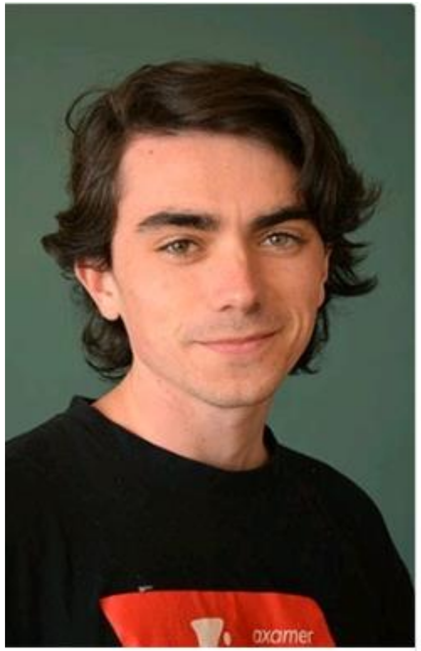
Northern Arizona University NAU Capstone New Mexico State University District

- Corey Burke
- Elizabeth Griffith
- Grant Hale
- Daniel McConnell
- Jack Viola

Team Composition



Corey Burke

Primary Roles:

Project Manager & CAD Engineer

Elizabeth Griffith

Primary Roles:

Financial Manager & Manufacturing Engineer

Grant Hale

Primary Roles:

Test Engineer & Standards and Regulations Manager

Daniel McConnell

Primary Roles:

Logistics Manager & Aurora Solar Manager

Jack Viola

Primary Roles:

Battery Manager & OpenDSS Architect

Competition Approach

The Teams Approach was to generate the most amount of energy while staying financially viable

The secondary objectives were to minimize losses and have innovative ideas

One or more multidisciplinary meetings every week

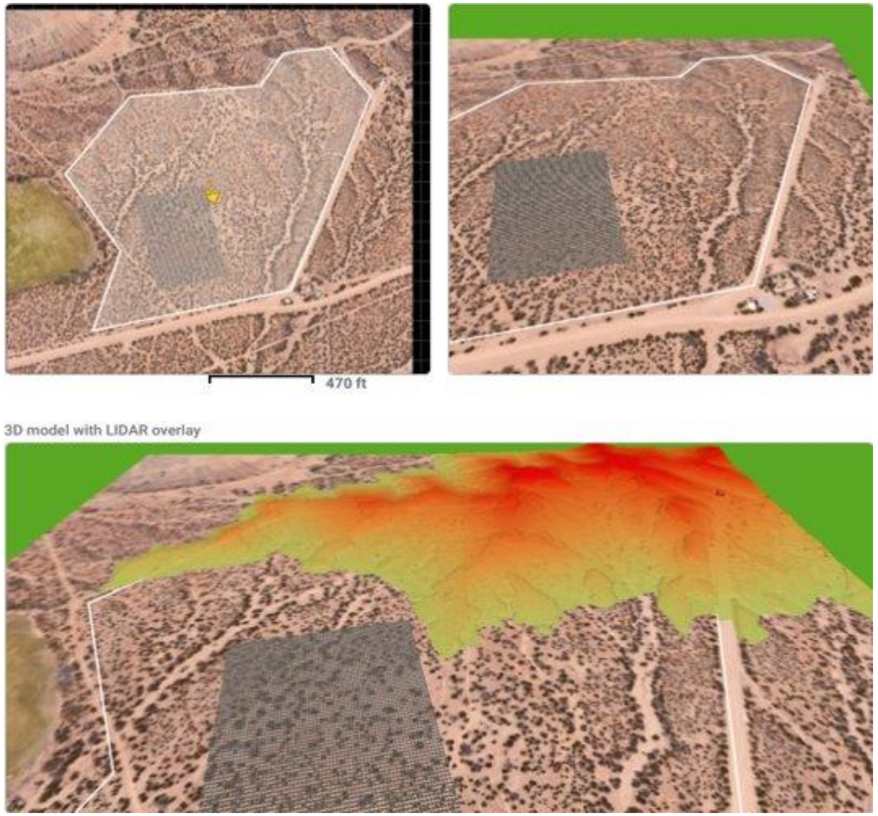
Met with business professor at NAU Kristin Kettel

System Design

- 3 sub systems
- Geothermal Substation Ground Mount system (3 MW)
- Pan American Center Solar Parking Awnings (2 MW)
- Hadley Hall Spanish Solar Tiles (164 kW)
- 220 kW Battery storage system

Section 1: Conceptual System Design

- **Geothermal Substation**
  - 3 miles east of campus
  - 30° tilt ground mount system
  - SunPower T5-SPR 310 mono crystalline (Silicone) panels
- 3 Inverters
  - SMA America: SC850CP-US

