# Economically Viable Intermediate to Long Duration Hydrogen Energy Storage Solutions for Fossil Fueled Assets



Zhili Feng
WE New Energy Inc
fengz@wenewenergy.com

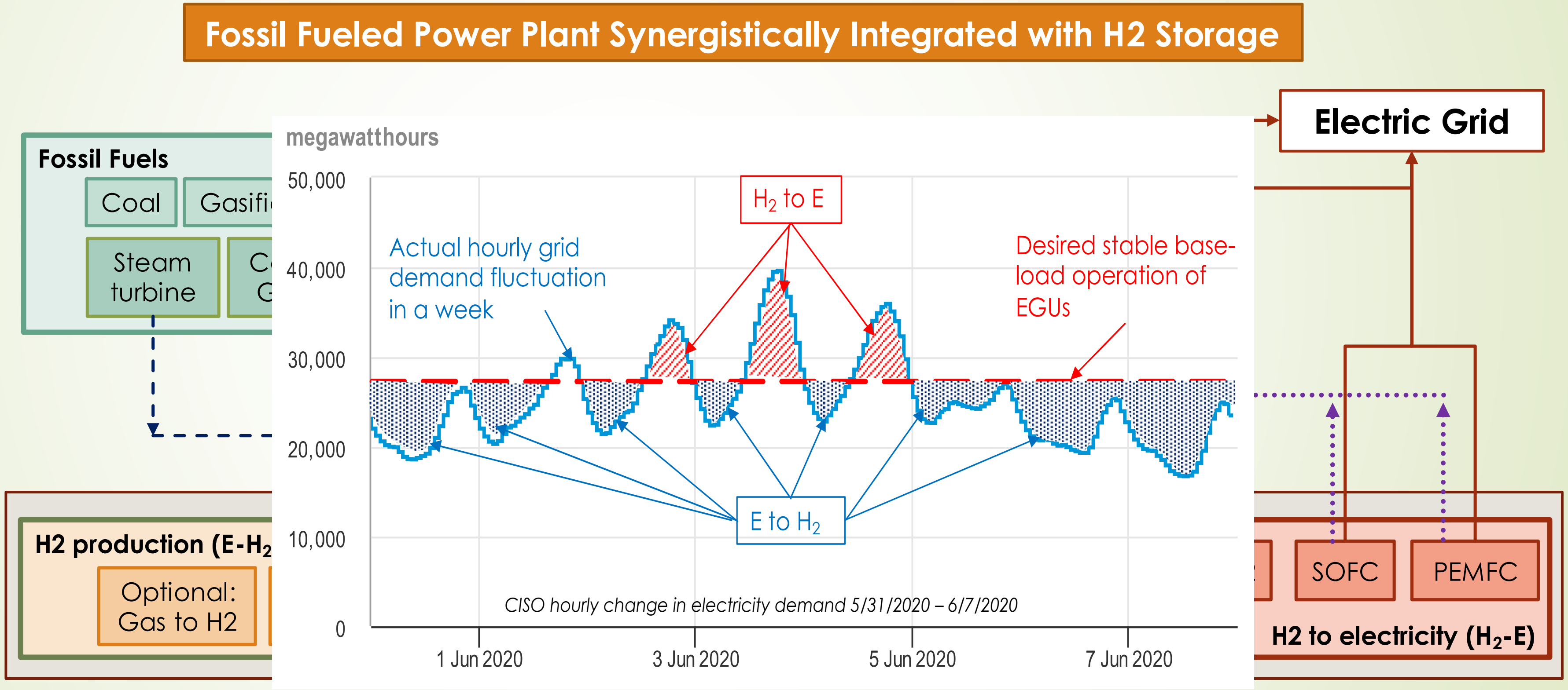
Project Team:
Exelon Corporation
Oak Ridge National Laboratory
West Virginia University

