Sustainability at Fermilab: Engaging Mission and Operations

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Agenda

- Sustainability Overview & Drivers
- Fermilab Sustainability Context
- Sustainability Strategy
- Carbon Free Electricity
- Net Zero Buildings
- Zero Emission Vehicles
- Sustainability in Science

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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.

Sustainable Development Definition:

- Way of organizing society so it can exist in the long-term
- Global definition of a condition where human societies must live and meet their needs without compromising the ability of future generations to meet their own needs.[1]
- UN Sustainable Development Goals provides a shared blueprint for countries to achieve peace and prosperity for all people and the planet, now and into the future.

1 *Our Common Future*, commonly called the Brundtland Report.

Sustainability Definition, Drivers, and Goals

Sustainability at DOE and Fermilab is defined broadly as those actions taken to:

- 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.

White House Federal Sustainability Plan (FY21-22)

EO 14008	EO14057	CEQ Implementing Guidance

↓

DOE (FY23)

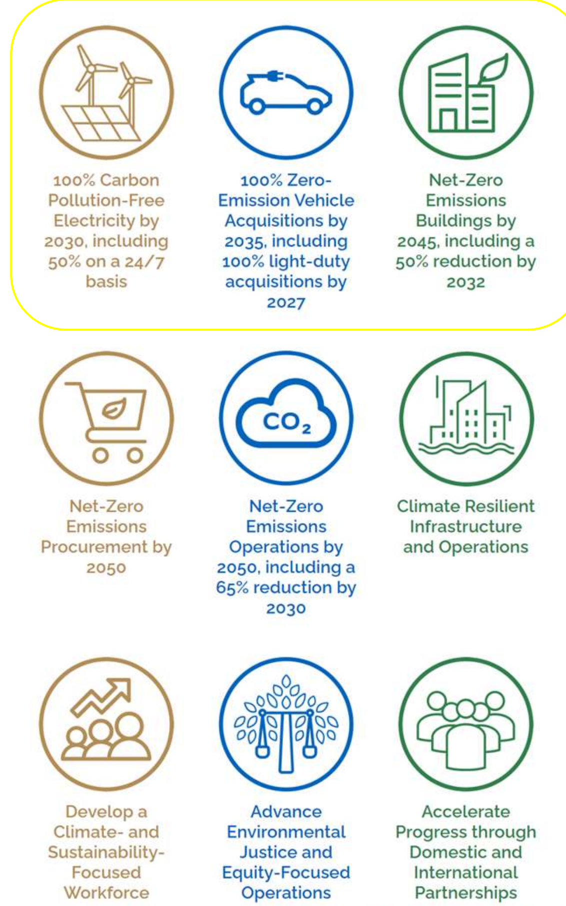
DOE Order 436.1A	SSP Guidance

↓

Fermilab (FY23)

FRA Prime Contract	Sustainability Management Team Charter

Federal Sustainability Plan Goals



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Sustainability Context

Global

Countries are increasingly making commitments and taking action to support sustainability but more work is needed.

United States

Federal Government leverages buying power and leads nation in advancing sustainability;
Funding through BIL, IRA, Chips+Science Act deliver unprecedented resources.

Science Community

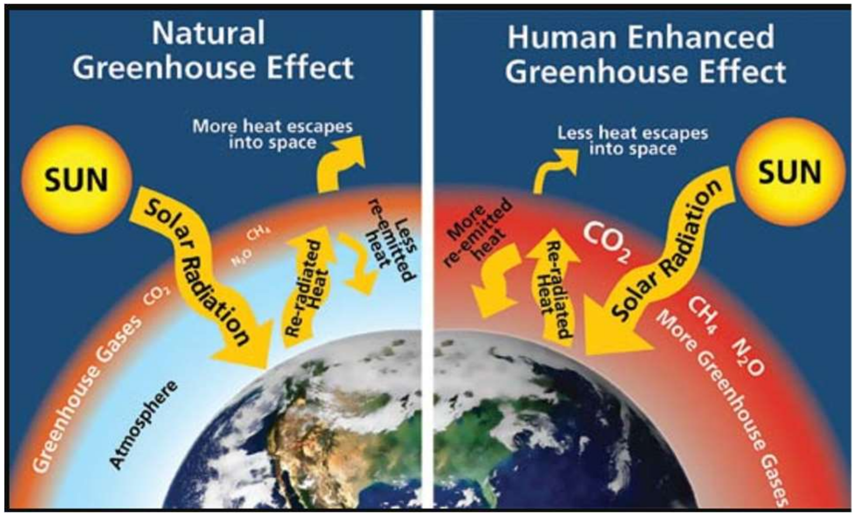
Increasing interest and discussion of sustainablity in accelerator and particle physics: Snow Mass and SustainableHECAP+ Initiative report.

Greenhouse Effect and 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.

The increase in greenhouse gas emission is predominantly from burning fossil fuels. In 2020, fossil fuels were the source of about 73% of total U.S. human-caused (anthropogenic) greenhouse gas emissions.



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

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

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

Greenhouse Effect and Climate Change

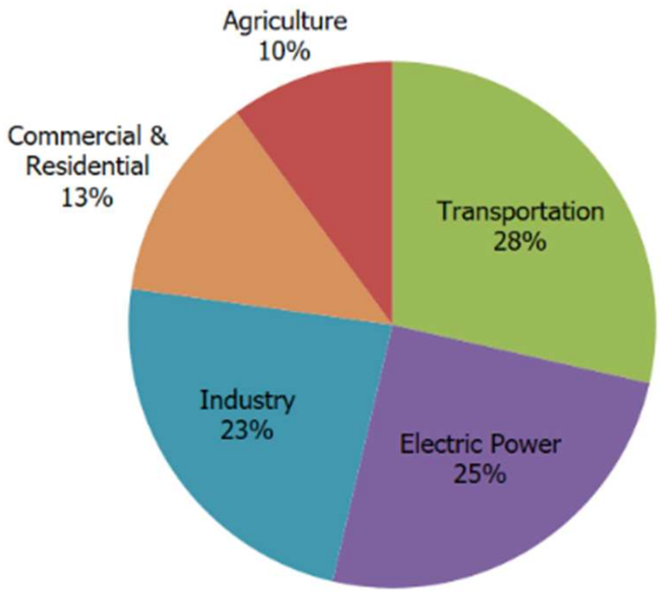
Global concern around increased global temperatures because it is having negative effects:

- 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.
- Raising 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.

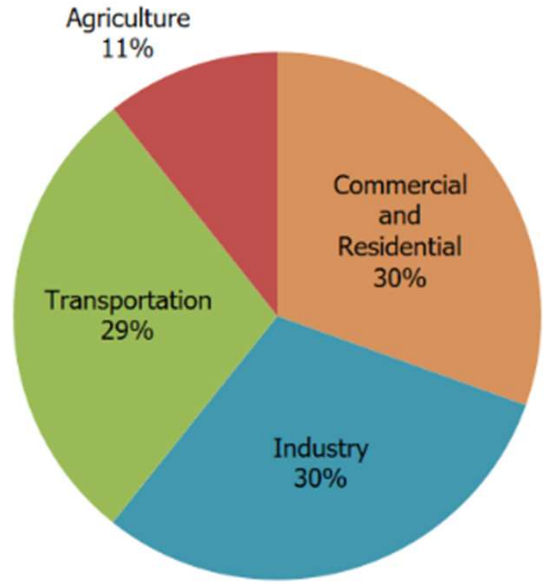
https://www.noaa.gov/education/resource-collections/climate/climate-change-impacts

Reducing greenhouse gas emission is critically needed to prevent further warming.

