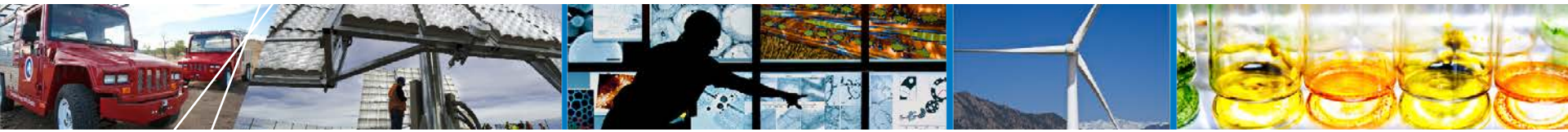
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

The Path to Zero: Ultra-efficient Architecture on the NREL Campus: S&TF and Master Planning



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Presentation Outline

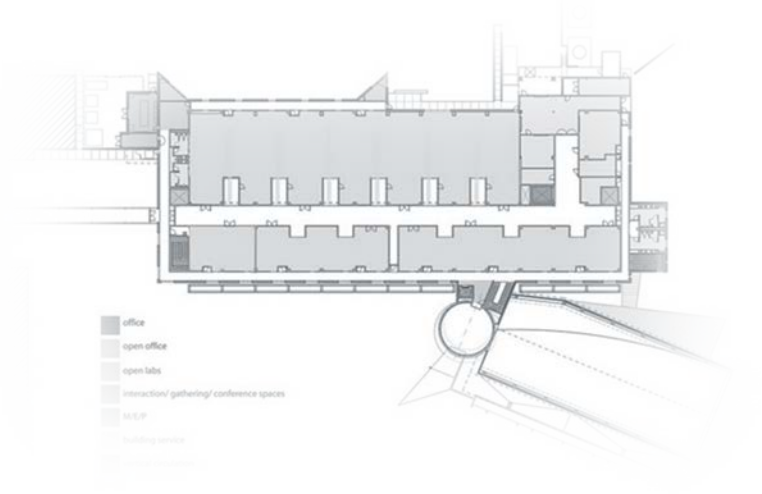
Objective. Describe the aspects of NREL's S&TF and Campus Master Planning in terms of how they have influenced ultra-efficient architecture on NREL's campus.

- **Science and Technology Facility**
  - Processes that aided in accomplishing ultra-efficient objectives
  - Building features
  - Lessons learned
- **Sustainable Campus Planning Process**
  - Key Features
  - Lessons Learned
- **Conclusions**

Science and Technology Facility Project Overview

- Completed in August 2006, the lab is 71,347 ft2.
- The lab is designed to accelerate renewable energy process and manufacturing research.
- Construction cost was $22.7 million ($318 gross ft2).
- Designed to IBC H5.
- Architect was the SmithGroup, Phoenix, AZ and general contractor is M.A. Mortenson.
- The first Federal LEED Platinum Building
- NREL's first LEED Platinum Building.

The RFP as a Tool to Accomplish Project Objectives



Equally-weighted objectives guided planning for the facility:

- Build a safe working environment for researchers
- Build a functional, flexible facility that encourages collaboration
- Meet aggressive goals for energy efficiency and sustainable design
- Complete the project within budget to achieve best value

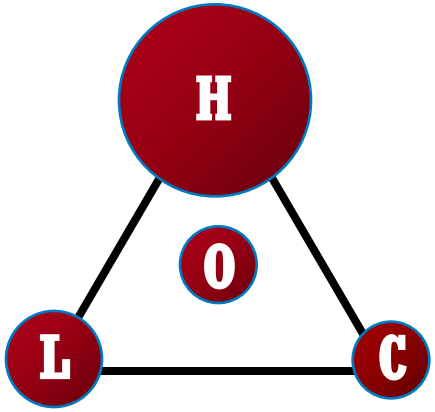
NREL formed an IPT to select the A\E team and provide project oversight

Integrated Project Team (IPT) had representation from:

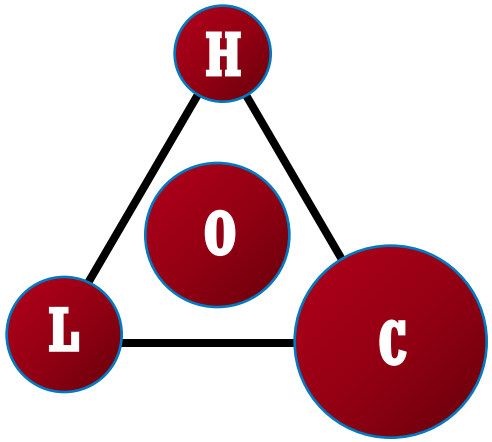
- Users
- ES&H
- Facilities Dept (cost and schedule)
- Energy perspective
- LEED\Image\Site

