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Divest from the Carbon Bubble? Reviewing the Implications and Limitations of Fossil Fuel Divestment for Institutional Investors[1]

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***A*bstract:** Climate change policies that rapidly curtail fossil fuel consumption will lead to structural adjustments in the business operations of the energy industry. Due to an uncertain global climate and energy policy framework, it is difficult to determine the magnitude of fossil energy reserves that could remain unused. This ambiguity has the potential to create losses for investors holding securities associated with any aspects of the fossil fuel industry. Carbon bubble risk is understood as financial exposure to fossil fuel companies that would experience impairments from assets stranded by policy, economics or innovation. A grassroots divestment campaign is pressuring institutions sell their fossil fuel company holdings. By September 2014, investors had responded by pledging to divest US $50 billion of portfolios. Though divestment campaigns are primarily focused on a moral and political rationale, they also regularly frame divesting as a strategy for mitigating stranded asset risk. We review aspects of the divestment movement alongside the context of carbon bubble risk. Several common hypotheses on reducing stranded carbon asset exposure through divestment are critically examined. We find that institutional investors are limited in their ability to reduce exposure to carbon through divesting and that the financial sector is likely to absorb many 'fossil free' funds.

Keywords: Green investing; Climate change; Carbon bubble; Fossil fuel divestment; Low carbon economy; Financed emissions; Decarbonized portfolio; Unburnable carbon; Oil and gas equities; Stranded assets

JEL Classifications: Q42, Q43, Q50, G00

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1. Introduction

When campaigners from the 350.org climate action network launched the *Go Fossil Free: Divest from Fossil Fuels* movement, founder Bill McKibben (2012) stated: "If it is wrong to wreck the climate, then it is wrong to profit from the wreckage. We believe […] organizations that serve the public good should divest from fossil fuels". Since 2012, nearly 1,000 divestment campaigns have launched across the world at universities, cities and religious institutions.

While these campaigns have mostly focused on a moral rationale for divesting, a parallel dialogue developed by financial analysts and investment banks describes the case for a *carbon bubble* in the asset prices of conventional energy companies. This has since become a key economic justification for institutions to consider divestment. Campaigns and their surrounding literature regularly express this idea.[2]

Leaton, et al. (2011) and the Carbon Tracker Initiative (CTI) developed the detailed the case for a carbon bubble resulting from strict climate policies that would damage the financial valuations of fossil fuel companies. Since then, a fast-moving debate has informed perspectives on how investors should consider the impact of climate targets on fossil fuel companies. According to the theory of finance, the current share price of an oil, gas or coal firm is the present value of all future cash flows. Thus, material impacts on earnings could result from legislation that dramatically changes the market's future expectations.

Divestment is suggested as a way to deal with the carbon bubble: (a) *indirectly* through a social movement that empowers legislation on climate change and (b) *directly* through reducing portfolio exposure to the financial risks energy companies faced under climate change policies. The idea of a carbon bubble has gained traction in financial markets as investors incorporate stranded asset risk into their outlooks. A growing number of institutions are committing to divest. Few would argue that avoiding a carbon bubble has not influenced such decisions. The idea of divesting from a carbon bubble is regularly cited by campaigns as a benefit.

Institutions are in the early stages of determining how to implement their divestment commitments. Few have actually reallocated investment capital. For large investors bound under fiduciary law, choosing to entirely divest from fossil energy companies is difficult because of the composition of contemporary financial products and the structure of the economy. The university endowments and pension funds targeted by divestment campaigns typically invest in pooled funds with assets dispersed heterogeneously across multiple sectors of the economy.

First, this paper reviews the concept of fossil fuel divestment and the idea of a carbon bubble. Then, we examine three working hypotheses for likely outcomes of using divestment as a strategy to: (a) mitigate an institution's exposure to carbon bubble risk; (b) reduce fossil fuel consumption by targeting oil and gas reserves listed on major financial exchanges and (c) direct the funds of institutional investors to toward green companies.

[2] For a few examples of how divesting from the carbon bubble is regularly described, see Cowles (2014), IMPAX Asset Management (2013) and Dennis, et al. (2014).

2. Divest from fossil fuels? A growing pool of funds commits to go fossil-free

Fossil fuel divestment campaigners want to signal that investing in oil, gas and coal infrastructure is no longer socially acceptable. Modeled after the perceived success of divestment and isolation campaigns against South African apartheid, the divestment campaign intends build political momentum for enacting meaningful climate legislation, diminishing the lobbying power of the oil, gas and coal industries by removing their social license to operate.

Arabella Advisors (2014) reports that divestment commitments have been made by more than 180 institutions and local governments and 656 wealthy individuals. Figure 1 summarizes our estimate for the timeline of total portfolio value committed to fossil fuel divestment over the first 24 months of the campaign from October 2012 through September of 2014. During this period, investors have pledged to divest of fossil fuel holdings estimated at up to $5 billion.[3]

Because each type of divestment commitment varies, they are classified in Figure 1 as (a) **strong**: an organization is beginning to divest, has moved money or has no fossil fuel companies remaining in their portfolio; (b) **mild**: an organization is exploring divestment, e.g. through forming a committee, or is beginning a limited approach to divestment; or (c) **weak**: an organization approves of the divestment concept but has not specified any further action.

We reviewed the annual reports of institutions and municipalities to estimate the cumulative value of portfolios committed to divestment. Three key points in the divestment campaign are noted on the top horizontal axis of Figure 1: (1) a commitment from the city of Seattle to divest in late-December 2012; (2) a divestment announcement by nine additional cities, bringing the total to ten in April of 2013; (3) an announcement by Stanford University that it would no longer invest its endowment directly in companies with a primary focus on coal mining in May of 2014.

There are active divestment campaigns on nearly 500 university campuses and in more than 100 cities worldwide.[4] As of October 2014, 14 universities & colleges, 31 towns & cities, 29 foundations, many churches and other organizations have made some form divestment commitment.

Ansar, et al. (2013) expect that the direct financial impact of divestment on fossil fuel companies will be limited. Divested shares are likely to be acquired by unconcerned investors. University endowments and pension plans are many orders of magnitude smaller than the global energy industry, valued at $4 to $5 trillion (Bullard, 2014).[5] Institutions generally have less than 5% of their assets committed to public fossil fuel equities. Despite these limitations, Ansar, et al. suggest that divestment could stigmatize fossil fuel lending, limiting access to debt markets by influencing major banks or multilateral institutions. The authors note that coal companies would likely face the largest impacts from their reliance on regional and fragmented markets. [6]

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[3] This paper reports all monetary values in nominal US dollars unless otherwise noted.

[4] Divestment commitments and campaigns are regularly updated at: http://gofossilfree.org/

[5] Valuations can be a moving target in times of commodity volatility. As global oil prices fell by 50% from June to December of 2014, the cumulative market cap for oil and gas companies fell by approximately 20% over this period.

[6] In November 2014, the World Bank pivoted its energy finance from coal to renewable energy, in part driven by the dialogue generated by divestment campaigns.

