APRIL 30 - MAY 2 2025

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Clean Sweep: Industrial Clean Heat Technologies

May 1, 2025
11:30 – 1:00 pm ET

U.S. DEPARTMENT of ENERGY

John O’Neill

Industrial Technologies Office

Agenda

1. Welcome and Introductions
2. Electrification in Industry
3. Furnaces of the present and the future
4. Electrifying Efficiency
5. Closing and Q&A

Today's Presenters

- **Kiran Thirumaran, Technical Account Manager & Research Associate**
  - Oak Ridge National Laboratory (ORNL)

- **Thiago Mikail de Oliveira, Senior Global Energy Consumption Manager**
  - Novelis

- **Malte Weiland, Sustainability Professional**
  - Siemens Smart Infrastructure

Kiran Thirumaran
Oak Ridge National Laboratory (ORNL)

Electrification in Industry

Electrification: The shift from any nonelectric source of energy to electricity at the point of final consumption

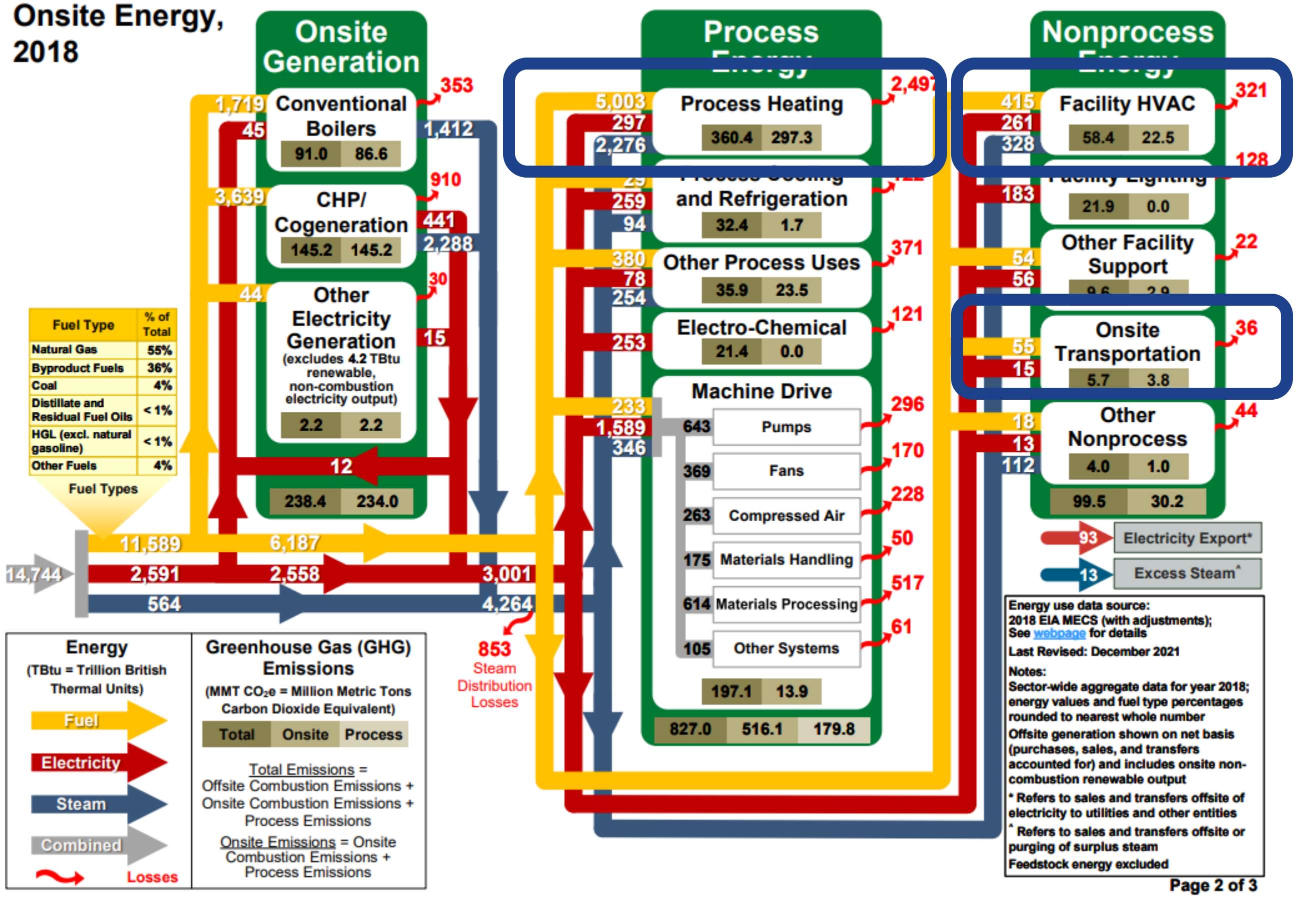
Common Electrification Strategies in Industries

- Process Heating
  - Direct resistance heaters
  - Infrared curing
  - Induction and Arc melting
  - Microwave drying
- Building HVAC
  - Electric Boilers
  - Heat pumps
  - Infrared and resistance heaters
  - Mechanical Vapor Recompression
- Forklifts and fleet vehicles

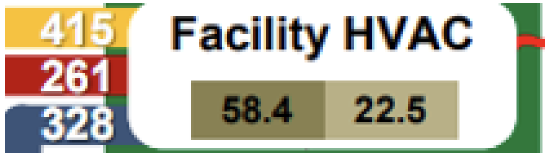
An electric arc furnace used in steel mini-mills

Status of Electrification in Industries

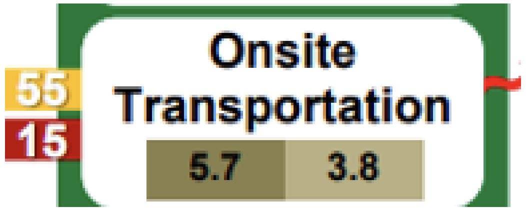
US Manufacturing Energy Footprint



Less than 5% of Process Heating Energy is from Electricity.



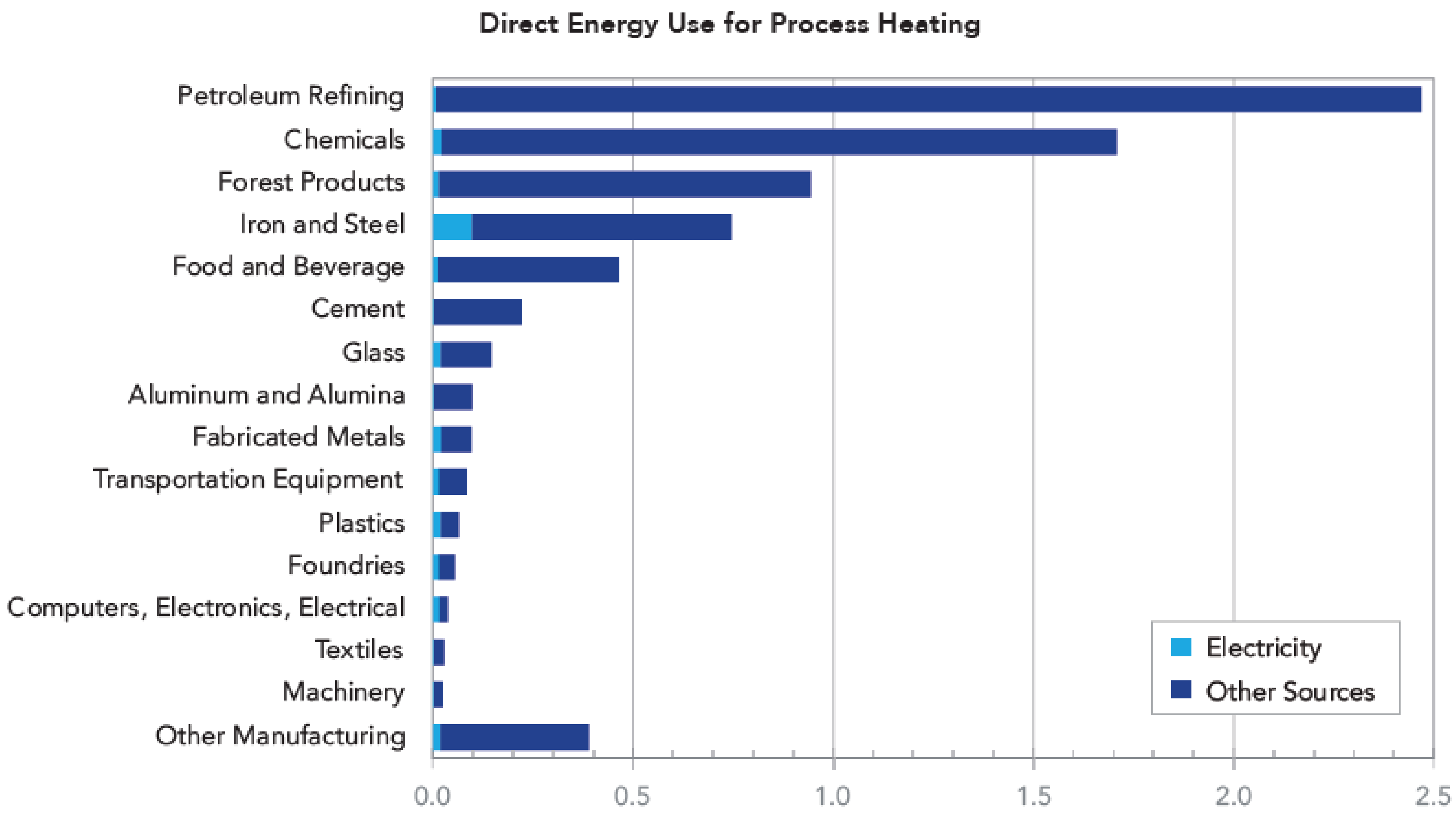
Less than 26% of Facility HVAC Energy is from Electricity.



