Valuation of Subsoil Energy Assets: Pilot Estimates for the U.S. National Balance Sheet

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Abstract

Energy plays a critical role in the U.S. economy. While the U.S. Government produces high quality estimates of physical quantities of subsoil assets like oil and natural gas reserves, the national economic accounts do not currently report a detailed accounting of natural resources on the national balance sheet (or Integrated Macroeconomic Accounts). This paper develops new estimates of the value of U.S. subsoil energy assets, focusing on oil and natural gas as test cases for improving the national accounts. We estimate the value of these assets as the net present value of natural resource rents, which are commonly estimated as a residual (i.e., subtracting intermediate input, labor, and estimated capital costs from total revenue). We develop a modified version of the residual method that uses the return on corporate bonds as a proxy for the rate of return to capital and adjusts depreciation costs to account for tax implications. Overall, we estimate the total value of U.S. oil and gas subsoil assets to be worth about $2.3 trillion in 2025. We then evaluate lower and upper bounds to illustrate the impact of key assumptions on valuation of these assets. Further vetting and refining of the methods, assumptions, and data sources for these estimates will serve as an initial step toward incorporating subsoil assets on the U.S. national balance sheet.

JEL Codes: E01, L71, P18, Q43, O13

Disclaimer

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1. Introduction

The wealth of a nation includes a wide range of assets. Most countries tabulate their wealth in monetary terms in their national economic accounts, as prescribed by the international statistical standard for producing national accounts—the *System of National Accounts* (SNA). The SNA outlines a *national balance sheet* that breaks out assets by type so policymakers and the public can better understand how different components of wealth are growing (or shrinking) over time. While the national balance sheet differentiates between *produced* assets (like buildings and machines) and *non-produced* assets (like land and subsoil minerals), consistent accounting methodologies should be applied across all asset types to maintain comparability in valuation. Recognizing the importance of natural resources to modern economies, the most recent version of the SNA (revised in March 2025) elevates natural resources (including subsoil mineral and energy resources) to be a standalone category on the balance sheet. As a step toward a more complete accounting of U.S. wealth, this paper estimates the value of subsoil crude oil and natural gas assets for the entire U.S. as of 2025.

But if the U.S. already tabulates and reports data for physical quantities of these assets, what is gained by tracking their value? Valuation conveys information that might be concealed by data on physical quantities alone. For example:

- Dollars are a common numeraire, allowing for straightforward comparison in economic terms across commodities and facilitating understanding of relative value and economic tradeoffs[1].
- Market-based asset valuation reflects the changing market value of commodities over time, even if the physical quantities of these assets remain static.
- Quantifying assets in physical terms does not reflect extraction/production costs[2].

Out of many natural resource assets not yet tracked in the U.S. national accounts, we focus on oil and gas in this paper for several reasons. Oil and gas play a critical role in the U.S. economy both as products for final use by households and as inputs to the production process of many other goods and services. The U.S. National Income and Product Accounts (NIPAs) estimate that the oil and gas extraction industry contributed $257 billion to Gross Domestic Product (GDP) in 2023. But this estimated flow of extraction in the U.S. does not reveal much about the underlying stock of U.S. energy assets, which form an important part of national net wealth. These pilot estimates help fill that gap.

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[1] For example, barrels of oil and cubic feet of gas are incomparable unless converted to common units. This point is further discussed in the *System of Environmental-Economic Accounting* (SEEA-CF), paragraph 5.94.

[2] Consider two countries with identical quantities of oil reserves but different extraction costs (e.g., conventional surface vs. deep well oceanic drilling). All else equal, these countries should place a different value on their respective reserves.

It is also useful for a country to know the extent and value of its assets for economic planning purposes, including for estimating potential government income from extraction licensing fees and royalties. Norway, for example, calculates these income streams and uses them in the national budgeting process. Other countries produce these statistics for their national balance sheet or as standalone satellite accounts. For example, the U.K. and Australia publish natural resource valuations as satellite accounts, whereas Canada publishes these figures as a section in their annual national balance sheet.

Prior work, including early work by the U.S. Bureau of Economic Analysis (BEA) on developing natural resource asset accounts, has singled out subsoil assets as an important gap in the national economic accounts (Landefeld, Carson, & others, 1994). Currently, the NIPAs include accumulation and depreciation of produced assets, but do not consider the depletion of natural resource assets. This omission has been documented for decades[3], and the 2025 SNA update prescribes accounting for depletion of natural resource assets in the national accounts. Oil and gas estimates represent a logical first step since the U.S. Government still collects high quality data for oil and gas, despite the discontinuance of a number of data sources on other minerals since BEA's 1990s work on the topic.[4] A pilot account for subsoil oil and gas assets could be a blueprint for development of other subsoil asset accounts as existing data gaps are bridged.

Although important data gaps remain, we find that existing U.S. data support reasonable pilot estimates of the aggregate value of U.S. crude oil and natural gas resources. Specifically, we estimate that the total value of U.S. subsoil oil and gas assets is between $2.3 trillion and $7 trillion in 2025, based on assumptions discussed below. These estimates draw on rich physical data from the U.S. Energy Information Administration (EIA), combined with economic data from BEA and EIA. We find that this value is sensitive to changes in underlying parameters such as the discount rate, rate of return to capital, and asset life, underscoring the importance of carefully considering each component of the methodology. We discuss alternative methods, outline the strengths and weaknesses of the chosen methodology, and discuss the path of future development of U.S. subsoil mineral and energy asset accounts.

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[3] *Nature's Numbers*, a follow-up publication to BEA's early work on natural resource asset accounts, notes: "First, there is no entry for additions to the stock of subsoil assets in the production or asset accounts. This omission is anomalous because businesses expend significant amounts of resources on discovering or proving reserves for future use. Second, there is no entry for the using up of the stock of subsoil assets in the production or asset accounts. When the stock of a valuable resource declines over time through intensive exploitation, this trend should be recognized in the economic accounts: if it is becoming increasingly expensive to extract the subsoil minerals necessary for economic production, the nation's sustainable production will be lowered. Third, there is no entry for the contribution of subsoil assets to current production in the production accounts. The contribution of subsoil assets is currently recorded as a return to other assets, primarily as a return to capital." (Nordhaus & Kokkelenberg, 1999)

[4] For example, detailed information regarding mineral assets has been reduced since the closure of the U.S. Bureau of Mines in 1996.

