New Visions to Polygeneration System In Total Site Context Assisted by Solar Energy

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1. Introduction

- **Key issues of the work are:**

- How Combination of aspects of *Process Integration, Total Site and Polygeneration* can work.

  Can these Tools & Analyses Collaborate?

- How fossil fuel and Renewable energy can be adapted

  Is it possible Reconciliation & Tradeoff?

If We Put All these together

Optimum Global Result is Acheivable

2. Process Integration

- Process integration has been commonly used as an effective tool for resource conservation and waste reduction.

- Prof. El-Halwagi (2006) defines process integration as a *holistic approach* to process design, retrofitting and operation which emphasis the unity of the process.

- *Heat integration* as part of Process integration is a systematic methodology that provides a global understanding of heat utilization within the process and employs this understanding in identifying the utility targets and optimizing heat recovery as well as energy-utility systems.

Process Integration and Cogeneration within an overall Energy Efficiency Strategy

Level 1: Good housekeeping(Primary actions like Steam losses reduction,…)

Level 2: Heat Recovery/Process Integration Actions

Level 3: Add Extra Units & Cycles (Heat Pump,…)

Level 4: Cogeneration/ Polygeneration(discuss later)

Payback Time (Investment / energy saving)

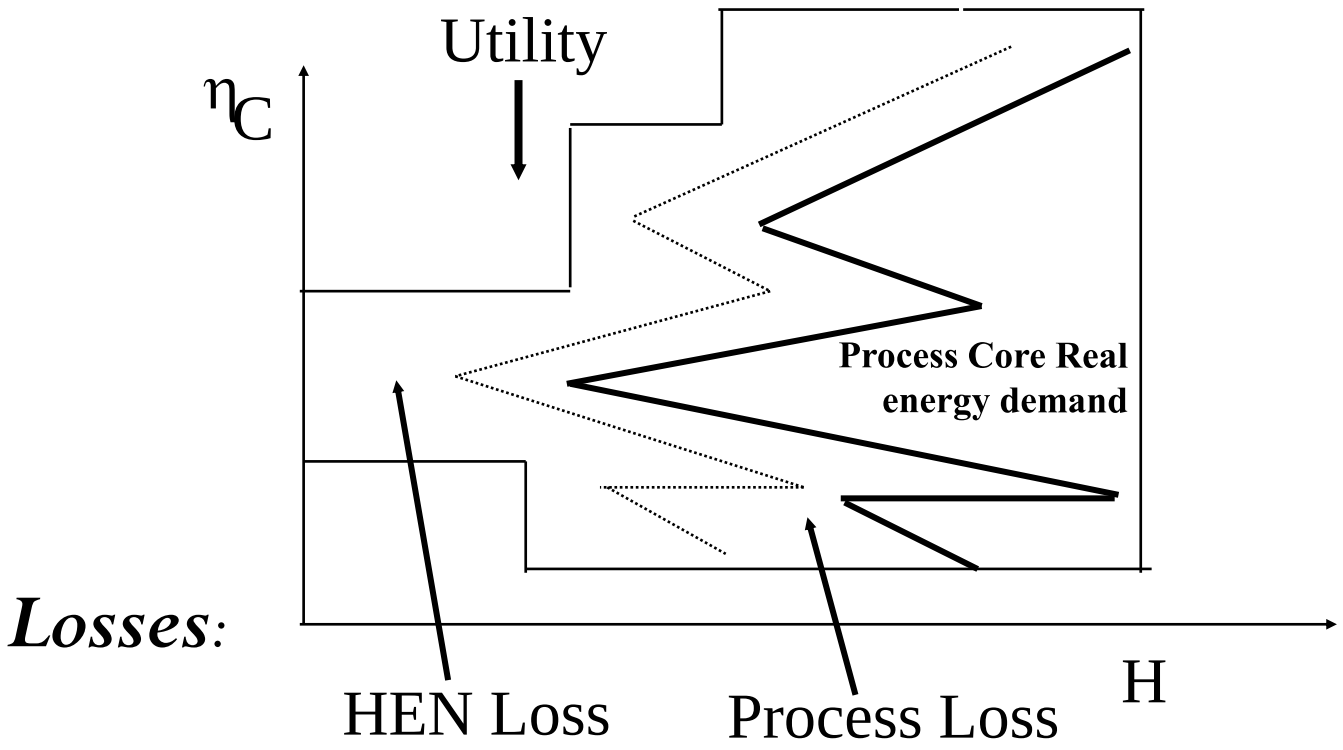
Increase top to Down (Two weeks to five years)

Process integration help us to show

- Where are the Losses?
- How can we make saving?

Real Energy Demand?

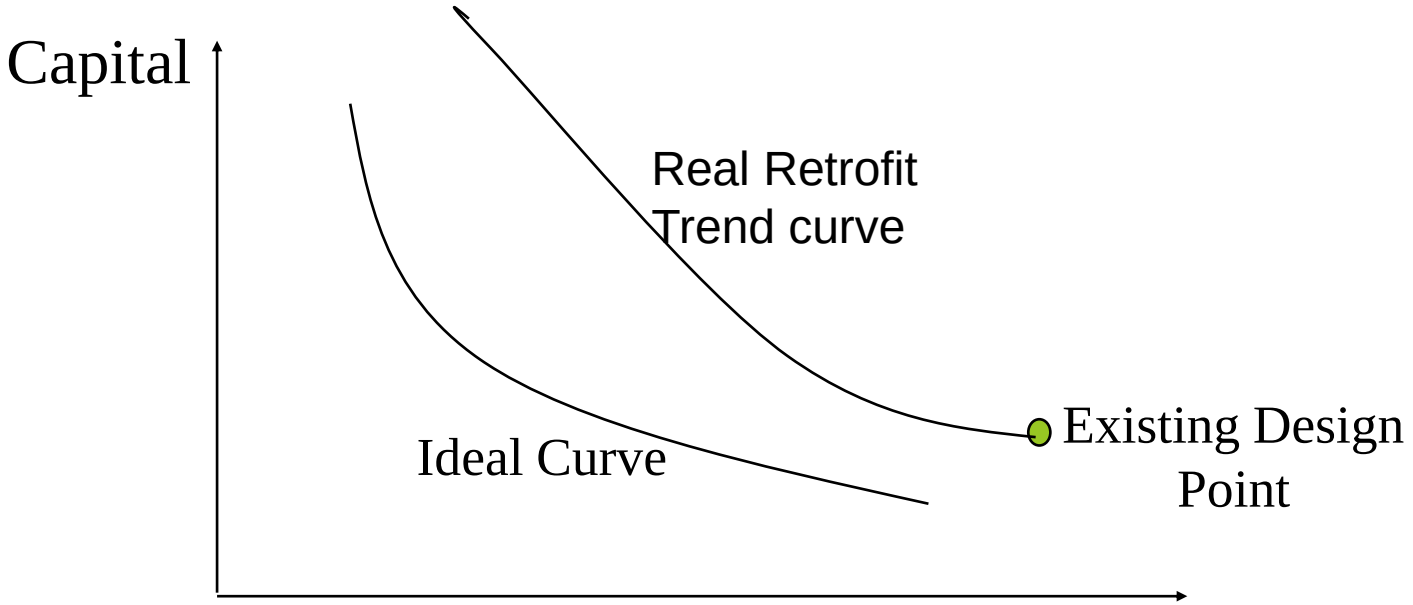
Process Integration give us good insight of Energy Losses in process



We just need small part of energy, Supplied by Utilities

Process Integration
Retrofit Trend

How can we make saving by a systematic method?



