

**H2@ SCALE PROGRAM  
COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENT  
(hereinafter "CRADA")  
NO. 554/2018.00**

**AMONG**

*Battelle Memorial Institute,  
Operator of Pacific Northwest National Laboratory  
under its U.S. Department of Energy Contract No.DE-AC05-76RL01830*

**AND**

*National Technology & Engineering Solutions of Sandia, LLC  
(a wholly owned subsidiary of Honeywell International, Inc.)  
As Operator of Sandia National Laboratories  
under its U.S. Department of Energy Contract  
No. DE-NA0003525  
(hereinafter "NTESS" or "SNL")*

**(hereinafter being jointly referred to as "Contractors" or individually as "Contractor")**

**AND**

*Seattle City Light (SCL)  
700 5th Ave Ste 3200  
Seattle, WA 98104*

**AND**

*Port of Seattle (Port)  
PO Box 1209, 2711 Alaskan Way  
Seattle, WA 98111*

**(hereinafter "Participants")**

**(hereinafter Contractors and Participants are jointly referred to as the "Parties"  
or individually as a "Party")**

**Large-scale Hydrogen Storage – Risk Assessment Seattle City Light and Port of Seattle**

**ARTICLE I: DEFINITIONS**

- A. "Government" means the United States of America and agencies thereof.
- B. "DOE" means the Department of Energy, an agency of the United States of America.

- C. "Contracting Officer" means the DOE employee administering the Contractor's DOE contract.
- D. "Generated Information" means information produced in the performance of this CRADA.
- E. "Proprietary Information" means information which is developed at private expense outside of this CRADA, is marked as Proprietary Information, and embodies (i) trade secrets or (ii) commercial or financial information which is considered privileged or confidential under the Freedom of Information Act (5 USC 552 (b)(4)).
- F. "Protected CRADA Information" means Generated Information which is marked as being Protected CRADA Information by a Party to this CRADA and which would have been Proprietary Information had it been obtained from a non-federal entity.
- G. "Subject Invention" means any invention of the Contractor or Participant conceived of or first actually reduced to practice in the performance of work under this CRADA.
- H. "Intellectual Property" means patents, trademarks, copyrights, mask works, Protected CRADA Information and other forms of comparable property rights protected by Federal law and other foreign counterparts.
- I. "Background Intellectual Property" means the Intellectual Property, if any, identified by the Parties in an Annex titled "Background Intellectual Property", which was in existence prior to or is first produced outside of this CRADA, except that in the case of inventions in those identified items, the inventions must have been conceived outside of this CRADA and not first actually reduced to practice under this CRADA to qualify as Background Intellectual Property.

## **ARTICLE II: STATEMENT OF WORK, TERM, FUNDING AND COSTS**

- A. Annex A is the Statement of Work.
- B. Notices: The names, postal addresses, telephone and email addresses for the Parties are provided in the Statement of Work. Any communications required by this CRADA, if given by postage prepaid first class U.S. Mail or other verifiable means addressed to the Party to receive the communication, shall be deemed made as of the day of receipt of such communication by the addressee, or on the date given if by email. Address changes shall be made by written notice and shall be effective thereafter. All such communications, to be considered effective, shall include the number of this CRADA.
- C. The effective date of this CRADA shall be the latter date of (1) the date on which it is signed by the last of the Parties or (2) the date on which it is approved by DOE. The work to be performed under this CRADA shall be completed within twenty-four months from the effective date.
- D. The Participants' estimated contribution is \$330,000.00 USD, which includes \$220,000 in-kind and \$110,000.00 funds-in contributions and is reflected below. The Government's estimated contribution, which is provided through Contractors' contracts with DOE, is \$770,000.00 USD, subject to available funding, and is comprised of the following

individual Contractor contributions: \$400,000.00 USD to Pacific Northwest National Laboratory; \$370,000.00 USD to Sandia National Laboratory.

