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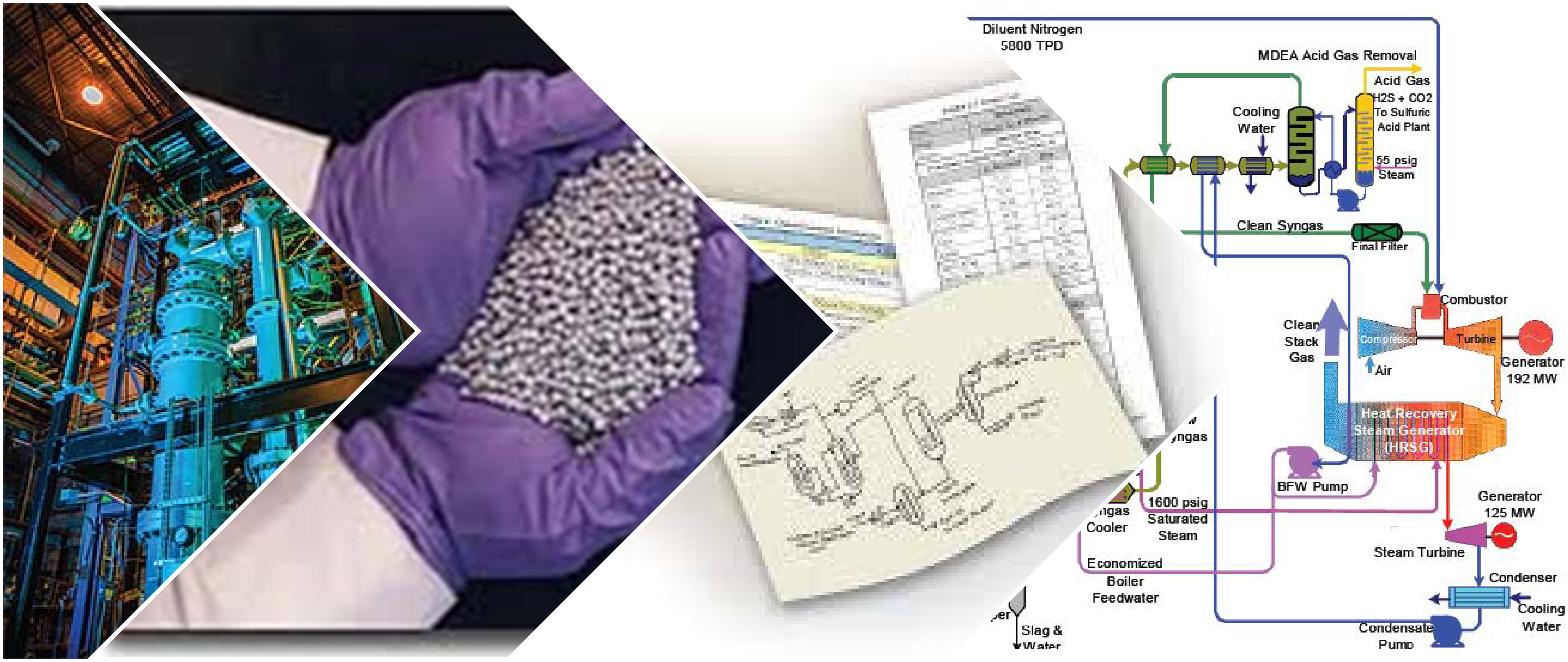

Introduction to Performing a Techno-Economic Analysis for Power Generation Systems

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U.S. DEPARTMENT OF ENERGY | *National Energy Technology Laboratory*

Techno-Economic Analysis (TEA)

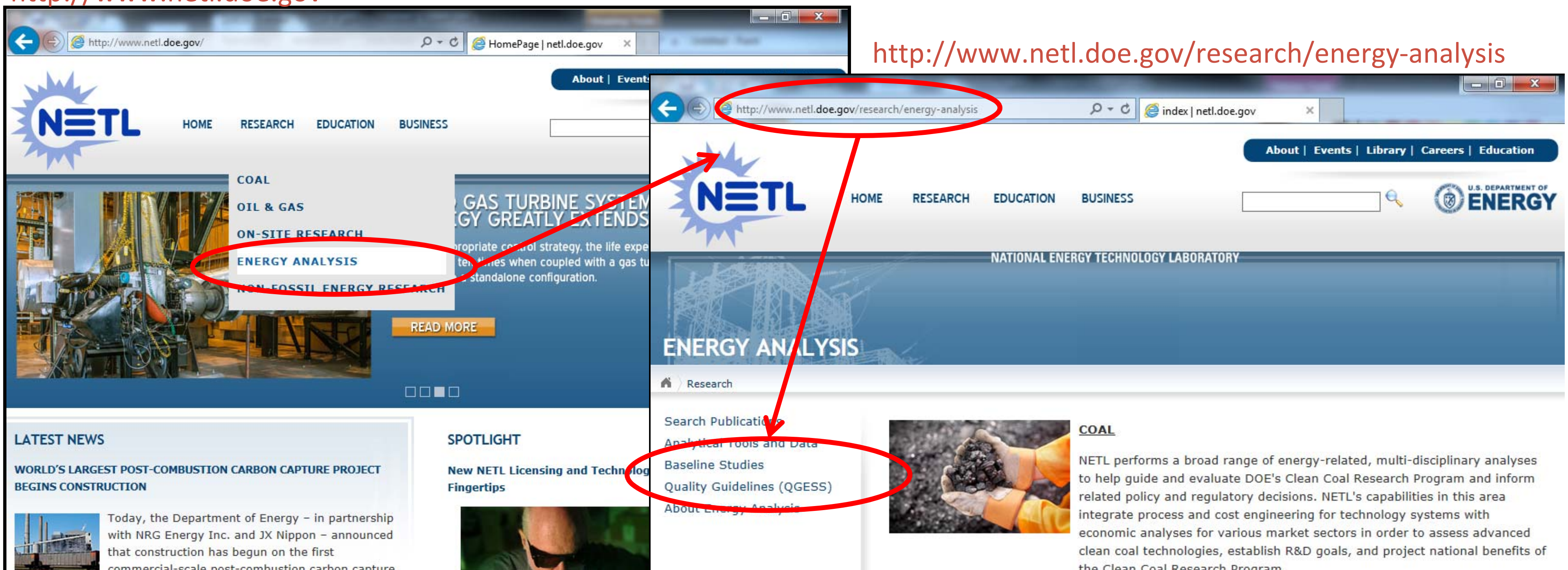
- A system performance and cost analysis at commercial scale
  - NETL's Bituminous Baseline
  - Key subset assessing advanced technology
- Cases in a TEA:
  - Reference case: state-of-the-art power plant should be similar to those found in the Baseline studies
  - Advanced case: Novel technology replaces SOA technology in reference plant
- Comparison between cases can provide:
  - Representation and quantification of the benefits of the novel technology.
  - Identification and potential quantification of performance and cost goals for the novel technology.
  - Identification of critical performance and cost parameters, inform R&D prioritization decisions.
- The common metric derived and compared is Cost of Electricity (COE) and net power plant efficiency (HHV & LHV)