Spend Money(Capital) to Save Energy

Process integration can do it systematically

3. Total site Concept

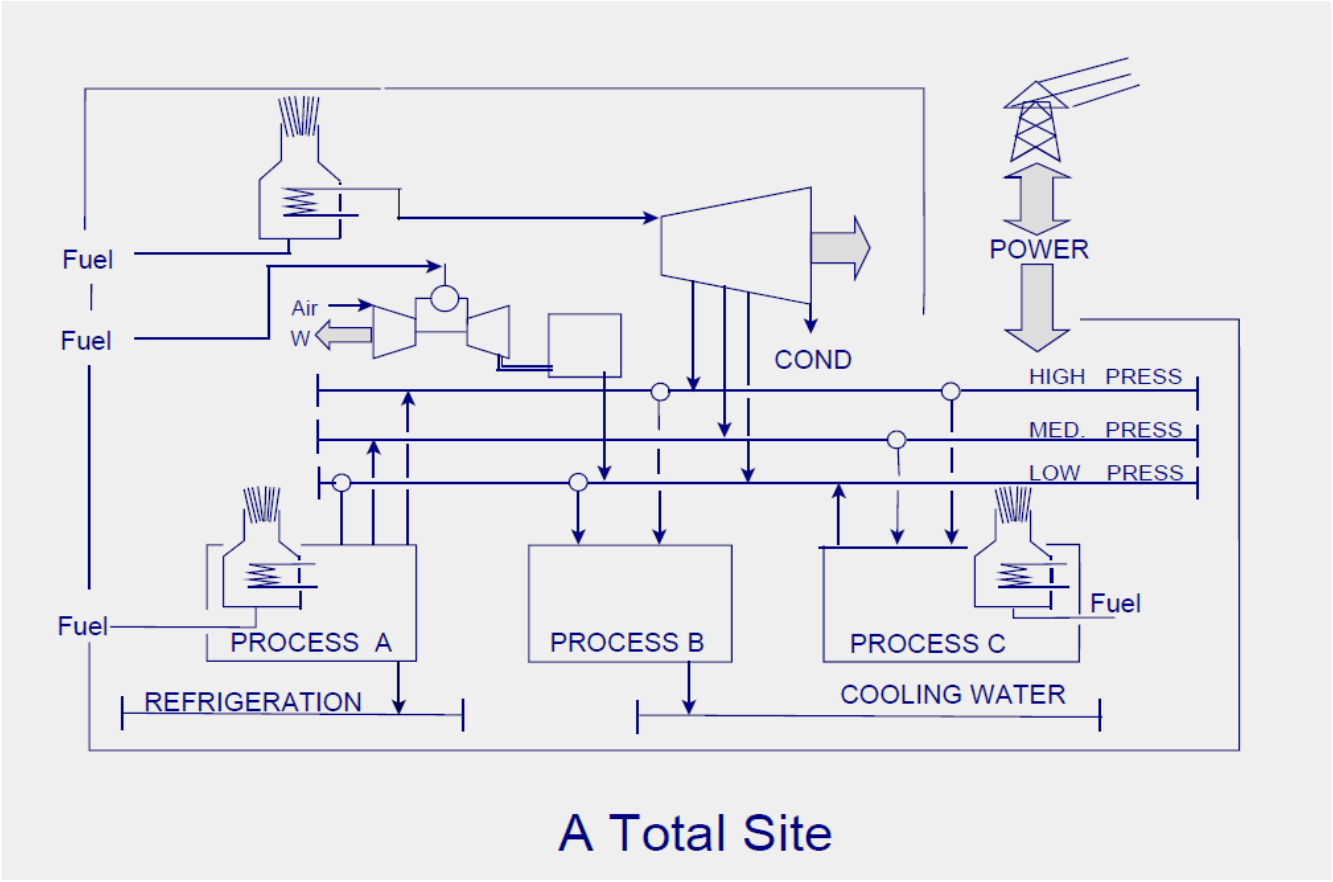
Total Site Energy Management is a focused on solving the site-wide issues of processes and is designed to deal with the problem of how best to supply the Heat and Power needs of an entire plant site.

This approach helps engineers in optimizing the cost and in reducing emissions via better usage of the invested infrastructure.

New looks

Let’s consider Following Items as Opportunities in the Total Site:

Energy level, Energy paths, Fuels, Utility Hardware, Processes, National Grid

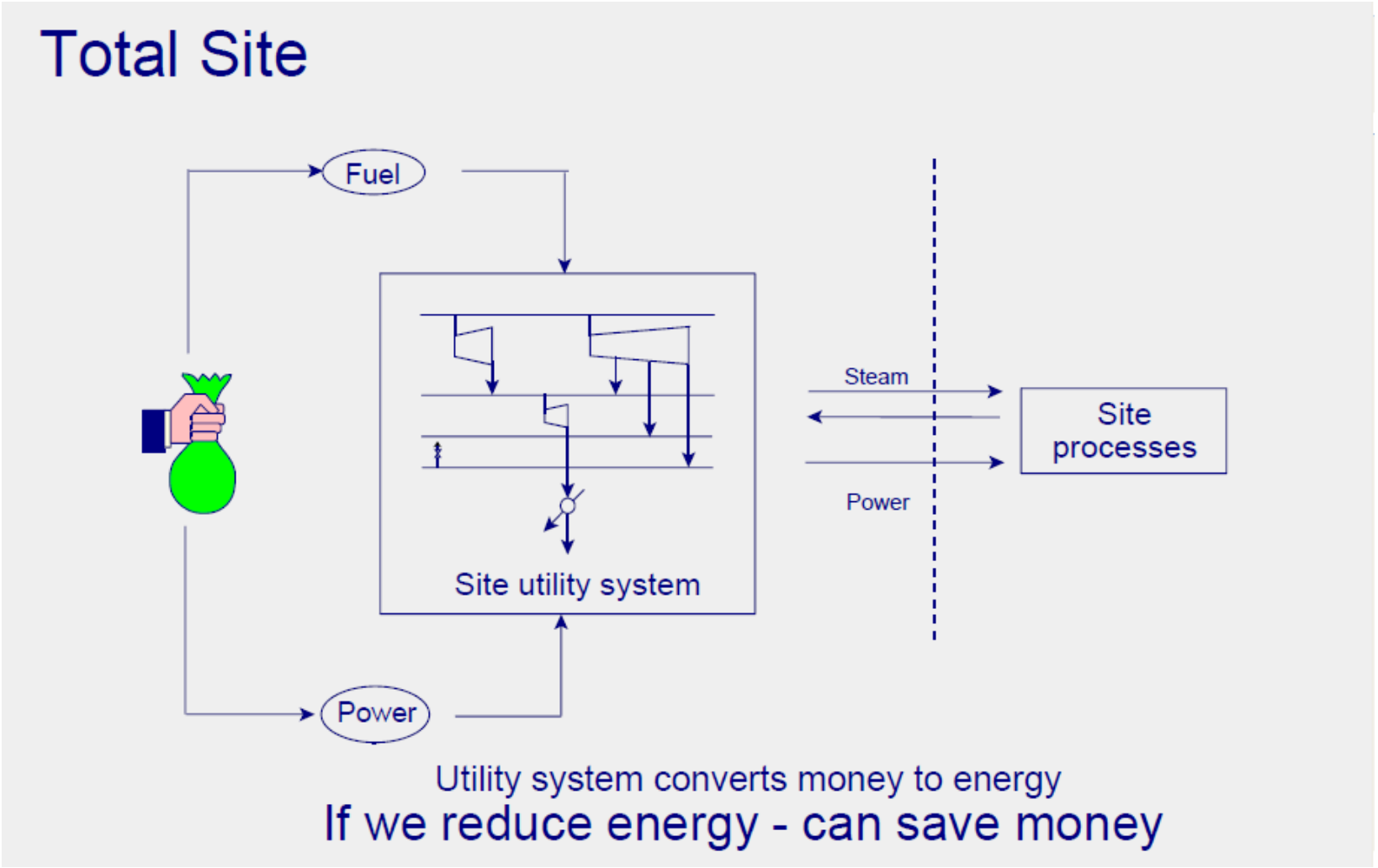


A Total Site

Professor Robin Smith(2)

