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Economic Value of Agro Waste in Developing Countries

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25.1 Introduction

Even with all the public policy programs in place, developing economies of the world are not close to achieving reasonable standards for food security, energy sufficiency, habitat preservation, and pollution-free environment. Exploring the scarcity concept may help us understand why this is the case. We, as a society, have unlimited wants and limited means. And, the limited means we have, are often dispensed to solve some issues, while ignoring other equally good ones. For example, what would a cash-strapped country primarily invest in? Would it: (i) address the food security problem by issuing vouchers to farmers that enable them to buy high-potency chemical fertilizers; (ii) address the energy sufficiency problem by building biorefineries that produce clean energy; (iii) address the habitat preservation problem by setting up monitoring stations that prevent incessant logging in protected rainforests; or (iv) simply do something else? How should we decide which mutually competing and equally pressing problems to solve? Obviously, we should select the most efficient solution. In other words, we must consider the program that justifies costs the most for the solutions it creates (Drummond et al. 1987). This type of process that compares one project's costs and consequences with another is what economists call the economic valuation.

In this chapter, we take up the economic valuation of agro-waste, with a special focus on developing economies. Here, we draw out the various possibilities and the limitations that an agro-waste reclamation program faces using the technique known as the cost-benefit analysis. This analysis technique was developed to assist governments and other not-for-profit agencies in making decisions on how to utilize public taxpayer monies in a way that maximizes public welfare.[1] The chapter will first outline a detailed summary of

1 Cost-benefit analysis is the most widely used economic valuation method in a public sector setting. Other methods more commonly used in health care sciences are cost-effectiveness analysis, cost-utility analysis, and cost-minimization analysis. See Evans and Hurley (1995) for more details. The cost-benefit analysis technique when applied to private sector decision-making is referred to as capital budgeting analysis.

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the positive attributes of a project (called "benefits") and negative attributes of a project (called "costs"). This will then be followed by the discussion of practical issues that might interfere with the outcome of the analysis. Finally, we provide an overview of the decision criteria by which a program's relative merits are evaluated in a manner that fits a specific country setting.

25.2 Cost-Benefit Analysis: Benefits

Agro-waste recycling carries the following socio-economic benefits: energy production, greater reliability of reclaimed resources for agriculture and other activities, product development, employment, and the reduction in environmental and health costs.

25.2.1 Energy Production

For many of the countries in Asia and Africa, energy shortages are the principal deterrent in socio-economic development and political stability. Today, about 17% of the 6.2 billion people in low- and middle-income countries do not have access to electricity (World Bank 2017a).[2] Such a situation is further exacerbated by the World Bank's decision to limit investments in coal-fired power stations in 2013 and in oil and gas exploration after 2019 as a part of a broader campaign to reduce greenhouse gas emissions. Considering these recent developments, one of the most promising ways to fill the gap in energy shortages is by drawing out a well-devised plan to use biofuels as replacements to fossil fuels. Within the use of biofuels as a fossil fuel substitute lies another interesting highlight – the local production of biofuels. Such production can not only reduce the country's reliance on imported crude oil, but can also reduce trade deficits.

25.2.2 Greater Reliability of Reclaimed Resources for Agriculture and Other Activities

In low- and middle-income countries as a group, agriculture utilized about 38% of land and 79% of annual freshwater withdrawals in the year 2014.[3] Studies have also noted the pattern of increasing droughts in developing countries, further making land and freshwater a valuable agricultural commodity.[4] Bioremediation is a process of reviving both contaminated land and water using bioagents such as microorganisms, plants, and fungi. Treuer et al. (2018) notes one such example for the forest conservation efforts in Guanacaste Conservation Area, Costa Rica. In 1997, nearly 12 000 metric tons of agro-waste, mainly composed of orange peels and orange pulp from a local fruit juice company, was dumped in designated zones marked as "degraded." After 15 years, ecologists found "richer soil, more tree biomass, greater tree-species richness and greater forest canopy closure" in the dumping region compared with a nearby area in which no dumping had

2 This includes 47% of Africa's one billion people (Sekoai and Yoro 2016) and 21% of India's 1.3 billion people (Sahni and Sinha 2018b).