~27% of Onsite Transportation is Electric

Source: EIA Manufacturing Energy Consumption Survey 2018.

Energy Used for Thermal Processing



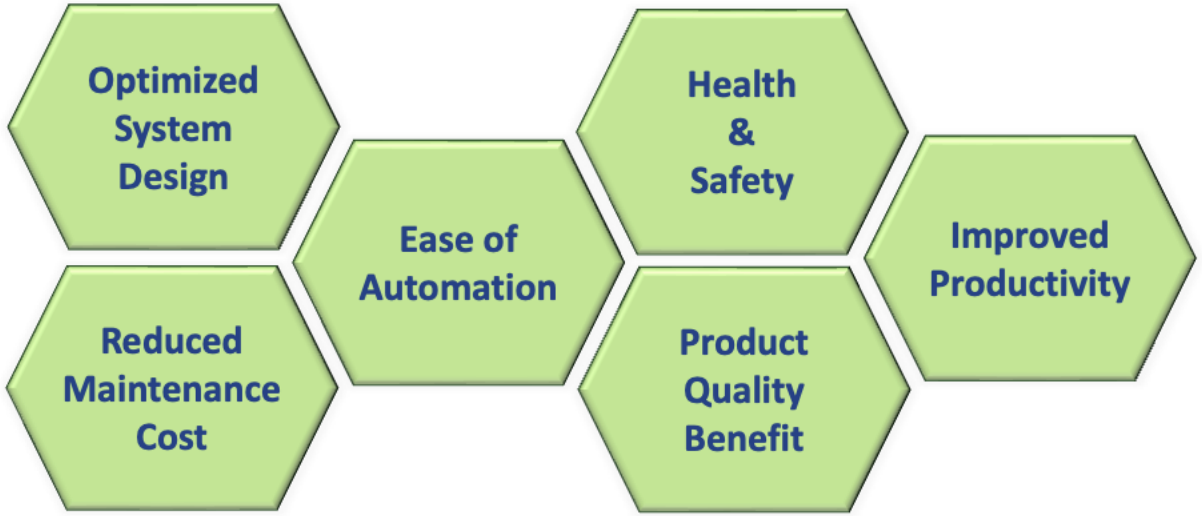
Process heating energy use by source for different industries (2018)

Source: AMO Manufacturing Energy and Carbon Footprints

Why Electrification?

While emission reduction is a driver for electrification, it is just one of the many benefits

- Productivity
- Product Quality (Scrap & Repair)
- Process Flexibility
- Up-time
- Labor Cost
- Capital (Equipment & Inventory)
- Product Features & New Products
- Health & Safety
- Environmental



Summary of electrified technologies. Data Source: AMO Process Heating Sourcebook. Improving Process Heating System Performance: A Sourcebook for Industry. U.S. Department of Energy 2015

Electrification Assessment Framework

Step 1: Establish Inventory and Energy Use

Step 2a: Identifying Strategies for Electrification

Step 2b: Assessing a Facility's Electric Infrastructure Readiness

Step 3: Evaluating and Prioritizing Projects

Step 4: Project Implementation

Step 1: Establish Inventory and Energy Use

Understanding the existing fuel-fired systems can help better plan for electric transition

Inventorying

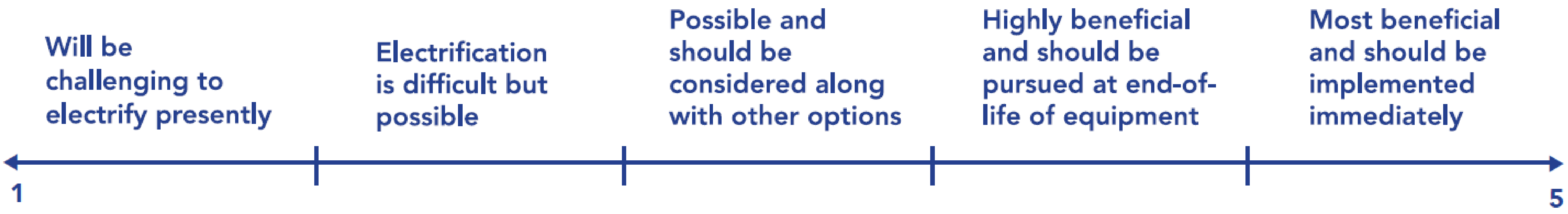
- Identifying existing system at the facility
- Determining key design and operational parameters

Establishing Energy Use (Baseline)

- Metering and Submetering
- Engineering estimates based on burner size and load fact
- Utility Bill Analysis

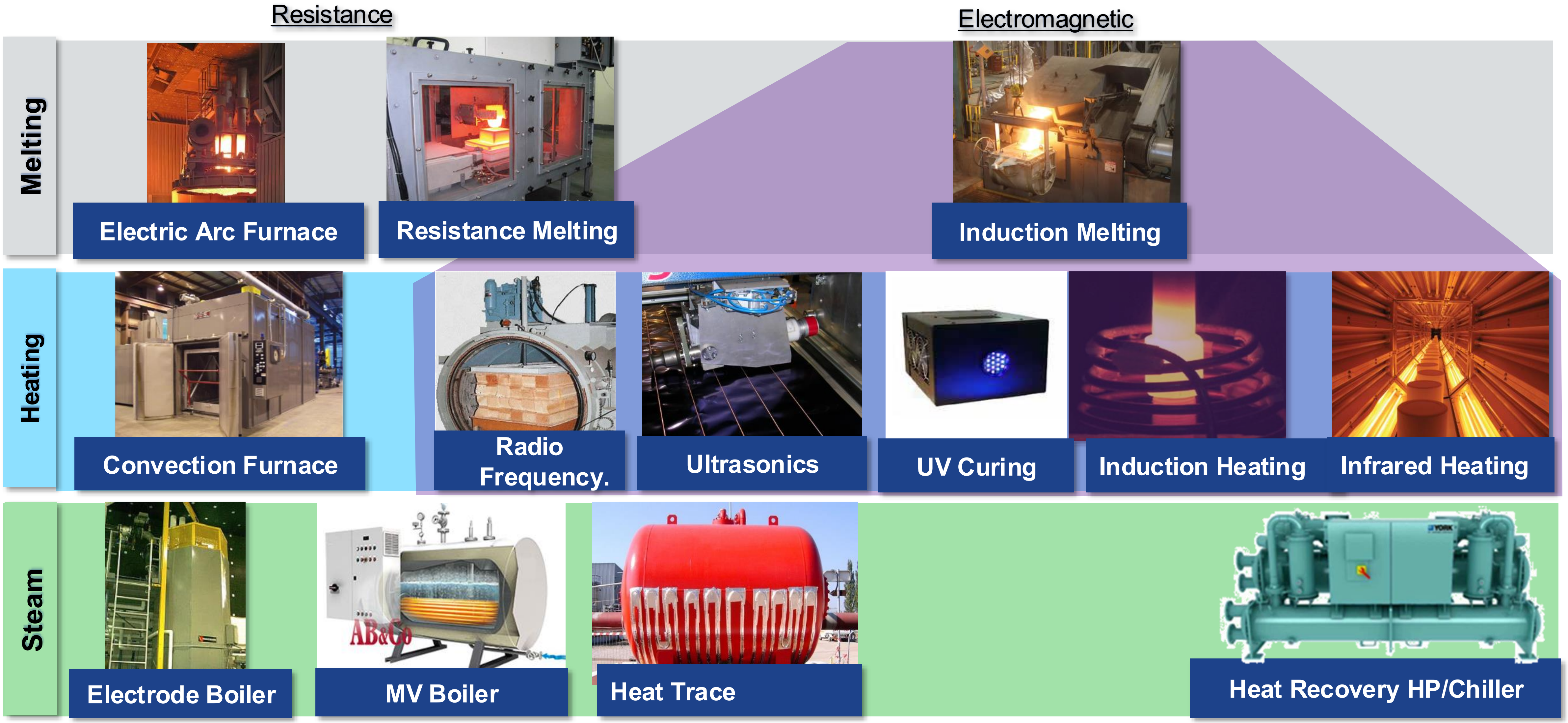
Suitability for Electrification (Example 1) - Rating Scale

A subjective rating scale based on the following factors



1. **How much energy is wasted in the process? can it be cut with electrification**
2. **Temperature range most suitable for electrotechnology**
3. **Is the process a bottleneck? Electrification can potential increase productivity**
4. **Are there major safety concerns with the process**

