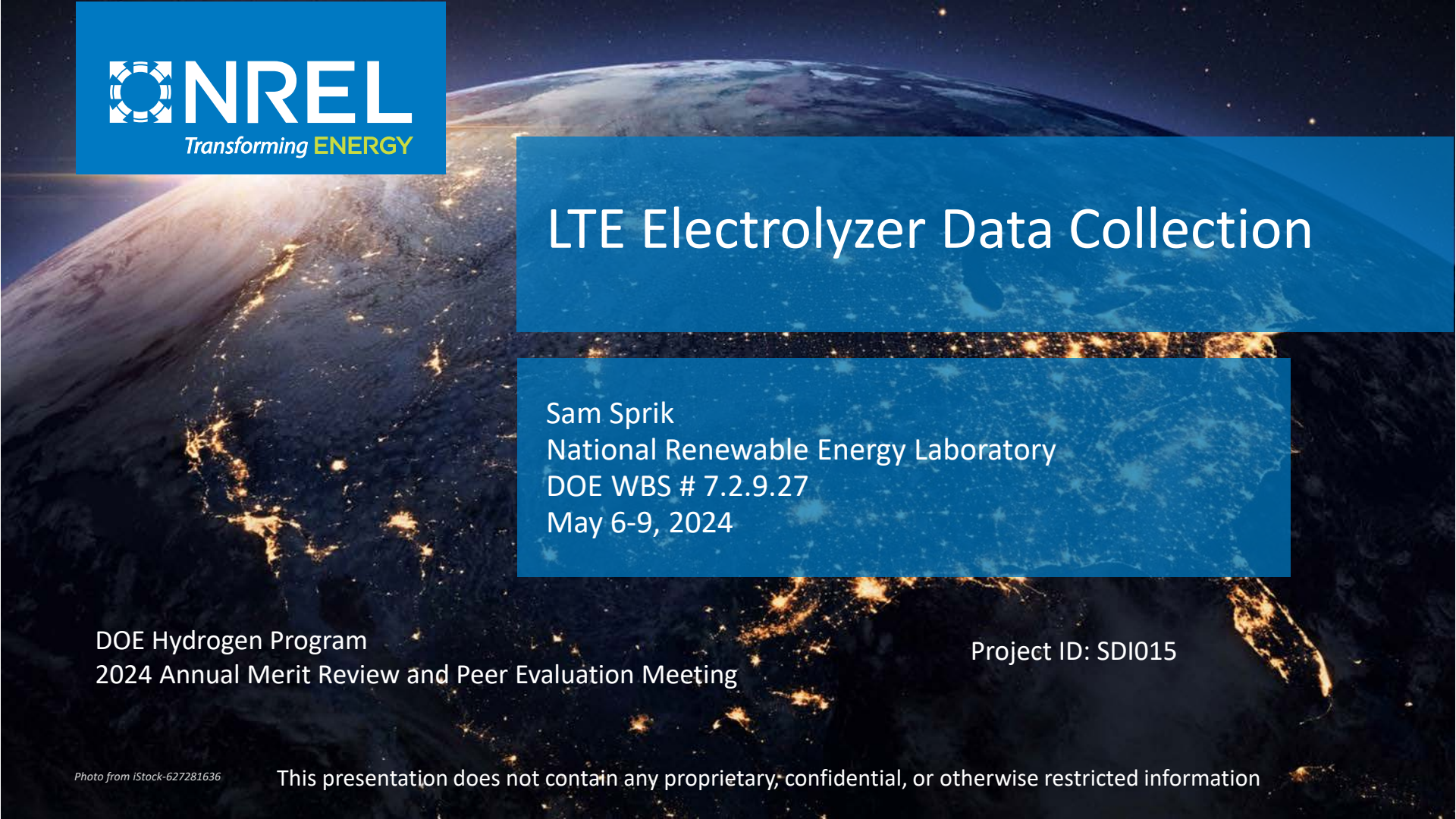


LTE Electrolyzer Data Collection

Sam Sprik
National Renewable Energy Laboratory
DOE WBS # 7.2.9.27
May 6-9, 2024

DOE Hydrogen Program
2024 Annual Merit Review and Peer Evaluation Meeting

Project ID: SDI015

Photo from iStock-627281636

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Project Goals

The goal for NREL is to collect, develop and publish performance metrics relative to low temperature electrolyzer installations. This will be done through the development of:

- Secure storage solution to house the collection of data from multiple projects
- Standardization of data to be collected and analyzed. This will be done using data templates developed with the help of partners involved with electrolyzer installations.
- Analysis that produces metrics of interest for all stakeholders
- Aggregation of results from multiple projects to view industry progress as a whole
- Publication of aggregated results in the form of composite data products (CDPs)

Collaboration with Idaho National Lab and their work with high temperature electrolyzer installations will enable efficient use of storage and analysis tools.

