Industrial energy efficiency
Global overview and case studies in U.S. and China

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Global overview

• Industry is the second largest source of CO2 emissions after the power sector, with total emissions of around 8.7 Gt CO2 in 2020.

• Three heavy industries – chemicals (such as plastic), steel and cement – account for nearly 60% of industrial energy consumption and around 70% of CO2 emissions.

• Emerging and developing countries account for 70-90% of the combined output of these commodities, with China alone responsible for almost 60% of global steel and cement production in 2020

Source: IEA, Industry direct CO2 emissions (MtCO2) in the Net, 2000-2020, IEA, Paris
IEA Sustainable Recovery Tracker: Governments worldwide have mobilised an unprecedented amount of fiscal support aimed at stabilising and rebuilding their economies – now around USD 18.2 trillion

Total energy efficiency-related government clean energy recovery spending, 2021-onwards

Note: This figure and section include government recovery spending from 2021 and beyond, and announced to the end of October 2021, based on measures highlighted in the IEA Sustainable Recovery Tracker.
Source: IEA (2021), Sustainable Recovery Tracker.
- Government-related energy efficiency RD&D spending focuses on transport and industry sectors.

Government energy efficiency RD&D spending in IEA member countries, 2000-2020
Cement sector looks to reduce clinker and favour alternative fuels

• 50-60% of cement CO2 emissions comes from clinker production
• The remaining emissions originate from combustion of fuels such as coal, gas, oil and petroleum coke.

The process of "calcination" splits the material into calcium oxide and CO2. A new substance called clinker emerges as marble-sized grey balls.
Cement sector looks to reduce clinker and favor alternative fuels

• A range of materials to replace clinker in cement: finely ground limestone and by-products from other industries, such as granulated blast furnace slag from steel production or fly ash from coal-fired power plants.
• Building codes standards for concrete that favour cements with lower clinker content, without compromising safety and performance.
• Increasing the lifespan of buildings can also reduce demand for cement, notably by investing more heavily in building retrofits and energy-efficient construction.
Cement sector looks to reduce clinker and favor alternative fuels

- Concrete recycle: widely “down cycled” for use in road or foundation beds but could be recycled much more. Uniform concrete structural components could be designed for reuse.
- Cement consumption can also be reduced by using alternative building materials like timber
- Cement kilns are conventionally fueled by fossil fuels; alternative fuels such as municipal and industrial waste streams and can contain biomass.
- CCUS
Cement policy toolkit: United States

- California SB-596: Achieve 40 percent cement emissions reductions below 2019 levels by 2035 and net-zero no later than 2045
- Marin County, CA: Bay Area Low-Carbon Concrete Codes - Sets maximum limits for the usage of cement in concrete based on carbon emissions
- New York NY A2591/S542: Directs state agencies and departments to create a low-carbon concrete standard for concrete used on any state-funded project
- Hawaii HB1282: “All state building construction that uses concrete to use post-industrial carbon dioxide mineralized concrete unless use of these materials will increase costs or delay construction.”
Cement policy toolkit: United States

• Honolulu, Hawaii: Resolution that “requests the city administration to consider using carbon dioxide mineralization concrete for all future city infrastructure projects utilizing concrete.”

• Colorado HB 21-1303: Requires state to establish maximum carbon content limits for construction materials including concrete, and requires concrete producers to disclose the carbon content of products purchased by state agencies through the use of Environmental Product Declarations.

• U.S. Conference of Mayors: Urges all 1400 member cities to prioritize the use of CO2 mineralized concrete in city projects that require concrete
Steel

• There are two main production process – primary production using iron ore as its main source of metallic input and secondary production, which is based on scrap.

• Secondary steel production avoids the initial refining step where oxygen needs to be removed from the iron ore, and as a result requires about 80-90% less energy.

• Primary steelmaking uses a blast furnace. Secondary steelmaking is performed in an electric arc furnace.

• Conventional steel production involves a coke-powered blast furnace to process the iron ore. The blast furnace produces molten iron, which is then fed into a basic oxygen furnace, often in conjunction with some scrap, which oxygen is injected to lower the carbon content to produce steel.
Steel

• A newer alternative and lower emission process is direct reduction electric arc furnace production where higher quality iron ore is melted in an electric arc furnace with oxygen and lime to make steel.

• Increase the scrap recycling rate. This means recovering more steel from old cars, machinery and appliances.

• Steel can sometimes be replaced by alternative materials, like carbon fibre.

