The Fiscal Implications of the US Transition away from Fossil Fuels: Appendix

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Title: Supplementary Information for: The fiscal implications of the U.S. transition away from fossil fuels

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Appendix Sections:

1. Data sources

The data underlying baseline estimates of coal, oil, and natural gas revenues in this analysis were gathered from hundreds of sources. In many cases, we were able to directly gather revenues collected from specific energy sources through specific revenue mechanisms. In other cases, data limitations ranging from moderate to severe required us to develop estimates that were specific to each revenue source. Details for our approach to gathering or estimating each major revenue and energy type are provided in this section.

Public revenues from coal, oil, and gas vary over time due to volatile energy prices and production. In addition, data are not consistently available for every year across every measure. As a result, picking a "snapshot" of revenue from any single year has the potential to misrepresent the longer-term contribution of fossil fuels to governments.

Moreover, energy market conditions have changed considerably over the last decade, as domestic oil, natural gas, and renewables have surged while coal has declined (EIA 2021). To address these issues, we use the average revenues collected between 2015 through 2020 as our baseline revenue estimate wherever possible. Where fewer than six years of data are available for a given source, we use the average of all available years between 2015 and 2020.

In some cases, revenue is reported in the aggregate “mining” sector. In those cases, we allocate these revenues to each fossil fuel by estimating the market value of coal, oil, natural gas, and nonfuel minerals produced in each state annually (see Appendix 1.6.1).

Table A1 summarizes the energy types and revenue mechanisms collected for this analysis. It indicates which sources are included, which are de minimus, and which we were unable to assesses. It uses the following legend:

- X: Data gathered and included in this analysis
- DM: Production of this energy source in the relevant jurisdiction is de minimus
- NA: Not applicable (the jurisdiction cannot levy a tax)
- NT: No tax (the jurisdiction could levy a tax but does not)
- NF: Not found (we were unable to find data for this source)

Table A1 Data coverage in this analysis

Revenue type	**Excise**	**Severance**		**Public lands**		**Local property**					**State Property**		**Corporate income/gross receipts**		**Personal Income**		**Sales & use**	
Energy type	**Petroleum products**	**Oil and gas**	**Coal**	**Oil and gas**	**Coal**	**Oil and gas**	**Coal**	**Refine-ries**	**Pipe-lines**	**Fossil power plants**	**Oil and gas**	**Coal**	**Oil and gas**	**Coal**	**Oil and gas**	**Coal**	**Oil and gas**	**Coal**
AK	x	x	dm	x	dm	x	dm	x	x	x	x	dm	x	dm	nt	nt	nt	nt
AL	x	x	x	x	nf	nf	nf	x	x	x	nt	nt	nf	nf	x	x	nf	nf
AR	x	x	dm	x	dm	x	dm	x	x	x	nt	nt	nf	dm	nf	dm	x	dm
CA	x	x	dm	x	dm	x	dm	x	x	x	nt	nt	x	x	nf	nf	x	dm
CO	x	x	x	x	x	x	x	x	x	x	nt	nt	x	x	nf	nf	x	x
IL	x	nf	nt	dm	nf	x	x	x	x	x	nt	nt	nf	nf	nf	nf	dm	nf
IN	x	x	nt	nf	nf	nf	nf	x	x	x	nt	nt	nf	nf	x	x	x	x
KS	x	x	x	nf	nf	x	nf	x	x	x	nt	nt	nf	nf	nf	nf	x	x
KY	x	x	x	nf	nf	x	x	x	x	x	x	x	nf	nf	x	x	nf	nf
LA	x	x	dm	x	x	x	nf	x	x	x	nt	nt	nf	nf	x	x	nf	nf
MS	x	x	nt	x	dm	nf	nf	x	x	x	nt	nt	x	x	nf	nf	x	dm
MT*	x	x	x	x	x	x	nt	x	x	x	x	x	x	x	x	x	nt	nt
ND	x	x	x	x	x	nt	nt	x	x	x	nt	nt	nf	nf	nf	nf	x	x
NM	x	x	x	x	x	x	nf	x	x	x	nt	nt	nf	nf	x	x	x	x
OH	x	x	x	nf	nf	x	x	x	x	x	nt	nt	x	nf	nf	nf	x	x
OK	x	x	x	x	x	x	x	x	x	x	nt	nt	nf	nf	x	x	x	x
PA	x	x	nt	x	nf	nt	nt	x	x	x	nt	nt	x	x	x	x	x	x
TX	x	x	x	x	x	x	x	x	x	x	nt	nt	nf	nf	nt	nt	x	x
UT	x	x	nt	x	nf	x	x	x	x	x	nt	nt	x	x	x	x	x	x
WV	x	x	x	x	x	x	x	x	x	x	nt	nt	nf	nf	x	x	x	x
WY	x	x	x	x	x	x	x	x	x	x	nt	nt	nt	nt	nt	nt	x	x
Other states	x	dm	dm	dm	dm	dm	dm	x	x	x	dm	dm	dm	dm	dm	dm	dm	dm
Federal	x	nt	nt	x	x	na	na	na	na	na	na	na	x	x	nf	nf	nt	nt
Tribal	nf^	nf	nf	x	x	na	na	na	na	na	na	na	nf	nf	nf	nf	nf	nf

*Montana levies a state property tax on certain coal production property, as well as oil and natural gas pipelines. ^We gathered data on petroleum product taxes for the Navajo Nation but no other tribes.

1.1. Petroleum product taxes

1.1.1. States

State petroleum product tax data primarily come from the Federal Highway Administration's (FWHA) Highway Statistics Series (FHWA 2021). These data are submitted by state revenue agencies, then aggregated in table MF-1 of the FWHA's report. Motor fuel data includes gasoline, gasohol, diesel, kerosene, liquefied petroleum gas (propane), liquefied natural gas, compressed natural gas, E85, and M85. The net tax receipts are then added to fines and miscellaneous receipts while refunds are subtracted to produce yearly adjusted total receipts for each state.

Aviation fuel and fuel used by marine craft are separated into a separate category by the FWHA and identified as "dedicated revenue from nonhighway gasoline." In some states, this revenue includes taxes on gasoline used in off-highway recreational vehicles, snowmobiles, and for agricultural purposes. Despite being discounted from the adjusted total receipts by the FWHA, these receipts were included in this analysis because they are revenues from a fossil fuel source.

Three anomalies were identified when the data were crosschecked against annual state revenue reports. Specifically, FWHA data for the years 2018 and 2019 in the District of Columbia, the years 2016 through 2018 in Oklahoma, and the year 2019 in Indiana differed by orders of magnitude relative to surrounding years. In these cases, the FWHA data were replaced with values from the DC Office of Revenue Analysis (Government of the District of Columbia 2020), the Oklahoma Tax Commission (Oklahoma Tax Commission 2020), and the Indiana Department of Revenue (Indiana Department of Revenue 2021).

1.1.2. Federal

Petroleum product revenues for the federal government were gathered from the Internal Revenue Service Excise Tax Statistics (IRS 2021a). They include revenues from the following sources: aviation fuel, aviation kerosene and other kerosene, compressed natural gas, diesel, dyed diesel, fuels used in inland waterways, gasohol, gasoline, gasoline for gasohol, kerosene in aviation, liquid aircraft fuel used in a fractional ownership program (FOP) (IRS 2021b, 720), liquified natural gas, liquified petroleum gas, oil spill liability trust fund, and special motor fuels. The largest two revenues sources, by far, are excise taxes on diesel and gasoline.

1.2. Severance taxes

Although states have a variety of names for taxes and fees levied on the value or the volume of coal, oil, and natural gas produced within their borders, we refer to all of them as severance taxes. Taxes are typically the dominant source of these revenues for states, but we also include fees charged by states to administer regulatory or environmental remediation programs. Most severance taxes are ad valorem taxes, where the tax rate is applied to the market value of the commodity at the wellhead or minemouth. Two exceptions are California and Pennsylvania, which collect the bulk of their revenue from fees applied to the volume of drilling (Pennsylvania) and production (for California).

In some states, such as Montana and North Dakota, severance taxes effectively replace local property taxes on oil and gas production. In these cases, state governments collect severance taxes based on the value of production, then directly distributed a portion of those revenues to localities where production occurred according to various formulae (Headwaters Economics 2014).

Most of these data were gathered through annual reports from state Departments of Revenue or, in some cases, state agencies responsible for administering the taxes and fees. Typically, coal severance tax revenues are reported separately from oil and natural gas. In some cases, oil and natural gas are reported together, and in some cases, separately. We gathered fuel-specific data wherever possible, but aggregate oil and natural gas together in our reporting of the data.

The federal government does not levy taxes or fees on the production of oil and gas. It does, however, collect an excise tax on coal production that is used to support the Black Lung Disability Trust Fund.

We conducted searches for data from fossil fuel-producing tribes (e.g., the MHA Nation, Southern Ute Indian Tribe, Jicarilla-Apache Nation), but were only able to identify data on severance taxes and petroleum products from the Navajo Nation. However, we note that other tribes also collect such taxes (e.g., Southern Ute Indian Tribe 2021).

1.3. Lease revenue from federal and tribal lands and waters

Our approach to the classification of revenues generated from federal leasing differs from how we approach other revenue sources in this analysis. For most other revenue sources, our figures and data tables show revenue flowing to the government entity that *collects* the revenue. However, federal and state governments sometimes share portions of these revenues with other government entities such as counties or municipalities. For example, North Dakota's severance taxes are shared with counties, cities, and other local governments according to a complex formula. Because we are working with hundreds of data points across 50 states over multiple years, estimating how revenues flow from one government entity to the next is beyond the scope of this analysis.

However, a large share of leasing revenue collected by the federal government flows to tribes and states, and these revenues represent an important source for some states and tribes. Because of the magnitude of these revenue flows, and because it is relatively straightforward to estimate them, leasing revenue from federal lands is shown in our tables and figures according to the government entity that *receives* the revenue, rather than the entity that collects it (i.e., the federal government).

Data on revenue from coal, oil, and natural gas development on federal and tribal lands (and in federal waters) was gathered from the Department of Interior's Office of Natural Resource Revenue (ONRR) data portal. To estimate how these revenues flow from the federal to the state and tribal level, we take several steps.

For states, ONRR categorizes revenues from states by commodity (i.e., fuel, mineral, or energy type) and "onshore" or "offshore." However, disbursements to states are not apportioned by commodity. To assess the value of the disbursement to each state by commodity, we first calculate the percentage of revenue collected from federal lands in each state by commodity type and whether it occurred onshore or offshore. For instance, in 2010, 92 percent of all ONRR revenue collected from federal lands in Alabama came from coal production. Then, we multiply that percentage by the disbursement to the state; for instance, we multiply the total onshore disbursement to Alabama by 92 percent to estimate how much revenue from coal production on federal lands flowed to the state. The only exception to this process was for offshore oil and gas production in the Gulf, which required no calculations on our part, as it is apportioned to states on the basis of a unique disbursement formula (see Appendix 1.3.1).

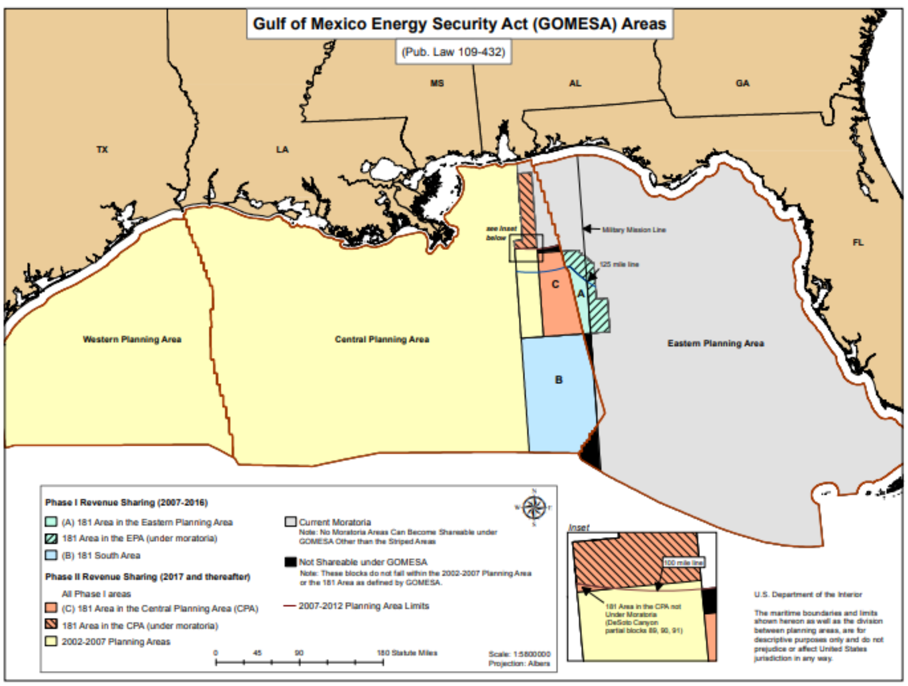
For tribes, we undertake a similar process, applying the share of revenue per commodity to the disbursements to tribes. While ONRR does not provide data on disbursements to individual tribes or members, on an aggregate basis we are able to estimate disbursements to tribes for (1) coal and (2) oil and gas production on tribal lands.

