

CAPITAL PLANNING, SELECTION, AND INVESTMENT INTEGRATING SUSTAINABILITY IN DECISION-MAKING

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Abstract. Inspired by Pope Francis's call for a new journey that instills the importance of conservation and care for the environment, we propose a practical model that mathematically incorporates sustainability issues into capital planning, selection, and investment.

Evidence suggests that managers apply net present value (NPV) methodologies in a way that disadvantages environmentally sustainable investments. If an NPV model does not consider the costs and risks of non-sustainable projects, then the potential benefits of alternative sustainable investments will appear much less valuable than present costs. Sustainable investments also often require larger initial investments with long-term benefits and distant cash flow time horizons that are discounted at exponentially higher rates. Moreover, identified environmental costs and

benefits are generally limited to savings associated with energy costs, while hidden reductions in externalities are ignored. Thus, as commonly used, NPV models bias *against* sustainable alternatives in investment selection.

This article integrates accounting, finance, and engineering literatures to develop a model that incorporates sustainability and environmental impacts into capital selection through a life-cycle impact assessment (LCIA) appraisal. We operationalize LCIA so that hidden environmental costs and benefits can be identified, analyzed, and priced, thus resulting in a better prediction of cash flows. The model also integrates environmental risks into the cost of capital by developing a sustainability risk-adjusted discount rate and sustainability-cost NPV that effectively captures the sustainability exposures of capital projects, thus resulting in a risk-adjusted sustainable framework for decision-making.

Keywords: sustainability in capital budgeting; environmental life-cycle impact assessment (LCIA); life-cycle costing (LCC); life cycle analysis (LCA)

Humanity is called to recognize the need for changes of lifestyle, production and consumption, in order to combat this warming or at least the human causes which produce or aggravate it. — Francis, *Laudato Si'* 23

1. INTRODUCTION

Choosing words from St. Francis of Assisi, Pope Francis's encyclical (Francis, 2015) on the environment begins with “*Laudato si'*,” or “praise be to you.” In this comprehensive document, the Pope describes in six chapters

1. the “state of the Earth” and what is happening to our common home;
2. the gospel of creation and how it requires humankind to provide proper stewardship to our planet;
3. the human roots of ecological crises: globalization's technocratic paradigm and the effects of modern anthropocentrism;
4. the recognition of interrelatedness among environmental, economic, social, and cultural ecologies;

5. the need for international political and religious dialogue with science; and
6. his recommendation for a new educational journey based on the Christian spirituality of simplicity that rejects extreme consumerism and creates a covenant between humanity and the environment.

Pope Francis's call for an educational journey toward a human covenant with the environment has been embraced by most universities. New curricula have attempted to integrate environmental awareness and conservation. Environmental Engineering and Environmental Studies have developed as stand-alone areas of specialization. Similarly, business schools are including sustainability in their mission statements. Unfortunately, however, topical areas in finance and accounting (Hopwood, 2009) have not developed practical frameworks by which sustainability can be taught (Werner & Stoner, 2015). To a large extent, textbooks in quantitative areas have not incorporated sustainability into theory or practice.

In this paper, we create a practical mathematical framework that integrates sustainability and environmental issues into a fundamental topic of corporate finance and managerial accounting: capital budgeting. Our goal is to convince academics and practitioners to consider changing their fundamental perspective concerning capital budgeting, and enable greater integration of available tools for incorporating sustainability into the investment selection process.

Capital budgeting concerns all the activities an organization undertakes to choose which long-term assets and investments best support the firm's operations, organizational goals, and strategy (Kim & Farraguer, 1981; Moore & Reichert, 1983). While capital budgeting encompasses the selection of investments in both intangible and tangible assets or projects, the focus of this paper primarily concerns a firm's investment in real, tangible, and long-term assets, e.g., machinery, plant, buildings, equipment, land, and other firms. Within the broader capital budgeting process, the decision of which long-term tangible assets to acquire has significant strategic and operational importance since these capital expenditures (CAPEX) usually represent a significant commitment of financial resources that remain invested over a long period of time. Decisions concerning fixed assets, such as the replacement of serviceable but obsolete equipment, or new CAPEX needed to increase output or achieve market expansion, require managers to complete detailed and significant analyses that have long-term impacts. Depending on the nature of the firm's business, the CAPEX resource allocation process

often constitutes the main vehicle for a company's strategic thrust, and thus eventually determines its long-run competitive position.

The amount of CAPEX investment is considerable and has been steadily increasing as machines and automation have replaced labor. Appendix 1 shows that, as of January 2015 in the United States, fixed assets¹ account for 19.5 percent of total assets and capital expenditures² among publicly listed companies.

