Indicators of innovation in clean and environmentally sound technologies in energy sector in developing countries: empirical evidence and assessment of existing indicators for four developing countries

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Data reflecting innovation capabilities and efforts in the energy sector are being gathered internationally for developed economies and for some of the biggest developing countries (BRICS). Membership in international organizations such as IEA play an important role: they provide a valuable service to collect and assess energy technology innovation consistently. In the case of smaller developing economies or least developed countries, however, there is not a lot of data available. This lack of homogenized data does not permit comparison and quantification of innovation capabilities among countries.

The collection of available data was carried out for a group of four developing countries – Mexico, Paraguay, Indonesia and Turkey – and it is a first step on the road to ultimately assess measurement of innovation gap in energy technology innovation between developed and developing countries. Based on review of databases from OECD, UIS, IEA and RICYT [1], evidence is provided about which indicators that carry valuable information on innovation capabilities in energy technology have been collected by the international organizations and are currently available for a "typical" developing country, and which important indicators are missing. Standardized statistics on innovation are found to be available to provide a broader picture of a country's innovation effort in general, but not much data is available specifically for the energy sector.

I. Characteristics of the countries included in the study

The group of countries considered in this study were picked to represent a variety in economic and technological level of development in three different continents: Indonesia and Paraguay are classified by OECD[2] as lower middle income countries, and Mexico and Turkey representing upper middle income countries. While **Mexico** is a member to OECD and included in the UIS Pilot Data collection on innovation statistics, **Paraguay** is considered in the UIS database only. Both countries are members of RICYT, which collects diverse data on innovation for the region, and also cooperates in assessing the countries within the OECD. **Turkey** is both a member of the OECD and the IEA, and **Indonesia** is a partner country to OECD. Both are considered in the UIS.

II. Indicators for measurement of innovation capabilities in energy sector and their availability for the country sample

The membership in different international, regional or sectoral organizations to a high level predetermines availability of different data. On the other hand, being a member of an organization that collects data on innovation certainly helps, but does not guarantee that the country is included in a specific database or indicator (in the case of, for example, RICYT). Also, it is not always explained if exclusion of a country is a result of a lack of data or a lack of

[1] OECD: Organization for Economic Co-operation and Development, UIS: UNESCO Institute for Statistics, IEA: International Energy Agency, RICYT: Network for Science and Technology Ibero-American and Inter-American

[2] In the list of countries on 2012 and 2013 flows for Development Assistance Committee in the Official Development Assistance.

innovation in the field. Considering the available literature and reports on innovation, the categories and metrics for measuring energy technology innovation are well understood. For example, Gallagher et al. (2011) mapped energy RD&D investments in the rapidly emerging developing countries (BRIMCS) through 2008 using public investments as a proxy for national effort. Many data gaps existed, especially for demand-side technologies.

The most complete set of indicators of progress in innovation efforts and capabilities in the energy sector is collected by the **IEA.** The set of indicators includes expenditures in RD&D in renewable and non-renewables, further subdivided into 6 categories and according to the technology characteristics. For Turkey, as a member of IEA, hence, there is relatively detailed information: the data was collected for years 1983 – 2009, however, there is no data available for each year (for example, for Turkey, no data available for the period 2010-2012), and there are many gaps in different categories with no exact explication for missing data. Also, it cannot be concluded, as one would expect, that the more recent the data the more robust they are.

