Process Integration Case Study for the Second Generation Ethanol Production

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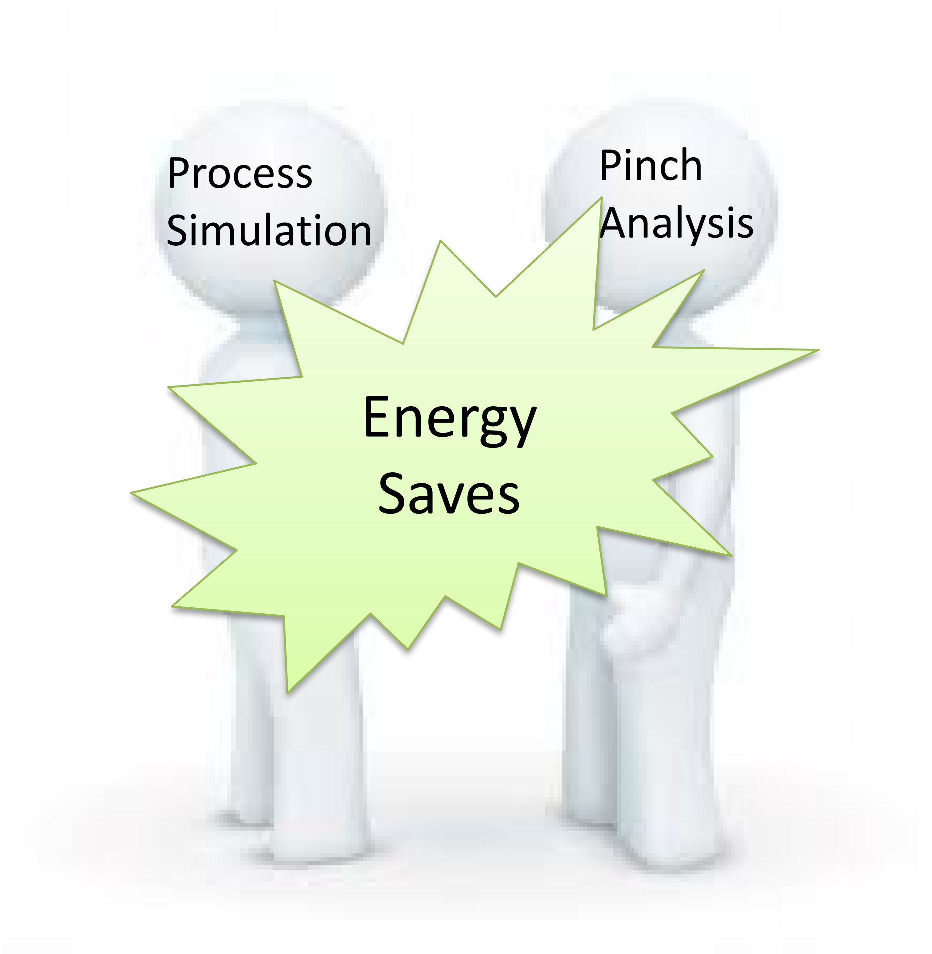
Objectives

- Increase the ethanol production by integrating 1st and 2nd generation plants with energy saving, without any additional biomass