3 Data obtained from World Bank (2017b) and World Bank (2017c).

4 For example, by studying the rainfall and human development data in India, Sahni and Sinha (2018a) show the impact of drought on violence in agricultural societies.

taken place. Therefore, reclaimed resources, to the extent that it is safe and socially acceptable for reuse, alleviates the pressure on virgin resources and reduces both environmental pollution and overall supply costs of the resource in question.

25.2.3 Product Development

Recent technological developments have used agro-waste innovatively in several profit-bearing initiatives.

25.2.3.1 Soil Amendments

As per the International Fertilizer Development Center in the year 2009, between 50% and 77% of the worlds production capacity of industrial fertilizers was controlled by a small group of firms in five fertilizer-producing countries (Hernandez and Torero 2013). Such high industry concentration puts enormous upward pressure in fertilizer prices. Also, the amount of industrial fertilizer consumption in low- and middle-income countries has increased from 97.2 kg ha^{-1} of arable land in 2002 to 138.2 kg ha^{-1} of arable land in 2014. In 2014, the lowest was in the Central African Republic at 0.3 kg ha^{-1} of arable land and the highest was in Malaysia with 2063.9 kg ha^{-1} of arable land.[5] And, with rising demand, costs also increase – industrial fertilizers are now far too expensive for farmers to afford without governmental assistance. This situation points to a growing need to use animal waste as an industrial fertilizer substitute. Potential benefits include the adequate disposal of animal manure, savings from foregone industrial fertilizer purchase, and prevented crop loss due to delays in fertilizer imports resulting from government inefficiencies.

25.2.3.2 Building Materials

There is an increasing concern over the depletion of earth-based building materials such as clay and sand. Shortage in these materials poses a particular type of problem in developing countries, not seen in other parts of the developed world. In the southern Indian state of Tamil Nadu, there is rampant illegal sand and gravel mining from riverbeds and beaches that not only causes widespread riverbank erosion, but, has also drawn violence between environmentalists and illegal mining cartels.[6] Similar illegal riverbed and coastal sand mining has been noted in Pakistan, Nepal, Bangladesh, Tanzania, and Zanzibar. Most of these circumstances create immense political turmoil and enormous loss in terms of foregone taxes due to illegal sand sale. Therefore, there is a need to search and develop sustainable alternatives. The protracted use of plant-based residues, such as rice straw ash and wheat straw, to partially replace conventional building materials, is currently being tested.

25.2.4 Employment

While it is difficult to pinpoint the precise impact of waste reclamation on employment due to the lack of reliable statistics, there can be no doubt in designating employment as the main motivating factor to set up a comprehensive agro-waste policy in a developing

5 Data obtained from World Bank (2017e).

6 For details, see https://ejatlas.org/conflict/illegal-sand-mining-in-tamil-nadu.

country. A new facility may have job implications well beyond direct employment. Indirect employment arising from related industry services such as providers of materials and technology may also have a positive impact on employment numbers.

25.2.5 Environmental and Health Benefits

25.2.5.1 Cost Savings from Reduced Carbon Dioxide Emissions

Atmospheric carbon dioxide (CO_2) levels have been increasing consistently over the past few decades – from 1.1 metric tons per capita in 1960 to 3.5 metric tons per capita in 2014 in the low- and middle-income countries alone (World Bank 2017d). Biofuels are carbon-neutral, that is, the amount of CO_2 consumed by the plant over its life is roughly equal to what the plant waste releases when burned as a fuel. Thus, the use of biofuels in place of fossil fuels can achieve sizable reductions in CO_2 emission levels.

25.2.5.2 Cost Savings from Reduced Crop Burning as a Means to Clear Land for Harvest

Stubble burning, a once popular way to clear the land for the next cycle, is now banned or closely regulated with permits in developed countries such as the UK and Canada. Still, the practice is fairly common in many developing countries in Asia and Africa.[7] Consider the case of India. Several million tons of post-paddy harvest crop is burned during the two weeks starting mid-October in the states of Punjab, Haryana, and western Uttar Pradesh. In this burning season, haze in the nation's capital, New Delhi, causes travel delays and restrictions, school closures, and increased hospital visits of mostly children and seniors for respiratory problems due to overexposure to particulate pollution. In 2010, about 42 000 deaths were attributed to stubble burning across India, a number that has increased to 65 000 in 2017 (Tallis et al. 2017). Therefore, an agro-waste reclamation policy that weakens stubble burning can lead to monetary savings and environmental protections.

