EB-2015-0029
EB-2015-0049

Union Gas Limited and
Enbridge Gas Distribution Inc.

Applications for Approval of 2015-2020
demand side management plans.

IGUA Compendium
for Union Gas Panel 3

gowlings

UNION GAS LIMITED
Total Customers by Service Type and Rate Class
All Customer Rate Classes that DSM Programs will be Developed For and Offered To
Year Ended December 31, 2014

Line No.	Particulars	Residential (a)	Commercial (b)	Industrial (c)	Total (d)
	General Service				
1	Rate M1 Firm	995,647	78,652	3,990	1,078,289
2	Rate M2 Firm	8	5,708	1,224	6,940
3	Rate 01 Firm	303,618	28,129	33	331,780
4	Rate 10 Firm		1,866	153	2,019
5	**Total General Service**	**1,299,273**	**114,355**	**5,400**	**1,419,028**
	Contract				
6	Rate M4		53	101	154
7	Rate M7		14	14	28
8	Rate 20		1	47	48
9	Rate 100		-	11	11
10	Rate T-1		7	29	36
11	Rate T-2		3	19	22
12	Rate M5		52	30	82
13	**Total Contract**	**-**	**130**	**251**	**381**
14	**Total Number of Customers**	**1,299,273**	**114,485**	**5,651**	**1,419,409**

*Customer count for storage is included within transportation

Ontario Energy Board

EB-2014-0134

Report of the Board

Demand Side Management Framework for Natural Gas Distributors (2015-2020)

December 22, 2014

Two stakeholders, both representatives of large volume customers, who did not feel that programs for large volume customers should be mandatory, recommended that the Board consider providing an opportunity for large volume customers to “opt-out” from, or not be required to help fund, a gas utility DSM program for large volume customers. They noted that the principle that ratepayer funded DSM should not be mandatory for large volume customers protects large volume customers as a class, but does not address a customer-specific issue where it was argued that many of these customers are self-motivated and have made significant energy efficiency investments on their own. These stakeholders noted that large volume customers do not need or desire a mandatory ratepayer funded DSM program and that in the event a customer believes that utility or third party expertise is helpful, that be provided outside of a rate funded DSM program.

6.2 Board Conclusions

As discussed in Section 4.2 – Budgets, the Board expects the gas utilities’ multi-year DSM plans will enable the delivery of results in the areas which have been identified as key priorities in the LTEP, Conservation Directive and by the Board.

Key priorities identified in the LTEP and Conservation Directive:

a) Implement DSM programs that can help reduce and/or defer future infrastructure investments;

b) development of new and innovative programs, including flexibility to allow for on-bill financing options;

c) increase collaboration and integration of natural gas DSM programs and electricity CDM programs; and

d) expand the delivery of low-income offerings across the province.

The Board identified priorities:

e) implement DSM programs that are evidence-based and rely on detailed customer data; and,

f) ensure that programs take a holistic-approach and identify and target all energy saving opportunities throughout a customer’s home or business.

It is important that the gas utilities' multi-year DSM plans focus on activities that will achieve a greater amount of long-term natural gas savings, better help participating customers manage their overall usage and ultimately their bills, and consider the guiding principles from Section xx and key priorities outlined above. The Board has provided a specific discussion of program types in the DSM Guidelines in Section 6.0. The gas utilities are expected to collaborate and integrate natural gas DSM program offerings across all sectors with Province-Wide Distributor and/or Local Distributor CDM programs throughout the course of the DSM framework period. As part of the multi-year DSM plans filed by the gas utilities, the Board expects that the gas utilities will include a discussion of the areas where programs have been coordinated and/or integrated with Province-Wide Distributor and/or Local Distributor, program aspects that have the potential to be integrated in the future and any barriers that have restricted the program from being coordinated and integrated with an electricity CDM program.

Additionally, the gas utilities DSM portfolios should include programs that are specifically designed to address customer groups with significant barriers to entry (e.g., small business customers). DSM portfolios should also include programs targeted to customers who are already very invested in energy efficiency and where more complex or customer-specific options are necessary.

The Board is of the view that rate funded DSM programs for large volume customers should not be mandated as these customers are sophisticated and typically competitively motivated to ensure their systems are efficient. The small number of customers in these classes further heightens the issues of one customer subsidizing business improvements of another. If a gas utility, in consultation with its large volume customers, determines that there is substantial interest in the gas utility providing expertise and a value-added service to help improve the energy efficiency levels of these customers' facilities, the gas utilities are able to propose a fee-for-service program which the Board will approve on its merits. The primary focus of any program proposed for large volume customers should be offering technical expertise, including conducting facility audits, advice for operational improvements, or engineering studies as opposed to capital incentives. Specifically, the gas utilities can propose a fee-for-service DSM programs to the customers in those classes identified as large volume rate classes in the table below. As can be seen in the table below, there is a very limited number of customers in these rate classes.

Table 1 – Large Volume Rate Classes

Enbridge Gas Distribution Inc.				
Rate Class	No. of Customers	2013 Annual Volumes (m^3)[22]	Percent of Total Annual Volumes[21]	Description of Rate Class
Rate 125	5	n/a	n/a	For applicants who use the EGD network to transport a specified maximum daily volume of natural gas that is not less than 600,000 m^3.

Union Gas Limited				
Rate Class	No. of Customers[23]	2013 Annual Volumes (m^3)[24]	Percent of Total Annual Volumes	Description of Rate Class
Rate T1	38	452,838,193	3%	Rate T1 is a contract rate for customers in Union's southern operations area who actively manage their own storage services, have an aggregated Firm Daily Contracted Demand up to 140,870 m3 and who consume a minimum of 2.5 million m^3 of natural gas each year. Customers in this rate class include manufacturing plants, chemical plants, large food processors/greenhouses and small specialty steel plants.
Rate T2	22	4,241,475,463	30%	Rate T2 is a contract rate for customers in Union's southern operations area who actively manage their own storage services and require a minimum aggregated Firm Daily Contract Demand of at least 140,870 m^3. Customers in this class include large power (cogeneration), large steel, large petrochemical plants and a large feedstock plant.
Rate 100	14	1,926,579,498	14%	For large commercial and industrial customers who have signed a Northern Distribution contract for firm natural gas delivery with Union Gas. These customers are typically large manufacturers requiring a very large volume of natural gas for industrial processes – such as steel, pulp and paper and mining. These customers, located in our northern and eastern operation areas, require a minimum consumption of 100,000 m3 of natural gas or more each day. These customers must maintain a 70% load factor over the course of a year.

The fee-for-service program would be different than the current large volume program approved by the Board. Rate funding recoverable from all customers in the large

[22] Rate 125 is made up of power generators who are billed on contract demand as opposed to actual throughput.
[23] As per EB-2014-0145, Exhibit A, Tab 2, Appendix A, Schedule 10
[24] As per EB-2014-0145, Exhibit A, Tab 2, Appendix A, Schedule 6

volume rate classes for a fee-for-service program can only be used for portfolio level administration costs, restricted to utility staff, marketing and evaluation activities. Any additional funding to support customer-specific deliverables, including facility audits, engineering reports or technology upgrades would need to be provided directly from the participating customer. The gas utilities may charge interested customers an appropriate fee to recover the cost of the energy efficiency consulting service it can provide. The Board expects that the gas utilities, with many years delivering DSM programs and an established expertise, as well an experienced DSM staff, can operate at a highly efficient level to source and acquire the opportunities available. In order to motivate the gas utilities to seek out these possibilities, the Board will enable the gas utilities to claim the verified gas savings that result from the fee-for-service large volume program. Achievement of the targets in these areas may result in a performance incentive. The performance incentive earned in relation to the fee-for-service large volume program will be recovered in the same manner as the gas utilities have traditionally recovered amounts. The Board feels that this approach strikes an appropriate balance by substantially reducing the cross-subsidization issues of large volume customers given the relatively small number of customers in the rate classes while maintaining the potential for considerable natural gas savings from large volume customers.

7.0 PROGRAM EVALUATION

Evaluation, Measurement and Verification ("EM&V") is the process of undertaking studies and activities aimed at assessing the impacts (e.g., natural gas savings) and effectiveness of an energy efficiency program on its participants and/or the market. Monitoring and EM&V also provides the opportunity to identify ways in which a program can be changed or refined to improve its performance. It is important to ensure proper EM&V studies are being undertaken to enable the pursuit of cost-effective DSM programs. Moreover, EM&V of DSM activities is important to support the Board's review and approval of prudent DSM spending, and requests to recover lost revenues and shareholder incentive amounts claimed by the gas utilities.

Traditionally, the evaluation process related to DSM programs has been a function that the gas utilities have managed, with input from key stakeholders included throughout the process. The Board sought stakeholder comment related to the Board taking on a larger role in the program evaluation process.

Ontario Energy Board

EB-2014-0134

Filing Guidelines to the Demand Side Management Framework for Natural Gas Distributors (2015-2020)

December 22, 2014

measures, the gas utilities will be providing a greater opportunity for customers to realize more significant benefits and receive more value for their investment.

6.1 DSM Programs with Long-Term Natural Gas Savings

A central component of the gas utilities' new DSM Plans should be a continued transition from programs that deliver short-term benefits, to those with long-term natural gas savings which will provide long-term value to energy consumers. By delivering DSM programs, the gas utility is in a unique and important position to help customers better manage their consumption and use natural gas more efficiently. This can ultimately reduce overall demand which has the potential to lower long-term costs to the gas utilities to the benefit of consumers. Programs should be designed and prioritized to deliver results that will lead to total bill reductions and continue to be in place over the long-term.

6.2 Pilot Programs

In addition to offering programs to its customers, the gas utilities should consider how pilot programs can help to better understand new program designs and delivery concepts, ultimately leading to greater natural gas savings and market penetration of programs. Pilot programs should involve the testing or evaluation of energy efficient technologies, alternative financing mechanisms or detailed, customer-specific natural gas usage information that may serve as a model for future DSM program development.

The Board further encourages the gas utilities to explore pilot programs based on a pay-for-performance funding/incentive recovery model, discussed in Section 5.0 of the DSM framework. With these types of programs, the gas utilities would be compensated for the natural gas savings achieved by the programs, rather than a direct full cost recovery model. Both the costs of the program and the shareholder incentive amount should be built into the proposed rate ($/m^3) of verified natural gas savings and be structured so that this price considers the additional risk of this compensation model.

6.3 Programs for Large Volume Customers

The Board continues to be of the view that programs designed for large volume customers are not mandatory. As discussed in Section 6.2 of the DSM framework, if a gas utility deems it appropriate to offer a program for its large volume customers[2], the program should be offered under a fee-for-service model with the primary focus on providing value-added, technical expertise to customers, including engineering studies on how the customer can more efficiently use their current energy systems and identifying areas of efficiency improvements. If a gas utility proposes a large volume fee-for-service program as part of its multi-year DSM plan, at a minimum, it should include the following program details:

- The rate classes of the targeted customers
- The anticipated costs the participating customers will need to provide in order to receive service and what the various services (e.g., facility audit, operational review, engineering study, etc.) are expected to cost
- The anticipated participation rates
- The projected annual and lifetime savings goals
- The forecasted administrative, marketing and evaluation costs, as well as the maximum shareholder incentive allocated to the program
- The subsequent total cost and rate impacts for all customers in the large volume rate classes

Costs from the large volume program should generally be recovered directly from the participating customer and not allocated to the large volume rate class. However, the gas utilities are able to allocate the administrative costs from the large volume fee-for-service program to the large volume rate classes, as discussed in the DSM framework. Administrative costs are generally the costs of staff who work on DSM activities. These costs are often differentiated between support and operations staff. Support staff costs are considered fixed costs or "overhead" that occur regardless of the level of customer participation in the programs. Operations staff costs vary, depending on the level of customer participation. The gas utilities should not allocate any operations staff costs to the large volume rate classes. These costs should be included in the fee charged by the gas utility to participating large volume customers.

6.4 Low-Income Programs

The purpose of DSM programs tailored to low-income consumers is to recognize that, these programs more adequately address the challenges involved in providing DSM programs for, and the special needs of, this consumer segment.

[2] Large volume customers are those customers in EGD's Rate 125 class, and Unions Rate T1, Rate T2 and Rate 100 classes.

and Reporting Requirements. Materials from the session including the meeting invitation, the attendance list and the presentation can be found at Exhibit A, Tab 3, Appendix B.

Consultative Session 4 – March 11, 2015

Union met with stakeholders to review the following items regarding the Plan: 2016-2020 Program proposal updates for all markets; the overall Portfolio budget; 2016-2020 Scorecards with proposed metrics and formulas; the proposed allocation of shareholder incentive across scorecards; and the allocation of budget across rate classes. Materials from the session including the meeting invitation, the attendance list and the presentation can be found at Exhibit A, Tab 3, Appendix B.

8.0 Proposed Treatment of Rate T1 Customers

In the Framework, the Board proposes that the Large Volume rate classes for Union be defined as Rate T1, Rate T2 and Rate 100. Beginning in 2016, Union is proposing to offer Rate T1 customers Commercial/Industrial Programs within the Resource Acquisition Scorecard rather than the Large Volume Program given the significant differences between Rate T1 and Rate T2 in terms of daily contracted demand and annual consumption.

In its 2013 Cost of Service Decision (EB-2011-0210), the Board approved the split of Rate T1 into a new Rate T1 rate class and a new Rate T2 rate class, effective January 1, 2013. Prior to the Board's Decision Union filed its 2013-2014 Large Volume DSM Plan, which was premised on Rate T1 before the split of the rate class. While the new Rate T1 remained in the Large Volume

Scorecard, the rate class was treated differently than Rate T2 and Rate 100. Specifically, the Programs offered to Rate T1 customers were consistent with the Commercial/Industrial Custom offering on the Resource Acquisition Scorecard. Rate T1 customers are similar in composition to customers in Union's Rate M4 and Rate M7 rate classes and Enbridge's Rate 100 rate class, none of which are defined as Large Volume in the Framework. Please see Exhibit A, Tab 3, Section 12.1 for Union's proposed treatment of Rate T1 customers.

9.0 Migration of Rate M4/M5/M7 Customers

In its EB-2011-0210 Decision, the Board approved Union's proposed Rate M4, Rate M5 and Rate M7 rate class eligibility changes effective January 1, 2014. As a result of this change, 22 Rate M4 and Rate M5 customers in Union's 2013 Board-approved forecast were required to move to Rate M7 effective January 1, 2014. Union's ratemaking process during Incentive Regulation Mechanism ("IRM") does not recognize the annual volumes associated with the transition of 22 customers from Rate M4 and Rate M5 to Rate M7, while Union's proposed 2016-2020 DSM budget reflects the current number of customers in all three rate classes. Due to Rate M7 rate class eligibility changes, the DSM costs in proportion to the current approved bill in Rate M7 are approximately two times greater than Rate M4 and three times greater than Rate M5. To address the discrepancy between the proportion of DSM costs in Rate M7 compared to Rate M4 and M5, Union proposes to pool the proposed DSM costs for these three rate classes and reallocate the costs in proportion to 2015 approved volumes. Union's approach is discussed in more detail at Exhibit A, Tab 3, Section 13.

UNION'S PROPOSED 2016-2020 DSM PLAN

Table 2

2016-2020 DSM Plan Budget

	Year				
	2016 ($000)	2017 ($000)	2018 ($000)	2019 ($000)	2020 ($000)
Program Budget					
Resource Acquisition					
Residential Development and Start-up	$ 1,850	$ -	$ -	$ -	$ -
Residential Incentives/Promotion	$ 8,745	$ 13,569	$ 15,916	$ 15,916	$ 15,916
Residential Evaluation	$ 559	$ 709	$ 859	$ 859	$ 859
Residential Administration	$ 991	$ 1,071	$ 1,071	$ 1,071	$ 1,071
Total Residential Program	$ 12,145	$ 15,349	$ 17,845	$ 17,845	$ 17,845
Commercial/Industrial Incentives/Promotion	$ 14,562	$ 14,571	$ 15,293	$ 14,957	$ 14,957
Commercial/Industrial Evaluation	$ 189	$ 189	$ 189	$ 189	$ 189
Commercial/Industrial Administration	$ 3,929	$ 4,076	$ 4,076	$ 4,076	$ 4,076
Total Commercial/Industrial Program	$ 18,680	$ 18,836	$ 19,558	$ 19,222	$ 19,222
Total Resource Acquisition Programs	$ 30,825	$ 34,185	$ 37,404	$ 37,067	$ 37,067
Performance-Based					
Performance-Based Incentives/Promotion	$ 297	$ 592	$ 837	$ 582	$ 802
Performance-Based Evaluation	$ 35	$ 35	$ 35	$ 35	$ 35
Performance-Based Administration	$ 216	$ 216	$ 216	$ 216	$ 216
Total Performance-Based Program	$ 548	$ 843	$ 1,088	$ 833	$ 1,053
Low-Income					
Low-Income Incentives/Promotion	$ 9,705	$ 10,647	$ 11,863	$ 12,419	$ 13,261
Low-Income Evaluation	$ 219	$ 212	$ 225	$ 244	$ 262
Low-Income Administration	$ 1,425	$ 1,425	$ 1,425	$ 1,425	$ 1,425
Total Low-Income Program	$ 11,349	$ 12,284	$ 13,514	$ 14,088	$ 14,948
Large Volume					
Large Volume Incentives/Promotion	$ 400	$ 349	$ 373	$ 397	$ 421
Large Volume Evaluation	$ -	$ -	$ -	$ -	$ -
Large Volume Administration	$ 409	$ 409	$ 409	$ 409	$ 409
Total Large Volume Program	$ 809	$ 758	$ 783	$ 807	$ 831
Market Transformation					
Optimum Home Incentives/Promotion	$ 841	$ -	$ -	$ -	$ -
Optimum Home Evaluation	$ -	$ -	$ -	$ -	$ -
Optimum Home Administration	$ 201	$ -	$ -	$ -	$ -
Optimum Home Program	$ 1,042	$ -	$ -	$ -	$ -
Programs Sub-total	**$ 44,573**	**$ 48,070**	**$ 52,787**	**$ 52,795**	**$ 53,899**
Portfolio Budget					
Research	$ 1,500	$ 1,000	$ 1,000	$ 1,000	$ 1,000
Evaluation	$ 1,300	$ 1,300	$ 1,300	$ 1,300	$ 1,300
Administration	$ 2,935	$ 2,842	$ 2,842	$ 2,842	$ 2,842
Pilots	$ 1,000	$ 1,000	$ 500	$ 500	$ 500
DSM Tracking and Reporting System Upgrades	$ 5,000	$ -	$ -	$ -	$ -
Portfolio Sub-total	$ 11,735	$ 6,142	$ 5,642	$ 5,642	$ 5,642
Total DSM Budget Pre-Inflation	**$ 56,308**	**$ 54,212**	**$ 58,429**	**$ 58,437**	**$ 59,541**
Cumulative Inflation @1.68%	$ 946	$ 1,837	$ 2,995	$ 4,027	$ 5,172
Total DSM Budget Post-Inflation	**$ 57,254**	**$ 56,049**	**$ 61,424**	**$ 62,464**	**$ 64,714**

