COLLABORATIVE MODELS FOR INTERNATIONAL CO-OPERATION IN CLEAN-ENERGY RESEARCH AND INNOVATION[1]

The aim of this paper is to present and describe different models of international co-operation in Research and Innovation (R&I) with the view to support greater international collaboration within Mission Innovation[2] (MI) and its eight Innovation Challenges (IC). Mission Innovation members are establishing an increasing number of new collaborative efforts which can foster transformational and breakthrough innovation and accelerate the low-carbon transition.Therefore, the question of how Mission Innovation can facilitate new international R&I collaborations in an effective and efficient way deserves in-depth analysis.

The document provides a description of several existing models of bilateral and multilateral research collaborations[3] and proposes three criteria to analyse their possible merits and limitations.This preliminary analysis could help identify successful MI collaborations and shape the debate among MI members on what additional actions could be undertaken – either at bilateral or multilateral level - to further tap into the transformative potential of MI and its ICs.

[1] This paper was developed in the context of the Analysis and Joint Research (AJR) Subgroup of Mission Innovation. Sangita Kasture (Ministry of Science & Technology, Government of India), Laurent Bochereau and Daniele Poponi (Directorate General for Research and Innovation, European Commission) were the lead authors of this paper with contributions from Sanjay Bajpay (Ministry of Science & Technology, Government of India), Cathy Chen (Natural Resources Canada), Lars Guldbrand (Swedish Ministry of Infrastructure) and Dean Haslip (Natural Resources Canada). We are grateful to colleagues within MI-member governments and MI-partner organizations (in particular Simone Landolina of the International Energy Agency and Paul Durrant of the International Renewable Energy Agency) for their input and review. We are also grateful to Prof. Ambuj Sagar from IIT New Delhi and Dr. Zdenka Myslikova from Tufts University for their valuable comments and suggestions.

[2] See Mission Innovation Website: http://mission-innovation.net/

[3]A first version of this paper was developed in October 2018, building on the experience gained from the European Union Framework Programmes for Research and Technological Development. The first version of the document was further developed by the authors into a second version, enriched with contributions from other members.

1. Background

As societies and economies become even more inter-dependent in an innovation-driven global economy, reinforced international cooperation is needed to capitalise on opportunities to accelerate the clean energy transition.

Global cooperation on clean energy R&I can greatly enhance the pace of energy systems transformation, making innovation an increasingly important pillar of the low-carbon transition. There is emerging evidence indicating that international R&I activities accelerate the generation of knowledge, avoid duplication of work, as well as increase competencies and the (measurable) outputs and impacts of researchers participating in international scientific network[4]. Joint international R&I efforts create new knowledge at a faster pace, and also allow this new knowledge to be diffused more rapidly, building on national and regional strengths in different technology areas (Prange-Gstöl, 2010).

Recent years have witnessed greater efforts to support the low-carbon transition through new international collaborations. Mission Innovation, created at the UNFCCC's 21st Conference of Parties, is increasingly acting as a 'global hub' in fostering new bilateral or multilateral collaboration programmes in clean-energy R&I. Between 2016 and 2018, 59 new research collaborations were launched by MI members[5]. Many of these new programmes were conceived and discussed in the context of the eight ICs, which foresee the participation of key experts from the public and private sectors and policy makers. Given that ICs are increasingly acting as catalysts of new transnational R&I projects, a number of experts participating in the same ICs have discussed the need or possibility to create a common collaboration framework that could facilitate international efforts in support of IC implementation.

[4] See, for example, European Commission (2019).

[5] http://mission-innovation.net/wp-content/uploads/2019/05/MI-Impact-Review-May-2019.pdf

2. Criteria for Assessing Transnational Collaborative Clean-Energy R&I Models

International co-operation in clean energy R&I can serve a wide range of strategic and political objectives in addition to the general aim of joining forces to accelerate technology development and innovation. These objectives can include, for example, consolidating political relations with a partner country, supporting domestic science competitiveness, establishing an R&I base in new sectors, or supporting industrial and trade policy (Kempener et al., 2014). The broader political and strategic framework underlying international co-operation obviously affects choices on 'whether', 'with whom', 'on what', but also 'how' to co-operate with one or more partner countries.

