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A Demanding Change: Oil & Gas in 2050

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Image courtesy: "Offshore Drilling for Oil at Sunset" by Dennis Thompson

Summary:

- **A consensus has emerged among the largest and most prominent industry forecasters that 2050 oil and gas demand will fall below current levels -- for the first time in the history of the segment -- despite an expected doubling of global GDP over the period.**

- **Since the pandemic low, oil and gas E&P stocks have soared, with current price-implied-expectations at historical extremes – starkly at odds with the energy transition consensus.**

- **This report highlights a useful metric for evaluating the emissions potential of proved undeveloped reserves, the reserves most sensitive to rapidly rising project IRRs due to "green decoupling". This metric can aid investors in framing the current risks to E&Ps, against a volatile backdrop of tremendous future demand uncertainty.**

Executive Summary

The year 2021 proved a landmark in the history of the oil and gas industry. Obscured by both the pandemic and an understandable fixation on the expected upward trajectory of oil and gas demand in the current decade, a consensus emerged among the largest and most prominent industry forecasters that 2050 demand will fall below current levels. This despite an expected doubling of global GDP to 2050, severing the virtual lockstep growth in hydrocarbon demand and economic growth witnessed over the last century.

A key feature of investor appeal for oil and gas, despite frequent bouts of uneconomic returns, has always been rock solid demand growth, an oligopolistic market structure, and sufficient sustained advantage to return capital to shareholders in the form of high dividends and buybacks. With the potential removal of one leg of this stool, perhaps two, the industry is at the dawn of a new era of uncertainty and volatility. While there are certainly valid non-consensus forecasts, as is always the case in markets, when the bulk of analysis forecasts a strong energy transition over the next 25 years, investors should take note.

Taking the average analyst estimates across the six providers below yields a forecast of 95 mb/d, 64 mb/d and 40 mb/d (million barrels per day) for the high, middle and low demand scenarios respectively. With 2021 demand estimated at 96.4 mb/d, it's striking that the consensus among the three best known independent forecasters, an equal number of integrated oil companies, as well as Bloomberg and IHS Markit, shows average demand in 2050 below current demand for the first time.

Exec Summary Figure 1
IEA, WoodMac, Rystad, British Petroleum, Lukoil & Shell Oil & Liquids Demand 2050 Scenario Analysis

Forecast	2050 High C	2050 Mid C	2050 Low C	Measure	Oil/Liquids
IEA	104	77	24	mb/d	Oil
WoodMac	110	35	30	mb/d	Oil
Rystad	76	51	38	mb/d	Oil
BP	95	55	30	mb/d	Liquids
Lukoil	99	74	45	mb/d	Liquids
Shell	86	94	72	mb/d	Oil

Range	*110-76*	*94-35*	*72-24*
Mean	*95*	*64*	*40*
Mean ex outlier	*98*	*64*	*36*
Bloomberg	*96*		
IHS Markit	*86*		

Source: WKA Analysis

The prospect of significant energy transition challenges over the next three decades has not cooled a blazing hot runup for oil and gas securities today. Exploration and production companies, given that their valuation is almost solely based on reserves, without midstream and downstream operations, highlight this point well. Since the pandemic low the SPDR S&P Oil & Gas Exploration & Production ETF (NYSE: XOP), with holdings of 61 U.S. E&P companies has gained 267% as Brent has climbed 175%, and the overall S&P has gained 101%. The reasons for this extraordinary runup, against the backdrop of a potential fundamental shift in the long-term dynamics of the industry, are numerous, including: a significant drawdown in oil inventories after a hard pandemic stop, historically low global spare capacity threatening to be overwhelmed by 2022 demand, and a sustained period of underinvestment leading to supply mismatches as demand conditions have shifted.

However, with any appreciable price gain comes a commensurate rise in implied performance expectations. Historically, the E&P industry has struggled to generate returns on capital above the cost of capital for extended periods of time, as exemplified by its performance over the last decade

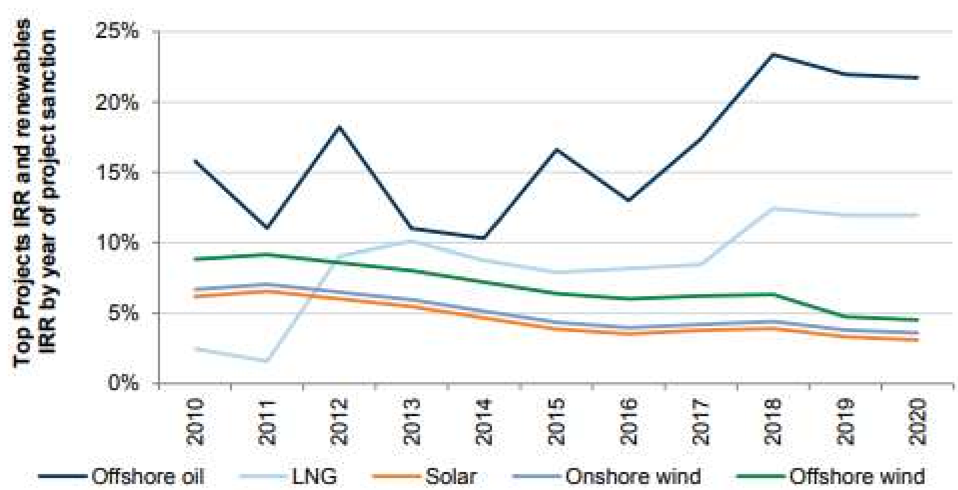
Exec Summary Figure 2
(ARCX: XOP) E&P Company Price Implied Expectations Analysis (2/20/2022)

Ticker	Name	Value (000,000)	ROIC	ROCE	WACC	ROCE Spread	ROIC Spread	FCF Yield	GAP	Implied Rev CAGR	3 Yr Rev CAGR (A)	5 Yr Rev CAGR (A)	Avg. Implied ROIC spread	3 Yr ROIC Spread (A)	5 Yr ROIC Spread (A)
CPE	Callon Petroleum	$ 2,901	11.1%	11.3%	8.2%	3.2%	3.0%	22.6%	1 <	_	32.6%	50.6%	_	0.0%	-1.6%
LPI	Laredo Petroleum Inc	$ 1,175	7.7%	29.2%	8.0%	21.2%	-0.3%	3.6%	1 <	_	-21.7%	3.2%	_	-1.7%	-2.4%
TALO	Talos Energy Inc.	$ 996	7.2%	18.0%	7.0%	11.0%	0.2%	27.3%	50 >	3.7%	-18.8%	_	5.7%	-0.4%	-0.4%
CDEV	Centennial Resource	$ 2,179	5.0%	7.0%	6.1%	0.9%	-1.0%	12.9%	50 >	3.9%	-2.0%	55.7%	-0.1%	-2.0%	-1.7%
MRO	Marathon Oil Corp	$ 15,982	4.6%	12.6%	6.3%	6.3%	-1.7%	11.0%	50 >	3.0%	5.2%	6.4%	3.4%	-4.2%	-4.8%
MTDR	Matador Resources Co	$ 5,244	10.1%	19.3%	8.7%	10.6%	1.4%	6.2%	50 >	3.7%	-3.6%	26.5%	34.4%	-0.3%	-1.7%
EOG	EOG Resources, Inc.	$ 65,308	8.4%	19.4%	6.3%	13.1%	2.1%	4.5%	52	3.9%	-19.5%	10.4%	9.7%	0.3%	-0.9%
CTRA	Coterra Energy Inc.	$ 18,379	7.0%	13.2%	5.0%	8.2%	2.0%	1.6%	1 <	_	-18.1%	6.1%	_	4.1%	2.8%
FANG	Diamondback Energy Inc.	$ 23,819	9.6%	13.4%	7.0%	6.4%	2.6%	-3.1%	67	4.1%	13.7%	52.0%	7.1%	-0.4%	-0.3%
CLR	Continental Resources	$ 19,224	12.4%	19.7%	6.4%	13.3%	6.0%	-4.8%	92	3.2%	11.1%	16.4%	27.3%	-0.9%	-1.6%
SWN	Southwestern Energy	$ 4,730	9.4%	16.7%	4.4%	12.3%	5.0%	-13.2%	1 <	_	-22.7%	-1.3%	_	0.6%	0.4%
OVV	Ovintiv Inc.	$ 10,574	0.6%	16.4%	7.5%	8.9%	-6.9%	13.9%	50 >	3.2%	1.2%	19.8%	8.7%	-3.3%	-4.2%
MUR	Murphy Oil Corp	$ 5,062	0.4%	9.1%	7.2%	1.9%	-6.8%	12.3%	50 >	3.2%	-12.4%	1.9%	0.4%	-4.1%	-4.6%
AR	Antero Resources Corp	$ 6,823	1.7%	11.7%	7.7%	4.1%	-6.0%	8.7%	50 >	3.3%	2.4%	6.0%	4.9%	-3.6%	-2.7%
XOM	Exxon Mobil Corp	$327,509	-0.1%	15.3%	5.7%	9.6%	-5.8%	8.5%	50 >	3.3%	-19.8%	-4.8%	-0.4%	-2.9%	-2.5%
OXY	Occidental Petroleum	$ 36,948	2.4%	7.6%	6.5%	1.1%	-4.1%	8.1%	50 >	3.2%	0.0%	15.3%	5.0%	-3.4%	-4.0%
HES	Hess Corporation	$ 29,074	3.3%	14.0%	6.9%	7.1%	-3.5%	7.5%	50 >	3.4%	-14.1%	-0.5%	3.7%	-4.5%	-6.0%
APA	Apache Corporation	$ 11,683	2.8%	22.7%	8.0%	14.7%	-5.3%	6.8%	50 >	3.4%	-22.1%	-4.2%	0.2%	-4.2%	-5.0%
RRC	Range Resources Corp	$ 5,308	-0.9%	17.4%	5.2%	12.2%	-6.1%	5.3%	50 >	3.4%	-22.6%	15.7%	3.5%	-3.4%	-3.4%
CNX	CNX Resources Corp	$ 3,209	-3.9%	8.9%	3.8%	5.1%	-7.7%	2.7%	1 <	_	24.3%	17.6%	_	-3.0%	-2.3%
CVX	Chevron Corporation	$257,192	4.3%	14.2%	6.1%	8.1%	-1.8%	-0.2%	50 >	3.3%	-22.9%	-3.8%	6.6%	-4.5%	-4.0%
KOS	Kosmos Energy Ltd	$ 1,934	2.8%	7.7%	9.8%	-2.1%	-7.1%	-2.5%	50 >	3.6%	-4.8%	26.9%	11.5%	-4.2%	-6.3%
COP	ConocoPhillips	$118,217	4.6%	21.9%	5.9%	16.1%	-1.3%	-6.7%	50 >	3.9%	-28.2%	-5.6%	12.3%	-2.7%	-3.2%
NOG	Northern Oil & Gas, Inc.	$ 1,585	-4.5%	30.2%	6.4%	23.8%	-10.9%	-7.7%	1 <	_	-9.8%	39.7%	_	0.4%	-0.6%
EQT	EQT Corporation	$ 8,393	-3.4%	6.6%	3.9%	2.6%	-7.3%	-13.5%	50 >	3.1%	-16.7%	-2.4%	0.4%	-4.6%	-3.2%
DVN	Devon Energy Corp	$ 36,385	4.8%	26.2%	6.7%	19.5%	-1.9%	-15.3%	50 >	3.2%	40.1%	-3.3%	7.2%	-4.9%	-5.2%
PXD	Pioneer Natural Resources	$ 56,976	10.4%	20.7%	5.9%	14.9%	4.5%	-20.2%	50 >	4.0%	-13.5%	15.5%	40.4%	-1.1%	-2.2%
TELL	Tellurian Inc	$ 1,164	-14.7%	-14.1%	8.1%	-22.2%	-22.8%	-21.2%	50 >	6.6%	90.8%	_	5.7%	-31.7%	-34.8%
PDCE	PDC Energy	$ 5,408	1.5%	24.8%	7.8%	17.0%	-6.3%	8.9%	50 >	3.6%	-7.0%	36.8%	21.2%	-2.9%	-5.1%
SM	SM Energy Company	$ 4,160	-4.5%	8.4%	8.4%	0.0%	-12.9%	6.7%	50 >	6.9%	-17.1%	-1.2%	23.8%	-5.5%	-6.6%

Source: New Constructs, FactSet, WKA Analysis

As can be seen from the Figure above, current market prices for the constituents of the XOP are impounding many years of returns above the cost of capital (see column "GAP"). In fact, 80% of the index is implying greater than 50 years of value creating returns (ROIC above WACC)! These frothy valuations are not only at odds with individual company return history (as seen in the rightmost column labeled "5 Year ROIC spread Actual") as well as aggregate historical industry returns, but the current valuations also defy the consensus that an energy transition could ultimately bring oil and gas demand below current levels by 2050. While public market equity investors may be proceeding in a business-as-usual fashion, E&P companies are experiencing clear financing stress related to the energy transition. Goldman Sachs estimates that the spread in the cost of capital of hydrocarbon versus renewable developments has widened by greater than ten percentage points over the last five years (Figure below).

