

Sustainability & Energy Efficiency

in United States Beet Sugar Processing

Presenter: Tanner Ring, Process Engineer



TANNER RING



University of North Dakota

- B.S. Chemical Engineering
- Concentration in Sustainable Energy Engineering

6 years - Factory Engineer: ACSC Drayton, ND

- Plant Expansion Team: 6,750 tpd to 15,000 tpd (ongoing)
- Purification, Evaporators & Condensate, Cooling Crystallizer, Juice Heaters...etc.
- Assisted: Gas Kiln, B VKT, Sugar Dryer, Pulp Dryers...etc.

3 years – Process Engineer: EAPC – Industrial Services

- Beet Sugar Sustainability Projects: Plant Capacity Studies, Biogas CHP, Turbine/Generators, SUGARS™ & Process Modeling
- Other Industries: Biogas, Candy, Cellulosic Fiber, Ethanol, Potatoes



AGENDA

Sustainability and Relevance to the US

Traditional Methods of Sustainability

Modern Methods of Sustainability

Future Methods of Sustainability

Q&A

SUSTAINABILITY & RELEVANCE TO THE US



....Why?

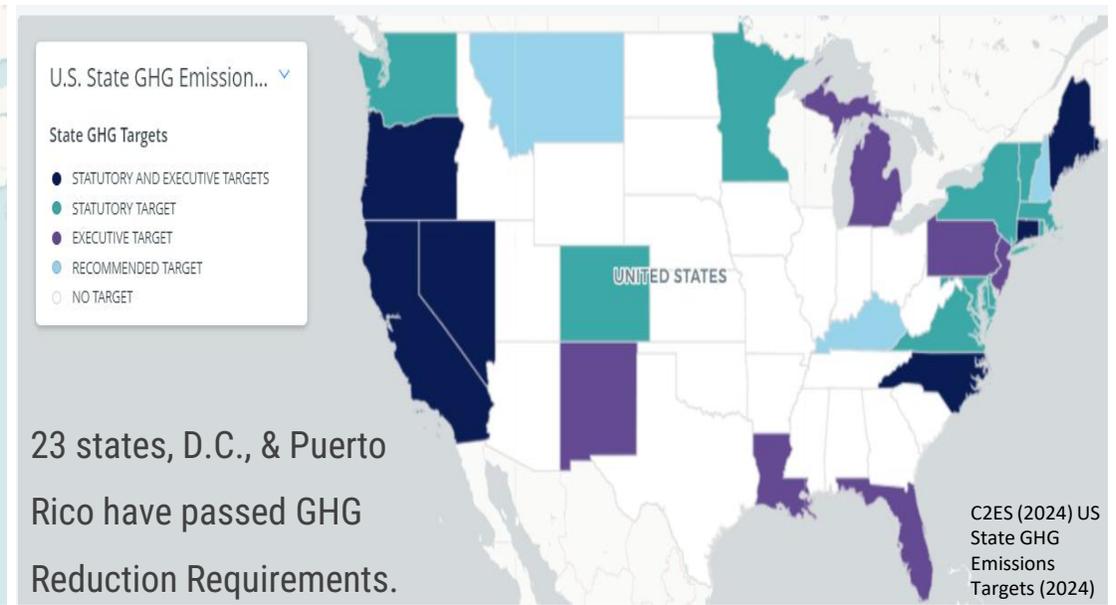
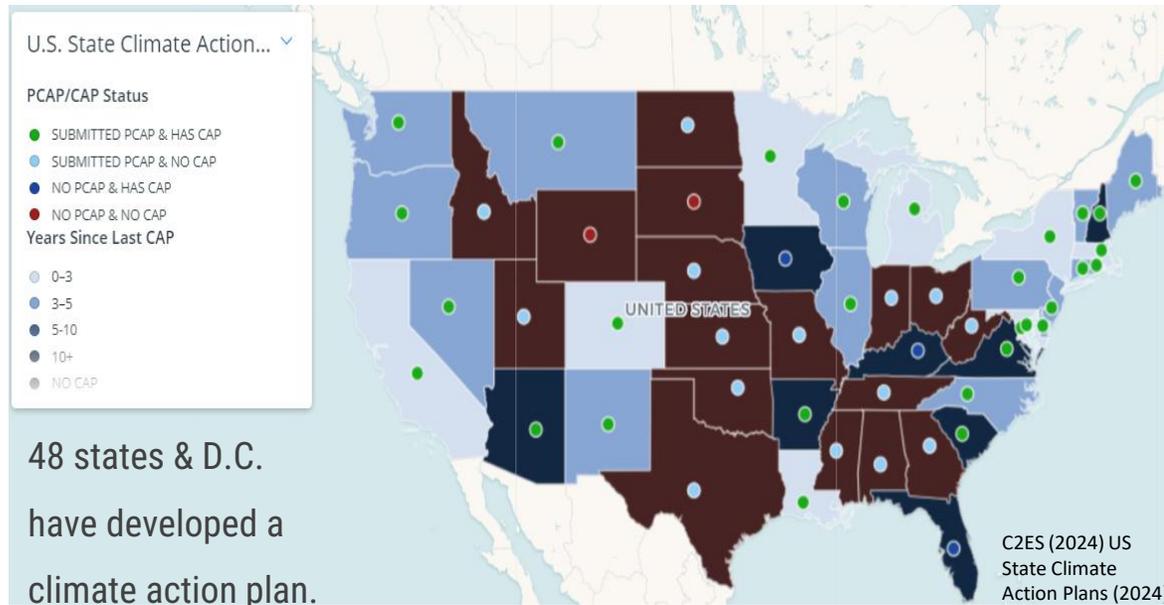
- Policy / Regulatory changes: Emissions targets, carbon pricing, etc.
- Market changes: Indirect (energy) and direct (sugar)
- Customer / Public / Social influences
 - Current Specialty Markets for Beet Sugar: Kosher, Vegan
 - Future Specialty Markets: Carbon Intensity (CI)?

SUSTAINABILITY & RELEVANCE TO THE US



Regulation - Carbon Reduction

- Lack of Federal action towards carbon reduction in the near-term.
- States are taking steps individually and in groups to reduce carbon emissions.

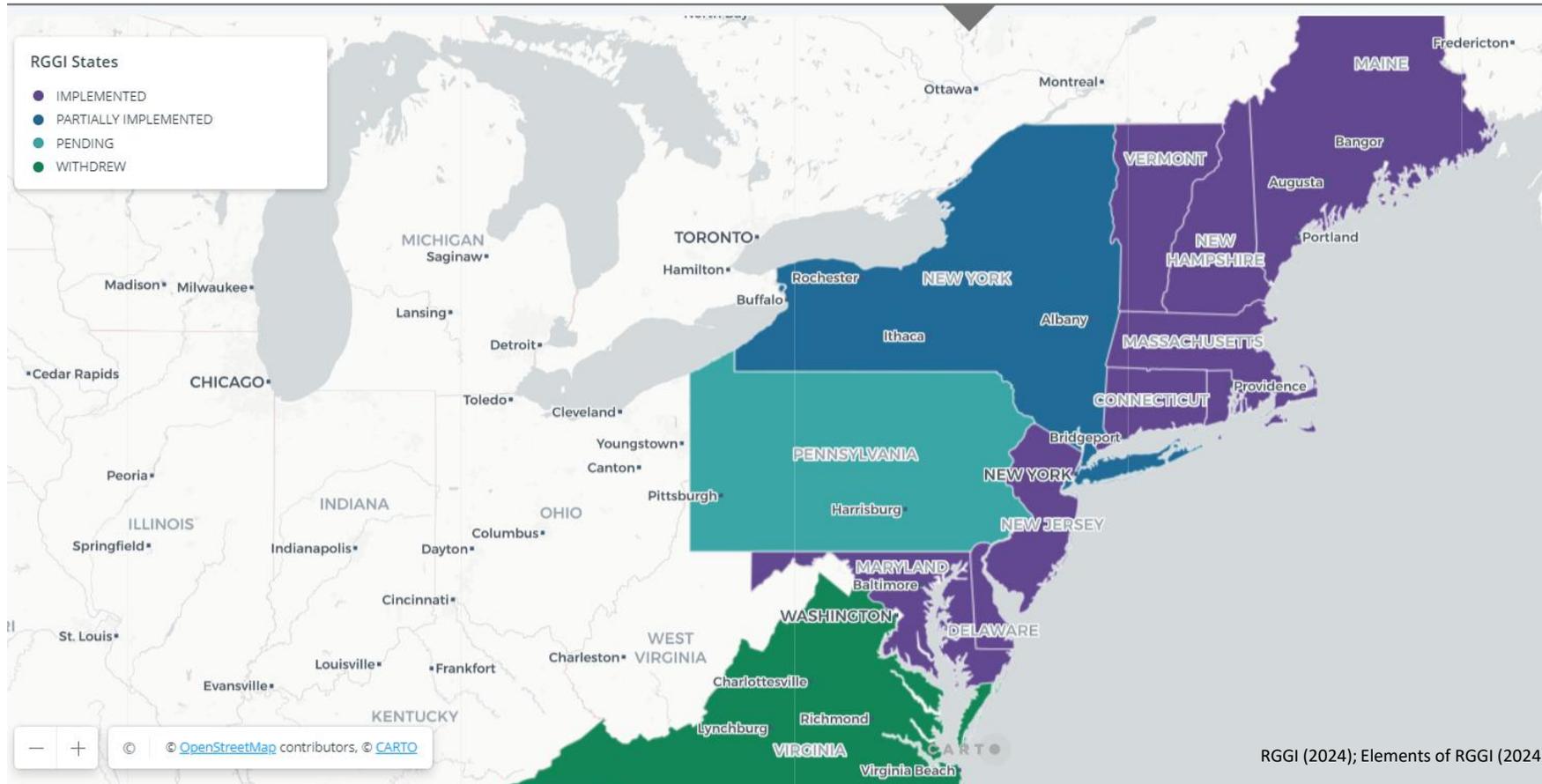


SUSTAINABILITY & RELEVANCE TO THE US



Regulation - Carbon Reduction

- 11 states in Regional Greenhouse Gas Initiative - “Cap and Invest” System.

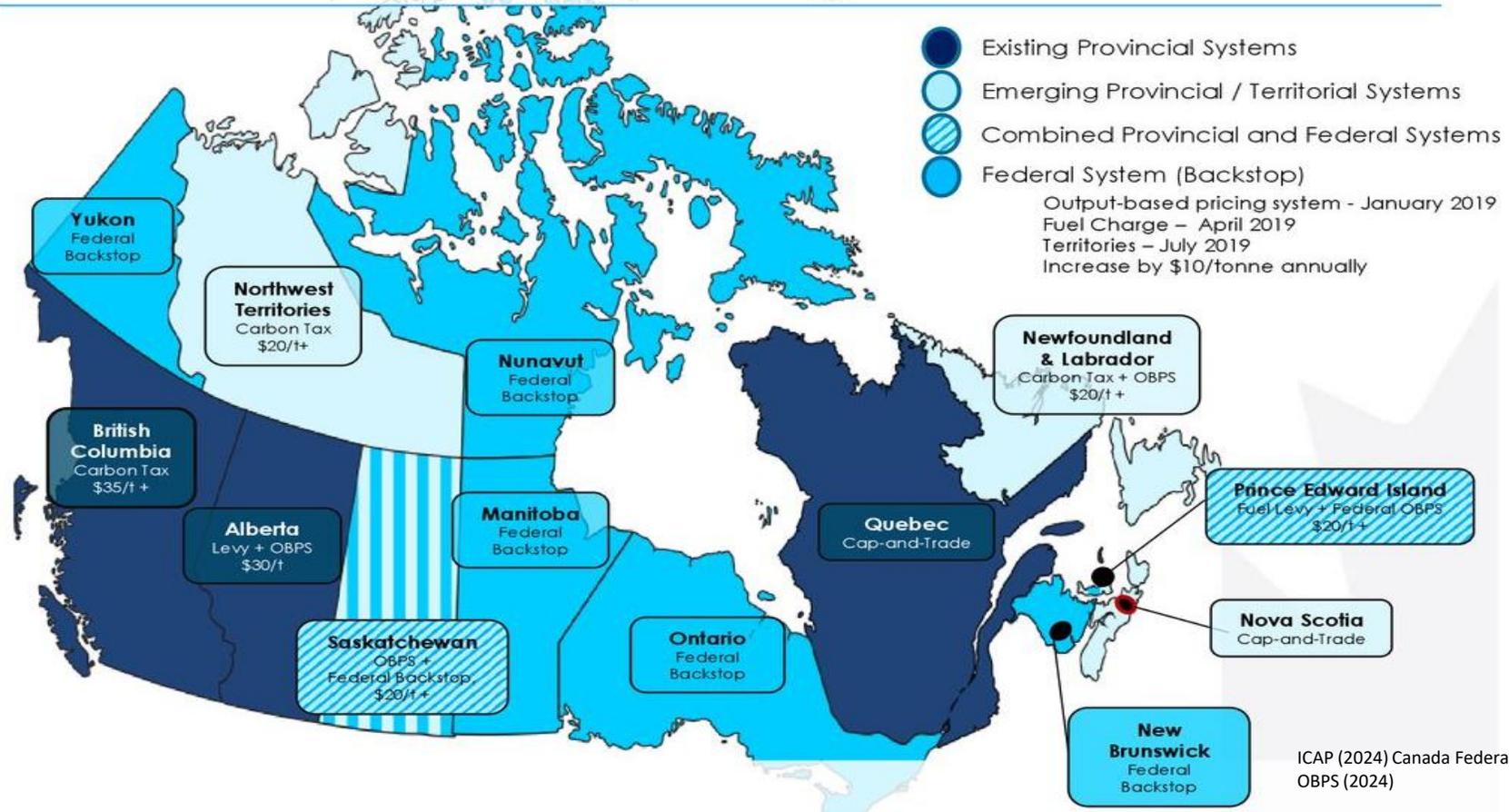


SUSTAINABILITY & RELEVANCE TO THE US



Carbon Reduction – Canada’s Twin System Carbon Market

Carbon pollution pricing in Canada



SUSTAINABILITY & RELEVANCE TO THE US



Carbon Reduction – European Union Emissions Trading System

- Cap-and-trade system to factor externalities of carbon emissions into OPEX.
 - Must pay for cost of fuel plus each metric ton of CO₂ it produces.
 - Depending on grade, 1 ton of coal yields 2 tons CO₂
 - 208 therms of natural gas (~=energy to a ton of coal) yield 1.1 tons CO₂