DOE NETL Advanced Energy Storage Initiative Program Project Review Meeting

April 5-6, 2021

# Project Concept:

## Synergistically integrated *hydrogen* energy storage system with coal and gas fueled EGUs (SIHES)

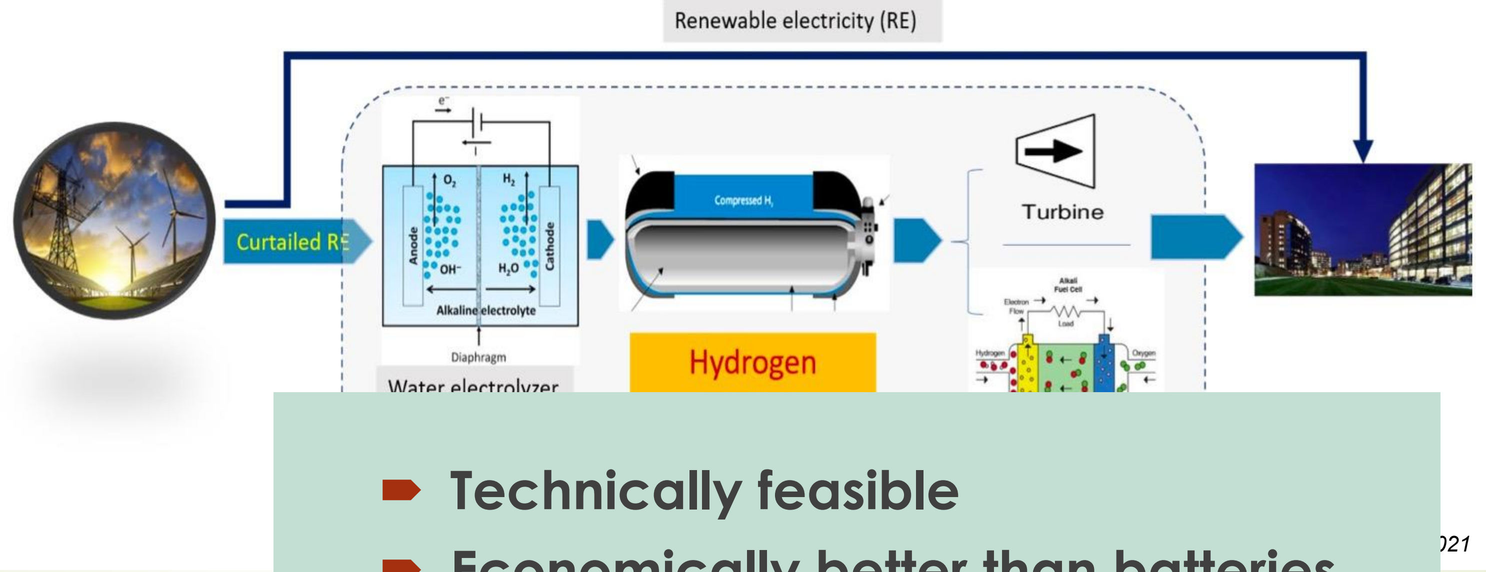



Grid fluctuation for illustration only

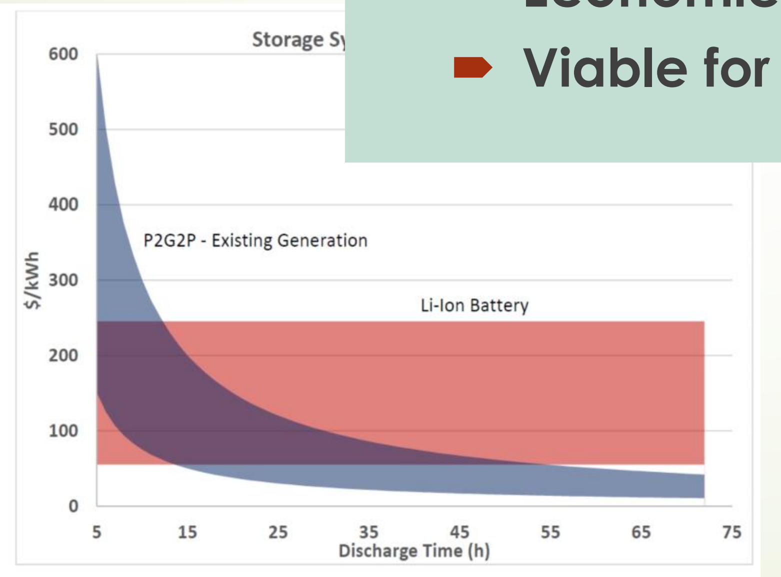
# Goals of SIHES

- **Technical Viability**: Enables EGUs to operate at optimal baseload operation conditions through the use of *sufficiently large* storage system to manage the dynamic changes in electric grid demand and electricity price over intermediate to long-durations (i.e., *from 12 hours to weeks*).