Exec Summary Figure 3
Project IRR for oil and gas and renewable projects by year of project sanction



Source: Goldman Sachs

When project IRRs, required returns on long duration, high-cost projects, increase significantly due to uncertainty around demand and the regulatory environment, fewer projects get funded, exploration budgets get cut and write-offs increase. This is validated by the expected 40% decline in the reinvestment ratio for all Oil & Gas in 2022 (based on current trends versus a 10-year average) and highlights an industry beset with poor regulatory clarity and lack of global coordination, in contrast with the electric utility industry, which has seen positive reinvestment ratios due to price support and more clear regulation. A truism in the industry is that high oil prices are the best cure for high oil prices, as additional capacity ramps and the pendulum swings to oversupply. Over the last decade however, the number of climate-related shareholder resolutions has almost doubled and the percentage of investors voting in favor has almost tripled, to roughly 40%, with a targeted focus on energy producers rather than on final energy consumption. The prospect of continued shareholder pressure and sustained high financing costs may significantly delay what was in years past an almost certain setup for a price crash (now exacerbated by renewed energy security concerns due to Russia's invasion of Ukraine). This volatile backdrop shows no sign of abating, as few doubt the fact that a meaningful energy transition is on the horizon. This issue is particularly challenging for E&P companies, as undeveloped properties are major drivers of firm value. On a NAV basis, E&P companies typically trade well above the discounted value of their proved developed reserves, with the balance of the market value representing implied optionality on proved undeveloped properties (PUD), and possibly more distant P2, P3. Since PUDs require future capital investments, they're keenly sensitive to economic conditions. The National Bureau of Economic Research (NBER) examined the relationship between firm value and proved reserves for 600 oil and gas firms in North America from 1999-2018 and found that proved undeveloped reserves growth and firm value were significantly negatively correlated.

WK Associates built a model portfolio to test the carbon risk sensitivity embedded in proved undeveloped reserves. For the 30 E&P firms in this report, undeveloped proved reserves averaged 40% of total reserves on an annual basis over the last decade. While the growth of aggregate undeveloped reserves is important to valuation, the emissions potential and financing implications of the change in reserves mix needs to be disaggregated (as highlighted by LNG's lower project IRR). The figure below shows the relationship between the change in emissions potential of undeveloped proved reserves and

Enterprise Value for the thirty E&P companies in Exec Summary Figure 2 over the last five years (we removed all firms in XOP that were not "pure play" upstream E&P companies). We plotted the change in undeveloped proved reserves over a given year, calculated the emissions potential of that change in reserves according to the hydrocarbon mix, and then performed a regression against Enterprise Value (firm value as dependent variable).

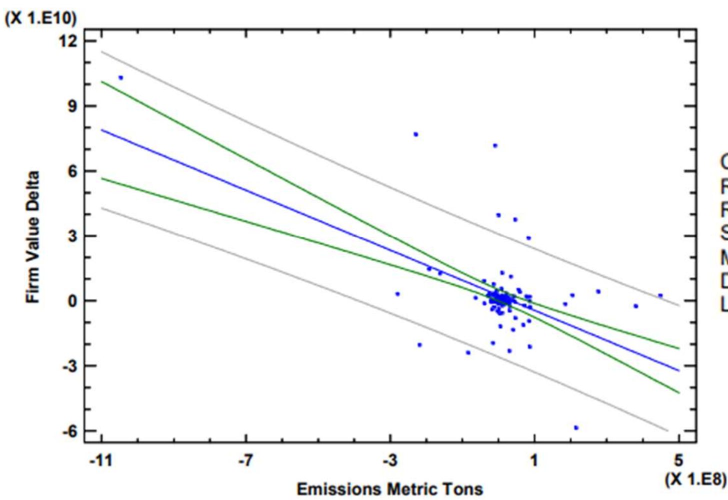
Exec Summary 4
Growth in Emissions Potential of Undeveloped Reserves & Firm Value

Coefficients

Parameter	Least Squares Estimate	Standard Error	T Statistic	P-Value
Intercept	2.47354E9	1.33408E9	1.85412	0.0663
Slope	-69.4842	10.1094	-6.8732	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	9.63326E21	1	9.63326E21	47.24	0.0000
Residual	2.30427E22	113	2.03918E20		
Total (Corr.)	3.2676E22	114			



Correlation Coefficient = -0.542965
R-squared = 29.4811 percent
R-squared (adjusted for d.f.) = 28.8571 percent
Standard Error of Est. = 1.428E10
Mean absolute error = 7.56303E9
Durbin-Watson statistic = 2.41602 (P=0.9875)
Lag 1 residual autocorrelation = -0.208819

Source: WK Analysis, FactSet, Statgraphics

As can be seen, an even greater negative correlation exists (-0.54 coefficient, versus -0.23) between CO_2 emissions and firm value. It's important to note that the growth in undeveloped proved reserves alone is impactful, but that growth does not *necessarily* give rise to a linear increase in emissions. The exact quantity of rise or fall in metric tons of CO_2 depends on the mix of proved undeveloped hydrocarbons that rise or fall (i.e., oil, natural gas and NGL).

We utilized emissions factors formulated by the Intergovernmental Panel on Climate Change for each type of hydrocarbon, a standard adopted around the world by governments and companies alike (including the U.S. Department of Energy and Exxon Mobil, outlined in Appendix II of this report). In order to understand the impact of potential emissions from PUDs on equity performance we compared an equal-weighted portfolio of E&P company returns, utilizing the 30 companies outlined in this report, from 2017-2021. In the first scenario, we simply held all 30 companies for the entire period. As can be seen in the Figure below this generated a 158% return. We then rebalanced the portfolio each year and removed the top quintile emitters (i.e., largest increase in potential emissions from undeveloped proved reserves), replacing them with the bottom quintile performers, which mostly consisted of firms that reduced emissions.

Exec Summary 5
Emissions-Based Portfolio Rebalancing

		Year 5	Year 4	Year 3	Year 2	Year 1	Return
30 Hold		**66.4%**	**5.4%**	**-16.2%**	**9.1%**	**61.0%**	
Portfolio Return	*Equal Weight*	166.37	175.41	146.99	160.34	258.21	**158%**
Rebalance Undeveloped		**66.4%**	**17.1%**	**-14.9%**	**-2.3%**	**84.0%**	
Portfolio Return	*Equal Weight*	166.37	194.80	165.70	161.97	298.03	**198%**
Rebalance Emissions		**66.4%**	**17.1%**	**-14.9%**	**-0.1%**	**85.9%**	
Portfolio Return	*Equal Weight*	166.37	194.80	165.70	165.61	307.86	**208%**

Source: WK Analysis

As can be seen, the portfolio return jumped dramatically to 208%, a move of 5000 basis points, or 32% improvement over the hold portfolio! An important observation from these data is that the growth or decline in PUDs and emissions, though highly correlated, sometimes diverged due to the relative mix of hydrocarbons. In addition to the potential portfolio implications outlined, there are individual security analysis benefits to utilizing a metric that tracks the potential emissions associated with undeveloped proved reserves, including the following:

- **Carbon Scoring** – As discussed earlier in this report, many hydrocarbon demand scenarios are now linked to emissions levels, where maximum allowable amounts are established in order to meet global warming targets. Increasingly, investment services and portfolio software providers are scoring an individual company's alignment with temperature benchmarks, sometimes referred to as "carbon scoring" where the analysis contrasts the company's stated targets against a benchmark. Calculating the emissions potential of undeveloped proved reserves would allow analysts to quantify a PUD threshold, or a level of undeveloped reserves that might affect the firm's ability to meet or exceed its stated emissions goals.

- **Precision** -- Increasingly analysts are incorporating higher discount rates as a "blunt force" margin of safety when valuing some oil and gas investments. A few investors we spoke with are utilizing an additional 200-500 basis points on top of the calculated rate for more extreme physical and transition risks. Understanding the trajectory of the emissions potential of PUDs for an individual security can allow analysts to accept their calculated rate without a blunt instrument margin of safety, but with a valuation adjustment to reflect the idiosyncratic risk of either growing or declining emissions potential for the undeveloped proved assets of the valuation target.

- **Corporate Strategy** – Clearly delineating emissions targets and the potential inherent in a firm's undeveloped proved reserves can help a company understand where it fits in a country, regional, or global strategy. Having quantifiable metrics allows companies to manage what they measure, helping to explore the way in which carbon offsets or operational emissions reductions can balance against future expected emissions. If these potential emissions can be aggregated at a market level, it will improve market efficiency with respect to the overall trajectory of emissions in coming years, as well as give context to an individual company's efforts within that overall path.

Numerous institutional investor surveys over the last year have indicated that investors understand the potential materiality of climate change in the valuation of companies. In the Robeco 2021 Global Climate Survey of the 300 largest institutional investors, with a total of $23.4 trillion in assets under management, 71% of respondents asserted that climate change was either a "significant factor" or "at the center" of investment policy (47% and 26% respectively). In addition, in the Greenwich 2021 survey of 101 investors with greater than $3B in assets, it was reported that 58% of respondents actively incorporated climate change considerations into their investment process, with approximately 75% doing so because the practice "improves risk-adjusted returns". Despite majorities in both surveys acknowledging the importance of climate risk, a significant number cited the need for more reliable data, models and disclosures to effectively evaluate the risks. The lack of perceived in-house expertise was a strong limiting factor (40% of investors in the Greenwich survey), as many investors didn't feel they had the requisite expertise to isolate the elements that impacted firm value. Of the respondents in the Greenwich survey roughly 31% utilized carbon emissions data as a factor in their internal analysis, leaving considerable room for more efficient pricing of this factor as adoption increases. As demonstrated in this report, under the right circumstances, investors can use these data to inform their analysis and generate potentially superior returns.

A Demanding Change

Introduction:

The year 2021 witnessed a rapid increase in corporate climate commitments, as well as renewed vigor in globally synchronized efforts to reduce GHG emissions[1]. Over the course of last year an august group of independent forecasters, including the IEA, WoodMac and Rystad, all issued reports on the future of oil and gas demand. With most country-level NetZero commitments centered on the year 2050[2], virtually all the named forecasters estimated *significantly* lower oil demand by that date (even under scenarios with only moderate rates of structural change in the energy industry). Against this uncertain long-long-term backdrop, oil and gas securities soared in 2021, largely indicating business as usual in public markets (and highlighting a disconnect with the distant consensus). While historical oil and gas returns have been persistently uneconomic over multi-year periods[3], the industry's insatiable demand profile has always provided a modicum of sustained advantage, along with its oligopolistic market structure. With that demand picture now blurry at best, the next thirty years pose a profound threat to what has historically been lockstep growth with global GDP over the last century[4].

This report attempts to assess the performance expectations impounded in current prices for a representative group of upstream E&P companies. It will also introduce a metric that can help investors assess the climate risk embedded in a company's reserves. The report consists of three parts: (1). Analysis of the "new" 2050 oil and gas demand consensus that has emerged over the last year, (2). A systematic

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[1] COP26, U.S.-China joint statement for the first time

[2] Energy & Climate Intelligence Unit

[3] https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-big-choices-for-oil-and-gas-in-navigating-the-energy-transition

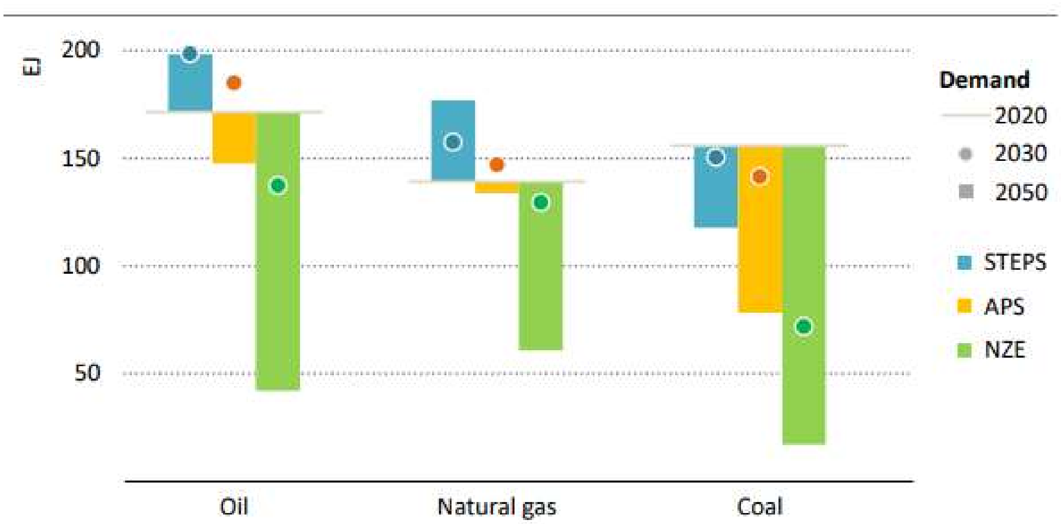
[4] There was a 92% coefficient of determination between global GDP (in current US$) and daily oil demand (mb/d) from 1965-2020, according to World Bank and BP Statistical Review data.

evaluation of current price-implied-expectations for the largest U.S. E&P companies, using a reverse discounted cash flow model, and (3). An assessment of the valuation insights that can be gleaned from calculating the emissions potential of undeveloped proved reserves for individual companies, as well as the metric's potential risk management benefits in the current environment.