Overview

Timeline and Budget

- Project start date: 8/1/2023
- Project end date: 9/30/25*
- FY23 $15k
- FY24 Planned DOE Funding: $320k

*Project continuation and direction determined annually by DOE

Barriers

Lack of information on operation and evaluation of low temperature electrolyzer installations including:

- System performance
- Reliability/Maintenance/Operational requirements
- Installation costs

Partners

- Sam Sprik (PI) - National Renewable Energy Laboratory (**NREL**)
- Idaho National Laboratory (**INL)** – Separately funded for similar work with high temperature electrolyzer installations. We will work together to develop data tools and analysis methods that provide a unified approach to evaluation of current status of all electrolyzer installations

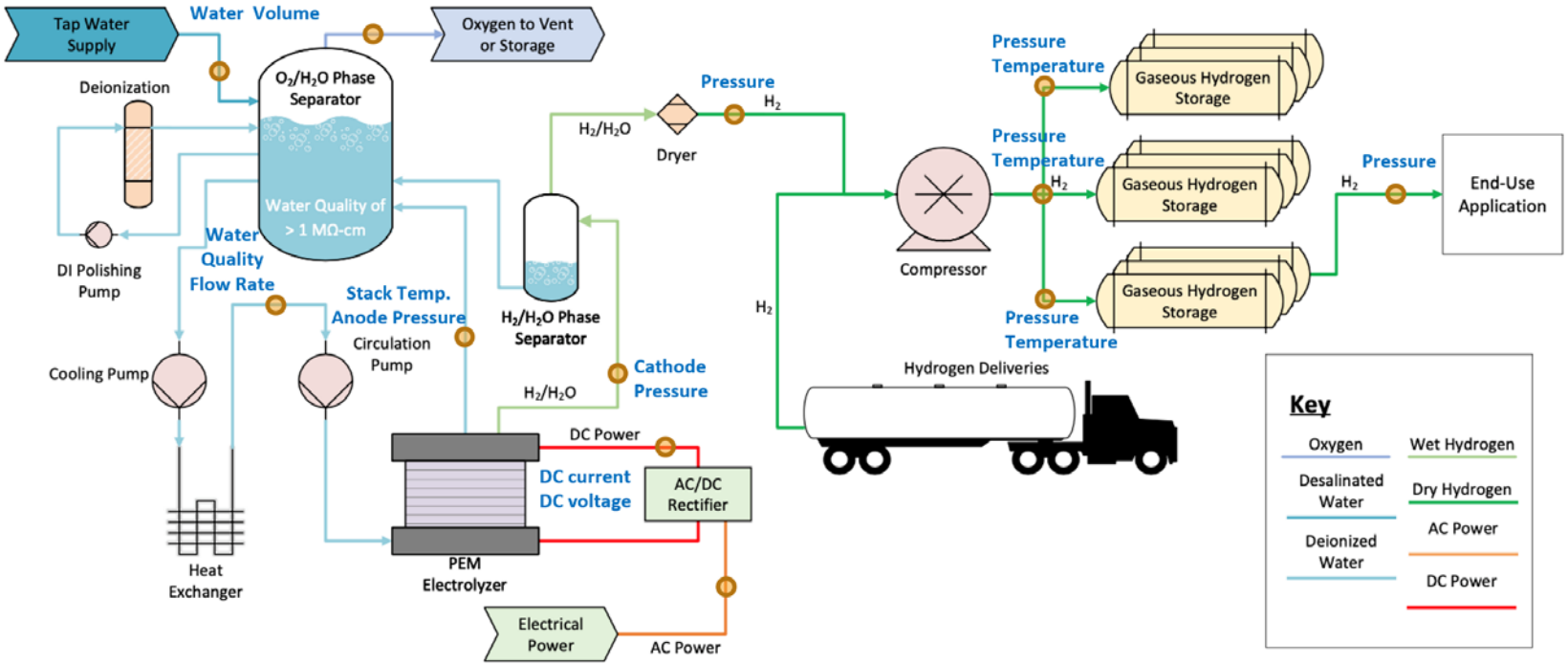
Relevance/Potential Impact

- This project will provide insights into the building of a clean hydrogen energy infrastructure by providing status of low temperature electrolyzer installations. It will guide stakeholders in decisions about deployments and research needs related to installation, operation and maintenance of systems based on how current systems are performing in the field.
- Hydrogen production from electrolysis is a potentially clean source of fuel with near zero greenhouse gas emissions and criteria pollutants when the electricity source is clean. The aggregated results from this project will inform stakeholders involved in building clean energy projects that produce good paying jobs in manufacturing, installation, maintenance and operation of these facilities.