The program budgets and their individual components (development and start-up, incentives/promotion, evaluation and administration) are consistent with the definitions provided in the Guidelines, Section 9.1.2. The Portfolio budget captures DSM activities that are not

Table 7

2016-2020 Performance-Based Scorecards

2016 Performance-Based Scorecard				
Metrics	Metric Target Scorecard			Weight
	Lower Band	Target	Upper Band	
RunSmart Participants	19	25	31	50%
SEM Participants	2	3	4	50%

2017 Performance-Based Scorecard				
Metrics	Metric Target Scorecard			Weight
	Lower Band	Target	Upper Band	
RunSmart Participants	75% of Target	2016 Actual times 125%	125% of Target	20%
RunSmart Savings (%)	5%	10%	15%	60%
SEM Participants	2016 Actual	2016 Actual + 2	2016 Actual + 4	20%

2018 Performance-Based Scorecard				
Metrics	Metric Target Scorecard			Weight
	Lower Band	Target	Upper Band	
RunSmart Participants	75% of Target	2017 Actual times 125%	125% of Target	10%
RunSmart Savings (%)	5%	10%	15%	40%
SEM Participants	2017 Actual	2017 Actual + 2	2017 Actual + 4	10%
SEM Savings (%)	4%	5%	6%	40%

2019 Performance-Based Scorecard				
Metrics	Metric Target Scorecard			Weight
	Lower Band	Target	Upper Band	
RunSmart Participants	75% of Target	2018 Actual times 125%	125% of Target	10%
RunSmart Savings (%)	5%	10%	15%	40%
SEM Savings (%)	2018 Actual	2018 Actual + 2%	2018 Actual + 4%	50%

2020 Performance-Based Scorecard				
Metrics	Metric Target Scorecard			Weight
	Lower Band	Target	Upper Band	
RunSmart Participants	75% of Target	2019 Actual times 125%	125% of Target	10%
RunSmart Savings (%)	5%	10%	15%	40%
SEM Savings (%)	2019 Actual	2019 Actual + 2%	2019 Actual + 4%	50%

Union's 2016 Performance-Based Scorecard focuses on Participant Metrics as savings for these offerings will not be realized until a full year (post implementation) of metered data is available for analysis. In future years Union has placed greater weightings on the savings metrics, consistent with the direction outlined in the Framework. Further information on the targets is included in Exhibit A, Tab 3, Appendix A, Section 1.2 where the program offering targets are discussed in further detail. The Scorecard Metric descriptions are provided below.

Scorecard Metric Descriptions

RunSmart Participants

The Participation Metric for RunSmart measures the number of customers that enter into an agreement with Union and participate in a site walk-through within a program year. This Metric is based on a number of customers without prior DSM participation history, consuming greater than 50,000 m^3 per year of natural gas. As identified at Exhibit A, Tab 3, Appendix A, Section 1.2, the Target assumes Union successfully engages 10% of customers without prior DSM participation history. For 2017-2020, the RunSmart participant targets will be determined by multiplying the previous year's achievement by 125%. The Upper Band and Lower Band targets will be calculated at 75% and 125% of the Target respectively[23].

SEM Participants

The SEM Participation Metric measures the number of customers that enter into a five-year agreement with Union to participate in the SEM offering, within a given program year. This Metric is based on an eligible pool of approximately 100 contract industrial manufacturing customers, consuming greater than 1,000,000 m^3 per year of natural gas. The Target assumes Union successfully engages 15% of the target market in the first three years of the program (approximately 15 customers by the 2018 program year). For 2017-2018, the SEM participant targets will be determined by adding two incremental participants to the previous year's participation achievement. The Lower Band will become the previous year's achievement and the Upper Band will be calculated as the Target plus two incremental participants[24]. This metric will not be included for 2019-2020 as a five-year customer commitment is required to establish a baseline and demonstrate savings.

[23] For illustrative purposes, if Union has 25 participants in 2016 than its 2017 Target will be 31 (2016 achievement of 25 times 1.25). Lower and Upper Band Targets will be 23 (2017 Target of 31 times 75%) and 39 (2017 Target of 31 times 125%).

[24] For illustrative purposes, if Union signs three customers to a five-year SEM agreement in 2016 than the 2017 Target will be five customers. The Lower Band target will be three participants (2016 achievement) and the Upper Band will be seven participants (2017 Target of five plus two).

RunSmart Savings (%)

The Savings Metric for RunSmart measures the aggregate percentage of savings achieved by the program participant within a program year. This metric is proposed to begin in 2017, as that is the first year that program participants will demonstrate savings. For 2017-2020, Lower Band, Target, and Upper Band performance levels are based on the offering's incentive design. RunSmart's tiered incentive structure has been designed to reward customers for savings. The Lower Band target is established as an aggregate savings of 5% to be demonstrated by RunSmart participants. The Target performance reflects the next tier of savings, 10%, while the Upper Band reflects an exemplary savings of 15%.

SEM Savings (%)

The Savings Metric for SEM measures the aggregate percentage of savings achieved by the program participants, within a program year. This metric is proposed to begin in 2018, which is the first year that program participants will demonstrate savings. SEM performance-based targets will change year-over-year as savings are measured on an on-going basis for participating customers over a 5-year period. While the 2018 scorecard targets are set based on expected savings, for 2019-2020 the targets will be established on a formulaic basis as follows: the Lower Band is the previous year's achievement, the Target is the previous year's achievement plus 2%, and the Upper Band is based on the Target plus 2%.[25]

[25] For illustrative purposes, if Union's 2018 SEM program achieves an aggregate savings of 5% from all SEM participants then the 2019 Lower Band will be 5%, the Target will be 7% (2018 achievement of 5% plus 2%) and the Upper Band will be 9% (2019 Target of 7% plus 2%).

APPENDIX A: PROPOSED 2016-2020 DSM PROGRAMS

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1.3 Large Volume

Background

Following extensive customer consultation in 2012, Union designed and delivered a DSM Program specifically for its Large Volume (T2 and Rate 100) Customers in 2013 and 2014. The program includes the following key elements:

- Customer incentives for studies, custom projects, and metering.
- Union technical staff to assist customers with Energy Efficiency Plans and projects.
- Technical training courses
- A Direct Access Budget specific to each customer to provide clarity on the amount of incentives available
- Union performance incentives based on achievement level relative to natural gas savings targets

Through close collaboration between Union and Large Volume Customers, the program participation rate in 2013 was 82% of T2 and Rate 100 customers and increased to 95% in 2014. The audited program cost and lifetime savings in 2013 were \$3.55 million and 1,664 million m^3 of natural gas respectively. These natural gas savings represent almost 60% of 2013 DSM program savings from all Union Rate Classes.

Under the new Framework, this program will conclude at the end of 2015

2015-2020 Demand Side Management Framework

The Framework offers the following conclusions to guide the design of a DSM Program for Large Volume Customers starting in 2016:

- No ratepayer-funded customer incentives
- Proposed fee for consulting service by Union technical experts
- Union performance incentives based on achievement level relative to natural gas savings targets
- Only portfolio-level staff costs can be ratepayer-funded

Customer Consultations

Union carried out consultations with 16 Large Volume Customers (44% of all Union's Rate T2 and Rate 100 customers) in February and March 2015 to share the new Framework and understand what features and benefits the customers value in a utility energy efficiency program. The detailed responses are tabulated in Attachment A and the results are summarized here:

- Some customers valued ratepayer-funded incentives and wanted them to continue in the program
- Some customers treat incentive payments as a revenue stream to offset costs of future energy saving initiatives.
- Most customers supported continuing involvement of Union technical experts with customers' energy teams and/or other technical staff.
- Four (4) customers specifically supported the idea of a program with an emphasis on technical support for energy teams, technical training and early-stage identification of energy efficiency opportunities, which would be funded through rates.
- The concept of fee-for-service offerings by Union was not attractive to customers as they believed that their internal processes would make them administratively complicated to access and inflexible in practice.
- Customers wanted to minimize the impact of deferral account dispositions and supported lower program costs.

This feedback has resulted in the development of a new program outlined below.

Union Conclusions

Union accepts the need articulated in the Framework to reduce the scale of ratepayer impact. The issue of cross-subsidization between ratepayers within each rate class, was addressed in 2013 by the creation of Direct Access Budgets for all Rate T2 and Rate 100 customers.

Union has concluded that it should not offer a program based on fee-for-service consulting services on energy management for the following reasons:

- It would not be appropriate to develop fee-for-service offerings with Board-approved regulated rates when these services are already offered competitively in the market.
- Making reliable determinations of the actual natural gas savings from projects Union participates in would be required for Union to track savings for the purpose of determining a performance incentive. It would not be justifiable for a customer to devote staff resources to this activity without receiving a customer incentive.
- Reporting and receiving a performance incentive based on customer savings achieved as a result of fee-for-service consulting would constitute a conflict of interest for Union.
- Consultations with Large Volume Customers showed that the nature of Union's technical interactions with the customer's energy team members and other staff does not lend itself to a fee-for-service approach.

Instead, based on direct customer input, Union has determined that it is appropriate for Union to offer a multi-year ratepayer-funded Rate T2/Rate 100 program that will support large volume customers by ensuring a continued focus on energy efficiency by providing training and resources that will sustain the efforts to date. The program cost to ratepayers would be reduced to $800,000/year.

In view of the demonstrated high participation rates in the prior years' ratepayer-funded programs, the results of customer consultations in February and March 2015, and contributing to the achievement of Goal (ii) in Section 1.4 of the Framework to "Promote energy conservation and energy efficiency to create a culture of conservation", Union believes this is a natural and appropriate evolution of the DSM programs for this market. The proposed program would include the following:

- Continuing specialized technical support and equipment audits by qualified Union Professional Engineers on an as-requested basis
- Coordinating and delivering training on energy near plant locations or online to minimize customer staff time away from the plant
- Eliminating customer incentive payments for studies, capital or operations & maintenance equipment investments
- Eliminating Union's performance incentive and Rate T2/Rate 100 energy saving targets
- Eliminating costs associated with energy saving targets and performance measurement
- Providing increased program cost certainty to customers by greatly reducing the magnitude of deferred costs to customers.

1.3.1 Customer Class(es) Targeted

Large Volume Customers

1.3.2 Rate Classes Targeted

- Rate T2 - Storage and Transportation Rates for Contract Carriage Customers (Union South).
- Rate 100 - Large Volume High Load Factor Firm Service (Union North).

1.3.3 Program Goals

- Provide all Large Volume customers with the tools, expertise and support to incorporate energy-efficiency into their everyday operations and practices through continuous improvement.
- Promote the identification of energy saving measures through proper analysis techniques.

- Support the development of a growing knowledge base of customer staff on natural gas efficiency-related topics by offering customized technical training programs locally or online, building on Union's demonstrated competency and success in this area

1.3.4 Program Strategy

To achieve these program goals, the program strategy for Large Volume Rate T2 and Rate 100 program consists of the following:

Union will provide dedicated technical expertise to assist customers in obtaining value from the identification, adoption and implementation of energy efficient actions throughout their sites, facilities and operations. Union will engage customers to increase awareness surrounding the positive benefits achieved through active energy management. The need for job-related technical training will be particularly high in the next few years due to demographic shifts in the workforce. Customers will be offered easy-to-access and low cost training initiatives designed to increase awareness, knowledge and skills related to improving the efficient use of natural gas in their plants' equipment and processes.

1.3.5 Program Offering

The Large Volume Rate T2 and Rate 100 offering is outlined below.

Description

<u>Technical Support</u>

The support of Union Professional Engineers with experience in industrial energy efficiency and natural gas utilization will be available to all Rate T2/Rate 100 customers, offering the following services:

- Support the activities of a plant Energy Team, or technical staff, such as arranging for visiting speakers, visits to other (non-competitor) plants and employee recognition for energy saving initiatives.
- Provide single-topic training presentations to the Energy Team and other customer staff at meetings on site (e.g. 'Lunch and Learn' sessions)
- Provide customers with copies of texts, such as the ISO 50001 Manual and the Fives North American Combustion Handbook, to enable them to achieve best practice standards in energy management.
- Energy efficiency calculation tools developed for the Energy Solutions Center will be made available as required.
- Under the customers' guidance, carry out research on available and emerging

technologies which, if applied, could result in improved energy efficiency and other benefits such as reduced emissions or maintenance requirements.

- Provide benchmarking information on the expected performance of natural gas equipment and processes where this will assist in determining the potential for improvements.
- Undertake energy use analysis of specific process equipment in collaboration with customer staff. Union staff can provide and utilize or loan measurement instrumentation and/or temporary flow metering and data-logging equipment. This kind of initial assessment has been shown to be an important precursor to customers undertaking a more in-depth study of the equipment using a consultant. Where applicable, Union staff will make use of industry-recognized software tools available from Natural Resources Canada and the U.S. Department of Energy :
    - RETScreen Energy Management Software
    - Steam System Tool Suite: Steam System Assessment Tool
    - 3EPlus Insulation Assessment Tool
    - Combined Heat & Power Application Tool
    - Process Heating Assessment and Survey Tool

Customer Training

- In consultation with Large Volume Customers in a given locality, Union will organize specialized 1- or 2-day training courses that meet the training needs of the customers on topics related to the efficient use of natural gas. These courses may be system related (e.g. steam system optimization) or on a specific technical topic (e.g. process temperature measurement and control). A list of suggested topics is provided in Attachment B, but others may be added on the basis of customer needs.
- Train all eligible staff in a range of relevant topics over the duration of the Program (2016-2020). Union will work diligently with Large Volume Customers to plan a range of training offerings that will meet their stated needs each year. A logistical challenge which Union will manage is sourcing the qualified training organizations, obtaining competitive bids and arranging course locations which are close enough to a plant or a group of plants that there will be no significant travel or accommodation required for customers' staff to attend. This will reduce the amount of time the staff will need to be away from the plant for training and therefore help to minimize the disruption of shift plans etc. In some cases courses may be offered online. Training plans for each year the Program runs will be developed through consultations with customers in January and February and training sessions will begin in April and run through November.

- To encourage the uptake of this training, customer departments sending staff for training will be required to pay only a nominal fee of $100 per attendee for each course to ensure attendance by those who register. The balance of the course costs will be covered by the Program costs, within rates.
- The overall participation rate (number of customers sending staff to courses) and the number of attendees per customer are expected to rise over the 5 years this Program will be offered. Especially in the early years, significant promotion will be undertaken to ensure that customers are aware of the Program and how it can meet their energy efficiency training needs.
- Initial estimates of the Program cost of delivering staff training local to plants indicate that it will increase from $0.29 million in 2016 to $0.38 million in 2020 (excluding inflation).

Target Market

Large Volume Industrial and Power Generation firm service contract customers

Market Delivery

- This energy efficiency program is delivered directly to customers in these rate classes by dedicated Technical Account Managers, who are Professional Engineers with a background in industrial energy efficiency and natural gas applications. In addition to providing technical support to customers' energy teams, they will act as the program contact person for the customer to communicate their training needs to Union in January and February of each year so that the Training Plans can reflect their input.
- Union will plan and deliver high quality industrial and power generation system energy efficiency training in locations that will meet customer needs. Union will qualify vendors, consultants and training organizations and select organizations on the basis of competitive bids wherever possible.
- Union will track the number and role titles of attendees from all Rate T2/Rate 100 customers in order to evaluate the overall reach of the program and compare progress year-on-year.
- Union will monitor attendee satisfaction with the content and delivery of each course offered, and will make adjustments based on customer feedback over the duration of the program to address weaknesses identified and build on strengths.
- The development of professional working relationships between Union staff and the staff of vendors, consultants and training organizations offering training will be a priority to ensure that the highest quality customized training will continue to be available to customers.

Barriers Addressed

- Rate T2 and Rate 100 customers in these rate classes utilize very large amounts of natural gas in their operations, representing 42% of Union's total volume throughput in 2014. Energy purchases are, in most cases, a significant fraction of their overall production costs. Due to the focus on core production competencies such as quality, reliability and safety, energy use continues to be viewed as a 'cost of doing business' allocated between business units at a given site, making it challenging to maintain a disciplined, focused approach to energy efficiency.
    - Union's technical support helps to address this barrier by providing resources to Energy Team members in identifying and quantifying potential actions that could result in saving of natural gas, and helping to recognize both customer staff who bring forward the ideas and those who act upon the ideas.

- In this customer group there is a wide range of equipment using large quantities of natural gas; examples include but are not limited to turbine or engine drives, steam raising, product smelting, reheating or heat treating, product drying or curing and space heating. The efficient operation and maintenance of equipment requires experienced and well trained operators, technicians and trades people. With demographic shifts currently occurring at these plants, there is a growing need for training of new staff or staff who move departments so that they understand the equipment they are working with. Given tight staffing situations at many plants, a barrier to undertaking the necessary training is making staff available for courses that may be held in other parts of North America, including the associated overnight stays and travel time and costs.
    - The customer training offering in this program is designed to address this barrier by making high quality training courses available in the vicinity of customer plants, and handling reservations and course logistics to make staff attendance convenient, with the least possible staff time away from the plant.

