

**Department of Energy  
Light Water Reactor Sustainability Program**

# ***Control Room Modernization for Light Water Reactor Sustainability***



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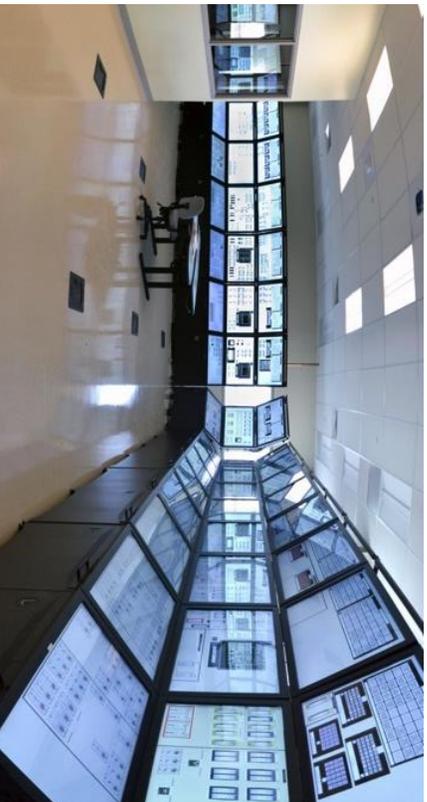
**Advanced Sensors and  
Instrumentation Webinar  
2017 NE I&C Review  
October 19, 2017**



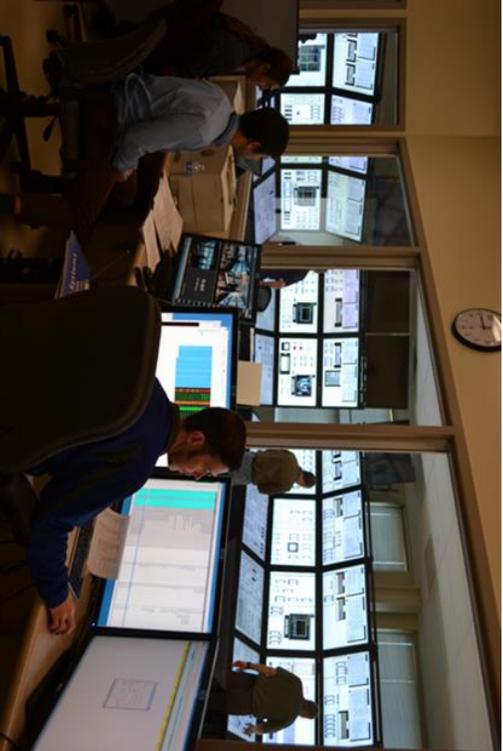
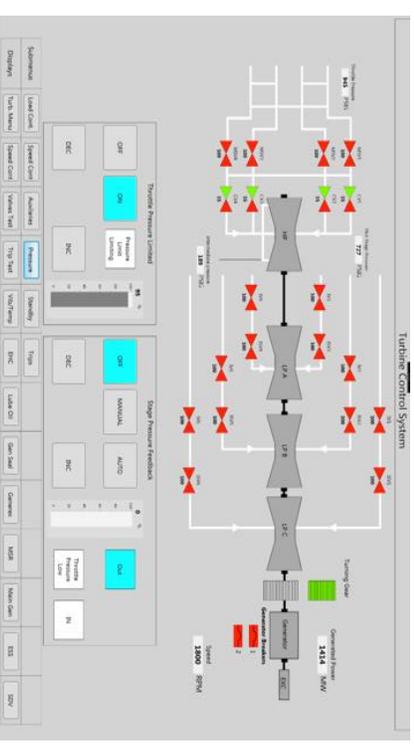
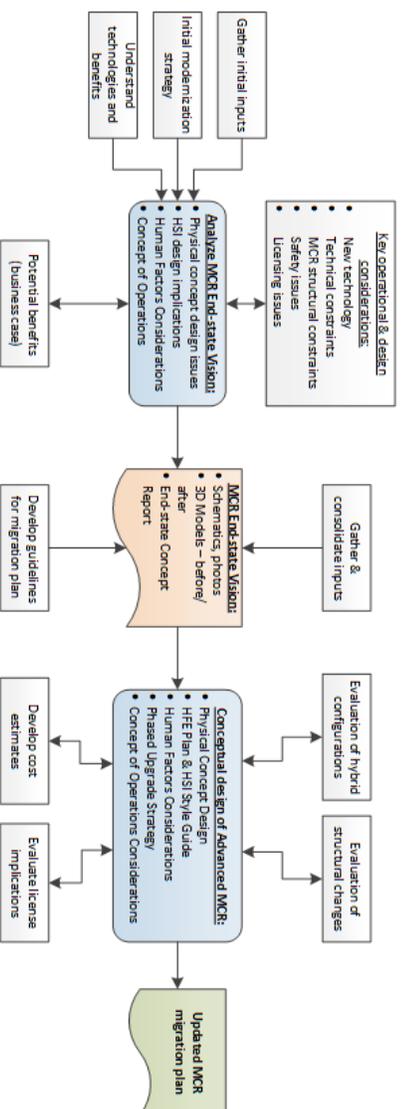
[www.inl.gov](http://www.inl.gov)

