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BEST PRACTICES IN THE FIELD OF MANUFACTURING ENVIRONMENT, HR, IMAGE BUILDING & BRANDING BY PULP & PAPER INDUSTRY

Energy Analysis of Multiple Effect Evaporator in an Indian Pulp & Paper Industry

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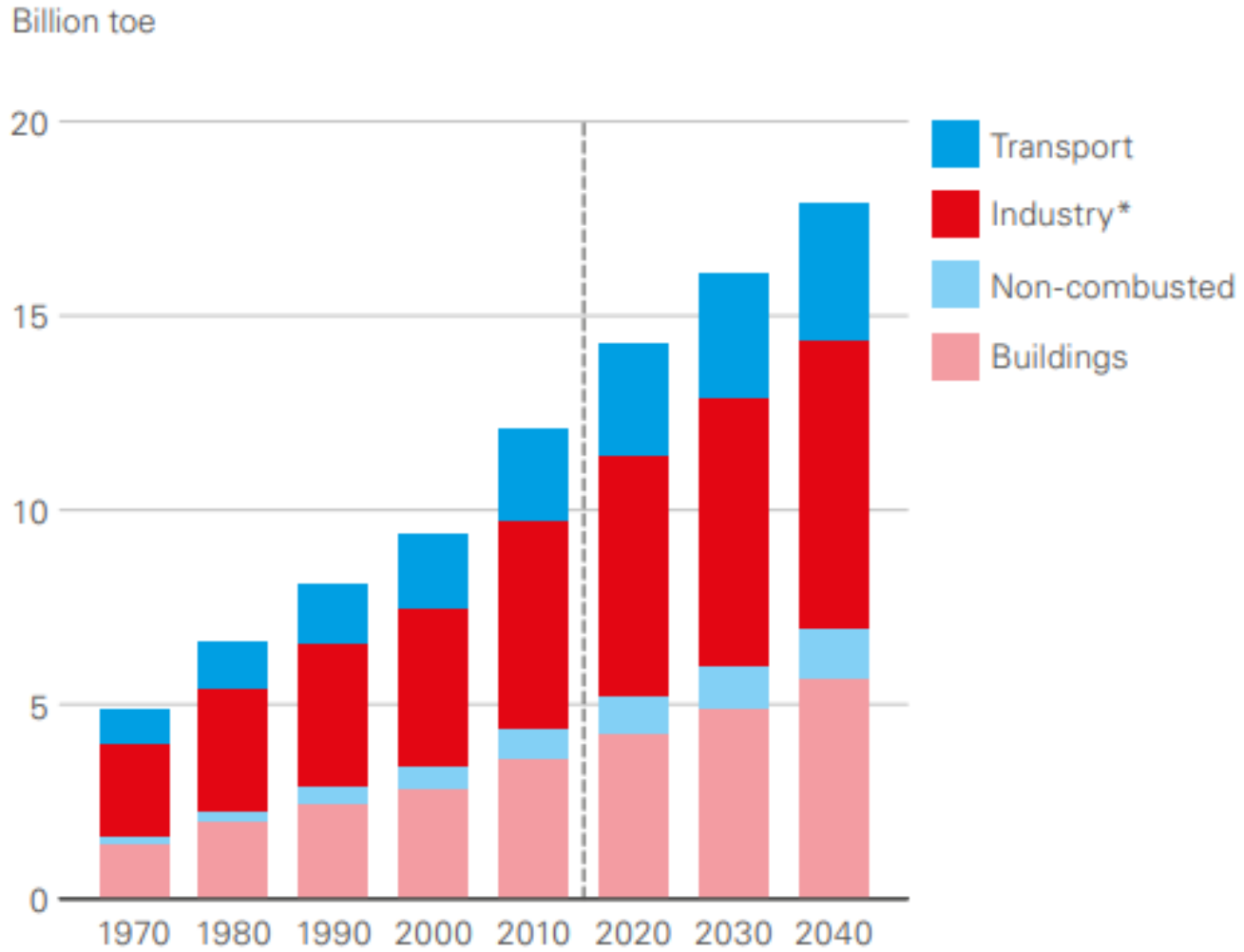
Presented By
Dr. Om Prakash Verma, Dr B R Ambedkar National Institute of Technology, Jalandhar
Dr. Surendra Pratap Singh, Pulp & Paper Research Institute, Rayagada