Total U.S. Greenhouse Gas Emissions



Total U.S. Greenhouse Gas Emissions by Economic Sector

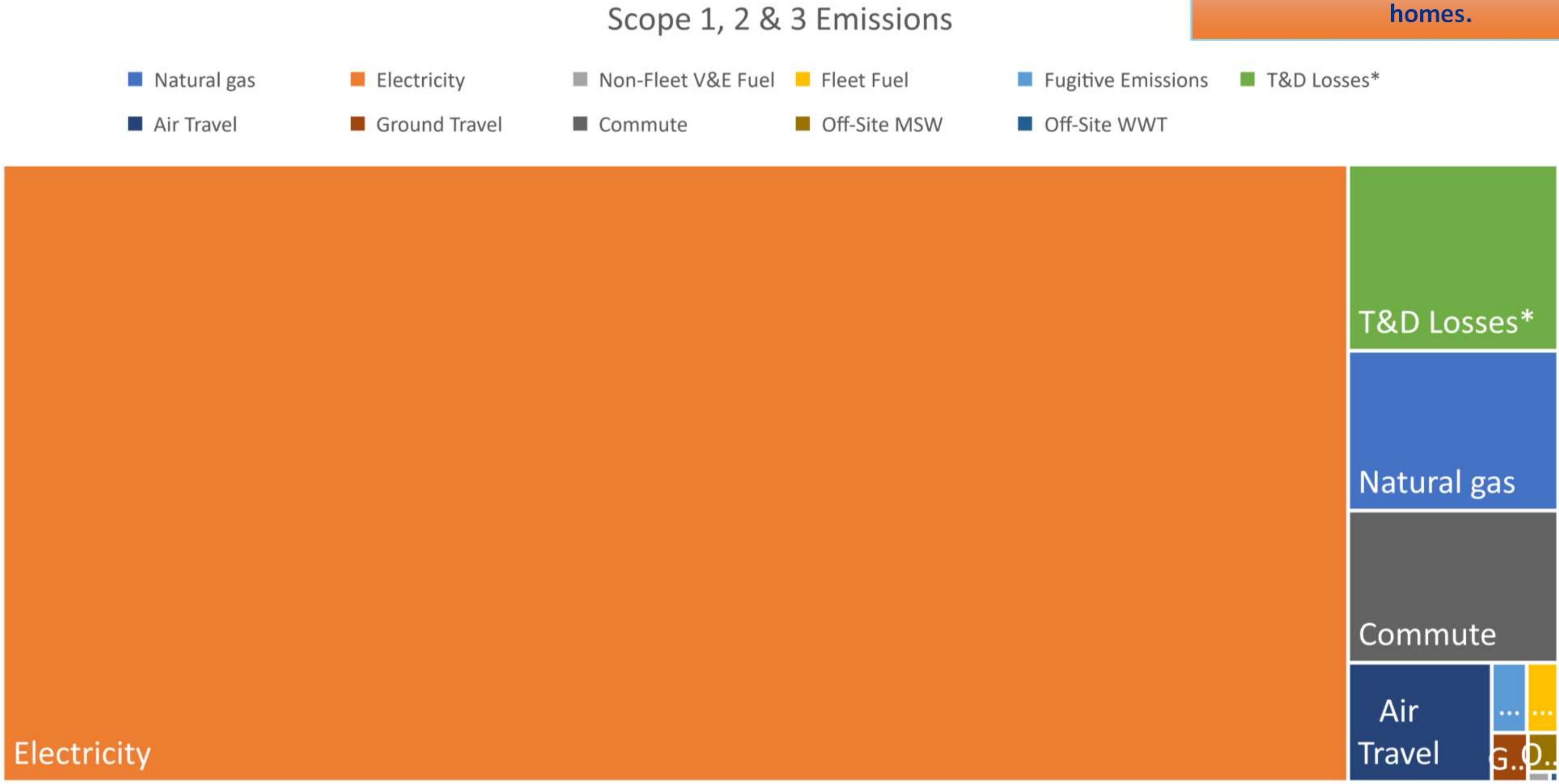


Total U.S. Greenhouse Gas Emissions by Economic Sector and Electricity End-Use

https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021

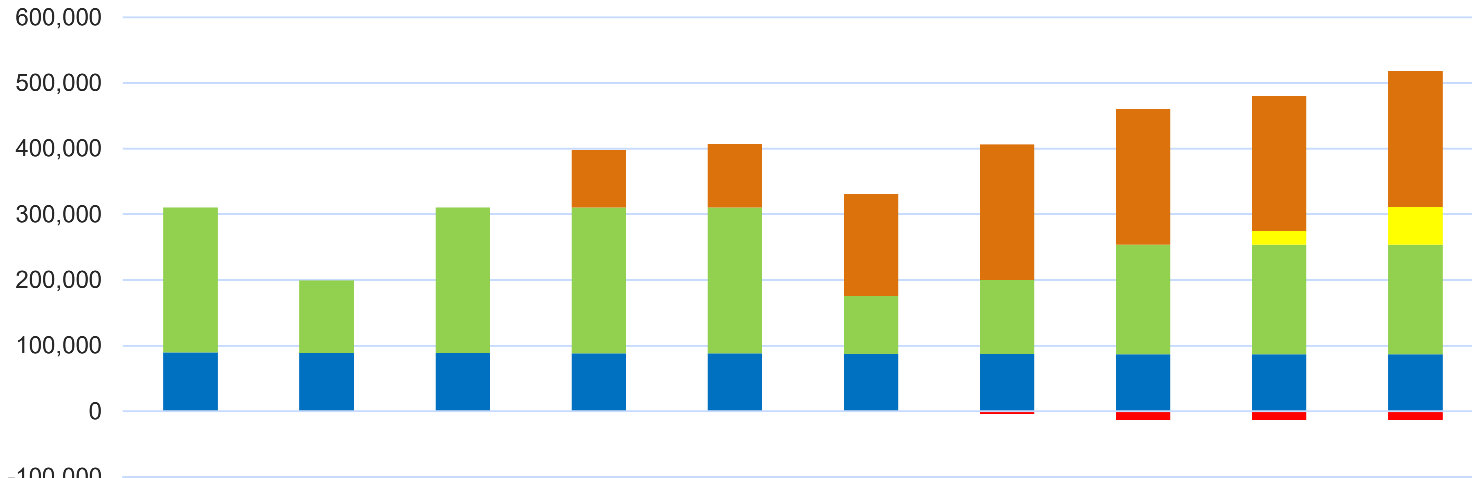
Fermilab FY 2023 Emissions: 71,490 MtCO2e*