1.3.6 Program Duration

- The offerings to the Rate T2 and Rate 100 customers will be delivered throughout the 2016– 2020 DSM Plan.
- A program review will take place in 2018 as the Framework proposes

1.3.7 Program Budget

The budget presented in Table 25 below does not include inflation

Table 25
Large Volume Program Budget

Program Cost ($000)	2016	2017	2018	2019	2020
Incentives/Promotion*	$400	$349	$373	$397	$421
Evaluation	$0	$0	$0	$0	$0
Administrative Costs	$409	$409	$409	$409	$409
Total	**$809**	**$758**	**$783**	**$807**	**$831**

* Includes Training Program Delivery Costs and Educational material costs

1.3.8 Projected Program Participation

As requested by the Board in the Framework, below is a summary of forecasted participants in Union's Large Volume program per offering. A participant represents a customer within the Rate T2/Rate 100 rate class. Customers can participate in both offerings.

Table 26
Large Volume Program Participation

	2016	2017	2018	2019	2020
Large Volume Participation	29	30	32	33	34

12.1.2. DSM and Infrastructure Planning

Union will perform a study commencing in 2015 to determine the potential effects DSM can have on deferring, postponing or reducing future capital investments. Union's preliminary proposed approach is outlined at Exhibit A, Tab 1, Appendix D.

12.2. DSM Tracking and Reporting System Upgrades

The information technology architecture behind Union's current DSM system was designed in 2000 and 2005 respectively to support the needs of DSM reporting at that time. Several upgrades to Union's DSM systems were made over the last ten years to accommodate the revised DSM reporting and processing requirements of the previous two DSM Frameworks.

The 2015-2020 DSM Framework includes new data reporting and processing requirements that can no longer be met by the architecture of the existing DSM systems. Union has conducted a preliminary review of both the current state of the DSM systems and the future requirements to meet the needs of the new DSM framework. The review process included identification and prioritization of DSM data requirements during the six year framework.

Future needs include the following functionality:

- Packaged Customer Relationship Management ("CRM") tool to manage DSM related contacts, customer activities, leads and opportunities;

- Core DSM tracking system to replace the existing systems. The primary functionality is to support all of the key DSM processes, including the ability to interface with Union's billing systems and financial software; and,
- Analytics and reporting to support the new DSM framework requirements.

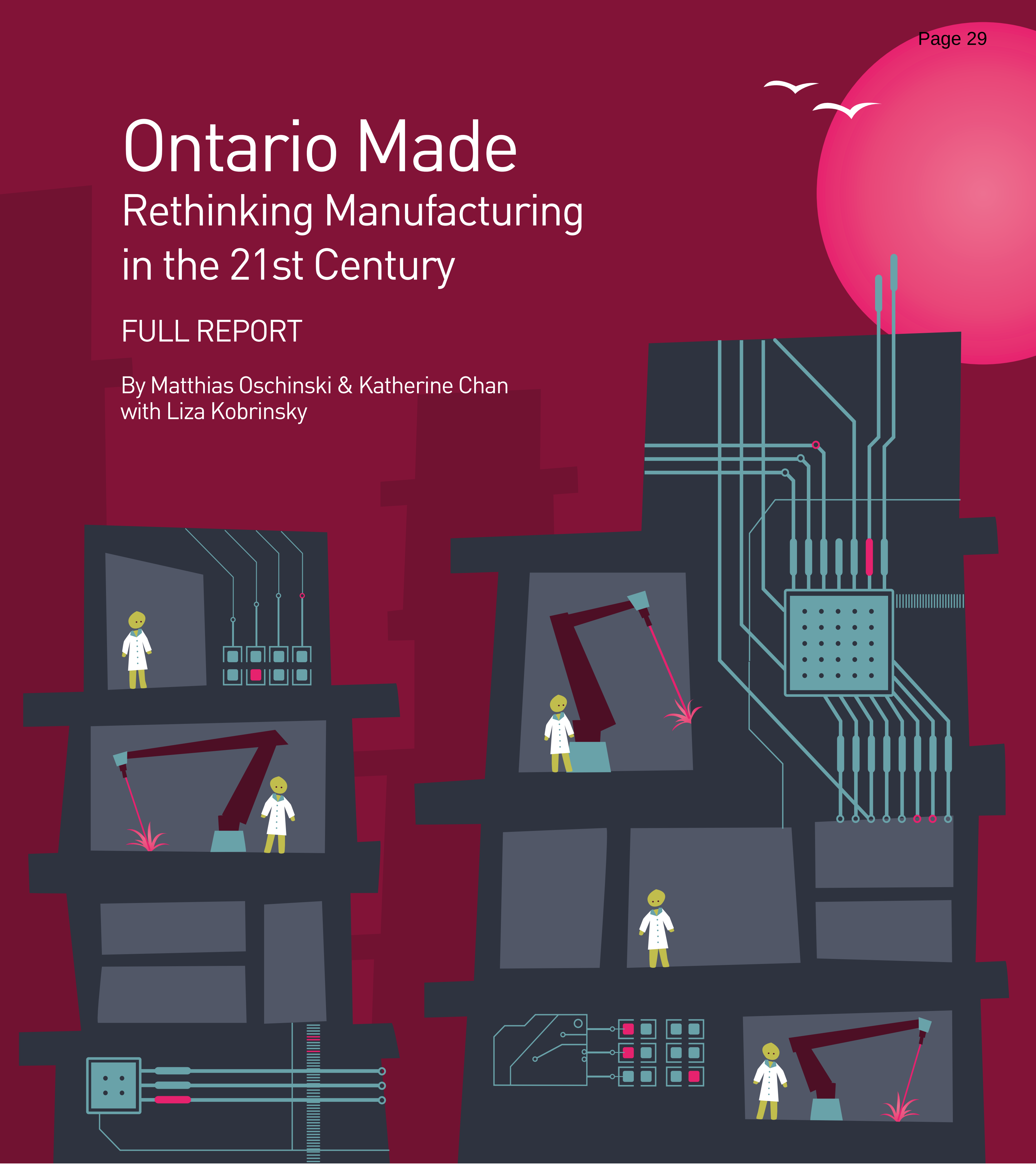
This project will replace the aging applications with current technology to meet the new DSM reporting requirements, maintain data integrity, utilize resources more efficiently and provide flexibility for future needs.

The preliminary review has provided a high-level estimate of $6 million to perform the necessary system changes. This is reflected in the DSM budget submission as $1 million in 2015 and $5 million in 2016. Any variance between the budget and actual cost will be captured in the DSMVA and subject to a full prudence review on disposition.

In addition, initial discussions with Enbridge are underway to determine if there are potential synergies in the replacement of the utilities' existing systems.

12.3. Collaboration

Union is committed to meeting the Board's objective of increasing DSM and CDM collaboration opportunities through the coordination and integration of program offerings. Union will



Ontario Made

Rethinking Manufacturing in the 21st Century

FULL REPORT

By Matthias Oschinski & Katherine Chan
with Liza Kobrinsky

Mowat Centre
ONTARIO'S VOICE ON PUBLIC POLICY

MOWAT RESEARCH #84
FEBRUARY 2014 | MOWATCENTRE.CA

School of Public Policy & Governance
UNIVERSITY OF TORONTO

Contents

This implies greater affordability of ICT investments for Canadian manufacturers relative to firms in the overall business sector, a further advantage over US manufacturers when prices are compared to US total business sector ICT investment. This trend presents an opportunity for Canadian manufacturers to invest more heavily in ICT M&E now if the sector is to remain competitive in the long run.

Ontario has also made significant headway in restructuring the business tax system to make it easier for firms to invest, through the harmonization of provincial and federal goods and services tax, the elimination of the capital taxes for manufacturing firms in 2007, and the reduction of Ontario's corporate income tax rates.[23] Furthermore, the lower relative price of M&E from the rising Canadian dollar provides additional incentive for manufacturers to invest more heavily in new M&E. However, Ontario manufacturers have yet to take full advantage of these opportunities. Why?

There are a few possible explanations to new capital investments lag. Firm size, access to financing and the issue of scalability remain obstacles for firm expansion. However, risk aversion and lack of competitive pressure are also factors that contribute to the under-investment in machinery and equipment and the widening productivity gap.[24]

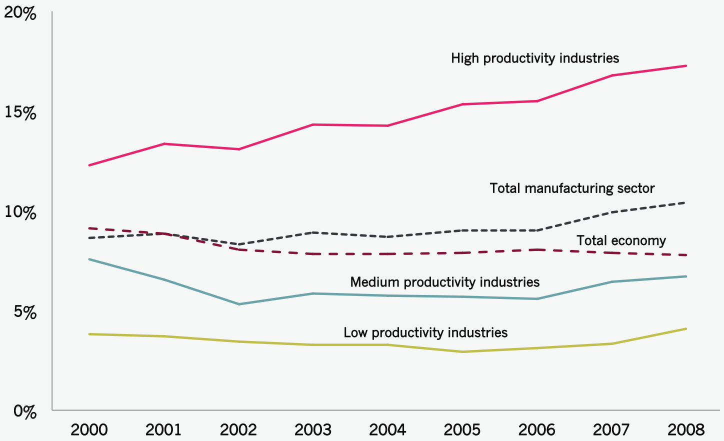
Energy efficiency

In addition to labour and capital, energy and water utilities are important input factors in the manufacturing production process.

Taking into account production numbers sheds some light on the efficiency with which these input factors are being used. Calculating the ratio of real value added to total utility costs for manufacturing in Ontario, Quebec and the rest of provincial Canada shows that Ontario's utility efficiency is actually highest in this group (see Figure 27). In other words, the data suggest that, in general, Ontario's manufacturing sector uses energy and water more efficiently than industries in other Canadian provinces—which might, in part, be due to the larger scale of production in this province.

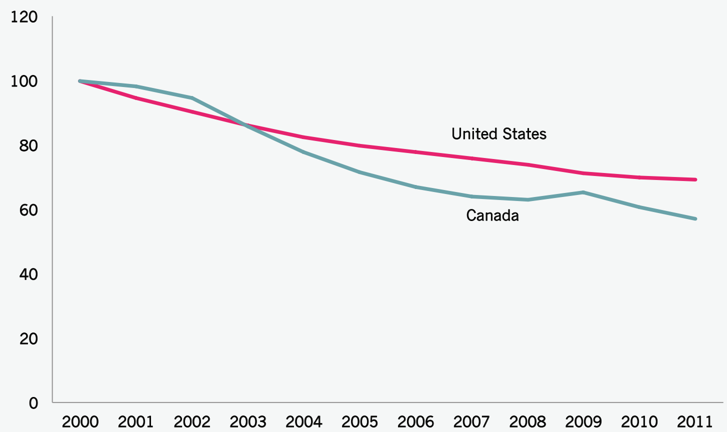
A look at disaggregated industries also reveals that energy is of varying importance as an input factor within the manufacturing sector. Figure 28 below illustrates that petroleum and coal manufacturing, paper manufacturing, primary metal manufacturing, non-metallic mineral manufacturing, chemical products manufacturing and wood product manufacturing are relatively energy intensive compared to other industrial subsectors.

FIGURE 24
Capital expenditures on M&E as a percentage of total output, 2000-2008



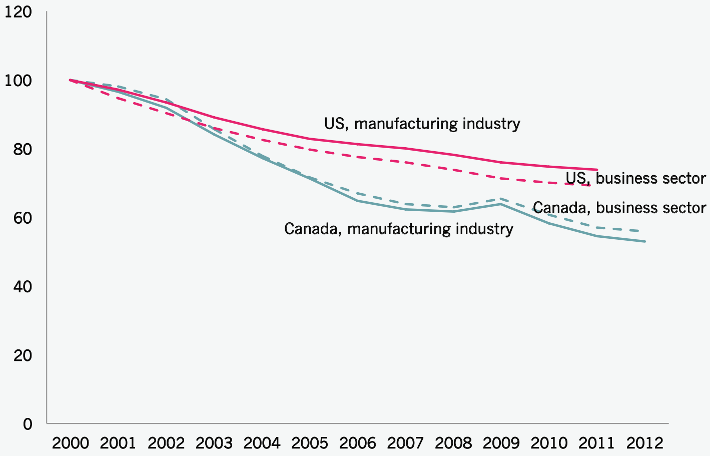
Source: Statistics Canada, CANSIM Tables 379-0025 and 029-0005

FIGURE 25
Price trend of total ICT investments in Canada vs United States (Price Index 2000 = 100)



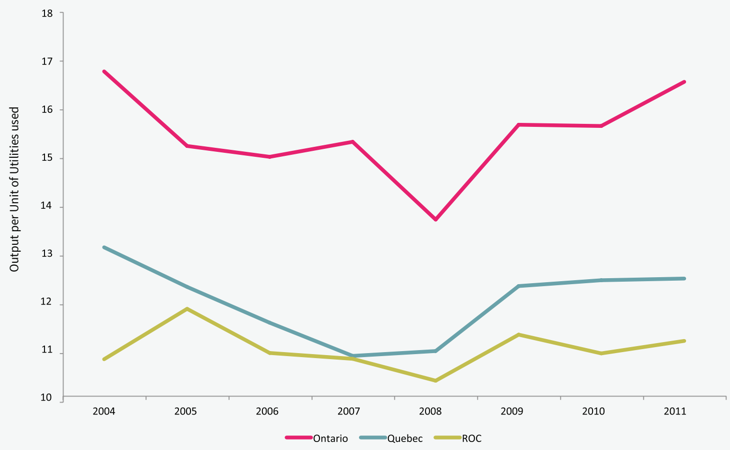
Note: Calculated as the change from total ICT investment implicit price deflators for total computer, communication and software ICT in the business sector in the US and Canada.
Source: CSLS Database of Information and Communication Technology (ICT) Investment and Capital Stock Trends: Canada vs. United States, available online: http://www.csls.ca/data/ict.asp

FIGURE 26
Price trends of ICT Investments, by sector (Price index 2000 = 100)



Note: Calculated as total ICT investment implicit price deflators for total computer, communication and software ICT investment in the US and Canada.
Source: CSLS Database of Information and Communication Technology (ICT) Investment and Capital Stock Trends: Canada vs. United States, available online: http://www.csls.ca/data/ict.asp

FIGURE 27
Utility Cost Effectiveness – Ontario, Quebec and Rest of Canada, 2004-2011



Source: Statistics Canada, CANSIM Table 301-0006, 379-0025

In order to assess Ontario's competitiveness with regard to energy usage, we compare energy efficiency in manufacturing industries relative to that of U. S. peers and peer jurisdictions in Germany. Given that Germany is currently the most productive manufacturing country, an inclusion of German peer jurisdictions in this analysis serves as a useful benchmark for Ontario's manufacturing sector.[25]

With regard to energy usage itself, our analysis focuses on the consumption of electricity and natural gas as input factors in the manufacturing production process. According to data provided by Natural Resources Canada, electricity and natural gas combined amounted for nearly 60 percent of energy consumption in manufacturing in 2010.

At around 30 percent, electricity usage was slightly higher than the consumption of natural gas, which had a share of roughly 28 percent of total energy usage. Oil, another common input factor in energy usage, was not considered in this analysis because consumption data is often missing at the detailed industry level. Moreover, as opposed to prices for electricity and natural gas, the price of oil is largely determined on international markets. Hence, regional variations in cost structures are likely to be less pronounced with regard to oil consumption compared to the use of electricity and natural gas.

To account for a proper comparison between Ontario and its peer jurisdictions, all energy consumption data were re-calculated to KWh.

Figure 29 displays energy efficiency—in terms of electricity and natural gas consumption only—in total manufacturing for Ontario relative to U.S. and German peers. As the ranking shows, Baden-Württemberg is the most energy productive jurisdiction in this group both with regard to electricity and gas usage, followed by Indiana, Bavaria and North Carolina. Out of these 19 jurisdictions, Ontario ranks 17th, or third last, in terms of energy efficiency.

It is important to note here that the results here reflect, at least in part, the composition of the manufacturing sector in each jurisdiction. As such, jurisdictions with a relatively high share of very energy intensive industries, such as paper manufacturing, primary metals and coal, will always end up at the lower end of the ranking.

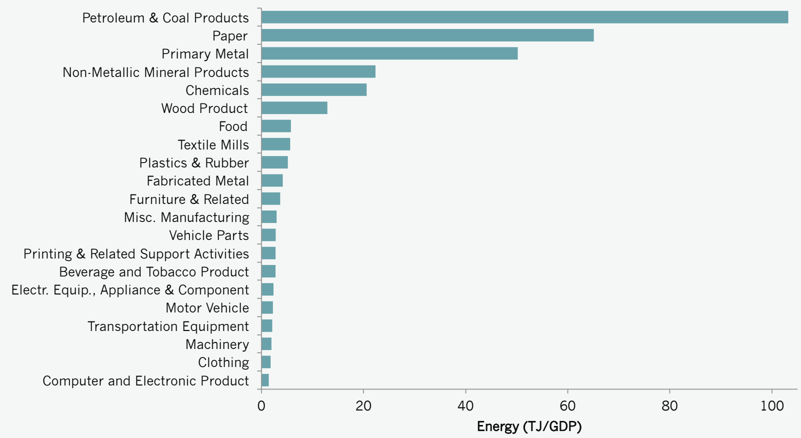
To get a more detailed picture, it is therefore important to disaggregate the manufacturing sector and compare sub-industries. When this is done for Ontario and its international peers in the U.S. and in Germany, our main result still holds—that Ontario lags most international peers in energy efficiency. This is in line with anecdotal evidence, which asserts that comparatively low electricity prices for industrial consumers in the past provided little incentive to upgrade machinery and equipment for more energy efficient production. In more recent years, however, energy costs in Ontario have been increasing and will continue to do so at least over the medium term. This should lead an added incentive to make energy efficiency a higher priority.

Over the past while, there has been ongoing discussion regarding rising electricity prices in Ontario and an increasing concern that price differences relative to U.S. states would harm the competitiveness of Ontario's manufacturers.

Does this concern hold? Figure 30 depicts electricity rates for industrial consumers in Ontario and its U.S. peers from 2000 and 2012. In 2000, the average price for electricity in U.S. peers was 3.4 cents per kWh compared to 5.4 cents per kWh in Ontario. The gap in electricity prices narrowed in subsequent years and reached a difference of roughly 0.7 cents per kWh by 2010.