As Pope Francis eloquently argues, there is a growing emphasis, social awareness, and an implicit expectation that firms—and the people who manage them—must behave in a more socially responsible and sustainable manner. Global warming, climate change, energy costs, and environmental degradation issues have heightened public scrutiny regarding the role of firms as agents partly responsible for these problems. As such, organizations are responding to and managing these pressures and risk exposures. Firms must increasingly identify all social, environmental, and economic impacts in order to assess, control, prevent, and eventually correct actions that might adversely affect human, animal, or plant life. Corporate commitment to sustainability is evidenced more and more by firms' participation in voluntary risk assessment and reporting initiatives such as the U.N.'s Global Compact (GC), the FTSE4 Good Indices, the Global Reporting Initiative (GRI), the Dow Jones Sustainability Indexes (DJSI), and through compliance with International Standards Organization certifications (ISO 14001 and ISO 26000).

However, evidence also suggests that the majority of firms fail to integrate sustainability in CAPEX decision-making models (Vesty, 2011). First, in applying these models, managers often view environmental costs and benefits through a lens of reducing energy costs, missing the myriad other threats and opportunities related to sustainable investing. Second, conventionally accepted Discounted Cash Flow (DCF)-based analytic methodologies, like Net Present Value (NPV) and the Internal Rate of Return (IRR), by construction do not favor sustainability-related investments (Hopwood, 2009; Kimbro, 2013). These commonly used capital budgeting models are built in ways that create bias *against* the selection of sustainable alternatives in capital project selection. For example, sustainable projects often require larger investments that

¹Cumulative book value of fixed assets per sector as of January 2015.

²Cumulative capital spending per sector, as reported in the Statement of Cash Flows, not including acquisitions.

require longer time horizons to develop positive cash flows.³ Because distant cash flows are discounted at exponentially increasing rates, such investments' promising long-term savings (cash inflows) appear small in present value terms. Also, the positive qualitative factors of sustainable alternatives might be hard to quantify, and the unobvious costs and risk-related externalities of less-sustainable alternatives can often be difficult to incorporate in the cost of capital and cash flow projections. Additionally, one might argue that discounting NPV techniques assume—incorrectly—that the benefit of future biodiversity preservation and “natural capital” conservation will decrease in future years. In other words, it will be wrong to assume that the *future* benefits of a sustainable investment will be *less valuable* than the present benefits of conservation as the application of discounting techniques imply. The Economics and Biodiversity Report of 2008 notes “that a 4 percent discount rate means that we value a natural service to our grandchildren (50 years hence) at one-seventh the utility we derive from it (today) ... is a difficult standpoint to defend” (TEEB, 2008). Finally, there are many hidden costs that are buried in overhead and general expenses that are not captured in current capital budgeting analysis. Managers could select equipment without understanding and evaluating the Full Cost or Life-Cycle impacts that capital assets might have. For example, firms might acquire equipment that requires to be cleaned with a hazardous substance, or uses a refrigerant that affects the ozone layer, or is cooled with fluids which become contaminated during the production process, or is lubricated with hazardous lubricants that require workers to use protective equipment that must be removed and disposed of in a special manner. Without a clear understanding of all the hidden costs associated with the acquisition of capital assets, firms cannot effectively make optimal capital budgeting decisions.

This paper thus proposes a model to integrate sustainability issues into capital budgeting decisions. The model incorporates sustainability and environmental analysis into decision-making by evaluating eco-efficiency (EE) through life-cycle impact assessment (LCIA) and risk measurement, all of which serve to estimate more completely and accurately the costs and benefits of capital investments.

The discussion is organized as follows. Section 2 examines the process by which firms evolve toward incorporating sustainability in their decision-making. Section 3 discusses the process of capital budgeting and the decision-making methodologies used in appraisal analysis. Section 4 discusses the three stages of analysis that incorporate

³See International Federation of Accountants (2012).

sustainability considerations into cash flow measurement and estimation methods used in net present value (NPV) and discounted cash flow (DCF) techniques. In this section, life-cycle impact assessment (LCIA) is discussed as an alternative to life-cycle cost (LCC), life-cycle assessment (LCA), and whole-life costing. LCIA is operationalized as it relates to environmental screening, environmental impacts assessment, and eco-efficiency analysis. Section 5 discusses the cost of capital and how to incorporate the threats associated with environmentally hazardous capital projects by quantifying risk exposure and sustainability costs, and Section 6 concludes.

2. ORGANIZATIONAL COMMITMENT TO SUSTAINABILITY

A firm's environmental strategy and its commitment to sustainability typically develop and mature in three stages or mindsets that inform how managers integrate sustainability issues into their decision-making processes. The stages evolve from an initial focus on compliance with regulatory pressures, to cost avoidance and profit maximization, and finally to a comprehensive value-enhancing strategic approach.

At the compliance level, environmental and sustainability analysis is driven primarily by the need to meet government or industry regulations. In this stage, a firm's efforts are directed mainly toward calculating the minimum costs associated with existing compliance requirements, and no attention is given to future risk, prevention, or the potential for a change in regulatory environment.

In the cost avoidance and profit maximization phase, firms have typically gained experience from measuring compliance costs and have learned to appreciate the benefits of prevention, and so move into the mindset of "investing to save" through a cost-avoidance process that tries to anticipate environmental costs. That is, managers might seek to maximize profit by simply weighing the trade-off between the costs of potential non-compliance and the benefits of investing in assets that prevent these costs.

