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ABSTRACT

Advocates in several countries have promoted a “green recovery” from the pandemic, with an emphasis on measures to address climate objectives. We evaluate proposals for the United States and find that as stated, ambitious plans to further cut emissions from transportation and electricity will require more inputs to produce the same outputs, resulting in recurring costs of up to $483 billion per year. We forecast that real GDP and consumption will be 2-3 percent less in the long run if policies are implemented as stated, underscoring the opportunity costs of achieving green objectives when resources might be more efficiently deployed.

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1. INTRODUCTION

Calls for a "green recovery" from the pandemic recession have triggered bold plans for economic policy interventions aimed at achieving environmental and especially climate goals (OECD 2020). These proposals capitalize on the aphorism to "let no crisis go to waste" in an effort to achieve long-term policy goals. This new political opening has created an opportunity for the U.S. Green New Deal, large parts of which have been adopted by former President Biden as part of his "Biden Plan." This integration of economic and climate policy promises a transformational change to the U.S. energy and transportation sectors, if the plan is implemented as it is currently written. We assess the economic costs of the energy and climate portion of the Biden Plan as it is currently expressed.

We find that the energy and climate proposals entail substantial economic costs, increasing resource costs by $363 billion per year. In addition, the implementation appears likely to impose indirect costs that increase the total burden by one-third. We recognize that the plan is currently a political platform more than a concrete policy proposal, but highlight the substantial economic cost that this initiative would entail. Our results are applicable to other green recovery plans that place similar emphasis on regulation and little scope for incentives.

Climate change is a real threat to human welfare, and a coherent policy response deserves serious consideration. It threatens to impose sizeable costs on people around the world, including in the United States. Changing the current climate trajectory could provide substantial net benefits to future citizens. Limiting the response to emissions reduction proscribes the range of policy reactions (Aldy and Zeckhauser 2020), and is likely to raise costs. By highlighting the costs of this particular set of policy proposals, we hope to trigger further discussion and development of more cost-effective strategies. Those strategies may include other tactics such as adaptation and amelioration.

Our findings underscore the importance of engaging in policy design work to reduce costs in achieving the policy objectives. Previous work could substantially inform the design of policies in ways that would reduce the opportunity cost. For example, the Biden Plan proposes a dramatic shift in the composition of electric generation while holding consumer prices constant. Adjustments in prices are one of the most powerful tools in the arsenal of economics. We suspect that gains could be realized by allowing prices to react, but price changes might be distributed in unequal ways across relevant political distributions, like income or urban-rural divides. Those political tradeoffs might intimidate politicians. Economists could help politicians and policymakers understand the distributional implications of a design that reduced opportunity costs by allowing prices to adjust, and how that would affect the progressivity of the intervention (A. Levinson 2019).

2. CLIMATE AND ENERGY POLICY

In contrast to the previous administration that emphasized increasing domestic fossil fuel production, President Biden has coordinated his energy proposals around climate action. Policy proposals in this area are influenced by the high profile of the Green New Deal, which has support among many Democrats. Similar proposals are proposed in other countries (cf. Green New Deal 2019, European Green Deal 2019, Korean Green Deal 2020, Japanese Green Deal 2021). Federal climate policy has been slow to develop in the United States relative to other OECD countries, though several states have adopted climate policies that contribute to actions that help reduce emissions relative to a baseline. Despite the lack of federal coordination, the United States appears met 2020 emissions targets, mostly because of increased reliance on natural gas, which is far less carbon intensive than coal (Council of Economic Advisers February 2020, New Climate Institute 2020). The United States began the process to rejoin the 2015 Paris Agreement on President Biden's first day in office, and future path of compliance with emissions reduction targets is uncertain.

The Biden Plan proposes more than a dozen climate and energy policies aimed at reducing America's carbon footprint, each of which has opportunity costs in terms of less economic activity in the short run and benefits in terms of reduced climate change impacts. These policies are detailed in Table 1. Some of these policy proposals are unlikely to impose large short-term costs, such as halting the U.S. withdrawal from the Paris Agreement or reverting to Obama-era rules to limit fugitive methane emissions from oil and gas operations.[1] Others, including those discussed below, would likely impose substantial economic costs. We quantify the opportunity costs of four climate policies that are likely the most impactful among Biden's proposals. The first would reduce fossil fuel consumption by light- and medium-duty vehicles by raising average fuel economy regulations, in an effort to erode the reliance of the transportation sector on petroleum and avoid associated emissions. The second would increase the share of electricity generation from renewable sources, displacing fossil generation in an effort to reduce emissions. The third would require additional renewable electricity generation to help satisfy the electrification of transport. A fourth, holding companies financially liable for historically emitted carbon and other pollutants, may help finance subsidies for renewables, but would impose additional opportunity costs, such as the impact of the implied higher uncertainty regarding future after-tax profits.

These plans for a policy-triggered transformation are ambitious. Unless people drive a lot less, the electrification of all, or even most, passenger vehicles would increase the per capita demand for electric power by about 25 percent at the same time that more than 70 percent of the baseline electricity generation (i.e., using fossil fuels) would be retired and another 11 percent (nuclear) would not expand. To put just the 25 percent in perspective: that is the amount of the cumulative increase in electricity generation per person since 1979, which is a period over which nuclear and natural gas generation tripled.