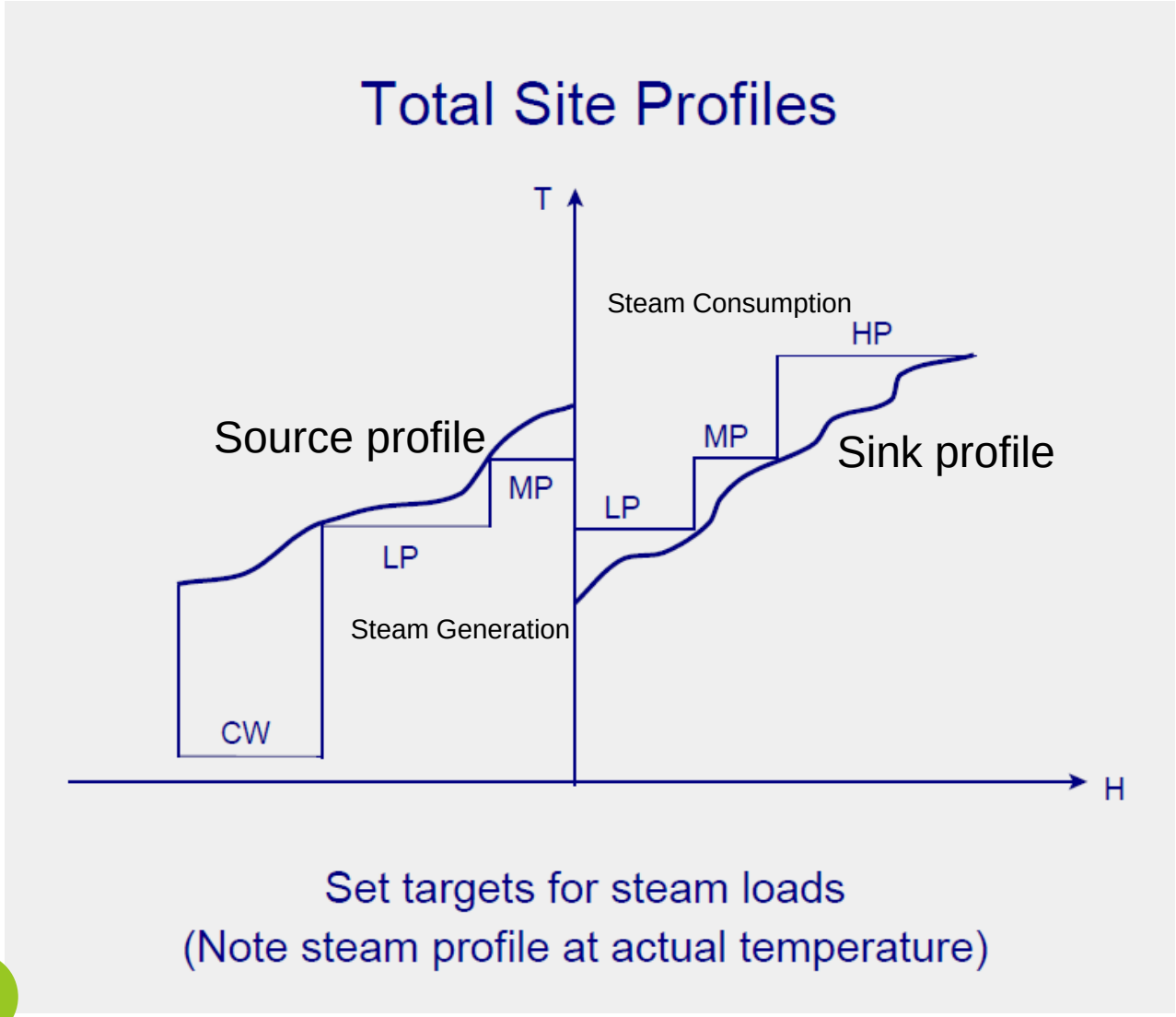
Interaction Between Utility System and Processes

These days, No Process Design without considering Utility Demand



Sink & Source Profiles

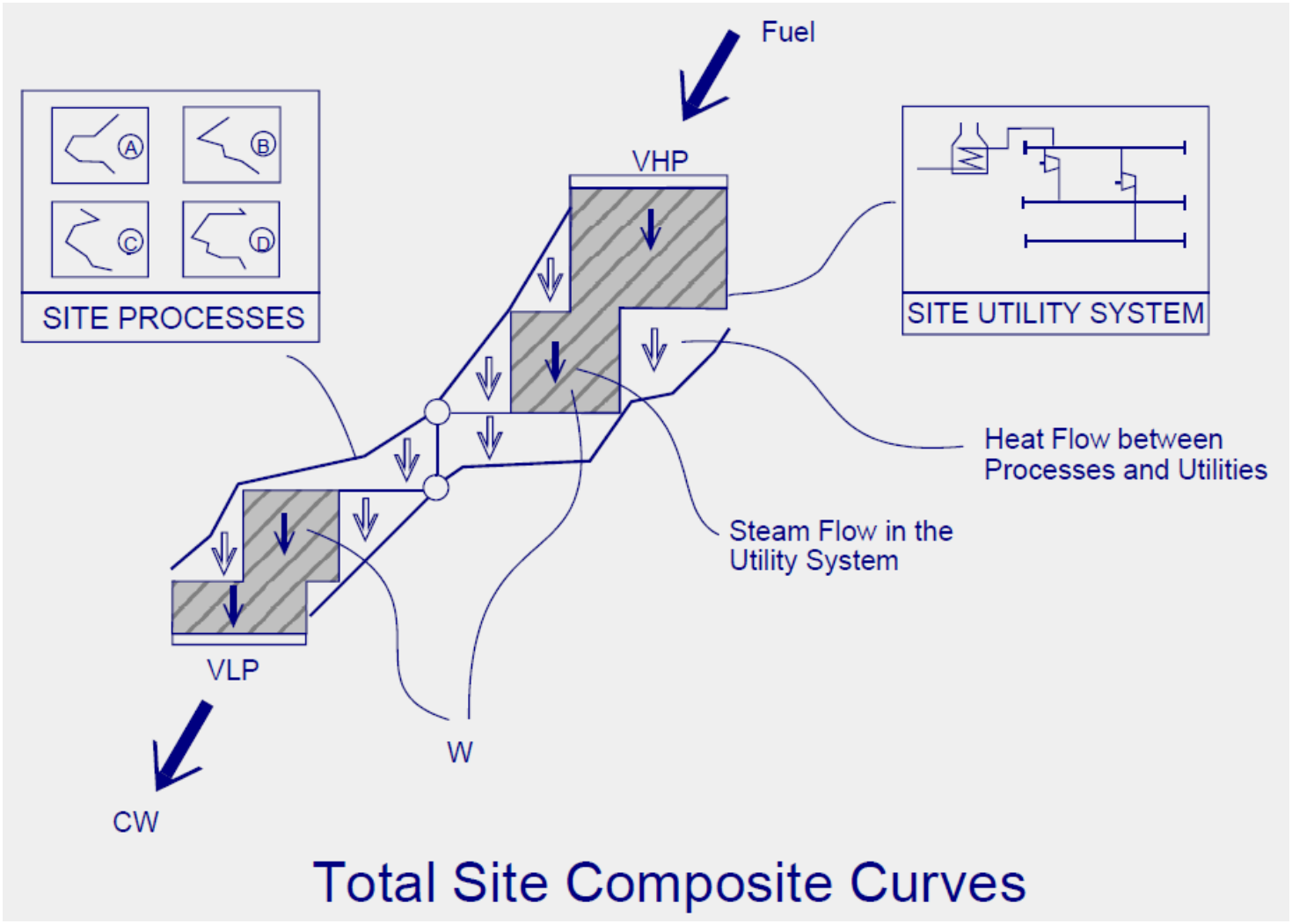
Placement of Utilities



Targeting *Heat & power*

Heat Flow Cascade & Power Generation*(shaded Area)*

Top to Bottom



4. Polygeneration

- Cogeneration and polygeneration are the efficient method of saving energy in which electricity, heating, cooling and water are produced simultaneously.
- The heat generated from cogeneration can be used for district heating or in process industries.
- The simultaneous production process can be based on the use of *gas turbines (GTs), steam turbines, or combustion engines*,
- and the primary energy source includes a wide range of fossil fuels, biomass, geothermal energy, or ***solar energy***.