We emphasize that the goal of this paper is to present proof-of-concept estimates, not official statistics. Like other pilot accounts, this research is an initial experimental phase in a multistep process that precedes production-grade statistics. To produce high-quality statistics that markets, policymakers, and the general public can rely on, it is first necessary to understand and assess:

- what is feasible using existing data and resources,
- data gaps to be filled, and
- methodological issues to be solved.

Thus, the estimates reported in this study should be interpreted as experimental, for the purposes of evaluating available source data and methodologies. Moreover, some methodological issues we grapple with in this pilot effect may be helpful to others, particularly as the international community updates the SEEA Central Framework in the coming years and tackles issues such as negative resource rents and depletion implementation in the new standard and accompanying guidance notes.

2. Historical Background

Subsoil assets have been conceptually included as a category on the national balance sheet for decades, appearing in the SNA manual as early as the 1993 edition. This was more theoretical than practical at the time, as few countries reported detailed estimates valuing subsoil mineral and energy assets in their published tables. BEA pursued research on different valuation methodologies (Landefeld, Carson, & others, 1994) and was at the forefront of natural resource accounting until research was paused in 1994.

Other countries continued to refine and advance methodologies on measuring natural resources for the national economic accounts. In 2008 the SNA defined mineral and energy resources on the national balance sheet (non-produced, non-financial assets) as "mineral and energy reserves located on or below the earth's surface that are economically exploitable, given current technology and relative prices" (2008 SNA, paragraph 10.179). In 2012, these methods of measuring natural resources were mature enough to be adopted and formally approved by the international statistical community as the *System of Environmental-Economic Accounting 2012—Central Framework* (SEEA-CF), which prescribes the methodology for natural resource accounts to accompany the suite of SNA-based economic accounts. Specific guidelines for the development of crude oil and natural gas accounts are found in section 5.5 (paragraphs 5.168–5.234) of the 2012 SEEA-CF manual.

Additional compilation guides and guidance notes have been prepared to help national statistical offices produce accounts that quantify natural resources and subsoil energy assets in particular. These include a UN manual specifically on energy accounts, the *System of Environmental-Economic Accounting for Energy: SEEA-Energy* (UN, 2019), as well as a recently developed OECD guide titled *Measuring natural resources in the national accounts: a compilation guide*, which is due to be published in late 2025 and is intended to support the implementation of the revised SNA-2025. [5] We draw numerous lessons from these documents and reference them throughout the paper.

While the national balance sheet as described in the SNA might include a single monetary value for subsoil oil and gas assets, SEEA provides more detailed guidance on disaggregating this information into granular accounts including both physical and monetary components. Figure 2.1 illustrates the standard SEEA framework for parallel physical and monetary subsoil oil and gas asset accounts, with the values that would be found on the SNA national balance sheet highlighted. A full set of SNA- and SEEA-based natural resource asset accounts requires physical data on the specific natural resource including quantities and (ideally) qualities of the subsoil asset—in this case crude oil and natural gas—along with rates of extraction and discovery and economic data to measure market value of the asset. In the next two sections, we summarize the statistical framework for physical and monetary subsoil oil and gas asset accounts, giving context for our methodology and results in the following sections.

Physical Subsoil Oil and Gas Account

	Crude Oil	Natural Gas
Opening stock		
Additions		
Discoveries/extensions		
Net Acquisitions		
Reappraisals		
Reclassifications		
Total additions		
Reductions		
Extraction		
Catastrophic losses		
Reappraisals		
Reclassifications		
Total reductions		
Closing stock		

Monetary Subsoil Oil and Gas Account

	Crude Oil	Natural Gas
Opening stock		
Additions		
Discoveries/extensions		
Net Acquisitions		
Reappraisals		
Reclassifications		
Total additions		
Reductions		
Extraction		
Catastrophic losses		
Reappraisals		
Reclassifications		
Total reductions		
Revaluations		
Closing stock	SNA balance sheet values	

Figure 2.1 *Standard SEEA framework for parallel physical and monetary subsoil oil and gas asset accounts. Additions and reductions may be given as totals only where data do not allow further breakdowns. Closing stock values from the monetary account are the values on the SNA national balance sheet.*

[5] The third draft of this document is out for global consultation as of this writing.

3. Physical Asset Accounts

A. Basic Structure

The main components of a physical asset account for a given time period are: the opening stock, additions, reductions, and closing stock (which becomes the next period's opening stock). Additions and reductions encompass several activities; for oil and gas, these include the discovery of new reservoirs or extensions to existing reservoirs, revised extraction expectations due to changing prices or extraction costs, changes in reservoir accessibility due to sale or purchase of drilling rights, and, of course, actual extraction of oil and gas. Data for all of these components of a physical asset account may be difficult to obtain, requiring detailed surveys or the purchase of proprietary data. In some cases, aggregated accounts are developed which only include the sub-categories, "total additions to stock" and "total reductions to stock" without further detail on the different categories of additions or reductions. Figure 2.1 shows the standard format for physical asset accounts.

B. Subsoil Asset Classification

As noted in section 2, the SNA defines energy resources as being "economically exploitable, given current technology and relative prices" (SNA-2008, paragraph 10.179). But subsoil energy assets vary widely in recovery costs and thus the economic viability of extraction. Countries have differing classification systems for subsoil assets, but SEEA defines the assets to be included in physical and monetary subsoil asset accounts according to criteria based on the UN Framework Classification for Resources (UNFC). Each country is responsible for mapping their own classification system to the UNFC, which uses three axes of classification:

- **E**: environmental-socio-economic viability,
- **F**: technical feasibility, and
- **G**: degree of confidence.

