CONSTRUCTING A SOCIAL PROFITABILITY INDEX

SOCIALLY RESPONSIBLE INVESTING IN ELECTRIC UTILITIES

ODESSA BÄCKFORS

EBBA JERNMARK BURROWS

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Constructing a Social Profitability Index: Socially Responsible Investing in Electric Utilities

Abstract:

Building on a theory about the Social Profitability Index (SPI), this paper is the first to construct an SPI in practice ranking investment opportunities based on social and financial returns within the electric utility industry. The social return is the investor-preference weighted social gain from avoiding carbon emissions by changing to renewable production technology in a firm. Using data from listed companies in the U.S. electrical utilities sector, we find that the SPI of a company is heavily dependent on its carbon intensity and moderately dependent on the company's location. This makes different technologies suit different companies due to the influence that location has on renewable technology efficiency. In conclusion, investing in "sinful", high carbon intensity electricity companies is optimal for socially responsible investors who can change part of the company technology through shareholder activism.

Keywords:

Socially responsible investing, Social Profitability Index (SPI), Sustainability ratings, Shareholder activism, Green transition, ESG, Renewable electricity, Fossil fuel emissions, Carbon intensity, Sustainable investing.

Authors:

Odessa Bäckfors (25093)
Ebba Jernmark Burrows (25203)

Tutor:

Marcus Opp, Professor, Department of Finance

Examiner:

Adrien D'Avernas, Assistant Professor, Department of Finance

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1 Introduction

Socially responsible investing (SRI), where environmental, social, and governance (ESG) issues are incorporated into investment decisions, is on the rise (Sandberg et al. 2009). Although investments in ESG-related assets are increasing (Matos 2020), estimated to reach a share of about 20% of all assets under management in 2026 (Alexander 2022), socially responsible capital can be argued to be scarce relative to conventional profit-seeking capital. Due to its scarcity, it is of large importance for socially responsible investors and funds to efficiently allocate their capital to maximize the total welfare (Oehmke and Opp 2023). In this paper, we make a contribution to the field of socially responsible investing by being the first to implement an index called the Social Profitability Index (SPI) for the electric utilities sector in the US for practical use. We show that, for socially responsible (SR) investors looking to optimize both financial and social return, the optimal allocation of capital is to invest in high carbon-intensive companies, conditional on assuring the funding is used by the company for changing to cleaner technology. Out of the ESG components that can be included in SRI decisions, we focus solely on the environment (E) and more specifically carbon emissions, since global warming is one of the most critical challenges of today. Moreover, the Paris Agreement, which is a legally binding treaty on climate change signed by 194 countries in 2016 (UNFCCC 2023), has as one of its main objectives to make finance flows consistent with a pathway towards low greenhouse gas emissions (UNFCCC 2016). The electric utility sector is of high relevance to study since it generates the largest amount of carbon emission: In 2022, 42% of total global sector carbon emissions came from power, followed by that of industry, transport, and buildings (IER 2023).

The purpose of this thesis is to put sustainable finance theory into practice by proposing a way to construct a Social Profitability Index, which could guide SR investors in investment decisions. Our thesis builds on Opp and Oehmke's newly published paper, *A Theory of Socially Responsible Investment*, where a Social Profitability Index is introduced in theory. SPI is an index suggesting an optimal way for impact investors to rank investments and allocate capital in terms of both financial and social return, where the latter is defined in terms of the amount of negative externalities avoided relative to the case of being funded by a purely profit-motivated investor maintaining status quo. Despite the magnitude of the investment object's current social costs, the SPI focuses on the change in social costs that a socially responsible investor could achieve through shareholder activism (Oehmke and Opp 2023).

In this paper, we aim to answer the following research question:

How can we construct a Social Profitability Index in practice that can rank investment opportunities based on optimizing the trade-off between financial cost and social benefit, and what are the properties of the suggested index?

We formulate the following hypotheses connected to our research question:

Hypothesis 1: Companies with high carbon intensity will receive higher values in our SPI compared to renewable energy companies.

Hypothesis 2: Sustainalytics' Environmental Risk Scores will correlate with our SPI, where high ERS will give high values in SPI.

Our analysis shows that carbon intensity is positively correlated with SPI and that companies with coal as their primary source for generating electricity receive the highest values in our SPI on average. We can conclude that investments in ”sinful” fossil fuel companies with high carbon intensity are the optimal choice for SR investors using the SPI as an investment criterion, subject to the investor successfully making the companies switch to cleaner energy production through shareholder activism. Furthermore, we find no correlation between the Environmental Risk Scores (ERS) from Sustainalytics and SPI. Thus, we can conclude that ERS cannot be used as a substitute for SPI since high Environmental Risk Scores do not necessarily translate to high values in SPI. We can also conclude that our SPI is sensitive to the estimate of the Social Cost of Carbon (SCC) (Nordhaus 2017), which is an input parameter used for pricing carbon emissions in our SPI and the investors' internalization of social costs (defined as g). Lastly, our analysis shows that companies will choose different types of energy production technologies when SPI proclaims a change, which is dependent on the current location, the SCC and g, and the investor's preference for financial vis á vis social return.

1.1 Creation of SPI

To create the SPI in practice, we have chosen to outline the social benefit by estimating the benefit of avoiding carbon emissions and financial cost as the cost of implementing a change to greener operations in a company. We only include companies from the electric utility sector in the index, as this sector generates the largest amount of carbon emission. Furthermore, creating an SPI index for the electric power industry is important due to the large and urgent need for investments in this sector to enable the energy transition. $4 trillion is needed to reach net-zero emissions by 2050 and clean energy investments must more than triple by 2030 to reach the goal (UNDP 2023). Although investments in renewables are increasing, 82% of the world's energy demand in 2022 was still met by fossil fuels (IER 2023). At the same time, investments in fossil fuels have been rather stable since 2015 (Bocco 2023). Therefore, to reach the objectives of the Paris Agreement, it is not enough to only increase fund flows to renewable energy companies; fund injections to dirty production also have to decrease if we are to limit the global temperature increase. Creating an SPI that directly involves fossil fuel companies instead of excluding them is thus highly relevant. The electric utility sector is also a good choice of industry due to the direct connection between business activity and emissions coupled with the small number of alternatives for electric power production. Also, the product itself, which is energy produced, is directly comparable across companies.

More specifically, companies producing electricity from the primary energy sources of coal, natural gas, nuclear, hydro, wind, and solar will be included in the study to see the difference in how fossil fuel investments compare to renewable investments, where nuclear is included in the definition of renewables. When evaluating how much emission can be avoided, we compare the current emission intensity to what could be achieved if the company switched part of their production to renewable energy sources since the renewable energy sources emit substantially less CO_2e relative to non-renewables. For example, coal plants generate, on average, 75 times more life-cycle

emissions when compared to electricity produced based on offshore wind (Schloemer et al. 2014). We exclude the possibilities of improving the operations in terms of other measures such as reducing business travel since it will result in negligible CO_2e emission savings. Moreover, we exclude the opportunity of investing in more efficient fossil fuel plants since it will give minor reductions of carbon emissions in comparison to switching to renewable energy plants and is costly.

Furthermore, we narrowed down the study by only focusing on listed U.S. electricity-producing companies. It is an interesting geographical market to study as the U.S. is the second largest polluter of carbon emissions after China, where China stands for 26.4% of the global carbon emissions and the US for 12.5% of the CO2e emission, based on data from 2021. In 2022, 31% of total U.S energy-related CO2e emissions came from the electric power sector, and of these emissions, 98% came from coal- and natural gas (EIA 2023b), showing that it is a market in urgent need of an energy transition.