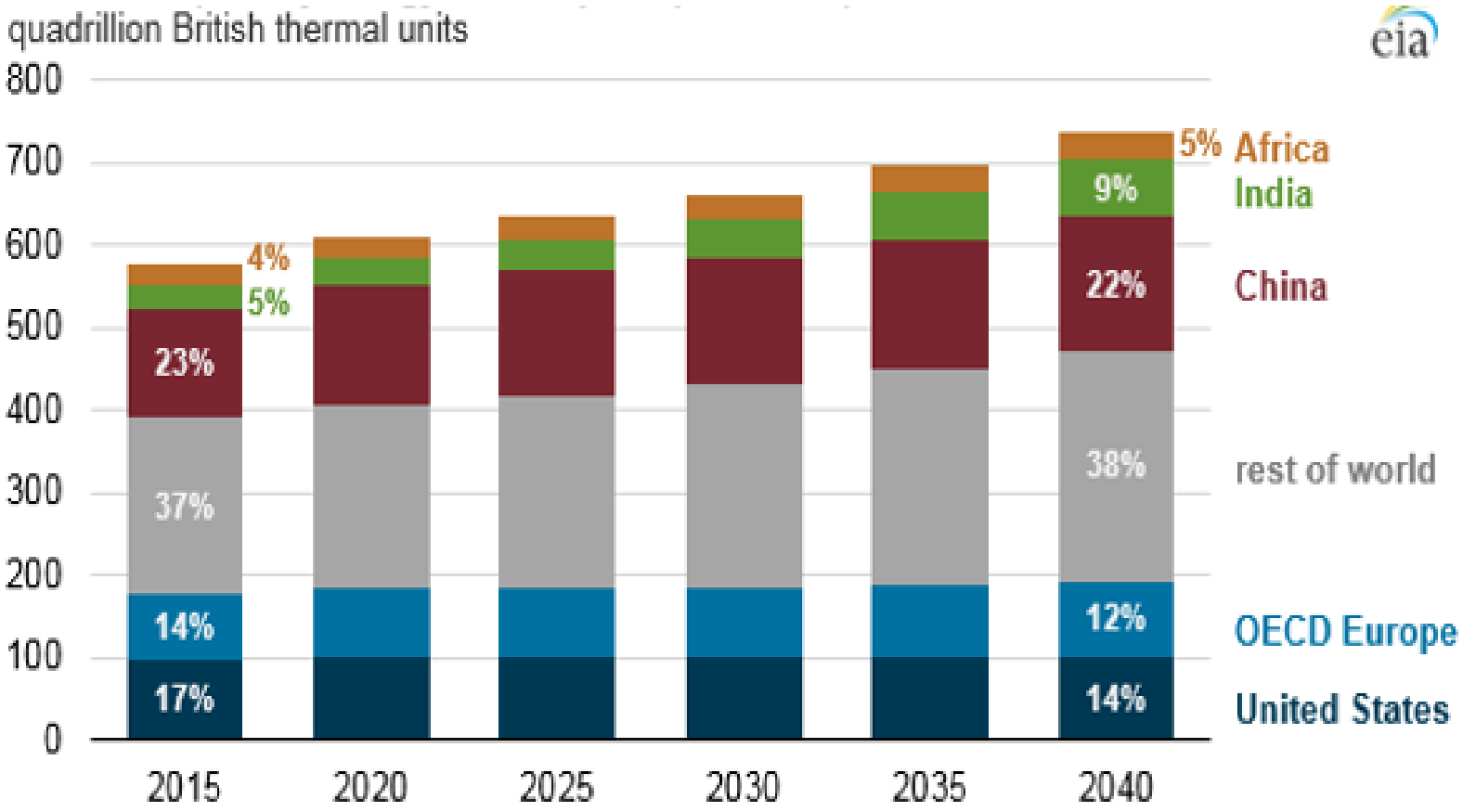
OUTLINE

Primary energy consumption



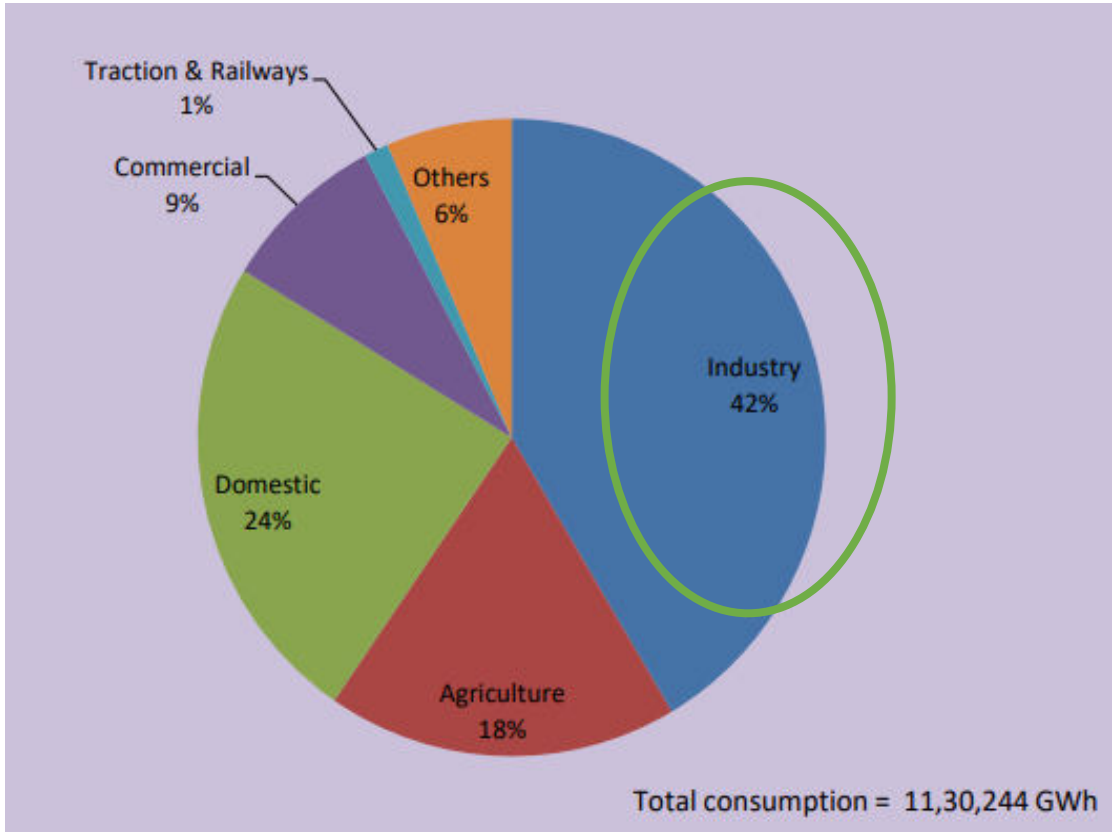
Source: Primary energy consumption by end-use sector. *Image via BP Energy Outlook 2019.*

World Total Primary Energy Consumption (2015-2040)



Source: U.S. Energy Information Administration, *International Energy Outlook 2018*

Sector wise energy consumption India



Source: Consumption of electricity by sector in India during 2017-2018 (Energy statistics 2019) by http://www.mospi.gov.in