Each deposit of a subsoil asset can be assigned a value from 1–4 on these axes (1–3 for environmental-socio-economic viability).

SEEA-CF outlines three classes for known deposits, defined according to criteria derived from the UNFC (see SEEA-CF Table 5.6, p.163).

- **Class A**: commercially recoverable resources
- **Class B**: potentially commercially recoverable resources
- **Class C**: non-commercial and other known deposits.

Technically all three classes should be included in SEEA physical and monetary asset accounts; however, data availability is often limited to class A only, and SNA-2025 restricts the value included on the national balance sheet to class A assets only. Additional terms often used for these assets include *proven reserves*, *proved reserves*, or *established reserves*, as these terms generally refer to the subset of class A that has the highest confidence and technical feasibility.

The U.K. Office for National Statistics produces a physical account for oil and gas reserves as part of their national accounts (ONS, 2023). They broadly follow the SEEA-CF three category system (classes A, B, and C are called "Proven," "Probable," and "Possible," respectively)[6]. The physical accounts are used in concert with the monetary account in a recent work quantifying depletion (ONS, 2024). Canada, on the other hand, focuses on measuring a single category, "established reserves," that closely approximates SEEA-CF class A plus a portion (about 50%) of class B (CAPP, 2025).

Like Canada, the flagship EIA estimates focus on a single category—proved reserves—for both crude oil and natural gas. This category is defined as "estimated volumes of hydrocarbon resources that analysis of geologic and engineering data demonstrates with reasonable certainty are recoverable under existing economic and operating conditions." EIA defines "reasonable certainty" as "assum[ing] a probability of recovery of 90% or greater," which would fit under the SEEA-CF class A classification (EIA, 2022).

C. Sample Physical Account

Figure 3.1 shows a sample physical subsoil oil and gas asset account table, using EIA data. This is presented here for comparison with the monetary asset account that is this pilot's primary focus, as well as to illustrate the results of different asset class definitions. The first definition used is *proved reserves* (approximately class A, which assumes no further discovery), as estimated by EIA. The

Physical Subsoil Oil and Gas Account

	Crude Oil (million bbl)		Natural Gas (billion ft^3)	
2023	Proved	25-year	Proved	25-year
Opening stock	**48,321**	**120,554**	**691,025**	**988,540**
Additions				
Discoveries/extensions	5,002		42,290	
Net Acquisitions	1,703		12,448	
Total additions	*6,705*	*4,767**	*54,738*	*45,686**
Reductions				
Extraction	4,705	4,705	41,946	41,946
Catastrophic losses				
Net Revisions	3,898*		100,202*	
Total reductions	*8,603*	*4,719*	*142,148*	*41,946*
Closing stock	**46,422**	**120,616**	**603,615**	**992,280**

Figure 3.1 *Standard SEEA framework for physical oil and gas subsoil asset accounts. Proved reserves are more certain than the reserves supporting a 25-year estimated lifespan.*
** Item calculated as a balancing item/residual from other entries in the column.*

[6] The UK defines proven resources as having >90% chance of being produced, probable as >50% chance, and possible as >10%.

second goes beyond proved reserves (to approximate a stock closer to encompassing all of class A) and is based on EIA's estimates of future extraction (which *do* allow for further discovery) assuming a 25-year asset life.[7] Each of these asset class definitions has a corresponding monetary value in the pilot monetary account estimates given below.

4. Monetary Asset Accounts

A. Asset Valuation

Both the SNA and SEEA-CF standards address the monetary value of natural resource assets, as they are important both economically and environmentally. Chapter 14 of the 2025 SNA describes the national balance sheet, which tabulates a country's aggregate assets and liabilities, broken down into a variety of components and subcomponents. Figure 4.1 tabulates a hypothetical *Asset account for the total economy*, illustrating the categories and subcategories on the asset-side of the

					Revaluation account			
Code	Stocks and changes in assets	Opening balance sheet	Capital and financial account	Other changes in the volume of assets	Nominal holding gains and losses	Neutral holding gains and losses	Real holding gains and losses	Closing balance sheet
AN	Non-financial assets	4 924	162	15	280	198	82	5 381
AN1	Produced non-financial assets (excluding natural resources)	2 718	180	- 7	126	121	5	3 017
AN11	Fixed assets (excluding produced natural resources)	2 479	145	- 2	111	111	0	2 733
AN12	Inventories (excluding produced natural resources)	114	25	- 3	7	4	3	143
AN13	Valuables	125	10	- 2	8	6	2	141
AN2	Non-produced non-financial assets (excluding natural resources)	25	0	- 1	2	1	1	26
AN21	Contracts, leases and licenses	22	0	- 1	2	1	1	23
AN22	Crypto assets without a corresponding liability designed to act as a medium of exchange	3	0	0	0	0	0	3
AN23	Purchased goodwill and marketing assets	0	0	0	0	0	0	0
AN3	Natural resources	2 181	- 18	23	152	76	76	2 338
AN31	Land							
AN32	Mineral and energy reserves							
AN33	Biological resources							
AN34	Water resources							
AN39	Other natural resources							
AF	Financial assets	8 231	437	3	84	136	- 52	8 755
AF1	Monetary gold and SDRs	770	- 1	0	12	16	- 4	781
AF2	Currency and deposits	1 482	90	0	0	30	- 30	1 572
AF3	Debt securities	1 263	86	0	40	25	15	1 389
AF4	Loans	1 384	78	0	0	28	- 28	1 462
AF5	Equity and investment fund shares/units	2 614	107	2	32	26	6	2 755
AF6	Insurance, pension and standardized guarantee schemes	470	48	1	0	7	- 7	519
AF7	Financial derivatives and employee stock options	21	14	0	0	0	0	35
AF8	Other accounts receivable/payable	227	15	0	0	4	- 4	242
AF	Financial liabilities	7 762	427	3	76	126	- 50	8 268
AF1	Monetary gold and SDRs	0	0	0	0	0	0	0
AF2	Currency and deposits	1 471	102	0	0	30	- 30	1 573
AF3	Debt securities	1 311	75	0	42	26	16	1 428
AF4	Loans	1 437	47	0	0	29	- 29	1 484
AF5	Equity and investment fund shares/units	2 756	105	2	34	28	6	2 897
AF6	Insurance, pension and standardized guarantee schemes	471	48	1	0	7	- 7	520
AF7	Financial derivatives and employee stock options	14	11	0	0	0	0	25
AF8	Other accounts receivable/payable	302	39	0	0	6	- 6	341
B90	*Net worth*	5 393	172	15	288	208	80	5 868

