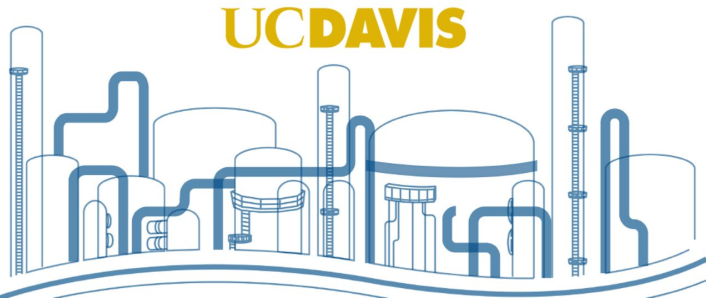
Panel 2- R&D Opportunities in thermal efficiency, generation, and storage

Panelists

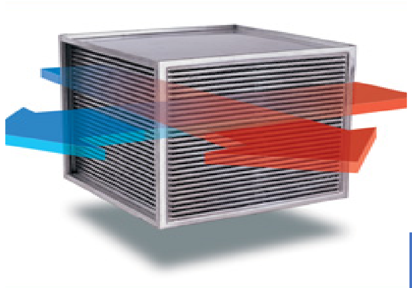
- *Andy Hooper, Brewmaster, Seismic Brewing*
- *Tom Maulhardt, Campbell Soup Supply Company*
- *Alan Rossiter, University of Houston*
- *Kevin Uy, CA Energy Commission*
- *Joel Zimmer, Salt Lake City Energy Management Engineer, Chevron*

Moderator

Vinod Narayanan
Associate Director, WCEC
Professor, Mechanical and Aerospace Eng.



UCDAVIS
Energy and Efficiency Institute

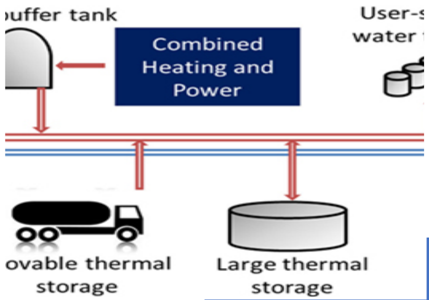


Thermal Efficiency

- Heat exchangers
- Waste heat recovery
- Insulation
- Controls
- Pre-cooling
- Evaporative cooling
- Building envelope efficiency
- Refrigeration efficiency
- HVAC efficiency
- Multi-effect evaporators

Thermal Generation

- High efficiency boilers; low NOx combustion
- Combined cooling heat and power (CCHP)
- Power cycles that use waste heat
- Solar thermal
- Solar PV + thermal