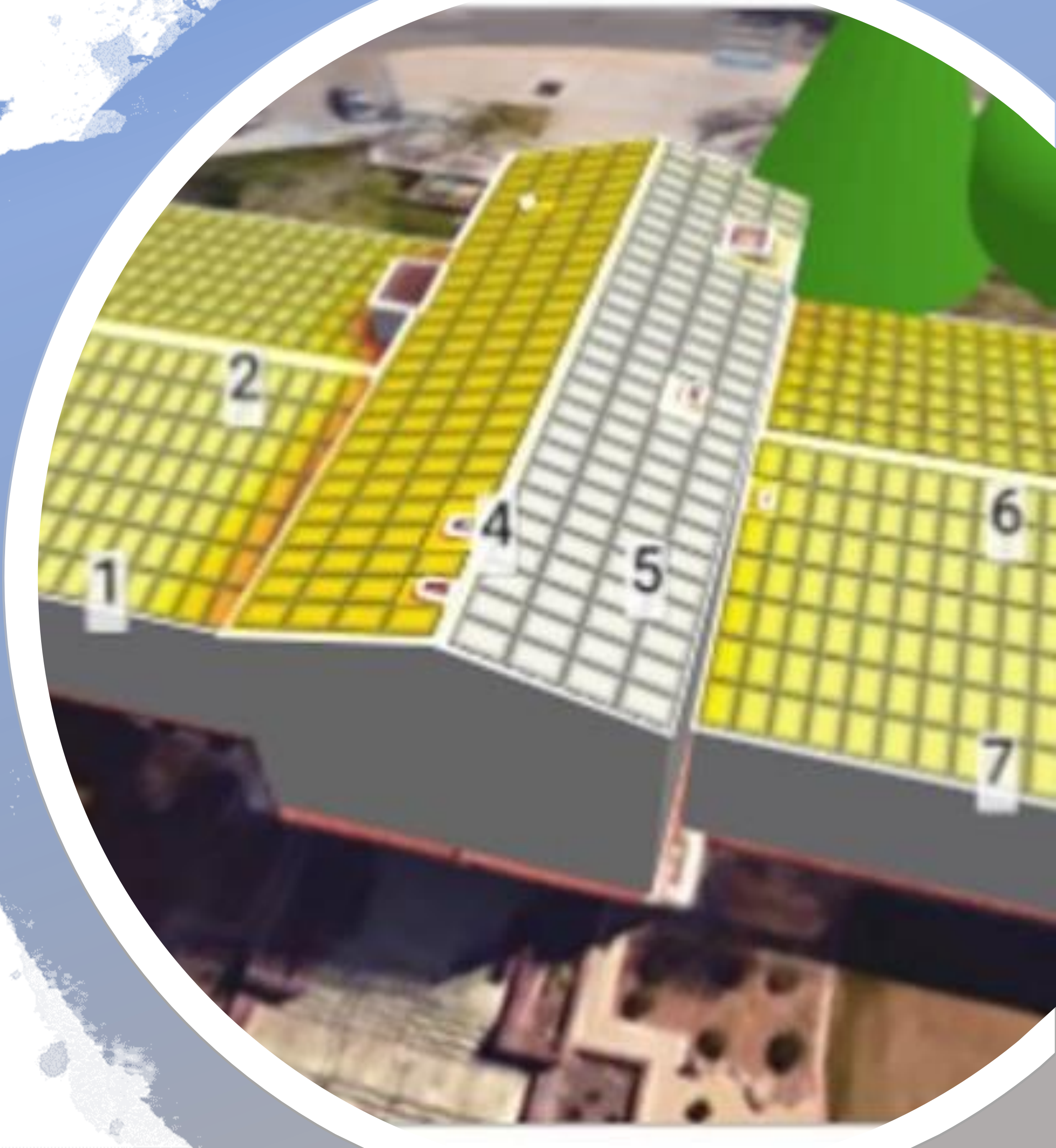


Section 1:
Conceptual System Design

- **Pan American Center Solar Parking Awnings**
    - Pan American Center parking lot
    - 577 shaded parking spaces
    - Extra revenue from parking passes
    - Parking lines need to be repainted in opposite direction
    - SunPower T5-SPR 310 mono crystalline (Silicone) panels
- 2 Inverters
    - SMA America: SC850CP-US

Section 1: Conceptual System Design

- Spanish Solar Tiles
  - Hadley Hall
  - Innovative
  - Maintains school style
  - Aesthetically pleasing
  - HanTiles
- 34 Inverters
  - ABB: PVI-3.6-OUTD-S-US-Z-A [208V]

