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U.S. DEPARTMENT OF ENERGY



Technoeconomic analysis for industrial projects: What is the cost?

Part 1

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Oak Ridge National Laboratory

Making a Business Case Virtual Training

October 13, 2026

U.S. DEPARTMENT of ENERGY

Goals of this session

- Introducing the concepts of Technoeconomic Analysis or TEA
- Understanding Economic Analysis in Industrial Settings
  - Nuances of TEA assumptions, methods, and functional units.

Dipti Kamath, Ph.D., CEM



- R&D Associate Staff Member at Oak Ridge National Laboratory
- 5+ years at ORNL

- Technical Expertise/ Research Interests
  - Life cycle assessment
  - Techno-economic analysis
  - System dynamics
  - Industrial workforce development
  - Energy-Intensive Industries: pulp & paper sector

Defining Technoeconomic Analysis or TEA

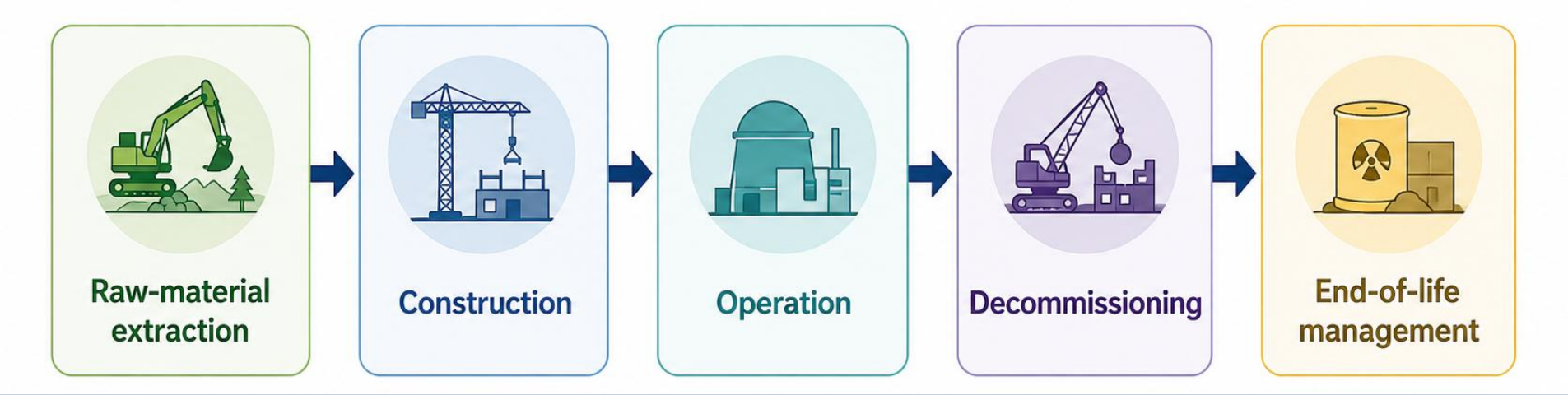
- Method for evaluating the economic performance of a technology.
- Assesses life-cycle costs, benefits, risks and timeframe to evaluate a technology.

Key Components:

- Technical Assessment – Technical feasibility, process design, scalability and performance against baseline.
- Economic Analysis – Costs (capital, operating and end of life), and revenue/benefit as appropriate.
- Financial Modeling – Translate technical and economical findings into actionable financial strategies.

Defining Life Cycle Assessment or LCA

- Method for evaluating environmental impacts across the full life cycle of a technology.
- Assesses environmental indicators, including human health, ecosystem and environmental quality, resource depletion and land use.



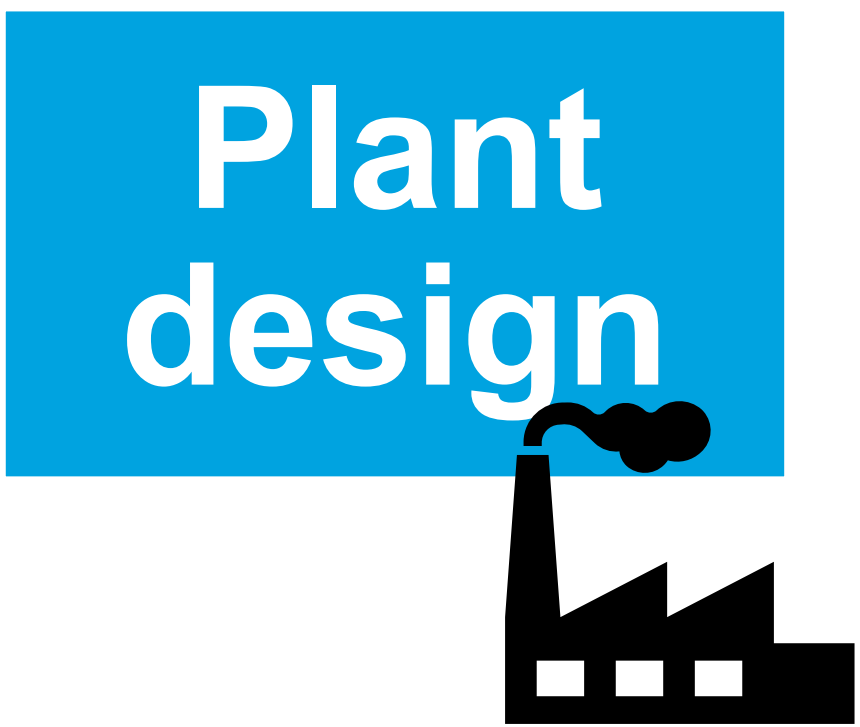
Differentiating TEA and LCA

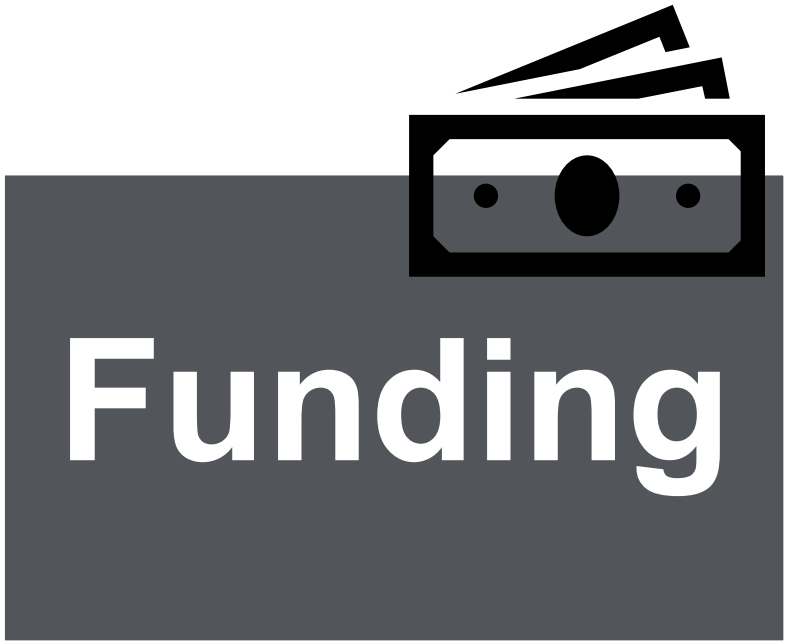
- **TEA and LCA address different comparison dimensions**
  - TEA focuses on economic and technical viability; LCA evaluates environmental impacts – both inform decision-making
- **Trade-offs between cost and environmental impact are common**
  - A technology may perform well economically or environmentally but rarely both without careful design
- **Early, combined TEA and LCA de-risk innovation**
  - Applying both from low TRLs guides design choices, reduces scaleup risk and supports credible investment decisions

Source: https://www.thechemicalengineer.com/features/the-process-scaleup-journey-part-3-tea-lca-finding-the-balance/

TEA and LCA can accelerate development in 3 key areas

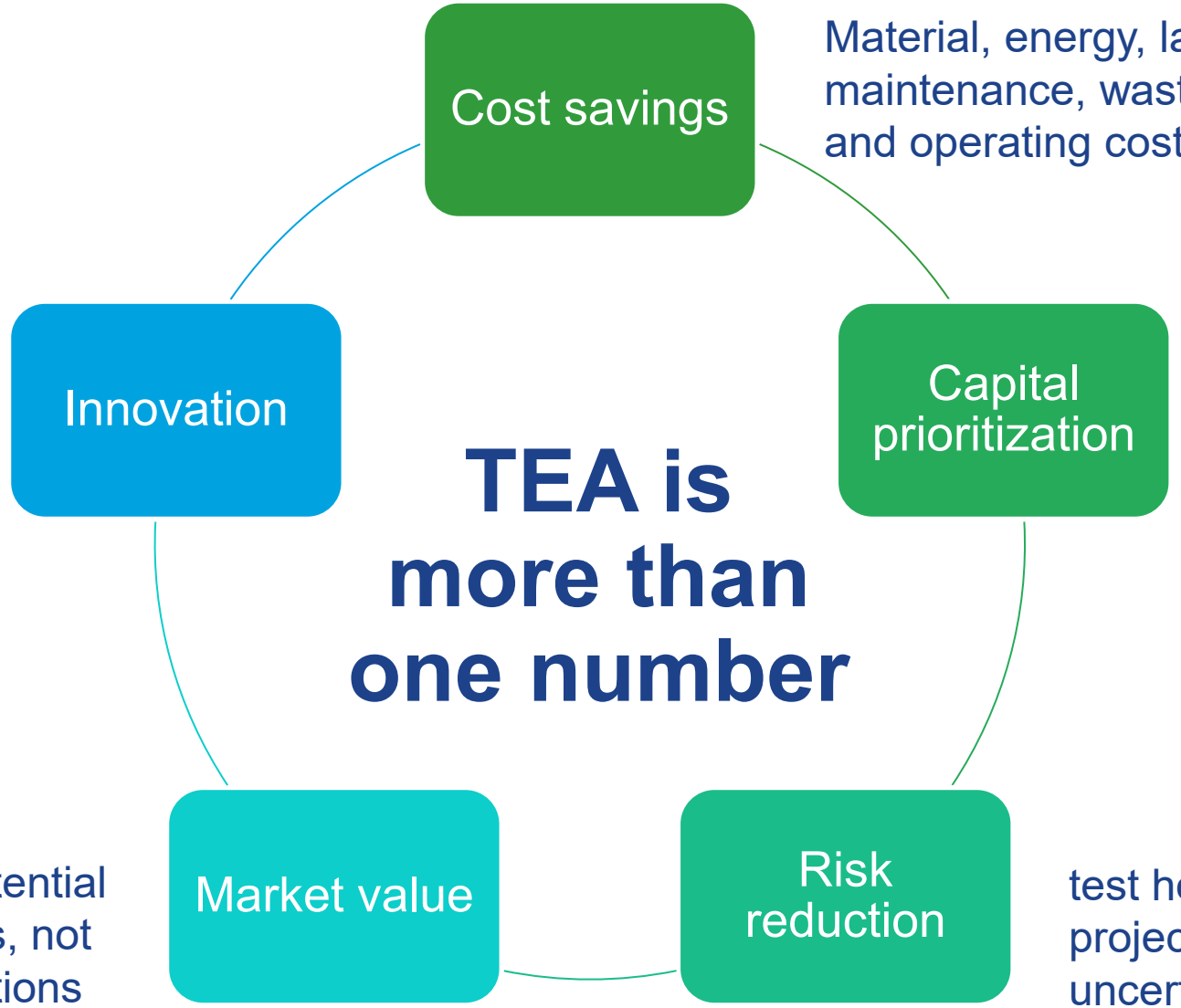






Source: https://www.thechemicalengineer.com/features/the-process-scaleup-journey-part-3-tea-lca-finding-the-balance/