OECD collects data to track innovation efforts for its member countries and some affiliated non-member countries. For Mexico and Turkey, the majority of these indicators is available. For Indonesia, a partner country to OECD, the data is considerably limited. There are data related to innovation in broader sense, and for the energy sector a set for the business enterprise sector[3] as a part of the Analytical Business Enterprise R&D Database (ANBERD). There are data on Main Science and Technology Indicators (MSTI), R&D Statistics, Patent Database, and Environment Statistics (Green growth indicators) that would potentially hold information on the innovation effort and capacity in clean and environmentally sound technologies. Within the indicators on R&D expenditures per industry, specifically the Structural Analysis R&D investments in electricity, gas and water supply contains data on energy innovation. The information (for Turkey available 2009-2011; for Mexico 1988-2009) is not further divided and sub-specified, however, so its explanatory value is low. Apart from this indicator, there are others that potentially carry valuable information if they were disaggregated to separate the information specifically for the energy industry (for both Mexico and Turkey, there is an extensive set of indicators on gross domestic expenditures on R&D, number of researchers, source of financing of the R&D available for the overall science and technology industry).

There are indicators designed as a part of an innovation policy platform and indicators that aim to refer specifically to technology transfer, commercialization and diffusion to measure innovation performance, and are available for Indonesia as well. But as in the previous case, the statistics are not sufficiently disaggregated to permit extracting information for the energy industry. There also are indicators on energy productivity that could potentially provide information on the progress in innovation in the field, but no more specification.

OECD also provides detailed statistics on patents in environmentally related technologies that include the three countries (Mexico, Turkey and Indonesia) in the time period from 1999-2011. These data are disaggregated enough to distinguish among patents in energy generation (from renewables and non-fossil sources), combustion technologies with mitigation potential, or technologies specific to climate change mitigation.

Lastly, OECD provides data on environmental statistics on green growth indicators through which it aims to monitor the transition towards a green economy and might serve as an indicator about innovation effort related to energy industry. The set is available for both

[3] Including private and public enterprises and institutes serving such enterprises.

Mexico and Turkey for 2000-2012, and apart of the information on patents (related generally to improvement in energy efficiency), for Mexico it includes information about public spending in environmentally related R&D (but with no specific part assigned to energy only).

Mexico and Paraguay are members to **RICYT** that carries out a public database including data on research and development. From the group of statistics, R&D expenditures in production, distribution and rational utilization of energy is the closest one to provide information about the energy sector or environmentally friendly activities, and alternatively R&D expenditures on control and care of the environment. For Mexico this indicator is available for the period from 1990-2011 (science and technology activities expenditures), and for Paraguay from 2001-2011 with data missing 2006-2007and 2009-2010 (R&D expenditures). Apart of that, their database collects information on science and technology personnel as well as other valuable general data about the number of researchers, etc.

As for the UNESCO Institute of Statistics' effort to develop a database of cross-country comparable statistics on innovation, no indicators that would explicitly distinguish and closely subdivide for energy sector were identified.

The availability and quality of data is organization dependent. It could be expected that because developing countries are not members to organizations such as IEA, they would not have a developed database on these relatively recently collected statistics.

III. Additional indicators for energy innovation evaluation

There are indicators that might be collected regionally and that could be taken advantage of when constructing a more complex indicators. For example, there is information on Paraguay collected by RICYT that for the same country might not be captured in the OECD databases (expenditures on R&D, science and technology, etc.). Moreover, the local organizations, here specifically RICYT, show effort for cooperation with broader international body (OECD, UNESCO) to further specify and harmonize their data collections and adapt them for international comparison. Latin American countries may be relatively well mapped in the general innovation statistics.

The construction of the Global Innovation Index brings an interesting idea to have such an index oriented sectorally on energy. In that case, which variables should be included to provide useful information on both capacities-capabilities (existing "stock") and effort (measured for example by different policy implementation in the industry)?

IV. Future path

The first step in this process analyzing the technology gap in the energy sector was to review the availability of data already homogenized, collected by international organizations. The next step will comprise of revising tasks and answering questions such as: Is there a track of information on innovation efforts in energy industry internally in each of the country, even if the international organizations do not provide/reflect this data? Or does the lack of international data indicate lack of technologies and capabilities in these countries? These questions would be answered through (1) assessing internal national data collections, and (2) the study would be carried out for more economically diverse countries per each region, including Africa.