International co-operation in clean energy R&I can be operationalised through various models (e.g., bilateral co-operation through joint R&I projects, multilateral funding programmes, etc.), some of which have also been used by MI members to implement the collaborative projects of Innovation Challenges.The 'optimal' choice of which clean-energy R&I co-operation model to implement with one or more partner countries should in theory be made on the basis of the best trade-off among the different aforementioned objectives, each likely to have different weights according to the different political contexts.

Assessing different collaborative transnational R&I models with the help of a theoretical framework based on an initial heuristics-based analysis of merits and limitations of each model can help policy makers make more effective and efficient decisions when launching a new collaborative initiative.

Building on the authors' experience in the design and management of international R&I collaborative programmes as well as literature review, three main assessment criteria are identified[6]:

- Technological effectiveness: Each model is assessed with respect to its prospective ability or likelihood to produce technology outcomes, which in the case of clean-energy R&I activities are the impacts on the advancement of

[6]The list presented here is not exhaustive and additional criteria could be considered.

science and technology underpinning technical improvements and cost reductions of clean energy technologies (De Coninck et al., 2008). It should be noted that the way 'technological effectiveness' can be assessed in the context of international R&I co-operation varies significantly throughout the technological cycle. For example, cost reductions can be more effectively assessed from the demonstration to deployment stages of the same technological cycle when the role of industry is essential, whereas a significant part of MI activities are expected to remain within low and medium TRLs.

- Enhanced international co-ordination and optimisation: This criterion relates to the extent to which the collaborative model can foster the alignment of R&I activities of two or more partners, the creation of critical mass through leveraging and synergies and the reduction of unnecessary duplication.
- Administrative feasibility: The implementation of new transnational R&I collaborations requires the design of legal and institutional frameworks defining the sectors to be covered, the nature of commitments (e.g. grants, in-kind contributions, etc.), the terms of the collaborations, etc. It also requires to have an institutional capacity in place as well as practical means to manage effectively the collaborations. In a multilateral context, 'administrative feasibility' might also relate to the practical ability to measure compliance (De Coninck et al., 2008). The term 'transaction costs' is often used to refer to new/additional administrative activities that need to be carried out to implement the collaborations, including setting up the institutional framework and intellectual-property rights (IPR) agreements.

3. Transnational Collaborative Clean-Energy R&I Models

With the aim of providing an initial analytical framework subject to further refinement, seven different models of international R&I co-operation were identified. The institutional scope of these models includes both (a) intergovernmental co-operation (government-to-government) and (b) collaborations implemented under initiatives or networks already established by existing international organizations (e.g., research initiatives under the IEA's Technology Collaboration Programmes). However, some

of the basic features underlying these models can also be applied to international collaborations among private-sector entities (e.g., corporations, industry associations).

The following description and analysis of collaborative models should be considered as a first step in the direction of a more comprehensive conceptual framework. The heterogeneity of the models discussed fits with the variety in national circumstances and resources, which in turn determine different technology portfolios and pathways. For each model, this document intends to describe its basic features and provide a preliminary assessment of its possible merits and limitations based on the three assessment criteria identified above.

3.1 Bi-lateral/ Multi-lateral Co-ordinated Calls

Definition: In a coordinated call, two or more countries agree to support R&I activities on a topic of common interest with each country launching separate calls encouraging international cooperation. Each country implements its call autonomously and funds only domestic applicants while projects selected for funding can be 'linked' from the onset through a mutually agreed Programme of Cooperation (PoC).

Setting Bi-lateral/ Multi-lateral Co-ordinated Calls in areas of common interest and mutual benefit is a common practice among MI countries. One example of this collaborative model is the Dutch India Water Alliance for Leadership Initiative (DIWALI), a joint programme launched by India and The Netherlands, under which two independent but coordinated calls were launched by the two countries. While the Indian Call focused on academia and R&D, the Dutch call was targeted at Small and Medium Enterprises (SMEs). Funding was provided independently to Dutch and Indian entities by the respective national funding entities.

