Phoenix Integration

2015 User Conference

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Marina Del Rey, CA

Optimizing Constructability to Reduce the Cost of Wind Energy

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Agenda

1. **Introduction**
2. Optimization Method
3. Case Study Applications
4. Conclusions / Next Steps

Project Overview

Goal: Develop a design method to enable project stakeholders to quickly and accurately evaluate design alternatives in terms of capital cost and revenue potential.

Scope:

- Turbine locations
- Substation location(s)
- Collection system layout
- Access road layout

Team Responsibilities

Mortenson construction

- Construction expertise and cost data
- Baseline infrastructure layouts

STANFORD UNIVERSITY

- Integration of construction costs
- Creation of optimization methods

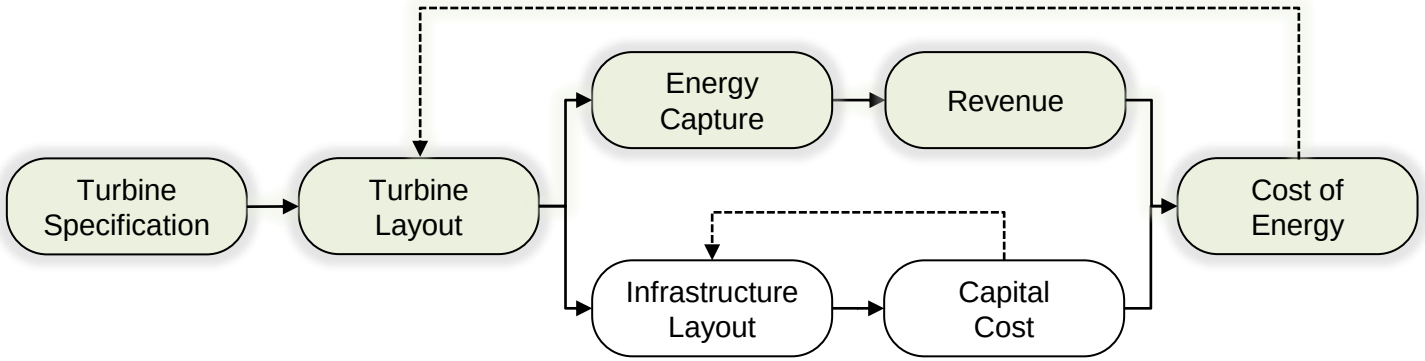
EDF renewable energy

- Turbine coordinates and wind data
- Land control and site constraints
- Owner cost information (e.g., turbines, O&M, PPA)

AWS Truepower® Where science delivers performance.

- Access to OpenWind software
- Energy capture modeling

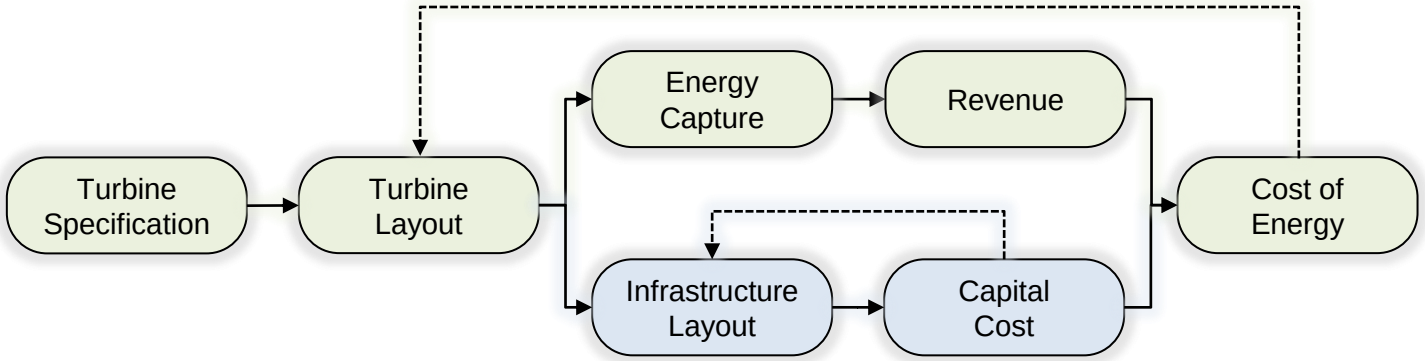
Conventional Design Process



REVENUE

- Responsibility of owner / design consultant
- Typically performed early in the design process
- Automated iteration / optimization

Conventional Design Process



REVENUE

- Responsibility of owner / design consultant
- Typically performed early in the design process
- Automated iteration / optimization

CAPITAL COST

- Responsibility of contractor
- Typically performed during detailed design and/or tender
- Manual iteration

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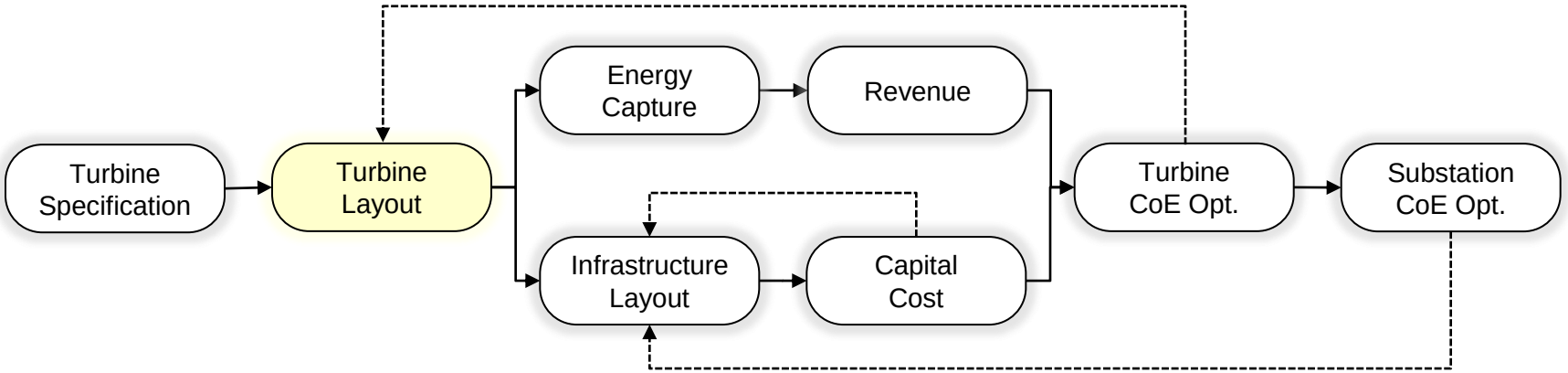
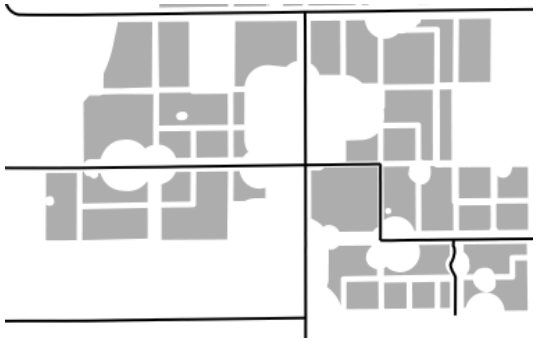
Optimization Process

