# A Survey on the LCOE

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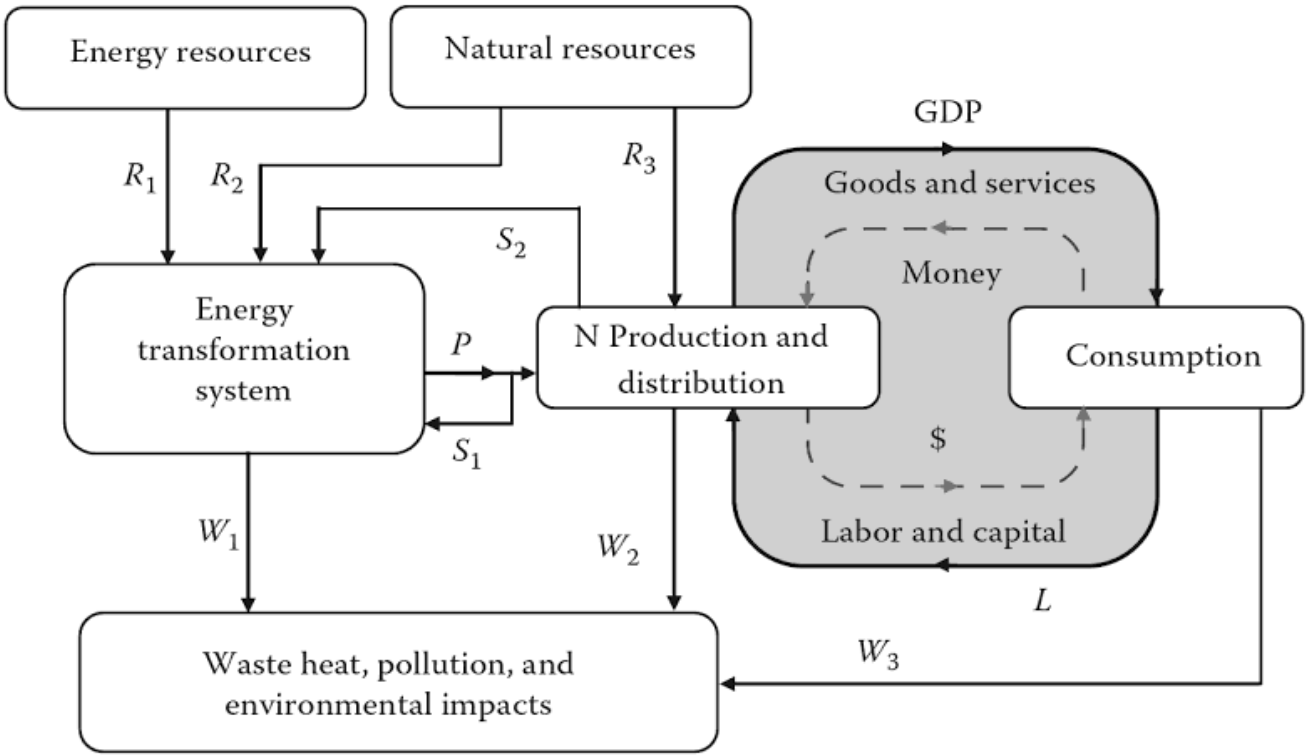
# Outline

- Introduction
- System Description and Overview of Metrics
- Opinions from Literature
- Conclusions and Recommendations

# Introduction

- Metrics are important for choosing **sustainable options**
- "Good" metrics = "Good" choice
- How to measure the **"goodness"**? Issues here!
  - Dimensions of Sustainability must be included
  - Time, space, rates, uncertainties, externalities, flexibility, modifiability, completeness, objectivity...
  - "Goodness" of your criteria?
- Case study on **LCOE** teaches lot