In contrast, managing sustainability using a strategic mindset requires firms to approach sustainability issues proactively by earnestly incorporating environmental costs and benefits as opportunities, enhancing managers' understanding of operations, processes, and systems. The strategic mindset also addresses the increasing demand for economic sustainability disclosure and governance sustainability performance information by regulators, investors, and firms (Kiron,

Kruschwitz, Haanaes, Reeves, & Goh, 2013).⁴ The strategic mindset not only weighs the costs and benefits associated with sustainable investments, but also considers how these costs and benefits might change over time, and how the firm's stakeholders might assign their own values to these costs and benefits—values that markets might not fully or accurately measure today. Unlike the compliance and cost-avoidance mindsets—both of which deal with environmental costs as constraints—the strategic approach sees information regarding environmental costs as a strategic business opportunity to create value.

Rapid progression through the stages to a strategic mindset can be attributed to increasing awareness in general of the sometimes difficult-to-quantify benefits of sustainable business practices. The June 2015 publication of Pope Francis's (and advisors') encyclical, *Laudato Si'*, further raised the profile of social and environmental responsibility in business, and calls for moral leadership in business practices. The encyclical underlines and amplifies a continuing trend of heightened social awareness and integration of moral leadership in business education (Garanzini, 2015), including a call by Werner and Stoner (2015) to educators specifically in finance—often considered “part of the problem” concerning unsustainable practices—to transform their teaching to address these issues and move toward a more just system.

Firms have become increasingly sensitive to environmental and sustainability issues for many reasons: they might be led by managers that, educated in the principles described above, prioritize these issues; they need to comply with current or future government or industry regulations and standards; they need to identify costs through product and process improvements that reduce inputs and waste; they might need to manage their image; or they might want to anticipate future regulations. Undoubtedly, firms need to measure and manage legal and regulatory costs as well as societal costs associated with public expectations regarding the need to preserve the environment and use natural resources carefully. Moreover, firms need to recognize that operating in a sustainable manner generates environmental benefits, savings, revenues, and ultimately value which might or might not be measurable. Regardless of the level of commitment to sustainability issues—compliance, cost avoidance, or strategic—managers can benefit from understanding how to integrate sustainability into the important task of deciding which capital expenditures maximize shareholders' and stakeholders' value while respecting the earth and the environment.

⁴In fact, there is evidence that disclosures concerning environmental, social, and governance dimensions of sustainability performance work to reduce firms' costs of equity capital (Ng & Rezaee, 2015), and thus enhance shareholder value.

3. CAPITAL BUDGETING IN PRACTICE

Capital budgeting is also called capital allocation decision-making, asset appraisal analysis, capital investment appraisal, and capital planning. Capital budgeting is the process by which an organization determines which long-term assets and investments—such as machinery, plant, building facilities, equipment, land, research and development—are worth acquiring to support the firm's operations and organizational goals (Kim & Farraguer, 1981). The process of acquiring long-term assets has significant strategic and operational importance since capital expenditures usually represent a significant commitment of financial resources which remain invested over a long period of time. Decisions related to the replacement of serviceable but obsolete equipment to achieve cost reductions, or capital expenditures necessary to increase product output or achieve market expansion, all involve detailed and significant analysis. Firms commit cash to a capital project or investment because they expect to generate even more cash in the future. The value of a capital project is based on how much cash a project might generate in the future in terms of dollars today; the higher the NPV or return, the greater the value of the project.

Because capital investments are typically long-lived, the accepted practices for making capital budgeting decisions involve longer-horizon techniques that consider the time value of money through discounted cash flows (DCF), e.g., the NPV and related Internal Rate of Return (IRR) decision metrics (Brotherson, Eades, Harris, & Higgins, 2013; Graham & Harvey, 2001; Kim & Farraguer, 1981; Pike, 1988). Shorter-horizon techniques such as the payback criterion fell out of favor long ago, primarily because such techniques lack an effective means to adjust for the risk of a potential investment, and they ignore the time value of money—as a result, the payback decision metric can result in suboptimal investment decisions. Similarly, managers who ignore the long-term risks inherent in environmentally sensitive assets will tend to commit errors, just as those who once employed the payback rule. Although payback and accounting rate of return are sometimes still used as secondary methods, discounted cash flow (DCF) methods are the primary and preferred methods in contemporary capital budgeting analysis (Brotherson et al., 2013; Graham & Harvey, 2001).

Firms with short-term horizons, as a general rule, end up making suboptimal allocation decisions. “Buying the cheapest” is no longer the acceptable approach used in modern capital budgeting. Most managers realize that the least expensive investment opportunity is rarely the best alternative in the long run. In line with this realization, preferred capital budgeting methods have evolved significantly during

the last twenty years. Before the 1980s, firms rarely used DCF and NPV methods; however, by 1999, 75% of surveyed firms used DCF and NPV to evaluate capital budgeting decisions (Graham & Harvey, 2001; Moore & Reichert, 1983), and in a recent survey, Brotherson et al. (2013) show that 95% of highly regarded “Best Practices” practitioners use a DCF methodology as the primary decision criterion. This paper thus aims to inspire continued evolution of the best practices in capital budgeting by providing managers with tools for more completely including all the risk factors—including environmental ones—associated with an investment opportunity.