ASSESSMENT CRITERIA	RATING	NOTE
Technological Effectiveness	MEDIUM	Scope/TRL-dependent
Leverage/Optimisation	LOW/MEDIUM	Topic-based alignment with loose coordination (PoC)
Administrative Feasibility	HIGH	Easy to implement by funding entities

Table 1: Assessment of Bilateral/Multilateral Coordinated Calls

Possible merits of this type of collaboration include the relatively low level of commitment by funding entities and applicants (as it can be initiated as aprogramme of cooperation based on shared general objectives) rather than more detailed and formal commitments, the ease of operationalisation and its rapid implementation. Lastly, research areas are based on common priorities of participating countries and research centres are funded in parallel by their own governments, avoiding the transaction costs related to funding foreign legal entities.

Possible limitations of this model include the risk of having divergence in focus and anticipated deliverables if the co-ordinated calls are not well connected (e.g. objectives, TRLs, IPR agreements). Second, there might also be a time lag in the start of the different coordinated programmes, which would negatively impact effective co-ordination between the two research consortia. Finally, project partners may find it difficult to arrive at a common programme if there is no umbrella guidance document.

3.2 Bi-lateral/ Multi-lateral Joint calls

Definition:In this model, two or more countries jointly implement a single call on a topic of mutual interest by soliciting joint proposals that are also evaluated jointly. As in the previous model, each participating country needs to commit an individual national contribution of public funds used to fund project participants from their own country. The main difference compared with the previous model is related to the fact that applicants need to prepare joint proposals that will be assessed by a joint panel

established by the participating countries. Although this model does not necessarily require setting up a dedicated funding mechanism, it usually requires a legal framework (e.g. a Memorandum of Understanding [MOU] establishing a bilateral collaboration programme).

Setting Bi-lateral/ Multi-lateral Joint Calls in areas of common interest and mutual benefit is also a common practice within MI although less frequent than the previous model. Examples of this approach are the EU's Horizon 2020 (H2020) programme, the India-US Joint Clean Energy Research and Development Centre (JCERDC), the ERA-NET co-funding scheme , the calls launched by India under the EU-India Co-Funding Mechanism for Research and Innovation Cooperation, China-Canada & China-Germany Intergovernmental Scientific Cooperation program and lastly the "BRICS" (Brazil, Russian Federation, India, China and South Africa) Calls for Proposals for Multilateral R&D Projects (see Annex1–a, b, c, g).

ASSESSMENT CRITERIA	RATING	NOTE
Technological Effectiveness	MEDIUM/HIGH	Scope/TRL-dependent
Leverage/Optimisation	MEDIUM/HIGH	Strong alignment of funding entities
Administrative Feasibility	MEDIUM	Transaction costs related to alignment of application/selection processes and et-up of joint panel

Table 2: Assessment of Bilateral/Multilateral Joint Calls

Possible merits of this model of joint calls include the fact that research areas are based on mutually agreed priorities of participating countries, while the joint evaluation and monitoring of projects ensures there is enough focus on objectives. Secondly, the funding of researchers in participating countries is assured by the respective governments, avoiding the legal transaction costs of funding foreign research teams (common to the first model). Last but not least, the larger critical

mass of projects funded can produce more significant impacts in terms of technology outcomes..

This model could also have some limitations, the first of which is the longer gestation period compared with the first model as the R&I objectives and application as well as selection processes need to be discussed and agreed by all participating countries and dedicated funding commitments ensured (this might not be a disadvantage *per se*, as an informed discussion on objectives is needed to ensure success of all programmes). Furthermore, this model is unlikely to be implemented by countries which do not have a legal framework for collaboration in place. However, the creation of a new legal framework describing the joint call arrangements may entail high transaction costs and lead to delays. Lastly, the joint selection and monitoring of projects can be time consuming and cumbersome to program managers.

3.3 Country Calls Open for participation to organisations from other countries

Definition: In this model, a call is launched by an individual country encouraging participation of foreign entities without funding from that entity's home country. The funding country might put some restrictions on how the funds are used; for example, the funds might be restricted to covering costs incurred by representatives from foreign entities while working in the country launching the call and the associated travel costs. In that case, the participating foreign entities would need to use existing funding or seek additional funding to carry out work in their own country. Such restrictions, however, are not a necessary feature of the model.

An example of this approach are the funding calls in several Mission Innovation challenges (IC1, IC2, IC3, IC4, and IC5), recently launched by India where the participation of researchers from concerned MI countries was mandatory.