Typical site issues in Indian Industries

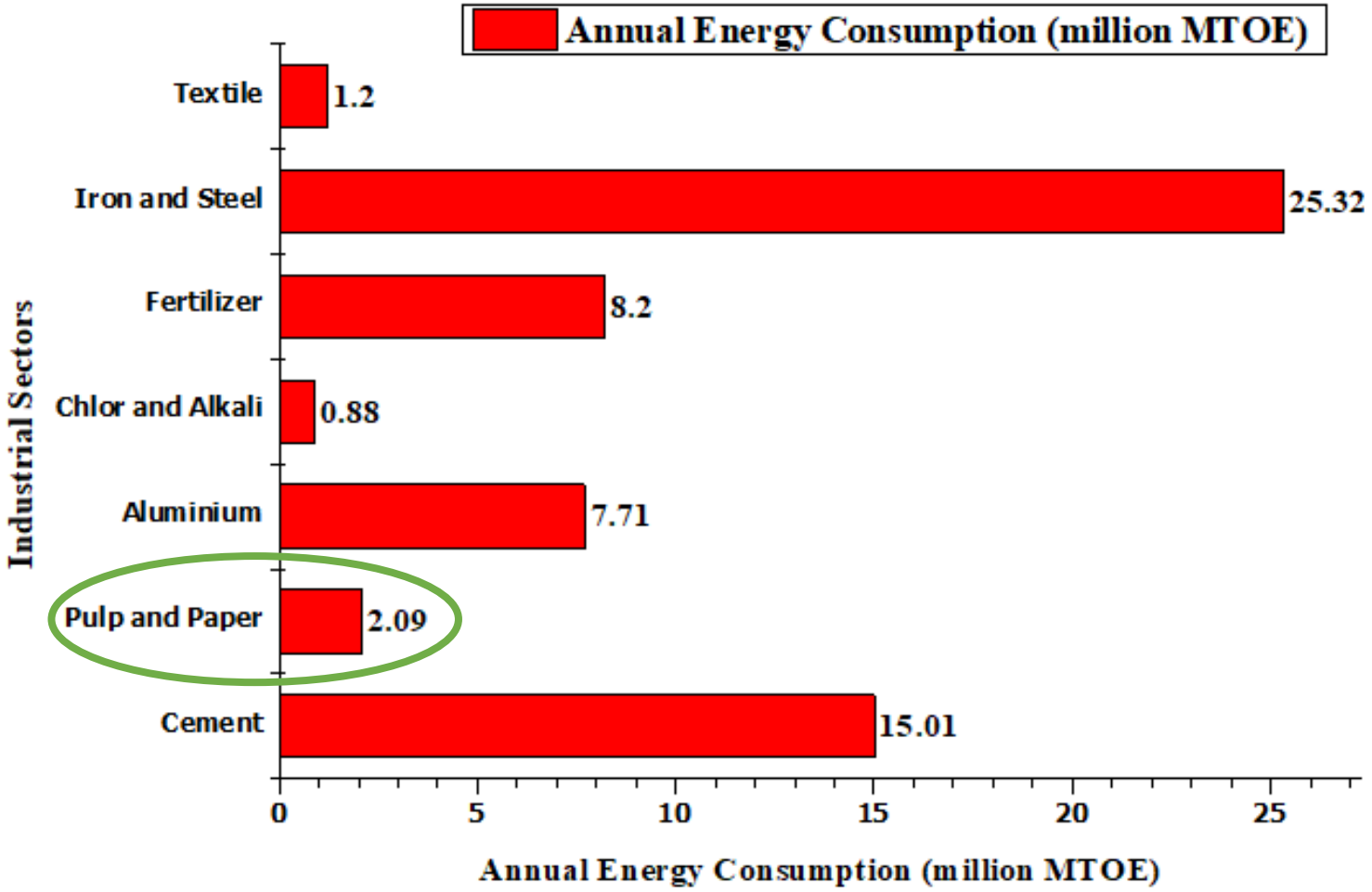
- Save water
- Reduce waste
- Meet new production specification

Sustainable development by process integration

- Reduce environment impact
- Optimized production plant
- Improve utility system performance
- Minimize operating cost
- Capital cost avoidan

Energy efficiency will need to be a key focus in all sectors

Annual Energy Consumption in India



Source: Data from Enhancing Energy Efficiency through Industry Partnership by BEE-2018

Why Paper Industry ?

- 5th largest **consumer** of **energy** in India.
- Accounts for 3.6 % of Indian primary energy use.
- In India, the average **energy consumption** of a typical **paper** mill is around 34.3 GJ/ton **paper** → that also includes **energy consumption** for wood chipping and pulping.
- Potential Contribution of Bioenergy to meet World's Future Energy Demand:
  - ✓ Renewable bioenergy
  - ✓ Renewable bioproducts and,
  - ✓ Renewable bioeconomy
- Paper industries currently process about 170 million tons of BL/year globally,
- With a total energy content of about 2EJ,
- Thereby making it a very significant biomass source.

Social & Economical impact of Paper Industry

- **Economy:** Indian Paper industry plays a key role in Indian economy, contributing around Rs. 500 billion to GDP.

