Dynamic foundations: the role of industrial efficiency in limiting 21st century warming to 2 degrees

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Keywords
climate change mitigation, decoupling, corporate strategy, low carbon targets, co-benefits, productivity, 2-degree pathway

Abstract

The Paris Agreement of 2015 built on individual country-level mitigation actions to present a vision of global action for holding the increase of average temperatures to well below 2 degrees Celsius above pre-industrial levels. While the Agreement offers a moral foundation for future action and a novel collaborative framework for global environmental governance, a significant gap remains between existing country commitments and the aspirational 2-degree pathway. Companies, cities, regions, and other non-state actors are stepping forward to reduce their own emissions and bridge the global gap.

The Science Based Targets initiative is a collaboration between the World Resources Institute (WRI), CDP (formerly the Carbon Disclosure Project), the World Wildlife Fund (WWF), and the United Nations Global Compact to help companies develop emission reduction targets consistent with a global 2-degree pathway. At the company level, the primary levers for achieving these reductions are efficiency improvements and decarbonization via fuel switching. As of June 2016, more than 160 companies have demonstrated the business case for mitigation investment by publicly committing to develop science-based targets that align their companies with a global 2-degree pathway.

Based on sector analyses and company targets, this paper describes cumulative emissions budgets, pathways, and mitigation practices for transitioning energy-intensive industry to a 2-degree pathway. The paper also discusses the role of science-based targets and other voluntary initiatives, sector programs, and policies in moving industry toward a 2-degree pathway. Whether emissions are reduced to a level that holds warming to 1.5 degrees or soars beyond 6 degrees, the industrial sector will play a central role in bringing about and responding to climate impacts.

Introduction

Based on current technologies and the structure of the global economy, industry is the largest sector source of greenhouse gas (GHG) emissions, accounting for a third of total global GHGs in 2010.[1] Most industrial sector GHG emissions result from direct fossil fuel combustion and the production of purchased electricity and heat. Figure 1 illustrates the composition of total global industrial sector GHG emissions by gas, and by source for carbon dioxide.

GHG emissions are often divided into three scopes. Scope 1 refers to all direct GHG emissions. Scope 2 includes indirect GHG emissions from consumption of purchased electricity, heat or steam. Scope 3 covers other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g. T&D losses) not covered in Scope 2, outsourced activities, waste disposal, etc.

Since the start of the industrial revolution in the 18th century, global industrial GHG emissions have moved in tandem with total GHG emissions (including transport and buildings) and

1. Fischedick, et al. (2014). Unless otherwise specified, the scope of industry in this paper covers activities over the whole lifecycle of physical products whose use delivers final services that satisfy current human needs, e.g., including waste/wastewater.

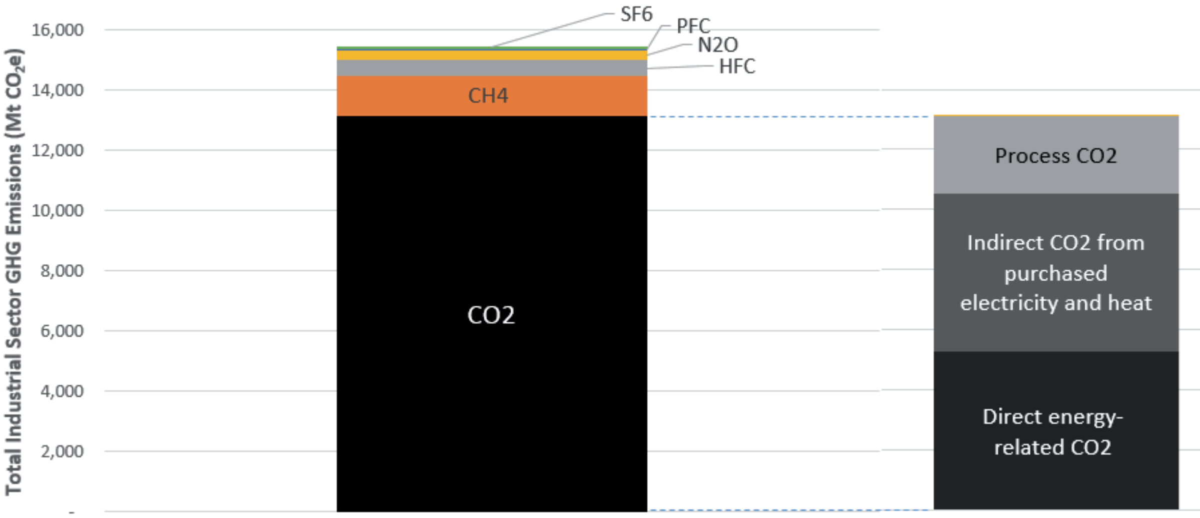

Figure 1. Total Global Industrial Sector Greenhouse Gas Emissions (2010). Sources: IEA (2012); JRC/PBL (2013).