Methodology



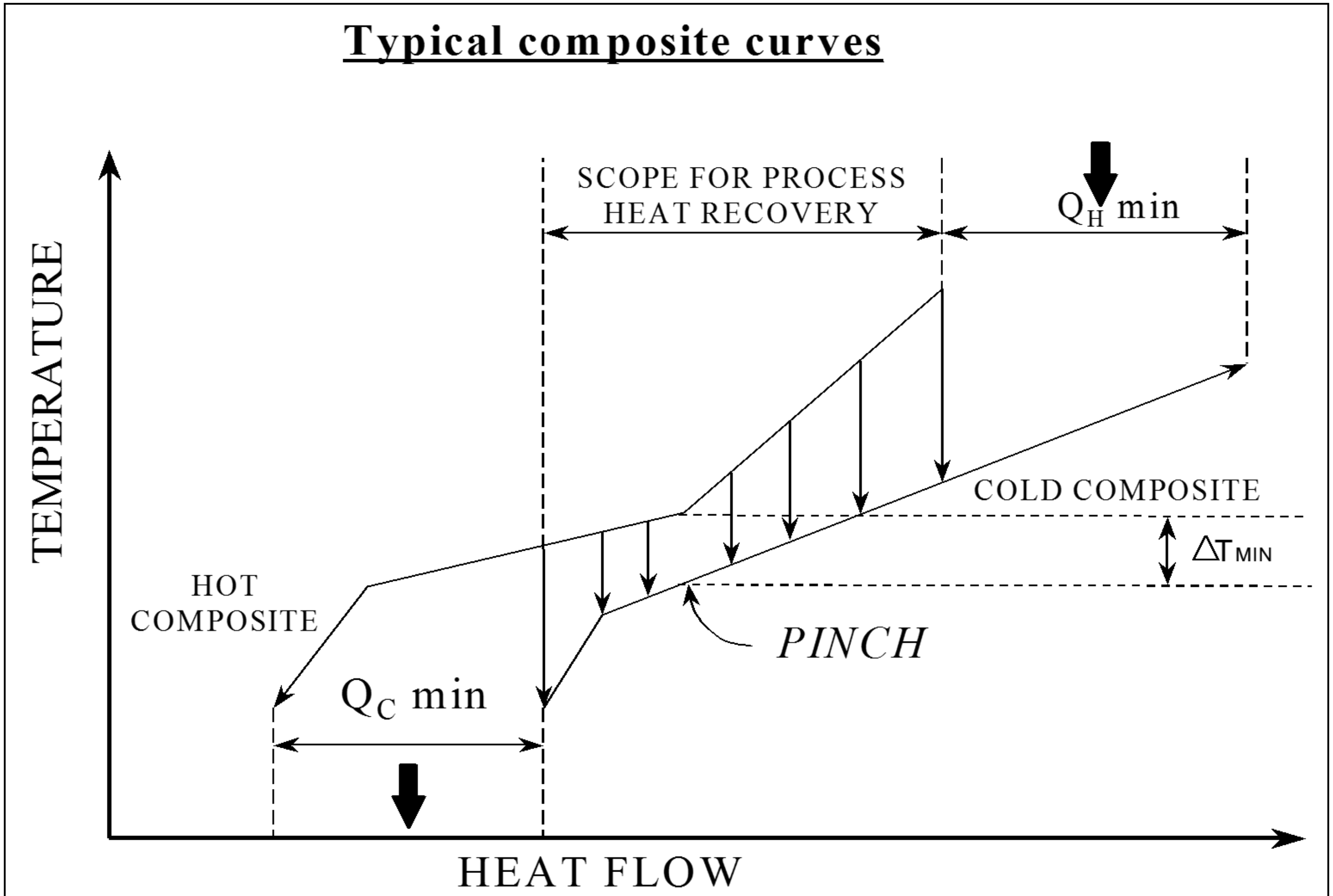
- Integration of 1st and 2nd Generation plants
- Increase ethanol production
- Improve process efficiency

Applications of Process Integration

Pinch Analysis is integral part of Process Integration, when

- Integrating heat needs with waste heat
- Generating steam/heat “appropriately”,
- Reusing / recovering raw materials,
- Integrating many processes / Co-production / Technology synergies,
- Upgrading byproducts