• CCUS
Chemicals sector: recycling plastics is key to efficiency

- Material and energy efficiency are important actions to reduce emissions in the chemical industry
- Increased recycling, replacing plastics with biomaterials and using nitrogen fertilisers more efficiently
- However, only about 14 to 18% of plastic is currently recycled at a global level
- A switch to producing plastics by using electric steam crackers or electrolysis-based chemical reactions also offers energy efficiency gains and could be powered by renewable energy rather than fossil fuels
Light industry: boosting energy efficiency

• Light industry includes the manufacture of vehicles, machinery, food, timber, textiles and other consumer goods, together with the construction and mining sector.

• In contrast to heavy industries, most technologies that can decarbonize light industry are ready to deploy.

• This is because more than 90% of heat demand in light industry is low- and medium-temperature, which can be more easily switched from fossil fuels to more efficient electric processes, especially heat pumps.

• Building systems, machine drives, smart manufacturing, DERs
Low hanging fruits?

The great abatement debate
Abatement-cost curve for global greenhouse-gas emissions
2020

By sector
- Industry
- Agriculture
- Transport
- Power generation
- Buildings

Savings from industrial-efficiency gains and plastics recycling are expected to exceed the costs
A switch from coal to gas in Asia-Pacific delivers abatement at a low cost
Switching from petrol or diesel to electric vehicles delivers abatement at a high cost

Cost of abatement
$'000 per tonne of CO₂ equivalent

0.0
0.2
0.4
0.6
0.8
1.0
1.2

Not abatable using technologies currently available at scale

Source: Goldman Sachs

The Economist

For Cement and Steel

Source: https://www.nature.com/articles/d41586-022-00758-4
Industrial Energy Efficiency Policies

- **Standard**
  - Around 40% of energy use of industrial motors is now covered by mandatory performance standards, up from 15% ten years ago.
  - Three-quarters of the 57 countries with minimum energy performance standards for industrial electric motors implemented their standards in the 2010s.
  - Ukraine is the most recent country to implement standards, which came into operation in September 2021.
Industrial Energy Efficiency Policy

• Mandatory audits and energy management systems

• Examples of mandatory audit requirements can be found both in emerging markets such as in Tunisia and Morocco and in advanced economies such as the European Union.

• Although necessary, such measures are only the first steps towards a clearer, more defined path to improve energy efficiency in the industry sector.
Specific programs

• India’s Perform, Achieve and Trade scheme (PAT)
  (PAT) scheme sets mandatory energy intensity improvement targets for large energy users in energy-intensive sectors.
  The scheme provides incentives for overachievement by allowing the trading of energy-saving certificates.
  The first cycle of the scheme (2012-2015) targeted large energy-intensive industries such as iron and steel, aluminium and cement.
  It managed to reduce the energy consumption of more than 400 covered entities by 5.3%, above the initial target of 4.1%.
  Subsequent cycles extended the scheme to further sectors and covered additional entities such as smaller energy users.
China’s “100,1 000,10 000” industrial enterprises programme

• First introduced in 2006 and extended in 2011 and 2017, the Key Energy-Consuming 100, 1 000, 10 000 Organisations Action sets mandatory energy-intensity improvement targets for the largest energy-consuming enterprises in China, most of which are in the industry sector.

• Targets have been set at the national level and then passed down to local levels for action by individual companies.

• The programme is linked to strong policies to support the development of energy service companies.
Barriers for adopting industry EE measures: Energy efficiency paradox

• Financing
Chinese energy service companies experience strong growth

- Energy service companies (ESCOs) provide energy solutions ranging from generation and supply to energy efficiency and retrofitting projects.
- ESCOs help consumers identify, finance and implement projects, thereby making it easier to invest.

- The global ESCO market as a whole increased by around 6% in 2020 to USD 33 billion.
- This growth was mainly centered in China, where investment rose by 12% despite the pandemic.
- The Chinese government also introduced additional tax incentives in May 2020 to encourage ESCO business development and innovation.

Source: IEA Annual ESCO market surveys.
Using the information of about 140 EPC contracts in China in 2010 and 2011