- Seattle City Light - \$110,000 In-Kind and \$75,000 Funds-In
- Port of Seattle - \$110,000 In-Kind and \$35,000 Funds-In

E. The Participants shall provide the Contractor (PNNL) with advanced funds as described below within thirty (30) days of receiving an invoice from the Contractor. The remaining funds shall be provided by the end of the first year with receipt of invoice from the Contractor.

- Seattle City Light - \$75,000 total; \$37,500 partial advance at execution of the CRADA
- Port of Seattle - \$35,000 total; \$17,500 partial advance at execution of the CRADA

Failure of the Participant to provide the necessary advance funding in the timeframe set forth herein is cause for termination of the CRADA.

F. No Party shall have an obligation to continue or complete performance of its work at a contribution in excess of its estimated contribution as contained in Article II.D., above, including any subsequent amendment.

### **ARTICLE III: PERSONAL PROPERTY**

All tangible personal property produced or acquired under this CRADA shall become the property of the Participant or the Government, depending upon whose funds were used to obtain it unless identified in the Statement of Work as being owned by the other Party.

Personal property shall be disposed of as directed by the owner at the owner's expense.

All jointly funded property shall be owned by the Government. The Participant shall maintain records of receipts, expenditures, and the disposition of all Government property in its custody related to the CRADA.

### **ARTICLE IV: DISCLAIMER**

THE GOVERNMENT, THE PARTICIPANTS, AND THE CONTRACTORS MAKE NO EXPRESS OR IMPLIED WARRANTY AS TO THE CONDITIONS OF THE RESEARCH OR ANY INTELLECTUAL PROPERTY, GENERATED INFORMATION, OR PRODUCT MADE OR DEVELOPED UNDER THIS CRADA, OR THE OWNERSHIP, MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OF THE RESEARCH OR RESULTING PRODUCT. NEITHER THE GOVERNMENT, THE PARTICIPANTS, NOR THE CONTRACTORS SHALL BE LIABLE FOR SPECIAL, CONSEQUENTIAL OR INCIDENTAL DAMAGES ATTRIBUTED TO SUCH RESEARCH OR RESULTING PRODUCT, INTELLECTUAL PROPERTY, GENERATED INFORMATION, OR PRODUCT MADE OR DEVELOPED UNDER THIS CRADA.

### **ARTICLE V: PRODUCT LIABILITY**

Except for any liability resulting from any negligent acts, or willful misconduct or omissions of Contractors or Government, Participant agrees to hold harmless the Government and the Contractors for all damages, cost and expenses, including attorney's fees, arising from personal injury or property damage as a result of the making, using, or selling of a product, process or

service by or on behalf of the Participant, its assignees or licensees, which was derived from the work performed under this CRADA.

## **ARTICLE VI: RIGHTS TO SUBJECT INVENTIONS**

Wherein DOE has granted the Participants and the Contractors the right to elect to retain title to their respective Subject Inventions.

- A. Each Party shall have the first option to elect to retain title to any of its Subject Inventions and that election shall be made: (1) for the Participant, within 12 months of disclosure of the Subject Invention to DOE or (2) for the Contractor, within the time period specified in its prime contract for electing to retain title to Subject Inventions. However, such election shall occur not later than 60 days prior to the time when any statutory bar might foreclose filing of a U.S. Patent application. The electing Party has one year to file a patent application after such election unless any statutory bar exists. If a Party elects not to retain title to any of its Subject Inventions or fails to timely file a patent application, the other Party shall have the second option to elect to obtain title to such Subject Invention within one year of notification and file a patent application within one year after such election, or no less than 30 days prior to a statutory bar, if any. For Subject Inventions that are joint Subject Inventions of the Contractor and the Participant, title to such Subject Inventions shall be jointly owned by the Contractor and the Participant.
- B. The Parties agree to assign to DOE, as requested by DOE, the entire right, title and interest in any country to each Subject Invention where the Parties (1) do not elect pursuant to this article to retain/obtain such rights, or (2) elect to retain/obtain title to a Subject Invention but fail to have a patent application filed in that country on the Subject Invention or decide not to continue prosecution or not to pay any maintenance fees covering the Subject Invention. If DOE is granted a patent on Participant's Subject Invention, the Participant may request a non-exclusive license and DOE will determine whether to grant such license pursuant to statutory authority.
- C. The Parties acknowledge that the Government retains a nonexclusive, nontransferable, irrevocable, paid-up license to practice or to have practiced for or on behalf of the United States every Subject Invention under this CRADA throughout the world. The Parties agree to execute a Confirmatory License to affirm the Government's retained license.
- D. The Parties agree to disclose to each other each Subject Invention which may be patentable or otherwise protectable under U.S. patent law. The Parties agree that the Contractors and the Participants will disclose their respective Subject Inventions to DOE and each other within two (2) months after the inventor first discloses the Subject Invention in writing to the person(s) responsible for patent matters of the disclosing Party.