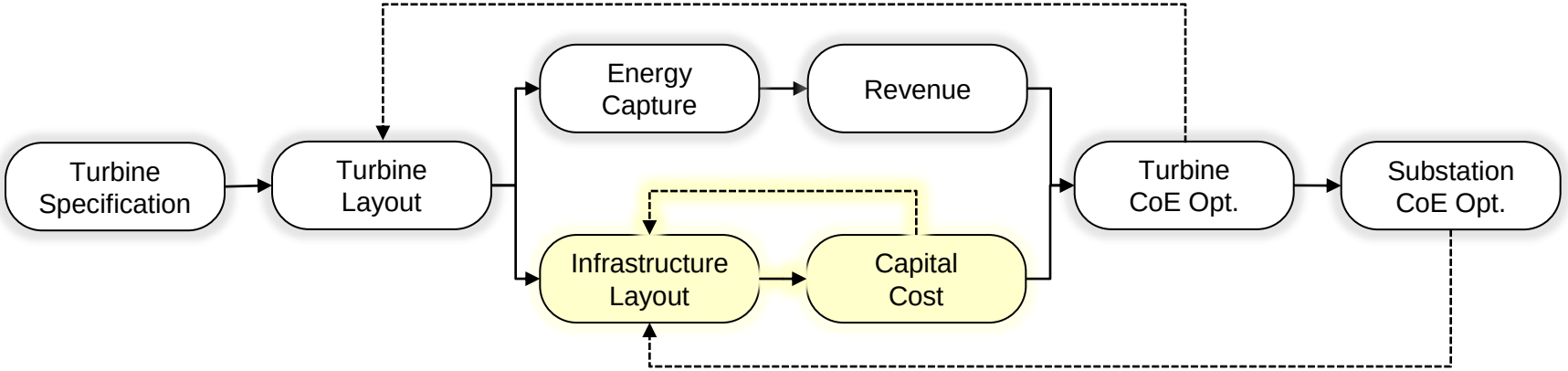


TURBINE LAYOUT

- Layout constraints are modeled as GIS layers
- Site is rasterized to create a list of feasible turbine positions

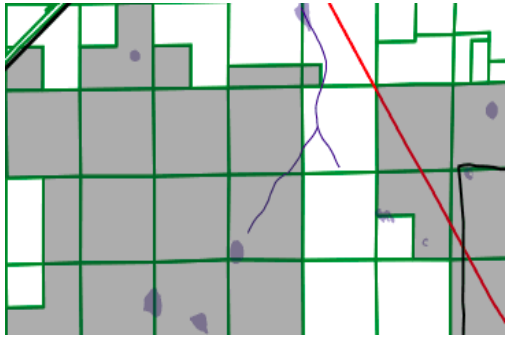


Optimization Process

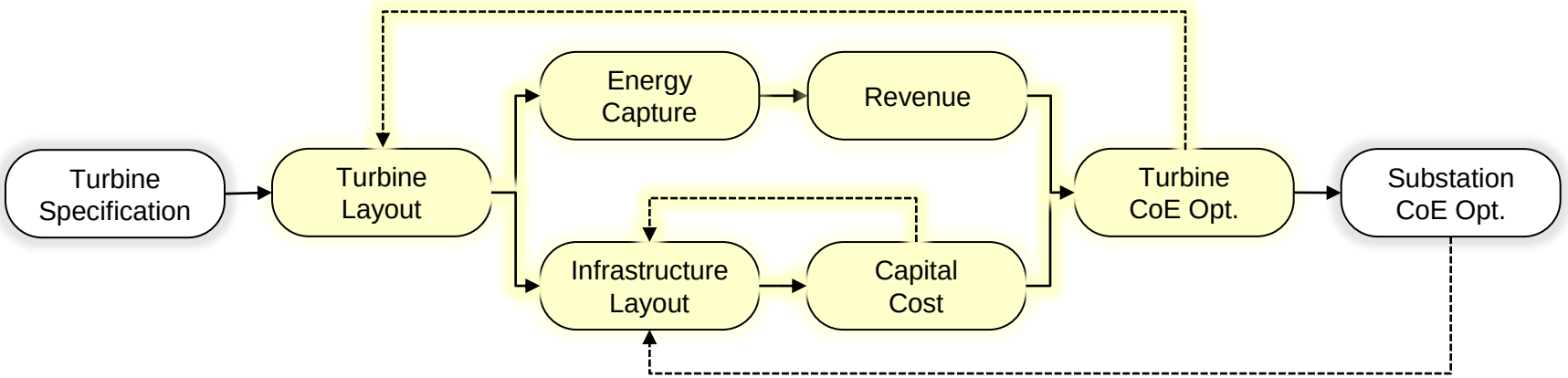


INFRASTRUCTURE LAYOUT AND COSTING

- Road and collection systems are assigned unit costs
- Costs are modeled as GIS layers
- A* and Esau Williams used for layout of roads and collection system

