



Sustainability at Fermilab: Engaging Mission and Operations

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Agenda



What is sustainability?

Etymologically:

Sustain + able + ity

Sustain = “keep up”, “keep going”, “or support something”.

As a societal goal, means to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations.¹



DOE and Fermilab Sustainability Goals



DOE Sustainability Goals:

- Maximize energy and water efficiency;
- Minimize chemical toxicity and harmful environmental releases, particularly GHG;
- Promote renewable and other clean energy development;
- Enhance climate adaptation resilience, and conserve natural resources while sustaining assigned mission activities.

Addressing Climate Change is a Sustainability Key Driver

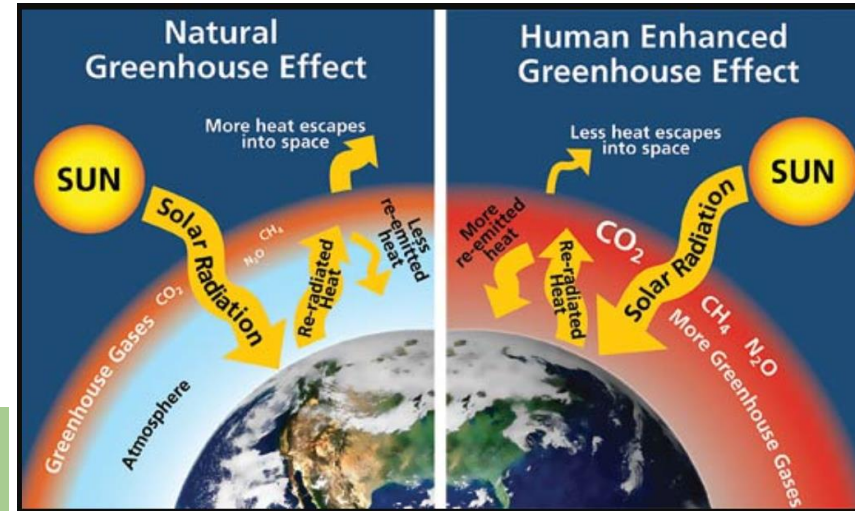
Sustainability is important for many reasons, including helping to address climate change.

Natural Greenhouse Effect is a natural warming of the earth when gases in the atmosphere trap heat from the sun that would otherwise escape into space, making the earth viable for life.

Human Enhanced Greenhouse Effect is an increased rise in global temperatures from higher concentrations of greenhouse gases, and carbon dioxide (CO₂) in particular.

Global concern around to numerous negative effects:

- Causing more frequent and/or intense extreme weather events, including [heat waves](#), [hurricanes](#), [droughts](#), and [floods](#).
- Exacerbating precipitation extremes, making wet regions wetter and dry regions drier.
- [Rising sea levels](#), due to melting ice sheets and glaciers and an increase in ocean temperatures (warmer water expands, which can contribute to sea level rise).
- Altering ecosystems and natural habitats; shifting animals' geographic ranges, seasonal activities, and migration patterns.



Concentration of CO₂ was roughly between **200 and 280** parts per million for past 800,000 years

<https://www.nps.gov/goga/learn/nature/climate-change-causes.htm>

Concentration of CO₂ is now **over 400** parts per million

Fermilab FY 2023 Emissions: 71,490 MtCO₂e*

Scope 1, 2 & 3 Emissions

Equivalent to the annual emissions from 11,500 average homes.

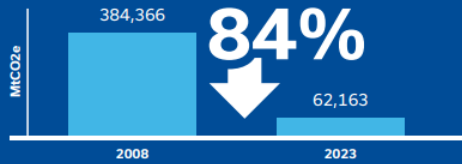
- Natural gas
- Electricity
- Non-Fleet V&E Fuel
- Fleet Fuel
- Fugitive Emissions
- T&D Losses*
- Air Travel
- Ground Travel
- Commute
- Off-Site MSW
- Off-Site WWT



*63,000 MtCO₂e is not included in total because emission are offset by renewable energy certificates

Fermilab Key Sustainability Metrics 2023

Carbon emissions



GOAL: Net-zero by 2050

Resource conservation



12X

Cooling water is reused 12 times before being discharged from the site



52%

of waste diverted (municipal solid waste)



81%

of construction and demolition debris diverted from landfill

Electrification



35%

carbon pollution-free electricity (FY23)

GOAL: 100% by 2030



42%

166/394 of Fermilab's buildings are electric (FY23)

GOAL: 100% by 2045



52%

zero emission vehicle acquisition

87 total vehicles ordered, 45 are mix of plug-in hybrid electric vehicles and battery-electric vehicles

GOAL: 100% acquisitions by 2035

Education and planning

16 staff trained on energy

121 staff trained on climate AND energy (Earth Day and training)

45 Sustainability Management Team members

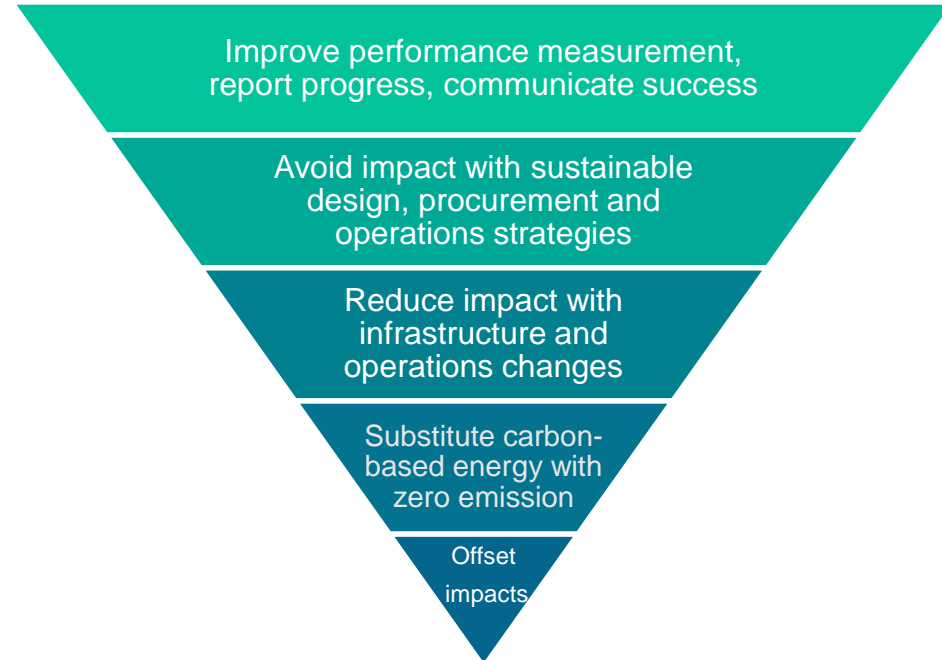
Fermilab Sustainability Strategy

Sustainability Vision: Be a global leader for sustainability in particle and accelerator physics and technology innovation.

