Cost Classification

The selling price may be twice the manufacturing costs.

We will focus on the manufacturing costs in ECE3031

Manufacturing costs can be classified into fixed costs and variable costs; manufacturing costs can also be divided into direct costs and indirect costs.

Manufacturing Cost = Fixed Costs+Variable Costs

- Fixed costs
  - Investment costs (interests and depreciation on capital investment - tooling, property tax, insurance)
  - Overhead costs (technical services/engineering, nontechnical services/office personnel, general supplies)
  - Management expenses (corporate management, legal staff, R&D staff)
  - Selling expenses (sales force, delivery and warehouse costs, technical service staff)
- Variable costs
  - Materials, and purchased parts
  - Direct labour, quality-control staff
  - Maintenance costs
  - Power/energy and utilities
  - Packaging and storage costs
  - Royalty/licensing payments

Manufacturing Cost = Direct Costs + Indirect Costs

- Direct Costs
  - Piece parts
    - Materials, tooling, setup, processing =>custom parts
    - Purchased parts (OEM)
  - Assembly
    - Labour (salaries and benefits)
    - Tooling (some capital costs)
- Indirect Costs
  - Overhead (administration, engineering, secretarial, utilities, capital, insurance, etc.)
  - Selling expenses (marketing, technical support etc.)

Components: Purchasing or Making?

For components used in your product, you can:

- Purchase finished components from a vendor (off-the-shelf)
- Have a vendor produce components designed In-house (out-sourcing)
- Manufacturing components In-house (In-house)

Factors affecting the decision:

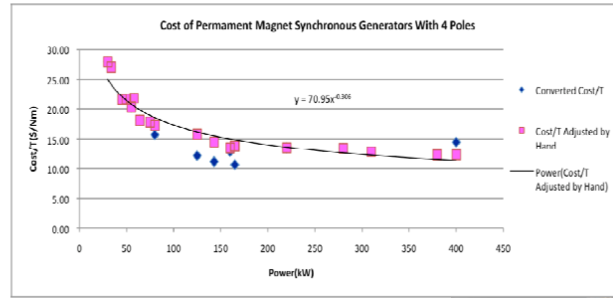
- Cost of the components
- In-house production capacity/expertise/investment
- Quality and experience
- Transportation costs

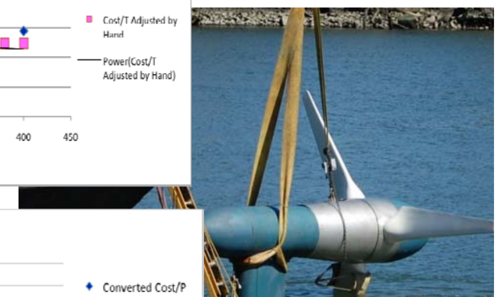
Cost Estimate Methods for Manufacturing a Product

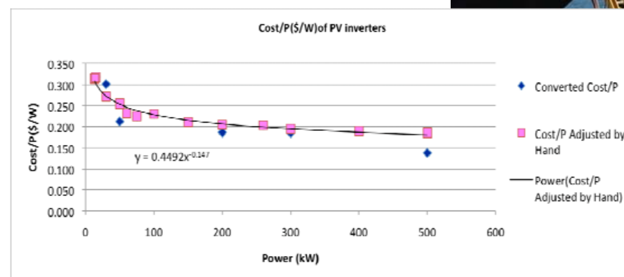
- Industrial Engineering Approach:
  - Separate elements of work are identified and summed into total cost per part
- Analogy:
  - Future costs of a design are based on past costs of a similar design (needs similar experience or published cost data)
- Statistical Approach:
  - Establish costs and initial parameters of the products such as power, weight, speed etc

$$Cost = 0.13937 x_1^{0.7435} \; x_2^{0.0775}$$

Cost of Generators and Converters







Cost Estimate - Industrial Engineering Approach

Costs of one DC Motor Controller at a Production Volume of 1000 per year

Operations	Material	Labour	Overhead	Total
Elec. parts	15.36	0.20	0.45	16.01
PCB assembly	0.52	2.23	0.33	3.08
Testing	0.21	0.34	0.76	1.31
Packaging	0.44	0.15	0.09	0.68
TOTAL				20.08