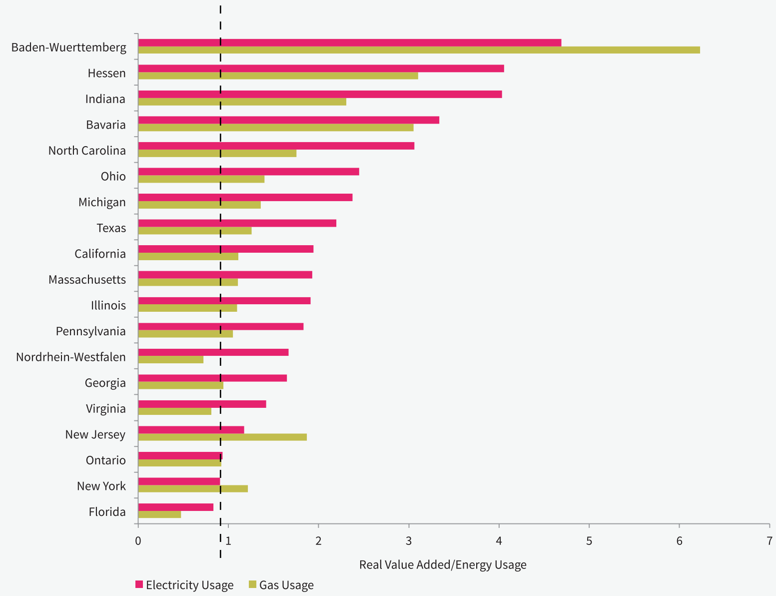
Yet, as Figure 30 also shows, prices began diverging drastically in 2011 and 2012 with Ontario experiencing a significant increase from around 8 cents per kWh in 2010 to 10.9 cents per kWh in 2012. At the same time, electricity prices in U.S. peer states dropped slightly from 7.4 cents per kWh in 2010 to 7.2 cents per kWh in 2012.

FIGURE 28
Energy Intensity in Canadian Manufacturing Industries, 2011



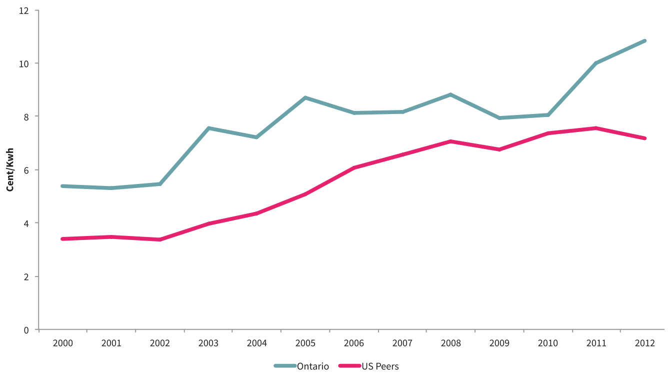
Source: CIEEDAC, Simon Fraser University

FIGURE 29
Energy Productivity Total Manufacturing - Ontario vs. US and German Peer Jurisdictions, 2010



Source: Source: Statistisches Bundesamt, US Energy Information Administration, AMPCO and IESO.

FIGURE 30
Electricity Cost Ontario vs US Peers, 2000-2012 (in Cents/KWh)



Source: NEB and EIA

A direct comparison between selected Canadian provinces and U.S. states illustrates this point further (see Figure 31). In 2000, electricity rates for industrial consumers were 5.4 cents/kWh in Ontario, compared to 3.2 cents/kWh in Michigan, 3.4 cents/kWh in New York and 2.8 cents/kWh in Ohio. By 2010, prices had converged, significantly narrowing these differences. From 2011 onward, however, the gap in prices has started to increase again.

The last column in Figure 31 reveals another interesting fact. While price levels were higher in Ontario compared to most North American peers in recent years, annual price increases occurred at similar speed: from 5.27 percent per year in New York to 7.2 percent per year in Alberta. The only notable exception in this group is Quebec where prices grew on average by 2.65 percent per year.

While comparing electricity costs across jurisdictions is important, a more insightful question might be around the efficiency of Ontario manufacturers in using electricity in production. Figure 32 below illustrates that manufacturers in U.S. peer jurisdictions manage to gain more output using the same amount of electricity compared to Ontario firms. Hence, while companies are not able to control the price of electricity in the province, they can, at least to a certain extent, influence the actual cost of electricity in the production process by addressing the issue of energy efficiency.

A look at international jurisdictions outside North America reveals that prices for electricity are about twice as high in Germany compared to the U.S. and prices for natural gas are about four times as high.

How, then, are German manufacturers able to stay competitive? A recent study by the European Commission shows that the answer is higher energy efficiency, i.e. the smarter use of energy in production.[26]

Thus, with electricity prices set to rise further in Ontario over the medium term, addressing the issue of energy efficiency in manufacturing production will become a crucial issue.

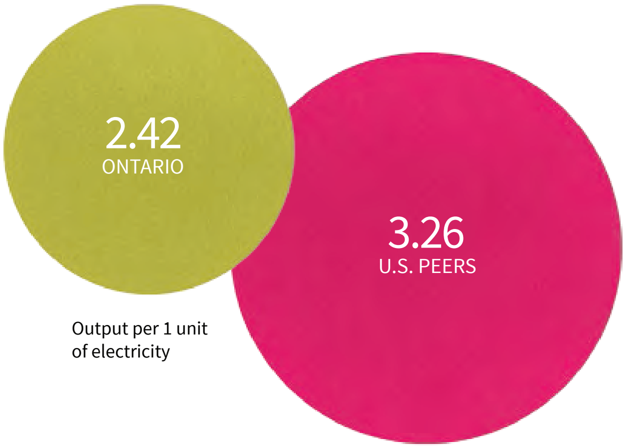
Alongside productivity and the related costs of inputs to production, additional success indicators serve to demonstrate the potential of firms to scale up and the possibilities for sustainable growth. The following two sections analyze Ontario's current situation at the sub-industry level.

FIGURE 31
Electricity Prices in selected Canadian provinces and U.S. states.

JURISDICTION	2000	2005	2010	2012	CAGR
Ontario	5.4	8.7	8.0	10.9	6.03
Alberta	4.6	6.1	7.2	10.6	7.20
Michigan	3.2	4.2	6.5	7.2	6.99
U.S. Peers Avg.	3.4	5.1	7.4	7.2	6.45
New York	3.4	6.4	8.1	6.3	5.27
Ohio	2.8	4.0	5.9	5.9	6.41
Quebec	3.8	4.3	5.2	5.2	2.65

Note: Values in real Canadian dollar; CAGR=year-over-year growth rate from 200-2012
Source: NEB and EIA.

FIGURE 32
Efficiency of electricity use in manufacturing—Ontario vs. U.S. peers



Source: NEB and EIA.

Scalability

A firm's ability to scale up production is an important indicator of success. In order to analyze and quantify the situation for Ontario's manufacturing sector, this analysis focuses on three aspects: high growth firms, survival rates and bankruptcies. Taken together, this can help identify the sector's resilience and those sub-industries with the highest growth potential.

High growth firms

Although productivity is an important ingredient to firm success, it is not the sole ingredient and should not be the end-goal for policymakers. Rather, empirical evidence shows that high growth entrepreneurial firms are responsible for a considerable share of job creation along with the added value they generate in an economy.

Though it is important for policymakers to focus on increasing the number of entrepreneurial manufacturing firms in Ontario, we recognize that growth does not automatically follow. Rather, it is imperative to foster the *quality* of entrepreneurship and to build on the support systems that help promising firms reach their full potential.[27]

As previously noted, the vast majority of manufacturing firms are small, accounting for as much as 86.6 percent of all firms. Small firms may be intentionally small in size to serve different needs. These include niche markets with customized products, since stylized products do not lend themselves to more standardized processes.

Correspondingly, while this report acknowledges the value smaller firms bring to the sector, it focuses on the opportunities for small firms to expand. Larger firms have a greater tendency to exert the potential direct and indirect benefits on employment, wages and value added on the economy. Empirically, the use of advanced production technology also tends to increase with plant size, with large manufacturing firms being more likely than smaller ones to engage in productivity-enhancing (albeit, riskier) production and process innovations.

This is significant for manufacturing firms in particular, since relatively larger firms (100 employees or more) are as much as 24 percent more productive than smaller firms, even after controlling for industry composition effects, firm age and organizational types. This trend does not appear in non-manufacturing sectors, where the relationship between size and productivity appears to be statistically insignificant within industries.[28]

A smooth and accessible growth path is therefore critical for small and medium-sized manufacturing firms. Expansion support for firms has a significant impact on the economy, especially considering that around 20 percent of the Canadian-US productivity gap can be explained by the relatively larger small business sector in Canada.

Furthermore, assisting smaller firms to scale up would not only increase the quantity and quality of employment, it would also place the necessary pressure for larger existing firms to remain competitive and help steer an innovation-driven manufacturing sector forward. The potential economic benefit becomes even more apparent when taking into account that as much as 58.3 percent of all manufacturing employment flows from total small and medium-sized enterprises in Ontario.[29]

ONTARIO ENERGY BOARD

FILE NO.:	**EB-2015-0029**	**Union Gas Limited**
	EB-2015-0049	**Enbridge Gas Distribution Inc.**

VOLUME: **Technical Conference**

DATE: **August 18, 2015**

Rethinking Manufacturing in the 21st Century".

EXHIBIT NO. KT4.3: MOWAT CENTRE REPORT ENTITLED "ONTARIO-MADE: RETHINKING MANUFACTURING IN THE 21ST CENTURY".

MR. ELSON: Thank you. I'm going to review some of the conclusions of this report and ask you to comment on them. But first I'll start by referring you to page 29 of this report.

UNIDENTIFIED FEMALE SPEAKER: Okay.

MR. ELSON: And on page 29 there is reference to a comparison, in terms of energy efficiency of Ontario, with 18 other jurisdictions, which is 19 in total, and the Mowat Centre concludes that Ontario ranks 17th or third-last in terms of energy efficiency.

Do you see that there in the underlying paragraph?

MS. NAPOLEON: Yes. This is Alice Napoleon.

MR. ELSON: Thank you, Ms. Napoleon. And further down the page, the authors of this report disaggregate the numbers and find that even when you do a comparison on a sub-industry level that Ontario lags most of its international peers in terms of energy efficiency. Do you see that there, as well?

MS. MALONE: Yes.

MR. ELSON: If you turn over the page to page 30 and you see figure 29, this is the figure that corresponds to what we were just discussing; do you see that there?

MS. NAPOLEON: Did you say figure 29?

MR. ELSON: Yes, figure 29, which is on the following page, page 30.

MS. MALONE: Yes, I do.

MR. ELSON: And this figure breaks out the electricity use and the gas use of Ontario versus these other jurisdictions; do you see that there? The gas use is in green and the electricity use is in pink. The pink is the upper bar and the green is the lower bar for each jurisdiction.

MS. MALONE: Okay, yes, I see that.

MR. ELSON: And I just want to confirm that I'm reading this figure correctly, and it looks to me that Ontario would be the fourth-least efficient of all these jurisdictions when you are looking at gas usage.

MS. NAPOLEON: The third, right, of these jurisdictions that were selected for this report; correct.

MR. ELSON: Now, that's third in terms of the electricity usage, but if you look at the gas usage, and you will see there is a dotted line here -- I'm just looking for confirmation that I'm reading this figure correctly, that there are three other jurisdictions which - - that are less efficient in terms of gas, so it is the -- Ontario is the fourth-efficient; do you see that there?

MS. NAPOLEON: That's correct, yes, we see that now. Thank you.

MR. ELSON: Thank you. Now, because Ontario's manufacturing sector uses natural gas less efficiently than these other jurisdictions, would it be reasonable to conclude that there is a higher DSM potential in Ontario in this sector compared to the other jurisdictions?

MS. NAPOLEON: Based on my limited review of this report, I do not -- I don't see the evidence specifically supporting the paragraph at the end of page 29, where they say that it's -- if you disaggregate the manufacturing sector and compare sub-industries for Ontario specifically.

However, if we hold the manufacturing sectors constant for each of these jurisdictions, it does suggest to me that there is substantial potential for improvement -- energy efficiency improvement, that is.

MR. ELSON: That is available. In other words, that would be -- a DSM potential would be the same way of describing that.

MS. NAPOLEON: Yes, DSM potential.

MR. ELSON: Thank you. I have no further questions.

MR. MILLAR: Thank you, Mr. Elson.

Mr. Poch, did you have a couple of things?

QUESTIONS BY MR. POCH:

MR. POCH: Just a very few. Panel, you --

MR. MILLAR: Could you introduce yourself?

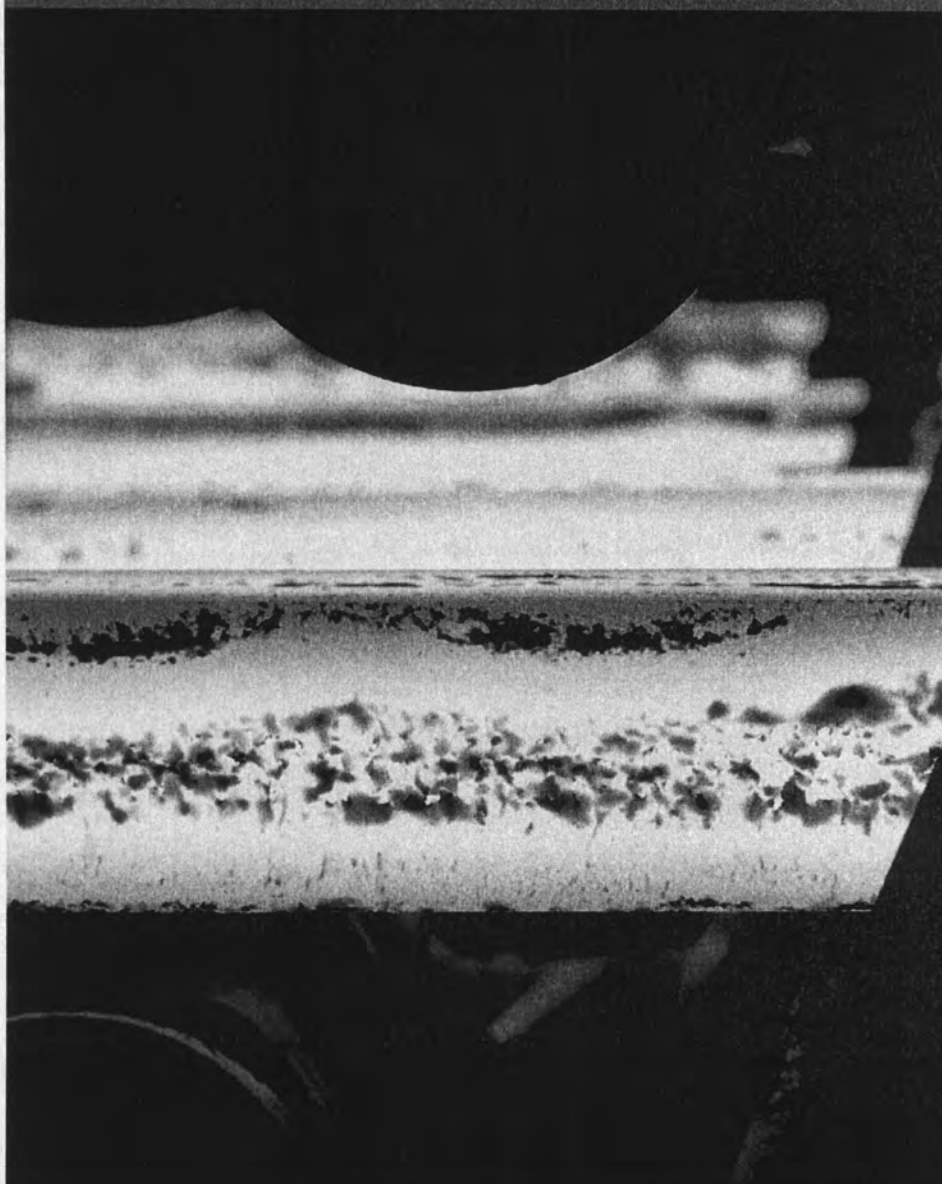
MR. POCH: Yes, I'm David Poch, I'm counsel for the Green Energy Coalition, and we are the organization that sponsored the evidence of reports of Mr. Chernick and Mr. Neme in this case.

I just wanted to confirm, in the evidence there is a reference to an AESC, or avoided energy supply cost, in New England, 2013 report, that includes DRIPE, demand reduced -- demand reduction induced price effects for electricity, U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

INDUSTRIAL TECHNOLOGIES PROGRAM

Meeting Energy Efficiency and Emissions Reduction Goals in the U.S. Steel Industry:

A Need for Breakthrough Production Technologies



About This Report

This report describes breakthrough production technologies under investigation worldwide that will be needed to help steel producers meet greenhouse gas emissions and energy efficiency goals that are currently unattainable using today's best practice technologies. The study also describes the current situation of the U.S. steel industry and provides a benchmark analysis of the industry's energy and carbon intensity compared to other major steelmaking countries. This work was sponsored by the Industrial Technologies Program (ITP) within the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE). ITP works with U.S. industry to reduce energy use and carbon emissions associated with industrial processes. Its mission is to improve national energy security, protect the environment, and ensure U.S. economic competitiveness by enhancing the energy efficiency and productivity of U.S. manufacturing. Its work includes sponsoring high-impact research and development in innovative energy-saving technologies, as well as engaging in industry outreach to promote best practice energy management in U.S. facilities.

Disclaimer

Acknowledgements

This report was prepared for the U.S. Department of Energy's Industrial Technologies Program (ITP) by Mauricio Justiniano of Energetics Incorporated and Christopher L. Weber of Carnegie Mellon University.