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



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

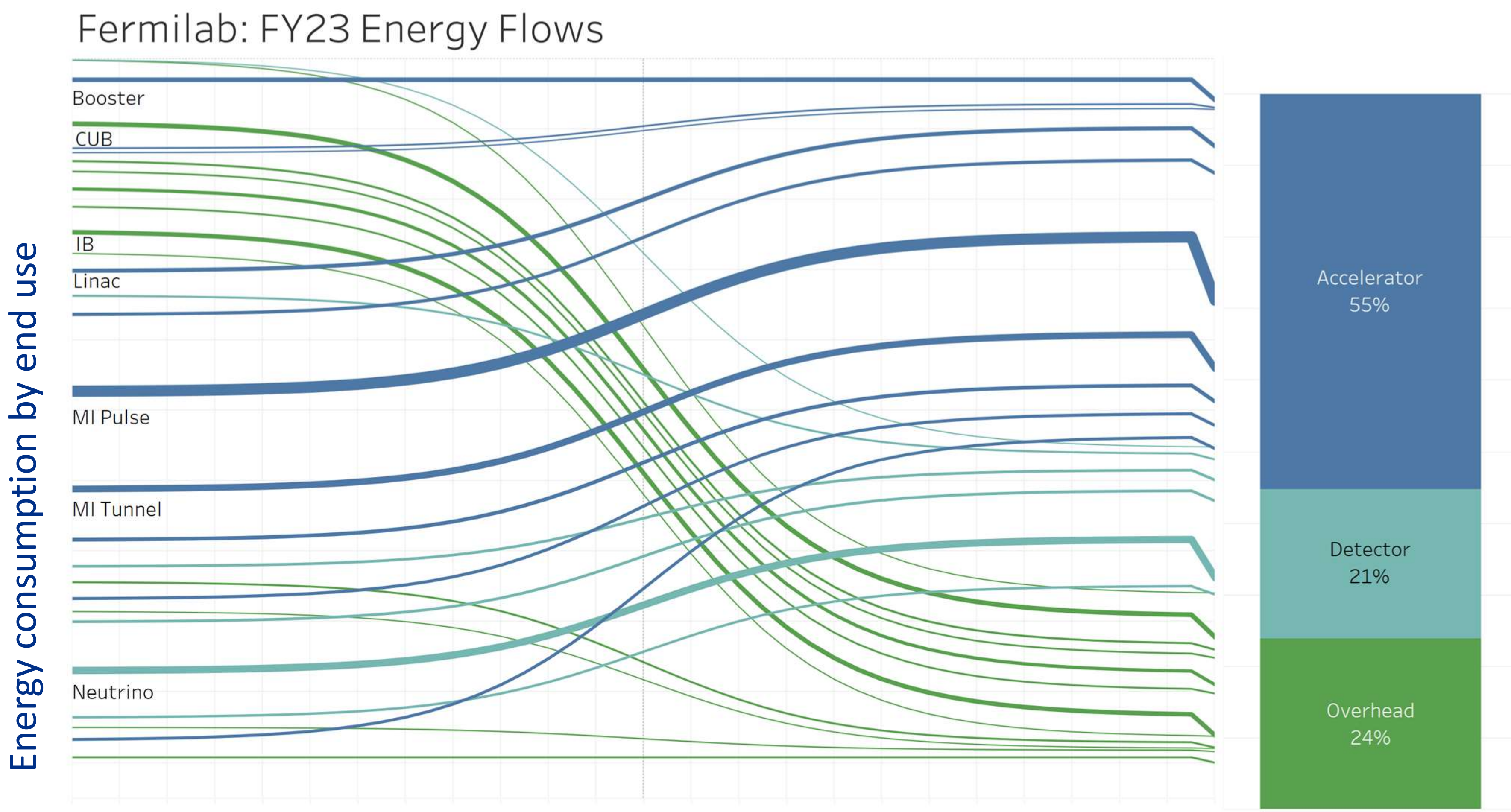
Fermilab Electricity Use and Projections



	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32
PIP-II				87600	96432	154872	205860	205860	205860	206424
Linac							-4416	-13104	-13104	-13152
LBNF									20304	57600
Current Scientific Infrastructure	221032	109995	221770	222134	222494	88115	112996	166961	166961	167307
Conventional Facilities	89384	89013	88646	88282	87922	87565	87212	86863	86863	86517

Conventional Facilities   Current Scientific Infrastructure   LBNF   Linac   PIP-II

Note: Projections reflect operating assumptions as of 1/1/25 and are greatly influenced by booster status (on/off), duration of maintenance shut-downs, and higher rep rate anticipated but not scheduled.

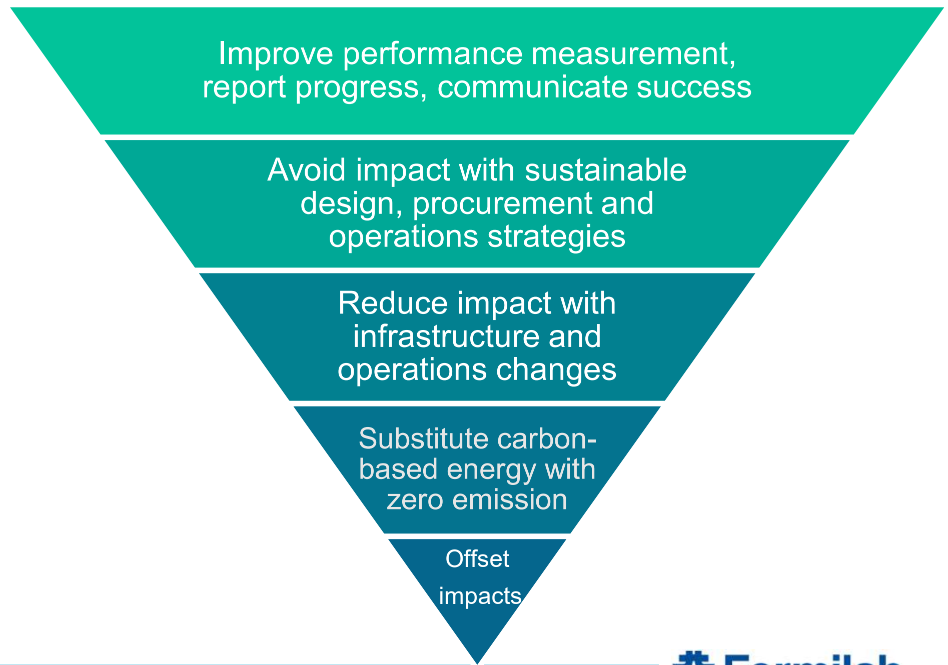

Fermilab: FY23 Energy Flows
Energy consumption by end use
Booster
CUB
IB
Linac
MI Pulse
MI Tunnel
Neutrino
Accelerator
55%
Detector
21%
Overhead
24%

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

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

Catherine Hurley

Sustainability Manager

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

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

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Incorporating Sustainability into ISD-Engineering Workflows

Initiation & Definition

- Sustainabilty integrated into mission need & project evaluation
- Sustainability costs sufficiently included in ROM Estimate
- Integrated design to maximize sustainable outcomes

Planning

- Sustainablity strategy for projects, tailored
- Integration with sustainablity strategy and plans
- Maximize sustainable design
- Consider performance contracts

Execution

- Maintain critical sustainabity design elements through value engineering
- Construction contractor actively engated with CCDD reporting
- Design phase sustainable design documentation

Closeout

- Construction phase sustainable design documentation
- Ensure operations staff understand sustainable operations requreiments

Tools Updated
- Project Implementation Manual

Tools to update
- Engineering Task Request
- Engineering Design Guide
- Engineering Specifications & Standards
- Sustainable Operations Guide
- Campus Plan & Strategy
- Engineering Design Reviews and Comment & Compliance Reviews

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Sustainable, Net Zero Carbon Buildings Approach

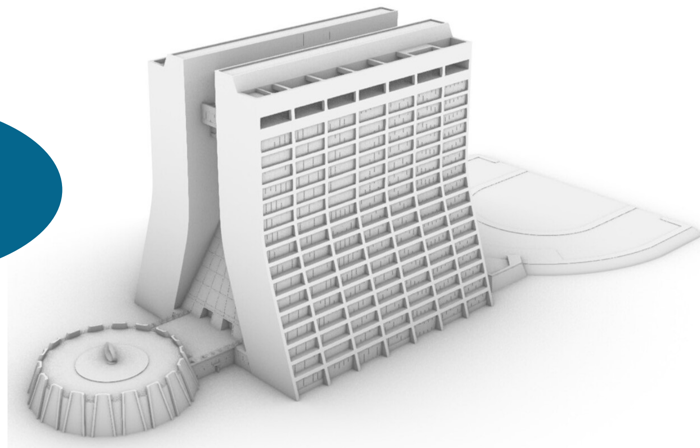
1. Energy Efficiency Measures
- Building Design
- Efficient Lighting
- Efficient plug loads
- Efficient HVAC
- Efficient controls
- Efficient occupant behavior

