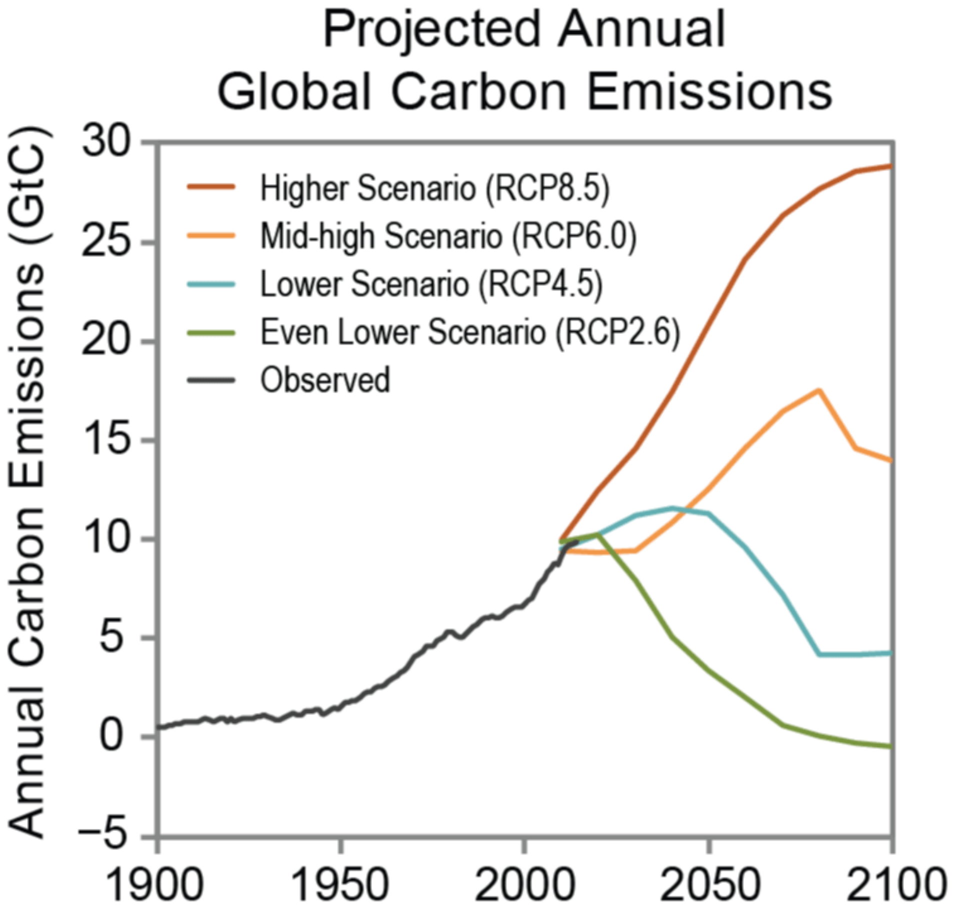
Source: Bladerunner and Starcraft Green Steel

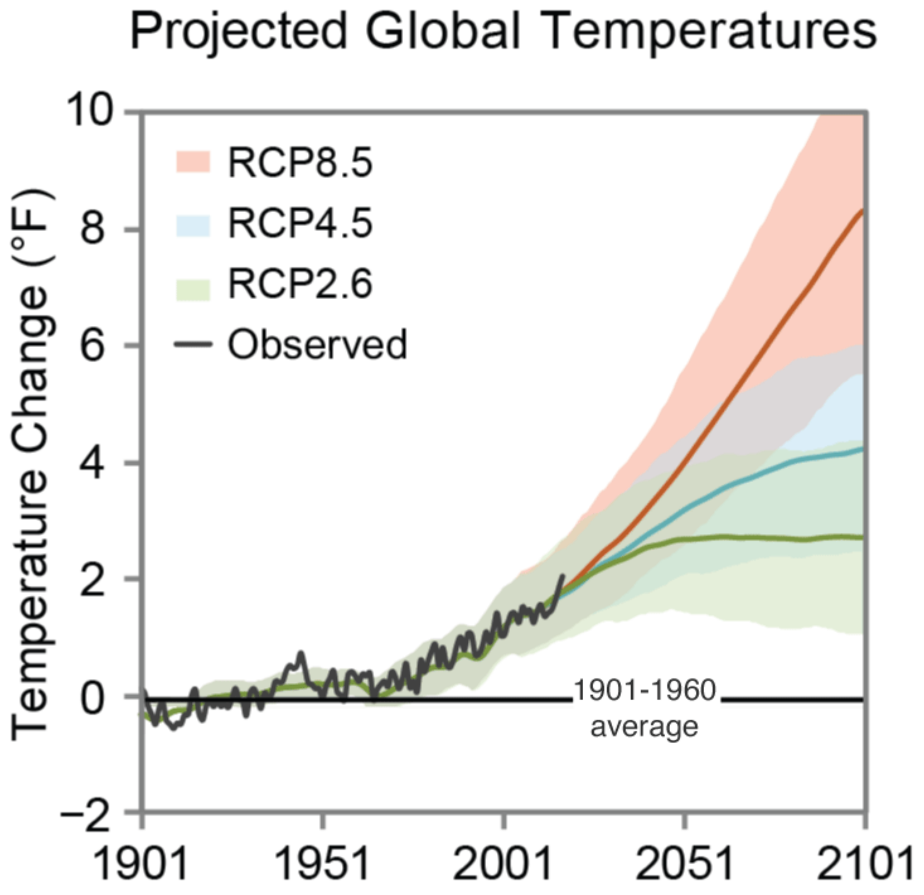
Electrified Processes for Industry Without Carbon

A New DOE Clean Energy Manufacturing Innovation Institute

Global Carbon Emissions will Continue to Increase



RCP xx – representative concentration pathways, radiative forcing (W/m2)



2017 Climate Science Special Report, Figure ES-3

The Effects of Climate Change are Disproportional

- Drought, flooding, and wildfires affect disadvantaged communities more than others
- Previous energy transitions were not equitable because of redlining and the location of polluting manufacturing plants
- Transition towards non-fossil fuel is still not equitable





Among Other Challenges

- The manufacturing skills gap in the U.S. could result in 2.1 million unfilled jobs by 2030.