Figure 4.1 *Sample SNA asset account for a fictitious economy. Note the variety of categories and subcategories, and that "natural resources" are their own category of non-financial assets, not combined with other non-produced, non-financial assets (as they were under the 2008 SNA). Source: 2025 SNA, table 14.2*

[7] These assumptions are discussed in more detail in section 4.C.

national balance sheet. As mentioned earlier in the paper, the 2008 SNA previously grouped natural resources among “non-produced, non-financial assets,” but the 2025 version places them in their own asset category, of which “mineral and energy reserves” is a subcategory along with other natural resources such as land and biological resources (e.g., livestock, timber, cultivated fish stocks).

An important distinction between SEEA-CF and the SNA is that, while SEEA-CF considers multiple classes of resources, the SNA focuses on known, commercially recoverable resources for valuation purposes. Specifically, the SNA states: “In the case of mineral and energy resources, SEEA Central Framework distinguishes three classes based on the UNFC: [A, B, and C]. The measurement of monetary estimates is typically restricted to the first class” (SNA 2025, paragraph 11.186).

Where possible, the national accounts measure the value of goods and services by their market value in a given period. This is straightforward for most goods and services because they are traded regularly in markets and national statistical offices can observe the prevailing market prices and quantities. Assets like oil fields and the corresponding mineral extraction rights, on the other hand, are infrequently traded in market transactions. The SNA and SEEA-CF therefore recommend that countries estimate the value of these assets as the present value of future resource rents derived from the underlying asset (2025 SNA, paragraph 14.56).

In principle, the current market value that someone would be willing to pay for a given subsoil asset is equal to the discounted stream of net benefits the asset is expected to yield. Thus, comparing mineral and energy resources valued in this way to other assets on the national balance sheet (such as equities, gold, or inventories) is an “apples to apples” comparison (current market value to current market value).

The net present value of future resource rent, given an estimated stream of rent RR_t, asset life of N years, and a discount rate of r, is given by:

$$V_t = \sum_{i=1}^{N_t} \frac{RR_{t+i}}{(1+r_t)^i}$$

Of the three important parameters in the NPV formula, our primary focus in this pilot is estimating the future stream of resource rent. This follows a two-step process: past resource rent is estimated using historical data, then these estimates are used to forecast future resource rent. We also discuss four possible assumptions regarding asset life and give estimated asset values under each. Throughout, we assume a discount rate of 2%.

B. Estimating Past Resource Rent

Natural resource rent is essentially the profit that the economic owner(s) of a natural resource asset retains after subtracting both production costs and opportunity costs (in the form of returns to capital). This may be estimated as a residual: what is left over after costs—including opportunity cost/return to capital—are subtracted from total revenue derived from these assets in a given period.

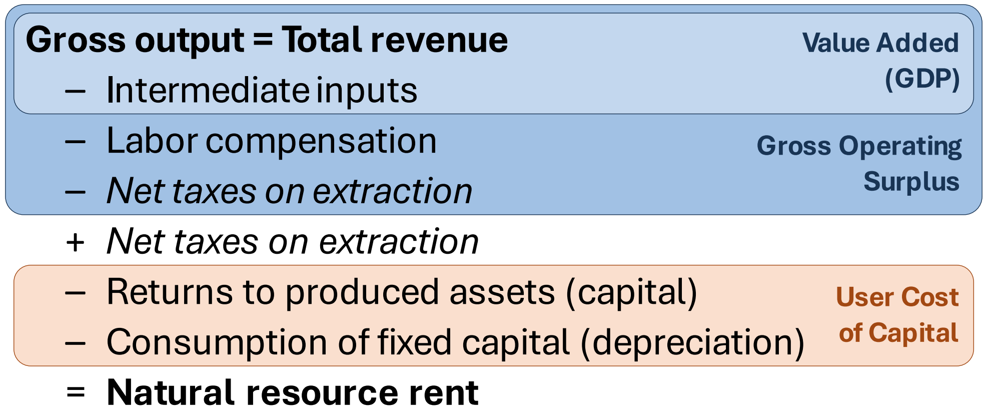

Figure 4.1 *General method for estimating resource rents from aggregated industry-level data (adapted from SEEA-CF 5.120).*

We consider two resource rent estimation methods for this pilot: a *top-down* method, based on highly aggregated national accounts data, and a *bottom-up* method, based on relatively disaggregated unit-level data.

i. Top-down Method

The top-down method uses aggregated data for the industry that extracts a given resource. A simple calculation of this method is illustrated in figure 4.2. The idea is to begin with business revenue and subtract the costs of intermediate inputs, labor, and capital. The residual or profit left over is an estimate of the natural resource rent that should accrue to the economic owner(s) of the resource.

