Preliminary Design Review

Clean Tech Titans

November 7th, 2023

Team Introduction & Client

7x24 Exchange Rocky Mountain Chapter

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Clean Tech Titans

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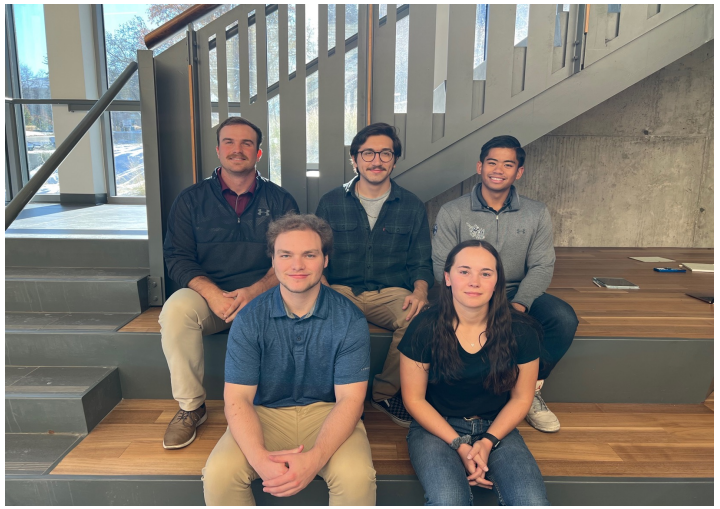

Agenda

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1. Problem Definition
2. Initial Research & Design Considerations
3. Design Decision
4. Schedule and Next Steps Update

Problem Definition

Problem Definition

Data Centers account for 1% of the world electricity demand. Thus, accounting for a significant amount green-house gas emission. This also comes at a time of increased regulation on data center energy consumption and accelerated demand for the services they provide.

Subsystem Breakdown

Energy Generation

Generation techniques required to meet the total energy demands of the data center facility.

Mechanical Design

Components relating to the meeting the cooling load of the critical IT equipment and support space. Including HVAC equipment, ducting, and energy efficiency measures.

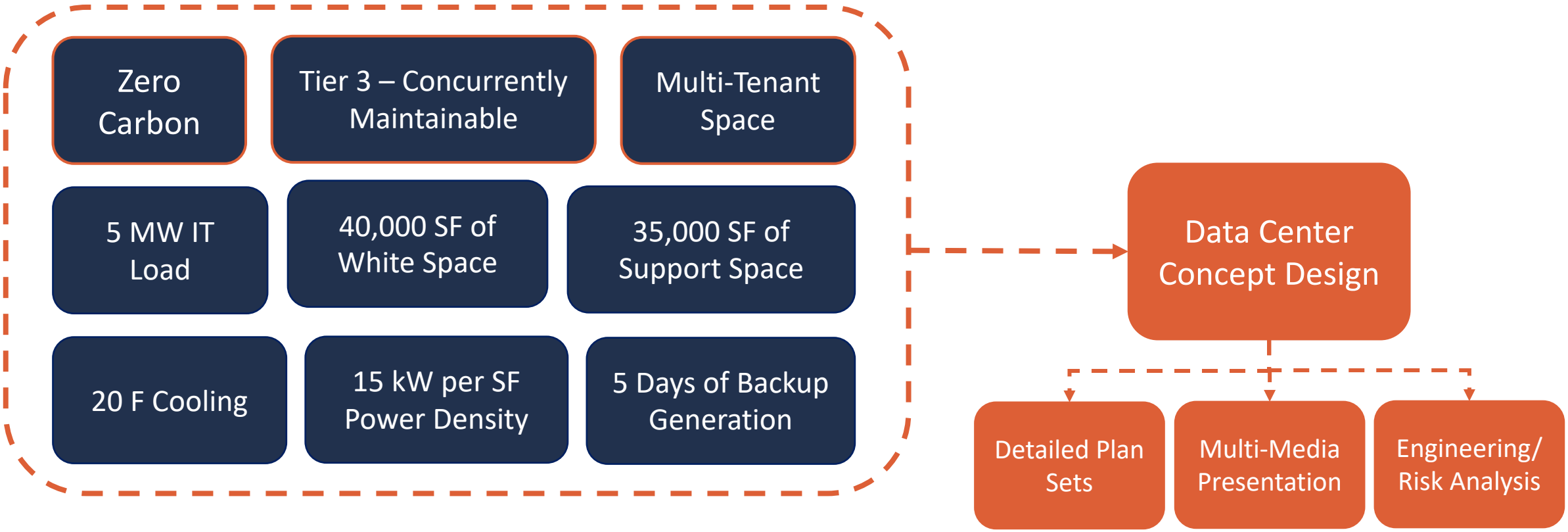
Electrical Design

Required components to store and distribute electricity to critical IT load and mechanical systems.

Civil Design

Building siting, envelope and floor plan layout required in order to meet space requirements of critical components.

Client Goals



Initial Research & Design Considerations

Tiering Standard

Tier I
Basic Capacity

Site-wide shutdowns are required for maintenance or repair work. Capacity or distribution failures will impact the site.

Tier II
Redundant Capacity Components

Site-wide shutdowns for maintenance are still required. Capacity failures may impact the site. Distribution failures will impact the site.

Tier III
Concurrently Maintainable

Each and every capacity component and distribution path in a site can be removed on a planned basis for maintenance or replacement without impacting operations. The site is still exposed to an equipment failure or operator error.