25.2.5.3 Cost Savings from Reduced Virgin Land and Water Use

Forests, pastures, rivers, and lakes provide unique habitats to numerous fish, animals, and plant life. Using treated land and water in place of virgin resources helps to conserve these habitats, producing substantial environmental gains.

25.2.5.4 Cost Savings from Reduced Disposal in Landfills

Landfills and dump sites contain solid agro-wastes and plant residues. These sites, over time, become a breeding ground for a variety of diseases and emit flammable and odorous greenhouse gases that adversely impact the environment. In addition to the cost savings from reduced emissions, most of the landfill wastes are energy rich and can be a valuable commodity to produce biofuels (see Section 2.1) and soil amendments (see Section 2.3.1).

7 See NASA's satellite imaging of stubble fires across India in 2016 at https://www.nasa.gov/image-feature/goddard/2016/first-comes-fire-then-comes-crops-in-india and central Africa in 2013 at https://www.nasa.gov/sites/default/files/753040main_20130603-africa_946-710.jpg.

25.3 Cost-Benefit Analysis: Costs

The costs associated with agro-waste recycling can be grouped in the following categories: cost of initial setup, cost of operations, cost due to rising food prices, cost of policy development, environmental and social costs, and health costs.

25.3.1 Cost of Initial Setup

We could hope for the picture to change in the coming years, but as it stands today, the cost of initially setting up an agro-waste processing unit is an overwhelming task for several developing countries. Let us consider the case of a commercial second-generation biofuel facility. The International Energy Agency's 2010 report estimates that financing and initial setup costs was between USD 125 million and USD 250 million. For countries such as Brazil, India, South Africa, Mexico, and Thailand, this does not pose a problem – a mix of foreign direct investment and domestic funding ensures the setting up of the biofuel facility. But in countries such as Cameroon and Tanzania, domestic funding sources are limited, and poor infrastructure and lack of skilled labor deter foreign companies from investing.

25.3.2 Cost of Operations

25.3.2.1 Supply of Waste

Biomass is a seasonally varying raw material. During the season when it is relatively cheap, biomass energy facilities buy and store large quantities of biomass from decentralized small-scale waste producers, sometimes from much wider distances. Such procurement, transportation, and storage are associated with huge logistical costs. Storage also gives rise to another problem – biomass has a tendency to decay resulting in lower quality over time and depressing its effective usage as a fuel substitute.

25.3.2.2 Supply of Skilled Labor

In general, studies show a net positive employment impact of starting a biomass energy facility in most developing countries. Jobs that are arduous and repetitive in nature such as gathering, collection, and transport of biomass are easily filled; however, those that require technical expertise go unfilled. Engineers are often in short supply except in countries that already have a long history of producing biofuels (e.g. Mexico, Brazil, India, and South Africa). Other developing countries find it hard to attract, train, and retain skilled workers and eventually lose them to other industries that offer more lucrative and stable employment.

25.3.3 The "Food Versus Fuel" Controversy

Both food and biofuel production entail the same set of land, water, labor, and other inputs, and any amount of diversion of these inputs away from food production into biofuel production might end up depressing an already growing population that are food insecure. Many premiere organizations including the UN, the IMF, the World Bank, and the Organization for Economic Cooperation and Development (OECD) also warn that biofuel expansion may exert an upward pressure on food prices in the future.[8]

25.3.4 Cost of Policy Development

Since the 1990s, several agro-waste reclamation projects have been carried out in developing countries in collaboration with external support agencies such as the World Bank. While some projects have succeeded, many have failed to support themselves over time or expand to accommodate the recipient country's growing waste production. One principal reason for this failure was found to be the lack of optimal institutional capacity, a governing agency that overlooks all aspects of the planned waste reclamation efforts. Governments seeking external support must identify subsequent resource requirements, understand socio-economic and political settings that might adversely influence waste processing efforts, and develop a comprehensive agro-waste policy that fully encompasses the short-term and long-term goals. While coming up with such a policy is feasible theoretically, in practice, it is a daunting task for many low- and middle-income countries.