Principle of Pinch Analysis

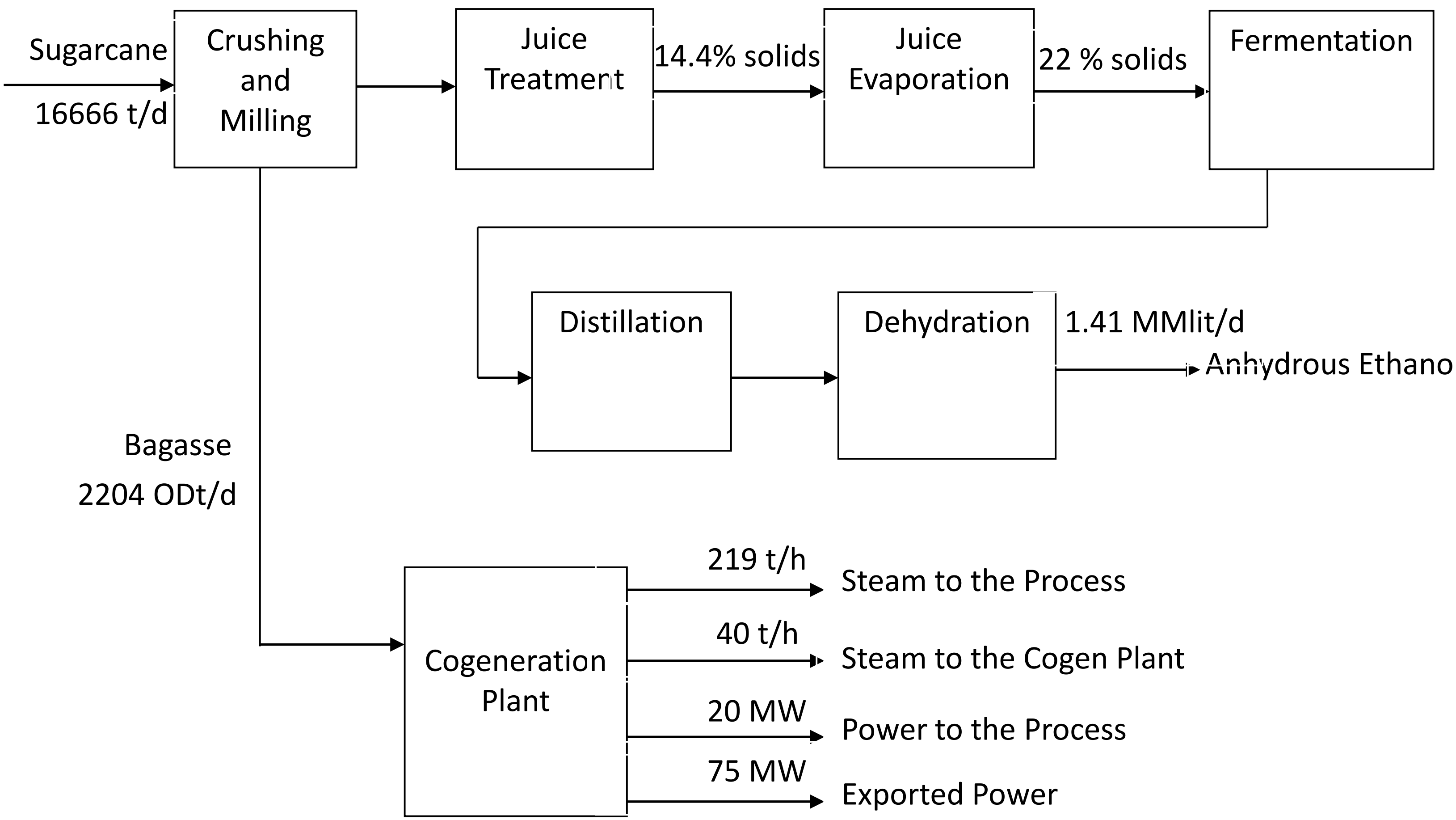


Pinch Analysis Example

First Generation Sugar Cane Ethanol Plant

3 million tons crush during 180-day harvest

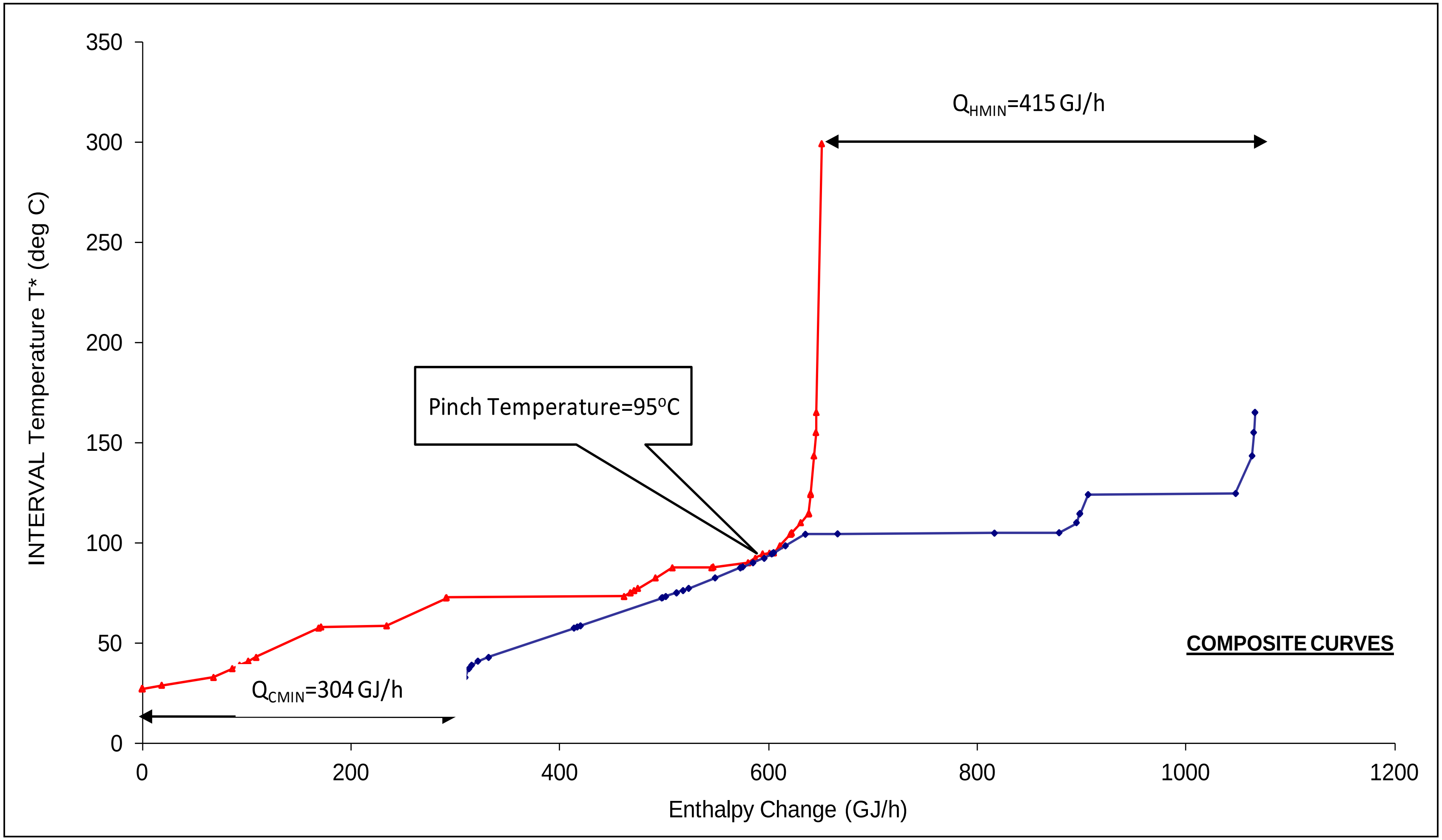
Sugarcane Ethanol Plant



Sugarcane Plant Main Heat Duties

Description	**Heat demand, GJ/h**	**Steam consumption, GJ/h**
Juice preheating before liming	87	24
Juice heating after liming	89	76
Imbibition and wash water heating	38	0
Juice evaporation	141	141
Wine preheating (to distillation)	79	0
Distillation (stripper column)	161	161
Distillation (rectifier column)	79	79
Molecular Sieves heating	7	3
Boiler Feed Water heating	41	76
Totals	**723**	**560**

Sugarcane Plant Composite Curves



Sugarcane Plant Pinch Results

• Pinch Temperature	95 °C
• Minimum ΔT selected	10 °C
• Minimum heating utility(QHMIN)	415 GJ/h
• Actual process steam consumption	554 GJ/h
• Maximum scope for heat recovery	**139 GJ/h**