Key Strategies



Key Objectives



Sustainability Management Team

Catherine Hurley



Sustainability Manager

- Lead Lab wide program
- Develop strategy
- Report & communicate progress
- Collaborate with DOE, NL's and external partners

- Chartered by COO
- Organizationally located in Infrastructure Services – Engineering
- 46 SMT members
- 14 groups / departments represented

Shivani Saikar



Energy Manager

- Analyze energy use
- Identify energy savings measures
- Develop projects
- Coordinate energy procurement

Kerry Aschenbach



Environmental Engineer

- Identify water savings measures
- Develop projects
- Advance sustainable & resilient buildings

Alyssa Rodway



Sustainability Associate

- Improve recycling & waste reduction
- Increase green purchasing
- Environmental justice

Sub-teams

Sustainability in Science	Water Management	Environmental Stewardship	Communications, Outreach & Reporting
Energy Management	Sustainable & Resilient Infrastructure	Sustainable Operations	Transportation

Sustainable, Net Zero Carbon Infrastructure



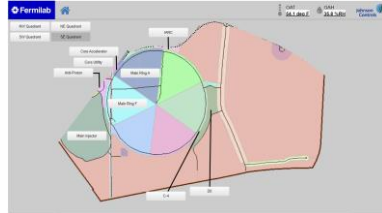
Traditional Energy Conservation Measures



Lighting



Transformers

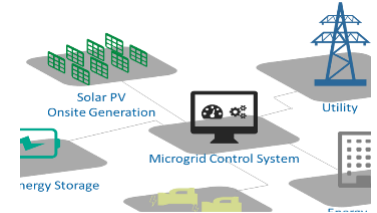


Controls

Innovative Energy Conservation Measures



Battery Energy Storage



Microgrid



Renewables



EV Charging

Fermilab Resilience and Efficiency Project

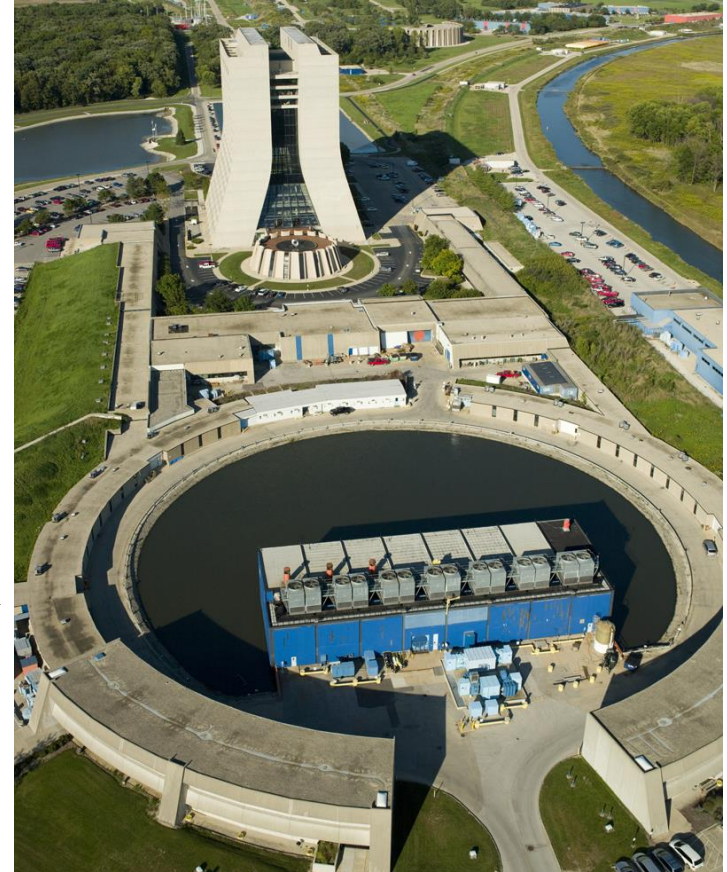
Ongoing Development – PV + BESS at Master Sub Station

- Goal to maximize on-site generation, provide resilience and minimize environmental impact
- Size and scope under development
 - Potential generation of approximately 135,000 MWh/year.
- Current analysis pending:
 - Interconnection allowances
 - FNAL feeder & load priorities and analysis (MCS)
 - Economic analysis



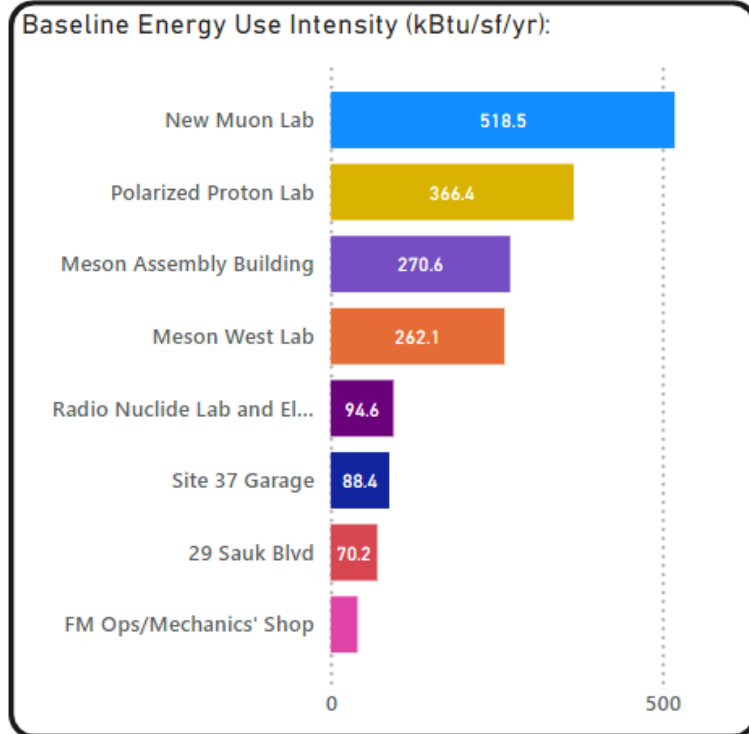
Central Utility Building Improvements Integrate Sustainability