the global economy.[2] Between 2005 and 2010, global industrial GHGs grew at an average annual rate of 3.5 %. The challenge for limiting average global warming to 2 degrees Celsius above pre-industrial levels is to break the linkage between industrial sector GHG emissions and the economic activity required to fulfil human development needs.

Industry is more GHG-intensive than buildings, transport, and power sectors. As such, the industrial sector will play a central role in the Nationally-Determined Contributions (NDCs) presented by countries in the 2015 Paris Agreement. In contrast with previous top-down approaches to international climate policy, the NDCs represent country offers largely based on bottom-up assessments. NDCs cut across multiple levels of climate engagement: country, sector, company, and facility. The NDC framework provides a new structure for coordinating the global 2-degree goal with national climate and energy policies and investments.

TIME AS THE MOST PRECIOUS RESOURCE: DECLINING GLOBAL BUDGETS

The IPCC's Fifth Assessment Report (AR5) provided a comprehensive picture of the relationship between GHG emissions and climate impacts based on an ensemble of climate models. One approach adopted in AR5 is to use cumulative carbon dioxide emissions budgets as an indicator of expected warming and other climate impacts. The AR5 scenario with the highest likelihood of limiting warming to less than 2 degrees yields a cumulative economy-wide 2011 to 2100 emissions budget of 630 to 1,180 Gt CO_2. To reach this level, total GHG emissions in 2050 must drop 49 % to 72 % below 2010 levels.[3] If we maintain 2014 rates of global emissions, the cumulative budget for this century will be exceeded at some point between 2030 and 2050.[4]

Subsequent analysis of non-carbon dioxide emissions impacts has found that the cumulative budget for avoiding 2-degree warming is significantly lower than previous exceedance-based estimates.[5] While the long-term picture indicates that aggregate emissions should drop to a net-zero level to limit climate impacts[6], cumulative and sector-level budget estimates are useful for guiding mid- and near-term company mitigation targets.

Industrial Sector Emissions Budget Estimates

While there's broad global consensus on the need to limit warming this century to less than 2 degrees, there is not a single cumulative budget or pathway associated with that target. Beyond climate uncertainty, the budgets and pathways vary depending on their reliance on emissions removal technologies. All scenarios that achieve the 2-degree target also include net negative emissions, at least in the second half of the century. While negative emissions will be costly, the ensemble of scenarios included in AR5, the IEA's publications, and academic articles include their deployment for cumulative emissions budget reduction.

Just as there's a range of aggregate global emissions budgets among models and scenarios, multiple approaches have been developed for calculating corresponding industrial sector emissions budgets for limiting warming this century to 2 degrees. A simplistic equal-mitigation approach would suggest that industrial sector carbon dioxide emissions must be reduced by at least 49 %, from 5.3 Gt direct CO_2 (13 Gt CO_2 direct and indirect) in 2010 to 2.7 Gt direct CO_2 (6.7 Gt CO_2 direct and indirect) in 2050; linear interpolation over this period yields an upper limit cumulative industrial sector budget of 163 Gt direct CO_2 (407 Gt CO_2 direct and indirect). Application of a constant (3 %) annual reduction rate over the 40-year period with 2050 emissions 72 % below 2010 levels yields a more conservative cumulative budget

2. Meanwhile, over the past 15 years more than 20 countries have decoupled their GHG emissions and GDP. While GHG-GDP decoupling is becoming increasingly prevalent, the larger challenge of decarbonizing industry still stands.

3. Clarke, et al. (2014). These numbers are based on scenarios with minimal overshoot (<0.4 W/m^2), i.e., less reliance on carbon removal technology deployment to achieve negative emissions in the second half of the century.

4. Le Quéré, et al. (2015) estimate 2014 total global emissions of 36 Gt CO_2, and ~141 Gt CO_2 cumulative emissions from 2011 to 2014.

