Distributional Impacts of Proposed Electricity Sector Policies

Maxwell Brown[*,∓], Jon Becker[*], Jared Carbone[†], Caroline Hughes[*], James McFarland[‡], Daniel Steinberg[*]

[*] US Department of Energy National Renewable Energy Laboratory
[†] Colorado School of Mines, Division of Economics and Business
[‡] US Environmental Protection Agency
[∓] Corresponding Author: Maxwell.Brown@NREL.gov

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The broad scope of proposed policies in the Build Back Better bill, including healthcare, child care, housing affordability, and energy sector transformation, seek to address distributional issues. Most relevant to this proposal are the provisions related to energy which aim to reduce greenhouse gas emissions while promoting equitable access to affordable energy. Although portions of the bill address transportation and industry, major components encourage the deployment of clean and renewable electricity generation technologies and the electrification of energy end-uses.

The most recent version of this bill has several technology-specific options that remain in flux and would imply different electric sector build-outs which ultimately have important consequences to the resulting distributional equity.

In this proposal, we demonstrate how we are uniquely positioned to estimate these distributional impacts given recent analysis directly related to and contributing to the ongoing discussion of proposed policies, recent developments in state-of-the-art and open source models, as well as key considerations for necessary modeling details.

Research Questions and Motivation

To develop a deeper understanding of the distributional outcomes of these proposed policies, particularly those focused on the evolution of the electricity grid, we seek to answer the following questions:

- What are the implications of the proposed policies both spatially (i.e., across US states) and demographically (i.e., across income, age, and race)?
- What are the efficiency trade-offs to insuring more equitable outcomes across demographic groups?

An important aspect of this work is the focus on distributional impacts - we know quite well that lower-income households spend a greater share of their income on energy and that certain regions of the country face greater inequity than others. Recently, policymakers have expressed greater interest in the equity and justice considerations related to energy transitions. Historically, federal incentives for clean energy generation have generally been implemented as investment or production tax credits, primarily for wind and solar generation technologies but more recently for carbon capture and sequestration (CCS) technologies via 45Q. Currently-proposed legislation broadens the technological scope to include more clean generation technologies while also considering transmission and clean hydrogen pathway provisions. Whether or not these pieces of legislation imply positive or detrimental impacts to lower-income households as well as the extent or lack of their progressivity remains an open question. A number of the core team members have a long history of conducting detailed analyses of power sector policy design and are currently engaged in evaluating the potential impacts of a suite of power sector tax credit policies, similar to those proposed in the draft Build Back Better legislation.

As shown in Figure 1, there is a wide geographical distribution for low-income households' energy burdens. The states with the highest energy burden, those along the Gulf Coast and Missouri, have a greater share of households that heat their homes with electricity in the winter and utilize air conditioning to a greater extent in the summer [EERE, 2018]. These states, particularly Alabama and Louisiana, also have a greater proportion of black citizens, leading to broader energy justice issues and opportunities pertinent to a historically underrepresented group.

Another important geographical aspect of this study is in the procurement and production of raw energy inputs, particularly coal and natural gas. both of these fuels are considerably concentrated with the top five states comprising 70% of coal production and 67% of natural gas production. Wyoming, with its relatively low population and high production of coal (40% of total coal production in 2019), is of particular concern given the vast majority analyses estimating a significant reduction in coal generation, even absent policy intervention [U.S. EIA, 2021]. This upstream perspective, combined with the obvious geographical considerations, requires a spatially-detailed and economy-wide representation to capture the full impacts of these proposed policies.