25.3.5 Environmental and Social Costs

Environmentalists have concern over the philosophy behind some resource reclamation efforts. Despite the legal framework within which they work, waste producers have a strong economic incentive to oppose any pollution control standards set. Adding to this fact, the success of a newly established waste reclamation facility heavily depends on the continuous supply of wastes. Collectively, this situation might give rise to a mentality that opposes all forms of resource conservation efforts and promote a heightened waste production paradigm.

In some countries, biofuel production results in significant social costs. In 2016, the palm oil industry, in partnership with the Colombian government, continued to expand palm oil plantations, despite deforestation concerns and displacement of farm workers.[9] A 2017 plan to build a biorefinery near the Kaziranga National Park, a world heritage site in the north-eastern state of Assam in India, has sparked concerns from those arguing that there will be a negative impact on the habitat of elephants, rhinos, and numerous other threatened and endangered wildlife.[10] Similar fears regarding habitat preservation, indigenous people's territory and culture protection, and the welfare of farmers have been raised by conservationists in Indonesia and Paraguay as well.

8 See the following article: https://www.theguardian.com/global-development/poverty-matters/2011/jun/01/biofuels-driving-food-prices-higher.

9 See the following article for details: https://www.laborrights.org/blog/201605/displacement-death-and-worker-exploitation-corporate-crimes-colombia%E2%80%99s-palm-oil-industry.

10 See the following article: https://news.mongabay.com/2017/11/biofuel-project-near-indias-rhino-heartland-sparks-protests.

25.3.6 Health Costs

Gathering and transporting raw agro-waste, as well as handling treated waste, may have significant occupational health risks to workers engaging in these activities. For some developing countries, educating and monitoring workers against these health risks may be a cumbersome task.

25.4 Practical Issues in Conducting a Cost-Benefit Analysis

A cost-benefit analysis offers the most comprehensive method of economic evaluation. But in practice, there are many issues to be addressed before a decision can be made – whether to accept a project. Each of the following subsections discusses the challenges involved in a cost-benefit analysis.

25.4.1 Valuation of Costs and Benefits

It is important to establish a uniform measurement unit for the various cost and benefit items enumerated earlier, so that a valid evaluation can be made. On economic grounds, the most simplistic approach is to assign a monetary value to both costs and benefits, so that comparisons across a wide range of agro-waste reclamation projects, and/or between agro-waste reclamation projects and other public policy projects, can be made. The monetary value of project inputs is based on the "opportunity cost" concept – the cost that is foregone by not doing the next best activity as a consequence of doing the given activity. Other monetary values are assigned based on the observed and stated preferences ("willingness to pay") of all the people in the society by determining how much they are collectively prepared to pay for an activity that benefits them or willing to get compensated for an inaction that causes harm. True value estimation of benefits and costs can also be distorted by the presence of mechanisms that cause deviations in free-market prices such as penalties (e.g. fines on stubble burning in India), incentives (e.g. voucher programs distributing affordable fertilizer to farmers in sub-Saharan African countries), quotas (e.g. a 5% mandatory biodiesel blending quota in Brazil), and other stakeholder monopolies along the supply chain of the agro-waste industry. Failing to correct for these distortions might lead to mistakenly allowing an ineffective project to commence into action ("Type I error") or delaying, rejecting, and scaling back of a useful project ("Type II error").

The tricky part is the valuation of activities that do not have a market, thereby making it extremely difficult to estimate prices to be used in the cost-benefit analysis. Generally speaking, most health-related activities fall into this category. For example, how does one measure the indirect and intangible costs associated with stubble burning? To do this exercise, we need to estimate the true value in a roundabout way – that is, by determining simultaneously the loss of life and life quality. Quality-adjusted life years (QALYs), a measure first introduced by Klarman et al. (1968), provides a score of years lived, relative to those years spent in perfect health. QALY varies between 0 (death) and 1 (perfect health). If the calculated quality of health is only two-thirds of perfect health, then a year spent in such a diseased state equals 0.67 QALY. Years spent in disability or more commonly called disability-adjusted life years (DALYs), proposed by Murray

(1994), measures the burden of illness through the reduction in "human function" (Murray 1994, page 438). DALY varies between 0 (perfect health) and 1 (death). Hence, the health assessment objective is to either maximize QALYs or minimize DALYs.