Product Pricing - Break-Even Chart (A Simplified Approach)

A break-even chart is designed to show graphically the profits and losses on a product's selling price and manufacturing costs: $ v.s. production units

- Determine the variable cost per product
- Determine the fixed cost (total)
- Draw the total cost as a function of product units
- Determine the sale price of the product, and draw the sales as a function of product units
- Determine the break-even point

Break-Even Chart

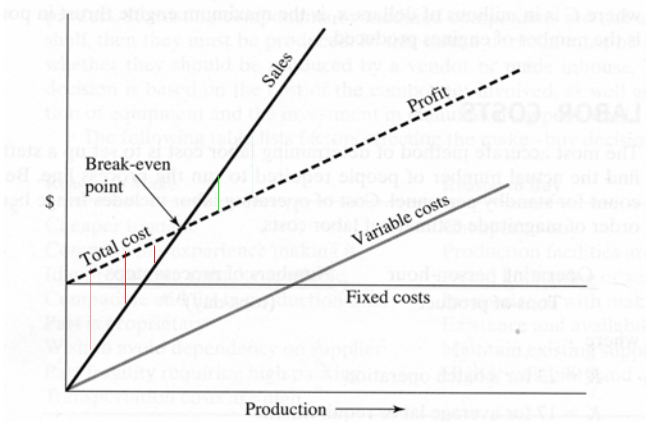


Figure 10.1 Break-even chart.

Introduction to the Concept of Engineering Economics

- Present and future worth
  - Interest/discount rate, compounding
- Series payment
  - Sinking fund
  - Capital recovery factor
- Comparison of alternatives
  - Present worth method
  - Annual cost method

Engineering Decisions Involve Trade-offs

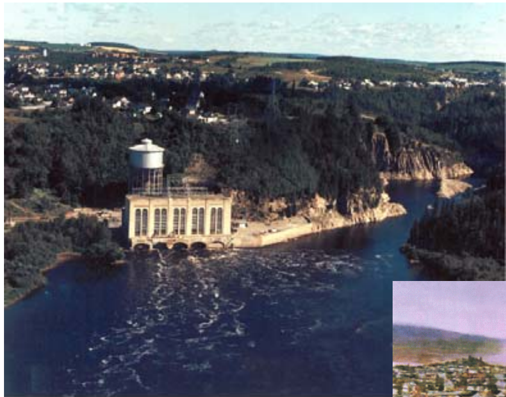
Common Factors to Consider

- Function
- Quality
- Cost/benefits (to be discussed here)
- Time
- Safety/standards/regulations
- Environmental/social impacts

Which System Should I Install? A 10kW small wind turbine or a 15kW photovoltaic system? - We need tools/knowledge to decide

Options	Cost: Capital Cost	Revenue: Electricity	Life Span	Revenue: Salvage Value
A. Wind turbine	$50,000	$2,800/year	20 years	$5,000
B. Solar system	$45,000	$2,260/year	30 years	$0

Grand Falls, NB – Pumped Hydro?