- **Economic Viability**: target *added* round-trip levelized cost of energy (LCOE) no greater than 10% of LCOE of today's fossil plant for 30 years operation ($5-10/MWh).
- **Phase I**
  - Focuses a *site-specific* conceptual design for a fossil power plant selected from the Exelon fossil fleet, to demonstrate both the technical and economic feasibility of SIHES.
  - Form the basis for subsequent Pre-FEED (Phase II), site demonstration, and eventual deployment of SIHES in fossil power generation.

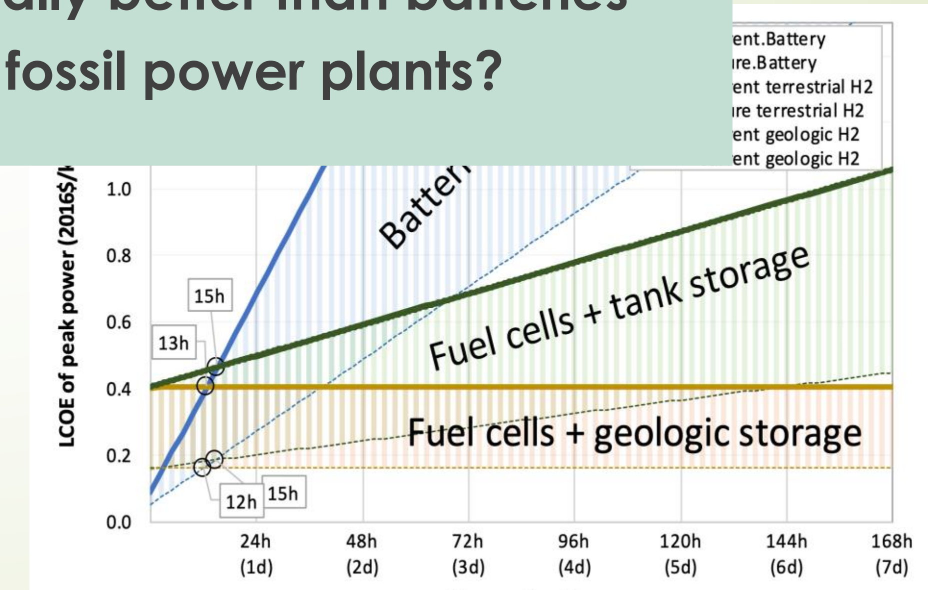
# Large-scale long-duration hydrogen-based energy storage for electricity grid




- **Technically feasible**
- **Economically better than batteries**
- **Viable for fossil power plants?**