Recent analyses focusing on grid decarbonization through proposed policies [Larson et al., 2020, Goldman School of Public Policy, 2020] have not considered the distributional consequences across income groups, though they have examined *gross* and not *net* employment impacts. Importantly, neither of these studies consider changes in household consumption, income, or broader general equilibrium impacts. Other work focusing on

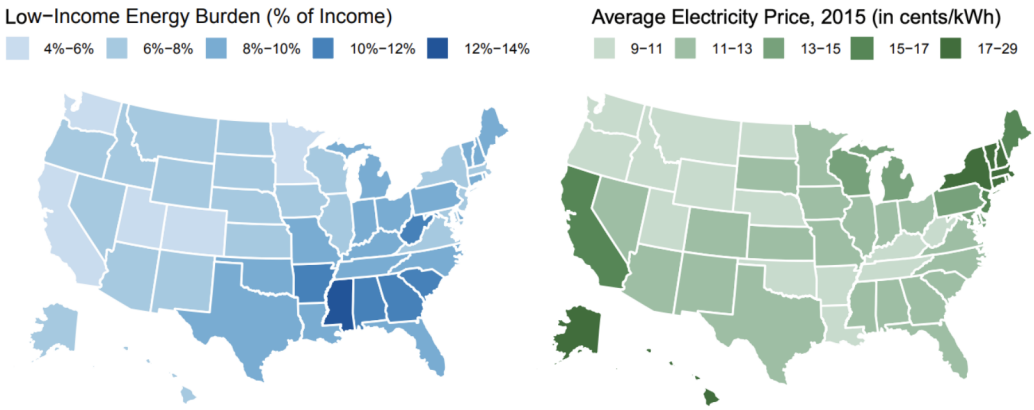


Figure 1: Energy Burden and Average Electricity Price by US State

electrification such as NREL's Electrification Futures Study [Murphy et al., 2021] did not consider impacts beyond the power system; that is, the authors did not account for the broader economic and environmental elements necessary for distributional analysis. Therefore, we would contribute to the literature by assessing proposed policies' net economic impacts as well as their means to and broader impacts from electrification - both alongside the primary focus of distributional analysis. The proposed work would be the only analysis that couples a detailed electricity grid model and a computable general equilibrium (CGE) model with both being best-in-class, publicly available, and at relatively high spatial resolution. The CGE representation is important as distributional impacts are likely to operate both through sources (jobs/income) and uses (cost of living), and that a major advantage of CGE analysis is the ability to consider both in a theoretically coherent framework.

Methods and Data

This study relies on the coupling of two models - the Regional Energy Deployment System (ReEDS; Brown et al. [2020]) and the Scalable Linked Dynamic Equilibrium (SLiDE) model. ReEDS is NREL's flagship capacity expansion model and has been used in over 100 different journal article and technical report publications. In 2021, following the ReEDS re-development and open source initiatives[1] led by Maxwell Brown, the model received an R&D100 award in the Software category. The ReEDS linear program solves for the least-cost combination of investment and operations for the contiguous United States with one of, if not the, highest regional details for models in this class with balancing area (where supply equals demand) and capacity resource regions (subregions with detailed characterization of renewable energy technologies) depicted in Figure 2. ReEDS also maintains a characterization of over 200 different electricity generation technologies including recent extensive expansions to its CCS representation, providing the fidelity needed to accurately assess the future of fossil fuel demand in the electricity sector.

SLiDE is a CGE model based on the Wisconsin National Data Consortium (WiNDC) National Open-source Tools for Equilibrium Analysis (blueNOTE) dataset and set of models