Tier IV
Fault Tolerant

An individual equipment failure or distribution path interruption will not impact operations. A Fault Tolerant site is also Concurrently Maintainable.

https://uptimeinstitute.com/tier-certification

Initial Research – Site Visits

Learning:

Tiering Standard	- Concurrently maintainable ≠ Fault Tolerant - Required for Each Critical System
Multi-Tenant	- Consider divided spaces - Privacy and Security considerations - Types of server customers use
Cooling	- Hot/Cold aisle containment - Air VS Liquid cooling - Heat Rejection

VISA

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

H5 DATA CENTERS

Initial Research – Literature Review

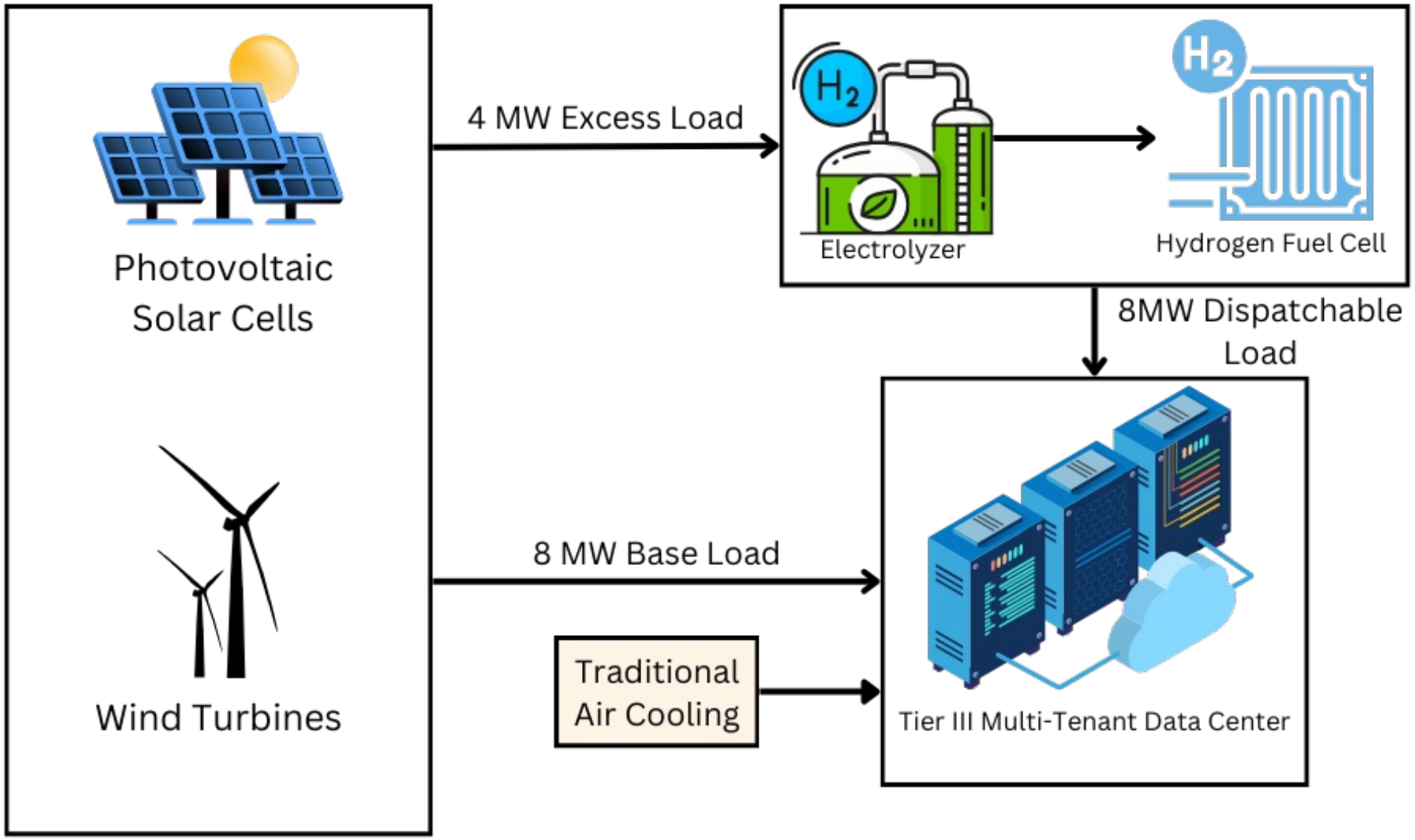
- Power Generation
  - Sources: Wind, Solar (PV, Concentrated), Geothermal, Hydrogen Fuel Cells
  - Considerations: Capacity, space and land requirements scalability, and ideal sites.
- Energy Storage Technologies
  - Technologies: Lithium-Ion Batteries, Lithium Sulfur batteries, hydrogen, thermal storage
  - Considerations: Energy density, efficiency, cost, and space.
- Energy Efficiency Measures
  - Measures: Plate-Frame heat exchanger, Economizing, hot/cold aisle containment, warmer chiller water, and ground-source heat pump.
- Cooling
  - Direct-to-Chip
  - Immersive
  - Traditional Air Cooled

Major Design Considerations

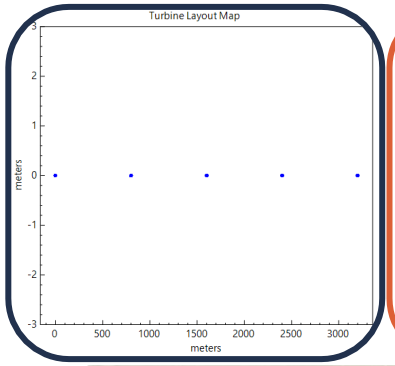
- Tiering Standard
- Zero-Carbon
- Viability of power generation options
- Cooling efficiency
- Cooling load
- Data center siting/placement
- White space layout
- One-line components