These disclosures should be in sufficiently complete technical detail to convey a clear understanding, to the extent known at the time of the disclosure, of the nature, purpose, and operation of the Subject Invention. The disclosure shall also identify any known actual or potential statutory bars, e.g., printed publications describing the Subject Invention or the public use or "on sale" of the Subject Invention. The Parties further

agree to disclose to each other any subsequently known actual or potential statutory bar that occurs for a Subject Invention disclosed but for which a patent application has not been filed. All Subject Invention disclosures shall be marked as confidential under 35 U.S.C. 205.

- E. The Parties agree to include within the beginning of the specification of any U.S. patent applications and any patent issuing thereon (including non-U.S. patents) covering a Subject Invention, the following statement: “This invention was made under a CRADA (identify CRADA number) between (name the Participant) and (name the laboratory) operated for the United States Department of Energy. The Government has certain rights in this invention.”
- F. The Parties acknowledge that DOE has certain march-in rights to any Subject Inventions in accordance with 48 CFR 27.304-1(g) and 15 U.S.C. 3710a(b)(1)(B) and (C).
- G. For each Subject Invention of the Contractor, the Participants have the option for six (6) months from the date that the Subject Invention was disclosed to the Participant to negotiate up to an exclusive license, in a defined field of use on agreed-upon reasonable terms and conditions, including the payment of negotiated license fees and royalties.

#### **ARTICLE VII: RIGHTS IN DATA**

- A. The Parties agree that they shall have no obligations of nondisclosure or limitations on their use of, and the Government shall have unlimited rights in, all Generated Information produced and information provided by the Parties under this CRADA, except for restrictions and copyright on data provided for in this Article or data disclosed in a Subject Invention disclosure being considered for Patent protection.
- B. PROPRIETARY INFORMATION: Each Party agrees to not disclose Proprietary Information provided by the other Party to anyone other than the Participants, Contractors and its subcontractors (if any) performing work under this CRADA without written approval of the providing Party, except to Government employees who are subject to the statutory provisions against disclosure of confidential information set forth in the Trade Secrets Act (18 U.S.C. 1905). Government employees shall not be required to sign non-disclosure agreements due to the provisions of the above-cited statute.

If Proprietary Information is orally disclosed to a Party, it shall be identified as such, orally, at the time of disclosure and confirmed in a written summary thereof, appropriately marked by the disclosing Party, within ten (10) days as being Proprietary Information.

All Proprietary Information shall be protected for a period of five (5) years from the effective date of this CRADA, unless such Proprietary Information becomes publicly known without the fault of the recipient, shall come into recipient's possession without breach by the recipient of any of the obligations set forth herein, can be demonstrated by the recipient by written record that it is known prior to receipt from disclosing party, is disclosed by operation of law, or is independently developed by recipient's employees who did not have access to such Proprietary Information.

Proprietary Information in tangible form shall be returned to the disclosing Party or destroyed with a certificate of destruction submitted to the disclosing Party upon termination or expiration of this CRADA, or during the term of this CRADA upon request by the disclosing Party. Notwithstanding the foregoing destruction of copies shall not extend to archival copies maintained in computer system backup files, permanent business records, or as may otherwise be required by receiving Party's internal document retention policies.