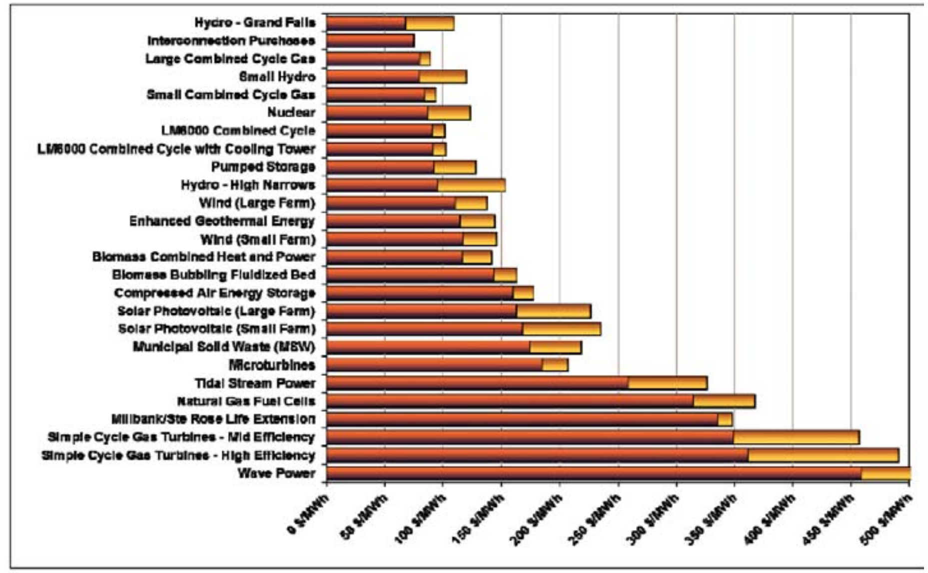
Adding 100MW to existing 66MW

Extra costs

Lost energy output

- Wind?
- Solar?
- Wave?

Levelized Cost of Electricity in NB



Questions

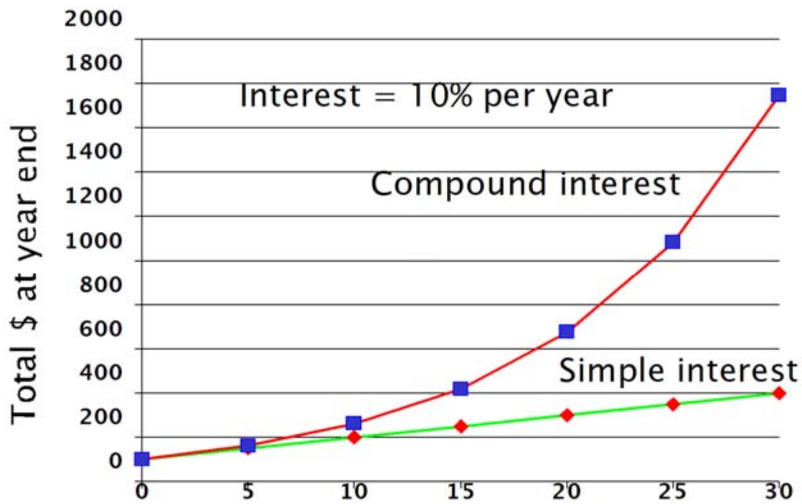
- If you have a choice of having \$100 today or \$100 a year later, what would you like to choose?
- Considerations: risks, lost opportunities, inflation, benefits etc.
- If you have a choice of having \$100 today or \$140 a year later, what would you like to choose? Need some help with the decision.
- How do you make the best decision?
- We will introduce some concepts to help with the decision

Present and Future Worth of Money

- P= amount of money today (Present Value)
- F= future amount (Future Value)
- N= number of interest periods
- i= interest rate (%) (also called the “rent”, or “discount rate”):

  $F=P+Pi$ or $F=P(1+i)$ after Year-1, ...
  - Simple interest: $F(N)=P(1+Ni)$, after Year-N
  - Compound interest: $F(N)=P(1+i)^N$, after Year-N
- “Compound interests” are very powerful

Compound Interest v.s. Simple Interest -Started with $100, 30 years later:



Future Worth -Power of Compounding

- In 1626, Willem Verhulst paid $24 to purchase Manhattan Island from the Canarsie Indians. If the Indians had invested the $24 in an investment account that earned 8% interest per annum, how much would it have been worth in 2016?
  - P = $24, i = 8%, N = 390 years
  - Simple F = $24 [1 + (0.08*390)]=$772.80
  - Compound F = $24(1 + 0.08)^390 =$260.3 trillion
- If the interest is 6%:
  - Simple F = $24 [1 + (0.06*390)]=$585.60
  - Compound F = $24(1 + 0.06)^390 =$0.178 trillion