Resources for TEA Development

- **Baseline studies**
  - A Series of documents that provide Baseline's for comparison
  - http://www.netl.doe.gov/research/energy-analysis/energy-baseline-studies
- **Quality Guidelines for Energy System Studies (QGESS) Documents**
  - A series of documents that provide the details to performing TEAs
  - http://www.netl.doe.gov/research/energy-analysis/quality-guidelines-qgess
  - Also includes a manuscript titled "**A proposed methodology for CO_2 capture and storage cost estimates"** that outlines a methodology for costing

http://www.netl.doe.gov

http://www.netl.doe.gov/research/energy-analysis



NETL Baseline

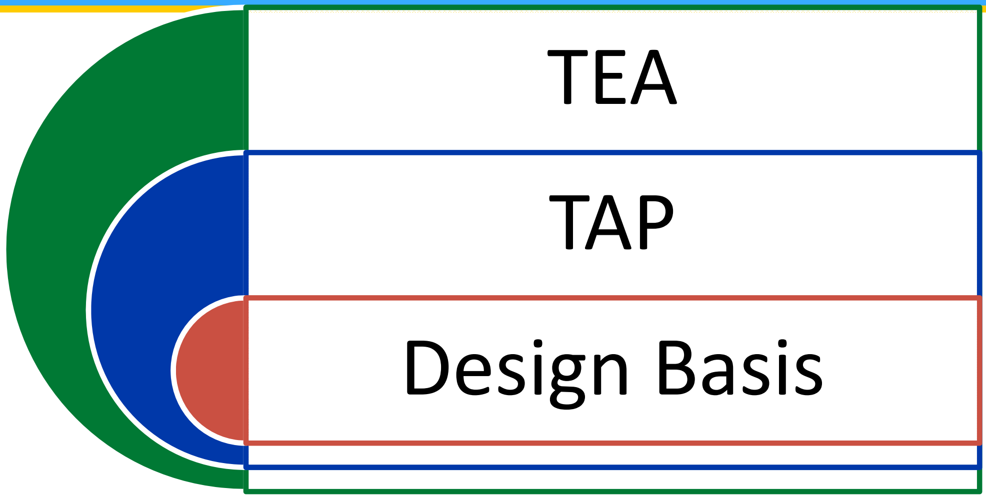
Volume	Title	Description
1	**Bituminous Coal and Natural Gas to Electricity, aka Bituminous Baseline**	Establishes performance and cost data for SOA fossil energy power systems for integrated gasification combined cycle (IGCC), pulverized coal (PC), and natural gas combined cycle (NGCC) plants with and without capture
3	**Low-Rank Coal and Natural Gas to Electricity, aka Low Rank Baseline**	Establishes performance and cost data for SOA fossil energy power systems for IGCC, PC, and NGCC plants using low rank coals

These documents provide:

1. **A starting point for model design basis**
2. **An outline for TEA reporting format (stream tables, auxiliary load tables, etc.)**

NETL Quality Guidelines for Energy System Studies (QGESS)

Title	Description
Detailed Coal Specifications	Provides detailed specifications for seven coals commonly used with detailed production information
Specifications for Selected Feedstocks	Provides recommended specifications for natural gas and coal that are commonly found in NETL energy system studies.
Process Modeling Design Parameters	Documents the process modeling assumptions most commonly used in systems analysis studies and the basis for those assumptions. The large number of assumptions required for a systems analysis makes it impractical to document the entire set in each report. This document serves as a comprehensive reference for these assumptions as well as their justification.
CO_2 Impurity Design Parameters	Summarizes the impurity limits for CO_2 stream components for use in carbon steel pipelines, enhanced oil recovery (EOR), saline formation sequestration, and co-sequestration of CO_2 and H_2S in saline formations.
Capital Cost Scaling Methodology	Provides a standard basis for scaling capital costs, with specific emphasis on scaling exponents. This document contains a listing of frequently used pieces of equipment and their corresponding scaling exponent for various plant types, along with their ranges of applicability.
Cost Estimation Methodology	Summarizes the cost estimation methodology employed by NETL in its assessment of power plant performance.
Estimating Carbon Dioxide Transport and Storage Costs	Addresses the cost of CO_2 transport and storage (T&S) in a deep saline formation with respect to plant location and region-specific aquifers.
Fuel Prices for Selected Feedstocks	Provides an estimate of the market price delivered to specific end-use areas of four coals that are commonly used as feedstocks in the energy system studies sponsored by NETL. Also includes the estimated market price for natural gas delivered to three different regions.