Part 1: The Forecasters:

In stark contrast with the ongoing debate over the timing of peak oil demand, the current consensus on expected long-long term O&G demand (typically 2050) shifted markedly over the course of 2020-2021, settling into a remarkably uniform consensus. The International Energy Agency published its annual World Energy Outlook (WEO) in October of 2021, and for the first time in its history oil demand to 2050 was forecast to decline under all examined scenarios (see Figure 1).[5]

Figure 1
International Energy Agency "World Energy Outlook 2021"



Source: IEA, Note: One Exajoule (EJ) is around 0.5 mb/d of oil

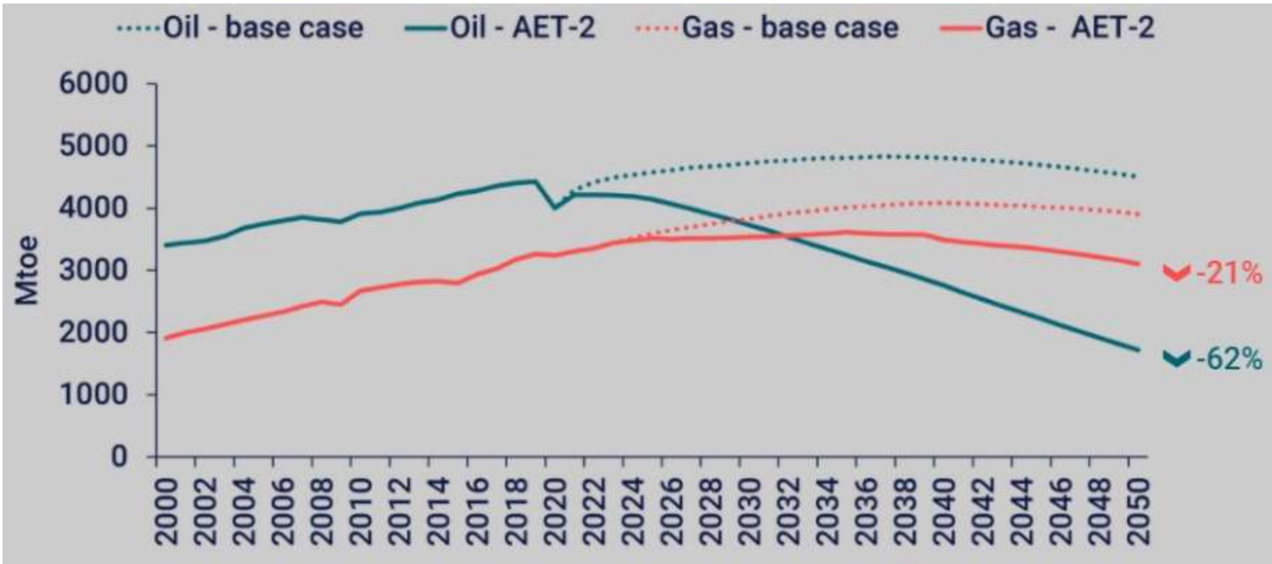
[5] It's important to note that the vast majority of the current industry debate centers on whether "peak" demand occurs by 2030 or is forestalled until after that date. Debate about 2050 demand is less strenuous given the fundamental uncertainty around the next decade's direction.

The IEA's 3 scenarios are labeled STEPS, APS and NZE. Under the Stated Policies Scenario (STEPS), a situation where global average temperatures hit 2.6 ºC above pre-industrial levels by 2100, oil demand levels off at 104 mb/d in the mid-2030s and then declines very slightly to 2050. Under the APS, or Announced Pledges Scenario, where global average temperature is held to 2.1 ºC (but not achieving net zero, so the temperature trend does not stabilize) global oil demand peaks soon after 2025 at 97 mb/d and declines to 77 mb/d in 2050. In the Net Zero Emissions path (NZE), a narrow roadmap to 1.5 ºC, oil demand falls to 72 mb/d in 2030 and to 24 mb/d by 2050. According to the IEA, under the NZE scenario, "By 2030, 60% of all passenger cars sold globally are electric, and no new ICE [Internal Combustion Engine] passenger cars are sold anywhere after 2035. Oil use as a petrochemical feedstock is the only area to see an increase in demand; in 2050, 55% of all oil consumed globally is for petrochemicals."[6]

Wood Mackenzie (WoodMac), a global energy consultancy, recently provided updates to its base case scenario for oil and gas demand (ETO) as well as its two more aggressive energy transition scenarios (AET-2 and AET-1.5). See Figure 2.

[6] https://iea.blob.core.windows.net/assets/0716bb9a-6138-4918-8023-cb24caa47794/NetZeroby2050-ARoadmapfortheGlobalEnergySector.pdf

Figure 2
WoodMac Oil & Gas Demand 2050, AET-2 Versus Base Case



Source: WoodMac

The ETO translates into a 2.5 °C to 2.7 °C pathway and represents WoodMac's assessment of the "most likely outcome", although the firm does not assign probabilities to its analysis[7]. It sees the current global economic recovery leading to energy-related CO_2 emissions rising over the next five years to a new high of 34 Bt in 2026, as well as the world's continued reliance on fossil fuels. By 2050 hydrocarbons share of the global energy mix only falls to 70%, from 80% today. Oil demand plateaus and begins a slow decline in the mid-2030s while gas demand continues to increase into the 2040s, fueled primarily by Asian economic growth. Under the ETO oil demand sits around 110 mb/d by 2050.

Given the experience of capital markets in 2021 and an "ever widening stakeholder community demanding clarity and action on decarbonization" WoodMac's team generated forecasts for both 2 °C and 1.5 °C pathways. The results of the analysis show striking variance with the base case. In its AET-2

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[7] https://www.woodmac.com/news/editorial/energy-transition-scenarios/

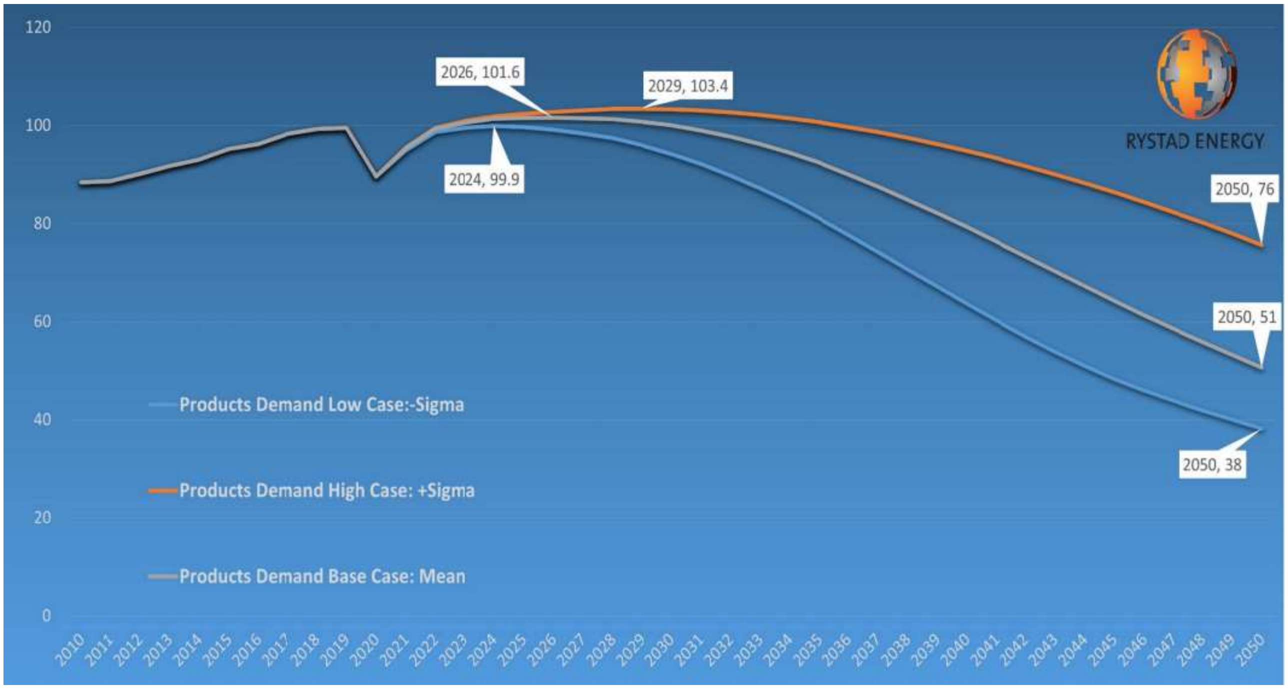
scenario, oil demand falls by 70% to 35 mb/d by 2050 as electric vehicles and hydrogen disrupt road transportation, while recycling limits the feedstock demand for plastics. AET-1.5 is even more aggressive with the demand decline starting almost immediately, ultimately falling below 30 mb/d by 2050. WoodMac warns that "No oil company is preparing for the scale of decline envisioned in any of these scenarios [AET-2 or AET-1.5]".[8] The dramatic difference between the IEA's APS and WoodMac's AET-2, with respect to 2050 oil demand, is primarily a feature of differing outcomes for petrochemical feedstock. The IEA sees a continued role for oil, while WoodMac forecasts oil's displacement by hydrogen.

Norwegian energy intelligence firm Rystad Energy presented its own forecast in 2021 with oil demand at 94 million bpd by 2030 and 38 million bpd by 2050 in its low case, and 51 million bpd in its "mean" case. Rystad expects faster growth of EVs than the IEA but disagrees that "behavioral change and biofuels will be able to remove 23 million bpd of demand by 2030."[9] However, the Rystad forecast is consonant with the IEA in that it sees lower oil demand by 2050 across all three of its scenarios (see Figure 3).

[8] https://www.woodmac.com/news/the-edge/what-different-scenarios-tell-us-about-the-future-of-oil-and-gas/

[9] "Oil Demand Set to Peak at 101.6 million bpd in 2026" April 21, 2021, Rystad, Sofia Guidi di Sante

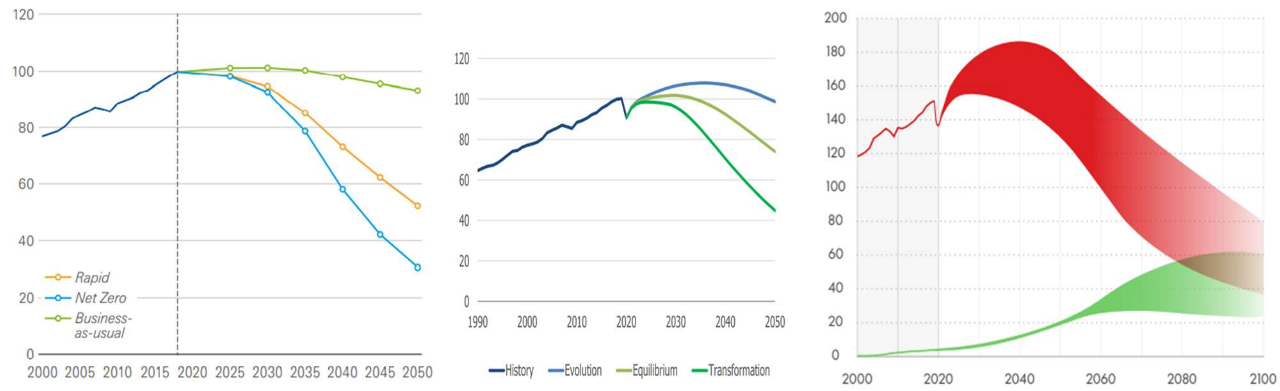
Figure 3
Rystad Energy's Long-Term Global Oil Demand Scenarios (Base, Low, High mb/d)



Source: Rystad

While many of the oil industry players themselves spend considerable effort on demand forecasting, only the largest public companies, with a global presence, tend to publish their world demand estimates. For instance, BP has been continuously publishing its "Statistical Review of World Energy" since 1952 and it has become a trusted source of data for the industry. Figure 4 shows the scenario analysis conducted by three large players: British Petroleum (NYSE: BP), Shell (NYSE: RDS.A) and Lukoil (LSE: LKOD).