Interest rate and time (compound periods) are important factors determining the future worth of money

Present Worth of Money

The present value of the future money by a discount rate

- $P=F(1+i)^{-N}$
- What the present sum will yield $1,000 in 5 years at an interest rate of 10% per annum?
  - $P=\$1000(1+0.1)^{-5}=\$620.9$
- Normal interest (posted interest rate): an annual rate which may compound at a different period; for example a mortgage, or a credit card
- Effective interest: equivalent annual rate
  - A credit card has a normal rate of 18% compounded monthly. What is the effective rate?
  - $i_{eff}=(1+0.18/12)^{12}-1=19.56\%$

Series Payment and Sinking Fund

- A - the amount of a regular end-of-period payment
- Total future value after N payments at interest (i)
  - $F=A+A(1+i)+A(1+i)^2+...+A(1+i)^{N-2}+A(1+i)^{N-1}$

$$F = \frac{A[(1+i)^N-1]}{i}$$

- **Sinking fund**: what regular series payments are necessary to acquire a given future amount?

$A=Fi/[(1+i)^N-1]$

- A boy is 9 years old. How much per year his parents need to put into an investment account earning 5%/year to fund his 4-year education when he is 18? (assuming $20,000/year is needed). Then:
  - $A=Fi/[(1+i)^N-1]=(4x\$20,000)x0.05/[(1+0.05)^9-1]=\$7,255$

Capital Recovery: from the Present Worth to the Series Payments

- A boy is 9 years old. How much per year his parents need to put into an investment account earning 5%/year to fund his 4-year education when he is 18? (assuming the cost of education is $14000X4=$56,000 in total now and is increasing at 6%/year)
- Need to find the future value of 4 year education; and then to find the regular payment (sinking fund)
- P=$14000x4=$56,000, N=9 (i.e. 18-9): $F=P(1+i)^N$=$56,000x$(1+0.06)^9$=$94,611;
- Then using the principle of sinking fund:
- $A=Fi/[(1+i)^N-1]$=$94,611x0.05/$[(1+0.05)^9-1]$=$8,580
- **Capital Recovery: $A=P[i(1+i)^N]/[(1+i)^N-1]$**

Comparison of Alternatives

There are several ways to compare alternative investments (or project costs)

- How to make a sound engineering decision -based on cost consideration? (We will only focus on the present worth and annual cost methods)

- Present worth
- Annual cost
- Rate of return
- Benefit-cost analysis

Present Worth Comparison

- The costs associated with each alternative capital option are all converted to a present sum of money (present worth), and the least present worth of these projects represents the best alternative
  - Identify all costs and the time of their occurrences
  - Identify discount rate (interest rate)
  - Calculate the present worth for all alternatives
  - Compare the results and select the best alternative

[The options of comparison have the same time frame]

Example: Payback Period

- The installation of a new sprinkler system in a building will save $11,000 per year in insurance. The installed cost of the new system is $42,000.
- What is the payback period (i.e. the investment is recovered from the savings)?
  - Simply payback: N=$42000/$11000=3.8 - not accurate
  - Payback at discount rate of 10%/year

Year-1 Year-2 Year-3.........

$11000 $11000/(1+0.1) $11000/$(1+0.1)^2$

Capital recovery: $A=P[i(1+i)^N]/[(1+i)^N-1]$ A=$11000, P=$42000, i=10%, N=????

===>N=5.7

Example: Present Worth Comparison

Two alternative capital investment plans to supply water (Note: these are costs). Which is more economical if money is worth: (1) 12%/year, or (2) 3%/year?

- Compare the present worth of options. The option with the lowest present worth costs less, and is the best option.