Understand Your Building Loads

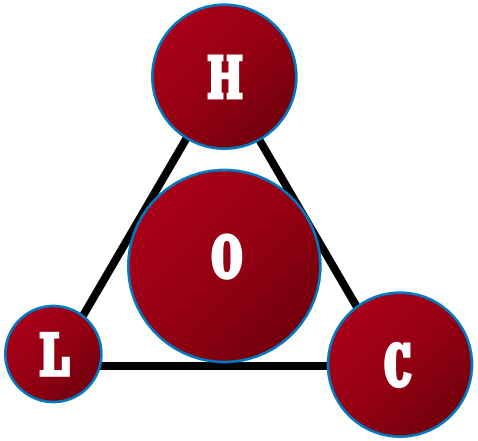
Skin-Load Dominated (small building in a cold climate)



Internal-Load Dominated (large building in any climate)



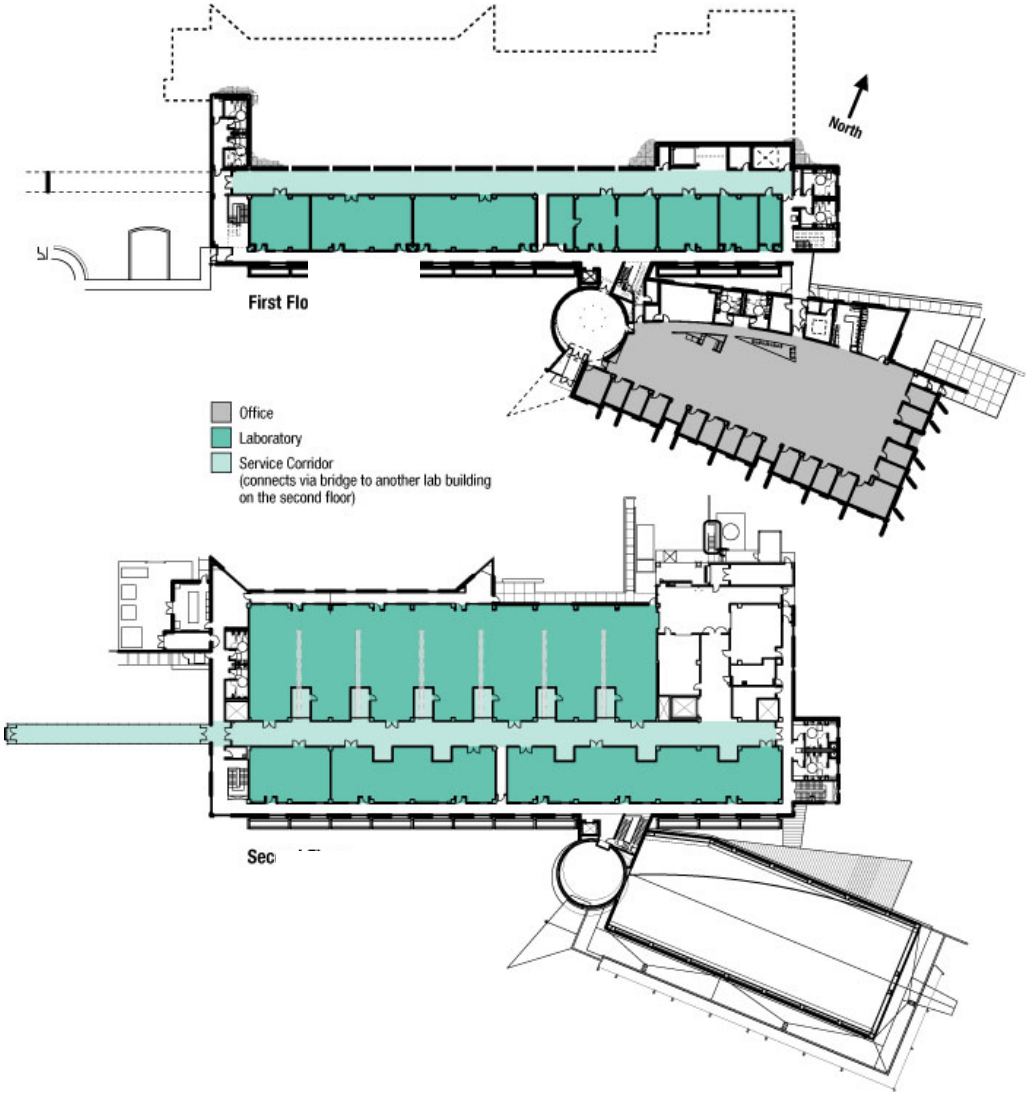
Ventilation & Process-Load Dominated (any climate)