2 Related Literature

In this section, we give an overview of the literature to which our paper is connected. Our paper contributes to the literature on socially responsible investing, such as Oehmke and Opp's paper *A Theory of Socially Responsible Investment* (Oehmke and Opp 2023), by filling the gap between the theory and practical construction of the Social Profitability Index. Furthermore, we contribute to the SRI field by proposing an index intended for SRI which is niched to the U.S. energy sector and focused on carbon emissions, while most mainstream indices are more general by incorporating several industries, geographical markets, and ESG factors. Additionally, unlike most other indices and ratings within SRI that only take into account social return, our SPI optimizes both the financial and social return. Lastly, our paper contributes to the field of shareholder activism, as our SPI is intended for investors to make an impact by actively engaging with the companies, unlike most mainstream indices and ratings which rely on impact through the financial market.

2.1 Socially Responsible Investing Today

As the interest and importance of SRI grows, the coverage of the topic in academia has subsequently increased as seen from the growing number of studies published in academic journals within the field of SRI (Renneboog, Ter Horst, and Zhang 2008) (Widyawati 2020). Although there is consensus among academics on a theoretical level that SRI positively impacts companies' sustainability performance, there is an ongoing debate about how to practically implement ESG criteria when making investment decisions (Sandberg et al. 2009). There is disagreement about which one of the two major SRI strategies, screening and shareholder activism, generates the largest actual impact on corporate practices. Screening can be divided into negative and positive screening, where negative screening is based on excluding investments that do not satisfy chosen ESG criteria(s) while positive screening reflects the selection of investments based on "best-in-class" performing assets. Shareholder activism entails investors taking an active role and investing in assets to improve current sustainability practices regardless of current ESG performance (Widyawati 2020). The mentioned SRI strategies are a popular topic, where almost 25% of papers published in academic journals be-

tween 2000-2009 mentioned activism, almost 14% mentioned the term "best-in-class", and about 22% covered the strategy of "filter or screen" (Capelle-Blancard and Monjon 2012).

Rivoli argues that screening is efficient through the effects on required returns and valuations, provided that perfect market assumptions are relaxed. The argument is that firms are more responsive to SRI the steeper the slope of the demand curve is for the firm's equity (Rivoli 2003). In contrast, Sparks and Cowton argue that through the lens of large institutional investors, shareholder activism is a more impactful method compared to passive engagement in terms of screening (Sparkes and Cowton 2004). Other researchers, such as Oehmke and Opp, also agree with Sparks and Cowton. Oehmke and Opp consider financial markets to be competitive, and because of this, they argue that negative screening does not have a large impact on the cost of capital of companies within "sin industries", such as the oil and gas industry as they consider financial markets to be competitive, and because of this, they argue that negative screening does not have a large impact on the cost of capital of companies within "sin industries", such as the oil and gas industry. Likewise, choosing to invest in "clean firms", such as renewable energy companies, which essentially is positive screening, they claim to not be efficient investment decision since these types of firms already perform well from an ESG perspective. Thus, they argue that socially responsible capital invested in these types of firms does not result in any change and could be better used elsewhere (Oehmke and Opp 2023).

Empirical studies on the effect of screening indices on corporate behavior have been done. McKenzie, Rees, and Rodionova studied the effect of the introduction of FTSE4Good environmental criteria, which was introduced in 2002, where companies had until 2005 to comply with said index. The treatment group consisted of 377 FTSE4Good firms that failed to meet the new criteria by 2002 but were included in the index, and the control group consisted of 652 non-FTSE firms failing to meet the same criteria by the same point in time. The study concluded that firms at risk of potential exclusion from the index were more likely to have complied with the FTSE4Good environmental criteria by 2005, thus proving the efficiency of the index, and screening as a strategy in terms of impact (Mackenzie, Rees, and Rodionova 2013).

Various methods and indices have been developed when it comes to the practicality of investing in a socially responsible way. Historically, and still today, negative screening is a prevalent strategy, roughly 40% of professionally managed European assets applied negative screening during 2019, which for instance could be the exclusion of so-called *sin industries* such as tobacco, weapons, and oil. The popularity has arisen from the simple nature of the negative screening strategy and not necessarily because it is the most efficient and impactful approach to socially responsible investing (Camilleri 2021). Another popular approach to SRI is to use ratings and indices to evaluate companies. Several indices, rankings, and ratings (Corporate Sustainability Systems, CSS in short) have been developed where corporate performance is rated based on sustainability, for example the Dow Jones SustainabilityIndex and the SustainabilityYearbook. All rankings and ratings use a score and some CSSs make use of bands to group companies with similar performance to simplify comparisons. Moreover, the economic aspect is present in a large majority of the CSS concerning the selection and/or evaluation of companies (Diez-Cañamero et al. 2020). Although the economic aspect is part of the assessment, none of the indices and ratings focus on the optimal choice of investment based on the tradeoff between social return and financial return, providing a gap in the previous mainstream supply of CSS (Camilleri 2021).

Another common rating is Sustainalytics ESG Risk Rating, where ESG Risk Scores are provided for different sectors and companies, where environmental, social, and governance risk scores are separately presented. The Environmental Risk Scores assess the degree to which a company's economic value is at risk driven by environmental issues. Moreover, the rating employs a two-dimensional framework that combines an assessment of a company's exposure to industry-specific environmental issues with an assessment of how well the company is managing those issues. The final Environmental Risk Score is a measure of unmanaged risk on an absolute scale of 0-100, with a lower score indicating less unmanaged ESG Risk. These risk scores function in a similar way to the above-mentioned ratings and indices in terms of being suited for the screening strategy. The scores can be found for most mid- and large-cap companies on Yahoo Finance. In this way, investors can make informed socially responsible investments by using the ERS to pick the best-in-class firms and avoid firms with high Environmental Risk Scores. At the same time, they receive returns data from Yahoo Finance, enabling them to form their perception about the optimal choice from both a financial and ESG perspective (Sustainalytics 2021).

An index intended for SRI but which is not part of the mainstream indices and niched to one sector is Bertolinelli et al.'s Social-Environmental Profitability Index (SEPI) (Bertolinelli, Pinti, and Bonelli 2022). SEPI is used to classify and rank projects based on a ratio of impact to costs. Instead of solely considering initial costs and lifetime costs for management and maintenance, the index also includes social and environmental benefits. The SEPI is intended to be used for the optimal allocation of public resources within the field of green infrastructure investments. To measure social and environmental impact, the SEPI takes into account the market value for the amount of green area per student, the market value for the amount of equipped area for sport/recreational/educational activities, the market value of the paved area, trees ornamental value and the value of stocked and absorbed CO2 by the lawn. The latter value is obtained by multiplying kg of stocked/absorbed CO2 by its price/kg on the European market based on the Emission Trading Scheme (ETS). The costs in the SEPI are based on the cost of the school ground renovation project and the costs for managing the school grounds per year, which are discounted. The SEPI index is one of few examples of indices considering social and environmental impact and costs, which is similar to the SPI. However, SEPI only focuses on public green infrastructure projects and the study is done on a small and specific geographical area in Italy. Thus, we contribute to the discussed paper by focusing on another sector and market.

2.2 Theoretical Framework

Oehmke and Opp (Oehmke and Opp 2023) explore how socially responsible funds can change firm behavior by efficiently reducing externalities and propose a theoretical investment model that combines social and financial return which they labeled the Social Profitability Index (SPI). This theoretical model constitutes the basis for the SPI constructed in our paper.

In Oehmke and Opp's model, abundant profit-seeking capital and scarce socially responsible capital are assumed. Moreover, the degree of the SR funds' internalization of external social costs is also assumed and varies between SR investors who are therefore willing to sacrifice financial return in exchange for social. From these assumptions, the SPI index is formed and intended to work as a way for SR investors to assess how to allocate SR capital optimally. In Oehmke and Opp's

model, a firm can choose between investing in dirty and clean production technologies, which we in this thesis derive from the choice between renewable energy production and fossil-fuel energy production. Moreover, Oehmke and Opp assume SR investors to have an impact mandate, meaning that besides the financial return, the SR investors recognize the social costs of externalities generated from not investing in a particular firm. In comparison, an SR investor with a narrow mandate only recognizes social costs as the direct externalities generated by the firm they have invested in. Oehmke and Opp highlight the importance of SR investors holding an impact mandate for SRI to have a real effect. Moreover, they highlight the relevance of estimating the SPI in practice using emission data from different production technologies, which we aim to do in our thesis.

