Sustainable Energy Development: An Economic Perspective

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Outline

1. Economics
2. Environmental Effects of Energy
3. Externalities
4. Cost-Benefit Analysis
5. CBA Example
What is economics?

**Economics**: A social science concerned with the allocation of scarce resources for satisfying unlimited wants
What is energy economics?

Energy economics or more precisely the economics of energy is a branch of applied economics where economic principles and tools are applied to understand energy consumption, production, markets, and externalities.

Energy economics constitutes an inter-disciplinary research from engineering, operations research, and other decision-support systems.

Energy issues have been analyzed from an economic perspective for more than a century now, but energy economics did not develop into a specialized branch until the oil shocks in the 1970s.
The term “Sustainable development” was first coined by a Brundtland Commission of the U.N., March 20, 1987:

“... sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”
Why are environmental considerations important?

Environmental stewardship must be a cornerstone of any scenario for sustainable energy development.

Environmental considerations affect virtually all aspects of energy decision making by:

- government
- private sector
- consumers
Challenge for sustainable advocacy

How can humankind equitably provide energy-derived benefits to a growing world population without degrading the environment or exhausting resources for which there are no apparent substitutes?
Energy-Prosperity-Environmental Dilemma

Energy

Environmental and economic degradation

- Prior befoultment
- Current damage
- Future harm

Economic and environmental progress

- Extension of economic opportunity
- Environmental cleanup, restoration, and protection
- Preservation of economic well-being
Adverse Impacts

Note that adverse impacts from energy include a vast legacy of:

- Prior damage
- Current pollution
- Real prospect of continued ecosystem degradation

Energy-derived pollutants include:

- Gases
- Liquids
- Solids
- Mixed phases
Benefits

Energy-driven economic progress benefits humankind by:

- Preserving and extending prosperity
- Improving the environment through redress of past damages
- Prevention of future pollution
Hidden costs

Human activities have economic consequences that are not always reflected in the prices of related goods and services.

Sometimes these *hidden costs* are so minute as to be inconsequential and not to justify their inclusion (or “internalization”) in the costs of the activity.
Example: PPCPs

Pharmaceuticals and Personal Care Products as Pollutants (PPCPs):

- Any product used by individuals for personal health or cosmetic reasons or used by agribusiness to enhance growth or health of livestock
- Diverse collection of thousands of chemical substances, including prescription and over-the-counter therapeutic drugs, veterinary drugs, fragrances, and cosmetics.

The drugs we take are not entirely absorbed by our bodies, and are excreted and passed into wastewater and surface water.

Research suggests that certain drugs may cause ecological harm.
Concept Introduced

Suppose two firms are located by a river. The first produces steel, while the second, downstream, operates a resort hotel.

The first uses the river as a receptacle for its waste, while the second uses it to attract customers seeking water recreation.

If the two facilities have different owners, an efficient use of the water is not likely to result.

The steel plant does not bear the cost of reduced business at the resort resulting from waste being dumped into the river, so it is not likely to be sensitive to that cost in its decision making. As a result, too much waste may get dumped in the river.
The externality in the above example arises when:

1. property rights are ill defined
2. rights are exchanged under something other than competitive conditions

Let’s now explore solutions
Private Resolution

The simplest solution is for the two parties to resolve the issue privately. This is generally only feasible when the number of affected parties is small.

In this particular example, the resort can simply bribe the steel mill with money in order for the mill to reduce its waste. Such types of arrangements rarely work in practice. But this example of individual negotiations raises to questions:

1. **Who has the properties right in this case?** Does the mill have to right to remove its waste, or does the hotel have the right to clean water?

2. **How can environmental risks be handled when prior negotiation is impractical?**
The Courts: Property Rules and Liability Rules

The two questions on the previous slide are routinely answered by the court system.

Court system responds to environmental conflicts by imposing either *property rules* or *liability rules*.

Property rules – specify the initial allocation of the entitlement.

Liability rules – rules that award monetary damages to the injured party.
An externality exists whenever the welfare of some agent, either a firm or household, depends not only on his or her own activities, but also on the activities under the control of some other agent.
Externality further defined

External effects, or externalities, can be positive or negative. Economists use the terms *external economy* and *external diseconomy*, respectively, to refer to those conditions.

Another type of externality is defined as an *pecuniary externality*. These types of externalities arise whenever the external effect is transmitted through altered prices.

Example: A new firm (such as Walmart) moves into an area and drives down the prices of certain goods. This drives down the prices of similar goods offered by small retailers in the area, and therefore, is an pecuniary diseconomy.
Many scholars believe that the supply and use of energy is accompanied by significant expenses that are not captured in present-day energy prices.

