and Curing (VOC & HAP Emissions)**
27	**11552 - Biological Air Emissions Control for an Energy Efficient Forest Products Industry (GO14310)**
28	Ongoing Pilot Scale Tests
29	Optimization of Pilot Scale Biotrickling Filter
30	**Improved Fiber Recycling**
31	**11551 - Development of Screenable Wax Coatings and Water-Based Pressure Sensitive Adhesives (GO14309)**
32	Ongoing Project - PSA's being developed



ID	Task Name	2008	2009	2010	2011	2012
		Qtr 1 Qtr 2 Qtr 3 Qtr 4	Qtr 1 Qtr 2 Qtr 3 Qtr 4	Qtr 1 Qtr 2 Qtr 3 Qtr 4	Qtr 1 Qtr 2 Qtr 3 Qtr 4	Qtr 1 Qtr 2 Qtr 3 Qtr 4
33	Development of new Benign Commercial PSA Labels					
34	Continue with Development of Commercial Products (Post Project Period)					

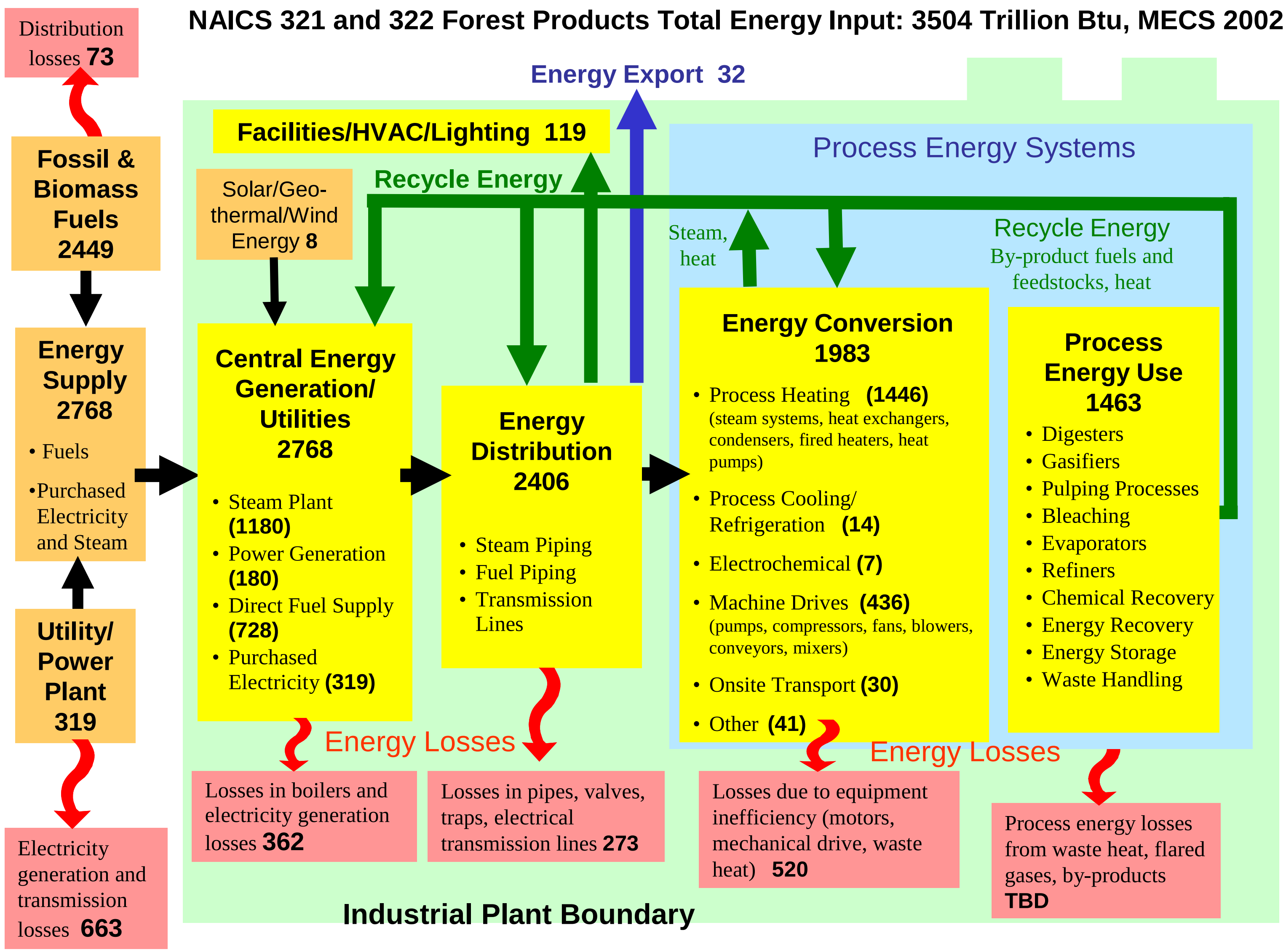
		In FY08, the bleachability of pulp containing redeposited hemicellulose will be demonstrated in the 2nd quarter of FY08. In the 4th quarter of FY08, the feasibility of integrating the process of extraction and redeposition of hemicellulose into mill operation will be demonstrated and the results will transferred to industry and the technology will be considered for mill implementation. Final report is pending. *[Project Title: Integrated Forest Products Refinery (IFPR) --University of Maine & International Paper]* 2. Develop an alternative pulping process that reduces the energy intensity of chemical pulping by 20% and will replace the kraft pulping process. In FY08, the Mini-Sulfide Sulfite Anthraquinone (MSS-AQ) alternative pulping concept definition study will be completed. Final report is pending. Initiate prototype development in FY09 if concept definition study shows the technology to be technically/economically feasible. [*Project Title: Integration of the MSS-AQ Pulping Process and Black Liquor Gasification* - NCSU] 3. Develop an autocaustizing technology that is compatible with gasification. In FY08, the concept definition study to assess the feasibility of using titinates in a gasifier for autocausticization will be completed. Final report is pending. Initiate prototype development in FY09 if concept definition study shows the technology to be technically/economically feasible. *[Project Title: Direct Causticization for Black Liquor Gasification - GA Tech Research Corporation]*	2. Demonstrate a reduction of energy intensity of chemical pulping by 20% in an alternative to the kraft pulping process. *Total potential savings = 5 trillion Btu/year* 3. Demonstrate 75-95% conversion of fixed carbon in a black liquor-titanate mixture during gasification. *Total potential savings = 6 trillion Btu/year*

Innovative Wood Drying and Curing <u>Objective</u> Develop technologies that will reduce the energy intensity of the wood products sector by 20% (saving 0.7 million Btu/ton of product).	1. Energy intensive Regenerative Thermal Oxidizers (RTOs) are currently used to control VOC and HAP emissions from industrial pulp, paper, and wood products processes. 2. Current technologies used to dry and cure lumber and wood composites are energy intensive. Current adhesives require temperatures in excess of 150 degrees F to cure.	1. Develop an alternative, energy-efficient wood drying technology to reduce VOC and HAP emissions. In FY07, the field trials to implement strategies for drying and pressing wood without emission controls was completed and the results were disseminated to the project partners. In FY08, complete the field testing for the process improvements and biological control system. If the technology proves successful, it will be transferred to industry. *[Project Title: Biological Air Emissions Control for an Energy Efficient Forest Products Industry of the Future - Texas A&M University-Kingsville, Bio•Reaction Industries, LLC, Stimson Lumber Company]*	1. Demonstrate an emissions technology or strategy that reduces the energy intensity of emissions control by 20% in a mill. *Total potential savings = 8 trillion Btu/year*
Improved Fiber Recycling <u>Objective</u> Increase the amount of fiber that can be utilized or recovered from waste paper by 10%.	1. Gross contamination and mix of fiber types hinders fiber recycling (e.g. mixing of unbleachables with other fibers) 2. The strength of fibers is degraded during conventional recycling processes which limits the paper grades that can be used (or necessitates the use of larger percentages of virgin fiber) and reduces the number of times paper can be recycled. 3. Pressure sensitive adhesives (PSAs) and wax coatings are the most problematic contaminants faced by paper recyclers. Current PSAs and wax coatings cannot be separated efficiently and their presence causes numerous recycling problems.	1. Reformulate the chemical compositions of water-based PSAs and wax coatings to allow for these contaminants to be easily screened during the recycling process. In FY07, new PSA formulations were developed and tested for screenability. For the wax coatings the correct mesophase behavior required to ensure removal of the wax coatings were identified will be investigated to determine how to optimize the wax coating. In FY08, the most promising candidates will be further developed with the help of end users to insure that they will be economically viable. If the reformulated wax coatings are easily screenable and economically viable, the technology will be transferred to industry. *[Project Title: Development of Screenable Wax Coatings and Water-Based Pressure Sensitive Adhesives – Univ. of Minnesota, Boise Cascade Corporation, Franklin International, The International Group, Inc]*	1. Demonstrate a 10% increase in the economic recovery of recycled fiber at a recycled fiber mill.

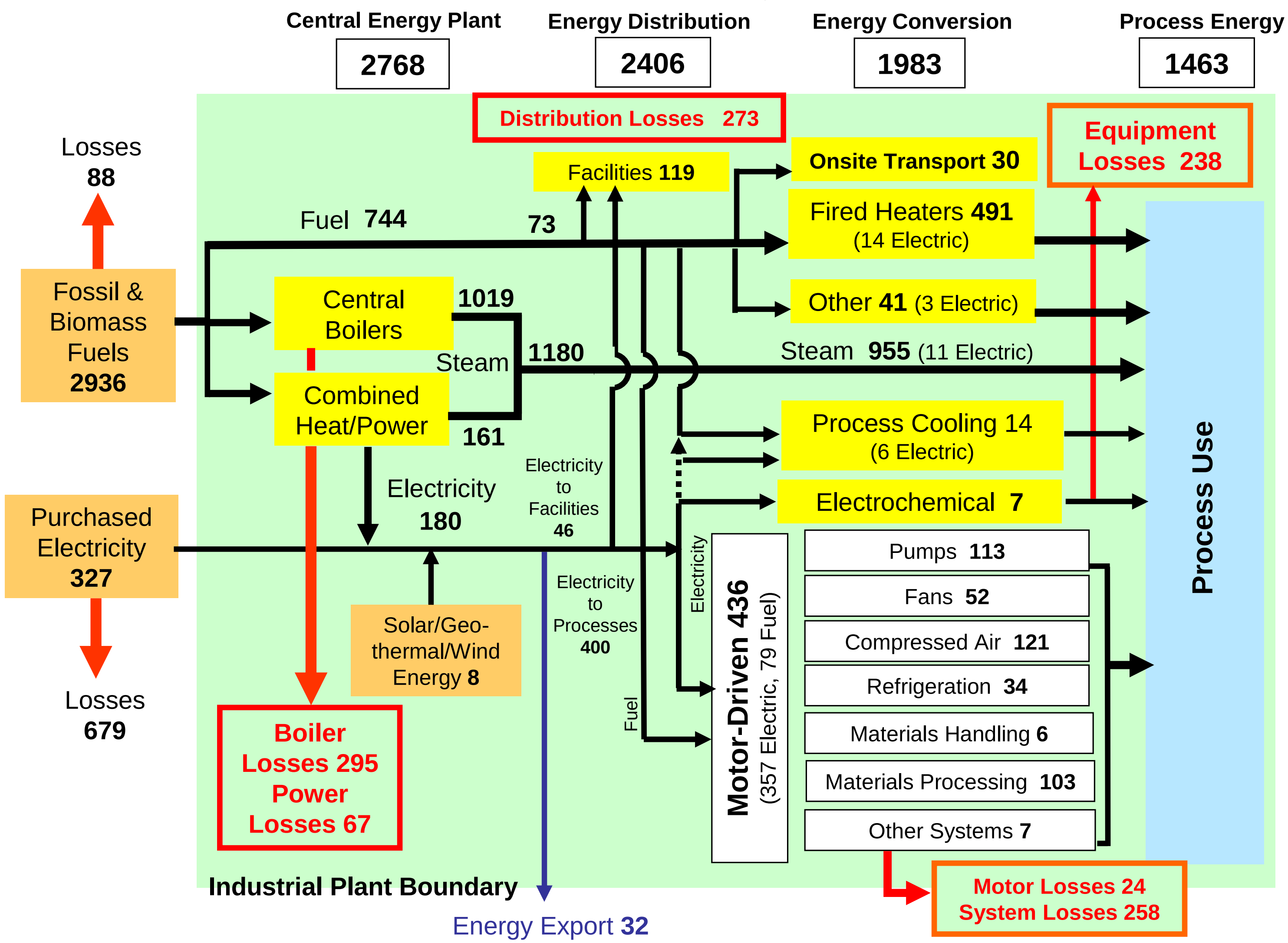
<u>SOURCES:</u>

Agenda 2020 The Path Forward: An Implementation Plan: http://www.eere.energy.gov/forest/pdfs/forest_roadmap.pdf
Setting the Industry Technology Agenda. The 2001 Forest, Wood & Paper Industry Technology Summit, TAPPI Press.
Energy and Environmental Profile of the U.S. Pulp and Paper Industry

NAICS 321 and 322 Forest Products Total Energy Input: 3504 Trillion Btu, MECS 2002



NAICS 321 and 322 Forest Products Total Energy Input: 3504 Trillion Btu, MECS 2002



Forest Products Industry Roadmap Summary
<u>Advancing the Forest "Biorefinery" – Extracting Value Prior to Pulping</u> • Demonstrate biomass and black liquor gasification with syngas clean-up and processing to fuels/chemicals • Demonstrate biomass and black liquor gasification with syngas cleanup and conversion to electricity • Demonstrate pyrolysis/liquefaction technologies that can be utilized to replace fossil fuels in manufacturing plants (e.g., lime kiln fuel) while also producing value-added products or product intermediate streams (e.g., activated carbon or resins for oriented strand board manufacture • Develop a hemicellulose/sugar extraction process that will produce extract of sufficient concentration and composition to produce (through fermentation processes) profitable fuels and/or chemicals (e.g., ethanol & acetic acid) • Develop a hemicellulose/sugar extraction process that will allow increased digester and/or recovery boiler throughput
<u>Breakthrough Manufacturing Technologies</u> • Develop and use a better understanding of sheet dewatering to cost-effectively increase solids before drying to the theoretical limit without compromising sheet structure – Alternatives to press dewatering – Avoid sheet reuptake of water (e.g., one-way press) – Extend current pressing limits – Alternatives to vacuum technology • Develop next generation technologies that improve energy transfer to the sheet for drying – Improve mass transfer – Increase cross-directional moisture uniformity • Develop novel variations on the sulfur chemistry of the traditional Kraft process, especially as facilitated by black liquor gasification – Polysulfide pulping – Splitting of sodium and sulfur – Tradeoffs between time, temperature, capital cost, and concentration during cooking – Explore impacts on fiber dewatering and quality of paper products from higher yield processes – Explore potential for black liquor gasification and sulfite pulping to enable replacement of current causticizing process • Develop alternative to refining as a way to generate bond strength that is more energy efficient and cost effective, without compromising drainage or formation – Effects of reintroducing extractable wood constituents and redeposition on pulp (e.g., hemicellulose) – Modification of fibers or fiber surfaces with additives, enzymes, or biological or chemical treatments – Alternative materials to cellulose fibers – Modification of fibers to enable higher filler levels – Increase the modulus of elasticity • Develop novel materials and material additives that deliver strength and optical properties at lower cost than fiber (better filler/improved pigments) – Innovative, low-cost materials and/or processes to improve filler-fiber bonding – Innovative, low-cost materials and/or processes to improve pigment coating bonding – Bio-based pigments and coatings • Develop full auto-causticizing technology – Better understanding of autocausticizing reagent properties

- Concept definition studies
  - More concentrated alkali (white liquor) stream
  - Pilot-plant demonstrations
- Evaluate a process approach that would integrate multi-technology selective separation processes
  - Electromechanical separations
  - Mechanical or membrane separations for partial dewatering
  - Liquid-liquid separations
  - Thermal separations
  - Lignin separation earlier in the process
- Develop energy-efficient mechanical defiberization processes, including radical alternatives (e.g., microwave, ultrasonic)
  - Polysulfide pulping
- Develop application of non-sulfur chemistries, such as enzyme pretreatment, soda-AQ, chemical (e.g.,solvents), biological, and borate
- Develop simplified, energy-efficient bleaching process (e.g., in chemicals used)

<u>Advancing the Wood Products Revolution</u>

- Develop more energy-efficient technologies for wood-based product manufacturing
  - Moisture-activated or non-heat activated adhesives
  - Reduce drying time for woodbased materials
- Reduce manufacturing VOC and HAP emissions of wood-based products
  - Methods to trap and burn VOCs
  - Reduce press emissions

<u>Next Generation Fiber Recycling & Utilization</u>

- Trial full-scale demonstrations of existing and prospective sorting equipment to evaluate performance, cost, rapidity of implementation, and overall efficiency. Establish performance and cost efficiencies. Consider basic engineering to understand how to effectively combine and fit new equipment into existing systems and structures
- Further develop and trial handling methods/systems for recovered paper (may include shredded paper) so that both volume and rate of speed during sorting are increased to significantly lower costs and maximize throughput
- Develop novel approaches to repulp and clean fibers from recovered paper that will lower energy use, reduce water consumption, allow the use of “dirtier” paper (lower cost), and limit the number of “operations” required
- Develop and trial technologies to remove other recyclables and gross contaminants (e.g., plastic, glass, metal, organic materials, etc.) from recovered paper through mechanical and/or sensor methods
- Discover fundamental mechanisms that cause separation of fiber types and contaminants. Use this knowledge to develop breakthrough technologies that improve product quality, productivity, and paper manufacturing runability

<u>Positively Impacting the Environment</u>

- Develop sulfur-free pulping technologies that can be economically integrated into the mill
- In-process capture, extraction, and fixation of VOCs, HAPs, and PM from wood products facilities

2.1.4 Metal Casting

Background

The U.S. metal casting industry is crucial to the U.S. economy and national security because it produces critical components that keep the automotive, defense, and energy sectors competitive in world markets. For instance, metal casters enable the automotive sector to produce lightweight, high strength components while meeting the need for safety and fuel efficiency. Lightweight, complex-shaped metal castings also play a critical role in military applications such as F22 fighter jets and the Seawolf nuclear submarines. Metal castings also represent critical components in power generation, oil and gas, and mining equipment. The majority of metal casters are small businesses (94% employ less than 250 people, 80% less than 100), often lacking the resources to perform research without collaborative efforts such as that facilitated through ITP. This industry is located in every state in the United States, with 2,190 foundries employing an estimated 220,000 people.

The metal casting industry consumes an estimated 257 trillion Btu annually. This includes 165 trillion Btu consumed by metal casters classified under NAICS 3315 plus an estimated 92 trillion Btu consumed in captive foundries. This is over a 21 percent decrease in the industry's energy consumption in 1998, when it was estimated that the industry consumed 328 trillion Btu. This decline is attributed to a 26.6 percent reduction in tonnage shipped when comparing 1998 to 2002 because a numer of metal casters went out of business.

The metal casting industry utilizes a variety of fuels and electricity to meet its energy needs. In 2002, forty-seven percent of the industry's energy consumption is supplied by natural gas and 33% from electricity. The remainder includes other fuel sources such as coke and breeze (coke is a solid carbonaceous residue derived from low-ash, low-sulfur bituminous coal used as a fuel and reducing agent in smelting iron ore; breeze is the fine screening from crushed coke most often used as a fuel source in the process of agglomerating iron ore.) In 2002, the industry spent $1.3 billion on purchased fuels and electricity. Major energy-consuming processes in metal casting include: melting, coremaking, moldmaking, heat treatment, and post-cast activities. The most energy- intensive of these processes is melting, which accounts for an estimated 55% of process energy costs (but varies by casting process). *ITP's analysis indicates that the energy intensity of melting processes (induction, cupola, and reverb) used in the casting industry could be reduced 20-50% through technological advances*. Major melt energy savings can occur by improving the efficiency of the melting process and by improving the efficiency of the overall process from design to post cast.

The Industrial Technologies Program Metal Casting activity has shown strong progress in making energy efficiency improvements in major areas of the casting process. For example, through improved design tools, advances in the understanding of material properties, and revolutionary process improvements, metal casters are increasing yield and reducing rejection rates thereby reducing the amount of metal that must be melted per ton of casting produced. The program has accelerated the adoption of the lost foam casting process; it is enabling metal casters to adopt new 'risering' and 'gating' practices to increase yield; and it is working with the industry and other EERE programs to deliver energy audits, BestPractices and other methods for saving energy in the near term. These activities contribute directly to DOE priorities to revolutionize the Nation's approach to energy efficiency.

The Metal Casting IOF will further strengthen its focuses on two parallel and closely related pathways: Advanced Melting, and Innovative Casting Processes.

Strategy

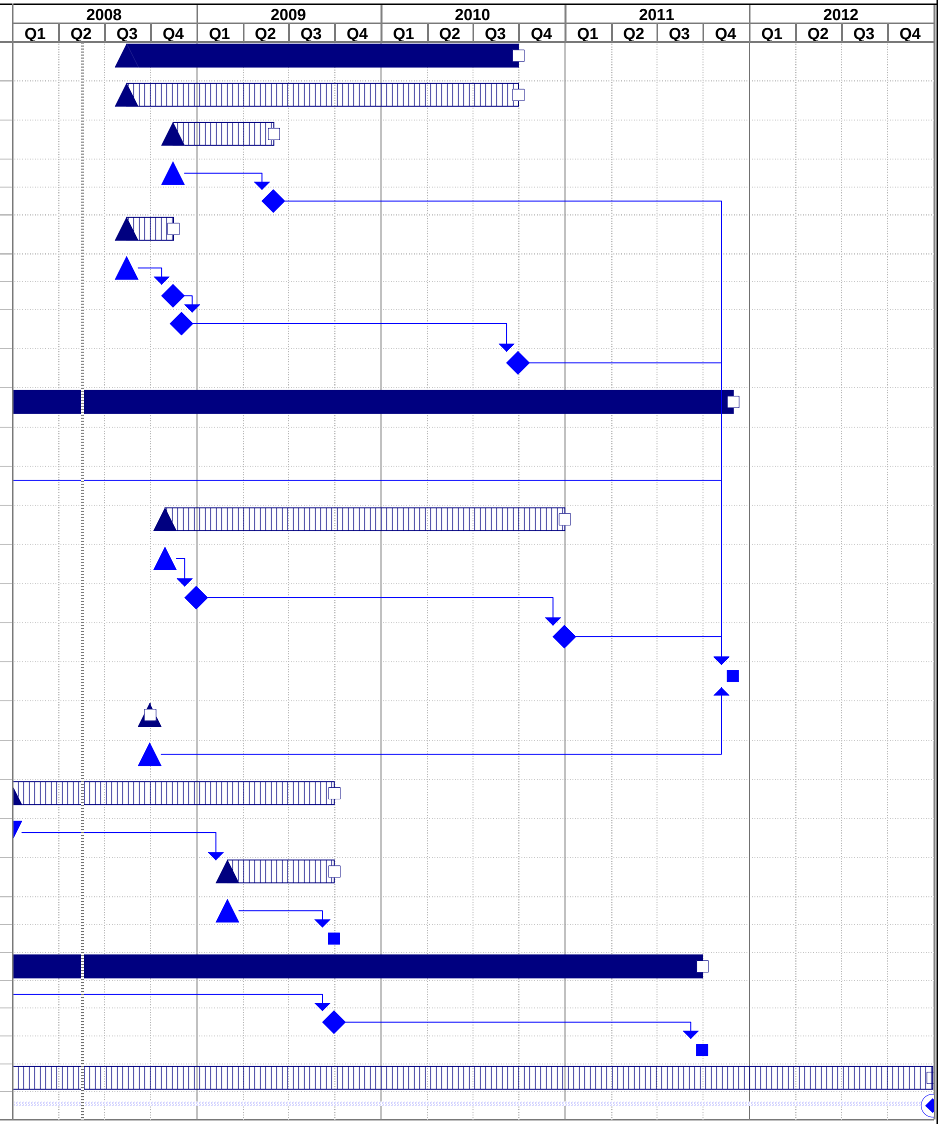
This multi-year strategy reflects both the existing metal casting sub-program mortgages and the DOE proposed FY08 metal casting sub-program budget. Within this proposed budget, the sub-program reflects a strong tilt towards near term energy saving technologies that can be applied commercially within the next 5 to 7 years.

The funded activities are university-based, mainly addressing the high priority research needs described in the *Metalcasting Industry Technology Roadmap: Pathway for 2002 and Beyond*. It focuses on two areas: Advanced Melting Technologies, and Innovative Casting Technologies. The former are activities aimed at reducing scraps and improving yields of castings, and improving melting practices in general. The latter are activities aimed at improved casting design methodologies for the wide array of casting alloys and process possibilities, improved properties data, and simulation tools that predict defects. When these tools are made available to the metal casting industry there will be a significant impact on energy savings across many industries.

Last updated: 5/5/2008

Metal Casting

ID	Name
1	Advanced Melting
2	Yield Improvement /Scrap Reduction
3	Simulation & Prevention of Hot Tear
4	Complete impact pressure spike model
5	Perform case study on production part
6	Establish New Melting Practices
7	Monitor and benchmark energy use and efficiency
8	Demonstrate Efficient Melting Technologies
9	New Energy Model for Melting
10	Parametric Design/process Modeling Tools
11	Innovative Casting
12	Computer Models Alloy Diversification for Lost Foam
13	Computer Models for Lost Foam Pattern
14	Design Tools to Improve Die Casting Applications
15	Computer Simulation Tools for Predicting & Minimizing Residual Stress
16	Computer Model for the Design of Tighter Tolerance Die Casting
17	Complete the Development of Design Tools for Producing Die Casting with Higher Strength
18	Develop an Innovative Casting Process for Higher Productivity and Energy Efficiency
19	Low Cost Semi-Solid Metal Feedstock
20	Technology for Manufacturing Low Cost Semi-Solid Metals
21	Improvements & Diversification in Metal Mold Casting
22	Develop Modeling Techniques for Optimizing Die Casting Cycle for Thermal Performance
23	Complete the Development of "Smart" Coatings to Extend Die
24	Finalize in-plant testing of optimized coating
25	Characterize deformation mechanism of smart coatings
26	BP Integration/ Technology Delivery
27	Portfolio Review
28	Portfolio Review
29	Portfolio Review
30	Cross_EERE Activities
31	For Future Development



Metal Casting Focus Area	Barriers	Pathways	Metrics
Advanced Melting (1) [Research will develop new design methodologies and establish new melting practices to increase yield of steel castings by 10% and thus reduce the energy consumption in melting by 10% (saving 1.4 million Btu/ton of steel cast).	• *Lack of parametric design capabilities* (3) [Parametrics in design tools allow changes in one parameter to adjust an entire model accordingly. Design tools with this capability facilitate casting weight and revert reduction, both large factors in casting process energy.] • *Lack of efficient scheduling and production techniques, such as alloying and furnace controls, that can reduce or eliminate energy intensive processes.* (4) [Scheduling and production techniques are essential tools in optimizing energy intensive molten metal handling.]	1. This pathway centers on computer modeling for predicting defects in steel castings, which will enable the re-writing of new standards for feeding rules, x-ray inspection, and unconventional methods for casting parts. In FY2008, researchers will develop measures to reduce at least 5% scraps incurred by "hot tears" in steel casting prodcution. [Casting designers can use these measures to predict where hot tears are likely to develop in a steel casting and what techniques can be implemented to prevent these hot tears.] In FY2009 methods and procedures will be established for measuring energy use in metal melting and handling operations; By 2011 an energy-efficiency model of steel foundry operations will be developed for measuring energy use in melting and handling. These developments will provide in part, a knowledge base needed to develop an innovative casting process with 20% higher productivity and efficiency in 2015.	Demonstrate a 10% increase in "True Yield" in steel castings in production runs. *Total potential savings = 40 trillion Btu/year*. ["True Yield" is the weight of 'good castings' produced divided by the total weight of poured metal, expressed as a percent.]
Innovative Casting Process (2) Advance casting processes by developing simulation tools; low cost semisolid feedstocks; and capabilities to cast different alloys; to increase yield and reduce scrap.	• *Lack of integrated design modeling tools for the various metal casting processes.* (5) [An integrated modeling tool will show the relationship between material properties, the specific casting process parameters, and impact on casting geometry. Inclusive of "parametrics" above, this kind of tool will drive casting weight and revert reduction.] • *Limited control of the variability in dimensions and material properties of castings.* (6) [Improve consistency of as-cast dimensions and casting microstructure to optimize machining stock. Reduced machine stock will reduce tons melted.]	1. In the *Computer Models and Alloy Diversification for Lost Foam* pathway, researchers will develop a simulation tool to model pattern displacement which occurs during the metal pouring stage in FY2008. These developments will provide in part, a knowledge base needed to develop an innovative casting process with 20% higher productivity and efficiency in 2011. 2. Research in the *Design Tools to Improve Die Casting Applications* pathway will develop simulation tools for predicting and minimizing residual stress in die castings in FY2009. Based on all the development work thus far, research will complete the development of design tools for producing die castings with higher strength in FY 2012 and will provide in part, a knowledge base needed to develop an innovative casting process with 20% higher productivity and efficiency in 2013. 3. *The Low Cost Semi-Solid Metal Feedstock* pathway will	Demonstrate a 10% increase in "True Yield" in lost foam castings in production runs. Demonstrate an 8% increase in "True Yield" in die castings in production runs.

Metal Casting Focus Area	Barriers	Pathways	Metrics
	• *Lack of new, efficient casting processes for high volume nonferrous and ferrous castings.* (7) [60% of castings are produced using the green sand process. Past and current research has shown alternative methods that result in casting weight and revert reduction.] • *Lack of thermal management capabilities including measures to control the rate of heat extraction during solidification processes.* (8) [Better thermal management will create higher integrity, thinner wall, and higher strength castings.] • *Processes for casting magnesium need improvement to meet market requirements for structural performance, light weighting, and volume.* (9) [Magnesium castings are generally limited to nonstructural components. Strength improvements will allow the transportation sector to better apply this alloy's weight savings capability -- only 9.5 lbs in 2002 automobiles.] • *Design engineers need data based on solidification rates and alloy microstructure for allowable high-cycle fatigue stress*. (10) [Reliable data on solidification rates and casting fatigue will enable more casting designs in engineered components. Alternatives to the casting process consume more energy.] • *The capability is needed to prototype*	provide the casting industry with a new, efficient casting process for nonferrous castings, and provide control of the variability in the material properties of Rheocastings. This "toothpaste" like flow instabilities, typically observed in the SSM processing, limit the production rate and reduce the final quality of castings. In FY2008, a technology for manufacturing low cost SSM feedstocks will be developed. These developments will provide in part, a knowledge base needed to develop an innovative casting process with 20% higher productivity and efficiency in 2011. 4. The Improvements & Diversification in Metal Mold Casting pathway will develop a model to prototype permanent mold castings that can meet the dimensional tolerance and casting integrity. Rearch will develop optimized multi-layered coatings and application methods for improved tooling performance in FY2008. [Result of this work will provide guidelines and processing parameters for commercial coating suppliers to produce the optimized coating structure.] Research will continue in modeling techniques for optimizing die casting cycle for thermal performance and develop improved productivity through innovative die cooling techniques in the next three years. [These techniques will assist in designing tooling with cooling lines to distribute the temperature more uniformly and result in less distortion, thus increasing productivity. The new guidelines for cooling line size and distance from the die cavity surface will be generated to increase the solidification rate and productivity.] Research will then continue down this pathway and complete the development of a smart coatings extend die life by over 10% in FY 2012. These developments will provide in part, a knowledge base needed to develop an innovative casting process for 20% higher productivity and efficiency in 2015.	Lower the cost of producing one pound of SSM feedstock to $1.20 - $1.36, from current cost of $2.25 (i.e. 40 to 47% reduction in cost/lb). Demonstrate an 8% increase in "True Yield" in permanent mold castings. *Total potential savings for Innovative Casting Process focus area = 25 trillion Btu/year*

Metal Casting Focus Area	Barriers	Pathways	Metrics
	permanent mold castings that are faithful to production dimensional tolerance and casting integrity. (11) [Prototype processes are needed that duplicate permanent mold casting solidification rates. Prototype castings must be dimensionally and structurally similar to their permanent mold production counterparts.]		

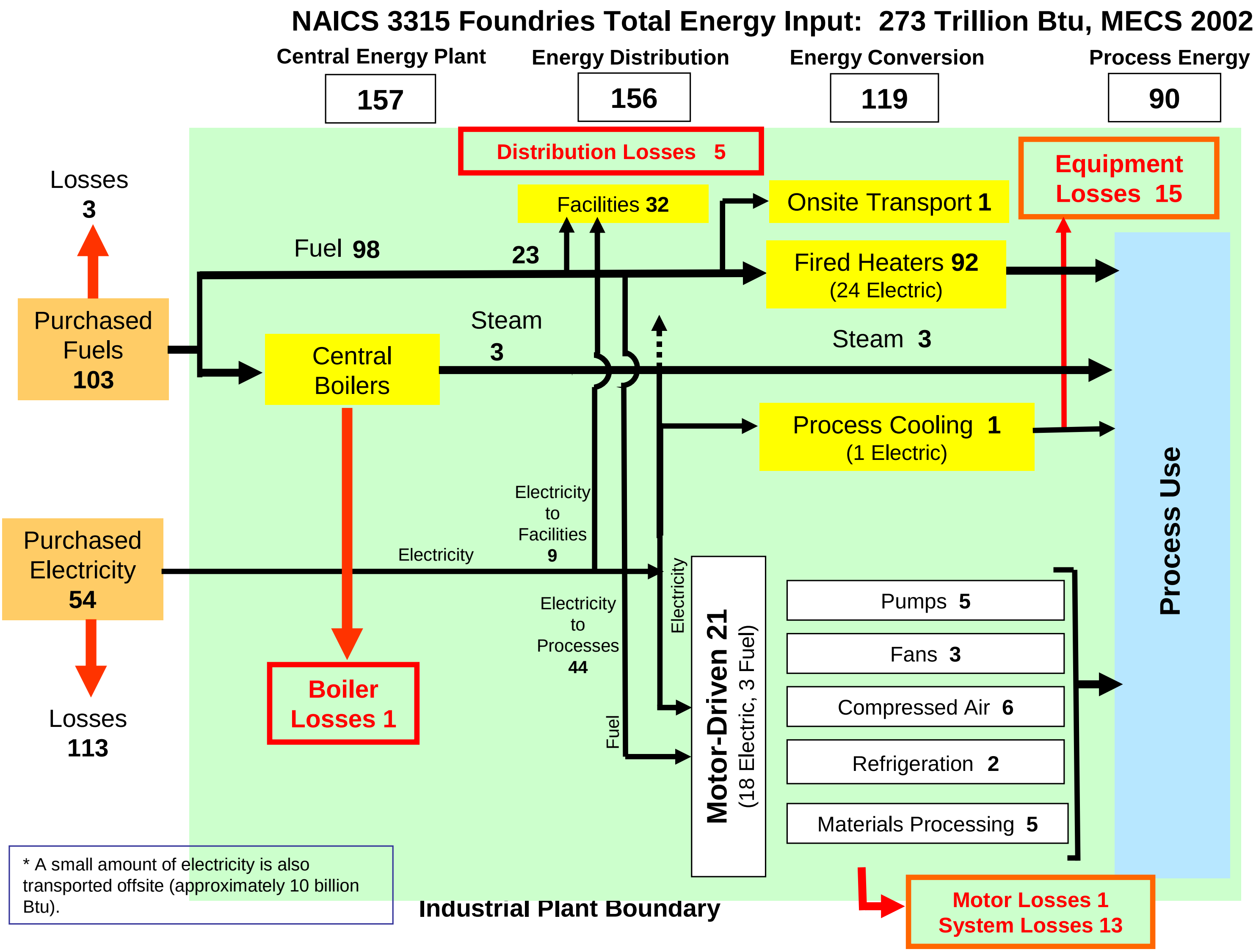
Sources:

(1) U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Industrial Technologies, Metal Casting Industry of the Future, *Energy and Environmental Profile of the U.S. Metal Casting Industry*, Washington DC, September 1999, pg. 10.
Note: In order to overcome the lack of parametric design capabilities the Metal Casting IOF is funding research establishing new design methodologies that will significantly improve the energy efficiency of melting. Current research is focusing on the downstream process of steel casting design and production. The essential approach is to use computer modeling for defect prediction in steel castings in the design stage before actual castings are made. Production yield can be increased significantly with this approach.

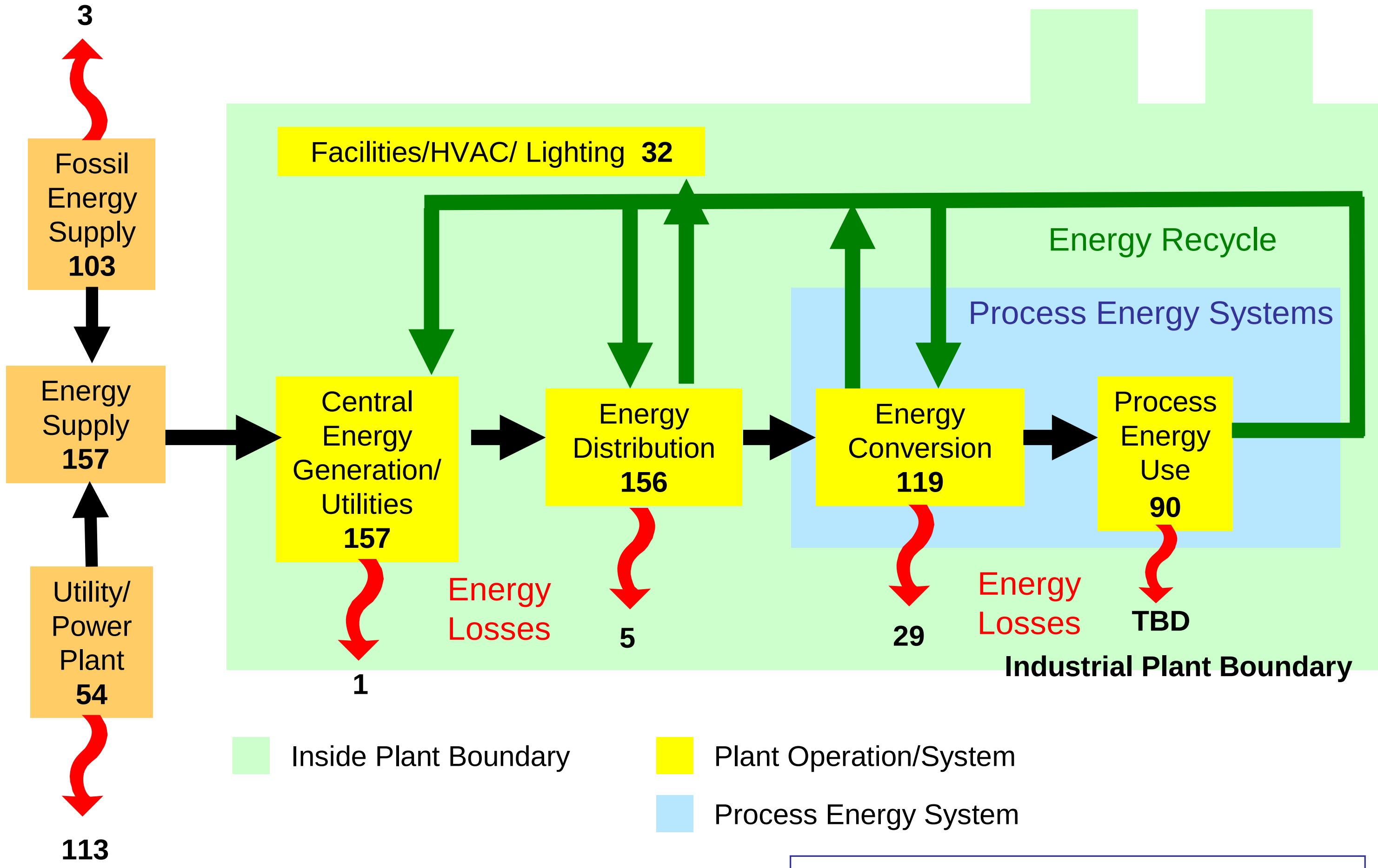
(2) U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Industrial Technologies, Metal Casting Industry of the Future, *Energy and Environmental Profile of the U.S. Metal Casting Industry*, Washington DC, September 1999, pg. 10.
Note: Research in this focus area will be conducted on four different pathways that will lead to the goal of developing an Innovative Casting Process for higher productivity and energy efficiency. The four pathways are:
- Computer Models and Alloy Diversification for Lost Foam
- Design Tools to Improve Die Casting Applications
- Low-Cost Semi-Solid Metal Feedstock
- Improvements and Diversification in Permanent Mold Casting.