For the small number (83) of counties and municipalities that have received federal leasing revenue since 2010, revenues were considered *de minimus* in our analysis. Only one outlier county, Sonoma County, CA, averaged more than a million dollars per year, and has no fossil fuel production. For counties that did receive disbursements, the median county received less than $10,000 nominally. Therefore, we do not report federal disbursements to local governments.

1.3.1. GOMESA Areas and Revenues

The Gulf of Mexico Energy Security Act (GOMESA), passed in 2006, simultaneously (1) placed a moratorium on oil and gas leasing through 2022 in the eastern portion of the Gulf of Mexico and (2) established a two-phase revenue-sharing agreement with "Gulf producing states" – Texas, Louisiana, Mississippi, and Alabama – along the western portion of the Gulf. During Phase I, 2007 to 2016, revenue-sharing only occurred from oil and gas production in a small section of the central Gulf, the blue areas in Figure A1. Starting in 2017, it was expanded to include production in the central and western Gulf (Comay and Humphries 2020).

Figure A1. GOMESA Areas



Source: Bureau of Ocean Energy Management (Bureau of Ocean Energy Management 2021)

Gulf states receive 37.5 percent of total leasing revenues, another 12.5 percent goes to the federal Land and Water Conservation Fund (LWCF) and the remaining 50 percent is deemed general federal revenue. The precise disbursement for each state is determined by formula by the Department of the Interior and depends on distance from leased tracts– which typically results in lower revenues for Alabama and Mississippi, which have shorter Gulf coastlines. However, no state may receive less than 10% of the total amount available to all states. Additionally, total shareable revenues (those that go to states and the LWCF) in Phase II are subject to annual cap, originally $500 million but recently expanded to $650 million (Comay and Humphries 2020).

Prior to GOMESA, Gulf states typically received 27 percent of revenue from leases within 3 miles of state waters, called 8(g) revenues (Comay and Humphries 2020).

1.4. Lease revenue from state lands and waters

Like the federal government, states lease land to private companies to develop energy resources, including coal, oil, and natural gas. And like the federal government, states generate considerable revenue from these leases, including "bonus" payments, royalties, rents, and other fees.

Data on revenues generated by these leases are published in a variety of sources and vary across states. For many western states such as Colorado, State Land Boards manage leases and associated revenues, and issue annual reports that include revenue data (Colorado State Land Board 2021). In other cases, such as Alaska, leases and revenues are handled by the state Department of Natural Resources, and revenue data are made available via online tools (Alaska Department of Natural Resources: Division of Oil and Gas 2021). For some states, such as Texas, revenue from these leases are published as part of statewide annual reports that provide revenue data from all major sources (Texas Comptroller of Public Accounts 2020). In other cases, such as California, we were unable to identify public-facing data, and obtained the relevant information through direct email communication with state government employees from the relevant offices.

1.5. Property taxes

In most states and localities, ad valorem property taxes are applied to the value of certain energy property. Property taxes are typically major revenue sources for local school districts, counties, and "special districts" that provide specialized services such as water or waste management, public health services, libraries, transportation, or other services that cover relatively large geographic areas (cities, towns, and other municipalities typically rely more heavily on sales taxes).

Property tax law varies widely across states and is extremely complex. Property values are typically determined by a mix of local- and county-level assessors, who apply formulae set by statutes and regulations to determine the assessed or market value of a property. Local property tax rates are then applied to the *taxable* value of the property (which is often a fraction of the assessed or market value) to determine the owner's tax liability.

Numerous factors add complexity to this already complicated process. First, some states do not allow local governments to apply their ad valorem tax rates to certain energy property. For example, Pennsylvania local governments collect no property taxes from coal, oil, or natural gas producing property. This includes equipment such as drilling rigs, along with the commodities themselves. In other states, ad valorem property taxes are applied to both the equipment and the value of the commodities. Second, certain pieces of equipment or, in some cases, entire properties, may be exempt from paying property taxes due to locally- or state-specified exemptions. For example, pollution abatement equipment installed at power plants or refineries is often exempt from property taxes. In some cases, entire power plants are exempt from paying property taxes due to locally-granted exemptions, which may be used to incentivize facilities such as power plants to locate in certain jurisdictions.

This section describes our approach for collecting and estimating property taxes revenues across a variety of energy property types. Because of wide variation in data availability, our confidence in these estimates ranges considerably by energy property type, as we describe below.

1.5.1. Coal, oil, and natural gas production property

Most local governments, and some state governments, levy property taxes on coal, oil, and natural gas production property. Tax bases and rates vary widely across states, as does reporting. Relevant taxable property may include equipment such as drilling rigs, mining machinery, wellheads, and gathering lines. The tax base may also include the value of the commodities themselves, such as the value of the coal, oil, and natural gas that is produced annually from a field or mine. In some states (e.g., California and Texas), the taxable value of a property is estimated by local assessors based on more complex calculations that seek to determine the net present value of underground resources.

In some cases, we were able to gather data on *tax revenue* collected from specific sectors (i.e., coal, oil, or natural gas production properties). In other cases, only data on the *taxable value* of these properties were available, either at the state-wide or county-level. In these cases, we follow Newell and Raimi (2018) by applying the state-wide average property tax rate (from the appropriate class of property) to the statewide taxable value of these properties to generate estimates of annual revenues.

For this analysis, we searched state records and contacted state officials in the 21 states where coal, oil, and natural gas production is concentrated. In a limited number of cases, we were unable to gather any data that would allow us to credibly estimate property tax revenues from these sources. However, our data gaps for this source were small, and we believe they are unlikely to substantially affect our key results.

1.5.2. Oil refining

As of January 1, 2020, the US EIA reported that there were 131 oil refineries operating across 30 states (EIA 2020). To estimate the property taxes paid by these facilities each year, we searched property tax records in the counties where these refineries operated. However, it was not possible to gather data directly for all refineries for two reasons. First, some county assessor websites did not provide adequate data on estimated market values, assessed values, or property taxes paid. Second, we did not have the capacity to carry out detailed searches, which are very time-intensive (often requiring hours of searching to gather data for a single refinery), for all 131 refineries.

To develop credible estimates, we carried out detailed searches for the 30 largest refineries in the United States (measured by barrels per day of processing capacity) and successfully gathered data on assessed property values and property taxes paid for the year 2020 for 19 of these 30 refineries. That data showed that, on average, refineries paid between $71.86 in property taxes for each barrel per day (b/d) of processing capacity, equal to roughly $0.20 per barrel of oil that could theoretically be processed each year. Rates ranged from $18 to $129 per b/d capacity ($0.05 to $0.35 per barrel per year of capacity). We believe that these wide variations are the result of differences in assessment practices across states, different property tax rates, and the application of property tax exemptions in certain jurisdictions.

To estimate nationwide property taxes paid for all refineries, we use the reported payments for the 19 refineries where we collected data. For those where data are not available, we applied the average rate of $71.86 per b/d ($0.20 per barrel per year) of processing capacity. This process led to a total estimate of refinery property taxes of $1.4 billion nationwide.

1.5.3. Gathering and transmission pipelines

To estimate property taxes paid on natural gas, crude oil, and petroleum product transmission and gathering pipelines,[1] we began by searching state government statistical reports. However, only a small number of states reported taxes assessed or taxes collected from these classes of property. Actual data on

[1] Gathering pipelines transport natural gas and crude oil from the wellhead to centralized transmission or processing points and are short distance. Transmission lines are longer-distance and often cross state lines. However, data on these two types of pipelines were typically reported together in state property tax reports, which is why we group them together here.

tax collections from pipeline property were gathered from five states: Alaska, Montana, Utah, Wisconsin, and Wyoming.

A larger number of states provided the statewide assessed values of pipeline property. To estimate property taxes paid, we multiplied these assessed values by the statewide average property tax rate in each state. Where available, we applied the statewide average property tax rate on *utility* property. We carried out this process for 12 states: Alabama, California, Colorado, Georgia, Louisiana, Minnesota, North Dakota, Ohio, Oklahoma, Oregon, Texas, Virginia, and Washington.

To estimate property tax revenues for the remaining 33 states, we gathered statistics on pipeline mileage by state from the US Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA). PHMSA reports statewide mileage for various types of pipelines, including those that do not transport fossil fuels, such as CO_2, hydrogen, and biogas pipelines. Because our analysis is focused on revenues generated by fossil fuel infrastructure, we exclude these pipelines and only include mileages from natural gas gathering, natural gas transmission, crude oil, and refined petroleum product pipelines.

Ideally, we would have used product throughput, rather than pipeline mileage, to generate estimates, which would have enabled us to estimate the value of products transported through each state annually. However, state-level throughput data are not available from public sources that we are aware of (the U.S. EIA publishes regional, but not state-level throughput data).

After assembling pipeline mileage statistics for each state, we developed estimates of property tax revenue per mile of pipeline for the 17 states where data had previously been gathered. Results ranged from a low of roughly $1,000 to a high of roughly $22,000 in property taxes paid per mile of pipeline annually. The mean estimate was $7,171.87 per mile (the median was $7,008.17).

To estimate revenues for the 33 states where data were not available, we multiplied the average estimate of $7,171.87 by statewide pipeline mileage in each state.

Combining these estimates with the data collected from the 17 states noted above, we estimate that total property taxes paid on oil and gas gathering and transmission pipelines in the United States are roughly $2.8 billion per year.

1.5.4. Natural gas distribution pipelines

Utility-owned natural gas distribution lines are often subject to local property taxes. While taxes are typically levied at the local level, state appraisal boards or equalization boards often appraise – or aggregate local appraisals of – the market value and/or taxable value of utility property.

Where available, we use state tax commission appraisal reports (e.g., Louisiana) to gather property values for major natural gas distribution utilities, then multiply this by a statewide average millage rate to estimate revenues. Some states report market values, others taxable values; we take care to not multiply a taxable value millage rate with total market value, or vice versa.

We were able to gather these data from seven states (Colorado, Iowa, Louisiana, Minnesota, Texas, Utah, and Washington State), and use them to establish an average ratio of property tax collected per mile of distribution line, using pipeline mileage data from PHMSA (2020). For these states, we find an average of $466 in property tax revenue per mile of gas distribution. For states where we do not have revenue data, such as Georgia, we multiply the PHMSA "Gas Distribution" mileage for that year (87,553 miles) by this average ($466) to estimate Georgia's total property tax revenue from natural gas distribution in 2019 ($40.8 million). We complete this exercise for years 2016 through 2019.

We identified two states that explicitly exempt utilities from local property tax, Wisconsin and Massachusetts, and exclude them from the estimate.

1.5.5. Power plants

Property tax data for US fossil fuel-fired power plants presented here are highly uncertain: tax records for specific power plants, even in aggregate, are challenging to find, even when such records are ostensibly public, and so these tax data do not represent aggregates of actual property taxes paid. Rather, this state-level estimate of total property taxes for US fossil fuel-fired power plants is based on the assumption that taxes are driven by power plant nameplate capacity (measured in megawatts (MW), with no differentiation among plant fuel, prime mover, capacity factor, age, or other potentially relevant variables due to severe data limitations) and land value. Assuming that property taxes scale with capacity and land value alone is a fundamental limitation that we are not able to validate given the lack of a complete database. Note that we also implicitly assume all fossil fuel-fired power plants occupy the same amount of space per unit of nameplate capacity.

Adjusting property taxes by plant capacity and land value requires an input to adjust, which is also highly uncertain. Here, we take two approaches: 1) based on exemplar states and 2) based on exemplar power plants. In each case, estimates proceed as follows. First, the estimated property taxes charged per MW ($/MW) are calculated for the exemplar and normalized by estimated land value. Second, this exemplar value [now ($/MW)/($/acre)] is multiplied by the nameplate capacity (MW) and land value ($/acre) for the system being analyzed to generate an estimate of taxes charged, aggregated to the state level to provide an overall state-level estimate of property taxes charged for fossil fuel-fired power plants.