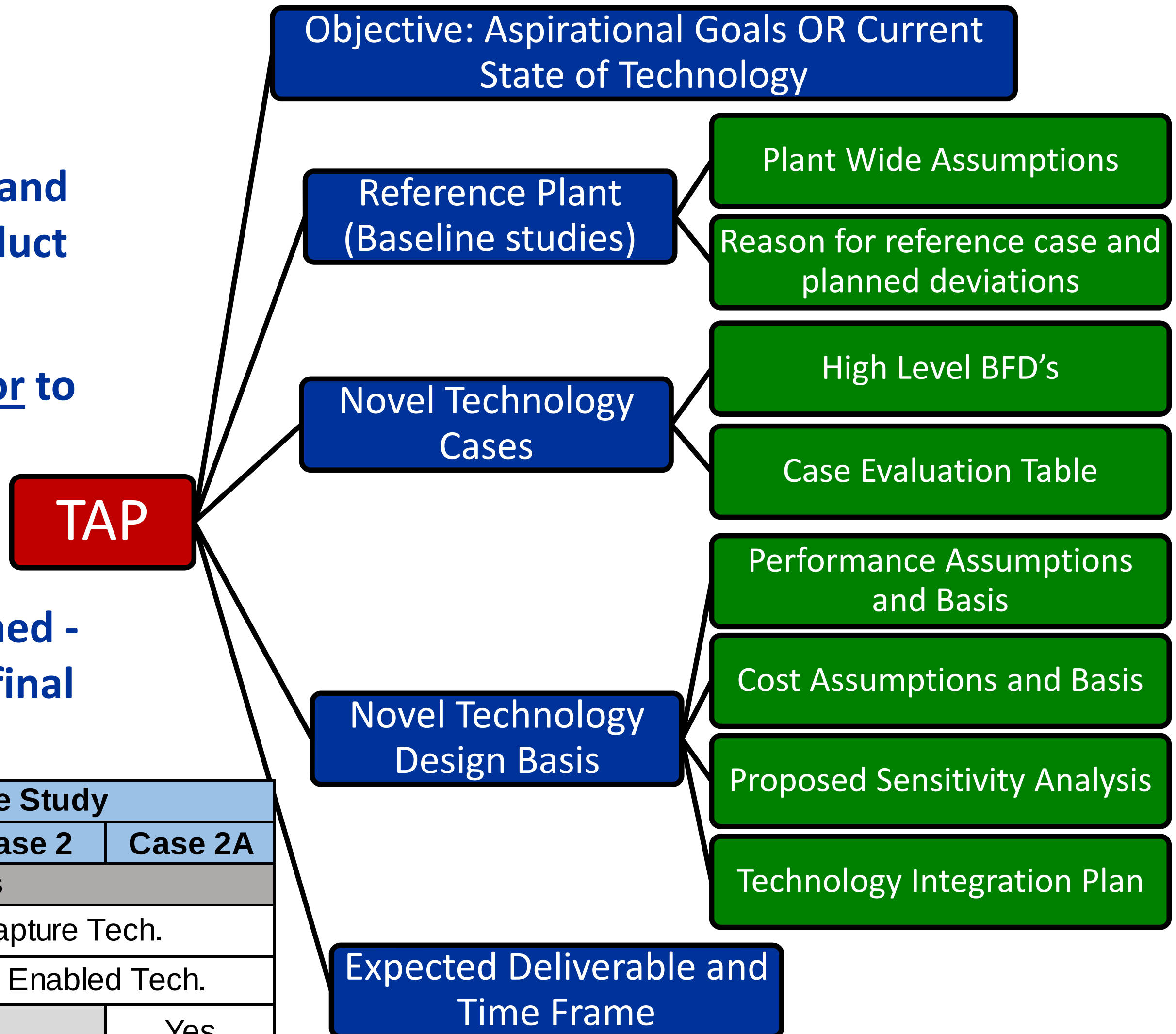
Steps to performing a TEA:

1. Form a Technology Analysis Plan
2. Create a Performance Model
3. Cost Estimating – COE
4. Reporting Requirements

Technology Analysis Plan (TAP)

What is a TAP?

- **A TAP discusses the approach and methodology required to conduct the TEA.**
- **Presented to stakeholders <u>prior</u> to starting the TEA**
  - **Document assumptions**
  - **Ensure valuable product**
- **Updated as the TEA is performed - changes should be noted in a final document**



Case	Baseline (Reference)	Case Study		
		Case 1	Case 2	Case 2A
Technology Combinations				
CO_2 Removal	Selexol	Novel Capture Tech.		
Enabling Tech.	Std. Tech.		Enabled Tech.	
CO_2 Purification	No			Yes

Steps to performing a TEA:

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Performance Model Results for Reporting

- **Build a performance model**
  - **Frequently completed in ASPEN, ChemCAD, Thermoflow, etc.**
  - **When applying novel technology:**
    - **Hold constant:**
      - PC: net power output constant
      - IGCC: hold combustion turbine power output constant
    - **Balance of plant equipment NOT affected by research area will be scaled**
    - **Changes in operating parameters that are different than those in the Baseline Studies must be justified in the TEA document**
- **Detailed Process Flow Diagram**

Performance Modeling Inconsistencies

- **Items that are often varied between the reference and novel cases without justification:**
  - **Condenser pressure**
  - **Steam cycle conditions (e.g. reheat temperature)**
  - **Combustion turbine conditions (e.g. turbine inlet temperature)**
  - **Cooling water temperature**
  - **ASU performance and oxygen quality**
  - **Emissions levels**
  - **Equipment selection**
- **These variations without justification may require further communication or resubmission of report**
- **Performance variations _NOT_ related to the Novel technology between the reference and novel cases should thoroughly explained**

