Energy Technology Innovation Partnerships

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Abstract

In recent years, there has been an increasing focus on energy technology innovation as a means to reach energy policy goals and meet ambitious climate targets. International collaboration in research, development and demonstration can play an important role in identifying priorities, challenges and innovation gaps, as well as sharing best practices to improve performance, reduce costs and deploy key energy technologies. Given the growing complexity and interconnection of energy systems, co-operation and networking can increase effectiveness, facilitate action and maximise the impact of innovation efforts.

Many partnerships around the world were designed to accelerate energy innovation, such as the IEA Technology Collaboration Programmes (TCPs) or more recently Mission Innovation (MI). Important contributions are also being made regionally, for example under the EU framework, and through initiatives with a mandate broader than innovation, for example the Clean Energy Ministerial (CEM).

However, despite the central role of innovation in global energy transitions and the potential of international collaboration, there is limited information available on the full landscape of multilateral initiatives and how they interact. As a result, the IEA is seeking to map and analyse energy technology innovation efforts, facilitate communication, and foster strategic engagement across platforms and mechanisms.

This immediate analysis aims to 1) inform discussions on how to support efficient co-operation and information sharing across various mechanisms; 2) compare the structure and activities of four selected mechanisms: TCPs, MI, CEM and the European Technology and Innovation Platforms; and 3) lay out opportunities for future work.

Highlights

Section A. Innovation to drive energy transitions

- Innovation processes from early-stage RD&D to deployment may take decades. Policy makers should take a holistic approach to RD&D funding for energy technology innovation, considering each effort in the context of wider processes.

- Public bodies are critical actors in energy technology innovation; the private sector also plays a vital role, especially to ensure that key technologies reach markets. Policy makers should explore ways to further tap into private-sector capabilities and investments.

- International collaboration may increase effectiveness, bring efficiency benefits and maximise the impact of energy technology innovation efforts. The IEA is enhancing efforts to track energy innovation, and can help facilitate multilateral initiatives and collaborations.

Section B. Mapping multilateral initiatives in energy technology innovation

- There are a growing number and variety of collaborative mechanisms relevant to energy technology innovation. They adopt different institutional frameworks, mandates, scopes of activities and technology focus areas, and may operate globally or regionally.

- Given the growing complexity of the landscape of international and regional partnerships on energy technology innovation, relevant stakeholders recognise the need for a better overview and broad mapping analysis. This could assist the IEA family to identify synergies and improve international strategies to advance clean technologies.

- An online, searchable repository of multilateral innovation partnerships may provide a valuable tool for decision makers and collaborative mechanisms to identify potential synergies between ongoing activities. The relevance and feasibility of such listing could be further discussed with the relevant stakeholders.

Section C. Comparative analysis of selected collaborative mechanisms

- The immediate analysis compares the IEA Technology Collaboration Programmes, the Clean Energy Ministerial, Mission Innovation, and the European Technology and Innovation Platforms against five criteria: institutional framework, membership structure, sector and/or technology focus, scope and outputs of activities, and cross-mechanism interactions.

- **Cross-mechanism collaboration.** There appears to be at least some overlap in technology focus and/or activities across different collaborative mechanisms, possibly inducing risks of duplication, the dilution of policy makers' attention, and fundraising and political support challenges. More in-depth and regular mapping could help identify areas for potential collaboration. Countries are often member of several collaborative mechanisms, which may enable or facilitate cross-mechanism collaboration.

- **Private-sector involvement.** There is substantial utility and interest from many of these initiatives in further deepening the engagement with private-sector actors to tap into potentially greater investments and capabilities. Future work could examine best practices related to private-sector involvement.

- **Measuring outputs and outcomes.** Further efforts could be undertaken to establish constructive evaluation and feedback frameworks within collaborative mechanisms. Delivering publicly available reviews of ongoing activities may help the innovation ecosystem identify areas for engagement across partnerships and enhance transparency.

Executive summary

In recent years, there has been an increasing focus on energy technology innovation as a means to reach energy policy goals and to meet ambitious climate targets. International collaboration in innovation, including in research, development and demonstration (RD&D), can play an important role in identifying common priorities, challenges and innovation gaps, as well as sharing best practices to improve performance, reduce costs and deploy key energy technologies. Given the growing complexity and interconnection of energy systems, co-operation and networking can increase effectiveness, facilitate collective action, bring efficiency benefits and maximise the impact of innovation efforts.

Many multilateral partnerships around the world were designed to accelerate energy innovation, such as the International Energy Agency (IEA) Technology Collaboration Programmes (TCPs) or more recently Mission Innovation (MI). Important contributions are also being made at the regional level, for example under the European Union framework, and through initiatives with a mandate broader than energy technology innovation, for example the Clean Energy Ministerial (CEM). The last decades have seen a growing number and variety of such collaborative mechanisms, operating under different institutional frameworks and mandates, with different scopes of activities and technology focus areas. However, despite the central role of innovation in global energy transitions and the potential of international collaboration, there is limited information available on the full landscape of these multilateral initiatives and how they interact.

As a result, the IEA is seeking to map and analyse energy technology innovation efforts, enhance communication, and foster strategic engagement across mechanisms. IEA member and partner countries, as well as the broader innovation ecosystem, would benefit from the identification of synergies to avoid duplication of efforts, conduct joint activities, and accelerate the development and deployment of clean technologies to achieve climate goals. The ambition is for this analysis to serve as a starting point in this endeavour, paving the way for further research in collaboration with the relevant stakeholders.

Section A of this paper introduces key concepts related to technology innovation processes as well as energy-specific trends in RD&D spending, and considers the benefits of international collaboration. Then, Section B examines selected multilateral initiatives relevant to energy technology innovation and existing efforts to map them, and provides illustrations of key global and regional mechanisms. Finally, Section C presents the findings of a comparative analysis among four selected mechanisms: TCPs, MI, CEM and the European Technology and Innovation Platforms (ETIPs).

Key conclusions from the analysis include:

- Apart from TCPs, non-legally binding agreements appear to be the preferred institutional basis, as collaborative mechanisms seek flexibility and responsiveness. The institutional framework should respond to the desired longevity and innovation activities planned by the initiatives. **Overall, a binding framework may provide a stable foundation for initiatives undertaking RD&D activities over longer time spans.**
- Countries from the IEA family (member countries, countries that are pursuing membership and Association countries) have the broadest participation across the

selected mechanisms. Given the overlapping activities and mandates of the partnerships examined, it is a challenge for decision makers and innovators to determine which engagements are a priority and most effective. Policy makers and energy technology innovation stakeholders may benefit from **an online and searchable repository of all innovation collaborative mechanisms classified by type, publicly available and regularly updated**, which could be featured on the IEA Innovation web portal (www.iea.org/innovation) if materialised. Further discussions with the relevant mechanisms could examine the relevance and feasibility of such a tool.

- The analysis of selected partnerships reveals a predominant focus on renewable energy, energy efficiency and cross-cutting technologies, with the highest crowding on solar energy, smart grids, and carbon capture and storage. Given the competing priorities of national RD&D budgets, it has never been more important for innovation partnerships to work towards their visions as effectively as possible. To develop synergies and economies of scale where possible, and to minimise unnecessary duplication of efforts, **collaborative mechanisms should regularly explore co-location opportunities for conferences and meetings as well as co-branding for relevant innovation activities.**
- The effectiveness of innovation partnerships depends on a variety of factors, ranging from adequate allocation of resources to the governance framework, as well as engagements of key public- and private-sector stakeholders at country level. It is critical that partnerships take a strategic, proactive approach to engaging with stakeholders at the most advanced knowledge frontier as well as from markets with the highest potential for innovative technology adoption, such as the People's Republic of China and India. **There are considerable opportunities for further expanding stakeholder and additional market participation in the initiatives under review.**
- Given the proliferation of multilateral efforts around clean energy technology innovation, there is clear potential for further and closer co-operation across initiatives. Innovation partnerships would also benefit from greater visibility and support in high-level political platforms such as under the Group of Seven (G7) and the Group of Twenty (G20), and efforts under the United Nations and regional fora. **There is an opportunity for the IEA to help support collaborative mechanisms in enhancing and streamlining co-ordination among key initiatives.**

Section A. Innovation to drive energy transitions

Key observations on energy technology innovation processes and trends

- Innovation processes from early-stage RD&D to deployment may take decades. Policy makers should take a holistic approach to RD&D funding for energy technology innovation, considering each effort in the context of wider processes.
- Public bodies are critical actors in energy technology innovation; the private sector also plays a vital role, especially to ensure that key technologies reach markets. Policy makers should explore ways to further tap into private-sector capabilities and investments.
- International collaboration may increase effectiveness, bring efficiency benefits and maximise the impact of energy technology innovation efforts. The IEA is enhancing efforts to track energy innovation, and can help facilitate multilateral initiatives and collaborations.

Innovation is a key driver of energy transitions. Energy research, development and demonstration (RD&D) can deliver cost reductions and efficiency improvements, and turn low-carbon strategies into action, services and products to address global energy challenges. This section provides a preliminary overview of energy technology innovation and RD&D funding trends, and explores the potential benefits of international collaboration.

1. What is energy technology innovation?

Innovation is known to be incremental, cumulative and assimilative, and to develop through an evolutionary process. This paper takes a broad view of energy technology innovation, which has been defined as material and knowledge combined in some novel application, involving energy conversion and/or the provision of a useful energy service (Grubler and Wilson, 2014). Scientific research (e.g. basic, applied) is an essential starting point of technology innovation, giving rise to discoveries that drive targeted research and development. Demonstration and deployment, also referred to as diffusion, are critical components in a well-functioning innovation system as well. These later stages in the cycle allow feedback from markets and policy makers, triggering further research. In practice, innovation is a complex process that is generally not linear, as illustrated in Figure 1.

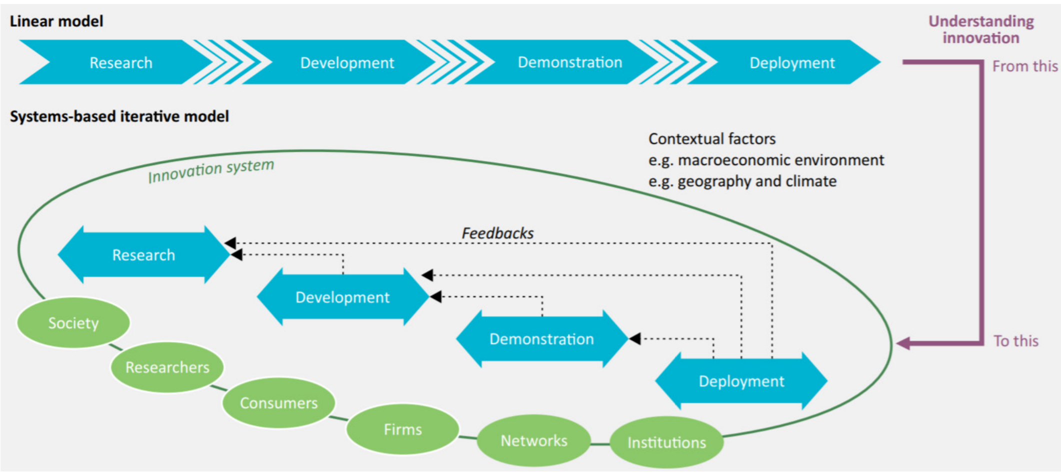
Technologies iteratively move through the four stages with various feedback loops and influences from external factors, including policy action, macroeconomic forces and even geography. Feedback loops in a given technology area may also influence innovation in other areas. Energy innovation in particular results from RD&D efforts driven by the collective learning of both suppliers and users of technology in the energy system.

For instance, RD&D in solar and wind technologies as well as strong policy support for renewables (e.g. incentives, industrial policies, deployment mandates) substantially reduced costs, increased performance and led to the broad deployment of intermittent sources. This process accelerated parallel RD&D efforts in other fields including energy storage, with the aim to stabilise grids and maximise the potential of renewables. Geography may play a role as well, such as for cooling technologies: standards and performance requirements vary based on local climate specificities. In hot and humid climates, for example, cooling demand is expected to increase dramatically in coming decades, and further RD&D is needed to reach greater coefficients of performance than existing devices operating in drier climates. International collaboration can help policy makers set the appropriate standards to spur innovation, transfer and adapt technologies across continents, or learn from international RD&D best practices to design domestic innovation strategies.

A full-scale energy transition from early-stage RD&D to deployment may take decades, due to the broad variety of required technologies, the typical lengths of technology readiness levels and development stages, deployment challenges, and the long lifespan of existing infrastructure (Gross et al., 2018). Disincentives may also hinder the improvement of existing energy technologies and development of new ones, such as high capital requirements while economic, technical and regulatory risks hamper access to finance, which may induce a "valley of death" between opportunity discovery and early commercial adoption. For these reasons, government intervention can assist in accelerating the innovation process beyond what would be expected from market forces alone, and catalyse early adoption (IEA, 2011).

Policy makers may benefit from a holistic approach to energy technology RD&D. Several components are common to successful innovation ecosystems, including coherent energy RD&D strategy and priorities, adequate public funding and policy support, coordinated energy RD&D governance and a strong collaborative approach, a vibrant knowledge society, industry engagement, dynamic and international networks, strong institutional and legal frameworks, and effective RD&D monitoring and evaluation. These elements should be aligned with broader energy and climate policy goals. Innovation can also result from both "push" and "pull" influences, where push may result from investments in the inputs (e.g. human capital, funding for RD&D), and pull from attention to market forces and output demand (Gallagher et al., 2012).

Figure 1. Evolution in thinking of innovation process



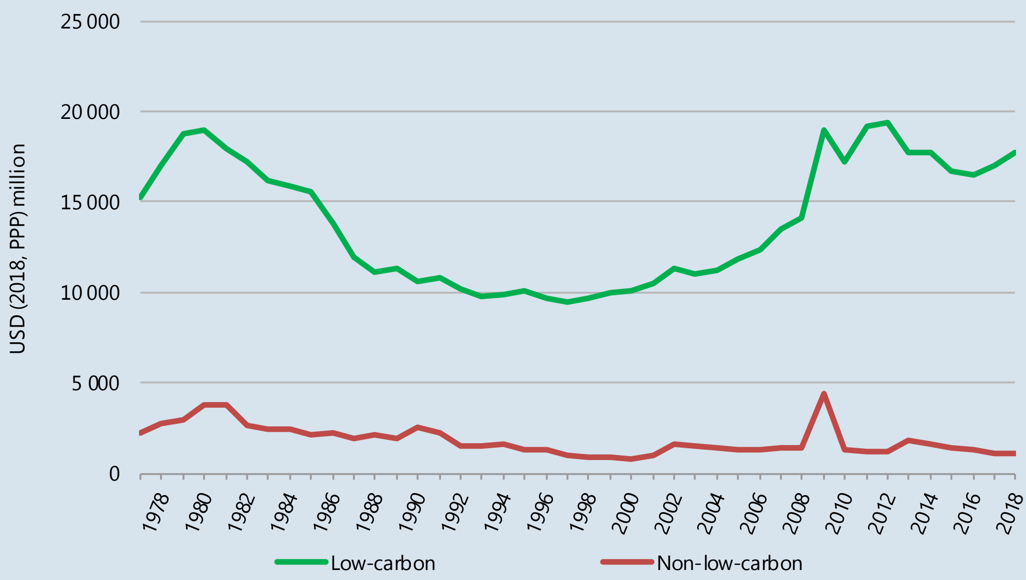
Source: Global Energy Assessment (2012), *Towards a Sustainable Future*.