Figure 4
British Petroleum, Lukoil & Shell Scenario Analysis



Source: BP, Lukoil, Shell & WKA Analysis

Each company has different names for their scenarios, as well as slightly different metrics for demand, summarized below:

- **British Petroleum** – BP has named its three scenarios Rapid, Net Zero and Business-as-Usual (BAU)[10]. Net Zero corresponds to 95% reduction in global carbon emissions by 2050, in line with limiting temperature rise to 1.5 °C. The Rapid scenario assumes more targeted sector specific measures, reducing emissions by 70%, roughly in line with a 2 °C outcome. The consumption of liquid fuels falls under both scenarios, declining to 30 mb/d by 2050 under Net Zero and less than 55 mb/d under Rapid. The BAU scenario assumes little progress is made and 2050 emissions stand at only 10% below 2018 levels. However, the consumption of liquid fuels in BAU is broadly flat at around 100 Mb/d for 20 years, before edging lower to around 95 Mb/d by 2050. It's important to note that BP aggregates liquid fuels (oil, biofuels and other) so its numbers are slightly higher than oil-only comps.

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[10] https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2020.pdf

- **Lukoil** – The second largest Russian oil producer, Lukoil, released its own demand forecasts under three scenarios called, Evolution, Equilibrium and Transformation, roughly corresponding to limiting temperature rise to 2.6 °C, 2 °C and to 1.5 °C respectively[11]. Like BP, Lukoil aggregates liquid fuels and sees year 2050 demand at 99 mb/d, 74 mb/d and 45 mb/d under Evolution, Equilibrium and Transformation.
- **Shell** – Transnational oil major Shell reports demand in terms of Exajoules (roughly 0.5 mb/d) and separates oil from other liquids in its forecast. Its three long horizon scenarios are called Islands, Waves and Sky 1.5, roughly corresponding to 2.5 °C, 2.3 °C and to 1.5 °C respectively[12]. The Islands path is characterized as "late and slow" progress, while Waves is dubbed "late but fast" and both envision a world that does not focus on a specific degree scenario outcome. Only Sky is explicitly aspirational. Under these scenarios Shell sees year 2050 oil demand at 192 ej/year, 209 ej/year and 160 ej/year under Islands, Waves and Sky respectively[13]. This translates to roughly 86 mb/d, 94 mb/d and 72 mb/d. In this case, the 2.3 °C "Waves" scenario corresponds to higher 2050 oil demand than the Islands path because of a focus by countries coming out of the pandemic on wealth accumulation, over autonomy and self-sufficiency (an assumption possibly upended by recent geopolitical events). This initial orientation subsequently puts demand on a higher for longer pathway that notches up the end state condition.

Taking the average of analyst estimates across the 6 providers above yields 95 mb/d, 64 mb/d and 40 mb/d for the high, middle and low scenarios outlined by each forecaster respectively (see Figure 5). With 2021 demand estimated to have been 96.4 mb/d, it's striking that the consensus among the three best

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[11] https://www.lukoil.com/FileSystem/9/570593.pdf

[12] https://www.shell.com/energy-and-innovation/the-energy-future/scenarios/the-energy-transformation-scenarios.html#iframe=L3dlYmFwcHMvU2NlbmFyaW9zX2xvbmdfaG9yaXpvbnMv

[13] 192 ej/year = 31,383 mmboe = 86 mb/d; 209 ej/y = 34,162 mmboe = 94 mb/d; 160 ej/year = 26,152 mmboe = 72 mb/d

known independent forecasters and an equal number of integrated oil companies shows average demand in 2050 below current demand, when global GDP will more than double over the same period.[14] One caveat is that multiple forecasters' "High" scenario is also their base case, and the various 1.5 °C projections are largely to indicate the degree of travel necessary to achieve more aspirational change. Finally, two prominent financial market data providers, Bloomberg and IHS Markit have estimates of 96 mb/d and 86 mb/d respectively for their base case 2050 targets. It's important to note that there are some forecasters that dispute the demand drop entirely, such as data intelligence firm Rapidan and supermajor Exxon (NYSE: XOM). Exxon sees 12% growth in liquids to 2050, rising to roughly 110 mb/d, joining WoodMac on the high side of the current consensus[15]. Contrarian forecasters like Robert McNally at Rapidan are the first to admit that peak oil 2030 and a drop below 2021 demand have become "the new normal" forecast, dubbing the scenario "green decoupling" and highlighting the billions in capital currently allocated to support the shift. Rapidan's contrary call is predicated on the fact that peak oil 2030 is almost entirely contingent on strong fuel efficiency standards being enforced in China and the U.S. with no backsliding (as fleet replacement to electric is a multi-decade process). A proposition he views with extreme skepticism.[16] In addition, the U.S. Energy Information Agency has put forth its own estimates for 2050 oil and gas demand, which it takes pains to note are "not designed to be a prediction of what is most likely to happen", but rather an extrapolation of current trends, whereby the reference scenario and all additional modeled scenarios show aggregate demand higher than today's levels.[17]

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[14] PwC forecast 2.6% per annum global GDP growth to 2050.

[15] This study only included integrated oil forecasts with three forecast scenarios. Exxon has provided a high forecast of 110 mb/d by 2050 and a low forecast of 70 mb/d by 2040: https://www.reuters.com/article/us-exxon-mobil-climate-report-idUSKBN1FM2PP. Total Energy forecasts 45 mb/d by 2050 under its "Rupture" scenario and approximately 85 mb/d under its "Momentum" scenario. Factoring both "high" forecasts into the consensus results in a mean of 95 mb/d:
https://totalenergies.com/sites/g/files/nytnzq121/files/documents/2020-09/total-energy-outlook-presentation-29-september-2020.pdf

[16] https://www.bain.com/insights/the-future-of-oil-webinar/

[17] Indeed, consumption in the IEA's "Reference case" reaches approximately 125 million barrels per day (b/d) by 2050, and consumption is highest in the "High Economic Growth case", where it reaches approximately 151 million b/d of total liquid fuels in 2050
https://www.eia.gov/outlooks/ieo/pdf/IEO2021_Climate.pdf and https://www.eia.gov/outlooks/ieo/pdf/IEO2021_Narrative.pdf

The important point to highlight, regardless of whether investors support the consensus[18] or the minority contrarian scenario, is that the industry needs to prepare to be robust to the consensus outcome. Currently, the vast majority are wholly unprepared for a lower demand outcome. According to this current consensus, oil demand 30 years from now will be lower than current demand.[19]

Figure 5
IEA, WoodMac, Rystad, British Petroleum, Lukoil & Shell Oil & Liquids Demand 2050 Scenario Analysis

Forecast	2050 High C	2050 Mid C	2050 Low C	Measure	Oil/Liquids
IEA	104	77	24	mb/d	Oil
WoodMac	110	35	30	mb/d	Oil
Rystad	76	51	38	mb/d	Oil
BP	95	55	30	mb/d	Liquids
Lukoil	99	74	45	mb/d	Liquids
Shell	86	94	72	mb/d	Oil
Range	*110-76*	*94-35*	*72-24*		
Mean	*95*	*64*	*40*		
Mean ex outlier	*98*	*64*	*36*		
Bloomberg	*96*				
IHS Markit	*86*				

Source: WKA Analysis

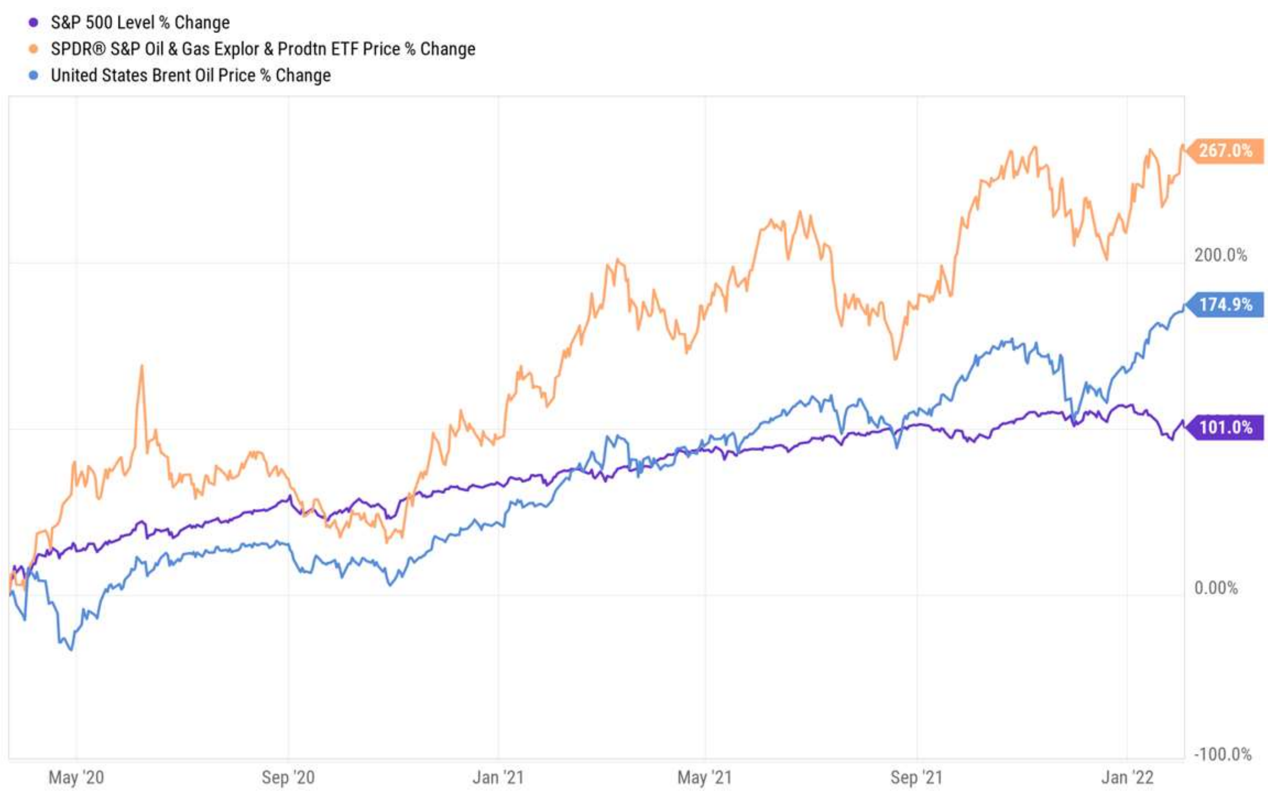
However, expectations for a strong energy transition over the next three decades has not cooled a blazing hot runup for oil and gas securities since the pandemic low. Exploration and production companies, given that their valuation is almost solely based on reserves, without mid and downstream operations,

[18] Many industry insiders see no Paris-aligned pathway possible without industrial level carbon capture and storage, hydrogen replacement for petrochemical feedstock and rigorous CAFÉ standards.

[19] This forecast is quite divorced from oil prices, for which there can be both bullish and bearish cases under the aggregate demand scenario.

highlight this point well. Figure 6 shows the performance of the SPDR S&P Oil & Gas Exploration & Production ETF (NYSE: XOP), with holdings of 61 U.S. E&P companies, against the performance of Brent crude and the S&P 500. As can be seen, XOP has gained 267% as Brent has climbed 175% and the overall S&P has gained 101%.[20]

Figure 6
S&P, XOP & Brent Gains Since the March 23rd Pandemic Bottom



Source: YCharts

The reasons for this extraordinary runup, against the backdrop of a potential fundamental shift in the long-long-term dynamics of the industry, are numerous:

[20] XOP also contains several integrated oil companies, refiners and biofuel firms. Please also see footnote 28.

- During the pandemic, economic activity hit a wall worldwide. This resulted in a massive oil demand drop and considerable oversupply, with some of the industry trading at multi-decade lows. Both the demand and supply factors have clearly reversed as economies have reopened. It's estimated that the demand resurgence led to a significant drawdown in oil inventories and an estimated 2 mb/d undersupply over the course of 2021.[21] In addition, potential demand destruction from higher prices has been less than comparable periods in history, implying higher current demand inelasticity and a greater probability of sustained high prices.[22]

- The price of oil is expected to continue to climb in the near term as spare capacity, defined by the IEA as production that can be launched within 90 days and sustained over an extended period, continues to get squeezed. As most spare capacity is in the Gulf, with Saudi Arabia and the UAE accounting for the majority of the estimated 2.5 mb/d, this is very little cushion given geopolitical tensions and an estimated increase in demand of 4.2 mb/d expected in 2022.