In our effort to enumerate the opportunity costs of the policy proposals, we do not assess the benefits those policies might deliver beyond rough estimates of the tonnage of carbon abatement. Given the global public good nature of emissions reductions, it is clear that U.S. citizens would capture some share of global benefits from these policies, but would bear all of the costs.[2] At the same time, the global benefits of solitary actions by the United States would be diffuse and small relative to climate policy targets. One way to interpret our focus on costs is to identify cost-effective policies for climate policy. Accounting for direct and opportunity costs is a first step. A full accounting of the benefits would determine if the costs are worth incurring, including distributional implications of both benefits and costs.

2.1. Regulation of motor vehicle fuel efficiency

For better or for worse, the United States has focused policy efforts on average fuel economy standards, even though more efficient alternatives exist (West and Williams 2005). These policies lead to a number of dynamic responses by both producers and consumers of motor vehicles, which can complicate analysis of the benefits and costs (Bento, et al. 2020). As a candidate, Biden (2020) pledged "rigorous new fuel economy standards aimed at ensuring 100% of new sales for light- and medium-duty vehicles will be zero emissions." This approach shares a common objective with other current policy proposals in this area, such as California governor Gavin Newsom's ban on non-electric vehicle sales after 2035 (2020). Importantly, under either approach—a prohibitive regulatory standard or an outright ban—there is no legal way for a consumer to purchase a new internal combustion vehicle *at any price*.

We provide a transparent analysis of this policy. The baseline for our analysis is the current law, representing a rollback of increased average fuel economy regulations that were imposed during the Obama Administration. We estimate a lower bound on the cost of this pledge by estimating the private-sector cost of increasing average fuel economy standards from 45 miles per gallon (MPG) to 80 MPG. This underestimates the stringency of the standard and ignores the extension of these standards in the medium-duty range.

We take the private-sector cost function to be quadratic in MPG, and therefore its marginal cost of increasing MPG to be linear in MPG.[3] We estimate the marginal cost schedule with information about two of its points, as illustrated in Figure 1. The first point is the $18 marginal cost estimated by Anderson and Sallee (2011) at 25 MPG (model year 2006). The second point is the average marginal cost of $116 inferred from inter-manufacturer trades in carbon credits during the model years 2012-2016 (Council of Economic Advisers 2020). Because the carbon credits were bankable, we treat the model years 2012-2021 as a single "fleet" with expected average standard fuel economy of 36 MPG. Moving along this cost function to the 80 MPG point would cost more than $12,000 extra per vehicle, which is the shaded area in Figure 1.[4] Fewer vehicles would be sold in this situation, albeit at a higher price. Taking both effects into account, we estimate the annual private cost in the new vehicle market of Biden's pledge to be at least $186 billion, not including the costs of expanding the electricity-generation industry's capacity to service the larger electric fleet. Even if increasing fuel efficiency from 45 MPG to 80 MPG cut in half emissions by new passenger vehicles, and did not unintentionally increase emissions elsewhere in the economy, the average cost per ton of carbon abated would be an order of magnitude above the likely global environmental benefit. Put another way, continuing to ratchet up fuel economy standards delivers expensive emissions abatement. The recent implied cost of abatement of $116/MPG per vehicle translates to an implied value of $86/ton of CO_2 equivalent emissions.

Such a policy would have other, indirect effects as well. First, consumers would be likely to change the portfolio of older cars in subtle ways. Older vehicles that are less fuel-efficient would likely stay in the fleet longer, because replacements would be harder and more expensive to obtain. At the same time, more fuel-efficient used cars would be more likely to be scrapped because still more efficient new vehicles would be able to be purchased under the policy. These two effects combine to reduce the marginal effect of continuing to use an average fuel economy standard instead of a different instrument (Bento, et al. 2020). It could be that a higher standard would help spur a technological breakthrough in manufacturing fuel-efficient automobiles. We are skeptical that regulation is the most cost-effective way to promote technological innovation.

2.2. Renewable electricity generation

In the spirit of the Green New Deal and other transformative recovery policies, as a candidate Biden proposed to fundamentally transform the U.S. electricity generation system by requiring a "carbon pollution-free power sector by 2035."[5] Because wringing the last bit of emissions from the power sector could be prohibitively expensive, we do not take this pledge literally. Instead we quantify the effects of a somewhat less ambitious policy of 80 percent of generation to come from emission-free sources by 2050, which has been modeled by Department of Energy personnel (Mai, Mulcahy, et al. 2014). It is notable that the Biden Plan promises to do this without affecting consumer price, effectively allowing end users to enjoy the same amount of electricity while reconfiguring the generation architecture of the U.S. electric grid.

In 2019, about 18 percent of electricity was generated by renewable sources (including hydroelectric but not nuclear). The platform is silent on the expansion of either hydroelectric or nuclear generation, so we hold those sources constant and model the policy as substituting renewable for fossil generation. In 2019, nuclear generated 20 percent of the annual total, although the nuclear share will likely fall as older plants are retired in coming years. Following Mai et al (2014), we interpret the platform as increasing (non-nuclear) renewable generation from 18 to 68 percent of total generation. We focus on the aggregate quantity of electricity provided, rather than a more granular analysis taking constraints on delivery into account. This is consistent with our understanding of the platform. To the extent that physical constraints bind more than Mai et al (2014) model them, our estimate of the costs is conservative.[6]

We calculate the cost of increasing the renewable share of electricity generation from 18 percent now to 80 percent by 2050. In keeping with the Biden platform documents that highlight the importance of not raising retail prices for groups of consumers, we assume the goal is achieved by subsidizing renewables and taxing nonrenewables in order to achieve the share target without affecting the net-of-subsidy retail price of electricity and thereby the quantity of electricity consumption. Because we allow for a portion of net generation to be fossil-based, we are implicitly assuming that remaining fossil generation can handle reliability and consistency constraints, which could be an issue for certain times and places in a more renewable-dependent electric grid.