Today's focus: Making the Business Case with TEA



Material, energy, labor, maintenance, waste, and operating costs

compare competing investments on the same financial basis

determine **where limited capital should go first**

test how sensitive a project is to uncertain conditions

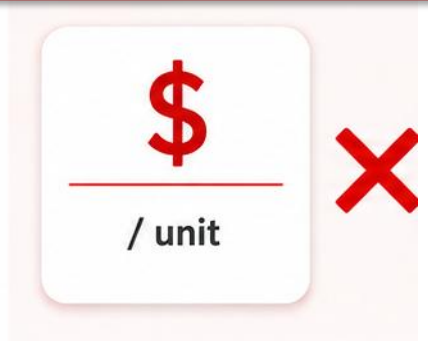
can include potential revenue effects, not just cost reductions

evaluate new technologies before making a full-scale investment

TEA is more than one number

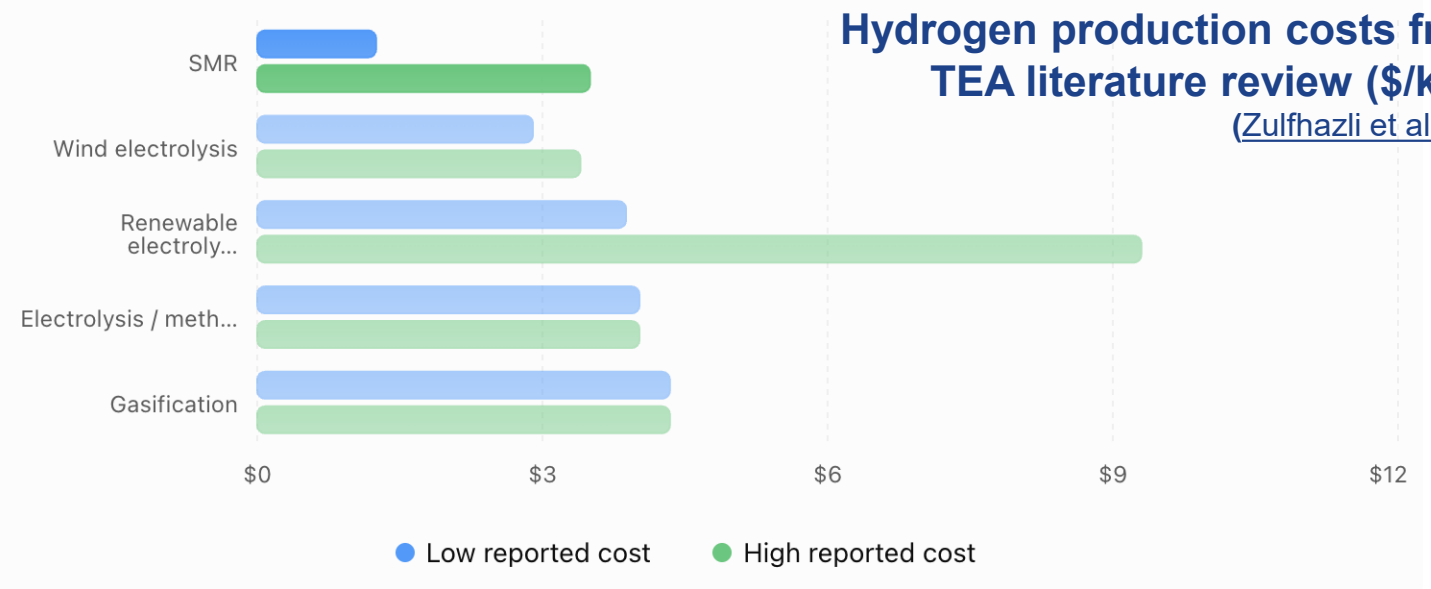
TEA should tell stories and serve as decision-making tool

What not to do



- ☒ A single value hides assumptions
- ☒ No visibility into tradeoffs
- ☒ Does not adequately inform R&D decisions
- ☒ Cross-study comparisons can be misleading when assumptions differ

Hydrogen production costs from a TEA literature review ($/kg H_2)
(Zulfhazli et al., 2022)



Source: Meyer, A. 2026, Zulfhazli et al., 2022

TEA is more than one number

TEA should tell stories and serve as decision-making tool

What we should do



- ☑ Suggest what drives costs and environmental impacts
- ☑ Compare pathways, scenarios, and scale-up options
- ☑ Show uncertainty and sensitivity to key variables
- ☑ Identify/priorities impactful tasks to optimize cost and environmental impacts and derisk
- ☑ Support go/no-go and investment decisions