(3) Cast Metals Coalition, *Metalcasting Industry Technology Roadmap: Pathways for 2002 and Beyond,* October 2003 pg. 17
(4) Cast Metals Coalition, *Metalcasting Industry Technology Roadmap: Pathways for 2002 and Beyond,* October 2003 pg. 23
(5) Cast Metals Coalition, *Metalcasting Industry Technology Roadmap: Pathways for 2002 and Beyond,* October 2003 pg. 16
(6) Cast Metals Coalition, *Metalcasting Industry Technology Roadmap: Pathways for 2002 and Beyond,* October 2003 pg. 12
(7) Cast Metals Coalition, *Metalcasting Industry Technology Roadmap: Pathways for 2002 and Beyond,* October 2003 pg. 22
(8) Cast Metals Coalition, *Metalcasting Industry Technology Roadmap: Pathways for 2002 and Beyond,* October 2003 pg. 25
(9) Cast Metals Coalition, *Metalcasting Industry Technology Roadmap: Pathways for 2002 and Beyond,* October 2003 pg. 22
(10) Cast Metals Coalition, *Metalcasting Industry Technology Roadmap: Pathways for 2002 and Beyond,* October 2003 pg. 11
(11) Cast Metals Coalition, *Metalcasting Industry Technology Roadmap: Pathways for 2002 and Beyond,* October 2003 pg. 13

2.1.4.1 Metal Casting Footprint



NAICS 3315 Foundries Total Energy Input: 273 Trillion Btu, MECS 2002



* A small amount of electricity is also transported offsite (approximately 10 billion Btu).

2.1.4.2 Metal Casting Roadmap Summary

The U.S. metal casting industry developed its second roadmap in early 2003. This roadmap discusses important challenges that are common to the industry. These challenges include the need to:

- Accelerate the rate of change among metalcasters. To accomplish this, the industry must increase training and technology transfer and motivate metalcasters to adopt new advances and technologies
- Identify and prioritize factors that reduce variability and develop measures to reduce their occurrences.
- Ensure casting quality and performance at the design stage. Incorporate and improve Advance Quality Planning (AQP), Design Failure Modes Effect & Analysis (DFMEA), and Process Failure Modes Effect & Analysis (PFMEA)
- Develop measures to improve process control in casting operations.
- Improve the efficiency and control of melting processes, which includes upstream metal preparation and downstream molten metal handling.
- Develop standards for quantitative measurement of internal and external casting quality attributes based on objective structural performance and superficial appearance requirements.
- Develop more economical processes for producing castings in an oxygen/contaminant-free environment.
- Improve automation in the casting processes and reduce the number of process steps.
- Improve safety performance and reduce environmental impact.
- Develop new pattern materials with less carbon content for lost foam casting.
- Develop the capability to produce mis-run-free, thin-wall castings.

Research projects funded under the focused areas "Advanced Melting" and "Innovative Casting" are formulated to meet most of the challenges listed above.

2.1.4.3 Metal Casting Bandwidth

Theoretical/Practical Minimum Energy Study: KERAMIDA Environmental, Inc. (Columbus, Ohio) recently conducted a study to evaluate energy requirement for various metal casting processes. This study evaluates the theoretical minimum and practical potential for reducing energy requirements, to produce one ton of molten metal in metal casting operations. This study examines several casting processes including: green sand, chemically bonded sand, lost foam, investment, permanent mold, and die casting as well as melting processes, including cupola, electric induction, electric arc, gas-fired crucible, and gas-fired reverberatory furnaces.

The theoretical minimum for each process or operation is defined as the absolute theoretical minimum energy required without regards to energy loss or practical operational consideration. The best practice minimum energy requirement for each process takes into account what is possible under actual operational conditions utilizing best practices in the industry. The practical minimum energy requirement is the actual minimum energy usage being achieved in practice in industry. Furthermore, potential waste heat recovery options are identified, and the influences of scrap levels and yield on energy requirements are evaluated for each named process.

2.1.5

Background

The U.S. steel industry is now being transformed through it's most significant restructuring in modern times. More than 30 steel companies declared bankruptcy since 1999. During this time, the industry has shuttered most of its corporate research facilities and eliminated their staffs. Numerous acquisitions have taken place, and many well known company names have vanished. Over the last five years, however, the pace of industry production has increased and an industry once fighting for survival is now able to implement process improvements, especially in energy efficiency, though relying on suppliers and outside researchers to develop these technologies. The ITP steel sub-program reflects the twin realities of eliminated research capability and the industry's ability to commission new, more energy efficient steel process technologies. But, a new threat has emerged in the form of the "BRIC" nations, Brazil, Russia, India and China. In China especially, low labor costs and government policies have enabled China to emerge as a major user, producer and worldwide marketer of steel. Industry restructuring is in part a result of this intense worldwide competition. This competition has required that U.S. producers minimize major cost elements and adopt the most efficient production technologies, especially energy-efficient technologies, in order to survive. However, the "pipeline" of new ironmaking and steel production innovations has been depleted due to the previous industry difficiulties. The industry needs to become even more efficient to remain competitive with aggressive foreign suppliers. Even though they are now profitable, steel companies do not have the financial resources and facilities to conduct needed process research and development. The industry is looking to DOE-ITP to catalyze a resurgence in the creation of new cost and energy efficient technologies.

Electric arc furnace (EAF) steelmakers have steadily taken market share (mostly the lower graded products) from the large integrated steelmakers. EAF production now accounts for well over 50 percent of domestic production. However, increases in both steel scrap prices and electric rates, and higher natural gas prices have hurt the EAFs. EAF steelmakers face additional challenges, including the high cost and limited availability of suitable steel scrap and direct reduced iron to feed their furnaces.

To survive in the long term, integrated mills need cost cutting technological advances that will make them more competitive globally. *ITP's steel energy bandwidth study reveals that today's steelmaking processes use at least 40% more energy than practically required.* Energy studies show that advances in steelmaking processes that eliminate coke and use less raw materials, electricity, and other fuels can yield energy savings of 18 percent.

There currently are two production routes for making steel:

Integrated Production

- Iron ore is fed into blast furnaces to produce liquid iron, which is then fed into oxygen furnaces to make steel

Electric Arc Furnace-Based

- Scrap and scrap substitutes are re-melted

Strategy

This multi-year strategy reflects both new FY08 steel steel activities and multi-year mortgages. Within this proposed budget the portfolio supports both energy saving technology that can be applied commercially withinin the next three to five years and high risk energy saving innovations (early stage-gate) that could be applied after 2015.

Two projects started as part of the AISI Technology Roadmap Program (TRP) are continuing. The TRP focuses on two topics: Yield Improvement and Breakthrough Technologies. The former are activities that minimize energy and material input without significantly changing the existing steelmaking process. The latter are early stage-gate projects now conducted by universities that could result in new steelmaking processes. These projects, co-sponsored with AISI, will be completed by the end of FY 2008. In addition to these, three other projects are considered to be late stage gate (Stage 3 or 4). One project is implementing a concept for reheating furnaces that minimizes scale formation on steel during reheating. Another project is pilot stage testing a new concept for making high quality iron using coal as the reductant. The third is a new project selected from the FY 2007 solicitation that aims at improving blast furnace efficiency through optimization of the charge material distribution.

It is essential that ITP continue its relationship with industry associations and their members. Indeed, it is important that these groups participate in a stakeholder workshop for portfolio development which will guide future ITP steel activities and establish it's next generation of priorities. It is expected that this workshop will occur in FY'08.

The FY'08 "Collaborative Energy Efficiency and Carbon Footprint" industry solicitation which will include steel, notes elements that can be incorporated into a future, more efficient and ultimately significantly different integrated steel making facility. The energy efficiency of steel production has increased with time, and more low cost, energy efficient mills are seeking routes to producing higher quality steel while continuing to maintain their traditionally low costs. It can be expected that new generation integrated facility will be able to produce high quality steel at a considerably lower cost and use less energy per ton produced than current generation integrated mills. To supply "iron units", this facility could incorporate a traditional, but more efficient blast furnace, or a direct reduced iron process. Steelmaking could be accomplished in a number of vessel types using traditional or pioneering processes. Specific elements that can be integrated into this overall activity are:

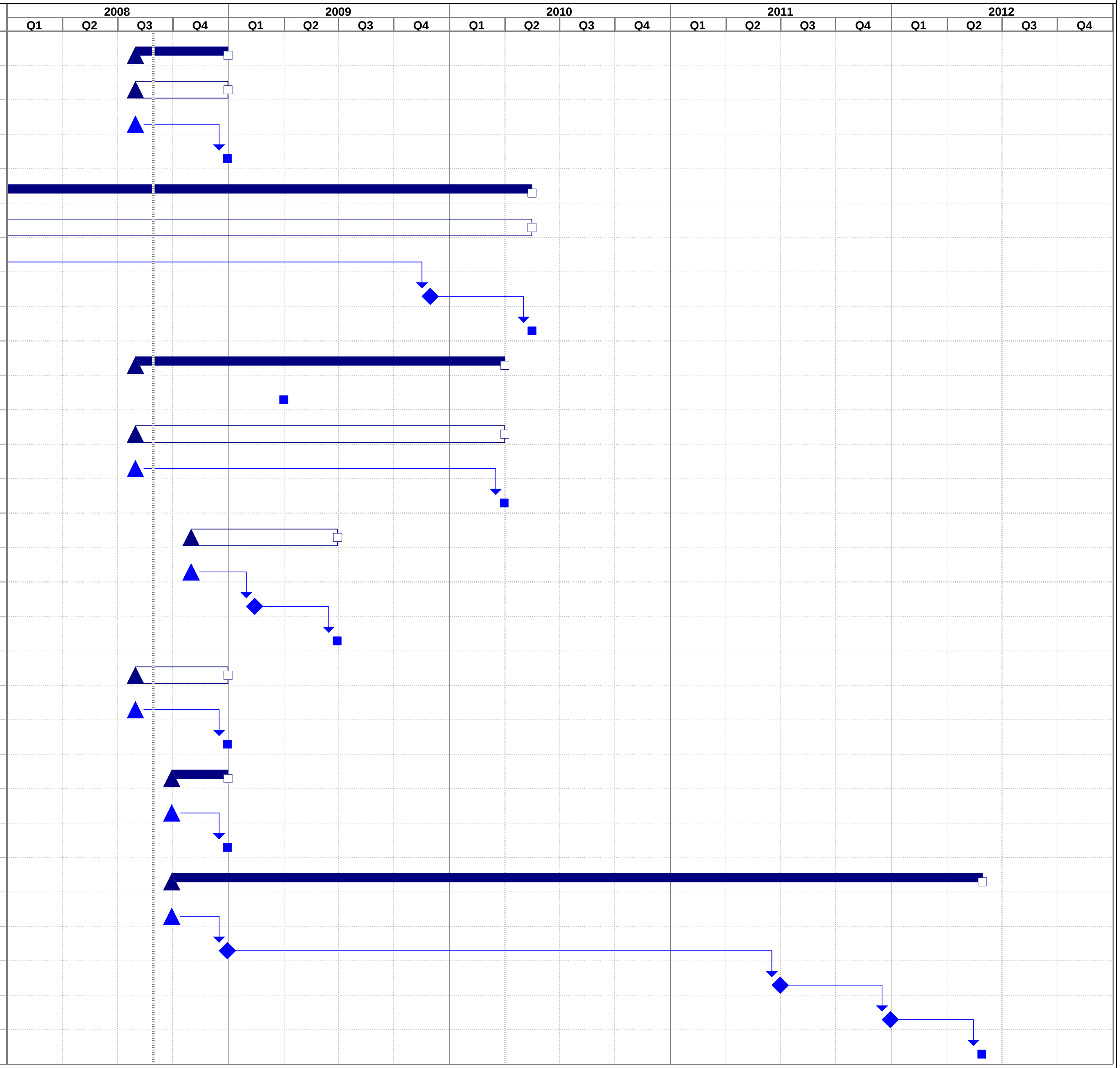
1. New or improved alternative ironmaking technologies, including direct reduced iron (DRI) technologies that have high potential to replace the blast furnace ironmaking process.

2. Technologies to improve the energy efficiency and reduce the carbon foot print of equipment currently used in energy-intensive process steps such as blast furnace iron making, basic oxygen steelmaking, electric arc furnace steelmaking, reheating, hot rolling, annealing, coating, etc.

Last updated: 5/5/2008

Steel

ID	Name
1	Next Generation Steelmaking
2	New Steelmaking Technologies to Complement IISI
3	Start Project
4	Conduct Industry Workshop
5	Cokeless Ironmaking
6	Iron Nodule Technology
7	Phase 2 - Continuation based on process efficiency results
8	Decision Point
9	End of Task
10	Advanced Process Development
11	Technology Roadmap Program (TRP): End of Task - Tech. Delivery
12	Minimization of Blast Furnace Fuel Rate
13	Start Project
14	CFD Model Development
15	Scale Free Reheat Furnace
16	Complete Preliminary Design
17	Demonstrate Scale-free Furnace
18	Final Report
19	Direct Flame Impingement
20	Field Test at Republic Steel
21	End of Task
22	BP Integration / Technology Delivery Planning
23	Workshops with AISI, SMA, AIST
24	Workshop Reports Complete
25	Steel Projects from Energy Efficiency and Carbon Footprint Solicitation
26	Solicitation Opens
27	Awards Made/Projects Begin
28	Demonstrations Begin
29	Demonstrations End
30	Draft Final Reports

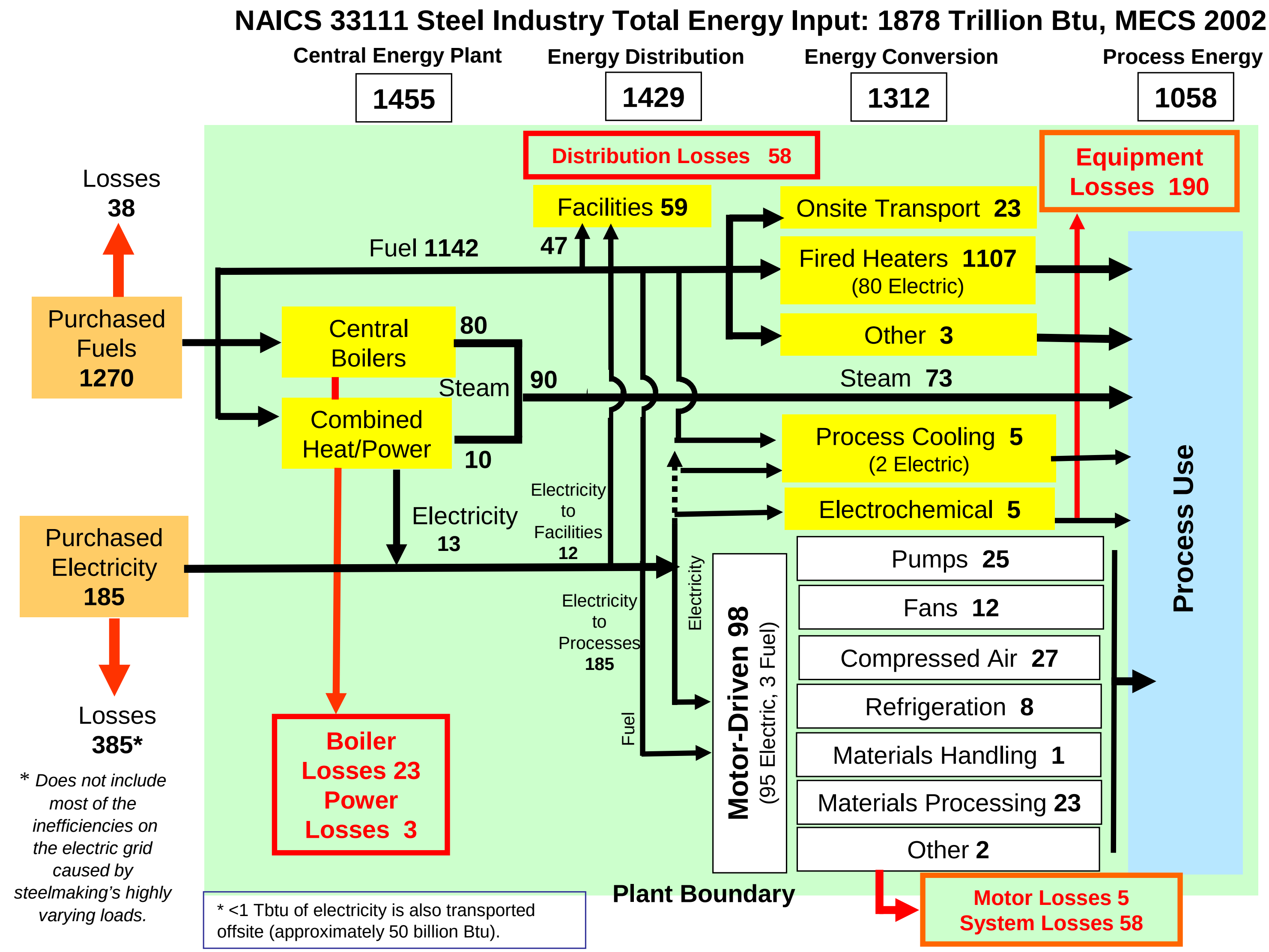


Steel Focus Area	Barriers	Pathways	Metrics
Next Generation Steelmaking <u>Objective</u> Develop revolutionary new steelmaking concepts that dramatically reduce energy intensity and carbon footprint.	• Current batch steel operations result in energy losses associated with transfer operations as well as operation of the processes themselves. • Current processes necessitate external heating to the raw materials, requiring lengthy heating times at high temperature to effectively transfer heat to the center of the material mass. Significant energy is thereby lost to the exhaust gas because of the high volume of air flow required by combustion.	1. Conduct industry workshop to identify ideas for transformational technologies (Q4-FY08).	1. Reduce energy per unit of steel produced 12% (from 15.9 MBtu/ton to 14.3 MBtu/ton of steel for integrated steelmaking, and from 6.8 MBtu/ton to 6.0 MBtu/ton of steel for scrap-based steelmaking). *Total potential savings = 50 trillion Btu/year*
Cokeless Ironmaking <u>Objective</u> In the future, cokeless iron making processes will convert iron ore into iron of the same quality as the pig iron produced by blast furnaces, be more energy efficient and have an overall lower cost.	• Higher grades of steel require higher quality iron. The challenge isto make large quantities of quality iron without blast furnaces or coke and use the nation's ample supply of domestic coals and iron ores. • Process scale up • Resultant iron nugget quality at pilot demonstration scale. • Require new Ironmaking process that will utilize alternative fuels as they become available	1. Develop a cokeless ironmaking technology that produces high-quality iron nuggets equivalent to pig iron produced in a blast furnace. Demonstrate energy-efficient production of high quality iron that is equivalent in quality to blast furnace pig iron and can be used directly by electric steelmaking processes (Q2-FY10). Steps include: • Identify the most promising iron ore reduction processes to replace the coke-using blast furnace. • The thermal and reducing capabilities of widely available coals such as bituminous and subbituminous can be harnessed to convert iron ore to iron metal with the heating taking place in furnaces of various types. • Control process conditions such as reaction temperature and furnace atmosphere to optimize iron ore reduction. • Provide a process step or other mechanism to separate impurities from the reduced iron ore.	1. Reduce energy and carbon dioxide per unit of iron produced relative to blast furnace by 28% (from 18 MBtu/ton to 13 MBtu/ton of iron produced). *Total potential savings = 64 trillion Btu/year*

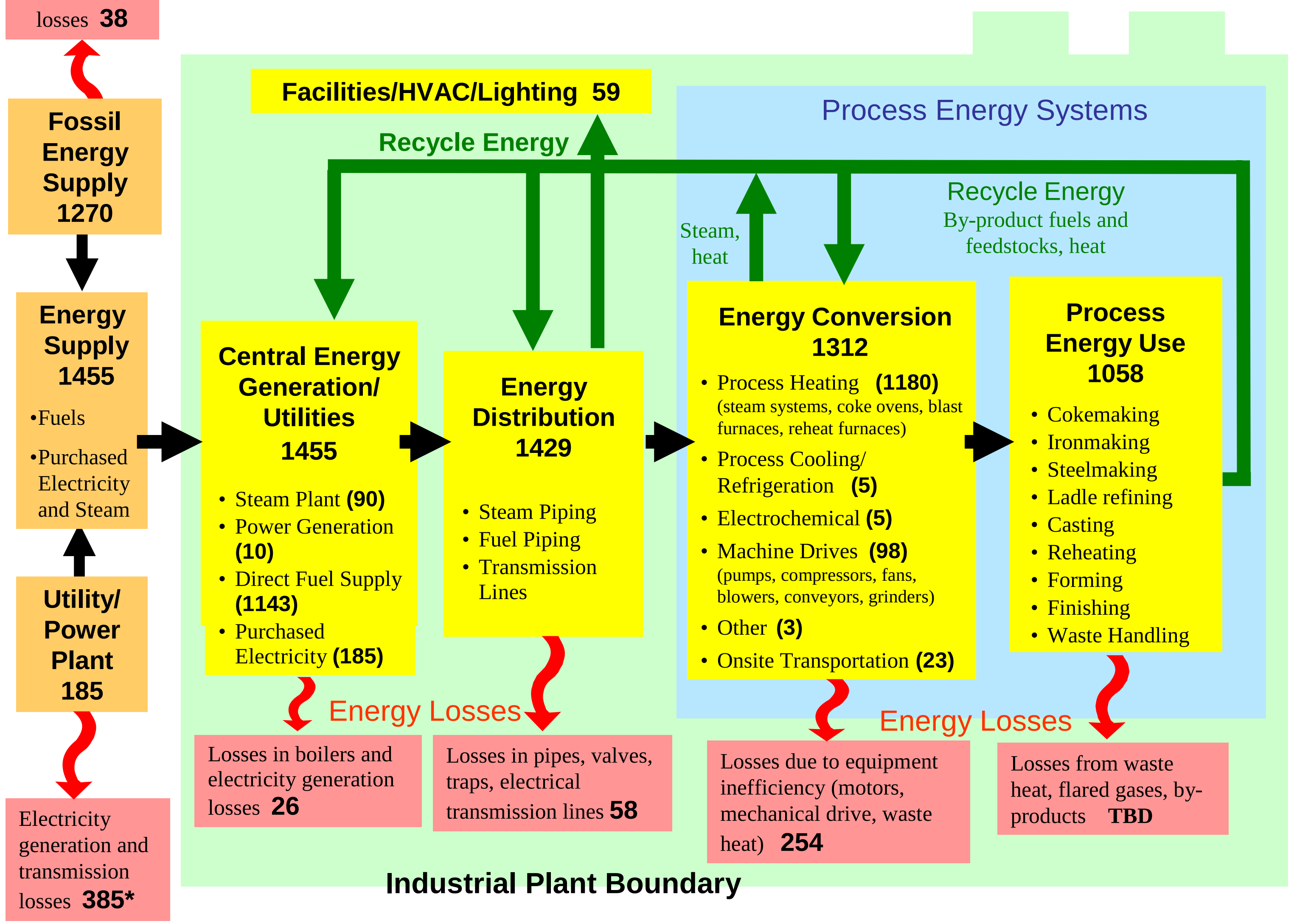
Advanced Process Development Objective Improve process efficiency and dynamics. Results will include greater yield and less loss, such as the loss that occurs when scale is formed during reheating.	• Pulverized coal is replacing an increasing percentage of coke in the blast furnace, athe primary source of iron for integrated steelmaking. As coal use increases, blast furnace productivity and stability is altered. This effects the gas distribution in the blast furnace, altering the efficiency of the blast furnace. • Measuring a blast furnace's gas distribution is challenging, and is difficult to do.	1. Use high-fidelity 3-D numerical simulation to optimize the distribution of solid materials charged into the blast furnace. Incorporate chemical kinetics and fluid flow into models to better predict blast furnace gas distribution, aiding in the optimization of solids distribution and overall blast furnace efficiency. Complete development of a computational fluid dynamics technique for optimizing burden in Q1-FY10.	1. Develop technique to guide optimizing the distribution of solids charged into the blast furnace, reducing energy use 5% (from 18 MBtu/ton to 17 MBtu/ton of iron). *Total potential savings = 1 trillion Btu/year*
	• A strong oxidizing environment exists in furnaces, even with low levels of oxygen, leading to the formation of slag. • Limitations to convetional furnace designs which do not exclude air (oxygen). • Excessive concentration of unburned gaseous fuels can create explosion hazard.	2. Create completely safe, energy-efficient reheat system that significantly minimizes or eliminates scale formation during steel reheating (Q1-FY0). Provide reducing environment in vicinity of steel being reheated by creating a new burner type. Use furnace heat balance program to calculate heat demand in various reheat furnace zones.	2. Develop and demonstrate a scale-free reheat furnace at a pilot-scale level that reduces energy use by 27% (from 1.2 MBtu/ton to 0.325 million Btu/ton of steel). *Total potential savings = 6 trillion Btu/year*

SOURCES:

(1) Multiyear Program Plan, 5.4.1.7.6 Steel Bandwidth; and draft "Table 1. Energy Saving Opportunities for EAF Steelmaking (Liquid Steel and Reheating/Rolling)" and draft "Table 2. Energy Savings Opportunity for Ore Based Steelmaking (Hot Metal and Reheating/Rolling)." Drafts tables are based on footnotes 4 and 5 below.
(2) *Steel Industry Technology Roadmap*, American Iron and Steel Institute, December 2001.
(3) Energy Use in the Steel Industry, A Historical Perspective and Future Opportunities, John Stubbles, September 2000.
(4) Theoretical Minimum Energies to Produce Steel for Selected Conditions, R.J. Fruehan, September 2000.
(5) Barriers and Pathways for Yield Improvement by Energetics, Inc. October 7,2003


NAICS 33111 Steel Industry Total Energy Input: 1878 Trillion Btu, MECS 2002
Central Energy Plant
1455
Energy Distribution
1429
Energy Conversion
1312
Process Energy
1058
Losses
38
Purchased Fuels
1270
Fuel 1142
Central Boilers
80
Steam
90
Combined Heat/Power
10
Electricity
13
Purchased Electricity
185
Losses
385*
* Does not include most of the inefficiencies on the electric grid caused by steelmaking's highly varying loads.
Boiler Losses 23
Power Losses 3
Distribution Losses 58
Facilities 59
47
Electricity to Facilities 12
Electricity to Processes 185
Electricity
Fuel
Onsite Transport 23
Fired Heaters 1107
(80 Electric)
Other 3
Steam 73
Process Cooling 5
(2 Electric)
Electrochemical 5
Motor-Driven 98
(95 Electric, 3 Fuel)
Pumps 25
Fans 12
Compressed Air 27
Refrigeration 8
Materials Handling 1
Materials Processing 23
Other 2
Equipment Losses 190
Process Use
Plant Boundary
Motor Losses 5
System Losses 58
* <1 Tbtu of electricity is also transported offsite (approximately 50 billion Btu).

NAICS 33111 Steel Industry Total Energy Input: 1878 Trillion Btu, MECS 2002



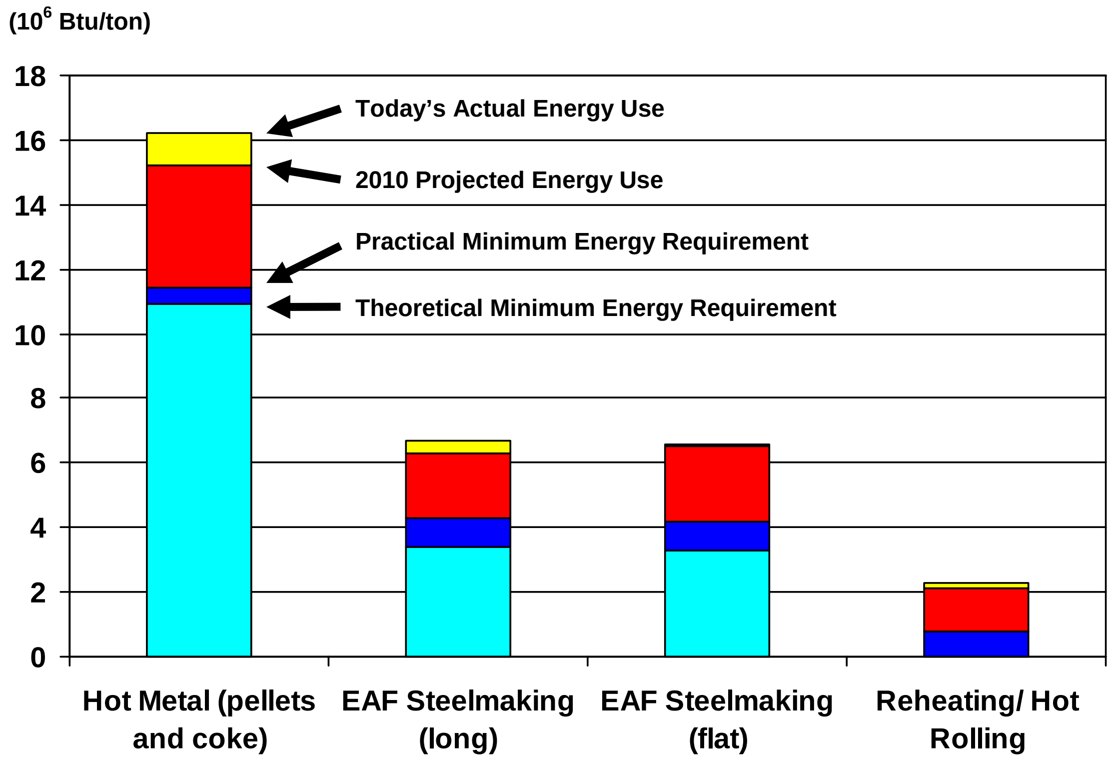
2.1.5.2

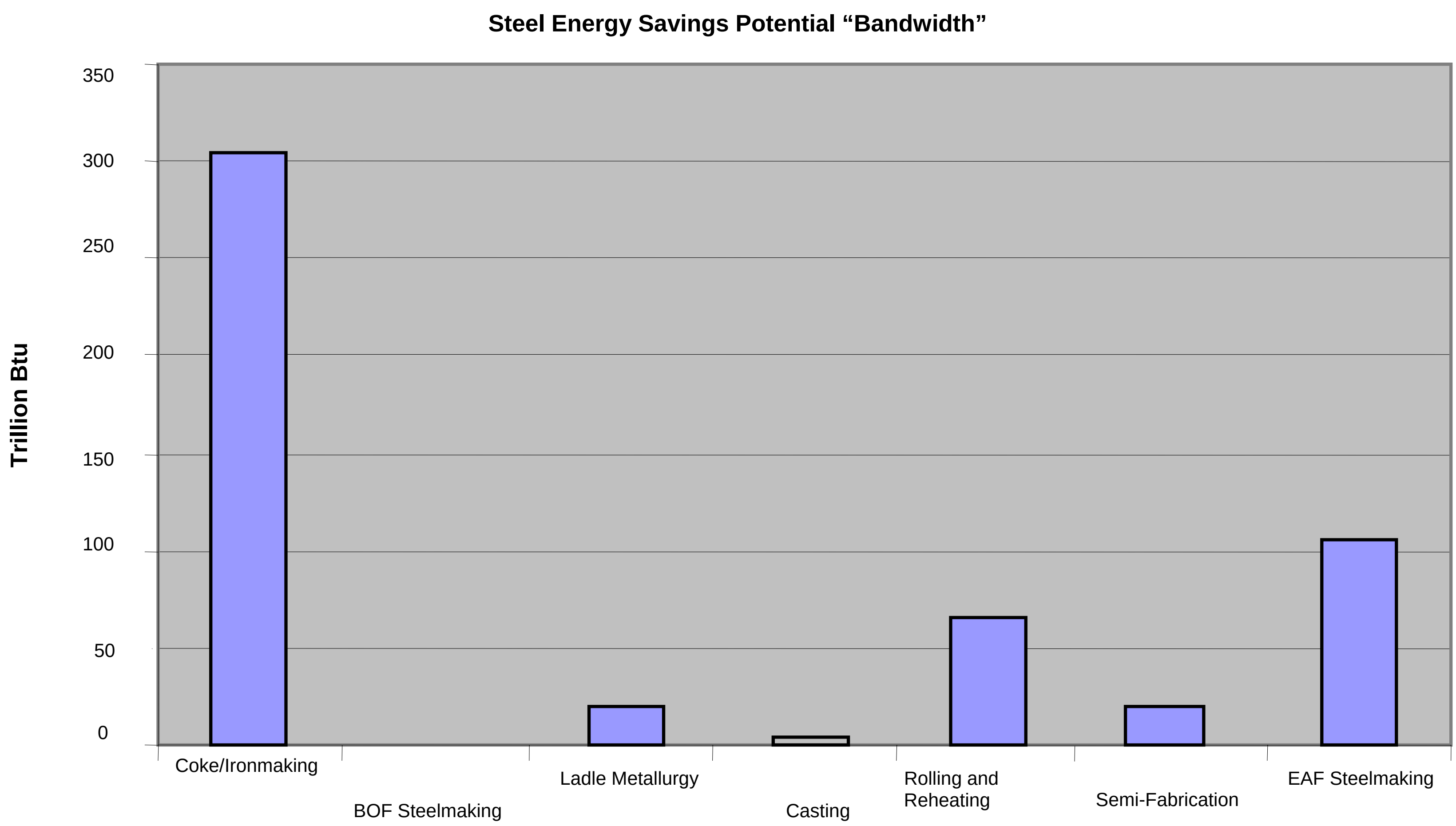
Typical R&D Needs from the Steel Industry Technology Roadmap
Ironmaking *Develop ability to use non-coking coals and low-value carbonaceous material* • Comprehensive model of the blast furnace, including fluid flow and kinetics • Improved taphole clays and taphole/refractory systems • Use of hot oxygen to increase coal injection rate *Better use of blast furnace off-gas and alternative fuels*
Steelmaking *Basic Oxygen Furnace* • Robust process sensors for the BOF (bath carbon, temperature, slopping, waste gas composition, dusty bin levels, furnace shell temperatures, turndown elements) • Models to optimize blast furnace and BOF operations • Charge control model for better end-point control • Integrated melter guidance system • Scrap preheating techniques *Electric Arc Furnace* • Understanding of how preheating feed materials affects the process • Understanding of how feed material size and shape affects melting time and yield • Artificial intelligence techniques for EAFs • Optimized operating cycles
Casting • Ability to understand and actively control fluid flow, temperature, and chemistry • Advanced heat transfer and fluid flow models • Ability to monitor and actively control fluid flow, temperature, and chemistry (including wireless systems) • Better understanding of the variation of heat transfer with casting conditions and alloy chemistry in strip casting
Rolling • Characterization of thermodynamics and kinetics of phase transformations under stress • Solidification modeling • Hot surface defect detection and classification techniques

2.1.5.3

Steelmaking Energy Bandwidth and Program Goal (includes all operations though finished product)					
Steelmaking Route	I 2010 Projected MBtu/ton	II Liquid Steel Energy Savings MBtu/ton	III Hot Metal Energy Savings MBtu/ton	IV Reheating/Rolling Energy Savings MBtu/ton	V Program Goal,[a] (I - II or III - IV) MBtu/ton
EAF long products	10.5	1.0	--	0.77	8.73
EAF flat products	10.3	1.125	--	0.60	8.575
Ore-based	20.0	--	3.05	0.65	16.3
Industry Weighted Average/shipped ton	**15.0**’	**--**	**--**	**--**	**12.3**

Steel Industry Energy Bandwidth




Steel Energy Savings Potential “Bandwidth”
Trillion Btu
350
300
250
200
150
100
50
0
Coke/Ironmaking
BOF Steelmaking
Ladle Metallurgy
Casting
Rolling and Reheating
Semi-Fabrication
EAF Steelmaking

2.1.6 Information Technologies

Background

Information technology (IT) incorporates the design, development, implementation and management of computer-based information and communication systems. The IT industry deals with the use of equipment and software to convert, store, protect, process, transmit and retrieve information. It extends from chip production to the ultimate information user by way of transmission systems including the Internet and data centers. Certain elements of the information technology chain are known to be energy intensive. This sector has experienced phenomenal growth during this decade, as production capacity has more than doubled. Furthermore, according to EIA projections, shipments from the U.S. semiconductor industry will grow by 206% between 2005 and 2030, far above most other manufacturing industries.

Data centers are one major, fast growing IT energy user. Power demand for data centers, which require energy for both equipment operation and facility cooling, is growing at 12% annually. The data center industry estimates 5,000 enterprise class and mid-tier data centers will be in operation in the U.S. by 2011. And as computers and other devices become more powerful, they normally require greater amounts of energy to operate.

Virtually all the electrical power feeding data centers ultimately ends up as heat. The trend toward smaller and more powerful computing equipment and the use of "blade" servers has produced data centers crowded with hundreds or even thousands of racks of servers creating a huge concentration of heat that must be removed. The power and associated costs to cool the data center can be as much or more than the cost of powering the IT equipment (servers, storage, and networking). Indeed, one study suggested that 63% of a data center's electrical use is associated with cooling the IT equipment. Soaring demand for information technology, increasingly powerful microprocessors and the growing popularity of compact blade servers means that data centers are more densely packed than ever – and that means a tremendous demand for cooling.

Strategy

The initial ITP activity in Information Technology will be a study to identify the largest IT energy using sectors and highlight the least energy efficient IT sectors. Included will be "Internet generation" communications systems as well as classic wired and wireless telephony elements which can be significant energy users and/or incorporate energy inefficiencies.