SUSTAINABILITY & RELEVANCE TO THE US



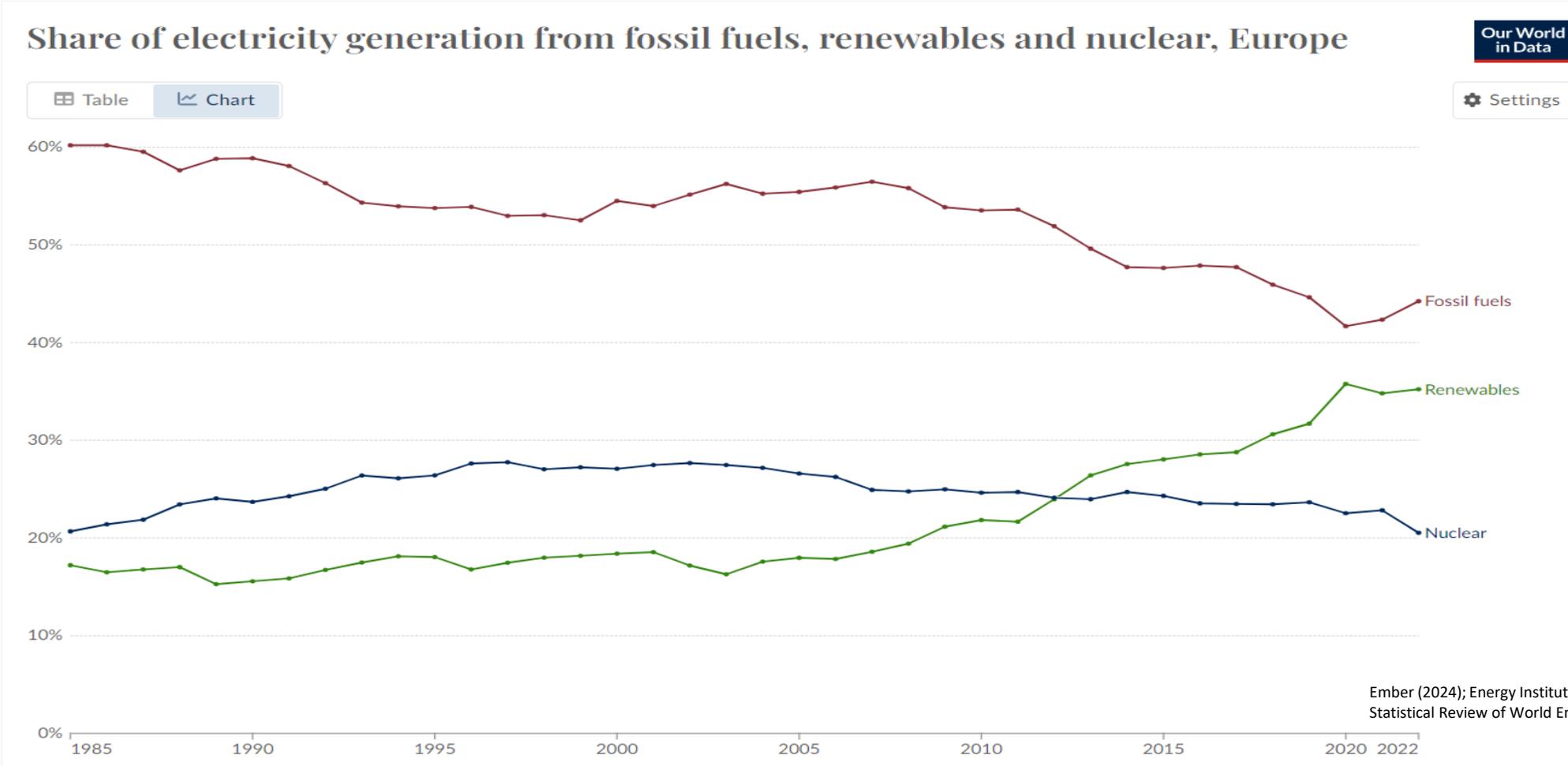
Carbon Reduction – European Union Emissions Trading System



SUSTAINABILITY & RELEVANCE TO THE US



Regulation and Market Forces Change the Global Fuel Mix – Europe



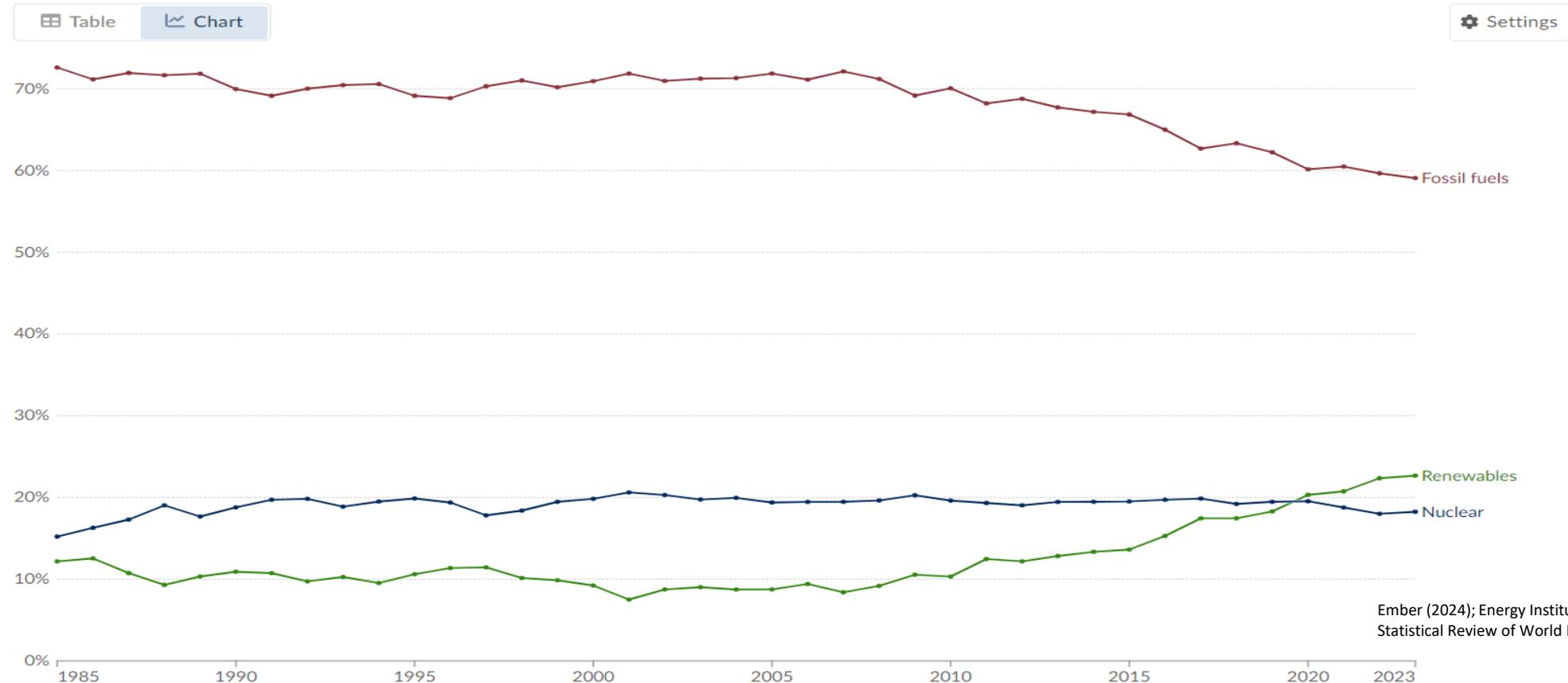
SUSTAINABILITY & RELEVANCE TO THE US



Regulation and Market Forces Change the Global Fuel Mix – United States

Share of electricity generation from fossil fuels, renewables and nuclear, United States

Our World
in Data



Ember (2024); Energy Institute -
Statistical Review of World Energy (2024)

SUSTAINABILITY & RELEVANCE TO THE US



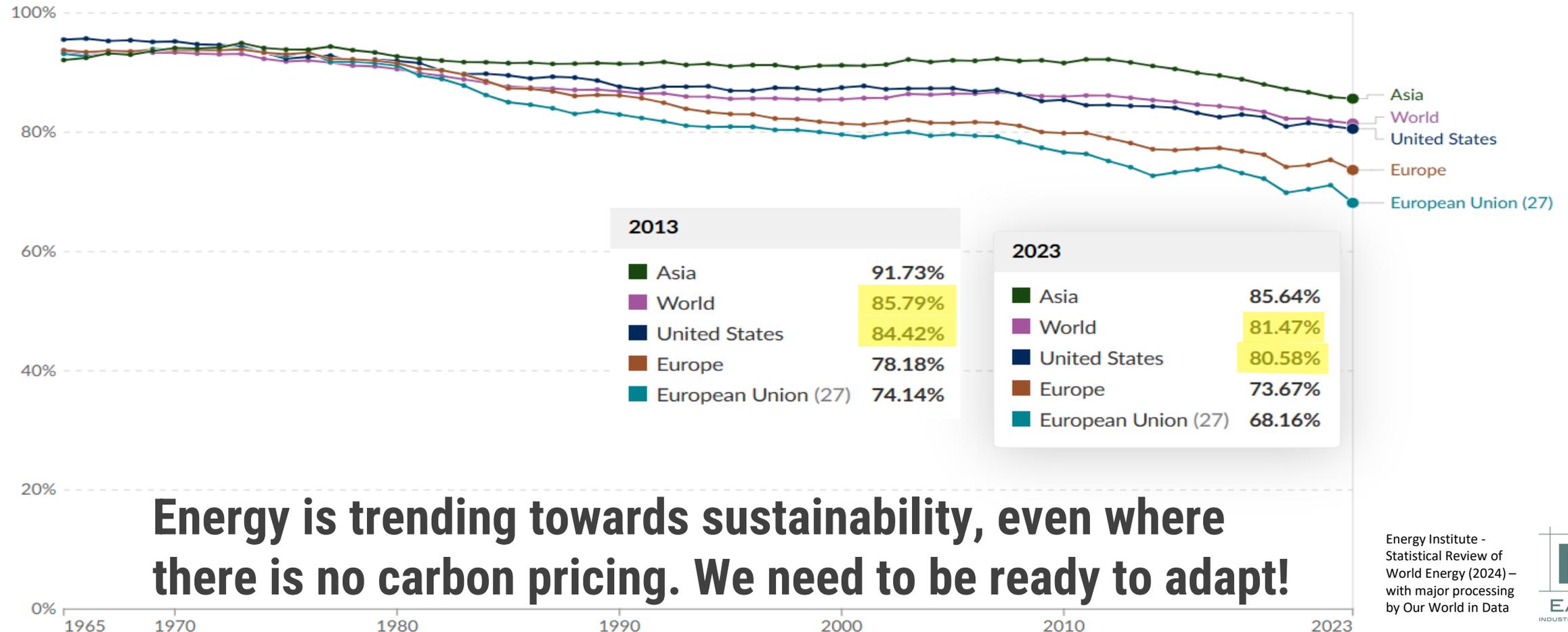
Share of primary energy consumption from fossil fuels

Measured as a percentage of primary energy, using the substitution method.

Our World in Data

Table | Map | Chart

Settings



Energy is trending towards sustainability, even where there is no carbon pricing. We need to be ready to adapt!

Energy Institute - Statistical Review of World Energy (2024) - with major processing by Our World in Data



SUSTAINABILITY & RELEVANCE TO THE US



....How?... Energy Efficiency and Process Optimization!

➤ Traditional Methods

- Focus on fundamentals: process efficiency and reducing fuel/power input costs.
- Improvements with positive, if small, ROI that we can do today.
- Many older factories with aging equipment due for replacement/upgrade.

➤ Modern Methods

- Focus on renewable energy and alternative revenue streams.
- Refined technologies for existing processes.

SUSTAINABILITY & RELEVANCE TO THE US



Consider: How would beet sugar carry on if fossil fuels were banned?