CHBC White Paper, Power-to-Gas: The Case for Hydrogen 2018




Penev et al, NETL, 2019

# Today $H_2$ based energy storage is better than battery, but may not be economically viable for long duration

**Added LCOE**

Li-Battery: $100-300/MWh

Hydrogen system: $50-60/WMh

Cost of electricity is not included

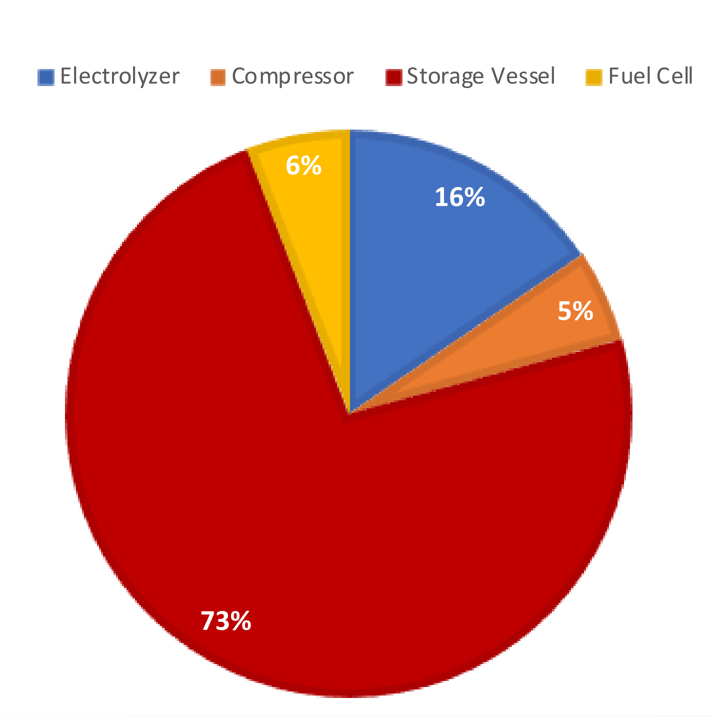
**Cost of storage vessel accounts for >70% of entire system cost**

Proportional to storage duration

The longer the storage duration, the higher percentage of storage vessel sub-system in the entire capital cost

| Energy Plant Type | LCOE $ per MWh |
|---|---|
| Offshore Wind | 130.40 |
| Coal with 30% CCS | 104.60 |
| Coal with 90% CCS | 98.60 |
| Biomass | 92.20 |
| Advanced Nuclear | 77.50 |
| Nat Gas Combined Cycle with CCS | 67.50 |
| PV Solar | 60.00 |
| Hydro-electric | 39.10 |
| Land Based Wind | 55.90 |
| **Natural Gas Combined Cycle** | **41.20** |
| Geothermal | 41.00 |
| **Energy Storage System** | **Additional LCOE $ per MWh** |
| Li-ion Battery | 100-300 |
| Today H2 based | 50-60 |

LCOE cost breakdown of hydrogen storage system




Data source: EIA, NREL, solarcellcentral.com 7/2020

**Basis for analysis:10MW, 7-day storage. 30-year operation life for hydrogen system, and 10 years for Li-ion battery**

# Proposed R&D

## Drastically reduce the cost of hydrogen storage subsystem

- Further develop our ultralow cost steel concrete composite vessel (SCCV) for tailored use in SIHES
- Scalability
  - 500-1000 kg H2 mass-produced vessels in shop
  - Super sized tens to hundreds tons of H2 (on-site construction)

## Effectively integrating hydrogen energy storage system with fossil assets

- Considerable room and **unique opportunities** exist in optimal integration of SIHES into fossil assets

## Techno-economic optimization

- Optimization of both system design and operation of SIHES for the highly dynamic storage demands and electricity fluctuations

## Target level of performance

- Baseline design for a specific type fossil power plant selected by Exelon
- Expected hydrogen energy storage parameters
  - Cost target: added round-trip E-$H_2$-E LCOE in the range of 10% of base LCOE of today's fossil plant (i.e. $5-10/MWh)
  - 300-800MWh for 1-10 days for 30-year operation

# Today's high-pressure $H_2$ storage vessels

- Commercially available low volume vessels
  - Most high-pressure tubes are limited by size such as lengths and diameters (up 20-30 inches)
- Hydrogen embrittlement concerns (especially under cyclic loading conditions)
  - No high-strength steels
  - **No weld is allowed**
  - Manufacturing process limited the size of tubes

H2 Refueling station in CA

Microsoft uses hydrogen fuel cells to power servers for 48 hours straight (July 27, 2020)

# Large volume high-pressure vessels require welding and other different manufacturing technologies


96-ft Long High-Pressure Steel Vessel for ammonia conversion manufactured in the US in 1970s