Many of these externalities are associated with the adverse environmental impacts of energy, including:

- costs of healthcare
- lost productivity
- air and water pollution
- remediation of damages from increasing extreme weather events
- aesthetic damage
- destruction of open space
- remediation of wastes
Market Allocation of Pollution

Air and water are treated in our legal system as common-pool resources, and it shouldn’t be surprising to anyone that the market misallocates these resources.

Free-access resources have a tendency to be overexploited.

Air and water resources have been overexploited as waste repositories.
Pollution is an Externality

Pollutant damages are commonly externalities.

When pollutants are injected into water bodies or the atmosphere, they cause damages to those firms and consumers downstream or downwind of the source, not the source itself.

These costs are not borne by the emitting source and hence not considered by it, although they are certainly by society at large.
Because these costs are significantly undervalued, the disposal of wastes is inefficiently attractive.

A polluting firm will then minimize costs by not choosing to abate anything, since the only costs it bears are its own control costs.

What is cheapest for the firm is not cheapest for society.
Stock Pollutants

In the case of stock pollutants, this problem is particularly severe.

Uncontrolled markets would lead to

- an excessive production of the product that generates the pollution
- too few resources committed to pollution control
- an inefficiently large amount of stock pollutant in the environment

Thus, the burden on future generations caused by the presence of this pollutant will be inefficiently large.
Example: Smog in China
Example: Smog in China
Example: Smog in China
Market Failure

Because the costs of pollution are borne partially by innocent victims rather than producers, it does not find its way into product prices.

Firms that attempt unilaterally to control their pollution are placed at a competitive disadvantage.

Therefore, the unimpeded market fails to generate the efficient level of pollution control, and firms are penalized for trying to control an efficient amount.

So government intervention is necessary.
Gov’t Intervention

There are two ways for the government to control pollution:

1. impose a legal limit on the amount of pollution allowed by each emitter

2. impose a tax or charge on each unit of pollution so that emitters internalize the costs

Another, more market-oriented type of solution is for the government to establish a cap-and-trade program.

The effectiveness of the policy instruments are easy to define in principle, but are very difficult to implement in practice.
Gov’t intervention to control GHG emissions faces an uphill battle. A perfect example of this is the challenge the White House faced with its nominee, Gina McCarthy, for the next EPA administrator: www.foxnews.com
Any action taken to moderate climate change provides a global public good, implying the strong possibility of free-rider actions.

Those who do not control greenhouse gases cannot be prevented from reaping the benefits of the actions of those who do.

Free-rider problems inhibit investment in research and development to reduce GHG emissions and inhibit participation of nations in a unilateral agreement.
Cost-Benefit Analysis (CBA)

- CBA estimates and totals up equivalent money value of the benefits and costs to the community of projects to establish whether they are worthwhile.
- Projects may include dams, highways, training programs, and health care systems.
- Problem with CBA is that of computation.
- Components of benefits and costs may be intuitively obvious, but intuition may fail with certain methods of measurement.
- Therefore, basic principles are needed as a guide.
Common Unit of Measurement

- All aspects of a project must be expressed in terms of a common unit – a “bottom line”
- The most convenient unit is money
- Thus, all benefits and costs of a project are measured in terms of their equivalent money value
- Benefits and costs must also be expressed in terms of dollars of a particular time
- This is due to the differences in the value of money at different times b/c of inflation
- Benefits and costs are often expressed in discounted or present value terms
Benefits are Often Measured by Market Choices

- Consumers purchases at market prices reveal the marginal benefit of consuming the product.
- Consumers are willing to increase their consumption up to the point where marginal benefits are equal to marginal costs.
- Therefore, the marginal benefit is equal to the market price.
- Marginal benefit declines with the amount consumed in the market place.
- Relationship between market price and quantity consumed is the “demand schedule”.
Gross Benefits are Measured as the Area Under the Demand Curve

- The increase in benefits resulting from an increase in consumption is the sum of the marginal benefit times each incremental increase in consumption.
- The marginal benefit curve is the same as the demand curve so the increase in benefits is the area under the demand curve.
Some Measurements of Benefits Require Valuation of Human Life

- It’s sometimes necessary in CBA to evaluate the benefit of saving human lives.
- However, there is considerable antipathy in the general public to the idea of placing a dollar value on human life.
- The controversy is often defused when it is recognized that the benefits reduce the risk of death.
The *impact* of a project is the difference between the benefits and costs accrued with and without the project. This is not the same as a before-and-after comparison.
CBA Involves a Particular Study Area

- The impacts of a project are defined for a particular study area
  - city
  - region
  - state
  - nation
  - world

