NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Sustainability, Feasibility, and Economics of a Fuel Cell-Powered Data Center

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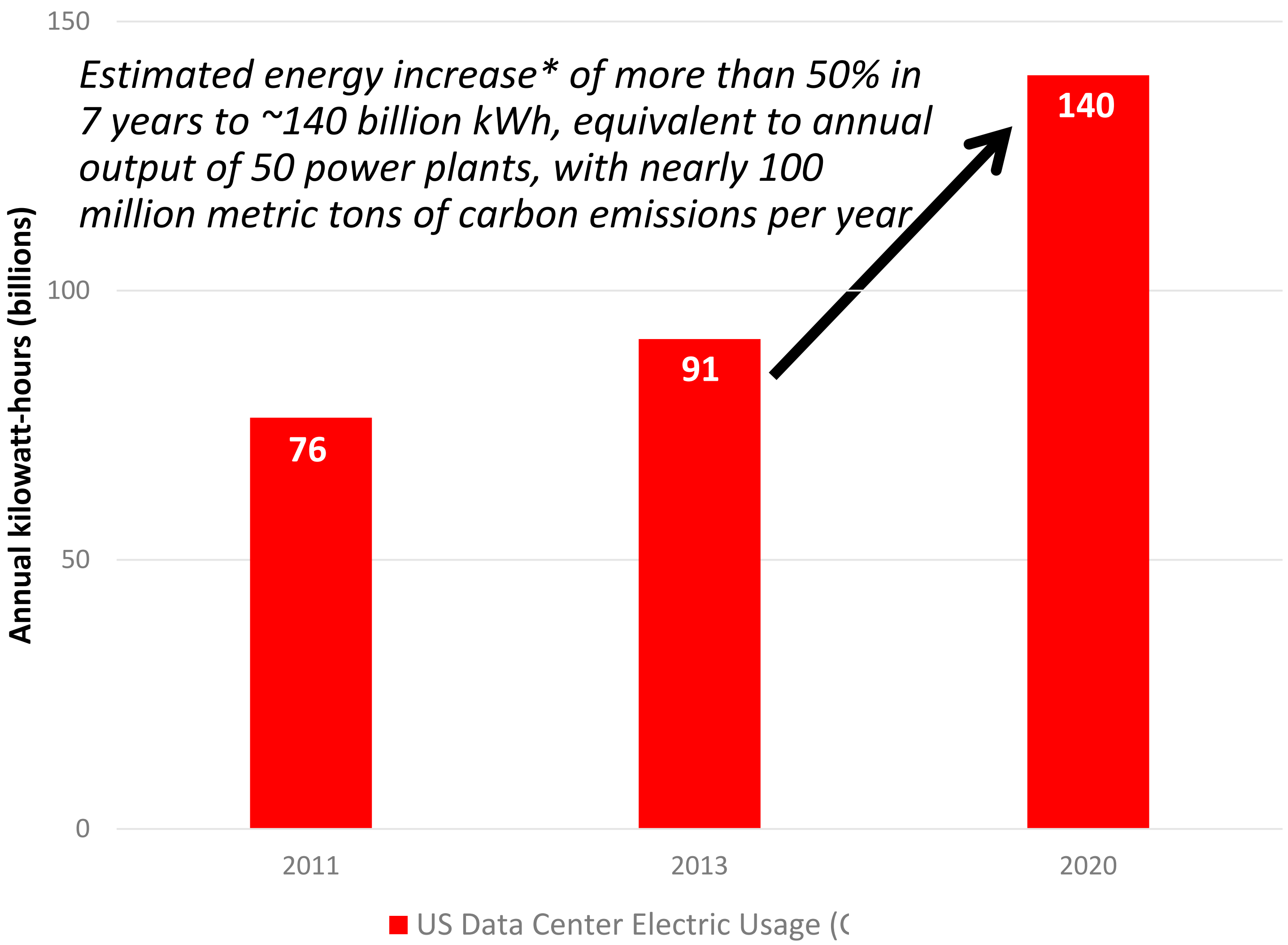
Data Center Energy Challenge –
High costs in power infrastructure, inefficiencies, and backup power required



* http://www.nrdc.org/energy/data-center-efficiency-assessment.asp

Carbon-Free Data Center Vision & Possible Future Energy Infrastructure – Rethink power delivery and distribution to and within data centers