- The industry has experienced a long period of underinvestment (since 2015). It takes many years to get most projects onstream and any sustained period of underinvestment leads to supply mismatches over a multi-year horizon should demand conditions shift (as they have). JPM has observed for the last two years that despite developed world downshifts[23], large developing economies like China and India should power a 1-2% annual increase in oil demand to 2030 (despite oil intensity declining faster in non-OECD). Underinvestment over the last five years as

[21] Martijn Rats, Global Commodity Strategist, Morgan Stanley, "Triple Deficit"

[22] Amrita Sen, Energy Aspects, Bloomberg Surveillance, Tuesday February 22, 2022

[23] Roughly 2/3rd of global demand has already peaked and declined, with the 1/3rd remaining driving growth.

companies shifted capital allocation strategies has redounded to the current moment and will likely persist in the short to medium term.[24]

The history of the industry is rife with boom-bust periods and the ebbing power of OPEC+ to stabilize the business will likely lead to continued volatility.[25] This coupled with profound shifts in future energy infrastructure equals tremendous uncertainty for the segment. With a 175% rise in the price of oil from the recent low the rising tide of oil demand has lifted many boats. However, with any appreciable price gain comes a commensurate rise in implied performance expectations. In the next section we try to unpack the expectations embedded in current E&P company prices.

Part 2: Great Expectations:

In theory, valuing an oil and gas Exploration & Production (E&P) company is a straightforward affair, but often devilishly difficult in practice. Since an E&P's raison d'être is to bring crude oil and natural gas out of the ground, a mainstay of valuation is ascribing some value to the hydrocarbon reserves that it accumulates. In contrast with net asset value assessments (NAV), a traditional discounted cash flow valuation (DCF) makes less sense. In a traditional DCF, a firm earns discrete cash flows for a designated period, hopefully in excess of the cost of capital, and then is ascribed some enduring value through a perpetuity. The possibility of enduring value only exists if reserves can be replaced economically for the entirety of an E&P's future as a going concern. It's difficult to say with confidence that any E&P company can grow in perpetuity between 1-3% and certainly not in consideration of the "green decoupling" consensus described in the opening section of this report.

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[24] JPM March 2020 initial Oil Supercycle thesis to current November 29, 2021, Global Energy: Supercycle IV OPEC+ 'Show me the Barrels'; $150/bbl on the horizon as capacity shocks; LT Brent raised to $80/bb, Christyan F Malek et al

[25] McNally, Robert, *Crude Volatility*, Columbia University Press 2017

Historically, the E&P industry has struggled to generate returns on capital above the cost of capital for extended periods of time, as exemplified by performance over the last decade, shown in Figure 7 below. As can be seen, roughly half the time, investors were not adequately compensated for the risk of holding E&P companies (negative spread but positive ROC), or simply experienced pure value destruction (negative ROC).

Important to note however, these returns came after an extraordinary decade of both positive returns and spreads for the overall industry. The fundamental nature of the business model, massive capital investments and long horizons for the realization of cash flows pose operating challenges that necessitate extreme capital discipline. A comprehensive study of the cash economics of the E&P business, utilizing cash flow return on investment (CFROI), a metric that approximates the cumulative IRR of all a company's projects, concluded that the average E&P company returned 3% per annum since 1955[26], which reflects the challenging economics of the industry.

Largely for this reason, the industry's preferred metric for evaluating performance is return on capital employed (ROCE). A measure that does not consider taxes, thus boosting the numerator in the equation (EBIT versus NOPAT), and utilizes "capital employed" in the denominator, where the calculation is total assets minus all current liabilities, versus total assets minus "excess" cash minus non-interest-bearing current liabilities for the "invested capital" calculation. In general, more capital-intensive businesses favor the ROCE metric because it boosts reported returns (as can be seen in Figure 8).

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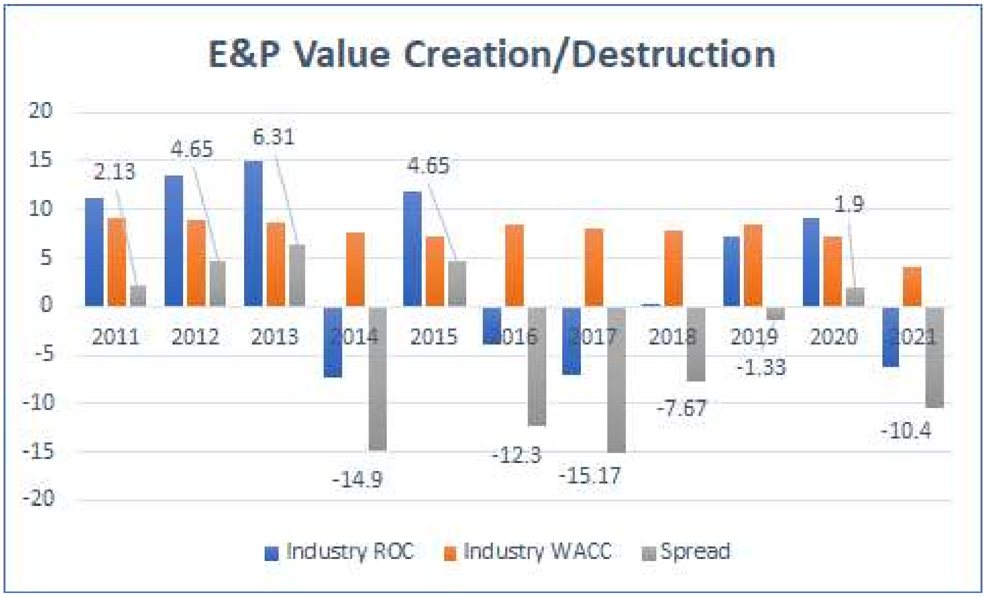
[26] Kevin Holt, CIO, Invesco, "The Math on E&P Stocks Doesn't Add Up" 2017

Figure 7
Oil Production Value Creation/Destruction



Source: Damodaran[27], WKA Analysis

Due to the factors described earlier in this report, 2022 is shaping up to be a banner year for E&P equity securities. The rise from the pandemic low has already been significant and the short to medium term outlook is promising, as oil prices continue to rise (amplified by geopolitical tensions).

Despite the limitations of a DCF in valuing E&P companies, utilizing a reverse discounted cash flow model with no effective perpetuity value (ultralong time horizon) can be instructive in evaluating the expectations impounded in current prices[28].

[27] Data courtesy of Damodaran at http://people.stern.nyu.edu/adamodar/New_Home_Page/dataarchived.html#returns

[28] See for details on GAP https://www.newconstructs.com/how-new-constructs-discounted-cash-flow-model-works/

See also for algo substantiation: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3467814

Figure 8
(ARCX: XOP) E&P Company Price Implied Expectations Analysis (2/20/2022)

Ticker	Name	Value (000,000)	ROIC	ROCE	WACC	ROCE Spread	ROIC Spread	FCF Yield	GAP	Implied Rev CAGR	3 Yr Rev CAGR (A)	5 Yr Rev CAGR (A)	Avg. Implied ROIC spread	3 Yr ROIC Spread (A)	5 Yr ROIC Spread (A)
CPE	Callon Petroleum	$ 2,901	11.1%	11.3%	8.2%	3.2%	3.0%	22.6%	1 <	–	32.6%	50.6%	–	0.0%	-1.6%
LPI	Laredo Petroleum Inc	$ 1,175	7.7%	29.2%	8.0%	21.2%	-0.3%	3.6%	1 <	–	-21.7%	3.2%	–	-1.7%	-2.4%
TALO	Talos Energy Inc.	$ 996	7.2%	18.0%	7.0%	11.0%	0.2%	27.3%	50 >	3.7%	-18.8%	–	5.7%	-0.4%	-0.4%
CDEV	Centennial Resource	$ 2,179	5.0%	7.0%	6.1%	0.9%	-1.0%	12.9%	50 >	3.9%	-2.0%	55.7%	-0.1%	-2.0%	-1.7%
MRO	Marathon Oil Corp	$ 15,982	4.6%	12.6%	6.3%	6.3%	-1.7%	11.0%	50 >	3.0%	5.2%	6.4%	3.4%	-4.2%	-4.8%
MTDR	Matador Resources Co	$ 5,244	10.1%	19.3%	8.7%	10.6%	1.4%	6.2%	50 >	3.7%	-3.6%	26.5%	34.4%	-0.3%	-1.7%
EOG	EOG Resources, Inc.	$ 65,308	8.4%	19.4%	6.3%	13.1%	2.1%	4.5%	52	3.9%	-19.5%	10.4%	9.7%	0.3%	-0.9%
CTRA	Coterra Energy Inc.	$ 18,379	7.0%	13.2%	5.0%	8.2%	2.0%	1.6%	1 <	–	-18.1%	6.1%	–	4.1%	2.8%
FANG	Diamondback Energy Inc.	$ 23,819	9.6%	13.4%	7.0%	6.4%	2.6%	-3.1%	67	4.1%	13.7%	52.0%	7.1%	-0.4%	-0.3%
CLR	Continental Resources	$ 19,224	12.4%	19.7%	6.4%	13.3%	6.0%	-4.8%	92	3.2%	11.1%	16.4%	27.3%	-0.9%	-1.6%
SWN	Southwestern Energy	$ 4,730	9.4%	16.7%	4.4%	12.3%	5.0%	-13.2%	1 <	–	-22.7%	-1.3%	–	0.6%	0.4%
OVV	Ovintiv Inc.	$ 10,574	0.6%	16.4%	7.5%	8.9%	-6.9%	13.9%	50 >	3.2%	1.2%	19.8%	8.7%	-3.3%	-4.2%
MUR	Murphy Oil Corp	$ 5,062	0.4%	9.1%	7.2%	1.9%	-6.8%	12.3%	50 >	3.2%	-12.4%	1.9%	0.4%	-4.1%	-4.6%
AR	Antero Resources Corp	$ 6,823	1.7%	11.7%	7.7%	4.1%	-6.0%	8.7%	50 >	3.3%	2.4%	6.0%	4.9%	-3.6%	-2.7%
XOM	Exxon Mobil Corp	$327,509	-0.1%	15.3%	5.7%	9.6%	-5.8%	8.5%	50 >	3.3%	-19.8%	-4.8%	-0.4%	-2.9%	-2.5%
OXY	Occidental Petroleum	$ 36,948	2.4%	7.6%	6.5%	1.1%	-4.1%	8.1%	50 >	3.2%	0.0%	15.3%	5.0%	-3.4%	-4.0%
HES	Hess Corporation	$ 29,074	3.3%	14.0%	6.9%	7.1%	-3.5%	7.5%	50 >	3.4%	-14.1%	-0.5%	3.7%	-4.5%	-6.0%
APA	Apache Corporation	$ 11,683	2.8%	22.7%	8.0%	14.7%	-5.3%	6.8%	50 >	3.4%	-22.1%	-4.2%	0.2%	-4.2%	-5.0%
RRC	Range Resources Corp	$ 5,308	-0.9%	17.4%	5.2%	12.2%	-6.1%	5.3%	50 >	3.4%	-22.6%	15.7%	3.5%	-3.4%	-3.4%
CNX	CNX Resources Corp	$ 3,209	-3.9%	8.9%	3.8%	5.1%	-7.7%	2.7%	1 <	–	24.3%	17.6%	–	-3.0%	-2.3%
CVX	Chevron Corporation	$257,192	4.3%	14.2%	6.1%	8.1%	-1.8%	-0.2%	50 >	3.3%	-22.9%	-3.8%	6.6%	-4.5%	-4.0%
KOS	Kosmos Energy Ltd	$ 1,934	2.8%	7.7%	9.8%	-2.1%	-7.1%	-2.5%	50 >	3.6%	-4.8%	26.9%	11.5%	-4.2%	-6.3%
COP	ConocoPhillips	$118,217	4.6%	21.9%	5.9%	16.1%	-1.3%	-6.7%	50 >	3.9%	-28.2%	-5.6%	12.3%	-2.7%	-3.2%
NOG	Northern Oil & Gas, Inc.	$ 1,585	-4.5%	30.2%	6.4%	23.8%	-10.9%	-7.7%	1 <	–	-9.8%	39.7%	–	0.4%	-0.6%
EQT	EQT Corporation	$ 8,393	-3.4%	6.6%	3.9%	2.6%	-7.3%	-13.5%	50 >	3.1%	-16.7%	-2.4%	0.4%	-4.6%	-3.2%
DVN	Devon Energy Corp	$ 36,385	4.8%	26.2%	6.7%	19.5%	-1.9%	-15.3%	50 >	3.2%	40.1%	-3.3%	7.2%	-4.9%	-5.2%
PXD	Pioneer Natural Resources	$ 56,976	10.4%	20.7%	5.9%	14.9%	4.5%	-20.2%	50 >	4.0%	-13.5%	15.5%	40.4%	-1.1%	-2.2%
TELL	Tellurian Inc	$ 1,164	-14.7%	-14.1%	8.1%	-22.2%	-22.8%	-21.2%	50 >	6.6%	90.8%	–	5.7%	-31.7%	-34.8%
PDCE	PDC Energy	$ 5,408	1.5%	24.8%	7.8%	17.0%	-6.3%	8.9%	50 >	3.6%	-7.0%	36.8%	21.2%	-2.9%	-5.1%
SM	SM Energy Company	$ 4,160	-4.5%	8.4%	8.4%	0.0%	-12.9%	6.7%	50 >	6.9%	-17.1%	-1.2%	23.8%	-5.5%	-6.6%