H = Heating load **L** = Lighting load **C** = Cooling load

O = Other, including ventilation & plug loads

Floor Plans

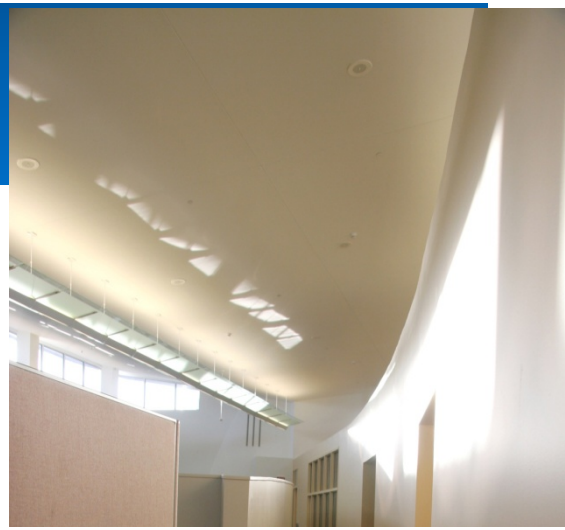


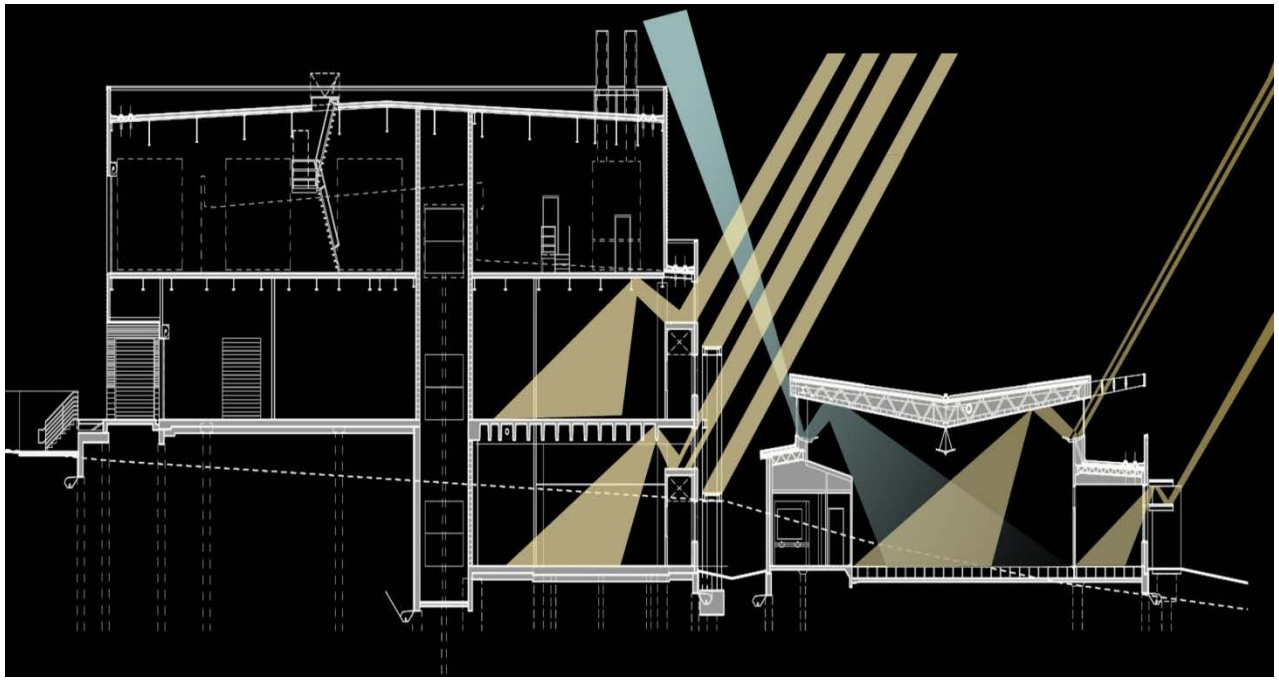
First Floor

Separation of laboratories from offices allows greater energy efficiency and more natural lighting

