

Rapid decarbonization requires industrial efficiency

Miying Yang¹, Steve Evans^{2, †}

Cranfield University, Cranfield, United Kingdom

Department of Engineering, University of Cambridge, Cambridge, United Kingdom

† se321@cam.ac.uk

Standfirst | The potential of efficiency to support decarbonization is underestimated and overlooked relative to more expensive and intensive actions. Implementing resource and energy efficiency strategies in industry could deliver rapid and cost-effective decarbonization.

Introduction

Three actions are urgently needed for the decarbonization of industry, which directly accounts for 29% of global carbon emissions¹: a shift to renewable energy supply to industry, the deployment of technologies such as hydrogen and carbon capture and storage (CCS), and improvement in resource efficiency and energy efficiency (REEE). The first two actions receive more attention, despite their financial, environmental, and geopolitical challenges (Fig.1, left). REEE² can greatly contribute to early emissions reductions³ yet its potential is vastly underestimated by governments and businesses. Many national policies and debates either ignore REEE or give it a small role.

In this Comment, we argue that REEE must be urgently prioritized to accelerate industrial decarbonization.

Defining efficiency

The principle of efficiency is achieving more with less. In industry, energy efficiency refers to using less energy to produce the same output (for example, using fewer kilowatt-hours to make a kilogram of cheese or a car) and is achieved by optimizing machinery, processes and systems to reduce energy consumption without compromising quality.

Resource efficiency is using less material (including water) to deliver the same output. It has an essential role in rapid decarbonization because it reduces the demand for raw materials (using 10kg less steel to make a car means that the entire impact of producing that 10kg of steel goes to zero).

The long-run rate of energy efficiency is around 1.3% per year⁴, but the [Science-based Targets Initiative](#) calls for about 4.6% from industry. This rate might sound high, but implementing simple actions and making focused efforts to increase efficiency should make this target feasible.

The potential of efficiency

Every company has some level of inefficiency. Taking action to identify those inefficiencies is relatively simple, cheap and fast, supporting rapid decarbonization. REEE can be delivered through a combination of technology changes, such as buying a more efficient oven, and

through strategic energy management (SEM)⁵. SEM delivers energy demand reduction by studying the operations of a factory and removing energy waste with actions such as not leaving machines on during downtime.

REEE is more cost-effective than buying decarbonization technologies like carbon capture and storage, as REEE does not require major investment. Indeed, REEE often helps companies generate long-term savings by reducing energy and material costs. In the United States⁵, for example, energy efficiency is recognized as the most cost-effective near-term strategy, with estimates suggesting that it could contribute up to 25% of the total emission target by 2050, delivered through technological upgrades and SEM practices. At Toyota's Burnaston plant in the UK, SEM application enabled a >70% energy reduction over 14 years^{6,7}. Similarly, an automotive supplier's plant in [Poland reported](#) an increase in energy efficiency by 20% over three years.

REEE has potential to greatly reduce industrial emissions. The International Energy Agency (IEA) estimates that energy efficiency (across sectors) could deliver 44% of the total emissions reduction needed to reach the goals of the Paris Agreement by 2040³. Similarly, the American Council for an Energy-Efficient Economy argue that whole-economy energy efficiency can cut greenhouse gas emissions by 50% by 2050⁸, including a 29% reduction of industrial emissions through REEE⁹. The [Rocky Mountain Institute](#) suggest that fossil fuel phase-out can happen by 2040 when efficiency is maximised.

The benefits are large, the cost is low, and the solutions are available today. Indeed, a report by McKinsey proposes that manufacturers can cut their current energy and material consumption in production by 30%. Yet, these benefits are largely overlooked by policy, which emphasizes new technologies and even not-yet-available technology. Focusing on what can be achieved now, by a thorough and systematic focus on efficiency, will steer industry towards meeting the science-based targets, save money and deliver a deep understanding of energy flows that ensure that future (more expensive) actions are well focussed.

Why efficiency is often overlooked

Despite recognition of the clear advantages of REEE by key organizations such as IEA, it does not receive the same attention in national decarbonization plans. A small number of governments have identified REEE as a part of their plans but emphasise technological upgrades as the main way to deliver efficiency, largely ignoring SEM and the low-cost or zero-cost solutions. In the UK², REEE is projected to contribute 18.6% of the total industrial emissions reduction target by 2050 (Fig.1, left). Of that reduction, 92% is expected to come from technological upgrades, such as equipment replacement, while only 8% is through SEM practices.

To understand how to better encourage and implement REEE, it is important to understand the reasons that REEE is overlooked. Based on our own research in studying REEE in manufacturing and in direct involvement in informing policy, we have identified four interconnected reasons.

First, resource and energy inefficiency is often invisible. For instance, people rarely know how much energy is being used when a machine goes into standby versus when it is turned on. This invisibility allows energy waste to persist unchecked in many companies.

Second, many companies mistakenly assume that efficiency, especially in the form of SEM, offers only incremental gains. We believe this misunderstanding arises from a lack of well-publicized examples and limited knowledge or education on the topic.

Third, REEE improvements are knowledge-intensive, relying on practices such as training, energy management and process optimization. It can be more complex to scale knowledge, through training and behaviour change, than to scale technological solutions, leading companies to favour the latter.