Step 2A: Identifying Strategies for Electrification



Summary of Major Electrotechnologies for Process Heating

Technology	Considerations	Advantages	Primary Applications
Resistance Heating	• Requires a traditional mode of heat transfer (conductive or convective) • Not very efficient (comparatively) for large applications	• Ideal for retrofit: Suitable for all materials and processes • High efficiency uniform direct heating for medium to high temperature	• Liquid heating such as lubricating oils, heavy or light oils and waxes. • Melting of glass and non-metallics
Electric Infrared Heating	• Required "line of site" to operate – not suitable for complex shapes • Cannot be used if the atmosphere contains gases, hazardous vapors	• Fast heating process • Compact and easy integration into current processes	• Drying of material or curing of paint
Induction Heating	• Material must be conductive • Production size - small production runs are not ideal • Requires high voltage power	• Precise heating • Continuous and rapid heating of parts	• Remelting of metals • Heat treatment
Microwave Heating	• Suitable material coupling with microwave • Material's sensitivity to rapid heating	• Provides quick and uniform volumetric heating • Selective Heating	• Drying application in food and chemicals sector. • Sterilization

Electrotechnology Screening – Decision Tree and Tables

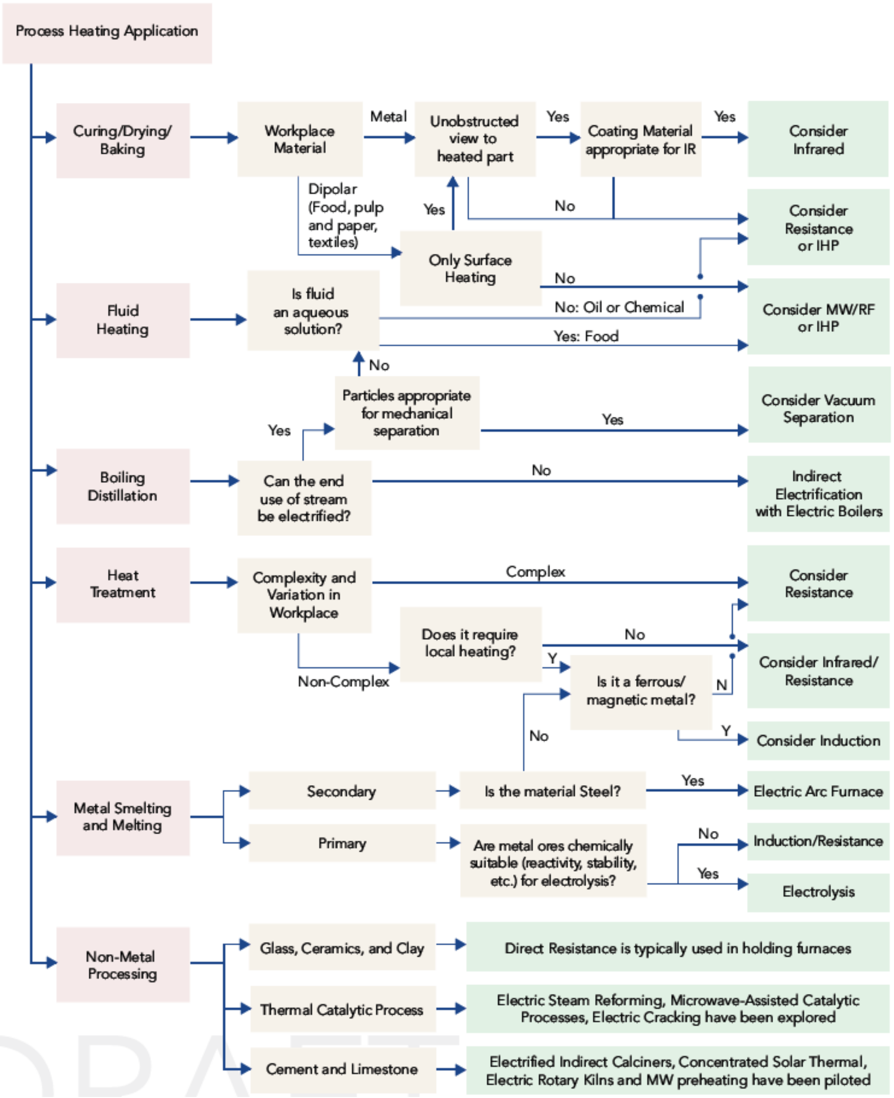


Table 3. HVAC Decision Table.

Criteria	Air/Water Source Heat Pumps	Electric Boilers	VRF Systems	Electric Resistance Heating	Geothermal Heat Pumps
Energy Efficiency	High	Medium	High	Low	Very High
Initial Cost	Medium	Low	High	Low	High
Operating Cost	Low	High	Low	High	Very Low
Maintenance	Medium	Low	Medium	Low	Medium
Regional Applicability	Dependent	Independent	Independent	Independent	Dependent
Scalability	High	High	Medium	Medium	Medium
Integration with Existing Systems	High	High	Medium	High	Medium
Temperature Regulation	High	Medium	High	Low	High
Indoor Air Quality (for Office)	High	Medium	High	Low	High
Environmental Control (for Manufacturing)	High	Medium	High	Low	High

Very high-performance characteristic
Favorable or high-performance characteristic
Medium or moderate performance characteristic
Low or less favorable performance characteristic

Table 4. Forklifts and Utility Vehicles Decision Table

Criteria	Lead-Acid Battery	Lithium-Ion Battery	Fuel Cell
Initial Cost	Low	High	High
Operating Cost	Moderate	Low	Moderate-High
Maintenance	High	Low	Low
Run Time	Moderate	High	Very High
Refueling/Recharging	Slow	Fast	Very Fast
Emissions	None	None	None
Indoor Air Quality	Excellent	Excellent	Excellent
Suitability for Multishift	Poor	Good	Excellent

Very high-performance characteristic
Favorable or high-performance characteristic
Medium or moderate performance characteristic
Low or less favorable performance characteristic

Step 2b: Assessing Facility's Electric Infrastructure

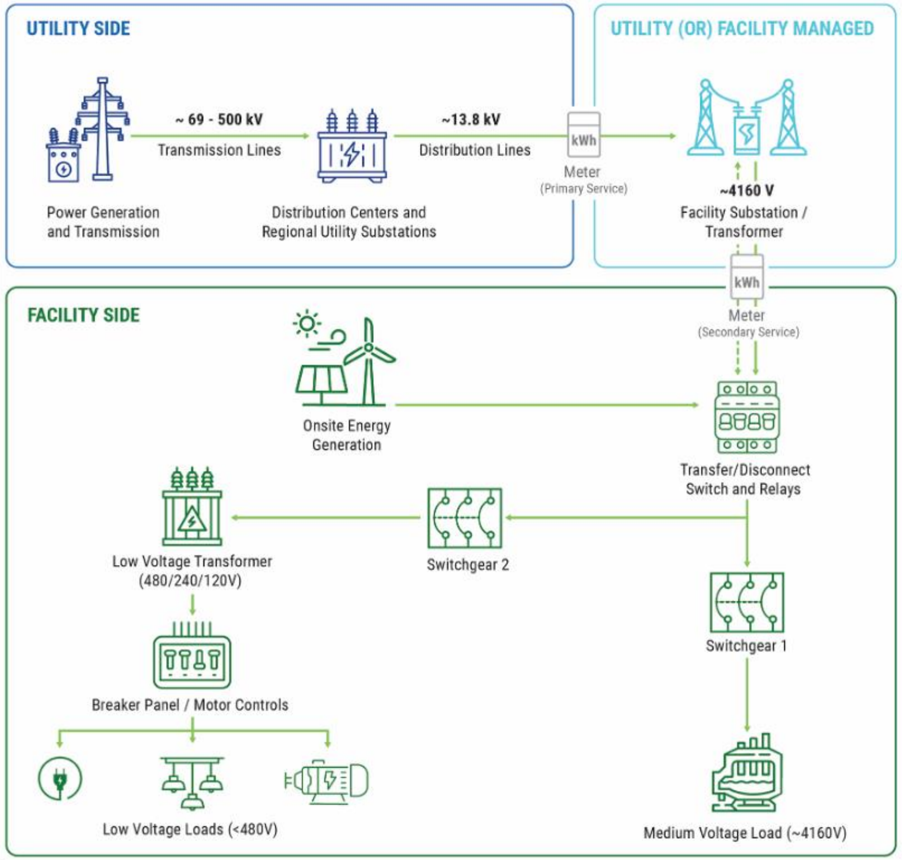
Estimate Increased Electric Load from Electrification → Assess Existing Electric Infrastructure → Identify Advanced Electricity Management Techniques

Major Components

- Substations transformers used to step down transmission voltage and associated feeders
- Facility owned transformers to step down voltage at the plant
- Switchgear, motor control centers and control panel used to distribute power throughout the plant
- Electric load

Actionable Items

- Assessing distribution feed from one line diagram
- Discuss with the utility representative to understand the substation and feeder capacity to serve facility loads



Example Inventory

Equipment Name/ID	Install Date (year)	Rated Capacity (MMBTU/h)	Typical Annual Operating Hours (h)	Operating Temperature (°F)	Load Factor	Fuel Used	Estimated Yearly Energy Use (gas or other fuel, MMBTU)	Baseline System Efficiency (%)	Proposed Electric System Efficiency (%)	Expected Increased Demand with Electrification (kW)	Electrification Suitability Rating
Process Heating Systems											
Furnace 1	2021	1.2	8,760	1700	42.00%	Natural Gas	4,415	50%	75%	235	Mid
Heat Treat Furnace 2	2010	3.5	1,664	1200	44.04%	Natural Gas	2,565	60%	75%	820	Mid
Gas Genera-tor	2011	1.6	1,664	1900	44.10%	Propane	1,174	80%	95%	395	Low
Drying Ovens	2010	1.5	3520	400	76.00%	Natural Gas	4,013	80%	95%	370	High
Total Process Heating System (A)							**12,167**		**12,167**	**1,820**	