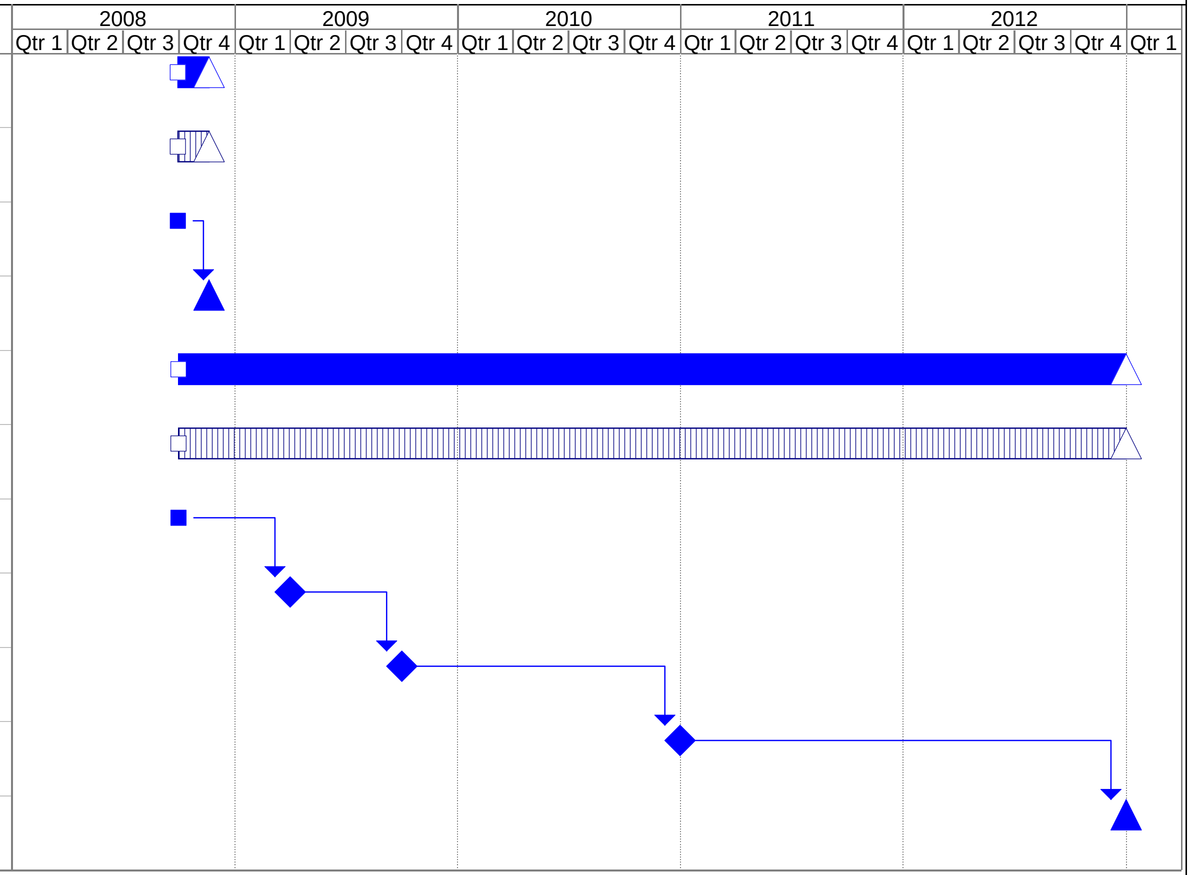
The next steps are to identify appropriate partners and conduct a workshop with these partners. Expected participants will be organizations that develop and use information technology, equipment and software, facility operators, national laboratories, educational institutions, other government agencies, industry associations and public interest groups with expertise in information technology. This stakeholder workshop will overall establish a government role in this area which is now supported by extensive industry sponsored research. The workshop will also identify IT technology needs which are compatible with ITP energy efficiency goals and capabilities, and will:

- Identify and address key, strategic drivers
- Establish a list of strategically driven needs
- Assemble the needs into multiple focus areas
- Pinpoint specific topics and roles for ITP action.

It is expected that the workshop will incorporate topics ranging from component manufacture to optimization of IT applications and investigate innovative hardware and software concepts to reduce energy use and heat generation in IT operations. Data centers are an excellent application of the strategy being developed here. Making the operation of data centers more efficient through hardware and software changes which reduce the energy used and thus, the heat generated has a double payback: the operation of the IT equipment of a data center is made more energy efficient (thereby generating less heat) and the quantity of energy needed for cooling is reduced.

ITP anticipates providing research funding for seed projects to investigate potentially fruitful approaches to reducing energy consumption and heat generation in data center components. Ultimately these redesigned components can be incorporated into a next generation data center. Furthermore, an additional activity which would provide an excellent integration of ITP R&D and BestPractices activities in IT would be a national data center testing and demonstration facility which could be used to verify the ability of new technologies to reduce data center energy consumption.

ID	Name
1	**Planning**
2	**Stakeholder Workshop for Portfolio Development**
3	Conduct workshop
4	Complete workshop report
5	**Technology Development**
6	**R&D Projects**
7	Golden starts procurement process
8	Solicitation released
9	Projects initiated
10	Short term, proof of concept projects completed
11	Longer term projects completed



Focus Area	Barriers	Pathways	Metrics
Enhanced Thermal Management in Data Centers	• Data center industry purchases lowest initial cost equipment, not the most energy efficient.	Demonstration to show reduced energy use and improved economics of reconfigured data centers incorporating semiconductor and ancillary improvements noted here.	Reconfigured data center which uses 25% less energy than latest generation and is economically attractive to this industry.
Ancillary Component Development	• Initial component cost is dominant factor in purchase decision. • Uninterruptible power supplies (UPS) consume considerable power and generate heat. • Multiple stages of transforming AC power to low voltage DC generate considerable heat, illustrating the inefficiency of this conversion process.	Create high efficiency UPS; create low cost, high efficiency transformers. Make practical the separation of server components by placing transformers outside the building structure, away from the air conditioned area; run servers directly on low voltage DC piped throughout the data center building.	Ancillary components which use 25% less energy and produce 25% less heat than current generation equipment.
Semiconductor Efficiency	• Trend toward smaller, more powerful servers such as blade servers, has created a major concentration of heat that must be removed.	Identify and pursue new concepts to reduce server component electrical consumption. Demonstrate proof of concept; completely turn over to industry.	A new generation of data center equipment which generates 50% less heat than current generation equipment.

2.1.7 Energy-Intensive Process R&D

Background

ITP has developed a new strategy, Energy-Intensive Process R&D (EIP), to address DOE's energy security strategic goal through improved industrial energy productivity and efficiency. The objective of the EIP is to focus ITP investments in several high impact, cross-cutting opportunities that provide the greatest energy savings and carbon reductions, while serving a broad industrial base. ITP is beginning this transition from predominantly industry-specific R&D to more crosscutting research in FY08.

Strategy

The core of the EIP strategy is the consolidation of R&D activities around four cross-cutting technology areas that could provide large energy benefits throughout the manufacturing supply chain, including industries identified by the National Association of Manufacturers such as the food & beverage, computer and electronic, and fabricated metal products industries. This technology-based strategy will allow ITP to maintain its historically close partnership with traditional end-user industries, while strengthening the participation and commitment of supplier and OEM industries to help develop and commercialize technology innovations.

There are several cross-cutting benefits of organizing around technology platforms, including:

- The ability to serve a wider range of U.S. industry and especially those that will continue U.S. global manufacturing leadership in energy and technology
- Sharpened focus on manufacturing technologies
- Maximum synergy among complementary technologies
- Greater flexibility in launching new initiatives
- More consistent, long-term R&D agenda versus discrete projects
- Easier to communicate with ITP stakeholders

Using the convening power of government to form working groups for future industrial cooperation, the Energy-Intensive Process R&D will focus on the following four platform areas:

- Industrial Reactions and Separations
- High Temperature Processes
- Waste Heat Minimization and Recovery
- Sustainable Manufacturing.

Last updated: 4/25/2008

2.1.7.1 Industrial Reactions and Separations

Background

Industrial reaction and separation processes transform raw materials (oil, natural gas, biomass, air, water, metals, and minerals) into energy, paper, chemicals and other products for use by utilities, manufacturing, and consumers. These key processes cross-cut several industries and are employed throughout the manufacturing chain. The petroleum refining industry uses chemical reactions and separations to turn crude oil into the gasoline and chemical feedstocks that keep the country running. The chemical industry uses reactions and separations to convert these feedstocks, natural gas, and other raw materials into basic inorganic and organic chemicals that are then further processed by the chemical and other manufacturing industries to produce finished goods. Chemical manufacturing alone produces more than 70,000 diverse products that are essential to the manufacturing sector. The paper making industry uses chemical reactions and separations to convert wood into energy and thousands of products that are essential for everyday needs in communication, education, packaging, and sanitation.

Opportunities abound to develop and implement advanced reaction and separation processes for the benefit of U.S. industrial competitiveness and energy security. Investments in reactions and separations can improve energy intensity in process industries, with separations being most critical in processes that involve water and require conventional distillation. Distillation alone accounts for about 15% of U.S. manufacturing energy use. Although improvements to individual installations won't necessarily offer enormous energy savings, cross-cutting improvements to separations aggregate to one of the largest opportunities for saving energy across multiple industrial sectors.

Key stakeholders include:

- Chemical and petrochemical industry
- Forest products industry
- Food processors
- Biorefineries, agri-processers, bioenergy industry.

Strategy

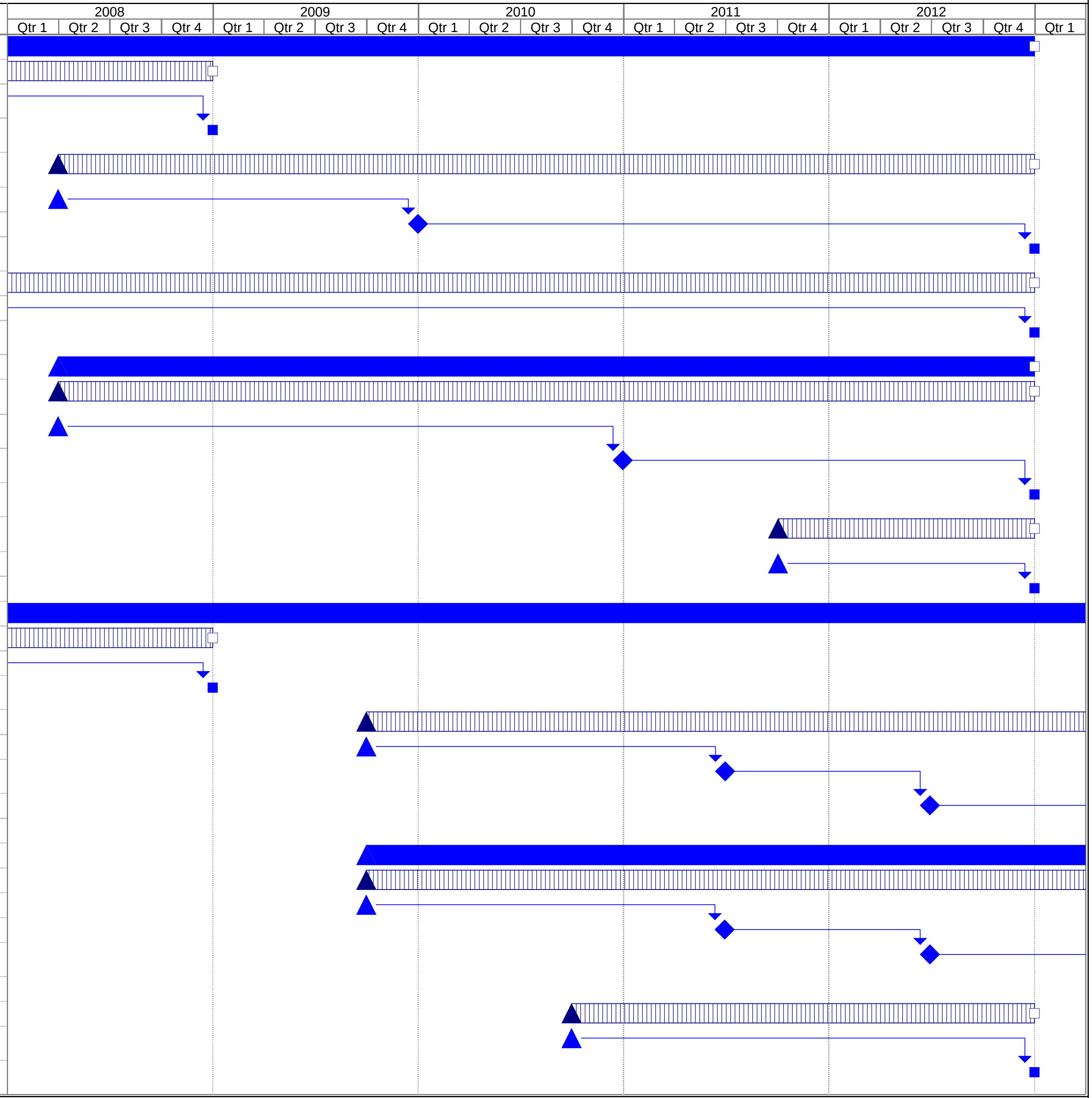
The industrial reactions and separations platform targets development and demonstration of advanced technologies for energy-intensive reactions and separations processes, focusing on accelerated development of cost-effective technologies for production of fuels, chemicals, and materials from renewable sources, which will increasingly form the basis for the 21st century economy.

The areas of technological focus for R&D investment under this platform include the following:

- Advanced Water Removal
- Advanced Gas Separations
- Hybrid Distillation
- Energy-Intensive Conversion Processes.

INDUSTRIAL REACTIONS AND SEPARATIONS

ID	Name
1	**Advanced Water Removal**
2	**Steam Cycle Washer**
3	Prototype development to reduce weak black liquor water content by 50%
4	Complete field test and initiate commercial introduction
5	**Water management applications for pretreatment, conversion, and product recovery processes**
6	Solicit for projects
7	Demonstrate feasibility for biorefinery applications
8	Demonstrate cost-competitive technologies in plant testing
9	**Paper web dewatering system**
10	Prototype development
11	Complete field testing to validate dewatering to 70% dryness
12	**Advanced Gas Separations**
13	**Advanced Membrane Separation Systems**
14	Solicit projects to address scale-up and manufacturability issues
15	Demonstrate on important process streams
16	Continue development for improved robustness, selectivity
17	**Molecular modeling tools for predicting molecule/adsorbent interaction**
18	Initiate projects
19	Develop modeling tool prototype
20	**Hybrid Distillation**
21	**Distillation Column Modeling Tool**
22	Technology development
23	Complete field testing and initiate commercial introduction
24	**Hybrid Systems**
25	Select hybrid systems for concept development
26	Demonstrate hybrid system concept feasibility at bench scale
27	Demonstrate 40% efficiency at bench scale
28	Scale-up hybrid system to pilot-scale unit
29	**Energy-Intensive Conversion Processes**
30	**Catalyst and reactor system development**
31	Identify and scale-up most promising catalysts
32	Demonstrate catalysts at lab-scale
33	Pilot-scale demonstration of oxidation and energy-intensive conversions for conventional systems
34	Scale-up reactor to pilot-scale unit
35	**Novel separations processes**
36	Solicit projects for olefin, chlor-alkali, ammonia, and chemical pulp production
37	Demonstrate feasibility for novel processes with 15% energy intensity reduction



Industrial Reactions and Separations			
Focus Area	Barriers	Pathways	Metrics
Advanced Water Removal <u>Objective</u> Develop non-thermal water removal technologies that will reduce the energy requirements for water removal in high-volume process industries and emerging biorefineries	• Uncertainties in applying new processes to different types of paper grades and biomass • Regulatory (environmental) concerns for new technology implementation • Technology acceptance in mature industries with sunk capital costs • Economic attractiveness of efficiently recovering dilute products	• Develop non-thermal water removal technologies that substantially reduce energy use in paper drying, black liquor concentration processes and other industrial processes. • Develop improved water management technologies for the production of large volume fuels, chemicals, and materials from renewable feedstocks, thereby improving price competitiveness with petroleum feedstocks • Develop water removal technologies for other large water-intensive applications, such as food processing	1. Demonstrate non-evaporative technology that would reduce the energy by 20% per gallon of water removed without process or product degradation. *Total potential savings for this focus area estimated at 500 trillion Btu/year*
Advanced Gas Separations <u>Objective</u> Increase energy efficiency of membrane and adsorption technologies for gas separations by 30%, including oxygen/nitrogen separations, along with H_2, CO_2, and CO separations by simplifying gas production processes	• Existing technologies for large-scale gas separation technologies result in gases that are not economically competitive in many applications • Large capital investments already made for existing, established technologies	• Develop robust membrane separation systems that operate on real process streams, integrate effectively with other processes, can operate in harsh high-temperature environments, are easy-to-install, and have lower maintenance costs • Investigate novel material concepts for dilute streams; develop scaleable, low-cost manufacturing techniques; identify step-change technologies that create surface areas; and develop simulation packages for membranes • Develop adsorbents with high selectivity for complex mixtures; integrate materials research and process development; improve adsorbent forms and geometries; and demonstrate on important process streams • Develop switchable adsorbents using non-thermal desorption technologies; improved high-performance conductors; non-conventional ways to desorb adsorbed molecules; process design tools for technology comparisons; non-conventional adsorbents (e.g., micelles, liquid crystals, enzymes, colloids); and molecular modeling tools	1. Demonstrate robustness of advanced membrane separation systems on real streams; correlate data on adsorbents for high selectivity in complex mixtures (FY 2009) 2. Demonstrate adsorption technology on key process streams (FY 2010) 3. Demonstrate molecular modeling tools that predict interaction of molecules with adsorbents (FY 2012) *Total potential savings for this focus area estimated at 60 trillion Btu/year*

Energy-Intensive Conversion Processes <u>Objective</u> Develop new catalysts, reaction processes, and purification processes to improve yields of the most energy-intensive conversion processes, including oxidations	• Existing catalysts have limited selectivity, stability, and durability and are often expensive • Limitations of homogenous gas-phase oxidation • Limited applicability and acceptance of new processes and alternate feedstocks	• Develop new catalysts, reaction processes, and purification processes that improve catalyst selectivity and conversion during the production of ethylene oxide, terephthalic acid, and phenol • Develop integrated catalyst, media, and reactor designs for new oxidation process • Develop novel separation technologies that enhance product purification, solvent recovery, and dehydration	1. Demonstrate 40% increase in reaction yields for conventional systems at pilot scale (FY 2012) 2. Demonstrate 15% energy intensity reduction at the pilot scale, using new manufacturing processes for olefin, chlor-alkali, ammonia, and chemical pulp production (FY 2015) *Total potential savings for this focus area estimated at 200 trillion Btu/year*

2.1.7.2 High Temperature Processing

Background

High temperature processing refers to the processing of raw materials and intermediate products at elevated temperatures in order to produce intermediate or finished products and alter the thermo-physical and chemical properties of the materials being heated, including both metals and non-metallic minerals.

Opportunities abound to develop and deploy improved technologies for processing raw materials and intermediate products (both metals and non-metals) at elevated temperatures that rely on the alteration of thermo-physical and chemical properties of materials to achieve product specifications in existing and emerging industries.

Key stakeholders include:

- Metal manufacturers
- Glass and ceramic manufacturers
- Metal casting industry
- Automotive industry.

Strategy

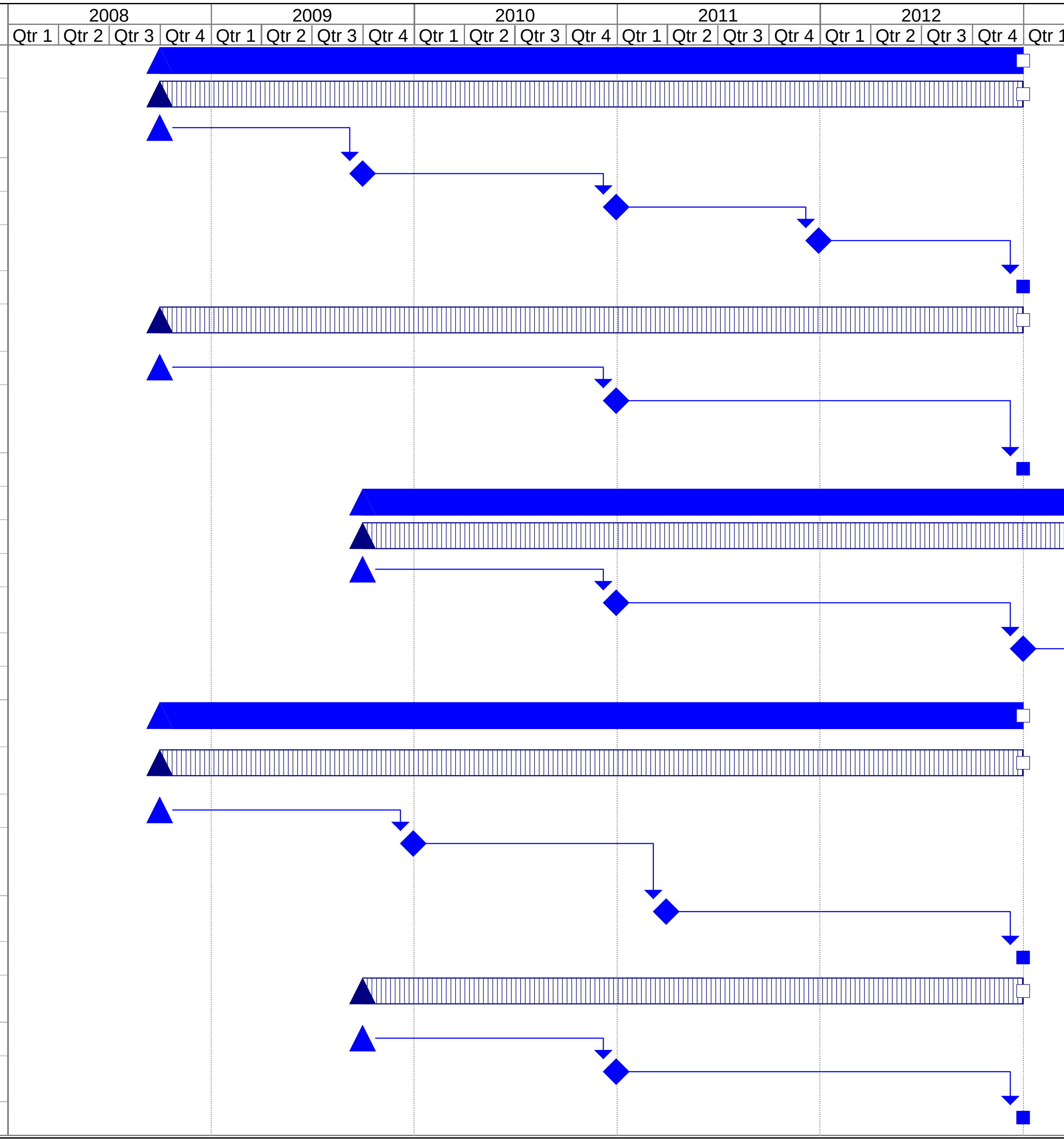
The overarching objectives of the cross-cutting high-temperature processing platform are to significantly increase the efficiencies of existing energy-intensive high-temperature processes; develop advanced materials and breakthrough technologies to significantly reduce energy intensity and greenhouse gas emissions; and develop new low-energy processes and products for emerging industries. Investments under this platform will reduce energy consumption by deploying lower-energy alternatives to conventional high-temperature processing technologies that currently account for nearly 50% of industrial energy usage today; and developing and implementing sophisticated transient thermal processing techniques to enable the manufacture of new energy devices that currently cannot be processed using conventional global high-temperature processes because of materials limitations.

The technology areas for R&D investment under this platform include:

- Low-Energy, High-Temperature Materials Processing
- New Materials Development
- Materials Processing for Enabling Emerging Industries.

HIGH-TEMPERATURE PROCESSING

ID	Name
1	**Low-Energy, High Temperature Material Processing**
2	**Excitation Technology**
3	Conduct technical assessment of excitation sources
4	Solicit for projects
5	Manufacture prototype systems
6	Demonstrate prototype systems and demonstrate in industrial processes
7	Complete commercialization planning
8	**Sensors and controls for high temperature processing**
9	Solicit for projects
10	Develop sensing and control systems for existing processes and evolving transient processing
11	Demonstrate in industrial applications
12	**New Materials Developments**
13	**New Material Systems**
14	Identify new materials systems (at least 5)
15	Conduct technical assessments of performance characteristics
16	Conduct pilot-scale demonstration
17	Complete commercialization planning
18	**Materials Processing for Enabling Emerging Industries**
19	**Low-cost manufacturing processes with increased conversion efficiency**
20	Initiate concept development
21	Develop technology concepts for processing high-temperature materials on broad areas of low-cost organic substrates
22	Demonstrate effective adaptation of 2 prototype systems
23	Complete commercialization planning
24	**Sensors and controls for enabling processes**
25	Initiate concept development
26	Develop sensing and control systems for laboratory units
27	Conduct pilot-scale demonstration



High-Temperature Processing			
Focus Area	Barriers	Pathways	Metrics
Low-Energy, High-Temperature Material Processing <u>Objective</u> Reduce energy demands associated with conventional heat soak treatment cycles by developing high-power, yet low-energy transient thermal processes	• Lack sufficient understanding of the effects of thermal transients on final material properties • Existing processes frequently require long treatment cycles • Infrastructure changes and costs impede large-scale implementation of alternate technologies	• Develop new low-energy, high-temperature transient processing methods, including those that shorten manufacturing cycles and those that could use alternative fuels in industrial processes • Develop advanced thermo-physical modeling techniques and integrated process monitoring and controls	1. Demonstrate feasibility for ≥20% energy reduction using at least three new low-energy, high-temperature transient processing methods (FY 2010) 2. Manufacture prototype systems and successfully demonstrate their commercial viability in plant trials (FY 2012) *Total potential savings for this focus area estimated at 150 trillion Btu/year*
New Materials Developments <u>Objective</u> Enhance the performance of advanced steels, alloys, and other materials by modifying compositions and prescribed thermal mechanical processing	• Unproven reliability, safety, and cost-effectiveness of new materials • Environmental impact and operational costs of new material production and use	• Develop key materials and alloys that enable enhanced and more efficient processes, while decreasing their environmental impact and operating costs • Develop new materials for additional applications, including transportation infrastructure, land vehicle systems, industrial reaction systems, power generation, and alternative energy areas	1. Demonstrate a minimum of 10% energy savings in at least three new materials systems in commercial manufacturing applications (FY 2013) 2. Achieve 20% energy savings from the demonstration of additional materials and expanded applications (FY 2015) *Total potential savings for this focus area estimated at 150 trillion Btu/year*
Materials Processing for Enabling Emerging Industries <u>Objective</u> Improve cost-competitiveness and performance of emerging alternative energy technologies that will enable the greater use of renewable energy in the U.S. in the next 15 years	• Difficulties controlling defects • Need to Reduce manufacturing costs and time • Inability to manufacture co-processed materials with vastly different melting points at a low cost • Need for large-scale deployment of new technologies	• Develop non-vacuum-based processing methods suitable for photovoltaics and other emerging alternative energy technologies • Develop technology concepts, such as plasma lamp technology, for processing high-temperature materials on broad areas of low-cost organic substrates • Develop sensing and controls systems for the new technology concepts	1. Demonstrate non-vacuum-based process heating technologies that increases production rates with 30% conversion efficiency (FY 2012) 2. Demonstrate 30% cost reduction and increased energy efficiency for processing alternative energy technologies (FY 2015) *Total potential savings for this focus area estimated at 100 trillion Btu/year*

2.1.7.3 **Waste Heat Minimization and Recovery**

Background

Waste heat minimization and recovery consists of equipment and technologies used to convert, transport, manage, and recover or reuse energy needed for industrial processes. These systems include process heating and steam, which account for most of the energy used in processes in U.S. manufacturing sectors. Because of inefficiencies and unrecovered waste heat, there are large energy losses associated with process heating operations and steam generation.

Opportunities abound in waste heat minimization and recovery to improve yields per unit energy for multiple elements of the material manufacturing and process industries by improving overall energy efficiencies through the use of advanced combustion and heat recovery systems.

Key stakeholders include:

- Glass, aluminum, petrochemical, chemical, forest product industries
- Food processors
- Energy, steel, specialty metals, refining
- Process and manufacturing equipment producers
- Biorefineries
- Alternate energy sector.

Strategy

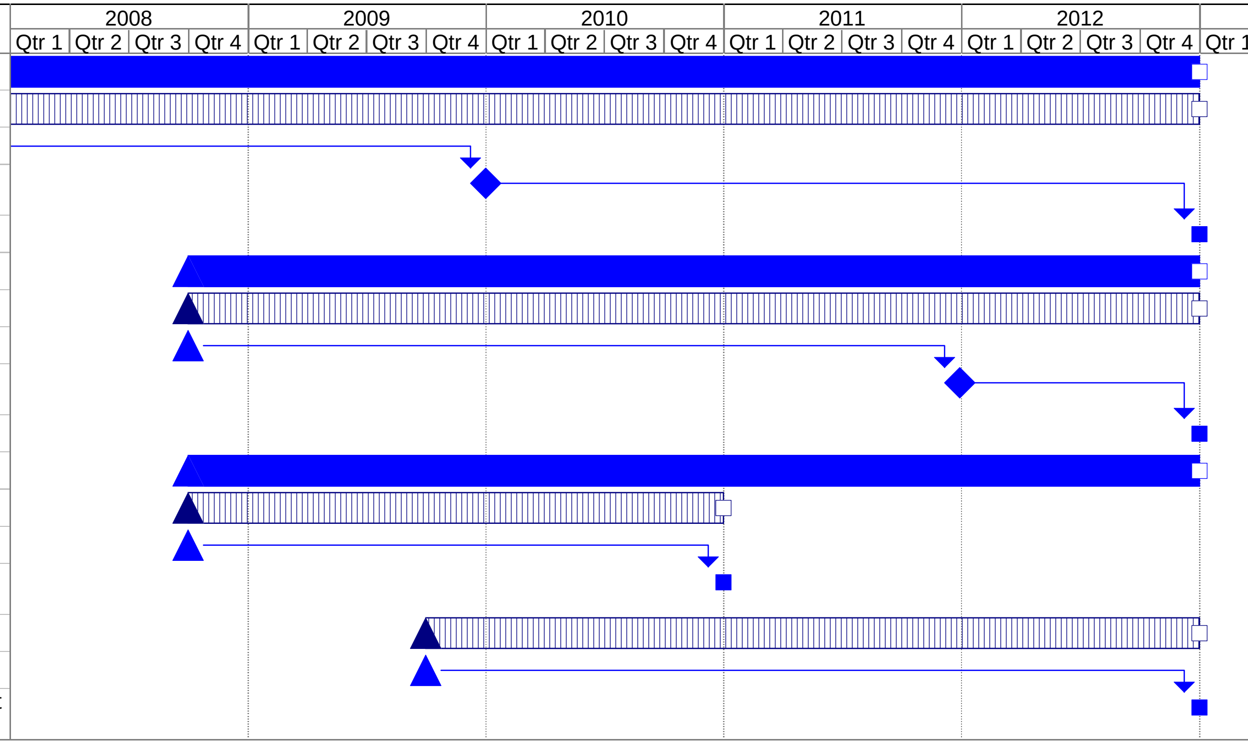
Minimizing and recovering waste heat from industrial processes is one of the largest energy savings opportunities, and will significantly improve overall manufacturing energy efficiency. Improving the market for steam boilers and furnaces requires investment in waste heat minimization technologies and advancing the deployment of relatively underused opportunities to reduce fuel demands using waste heat recovery. This includes concentrating on advanced heat transfer and energy conversion materials, coatings, systems, and testing; advanced heat transfer technologies; reduced fouling technologies; component- and system-level computational modeling and simulation; and advanced system validation.

The technology areas for R&D investment under this platform include the following:

- Super Boiler
- Ultra-High Efficiency Furnace
- Waste Heat Recovery Systems.

WASTE HEAT MINIMIZATION AND RECOVERY

ID	Name
1	**Super Boiler**
2	**Demonstration unit development and testing**
3	System development
4	Install Super Boiler for demonstration and monitoring
5	Complete demonstration
6	**Ultra-High Efficiency Furnace**
7	**Demonstration unit development and testing**
8	Solicit for projects
9	Pilot scale demonstration and performance testing
10	Install first commercial-scale furnace
11	**Waste Heat Recovery Systems**
12	**Integrated waste heat recovery package**
13	Solicit for projects
14	Install and demonstrate heat recovery system; quantify efficiency improvements and other
15	**Waste heat to electricity**
16	Solicit for projects
17	Develop units for mid-grade heat recovery with at least 5% conversion efficiency



Waste Heat Minimization and Recovery			
Focus Area	Barriers	Pathways	Metrics
Super Boiler Objective Develop technologies to produce steam with high efficiency, reliability, and lower costs; Super Boilers will generate steam with 25% greater efficiency and a smaller footprint than currently installed boilers	• Difficulty in achieving emissions reductions while increasing operational efficiency • Difficulty in expanding low emission designs to multi-fuel firing capability • Boilers are frequently rebuilt beyond their designed lifetimes instead of being replaced by new units	• Develop a boiler combining a suite of advanced technologies into a cost-effective, integrated package that includes stage-intercooled combustion with internal recirculation, micro-channel heat transfer, flue gas heat/water recovery, and smart control systems (first-generation) • Extend ultra-low emissions design from firetube boiler configurations to watertube configurations and advance multi-fuel firing capability (second-generation)	1. Demonstrate Demonstrate second-generation Super Boiler with similar system performance in a commercial installation and capable of utilizing a fuel other than natural gas (FY 2010) *Total potential savings = 230 trillion Btu/year*
Ultra-High Efficiency Furnace Objective Develop improved furnace technologies initially targeted for advanced aluminum and steel furnace applications	• Difficulty in developing new concepts without adding to process complexity • High capital costs; furnace designs need to be cost-effective to operate and demonstrate acceptable capital recovery • Risk associated with system reliability for novel technologies	• Develop ultra-efficient melting concepts with lower costs and reduced furnace size • Develop integrated furnace system incorporating advanced materials and sensors and controls to optimize performance	1. Demonstrate ability of prototype system to achieve >10% increase in furnace efficiency (FY 2010) 2. Demonstrate advanced furnace system in commercial aluminum or steel plant (FY 2012) *Total potential savings for this focus area estimated at 90 trillion Btu/year*
Waste Heat Recovery Systems Objective Develop and demonstrate cost-competitive technologies that recover and utilize waste heat from industrial applications	• Waste heat recovery can increase process complexity • Heat-exchange equipment encounters significant fouling and corrosive gases • Risk associated with recovery system reliability for novel technologies • High current cost of recovering waste heat to produce electricity	• Develop a cost-effective, integrated waste heat recovery package combining a suite of advanced technologies that can be deployed in multiple industry applications • Develop compact, light-weight, cost-effective materials, components, and systems to convert waste heat to high-value electricity at least one order of magnitude lower than benchmark technology	1. Demonstrate advanced, integrated waste heat recovery package in an industrial plant (FY 2010) 2. Demonstrate a low-temp (~150°C) heat-to-electricity unit that produces 100-W at 5% conversion efficiency in forest products, chemical, and petroleum refining industry applications (FY 2013) 3. Demonstrate a high-temperature (>700°C) heat-to-electricity unit that produces 100-W electricity at 12-14% conversion efficiency in glass and aluminum industry applications (FY 2015) *Total potential savings for this focus area estimated at 260 trillion Btu/year*

2.1.7.4 Sustainable Manufacturing

Background

Sustainable manufacturing supports the entire spectrum of manufacturing industries, enabling increased productivity and efficiency in a variety of core industrial processes. Investments in sustainable manufacturing will improve energy efficiency by developing and deploying technologies that enable the manufacture of components that have multiple market applications; and coupling various design options, materials combinations, and manufacturing technologies to reduce process steps or parts count to remove energy intensity from the supply chain at the systems level.

Key stakeholders include:

- Metal-forming/cutting and heat-treating industries
- Metals processing, forming, and component suppliers
- Transportation manufacturing
- Fabricated consumer product industry
- Process and manufacturing equipment producers
- Mining, chemical, petroleum, agriculture, pulp and paper.

Strategy

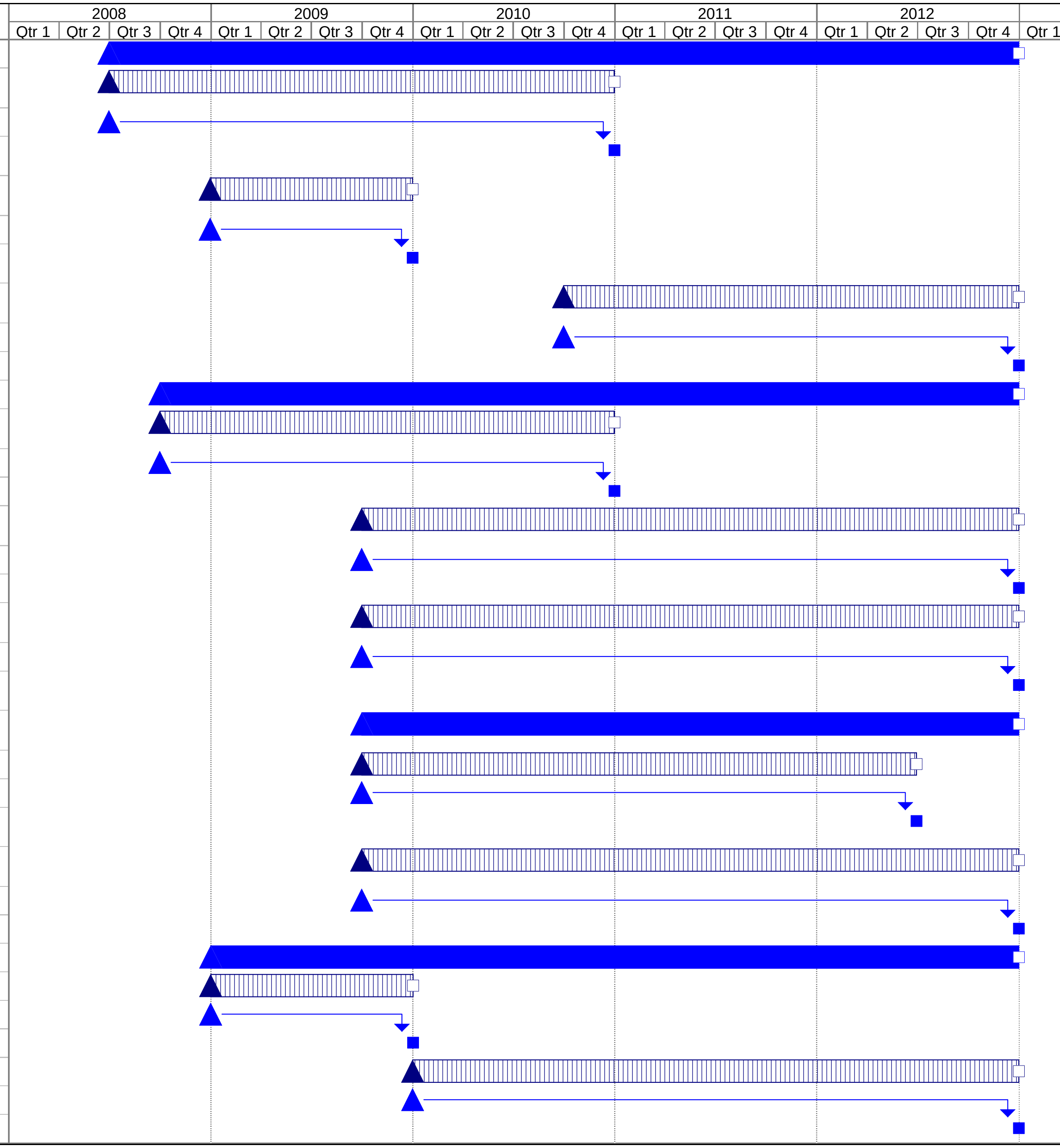
The sustainable manufacturing platform will improve yields per unit energy cost for multiple elements of the manufacturing supply chain and reduce waste and/or improve energy efficiency, while demonstrating air- and water-neutral production methodologies. Sustainable manufacturing focus areas are aligned with the need to address the efficient use of energy and sustainable energy resources in the processing of energy-intensive materials and components; the desire to increase the use of sustainable, renewable, and recyclable materials in the manufacture of energy-intensive products; and the identification of technology opportunities that exist with the global integration of intelligent design, process control, fabrication and assembly, and real-time product control.