Figure 2 illustrates our cost calculations, showing generation quantities on the horizontal axis and marginal costs on the vertical axis. The green curve is the marginal cost curve for renewables while the black curve is the curve for fossil fuels. Because we show the fossil-fuel curve as a mirror, moving to the right in the figure indicates a change in the composition of generation without changing the total. Holding the total generation constant, for the moment, makes sense if consumer demand does not shift and the policies are implemented in such a way as to hold retail prices constant. The baseline quantity's marginal costs are indicated with the gray vertical line. The blue vertical line shows the result of achieving the 80 percent target.

Switching 2.1 billion megawatt-hours (MWh) per year of electricity generation from nonrenewable to renewable resources requires a resource cost equal to the cost difference between the two sources of supply. In the baseline, there is already a resource cost difference at the margin due to longstanding subsidies for renewables. We estimate that difference to be $22 per MWh, which is the baseline vertical distance shown in Figure 2 between the two marginal cost curves. According to Mai et al (2014), expanding renewables to 80 percent would add another $50 per MWh to the marginal cost of renewable supply. Meanwhile, the gap between marginal supply sources increases another $16 by moving down the supply curve for nonrenewables.[7] On average, that is a cost gap of $55 per MWh, bringing the total industry resource cost to $115 billion annually, as entered in the bottom panel of Table 2.[8] In other words, $115 billion is the additional cost for the industry to produce the same quantity of electricity. Previous work has demonstrated that the marginal cost increase is linear up to the 80 percent threshold (Elliston, Riesz and MacGill 2016).

The high renewable generation outcome can theoretically be achieved with renewable subsidies of $202 billion annually and nonrenewable taxes of $13 billion, which is a net subsidy of $189 billion annually.[9] We assume that is financed with relatively efficient taxes, namely flat-rate labor-income taxes and excise taxes on consumption goods. These excise taxes could include settlements with oil and other companies pursuant to the fourth item of the Biden Plan that we assess: exacting reparations from companies that emitted carbon and other pollution in the past. As noted previously, $115 billion of this is an annual resource cost, which makes the remaining $58 billion a redistribution to the inframarginal suppliers of renewables. This redistribution itself has a deadweight cost in the labor market, which for the purposes of Table 4 we assume to be $0.50 per dollar or $29 billion annually.[10] Combining the industry resource cost and the labor market deadweight costs, the electricity generation changes increase resource cost by $144 billion annually.

Because the additional "resources" used in electricity generation are ultimately some combination of labor, capital, and raw materials, our approach is qualitatively consistent with the Biden Plan claims that it would create jobs in that industry.[11] However, in order to reach conclusions about aggregate employment, we must keep track of all of the parties to a subsidy transaction, including taxpayers and lenders to the government, which we do with the neoclassical growth model. We must also recognize that the Biden Plan affects the real wage either by taxing labor or consumption to pay for the subsidies, as in our model, or by increasing the real price of energy.

At first glance, subsidizing renewable energy would be analogous to hiring workers to build roads or military bases, which are projects shown to increase aggregate employment (Ramey 2011). To the extent that the analogy is apt, we note that employment increases less in the aggregate than in the industry; the projects reduce employment outside the industry. However, road and military projects are often temporary and thereby not financed by a commensurate and contemporaneous tax on labor or consumption, whereas the additional resources used by renewable energy will be ongoing. Moreover, perhaps unlike road building and other projects, the added annual tax burden for expanding renewable energy, $173 billion, significantly exceeds the annual cost of the resources drawn into the industry, $115 billion.

2.3. Renewable electricity generation for an electric vehicle fleet

In addition to improving average fuel efficiency of petroleum-fueled vehicles, increasing penetration of electric vehicles into the fleet can help mitigate carbon emissions. Electric vehicles rely on the electric grid for charging, and the underlying grid is much greener in some parts of the country relative to others, such that an additional electric vehicle has negative climate benefits in some states (Holland, Mansur, et al. 2016). Furthermore, the costs of those emissions is not limited to global stock pollutants, and some populations bear disproportionate costs from electric generation for additional vehicles (Holland, Mansur, et al. 2019). In part in response to these studies, the Biden plan proposes to serve incremental demand for electricity to charge vehicles with renewable generation.