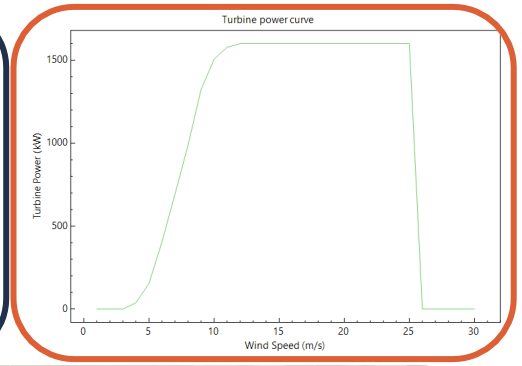
Concepts Explored

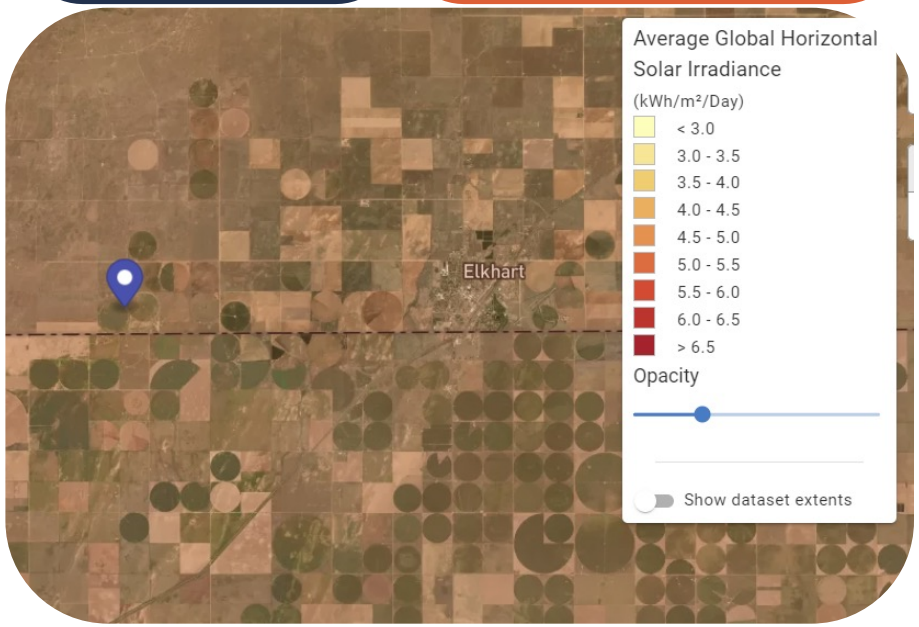
Package 1 - Solar, Wind, & Hydrogen



Concept Package 1: Solar + Wind + Hydrogen







Location: Southeast Bent County

Cooling Method: Traditional Air Cooling (CRAC/CRAH)

Wind: GE 1.6 MW 100m

- Energy Density of 500 W/m^2
- 1x the of demand will be supplied through wind
- Requires 74 acres of 8 MW windfarms

Photovoltaic Solar:

- Energy Density of 5.5-6 kWh/m^2/Day
- 0.5x the demand will be supplied through Solar
- Requires ~25 acres of 4 MW solar arrays (swivel?)

Hydrogen Fuel Cells:

- Excess capacity for Hydrogen production with onsite electrolyzer
- 0.5x of total capacity can be supplied by hydrogen fuel cell

Concept Package 1: Solar + Wind + Hydrogen

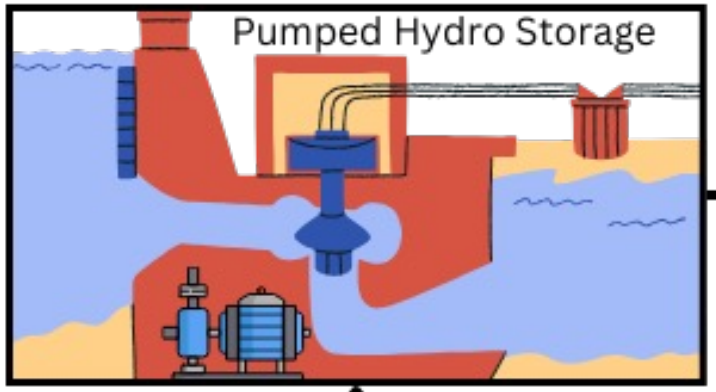
Benefits

- Integration of diverse renewable energy technologies ensures redundancy for enhanced reliability.
- Minimal water consumption is a key operational feature, promoting sustainability.
- Access to government incentives is facilitated through the utilization of wind, solar, and hydrogen technologies.
- Air-cooled data centers benefit from economies of scale, optimizing operational efficiency.
- Ergonomically designed CRAC units eliminate the need for server reconfiguration, streamlining maintenance processes.

Costs

- The substantial land requirements, amounting to 1.5 times the total capacity, pose a notable challenge.
- An additional capacity is imperative to support dispatchable power sources, introducing an extra operational burden.
- The implementation of large-scale wind, solar, and hydrogen technologies proves to be financially demanding.
- High latency connections and restricted access to fiber connection lines contribute to limitations in connectivity.