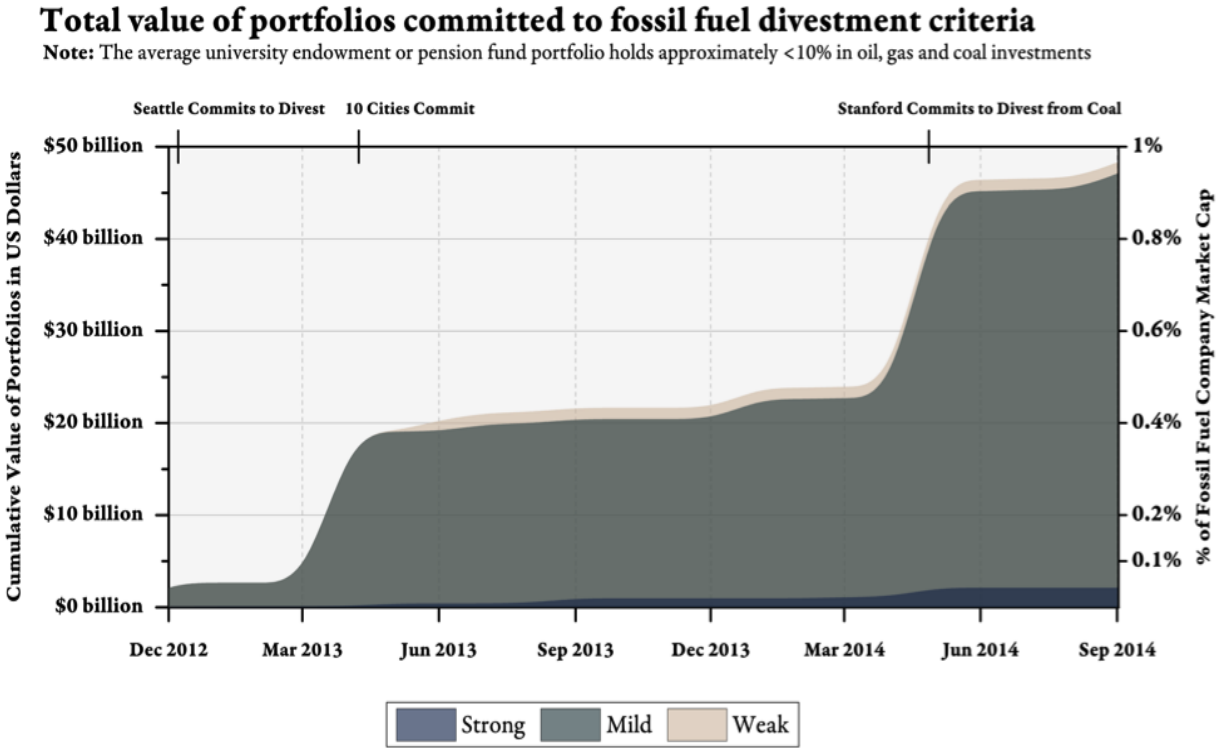

Figure 1 - Cumulative value of portfolios (left-axis) committed to some form of oil, gas or coal divestment criteria through September 2014. Total portfolio value committed to divestment criteria as proportion of 2014 fossil fuel company market cap (right-axis). *Notes on classifications*: [Strong]: exhibits organizations which are: (i) beginning the process of divestment, (ii) are in the process of divesting or (iii) have stated that they have no oil, gas & coal investments remaining in their portfolio; Mild]: commitments represent the formation of exploratory committees or some form of stakeholder approval or partial divestment such as Stanford's divestment from coal; [Weak]: commitments entail statements of approval with no perceivable action.

2.1 Interest in the math: opinions on the financial cost of divestment

Institutions commonly respond to divestment campaigns by considering the potential financial impact of selling their oil, gas and coal holdings. We summarize several initial studies that have informed opinions about the potential impacts of fossil fuel divestment on portfolio performance.

A model portfolio was developed by Geddes (2013) to back-test the impact on performance from placing a negative screen on fossil fuel stocks. This fully divested model portfolio's annualized rolling returns are found to be 0.1% to 0.2% higher than a Russell 3000 benchmark from 1997 through 2008. Portfolio volatility is examined through removing thirteen of the highest GHG-emitting coal companies from an optimized Russell 3000 portfolio, resulting in a 0.14% tracking error. Geddes concludes that divesting from fossil fuels can have a minimal affect on a portfolio's performance and risk.

Morgan Stanley Capital International (2013) estimated that divesting the MSCI All Country World Investible Market Index (MSCI ACWI IMI) of fossil-fuel assets over five years (2008-2013)

would have increased active returns by an average of 0.22% annually and increased overall tracking error by 1.9%. Over ten years, an ex-carbon portfolio slightly underperformed the MSCI ACWI IMI by -0.16% with a tracking error of 0.99%. MSCI suggests that an energy bull market in the early years of this time series accounts for the underperformance in the divested index, concluding that fossil fuel divestment has the potential to reduce overall risks to a portfolio because of volatility in the energy sector. If this is the case, screening fossil energy companies could allow for modest risk-adjusted outperformance against un-divested benchmarks.

Additional divestment scenarios on the MSCI ACWI were reviewed by IMPAX Investment Management (2013). IMPAX replaced fossil fuel stocks with actively and passively managed investments in renewable energy and energy efficiency companies. Over a 5 to 7-year period, these alternative portfolios outperformed the market by 0.1% to 0.5%.

Shapiro and Pham (2011) estimated the financial contribution of energy company investments to 34 major US public employee pension plans over five years (2005-2009). The sectoral distribution of S&P 500 market value was used to estimate the amount of energy holdings in each portfolio. This methodology indicated the average pension portfolio held 4.6% in oil and gas stocks, which contributed a greater amount to total returns than any other sector during this period, an average of 15.7%.

Institutions may incur additional expenses through implementing divestment commitments. These potential costs are discussed by Fischel (2015) as: (a) trading costs from broker commissions; (b) higher management costs from continued compliance and (c) costs from limiting diversification. Fischel models diversification costs with optimized divested and unrestricted portfolios built from sector specific indices over fifty years (1965-2014). During this period, the portfolio restricted from investing in oil & gas stocks showed 0.5% lower risk-adjusted returns. The cross-sector correlation of returns modeled by Fischel suggests that energy companies may hold the largest potential of any sector for diversified returns.

Each of these studies demonstrate notable gaps in exploring the potential financial impacts of divestment by:

(a) focusing solely on back-testing, and thus mis-representing how reasonable future climate and energy scenarios may impact institutional investors;

(b) analyzing short timeframes within the current decade, an inadequate scope for pensions and endowments investing for the long-term (with the exception of Fischel (2015);

(c) estimating the impact of divestment by comparing indices, rather than analyzing portfolio data from institutions;

(d) being potentially biased either way: Fischel (2015) and (2011) have direct links to funding from the petroleum industry and support a negative view on divestment, while Geddes (2013) and IMPAX Asset Management (2013) were developed by fund managers that stand to benefit greatly from divestment commitments and hold a positive view on divestment; in summary, this body of grey literature has not been subjected to the scrutiny of anonymous peer-review.

Despite an evolving literature, the potential financial impact of fossil fuel divestment is still undecided. All opinions on the costs institutions may incur by divesting or continuing to hold fossil fuel stocks are currently speculative. No data is available on the performance of financial markets under global carbon constraints. Modeling on the impact of stranded assets is limited. As more

institutions implement divestment commitments, historical performance data will become available to support claims. We suggest that climate-energy-economy models could assist in anticipating the impact of carbon budget scenarios on the financial performance of model portfolios.

3. The carbon bubble hypothesis: Risks from stranded assets

Where the divestment movement intends to motivate investor action through articulating a moral case, the carbon bubble hypothesis describes an economic rationale for reducing exposure to fossil fuel companies. This concept gained rapid mainstream acknowledgments. For example, in his role as Bank of England Governor, Mark Carney recently told a World Bank seminar that, "the vast majority of reserves are unburnable," (see Hay 2014). The Bank of England is expected to report on its exposure to stranded assets later in 2015. As we review, a growing number of investment banks and agencies from HSBC to S&P are beginning to consider stranded assets alongside the formulation of strategies for advising clients to mitigating their financial impact.

3.1 A range of carbon budgets: which reserves are unburnable?

The carbon bubble hypothesis has resulted from comparing the reserves reported by oil, gas and coal companies to the available *carbon budgets* for cumulative greenhouse gas (GHG) emissions established by climate models (see Leaton et al., 2011). Each estimate for a remaining carbon budget is determined by forecasting the cumulative GHG emissions that would limit the increase in global average surface temperatures. A common carbon budget scenario will calculate the cumulative CO_2 equivalent GHG emissions that can be released to maintain an 80% or 50% probability of 2˚C warming this century. This is commonly referred to as a two-degree scenario (2DS). A specific carbon budget can be compared to potential sources of greenhouse gases, such as the reserves and resources of publicly listed oil, gas and coal companies.

Meinshausen (2009) estimates that the carbon budget for emissions from 2000-2050 to achieve a 2DS should not exceed 886 $GtCO_2$ (80% probability) and 1,437 $GtCO_2$ (50% probability). The P1 reserves[7] held by only the top 100 oil, gas and coal companies are reported to represent potential emissions of 745 $GtCO_2$ (see Carbon Tracker Initiative (2011). With cumulative emissions from the first decade of the 21st century estimated by Friedlingstein, et al. (2010) to be more than 310 $GtCO_2$, burning the P1 reserves of listed fossil fuel companies along with those of state entities before 2050 would thus exceed a 2DS carbon budget. Therefore, achieving a reasonable probability of a 2˚ climate goal would require some P1 reserves to remain unused, or *stranded*.