Can be used to evaluate facilities infrastructure requirement

Step 3: Evaluating and Prioritizing Projects

Evaluating Impact
- Evaluating project's technical feasibility
- Evaluating other impacts
- Perform a holistic cost comparison

Evaluating Project's Technical Feasibility
- Study existing process requirement
- Perform technology feasibility screening
- Ensure product quality requirements

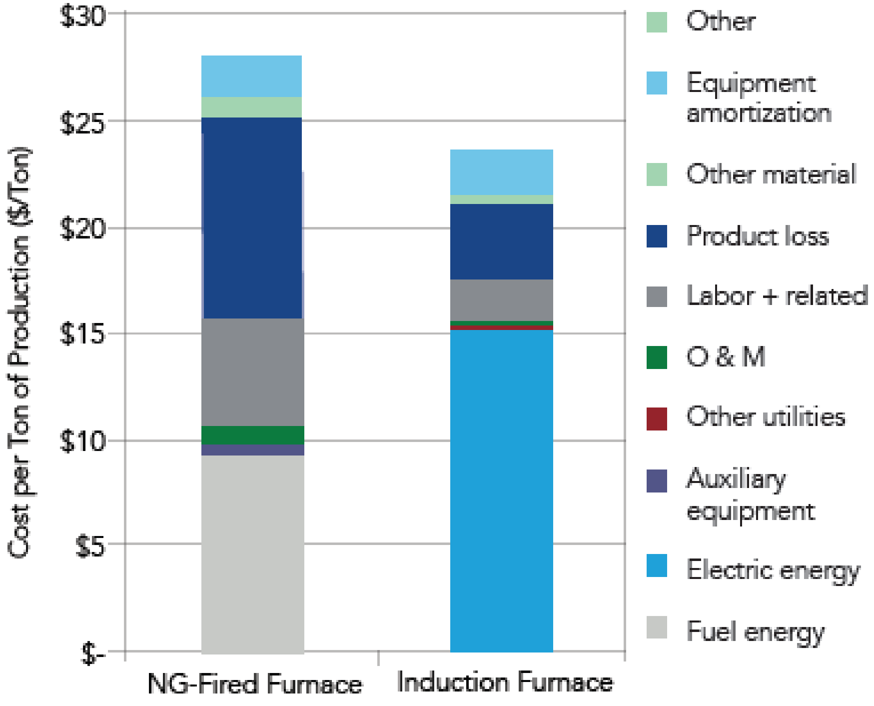
Evaluating Energy Availability and Reliability
- Plan capacity and grid upgrades
- Evaluate impact on power system reliability and resilience
- Plan for energy resilience
- Integrate advanced electricity management techniques
- Procure energy

Identifying Financing Opportunities
- Financing strategies
- Financial incentives

Drafting Facility-Level Electrification Plan
- Identify short-term projects
- Identify mid-term and long-term projects

Holistic Comparison of Cost

Evaluation of an electrification project should involve consideration of all relevant co-benefits



From case study on NG-Fired Furnace vs Induction Furnace in a Forging Plant

Some Unique Considerations when implementing electrification projects

1. System design and testing
2. Auxiliary Infrastructure Upgrades
3. Optimized Operations
4. Energy Reliability
5. Workforce Education

Drafting an Electrification Plan

An electrification plan uses key insights from the assessment and defines actionable next steps aligned with priorities and infrastructure readiness.

Projects are categorized as short-term, mid-term, or long-term, with next steps drafted based on key factors:

- Equipment end-of-life
- Electrical capacity considerations
- Project cost
- Other organizational priorities

Time-sensitive external drivers, such as rebates and incentives, can impact project prioritization and scheduling.

Example Electrification Plan

Electrification Plan					
Company Name: Company ABC					
Facility Address: ABC Street, Oak Ridge, Tennessee					
Contact: Mark Smith					

Electrification Projects

	Equipment End of Life	Implementation Cost	Emission Reduction	Electric Demand Increase	Notes
Induction	2030	$400,000	80 MT/year	200 kW	
Resistance heat treatment oven	2027	$275,000	64 MT/year	160 kW	
Electrify Steam Boilers	2035	$350,000	85 MT/year	250 kW	
Electric RTU	2026	$120,000	24 MT/year	60 kW	
Electric Forklifts	2025	$200,000	20 MT/year	50 kW	Total 10 units
Electrify Utility Vehicles	2027	$140,000	15 MT/year	15 kW	Total 5 units

Electric Capacity Available

Capacity Available at the Site This is based on the capacity available at the switchgears. *(From result C1 in the Electrification Readiness Worksheet)*	100 kW
Potential Capacity with Facility-Level Upgrades This is based on the capacity available at the switchgears. *(From result B1 and B2 in the Electrification Readiness Worksheet)*	1000 kW
Potential Capacity with Utility Upgrades This is based on the capacity available at the switchgears. *(From result A1 in the Electrification Readiness Worksheet)*	2000 kW

Electrification Plan

Short Term Projects	Mid Term Projects	Long Term Projects
Electric Forklifts	▶ Electrify Utility Vehicles ▶ Resistance Heat Treatment Oven	▶ Induction Furnace ▶ Implement Onsite Solar ▶ Explore load management with microgrids.

Project Activity Tracking

Activity/Task	Task Lead	Start Date	Duration	Status
Upgrade Forklifts and Utility Vehicles: Fleet Analysis	Alice Brown	2024-08-15	1 month	Initiated
Upgrade Forklifts and Utility Vehicles: Vendor Selection	Alice Brown	2024-09-15	1 month	Planning
Electrify Forklifts: Procurement and Installation	John Doe	2025-02-01	3 months	Not Started
Electrify Utility Vehicles: Procurement and Installation	John Doe	2025-09-01	3 months	Not Started
Install Electric RTU: Site Assessment	Jane Smith	2025-09-01	1 month	Not Started
Install Electric RTU: Electrical Upgrades	Jane Smith	2025-11-01	2 months	Not Started
Resistance Oven Installation: Energy Audit	Tom Wilson	2026-01-01	1 month	Not Started
Resistance Oven Installation: Procurement & Delivery	Tom Wilson	2026-05-01	3 months	Not Started
Induction Furnace: Feasibility Study	Emily White	2027-01-01	3 months	Not Started
Onsite solar and microgrid: Feasibility Study	Emily White	2027-04-01	6 months	Not Started

Breakout Discussion

1.) Please introduce yourself and provide a summary of your experience with electrification.

- **Have you evaluated, piloted, or implemented any electrification projects at your site (such as for process heating, HVAC, or forklifts)?**
- **If so, could you share any specific challenges you encountered or lessons learned from your experience with electrification?**

Thiago Mikail de Oliveira

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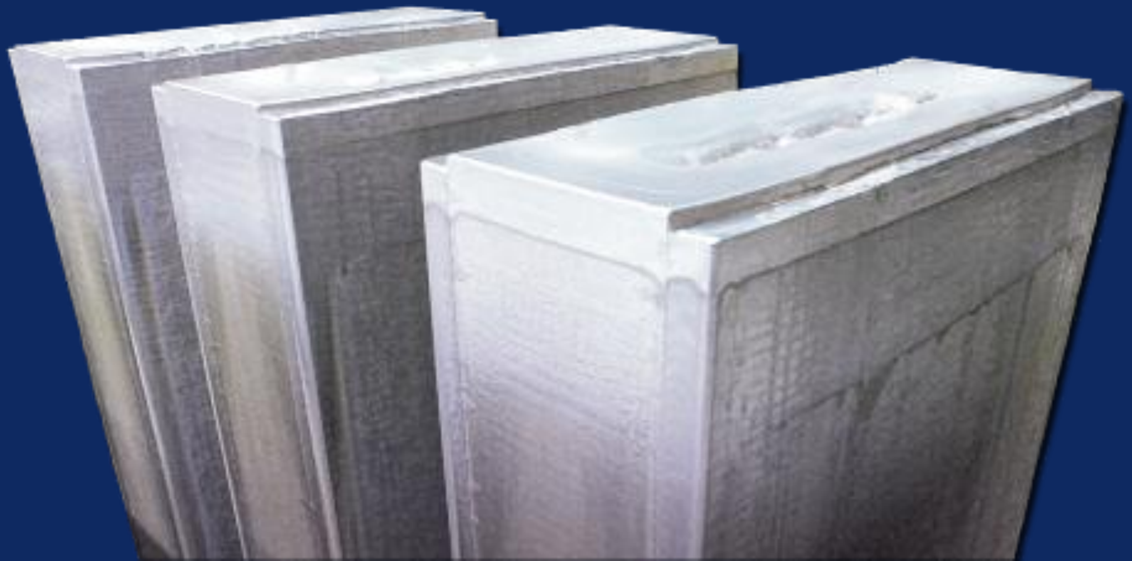
FURNACES OF THE PRESENT AND THE FUTURE

April 2025

Thiago Mikail de Oliveira



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VISION 3X30 – OUR GUIDING PRINCIPLES