In all cases, land values are taken from Davis et al.'s (2021) per-acre cross section estimates of single family parcel as-is values. This use of single-family parcel value is a limitation of this work, given that power plant land is industrial. We were not able to identify more specific sources of county level land value data for the whole country. Given the use of relative valuation, we claim this approach is reasonable to first order, especially because our review of specific property tax data for fossil fuel-fired power plants generated estimates of tax per MW spanning six orders of magnitude.

State-based estimates

For state-based estimates, we use New York and Texas as exemplar states. Normalized tax estimates are extended to other states at the state level for both average single family land values and total fossil fuel-fired power generation capacity, based on 2019 generator-level data from EIA 860 (EIA 2019) for generators for which Energy Source 1 is a fossil fuel as defined in Grubert (2020).

For New York, the normalized tax estimate is [($14,900/MW)/($2.2 million/acre)]. Data collected by NYSERDA and the Long Island Power Authority (LIPA) for the New York City area cover about a third of the state's power generation capacity (11 of 29 GW), centered on some of the nation's most valuable land, and average property taxes charged of $36,000/MW. LIPA argues that "fair" taxes for its Long Island steam units would be about $2,375/MW (in 2018 dollars) (LIPA 2019). Assuming the utility's estimate of fair taxes is reasonable for the remainder of New York's power plants, capacity-weighted New York fossil plant taxes are estimated at $14,900/MW with average statewide single family land value of $2.2 million/acre.

For Texas, the normalized tax estimate is [($1,410/MW)/($190,000/acre)]. We collected data for Texas in much the same way as the NYSERDA team collected data for New York City, by manually searching property tax rolls. Out of 173 power plants we reviewed, we identified records for 45, with average taxes assessed of $1,410/MW. Limitations of the data are discussed in greater detail below. Average statewide single family land value is $190,000/acre.

Plant-level estimates

In our second approach, we aggregate tax payment data from the generator (MW) and county ($/acre) level to generate estimates at the state level. These estimates are much higher, and much noisier. Using examples from New York (Caithness), Georgia (Scherer), Utah (Intermountain), California (Colusa), and Texas (Freeport and Bastrop), estimates of total US property taxes paid by fossil fuel-fired power plants range from $7 to $42 billion. We believe these to be large overestimates for several reasons.

For example, Intermountain appears to be the sole Utah fossil fuel-fired power plants with a non-zero tax record: in data from the Utah State Tax Commission Property Tax Division's Annual Statistical Report (Utah State Tax Commission Property Tax Division 2020), only two counties show non-zero taxes charged for "electric generation," both of which host large power generation facilities designed to export to California (the other is Milford Wind, in Beaver County), which may be the reason that they are ineligible for exemptions that reduce property tax liability for other plants.

The Texas plants were selected from among the records we identified precisely because the identified taxes were relatively high [e.g., $2 million for a 260 MW plant (Freeport Energy Center) versus $3,000 for a 240 MW plant (Trinidad)] and thus deemed more likely to be the correct record covering the entire asset, given that property taxes for a given power plant are often distributed across land, various capital equipment, fuel stocks, and other improvements that might be associated to multiple records across multiple addresses with very limited descriptions. For example, Martin Lake – a 2.4 GW lignite plant with replacement cost in the billions of dollars – is entirely coincident with two parcels that are valued at less than $1 million in the county records with essentially no description. Although other nearby parcels that are likely plant-related are valued more highly, no clearly related parcel is valued at more than a few million dollars, and these appear to be largely associated with the nearby coal mine. For context, of the 45 records of Texas power plant property taxes identified in this effort (out of 173 that we attempted to find in tax rolls), 11 facilities had 2020 or 2021 property taxes levied at $0.

In other examples, such as the Scherer and Colusa plants, records were identified from utility press releases, suggesting some interest in advertising the (presumably large) sum which may not be representative of the broader universe of plants.

Because of these issues associated with the plant-level estimates, we prefer the state-level approach. Values are very similar based on either the New York or Texas exemplars, at $2.0 billion (based on New York) and $2.1 billion (based on Texas). We thus take the average, presented both in absolute and $/MW terms in Table S2. National average taxes are estimated at $2,500/MW, ranging from about $280/MW (Mississippi) to $15,000/MW (New York).

Table A2 Estimated Property Taxes for Fossil Fuel-Fired Power Generation

Location	**Estimated rate (2020$/MW)**	**Estimated total (2020$ million)**
National Average	*2,493*	*2,068*
AK	1,397	3
AL	450	9
AR	336	4
AZ	1,724	36
CA	13,055	537
CO	2,967	38
CT	1,678	14
DE	1,597	6
FL	2,148	127
GA	668	19
HI	14,600	35
IA	635	7
ID	1,092	1
IL	2,075	65
IN	514	14
KS	629	6
KY	588	13
LA	1,343	33
MA	4,083	46
MD	3,105	40
ME	721	2
MI	758	17
MN	1,350	16
MO	722	14
MS	281	4
MT	1,016	3
NC	737	19
ND	1,000	5
NE	763	5
NH	909	2
NJ	4,909	67
NM	1,074	7
NV	1,919	18
NY	15,415	454
OH	675	19
OK	547	12
OR	2,944	15
PA	1,469	56
RI	2,003	4
SC	824	11
SD	725	1
TN	562	8
TX	1,364	134
UT	2,291	19
VA	2,711	56
VT	764	0
WA	3,212	18
WI	827	12
WV	383	6
WY	1,494	12

Establishing either appraisal values or property taxes (assessed or paid) is extremely challenging due in part to unclear property descriptions, mismatched addresses, and missing information. Public claims about property taxes paid in news media may exclude the time frame over which property taxes are expected (see, e.g., Skabelund (2021)). The lack of clarity about who is paying how much, and for what, means that the assumption that large power plants are necessarily major sources of revenue for their localities bears scrutiny on a case-by-case basis.

1.6. Corporate income, personal income, sales and use taxes

1.6.1. Apportioning "mining" revenues to coal, oil, and natural gas

Tax revenue generated by the coal, oil, and natural gas industries is sometimes grouped in state government publications into a single category of "mining" (North American Industry Classification Code 21), which also includes revenues from non-fossil fuel mining, such as metals, sand, or gravel. This makes it difficult to identify the levels of revenue generated in each state from fossil fuel production related to other mining activities.

To estimate the share of "mining" tax revenues from coal, oil, and natural gas, we apportion "mining" revenues based on the value of coal, oil, natural gas, and non-fuel minerals produced in each state annually using data from the U.S. EIA and the U.S. Geological Survey (USGS).

The value of coal, oil, and natural gas was calculated by multiplying the volume of production of each fuel in each state by benchmark market values for each commodity annually from 2010 through 2019, with data gathered from the U.S. EIA. For coal, we multiplied the volume of each coal rank (anthracite, bituminous, subbituminous, and lignite) by average nationwide prices for each coal rank annually. For oil, we multiplied the volume of field crude oil produced by the annual average spot price for West Texas Intermediate (WTI) oil. For natural gas, we multiplied the volume of marketed natural gas production by the annual average Henry Hub spot price. To estimate the value of non-fuel minerals, we use data from USGS Annual Minerals Handbooks from 2010 through 2017 (the most recent available year) (USGS 2021).

We adjusted all values to 2019 U.S. dollars, then divide the estimated value of production for each fuel in each state in each year by the value of all fuels plus non-fuel minerals for the same state in that same year. For example, in 2017 in Wyoming, we estimate the following (Table A3):

Table A3 Estimated values of fuel and non-fuel mining in Wyoming in 2017

Commodity type	Coal	Oil	Natural gas	Non-fuel minerals
Value ($2019 M)	$4,823	$4,009	$4,955	$2,627
Share of total	29%	24%	30%	16%

Data sources: U.S. EIA for fuels, USGS for non-fuel values

Based on these values, we would estimate that $1 million worth of sales and use tax revenues from the "mining" industry in Wyoming could be apportioned as roughly $290,000 from coal, $240,000 from oil, and $300,000 from natural gas, with $160,000 in revenue from non-fuel minerals excluded from our revenue estimates.

We follow this process for states and the federal government when apportioning "mining" industry revenues from sales and use taxes, corporate income taxes, and personal income taxes.

1.6.2. Sales and Use Taxes

We gathered sales tax and use tax data from state annual revenue reports, state Comprehensive Annual Financial Reports (CAFRs), or state tax commissions' online data portals. Typically, states bundle sales taxes and use taxes in their reporting, but some states split them out or only impose them for certain products. Where possible, we collected data from 2010 through 2020.

Some states do not report sales and use tax *receipts* by industry or sector, but instead report total taxable *sales* or *revenue*. In these cases, we estimate tax *receipts* by multiplying total taxable sales or revenue by an average effective sales tax rate, which is either provided in the relevant state report or calculated from economy-wide sales tax receipts divided by economy-wide taxable sales (again, using underlying data from relevant state publications or websites).

1.6.3. Corporate and Personal Income Taxes

At the state level, we gathered corporate income tax (or, in some states, "gross receipts" or "franchise" tax) and personal income tax revenue data from state annual revenue reports, state Comprehensive Annual Financial Reports (CAFRs), Corporate Statistics of Income reports, or tax commissions' online data portals. Where possible, we collected data from 2010 through 2020.

Most states do not report corporate or personal income tax *receipts* by sector, but instead report taxable *income*. In these cases, we estimate tax *receipts* by multiplying total taxable income in the mining sector by an average effective income tax rate, which is either provided in the relevant state report or calculated from economy-wide sales tax receipts divided by economy-wide taxable sales (again, using underlying data from relevant state publications or websites). As with other revenue streams where all revenues are reported in the "mining" industry, we apportion these revenues to coal, oil, natural gas, and non-fuel minerals based on the calculations described in Appendix 1.6.1.

For state-level corporate income taxes, it is possible that companies in the "mining" sector pay an effective tax rate that is higher or lower than the statewide average. However, we are not aware of any data that would allow us to estimate any such variation, and any variation would not affect our high-level results: We were able to gather data and estimate revenues from state corporate income taxes from eight states, accounting for roughly $200 million, roughly 0.2 percent of our total revenue estimate.

At the federal level, we gathered corporate income tax data from the Internal Revenue Service (IRS). Data from 2000 through 2013 (IRS 2020) and 2014 through 2017 (IRS 2021c) (the most recent available year) were gathered from the IRS website. We gathered data on "total income tax after credits" from the following sectors, which were classified in our analysis according to the relevant upstream, midstream, or downstream segment. Table A4 provides details.

Table A4 Federal corporate income tax categories included in this analysis

Industry classification	Segment	Energy type
Coal mining	Upstream	Coal
Natural gas distribution	Downstream	Natural gas
Oil and gas extraction	Upstream	Oil and natural gas
Petroleum and petroleum products [wholesale trade]	Downstream	Oil
Petroleum refineries (including integrated)	Midstream	Oil
Support activities for mining	Upstream	Coal, oil, and natural gas
Gasoline stations	Downstream	Oil
Pipeline transportation	Midstream	Oil and natural gas

Note: For the "support activities for mining" category, we apportion tax revenues to coal, oil and natural gas, and nonfuel minerals according to the same process described in Appendix 1.6.1.

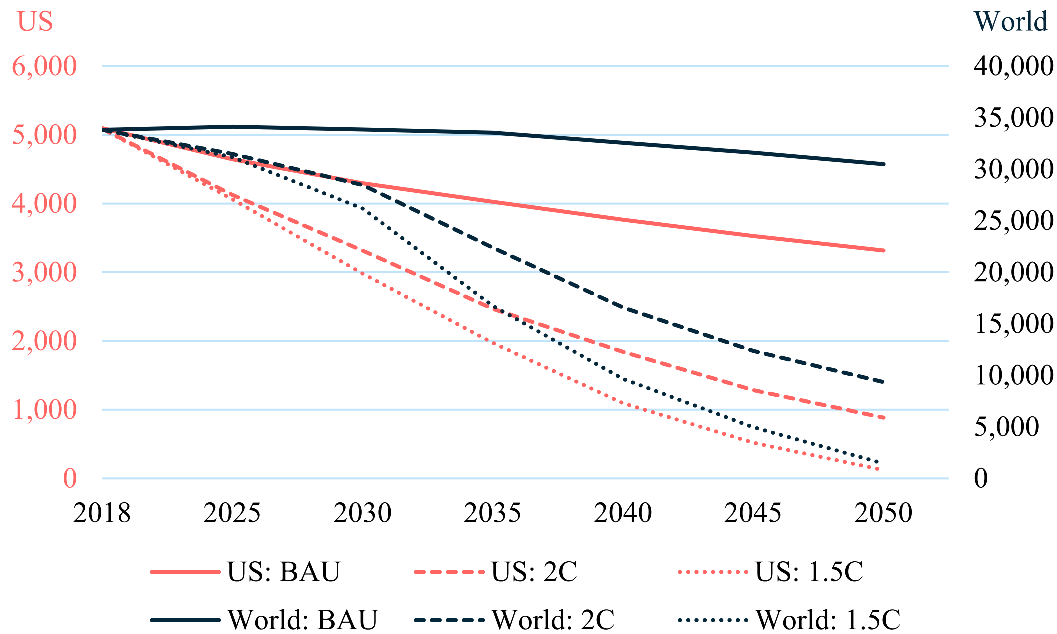
2. Estimating changes to future revenue

There are many modeling efforts that have estimated the changes needed in the global energy system to achieve different levels of greenhouse gas emissions reduction. For this analysis, we use bp's 2020 Energy Outlook to identify three plausible scenarios that illustrate a wide range of potential energy futures, each with different implications for U.S. fossil energy production and consumption, along with their associated public revenues.