➤ **Future Methods**

- Focus on reducing or eliminating carbon emissions.
- New and outside the box solutions and processes.
- Cutting edge technology still being developed.



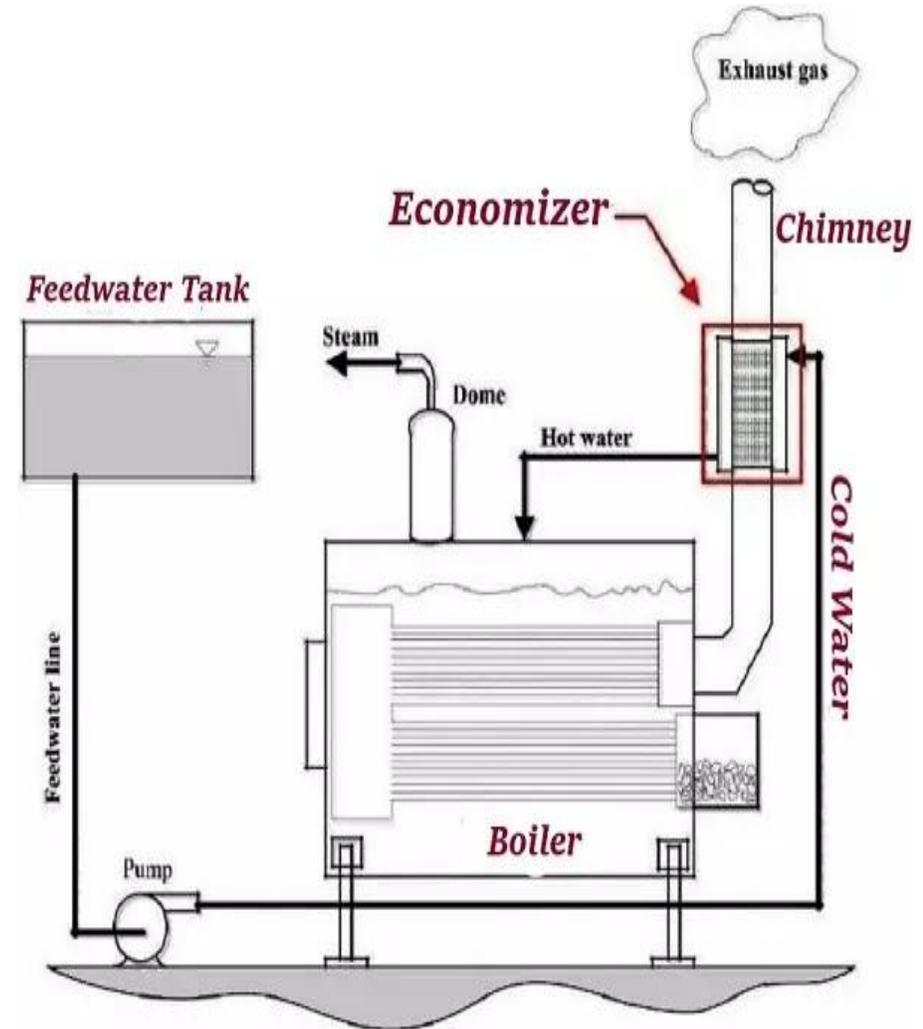
TRADITIONAL METHODS OF SUSTAINABILITY FOR BEET SUGAR FACTORIES

TRADITIONAL METHODS



Boiler Economizers

- Preheat boiler feedwater using flue gas (waste heat).
- Boiler efficiency gains of ~1% for every 40°F reduction in flue gas temperature.
- Can reduce fuel requirements by 5 to 10%, payback in as little as 2 years.



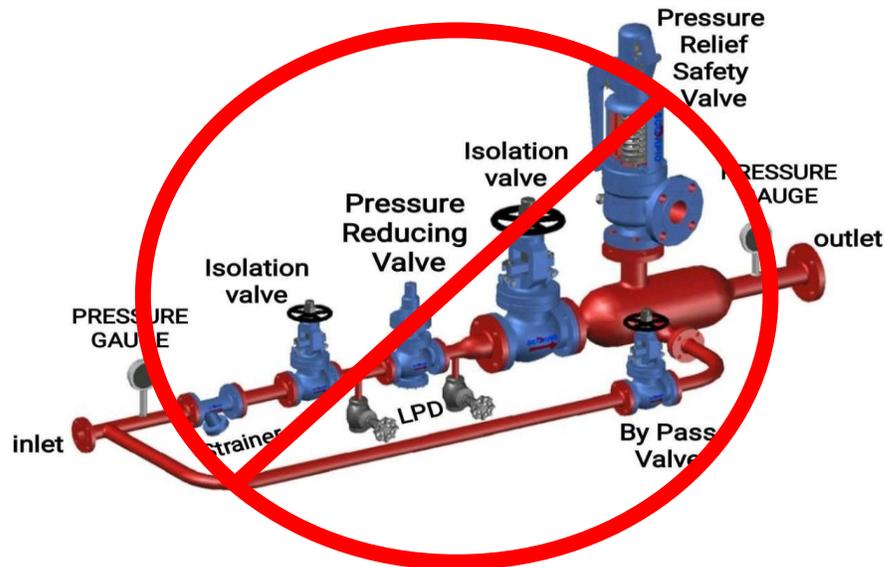
Waqar (2024); Boiler Economizers (2024)

TRADITIONAL METHODS

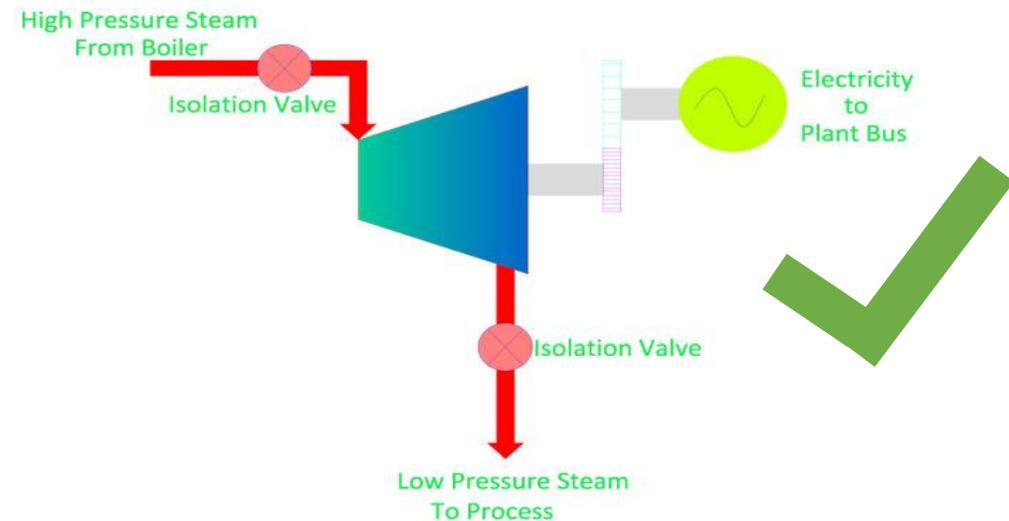


Turbine Generators

- Don't waste energy using knockdown valve stations for live steam...make electricity while you reduce the pressure!
- Small turbines (>25 MW) have come down in price, up in efficiency.
- Average payback 3 to 7 years.



Eldhose (2020); Pressure Reduction Assembly and Component (2025)



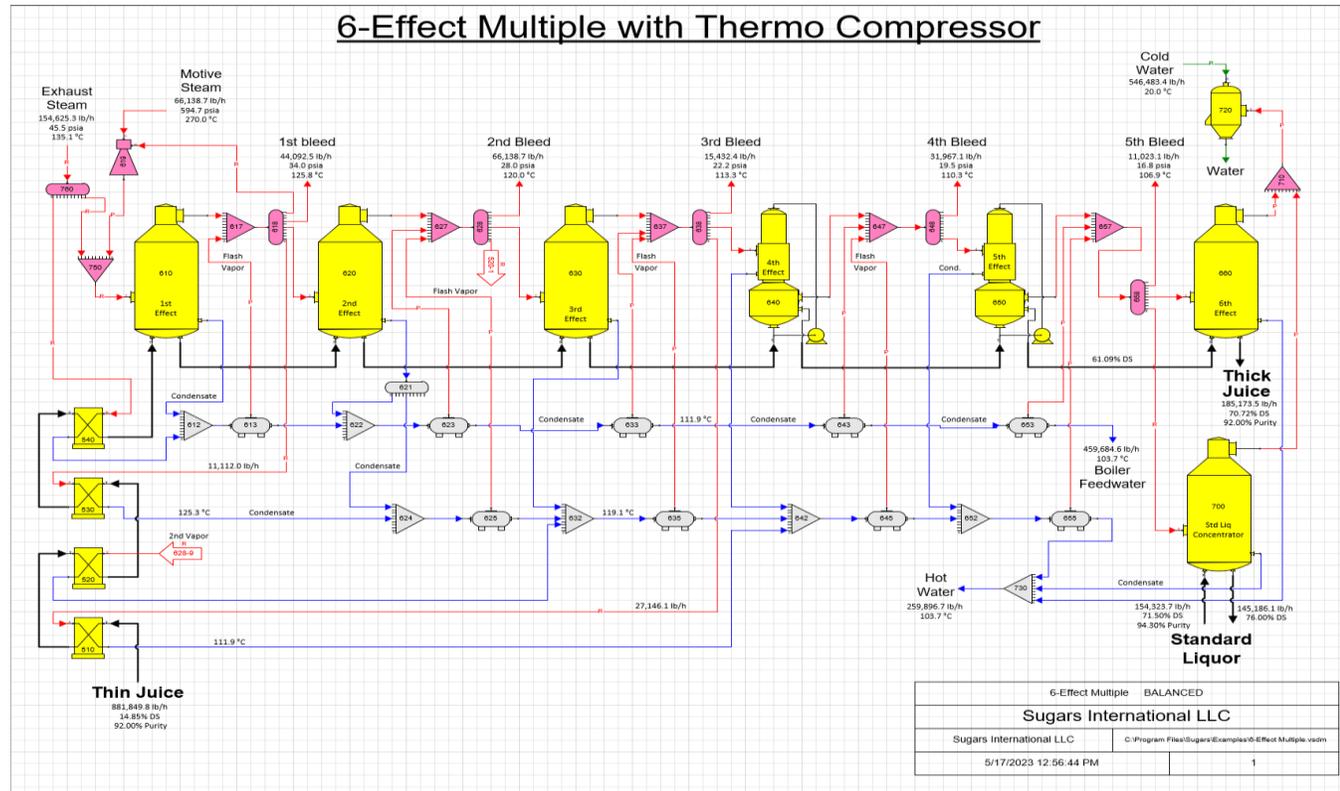
Turtle Turbines (2021); Pressure Reducing Turbine (2025)

TRADITIONAL METHODS



Multiple Effect Evaporator Trains

- Optimum number of effects increases with steam costs and overall plant throughput. Eight is the practical max for beets.

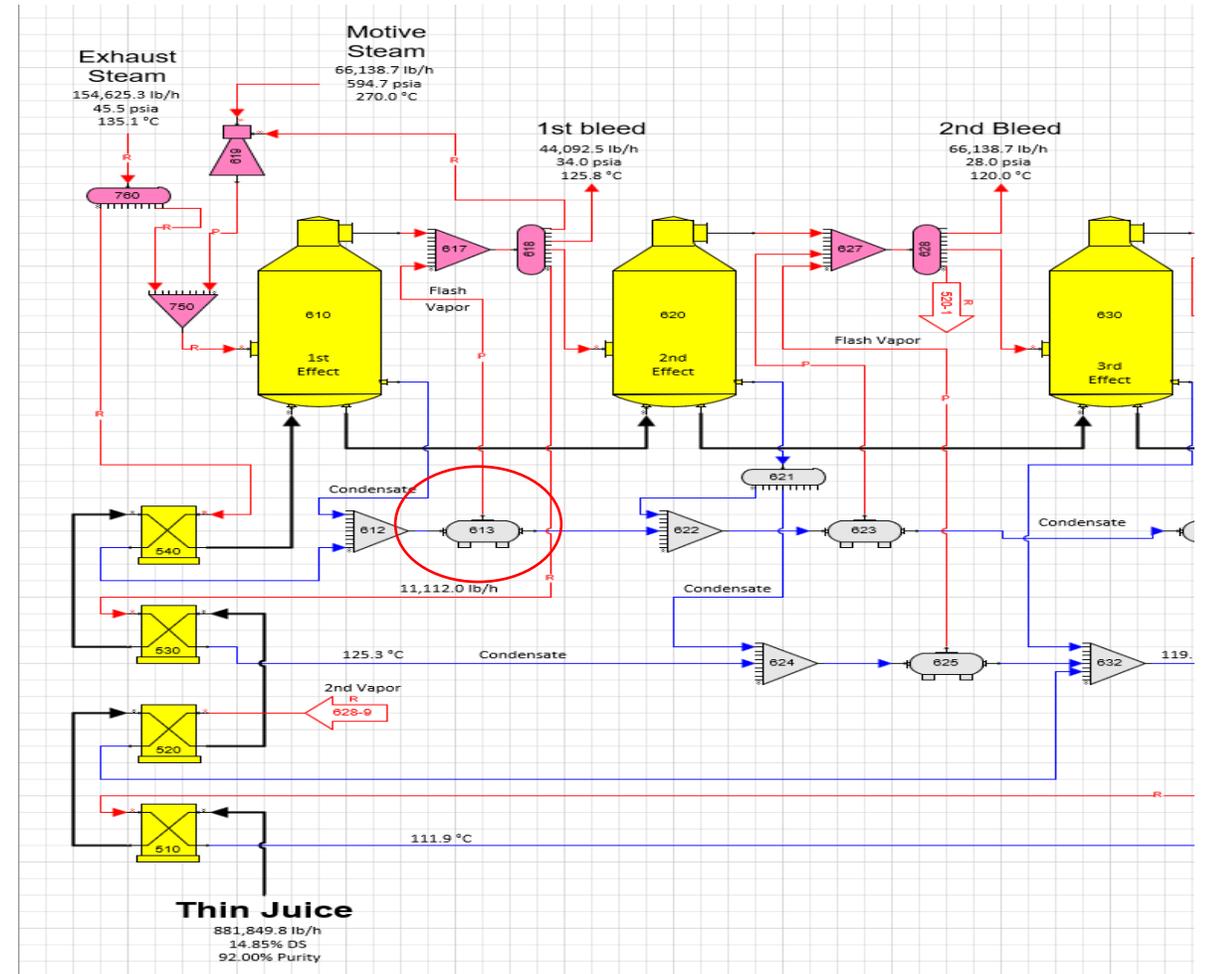


TRADITIONAL METHODS



Condensate Recovery

- Each vapor/effect should have its own flash tank to maximize energy recovery
- Payback depends on current energy efficiency, average 2 to 5 years.