Having a narrow mandate as an SR investor could be connected to the rich literature about screening strategies, as the objective is to invest in the firm with the smallest social costs generated today. However, holding an impact mandate requires a more active approach. For an SR investor with an impact mandate, it could be more beneficial to invest in a dirty fossil fuel company due to the possibility of avoiding a larger extent of social costs given the financial return is sufficient. However, investing with an impact mandate in a fossil fuel energy-generating company is conditional on actively promoting clean technology. Thus the SPI could be said to belong to the literature about shareholder activism. In summary, we contribute to the literature about shareholder activism by constructing an investment index for SR investors with a broad impact mandate. We fill a gap in the literature about indices, rankings, and ratings since the most commonly used CSSs are based on screening strategies and targeted to SR investors with a narrow impact mandate.

3 Model Setup

In this section, we describe in detail how we construct our SPI. To begin with, our SPI has two main parts: estimation of the financial costs and estimation of the avoided social cost of carbon due to the change in company-induced emissions that the investor can (and wants to) accomplish.

3.1 Constructing the SPI

Our SPI is a linear combination of the financial cost and the social benefit, where the financial cost is weighed with a weight of 1 for all investors and the social benefit is weighed with an investor-specific constant g, the degree of the internalization of social costs. The range of g is $[0, 1]$, assuming a non-SR investor is indifferent to social costs (resulting in the lower bound $g = 0$), and that no investor weighs the social cost of carbon more than the actual cost (resulting in the upper bound $g = 1$). The weight of 1 on the financial cost is based on that investors all value their own money equally. Effectively, g measures the willingness to sacrifice financial returns in exchange for social return.

3.1.1 SPI definition

For an investment of I dollars, our SPI for company i is defined as in equation (1).

$$SPI_i = \frac{\max_{t \in T}(-g * SCC * \Delta CO_2 e_{it} - IC_{it})}{I_i} \tag{1}$$

An SR investor will, through shareholder activism, replace part of the current electricity-producing fleet in the company i with a more sustainable technology $t \in T$, where T is the set of optional technologies available if the social gain of that change multiplied with the investor's g is larger than the cost of the replacement. In our paper the set of optional technologies available to implement, T is $T = \{$Wind power (Onshore) and Solar power (PV)$\}$. We define the social gain as the total decrease in CO_2e emissions multiplied by the Social Cost of Carbon (SCC). The SCC is defined as the discounted economic cost generated by an additional unit of CO_2e emissions, quantifying the climate change impact (Nordhaus 2017). The investment in a company i, denoted I_i, is upper bound by the market cap of the company i, MC_i, and by the amount the investor is willing to invest. This gives us:

$$I_i = \min(MC_i, I). \tag{2}$$

The term IC_{it} is the investment cost in technology t for company i. To calculate this we need to know how many MWh the investment will produce during its lifetime, ΔMWh_{it}, which technology the investment will be in, the cost of that technology, as well as the capacity factor of that technology in the area that the company operates in. A capacity factor is a type of efficiency that measures how much of the power generating capacity (usually measured in MW) a wind turbine or solar panel can use in a particular location. The capacity factor can differ quite a lot in different geographical areas. For example, a wind turbine produces much more electricity when placed in a windy area than in a sheltered one. The capacity factor for technology t and company i, c_{it}, that we use is the median of all the reported capacity factors in the state(s) in which the company i operates. We make this choice since we assume the areas with the best capacity factors will already be in use and we use the median instead of the mean since it is not sensitive to outliers. Also, we have a cost measure a_t, defined as the capacity in MW per dollar invested in a technology t (all costs included, for detail see section 4.2). To translate the MW per dollar to MWh per dollar, we also need the lifetime L_t of technology t in years, and the fact that there are $8,760$ hours in a year. We get an expression for the investment cost of technology t for company i as follows:

$$IC_{it} = \frac{\Delta MWh_{it}}{a_t * 8760 * c_{it} * L_t} \tag{3}$$

Now, we need an expression for the amount of energy that is optimal to replace, ΔMWh_{it}. Our first bound on that change is that the investor can not make the company invest more money in new technology than the investment amount I_i. This gives us:

$$\Delta MWh_{it} \leq I_i * \left(\frac{1}{a_t * 8760 * c_{it} * L_t} \right)^{-1} = I_i * a_t * 8760 * c_{it} * L_t. \tag{4}$$

We also assume the change leaves the total produced MWh in a year, E_i, constant. So, the investor cannot make a change so big that the company will produce more MWh in a year than it

currently does, giving us the second condition

$$\Delta MWh_{it} \leq E_i * L_t. \tag{5}$$

If the marginal benefit MB_{it} for an investor to act sustainable is positive, i.e. that the g-weighted social benefit of changing technology is higher than the cost, the investor will make the biggest change possible to the company with regards to the investment size. Directly from (4) and (5) we then get:

$$\Delta MWh_{it} = \begin{cases} \min\left(I_i * a_t * 8760 * c_{it} * L_t,\ E_i * L_t\right) & \text{if } MB_{it} > 0, \\ 0 & \text{otherwise,} \end{cases} \tag{6}$$

which combined with equation (3) would give us a new expression for IC_{it};

$$IC_{it} = \begin{cases} \min\left(I_i,\ \dfrac{E_i}{a_t * 8760 * c_{it}}\right) & \text{if } MB_{it} > 0, \\ 0 & \text{otherwise.} \end{cases} \tag{7}$$

Now, we have defined all expressions in (1) except ΔCO_2e_{it}, which is the change in CO_2e emissions a SR investor could bring. If the change is negative, we have fewer emissions than before and therefore would be avoiding emissions by changing to the technology t, which explains the minus sign before the g in equation (1). We calculate ΔCO_2e_{it} by multiplying the difference between the current emission intensity (in tCO_2e/MWh) of company i (EI_i) and the emission intensity of the new technology with the change in MWh the SR investor accomplish through shareholder activism. Which results in the following:

$$\Delta CO_2e_{it} = \Delta MWh_{it} * \left(\frac{b_t}{L_t * 8760 * c_{it}} - EI_i\right). \tag{8}$$

The rightmost term is the emission intensity of the new technology, where b_t is CO_2e emissions per MW for technology t (including manufacturing emissions and lifetime emissions), and L_t is the lifetime of technology t in years. We use the same ΔMWh_{it} as in equation (6). As before, 8760 is the number of hours in a year and c_{it} is our capacity factor. Then we have that:

$$\frac{b_t}{L_t * 8760 * c_{it}}$$

is equal to the number of metric tonnes of CO_2e emissions per produced MWh for the new technology t in company i. Using equation (7) we can derive that the cost per produced MWh as:

$$\frac{1}{a_t * 8760 * c_{it} * L_t}.$$

Replacing 1 MWh in company i with energy from technology t therefore gives an investor the following marginal benefit MB_{it}.

$$MB_{it} = g * SCC * \left(EI_i - \frac{b_t}{L_t * 8760 * c_{it}} \right) - \frac{1}{a_t * 8760 * c_{it} * L_t}. \tag{9}$$

If MB_{it} is positive, the SPI will be positive, otherwise it will be equal to zero. Now we have defined our SPI completely, and through equations (1), (2), (6), (7), (8), and (9) we can get a new expression for SPI, see equation (10). A summary of the input data needed to calculate our SPI is shown in Table 1.