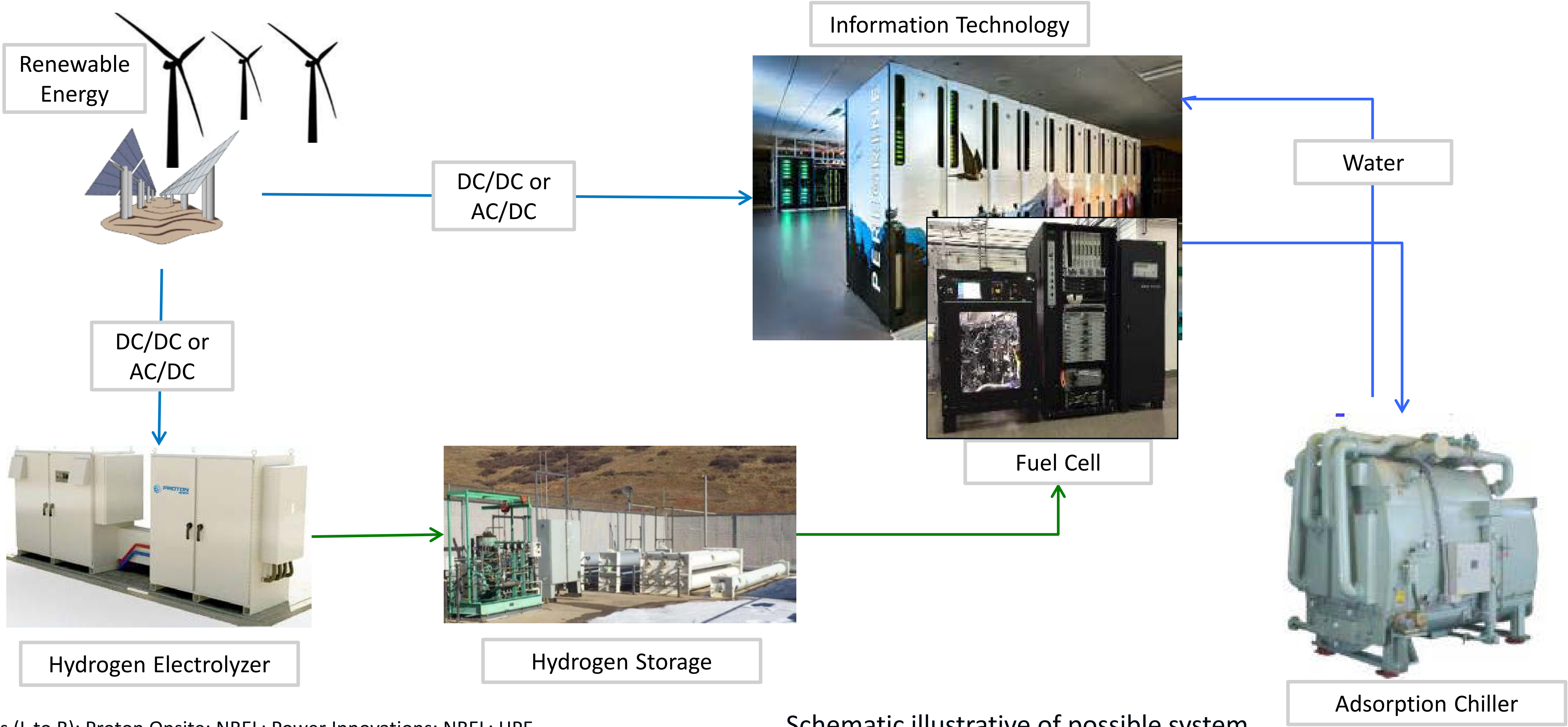
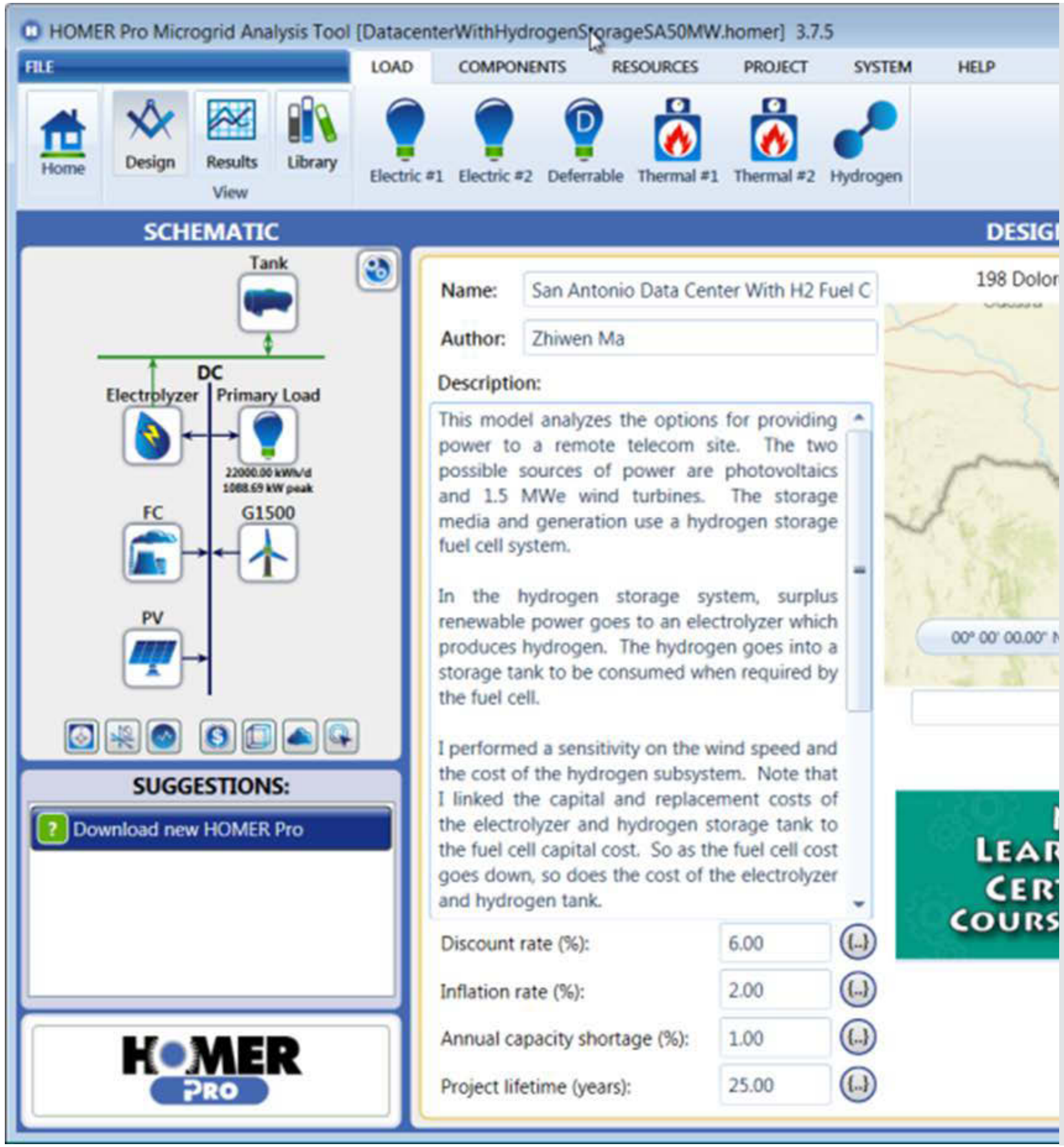