5. Rogelj, et al. (2016) present a broad range of budgets based on varying assumptions.

6. Geden (2016) argues that a net zero emissions target is more actionable than 2-degree budgets. However, some existing industrial companies and stakeholders find net zero targets to be unrealistic and detrimental to current efforts.

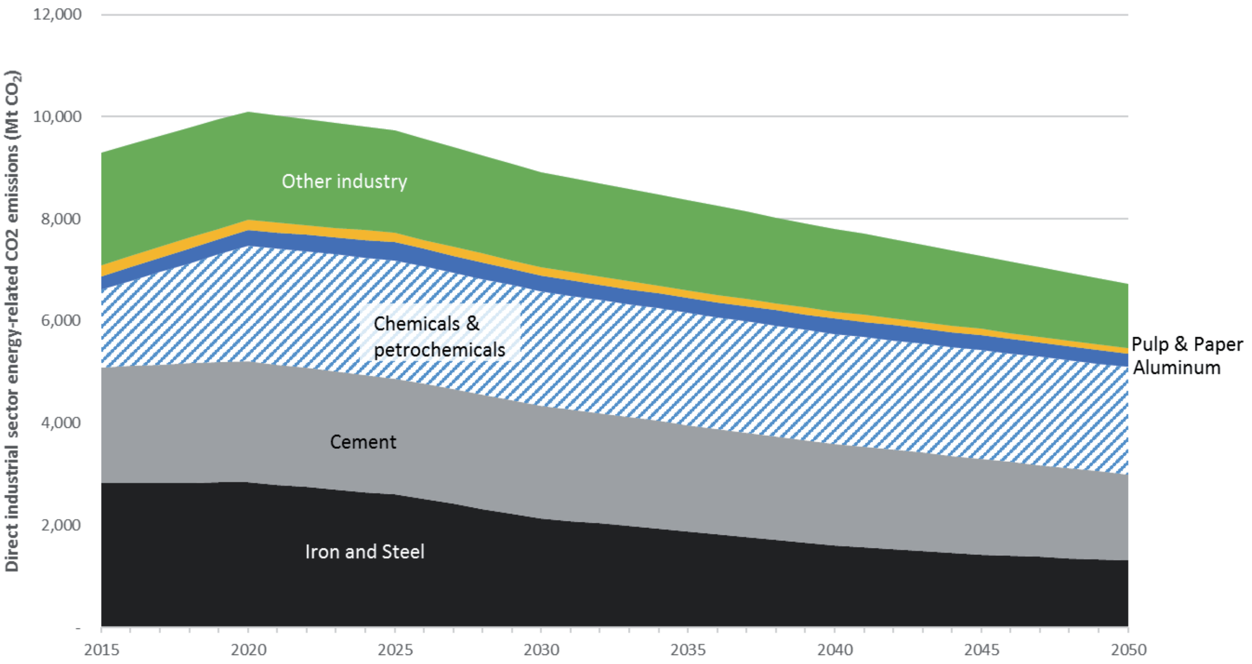

Figure 2. Annual Industrial Subsector Emissions under a 2-Degree Scenario (2015–2050). Source: IEA, 2016. Note that 2015 data are interpolated from published 2013 and 2020 data.

of 123 Gt direct CO_2 (306 Gt CO_2 direct and indirect). Extending the 2010 rate of global industrial sector carbon dioxide emissions exceeds these simple cumulative 2-degree budgets at a point between 2033 and 2041. These 2050 interpolation-based approaches can be characterized as 'absolute contraction' methods based on the assumption that sectors move in tandem.

The IEA also models 2-degree emissions and energy-use pathways in its *Energy Technology Perspectives* (ETP) series of reports and datasets. The ETP model uses technology data to calculate least-cost emissions budgets within and among sectors. Figure 2 illustrates global annual Scope 1 CO_2 emissions among industrial subsectors according to the ETP's 2-degree scenario.

The ETP scenario yields a cumulative direct (Scope 1) gross emissions budget of 310 Gt CO_2 between 2015 and 2050.[7] The ETP 2-degree emissions pathways are the basis of the Sector Decarbonization Approach (SDA) for guiding company emissions reduction targets.[8] Whereas absolute contraction methods assume immediate emissions reductions equally apportioned among all sectors and companies, the SDA uses a peak-and-decline pathway that gradually reduces emissions among sectors according to modelled production technologies, demand, and mitigation costs.