ASSESSMENT CRITERIA	RATING	NOTE
Technological Effectiveness	MEDIUM	Scope/TRL-dependent
Leverage/Optimisation	LOW/MEDIUM	Sourcing foreign expertise
Administrative Feasibility	MEDIUM	Easy to implement

Table 3: Assessment of Unilateral Calls open to international partners

Possible merits of this model include quick start, faster decision-making, and the leveraging of national funding to international cooperation.

Among the possible limitations of this model could be the lack of reciprocity in funding and limited interest from foreign entities to take part due to the restricted funding possibilities.

3.4 Matching fund mechanisms (or Co-fund mechanisms)

Definition: In this model, one or several countries may provide financial support to their own R&I entities participating in research proposals submitted to calls launched by another country. For example, the final decision to support or not the participating entities from country ‘A’ in the proposal retained for funding by country ‘B’ remains under the responsibility of the R&I entity of country ‘A’ as additional eligibility criteria may apply.

One example of this model are the so-called ’Co-funding mechanisms’ set up by some countries (e.g. India) to allow their own research organisations that have applied to specific project calls of the EU's H2020 Framework Programme to receive grants when the H2020 proposal is selected for funding (see Annex 1-b). A similar example includes the China-EU Innovation Flagship Cooperation program and the China-EU Innovation Cooperation program (both relevant to the H2020 program).

ASSESSMENT CRITERIA	RATING	NOTE
Technological Effectiveness	MEDIUM/HIGH	Scope/TRL-dependent
Leverage/Optimisation	MEDIUM/HIGH	Increased critical mass of funding and expertise
Administrative Feasibility	MEDIUM/HIGH	Implementation risks if co-funding is not automatic

Table 4: Matching Funds

Among the possible merits of this model are: (a) Assessment of R&I priorities could be done easily from calls prepared by main funding entities; (b) IP issues are likely to be easily resolved (unless there is a need for a bilateral IPR agreement to be agreed upon, foreign research organizations will need to abide by the IPR provisions established in the frame of each framework research programme);(c) Project selection and monitoring takes place separately; (d) Joint R&I can take place inboth countries in a balanced way; (e) Financial transfers from one country to another are not needed; (e) Requirements for legal framework are simpler; (f) Ease of operation is likely to be higher.

The main possible limitation of this model is that the R&I activities supported by the co-funding country might not be fully aligned (e.g. in scope and objectives) with its national needs, where research entities would take advantage of national funding while 'pitching' for calls launched by another country. In general, open calls with matching fund mechanisms are not very common as it becomes difficult to align the exact research objectives between the partner countries.

3.5 Mutual Opening Agreements

Definition: Mutual opening agreements of R&D programmes between countries foresee that R&I entities from country "A"could participate in calls launched by country "B" as well as receive funding from the latter, and vice versa. With this approach, one country stipulates in its own research programme that participants from a partner country (or countries) can receive funding for specific project calls.

This approach often relies on S&T framework agreements already in place or the creation of new ones.

As one example of this approach, the EC and the US National Institutes of Health (NIH) signed an agreement stipulating that the Horizon 2020 Programme can provide automatic funding to entities established in the USA participating in health-related successful proposals. Similarly, NIH can provide funding to Europe-based entities.

ASSESSMENT CRITERIA	RATING	NOTE
Technological Effectiveness	MEDIUM/HIGH	Increased pool of expertise
Leverage/Optimisation	MEDIUM/HIGH	Leverage of foreign funding
Administrative Feasibility	MEDIUM	Easy to implement once mutual opening agreement is signed

Table 5: Mutual Opening Agreements

A possible advantage of this model is that it opens up national funding to international participants on the basis of reciprocity. This model appears to be highly effective in terms of achieving objectives and ease of operation. However, in terms of possible limitations, the initiation of this collaborative framework can have high administrative or transaction costs, as creating the conditions (e.g. the political endorsement) for national funding crossing borders can be a daunting task to policy makers. Lastly, it might also be difficult to select common interest objectives matching national needs.