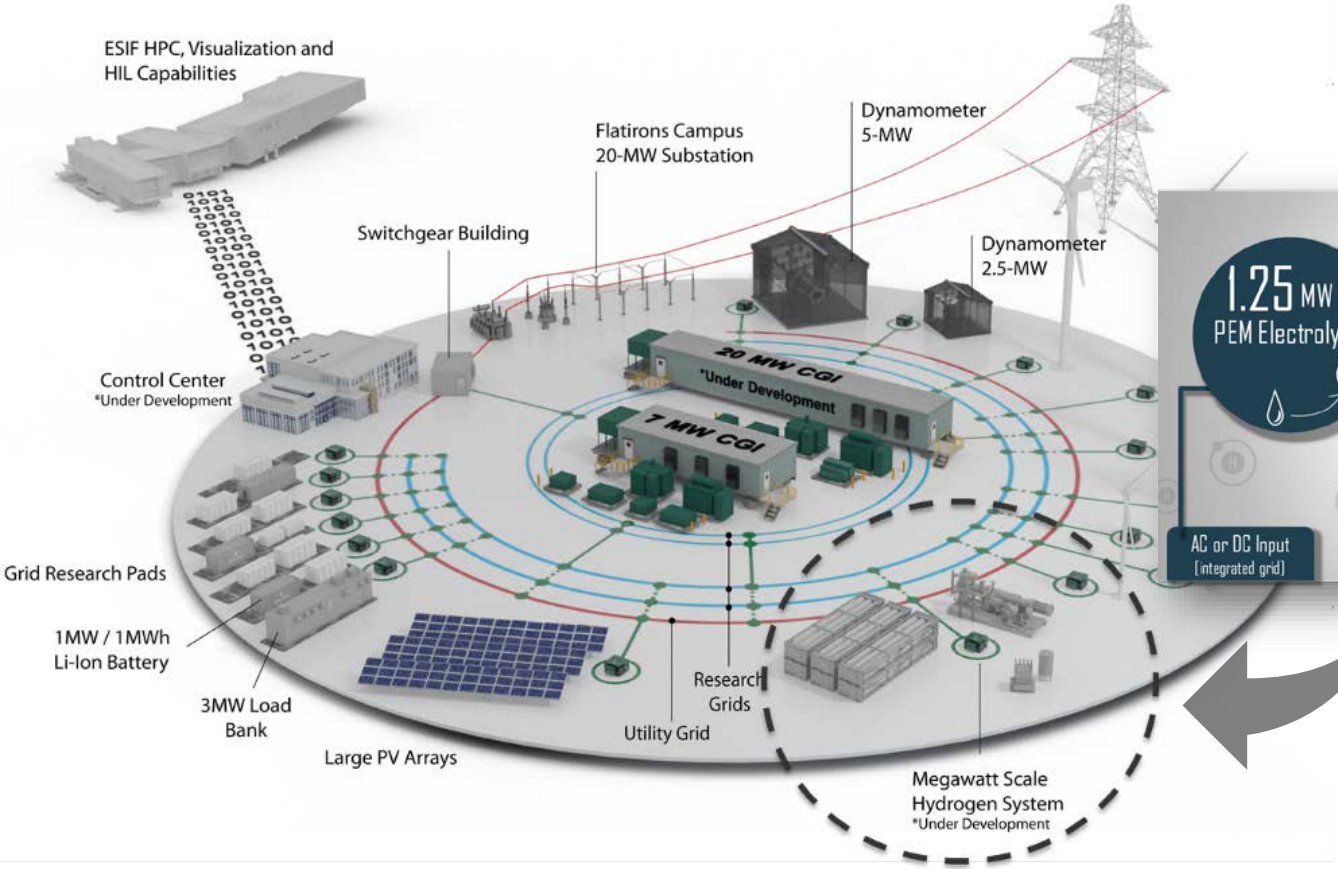
Approach: System Context of Electrolyzer

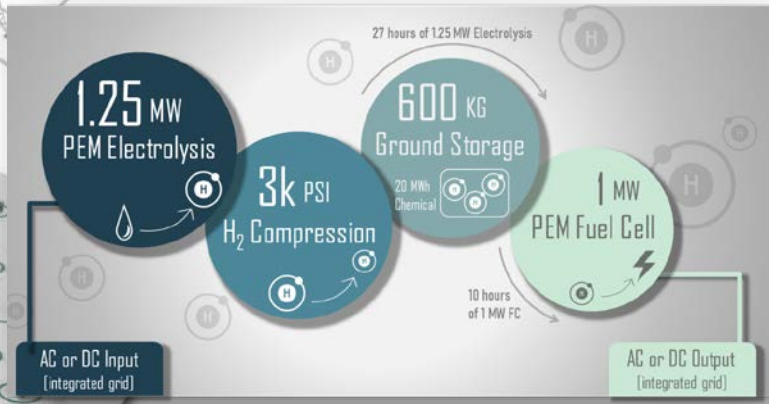
- Stack
- DI Water
- Dryer
- Heat exchangers
- Water pumps
- Monitor
- Controls
- Safety
- Power Converter

Approach: System Context of Electrolyzer

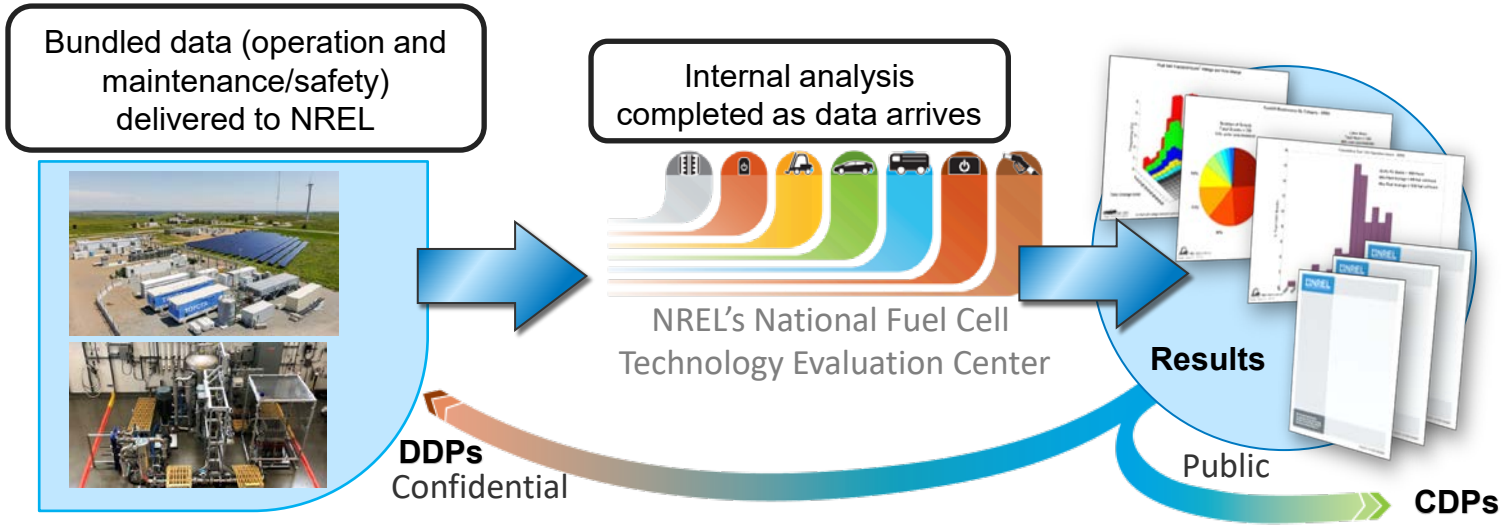


Approach: ARIES Flatirons Grid Equipment





Approach: NFCTEC Data/Analysis/Results Handling



Detailed Data Products (DDPs)
- Individual data analyses
- Identify individual contribution to CDPs
- Only shared with partner who supplied data