What Is EPIXC ?

- DOE's 7th Clean Energy Manufacturing Innovation Institute (DOE Agreement signed 10/2/2023) through IEDO
- Mission: Develop and scale innovative electric heating concepts for advanced manufacturing to decarbonize industrial processes
- Led by ASU (via ASURE, research arm)

    CEO - Sridhar Seetharaman, Arizona State University

    CTO – Michael Baldea, The University of Texas at Austin

- A public private partnership with over 100 companies
- Five-year Federal budget is $70M + $74.5M non Fed matching

EPIXC

Vision - Electric heating is economical and supports manufacturing decarbonization ***everywhere for everyone.***

EPIXC Organization & Operating Structure

- RD&D organized under 3 Key Technical Areas
  - demonstrate electric heating technologies, covering diverse temperatures (150°C to over – 1600°C), and heat duty
  - develop models and methods for design, optimization, and control of electric heating processes
  - develop and implement economic, environmental, and societal impact assessment tools and trustworthy data sets
- Technical education & workforce development (TEWD) program
- DEIA will be incorporated into all our activities

EPIXC Organization & Operating Structure

- 5 Key Application Areas
  - Chemicals & refining
  - Iron & steel
  - Forrest products/pulp & paper
  - Cement
  - Food & beverage
- Develop a road map and release RFP’s for RD&D, EWD activities
- Initiate 4 high-impact (jumpstart) and 1 EWD projects in first budget period

Our Core Partners

And Participants from Across the Industrial Supply Chain

Grid and Power Integration

Salt River Project
Rocky Mountain Institute
EPRI
Arizona Public Service Company,
Rondo Energy

Research/Innovative Technology

Primetals
Cober
VIA Shell Energy
Danieli GE
nZero
ExxonMobil
Siemens SaintGobain
Emerson
EPRI
GTI-Energy
Antora

Educators, Unions and Career-Guidance

United Steel Workers
Skillpointe
Kuder Inc.
Intertribal Education Foundation,
Maricopa Community Colleges
National Inter-Tribal Energy Council

Manufacturers

Nucor Steel
Steel Dynamics Innovation Holding,
RMI Smartex,
Saint Gobain, Cemex Limelight Steel,
Ash Grove Cement, Frito-Lay,
Emerson Chemours, Bechtel
BASF Chemical
Gerdau Midland Siemens
Tata Steel, SABIC, Archer Daniels
SSAB Americas Shell
ExxonMobil Cober
Dow Vallourec Hitachi America
Eastman

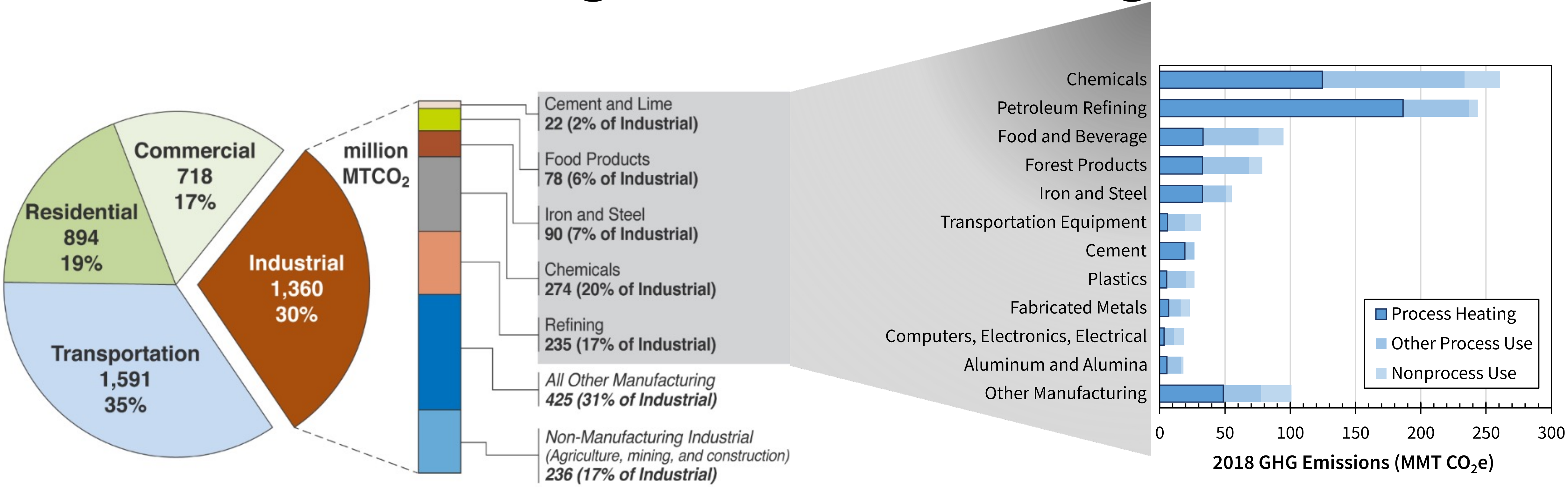
EPIXC

Goals and Targets

- EPIXC aims to reduce industrial manufacturing emissions (over 15 years) by up to 60 MMT CO_2e and energy use by 210 TBTU
- EPIXC will advance education and workforce development (EWD), to train at least 3000 individuals for jobs over five years;
- At least 40% of learners engaged with EPIXC will be members of underrepresented groups including members of disadvantaged communities (DACs).