- C. PROTECTED CRADA INFORMATION: Each Party may designate and mark as Protected CRADA Information any Generated Information produced by its employees, which meets the definition in Article I and, with the agreement of the other Party, so designate any Generated Information produced by the other Party's employees which meets the definition in Article I. All such designated Protected CRADA Information shall be appropriately marked.

For a period of five (5) years from the date Protected CRADA Information is produced, the Parties agree not to further disclose such information and to use the same degree of care and discretion, but no less than reasonable care and discretion, to avoid disclosure, publication or dissemination of such information to a third party, as the Party employs for similar protection of its own information which it does not desire to disclose, publish, or disseminate except:

- (1) as necessary to perform this CRADA;
- (2) as published in a patent application or an issued patent before the protection period expires;
- (3) as provided in Article X [REPORTS AND ABSTRACTS];
- (4) as requested by the DOE Contracting Officer to be provided to other DOE facilities for use only at those DOE facilities solely for Government use only with the same protection in place and marked accordingly.
- (5) to existing or potential licensees, affiliates, customers, or suppliers of the Parties in support of commercialization of the technology with the same protection in place. Disclosure of the Participant's Protected CRADA Information under this subparagraph shall only be done with the Participant's consent; or
- (6) as mutually agreed to by the Parties in advance.

The obligations of this paragraph shall end sooner for any Protected CRADA Information which shall become publicly known without fault of either Party, shall come into a Party's possession without breach by that Party of the obligations of paragraph above, or shall be independently developed by a Party's employees who did not have access to the Protected CRADA Information. Federal Government employees who are subject to 18 USC 1905 may have access to Protected CRADA Information and shall not be required to sign non-disclosure agreements due to the provisions of the statute.

- D. COPYRIGHT: The Parties may assert copyright in any of their respective Generated Information. Copyrights in co-authored works by employees of the Parties shall be

held jointly, and use by either Party shall be without accounting.

The Parties hereby acknowledge that the Government or others acting on its behalf shall retain a nonexclusive, royalty-free, worldwide, irrevocable, non-transferable license to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or on behalf of the Government, all copyrightable works produced in the performance of this CRADA, subject to the restrictions this CRADA places on publication of Proprietary Information and Protected CRADA Information.

When a Party writes computer software produced in the performance of this CRADA, the Party will provide the source code, object code, and expanded abstract, and the minimum support documentation needed by a competent user to understand and use the software to DOE's Energy Science and Technology Software Center (ESTSC) via [www.osti.gov/estsc](http://www.osti.gov/estsc). The Party shall inform ESTSC when it abandons or no longer commercializes the computer software. Until such notice to ESTSC, the Government has for itself and others acting on its behalf, a royalty-free, nontransferable, nonexclusive, irrevocable worldwide copyright license to reproduce, prepare derivative works, and perform publicly and display publicly, by or on behalf of the Government (narrow license) After the Party owning the Computer Software abandons or no longer commercializes the Computer Software, the Government has for itself and others acting on its behalf, a royalty-free, nontransferable, nonexclusive, irrevocable worldwide copyright license to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or on behalf of the Government. (broad license)

The Parties agree to place Copyright and other notices, as appropriate for the protection of Copyright, in human-readable form onto all physical media, and in digitally encoded form in the header of machine-readable information recorded on such media such that the notice will appear in human-readable form when the digital data are off loaded or the data are accessed for display or printout.

## **ARTICLE VIII: U.S. COMPETITIVENESS**

The Parties agree that a purpose of this CRADA is to provide substantial benefit to the U.S. economy.