The technology areas for R&D investment under this platform include the following:

- Net and Near-Net Design and Manufacturing
- Engineered Functional Materials and Coatings
- Advanced Casting, Forming, Joining, and Assembly
- Integrated, Predictive Manufacturing and Energy-Efficient Material Handling and Plant Operations.

SUSTAINABLE MANUFACTURING

ID	Name
1	**Net and Near-Net Shape Design and Manufacturing**
2	**Reduced energy near-net shape fabrication and forming technologies**
3	Solicit for projects
4	Demonstrate minimum 10% material yield improvement in three technologies
5	**Advanced melt and pour process control for near-net shape casting**
6	Deliver prototype components
7	Demonstrate in application such as automotive powertrain cases
8	**Develop tool-less free form manufacturing process**
9	Initiate concept development
10	Deliver prototype components
11	**Advanced Casting, Forming, Joining, and Assembly**
12	**Solid-state welding for advanced high strength steels**
13	Initiate concept development
14	Demonstrate at production rates
15	**Reduced energy casting and forming technologies**
16	Solicit for projects
17	Demonstrate concepts in industrial applications
18	**Integrated process control and NDE for forged components**
19	Initiate concept development
20	Demonstrate 10% reduction in out-of-spec product for in plant line
21	**Integrated, Predictive Manufacturing and Energy-Efficient Material Handling and Plant Operations**
22	**Integrated manufacturing control**
23	Solicit for projects
24	Demonstrate predictive inferential process control algorithms and models in plant operations
25	**Advanced factory materials handling and delivery systems**
26	Solicit for projects
27	Demonstrate systems in high-volume plant operations
28	**Engineered Functional Materials and Coatings**
29	**Analysis and Planning**
30	Establish working team
31	Identify barriers and solutions
32	**Material processing technology development**
33	Solicit for projects
34	Begin industrial demonstrations



Sustainable Manufacturing			
Focus Area	Barriers	Pathways	Metrics
Net and Near-Net Design and Manufacturing <u>Objective</u> Enable the development of highly-capable net and near-net shape forming and manufacturing technologies deployed within highly integrated design, process control, and intelligent manufacturing operations	• Existing free form fabrication for tool-less near-net shape forming has not achieved expected energy efficiency, material sustainability, and cost goals • Net and near-net shape manufacturing technologies lack intelligent tools and controls required to maintain competitiveness • Incomplete knowledge of relationship between materials properties and performance	• Develop reduced energy net and near-net shape metal fabrication and forming technologies that integrate design, process control, and real-time product properties • Integrate advanced melt and pour process control for near-net shape castings for applications such as automotive powertrain cases • Develop tool-less free form manufacture process for net-shape aluminum components for applications such as automotive chassis	1. Demonstrate a minimum of 10% material yield improvement for at least three reduced-energy net and near-net shape metal fabrication and forming technologies (FY 2010) 2. Demonstrate and validate >20% energy input reduction for selected metal forming and manufacturing operations with integrated efficient material handling systems (FY 2015) *Total potential savings for this focus area estimated at 140 trillion Btu/year*

Advanced Casting, Forming, Joining, and Assembly <u>Objective</u> Integrate design, process control, and intelligent manufacturing into casting, forming, joining, and assembly operations for increased energy efficiency and industrial competitiveness	• Successful deployment of energy efficient, high-yield materials depends on technologies that fully integrate design, development, and real-time control in a sustainable environment • Lack of robust integration techniques for employing intelligent manufacturing tools and controls to achieve efficient casting, forming, joining, and assembly • Joining and assembly must be accomplished without compromising dimensional and structural integrity	• Develop reduced-energy casting and forming technologies that integrate design, process control, and real-time product properties and performance monitoring that result in 10% material improvement • Develop cold forming and solid-state joining of aluminum structural components for applications such as vehicle bodies • Demonstrate manufacturing integration of efficient material handling and industrial plant operations to validate 20% energy input reduction for selected metal forming and manufacturing operations	1. Demonstrate >15% energy savings for solid-state welding for Advanced High Strength Steels (AHSS) at production rates (FY 2010) 2. Demonstrate an integrated process control and non-destructive materials characterization method that achieves a 10% reduction in out-of-spec products in a finished aluminum forged component line or similar application (FY 2012) 3. Demonstrate integrated forming, solid-state forming, and high-speed machining with intelligent process control and product characterization to achieve at least a 10% increase in material and/or product yield and 10% energy input reduction (FY 2015) *Total potential savings for this focus area estimated at 75 trillion Btu/year*

Integrated Predictive Manufacturing and Energy-Efficient Materials Handling and Plant Operations <u>Objective</u> Integrate predictive and intelligent design, material processing, physical and mechanical property sensing, and real-time process control and feedback into a sustainable manufacturing environment by focusing on the elimination of lost product, end-product optimization, energy efficient material handling and transport, and sustainable plant operations	• Lack robust predictive process and manufacturing control systems, integrated materials handling and management strategies, and real-time quality control systems needed to eliminate material and product waste • Manufacturers have been slow in adopting integrated intelligent manufacturing tools and controls for efficient and sustainable materials handling and plant operations	• Develop predictive inferential process control algorithms for key applications, such as multi-process metal forming operations • Develop and demonstrate integrative non-destructive and real-time product and process control tools to reduce material and product rejections • Develop real-time predictive control tools for energy-efficient materials processing and handling to reduce energy in high-volume operations, such as automotive vehicle paint lines	1. Demonstrate in-factory energy control and material recovery/abatement processes to reduce energy and waste materials by 20% for an automotive paint line serving 200,000 vehicles (FY 2013) 2. Demonstrate integrated non-destructive and real-time product and process control tools to reduce manufacturing material and product rejection rates by over 15% (FY 2013) 3. Demonstrate integration and intelligent control of multiple non-destructive evaluation, physical, and mechanical characterization tools, and advanced vision systems for complex multi-material fabricated structures (FY 2015) *Total potential savings for this focus area estimated at 130 trillion Btu/year*
Engineered Functional Materials and Coatings <u>Objective</u> Develop and deploy materials and coating technologies to enhance energy efficiency, reduce environmental impact, and improve sustainability of manufacturing processes; replace energy-intensive processes; or improve the energy efficiency of end-products	• Product performance requirements are constantly evolving and driving demand for advanced functional materials and surfaces, along with low-cost, energy-efficient manufacturing processes • Difficulties integrating sustainable manufacturing processes into existing plant infrastructure and operations • Difficulties integrating non-homogenous materials into a functional component/process	• Develop near- and long-term thermal, mechanical, chemical, and electrical performance targets for high energy-consuming manufacturing process equipment and products • Develop high-potential engineered functional material and coating technologies, such as: (1) ultra-hard, ultra-tough surfaces to improve reliability of forming and removal processes; (2) non-traditional surface processes to replace energy-intensive heat treatments • Integrate advanced engineered functional material and coating technologies into the manufacturing sector by: (1) developing material/surface treatment systems into manufacturing processes; (2) documenting energy and emissions metrics	1. Demonstrate manufacturing processes that reduce energy consumption by 25% by utilizing advanced materials and engineered surfaces (FY 2015) *Total potential savings for this focus area estimated at 100 trillion Btu/year*

2.1.8 Nanomanufacturing

Background

Nanomanufacturing is leading the next industrial revolution. Like historical developments of steam engines, electricity, and transistors, nanotechnology is a new frontier of science that is primed to completely disrupt a wide range of markets, industries, and business models worldwide. Similarly, it will provide our future manufacturing base with a new, radically precise, less expensive, and more flexible way of making products. Nanomanufacturing is the cost-competitive high-volume production of uniform nanomaterials and the integration of these nanomaterials into intermediate devices and finished products while retaining their unique properties at the nanoscale.

The U.S. government has invested $8.3 billion in nanotechnology research over the past seven years, under the framework of the National Nanotechnology Initiative (NNI). However, the vast potential of nanotechnology cannot be fully realized without significant investment in applied research to translate scientific discoveries into new manufacturing processes and products.

By employing nanotechnology, industry can:

- Increase productivity through higher reaction rates and/or lower processing temperatures. Nano-catalysts will improve the efficiency and specificity of chemical reactions.
- Produce new and improved materials that provide superior life-cycle benefits. Nanoparticles can make metals lighter, stronger and harder, and can impart better formability and ductility properties to ceramics.
- Reduce friction in mechanical systems. High wear resistance coatings and the use of nanoscale lubricants will reduce the energy requirements of energy systems.
- Allow for revolutionary, cost-effective production capabilities.
- Allow for precise control of defect quantification and location, thereby reducing raw material volumes, byproducts, and wastes.

Key stakeholders include:

- Federal agencies in the National Nanotechnology Initiative, including NIST, NSF, DOE Office of Science, and DOD
- DOE National Laboratories
- Technical Societies (e.g., ASME, American Chemistry Council, etc.)
- Nanotechnology developers.

Strategy

Industrial participants at the *2007 Nanomanufacturing for Energy Efficiency Workshop* (Baltimore, MD) repetitively voiced their needs for:1) high volume, reliable and consistent supply of nanomaterials, and 2) scalable unit operations to incorporate nanomaterials into products. Therefore, ITP will address these two major barriers that hinder the transition of nanoscience into industrial processes and products, by engaging:

- The development of innovative, pre-competitive process technologies for low-cost manufacturing of nanomaterials for a broad range of applications, including industrial processes, other energy technologies such as solar and fuel cell products, and general consumer products, and
- The development of technologies to enable the utilization of nanomaterials, either directly as a material (i.e., surface coated with nanocatalysts for much higher yield), or indirectly as an 'intermediate' device (i.e., nanosensors for thermal management), in energy-intensive industrial processes to improve overall efficiency.

To be successful in these two areas, efforts will also be required in:

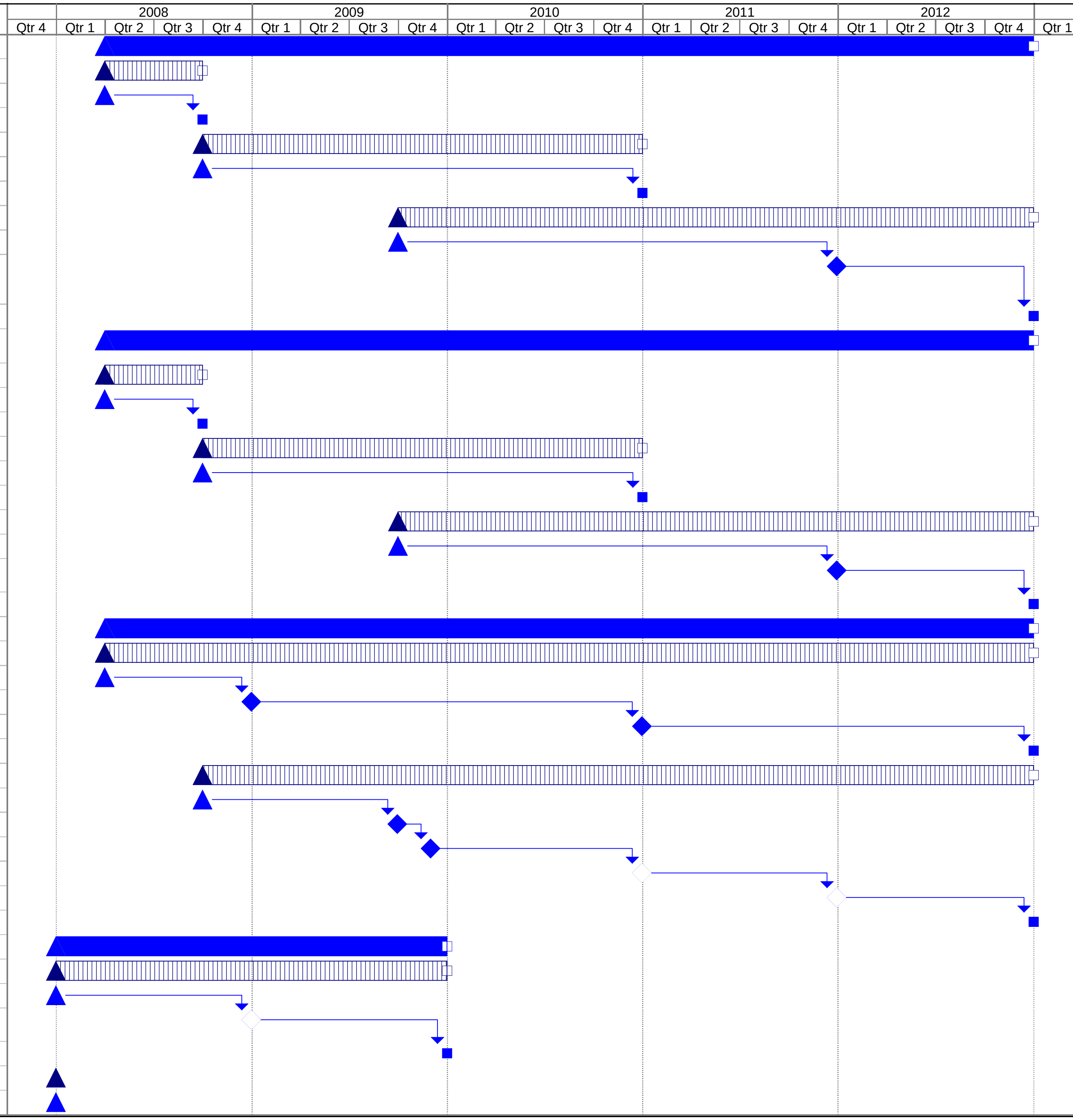
- Scaling-up laboratory fabrication methods techniques to low-cost, high-volume production, and integrating across scales: nanomaterials to nanointermediates to nano-enabled products, and
- Establishing and refining process and quality control techniques while manufacturing technologies are still evolving.

The ITP nanomanufacturing activity is also designed to be complementary to other programs of the NNI.

Last updated: 1/23/2008

NANOMANUFACTURING

ID	Name
1	**Nanomaterials Utilization in Industrial Processes**
2	**R&D Concept Definition Studies**
3	Start initial studies with national labs
4	Complete initial studies with national labs
5	**Nanomanufacturing R&D Projects: 1st Round**
6	Solicit 1st round of projects
7	Complete initial projects, move into stage 2
8	**Nanomanufacturing R&D Projects: 2nd Round**
9	Initiate lab call for "quick-win" projects
10	Move at least two technologies into stage 3 scale-up and develop two non-destructive quality control methods for incorporating nanomaterials into products
11	Conduct at least 1 industrial demonstration
12	**Enabling Proccesses for Nanomaterial Manufacturing**
13	**R&D Concept Definition Studies**
14	Start Initial Studies with National Labs
15	Complete Initial Studies with National Labs
16	**Nanomanufacturing R&D Projects: 1st Round**
17	Solicit 1st round of projects
18	Complete initial projects, move into stage 2
19	**Nanomanufacturing R&D Projects: 2nd Round**
20	Initiate lab call for "quick-win" projects
21	Develop two non-destructive quality control methods for nanomaterials production
22	Develop two production processes for nanomaterials
23	**Crosscutting Issues**
24	**Industry Committee**
25	Establish committee
26	Obtain initial feedback on user center(s)
27	Obtain committee feedback on research
28	Obtain committee feedback on research
29	**Nanomanufacturing User Center(s)**
30	Begin planning
31	Make decision on support for center(s)
32	Begin implementation (pending decision)
33	Have 5-10 external partners
34	Have 10 external partners
35	Have 10 external partners
36	**Studies and Analysis**
37	**Develop RD&D Plan**
38	Complete initial plan
39	Update plan, incorporating metrics and industrial feedback
40	Update plan, integrating research portfolio
41	**Industrial Nanomanufacturing Roadmap**
42	Publish roadmap



Nanomanufacturing			
Focus Area	Barriers	Pathways	Metrics
Enabling Processes for Nanomaterials Production (Stage 2 R&D) <u>Objective</u> Improve reliability of nanomaterials supplies and scale up production processes	• Lack of reliability of nanomaterials supplies • Lack of technologies to improve materials properties and performance • Lack of ability to disperse stable nanomaterials through final production • Lack of processing capabilities for high temperature processes • Lack of process control methods for nanomanufacturing processes	• Develop a series of economic scalable production systems that will produce uniform nanomaterials for a variety of markets • Develop robust, online characterization/monitoring tools for the production of nanomaterials to measure size, shape, and distribution for liquids and gas phases • Validate process scalability, product quality, and reproducibility	1. Two production processes for nanomaterials will be developed for commercial investments (stage 3/4) by FY12 2. Two non-destructive quality control methods for nanomaterials production will be developed by FY11
Nanomaterials Utilization in Industrial Processes (Stage 2 R&D) <u>Objective</u> Scale up manufacturing processes for utilization of nanomaterials in energy-related products	• Lack of scalable unit operations for reliable, cost-effective incorporation of nanomaterials into nanointermediates and products • Lack of ability to preserve the functionality of nanomaterials when incorporating them into nano-intermediates and products • Lack of characterization/monitoring tools for production processes that utilize nanomaterials • Lack of standard testing methods for quality of intermediates containing nanomaterials	• Modify existing (non-nano) industrial processes to incorporate nanomaterials into liquids, films, polymers, patterning, sprays, ceramics, metals, etc. for industrial applications • Develop non-destructive quality control testing methods for processes that integrate nanomaterials into industrial "nano-enabled" products • Scale up nanomanufacturing and process monitoring/control processes. • Validate process scalability, product quality, and reproducibility • Make systems available to industry through user facilities	1. Two nanomanufacturing processes will be scaled up for commercial investments (stage 3/4) by FY11 2. Two non-destructive quality control methods will be developed for processes of incorporating nanomaterials into products by FY11 3. One nanomanufacturing user facility will be set up for commercial use by FY09

Supporting Activities	Description
Studies & Analysis *<u>Objective</u>* *Support R&D strategy decision making by analyzing energy savings and R&D investment opportunities to maximize the subprogram's impact.*	1. Analysis of nanotechnology for energy applications: energy and economic impacts 2. Evaluation of options to convert nanoscale science R&D into applications R&D and commercialization 3. Evaluate options for industrial access to DOE funded nanomanufacturing capabilities to accelerate nanotechnology commercialization.
Technology Delivery *<u>Objective</u>* *Provide industry input to R&D strategy and promote commercialization of technologies.*	1. Form industry stakeholder interface 2. Implement mechanisms for giving industry access to ITP-funded nanomanufacturing facilities and investigate incubation support for entrepreneurial commercialization partners.
Cross-EERE Activities	1. Develop process to mine DOE-SC basic research projects and convert promising technologies into energy applications by technology innovation R&D 2. Develop interfaces with EERE programs performing enabling R&D to accelerate potential commercialization of nanotechnologies for energy efficient and renewable energy products

2.1.9 Industrial Distributed Energy

Background

Combined Heat and Power (CHP) is the sequential production and use of electricity and thermal energy from a single fuel. The widely recognized benefits of CHP include energy savings, cost savings, and reductions of CO_2 and other pollutants. CHP is a realistic, near-term option for large energy efficiency improvements and significant CO_2 reductions. While CHP is a well-established practice in large industrial processes with sizable electricity and thermal loads, *analyses indicate that there is still a largely untapped potential in applications less than 5 MW in electrical demand*. Increased deployment of CHP can help contribute to a 25% reduction in U.S. industrial energy intensity by 2017 and an 18% reduction in U.S. carbon intensity by 2012.

Industrial demand accounts for approximately one-third of U.S. energy and represents significant opportunities for energy savings. Relative to the separate generation of electricity and heat, CHP is one of the most effective commercially available alternatives for accomplishing sizable near-term energy savings and corresponding GHG reductions. A fully developed CHP market can lower energy consumption, offset imported oil, create job opportunities and improve the overall economic competitiveness of the United States.

All players in the energy industry are coping with fuel supply and price uncertainties, new and evolving federal and state energy policies, and the emerging need for new power infrastructure (generation, transmission and distribution). There are several key “big picture” drivers for energy utilization in industry:

- Projectections for increased worldwide energy use
- Availability of fuels and feedstocks
- Energy price volatility
- Environmental regulation of CAP and GHG
- Fuel flexibility to enable renewable and domestic energy use

All of these factors contribute to the competitive positioning of CHP. The CHP community finds itself facing a unique window of opportunity where many forces are converging to drive a complete re-evaluation of how energy is traditionally supplied, delivered and used. Because of the capital-intensive nature of electricity supply and transmission, the consequences of the decisions that national and state officials will make on technical approaches, private-public sector partnerships, environmental cost-benefit tradeoffs, portfolio of supplies, and financing and cost-recovery are those that we will be living with for decades. The CHP and broader clean distributed energy (DE) community needs to present a clear vision of how the value of what we offer addresses national, state and local energy issues and how our proposed alternative should fit in the evolving energy model. Key stakeholders include the United States Clean Heat and Power Association (USCHPA), States, and Industries with intensive heating and cooling loads.

Strategy

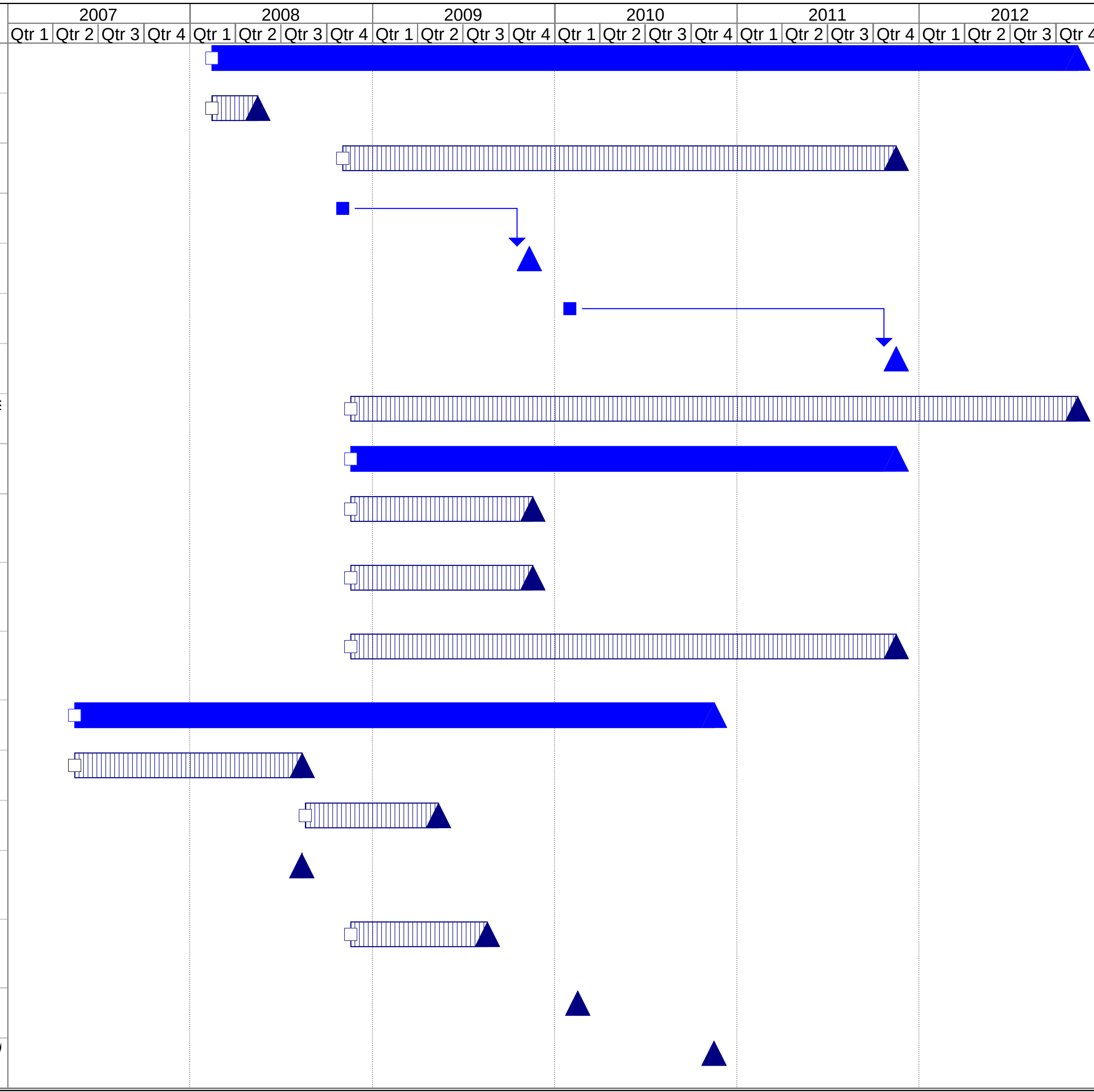
The programmatic approach developed recognizes the historic barriers to CHP market development, builds off of the success of predecessor DOE programs (DG/CHP Programs in Distributed Energy and Office of Electricity), leverages proven ITP technology delivery initiatives, and outlines a set of approaches and activities that done in partnership with key stakeholders will allow ITP to:

- Lead the deployment of technologies that will improve energy efficiency, reduce CO_2 emissions and improve industry competitiveness
- Address the barriers inhibiting CHP investment
- Serve as an independent voice of credibility on how to best deploy and apply CHP to optimize CO_2 reductions in industry
- Develop a strong coordinated communications plan to make to make CHP and industrial energy efficiency synonymous with industrial greenhouse gas reductions

ITP is undertaking a number of activities to spur widespread deployment of CHP in the United States. We are emphasizing innovative systems and applications that offer the greatest potential to reduce GHG through energy efficiency and displacement of fossil fuels by alternative fuels and waste energy streams. We provide technical expertise and catalyze consensus to resolve regulatory and institutional barriers that inhibit market development. The program also accelerates deployment of innovative CHP solutions by supporting demonstrations and technology performance validation projects done collaboratively with the private sector and other public sector entities. Partnering with private industry and states facilitates the transfer of innovation, information, tools, and services to a more local and regional level where key CHP regulatory policies are developed and where site-specific decisions on capital investment are made.

INDUSTRIAL DISTRIBUTED ENERGY

ID	Name
1	**Technology Development**
2	Program Plan for FY08
3	**Resume ARES R&D**
4	Begin Phase II of ARES
5	Complete Phase II of ARES
6	Begin phase III of ARES
7	Complete phase III of ARES
8	Develop advanced DG and TA technologies
9	**Technology Validation**
10	Commissioning of CHP system at food processing plant
11	Commissioning CHP system integrated into data center
12	Measurement and validation study on up to seven CHP installations
13	**Market Transformation/Commercialization**
14	Develop initial plan for RAC metrics
15	Implement RAC metrics at all centers
16	Rename RACs to Clean Energy Application Centers
17	Solicit proposals for Regional Clean Energy Application Centers
18	Initiate operation of new RCHP Centers
19	Achieve CHP2010 challenge goal of 92 GW



Focus Area	Barriers	Pathways	Metrics
Technology Development	• Emissions regulations keep getting tighter • Economic return and "spark spread" inhibit equipment purchases • Materials and operational capability issues with non-traditional [i.e. biomass/biogas] fuels • Lack of equipment to capture low-grade waste heat • Scalability of equipment	Develop clean, energy efficient distributed generation technologies that are capable of running on natural gas or renewable biomass/biogas fuels with no degradation of emissions profile, performance, or reliability, availability, maintainabilitiy or durability (RAMD). Technologies include: • Advanced Reciprocating Engines Systems • Microturbines • Turbines • Fuel Cells Technology development of thermal energy recovery technologies: • Desiccants • Chillers • Heat Exchangers Development of integrated systems that capture and use waste energy streams to produce useful energy forms with minimal incremental fuel input.	Clean DG, TAT, and CHP systems that are economic, and meet or exceed environmental requirements. AREAS Phase 2: 47 % efficient, 0.1 gBHP NOx. ARES Phase 3: 50% efficient, 0.1 gBHP NOx.
Technology Validation	• Companies are reluctant to be the first to adopt new technologies • Unproven technologies face financing obstacles • Need scalability, transferability, and replicability	Cost-shared demonstrations projects in targeted sectors: • High energy intensity • High energy consumption • High growth [such as data centers] • Non-traditional [such as food processing] • High opportunity for replicability • Have not fully implemented all energy efficiency opportunities	DG, TAT and CHP systems that are utilized and replicated across all industrial sectors. Demonstrate a CHP system at a food processing plant. Demonstrate a CHP system at a data center facility.
Market Transformation/ Commercialization	• Utility resistance • Regulatory Issues • Financing Risk • Knowledge Gap of Value Proposition	• Partnerships in priority sectors and states • Communications and outreach campaign' • Analysis • Technical outreach/best practices • Education and Training • Regional Application Center assistance	CHP systems are considered and evaluated in all energy efficiency projects.

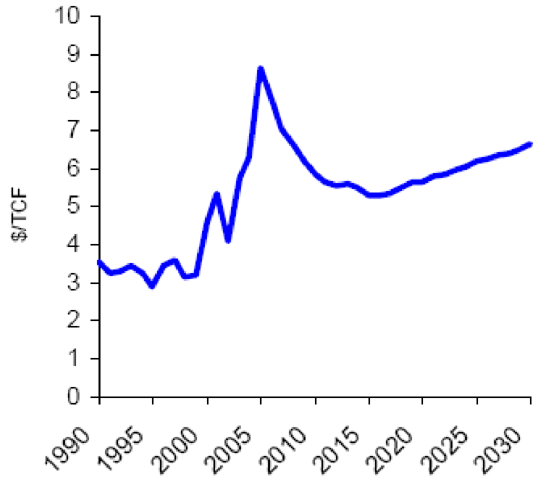
2.1.10 Fuel and Feedstock Flexibility

Background

U.S. industry, the largest user of energy domestically, is principally dependent on natural gas as a single major source of fuel or feedstock. After decades during which natural gas for industrial use traded at or below $3.50/thousand cubic feet (TCF), the turn of the millennium marked the beginning of unprecedented increases and volatility in natural gas prices. Increased use of the fuel across the economy coupled with diminishing domestic natural gas supply and production appear to have driven a fundamental shift in natural gas price behavior. In fact, Department of Energy (DOE) Energy Information Agency (EIA) projections indicate that the price of natural gas over the next 20 years will likely be more than double those of the past (see graphic below). In this environment, many industrial users whose competitiveness is predicated on inexpensive natural gas must seek alternatives for their energy requirements.

Alternative fuel use presents a sizeable opportunity for reducing natural gas use, particularly with the escalation in natural gas and petroleum prices since 2004. ITP is initiating a fuel flexibility program to accelerate the market adoption of emerging technology options for industry, such as the utilization of gasified fuels, landfill gas, and electrotechnologies. In March 2007, DOE completed an assessment* of whether flexible, alternative fuel use in industry presents a sizeable opportunity for the reduction in consumption of natural gas. In that assessment, opportunities and constraints were developed in light of three main areas:

- *Alternatives to natural gas and their displacement potential:* Addresses the maturity of technical solutions, the readiness and availability of alternative fuels/resources, the costs and risks required to adopt fuel flexibility options, the potential displacement amounts within individual industrial sectors, and short-term and long-term goals.
- *Industry interest in the initiative:* Addresses industrial actions underway to adopt fuel flexible solutions, industrial views on constraints (e.g., regulatory, technical), and industry's ability to overcome these constraints.
- *Appropriate government (specifically DOE) role:* Addresses gaps between actions industry has already taken and the identified constraints, constraints best addressed by the federal government, and targeted actions DOE can take to optimize the impact of industrial fuel flexibility and achieve displacement goals.



Source: EIA AEO 2007

The analysis determined there are significant opportunities for fuel and feedstock flexibility, and suggested a set of activities DOE could undertake to accelerate a program for industry. (The *Opportunities and Constraints* report listed some 30 potential actions matched to the specific constraints identified by industry. These form the basis of this program plan.)

Strategy

DOE's early work to evaluate the initial scope and possible outcomes for such a program has shown the need for research and demonstrations as well as targeted investigations, to prove the viability of fuel and feedstock flexibility options to a wide industrial audience. In broad terms, the program, which will be initiated in FY08, needs to be cross-cutting and provide insights into various methods to reduce the industrial consumption of natural gas. More importantly, the program needs to catalyze actions so that results are highlighted early and drive additional projects undertaken by industry. To that end, the program is designed to undertake actions in three broad categories:

- *Process Integration:* Conduct technical research to develop fuel flexible hardware.
- *Technology Validation:* Demonstrate the effectiveness of fuel flexible technologies in strategic applications.
- *Technology Platform Analysis & Education:* Enhance knowledge among industrial decision makers, catalyze stakeholder collaboration, generate reliable data, and analyses.

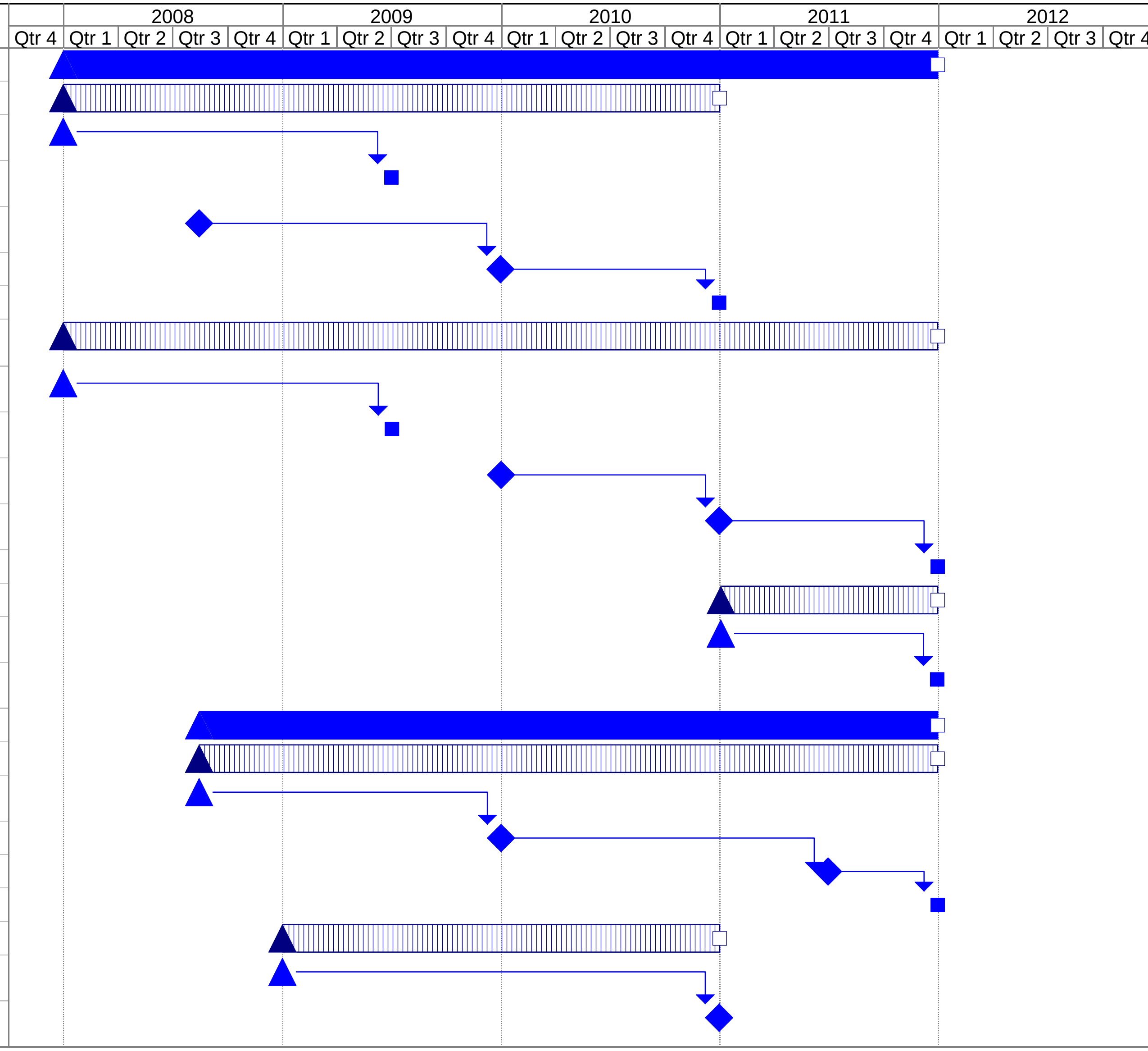
- Due to the breadth of potential program activities and the limited amount of available funding, early activities will emphasize (i) facilitating the use of natural gas alternative sources, (ii) demonstrating the technology requirements that need to be performed in an industrial setting, (iii) facilitating alternatives to natural gas as a feedstock in the broader chemicals sector, and (iv) disseminating industry-derived information on the management of technical, economic and regulatory issues. Related to this last point, the program needs to assess its ability to create a broad set of actions such that the net result of the entire portfolio of actions reduces greenhouse gas emissions.

* Booz Allen Hamilton, "Analysis of Fuel Flexibility Opportunities and Constraints in the U.S. Industrial Sector," Draft, March 7, 2007, Prepared for the Industrial Technologies Program, Office of Energy Efficiency and Renewable Energy, United States Department of Energy

Last updated: 4/25/2008

FUEL AND FEEDSTOCK FLEXIBILITY

ID	Name
1	**Process Integration**
2	**Fuel Characterization and Modification**
3	Analyze gas characteristics for impact on product quality
4	Identification of Gas Characteristics for use in Two Priority Applications
5	Establish or use existing laboratory facility testbed
6	Testbed Up and Running
7	Develop Emission Profiles
8	**Equipment Adaptation and Process Modeling for Conversions**
9	Develop Tool to Assist Industry Understand changes in conversion
10	Dissemination of Robust Process Modeling Tool
11	Support R&D on Burner & Fuel Supply Headers for Lower BTU Gas
12	Complete Modified Burner designed to run on <500 Btu/scf Gas
13	Complete Research
14	**Innovative Concept Development**
15	Establish Pilot Tests for Using Syngas as Alternative Feedstock
16	Pilot-scale Demo Conducted at Chemical Facility in FY11
17	**Technology Validation**
18	**Quality Performance Testing**
19	Establish or Use Existing Testbed to determine impacts of various syngas blending
20	Testbed Established
21	Complete initial testing of Syngas Blending
22	Complete Testing
23	**Industrial Market Demonstrations**
24	Support Efforts to showcase fuel and feedstock flexibility (FFF)
25	2-3 Pilot Scale demos running that validate benefits



Focus Area	Barriers	Actions	Metrics/Milestones
Process Integration *Fuel Characterization and Modification*	Without greater understanding of how fuel and feedstock flexibility will affect the chemistry of existing processes, and especially regulatory agreements and permits, industry is reluctant to move to a more fuel flexible regime. Specifically regarding fuel characterization, end-users have concerns about a) how air emissions will differ from existing operations what impact that will have on environmental permitting; b) how to integrate lower heating value syngas into industrial processes; and, c) how best to remove impurities in syngas to avoid downstream fouling.	1) Determine industrial issues and problems relating to use of alternative fuels. 2) Analyze impacts of alternative fuels on product quality. Document their gas and emissions characteristics and disseminate to industry. 3) Evaluate performance of fuel flexibility combustion systems, industrial burners, and advanced sensor and control systems. 4) Support R&D for processes for gas conditioning and for hot gas cleanup. 5) Develop and document options for variations in use of opportunity fuels and disseminate information to industrial end users and associations.	Develop a database of gas properties and emissions for alternatives to natural gas for industrial burners and other burner systems (FY08). Document impact of alternative fuels on product quality and the conditions for use in at least two priority applications (FY09). Develop technology option(s) for reducing emissions from combustion of alternative fuels to acceptable levels. (FY10). Establish or use existing laboratory scale test facilities to: - Document data on performance, emissions and reliability of reciprocating engines under a range of fuels (FY10)
Process Integration *Equipment Adaptation / Optimization and Process Modeling for Technology Conversions*	Industrial end-users have concerns about the mechanical and technical challenges in moving to fuel flexible technologies. Specifically, they are concerned about a) identifying the technical challenges and potential solutions; b) integrating lower Btu gas with boiler equipment; c) dealing with impurities from coal liquefaction and biomass pyrolysis; and d) designing handling systems for co-feed materials.	1) Create tools and/or models to address process conversion to opportunity fuels and optimizing system efficiency. 2) Support RD&D to design and test burner and fuel supply headers to run on lower Btu gas. 3) Support RD&D to prevent fouling of burners and boilers utilizing alternative fuels. 4) Support demonstration for more effective use of co-feed material handling systems. 5) Identify and clarify regulatory issues – such as those for wastewater, solids storage & handling, or feedstock harvesting – which may impede use of alternative fuels in direct fire and gasification.	Develop a process modeling tool to identify technical and process changes required during conversion to alternative fuel systems. Make model available to end-user industries (FY09). Complete design of modified burner to run on gas with Btu content of less than 500 Btu/scf (FY10). Validate burner equipment in field demonstration (FY11). Complete two pilot-scale demonstrations of co-feed material handling systems operating at efficiencies equivalent to conventional single-feed systems (FY10). Disseminate a guidance document for industry related to regulatory requirements (FY11).