Leaton, et al. (2013) update the original CTI estimate for a 21st century carbon budget to a total of 1,550 $GtCO_2$. For a 50% probability of achieving a 2DS, they estimate a 2013-2049 carbon budget of 1,075 $GtCO_2$, and a 2050-2100 budget of 475 $GtCO_2$. They identify *listed reserves* as P2 reserves[8] on the books of publicly traded companies, as distinct from reserves wholly owned by national entities. The authors estimate that listed reserves are approximately 25% of the world total,

[7] P1 reserves (or "proven reserves") are considered to have at least a 90% certainty of development.

[8] P2 reserves include those that could be developed, i.e. proved (90% probability) plus probable (50% probability).

and contain 1,541 $GtCO_2$. By allocating a corresponding 25% of the remaining carbon budget to listed reserves, they identify 60-80% of listed reserves as potentially stranded assets.

Most scenarios used to estimate unburnable carbon have relied on models from the IPCC's 4th Assessment Report. The IPCC's 5th Assessment Report (2013) updates climate scenarios for a carbon budget through the year 2100, suggesting a more stringent cap for emissions.[9] The 21st century carbon budget estimated in AR5 is 33% smaller than that of Leaton, et al. (2013), of which a 25% allocation would leave listed reserves with just 181 $GtCO_2$ of burnable assets and 88% stranded assets.

An integrated assessment model from McGlade and Ekins (2015) projects 2,900 $GtCO_2$ of potential emissions from burning all remaining fossil fuel reserves. [10] A 2DS carbon budget of 870 to 1,240 $GtCO_2$ through 2050 suggests that 33% of the world's oil, 50% of its gas and 80% of its coal reserves would be stranded. The authors apply their model in an attempt to determine where stranded assets may be located, and find that due to geographic and economic factors, Canada would use the least of its oil reserves, the Middle East the least of its gas reserves and the US & Former Soviet Union the least of their coal reserves.

The estimated amount of unburnable carbon in each of these scenarios varies by how quickly carbon mitigation technologies are deployed, such as carbon capture and sequestration (CCS). With 13 large-scale CCS projects currently operating, Leaton, et. al (2013) project that an additional 3,790 operational CCS projects by 2050 would increase the 2DS carbon budget available for fossil fuels by 12-14%.

3.2 Financial impacts from stranded assets?

Paun, et al. (2015) of HSBC Global Research define stranded assets as those that lose value or turn into liabilities before the end of their expected economic life.

Much like the rapid asset price declines characteristic of other historical financial bubbles, a carbon bubble burst scenario is said to occur as the market forms an opinion on the impact of stranded assets from climate policy or other factors. Short-term losses could ensue as investors panic over an uncertain impact from newly established climate policy. Long-term losses may accumulate as energy companies report cash flow disruptions and lower earnings from declining demand.

As Inkpen and Moffett (2011) note, current share prices of energy companies reflect investor expectations about the net operating cash flow each firm can generate in the future. When investors and industry experts are assuming a sufficiently high future price for fuels, company valuations reflect higher cash flow potential. If energy prices consistently remained below thresholds supporting investment in marginal production, valuations of high-cost producers would suffer.

Should strictly enforced policies establish a 2DS carbon emissions ceiling, the resulting price environment would likely make many deepwater, shale oil, LNG and heavy oil projects unviable.

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[9] A more rigorous projected carbon budget results from a higher global warming impact from non-CO2 gases, e.g. methane. For example, IPCC AR5 projects a global warming potential for methane that is 19% higher over 20 years than AR4 (Table 8.7).

[10] This estimate accounts for the distribution and location of oil (1.29 billion barrels), gas (192 trillion cubic meters), hard coal (728 Gt) and lignite reserves (276 Gt).

The cost of developing the marginal barrel from these unconventional resources wouldn't be justifiable in the market conditions established by 2DS climate policy. Spedding, et al. (2013) of HSBC Global Research details the case that a low carbon world means high cost projects would be deferred or cancelled by oil and gas majors. Unburnable carbon is estimated to range from 1% of British Gas' reserves to 17% for Statoil.

As a high-cost producer, Canada would likely face dramatic impacts from low-demand scenarios. A Citibank report by Syme, et al. (2013) notes that the reserves of Canadian oil companies are relatively expensive to develop, largely due to the high production cost of oil sands. Sustained exposure to a low energy price environment would impair industry performance and expansion. CanOils (2015) draws performance estimates from a database of the Canadian oil and gas industry to estimate that less than 20% of leading companies would be able to sustain operations during a prolonged period of West Texas Intermediate (WTI) benchmark prices at $50/barrel (bbl).[11] At this price level, nearly 70% of Canada's oil industry is projected to report deficits on annual and quarterly financial statements. Less than one-fifth of producers are expected to recover their investments at $60/bbl.

Supply curves for the equivalent rate of global oil production estimated at various price levels are adapted from Leaton, et al. (2014) for Figure 2. As oil constitutes approximately 40% of global emissions, it is assigned an equivalent amount of remaining carbon budgets until 2050. The resulting carbon budget for emissions from oil use is applied to the 2DS budgets developed by Meinshausen, et al. (2009), the IPCC AR5, Leaton, et al. (2014) and Leaton, et al. (2013), these points are overlaid on the supply curve in Figure 2.

Alberta is identified by Leaton, et al (2014) as carrying more carbon bubble risk than any other region. Due to their high costs, many Canadian oil sands reserves are largely above the projected high-risk 2DS threshold. McGlade and Ekins (2015) forecast that effective 2DS policies could leave more than 74% of Canada's reserves as unburnable before 2050, with or without deployment of carbon capture. Figure 2 projects a cost curve for Canadian oil sands projects from Vigna, et al (2013) of Goldman Sachs, showing bands for the price environment considered to correspond with each carbon budget scenario for oil. It is important to note that it is difficult to estimate the oil production levels that may result from various market price scenarios. For example, in early 2015 many oil well drillers have reduced prices to maintain a workload that keeps their company from defaulting, reducing the cost of drilling wells and the resulting breakeven oil price. How long such practices could be sustained is an open question.

Redmond and Wilkins (2013) of Standard & Poor's (S&P) carried out a carbon stress test to determine the impact of GHG constraints on energy company credit ratings. Medium and small companies are expected to suffer the largest financial impact from carbon policy. Companies operating on this scale would face negative outlook revisions and downgrades before 2020 in a 2DS. International oil companies (IOC) would experience more limited impacts.

[11] Oil is available from a wide range of locations and in different blends of sulfur content (sweet vs. sour) and density (light vs. heavy). Benchmark prices standardize oil based on quality and location, serving as markers for trading and pricing oil. The North American benchmark price for a barrel of oil is *West Texas Intermediate* (WTI). The global benchmark price is *Brent* (North Sea). Roughly two-thirds of the world's crude oil sells at prices tied to Brent.