By using aggregated, industry-level data, this method is able to leverage existing national accounts data. This data has already been vetted and will be regularly produced for existing purposes in the NIPAs. However, because it was compiled for another purpose, the level of industry aggregation in the existing accounts is also a limiting factor. For example, in the NIPAs, oil and gas are combined into a single industry, so the top-down method can only estimate the resource rents for oil and gas as a single composite asset, not separately.[8]

The national economic accounts include data series by industry for gross output, intermediate inputs, labor compensation, and production taxes/subsidies. Estimating the user cost of capital is the central problem in using the top-down method to estimate resource rent. The national accounts do include series for fixed capital stock and consumption of fixed capital by industry, and a naïve approach to estimating the user cost of capital might be to choose a “reasonable” rate of return to capital r, then let user cost of capital = $rK + CFC$, where K is the stock of fixed capital and CFC is consumption of fixed capital, taken directly from the national accounts. However, one downside of this approach is that it creates a practical and conceptual issue, primarily that it tends to produce

[8] This may be acceptable in the case of oil and gas, since they are commonly extracted together from the same deposit, but is more problematic in the context of non-energy subsoil assets: iron, copper, gold, nickel, etc. For example, metal mining in the NIPAs is split into only two industries: copper/nickel/lead/zinc mining and iron/gold/silver/other metal mining. The top-down method may not be useable in these contexts.

negative estimated resource rent for oil and gas in many years, which is inconsistent or does not align with other observable data sources. For example, the oil and gas industry's corporate profits do not follow this pattern of persistent negative years. Section 3.C discusses refinements to the top-down method that appear to reduce or eliminate these inconsistencies.

ii. Bottom-up Method

The bottom-up method, recommended by the World Bank in their technical guidance on estimating natural resource wealth (The World Bank, 2021), uses relatively disaggregated unit-of-production-level data,[9] such as prices and per-unit extraction cost data. The first step is to estimate unit-level resource rent; this estimate is then multiplied by the quantity extracted. The formulas for both steps

$$\pi_t = (p_t - c_t)$$
$$RR_t = \pi_t q_t$$

are given here:

where π_t is the unit rent, p_t is the price, c_t is the unit cost of capital, including a "normal" rate of return to fixed capital and depreciation or consumption of fixed capital, and RR_t is the total resource rent in period t.

This method is typically applied in cases where national accounts data are too aggregated to be useful, but unit-level data may also be difficult to obtain. We considered using this method to estimate resource rent separately for oil and for natural gas, but given the heterogeneity in the cost data for extraction of oil and gas in the U.S., limited available data to calculate the per-unit user cost of capital was the main barrier for using this method. However, we highlight this method as it may be needed in the future for valuing other mineral resources.

iii. U.S. Methodology for Pilot Estimates

Our initial attempts at estimating U.S. oil and gas resource rent using the top-down method had produced puzzling estimates, which stem from an issue that other countries face when compiling this account. Namely, our initial estimates of resource rent were implausibly low, with several years in our reference period (1998–2023) having negative values. This occurred because we followed conventions in the literature that assume that the user cost of capital was equal to $rK_t + CFC_t$, where r was a constant rate of return, K_t the stock of fixed assets[10] in year t, and CFC_t the consumption of fixed capital[11] in year t. An acyclical return on capital, while convenient computationally, does not conform with either economic data or intuition, pulling resource rents below zero for many years in our sample. This difficulty is not unique to the U.S. context. For example, Canada's national

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[9] Barrels of oil or (billions of) cubic feet of natural gas.

[10] *Net Stock of Private Nonresidential Fixed Assets* (current cost) (BEA, 2024).

[11] *Components of Value Added* (BEA, 2024).

statistical agency also estimates negative resource rent values for subsoil assets; they address the issue by setting estimated resource rent to zero instead for these years (Statistics Canada, 2006).

Instead, for the estimates given in this pilot account, we use the top-down method with two refinements to the estimation of user cost of capital. First, we make the rate of return to capital responsive to changing market conditions by setting it equal to the rate of return on corporate AAA-rated bonds. At an aggregate level, this is a sensible cost of capital that varies over the business cycle. Second, since businesses can reduce their reported taxable income by the depreciation of their capital stock, assuming the industry bears the full cost of depreciation without considering its tax consequences is not a realistic assumption. We therefore assume that the amount they save via these tax deductions ($\tau_t CFC_t$, where τ_t is the statutory federal corporate tax rate in year t) is not considered part of the cost of capital.

Other data series (gross operating surplus and net taxes on extraction[12]) are taken directly from the *Components of Value Added* section of the BEA industry accounts (BEA, 2024). Figure 4.2 illustrates this pilot account's specific application of the top-down method for estimating resource rent (compare with the general method shown in figure 3.2).

C. Forecasting Future Resource Rent

Gross operating surplus

\+ Net taxes on extraction

− r_t^{AAA} × stock of fixed capital

− $(1-\tau_t)$ × consumption of fixed capital

User Cost of Capital

= **Natural resource rent**

Figure 4.2 *The top-down method as used in this pilot account. The rate of return to capital (r) is held equal to the corporate AAA-rated bond rate of return, while τ is equal to the statutory federal corporate tax rate.*

Since we are trying to estimate the current market value based on the expected net present value of future resource rents, the next step is to forecast the stream of future resource rent based on past resource rents and other indicators that covary with rents. This includes future prices, extraction quantities, and the lifetime of the asset in question.

We model the dependence of future rent on prices and quantities using EIA forecasts of oil and gas prices and extraction quantities through 2050. Resource rent is modeled as a function of these prices and quantities:

$$RR_t = \alpha + \beta_{op} p_t^{oil} + \beta_{oq} q_t^{oil} + \beta_{or} p_t^{oil} q_t^{oil} + \beta_{gp} p_t^{gas} + \beta_{gq} q_t^{gas} + \beta_{gr} p_t^{gas} q_t^{gas} + \varepsilon_t$$

[12] Note from figure 3.2 that other combinations of data series would be equivalent: for instance, value added minus labor compensation is equivalent to gross operating surplus plus net taxes on extraction/production.

and model parameters are estimated over the historic period using OLS regression. The calibrated model is then used to forecast resource rent based on EIA predictions of oil and gas price, quantity, and revenue (price × quantity).