Source: New Constructs, FactSet, WKA Analysis

As can be seen from Figure 8, current market prices for the constituents[29] of the XOP (S&P Oil & Gas Exploration & Production) are impounding many years of returns above the cost of capital. In fact, 80% of the index is implying greater than 50 years of value creating returns (ROIC above WACC)! To say the

[29] We deleted numerous names from XOP to get a pure play index of upstream oil and gas E&P companies. Eliminated business models included refining, biofuel, fracking, enhanced oil recovery, ethanol, marketing and transportation, LNG import facility construction, landowners, mineral rights acquirers and clean energy fuels, resulting in the exclusions of the following: REGI, MNRL, ALTO, REX, PBF, VLO, CVR, CLNE, INT, TPL, MPC, DK, PSX, HFC, GEVO, GPRE, NFE, OAS, DEN, PARR, MCF, WLL, MGY. In addition, we removed 3 firms where we had no "GAP" data.

least, the current expectations of more than 50 years of never-before-seen returns does not exactly square with the situation the industry currently faces. In sum, these frothy valuations are not only at odds with individual company return history (as seen in the rightmost column labeled "5 Year ROIC spread Actual") as well as the historical industry returns outlined earlier, but the current valuations also defy the consensus that an energy transition could ultimately bring oil and gas demand below current levels by 2050. See Appendix 1 for a complete discussion of GAP and reverse cash flow modelling.

Despite this, for more senior observers of multiple oil and gas industry cycles, these arguably euphoric valuations are consistent with the historical boom-bust nature of the segment (where valuation extremes are not uncommon). Perhaps more importantly, current valuations imply a business-as-usual outlook amongst investors currently bidding up the names, without regard for the expected energy transition (i.e., nothing has really changed in how investors value these companies). For the reasons outlined previously (inventories, spare capacity and capital expenditures), this approach has been vindicated as a rational investment decision, at least in the short term.

Some studies indicate that investors with longer expected holding periods are uncomfortable with the regulatory uncertainty and volatility around future demand and are simply opting out of investing in E&P companies altogether (over 800 firms representing $6 trillion in AUM have pursued an exclusionary approach to oil, gas and coal), leaving the remaining investors to price securities in line with historical norms[30]. This is a troubling situation for investors that want exposure to hydrocarbon names – especially

[30] See: https://2degrees-investing.org/wp-content/uploads/2019/11/MASTER_Fossil_Fuel_Ownership_Nov_2018.pdf

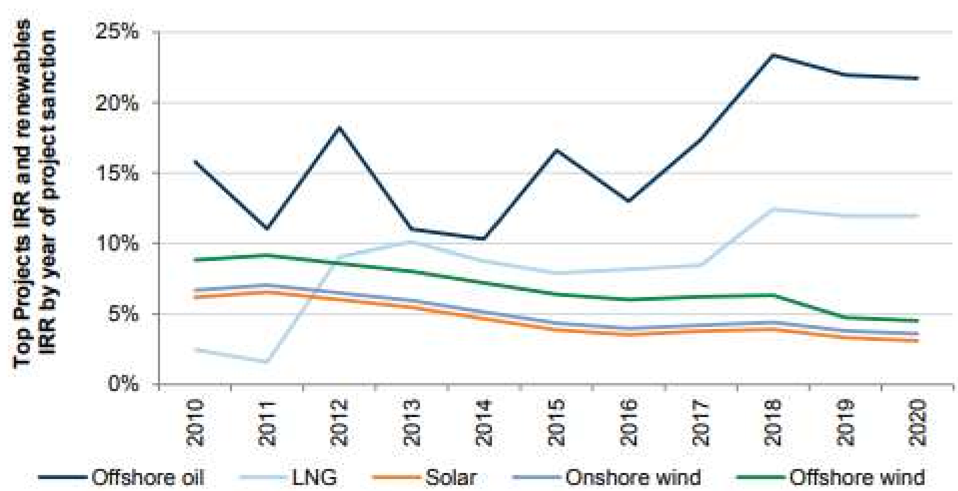
See: https://www.oxfordenergy.org/wpcms/wp-content/uploads/2019/01/Energy-Transition-Uncertainty-and-the-Implications-of-Change-in-the-Risk-Preferences-of-Fossil-Fuel-Investors-Insight-45.pdf to firms actively navigating the expected transition -- but find an assessment of the associated risks challenging.

At root, absent enormous advances in technology, the industry is facing an emissions problem, as consensus future demand scenarios envision a steep reduction in output due to the climate implications. The final section of this report will introduce a metric to help investors more finely tune the risks associated with the energy transition for the oil and gas E&P segment.

Part 3: Material Risks

While public market equity investors may be proceeding in a business-as-usual fashion, E&P companies are experiencing clear financing stress related to the energy transition. Goldman Sachs estimates that the spread in the cost of capital of hydrocarbon versus renewable developments has widened by greater than ten percentage points over the last five years (Figure 9).

Figure 9
Project IRR for oil and gas and renewable projects by year of project sanction



Source: Goldman Sachs

When project IRRs, required returns on long duration, high-cost projects, increase significantly due to uncertainty around demand and the regulatory environment, fewer projects get funded, exploration budgets get cut and write-offs increase. This is validated by the expected 40% decline in the reinvestment ratio for all Oil & Gas in 2022 (based on current trends versus a 10-year average) and highlights an industry beset with poor regulatory clarity and lack of global coordination, in contrast with the electric utility industry, which has seen positive reinvestment ratios due to price support and more clear regulation[31]. A truism in the industry is that high oil prices are the best cure for high oil prices, as additional capacity ramps and the pendulum swings to oversupply. Over the last decade however, the number of climate-related shareholder resolutions has almost doubled and the percentage of investors voting in favor has almost tripled, to roughly 40%, with a targeted focus on energy producers rather than on final energy consumption. The prospect of continued shareholder pressure and sustained high financing costs may significantly delay what was in years past an almost certain setup for a price crash. This volatile backdrop shows no sign of abating, as few doubt the fact that a meaningful energy transition is on the horizon. Absent a global carbon tax regime or coordinated country-level emissions reductions, investors should gird for continued instability.

This issue is particularly challenging for E&P companies, as undeveloped properties are major drivers of firm value. As can be seen in Figure 10, the probability of development for various categories of oil and gas reserves are not the same. As a firm moves down the chain of various commercial categories, the probability of development decreases. A reserve is only considered proven if it's probable that a minimum of 90% is recoverable and economically profitable, with proved reserves divided into developed and undeveloped.

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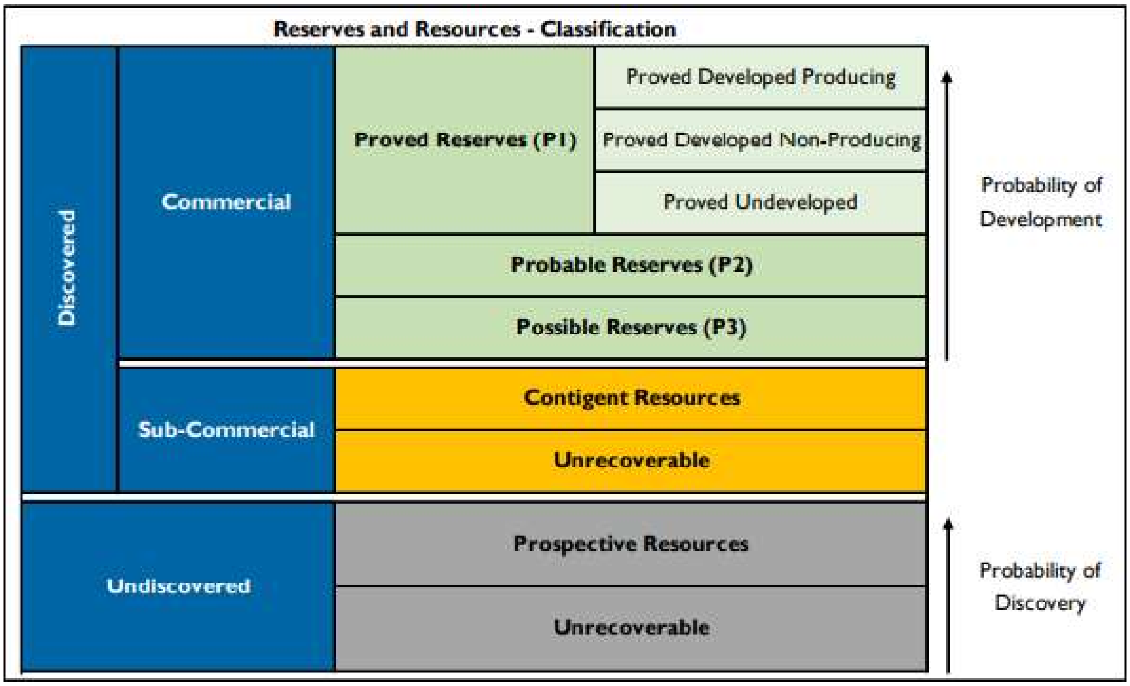
[31] https://www.goldmansachs.com/insights/pages/gs-research/dual-action-of-capital-markets-transforms-net-zero-cost-curve/the-dual-action-of-capital-markets-transforms-the-net-zero-cost-curve.pdf

Figure 10
Reserve Categories Versus Probability of Development



Source: Valuescope

On a NAV basis, E&P companies typically trade well above the discounted value of their proved developed reserves, with the balance of the market value representing implied optionality on proved undeveloped properties (PUD), and possibly more distant P2, P3 according to some studies[32]. Since PUDs require future capital investments, they're keenly sensitive to economic conditions. In a recent paper[33], the National Bureau of Economic Research examined the relationship between firm value and proved reserves for 600 oil and gas firms in North America from 1999-2018 and found that proved undeveloped reserves growth and firm value were significantly negatively correlated (see Figure 10).

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[32] https://www.tandfonline.com/doi/pdf/10.1080/23322039.2017.1385443

[33] https://www.nber.org/system/files/working_papers/w26497/revisions/w26497.rev0.pdf

Figure 10
Oil Reserves & Firm Value

	(1)	(2)	(3)	(4)	(5)	(6)
Total reserves	0.0260**		0.0263*			
	(0.024)		(0.073)			
Growth total reserves		-0.0000420**	-0.0000411**			
		(0.021)	(0.024)			
Developed reserves				0.835*		1.595***
				(0.065)		(0.004)
Undeveloped reserves				-0.112		-0.234**
				(0.136)		(0.011)
Growth developed reserves					0.00346	0.00502**
					(0.136)	(0.039)
Growth undeveloped reserves					-0.000850***	-0.000928***
					(0.001)	(0.000)

Source: National Bureau of Economic Research

As can be seen from the data, the highlighted coefficient and p-value for the level of undeveloped reserves *growth* against firm value (Tobin's Q) is significant and economically impactful (column 6 highlighted), as a single standard deviation increase in growth of PUDs decreases firm value by 2.6% of the mean. To the left in Column 4, which represents the relation between firm value and the absolute level of reserves, rather than the growth of reserves, there is a high positive correlation with developed reserves and a negative correlation with undeveloped reserves, but both, arguably, are insignificant as the p-value (in parenthesis 0.136 and 0.065) are above the indicated 1% test level[34].

Given that reserves reporting is typically sub-categorized into oil, natural gas and natural gas liquids segments (NGL), a finer grained analysis of the relation between the emissions potential of these reserves

[34] The p-values in parentheses are based on clustered standard errors across firms. A single asterisk indicates significance at the 10% level, two asterisks the 5% level and three asterisks the 1% level.

and firm value can aid in securities analysis.[35] For the 30 E&P firms in this report, undeveloped proved reserves averaged 40% of total reserves on an annual basis over the last decade. While the growth of aggregate undeveloped reserves is important to valuation, the emissions potential and financing implications of the change in reserves mix needs to be disaggregated (as highlighted by LNG's lower project IRR in Figure 9). Figure 11 below shows the relationship between the change in emissions potential of undeveloped proved reserves and Enterprise Value for the thirty E&P companies in Figure 8 over the last five years. We plotted the change in undeveloped proved reserves over a given year, calculated the emissions potential of that change in reserves according to the hydrocarbon mix, and then performed a regression against Enterprise Value (firm value as dependent variable).