Focus Area	Barriers	Actions	Metrics/Milestones
Process Integration *Innovative Concept Development*	Industrial end-users lack advanced, innovative, commercially ready fuel flexible technologies.	1) Support R&D for early-stage development of innovative fuel flexible technologies and identification of pathways to full-scale production and commercialization (e.g., gasifiers in the 30-70MW range). 2) Evaluate syngas as an alternative feedstock for a bulk chemical production (other than in ammonia process or in smaller scale operations)	Complete concept development and market analysis for at least three innovative fuel flexibility technologies for industrial application that can match or exceed energy and cost efficiencies when compared to conventional technologies (FY11). Conduct pilot-scale demonstration from a slipstream or similar process that does not interrupt existing operations at a chemical facility to validate technical and economic feasibility (FY11).
Technology Validation *Quality Performance Testing*	End-users who currently rely on the high heating value and high purity characteristics of natural gas for product quality cannot make the switch to a fuel flexible source without specific demonstrations to assure minimal impact on quality and performance.	1) Evaluate impact of low and medium Btu syngas on product quality derived from process heating operations, with particular emphasis on production processes that rely on flame temperature for product quality 2) Based on results of initial studies, convene a working group with gas owners & operators to examine issues and paths forward related to syngas/natural gas blending.	Complete testing and analysis of quality impacts from using low and medium Btu syngas in process heating operations, with particular emphasis on processes sensitive to flame quality (FY09). Establish or use an existing laboratory testbed facilitiy to determine how much syngas can be blended with natural gas without adversely affecting air emissions, turbine performance, equipment performance, and reliability of industrial equipment, including boilers, and process heaters (FY10). Complete initial testing of syngas blending in testbed (FY11). Verify ability of lower-Btu syngas/natural gas blends to meet required user needs and determine optimum blending ratios (FY10). Workshop report on syngas/natural gas blending identifying R&D, market and commercialization issues and path forward (FY11).

Focus Area	Barriers	Actions	Metrics/Milestones
Technology Validation *Industrial Market Demonstrations*	Without demonstrations of effective adoption of fuel flexibility and CHP technologies, industry managers are reluctant to undertake the financial risk of conversion.	Validate and showcase alternative fuels for process heating applications such as 1) CHP, 2) gasifiying fuel sources such as petcoke into multiple product streams and 3) direct firing replacement of natural gas.	Determine the technical and economic feasibility of fuel and feedstock flexibility by conducting 2-3 pilot-scale (or larger) demonstrations at industrial sites (FY10). Demonstrate at pilot scale (or larger) industrial equipment operating on landfill gas or other opportunity fuel (FY09). Demonstrate at an industrial site for at least one fuel source the technical and economic equivalence to natural gas. [(FY11).

Supporting Activities	Barrier	Year Started	Description
Studies & Analysis *Objective* *Support R&D strategy decision-making by analyzing fuel and feedstock flexibility and R&D investment opportunities to maximize the subprogram's impact.*	The full technological options of fuel and feedstock flexibility are not understood in detail	FY08	Perform application assessment analyses for promising technology platforms (e.g., gasification using petcoke, MSW, etc; CHP using syngas or opportunity fuels; biomass combustion; electrotechnology.
	Use of electrotechnologies is constrained by the fact that electricity is more expensive per unit energy than natural gas and, depending upon the nature of the regional electricity market, may be as volatile or more so. Also many electro-technologies do not scale well in that there are little or no economies of scale above a given module size	FY08	Determine the geographic areas, types of industrial applications, and load profiles that characterize the best candidates for electro-technologies. Create a database of examples that model industrial users can apply to their operations to determine cost savings possible through use of electrotechnologies. Develop and best practices share economic and technical assessments based on actual data from process heaters units that should be targeted for replacement with fuel-flexible equipment. Examine life-cycle net energy issues related to electrotechnologies.
	Examine knowledge base of alternative feedstocks for bulk chemical production	FY10	Determine where there is technical and economic potential and interest in a pilot test of chemical production via an alternative feedstock.
	Regional resources and supply chain requirements related to biomass and petcoke present issues	FY10	Evaluate and analyze optimal combinations of gasifiers, feedstock, and specific applications with a regional focus to identify opportunities to use petcoke in close proximity to where it is generated.
BestPractice Integration *Objective* *Provide outreach to industry, garner input to the fuel flexibility strategy, and promote awareness and implementation of technologies.*	There is limited awareness of information related to success stories, which in turn limits end-users ability to apply information to other projects	FY08	Initiate data and delivery of efforts going on worldwide - consider web-accessible database and targeted workshops. MILESTONE: Conduct workshop, in FY08, to disseminate information as to the state-of-the-art in fuels and feedstock flexibility.
	Industry may be unaware of federal and state incentives available for advanced technologies	FY09	Assemble listing of financial incentives available for technology pathways. Financial risk guarantees for innovative projects. Determine the role of ITP in mobilizing EPAct loan guarantees in the industrial sphere.
	Not all fuel flexible options reduce project-specific carbon emissions	FY09	Determine way to evaluate and blend portfolio so that overall balance of carbon is neutral. Explore current activity with respect to carbon capture & sequestration and how it applies to industry, specifically with respect to locations where industrial CO_2 can be used to enhance oil recovery (e.g. Texas).

2.1.11 Industrial Materials

Materials - (MAP21 - Materials and Processing for the 21st Century)

Background

Materials are critically important to our nation in all areas including energy, economic and strategic security. Materials are and will be key in greatly improving our nation's energy efficiency and strategic positions while enabling decreased environmental impacts. The National Academies (NA) report on 1) Globalization of Materials R&D: Time for a National Strategy states *" Maintaining access to as well as generating cutting-edge science and technology is essential if the nation is to sustain economic leadership and a strong national defense capability."* and *"The United States can gain from Materials Science and Engineering R&D globalization if it fosters increased productivity, efficiency, and a capacity for innovation". Also, t*he NA report Rising Above the Gathering Storm *describes "America must act now to preserve its strategic and economic security capitalizing on its knowledge-based resources, particularly in S&T, and maintaining the most fertile environment of new and revitalized industries that crete well-paying jobs".* Materials and desigs are the framework of our capabilites and are critically important throughout all segments of the economy i.e. manufacturing, transportation (including ground, air, and infrastructure), buildings, infrastructure, power generation and defense.

Strategy

The Materials MAP21 program consists of three major technical areas *1) Advanced Strategic Materials 2) Thermal and Degradation Resistant Materials and 3) Advanced Materials for Energy Systems*. There is a critical need in industrial operations and other sectors of the economy for materials with much improved degradation resistance, compatibility, thermal properties, strength, and service life. In addition, new limitations are evolving in some of the newer materials and alloys in use today. The program will include both near term *breakthrough* activities and longer term *R&D* leading to *commercialization.* The R&D will lead to increases in the performance of current and modified materials and the development of new advanced materials. New materials opportunities and processing challenges, (fabrication, joining, and forming) include 1) low cost titanium, magnesium and copper which are coming to the forefront industrially due to the need for corrosion resistance, light weight and materials compatibility, 2) new alumina forming advanced steels to replace alloys made with strategic materials including Nickel and Cobolt, 3) materials in new manufacturing systems especially in regard to thermal management and on the use of biofuels for energy systems including industrial scale processing systems, engines, heating systems and power generation, 4) bulk amorphous materials that possess high degradation resistance and hardness, 5) innovative light weight high strength materials ie. Mg, driven by fuel efficiency in the aerospace and transportation industries, 6) functional materials for energy systems including photovoltaics, light emitting materials, batteries, and thermoelectrics 7) ultrahard nanocoatings for hydraulics and tooling to reduce friction and wear, 8) bulk low cost processing of super hard - wear resistant materials, 9) advanced membranes for use in energy recovery from flue gas, 10) nanoceramics for use as industrial process sensors, 11) degradation resistant refractories for use in high temperatre - high alkali processes, and 12) aerogel materials as highly efficient thermal insulation. For example, traditional industrial applications for titanium include desalination, automotive, petrochemical, chemical, and heat exchanger, due to its inherent properties while the aerospace demand has driven the costs to record highs. The need for titanium is projected to potentially triple by 2015 and the automotive sector has identified magnesium as a key material in meeting its fuel efficiency goals. Magnesium, the lightest structural metal, offers one of the greatest opportunities for reducing vehicle weight. Several organizations, including the American Foundry Society and the United States Automotive Materials Partnership, have produced roadmaps for the development of magnesium for automotive applications. Efforts in the program will be in concert with DOE EERE, Bioenergy, Buildings, Solar, and Transportation; DOE OS; NSF and DOD).

Last updated: 02/18/2008

Materials

ID	Name
1	**New Materials Development**
2	Titanium
3	Initiate field test
4	Ti to be a separate program
5	
6	Materials for Industrial Utilization of Biofuels
7	Complete Biofuels materials test facilities & begin tests
8	Evaluate materials behavior and computational models
9	Develop and test prototypes in industrial systems
10	Alumina Forming Advanced Steels
11	Alloy development and industrial interactions
12	Industrial suppliers efforts, testing and evaluations
13	Support role Commercialization and ind. trials
14	Bulk Amorphous Materials
15	Initiate industrial interactions and tests
16	Develop next generation materials and applications
17	Support role in Commercialization efforts
18	Innovative Light Metals (Mg)
19	Development of Mg for energy systems
20	Prototype testing and eval. in Alt energy systems
21	Install and test components in ind. systems
22	Advanced Functional Materials for Energy Systems
23	Development of Functional materials
24	Prototype testing of functional materials
25	Install and test in industrial systems
26	Nanocoatings for High Eff. Ind. Hydraulics and Tooling
27	Verify energy benefits with prototypes and products
28	Demo. 50% benefit of wear and commercialize
29	Bulk AlMgBoride Hard-Wear Resistant Mat.
30	Demonstrate pilot plant scale production
31	Reduce cost of materials and commercialize
32	Advanced Membrane Separations Technology
33	Select one prototype mat. and initiate testing
34	Eval. prototype & fabricate and test in Ind. Env.
35	Nanoceramics for Industrial Process Sensors
36	Demonstrate functionalized catalytic structure
37	Performance validation and commercialization
38	Novel Refractory Mat. for High Temp. Alkali Env.
39	Develop new refractory materials and production
40	Demo. hot repair and themal eff. in Ind. tests

R&D Focus Area	Barriers	Pathways	Metrics
New Materials Development <u>Objective</u> Develop new materials that will require less processing in producing them and benefit user industries by increasing industrial process energy efficiencies, improving operational characteristics in use, extending service life, and be more economical to use.	1. Lack of low cost Titanium and Magnesium with useful industrially relevant end use properties	1. Develop manufacturable Titanium alloys and components from new low cost powder technology.	1.Enable 50% more energy efficient production of Ti alloy sheet and also reduce cost by up to 75% 1.Reduce energy use (fuel) of aerospace transportation sector by 20% (~100TBtu/yr); (In concert with DOD) 1.Reduce energy use (oil) of land based transportation by 20% (in concert with EERE Transportation and DOD. (2012) 1. Reduce energy use and enable large scale water purification – desalination by 20% (In concert with DOD)
	2. Lack of knowledge of the effects of biofuels on industrial processing systems and equipment	2. Develop a) testing and modeling capabilities to determine the affects of biofuel and biofuel additions on industrial process equipment and b) modify or develop new materials to enable the use of biofuels in industry	2.Develop biofuels materials degradation facility and begin materials testing. (2008) 2.Enable biofuels substitution in national industrial and transportation system (In concert with EERE Bioenergy, EERE Transportation and DOD). (2009)
	3. Lack of knowledge on the cause/s of degradation issues with currently available select alloys and the lack of economical next generation alloys	3. Develop new economical alumina protected steel alloys to outpace nickel alloys in capability.	3.Develop alumina forming advanced steel alloys and evaluate their behavior in industrial trials. (2010) 3.Enable 15% energy benefits in production systems through improved operations and less corrosion (~100TBtu/yr)(2020)
	4. Lack of manufacturing capabilities in being able to produce and utilize bulk amorphous alloys	4. Develop bulk amorphous materials to enable less friction and wear in industrial processes and equipment.	4.Complete industrial testing and initiate commercialization of new bulk amorphous materials. (2010) 4.Enable up to 30% improvement in operations and end use applications using hard materials and low friction components
	5. Lack of the availability of light metals and alloys able to meet critical requirements in future industrial applications	5. Develop industrial processes and manufacturable light metal Magnesium alloy components.	5.Complete industrial testing and initiate commercialization of new low cost Magnesium alloy sheet and near net shape processing. Enable 30% energy benefits. (In concert with EERE Transportation and DOD) (2011)
	6. Current materials lack characteristics required for economical advanced batteries, thermoelectrics, photovoltaics, and light emitting materials	6. Develop materials that meet industrial scale manufacturing and end-use requirements	6.Enable 2X conversion efficiency gain and 2x less manufacturing costs (2014); develop light emitting materials with up to 15X improvements over current systems (2014)
	7 . Ineffective or unavailable corrosion, erosion, and wear-	7.Develop robust ultrahard materials that can survive and keep their	7. Validate AlMgB14 nanocoating and powder processing technologies. Verify energy savings from friction reduction for

	resistant coatings.	qualities in harsh mechanical and chemical processing environments.	both hydraulic and tooling systems by using test prototypes with real product geometries. (2008) 7. Demonstrate 50% improvovement in friction and component life for ultra-hard boride coated tools and hydraulic omponents (2010)
	8. Technology for economic, bulk processing of super hard materials and fabrication of components not currently available.	8. Develop AlMgBoride bulk materials (New Start 2007)	8. Demonstrate manufacturing technology commensurate with prototype scale quantities (e.g., 1,000 Kg/month) of wear-resistant boride powder at a cost not to exceed $299/Kg will be formulated (2008) enabling commercial introduction of ultra-hard boride materials (2011).
	9. Lack of adequate membrane and catalyst materials for energy efficient, high performance separations and chemical processing.	9. Develop and evaluate membrane and substrate materials with sufficient corrosion and fouling resistance to water vapor from industrial gas streams (New Start FY2007)	9. Identify materials for membranes and substrates with heat and mass transfer sufficient to increase condensing water flux by 50%; plus toughness, ductility, corrosion resistance, and fouling resistance sufficient to operate in industrial environments. Select one prototype material for evaluation in the industrial environment for which it was developed (2008) 9. Fabricate and test prototype Transport Membrane Condenser system for recovery of heat and water from low-temperature process streams (2010)
	10. Lack of reliable sensors and control systems for real time feedback control of combustion processes and burner efficiency	10. Development of nanoceramic materials for novel sensors for combustion optimization in industrial processing. New Start (FY 2007)	10. Performance validation of a prototype sensing element in a simulated service environment for closed-loop, feedback control of industrial combustion with increased efficiency $\geq$ 0.5% with fuel savings $\geq$ 24 trillion Btu/yr (2009)
	11. Ineffective or unavailable high-temperature materials and refractories for optimum performance processing.	11. Reduce energy losses through development of advanced refractories for boilers, furnaces and kilns.	11. Develop new prototype refractory materials production and applications techniques for refractory systems with improvements of 20% in thermal efficiencies and $\geq$100% in life span (2008) 11. Validate life span and thermal efficiency performance of advanced refractories in plant field tests (2010)
	12. High levels of energy loss from industrial process streams, exhaust gases and fluids, containers, and equipment.	12. Develop manufacturing and installation protocols for application low thermal conductivity nanoporous, aerogel insulation to industrial systems. (FY2007)	12. Extend maximum use temperature of aerogel insulation to 1200F, and reduce estimated production cost by approximately 10%. Complete in-service tests of prototype materials to validate performance (2008) (Project ending in 2008)

Supporting Activities	Description
Studies & Analysis To inform programmatic planning and decision -making.	Globalization of Materials R&D: Time for a National Strategy; The national Academies, Aug 2005 Broad Federal Effort Urgently Needed to Create New, High-Quality Jobs for All Americans in the 21st Century, NEWS, The national Academies, 2005 Rising Above the Rising Storm, The national Academies, 2005 Industrial Technoloiges Program Research Plan for Energy Intensive Industries, Battelle, Oct. 2007 Industrial Markets for Titanium Manufacturing Energy Consumption and Impact of Lower Cost Processing, EHK Technologies, 2007 Energy Efficient, Economical Titanium and Titanium Alloy Production Using New, Low Cost Titanium Powders, ORNL 2007 Assessment of Market and Commercial Opportunities for Ultra hard Materials, Delta Research, MMPaCT, 2007 Engineering Scoping Study of Thermoelectric Generator Systems for Energy Efficiency Improvements of Industrial Manufacturing Processes, PNNL & BCS, Inc., September, 2006 Opportunity Analysis for Recovering Energy from Industrial Waste Heat and Emissions, PNNL, April, 2006 Energy Impacts of Corrosion, Energetics, Inc., September, 2005 Refractories for Industrial Processing: Opportunities for Improved Energy Efficiency, ORNL and BCS, Inc., December, 2005
Technology Delivery Success Stories (Available on web).	Case Studies: • Development and Demonstration of Advanced Tooling Alloys for Molds and Dies: A Technology Transfer and Commercialization Case Study of RSP Tooling (April 2005) • Advanced Materials for the Pulp and Paper Industry (2005) • Intermetallics for Manufacturing (2005) Recent Highlights: • Award Winning Treatment Process Hardens Stainless Steels and Improves Corrosion Resistance (December 2006) • Development of R&D 100 Award Winning Alloys Resistant to Metal Dusting (October 2006) • Real-Time Characterization Project Addresses a Priority Need in Nanomanufacturing (October 2006) • Metal Infusion Surface Treatment (MIST) Technology Wins R&D 100 Award (July 2006) • New Software Tool Identifies Opportunities for Energy Savings in Galvanizing Lines (June 2006) • Novel Ceramic and Refractory Components (March 2006) • Corrosion Resistant Materials for Molten Metal Processing (February 2006)
Cross-EERE Activities	• Our Solar Future, The US Photovoltaic Industry Roadmap for 2030 and Beyond, US DOE, EERE, Solar Energy Technologies Program (Sept. 2004) • Energy Savings Potential for Slid State Lighting in General Lighting Applications, rthur D. Little, Inc., Office of Building Technologies, US DOE, (April 2001) • Annual DOE Energy Materials Coordinating Committee (EMaCC) Report • Organize Annual Inter-Agency Communications and Coordination Meeting on Metals Research

2.1.12 Combustion

Background

Combustion systems are used to generate steam and heat for use in vital manufacturing processes, to heat processing materials as diverse as metals and chemical feedstocks, and to change the mechanical and chemical properties of materials and products. These functions are critical to the production of basic manufactured goods used in all segments of the U.S. economy.

The performance of an industrial combustion system is generally determined by the performance of individual boiler or furnace subcomponents and the compatibility of various component technologies within the overall system design. The challenge is to optimize energy efficiency, operating and capital costs, and compliance with emission regulations at the same time in the face of the following challenges:

- Boiler and furnace system design parameters are inter-related and interdependent,
- Pushed to extreme performance, new problems will occur (control, safety, and durability),
- System integration and component compatibility issues are complicated, and
- One single conventional technological approach will not meet all needs, so that many different technology platforms are needed.

ITP's "Energy Use and Loss Analysis" estimates 400 trillion Btu of savings could be achieved through the development and deployment of advanced boilers alone. Combustion R&D currently centers on steam generation.

The Combustion subprogram is being transferred into the Energy Intensive Processes Program Area. Program components will be most included in the Waste Heat Minimization and Recovery Platform. The main intent of combustion related activities remain the same.

Strategy

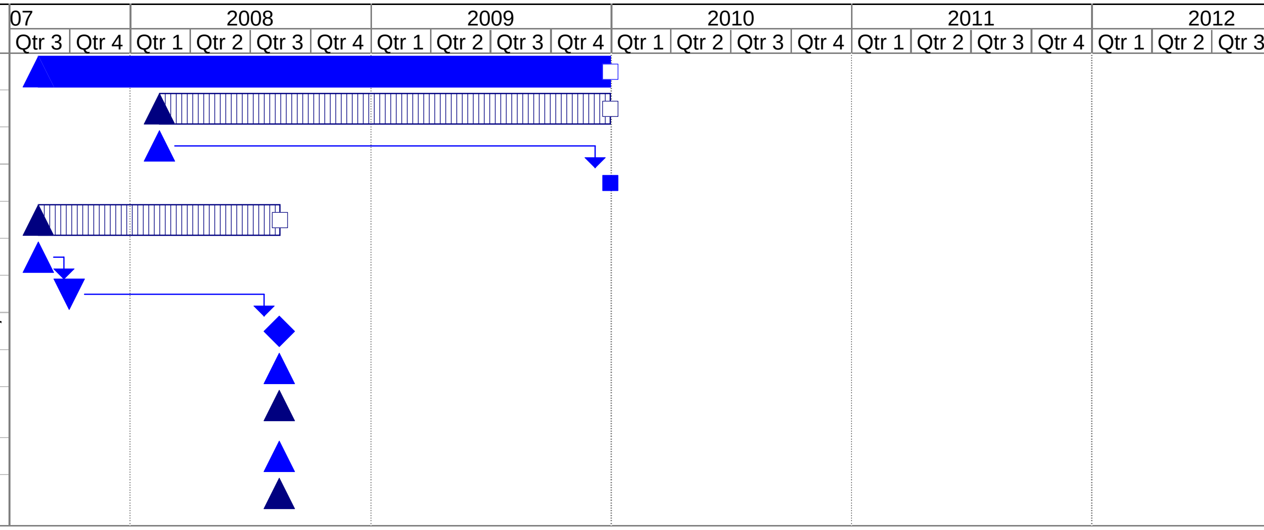
The Combustion subprogram supports a portfolio of cost-shared, pre-competitive R&D projects to develop advanced technologies that will improve the energy efficiency of fired industrial systems. Fired systems consume approximately two-thirds of the energy used by industry. The focus of the portfolio is on R&D that is too risky for industry to fund alone yet will have high impacts on industrial energy use. Projects in the portfolio are focused on developing both revolutionary technologies and incremental improvements to existing processes, thereby addressing both long-term goals and short-term opportunities to improve energy efficiency.

The Combustion program is currently focused on steam generation. Technical barriers, metrics, and goals were identified through interaction with private sector stakeholders. ITP then defined R&D pathways appropriate for federal funding. These pathways will lead to the development of competitive technologies that will improve the efficiency of industrial manufacturing by reducing energy use, lowering emissions, improving productivity, and lowering capital and operating costs.

Last updated: 5/9/08

COMBUSTION

ID	Task Name
1	**Steam Generation**
2	**First Generation Super Boiler**
3	Complete Tests
4	Commercialize
5	**Second Generation Super Boiler**
6	Restart Projects
7	Start Lab Evaluations
8	Transfer to Energy Intensive Processes platforn
9	**Process Heating**
10	Ultra-high efficiency furnace - Transfers to Energy Intensive Processes
11	**Combustion System Design Tools**
12	Advanced Combustion Components & Design Tools - Transfers to Energy Intensive Processes



Focus Area	Barriers	Pathways	Metrics
Steam Generation (1) Note: Super Boiler is also discussed under "Waste Heat Minimization and Recovery")	• Available heat exchangers and waste heat recovery technologies have high capital and installed costs. • With current technology, it is difficult to simultaneously reduce emissions and increase efficiency. • Conventional technologies can not be easily adapted to the diversity of many different boiler design configurations. • Advanced burner developed for a particular boiler design may not transfer successfully to other boilers. • The turndown instability of lean premixed combustion systems is a barrier to reducing NOx emissions. (2)	Combustion currently funds the development of an ultra high-efficiency, ultra low-emission packaged firetube boiler. This "Super Boiler" technology will be applicable to very broad industrial steam generation uses. It will achieve 95 percent energy efficiency while producing only 5 parts per million nitrogen oxides and carbon monoxide emissions. A suite of component technologies including an ultra-low NOx burner, a high-intensity heat exchanger, an advanced transport membrane condenser for latent heat recovery, and a smart control system are packaged together on a new boiler platform. The individual technology components developed under this project will be retrofittable to many types of existing boilers. The first generation "Super Boiler" is currently being field tested. Research on the second generation "Super Boiler," with a watertube configuration, same efficiency and emissions goals, has been initiated. A Multi-Staged Printed Circuit Boiler for Industrial Applications is also being developed.	Develop firetube boilers with >94% fuel to steam efficiency, <5ppmv NOx and CO, and 50% reduced size and weight. Develop watertube boilers with >94% fuel to steam efficiency, <2ppmv NOx and CO, and 50% reduced size and weight. The watertube Super Boiler project will be merged with the Waste Heat Minimization and Recovery Platform in the Energy Intensive Processes Program Area. *Total potential savings = 226 trillion Btu/year*
Process Heating (1)	• Low compatibility of various combustion components within a furnace system. • Unreliable component technologies when operated at maximum performance limits. • High level of integration of industrial heating equipment with the other manufacturing process steps within a plant compromise system efficiency. • Narrow focus on specific designs on conventional process heating furnaces. (4)	A high efficiency Integrated Process Heater has been developed for the petroleum and chemical industry. This technology utilized sophisticate CFD modeling in the early phase of the furnace system design and component integration compatibility evaluation. The CFD modeling effort enabled this integrated process heater to achieve extremely uniform temperature distribution and improve the overall efficiency over conventional furnaces. An ultra low NOx burner with natural draft air was incorporated into the combustion system design. The process heater has been designed and is projected to exceed 95% efficiency with NOx below 10 ppm. This research is complete. An ultra high efficiency furnace will be developed and tested under the Waste Heat Minimization and Recovery Platform.	This activity has ended. Future Process heating activities will be conducted within the Waste Heat Minimization and Recovery Platform of the Energy Intensive Processes Program Area.

Focus Area	Barriers	Pathways	Metrics
Combustion Components and Design Tools (1)	• No reliable design tools to predict the efficiency and safety performance of new combustion systems. • Inaccuracy of CFD models for furnace flame predictions due to lack of understanding of the effects of turbulent flow on combustion chemistry. • Inadequate technologies for measuring and controlling key combustion parameters for ultra low emissions. • Limited performance on conventional waste heat recovery technologies.(4) (5)	Current R&D projects include the development of Advanced Diagnostics and Control for Furnaces, Fired Heaters and Boilers.	Develop a model for managing the combustion characteristics of a chemicals process heater that will result in an increase in efficiency of at least 10%. This activity is ending. Specific elements will be incorporated in the Waste Heat Minimization and Recovery Platform of the Energy Intensive Processes Program Area.

Sources

(1) U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Industrial Technologies, Industrial Combustion Vision, Washington DC, May, 1998, pg. 7.

(2) U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Industrial Technologies, Industrial Combustion Technologies Roadmap, Washington DC, July 2002, pgs. 19-24.

(3) Industrial Technologies Program Government Performance and Results Act Report, Fiscal Year 2005, Energetics Incorporated, December 2003, pg. 24.

(4) U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Industrial Technologies, Industrial Combustion Technologies Roadmap, Washington DC, July 2002.

(5) U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Industrial Technologies, Workshop Report, "Improving Industrial Burner Design with Computational Fluid Dynamics Tools, pgs. 15-16.

2.1.12.1 Combustion Roadmap

Technologies	Description
T1. Waste Heat Recovery	
Combustion Air Preheating	Waste heat transfer to incoming air stream by using cost-effective heat exchanger designs.
Condensing Heat Exchanger	Extract sensible and latent heat from flue gases by cooling the flue gases below the water vapor dew point.
Integrated System Design for Waste Heat Recovery	Design new systems to enable integrated waste heat recovery to reduce cost of waste heat recovery.
Hydrogen Generation	Produce H_2 by using waste heat as an energy source for a fuel reformer.
Organic Rankine Cycle	Use low temperature waste heat to power a rankine cycle and generate electricity.
Absorption Refrigeration	Use waste heat conversion to refrigeration.
Feedstock Preheating	Transfer waste heat to incoming feedstock
T2. Low Emission Combustion	
Improve Flame Stabilization	Enable operation of burners with fuel/air/flue gas ratios that significantly reduce NOx emissions.
Flame Sensors	Burner balancing and tuning for low emissions based on feedback from individual flames
Flue Gas Emission Sensors	Low cost emissions sensors that allow burners to operate at lower excess air and with low emissions.
T3. Design and Development Tools	
Enhanced Computational Fluid Dynamics(CFD) Models	Improve development and design precision based on predicted flow, heat transfer and chemistry
Validation Facilities	Confirm enhanced CFD predictions with pilot-scale testing.
Integrated Modeling	Models that can be used for real-time optimization of furnaces and boilers.

Technologies	Description
T4. Performance Optimization and Controls	
Integrated Designs	Integrate combustion heat recovery systems with furnace/boiler configuration.
Optical Temperature Sensors	Optimize furnace operation based on feedback from workpiece sensor.
Uniform Heat Flux Distribution	Shape flame for optimal heat transfer to load
Flame property sensors	Modify flame shape or composition based on feedback properties
Real time burner adjustment	Integrate sensors with burner control system to optimize performance in real-time.
High temperature materials	Materials with cross-cutting use such as durable, high temperature refractories, corrosion resistant heat exchanger materials and high temperature metal alloys.
Industry specific process quality controls	Improved control of product quality and yield.
Model based control	Tune process operation based on predicted performance.
T5. Novel Processes	
Oxygen enriched combustion	Reduce process size, emissions and heat loss with oxyfuel combustion.
Biomass derived fuels	Replace or augment fossil fuels with renewable biomass fuel
Fuel flexibility	Ability to utilize multiple fuels while maintaining emissions and performance.
Integrated optimized heating system	A modular heating system that can be applied in a wide range of industrial processes.

2.1.13 Sensors and Automation

Background

The overall goal of ITP's crosscutting Sensors and Automation portfolio is to identify, develop and deploy integrated measurement systems for operator-independent control of manufacturing processes. These real-time on-line systems can be used by more than one industry and are fully compatible with the harsh industrial environment. Ultimately, systems will enable a level of productivity and product quality currently unattainable under human or machine control and produce a gain of at least 5% in energy efficiency. The Program's focus is on optimizing *systems* rather than developing individual components.

Strategy

After nine years in which seven ITP sensor portfolio technologies were commercialized, and are in use saving energy for industry, the ITP sensors activity is now in transition. The following will occur as a result of this transition:

- Existing Projects: Existing projects are being funded to completion.
- Commercialization/Deployment: By design, and as required by S&A, awardee teams are experienced in the manufacture and marketing of the types of technologies associated with their projects. ITP assistance to accelerate industry adoption is being provided through completed project fact sheets, success stories, technology readiness assessments and promotion at industry events.
- Legacy: S&A fact sheets, energy analyses, workshop output, and portfolio review presentations and documentation will be maintained on the ITP web site.
- Future: Sensors and industrial control systems will be incorporated into crosscutting technology platforms as appropriate.

S&A has been focusing on high payoff crosscutting technologies in three focus areas 1) advanced sensor technologies, 2) system performance monitoring and optimization, and 3) robotics. S&A fosters commercial introduction of its technologies by requiring for each project, partners for R&D, manufacturing the technology produced by the R&D, marketing that technology and, end user hosting to demonstrate the technology. All projects are cost shared, generally at 50%.

1) Sensors along with control systems are the cornerstone of modern industrial production. Sensors in concert with control systems provide the lowest cost route to energy savings through increased productivity and improved product quality. Sensors can be used to supply information to process control systems and can be used to establish the operating efficiency and "health" of industrial manufacturing infrastructure. Current sensor focus is on machine vision and microelectro mechanical system (MEMS) replacements for classic sensing systems. The goal is to improve product qualitythere-by reducing sub-par production ("rejects"), reducing the amount of product that is recycled, and consequently saving energy.

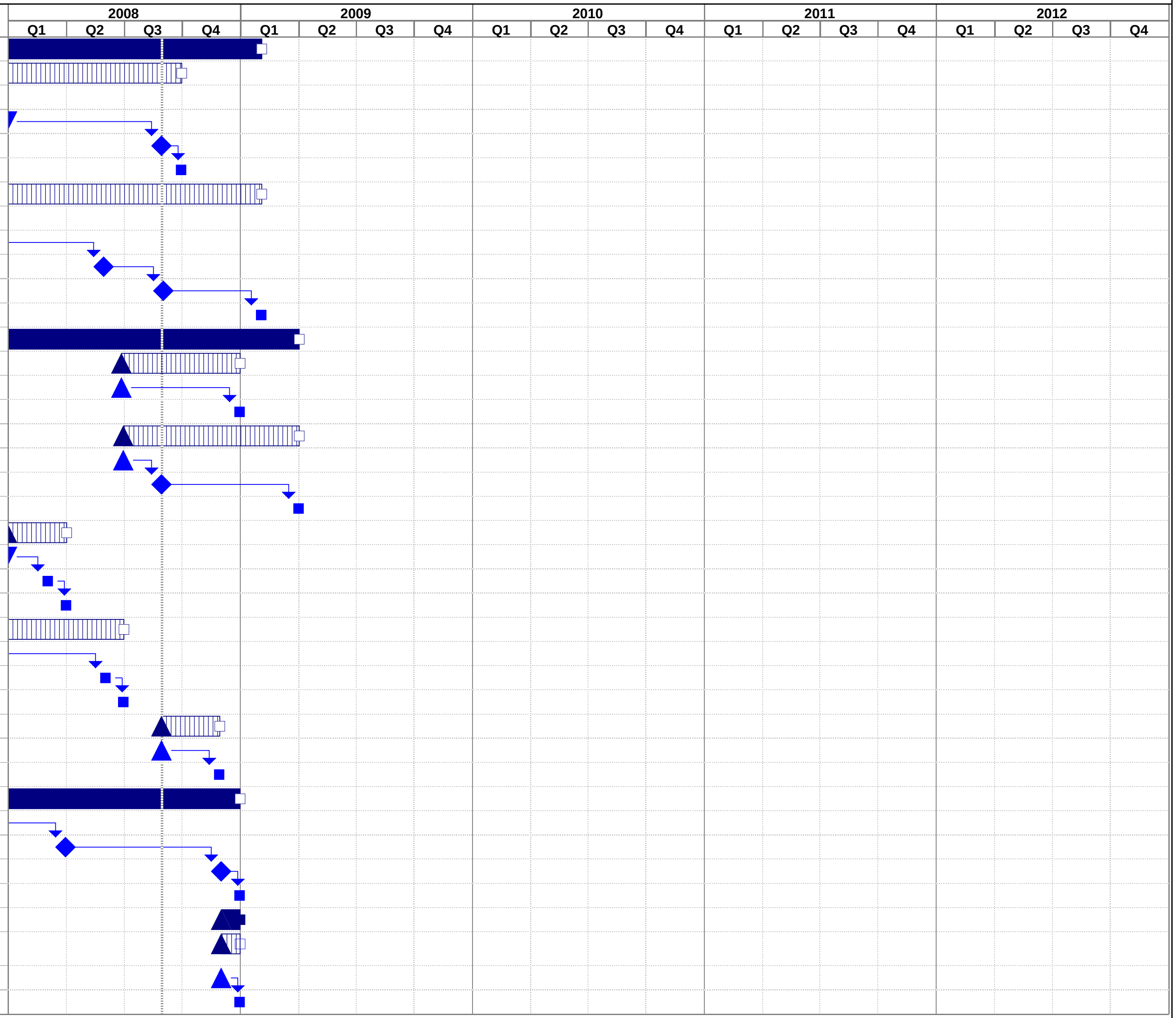
2) "Smart" systems will enable a level of productivity and product quality currently unattainable under human or machine control and produce a gain of at least 5% in energy efficiency. S&A is developing technologies that will facilitate the use of smart systems by more than one industry and in harsh industrial environments. For example, industry is turning to wireless technology as it continuously seeks to reduce costs, while realizing the productivity gains possible with advanced sensor and control systems. Wireless sensor systems hold the potential to help U.S. industry use energy and materials more efficiently, lower production costs, and increase productivity. Although wireless technology has taken a major leap forward with the boom in wireless personal communications, applications to industrial sensor and control systems must meet some distinctly different challenges. Presidential advisors have forecast that ubiquitous wireless sensors can improve production energy efficiency by 5 to 10%.Despite the technological advances resulting from cell phone development, many challenges remain before wireless systems can operate successfully in an industrial environment: security, interference rejection and long lasting wireless power, to name a few. These problems exemplify the R&D needs which must be met before wirelessly directed production lines can become reality.