- DOE funded major renovation of the Central Utility Bldg.
- Selected heating and cooling equipment will lead to 88% reduction in natural gas use within project budget
- Sustainable design features, compliant with Guiding Principles for Federal Sustainable Buildings:
 - Commissioning (optimizing) of plant at start up
 - Maximize daylighting and LED lighting with occupancy sensors
 - Variable speed controls
 - Bird safe architecture
 - 30% better than ASHRAE efficiency requirements
 - Building sited to avoid ecologically sensitive areas; re-utilization of existing footprint and infrastructure
 - EV charging stations
 - Energy and water metering
 - Recycling 50% of construction waste
 - Maximize use and reuse of alternative water as opposed to potable water



Electrification Study

- Goal: Develop building level roadmaps for electrification
 - Target buildings not included in FREP or UIP
- Scope of work:
 - Evaluate infrastructure for energy efficiency opportunities and elimination of natural gas use
 - Electrical infrastructure evaluation
 - Natural gas and HVAC systems review
 - Backup generator systems assessment
 - Building envelop and architectural evaluation
 - Electrical, and Mechanical Upgrade Options
 - Impacts of ZEV Master Plan
 - Develop building electrification plan with ROM cost estimate
- Timeline:
 - Study On-going: April - September



Zero Emission Vehicle Master Plan

EV Charging Master Plan



66 EV charging stations at ~27 locations



Maximize ZEVs, seeking lowest emission replacement whenever possible



Accept PHEVs & biodiesel replacements as needed while market adjusts



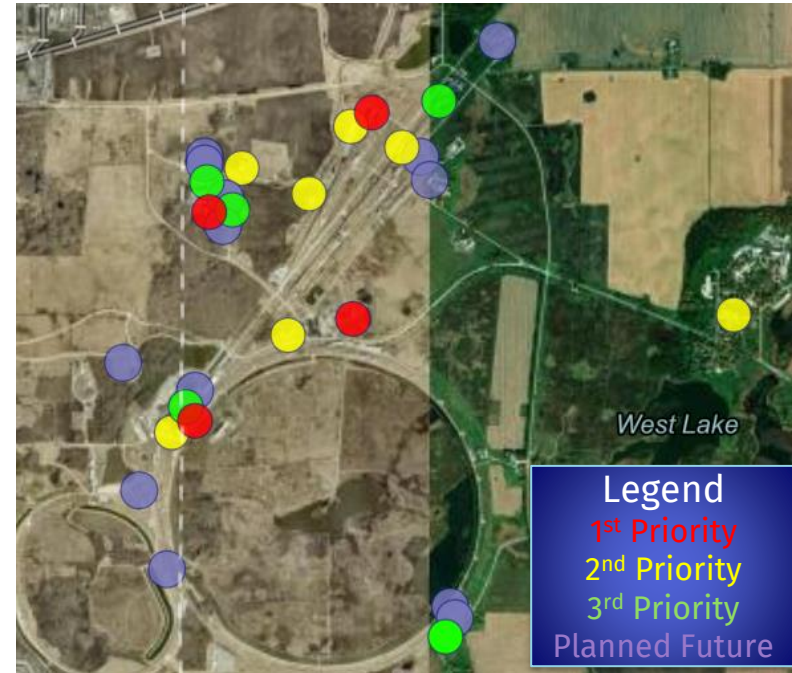
~78% can be electrified now, 15% have a PHEV replacement, 7% do not have an adequate replacement



Acquisitions vs. fleet makeup – in 2027 acquisitions need to be 100% ZEVs, fleet will take time to convert over fully

Phase 1 Electric Vehicle Charging Station Project

- Fleet ZEV and EVSE master plan developed in FY23
 - 66 EVSE needed at 27 locations vs 2 EVSE existing
- Phase 1 Project Defined
 - 24 Dual port EVSE needed to support FY24 ZEVs ordered through GSA
 - 32 Fully Electric and 15 plug-in hybrid electric arriving in waves
 - Conceptual design completed: in-house engineering resources
- Leveraging multi-approach strategy:
 - Completing detailed design on Phase 1 project
 - Maximize use of existing Level 2 Charging Stations
 - Leverage existing Level 1 outdoor outlets
 - Add EV charging into scope for Fermilab Resilience and Efficiency Project
- Stakeholder outreach completed to inform Employee EV Charging program changes to support sharing stations with Fleet
- Fermilab awarded DOE Green Fleet Award for FY 24 Vehicle Procurements



Sustainability in Science Focus Areas and Examples

Engaging the science and engineering community to achieve long-term sustainability goals

Incorporate sustainability into new scientific infrastructure and activities.



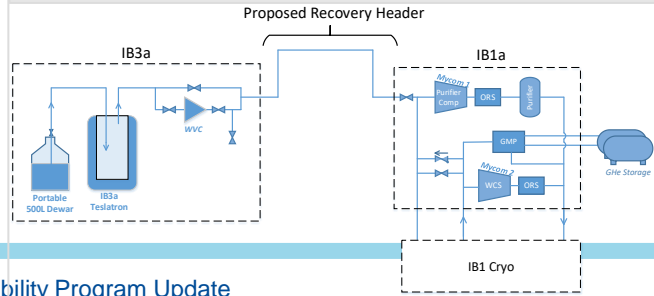
PIP-II cavities are nitrogen-doped and mid-T baked and will help cut the cryogenic losses of this machine by up to a factor of two

Enhance scientific infrastructure and activities to support sustainability.

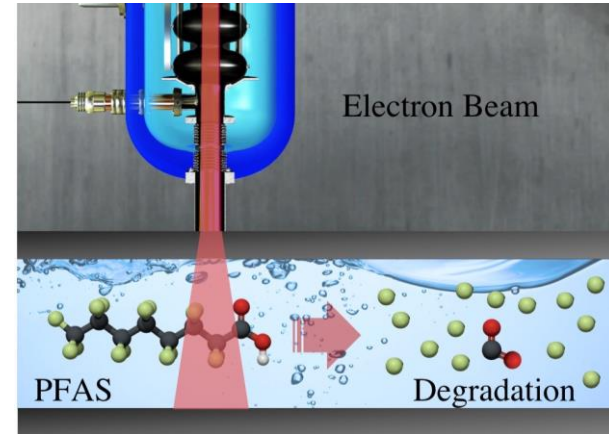
Conceptual over the roof recovery pipe routing from IB3a to IB1.



Simplified Schematic of IB3a to IB1a Recovery System.



Export technology and capabilities to advance sustainability in the world.