- A. In exchange for the benefits received under this CRADA, the Participant therefore agrees to the following:
1. Products embodying Intellectual Property developed under this CRADA shall be substantially manufactured in the United States, and
  2. Processes, services, and improvements thereof which are covered by Intellectual Property developed under this CRADA shall be incorporated into the Participant's manufacturing facilities in the United States either prior to or simultaneously with implementation outside the United States. Such processes, services, and improvements, when implemented outside the United States, shall not result in reduction of the use of the same processes, services, or improvements in the United States.

B. The Contractors agrees to a U.S. Industrial Competitiveness clause in accordance with its prime contract with respect to any licensing and assignments of its Intellectual Property arising from this CRADA, except that any licensing or assignment of its intellectual property rights to the Participant shall be in accordance with the terms of paragraph A of this Article.

#### **ARTICLE IX: EXPORT CONTROL**

EACH PARTY IS RESPONSIBLE FOR ITS OWN COMPLIANCE WITH EXPORT CONTROL LAWS AND REGULATIONS. EXPORT LICENSES OR OTHER AUTHORIZATIONS FROM THE U.S. GOVERNMENT MAY BE REQUIRED FOR THE EXPORT OF GOODS, TECHNICAL DATA OR SERVICES UNDER THIS AGREEMENT. THE PARTIES ACKNOWLEDGE THAT EXPORT CONTROL REQUIREMENTS MAY CHANGE AND THAT THE EXPORT OF GOODS, TECHNICAL DATA OR SERVICES FROM THE U.S. WITHOUT AN EXPORT LICENSE OR OTHER APPROPRIATE GOVERNMENTAL AUTHORIZATION MAY RESULT IN CRIMINAL LIABILITY.

#### **ARTICLE X: REPORTS AND ABSTRACTS**

The Parties agree to produce the following deliverables: an initial abstract suitable for public release; and a final report, to include a list of Subject Inventions. It is understood that the Contractors have the responsibility to provide this information at the time of its completion to the DOE Office of Scientific and Technical Information. The Participants agree to provide the above information to the Contractors to enable full compliance with this Article.

The Parties agree to submit, for a period of five years from the expiration of this CRADA and, upon request of DOE, a non-proprietary report no more frequently than annually on the efforts to utilize any Intellectual Property arising under the CRADA.

The Parties agree that neither will use the name of the other Party or its employees in any promotional activity, such as advertisements, with reference to any product or service resulting from this CRADA, without prior written approval of the other Party.

#### **ARTICLE XI: FORCE MAJEURE**

No failure or omission by the Contractors or the Participants in the performance of any obligation under this CRADA shall be deemed a breach of this CRADA or create any liability if the same shall arise from any cause or causes beyond the control of the Contractors or the Participants, including but not limited to the following, which, for the purpose of this CRADA, shall be regarded as beyond the control of the Party in question: Acts of God, acts or omissions of any government or agency thereof, compliance with requirements, rules, regulations, or orders of any governmental authority or any office, department, agency, or instrumentality thereof, fire, storm, flood, earthquake, accident, acts of the public enemy, war, rebellion, insurrection, riot, sabotage, invasion, quarantine, restriction, transportation embargoes, or failures or delays in transportation.



**ARTICLE XII: DISPUTES**

The Parties shall attempt to jointly resolve all disputes arising from this CRADA. In the event a dispute arises under this CRADA, the Participant is encouraged to contact Contractor's Technology Partnership Ombudsman in order to further resolve such dispute before pursuing third-party mediation or other remedies. If the Parties are unable to jointly resolve a dispute within a reasonable period of time, they agree to submit the dispute to a third-party mediation process that is mutually agreed upon by the Parties. To the extent that there is no applicable U.S. Federal law, this CRADA and performance thereunder shall be governed by the laws of a court of competent jurisdiction

**ARTICLE XIII: ENTIRE CRADA, MODIFICATIONS AND TERMINATION**

This CRADA with its annexes contains the entire agreement between the Parties in performing the research described in the Statement of Work (Annex A) and becomes effective on the later date of either the date the last Party signs the document or receipt of advance funding, if any. Any agreement to materially change any terms or conditions of the CRADA and annexes shall be valid only if the change is made in writing, executed by the Parties hereto, and approved by DOE.