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Highly Circular

75% Recycled Content

Push the boundries on the recycled content in our products

Low Carbon

< 3 tCO2e/tFRP

Be the lowest emissions flat rolled products (FRP) aluminum provider

Industry Frontrunner

Leader in Return On Invested Capital (ROIC)

Grow profitability to continue to fuel first-mover investments

OVERARCHING STRATEGY

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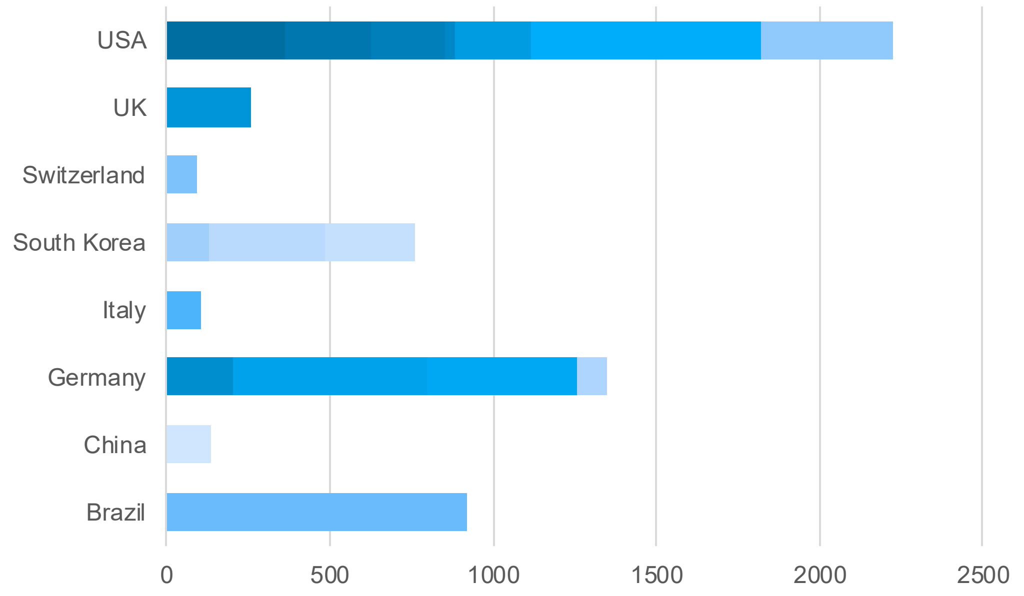
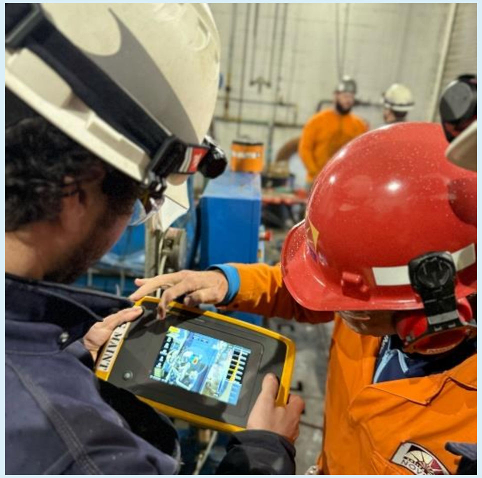


- 19 casting centers on 4 continents
- Diversity in furnaces design (type, controls, auxiliary, etc.)
- The challenge: scalable, adaptable strategy for decarbonized melting
- Strategy: Corporate target setting, plants execution based on Opex and Capex initiatives.

Target Setting for Plants

Opex Initiatives

- Metering and Management Systems
- Routine Management
- Treasure Hunt



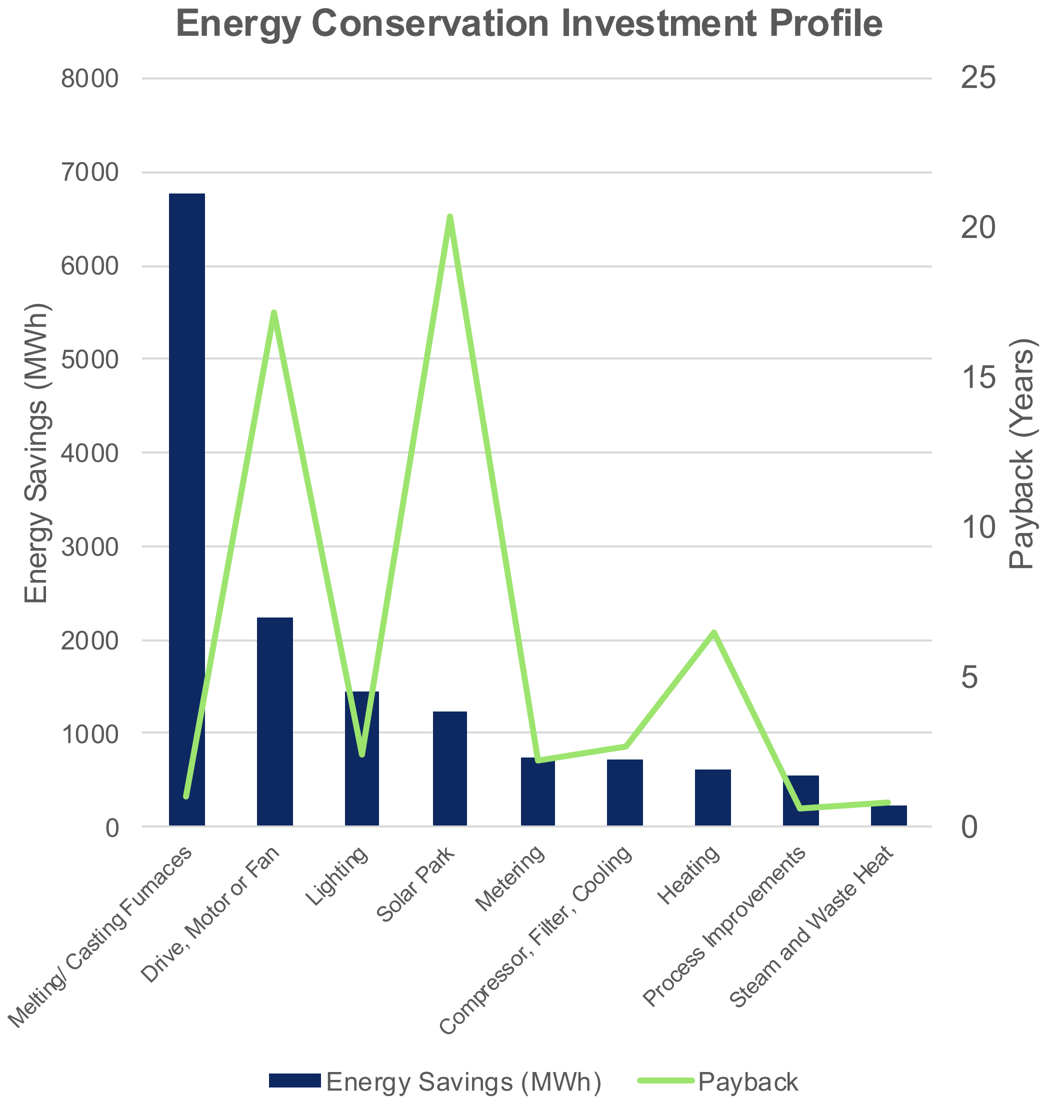
Capex Initiatives

- Priorization necessary
- Following EPN = Energy Priority Number

EPN = CO_2 x Payback

CO2 reduction (t/year)	Scale	Payback (Years)
1000	10	1
8000	8	3
5000	5	5
3000	3	8
1000	2	12

WHY IDEAL FURNACES?



- **Two Strategic Goals at the Same time**: Our casting furnaces present the most significant opportunities for energy savings in terms of absolute CO2 reduction on Operations and payback potential as demonstrated in FY23 initiatives.
- **Ideal Furnace Program**: We refer to this suite of enhancements aimed at reducing natural gas consumption in our casting furnaces as the 'Ideal Furnace' initiative.
- **Phased approach**: We have various levels of mechanical and automation. The investment is being made to capture the lowest hanging fruits first.