If households are to maintain their uses of electricity as well as charge their electric vehicles, more electricity generation would be needed than assumed by Mai et al (2014). We calculate that this incremental demand is 1 billion MWh per year (relative to a baseline of 4.1 billion MWh per year) and would increase the marginal cost of renewables from $117 per MWh to $136 (Table 2). The expanded-capacity allocation is shown in Figure 2 as the two vertical red lines indicating movements up both the renewable energy and the fossil fuel supply curves. The additional resource and social costs are shown in Table 2 as $62 billion per year and $71 billion per year, respectively. The cost of generating the extra 1 billion MWh using the baseline fossil fuels at baseline marginal cost ($45 per MWh) is counted separately in our estimate of the cost of increasing vehicle fuel efficiency.[12]

2.4. Stranding fossil fuels

In addition to consumers and producers, transitioning away from reliance on fossil fuels affects one other important group of Americans. The United States is unique in the world insofar as private citizens own the majority of the mineral deposits. In other countries, devaluing fossil fuel deposits undermines only the government's balance sheet. While U.S. federal and state governments own substantial mineral property, about three-quarters of production comes from private mineral property. Changing

Table 3 shows estimates of the value of proved reserves of oil, natural gas, and coal at the end of 2018. We estimate these values from state-level proved reserves published by EIA, applying a version of the net price rule suggested by Davis and Cairns (1999).[13] The aggregate estimated value of the deposits in the ground is $4.95 trillion. Table 3 shows the composition of this value across different fuels and different states, taking into account both physical and geographical differences in reserves. The energy embodied in a barrel of oil is more valuable than the same amount of energy in a coal deposit, just as reserves on the North Slope of Alaska are likely to be less valuable than comparable reserves located nearer to population centers.

Oil reserves account for just over half of the total value, even though domestic petroleum accounts for only about one-third of energy attributable to domestic fossil fuel production. In contrast, coal accounts for only about 11 percent of the total proved reserves value, even as it contributes twice as much to the proportion of domestic fossil fuel production. The single largest category is the value of proved oil reserves in Texas—we estimate those reserves to be worth over $1.1 trillion, or about 40 percent of the total U.S. proved oil reserves.

Table 3 gives a sense of incidence of an anti-fossil fuel policy. The states with the largest values of natural capital stocks in fossil fuels are Texas, North Dakota, Pennsylvania, Oklahoma, New Mexico, West Virginia, and Wyoming. Policies that restrict the production of fossil fuels will especially pass through to the value of the natural capital assets. Private citizens own over 70 percent of these assets and stand to absorb lower capital values. Because of absentee ownership, citizens in states other than where resources are located may absorb lowered values; as an example, Texans control mineral rights across the country (Brown, Fitzgerald and Weber 2019), so may bear an especially high share of the cost of stranding those assets.

The variation in ownership of mineral reserves varies across states. The federal government is a major mineral owner, especially in western states. The federal government also controls most offshore resources. We make estimates of the disposition of fossil fuel reserves.[14] We estimate that the federal government owned proved reserves are worth at least $785 billion. This compares to an estimate of $309 billion (1981$) by Boskin et al. (1985), which would be $722 billion in 2018.[15] In 2019 the federal government earned a return of $8.6 billion from fossil fuels in 2019, amounting to a total of 93.5 percent of federal natural resource revenue (ONRR).

As we have modeled the Biden Plan, nonzero fossil fuel production would still occur in the U.S. and inframarginal fossil fuel reserves would still retain some value. According to our Figure 2, fossil fuel producers lose in two ways: producing less and paying tax on what they do produce. The total of these is $30 billion annually, as shown in Table 2. Discounted at the after-tax return that loss has a present value of $841 billion, or about $6800 per household on average.[16] This analysis excludes a third important pathway, which is the depreciation of the value of natural capital on the form of mineral deposits. Because the value of this capital is tied to fossil fuel prices, which are likely to end up lower under the policies described above, the depreciation of capital values is another important channel that we do not enumerate.

3. LONG-RUN EFFECTS ON THE ECONOMY

Table 4 is the bridge between our energy-industry analysis and the macroeconomy. Table 4 specifies for each of the three regulatory policies discussed in 2.1-2.3, how the total opportunity cost is comprised of additional resource cost and redistribution. Because candidate Biden also promises to transform electricity generation without increasing retail electricity prices, subsidies will be needed, which we assume to be financed efficiently (a flat-rate labor-income tax). We assess the additional resource cost to be $363 billion per year. Redistribution adds $120 billion per year.

Table 5 shows the results using the tax and productivity parameters in the neoclassical growth model. [17] The redistribution needed to support baseline energy prices adds to the labor wedge, reducing the post-wedge by one percent. Because productivity and capital-stock changes have offsetting income and substitution effects in our model, the addition to the labor wedge is the main reason that long-run employment changes in our model.

We assume no additional capital-tax distortion from the GRP. Capital intensity falls 2.5 percent because of the productivity shock. The combination of less capital per worker and less TFP results in real wages that are lower by 2.5 percent. The aggregate capital stock falls 2.8 percent because it is the product of workers and capital intensity. Real GDP and consumption fall 2.8 percent due to the combination of less labor, lower capital intensity, and less TFP.

4. ASSESSING COSTS ALONG A TRANSITION

In estimating the long-run costs associated with proposals to fundamentally transform the energy system, at least a conceptual discussion of costs along the transition is relevant. Because the physical transformation would require a period of time, here we address the transition path.

First, the economic experience or political changes along the transition may change the long-run policy goal. An example of this is in the renewable electricity generations pace. President Biden originally proposed a target of 80 percent of generation from carbon-free sources, but later amended the platform to zero carbon-based sources (Dennis and Grandoni 2020). Our estimates are analogous to the first long-run goal, but are conservative relative to the second goal. To the extent that the goalposts move as a policy is developed, our estimates are calibrated to the current proposals. In principle, the policy goals might become more or less ambitious, meaning our cost estimates are too low or too high relative to realized costs.