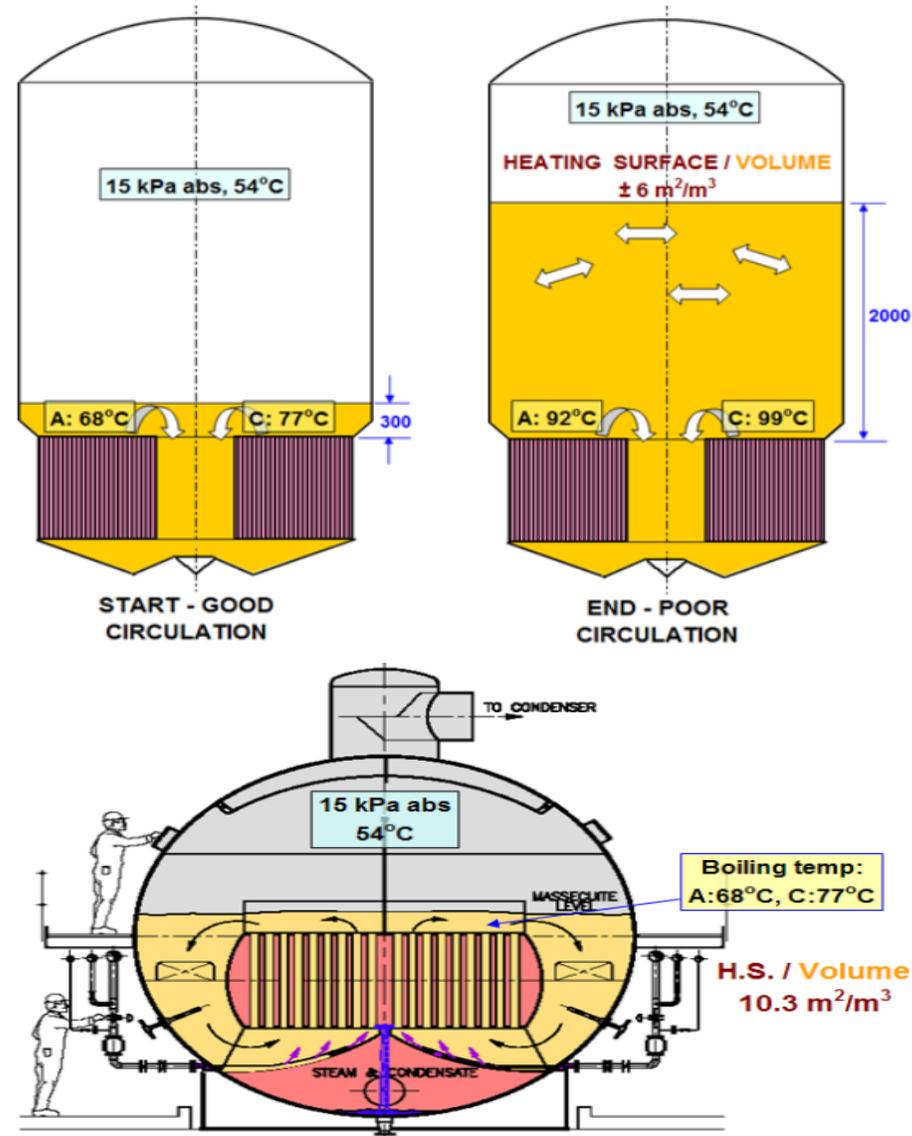


TRADITIONAL METHODS



Continuous Vacuum Crystallization

- High surface to volume ratios
- Low change in volume in a single cell = low hydrostatic head increases on calandria = lower boiling rise and better circulation.
- Low pressure steam gives lower temperature differential between steam and massecuite, higher OHTC.
- Overall, can shift down one or two grades of vapor compared to batch.



TRADITIONAL METHODS



(Downward) Vapor Shifting

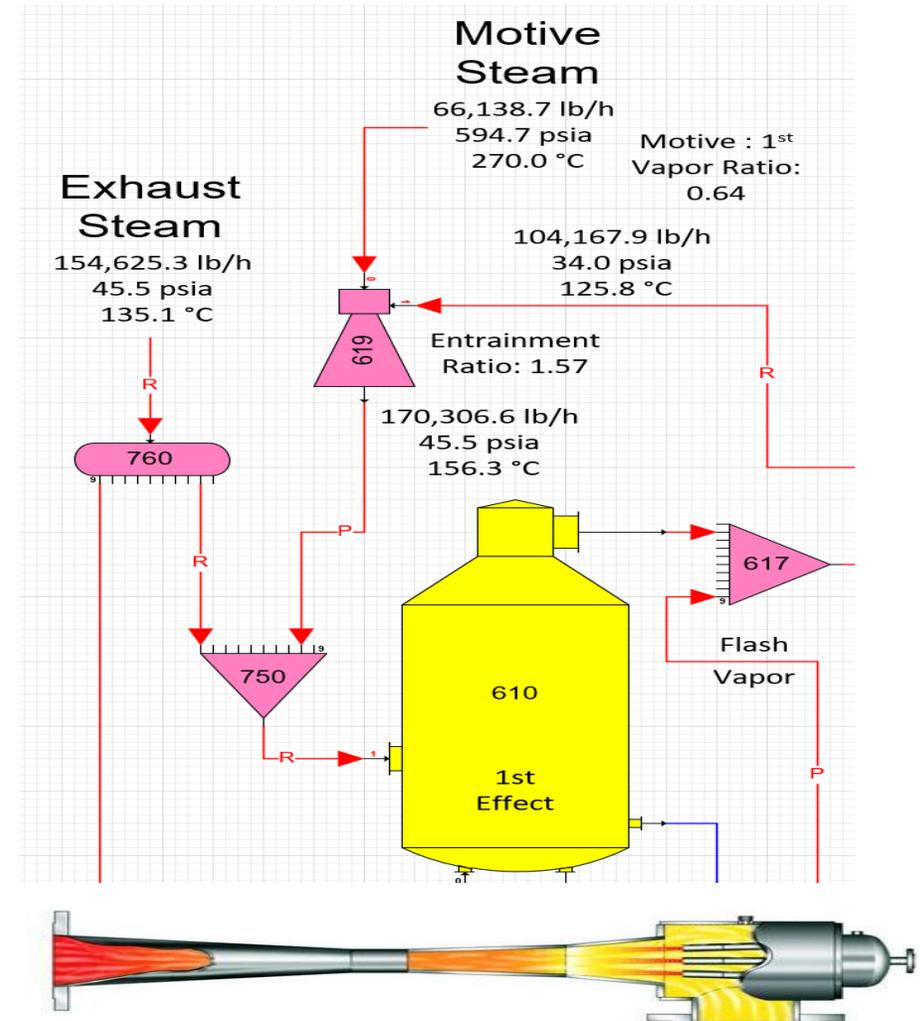
- Use the lowest vapor possible for process heating.
 - It is entirely possible to use only 4th Vapor and below.
 - Except Thin Juice Heaters and 3rd vapor for trim on frozen beets.
 - High efficiency requires a balanced evap train, steam network, and process heaters.
- ***Take full advantage of your multi-effect train!***
- Vapor shifting is ultimately what reduces steam demand and saves money on fuel.

TRADITIONAL METHODS



Thermal Vapor Recompression

- Uses small flow of live steam to upgrade a higher flow of lower-pressure steam to mid-pressure.
- Roughly equal efficiency to another evaporator effect, cheaper, smaller.
- Great for plants if:
 - Excess boiler, limited evap. and/or turbine.
 - Electricity is relatively costly vs boiler fuel.
 - Generally, true in US.



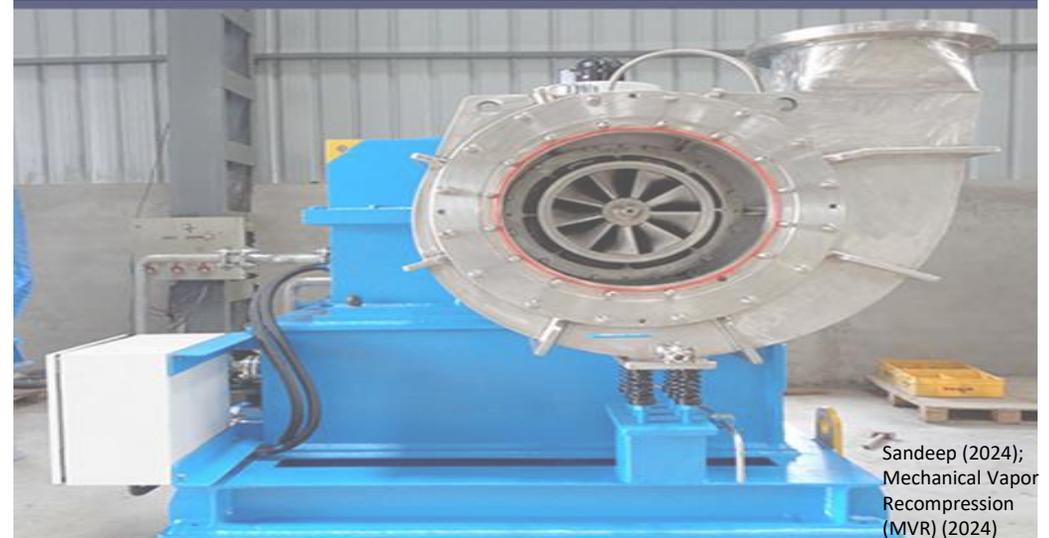
Minton (2010); TVR (2024)

TRADITIONAL METHODS

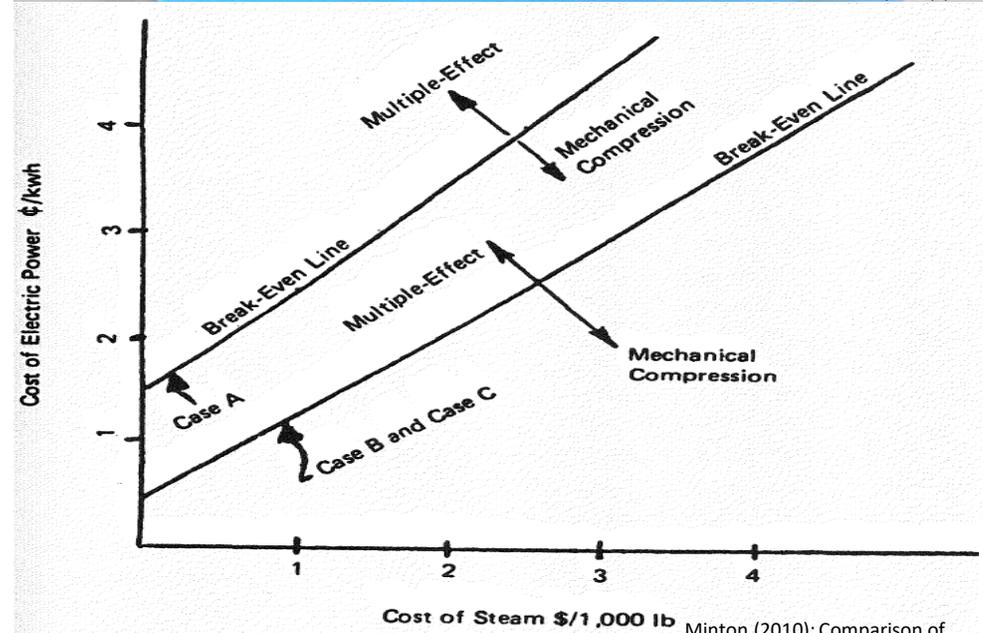


Mechanical Vapor Recompression

- Uses electricity to run a compressor to upgrade lowest pressure steam to a higher pressure.
- Great for plants if:
 - Boiler is at capacity, footprint limited.
 - Electricity is relatively cheap vs boiler fuel.
 - Generally, not true in US.