[1]See: nrel.gov/analysis/reeds/

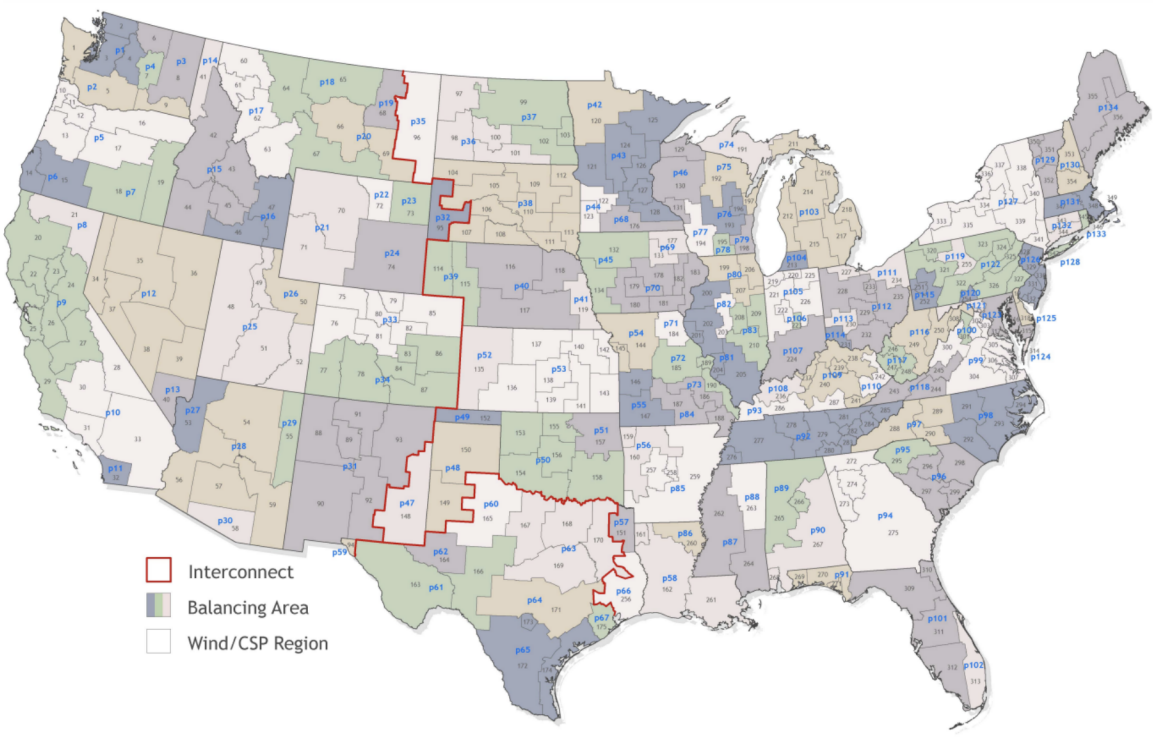


Figure 2: ReEDS Balancing Areas and Resource Supply Regions

[Rutherford and Schreiber, 2019]. The SLiDE model expands on blueNOTE by increasing the technology fidelity in energy sectors, relaxing the full employment assumption, and adding the ability to conduct analysis at different geographic and sectoral scales. The model currently solves at the US state level with five representative income quintiles as households. The relaxation of the full employment assumption, consistent with Balistreri [2002], is important for distributional analysis given electricity's presence as an intermediary in both demanding fuels from other sectors and supply energy to households and firms. The model is open source[2] through an MIT License and written in the Julia/JuMP programming language.

The SLiDE and ReEDS models are linked using the methods outlined by Böhringer and Rutherford [2008]. To summarize, the electricity sector in SLiDE is exogenized and then parameterized using data from ReEDS such as the quantities of fossil fuel use, capital and labor demand, and electricity price and quantity. SLiDE solves then updates the ReEDS local electricity demand curve, fossil fuel prices, as well as capital and labor price indices. The models converge once the demand prices and quantities in ReEDS are matched by those in SLiDE while remaining consistent over several iterations. The models use this routine to first establish a benchmark from which counterfactuals deviate. This framework has been used before with ReEDS being linked with MIT's model of the US economy, the US Regional Energy Planning (USREP) model, to perform a distributional analysis of carbon tax revenue recycling mechanisms in Caron et al. [2018][3] and was most-recently used to

[2]See: github.com/nrel/slide

[3]This work, co-authored by Maxwell Brown, has also received significant media attention from an Op-Ed by former Colorado Governor Bill Ritter Jr in the Denver Post (denverpost.com/2018/04/13/the-good-tax/)

evaluate Section 115 of the Clean Air Act. In 2019, Maxwell co-lead the development of the linked USREP-ReEDS model with Mei Yuan[4] following the redevelopment of ReEDS. In January 2022, Maxwell updated the linked model to include the most-recent version of ReEDS and, in doing so, has paved the way for the updated linkage with SLiDE.