New Aspects in Cogeneration
Again More Opportunities

- Which Energy Paths in system?

Good news, there are Thousand Ways

Let's Examine those

- Which Hardware can be used?

Good news, there are many Hardware Types & Sequences

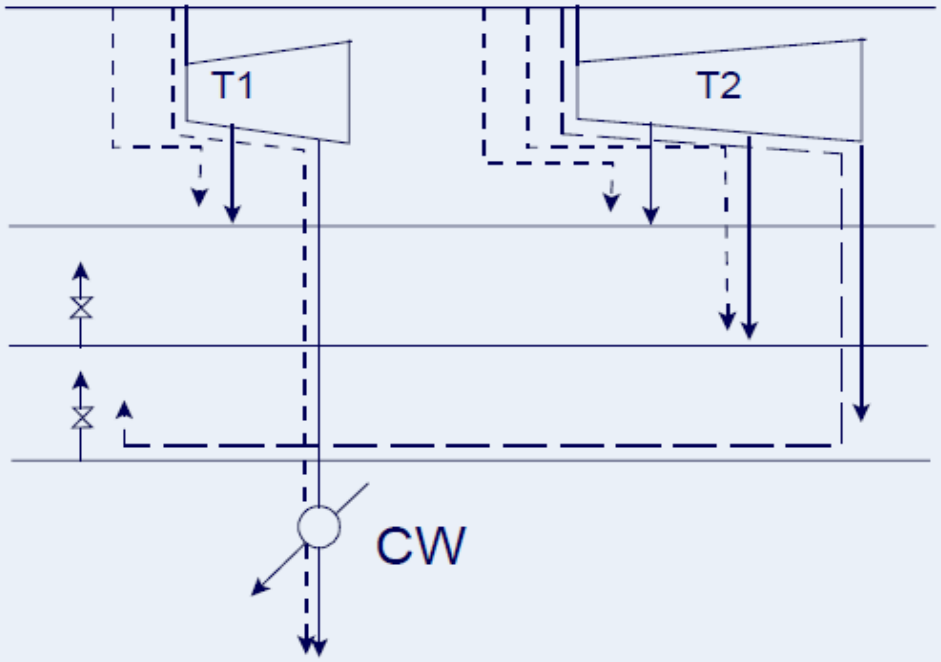
Let's choice the best Configurations

The Best energy Paths & The Best Configurations

Optimum Results

Which energy path you like to choice it is up to you!
Don’t worry, there is Systematic Approaches

There are many steam paths through the system



- Which path (turbine flows) do we modify first?
- What is the order for the modifications?
- Is there a systematic method of achieving this?

Assign an Equation to any Hardware like Turbine as one of the Hardware in Utility System

Modelling Equations - Size and Load

In each modelling interval:

Modelling equation

$$W = n_{gt} \cdot m_f - W_{gt,int}$$

Rule of thumb

$$W_{gt,int} = L_{gt} \cdot W_{gt,max}$$

For the maximum power the following will be valid:

$$W_{gt,max} \cdot (L_{gt} + 1) = n_{gt} \cdot m_{f,max} \qquad m_{f,max} \cdot NHV = A_{gt} + B_{gt} \cdot W_{gt,max}$$

$$W_{gt,max} = \frac{1}{B_{gt}} \cdot [m_{f,max} \cdot NHV - A_{gt}]$$

$$n_{gt} = \frac{L_{gt} + 1}{B_{gt}} \cdot \left[NHV - \frac{A_{gt}}{m_{f,max}} \right] \qquad W_{gt,int} = \frac{L_{gt}}{B_{gt}} \cdot [m_{f,max} \cdot NHV - A_{gt}]$$

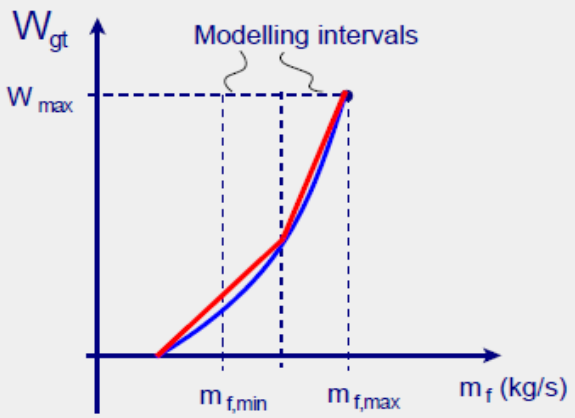
Each hardware has correlation

Turbine Network Means

bundle of equations for Analysis system

Power-Fuel Operating Curve for Gas Turbines

The efficiency with current load can be interpreted as power versus fuel flow relationship



- Similar trends to steam turbines
- Reflects the change of **η** with load
- The relationship is non-linear
- It can be approximated by linear segments

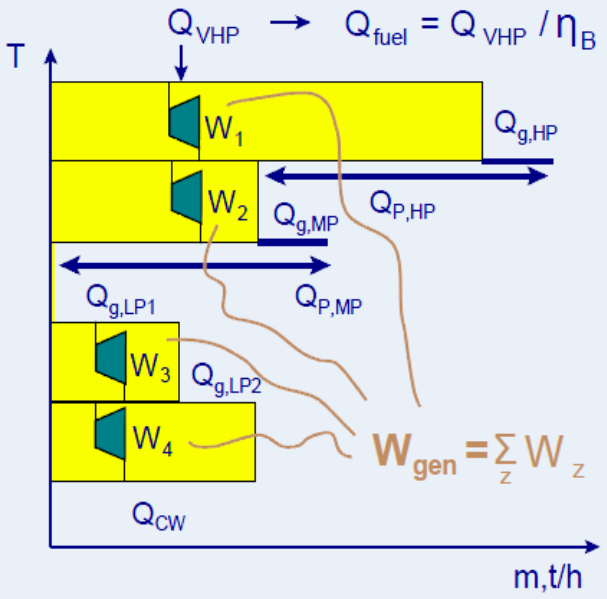
Cogeneration New Tool

R curve Method

Cogeneration Efficiency & R ratio are

Two terms for Evaluation of Different Configurations

Cogeneration efficiency and R-ratio (continued)



$$Q_{usg} = \sum_{mains} Q_{p,main} \qquad Q_{supply} = Q_{fuel} + \sum_{mains} Q_{g,main}$$

Efficiency of cogeneration by the utility system

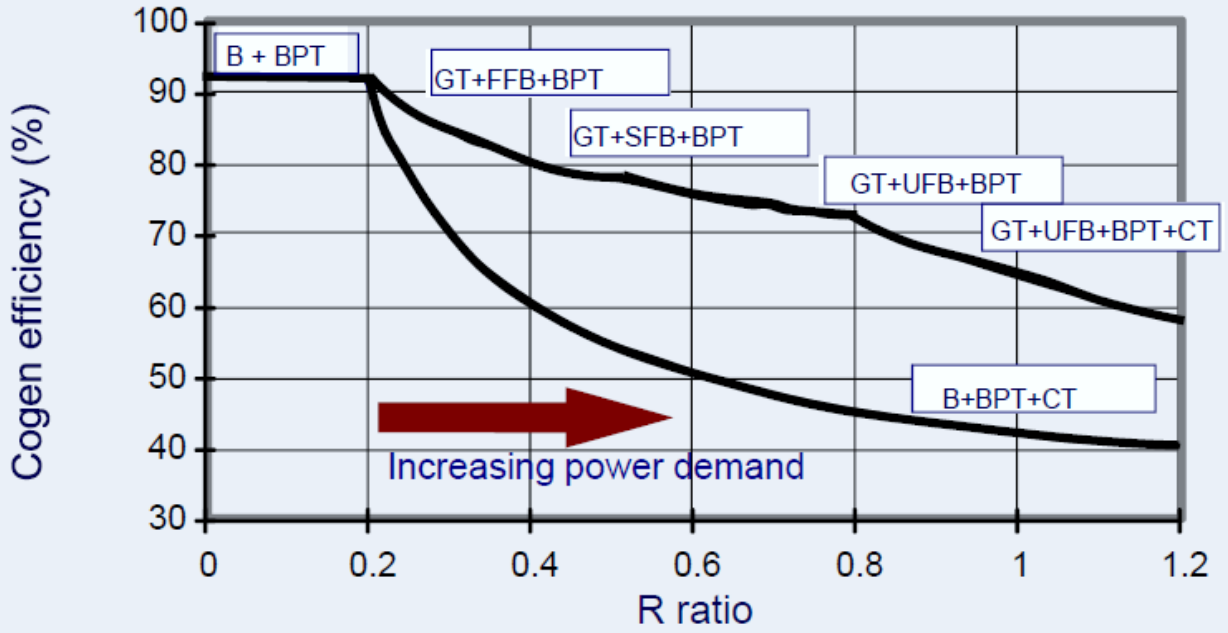
$$\eta_{cogen} = \frac{W_{gen} + Q_{usg}}{Q_{supply}}$$