We considered utilizing scenarios from a range of organizations, but settled on bp for three main reasons: first, the bp scenarios provide a plausible yet wide range of potential futures for the energy system, including scenarios with deep decarbonization; second, scenario results are publicly available and easily accessible; and third, bp's scenarios include projections for the United States, whereas scenarios from other organizations (e.g., the IEA's World Energy Outlook (IEA 2020)) provide data only for the aggregate North America region. Scenarios from the US EIA were considered but not utilized because they do not currently include scenarios with deep decarbonization.

We use the following three scenarios from bp's 2020 Energy Outlook: Business as usual (BAU), which assumes that policies, technologies, and consumer preferences evolve similarly to recent trends; Rapid Transition, which we refer to as 2C, and which includes a variety of policies to reduce emissions from power, transport, buildings, and industrial sectors, and is consistent with limiting warming to "well below" 2°C by 2100; and Net Zero, which we refer to as 1.5C, and which couples the trends in the RT scenario with substantial societal changes to limit warming to 1.5°C by 2100. The energy-related net carbon dioxide (CO_2) emissions from these three scenarios for the United States (US) and the world are shown in Figure A2.

Figure A2 US and World CO_2 emissions under three scenarios (millions metric tons)



Projection source: bp (2020)

To estimate changes in different revenue types under these scenarios, we group revenues by phase (i.e., upstream, midstream, and downstream) and energy type (i.e., coal, oil, and natural gas). We then calculate the changes in production (upstream), processing (midstream), and consumption (downstream) for each energy type under the three scenarios. These changes are calculated as the difference between levels in each projection year (2025 through 2050, in five-year increments) and the average level in our baseline period, which is 2015 through 2020.

For example, the US consumed 36.4 exajoules (EJ) of oil on average each year from 2015 through 2020. Under the BAU, 2C, and 1.5C scenarios, consumption in 2050 falls to 25.3, 11.3, and 5.6 EJ, respectively. To estimate how these changes in consumption affect revenues, we apply the relevant reduction under each scenario to the baseline (2015-2020) level of revenue associated with oil consumption. Table A5 illustrates how these changes affect revenues in one example: petroleum product tax revenues at the federal and state level:

Table A5 US oil consumption and petroleum product tax revenues under three scenarios

	2015-2020 baseline	2025	2030	2035	2040	2045	2050
Oil consumption (EJ)	36.4						
BAU	36.4	35.1	33.1	30.8	28.9	27.0	25.3
		-4%	-9%	-15%	-21%	-26%	-30%
2C	36.4	33.7	30.2	25.3	19.9	15.1	11.3
		-7%	-17%	-30%	-45%	-59%	-69%
1.5C	36.4	33.6	29.4	23.2	14.4	8.9	5.6
		-8%	-19%	-36%	-60%	-76%	-85%
State revenue ($2019, B)							
BAU	$48.63	$46.88	$44.20	$41.20	$38.55	$36.07	$33.86
2C		$45.09	$40.38	$33.85	$26.61	$20.14	$15.14
1.5C		$44.93	$39.31	$30.95	$19.28	$11.88	$7.43
Federal revenue ($2019, B)							
BAU	$39.67	$38.24	$36.06	$33.61	$31.45	$29.42	$27.62
2C		$36.78	$32.94	$27.61	$21.70	$16.43	$12.35
1.5C		$36.65	$32.07	$25.25	$15.73	$9.69	$6.06

Note: Baseline energy data from and projected changes in consumption from bp (bp 2020; 2021). Revenue estimates by authors.

We follow the same approach for all phases and energy sources, applying the changes observed in each scenario. Percentage changes for each phase and energy source in each projection year are provided in Table A6. Several details are worth noting.

First, the bp 2020 1.5C scenario does not provide projections for coal, oil, or natural gas production or refining. For these values, we turn to the IEA's 2021 Net Zero by 2050 report (IEA 2021). As noted above, the report does not provide US-specific projections. However, it does provide projections on North American oil and gas production; global coal production; and global refining through 2050. Although these coarse regional groupings do not capture the nuances that are specific to US coal, oil, and natural gas markets and industries, they do provide a credible proxy in the absence of more precise geographic detail. Because many nations, sub-national jurisdictions, and large corporations have announced goals to reach net-zero emissions by 2050 (United Nations 2021), we believe that it is important to estimate changes in revenues under such a scenario, even if the underlying projections are coarse.

Second, revenue data for a variety of sources aggregate oil and natural gas into a single category, which we label "Oil and NG." Where this is the case, we apply an aggregate change in oil and gas production to estimate changes in revenue sources that do not distinguish between the two. To do this, we combine the energy content (in EJ) of oil and natural gas produced in each year of bp's baseline data and projection scenarios to generate a total "Oil and NG" figure.

Third, to estimate changes in refining-related revenue, we use changes in refining throughput (typically measured in millions of barrels per day). However, bp does not provide US-specific data on refining throughput. Instead, we use changes in global refining throughput, for which bp projections are available for two of the three scenarios (BAU and 2C) and the IEA for one scenario (1.5C).

Fourth, bp does not provide projections on pipeline throughput at the global or US level. To approximate changes in pipeline-related revenue, we use our aggregate measure of upstream oil and natural gas production, which should be a reasonable, if imperfect, proxy for pipeline throughput.

Finally, for power plant property taxes, we do not apply fuel-specific changes because our baseline estimates of property tax revenue from power plants are not fuel specific. Instead, we estimate revenues from all fossil fuel-powered power plants. For this reason, we apply changes in aggregate fossil fuel-fired electricity generation, combining coal, natural gas, and oil into a single group that we label "fossil." Again, this approach produces a plausible, if imperfect, scenario of the future.

Table A6 Revenue changes (relative to 2015-2020) by energy type under three scenarios

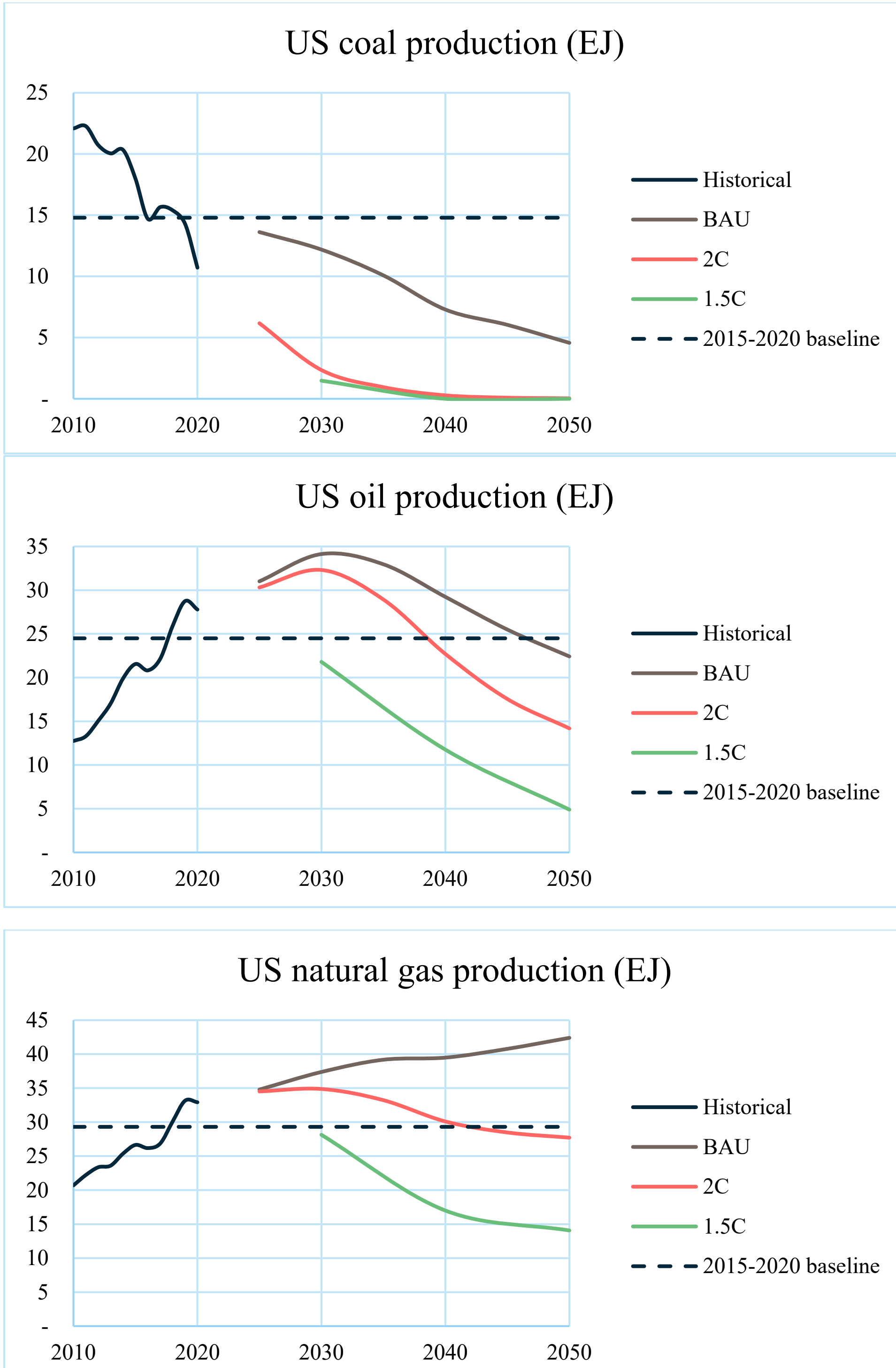
Phase	Scenario	Energy	2030	2040	2050
Upstream	BAU	Oil	0.37	0.20	-0.05
Upstream	2C	Oil	0.29	-0.07	-0.39
Upstream	1.5C	Oil	-0.11	-0.52	-0.80
Upstream	BAU	NG	0.28	0.35	0.45
Upstream	2C	NG	0.19	0.03	-0.05
Upstream	1.5C	NG	-0.04	-0.42	-0.52
Upstream	BAU	Coal	-0.18	-0.51	-0.69
Upstream	2C	Coal	-0.84	-0.98	-1.00
Upstream	1.5C	Coal	-0.90	-1.00	-1.00
Upstream	BAU	Oil and gas	0.33	0.28	0.20
Upstream	2C	Oil and gas	0.25	-0.02	-0.22
Upstream	1.5C	Oil and gas	-0.07	-0.47	-0.67
Midstream_Refining	BAU	Oil	-0.01	-0.07	-0.11
Midstream_Refining	2C	Oil	-0.10	-0.35	-0.56
Midstream_Refining	1.5C	Oil	-0.28	-0.57	-0.85
Midstream_Pipeline	BAU	Oil and gas	0.33	0.28	0.20
Midstream_Pipeline	2C	Oil and gas	0.25	-0.02	-0.22
Midstream_Pipeline	1.5C	Oil and gas	-0.07	-0.47	-0.67
Downstream	BAU	Oil	-0.07	-0.19	-0.29
Downstream	2C	Oil	-0.15	-0.44	-0.68
Downstream	1.5C	Oil	-0.18	-0.60	-0.84
Downstream	BAU	NG	0.11	0.16	0.18
Downstream	2C	NG	-0.05	-0.30	-0.42
Downstream	1.5C	NG	-0.24	-0.55	-0.66
Downstream	BAU	Coal	-0.44	-0.65	-0.80
Downstream	2C	Coal	-0.83	-0.97	-1.00
Downstream	1.5C	Coal	-0.84	-0.98	-1.00
Downstream_Power	BAU	Fossil	-0.08	-0.11	-0.15
Downstream_Power	2C	Fossil	-0.37	-0.68	-0.77
Downstream_Power	1.5C	Fossil	-0.57	-0.91	-0.90

Notes: (1) Neither BP nor the IEA provide details on coal production in the 1.5C scenario. We assume, therefore, that US coal production declines more rapidly in the 1.5C scenario than in the 2C scenario, which leads us to assume that US coal production reaches zero in 2040. We use linear interpolation for 2030 values; (2) Refining in the net zero scenario is based on IEA. Detailed data are not available, but the report states (on p. 102) that global refinery runs decrease by 85% from 2020 to 2050. We use linear interpolation for 2030 and 2040; (3) Changes in midstream oil and gas revenue are set equal to upstream oil and natural gas production due to lack of projections on pipeline throughput, capacity, or other relevant measures.