3) Robots are flexible, taskable and reprogrammable manipulators. Virtually every S&A discipline can contribute toward making a robotic system successful. Many of the technologies associated with sensing and measurement, process control and automation are applicable to robotics. A robotic system can be thought of as a programmable mechanically articulated device that works to enhance the efficiency of a system which normally operates in the manual mode. A key difference between robotics and automation is that robotic systems are usually reprogrammable to accomplish different tasks while automation systems generally are not. A robotic system can enable the replacement of continuously run furnaces with on-demand induction heaters, reducing energy consumption by at least 25%. The strategy utilized in S&A's current robotics project is to create a robotically enhanced manufacturing line (REML) in which high-temperature compatible labor robots perform repetitive manufacturing steps that will allow the replacement of continuously run furnaces with on-demand induction heating. The final efforts will include documentation of opportunities for energy reduction (a 22% energy saving has been shown), productivity and environmental impact improvements associated with REML implementation in roller bearing production

Last updated: 5/5/2008

Sensors & Automation

ID	Task Name
1	Advanced Sensor Technologies
2	Honeywell Sensing Project
3	Critical Review
4	GC Field Test with Sampling System
5	End of Task
6	Tech Delivery
7	OG Surface Quality Project
8	Complete Market Analysis
9	Critical Review
10	Complete Root Cause Identification
11	Complete Testing
12	Draft Final Report (Tech. Delivery)
13	System Performance Monitoring and Optimization
14	ORNL Wireless
15	First Draft of First Wireless Standard
16	Complete Wireless Lab Testing
17	Eaton Wireless Project
18	Begin Plant Demo
19	Critical Review
20	Final Report
21	GE Wireless Project
22	Collect Field Test Data
23	Final Report
24	Tech. Delivery
25	Honeywell Wireless Project
26	Start Long Term Test
27	Draft Final Report
28	Tech. Delivery
29	STTR-KCF Technologies Power Harvesting
30	Critical Review
31	Draft Final Report
32	Robotics
33	Model Optimized Production Line
34	Implement Pilot Production Facility
35	Complete All Testing and Prepare Final Report
36	Tech. Delivery
37	Cross-EERE Activities
38	Conventional & Wireless Sensing for Product Quality Measurement
39	Transfer Technologies to Freedom Car
40	Tech. Delivery



R&D Strategy Focus Areas	Barriers	Pathways	Metrics
Advanced Sensor Technologies <u>Objective</u> Create commercially viable, industrially compatible sensors for use in process and equipment monitoring and process control.	1. Capital investment. 2. Sensor robustness and compatibility with the industrial environment. 3. Overly sophisticated sensors and control systems requiring operation by technically sophisticated personne. 4. Inappropriate user interface 5. Lack of cost-effective, reliable, robust sensors to monitor the process goal directly (e.g., sensors which measure temperature of workpiece, not of the furnace).	1. Complete development of process gas composition analyzer , couple with standardized sampling system and evaluate performance at industrial sites. Complete installation of microanalyzer at operating field sites (Q3-FY08). Use the following guidelines for sensors development: - Improve sensor capabilities and performance by following laboratory evaluation with plant production line testing and long term performance evaluation. - Make sensors compatible with the industrial environment. Specifically, sensors which are real-time, on-line and non-intrusive and which are fully compatible with the industrial environment is a long term goal. - Structure each project to enhance the likelihood of industrial adoption: each project team must include a member R&D organization plus an organization that is experienced in manufacturing the type of technology under development, an organization with experience in marketing the technology to the target market and a host site where the technology will be evaluateed and demonstrated.	1. Demonstrate improved process control due to use of micro gas composition analyzer resulting in energy savings of 1-5% depending on the application. *Total potential savings = 8 trillion Btu/year*

R&D Strategy Focus Areas	Barriers	Pathways	Metrics
System Performance Monitoring and Optimization <u>Objective</u> Develop open architecture, non-proprietary wireless sensor systems that are competitive with wired systems in performance and cost.	1. Limited performance characteristics and capabilities of current systems. 2. Limited sustained performance of current systems. 3. High cost of current systems 4. Perceived lack of security in wireless sensor systems. 5. Lack of applicable standards for reliable, robust wireless sensor networks.	1. Identify/modify/devise wireless systems meeting functionality, reliability and performance goals. 2. Create power system that matches wireless sensor system life - Identify battery + power management circuitry - Extract power from environment using power harvesting. 3. Facilitate development of standards for industrial wireless sensor networks which assure security..	1. Demonstrate the prompt identification of sub-performing, inefficient motors, saving 3-10% of electricity use of the motors for which this technology is applicable. *Total potential savings = 36 trillion Btu/year*
Robotics <u>Objective</u> Use robots to enable use of on demand induction heating in manufacture of roller bearings.	1. Uniform induction heating to cover range of workpiece geometries. 2. Shielding that minimizes electromagnetic flux leakage 3. A means to sense, grip and accurately position workpiece in induction heater	1. Develop a robotically enhanced manufacturing line (REML). Establish range of tooling, coils and heating recipes to heat workpiece uniformly. Identify and evaluate shielding candidates. Develop an approach to optimize robot gripper force and minimize heated workpiece distortion and heat transfer.	1. Reduce energy consumption on a small-lot production line by 5-30% (depending on the application). *Total potential savings = 1 trillion Btu/year*

Supporting Activities	Sources
Studies & Analysis Objective Support R&D strategy decision making by analyzing energy savings and R&D investement opportunities to maximize the subprogram's impact on American industry.	1. *Industrial Wireless Technology for the 21st Century*, 1Q 2003, is a vision document reporting results of a workshop attended by users and producers of wireless systems and components. This widely acclaimed document continues to guide S&A wireless sensor activities. 2. *Assessment Study on Sensors and Automation in the Industries of the Future: Reports on Automation, Industrial Control, Information Processing and Robotics*, 1Q 2005, presents the results of four coordinated studies to identify possible new focus areas for S&A. Inferential process control was recommended by two of the four sectors analyzed and was chosen as an S&A focus area. This report is posted on the S&A web site. 3. *Sensors, Control Systems, Information Processing and Robotics: Enabling Process Change* reported on the results of a workshop held in 3Q FY 2005 to identify future S&A developments which could result in energy saving process changes in existing processes and would make feasible the effective operation of emerging processes. The completed report will be posted on the S&A web site. 4. The detailed *Workshop to Identify R&D Topics on Inferential Process Control* was held in 2Q 2006. It provides detailed guidance to enable ITP S&A to convert inferential process control from a concept into an important transformational technology to be used by industry. 5. *Robotics in Manufacturing Technology Roadmap* resulted from a workshop that was held during 3Q 2006 and identified logical steps to advance and coordinate the R&D and application of robotics to American industry. The roadmap to be used by industry in advancing industrial robotics. Roadmap elements that overlap ITP goals would guide any future S&A robotics activities.
BestPractice Integration/Technology Delivery Objective Promote American industry awareness of energy efficiency and awareness of the availability and benefit of S&A technologies	The FY 2007 annual portfolio peer review of the Sensors & Automation (S&A) activity was held at Sensors Expo. Sensors Expo, a conference and trade show that typically attracts over 5000 attendees, was held this year at the Rosemont, Illinois convention center on June 12-14. It was an excellent location to make industry aware of the energy saving technologies emerging from S&A. The major emphasis this year for the entire conference was on wireless sensor systems such as those which are now emerging from S&A sponsorship. The portfolio review attracted an interested audience which was 25% larger than the previous year. (The FY 2006 portfolio review was also held at Sensors Expo.) ITP S&A partners described energy savings which can result from the application of wireless sensor condition-based monitoring systems to electric motors, steam systems and other manufacturing infrastructure. Illustrating that cost is the major driver to adoption of this energy saving, enabling technology, industry is looking to wireless sensor use to result in fewer costly process upsets and unexpected shut downs.

2.1.14 Technology Delivery

Technology Delivery supports the mission of the Industrial Technologies Program (ITP) through the development, implementation and dissemination of Best Practices in energy management that realize the best energy efficiency and pollution prevention options from a system and life-cycle cost perspective. Technology Delivery targets both energy-intensive large and small-medium sized manufacturing facilities in the United States. The activities currently funded under Technology Delivery make-up the bulk of the Save Energy Now initiative.

Technology Delivery conducts as wide range of energy savings assessments in manufacturing facilities; some system specific in primarily large facilities and through the Industrial Assessment Centers in small-medium sized plants. Technology Delivery encourages replications of assessment results and methodologies particularly in the largest 4,000 manufacturing plants that consume about 58 percent of the manufacturing energy. Technology Delivery also develops system tools to analyze facility energy use and develops and delivers accompanying training aimed at plant floor personnel who can implement the system improvements. Key to the Technology Delivery program area is a robust set of partnerships with entities that are best suited to reach the largest number of manufacturing facilities; State Energy Offices, utilities, and key industrial trade associations are being tapped to promote Save Energy Now and encourage project implementation to enhance energy savings.

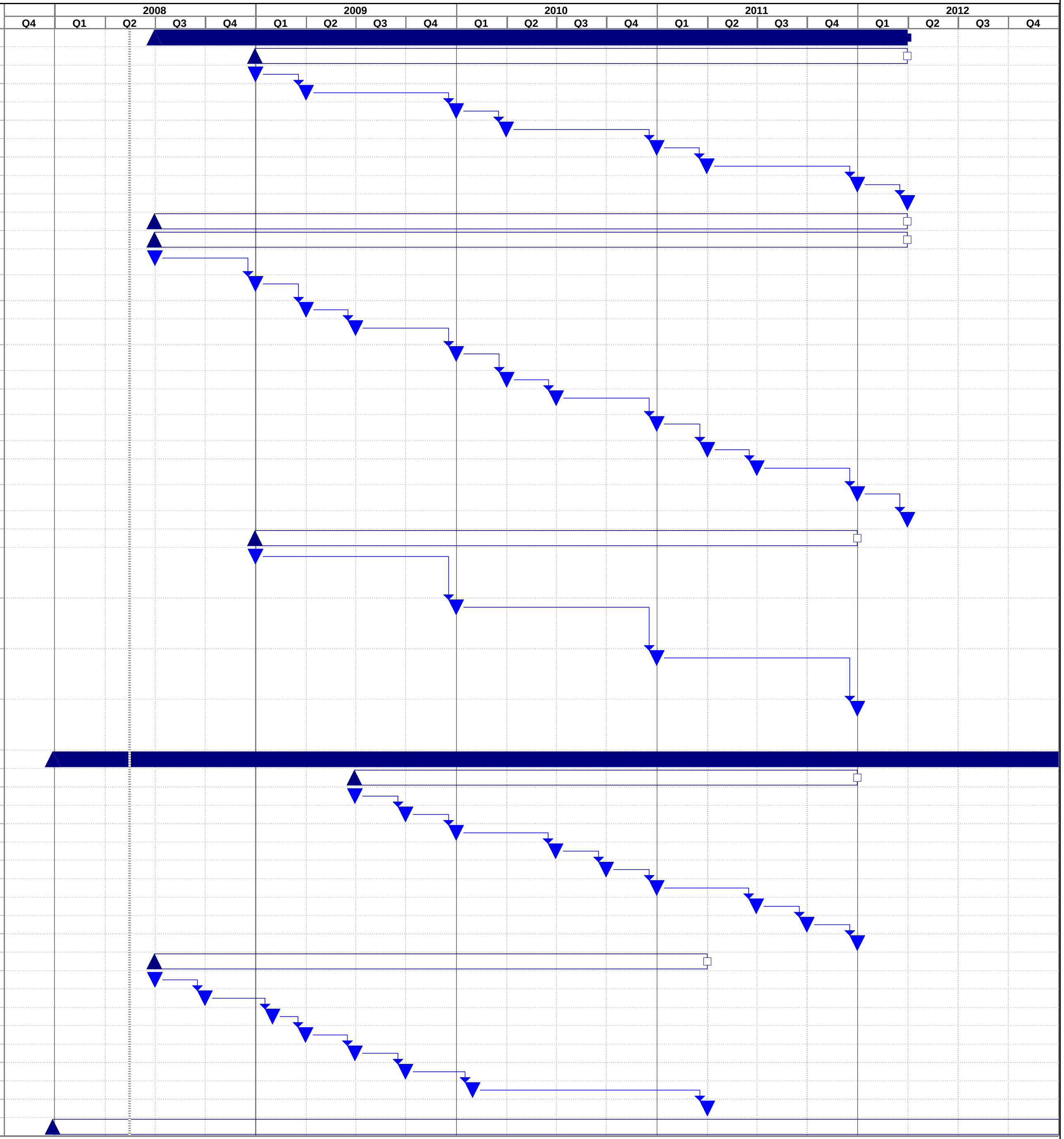
Technology Delivery recognizes industrial plants that have acted upon and implemented energy saving recommendations from Save Energy Now and IAC energy savings assessments in a formal recognition program.

In addition to the activities above, there are several additional activities under development which create a pathway to achieving a 25 percent improvement in energy intensity over the next ten year period. These activities include the development of a comprehensive plant energy efficiency certification protocol. In addition, these activities will provide a long-term strategy for the industrial manufacturers to address and achieve cost-saving energy improvements leading to overall improved economic health.

Last updated: 5/9/2008

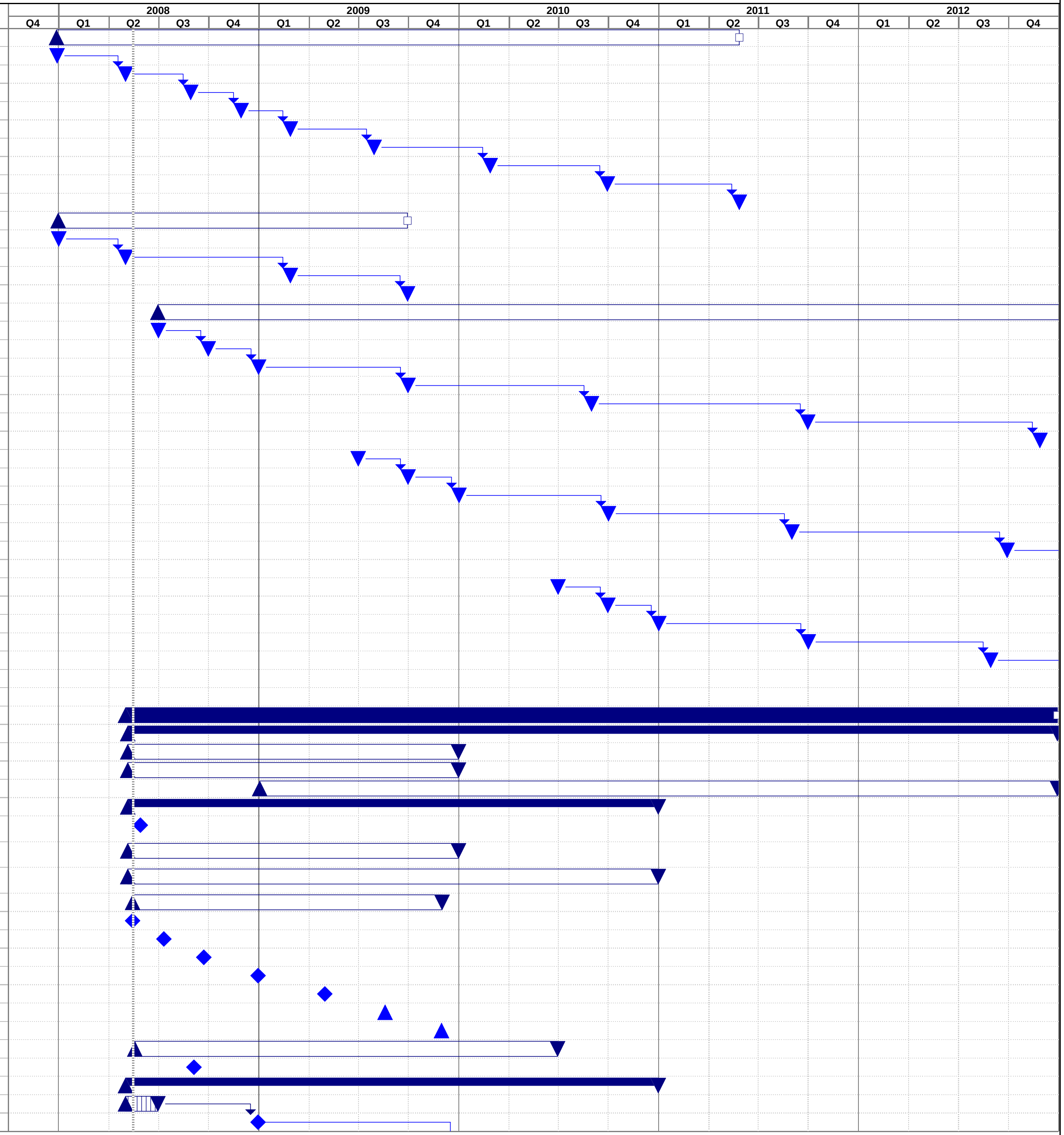
Technology Delivery

ID	Name
1	Assessment
2	Large Plant Assessments
3	Begin Transfer Assessments to States, Utilities and Others
4	Conduct 250 Assessments
5	Award States, Utilities and Others to Conduct Assessments
6	Conduct 150 Assessments
7	Award Additional States Utilities, and Others for Assessments
8	Conduct 100 Assessments
9	Award Additional States Utilities, and Others for Assessments
10	Conduct 100 Assessments
11	Industrial Assessment Centers
12	Industrial Assessment Centers (IAC) Base Operations
13	20% Plants Receiving IAC Assessments Will Achieve Energy Saver Plant or Energy Champion Status for Previous Calendar Year
14	200 Engineering Students Receive Hands-on Training in Energy Efficiency Through the IACs
15	IACs Conduct 300 Assessments
16	20% Plants Receiving IAC Assessments Will Achieve Energy Saver Plant or Energy Champion Status for Previous Calendar Year
17	200 Engineering Students Receive Hands-on Training in Energy Efficiency Through the IACs
18	IACs Conduct 300 Assessments
19	20% Plants Receiving IAC Assessments Will Achieve Energy Saver Plant or Energy Champion Status for Previous Calendar Year
20	200 Engineering Students Receive Hands-on Training in Energy Efficiency Through the IACs
21	IACs Conduct 300 Assessments
22	20% Plants Receiving IAC Assessments Will Achieve Energy Saver Plant or Energy Champion Status for Previous Calendar Year
23	200 Engineering Students Receive Hands-on Training in Energy Efficiency Through the IACs
24	IACs Conduct 300 Assessments
25	and Manufacturing Extension Partnership (MEP) Coordination
26	IACs Will Train/mentor 26 Local MEPs in Energy Efficiency Tools, Resources and Practices, Leveraging the MEPs' Extensive Client Base to Impact the Energy Efficiency of an Additional 1800 Small to Medium-sized Manufacturers
27	IACs Will Train/mentor 26 Local MEPs in Energy Efficiency Tools, Resources and Practices, Leveraging the MEPs' Extensive Client Base to Impact the Energy Efficiency of an Additional 1800 Small to Medium-sized Manufacturers
28	IACs Will Train/mentor 26 Local MEPs in Energy Efficiency Tools, Resources and Practices, Leveraging the MEPs' Extensive Client Base to Impact the Energy Efficiency of an Additional 1800 Small to Medium-sized Manufacturers
29	IACs Will Train/mentor 26 Local MEPs in Energy Efficiency Tools, Resources and Practices, Leveraging the MEPs' Extensive Client Base to Impact the Energy Efficiency of an Additional 1800 Small to Medium-sized Manufacturers
30	Partnerships
31	Voluntary Agreements
32	Recognition Event
33	60 Companies Pledge
34	Energy Awareness Campaign
35	Recognition Event
36	120 Companies Pledge
37	Energy Awareness Campaign
38	Recognition Event
39	240 Companies Pledge
40	Energy Awareness Campaign
41	25 and 10 Pledge
42	Develop Pledge
43	Sign 15 Pledges
44	Semi Annual Pledge Status Report
45	Sign 15 Pledges
46	Pledge Annual Report
47	Sign 15 Pledges
48	Semi-Annual Pledge Report
49	25 and 10 Day
50	States



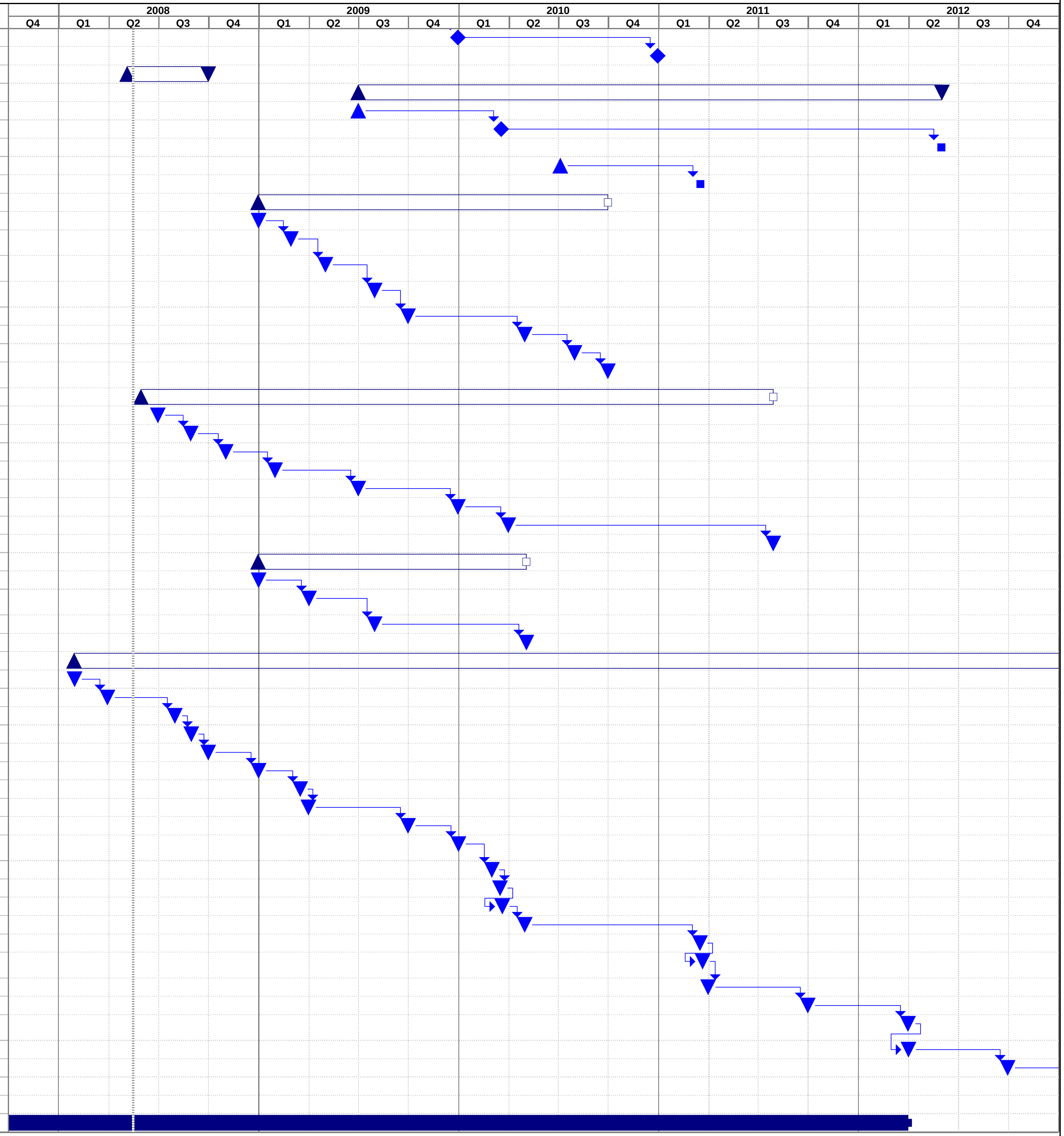
Technology Delivery

ID	Name
51	State Resources Website
52	Release States Resource Page
53	Update State Data
54	Integrate Incentive and Resource Database
55	Add State Events Function
56	Requirements Analysis for Upgrade
57	Update Site and Database
58	Requirements Analysis for Upgrade
59	Update Site and Databases
60	Requirements Analysis
61	State Assessments
62	Issue Solicitation
63	Award 19 States
64	Complete 96 Assessments
65	Report Results on States Site
66	State SEN
67	Issue Solicitation
68	Merit Review
69	Make 3 Year Award to 16 States
70	Report 1st Year Savings
71	Report 2nd Year Savings
72	Report 3 Year Savings
73	Complete Projects
74	Issue Solicitation
75	Merit Review
76	Make 3 Year Award to 30 States
77	Report 1st Year Savings
78	Report 2nd Year Savings
79	Report 3 Year Savings
80	Complete Projects
81	Issue Solicitation
82	Merit Review
83	Make 3 Year Award to 30 States
84	Report 1st Year Savings
85	Report 2nd Year Savings
86	Report 3 Year Savings
87	Complete Projects
88	Supply Chain
89	Incorporate SEN Brand into Supply Chain initiative
90	Co-branded Outreach Materials with EPA, DOC, and DOD
91	Co-branded Outreach Materials with Tech Organizations
92	Co-branded Outreach Materials with Pledge Leaders
93	Participation from Leaders & Decision Makers
94	Meeting with EPA, DOC, and DOD to Leverage Supply Chain Activities
95	Meetings with Industrial Technology Organizations to Leverage Supply Chain Activities
96	Develop Testimonials and Case Studies to Attract Industry Leaders and Decision Makers
97	Supply Chain Workshops with Targeted Supply Chains
98	Utilities Workshop
99	Automotive Workshop
100	Food Processing Workshop
101	Heavy Appliance
102	Aerospace
103	Construction Materials Workshop
104	Big Box Workshop
105	One on One Company Meetings
106	Southeast Regional Summit
107	Incorporate SEN recognition into Supply Chain initiative
108	Finalize SEN Supply Chain Recognition within SEN
109	Recognize Supply Chain Efforts at Energy Champion Awards



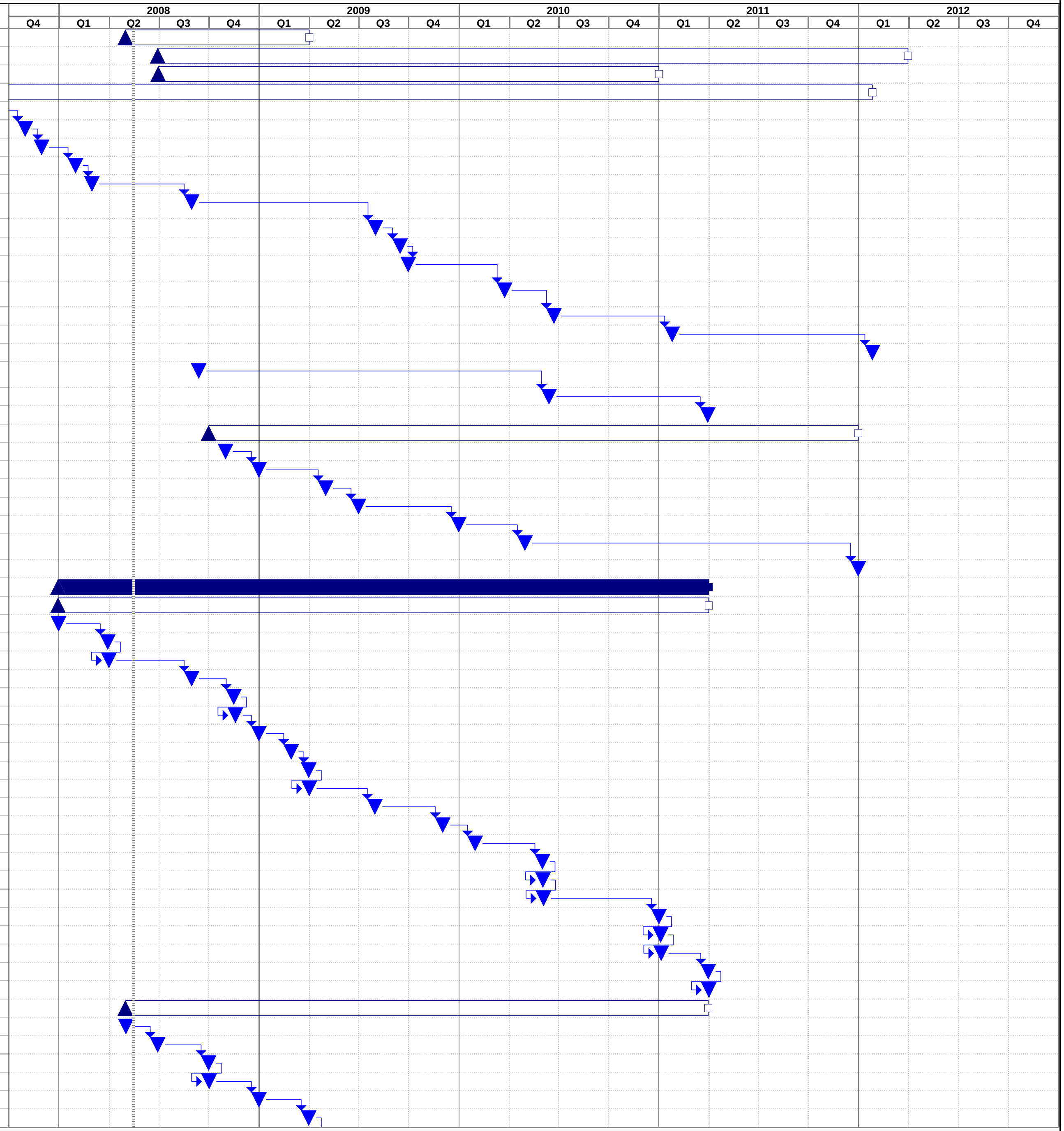
Technology Delivery

ID	Name
110	Recognize Supply Chain Efforts at Energy Champion Awards
111	Recognize Supply Chain Efforts at Energy Champion Awards
112	Enhance SEN Components and Apply it to Supply Chain Initiative
113	Solicitations
114	SEN Implementation Plans by Sector Release
115	Sector Implementation Plans Selections
116	Evaluate Progress on Supply Chain Plans
117	Crosscutting R&D Release
118	Crosscutting R&D Selections
119	Financing Partnerships
120	Detailed Project Plan
121	Report on Innovative Financing and Energy Efficiency Deployment Measures Based on State, FEMP, and Overseas Experience
122	Analysis to Identify Industrial Market Sectors and Energy Efficiency Measures That Could Best Utilize ESCO/3rd Party Services
123	Develop Procedures, Templates, and Outreach Materials for Expediting New EE Financing Options and 3rd Party Contacts
124	Outreach Programs with Targeted Market Sectors
125	Outreach Programs with Targeted Market Sectors
126	Outreach Programs with Targeted Market Sectors
127	Revise Templates and Procedures and Integrate into ITP Toolkit and Training
128	Utilities
129	Utility EPAct Action Plan Meeting
130	Utility EPAct Action Plan Report
131	Article in Utility Journal
132	Utility Training Session
133	American Public Power Conference Panel
134	EEI Regional Workshop
135	Utility Communication Plan
136	Utility Communication Plan Implementation
137	University Competition
138	Research Options/Strategies for University Competition
139	Identify Best Option/Strategy for University Competition and Draft Solicitation
140	Release Solicitation
141	Make Awards
142	International
143	Complete Plan for Implementing China Agreement
144	Complete Phase I SOTACT Handbook
145	Initiate SEN Assessments in China
146	QuickPep Chinese Translations
147	Complete 2 China Policy Studies
148	Initiate End-User Training in China
149	Translate ITP publications for Use in China
150	Formalize Partnership Agreement with UNIDO
151	Complete Plan for Development of 2 IACs in China
152	Follow-up on Chinese Assessment Activities to Gather Implementation Data
153	Work with Steel Task Force to Identify Demonstration Projects
154	Deliver 1/2 Day Awareness Training in India
155	Deliver 1/2 Day End-User Training in India
156	UNIDO Use of ITP Outreach Material in 3 Developing Countries
157	Complete 2 Case Studies for Steel Task Force
158	Continue Tech Transfer Activities to Promote Adoption of US Technologies by Chinese Industry
159	UNIDO Use of BestPractices Tools in 3 Developing Countries
160	Draft ISO Energy Management Standard
161	UNIDO Use of ITP Outreach Materials Spreads to 6 Developing Countries
162	Replicate Industrial EE Efforts in Other Nations
163	International Workshop on Plant Certification for Energy Efficiency
164	UNIDO Use of BestPractices Tools in 6 Developing Countries
165	Replicate Industrial EE Efforts in Other Nations
166	Tools Training and Certification

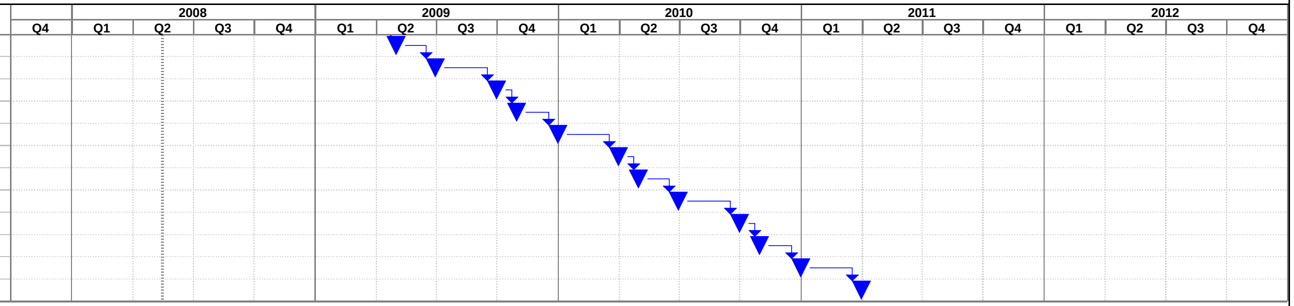


Technology Delivery

ID	Name
167	Tools Development
172	Tool Training
182	Industrial Buildings
194	Plant Certification
195	ISO Standard Briefing of Ed Pinero CEQ-FEE
196	Industry Meeting on Certification
197	ISO Standard Stakeholder Meeting
198	Identify ANSI Systems Standards Developer
199	Launch Quick Start Energy Management Website Portal
200	Systems Assessment Standards and Energy Management Standard Developed and Ready to Field Test in Texas
201	Initiate Texas Pilot Project on Plant Certification
202	Identify and Select 3rd Party Certifying Organization
203	Begin Filed Testing of Measurement and Verification Methodology in Pilot Plants
204	Begin Training Certified Practioners in Energy Management and Systems Assessments
205	First Plant Receives 3rd Party Certification Based on Results of Pilot
206	National Launch of 3rd Party Certification Program
207	3rd Party Fee-based Certification Business Model Established
208	Hold first ISO energy management stardard development committee meeting.
209	Draft ISO energy management standards completed
210	Publication of ISO energy management standards
211	Data Centers
212	Training Curriculum Available
213	DC Pro Tool Suite Ready for Public Release
214	Initial Qualified Specialists Certified
215	Best-in-Class Guidelines Available
216	Federal Data Center Energy Efficiency Demonstration
217	Certification Process to Validate Energy Management and Continual Improvement of Energy Efficiency Available for Data Centers
218	First Data Center Certified by Third Party Organization
219	Communications, Outreach and Recognition
220	Communications and Outreach
221	Complete Branding Guidelines
222	Publish 12 E-Bulletins
223	Publish 4 Energy Matters
224	Establish Communications Plan
225	Create and Update SEN Materials for Internal and External Audiences
226	Publish 10 Case Studies
227	SEN CD-ROM 2.0
228	Report on Media Tracking
229	Publish 12 E-Bulletins
230	Publish 4 Energy Matters
231	Complete Website Redesign
232	SEN CD-ROM 3.0
233	Report on Media Tracking
234	Show ITP Presence at 10 Events
235	Publish 12 E-Bulletins
236	Publish 4 Energy Matters
237	Show ITP Presence at 10 Events
238	Report on Media Tracking
239	SEN CD-ROM 3.0
240	Publish 12 E-Bulletins
241	Publish 4 Energy Matters
242	Recognition
243	Identify 2008 Awardees
244	Notify New Awardees
245	Present 2007 Awards at Events Across the Country
246	Begin Presenting 2008 Awards at Events Across the Country
247	Energy Champion Awards Event
248	Complete Presenting 2008 Awards at Events Across the Country



ID	Name
249	**Identify 2009 Awardees**
250	**Notify New Awardees**
251	**Begin Presenting 2009 Awards at Events Across the Country**
252	**Save Energy Now Leader Awards**
253	**Energy Champion Awards**
254	**Complete Presenting 2009 Awards at Events Across the Country**
255	**Identify 2010 Awardees**
256	**Notify New Awardees**
257	**Begin Presenting 2010 Awards at Events Across the Country**
258	**Save Energy Now Leader Awards**
259	**Energy Champion Awards**
260	**Complete Presenting 2010 Awards at Events Across the Country**



2.1.14.1 Assessments

Background

ITP's technology delivery approach offers are a variety of energy assessments that enable industrial plants across the country to identify and implement energy-efficient upgrades and best energy management practices.

In 2005 the Save Energy Now (SEN) initiative was established as national initiative dedicated to helping industry reduce fossil energy use and carbon emissions while reinforcing energy efficiency as a profitable business model. The long-term goal of the new Save Energy Now Leaders initiative is to drive a 25% reduction in energy intensity in ten years. Through this initiative, Energy Savings Assessments (ESA's) are provided to encourage large industrial plants to reduce their energy intensity. These assessments focus on steam, process heating, compressed air, pump, and or fan systems within the plant.

ITP's Industrial Assessment Centers (IACs) program offers assessments and follow-up for small- and medium-sized U.S. manufacturers to identify opportunities for saving energy. An important benefit of the IAC program is the training of the next generation of energy-savvy engineers. The IACs are located at 26 ABET-accredited engineering schools across the country (Figure 3-a). Rutgers University serves as the Technical Field Manager, working in close collaboration with DOE and providing technical management for the IAC program. Under the supervision of professors, students perform 1-2 day assessments on a manufacturing facility's energy use, waste, and productivity.

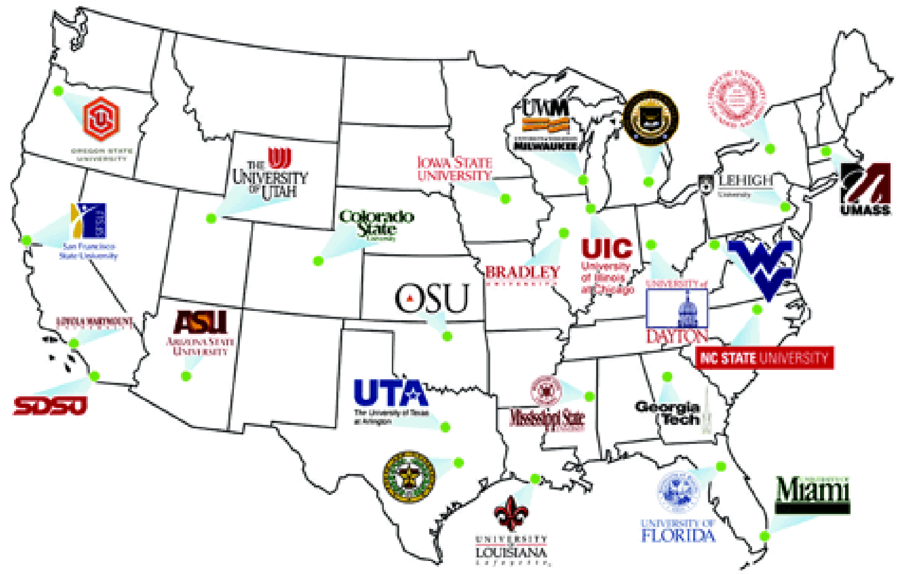


Figure 3-a. Location of ITP's Industrial Assessment Centers

Strategy

ESA's and IAC assessments continue to play an important role within the context of the Save Energy Now Leaders initiative:

- Both ESAs and IAC assessments in the future will give preference to Save Energy Now Leader companies.
- ESAs may be performed on multiple systems within a given plant based on the needs of the company
- Follow-up assessments by ESA Experts and IACs as well as technical assistance may also be provided to aid in assessment recommendation implementation
- IACs continue to train the next generation of energy savvy engineers, providing industry with the skilled workforce needed to face the energy challenges of the future.

Over time, partner organizations such as states, utilities, and engineering consultants will take a larger role in providing assessments:

- ITP will continue to provide a core level of ESA and IAC assessments
- States and other organizations will expand the reach of ITP by providing an increasing number of ESA and IAC style assessments to a broad range of industrial companies

- DOE focus will be to provide support to train Energy Experts and engineering students (IACs), ensure assessment quality, collect data and guide the overall assessment efforts.