SUBSECTOR PATHWAYS AND RELATED INITIATIVES

Based on projected demand, technology trends, and abatement costs, this section describes the ETP 2016 emissions budgets and pathways for industrial subsectors to align with the global 2-degree pathway. These data reflect gross Scope 1 emissions.

Industry-wide carbon capture begins in 2020 under the 2-degree scenario and amounts to 25 billion tonnes carbon dioxide between 2015 and 2050.

Iron and steel

The cumulative 2015–2050 emissions budget for the global iron and steel subsector is 75 billion tonnes carbon dioxide. The 2-degree pathway reduces gross steel subsector emissions in 2050 to 54 % below 2015 levels. At continued 2015 rates of emissions, the total cumulative budget would be exceeded by 2041. Existing international initiatives that could coordinate with this budget information include World Steel, the Eurofer Low Carbon Steel Roadmap 2050, the China Iron and Steel Research Institute (CISRI), and the Steel Institute VDEh in Germany.

Cement

The cumulative 2015–2050 emissions budget for the global cement subsector is 76 billion tonnes carbon dioxide. The 2-degree pathway reduces gross cement subsector emissions in 2050 to 26 % below 2015 levels. At continued 2015 rates of emissions, the total cumulative budget would be exceeded by 2045. Existing international initiatives that could coordinate with this budget information include the Cement Sustainability Initiative (CSI), the Portland Cement Association (PCA), and CEMBUREAU.

Chemicals and petrochemicals

Chemicals and petrochemicals is the largest industrial subsector in terms of projected demand growth. The cumulative 2015–2050 emissions budget for the global chemicals and petrochemicals subsector is 77 billion tonnes carbon dioxide. The 2-degree pathway increases gross chemicals and petrochemicals subsector emissions in 2050 to 38 % above 2015 levels

7. In the 2-degree pathway the industrial sector captures 25 billion tonnes carbon dioxide between 2013 and 2050.

8. Krabbe, et al. (2015) describe the assumptions used to translate emissions pathways into intensity targets for company reference.

Table 1. Methods for Science-based Target Setting.

Method	Geographic Scope	Sector Scope	Metric
Absolute Contraction	Global	Total economy; parallel sectors	Absolute annual reductions or cumulative budgets
Corporate Finance Approach to Climate-Stabilizing Targets (C-FACT)	Developed versus developing countries	Company-specific forecast of contribution to GDP	Absolute annual target based on carbon-GDP intensity reduction rate
Climate Stabilization Index (CSI)	Developed versus developing countries	Company-specific based on contribution to GDP	Economic intensity (g CO_2e/$ value added)
Centre for Sustainable Organizations (CSO)	Developed versus developing countries	Company-specific based on contribution to GDP	Context-based assessment score based on emissions per dollar of contribution to GDP.
Greenhouse gas emissions per unit of value added (GEVA)	Global	Total economy; sector; company	Economic intensity (g CO_2e/$ value added)
Sectoral Decarbonization Approach (SDA)	Global	Subsector-specific	Physical intensity (g CO_2e/tonne product)
3 % Solution	U.S.	Subsector-specific	Absolute annual target (2020)

due to demand growth. Existing international initiatives that could coordinate with this budget information include the International Council of Chemical Associations (ICCA) and the CEFIC Roadmap.

Aluminium

The cumulative 2015–2050 emissions budget for the global aluminium subsector is 11 billion tonnes carbon dioxide. The 2-degree pathway maintains gross aluminium subsector emissions in 2050 at the same level as 2015 levels. Existing international initiatives that could coordinate with this budget information include the International Aluminium Institute (IAI) and the Aluminium Stewardship Initiative.

Pulp and paper

The cumulative 2015–2050 emissions budget for the global pulp and paper subsector is 5.7 billion tonnes carbon dioxide. The 2-degree pathway reduces gross cement subsector emissions in 2050 to 47 % below 2015 levels. At continued 2015 rates of emissions, the total cumulative budget would be exceeded by 2037.