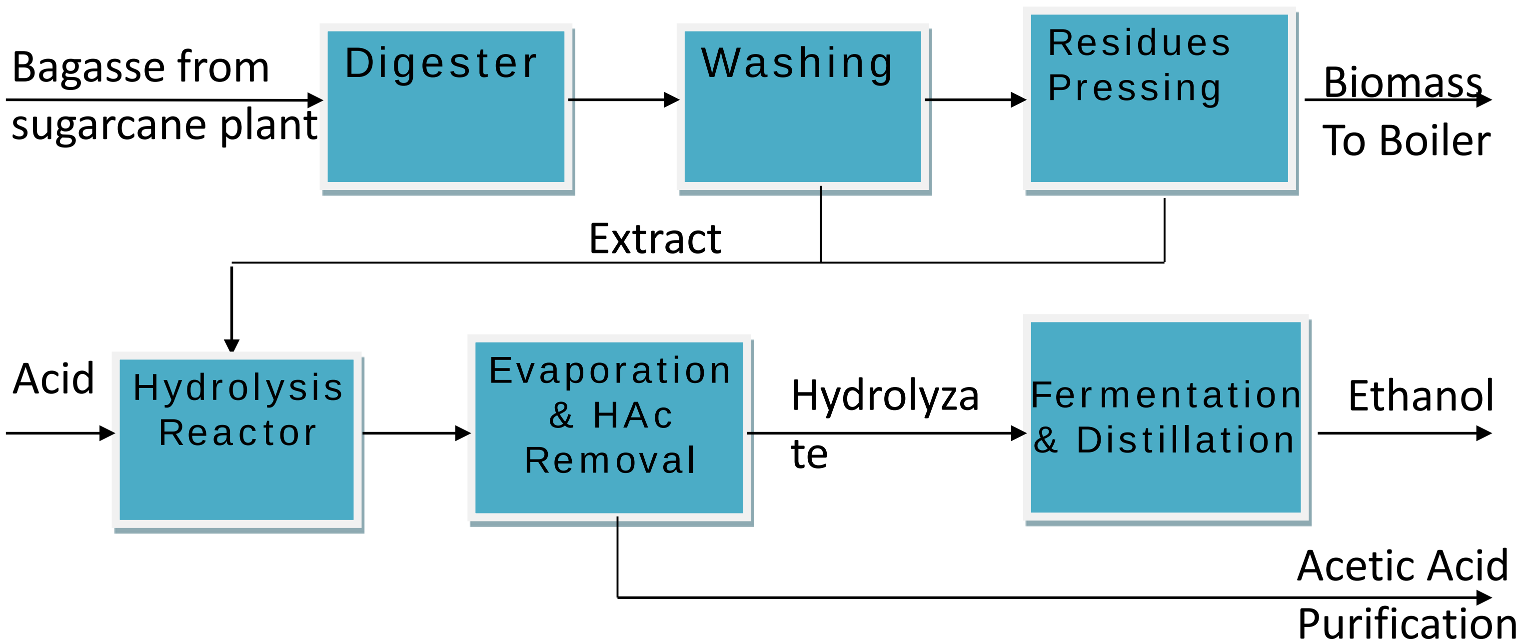
Second Generation Ethanol Plant

Cellulosic Ethanol and Acetic Acid from Bagasse Feedstock

Second Generation Ethanol Plant

- American Process has developed hemicellulose extraction process termed "Green Power +™"
  - Liquid Hot Water digestion of Bagasse
  - Hemicelluloses are acid hydrolyzed to Pentose sugars and Acetic Acid
  - Acetic Acid is separated by evaporation & purified
  - The sugars are fermented to beer
  - The beer is distilled to produce ethanol
  - Unreacted solids material are concentrated and burned in the boiler.

Green Power+™ 2nd Gen. Plant



GP+ Plant Main Heat Duties

Description	Heat Demand, GJ/h	Power demand, MW
Biomass presteaming	18	7.4
GP+ Digester heating	167	
Biomass wash water heating	36	
Hydrolysis reactor heating	37	
Sugar solution evaporation (MVR)	33	5.8
Beer preheating	26	
Distillation (beer column)	40	
Distillation (rectifier column)	40	
Acetic Acid plant (MVR)	38	3.6
Totals	**436**	**16.8**

The sugar solution evaporation and concentration of acetic acid is performed in Mechanical Vapor Compression (MVR) Evaporator