3.6 Collaborative Platforms

Definition: In this model, a collaborative platform is established to support international research collaborations among partner countries, e.g. by facilitating the creation of multiple networks of research teams working in projects funded by their

own governments without creating a common funding pool. One common mechanism underlying this model is that of 'task sharing', in which the activities of an international R&D programme are allocated by participating countries to national research institutions, based on the expertise and strengths of each[7].

Examples of such a model include EUREKA (see Annex1-d), which does not have a common fund, and many of the activities carried out by the IEA's Technology Collaboration Programmes (see Annex 1-e). The work of ICs and the Analysis and Joint Research (AJR) group also falls into that category as a platform for identifying common R&I priorities and designing adequate funding mechanisms such as the ones described in this paper. International incentive prizes (e.g. the global cooling prize[8] and the artificial photosynthesis prize[9]), where one or several MI members are providing funding through a worldwide competition, can also be an effective and easy mean of implementation.

ASSESSMENT CRITERIA	RATING	NOTE
Technological Effectiveness	MEDIUM	Increased pool of expertise
Leverage/Optimisation	MEDIUM	Ad-hoc alignment of international funding
Administrative Feasibility	MEDIUM	Flexible implementation by funders

Table 6: Collaborative Platform

The main possible merit of this approach is that a number of countries (e.g., MI members) can come together to select long term, strategically significant initiatives. Such initiatives may be identified by the contribution of experts involved in existing collaboration frameworks and listed in the collaborative platform. Since there is no common funding, each country is free to decide what topic it wants to allocate R&I funding (e.g.on the basis of 'task sharing'). IP issues can be resolved by the participants in the platform on the basis of individual merit. As this model might deal with strategically significant initiatives and often involves industry, the Intellectual

[7] See IEA (2019) for a recent review of Energy Technology Innovation Partnerships.
[8] https://globalcoolingprize.org/
[9] https://ec.europa.eu/research/eic/index.cfm?pg=prizes_sunfuel

Property Rights (IPR) issues about the technology developed are to be discussed and settled at the time of the agreement.

However, there is also the possible limitation that match-making between different countries for similar research goals may be challenging and setting up such collaborative platform might entail high transaction costs.

3.7 International R&I Programme with Joint Funding

Definition: Several countries agree to set-up together a joint fund which is implemented by a single entity, either an existing one or a new one created for this specific purpose. Each country contributes annually to the fund that can provide financial support to individual entities or consortium of entities. Depending onthe arrangements, some of the supported entities may be established outside the participating countries.

There are already a few examples of such international programmes with a dedicated joint fund such as the Human Frontier Science Programme (see Annex 1-f) [10], the Green Climate Fund, as well as the International Energy Agency's Technology Collaboration Programme on Greenhouse Gas Reductions.

ASSESSMENT CRITERIA	RATING	NOTE
Technological Effectiveness	MEDIUM/HIGH	Poolingof technical expertise
Leverage/Optimisation	HIGH	Pooling of international funding
Administrative Feasibility	LOW/MEDIUM	Timely/complex to establish

Table 7: International R&I Programme with Joint Fund

This model has the merit of 'bypassing' the need for setting up new, multiple bilateral co-operation frameworks with joint funding, which are often characterized by high transaction costs related to identifying areas of cooperation, negotiating a legal text

[10] The Global Sustainable Energy Innovation Fund (SEIF) proposed by WEF as one of the "Mission Innovation Big Ideas" also fits into this category.

for agreement, and most importantly delivering concrete outcomes (e.g. joint innovation outputs). An international facility has also the advantage of pooling technical expertise from different countries to review proposals and provide technical assistance.

Obviously, this model is not immune to limitations, given that setting up such programme could also entail high transaction costs for participating members, and would require a formal financial commitment. Furthermore, each member of the multilateral fund might have to set up an agreement with the funding entity, in order for funds to be transferred.

4. Corporate and public-private transnational RD&D collaborative models

Private-sector entities (e.g., industrial companies, industry associations, or institutional investors) are obviously among the main actors in the research consortia carrying out projects launched by international R&I programmes of governments or international organisations. In addition, the financing models underlying R&I programmes initiated by governments might also rely on public-private partnerships to a significant extent.

