Mission Innovation is mission critical

The Paris Agreement's Mission Innovation initiative to accelerate government spending on clean energy research is currently succeeding in its quest to support carbon mitigation. It should be renewed for an additional five years, with increased ambition, and changed to better integrate the private sector.

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New innovative clean energy and decarbonization technologies are needed if the world is to meet its goals to reduce the threat of climate change[1]. Public investment has a crucial role to play in support of energy innovation in basic energy sciences as well as later-stage applied research, development and demonstration (RD&D), especially to address market failures or public goods related to climate change[2].

In 2015, a group of 24 governments, including the European Union (EU), formed the Mission Innovation (MI) initiative to promote the acceleration of clean energy technology innovation. Members agreed to double their annual clean energy RD&D public expenditures between 2015 and 2020, from US$14.5 billion in 2015 to US$28.9 billion in 2020 in total (unless otherwise stated, all dollar figures in the paper are given in constant 2018 US$). This intended expenditure doubling was instrumental to the group's goal to develop and scale breakthrough technologies and accelerate the pace of clean energy innovation to achieve performance breakthroughs and cost reductions. MI members also committed to collaborate on a range of projects such as public–private sector engagement, technology-specific research groups, joint publications or events to raise awareness about various innovation-related initiatives.

Overall, MI member states in aggregate increased RD&D spending by 38% since 2015 according to the MI Secretariat country highlights reports[3–5]. While the group as a whole will fall short of doubling their investments by 2020, nearly all countries involved substantially increased their RD&D spending on clean energy, thereby reducing free ridership in the global economy to address a global commons challenge. Moreover, the economic costs of many of the clean energy technologies targeted have dramatically fallen due to ongoing technological innovation and economies of scale. By widening the geographic span of global clean energy innovation and setting explicit RD&D spending targets, albeit overly ambitious ones, MI spurred increased global competition in the field in both industrialized and developing countries. Member countries strengthened their energy innovation institutions, increased RD&D activity and contributed to knowledge production around the world.

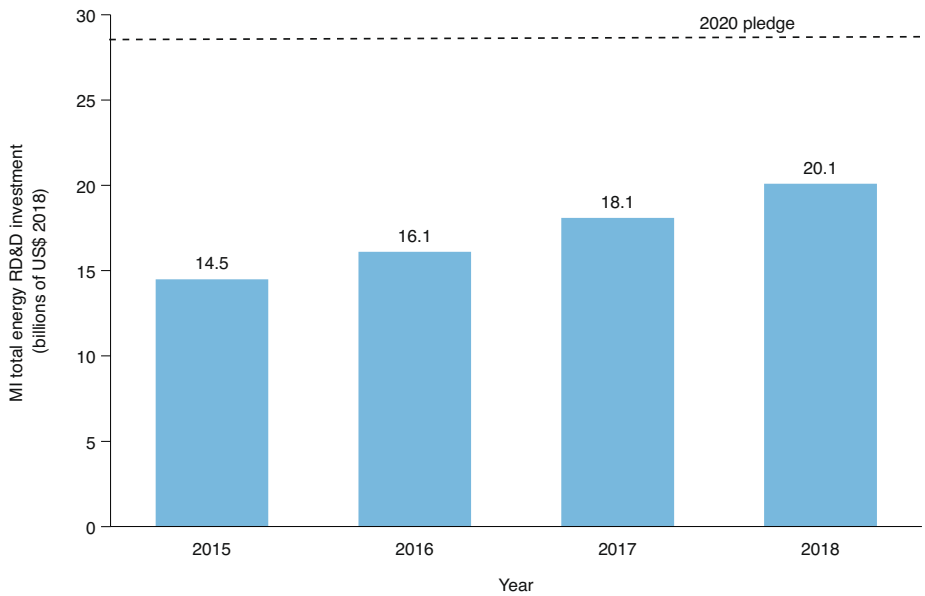

Fig. 1 | Clean energy RD&D public expenditures in the MI member countries for 2015–2018. Shown here are the expenditures reported by the countries to the MI Secretariat over time (in constant 2018 US$)[3,4], compared to the initial pledged total[5]. The estimates are based on officially reported data to the MI Secretariat. Eight countries did not formally submit information on their progress to the MI Secretariat for at least one of the years: Australia in 2018, Austria in 2017 and 2018, Brazil in 2017 and 2018, Indonesia in 2017 and 2018, Mexico in 2018, South Africa in 2017 and 2018, United Arab Emirates in 2017 and 2018, and the US in 2016, 2017 and 2018. In these cases, we estimated the expenditure in two ways: IEA submissions based on the IEA RD&D database[24] are used for IEA member countries (the US, Australia, Austria and Mexico); for non-IEA members, we used the previous year's MI expenditure (that is, we assume no change in expenditure level). Additionally, the IEA RD&D database[24] is used for the US clean energy RD&D estimate also for the baseline year, because the US baseline submission included expenditures on all energy RD&D, including fossil fuels. Values reported by member countries to MI in US$ were converted to constant 2018 US$, using conversion factors from the IEA.