Since virtually all capital budgeting decisions are analyzed with the use of computer software, it is relatively easy to calculate NPV or IRR, and the chief difficulties concern estimating cash flows, residual value, risk and the cost of capital, and the intangible benefits (or costs) of acquiring the asset. Hence the real difficulty of deciding the merits of an investment is not the determination of which decision metric to use but, rather, it is determining the inputs necessary for these calculations. Specifically, to calculate the inputs of any NPV methodology, firms need to determine:

1. all cash inflows (cash savings, additional sales, salvage inflows, etc.) and cash outflows (initial cost of the asset, energy costs, maintenance, repairs, depreciation, disposal costs, etc.) each project will generate each year;
2. how to quantify the non-cash benefits: either through reducing the discount rate or transforming these through cash flows;
3. how many years the capital asset will last from “cradle to grave”;
4. how to incorporate the uncertainty and risk of these cash flow predictions into the cost of capital for *each* project, taking into account its individual risk; and
5. the cost-of-capital or risk measure that will be used to discount the predicted cash flows for each alternative.

In sum, to calculate NPV for each capital asset alternative, managers need to:

1. determine the cash outflow of the initial investment (CF_0);
2. estimate the cash inflows and outflows (cash flows at time i , or CF_i) for each year over the life of the asset;

3. estimate the risk, reflected in the cost of capital (r) for each asset; and
4. specify the number of years (i) expected as the true life of the asset, i.e., “from cradle to grave.”

NPV = Present Value (PV) of all future cash flows (CF_i) discounted at the cost of capital (r) - Initial cost of the project (CF_0)

NPV essentially summarizes, in one number, the total dollar benefits and costs of an investment, all converted into today's dollars, i.e., present value (Buser, 1986). The discount rate, also known as the cost of capital, determines at what rate of exchange the future cash flows are converted into today's dollars. In present value terms, when a potential capital investment's benefits exceed its costs, the project will increase value for stakeholders, and thus should be undertaken. Conversely, a negative NPV indicates that undertaking the investment will destroy value for the firm's stakeholders.

4. INCORPORATING SUSTAINABILITY INTO NPV AND DCF: PREDICTING CASH FLOWS

Firms must evaluate all future cash flows that each investment will generate. Cash flows for the life of *each* project—from cradle to grave—must be estimated. To predict these future cash flows, the impact of all areas affected by the proposed capital expenditure must be evaluated, as well as the riskiness of the expected cash flows, which will later be used to estimate the cost of capital.

4.1 Identify, Evaluate, and Measure General Costs and Benefits

A basic screening of the traditional capital budgeting items to be included in the cash flow calculation is the first step in quantifying cash inflows and outflows. Appendix 2 provides a starting point for this.

We argue that to incorporate sustainability fully into the estimation of cash flows, life-cycle impact assessment (LCIA) must be used. LCIA goes beyond life-cycle cost analysis (LCC) and life-cycle assessment (LCA), both of which do not typically incorporate environment-related costs and benefits.⁵ Although LCC takes into account user costs as well

⁵The terminology and definitions are sometimes ambiguous. In some instances, LCC and LCIA measure and incorporate the same measurements and thus are exactly the same.

as agency costs related to activities like maintenance and repairs, it often ignores indirect environmental costs.⁶ LCIA includes LCC *as well as* environmental impacts related to all stages in the life of an asset—from cradle-to-grave. LCIA provides the optimal structure for firms to understand better the financial and environmental effects—both costs and benefits—of capital assets, products, services, and activities, and thus results in a more comprehensive model that predicts future cash flow impacts. Specifically, LCIA requires generating an inventory of activities that could impact cash outflows (costs) and cash inflows (benefits). Appendix 2⁷ provides a checklist or inventory list of activities that result in cash inflows and outflows, thus facilitating the consideration of environmental-related costs. For a complete assessment of a project's merits, managers must estimate items such as insurance fees to cover handling of hazardous substances, waste disposal costs, landfill costs and taxes, remediation/clean-up costs, shut-down costs, the probability of fines and prosecutions, and asset disposal costs, to name a few. A thorough assessment of each project must include all potential environmental costs and benefits, and the checklist in Appendix 2 provides a blueprint for managers to quantify risks and opportunities associated with each investment.

4.2 Estimating Cash Flows Using Life-Cycle Impact Assessment (LCIA)

Many environmental costs are hidden in overhead and general administrative expense accounts, and their impact is not properly priced into the assets and activities that created them. Relevant costs and benefits are essential components of capital investment⁸ analysis that unfortunately are too often ignored. LCIA helps to identify these costs clearly.