Package 2: Solar and Pumped Hydro Storage



8 MW
Dispatchable
Load

4 MW
Excess
Capacity

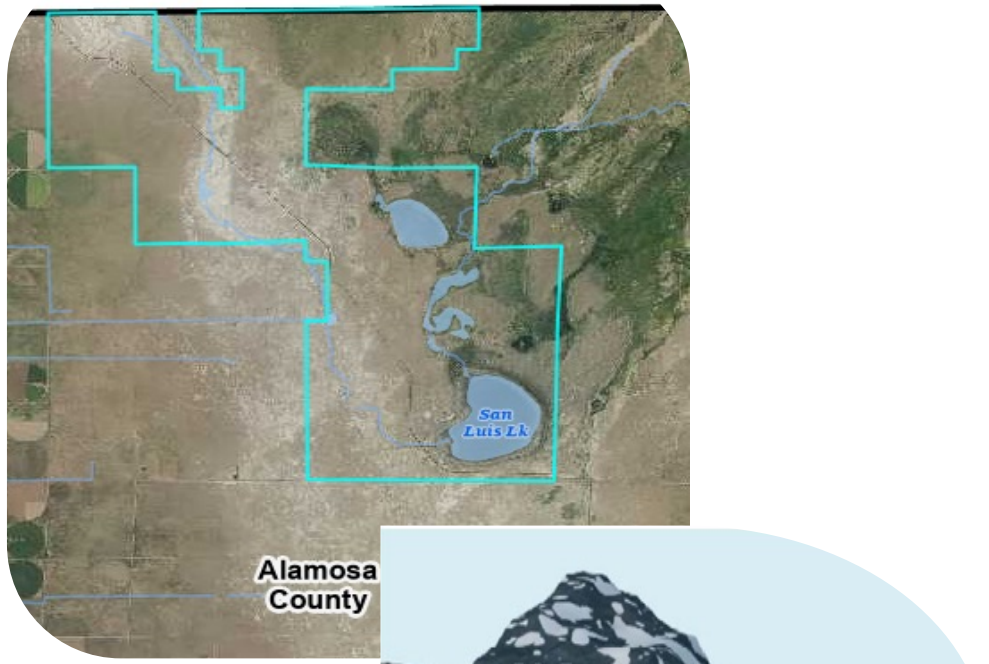
Traditional
Air Cooling

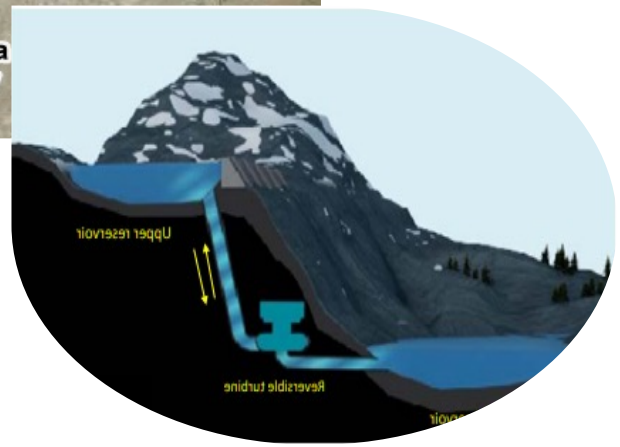
Photovoltaic
Solar Cells

8 MW Baseload Capacity

Tier III Multi-Tenant Data Center

Concept Package 2: Solar + Hydro Storage





Location: Northern Alamosa Country

Cooling Method: Traditional Air Cooling (CRAC/CRAH)

Photovoltaic Solar:

- Energy Density of 0.15 MW / acre
- 1.6x the peak demand will be supplied through solar
- Requires ~60 acres of 8 W 2-axis solar arrays

Pumped Hydro Storage:

- Excess generation will be used to pump water from a lower reservoir to a higher reservoir, storing electricity in the form of potential energy
- A standstill to full capacity ramp rate of less than 5 minutes

Concept Package 2: Solar + Pumped Hydro Storage

Benefits

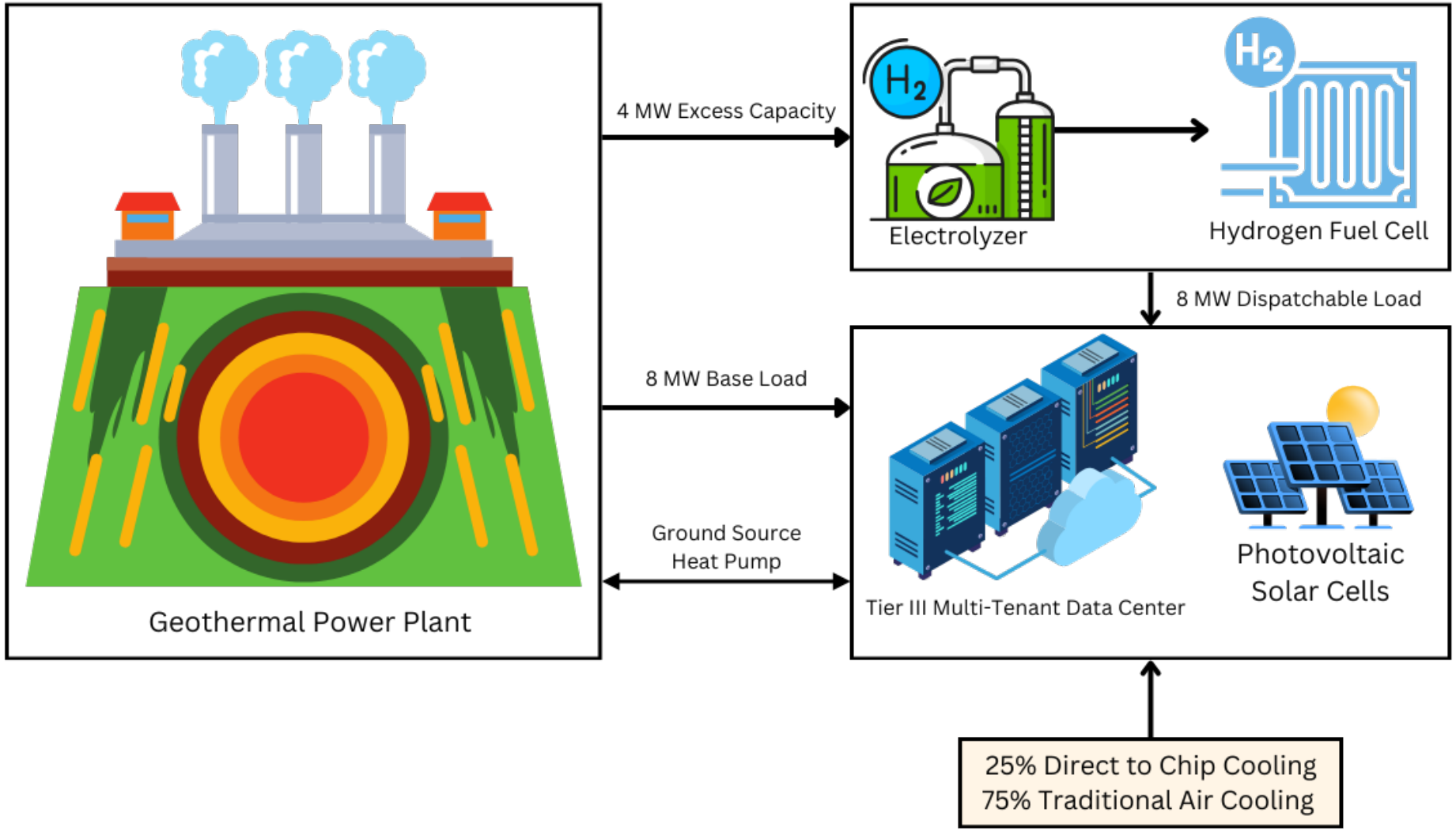
- Integration of a storable renewable energy increases redundancy and fault tolerance.
- Water can be used use in a multitude of uses and cycles.
- Access to government incentives is facilitated through the utilization of solar technologies.
- Using the water responsibly can positively influence the environment.
- Air-cooled data centers benefit from economies of scale, optimizing operational efficiency.
- Ergonomically designed CRAC units eliminate the need for server reconfiguration, streamlining maintenance processes.