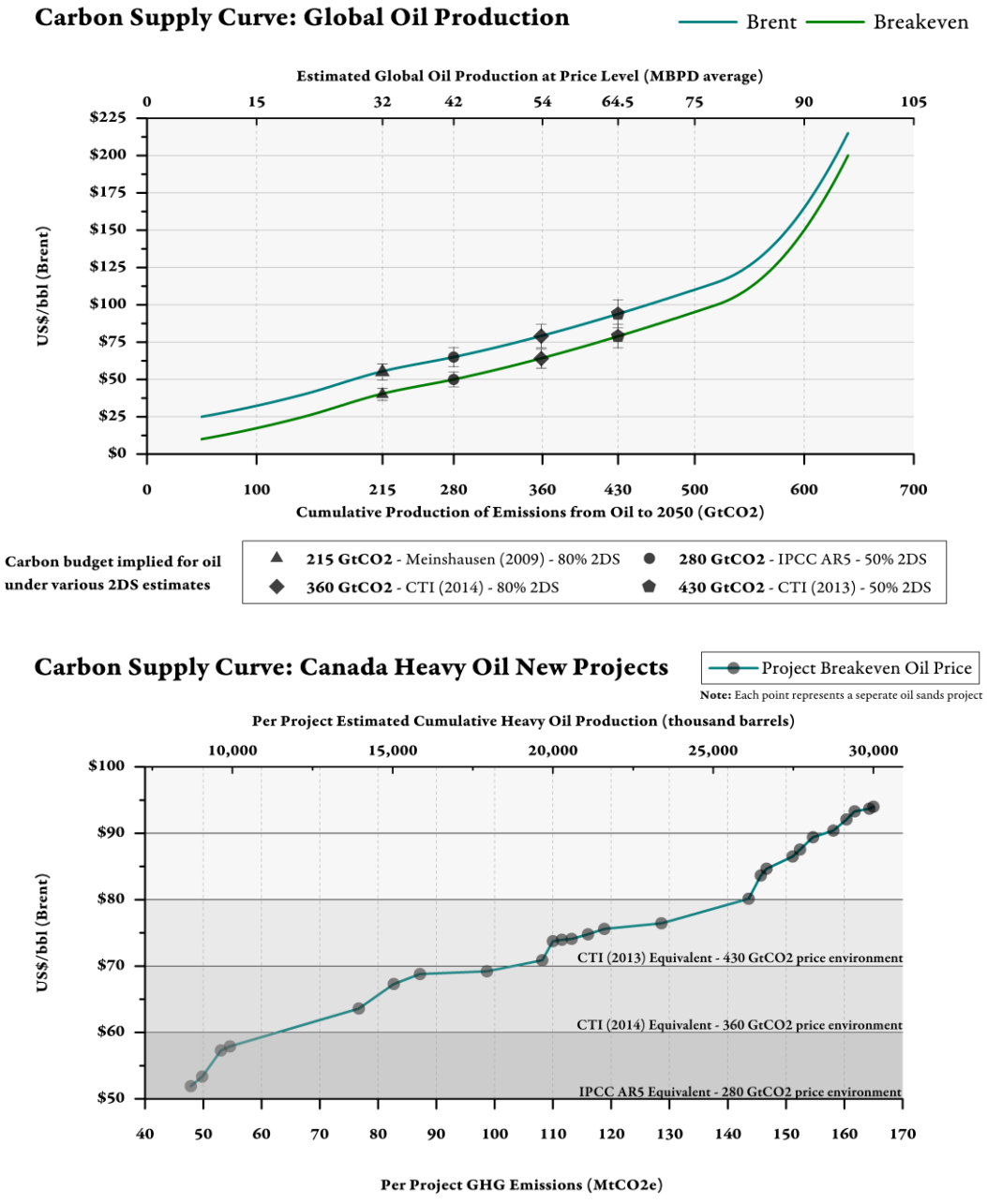

Figure 2 Carbon Supply Curve for Global Oil Production (above) and Carbon Supply Curve for Canada Heavy Oil New Projects (bottom)

Lewis (2014a) projects that policies and technologies consistent with a 2DS would put $28 trillion of fossil energy company revenues at risk. Policies for a 2DS are estimated to incur losses of $19.3 trillion, $4 trillion and $4.9 trillion for oil, gas and coal respectively. This scenario estimates

that demand for oil would be curtailed by 45 trillion tonnes over two decades, an amount equivalent to four years of demand at the 2011 rate of consumption.

Bauer, et al. (2013) use a general equilibrium multi-regional climate-economy model to estimate the impact of climate stabilization on cumulative fossil fuel revenues. Carbon prices sufficient to obtain a 2DS target through the year 2100 would raise approximately $32 trillion while revenues for oil, gas and coal producers are reduced by $12 trillion. This revenue from carbon taxes is highlighted as providing an opportunity to compensate potential losers from policy. Though oil loses the most value in this scenario, coal loses the most by physical volume, with as much as 85-90% remaining underground.

While the primary carbon bubble hypothesis has focused on scenarios where climate policies create stranded fossil fuels assets, Lewis (2014b) explores an economic case for stranded assets where increasingly costly fossil fuels make alternatives more viable. As improvements in renewables and efficiency technologies undermine the long-term demand for fossil fuel energy, a *peak demand* environment is created for oil, gas and coal. Three major trends support this possibility: (1) a limited increase in conventional crude output post-2005 (2) a decline in the energy productivity of capital expenditures for major oil companies and (3) limits to the projected net export availability in major exporting nations as their populations require increasing consumption. If these factors combine, the continued economic case for fossil fuel dependency would become a more painful option than restructuring the economy around alternative energy sources.

Paun, et al. (2015) highlight that investors are increasingly considering economic factors as a catalyst for creating stranded energy assets, often ahead of climate regulation risks. An asset is considered to be economically stranded when the current energy economy leads an energy company to curtail production plans of a proven reserve or to cease production that was underway.

Meyer and Brinker (2014) suggest that the carbon bubble hypothesis has drastically overestimated IOC exposure to stranded asset risk by misclassifying the proven reserves held by each company. They argue that proven reserves are the primary driver of upstream valuations. Since up to 90% of the proven reserve value can be captured in the first 10 to 15 years of a project's production, the financial valuation attributed to reserves beyond this horizon is likely marginal. As many IOC's are integrating 'shadow' prices for carbon into their project investment decisions, they may be effectively hedging their exposure to carbon risk, reducing investor stranded asset risk to a greater extent than carbon bubble advocates have indicated.

Prompted by shareholders for a response to the prospect of a carbon bubble, ExxonMobil and Shell assert the concept is a distraction from the energy needs of a growing global populations. These companies estimate their reserves would face little chance of being stranded due to regulatory change in the next few decades.

Now that contemporary perspectives on fossil fuel divestment and the carbon bubble have been summarized, we will examine several key hypotheses regarding the ability for institutions to divest from a carbon bubble.

4. Can institutions divest from unburnable carbon? Evaluating hypotheses about the efficacy of divested funds

The fossil fuel divestment movement is attempting to work on two parallel levels: (1) one of a social narrative, which intends to act on symbols, morals and values, and (2) a level that involves action on financial, physical and technical considerations. While the first level is the primary goal and focus of the movement, the second level is also frequently referenced when detailing a rationale for divestment. A number of hypotheses have been suggested for the potential impact of divestment on avoiding or mitigating a carbon bubble. We explore three key hypotheses regarding divestment and the carbon bubble in this section through a review of reports, data, and our own research. While these hypotheses aren't presented in this paper as verbatim, they are summarized from publications, articles, speeches, blogs and our dialogue with divestment campaigners and carbon bubble proponents.

4.1 Hypothesis A: Divesting from oil, gas and coal companies is prudent because it protects an investor from the financial risks of exposure to stranded carbon assets

Campaigners for divestment and many advocates of carbon bubble risk have recommended that investors should sell off their investments in fossil energy companies to reduce their exposure to unburnable carbon (see 350.org, 2014; Cowles, 2014; Denniss et al., 2014; IMPAX Asset Management, 2013).

We have measured the total exposure to greenhouse gas emissions as the *carbon shadow* of a portfolio. A carbon shadow represents the GHG emissions embodied in an investor's portfolio returns. This metric could be used to gauge an investor's financial risk to climate policy or low carbon scenarios. The size of an investor's carbon shadow varies based on asset allocation decisions. We posit that funds with a large shadow would face a higher probability of financial loss from low emission scenarios.

In Ritchie and Dowlatabadi (2014) we attempt to develop a readily accessible framework for estimating the GHG exposure of investors through calculating a portfolio's carbon shadow. This model is applied to analyze the CAD $952 million endowment (2012 market value) of our host university which has an endowment-to-operating budget ratio of roughly 1:1.

Our campus' carbon shadow was measured to be 550,000 tCO2e in 2012, roughly nine times larger than the emissions released from on-campus activities during that year. The university's on-campus scope 1 and 2 GHG emissions during 2012 were 60,715 tCO2e.[12] This model was used to consider scenarios for implementing divestment as a strategy for reducing the carbon shadow of the campus endowment and institutional investors in general.