A potentially surprising result of this scenario analysis is that certain elements of the fossil energy system, particularly oil and gas production, are considerably higher in 2030 than during the baseline period, even under the 2C scenario. This result reflects three key factors. First, bp's scenarios, including its 2C scenario, envision strong global demand for oil and, particularly for natural gas over the next one to two decades. In the 2C scenario, natural gas consumption growth rapidly displaces coal from the power, industrial, and buildings sectors globally, reducing global greenhouse gas emissions (assuming methane leaks are kept to a minimum). Compared with most other scenarios that include rapid emissions reductions, bp's 2C scenario envisions relatively high levels of global natural gas consumption and low levels of global coal consumption (Newell et al. 2021).

Second, as noted in the main text, US oil and gas production grew by 28 percent from 2015 through 2019, and only declined modestly in 2020. Because future production in the bp scenarios is based upon the most recent (2020) levels, it remains high relative to the average over the baseline period. If we had chosen a single recent base year of 2019 or 2020, revenue would appear to grow for a shorter period of time and decline earlier relative to the 2019 or 2020 baseline. If we had chosen an earlier baseline period of 2010 through 2020, upstream oil and gas revenues would appear to be even more resilient. Figure A3 illustrates recent trends (2010-2020), our historical baseline (2015-2020 average), and scenario projections (2025-2050) for coal, oil, and natural gas production.

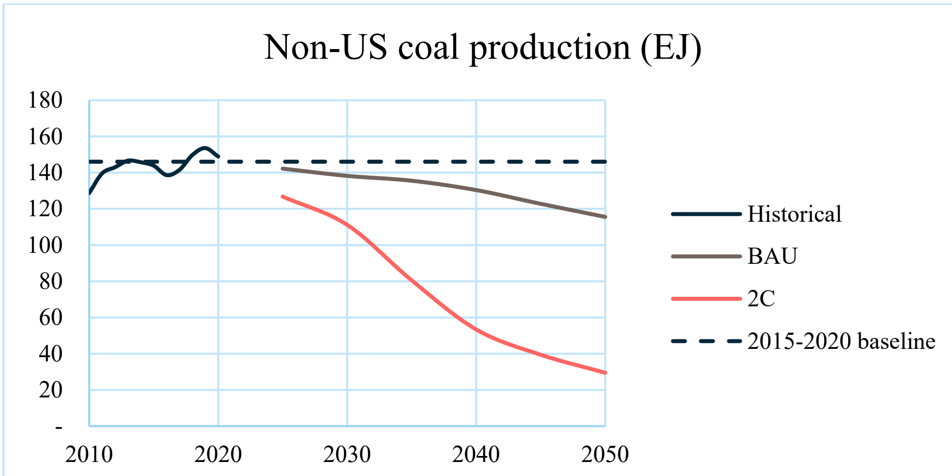
Figure A3 US coal, oil, and natural gas production: history, baseline, and projections

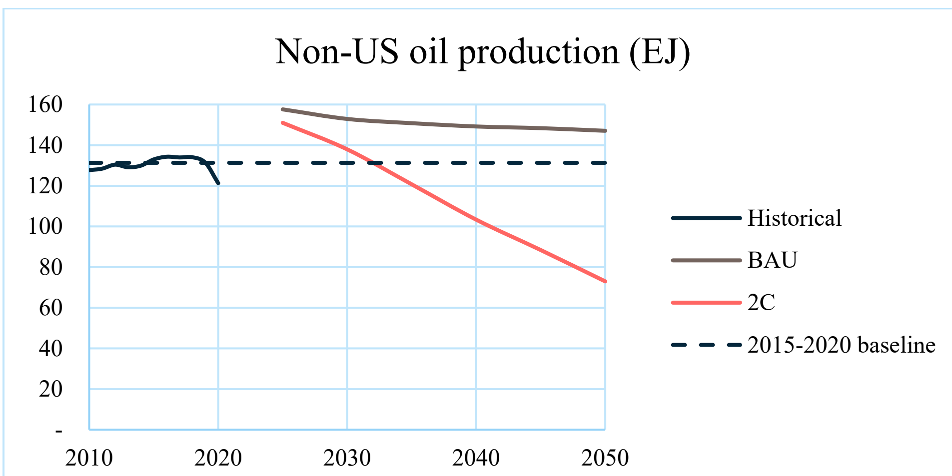


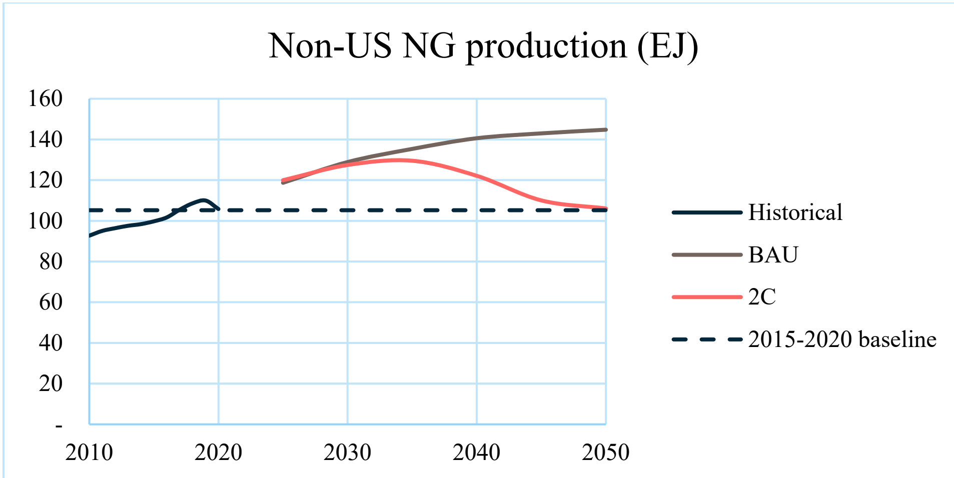
Data sources: Historical data from bp (2021) BAU and 2C scenarios from bp (2020) 1.5C scenario from IEA (2021)

Third, bp's scenarios reflect a relatively optimistic view of future US oil production compared with the rest of the world. In percentage terms, US oil production declines by 7 percent by 2040 compared with a decline of 21 percent for the rest of the world. For other fossil fuels, US coal production falls more rapidly than the rest of the world, while US natural gas production follows a similar trajectory to the rest of the world. Figure A4 illustrates these trends outside of the US under the bp scenarios. Note that data limitations prevent us from displaying projected changes under the 1.5C scenario.

Figure A4 Non-US coal, oil, and natural gas production: history, baseline, and projections







Data sources: Historical data from bp (2021), BAU and 2C scenarios from bp (2020). Data from 1.5C scenarios are insufficient to include in these figures.

Finally, Table A7 identifies our classification system for identifying the three phases (upstream, midstream, and downstream) for which different types of fossil energy-related revenues are generated.

Table A7 Classification of fossil energy phases

Activity	Phase
Coal production	Upstream
Oil production	Upstream
Natural gas production	Upstream
Oil and gas pipelines	Midstream
Oil refineries	Midstream
Power plants	Downstream
Other coal, oil, and gas distribution and consumption	Downstream

3.Results in detail

3.1. Baseline revenue data by energy source and tax type

This section presents detailed information on annual average revenues from each energy source by revenue type, energy type, and state. Tables A8 through A11 present data from upstream, midstream, downstream, and total, respectively.

Table A8 2015-2020 average annual upstream revenues by revenue type, energy type, and state ($2019 millions)

Revenue type	Federal lands		State lands		Severance		Property		Corporate income/franchise		Personal Income		Sales and use	
State	Coal	Oil & gas	Coal	Oil & gas	Coal*	Oil & gas	Coal	Oil & gas	Coal	Oil & gas	Coal	Oil & gas	Coal	Oil & gas
AK		$21.6		$1,295.1		$438.9		$125.0		$68.7				
AL	$0.0	$17.1		$52.6	$4.5	$49.4					$3.6	$4.3		
AR		$1.0	$0.0	$0.8		$53.8	$0.0	$26.0					$0.0	$9.3
CA		$35.7		$118.2		$130.3		$326.6		$20.4		$201.9		$33.5
CO	$14.6	$60.1	$4.7	$117.1	$4.2	$136.8	$17.2	$773.4	$0.4	$2.6			$4.1	$39.8
IL		$0.1					$4.4	$6.1			$12.3	$3.6		
IN		$0.0				$1.2					$6.7	$0.4	$7.2	$0.5
KS		$0.6			$0.1	$40.7		$102.7					$0.0	$10.1
KY	$0.1	$0.1			$122.1	$17.2	$8.8	$10.6			$21.1	$2.9		
LA		$52.9		$638.1	$0.2	$514.8		$209.3			$0.7	$154.5		
MS		$16.0		$7.0		$71.8			$0.5	$12.8			$0.3	$10.4
MT	$1.1	$27.0	$8.8	$13.4	$69.0	$121.8		$3.7	$0.4	$1.5	$2.1	$5.6		
ND	$0.4	$56.4		$285.8	$11.8	$2,144.7							$5.2	$121.7
NM	$6.1	$640.1	$3.4	$799.1	$8.5	$438.9		$167.0			$1.6	$45.0	$7.4	$188.2
OH		$0.6			$3.4	$42.5	$15.1	$25.8					$6.7	$10.8
OK	$0.2	$5.3		$70.6		$560.3		$211.6			$2.2	$562.1	$0.3	$41.4
PA		$0.0		$85.6		$212.1			$20.7	$33.4	$32.7	$52.4	$15.6	$30.2
TX		$33.4		$1,746.8		$4,316.8		$2,277.6					$14.3	$1,272.0
UT	$18.9	$58.8		$40.4		$36.9	$5.6	$50.3	$0.7	$2.3	$5.5	$18.2	$3.1	$10.4
WV	$0.1	$0.2	$0.1	$9.9	$280.7	$163.2	$128.0	$123.8			$75.1	$30.0	$11.0	$4.3
WY	$288.4	$361.1	$98.3	$257.5	$223.6	$1,314.7	$194.2	$1,211.4					$27.6	$58.4
Federal	$643.5	$6,515.4			$585.8				$36.8	$575.5				
Tribal	$74.4	$754.4				$4.8								
Other states	$0.0	$2.8									$5.6	$2.6	$16.2	$7.7
Total	$1,047.7	$8,660.7	$115.2	$5,537.8	$1,310.2	$10,811.8	$373.3	$5,761.2	$59.4	$717.2	$169.2	$1,083.7	$119.1	$1,848.6

*For federal lands, this is the coal excise tax.

Table A9 2015-2020 average annual midstream revenues by revenue type, energy type, and state ($2019 millions)

Revenue type	Corporate income/franchise		Property	
State	Coal	Oil & gas	Oil & gas pipeline	Oil refining
AK			*	$11.7
AL			$36.1	$10.0
AR			$60.9	$6.5
CA			$15.8	$136.2
CO			$89.6	$7.3
IL			$114.5	$77.6
IN			$60.6	$33.1
KS			$116.1	$28.8
KY			$56.4	$20.8
LA			$64.4	$206.9
MS			$85.1	$28.1
MT			$135.8	$15.9
ND			$71.3	$6.4
NM			$66.0	$9.8
OH			$334.4	$42.9
OK			$139.6	$37.3
PA^		$63.4	$97.0	$42.9
TX			$519.9	$467.3
UT			$29.5	$14.5
WV			$29.9	$1.6
WY			$24.7	$12.0
Federal	$393.8	$3,379.7		
Other states			$751.3	$131.4
Total	$393.8	$3,443.1	$2,899.2	$1,348.8

*Included in "upstream" property tax oil and gas revenue. ^Data only available for Pennsylvania. Includes sales/use tax from refineries.