As a result, MI should be renewed for another five years. As economies introduce new economic stimulus related to the COVID-19 pandemic, inclusion of continued MI targeted clean energy RD&D investments will be a critical element to staying the course to achieve deep decarbonization. To that end, the next phase of MI should focus more directly on improving private sector integration, among other changes.

The historical record of Mission Innovation

The evolution of MI members' clean energy RD&D expenditures since 2015 is depicted in Fig. 1 based on reporting to the MI secretariat in Country Highlights reports[3–5]. Of MI's 25 members, four (Chile, Mexico, the Netherlands and the UK) had already

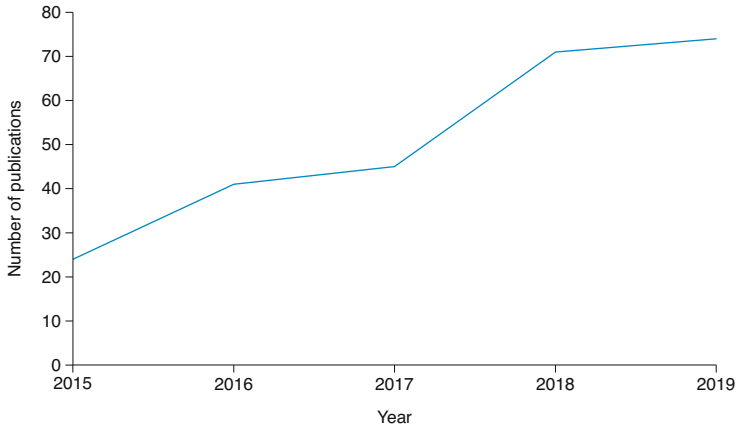

Fig. 2 | Total scientific publications for solar PV technology in Mexico, Brazil and Chile in 2015–2019. Data from Web of Science Citation Index Expanded.

reached their goal of doubling by 2018, the latest reporting year for publicly available data from the MI secretariat. Additionally, twelve members were more than halfway to doubling their expenditures (that is, in 2018, their expenditures were at least 50% higher than in 2015), and seven members increased their expenditures, but by less than 50%. One country, Italy, reduced expenditures. Morocco joined MI in 2019 so their reporting data will be forthcoming next year.

China is on track to honour its pledge to double government RD&D spending on clean energy by 2020. This achievement is especially significant because of its scale: it will go from US$4 to US$8 billion, which will put its officially reported RD&D spending on clean energy on par or ahead of the United States.

US investments in clean energy RD&D increased by 42% between 2015 and 2020 from US$4.8 billion to US$6.8 billion in current dollars based on the DOE energy RD&D budget[6]. This is thanks to continued support from congressional appropriations even though the Trump administration proposed drastic cuts of more than 60% to clean energy RD&D every year in its budget request to Congress[6].

While Germany has increased its public expenditures by nearly 50% between 2015 and 2018, the European Commission only reported a 15% increase between 2015 and 2018 for the EU as a whole. Japan increased its investments in clean energy RD&D by more than 50% by 2018[3–5]. The European Union MI member countries achieved a 46% increase by 2018, and are not expected to have doubled their investment by 2020[3–5]. The EU recently announced a major US$1 trillion battery initiative, however, that will dramatically increase its profile in clean energy RD&D in later years.

Changes in spending levels by the US government historically have been significant to global progress in clean energy because the United States was by far the largest public investor in global clean-energy RD&D[2]. With China's pronounced increase in clean energy RD&D, the United States either has a rival or shares the global burden, depending on one's perspective.

In the developing world, it is noteworthy that by 2018 both India and Brazil had increased their investments by 44% and 61% respectively. Both countries have also improved their internal reporting systems and harmonized their energy RD&D data to assure comparability. Mexico joined the International Energy Agency (IEA) in 2018, and officially started to report a detailed budget for energy RD&D expenditures for 2013 onwards.

Some may argue that the failure to attain the goal of doubling global funding for clean energy RD&D in five years undercuts MI's usefulness, but we would disagree. In the first place, the goal of doubling investments may simply not have been practicable, and the fact that investments have increased 38% between 2015 and 2018 is certainly positive, if insufficient to honour the pledge of doubling by 2020.

But doubling investments was never the only goal. When countries negotiated the Paris Agreement, a predominant concern was the high technological cost of climate mitigation. Mission Innovation was intended to address such costs and thus became a crucial component of the Paris Agreement package. Costs for low-carbon energy technologies have fallen spectacularly since 2015. Between 2015 and 2020, for example, 60-cell monocrystalline solar photovoltaic (PV) module costs are estimated to have declined by 57%[7]. In onshore wind, where costs had already come down dramatically by 2015, unsubsidized levelized costs are estimated to have declined another 24% between 2015 and 2020[8]. These cost declines spurred massive growth in deployment of renewable energy around the world. Installed capacity of solar installations in MI countries has risen 265% since 2015[9].