Technology innovation processes are not linear. They are subject to a variety of internal and external feedback loops and influencing factors, including policy action. International collaboration can help policy makers better navigate through these feedback loops thanks to knowledge transfer.

Box 1. How much is being spent on energy technology innovation?

In International Energy Agency (IEA) member countries, government spending on low-carbon energy RD&D reached USD 17.8 billion in 2018 (in purchasing power parity terms, or "PPP"), consolidating the 2017 increase after years of decline, as illustrated in the figure below. The United States, Canada, Japan, France, Germany and other IEA member countries adopted this trend, recognising the importance of further investment in low-carbon RD&D. Simultaneously, other energy technology spending remained flat in 2018 after the 2017 decrease, at about USD 1 billion (2018, PPP).[1]

Evolution of energy RD&D public spending in IEA member countries



Source: IEA (2019b), *Energy Technology RD&D Budgets 2019*.

As IEA member countries recognise the importance of RD&D to develop low-carbon energy technologies and achieve climate goals, public spending in innovation increased in 2018 while spending in non-low-carbon innovation remained flat after a decrease in 2017.

Public agencies are not the sole actors in energy technology innovation, and the private sector plays an important role in ensuring that key technologies reach markets. As a result, tracking corporate activities and investments in energy innovation may help policy makers understand the broader innovation ecosystem, better engage with private-sector actors to tap into greater investment potential and capabilities, and strategically allocate public RD&D investments in those technology areas that remain underfunded due to high risks and costs.

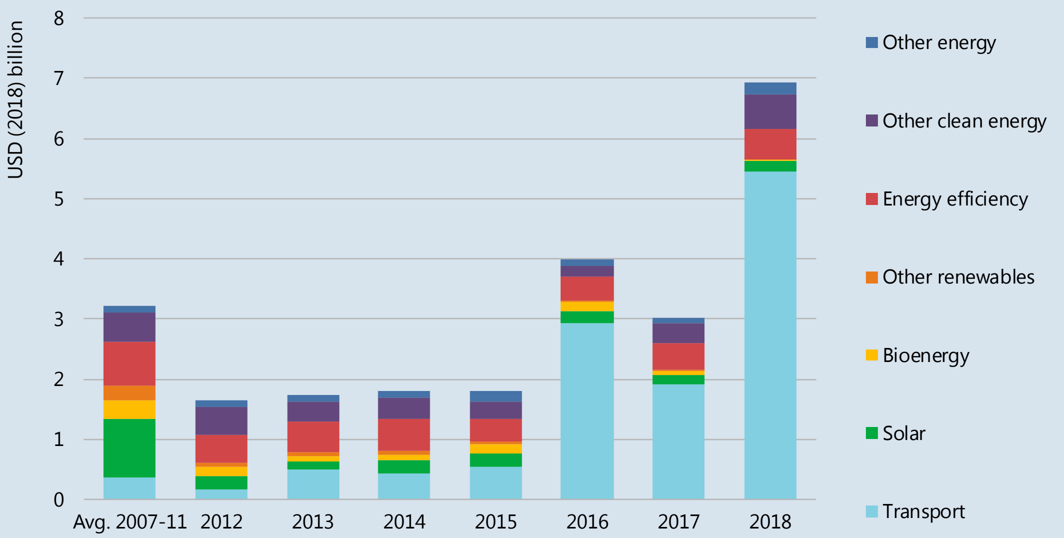
In 2018, global reported corporate RD&D investment in low-carbon energy technology is estimated to have grown by 5% to about USD 65 billion (in USD 2018 constant prices), with

[1] In the current IEA RD&D categorisation (IEA, 2018b; IEA, 2019b), low-carbon energy technologies are defined as: energy efficiency, carbon capture and storage, renewable energy sources, nuclear, hydrogen and fuel cells, other power and storage, and other cross-cutting technologies and research. Non-low-carbon energy technologies represent coal, gas, oil and other fossil fuels.

transport leading the way, after a five-year period of average 6% growth rate. Renewables mobilised USD 6 billion of corporate RD&D investments in 2018 – a 6.5% year-on-year growth rate. A major factor in recent years has been increasing RD&D spending by the automotive sector, as well as greater focus on electricity storage, smart electricity systems and energy efficiency (including insulation and lighting), and nuclear (IEA, 2018a; IEA, 2019a).

Global venture capital (VC) deals and activities related to early-stage technologies may also provide valuable information to policy makers, as illustrated in the figure below. While they can be volatile over periods as short as three to five years, data on VC deals highlight which energy sectors are likely considered most promising by market actors (e.g. attractive return on investment). Governments should ensure strategic energy technology areas are not underfunded and remain appealing to the broader innovation ecosystem.

Global VC investments in energy technology start-ups



Source: IEA (2019a), *World Energy Investment*.

In 2018, VC reached USD 6.9 billion (USD 2018), a new high since the early 2010s bust. Private actors focused on the transport sector with an appeal for clean mobility, while deals related to renewables lost momentum.

2. International collaboration to support energy technology innovation

International collaboration can increase effectiveness, bring efficiency benefits and maximise the impact of energy technology innovation efforts. Scholars have highlighted the need for collaborative energy RD&D for years (Stern, 2010; Weiss and Bonvillian, 2009; Kempener et al., 2014). The fundamental question is not whether to collaborate internationally, but rather how best to do it and with whom. By participating in multilateral RD&D or innovation-related efforts, countries may gain numerous benefits at the different stages of innovation, including access to facilities and expertise; strategic knowledge transfer; common technology standards to facilitate R&D, spur innovation and enable industrial emergence; information sharing related to national RD&D and innovation policies and market analysis, accounting for complex feedback loops; joint studies that may not otherwise be feasible (e.g. mapping of sun and wind resources in large regions, planning cross-border grid integration); improved competitiveness by spreading the costs and risks of RD&D and forming joint ventures; reduced costs of emerging technologies through demonstrations and pre-commercial deployments in markets that are larger than those available domestically; and access to international markets for innovative technologies.

Collaborative mechanisms in energy technology innovation play an important role in addressing challenges of global significance such as climate change, and achieving international goals such as the nationally determined contributions (NDCs) of the Paris Agreement, and the United Nations (UN) Sustainable Development Goals (SDGs). International and cross-sectoral efforts can provide greater confidence that individual and collective actions align in terms of priorities, technology areas and desired goals for collaboration (IEA, 2011). There is particular relevance, for instance, to SDG7 on access to affordable and clean energy. Many of the collaborative mechanisms introduced in Section B aim to achieve this goal, such as the African Union–European Union Partnership on Climate Change and Sustainable Energy, which features joint research and innovation as well as capacity building activities to support the development and integration of renewable energy sources on the African continent. International collaboration exists in many models ranging from bilateral agreements to regional networks to multilateral fora such as those examined in Sections B and C. However, there is no global platform for comparison and appraisal of the related activities of these collaborative partnerships to ensure the effective use of expertise and resources.

Globalisation sparks an increasing number of open-innovation frameworks that help pool resources to accelerate R&D, underwrite demonstration and stimulate faster deployment of proven technologies (IEA, 2017). For example, digitalisation is set to transform global energy systems, making it more connected, reliable and sustainable, with profound implications for energy actors on both the energy demand and supply sides. Sound policy and market design, along with international collaboration, will be critical in steering digitally enhanced energy systems along the desired energy transition pathways.

The IEA and other international organisations are enhancing efforts to track energy innovation and to collaborate through a range of multilateral fora and mechanisms for technology innovation. The past decade has seen the inception, development and in some cases decline of numerous innovation-related initiatives, arguably revealing an evolutionary trend of growing interest for collective action to achieve sustainable, secure and affordable energy, sharing development costs and learning to speed progress.

Section B. Mapping multilateral initiatives in energy innovation

Key conclusions from mapping multilateral initiatives in energy innovation

- There are a growing number and variety of collaborative mechanisms relevant to energy technology innovation. They adopt different institutional frameworks, mandates, scopes of activities and technology focus areas, and may operate globally or regionally.
- Given the growing complexity of the landscape of international and regional partnerships on energy technology innovation, relevant stakeholders recognise the need for a better overview and broad mapping analysis. This could assist the IEA family to identify synergies and improve international strategies to advance clean technologies.
- An online, searchable repository of multilateral innovation partnerships may provide a valuable tool for decision makers and collaborative mechanisms to identify potential synergies between ongoing activities. The relevance and feasibility of such listing could be further discussed with the relevant stakeholders.

Global challenges call for co-operation on a global scale to either create a public good or protect shared natural resources. Today, a plethora of international partnerships and multilateral initiatives create a vast ecosystem, and more continue to be established, to address the increasingly urgent environmental challenges the world faces as a global community.

This section explores the evolution of the international collaboration landscape and examines existing efforts to map multilateral initiatives relevant to energy innovation.

1. A dense energy innovation ecosystem

International collaboration in response to global challenges

The evolution of collaboration, both regional and international, reflects the ever-changing landscape of environmental and energy challenges and technology innovation. The global environment movement only started in the 1960s, although some natural resources were recognised as scarce prior to the 1950s (Makuch and Pereira, 2014). As countries became more aware of local (e.g. air pollution, acid rain, energy security) and global challenges (e.g. climate change, worldwide energy access), the dialogue around international collaboration steadily became stronger. Inevitably, innovation became part of the dialogue because technology solutions were needed.

Starting from the 1970s, several trends are worth highlighting. The 1972 Stockholm Conference resulted in two important outcomes: the Stockholm Declaration and the creation of the United Nations Environmental Programme. Although a non-legally binding instrument, the adoption of the declaration and specifically Principle 21 laid out the concepts of permanent sovereignty and the obligation not to harm other states in the enjoyment of one's own natural resources. These principles became the cornerstone concepts of international environmental responsibilities for the next few decades. Around this period several international organisations were established, either created in their own right, for example the Organisation of Economic Co-operation and Development (OECD) when the OECD Convention entered into force in 1961, or as the condition of an international treaty.

The IEA was established in 1974 in response to disruptions to global oil supply, specifically the crisis of 1973-74. While this remains a key aspect of its work, the mandate of the IEA has evolved to include the full spectrum of energy issues and energy technology innovation. The IEA Technology Collaboration Programmes (TCPs), known as Implementing Agreements prior to 2016, were established as a mechanism for international collaboration that same year. Many of the original TCPs still exist today, having altered their programme of work to address emerging technologies specific to their energy topic or sector.

National and global political commitments related to environment and energy challenges continued to evolve. The 1992 UN Conference on Environment and Development (UNCED), also known as the Rio Conference, further solidified international co-operative principles and the idea of shared global responsibility. The principle of common but differentiated responsibilities became a key guiding principle. This principle features in both the Rio Declaration and 1994 UN Framework Convention on Climate Change (UNFCCC) (UNFCCC, 1992).

The UNFCCC marked a significant shift in the international dialogue on the environment and climate change, having a direct subsequent impact on international co-operation. The convention provided a framework of obligations that could be flexibly implemented, therefore encouraging maximum state participation. In 2005, the entry into force of the Kyoto Protocol under the UNFCCC was a major achievement, with states committing to quantify emission reduction targets under an established timetable. Since the Kyoto Protocol, the number of partnerships and multilateral initiatives addressing clean energy issues has steadily increased. In many cases, these initiatives originate from the commitment of UNFCCC parties at Conference of the Parties (COP) meetings, such as the Clean Energy Ministerial (CEM) at COP15 in 2009.

The Paris Agreement at COP21 was a further milestone for international collaboration in the global energy sector, with 190 countries declaring NDCs. Its entry into force in November 2016 instigated an immediate call to action for countries and stakeholders worldwide. The Paris Agreement's framework relies on countries both implementing their existing NDCs as well as ramping up efforts to meet the below-2°C goal. Another result of COP21 was the establishment of Mission Innovation (MI), a multilateral initiative to complement the deployment mandate of the CEM with member countries pledging to double their investment in clean energy RD&D.

Today, particular emphasis needs to be placed on strengthening interaction among collaborative mechanisms, as suggested in the analysis in Section C. Considering the complex international ecosystem of energy innovation partnerships and initiatives, the aim should be to effectively use limited public budgets, leverage private-sector capabilities and investments, and accelerate innovation in support of global energy goals, as the necessity for urgent action has not diminished.

Case studies: Global collaborative mechanisms

This subsection introduces three global collaborative mechanisms for energy technology innovation, i.e. not limited in mandate to a given region: the IEA TCPs, MI and the CEM.

Case study: IEA Technology Collaboration Programmes

A TCP is a co-operative project established by at least two IEA member countries to carry out a wide range of activities such as energy technology RD&D and analysis, capacity building, dissemination and scientific exchanges.[2] The majority of TCPs carry out energy technology analysis and dissemination activities. Many TCPs undertake applied research and innovation activities, and some carry out fundamental research.

Some 80 TCPs have been created in the past four decades, with 38 currently operating. Today around 6 000 experts from nearly 300 public- and private-sector organisations from 55 countries (IEA member and non-member countries) participate in TCPs across five broad technology areas: energy efficiency end-use technologies (buildings, transport, industry and electricity), renewable energy and hydrogen, fossil fuels, fusion power, and cross-cutting issues.

While they are part of the IEA global innovation network, TCPs are functionally and legally autonomous from the organisational structure of the IEA. Each TCP is organised under the auspices of an Implementing Agreement, which is most commonly used to describe the legal text of a TCP. The legal text includes key provisions regarding the purpose, management and implementation of the TCP. The activities of each TCP are overseen by an executive committee (ExCo) comprising representatives designated by each participant. The ExCo makes decisions on the management, participation and implementation aspects of the TCP. Some TCPs entrust the management functions of the TCP, or of a particular activity, to an operating agent (OA).

The IEA does not provide direct financial support to TCPs through funding, either as a signatory or as a programme manager (i.e. OA). However, the IEA Secretariat provides guidance, advice and support by acting as conduit between TCPs and policy makers, and by promoting TCP outcomes where possible. The IEA also provides legal advice in relation to processes, procedures and the legal structure of TCPs.