Eco-efficiency requires an integrated assessment of the environmental and economic aspects of assets and services from a life-cycle perspective. The concept of life-cycle includes *everything*. In other words, LCIA goes beyond the typical “useful-life” methodology frequently used in accounting. Unlike economic analysis, in LCIA all the impacts of a capital asset are summed up along the whole life-cycle to give a complete understanding of the entire impact of owning a capital asset. The costs of buying, financing, installing, maintaining, operating, repairing, replacing, and disposing of an asset are considered outflows of cash. All energy savings, rebates, tax-savings, depreciation, and productivity

⁶See Nishijima and Faber (2009).

⁷Appendix 2 incorporates the recommendations in Epstein and Buhovac (2005), De Beer (2006), Corotis (2009), and Hastings (2015).

⁸See Balachandran, Balakrishnan, and Sivaramakrishnan (1997).

improvements are considered inflows of cash. These cash inflows and outflows are projected over the life of the asset, adjusted for inflation and anticipated uncertainty, to determine the NPV of each capital project. LCIA involves a comprehensive evaluation of all the direct and indirect environmental impacts of a capital asset throughout its life and beyond its “useful” stage. Thus, managers who duly identify and analyze the full scope of a capital asset’s environmental consequences will be better equipped to make optimal investments that price *a priori* pollution prevention rather than remediation and “end of the pipe” solutions.

4.3 Use of LCIA for Initial Environmental Screening

In this stage, an initial environmental screening covering all potential indirect and direct items that have a high probability of generating an environmental impact is performed. Whether the capital budgeting decision involves a single project or a selection among different asset alternatives, all possible impacts must be measured and assessed *before* going through any financial analysis. Appendix 3 offers an example of an initial environmental screening checklist that could apply for the purchase of a machine or equipment. Of course, each organization and asset class will have particular issues that should be tailored accordingly.

The information from the Initial Inventory checklist in Appendix 2 and the Environmental Screening in Appendix 3 provide raw data and information that managers can use as the starting point for more refined quantification of sustainability and environmental costs. In particular, Appendix 3 could help evaluate the life-cycle impacts of capital assets so that appropriate impact assessments are generated and quantified. Appendix 3 also includes a column that evaluates the level of toxicity of operational externalities. In building Appendix 3, we have used the Environmental Protection Agency (EPA) Toxic Substance Inventory as a reference; however, there are many other sources from which managers can assess the level of toxicity, and we recommend using appropriate standards of risk mitigation that should go beyond minimal safety regulations (for examples, see the US National Institutes of Health [NIH] *Hazardous Substance Databank* and the US Environmental Protection Agency [EPA] *Toxic Substance Inventory Report* [EOTOX]).

4.4 Evaluate Eco-efficiency and Quantify Impacts

If the environmental screening reveals that the asset does create waste or externality, then this item must be evaluated and its impact must be categorized using an impact category similar to the one presented in Appendix 3. Many of these costs are “external” costs that are generally

not considered in capital budgeting decisions, yet these “externalities” have an impact on human health or eco-systems through the release of toxic substances. Unfortunately, it is neither the firm nor the consumer that bears these costs, but society as a whole and—eventually—future generations. Such impacts are obviously more difficult to quantify, and it is up to the firm to assess the weight it will give them in the capital budgeting analysis. On the other hand, it would seem justifiable and responsible to integrate these costs in the decision-making if managers can reasonably foresee legislation that internalizes external costs for certain wastes, emissions, materials, or externalities. This could be the case for CO₂ taxes on fossil fuels or carbon emission taxation. For a more detailed analysis, various assessments have been developed that help quantify toxicity potential (Bunke & Graulich, 2002; Bunke, Gensch, Möller, Rüdenauer, Ebinger, & Graulich, 2003).

In terms of capital investments in buildings, several green ratings systems have developed metrics that define and measure both current and future building performance. “Green metric” systems for buildings that can be employed and integrated into the capital budgeting process are: Leadership in Energy and Environmental Design for Existing Buildings: Operations and Maintenance (LEED-EB: O&M), Green Globes for Continual Improvement of Existing Buildings (GG-CIEB), the Green Guide for Health Care (GGHC), and the BRE Environmental Assessment Method (BREEAM).

5. INCORPORATING SUSTAINABILITY INTO THE COST OF CAPITAL AND FINAL INVESTMENT DECISION

The value of a capital investment depends on the expected cash flows discounted at a rate that reflects the riskiness of each cash flow. If this value is greater than the original investment cost, then the project has a positive NPV; if it is less, it has a negative NPV. Positive NPV projects create value while negative NPV projects destroy it.

The discount rate or the cost of capital is a function of the project's perceived riskiness, with risky projects requiring higher returns compared to less risky ones. For example, a firm will use a much lower discount rate in its decision whether or not to replace aging equipment (more certain expected cash flows, lower risk) as compared to a decision regarding a risky new product launch. Risk can be defined as the probability of exposure to any event or action that will adversely affect an organization's ability to create value. There is some evidence that firms evaluate risky investments by estimating expected values, standard

deviations, and semi-variances of net cash flows for each alternative investment, as well as multiple-criteria capital budgeting models under risk by using higher discount rates that incorporate higher risk factors (Kwak, Shi, Lee, & Lee, 1996; Lin, 1993; Pike, 1983).