Source: Isa Ferrall-Wolf, NREL

EPIXC: Electric Heating as a Global Strategic Asset

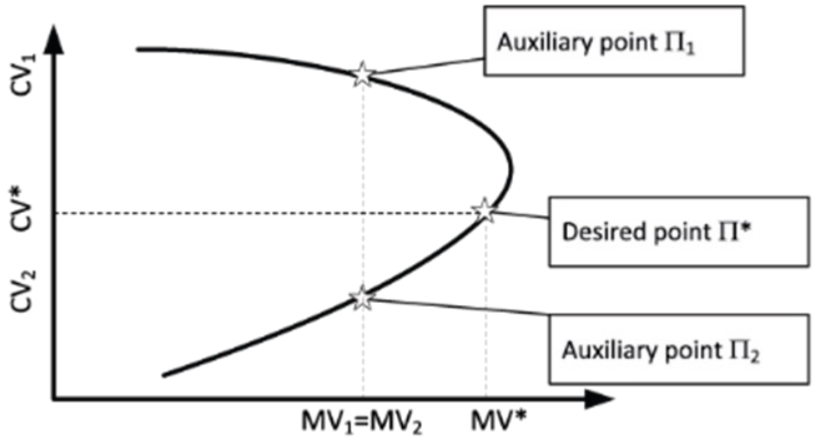


- Target at least 50% reduction in CO_2/criteria pollutants at cost parity
- Leverage **time/space precision** co-benefits of electric heat delivery: higher product quality, homogeneity, uniqueness
- Electric heating eliminates **exogenous**, non-process emissions
- **Preserve core process technology, leverage incumbent capital** and accelerate technology deployment

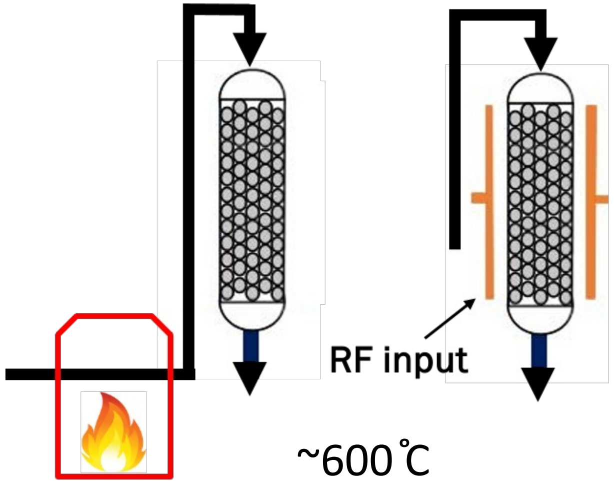
Possible Jump Start Projects

Grid Synchronized Electric Distillation

<u>**Embracing intermittency:**</u> Grid synchronized periodic operation

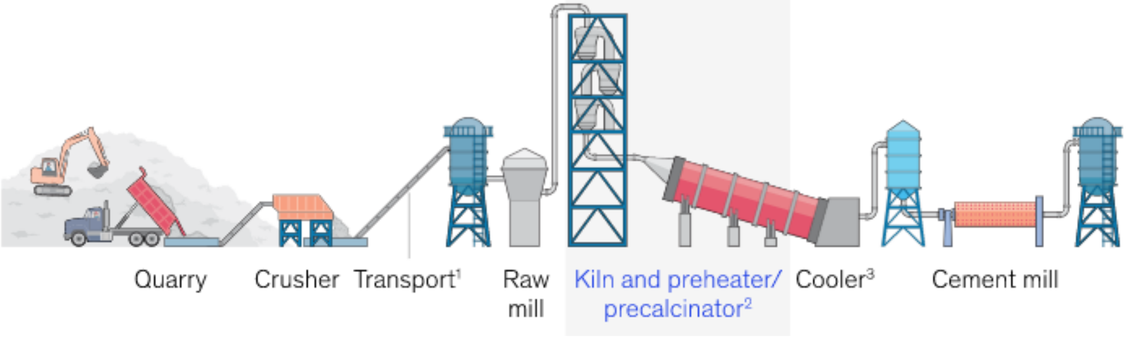


Electromagnetic Heating for High-Temperature Reactors Targeting Endothermic Reactions

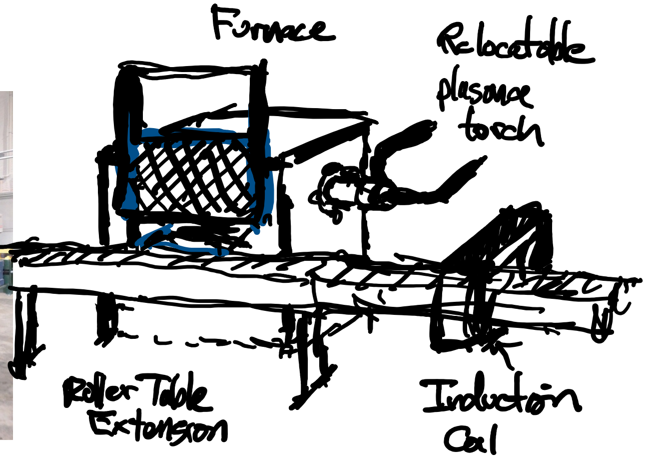


Possible Jump Start Projects

Electrified Calciner for Lime Production



Electrified Re-heating of Steels



Complex Dynamics of the Transition towards Electrification

New Grid Mixes

Electricity producers

New Markets

Electricity trading

Carbon markets

When and where does it become economical?