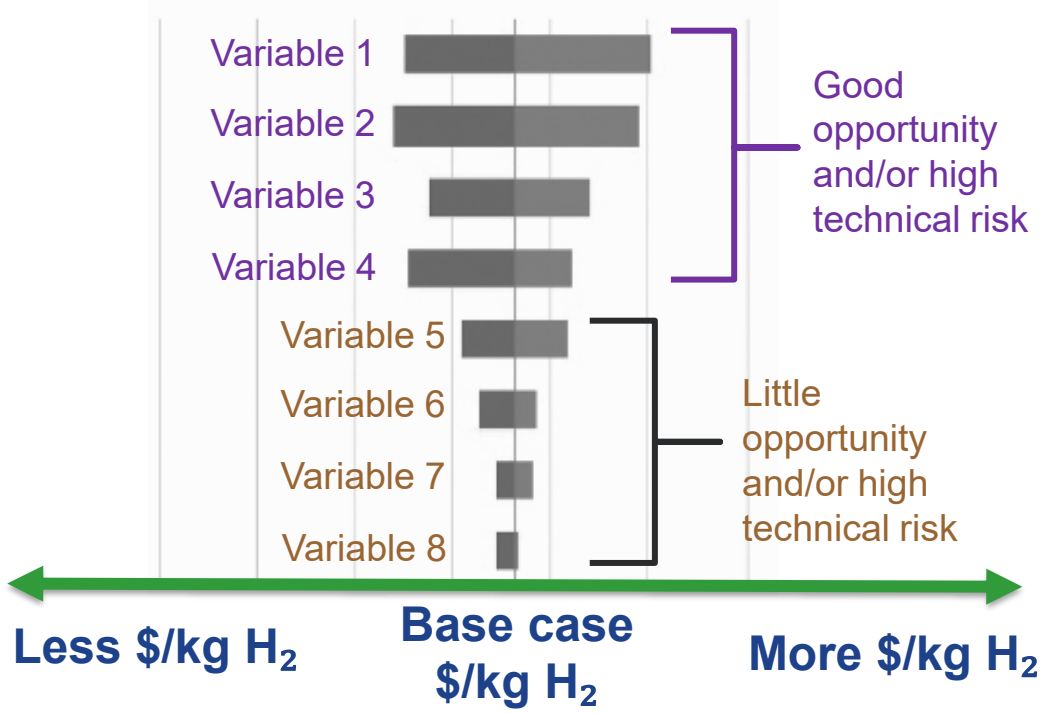
Source: Meyer, A. 2026

TEA is more than one number

TEA should tell stories and serve as decision-making tool

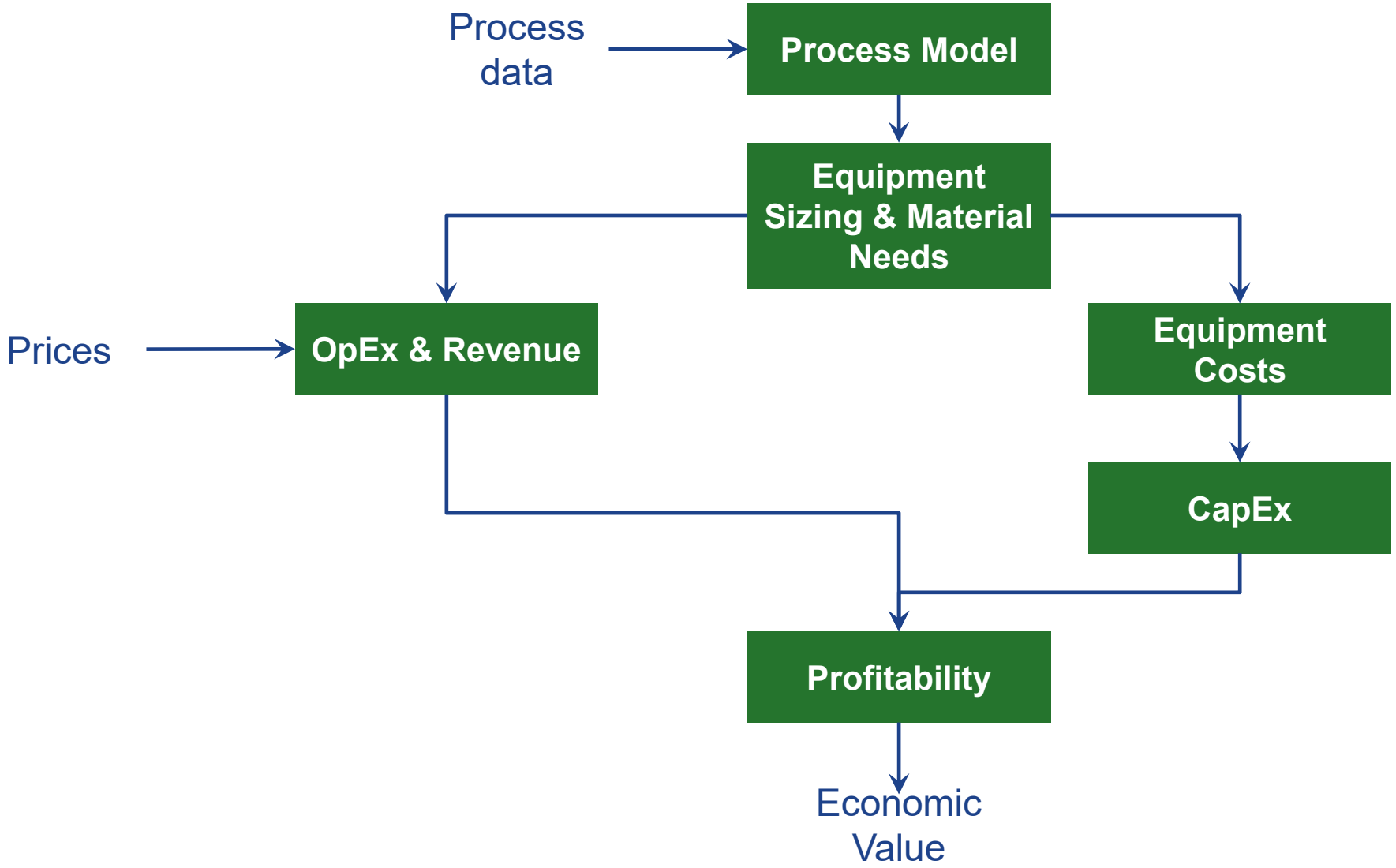
Tornado Chart

Determine key cost factors and areas of uncertainty



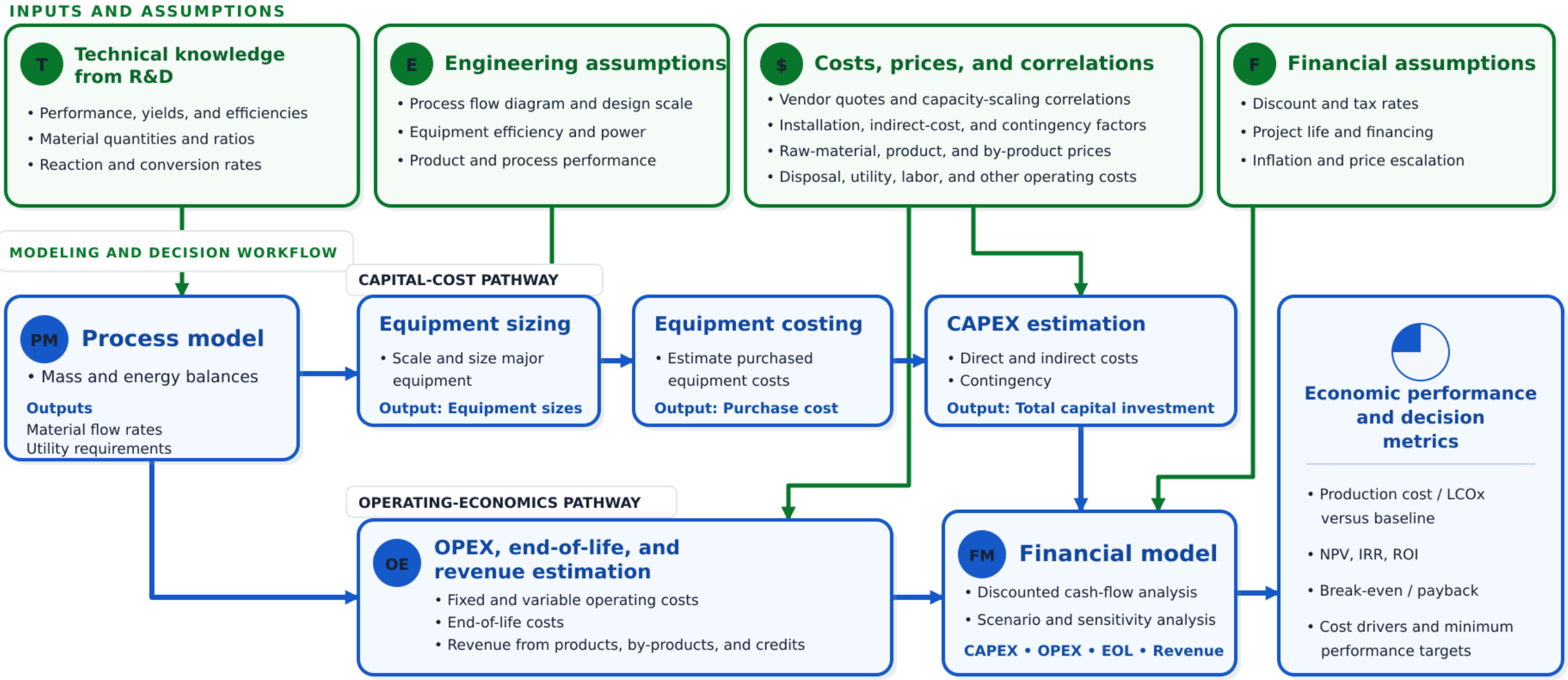
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TEA Methodology and Information Flow

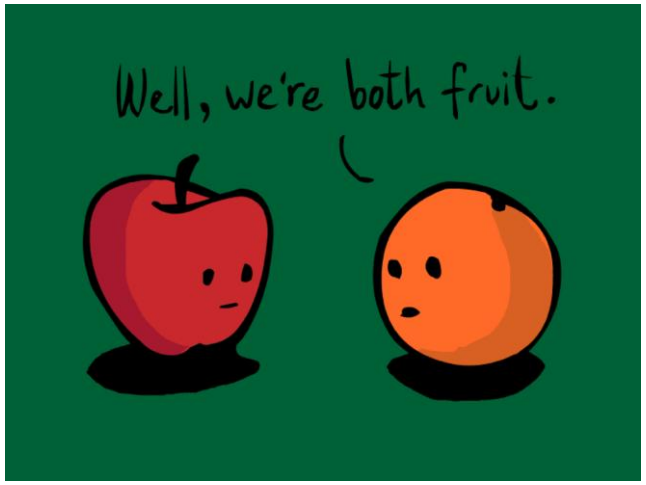


Adapted from: https://assessccus.globalco2initiative.org/wp-content/uploads/TEA-for-Hard-Tech-Innovation.pdf

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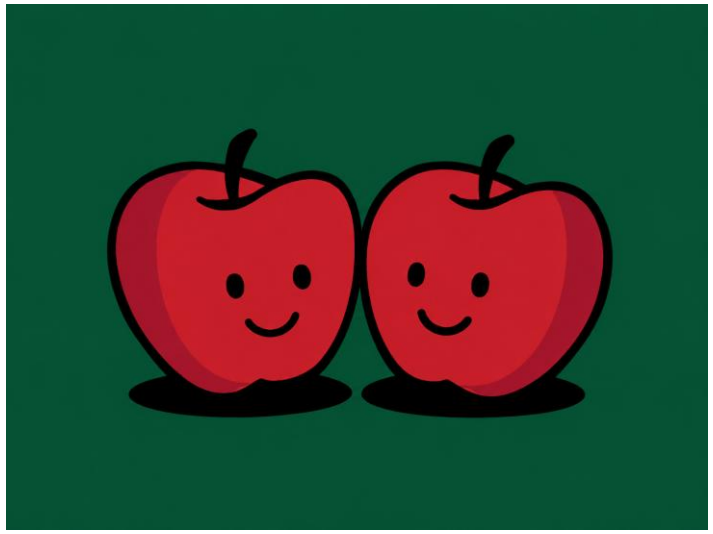