# Low-Cost Steel Concrete Composite Vessel (SCCV) for Stationary High-Pressure Hydrogen Storage



- SCCV is an innovative solution specifically designed and engineered for stationary high-pressure gaseous **hydrogen** storage applications
  - Addressing the two critical challenges: **high capital cost** and **safety** concerns of hydrogen embrittlement of high-strength steels.
  - Invented by the PI, US Patent 9,562,646 B2, ASME Pressure Vessel Code Case 2949
- Novel design
  - Eliminate hydrogen embrittlement problem **by design**
  - Enable use of cost-effective commodity materials (concrete and steels)
- Advanced **welding**, manufacturing and sensor technologies for reduced cost and improved safety
  - Can be fabricated with today's commercially ready manufacturing technologies in the US
  - Scalability enabled by advanced welding technologies:
    - 500 – 2000 kg H2 mass-produced vessels in shop
    - Super sized tens to hundreds tons of $H_2$ Vessels (on-site construction)

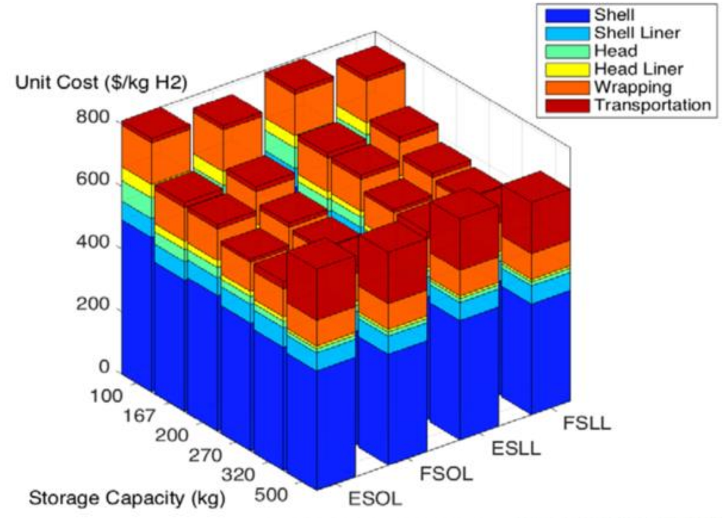
Manufacturing of first demonstration SCCV

# SCCV is cost competitive



- Today's vessel cost: $1000-1500/kg $H_2$
- Our technology:
  - $500-600/kg H2 at 875 bar (US price).
  - Reference SCCV design: 1500kg $H_2$ in moderate volume production (24 identical vessels per order)
- Improvement in design, manufacturing and economics of scale will further reduces the cost to ***$200-300/Kg H2 at high volume production***

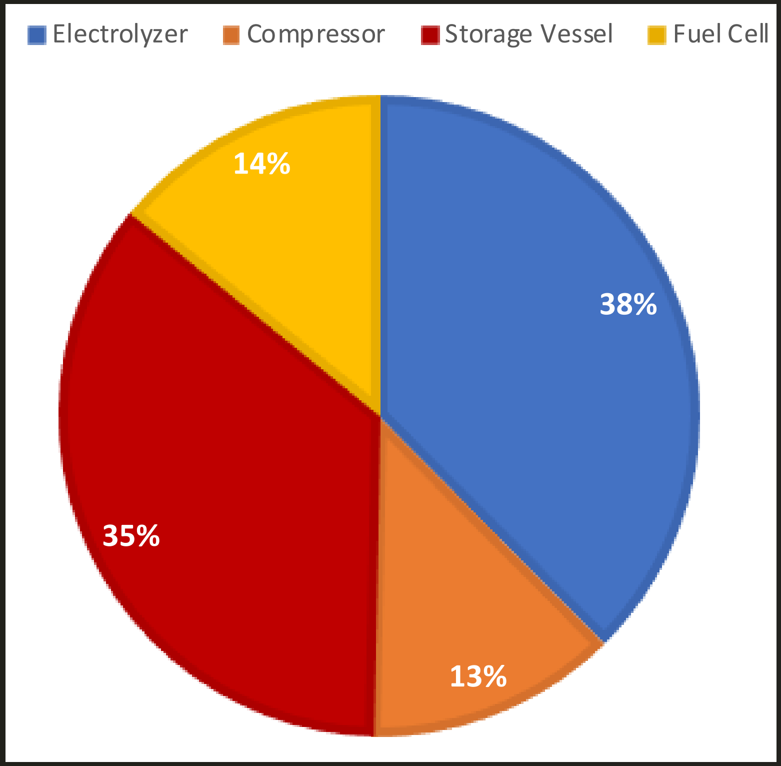
| | 100 kg | 167 kg | 200 kg | 270 kg | 320 kg | 500 kg |
|---|---|---|---|---|---|---|
| FSOL | 771 | 639 | 585 | 568 | 574 | 680 |
| FSLL | 765 | 635 | 583 | 566 | 572 | 679 |
| ESOL | 810 | 669 | 660 | 613 | 604 | 707 |
| ESLL | 805 | 665 | 658 | 611 | 603 | 706 |