Photo credits (L to R): Proton Onsite; NREL; Power Innovations; NREL; HPE

Schematic illustrative of possible system

Modeling Objectives and Methods



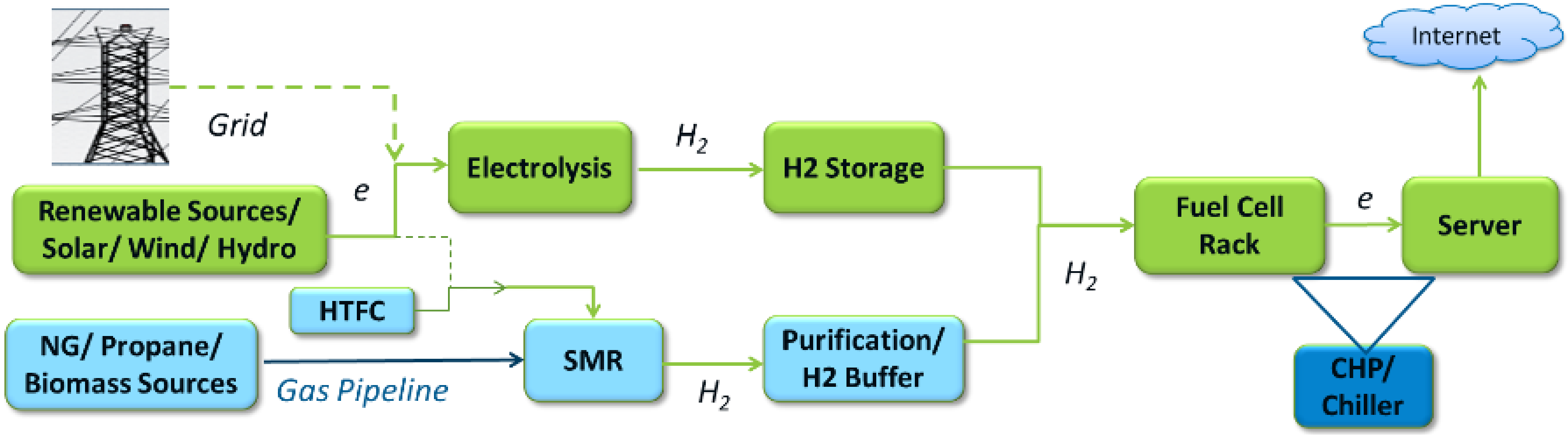
Utilize hydrogen as energy storage to integrate renewable solar and wind resources for a data center

- Model Scope: The hydrogen generation , storage, and consumption equipment will be defined in a conceptual block diagram. These components and subsystems will be included in a **HOMER** model to:
  - create equipment sizing (quantity and footprint)
  - annual renewable generation profile (based on Quincy, WA and San Antonio, TX locations)
  - annual renewable hydrogen generation profile
  - annual hydrogen demand profile
  - equipment cost estimates (based on current technology status, which are undersized for this full scale rollout)
- Model Results
  - Verified required capacity, load, and hydrogen storage.
  - Generated electricity and hydrogen generation profile.
  - Sized equipment.
  - Estimated electric and capital cost.

Partner Scenarios - System Modeling (in progress)

Scenarios	Sizing	Economics

• Two Suggested Locations
• Energy Sources
  • 100% renewable (PV and wind)
  • Natural gas to hydrogen
  • Grid independent and grid dependent
	• Renewable generation name plate
	• Renewable generation output estimate
	• Electrolysis name plate
	• Hydrogen production estimate
	• Hydrogen storage
	• Equipment footprint
	• 50 MW 24/7 demand
		• Renewable generation and hydrogen infrastructure
		• Data center total cost of ownership
		• Capital costs
		• Operation and maintenance costs
		• Cost estimates include current and projected