2. Eliminate Fossil Fuel Use
- Heat Recovery Chillers
- Heat Pumps
- Electric Boilers
- Electric Furnaces
- Electric Vehicles
- EV Charging

3. Carbon Pollution Free Electricity
- On Building Renewables
- Campus Scale Renewables
- Purchased Carbon Pollution Free Electricity

4. Energy Infrastructure Connections
- Energy Storage
- District Heat Recovery
- Other carbon free energy pipeline

5. Supply Chain Sustainability
- Green Purchasing
- Waste Reduction & Recycling
- Green Construction



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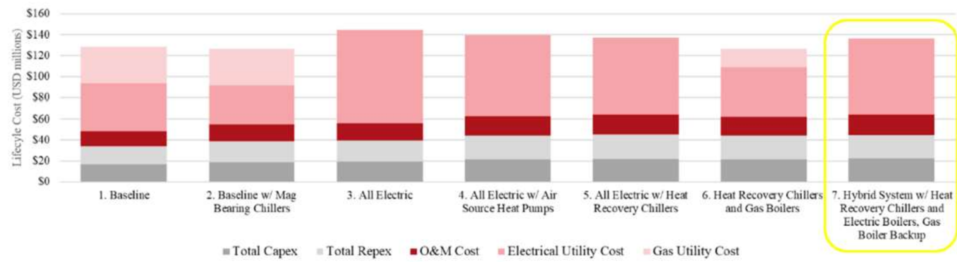
Central Utility Building Improvements Integrate Sustainability

- Sustainability and decarbonization embedded early in the design process (Pre CD-2)
- Selected heating and cooling equipment configuration will lead to 88% reduction in natural gas use while maintaining 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
  - Sustainable siting: building sited to avoid ecologically sensitive areas; re-utilization of existing footprint and infrastructure; promotion of sustainable commutes, EV Charging
  - Energy and water metering
  - Recycling 50% of construction waste
  - Maximize use and reuse of alternative water as opposed to potable water

Decarbonization LCCA Results



Selected Scenario Details

Heating Equipment	Cooling Equipment
(2) 5,800 MBH Electric Boilers (4) 1,450 MBH Heat Recovery Chillers	(4) 1,250-ton Magnetic Bearing Chillers

- 50% of peak heating load is met by heat recovery chillers
- 50% is met by electric boilers
- Natural gas back-up boilers installed for resilience
- 88% reduction in natural gas use
- Space allocation included for future heat recovery system to support Wilson Hall heating

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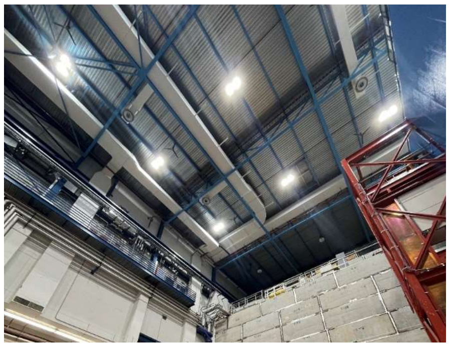
Fermilab Resilience and Efficiency Project

Net Zero Buildings
Carbon Pollution Free Electricity

Project Goal: Reduce energy consumption, increase clean energy and improve reliability in support of DOE's sustainability goals.



Proposed Project Scope:

- ESPC Enable leveraging $600k AFFECT Grant
- Energy and water conservation measures at ~22 buildings
- Address maintenance, modernization, electrification, and other sustainability goals
- Utility scale solar photovoltaic system - 2MW, 10 acres minimum
- Energy Storage and Micro- or Nano grid

IGA Kick-off Meeting Highlights:

- Strong collaboration between Site and DOE
- Continuity in contractor leadership
- Planned solar PV contracting framework provides financial incentives
- Strong Fermilab planning will lead to a quicker contract award

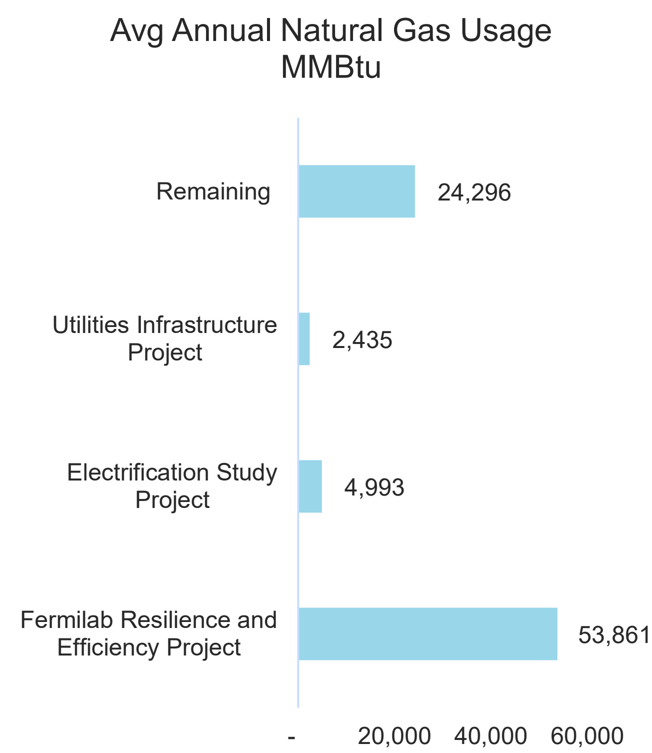
PROJECT PHASES & STATUS

- ✓ Acquisition Planning
- ✓ ESCO Selection
  Ameresco selected as ESCO 9/15
- Investment Grade Audit
  ✓ IGA kick-off meeting 12/19
- Contract Award
- Installation
- Performance Period

Net Zero Buildings

Electrification Study

- Objective:
  - 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:
  - SOW development – Completed
  - Consultant selection – January - March
  - Study – April - September



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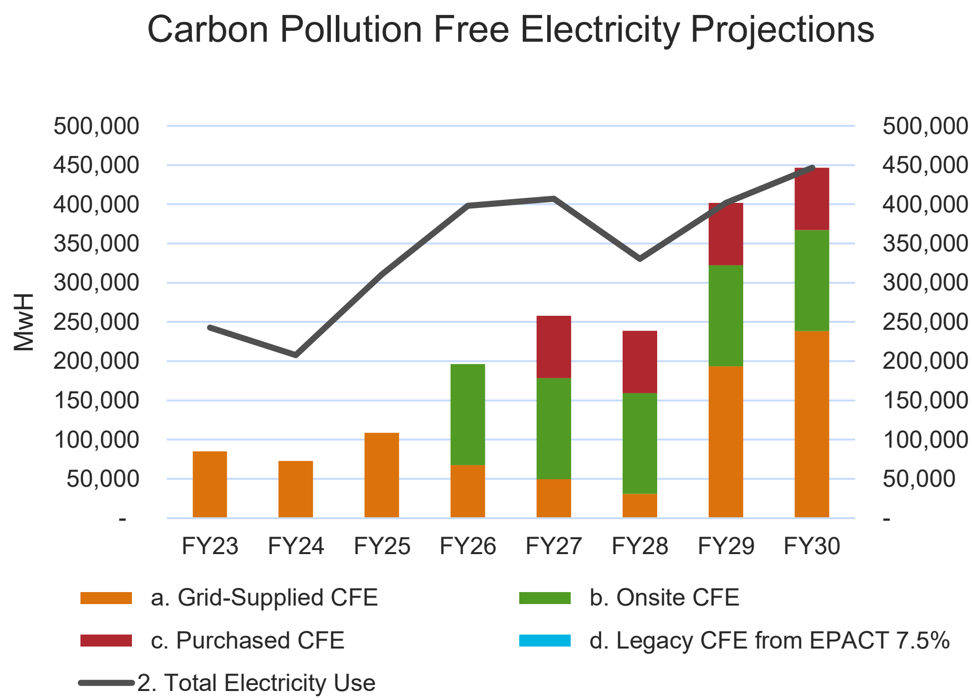
Carbon Pollution Free Electricity (CFE)