Performance Model

QGESS documents frequently referenced

- **QGESS on Process Modeling Design**
  http://www.netl.doe.gov/File%20Library/Research/Energy%20Analysis/Publications/QGESS_ProcessModDesignParameters_Public_Rev2_20140513.pdf
  - Site Conditions
  - Steam cycle conditions
  - Coal Combustion parameters
  - Gasifier Performance
  - Syngas processing
  - Sulfur processing
  - Equations of State
  - Cooling water parameters
- **Feedstock: QGESS on Feedstock Specifications**
  http://www.netl.doe.gov/File%20Library/research/energy%20analysis/publications/QGESSSec1.pdf
  - Natural Gas Composition
  - Various Coal Compositions
  - Limestone analysis
  - Lime analysis
  - LHV and HHV
- **CO_2 Specifications: QGESS on CO_2 Impurities**
  http://www.netl.doe.gov/File%20Library/Research/Energy%20Analysis/Publications/QGESS_CO2Purity_Rev3_20130927_1.pdf
  - CO_2 delivery pressure
  - Individual contaminate concentration limits
  - CO_2 minimum concentration
  - Specifications for intended use (Saline, EOR, etc.)
  - Venting concerns

Performance Model Results for Reporting

Material and Energy Balances

- Consistent with the level of detail found in the Baseline reports Material balance should including
  - All inputs feedstock, catalyst, limestone, etc.
  - All outputs such as stack gas, waste water, solid waste disposal
  - Stream compositions
- Energy Balance should include
  - Thermal energy input from fuel
  - Major auxiliary loads
  - Detailed loads for new technology

Model Results

- Total power from turbines
- New auxiliary loads
- Net Power
- Heat rate, efficiencies, etc.
  - HHV Commonly used for NETL reporting purposes
- Water withdraw, consumption, and discharge
  - If new technology creates impurities in water discharge, this must be documented
- CO_2 impurities
- Air emissions
- Equipment and auxiliary loads NOT affected by novel technology will be scaled appropriately

POWER SUMMARY (Gross Power at Generator Terminals, kWe)	
Gas Turbine Power	464,000
Sweet Gas Expander Power	7,500
Steam Turbine Power	276,300
TOTAL POWER, kWe	**747,800**
AUXILIARY LOAD SUMMARY, kWe	
Coal Handling	460
Coal Milling	2,180
Sour Water Recycle Slurry Pump	180
Slag Handling	1,120
Air Separation Unit Auxiliaries	1,000
Air Separation Unit Main Air Compressor	53,820
Oxygen Compressor	10,260
Nitrogen Compressors	33,340
Boiler Feedwater Pumps	3,980
Condensate Pump	230
Quench Water Pump	520
Circulating Water Pump	4,200
Ground Water Pumps	430
Cooling Tower Fans	2,170
Scrubber Pumps	220
Acid Gas Removal	2,590
Gas Turbine Auxiliaries	1,000
Steam Turbine Auxiliaries	100
Claus Plant/TGTU Auxiliaries	250
Claus Plant TG Recycle Compressor	2,090
Miscellaneous Balance of Plant[2]	3,000
Transformer Losses	2,610
TOTAL AUXILIARIES, kWe	**125,750**
NET POWER, kWe	**622,050**
Net Plant Efficiency, % (HHV)	39.0
Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,238 (8,756)
CONDENSER COOLING DUTY 10^6 kJ/hr (10^6 Btu/hr)	**1,540 (1,460)**
CONSUMABLES	
As-Received Coal Feed, kg/hr (lb/hr)	211,783 (466,901)
Thermal Input[1], kWt	1,596,320
Raw Water Withdrawal, m^3/min (gpm)	17.9 (4,735)
Raw Water Consumption, m^3/min (gpm)	14.2 (3,755)

Reporting Novel Equipment

- **Novel equipment should be reported at a greater level of detail than found in the Baseline study**

- **Items to include:**
  - **Design equations (if developed)**
  - **Scaling methodology and equations**
  - **Design basis (kinetics, volumetric throughput, etc.)**
  - **How was the data for the above collected (TGA, lab scale bubbling bed, etc.)**

Steps to performing a TEA:

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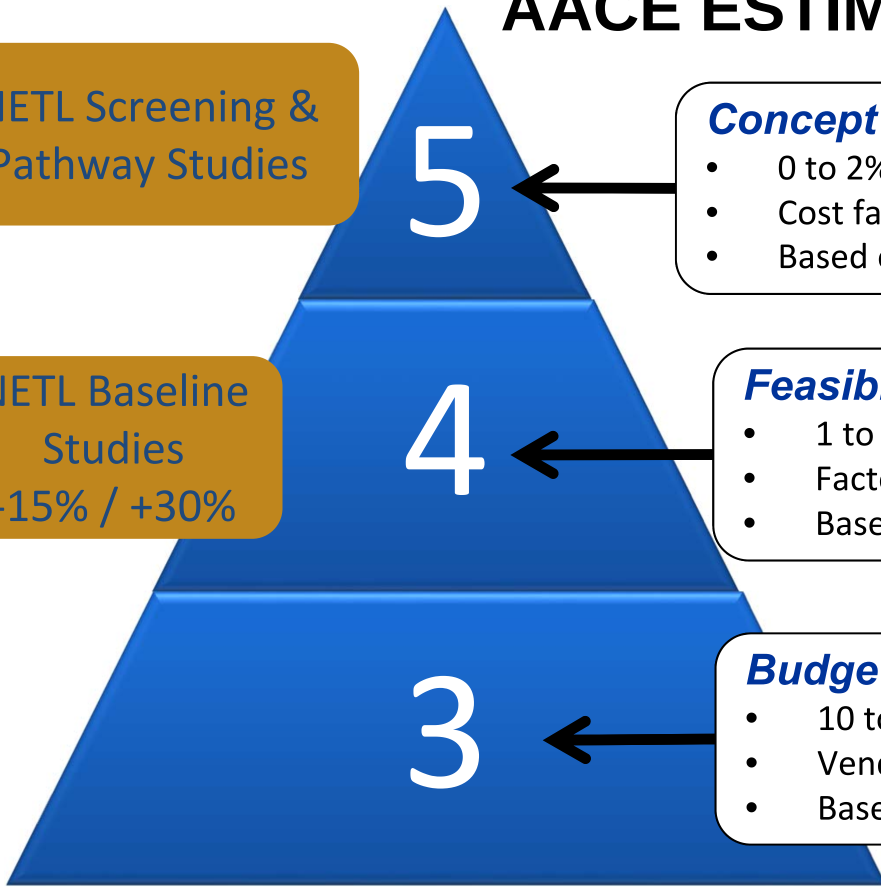
Classes of NETL Cost Estimates