Scope

The policies explored would encompass a stylized suite closely aligned with what is being considered in current legislation such as the Build Back Better bill. This generally includes extending existing production and investment tax credits at various levels while also applying new tax credits to currently unincentivized technologies, clean hydrogen pathways, CCS generation and pipeline/storage capacity, as well as potential incentives to bolster existing generation assets. Related to existing assets, there is the potential for policies to support existing nuclear generation facilities as well as the upgrades of existing fossil fuel fired units to include CCS.

The stylized suite of scenario options will also be run alongside variations to prevailing market conditions such as low/high natural gas prices and low-, medium-, and high-electrification consistent with Murphy et al. [2021]. The findings from this project will include consumer welfare impacts across income groups as a measure of distributional equity as well as a broad array of economic indicators such as consumer price indices, gross domestic product, net employment impacts, and balance of trade among others. The results specific to the electricity grid are detailed generation and transmission capacity build-outs, emissions, and electricity prices. All results would be at the state-level and through 2050. Finally, we examine the efficiency implications of more equitable policy outcomes via compensation mechanisms (see. e.g., [Caron et al., 2018]).

To allow for a more rigorous equity analysis, we plan to extend our existing household data and representation to include different demographic dimensions such as race and age. Currently, households in SLiDE are segmented by region and household income quintile, informed by data from the US Census Current Population Survey (CPS) Annual Social and Economic Supplement (ASEC) [U.S. Census Bureau, 2021]. The CPS provides detailed income transfer information, with demographic representation including but not limited to sex, race, Hispanic origin, and education. The SAGE model [Marten et al., 2021] aggregates CPS data into the five representative household quintiles and estimates, via TAXSIM [Feenberg and Coutts, 1993], average and marginal tax rates required for the household disaggregation. The population and tax data generated via this process is included in the WiNDC buildstream, beginning with version 3.0 and is leveraged to build the SLiDE input dataset. The CPS ASEC person data is key to an efficient, initial approach to further disaggregating household groups into more detailed demographic representations: it can be used to calculate disaggregation scaling factors that can be applied to all SLiDE model parameters at either the beginning or end of the build stream.

Given the detailed spatial and income resolution of SLiDE's current households, explicit endogenous representation of the extra household dimensions could introduce computational issues that requires us to simplify the regional aggregation from the state-level to an aggregated set of regions (e.g. North and South Dakota become 'the Dakotas'). Alterna-

to a popular video recently released on YouTube (youtube.com/watch?v=aznOL753eiQ)

[4]Research Scientist, MIT Joint Program on Science and Policy of Global Change

tively, a post-solve disaggregation of household region-income groups by extra demographic dimensions could still yield valuable equity insights at the state-level. We've just begun this capability development and have a clear idea of what is required for each pathway – the remaining question is in the more detailed model's stability.

Progress-to-Date and Next Steps

As of January 2022, we have released SLiDE v1.0, which is currently being used in decarbonization and distributional analyses. The development version of SLiDE includes a more-detailed set of electricity generation technologies that is calibrated to ReEDS using its levelized cost of electricity (LCOE) outputs. With the re-developed linkage between ReEDS and USREP, we have begun importing data from the newest version of ReEDS into SLiDE in the same fashion. Once that linkage is established and tested, in Spring through Summer 2022, we would be ready to begin analysis of proposed policies and sharing of preliminary results.

Naturally, we will communicate our findings via the NBER-organized activities. In addition, we plan to make them available to stakeholders via NREL's Cambium tool. One potential method is to deploy a web-pased results explorer such as NREL's Cambium[5] tool which would allow users to interactively explore an array of different scenarios and results. Another method is to produce a video providing an approachable explanation for the background, methods, and key findings of the study. The goal of this is always to broaden our audience and allow more people to understand energy policy and its implications.

[5]See: https://www.nrel.gov/analysis/cambium.html

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