The estimated life of oil and gas subsoil assets is heavily dependent on the assumptions we make about the future discovery of new assets. The most conservative assumption, found in SEEA-CF 5.212–5.213, is to divide the current *proved* stock of the asset by the current extraction rate. In our data, this yields an expected lifespan of ~13 years. However, this is only a subset of commercially recoverable reserves, so this should be taken as a lower bound of expected oil and gas resources. At the other extreme, we could assume that discovery will always be enough to equal extraction; while this is theoretically impossible on long enough time scales (i.e., oil and gas resources are clearly finite, though large), it does however reflect the relationship between extraction and discovery over the past several decades, as seen in figure 3.4. This is an upper bound for illustrative purposes only, as we should be clear about the caveat that this assumption falls outside the scope of SNA and SEEA standards. In section 5, we present estimates of the value of subsoil oil and gas under these lower-bound and upper-bound assumptions, together with estimates under more reasonable assumed asset lives of 25 years (corresponding to the limit of EIA's projections) and 75 years. Although a conservative implementation of SEEA would feature only estimates based on a 13-year asset life (proved reserves divided by current extraction rates), we believe that providing the estimates for longer asset lives provides needed context, based on the practical experience of the last few decades (see figure 3.4) and that the asset stock should include commercially recoverable resources beyond proved reserves in class A.

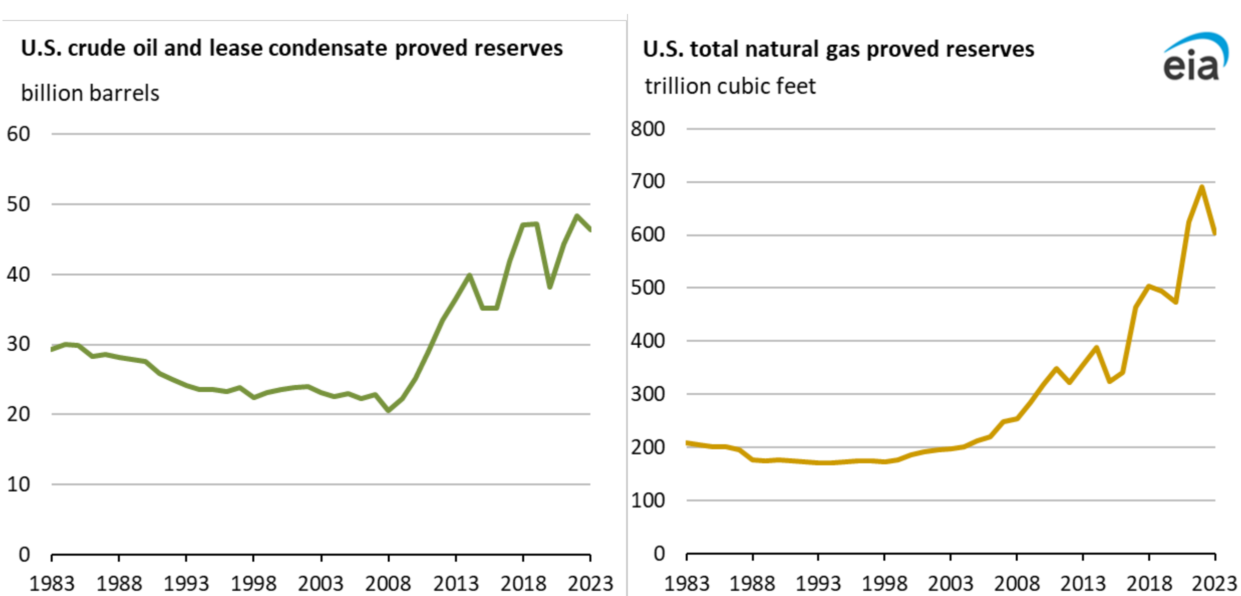

Figure 3.4 *U.S. proved reserves of oil and gas show a pronounced upward trend despite increasing rates of extraction. (Source, U.S.* Crude Oil and Natural Gas Proved Reserves, Year-end 2023, *EIA 2025)*

5. Data Sources

As described in the previous section, we forecast future subsoil oil and gas resource rent using EIA projections of price and quantity as predictors. The parameters for the forecasting model are determined from historical data covering 1998–2023 using OLS regression, with historical (EIA) price and quantity as the independent variables. Rent is estimated in the historical period using economic data from BEA and Moody's.

A. EIA Historical Data

Data for crude oil and natural gas production, wellhead prices, and reserves are from the U.S. Energy Information Administration (EIA). Historical data, forecasts, and projections are available for production in a continuous time series from 1998-2050. The historical data series used are:

- Historical crude oil production (1998–2022) from *2022 Petroleum Supply Annual*, Crude Oil Production table.
- Historical dry natural gas production (1998–2022) from *2022 Natural Gas Annual*, Table 2: Natural Gas Production, Transmission, and Consumption by State.

EIA does not have a consistent historical data series for wellhead prices for crude oil or natural gas for the years included in this analysis, so this analysis relies on unpublished estimated wellhead prices used in EIA's National Energy Modeling System (NEMS) for 2000-2022.

B. EIA Forecasts/Projections

EIA forecast and projected data on production and prices is drawn from two sources, the *February 2024 Short-Term Energy Outlook* (STEO) and the *2023 Annual Energy Outlook* (AEO). The STEO provided forecast estimates for 2023-2025. The AEO provided projection estimates for 2026-2050. EIA does not produce forecasts or projections for crude oil proved reserves or dry natural gas reserves.

STEO forecasts are based on EIA's Short-Term Integrated Forecasting System, which is based on a set of econometrically estimated equations in a balanced system and historical values to forecast future values including crude oil and natural gas production. We use:

- Forecast crude oil production data (2023–2025) from STEO Table 4a, U.S. Petroleum and Other Liquids Supply, Consumption, and Inventories.
- Forecast natural gas production (2023–2025) from STEO Table 5a, U.S. Natural Gas Supply, Consumption, and Inventories.