Table 1 below summarizes a divestment scenario where the endowment's reported market value of specific oil and gas holdings were moved into six randomly selected renewable energy companies. The new portfolio consisted of three solar PV companies, a waste-to-energy company, a

[12] Ritchie and Dowlatabadi (2014) describes the methods used for carbon shadow calculations and for obtaining the results of these scenarios.

battery manufacturer and a wind turbine company.[13] Values for each investment's carbon shadow are in units of tonnes of carbon dioxide equivalent per million investment dollars (tCO2e/mn$inv).

Table 1. Divestment Scenario 1: Oil & Gas into Renewable Energy Companies

Value of Investment	Current Holdings	tCO_2e/ mn$inv	Divestment Scenario One Holdings	tCO_2e/ mn$inv
$ 1.76 M	Cenovus (Oil & Gas)	1,600	EnerSys (Batteries)	350
$ 1.36 M	Ensign Energy (Oilfield Services)	2,300	Broadwind (Wind)	360
$ 1.16 M	Encana (Oil & Gas)	770	Canadian Solar (Solar)	1,200
$ 1.03 M	Talisman Energy (Oil & Gas)	1,400	First Solar (Solar)	880
$ 1.02 M	Baytex (Oil & Gas)	450	Solarcity (Solar)	40
$ 0.85 M	Canadian Natural Resources (Oil & Gas)	1,100	China Recycling Energy (Waste-to-Energy)	10
$7.18 M	**Original annual carbon shadow**	7,620	**Scenario one annual carbon shadow**	2,840

Note: All values in millions of US dollars, price-sales (P-S) ratios accurate as of the endowment's disclosure dated October 23rd, 2012

The original carbon shadows of these oil and gas holdings totaled 7,620 tCO2e over this year. Implementing divestment in this way has resulted in a 63% reduction for these holdings, while the endowment's aggregate carbon shadow is reduced by 0.8%. Though not a negligible reduction, this is a smaller impact than would be expected because renewable energy is considered as a low or zero emission energy source.[14] These oil and gas companies represent roughly 10% of our campus' investments in the fossil energy sector.

The performance of this scenario leads us to estimate that similar divestment strategies which replaced oil & gas holdings with renewable energy companies would reduce our endowment's exposure to GHG emissions by a small fraction. A thin market of renewable energy companies would quickly lead to diminishing marginal carbon shadow reductions. As this scenario is intended to test the GHG effects of various investment allocation decisions, strategic factors of return and risk aren't included. The boundary for this analysis is the campus endowment's exposure to GHGs, thus results aren't intended to project the impacts of divestment across the economy, or on specific companies.

We consider this as only one of the many possible ways for fulfilling a divestment commitment. However, we imagine that the implementation of divestment would ultimately want to be consistent with the broader aims of these campaigns. Divestment campaigns generally do not place their primary focus on re-investing divested funds in renewable energy. This is regularly considered as an ancillary goal. Yet, many of the parallel movements, such as Divest-Invest, which we cover in Section 4.3, state that their primary intention is to divest in order to invest in a low carbon economy.

[13] While these holdings could potentially be optimized in an attempt to seek even lower carbon, this allocation reflects a random selection of renewable energy companies from a larger basket.

[14] Additionally, divesting from fossil energy companies is considered yield a greater result as fossil fuel combustion has comprised more than 90% of total global GHG emissions from 2003-2012.

In order to make an appropriate analogy, we have compared companies focused on oil and gas extraction with the firms manufacturing the equipment that 'extracts' the solar, wind and biomass power from natural flows, i.e. two types of capital stock that access the energy flows of nature. As fossil fuel provides more than 87% of commercial energy, development of renewable energy infrastructure would require the considerable use of fossil fuels until it is capable of being manufactured through energy derived from renewable energy sources.

Our recent paper (2014) explored an additional divestment scenario that intended reduce the endowment's carbon exposure through redistributing holdings of exchange-traded funds (ETFs) among those with the lower carbon shadows. Roughly 80% of our campus endowment's fossil fuel industry holdings are in various pooled funds. This scenario was found to reduce the endowment's carbon shadow by as much as 11% if holdings shifted to an ETF with more than 33% of its holdings in the financial sector.

Thus, we conclude that financial institutions will be favored when low carbon metrics are applied at a high-level to asset allocation decisions and that institutional investors have a limited ability to reduce their exposure to carbon through divesting for several reasons: (1) as Ansar (2013) notes, holdings of fossil fuel companies usually make up a small portion of endowments (roughly <5%); (2) renewable energy companies are still part of a broader fossil fuel economy, as the renewable energy supply chain still uses significant amounts of fossil fuels; and (3) the range of investible renewable energy companies is small: oil and gas company valuations are larger than wind, solar, geothermal and biomass companies by about 40-to-1 on global exchanges.

The conventional discussion on unburnable carbon has focused on the supply-side, considering the stranded assets of energy producers. Our scenarios suggest that stringent carbon policy would hold an equal potential to create stranded assets for investors throughout other sectors of the economy. Were the supply-side of the fossil fuel equation to face a carbon bubble scenario, so would significant portions of the demand side for fossil fuel products.

Auto manufacturers, agricultural producers, construction and a wide array of the processes used in production and consumption of modern goods and services would face costs from reducing or eliminating fossil fuel use in their operations, even in a carbon policy framework. Cash flow disruptions would be likely for many firms outside of the energy industry, meriting stranded asset concern for investors in many sectors. As this scenario demonstrates, investing in renewable energy infrastructure will continue to expose an endowment to considerable levels of emissions through the coming decades.

While we agree with proponents of the carbon bubble hypothesis that this exposure will carry financial implications, decarbonizing an institutional portfolio to avoid these impacts will remain a difficult task. Investment holdings are claims on future income streams and their potential to be disrupted by a dramatic change in our total primary energy supply is not negligible.

4.2 Hypothesis B: Focusing on listed reserves is important because shutting down publicly traded energy companies would keep a significant portion of future oil, gas and coal reserves underground

The fossil fuel divestment movement targets major independent oil companies because of the GHG emissions embedded in their reserves and their political influence. Carbon bubble literature regularly focuses on the listed reserves of these companies. As the movement's leader and originator Bill McKibben (2012a) stated, "We need to view the fossil-fuel industry in a new light. It

has become a rogue industry, reckless like no other force on Earth. It is Public Enemy Number One to the survival of our planetary civilization". While campaigners have targeted these specific companies, publicly traded oil and gas is playing a diminishing role in global energy production. This places a natural limit on the efficacy of targeting the firms on global financial exchanges and their listed reserves.

In analyzing five recent years (2006-2011) of the oil and gas industry, Mitchell and Mitchell (2014) found that the liquid fuel output from publicly listed companies declined by more than 4%. Their data estimates that national oil companies have exclusive access to almost 75% of the worlds currently proved oil reserves. [15] Growth in conventional oil output during these years resulted from companies that are under full or partial state control, such as Brazil's Petrobras or Saudi Arabia's Aramco. Nelson, et al. (2014) project that governments and government-owned companies are projected to receive nearly 87% of the net present value of future oil production between 2014 and 2050.

The balance and distribution of world liquid fuel output is slowly shifting away from the publicly listed 'brand name' oil companies of the 20th century such as Exxon Mobil or Shell. Sovereign nation balance sheets along with international debt and debtor relationships will work to ensure that national oil company (NOC) resources will be extracted. We suggest that until Saudi Arabia's national revenues are supported by non-oil income, their oil will be produced.

Aissaoui (2013) analyzed the fiscal policies pursued by Organization of Petroleum Exporting Countries (OPEC) members and found that they need high prices for their oil to break even on their national budgets. He estimates that Libya, Venezuela, Ecuador, Iraq, Nigeria, Algeria and Iran all need more than $90 per barrel.

As noted by Bullard (2014), governments are also among the largest investors in all forms of fossil fuel extraction. The Government of India holds $38 billion (16%) of global coal investments. The largest 25 investors in oil and gas firms control nearly $1 trillion (20%) of top global oil and gas holdings; 30% of these investments are held by governments such as Russia, Colombia, Norway, India and China.