Region	Plant	Energy Conservation Measure	NG Energy Savings (MWh/ yr)	Cost savings (1000$ / yr.)	Funds (1000$)	Payback
NSA	Pinda	**[Ideal Furnace]** Furnace Control System Optimization	31.338	1.400	1.380	1
NE	Voerde	**[Ideal Furnace]** Regenerative Burner on SO1	13.520	893	1.800 + 1.800 (gvnt)	2
NE	Norf	**[Ideal Furnace]** Regenerative burner Melter 1	11.174	579	1.000 + (1.000 gnvt)	2
NE	Latchford	Routine management Energy Implementation	6.395	308	250	1

Top 4 Projects Implemented Projects with biggest savings in FY23

A GUIDELINE FOR A TODAY IDEAL FURNACE

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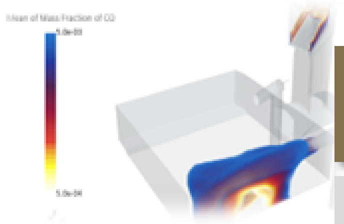
In-furnace Camera Vision

Reduction: 2-5%, depending on operations

Cost: medium



Ecomode/ Burner Controls

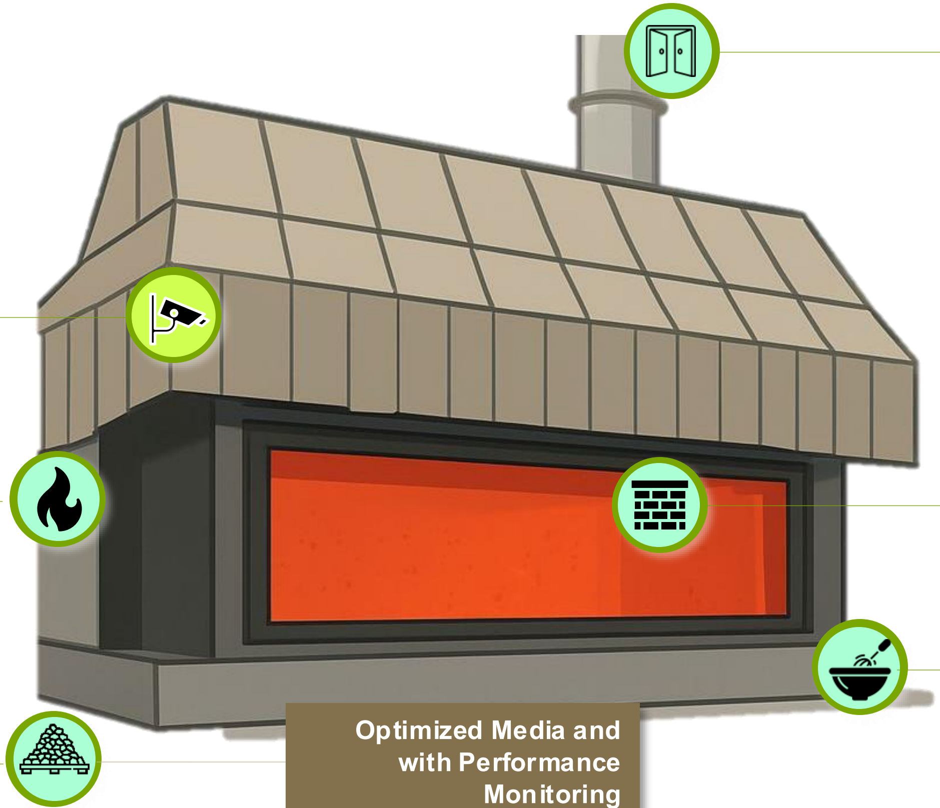
Reduction: 5-10%, automatic

Cost: medium

Regenerative Beds

Reduction: 25% automatic

Cost: high



Optimized Media and with Performance Monitoring

Reduction: 2-5% depending on operations

Cost: low

Exhaust Optimation

Reduction: 5-15% automatic

Cost: low

High-Emissivity Refractory or Coating

Reduction: 5-10% automatic

Cost:medium

Eletro-Magnetic Stirrer

Reduction: 5-10% automatic

Cost: medium-high

PLANTS MUST PREPARE TO ADOPT NEW TECHNOLOGY

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Melting Technologies

Hydrogen, Oxyfuel, Plasma, etc

CCUS

Plant of the Future

Simulate and Optimize

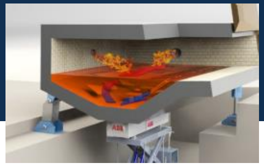
AI Furnace Control

Real-time Recommendations

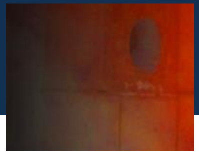
Scheduling Tool

Ideal Furnaces

Machine Vision



Magnetic Stirrer



High Emissivity Coating

Regen Burners

FORGING A CLEANER FUTURE

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People	
	▪ Evolving scenario, new expertise ▪ Learning is a constant

People

- Evolving scenario, new expertise
- Learning is a constant

Process

- Company process to embrace and scale what is relevant
- Drop as soon as possible what is not
- Constant exchange with partners, academia, competitors, etc

Technology

- One size won’t fit all
- Electrification is a trend
- How prepared we are

Malte Weiland

Siemens Smart Infrastructure

Electrifying Efficiency

Siemens All-Electric Powder Coating Paint Line

Malte Weiland,
Siemens Smart Infrastructure, Electrical Products

SIEMENS

Why?

- Business was experiencing exponential growth due to the boom in infrastructure spending and data center construction

- Customer and internal requirements for decarbonization of our products

- Original powder coating paint line was approaching the end of its useful life, Siemens saw an opportunity to update the system and decarbonize at the same time
    - New system was installed without any disruption to production on the factory floor

Our DEGREE sustainability framework

Decarbonization – Support the 1.5°C target to fight global warming

Ethics – Foster a culture of trust, adhere to ethical standards, and handle data with care

Governance – Apply state-of-the-art systems for effective and responsible business conduct

Resource efficiency – Achieve circularity, dematerialize, and conserve biodiversity

Equity – Foster diversity, equity, inclusion, and community development to create a sense of belonging

Employability – Enable people to stay resilient and relevant in a permanently changing environment

A 360° approach to our core sustainability values

Our DEGREE sustainability framework

Accelerating the implementation of DEGREE: ambitions achieved ahead of 2025

	DEGREE ambitions	Baseline	Progress until end of FY24	Ambitions	Achieved
Decarbonization	1. Reduce emissions in own operations by 55% by 2025	FY 19: **737 kt CO_2e**	-60%	-55% by 2025	✓
	Reduce emissions in own operations by 90% by 2030 and compensate residual emissions	FY 19: 737 kt CO_2e	-60%	-90% by 2030	
	2. Net-Zero supply chain by 2050, 20% emissions reduction by 2030	FY 20: **8,098 kt CO_2e**	-2%	-20% by 2030 -100% by 2050	

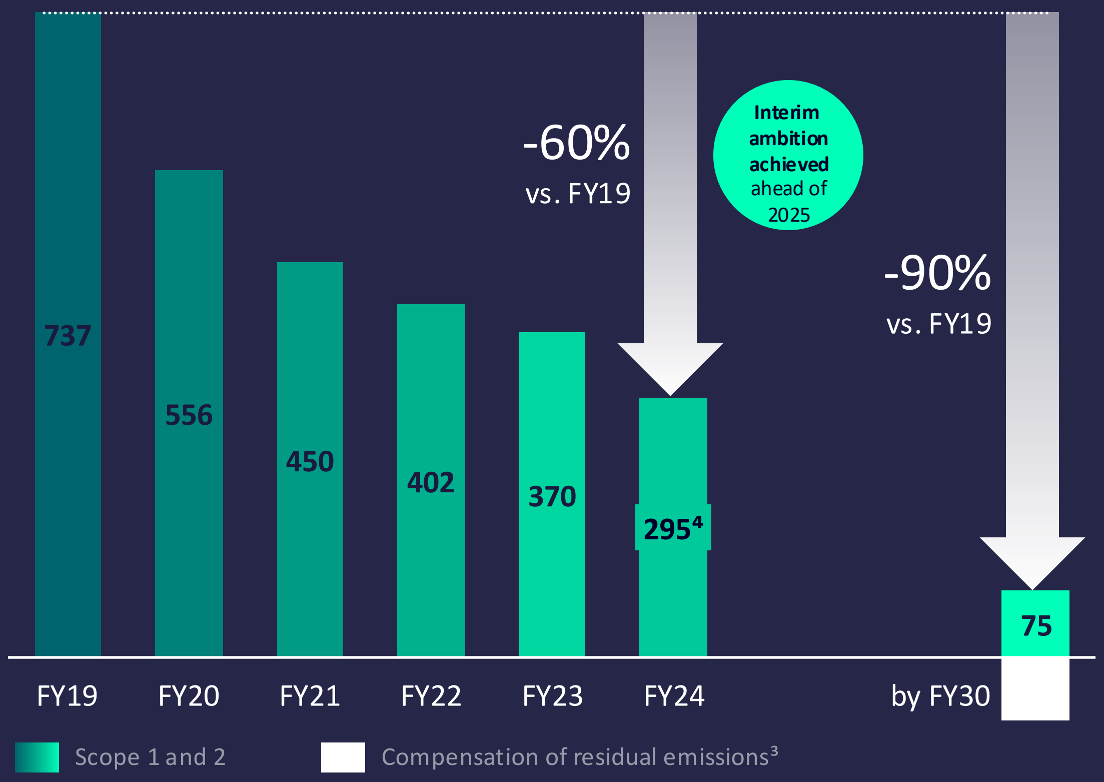
1 Assessment based on the Siemens internal ESG/Sustainability Index, which is based on CO_2e reduction and digital learning hours

2 Prior periods are presented on a comparable basis, based on an adjusted portfolio scope

SIEMENS

Decarbonizing our operations – CO_2e reductions in Scope 1 and 2 emissions lead the way to support our 1.5 °C-aligned SBTi Net-Zero commitment

CO_2 footprint in own operations[1]



We reached our DEGREE interim ambition (w/o SHS)

DEGREE ambition #1

✓	**Reached** our FY25 interim DEGREE ambition of -55% Scope 1 and 2 emissions from a FY19 base year one year in advance **(-60%)**
✓	FY30 ambition: reduce emissions in own operations by 90% by 2030 and compensate residual emissions
✓	Already 21% electric cars at Siemens (up from 11% in FY23)
✓	Already 91% of electricity from renewable sources[2] (up from 80% in FY23)
✓	Invest of ~€650m in operational decarbonization between FY22–FY30 (for fleet electrification, buildings, and production emissions)