<table>
<thead>
<tr>
<th>Model number</th>
<th>Dependent variable</th>
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<td></td>
<td></td>
<td>ln(investment)</td>
<td>ln(annual energy saving)</td>
<td>ln(annual energy saving in RMB)</td>
<td>ln(contract length)</td>
<td>ln(investment)</td>
<td>ln(annual energy saving)</td>
<td>ln(annual energy saving in RMB)</td>
<td>ln(contract length)</td>
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</tbody>
</table>
| Log(ESCO’s registered capital) | 0.199  | 0.160  | 0.154  | 0.076  | 0.282  | 0.223  | 0.219  | 0.069  | ***
|                       | (0.073) | (0.074) | (0.068) | (0.040) | (0.078) | (0.084) | (0.075) | (0.036) | **
| Log(client’s registered capital) | 0.131  | 0.074  | 0.105  | 0.006  | 0.147  | 0.091  | 0.157  | 0.005  | **
|                       | (0.052) | (0.052) | (0.049) | (0.026) | (0.058) | (0.063) | (0.058) | (0.025) | **
| Financing type (base case: loan) | Equity | 0.1725  | 0.1594  | 0.1523  | 0.032  | 0.1592  | 0.1289  | 0.1293  | 0.058  | ***
|                       | (0.324) | (0.326) | (0.305) | (0.159) | (0.340) | (0.371) | (0.337) | (0.140) | **
|                       | Fund    | 0.0360  | 0.0813  | 0.0927  | 0.0830  | 0.0654  | 0.1154  | 0.314  | -0.680  | **
|                       | (0.182) | (0.168) | (0.171) | (0.091) | (0.196) | (0.170) | (0.126) | (0.170) | **
|                       | Leasing | -0.154  | -0.604  | -1.283  | -0.654  | -1.154  | -0.314  | -0.290  | -0.680  | *
|                       | (1.353) | (0.907) | (0.884) | (0.649) | (1.330) | (1.045) | (0.905) | (0.511) | **
|                       | Mixed   | -0.362  | -0.362  | -0.362  | -0.362  | -0.362  | -0.362  | -0.362  | -0.362  | *
|                       | (0.529) | (0.524) | (0.503) | (0.256) | (0.716) | (0.710) | (0.671) | (0.276) | **
| Industry type (base case: communication and electronics) | Construction | 1.241  | 1.278  | 0.957  | 1.163  | 1.666  | 2.095  | 1.637  | 0.411  |
|                       | (0.539) | (0.551) | (0.495) | (0.264) | (0.648) | (0.698) | (0.589) | (0.255) | **
|                       | Paper and textile | 0.850  | 1.389  | 1.085  | 0.458  | 0.946  | 1.276  | 1.100  | 0.337  |
|                       | (0.562) | (0.574) | (0.530) | (0.278) | (0.625) | (0.683) | (0.586) | (0.251) | **
|                       | Mining | 1.588  | 2.479  | 1.957  | 0.346  | 1.551  | 2.508  | 1.928  | 0.265  |
|                       | (0.504) | (0.502) | (0.449) | (0.241) | (0.563) | (0.589) | (0.494) | (0.218) | **
|                       | Petro and chemical | 0.721  | 1.863  | 1.468  | 0.431  | 0.966  | 2.041  | 1.658  | 0.348  |
|                       | (0.510) | (0.521) | (0.473) | (0.245) | (0.556) | (0.603) | (0.510) | (0.213) | **
|                       | Power and mechanical | 1.230  | 1.663  | 0.892  | 0.348  | 1.247  | 1.609  | 1.046  | 0.348  |
|                       | (0.538) | (0.536) | (0.533) | (0.273) | (0.582) | (0.632) | (0.591) | (0.244) | **
| Whether a project qualifies for government subsidy | Constant | 6.634  | 7.393  | 5.927  | 1.137  | 6.530  | 7.001  | 6.540  | 1.267  |
|                       | (0.567) | (0.567) | (0.517) | (0.273) | (0.624) | (0.655) | (0.563) | (0.244) | **
|                       | # of obs | 109  | 115  | 101  | 99  | 84  | 88  | 79  | 71  |
|                       | Adj R-square | 0.382  | 0.378  | 0.372  | 0.254  | 0.426  | 0.346  | 0.379  | 0.104  |
Our findings

• Lack of access to capital is a major barrier for EPC to get its investment financed in developing countries like China

• Cost of capitals for ESCOs and the clients, especially for ESCOs, is a major factor influencing contract terms and the resulted energy savings
Barriers for adopting industry EE measures

• Firms’ implicit discount rate
The USDOE Industrial Assessment Centers (IACs) can help small and medium sized US manufacturers save energy, improve productivity, and reduce waste by providing **no-cost technical assessments** conducted by university based teams of engineering students and faculty.

After the site visit, the IAC team provides a comprehensive report with specific details on all opportunities for improving competitiveness identified during the assessment, including applicable rebates and incentives.
Our findings

- Using the Industrial Assessment Centers (IAC) database from 2002 to 2011, with more than 30,000 energy efficiency recommendations.
- Implied discount rates of medium to small industrial firms range from 40 to 45%, and the average payback threshold is about 9 months.
- Three types of recommendations: energy management, waste minimization/pollution prevention, and direct productivity enhancements.
- Compared with direct productivity enhancements, energy, waste and pollution related recommendations have higher discount rates and thus are less likely to be implemented.
Thank you

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