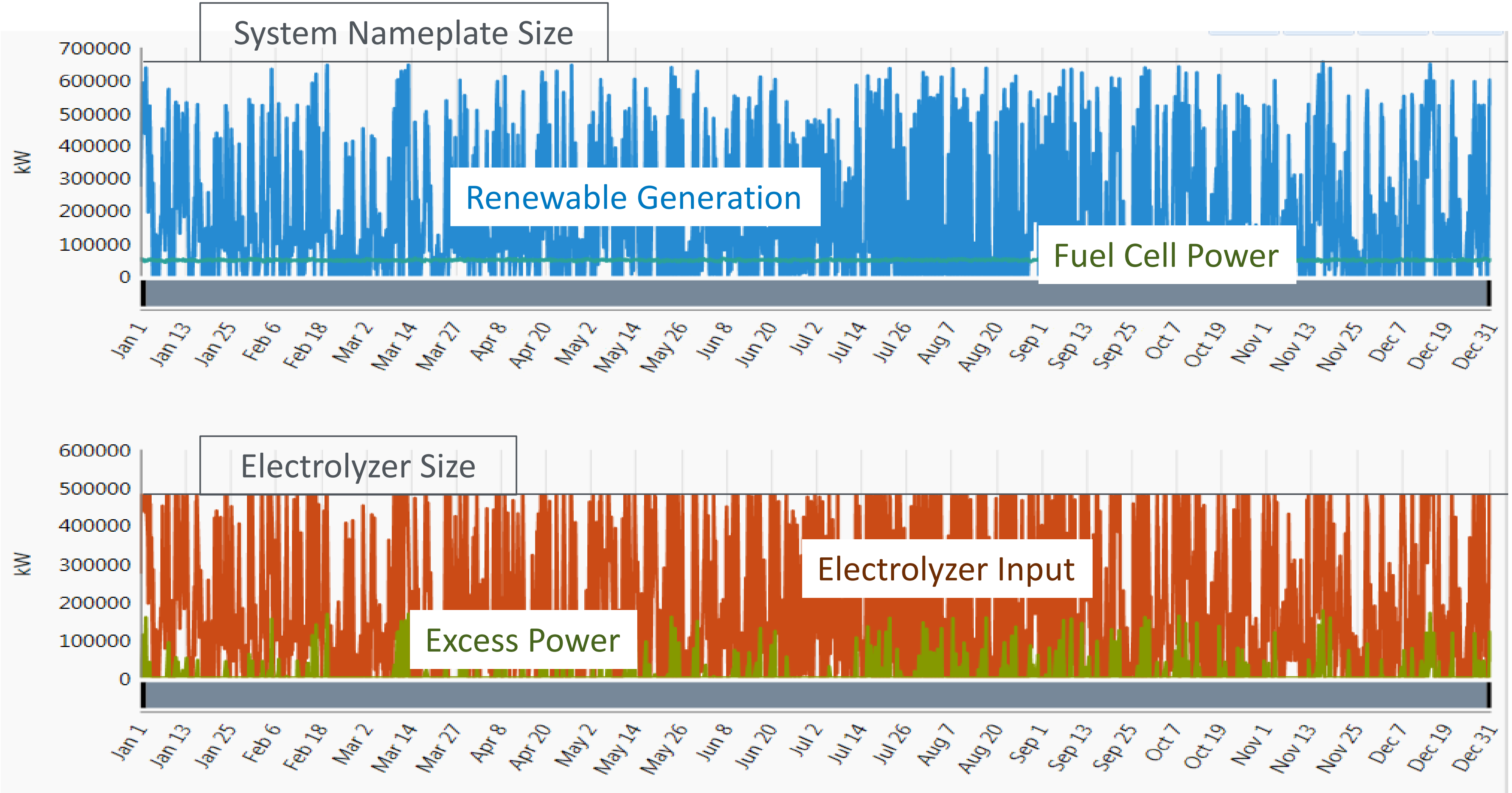


Component Cost Estimates

DRAFT

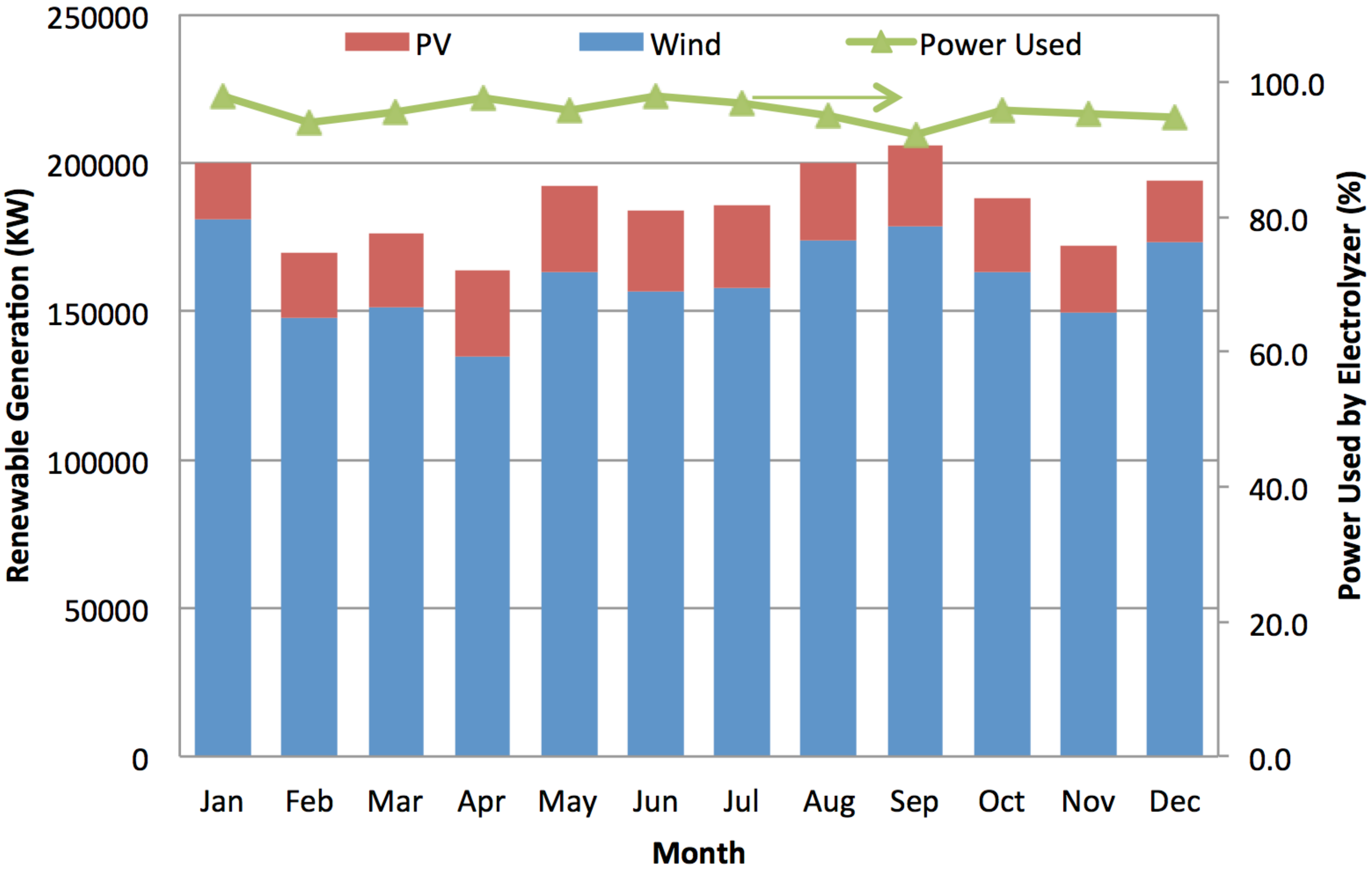
Installed Components	Current Cost (2016)	Projected Cost (2030?)	Reference Source
Wind ($/kW)	1,397	1,200	NREL report TP53045
Solar ($/kW)	1,500	1,000	GTM Research and DOE SunShot
Fuel cell ($/kW)	300 (eff. 50%)	50 (eff. 50%)	Industry and DOE Goal
Electrolyzer ($/kW)	1200 (eff. 65%, 25 yrs continuous)	800 (eff. 75%, 25 yrs)	NREL report TP53045 and internal discussion