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[35] XOM and others provide additional information on "bitumen" and "synthetics" as separate categories of reserves.

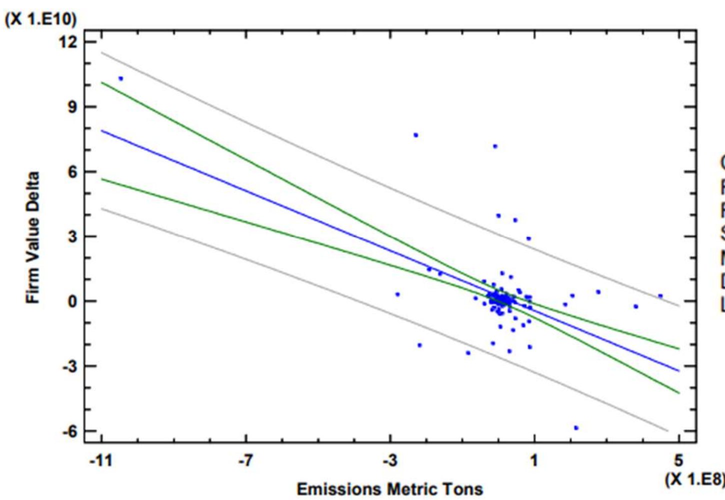
Figure 11
Growth in Emissions Potential of Undeveloped Reserves & Firm Value

Coefficients

Parameter	Least Squares Estimate	Standard Error	T Statistic	P-Value
Intercept	2.47354E9	1.33408E9	1.85412	0.0663
Slope	-69.4842	10.1094	-6.8732	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	9.63326E21	1	9.63326E21	47.24	0.0000
Residual	2.30427E22	113	2.03918E20		
Total (Corr.)	3.2676E22	114			



Correlation Coefficient = -0.542965
R-squared = 29.4811 percent
R-squared (adjusted for d.f.) = 28.8571 percent
Standard Error of Est. = 1.428E10
Mean absolute error = 7.56303E9
Durbin-Watson statistic = 2.41602 (P=0.9875)
Lag 1 residual autocorrelation = -0.208819

Source: WK Analysis, FactSet, Statgraphics

As can be seen, an even greater negative correlation exists (-0.54 coefficient, versus -0.23) between CO_2 emissions and firm value. Again, it's important to note that the growth in undeveloped proved reserves alone is impactful, but that growth does not *necessarily* give rise to a linear increase in emissions. The exact quantity of rise or fall in metric tons of CO_2 depends on the mix of proved undeveloped hydrocarbons that rise or fall (i.e., oil, natural gas and NGL). We utilized emissions factors formulated by the

Intergovernmental Panel on Climate Change[36] for each type of hydrocarbon, a standard adopted around the world by governments and companies alike (including the U.S. Department of Energy and Exxon Mobil). Please see Appendix 2 for more information regarding the IPCC factors.

In order to understand the impact of potential emissions from PUDs on equity performance we compared an equal-weighted portfolio of E&P company returns, utilizing the 30 companies outlined in this report, from 2017-2021. In the first scenario, we simply held all 30 companies for the entire period. As can be seen in Figure 12, this generated a 158% return. We then rebalanced the portfolio each year and removed the top quintile emitters (i.e., largest increase in potential emissions from undeveloped proved reserves), replacing them with the bottom quintile performers, which mostly consisted of firms that reduced emissions.

Figure 12
Emissions-Based Portfolio Rebalancing

		Year 5	Year 4	Year 3	Year 2	Year 1	Return
30 Hold		**66.4%**	**5.4%**	**-16.2%**	**9.1%**	**61.0%**	
Portfolio Return	*Equal Weight*	166.37	175.41	146.99	160.34	258.21	**158%**
Rebalance Undeveloped		**66.4%**	**17.1%**	**-14.9%**	**-2.3%**	**84.0%**	
Portfolio Return	*Equal Weight*	166.37	194.80	165.70	161.97	298.03	**198%**
Rebalance Emissions		**66.4%**	**17.1%**	**-14.9%**	**-0.1%**	**85.9%**	
Portfolio Return	*Equal Weight*	166.37	194.80	165.70	165.61	307.86	**208%**

Source: WK Analysis

As can be seen, the portfolio return jumped dramatically to 208%, a move of 5000 basis points, or 32% improvement over the hold portfolio! An important observation from these data is that the growth or

[36] https://www.ipcc-nggip.iges.or.jp/EFDB/main.php

decline in PUDs and emissions, though highly correlated, sometimes diverged due to the relative mix of hydrocarbons. Here are some examples:

- **Talos Energy** (NYSE: TALO) a Gulf coast offshore E&P had a significant 334% rise in undeveloped proved reserves in Year 4 and potential emissions jumped an even greater 370% due to the oil content of those reserves, while Centennial Resource Development (Nasdaq: CDEV), a Permian operator, increased its PUDs in Year 2 by 6% while potential emissions only jumped 4% due to the focus on natural gas.

- **Murphy Oil** (NYSE: MUR), a U.S. operator with undeveloped reserves in Australia, Brazil, Brunei, Mexico and Vietnam decreased its PUDs in Year 2 by 14% but witnessed an emission decrease of 21% due to the write off of oil-rich properties. In contrast, in the same year, Marathon Oil (NYSE: MRO) cut undeveloped proved by 8% but only saw a 6% reduction in emissions potential due to the removal of less dense hydrocarbons from its portfolio.

- Global independent E&P **Hess** (NYSE: HES) managed to cut its potential emissions from undeveloped proved reserves in half over the last decade, while simultaneously ramping up its total PUDs from 19% to 30% over the same period (undeveloped proved/total proved). The firm accomplished this feat by de-emphasizing oil and boosting natural gas and NGL reserves.

Differences like these can result in small changes to the portfolio rebalancing, whereby the incremental return from the more fine-grained focus on emissions potential, rather than just undeveloped proved reserves, can allow investors to potentially earn incremental return (1000 basis points in our rebalancing, see Figure 12). With a relatively small pool of companies (30) the benefits to the rebalancing become more evident in the out years as removal of the largest emitters have a more pronounced effect. The differences between the remaining companies narrow and the sorting more fully captures the differences outlined above (as seen in the Year 1 & 2 returns of the rebalancing).

Conclusion:

Interestingly, over the last decade, virtually all the E&P companies seem to realize the potential negative effects of growing undeveloped proved reserves in the current environment, as only 3 companies saw a rise in the proportion of these reserves to total proved resources over the period -- and 2 of the 3 started from a base of zero (i.e., they started with no undeveloped proved reserves). The sole company to grow its proved undeveloped as a percentage of total proved over the period was Exxon Mobil (NYSE: XOM), and only by a small amount, from 27% to 33%. Notably, the company also reduced its potential emissions from these reserves 43% by halving oil and gas volumes and boosting NGLs.

In addition to the potential portfolio implications outlined, there are individual security analysis benefits to utilizing a metric that tracks the potential emissions associated with undeveloped proved reserves, including the following:

- **Carbon Scoring** – As discussed earlier in this report, many hydrocarbon demand scenarios are now linked to emissions levels, where maximum allowable amounts are established in order to meet global warming targets. The implicit assumption is that countries, financiers and governments will increasingly adopt varying degrees of regulatory pressure and incentives to "enforce" these targets. Increasingly, investment services and portfolio software providers are scoring an individual company's alignment with temperature benchmarks, sometimes referred to as "carbon scoring" where the analysis contrasts the company's stated targets against a benchmark. Carbon scoring then highlight how much reduction is still required of the company, or if the firm is exceeding targets. Those that exceed targets are typically awarded higher scores. As an example, Bloomberg's carbon scoring method has seen higher scores correlate with company outperformance.[37] Calculating the emissions potential of undeveloped proved reserves would allow analysts to quantify a PUD threshold, or a level of undeveloped reserves that might affect the firm's ability to meet or exceed its stated emissions goals. Putting this number in sharp relief would help investors understand the challenges and risks.

- **Precision** -- Increasingly analysts incorporating higher discount rates as a "blunt force" margin of safety when valuing some oil and gas investments. A few investors we spoke with are utilizing an additional 200-500 basis points on top of the calculated rate for more extreme physical and transition risks. In some circles, for upstream producers, industry standard oil and gas PV10 is now closer to PV15. This creates a significantly higher hurdle for the standard EV/PV10 heuristic in evaluating investment opportunities. Understanding the trajectory of the emissions potential of PUDs for an individual security can allow analysts to accept their calculated rate without a blunt instrument margin of safety, but with a valuation adjustment to reflect the idiosyncratic risk of either growing or declining emissions potential of undeveloped proved assets for the valuation target.

- **Corporate Strategy** – Clearly delineating emissions targets and the potential inherent in a firm's undeveloped proved reserves can help a company understand where it fits in a country, regional, or global strategy. Having quantifiable metrics allows companies to manage what they measure, helping to explore the way in which carbon offsets or operational emissions reductions can

[37] https://www.bloombergquint.com/markets/big-oil-learns-carbon-scores-matter-to-investors-green-insight

balance against future expected emissions. If these potential emissions can be aggregated at a market level, it will improve market efficiency with respect to the overall trajectory of emissions in coming years, as well as the context of an individual company's efforts within that overall path.

Numerous institutional investor surveys over the last year have indicated that investors understand the potential materiality of climate change in the valuation of companies. In the Robeco 2021 Global Climate Survey of the 300 largest institutional investors, with a total of $23.4 trillion in assets under management, 71% of respondents asserted that climate change was either a "significant factor" or "at the center" of investment policy (47% and 26% respectively).[38] In addition, in the Greenwich 2021 survey of 101 investors with greater than $3B in assets, it was reported that 58% of respondents actively incorporated climate change considerations into their investment process, with approximately 75% doing so because the practice "improves risk-adjusted returns".[39]

Despite majorities in both surveys acknowledging the importance of climate risk, a significant number cited the need for more reliable data, models and disclosures to effectively evaluate the risks. The lack of perceived in-house expertise was a strong limiting factor (40% of investors in the Greenwich survey), as many investors didn't feel they had the requisite expertise to isolate the elements that impacted firm value. Of the respondents in the Greenwich survey roughly 31% utilized carbon emissions data as a factor in their internal analysis[40], leaving considerable room for more efficient pricing of this factor as adoption increases. As demonstrated in this report, under the right circumstances, investors can use these data to inform their analysis and generate potentially superior returns.

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[38] https://www.robeco.com/docm/docu-202103-robeco-global-climate-survey.pdf

[39] https://cdn.pficdn.com/cms/pgim4/sites/default/files/2021-04/Seeking-Higher-Ground-Institutional-Investors-Respond-Climate-Change.pdf

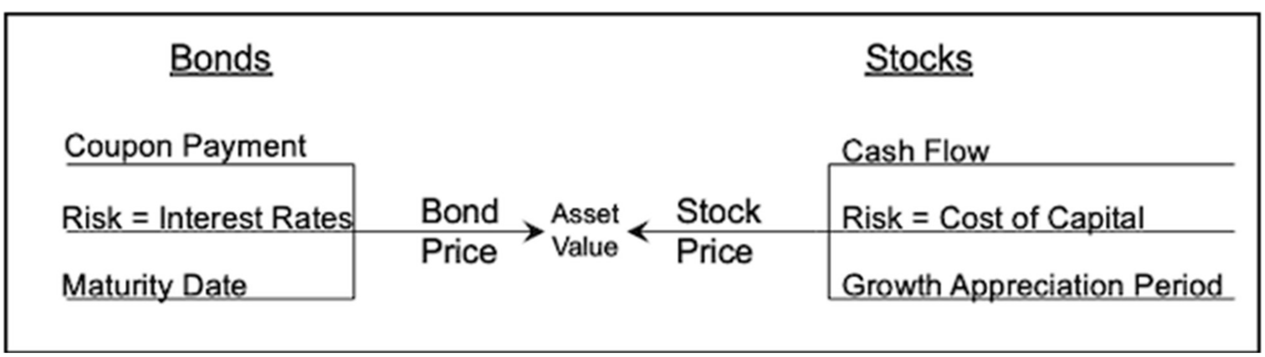
[40] Of the 58% of respondents that actively incorporated climate change considerations, 54% of those utilized carbon emissions data in their internal analysis

Appendix I: Reverse Discounted Cash Flow [Source: New Constructs LLC][41]

Bad DCF models are misleading. We won't argue that, but DCF analysis remains extremely helpful when used to reverse engineer what companies must do to justify their stock price, aka "expectations investing". The right way to use DCF models is not to try to predict the future, but to quantify the future that the stock price is predicting.