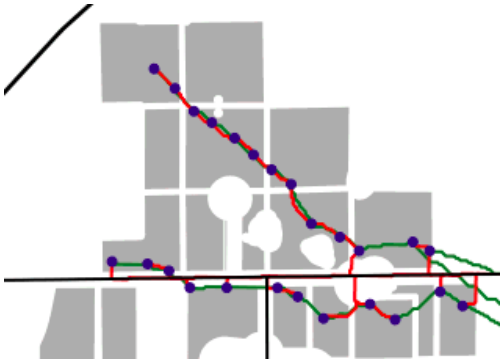


Optimization Process

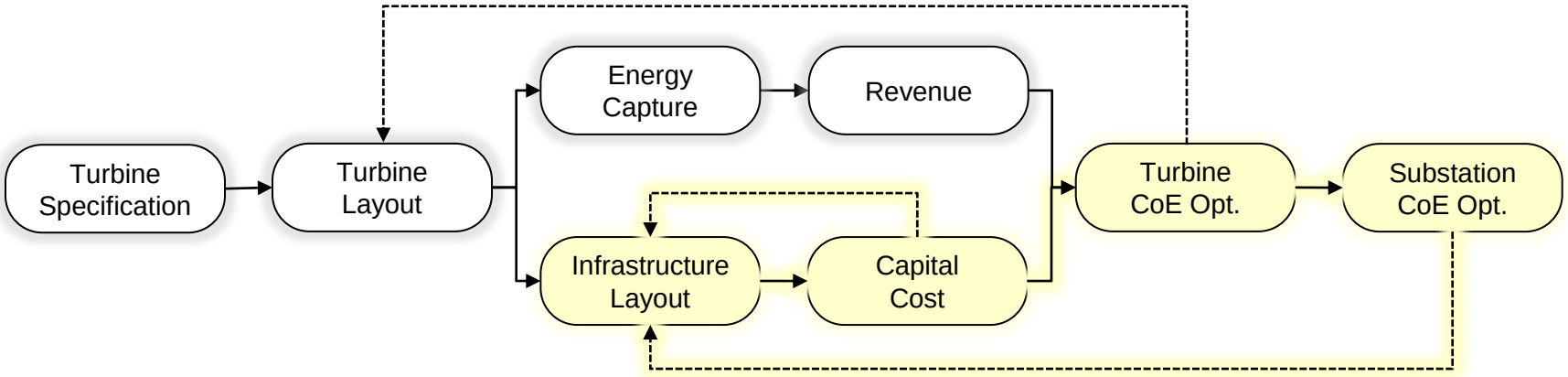


TURBINE POSITION OPTIMIZATION

- System-level optimizer
- Objective: *Minimize* cost of energy
- Variables: Turbine positions (x,y)



Optimization Process