Costs

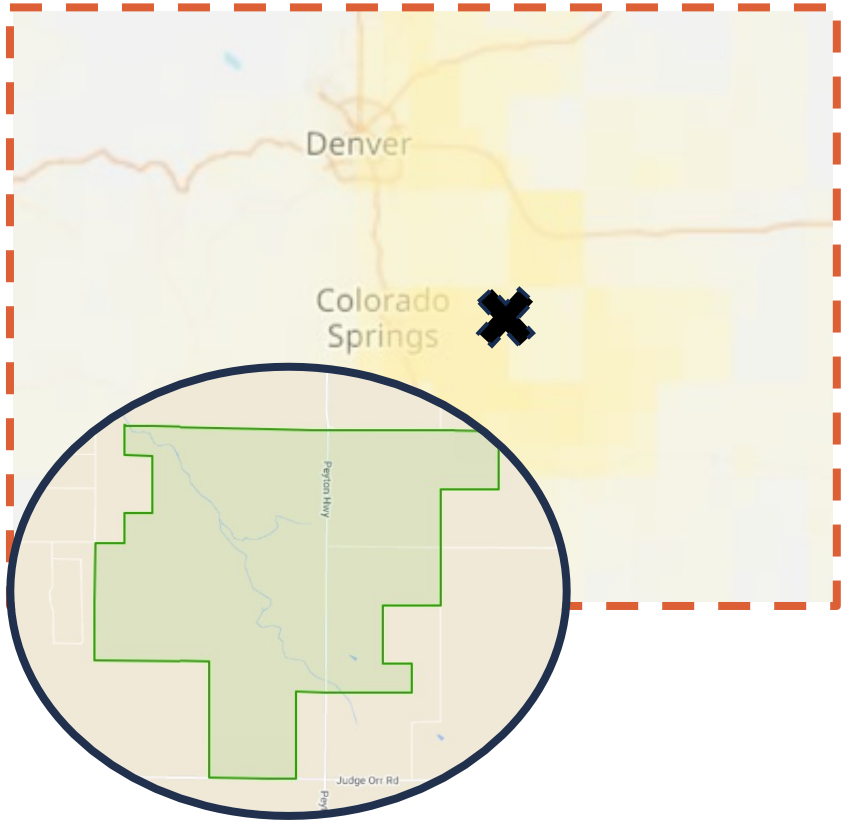
- The substantial land requirements, ~50 acres for the solar and ~20 for the pumped storage.
    - Requires 100m height change for pumped storage
- Large financial obligations for this demand of land.
- Lengthy timeframe in permitting for large solar arrays and pumped storage.
- The location poses a potential latency issue with the lack of fiber interconnections near our location.
- Load diminishes significantly in the winter and at night.
- Pumped storage does not work in sub-freezing temperatures.

Design Decision

Package 3: Geothermal, Hydrogen, and Solar



Concept Package 3: Geothermal + Hydrogen and Solar



Location: El Paso Country, 4230.44 Acres

Cooling Method: 25% Direct-to-Chip Cooling & 75% CRAC/CRAH with aid of Ground-Source heat pump

Deep Enhanced Geothermal Systems:

- Energy Density of 7 MWe/acre
- 1.5x the capacity of the total load
- Requires 3.4 acres of land to achieve this load

Hydrogen Utilization:

- Excess capacity for Hydrogen production with onsite electrolyzer
- 0.5x of total capacity can be supplied by hydrogen fuel cell