Finally, manufacturing leaders often believe that decarbonization will be expensive. Managers with this mindset often search for solutions that cost money, assuming that low-cost or no-cost solutions do not exist. Our observation is that those people who believe that decarbonization is expensive tend to prove themselves right.

All of these factors directly affect policy makers, who receive these opinions when they seek industry advice. As a result, policies tend to further steer managers away from prioritizing REEE, creating a reinforcement loop and slowing industrial decarbonization. This lack of attention to the benefits of REEE is echoed across academia, with very limited large-scale studies of the potential of REEE.

Implementing efficiency

REEE should be a key part of any national industrial decarbonization policy. It delivers faster decarbonization while preparing for the later, more challenging stages of industrial decarbonization. REEE must become a dominant component of government and business strategies, and it must happen quickly. Here, we suggest three actions for policymakers and businesses to increase REEE.

First, governments and businesses should commit to only sourcing from suppliers that achieve an annual energy reduction of at least 5%. Clear guidance should be provided to these suppliers on where and how they can get the knowledge and skills needed to deliver these targets at little additional cost.

Second, companies should build their own knowledge and competence by hitting those same targets inside their own organization. They should use this small but growing set of ‘subject masters’ to teach the next cohort and so on, creating a snowball effect of knowledge transfer and capacity building.

Finally, start now. Time is running out. Do not wait for formal qualifications in energy efficiency – self-teaching is not only possible but highly effective, particularly when in collaboration with colleagues and/or other businesses. Implementing REEE will lower emissions and operational costs, reduce the burden on infrastructure and provide much needed early progress on decarbonization.

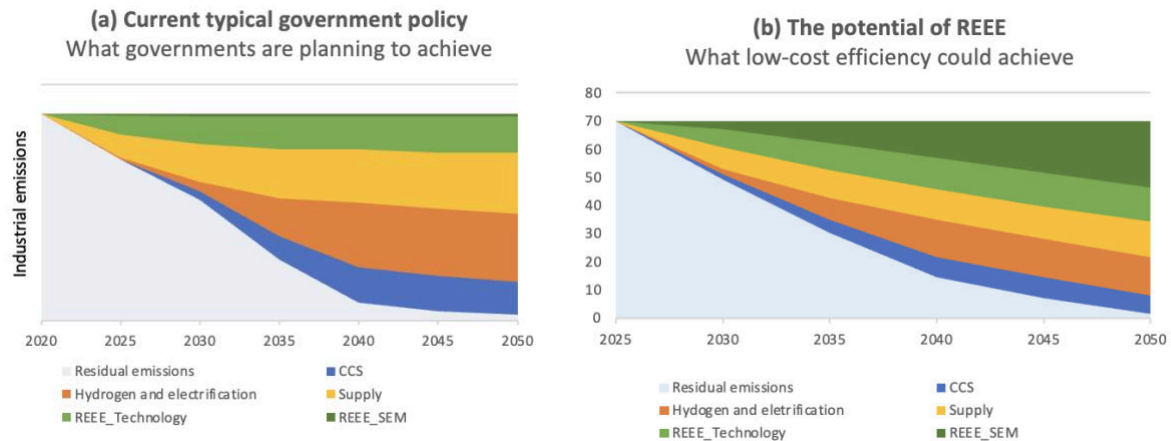


Figure 1. Resource efficiency and energy efficiency policy and potential in industrial decarbonization.

Current typical government policies (left, based on the UK²) rely on expensive, large-scale and sometimes unproven technologies. Resource efficiency and energy efficiency (REEE) through technology upgrades (REEE-Technology) and strategic energy management (REEE-SEM) are faster, cheaper, and safer ways to reduce industrial carbon emissions and should have a large role in industrial decarbonization policies (right). The right-hand graph illustrates an example hypothetical industrial decarbonization policy where annual efficiency improvements of 2.8% provide – 50% of industrial CO₂ emissions reductions by 20250.

References

1. Liu, Z., Deng, Z., Davis, S. J. & Ciais, P. Global Carbon Emissions in 2023. *Nature Reviews Earth and Environment* **5**, 253–254 (2024).
2. HM Government. *Industrial Decarbonisation Strategy*. (2021).
3. International Energy Agency. *Market Report Series Energy Efficiency*. (2018).
4. International Energy Agency. *Energy Efficiency*. (2023).
5. Cresko, J. et al. *US Industrial Decarbonization Roadmap*. (2022).
6. House of Lords. *Science and Technology Committee: Waste Reduction*. (2008).
7. Evans, S., Bergendahl, M., Gregory, M. & Ryan, C. *Towards a Sustainable Industrial System (University of Cambridge Institute for Manufacturing and Cranfield University)*. *International Manufacturing Professors Symposium in Cambridge UK*. (2009).
8. Nadel, S. & Ungar, L. *Halfway There: Energy Efficiency Can Cut Energy Use and Greenhouse Gas Emissions in Half by 2050 (ACEEE)*. (2019).
9. Whitlock, B. A., Elliott, N. & Rightor, E. *Transforming Industry: Paths to Industrial Decarbonization in the United States*. (2020).