With the right enabling frameworks, private-sector entities can also set up corporate transnational R&I collaborations. For example, a few automotive companies have set up joint R&I centres where research is carried out on alternative fuels and engines as well as technologies to increase energy efficiency[11]. This might be a private sector instantiation of the government-to-government joint research model (Section 3.2).

While private sector entities and national governments will differ in the activities they undertake and in the manner that they operate, the seven models described above can also apply to hybrid frameworks, that is collaborative mechanisms created jointly by governments, international organizations, and private-sector entities. One such

[11]https://media.groupe-psa.com/en/psa-peugeot-citro%C3%ABn/press-releases/innovation-technology/official-launch-joint-venture-%E2%80%93-bmw-peugeot

example is an independent international sustainable energy innovation accelerator fund recently proposed by the World Economic Forum in the margins of the fourth Mission Innovation Ministerial meeting[12]. Another recent example is Breakthrough Energy Ventures Europe(BEV-E), a joint investment fund aimed at helping innovative European companies develop and bring to market radically new clean energy technologies[13].

5. Conclusions

This paper described seven models of international R&I co-operation and proposed a preliminary assessment of their possible respective merits and limitations based on three criteria. Several examples of on-going cooperation based on some of these models were also presented for clarification purposes. A preliminary review of corporate and blended public-private R&I collaborations was also carried out in order to better understand the differences and commonalities of the public and private funding contexts.

The discussion on the possible merits and limitations of each model carried out in the previous sections could only be framed in a general and hypothetical way, as these merits and limitations are obviously specific to the context of each collaboration, including the agreed deliverables, the institutional R&I capacity of the partners, the specifics of their national energy systems, etc. This shows that there are many variants for each of the seven models. Despite these limitations, a conceptual framework for international co-operation in clean energy R&I describing different collaborative models with their respective merits and limitations can be an initial and useful guiding tool for policy makers.

[12]https://home.kpmg.com/xx/en/home/media/press-releases/2018/05/accelerating-sustainable-energy-innovation.html

[13]Half of the €100 million equity of the BEV-E fund will come from Breakthrough Energy Venture (or its affiliates), and the other half from *InnovFin* – a financial instrument managed by the European Investment Bank and funded through the EC's Horizon 2020 framework research programme. See http://mission-innovation.net/2018/11/08/breakthrough-energy-europe-a-new-e100-million-clean-energy-investment-fund/

A variety of criteria can be applied to assess the different collaborative models available to governments to implement international co-operation in clean-energy R&I. Three criteria, namely 'Technology effectiveness', 'Enhanced international co-ordination and optimisation' and 'Administrative feasibility', were proposed to assess the merits and limitations of the seven models, as a first step towards the creation of a more solid conceptual framework.

Of the seven models described, five relate to bilateral co-operation. The choice of which model to "use" for a new collaboration between two countries is contingent upon the particular needs of the collaborators, their institutional R&I setting, the broader political and strategic objectives, etc. Similar considerations would apply to joining an existing multilateral framework or launching a new one, though some important differences can be discerned between the two pathways. For example, within bilateral frameworks it could be easier to match technology development needs and to leverage synergies in R&I capacity. Multilateral frameworks, on the other hand, could allow pooling of a richer and more diverse know-how and expertise, potentially leveraging economies of scale in the management of a common funding pool.

This preliminary work can help identify and analyse MI best practices and serve as a tool for guiding the identification of suitable models for implementing some current and future MI activities. Further analysis could help shape the debate among MI members on what additional actions could be undertaken – either at bilateral or multilateral level - to support IC implementation.

References

De Coninck, H., Fischer, C., Newell, R.G., Takahiro, U., 2008, International technology-oriented agreements to address climate change, Energy Policy 36: 335-356.

European Commission, 2019, Assessment of the Union added value and the economic impact of the EU Framework Programmes, https://publications.europa.eu/en/publication-detail/-/publication/af103c38-250d-11e9-8d04-01aa75ed71a1/language-en.

International Energy Agengy, 2019, Energy Technology Innovation Partnerships, https://webstore.iea.org/energy-technology-innovation-partnerships.

Kempener, R., Bunn, M., Diaz Anadon L., 2014, Maximizing the Benefit from International Cooperation in Energy Innovation, in Diaz Anadon, L., Bunn, M., Narayanamurti, V., (Eds.), Transforming U.S. Energy Innovation, Cambridge University Press, New York, USA.