Case study: Mission Innovation

MI is a global initiative focusing on scaling up RD&D for the clean energy technologies of the future. It was launched in November 2015 during the UNFCCC's COP21 in Paris, with the aim "to accelerate the pace of clean energy innovation to achieve performance breakthroughs and cost reductions to provide widely affordable and reliable clean energy solutions that will revolutionize energy systems throughout the world over the next two decades and beyond" (MI, 2016).

MI governments have pledged to double their public clean energy RD&D investment over the five-year period from 2015-20. In addition, MI members encourage collaboration among partner countries, information sharing, and co-ordination with businesses and investors. MI itself is an umbrella initiative with a subset of voluntary initiatives, known as the Innovation Challenges, mutually identified and agreed as areas of common interest and importance to MI members. MI Innovation Challenges cover the entire spectrum of RD&D from early-stage

[2] A TCP is established as a "special activity" under Article 65 of the IEA's constitutional document, the International Energy Programme Agreement (IEP, 1974). Further information on TCPs is available at www.iea.org/tcp.

research needs assessments to technology demonstration projects. MI membership consists of 23 countries and the European Commission.

Case study: Clean Energy Ministerial (CEM)

The CEM is an international forum focusing on clean energy technology deployment. It was founded in December 2009 during the UNFCCC COP15 in Copenhagen to achieve three aims: a) promote the deployment of clean energy technologies and solutions; b) share lessons learned; and c) encourage the transition to a global clean energy economy. The objective of the CEM is "to accelerate the global clean energy transition through a voluntary, efficient, global partnership of the world's largest and most forward-leaning economies" (CEM, 2016).

While CEM's primary focus is deployment, energy technology innovation is part of the activities of some of the 14 initiatives and 8 campaigns operating today. CEM initiatives focus on three key areas: energy supply and system integration to assist governments in identifying and adopting the best policies to produce clean and cost effective energy; energy demand to increase energy efficiency across end-use sectors; and cross-cutting support on topics related to both energy production and consumption. CEM membership consists of 25 countries and the European Commission.

Case studies: Regional collaborative mechanisms

Acknowledging that regional collaborative mechanisms make substantial contributions to the energy landscape as well as the technology innovation ecosystem, this subsection introduces mechanisms leading collaborative activities across five regions: Africa, the Arab region, Asia-Pacific, Europe and Latin America. Additional research could seek to cover the exhaustive list of relevant regional mechanisms.

Preliminary analysis suggests that regional collaborative mechanisms address a broad range of energy themes, without focusing specifically on technology innovation. The initiatives led by the European Union appear to be an exception in that regard given their proactivity in all stages of energy RD&D (see below). This observation, which should be further investigated and refined by additional research in collaboration with the relevant regional stakeholders, would imply that there is a potential for greater cross-mechanism collaboration around the globe. Regional collaborations could benefit, for instance, from closer co-operation with the IEA TCPs, or the European Union's innovation-intensive work streams.

Case study: Mechanisms for the African region

An increasing number of regional mechanisms supporting energy innovation in Africa engage in cross-mechanism collaboration, among them the African Union (AU), the East African Community (EAC) and the Economic Community of West African States (ECOWAS). The AU was established in 2002 and considers energy through the AU Commission's Department of Infrastructure and Energy, as well as through the New Partnership for Africa's Development (NEPAD). Many initiatives focus on energy access, regional integration and renewable energy to tap into the continent's unexploited potential.

In 2017, the AU and the European Union crafted an AU-EU Research and Innovation (R&I) Partnership on Climate Change and Sustainable Energy (CCSE), which is expected to feature joint research and capacity building in areas including: 1) development and integration of renewable energy in the energy system; 2) planning and modelling future sustainable energy systems; 3) including society as an important stakeholder; 4) market, pricing and business models for future sustainable energy systems; and 5) strengthening basic research and technology development (European Commission, 2017). This illustrates how two regional collaboration mechanisms can engage in cross-mechanism co-operation to achieve joint energy goals.

As part of the EAC, the **East African Centre of Excellence for Renewable Energy and Energy Efficiency (EACREEE)** seeks to "facilitate creation of an enabling environment for renewable energy and energy efficiency markets and investments". Since 2013, the EACREEE has provided policy support, co-funding opportunities for public tenders, and capacity building and networking activities including with research institutions. ECOWAS has had a corresponding body since 2010, the **ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE)**, which conducts similar activities.

These mechanisms appear to be explicitly mandated to conduct projects in collaboration with other regional and global programmes, paving the way for enhanced cross-mechanism collaboration. For instance, the EACREEE's second of eight priorities is to develop regional projects and "create synergies with ongoing programmes (e.g. GIZ, Energy and Environment Partnership in Southern and Eastern Africa, WB, AfDB, UN, EU)".[3] Similarly, ECOWAS collaborates with the International Renewable Energy Agency (IRENA) and other institutions as part of the West Africa Clean Energy Corridor (WACEC). Substantial efforts are being made in the Africa Clean Energy Corridor (ACEC), also implemented by IRENA in collaboration with over 30 governments, regional organisations, development partners and financial institutions. Further research would examine these cross-mechanism collaborations, as well as the role of other institutions including financing actors such as the AfDB.

Case study: Asia-Pacific mechanisms

Regional and international collaboration on low-carbon energy technology within the Asia region has increased in the last decade, mostly through the expansion of existing fora rather than the creation of new mechanisms (IEA, 2014). Energy-related work under the framework of the Asia-Pacific Economic Cooperation (APEC) and the Association of Southeast Asian Nations (ASEAN) illustrate such long-standing co-ordination. It should be noted that the Asia-Pacific Partnership on Clean Development and Climate (APP) was active over the 2005-11 period.

The APEC Energy Working Group (EWG), established in 1990, seeks to maximise the contribution of the energy sector to the region's economic and social well-being while mitigating the environmental effects of energy supply and use. APEC began as an informal ministerial-level dialogue in 1989 with 12 founding Asia-Pacific economies taking part. There are now 21 members and, since 1993, there have been annual APEC Economic Leaders' Meetings. The APEC EWG is one of the longest-standing initiatives for regional energy co-operation, alongside the European Union, and the IEA is featured among EWG guests. The EWG has established five key mandates: 1) reducing energy intensity; 2) doubling renewable energy; 3) rationalising and phasing out inefficient fossil fuel subsidies; 4) low-carbon development; and 5) enhancing energy security.

The APEC EWG hosts four Expert Groups (Clean Fossil Energy, Energy Efficiency & Conservation, Energy Data & Analysis, New & Renewable Energy Technologies); two Task Forces (Low-Carbon Model Town, Energy Resiliency); and two centres (Asia Pacific Energy Research Centre [APERC], APEC Sustainable Energy Centre). APERC generally conducts energy policy and market research for several countries at a time, such as in the Peer Review on Low Carbon Energy Policies (PRLCE) project or the Cooperative Energy Efficiency Design for

[3] GIZ = German Agency for International Cooperation; WB = World Bank; AfDB = African Development Bank.

Sustainability (CEEDS) initiative. These activities typically include workshops gathering sectoral experts and officials from several participating APEC economies.

ASEAN has been proactive in the energy sector for over 20 years. ASEAN is an international organisation covering a range of economic, political and socio-cultural issues, founded in 1967 by Indonesia, Malaysia, the Philippines, Singapore and Thailand, with Brunei Darussalam, Viet Nam, the Lao People's Democratic Republic (Lao PDR), Myanmar and Cambodia later joining. ASEAN has held Energy Ministers Meetings since 1980, as well as ASEAN+3 (People's Republic of China, Japan, Korea) Energy Ministers Meetings since 2004, and has been working on energy efficiency and renewable energy technologies since at least 1995. The ASEAN Centre for Energy was established in 1999 and addresses renewable energy, energy efficiency and nuclear energy as well as fossil fuel-related considerations. ASEAN regularly partners with a range of organisations, including the IEA.

The APEC EWG and ASEAN's Centre for Energy contribute to both global and regional collaboration on energy technology innovation for Asia-Pacific countries. For instance, recent low-carbon energy technology innovation-related research conducted by APERC addressed themes including hydrogen (APERC, 2018), nuclear power (APERC, 2017) and lowering oil demand in transport (APERC, 2016) in the Asia-Pacific. Within the framework of ASEAN, the Centre for Energy explicitly mentions multilateral collaboration as part of its vision, and features co-operation with ASEAN+3, Canada, the European Union, Germany, Japan, Norway and the United States. Its ASEAN-German Energy Programme (2016-25), formerly Renewable Energy Support Programme for ASEAN (2010-15), sponsored by the German Federal Ministry for Economic Cooperation and Development (BMZ), aims to foster the use of renewable energy in the region, as well as energy efficiency. It explicitly includes innovation elements, such as "Activity No. 4: Empower the ASEAN R&D Network on Renewable Energy". As part of the ASEAN-Japan Energy Efficiency Partnership, the Energy Conservation Center, Japan (ECCJ) shares information with ASEAN "on the advanced technologies and products so as to create more opportunities for private sectors to promote" energy efficiency and conservation through business.

Further research could examine ongoing activities with the APEC EWG and ASEAN's Centre for Energy, as well as the interactions between these initiatives and other relevant international collaboration mechanisms. The role of multilateral development banks in energy technology innovation, such as the Asian Development Bank, could also be explored.

Case study: Arab region mechanisms

The Regional Centre for Renewable Energy and Energy Efficiency (RCREEE) contributes to regional collaboration on energy technology innovation for Arab countries. The RCREEE is an intergovernmental organisation that, since 2008, "aims to enable and increase the adoption of renewable energy and energy efficiency practices in the Arab region". It conducts a broad variety of research and analysis activities relevant to its members, as well as offers RD&D grant opportunities to regional actors.

The RCREEE counts 17 Arab countries and territories among its members, as well as numerous external partnerships. The organisation partners with regional governments and international organisations to foster dialogue, design strategies and increase capacity of clean energy in the region, most notably through a "solid alliance with the League of Arab States" (LAS). It is financed through member contributions, government grants provided by Germany through the GIZ, Denmark through the Danish International Development Agency (DANIDA), and Egypt through its New and Renewable Energy Authority, as well as through several fee-for-service contracts. RCREEE has also partnered with IRENA, the World Bank and others to craft and implement low-carbon energy roadmaps. It currently seeks further collaboration with Asian stakeholders. Such bilateral, regional and international collaboration could be examined in future research.

Case study: European Union mechanisms

EU initiatives illustrate regional co-operation on all aspects of the energy landscape, including RD&D. EU energy technology innovation efforts are part of a broader EU internal ecosystem of institutionalised co-operation.

Since 2007, the European Union has taken an increasingly strategic approach to energy innovation, identified priorities and involved private-sector actors, through the European Strategic Energy Technology Plan (SET Plan). This forms part of the EU Energy Policy Framework. The SET Plan was designed to tackle two key objectives: reduce the cost of clean energy within Europe and involve EU industry at the forefront of energy technology innovation. The European Commission established European Industrial Initiatives (EIIs) as public-private partnerships to implement research agendas under the SET Plan, illustrating how collaborative mechanisms can leverage private-sector capabilities and investments.

In 2015, the European Commission launched the Energy Union strategy with a forward-looking climate change policy, and identified 10 key action areas. It followed an energy policy review of the SET Plan and the release of the Integrated SET Plan (European Commission, 2015). The six EIIs, which had not delivered as intended to advance the SET Plan, were merged with eight existing European Technology Platforms (ETPs)[4] to form nine energy-specific ETPs, thereafter rebranded European Technology and Innovation Platforms (ETIPs) (European Parliament, 2017a). ETIPs operate similarly to other ETPs, but specifically support the implementation of the Integrated SET Plan. They bring EU policy makers, industry and research centres together on innovation priorities. ETIPs cover a broad scope of energy technologies, such as smart grids, wind, solar and ocean power.

In addition to the ETIPs, the EU R&I ecosystem includes a wide range of other collaborative mechanisms or instruments for member countries to participate in the development of energy technology (IEA, 2014b).[5] Among them are collaboration projects completed under the EU framework programmes (including Horizon 2020), the European Energy Research Alliance (EERA), Implementation Working Groups, Joint Programming Initiatives, European Innovation Partnerships, European Institute of Innovation & Technology (EIT), Joint Undertakings and other public-private partnerships, and funding instrument ERA-NET Cofund. Further analysis of the European Union's energy innovation landscape and the relationships among mechanisms as well as with other global mechanisms, may be found in existing research initiated by ETIP Smart Networks for Energy Transition (ETIP SNET 2019, see following subsection on recent efforts to map collaborative efforts).

[4] European Technology Platforms (ETPs), which were introduced in the early 2000s, are industry-led stakeholder fora recognised by the European Commission as key actors in driving innovation, knowledge transfer and European competitiveness in their sector. ETPs develop research and innovation agendas and roadmaps for action at EU and national level to be supported by both private and public funding (ETIP Bioenergy website; European Parliament, 2017b).

[5] Exhaustive information related to innovation projects in the European Union may be found on CORDIS, the Community Research and Development Information Service, which is the European Commission's primary source of results from the projects funded by the EU framework programmes for research and innovation (from the first framework programmes to Horizon 2020).

Case study: Latin American mechanisms

Several mechanisms contribute to international collaboration in the energy sector in Latin America, with some degree of focus on technology innovation. Among them, the Latin American Energy Organisation (OLADE – Organización Latinoamericana de Energía), which is composed of 27 member countries from Central and South America and the Caribbean (Algeria is also a participating country, although not a member). Since 1973, it has supported regional and sub-regional energy integration, sustainable development and energy security, and it currently seeks to "consolidate [its role] as the main technical reference body in Latin America and the Caribbean in matters related to energy" (OLADE, 2018). In recent years, OLADE has crafted many partnerships with regional institutions, including with universities such as the University of Chile, to develop and implement research programmes. However, most activities appear to focus on other energy themes than specifically on technology innovation and RD&D.

Other America-wide institutions contribute to energy collaboration and technology innovation at the Latin American regional level. The Organisation of American States (OAS), for instance, hosts an OAS Sustainable Energy Section within its Department for Sustainable Development. The section's primary mission is to "support the development and use of sustainable energy technologies and services" in technology areas including renewable energy, energy efficiency, fossil fuels and trans-boundary interconnections. Latin American member countries benefit from the presence of North American partners (including the United States and Canada), as illustrated in the following example of the Energy and Climate Partnership of the Americas (ECPA), supported and financed by OAS members.

The **ECPA** promotes regional energy co-operation for a clean energy future, with a focus on achieving greater sustainable energy access in Latin America and the Caribbean region. Energy research and innovation is mentioned as a key priority, with the goal to "encourage technological development of innovative systems that make renewable energy widely affordable and available, while fostering applied research based on country-specific needs." Initiatives include the Energy Innovation Centre, opened in 2010 thanks to financing from the Inter-American Development Bank (IDB) and the US Department of Energy (DoE) to co-operate on technology RD&D in fields including energy efficiency, renewable energy and fossil fuels. Further research could clarify which activities are currently ongoing within the Energy Innovation Centre and examine the participating role of the IDB and DoE, as well as other North American partner countries such as Canada, which typically put emphasis on the role of innovation (ECPA, 2016).