New Capacities, Connections and Flows

National grid(s)

Regional grids

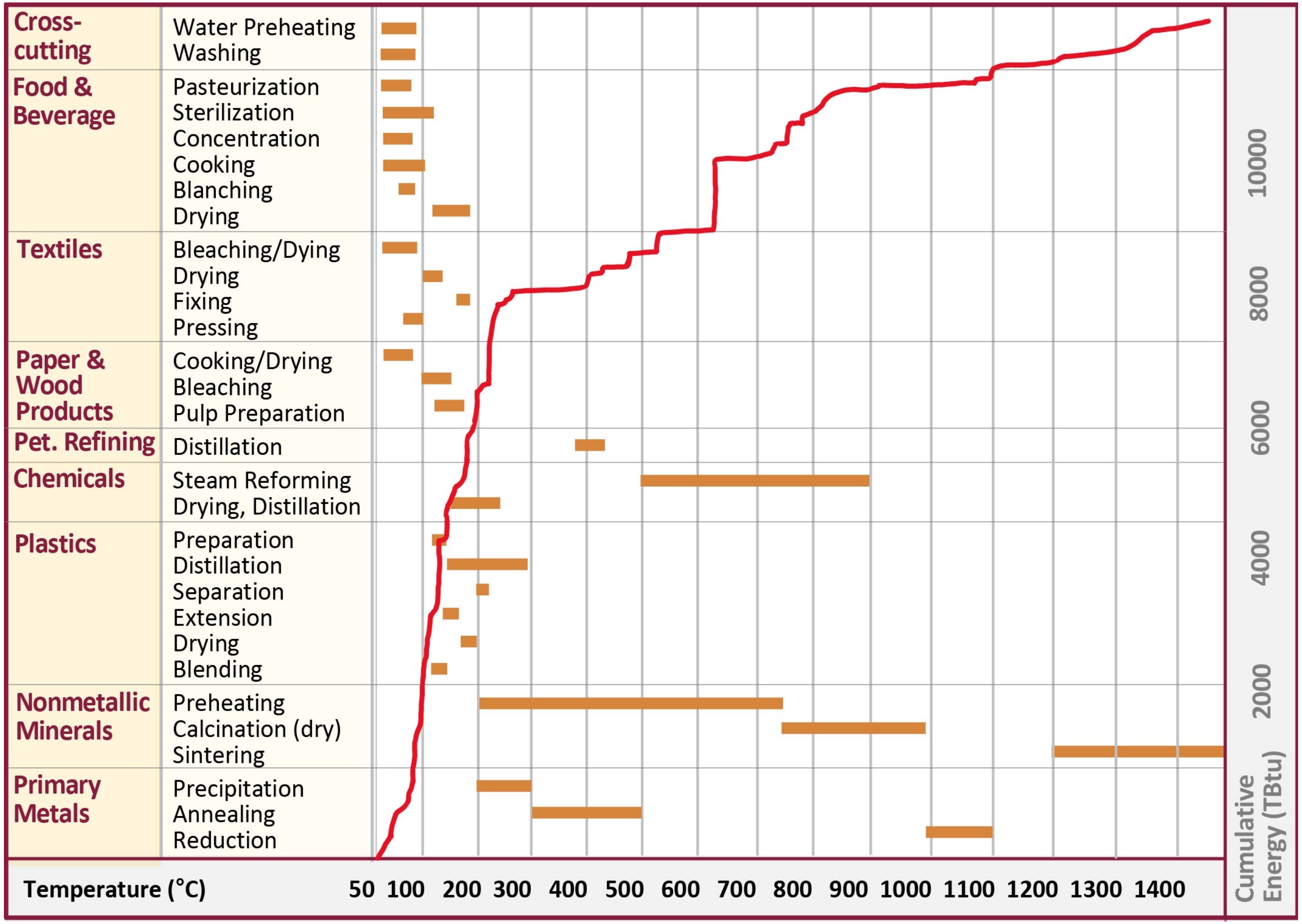
Microgrids

Electricity users

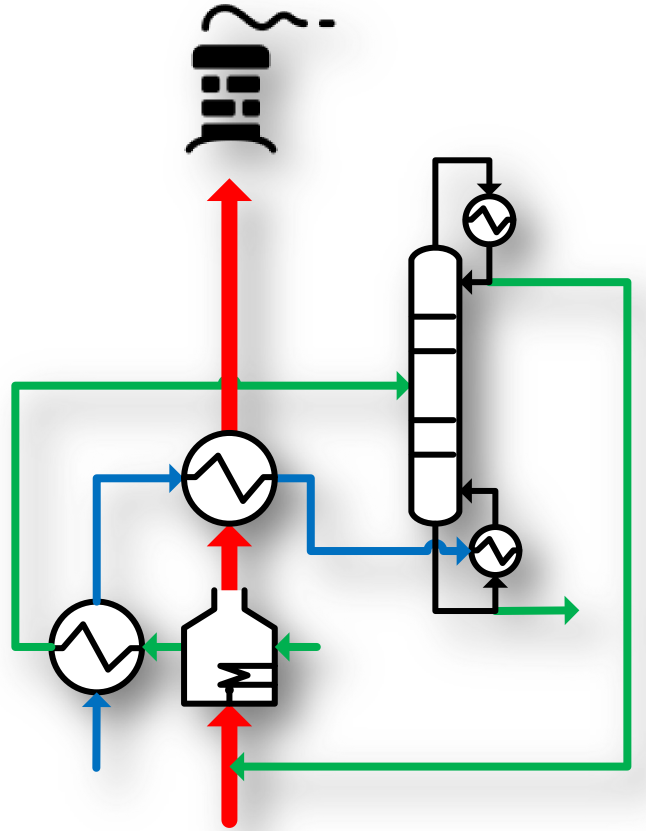
Increased demand and flexibility

Challenge 1

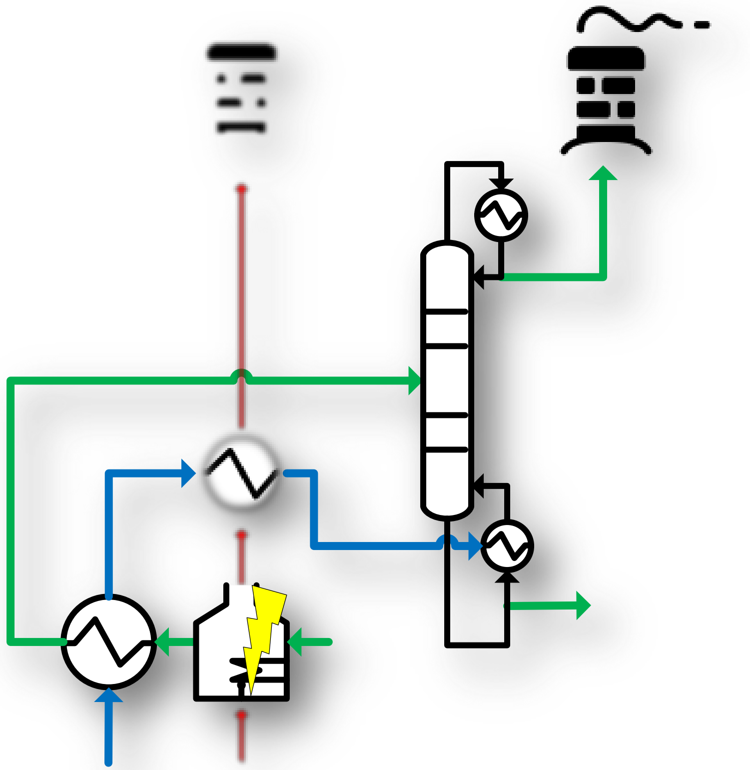
- Diversity of temperatures
- Heterogeneity of applications



Challenge 2: Technology Selection and Process Integration