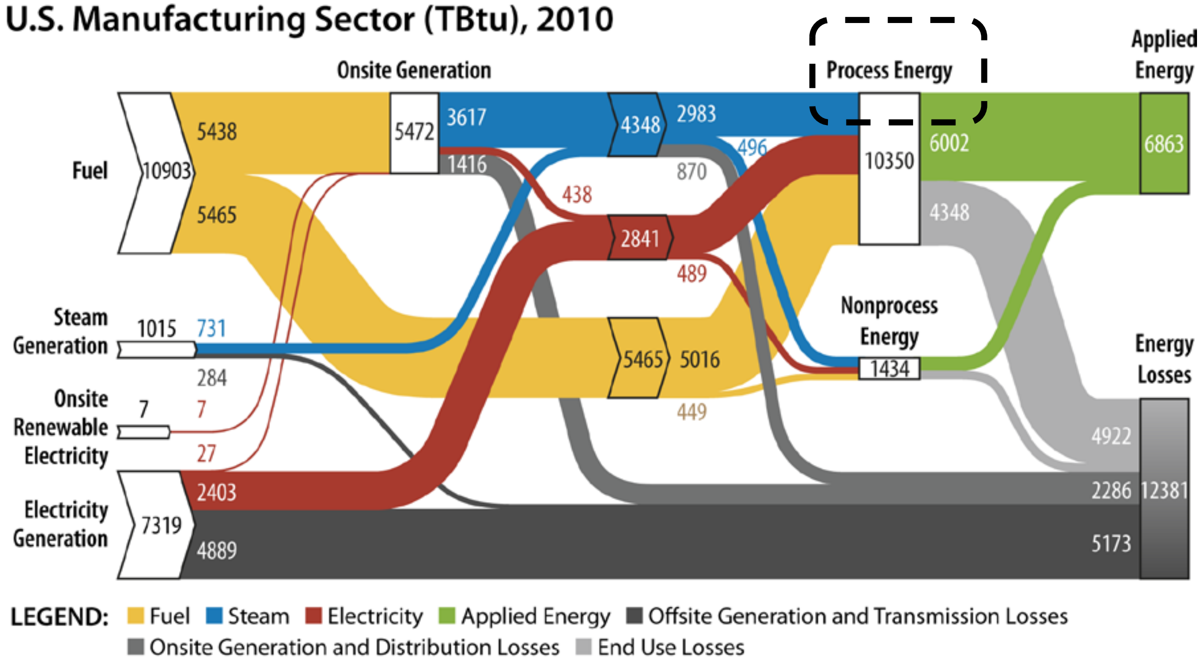


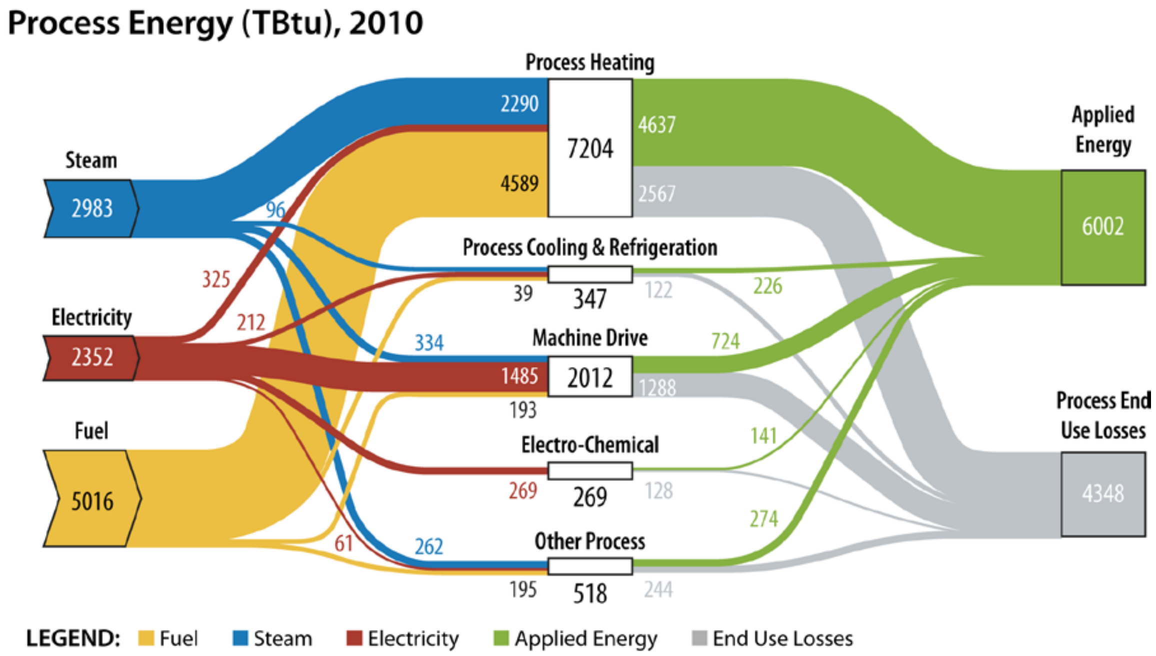
Thermal Storage

- Hot storage
- Cold storage
- Sensible vs latent storage
- Phase change materials
- Ice storage
- Thermochemical storage

US manufacturing section annual primary and process energy flow

Process heating & cooling, refrigeration, machine drives





Kurup, P., and Turchi, C., National Renewable Energy Laboratory, 2015, "Initial Investigation into the Potential of CSP Industrial Process Heat for the Southwest United States," Technical report NREL/TP-6A20-64709

Industrial Process Heating Energy Use

Table 8. U.S. natural gas consumption for direct process heating and conventional boiler use in high-use industry sectors[71]