SUBSTATION POSITION OPTIMIZATION

- Subsystem-level optimizer
- Objective: *Minimize* cost of energy
- Variables: Substation position(s)

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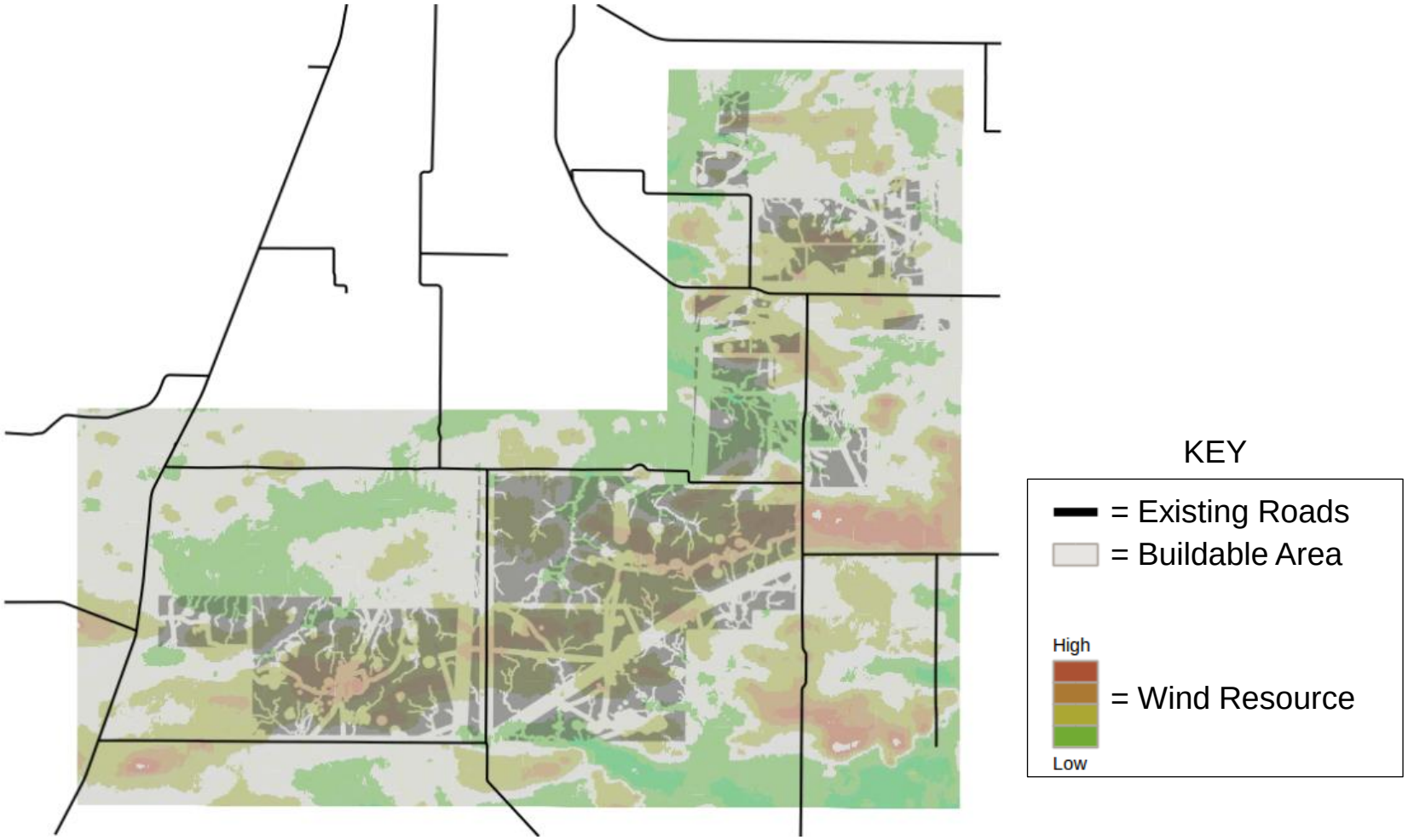
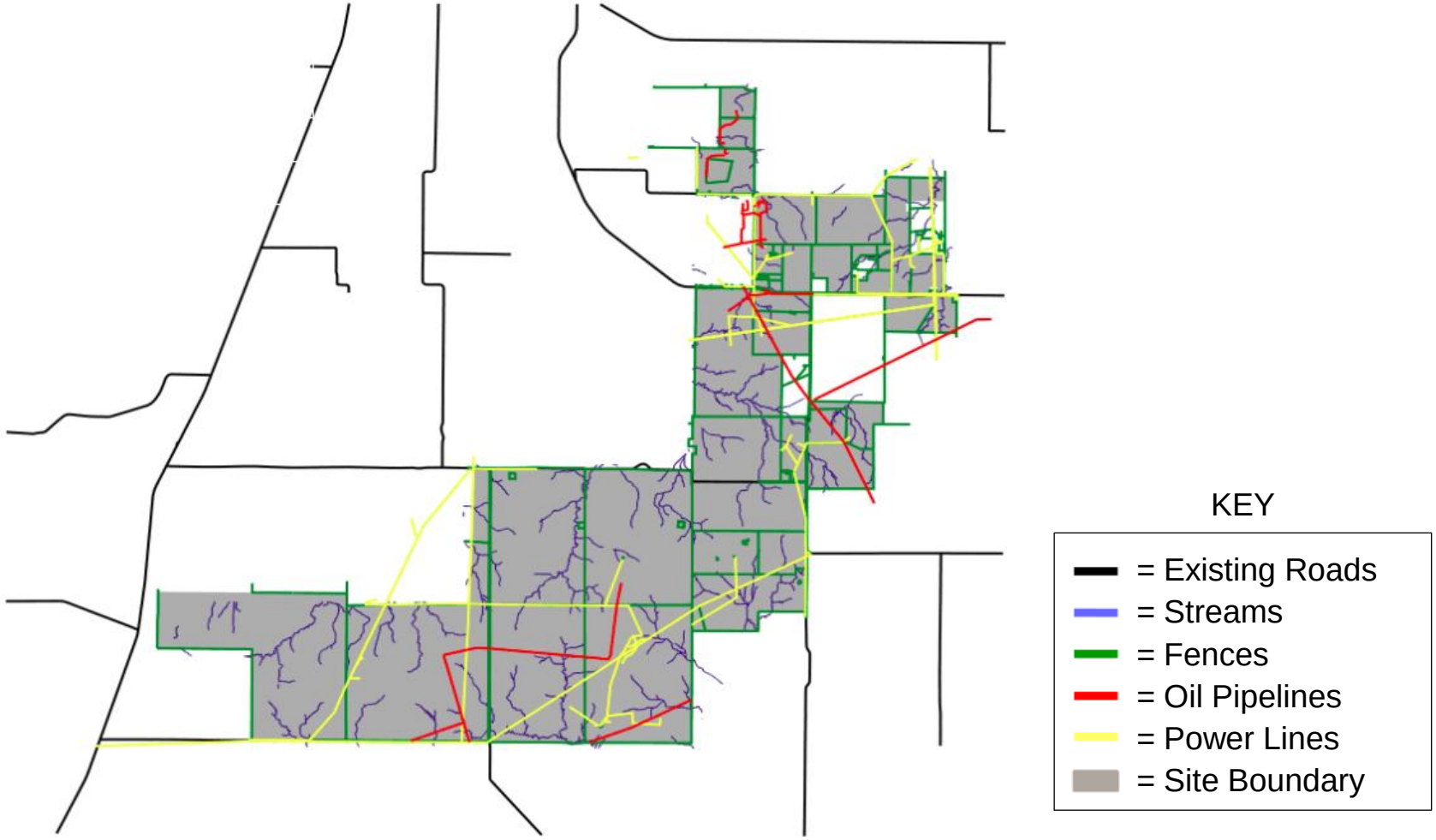
Case Study Overview

