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Review and classify the GHGs-related indicators

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ABSTRACT

Indicators can examine these changes, and monitor the use of economic and social resources, as well as the changes occurring in the efficiency of energy use and the environmental problems caused by energy use (such as greenhouse gases (GHGs) emissions). Environmental indicators can also be used to evaluate the results achieved in energy policy implementation and as a reference for the formulation of new policies. Using indicators to monitor the environmental impacts and to evaluate the efficacies of policies and regulations has been practiced for a long time; and it can serve as a useful tool for decision-making and for comparison between different countries. The objectives of this study were: (1) to conduct a literature review on the indicators that have been used in GHGs-related studies; (2) to develop a driving force-pressure-state-impact-response (DPSIR) model that incorporates GHGs-related indicators and then evaluate their relationships using a cause-effect chain of GHGs emission. This review does not aim to assess or compare different accounting systems that often support the selection of indicators, but try to organize this information that requiring clear boundaries be established, and define what will be extended implication in the future.

Contents

1. Introduction

The challenge of reducing greenhouse gases (GHGs) emission at local or global levels requires behavioral changes in life styles and energy consumption patterns in people, and the use of more

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energy-efficient production, processing and distribution technologies [1–5]. For instance, the decarbonization of fossil fuels through geological carbon dioxide (CO_2) capture and storage has the potential to significantly contribute to decreasing anthropogenic GHGs emissions [6]. Indicators have also been used extensively to deal with the policy-making issues related to GHGs in reduction, mitigation, and adaptation [7,8].

In the Fourteenth Conference of the Parties (COP-14), it reiterated that the activities to be funded should be country-driven, cost-effective, and integrated into national sustainable development and energy-efficient strategies [9]. It warrants a better understanding on the cost of GHGs reduction and the marginal damage associated with each additional tonnage of GHGs emitted into the atmosphere. As above, there is a direct relationship between GHGs emission reduction (particularly the reduction in CO_2 emissions) and individual nations' energy structure and energy utilization. Because energy supply is of vital importance to a country's economic development, climate change has become one of the most sensitive political issues for the international community.

Human activities, mainly from fossil fuel burning, have substantially increased the CO_2 concentrations in the atmosphere. They also capture the marginal contributions to climate change, which are most amenable to influence from policy and technological changes. Excessive human activities can have undesirable impacts in the long run, and these impacts including environmental degradation and climate change are captured by a negative term in the utility function. The flow of undesirable production becomes a source of inefficiency. As awareness of the potential impacts of human-induced climate change has grown, so has the desire to plan for the impacts of climate change so negative hazards can be mitigated and benefits [10,11]. Some researchers have quantified adaptive capacity based on frequency of occurrence of past hazard events [12–14]. In a vulnerability assessment framework, present-day and future estimates of adaptive capacity were sought quantitatively. Overall, the most appropriate indicators of responsibility are likely to lie between the beginning and end of the cause-effect chain [15]. The influence of adaptation and mitigation, the cost of GHGs emissions reduction, and the efficiency of energy structure of a country should be considered in the cause-effect chain.

The indicators can be physical, biological, or socio-economic and used to represent key elements of complex ecosystems and/or environmental issues. Indicators have also been used extensively to deal with policy-making issues related to GHGs in reduction, mitigation, and adaptation [7,16]. GHGs-related indicators were linked to many socio-economic and environmental indicators, including GDP growth rate, energy consumption, and environmental protection expenditures [15,17,18]. The GHGs-related indicators associate with several dimensions, including environment, ecosystem, economics, and society. For example, CO_2 emission per unit of GDP is considered as the indicator most closely related to a country's economic development [19–21].

2. The global GHGs-related indicators

2.1. International Energy Agency

IEA (International Energy Agency/Organization for Economic Co-operation and Development (OECD)) [22] built the international energy demand-and-supply databases using the national reference approach under IPCC's guidelines [23]. Generally speaking, indicator database includes: total amount emissions, CO_2 emissions per capital, CO_2 emissions per GDP, and emissions per unit energy use and statistics on 137 countries' historical CO_2 emissions from fossil fuels. The IEA's project on energy indicators was established in 1996. Their analytical framework and data developed under this project have become important tools for IEA analysis of energy use developments. The indicators (and the associated databases) help to reveal key couplings between energy use, energy prices and economic activity. This insight is crucial when assessing and monitoring past and present energy efficiency policies and for designing effective future actions. Data developed for the IEA indicator project are also used for other IEA analytic activities, such as the World Energy Outlook publication and several energy efficiency and energy technology projects within the IEA Secretariat [24].

2.2. European Environmental Agency

European Environmental Agency (EEA) management board approved the core set of indicators in March 2004 [17]. EEA's core of GHGs indicators assessment grouped by topic is: agriculture, air pollution and ozone depletion, biodiversity, climate change, energy, fisheries, terrestrial, transport, waste, and water. The assessments and projections focus on GHGs emission trends, policies and measures, and climate change impacts and adaptation actions in Europe. The EEA supports implementing the Kyoto Protocol in the EU, evaluating EU policies and developing long-term strategies to mitigate and adapt to climate change.

The EU-funded ODYSSEE [26] project's indicators are macro-indicators, defined at the level of the economy as a whole, of a sector, and as an end-use. All previous types of indicators are also expressed in terms of CO_2. Six types of indicators are considered to monitor energy efficiency trends or to compare energy efficiency performances: energy intensities; unit consumption or specific consumption; "bottom-up" energy efficiency index; adjusted indicators (to make cross-country comparisons to adjust for structural differences between countries); diffusions indicators (e.g. for monitoring); target indicators (CO_2 indicators).

2.3. The Climate Analysis Indicators Tool (CAIT)

The Climate Analysis Indicators Tool (CAIT) [15] includes a wide variety of climate-relevant data and indicators that can be viewed through an interactive and customizable interface. It provides a description and sources of the data (except for GHGs data sources), as well as a conceptual framework for classifying indicators that are relevant to climate protection. The indicators presented in CAIT are grouped into three categories: GHGs emissions, socio-economic, and natural factors. For GHG emissions-related indicators, CAIT includes numerous analysis features that allow for a range of comparisons across gases, sectors, countries, and years, its interface includes UNFCCC Parties to the Convention Secretariat, U.S. states, and countries' vulnerability and adaptive capacity. Socio-economic indicators are framed broadly and include numerous indicators related to the capabilities that countries may have to protect the climate system, including health, education, income, governance and other indicators. Finally, natural factor indicators represent those factors that tend to lie largely beyond the reach of public policy (like climatic conditions, fossil fuel reserves, and geography), but which nevertheless may significantly influence GHGs emissions.

2.4. The Organization for Economic Co-operation and Development (OECD)

An overview of recent work on sustainable development indicators in the OECD countries [25]. Much of the impetus behind these efforts is a consequence of the 1992 World Summit on the Environment and Development, where a specific agency (the United Nation's Commission on Sustainable Development, UNCSD) was