The **UN Economic Commission for Latin America and the Caribbean (UNECLAC)** also plays a role in the region's energy landscape, with some activities related to the innovation ecosystem. For instance, the project Towards a Low-Carbon Economy in Latin America: Policy Options for Energy Efficiency and Innovation (2012-15) explored policy options to strengthen the region's innovation ecosystem regarding energy efficiency (UNECLAC, 2016). Similarly to OLADE and ECPA, however, further research could examine the specific contribution of these mechanisms to advancing energy technology innovation by mapping ongoing activities and priorities.

There appears to be a growing trend towards international collaboration among Latin American collaborative mechanisms. OLADE, for instance, co-operates with other countries bilaterally, such as with Germany's GIZ and the Institute of Energy Economics, Japan (IEEJ), but also with other regional or international organisations such as the IDB, the European Union and the UN. In 2018, OLADE signed 18 Inter-Institutional Cooperation Agreements to advance joint agendas and "enhance the results for the benefit of the Member Countries", illustrating growing appetite for international collaboration.

2. Efforts to map energy innovation collaborations

The broad diversity of collaborative mechanisms

International collaboration related to energy innovation emerged progressively over a period of about half a century. As a result, there is a broad variety of collaborative mechanisms today, as illustrated in the examples presented above. Section C will explore a selection of four collaborative mechanisms in more details, namely 1) TCPs; 2) MI; 3) CEM; and 4) ETIPs.

Collaborative mechanisms in energy innovation may generally be categorised according to type and level of operation. Types correspond to the mechanism's mandate, main activities, institutional framework, technology focus, etc., whereas levels correspond to the adopted geography of the arrangement, which can be bilateral, regional, or global. This paper generally focuses on mechanisms operating at the regional and global levels, acknowledging that valuable contributions are being made by bilateral collaborations as well. In addition, this paper primarily addresses collaborative mechanisms focusing on technology, while many multilateral initiatives focus on other aspects of energy innovation, such as innovative policy making, business models, governance, etc.

The observation of existing international partnerships related to energy technology innovation suggests that collaborations may take place in different ways. As illustrated in the case study presentations above, some mechanisms choose to focus on earlier stages of the innovation process, such as MI's clear focus on RD&D public spending, while others aim at accelerating the deployment of relevant technologies, such as CEM. In addition to the mandate defined by its member countries, the institutional and legal framework of the mechanism may vary, from legally binding agreements such as that of the IEA TCPs to more flexible project-based voluntary collaborations. The involvement of private-sector actors varies from little interaction to extensive public-private partnerships, such as the ETIPs and other EU initiatives. Activities may also vary significantly across mechanisms, from fundamental and applied RD&D conducted in laboratories and research centres to policy and market analysis during roundtable events gathering decision makers and business executives.

There are many collaborative efforts with a mandate broader than energy technology innovation making important contributions to the energy and climate dialogue. For instance, within international political fora such as the Group of Seven (G7) and Group of Twenty (G20), thematic discussions continue on the economic impacts of climate and energy, although they are among many other topics. Under the framework of the UN, while there is no specialised UN agency dedicated to energy innovation, there are countless UN bodies considering energy technologies,[6] including the Climate Technology Centre and Network (CTCN). The CTCN was established in 2010 as an operational arm of the UNFCCC Technology Mechanism. It consists of a climate technology centre based in Copenhagen and a global network of public and private organisations that deliver three core services: technical assistance at the request of developing countries to their national designated entity, access to information, and networking activities among stakeholders. CTCN has constituted a broad database of international networks or collaboration programmes related to climate change technologies. The UN Industrial Development Organization (UNIDO) provides services for improved energy efficiency for transitioning economies, and partnered with the Global

[6] For a detailed overview of UN initiatives by stage of innovation, see Figure 9 of UNFCC (2016). NB: these initiatives are not necessarily related to energy innovation given the UNFCCC mandate, but rather to climate change technology innovation.

Environment Facility (GEF) to launch the Global Cleantech Innovation Programme (GCIP). The SE4ALL initiative, which has a relationship agreement with the UN, aims to make energy accessible, cleaner and more efficient for all by 2030.

IRENA is also a key stakeholder in the innovation landscape, although it does not primarily focus on technology innovation collaboration. IRENA is an international organisation founded in 2009 to support countries in their transition to a sustainable energy future. IRENA is exclusively dedicated to accelerating the deployment of renewable energy technologies, with the objective to promote the widespread and increased adoption and the sustainable use of all forms of renewable energy. IRENA facilitates and supports, as a co-ordinator or as the secretariat, a number of initiatives run by member and non-member countries. Some IRENA initiatives relate to technology innovation, such as Clean Energy Corridors and Renewable Energy Roadmaps.

Other multilateral initiatives following energy technology innovation may include: the World Economic Forum, which tracks the latest trends in innovation across all sectors with a focus on innovation systems and technology; the World Bank Group, which provides funding and/or technical support to local and regional structures supporting innovation such as the Climate Innovation Centres; the Carbon Sequestration Leadership Forum, one of many multilateral networks with a dedicated technology focus, in this case the development of carbon capture, utilisation and storage (CCUS); the Renewable Energy and Energy Efficiency Partnership (REEP), an international organisation that investigates financing mechanisms to increase market readiness in low-income countries; the Renewable Energy Policy Network for the 21st Century (REN21), a network focused on facilitating renewable energy knowledge exchange and policy discussion; the Biofuture Platform (BfP), comprising 20 member countries with the IEA as BfP Facilitator in 2019, focused on the sustainable upscaling of the bio-economy to increase the contribution of sustainable modern bioenergy to energy demand; as well as private-led initiatives such as the Breakthrough Energy Coalition, an international group of investors, companies, funds and banks committed to accelerating the commercialisation of new reliable and affordable energy technologies that can help tackle climate change.

Recent efforts to map energy innovation initiatives

Efforts are being made to map and better understand the actors in this ecosystem and their respective relationships. These efforts include reviews by international organisations, academic works, and internal evaluation by the partnerships and initiatives themselves.

The UNFCCC regularly takes stock of initiatives within the ambit of its convention. In 2013, it launched a global inventory of international initiatives that support climate change mitigation. Later, following the adoption of the Paris Agreement, one of its subsidiary bodies prepared a mapping of climate technology development and transfer activities and initiatives relevant to the implementation of the Paris Agreement, focusing on the technology framework under Article 10 of the agreement (UNFCCC, 2016). This mapping did not specifically focus on energy technologies, but rather on the broader climate change mitigation technologies ecosystem. Among others, the UNFCCC concluded that "technology collaboration, including at the RD&D stage, is evidenced in the number of multilateral technology-specific initiatives as well as in bilateral programmes, which, however, have not been mapped systematically."

In 2014, the IEA conducted a mapping exercise of 28 multilateral initiatives on low-carbon energy technologies through a case study of the Asia region and found that the trends in the characteristics and variety of these initiatives warranted further exploration (IEA, 2014a). Among others, it concluded that "there is surprisingly little information – readily available in a single location – in either academic or public policy literature that seeks to map comprehensively the array of multilateral collaborative initiatives that are now addressing low-carbon energy technologies." This typically remains the case today (UNFCCC, 2016).

As a part of its own modernisation vision, in 2015, the IEA began enhancing its efforts and tracking activities on energy innovation with the view to strengthen international collaboration among its member and non-member countries. The IEA TCPs already existed as a complex network of over 30 collaborative partnerships exchanging knowledge and conducting various levels of policy best practice development, research and technology analysis. In addition, the IEA Technology Roadmaps provided sector-specific guidance on technology development and tracking of public-sector expenditures on energy RD&D as well as VC funding of energy innovation.

The IEA *Tracking Clean Energy Progress* (TCEP; IEA, 2019c) initiative is a relatively new web portal that annually assesses the latest progress made by key energy technologies, and how quickly each technology is moving towards the IEA Sustainable Development Scenario. The most recent addition to the IEA's work is the Clean Energy Transitions Programme (CETP) launched in 2017 with aims to leverage the Agency's energy expertise across all fuels and technologies to accelerate global clean energy transitions, particularly in major emerging economies.

In 2018, the Austrian Federal Ministry for Transport, Innovation and Technology, in a project initiated by the delegates of the IEA End-Use Working Party, began a visual thematic mapping of the activities of the TCPs (Eggler et al., 2018).

In 2019, the ETIP Smart Networks for Energy Transition (SNET) published a detailed, sector-specific mapping of key European initiatives (see previous subsection on EU mechanisms), and provided a comparative analysis on what they do and how they interact with one another as well as with the IEA TCPs, MI and CEM. This ETIP SNET work stream sought to identify potential synergies among initiatives, thereby contributing to the long-term goal to "achieve fully-coordinated participation" of all stakeholders and avoid "silo visions, missions, roadmaps and implementation plans" (ETIP SNET, 2019). The SNET analysis concluded, among others, that "potential overlaps have been identified in the tasks [and that] coordination shall be sponsored to have the widest possible consciousness about the approaches and results to foster mutual sharing and leverage strengths". For instance, it identified areas of potential collaboration across mechanisms such as among ETIPs, TCPs and MI Innovation Challenges. Future mapping of international efforts in energy technology innovation may build on SNET's methodology and main findings.

At present, it remains challenging for policy makers to fully understand the similarities and/or differences among mechanisms (e.g. activities, technology focus and outcomes). As illustrated in the comparative analysis in Section C, there is often apparent overlap in membership across collaborative mechanisms (a given member country is usually part of several mechanisms). In addition, the mandate of different mechanisms may appear somewhat similar, as the majority fall under the umbrella of accelerating clean energy innovation or the deployment of cleaner technologies. The activities undertaken under different mechanisms may also appear similar, as most mechanisms include, for instance, policy analysis, information sharing, seeking funding opportunities, etc. Technology focus areas may also overlap, especially in technologies identified as strategic by energy innovation stakeholders (e.g. hydrogen, energy storage, clean mobility, CCUS).

Despite existing efforts to map multilateral partnerships relevant to energy technology innovation, there is currently no online, exhaustive repository listing all multilateral initiatives

classified by type, publicly available and regularly updated. Such a map may allow energy innovation stakeholders to better understand the differences among mechanisms, identify areas of future collaboration, connect and engage with one another, and more broadly strengthen the impact of innovation efforts. Such online repository would build on relevant existing research such as the UNFCCC's mapping of climate technology multilateral partnerships in 2016, the mechanisms' own mapping efforts such as ETIP SNET analyses, and the IEA country in-depth review innovation chapters. If materialised, it could be featured on the IEA Innovation web portal. Further discussions with the relevant stakeholders could examine the relevance of such a tool, assess its feasibility, as well as lay out a methodology to design it.

Section C. Comparative analysis of selected collaborative mechanisms

This section provides a comparative analysis of four international partnerships identified as relevant to energy technology innovation activities. Future research, if relevant and feasible, could seek to map all multilateral initiatives and thereafter conduct similar analysis to identify areas of potential synergies between ongoing activities.

Key conclusions from the comparative analysis of selected collaborations

- The immediate analysis compares the IEA TCPs, the CEM, MI and the ETIPs against five criteria: institutional framework, membership structure, sector and/or technology focus, scope and outputs of activities, and cross-mechanism interactions.
- **Cross-mechanism collaboration.** There appears to be at least some overlap in technology focus and/or activities across different collaborative mechanisms, possibly inducing risks of duplication, the dilution of policy makers' attention, and fundraising and political support challenges. More in-depth and regular mapping could help identify areas for potential collaboration. Countries are often member of several collaborative mechanisms, which could enable or facilitate cross-mechanism collaboration.
- **Private-sector involvement.** There is substantial utility and interest from many of these initiatives in further deepening the engagement with private-sector actors to tap into potentially greater investments and capabilities. Future work could examine best practices related to private-sector involvement.
- **Measuring outputs and outcomes.** Further efforts could be undertaken to establish constructive evaluation and feedback frameworks within collaborative mechanisms. Delivering publicly available reviews of ongoing activities may help the innovation ecosystem identify areas for engagement across partnerships and enhance transparency.

1. Scope and methodology

As detailed in the Annex, following the results of the 2018 Committee on Energy Research and Technology (CERT) survey, the IEA Secretariat has been asked to prepare a short paper on priority partnerships and multilateral initiatives selected by CERT delegates. This section seeks to present the main trends and inform discussions related to collaboration with these initiatives.

The following criteria were used to select a sample of collaborative mechanisms: 1) mechanisms mentioned as part of the 2018 CERT survey; 2) mechanisms focusing on energy technology innovation; and 3) mechanisms including governments as members (e.g. intergovernmental partnerships) or with a more diverse membership but which were initiated and/or remain predominantly led by more than two national governments or intergovernmental organisations (bilateral initiatives are not covered).

The analysis only considers a small sample from the innovation ecosystem, acknowledging the breadth and variety of energy technology and innovation actors, as well as other mapping and review efforts. Further efforts may seek to constitute an exhaustive map of all collaborative mechanisms.

The following three global initiatives are analysed: the TCPs, the CEM, and MI; as well as the regional ETIPs.

These four international partnerships are analysed against the following typology (IEA, 2014a):

1. **Institutional framework**: whether a partnership is based on a binding legal agreement, or founded on a non-binding document such as a political declaration; whether it is given a specific mandate; how it is funded

2. **Membership**: whether a partnership aims at global or regional membership; whether it includes only IEA countries or includes developing and less developed economies; and whether its members comprise only national governments or also non-government or other entities participating on an equal footing

3. **Sector and/or technology focus**: whether a partnership focuses on a single technology cluster or sector, or whether it is more cross-cutting in its technology focus

4. **Activities (scope and outcomes)**: whether the activities of a partnership consist of technology RD&D, innovation policy or networking events, technology analysis, capacity building, providing funding opportunities, etc.; and whether the mechanism is equipped with review frameworks and performance evaluations

5. **Cross-mechanism interactions**: whether the mechanisms under examination interact with one another through any of the following means: institutional (such as memoranda of understanding, letters of intent, other formal arrangements and/or observer status); political support (referencing an initiative in the high-level documents of another initiative); and technical/working level (regular working-level interaction).

2. Analysis

Institutional framework

Key takeaways: Institutional framework

- Collaborative mechanisms appear to shift towards more flexible arrangements, away from traditionally legally binding agreements, as members favour voluntary contributions and expect responsiveness from their institutional structure, organisation chart and work programmes.
- All four collaborative mechanisms have an umbrella mandate to support energy technology innovation, and initiatives at the project level are generally technology-specific. Collectively, the mechanisms appear to cover the entire energy innovation spectrum.
- The IEA family and the broader energy technology innovation ecosystem may benefit from further analysis identifying funding instruments best practices to support the efforts of collaborative mechanisms.