Sandeep (2024);
Mechanical Vapor
Recompression
(MVR) (2024)



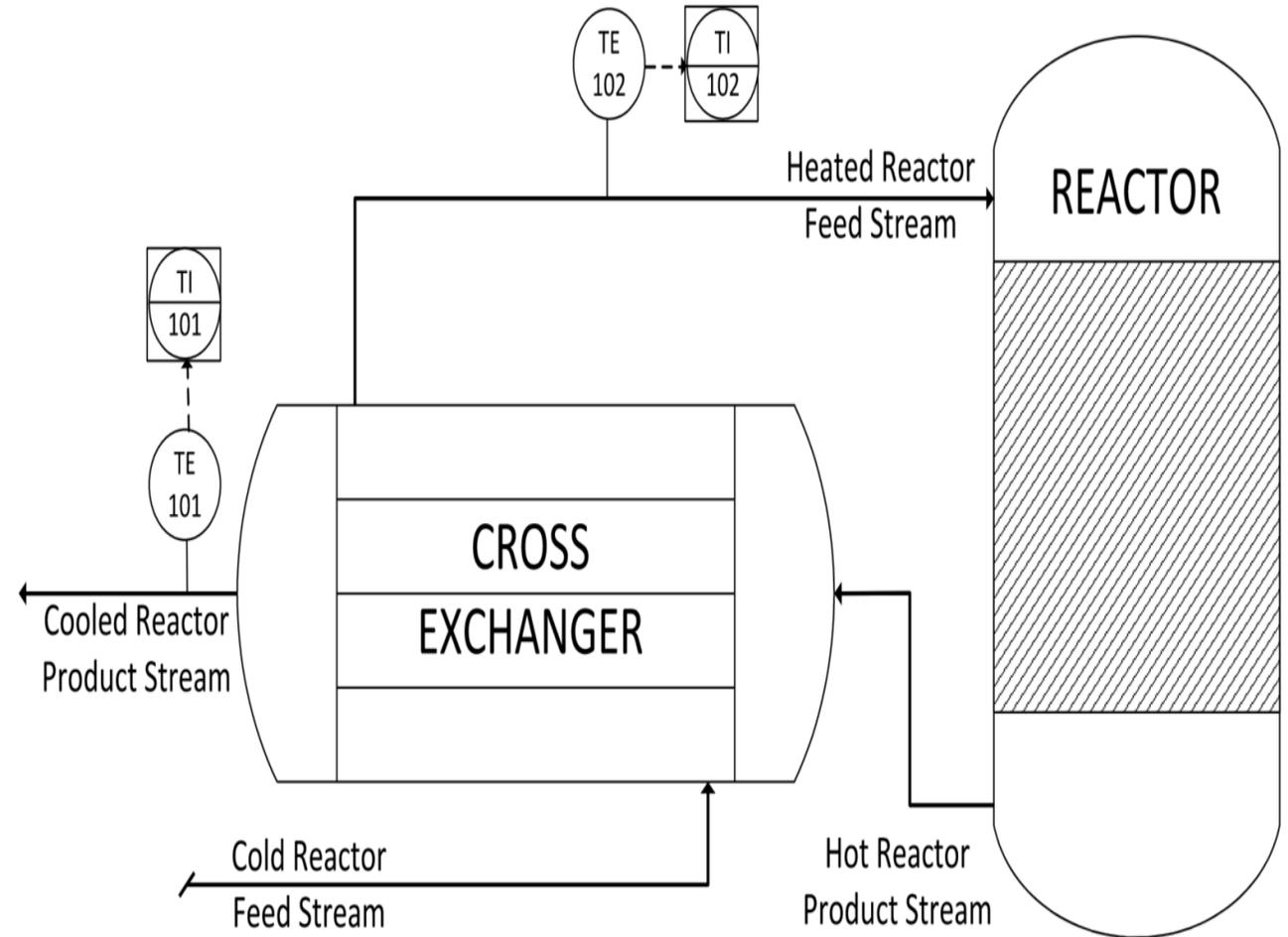
Minton (2010); Comparison of
vapor compression systems and
multiple effect systems (2024)

TRADITIONAL METHODS



Process Cross-Exchange Heaters

- Pre-heat or cool fluids with themselves, or across processes.
- Example: Cross exchange pasteurized and unheated pressed pulp water before introduction to diffuser.



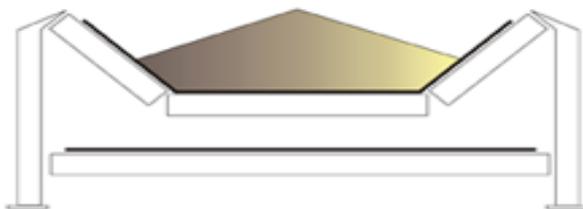
Seams (2023); Designing Controls for the Process Industries (2025)

TRADITIONAL METHODS

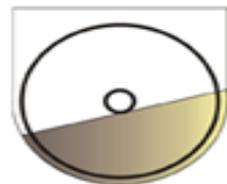


Optimal Equipment Selection

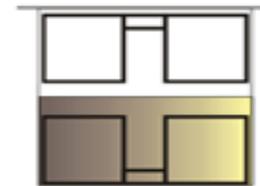
- Generally: En-masse drag conveyors more power efficient than belts, belts more power efficient than screws.
 - Space efficiency does not necessarily follow.
- Energy efficiency is just one of many competing needs.



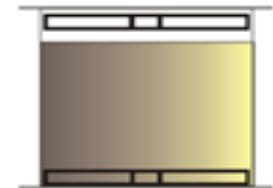
Belt Conveyor
20-25%



Screw Conveyor
45%



Paddle/Drag Conveyor
45-50%



EnMasse Conveyor
90%

Comparison of effective utilization of space versus physical size of conveying media

TRADITIONAL METHODS



Optimal Equipment Selection (cont'd)

- In general, agitators are ~5x more efficient for mixing than pumped recirculation.
- If already pumping into a tank, consider eductor nozzle system on the inlet instead. Free mixing!



Cleveland Mixer (2024); Right Angle Top Entry Mixers (2024)



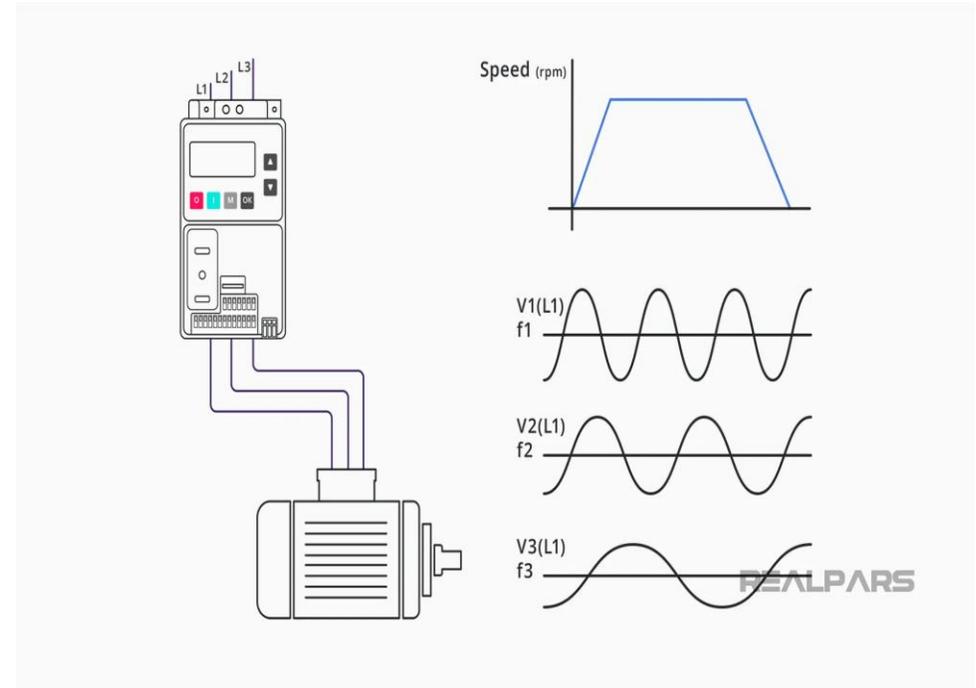
SNP (2024); Positioning of Eductor Nozzles (2024)

TRADITIONAL METHODS



Variable Frequency Drives (VFDs)

- Minimizes power use by running motors at lower speed.
- Nominally 40 to 60% more efficient than traditional starters.
- Local utilities may offer rebates for VFD installs and continued use.



Tomoto (2022) VFD Basics (2024)

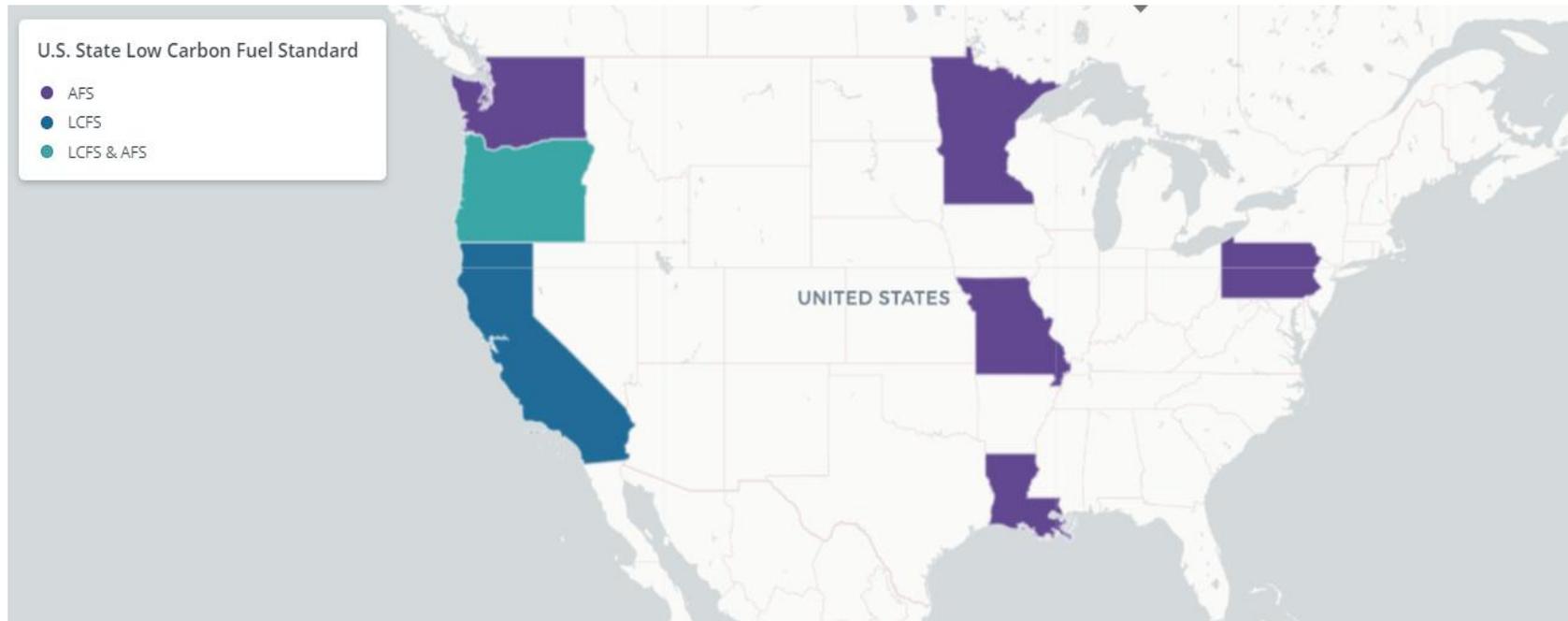


MODERN METHODS OF SUSTAINABILITY FOR BEET SUGAR FACTORIES

MODERN METHODS

Partner with Low CI Fuel Producers

- States are developing low carbon and alternative fuel standards.
- Starchy/sugary ag waste is a highly sought after feedstock.



C2ES (2024) Low Carbon and Alternative Fuel Standard (2024)

MODERN METHODS

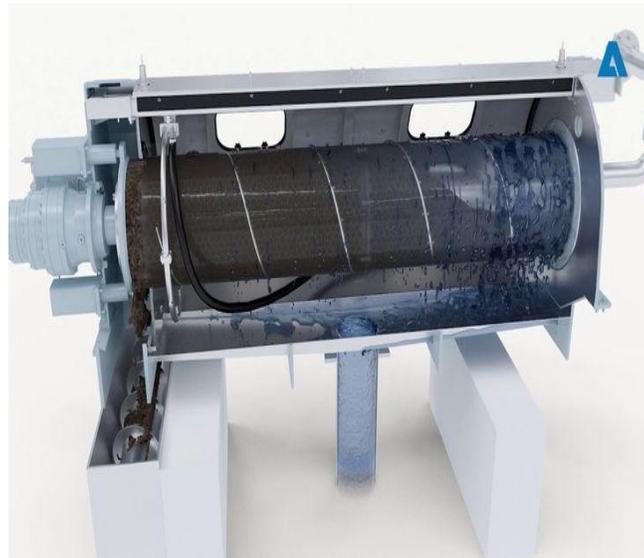
Partner with Low CI Fuel Producers (cont'd)

- Giving away waste product is better than paying to dispose of it, selling is best.
- What products do ethanol producers want?
 - Whole beets, even if degraded.
 - Beet chips (but not weeds).
 - Maybe dumped wet and pressed pulp.