$$SPI_i = \frac{\max_{t \in T}(0,\ \min\left(I_i * a_t * 8760 * c_{it} * L_t,\ E_i * L_t\right) * MB_{it})}{I_i} \tag{10}$$

Table 1: SPI input data

Name	**Definition**	**Type**
SCC	Social Cost of Carbon ($/ metric tonnes CO_2e)	Global
T	Set of technologies an investor can change to	Global
g	Degree of internalisation of social cost ($g \in [0, 1]$, no unit)	Investor
I	Investment size ($)	Investor
I_i	min(MC_i, I), the amount invested in company i ($)	Investor & Company
MC_i	Market Capitalization of company i ($)	Company
E_i	Energy produced in a year by company i (MWh/year)	Company
EI_i	Emission intensity for company i (metric tonnes CO_2e/MWh)	Company
c_{it}	Median(capacity factors for technology t in the area of company i) ($\in [0, 1]$, no unit)	Company & Technology
a_t	MW per dollar of a technology t (MW/$)	Technology
b_t	tCO_2e emissions per MW of technology t (including manufacturing emissions) (metric tonnes CO_2e/MW)	Technology
L_t	Lifetime of technology t (years)	Technology

4 Data

In the following section, we describe the data used and provide a critical evaluation of the sources.

4.1 Company Data

To find our data, we look at all companies classified to the sector *Utilities - Regulated Electric* by Yahoo Finance which is 32 companies in total. We require that the companies' headquarters and head of operations be in the U.S. The company must generate and sell electricity, where the majority

should be generated through coal, natural gas, nuclear energy, solar power, hydropower, or wind power. If the company has operations other than electricity generation, such as selling gas or owning electric grids, this part of the business should be negligible. Furthermore, we require the companies to have accessible information about their amount of sold electricity and the GHG emission Scope 1 and 2 data connected to its electricity generating operations. We have found that most large-cap and mid-cap companies meet all requirements. When gathering data for Scope 2 emissions, we chose location-based estimates as they are more accurate than market-based estimates. However, some companies lack location-based estimates and thus we use the market-based estimates for these companies. This could cause both under- and overestimation of the SPI values. On the other hand, the difference between the estimates of Scope 2 emissions from the different methods is marginal; additionally, the Scope 2 emissions are small in comparison to the companies' Scope 1 emissions. Hence, we consider this to be a small source of error regarding the accuracy of the data.

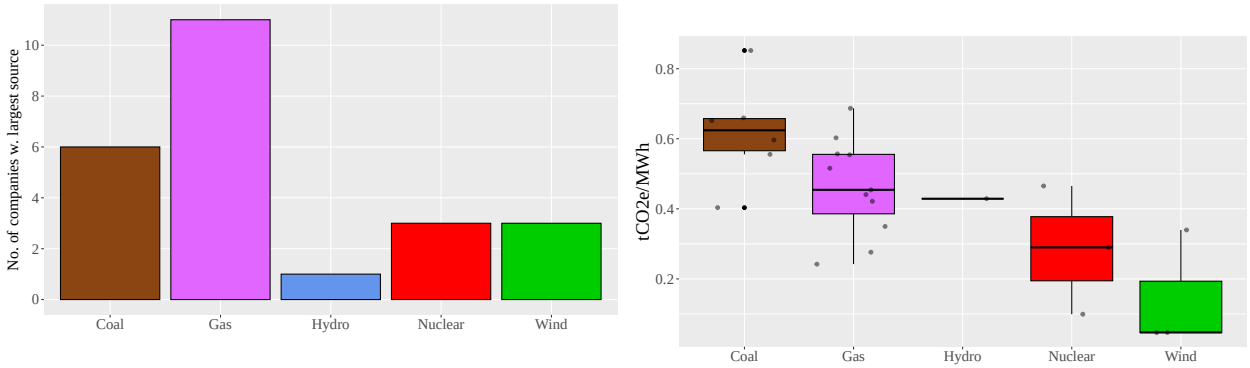
For each company, the area in which the company operates (in terms of U.S. states), the amount of net generated electricity in 2022, and the Scope 1 and 2 GHG emissions in 2022 are collected from company reports. The energy produced and carbon emissions data are found in the companies' CDP Climate Change Questionnaires. CDP is a not-for-profit charity and provides the largest TCFD-aligned (The Task Force on Climate-related Financial Disclosure) environmental database in the world (CDP 2023). One limitation of the CDP database itself is that it is not a requirement for the data reported to be third-party verified, and no screening of the companies has been done yet of the CDP responses submitted for the year 2022. The majority of companies use the GHG Protocol for guiding their reporting which is an acknowledged standard (GHG 2023) but not all, making the data points not fully comparable. In conclusion, third-party verified data that is reported according to the same standard, such as the GHG protocol, would make the data more reliable.

Next, the Scope 1 and 2 emissions are combined to a "total" tCO_2e emissions statistic. We ignore Scope 3 emissions since they are not comparable across companies due to differences in business operations. Additionally, the majority of emissions from electricity generation fall into Scope 1 and 2. Emissions in Scope 3 for electricity generating companies are made up of mostly emissions from gas sold, which is out of our scope as we only consider the companies' activity of generating and selling their own-produced electricity. Including Scope 3 emissions would in that sense make the input data less accurate. On the other hand, there are emissions from Scope 3 connected to the activity of generating electricity that are not covered by the Scope 1 and 2 emissions. Ideally, the relevant part of the companies' Scope 3 emissions should be included, but that can only be done if the Scope 3 reporting is detailed for all companies, which it is not.

For every company where it is available, we collect Sustainalytics' Environmental Risk Scores which we find on Yahoo Finance (dated 1st of January 2023). All other company-related data is from 2022, except the market capitalization (dated 22nd of November 2023, collected from Yahoo Finance). One limitation of the Environmental Risk Scores data is that some of the companies in our data set do not have scores.

Our data set contains 24 companies in total, where 22 of them generate the majority of their electricity based on fossil fuels (coal and gas) and the other two companies generate the majority of their electricity from renewable sources (in this case wind). Since many companies use several different types of energy sources for electricity generation we also look at the largest energy source in each company. The distribution is shown in Figure 1a and we can see that 17 of the companies

have fossil fuels as the largest energy source and seven companies have renewables or nuclear power as the largest energy source. One limitation of our data sample is that it consists of only 24 companies in total as those were all companies from the sector *Regulated Utilities* meeting all the requirements. A larger sample is to be preferred for increasing the reliability of the results. The carbon intensity of the companies ranges from 0.047 tCO_2e/MWh to 0.85 tCO_2e/MWh as seen in Figure 1b, with a mean of 0.44 (± 0.20) tCO_2e/MWh. The market cap ranges from $\$2.69$B to $\$75.9$B with a median of $\$14.65$B and mean $\$21.85$B ($\pm 19.923$B). For the companies that have an Environmental Risk Score, the mean value is 13.9 ± 2.9. The eight companies without a risk score are younger, greener, and smaller companies, but the in-group variation is larger than the between-group variation.



(a) Percentage of companies that have an energy source as its largest.

(b) Carbon intensity boxplot per largest energy source.

Figure 1: Energy sources and carbon intensities for the companies in the dataset.