AACE ESTIMATE CLASS



NETL Screening & Pathway Studies

Class 5 — *Concept Screening (e.g. -20%/ +100% Accuracy)*

- 0 to 2% project definition
- Cost factored on system / major subsystem capacity
- Based on technical analogs / engineering judgment

NETL Baseline Studies -15% / +30%

Class 4 — *Feasibility Study (e.g. -15% / +50% Accuracy)*

- 1 to 15% project definition
- Factored equipment costs
- Based on preliminary mass and energy balances

Class 3 — *Budget Estimate (e.g. -10% / +30% Accuracy)*

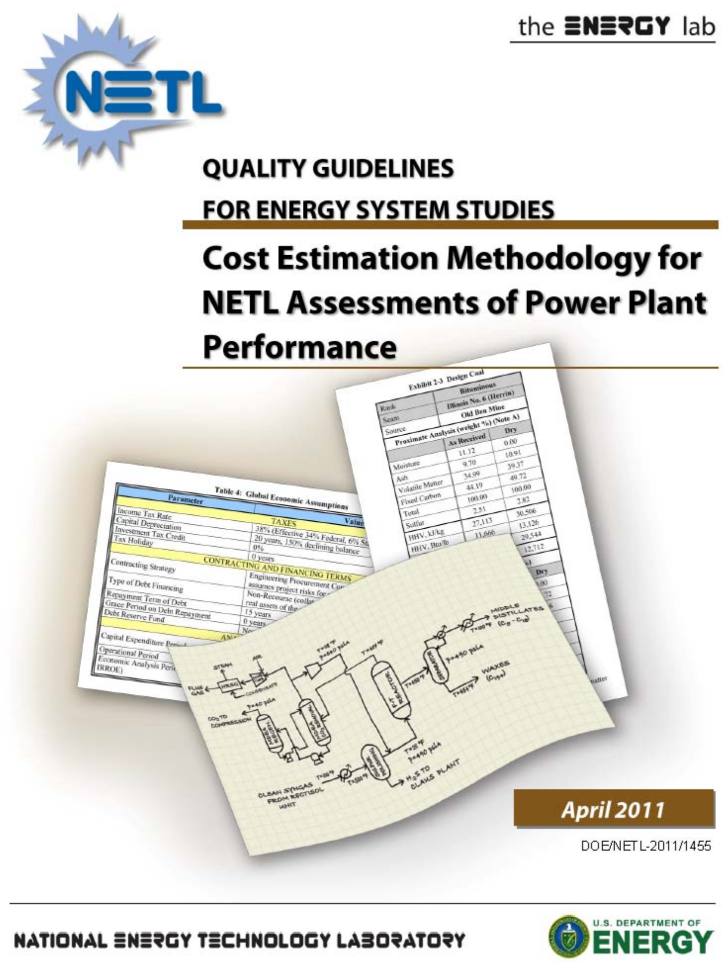
- 10 to 40% project definition
- Vendor quotes, third-party EPC estimates
- Based on detailed process and economic modeling

Process flow diagrams (PFDs) and piping and instrument diagrams (P&IDs) are the primary documents that define project scope. Association for the Advancement of Cost Engineering International (AACE) Recommended Practice No. 18R-97 describes the AACE cost estimate classification system.

QGESS: Cost Estimation Methodology

- **Capital Cost Breakdown**
  - Estimate Class
  - Contingency Guidelines
  - Owner's Cost Recommendations
  - Estimate Scope
  - Project Scope

- **Economic Analysis**
  - Global Economic Assumptions
  - Recommended Financing Structures
  - Estimation of COE


the ENERGY lab

QUALITY GUIDELINES
FOR ENERGY SYSTEM STUDIES

Cost Estimation Methodology for NETL Assessments of Power Plant Performance

April 2011

DOE/NETL-2011/1455

NATIONAL ENERGY TECHNOLOGY LABORATORY

U.S. DEPARTMENT OF ENERGY

http://www.netl.doe.gov/File%20Library/research/energy%20analysis/publications/QGESSNETLCostEstMethod.pdf

Economic Analysis – COE

- **Cost of electricity (COE) is the minimum revenue a power plant must receive for the electricity generated to cover cost and stated IRROE**
  - **Determining the COE involves a complex set of financial assumptions**
  - **To simplify the COE calculation, a Capital Charge Factor (CCF) has been developed.**
    - **Simplifies and unifies common financial terms and assumptions**
    - **Annualizes the capital cost over the life of the plant**
- **A simplified equation can be utilized to determine the COE to unify assumptions**

$$\mathrm{COE} = \frac{\begin{matrix}\textit{First year}\\ \textit{capital charge}\end{matrix} + \begin{matrix}\textit{first year}\\ \textit{fixed operating}\\ \textit{costs}\end{matrix} + \begin{matrix}\textit{first year}\\ \textit{variable operating}\\ \textit{costs}\end{matrix}}{\begin{matrix}\textit{annual net megawatt hours}\\ \textit{of power generation}\end{matrix}}$$

$$\mathbf{COE} = \frac{\mathbf{CCF \cdot TOC + OC_{FIX} + CF \cdot OC_{VAR}}}{\mathbf{CF \cdot MWh}}$$