Second Floor

Lab Cross-Section

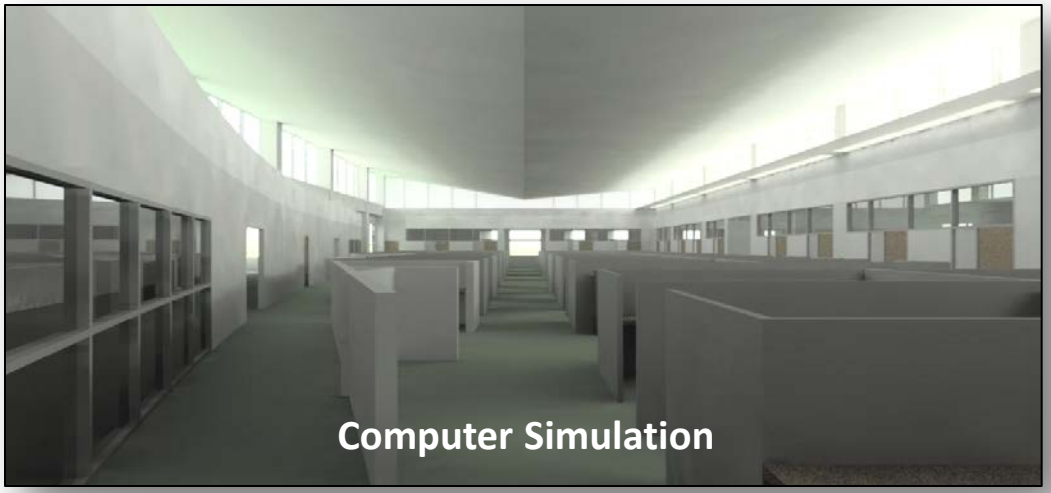




Solar Orientation

Office section is oriented 7.5 degrees west of due south; the laboratories are 15 degrees east of true south. Both positions are near optimal for natural daylighting.

Office/Office Support Area



The Office module was designed for 100% ambient daylighting between 10:00 am and 2:00 pm

Daylighting Commentary

- Ambient daylighting in the office area is glare free and provides even illumination.
- Views from the labs are a welcomed feature.
- Discussed cost trade offs of other types of shade structures (for future projects).
- Lighting controls integration was challenging.
- Perceived light pollution issue important to teach the occupants how to interact with their space.

Wing walls on the east

Office area with shade structure impacting view

S&TF Labs

The "Centerpiece" - 10,425 ft2 Process Development and Integration Laboratory

Large view window with North and South clerstories in the PDIL

Pedestrian corridor allows views from labs on the south side

Service Corridor and Utilities

A 12 ft wide service corridor with "notches" for noise producing equipment

Utility trench from corridor into PDIL

Easy access to utilities for on-going maintenance is an important consideration in design (for energy savings and safety)

Energy Conservation Measures (ECMs)

In addition to VAV fume hoods -

- Lab ventilation air heat recovery (runaround loop)
- Fan coils for lab sensible cooling w/o requiring extra expensive conditioned OA
- Increased supply air temperatures
- Lab fan power minimization and exhaust fan staging
- High efficiency condensing boiler
- High efficiency VSD chiller
- Office under floor air system
- Evaporative cooling
- Process cooling water energy recovery to ventilation
- Daylighting controls for office & labs

ECM Results

Simple Paybacks for the Energy Efficiency Measures

Measure	Incremental Cost ($)	Savings ($/yr)	Payback (yrs)
VAV w/o HR	$300,000	$92,120*	3.3
Add HR	$80,000	$36,487	2.2
Lab supplementary cooling & raised primary SATs	$150,000	$14,873	10.1
Overhangs, & glazing		$4,400	
Lighting power density		$5,694	
Daylight controls	$10,000	$4,111	2.4
Office underfloor air & evap cooling	$20,000	$3,103	6.4
Chiller plant upgrades	$33,000	$12,607	2.6
Tower free cooling	$60,000	$6,754	8.9
Process CHW for preheat	$48,000	$4,752	10.1
Lab AHU evaporative	$20,000	$3,758	5.3
Fan pressure drops		$19,064	
Fan staging	$37,500	$4,691	8.0
Boiler & DHW	$24,000	$8,972	2.7

*** VAV included in the base case**

ECM Results

**Simulated and Measured Energy performance for the S&TF –
24% less than Standard 90.1-2004 Appendix G Performance Method**

System	Simulated	Measured (4\07-3\08)	Measured 4\08-3\09)
Ventilation	9.6 kWh\gft^2	10.1 kWh\gft^2	10.5 kWh\gft^2
Cooling	4.8 kWh\gft^2	13.0 kWh\gft^2	11.9 kWh\gft^2
Lighting	2.3 kWh\gft^2		
Process\Plug	21.3 kWh\gft^2	15.7 kWh\gft^2 (1)	17.6 kWh\gft^2 (1)
Heating	91.9 kBtu\gft^2	136.7 kBtu\gft^2	132.7 kBtu\gft^2
Total (electric and gas)	223.4 kBtu\gft^2	269.0 kBtu\gft^2	269.0 kBtu\gft^2 (2)