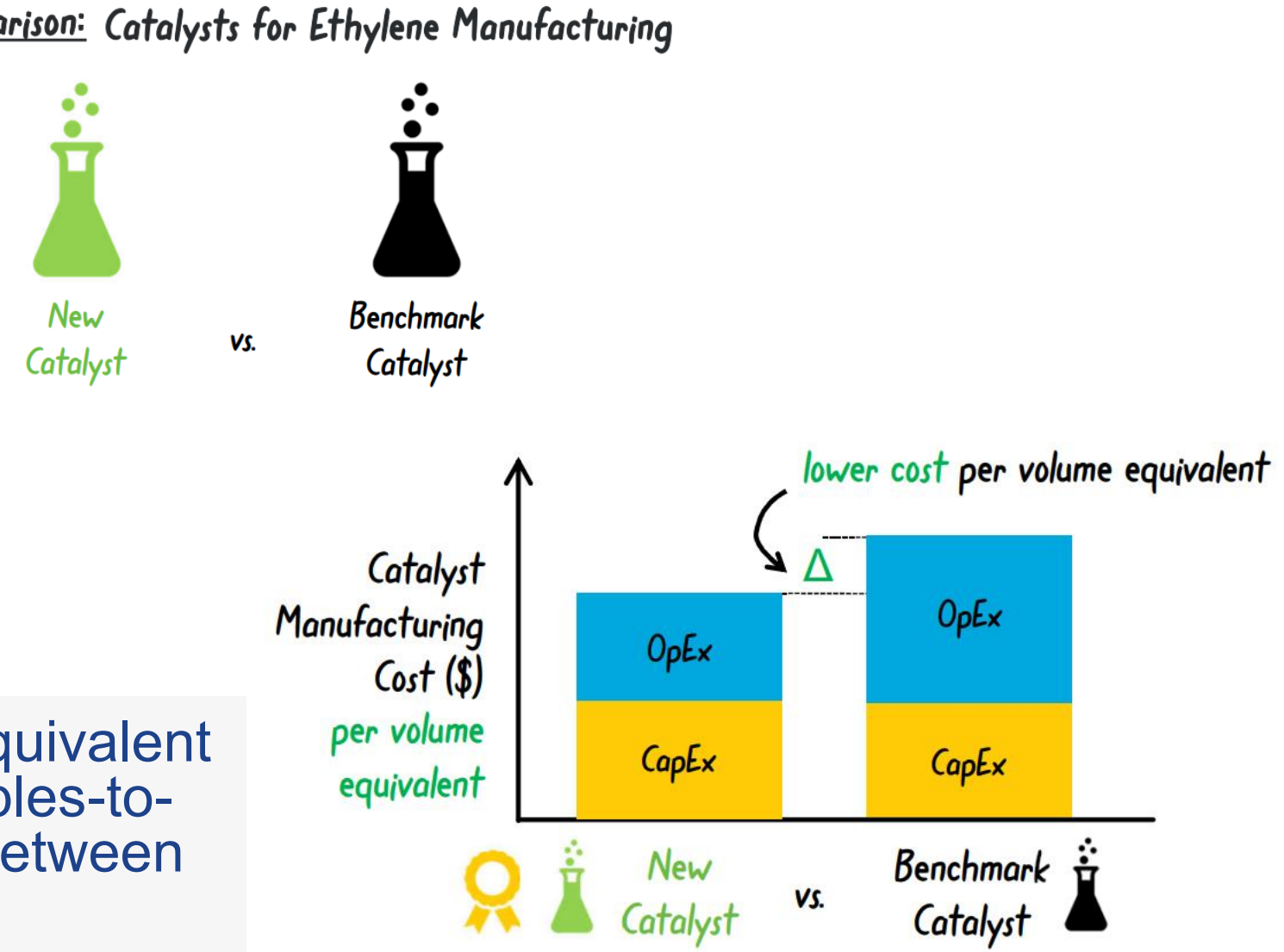
Functional Units



Source: LCA & TEA Training from DOE

Functional Units



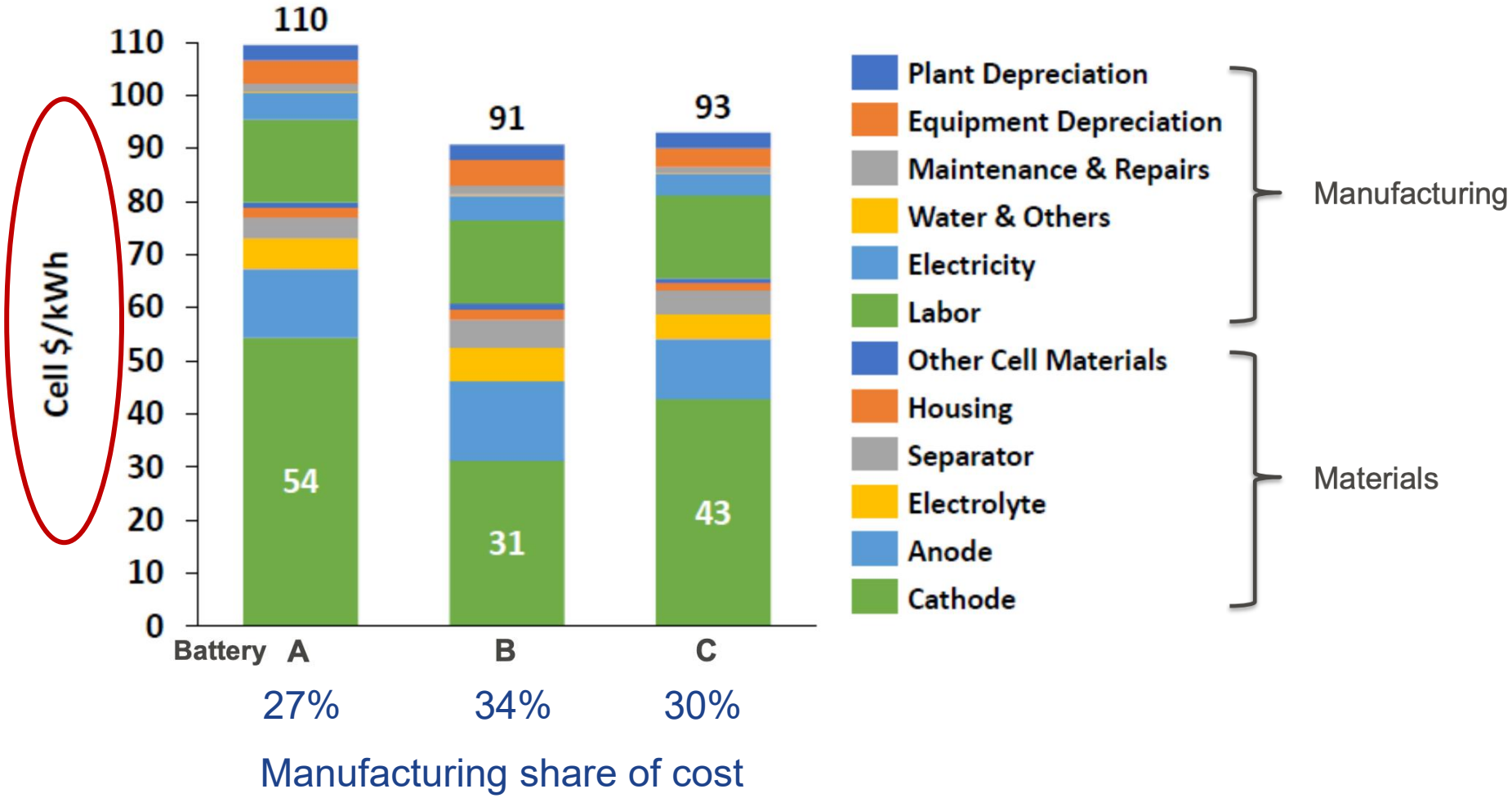


The use of a performance-equivalent functional unit enables “apples-to-apples” cost comparisons between technologies.

Source: LCA & TEA Training from DOE

Example TEA for a product

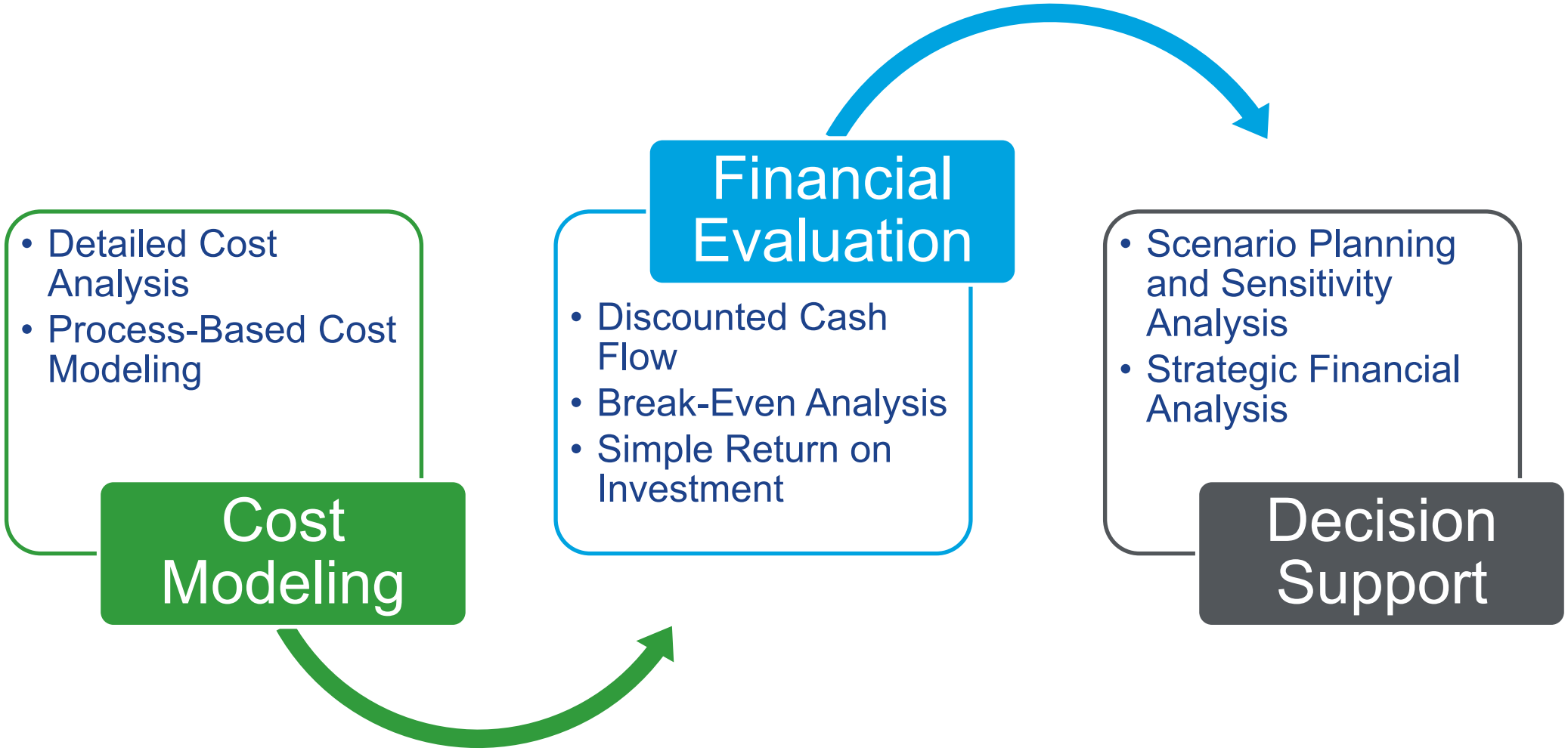
Battery Cell – Production Costs Only



Source: https://arpa-e.energy.gov/sites/default/files/2025-06/Techno-Economics%20for%20ARPA-E%20Performers.pdf

TEA Components

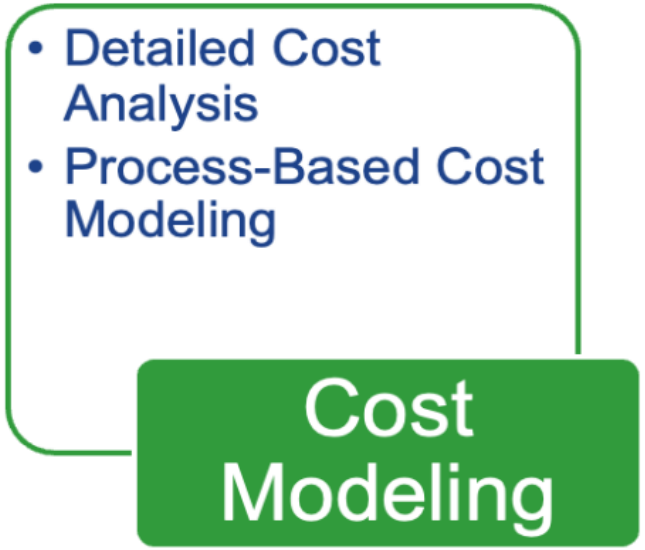
Core methods used to define cost, evaluate financial performance, and test decision robustness



Adapted from: https://arpa-e.energy.gov/sites/default/files/2025-06/Techno-Economics%20for%20ARPA-E%20Performers.pdf

Cost Modeling

- Detailed Cost Analysis (DCA)
  - A thorough examination of costs, considering factors like fixed vs. variable costs, labor costs, materials costs
- Process Based Cost Modeling (PBCM)
  - Model of cost of product or process by analyzing individual processes of involved in its production. PBCM breaks down operations into specific tasks or process steps and assign costs to each



Detailed Cost Analysis (DCA)

- Builds a complete cost estimate using fixed and variable costs, including direct and indirect expenses.