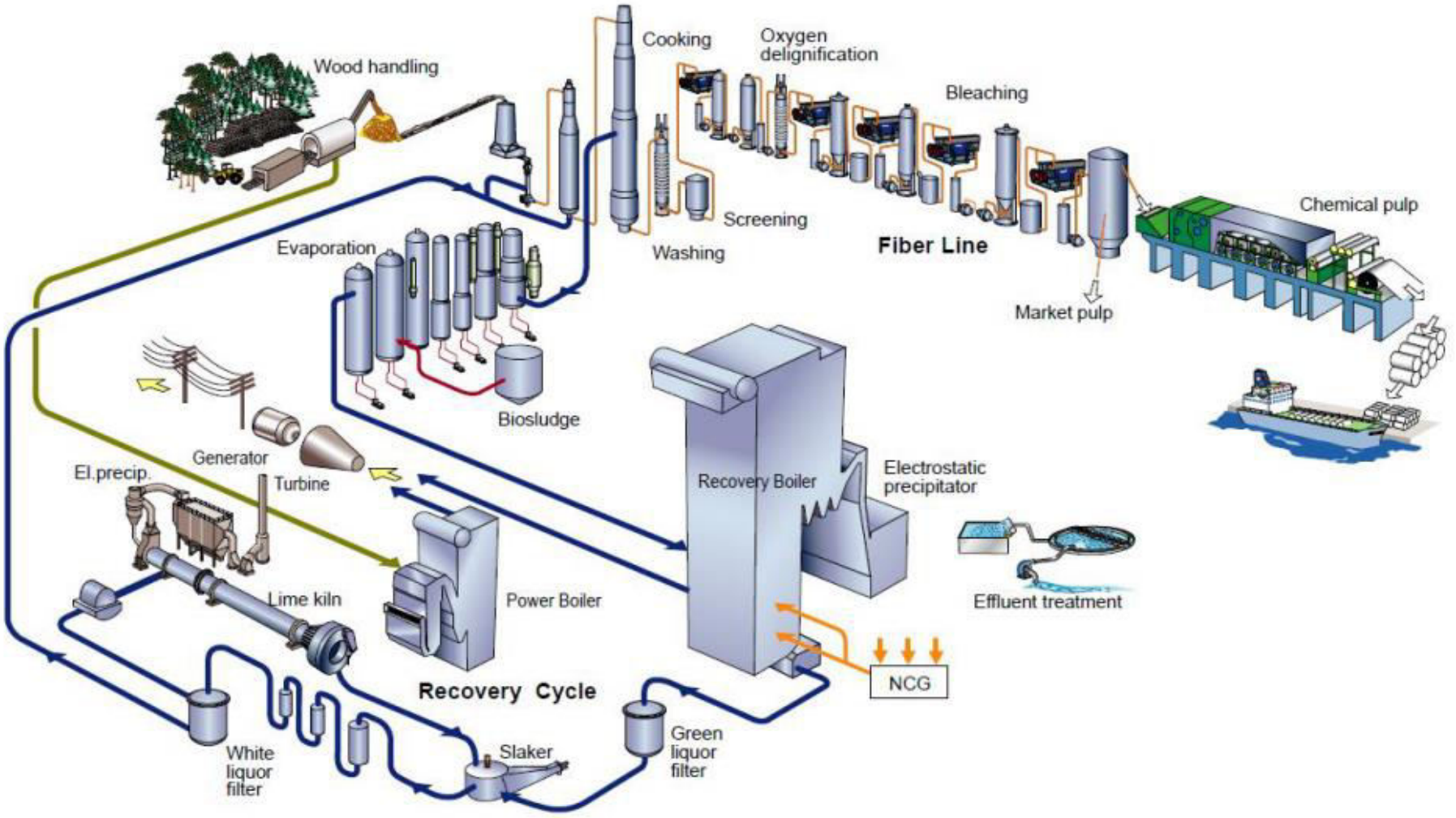
- **Employment:** more than 0.5 million people directly and 1.5 million people indirectly

- **Knowledge:** Paper is a significant medium to actuate knowledge based economy forward in new millennium

- **Literacy:** Demand of paper in India is expected: ↑ by 53% in next 6 years

  ✓ "**Sarva Shiksha Abhiyan**" program that plans to improve education, both quantitatively and qualitatively, primarily in rural areas.

Layout of Paper mill



Source :Overview of a conventional Kraft pulp mill © 2008 Kvaerner Pulping.

Multiple Stage Evaporator

- Weak BL needs to be evaporated
- To achieve relatively high solids concentration using a ***Multiple Effect Evaporators*** (***MEE***)
- Effective use of steam energy

Average Steam Consumption	
Area	**SC (t/ADt)**
Cooking	**1.2**
Bleaching	**0.82**
Chemical Preparation	**0.22**
Pulp Dryer	**1.62**
Multiple Effect Evaporator	**2.09**
Recovery boiler	**0.55**
Miscellaneous	**0.10**
Total	**6.60**

Source [Internet]: Voith Paper mill, Germany

✓ Energy consumption across MEE → Significant fraction of total consumption

Issues with MSE

- **Black Liquor:** Complex solution of water, organic, & inorganic components.
- **Need to Concentrate**: From initial concentration of ~12–14% to ~ 40–55% solids content
- **Huge energy needed:** Requires huge amount of water evaporation
- **Typical heat and power demands:** 4–5 GJ/ ADt and 20–30 kWh/ADt.
- **High viscosity:** Concentrated black liquor has **high viscosity**
- **Fouling and Scaling:** Causing significant problems of fouling and Scaling