Focus Area	Barriers	Pathways	Metrics
Energy Savings Assessments Teams of Qualified Specialists provide no-cost Energy Savings Assessments (ESA's) to large manufacturing plants each year.	• Industrial facilities are not always aware of opportunities to improve plant processes that will result in energy savings and ultimately cost savings • Plant personnel do not have the time or resources to spend on energy efficiency and energy efficiency improvements • Energy use, while it can be a substantial cost of making product, is not often a priority when compared to issues such as safety, production and personnel issues.	• Provide tool based assessments (ESAs) that have a proven track record of success. • Identify new opportunities for conducting assessments that will expand the type of assessment, the provider of the assessment and will more aggressively address project implementation and follow-up. • Leverage partner organizations such as States and utilities that provide their own assessments. Work with these organizations to provided a continuum of resources that will achieve the highest level of savings and implementation opportunities for plants. • Develop databases and other internal resources and reporting measures that capture all of the ITP and externally provided assessments so that results can be measured and reported in a consistent fashion.	• In partnership with States, utilities and others 500 industrial energy assessments / audits will be conducted annually to address the needs of companies and plants as it pertains to energy efficiency. Assessments will be collaborative and include project assistance and project implementation support. Assessments will be one of the key tools in helping industry define opportunities for improving their overall energy intensity by 25 percent over a 10 year period of time. • Have a good implementation rate of recommendations made from ESA's. • Increasing numbers of companies hire energy professionals and/or utilize their in-house expertise to adopt energy efficiency measures.
Industrial Assessment Centers (IAC) (1) ITP provides plant-wide energy, waste and productivity assessments to small and medium-sized companies each year with the goal of helping companies bridge the knowledge and resource gap and result in implemented energy-saving projects.	• Small and medium sized companies with energy bills of less than $3 million are unaware of low-cost, high- ROI, energy opportunities. (2) • They also lack the know-how, staff and resources to effectively identify opportunities, propose solutions, and present to management. This results in a disproportionate burden on these already economically challenged businesses, in times of rising energy costs and/or disruptions in supply. (3,4) • Engineering curriculum rarely includes components on energy management,	• Teams of engineering faculty and students from 26 university-based IACs provide no-cost energy, waste and productivity assessments to small and medium-sized companies each year. These assessments help these companies bridge the knowledge and resource gap and result in implemented energy-saving projects. • Assessment results are catalogued in a user-friendly, publicly available website, further bridging the knowledge gap for a wider group of companies. • Companies receiving assessments replicate assessment findings and	• The target industrial audience is very large and is continually in flux, with new companies needing to be informed of recent developments in industrial energy efficiency practices as well as older companies needing assistance determining ways to start or continue to improve their energy efficiency. In addition, the need for education and training of new energy efficiency engineers will not stop: new graduates from the IACs will be continually needed as the older graduates retire or move on to other jobs. However, in time the industrial

	particularly in the non-power energy disciplines, such as mechanical systems. New engineers are not equipped to analyze energy impacts in engineering design and decision-making when entering the workforce. (1,5,6,7) • New engineering graduates typically lack real world practical experience working in manufacturing and industrial plants.	implement additional energy saving projects at sister companies. • A cadre of energy savvy engineers with real world experience is being trained for entry into the workforce to provide future impacts for entities of all types. • IACs will leverage the outreach of the NIST Manufacturing Extension Partnership (MEP) program in order to impact a larger number of small to medium sized companies. This will accomplished by mentoring and working collaboratively with MEP center staff to increase their awareness of ITP's energy efficiency tools and resources, thereby enabling the MEPs to transfer this knowledge to their extensive company client base.	culture will change, and companies will become more willing to provide support to the colleges educating their future energy management staff. As this happens, the requirement for federal funding will lessen.

2.1.14.2 Partnerships

Background

Despite progress in decreasing its energy and carbon intensity over the past 20 years, U.S. industry remains significantly underinvested in energy efficiency. ITP addresses the market, technological, and cultural barriers and finds ways to spur investments in the many remaining *cost-effective* opportunities to save energy and reduce carbon emissions. A key mechanism for accomplishing this is our Save Energy Now Leaders national initiative to drive a 25% reduction in industrial energy intensity in ten years. Through this initiative, ITP engages U.S. industry to implement cost-effective energy intensity and carbon reduction strategies. Save Energy Now is about partnerships. ITP alone cannot engage the thousands of industrial facilities across the country. In order to be successful, Save Energy Now must leverage access, resources and knowledge with other groups and industry to meet common goals.

Approach

The approach for Partnerships is to create a value-added chain that includes ITP and the Federal sector, State and local governments, not-for-profit energy efficiency organizations, utilities and the multitude of industrial trade associations who all share the common goals of energy and environmental improvements while sustaining the economic health of the industrial manufacturing sector. ITP engages the various partner organizations to determine what we can best bring to the table **-** within budget constraints **-** that allows these entities to deliver benefits to industrial end users. The outcome will be to transfer "ownership" of certain ITP activities to states, utilities, or others who are more appropriate for resource and tool delivery.

Focus Area	Barriers	Pathways	Metrics
Voluntary Agreements Leaders of industrial companies are invited to take a bold pledge to reduce their corporate energy intensity and carbon emissions.	• Industry must maintain market competitiveness while reducing energy intensity • Industry lacks resources (e.g., information on available technologies and practices, technical know-how, access to capital) to identify and implement energy efficiency improvements	• Create a Save Energy Now Leader Pledge program where corporations, plants and supply chains agree to improve their energy intensity by 25% or more over 10 years and thereby demonstrating to the rest of industry that such an aggressive energy intensity reduction can be achieved cost-effectively. • Provide proven, cost-efficient energy management techniques and waive fees for ITP training workshops. • Provide tailored technical assistance and training on software tools. • Recognize program participation at national, state, and local levels. • Let companies use Save Energy Now logo to publicize their participation. • Create searchable database of current and past projects and success stories as a resource for pledging companies. • Encourage other stakeholders, i.e. utilities and local governments, to recognize corporate achievements. • Identify key partner organizations that can deliver the Save Energy Now tools resources and messages to the end-users (industrial plants and companies.) Identified organizations include, the Manufacturing Extension Partnerships (MEPs), National Association of Manufacturers, key trade associations and others who can take ownership in delivering ITP tools and resources to their customer/client bases. ITP will provide these organizations and entities the resources needed (or access to the	• Increase the number of companies that sign the Save Energy Now Pledge (FY08 goal is 60) and disseminate energy efficient technical know-how across industry, leading to a 25 percent reduction in industrial energy intensity by 2017. • Pledge participants will report savings annually to achieve recognition status. • Emphasis on reducing energy and carbon intensity will become a part of industrial manufacturing culture.

		resources needed) to engage individual companies and plants in energy efficiency practices and projects. • Partner organizations will have a 25 in 10 pledge category and recognition for their successes.	
State Partnerships States and state organizations are essential partners for ITP to reach large numbers of industrial facilities.	• No central repository of industrial efficiency resources (8) • Lack of awareness of local and regional resources (9) • Unique requirements in each state/region depending on the industry type, size, and primary energy source, negating one-size-fits all approach (10) • Need to reach more manufacturers with the tools and resources of ITP SEN (11) • Lack of internal resources to conduct assessments (12) • Unique requirements in each state/region depending on the industry type, size, and primary energy source, negating one-size-fits all approach (13) • Lack of internal resources (14) • Inability of staff to make business case to decision makers (15) • Need for technical assistance in implementation (16) • Need for objectivity and certainty on sustained technology performance (17) • Short funding cycle, disrupting continuity of effort (18).	• Update current ITP State activities Web site to illustrate current ITP activities and industrial demographics. • Develop an incentive and resource database containing all rebates, incentives and resources available to manufacturers from state and local governments, non-profits, and utilities to help improve energy efficiency. • Incorporate announcement of events that are organized by the various state agencies into each state page. • Conduct requirements analysis to determine future enhancements. • Award and complete 19 State Save Energy Now plant assessments at local industrial facilities. • Report results of the 19 awarded assessments in states resource page. • DOE plans a solicitation to the states that will be a three year award for 16 to the states to begin the process of transferring Save Energy Now resources to the States. These awards will focus on providing resources to the states to conduct marketing and outreach, implement local training centers, conduct Save Energy Now assessments, conduct technology demonstrations, implement emerging and commercialize energy efficient technologies. A major component of this effort will also be to help	• Provide a current and up to date central repository of all of the tools and resources available to a manufacturer, organized by state along with a list of activities ITP has performed in each state • Leverage a small amount of funds to reach more manufacturers with the tools and services of SEN to increase the number of plants to receive assessments • Provide the states with the tools and resources to assume an ownership role of the Save Energy Now activities, and customize resources to meet the local needs of manufacturers. • States will report energy savings annually and will be recognized for success. • States will be partners in the Save Energy Now campaign and will have ownership of helping local manufacturers stay competitive through efficiency. • ITP will be out of the delivery business and focused on adding value to local state efforts by addressing their priority needs.

		manufacturers implement projects through technical assistance, access to capital, and identification of appropriate rebates and incentives available to help mitigate the cost of the projects. • In year 2 DOE will issue another solicitation to the states that will be a three year award for an additional 16 to the states to begin the process of transferring Save Energy Now resources to the States. • In year 3 DOE will issue another solicitation to the states that will be a three year award for an additional 16 to the states to begin the process of transferring Save Energy Now resources to the States.	
Supply Chain The Supply Chain Initiative drives energy savings throughout their supply chains using ITP's Save Energy Now, and with targeted high-impact industries to develop roadmaps to identify research needs to decrease the embedded energy intensity of final products.	• Gain recognition of SEN's applicability across industrial supply chains • Attract new/more companies to SEN through the supply chain initiative • Formulating a recognition plan that is attractive for pledge members to encourage their suppliers to join • Organizing suppliers to address energy savings as a supply chain • Addressing R&D needs of suppliers who supply multiple supply chains	• Enlist supply chains into voluntary Save Energy Now Leader pledge program to demonstrate energy efficiency results • Co-brand testimonials, presentations, and outreach materials with EPA, DOC, industrial technical organizations, and pledge members to demonstrate energy savings opportunities through supply chains. • In FY08-FY09, work with EPA and DOC voluntary programs and partnerships to leverage resources and attract industry leaders and decisions-makers. • In FY08-FY09, facilitate supply chain workshops with supply chains to develop plans on how to implement SEN down their supply chains. • Conduct company one-on-one meetings to develop plans on how to implement SEN down their supply chains.	• Target new and more industries for energy savings by implementing SEN across supply chains.

		• In FY08, enhance SEN recognition to include supply chain activities. • In FY09, conduct solicitation for supply chains to develop SEN implementation plans. • In FY10, conduct R&D solicitation to address R&D needs for suppliers who crosscut multiple supply chains.	
Deployment Support and Financing This ITP deployment and financing strategy is to integrate ITP R&D and TEAM activities with current and new Technology Delivery Venues and Partnerships while highly leveraging existing resources within ITP (i.e., IACs, RACs, etc.) and other EERE program offices (excluding FEMP).	• Potential changes in production or the process during the term of a contract with 3rd party financier add risk to guaranteed savings approaches • Accounting requirements for shared savings approaches can be daunting due to Sarbanes-Oxley, which has introduce much more complexity in the contract process. It is no longer easy to shift risk • General feeling that an ESCO or third party may not understand the plant process well enough to effectively implement a project • There could be concern about confidentiality of intellectual property any time a third party is involved in a process modification • Energy efficiency investment must, like all potential investments, meet strict payback hurdles. All industrials are tight on capital and must prioritize investment opportunities.	• Identify key barriers to energy efficiency investments in the industrial sector. • Review existing financing options for industrial energy efficiency projects and identify shortcomings. • Identify innovative state and overseas approaches to financing that could be effectively incorporated into a national program. • Work with ESCOs and the financing community to develop innovative financing and implementation programs for industrial energy efficiency deployment. • Identify value-added services that ESCOs and other third party providers can bring to energy efficiency investments. • Identify specific industrial market segments that can best benefit from these services. • Develop joint solutions that build on the value added services of third party providers and the specific needs of industry. • Roll-out the recommended solutions at annual meetings, trade shows, ITP website, through webinars, etc. • Highlight success stories and comment procedures/approaches.	• Resources will be readily accessible to assist manufacturing facilities with the means to address the financial and technical constraints associated with energy and environmental project implementation. • Partners such as utilities and states will provide information and access to these resources. • Partnerships between industry, ESCOs and other 3rd party financiers to implement energy efficiency projects and investments are a well-established practice in the United States.

		• Fold these results into the SEN toolkit and training program.	
Utilities Utilities are the front-line partners for engaging industrial facilities in energy and environmental projects.	• Need to incorporate utilities into the deployment strategy (18) • Due to natural market conditions industry remains significantly underinvested in energy efficiency • Federal government is not well suited to deliver resources directly to the end-users • Industrial customers are resource and time constrained, opportunities to engage in new projects or implement new ways of doing business provide particular challenges for industry, no matter how beneficial these may be.	• Engage the utility community and develop partnerships to provide utilities with the tools and resources to help improve the energy efficiency of the industrial customers they serve. This includes providing outreach material through national utility associations, developing of a utility action plan, and conducting training with utility personnel so they have the resources available to help their industrial customers.	• Utilities nationwide will adopt aggressive industrial energy efficiency demand side management programs and be largely responsible for the ability of facilities to achieve "25 –in-10" goals. • Utilize the gas and electric utilities as a channel to reach manufactures to help improve their energy efficiency. By providing the utilities with these resources, ITP will reach more manufacturers because the utility personnel have an established relationship with the manufacturers and are the first people who are called when their energy bills are high • Adoption of many aspects of the delivery of ITP plant resources will belong to the private sector, including utilities, trade associations and other key partner groups. Substantially larger numbers of industrial facilities will be reached due to the leverage of these partner organizations. The unique relationships of the industrial facilities to these partner organizations will insure greater adoption of projects and improvements.
University Competition This competition will focus on bringing cutting-edge energy and	• New engineers are not equipped to analyze energy impacts in engineering design and decision-making when entering the workforce or to address	• University competition (DOE solicitation) to develop novel approaches to in-plant industrial challenges.	• Enhanced connection and partnership between universities and innovative ideas in lock step with industry needs. Universities

environmental technologies from universities to the plant floor, which is typically not a cost-effective option for most facilities.	current issues in industrial energy efficiency. • Disconnect between engineering curriculum and industry needs.		prepare graduates that can “hit the ground running” in industry and develop and implement novel approaches to address industrial energy efficiency needs. • Top universities participate in the competition. • Industrial associations partner to issue the competition and sustain it over time.
International ITP works with interested international partners to deliver energy and environmental resources to support industrial energy efficiency needs in these countries.	• Intergovernmental complexities • Energy reduction targets vary among partner countries • Different policy perspectives • Language/cultural differences • Varying natural resources and infrastructures • Varying budget priorities/cycles/exchange rates • Time Zone difference	• MOUs with partnering countries [ex. China] or partnering organizations [ex. UNIDO]. • Translate and distribute U.S. software tools, training, and publications. • Support the development of IACs in partnering countries. • Provide pilot energy savings assessments in partnering countries. • Provide pilot training and awareness classes in partnering countries. • Continue APP task force activities. • Continue SOTACT activities with cost-shared State funding. • Participate in the development of an international ISO energy management standard. • Participate in an international workshop on plant certification. • Demonstrations of emerging and commercial U.S. produced technologies. • Technical transfer activities to promote adoption of U.S. technologies by other member countries.	• Partnerships between emerging and developed countries. Shared best-practices among partner counties. Self-replicated, self-funded future industrial energy efficiency activities. Increased commercialization and sales of U.S.-produced energy-efficiency technologies, knowledge and services. • Establishment of partnerships between emerging and developed countries to share best practices information. • Increase in self-replicated and funded industrial energy efficiency activities. • Increase in the commercialization and sales of U.S.-produced energy efficiency activities.

2.1.14.3 Tools, Training and Certification

Background

Technology Delivery is developing a variety of new products, services, tools and energy-efficiency resources to assist industry in accelerating their energy intensity reductions. ITP is asking industrial plants, corporations and supply chains in FY2008 to pledge to reduce their energy intensity by 25% or more over a ten-year period. Therefore, all new ITP energy efficiency products being developed or upgraded are being directed towards helping companies meet the "25-in-10" pledge. For example, ITP's software tools are being improved and upgraded to ensure that they are easy to apply and can effectively assist plant personnel in performing energy assessments, and validating and documenting energy saving results.

Building off the portfolio of ITP tools and success in performing Save Energy Now energy assessments, ITP is embarking with industry to standardize the process of implementing an energy management program. DOE is partnering with NIST, EPA, the American National Standards Institute (ANSI) and leading industrial companies to create voluntary, industry ANSI-accredited standards to allow manufacturing facilities to certify their continual improvement of energy intensity.

Finally, ITP is expanding its portfolio of tools and training to address significant energy savings associated with industrial building facilities and rapidly growing sectors of the economy such as data centers.

Approach

ITP tools and energy efficiency resources have demonstrated value to industry in stimulating investment in energy efficiency that would have not occurred otherwise. To date, we have impacted over 16,000 manufacturing facilities. In accord with the "25-in-10" goal, ITP needs to influence the majority of the 200,000 manufacturing facilities in the United States by accelerating their energy intensity reduction rate to 2.5% per year (more than double the current rate of improvement). We are working with industry to codify and create voluntary industry standards that "institutionalize" Save Energy Now best practices and protocols so that manufacturing plants can certify their energy efficiency program. A key mechanism for companies to meet the pledge will be certification of plants for energy efficiency.

Focus Area	Barriers	Pathways	Metrics
Plant Certification The ANSI-accredited plant energy-efficiency certification process is a voluntary third-party certification program being developed by industry and governmental organizations to promote improvements in current industrial energy management practices and elevate energy management within corporate priorities.	• Currently, there is no platform for a consistent approach to industrial energy efficiency and energy management • There is no mechanism to promote sustainable energy savings within industry • There are no common standards of how to assess specific industrial energy systems, such as steam, process heating, compressed air and pumping • There is no way for industry to receive third party validation of their energy efficiency gains and carbon emission reductions at the plant facility level.	• Develop and test system assessment standards • Revise ANSI energy management standard and test its applicability in pilot plants with the energy management tool • Develop and test facility-level measurement and verification standard and the overall third-party certification process with pilot plants • Launch American National Standards Institute-accredited certification process at facility-level with third-party validation throughout the U.S.	• Facilities have the mechanism to have their industrial energy management and energy intensity validated by a respected and internationally-recognized third-party certification system. • Third-party certifying organization is financially self-sufficient and not dependent on DOE funding. • Supply chains require that their suppliers get certified as proof that an energy management program is being implemented and energy savings are being achieved. • First plant certified in 2010. • 1,500 plants certified by end of 2013. • 5,000 plants certified by end of 2016.
Training The training program focuses on delivering the tool suite and insures that plant personnel and end users can effectively apply the resources developed by DOE.	• Effective implementation of energy efficiency practices and projects requires training • Tool training opportunities are limited, but when accomplished training has a substantial impact for the investment • There is a need to develop a cadre of trained specialists who can use DOE and other industry tools as part of their business portfolio to deliver industrial energy efficiency.	• Develop web-based training as a means to reach more users. • In conjunction with partnership activities, work with external entities to grow training hosts outside of the ITP fully funded model; States, and utilities would be target hosts • Develop overall plant energy management training module in conjunction with EPAct section 106. • Provide continuous updates and modifications to existing training curriculum to insure the most accurate and up-to-date material is included to remain consistent with new and	• Approximately one-third of all plants that participate in a DOE end-user training program implement actions in their facilities as a result of participating in training and approximately one-half of participants who participate in Qualified Specialist training result in actions taken in facilities. In FY2008 this will account for almost 3.9 trillion Btu in industrial energy savings. • Adoption of all aspects of the training delivery activity by the private sector, under the guidance but with minimal financial support, from the Federal Government. • Provide multiple training venue options including distance learning

		updated tools.	and electronic formats to achieve maximum reach. • Transition the hosting of training sessions to states and utilities to best service their customers and clients needs. • Training is integrated with the ANSI-accredited standard adoption required in the energy efficiency certification process for manufacturing plants.
Industrial Buildings The IAC program experience has shown that implementation of industrial buildings recommendations yield simple paybacks of 1-2 years.	• Unique requirements and opportunities depending on the industry type, size, available energy, lighting demands - negating a one-size-fits all approach • Lack of internal resources. • Inability of plant staff to make compelling business case to decision makers • Need for technical assistance in implementation • Need for objectivity and certainty on sustained technology performance • Savings opportunities are assumed small and unavailable.	• Develop communications regarding resources – current tax benefits via BTP software • Develop integrated industrial buildings QuickPEP scoring module and industrial buildings software tool. • Validate QuickPEP Module and Industrial Buildings tool. • Develop training for tool. • Develop plans to facilitate Industrial Buildings BestPractices and technologies through federal and state and utility-based Save Energy Now delivery. • Demonstrate technologies • Implement emerging and commercialized energy and water efficient industrial buildings and facilities technologies, in partnership with states and utilities/ESCOs. • Provide options for clean energy / CHP . • Provide options for renewable energy. • Develop documents / webcasts	• Agreements with utilities and ESCOs to deliver industrial building BestPractices and technologies. • Industrial building technologies and best practices are commonly implemented whether domestically or internationally. • Leverage partnerships with industry, state, utility/ESCO partners to deliver these Industrial Buildings BestPractices. • Provide Industry, State/Regional Experts with the tools and resources to conduct Save Energy Now activities including industrial buildings. • Convey tool, training, webcasts and fact sheets into integrated industrial energy systems software tool, training and catalog systems for low-cost electronic delivery. • Minimally customize these resources for manufacturing sub-sectors where the average industrial buildings consumption in the sub-sector is > 10% of the total consumption in the

		including streaming video archives for industrial buildings. • Leverage / update CHP and buildings resources as required	sub-sector. • Save 0.25 Quad / year - source energy in industrial buildings.
Data Centers ITP is building a portfolio of energy efficiency resources to assist data center operators to capture energy savings.	• Lack of definitions for equipment and data center energy efficiency • Differing priorities between IT and facility managers • Adoption of energy efficiency practices and technologies viewed as a risk	• Develop "DC Pro" tool suite with consensus metrics that will facilitate IT and facility people to more effectively communicate and establish complementary priorities • Develop "Best in Class" guidelines • Develop Qualified Specialist certification program • Create Save Energy Now case studies of energy efficiency success stories through performing pilot energy assessments	• Save 10 billion kWh per year by 2011. • 200 people certified as Data Center qualified specialists by 2011. • 1,500 data centers have reduced their energy intensity by 25% from 2008 to 2011. • Distributed generation systems are commonly implemented at data centers. • DCIE performance rating factor (IT to Total data center energy use) of 0.70 or more achieve by >50% of large enterprise class data centers.
Tools and Guidelines ITP seeks to increase the involvement of partners in developing and disseminating tools, thereby improving industry awareness of energy savings opportunities and ITP tools as well as raising the priority of energy savings projects at plants.	• Plants are often unaware of low-cost, high-ROI, energy savings opportunities1 • Plants often lack the expertise or training needed to identify and implement energy efficiency projects. This expertise includes the ability to identify opportunities, propose solutions, and present these results to management for funding (1) • Plant engineers and operators have expertise in the use of more than 2 ITP Tools along with limited time (19) • Plants are often unaware of the available ITP tools (1,19,20) • Current tool users are often only single tool users that are unaware of the other ITP tools that could help them save energy in other parts of	• Increase the involvement of partners in developing and disseminating tools. Increased involvement will improve industry awareness of energy savings opportunities and ITP tools as well as raise the priority of energy savings projects at plants • Expand existing tool capabilities via ITP's Web site • Expand individual stand alone existing tool capabilities • Utililize tool suite to assist plants in adopting ANSI-accredited energy management system assessment standards	• By 2012 18% of the large energy using plants will realize energy savings utilizing DOE Software Tools. • DOE Software tools will take on an increase role in assisting plants in their energy management and ANSI Certification efforts. • Well developed software tools will allow industrial plant personnel to engage in energy efficient projects and the use of ITP tools to facilitate project implementation. • Actions taken that result in energy savings from individuals who have acquired ITP software tools is measured.

	their plant (20,21) • Current tools were developed by different partnerships and organizations, resulting in different designs and capabilities. These differences require users to devote time to learn how to use each.		

2.1.14.4 Technical Information and Outreach

Background

Through communications, ITP broadens awareness about industrial energy efficiency benefits and opportunities and provides access to technical information, tools and methods. Outreach activities establish ITP as a key industrial resource in energy efficiency and facilitate collaborations across industries. Through outreach, ITP can extend its reach to more facilities and other organizations that can promote the Program's resources. We have a comprehensive portfolio of technical information and tools to help plants learn about and deploy energy efficiency measures. By building awareness, providing access to resources, and maintaining outreach, ITP creates a call to action for industry, facilitates adoption of technologies and methods, and ultimately helps transform behavior with regard to industrial energy use and energy management practices.

Approach

ITP is developing multiple delivery items for industrial audiences ranging from end users to states energy offices, utilities, and others interested in industrial energy efficiency. We continue to expand our audiences and adapt our communications products to meet evolving priorities. ITP also recognizes companies who pledge to reduce their energy intensity 25% over ten years.

Focus Area	Barriers	Pathways	Metrics
Technical Information ITP develops a portfolio of technical publications to help industrial end users understand and apply energy efficiency practices.	• The size and diversity of the industrial audience creates a need for ongoing communication to broadly deliver ITP resources and strategies. • ITP partners such as associations and utilities need access to ITP branded resources to boost or complement their own activities. • Industrial plants may not be aware of cost, productivity, and environmental benefits and opportunities of implementing energy efficiency • Industrial plants need access to reliable, proven resources, methods, and technology information that enable them to take action on improving energy efficiency	• Develop and maintain a robust portfolio of industrial energy efficiency resources to increase awareness of opportunities, technical knowledge, and increase commercialization of technologies. ITP creates and makes available these resources for printed or electronic distribution: • Technical tip sheets, sourcebooks, guides, and briefs • Assessment and corporate management case studies • ITP assessment and analysis software tool suite • Energy Matters online quarterly with a focus on technical and practical information • Technology fact sheets • The Save Energy Now CD: portable collection of tools and information resources • Topical Webcasts: focus on system specific tools or training • Produce the monthly ITP E-Bulletin for program current news • Establish and adhere to program identity, including consistent use of Save Energy Now brand and logo, creating branding and co-branding guidelines and opportunities.	• ITP will collect metrics and feed-back on the use of its resources by industrial customers. For *Energy Matters* and *E-Bulletin*, ITP measures increases in recipients, Web statistics, and feedback. We will track *Energy Matters* article reprints by other media to measure reach to other audiences. The success of the *E-Bulletin* will also be measured by increased activity in other program areas or website.
Website Management	• Accessibility and searchability are limited, making it hard for companies	• ITP, BestPractices, and Save Energy Now Web sites: provide a constant	• ITP's websites provide a valuable measure of progress toward

ITP's websites provide the main point of access to resources, tools, and activities.	to find the information needed	and up-to-date home for resources and program information • Increase reach and accessibility so website helps change behavior through repeat visits and by attracting new visitors. • Maintain news and events on the Web sites	increasing awareness and action. Recognized statistical techniques (on audience size, paths from other sites, downloads, etc) will be used to measure success. ITP evaluates accessibility from search engines, such as Google, and continually adapts content to optimize searches.
Outreach and Media Outreach expands and strengthens program identity and increases awareness of activities, results, and opportunities - necessary steps toward assimilation of energy management practices.	• Need to multiply ITP's reach, and industrial audiences will progressively gain interest and motivation to improve energy efficiency and participate with the program.	• Expand and strengthen program identity and increases awareness of activities, results and opportunities through outreach activities • Target and attend energy events across the country • Develop and promote activities through corporate reports, brochures, and results summaries • Create targeted campaigns and mailings	• Responsiveness to other program areas is a reflection of successful outreach implementation. Actions range from tool download/use to training to implementing new technologies. Outreach will also contribute to the quality and level of participation by partnering organizations. Media coverage tracking/reporting measures reach and success of name recognition.
Information Center The EERE Information Center provides an on-call staff of specialists to assist end users and service providers.	• Need to transform behavior of industry decision-makers by improving their awareness of energy-saving opportunities	• Enable decision-makers to obtain the necessary technical, financial, and management support to successfully implement them and then to replicate their success at other plants within their company	• One indicator of success is the # of clients who take action. Success would also result in clients returning with additional inquiries as they build their knowledge and support to expand their activities to save more energy and have their coworkers contact the Information Center with inquiries of their own.
Recognition ITP recognizes and rewards plants and companies who have achieved significant energy savings.	• There are no programs in place to recognize and reward plants and companies that have made significant progress in saving energy and implementing energy saving best practices and technologies • Department of Energy does not have any other award programs to	• Recognize and reward plants and companies who have achieved significant energy savings • DOE ITP Recognition Program recognizes 2 levels of plant energy savings as well as replication of energy savings within companies.	• The culture of the U.S. industrial base will respond to the recognition activities being conducted by ITP by investing in energy efficiency. The industrial sector will understand the value of energy efficiency in terms of cost savings, environmental benefits,

	recognize significant efforts related to energy use • Companies often require positive marketing incentives in order to see the benefits of investing in energy efficiency.		and improved competitiveness.

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2.2 Cross-cutting Issues

2.2.1 Communication and Outreach

Communications and Outreach Strategy

The Industrial Technologies Program is the lead government agency responsible for improving energy efficiency and reducing carbon emissions in industry. Our goal is to drive a 25% reduction in U.S. industrial energy intensity by 2017 in support of the Energy Policy Act of 2005 (EPAct 2005). At the highest level, we will achieve this by:

- Promoting a corporate culture of energy efficiency and carbon management
- Developing real-world energy solutions for industry
- Expanding the use of proven technologies and practices

Implementing this strategy will require clear communication to a variety of external and internal audiences. Unlike other EERE programs, ITP must convey the value of efficiency improvements in many different applications throughout industry. Public-private partnerships are essential in delivering our communication products and services to such a large and diverse economic sector. We use our relationships with organizations that possess strong ties to large subsets of industry to create a multi-channel delivery approach that leverages limited ITP resources to greatly expand outreach and effectiveness.

In 2008, ITP is launching a major campaign to promote the EPAct 2005 goal of reducing industrial energy intensity by an average of 2.5% over 10 years, which will require elevating energy efficiency as a corporate priority within industry. Accomplishing this will require a comprehensive communications and outreach strategy that clearly defines key messages, products, channels, partners, and events. Every ITP staff member is in effect a "program ambassador" as well as customer service representative, and must be able to deliver a consistent message to both existing and potential partners.

ITP's communications and outreach strategy will focus on five key elements to achieve Program goals:

- *Communications Products* – Create/update targeted publications to promote awareness of ITP products and services (including current R&D projects) and to make the business case for energy efficiency and carbon reduction (including fact sheets, success stories, case studies, brochures, presentations, journal articles, press releases, annual reports, and commercial products catalog); maintain up-to-date website and continually improve its ease of use; develop innovative web-based products
- *Stakeholder Development* - Develop and carry out activities to expand ITP's stakeholder base, encourage companies to elevate energy efficiency as a corporate priority, facilitate dialog between industry and ITP on working together to achieve mutual goals, and engage stakeholders as partners in disseminating ITP products and promoting energy efficiency
- *State, Regional, and International Partnerships* – Establish partnerships with states to cooperatively seek energy intensity reductions; hold strategic events with states to conduct training and energy assessments and publicize state energy intensity reduction achievements; strengthen partnerships with International Energy Agency, China, and other countries to maintain a U.S. leadership role in international energy efficiency
- *Voluntary Agreements, Certification, and Recognition Programs* – Create and implement Save Energy Now/"25 in 10" initiative to reduce industrial energy intensity by 25% over 20 years; conduct a major marketing campaign to promote the initiative and encourage corporate pledging; develop an ANSI standard to certify industrial facilities for energy management and energy intensity improvement; recognize industrial companies' accomplishments in reducing energy intensity
- *Events* – Conduct technology showcases and demonstration events; participate in other media events to launch new technologies or publicize industrial accomplishments; conduct pledge signing events for the Save Energy Now/"25 in 10" initiative; participate in MOU signing events

ITP's Communications and Outreach Strategy	
Element	**2008 Milestones**
Communications Products	• Release Save Energy Now CD (version 3) • Update and publish *Energy Technology Solutions* product catalog • Prepare and post updated fact sheet for every active R&D project • Publish new ITP strategic plan
Stakeholder Development	• Expand activities with National Association of Manufacturers (NAM) • Sign MOU with USCAR • Develop partnerships with copper, titanium, and cement industries • Develop industry steering committee to advise ITP management
State, Regional, and International Partnerships	• Develop and sign MOUs with three (3) additional states • Develop a resource assessment plan with NASEO • Select ~20 states to receive funding to conduct Save Energy Now assessments
Voluntary Agreements, Recognition, and Certification Programs	• Launch Save Energy Now/"25 in 10" initiative with at least 60 companies signing voluntary agreement to reduce energy intensity by annual average of 2.5% per year over 10 years • Present Energy Champion awards at NAM National Manufacturing Week • Complete key steps in the development of a plant energy management certification process, including revisions to ANSI standards and development of system assessment protocols and measurement/verification methodology
Events	• Conduct Super Boiler demonstration at Clement Pappas & Co. in Ontario, CA • Support and participate in Southeast Energy Summit • Conduct CEO Save Energy Now/"25 in 10" pledge-signing ceremony • Host event at large industrial facility to celebrate completion of 500th Save Energy Now assessment

Figure 2-c: **ITP's Communications Strategy**

Collection of Market Information for Decision-Making

ITP collects market information from a variety of sources for use in technology development decision-making. This information often becomes integral to ITP's analytical studies and reports. More discussion on this topic can be found in Section 3.

Dissemination Channels to ITP Stakeholders and Contribution to Program Success

ITP relies heavily on partnerships and leveraging opportunities with organizations such as trade and technical associations, state energy offices, utility companies, and other federal agencies to disseminate vital information and services. In FY08, ITP's collaboration with NIST's Manufacturing Extension Partnerships on plant audits is being expanded to help more plants identify opportunities for improving energy performance. In addition, ITP will increase efforts use a wider variety of venues and channels (e.g., technical and financial print media, novel web-based methods, and regional and national events) to communicate to stakeholders. A more robust network of dissemination partners and mechanisms will accelerate the spread of information and deployment of new energy-efficient technologies that can help industry achieve greater near-term benefits.

Program Use of Stakeholder Feedback

ITP uses feedback from stakeholders throughout the technology development lifecycle, from strategic planning through technology commercialization, and highly values this input. The feedback is often received via peer review activities, which is discussed further in Section 3.3.1.

Interaction with EERE's Corporate Technology Advancement and Outreach Office

ITP coordinates communications and outreach activities with EERE's Technology Advancement and Outreach Office. EERE's Technology Advancement and Outreach liaison to ITP ensures that ITP follows the guidance set forth regarding communications and outreach activities.

2.2.2 Other Cross-cutting Issues

Commercialization and Deployment

Commercialization and deployment of new technologies is a critical issue that ITP is emphasizing throughout the R&D cycle – from planning, solicitation, and project selection through the various stages of R&D. ITP recently completed 25 Commercialization Readiness Assessment Briefs for its technologies, which included a set of observations and recommendations that the Program will incorporate into its management procedures. These recommendations include:

- Proposals funded by ITP should
  - Identify a commercialization champion to position technology for market adoption
  - Express the awardee organization's commitment to commercialization
  - Include a competitive analysis identifying both present solutions and other emerging technologies addressing the same need
- Funding Opportunity Announcements (FOAs) will
  - Require the applicant to demonstrate understanding of a technology's market and commercialization aspects
  - Request details relating to the planned commercialization of the technology
- A targeted completion date and milestones will be required for the commercialization process
- Awardees will be explicitly reminded of their obligations under a federal contract to disclose any new inventions arising from funded research
- GFO Project Managers will increase communications with ITP's Technology Managers regarding progress on both the technical and commercialization fronts
- Program managers will continue to emphasize leadership on commercialization and deployment

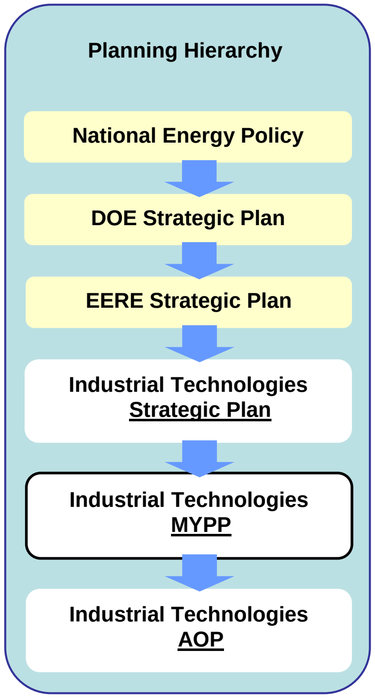
Furthermore, ITP will participate on the soon to be developed FEMP TEAM Coordinating Council within EERE to support FEMP's implementation of Executive Order 13423 to reduce DOE energy intensity. In order to assist in the deployment of ITP technologies and knowledge throughout DOE, ITP intends to provide a webinar on ITP opportunities for interested energy complex Facility Managers and ESCOs, and also provide technical assistance where appropriate.

3 Program Portfolio Management

3.1 Program Portfolio Management Process

ITP's portfolio management process is described below.

3.1.1 Planning Inter-Relationships



The ITP Multi-Year Program Plan is designed to provide a mid-to-long range perspective on ITP programs, and is a critical component in meeting the U.S. Department of Energy's Goals in an environment of limited resources.

This plan is designed to provide a level of detail at the program level that is derived from top-level policy, beginning with the National Energy Policy and flowing down through the Department of Energy's Strategic Plan and EERE's Strategic Plan. The MYPP is designed to guide and support government officials and stakeholders alike as they examine internal and external environments; identify and evaluate alternatives, risks, and trends; anticipate change; prioritize actions in light of limited funding; and develop long-term understanding the long-term implications of current choices. The MYPP translates ITP's strategies and strategic objectives into specific technical, funding, and schedule requirements that meet all EERE expectations and requirements, including all metrics for effective performance evaluation

There are a series of critical planning documents that underpin EERE's Strategic Management System. The goal cascade in Section 1.5 and accompanying planning hierarchy graphic highlight the inter-relationship of other key strategic planning elements with the MYPP.

The MYPP is used to guide the allocation of resources and to identify the technology focus areas that are key to achieving ITP's goals of reducing industrial energy intensity and carbon emissions, specifically, a 25% reduction in energy intensity by 2017 in support of EPAct 2005. The plan identifies key technical focus areas, explains the primary technical and market barriers faced in accomplishing the objectives, lays out pathways for achieving the goals for each focus area, and defines metrics to help evaluate and adjust the pathways – thus keeping the plan flexible and current. The MYPP is designed to undergo periodic review and updates. The overall plan will be reviewed annually; each technology planning element will perform a quarterly update and review. The MYPP will serve as the foundation for integrating and prioritizing the technical objectives of the planning elements into a corporate-level resource request.

ITP currently utilizes the milestone planning process to provide planning structure for its current portfolio, and to assist in developing a vision for the future. The basic decision process is illustrated below in Figure 3-b.

The process begins with the consideration of the primary mission of EERE and the U.S. Department of Energy, and an understanding of how that mission fits within the planning, regulatory and budgetary framework faced by ITP (known as the "mission logic"). The mission logic is then combined with an understanding of ITP's customers, R&D needs, organizational strategy, and external stakeholders' needs; this refined logic is then cross-walked with DOE's mission and objectives. By balancing the needs and driving forces behind industry with the greater social good, priorities are set within the context of inherently governmental activities, resulting in the identification of technical objectives that serve both a public and private need.

At the federal decision-making level, these various inputs are translated into essential areas of R&D, represented by technology focus areas for each industry and cross-cut planning unit. A basic milestone chart is prepared for each technology focus planning area, essentially creating a 5-year opportunity analysis. Each opportunity analysis/milestone chart is a balance of goals against achievable metrics.

By taking into consideration the capabilities and resources of government, including knowledge of people in the organization, dollar size of the investments ITP can make, market opportunities and barriers, and potential impact of investment decisions, the planning process supports better-informed decision-making within ITP.