Composite Data Products (CDPs)
- Aggregated data across multiple systems, sites, and teams
- Publish analysis results without revealing proprietary data[1]

1. Results published via NREL Tech Val website, conferences, and reports

Approach: Data, Storage, Analysis, Publication

Project Approach

In collaboration with partners who install and operate systems, and with INL on the high temperature electrolysis side, NREL will collect, develop and publish performance metrics relative to low temperature electrolyzer installations. This will be done through the development of a secure storage solution to house the collection of data, standardization of data inputs to be collected from the projects, analysis that produces metrics of interest, aggregation of results from multiple projects, and publication of those aggregated results in the from of composite data products (CDPs).

Approach: Storage Planning - Roles

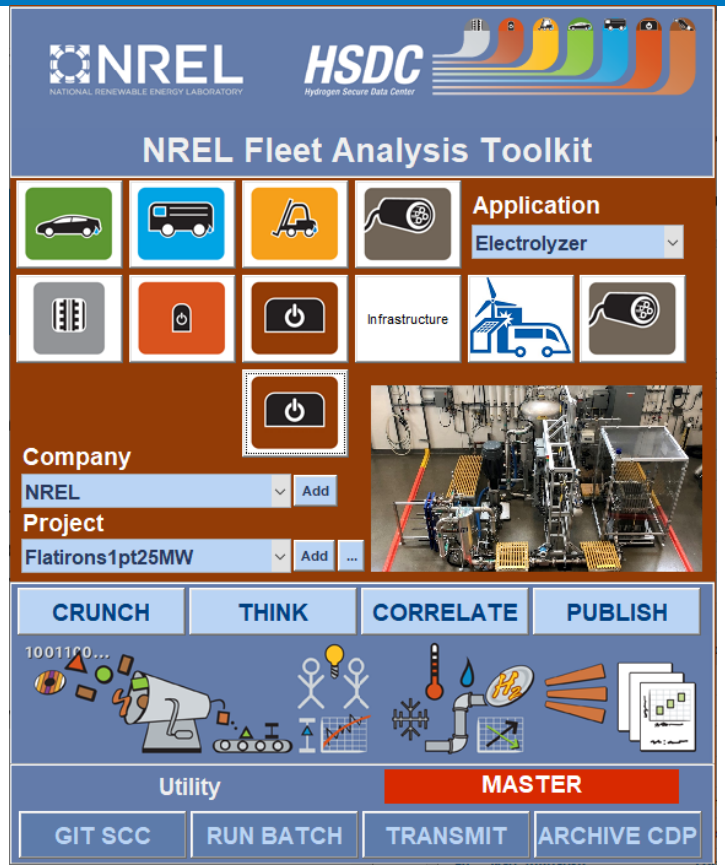
Planning for storage and roles

- Partners – authenticated users
  - Upload data to their private space
  - View analysis on their data
  - View aggregated results with their data overlayed
- Super User (NREL)
  - Sees all partner data, runs analysis and stores results, makes draft aggregated results for all to review.
- Aggregated Results Review (DOE and Partners)
  - Sees draft aggregated results before published
- Public Viewers
  - Final approved results posted for all to see; authentication required?

Approach: HERO

- NFCTEC data capabilities uses a prototype system of common web services, designed at NREL, called Hybrid Environment Resources and Operations (HERO).
- Core services include
  - Auth, to provide authentication and authorization,
  - a Data Repository to store and organize public and private data,
  - a Task Engine, for defining distributed and hybrid compute,
  - and Search to quickly find resources using metadata.
- Resources and operations across these core services are secured with OAuth 2.0 and multi factor authentication (MFA), and further protected with fine grained access control.
- HERO follows an API first approach and is complete with front end web applications for ease of use. Front end web applications are designed as micro front ends (MFE) which are easy to maintain and can be reused with minimal custom coding on other applications.
- HERO is built on Amazon Web Services (AWS) and relies on the Well-Architected Framework to create secure, reliable, efficient, and cost-effective web applications.