AEO projections are based on EIA's National Energy Modeling System (NEMS), which covers production, imports, exports, conversion, consumption, and prices in U.S. energy markets. NEMS is a broad system that considers macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, technology characteristics, and demographics relationships and produces a general equilibrium solution for energy supply and demand conditions in U.S. energy markets on an annual basis. We use the following AEO series for 2026–2050:

- Projected crude oil production from AEO Table 11, Petroleum and Other Liquids Supply and Disposition.
- Projected crude oil wellhead prices from AEO Table 58, Lower 48 Crude Oil Production and Wellhead Prices by Supply Region.
- Projected dry natural gas production from AEO Table 14, Oil and Gas Supply.
- Projected natural gas wellhead prices from AEO Table 59, Lower 48 Natural Gas Production and Supply Prices by Supply Region .

Data for projection years 2026-2030 were smoothed using updated historical data and forecast data through 2025. This was necessary due to deviations from early year AEO projections due to large shifts in crude oil and natural gas production and spot prices following the Russian invasion of Ukraine.

C. BEA and Moody's Economic Data

Economic data from BEA and Moody's are used to estimate returns to capital and resource rent for the oil and gas industry. BEA's Industry Accounts include data for the (combined) oil and gas industry on output, labor compensation, gross operating surplus, taxes on extraction/production, and consumption of fixed capital. BEA's Fixed Asset Accounts provide data on the capital stock held by the oil and gas industry. Four BEA data series are used:

- Gross operating surplus for the oil and gas extraction industry from *Components of Value Added* (table UVCT40-A, line 7).
- Net taxes on production for the oil and gas industry from *Components of Value Added* (table UVCT3-A, line 7).
- Consumption of fixed capital for the oil and gas industry from *Components of Value Added* (table UVCT42-A, line 7).
- Fixed capital stock for the oil and gas industry from *Current-Cost Net Stock of Private Equipment by Industry* (table 3.1ESI, line 6).

Moody's *Seasoned AAA Corporate Bond Yield* (DAAA) series (accessed via FRED, Federal Reserve Bank of St. Louis) provides the bond return rates used as proxies for returns to capital.

D. Future Data Needs

A nice feature of this pilot account for oil and gas is that most of the data used are already produced annually for other purposes and are expected to continue being produced annually for this reason. This avoids a major roadblock in the way of other pilot accounts' transition to production-grade statistical accounts, which may require separate new data collections.

***Figure 6.1** Estimated resource rent for the oil and gas industry, 1998–2023. Oil and gas prices as well as corporate profits for oil and coal companies are shown for context.*

The exception that could make annual production of this account difficult is EIA's projections of future production and prices. While these projections have been updated multiple times, they are not updated annually (or regularly). Unless the frequency and regularity of these updates are increased, alternate data (perhaps purchased from private companies) or alternate methodologies for estimating future resource rent in the oil and gas industry would need to be identified in order to compile this asset account annually. Another exception would be that the physical data for oil and gas reserves is not produced on the same schedule as the economic data. Finally, while EIA reports proved reserves, official estimates of probable reserves to cover the remaining class A 'commercially recoverable resources' would better align this account with SNA and SEEA standards and facilitate international comparability.

6. Results

Our results first show the initial estimates of historical resource rent for the oil and gas industry. As shown in figure 4.3, we estimate this rent by adding the oil and gas industry's gross operating surplus (GOS) and net taxes on production (T), then subtracting estimated returns to capital, estimated as the product of the rate of return on AAA bonds times the industry's capital stock ($r^{AAA} \times K$) plus the industry's consumption of fixed capital (CFC) times 1 minus the federal corporate tax rate (τ). Results for our historical time window (1998–2023) are shown in figure 6.1. For illustration purposes, we also chart oil and gas prices and corporate profits over the same time series to show how the time-series patterns are correlated over this sample period. There are relatively few years where resource rents are negative, but when they are negative, we see similar declines in prices and profits to explain these drops.

Next, the resource rent is projected into the future. Through 2050, this is done using a basic OLS regression approach, with projected oil and gas prices, production, and revenue as predictors. Since

Monetary Subsoil Oil and Gas Account

(trillions of $2017)

2024	Proved	25-year
Opening stock		
Additions		
Reductions		
Revaluations		
Closing stock	**1.00**	**2.36**

Figure 6.3 *Pilot estimates for the monetary subsoil oil and gas account. Blank cells are not estimated at this time, and the table is abbreviated (compared to figures 2.1 and 3.1) because only the 2024 closing stock/2025 opening stock values are estimated. Data are combined for oil and gas, unlike in the physical asset account table, due to data constraints.*

EIA's projections end in 2050, an MA(5) model is used to extrapolate the resource rent path from 2050–2100. Finally, for our extreme upper bound estimates we assume resource rent continues to grow at 1.06% from 2100–infinity. These results are shown in figure 6.2, along with the discounted present value of the resource rent stream given these different asset life thresholds.

We estimate oil and gas asset values under four different assumptions about the life of U.S. subsoil oil and gas assets: 13 years (current proved reserves divided by the current extraction rate; lower bound; closest to the SNA 2025 guidelines), 25 years (the period for which EIA projects production and prices), 75 years, and infinite (extreme upper bound). In 2017 dollars, we estimate a value of ~$1 trillion for the current proved reserves; this gives a firm lower bound on the total asset value. The extreme upper bound is ~$15.7 trillion, with values of ~$2.3 trillion for a 25-year asset life or ~$7 trillion for a 75-year asset life.