Questions Answered

- What capital and operating costs define the project?
- What is the expected cost per unit of output?
- Which cost categories should receive more attention?

METHOD

01	02	03	04
Set scope	**Estimate capital**	**Estimate operations**	**Normalize**
Define the product, production scale, process boundary, and comparison baseline.	Include equipment, installation, engineering, site, and indirect costs.	Include materials, utilities, labor, maintenance, waste, and overhead.	Annualize capital and divide total annual cost by useful output.

CORE CALCULATION

Unit cost = (annualized capital + annual operating cost) / annual output

Best Fit:
Expanded TEA, when process design and cost data are detailed enough to refine screening estimates.

TYPICAL OUTPUTS

Total capital	Annual operating cost	Unit cost	Main cost drivers

Source: https://arpa-e.energy.gov/sites/default/files/2025-06/Techno-Economics%20for%20ARPA-E%20Performers.pdf

Process Based Cost Modeling (PBCM)

- Connects process design and operating data to cost by modeling each task, equipment step, and resource requirement.

Questions Answered

- Which process steps contribute most to unit cost?
- How do cycle time, yield, and utilization affect cost?
- Where could process improvements reduce cost?

PROCESS MODEL

01	02	03	04	05
Feed preparation	**Core process**	**Separation**	**Finishing**	**Waste handling**
Materials	Energy and labor	Equipment time	Yield and quality	Treatment and disposal

CORE CALCULATION

Step cost = resource use × rate

Unit cost = sum of step costs / saleable output

TYPICAL OUTPUTS

Cost by step | **Bottlenecks** | **Yield or scrap penalty** | **Scale effect**

Best Fit:
Detailed TEA, when a process flow diagram and step-level operating data are available.

Source: https://arpa-e.energy.gov/sites/default/files/2025-06/Techno-Economics%20for%20ARPA-E%20Performers.pdf

Classroom Exercise!

Illustrative training case. Values are hypothetical.

Process Exhaust Heat Recovery

- A facility is considering a heat exchanger that will recover heat from a continuous dryer or oven exhaust and use it to preheat incoming air.
- You must determine whether the energy, financial, and other benefits justify the investment and implementation risks.

CURRENT ENERGY & PRODUCTION	
Current natural gas (NG) use	80,000 MMBtu/year
Annual production	100,000 units
Gas price	$6/MMBtu
Electricity prices	$80/MWh

ANTICIPATED CHANGES WITH PROJECT	
Expected NG reduction	20%
Additional electricity	100 MWh/year
Additional maintenance	$12,000/year

PROJECT FINANCIALS	
Equipment	$280,000
Installation	$140,000
Engineering and commissioning	$40,000
Contingency	$40,000
Utility incentive	$50,000
Project life	10 years
Discount rate	8%
Residual value in year 10	$20,000

Process Exhaust Heat Recovery: Cost & Performance

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- Calculate total installed cost and net investment after the incentive.
- Calculate annual gas savings, added electricity cost, and net annual savings.
- Estimate the change in energy cost per unit of production.

Net savings = fuel savings - added electricity - added maintenance

Process Exhaust Heat Recovery: Cost & Performance

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Net savings = fuel savings - added electricity - added maintenance

- Calculate total installed cost and net investment after the incentive.
  - Total installed cost: 280,000+140,000+40,000+40,000=500,000
  - Net cost = 500,000-50,000 = 450,000
- Calculate annual gas savings, added electricity cost, and net annual savings.
  - Gas: (80,000x 20%)x6 = 96,000$ decrease
  - Electricity: 100x80 = 8,000$ increase
  - Net savings = 96,000-8,000-12,000 = 76,000$ => NG savings – electricity cost increase – additional maintenance => 0.76$/ unit decrease in cost
- Estimate the change in energy cost per unit of production.
  - 96,000-8,000=88,000/100,000 = 0.88$/unit reduction in cost due to energy only (not including maintenance here)

Approaches for collecting TEA data

What options do you use or might consider using?

Approaches for collecting TEA data

Approach	Pros	Potential difficulties	Ways to simply
Get direct quotes from manufacturers /contractors	Most accurate	• Potentially time-intensive • May require authorization for outside contact • Rare to get a response if you don't appear to be a serious (IP concerns) or near-term (uncertainty around future costs or production/service) customer	• Only seek quotes for the components/services you expect to be most expensive

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Use estimating charts	Comprehensive indices exist for both plant and equipment costing (e.g., M&S Cost Index, and Chemical Engineering Index)	• Inflation and scaling factors are not always helpful considering that tech changes over time, inflation can occur at different rates for different equipment • Access to up-to-date indices like M&S and CE is subscription-based	• Use open-access inflation and scaling factors (may not be up-to-date, but can enable the order-of-magnitude estimates that are often sufficient for early TEA work)

Source: https://arpa-e.energy.gov/sites/default/files/2025-06/Techno-Economics%20for%20ARPA-E%20Performers.pdf

Approaches for collecting TEA data

Approach	Pros	Potential difficulties	Ways to simply
Review academic literature for cost-relevant data	Good (and often necessary) for data on emerging/not-yet commercial technologies	• Journal access needed • Data will likely need to be scaled • Sometimes the best that can be found on new tech is materials/energy input data	• Use academic literature to identify key differences between a new technology and conventional tech that could drive cost differences

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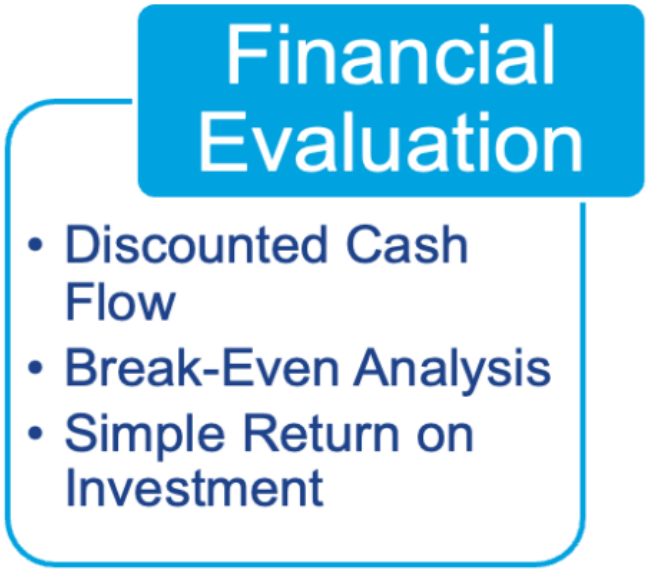
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Process modeling (e.g., Aspen)	Simultaneously estimate cost and performance data, scaling often built-in	• Need a license to access most software	

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Financial Evaluation

- Discounted Cash Flow (DCF)
  - Calculates the present value of future cash flows to assess project's long term
- Break-Even Analysis
  - Determines the point at which the product costs are covered by revenue
- Simple Return on Investment (ROI) Calculation
  - A basic measure of the potential profitability of the project



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Discounted Cash Flow (DCF)

- A structured estimate of capital, operating, and unit production costs
- Converts future project cash flows to present value using a selected discount rate and project life.

Questions Answered	
	Does the project create value at the required return?
	When do discounted cash flows recover the investment?
	How sensitive are NPV and IRR to key assumptions?

TYPICAL OUTPUTS

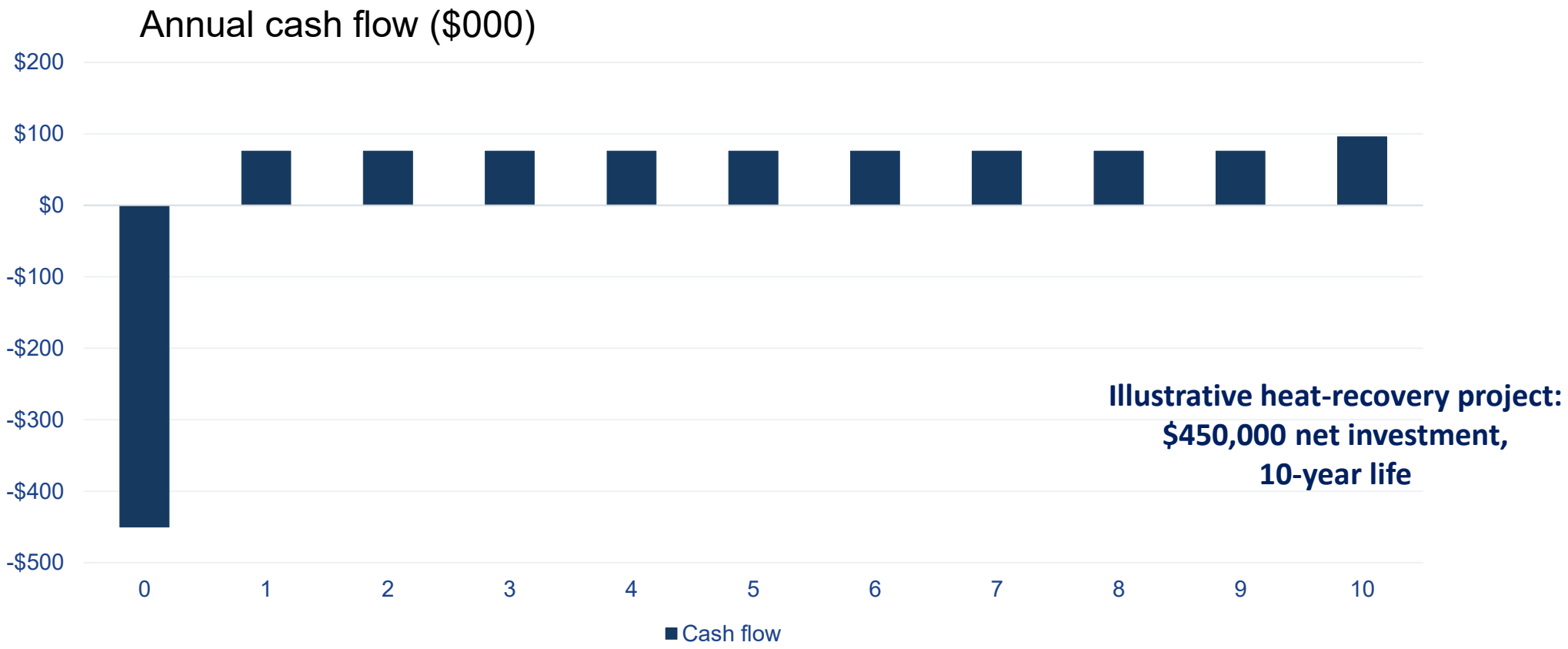
Net present value	**Internal rate of return**	**Discounted payback**	**Cash profile**