Name:	**Bobcat Bluff**	**Roosevelt**
Production Capacity:	150 MW	300 MW
Site Area (Acres):	14,000	62,000
Number Of Turbines:	100	150
Number Of Substations:	1	2

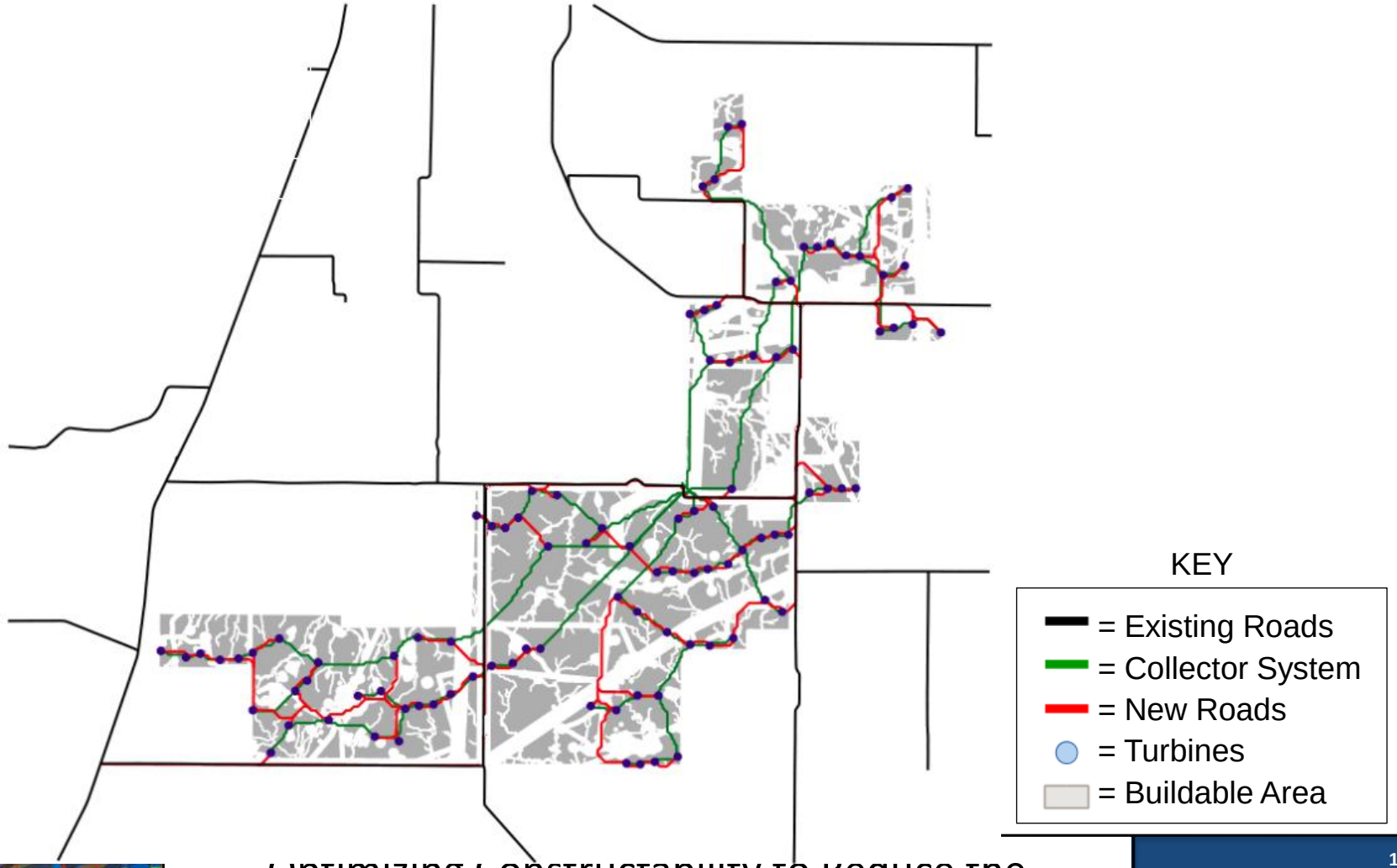
Bobcat Bluff: Site Conditions



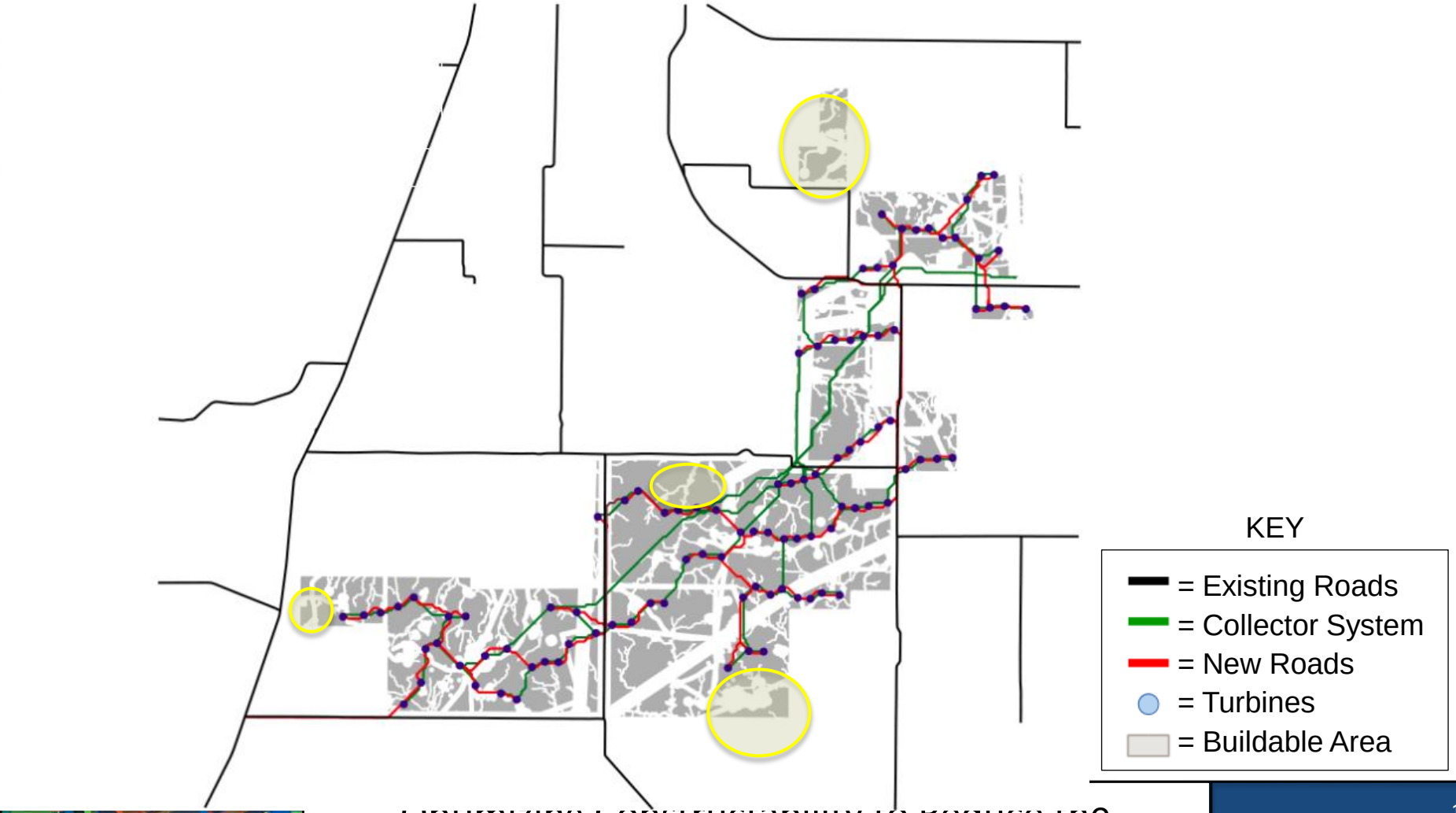
Bobcat Bluff: Site Conditions (cont.)