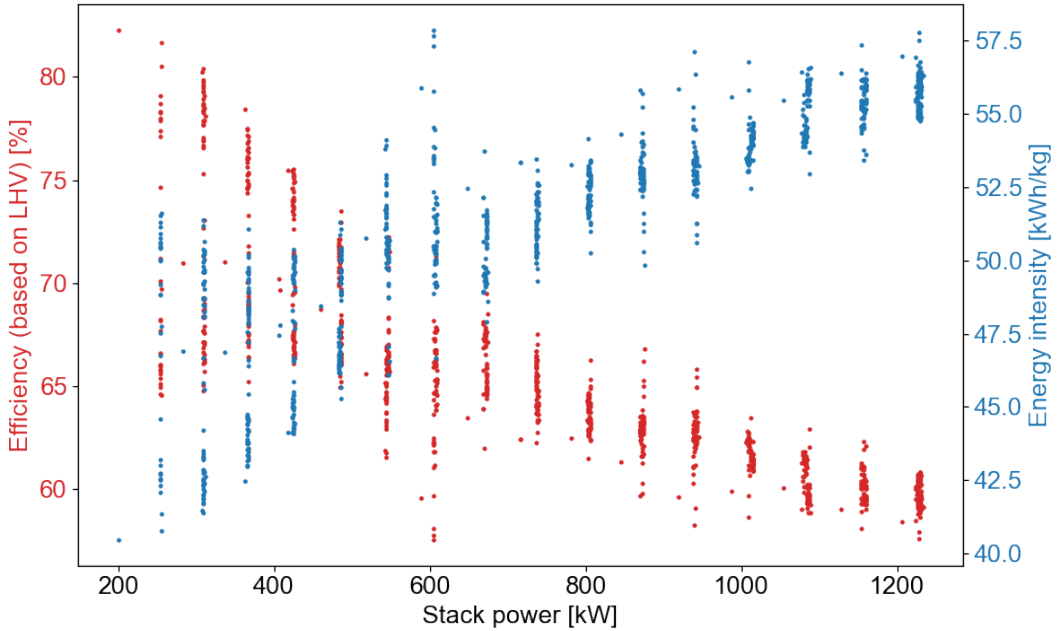
Approach: Update Tools

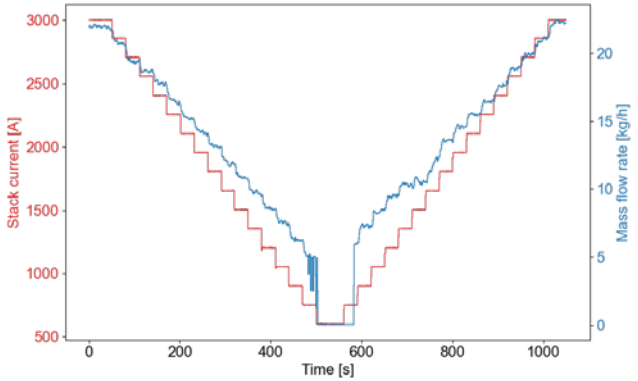


- Use existing tools at NREL that can process multiple batches of data for many different applications.
- Built in Matlab, functions are easily copied/edited/updated to handle the latest application data.
- Many analysis already built up for handling maintenance data, performance, degradation and cost data.

Accomplishments and Progress: Preliminary Electrolyzer System Data

- System at NREL being used for multiple research projects.
- Data from mass flow meter data used to calculate efficiency.
- This shows data from sensors fluctuate and providing one number for efficiency of a stack does not capture the full operating range.





Stats	Efficiency (based on LHV) [%]	Energy intensity [kWh/kg]
Mean	65.2	51.4
Min	57.5	40.5
Median	64.2	51.9
Max	82.3	57.9
Std	5.0	3.7

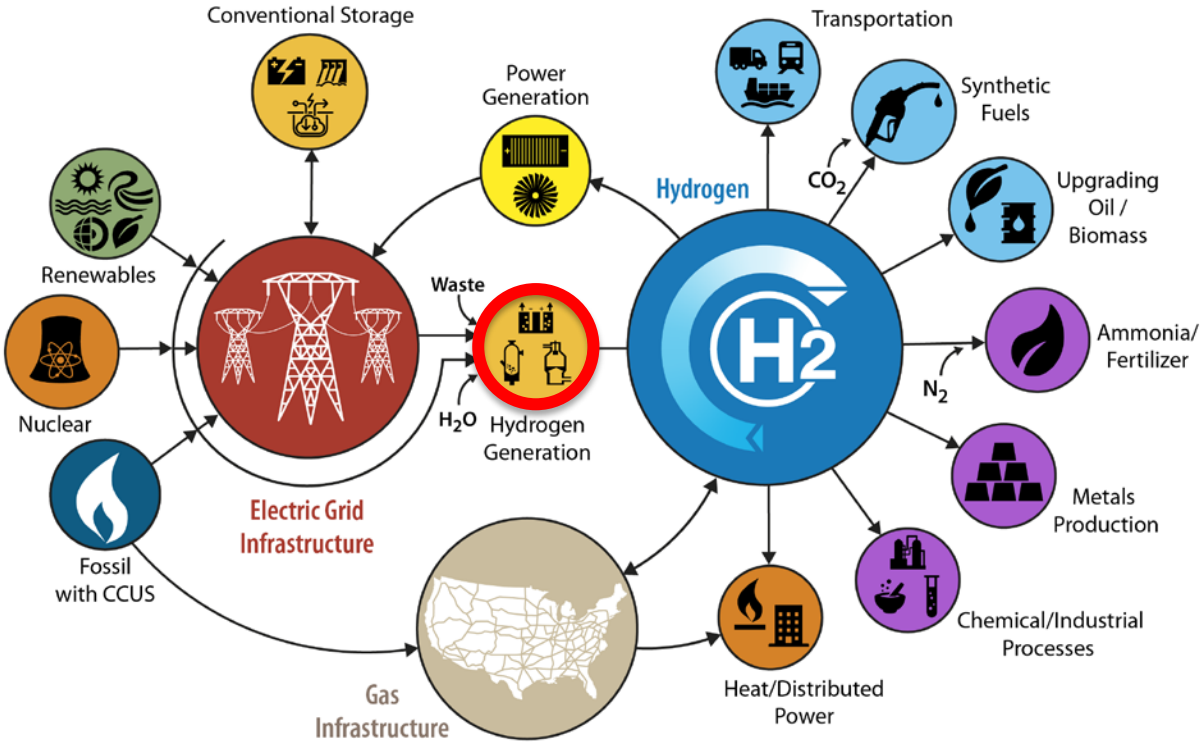
Approach: Safety Planning and Culture

- Work for this project is primarily analysis and when running NREL electrolyzers for data, work has been done in agreement with NREL's safety culture and Hazard Analysis Review procedures.
- Please visit Daniel Leighton's AMR presentation for more information: TA048 ARIES/Flatirons Facility – Hydrogen System Capability Buildout.