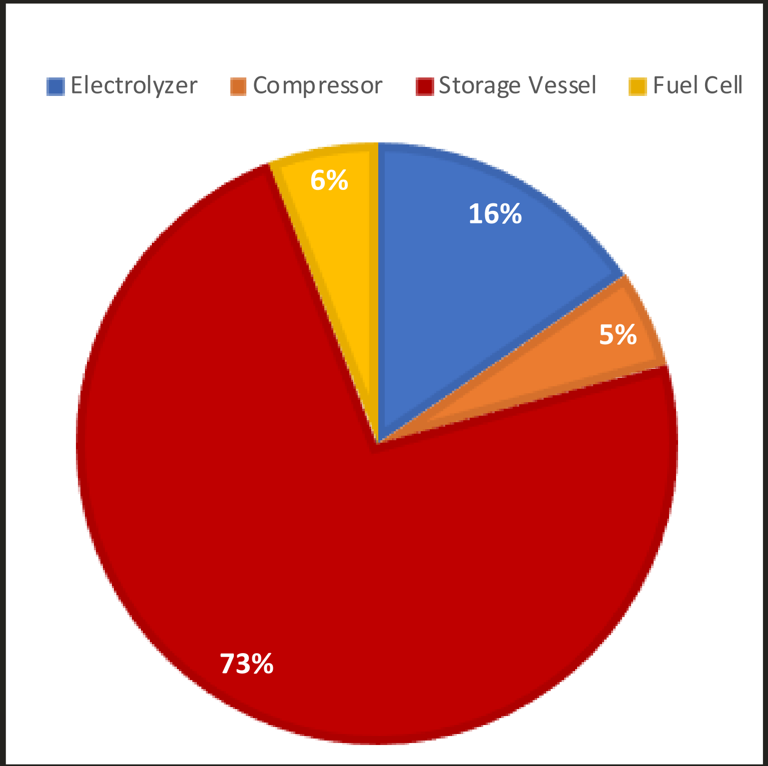
# SIHES could drastically reduce the capital cost of $H_2$ energy storage, potentially economically viable (preliminary results)



## Our E-$H_2$-E technology




## Today's technology




| Energy Plant Type | LCOE $ per MWh |
|---|---|
| Offshore Wind | 130.40 |
| Coal with 30% CCS | 104.60 |
| Coal with 90% CCS | 98.60 |
| Biomass | 92.20 |
| Advanced Nuclear | 77.50 |
| Nat Gas Combined Cycle with CCS | 67.50 |
| PV Solar | 60.00 |
| Hydro-electric | 39.10 |
| Land Based Wind | 55.90 |
| **Natural Gas Combined Cycle** | **41.20** |
| Geothermal | 41.00 |
| **Energy Storage System** | **Additional LCOE $ per MWh** |
| Li-ion Battery | 100-300 |
| Today H2 based | 50-60 |
| **Our H2 based** | **5-20** |

**Basis for analysis:10MW, 7-day storage. 30-year operation life for hydrogen system, and 10 years for Li-ion battery**

Data source: EIA, NREL, solarcellcentral.com 7/2020

# Team

- WE New Energy Inc (lead)
- Exelon
- Oak Ridge National Laboratory
- West Virginia University