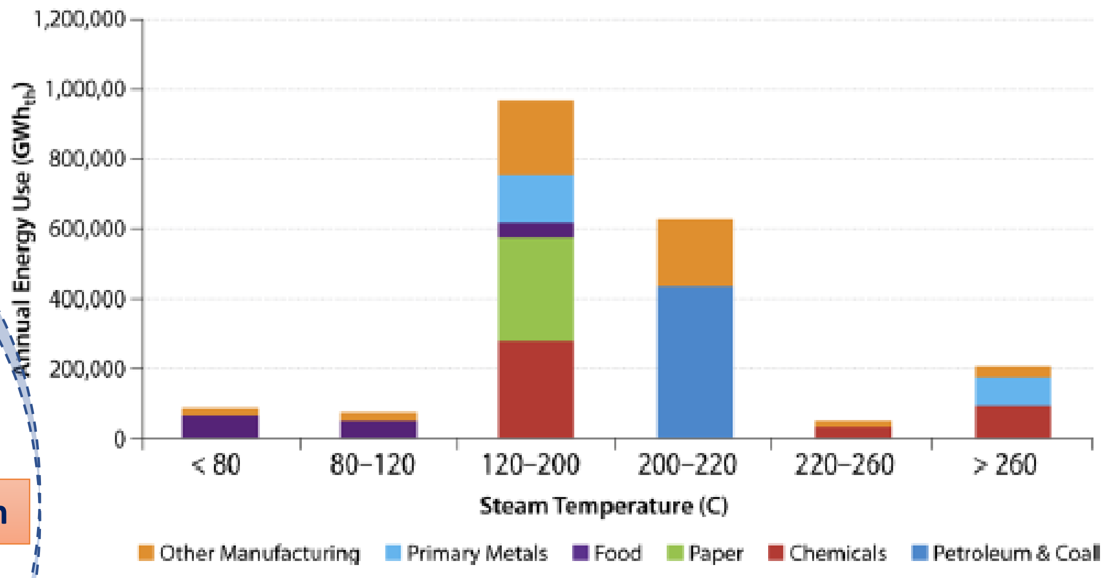
		Natural Gas Consumed per Year	
MECS Code	MECS subsector	Trillion Btu	GWh_{th}
311	Food	339	99,400
322	Paper	170	49,800
324	Petroleum and Coal Products	618	181,000
325	Chemical	722	212,000
331	Primary Metals	289	84,700
		TOTAL	627,000

~1/6th

~1/10th

Table 10. Estimated natural gas consumption for direct process heating and boiler use in California for select MECS industries

NAICS Code	MECS sector	Natural Gas Consumption for Process Heating (GWh_{th}/yr)
311	Food Manufacturing	10,200
322	Paper Manufacturing	1,244
324	Petroleum and Coal Products Manufacturing	31,211
325	Chemical manufacturing	3,526
331	Primary Metal Manufacturing	2,134



US Industry Waste Heat Profile

Table 4 - Temperature Classification of Waste Heat Sources and Related Recovery Opportunity

Temp Range	Example Sources	Temp (°F)	Temp (°C)	Advantages	Disadvantages/ Barriers	Typical Recovery Methods/ Technologies
Medium 450-1,200°F [230-650°C]	Steam boiler exhaust	450-900	230-480	More compatible with heat exchanger materials		Combustion air preheat
	Gas turbine exhaust	700-1,000	370-540			Steam/ power generation
	Reciprocating engine exhaust	600-1,100	320-590	Practical for power generation		Organic Rankine cycle for power generation
	Heat treating furnace	800-1,200	430-650			Furnace load preheating, feedwater preheating
	Drying & baking ovens	450-1,100	230-590			Transfer to low-temperature processes
	Cement kiln	840-1,150	450-620			
Low <450°F [<230°C]	Exhaust gases exiting recovery devices in gas-fired boilers, ethylene furnaces, etc.	150-450	70-230	Large quantities of low-temperature heat contained in numerous product streams.	Few end uses for low temperature heat	Space heating
	Process steam condensate	130-190	50-90		Low-efficiency power generation	Domestic water heating
	Cooling water from:					Upgrading via a heat pump to increase temp for end use
	furnace doors	90-130	30-50		For combustion exhausts, low-temperature heat recovery is impractical due to acidic condensation and heat exchanger corrosion	
	annealing furnaces	150-450	70-230			Organic Rankine cycle
	air compressors	80-120	30-50			
	internal combustion engines	150-250	70-120			
	air conditioning and refrigeration condensers	90-110	30-40			
	Drying, baking, and curing ovens	200-450	90-230			
	Hot processed liquids/solids	90-450	30-230			

US Department of Energy Industrial Technologies Program, 2008, “Waste Heat Recovery- Technology and Opportunities in U.S. Industry,: Prepared by BCS Inc.