- Goal
  - 100% CFE by 2030 w/ 50% 24/7
- Strategy
  - Diversify energy sources to add CFE from on-site and off-site purchased
- Assumptions
  - Grid-supplied CFE based on our grid mix for PJM disclosed by our supplier Direct Energy
    - Current: 35% - Nuclear is 33%, Solar is 1%, Wind is 1%
    - Projected: Increase to 50% by FY30
  - On-site CFE potential of 60 MW (min. 2MW planned for FREP)
  - Off-site contracted CFE planned to take advantage of utility scale investments



Vehicle Electrification and Charging Station Master Planning Effort

Step 1: — Completed

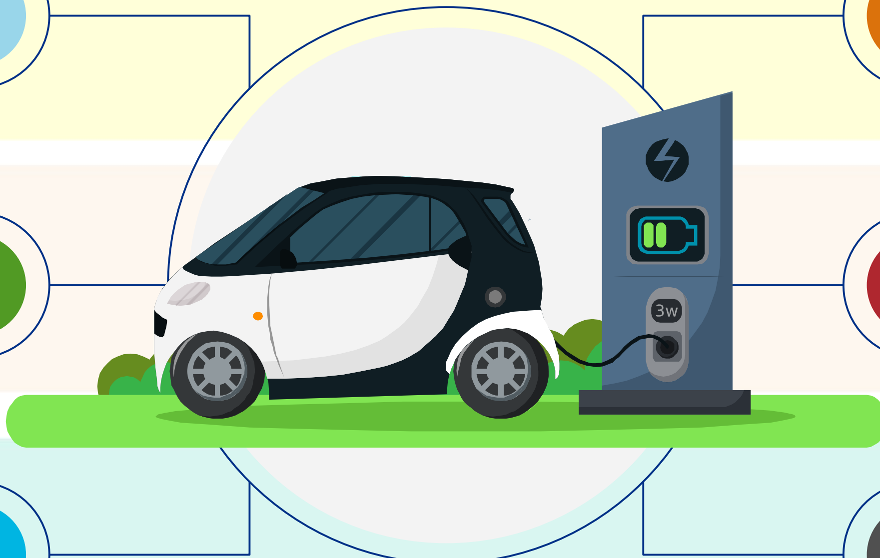
- **1a** Fleet vehicle conversion to EV's
- **1b** Fleet vehicle EV charging needs

Step 2: — Planned

- **2a** Electric All Terrain Vehicles (ATVs)
- **2b** All Terrain Vehicle EV Charging

Step 3: — Planned

- **3a** Other electric equipment
- **3b** Public EV Charging: Users, Visitors, etc.



Zero Emission Vehicle Master Plan

EV Charging Master Plan

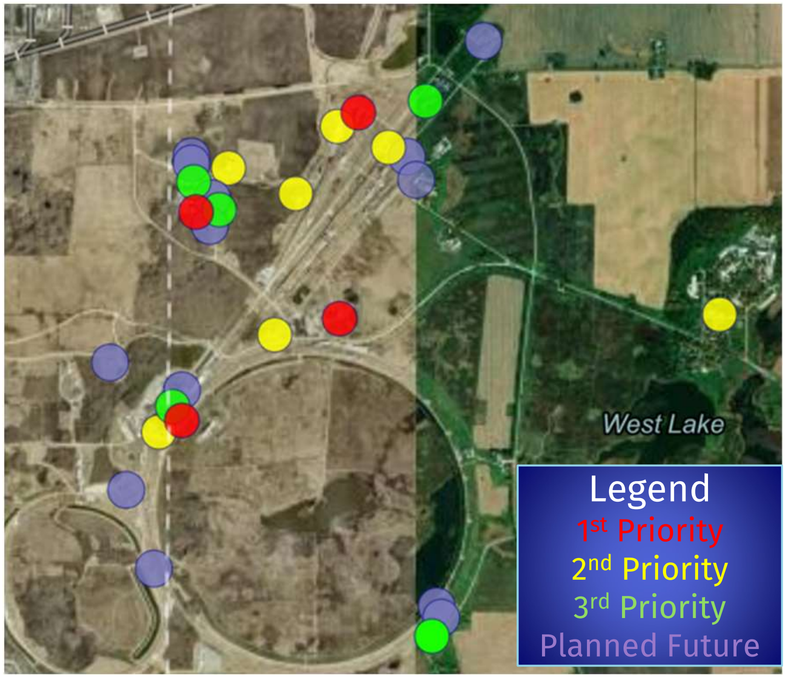
66 EV charging stations at ~27 locations

- 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

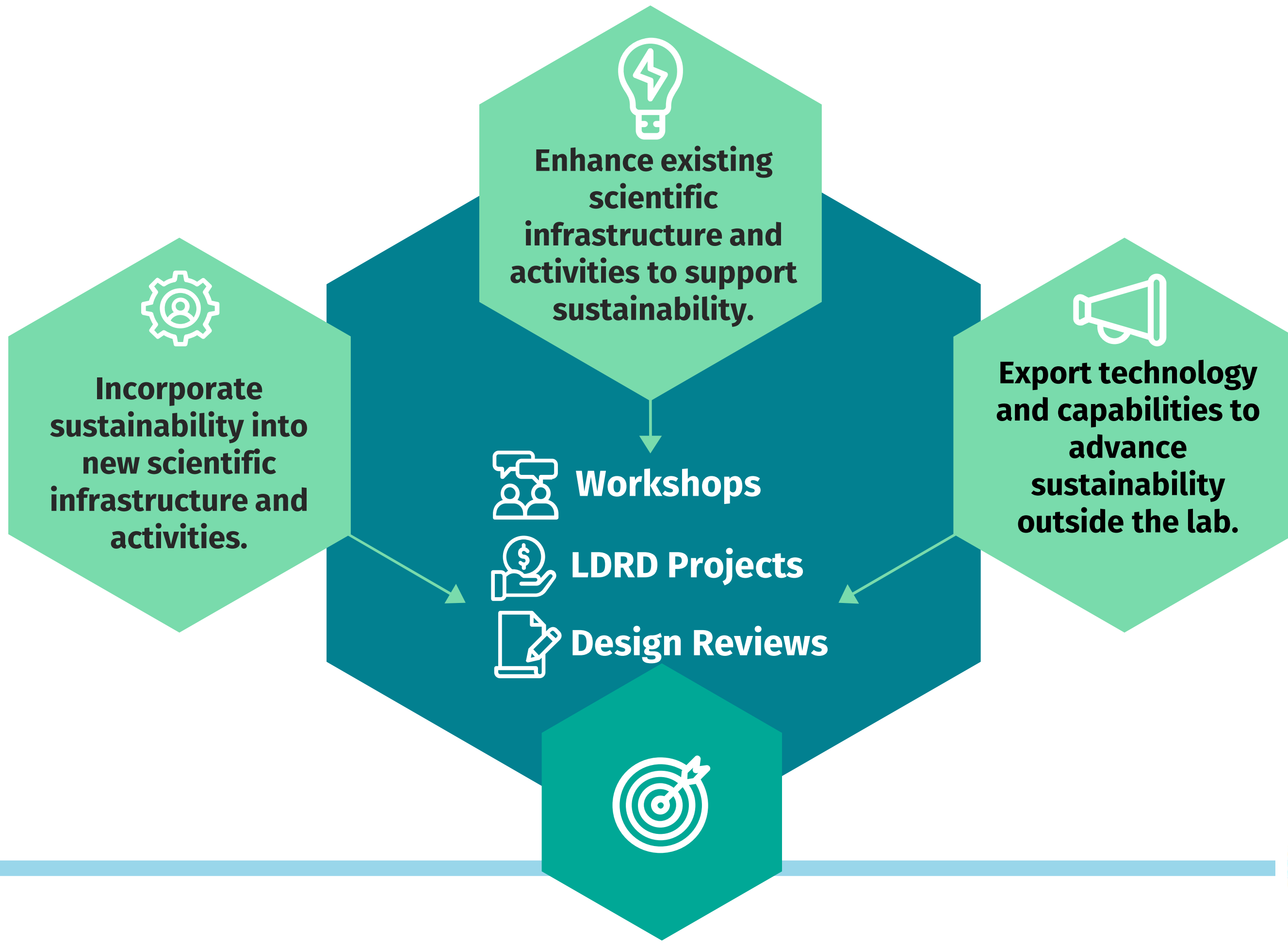
Phase 1 Electric Vehicle Charging Station Project