Prange-Gstöl, H. (Ed.), 2010, International Science and Technology Cooperation in a Globalized World. Edward Elgar, Cheltenham, UK.

Annex 1

a) The ERA-NET instrument under the European Commission's Framework Research Programme Horizon 2020[14] aims at coordinating the research efforts of the participating EU Member States, Associated States and Regions as well as of selected global partners. The rationale of ERA-NET is to tap the benefits of 'joint programming', by addressing research challenges which cannot be tackled effectively by national research programmes that are often operating in an isolated way. Joint programming aims at bringing a partnership approach and a common vision among the EU Member States, pooling national efforts and making better use of resources.

Participating member states each commit an individual national contribution to the joint call, which also receives top-up funding from the Commission. The projects resulting from the call receive financial support from the national programmes on the basis of a grant agreement between the national programmes and the project participants from their country. The rationale of ERA-NETs for the European Commission is to provide top-up funding of single joint calls for transnational research and innovation in selected areas with high European added value and relevance for Horizon 2020. This aims at increasing substantially the share of funding that European Union's Member States dedicate jointly to challenge-driven research and innovation agendas. Financial contributions of Member States can be in cash or in-kind in order to broaden the scope of ERA-NETs towards the coordination institutional funding of governmental research organizations. The ERA_Net instrument has also been used to support the implementation of ICs, e.g. with the 'ACT' calls related to IC3 and the 'Joint Programming Platform Smart Energy Systems' call in support of IC1.

[14]The ERA-NET model as described here applies only to the EC's H2020 program, which will end in 2020. The architecture of the next EC's Framework Programme, Horizon Europe, is currently under development.

b) The EU-India Co-Funding Mechanism for Research and Innovation Cooperation is a co-funding mechanism (CFM) set up by the Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India and the European Commission (EC) to support joint projects between European and Indian universities, research institutions and companies. Under this CFM, funding will be made available by DBT to successful Indian participants of consortia carrying out certain India–EU collaborative projects under H2020. The program is widely open to foreign participation, of Indian teams, for which DBT co-funding is available in respect of specific calls for proposals. Indian researchers, enterprises (MSMEs), research institutions and universities can team up with their European partners to build research consortia applying for grants under H2020. Through participation in H2020, beneficiaries can gain great benefits from access to excellent knowledge, access to research data and access and connection to world-leading scientific networks and research teams.

The CFM will be used for certain pre-identified Horizon 2020 calls for proposals in priority areas such as: agriculture (including food), biotechnologies, bio-energy, health, water resources, new materials and nanotechnology. A maximum of three crore Indian rupees (INR 30,000,000) per project will be made available by DBT to successful Indian participants.

In addition to the topics eligible for DBT funding under the CFM, Indian participation is welcomed in all Calls for Proposals of Horizon 2020, where Indian partners can participate on their own funds, or by using other sources of funding.

c) The BRICS (Brazil, Russia, India, China and South Africa) Science Technology and Innovation Framework Programme aims to support excellent research on priority areas which can best be addressed by a multinational approach. The initiative should facilitate cooperation among the researchers and institutions in the consortia which consist of partners from at least three of the BRICS countries.

The main aims of this programme are :

- To support excellent basic and applied research joint projects submitted in specified research fields identified by the BRICS partners through a multinational approach;
- To provide an opportunity for young and emerging researchers within BRICS countries to meet and interact;
- To contribute meaningfully to research capacity development through the provision of Masters' and Doctoral scholarships and student exchange programmes.

The Collaborative multi-lateral projects are supported in basic, applied and innovation research projects in eleven thematic areas including New and renewable energy, and Energy Efficiency.

d) EUREKA is a leading platform for bilateral and multilateral research and development (R&D) collaboration across Europe and globally to bring innovative ideas to the markets. It is an intergovernmental (European-led, non-EU) organisation formed by 41 countries, including key knowledge economies. EUREKA, is characterised by a bottom-up approach and supports innovative ideas from any sector.