Conventional process



Electric heating

- Heat integration?
- Fate of fuel gas?
- Electric heater?
- Power availability?

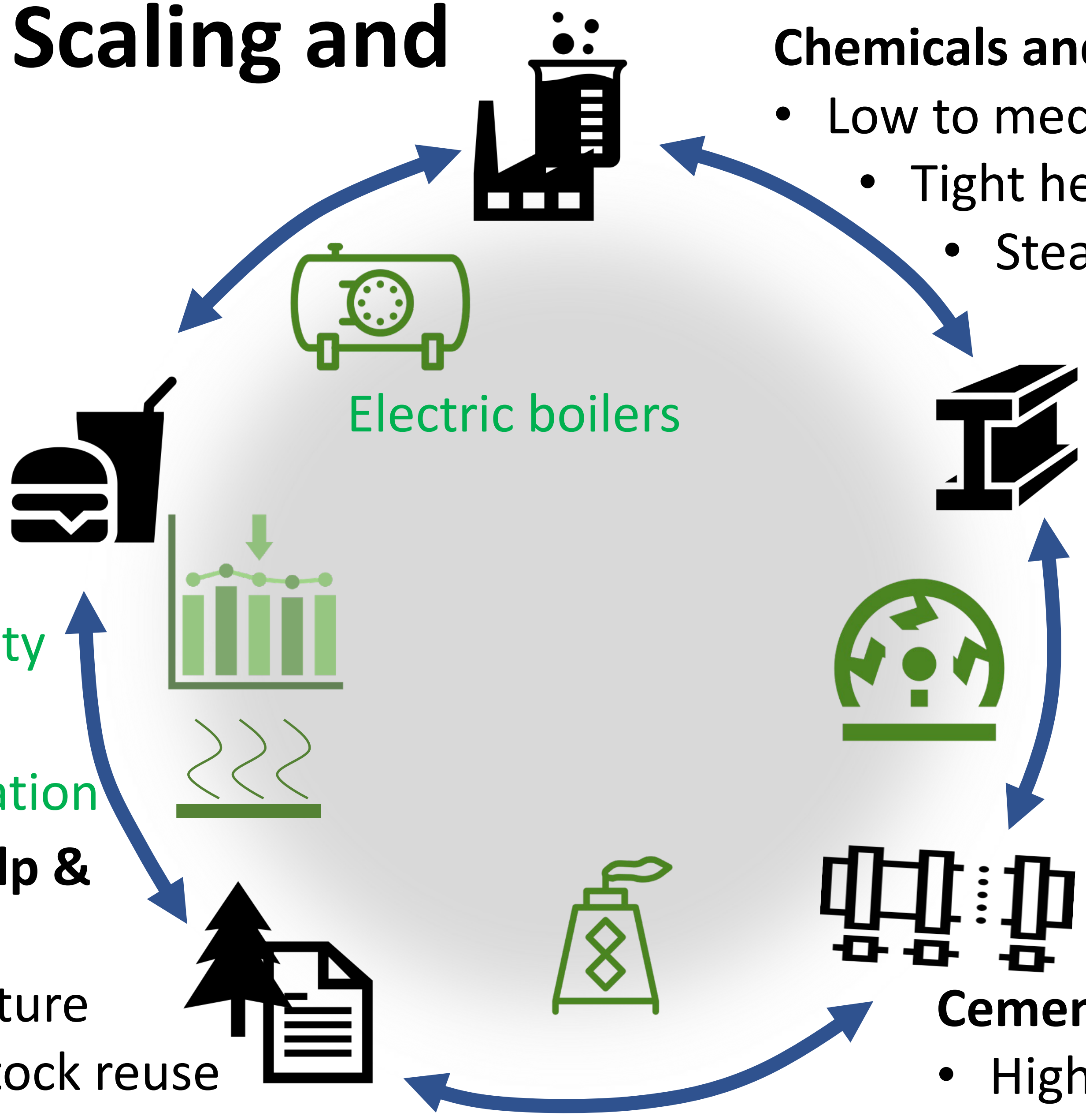
Not a one-to-one equivalence

EPIXC

Challenge 3: Scaling and Replication

Chemicals and Petroleum Refining
- Low to medium temperature
  - Tight heat integration
    - Steam heating