Economic Analysis – COE

$$\text{COE} = \frac{\mathbf{CCF} \cdot \text{TOC} + \text{OC}_{\text{FIX}} + \mathbf{CF} \cdot \text{OC}_{\text{VAR}}}{\mathbf{CF} \cdot \mathbf{MWh}}$$

Plant Type	CCF w/ CC	CF
PC	0.124	0.85
IGCC	0.124	0.80
NGCC	0.111	0.85

- The **CCF** takes into account the financial aspects of the plant and represents them in a single factor that can then be used to annualize the capital over the life of the plant. Greater detail can be found in the QGESS documents.
- The **MWh** parameter is the net power generated (at 100% CF) by the plant.
- The **CF** parameter Capacity Factor, which is assumed to be equal to the availability

Economic Analysis – Operating Costs (RR)

$$COE = \frac{CCF \cdot TOC + \mathbf{OC_{FIX}} + CF \cdot \mathbf{OC_{VAR}}}{CF \cdot MWh}$$

Fixed Operating Costs (OC_{FIX})	Variable Operating Costs (OC_{VAR})
Annual Operating Labor Cost	Maintenance Material Cost
Maintenance Labor Cost	**Fuel**
Administrative & Support Labor	Other Consumables
Property Taxes and Insurance	Waste Disposal
Additional OC_{Fix} for new technology	Emission Costs
	Byproduct Revenues
	Additional OC_{Var} for new technology

Operating Costs reported should be similar to those found in the Baseline Reports

Economic Analysis – Capital Costs (RR)

$$COE = \frac{CCF \cdot TOC + OC_{FIX} + CF \cdot OC_{VAR}}{CF \cdot MWh}$$

- **TASC / TCR**
  - **TOC**
    - **TPC**
      - **EPCC**
        - **BEC**
          - process equipment
          - supporting facilities
          - direct and indirect labor
        - EPC contractor services
      - process contingency
      - project contingency
    - pre-production costs
    - inventory capital
    - financing costs
    - other owner's costs
  - escalation during capital expenditure period
  - interest on debt during capital expenditure period

Bare Erected Cost
Engineering, Procurement and Construction Cost
Total Plant Cost
Total Overnight Cost
Total As-Spent Cost

BEC, EPCC, TPC, TOC and TCR are all "overnight" costs expressed in base-year dollars.

TASC is expressed in mixed-year current dollars, spread over the capital expenditure period.

Capital Costs Basis of Novel Equipment

- **Capital costs (projected commercial costs) for unique equipment may be calculated by several methods: (RR)**
  - **Scaled: The equipment can be scaled if analogous equipment is available either in an NETL baseline study or otherwise**
  - **Bottom-up: Build cost from metal and manufacturing cost estimates**
  - **If neither a scaled approach or a bottom-up estimate can be produced - research goals or bearable costs can be estimated**
    - **This approach is occasionally used at laboratory scale projects**
  - **Report what the basis is for cost (experimental scale)**
- **The methodology, reference equipment, and sources of data should be documented in detail within the TEA**
- **Balance of plant will be directly used or scaled from the Baseline reports**

Contingency Estimation

- Contingency is to cover the known-unknowns or costs that will likely occur based on past experience due to incomplete engineering design
  - Example: early in the design phase, the plant will have high contingencies, future plants should have lower contingencies, but more known costs
- Two types of contingencies are used:
  - Project Contingency: AACE 16R-90 states that project contingency for a “budget-type” estimate (AACE Class 4 or 5) should be 15 percent to 30 percent of the sum of BEC, EPC fees and process contingency.
  - Process Contingency: intended to compensate for uncertainty in cost estimates caused by performance uncertainties associated with the development status of a technology.
- Each “process” in the TEA is assigned a contingency

Technology Status	Process Contingency
New Concept – limited data	40+%
Concept with bench scale data	30-70%
Small Pilot scale data	20-35%
Full sized modules tested	5-20%
Commercial process	0-10%

Contingency Estimation

- **Generally, novel technology should have a <u>higher contingency</u> than those in the Baseline studies**
- **Level of Contingency used should be relative to the development level and engineering completeness of the cost estimate for the novel technology.**
- **If R&D cost targets, if applicable, contingency might be inclusive**
  - **When assessing progress towards R&D targets, appropriate contingencies should be included**

(From NETL's Baseline)

Process Contingency	
Slurry prep and Feed pump	5%
Gasifier and syngas cooler	15%
Two stage Selexol	20%
Mercury Removal	5%
CO_2 removal (PC & NGCC)	20%
Combustion Turbine	5%
AHT in IGCC	10%
Instrumentation and controls	5%

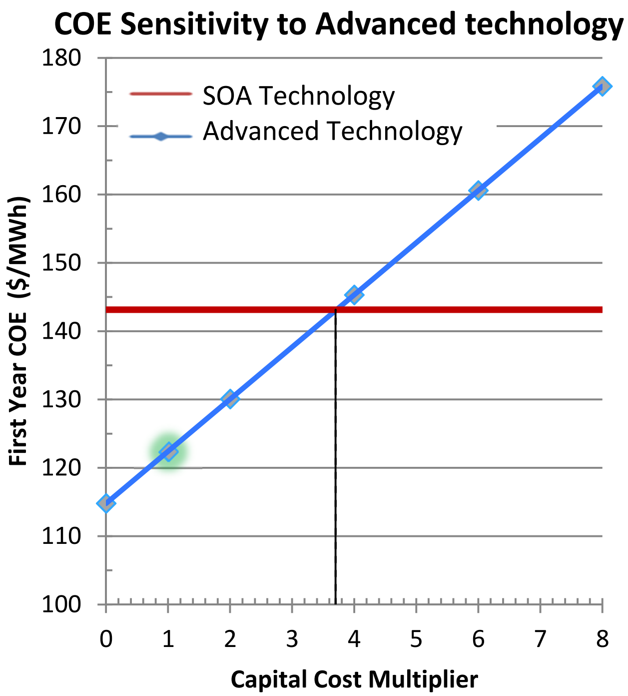
Process contingencies range between 2-5% of overall TPC

- **Contingency is not:**
  - To cover poor engineering or poor estimates
  - Accuracy
  - Cover a scope change
  - Account for delays
  - Unexpected cost escalation
  - Plant performance after startup

Economic Analysis – COE

Once COE has been calculated:

- Compared to reference to novel cases(RR)
- Sensitivity analysis can be conducted to guide research or suggest future goals (RR)
    - Examples include:
    - Capital cost,
    - changes in kinetics
    - reduced pressure drop,
    - reduced heat of reaction to reduce regeneration duties
- This information can be utilized to determine if a parameter is critical.