The Contractors enter into this CRADA under the authority of its prime contract with DOE. The Contractors are authorized to and will administer this CRADA in all respects unless otherwise specifically provided for herein. Administration of this CRADA may be transferred from the Contractors to DOE or its designee with notice of such transfer to the Participants, and the Contractors shall have no further responsibilities except for the confidentiality, use and/or nondisclosure obligations of this CRADA.

This CRADA may be terminated by either Party with thirty (30) days written notice to the other Party. If Article II provides for advance funding, this CRADA may also be terminated by the Contractors in the event of failure by the Participant to provide the necessary advance funding. Each Party will be responsible for its own costs arising out of or as a result of this termination. The obligations of any clause of this CRADA that were intended to survive the expiration of the period of performance, for example, confidentiality, use and/or non-disclosure obligations, shall also survive any termination of this CRADA.

**ARTICLE XIV: BACKGROUND INTELLECTUAL PROPERTY**

Each Party may use the other Party's Background Intellectual Property identified in an Annex to this CRADA solely in performance of research under the Statement of Work. This CRADA does not grant to either Party any option, grant, or license to commercialize, or otherwise use the other Party's Background Intellectual Property outside of the CRADA. Licensing of Background Intellectual Property, if agreed to by the Parties, shall be the subject of separate licensing agreements between the Parties. Each Party has used reasonable efforts to list all relevant Background Intellectual Property, but Background Intellectual Property may exist that is not identified. Neither Party shall be liable to the other Party because of failure to list Background Intellectual Property.

This Agreement may be signed in one or more counterparts, each of which shall be deemed an original, and all of which taken together shall be deemed one and the same instrument.

**FOR CONTRACTOR:  
(Battelle Memorial Institute)**

BY \_\_\_\_\_ Jud Virden \_\_\_\_\_

SIGNATURE \_\_\_\_\_

TITLE \_\_\_\_\_ Associate Laboratory Director \_\_\_\_\_

DATE \_\_\_\_\_

This Agreement may be signed in one or more counterparts, each of which shall be deemed an original, and all of which taken together shall be deemed one and the same instrument.

**FOR CONTRACTOR:**

**(National Technology & Engineering Solutions of Sandia, LLC)**

BY Mary Monson

SIGNATURE \_\_\_\_\_

TITLE Sr Manager, Technology Partnerships & Business Development

DATE \_\_\_\_\_

This Agreement may be signed in one or more counterparts, each of which shall be deemed an original, and all of which taken together shall be deemed one and the same instrument.

**FOR PARTICIPANT:  
(Seattle City Light)**

BY \_\_\_\_\_

SIGNATURE \_\_\_\_\_

TITLE \_\_\_\_\_

DATE \_\_\_\_\_

This Agreement may be signed in one or more counterparts, each of which shall be deemed an original, and all of which taken together shall be deemed one and the same instrument.

**FOR PARTICIPANT:  
(Port of Seattle)**

BY \_\_\_\_\_

SIGNATURE \_\_\_\_\_

TITLE \_\_\_\_\_

DATE \_\_\_\_\_

**ANNEX A - STATEMENT OF WORK (SOW)  
For CRADA No. PNNL/554**

**between**

**BATTELLE**

**As operator of Pacific Northwest National Laboratory (“PNNL”)  
Under its U.S. Department of Energy Contract  
No. DE-AC05-76RL01830 (hereinafter “Battelle” or “Contractor”)**

**And**

**National Technology & Engineering Solutions of Sandia, LLC  
(a wholly owned subsidiary of Honeywell International, Inc.)  
As Operator of Sandia National Laboratories  
under its U.S. Department of Energy Contract  
No. DE-NA0003525  
(hereinafter “NTESS” or “SNL”)**