Table A10 2015-2020 average annual downstream revenues by revenue type, energy type, and state ($2019 millions)

Revenue type	Corp. income/franchise		Excise	Property	
State	NG distribution	Petroleum products	Petroleum products	Fossil power plants	NG distribution
AK			$32.52	$3.38	$2.86
AL			$688.05	$9.38	$26.19
AR			$490.61	$4.25	$12.93
CA			$6,165.31	$532.56	$106.21
CO			$680.93	$37.65	$8.70
IL			$1,299.85	$64.67	$51.80
IN			$879.70	$13.70	$34.25
KS			$477.00	$6.11	$15.10
KY			$809.69	$12.82	$14.76
LA			$632.07	$32.62	$11.10
MS			$439.24	$3.96	$12.86
MT			$229.74	$3.15	$5.39
ND			$204.92	$4.97	$2.97
NM			$307.29	$7.08	$30.72
OH		$79.34	$1,935.90	$18.77	$47.02
OK			$508.80	$11.45	$15.76
PA			$3,645.00	$55.30	$35.20
TX			$3,745.67	$133.10	$64.28
UT			$475.21	$18.43	$17.95
WV			$399.93	$5.49	$5.92
WY			$177.53	$11.44	$3.21
Federal	$156.55	$1,068.74	$39,671.56		
Tribal			$13.35		
Other states			$24,405.27	$1,062.51	$461.93
Total	$156.55	$1,148.08	$88,315.13	$2,052.76	$987.12

Table A11 2015-2020 average annual total revenues by phase, energy type, and state ($2019 millions)

Phase	Upstream		Midstream		Downstream			
State	Oil & gas	Coal	Oil refining	Pipelines	NG Distribution	Fossil power plants	Petroleum products	Other*
AK	$1,949.3		$11.7		$2.9	$3.4	$32.5	
AL	$123.4	$8.1	$10.0	$36.1	$26.2	$9.4	$688.1	
AR	$90.9	$0.0	$6.5	$60.9	$12.9	$4.2	$490.6	
CA	$866.6		$136.2	$15.8	$106.2	$532.6	$6,165.3	
CO	$1,129.8	$45.1	$7.3	$89.6	$8.7	$37.7	$680.9	
IL	$9.9	$16.7	$77.6	$114.5	$51.8	$64.7	$1,299.9	
IN	$2.2	$13.9	$33.1	$60.6	$34.3	$13.7	$879.7	
KS	$154.0	$0.1	$28.8	$116.1	$15.1	$6.1	$477.0	
KY	$30.8	$152.1	$20.8	$56.4	$14.8	$12.8	$809.7	
LA	$1,569.7	$1.0	$206.9	$64.4	$11.1	$32.6	$632.1	
MS	$118.0	$0.7	$28.1	$85.1	$12.9	$4.0	$439.2	
MT	$173.0	$81.3	$15.9	$135.8	$5.4	$3.2	$229.7	
ND	$2,608.6	$17.5	$6.4	$71.3	$3.0	$5.0	$204.9	
NM	$2,278.3	$27.0	$9.8	$66.0	$30.7	$7.1	$307.3	
OH	$79.8	$25.2	$42.9	$334.4	$47.0	$18.8	$1,935.9	$79.3
OK	$1,451.3		$37.3	$139.6	$15.8	$11.4	$508.8	
PA	$413.7	$69.0	$106.2	$97.0	$35.2	$55.3	$3,645.0	
TX	$9,646.6	$14.3	$467.3	$519.9	$64.3	$133.1	$3,745.7	
UT	$217.2	$33.8	$14.5	$29.5	$18.0	$18.4	$475.2	
WV	$331.3	$495.0	$1.6	$29.9	$5.9	$5.5	$399.9	
WY	$3,203.1	$832.1	$12.0	$24.7	$3.2	$11.4	$177.5	
Federal	$7,091.0	$1,266.0	$3,379.7	$393.8			$39,671.6	$1,225.3
Tribal	$759.2	$74.4					$13.4	
Other states	$13.1	$21.8	$131.4	$751.3	$461.9	$1,062.5	$24,405.3	
Total	$34,310.4	$3,067.1	$4,791.9	$3,293.0	$987.1	$2,052.8	$88,315.2	$1,304.6

* Includes corporate income taxes for petroleum products and natural gas distribution

3.2. Revenue projection results

This section provides detail on projected revenues from different energy sources and tax types under three policy scenarios. Table A12 through A14 show nationwide results under each scenario by phase, energy type, and revenue instrument. Tables A15 through A17 show results under each scenario by type of government, phase, and energy type.

Table A12 Nationwide revenue projections under the Business-As-Usual scenario ($2019, millions)

Scenario	Phase	Energy type	Revenue type	2015-2020	2030	2040	2050
BAU	Upstream	Coal	Corporate income and franchise	$59.44	$48.98	$29.29	$18.36
BAU	Upstream	Coal	Excise tax	$420.31	$346.33	$207.11	$129.84
BAU	Upstream	Coal	Federal lands	$1,047.74	$863.32	$516.29	$323.66
BAU	Upstream	Coal	Personal income	$169.20	$139.42	$83.38	$52.27
BAU	Upstream	Coal	Property tax	$373.29	$307.59	$183.95	$115.31
BAU	Upstream	Coal	Sales/sales and use tax	$119.12	$98.15	$58.70	$36.80
BAU	Upstream	Coal	Severance	$889.93	$733.29	$438.53	$274.91
BAU	Upstream	Coal	State lands	$115.23	$94.95	$56.78	$35.60
BAU	Upstream	Oil and gas	Corporate income and franchise	$717.15	$953.16	$915.97	$863.99
BAU	Upstream	Oil and gas	Federal lands	$8,660.71	$11,512.34	$11,041.90	$10,377.50
BAU	Upstream	Oil and gas	Personal income	$1,083.70	$1,440.32	$1,384.13	$1,305.58
BAU	Upstream	Oil and gas	Property tax	$5,650.67	$7,491.16	$7,228.09	$6,854.55
BAU	Upstream	Oil and gas	Sales/sales and use tax	$1,848.61	$2,456.69	$2,361.42	$2,228.23
BAU	Upstream	Oil and gas	Severance	$10,811.73	$14,433.55	$13,583.92	$12,343.48
BAU	Upstream	Oil and gas	State lands	$5,537.76	$7,356.07	$7,078.32	$6,689.98
BAU	Midstream	Oil and gas	Corporate income and franchise	$3,773.54	$3,876.39	$3,650.85	$3,492.54
BAU	Midstream	Oil and gas	Property tax	$4,247.98	$5,191.37	$4,959.17	$4,697.24
BAU	Midstream	Oil and gas	Sales/sales and use tax	$63.37	$62.86	$59.02	$56.58
BAU	Downstream	Fossil power plants	Property tax	$2,052.76	$1,897.73	$1,831.31	$1,739.94
BAU	Downstream	Oil and gas	Corporate income and franchise	$156.55	$173.88	$181.32	$184.19
BAU	Downstream	Oil and gas	Property tax	$987.12	$1,096.39	$1,143.33	$1,161.42
BAU	Downstream	Petroleum products	Corporate income and franchise	$1,148.08	$1,062.34	$926.50	$813.78
BAU	Downstream	Petroleum products	Petroleum product taxes/fees	$88,315.54	$81,720.16	$71,270.46	$62,599.42
BAU	**Total**	**Total**	**Total**	$138,249.52	$143,356.42	$129,189.75	$116,395.15

Table A13 Nationwide revenue projections under the 2C scenario ($2019, millions)

Scenario	Phase	Energy type	Revenue type	2015-2020	2030	2040	2050
2C	Upstream	Coal	Corporate income and franchise	$59.44	$9.44	$1.12	$0.16
2C	Upstream	Coal	Excise tax	$420.31	$66.77	$7.95	$1.14
2C	Upstream	Coal	Federal lands	$1,047.74	$166.43	$19.83	$2.83
2C	Upstream	Coal	Personal income	$169.20	$26.88	$3.20	$0.46
2C	Upstream	Coal	Property tax	$373.29	$59.30	$7.07	$1.01
2C	Upstream	Coal	Sales/sales and use tax	$119.12	$18.92	$2.25	$0.32
2C	Upstream	Coal	Severance	$889.93	$141.36	$16.84	$2.41
2C	Upstream	Coal	State lands	$115.23	$18.30	$2.18	$0.31
2C	Upstream	Oil and gas	Corporate income and franchise	$717.15	$895.58	$703.77	$558.62
2C	Upstream	Oil and gas	Federal lands	$8,660.71	$10,818.05	$8,489.65	$6,710.53
2C	Upstream	Oil and gas	Personal income	$1,083.70	$1,353.31	$1,063.48	$844.13
2C	Upstream	Oil and gas	Property tax	$5,650.67	$7,036.43	$5,555.00	$4,436.48
2C	Upstream	Oil and gas	Sales/sales and use tax	$1,848.61	$2,308.24	$1,814.33	$1,440.74
2C	Upstream	Oil and gas	Severance	$10,811.73	$13,578.95	$10,490.90	$7,977.63
2C	Upstream	Oil and gas	State lands	$5,537.76	$6,911.05	$5,437.90	$4,326.26
2C	Midstream	Oil and gas	Corporate income and franchise	$3,773.54	$3,522.45	$2,567.37	$1,809.53
2C	Midstream	Oil and gas	Property tax	$4,247.98	$4,829.95	$3,715.44	$2,858.01
2C	Midstream	Oil and gas	Sales/sales and use tax	$63.37	$56.82	$40.89	$28.17
2C	Downstream	Fossil power plants	Property tax	$2,052.76	$1,286.58	$655.21	$467.22
2C	Downstream	Oil and gas	Corporate income and franchise	$156.55	$148.34	$109.47	$90.94
2C	Downstream	Oil and gas	Property tax	$987.12	$935.39	$690.24	$573.41
2C	Downstream	Petroleum products	Corporate income and franchise	$1,148.08	$970.49	$639.39	$363.85
2C	Downstream	Petroleum products	Petroleum product taxes/fees	$88,315.54	$74,654.88	$49,185.26	$27,989.40
2C	**Total**	**Total**	**Total**	**$138,249.52**	**$129,813.92**	**$91,218.75**	**$60,483.56**

Table A14 Nationwide revenue projections under the 1.5C scenario ($2019, millions)

Scenario	Phase	Energy type	Revenue type	2015-2020	2030	2040	2050
1.5C	Upstream	Coal	Corporate income and franchise	$59.44	$5.94	$0.00	$0.00
1.5C	Upstream	Coal	Excise tax	$420.31	$42.03	$0.00	$0.00
1.5C	Upstream	Coal	Federal lands	$1,047.74	$104.77	$0.00	$0.00
1.5C	Upstream	Coal	Personal income	$169.20	$16.92	$0.00	$0.00
1.5C	Upstream	Coal	Property tax	$373.29	$37.33	$0.00	$0.00
1.5C	Upstream	Coal	Sales/sales and use tax	$119.12	$11.91	$0.00	$0.00
1.5C	Upstream	Coal	Severance	$889.93	$88.99	$0.00	$0.00
1.5C	Upstream	Coal	State lands	$115.23	$11.52	$0.00	$0.00
1.5C	Upstream	Oil and gas	Corporate income and franchise	$717.15	$663.88	$376.77	$235.84
1.5C	Upstream	Oil and gas	Federal lands	$8,660.71	$8,014.11	$4,545.08	$2,835.20
1.5C	Upstream	Oil and gas	Personal income	$1,083.70	$1,003.19	$569.34	$356.38
1.5C	Upstream	Oil and gas	Property tax	$5,650.67	$5,242.29	$2,986.33	$1,903.75
1.5C	Upstream	Oil and gas	Sales/sales and use tax	$1,848.61	$1,711.46	$971.48	$608.64
1.5C	Upstream	Oil and gas	Severance/production	$10,811.73	$9,947.23	$5,585.25	$3,310.53
1.5C	Upstream	Oil and gas	State lands	$5,537.76	$5,129.20	$2,913.74	$1,832.37
1.5C	Midstream	Oil and gas	Corporate income and franchise	$3,773.54	$2,797.97	$1,660.18	$636.47
1.5C	Midstream	Oil and gas	Property tax	$4,247.98	$3,654.94	$2,103.13	$1,155.73
1.5C	Midstream	Oil and gas	Sales/sales and use tax	$63.37	$45.62	$27.25	$9.50
1.5C	Downstream	Fossil power plants	Property tax	$2,052.76	$874.59	$182.77	$199.56
1.5C	Downstream	Oil and gas	Corporate income and franchise	$156.55	$119.06	$69.82	$52.94
1.5C	Downstream	Oil and gas	Property tax	$987.12	$750.75	$440.23	$333.82
1.5C	Downstream	Petroleum products	Corporate income and franchise	$1,148.08	$944.80	$463.41	$178.56
1.5C	Downstream	Petroleum products	Petroleum product taxes/fees	$88,315.54	$72,678.57	$35,647.58	$13,735.31
1.5C	**Total**	**Total**	**Total**	**$138,249.52**	**$113,897.10**	**$58,542.34**	**$27,384.62**