Our DCF starts with the principle that stocks can be valued in the same way as bonds. As shown in Figure 1, the drivers of future cash flow between the two types of securities are analogous. The only difference is that the future cash flows for bonds are contractually determined while the future cash flows for stocks are undetermined. However, if one accepts the premise that the value of an asset equals the present value of future cash flows, then it follows that reverse DCF models can quantify the future cash flows required to justify stock prices.

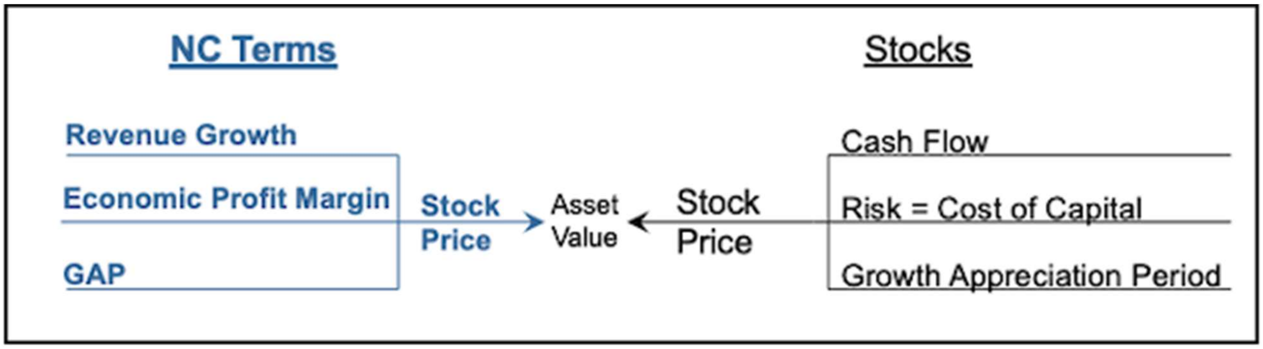
Appendix Figure 1: The Basic Valuation Recipe: Same for Stocks and Bonds



In Figure 2, we categorize the drivers of a stock's implied future cash flows into more intuitive terms.

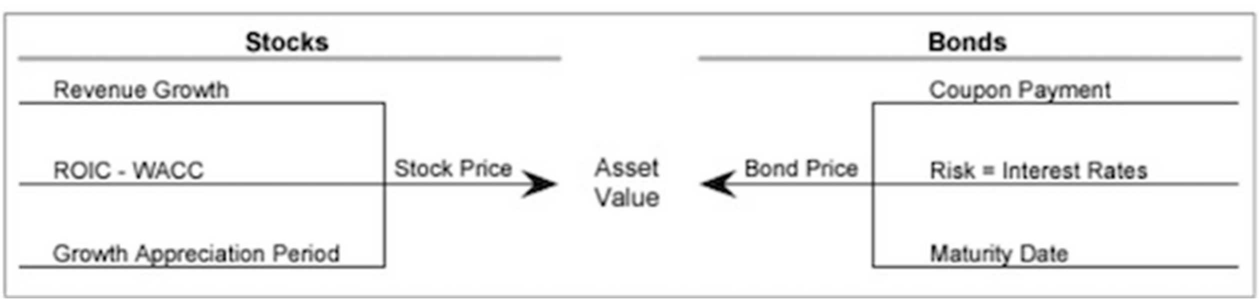
[41] https://www.newconstructs.com/how-new-constructs-discounted-cash-flow-model-works/

Appendix Figure 2: Simpler Terms for Measuring Cash Flows



We think it is easier to think about the future cash flows implied by stocks prices in these terms because they capture the core drivers of business success: Revenue Growth: how fast will the business grow? ROIC – WACC: how profitable with the business be? Growth Appreciation Period (GAP): for how long will the business grow profits? In Figure 3, we match the more intuitive drivers for equity cash flows with the drivers of bonds. With this understanding, we can focus on using our reverse DCF to get the answers to these questions from Mr. Market.

Appendix Figure 3: The New Constructs Valuation Recipe: Same for Stocks and Bonds



Most of the time, we forecast Revenue Growth and ROIC – WACC over a very long forecast horizon, not just five or 10 years (more details below). Then, we solve for the Growth Appreciation Period (GAP) needed for the DCF model to produce a stock price equal to the current stock price. In other words, we provide forecasts for three of the four variables in the equation and solve for the 4th variable. Our DCF models do not rely on static forecast horizons such as five or ten years as do traditional DCF models. Our models are dynamic, which means we calculate values for the stock based on multiple forecast horizons. The key to this approach is a terminal value in each forecast horizon that assumes zero growth (e.g., NOPAT/WACC not WACC-g) after the forecast horizon. Rather than trying to capture all the future growth in cash flows in a static time frame (e.g., five years), our models calculate the value attributable to shareholders over 100 forecast periods.[42]

[42] See webinar: https://www.youtube.com/watch?v=3T9Pl1W8GcQ

Appendix II: IPCC Emissions Factors Background

The Intergovernmental Panel on Climate Change (IPCC) is a body composed of sovereign nations assembled under United Nations auspices that provides the world with objective, scientific information relevant to understanding the risk of human-induced climate change, as well as its natural, political, and economic impacts and possible response options.

In its Guidelines for National Greenhouse Gas Inventories published in 2006[43], the IPCC included "Default CO_2 Emissions Factors for Combustion" (DEFC, acronym ours, see Appendix Figure 4). The carbon content of different fossil fuels and the reserves from which they originate can vary considerably both among and within primary fuel types on a per mass or per volume basis. However, the IPCC's measurement of effective CO_2 emissions of fuels upon combustion as reflected in the DEFC avoids this complication.

Fossil fuel combustion processes are optimized to derive the maximum amount of energy per unit of fuel consumed, which delivers the maximum amount of CO_2. Efficient fuel combustion ensures oxidation of the maximum amount of carbon available in the fuel. CO_2 emission factors for fuel combustion are therefore relatively insensitive to the combustion process itself and hence are primarily dependent exclusively on the carbon content of the fuel.

For these reasons and due to the global credibility of the IPCC, the U.S. Environmental Protection Agency (U.S. EPA) uses the DEFC in its the basis for the Emission Factors for Greenhouse Gas

[43] https://www.ipcc-nggip.iges.or.jp/public/2006gl/

Inventories[44] used by the U.S. EPA Center for Corporate Climate Leadership, which has in turn been used by ExxonMobil[45] and other companies to calculate their Scope 3 greenhouse gas emissions[46].

In June 2016, the oil industry sustainability group IPIECA published "Estimating petroleum industry value chain (Scope 3) greenhouse gas emissions. Overview of methodologies[47]." The document draws on the WRI and the World Business Council for Sustainable Development (WBCSD) GHG Protocol Scope 3 Standard to outline approaches used by the oil and gas industry to estimate scope 3 emissions. Exxon drew on the IPIECA methodology to report its Scope 3 emissions noted earlier[48]. The document is also available on the website of the American Petroleum Institute (API)[49].

The IPCC effective CO_2 emission factors are also the reference coefficients for ISO Standard 14064[50] on the quantification and reporting of greenhouse gas emissions. These are also the metric used in the Carbon Disclosure Project (CDP) Scope 3 disclosure guidance for oil companies[51].

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[44] https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf

[45] ExxonMobil has participated in the Intergovernmental Panel on Climate Change (IPCC) since its inception in 1988. https://corporate.exxonmobil.com/-/media/Global/Files/energy-and-carbon-summary/Energy-and-carbon-summary.pdf

[46] https://corporate.exxonmobil.com/-/media/Global/Files/energy-and-carbon-summary/Energy-and-Carbon-Summary.pdf Page 43

[47] https://www.ipieca.org/resources/good-practice/estimating-petroleum-industry-value-chain-scope-3-greenhouse-gas-emissions-overview-of-methodologies/

[48] https://corporate.exxonmobil.com/Sustainability/Energy-and-Carbon-Summary/Scope-3-emissions

[49] https://www.api.org/~/media/Files/EHS/climate-change/Scope-3-emissions-reporting-guidance-2016.pdf

[50] http://www.iso.org/iso/catalogue_detail?csnumber=38381; WK Associates submitted a June 14, 2021 comment to the SEC endorsing the IPCC effective CO_2 emissions factors as a tool for evaluating the emissions potential of oil

[51] https://b8f65cb373b1b7b15feb-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/guidance_docs/pdfs/000/000/469/original/CDP-Scope-3-Category11-Guidance-Oil-Gas.pdf?1479754082

Appendix Figure 4: IPCC Default CO_2 Emissions Factors for Combustion

Fuel		heating Value	CO_2 emission factors for fuel consumption data that have been supplied on different measurement bases					
			Energy basis	Mass basis	Fuel density information[1] Of liquids (kg/litre fuel)	Of gases (kg/m^3 of fuel)	Liquid basis	Gas basis
		TJ/Gg	kg/TJ	kg/tonne			kg/ litre	kg/m^3
Oil products	Crude oil	42.3	73300	3100.59	0.8		2.480472	
	Orimulsion	27.5	77000	2117.5				
	Natural Gas Liquids	44.2	64200	2837.64				
	Motor gasoline	44.3	69300	3069.99	0.74		2.2717926	
	Aviation gasoline	44.3	70000	3101	0.71		2.20171	
	Jet gasoline	44.3	70000	3101	0.71		2.20171	
	Jet kerosene	44.1	71500	3153.15	0.79		2.4909885	
	Other kerosene	43.8	71900	3149.22	0.8		2.519376	
	Shale oil	38.1	73300	2792.73	1		2.79273	
	Gas/Diesel oil	43	74100	3186.3	0.84		2.676492	
	Residual fuel oil	40.4	77400	3126.96	0.94		2.9393424	
	Liquified Petroleum Gases	47.3	63100	2984.63	0.54		1.6117002	
	Ethane	46.4	61600	2858.24		1.3		3.715712
	Naphtha	44.5	73300	3261.85	0.77		2.5116245	
	Bitumen	40.2	80700	3244.14				
	Lubricants	40.2	73300	2946.66	1		2.94666	
	Petroleum coke	32.5	97500	3168.75				
	Refinery feedstocks	43	73300	3151.9				
	Refinery gas	49.5	57600	2851.2				
	Paraffin waxes	40.2	73300	2946.66				
	White Spirit/SBP	40.2	73300	2946.66				
	Other petroleum products	40.2	73300	2946.66				
Coal products	Anthracite	26.7	98300	2624.61				
	Coking coal	28.2	94600	2667.72				
	Other bituminous coal	25.8	94600	2440.68				
	Sub bituminous coal	18.9	96100	1816.29				
	Lignite	11.9	101000	1201.9				
	Oil shale and tar sands	8.9	107000	952.3				
	Brown coal briquettes	20.7	97500	2018.25				
	Patent fuel	20.7	97500	2018.25				
	Coke oven coke	28.2	107000	3017.4				
	Lignite coke	28.2	107000	3017.4				
	Gas coke	28.2	107000	3017.4				
	Coal tar	28	80700	2259.6				
	Gas works gas	38.7	44400	1718.28				
	Coke oven gas	38.7	44400	1718.28				
	Blast furnace gas	2.47	260000	642.2				
	Oxygen steel furnace gas	7.06	182000	1284.92				
Natural gas	Natural gas	48	56100	2692.8		0.7		1.88496
Other wastes	Municipal waste (Non biomass fra	10	91700	917				
	Industrial wastes	NA	143000	NA				
	Waste oils	40.2	73300	2946.66				
Biomass	Wood or Wood waste	15.6	112000	1747.2				
	Sulphite lyes (Black liqour)	11.8	95300	1124.54				
	Other primary solid biomass fuels	11.6	100000	1160				
	Charcoal	29.5	112000	3304				
	Biogasoline	27	70800	1911.6				
	Biodiesels	27	70800	1911.6				
	Other liquid biofuels	27.4	79600	2181.04				
	Landfill gas	50.4	54600	2751.84		0.9		2.476656
	Sludge gas	50.4	54600	2751.84				
	Other biogas	50.4	54600	2751.84				
	Municipal wastes (Biomass fractio	11.6	100000	1160				
	Peat	9.76	106000	1034.56				
These emission factors are 'cross-sector'; that is, they can be used by reporting entities from any sector, such as the manufacturing, energy or institutional in								
Notes:	1, Fuel density data come from GHG Protocol's tool for stationary combustion							

Appendix III: Emissions Embedded in Reserves (EER) metric

The full background and methodology for calculating the Emissions Embedded in Reserves (EER) metric is presenting in a study[52] submitted on June 14, 2021 to the U.S. Securities and Exchange Commission (SEC) for its Climate Disclosure comment request period.

[52] https://www.sec.gov/comments/climate-disclosure/cll12-8916955-245033.pdf