Electronic Beam Applications at IARC:
Destruction of PFAS, Water Treatment,
Destruction of Toxins in Soil

Sustainability in Science Focus Areas and Activities

Engaging the science and engineering community to achieve long-term sustainability goals



Incorporate sustainability in scientific infrastructure

New Initiative:

- Workshop to sustainability for particle accelerators.

Support Active Idea:

- Energy savings for Main Injector RF Cavities



Innovate to operate scientific infrastructure more sustainably

New Initiative:

- Baseline accelerator energy use and identify systems that can be optimized for energy savings

Support Active Idea:

- Low conductivity water system upgrade



Export capabilities to advance sustainability in the world

New Initiative:

- Fermilab IARC industrialization effort is exploring development of emerging technologies application concepts to support sustainability.

Support Active Idea:

- Collaborate with Superconductivity Global Alliance to host workshop

Redefining Implementation through Living Lab Framework

Living labs are open innovation ecosystems in real-life environments using iterative feedback processes throughout a lifecycle approach of an innovation to create sustainable impact.

OPERATIONS



LIVING
LAB

LEARNING



RESEARCH



INNOVATION

We are exploring sustainability solutions that can be created, prototyped, tested and scaled up at Fermilab.

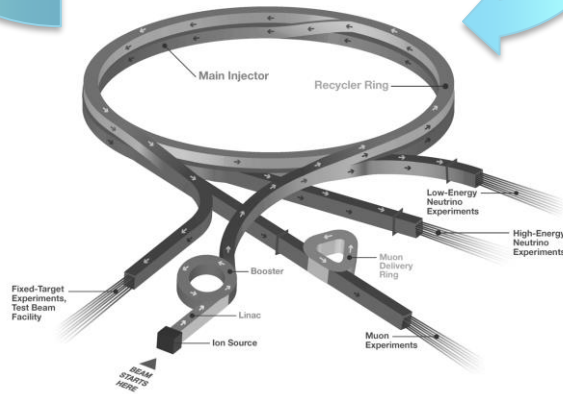
Living Laboratory at Fermilab

Concept

Fermilab Conventional Facilities



Fermilab Accelerator Complex



Technologies for deep energy, net zero emissions building retrofits

Innovative approaches to reducing accelerator complex energy use

Testbed for integrating clean energy in energy intensive, pulsing energy power

Data Analytics AI and Machine Learning

Accelerator technology applied to societal problems

Industry Partnerships

National Lab Partnerships

Federal Agency Partnerships

Community Partnerships

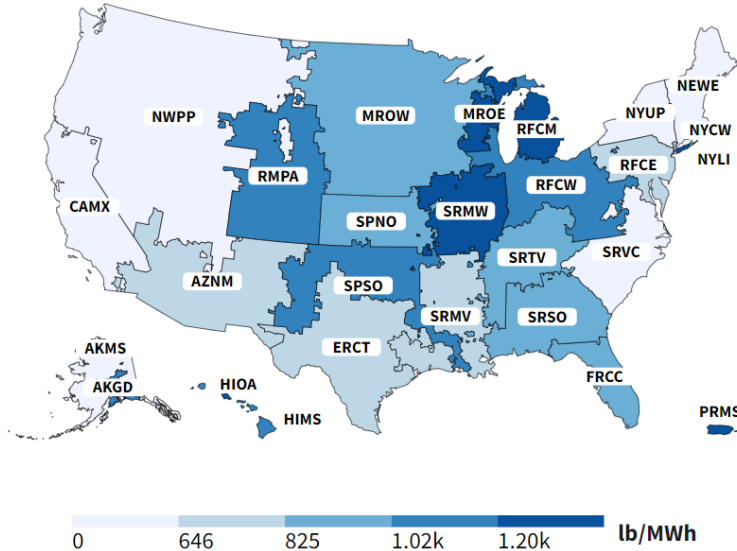
Educational Partnerships

Thank you.



Fermilab Emissions Based on Grid Region

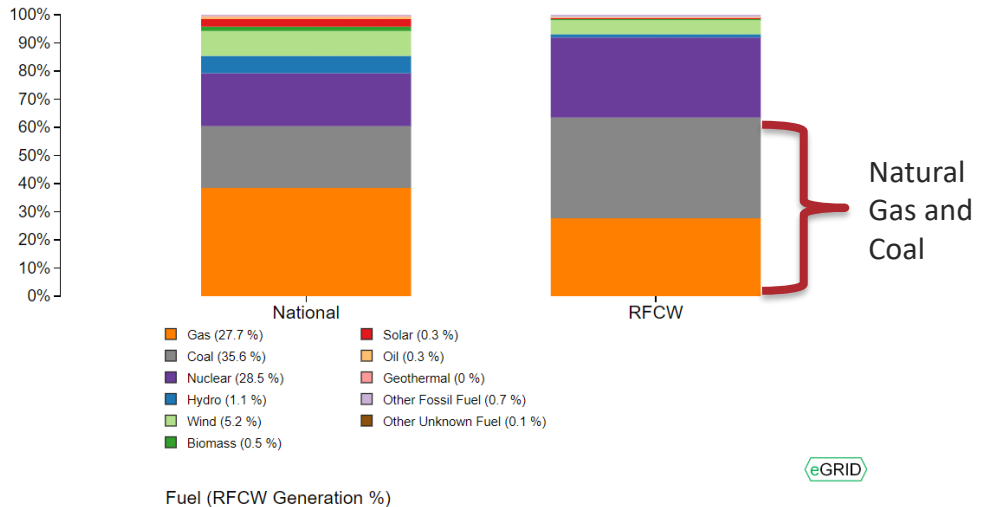
CO₂ total output emission rate (lb/MWh)
by eGRID subregion, 2021



Fuel Mix

This chart compares fuel mix (%) of sources used to generate electricity in the selected [eGRID subregion](#) to the national fuel mix (%).