25.4.2 Discount Rate

Next, we need to establish a common time reference to compare costs and benefits that happen at different dates. Based on natural human behavior, people have positive time preferences, and therefore all costs and benefits that are realized in the future must be "discounted" to what it is worth today. Now, we must determine by how much the future costs and benefits are to be reduced to reflect today's value. This procedure has a two-pronged approach, illustrated below.

25.4.2.1 Determination of the "Opportunity Costs of the Project's Funds"

This cost is the market-driven risk-adjusted rate of return on the next best investment strategy to which funds employed might otherwise have been put. This return computation is tricky for many developing countries where capital markets are of limited sophistication as it is not always possible to calculate many of the variables that are known to be relevant.

25.4.2.2 Determination of Society's Collective Time Preference Discount

Governments' taste for the consumption at present over the consumption in future dictates certain adjustment weights to the project's otherwise market-based after-risk rate of return calculated previously. A "perfect" estimation of these weights is futile for developing countries; however, a valid approximation can be obtained based on the society's mix (poor vs. rich, young vs. old), population growth rate, political motives, and measures aimed at correcting market irrationality. For more discussion on this, see OECD (2009).

Improper discount-rate estimation may lead to the same perils discussed in Section 4.1. Assume that projects are of the high capital investments – low running costs profile with benefits in the distant future. A discount-rate that is "too-low" inflates future benefits in present value terms, thereby allowing a bad investment to go ahead (Type I error). Likewise, a discount rate that is "too-high" depresses future benefits in present value terms, thereby rejecting a good investment (Type II error).

Typically, discount rates in developing countries are higher (8–15%) than in developed countries (3–7%) (ADB 2013).

25.4.3 Analysis Period

How can citizens that face immediate deteriorating health, poverty, and unemployment concerns approve of governments that require them to make sacrifices on their current needs in order to participate in projects that will not yield benefits in time to improve their welfare? This is the dilemma that many local governments in developing countries face when they have a public policy investment decision to make. A project, however good and environmentally-sensible, which takes a long time to show gains is unequivocally rejected. At the same time, a project that is assessed over a small horizon may not be economically prudent considering the large project expenditures that come with the initial setup. Therefore, the selection of an appropriate analysis period becomes one of the key deciding factors to bring a project to its fruition.

The analysis period is also closely related to the choice of discount rate (see Section 4.2). A high discount rate compels a shorter analysis period because benefits that accrue over longer horizons become too insignificant to make a difference at the present time. The opposite is true when the discount rate is set low.

25.4.4 Impact of Corruption

In a manner of speaking, most agriculture-based countries get low scores for governance (World Bank 2008, page 245). This paints a poor picture – the governments and related agencies implementing policies are riddled with inefficiencies, vested interests, and corruption, adding a strain on the project's operational costs. In fact, governance issues are the main reason why many of the 1982 World Development Report's recommendations on agriculture failed. Bribery is also the key reason why deviations from environmental regulations such as land, water, and air pollution often go unpunished. Corruption influences agricultural projects in many ways. They are outlined here.

25.4.4.1 Improper Resource Administration

Land and water administration institutions are seldom independent from political pressure and are sometimes forced to authorize development in protected lands and water bodies. In Kenya, there was a systemic problem of forced eviction and land grabbing by public officials during 1980–2005. Conflicts over land displaced millions of farmers in Columbia since the late 1990s. Additionally, farmers' livelihood shrinks with the payment of bribes to public officials to obtain services such as land registration, access to irrigation systems and ground water, and access to electricity. In India, the collective annual worth of bribes given by users of land administration services is USD 700 million, almost equal to the public spending channeled toward a sustainable environment agenda.