## Control Room Modernization

- Addresses obsolescence and reliability issues for the legacy I&C systems of the LWR fleet.
- I&C obsolescence is a potentially life-limiting issue for currently operating nuclear plants.
- Enables significant business improvement through the implementation of new control room technologies – improved operator performance and reduced O&M cost.
- II&C Pathway has unmatched resources to conduct this research: Human Systems Simulation Laboratory, Human Factors and Human Reliability staff, operator performance measurement technology, nuclear plant design and operational experience.
- Have major nuclear utilities as collaborators in this research – partnering with the II&C Pathway to modernize their control rooms as they undertake digital upgrades for their I&C systems.

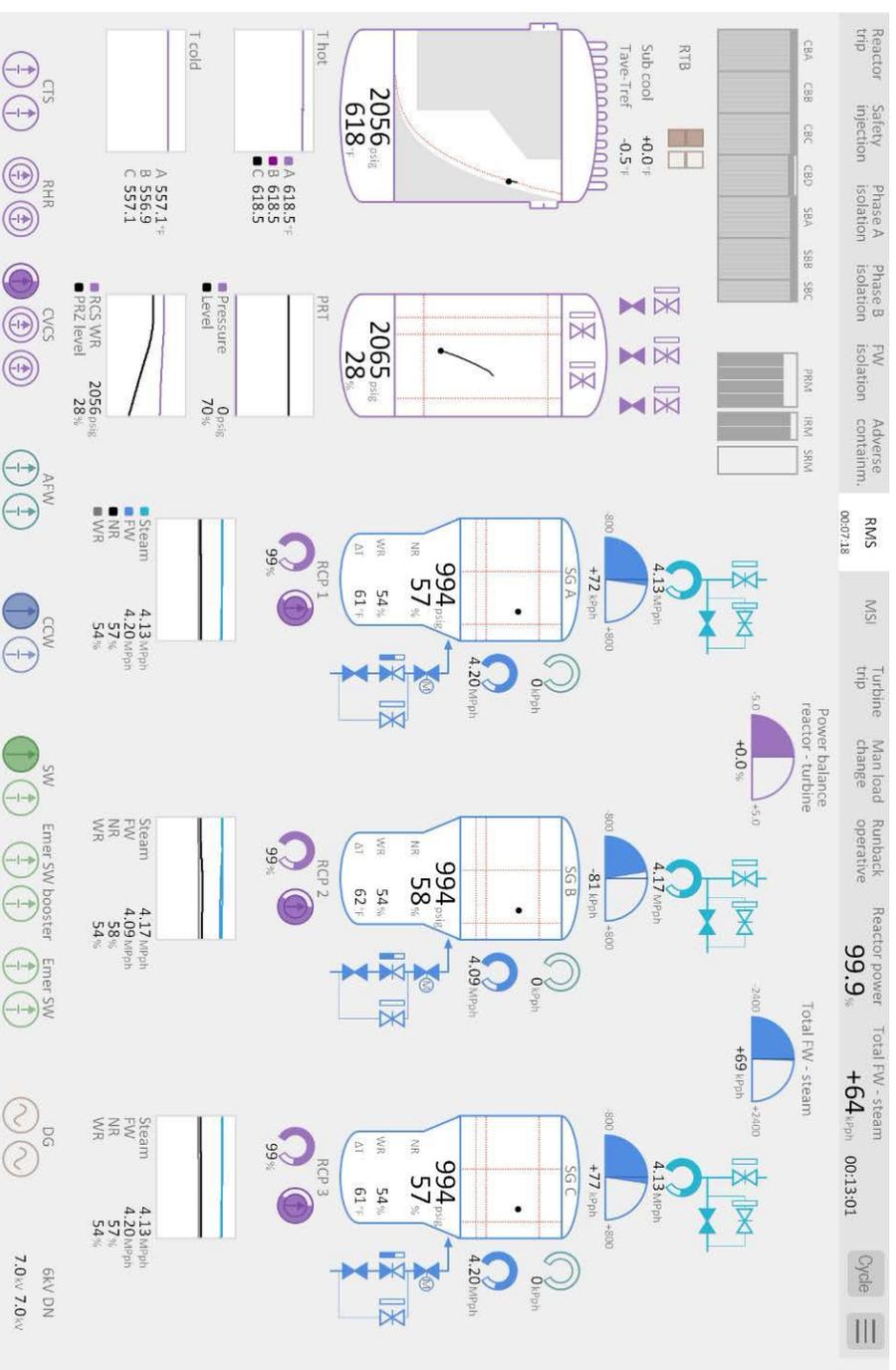


# Control Room Human Factors Studies

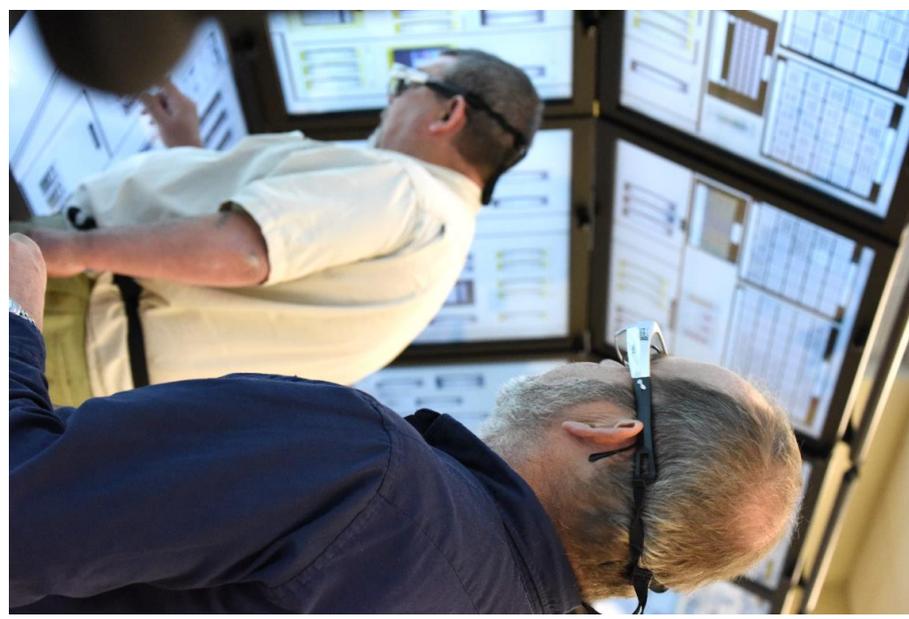
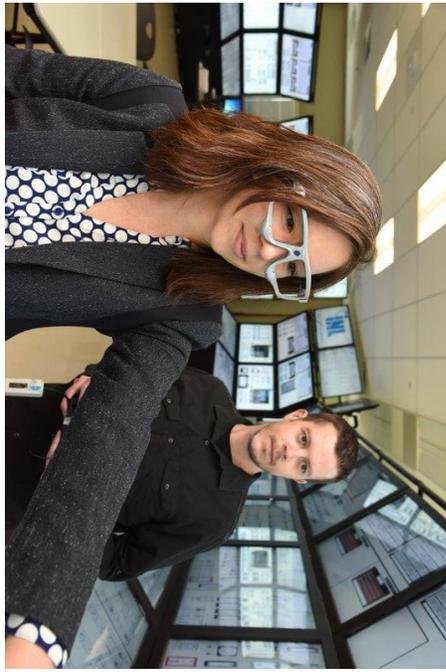
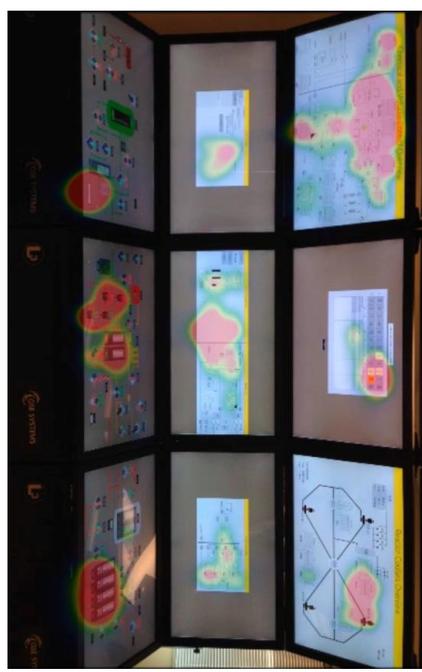