- Nature of the study area is usually specified by the organization sponsoring the analysis
Double Counting Must be Avoided

- Sometimes an impact of a project can be measured in two or more ways.
- E.g., an improved highway can reduce travel time and the risk of injury.
- Consequently, the value of properties in the areas served by the highway should be enhanced.
- Therefore, the increase in property values due to the project, would make for a good measure of the benefits.
- But, if the property values are used to measure the benefits, then it is unnecessary to include the value of time and the saved lives in the calculation of benefits.
Decision Criteria

- If the discounted present value of the benefits exceeds the discounted present value of costs then the project is worthwhile.
- This is equivalent to the net benefits being positive.
- Another equivalent condition is that the ratio of the present value of the benefits to the present value of the costs must be greater than one.
- If the funds required for carrying out the project with positive net present value are less than the funds available, then the discount rate used in computing the present values is too low and does not reflect the true cost of capital.
- Sometimes it takes trial and error to determine the find the discount rate that yields the true cost of capital.
Let’s look at a simple example

- Consider an expansion of New Circle Rd.
- The improvement of the road would lead to more capacity which leads to time savings and lowers the risk of accidents
- But inevitably there will be more traffic than what is carried by the existing highway
Here is a highly simplified example using hypothetical data

<table>
<thead>
<tr>
<th>Table 1. Hypothetical CBA Data</th>
<th>No Expansion</th>
<th>Expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rush Hours</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passenger Trips (per hour)</td>
<td>3,000</td>
<td>4,000</td>
</tr>
<tr>
<td>Trip Time (minutes)</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Value of Time ($/minute)</td>
<td>$0.10</td>
<td>$0.10</td>
</tr>
<tr>
<td>Time Cost of a Trip ($/minute)</td>
<td>$5.00</td>
<td>$3.00</td>
</tr>
<tr>
<td>Time Cost Saved ($/minute)</td>
<td></td>
<td>$2.00</td>
</tr>
<tr>
<td><strong>Non-Rush Hours</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passenger Trips (per hour)</td>
<td>500</td>
<td>552.56</td>
</tr>
<tr>
<td>Trip Time (minutes)</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>Value of Time ($/minute)</td>
<td>$0.08</td>
<td>$0.08</td>
</tr>
<tr>
<td>Time Cost of a Trip ($/minute)</td>
<td>$2.80</td>
<td>$2.00</td>
</tr>
<tr>
<td>Time Cost Saved ($/minute)</td>
<td></td>
<td>$0.80</td>
</tr>
<tr>
<td>Traffic Fatalities (per year)</td>
<td>12</td>
<td>6</td>
</tr>
</tbody>
</table>
### Benefits Per Hour

**Table 2. Benefits per hour**

<table>
<thead>
<tr>
<th>Type</th>
<th>Trips Which Would Be Taken Anyway</th>
<th>Trips Generated by the Project</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rush Hour</td>
<td>$6,000.00</td>
<td>$1,000.00</td>
<td>$7,000.00</td>
</tr>
<tr>
<td>Non-Rush Hour</td>
<td>$400.00</td>
<td>$22.22</td>
<td>$422.22</td>
</tr>
</tbody>
</table>
Benefits Per Year

**Table 3. Benefits per year**

<table>
<thead>
<tr>
<th>Type</th>
<th>Trip Which Would Be Taken Anyway</th>
<th>Trips Generated by the Project</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rush Hour</td>
<td>$9,360,000</td>
<td>$1,560,000</td>
<td>$10,920,000</td>
</tr>
<tr>
<td>Non-Rush Hour</td>
<td>$2,880,000</td>
<td>$160,000</td>
<td>$3,040,000</td>
</tr>
<tr>
<td>Total</td>
<td>$12,240,000</td>
<td>$1,720,000</td>
<td>$13,960,000</td>
</tr>
</tbody>
</table>
### Table 4. Schedule of Benefits and Costs for the Project

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1-4</td>
<td>0</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5-29</td>
<td>16.36</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>16.36</td>
<td>-100</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
### Table 5. Net Present Value of Benefits and Costs

<table>
<thead>
<tr>
<th></th>
<th>Present Value ($ millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Benefits</strong></td>
<td>304.11</td>
</tr>
<tr>
<td><strong>Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Right-of-Way</td>
<td>44.79</td>
</tr>
<tr>
<td>Construction</td>
<td>190.39</td>
</tr>
<tr>
<td>Maintenance</td>
<td>18.59</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td>253.77</td>
</tr>
<tr>
<td><strong>Net Benefits</strong></td>
<td>50.34</td>
</tr>
</tbody>
</table>
Thank You

Questions?