Second, the time path of the transition may affect the costs that are incurred. Sticking with the renewable electricity example, President Biden originally proposed the 80 percent renewables target by 2050, but later accelerated the timeline to achieve zero carbon emissions by 2035. Moving the goalposts is one thing, but accelerating the timetable may also affect our estimates. In macroeconomics, this is often referenced as “investment adjustment costs” (see the review by Chirinko 1993). A faster transition will not be less costly than a slower transition. Achieving 80 percent of generation from renewables by 2035 will not be less costly than achieving the same goal by 2050. Hitting the same target by 2030 would not be less costly than by 2035. What does potentially differ in that case is the accrual of benefits, which we have not addressed here.

5. DISCUSSION

Transforming the energy system over the next 15 years is an ambitious proposal. The rate of technological change is a key consideration. Our estimates extrapolate today's technology as a baseline. If technology advances in the interim, effectively lowering the marginal cost of renewable electricity generation, then welfare clearly increases as it would with any positive supply shock. The U.S. energy system has benefited from just such a shock in the past 15 years, as unconventional oil and gas production has allowed the displacement of coal.

Green recovery policies are articulated in terms of goals rather than instruments, which leaves considerable room for consideration of cost-reducing strategies. Recent economics research has provided a wealth of evidence about the sensitivity of consumers to changes in terms of electricity service. This ranges from reactions to price that depend on market structures, heterogeneities, and timing (Lijesen 2007, Miller and Alberini 2016, Burke and Abayasekara 2018), as well as to various information interventions (e.g., Jessoe and Rapson 2014) that provide consumers with a better idea of their actual electricity usage. These non-price design features may offer some promise, given that Ito (2014) finds that nonlinear pricing schemes for electricity do not trigger as a strong a behavioral response as the average price. The ability to change behavior via framing and salience may provide an implementation strategy far lower than the direct regulation that has been proposed thus far.

Regulation is likely to impose greater opportunity costs than price-based mechanisms. Metcalf and Stock (2020) provide relevant analysis of the introduction of carbon pricing in Europe, concluding that the macroeconomic impacts are not significantly negative. The reliance on mandates and technological standards in green recovery proposals, in contrast to tradable allocations or price mechanisms, is an important source of opportunity costs.

The temptation to latch onto straightforward but transformative energy policies is highlighted by the cautionary tale of energy efficiency gains advertised by McKinsey (2009). Detailed analysis of weatherization projects has shown that the returns are much smaller than engineering estimates suggest, and may even be negative (Zivin and Novan 2016, Fowlie, Greenstone and Wolfram 2018). This experience should temper exuberant predictions of a technological tipping point.

Similar stories abound across the energy landscape; cellulosic ethanol, seen as a lower-carbon transport fuel with an abundant feedstock, has been "five years away" for over a generation.

Political platforms are not detailed policy proposals, but directional documents intended to provide a vision of political leadership. Many details are filled in later, if voters invest their votes in the vision articulated in the platform. The analysis presented here highlights the importance of that policy design and implementation step. If implemented literally without adjustment or nuance, the bold transformation of the energy system articulated in the Biden plan, or variants more closely adhering to the Green New Deal, promise substantial economic opportunity costs.

One looming issue not detailed in the Biden Plan but directly related to ongoing international efforts to take bolder action on climate issues is the imposition of tariffs based on embodied emissions or additional emissions. Such a border carbon adjustment could, if poorly designed, disrupt trade flows with a serious negative economic consequence (Prag 2020). This is an example of a policy detail that will become clearer in the event that a bold plan to transform the energy system were implemented. While border adjustments might protect some domestic producers, its implementation is uncertain and poses a threat to international trade.