The importance of integrating risks into management decisions and in particular into capital allocation decisions cannot be underestimated. These risks might be strategic, operational, reporting, or compliance risks (Epstein & Buhovac, 2005). Sustainability issues are a component of each of these risk categories. Strategic risks relate to the firm's choice of strategies and include industry, transaction, technological, political, and organizational risks. Operational risks relate to threats from ineffective business processes. Reporting risks relate to the reliability, accuracy, and timeliness of information systems, both internal and external. Compliance risks relate to the inability of the firm to comply with applicable laws and regulations.

There are two main approaches toward integrating sustainability issues into capital budgeting decisions: the differential risks for sustainable costs and benefits can be incorporated into a "Sustainability Risk-Adjusted Discount Rate," or the manager can quantify the "Sustainability Cost NPV" that captures risk by assessing the sustainability exposure and potential costs inherent in each project.

5.1 The Sustainability Risk-Adjusted Discount Rate

To develop the "Sustainability Risk-Adjusted Discount Rate," managers need to evaluate each capital project using an environmental risk inventory and through an eco-efficiency assessment (Appendices 3 and 4). If the inventory and assessment suggest that a prospective project presents higher environmental risk, that project should bear a higher discount rate (and vice-versa). Using these tools, managers can determine an incremental discount rate that will be added to the cost of capital of the environmentally risky project, thereby "penalizing" the project with a higher discount rate and a lower NPV. Conversely, investments that reduce the probability of pollution and/or non-compliance with regulations, or decrease the risk of other environmental hazards, will be evaluated at a lower risk-adjusted cost of capital and therefore generate a higher NPV. The first principle of discount rates is that they should reflect the risks of the cash flows to be discounted. Managers should appropriately assign higher rates to expected cash flows that bear more uncertainty, and vice-versa.

In general, managers can think of sustainability risk as the uncertainty of sustaining growth because certain practices may carry negative externalities that result in the deterioration of the firm's reputation or its value chain, or that adversely impact other related systems. A changing legal landscape might also make an otherwise acceptable investment less attractive if it increases the firm's risk of entanglement in costly disposal, cleanup, or litigation. The reality of sustainability or environmental risks calls for adding a risk premium—distinct from the firm's business and financial risks—to a firm's cost of capital. Firms that use a high degree of financial or operational leverage are particularly vulnerable to environmental risk factors—if environmental litigation occurs or penalties are assessed, such firms face a greater probability of financial distress or even bankruptcy. As the decision-maker uses the Environmental Screening tool in Appendix 3 to sharpen her assessment of the project's NPV, she should also strive to ascertain the real risk of these costs ballooning in a regulatory environment that potentially becomes more hostile over time.

Governments are increasingly instituting regulations in response to environmental degradation world-wide. In anticipation of such regulations, forward-looking companies should regard the following investments as reducing risk, and adjust discount rates appropriately: improved plant efficiency; the use of alternative fuels; upgraded, more efficient, or safer technologies; and expansion of portfolios to renewable energies; among other things. The realities of an uncertain and shifting environmental and regulatory landscape support the use of higher discount rates for projects that increase the chance of untoward environmental costs (thus presenting higher sustainability risk), and lower discount rates for more sustainable investment projects that reduce future risk of environmentally-related costs (and therefore present lower sustainability risk).

Consider the following brief example: a firm must choose between two assemblies of manufacturing equipment. The first (A) costs \$50 million today and saves the firm \$10 million per year for ten years. This assembly uses a modest amount of hazardous material, emits particles into the air, and might require special disposal at the end of its useful life, depending on the regulations ten years hence. However, assembly A meets *current* environmental regulations. The second assembly (B) also costs \$50 million and saves the firm only \$9 million per year over ten years. However, assembly B is much cleaner and has none of the emissions or disposal risks of equipment A. If the firm's managers blindly apply a 10% discount rate—irrespective of sustainability risk—to both assemblies, the NPV for A is \$11.45 million

and the NPV for B is \$5.30 million. The managers would (erroneously) accept equipment assembly A, concluding that it would add nearly twice as much value as B. However, a complete analysis should include a sustainability risk adjustment for the differential risks of the two assemblies, particularly for the high uncertainty concerning the ability of A to meet future regulations, and its potentially high disposal costs. If the managers account for sustainability risk, they might apply an adjusted 14% discount rate to assembly A and a 9% rate to assembly B. The final decision would favor assembly B's \$7.76 million NPV over A's appropriately risk-adjusted \$2.16 million NPV.

In fact, some researchers argue that future environmental benefits should not be discounted at all. With roots as far back as Ramsey (1928), some economists argue for not discounting the future cash flows of public projects, saying that for government to do so was "ethically indefensible." The logic of this view derives from the assertion that future generations do not participate in today's financial market negotiations, and therefore their interests are underrepresented in balancing future benefits against present costs. Managers might do well to consider the welfare of future generations when balancing the costs and benefits of sustainable development; discounting environmental benefits at a lower rate is one step in this direction.