Our Siemens commitments (w/ SHS)

✓	Validated 1.5 °C-aligned SBTi Net-Zero target	SCIENCE BASED TARGETS – DRIVING AMBITIOUS CORPORATE CLIMATE ACTION
✓	100% electrical vehicles, 100% renewable energy, and 100% net-zero buildings by 2030	CLIMATE GROUP EV100, CLIMATE GROUP RE100, CLIMATE GROUP EP100

1 Siemens without SHS, in 1,000 metric tons of CO_2e
2 70% already meets the new requirements of RE100 (plant age <15 years)
3 With high-quality carbon offsets
4 Without Innomotics: ~277 kt

SIEMENS

Brownfield Decarbonization Case Study – Grand Prairie, TX Plant

Baseline Total Energy Consumption
48,000 MMBTU

Gas
22,758 MMBTU
48%

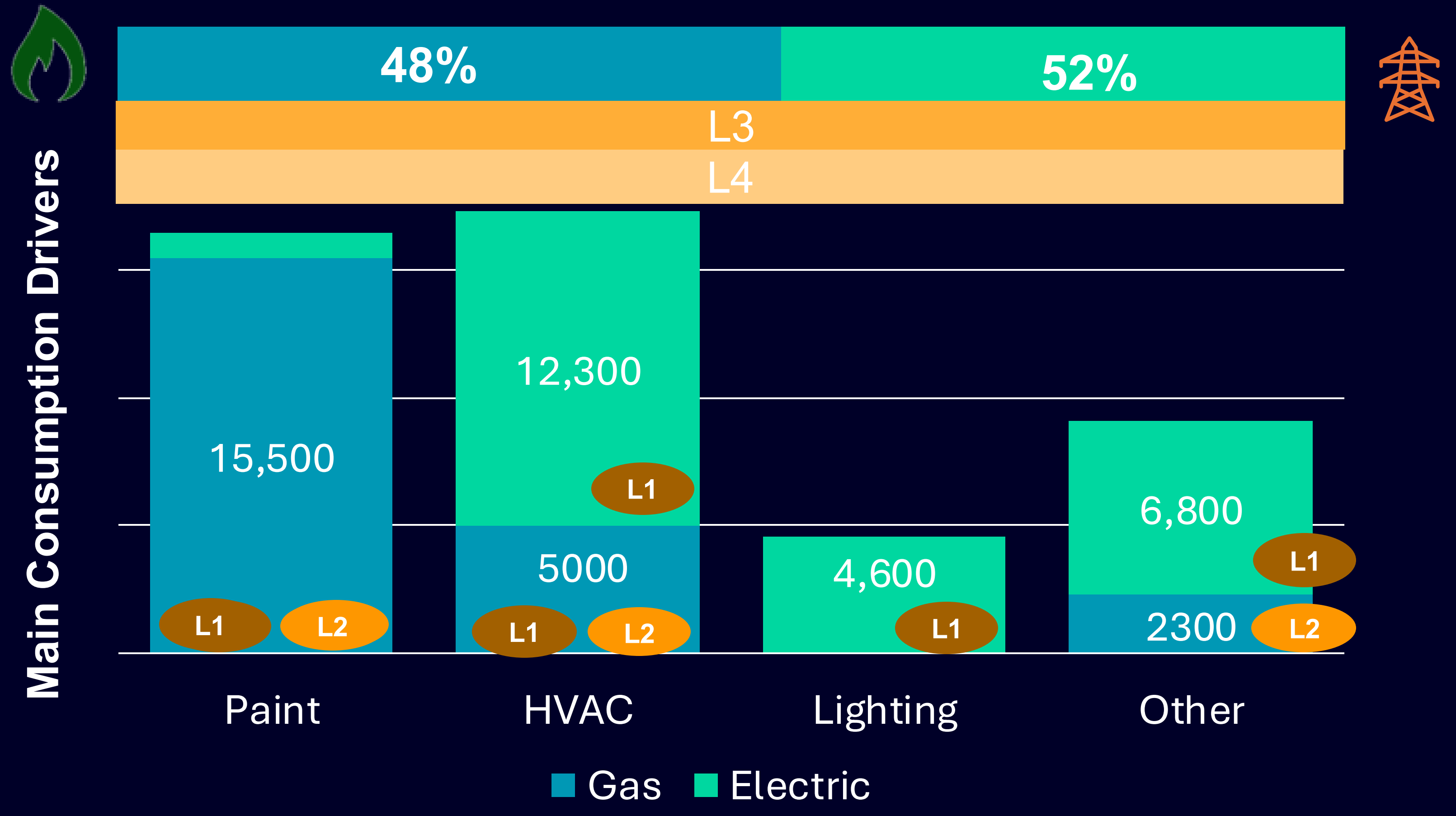
Electric
24,735 MMBTU
52%

Location Based Emission (2021) *Before RECs*	Market Based Emission (2021) *After RECs*
4,263Mt CO_2e	1,662 Mt CO_2e