Members of collaborative mechanisms appear to seek greater flexibility, as legally binding agreements are increasingly perceived as burdensome. Since the early 2000s, the institutional basis of initiatives has moved towards non-legally binding engagements such as political declarations or joint communiqués, shifting away from traditional binding and treaty-based agreements. The initiatives considered in this study illustrate this trend, as shown in Table 1, especially when taking into consideration that the majority of them were established in the last decade. This change may represent a shift in the culture of international affairs in favour of more numerous, flexible and shorter-term initiatives.

Initiatives based on non-legally binding frameworks may benefit from the flexibility and agility of the arrangement, which can make it easier to quickly set up and amend the objectives and guiding principles. In addition, a voluntary approach makes it easier for a member to pick and choose priority projects according to interests and political goals, or on the contrary to withdraw involvement from a given project or technology area (e.g. reluctance to work on nuclear energy or CCUS technologies, versus systematic participation in renewable energy or energy efficiency-related collaborations). Members also seek less formality to increase efficiency and decrease potentially lengthy and burdensome legal or institutional processes.

Contractual or treaty-based arrangements lay out the rights and obligations of each party to the agreement up front, which means that responsibilities are clear and predefined rather than developed incrementally. However, it may be procedurally slower to implement changes and new work programmes under such arrangements.

In the selection of four mechanisms, TCPs are the only initiatives governed by a binding contractual agreement, also called the Implementing Agreement (IA). An IA contains a number of key provisions including, but not limited to, the governance structure, term, objectives, voting procedure, finance obligations and intellectual property rights. The ExCo of a TCP, which consists of one or more representatives from each participant, may amend its IA at any time, usually by unanimous vote. Interestingly, TCPs are also the longest existing initiatives within the sample with the first TCPs established in 1975, which may suggest that legally binding agreements are associated with greater longevity of collaborative work.

TCPs are generally set up with a long-term vision that is achieved under five-year terms renewed under the oversight of the CERT and its Working Parties, whereas more recent mechanisms are established to achieve predefined goals within a certain time frame, such as MI and its goal to double RD&D spending over the five-year 2015-20 period. Several TCPs created in 1975 still exist today and, under the direction of their ExCos, have adapted their programme of work to energy innovation needs in their sector.

The other three mechanisms, CEM, MI and ETIPs, are all established through a variety of non-binding arrangements such as joint communiqués, terms of reference or political declarations. Both CEM and MI have enabling frameworks that were developed after countries publicly stated their support for and commitment to the mechanism. The enabling framework may outline the endorsed mission, objectives, membership, work processes and, if applicable, the role of a steering committee. Both the CEM and MI enabling frameworks outline the process to amend or modify the text, usually by consensus, and specifically state that the framework does not create any legally binding obligations on any member.

The terms of reference (ToR) of each ETIP follows a similar format linking its work to the implementation of the SET Plan and outlining the governance structure, which usually consists of a number of different bodies such as a governing board or steering committee and working groups.

The four mechanisms have a broad umbrella mandate to support energy innovation, while activities at the project level are generally technology-specific. CEM and MI as collaborative mechanisms, for instance, have a broad mandate dedicated to clean energy. Their individual initiatives are generally dedicated to a specific sector or technology area, and some work streams are cross-cutting. Given CEM's focus on deployment and MI's on RD&D, they collectively cover the entire innovation cycle despite having distinct work programmes and deliverables, and are as a result arguably complementary mechanisms. TCPs and ETIPs are also generally dedicated to a specific sector or technology.

Table 1. Institutional basis and mandate by multilateral effort

	Institutional framework			Mandate	
	Binding	Non-legally binding			
	Legal agreement	Political declaration	Terms of reference	Global fora	Regional fora
TCPs	x			x	
MI Challenges		x		x	
CEM initiatives		x		x	
EU-ETIPs			x		x

Governments may consider different institutional approaches when establishing energy technology innovation collaborative mechanisms. Current trends suggest a growing appetite for flexible and responsive arrangements relative to traditional legally binding agreements.

The funding structure of each collaborative mechanism varies although all are predominantly funded by either voluntary financial or in-kind contributions. Each TCP, for instance, is financed by its participants through cost-shared or task-shared contributions, or a combination of both. Under the task-sharing model, participants provide in-kind resources and personnel whereas under a cost-sharing model the participants usually contribute to a common budget as well as to each initiative or task. Some TCPs combine both models, using a common fund to finance the secretariat functions of the TCP and then at project level functioning on in-kind contributions.

The CEM Secretariat is funded by voluntary contributions from the CEM member countries. The CEM initiatives themselves rely on the in-kind and voluntary contributions of the designated co-leads and initiative members. In some cases, philanthropic and multilateral foundations also intend to or already provide funding. In some instances, there may be a common fund to pay for the services provided by a third-party co-ordinator. For example, participants in the Electric Vehicles Initiative (EVI) contribute to a common fund to support the initiative's work programme and related efforts co-ordinated by the IEA.

Similarly, MI Innovation Challenges are usually solely sustained through in-kind contributions of participating governments. However, some participants have launched calls for proposals for funding projects at the national or international level (illustrated in Table 3). For example, in 2018 the Indian Department of Science and Technology announced two funding proposals of USD 5 million each to support MI member countries collaborating with Indian organisations on smart grids innovation.

As a European industry-led mechanism, ETIPs are often co-funded by the European Commission's framework programme for research and innovation (Horizon 2020) as well as by industry associations and other relevant stakeholders. For instance, the primary objective of Intensys4EU (INTegrated ENergy SYStem, a pathway for EUrope) is to provide co-ordination support to the ETIP SNET. Alternatively, ETIP secretarial duties are shared among several members with one entity acting as the lead, such as ETIP for Renewable Heating and Cooling (RHC-ETIP) in which the Association of European Renewable Research Centres (AERRC) co-ordinates efforts by the other five entities that provide analysis or logistical or communications support, through up to two employees.

Further efforts may be undertaken to analyse the funding instruments used by collaborative mechanisms. Relevant stakeholders note that both financial and in-kind contributions from members may become scarce as countries face limited budgets and capacities. Governments may be reluctant to engage in international collaboration due to the induced or perceived costs. In addition, the growing number of collaborative mechanisms has led to increasing competition with regard to funding. As a result, IEA countries and the broader energy technology innovation ecosystem may benefit from identifying best practices on how to best leverage public and private sources of funding to support innovation efforts.

Membership

Key takeaways: Membership

- Membership across the entire sample continues to grow and diversify, with an increasing role of emerging economies. Countries from the IEA family have the broadest participation across the selected mechanisms.
- Regional initiatives may allow countries that are not necessarily members of global efforts to take part in collaborative mechanisms and benefit from international co-operation. Such broad membership may accelerate innovation processes and the deployment of key energy technologies.
- There appears to be a membership overlap across collaborative mechanisms, which may facilitate or hinder cross-mechanism collaboration. For instance, all MI and CEM member countries participate in at least one TCP.
- Collaborative mechanisms and energy innovation stakeholders may benefit from further research on private-sector participation to leverage corporate capabilities.

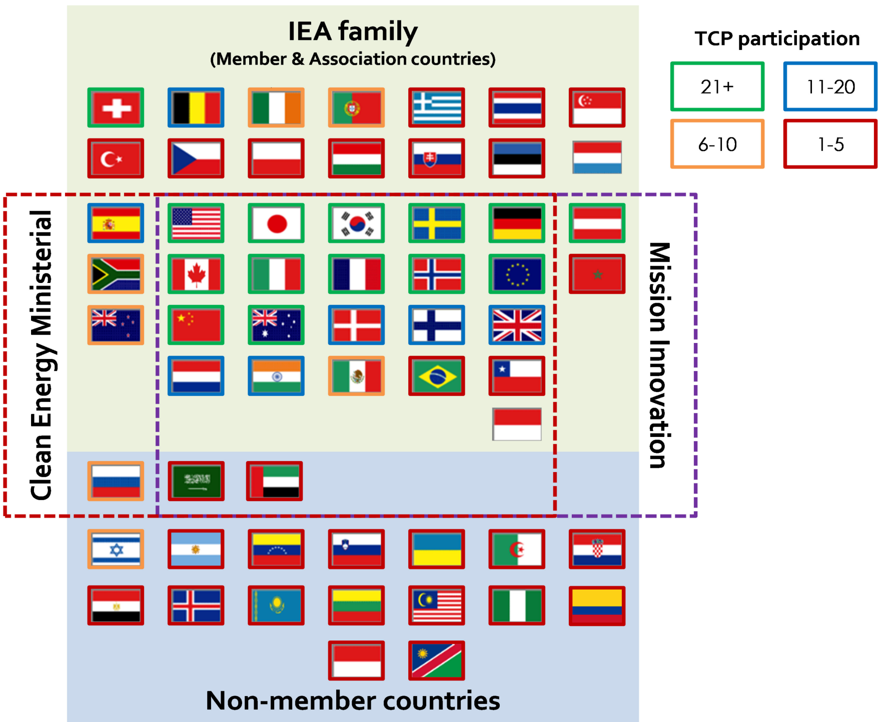
International or regional multilateral initiatives benefit from involving the broadest possible spectrum of relevant public and private stakeholders. The collective membership of the mechanisms under consideration includes national governments, international organisations, not-for-profit organisations, academia, private companies (from multinational to small and medium-sized enterprises), and individual professionals and experts. Membership across the entire sample continues to grow and diversify. In 2017, Colombia joined a TCP for the first time, followed by Argentina in 2018. MI welcomed the Netherlands as a member country in 2016, and Austria in 2017. The Netherlands joined CEM as a new member in 2018.

The IEA family (member and Association countries) has the highest participation within the selected collaborative mechanisms, with the exception of Association countries in ETIPs. The spread and diversity of membership across all initiatives highlight the extent to which many countries already work together on energy issues. In some instances, countries show a preference for a specific mechanism but eventually join the full suite of initiatives. For example, 9 of the 25 MI member countries participate in the activities of all 8 MI Innovation Challenges, and 5 other members (China, Finland, the Netherlands, Saudi Arabia and Sweden) are involved in at least 7 MI Innovation Challenges.

Among the Association countries, China has the highest membership across TCPs, CEM and MI. China is currently a member of 23 TCPs, and a few other TCPs recently invited China to join. India has the second-highest membership across these three initiatives after China, with a particularly strong presence in MI, being member of all eight challenges. South Africa participates in both TCPs and CEM but is not currently a member of MI. Saudi Arabia and the United Arab Emirates are more strongly represented in CEM and MI initiatives than TCPs.

Shown in closer detail in Figure 2, the IEA, CEM, MI and TCPs share an overlap of 22 member countries. Each of the CEM and MI member countries participate in at least one TCP with the exception of Indonesia.[7] Notably, the majority of the countries within this overlap are members of over 20 TCPs.

Figure 2. Overview of IEA family, CEM, MI and TCP membership



Note: data as of May 2019.

As collaborative mechanisms multiplied in the last decade to accelerate energy technology innovation, governments and/or public bodies have become active members in several initiatives, inducing complex membership overlaps across multilateral efforts.

[7] At the time of drafting, an Indonesian private-sector entity is in the final stage of the membership process to become a sponsor in the TCP on Greenhouse Gas R&D (GHG TCP).

Regional collaborative mechanisms also seek broad membership and may include countries not necessarily present in global initiatives. ETIPs unsurprisingly have an elevated EU membership, which includes several countries that do not participate in any of the other selected initiatives such as Lithuania, Luxembourg and Romania. In addition, ETIP membership extends more broadly to other European countries. For instance, the Bioenergy ETIP has an extensive list of stakeholders,[8] with European countries such as Bosnia and Herzegovina, Iceland and Moldova as well as a non-region-specific category for the rest of the world including 19 stakeholders.

The four collaborative mechanisms generally recognise the essential role of the private sector and seek further engagement. TCPs and ETIPs are the only two mechanisms that allow both government and non-government entities to become members. In TCPs, there are two categories of membership, contracting party for national governments and sponsor for any non-government or non-intergovernmental entity – which is a unique feature among selected mechanisms. It should be noted that despite such framework, the majority of TCP members are public bodies. Membership to CEM and MI is restricted to national governments, although a member country may designate in-country technical experts from analytical institutions to participate in an initiative on its behalf.

CEM proactively seeks further engagement with private-sector actors to leverage their expertise, influence and capital. More than 100 private-sector companies participate in the technical work of the CEM, which results from both CEM stakeholders reaching out to private-sector actors, and vice versa. CEM also leads, in collaboration with the IEA, an Investment and Finance Initiative (CEM-IF) that aims at sharing best practices and co-operating to develop "frameworks conducive to mobilizing investment and financing, particularly from private sources, for deployment of clean energy at scale", which aligns with the purpose of further engaging with private actors. Activities that engage with industry may benefit from a market-driven perspective.

Engaging with the private sector remains challenging, in part due to public-private cultural differences but also due to diverging interests. Relevant stakeholders acknowledge that collaborative mechanisms that rely on public participants for the most part may not be adapted to private-sector actors. Before engaging in collaboration, industry stakeholders generally seek concrete roadmaps and work programmes, and clear definitions and directions related to mandate, inputs, activities and expected outputs. While they are likely to engage with pubic bodies to seek funding or advance their policy interests, they are less likely to engage in information-sharing activities given their tendency towards confidentiality and competitiveness, and their general adversity to political-level interactions. For these reasons, stakeholders may benefit from further analysis related to private-sector involvement to best leverage private-sector capabilities.

[8] The Bioenergy ETIP defines stakeholder as members of the European Biofuels Technology Platform (EBTP) steering committee, working groups and task forces; organisations that have directly registered their details with the platform and/or have attended the stakeholder plenary meetings; or organisations that are active in advanced biofuels RD&D in Europe (these are included to provide a comprehensive view of European biofuels and bioenergy research and industry – a listing does not imply the organisation is actively participating in ETIP Bioenergy).

Sector and/or technology focus

Key takeaways: Sector and/or technology focus

- The majority of initiatives under the selected mechanisms focus on low-carbon energy innovation (renewable energy, energy efficiency, system integration). There is a growing attention on cross-cutting themes, but many activities remain sector- or technology-specific.
- There appears to be substantial overlap between sector or technology focus areas across the selected mechanisms. In eight instances, three or four of the mechanisms conduct work on the same technologies. Popular themes include CCUS, smart grids and solar.
- Duplication of efforts may dilute attention from policy makers and induce fundraising or political support challenges. Mechanisms would benefit from the identification of opportunities for synergies, resource and expertise sharing, and co-location for events.