Accomplishments and Progress: Use of NREL 1.25MW Equipment Installed and Integrated

Approach: H2@Scale – Electrolyzer Context

This project investigates the performance of electrolyzer installations in their environment



Approach: Develop and Use Template for Operation, Maintenance, Performance

Electrolyzer Operation

Data does not need to be provided via Excel spreadsheet, provided the information below is clearly identified in the data file and formatted the same for each report.

Template updated: Jan 23, 2018 (NREL)

Electrolyzer Operation

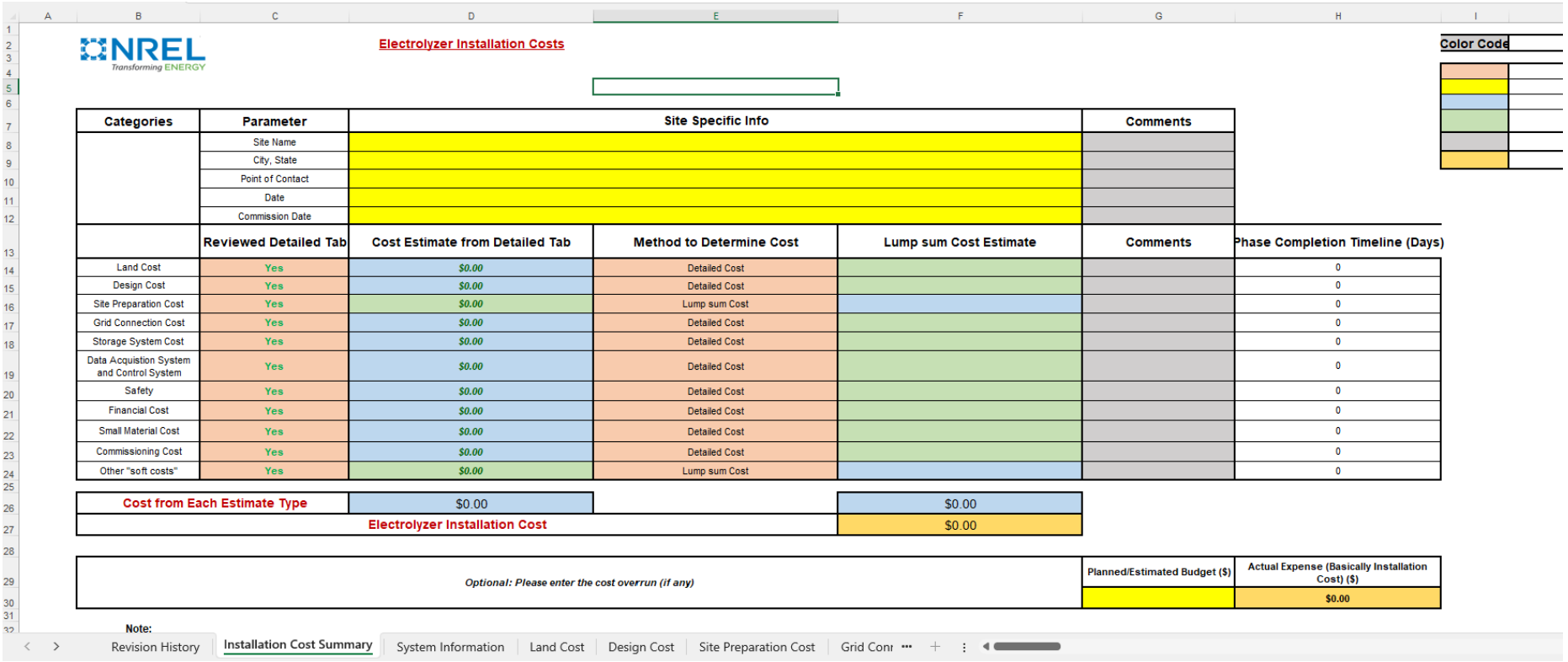
Start Time (yyyymmddHHMMSS)	*Start TimeStamp*
System ID	*unique electrolyzer*

Data files submitted should contain the unique name as well as a
a time stamp for the start of each set of data
(example: Stack01_20180115_155905.csv)
Data will be converted to Matlab *.mat files

Component	N/A	Electrolyzer Stack			Electrolyzer System (including BOP)							
Measurement	Time	Voltage	Current In	Stack Hours	Voltage	Current In	System Hours	State	Stack Temperature	Ambient Temperature	H2 Pressure Out	H2 output
Units	Frequency	Volts	Amperes	Hours	Volts	Amperes	Hours	Example: 0=Off, 1=On, 2=Standby, 3=Start, 4=Shutdown	deg C	deg C	bar	kg/s

Instructions | Site Summary | Performance Data | Electrolyzer | Maintenance | Safety & Leak Checks | Compression | Operation Cost | H2 Quality

Approach: Develop and Use Template for Installation Costs



NREL Transforming ENERGY

Electrolyzer Installation Costs

Color Code

Categories	Parameter	Site Specific Info	Comments
	Site Name		
	City, State		
	Point of Contact		
	Date		
	Commission Date		