# System Description

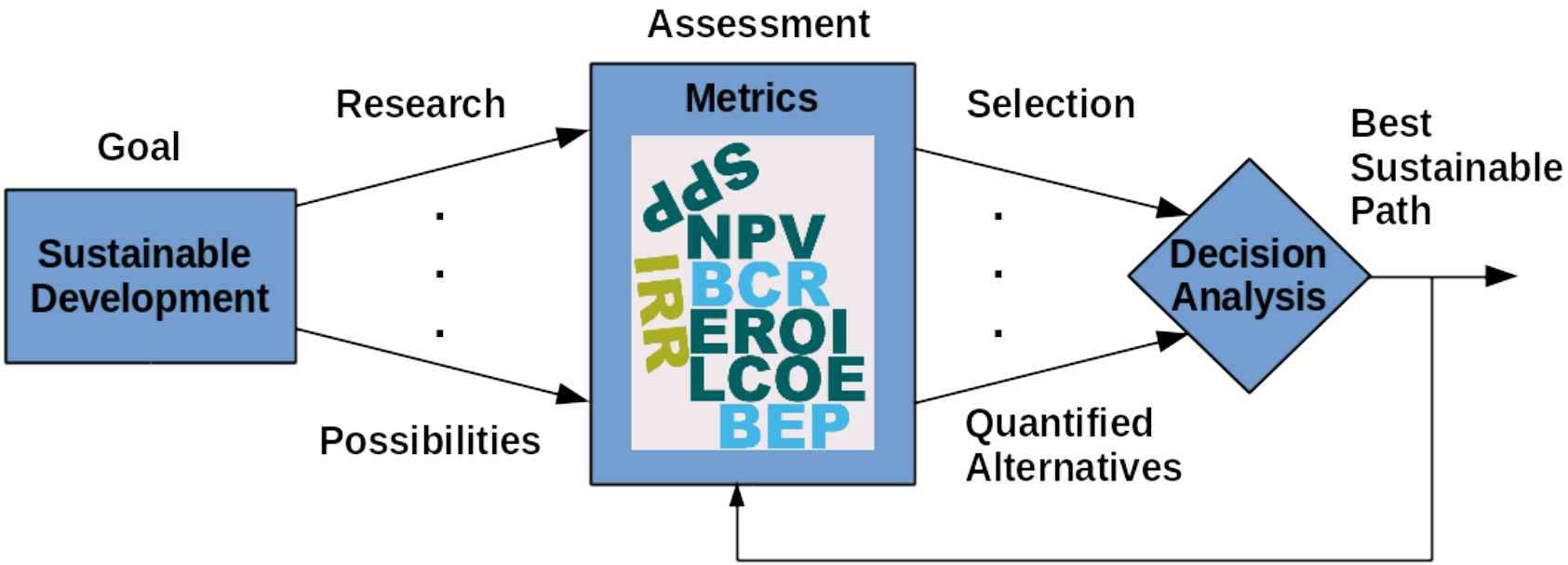



**Source:** Frank Kreith, Principles of Sustainable Energy Systems, 2$^{nd}$ ed., CRC Press, 2014

| Symbol | Meaning |
|---|---|
| $GDP$ | Cost of Product and Services (Unit or dollar) |
| $P$ | Consumer energy produced for sale |
| $R_i$ | Flows of primary energy and natural resources |
| $S_1$ | Energy needed to run the system (fuel/electricity) |
| $S_2$ | Energy (equipment and materials) needed to extract and process energy |
| $N$ | Net energy to the Economy |
| $L$ | Labor and investment taxes |
| $W_i$ | Waste flows |

# Metrics

The process of finding sustainable path and the role of metrics



# LCOE: Overview of opinions

- LCOE is limited, not suitable to compare renewables with non-renewables
- Limitations are not inherent, user may lack the expertise
- LCOE can be customized to be more effective for renewables
- Monte Carlo + LCOE can be effective for uncertainties

# LCOE: Some Opinions

- LCOE ignores the intermittent nature of various renewables. (P. L. Joskow)
- Correction factor is needed for renewables. (S. Reichelstein and A. Sahoo)
- Use of "storage" and LCOE + Monte Carlo. (M. Obi et al.)
- "System LCOE" with "integration costs[1]". (F. Ueckerdt et al.)

[1] "the extra investment and operational cost of the nonwind part of the power system when wind power is integrated", R. Sims et al. Integration of renewable energy into present and future energy systems. IPCC special report on renewable energy sources and climate change mitigation. Cambridge University Press, 2011.