1. **Process\plug and lighting are combined**
2. **In Oct 2010, we changed the humidity set point form 28% to 20% , this resulted in a reduction on natural gas use of 32% and a reduction in water use of 20%**

Note: we added a 94 KW PV system since the building was built

Taken from the Labs for the 21st Century S&TF Case Study (www.labs21century.gov)

Keys to Success

- Understanding how energy was used in the building –guided the building zoning.
- RFP as a design tool – specifically setting measurable energy\sustainability goals and criteria for A\E selection.
- Having “champions” committed to energy efficient design .
- Use building simulation as a tool in the design process
- Through measuring the performance overtime, we have been able to continue to find improvements in energy efficiency

- Energy savings strategies
  - Significant savings beyond VAV are technically & economically feasible
  - Indirect\direct evaporative climate works well in our climate.
  - Daylighting controls\zoning needed
  - Recent reduction in humidity level resulted in significant energy\water savings and researchers are content

Developed the NREL-wide Campus-wide General Development Vision in 2003

"NREL's vision is to develop a world-renowned, high-performance research center that showcases energy technology innovation and leadership and embraces the best in energy and ecological conservation practices." *- James L. Spigarelli, President and CEO of the Midwest Research Institute*

- Planning allows you to look at energy supply and demand as one integrated system.
- Campus planning establishes a framework for building orientation, transportation, parking, storm water management, campus amenities, establishing density, and maintaining open space.
- It provides opportunities for using renewables that go beyond the building boundaries.

Energy Goals for the NREL Campus

Demand reduction

- Understand how buildings uses energy ; implement the cost-effective energy and water efficiency retrofits
- Use principals of energy efficiency and low energy design to reduce energy demand in all new construction
- Operate central plants efficiently
- Alternative transportation