Panelists

- What is the current status of process heating, generation and storage in your industry?
- Where do you see bottlenecks? Room for improvement in (a) near term, (b) medium term and (c) long term?
- What are the potential barriers to adoption of above improvements?
- Does a collaborative effort in addressing needs make sense? What do you envision a collaboration looking like?
  - Are there sufficient common areas between food and petrochemical processing to pursue joint projects?
  - Are there things that UCD faculty and researchers can help with to bridge the knowledge or technology translation gap?

Oil & Gas Industry Energy Collaboration with the Food & Beverage Sector

Panel Discussion Talking Points

UC Davis, July 31, 2019

Joel Zimmer

Energy Management Engineer

Chevron

Salt Lake City Refinery

Thermal Efficiency

- Furnace Efficiency & Emissions
  - Minimizing excess O2
    - Tuning & controls
  - Performance monitoring
    - Track KPIs: O2, CO, stack temperature, fired duty intensity
- Heat Exchanger Performance
  - Heat exchanger design
    - Conventional shell & tube; shell & tube with extended surfaces; plate & frame
    - Pinch analysis for heat exchanger networks within complex process units
  - Performance monitoring
    - Track KPIs: approach temperature, U-value
  - Connection between heat exchangers and furnaces
    - Performance of key heat exchangers dictates process unit heat integration
    - Heat integration dictates furnace fuel consumption and emissions (CO2 & NOx)

Oil & Gas Industry Energy Collaboration with the Food & Beverage Sector

Panel Discussion Talking Points

UC Davis, July 31, 2019

Alan Rossiter

Executive Director, External Relations

UH Energy, University of Houston

Oil & Gas and Food & Beverage Industries – A Quick Comparison

	Food & Beverages	Oil & Gas (inc. Downstream)
Edible	Yes (mostly)	No (mostly)
Equipment	heat exchangers, heaters, refrigerators, vessels, filters & centrifuges, pumps, compressors, piping	heat exchangers, heaters, refrigerators, vessels, filters & centrifuges, pumps, compressors, piping
Size, tpa	1-1,000,000	10-30,000,000
2014 US Energy Consumption, TBtu	Food: 1113 Beverages: 86	Petroleum & Coal Products (mostly Oil Refining): 4168 Chemicals: 6297
Typical Operating Mode	Batch	Continuous
Process Temperatures, ^{o}F	-10 to 500	-400 to 1400
Process Pressures, psia	0.1-30	0.1-45,000

Thermal Efficiency, Generation, and Storage Themes

- Boiler & Furnace Efficiency
  - ➢Low temperature stack heat recovery
- Heat Integration
  - ➢Simple vs. complex systems
- Utility Systems
  - ➢Integration of renewables
- Thermal Storage
  - ➢Appropriate applications