Generation



Emission Rates

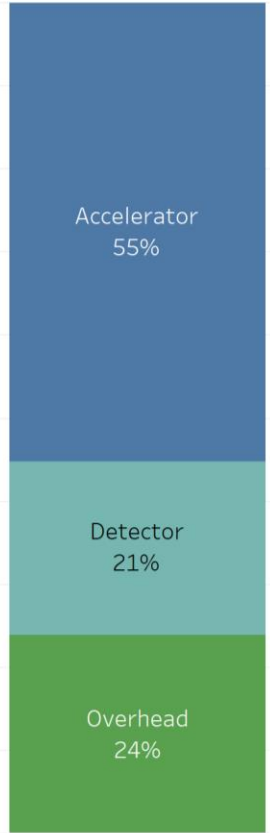
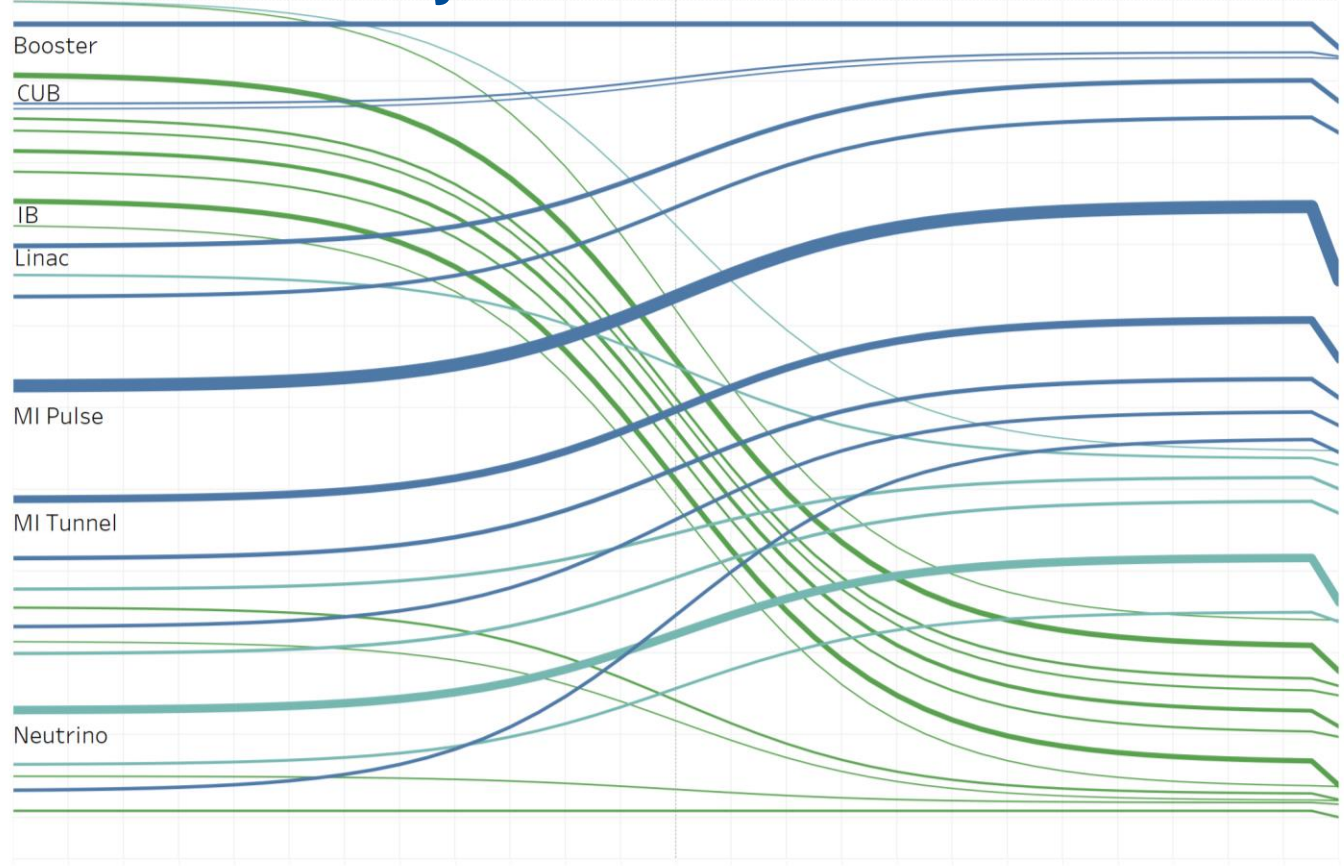
This chart compares the average emission rates in pounds per MWh in the selected [eGRID subregion](#) to the national average