4.2 Technology data and Social cost of carbon

Since companies in different geographical areas within the renewable energy industry can have very different possible efficiencies of their power plants, we need fine-grained data on the cost, emissions, and capacity of each technology available to change. We restrict the possibilities of change in technology to implementing either wind power or solar power, due to data accessibility. The first measure we want is the generating capacity (MW) we get per dollar spent (a_t), including fixed and running costs during the lifetime of the technology, appropriately discounted. This we get from the U.S. National Renewable Energy Laboratory for both onshore wind power (NREL 2022a) and photovoltaic (PV) solar power (NREL 2022b). The costs include everything from equipment, land, and interconnection costs to legal fees, administration labor, and maintenance. Second, we want the lifetime tCO_2e emissions per MW (b_t) and the lifetime of the technology (L_t), which we find from the life-cycle GHG assessments for wind (Dolan and Heath 2012) and solar (Hsu et al. 2012) respectively. The data highlights a mean carbon intensity of 0.011 tCO2-eq/MWh for wind and 0.048 tCO2-eq/MWh for solar in the U.S. So, solar power is generally more emission-intensive than wind with a factor ~ 4, but is also generally cheaper per produced MWh with a factor ~ 0.75 (EIA 2023a). When comparing our dataset's mean emission intensity, 0.44 ± 0.20 tCO2-eq/MWh,

it is clear that fossil-powered electricity generation is much more carbon-intensive than renewable-powered. In Table 2 we can see the technology data values we will use.

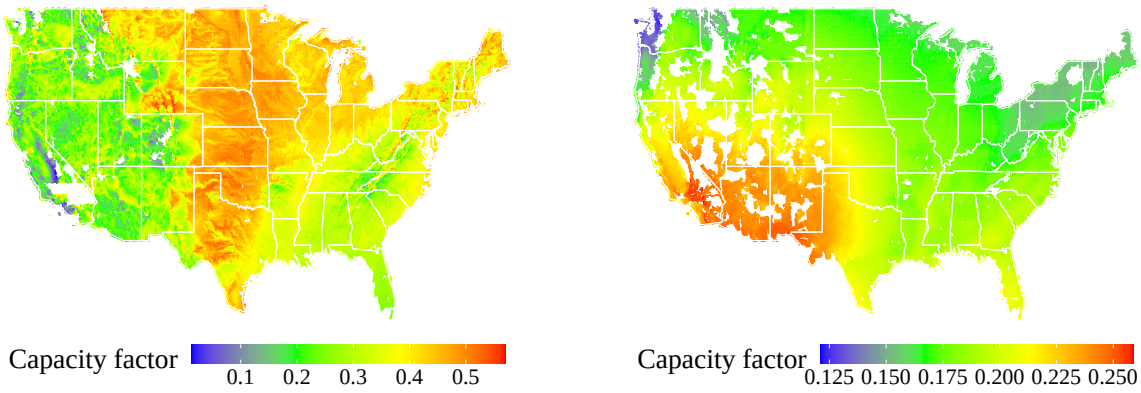
Table 2: Technology data.

Tech	$\mathbf{a_t}$ (MW/$)	$\mathbf{b_t}$ (tCO_2e/MW)	$\mathbf{L_t}$ (years)
Wind	$3.81 \cdot 10^{-7}$	578	20
Solar	$4.45 \cdot 10^{-7}$	2420	30

To translate the technology-specific data to the expected MWh produced for each company we use area-specific capacity factors. Capacity factors for both wind and solar power all around the U.S. are provided by the U.S. National Renewable Energy Laboratory (Lopez 2023b) (Lopez 2023a). We use solar capacity factors from 2020 and wind from 2021, with "reference access" which means some areas are excluded because of environmental protections. Having capacity data from 2022 would have improved the reliability of the data. Summary data and capacity factors by geography are presented in Table 3 and Figure 2 respectively.

Table 3: Capacity factor data.

Tech	**Min.**	**Mean**	**Median**	**Max.**	**Sd.**
Wind	0.01	0.36	0.37	0.57	0.09
Solar	0.12	0.19	0.19	0.26	0.02



(a) Wind Capacity Factors (Lopez 2023b). (b) Solar (PV) Capacity Factors (Lopez 2023a).

Figure 2: Capacity factors in the U.S. by location.

Translating tCO_2e emissions to a cost in USD, we use estimates of the Social Cost of Carbon (SCC). The estimates can differ a lot since there is uncertainty about both the consequences of climate change and how much emissions we will have in the future. We will use the cases presented in Table 4, which are the 5% to 95% percentile values of the social cost of carbon calculated with a near-term risk-free discount rate of 2% by Rennert et al. (Rennert et al. 2022), converted from

2020 USD to 2022 USD with a cumulative inflation rate of 13% (USDL 2023). For comparison, the mean primary market auction price of EU CO2 emission allowances was €79.62 ± 7.70/tCO$_2$ in 2022 (EEX 2023), which corresponds to \$$83.6 \pm 8.1$/tCO$_2$ using the 2022 mean closing exchange rate.

Table 4: SCC data (2022 USD)

Scenario	**SCC** (\$/tCO$_2$e)
5th percentile	49.72
50th percentile	209.05
95th percentile	413

5 Empirical Analysis

One of our key findings is that companies with higher carbon intensity have a higher SPI, as seen in Figure 3. This supports our hypothesis that fossil fuel electricity-producing companies are preferred investment options for SR investors as opposed to greener companies generating electricity through renewable sources. This is also in line with Oehmke and Opp's theory about the SPI (Oehmke and Opp 2023). As Figure 4 shows, all companies with coal as the largest energy type score higher in the SPI compared to companies with wind or hydro as the largest energy source. Companies with a carbon intensity larger than 0.5 tCO$_2$e/MWh (42% of the sample) receive about 1.5 or higher value in the SPI for this specific SCC and g. The value of the SPI is the return on investment. However, since the value depends greatly on the uncertain term $g*SCC$, it is more interesting how companies' SPI compare to each other rather than the actual index value. For exploring how the SPI varies we want a large enough g and SCC to have non-zero SPI values for most companies. Therefore, the case where we have SCC$=$ \$$209.05$/tCO$_2$e and g=1 will be presented. For results with a smaller g we refer to Figure A3 in Appendix.

The company with the largest carbon intensity, where the largest energy source is coal, also receives the highest value in SPI. Looking at the mean SPI value, companies with coal as the major energy source have the largest SPI mean value, followed by gas, followed by hydro, nuclear, and then wind. Moreover, the only two companies in the data set with the majority of the energy generated being renewable received a 0 in the SPI, meaning it should be the last choice for SR investors according to SPI. However, companies with gas as the largest energy source have a large spread with SPI values from almost 0 to about 2.5 which is close to the company having the highest value in the SPI.

The SPI does not correlate perfectly with the carbon intensity, see Figure 3, but it is the most significant factor. The rest of the variation is explained by the individual firm's prerequisites, namely capacity factors, and how a large part of the business energy generation is compared to market cap (this affects only two companies in our sample).

For a small investment (defined as an investment size low enough for the energy change constraint (5) not to be hit), a company's carbon intensity and its technology capacity factors explain all variation in the SPI. For non-zero SPIs, it is also through a linear relationship, as seen in Table

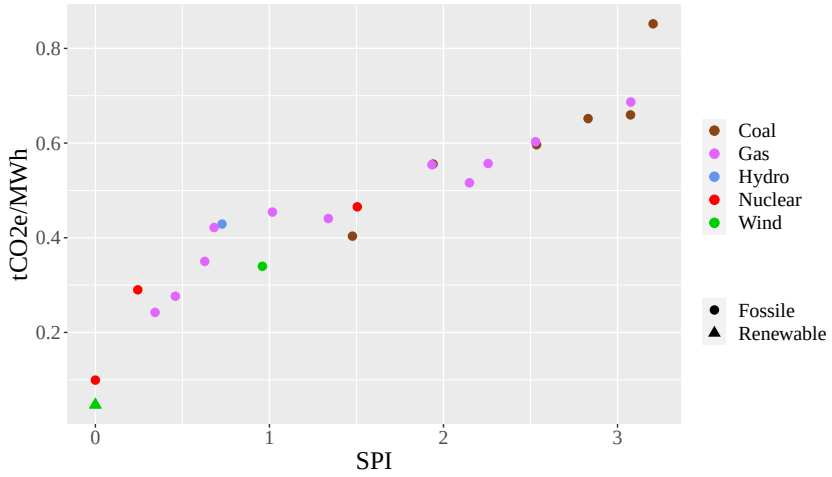


Figure 3: SPI values for individual companies compared to their carbon intensity (tCO_2e/MWh). The SPI is calculated for a small investment, SCC$= \$209.05/tCO_2e$, and $g = 1$. The two renewable energy companies both have a zero SPI and carbon intensities of around 0.05, so they overlap in the graph.