3.1.2 Critical Baseline Metrics

In addition to the broad metrics used to measure the success of the pathways in achieving desired goals in each technology focus area, ITP defines critical baseline metrics to evaluate technical progress in each focus area. These metrics connect R&D progress to programmatic performance by identifying and quantifying the key technical parameters of a specific focus area. By setting a starting point baseline for the parameter and then projecting a target baseline indicative of successful completion of R&D, continuing comparisons can be made that indicate the rate of technical progress achieved. In short, a critical baseline metric:

- Provides a technology dimension to the barrier-pathway-metrics logic
- Is associated with a particular focus area and provides a technology-related metric, not necessarily mission- related (e.g., Btus)
- Clarifies quantitatively the highest priority technical issues for each focus area, (e.g. cokeless ironmaking within Steel, as shown in Figure 3-a)
- Establishes a single technology-based baseline metric against which to judge progress of a focus area
- Includes a projected target metric that can be compared to the baseline metric to determine when a focus area effort is completed
- Provides a top-level view of measurable technical progress in a focus area

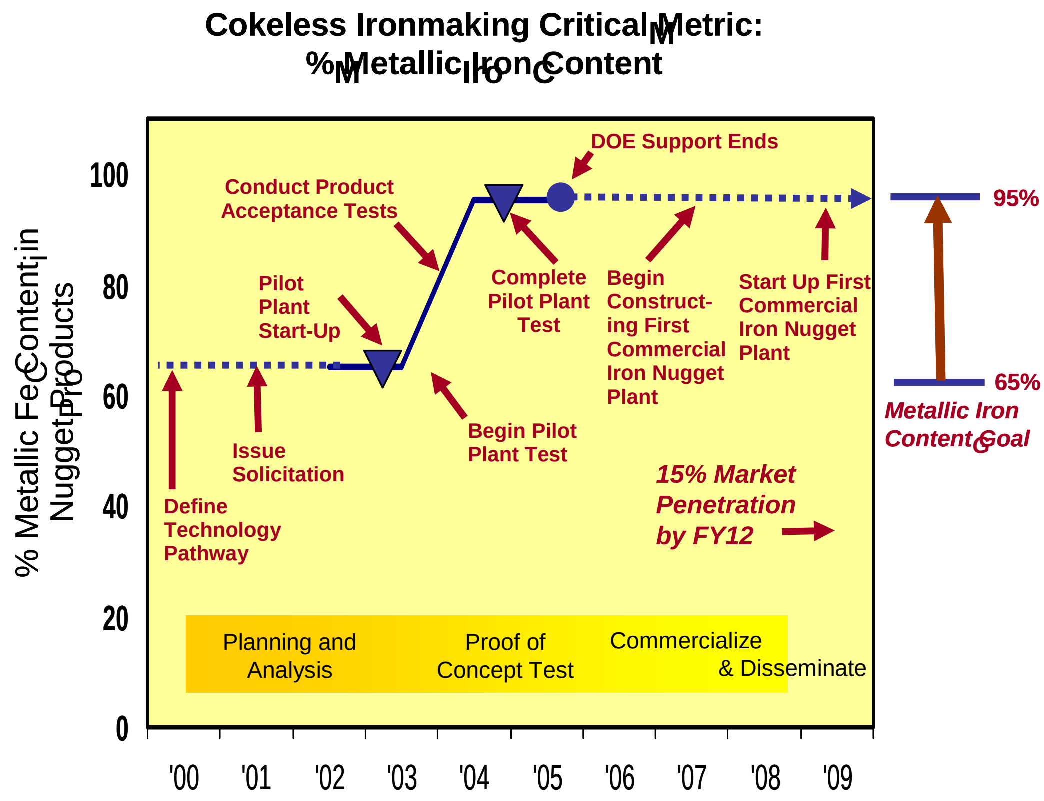


Figure 3-a. Example of a Critical Baseline Metric

3.1.3 Detailed Decision Components

As the opportunity analysis matures, additional analyses are performed that develop greater detail and provide an even higher quality analysis on which to base government investment decisions. Three examples of more detailed analyses are:

Total Development Cost (TDC) – TDC is defined as the total ITP dollars spent to achieve a key quantitative goal. A roll-up of all pathway costs determines the TDC of a focus area. The roll-up of the TDC for all focus areas equals the TDC for a milestone planning unit. By converting to cost, a determination is made of the cost it takes to achieve a key milestone endpoint that has a pass-off associated with it – to Best Practices (BP)/ Commercialization or somewhere outside the milestone chart.

Total Energy and Carbon Footprint – The total energy and carbon footprint of an opportunity indicates the magnitude of the potential impact that could be achieved. For the most energy-intensive industrial processes, ITP has developed energy bandwidths that indicate the percentage reduction in current energy use that could be achieved through R&D. These bandwidth data, combined with the energy/carbon footprint for a process, allow calculation of total potential energy savings for a given opportunity.

Multi-Year Prioritized Plan – A subset of the Milestone Chart or Opportunity Analysis is the Multi-Year Prioritized Plan. This plan consists of a multi-year plan that has been prioritized based on total available funds. Total available funds are defined as the total appropriated budget for the current year, and the revised projected budget, based on that appropriation for out years through the end year of the MYPP. Projected funds are determined by ITP and EERE management, and represent the "most reasonable" estimate for future funding. Prioritized plans are prepared every year when AOP's are written for the upcoming year.

The decision process is illustrated in Figures 3-b and 3-c below.

3.1.4 Risk Assessment

ITP considers several types of risks during the development and eventual implementation of advanced industrial technologies, including:

- *Technical Risk*: Will the technology work as envisioned?
- *Financial Risk*: Will the costs and returns meet expectation?
- *Operation Risk:* Could the technology interrupt production if not successful?
- *Market Risk:* Will the technology become obsolete or less desirable during development?
- *Internal Risk:* Will changes in personnel or company objectives affect implementation?

ITP is incorporating Stage-Gate management and risk analysis into the planning and execution of its research activities. The program is placing increased emphasis on the evaluation of market risk for new technologies to be deployed in the industrial sector. Specifically, ITP is analyzing and documenting the market potential, commercial readiness, and technology payback periods of its key technology investments, as well as identifying strategies to address market barriers and facilitate commercialization. The Stage-Gate process was discussed further in Section 2.

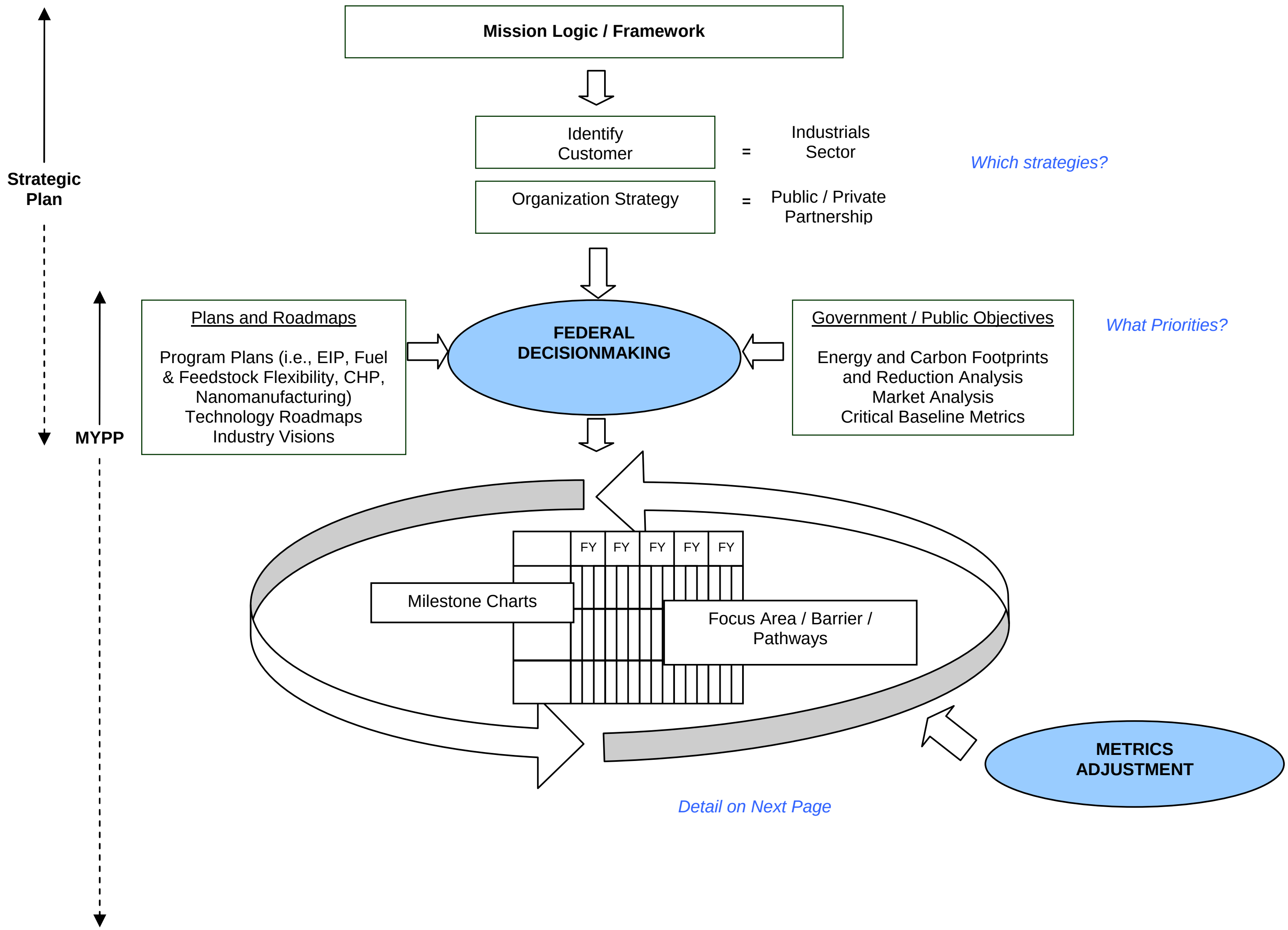


Figure 3-b. ITP Decision Process

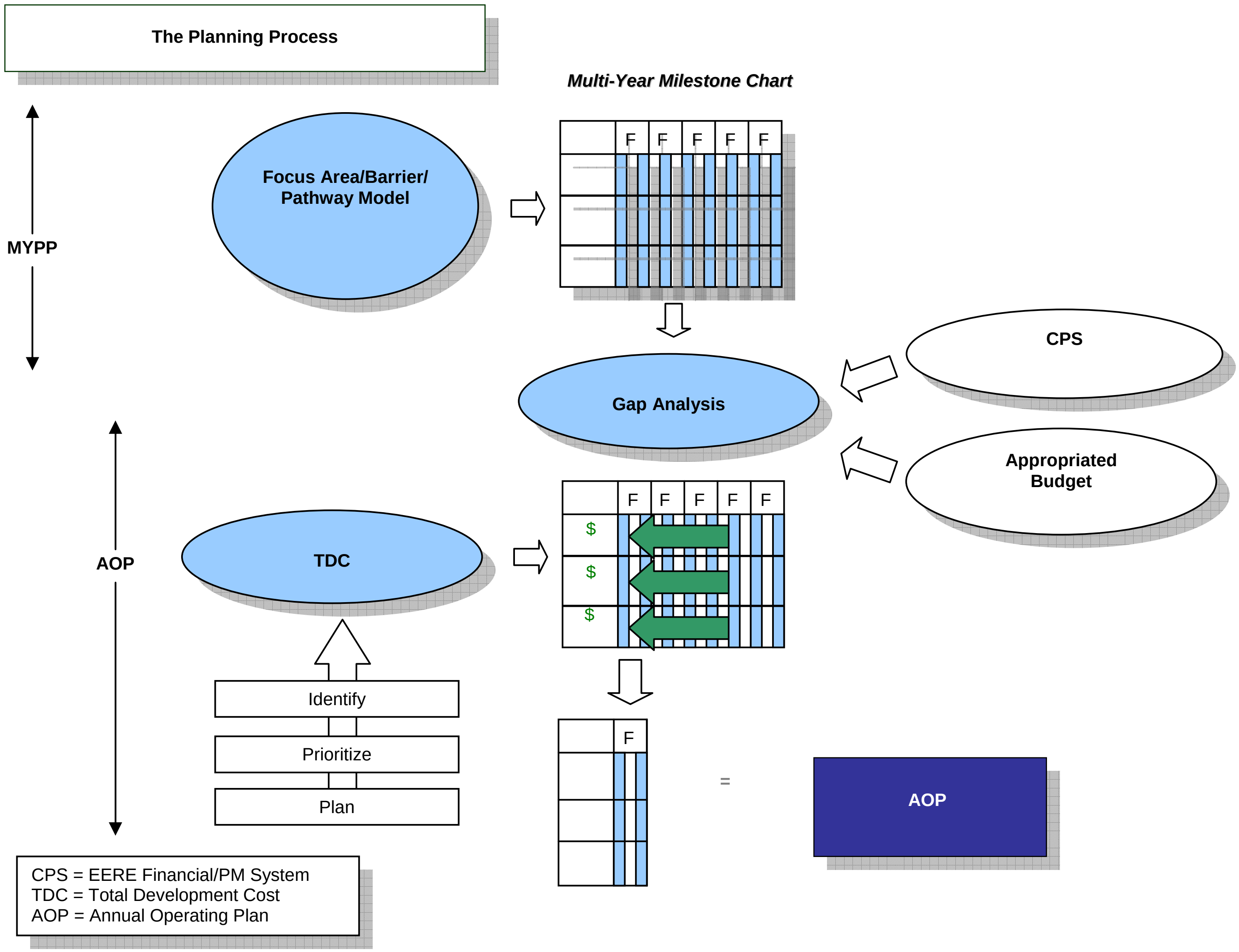


Figure 3-c. ITP Decision Process Detail

3.1.5 Peer Review Feedback Incorporation

As described in more detail in Section 3.3, ITP conducts peer review activities on a regular basis. Feedback from peer reviews is reviewed by ITP staff and actions are taken to address the feedback when appropriate. Actions undertaken could range from the re-direction of a research project to the re-direction or elimination of an element focus area. Feedback received could also influence the solicitation of future research topics. New technology areas could be suggested, or topic areas may receive additional emphasis to better balance the portfolio within an element.

3.1.6 Program Funding Mechanisms and Project Selection Process

ITP funds research projects through grants and cooperative agreements. Projects generally last from two to five years, and cost-sharing ranges from a minimum of 20% for applied research to a minimum of 50% for technology demonstrations. Projects are allocated funding on an annual basis. The Project Management Center (PMC) is responsible for executing research awards.

Universities selected through competitive solicitation to be in the Industrial Assessment Center program are also funded on an annual basis.

Each solicitation ITP conducts has a rigorous project selection process. Specific evaluation criteria are used to rate each proposal, with reviews being conducted by a merit review committee consisting of subject experts. A consensus is reached by the merit review committee, and specific projects are recommended. ITP then conducts a programmatic review before the Source Selection Official recommends approval of awards.

3.1.7 Cost Management and Monitoring

ITP monitors costs on a monthly basis, and receives detailed reports from the Project Management Center on costing information that is derived from DOE financial systems such as STARS.

The Project Management Center collects information on costing that is derived from DOE financial systems such as STARS and provides detailed reports to ITP staff monthly. Cost information is evaluated to determine funding actions and manage uncosted.

Extensive focus has been placed on the effective management of uncosted carryover balances to both reduce and optimize these balances using sound management practices. The Program has set an uncosted balances target for the end of FY 2008 that is at the minimum level considered necessary to ensure that the Program's progress continues unimpeded.

3.2 Program Analysis and Industry Input

ITP conducts rigorous analysis within its program elements, ranging from general trend studies and energy consumption analysis to potential opportunities and impacts of new technologies. ITP uses the results of its analytical activities to better focus its research activities. A broad look at the analytic approach and application is seen in the focus area/barrier/pathway model in Figure 3-d.

As shown in Figure 3-d, industry input (typically in the form of technology visions and roadmaps) is a key input to shaping the program. ITP works cooperatively with various industrial sectors to determine how industry priorities align with EERE/ITP mission and goals. The intersection of the industry input – mainly in the form of technology roadmaps – with Program goals has guided ITP in selecting R&D that will be valuable to industry, and will result in technologies that companies will adopt. The numerous industry technology roadmaps can be found on the ITP website.

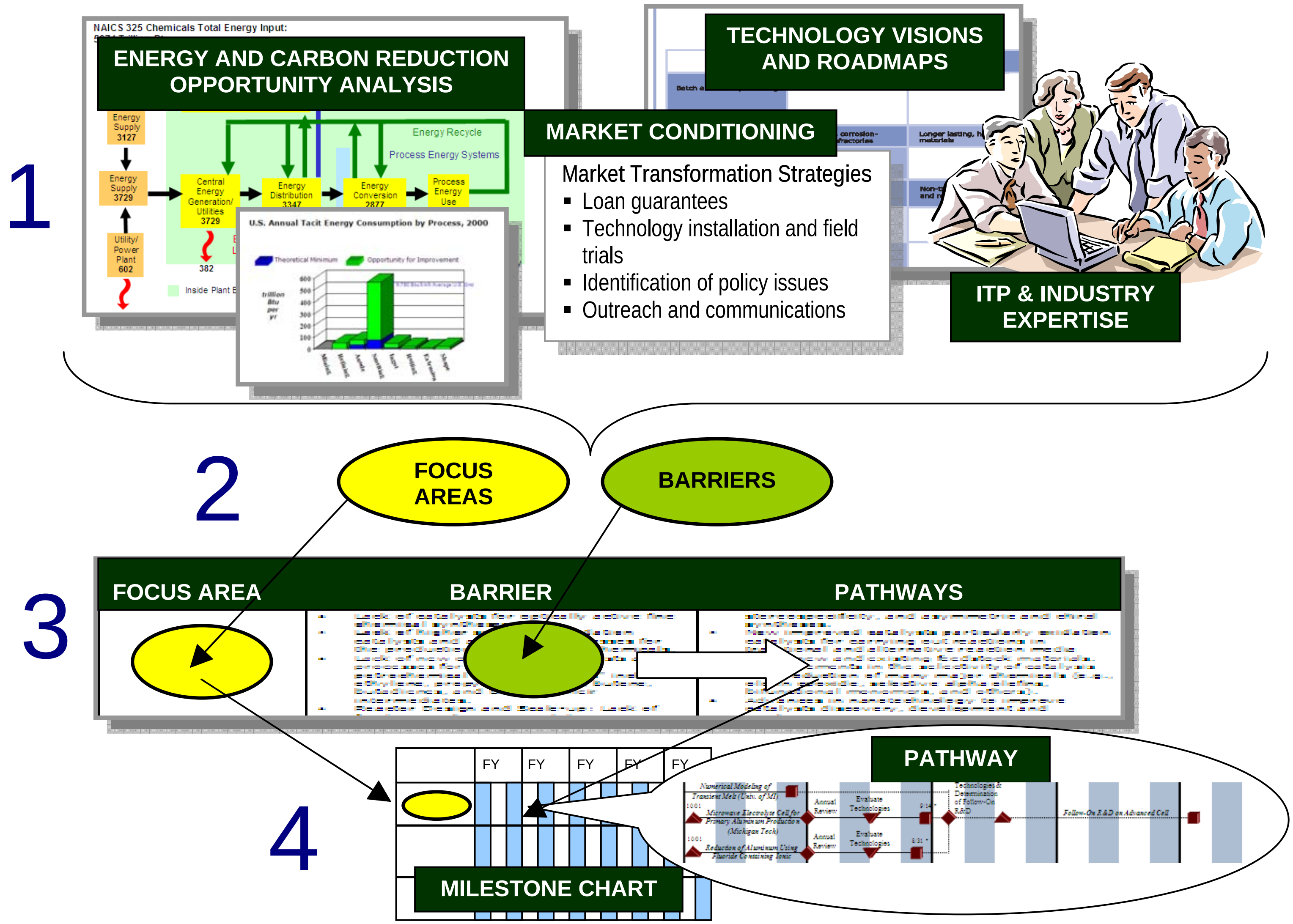


Figure 3-d. ITP Focus Area/Barrier/Pathway Model

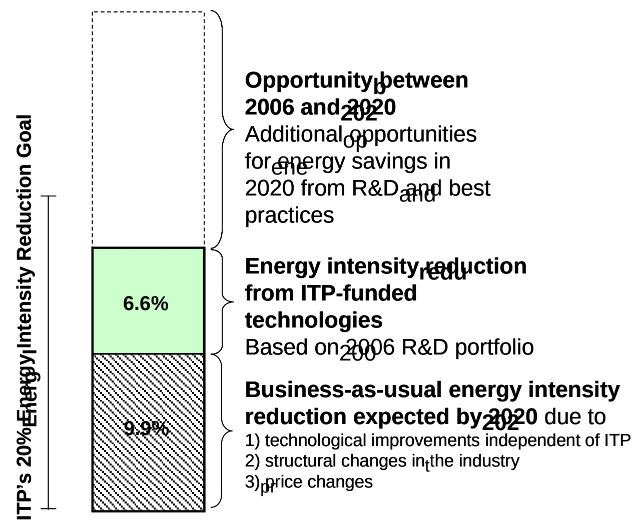
3.2.1 Analytical Tools Used by the Program

The primary analytic tool ITP uses is the GPRA model for individual technology benefits.

3.2.2 Analytical Work Sponsored

Over the past several years, ITP has sponsored the development of numerous energy footprints and energy bandwidth reports. A description of these studies follows, and a summary of publications is listed in Section 3.2.5. ITP also sponsors the GPRA analysis annually, with the most recent official results presented in Section 3.3.2.

Figure 3-e. Use of Analysis to Measure Contribution to Energy Intensity Reduction Goals (2006 Goal of 20% Reduction by 2020; Steel and Aluminum Portfolios Only)



Contribution to Energy Intensity Reduction

Analysis is used to estimate the contribution that ITP-supported technologies will make toward meeting the Program's energy intensity reduction goals. For example, Figure 3-e shows the results of an analysis to determine the contribution of ITP-funded R&D projects to reducing the energy intensity of steel and aluminum manufacturing.

Bandwidth Studies

The purpose of a "bandwidth" study is to provide a realistic estimate of the potential amount of energy that can be saved in an industrial process. The bandwidth refers to the difference between the amount of energy that would be consumed in a typical process today using commercially available technology, the level of energy efficiency that is reasonably achievable, and the minimal amount of energy needed to carry out the process (based on the 2nd Law of Thermodynamics). Results from ITP's individual bandwidth studies for industry are included in the implementation plans found in Section 2, and are available on ITP's website.

Footprint Studies

A series of Energy Footprints has been developed to map the flow of energy supply and demand in U.S. manufacturing industries. Identifying the sources and end-uses of energy helps to pinpoint areas of energy-intensity and characterize the unique energy needs of individual industries.

Most importantly, the footprints identify where energy is lost due to inefficiencies, both inside and outside the plant boundary. Losses are critical, as they represent immediate opportunities to improve efficiency and lower energy consumption. Detailed energy footprint summaries for each of the industries that ITP focuses on are found in Section 2.

The results of the energy footprint and bandwidth studies helped inform the selection of the "technology platforms" that comprise ITP's Energy Intensive Process R&D (Figure 3-f).

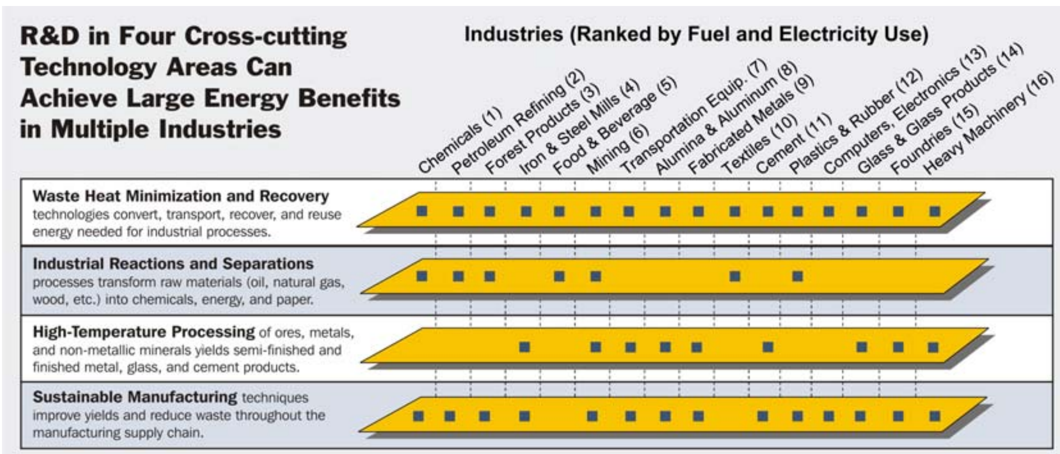


Figure 3-f. Technology Platforms Chosen Based on Rigorous Analysis

Market Analysis

Market analysis is a valuable tool for identifying the potential market(s) for a new technology, determining the likely acceptance and success of the technology in those markets, and estimating the future benefits that can be expected once the technology is commercialized and adopted. A variety of analyses are being performed to evaluate and characterize the potential markets for key technologies either proposed to or under development by ITP. These include:

- Development of market fact sheets that quantify expected markets and estimate technology penetration rates
- Thorough characterization of market potential, market barriers, and commercialization strategy as part of the solicitation and merit review process for new projects
- Development of commercial readiness assessments of key technologies, new program areas, and new projects
- Development of market transformation strategies in support of *the Save Energy Now* initiative and application of ITP technologies

ITP's Planning and Analysis Activities		
Element	2008 Milestones	Expected Completion
Planning	• Footprint and bandwidth studies • Energy Intensive Process research plan • CHP strategy document • Fuel and Feedstock Flexibility report • Nanomanufacturing workshop report	• FY07 • 1st Quarter • 1st Quarter • 2nd Quarter • 2nd Quarter
Focus	• Climate change/carbon analysis and projections • Commercial Readiness Assessments (CRAs) for 24 completed technologies • Initiation of next steps based on CRA recommendations • Initiate CRAs on new program/projects • Update *Impacts* commercialization database	• 1st Quarter • 2nd Quarter • 3rd Quarter • 4th Quarter • 2nd Quarter
Execution	• Solicitations and new starts based on the analyses • GPRA analysis • Stage-Gate evaluation of R&D projects • Incorporation of market risk identification and commercialization planning into solicitations • Work with RACs and MEPs for communication and outreach	• 3rd Quarter • 3rd Quarter • Ongoing • 2nd Quarter • Ongoing
Results	• Publication/dissemination of updated *Energy and Environmental Profile of the U.S. Petroleum Refining Industry* • Publication of EIP and CHP R&D plans and Fuel/Feedstock and Nanomanufacturing reports • Dissemination of GPRA results • Publication/dissemination of ITP *Impacts* report	• 1st Quarter • 2nd Quarter • 2nd Quarter • 2nd Quarter

3.2.3 Impact on Decision Process

Overview of Decision Process

ITP currently utilizes the milestone planning process to provide planning structure for its current portfolio and to assist in developing a vision for the future. The basic decision process is illustrated below in Figure 3-d.

The process begins with the consideration of the primary mission of EERE and the U.S. Department of Energy, and an understanding of how that mission fits within the planning, regulatory, and budgetary framework faced by ITP. This is known as the *mission logic*. Combining that logic with an understanding of ITP's customers, ITP's R&D needs, and a firm understanding of the organizational strategy of ITP, the decision process then considers the needs of ITP's external stakeholders within the perspective of the objectives of government. By balancing the needs and driving forces behind industry with the greater social good, priorities are set within the context of inherently governmental activities, resulting in the identification of technical objectives that serve both a public and private need.

At the federal decision-making level, there is a translation of these various inputs into essential areas of R&D, represented by the technology focus areas that are identified in each industry and cross-cut planning unit. By narrowing the planning exercise to several high-level technology focus areas, it is possible to produce a basic milestone chart for each planning area that essentially represents a 5- year opportunity analysis.

Each opportunity analysis/milestone chart is a balance of goals against achievable metrics. By taking into consideration the capacities and capabilities of government, including knowledge of people in the organization, dollar size of the investments ITP can make, and potential impact of investment decisions, the planning process supports better-informed decision-making within ITP.

3.2.4 Key Analytic Assumptions Employed

ITP uses EIA data such as the Annual Energy Outlook and the Manufacturing Energy Consumption Survey, Department of Commerce data, and data provided by industry associations in its analysis. In forward-looking analysis, ITP attempts to be conservative in assumptions made.

3.2.5 Analytic Publications

The following studies are completed, with publications describing results available on the ITP website:

- *Energy and environmental profiles* for the aluminum, chemicals, forest products, glass, metal casting, mining, petroleum refining, steel, and supporting industries.
- *Bandwidth studies* for the aluminum, chemicals, forest products, glass, mining, metal casting, petroleum refining, and steel industries.
- *Energy footprints* for the aluminum, cement, chemicals, fabricated metals, food processing, forest products, glass, metal casting, mining, plastics, petroleum refining, steel, textiles, and transportation equipment industries (see Figure 3-g).
- *Energy use and loss analysis* identifying and quantifying opportunities for energy savings in manufacturing and mining.
- *Impacts CY 2005* quantifying the benefits of ITP-supported technologies that have been commercialized and are being deployed in the market.

Industry	NAICS
All Manufacturing	
Alumina & Aluminum	3313
Cement	327310
Chemicals	325
Fabricated Metals	332
Food and Beverages	311,312
Forest Products	321,322
Foundries	3315
Glass & Glass Products, Fiber Glass	3272, 3296
Iron & Steel Mills	331111
Machinery & Equipment	333,334,335,336
Mining Energy	
Petroleum & Coal	324
Plastics & Rubber	326
Textiles	313,314,315,316

Figure 3-g. Available Energy Footprints

The following publications are being completed and will be disseminated to the appropriate audiences in FY08:

- *Program plans for new ITP areas* including Energy Intensive Processes, Fuel and Feedstock Flexibility, Combined Heat and Power, and Nanomanufacturing
- *Commercial readiness assessments* for 24 ITP technologies.

Other studies of importance to individual program elements are referenced in Section 2.

3.3 Performance Assessment

ITP engages in the following performance assessment activities, which are discussed further in the following section: results-based performance reporting, peer reviews, technology tracking, and other performance assessments.

3.3.1 Performance Assessment Strategy and Plan

ITP's strategy for performance assessment is centered on the activities listed below, which occur on an ongoing basis.

Results-Based Performance Reporting

ITP reports using DOE's Joule Performance Measurement Tracking System, R&D Investment Criteria, and OMB's Program Assessment Rating Tool (PART). These activities are coordinated with the EERE Business Administration office. ITP provides quarterly and annual results for the Joule system, annual results for PART, and the R&D Investment Criteria as required.

Peer Reviews

ITP regularly engages external peers to conduct both prospective and retrospective reviews of program activities in order to ensure that the program is focusing its scarce resources on the most important technical opportunities, selecting high quality research proposals, and prudently investing public funds to maximize program benefits. Along with the development of a more rigorous planning process, ITP has improved its multi-level review process. Peer review activities are conducted by outside, independent experts of both program and subprogram portfolios to assess quality, productivity, and accomplishments. Reviewers also assess relevance of program success to EERE strategic and programmatic goals and overall management. Below is a summary of the three major components that were instituted beginning in Fiscal Year 2004.

1. "State of the Program" Corporate Programmatic Peer Review

Conducted every other year, the corporate peer review focuses on the broader strategies and focus of the overall program. The last corporate peer review was conducted in 2006, and the next corporate peer review is scheduled for 2008.

Leader: ITP Program Manager
Reviewers: Independent "Panel" – Contract e.g. NAS, etc.
Presenters: Lead Technology Managers, Technology Managers, Selected Others
Participants: Industry, Other Programs, Other Agencies
Criteria:

1. Do we have the right goals?
2. Are our strategies correct?
   Have we been achieving success (progress against objectives, energy savings, etc.)?
   Are we positioned for future success?
3. Are our measures driving success?
4. Are our practices (business, communications, outreach) suitable and improving?
5. Add sessions on:
   Strategy/Planning

Investment
Focus Areas

Results/Protocol: Programmatic peer review report – signed by panel with recommendations.

2. "PMC Project Reviews"

As part of its oversight and management of the ITP portfolio, the Project Management Center will conduct peer reviews of individual project performance. These project baseline reviews are conducted at least once a year for each project, and are conducted at the discretion of the project manager.

Leader: Golden or NETL
Reviewers: Golden or NETL, Headquarters Technology Managers
Presenters: Principal Investigators
Participants: Industry, Lab, Principal Investigators, Other Technology Managers, Other Programs
Criteria:
1. Status of the project against cost, technical, schedule, baselines?
2. Evaluate scope – (increased emphasis, redirect, downselect, no change

Results/Protocol: A memo to file per project – documenting review including any recommendations, to contractors or scope changes.

Technology Tracking

ITP has assessed the progress of the technologies supported by its research programs for more than 20 years. ITP managers have long recognized the importance of developing accurate data on the impacts of their programs. Such data are essential for assessing ITP's past performance and can help guide the direction of future research programs.

Energy savings associated with specific technologies are estimated by Pacific Northwest National Laboratory (PNNL) through a rigorous process for tracking and managing data. When a technology's full-scale commercial unit is operational in a commercial setting, the technology is considered commercially successful and is placed on the active tracking list. When a commercially successful technology unit has been in operation for about ten years, that particular unit is then considered a mature technology and typically is no longer actively tracked. The active tracking process involves collecting technical and market data on each commercially successful technology, including details on the following:

- Number of units sold, installed, and operating in the United States and abroad (including size and location)
- Units decommissioned since the previous year
- Energy saved
- Environmental benefits
- Improvements in quality and productivity achieved
- Any other impacts, such as employment and effects on health and safety
- Marketing issues and barriers

Information on technologies is gathered through direct contact with either the technology's vendors or end users. These contacts provide the data needed to calculate the technology's unit energy savings, as well as the number of operating units. Therefore, unit energy savings are calculated in a unique way for each technology. Technology manufacturers or end users usually provide unit energy savings or at least enough data for a typical unit energy savings to be calculated. The total number of operating units is equal to the number of units installed minus the number of units decommissioned or classified as mature in a given year – information usually determined from sales data or end-user input. Operating units and unit energy savings can then be used to calculate total annual energy savings for the technology.

The cumulative energy savings measure includes the accumulated energy saved for all units actively tracked. These energy savings include the earlier savings from now mature and decommissioned units. Once cumulative energy savings have been determined, long-term impacts on the environment are calculated by estimating the associated reduction of air pollutants. This calculation is based on the type of fuel saved and the pollutants typically associated with combustion of that fuel and uses assumed average emission factors.

Program benefits documented by PNNL are conservative estimates based on technology users' and developers' testimonies. These estimates do not include either derivative effects, resulting from other new technologies that spin off of ITP technologies or the secondary benefits of the energy and cost savings accrued in the basic manufacturing industries downstream of the new technologies. Therefore, actual benefits are likely to be much higher than the numbers reported here. Nonetheless, the benefits-tracking process provides a wealth of information on the program's successes.

Other Performance Assessments

From time to time, ITP's performance is assessed by other means. These studies are often conducted for the entire EERE office, and could be general program evaluation studies, or internal technical program reviews. No set schedule for these performance assessments. ITP also conducts an annual GPRA analysis of expected portfolio benefits.

3.3.2 Data Collection to Support Routine and Periodic Performance Assessment

Corporate Benefits Data

"Using the program-provided outputs and assumptions, PBA works with the Benefits Analysis Team to prepare the technical assumptions needed to run the GPRA-NEMS and GPRA-MARKAL models. These models estimate the economic, energy, and environmental outcomes that would occur over the next 20 and 50 years, respectively, if the program is successful and the future unfolds according to the business-as-usual scenario. PBA then compares the outcomes of model runs that include EERE's programs with the outcomes of runs without EERE's programs. The benefits of EERE programs are determined by the improved economic, energy, and environmental outcomes provided by EERE's activities.

"In the coming years, PBA will extend its benefits estimation tools to address a range of uncertainties. PBA is developing alternative scenarios that will be used to illustrate the value of the current EERE portfolio under different futures along with tools and methods to explore how alternative program goals, budgets, and schedules can make EERE's benefits more robust to withstand uncertainties."

Official Benefit Projections

The Government Performance and Results Act (GPRA) of 1993 seeks to shift the focus of government decision-making and accountability away from the preoccupation with the activities that are undertaken, such as grants dispensed, to a focus on the results of those activities, such as real gains in responsiveness, or program quality. Under the Act, agencies are to develop multi-year strategic plans, annual performance plans, and annual performance reports that evaluate the success of the organization's strategic plan. The intent is to make government more accountable for results to its ultimate customer – the taxpayer. Each year, ITP estimates the future benefits of its program activities, pursuant to the requirements of GPRA. These estimates (Figures 3-h and 3-i) are based on the composition of projects contained in the current portfolio, which varies from year to year.

Item	2010	2015	2020	2025	2030
Primary Energy Savings (TBtu)	192	721	1,526	2,337	2,086
Baseline Industrial Energy Use[1] (TBtu)	34,460	35,600	36,950	38,770	40,580
Primary Energy Savings as Percent of Baseline (%)	0.6	2.0	4.1	6.0	5.1

Figure 3-h. Industrial Technologies Program: GPRA 2008 QM Rollup[2]

[1] DOE/EIA, *Annual Energy Outlook 2006*, Reference Case Forecast.

[2] GPRA08 Quality Metrics Methodology and Results, INDUSTRIAL TECHNOLOGIES PROGRAM, October 2006

GPRA 2008 PROJECTED PROGRAM BENEFITS

INDUSTRIAL TECHNOLOGIES PROGRAM

Planning Element	YEAR 2010	YEAR 2020	YEAR 2030
	Primary Energy Savings (TBtu)	Primary Energy Savings (TBtu)	Primary Energy Savings (TBtu)
Aluminum	0.4	13.2	12.2
Chemicals	8.1	281.2	260.9
Forest Products	1.8	50.4	90.8
Metal Casting	0.0	39.5	87.4
Steel	15.8	98.8	277.5
Industrial Materials	0.04	93.7	308.7
Sensors & Automation	7.3	138.9	17.0
Combustion	2.0	294.7	572.4
IAC	8.4	75.1	98.2
Best Practices	147	456	456

Source: *GPRA08 Quality Metrics – Methodology and Results," Energetics Inc., October 2006*

Figure 3-i. Industrial Technologies Program: GPRA 2008 Projected Program Benefits

Unquantifiable Benefits and Externalities

Beyond direct energy and environmental savings, technologies developed by ITP also often provide other benefits that are not as easy to quantify. These benefits include increases in productivity, retention of jobs, and non-energy cost savings.

Program Impact in 2020 and 2050

The Industrial Technologies Program covers a wide range of technologies, industries, and end-use applications. The heterogeneity of the program's R&D activities makes it difficult to represent program activities explicitly in the MARKAL-GPRA06 framework. Instead, the projected ITP goals by various industries were aggregated into MARKAL-GPRA06 industrial energy-use demand categories as a set of conservation supply curves.

The potential savings represented in these conservation measures yield an overall reduction in delivered energy consumption. The reduction in electricity demand also leads to the reduction in coal and gas-based generation. Both conservation and reduction in electricity demand result in less investment in end-use devices and electric-generation capacity on the supply side. The environmental benefits estimated for ITP's R&D activities are shown in Figure 3-j.

Annual Benefits	2020	2050
Environmental		
Carbon Savings (million metric tons carbon equivalent/yr)	31	18
Cumulative Carbon Savings (million metric tons carbon equivalent)	174	791

Figure 3-j. FY07 Industrial Technologies Program: Environmental Benefits Estimates for (MARKAL-GPRA08)

Base Case without Program Activities in 2020 and 2050

Without ITP program activities, the industrial sector will consume a higher quantity of energy, as the development and adoption of energy-efficient technologies would be significantly reduced.