For Water Supply	Plan A Pipeline	Plan B Pumping Station
Construction cost	\$1,000,000	\$200,000
Life	40 years	40 years (structure) 20 years (equipment)
Cost of replacing equipment at the end of 20 yr	0	\$75,000
Operating costs	\$1000/yr	\$50,000/yr

12% Case

- Present worth of regular payments (capital recovery):

  $P=A\,[(1+i)^N-1]/[i(1+i)^N]$ (A=1000 or 50,000; i=12%)
- Present worth (Plan A) = $P_c+1000[(1+i)^{40}-1]/[i(1+i)^{40}]=$ \$1000000+\$1000x8.2438=\$1,008,244
- Present worth (Plan B) = $P_c+50000[(1+i)^{40}-1]/[i(1+i)^{40}]+$ $\$75000/[(1+i)^{20}]$

  =\$200000+\$50000x8.2438+\$75000x0.01075

  =\$612,996

Plan B has a lower present worth

Plan B is a better (i.e. with a lower cost) alternative

3% Case

- Present worth of regular payments:

  $P=A\,[(1+i)^N-1]/[i(1+i)^N]$ (A=1000 or 50000; i=3%)
- Present worth (Plan A) = $P_c+1000[(1+i)^{40}-1]/[i(1+i)^{40}]=$ \$1000000+\$1000x23.115=\$1,023,115
- Present worth (Plan B) = $P_c+50000[(1+i)^{40}-1]/[i(1+i)^{40}]+$ $\$75000/[(1+i)^{20}]$

  =\$200000+\$50000x23.115+\$75000x0.5537

  =\$1,397,276

Plan A has a lower present worth

Plan A is a better (i.e. with a lower cost) alternative

Annual Cost Approach

- To compare alternatives by annual cost, all cash flow are changed to a series of uniform payments
- If a lump-sum cash flow occurs at some time, it is converted to the present value (Calculate Present Worth) and then spread uniformly over the life of project (Capital Recovery)
- The least 'annual cost' option is selected
- (Useful when different time frames are involved)

Compare two alternatives

Installation of a partial or full sprinkler system in a building, at 10% discount rate (interest rate). Which option is better?
- The options have different time frames

	System Cost (now)	Insurance Premium/year	Life Span of the System
Partial System	$8,000	$1,000	15 years
Full System	$15,000	$250	20 years

- Annual cost (Partial)=$A+P[i(1+i)^N]/[(1+i)^N-1]$
  $=1000+8000[0.1(1+0.1)^{15}/[(1+0.1)^{15}-1]=2051.75$
- Annual cost (Full)=$A+P[i(1+i)^N]/[(1+i)^N-1]$
  =250+15000[0.1(1+0.1)20/[(1+0.1)20 -1]=2011.90
- They are too close, and other factors may be considered when selecting the alternatives
- Q - what happen if there is a cost of $2,000 at Year-8?
  [should convert $2K to P (N=8), and then to A (N=15 or 20)]

An Example

- You are considering two options to own a car: a regular gas-engine car for a purchase cost of $20,000; or a hybrid car for a purchase cost of $28,000. The total operating costs are $2,800/year for the regular car, and $1,400/year for the hybrid car. The resale values at the end of 10 years (i.e. the amount you will get back) are $1,500 for the regular car and $2,500 for the hybrid car. At the end of Year-5, the hybrid car needs a replacement battery pack at the cost of $1,800. Which car is more economical, at a discount rate of 10% (i.e. 0.1)?
- Present worth
- Annual cost

Options	Initial Purchase Cost	Yearly Cost	Battery Cost in 5 years	Resale Value in 10 years
A. Regular Car	$20,000	$2,800	$0	$1,500
B. Hybrid Car	$28,000	$1,400	$1,800	$2,500

Design for the Environment (DFE)

- **What is DFE?**

A framework for integrating life cycle environmental performance considerations, costs, functional performance, quality, durability, cultural, legal, and technical criteria into the design and development of products, processes, and services.