5. The carbon intensity (tCO_2e/MWh) has a positive coefficient in the regression shown, and the capacity factor for the technology that is optimal to switch to is also positive, showing that a higher capacity factor results in a higher SPI. The capacity factor for the non-optimal tech is not significant. The results of the regression are expected due to our construction of the SPI. The R^2 value is not equal to 1 in Table 5 due to rounding error. The magnitude of the carbon intensity and capacity factors are similar but with a higher mean value for the carbon intensity, as mentioned in Section 4.2. The size of the regression coefficients thereby tells us that while carbon intensity matters the most for the resulting SPI, the capacity factors are important.

If the constraints (5) are hit, the SPI becomes lower as investment I goes up, until you hit the market cap constraint in investment (2). The market cap and the amount of energy generated by the companies have no overall correlation with the value in SPI even for bigger investments (see Appendix, Figure A2). This is due to the energy change constraint not affecting most companies and that the amount of energy generated is not significantly correlated with the carbon intensity.

In contrast to our second hypothesis, we find that there is no correlation between a company's SPI and its Sustainalytics Environmental Risk Scores. The second hypothesis, of the ERS being correlated with SPI is rejected at a 5% significance level, where we can see the result from Kendall's tau test in Table 6. Figure 5 illustrates this for our standard case. We use Kendall's rank correlation tau test since it does not test linearity, only monotonicity. The τ_B is the share of concordant pairs minus the share of discordant pairs, so the result $\tau_B = 0.1$ means the rank in ERS does not strongly indicate a similar rank in SPI. Thus, higher Environmental Risk Scores can not be equated to a good investment choice in terms of SPI but not a bad one either. The same result holds for different values for SCC and different values of g. Carbon intensity is not either significantly correlated to the Environmental Risk Scores, partly explaining the lack of correlation between SPI and ERS. See Figure A1 and Table A1 in Appendix. The absence of a correlation between Sustainalytics Environmental Risk Scores and the SPI could also be due to the ERS not solely being based on

Table 5: Regression of non-zero SPI on input variables for standard case.

	Dependent variable:
	SPI
tCO_2e/MWh	5.377^{***} (0.160)
wind capacity factor:optimal tech wind	6.669^{***} (0.514)
optimal tech solar:solar capacity factor	10.478^{***} (1.632)
wind capacity factor:optimal tech solar	-0.515 (1.520)
optimal tech wind:solar capacity factor	-1.133 (1.818)
Constant	-3.381^{***} (0.393)
Observations	21
R^2	0.994
Adjusted R^2	0.992
Residual Std. Error	0.090 (df = 15)
F Statistic	471.610^{***} (df = 5; 15)
Note:	*p<0.1; **p<0.05; ***p<0.01

carbon emissions. They include other environmental issues for the electricity industry that are not included in our SPI, making SPI and the Environmental Risk Scores not fully comparable.

Table 6: Kendall's rank correlation tau test for SPI and ERS.
Note: H1: true τ_B is not equal to 0.

τ_B	**T**	**p-value**
0.1	66	0.6259

Furthermore, our results show that the preferred choice of new technology is dependent on the companies' prerequisites in terms of location which results in different capacity factors. The choice of what to invest in, or to not invest at all, also depends on the input variables in terms of SCC and g. Figure 6a shows how many companies will invest in new technology for different values of g, and the color represents what share of those companies chose solar power over wind for that change. Figure 6b shows the SPI for different g for individual companies, with color depending on which technology the company invests in. This is what the mean SPI and share of technologies in Figure 6a is calculated on.

In total, 21 of 24 companies eventually get a non-zero SPI for $g = 1$ and SCC$= \$209.05/tCO_2e$, and will make a change of technology. 3 companies will not make a change regardless of the value of g due to not having a positive SPI value for any reasonable g and SCC. We see that our data sample mainly tends toward choosing wind, but some chose solar. The increased share of solar power as g is larger is only due to that more companies are getting a positive SPI and not that specific companies prefer different technologies as a function of g. Therefore the emission intensity between the two technologies is similar enough to make the cost the determining factor. Moreover, which technology

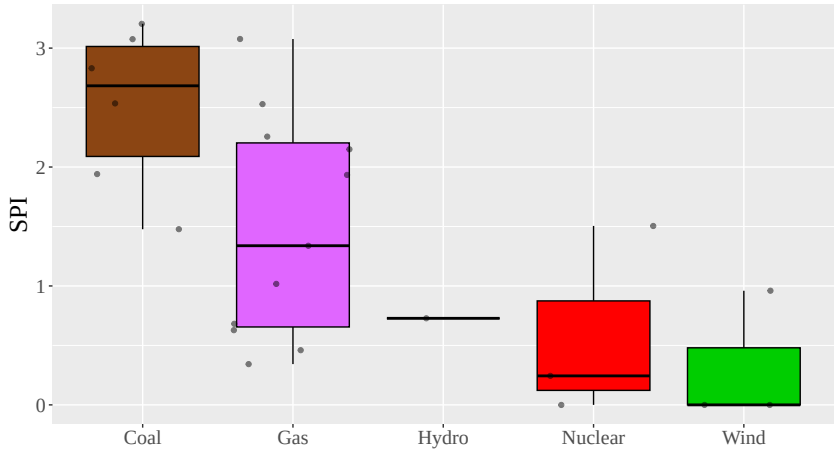


Figure 4: How the SPI differs depending on the largest energy source in a company. The jitter is individual companies' SPIs. The SPI is calculated for a small investment, SCC$= \$209.05/\text{tCO}_2\text{e}$, and $g = 1$.

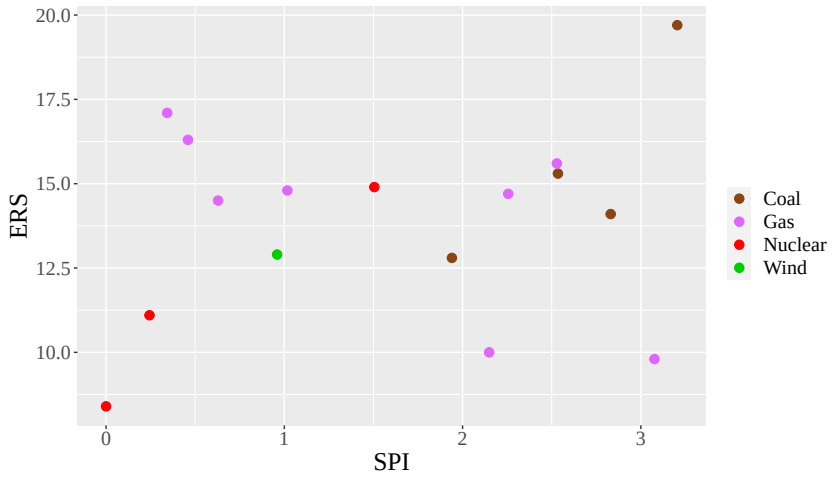
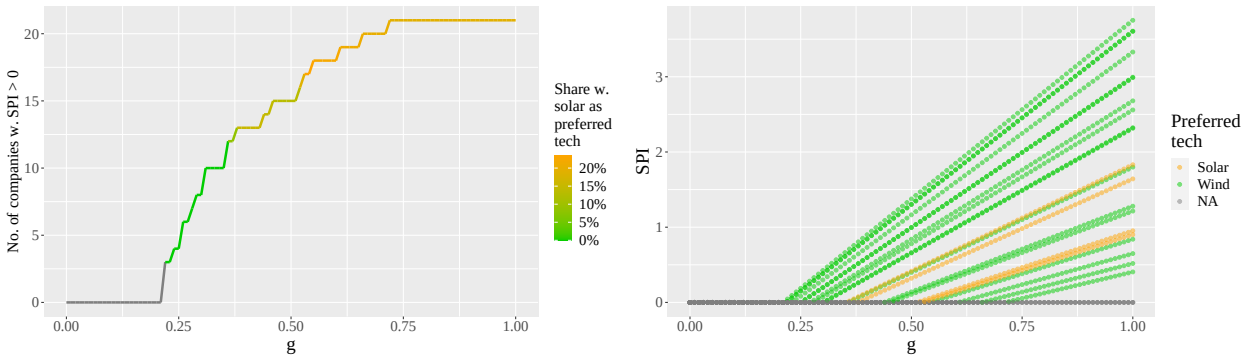