Executive Summary

The steel industry is an important contributor to the U.S. economy and provides a vital raw material to the industrial supply chain. Steel has been produced for hundreds of years, but the processes used in its manufacture have changed over time. Through the 1960s and 1970s, the industry moved from open-hearth furnaces to more efficient basic oxygen furnaces to make steel from liquid iron. As the availability of steel scrap increased over time, and as electric arc furnace (EAF) technologies became available for the production of flat products, the industry increased its use of the even more efficient EAFs, which accounted for almost 62% of U.S. steel production in 2009. These production shifts have contributed to a significant decline in energy intensity, helping the U.S. steel industry position itself as the most energy-efficient global steel producer. Reducing carbon emissions has also been a major priority for the industry. Since 1990, the U.S. steel industry reduced its carbon emissions by 35%, achieving one of the lowest carbon dioxide emission intensities among steel-producing countries worldwide. The U.S. steel industry's carbon dioxide intensity is now the second lowest in the world, after Korea.[1]

The U.S. steel industry has almost fully achieved the energy efficiency and carbon emission reductions that can be obtained using today's best available technologies. Additional breakthrough steelmaking technologies and processes will be needed to achieve proposed domestic and global policy goals for energy efficiency and carbon emission reductions. This paper describes breakthrough technologies currently being investigated worldwide that could help the U.S. steel industry achieve currently unattainable carbon emissions and energy intensity levels in the production of steel.

[1] Data derived from International Energy Agency, *World Energy Statistics and Balances Database 2009 Edition* (Paris, France: International Energy Agency, 2009).

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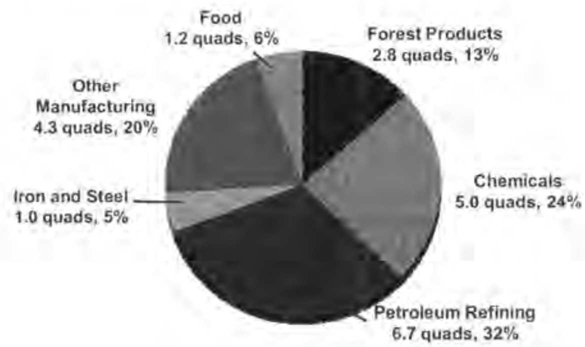
Section 1. Overview of the U.S. Iron and Steel Industry

Steel is a ubiquitous raw material used for transportation equipment, construction, machinery and equipment, household goods, and containers, among others. In 2009, the U.S. steel industry produced goods valued at $110 billion dollars. Eight companies produced pig iron in integrated steel mills at 18 locations, and 57 companies produced raw steel at 116 plants. There are hundreds of additional facilities that manufacture final products from semi-finished shapes.[2] Together, the industry employed 159,000 workers in two major sectors: iron and steel mills and ferroalloy production (98,900 workers), and steel products from purchased steel (60,100 workers). Steel is predominantly made in the eastern and mid-western states, where raw materials and ores used in steelmaking are found. More than 40% of steel industry employees are employed in Pennsylvania, Ohio, and Indiana. Almost 90% of the total employment is concentrated in establishments employing more than 100 people.[3]

Figure 1.1. U.S. Manufacturing Energy End Use by Sector (2006)



Note: The end-use total (21.1 quadrillion British thermal units) includes feedstocks and does not include off-site losses.

Source: U.S. Energy Information Administration, *2006 Manufacturing Energy Consumption Survey (MECS)* (Washington, DC: U.S. Energy Information Administration, 2008).

There are two main types of steel manufacturing facilities: classic integrated mills (mainly ore-based) and electric arc furnace facilities (which are mainly scrap-based). Together, they produced 65.5 million tons in 2009, a sharp decline from the average ten-year annual production of 101 million tons.[4]

In 2008, steel imports accounted for 13% of the total apparent consumption.[5] [6] Between 2005 and 2008, the majority of steel imported into the U.S. came from Canada (18% of imports), the European Union (15%), China (12%), Mexico (10%), and other regions (45%).[7]

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[2] U.S. Geological Survey, *2010 Mineral Commodity Summaries – Iron and Steel* (Washington, DC: U.S. Geological Survey, 2010), 80–81, http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/mcs-2010-feste.pdf.

[3] U.S. Department of Labor, Bureau of Labor Statistics, "Steel Manufacturing," *Career Guide to Industries, 2010–11* Edition (Washington, DC: Bureau of Labor Statistics, December 2009), http://www.bls.gov/oco/cg/cgs014.htm.

[4] American Iron and Steel Institute, *Annual Statistical Report 2009* (Washington, DC: American Iron and Steel Institute, 2010).

[5] U.S. Geological Survey, *2010 Mineral Commodity Summaries – Iron and Steel* (Washington, DC: U.S. Geological Survey, 2010), 80–81, http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/mcs-2010-feste.pdf.

[6] Apparent consumption is defined as production + imports - exports ± stock change.

[7] U.S. Department of Commerce, International Trade Administration, *Steel Industry Executive Summary: March 2010* (Washington, DC: U.S. Department of Commerce, 2010).

Energy Use and Emissions Profile

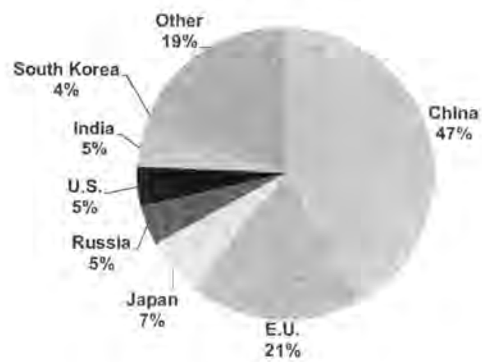
In 2006, iron and steel manufacturing accounted for 5% of total industrial energy end use (excluding off-site electricity generation and transmission losses) and ranked as the fifth-largest energy-using manufacturing sector, as figure 1.1 shows.[8] In 2006, the industry spent $6.7 billion in purchased fuel and electricity and consumed 1.6 quadrillion British thermal units (Btu) of primary energy (including off-site losses and feedstocks), which represents about 1.6% of the total U.S. primary energy consumption.[8,9] Carbon dioxide (CO_2) emissions associated with this energy consumption totaled 141 million metric tons (MMT), including indirect emissions from electricity generation. This represents 8% of the total emissions from the U.S. industrial sector and over 2% of the total emissions from all sectors of the economy.[10] An additional 1.3 MMT CO_2 were generated from non-energy sources (emissions from industrial processes where CO_2 is a by-product of chemical reactions other than combustion).[11] Most process emissions in steel manufacturing result from the use of metallurgical coke to produce pig iron.

The steel industry's current recycling rate is approximately 80%. More steel is recycled than paper, plastic, aluminum, and glass combined.

Current Situation

In 2009, the U.S. represented 5% of the world's steel production, while China accounted for a 47% share (see figure 1.2). China's global share is greater than the combined production of the five next-largest producers (the U.S. , the European Union, Russia, Japan, and India). In 2009, global crude steel production declined by 8%, but China and India were the only two major steel producers that increased production, by 14% and 3%, respectively.[12]

Figure 1.2. Global Share of Crude Steel Production (2009)



Source: World Steel Association, *World Crude Steel Production* (Brussels, Belgium: World Steel Association, January 2010).

Because of the widespread use of steel in industry and infrastructure, the health of the steel industry is commonly used as an economic indicator. The recent economic downturn was clearly reflected in the steel industry, which experienced a 6.3% decline in domestic steel production in 2008 and a 35% decline in 2009.

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[8] U.S. Energy Information Administration, *2006 Manufacturing Energy Consumption Survey (MECS)* (Washington, DC: U.S. Energy Information Administration, 2008), http://www.eia.doe.gov/emeu/mecs/.
[9] U.S. Census Bureau, *"Statistics for Industry Groups and Industries," Annual Survey of Manufactures* (Washington, DC: U.S. Census Bureau, 2009), http://www.census.gov/manufacturing/asm/index.html; U.S. Energy Information Administration, Table 40, *Annual Energy Outlook 2010* (Washington, DC: U.S. Energy Information Administration, May 2010), http://www.eia.doe.gov/oiaf/aeo/.
[10] U.S. Energy Information Administration, Table 40, *Annual Energy Outlook 2010* (Washington, DC: U.S. Energy Information Administration, May 2010), http://www.eia.doe.gov/oiaf/aeo/.
[11] U.S. Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2008* (Washington, DC: U.S. Energy Information Administration, 2009), http://www.eia.doe.gov/oiaf/1605/ggrpt/pdf/0573 (2008).pdf.
[12] World Steel Association, *World Crude Steel Production* (Brussels: Belgium World Steel Association, 2010), 1–3.

Section 2. Analysis of the Industry's Energy Use and CO_2 Emissions

In the last 50 years, the U.S. steel industry experienced two major production changes that led to structural shifts in its energy and CO_2 emissions profile. This first change was a shift in production from the use of open hearth furnaces (OHFs) to the use of basic oxygen furnaces (BOFs); the second was an increase in production with the use of electric arc furnaces (EAFs). These production changes, coupled with continued technological advancement and the deployment of sophisticated process controls and modeling, have improved energy efficiency and reduced the industry's energy and carbon intensities by approximately half since the 1970s. Consequently, the U.S. steel industry now ranks among the cleanest and most efficient major steel producers. However, because the industry has already shifted its production structure and improved its energy efficiency, it has relatively few "easy" energy efficiency and emissions improvements left to make.

Declining Energy and Carbon Intensity

Several key studies estimate system-wide total energy use at about 20 million Btu/ton of steel for BOF production and 10 million Btu/ton for EAF production from scrap. Table 2.1 shows estimates of average energy intensities in the sector for both BOF and EAF production pathways.

Table 2.1. Energy Intensity Estimates of Iron and Steel Production Processes (million Btu/ton steel)

<table>
<tr><th></th><th>Agglomeration</th><th>Cokemaking</th><th>Steelmaking</th><th>Reheating/ Hot Rolling</th><th>Total</th><th>Source</th></tr>
<tr><td>World Average Basic Oxygen Furnace (BOF)</td><td>3.0</td><td>2.0</td><td>13.0</td><td>3.0</td><td>21.0</td><td>International Energy Agency, 2007</td></tr>
<tr><td>U.S. BOF 2010 (Forecasted)[a]</td><td colspan="3">16.0</td><td>2.1</td><td>18.1</td><td>Steel Bandwidth Study, 2004</td></tr>
<tr><td>U.S. Electric Arc Furnace (EAF) 2010 (Forecasted)[a]</td><td>N/A</td><td>N/A</td><td>7.0</td><td>2.0</td><td>9.0</td><td>Steel Bandwidth Study, 2004</td></tr>
</table>

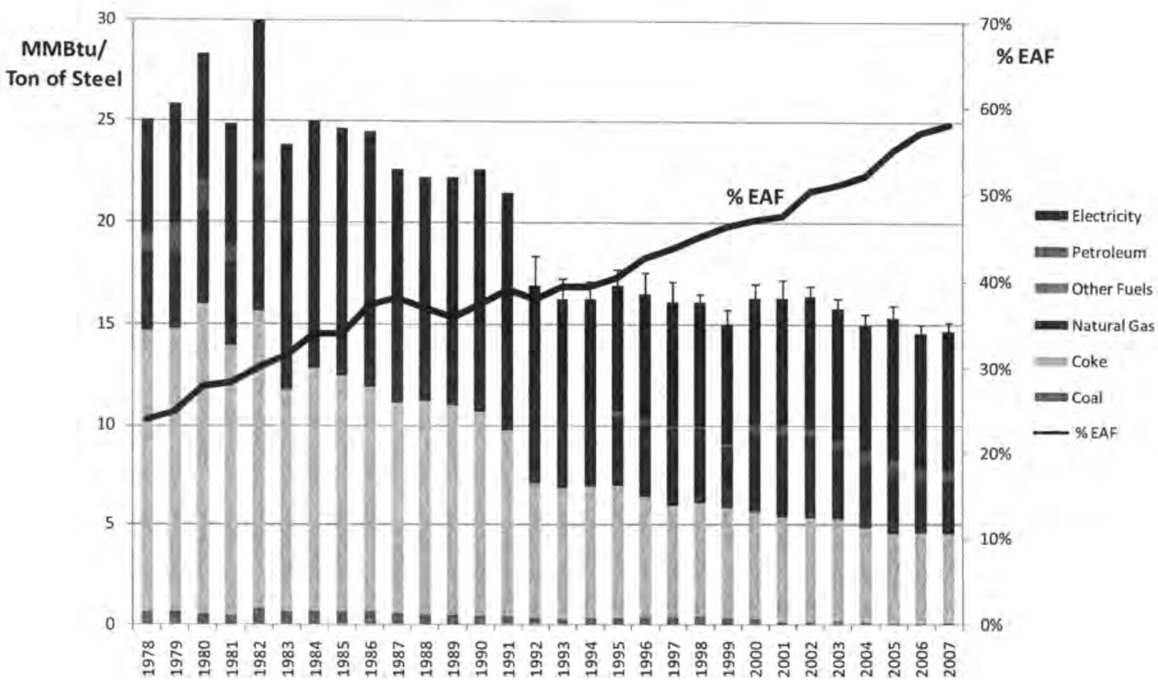
Notes: System boundaries are not always equal, but efforts were made to coordinate between the different studies. All energy estimates are shown as primary energy equivalents. BOF Steelmaking includes blast furnace ironmaking.

[a] Values represent energy intensity projections for the year 2010, as estimated in the 2004 Steel Industry Energy Bandwidth study. Reheating/Hot Rolling includes some finishing processes.

Sources: International Energy Agency, *Tracking Industrial Energy Efficiency and CO_2 Emissions* (Paris, France: International Energy Agency, 2007); U.S. Department of Energy, *Steel Industry Energy Bandwidth Study* (Columbia, Maryland: Energetics Incorporated, 2004); U.S. Department of Energy, *Energy Use In The U.S. Steel Industry: An Historical Perspective And Future Opportunities* (Mason, Ohio, J. Stubbles, 2000).

Our analysis shows that since the 1970s, the industry's energy and carbon intensities have been reduced by approximately half. Figure 2.1 shows a time series of the U.S. steel industry's energy intensity, defined as primary energy per ton of steel produced (million Btu per ton [MMBtu/ton]). Similarly, figure 2.2 shows the carbon intensity, defined as metric tons CO_2/ton steel.[13] Energy intensity declined from 25–30 MMBtu/ton in 1978 (the first year data were available) to below 15 MMBtu/ton today. Similarly, the CO_2 emissions intensity of U.S. steel dropped from approximately 2.2 metric tons CO_2/ton in the early 1970s to approximately 1 metric ton CO_2/ton today.[14]

Figure 2.1. Historical Energy Intensity, Fuel Mix, and Share of Electric Arc Furnace Production in U.S. Steel Manufacturing



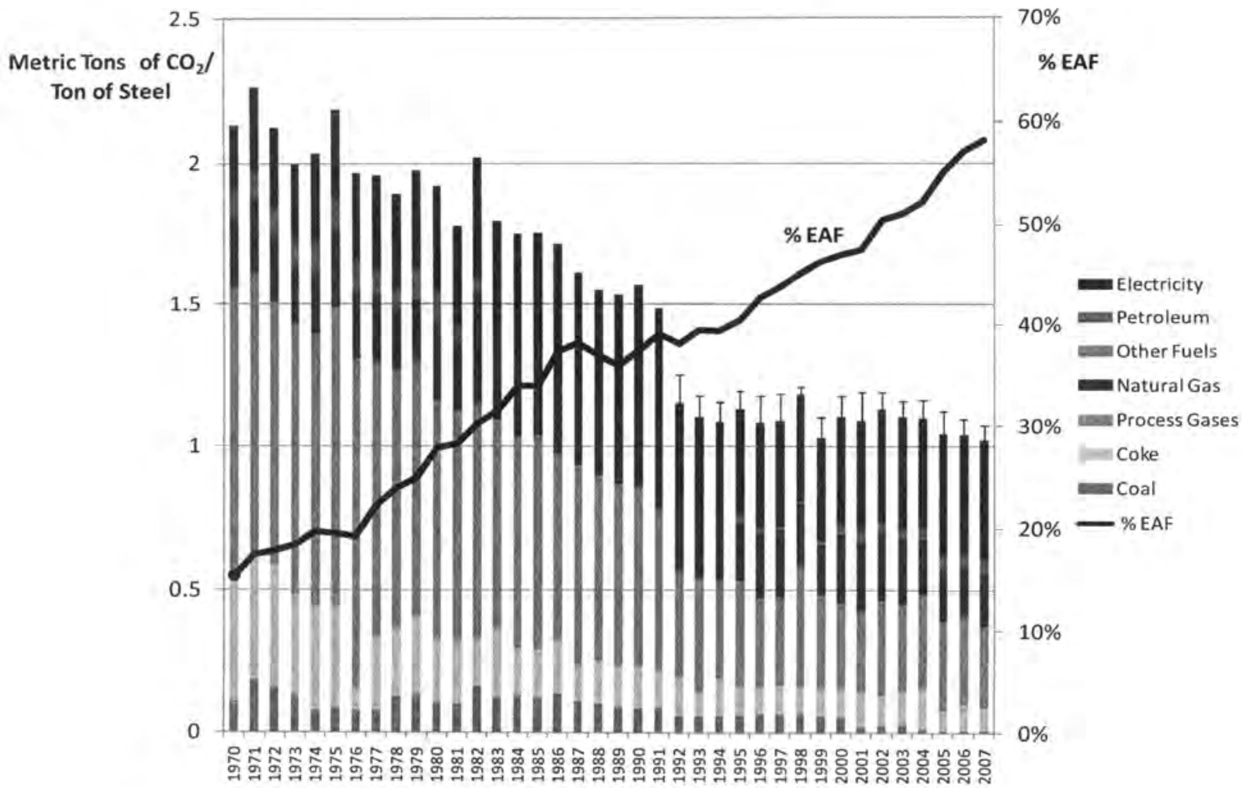
Notes: The bars (left axis) break down emissions by fuel type. The line (right axis) shows the share of steel produced by electric arc furnaces (EAFs). Limitations in the energy data prevented calculations before 1978.

Sources: Data derived from International Energy Agency, *World Energy Statistics and Balances Database 2009 Edition* (Paris, France: International Energy Agency, 2009); U.S. Geological Survey, "Iron and Steel," *2008 Minerals Yearbook* (Washington, DC: U.S. Geological Survey, 2010); and American Iron and Steel Institute, *Annual Statistical Report 2009* (Washington, DC: American Iron and Steel Institute, 2010).

[13] All tons are U.S. short tons unless denoted as metric tons.

[14] In later years (post-1992), data were available on electricity and heat from coke products—mainly blast furnace gas and coke oven gas—and positive error bars assume that this energy/CO_2 is allocated to the steel sector, whereas the main result assumes this energy/CO_2 is allocated to other sectors (i.e., it was sold as energy inputs to another sector).