GP+ Plant Pinch Results

- Pinch Temperature 101 ^{o}C
- Minimum ΔT selected 10 ^{o}C

- Minimum heating utility(QHMIN) 103 GJ/h

Combined 1st & 2nd Generation Plants

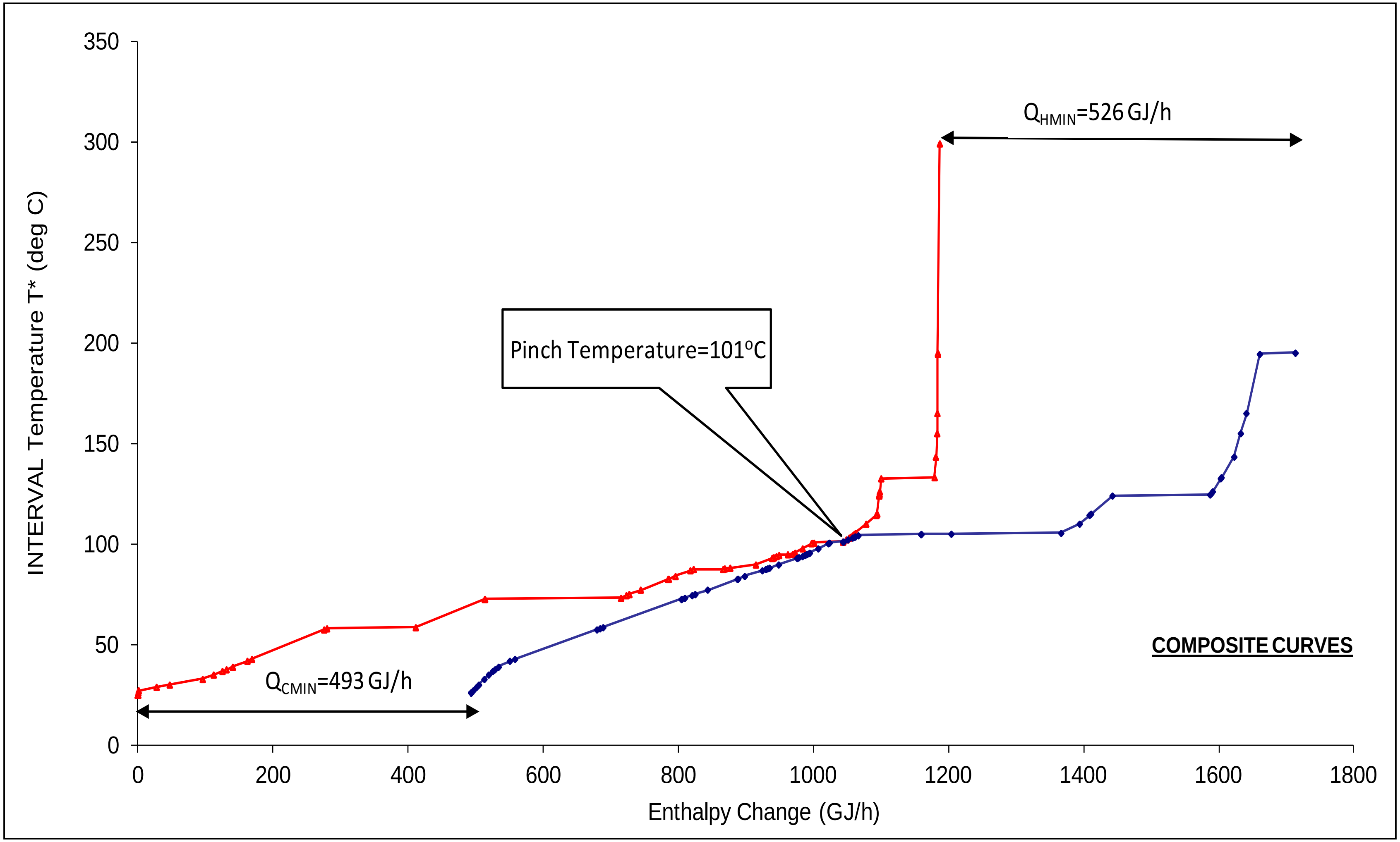
	Host sugarcane ethanol plant	Host ethanol plant combined with GP+
Sugarcane crush, t/d	16666	16666
Anhydrous ethanol production, MMlit/d	1.41	1.65
Acetic Acid production, t/d	-	123
Bagasse generated from process, ODt/d	2203	2203
Steam generated from Bagasse, GJ/h	1183	791
Steam generated from Bagasse, t/h	414	292
Specific steam generation from bagasse, t/t	2.16	2.61
Steam consumed in the plant, t/h	259	259+47 (at least) =306
Steam consumed in the process, t/h	219	219+47 (at least)=266
Power consumption, MW	20	37

The steam consumption is more than available from leftover bagasse solids!

Pinch Analysis for the Integrated plant

First Generation Sugarcane Ethanol Plant with Green Power+ Bagasse Extraction to Cellulosic Ethanol and Acetic Acid