Best Fit:
Projects with front-loaded capital and cash flows that extend over multiple years.

Source: https://arpa-e.energy.gov/sites/default/files/2025-06/Techno-Economics%20for%20ARPA-E%20Performers.pdf

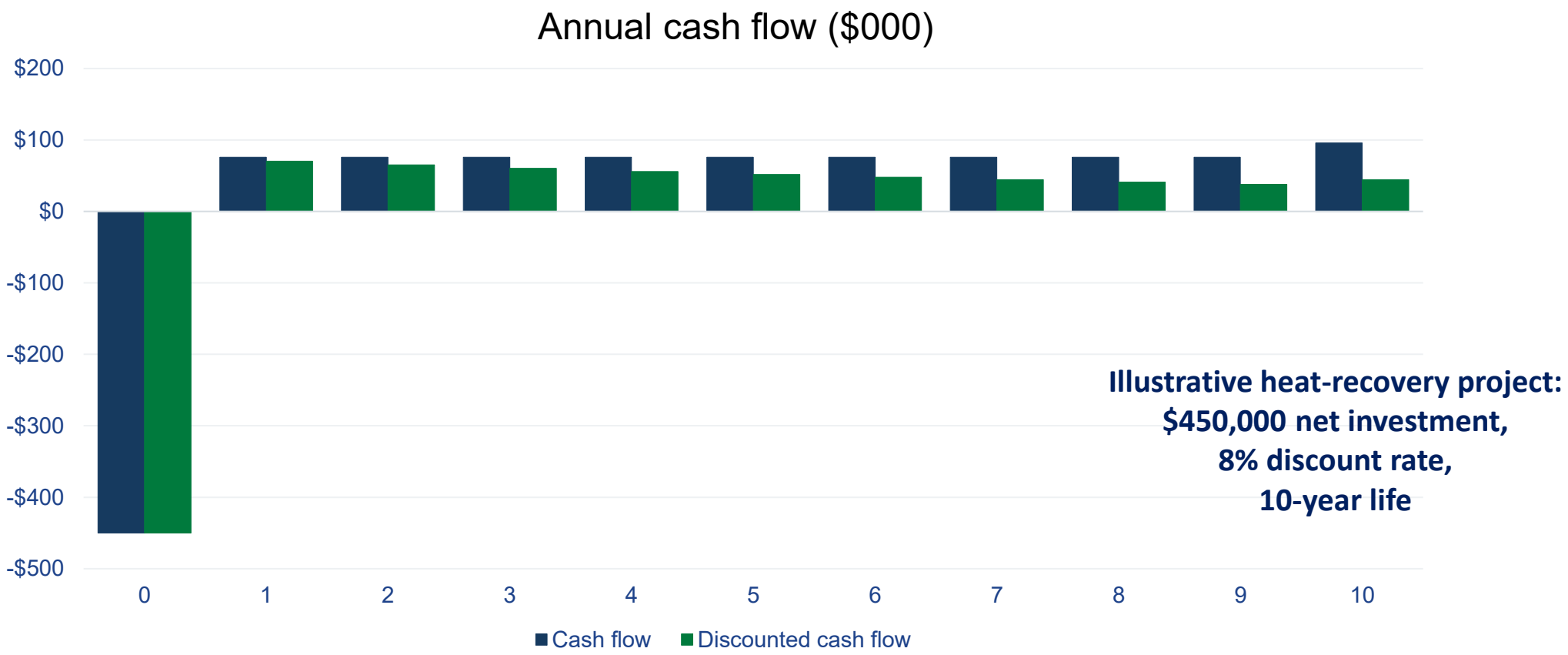
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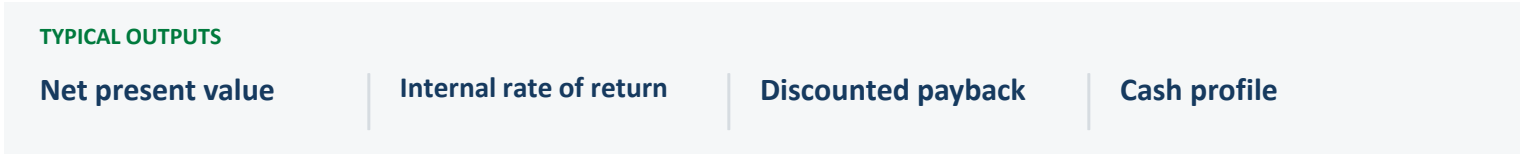


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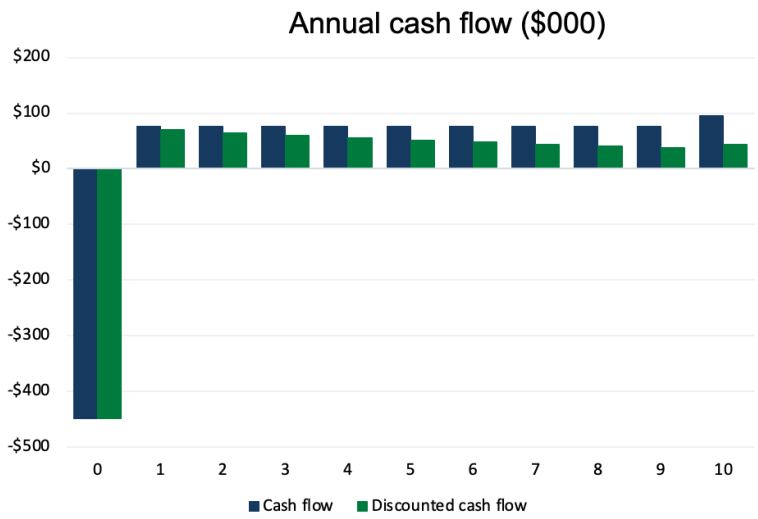
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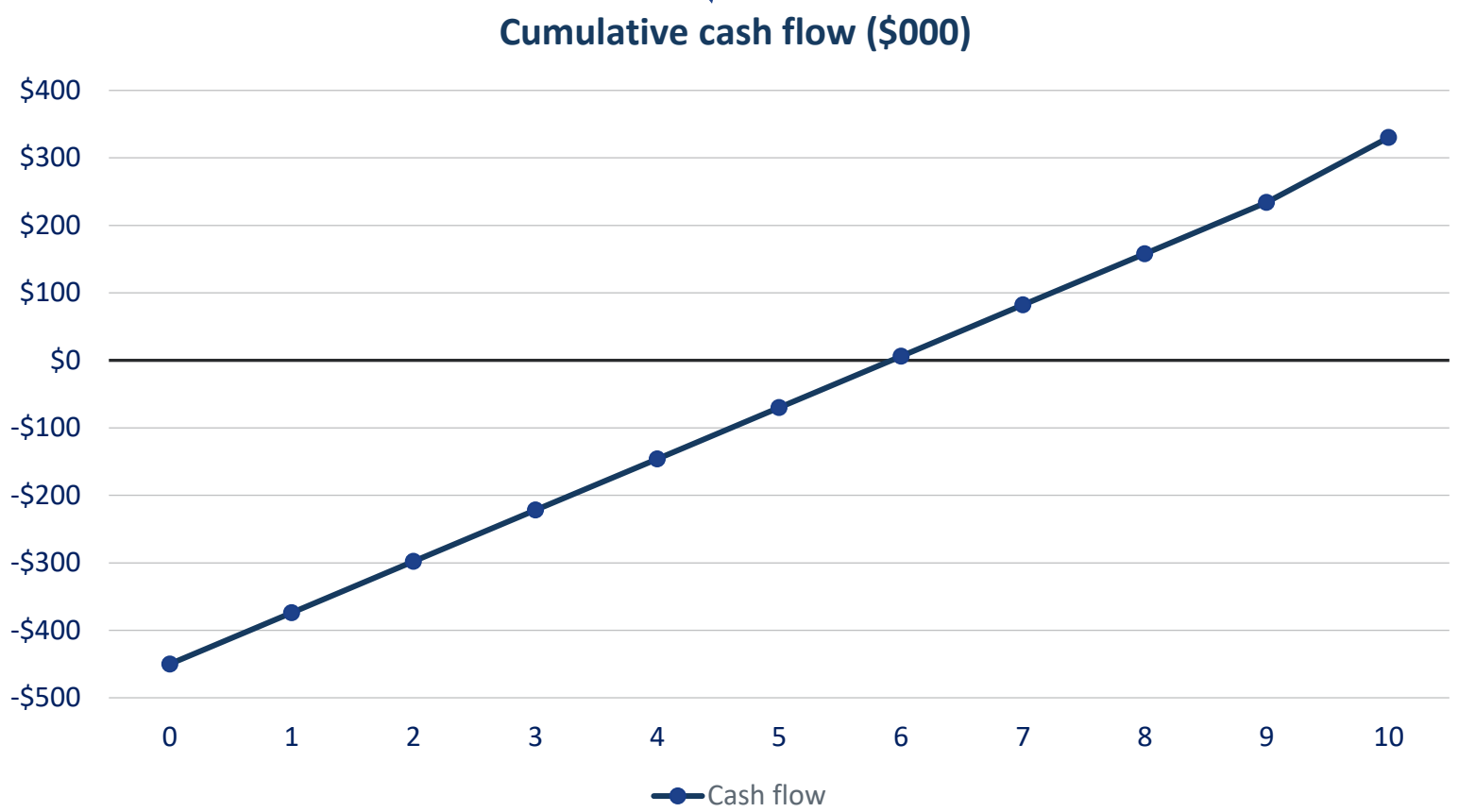
- Net Present Value or NPV:
  - Converts future cash flows into their “present value,” recognizing that money available now is more valuable than the same amount received later
- Internal Rate of Return or IRR:
  - Expected annual percentage growth rate of an investment
- Discounted Payback Period:
  - Calculates the exact time required to recoup an initial investment based on the present value of a project's projected cash flows