Food and beverage
- Low temperature
- Batch processing
- Regulated, consumer-facing



Steel and metals
- High temperature
- Difficult environment

Forest products (pulp & paper)
- Medium temperature
  - Natural feedstock reuse

Cement
- High temperature
- Non-heating CO_2 emissions

Challenge 4: Skilled Workforce

EPIXC engages the entire supply chain

Grid and Power Integration

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Rocky Mountain Institute
EPRI
Arizona Public Service Company,
Rondo Energy

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Manufacturers

Nucor Steel
Steel Dynamics Innovation Holding,
RMI Smartex,
Saint Gobain, Cemex Limelight Steel,
Ash Grove Cement, Frito-Lay,
Emerson Chemours, Bechtel
BASF Chemical
Gerdau Midland Siemens
Tata Steel, SABIC, Archer Daniels
SSAB Americas Shell
ExxonMobil Cober
Dow Vallourec Hitachi America
Eastman

Challenge 5: Sensors, Modeling and Analysis Tools

EPIXC will generate trustworthy data from our own test beds

Steel

Peaslee Steel Manufacturing Research Center

Grid

NREL Advanced Research on Integrated Energy Systems

ASU Power Systems Engineering Research Center

Chemicals/Refining

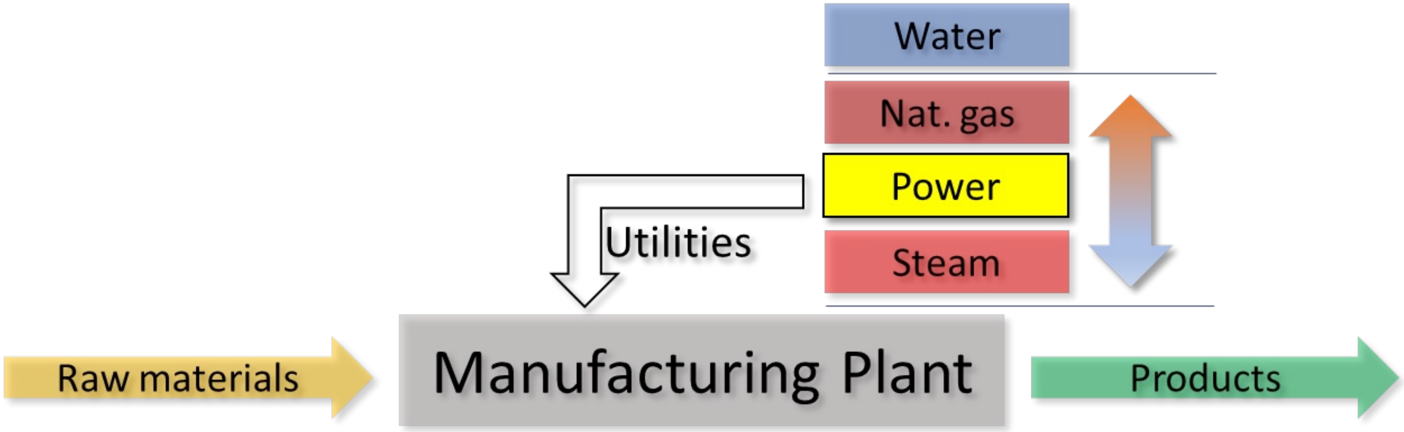
James R. Fair Process Science and Technology Center