  ✓ **Reducing Heat Transfer capabilities**
  ✓ **Increasing energy cost**

Process Sketch

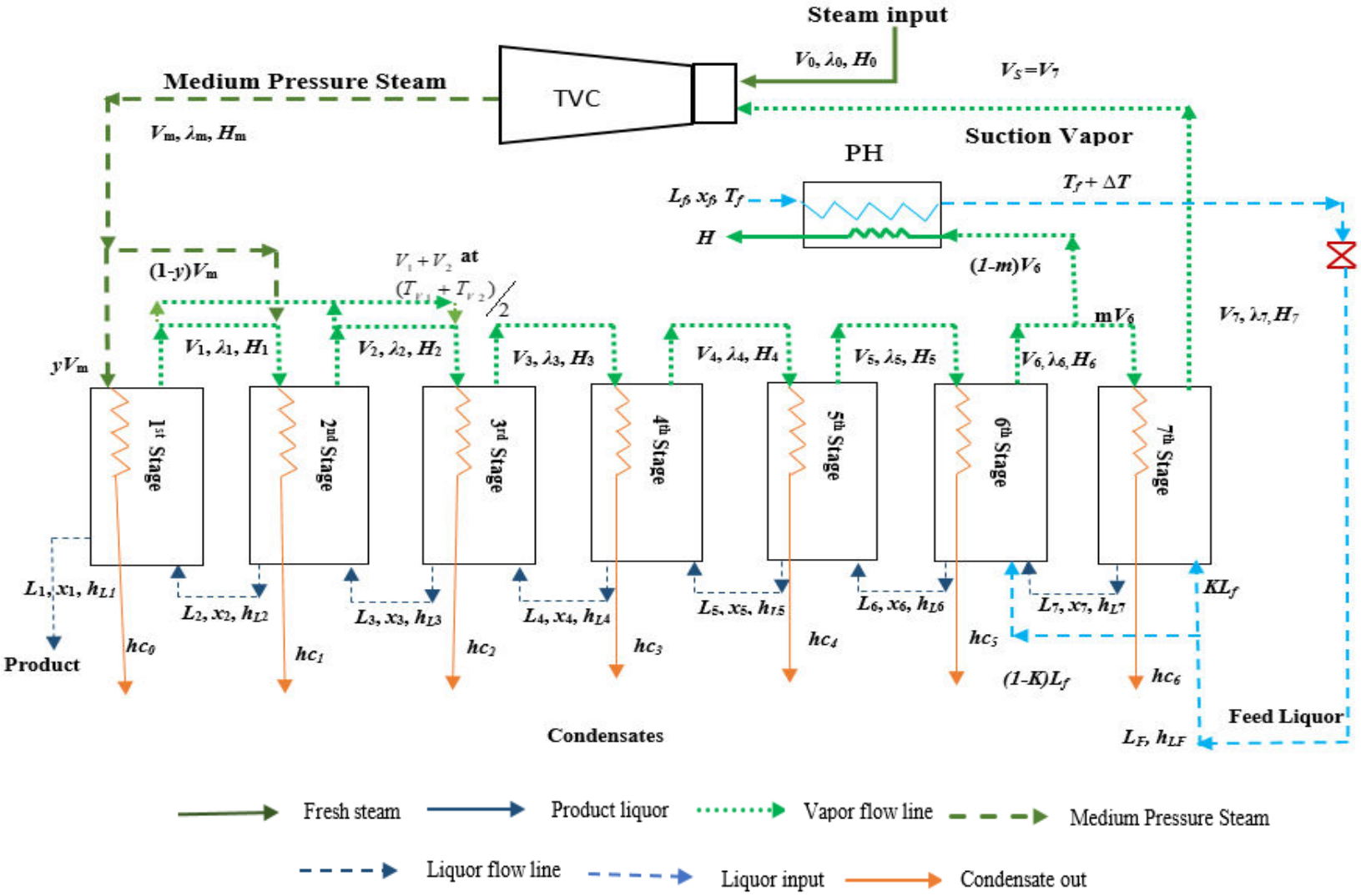
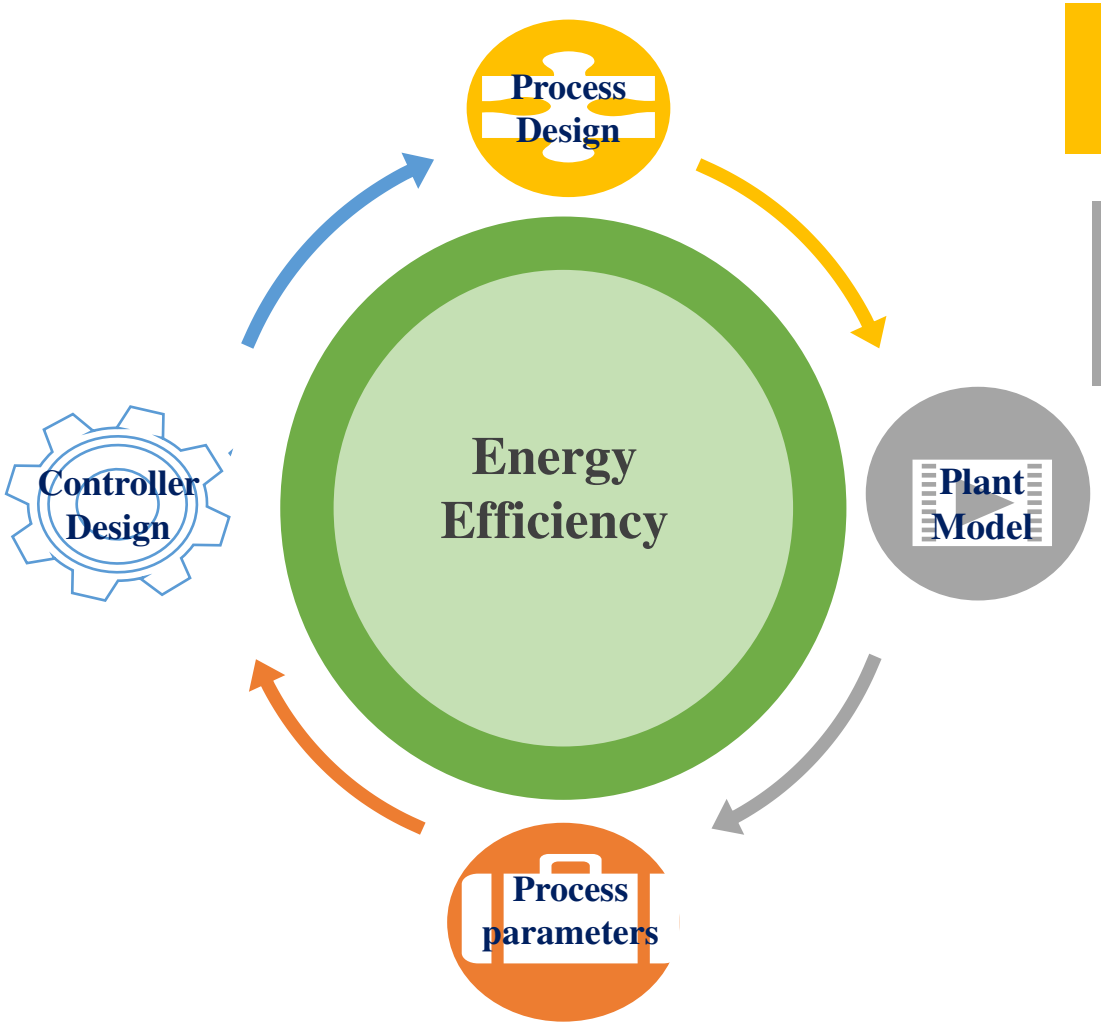


Fig.: Schematic of ERS integrated MEE model

Energy Efficiency Analysis



Energy Reduction Scheme

Steam-, Feed- split, TVC, Preheater, etc.

Plant Modeling

- Steady-State Nonlinear Algebraic Equations
- Dynamic-State Nonlinear ODEs Equations

Process parameters Estimation

Optimum Temperature, Steam input, Flowrate etc.