<https://www.epa.gov/egrid/power-profiler#/RFCW>



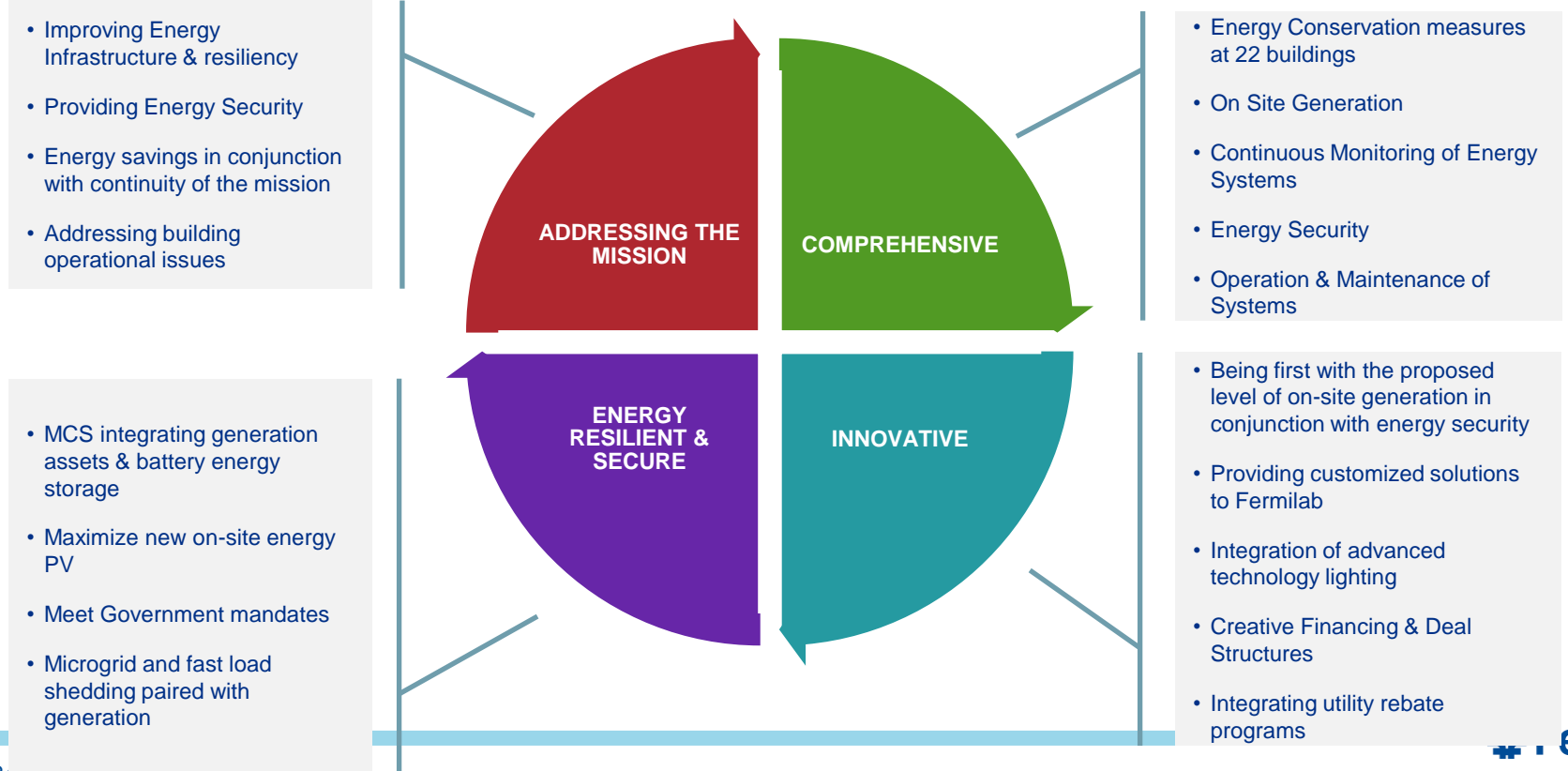
Fermilab Electricity Breakdown FY 2023

Energy consumption by end use



Fermilab Resilience and Efficiency Project

Zero Emission Energy & Buildings

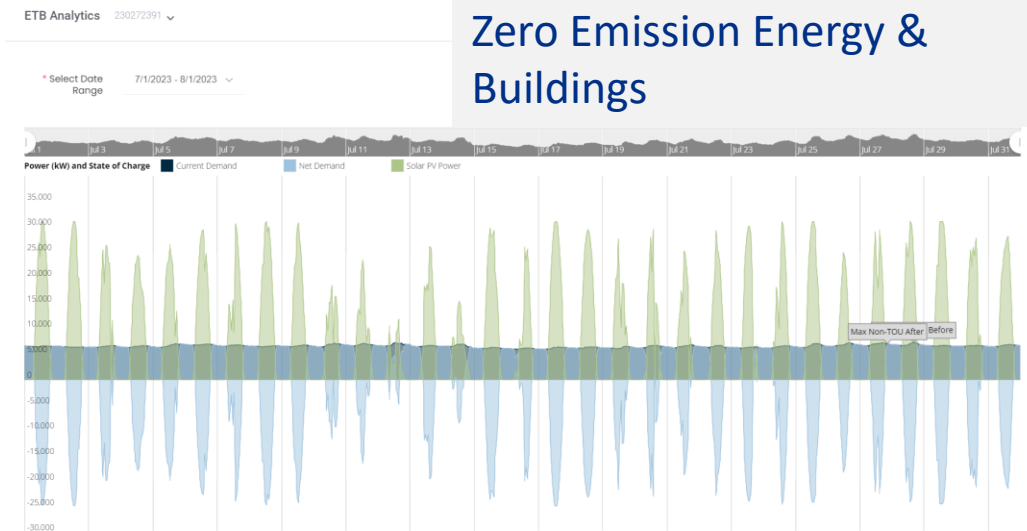


Fermilab Resilience and Efficiency Project

Ongoing Development – PV

- Solar generation will exceed base load at peak generation and be net metered with ComEd.
- Projected generation of approximately 134,805,700 kWh/year.
- Offsetting overall fossil fuel electrical usage by more than half.

Zero Emission Energy & Buildings



Result summary

Module DC Nameplate
97.44 MW

Performance Ratio
85.3%

Inverter AC Nameplate
82.40 MW (DC/AC Ratio: 1.18)

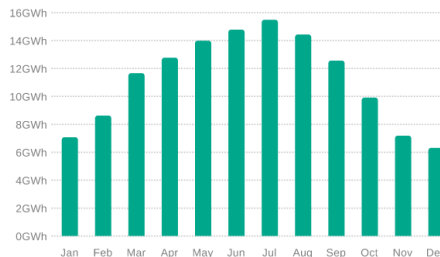
Shade loss
2.1%

Energy production
134805.7 MWh/year

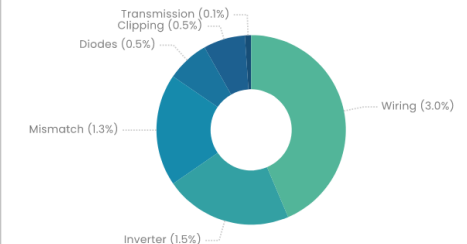
Rear irradiance gain
6.5%

Specific yield
1383.5 kWh/kWp/year

Energy production



System loss



Sustainability and 2023 Particle Physics Project Prioritization

Panel (P5) Report

A 10-year strategic plan for US particle physics, in the context of a 20-year global strategy

6 Investing in the Future of Science and Technology

6.9 Sustainability and the Environment

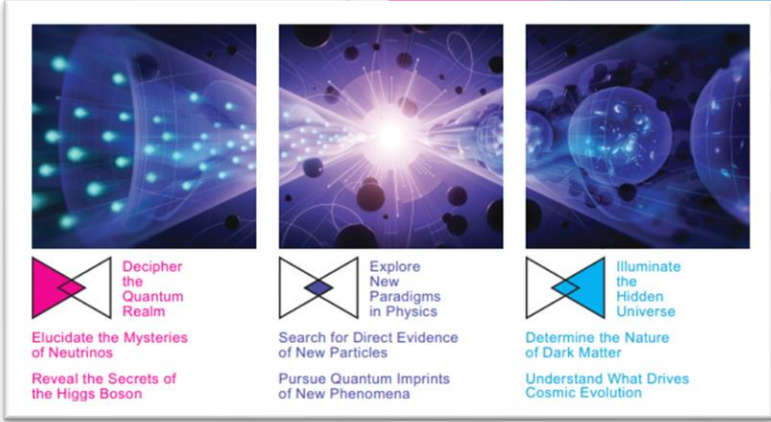
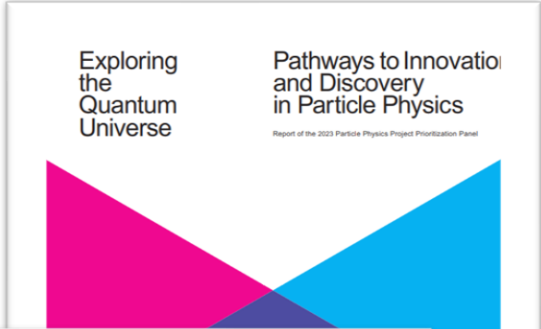
Commitment to sustainability is a high priority for particle physics activities. This includes energy and carbon management, energy efficiency and savings, and environmental impact. It concerns present and future accelerators as well as testing and computing facilities.