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Notes

[1] Moreover, the costs of methane-emissions limits are already counted separately in the CEA sample of 20 regulations. Further consideration could be given to the relative costs of fuels- and climate-focused approaches to energy and environment, in particular the distributional and geographical impacts as in Brown, Fitzgerald, and Weber (2019).
[2] This issue leads to the divergence between global and domestic social cost of carbon, which has been acknowledged at least since 2010 (United States Government, Interagency Working Group on Social Cost of Greenhouse Gases 2010).
[3] We note that because of the technological ambition of the standard, the actual cost function is likely more convex than quadratic in the relevant range. Compliance with an 80 MPG standard requires consumers to forego essentially all vehicles with fuel economy less than a Toyota Prius, which itself would be less than the fleet average. Our functional form assumption is therefore conservative.
[4] At 80 MPG, the marginal cost is about $512 per MPG per vehicle. At the baseline MPG of 45, the marginal cost is about $197. Therefore the average marginal cost of the first increase in MPG and of the last increase in MPG is about $355 per MPG per vehicle. Applied to a 35-MPG increase in the standard, that is more than $12,000 per vehicle. Our approach does not specify to what degree this cost is borne as higher retail prices versus lesser vehicle quality as perceived by consumers. Bento et al (2020) point out that producers may sell some high-efficiency vehicles below marginal cost as a strategy to comply with fuel efficiency standards. That behavior reduces costs borne by consumers but compounds the costs to producers. This paper does not fully describe the incidence of those costs.
[5] https://joebiden.com/clean-energy/
[6] Mai, Bistline, et al. (2018) studied the predictions of different energy system models to determine modeled paths for renewable penetration into electricity generation. None of the models approached the 80 percent target. How much of the target is realized due to market rather than policy incentives determines the opportunity cost of action. Renewable electricity generation has some attractive economic attributes, such a very low or zero marginal cost. While this pulls more renewables into the generation mix, the relatively high fixed costs create an offsetting incentive that policy often targets. Where this comes out is unclear (Heal 2020), and is the reason we rely on energy forecasts.
[7] We obtain the $16 by assuming a price elasticity of nonrenewable supply of two. This is the price elasticity of supply across all fossil sources, which exceeds the supply elasticity across single fuels, which themselves show evidence of raising in recent years (Newell and Prest 2019, Newell, Prest and Vissing 2019).
[8] Expanding renewables the first MWh costs only $22 more than the nonrenewable alternative whereas the last MWh of renewables costs $22 + 50 + 16. To a first-order approximation, the quantity-weighted average of the extra costs in between is the average of these two endpoints; this is a generalization of the Harberger-triangle method.
[9] To be conservative as to the impact of President Biden’s agenda, we assume that the federal government obtains the $13 billion in annual fossil-fuel taxation without losing any of its existing revenue from mineral royalties and leases. More likely the losses would be in the single-digit billions.
[10] Labor tax collections that are consumed as part of the policy have income and substitution effects on aggregate labor supply, which we assume exactly offset. The collections that are redistributed have, to a first approximation, only the substitution effect, which is reflected in the 50 percent marginal deadweight cost factor (Council of Economic Advisers February 2020). Note that in using the neoclassical growth model we do not separately assume labor-market deadweight costs because those are outcomes of the model.
[11] In order to calculate an increase in energy-industry employment, one could assume that the new activity in the industry is about as labor-intensive as the rest of the economy with about the same annual compensation per employee. If so, that would be about 1.3 million additional energy-industry jobs in the long-run, including the employees needed to expand capacity to accommodate additional electric vehicles (Section II.C). As explained below, this additional employment comes at the expense of even more jobs outside the energy industry.
[12] Specifically, in using the GHG credit market as the foundation for Figure 1, we already recognize consumers’ willingness to incur higher electric bills in order to economize on fueling their vehicle.
[13] Using proved rather than technically-recoverable reserves makes this figure conservative relative to the total amount of fossil fuel resources in place in the United States. This measure makes for a more relevant estimate of the resource that has been demonstrated to exist and is profitable to extract at current prices.
[14] These estimates use ownership shares from Fitzgerald and Rucker (2016).
[15] Boskin et al. (1985) attempt to place a value on both *undiscovered* and discovered resources. Proved reserves are a subset of discovered resources.

[16] Arguably, producers might be able to mitigate these losses by accelerating their production before the fossil-fuel restrictions take full effect. Accelerated fossil production would hurt the short run economics of renewable energy, and possibly contribute adversely to climate change more than the baseline policy does. Also note that Table 3 estimates the cross-state incidence by the location of proved reserves; the owners of the production factors could live elsewhere in the country or even outside the United States.

[17] Table A1 shows the baseline and GRP tax and productivity parameters that underlie the analysis reported in table 5.

Table 1. Biden Climate/Energy Proposals

Proposal	Brief Description	Our model
Methane limits	Restore limits for oil and gas operations	Part of our estimates of reversing Trump's Obama reversals
ANWR restrictions	Permanently protecting Artic National Wildlife Re	
No new federal oil and gas leasing	Both on shore and offshore	
Tighter standards for fuel economy/emissions by passenger vehicles	Ensuring 100% of new sales for light and medium duty vehicles including trucks will be zero emissions	In order to rely on historical compliance transactions, we model a less ambitious standard: 80 miles per gallon for passenger vehicles only.
Carbon pollution-free power sector by 2035	Nuclear generation would continue but no new nuclear capacity	In order to rely on detail estimates by DOE personnel, we assume a less ambitious goal: 20 percent fossil fuel generation by 2050. Subsidies are used to maintain retail prices.
Net zero emissions by 2050	Includes carbon capture.	No cost is assessed in this paper, aside from those cited above.
Polluters pay	Reparations owed by businesses that emitted carbon dioxide and other pollutants in the past	Excise taxes with revenue contributing to the renewable electricity subsidies that maintain retail electricity prices.
Clean energy research	$400 billion over 10 years, including creating ARPA-C	No cost assessed, except to the extent financed with the taxes on corps and high-income.
Rejoin Paris agreement	Also includes diplomatic efforts to increase national pledges.	No cost is assessed in this paper.
Reduce carbon footprint of buildings	50 percent reduction by 2035.	
Climate-related financial risk	Details unspecified	
Displaced community aid	Fulfill obligations to communities and workers invested in coal.	

Table 2. Costs and quantities of electricity by source
For three policy scenarios.

Annual outcome	Baseline	80% RE	Expanded fleet
Renewable sources			
Aggregate billion MWh	0.7	2.8	3.6
Increment		2.1	0.8
Marginal cost, $/MWh	67	117	136
Subsidy, $ billion	16	202	327
Fossil fuel sources			
Aggregate billion MWh	2.9	0.8	1.0
Increment		-2.1	0.2
Marginal cost, $/MWh	45	29	30
Tax, $ billion	0	13	15
Producer surplus, $ billion (difference from baseline)	0	-30	-29
Nuclear			
Aggregate billion MWh	0.5	0.5	0.5
All sources			
Aggregate billion MWh	4.1	4.1	5.1
Increment		0	1
Resource costs, $ billion			
Relative to baseline	0	115	177
Increment		115	62
Social costs, $ billion			
Relative to baseline	0	144	214
Increment		144	70

Note: Each panel reports metrics for a segment of electricity supply. The final panel is the aggregate of the others.