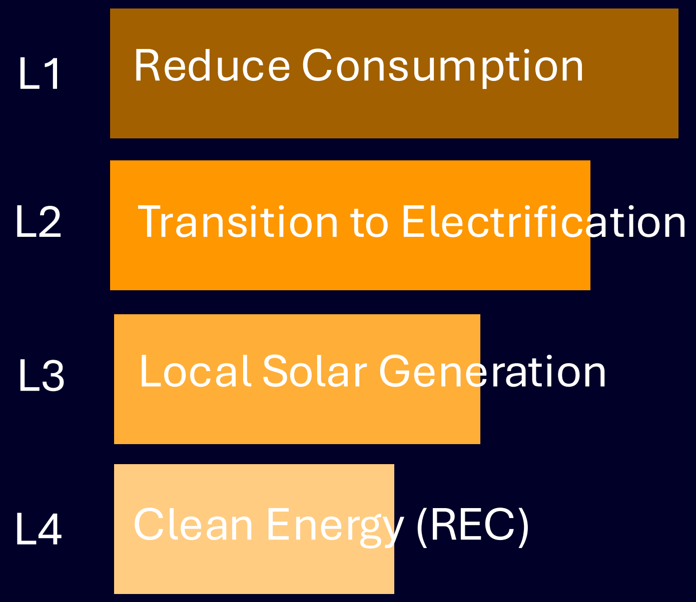
Electrical Products Produced

Main Consumption Drivers & Decarbonization Levers

Total Energy Consumption ~ 48,000MM BTU



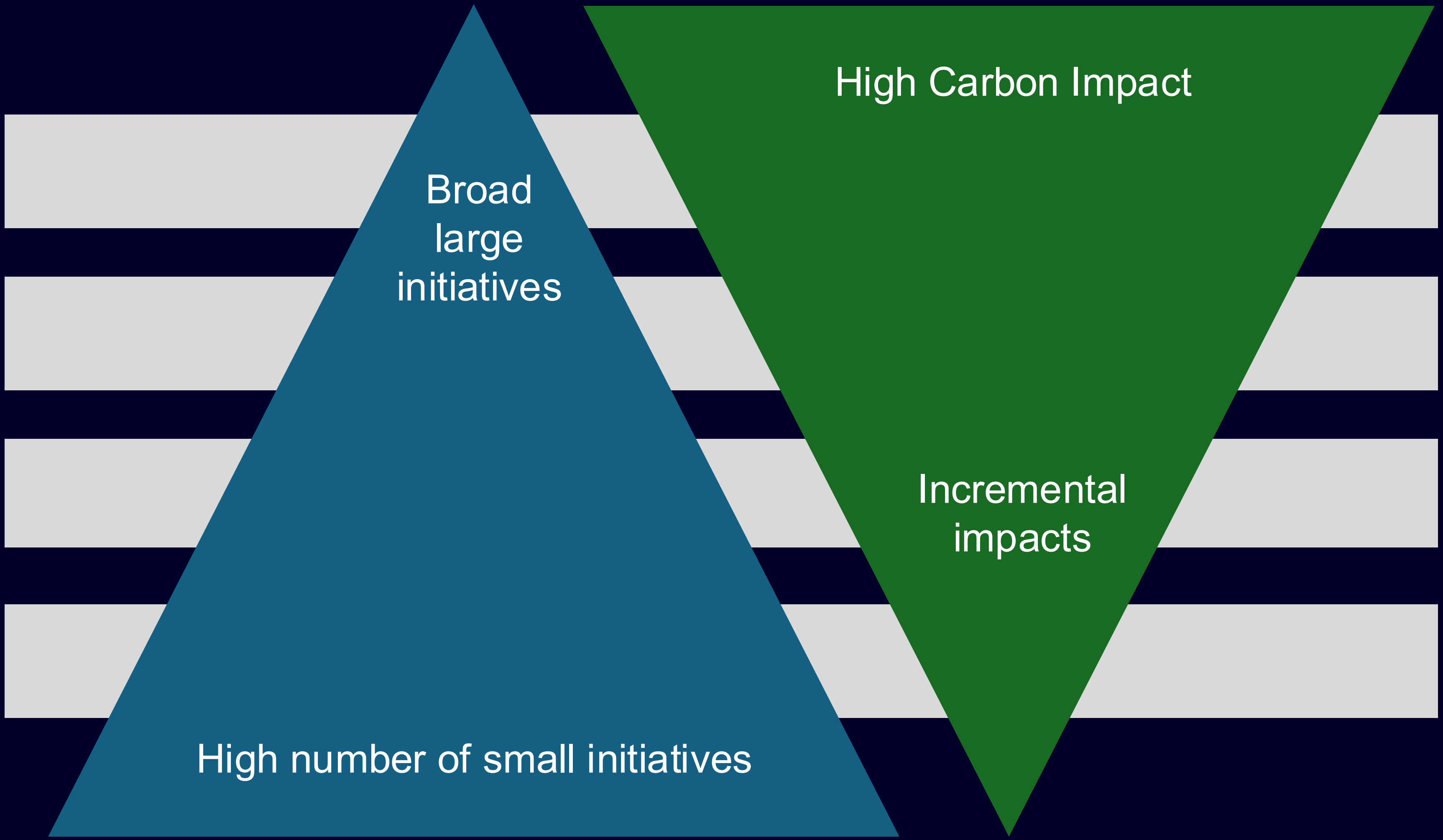
Decarbonization Levers



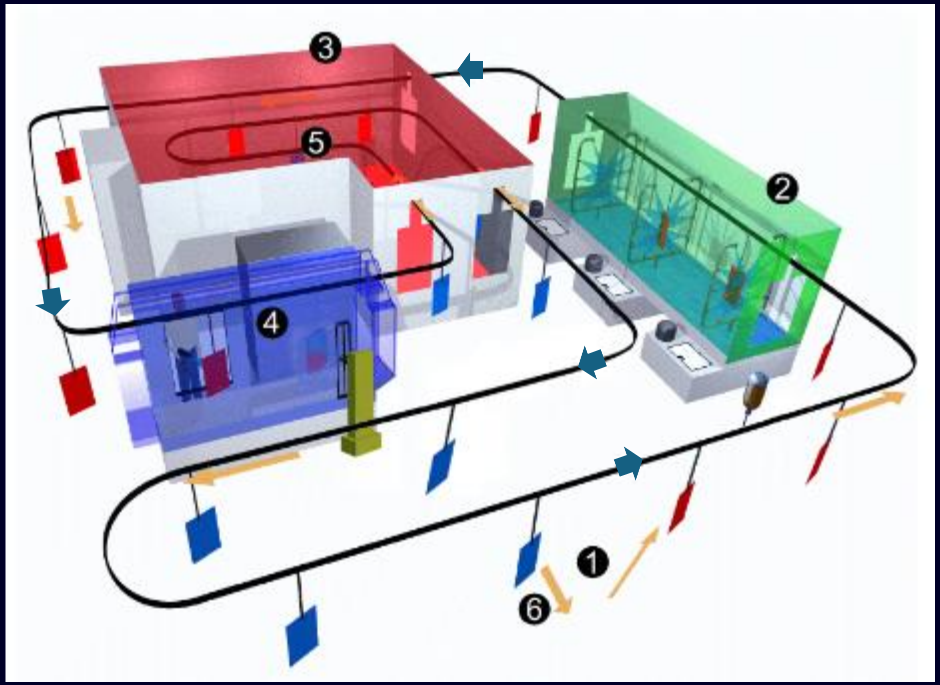
SIEMENS

Key Grand Prairie Factory Decarbonization Projects

1. Electrify Paint Line Ops
2. HVAC & Lighting
3. Onsite Solar Generation
4. Forklift & EV Chargers



Powder Coat Painting – Applications & Sustainability Challenges



Typical Layout Plan for Powder Coat Painting
1. Loading area for the workpiece need to be coated
2. Multiple stage pretreatment/cleaning system
3. Dry-off oven
4. Powder spray booth
5. Curing oven
6. Unloading area for finished workpiece

Sustainability Focus Areas @ Grand Prairie Paint Line

Load → 5 Stage Pre-Treatment, 2 heated stages +120 deg → 250 deg Oven (12k cu ft) → Paint Application → 400 deg Oven (50k cu ft) → Unload

Front End Processes:

- Lower E Powder Paint
- Enhance cleaning chemistry
- Replace Gas Heaters w/ Electric
- Enhanced Insulation / Heat Loss Reduction

Back End Dry/Cure Process:

- Replace Gas Heaters w/ Electric incl. IR
- Enhanced Insulation / Heat Loss Red
- VFD Applications where appropriate

Impacts:

- **One of the nation's first all-electric powder coating paint line for the electrical distribution industry**
- **Gas: 68% Site Reduction (- 15,500 MM BTU), + electrical/+RECs**

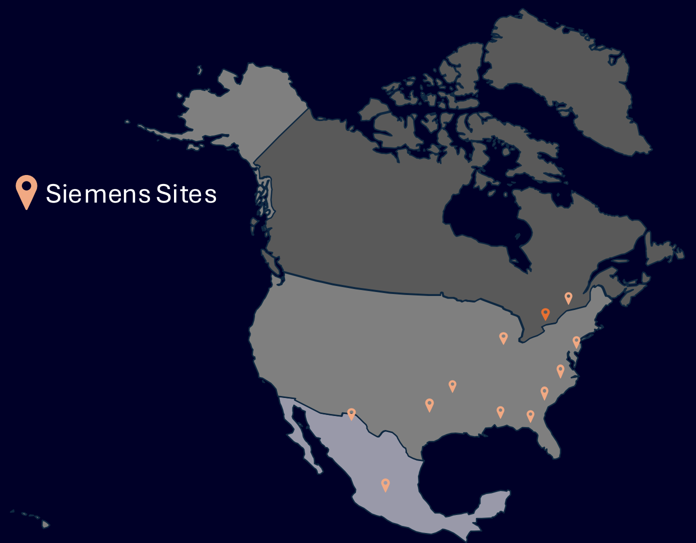
SIEMENS

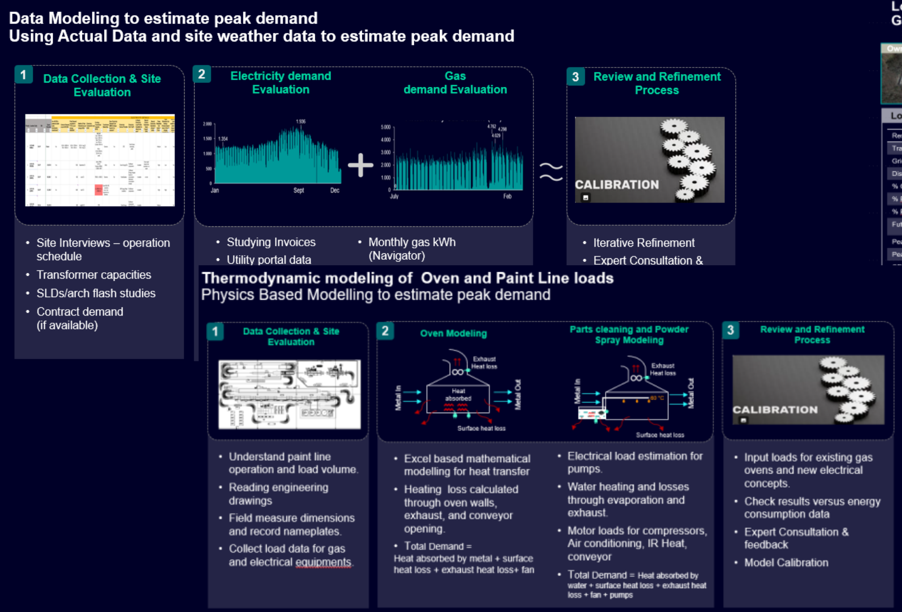
Collaboration with Energy Providers

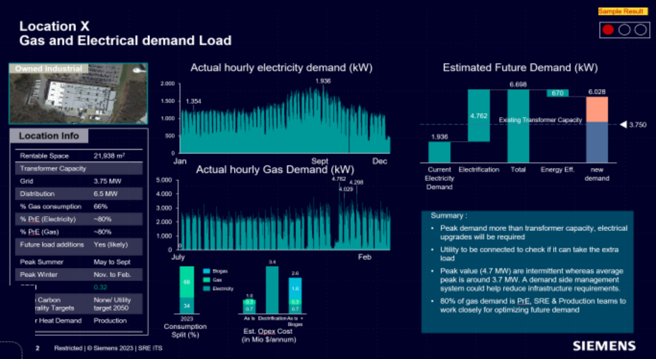
Identify existing electricity & gas demand for major sites

Estimate total future electricity demand for electrification by data modelling

Identify gaps to existing electrical infrastructure & high-risk sites







Challenges

- Demonstrating why decarbonization projects are a good business decision and will improve business, production and efficiency
  - Increased capacity and reduction in overall costs
- Research and Discovery – Collaboration with several builders of powder coating paint systems to gain a comprehensive understanding of the process
- Deep, detailed day-by-day planning, and execution

Advice to Other Organizations

- Planning ahead for the short and long term while the current system is still up and running. i.e. utility, infrastructure backlog
- Continue tracking improvements to the overall operation to validate the decision to leadership and that further improvements can continue to deliver business and sustainability wins.
- Look for efficiencies in other buildings systems (HVAC, Domestic Hot Water)

Decarbonization of this Site is Just a Start…

- **Apply Learnings @ new Pomona and Fort Worth facilities**
- **Apply Concepts @ Other Brownfield Sites**
- **Continued Enhancements @ Grand Prairie**
- **Continued engagement with SMEs**

Q & A

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