Concept Package 3: Geothermal + Hydrogen and Solar

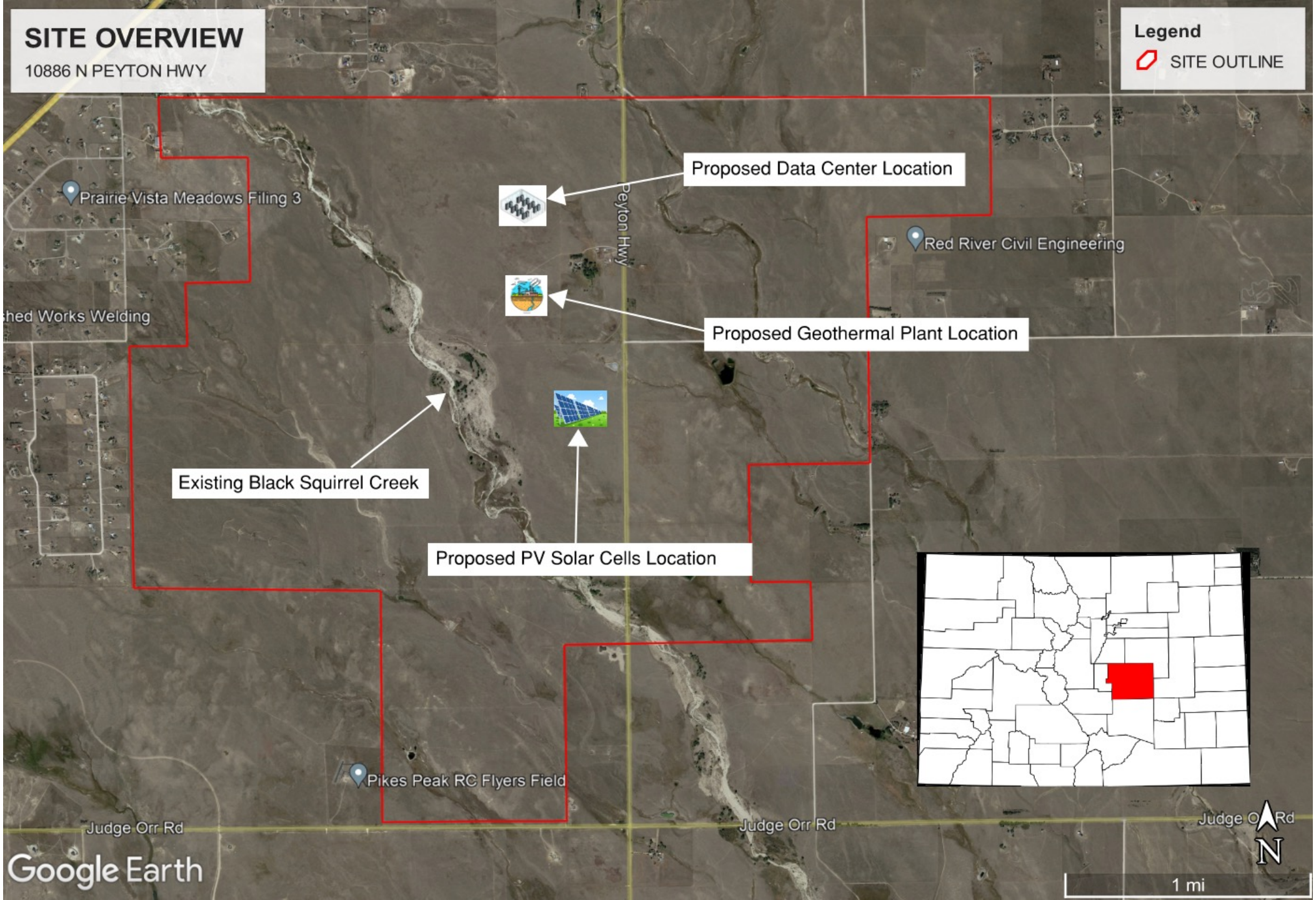
Benefits

- Geothermal provides a non-variable source of energy generation for most of our electric load
- Very high energy density for our renewable energy generation possibilities
- We intend to also have a geothermal heat pump (for cooling) at this site, so the water can be recycled into that
- With all the water we are using at this site, we intend to have direct-to-chip cooling using either water or some other refrigerant
- Geothermal wells require little maintenance to ensure they are running properly