Controller Design

Transient Behavior and Tuning

Solution Approaches

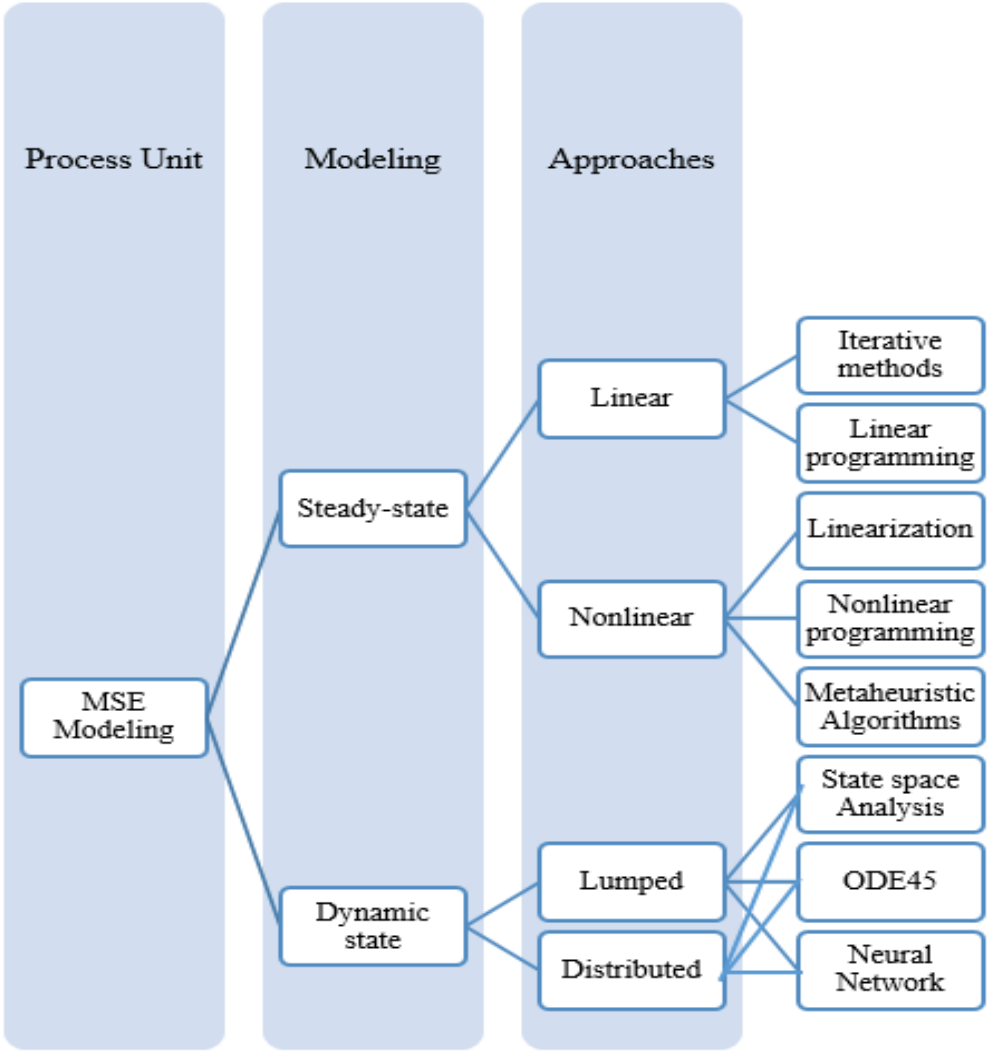


Fig.: Solution approaches adopted for solving the MEE models

Optimization Problem

$$Maximize: \quad f(z) = SE = \frac{L_f - L_1}{V_0}$$

$$Subjected\ to: g_i(z_1, z_2, ..., z_n) \geq 0$$

$$h_i(z_1, z_2, ..., z_n) = 0$$

- Equality Constraints

$$yV_m(\lambda_m - hc_m) + L_1(H_1 - h_1) + L_2(h_2 - H_1) = 0 \quad (1)$$

$$U_1A_1(T_m - T_1) - yV_m(\lambda_m - hc_m) = 0 \quad (2)$$

$$(1-y)V_m(\lambda_m - hc_m) + L_2(H_2 - h_2) + L_3(h_3 - H_2) = 0 \quad (3)$$

$$U_2A_2(T_1 - T_2) - (1-y)V_m(\lambda_m - hc_m) = 0 \quad (4)$$

$$(L_3 - L_1)(\lambda_{avg} - hc_{avg}) + L_3(H_3 - h_3) + L_4(h_4 - H_3) = 0 \quad (5)$$

$$U_3A_3(T_2 - T_3) - (L_3 - L_1)(\lambda_{avg} - hc_{avg}) = 0 \quad (6)$$

$$(L_i - L_{i-1})(\lambda_i - hc_i) + L_i(H_i - h_i) + L_{i+1}(h_{i+1} - H_i) = 0 \quad (7)$$

$$U_iA_i(T_{i-1} - T_i) - (L_i - L_{i-1})(\lambda_i - hc_i) = 0 \quad (8)$$

$$(L_6 - L_5)(\lambda_5 - hc_5) + L_6(H_6 - h_6) + L_7(h_7 - H_6) + (1-k)L_f(h_f - H_6) - (1-k)L_fCp\Delta T = 0 \quad (9)$$

$$U_6A_6(T_5 - T_6) - (L_6 - L_5)(\lambda_5 - hc_5) + (1-k)L_fCp\Delta T = 0 \quad (10)$$

$$m(L_7 + (1-k)L_f - L_6)(\lambda_6 - hc_6) + L_7(H_7 - h_7) + kL_f(h_f - H_7) - kL_fCp\Delta T = 0 \quad (11)$$

$$U_7A_7(T_6 - T_7) - m(L_7 + (1-k)L_f - L_6)(\lambda_6 - hc_6) + kL_fCp\Delta T = 0 \quad (12)$$

Proposed Metaheuristic algorithm: FDA

- Flow Direction Algorithm (FDA) is inspired by the flow direction of the outlet point with lowest height of the basin.