Under their collaborative mechanisms' umbrella mandate covering the entire energy spectrum, individual initiatives are generally technology-specific, with a trend towards cross-cutting themes. None of the mechanisms under consideration are sector-specific, although there are different thematic trends within each mechanism. TCPs illustrate a sectoral or technology-specific focus. They are generally categorised first by sector (e.g. buildings, transport), then by technology area (e.g. district heating and cooling, heat pumping, advanced fuel cells, hybrid and electric vehicles). Collectively, TCP initiatives (ranging from RD&D to technology policy analysis) cover most of the energy spectrum and are relatively evenly spread across sectors and technologies, including fossil fuels. Similarly, industry-led ETIPs tend to focus on a given technology (e.g. bioenergy, wind, deep geothermal). There are two TCPs explicitly focused on cross-cutting technologies, as well as two ETIPs (RHC-ETIP, SNET), which is relatively fewer than in MI or CEM.

MI Innovation Challenges, for instance, involve both cross-sector, cross-technology activities (smart grids, off-grid access to electricity, converting sunlight, clean energy materials, affordable heating and cooling in buildings) and technology-specific activities (carbon capture, sustainable biofuels, renewable and clean hydrogen). Similarly, CEM work streams cover both energy supply and demand sectors, with an increasing focus on system integration. Several CEM cross-cutting initiatives provide support to the whole spectrum of clean energy. The variety and number of cross-cutting initiatives among these more recent global collaborative mechanisms suggest that integration technologies such as smart grids, power systems and hydrogen are playing an increasingly important role.

The selected collaborative mechanisms generally focus on renewable energy, energy efficiency and cross-cutting technologies, as well as systems integration. There is a slightly stronger concentration of initiatives related to renewable energy compared with energy efficiency and cross-cutting technologies. There are numerous TCPs and ETIPs dedicated to a single renewable energy source, although neither mechanism was created with a specific renewable energy mandate. Conversely, all of the mechanisms have one initiative dedicated to carbon capture and storage (CCS), which suggests that it remains a priority technology for RD&D. Compared with the other mechanisms, there are several TCPs focused on fossil fuel technologies; initiatives established more recently appear to focus on non-fossil fuel energy sectors.

There appears to be a substantial overlap in sectoral or technology focus areas across collaborative mechanisms. An overview of the sector and technology areas covered by the selected collaborative mechanisms against the IEA TCEP classification is presented in Table 2. The IEA TCEP work streams track the progress of key sectors and technology areas against where they need to be to achieve global energy transition goals. As part of its growing focus on innovation, TCEP will increasingly provide information related to energy technology innovation.

The following observations can be made:

- There are at least three cases where all four mechanisms conduct work on the same technologies: 1) CCS; 2) smart grids (including smart cities); and 3) solar power (including photovoltaics, sunlight conversion technologies and solar thermal power).
- There are at least five cases where three mechanisms conduct work on the same technologies: 1) heating and cooling (which includes renewables, solar, heat pump technologies and general building equipment); 2) nuclear power; 3) bioenergy (including biofuels) ; 4) wind power; and 5) hydrogen.[9]
- There are at least five cases where two mechanisms conduct work on the same technologies: 1) appliances and lighting; 2) electric vehicles; 3) geothermal power; 4) ocean power; and 5) power systems.

It is apparent that numerous initiatives are focusing on the same sector or technologies, which may indicate possible synergies. This analysis does not take an in-depth look at the specific work of each initiative, and detailed information is not always publicly available. As a result, initiatives under the selected collaborative mechanisms may well work on different aspects of the same sector or technologies, which would explain an overlap. In such instances, enhanced cross-mechanism collaboration may optimise this complementarity and ensure efforts are not duplicated. Duplication is likely to dilute attention from policy makers and may as a result induce fundraising or political support challenges. Relevant stakeholders acknowledge that even in those instances where efforts are not duplicated, the perception of duplication induces a degree of competition, including for funding.

In areas where there are overlapping interests, initiatives may benefit from identifying opportunities to collaborate directly, co-establish strategic priorities, share knowledge and networks, co-locate events (e.g. conferences, workshops and member meetings), and communicate together, so as to boost efficiency and the pool of resources. Co-branding of relevant innovation activities may increase impact and allow reaching broader audiences.

Further efforts may be undertaken to examine how cross-mechanism collaboration can help avoid the duplication of efforts. Each collaborative mechanism may focus on its specific value added, expertise and network, and collaborate with other mechanisms to maximise the impact of collective efforts. Internal periodic assessment of activities and outputs against that of other mechanisms may also help the relevant stakeholders better understand the broader innovation landscape and increase confidence in collaborative mechanisms' ability to deliver on strategic priorities.

[9] CEM is expected to expand its work streams to hydrogen-related technologies, including via its recent Nuclear Innovation: Clean Energy Future (NICE Future) partnership (CEM News, May 2018).

Table 2. Sector and technology focus of the selected multilateral efforts

<table>
<tr><th></th><th>TCPs</th><th>MI Innovation Challenges</th><th>CEM initiatives</th><th>EU-ETIPs</th></tr>
<tr><td rowspan="2">Buildings</td><td colspan="2">Heating and cooling</td><td></td><td>Heating and cooling</td></tr>
<tr><td>Appliances, lighting</td><td></td><td>Appliances, lighting</td><td></td></tr>
<tr><td rowspan="4">Fossil fuels</td><td colspan="4">CCUS</td></tr>
<tr><td>Oil recovery</td><td></td><td></td><td></td></tr>
<tr><td>Greenhouse gas</td><td></td><td></td><td></td></tr>
<tr><td>Gas and oil</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Industrial processes</td><td>Energy intensity</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Standards</td><td></td></tr>
<tr><td>Nuclear power</td><td>Nuclear energy</td><td></td><td colspan="2">Nuclear energy</td></tr>
<tr><td rowspan="6">Renewables</td><td colspan="2">Bioenergy and biofuels</td><td></td><td>Bioenergy and biofuels</td></tr>
<tr><td>Wind</td><td></td><td colspan="2">Wind</td></tr>
<tr><td colspan="4">Solar PV, solar thermal, sunlight conversion</td></tr>
<tr><td>Geothermal</td><td></td><td></td><td>Geothermal</td></tr>
<tr><td>Ocean</td><td></td><td></td><td>Ocean</td></tr>
<tr><td>Hydropower</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Transport</td><td>Electric vehicles</td><td></td><td>Electric vehicles</td><td></td></tr>
<tr><td>Fuel economy</td><td></td><td></td><td></td></tr>
<tr><td rowspan="8">Cross-cutting themes and energy integration</td><td colspan="4">Smart grids, smart cities</td></tr>
<tr><td colspan="3">Hydrogen</td><td></td></tr>
<tr><td>Demand management</td><td></td><td></td><td></td></tr>
<tr><td>Scenario modelling</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Clean materials</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Power systems</td><td></td></tr>
<tr><td></td><td></td><td>Finance</td><td></td></tr>
<tr><td>Gender</td><td></td><td>Gender</td><td></td></tr>
</table>

There are apparent overlaps between sector or technology focus areas across the selected energy technology innovation collaborative mechanisms. Enhanced cross-mechanism co-ordination may help avoid the duplication of innovation efforts.

Activities: Scope and outcomes

Key takeaways: Activities

Scope of activities

- All four mechanisms appear to conduct activities of similar types, such as stakeholder dialogue, analyses and reports, and capacity building. As a result, there may be an opportunity to conduct these activities jointly.
- Fewer activities involve direct energy technology RD&D. Conversely, a growing number of activities offer funding opportunities.
- Further analysis may refine activity categories, provide a detailed list of what mechanisms do and identify areas for potential consolidation.

Measuring activity outputs and outcomes

- Monitoring outputs and outcomes may help collaborative mechanisms optimise resource use, set strategic priorities and increase visibility.
- Collaborative mechanisms typically conduct such evaluation annually, though generally for internal distribution only. More publicly available information may facilitate strategic engagement across partnerships.
- Recent trends suggest that constructive evaluation and feedback frameworks, such as recent encouraging informal reviews by CEM, help members and stakeholders improve the mechanism's activities and increase the impact of its work.

Scope of activities

As acknowledged in the previous subsection, this paper does not attempt to provide in-depth analysis of all activities undertaken by the selected collaborative mechanisms, but instead a high-level overview seeking to help identify areas of potential cross-mechanism collaboration.

While all mechanisms fall under the umbrella mandate of supporting energy innovation, day-to-day activities may take significantly different shapes. Preliminary analysis of ongoing or recent initiatives suggests that they can be broken down in at least five categories: 1) direct technology RD&D; 2) events and stakeholder dialogue; 3) technology innovation analysis (e.g. policy, market, technology readiness); 4) capacity building and dissemination; and 5) funding for innovation. Further research may refine and expand these categories, while ensuring they are mutually exclusive and collectively exhaustive. Such categorisation may help policy makers identify whether activities can be conducted jointly between two mechanisms, or whether some activities are not performed enough.

A selection of activities undertaken by the four collaborative mechanisms is featured in Table 3, along the proposed categories. Although this paper does not attempt to cover all activities, the following general observations can be made:

- **Stakeholder dialogue, innovation roadmap design and technology policy analysis are the prevalent types of activity**. High- and working-level dialogues on innovation policy, for instance, take place across all four collaborative mechanisms in international, sector-specific and regional fora, committee and Working Party meetings, and workshops. Cross-mechanism collaboration may allow conducting such activities jointly, where relevant.

- **There is relatively less emphasis on direct RD&D**. Only some TCPs directly undertake laboratory RD&D, although many initiatives under the other mechanisms produce technology reports and studies. Figure 3 illustrates how the vast majority of TCPs carry out energy technology analysis and dissemination activities, many carry out applied research and innovation activities (technology readiness levels [TRLs] 6-9), and only some carry out fundamental research on pre-commercial technologies (TRLs 1-5).
- **There is a growing number of initiatives providing competitive funding or grant opportunities** to facilitate the development of energy technologies.[10] This trend may allow collaborative mechanisms to finance early-stage RD&D, for instance, without directly conducting it themselves. Cross-mechanism co-ordination may be relevant in this regard. TCP stakeholders may choose to seek new funding with another mechanism equipped with funding instruments; in parallel, TCPs may help stakeholders in charge of funding initiatives to identify strategic technologies or innovation gaps that may require funding, and co-design calls for proposal.

Cross-mechanism collaboration may increase the impact of ongoing activities. Given the overlaps identified in the previous subsections (membership, sector or technology focus areas), there may be an opportunity to conduct some initiatives jointly, for instance activities with potential overlap which run separately today.

Further efforts, in collaboration with the relevant stakeholders, may be undertaken to 1) refine the categorisation of activity types,[11] 2) provide an exhaustive list of all ongoing initiatives across the selected mechanisms; 3) identify possible synergies (e.g. co-location of events, joint reports) or activity areas possibly undercrowded (e.g. direct RD&D); and 4) examine best practices regarding funding innovation and explore co-funding scenarios.

Table 3. Sample of initiatives by selected collaborative mechanisms

Categories	TCPs	CEM	MI	ETIPs
Technology RD&D	• Joint Annex development of affordable domestic heat pump/storage system under IC7 (HPT TCP/ECES TCP) • Modelling (AFC TCP, ETSAP TCP) • Pilot projects (EBC TCP, CTP TCP)			
Stakeholder dialogue and events	• Conferences e.g. International Conference on Solar Heating and Cooling for Buildings and Industry (SHC TCP) • Peer-to-peer workshops (majority)	• Annual ministerial meetings (Secretariat) • Workshops targeting state-level policy makers (21CPP, NICE Future, CCUS, SCET, PSF, LTES, DG Campaign) • Campaign events such as the Equal by 30 (C3E), distributed generation campaign	• Annual ministerial meetings (Secretariat) • Deep dive workshops (IC1 and IC6)	• Regional workshops (all)

[10] This reflects the broader trend of access to finance for climate technologies (UNFCCC, 2016). "There are a growing number of initiatives and projects that are providing access to finance for climate technologies. Project developers and climate technology companies, however, continue to experience difficulties in accessing public and private finance, particularly for new technologies with a limited track record in a market and with higher capital costs. At the same time, financiers and investors complain about the lack of investible projects."

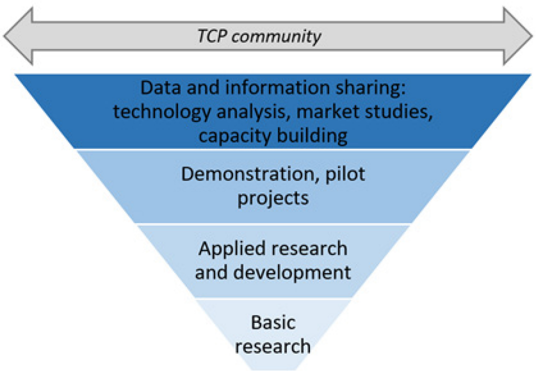
[11] For instance, analysis by approach (e.g. technology, economy, policy) or by TRL (ETIP SNET, 2019).

Categories	TCPs	CEM	MI	ETIPs
Innovation analysis (tech, policy, market)	• Reports and publications e.g. Spotlight on Ocean Energy (OES TCP, 2018), Wind Energy in Cold Climates (Wind TCP, 2018)	• Thought-leadership publications (21CPP) • Policy Insights (ISGAN) • Product-specific technical analyses (SEAD) • Global EV Outlook (EVI; IEA, 2019d)		• Reports (e.g. Future emerging technologies for the ocean energy sector (JRC 2018) and Digitalization of the energy system and customer participation (ETIP SNET, 2018))
Capacity building	• Online academy – regular webinars (DSM, ISGAN, SHC, CCC, GHG, Bioenergy & PVPS TCPs)	• Global EV Pilot City Programme (EVI; IEA, 2018c) • Online Academy (ISGAN) • Expert Knowledge Exchanges (21CPP) Ask an Expert Platform (Solutions Centre)		• Webinars (ETIP Ocean, ETIP SNET)
Funding for innovation	• Grants: by grant selection, provide funding to DHC projects from its membership (DHC TCP)	• Awards and prize money (Global LEAP, EMWG, ISGAN, C3E)	• Call for funding proposals (IC1 and IC2)	

Note: See abbreviations and acronyms table.

There are overlaps between activity types across collaborative mechanisms, particularly regarding stakeholder dialogues and events, innovation analysis and capacity building. Policy makers should aim for a consolidation of efforts (e.g. co-location of events, joint reports and disseminations).

Figure 3. Overview of TCP activities



TCPs are the only mechanisms in the selection to directly conduct energy technology RD&D. Fewer TCPs carry out TRL 1-5 basic research; many carry out TRL 6-9 applied research or demonstration; all conduct technology, market or policy analysis.

Outputs and outcomes

Another tool policy makers may use to identify areas for strategic engagement with other initiatives is an effective evaluation framework.