Steps to performing a TEA:

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Reporting Requirements

- TAP – share with stakeholders
  - State which Baseline case will be used as a reference case
  - State Design and Cost Assumptions and Basis

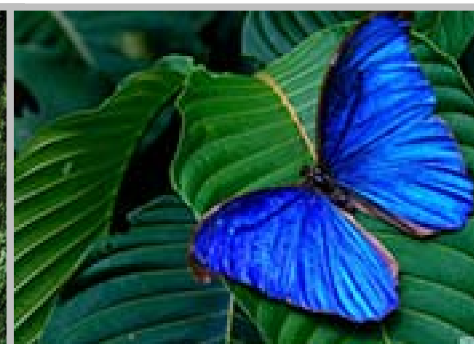
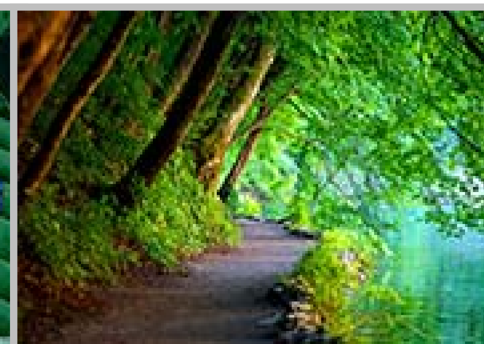
Stakeholders

- Updated TAP
- Performance Modeling
  - Block Flow diagram
  - Detailed Simulation Model
  - Material and Energy Balance
- Cost Estimating - COE and Cost of Carbon Captured
  - Detailed COE calculations
  - Detailed TOC cost estimates
  - Sensitivity Studies
  - Cost of CO_2 Captured

Reporting Requirements

- **The TEA report should:**
  - **Provide reasoning for new equipment design basis – experimental data is preferred**
  - **Have a level a detail equal or greater than that outlined in the Bituminous Baseline (particularly for novel equipment)**
  - **Provide a basis for both design and costing of novel equipment**
- **Remember to:**
  - **Choose a Baseline study that can easily use the new technology**
  - **Justify any variations from the Baseline outside of the new technology**
  - **Provide enough detail to reproduce stated number**
  - **Once complete, use the information to guide research**



For More Information, Contact NETL

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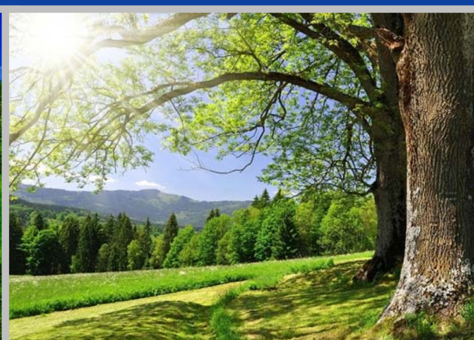

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ADDITIONAL INFORMATION

Economic Analysis – COE

$$\mathbf{COE} = \frac{\mathbf{CCF \cdot TOC + OC_{FIX} + CF \cdot OC_{VAR}}}{\mathbf{CF \cdot MWh}}$$

- **Where (all items below are to reported (RR)):**
  - COE = Revenue received by the generator during the power plant's first year of operation
  - CCF = Capital charge factor
  - TOC = Total overnight capital
  - OC_{FIX} = Sum of all fixed annual operating costs
  - OC_{VAR} = Sum of all variable annual operating costs at 100 percent capacity
  - CF = Plant capacity factor
  - MWh = Annual net megawatt-hours