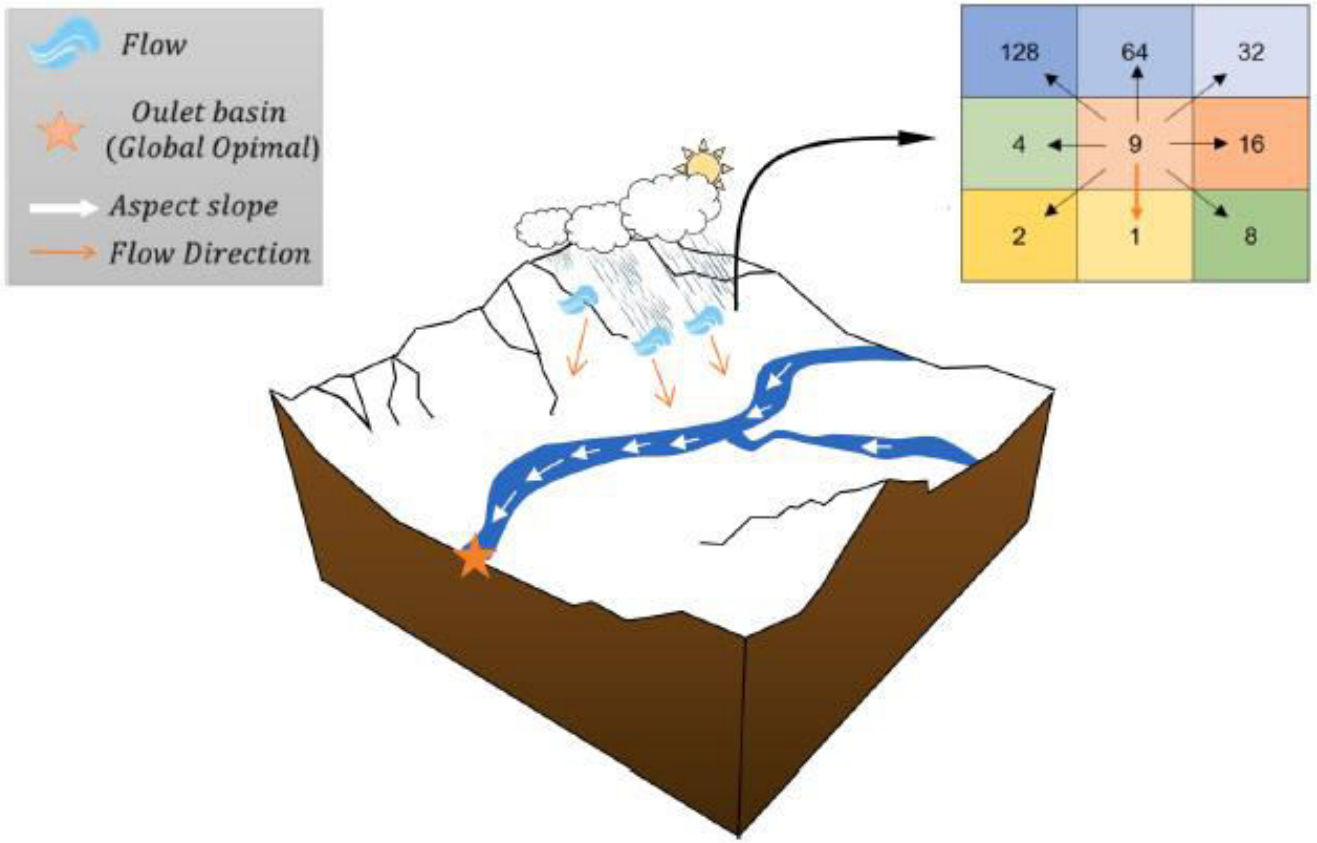


Fig.: Schematic scheme of moving flow to outlet of basin and D8 method.