Figure 2.2. Historical Carbon Dioxide (CO_2) Intensity, Fuel Mix, and Share of Electric Arc Furnace Production in U.S. Steel Manufacturing



Notes: The bars (left axis) break down emissions by fuel type. The line (right axis) shows the share of steel produced by electric arc furnaces (EAFs). The International Energy Agency has not tracked all items in its energy statistics consistently over the years; for example, data for coke oven and blast furnace gas are not available before 1992. Includes non-energy emissions from coke reduction in blast furnaces.

Sources: Data derived from International Energy Agency, *CO_2 Emissions from Fuel Combustion Database 2009 Edition* (Paris, France: International Energy Agency, 2009); *2008 Minerals Yearbook* (Washington, DC: U.S. Geological Survey, 2010); and American Iron and Steel Institute, *Annual Statistical Report 2009* (Washington, DC: American Iron and Steel Institute, 2010).

Our analysis draws from several key sources of data, including several International Energy Agency (IEA) energy balances and CO_2 emissions databases[15] and production data from the United States Geological Survey and the American Iron and Steel Institute.[16] Process-specific and country-specific data currently being gathered by World Steel and the Asia-Pacific Partnership were unavailable for this analysis.

[15] International Energy Agency, *CO_2 Emissions from Fuel Combustion* (Paris, France: International Energy Agency, 2009); International Energy Agency, *Energy Balances of OECD Countries* (Paris, France: International Energy Agency, 2009), 1–354.

[16] U.S. Geological Survey, "Iron and Steel," *2008 Minerals Yearbook* (Washington, DC: U.S. Geological Survey, 2010).

It is challenging to make comparisons across existing iron and steel energy studies. Iron and steelmaking are complex processes involving several steps, some of which are occasionally omitted from system-level analyses. Accounting challenges, such as the following, can occur across the entire system and skew study results:

- *Double counting of energy flows:* Energy associated with coking coal, as well as its associated products of coke, coke oven gas, and blast furnace gas, may both be counted.
- *Double counting of emissions:* Emissions associated with ore reduction may be counted as both process and energy-related emissions.
- *Upstream boundary issues:* Energy use at mines for iron ore agglomeration (i.e., sintering and/or or pelletizing) and energy used in coke ovens may be included or excluded in totals.
- *Downstream boundary issues:* Whether to take energy or emissions credits for energy production from blast furnaces and cokemaking being sold to other consumers.
- *Issues of energy accounting for electricity:* The energy content of electricity can be counted as either primary or end-use energy.
- *Ore quality:* The varying quality of ores and coking coals throughout the world.
- *Heterogeneity:* The treatment of steel as a homogenous commodity, when in fact there are several different types with very different energy intensities.

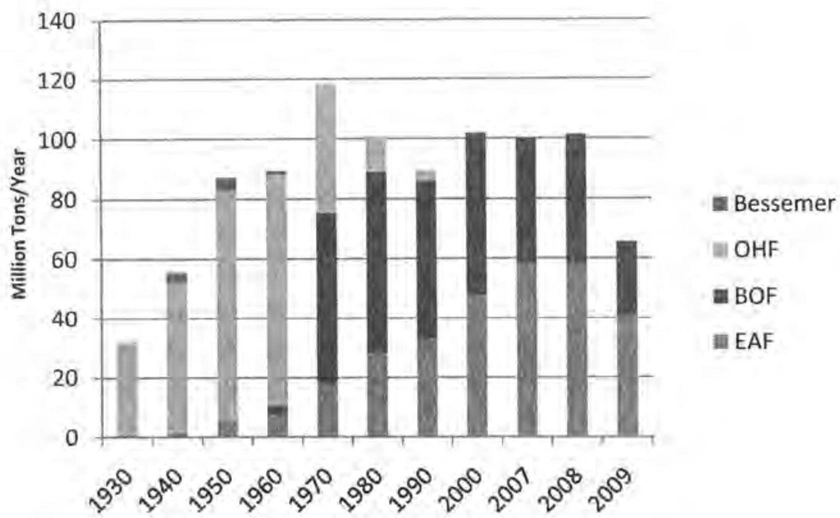
Because of these accounting challenges and a general lack of energy data at the plant level, our analysis uses a top-down approach.

Factors Driving the Decline in Energy and CO_2

The significant decrease in the industry's energy and carbon intensity resulted from two key factors: improved energy efficiency and the changing structure in energy use resulting from increased production of BOF and EAF steel.

Between 1960 and 1990, the dominant mode of primary (ore-based) iron and steel production shifted from energy-inefficient OHF and Bessemer converters to the more energy-efficient BOF. From 1970 forward, the increased availability of steel scrap (from an increase in retired infrastructure and transportation equipment), the technical developments leading to the ability to make thin-gauge flat products using EAF, and the promotional efforts of proponents of steel recycling, such as the Steel Recycling Institute, increased EAF production. EAFs can make steel from recycled scrap or from direct reduced iron (DRI) and are even more efficient than the blast furnace-BOF route. Steel production from recycled scrap completely eliminates the need for iron production in blast furnaces. In addition, DRI furnaces can operate at lower temperatures and can be more energy efficient than blast furnaces. EAF production now eclipses primary steel production from ore, accounting for 62% of all steel produced in 2009. Figure 2.3 illustrates these trends.

Figure 2.3. Production of U.S. Steel by Process, 1930–2009



Sources: *2008 Minerals Yearbook* (Washington, DC: U.S. Geological Survey, 2010), and American Iron and Steel Institute, *Annual Statistical Report 2009* (Washington, DC: American Iron and Steel Institute, 2010).

In the last three decades, the share of EAF steel production rose from below 20% to over 60%. During this time period, clear contributors to the industry's CO_2 and energy intensity changes were the structural effects of decreased coal and coke use and increased electricity and natural gas use associated with EAF production. The elimination of OHFs in the 1970s and 1980s also helped lower the industry's energy intensity. The energy efficiency of today's main production processes (BOF and EAF) have clearly improved as well, with significant advances in areas such as in process modeling and controls. The halving of the industry's energy and carbon intensities would not have been possible via structural changes alone.

It is difficult, however, to estimate exactly how much each factor (structural changes and energy efficiency improvements) contributed to the decline in energy intensity, given the current data. A 1999 study from Lawrence Berkeley National Laboratory (LBNL) reported that about two-thirds of the changes in energy intensity in the steel industry between 1980 and 1991 were due to efficiency improvements rather than structural changes. The report attributed this efficiency gain to the near-universal implementation of continuous casting and increased use of pellets for blast furnace feed.[17]

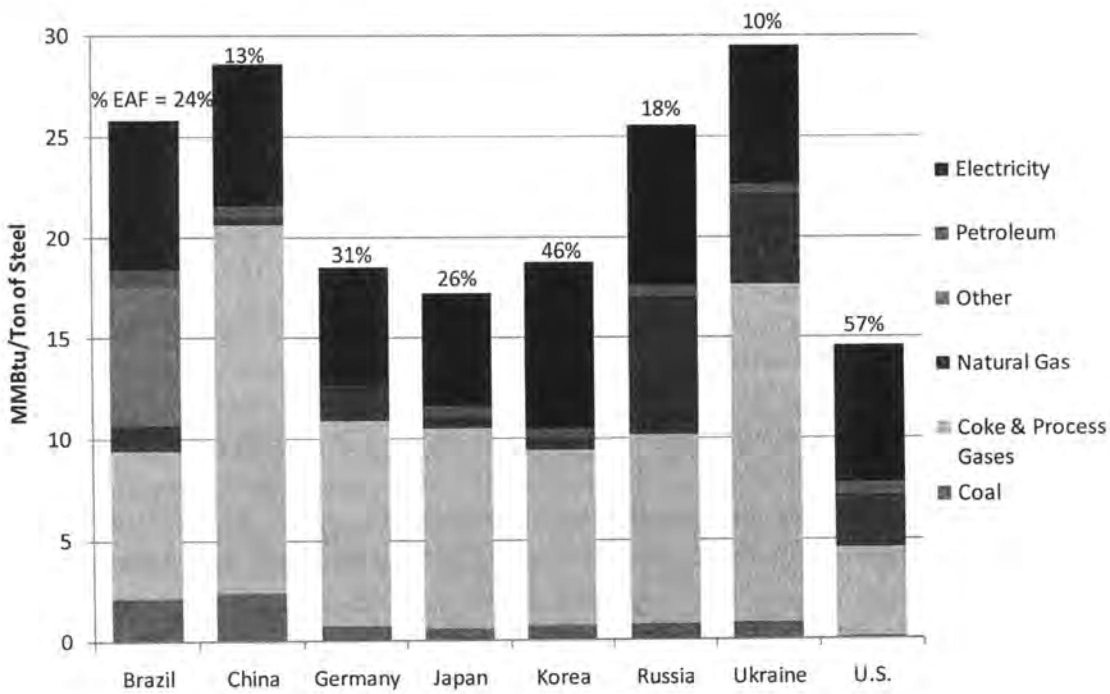
[17] E. Worrel, N. Martin, L. Price, *Energy Efficiency and Carbon Dioxide Emissions Reduction Opportunities in the U.S. Iron and Steel Sector* (Berkeley, CA: Lawrence Berkeley National Laboratory, 1999).

Comparison with Major Steel Producers

Given the improvements achieved over the last few decades, the U.S. ranks among the most efficient and lowest CO_2-emitting of the top nine global steel producers.

Figures 2.4 and 2.5 show the energy and CO_2 emissions intensities of the top world steel producers along with the percentage of production made via EAFs. In general, countries in the Organization for Economic Co-operation and Development (OECD), such as Germany, Japan, Korea, and the U.S. , have similar energy and CO_2 intensities in the range of 15–18 MMBtu/ton and 0.9–1.2 metric tons of CO_2/ton. The U.S. has the lowest energy intensity and the highest proportion of EAF use of the group. Non-OECD countries (Brazil, China, Russia, and Ukraine) show higher energy intensities of 25–30 MMBtu/ton and CO_2 intensities of 1.5–2.1 metric tons of CO_2/ton. Data is from 2006, the most recent data that is broadly available.[18]

Figure 2.4. Energy Intensity Comparisons of Major Global Steel Producers and Percentage of Electric Arc Furnace (EAF) Production, 2006

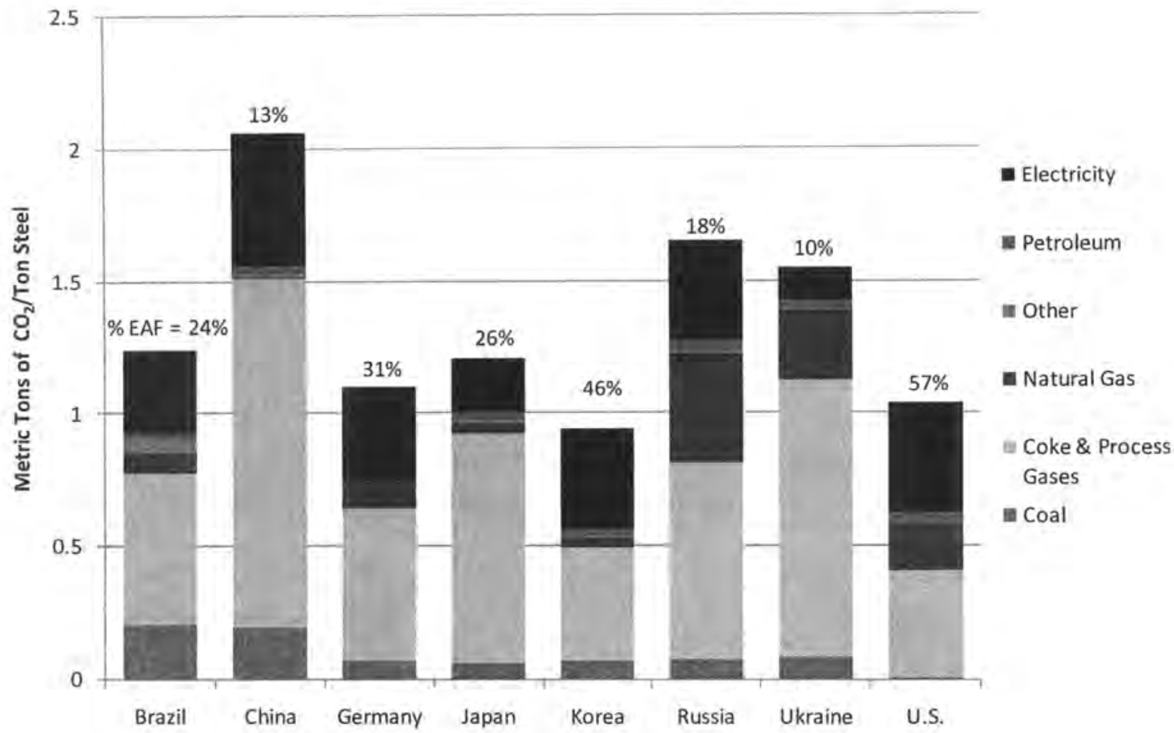


Note: Charcoal use for iron reduction accounts for most of the "other" fuel category in Brazil.

Source: Data derived from International Energy Agency, *World Energy Statistics and Balances Database 2009 Edition* (Paris, France: International Energy Agency, 2009).

[18] Energy and emissions data for India are not shown because of an unknown data problem in the IEA data set.

Figure 2.5. Carbon Dioxide (CO_2) Intensity Comparisons of Major Global Steel Producers and Percentage of Electric Arc Furnace (EAF) Production, 2006



Source: Data derived from International Energy Agency, *CO_2 Emissions from Fuel Combustion Database 2009 Edition* (Paris, France: International Energy Agency, 2009).

A major determinant of both energy and CO_2 intensity is the percentage of production made via EAF, which is highly related to the percentage of production made from scrap. Countries with very high EAF production, such as the U.S. and Korea, have much lower energy and CO_2 intensities due to the lower energy requirements of EAF production (see table 2.1). The presence of outdated OHF production in the Ukraine (33% of production) and Russia (20% of production) raises these countries' energy and CO_2 intensities. In fact, regressing the energy intensities using the percentage of EAF production statistics shows a high coefficient of determination (R^2) value of 0.76, which implies that 76% of the variation in energy intensities across countries can be explained by their share of EAF production. However, there are countries with relatively low EAF production and low energy intensities (such as Japan) and countries with somewhat high EAF production and relatively high energy intensities (such as Brazil); this reflects actual efficiency differences between countries using similar technology.

Our analysis calculates the energy and carbon intensities of major steel producers by using the same top-down analytical approach featured in the previous section of this report. The IEA data sources utilized are available for all major steel producers in the world, making it possible to quantitatively compare the energy and carbon intensity of the U.S. steel industry with other major producers. It must be noted that the potential relative error in this methodology is fairly large, and the IEA itself has noted that the data is only useful for broad generalizations and is likely not valid for detailed comparisons.[19]

Comparing CO_2 intensities is challenging because the percentage of production using different production pathways is only one of three variables that affect CO_2 intensity. A second variable is the carbon intensity of electricity, which is an important factor in countries with significant EAF production (see section 3.3). This is evident when comparing the energy and CO_2 intensities of the U.S. and Korea. The U.S. has lower energy intensity but slightly higher CO_2 intensity than Korea, which can be attributed to the higher CO_2 intensity of electricity production (611 grams [g] CO_2 per kilowatt-hour [kWh] for the U.S. versus 460 g CO_2/kWh for Korea).[20]

Performing a regression analysis using the percentage of production from EAF and the CO_2 intensity of electricity, the total R^2 for CO_2 intensity is 0.82. The percentage of production from EAF accounts for 72% of the variation and the carbon intensity of electricity production accounts for another 10%. The remaining 18% variation in the CO_2 intensity of steel production can be explained by other factors, notably the fuel mix in BOF production and the energy efficiency in each production pathway.

While figures 2.4 and 2.5 clearly show that the U.S. steel industry ranks among the most efficient and clean major producers in the world, the aggregate data make it difficult to ascertain exactly where the U.S. lies compared to other efficient producers such as Japan and Korea. Better data availability by production type would assist greatly in making these comparisons.

Need for Additional Reductions

While the U.S. steel industry has significantly reduced its energy and carbon intensity, it must make additional progress to achieve system-wide improvements. Several authors have reported the practical minimum energy use and the "best available technologies" energy use for different processes and furnace types, as table 2.2 shows. The practical minimum energy use is limited by the energy requirements of real-world operations, while the best available technologies energy use represents the lowest energy intensity achievable using the best technologies commercially available.

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[19] International Energy Agency, *Tracking Industrial Energy Efficiency and CO_2 Emissions* (Paris, France: International Energy Agency, 2007).

[20] The Greenhouse Gas Protocol Initiative, *Indirect CO_2 Emissions from Purchased Electricity Worksheet, Version 3.0, December 2007 Edition* (Washington, DC: World Resources Institute, 2007).

Table 2.2. Energy Intensity Estimates of Iron and Steel Production Processes (million Btu/ton steel)

	Agglomeration	Cokemaking	Steelmaking	Reheating/ Hot Rolling	Total	Source
Practical min., Basic Oxygen Furnace (BOF) Liquid Steel & Reheating/Rolling [a]	1.4	0.7	7.1	0.8	10.0	Steel Bandwidth Study, 2004
Practical min., Electric Arc Furnace (EAF) Liquid Steel & Reheating/Rolling [b]	N/A	N/A	4.3	0.8	5.1	Steel Bandwidth Study, 2004
BF-BOF Using Best Available Technologies [c]	1.9	0.9	10.8	2.1	15.7	Worrel et al., 2007
EAF-Scrap Using Best Available Technologies [c]	N/A	N/A	4.7	2.1	6.8	Worrel et al., 2007

Notes: System boundaries are not always equal among the sources. All energy estimates are shown as primary energy equivalents.

[a] BOF liquid steel estimate corresponds mainly to ironmaking plus theoretical minimum energy estimates for agglomeration and cokemaking. In theory, cokemaking and agglomeration are not necessary for integrated steel production, but they are virtually always part of actual integrated steelmaking. Excludes finishing processes after hot rolling.

[b] Includes liquid steel production and reheating/rolling operations only. Excludes finishing processes after hot rolling.

[c] Excludes finishing processes after hot rolling.