Pulp & Paper

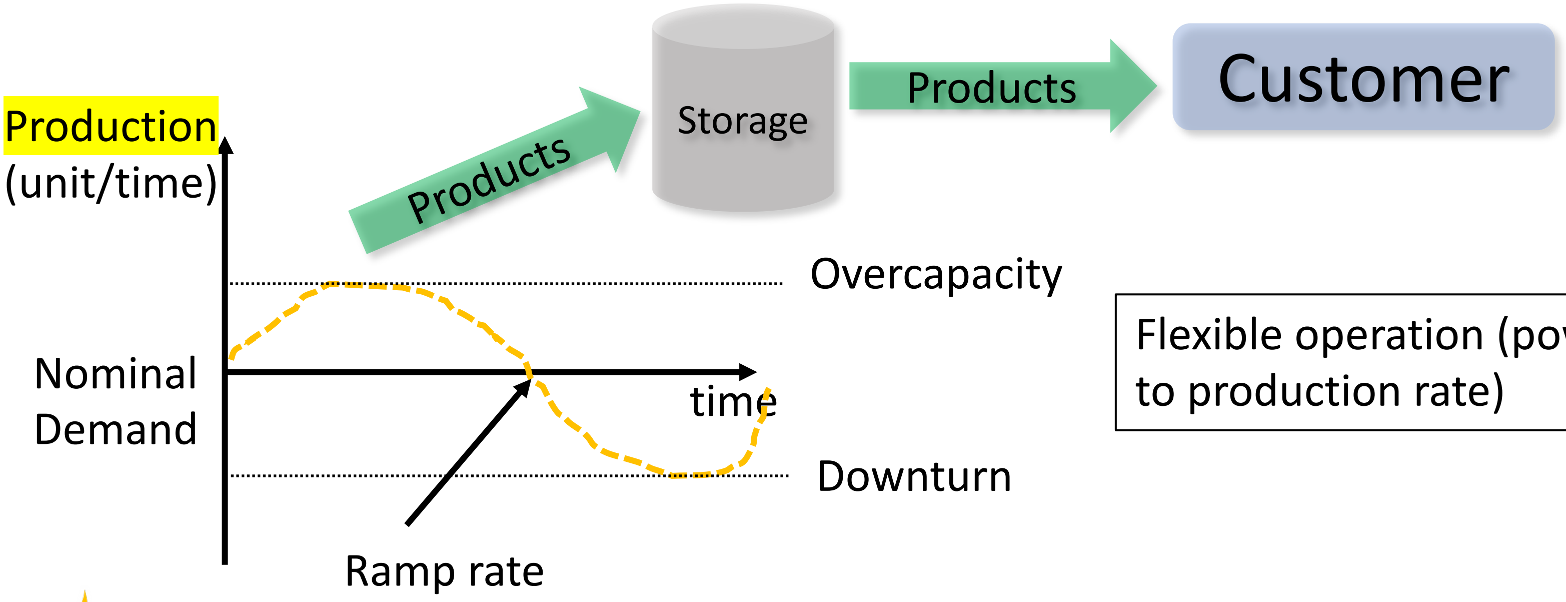
NCSU Pulping Technical Services

Established consortia and industrial innovation ecosystems increase relevance and boost tech transfer

Challenge 6: Safety and Grid Integration



Replace combustion heating with electric heating



Flexible operation (power proportional to production rate)

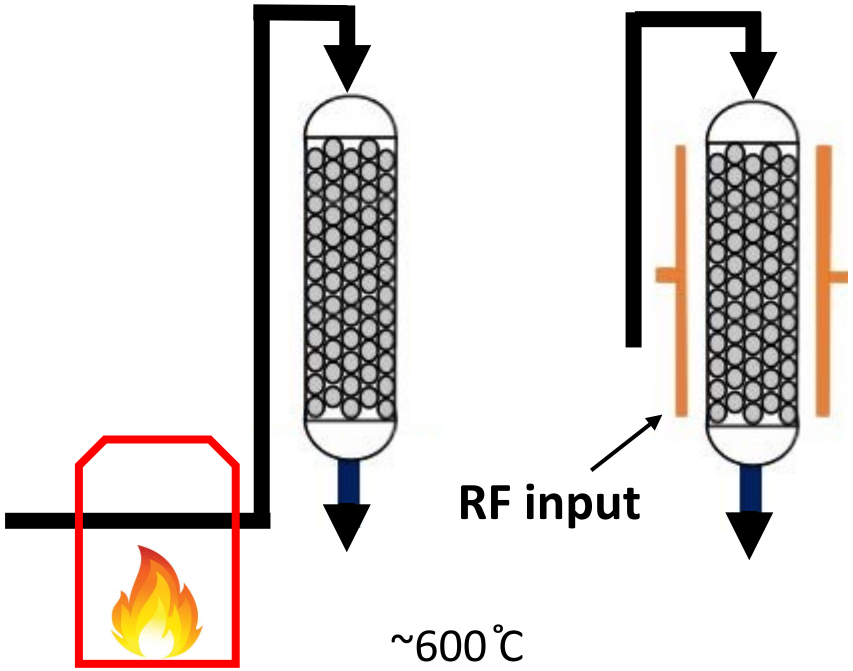
EPIXC will study new operating modalities for power system integration

Opportunity 1: Switching from boundary to volumetric heating

Jumpstart project: Electromagnetic heating for electrification of endothermic reactions

- Isothermal (vs. adiabatic) operation
- 50% lower reactor volume
- Challenges: reactor and catalyst design, coking

Scale-up: propylene dehydrogenation
TEA: $30M increase in CAPEX for
600,000 ton/year plant (around 9%)
Partners: NETL, TAMU, UT, Dow Chemical, Shell, BASF



Opportunity 2: Grid Integration

Jumpstart Project: Grid Synchronized Electric Distillation

[1] Jacobsen and Skogestad, AIChE J. 1991
[2] Koggersbol et al. Comput. Chem. Eng., 1996

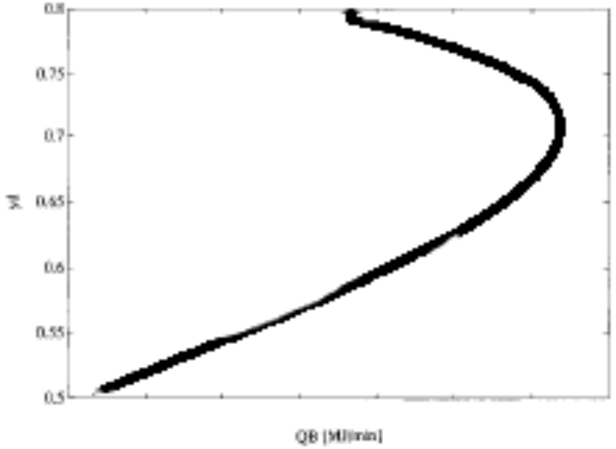
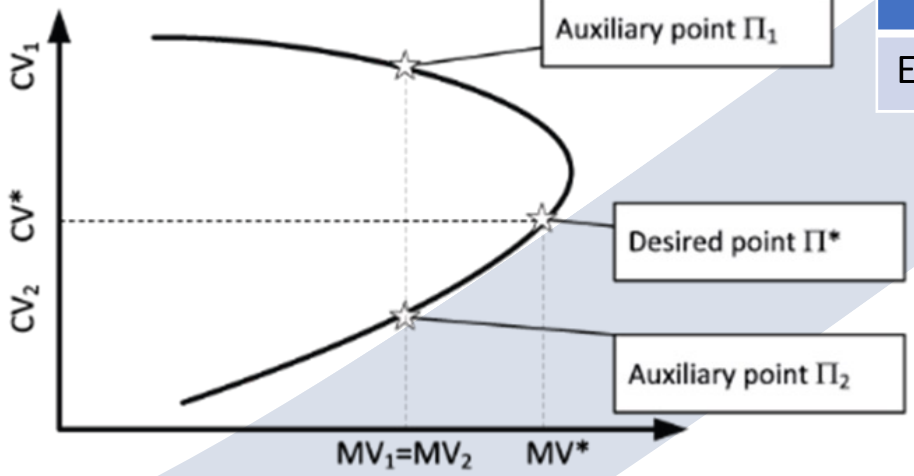