Important to:

- Establish and launch at an early stage a full lifecycle sustainability effort.
- Promote energy efficient accelerator concepts, as well as identification and development of energy saving accelerator technology.

Accelerator technologies play a key role in sustainability:

- Investments in high field magnets are benefiting materials science, fusion energy research (FES), and commercial development
- Innovation in electric power generation, management and distribution also contribute to sustainable development.



Sustainability and 2023 Particle Physics Project Prioritization Panel (P5) Report

A 10-year strategic plan for US particle physics, in the context of a 20-year global strategy

6 Investing in the Future of Science and Technology

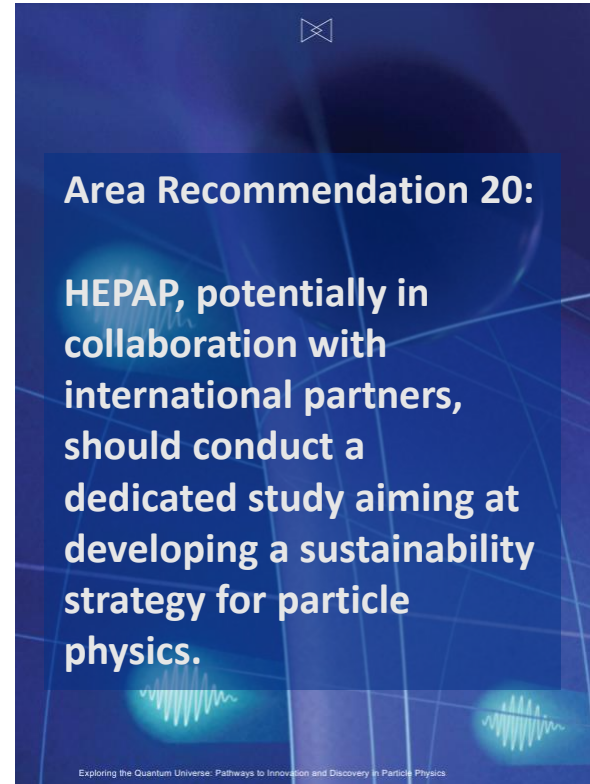
6.9 Sustainability and the Environment

Benefits:

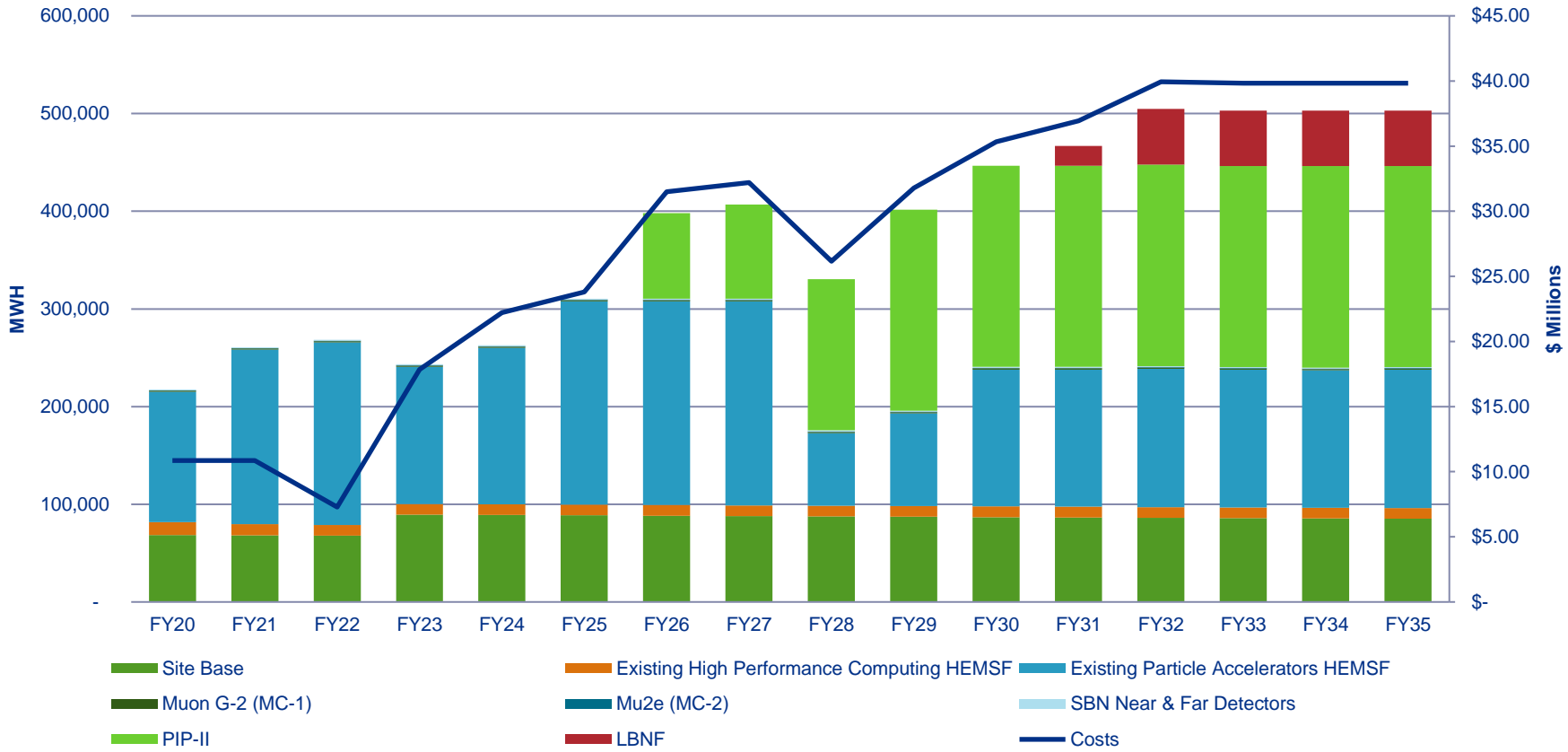
- Affect the affordability of new accelerators.
- Demonstrate the responsible role of the HEP community in society.