Nelson, et al. (2014) estimate in a recent Climate Policy Initiative (CPI) report that the most of the $25 trillion in potentially stranded oil and gas assets would be on the books of governments. National governments own 50-70% of global fossil resources and collect taxes on the operations of private sector energy companies. CPI's models estimate that the largest potential for emission reductions lie in reducing the use of coal but 75% of stranded asset value would be in oil reserves. Bauer, et al. (2013) estimate that more than 40% of the $30 trillion in 21st century fossil fuel revenues would be captured by the Middle East & North Africa region.

Were divestment campaigns to stigmatize lending to fossil fuel projects, many state controlled companies have sovereign funds that can continually support extractive activities, even if they would need to undergo significant restructuring. During the oil price declines that took place during 2014, the Saudi Arabian Oil Co., Abu Dhabi National Oil Co. and Kuwait Petroleum Corp boosted their production to a record number of drilling rigs, while IOCs reduced investment. These

[15] Mitchell and Mitchell classify ownership of proved oil reserves as: wholly public companies (5%), fully nationalized companies (23%), publicly listed national oil companies (47%), other (21%) and mixed (4%).

companies are expected to increase their aggregate investment in oil exploration and production investment by 4.5% in 2015, while global oil investment falls by 17%. State owned companies have greater flexibility to pursue investment patterns that are counter-cyclical to current market conditions.

Though state-owned reserves are likely to dominate the future of fossil fuel extraction, Leaton, et al. (2013) make a case that private companies are responsible for over half of potential production through 2050. State-owned entities have many partially listed companies, increasing the amount of listed reserves. Yet, our perspective is that were these partially listed companies to face collapsing share prices due to investors fleeing a carbon bubble, their oil reserves would still be burned. The assets of these companies would likely be nationalized and absorbed into their state owned entities.

4.3 Hypothesis C: Large institutions can substitute green energy investments for holdings of fossil energy companies

As the Divest-Invest organization states in the header of its website: "Divest from fossil fuels, invest in climate solutions." A subsidiary goal of fossil fuel divestment campaigns is to substitute holdings of fossil energy companies with investments in renewable energy (see 350.org 2013). Institutional investors will face challenges with this substitution for two main reasons: (1) fund managers can easily honor divestment commitments through shifting investments into sectors that appear low-carbon merely because they are in a tertiary sector of the economy and (2) equity holdings of fossil fuel companies have different characteristics than viable investments in renewable energy projects or companies.

4.3.1 Low carbon investments: only a label?

One industry may benefit significantly from the divest-invest strategy: our recent research (2014) suggests that because of their apparent low GHG impacts, financial institutions will be a prime target for divested funds seeking to go 'fossil free'. Divestment strategies that intend to optimize investor earnings per unit of carbon will naturally be biased to re-invest in financial institutions.[16] These institutions demonstrate a high level of earnings per unit of carbon consumed in their operations. Yet, financial intermediaries are directing capital throughout the economy and may still be investing in fossil fuel projects.

As an example, the Fossil Free investment offering developed by Canadian-based fund manager Genus Capital in response to the 350.org divestment campaign screens companies involved in the extraction, transportation and processing of fossil fuels. In their domestic portfolio, this removes roughly 25% of the Toronto Stock Exchange. Canadian energy companies are replaced with the major Canadian banks which invest heavily in oil and gas extraction. More than half of Genus' Canadian fossil free portfolio is in financial institutions. A large influx of capital into banks could potentially support lower interest rates on loans to oil companies pursuing the development of marginal reserves, directly undermining the aims of divestment commitments.

In 2014, the National Resources Defense Council partnered with FTSE and BlackRock Investments to create a branded 'ex-fossil free' index, a move hailed by 350.org (as reported in Clark 2014). The initial prospectus of this fund (see FTSE Group 2014) notes that it invests in 60 oil

[16] Especially in Canada as roughly 25% of the TSX market cap is largely energy companies and another 50% are banks that finance the fossil fuel sector.

& gas companies (2.3% of assets). One of its 10 largest holdings is JP Morgan, a bank heavily invested in coal (see Collins, et al. (2014).

State Street and iShares have launched Low Carbon Target ETFs. Each of these ETFs emphasizes investment in "companies with low carbon emissions relative to sales and per dollar of market capitalization". Both funds track the MSCI ACWI Low Carbon Target GR USD and have a combined $240 million in assets under management as of February 2015. These two ETFs allocate most of their investments to banks. Both the iShares MSCI ACWI Low Carbon Target (CRBN) and the SPDR MSCI ACWI Low Carbon Target ETF (LOWC) have roughly 20% of their investments in the financial sector. The top 25 holdings of LOWC include the major oil companies of Enbridge and Schlumberger.

These strategies will likely continue to bias investment business activities that create the demand for fossil fuels, i.e. moving funds from the primary (oil, gas and mining) or secondary (manufacturing) sectors of the economy and into the tertiary. Divesting in this way would have little impact on an endowment's exposure to financial losses from a carbon bubble. To varying degrees, the tertiary sector is enabled by the energy economy supplied by the primary sector. Significantly changing the primary sector will be a carbon intensive activity, regardless of whether renewable energy or further fossil fuel energy is implemented.

Though many of the initial low carbon investment products may do little to reduce exposure to aggregate emissions, could institutional investors shift investments out of oil and gas equities directly to green companies?

4.3.2 Will institutions choose to substitute oil and gas equities with green equities?

Bullard (2014) of Bloomberg New Energy Finance suggests that institutional investors select fossil fuel companies for their portfolios because they offer four desirable characteristics: scale, liquidity, growth and yield. In terms of scale, combined Q3 2014 valuations for high-carbon equities were more than $5 trillion: fossil energy ($4.5 trillion) and the fossil components of utility companies (more than $1 trillion). This economic sector ranked second largest in aggregate market value.[17] Bullard also notes that oil and gas company equities consistently rank among the highest performers for dividend yield on global capital markets, with regular dividends that average more than 2%. Pension and university endowment funds exist to provide an income stream that supports the initiatives and priorities of their stakeholders and trustees; we analyze this dynamic in a recent paper (see Ritchie and Dowlatabadi 2015).

To compare metrics of growth, scale and yield for oil and gas equities with green equity investments, we evaluated 185 oil and gas companies alongside 280 green companies: wind and solar energy (n=109), energy efficiency (n=32), biomass & biofuels (n=32), recycling & green chemicals (n=25), sustainable transportation (n=21), energy storage (n=18), demand side management and smart grid technologies (n=16), water conservation (n=14), fuel cells (n=7) and geothermal power (n=6). These results are summarized in Figure 3. The top 100 green equities showed volatile growth potential, outperforming the total price returns of the top 100 oil and gas companies in six out of the last eleven years. Renewable energy equities compare less favorably with oil and gas in terms of scale and yield.

[17] The economic sector with the largest market value at this time was the financial sector ($9.3 trillion).

Equity Scale: Green v. Oil & Gas
Comparing market capitalization (in USD trillions)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Green Equities 280 wind, solar, etc...	0.36	0.35	0.46	0.57	0.65	0.40	0.78	0.84	0.72	0.74	0.94
Oil & Gas Equities 185 integrated and E&P	1.46	1.95	2.11	2.64	3.38	2.06	2.95	3.81	3.46	3.22	3.49

Equity Growth: Green v. Oil & Gas
Comparing average rates of total price return

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Green Equities Top 100 in market cap	6%	-5%	19%	13%	-10%	-14%	4%	11%	15%	10%	12%
Oil & Gas Equities Top 100 in market cap	7%	15%	8%	2%	-1%	-5%	2%	16%	7%	5%	2%

Equity Yield: Green v. Oil & Gas
Comparing average rates of dividend yield

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Green Equities Top 100 in market cap	1.24%	1.23%	1.44%	0.85%	1.05%	2.06%	1.14%	1.33%	1.53%	1.29%	1.11%
Oil & Gas Equities Top 100 in market cap	2.27%	1.95%	1.80%	1.90%	2.06%	4.34%	2.27%	1.81%	2.18%	2.00%	2.06%