Accelerated EVSE implementation & inadequate electrical infrastructure leads to funding and execution challenges

- Fleet ZEV and EVSE master plan developed in FY23
  - 66 EVSE needed at 27 locations
  - 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
  - Conceptual design completed with in-house engineering resources
- Phase 2 Project ROM cost estimate completed
  - Average estimated all-in cost per station is $90k due to substantial electrical upgrades needed
  - ~$2.2M estimated total for Phase 1 ($600k for Phase 1A)
- Execution pathways under consideration
  - GSA IDIQ for Design Build Contracts
  - GSA BPA for Charging as a Service



Sustainability In Science Strategic Focus Areas



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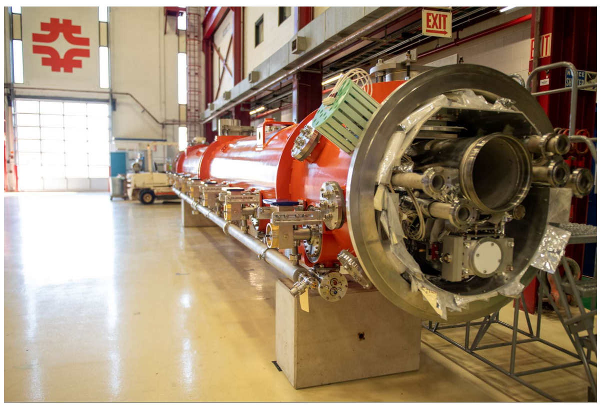
Sustainability in Science Focus Areas and Examples

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

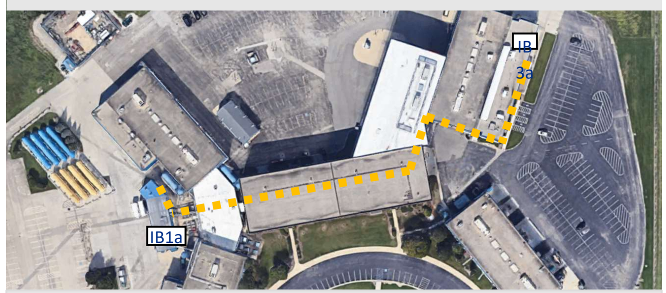
Incorporate sustainability into new scientific infrastructure and activities.



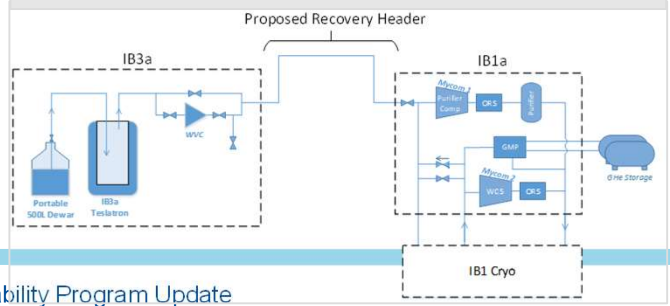
Nitrogen doped SRF cavities used in the LCLS-II accelerator will help cut the cryogenic losses of this machine by up to a factor of two

Enhance scientific infrastructure and activities to support sustainability.

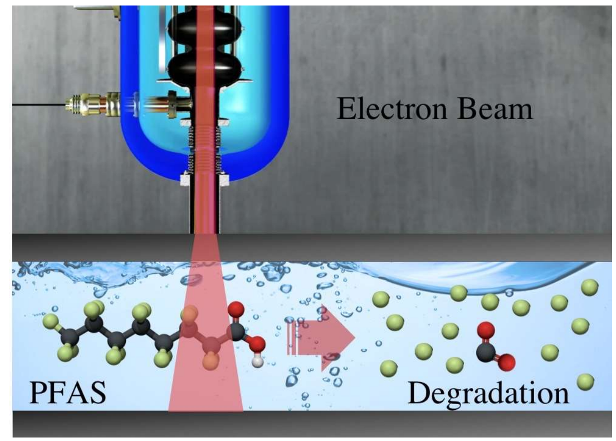
Conceptual over the roof recovery pipe routing from IB3a to IB1.



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

Projects

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

Incorporate sustainability in scientific infrastructure

New Initiative:
- Hold workshop on sustainability for particle accelerators to help generate next generation ideas.

Support Active Idea:
- Energy savings for Main Injector RF Cavities - Develop an alternative cavity framework that would use superconducting cavities instead of the current copper cavities to save on electricity during PIP-II era.

Innovate to operate scientific infrastructure more sustainably

New Initiative:
- Baseline and benchmark accelerator energy use into stage-by-stage process buckets; Identify major energy use systems that can be optimized for energy savings and need for monitoring and metering investments.

Support Active Idea:
- Low conductivity water system upgrade: Modernize this system to meet the increased cooling needs for PIP-II and LBNF. A new system would deionize the water using modern electrical systems and removes the need for using different acids.

Export capabilities to advance sustainability in the world

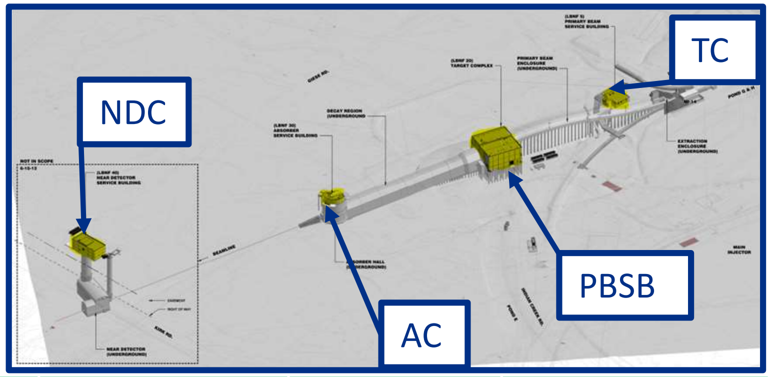
New Initiative:
- Fermilab IARC industrialization effort is exploring development of emerging technologies application concepts to support sustainability that could engage external partners and be considered for a pilot demonstration project in the future.

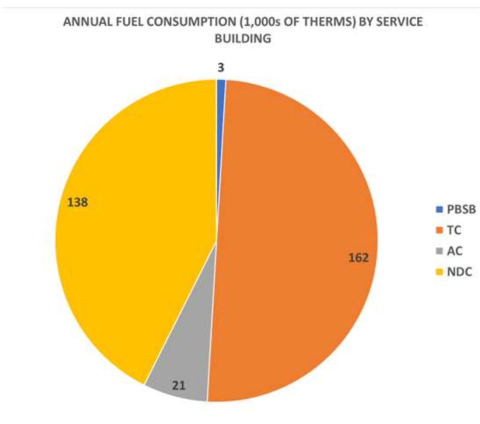
Support Active Idea:
- Collaborate with Superconductivity Global Alliance to host workshop at Fermilab for SGA to bring together stakeholders from science, industry, and financing to promote superconductivity solutions for net zero and sustainability challenges.