25.4.4.2 Informal Banking Services

Public- and private-sector commercial banks, village banks (rural banks), cooperative banks, and insurance companies form the basic network of formal financial institutions in most developing countries and are often not well-suited to serve the needs of poor farmers. Studies in Kenya show that poor farmers do not trust banks and are unwilling to incur the account opening and withdrawal charges.[11] Farmers also refrain from using bank loan services because they are unwilling to bear the risk of losing collateral, unable to meet the requirements of collateral, or do not tolerate the rigidity of loan options. Instead, the primary source of money access and lending for poor farmers comes from professional and nonprofessional money brokers (commonly referred to as "loan sharks") whose terms are based on familiarity (kin-, religion-, or ethnic-based memberships, and geographical location), dictating the cost of doing business, the size of the loan, and the rate of interest charged. The National Crime Records Bureau (2015) of India

11 See Dupas et al. (2012) for more details.

reports that debt burden from informally borrowed loans and the harassment that accompanies it are the main contributors to thousands of farmer suicides every year.[12]

Most of these costs are unnecessary and cannot be priced using conventional economic models. However, some of the costs can be branched out through investments in technology and innovations.

25.5 Decision Rule

On what basis is project selection made? The decision rule favored in most economic analysis is the net present value (NPV) criterion, which simply states that the discounted stream of net economic benefits (benefits minus costs) must at least exceed zero.

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t}$$

where B_t is the aggregate benefits in year t, C_t is the aggregate costs in year t, n is the number of years used in calculations of benefits and costs (from 25.4.3), and r is the discount rate (from 25.4.2). When comparing more than one project, the rule of thumb is to always select the project with the highest NPV.

25.5.1 Special Cases

There are rare occasions when the project with the highest NPV is sidelined and other positive NPV projects (that is, projects with NPV greater than zero) are selected instead. Many other decision rules that complement the NPV criterion come into play in these types of situations.

- It is well established that the rate of return from public policy projects must be at least as high as the return from the next best alternative use of project funds. For example, how does the rate of return on a wastewater recycling facility fare against the annual return from a fixed term bank account or against the rate of return on a public education program? These comparisons can be made by the creation of a criterion that is based on a return measure instead of a monetary value. We compute what is known as the "internal rate of return" (IRR) of a project – that is, the annual rate that equates the stream of benefits to its cost counterpart.

$$\sum_{t=1}^{n} \frac{B_t}{(1+IRR)^t} = \sum_{t=1}^{n} \frac{C_t}{(1+IRR)^t}$$

  When many positive NPV projects are available, it is also possible to rank and compare projects based on their respective IRR. The IRR criterion will dictate the selection of the project with the highest IRR.

12 The National Crime Records Bureau (2015) tracks suicides by category year-wise since the mid-1990s. Farmer suicide figures also showed an unexpected rise of about 42% between the 2014 (total suicides: 5650) and 2015 (total suicides: 8007).

- Governments facing hard budget constraints want a measure that delivers the maximum output for cost under the stringent economic conditions they face. In these situations, the criterion referred to as the benefits-to-costs ratio (BCR) is used. This criterion is presented as a ratio of discounted benefits to discounted costs, which must be at least greater than one.

$$BCR = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t} \Big/ \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$$

  The decision rule based on the NPV criterion and the BCR criterion provide the same result when analyzing one project facing a dichotomous choice – that is, either to "accept" or to "reject." But, the economic interpretation of the BCR criterion – the benefits (present value) for every unit of investment capital spent, is particularly useful when more than one project needs to be ranked based on their relative merits. For example, a small project having a BCR of 4.0 would be ranked above a large project having a BCR of 2.0, even if the former has a smaller NPV than the latter. Therefore, governments can decide whether to implement one big project or a combination of several small- and medium-sized projects to achieve the same stated objectives.
- Sometimes, various levels of financing constraints force low-income countries to choose the "do-minimum" option in public policy projects. Under these circumstances, the group of positive NPV projects can be ranked by expenditure, and the selection criterion will dictate the nomination of the project that carries the lowest cost profile. This criterion is called the least-cost option.
- Financiers of public policy projects might be interested in knowing the quickest possible time frame to recover their investment capital. The payback period (a time-based measure) criterion is used for this purpose, which gives the number of years necessary to earn back the initial capital investments put into projects, forming a lower bound of the financiers' investment horizons (in years) to make a positive return for the project.

25.5.2 Sensitivity Analysis

Is the decision rule robust or fragile to changes in parameters and inputs of the project? The answer to this question relies on conducting a sensitivity analysis – that is, the identification of various forms of uncertainties that might affect the economic valuation of the project. It involves the following steps: (i) identify the parameters that are vital to the decision rule; (ii) calculate "switching values" of those parameters; and (iii) gather as much information about related market uncertainties.