5.2 The Sustainability Cost NPV

Another way of quantifying risks is to calculate a Sustainability Cost NPV by quantifying sustainability-negative impacts and subtracting this amount from each project's NPV calculation. This involves identifying, classifying, and quantifying risks by multiplying each probability with each measurable impact for each capital project and then discounting these risk exposures to arrive at a negative present value or sustainability cost measure that will be subtracted from the positive NPV of each project.

$$\text{Risk Exposure} = (\text{Probability of failure}) \times (\text{Cost of failure})$$

Calculating the Sustainability Cost NPV:

1. Calculate the potential costs associated with each risk category.
2. Estimate the probability that each risk could materialize.
3. Multiply the potential cost(s) of each risk by its expected probability to calculate the expected value of each risk.

4. Estimate when the risk may develop. In the case of machines, the probabilities might increase as the asset gets older.
5. Calculate the NPV of each risk.
6. Aggregate and add the NPVs of all sustainability risks.
7. Subtract the Sustainability Cost NPV from the NPV calculation for each capital alternative.

6. CONCLUSION

There is evidence that most managers do not consider indirect environmental costs, savings, and externalities in capital budgeting decision-making and analysis. This could be because historically, most universities and textbooks have not adequately incorporated sustainability into quantitative topics like capital budgeting. There are also concerns that conventionally accepted analytic DCF methodologies like NPV and IRR do not favor sustainability-related investments and could even create bias *against* sustainable alternatives in capital selection. Furthermore, there are many hidden costs buried in overhead and in general expenses that are not captured in current capital budgeting analyses.

In today's highly connected and well-informed markets, managers realize that acknowledging and managing sustainability-related risks is no longer an option but a necessity for firm survival. Firm value encompasses all the activities of a company. Some of these activities have wider impacts on society and the environment than others, but they all have the potential for creating sustainable growth and development so long as management fully identifies and properly values the environmental costs, benefits, and risks associated with a firm's investments.

This article highlights the importance of identifying, measuring, and evaluating all the costs and savings of alternative capital investments, and provides models for managers to include sustainability risk factors in their decision-making. Using Life-Cycle Impact Assessment (LCIA), we identify sustainability-related costs from "cradle to grave" to provide a template by which hidden environmental costs and benefits may be identified, analyzed, and priced. In addition, we develop a framework for managers to justify applying a sustainability risk-adjusted discount rate, thereby appropriately adjusting for the increased risk that less-sustainable investments present to the firm, as well as for the risk reduction offered by more sustainably-oriented investments.

Effective action toward sustainability risk mitigation requires that managers appropriately execute risk assessment exercises like those proposed in this paper. These exercises should be approached as methodically as possible. Business decisions depend critically on future estimates, and robustly designed risk assessment tools offered in this paper will help managers make predictions with greater precision. Risk assessment will naturally differ from one firm to the next; however, there are a few commonalities. Risk assessment should quantify the risks so managers can anticipate the full picture of possible damages that may arise from unsustainable practices and the looming risks of regulatory change. An appreciation for the degree of impact in different scenarios is also vital.

A firm faces risks within its operating environment, and managers must consider the risks posed by water wars, climate change, social unrest, and other direct and indirect consequences of environmental damage. For example, a drought is not just an environmental issue but also a fundamental business risk involving processes such as raw materials procurement or sales efforts in impacted markets. Environmental degradation might cause governments to regulate more aggressively, making once-acceptable levels of effluent suddenly unlawful and costly. While sustainability initiatives might cynically be associated with “feel-good” marketing, viewing decisions through the lens of risk management changes the potential value proposition for skeptical business leaders. Managers should build for resilience in uncertain terrain. By using risk-assessment tools in NPV analysis that skew managers toward projects that reduce environmental risks, savvy companies may capitalize on opportunities to get ahead of institutional investors, regulators, and shareholders demanding more accountability and care for our common home.

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APPENDICES

APPENDIX 1: Fixed Assets and CAPEX Spending in the United States as of January 2015

Industry*	No. of firms	Fixed Assets / Total Assets	CAPEX / Total Assets
Consumer Nondurables ¹	194	21.15%	3.13%
Consumer Durables ²	184	18.71%	3.34%
Manufacturing ³	159	32.77%	3.00%
Energy ⁴	688	104.61%	14.66%
Chemicals ⁵	159	50.00%	5.09%
Business Equipment ⁶	1132	19.97%	3.56%
Telecom ⁷	242	45.00%	4.49%
Utilities ⁸	40	98.86%	6.98%
Shops ⁹	343	22.02%	5.71%
Healthcare ¹⁰	1133	16.77%	1.90%
Bank & Financials ¹¹	977	0.37%	0.27%
Other ¹²	620	36.97%	5.11%