MODERN METHODS

Value-added Wastewater Treatment

- Treat wastewater in a digester system to produce biogas and low BOD water.
- Pretreat: Separate solids from water. Give away or sell as fertilizer instead of filling pond.
- Post-treat: Compost removed sludge, sell as premium fertilizer. Easier transport, too!



Andritz (2023); C-Press Screw Press (2024)



Guberman (2020); What is Commercial Composting and How Can Cities Manage Organic Waste? (2024)

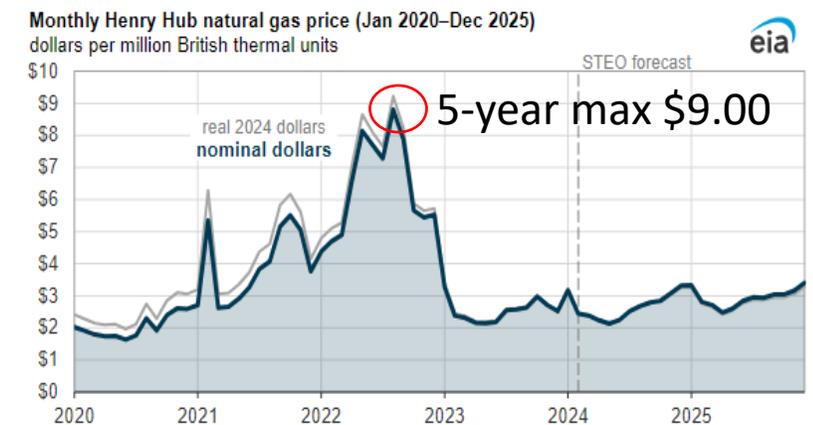
MODERN METHODS

Biogas and Renewable Natural Gas (RNG)

- Anaerobic digestion of pulp, tailings, molasses, raffinate/CSB, and other by-products to create methane.
- Burn gas to make green electricity/steam, or upgrade and sell to utility.
- Next crop absorbs carbon emitted, net zero.
- Price premiums for RNG available in certain markets
Varies by market, Average \$20-30/MMBTU.
- \$100/MMBTU have been seen for short term contracts.



AB Group (2023); Biomethane Festival and Inauguration of the Largest Biomethane Plant in Europe(2024)



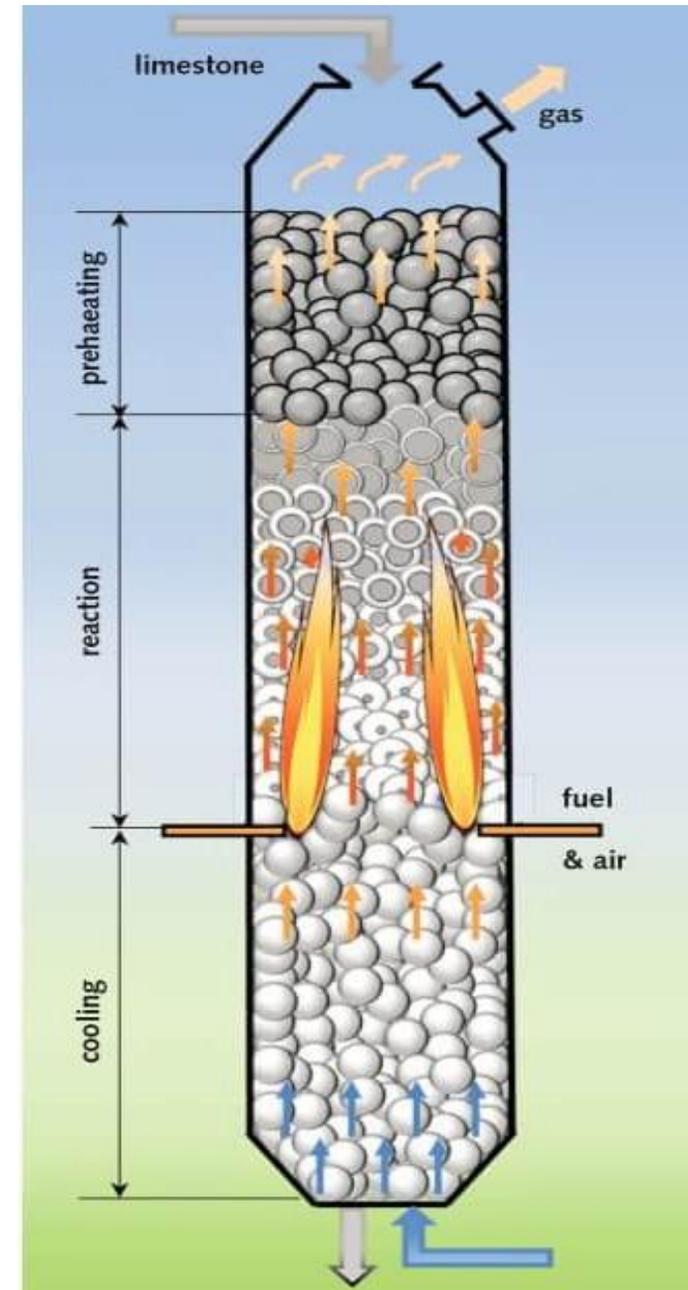
US EIA (2024); Short-Term Energy Outlook (2024)

MODERN METHODS



Natural Gas Lime Kilns

- Natural gas has 20% lower energy density than coke (by mass) but produces 30% fewer emissions.
 - Current avg US price per MMBTU:
 - Coke: \$12
 - Gas: \$3.50
- If biogas/RNG used, kiln is considered carbon neutral or negative.
 - CO₂ from lime kiln ultimately bound as calcium carbonate in purification, not emitted.



Rotary Kiln (2024) Environmental Protection Vertical Kilns (2024)



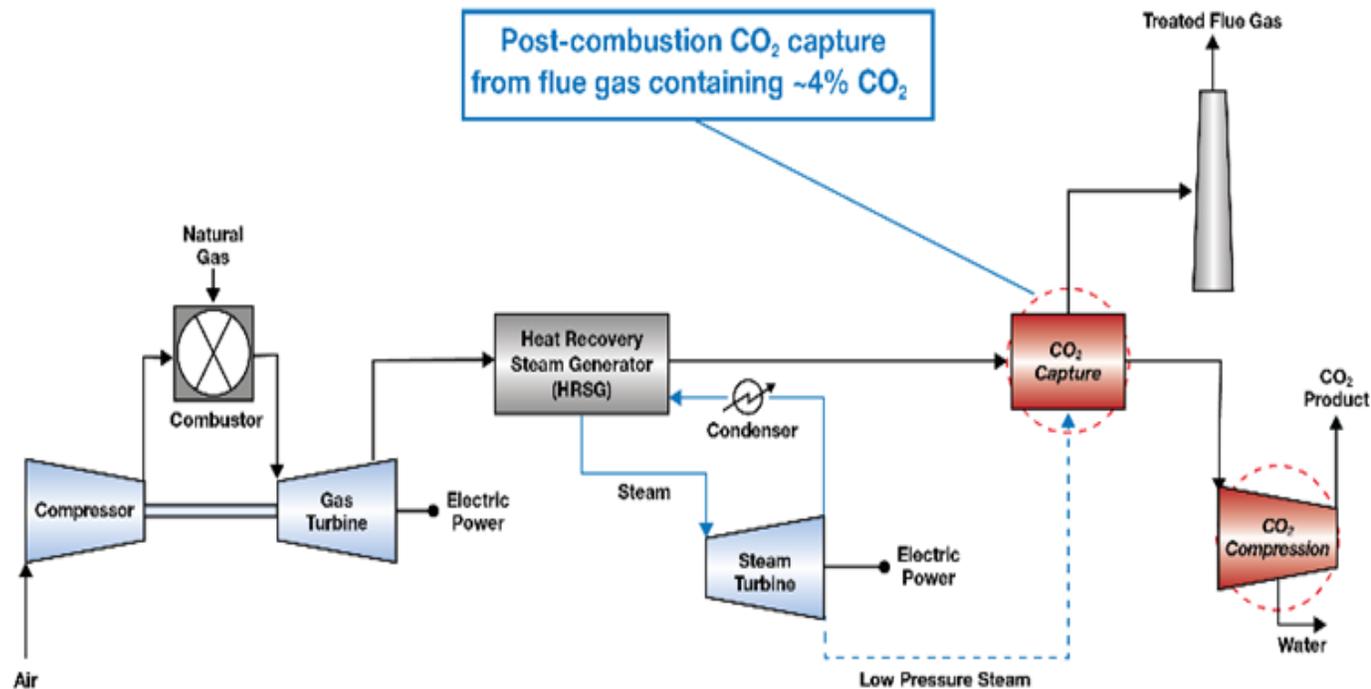
FUTURE METHODS OF SUSTAINABILITY FOR BEET SUGAR FACTORIES

FUTURE METHODS



Carbon Capture & Sequestration

- Capture CO₂ emissions at point of release where it is concentrated.
 - Point source capture is far easier than pulling it from atmosphere in diffuse form.

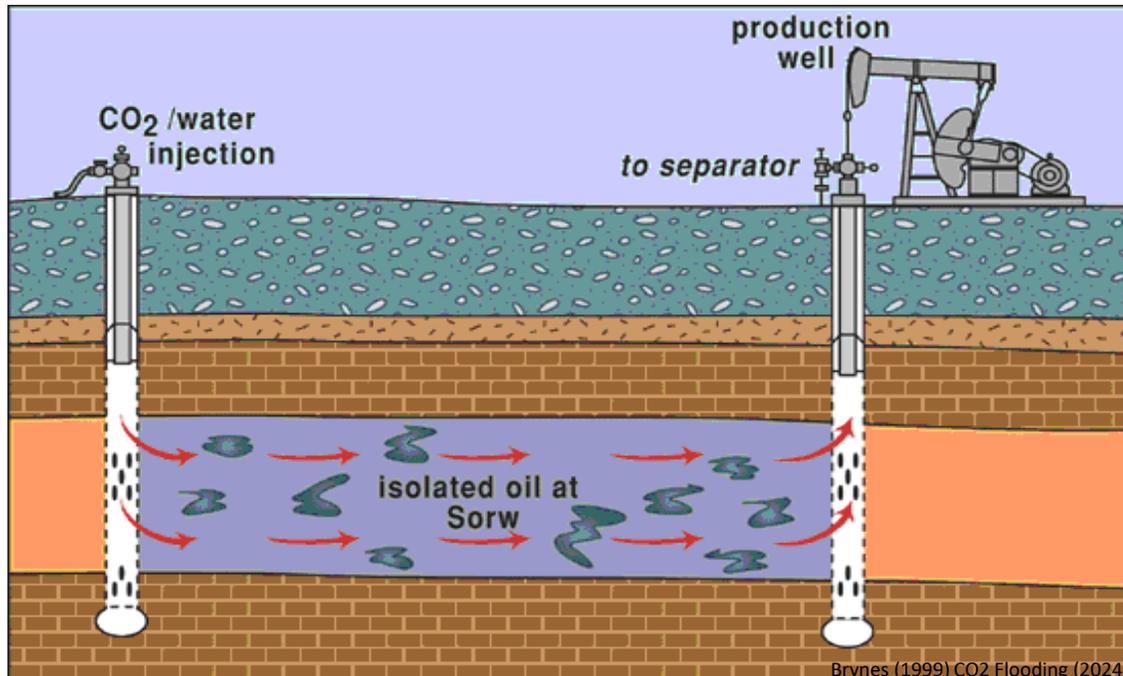


FUTURE METHODS



Carbon Capture & Sequestration (cont'd)

- CO₂ can be compressed and sold for value added products.
- Can be sequestered underground on site if local geology is appropriate.
- This technique allows sugar industry to operate without changing our core processes.