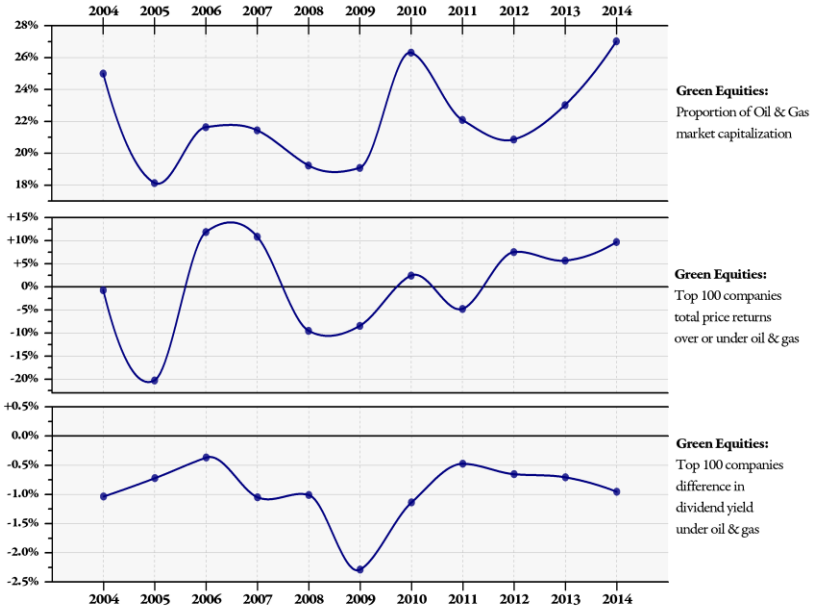

Figure 3. Comparing Equity Performance for 280 Green Companies v. 185 Oil & Gas; data on scale, growth and yield **(left)** and trend-lines over the last decade **(right)**

Pension or endowment managers optimizing for dividend yield and with low risk tolerance will find difficulty substituting their oil and gas equities for green companies. Funds with a fiduciary responsibility understandably have a conservative culture that limits interest in the developing universe of novel green economy investments. Balchunas (2015) recently highlighted this volatility in a report for Bloomberg on two key green energy ETFs, Guggenheim Solar (TAN) & Market Vectors Global Alternative Energy (GEX). Despite recent double-digit gains for these funds in 2015, the two ETFs had underperformed the S&P 500 by more than 100% since 2009.

Regardless, were the idea of divesting and reinvesting to catch on, the results may be unanticipated by campaigns. A rapid and large injection of yield-seeking investment has the tendency to create an unsustainable financial dynamic, rather than aiding in the long-term development of a market. Presently, a sudden divestment driven influx of large institutional investors into renewable energy companies could result in a 'green' bubble, much larger than the bubble in renewable energy companies from 2005-2011. Such a boom-bust cycle would sour investor sentiment for many years. Losses would result for institutions riding a divest-reinvest wave without enough industry revenues to justify valuations.

Could we really expect that switching investments from fossil fuel companies to renewable energy companies would be straightforward? Renewable energy generation assets have high initial capital expenditures and relatively low ongoing operational expenditures. A solar module or wind turbine has access to free fuel. These physical characteristics are likely to structure viable renewable energy investments as fixed income, where returns are provided as a sustainable yield.

Successfully investing in renewable energy will require significant changes to institutional investment policy that shifts focus to asset classes of fixed income, infrastructure, real estate and private equity. Climate bonds, renewable energy yieldcos, and securitized solar already provide viable investments that support development of solar cells and wind turbines. Institutional investors can realize this potential by modifying the targeted asset mix of their portfolio, changing their risk profile, adjusting expectations for the timing of returns and trading the upside potential of oil and gas equities for low volatility. This may not significantly reduce an endowment's carbon shadow in the short term, but would do more to mitigate carbon bubble risk than divesting and reinvesting funds in tertiary sectors of the economy.

Investments labeled as 'low carbon' are likely to spread as the divestment movement continues. Financial institutions understand this, and are launching a range of investment offerings with metrics that can appeal to the movement's logic. Divestment commitments signal that demand exists for these financial products. Unfortunately, many of these funds and securities are likely to be little more than label. For these 'fossil free' funds to actually aid in the development of a low carbon economy, they will need to move beyond simply substituting renewable energy for fossil fuel energy and into the forms of infrastructure, specifically transportation infrastructure, that create our dependencies on unsustainable levels of oil, gas and coal use.

5. Summary & Conclusions

In this paper we have provided an overview of fossil fuel divestment and the carbon bubble in the context of institutional investors. Several common hypotheses for fossil fuel divestment in the context of a carbon bubble risk were assessed. Our analysis indicates that: (a) institutional investors will have a limited ability to use divestment as a strategy for isolating their holdings from exposure to greenhouse gases; (b) institutions are exposed to notable financial risks from a low carbon future through their holdings in all sectors of the economy, not just oil, gas and coal producers; (c) using divestment to reduce fossil fuel consumption through focusing on international oil companies and listed reserves will have significant limits; (d) divesting from oil and gas producers to reinvest in renewable energy will require critical changes to institutional investment policies and expectations; and (e) institutional investors are likely to favour re-investment in tertiary sectors of the economy rather than in technologies or processes that could reduce fossil fuel use.

Despite these limitations, there is still a case for institutions to consider divestment. Moral leadership is about more than a purely financial logic. Institutions that commit to divestment or develop a policy to assess stranded asset risk can produce signals that change the wider institutional investing landscape. Our analysis of these hypotheses is positivist and not normative.

Though divestment at this point is primarily symbolic, its significance shouldn't be immediately dismissed. To see why, it is worthwhile to examine our own personal relationships to the symbolic powers that money and finance holds on our own motivations, perceptions and thoughts. Conversations on divestment could serve as a catalyst for reflecting on these associations and changing our shared expectations.

Even as invoking the imagery of a carbon bubble is suggestive of a sudden burst, there are a series of cumulative technological, social and economic factors that are likely to erode the balance sheet of conventional oil and gas energy companies. An increasingly costly marginal barrel of oil is threatening profit margins and undermining sales for many producers, even without climate policies.

Hudson, et al. (2014) writes for UBS that it is possible we could look back at the divestment campaign as an inflection point that led to low carbon investing:

"We highlight the fossil fuel disinvestment campaign as a potentially effective movement […] many of those engaged in the debate are the consumers, votes and leaders of the next several decades […] time, youthful energy and stamina are on the side of the fossil fuel divestment campaign."

As more institutions explore divestment, their commitments could end up being a novel form of financial 'greenwash'. However, they could also earmark tens of billions for a low carbon economy. For the dialogue on divestment to rise above symbolism, it would include a strategy for divested funds based on energy transition policies at every scale: national, provincial, state, regional, municipal and local. Though the divestment movement also hopes their efforts can remove roadblocks to Federal or international carbon tax policies, a number of more regionally focused intermediate policies can immediately apply the work of divestment campaigners toward reducing demand for fossil fuels.

Prototypes can be seen in some of the emerging energy finance institutions, especially in the US northeast and Germany. Early actors in creating policy frameworks and institutions for divested funds could benefit from increasing amounts of investment dollars seeking to go fossil free. The narrative of divestment has been heavily focused on the supply-side, but reducing demand for fossil

energy needs equal focus. Reorganizing the oil, gas and coal dependent production processes in many sectors will require forward-looking investments. Reducing liquid fuel demand for transportation needs will be of prime importance.

The technical dissonance currently inherent in carrying out a divestment commitment will need to be substantially addressed by the movement's narrative in more concrete ways. Otherwise, those who aren't naturally sympathetic towards their worldview will continually undermine, dismiss or ignore calls to divest. Fund managers unwilling to politicize their assets could then become easier allies. Regardless, fiduciary limitations on institutional fund managers will require a close examination of the technical fine points involved in switching asset allocations.

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References

[1] 350.org. (2014, January). Time for the carbon bubble to take center stage at the World Economic Forum. Retrieved on May 1, 2015, from http://350.org/press-release/time-for-the-carbon-bubble-to-take-center-stage-at-the-world-economic-forum/

[2] 350.org, Ressler, L., & Schellentrager, M. (2013). "A Complete Guide to Reinvestment", Retrieved on February 19, 2015, from https://s3.amazonaws.com/s3.350.org/images/Reivestment_Guide.pdf

[3] Aissaoui, A. (2013). *Modeling OPEC Fiscal Break-even Oil Prices: New Findings and Policy Insights*. *Economic Commentary* (Vol. 4). Retrieved from http://www.apicorp-arabia.com/2013-economic-commentary

[4] Ansar, A., Ben Caldecott, & Tilbury, J. (2013). *Stranded assets and the fossil fuel divestment campaign: what does divestment mean for the valuation of fossil fuel assets? Stranded Assets Programme* (pp. 1–81).