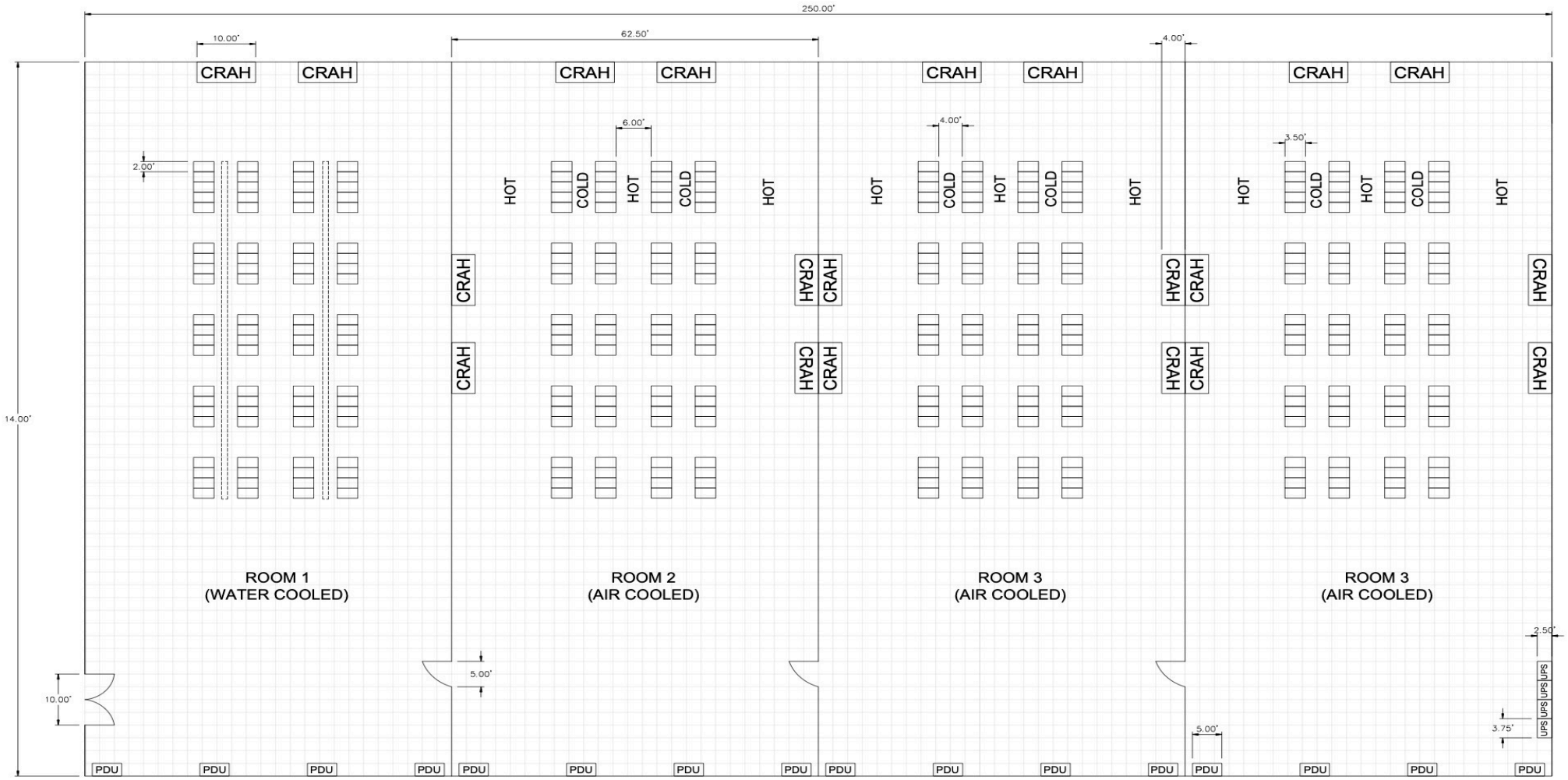
Costs

- Substantial up-front costs for well drilling and boring for geothermal heat pumps
  - Geothermal Energy wells must be drilled anywhere from 1 to 6 miles deep
- Lengthy timeframe in permitting for large-scale geothermal energy generation sites
- We will have large water usage requirements for this site due to the nature of the energy generation and cooling

Site Plan


SITE OVERVIEW
10886 N PEYTON HWY
Legend
SITE OUTLINE
Proposed Data Center Location
Proposed Geothermal Plant Location
Existing Black Squirrel Creek
Proposed PV Solar Cells Location
Prairie Vista Meadows Filing 3
Red River Civil Engineering
Peyton Hwy
Pikes Peak RC Flyers Field
Judge Orr Rd
Judge Orr Rd
Judge O Rd
Google Earth
N
1 mi

Floor Plan



□ = 2.5'

84 SERVERS PER ROOM

336 TOTAL SERVERS

0 10' 20'
SCALE: 1" = 10'

COLORADO SCHOOL OF MINES @150 | 1874-2024

PROJECT: ZERO-CARBON, TIER III, MULTI-TENANT DATA CENTER

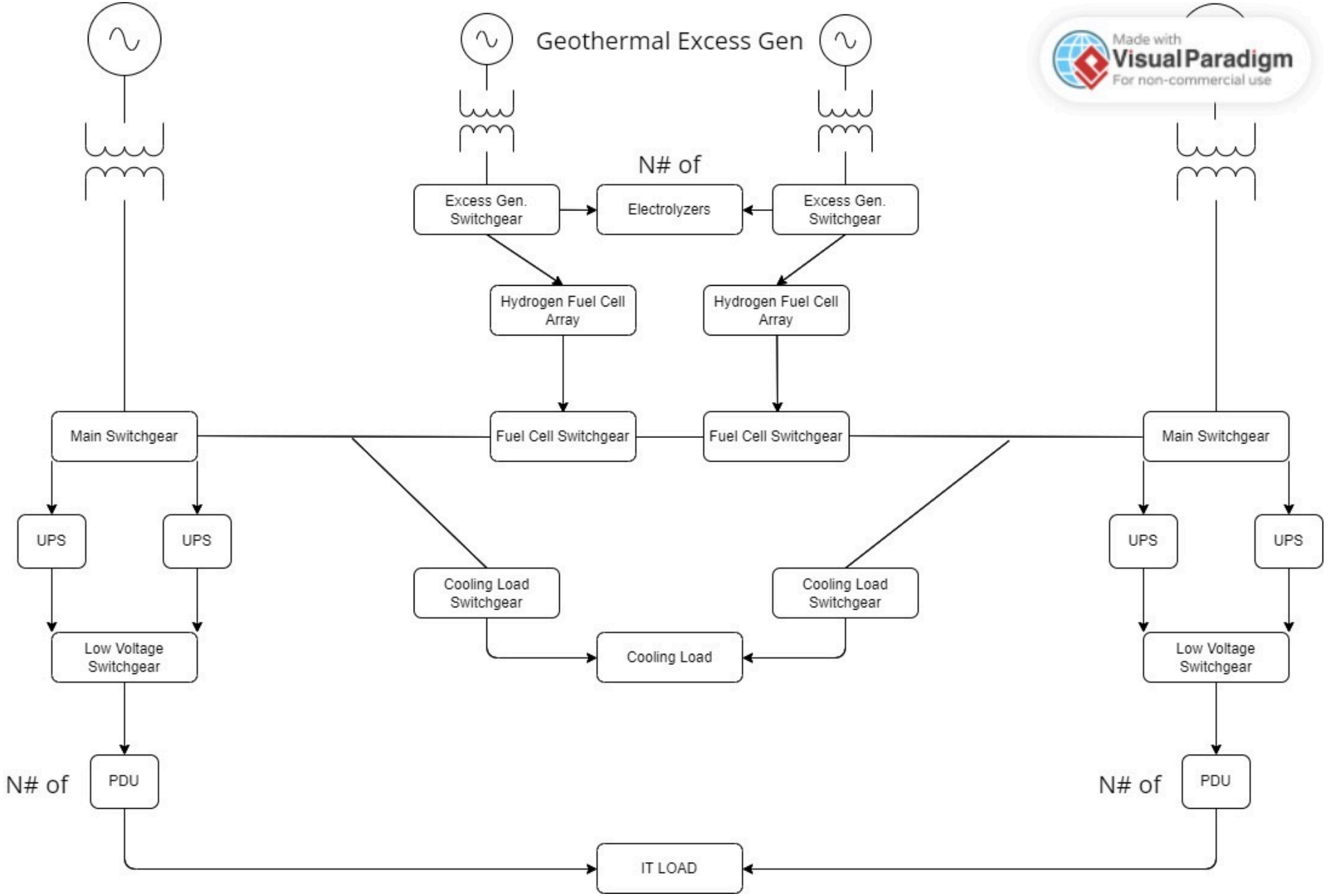
TEAM: THE CLEAN TECH TITANS

SHEET NAME: WHITE-SPACE FLOOR PLAN

SCALE: 1" = 10'