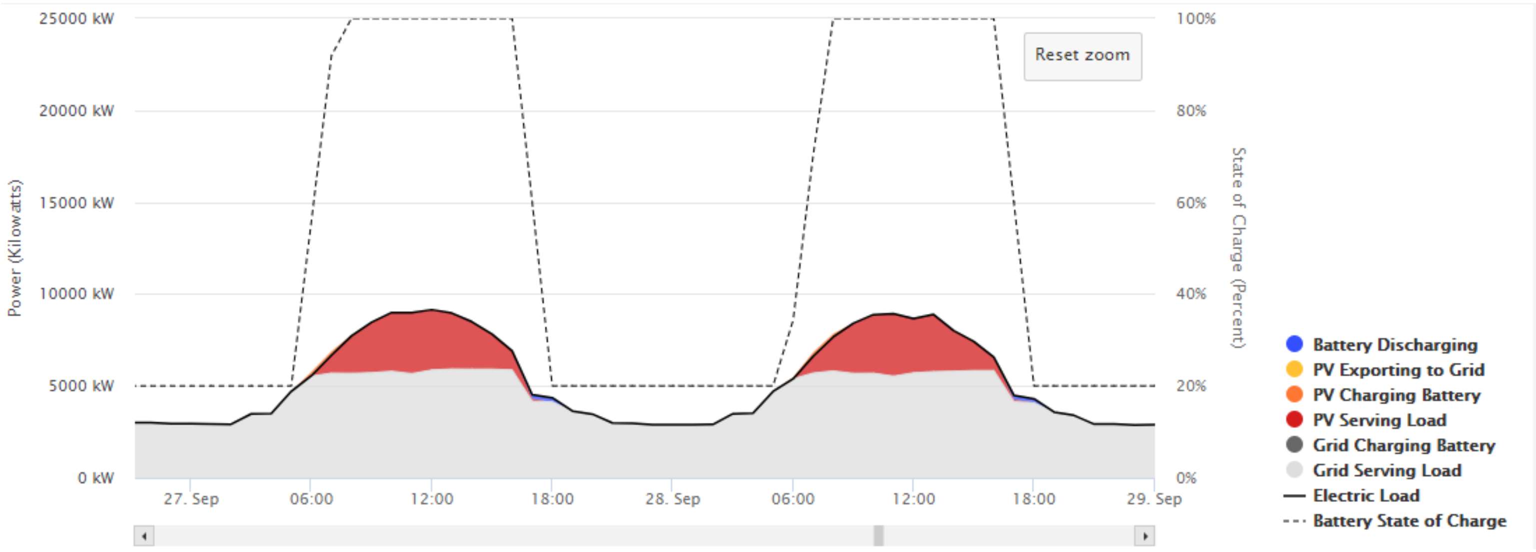


Section 1:
Conceptual System Design

- Saltwater battery system with 580 kWh capacity
  - Wide Charge/discharge range
  - Innovative
  - Pre-optimized package commercially available
  - Grid-tied system with capability of running during grid outage