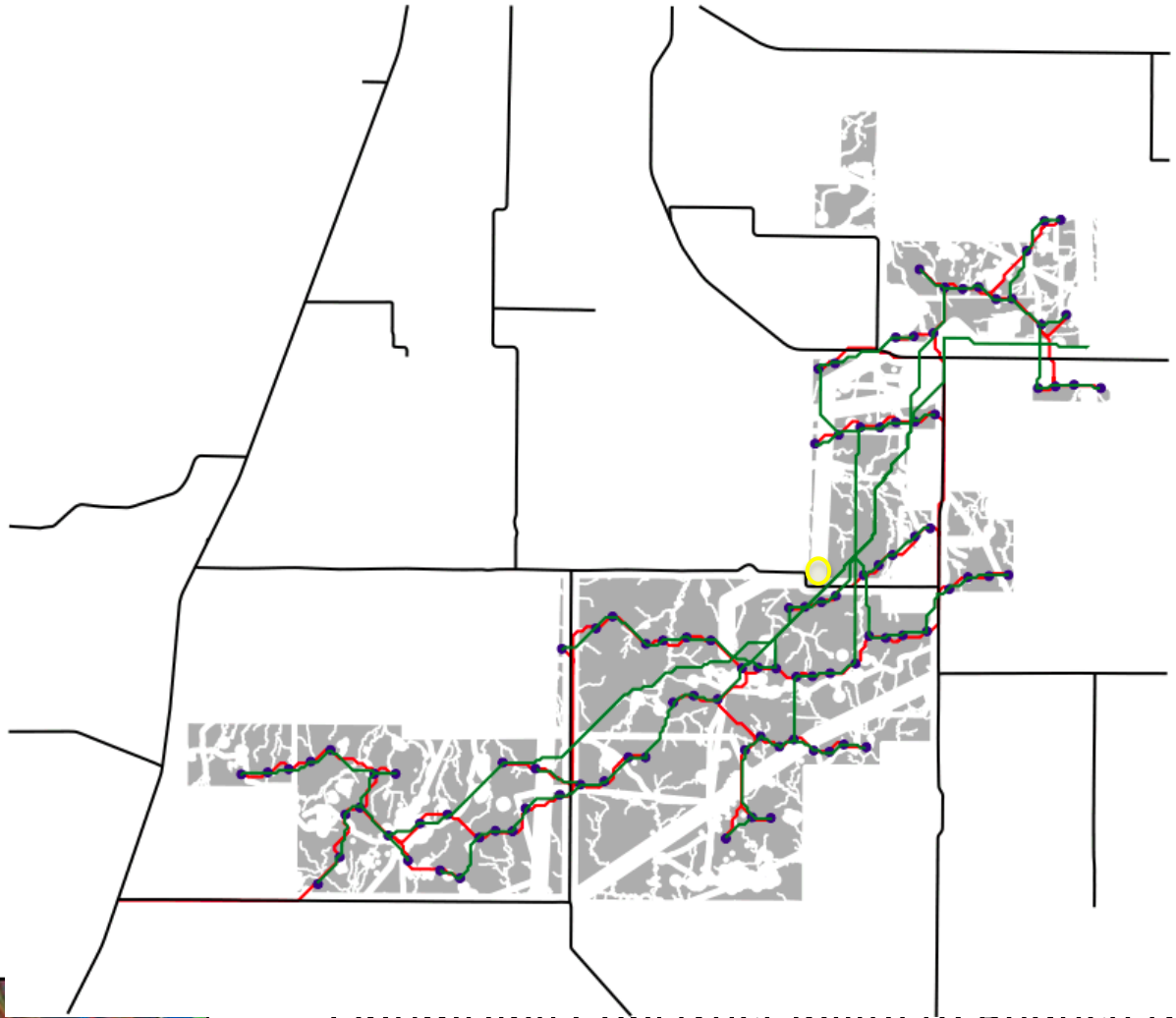
Bobcat Bluff: As Built

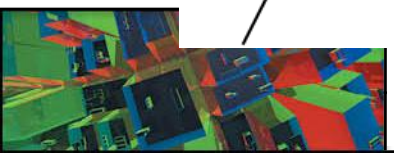


Bobcat Bluff: Optimized Turbines



Bobcat Bluff: Optimized Substation

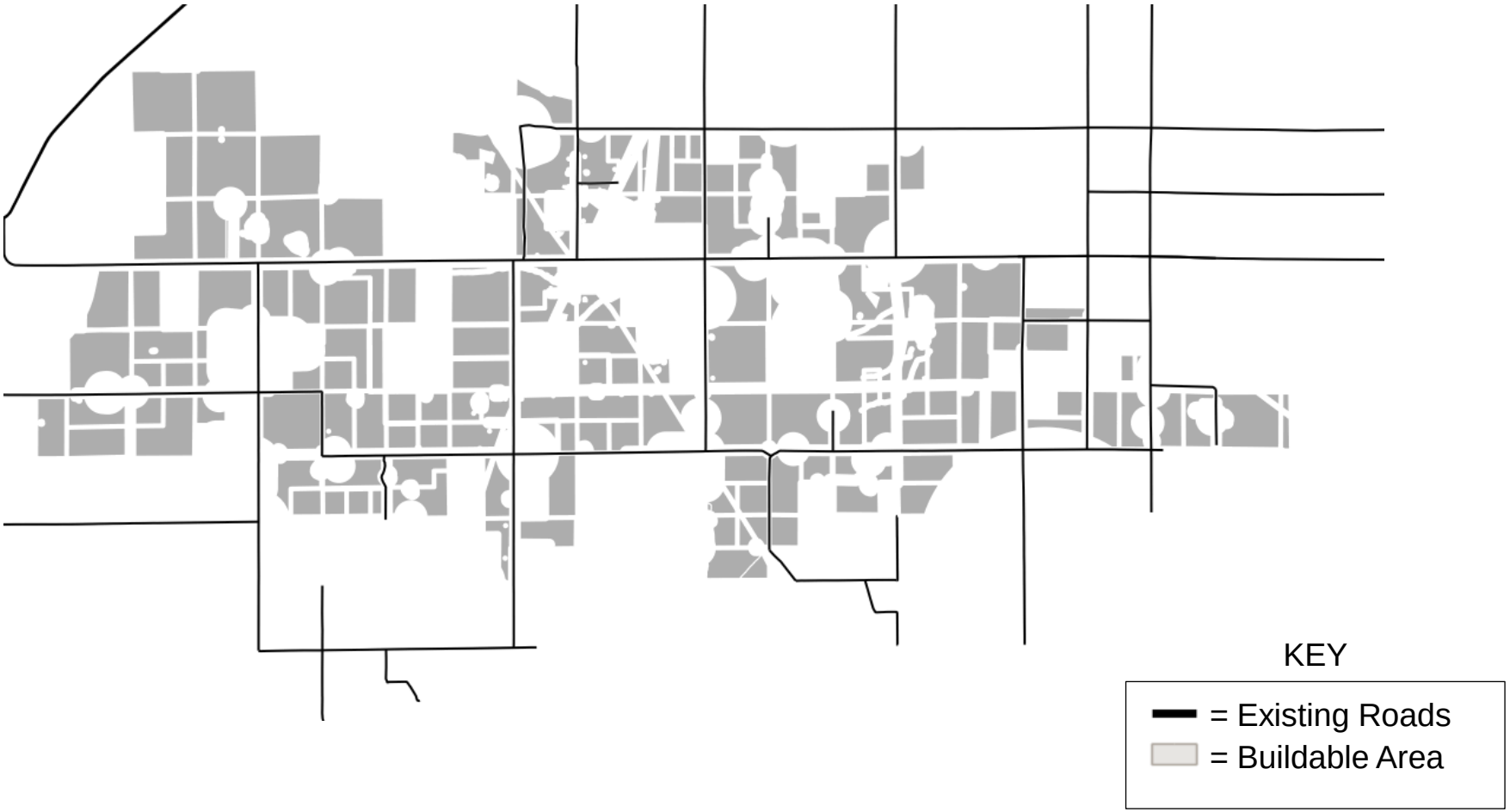




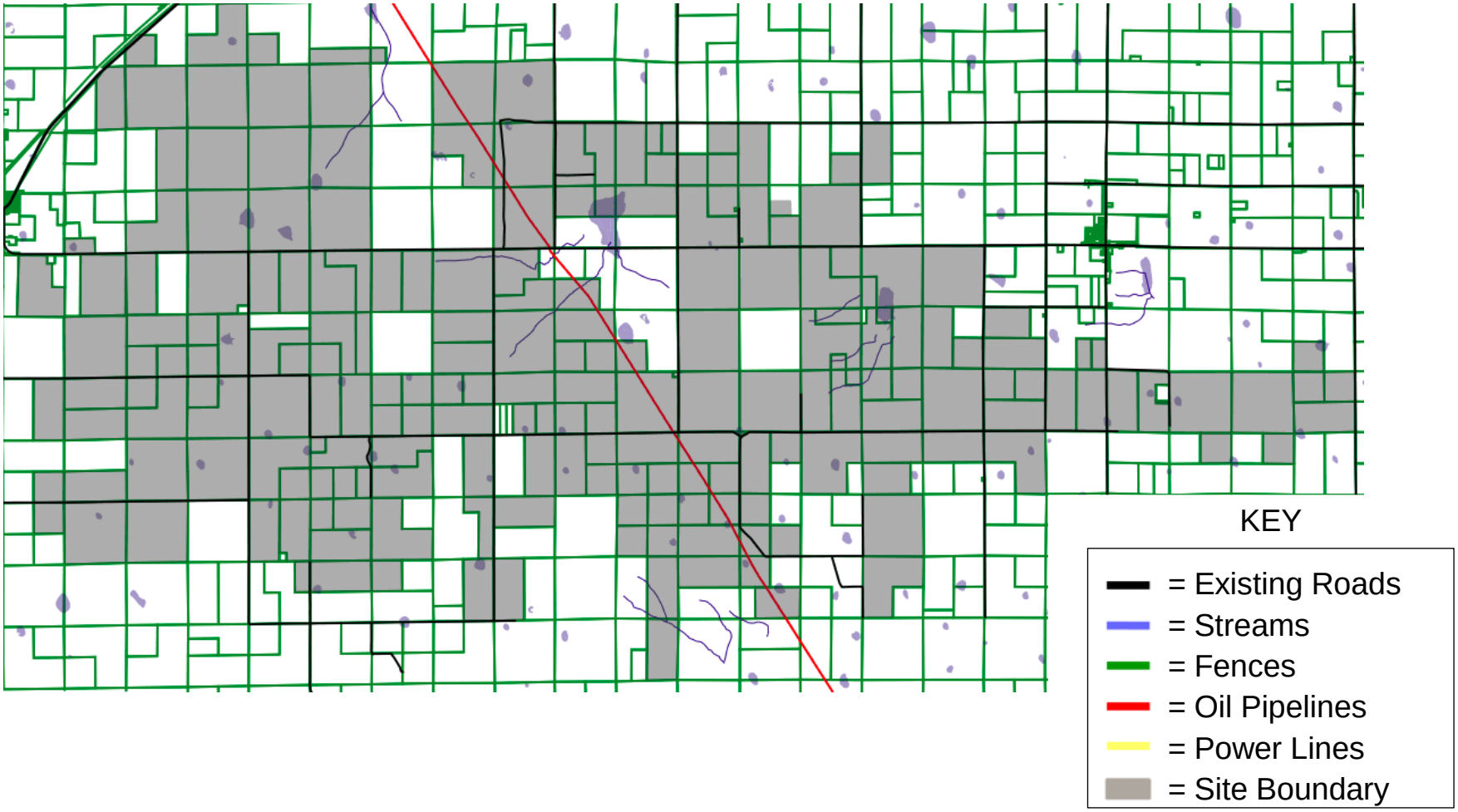
Bobcat Bluff: Results

Design Alternative	Construction Cost (M USD)	Net Energy (GWh)	Cost of Energy (USD / MWh)
As Built	**50.40**	**535.15**	**49.01**
Optimized Turbine Positions	**-3.54** (7.0%)	**533.37**	**-1.80** (3.7%)
Optimized Turbine + Substation Positions	**-3.82** (7.6%)	**533.45**	**-2.00** (4.1%)