DATE: 11/02/2023

High-Level Electrical One Line


Geothermal Excess Gen
N# of
Excess Gen. Switchgear
Electrolyzers
Excess Gen. Switchgear
Hydrogen Fuel Cell Array
Hydrogen Fuel Cell Array
Main Switchgear
Fuel Cell Switchgear
Fuel Cell Switchgear
Main Switchgear
UPS
UPS
UPS
UPS
Cooling Load Switchgear
Cooling Load Switchgear
Cooling Load
Low Voltage Switchgear
Low Voltage Switchgear
N# of
PDU
N# of
PDU
IT LOAD
Made with VisualParadigm
For non-commercial use

Cooling Calculations

Cooling & Load

	Total Load	Single Server Rack
Number of Racks	334	1
Electrical Load	5 MW	15 kW
Sensible Heat Load (Btu/hr)	1706000 Btu/hr	5108 Btu/hr
Sensible Heat Load (Ton)	142.16 ton	4.2 ton
Air Cooling (CFM)	96910 CFM	290 CFM
Direct-to-Chip (GPM)	170.6 GPM	0.51 GPM

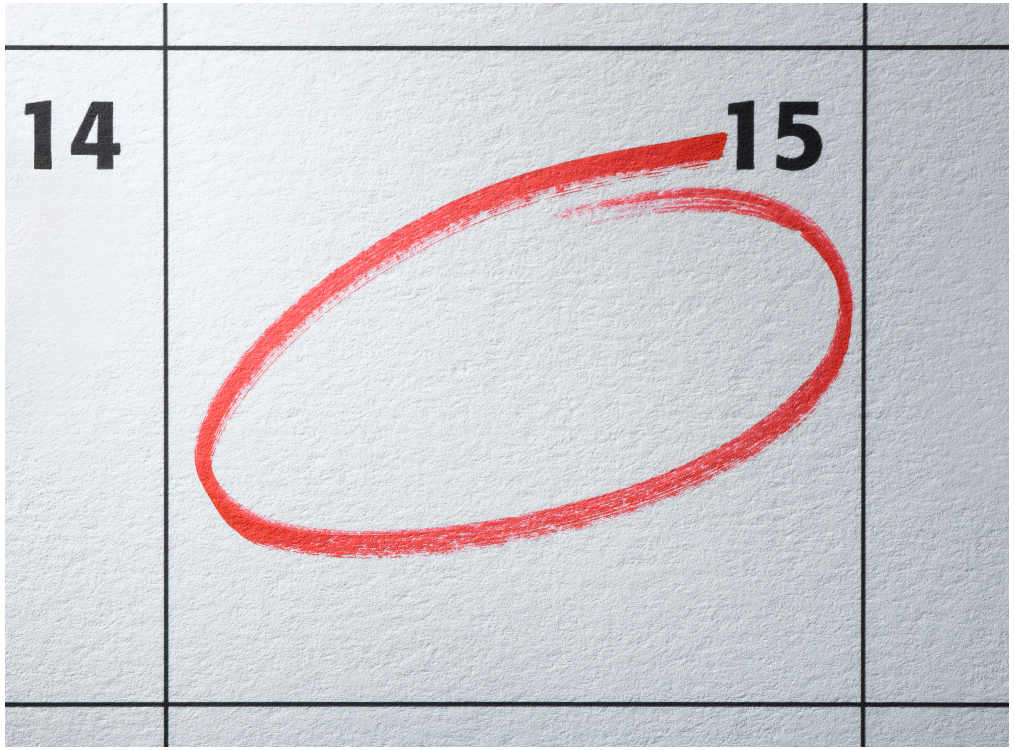
Schedule & Next Updates

Project Planner

ACTIVITY	PLAN START	PLAN DURATION	PERCENT COMPLETE
Sprint 4	26-Oct	53	100%
Complete site plan with building shell	9-Nov	1	100%
Create preliminary mechanical one-lines for viability analysis purposes.	31-Oct	33	100%
Create preliminary electrical one-lines for viability analysis purposes	31-Oct	33	100%
Established energy sources/generation	31-Oct	26	100%
Risk analysis	7-Nov	27	75%
Alternative energy generation analysis	7-Nov	27	75%
Create PDR Presentation	31-Oct	7	75%
PDR Dry run	2-Nov	1	100%
Preliminary Design review	7-Nov	1	100%
Next Steps Letter	8-Dec	27	0%
Prepare Sprint 5 backlog	5-Dec	1	0%
Sprint 4 Reivew	5-Dec	1	0%
Plan client action items from PDR	8-Dec	28	0%
Second semester scheduling/planning	9-Dec	13	0%
Sprint 5	5-Dec	4	0%
Preliminary redundancy analysis	6-Dec	1	0%
Tiering discussion	7-Dec	1	0%
PDR Updated Submission	8-Dec	11	0%
Project Goal Attainment	8-Dec	4	0%
Prepare Sprint 6 Backlog	10-Dec	1	0%

Next Steps

- Plan for the spring semester
- Begin redundancy design
  - Cooling
  - Electrical
  - Backup power
- Begin planning for a multi-tenant facility
  - Number of rooms
  - Type of servers
  - Flexibility
- Develop more polished plans
  - Site
  - Utility sources
  - Power generation pathways



Thank you for your time and attention! Questions?