Science-based targets for companies

The Science Based Target Setting (SBT) initiative was cofounded by the World Resources Institute (WRI), CDP (formerly the Carbon Disclosure Project), the World Wildlife Fund (WWF), and the United Nations Global Compact in 2014. The purpose of the SBT initiative is to increase corporate ambition on climate action by changing the conversation on GHG emissions reduction target setting and creating an expectation that companies will set targets consistent with the level of decarbonisation required by science to limit warming to less than 2 °C compared to pre-industrial temperatures. To move SBTs toward standard business practice, the initiative has set a goal of recruiting at least 250 leading companies to publicly commit to reduction targets in line with climate science by 2018. Recruitment of these companies will also serve to demonstrate to policy-makers the scale of ambition achievable among leading companies, and begin to bridge the remaining gap between countries' announced Nationally-Determined Contributions (NDCs) and the 2-degree target.[9]

In its compilation of new and previous related work, the SBT initiative identified the seven methods described in the table below for companies to align their emission reduction targets with a 2-degree pathway.

The simplest method for science-based target setting is to allocate equal and parallel reductions to all existing sources such that 2050 emissions are reduced at least 49 % below 2010 levels. If all companies and other emissions sources cut emissions at this rate warming this century would likely remain below 2 degrees. While the absolute contraction method is simple and transparent, it is neither cost-efficient nor fair. Marginal abatement costs vary significantly across sectors and countries.[10] The political and equity implications of the absolute contraction approach are untenable due to the limitation of growth opportunities for low-income countries.

The GEVA approach targets the same level of emissions reduction (commensurate with a 2-degree pathway) in combination with continuous economic growth. Assuming aggregate global GDP growth of 3.5 % per year, the GEVA method provides a simple target of 5 % annual reduction of company greenhouse gas emissions per unit value added. Insofar as GEVA treats all sectors similarly, it is not cost-efficient. However, the linkage of emissions with economic growth rates allows for flexibility and a shift of emissions from declining to growing industries/countries.[11] The C-FACT, CSI, and CSO methods are variations on GEVA's GDP-centric approach with nuances regarding geographic scope, growth assumptions, and output metrics.

9. Fawcett et al (2015) found that announced NDCs have a greater than 50 % likelihood of 2–3 degree temperature rise this century and an 8 % chance of limiting warming to less than 2 degrees.

10. McKinsey (2009) quantified 2020 expected costs per sector and technology in their series of reports.

11. Randers (2012) describes the assumptions, benefits, and shortcomings of the GEVA approach.

The 3 % Solution and the SDA are more recent methods developed by SBT initiative partners to identify cost-efficient options for limiting warming to 2 degrees. Both methods incorporate varying demand projections and abatement options to calculate subsector-specific least-cost emissions reductions. Whereas the 3 % Solution is focused on U.S. industries to 2020, the SDA is a global method with results to 2050. The IEA's 2-degree scenarios in its Energy Technology Perspectives (ETP) series of reports and modelling results are the basis for SDA sector pathways and allocations.[12] For sectors with granular ETP data, the SDA provides physical emissions intensity or annual absolute emissions targets at the company level. However, the SDA's sector-specific nuance also sometimes functions as a weakness by providing aggregated median performance indicators that are less relevant for leading companies with unique production processes. For example, the SDA provides steel subsector 2-degree pathway information in terms of kg CO_2/tonne crude steel. This type of aggregated physical intensity information is not particularly useful for steel companies that produce secondary steel in electric arc furnaces, especially if they are using advanced technologies.

The reason that there are seven methods described here is that there is not a single SBT method that's best in all sectors and company situations. Companies' emissions intensiveness, mitigation options, and demand growth affect the ambition of targets generated by the different methods. Moreover, many companies develop their own target-setting approach that may be related to one or more of the reference methods described above.

The lack of universal, comprehensive methods is not preventing companies from setting science-based targets. The SBT initiative has issued a call to action for companies to set targets according to the following five criteria:

- Boundary: The target must cover company-wide Scope 1 and Scope 2 emissions and all relevant GHGs as required in the GHG Protocol Corporate Standard.
- Timeframe: The target must cover a minimum of 5 years and a maximum of 15 years from the date of announcement of the target.
- Level of ambition: At a minimum, the target will be consistent with the level of decarbonization required to keep global temperature increase to 2 °C compared to pre-industrial temperatures, though companies are encouraged to pursue greater efforts towards a 1.5 ° trajectory.
- Scope 3: An ambitious and measureable Scope 3 target with a clear time-frame is required when Scope 3 emissions cover a significant portion (greater than 40 % of total scope 1, 2 and 3 emissions) of a company's overall emissions. The target boundary must include the majority of value chain emissions as defined by the GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard (e.g. top 3 categories, or ⅔ of total scope 3 emissions).
- Reporting: The company will disclose company-wide absolute GHG emissions inventory on an annual basis.