Process Optimization Themes

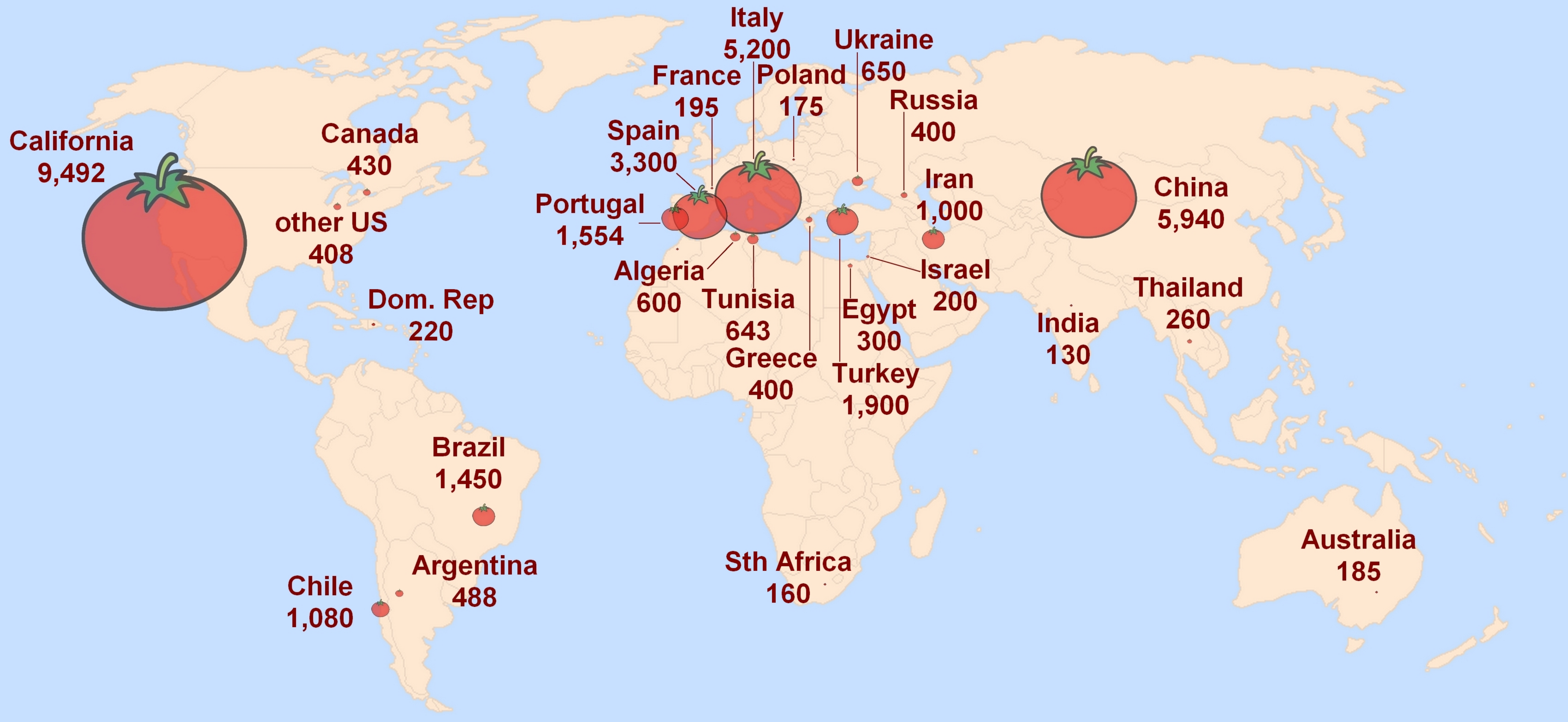
- Design Optimization
  - ➢Technologies – e.g., new catalysts
  - ➢Equipment – e.g., separations, saturators
  - ➢Systems – e.g., heat integration
- Real-time Optimization
  - ➢IIoT
  - ➢Smart Manufacturing
- Process Intensification
- Electrification