Figure 5. Multiple steady states for heat input Q_B for one-stage propanol-acetic acid column.
Reflux $L = 9.5$ kmol/min

1990s *output multiplicity* demonstrated for distillation columns **[1,2]**

[3] Yan et al., AIChE J., 2018
[4] Yan et al., Ind. Eng. Chem. Res., 2018,
[5] Yan et al., Ind. Eng. Chem. Res., 2021a
[6] Yan et al. Ind. Eng. Chem. Res. 2021b



Embracing intermittency:
Grid synchronized periodic operation

vs. Conventional	CAPEX	Energy Conversion Efficiency	Operating Flexibility
Electric	$7-8/gal	+20%	20%

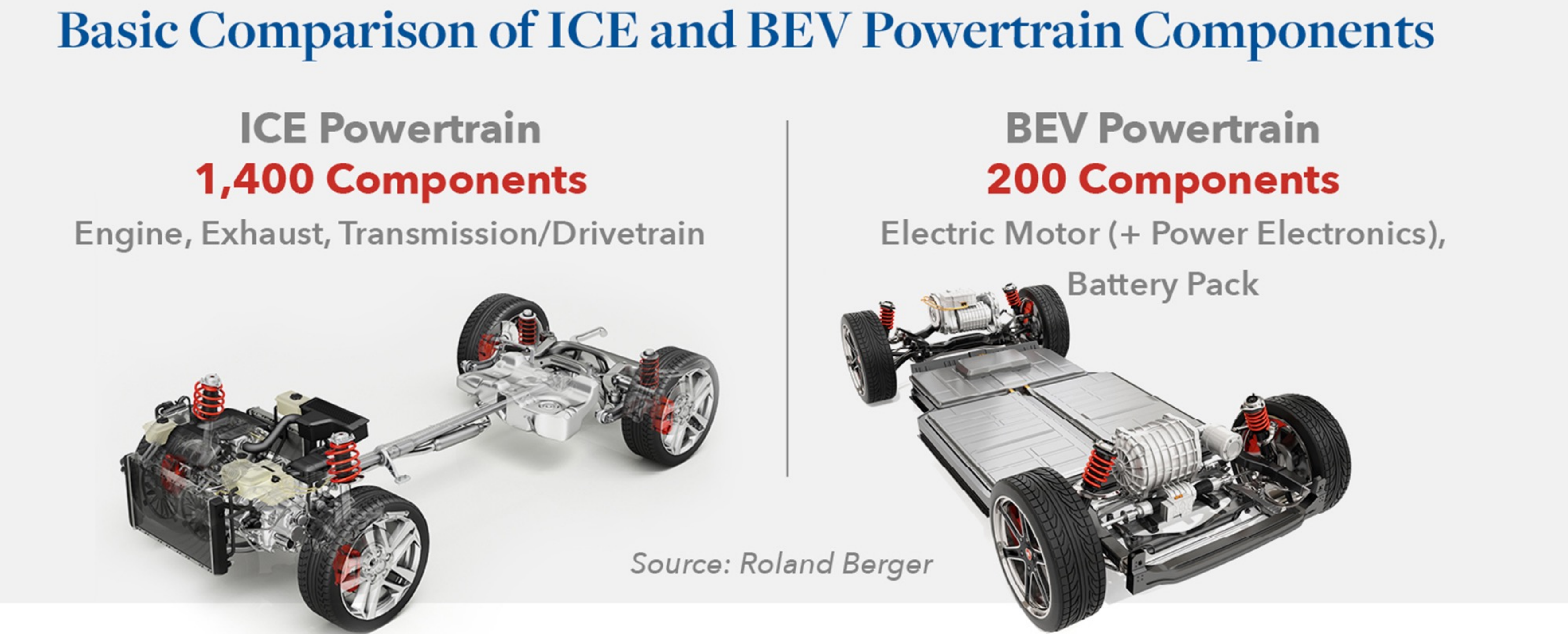
2020s periodic operation demonstrates energy savings **[3,4]**

Mixture	Methanol/ 1-propanol	Cyclohexane/ toluene/m-xylene	Ethylene glycols
Energy Savings	1.4% [4]	3.9% [5]	2.15% [6]

Partners: UT, TAMU, ASU, Shell, NETL, NREL, Siemens PSE

EPIXC

Opportunity 3: Lower Device Cost



Electric boilers are about 40% cheaper than conventional ones

Jadun et al NREL/TP-6A20-70485

EPIX

Opportunity 4: Co-benefits and unique capabilities

- Precise, localized heat delivery
  - More degrees of freedom for control
  - Impart unique spatial properties to products during processing (e.g., heat treating)
- Fast heating
  - Fast plant startup and shut-down
- Lack of oxidative environment
  - Reduced product degradation

Status and Important First-Year Milestones

Q4 2023 Initiate Roadmap, RFP for jumpstart projects
Initiate education/workforce development jumpstart project
Initiate energy justice project in Port Arthur
Form governing board, technical advisory boards

Q2 2024 Complete Roadmap, issue first project RFP

Thank you!

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