Power-to-heat ratio for the process demands

$$R = \frac{W_{proc}}{Q_{usg}}$$

Note:
Q_g may not be supplied entirely from fuel in the processes. It may be supplied from other process sources such as an exothermic reaction.

Let's Plot Cogeneration Efficiency Against R ratio Then Evaluate Different Configurations



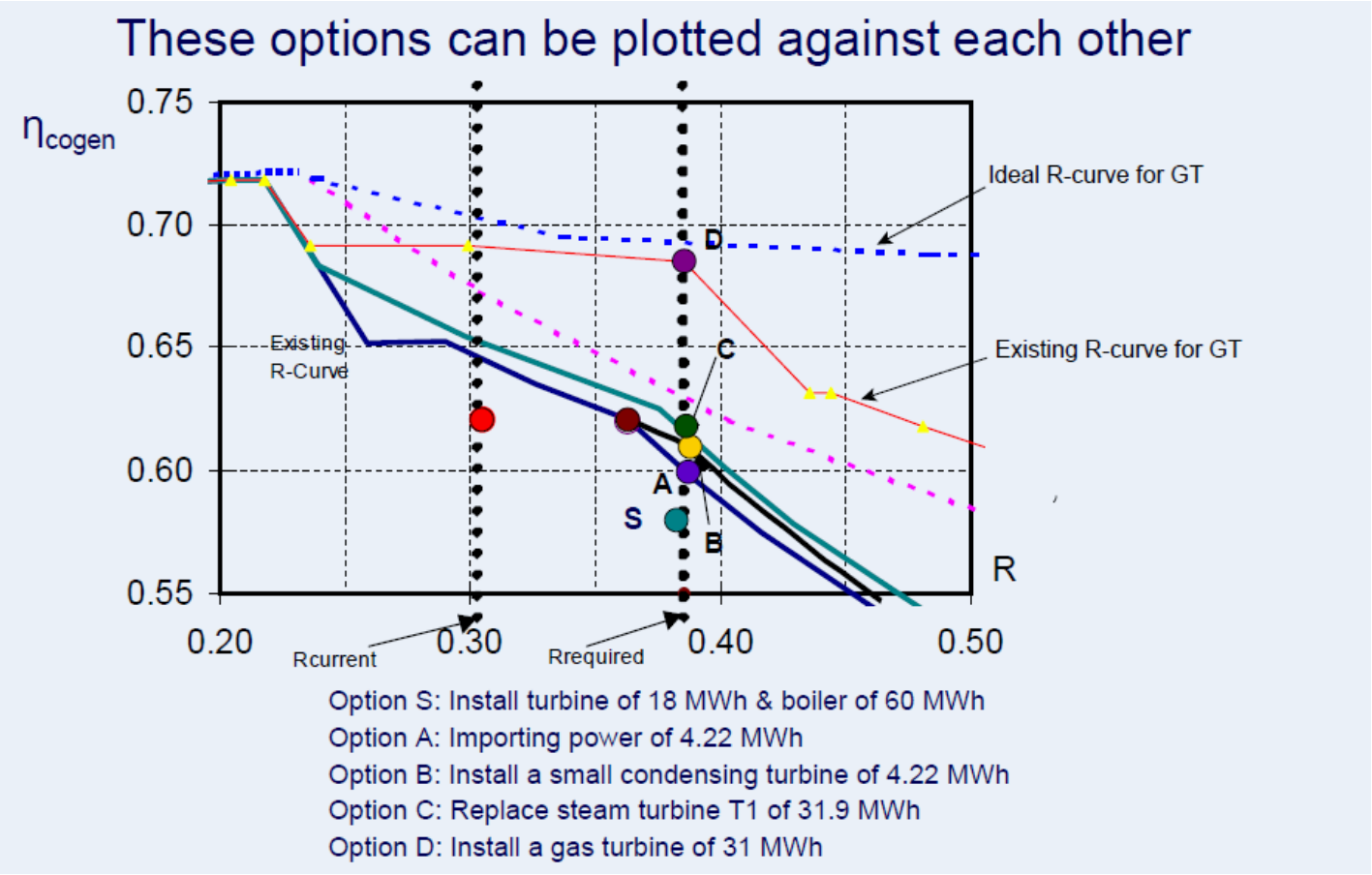
(Kenney,W.F. (1984), Energy Conservation in the Process Industries, Academic Press)

What we are expecting from R-curve

Extend and improve R-curve to :

- find out how to improve the operation of an existing system
- determine options for power import or export
- indicate good directions for energy retrofit
- identify promising options for debottlenecking

Many Options can be developed for a given Example
Different route for each Utility set up