Moreover, almost all MI countries have made improvements to their national energy innovation systems. Demonstrable progress can be seen in output variables such as scientific publications and patent applications, even among developing countries. In Mexico, Brazil and Chile, for example, the number of scientific publications increased more than threefold for solar PV technologies between 2015 and 2019 (Fig. 2).

Globally, overall green patent applications have declined since 2010[10], but patent applications for some types of clean energy grew between 2016 and 2019 during the MI period[11]. Specifically, patents grew for hydropower by 4%, geothermal by 11%, energy efficient technologies by 13% and wind by 65% in this period. More mature technologies experienced declines in patent applications, specifically 8% for nuclear. Solar experienced a pronounced decline of 45% between 2013–2016 but then a modest rise of 10% between 2016–2019. Green energy patents filings are concentrated in Japan, China, the United States, Germany and Korea. Altogether, these countries accounted for 76% of green patent applications in 2019[11]. While additional analysis is needed to link these exact gains to the specific increase in RD&D spending under the MI mantel, prior research indicates a good correlation between RD&D spending and patent generation[12–14].

Renewal, increased ambition and change

When MI's members meet virtually on 23 September 2020, they will debate whether to renew commitments going forward or suspend the effort. We urge renewal and increased ambition, as well as greater integration of the private sector, improved policy alignment, lesson sharing, provision of technical assistance for data collection and reporting, and evaluation of the experience with international collaboration.

MI should set new goals for 2025. Those countries who have not yet doubled their clean energy RD&D investments should do so before 2025. The four countries that already have doubled should consider doing so again given that their total investments are relatively small. After doubling their 2015 levels, the United States and China should increase investments in low carbon energy by at least a further 50% above 2020

levels by 2025. The EU's total investments, including individual member countries, should increase by at least 50% above 2020 levels as well.

Several members stand out as leaders in greening their economies, including the EU, South Korea and Morocco. The fact that some members, notably the EU and South Korea, have already chosen to add a large clean energy RD&D component to COVID-19 economic stimulus plans could give momentum for discussions of an ambitious renewal among other members[15,16].

One important modification to MI's goals should be to strengthen the involvement of the private sector. Involvement of private sector entities allows early stage technologies to benefit from well-developed business expertise and networks that can fast track deployment by reducing venture and technology risk and providing ready access to markets needed to ensure ventures can scale successfully. The logic of this approach is already in play today with the race to develop a vaccine for COVID-19, but includes other examples such as the US space race[17] and the Sematech public–private partnership[18].

While a group of private firms and individuals created the investment companion Breakthrough Energy Coalition to complement MI, it has fewer than 50 contributors and is mainly investing in start-up businesses rather than underlying technology research and development[19]. Going forward, MI countries should require their private sector firms to report on their aggregate investments in clean energy RD&D at least at the category level (for example, wind, solar, battery storage) and clarify how state-owned enterprise RD&D is reported in overall numbers. To widen ambition, each MI country should endeavour to establish at least one public–private partnership domestically and should consider bi- or multi-lateral public–private partnerships. Besides engaging with large firms, MI member countries should also stimulate public–private partnerships with their local small and medium enterprises. Smaller firms can be more entrepreneurial and open to an innovative culture, especially in the countries with relatively young clean energy ecosystems such as Mexico and Brazil.

Many countries have inconsistent and conflicting policies in innovation and technology deployment. Yet harmonizing policy strategies can help achieve more effective results from the same level of spending[20]. Innovation policy is most effective when it sets ambitious direction, specific steps and milestones to achieve[21]. When the public sector fails to set such directions, private sector choices unintentionally create directions that may lead to high-carbon sectors[22].

Therefore, in its second phase MI should encourage its members to improve their policies for innovation and technology deployment and commit to create coherent and aligned policy incentives for clean energy with specific targets and milestones. Doing so would mean that continuing to stretch goals for increased investment in clean energy RD&D in the future would be even more productive than in 2015 when some countries' baselines were low or underassessed[23].

Mission Innovation also provides a forum for sharing experience and success in technological innovation that can spread learning and promote collaboration between developed and developing world efforts. Over the past five years, members have built a meaningful shared experience of striving together towards a common goal of achieving significant energy innovation breakthroughs. MI should also be a platform that incentivizes public sharing of lessons from failures, so common in energy innovation efforts, in both technology and policy design and implementation.

There are two smaller, but important, recommendations we also propose for a renewed MI. The first is to provide technical support for all countries in their data collection and reporting, no matter whether they are updating or building new data platforms. The IEA is one option for provision of technical support, but others are available as well. Second, when policy makers from MI countries gather to assess the first five years, they should agree to re-evaluate efforts to set up international collaborations on improving multiple technologies, since these collaborations have not yet been independently evaluated.

Inventing new low-carbon technologies and reducing the costs of existing ones remains imperative if countries are to achieve net zero greenhouse gas emissions by mid-century. The increased investment will also contribute to preserving and creating jobs in the clean energy economy, helping COVID-19 affected economies to overcome the current economic crisis. It would be a wasted opportunity to let the momentum generated by Mission Innovation since 2015 to falter or even vanish. ❐

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Competing interests

The authors declare no competing interests.