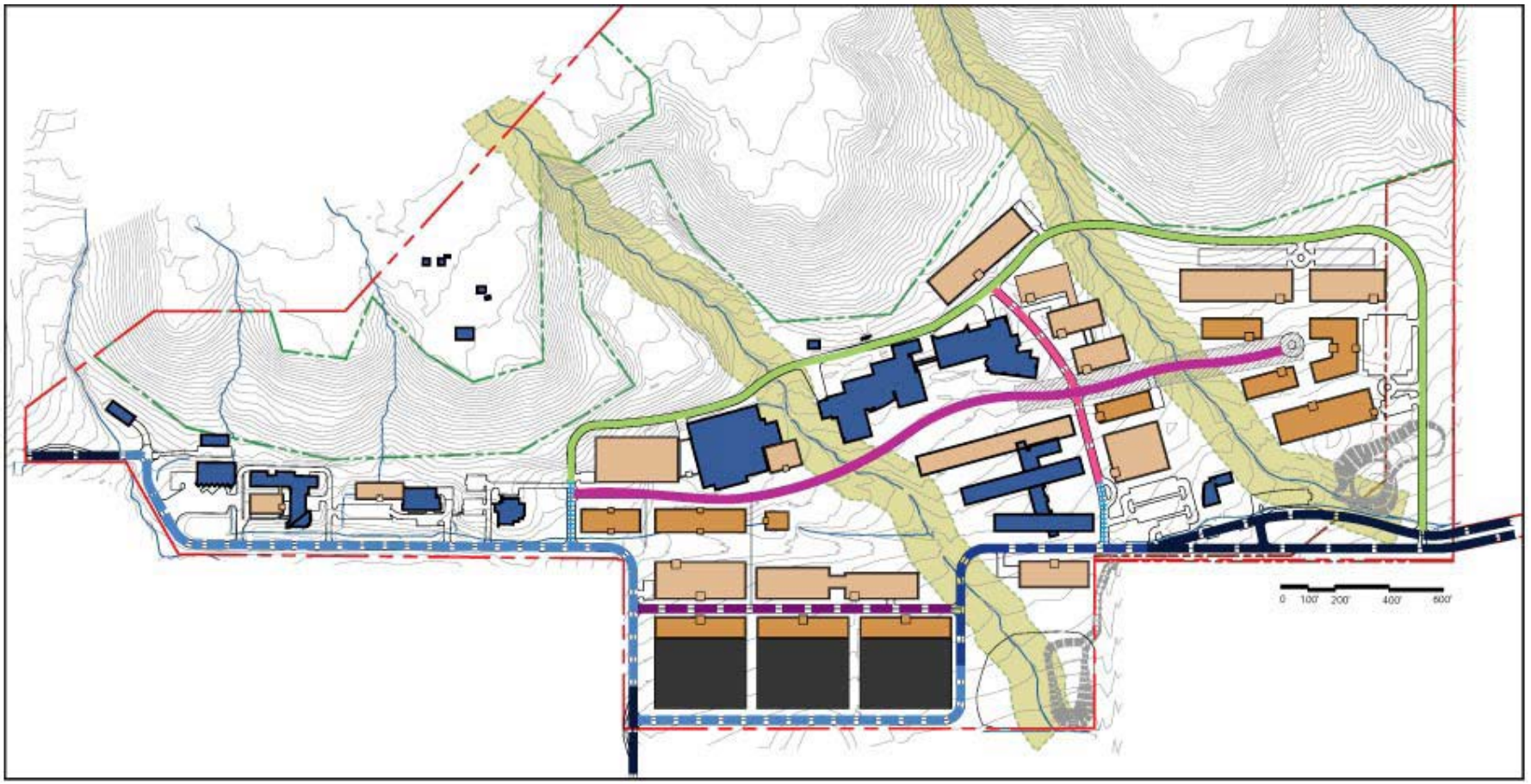
Supply side options

- Use combined heat and power systems
- Use on-site renewables for demonstration and where it is cost-effective
- Buy green power (over the next 25 years) so that 100% of our power will be from renewable sources