* Fama & French industry classification

¹Food, Tobacco, Textiles, Apparel, Leather, Toys

²Cars, TVs, Furniture, Household Appliances

³Machinery, Trucks, Planes, Off Furn, Paper, Com Printing

⁴Oil, Gas, and Coal Extraction and Products

⁵Chemicals and Allied Products

⁶Computers, Software, and Electronic Equipment

⁷Telephone and Television Transmission

⁸Utilities

⁹Wholesale, Retail, and Some Services (Laundries, Repair Shops)

¹⁰Healthcare, Medical Equipment, and Drugs;

¹¹Finance

¹²Mines, Const, Bld Mat, Trans, Hotels, Bus Serv, Entertainment

APPENDIX 2: Inventory of Costs and Benefits

Cash outflows		Cash inflows	
Initial, operating, remediation, externalities, and other costs	Y/N?*	Operating, remediation, externalities, and disposal benefits	Y/N?*
purchase price		increase production	
sales taxes		increase in revenues & sales	
transportation costs		tax rebates	
interest/financing costs		tax savings	
installation costs		energy savings rebates	
license and permit costs		water conservation savings and rebates	
calibration costs		revenues from recycled externalities	
water costs		increase in useful life	
emissions and externalities costs		salvage value of capital asset	
costs of monitoring emissions			
plant or land space costs			
maintenance costs (labor and supplies)			
training costs (material handling and disposal)			
repair costs			
material inputs (ink, detergents, fuel, oil, etc.)			
insurance costs			
insurance fees to cover handling of hazardous substances			
hazardous materials & substances disposal			
supplies and maintenance waste disposal			
landfill costs and taxes related to material disposal			
remediation/clean up costs			
shut-down costs			
fines and prosecutions			
legal costs			
capital asset disposal costs			

*If yes, explain and quantify.

APPENDIX 3: Environmental Screening

Environmental Inventory	Y/N?	If yes, please explain which material or chemical	Remediation or disposal costs	Toxicity potential 1-5* 1=Low; 5=High
1. Require hazardous raw materials?				
2. Require hazardous lubricants?				
3. Require hazardous cleaning agents?				
4. Create waste water?				
5. Emit particles into the air?				
6. Generate heat or noise?				
7. Do employees need special protection equipment or clothing in order to operate around asset?				
8. Require plant modification to offset environmental impact?				
9. Have non-recyclable parts?				
10. Do parts need special disposal?				
11. Require reporting to regulatory agency (e.g., EPA)?				
12. Require inspections from regulatory agencies?				
13. Do parts and maintenance equipment require special storage facilities?				
14. Do parts and maintenance equipment require special transportation?				
15. Does the equipment require special disposal?				

* For detailed level of toxicity please refer to:

1. The National Institutes of Health (NIH) Hazardous Substances Databank (HSDB) and Toxicology Database (TOXNET) at <http://toxnet.nlm.nih.gov>, and/or

2. US Environmental Protection Agency (EPA) Toxic Substances Control Act (TSCA) for Aquatic Life, Terrestrial Plants and Wildlife (U.S. EPA, EOTOX, version 4, 2016).

APPENDIX 4: Impact Assessment and Eco-Efficiency Analysis

Impact Assessment	Item	Measurement Unit	Source
Waste	W	kg of waste equivalent	All
Toxic waste	TW	kg of toxic waste equivalent	Manufacturing
Air pollution	AP	kg of sulfur oxides (SO ₂) equivalents	Manufacturing, combustion, power plants
		kg of nitrogen oxides (NO ₂) equivalents	Manufacturing, transport
		kg of carbon monoxide (CO) equivalents	Manufacturing
		kg of particulates	Manufacturing
		Kg of mercury (Hg) equivalents	Manufacturing, power plants
		kg of Volatile Organic Compounds (VOCs)	Manufacturing, solvents, transportation
Indoor air quality	IAQ	kg of radon (Rn) equivalents	Land sites, mineral extraction
		kg of formaldehyde (H ₂ CO) equivalents	Manufacturing, maintenance and cleaning
		kg of asbestos	Plant insulation
		kg of Volatile Organic Compounds (VOCs)	Manufacturing, solvents
Inspection costs	IC	# of inspections per year	Plant and equipment
Global warming potential	GWP	kg of carbon dioxide (CO ₂) equivalents	Manufacturing, transportation
		kg of methane (CH ₄)	Manure, agriculture, solid waste, landfills
Water acidification potential	AP	kg of sulfur dioxide (SO ₂) equivalents	Manufacturing, power plants
		kg of ammonia	Manufacturing, food processing
Ocean acidification	OA	kg of carbon dioxide (CO ₂) equivalents	Manufacturing, transportation
Aquatic eutrophication potential	aEP	kg of phosphate (PO ₄ ³⁻) equivalents	Fertilizers
		kg of nitrates (NO ₃)	Fertilizers
Terrestrial eutrophication potential	tEP	kg of phosphate (PO ₄ ³⁻) equivalents	Fertilizers
Photochemical ozone creation potential	POCP	kg of ethylene (C ₂ H ₄)	Chemical plants, petro-chemical, agriculture