Storage ($/kg)	500 (10 yrs)	7 (20 yrs) Cavern	Refer to DOE MYRDD and TP53045

Annual Renewable Generation, Fuel Cell, Electrolyzer and Excess Power Estimate Scenario 1 Quincy WA



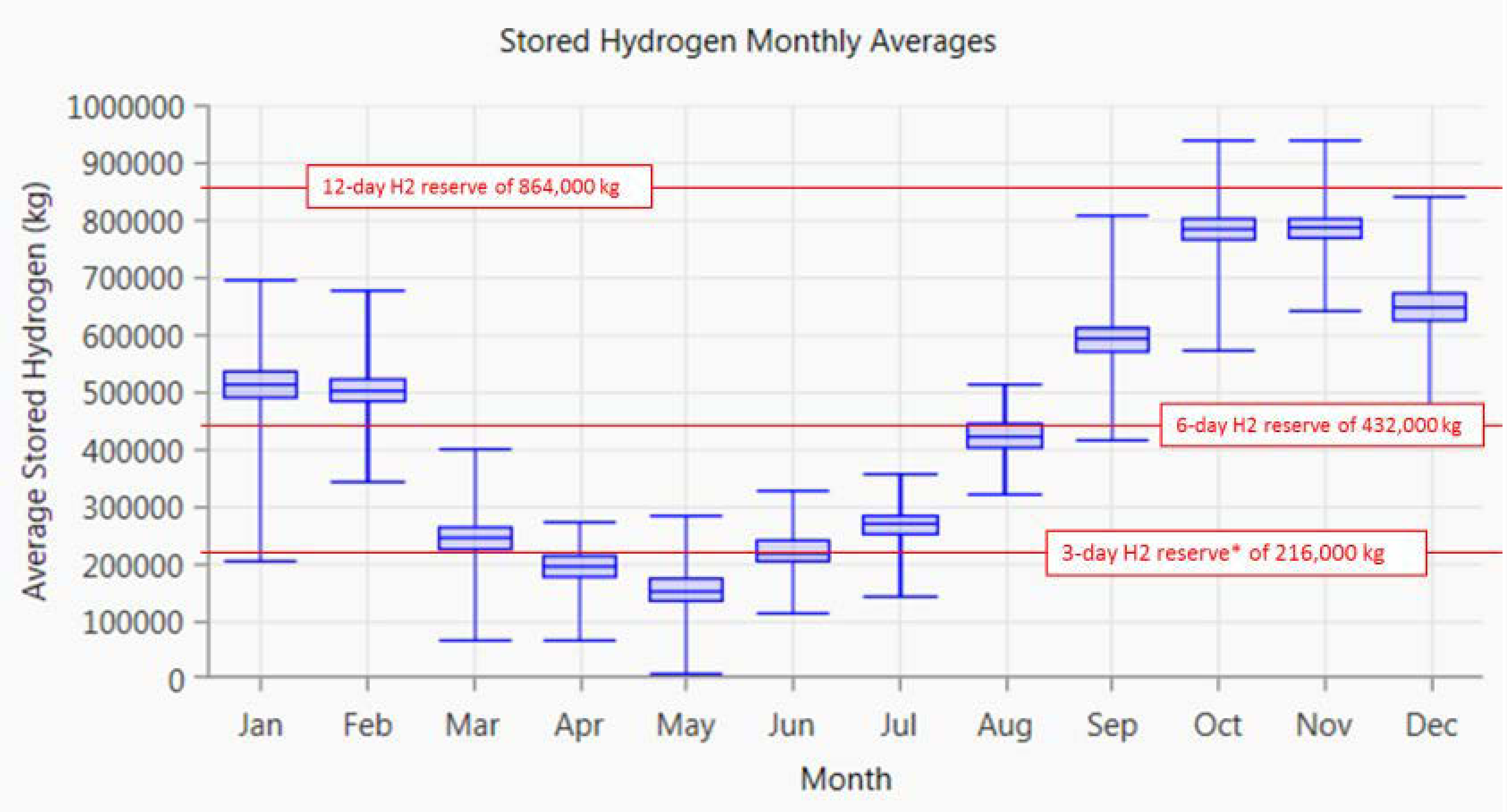
- Generation does peak at nameplate capacity
- FC Power constant for Data Center demand
- Electrolyzer size limited to 480 MW, which results in small amounts of excess renewable generation (< #%)