Evaluation frameworks are based on the regular monitoring and measuring of an initiative's outputs and outcomes. The outputs of an initiative are what the initiative produces: a report, an event for stakeholder dialogue or a training session. Measuring output implies monitoring the initiative and regularly compiling the number of such outputs: the number of reports or events in a given year, the number of stakeholders who benefit from the initiative's trainings. The outcomes of an initiative are the shifts, benefits or consequences resulting from the outputs: an innovation policy adopted by the government of a member country based on a policy report and recommendations, an increase in technology performance following resource sharing between two research institutions, increased knowledge of policy makers following a stakeholder dialogue. Measuring outcomes, where possible, implies a focus on the impact of an initiative and an objective assessment of whether activities deliver on the expected goals or targets. For instance, while webinars and online academies are increasingly used for capacity building, further research and analysis would be required to measure the impact of participation and dissemination. As a result, measuring outputs and outcomes may play a key role in improving the effectiveness of collaboration efforts and increasing visibility and impact.

Evaluation frameworks may be valuable tools for collaborative mechanisms to optimise resource use, set strategic priorities and increase visibility. Mechanisms may monitor activities and regularly check whether they deliver on expected goals to better understand the ecosystem around the initiative, including: whether the initiative receives enough funds, resources or political support; whether it could benefit from a cross-mechanism collaboration due to visible synergies; whether the co-ordinating entity is successful in engaging with the relevant stakeholders including private-sector actors; whether the work stream is still compatible with members' priorities or whether it should be discontinued after a given period. By keeping an overview of their initiatives, mechanisms may 1) optimise resource use by focusing on strategic initiatives and/or phasing out outdated ones; 2) dynamically refine priorities and become more flexible, thereby delivering on a growing appetite for responsiveness, as examined previously; 3) increase visibility and impact by showcasing success stories; 4) enhance transparency in relation to their funders, members and stakeholders, which may increase confidence in the co-ordinating entity and the mechanism's governance, and overall facilitate fundraising for future activities.

At present, most partnerships conduct their own internal reviews. This information is usually not made publicly available. However, the selected mechanisms use such reviews to track their progress and implementation. For example, the relevant IEA Working Parties, under the direction of CERT, review TCPs at the end of each five-year term if a new term is requested. This approach is particularly important for initiatives such as those under MI Innovation Challenges, where members have committed to deliver results within a specific time frame. MI regularly reviews and tracks the progress of its Innovation Challenges, seeking to identify and address any hurdles well ahead of the agreed target date. Mechanisms and the broader innovation ecosystem may benefit from more publicly available information on ongoing activities to identify areas of possible collaboration.

The ability to put forward new ideas and create additional work streams is facilitated by a mechanism's governance structure. CEM and MI, for instance, use a distributed leadership model where several co-leads are in charge of co-ordinating activities. All eight MI Innovation

Challenges have at least two co-leads, and nine countries participate in all MI Innovation Challenges, which allows the mechanism to share best practices internally among initiatives.

While the perception of evaluation frameworks tends to be negative, there are encouraging examples of constructive and successful models. CEM, for instance, conducts formal reviews every two years, through an independent panel of experts that conducts interviews, examines reports, and maps and investigates all activities. This review remains private for CEM members. In addition to these formal evaluations, an informal review by the CEM members and the Secretariat has been recently tested. It consists of three consecutive steps. 1) The Secretariat sends a questionnaire to all of the mechanism's initiatives, asking about their annual activities and specific achievements. CEM stakeholders prepare written and oral responses to these questions. 2) Later, in an informal, open meeting in front of all CEM members, the same questions are asked orally to each initiative, which in turn presents its conclusions. The presence of CEM members as well as of representatives from other initiatives ensures the quality of interventions. 3) Following these written and oral responses, CEM members collectively attribute a "score" to each activity, such as "green" or "orange", accompanied with detailed recommendations and/or requests.

An initiative is typically "green" when it presents a detailed work programme, tangible outputs and outcomes, a strategy to deliver on key priorities or meet specific goals, or other satisfactory components. An initiative may be attributed with an "orange" score because CEM members seek more information related to their detailed roadmap, without implying that ongoing activities are not delivering. Upon provision of a more detailed work programme or the requested information, the initiative can move back to the "green" category. In addition to the "green" and "orange" categories, CEM members may choose to discontinue some activities because they achieved the expected goals under their mandate ("graduates") or because the initiative does not align well enough with the mechanism's overarching strategy.

Such an evaluation framework may bring benefits to stakeholders. Following the first instance of this CEM test review, the vast majority of initiatives scored "green" either directly or after providing more detailed work programmes upon scoring "orange". This suggests that CEM stakeholders assessed their own activities, outputs and outcomes, and confronted these to their mandate and expected goals, which is beneficial for the initiative's credibility, visibility and efficiency. The test review also allowed CEM members to better understand the specific activities undertaken under their mechanism's initiatives, and to ensure resources are used effectively in accordance with their priorities. Two activities were discontinued, one being a CEM "graduate" after CEM members concluded it achieved its mandate, one because it did not align well with CEM priorities anymore.

Policy makers may benefit from systematic and regular feedback processes. To that end, further efforts may be undertaken to 1) identify best practices in how to monitor and evaluate the activities under key collaborative mechanisms; 2) provide key metrics relative to outputs and outcomes to innovation stakeholders; and 3) assist with the design, testing and co-ordination of evaluation frameworks so that they benefit both members and innovation stakeholders and provide constructive feedback to the ecosystem.

Cross-mechanism interactions

Key takeaways: Cross-mechanism interactions

- The selected collaborative mechanisms present a varied but substantial level of interaction among them. Technical and/or working-level collaboration is the most common form, before political support and formalised collaboration.
- There is a growing number of and interest in cross-mechanism co-ordinated initiatives. Policy makers could further explore such opportunities, including between early-stage innovation and deployment-related initiatives.
- Cross-mechanism collaboration requires effective and streamlined co-ordination. Further efforts may be undertaken to examine the role of co-ordinating entities in a mechanism's ability to coordinate externally, identify best practices in existing interactions, and explore frameworks for effective co-ordination.

An examination of the connections among the selected collaborative mechanisms shows that there is a varied but substantial level of interaction among them. It is clear that the mechanisms are not operating in isolation and appear to have an awareness of the technical work of the others. The mechanisms were analysed against three types of connections: 1) institutional arrangements (memoranda of understanding, letters of intent and other formal agreements); 2) political support (referencing other initiatives in high-level documents); and 3) working level (e.g. regular technical collaboration, participation in workshops and meetings).

Technical and working-level interaction is the most common interaction, for each mechanism working with the other three, as shown in Figure 4. This form of interaction may include participating in the work programme of an initiative, presenting at a technical workshop or sharing research information. Political support, such as referencing another initiative in high-level documents, was the second-most-common interaction. Finally, at present, there is only one instance of an MI Innovation Challenge having formalised co-operation with a TCP that is also a CEM initiative (read below: International Smart Grid Action Network [ISGAN]).

Figure 5 provides a simplified representation of the intensity of these relationships in terms of number of collaborations among initiatives under each of the mechanisms. A detailed overview of these interactions also shows substantial interaction among initiatives under the same mechanism, notably across TCPs and across CEM initiatives.

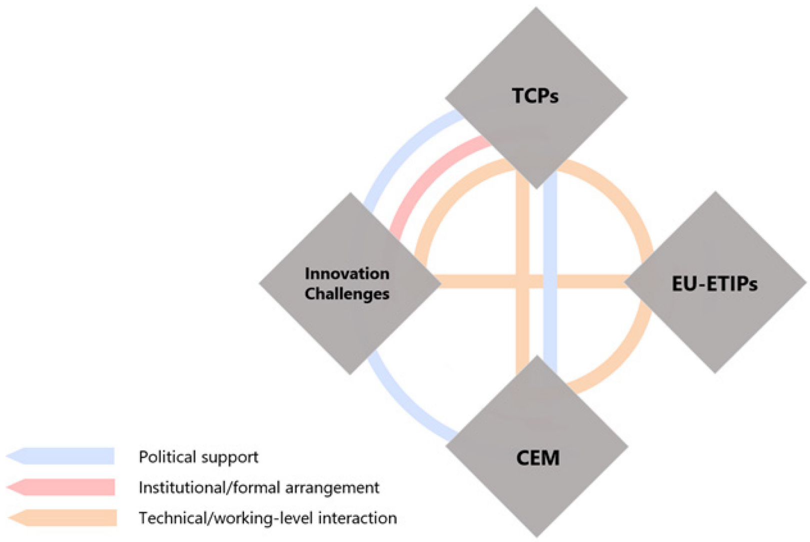
CEM initiatives and MI Innovation Challenges are linked by the complementarity of their respective mechanism's mandate. CEM and MI hold annual consecutive ministerial meetings allowing for high-level political support of both the energy technology innovation RD&D through MI and deployment through CEM. However, CEM and MI do not interact at the working level, which may be due to the fact that the two mechanisms aim at tackling different challenges. While some solutions may be equally beneficial to earlier stage RD&D (MI) and to deployment-related challenges (CEM), in many cases the policy response is likely to be different. Nevertheless, deployment-related considerations may provide valuable feedback loops to early-stage innovation processes, as explained in Section A. As such, within the limits on how far approaches could be aligned, both mechanisms support closer co-ordination. Similarly, at a substantive level, there are many areas in which both CEM and TCPs are active and could explore further opportunities for collaboration. The TCP on Clean

Energy, Education and Empowerment (C3E TCP) that is also a CEM initiative provides an interesting case study with its own benefits and challenges.

MI and TCPs interact using all three types of connection, which may indicate that the two mechanisms are mutually supportive, allowing each to benefit from the institutional basis and structure of the other. As part of MI Innovation Challenge 7 related to affordable heating and cooling of buildings, for instance, Heat Pumping Technologies TCP and Energy Storage TCP (ECES TCP) are collaborating on the construction of a Comfort and Climate Box. The contractual arrangements of TCPs, which usually include multi-annual work plans, may offer structure for the MI Innovation Challenge proposals and grant offers. The similarities in sector and technology focus of these two initiatives may also be a contributing factor to the connections.

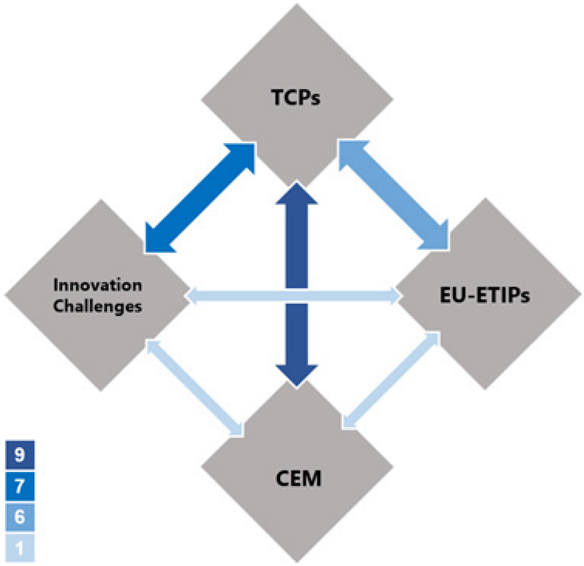
Current trends suggest a growing interest among innovation stakeholders for cross-mechanism collaboration. In recent years, for instance, the CEM steering committee has been proactively examining potential interactions with other collaborative mechanisms, with early achievements such as avoiding event-scheduling conflicts. On substance, several technology areas have been identified as strategic for further co-ordination, particularly with MI Innovation Challenges or TCPs that address earlier stages of innovation. These could include areas previously identified in Table 2, such as CCUS, hydrogen, energy efficiency, and heating and cooling, as well as the example of smart grids detailed below.

Figure 4. Relationships among selected collaborative mechanisms



Working-level interactions are the most common, for each mechanism working with the other three. Policy makers and energy innovation stakeholders may benefit from further analysis assessing the strength of these interactions per activity type, and the inclusion of other regional mechanisms.

Figure 5. Intensity of relationship among selected mechanisms (number of recorded interactions)



Among selected mechanisms, TCPs rank highest in terms of number of interactions with other mechanisms, even when accounting for the greater number of TCPs.

Out of the 22 CEM initiatives and campaigns, only one explicitly engages with MI Innovation Challenges at present. **ISGAN** is an existing collaboration between CEM and the IEA TCP ecosystem, being both a CEM initiative and a TCP. After having identified possible synergies between existing activities and MI Innovation Challenge 1 related to smart grids, ISGAN and MI signed a letter of intent "to foster effective collaboration and to further explore opportunities for joint activities on … Smart Grids as storage integration and flexibility options" such as joint workshops (ISGAN, 2018).

Innovation stakeholders acknowledge that engaging with other collaborative mechanisms can be challenging. While a given country may be part of several collaboration mechanisms, it is likely to be represented by different public institutions, ministries or agencies in each mechanism, which may be an enabler or a barrier to effective co-ordination. Differences in leadership, responsibilities, underlying interests or political power may influence the ability to collaborate across mechanisms. Public bodies are also under increasing resource pressure (e.g. funding, staff, capabilities). Whether contributions are funding or in-kind, members may lack the necessary capacity to engage in cross-mechanism collaboration, although co-ordination generally increases efficiency and optimises resource use. As a starting point to initiate cross-mechanism co-ordination, collaborative mechanisms should regularly explore co-location opportunities for conferences and meetings, and co-branding for relevant innovation activities, as outlined in the previous subsections.

The broad variety of co-ordination instruments used internally may challenge a mechanism's ability to co-ordinate externally. Given that the co-ordinating entity changes from one initiative to another (within the same mechanism), and that not all co-ordinating entities are of the same type, there is no general, streamlined rule for cross-mechanism collaboration. An initiative's likelihood to engage with an activity from another mechanism may greatly depend on the co-ordinating entity's own interests, networks and resources.

Some initiatives may engage in cross-mechanism collaboration thanks to their co-ordinating entity's connections in a given sector, whereas others may not because their co-ordinating entity lacks the necessary resources or bandwidth.

Cross-mechanism collaboration requires effective and streamlined co-ordination, based on each mechanism's internal co-ordination instruments. The selected collaborative mechanisms vary in structure, although most activities are supported by a secretariat or co-ordinator. Different mechanisms use a variety of titles for the same type of function. TCPs are usually supported by an OA (similar to an executive secretary) who acts as the legal personality of the TCP. An OA may enter into contracts on behalf of the TCP, hold intellectual property, manage the accounts and provide strategic guidance on the TCP's work programme. Some TCPs have a secretary, which may or may not be in addition to the OA, specifically dedicated to the administration and organisation of meetings and documents.