# Plant Overview Displays with Information-Rich Graphics

- Working with Halden Reactor Project
- Important Plant Parameters
- Exploit human capabilities to acquire information quickly
- Improve collective situation awareness
- Reduce operator workload to monitor the plant



# Objective Performance Measurement - Eye Tracker Technology



# Methodologies Conform to NRC Regulatory Guidance

NRC NUREG-0711 & 0700

Planning and Analysis	Design	Verification and Validation	Implementation and Operation
HFE Program Management	Human-System Interface Design		
Operating Experience Review	Procedure Development	Human Factors Verification and Validation	Design Implementation
Function Analysis & Allocation	Training Program Development		Human Performance Monitoring
Task Analysis			
Staffing & Qualification			
Treatment of Important Human Actions			

## Evaluation Phase

Pre-Formative ( <i>Planning and Analysis</i> )	Formative ( <i>Design</i> )	Summative ( <i>Verification and Validation</i> )	Post-Summative ( <i>Implementation and Operation</i> )
[11] Design Requirements Review	[21] Heuristic Evaluation	[31] System Validation	[41] Requalification against New Standards
[51] Baseline Evaluation	[61] Usability Testing	[71] Integrated System Validation	[81] Operator Training
[91] Cognitive Walkthrough (Task Analysis)	[101] Operator Feedback on Design	[111] Operator Feedback on Performance	[121] Operator Experience Reviews

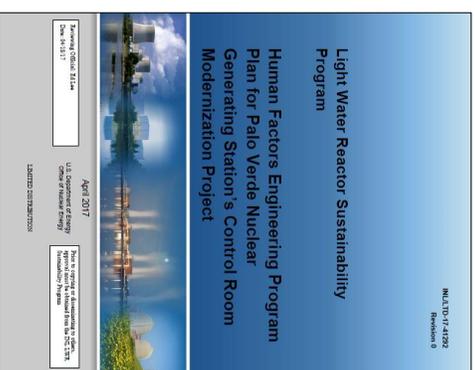
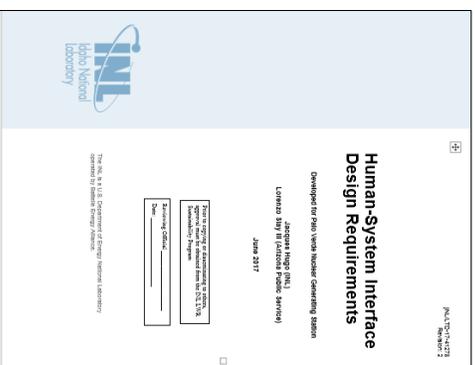
Corresponding Phases in NUREG-0711:

## Evaluation Type

Expert Review  
(*Verification*)