Sources: U.S. Department of Energy, *Steel Industry Energy Bandwidth Study* (Columbia, Maryland: Energetics Incorporated, 2004); E. Worrel, L. Price, M. Neelis, *World Best Practice Energy Intensity Values for Selected Industrial Sectors* (Berkeley, CA: Lawrence Berkeley National Laboratory, 2007).

Using global data from a 2007 LBNL study and the recent U.S. production mix of 62% EAF and 38% BOF, the average total energy intensity for the industry, using best available technologies, would be about 10 MMBtu/ton (excluding finishing processes after hot rolling).[21] Efficiency improvements are available in the U.S. across all aspects of iron and steel production, including sintering, cokemaking, blast furnaces, electric arc furnaces, and rolling and finishing.[22]

Because the U.S steel industry has already shifted its structure toward scrap-based production and engaged in decades-long efforts to root out inefficient producers and strive for energy efficiency, the

[21] E. Worrel, L. Price, M. Neelis, *World Best Practice Energy Intensity Values for Selected Industrial Sectors* (Berkeley, CA: Lawrence Berkeley National Laboratory, 2007).

[22] International Energy Agency, *Worldwide Trends in Energy Use and Energy Efficiency* (Paris, France: International Energy Agency, 2008).

industry has relatively few "easy" energy efficiency and emissions improvements left to make, The IEA estimates that using best available technologies, such as blast furnace improvements, improvements in finishing operations, and power generation using blast furnace gas, the U.S. could only achieve a CO_2 emissions reduction of 0.14 tons of CO_2/ton steel.[22] This represents the third-lowest reduction potential among the countries and regions in the IEA study. The majority of the identified CO_2 emissions reduction opportunities are blast furnace improvements, which include control systems, increased use of pulverized coal and natural gas, and BOF gas recovery.[22] In early 2010, there were 11 blast furnaces using pulverized coal in the U.S.[23]

Even if the industry adopts all of today's best available technologies, it will be very difficult for the steel industry to meet the CO_2 emissions reduction goals called for in proposed climate policies. Available reductions using best available technologies amount to a mere 12% of current emissions intensities, while proposed policies call for 50%–80% economy-wide reductions. In addition, although it is possible to operate at the highest energy efficiency levels offered by best available technologies, it is currently economically unattractive to do so. Given the ubiquitous nature of steel, simply using less steel will not contribute sizable reductions, and steel substitutes can often be more energy and CO_2 intensive. Additionally, a further increase in EAF production is limited by the amount of available scrap; a primary reason why many developing economies have such low EAF production, despite the efficient nature of the process. Further energy efficiency and CO_2 emissions improvements will require radical changes in iron and steelmaking technologies. This is the focus of section 3.

[23] Association for Iron & Steel Technology, *Iron and Steel Technology Magazine* (Warrendale, PA: Association for Iron & Steel Technology, March 2010).

Section 3. Pathways for Low-Carbon Steelmaking

In the last two decades, reducing energy use and carbon emissions has been a priority for major U.S. steel producers. Between 1990 and 2007, the industry reduced its carbon intensity by almost 35%. The largest drop occurred in the early 1990s, which resulted from OHF shutdowns, increased share of BOF and EAF production, and technical developments enabling the production of flat steel using EAFs.

The U.S. steel industry operates at energy and carbon intensity levels close to the best-achievable levels using existing technologies. Additional CO_2 emission reductions in steel manufacturing will require the following:

1. Development and commercialization of transformational technologies to make iron and steel
2. Advances in cost-effective carbon capture and sequestration (CCS) technologies
3. Generation of low-carbon electricity

Significant funding for technology development and demonstrations is needed to advance transformational iron and steel processing and CCS technologies. Sections 3.1 and 3.2 describe these opportunities and their current status.

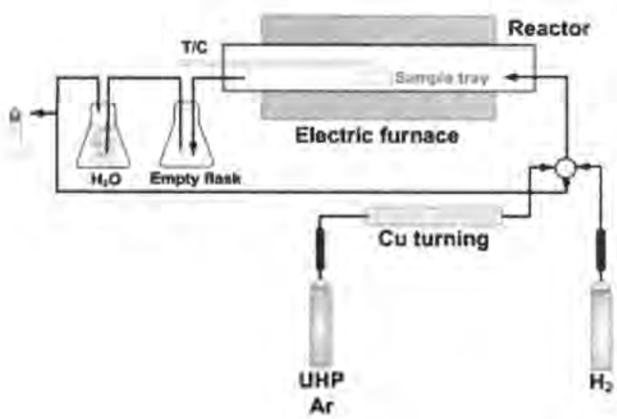
Section 3.3 analyzes how much the carbon intensity of steel production could be reduced if the U.S. electricity supply shifts to lower-carbon generation.

Section 3.1. Transformational Iron and Steel Technologies

Several global research and development (R&D) efforts are working to produce steel using transformational iron and steel technologies that can help the industry reduce or eliminate emissions.

Because the primary source of emissions in the steel industry is the consumption of the reducing agent in ironmaking, most of these technologies target reducing agent emissions.

Figure 3.1. Suspension Hydrogen Reduction



Source: American Iron and Steel Institute, "Suspension Hydrogen Reduction of Iron Oxide Concentrate," (Washington, DC: American Iron and Steel Institute, 2008) http://www.steel.org/AM/Template.cfm?Section=[illegible]&TEMPLATE=/CM/ContentDisplay.cfm

Hydrogen Reduction of Iron

Hydrogen can be reacted with iron oxides at elevated temperatures to produce iron, with water as the only by-product. This approach relies on an abundant and affordable supply of hydrogen, which can be used in its pure form or as syngas. Clean hydrogen production methods include natural gas reforming and water electrolysis.

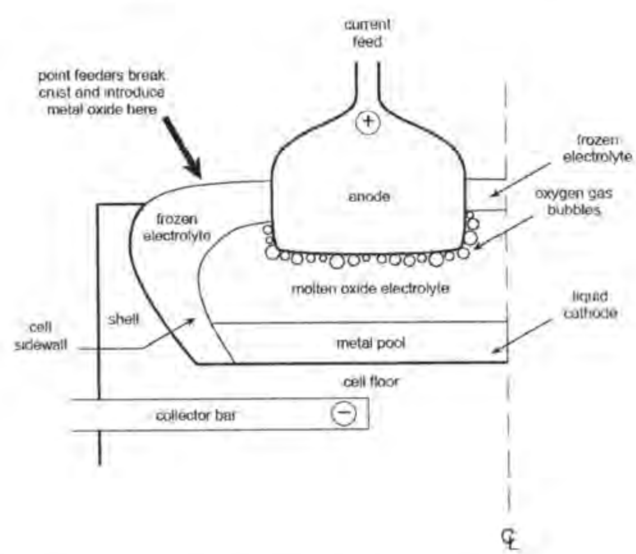
Technology Status: The U.S. Department of Energy's Industrial Technologies Program supported an effort, led by the University of Utah, American Iron and Steel Institute (AISI), and eight AISI members, to evaluate concepts for an industrially viable suspension hydrogen reduction process that can reduce emissions associated with iron making. The project started in 2005 and Phase I ended in 2007. The Phase I effort focused on detailed material and energy balances, thermochemical and equilibrium calculations, evaluations of impurity behavior, and bench-scale tests on a simulated suspension reduction process. Figure 3.1 shows a flow diagram of the suspension hydrogen reduction process. The concept proved viable, and AISI is continuing the work. This program will expand the pilot project to develop scale-up parameters. The concept has been successfully demonstrated with hydrogen, natural gas, and coal as a reducing agent.

Electrolytic Reduction of Iron

Electrolysis can be used to make iron with electrons acting as reducing agents. Electrolysis is the predominant process used to make aluminum and many other metals. The use of carbon-free anodes makes this technology completely free of process carbon emissions, resulting in oxygen as the only effluent. Carbon emissions can still be generated during the production of electricity needed in the electrolytic process, but they are minor compared to present methods. This subject is discussed in section 3.3.

Technology Status: AISI, the Massachusetts Institute of Technology (MIT), and nine industrial partners collaborated in a project—co-funded by the U.S. Department of Energy's Industrial Technologies Program—to assess the technical viability of the carbon-free production of iron by molten oxide electrolysis. The project involved identifying electrolyte chemistries, selecting anode and cathode materials, and laboratory-scale testing that resulted in the production of metal and oxygen. AISI and MIT are working to scale-up the rate of iron production and exploring material options to extend the life of the electrodes. It is envisioned that this work will lead to the construction of a pilot-scale cell to further validate the viability of the new process and identify optimization parameters. Figure 3.2 presents a schematic of the molten oxide electrolysis process. In addition to these efforts, electrolysis of iron ore is also being studied by the Ultra–Low Carbon Dioxide Steelmaking (ULCOS) European consortium.

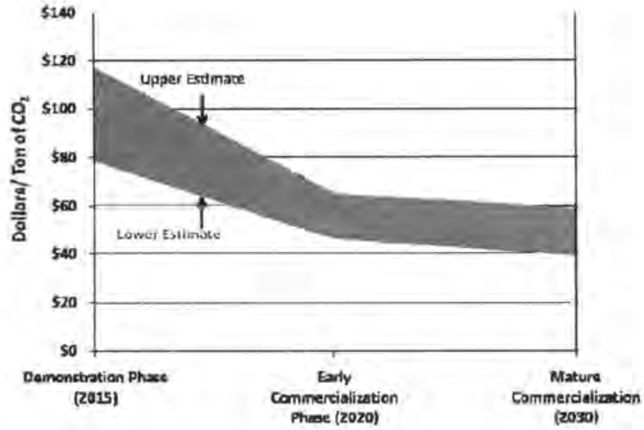
Figure 3.2. Molten Oxide Electrolysis



Source: American Iron and Steel Institute, "Technical Feasibility Study of Steelmaking by Molten Oxide Electrolysis" (Washington, DC: American Iron and Steel Institute, 2005). http://www.steel.org/AM/Template.cfm?Section=Fact_Sheets2&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=19069

Section 3.2. Carbon Capture and Sequestration

Figure 3.3. Estimated Cost of Carbon Capture and Sequestration



Notes: Assumes a conversion of USD$1.3 per euro (approximate rate in November 2008). These estimates primarily apply to CCS applications in power generation and may be somewhat different for industrial applications.

Source: McKinsey and Company, *Carbon Capture and Storage: Assessing the Economics* (New York, New York: McKinsey and Company, 2008), http://www.mckinsey.com/clientservice/sustainability/pdf/CCS_Assessing_the_Economics.pdf

Carbon capture and sequestration (CCS) represents an opportunity to reduce carbon emissions in the steel industry. In CCS, CO_2 is separated from the point of emissions, transported to a "storage location," and isolated from the atmosphere for the long term (i.e., sequestered). Storage options include physical locations such as depleted oil and gas fields as well as geological, ocean, and mineral storage.

Currently, several of the technologies involved with CCS remain in the early stages of development, and the economics of CCS are unclear. Other uncertainties surrounding CCS include environmental concerns, the legal and regulatory risks of CO_2 transport and storage, energy requirements, and the future availability of funding for demonstrations. Individual elements of carbon capture, transportation, and long-term storage have been demonstrated, but their integration with commercial systems requires significant research and demonstration efforts. Carbon dioxide capture using today's technology is estimated at $150 per ton of carbon.[24] [25] A November 2008 study published by McKinsey and Company estimates that when the first demonstration projects are built in 2015, the cost of CCS will range between $80 and $120 per metric ton of CO_2. This study reports that costs are expected to decrease to about $40–$60 per metric ton of CO_2 by 2030, as the technology advances through demonstrations and global commercialization.[26] Figure 3.3 shows these upper- and lower-bound cost estimates.

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[24] U.S. Department of Energy, Office of Fossil Energy website, "Carbon Capture Research," September 2007, http://www.fossil.energy.gov/programs/sequestration/capture/index.html.

[25] McKinsey's estimates primarily apply to CCS applications in power generation and may be somewhat different for industrial applications.

[26] McKinsey and Company, *Carbon Capture and Storage: Assessing the Economics* (New York, New York: McKinsey and Company, 2008) 16–31, http://www.mckinsey.com/clientservice/sustainability/pdf/CCS_Assessing_the_Economics.pdf. Assumes a conversion of USD$1.3 per euro (approximate rate in November 2008, when the report was published).

Global CCS Projects in Iron and Steel

Steel manufacturing may represent an attractive opportunity for CCS because highly concentrated CO_2 emissions are easily accessible from flue gases. Applications of CCS may include modifications to the blast furnace and smelting reduction processes and oxygen operation combined with in-process CO_2 capture. According to the World Steel Association, coal-based iron-making technologies associated with CCS are likely to have the earliest maturities of all of the emerging technologies targeting lower environmental footprints in steel manufacturing.[27]

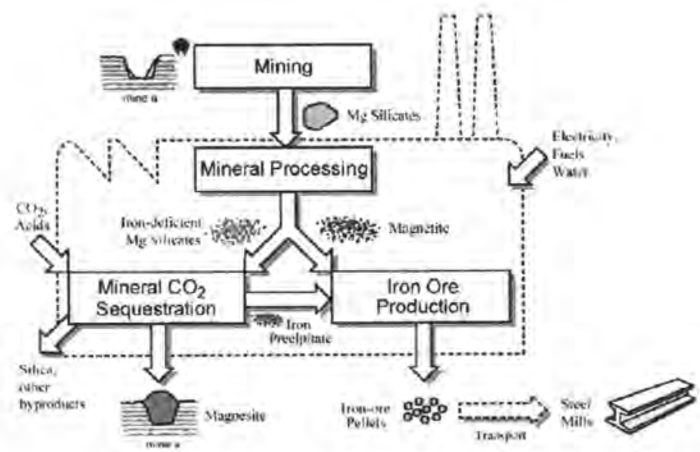
The following projects represent some of the global CCS R&D efforts that are targeting applications in steel manufacturing. These are long-range projects that rely on a low-carbon, affordable, and abundant energy supply. In addition to the need for improved economics, these technologies face significant technical challenges, which include materials selection and materials development as well as technical processing issues.

American Iron and Steel Institute Breakthrough Program

Integrating Steel Production with Mineral Sequestration

This project targeted the development of a combined iron reduction and carbon sequestration plant that uses serpentine ores as the source of iron and disposes of its own CO_2 (plus additional CO_2 from other sources) in the mineral tailings that are left at the end of the iron reduction process. The project focused on the development of various chemical pathways available for mineral sequestration that result in the production of an iron oxide concentrate ready for reduction in the blast furnace or direct reduction furnace. The synergy between steel production and mineral CO_2 sequestration comes from the chemical substitution of iron for magnesium in silicate minerals such as serpentine or peridotite ores. These rocks generally contain 24%–28% magnesium by weight and 5%–7% iron by weight (as iron oxide). Figure 3.4 shows a schematic of the process, which uses silicate minerals as low-grade iron ores.

Figure 3.4. Integrating Steel Production with Mineral Carbon Dioxide Sequestration



Source: K. Lackner, T. Yegulalp, F. Duby, S. Krevor, C. Graves, "Integrating Steel Production with Mineral CO_2 Sequestration" (presentation at 9th AISI/DOE TRP Industry Briefing Session, October 10, 2007).

[27] World Steel Association, *"Breaking Through the Technology Barriers"* (Brussels, Belgium: World Steel Association, December 2009), http://www.worldsteel.org/pictures/programfiles/Fact%20sheet_Breakthrough%20technologies.pdf.

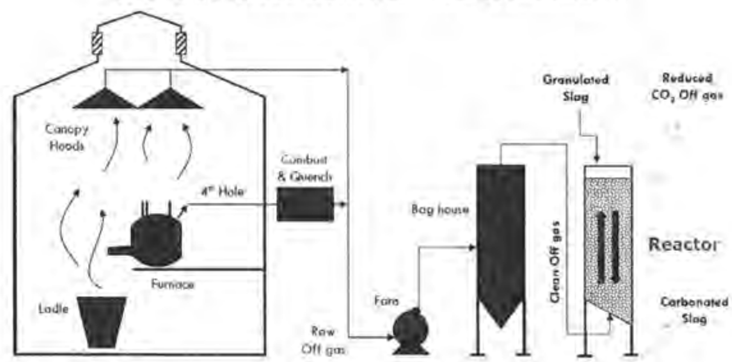
Technology Status: This project, supported by the U.S. Department of Energy's Industrial Technologies Program, ended in 2008. The research team completed a comprehensive review of serpentine dissolution techniques and developed a kinetic model describing serpentine dissolution under varying conditions of temperature, pH, and solvent composition. In 2010, AISI, on behalf of North American Steel Industry, invited proposals for research focusing on CO_2 capture and sequestration. Unfortunately, due to the paucity of funding, no award was made. This effort and other innovative research projects will form the basis for future R&D programs.

Geological Sequestration of CO_2 with Slag

Hydrous carbonates form at the surfaces of various oxides in the presence of water and ambient CO_2 activity. This project targeted the development of a process to improve the hydrous carbonate formation reaction in slag to remove CO_2 directly from steel furnace exhaust gases. In this process, furnace exhaust streams containing CO_2 from either BOF or EAF furnaces are placed in contact with reclaimed steelmaking slag in a reactor to enable the production of carbonates. The resulting products can then be reused for polymer filler, agricultural, and construction applications.

Technology Status: This two-year project, supported by the U.S. Department of Energy's Industrial Technologies Program, ended in 2007. Bench-scale tests were completed utilizing a two-stage slurry reactor and a gas bubbling reactor. This project revealed that slag has limited capacities (approximately 20%–25%) to sequester steelmaking CO_2. The low sequestration rates translate to the need to dispose of large quantities of product, resulting in further energy use and additional costs. Other materials could potentially be mixed with slag to improve its sequestration capacity, but this concept needs further research. Because of scarce funding and AISI's focus on other projects, further research on this project is not being pursued. Figure 3.5 shows a graphical representation of this technology applied to an EAF furnace.

Figure 3.5. Geological Sequestration of Carbon Dioxide (CO_2) with Slag (Electric Arc Furnace Application)



Source: American Iron and Steel Institute, "Geological Sequestration of CO2 by Hydrogen Carbonate Formation with Reclaimed Slag" (Washington, DC: American Iron and Steel Institute, 2005). http://www.steel.org/AM/Template.cfm?Section=Fact_Sheets2&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=18068.