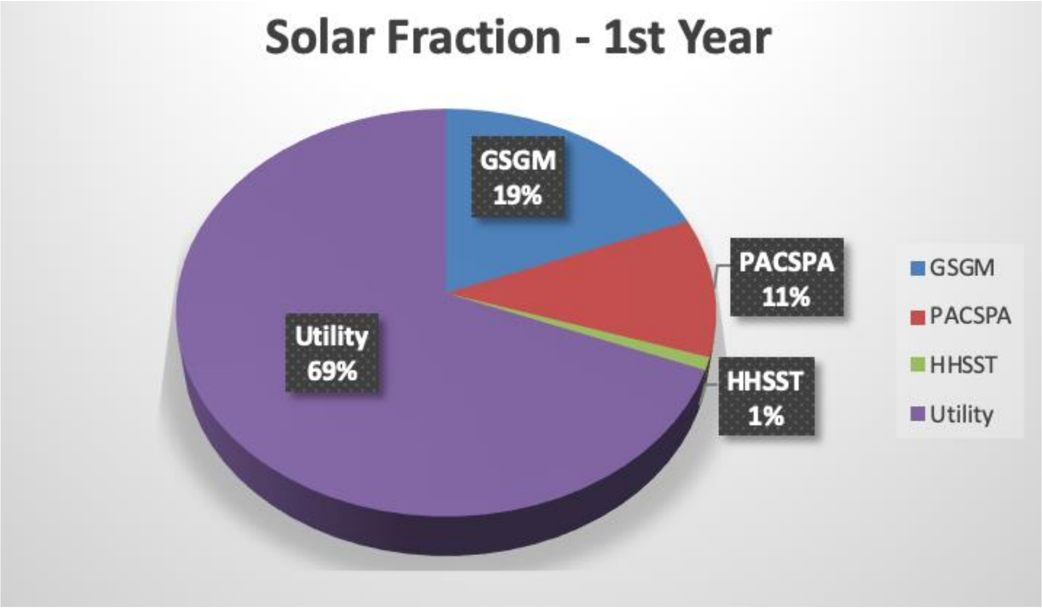
Expected Operation

- PV and Battery Reduce peak consumption
- Battery charged by PV system
- Battery discharge when PV stops producing
- Battery discharges during outage



Expected Operation

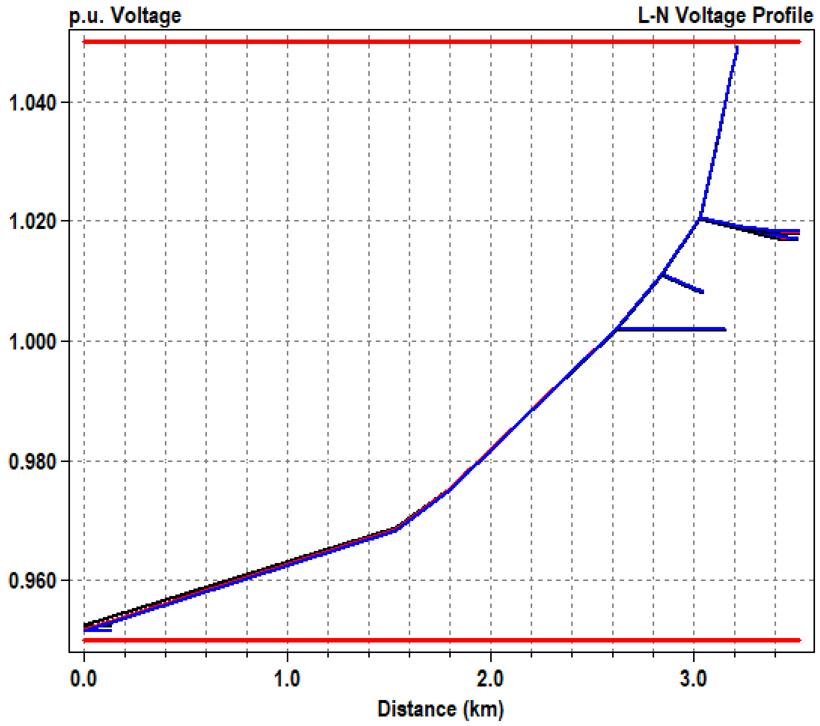
- System supplies 31% of the consumption provided
- Solar farm (GSGM) can be expanded when battery storage is more financially viable
- Battery storage costs are expected reduce 21-67% by 2030
- The critical load of 16% is estimated to survive 31% of 2-hour outages

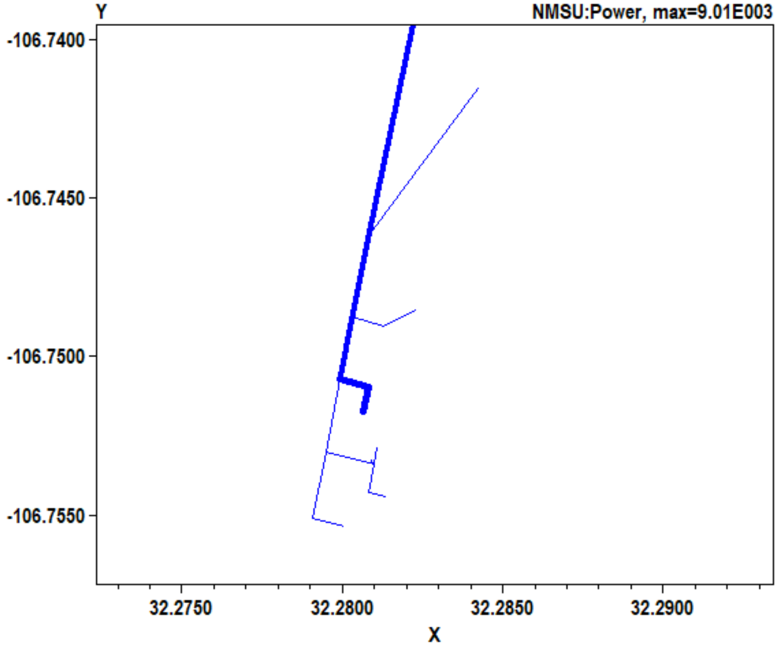


Section 2:
System Impact Analysis

Power flow modeling in OpenDSS:

- Loss/fault analysis
- Transmision phase shifting
- Base kV mismatch
- Service drops



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Power Conversion Elements

Bus                 (node ref)  Phase     Magnitude, kV (pu)    Angle

ELEMENT = "PVSystem.PV_DIRTLOT"
DIRTLOT_PV           ( 28)     1         2.2873 ( 0.9523) /_    8.6
DIRTLOT_PV           ( 29)     2         2.2856 ( 0.9516) /_ -111.0
DIRTLOT_PV           ( 30)     3         2.2857 ( 0.9517) /_  129.0
DIRTLOT_PV           (  0)     0              0 (      0) /_    0.0

ELEMENT = "PVSystem.PV_HADLEY"
HADLEY_PV            ( 34)     1         2.5187 (  1.049) /_   31.8
HADLEY_PV            ( 35)     2         2.5195 (  1.049) /_  -87.9
HADLEY_PV            ( 36)     3         2.5198 (  1.049) /_  152.2
HADLEY_PV            (  0)     0              0 (      0) /_    0.0

ELEMENT = "PVSystem.PV_PARKLOT"
PARKLOT_PV           ( 31)     1          2.406 (  1.002) /_   27.4
PARKLOT_PV           ( 32)     2         2.4065 (  1.002) /_  -92.3
PARKLOT_PV           ( 33)     3         2.4063 (  1.002) /_  147.8
PARKLOT_PV           (  0)     0              0 (      0) /_    0.0

ELEMENT = "Storage.DIRTLOT_BATT"
DIRTLOT_PV           ( 28)     1         2.2873 ( 0.9523) /_    8.6
DIRTLOT_PV           (  0)     0              0 (      0) /_    0.0
```

System Operation

- Battery Controller
  - **Peak Shaving** – dictates when the battery sub-system is charging vs. discharging
  - **Discharge Rate Regulation** – extends battery life by preventing overdrawing power
  - **Power Factor Correction** - real-time impedance matching to optimize conversion power factor
- Inverter microcontroller
  - **Maximum Power Point Tracking (MPPT)** - stabilizes voltages going to other sub-systems and service loads

```
New StorageController.dirtlot_battctl element=Line.L00 ElementList=dirtlot_batt terminal=1
~ ModeDischarge=peakshave ModeCharge=Time TimeChargeTrigger=9.5 TimeDischargeTrigger=14.5
~ kWTarget=300 PFTarget=0.98 %ratekw=30
```

Section 3:
Financial Model

- PPA Price: $0.023/kWh (ac)
- Utility charge: $0.01/kWh (ac)

- Battery stacking
  - Demand charge reduction
  - PV utilization
  - ITC
  - Backup power
  - Carbon offset
- Valuation of resilience premium
  - Modeled University in calculator

System	Internal Rate of Return (IRR)
Geothermal Substation Ground Mount	19.65%
PanAmerican Center Solar Parking Awnings	270.15%
Hadley Hall Spanish Solar Tiles	25.40%
Battery Storage using REopt Lite	-4.67%

System	Net Present Value (NPV)
Geothermal Substation Ground Mount	($100,433)
PanAmerican Center Solar Parking Awnings	$194,079
Hadley Hall Spanish Solar Tiles	($26,689)
Battery Storage using REopt Lite	($65,048)
Summary NPV	**$1,909**

System	Customer Net Present Value (NPV)
Geothermal Substation Ground Mount	($3,531,408)
PanAmerican Center Solar Parking Awnings	($2,107,310)
Hadley Hall Spanish Solar Tiles	($203,486)
Summary NPV	**($5,842,204)**

Section 4:
Building and Site Plan

- Land Use and Zoning
- Location Suitability and Attractiveness
- District Master Plan
- Other Land Uses and Building Regulations

Construction and Development Plan

- Permitting and Relevant Code Analysis
- Construction Approach
- Engaging Decision Makers
- Feasibility

Innovation

- Solar tiles
  - Functionable and maintains Spanish Renaissance style
  - Located on a high traffic building
- Parking structure
  - Increases shaded spots on campus by 577 spaces
  - Generates annual revenue with parking pass
- Saltwater batteries
  - Easily recyclable
  - Similar capabilities to Lithium Ion

Optimization Strategy

- PV System
  - Modeled in Aurora Solar and SAM
  - 5.1 MW System
  - Monocrystalline modules

- Battery storage
  - Sizing optimized in REopt Lite
  - Input and modify original PV system size
  - Hospital consumption model used
  - Critical load factor of 16%

QUESTIONS?