Identifying the parameters that affect the cost- and benefit-streams the most is an important step in risk management. This is because the changes in the largest cost and benefit items are more likely to alter the findings of the decision rule. When tabulating the costs of a biofuel facility, the key contributing factor in many cases is the cost of ongoing operations. Like chemical facilities, biofuel facilities transport and store large amounts of combustible ingredients such as biodiesel, bioalcohol, biogas, feedstock, and wood. Given this fact, what happens when typical process hazards (fire, explosion, leak/uncontrolled reaction, and steam flashes) cause facility shutdowns?[13] How would

13 For a detailed list of biofuel project and plant hazards, see Nair (2011).

such an incident raise the operating costs and by how much? To accommodate such incidents, we come up with operating cost scenarios and recheck the decision rule calculations. Would the NPV still be positive if the operating costs go up by 10% and everything else remains the same? Now, by 20%, 30%, and so on. Such an analysis provides a cutoff amount (also referred to as "switching value") for operating costs after which NPV turns from positive to negative and the project is no longer financially feasible. In the same way, the adjustment to the largest benefit-causing factor also needs to be assessed for its vulnerabilities.

Can we anticipate all the possible things that can go wrong with the project? In many cases, uncertainties related to specific market events (e.g. demonetization, wage law changes, labor strike, and technology change) may play a major role in determining whether a project is successful. For example, many Zimbabwean public policy projects that started in the 1980s with an analysis period of over 20 years faced the effects of unexpected hyperinflation.

Developing a conceptual estimate of switching values for each of the project parameters and market variables provide the decision maker with valuable priorities.

25.5.3 Typical Benchmarks for Key Financial Parameters

Table 25.1 provides the International Finance Corporation's benchmarks for key financial parameters used in some of its public policy projects for developing countries. Actual estimates may vary depending on country-specific or project-specific conditions.

Table 25.1 Typical benchmarks for key financial parameters.

Parameters	Biomass to energy *Source:* IFC (2017)	Hydroelectric power *Source:* IFC (2015)	Miscellaneous *Source:* ADB (2013)
NPV	>0, depending on project risk	≥25% of investment	
IRR	≥10%	≥10%	
Payback	<10 yr	<10 yr	
Discount rate	≥9%		
By Institution			
– World Bank			10 – 12%
– AfDB[a]			10 – 12%
– IADM[b]			12%
By Country			
– Philippines			15%
– India			12%
– Pakistan			12%

[a] African Development Bank.
[b] Inter-American Development Bank.

25.6 Summary

As developing countries move toward more agro-waste reclamation campaigns, questions about it still linger. What are the benefits of reuse? Is it worth the effort? At present, conservative estimates indicate 40% of the land area and 70% of the freshwater resources are utilized by various agricultural activities. Moreover, most of the rainforests located in developing countries are under a direct threat due to aggressive agricultural expansion. Therefore, waste reclamation efforts in general, and those pertaining to agro-waste in specific, play a significant role in reducing the use of virgin land and water. In addition to this, the production of biofuels from farm waste both improves a country's energy security and reduces the dependence on fossil fuels, which comes with its own benefits in the form of greenhouse gas emission reductions.

Last, but not least, the health gains that are associated with reduced stubble burning and landfill disposal are also substantial. But, waste reclamation efforts are costly. The initial setup costs, ongoing operations costs, environment-related costs, and social costs all add up to be a significant figure, especially for cash-strapped countries. Further, developing countries lack adequate institutional capacity and investor protections to govern public policy projects that make foreign investments hard to obtain.

The cost-benefit analysis equates these cost- and benefit-streams in present value terms. If the analysis results in positive net benefits, the project is green-flagged, otherwise, the project is dropped. Sufficient care must also be taken to understand the various project-specific and market-driven uncertainties that might affect the economic valuation of the project. A sensitivity analysis is performed, and switching values are tabulated for all influential factors.

Despite the hurdles, reuse of agro-waste is a beneficial economic activity. More and more countries must develop comprehensive waste reuse policies and address their growing food, energy, and pollution concerns. Such a plan must include a study on all aspects of the cost-benefit analysis discussed in this chapter. In particular, those that are related to the local socioeconomic attitudes toward agro-waste production and reuse, the effects of corruption on public policy, the measurement of non-monetary environmental and health gains and losses, society's time preferences, and waste management technical know-how would be particularly useful in providing us the tools required to assess project risks and perform a more robust cost-benefit analysis.