Contingency Estimation

From the Bituminous Baseline Study - GEE IGCC with Capture

Item No.	Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	Total Plant Cost $	Total Plant Cost $/kW
	Case:	**B4B – E-Gas IGCC w/ CO_2**						**Estimate Type:**	**Conceptual**		
	Plant Size (MW,net):	**514**						**Cost Base ($x1,000):**			**Jun 2011**
	1	Coal & Sorbent Handling									
1.1	Coal Receive & Unload	$4,536	$0	$2,186	$0	$6,722	$672	$0	$1,479	$8,873	$17
1.2	Coal Stackout & Reclaim	$5,862	$0	$1,402	$0	$7,263	$726	$0	$1,598	$9,587	$19
1.3	Coal Conveyors & Yd Crush	$5,450	$0	$1,387	$0	$6,836	$684	$0	$1,504	$9,024	$18
1.4	Other Coal Handling	$1,426	$0	$321	$0	$1,747	$175	$0	$384	$2,306	$4
1.9	Coal & Sorbent Hnd. Foundations	$0	$3,029	$7,916	$0	$10,945	$1,095	$0	$2,408	$14,447	$28
	Subtotal	**$17,273**	**$3,029**	**$13,211**	**$0**	**$33,513**	**$3,351**	**$0**	**$7,373**	**$44,238**	**$86**
	4	Gasifier & Accessories									
4.1	Syngas Cooler Gasifier System	$137,262	$0	$76,506	$0	$213,769	$21,377	$29,564	$40,623	$305,333	$594
4.2	Syngas Cooler	w/4.1	$0	w/ 4.1	$0	$0	$0	$0	$0	$0	$0
4.3	ASU & Oxidant Compression	$222,841	$0	w/equip.	$0	$222,841	$22,284	$0	$24,513	$269,638	$525
4.4	LT Heat Recovery & FG Saturation	$28,817	$0	$10,949	$0	$39,766	$3,977	$0	$8,749	$52,492	$102
4.5	Misc. Gasification Equipment	w/4.1&4.2	$0	w/4.1&4.2	$0	$0	$0	$0	$0	$0	$0
4.6	Flare Stack System	$0	$1,981	$801	$0	$2,782	$278	$0	$612	$3,672	$7
4.8	Major Component Rigging	w/4.1&4.2	$0	w/4.1&4.2	$0	$0	$0	$0	$0	$0	$0
4.9	Gasification Foundations	$0	$9,765	$5,824	$0	$15,589	$1,559	$0	$4,287	$21,434	$42
	Subtotal	**$388,921**	**$11,746**	**$94,080**	**$0**	**$494,747**	**$49,475**	**$29,564**	**$78,784**	**$652,569**	**$1,271**
	5A	Gas Cleanup & Piping									
5A.1	Double Stage Selexol	$162,818	$0	w/equip.	$0	$162,818	$16,282	$32,564	$42,333	$253,996	$495
5A.2	Elemental Sulfur Plant	$12,406	$2,418	$15,897	$0	$30,721	$3,072	$0	$6,759	$40,552	$79
5A.3	Mercury Removal	$1,867	$0	$1,411	$0	$3,278	$328	$164	$754	$4,524	$9
5A.4	Shift Reactors	$8,605	$0	$3,440	$0	$12,044	$1,204	$0	$2,650	$15,898	$31
5A.5	Particulate Removal	w/4.1	$0	w/4.1	$0	$0	$0	$0	$0	$0	$0
5A.6	Blowback Gas Systems	$657	$369	$206	$0	$1,232	$123	$0	$271	$1,626	$3
5A.7	Fuel Gas Piping	$0	$926	$606	$0	$1,532	$153	$0	$337	$2,022	$4
5A.9	HGCU Foundations	$0	$838	$565	$0	$1,403	$140	$0	$463	$2,007	$4
	Subtotal	**$186,353**	**$4,551**	**$22,125**	**$0**	**$213,029**	**$21,303**	**$32,727**	**$53,566**	**$320,626**	**$624**

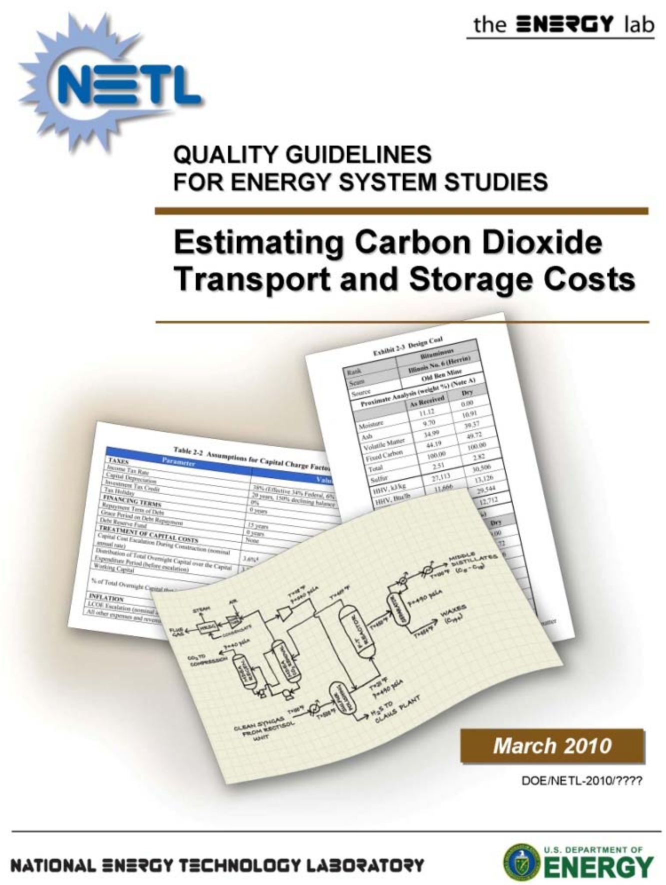
Economic Analysis – Cost of CO_2 Captured

$$Cost\ of\ CO_2\ Captured = \frac{(COE_{\mathbf{With\ CC}} - COE_{\mathbf{Without\ CC}})}{CO_2\ Captured}$$

- **Where:**
  - $COE_{With\ CC}$: The plant modeled with novel technology
  - $COE_{Without\ CC}$: Reference non-capture plant
    - Generally Case 11 in the Bituminous Baseline Rev. 2
  - CO_2 captured equals the rate of CO_2 captured, tonne/MWh
  - it does *NOT* include the cost to transport and store (T&S) CO_2

Cost of CO_2 Transport and Storage (T&S)

- **Reported separately from plant capital and O&M costs**
  - TS&M capital and O&M costs levelized using same methodology as inside-the-gate costs
  - Added on as O&M-type costs maintaining the perspective of the plant
- **Pipeline transport of 50 miles**
- **Storage costs**
  - Site screening and evaluation
  - Injection wells and equipment
  - O&M costs
  - Pore volume acquisition costs
- **Monitoring costs**
  - Liability fund
  - Monitoring costs



Capital Costs – Research Goals and Bearable Costs

- **Research goals – Intended targets for the costs of technology under development**
  - Detailed descriptions as to the reason for the selection of the targets should be provided
  - Available data that supports the goal selection should be provided
- **Bearable costs – The costs at which the technology meets a specific goal**
  - If a goal has been provided (e.g. < 30 percent increase in COE), the bearable cost to meet the goal can be calculated