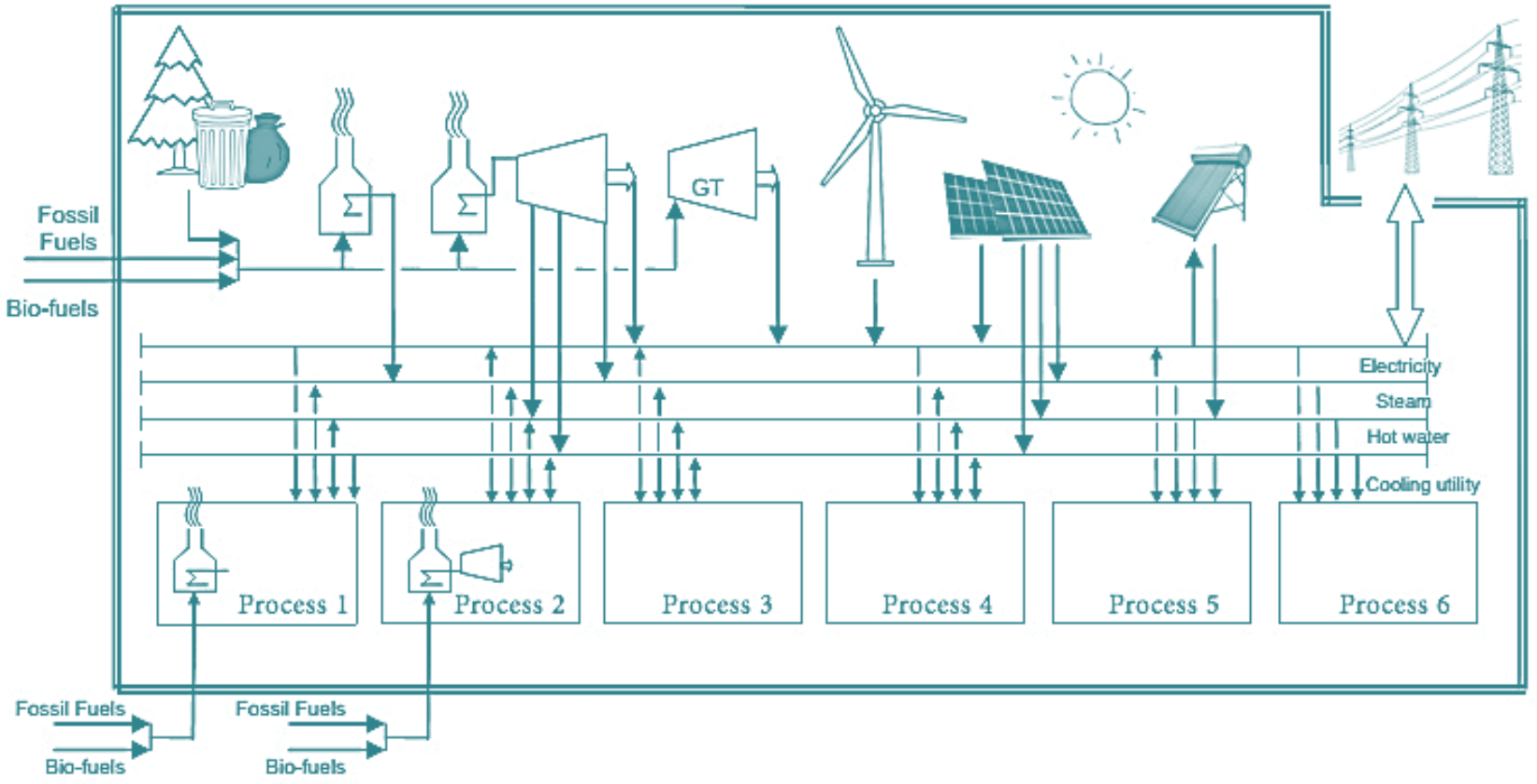


5. Assisted Solar System

- Like conventioal CHP, solar cogeneration is ideal for facilities that use significant amounts of hot water on a daily basis. Traditional CHP systems heat water with waste heat created from natural gas turbines during electricity production. Solar cogeneration works in a similar fashion but without using non-renewable resources.
- Solar cogeneration's advantages over traditional cogeneration are reduced greenhouse gas emissions and stable energy prices.

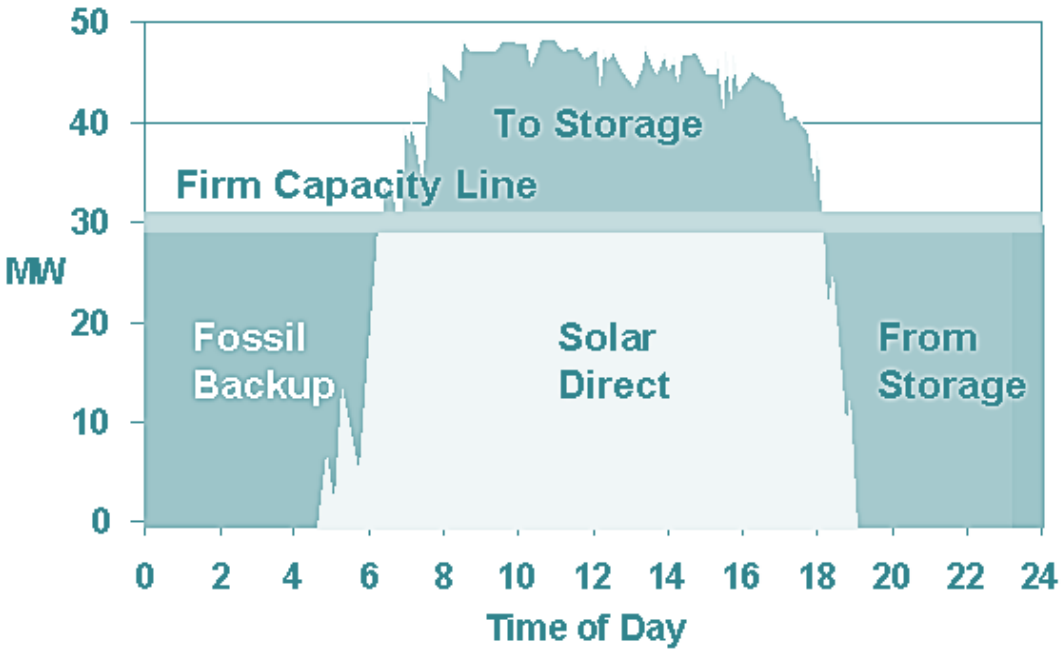
Introducing Renewable Energies to Total Site & Polygeneration system

New Vision on Total Site (New Resources)