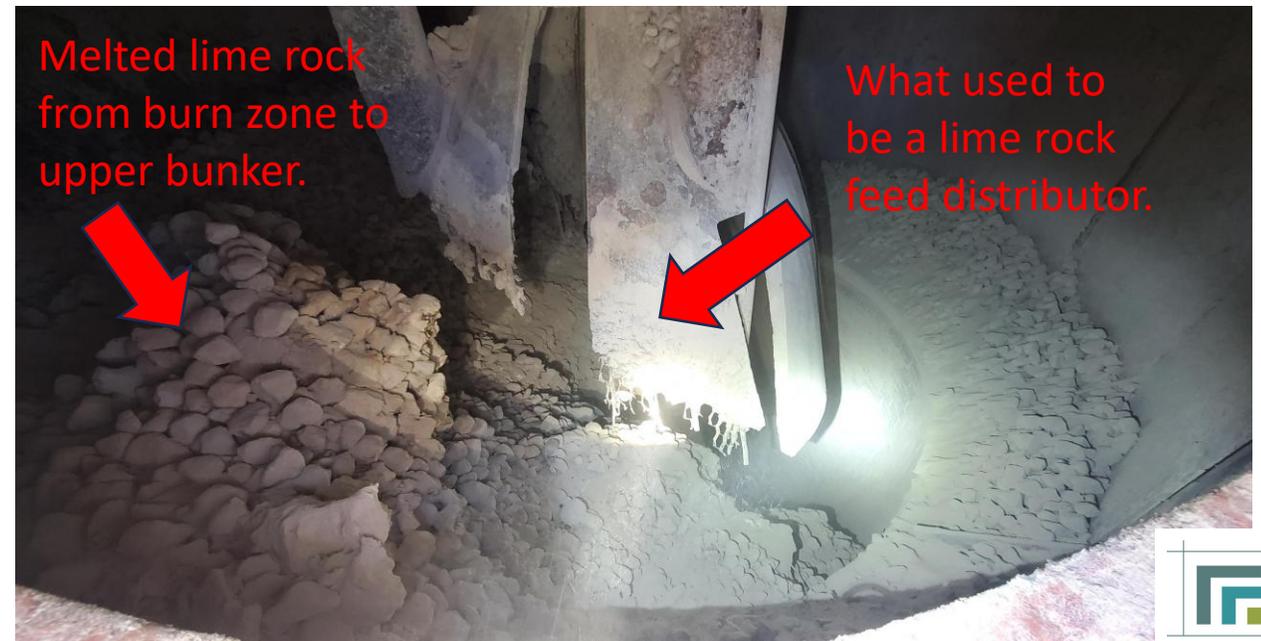
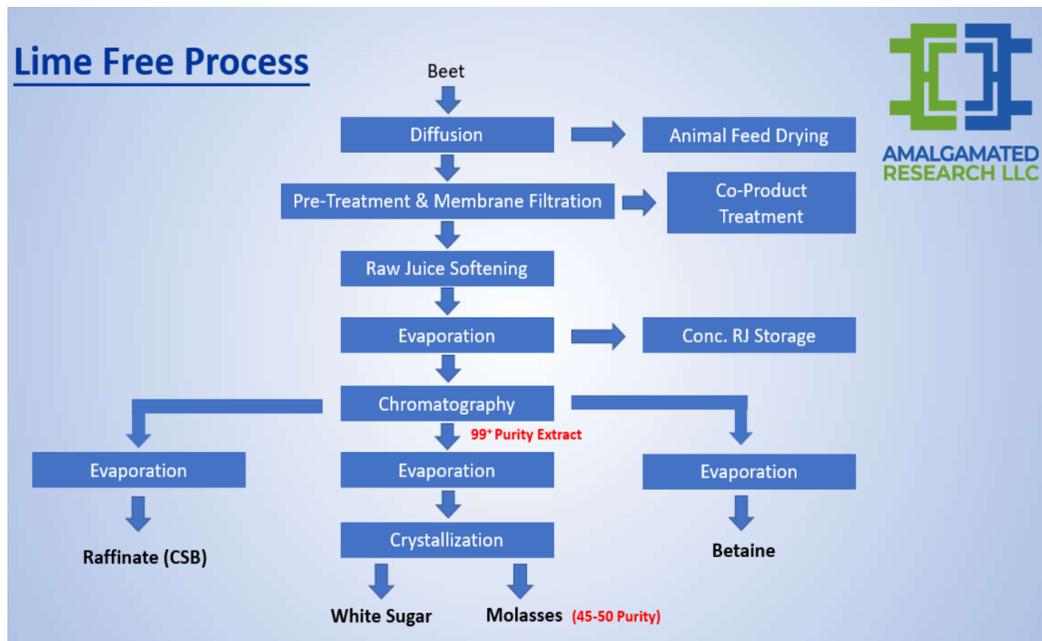


FUTURE METHODS



Alternatives to Fossil-Fuel Power – Limeless Purification Systems

- Eliminates kiln, milk of lime system, carbonation/purification station and associated heat exchangers.
- Currently proven at pilot scale, working to industrialize.



FUTURE METHODS



Alternatives to Fossil-Fuel Power– Beet Pulp Fuel (Direct Fired)

- Cane industry already burns bagasse for fuel.
- Pulp can be burned in minimally or unmodified stoker boilers.

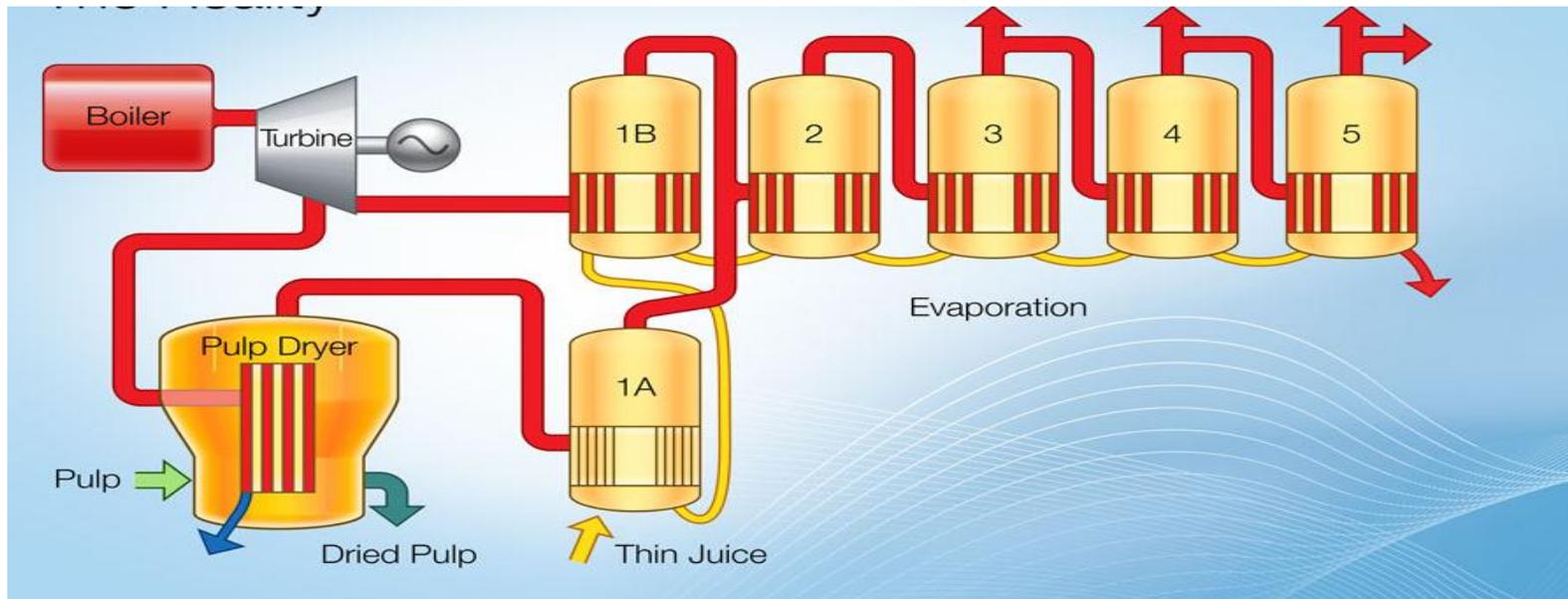
Fuel	Calorific Value (BTU/lb)	
BEET PULP	7,000 to 8,000 4,000 to 5,000 1,400 to 2,300	@ 80 – 90 % DS (dry pulp) @ 30 – 40% DS (pressed pulp) On as-fired basis (wet pulp)
CANE BAGASSE	7,000 to 9,000 3,000 to 4,000	@ 80 – 90% DS (dried bagasse) On as-fired basis (wet bagasse)
PRB Coal (Subbituminous)	8,000 to 9,500	@ 70% DS (standard)

FUTURE METHODS



Alternatives to Fossil-Fuel Power – Beet Pulp Fuel (Direct Fired) (cont'd)

- Theoretical case: At 4.25% fuel OB and 5.25% pulp OB, pulp at 10% DS can provide all energy for plant steam demand if burned in boilers.
- Mature solution involves steam dryer to increase heating value of pulp.

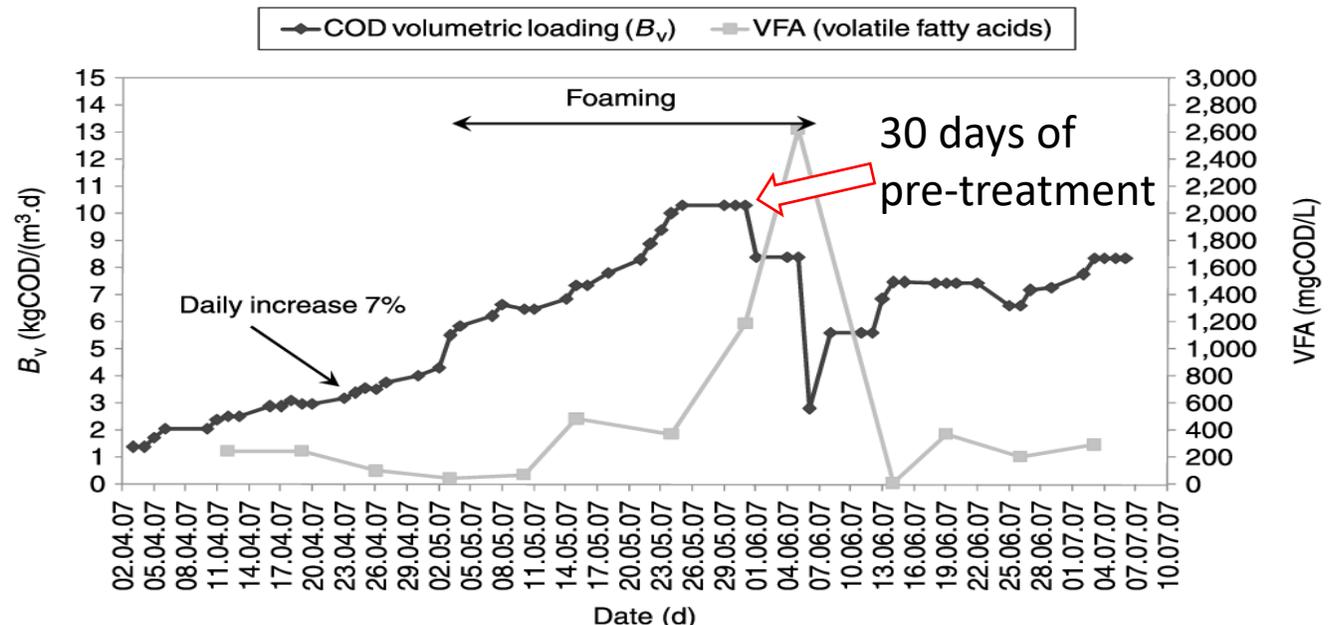


FUTURE METHODS



Alternatives to Fossil-Fuel Power – Beet Pulp Gasification

- High-temperature pulp drying in traditional rotary drums accounts for 50% of energy used in plant and 25-30% of emissions on average.
- May be more energy efficient to convert pressed pulp to biogas and burn in boilers.
- Yield ~1 MMBTU biogas per 630 tons of pressed pulp.
- Working to improve this with pre-treatment.



Brooks, et al. (2008) Biogas from sugar beet press pulp as a substitute of fossil fuel in sugar beet factories (2024)

FUTURE METHODS



Alternatives to Fossil-Fuel Power – MDS By-product Fuels (Biogas)

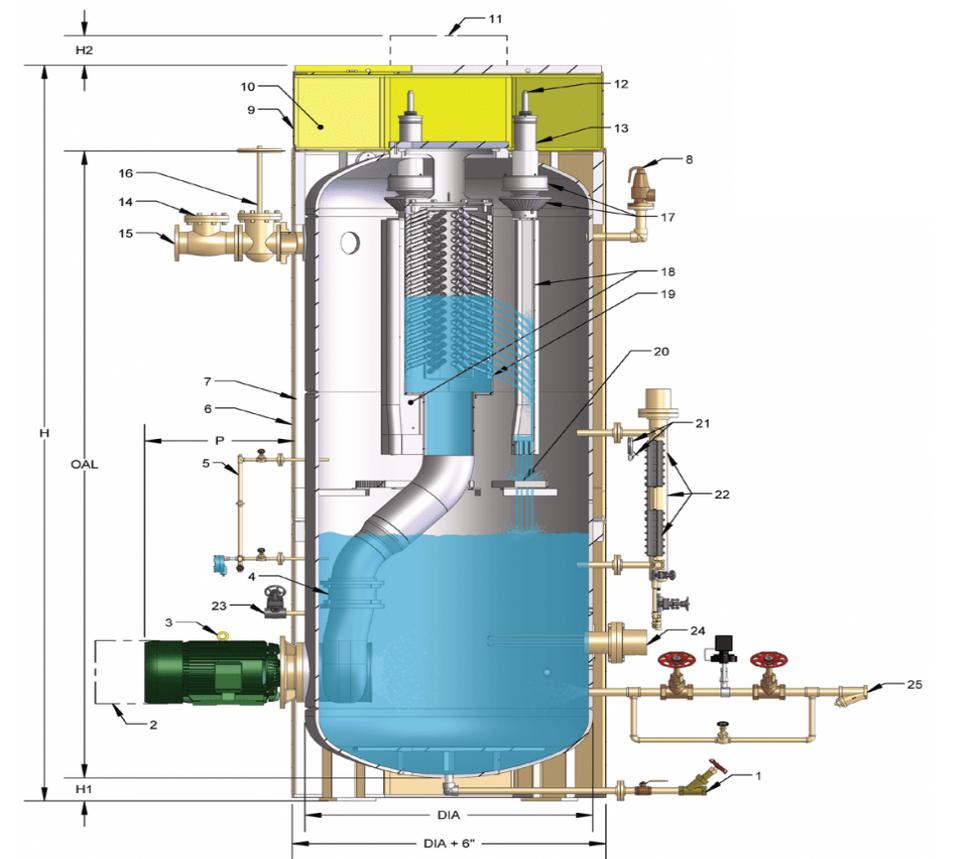
- Biogas from concentrated separator by-product (CSB) or raffinate
 - Thermal energy yield ~3.7 MMBTU/US ton.
- Roughly 2,500 tons of raffinate per day gasified needed to power a 4.25 standard fuel on beet plant slicing 10,000 tpd.
- Multiple plants (~40,000-50,000 tpd slice) sending molasses to a centralized MDS will produce enough CSB to fully power one plant.