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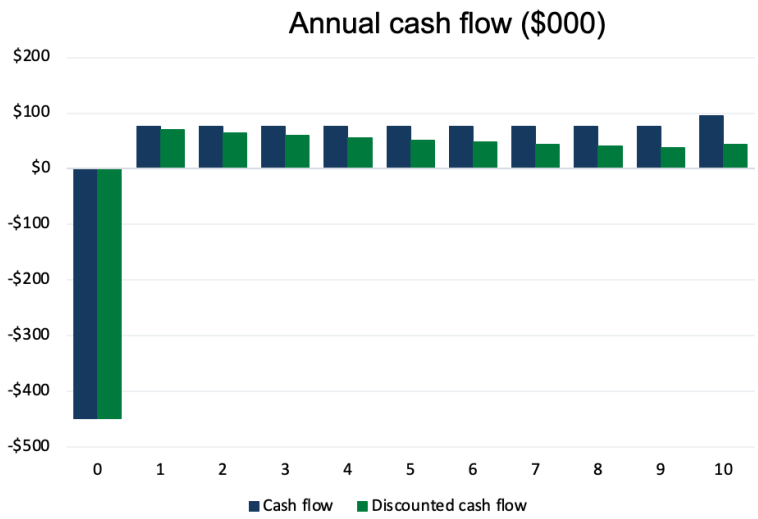
NPV and Payback from DCF



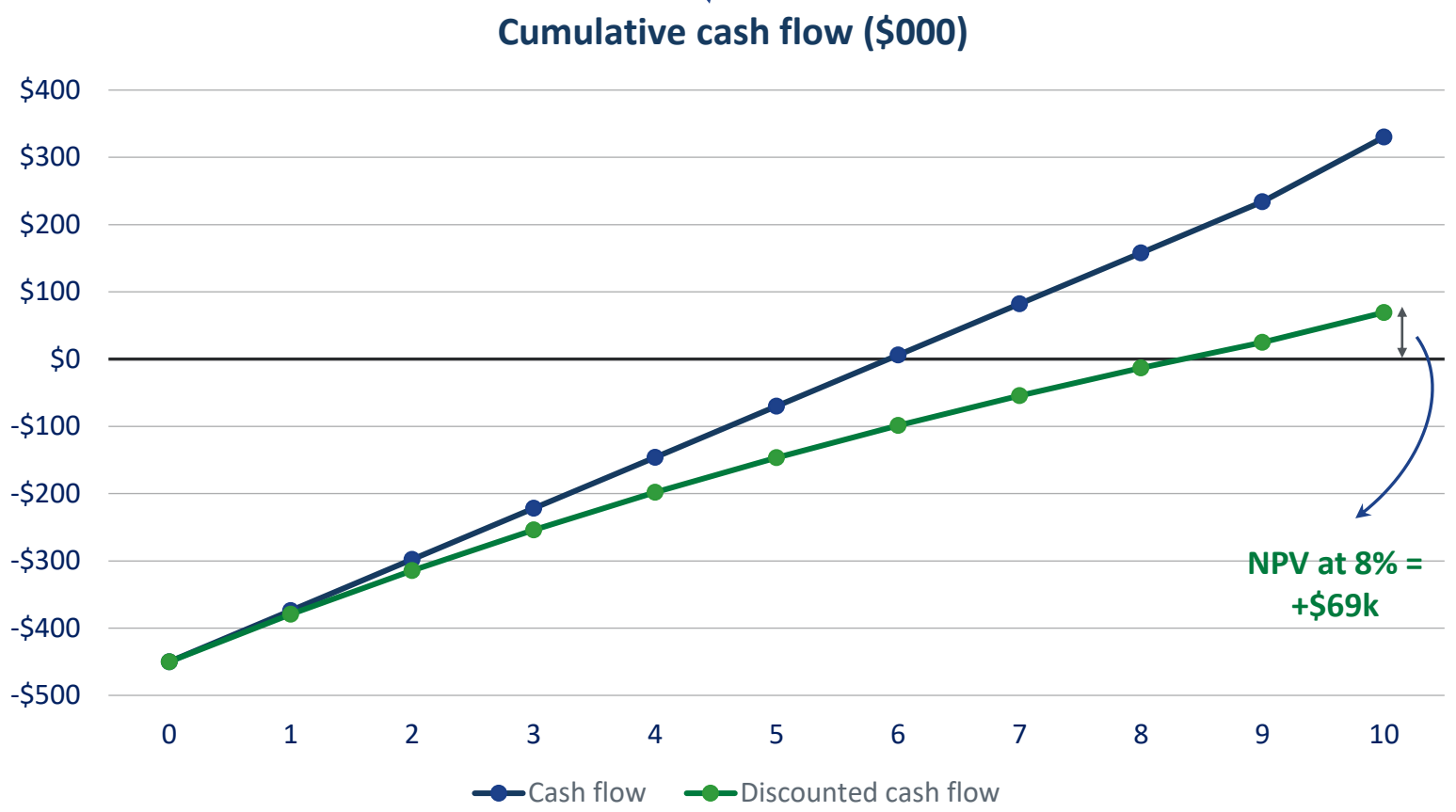
Illustrative heat-recovery project:
$450,000 net investment,
8% discount rate,
10-year life



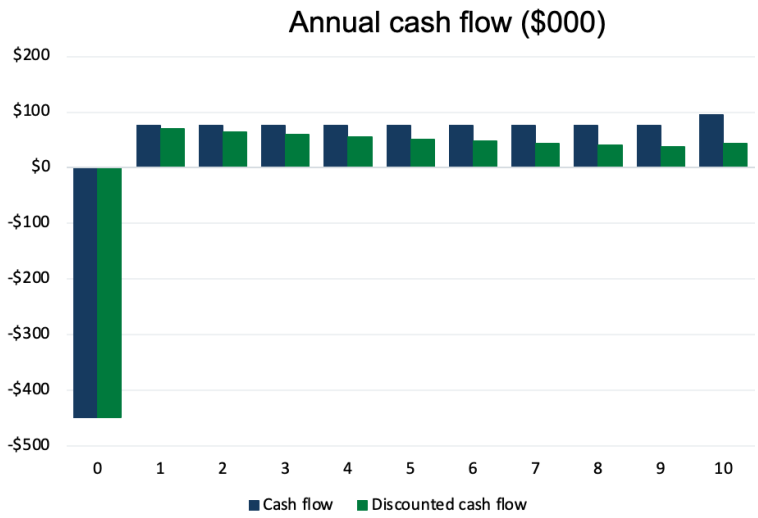
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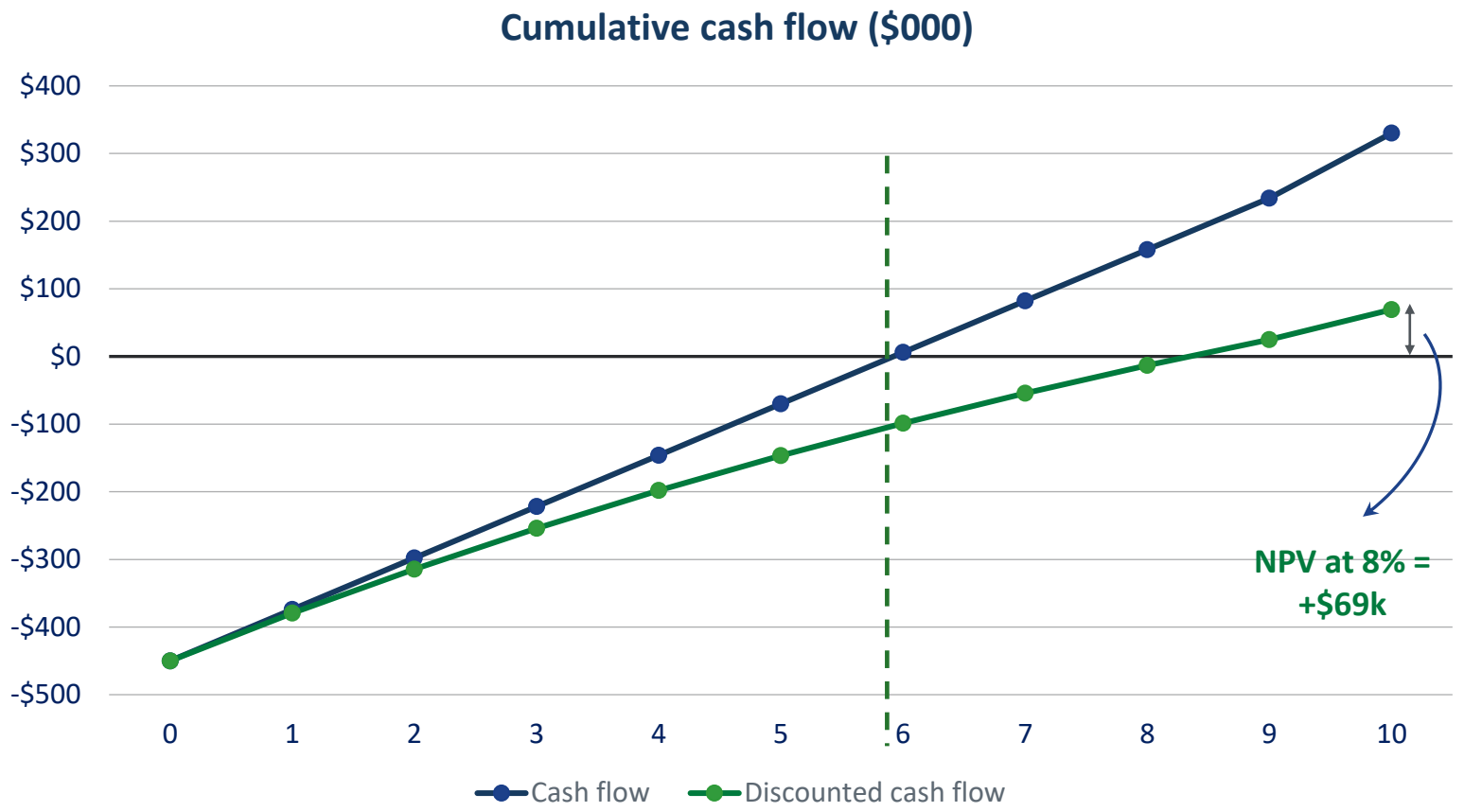