	Reviewed Detailed Tab	Cost Estimate from Detailed Tab	Method to Determine Cost	Lump sum Cost Estimate	Comments	Phase Completion Timeline (Days)
Land Cost	Yes	$0.00	Detailed Cost			0
Design Cost	Yes	$0.00	Detailed Cost			0
Site Preparation Cost	Yes	$0.00	Lump sum Cost			0
Grid Connection Cost	Yes	$0.00	Detailed Cost			0
Storage System Cost	Yes	$0.00	Detailed Cost			0
Data Acquistion System and Control System	Yes	$0.00	Detailed Cost			0
Safety	Yes	$0.00	Detailed Cost			0
Financial Cost	Yes	$0.00	Detailed Cost			0
Small Material Cost	Yes	$0.00	Detailed Cost			0
Commissioning Cost	Yes	$0.00	Detailed Cost			0
Other "soft costs"	Yes	$0.00	Lump sum Cost			0

Cost from Each Estimate Type	$0.00	$0.00
Electrolyzer Installation Cost		$0.00

Optional: Please enter the cost overrun (if any)	Planned/Estimated Budget ($)	Actual Expense (Basically Installation Cost) ($)
		$0.00

Note:

Revision History | Installation Cost Summary | System Information | Land Cost | Design Cost | Site Preparation Cost | Grid Con

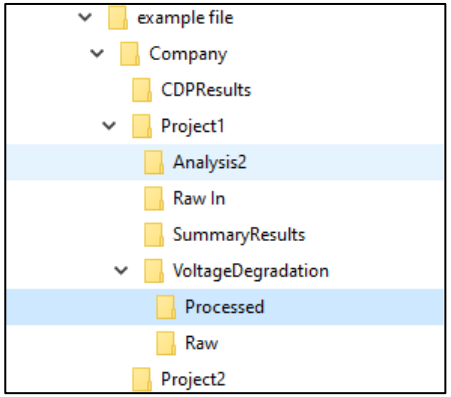
Storage of Data and Results

NFCTEC Today

- Receive data in templates, csv or Matlab files
- Manual moving of files and results
- Not connected to outside world other than through publication of results
- Only accessible at physical location
- Very structured folder and file naming
  - Easy to add new project if data is in same format
- Matlab GUI to select top level file locations and which projects to include in analysis.
- Matlab code for processing and analyzing data
- Review with partners and publication of results are every 6 months

Future

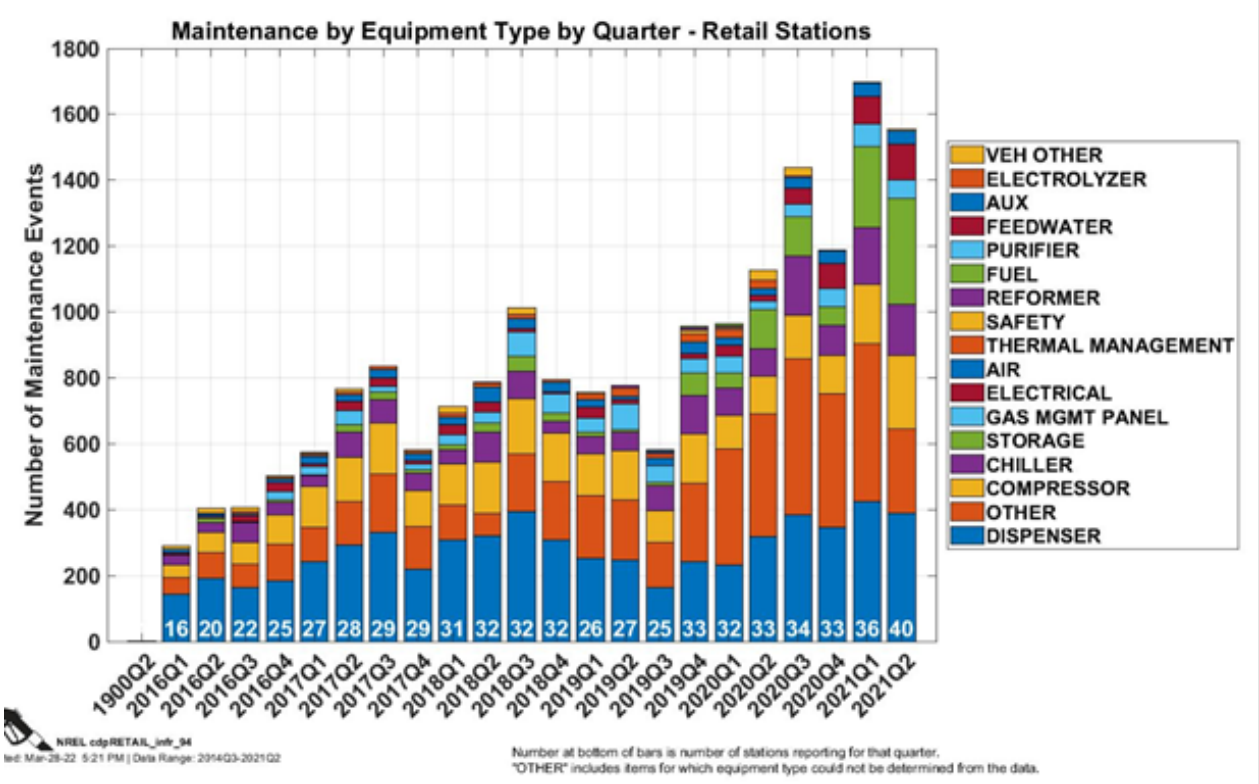
- Database in the cloud with user permissions
  - $$ large effort at first
  - $ adding new data as available, adding new results to the database
- Still use Matlab for analysis (other options)
  - $ Normal effort, adding new analysis
- Results accessed immediately but publication still needs review. Result data would be accessible.