[5] Arabella Advisors. (2014). *Measuring the Global Fossil Fuel Divestment Movement*. *arabellaadvisors.com*.

[6] Balchunas, E. (2015, May 14). Clean Energy ETFs Are on a Tear. Retrieved May 20, 2015, from http://www.bloomberg.com/news/articles/2015-05-14/clean-energy-etfs-are-on-a-tear

[7] Bauer, N., Mouratiadou, I., Luderer, G., Baumstark, L., Brecha, R. J., Edenhofer, O., & Kriegler, E. (2013). Global fossil energy markets and climate change mitigation – an analysis with REMIND. *Climatic Change*, 1–14. http://doi.org/10.1007/s10584-013-0901-6

[8] Ben Collins, Kornfield, J., & Kresowik, M. (2014). *Coal Finance Report Card 2014* (pp. 1–50). Rainforest Action Network.

[9] Bullard, N. (2014). *Fossil fuel divestment: a $5 trillion challenge*. *Bloomberg New Energy Finance White Paper Series* (pp. 1–19).

[10] CanOils. (2015). *How Sustainable is Canadian Oil & Gas at $50 per Barrel?* (pp. 1–16).

[11] Clark, P. (2014, April 28). FTSE joins Blackrock to help investors avoid fossil fuels. Retrieved May 12, 2014, from http://www.ft.com/cms/s/0/14787a44-cef6-11e3-ac8d-00144feabdc0.html

[12] Cowles, J. H. (2014). *Storms on the Horizon* (pp. 1–8). IMPAX Asset Management.

[13] Denniss, R., Pender, H., & Swann, T. (2014). *Climate Proofing Your Investments: Moving Funds Out of Fossil Fuels*. *Market Forces*.

[14] Fischel, D. R. (2015). *Fossil Fuel Divestment: A Costly and Ineffective Investment Strategy*. *divestmentfacts.com*.

[15] Friedlingstein, P., Houghton, R. A., Marland, G., Hackler, J., Boden, T. A., Conway, T. J., et al. (2010). Update on CO2 emissions. *Nature Geoscience*, *3*(12), 811–812.

[16] FTSE Group. (2014). FTSE Developed ex Fossil Fuels Index Series, 1–3.

[17] Geddes, P. (2013). *Do the Investment Math: Building a Carbon-Free Portfolio* (pp. 1–9). Aperio Group.

[18] Hay, J. (2014, October 10). Carney raises the heat on climate: you can't burn all the oil. Retrieved October 13, 2014, from http://www.emergingmarkets.org/Article/3389530/Carney-raises-the-heat-on-climate-you-cant-burn-all-the-oil.html

[19] Hudson, J., Jeaneau, H., Zlotnicka, E. T., & Houchois, P. (2014). *ESG Keys: Fossil Fuel Disinvestment*. *UBS Global Research Equities - Global Sustainability* (pp. 1–16).

[20] IMPAX Asset Management. (2013). *Beyond Fossil Fuels: The Investment Case for Fossil Fuel Divestment* (pp. 1–10).

[21] Inkpen, A. C., & Moffett, M. H. (2011). The Global Oil & Gas Industry. *PennWell Books*. PennWell Books.

[22] IPCC. (2013). Climate Change 2013: The Physical Science Basis. (T. F. Stocker, D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, et al.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

[23] Le Quéré, C., Peters, G. P., Andres, R. J., Andrew, R. M., Boden, T. A., Ciais, P., et al. (2014). Global carbon budget 2013. *ESSD*, *6*(1), 235–263.

[24] Leaton, J., Campanale, M., & Leggett, J. (2011). *Unburnable Carbon*. *Carbon Tracker Initiative* (pp. 1–36). London, UK: Carbon Tracker Initiative.

[25] Leaton, J., Fulton, M., Capalino, R., Spedding, P., Sussams, L., & Andrich, M. (2014). *Carbon Supply Cost Curves: Evaluating Financial Risk to Oil Capital Expenditures* (pp. 1–71). Carbon Tracker Initiative.

[26] Leaton, J., Ranger, N., Ward, B., Sussams, L., & Brown, M. (2013). *Unburnable Carbon 2013: Wasted capital and stranded assets*. Carbon Tracker Initiative & The Grantham Research Institute.

[27] Lewis, M. C. (2014a). *Stranded assets, fossilised revenues*. *ESG Sustainability Research* (pp. 1–35).

[28] Lewis, M. C. (2014b). *Toil for oil spells danger for majors*. *ESG Sustainability Research* (pp. 1–134).

[29] McGlade, C., & Ekins, P. (2015). The geographical distribution of fossil fuels unused when

limiting global warming to 2 ℃. *Nature*, *517*(7533), 187–190. http://doi.org/10.1038/nature14016

[30] McKibben, B. (2012a, July). Global Warming's Terrifying New Math. Retrieved March 18, 2014, from http://www.rollingstone.com/

[31] McKibben, B., & Naidoo, K. (2012). Do the math, fossil fuel investments add up to climate chaos. Retrieved November 2014, from http://gofossilfree.org/

[32] Meinshausen, M., Meinshausen, N., Hare, W., Raper, S. C. B., Frieler, K., Knutti, R., et al. (2009). Greenhouse-gas emission targets for limiting global warming to 2 °C. *Nature*, *458*(7242), 1158–1162. http://doi.org/10.1038/nature08017

[33] Meyer, N., & Brinker, L. (2014). *Deflating the Carbon Bubble*. *IHS Energy*.

[34] Mitchell, J. V., & Mitchell, B. (2014). Structural crisis in the oil and gas industry. *Energy Policy*, *64*, 36–42.

[35] Morgan Stanley Capital International. (2013). *FAQ: Responding to the Call for Fossil-fuel Free Portfolios*. *MSCI ESG Research Brief*.

[36] Nelson, D., Hervé-Mignucci, M., Goggins, A., Szambelan, S. J., Vladeck, T., & Zuckerman, J. (2014). *Moving to a Low-Carbon Economy: The Impact of Policy Pathways on Fossil Fuel Asset Values*. *CPI Energy Transition Series* (pp. 1–47).

[37] Paun, A., Knight, Z., & Chan, W.-S. (2015). Stranded assets: what next? *HSBC Climate Change*, 1–28.

[38] Redmond, S., & Wilkins, M. (2013). *What A Carbon-Constrained Future Could Mean For Oil Companies' Creditworthiness*. *RatingsDirect* (pp. 1–11).

[39] Ritchie, J., & Dowlatabadi, H. (2014). Understanding the shadow impacts of investment and divestment decisions: Adapting economic input–output models to calculate biophysical factors of financial returns. *Ecological Economics*, *106*, 132–140. http://doi.org/10.1016/j.ecolecon.2014.07.005

[40] Ritchie, J., & Dowlatabadi, H. (2015). What Divesting May Yield: Revisiting "The Grasshopper and the Ant" in the Context of University Endowments. *Journal of Environmental Investing*, 6(1), 51–74. http://doi.org/http://www.thejei.com/wp-content/uploads/2015/05/Complete_Divestment_JEI_5-14-151.pdf

[41] Shapiro, R. J., & Pham, N. D. (2011). *The Financial Contribution of Oil and Natural Gas Company Investments to Major Public Pension Plans in Seventeen States, Fiscal Years 2005-2009* (p. 110). Sonecon.

[42] Spedding, P., Metha, K., & Robins, N. (2013). *Oil & carbon revisited*. *HSBC Climate Change* (pp. 1–28). London, UK.

[43] Syme, A. R., Alsford, M. J., Cunningham, G., Garadaghi, M., Greenwood, M., Handa, S., et al. (2013). *Global Oil Vision* (pp. 1–152). Citi.

[44] Vigna, della, M., Tarr, H., Morris, H., Jost, C., Hackworth, P., Brooker, R., & Kumar, N. (2013). *380 Projects to Change the World*. *Goldman Sachs Equity Research*.