- **Traditional Design Concerns**

In typical traditional design approach, designers were to consider several technical parameters such as:

- Product performance and quality
- Manufacturing costs
- Product reliability/safety

Environmental Issues in Design

- In an environmental conscious world, professional designers face more challenges in the designing stage. Designers are required to take into consideration environmental concerns such as:
  - Resources
  - Energy efficiency
  - Recyclability
  - Hazardous or harmful environmental releases
  - Life cycle costs

Without considering environmental concerns...

- If a professional designer decides not to consider environmental issues at the designing stage, the potential risks would be:
  - Loss of natural resources
  - Decrease in biodiversity
  - Degradation of water quality
  - Degradation of air quality
  - Loss of reusable and recyclable materials
  - Climate change

  etc.

Definitions - Life Cycle

- Product Life Cycle : ‘Cradle-to-Grave’
- The stages of a product's life, beginning with raw material acquisition and continuing through processing, materials manufacturing and product fabrication, and concluding with product consumption and any of a variety of waste management options. The stages include:
  - extracting and processing raw materials & energy
  - manufacturing (product fabrication, and packaging steps)
  - transportation and distribution
  - use, re-use and maintenance
  - recycling
  - final disposal (Point Lepreau - decommissioning..)

Definitions - cont’d

- Life Cycle Assessment (LCA) :

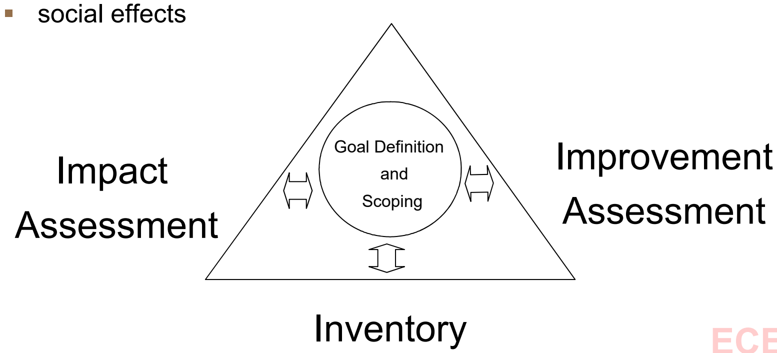
A concept and a method to evaluate the environmental effects of a product or activity holistically, by analyzing its entire life cycle.

- This includes
  - Identifying and quantifying energy and materials used
  - Identifying and quantifying wastes released to the environment
  - Assessing the environmental impact of wastes released
  - Evaluating opportunities for improvement.

The life cycle assessment consists of four complementary components -initiation, inventory, impact, and improvement.

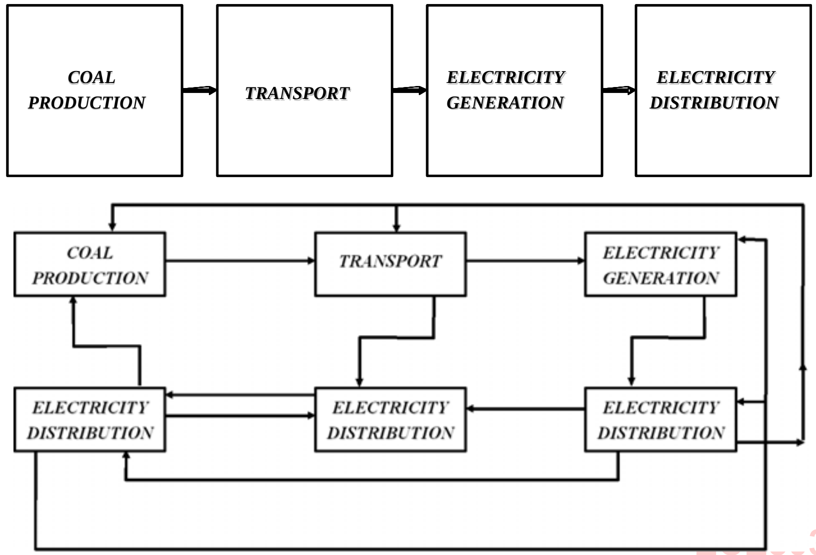
What Does LCA Address?