Figure 5: Environtmental Risk Scores compared to SPI. The SPI is calculated for a small investment, SCC$= \$209.05/\text{tCO}_2\text{e}$, and $g = 1$.

has the cost advantage is largely determined by the capacity factor in the area the company operates.

For example, the companies with tickers OGE and PNM both have gas as the major energy source, but since they are located in different states the choice of technology differs. OGE is located in Oklahoma and Western Arkansas which is a naturally windy area, while PNM is located in New Mexico which is a naturally sunny area (see the capacity factors in Figure 2). According to the SPI shown in Figure 7, OGE should always change to wind for a g above 0.25, and for a g about 0.4 and higher PNM should always change to solar.



(a) Number of companies with a positive SPI. The colour shows the proportion of companies that have chosen solar.

(b) SPI vs g for all companies, and the technology the companies change to.

Figure 6: SPI and number of companies with a positive SPI for different g, for SCC=\$209.05/tCO_2e.

5.1 Robustness

A sensitivity analysis on cost and CO_2e intensity of our technologies shows that with a $\pm 20\%$ factor difference in our technology input variables a_t and b_t, the changes are minimal. A cost reduction in solar power means that a few more companies would choose solar power over wind power, and vice-versa if the opposite was true. It also slightly shifts the SPI curve backward or forward depending on the direction of the technology variable change. A CO_2e intensity change matters even less. Even when wind power's carbon intensity is multiplied by a factor of five, reaching the level of solar power's carbon intensity, not many additional companies choose solar over wind power.

Lastly, we found that SPI is largely dependent on the value of SCC as seen in Figure 8). For example, an investor with $g = 0.5$ gets a value of 0 in the SPI for all companies if the SCC used is $\$49.72$ and a value of around 2 depending on the company if the SCC is estimated to be $\$466.69$. Moreover, the value-determining factor of avoided emissions is $SCC * g$, so the importance of the price of carbon for SPI value grows with g. When SCC is at $\$49.72$, only the investors with a g close to 1 will change a company's technology as the return is not positive in comparison to the status quo, which is not the case at higher estimates of SCC.

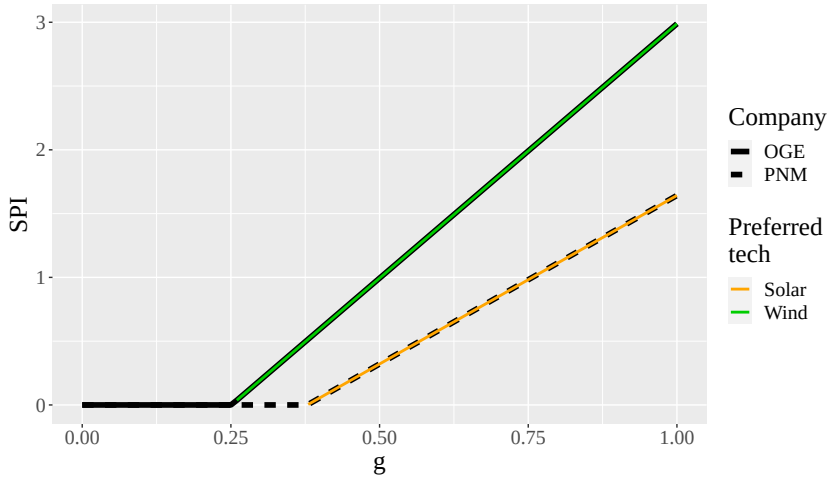


Figure 7: SPI vs g for two similar companies operating in different areas with the technology an SR investment is in.

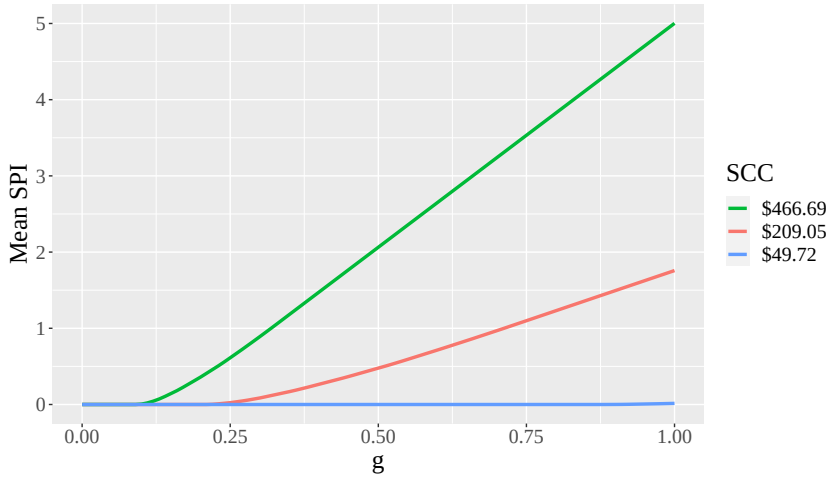


Figure 8: How the mean value of SPI depends on g for different SCC's.

6 Discussion

In this section, we discuss the limitations of our model setup and suggest future extensions. Finally, we provide a conclusion to our findings.

6.1 Limitations

Our SPI is mainly sensitive to the estimate of the Social Cost of Carbon. Since the estimates of SCC differ largely in the literature and are subject to high uncertainty, it constitutes a source of error when looking at the results from our SPI. Continued research within the field of pricing of carbon would

result in more reliable results. If the true SCC is in the lower end of the values we investigated, this would mean that an SR investor would be indifferent between investing in most companies, only having a few companies having a non-zero SPI. The emission discrepancy in using life-cycle assessment-based carbon intensities for wind and solar while getting the company carbon intensity from Scope 1 and 2 emissions should not affect the results much. Assumptions about shareholder activism effects and the SCC have a much bigger impact.

Several assumptions limit the applicability of our SPI. First, we have not considered the point in time when investments in PPE (Property, Plant & Equipment) have taken place in the companies due to the complexity of finding this data. Thus, we have not considered the opportunity cost of dismantling a plant that has been newly invested in, in comparison to dismantling a plant that is about to be obsolete. However, as the large majority of the companies are old, the investments in PPE probably occur regularly instead of at one point in time, reducing the possible impact on between-company SPI as a consequence of our choice to neglect the timing of investments.

Second, we assume that the SR capital invested following SPI will be used for *replacing* existing fossil fuel plants with renewable energy plants. However, if the SR capital instead is used for *expanding* to renewable sources on top of the regular supply of fossil fuel energy, the total pool of fossil fuel energy in the world will stay unchanged. This would generate no reduction in global warming, as divestments from fossil fuels are necessary to be able to reduce emissions. Thus, SR investors must succeed in the boardrooms by divesting current fossil fuel operations in favor of renewable energy.