Key Areas of Opportunity:

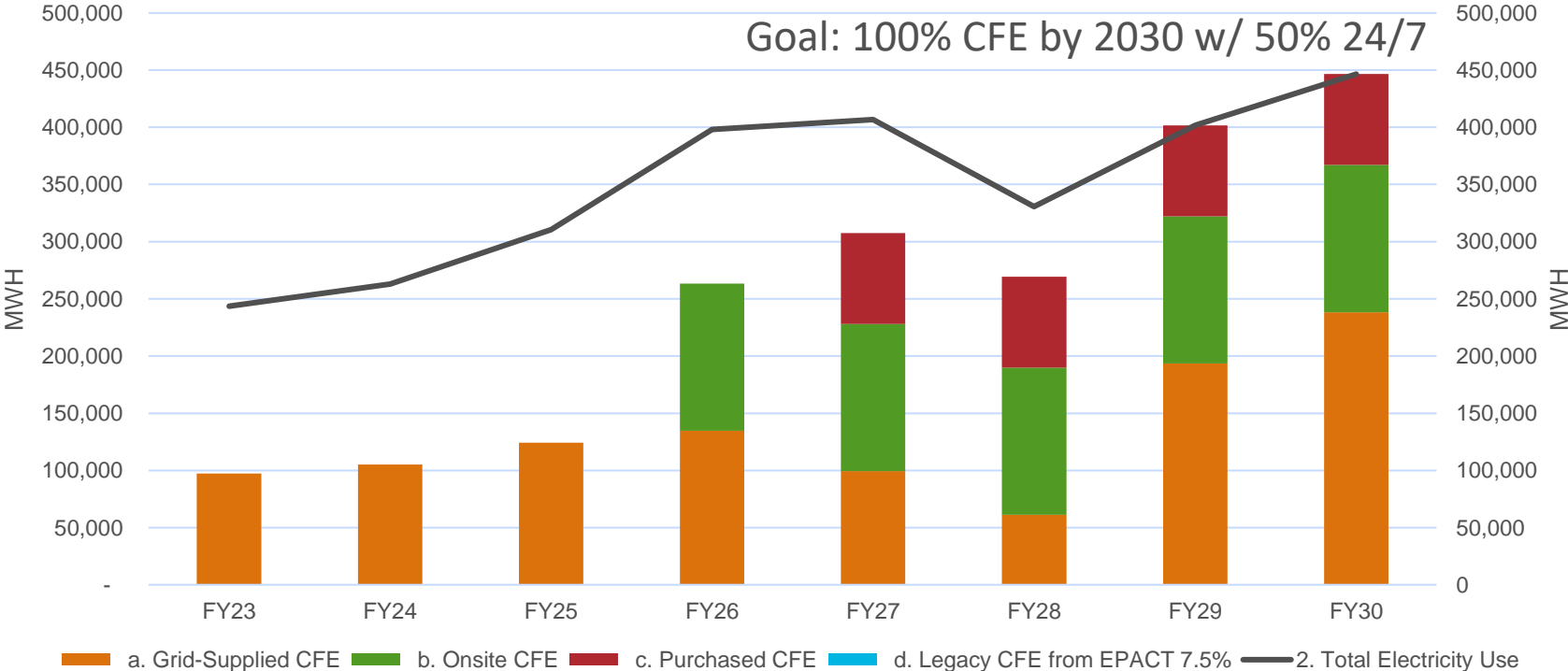
- Define sustainable requirements on industrially procured technology, including construction, electrical, and cooling equipment
- Reduce carbon footprint of civil engineering components
- Reduction of CO₂ from gases and capture/re-use
- Re-use of materials and limit of natural resource and raw material use, including critical materials
- Reduction in travel
- Development of consistent metrics for sustainability of research, construction, and operations.



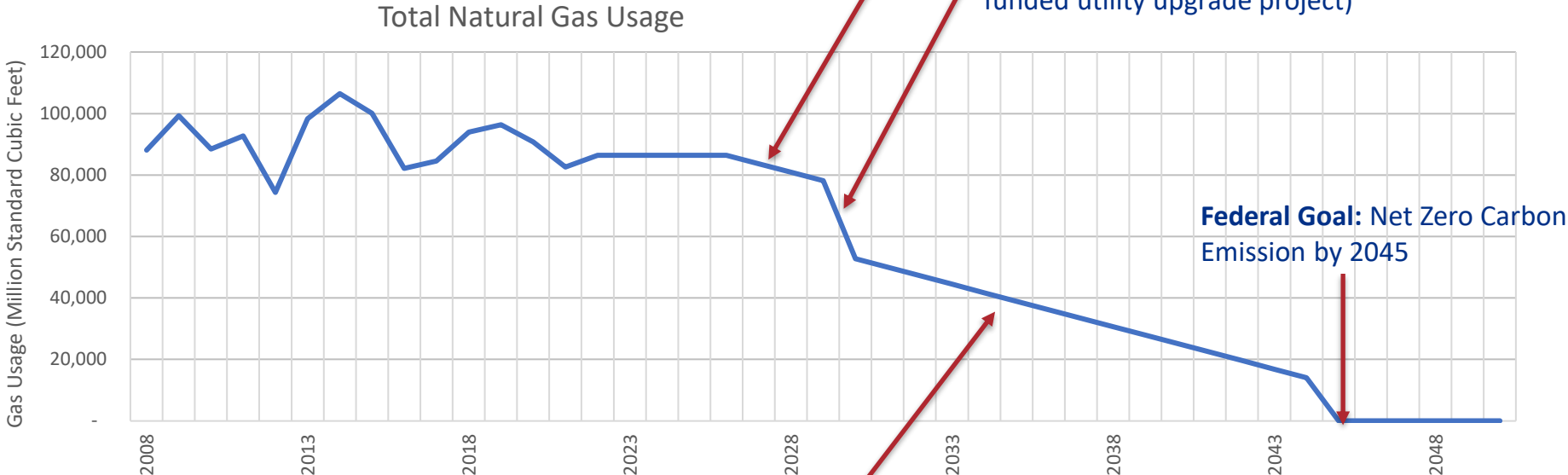
Fermilab Electricity Use and Projections



Zero Emission Energy Plan and Projection



Reduction of Natural Gas Use for Net Zero Buildings Goal



Planning:
Reduction from FREP Project
(ESPC funded efficiencies at multiple buildings)

In progress:
88% reduction at CUB from UIP Project (SLI funded utility upgrade project)

Federal Goal: Net Zero Carbon Emission by 2045

Study underway:
Incremental reduction as building and feeder specific projects are completed.



Communications and Engagement



Annual Earth
Day Fair



Monthly Fireside
Chats with
Sustainability



Annual
Reporting