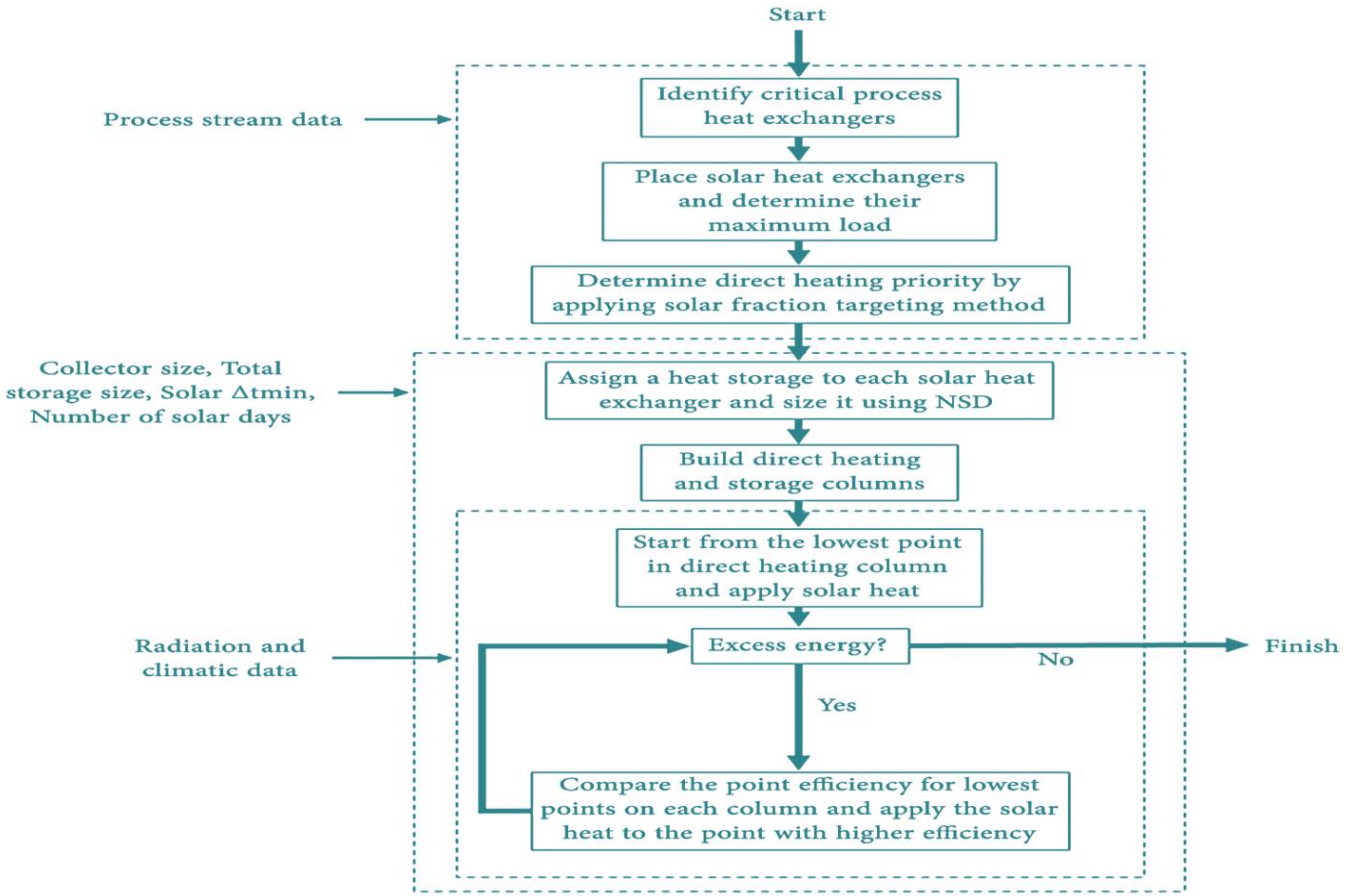


Solar Assisted system
Well known Available in the literature

- Adaption of Fossil fuel and Solar

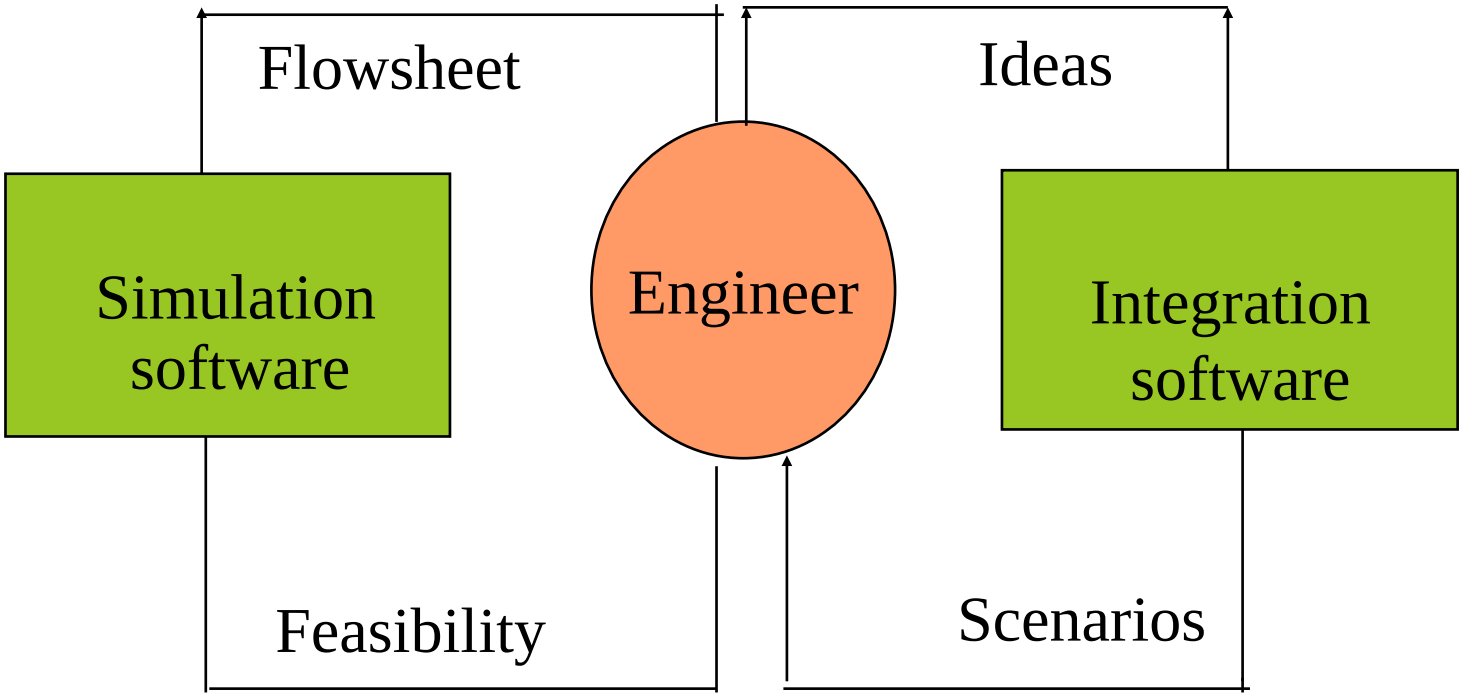


Where and How we can supply Solar Energy in our System

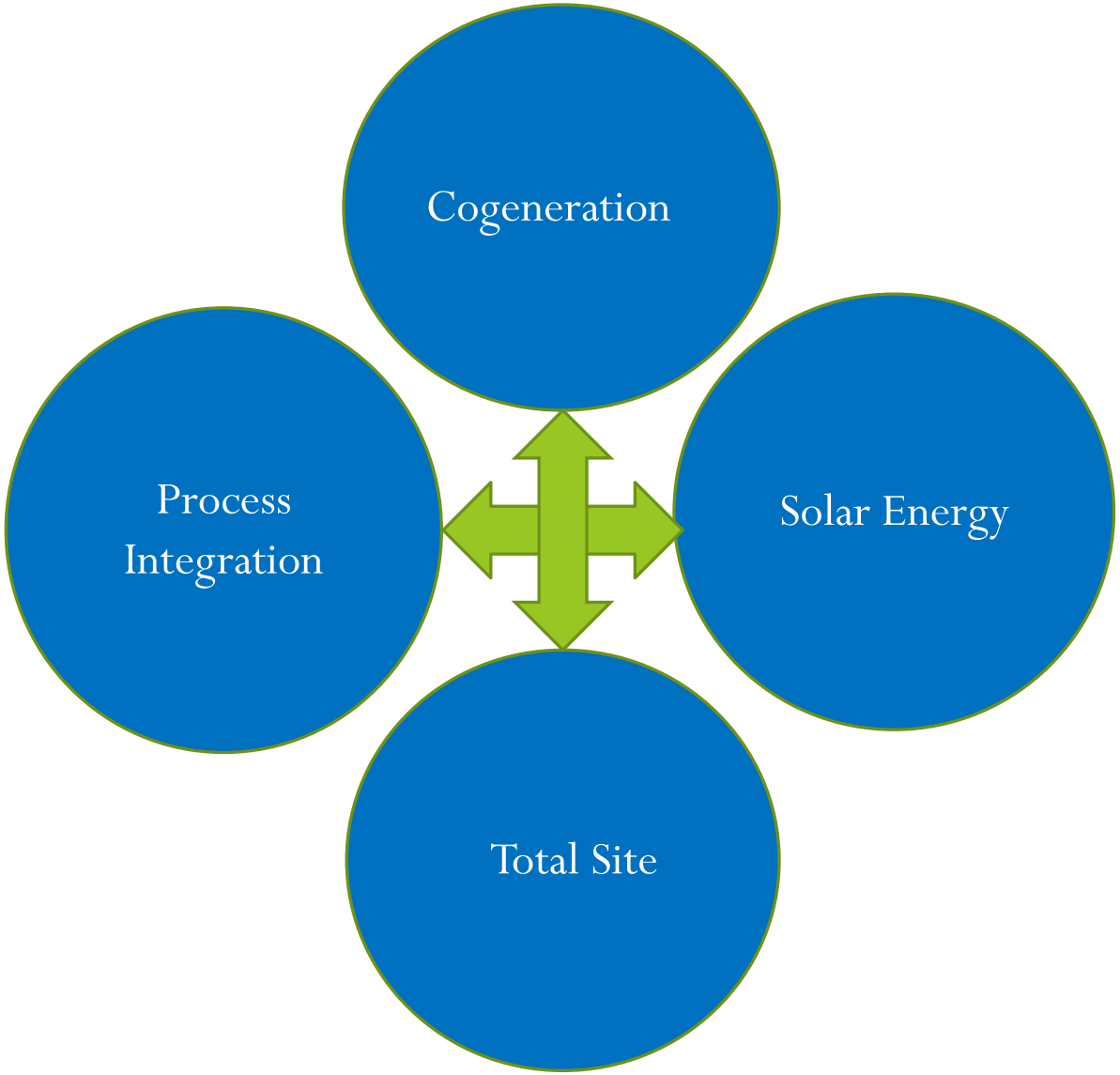


Here is one of the Algorithm

If you apply All aspects introduced here
By
Simulations & Integrations
Softwares
Final Optimal Design