12. Krabbe et al. (2015) describe the background, assumptions, and results of the SDA in detail.

As of June 2016 more than 160 companies have publicly committed to setting SBTs and more than a dozen companies have published targets that meet the eligibility criteria described above. Participating companies have headquarters in more than 20 countries and approved SBTs cover sectors ranging from food and beverage manufacturing to energy companies, pharmaceuticals, and technology equipment manufacturing. Company motivations include competitive advantage (e.g., more efficient industrial producers), risk mitigation (e.g., supply chains affected by climate impacts), regulatory hedging, reputational risk/stakeholder pressure, and moral conviction. Growing uptake indicates that SBTs are well on their way to becoming standard practice for leading companies.

The SBT initiative provides reference information, company guidance, and recognition of company leadership. Companies are left to determine how they will implement their SBTs and the public reporting requirement provides a mechanism for maintaining accountability. By organizing a critical mass of companies across sectors, the SBT initiative also demonstrates the feasibility of low emissions transformation for policymakers and investors.

Options for Reducing Industrial Sector Emissions

Industrial sector GHG emissions are by products of numerous decisions along product value chains. Five categories capture the range of industrial sector GHG mitigation options along value chains:

1. Energy efficiency – best practice technologies can help reduce process energy requirements.
2. Emissions efficiency – fuel switching away from coal and other fossil fuels toward clean electricity, or using CCS to remove energy-related emissions.
3. Material efficiency – either in production via reduced yield losses, recycling, re-use of old materials or in product design through light-weighting and other material substitutions.
4. More intensive product use – for example via extended lifespans or new business models that foster dematerialization.
5. Reducing demand through behaviour change, structural change, or saturation effects.

Energy efficiency improvements play a foundational role in industrial sector GHG emissions mitigation. Whereas demand reduction and some types of material efficiency can conflict with company business models by reducing revenue, efficiency improvements fit in the strategies of incumbent companies by simultaneously reducing costs and emissions.[13] Numerous studies have found that efficiency improvements are not sufficient to achieve required emissions reduction singlehandedly. The IEA for example found that implementation of end-use fuel efficiency could achieve 40 %, fuel and feedstock switching can achieve 21 %, recycling and energy recovery can achieve 9 %, and CCS can bridge 30 % of the gap between a 6-degree

13. Material efficiency can be even more profitable for a company than energy efficiency, as material costs often make up for much higher shares than energy cost. Industrial symbiosis can also be a very attractive alternative, where possible.

pathway and a 2-degree pathway.[14] In their study of global steel, cement, plastic, paper, and aluminium production, Allwood et al. (2010) found that ambitious technical efficiency improvements only reduced 2050 emissions by 14 % below 2010 levels – well short of their 50 % target.[15] Although energy efficiency improvements are not sufficient for companies to achieve science-based GHG reduction targets, they serve as a key mitigation option for existing industrial companies.

LEADING HORSES TO WATER: THE ROLE OF VOLUNTARY PROGRAMS

A growing number of companies are voluntarily tracking their GHG emissions and reporting them publicly every year. In fact, there was a 20-fold increase in companies that disclosed through CDP from 2003 to 2014, resulting in 1,825 companies reporting to the climate change questionnaire in 2014 alone. Alongside tracking emissions, 75 % of these companies have also set GHG emissions reduction targets.[16] However, a study conducted by We Mean Business, a coalition of international organizations[17] points out that most companies are not setting targets in line with science and very few companies have set public targets that reach beyond 2020.[18] This is confirmed by academic research that found little compelling evidence that carbon management practices resulted in reduced emissions.[19] The Science Based Targets (SBT) initiative fills this gap by providing guidance for companies to align their mitigation targets with a global 2-degree pathway.

The SBT initiative builds on academic research findings that voluntary environmental programs can achieve improvements at low cost when serving as a complement to mandatory minimum-performance regulations.[20] The idea is that these companies are defining new best practices that public recognition can turn into sector norms. A longer-term outcome of these types of voluntary initiatives is that they influence subsequent sector and technology-related regulatory policies.

