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An assessment of alternative carbon mitigation policies for achieving the emissions reduction of the Clean Power Plan: Case study for the state of Indiana

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HIGHLIGHTS

- The carbon tax trajectory for achieving the CPP is identified for Indiana.
- The RPS target by period for achieving the CPP is identified for Indiana.
- Carbon cap and tax are more cost effective than RPS focusing on the energy system.
- Carbon cap and tax lead to more diverse generation portfolios than RPS.

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ABSTRACT

National carbon mitigation policy included in the Clean Power Plan (CPP) targets electric power generation facilities and may have substantial impacts at the national level. The subnational impacts will vary because the level of dependence on coal for electricity generation varies substantially across states. Indiana represents a state where the CPP impacts may be relatively large due to heavy dependence on coal for electricity generation. Therefore, this paper presents analysis of the efficacy and cost of alternative approaches to carbon mitigation policy, taking Indiana as an example.

A state-level energy system model, IN-MARKAL, was developed based on the MARKAL framework to explore alternative policy scenarios. Results show that a renewable portfolio standard (RPS) is relatively cost effective in achieving carbon emissions reduction for Indiana from the perspective of the power system alone, but that the RPS may also lead to a generation mix dominated by coal and wind. Carbon cap and carbon tax outperform the RPS when considering the entire energy system modeled in IN-MARKAL, which also lead to a more diverse generation portfolio for the state.

1. Introduction

National carbon mitigation policy targeting the power sector has become a serious possibility with the finalization of the Clean Power Plan (CPP). Such a policy could lead to substantial changes at the national level, but the impacts at the state level may be even more dramatic. Indiana is an example of a state where the impacts are likely to be relatively large because Indiana relies heavily on coal for electricity generation. Around 90% of electricity generation in state was from coal in 2010 (EIA, 2010a), versus 45% at the national level (EIA, 2010b). Since coal is much more carbon intensive than other fossil fuels (Table 1-1), such a coal-dominated generation portfolio is a large source of CO_2 emissions, resulting in Indiana ranking among the top 10 states nationally on the basis of total CO_2 emissions over the last two decades (EIA, 2011).

In the possible event that Indiana will have to act on carbon mitigation driven by the CPP, it is important for state policymakers to understand the costs and efficacy of alternative strategies. Although there is no lack of literature on the impact of carbon policies, no research has been conducted to address this issue for Indiana, which could be viewed as representative of states with coal-dominated generation portfolios.

Alternative scenarios explored in this study include a BASE, or business as usual, scenario, a carbon cap scenario, a carbon tax scenario and a renewable portfolio standard (RPS) scenario.

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Table 1-1
Fuel Emission Factors in kg CO_2/MMBtu.Source: Appendix H of the instructions to Form EIA-1605, available at: www.eia.gov/survey/form/eia_1605/excel/Fuel_Emission_Factors.xls.

Fuel	Emission factor
Coal	95.52
Natural gas	53.06
Distillate fuels	73.15
Heavy fuel oil	78.8
Petroleum Coke	102.12

2. Methods

2.1. MARKAL model and U.S. applications

MARKAL (short for MARKet ALlocation) is a bottom-up, dynamic, and for most versions linear programming based energy model (LouLou et al., 2004). It provides a flexible framework to model an entire energy system, rather than the electricity sector alone, and is capable of capturing the interplay between various sectors of the energy system through overall system dynamic optimization.

A user-defined 'Reference Energy System' depicts a network that includes all energy carriers involved with primary supplies (e.g., mining, petroleum extraction, etc.), conversion and processing (e.g., power plants, refineries, etc.), and end-use demand for energy services (e.g., automobiles transportation, residential space cooling, etc.). The model minimizes the discounted sum over time of total system cost of satisfying end-use demand for energy services subject to various user-defined technological, environmental, economic and political constraints.

MARKAL can be used to identify cost-effective responses to political restrictions, to evaluate new technologies, to assess the effect of regulations, taxes and subsidies and to project inventories of air pollutant emissions. Seebregts et al. (2002) provides a succinct overview of MARKAL model developments and selected applications.