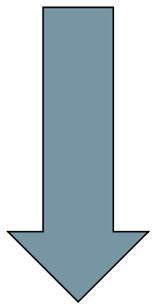
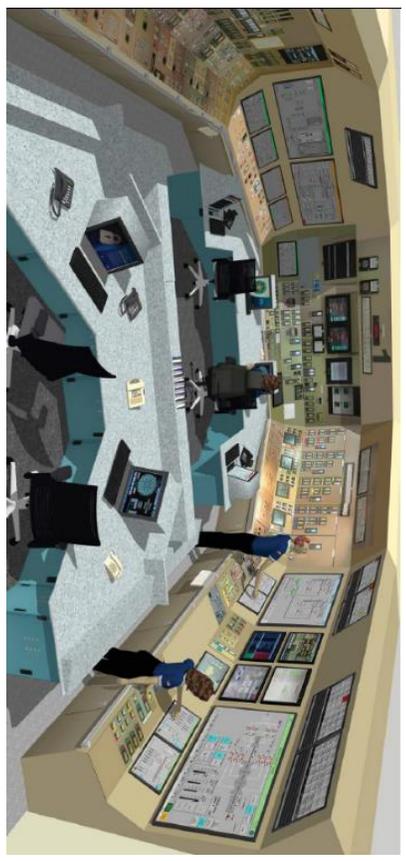
User Study  
(*Validation*)

Knowledge Elicitation  
(*Epistemition*)





# Migration to a Fully-Digital Control Room

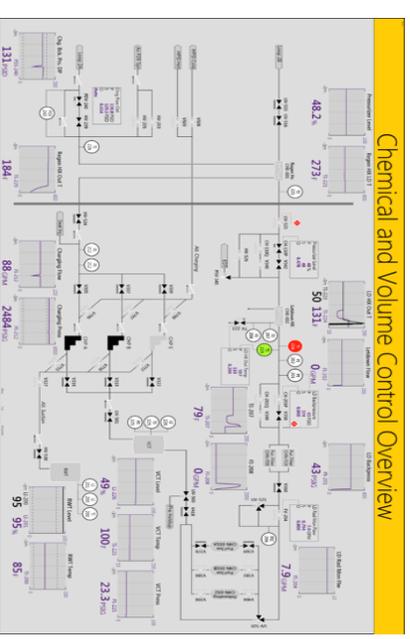
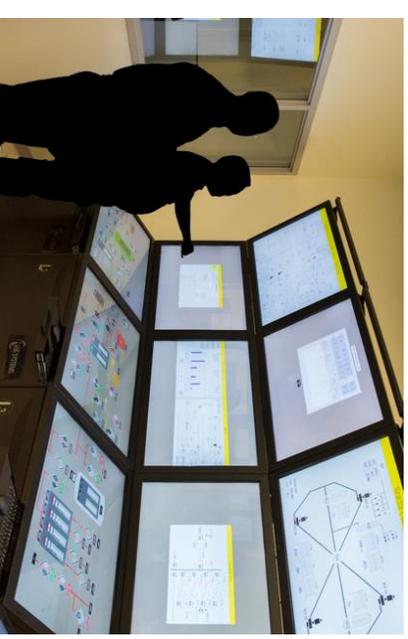
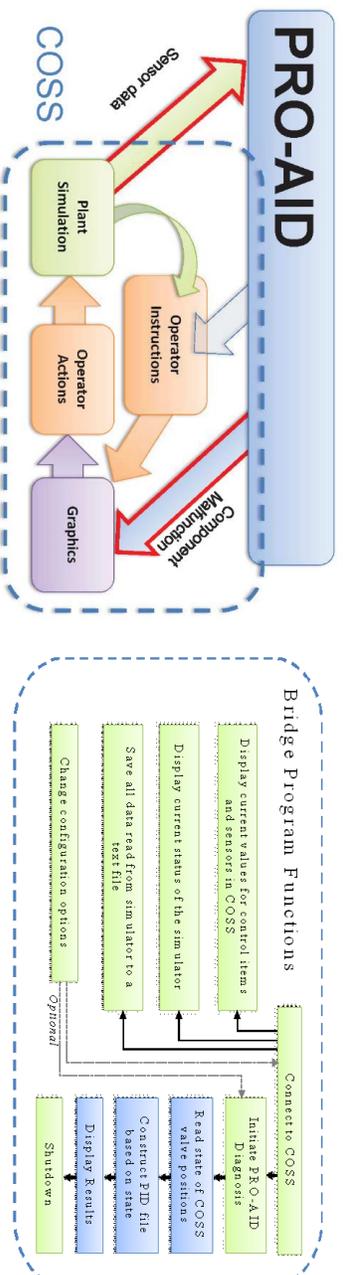