Renewable Hydrogen Production Modeling



- ~33% renewable generation capacity factor (location specific)
- Electrolyzer follows variable renewable generation
- Nameplate size to ensure sufficient storage during low or no renewable generation
- Example – 100% renewable, WA location has 635 MW generation (525 MW is wind) and 250 MW of electrolysis
- Smaller systems for other intermediate scenarios

Renewable Hydrogen Storage Modeling (Quincy, WA site)

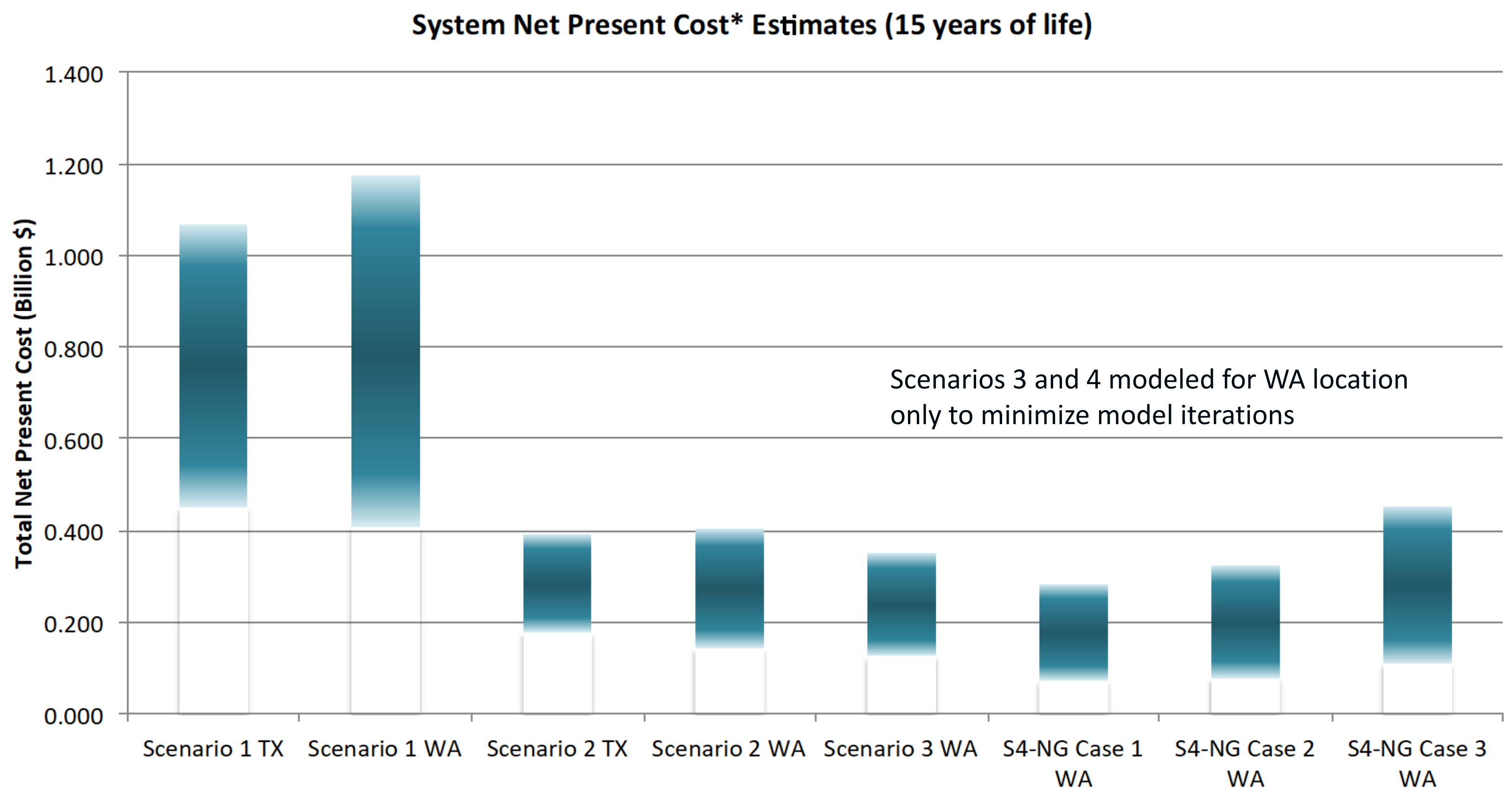


- Hydrogen storage for minimum 3 day reserve (216,000 kg)
- 50 MW, 24/7 demand = 72,000 kg H_2/day (~50% efficient fuel cell)
- Some months hydrogen production is less than demand (e.g., February to April in WA)
- System footprint and hydrogen storage is largest for 100% renewable scenarios (e.g., ~650 acres in WA)

Multiple System Scenarios Modeled

		Facility power to racks?	24/7/365 operation of FCs?
