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Achieving California's 80% greenhouse gas reduction target in 2050: Technology, policy and scenario analysis using CA-TIMES energy economic systems model

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HIGHLIGHTS

- We model the California Energy System to 2050 under policy and technology scenarios.
- The model optimizes technology and resource investments to meet emissions targets.
- Deep emissions cuts (> 74%) are achieved across all reduction scenarios.
- Carbon capture enables negative emission biofuels and allows more petroleum use.
- Greenhouse gas mitigation cost is small compared with total economic activity.

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ABSTRACT

The CA-TIMES optimization model of the California Energy System (v1.5) is used to understand how California can meet the 2050 targets for greenhouse gas (GHG) emissions (80% below 1990 levels). This model represents energy supply and demand sectors in California and simulates the technology and resource requirements needed to meet projected energy service demands. The model includes assumptions on policy constraints, as well as technology and resource costs and availability. Multiple scenarios are developed to analyze the changes and investments in low-carbon electricity generation, alternative fuels and advanced vehicles in transportation, resource utilization, and efficiency improvements across many sectors. Results show that major energy transformations are needed but that achieving the 80% reduction goal for California is possible at reasonable average carbon reduction cost ($9 to $124/tonne CO_2e at 4% discount rate) relative to a baseline scenario. Availability of low-carbon resources such as nuclear power, carbon capture and sequestration (CCS), biofuels, wind and solar generation, and demand reduction all serve to lower the mitigation costs, but CCS is a key technology for achieving the lowest mitigation costs.

1. Introduction

California is one of the leading nations/states around the world in developing policy instruments to address the issue of climate change. In 2005, it set an aspirational long-term goal of reducing greenhouse gas (GHG) emission 80% below 1990 levels by 2050. The state subsequently implemented legislation setting a binding target that GHG emissions be brought back down to the 1990 level by 2020. This path to achieving the near-term GHG goal included implementation of a number of policy mechanisms including the cap-and-trade program, vehicle efficiency and fuel carbon standards, and others (CARB, 2008). There is significant uncertainty as to how to achieve the deep reductions in GHG emissions that are needed to stabilize atmospheric concentrations of GHGs, what they would cost and what policy measures would be needed. The CA-TIMES model was developed to help answer some of these questions about how to achieve the long-term GHG emissions goals by 2050 while still meeting the demand for energy (McCollum et al., 2012).

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1.1. Literature review

A number of scenario and energy modeling analyses have investigated how California can achieve substantial reductions in GHG emissions. Several studies have been performed to understand the role of efficiency, advanced technologies and alternative fuels in reducing transportation GHG emissions (CARB, 2009, 2012; Leighty, 2012; Yang et al., 2009). A number of scenario studies have looked across multiple sectors to understand the various roles of each in contributing to the GHG targets (CCST, 2011; Greenblatt, 2013; Wei et al., 2013; Williams et al., 2012), but these studies do not explicitly take costs into consideration in an integrated systems modeling approach. Other more detailed macroeconomic models of California (e.g. (ICF, 2010; Roland-Holst, 2008)) only look to the near-term 2020 targets and have not investigated the very-low GHG, longer-term timeframe of 2050. Other modeling and scenario studies have looked at the decarbonization at the global level (GEA, 2012; IEA, 2012), which provides a useful look at global trends, energy use and interactions between regions. These studies provide useful points of comparison for CA-TIMES modeling and highlight the benefits of using an integrated cost optimization model to explore technology, resource and policy scenarios for California's energy future.

1.2. Study goals

The goal of the CA-TIMES model and this particular paper is to provide an integrated analysis across energy demand and supply sectors for California's policy makers and stakeholders, specifically for meeting the 80% GHG reduction goal for 2050. This integration is important for understanding the role of different sectors, technologies, resources and policies in the transition to a decarbonized energy system, and critical tradeoffs across sectors such as limits on low-carbon resources, all while attempting to mitigate GHGs in the least-cost manner.

2. Methods

2.1. Modeling overview

CA-TIMES is a bottom up, technologically rich, integrated economic optimization model of the California Energy System based upon the MARKAL/TIMES modeling framework (Loulou and Labriet, 2007). CA-TIMES covers all sectors of the energy economy of the state (Fig. 1), including energy supply (energy resources and feedstocks (oil, gas, and biomass), fuel production/conversion, fuel imports/exports, electricity production, and fuel delivery), and demand (i.e., residential, commercial, industrial, transportation, and agricultural end-use sectors). Note that CA-TIMES does not currently model or track emissions from non-energy sectors (e.g. landfills, livestock, cement production, refrigerants, etc.).