We consider the 25-year asset life to be the most realistic of these asset life assumptions given current knowledge of reserves and other estimates of commercially recoverable resources. Figure 6.3 presents the estimates for 13-year asset life and 25-year asset life in the standard monetary

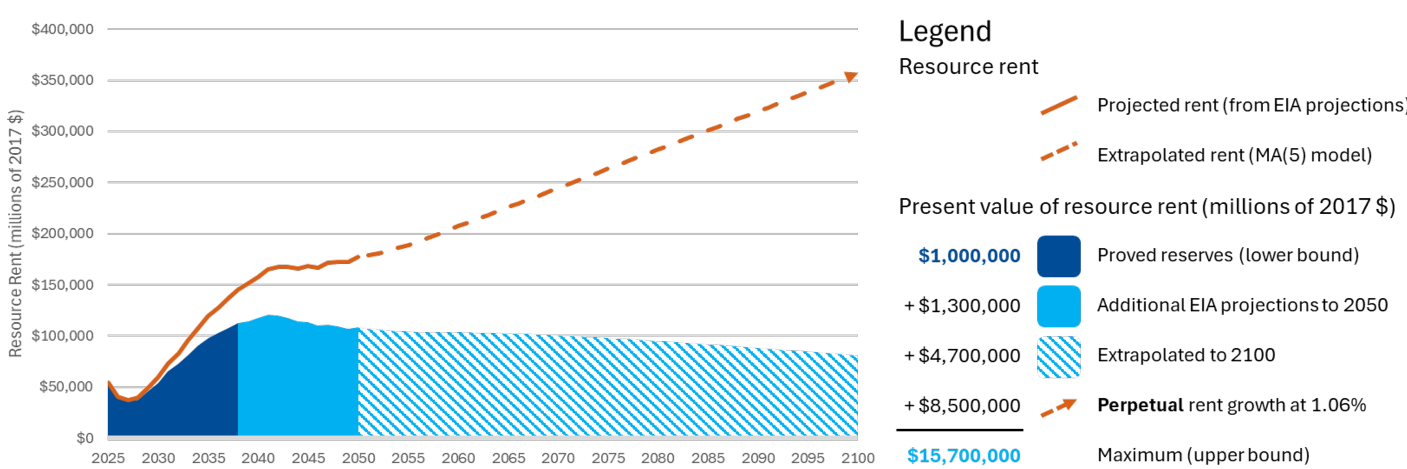

Figure 6.2 *Projected/extrapolated future resource rent for the oil and gas industry, and its discounted present value. Four asset life thresholds are shown: 13 years (based on proved reserves and current extraction rates), 25 years, 75 years, and infinity.*

subsoil energy asset account framework, corresponding to the sample physical asset account table shown in figure 3.1.[13]

7. 2025 SNA and Measures of Depletion

The 2025 SNA emphasizes net measures of economic activity (such as Net Domestic Product (NDP) or Net Domestic Income (NDI)). Specifically, the SNA now encourages national statistical offices to, "give greater focus to the compilation of net measures . . . alongside the traditional gross measures . . . to complement them" (2025 SNA, paragraph 1.40). Net measures are not new; traditionally, they subtract depreciation (also called "consumption of fixed capital") from their gross-measure counterparts to account for the fact that physical capital has diminished in value from wear and tear in the process of production and income generation. The remaining net value is a useful measure of economic activity that the SNA considers "conceptually superior" to the gross value (SNA 2025, paragraph 1.42).

Importantly, the 2025 SNA expands the "net" concept to incorporate depletion of natural resources as well as depreciation of capital. As early as Adam Smith (1776), production inputs have been known to include natural resources along with labor and capital. If stocks of natural resources diminish in production, a "net" measure of production or income should reflect these costs of production, as well as the costs associated with depreciation of capital. Incorporating depletion of natural resources into value-added measures provides a more complete and consistent accounting for production costs.

For non-renewable resources, the 2025 SNA defines depletion as being "equal to the quantity of the resource that is extracted" (2025 SNA, paragraph 7.287). New discoveries are accounted for as "other changes in the volume of assets" on the balance sheet rather than being netted out of depletion, since they do not represent regeneration of the resource[14]. This mirrors the treatment of produced capital, where depletion is distinct from new capital formation. In monetary terms, depletion is "equal to the change in the [monetary] value of the natural resource that is *due to physical depletion*" (2025 SNA, paragraph 7.294, emphasis added). To estimate this, we propose two methods using data from the physical and monetary subsoil energy asset accounts.

A simpler approach would be to use a straight-line depletion estimate, which assumes a constant rate of extraction in proportion to the remaining asset stock for the life of the asset, a simplification

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[13] Data from Rystaad indicates that commercially recoverable resources beyond proved reserves (i.e., probable reserves) in the U.S. are substantial. In untabulated results, we evaluated a number of approaches that justify an asset life of class A resources to be ~25 years.

[14] If, in a given period, we extract two barrels of oil from the ground and discover three, physical depletion for that period would still be two barrels.

that should be revisited in future work. Using this method, we estimate depletion of U.S. subsoil energy resources (oil and gas combined) at about $92 billion

The SNA-recommended approach begins with the monetary value and physical stock of the asset at the beginning and end of the year. From these, implicit beginning- and end-of-period per-unit prices can be calculated. The average implicit price is then multiplied by extraction for the year to get an estimate of the value of depletion (2025 SNA, paragraph 7.296). This method is not well suited to this pilot, since oil and gas are not separable in the monetary account, and are not measured with the same units in the physical account.

Another issue for future work, which may include further discussion in the upcoming SEEA Central Framework Update, is how to handle other changes to physical quantities of subsoil assets. The SNA and SEEA Central Framework are clear that depletion is rooted in production/extraction activities, and that discoveries and extensions are treated separately. U.S. data show that "revisions and other changes" and "acquisitions and divestitures" account for significant changes in the stock of oil and gas reserves in the U.S. In some cases, production or acquisition can present new opportunities for drilling that increase the quantity available for extraction. The methodological question this raises is whether, conceptually, this is closer to "reversing depletion" or to "new discovery." Because this issue lies at the intersection of both the SNA and SEEA-CF, it would be useful for the SEEA-CF Update to consider this among other issues in *A9 - Consistency with the 2025 SNA revision issues*.

The key point of this section is not a particular estimate of depletion; rather, it is that depletion is an important calculation for modern national economic accounts and that calculating it requires high quality, detailed estimates of physical and monetary asset accounts such as those under development in this paper. This paper focuses on oil and gas as a proof-of-concept exercise and it is clear that high quality estimates of the stocks of these resources (in both physical and monetary terms) are important for the national balance sheet as well as for measuring depletion, NDP, and NDI. By extension, measuring other subsoil assets in this way would allow a more complete picture of the U.S. balance sheet and the costs of production.

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