Sustainability in Science, New Infrastructure – LBNF DUNE NSCF

Goal: Assess opportunities to eliminate natural gas use to support federal building performance standard and net zero emissions goals.

- Evaluated strategies for two key scenarios:
  - Achieving electrification on day 1
  - Enabling future electrification with "net-zero ready" facilities
- All scenarios result in energy savings compared to current design
- Presented to project team and Site Office FPD
- Next Steps: further develop design and cost estimate to support a final decision on whether to take action





	PBSB	TC	AC	NDC
RECOMMENDED OPTION	#1 – Replace Gas Coil with Electric Resistance Coli or Air-Source Heat Pump	#4 – Replace Air Cooled Chillers with Water-to-Water Het Pumps with NG Boiler Back-up	#1 – Replace Gas Coil with Either Electric Resistance Coli or Air-Source Heat Pump	#4 - Replace Air Cooled Chillers with Water-to-Water Het Pumps with NG Boiler Back-up
DAY 1 ELECTRIFICATION CONSTRUCTION COST ($1,000)	$250	$1,950	$600	$4,800
ENABLE FUTURE ELECTRIFICATION ($1,000)	$100	$100	$450	$600

Opportunities for Greater Success

Sustainability Communications

Provide more opportunities to highlight sustainability vision and accomplishments

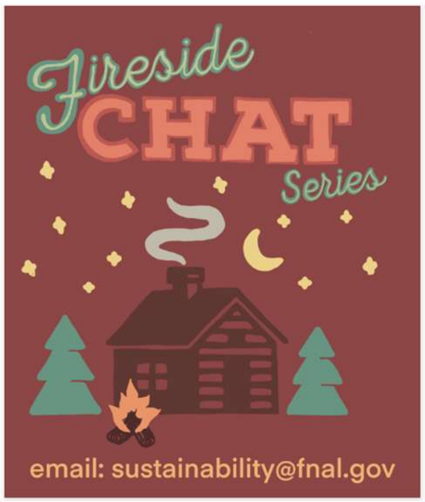
Science and Engineering Engagement

Develop more pathways for scientists and engineers to develop their sustainable science ideas

Operations Engagement

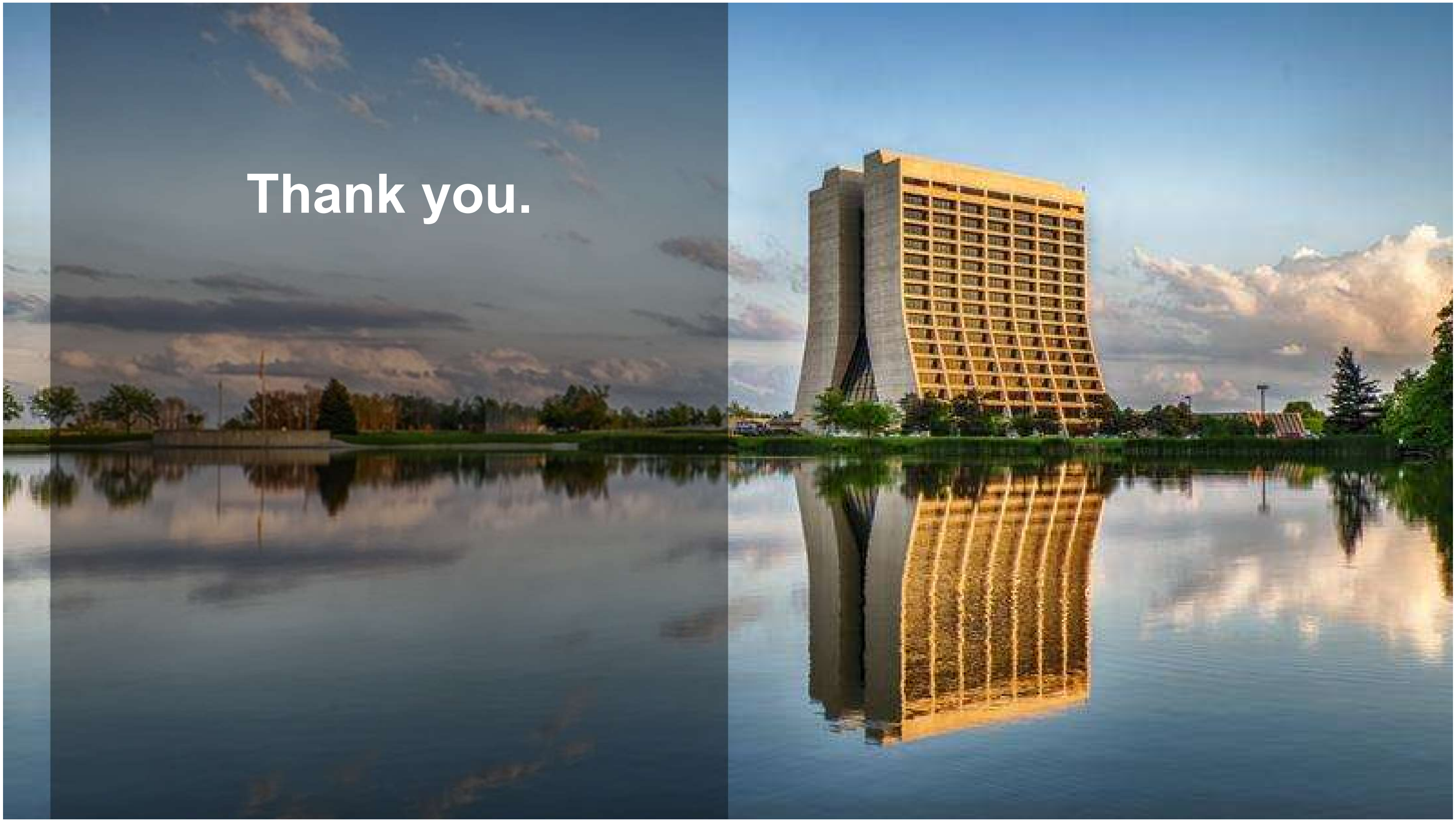
Greater visibility within operations leadership for role each organization plays and appropriate staff engagement