Under the CEM, each initiative has a lead member country (or co-leading countries), and co-ordinator or OA, adopting a broad variety of co-ordination and operation models. For the majority of CEM initiatives and campaigns, the lead member country or countries appoint a globally recognised technical institution to provide analytical support as well as the organisational and logistical services. In some instances, such as the EVI, Power System Flexibility campaign and CEM-IF, the IEA acts as co-ordinator under agreed ToRs. The National Renewables Research Laboratory (NREL) acts as the operating agent for the 21st Century Power Partnership, the Clean Energy Solutions Centre and the NICE Future initiatives. In this role, NREL is responsible for executing the programme of work, ensuring stakeholder co-ordination, marketing and communications functions, analysis, and all other products and services that the initiatives provide. The IEA and IRENA co-ordinate the Multilateral Solar and Wind Working Group. IRENA acts as co-ordinator of the CEM Campaign on Long-Term Energy Scenarios (LTES). CEM is also promoting a construct where an international organisation partners with a national technical institution to share the operating agent and/or co-ordinator functions. For example, the IEA and the China Society of Automotive Engineers – Shanghai International Automobile City Group co-host the secretariat of the Pilot City Programme under the EVI.

The role of the co-ordinating entity in cross-mechanism collaboration could be further investigated. Using different co-ordinating instruments internally allows mechanisms to identify and learn best practices related to working with different types of stakeholders. To streamline external co-ordination, collaborative mechanisms may examine the specific mandate given to co-ordinating entities regarding strategic engagement with other ongoing initiatives, and assess whether these should be given a more proactive role in doing so.

To that end, further efforts could be undertaken to 1) refine the classification and analysis of existing connections, particularly for working-level interactions (participation in events, joint research and publications, or proactive resource sharing are all working-level interactions of different strengths); 2) examine the influence of internal co-ordination instruments on a mechanism's ability to engage externally; and 3) explore success stories and best practices of initiatives collaborating across different mechanisms.

Conclusion

The ambition is for this paper to serve as a starting point in fostering co-operation among collaborative mechanisms active in the field of energy technology innovation. Further research should be conducted, in collaboration with the relevant stakeholders, building on the following key observations.

Policy makers and energy technology innovation stakeholders may benefit from an online, searchable repository of all collaborative mechanisms classified by type, publicly available and regularly updated. A repository may help policy makers fully understand the landscape of energy innovation partnerships, and specifically the differences and/or similarities among them. The relevance and feasibility of such listing could be further discussed with relevant stakeholders, acknowledging existing efforts to map multilateral initiatives. If materialised, it could be featured on the IEA Innovation web portal (www.iea.org/innovation).

Collaborative mechanisms may benefit from enhanced, streamlined co-ordination among complementary or similar initiatives. The analysis of selected mechanisms and an overview of the broader innovation ecosystem suggest that mechanisms appear to present a certain degree of overlap: membership, sector and/or technology area, types of activities, etc. Overlaps may be complementary, but may also lead to greater competition for resources and support, and in some cases to the partial duplication of efforts. Further efforts could be undertaken to better understand and quantify these risks, in collaboration with the relevant stakeholders. It is also often challenging for collaborative mechanisms to identify possible synergies and engage with other ongoing activities. There is an opportunity to support multilateral initiatives in further interacting with one another, and in designing effective co-operative frameworks. Stakeholder events such as the TCP Universal Meeting provide occasions to identify opportunities to further strengthen innovation partnerships and enhance communication of related outputs.

Collaborative mechanisms appear to seek further private-sector engagement. Public bodies are not the sole actors in energy technology innovation, and policy makers increasingly seek to tap into the private sector's investments and capabilities. Relevant stakeholders acknowledge that public-private co-ordination should be strengthened, while noting the challenges in doing so – often due to cultural differences or diverging interests. Further efforts could examine best practices related to private-sector engagement in energy technology innovation, and provide support to multilateral initiatives in doing so.

Output-oriented frameworks to evaluate ongoing activities could be further explored and tested. Evaluation frameworks that regularly monitor the advancement of initiatives by focusing on outputs and outcomes may help optimise allocation of innovation efforts. The benefits of such frameworks, however, need to be communicated to the public to mitigate the risk of adverse perception. Recent instances of new evaluation practices show that a constructive and inclusive framework can help initiatives deliver on their strategic goals. Further efforts could provide support to collaborative mechanisms in building, testing and implementing these tools.

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Annexes

Background on CERT Task Force #1

CERT's established role among IEA standing groups and committees is to promote and implement co-operation on energy research and development.[12] In June 2017, CERT approved the *IEA Medium-Term Strategy for Energy Research and Technology 2018-2022* [IEA/CERT(2017)15] (IEA, 2018). The governing board approved and IEA ministers endorsed the strategy at the IEA ministerial meeting on 7-8 November 2017. The strategy affirms the role of the IEA Secretariat and CERT to continue to support, facilitate and co-ordinate the IEA's collaboration with other international partnerships and multilateral initiatives, in light of the evolving landscape of multilateral initiatives on energy technology research, innovation and deployment.

At the 79th CERT meeting on 13-14 February 2018, CERT delegates considered the committee's strategic key priorities for 2018 and the term of the strategy. To support these priorities through a shared leadership model, delegates agreed to establish three CERT Task Force groups to be supported by the IEA Secretariat; CERT Task Force #1 on Partnerships, CERT Task Force #2 on CERT Operations, and CERT Task Force #3 on TCPs Enhancement. The mandate of CERT Task Force #1[13] is to examine the potential linkages and synergies with international partnerships and multilateral initiatives relevant to CERT and IEA activities.

CERT delegates discussed this mandate and possible activities at the 80th CERT Meeting on 4-5 June 2018. These discussions led to the development and circulation of a survey to all CERT delegates. The survey aimed to gather delegates' views on three topics: enhancing the strategic value of CERT, actions to make CERT operations more dynamic and maximising the benefits of attending CERT meetings. Delegates were asked to identify partnerships and initiatives of high national interest, and to offer directions on future IEA Secretariat and CERT activities.

Based on the results of the 2018 CERT survey, the IEA Secretariat has been asked to prepare a short paper on priority partnerships and multilateral initiatives selected by CERT delegates. This paper seeks to present the main trends and provide recommendations to the IEA and CERT delegates to enhance collaboration with these initiatives.

[12] IEA (1975), IEA/GB(75)94, Annex II, paras (e)

[13] Task Force #1 members include Amanda Wilson (lead, Canada), Alicia Mignone (CERT chair), Nicole Thomas (Australia), Anne Sofie Bender (Denmark), Peter Horvath (European Commission), Pentti Puhakka/Pia Salokoski (Finland), Michele de Nigris (Italy), Nelson Mojarro (Mexico), Torgeir Knutsen (Norway), Lars Guldbrand (Sweden), Steve Martin (United Kingdom) and Nicholas Sherman (United States), as well as Simone Landolina and Claire Hilton (IEA Secretariat).

Abbreviations and acronyms

ACEC	Africa Clean Energy Corridor
AERRC	Association of European Renewable Research Centres
AfDB	African Development Bank
APEC	Asia-Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
APP	Asia-Pacific Partnership on Clean Development and Climate
ASEAN	Association of Southeast Asian Nations
AU	African Union
BfP	Biofuture Platform
BMZ	German Federal Ministry for Economic Co-operation and Development
CCS	carbon capture and storage
CCSE	Climate Change and Sustainable Energy
CCUS	carbon capture, utilisation and storage
CEEDS	Cooperative Energy Efficiency Design for Sustainability
CEM	Clean Energy Ministerial
CERT	Committee on Energy Research and Technology's
CETP	Clean Energy Transitions Programme
CO_2	carbon dioxide
COP	Conference of the Parties
CORDIS	Community Research and Development Information Service
CTCN	Climate Technology Centre and Network
DANIDA	Danish International Development Agency
DoE	Department of Energy
EAC	East African Community
EACREEE	East African Centre of Excellence for Renewable Energy and Energy Efficiency
ECCJ	Energy Conservation Center, Japan
ECOWAS	Economic Community of West African States
ECPA	Energy and Climate Partnership of the Americas
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EERA	European Energy Research Alliance
EII	European Industrial Initiative
EIT	European Institute of Innovation & Technology
ETIP	European Technology and Innovation Platform
EU	European Union
EVI	Electric Vehicles Initiative
EWG	Energy Working Group
ExCo	executive committee
G7	Group of Seven
G20	Group of Twenty
GCIP	Global Cleantech Innovation Programme
GEF	Global Environment Facility
GIZ	German Agency for International Cooperation
IA	Implementing Agreement
IDB	Inter-American Development Bank
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
Intensys4EU	INTegrated ENergy SYStem, a pathway for EUrope
IRENA	International Renewable Energy Agency
ISGAN	International Smart Grid Action Network
Lao PDR	Lao People's Democratic Republic
LAS	League of Arab States
LTES	Long-Term Energy Scenarios
MI	Mission Innovation
NDCs	Nationally Determined Contributions
NEPAD	New Partnership for Africa's Development
NICE Future	Nuclear Innovation: Clean Energy Future
NREL	National Renewables Research Laboratory
OA	operating agent

OAS	Organisation of American States
OECD	Organisation of Economic Co-operation and Development
OLADE	Organización Latinoamericana de Energía (Latin American Energy Organisation)
PPP	purchasing power parity
PRLCE	Peer Review on Low Carbon Energy Policies
R&D	research and development
R&I	Research and Innovation
RCREEE	Regional Centre for Renewable Energy and Energy Efficiency
RD&D	research, development and demonstration
REEP	Renewable Energy and Energy Efficiency Partnership
REN21	Renewable Energy Policy Network for the 21st century
SDGs	Sustainable Development Goals
SET	Plan Strategic Energy Technology Plan
SNET	Smart Networks for Energy Transition
SIO	Strategic Initiatives Office
TCEP	Tracking Clean Energy Progress
TCPs	Technology Collaboration Programmes
ToR	terms of reference
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNECLAC	United Nations Economic Commission for Latin America and the
UNFCCC	UN Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
VC	venture capital
WACEC	West Africa Clean Energy Corridor
WB	World Bank

Technology Collaboration Programmes

4E TCP	Technology Collaboration Programme on Energy Efficient End-Use Equipment
AFC TCP	Technology Collaboration Programme on Advanced Fuel Cells
AMF TCP	Technology Collaboration Programme on Advanced Motor Fuels
AMT TCP	Technology Collaboration Programme on Advanced Materials for Transportation
Bioenergy TCP	Bioenergy Technology Collaboration Programme
C3E TCP	Technology Collaboration Programme on Clean Energy Education and Empowerment
CCC TCP	Technology Collaboration Programme on Clean Coal Centre
Combustion TCP	Technology Collaboration Programme on Clean and Efficient Combustion
CTI TCP	Technology Collaboration Programme on a Climate Technology Initiative
CTP TCP	Technology Collaboration Programme on Tokamak Programmes
DHC TCP	Technology Collaboration Programme on District Heating and Cooling
DSM TCP	Technology Collaboration Programme on Demand-Side Management
EBC TCP	Technology Collaboration Programme on Buildings and Communities
ECES TCP	Technology Collaboration Programme on Energy Storage
GHG TCP	Technology Collaboration Programme on Greenhouse Gas R&D
GOT CP	Technology Collaboration Programme on Gas and Oil Technology
HEV TCP	Technology Collaboration Programme on Hybrid and Electric Vehicles
HPT TCP	Technology Collaboration Programme on Heat Pumping Technologies
HTS TCP	Technology Collaboration Programme on High-Temperature Superconductivity
Hydrogen TCP	Hydrogen Technology Collaboration Programme
Hydropower TCP	Hydropower Technology Collaboration Programme
IETS TCP	Technology Collaboration Programme on Industrial Technologies and Systems
ISGAN TCP	Technology Collaboration Programme on Smart Grids
NTFR TCP	Technology Collaboration Programme on Nuclear Technology of Fusion Reactors
OES TCP	Technology Collaboration Programme on Ocean Energy Systems
PVPS TCP	Technology Collaboration Programme on Photovoltaic Power Systems
PWI TCP	Technology Collaboration Programme on Plasma Wall Interaction
RFP TCP	Technology Collaboration Programme on Reversed Field Pinches

EOR TCP	Technology Collaboration Programme on Enhanced Oil Recovery
ESEPF TCP	Technology Collaboration Programme on Environmental, Safety and Economic Aspects of Fusion Power
ETSAP TCP	Technology Collaboration Programme on Energy Technology Systems Analysis
FBC TCP	Technology Collaboration Programme on Fluidized Bed Conversion
FM TCP	Technology Collaboration Programme on Fusion Materials
Geothermal TCP	Technology Collaboration Programme on Geothermal Energy
SH TCP	Technology Collaboration Programme on the Stellarator-Heliotron Concept
SHC TCP	Technology Collaboration Programme on Solar Heating and Cooling
SolarPACES TCP	Technology Collaboration Programme on Concentrated Solar Power
ST TCP	Technology Collaboration Programme on Spherical Tori
Wind TCP	Technology Collaboration Programme on Wind Energy

Energy Technology Innovation Platforms

ETIP Bioenergy	European Technology and Innovation Platform Bioenergy
ETIP DG	European Technology & Innovation Platform on Deep Geothermal
ETIP Ocean	European Technology and Innovation Platform for Ocean Energy
ETIP PV	European Technology & Innovation Platform Photovoltaic
ETIP RHC	European Technology and Innovation Platform on Renewable Heating and Cooling
ETIP SNET	European Technology and Innovation Platform on Smart Networks for Energy Transition
ETIP Wind	European Technology and Innovation Platform on Wind Energy
SNTEP	Sustainable Nuclear Energy Technology Platform
ZEP	European Technology Platform for Zero Emission Fossil Fuel Power Plants

Clean Energy Ministerial initiatives

21CPP	21st Century Power Partnership
C3E	Clean Energy Education and Empowerment - Women in Energy
CCUS	Carbon Capture, Utilisation and Storage
CEM-IF	CEM Investment and Finance Initiative
EMWG	Energy Management Working Group
EVI	Electric Vehicles Initiative
Global LEAP	Global Lighting and Energy Access Partnership
ISGAN	International Smart Grid Action Network
NICE Future	Nuclear Innovation: Clean Energy Future
RDEI	Regional and Global Energy Interconnection Initiative
SCET	Sustainable Cities and Eco-energy Towns initiative
SEAD	Super-Efficient Equipment and Appliance Deployment
Solar and Wind	Multilateral Solar and Wind Working Group
Solutions Centre	Clean Energy Solutions Centre

Mission Innovation Challenges

IC1	Smart Grids Innovation Challenge
IC2	Off-Grid Access to Electricity Innovation Challenge
IC3	Carbon Capture Innovation Challenge
IC4	Sustainable Biofuels Innovation Challenge
IC5	Converting Sunlight Innovation Challenge
IC6	Clean Energy Materials Innovation Challenge
IC7	Affordable Heating and Cooling of Buildings Innovation Challenge
IC8	Renewable and Clean Hydrogen Innovation Challenge

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INTERNATIONAL ENERGY AGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 30 member countries, 8 association countries and beyond.

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Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea
Luxembourg
Mexico
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
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United Kingdom
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