Scenario 1	Wind/PV to H2 to powering IT	No	Yes
Scenario 2	Wind/PV to H2 to powering IT Wind/PV to directly powering IT	Yes	No
Scenario 3	Wind/PV to H2 to powering IT Wind/PV to directly powering IT Grid power	Yes	No
Scenario 4, Case 1	Natural gas with SMR to H2 Grid power	No	Yes
Scenario 4, Case 2	Natural gas with SMR to H2 High temp FC for power	No	Yes
Scenario 4, Case 3	Natural gas with SMR to H2 High temp FC for power Wind/PV to H2 to powering IT	No	Yes

System Economic Estimates (excludes data center costs)



- *High estimates based on current costs and low estimates based on projected costs
- Lower capital cost does not necessarily result in lower total cost of ownership

Modeled scenarios

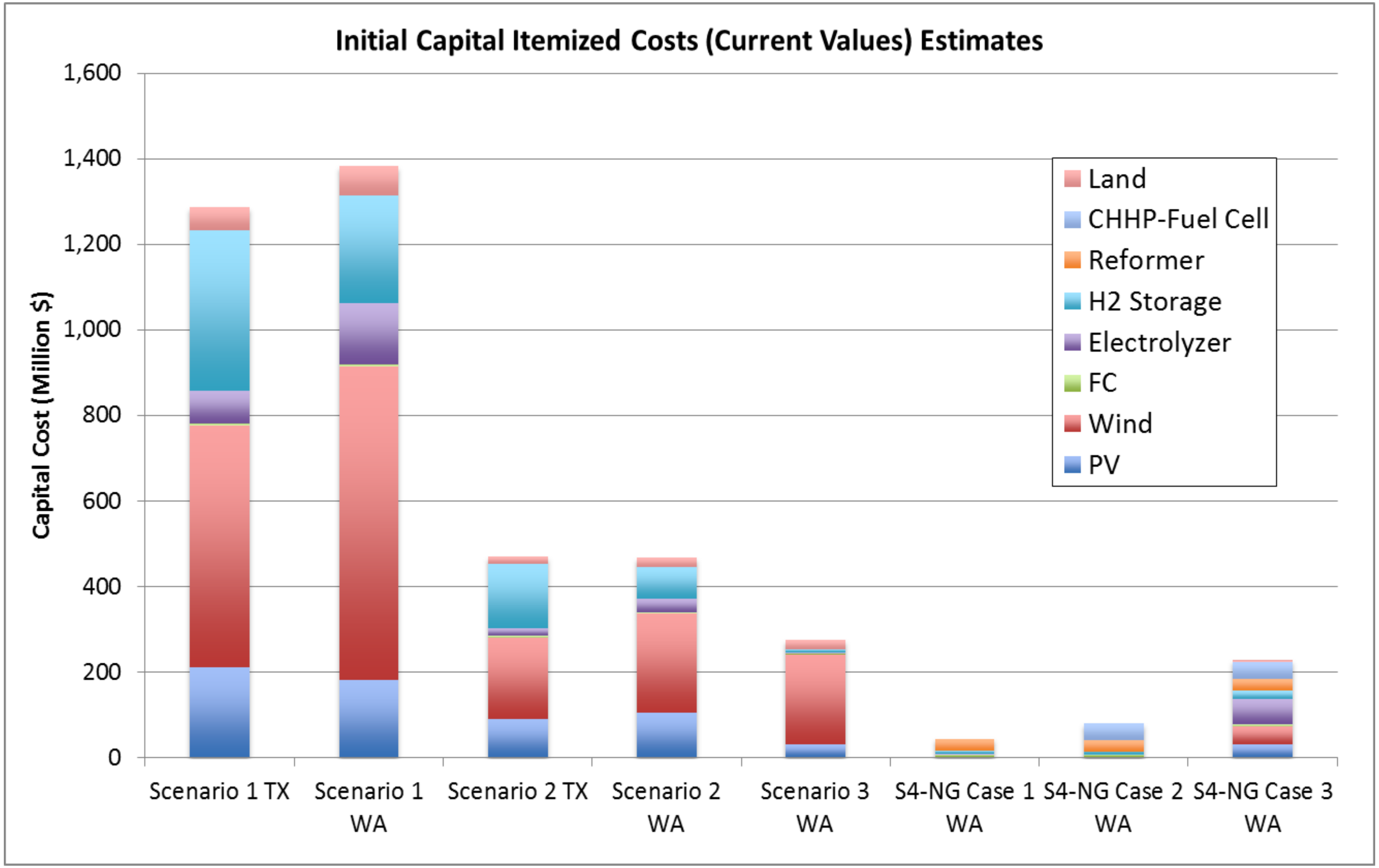
Scenario 1: Grid-independent, renewable generation to hydrogen directly to fuel cell power in server racks.