Sources: 80% RE from Mai et al (2014), other outcomes and scenarios from Figure 2. The resource cost for the expanded fleet excludes what the fleet's electricity would cost at baseline fossil MC.

Table 3. Indicators of the Incidence of Proposed Energy Regulation by State

State	Value of Proved Reserves (2018, $ billions) Natural Gas	Oil	Coal	Sum	Loss of fossil producer surplus under 80 percent RE target $ billions
AK	17	151	2	169	29
AL	4	4	33	41	7
AR	28	2	7	37	6
CA	5	156	-	162	27
CO	72	102	9	184	31
IL	-	-	82	82	14
IN	-	-	20	20	3
KS	7	20	-	27	5
KY	4	1	40	45	8
LA	104	32	1	138	23
MI	4	3	4	11	2
MT	1	16	29	47	8
ND	34	355	17	406	69
NE	-	1	5	6	1
NM	72	193	-	265	45
OH	90	13	4	106	18
OK	120	156	0	277	47
PA	315	8	67	390	66
TX	436	1,175	7	1,618	275
UT	9	25	7	40	7
WV	116	13	125	254	43
WY	61	72	70	204	35
Other States	9	10	13	31	5
Offshore	20	346	-	366	62
US	1,516	2,889	548	4,952	841

Note: Producer surplus loss is a present value.
Sources: EIA (2019b), Davis and Cairns (1999), Table 5

Table 4. Regulation as tax and productivity wedges

	$ billion/yr			Redistribution as		Resource cost as
	Resource cost	Redistribution	Total cost	$ billions/yr	% of wages	% of GDP
Renewable Electricity Generation	115	58	144	58	0.5%	0.6%
Generation capacity for an electric vehicle fleet	62	61	93	61	0.5%	0.3%
80 MPG average for new vehicles	186	0	186	0	0.0%	0.9%
Energy-policy total	363	120	423	120	1.0%	1.8%

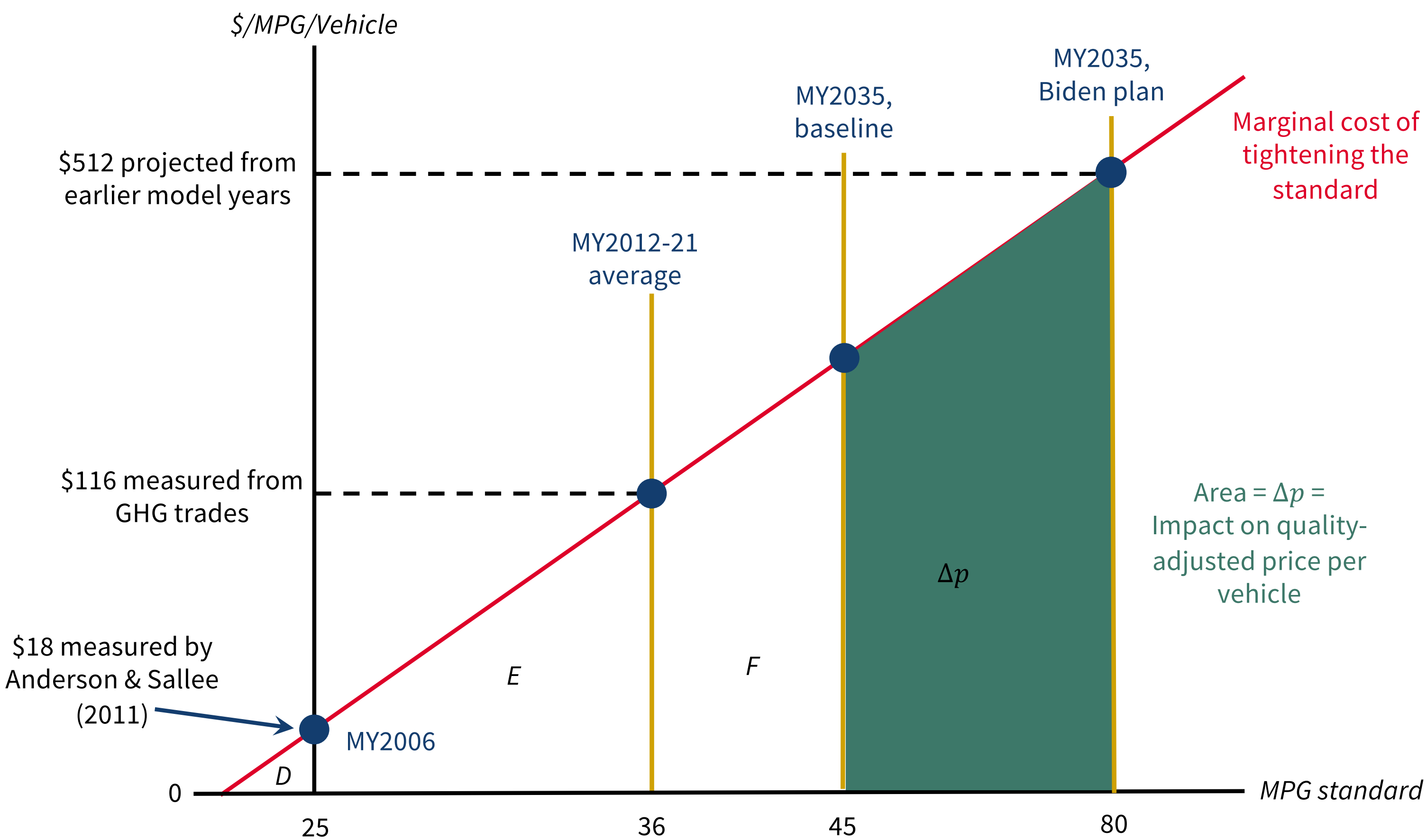
Note: The table shows the derivation of the additions to labor wedges and Total Factor Productivity (TFP) reported in Table 5. Redistribution contributes to the labor wedge while resource costs reflect reductions in TFP.