Table A15 Revenue projections under the Business-As-Usual scenario by government type ($2019, millions)

Government type	Phase	Energy type	2015-2020	2030	2040	2050
Federal	Downstream	Oil and gas	$40,896.85	$37,871.70	$33,058.66	$29,061.55
Federal	Midstream	Oil and gas	$3,773.54	$3,876.39	$3,650.85	$3,492.54
Federal	Upstream	Coal	$1,266.04	$1,043.19	$623.86	$391.09
Federal	Upstream	Oil and gas	$7,090.95	$9,424.48	$9,056.78	$8,542.79
Local	Downstream	Fossil power plants	$2,052.76	$1,897.73	$1,831.31	$1,739.94
Local	Downstream	Oil and gas	$987.12	$1,096.39	$1,143.33	$1,161.42
Local	Midstream	Oil and gas	$4,221.06	$5,155.59	$4,924.80	$4,664.81
Local	Upstream	Coal	$372.32	$306.78	$183.47	$115.01
Local	Upstream	Oil and gas	$5,524.47	$7,323.47	$7,066.89	$6,702.43
State	Downstream	Oil and gas	$48,709.56	$45,071.95	$39,308.51	$34,526.09
State	Midstream	Oil and gas	$90.28	$98.64	$93.40	$89.01
State	Upstream	Coal	$1,481.52	$1,220.74	$730.04	$457.65
State	Upstream	Oil and gas	$20,935.74	$27,886.35	$26,500.47	$24,503.49
Tribal	Upstream	Coal	$74.39	$61.29	$36.65	$22.98
Tribal	Upstream	Oil and gas	$759.17	$1,009.00	$969.63	$914.60
Total	**Total**	**Total**	$138,235.76	$143,343.69	$129,178.65	$116,385.39

Table A16 Revenue projections under the 2C scenario by government type ($2019, millions)

Government type	Phase	Energy type	2015-2020	2030	2040	2050
Federal	Downstream	Oil and gas	$40,896.85	$34,586.93	$22,798.82	$13,002.56
Federal	Midstream	Oil and gas	$3,773.54	$3,522.45	$2,567.37	$1,809.53
Federal	Upstream	Coal	$1,266.04	$201.11	$23.96	$3.42
Federal	Upstream	Oil and gas	$7,090.95	$8,855.14	$6,958.64	$5,523.42
Local	Downstream	Fossil power plants	$2,052.76	$1,286.58	$655.21	$467.22
Local	Downstream	Oil and gas	$987.12	$935.39	$690.24	$573.41
Local	Midstream	Oil and gas	$4,221.06	$4,796.34	$3,689.02	$2,837.04
Local	Upstream	Coal	$372.32	$59.14	$7.05	$1.01
Local	Upstream	Oil and gas	$5,524.47	$6,878.87	$5,431.14	$4,338.11
State	Downstream	Oil and gas	$48,709.56	$41,175.16	$27,127.64	$15,437.28
State	Midstream	Oil and gas	$90.28	$90.43	$67.30	$49.14
State	Upstream	Coal	$1,481.52	$235.34	$28.04	$4.01
State	Upstream	Oil and gas	$20,935.74	$26,219.56	$20,420.24	$15,841.52
Tribal	Upstream	Coal	$74.39	$11.82	$1.41	$0.20
Tribal	Upstream	Oil and gas	$759.17	$948.04	$745.00	$591.34
Total	**Total**	**Total**	$138,235.76	$129,802.29	$91,211.09	$60,479.20

Table A17 Revenue projections under the 1.5C scenario by government type ($2019, millions)

Government type	Phase	Energy type	2015-2020	2030	2040	2050
Federal	Downstream	Oil and gas	$40,896.85	$33,645.97	$16,514.18	$6,389.09
Federal	Midstream	Oil and gas	$3,773.54	$2,797.97	$1,660.18	$636.47
Federal	Upstream	Coal	$1,266.04	$126.60	$0.00	$0.00
Federal	Upstream	Oil and gas	$7,090.95	$6,564.20	$3,725.39	$2,331.91
Local	Downstream	Fossil power plants	$2,052.76	$874.59	$182.77	$199.56
Local	Downstream	Oil and gas	$987.12	$750.75	$440.23	$333.82
Local	Midstream	Oil and gas	$4,221.06	$3,630.03	$2,088.99	$1,146.88
Local	Upstream	Coal	$372.32	$37.23	$0.00	$0.00
Local	Upstream	Oil and gas	$5,524.47	$5,125.46	$2,920.00	$1,862.18
State	Downstream	Oil and gas	$48,709.56	$40,085.15	$19,661.07	$7,575.57
State	Midstream	Oil and gas	$90.28	$70.54	$41.39	$18.36
State	Upstream	Coal	$1,481.52	$148.15	$0.00	$0.00
State	Upstream	Oil and gas	$20,935.74	$19,318.94	$10,903.76	$6,638.97
Tribal	Upstream	Coal	$74.39	$7.44	$0.00	$0.00
Tribal	Upstream	Oil and gas	$759.17	$702.77	$398.84	$249.66
Total	**Total**	**Total**	$138,235.76	$113,885.77	$58,536.79	$27,382.48

4. Considering revenue replacement options

4.1. Economic and Practical Considerations

This section provides a framework for assessing possible new (or expanded existing) revenue sources along with a menu of policy options. That framework considers various factors that are important for policymakers as they assess options for revenue replacement.

Chief among those factors is the need for revenue neutrality. However much tax and fee revenue is lost in the process of decarbonizing the U.S. economy requires that we identify an amount of replacement funding needed to maintain current services.[2] Beyond that, there are various factors to consider. One factor is *revenue stability*. How does a potential replacement revenue source compare to fossil fuel revenues in terms of volatility and reliability over the business cycle? Does the new revenue source add to the overall variance of federal or state revenues or reduce its variance?

How revenue sources are affected by the business cycle may have different implications at the federal and state level. The federal government may wish federal revenues to fall during economic downturns. Declining tax revenues during a recession can act as a policy device to mitigate recessionary pressures because lower taxes imply higher disposable income for consumers. Conversely, the federal government may wish tax collections to rise during economic upturns, in part to mitigate any inflationary pressures that may arise in a booming economy, and in part to pay down debt incurred during downturns. Nearly all state governments, in contrast, are subject to balanced budget rules and cannot borrow to fund budgetary shortfalls in their general fund.[3] State governments, then, may find it desirable to construct revenue streams that match spending needs over the business cycle. To the extent that state spending needs rise during recessions, or vice-versa, this would suggest the opposite, with countercyclical revenue sources being more desirable.[4]

A second consideration in designing replacement revenue streams is *fairness*. Who will bear the burden of the new taxes or fees? Here it is important to distinguish between the *statutory incidence* (who literally pays the tax or fee) and the *economic incidence* (whose real income is affected by the tax or fee. These incidence measures can differ as prices change in response to the tax or fee. As a rule of thumb, the economic incidence of a tax falls on those sides of a market (e.g., producers or consumers) least able to respond to higher prices (lower price elasticities of demand).[5]

A third consideration is *efficiency*. In general, taxes impose costs on society separate from the revenue collected. Taxes, for example, can discourage labor supply, capital investment, and business formation, among other things. They can also affect consumer decisions on how to spend income in ways that reduce consumer well-being. Different taxes have different efficiency impacts. In general, taxes on capital

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[2] Our focus is on maintaining current services rather than revenues. If decarbonization leads to out-migration, for example, in a particular state and a decrease in required revenues for state-provided services, we would model new revenues sufficient to provide the new level of required services.

[3] See Clemens and Veuger (2020). Many states, however, have rainy day or permanent funds - budgetary savings accounts that can help fund state programs during economic downturns, and some states - including major fossil fuel states such as Alaska, North Dakota, and Wyoming, have permanent funds that help cushion public finances during downturns (Newell and Raimi 2018).

[4] Again, rainy day funds would allow for less variable revenue over the business cycle. Historically, however, state governments generally have had a poor record of adequately funding rainy day funds during economic expansions (Cantlon 2021).

[5] See Rosen (2002) and Fullerton and Metcalf (2002), among other sources, for more on this point.

income are found to have a higher efficiency cost than taxes on wage income setting up a classic trade-off between equity and efficiency, as taxes on capital may be more efficient but less equitable, and vice versa.[6]

Practical considerations also come into play. How costly is it for the government to administer the tax and monitor compliance? How costly is it for taxpayers to comply with the tax? Should the government replace lost revenues with fees or taxes?[7] At the federal level, whether a levy is deemed a tax or a fee may only be of consequence politically. But at the state level, many states have legislative or constitutional provisions that create meaningful distinctions between fees and taxes that differentially constrain their use of these instruments. California, for example, requires a supermajority vote of each branch of the state legislature for a new tax whereas fees (or other fiscal measures) only require a simple majority. Massachusetts requires all state tax legislation to originate in the House whereas fee legislation may originate either in the House or the Senate.[8]

4.2. Factors affecting Federal Revenue Replacement Options

The federal motor fuels excise tax is earmarked for the Highway Trust Fund (HTF). The HTF is the source of revenue for all federal highway programs and 80 percent of public transportation spending (Kirk and Mallett 2021). In recent years, this excise tax revenue has fallen short of HTF spending needs and general revenue has made up the difference. This historic linkage between federal motor fuel excise taxes and highway spending may create a heuristic that creates a political constraint that the replacement for fuel excise taxes be somehow related to driving (through a vehicle-miles-traveled (VMT) or vehicle tax).[9]

An additional consideration at the federal level is concern over Native American tribal funds. Severance taxes have been a significant source of revenue for a number of Indian tribes, but as noted in the main text, we were unable to identify detailed data on these revenues.

Finally, a relevant consideration is the degree to which the federal government should be prepared to provide additional intergovernmental aid to state and local governments during the transition to a zero-carbon economy. Federal intergovernmental aid to state and local governments comprised 18 percent of state and local revenues in 2018 (Tax Policy Center 2021). Nearly two-thirds of this aid is for health care programs (Tax Policy Center 2020). If federal policy is driving national decarbonization and the resulting adverse revenue impact on state governments, it is a reasonable policy question to ask how the federal government should assist state governments in filling revenue gaps.

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[6] See Auerbach and Hines (2002) for an overview of the efficiency costs of taxation. For a summary of the voluminous literature on the economic effects of taxation, see chapters 18 and 19 of Gayer and Rosen (2013).
[7] Fees and taxes differ in that fees are viewed as a payment for some government provided service (e.g. entrance to a national or state park, roadway, bridge, or tunnel tolls) while taxes are not directly related to the use of a government provided service. But the lines between taxes and fees can be fuzzy. Federal motor vehicle fuel excise taxes are earmarked for the Highway Trust Fund to maintain federal highways. Since gasoline taxes, for example, must be paid whether one drives on an interstate highway system or not, the federal excise tax is properly viewed as a tax rather than a fee.
[8] The California supermajority rule for taxes led the state Chamber of Commerce to challenge CARB's authority to auction allowances under its cap and trade system as a tax and therefore impermissible. The California Court of Appeal ruled in a 2017 case that auctioning allowances was not a tax. See Perkins Coie (2017). The Massachusetts rule is based on personal correspondence with State Senator Michael Barrett (July 27, 2021).
[9] Put differently, the motor vehicle excise tax could be viewed as a benefit tax where the tax (partially) pays for the roadway services consumed by drivers.

4.3. Factors affecting State Revenue Replacement Options

At the state level, two other considerations come into play as we think about revenue replacements for motor fuel excise taxes. First, as noted above, the majority of states have some form of a balanced budget requirement for their operating budget.[10] An Urban Institute report notes that as of 2017, 44 states require the governor to propose a balanced budget, 41 states require the legislature to pass a balanced budget, and 40 states require the governor to sign a balanced budget (Rueben and Randall 2017). States vary in the stringency of their balanced budget rules, and Poterba (1994) finds that the rules are binding and do constrain spending when states experience adverse revenue shocks. The presence of these rules suggests the importance for state governments to choose revenue instruments that are positively correlated with shifts in state spending across the business cycle.