CCS Projects in Europe

Ultra–Low Carbon Dioxide Steelmaking (ULCOS) is a consortium of 48 European companies and organizations from 15 countries that launched a cooperative R&D initiative to enable significant CO_2 emission reductions from steel production. The consortium targets CO_2 emission reductions of at least 50% from today's best production routes. The following carbon capture technologies are being developed under the ULCOS program. The earliest possible implementation date expected for these technologies is 2020.

Top Gas Recycling Blast Furnace (TGR-BF) with CO_2 Capture and Sequestration

Off-gases from the blast furnace conventionally include carbon monoxide (CO), CO_2, nitrogen (N_2), and hydrogen (H_2). In this process, injected oxygen and decarbonated off-gases replace preheated air in the furnace, which removes unwanted N_2 from the gas and facilitates CO_2 capture and sequestration. At the same time, CO is separated and recycled back into the furnace and used as a reducing agent, decreasing the amount of coke needed in the furnace. The separation and purification of CO_2 is made possible by a combination of pressure swing adsorption (PSA) and a cryogenic process.[28]

Technology Status: A gas separation plant was constructed next to an experimental blast furnace owned by Swedish company LKAB in Luleå, Sweden. Experiments were carried out on the blast furnace to operate with pure oxygen and with re-injection of CO gas. The combination of the modified blast furnace and the gas separation plant was successfully tested in 2007. Plans are underway to scale the technology into a commercial-scale blast furnace. Remaining challenges include scale-up of the PSA gas separation process and the optimization of CO recirculation, required modifications for the furnace to operate in the oxygen-blown environment, and CO_2 purification and compression as well as overall integration.[29]

ULCORED: Advanced Direct Reduction with CCS

In this process, iron pellets are produced in a sintering plant, where off-gases are cleaned before being released. The pellets then feed a direct reduction reactor, which uses natural gas to reduce the iron ore. Before being injected into the reactor, natural gas is treated in a gas conditioning plant together with the reactor off-gases and converted into a mixture of H_2, CO (the reducing agent), and CO_2, which is removed before injection and is sufficiently clean for storage.[30]

Technology Status: ULCORED is expected to begin testing at the pilot scale in the near future. Key areas of development include the gas conditioning plant for partial oxidation of natural gas, PSA for CO_2 separation, and the recirculation system for the reducing agent.[31]

HIsarna

HIsarna is a combination of two processes called HIsmelt and Isarna. HIsarna is a bath melting process that uses a combination of the following three new technologies:

- Coal preheating and partial pyrolysis in a reactor

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[28] ULCOS, "Top Gas Recycling," http://www.ulcos.org/en/research/blast_furnace.php.
[29] Global Carbon Capture and Storage Institute, *An Ideal Portfolio of CCS Projects and Rationale for Supporting Projects* (Sydney, Australia: L.E.K. Consulting, October 2009), http://www.globalccsinstitute.com/sites/default/files/LEK_Global_CCS_Portfolio_Final%20Report.pdf.
[30] ULCOS, "ULCORED," http://www.ulcos.org/en/research/advanced_direct_reduction.php.
[31] Global Carbon Capture and Storage Institute, *An Ideal Portfolio of CCS Projects and Rationale for Supporting Projects Appendix* (Sydney, Australia: L.E.K. Consulting, October 2009), http://www.globalccsinstitute.com/sites/default/files/LEK-An-Ideal-Portfolio-of-CCS-Projects-and-Rationale-for-Supporting-Projects-Appendix.pdf.

- A melting cyclone for ore melting
- Smelter vessels for final ore reduction and iron production

Instead of using coke, HIsarna uses preheated coal, which is charged into the melting cyclone reactor together with iron ore fines and injected oxygen. The resulting molten iron is then sent to the steel plant. The process requires significantly less coal than conventional routes, thereby reducing CO_2 emissions by as much as 20%. This makes HIsarna an ideal candidate for CO_2 capture. Another major advantage of this process is that it allows for partial substitution of coal with biomass, natural gas, or possibly hydrogen.[32]

Technology Status: The three new technologies of HIsarna have been proven, independently, at the small scale. The smelt cyclone technology was developed by Corus, and the smelting technology is licensed by Rio Tinto. The development of a 65,000 ton-per-year pilot plant is underway at Saarstahl, Germany. Additional work is continuing to explore using CCS and biomass technology in combination with HIsarna. If successful at pilot-scale testing, the plant will be extended to a semi-industrial scale with an annual capacity of 700,000 tons.[33]

POSCO CO_2 Breakthrough Framework in Korea

This is an R&D program led by Korean steelmaker POSCO targeting carbon-lean steelmaking, which involves enhanced hydrogen utilization and carbon capture and sequestration process development in steelmaking. POSCO has developed and commercialized a process, called FINEX, which uses non-coking coal and replaces the sinter plant with a series of fluidized bed reactors from which CO_2 can be removed when capture processes are in place. Two capture technologies are being investigated in this initiative: CO_2 absorption using an ammonia solution from blast furnace gas, and the combustion of FINEX PSA tail gas with oxygen.[34]

Technology Status: To date, the CO_2 capture system requires scale-up, and the purity of the CO_2 stream has to be improved to meet compression, transport, and storage requirements.[35]

[32] ULCOS, "HIsarna smelter technology," http://www.ulcos.org/en/research/isarna.php.
[33] Global Carbon Capture and Storage Institute, *An Ideal Portfolio of CCS Projects and Rationale for Supporting Projects Appendix* (Sydney, Australia: L.E.K. Consulting, October 2009), http://www.globalccsinstitute.com/sites/default/files/LEK-An-Ideal-Portfolio-of-CCS-Projects-and-Rationale-for-Supporting-Projects-Appendix.pdf; ULCOS, "European steelmakers and Rio Tinto join forces in combating climate change," September 2008, http://www.ulcos.org/en/docs/Ulcos.org_Press_European_Steelmakers.pdf.
[34] POSCO-India, "POSCO completes commercialization of FINEX Technology," May 2010, http://posco-india.com/website/press-room/posco-completes-commercialization-of-finex-technology.htm; POSCO-India, "POSCO CO_2 Breakthrough Framework and Its Position on Post-Kyoto Regime" (presented at the Korea-EU Workshop on Climate Change Policies and Business Contribution, Seoul, Republic of Korea, September 28, 2008), http://www.delkor.ec.europa.eu/home/newsevents/events/document_files/Session3/Session3_7%20Jang.pdf.
[35] U.S. Department of Energy, Office of Fossil Energy website, "Carbon Capture Research," September 2007, http://www.fossil.energy.gov/programs/sequestration/capture/index.html.

Section 3.3. Impact of Electricity Generation on the Steel Industry's Carbon Intensity

As the production of EAF steel has increased over the last few decades, purchased electricity has become an increasingly important component of the energy and greenhouse gas (GHG) profile of the U.S. steel industry.[36] Because of the increasing use of electricity, the carbon intensity of the U.S. electrical grid has an indirect effect on the carbon intensity of the steel industry, both today and in the foreseeable future. Thus, improvements in the efficiency of power generation present an important opportunity to reduce the carbon intensity of the steel industry. For example, combined-cycle generators and combined heat and power systems can significantly increase the thermal efficiency of power plants and, in turn, lower CO_2 emissions.

An additional pathway for reducing the CO_2 intensity of steel production is to change the electricity fuel mix for power generation. Our analysis shows that because of its high reliance on coal, today's U.S. electricity generation fuel mix is relatively carbon-intensive by world and developed country standards. In 2007, the world average generation mix consisted of approximately 68% conventional thermal-fired electricity, 16% hydroelectric, 2% other renewables, and 14% nuclear power.[37] In comparison, the U.S. fuel mix was approximately 72% thermal (49% coal, 21% gas, and 2% oil), 19% nuclear, 6% hydroelectric, and 3% other (from renewable sources).

Figure 3.6 shows the fuel mix of the eight largest electricity-generating countries and their resulting carbon intensities. Of this group, China and India have the highest carbon intensities (top axis), while Japan and Korea have the lowest carbon intensities. As the figure shows, carbon intensity is highly correlated to the percentage of coal generation in a country's fuel mix. This explains why the U.S. has a higher carbon intensity than the United Kingdom, which has a higher percentage of carbon-free generation (nuclear, hydro, and renewables). A relatively higher coal percentage can be offset by the use of low-carbon fuels; for example, in Korea, nuclear generation accounts for 34% of generation. However, the general rule follows that the higher the share of coal in the generation mix, the higher the carbon intensity. Therefore, future reductions in the carbon intensity of U.S. electricity generation are likely to be achieved from reductions in the share of coal-fired generation or application of CCS (if successful).[38]

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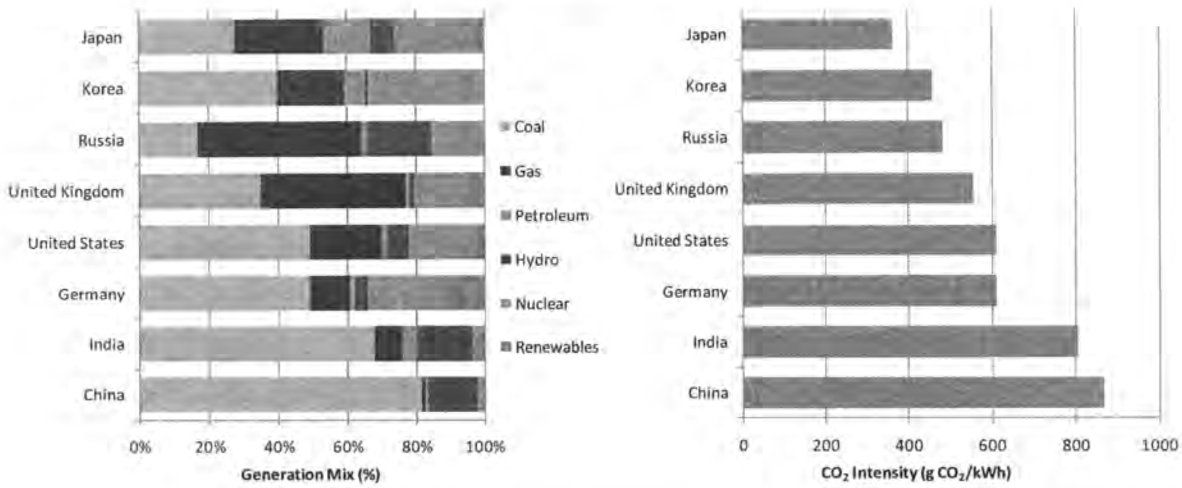
[36] International Energy Agency, *Energy Balances of OECD Countries* (Paris, France: International Energy Agency, 2009), 1–354.

[37] U.S. Energy Information Administration, *International Energy Statistics* (Washington, DC: U.S. Energy Information Administration, 2009), http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm.

[38] International Energy Agency, *Climate Policy Uncertainty and Investment Risk* (Paris, France: International Energy Agency, 2007), 1064–1074; A. Newcomer, S. Blumsack, J. Apt, L. Lave, G. Morgan, "Short Run Effects of a Price on Carbon Dioxide Emissions from U.S. Electric Generator," *Environmental Science & Technology* 42: 3139–3144.

Figure 3.6. International Electricity Generation Fuel Mix (%) and Carbon Intensity (grams of carbon dioxide [CO_2] per kilowatt-hour [kWh]), 2007



Source: U.S. Energy Information Administration, *International Energy Statistics* (Washington, DC: U.S. Energy Information Administration, 2009); International Energy Agency, Energy Balances of OECD Countries (Paris, France: International Energy Agency, 2009), 1–354.

Accounting for the carbon intensity of electricity is complicated due to the temporally and spatially varying mix of electricity production and consumption.[39] Thus, national averages are often used as proxies for the actual impacts of electricity consumption by industries, although high-quality data in the U.S. has allowed for some more-detailed regional analyses. Our analysis utilizes the national fuel mix average. However, it should be recognized that the electricity fuel mix varies considerably in space throughout the continental U.S. as well as in time seasonally, diurnally, and annually.[40]

Several sources have projected changes in the future U.S. fuel mix, under different scenarios. The U.S. Department of Energy's Energy Information Administration's *Annual Energy Outlook* (AEO) projections can be considered an important base case but a pessimistic one for CO_2 reductions. The base-case analysis assumes that the U.S. does not collectively reduce economy-wide GHG emissions; the change in fuel mix is thus purely due to projected price changes and the economic competitiveness of different generation technologies. The Electric Power Research Institute's PRISM and MERGE analyses attempt to do the opposite task: determine the technical potential (PRISM) and least-cost combination of technologies (MERGE) to meet typical climate policy goals.[41] The AEO and PRISM/MERGE analyses can be regarded as likely best-case and worst-case scenarios for future reductions in the carbon intensity of the U.S. electricity sector.

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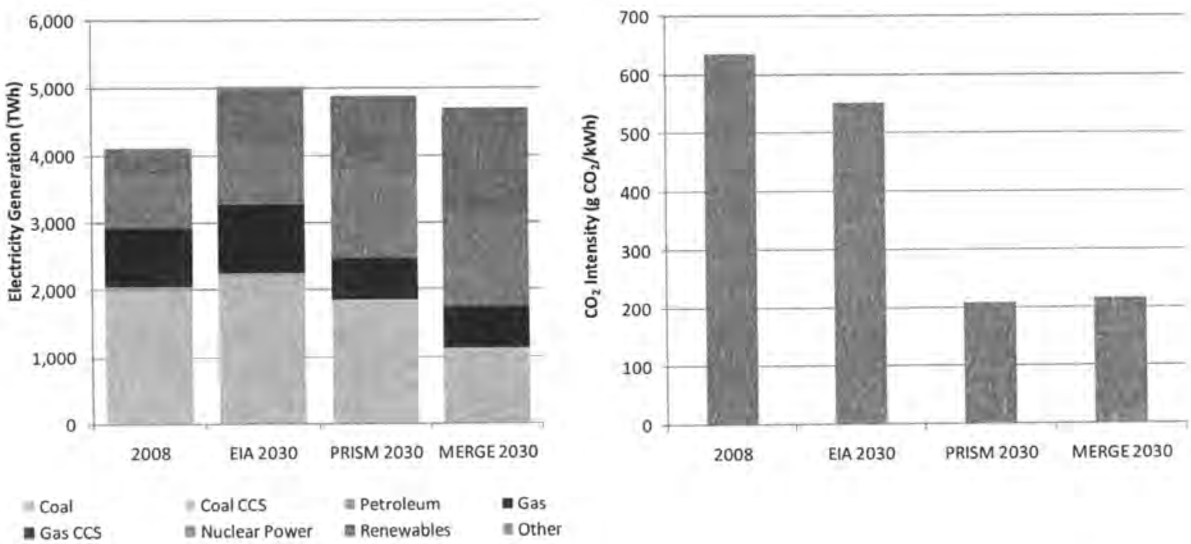
[39] C.L. Weber, P. Jaramillo, J. Marriott, C. Samaras, "Life Cycle Assessment and Grid Electricity: What Do We Know and What Can We Know?" *Environmental Science & Technology* 44: 1895–1901.
[40] Global Carbon Capture and Storage Institute, *An Ideal Portfolio of CCS Projects and Rationale for Supporting Projects* (Sydney, Australia: L.E.K. Consulting, October 2009), http://www.globalccsinstitute.com/sites/default/files/LEK_Global_CCS_Portfolio_Final%20Report.pdf.
[41] Electric Power Research Institute, *PRISM/MERGE Analyses 2009 Update* (Palo Alto, CA: Electric Power Research Institute, August 2009).

Figure 3.7 shows the 2008 U.S. fuel mix, 2030 projections of the future U.S. electricity fuel mix (left axis), and 2030 carbon intensity (right axis) of electricity generation. Even in the pessimistic case, where it is assumed that there are no mandatory climate policies through 2030, the AEO shows a 13% reduction in carbon intensity by 2030, mostly from the increased utilization (due to improved price competitiveness) of renewables and decreased reliance on coal. On the more optimistic side, the PRISM and MERGE models show an approximately 65% decrease in carbon intensity due to large increases in the use of renewables and nuclear generation (with some carbon capture and sequestration) and large reductions in both coal and gas-fired generation. In the context of steelmaking, because electricity represents a large share of the energy (50%) and carbon burden (40%) of making steel in the U.S., these reductions could result in a 30% decrease in the carbon intensity of steel production, assuming the share of electricity in the carbon footprint remains constant (i.e., assuming the EAF share of production remains steady).

Figure 3.7. U.S. Electricity Generation Fuel Mix and Carbon Intensity Projections (2008–2030)



Sources: Data for the 2008 and EIA 2030 bars are derived from U.S. Energy Information Administration, *Annual Energy Outlook 2010* (Washington, DC: U.S. Energy Information Administration, 2010). Data for the PRISM 2030 and MERGE 2030 bars are derived from Electric Power Research Institute, *PRISM/MERGE Analyses 2009 Update* (Palo Alto, CA: Electric Power Research Institute, August 2009).

Section 4. Conclusions

Over the last few decades, the U.S. steel industry drastically increased its energy efficiency and decreased its carbon emissions while employing new technologies and process controls. These improvements are results of the increased availability of scrap for efficient electric arc furnace production and of the industry's dedication to increasing energy efficiency in both virgin and scrap-based production. Together, these changes have made the U.S. one of the most energy and carob-efficient global steel producers today.

Because the U.S. steel industry is approaching the energy and carbon efficiency limits obtainable with today's best available technologies, achieving the additional improvements in proposed climate change policies poses a difficult challenge. Further improvements will require radical changes in iron and steelmaking technologies, including the use of electricity for the electrolytic reduction of iron-bearing ores, the application of other alternative reducing agents, or the widespread use of carbon capture and sequestration. To date, these technologies remain unproven, and significant research and development investments are needed to enable commercial-scale deployment.

The Industrial Technologies Program (ITP) is the lead government program working to increase the energy efficiency of U.S. industry—which accounts for about one-third of U.S. energy use. In partnership with industry, ITP helps research, develop, and deploy innovative technologies that companies can use to improve their energy productivity, reduce carbon emissions, and gain a competitive edge.

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March 2011

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