Great Collaboration between components

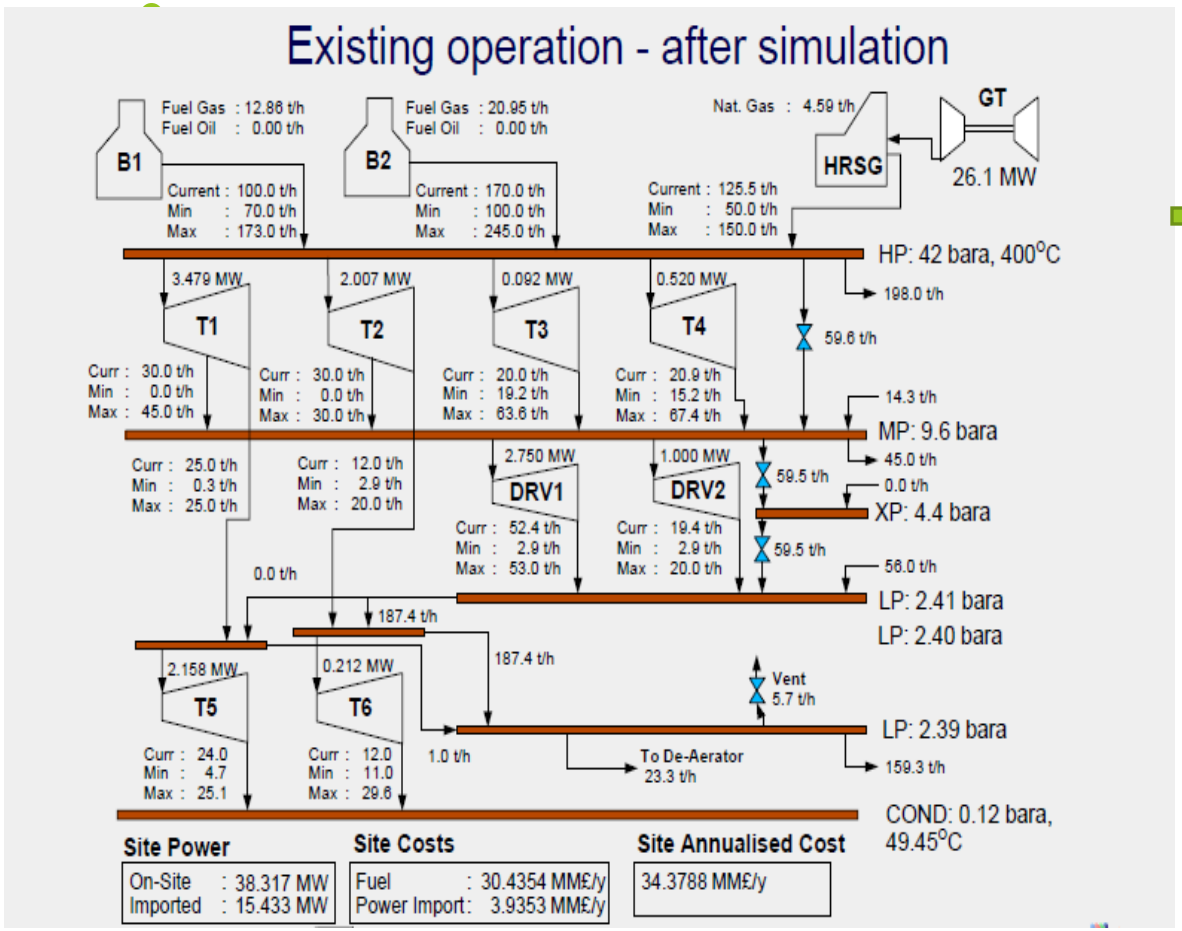


Finally, a Case Study (Professor Robin Smith(2))

(4 processes & 12 utility hardware, 8 Steam Level)

34.38 M£/yr Site Utility cost

Utilities System



Processes

A

B

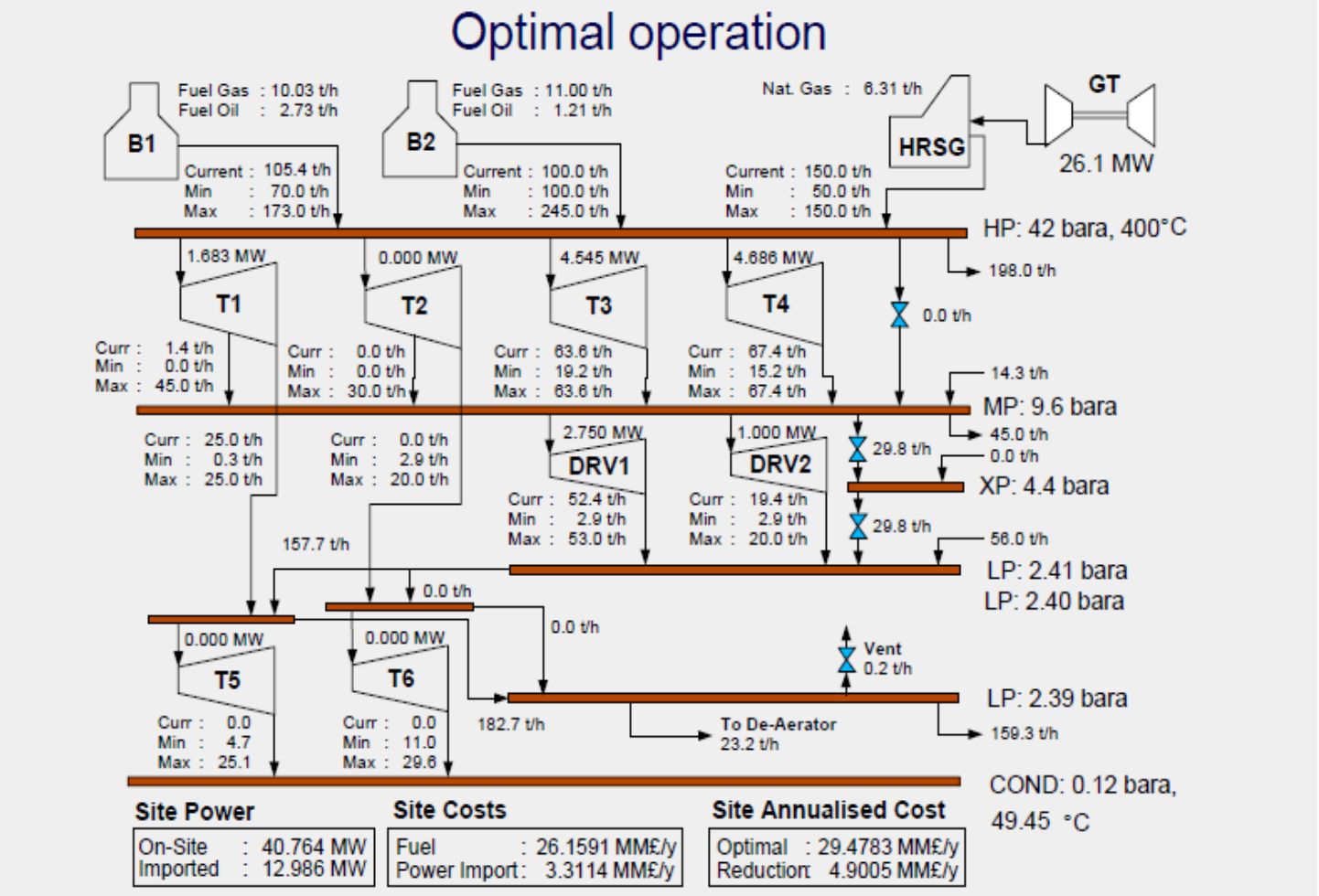
C

D

About Ten Millions Dollars Saving

All concepts applied

29.48 M£/yr Better Site Utility Cost



6.conclusion

- Here, Process Integration and Total Site concepts have been improved Polygeneration system outputs.
- Methodology has taken advantages of renewable energy to make new design more efficient.
- Each of above aspects had their own benefits
- Introducing Renewable energy to Traditional system to make cleaner Technologies
- Better understanding of process(compare to pure mathematical methods)
- More reliable and Flexible system in term of control and safety

(Less demand from National Grid, Simplify operation)

- Finally, Approach Can save **millions of dollars**

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Thank You for your attention

Questions & Comments?