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# Conceptualizing sustainable development of conventional power systems in developing countries – A contribution towards low carbon future

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ABSTRACT

A transition plan for conventionally structured generation portfolios dominantly based on coal fired plants has been offered through four models. The models are primarily focused on elevated penetration of facilities based on intermittent renewable sources and $CO_2$ emission reduction by at least 20% compared to the initial state, accordingly addressing balancing output power variation problems and social aspects of the considered society. These models are:

- Flexible generation portfolio model, which can provide balancing power by itself;
- Open system model that provides balancing power at the balancing market;
- Hybrid system model with hybrid plants based on wind, hydro and solar energy, having the ability to store, convert and use this energy for balancing purposes;
- Mix model that includes options from the previous three.

The models are elaborated on an arbitrary conventional power system and simulated applying International Atomic Energy Agency's software tools.

Considering chosen technical, economic, environmental and social parameters, conducted analyses resulted with the Mix model as the most suitable option for a sustainable development of the treated power system type. Due to similarities between generation portfolio structures in developing countries, the model can provide guidelines for sustainable planning and contribute to a low carbon future.



## 1. Introduction

Due to increased concerns regarding rising demand for electricity, hardly predictable oil prices and greenhouse gas (GHG) emissions, the search for clean and efficient energy sources has been intensified. Governments are designing energy and environmental policies to minimize their exposure to volatile international fossil fuel prices and reduce carbon emissions in the energy sector, in particular the electricity power sector [1]. Appropriate directives, e.g. Ref. [2], strategies, e.g. Refs. [3–6] and guidelines have been issued, in order to promote the use of renewable energy sources (RES) and lead to their proper integration. In addition, conclusions of the UN Climate Change Conference held in Paris in December 2015 emphasize the transition towards a clean economy, suspending dangerous climate change. Additionally, a very important aspect linked to energy use is assigned to social issues of a country, as outlined in Refs. [7–9].

All this has been placed in the context of sustainable development in this paper, with a focus on the generation portfolio planning of an energy system. Generation portfolios represent a very important sub-system within energy systems and have a very important role within comprehensive sustainable development planning of a country. Thus, sustainable generation portfolio planning development here has been looked at as a process of change in which the exploitation of resources, the direction of

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**Nomenclature**

| | |
|---|---|
| BAT | Best available technologies |
| CCGT | Combined cycle gas turbine |
| EPB&H | Public Enterprise Elektroprivreda of Bosnia and Herzegovina |
| EISD | Energy indicators for sustainable development |
| GHG | Greenhouse gas |
| HPP | Hydro power plant |
| HPS | Hybrid power system |
| HSSW | Hybrid power system based on solar and wind energy |
| LOLP | Loss of load probability |
| O&M | Operation and maintenance |
| PHPP | Pumped-storage hydro power plant |
| PVPP | Photovoltaic power plant |
| RoR | Run-off river |
| TPP | Thermal power plant |
| WPP | Wind power plant |

investments and the orientation of technological development enhance both current and future potential to meet human needs, evaluating sustainability in this paper through the consideration of several indicators, i.e. technical, economic, environmental and social parameters of the considered power system.

### 1.1. Research focus and objective

Most power systems in developing countries and countries in transition are based on conventional energy sources, mainly on coal fired thermal power plants (TPP) used for base load generation and hydro power plants (HPP), also used to cover variations in consumption. Most often is the ratio of installed power and electricity production in such conventional systems in favor of TPP. Such systems are characterized by inflexibility and have been traditionally designed to meet own power needs.

Given that energy represents one of the most important factors in the overall efforts for achieving sustainable development, countries tend to adopt such strategies and policies that will align their energy system's transition with the goals of sustainable development. In developed countries the debate on sustainability is mainly related to environmental protection, while in underdeveloped and developed countries the focus is more set to economic and social issues. This is also one of the reasons why developing countries resort to traditional power system planning by relying on national energy resources, fossil fuels (coal) in this sense, trying in this way to keep jobs as well, e.g. for those employed in TPP and coal mines. Thus, when projecting sustainable transition of power generation portfolios in underdeveloped and developing countries, social issues should be taken into account in particular. Inter alia, the social dimension reflects also the need for people to have access to electricity at an affordable price and in these countries there are still people which have no access to electricity [7–9]. Thus, the research focus of this paper are conventionally structured power generation portfolios, mainly in developing countries and their proper transition towards sustainable systems. Due to the generation portfolio energy mix and economic and social circumstances in these countries, it is much more difficult for those power systems to access sustainable development, compared to systems of developed and richer countries.

Having also in mind the overtaken obligations from directives and development strategies [1–4], conventional power systems need to make special efforts and find adequate ways to achieve sustainable development. Accordingly, measures taken to reduce emissions, with a focus on GHG, increased penetration of generation facilities based on intermittent RES, electricity market liberalization, approaching sources of electricity to consumers by means of distributed generation and increasing at the same time electricity access through micro systems, etc. represent “new” working conditions and considerable challenges for traditional power systems.

The objective of this paper is to explore and propose a viable transition concept for conventional power systems into sustainable ones, by reaching specific RES share and decarbonization targets and bearing in mind the social aspect of the considered society, all discussed and elaborated through chosen sustainability indicators. Considering the so called “new” working conditions set before conventional power systems, a mid-term development and transition plan until year 2035 has been offered through four models, addressing also challenges in balancing output power variations from intermittent RES. The described research has been performed on an arbitrarily conceived generation portfolio of a conventional power system, which structure is based on a real power system in exploitation. With respect to similarities between generation portfolios of developing countries, and a special focus on South East European countries, proposed models can provide guidelines for an acceptable transition of conventionally structured generation portfolios into sustainable ones, within the framework of a low carbon future.

### 1.2. State of the art

In available literature a variety of models used for sustainable development simulations are offered, e.g. reduction of GHG emissions (decarbonization) [10–12], integration of intermittent RES, finding the most appropriate way for balancing their output power variations [13–19], as well as determining the maximum acceptable level of RES penetration in a power system, as in Ref. [20].

Thus, in Ref. [11] an integrated optimization modeling approach has been developed for $CO_2$ abatement planning through emission trading scheme and clean development mechanism. A number of studies and plans are available for China, an intensively developing country. Binding reductions in intensity of $CO_2$ emissions per unit of gross domestic product have a significant reflection of the economy and the energy system of the country. In Ref. [12] 18 Chinese energy modeling tools have been reviewed and compared.

A frequently used software tool in a variety of sustainable development simulations is EnergyPLAN [20–24]. In Ref. [21] the feasible wind power penetration in the existing Chinese energy system has been discussed using EnergyPLAN. EnergyPLAN has also been used in Ref. [24] where different future strategies for the Portuguese power system have been considered, including a 100% RES scenario. The concept of 100% RES has been considered in Ref. [23] for developing a model of the Hvar island power system, using the same software tool. EnergyPLAN has also been used in Ref. [20] to model the Irish energy system, identify future energy costs and the maximum wind penetration possible by 2020. In Ref. [25] EnergyPLAN has also been applied in combination with TIMES software for planning electricity systems with high penetration of renewables.

One of the software tools used in sustainable development planning is PRIMES, applied in Ref. [10] where decarbonization of the EU economy by 2050 has been addressed. Another tool is the LEAP program used for the analysis of energy policies and programs to mitigate climate change, as e.g. in Ref. [26].

In future energy system plannings, hybrid power systems (HPS) are increasingly attracting attention and are seen as part of the solution that can contribute to sustainable development [27].