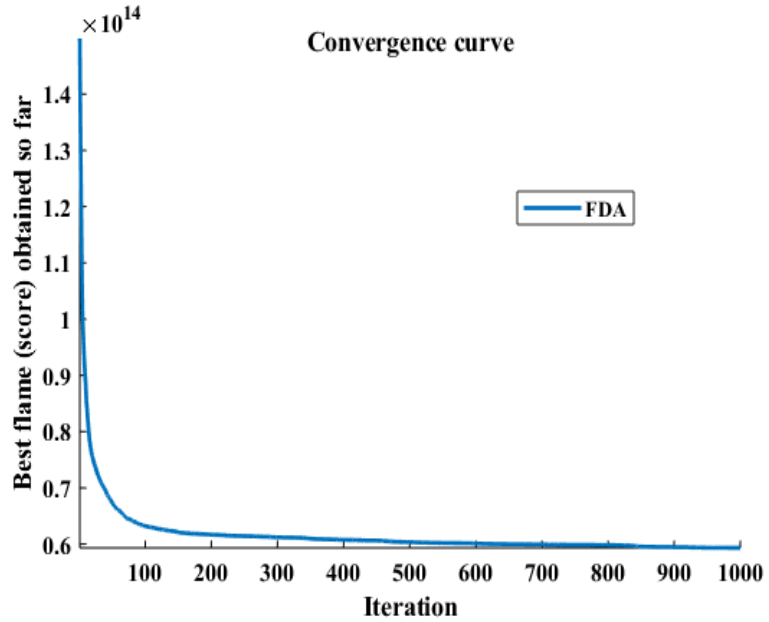


Fig.: Convergence curve of FDA

Result Analysis

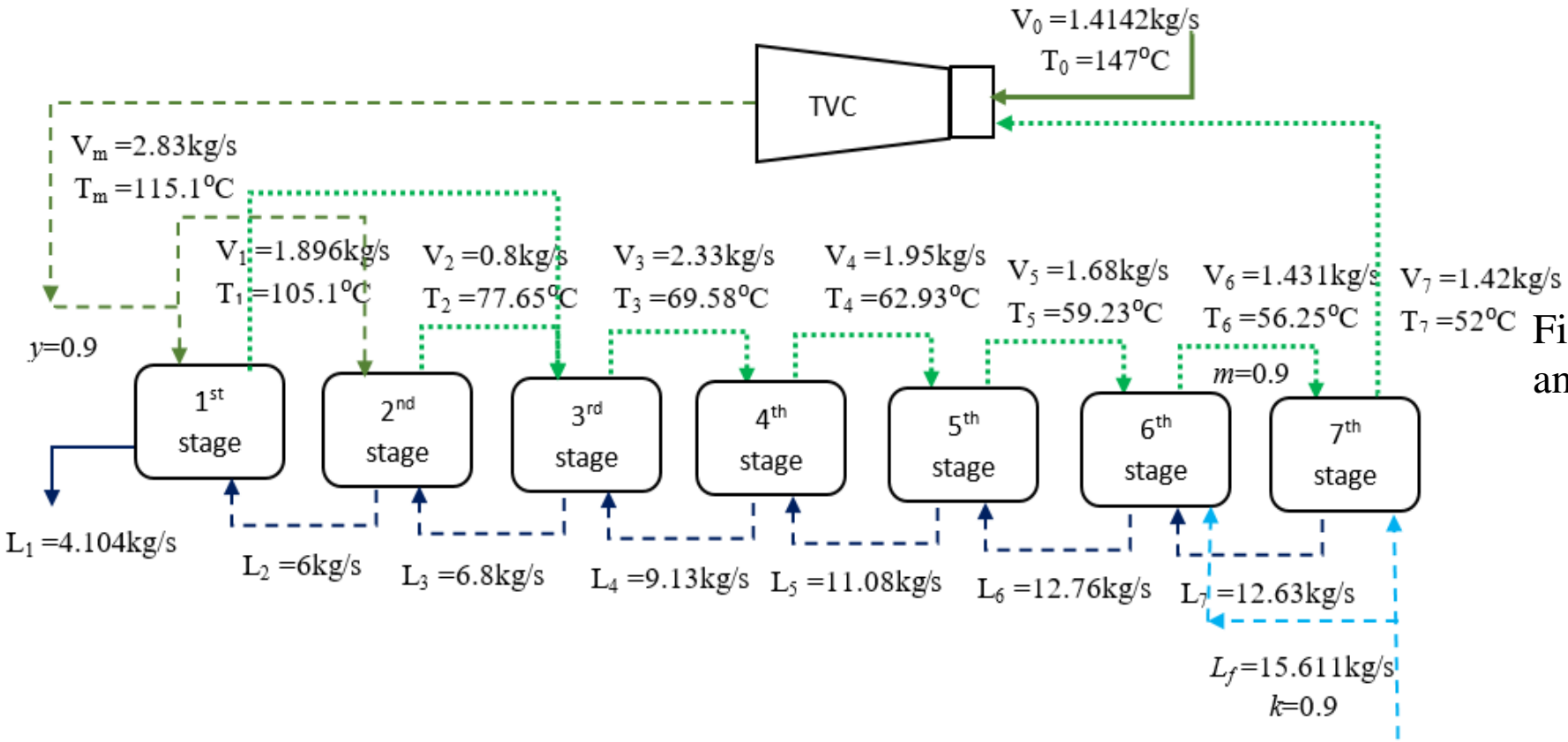


Fig. 5 Flow sheet of the proposed MEE by employing FDA

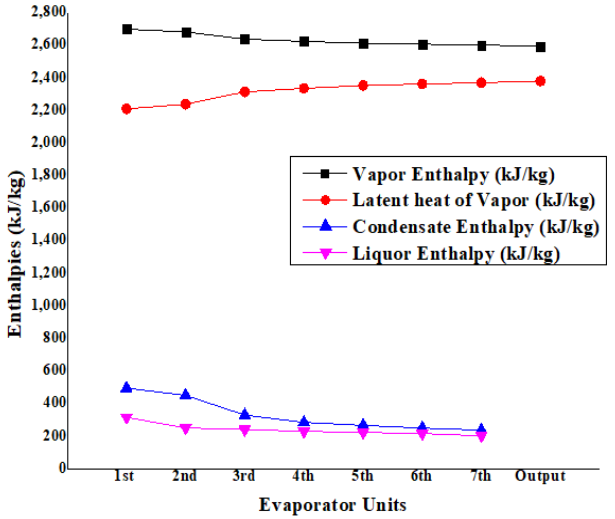


Fig. Heat Enthalpy Variation of Vapor and Liquor during MEE operation

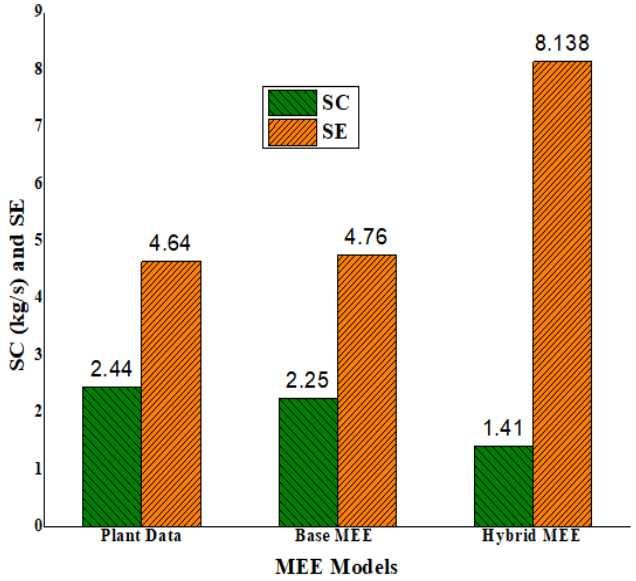


Fig.: Variation in SC and SE at different operating condition

Conclusion

- Energy integration escorts, considerable amount of energy saving, enhancement in energy efficiency and increased self-sustainability of the industry.
- The principle of process integration and numerical optimization with the utilization of NIAs (here FDA) are the keys to reduce the energy utilization in an optimal manner.
- The deviation in the results of plant operated and base MEE model are deviated by 7.79% and 2.52% for SC and SE respectively.
- This investigation shows hybrid MEE has an efficient energy reduction by means of SC (42.21%) and thereby enhancement in SE (75.4%) than that of plant operated model which leads to reduction in economic and environmental issues.


Thank
you