Scenario 2: Grid-independent, renewable generation to hydrogen production to fuel cell power and to supply power to servers in rack.

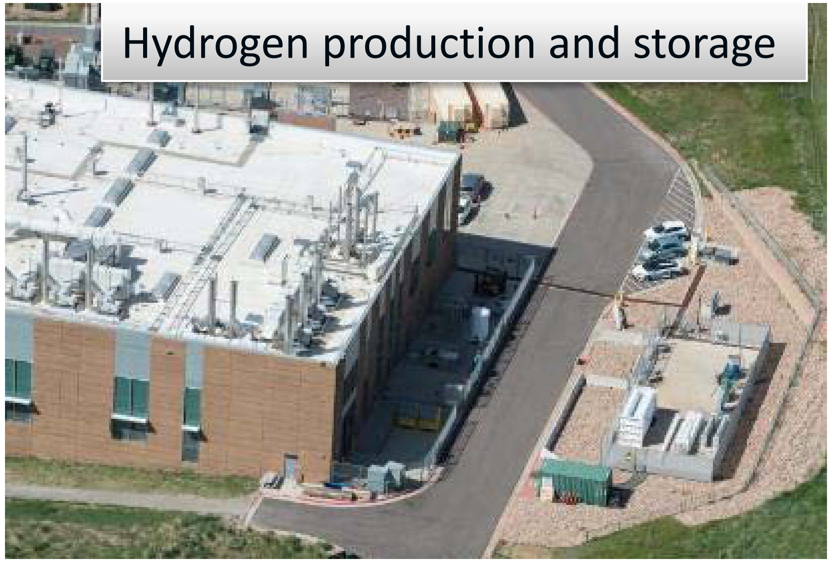
Scenario 3: Grid-tied, renewable and fuel cell power supply.

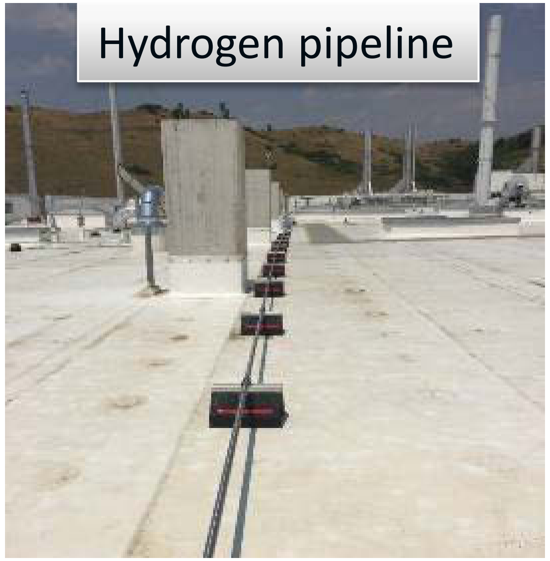
Scenario 4: Three cases: Reforming natural gas hybrid with grid and renewable to produce hydrogen to supply fuel cells to power server racks.

Modeling – Economic Results Summary



Hardware Proof-of-Concept at NREL





Proof-of-concept of the integrated system for verification of safe operation in data center

- A collaboration among industry and national lab to demonstrate the fuel cell power supply and electric control system.
- Integrated fuel-cell IT rack at NREL's Energy Systems Integration Lab; completing safe operation verification

Photos from NREL (top row) and Power Innovations (bottom)

Summary

Holistic System Vision

- Conceptual models for size, performance, and economic estimates
- Economically viable near-term option includes natural gas
- Lowest up-front costs may not be lowest total cost of ownership options

Product Acceleration

- Verify proof-of-concept in a functional data center
- Identify codes and standards for hydrogen fuel cells in data centers
- Automotive fuel cell in a new application => increase quantity and decrease cost
- Partners include product developers and end users

What's Next

- Identify systematic solutions for challenges
- Refine and define system
- Improve estimates
- Validate system and install at scale
- Develop code and standard complying data center.
- Synergize hydrogen infrastructure with fuel cell racks.

With the sustained drop of the cost for renewable power, long-term renewable hydrogen to supply fuel cells for powering a data center can realize both decarbonization and economic returns.

Questions?

Thank you

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