Table 5. Macroeconomic effects of the Green Recovery Plan
With various labor-supply elasticities

		Impact as % of baseline		
	Baseline values	**Full Agenda**	Less elastic labor supply	More elastic labor supply
After-tax shares				
Labor	0.52	**-1.0%**	-1.0%	-1.0%
Capital	0.76	0	0	0
Normalized TFP	1	**-1.8%**	-1.8%	-1.8%
Labor market				
Normalized FTEs	1	**-0.4%**	-0.2%	-0.5%
Real wage rates, pre-tax	0.7	**-2.5%**	-2.5%	-2.5%
Labor income	0.7	**-2.8%**	-2.7%	-3.0%
Capital market				
Capital stock	2.5	**-2.8%**	-2.7%	-3.0%
Capital intensity	2.5	**-2.5%**	-2.5%	-2.5%
Aggregates				
Real GDP normalized	1	**-2.8%**	-2.7%	-3.0%
Real consumption	0.82	**-2.8%**	-2.7%	-3.0%

Note: Each row is a measure of economic activity, with quantities expressed in per capita terms. Each column has different assumptions about the wage elasticity of aggregate labor supply. Each entry is the percentage different between the Biden outcome and the baseline outcome, as projected for the steady state of the neoclassical growth model.

Figure 1. The Opportunity Costs of Vehicle Fuel Efficiency



Source: Mulligan (2020) and Anderson & Sallee (2011). Note that $116/MPG/Vehicle is equivalent to $86 per ton of GHG.

Figure 2. The Composition of Non−nuclear Electricity Generation

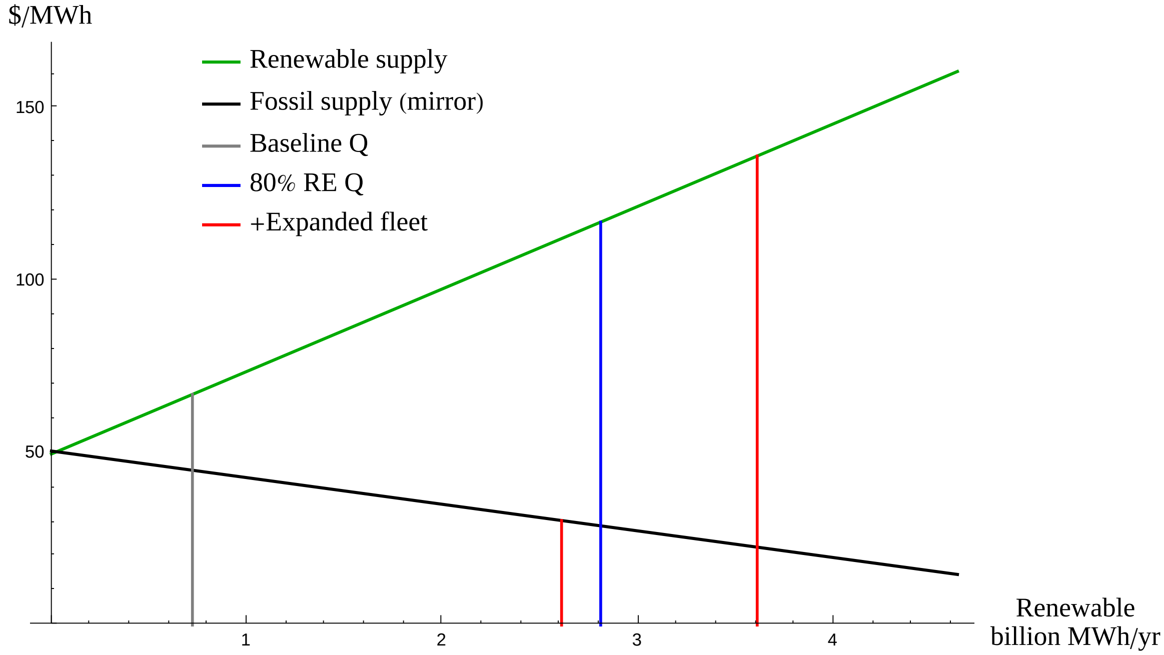


Table A1. Tax and productivity parameters

Policy category	Labor-income tax rate Additive	Multiplicative	Capital-income tax rate	TFP
Baseline	**48.0%**	**0**	**24.4%**	**1**
Green Recovery Plan	0	1.0%	0	-1.8%
Baseline + GRP	**48.5%**	**NA**	**24.4%**	**-1.8%**
% impact on after-tax share	-1.0%		0.0%	