Real food that matters for life's moments

Campbell's

Thermal Processes in the Tomato Processing Industry

Global Tomato Processing in 2017: 37,47 million mT

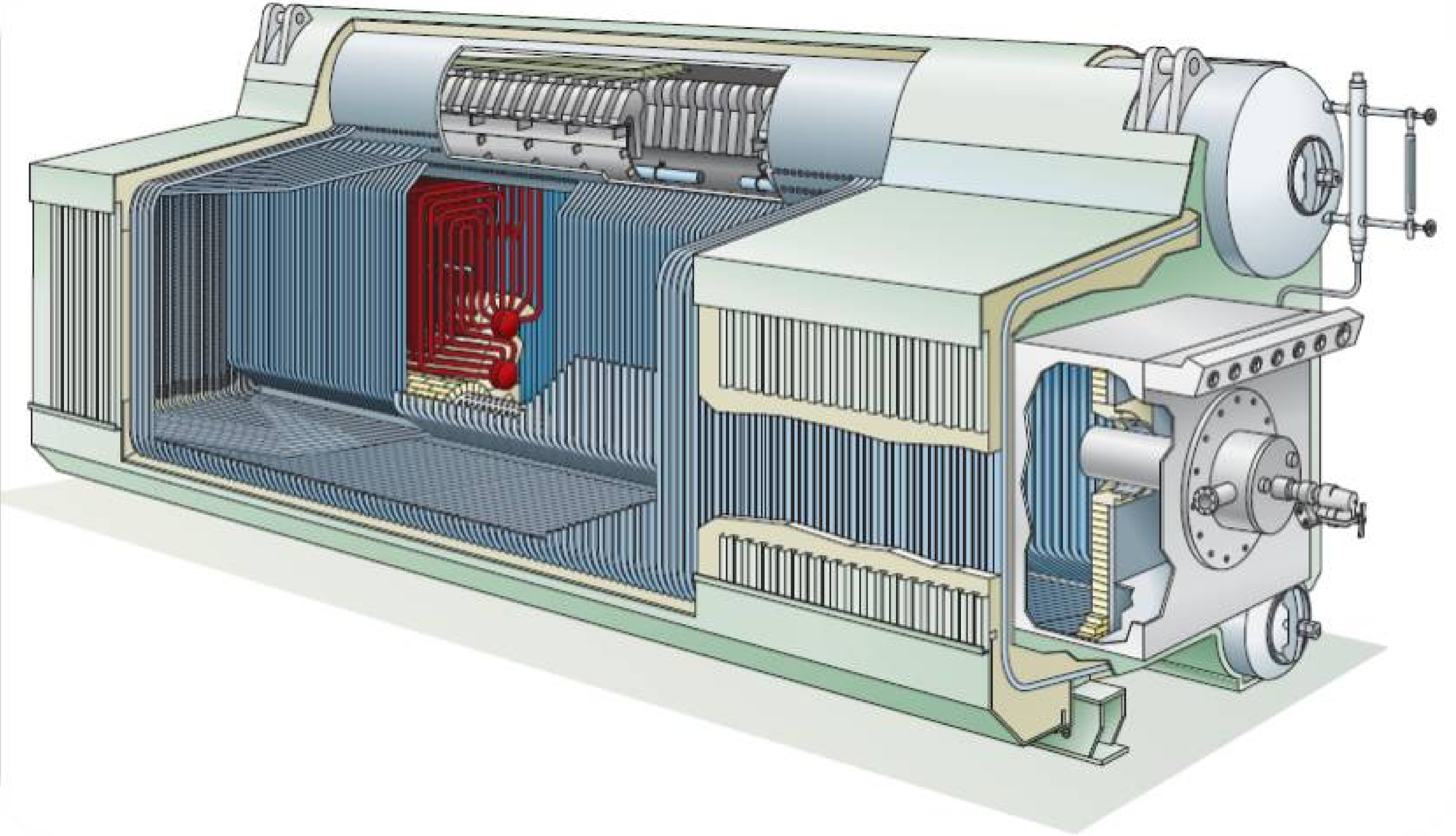


Thermal Processes in Tomato Production

- The processes that produce tomato products, like tomato paste and diced tomatoes, use heat in many steps.
- That heat is supplied by steam, which is created by combusting natural gas in large boilers (at least in our facilities).
- Making tomato paste requires evaporating water from tomato juice to concentrate the amount of solids from an initial 5% to 30% or more.
- Most tomato processing is aseptic, and steam is used to create a sterile environment.   Aseptic products don’t require refrigeration during storage and won’t spoil, which makes them more economical to produce.