References

ADB (2013). *Cost-Benefit Analysis for Development: A Practical Guide*. Manila, Philippines: Asian Development Bank.

Drummond, M., O'Brien, B., Stoddart, G., and Torrance, G. (1987). *Methods for the Economic Evaluation of Health Care Programmes*. Oxford University Press.

Dupas, P., Green, S., Keats, A., and Robinson, J. (2012). *Challenges in Banking the Rural Poor: Evidence from Kenya's Western Province*. Working Paper 17851,. National Bureau of Economic Research.

Evans, D. and Hurley, S. (1995). The application of economic evaluation techniques in the health sector: the state of the art. *Journal of International Development* 7 (3): 503–524.

Hernandez, M.A. and Torero, M. (2013). Market concentration and pricing behavior in the fertilizer industry: a global approach. *Agricultural Economics* 44 (6): 723–734.

IFC (2015). *Hydroelectric Power: A Guide for Developers and Investors*. Washington, DC, USA: International Finance Corporation.

IFC (2017). *Converting Biomass to Energy: A Guide for Developers and Investors*. Washington, DC, USA: International Finance Corporation.

Klarman, H.E., Francis, J.O., and Rosenthal, G.D. (1968). Cost effectiveness analysis applied to the treatment of chronic renal disease. *Medical Care* 6 (1): 48–54.

Murray, C.J.L. (1994). Quantifying the burden of disease: the technical basis for disability-adjusted life years. *Bulletin of the World Health Organization* 72 (3): 429–445.

Nair, S. (2011). Identifying and managing process risks related to biofuel projects and plants, Hazards XXII, IChemE Symposium Series No. 156.

National Crime Records Bureau (2015). *Accidental Deaths and Suicides in India 2015*. Government of India, New Delhi, India: Ministry of Home Affairs Publications.

OECD (2009). *Measuring Capital - OECD Manual 2009*, 2e. Paris, France: OECD Publishing.

Sahni, H. and Sinha, E. (2018a). Climate Shock and Violence, paper presented at the Population Association of America Conference, Denver, CO, USA (April 26–28, 2018).

Sahni, H. and Sinha, E. (2018b). Electricity and Education, paper presented at the American Economic Association Conference, Philadelphia, PA, USA (January 5–7, 2018).

Sekoai, P. and Yoro, K. (2016). Biofuel development initiatives in sub-Saharan Africa: opportunities and challenges. *Climate* 4 (2): 33.

Tallis, H., Polasky, S., Shyamsundar, P. et al. (2017). The Evergreen Revolution: Six ways to empower India's no-burn agricultural future. University of Minnesota, St. Paul, MN; The Nature Conservancy, Washington, DC; International Maize and Wheat Improvement Center, Mexico; and Borlaug Institute for South Asia, Ludhiana, India.

Treuer, T., Choi, J., Janzen, D. et al. (2018). Low-cost agricultural waste accelerates tropical forest regeneration. *Restoration Ecology* 26 (2): 275–283.

World Bank (2008). *World Development Report 2008: Agriculture for Development*. Washington, DC, USA: World Bank.

World Bank (2017a). Access to electricity (% of population covered). URL: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=XO. Data retrieved on 11/21/2017 from World Development Indicators.

World Bank (2017b). Agricultural land (% of land area). URL: https://data.worldbank.org/indicator/AG.LND.AGRI.ZS?locations=XO. Data retrieved on 11/21/2017 from World Development Indicators.

World Bank (2017c). Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal). URL: https://data.worldbank.org/indicator/ER.H2O.FWAG.ZS?locations=XO. Data retrieved on 11/21/2017 from World Development Indicators.

World Bank (2017d). Carbon dioxide emission (metric tons per capita). URL: https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?locations=XO. Data retrieved on 11/21/2017 from World Development Indicators.

World Bank (2017e). Fertilizer consumption (kgs/hectare of arable land). URL: https://data.worldbank.org/indicator/AG.CON.FERT.ZS?locations=XO. Data retrieved on 11/21/2017 from World Development Indicators.