A second consideration is the possibility of tax exporting. Tax exporting refers to the payment of taxes by people or businesses outside the state's jurisdiction. Federal deductibility of some state and local taxes is one form of tax exporting. A taxpayer paying a federal marginal tax rate of τ has their federal taxes reduced by \$$\tau$ for every dollar of deductible state taxes. In effect, the state or local government exports τ percent of its eligible taxes to the federal government. Federal tax exporting could affect state and local government decisions on revenue replacements for lost fossil fuel taxes. Feldstein and Metcalf (1987) show that states have relied more heavily on taxes that are deductible at the federal level but that overall state spending is not affected by federal deductibility. Their work suggests that states will respond to the incentive to take advantage of federal deductibility. The 2017 tax reform, however, significantly curtailed the value of federal deductibility by capping the deduction at $10,000 per return while also raising the standard deduction significantly. While states most at risk for losing fossil fuel tax revenue tend to have deductible state and local taxes below the $10,000 cap, they also have low rates of itemized deductions (Watson 2021). This matters since the ability to deduct state and local taxes is limited to taxpayers who itemize their deductions. The increase in the standard deduction in the 2017 tax reform reduced the number of returns with itemized deductions significantly.

States can also export taxes to out of state residents. States with large amounts of tourism tend to levy higher than average sales taxes and hotel occupancy taxes in hopes of exporting taxes to out of state tourists. Tax exporting is more likely when the good or service being taxed is unique and not easily substitutable by goods or services from other states. Exportability is related to the price elasticity of demand. If goods are easily substitutable by goods or services from other states, raising taxes in one state would lead to a sharp reduction in demand for the in-state good and hence an inability to export the tax. For fossil fuel extraction, the evidence is mixed, indicating that it is unclear of the extent to which taxes are exported in large measure to out of state residents (Brown, Maniloff, and Manning 2020).

4.4. Federal Revenue Replacement Options

Previously, we show that the federal government could see revenues falling by $44 billion annually by 2050 in a Net Zero scenario, primarily due to reduced motor fuels excise taxes. Importantly, some of that revenue loss may be offset by lower federal expenditures on damages from climate change, though this is beyond the scope of our analysis. Rather we focus on revenue replacement to hold overall services constant. While carbon fee revenues could make up for a large portion of lost revenues during the decarbonization process, by definition, carbon fee revenues will go to zero as the country approaches full decarbonization. So, we must look to other revenue sources.

[10] Balanced budget rules typically do not apply to capital or pension fund budgets.

Excise taxes, of which motor fuel excise taxes predominate, accounted for 2.5 percent of total federal receipts in 2020. In contrast, individual income taxes account for 47 percent and corporate income taxes 6 percent (Office of Management and Budget 2021). Payroll taxes for Social Security and Medicare account for another 38 percent of total receipts, but are earmarked for these two programs, so are not possible replacement sources. Among existing taxes, that leaves income taxes. While an economic argument might be made replacing some or all of the lost fossil fuel tax revenues through increases in income tax collections (either through rate increases, base broadening, or better enforcement), politically this may be challenging. No other existing federal revenue source is large enough to make up lost fossil fuel tax revenue. That suggests a need for new revenue sources.

As noted in the main text, one potential source would be to enact a modest Value Added Tax (VAT). VATs are common in most of the world; in fact, the United States is an outlier in not having a VAT. A VAT is a form of consumption taxation and has been long favored in various forms by tax experts (see, for example, Graetz (2002) and Metcalf (1995)). An analysis of a particular VAT plan put forward by then Yale Law professor, Michael Graetz, carried out by Toder et al. (2012) highlights the various advantages and disadvantages of a VAT. In brief, it reduces the number of income tax filers, lowers marginal tax rates on most workers, eliminates the tax on the normal return to capital (but not extraordinary returns such as are earned by "unicorn" tech start-ups), and can be fine-tuned to avoid large redistributional shifts. Its major disadvantage is the need to set up a new administrative infrastructure to oversee the tax – a disadvantage shared by *any* new tax – as well as a long-standing suspicion of the tax by those who view a VAT as a contributor to larger federal spending, a suspicion arising from the fact that most European governments employ a VAT and also have higher shares of national spending in GDP than does the United States.[11]

Another possible tax replacement – and one more directly related to motor fuel excise taxes – is a VMT tax. As noted above, a VMT tax has become increasingly of interest as electric vehicles (EVs), plug-in hybrids, and more fuel efficient cars have eroded motor vehicle fuel excise tax revenue and contributed to shortfalls in funding for the federal HTF. A VMT tax also serves as a Pigouvian tax since most of the external damages arising from driving are associated more with the driving itself (e.g. congestion and accident externalities) than pollution from the fuels that power vehicles (see Parry and Small (2005), for example). The major challenges to implementing a VMT tax are administrative and political. Levying the tax requires knowing how many miles per year the vehicle is driven, which may raise privacy concerns if tracking devices are required in cars to log miles. Alternatively, annual motor vehicle inspections could record odometer readings that could be reported to the IRS. No tracking is required in that case but only a handful of states currently require annual motor vehicle inspections. The current fuel excise tax is collected at roughly 1,300 fuel distribution centers (Kile 2021) whereas a VMT tax would need to be collected from all vehicle owners. Piggybacking VMT data collection on current personal and corporate income tax forms (the latter for trucking) would reduce administrative costs to a degree.

Kile (2021) notes in CBO testimony to Congress that the VMT tax, like the current fuel excise tax, is regressive, though it is not clear which would be more regressive. One study in Oregon (McMullen, Zhang, and Nakahara 2010) suggests such a switch would be mildly regressive, but was carried out before the increased penetration of plug-in-hybrids and EVs, vehicles more likely to be purchased by higher income drivers.

Kile (2021) also notes that limiting the VMT tax to commercial trucking would reduce administrative and privacy concerns. Applying a VMT tax to commercial trucking also makes sense given the greater road damage arising from the heavier vehicles. However, this would come at the cost of significantly reduced revenue. Diesel fuel powers most commercial trucks, and diesel excise tax collections account for a little

[11] The evidence does not back up this assertion. See, e.g., Lee et al.(2013).

more than one-quarter of motor fuel excise revenues, according to data from the Federal Highway Administration.("Table FE-210 - Highway Statistics 2019 - Policy | Federal Highway Administration" n.d.) As described in the main text, the Congressional Budget Office (2019) estimates that a $0.05 per mile tax levied on commercial trucks would raise up to $12.8 billion annually, and a back of the envelope calculation of 2017 light duty VMT and fuel economy data (FHWA 2019), suggests that a $0.01 per mile tax on passenger vehicles would raise $28.5 billion per year. On average, drivers would pay a similar level of tax per mile driven,[12] and revenues would total roughly $40 billion, equal to the average annual federal revenues from motor vehicle excise taxes from 2015 to 2020. Note that a VMT tax could also apply to commercial jet fuel based on airplane travel logs kept by commercial carriers.[13]

Another revenue option at the federal level is to repeal existing fossil fuel tax breaks. The most recent U.S. Treasury Greenbook (U.S. Department of the Treasury 2021) estimates this would raise $35 billion over the FY 2022 – 2031 period. If carbon pricing or other policies were in place to accelerate clean energy deployment, it might also be possible to eliminate clean energy subsidies in the tax code which, based on the Greenbook estimates, would save $265 billion over the next decade.

[12] For commercial trucks with an average fuel economy of 5.3 miles per gallon for a semi-tractor trailer, this is equivalent to an excise tax rate of $0.26 per gallon – comparable to the current $0.24 per gallon federal diesel excise tax rate. For passenger vehicles with an average fuel economy of 22.3 miles per gallon in 2017, this is equivalent to $0.18 per gallon, equal to the current federal gasoline tax rate (FHWA 2019).

[13] A VMT tax could also be adjusted for vehicle weight given the greater road damage from heavier vehicles (especially trucks). See Small et al. (1991) for a discussion of this point.

5. Calculating tax effort

Beyond looking at what revenue state and local governments *do* raise, it is important to consider what they *could* raise if they made changes to their fiscal policies. Tax effort can be calculated different ways but can generally be understood as a measure that captures the share of revenue that governments *could* raise relative to the revenue they *do* raise.

Tax effort is commonly defined as the ratio of actual tax revenues to some measure of average or "optimal" revenues collected by other jurisdictions (Tannenwald 1999). Actual revenues are measured by the taxes levied by states, while the "optimal" tax revenue is known as the tax capacity. There are a number of accepted methods for calculating tax capacity, but here we use a Representative Revenue System, which applies the national average tax rate to the assessed value of tax bases in each state (Federation of Tax Administrators 2016).

The actual revenue raised across sources was reported by the US Census in the 2012 Annual Survey of State and Local Government Finances (US Census Bureau 2012), which we normalize to a per capita basis. To calculate capacity, we follow a 2016 report from the Urban Institute (Gordon, Auxier, and Iselin 2016), the most recent available report that we identified that suites our purposes. Our property tax capacity estimates are from Urban Institute, which estimate these measures by summing residential, corporate, farm, and utility property values using values from the IRS (Internal Revenue Service 2013). Individual income tax capacity across states due to differences in state-level income tax exemptions and deductions, as well as differences in tax brackets and marginal tax rates. To avoid these complexities, we follow the Urban Institute's method of calculating individual income tax capacity as equal to each state's Total Taxable Resources (TTR) as calculated by the U.S. Department of Treasury (2012). TTR captures the income produced in a state plus the out-of-state income minus federal taxes and social insurance payments. For corporate income tax capacity, we again rely on the Urban Institute's calculations, which derive this measure using a three-factor formula based on corporate sales, payroll, and property provided by the US Census Bureau. General sales tax capacity was derived from Bureau Economic Analysis (BEA) Personal Consumption Expenditures (BEA 2013) using the method outlined by the Urban Institute.

Each state's tax effort is calculated for each measure by dividing the per capita revenues by the per capita capacity for each state. States with tax efforts near 100% are close to utilizing the full value of that particular revenue source. In some cases, tax effort may exceed 100%. For example, oil prices in 2012 were quite high (the West Texas Intermediate spot price averaged $94 in nominal dollars), resulting in Alaska, which derives most of its corporate income tax revenue from oil producers, having a corporate income tax effort of over 500%.

Table A18 demonstrates the lower tax effort exerted by the states with the highest fossil fuel revenues in three out of four major tax types. Property tax effort, individual income tax effort, and corporate income tax effort in fossil-dependent states is, on average, 15 percent, 36 percent, and 6 percent lower than other states, respectively. Sales tax effort in fossil-dependent states is 39 percent higher, on average. This suggests that states with large fossil fuel revenues have the capacity to increase certain tax rates while still falling well within the range of other states. Increased reliance on property and income taxes relative to sales taxes would typically be expected to create a more progressive fiscal regime, though this would depend on the details of policy design (President's Advisory Panel on Tax Reform 2005).

Table A18 Tax effort by state and tax type (2012 data)

State	Property tax	Individual income tax	Corporate income tax	General sales tax
Alaska	113.3%	0.0%	501.7%	22.3%
Colorado	81.9%	92.2%	59.4%	99.6%
Louisiana	76.6%	55.0%	38.9%	163.1%
Montana	70.8%	109.9%	153.5%	0.0%
New Mexico	59.8%	63.4%	141.5%	154.5%
North Dakota	48.4%	71.8%	163.8%	148.0%
Oklahoma	56.4%	76.7%	84.2%	129.5%
Texas	140.7%	0.0%	0.0%	127.6%
West Virginia	86.1%	129.9%	101.0%	78.4%
Wyoming	116.9%	0.0%	0.0%	163.3%
Median of above states	79.2%	67.6%	92.6%	128.5%
Median of all other states	93.0%	105.5%	99.0%	92.6%

Data sources: Author's calculations based on data from the Census (2012), IRS (2013), and Department of Treasury (2012).

6. Limitations

This analysis has several limitations. First, we do not attempt to estimate current and future revenues associated with clean energy, which may be substantial.

Second, data limitations are considerable in some cases. Local property tax revenues are particularly difficult to gather. Where data were not publicly available, we contacted relevant state and local agencies via email and phone, but were not always successful in gathering the requested information. We have complete or near-complete data for severance taxes, petroleum product taxes, and public lands revenues, with less consistent coverage for property taxes, sales & use taxes, and income taxes. Data for tribal revenue data are quite limited. There are over 550 federally recognized tribes, and tax policies vary across each. Because of these complexities, the large number of tribes, and a paucity of public data, we were not able to include tribal revenues from most sources.

Finally, data limitations prevent our estimating revenues from certain sectors that are closely tied to fossil energy, such as import/export facilities, rail transport of coal, and payments in lieu of taxes, which may be substantial for certain communities.

Additional research and data collection would be valuable to help fill these gaps and provide a more robust picture of public revenues that may be affected by a transition away from fossil fuels.

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