In the U.S., the MARKAL framework is used by the Environmental Protection Agency (EPA) for numerous technology and emissions evaluations. A national MARKAL database and a 9-region MARKAL database have been developed and are regularly maintained and updated by EPA (EPA, 2014).

In addition to EPA MARKAL databases, a few regional or state level MARKAL models have been developed in the U.S. The Ohio MARKAL model was developed and used to evaluate the prospects for biomass co-firing in Ohio to generate commercial electricity and to analyze key economic, environmental, and policy issues related to energy needs for Ohio's future (Shakya, 2007). This model contains a detailed power sector, but lacks details in other sectors.

Levin et al. (2010) published a MARKAL model for the state of Georgia and applied it to analyze the evolution of its electricity generation portfolio under different scenarios with regard to the cost of efficiency improvements. They also used this model to address state-level impacts of a renewable electricity standard and a carbon tax in Georgia (Levin et al., 2011). No end-use sectors are presented in this model. Demand for electricity in the base year and beyond is specified explicitly and exogenously.

The NE-MARKAL initiative, which began in 2003 through collaboration between Northeast States for Coordinated Air Use Management and the EPA, has resulted in the development of a MARKAL model tailored specifically to the energy infrastructure of the Northeast (NE-MARKAL). NE-MARKAL is a comprehensive energy system model including details in end-use sectors and the electricity generation sector and simplified structures to reflect resource supply and refineries. The model was mainly designed to facilitate an in-depth understanding of technology, economic, environmental and public health consequences of air quality and climate initiatives (NESCAUM, 2014).

The CA-TIMES model was developed at UC Davis (STEP, 2014) to provide guidance regarding the least-cost and most appropriate options to achieve carbon emissions mitigation goals outlined in AB32 (California Global Warming Solutions Act of 2006). It covers all sectors of the California energy economy McCollum et al. (2012) used CA-TIMES to explore low carbon scenarios with focus on the potential evolution of the transportation, fuel supply, and electric generation sectors over the next several decades in response to various energy and climate policies in California.

2.2. IN-MARKAL

2.2.1. Model structure

IN-MARKAL is an energy-economy model representing major sectors of Indiana's energy system. It has a planning horizon from year 2007 to 2045, which is divided into 13 three-year periods.

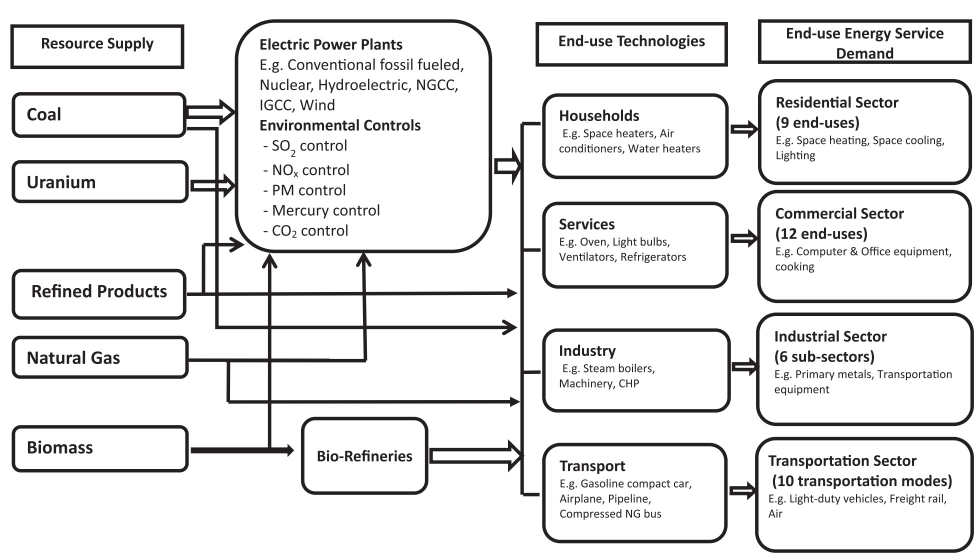

Fig. 2-1. IN-MARKAL Model Structure.