Save the Date

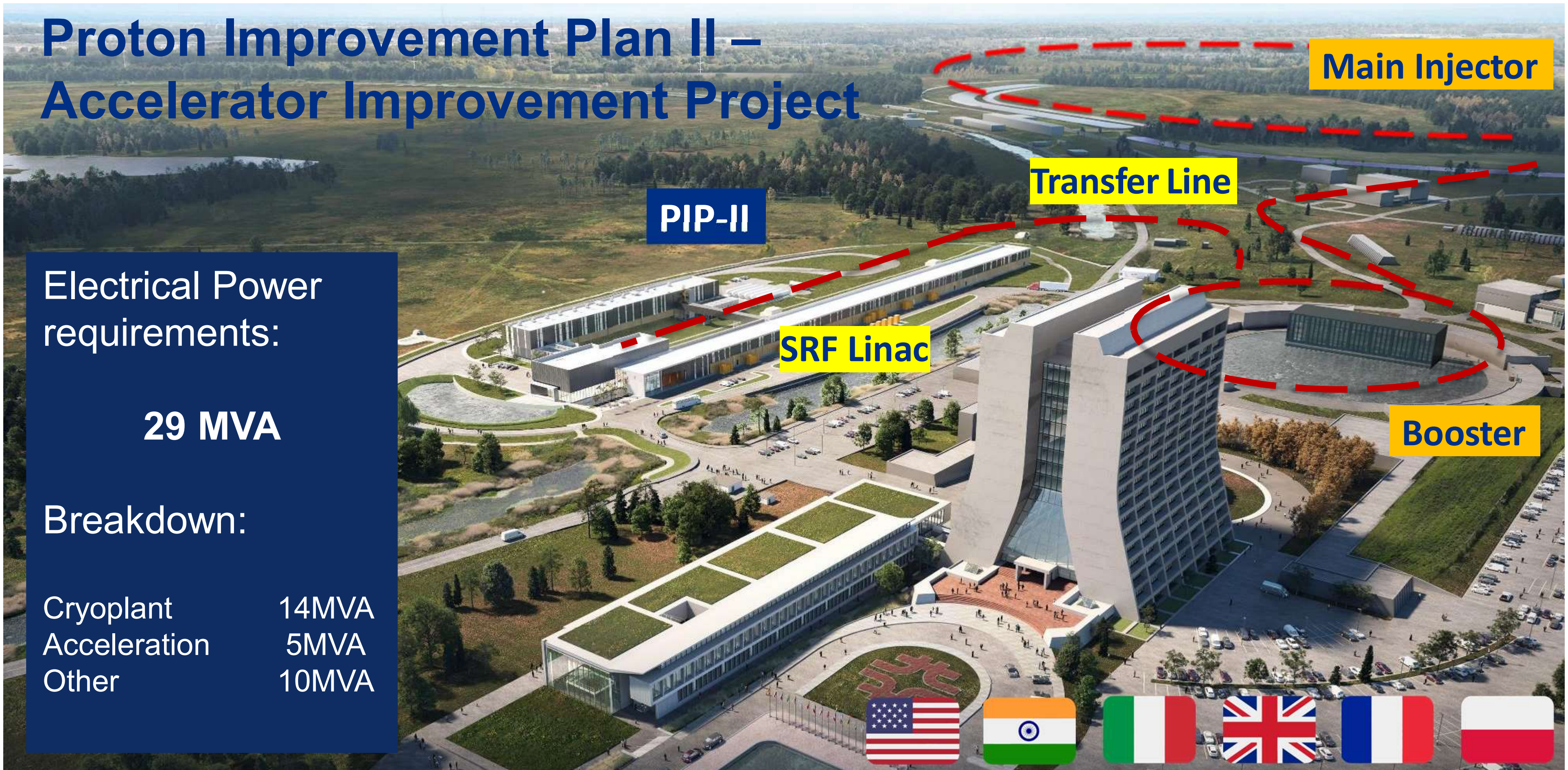


- Fireside Chats with Sustainability
  - February 22 – Users Center: 4 – 6:00 pm
  - Planned for 4th Thursday of the month

- Earth Day 2024
  - Fair: April 24 - Wilson Hall Atrium: 11:30 – 1pm
  - Colloquium: April 24 – Wilson Hall 1W – 4pm


Thank you.

Proton Improvement Plan II – Accelerator Improvement Project



Electrical Power requirements:

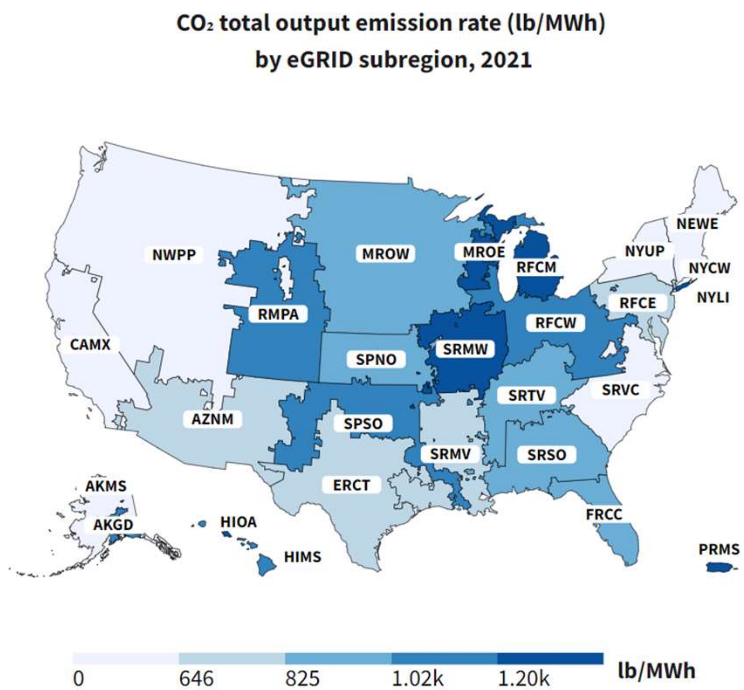
29 MVA

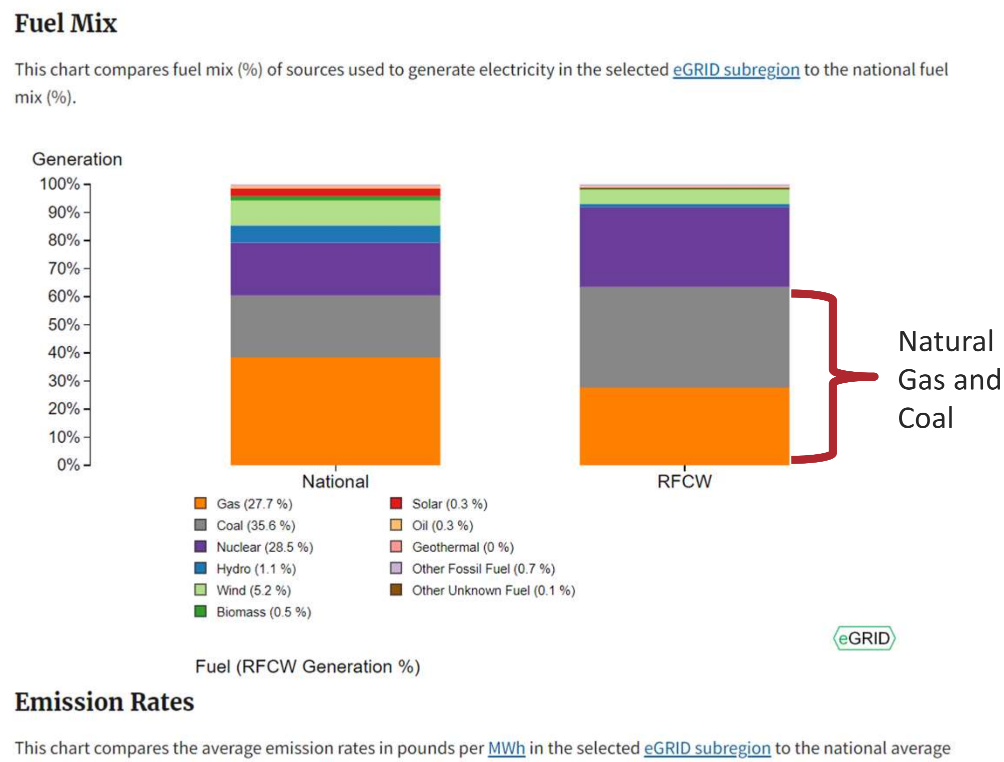
Breakdown:

Cryoplant	14MVA
Acceleration	5MVA
Other	10MVA

PIP-II is an essential upgrade to Fermilab accelerator complex to enable the world's most intense beam of neutrinos to LBNF/DUNE, and a broad physics research program for decades to come.

Fermilab Emissions Based on Grid Region





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

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