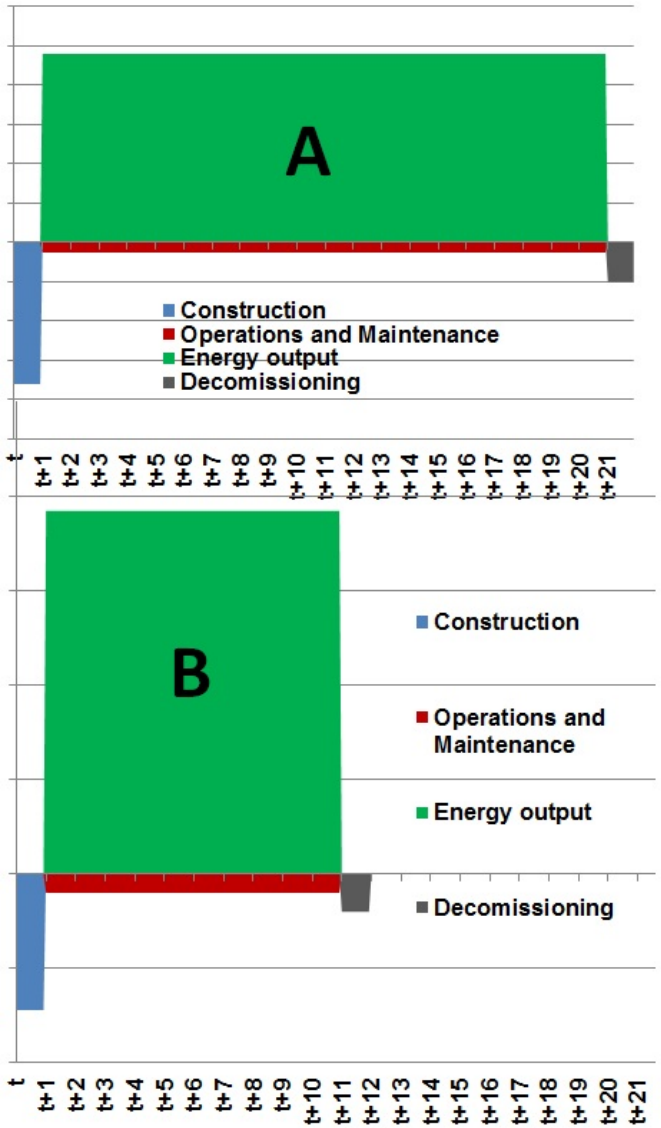
# Effectiveness framework for the metrics

| Metric | SPP | NPV | IRR | BCR | EROI | LCOE |
|---|---|---|---|---|---|---|
| **Meaning** | Simple Payback Period | Net Present Value | Internal Return Rate | Benefit Cost Ratio | Energy Return on Energy Invested | Levelized Cost of Energy |
| **Output Unit** | [Years] | [$] | Unitless | Unitless | Unitless | [$/kWh] |
| **Output** | Years to payback cost | Discounted profit | Disc. rate to breakeven | Ratio | Ratio | Cost per unit power |
| **Inclusion of discount/inf. rate** | Not Direct | Yes | Yes | Yes | Not Direct | Yes |
| **Inclusion of uncertainties** | Not Direct | Yes | Yes | Yes | Not Direct | Yes |
| **Inclusion of externalities** | Not Easy | Possible | Possible | Possible | Not Possible | Possible |
| **Inclusion of Time factor (Forecasting)** | Not Easy | Possible | Possible | Possible | Not Possible | Possible |
| **Degree of Comparability (Output)** | Weak | Weak$^{\dagger}$ | Weak | Not Possible | Weak | Strong$^{\ddagger}$ |

$^{\dagger}$: Projects should have equal lifespans for healthy comparison

$^{\ddagger}$: For ranking recommended

# Shortcoming of EROI: Timeless




Source: `http://www.theoildrum.com/files/EROI_Importance_of_time.jpg`

# LCOE in short

**Advantages:**

- Main advantage of the LCOE: Provides **"common basis"** for comparison
- May not be **"complete"**, yet the most **"effective"** for Sustainability
- Flexibility to be included in Monte Carlo like studies

**Caveats:**

- Difficult to include, uncertainties, externalities
- Even included "objectivity" is questionable

# The moral of the story!:

If you want to invent your own metric, remember the trade-off:

- More precision comes with more specialized (customized) metric $\rightsquigarrow$ More limited metric
- More flexibility $\rightsquigarrow$ Political manipulation tool!

Thanks for your patience!

Questions?