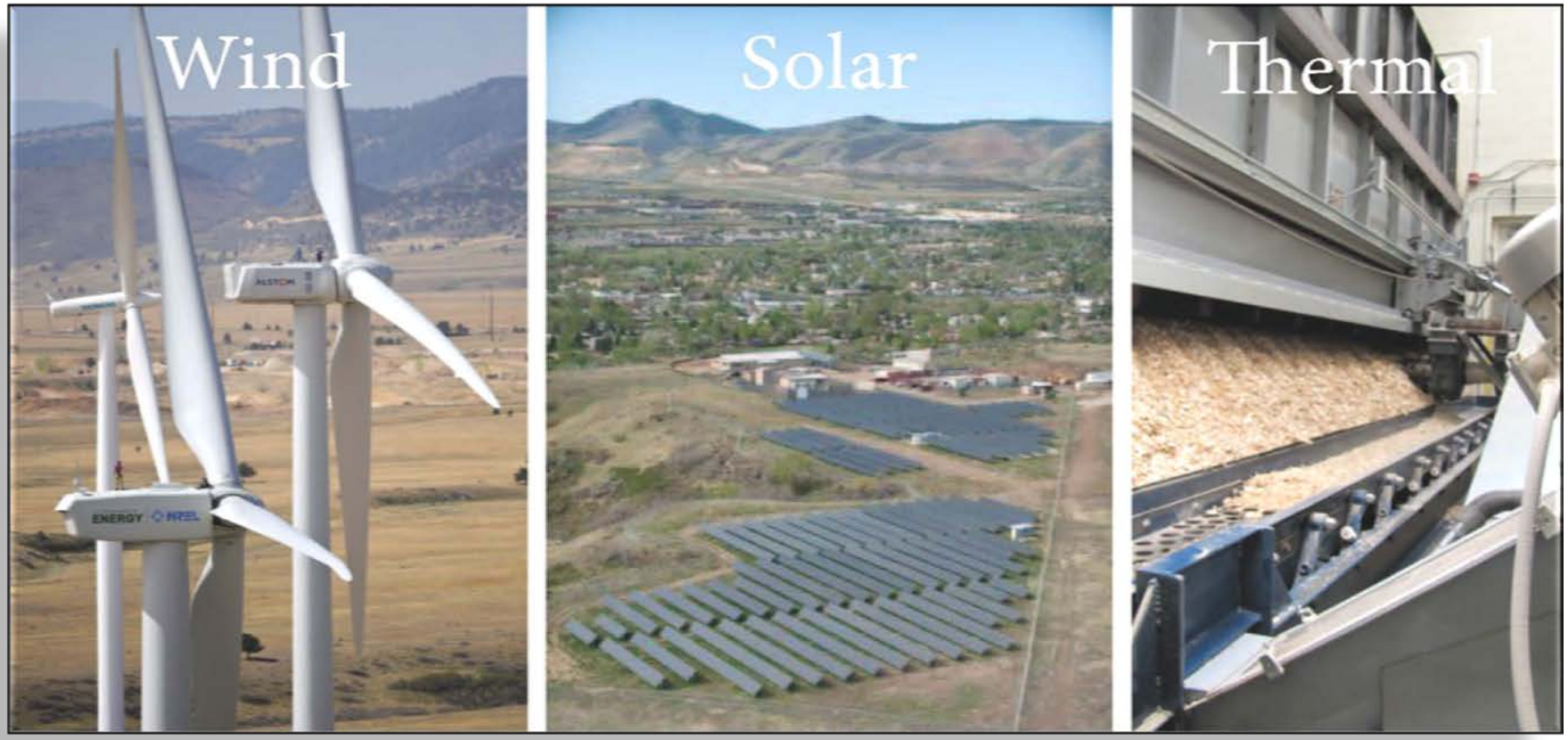
NREL's Sustainable Campus Planning

Current Site and Facilities

NREL's Overall Campus Plan



NREL Campus On-site Renewable Energy



Developing a Sustainable Campus

- Highly Efficient Buildings approaching net zero energy
- Onsite Renewable Power Generation Capacity > 15 MW
  - PV arrays rated at 4.6 MW
  - Research turbines 10+ MW
  - Renewable Fuel Heating Plant rated at 2.5 MW thermal output
- Alternatively Fueled Vehicle Fleet

DEVELOPMENT PRIORITIES

- Safe, secure and sustainable
- Iconic facilities
- LEED Platinum/Gold certified facilities
- Carbon neutral
- Highly efficient, near-net zero energy buildings
- Living Laboratory

Existing and Future Onsite PV at STM*

720kW PV

94 kW PV
on STF rooftop

408 kW on
RSF2 rooftop

525 kW on visitor
parking structure

1404 kW PV on
Parking garage rooftop

450 kW on
on RSF 1 rooftop

*Plus 1083 KW at the NWTC

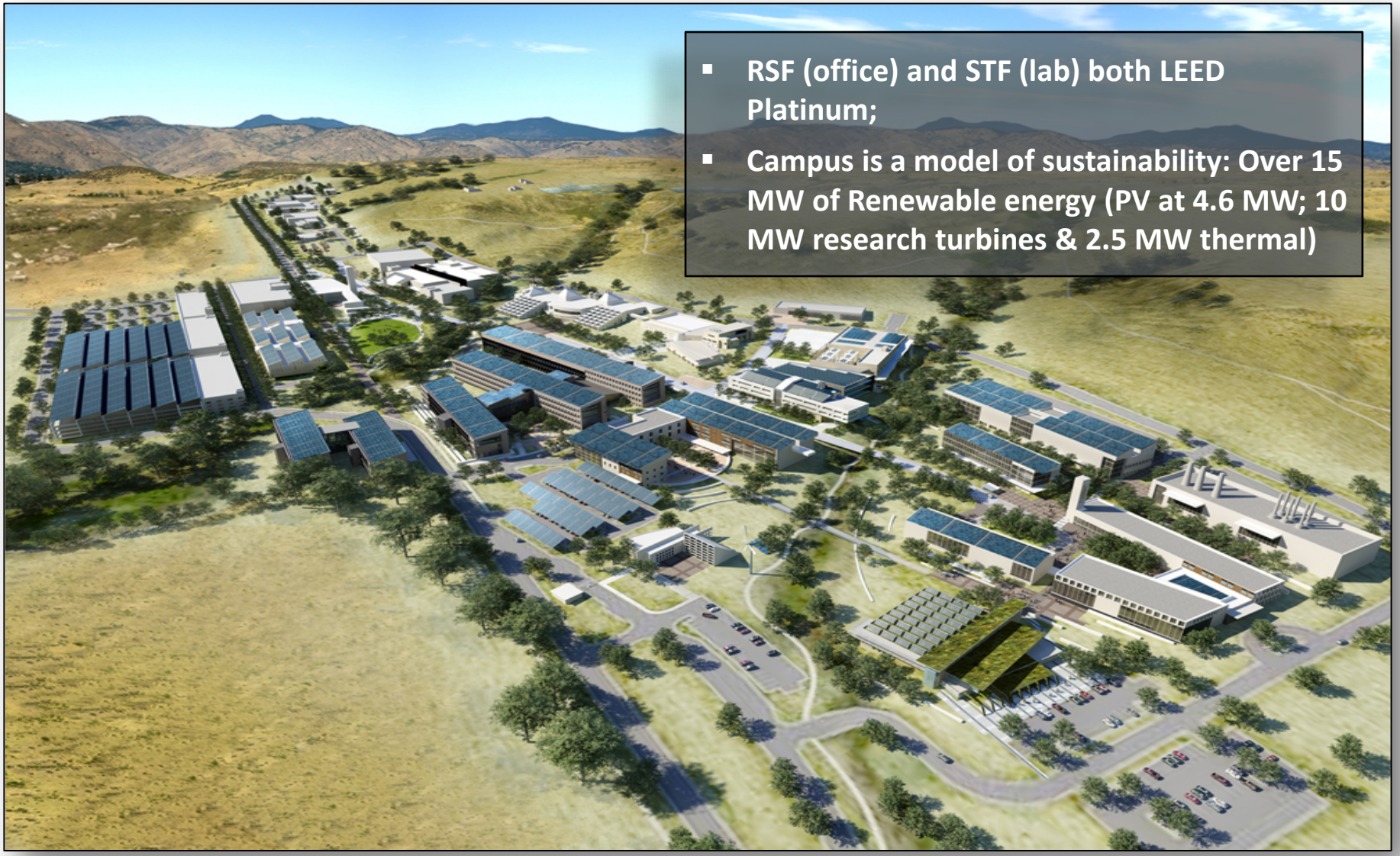
AFUF	Alternative Fuel User Facility
ESIF	Energy Systems Integration Facility
FTLB	Field Test Laboratory Building
IBRF	Integrated Biorefinery Research Facility
NGBRF	Next Generation Biorefinery Facility
OTF	Outdoor Testing Facility
RFHP	Renewable Fuels Heating Plant
RFVSF	Renewable Fuels and Vehicle Systems Facility
RSF	Research Support Facility
S&TF	Science & Technology Facility
SEB	Security Entrance Building
SERF	Solar Energy Research Facility
SRRL	Solar Radiation Research Laboratory
TSRF	Translational Science Research Facility
TTF	Thermal Test Facility