Focus on Energy Efficiency - Boilers

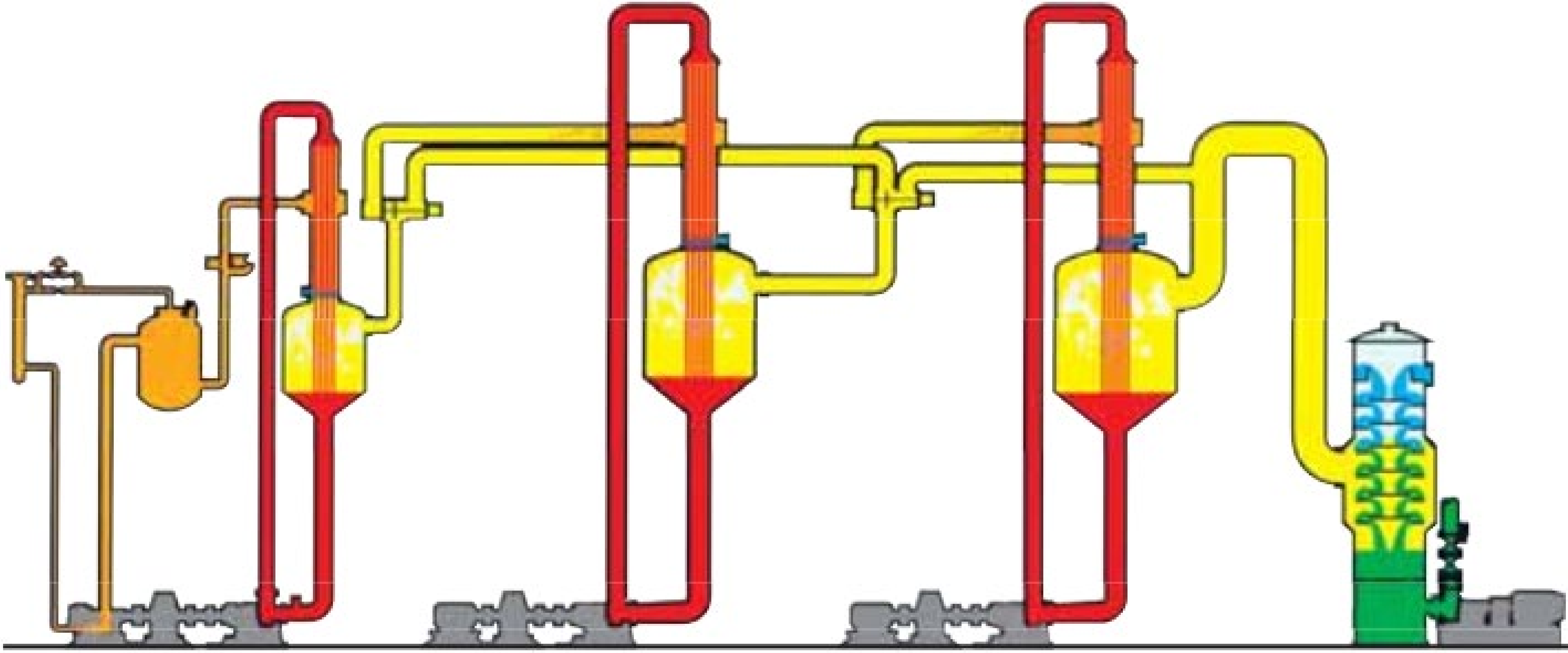
- Boilers are tuned prior to each season to deliver maximum efficiency across a wide range of firing rates.
- Feedwater economizers preheat water entering the boilers with the residual heat from exhaust gases, increasing overall efficiency.
- Returning hot condensate, and even hot tomato evaporate water, to the boilers reduces the need to preheat boiler feedwater.
- Virtually all steam pipes and heat exchangers are insulated to prevent heat loss.



Focus on Energy Efficiency - Evaporators

- Evaporation of water from tomatoes to create tomato paste is a critical process that is also very energy intensive.
- Steam from the boilers is used to drive turbines coupled to large evaporator circulation pumps and vapor compressors. The exhaust steam from these turbines is used to heat the tomato paste in the evaporators, effectively using a large % of the overall energy contained in the natural gas fuel.
- Multiple effect evaporators and Mechanical Vapor Recompression (MVR) evaporators are used to increase the amount of water evaporated for each pound of steam.

Triple Effect Evaporator



Current Tomato Processing Practices

- Tomato ingredient production uses processes that have been fine-tuned to maximize efficiency, throughput, reliability, and food safety. These are all key factors in controlling the cost of production.
- Current alternatives to using natural gas to create the steam for process heat are either much too expensive, or not able to operate at sufficient capacity to be implemented commercially.
- Electrification of steam generation would require major investments in electrical infrastructure and electricity costs that are an order of magnitude lower than what they are currently to be competitive.

Near Term Opportunities

- More efficiency improvements and better process control
- Economies of scale from greater capacity
- Growing tomatoes with higher initial solids
- Waste heat recovery
- High pressure processing
- Solar thermal

Mid to Long Term Opportunities

- Concentration without evaporation
- Renewable fuels as affordable as fossil fuels and identical in function
- Extremely cheap renewable electricity for electrification
- Something else???