Composite Curves for Integrated Plant

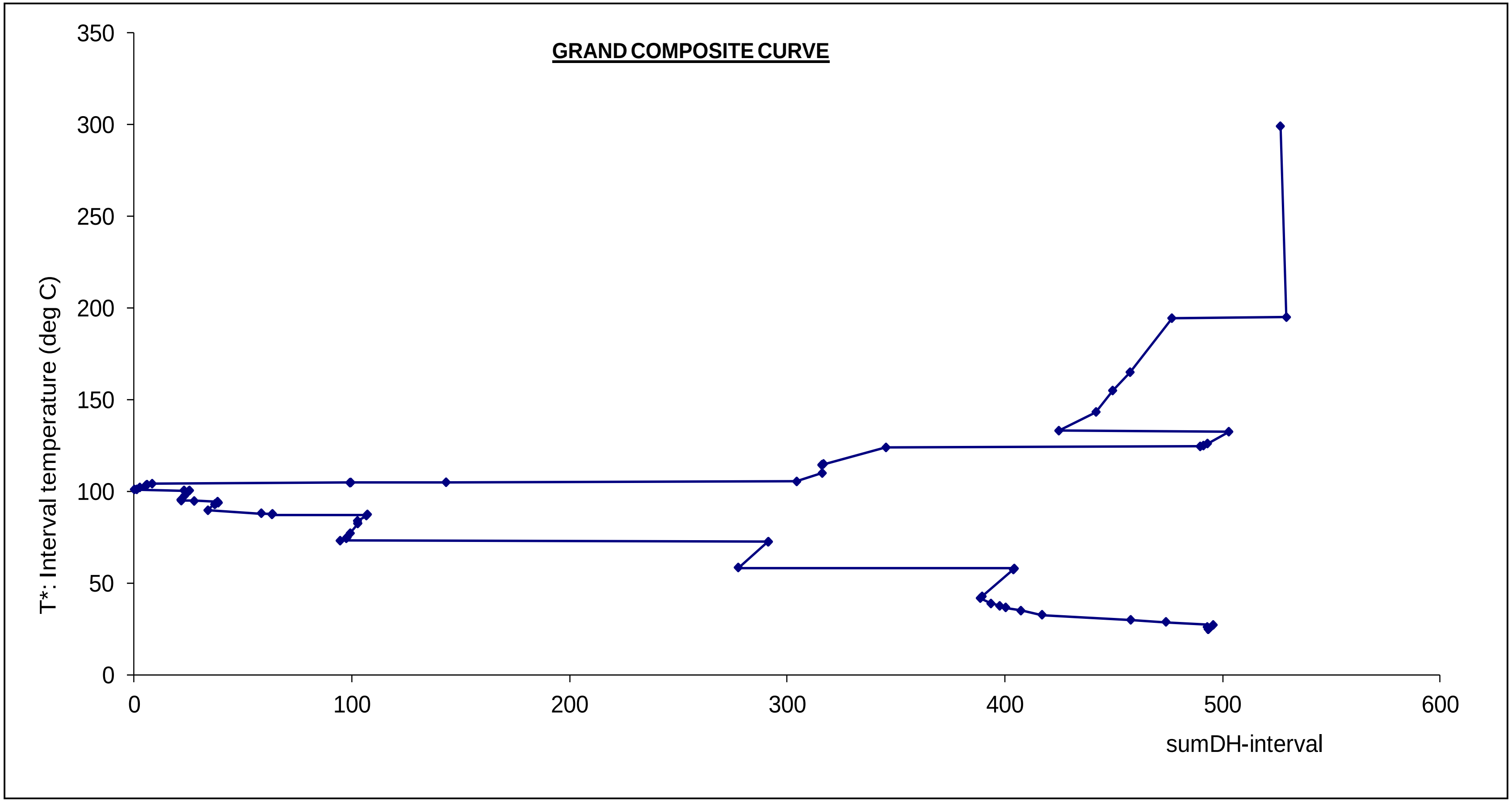


Integrated Plant Pinch Results

- Pinch Temperature 101 ^{o}C
- Minimum ΔT selected 10 ^{o}C

- Minimum heating utility(QHMIN) 526 GJ/h

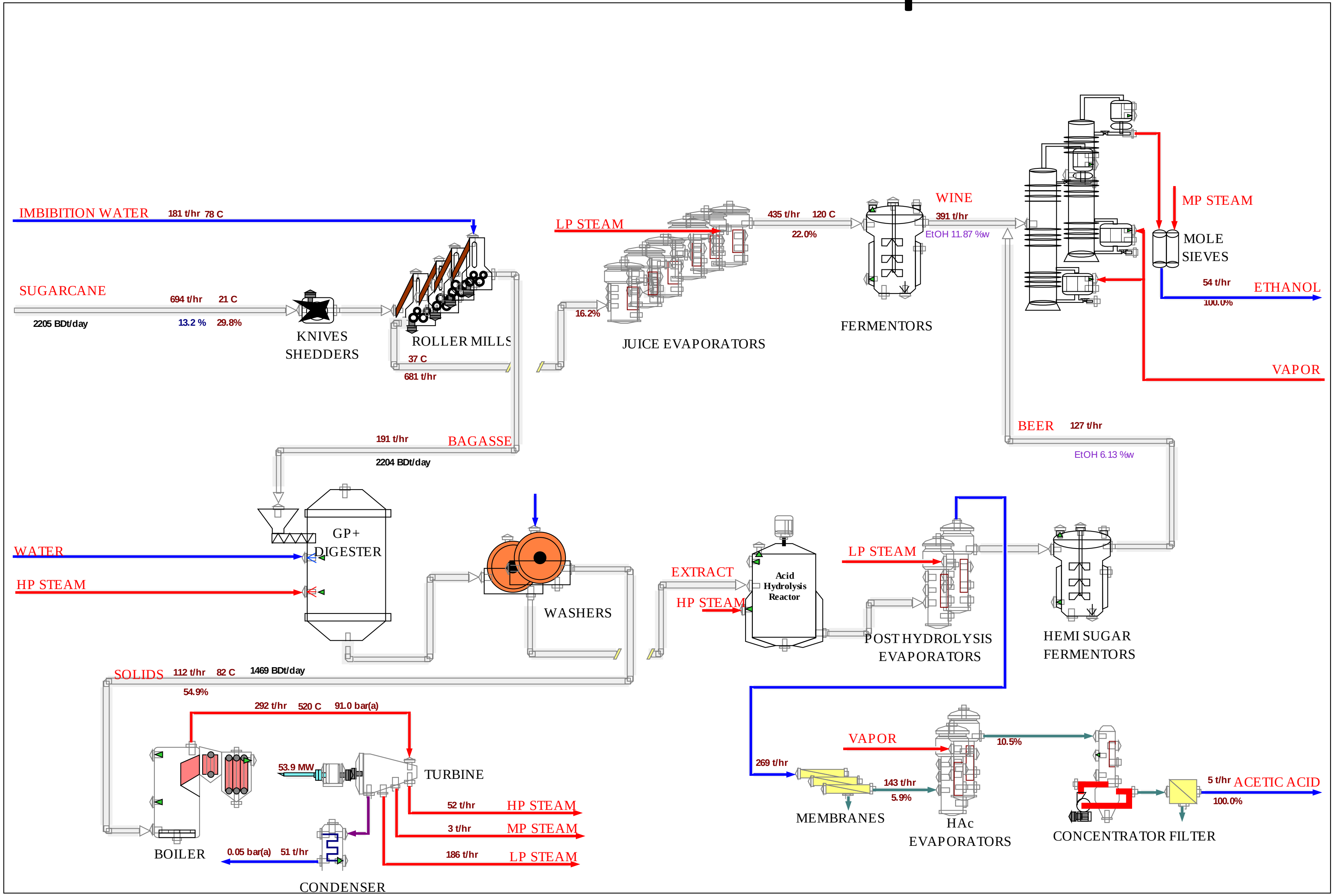
Grant Composite Curve



Comparison of Performance before and after Integration of 2^{nd} Gen. Ethanol

	Host sugarcane ethanol plant	Integrated plants with 2^{nd} generation ethanol
Sugarcane crush, t/d	16656	16656
Anhydrous ethanol production, MMlit/d	1.41	1.65
Acetic Acid production, t/d	-	123
Bagasse generated from process, ODt/d	2203	2203
Steam generated from Bagasse, GJ/h	1183	791
Steam generated from Bagasse, t/h	414	292
Specific steam generation from bagasse, t/t	2.16	2.61
Steam consumed in the plant, t/h	259	244 (306)
Steam consumed in the process, t/h	219	233 (266)
Steam consumed in the cogeneration plant, t/h	40	11
Process steam consumption per ton of cane, kg/t	316	336
Steam to the turbine condenser, t/h	158	51
Total Power generation, MW	95	54
Power consumption, MW	20	29 (37)
Net exported power, MW	75	25 (17)

Simulation Model in apiMAX™



Results Summary

- Pinch Analysis was applied to stand-alone sugarcane ethanol mill to find **25% steam energy savings**
- The integration resulted in **17% increase in ethanol** and by-product acetic acid production **without any additional biomass**

Conclusions

- Combination of two optimized plants can be improved by process integration
- Reducing steam consumption allows leveraging of existing boiler and turbines
- Common distillation system can be used for 17% incremental ethanol production
- Additional cellulosic ethanol can be made from bagasse without bringing additional biomass to the site
- Techno-economic evaluation is necessary to calculate trade-off with power sales and the investment payback