Solar Furnace
SRRL
Shipping
IBRF
IBRF
AFUF
TTF
OTF
RFHP
SERF
STF
FTLB
NGBRF
TRSF
TRSF II
RSF II
RSF I
RSF II
Central Plant
RFVSF
ESIF II
ESIF
Conference Center
Visitors' Center
Site Entrance

Future Building Site
Building in Progress
Existing Building
Solar Arrays

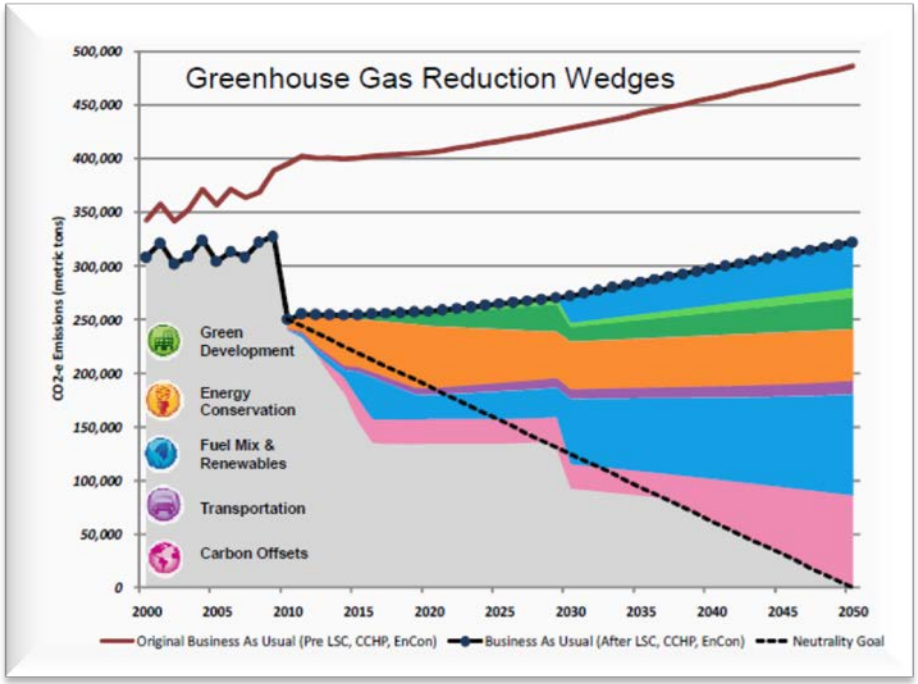
North
0
200
400

NREL Campus Build-out Vision as Living Lab



What were the key factors that led to this innovative campus plan?

- Buy-in from the top
- Vision that recognizes and balances competing needs
- Consensus building regarding the plan ("Bring the right people together")
- From the energy point of view – Hierarchy of Actions – People, Conservation; Renewables; Offsets
- A Portfolio of actions required for Deep Savings




Thank you!!