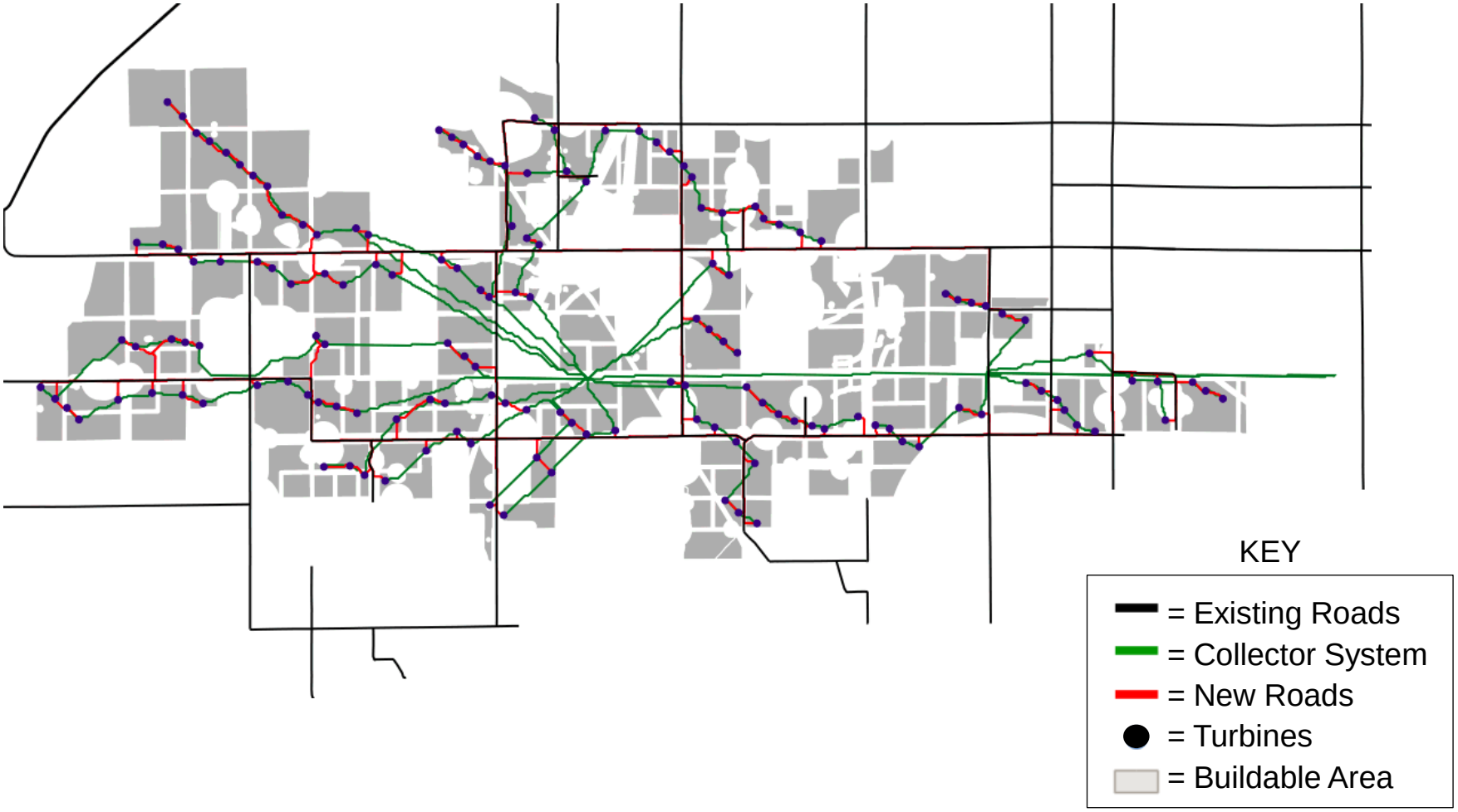
Roosevelt: Site Conditions



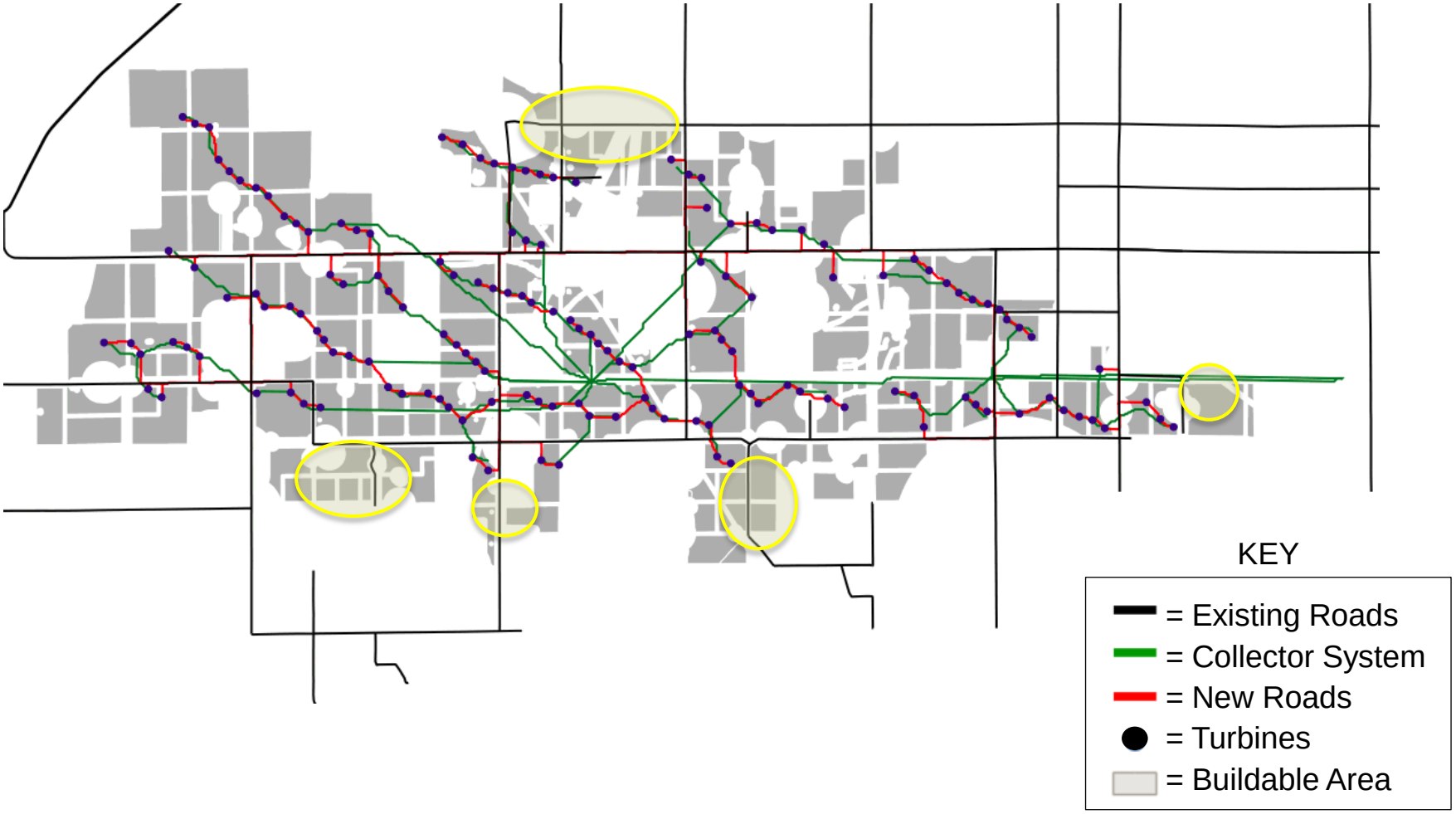
Roosevelt: Site Conditions (cont.)



Roosevelt: As Built



Roosevelt: Optimized Turbines



Roosevelt Results

Design Alternative	**Construction Cost** (M USD)	**Net Energy** (GWh)	**Cost of Energy** (USD / MWh)
As Built	**90.37**	**1450**	**36.28**
Optimized Turbine Positions	**-6.90** (8.2%)	**1448**	**-2.20** (6.4%)
Optimized Turbine + Substation Positions	-	**-**	-

Conclusions

- Significant savings in capital cost and reductions in cost of energy can be achieved by considering project constructability early in the design process

- Success of method is dependent on:
  - Early contractor involvement
  - Willingness to share data across project teams

Current and Future Work

Analysis:

- More accurate modeling of:
  - O&M costs
  - PPA pricing
  - Land lease costs
  - Electrical losses
- Better understand impact of grid size

Optimization:

- Turbine type, number and hub height
- Crane travel path

Acknowledgements

- Todd Bell
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