List of potential analysis topics from electrolyzer projects

- Start date – and other dates of importance
- Locations/Regions (may be affected by local weather and available end uses)
- Stated capacity vs actual usage
- Costs – Installation, operation, maintenance
- Hub phase, or another program
- Capacity online vs planned
- End use application
- Hours accumulated on stack
- H2 produced
- H2 stored
- H2 delivered
- Capacity utilization
- Degradation
- System performance
- H2 used by end use application
- H2 vented/unaccounted for
- Maintenance/Reliability
- Safety Reports

Example Maintenance CDP from another application: Fueling Station Data



Accomplishments and Progress: Planning and Data

- Leveraging past tools used in NFCTEC for analysis of incoming data. Updating functions in Matlab.
- Planning stage near complete for storage of data and authenticated access
- Templates shared with potential data providers
- Starting to use NREL in-house data from 1.25 MW electrolyzer

Accomplishments and Progress:
Response to Previous Year Reviewers' Comments

- This project has not been previously reviewed

Collaboration and Coordination

NREL	Lead the data collection and analysis for low temperature electrolyzer installations. Provide data from electrolyzer installations at NREL to the project and work with partners with installed electrolyzer projects as they become available.
INL	Separately funded for similar work with high temperature electrolyzer installations. We will work together to develop data tools and analysis methods that provide a unified approach to evaluation of current status of all types of electrolyzer installations

Partners with electrolyzer installations needed. Several project partners contacted with installed electrolyzer systems.
They will provide data, review results, and give feedback

Remaining Challenges and Barriers

- Finish storage solution to provide partners easy access to provide data and view their analysis results.
- Gather list of priority metrics/targets and make sure we are asking for the right data to address them.
- Provide great analyses to the benefit of the partners providing data and to the electrolyzer industry.

Proposed Future Work

- Test out new data storage system using NREL electrolyzer data
- Gather data from external projects and finish authentication feature for projects to upload their own data.
- Aggregate data from several projects and create composite data products (CDPs) on several interesting metrics
- Automate analysis for incoming data with goal to have quick turnaround on results.

Any proposed future work is subject to change based on funding levels.

Summary

Relevance:

- Enable clean energy buildout by informing stakeholders of status of low temperature electrolysis systems installed in the field

Approach:

- Work with electrolyzer project partners to collect, aggregate, review and publish on performance of low temperature electrolyzer systems

Accomplishments and Progress:

- Developed method to authenticate users and store data using NREL HERO system
- Starting to work with data from NREL system while working with partners to get additional electrolyzer system data.
- Leveraging existing code to provide aggregated analysis

Future Work:

- Test out new data storage system using NREL electrolyzer data
- Gather data from external projects and finish authentication feature for projects to upload their own data.
- Aggregate data from several projects and create composite data products (CDPs) on several interesting metrics
- Automate analysis for incoming data with goal to have quick turnaround on results.

Thank You

www.nrel.gov

NREL/PR-5700-89518

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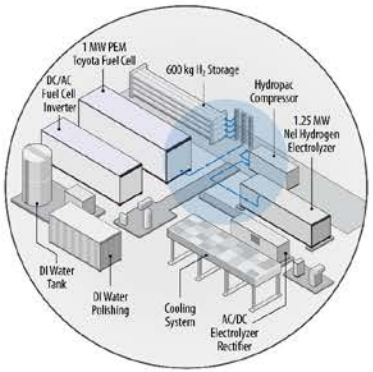
Technical Backup and Additional Information

Technology Transfer Activities

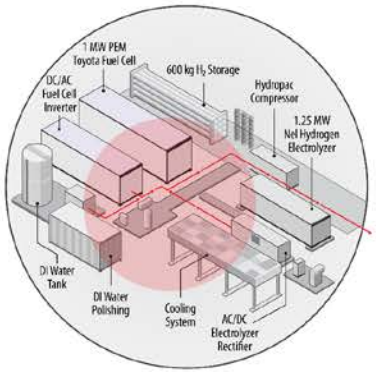
This project plans to provide:

- Status, progress, and needs of low temperature electrolyzer industry through publications of aggregated results from multiple installations.

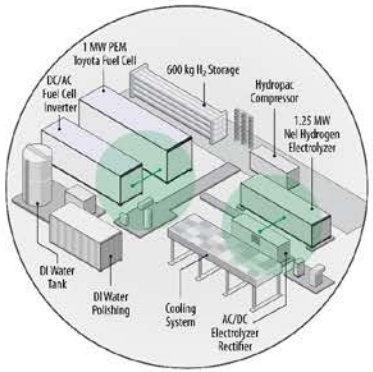
Technical Backup Slide: Systems Integration



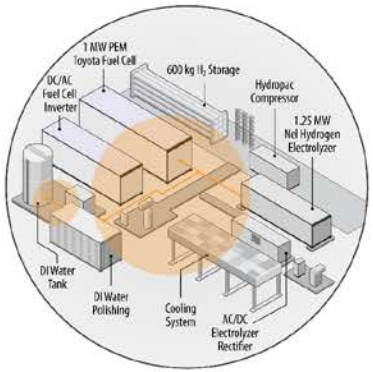
Hydrogen Connections



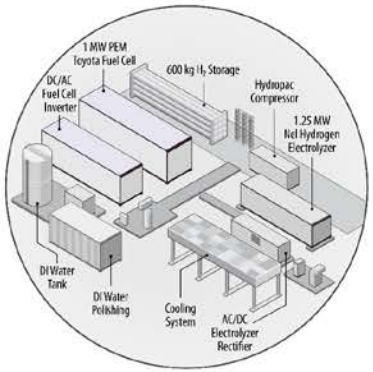
13.2 kW Grid Connections



DC Connections



DI Water Connections



System Map