NPV and Payback from DCF

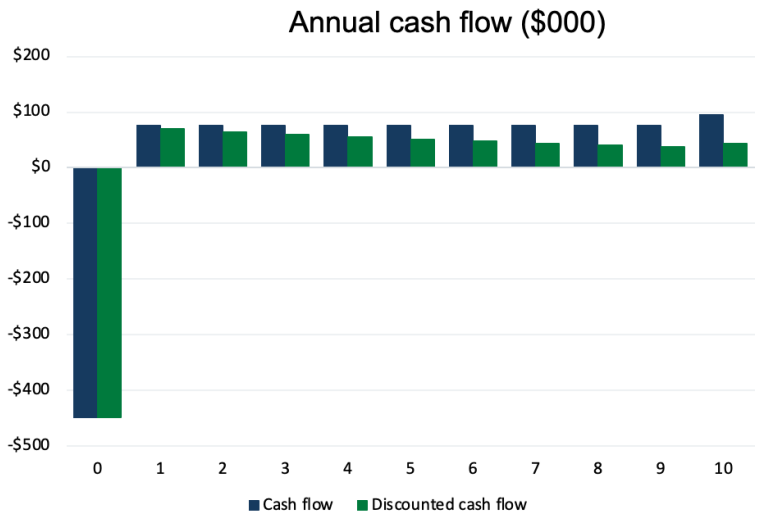


Simple Payback: **5.9 years**

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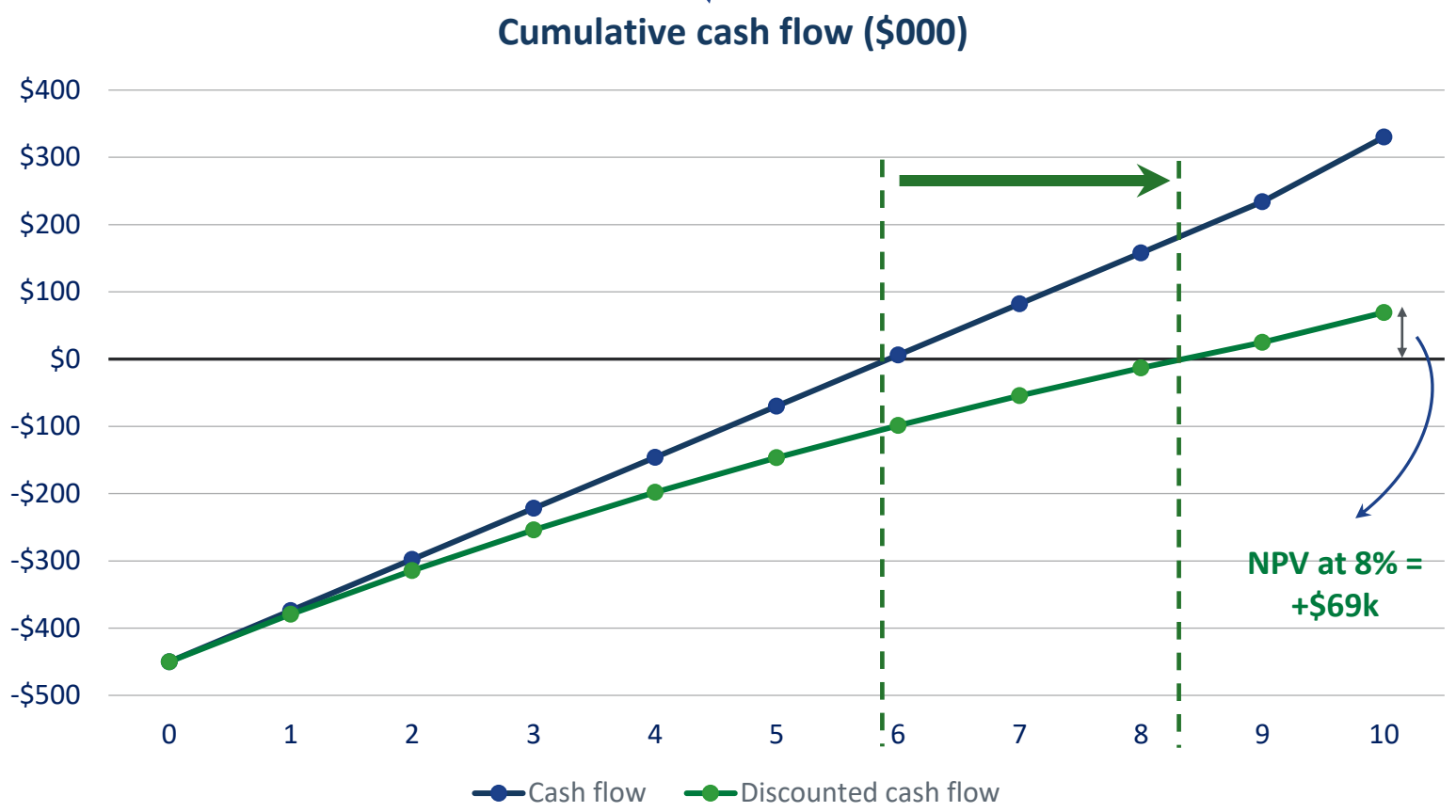
NPV and Payback from DCF



Illustrative heat-recovery project:
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Simple Payback: **5.9 years**

Discounted Payback: **8.3 years**



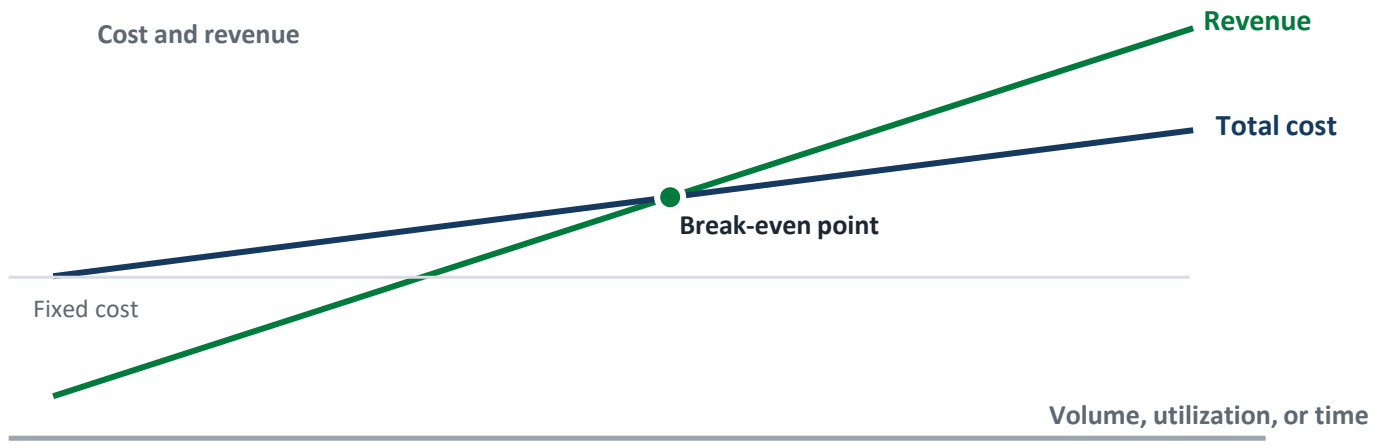
Break-Even Analysis

- Finds the point where cumulative or annual revenue equals total cost. The method can use volume, sales, utilization, or time.

Questions Answered	
	How much output must the project sell to cover cost?
	What utilization or price reaches break-even?
	How far is the expected case from the threshold?

Best Fit:
Early screening and expanded TEA, especially when price and variable cost can be estimated.

ILLUSTRATIVE RELATIONSHIP



CORE CALCULATION

Break-even volume = fixed cost / (price per unit - variable cost per unit)

TYPICAL OUTPUTS

Break-even volume	**Required sales**	**Required utilization**	**Time to break-even**

Source: https://arpa-e.energy.gov/sites/default/files/2025-06/Techno-Economics%20for%20ARPA-E%20Performers.pdf

Simple Return on Investment (ROI)

- Measures the expected profitability of a project as a percentage of the investment. Simple ROI does not discount future cash flows.

Questions Answered	
	How large is the benefit relative to the investment?
	How does the project compare with other simple options?
	Does the return clear an internal screening threshold?

CORE CALCULATION

$$\text{ROI (\%)} = \frac{\text{Total benefits - Total costs}}{\text{Initial investment}} \times 100$$

Best Fit:
Quick project screening when benefits and costs occur over a comparable period.

TYPICAL OUTPUTS

ROI percentage	Simple payback	Option ranking	Screening decision

Source: https://arpa-e.energy.gov/sites/default/files/2025-06/Techno-Economics%20for%20ARPA-E%20Performers.pdf

During next class, we will go over:

- Go over:
  - Discount rates
  - IRR
  - Break even
  - ROI
- The classroom exercise for the Financial Evaluation
- The details of TEA Decision Support component
- The classroom exercise for the Decision Support
- Types of TEA
  - Assessment Process Steps
- Some tips for conducting and reviewing TEA
- Other resources for TEA

THANK YOU!

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