FUTURE METHODS



Electrification – Equivalent Equipment

- Industrial-grade electric replacements for most sugar equipment already exist and is at or close to scale required.
 - Boilers, heat exchangers, kilns, pulp and sugar dryers.
- Gives another option to keep industry going without much change to the core processes.



- | | | |
|----------------------------------|-------------------------------|-------------------------------|
| 1 - Blowdown Valves | 10 - Conduit Entrance Panel | 19 - Nozzle Header Assembly |
| 2 - Pump Removal Clearance | 11 - Header Removal Clearance | 20 - Counter Electrode |
| 3 - Circulation Pump w/VFD | 12 - Conductor Rod | 21 - Pressure Manifold & Gage |
| 4 - Check Valve | 13 - High Voltage Insulators | 22 - Water Column & Gage |
| (for multiple pumps only) | 14 - Back Pressure Regulator | 23 - Surface Blowoff |
| 5 - Conductivity Cell | 15 - Steam Outlet | 24 - Standby Heater |
| 6 - Sheet Metal Enclosure | 16 - Non-Return Valve | 25 - Feedwater Valve w/Bypass |
| 7 - Insulation | 17 - Insulator Shields | 26 - Manhole |
| 8 - Safety Valves (2) | 18 - Electrode/Strike | |
| 9 - Electrode Terminal Enclosure | Plate Assembly | |

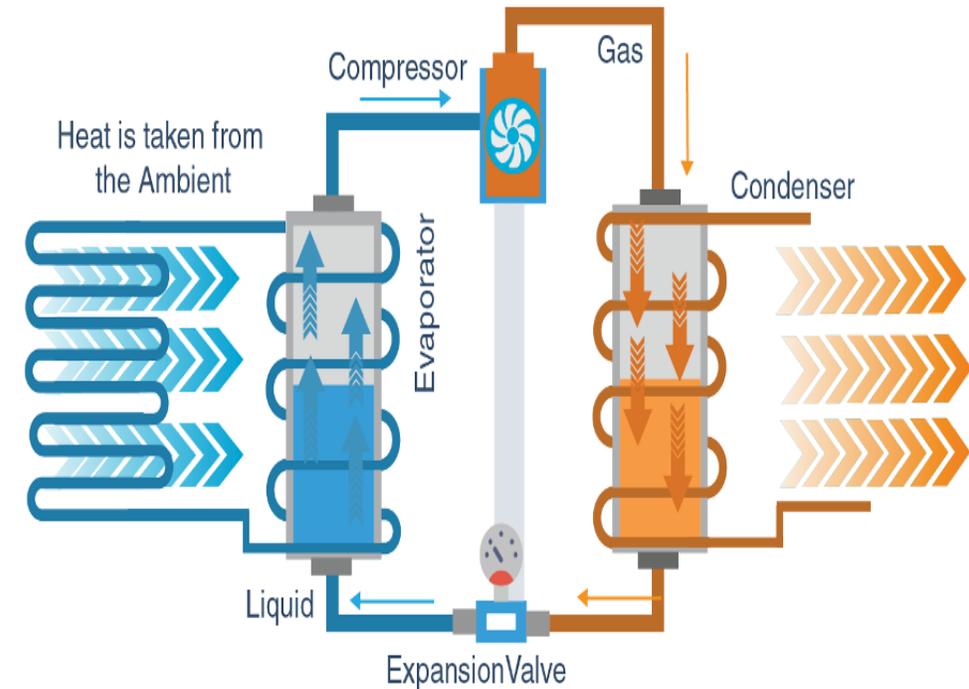
Precision Boilers (2024) HVJ Jet Type Electrode Boiler(2024)

FUTURE METHODS



Electrification – New Energy Efficiency Tools

- Heat pumps use electricity to pull heat from a colder fluid and force it to vent to hotter fluids.
 - Industrial units are new to the market, Coefficient of Power up to 4:1.
 - 1 kW of electricity input yields 4 kW of heat.
 - Current lift temps up to 200°C, unit capacities up to 50 MW (170MM BTU/h)
- Sugar application: pull energy from last condensate/seal water (waste heat) and heat a closed-recirc loop for process heating.



$$\begin{matrix} \text{Heat is taken from} \\ \text{the Ambient} \\ \text{(Free 2-3 kW)} \end{matrix} + \begin{matrix} \text{1kW of grid} \\ \text{Electricity} \end{matrix} \sim \begin{matrix} \text{3~4 kW of} \\ \text{Heat} \end{matrix}$$

Aspiration Energy (2024) Heat Pumps (2024)

FUTURE METHODS

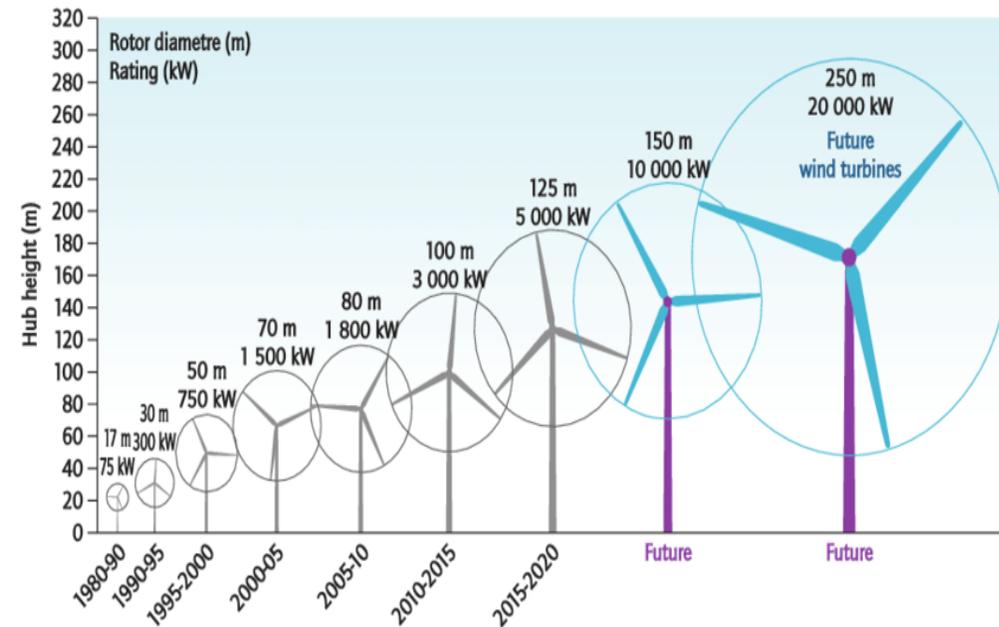


Electrification – Onsite Green Power Production

- The price of electricity will rise due to huge increase in demand if nation de-carbonizes.
 - ROI for all energy efficiency and production projects increases with electrical cost.
 - Invest in solar and/or wind to generate zero carbon power onsite.



Akuo Energy (2018) 17 MW of Trina Solar PV Modules, Piolen, (France) (2024)



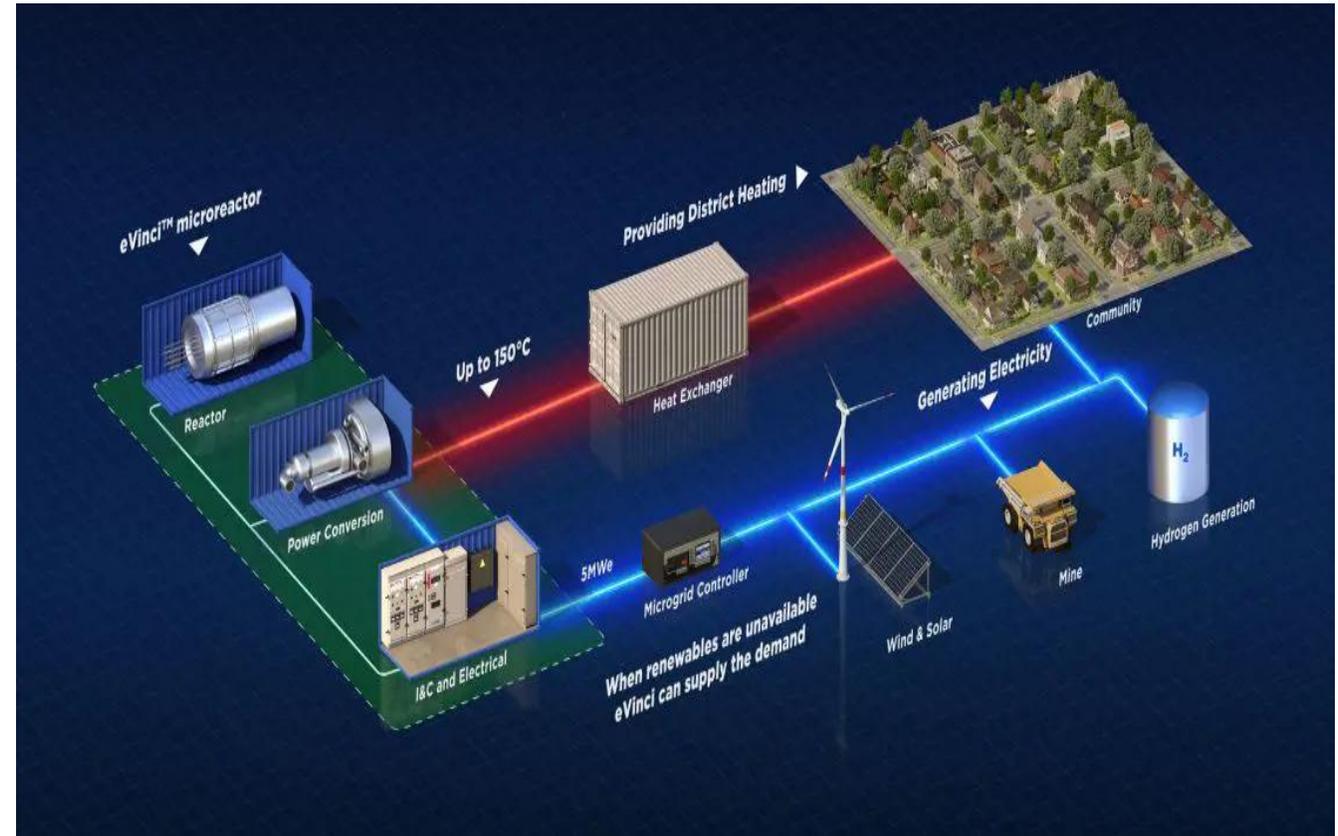
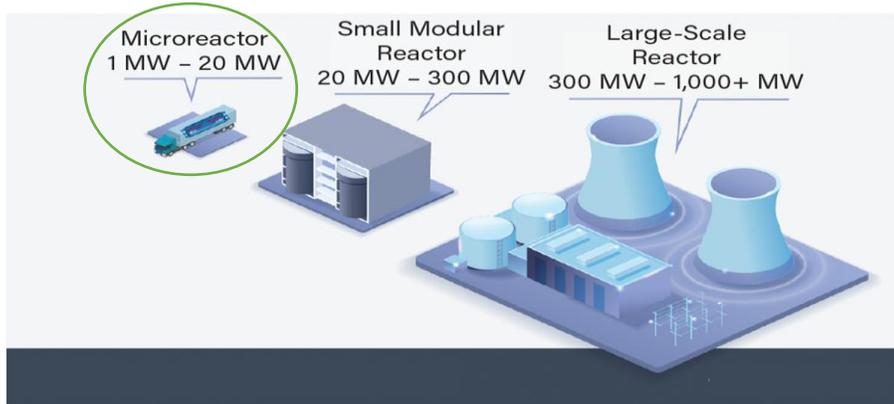
Johnson (2020) Wind Power Turbine Sizes (2024)

FUTURE METHODS



Electrification – Nuclear Power

➤ Three companies have made good progress on micro nuclear reactors, testing 2026.



WRAPPING UP



Sustainability – The Why

- Need to be ready for anything the markets and/or government dictate

Energy Efficiency – The How

- Traditional: Fundamentals first
- Modern: Renewable energy and alternative revenue streams
- Future: Complete decarbonization and transformative new tech

Remember The Goal

- \$\$\$
- We can't do anything at all if we aren't profitable



Questions?