# Computerized Operator Support Systems

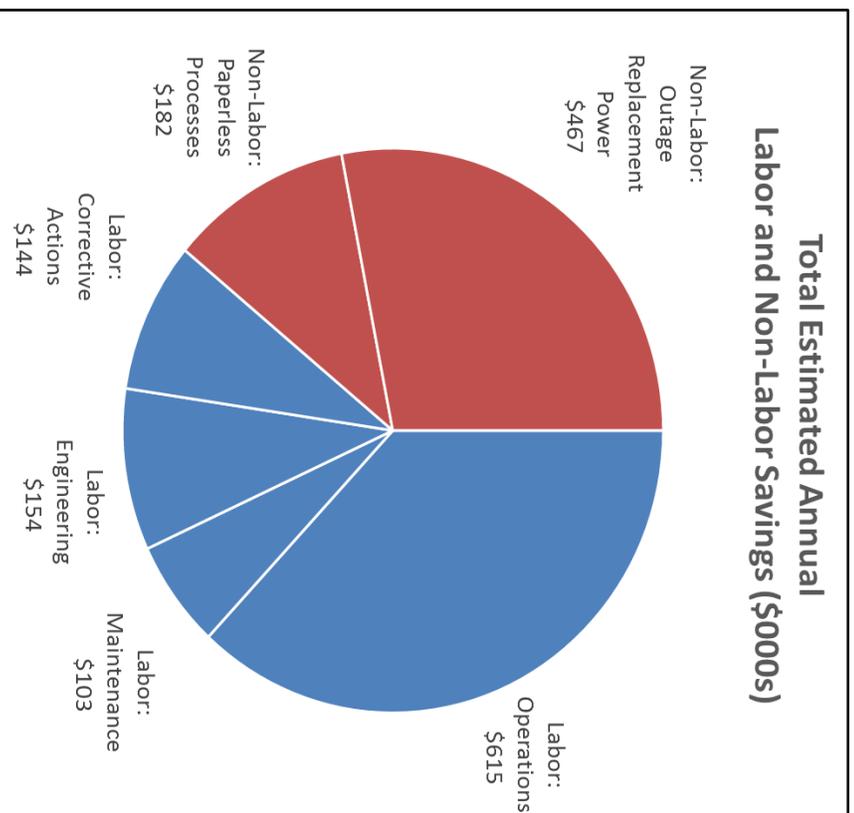
Collaborative Research between Argonne National Laboratory and Idaho National Laboratory

$$[dQ_{mass}] = [dw_{in}] - [dw_{out}] \quad [dQ_{mass}] = \left[ -d\Delta P + \frac{2W_0}{(\dot{Q}_{max})_0} dw \right]$$

Sensor Trend	Status Indicators	Fault Diagnosis
$[\Delta P] = / -$ and $[dw] = -$	n/a	Sensor Error
$[\Delta P] = -$ and $[dw] = / -$	n/a	Sensor Error
$[dw_{in}] = \downarrow$ and $[dw_{out}] = \uparrow$ and $[P] = \uparrow$	$\Rightarrow d[Q_{mass}] = \uparrow$ and $d[Q_{mass}] = \downarrow$	Leak
$[dw_{in}] = \uparrow$ and $[dw_{out}] = \downarrow$ and $[P] = \downarrow$	$\Rightarrow d[Q_{mass}] = \downarrow$ and $d[Q_{mass}] = \uparrow$	Leak
$[\Delta P] = \uparrow$ and $[dw] = \downarrow$	$\Rightarrow d[Q_{mass}] = \downarrow$ and $d[Q_{mass}] = -$	Blockage
$[\Delta P] = \downarrow$ and $[dw] = \uparrow$	$\Rightarrow d[Q_{mass}] = \uparrow$ and $d[Q_{mass}] = -$	Opposite of Blockage



# Control Room Modernization Business Case Development



## Control Room Modernization BCM Present Value

Discount Rate (Internal Rate of Return):	10%
No. Years of Benefit:	15 years
Annual Benefit (Labor)	\$ 1.02 million
Annual Benefit (Non-Labor)	\$ 0.65 million
Annual Benefit (KPI)	n/a million
Total Annual Benefit:	\$ 1.66 million
First Year Realized Benefit:	\$ 3 million
Estimated Net Zero NPV Investment:	\$10.46 million

## ***For Additional Information***

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