EUREKA offers many flexible collaborative platforms:

- Network projects – Market-driven international R&D projects supported by the public administrations and public funding agencies that represent EUREKA in each of its member countries.
- Eurostars – Bilateral and multilateral collaborations between research and development (R&D)-performing small to medium enterprises (SMEs) in EUREKA member countries. The Eurostars programme includes a top-up from the EU's Horizon 2020 budget.
- Clusters - Long term, strategically significant industry-led sectoral initiatives that aim to develop new technologies of importance for European competitiveness, enabling collaboration between SMEs and industry.

- Globalstars – Bilateral and Multi-lateral collaboration between EUREKA countries and non-EUREKA partner countries (without the need for a bilateral Memorandum of Understanding). Funds are not combined into a single budget (no "common pot"), and countries can decide flexibly what they invest.

e) International Energy Agency's Technology Collaboration Programmes: Shortly after establishing the International Energy Agency (IEA) in November 1974, its founding countries created a mechanism for international collaboration currently known as a Technology Collaboration Programme (TCP). A TCP is a cooperative programme established by at least two IEA member countries to carry out a wide range of activities such as energy research, development, demonstration as well as technology analysis, capacity building, dissemination and scientist exchanges. While they are one of several actors in the IEA Energy Technology Network, TCPs are functionally and legally autonomous from the organisational structure of the IEA.

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: (i) energy efficiency end-use technologies (buildings, transport, industry and electricity), (ii) renewable energy and hydrogen, (iii) fossil fuels, (iv) fusion power, and (v) cross-cutting issues.

There are two categories of participants in TCP: entities representing a government may participate as Contracting Parties, while entities that are not designated by a government may participate as Sponsors. At the beginning of 2019, 16 of 38 TCPs include private sector participation, either specific companies or through industry associations.

Each TCP is organised under the auspices of an Implementing Agreement, which is most commonly used to describe the legal context of a TCP. The Implementing Agreement includes key provisions regarding the purpose, management and implementation of the TCP. The activities of each TCP are overseen by an Executive Committee (ExCo) comprised of representatives

designated by each participant. The ExCo takes 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 (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[15].

f) The Human Frontier Science Program (HFSP) is an international program of research support, funding frontier (basic) research in life sciences. HFSP is supported by 13 countries and the European Union. HFSP has an implementing body, the International Human Frontier Science Program Organization (HFSPO) with a Secretariat carrying out management and administrative tasks.

Key elements of HFSP's mission are:

- Support for innovative, cutting edge research at the frontiers of the life sciences
- Encouragement of high risk research
- Promotion of international collaboration in the spirit of science without borders
- Support for financial and intellectual independence for early career researchers

HFSP was a created as a means to encourage international collaboration in basic research. The funds are combined into a single budget and are allocated to awards on the basis of HFSPO's own peer review system on the sole basis of scientific excellence. Research grants are awarded for novel partnerships involving extensive collaboration among teams of scientists working in different countries and in different disciplines.

[15]Further information is available at www.iea.org/tcp

g) Indo-US Joint Clean Energy Research and Development Centre (JCERDC): Under the Partnership to Advance Clean Energy (PACE) umbrella, the U.S. Department of Energy (DOE) and the Government of India signed an agreement to establish the Joint Clean Energy Research and Development Centre (JCERDC) to promote clean energy innovation by teams of scientists and engineers from India and the United States. To achieve this objective, the Indo-US JCERDC supports multi-institutional network projects using a public-private partnership model of funding. The funding contribution from private partners could be in kind form. The JCERDC is funded by the Indian Ministry of Science and Technology and the U.S. Department of Energy. The priority areas mutually agreed between two countries. are Solar Energy, Second Generation Biofuel, Energy Efficiency of Buildings, Smart Grids and Energy Storage.

The Indo-U.S. Steering Committee on Clean Energy Science and Technology Cooperation provides high-level review and guidance for the activities of the JCERDC. A Joint High-Level Experts Panel of twelve preeminent private and public sector academic experts provide the JCERDC with critical suggestions and insights and also act as an advisory body for the Steering Committee. Project Monitoring Committees (PMC) set up – one in each priority area monitors the consortia progress in conformity with the outputs, milestones, targets and objectives of the Project. The PMC for each consortium comprises of eminent experts from the relevant field and members of the Government of India.