Third, we do not assume we replace all the carbon-intensive energy first. Instead, we assume all energy in a company to have the same carbon intensity. This makes our SPI biased toward high-carbon-intensity firms for smaller investments. An extension to the study could be to use more detailed information about the energy configuration in a company to solve this problem.

Lastly, when constructing our SPI we assumed the investor would be able to spend the whole investment amount on investing in a new technology. However, this is equivalent to giving the money away against the assurance that the company will use it to replace part of its electricity-generating fleet, which is a strong simplification of what an actual investment process would be like. More realistically, an investor would invest in the form of buying stocks or buying bonds, and also make her own analysis about the financial return from holding the stock or bond. We have not made an attempt to estimate alpha. Furthermore, when buying stocks and exerting shareholder power through them, voting rules, company liquidity, the board, and other shareholders play an important part in what type of changes an investor can accomplish. Future studies could look at how efficiently the SPI could be applied in reality by making use of shareholder activism.

6.2 Concluding Remarks

Our results imply that for an SR investor with the possibility to impact company operations through shareholder activism, investments in carbon-intensive companies are preferred over investments in green firms when there exists an alternative technology that is cleaner than the current technology of the carbon-intensive companies. This result can be explained by the large reduction of carbon that can be achieved by changing to cleaner technology in a current carbon-intensive company. At the same time, companies with natural gas as their largest energy source can be both good and bad

investment choices according to our SPI. This can be explained by differences in the rest of the companies' energy mixes, where some companies are leaning more towards fossil fuels in general and some lean more towards renewable or nuclear power. It can also be explained by the fact that natural gas is a less carbon-intensive energy source in comparison to coal.

In contrast to the mainstream indices today which take a screening approach to SRI and thus suggest SR investors to invest in firms that are already "best-in-class", we show that SR investors with an impact mandate should do the opposite according to our SPI. However, we cannot generally say that a screening approach gives the opposite investment recommendation compared to SPI since not all environmental indices correlate with carbon intensity, which we showed for Sustainalytic's Environmental Risk Scores.

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Appendix

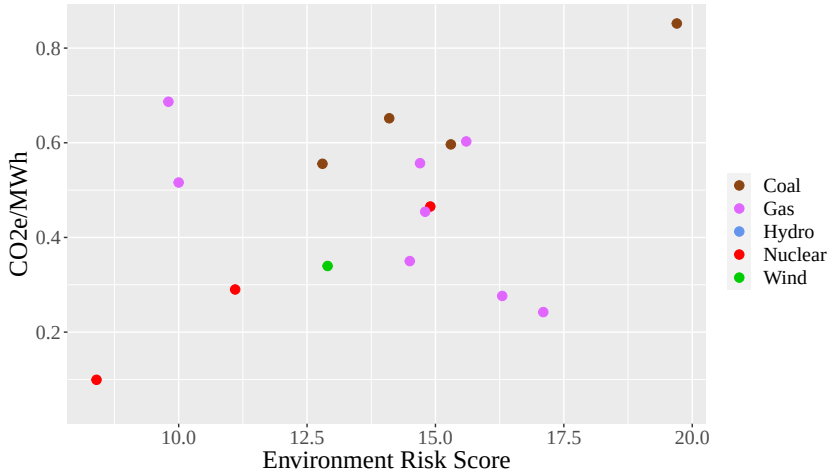


Figure A1: Sustainalytics' Environment Risk Score of a company compared to it's carbon intensity.

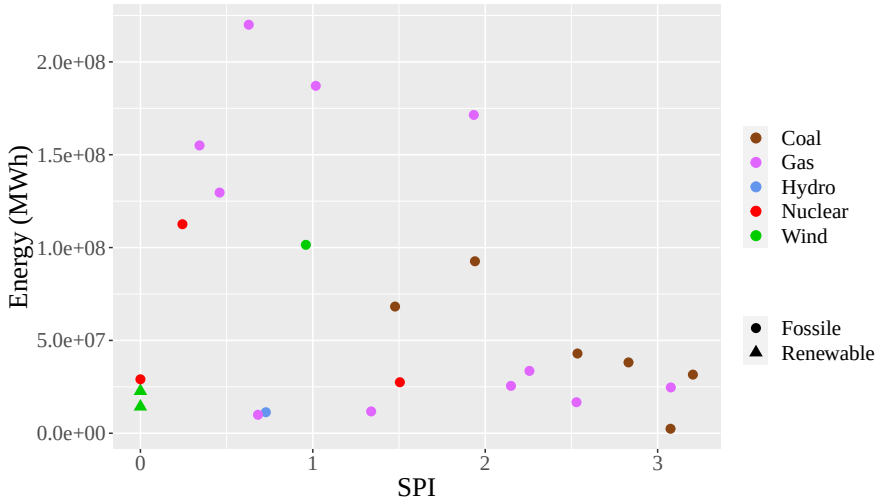
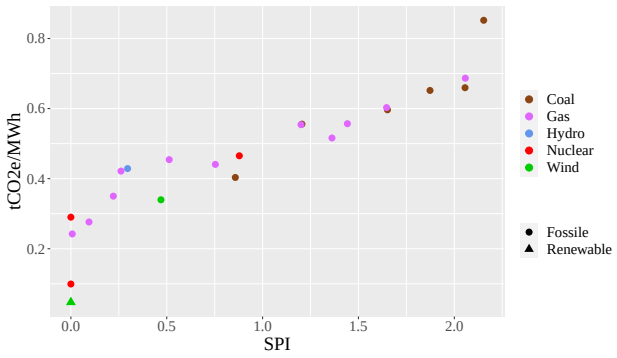
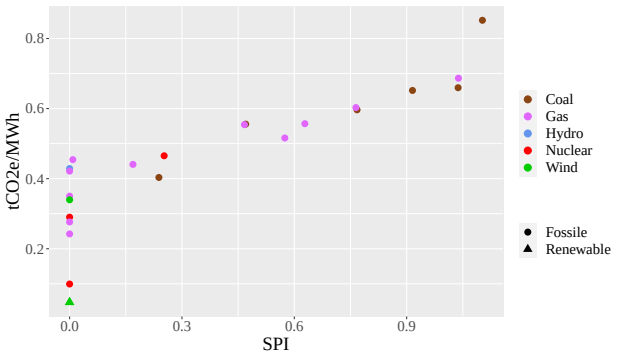


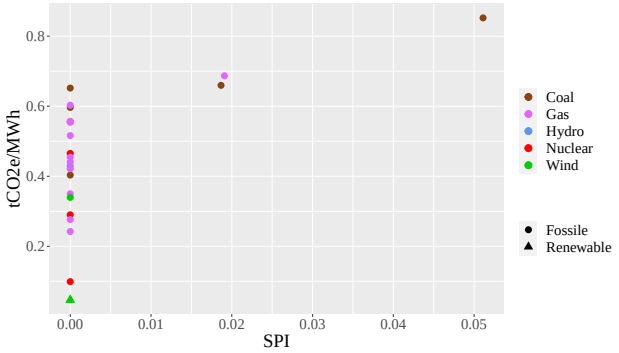
Figure A2: Total produced energy for companies relative to SPI. No significant correlation. For small investment, SCC= \$209.05/tCO2e, $g = 1$.



(a) SPI vs carbon intensity for g=0.75, SCC= \$209.05/tCO$_2$e, and a small investment.



(b) SPI vs carbon intensity for g=0.5, SCC= \$209.05/tCO$_2$e, and a small investment.



(c) SPI vs carbon intensity for g=0.25, SCC= \$209.05/tCO$_2$e, and a small investment.

Figure A3: SPI vs carbon intensity for a few different g.

Table A1: Kendall's rank correlation tau test for tCO$_2$e/MWh.
Note: H1: true τ_B is not equal to 0.

Variable	τ_B	**T**	**p-value**
ERS	0.1167	67	0.5643
SPI	0.8998	-	$8.591e-10$