- Environmental impacts of the system under study in areas of
  - ecological health
  - human health
  - resource depletion
- Does not address
  - economic considerations, or
  - social effects

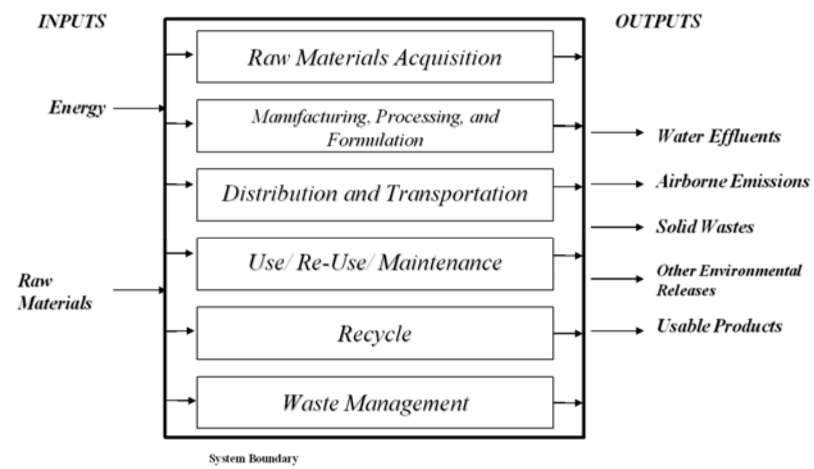


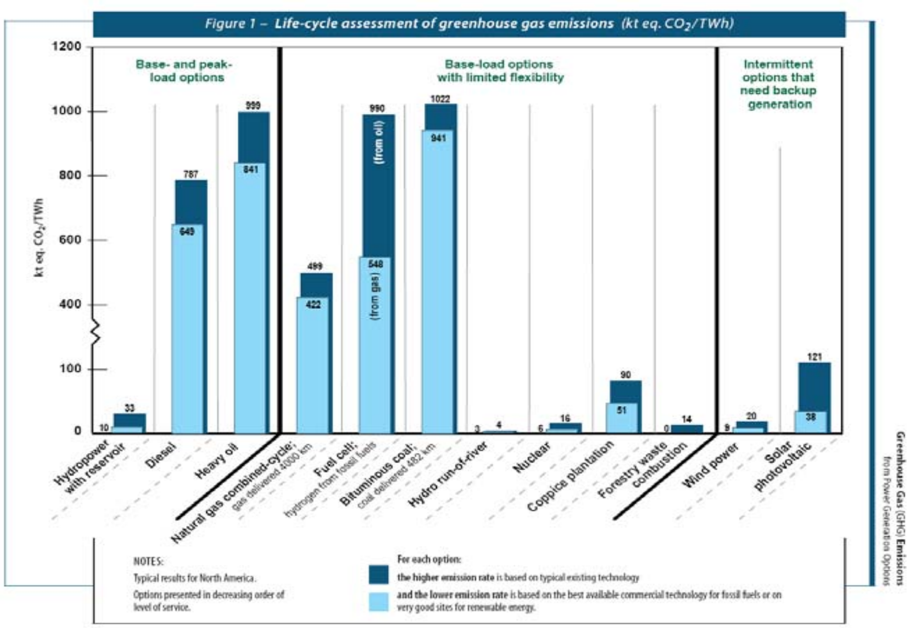
Life Cycle Inventory - 2nd Step of LCA

- GHG from electricity production from coal – 1st Step



Life Cycle Inventory - Process





A 950MW CHP Power Plant

– 32 Employees