This version of CA-TIMES (v1.5) is an improved version of a model described in a previous publication (McCollum et al., 2012). Full documentation of CA-TIMES model and assumptions can be found at Yang et al. (2014).

2.2. Modeling methods

CA-TIMES is primarily run as a cost-minimization model in most of the scenarios described in this paper. In this approach, the objective of the model is to meet exogenously specified energy

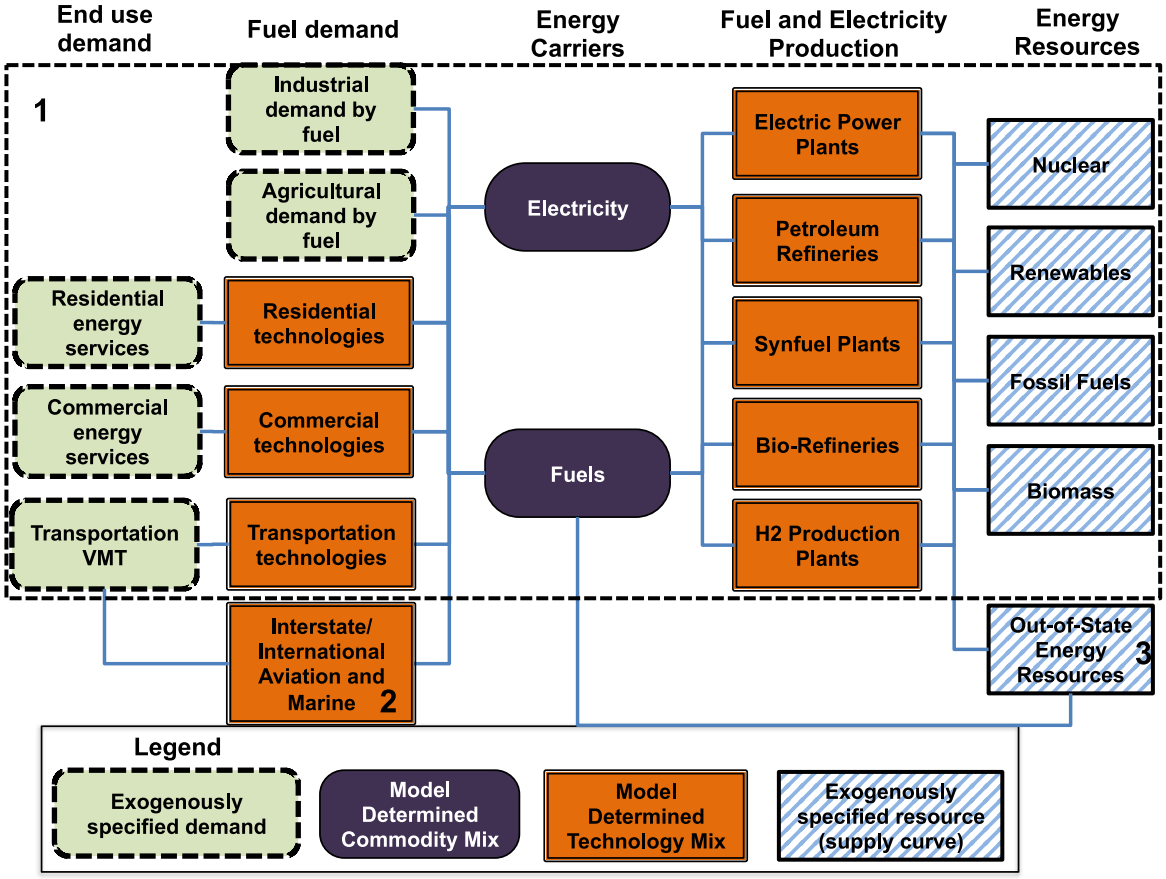

Fig. 1. Schematic representation of CA-TIMES model. The numbers refer to three categories of emissions sources: *Included* (sources in dashed box 1), *Overall* (sources 1+2), and *Lifecycle* (sources 1+2+3) emissions explained in Section 3.5.