HORIZONTAL INTEGRATION: SECTORAL APPROACHES TO NDC IMPLEMENTATION AND LONG-TERM MITIGATION

Sectoral approaches can accelerate GHG mitigation by disseminating best practices, for example through SBTs, guiding NDC implementation, and leveraging local resource availability. On the other hand, political resistance to deindustrialization and trade dependence complicates the widespread adoption of sectoral approaches. Industry associations are limited by anti-trust and competitiveness rules, but they could be well-positioned to address political concerns as well as the emissions uncertainty related to intensity targets – i.e., adoption of best-practice methods will still result in GHG emissions corresponding with final production levels.[21] As countries begin to implement their NDCs, Korea's top-down "Roadmap to Achieve National GHG Reduction Goals" exemplifies the potential informational benefit of company-SBT-integrated sectoral approaches. While most countries have less structured NDCs, such as the United States' 26–28 % reduction from 2005 to 2025, sectoral approaches can guide implementation, NDC updating for 2020, and long-term low-carbon strategy development.

Agenda for Future Research

Development and popularization of science-based targets can accelerate the industrial sector transition to a low-carbon economy. SBTs provide a global, cross-sector mechanism to define new best practices, mobilize investment capital, and stimulate the development of new institutions to coordinate mitigation action. Seven areas of further research are suggested here to advance SBTs and the larger low-carbon transformation of the industrial sector.

- Is carbon intensity a more relevant and useful summary metric than energy efficiency? How can decomposition analysis elucidate the role of efficiency improvements, fuel switching, demand abatement, structural change, and leakage in emissions reductions?
- What data, modelling approaches, and institutional structures are needed to assemble a single integrated SBT method to consistently and equitably cover all sectors and companies? Given the transformation needed to limit warming this century to 2 degrees, what's the role of existing company improvement/adaptation versus closures and sector churn?
- Can energy efficiency improvements facilitate the deployment of negative emissions technologies in industry? How can circular economy frameworks and cross-sector planning reduce the costs of carbon removal?
- More than 20 countries have achieved sustained de-linking of GHG emissions and GDP growth. Meanwhile, many countries are reducing industrial activity before reaching previously observed income and saturation levels.[22] What's the role of industrial sector productivity gains, deindustrialization (i.e., the reduction of industrial activity), and leakage/trade in observed and prospective delinking? Should deindustrialization be incorporated into NDCs and new climate transition institutions?
- What types of policy approaches are most cost-effective for achieving industrial sector emissions mitigation? CDP research[23] found that companies with lower emissions performance earned higher returns on investment – can industrial subsectors grow into low-carbon transformation or do they need a regulatory push?
- How can company-level voluntary initiatives best address the equity and distributional challenges of common but differentiated responsibilities? Are simplifying global convergence assumptions (such as that used in the SDA) adequate and fair?

14. IEA (2009).
15. Allwood, et al (2010) present alternate CCS, recycling, demand reduction, and innovation scenarios that achieve more emissions mitigation.
16. Does not include separate energy-based targets.
17. BSR, The B Team, CDP, Ceres, The Climate Group, The Prince of Wales's Corporate Leaders Group and WBCSD.
18. We Mean Business. The Climate Has Changed, 2014 (p 13).
19. Doda, et al (2015).
20. Borck and Coglianese (2009) develop a typology of voluntary environmental programs to assess the factors that lead to maximum effectiveness.
21. Akimoto et al. (2008) discuss the emissions unpredictability of sectoral intensity schemes.
22. Rodrik (2016).
23. CDP (2014).

- Company and facility level GHG performance data are becoming increasingly available. Given the dispersion of GHG emissions intensities and capacity utilization rates within and among manufacturing subsectors[24], how much could emissions be reduced via production re-allocation to the highest-performing facilities? On a more general level, what are the drivers of GHG performance (regulatory policy, exposure to trade/competition, vintage of equipment, fuel/resource availability)?

These interdisciplinary research questions can help to identify strategies for private sector leadership in the transition to a low-carbon economy.

Conclusions

Emissions-intensive industrial activity has put enough greenhouse gases in the atmosphere that climate impacts are becoming increasingly evident. Radical transformation of industry is needed to achieve the global target of limiting warming to 2 degrees this century. Indeed, the industrial sector will determine if and when the 2-degree threshold is surpassed. To communicate high-level climate targets, this paper presented emissions budgets for the industrial sector and emissions-intensive subsectors. These budgets and the move toward company science-based targets present new norms for private sector leadership and support of NDC implementation. Additional research is needed to understand the opportunities and risks inherent in the low-carbon transformation of the industrial sector. As the need to reduce GHG emissions becomes more clear, emissions intensity may become a more prevalent industrial performance metric than energy efficiency.

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