**And**

**Seattle City Light (SCL)**

**And**

**Port of Seattle (Port)**

**Large-scale Hydrogen Storage – Risk Assessment Seattle City Light and Port of Seattle**

**I. PURPOSE**

This CRADA presents the strategy that Pacific Northwest National Laboratory (PNNL) and Sandia National Laboratories (SNL) will take to support Seattle City Light (SCL), and the Port of Seattle (Port) in performing a risk assessment of large-scale hydrogen storage. Risk assessment is often used to ensure that adequate measures are taken to protect workers and the public, the environment, infrastructure, and assets. A detailed risk assessment can also be used to direct funding and upgrades, to specific components and sub-systems in order to mitigate risks to the larger system. In this way risk assessments are often employed as a part of a larger risk management strategy, with the goal of minimizing the occurrence of hazards and to identify means to limit their consequences.

Risk assessment is often used to engage and inform regulators, and to communicate how specific regulations are being met. However, it is important to note that the proposed work is not intended for SCL and the Port to use in order to gain regulatory acceptance for their proposed activities. The work performed as a part of this effort will be a preliminary risk assessment for early-stage component and system designs and should be considered research and development (R&D). As such, the proposed work will be performed to a quality level and design maturity consistent with R&D and is not considered appropriate for final safety analysis and regulatory compliance purposes.

Previous and on-going work at SCL and the Port demonstrated the utility of deploying hydrogen systems at the Port. The deployment of hydrogen at the Port is a part of a larger vision of using hydrogen to address a range of issues for SCL and the Port. These include large-scale fueling of MD/HD vehicles, cargo-handling equipment (CHE), and harbor vessels to reduce emissions; support of adjacent LD vehicles; support of critical port operations during extreme events (i.e., resiliency); deferral of more capital- and time-intensive electrical distribution system upgrades while still supporting evolving port operations and decarbonization efforts; facilitating electrification by establishing energy storage as a grid resource, starting at strategic port locations; creation of a flexible market resource that can be used by SCL to generate revenue via arbitrage; support of planned future maritime operations that involve heavy use of hydrogen for ocean-going vessels; and future end-use applications involving natural gas pipeline hydrogen injection. Ultimately, the success of these activities is underpinned by the deployed storage capacity. Large-scale deployment of hydrogen systems will require hydrogen storage at a scale that has not been demonstrated. In addition, the ideal location for such multi-use systems is near the end user which will often necessitate deploying into urban and/or industrial areas.

A detailed risk assessment using the Port as a test case is necessary to ensure the deployment of large-scale hydrogen is successful. Many technologies have been proposed for hydrogen storage; however, these technologies need to be analyzed as they apply to an actual site. The physical infrastructure and hydrogen use cases for the Port will be analyzed, and a risk assessment for compressed hydrogen, liquified hydrogen, and Liquid Organic Hydrogen Carrier (LOHC) storage will be performed. These risk assessments will be useful for understanding how each of these technologies would perform in terms of facility and public safety. The operating states of the proposed hydrogen systems at the Port will be analyzed and incorporated into the storage risk assessment. Scalability will also be analyzed to understand how future port uses would affect the overall risk assessment. Finally, using the risk assessment as a tool to inform engagement and to gain stakeholder acceptance will be explored.

### **Benefit to PNNL/SNL/DOE**

The results of this CRADA, and an impact of the DOE funding, will facilitate the consideration of hydrogen as a key fuel in the Port's and SCL's energy infrastructure plans and may accelerate by several years the adoption of hydrogen, fuel cells, and other low/no-carbon technologies in SCL's service territory. This risk analysis will be a key resource for future planning and can be used to guide other large scale hydrogen deployments.

### **Benefit to CRADA Participant**

This project will accelerate the Port and SCL's consideration of hydrogen for energy storage and port operations by performing a large-scale hydrogen storage risk assessment. The four key areas for this project are:

- 1) Risk assessment of various large-scale storage options of hydrogen, relevant to urban and industrial areas. This will be the primary task of this work. The risk assessment will focus on applying well-developed hydrogen risk assessment methods (e.g. HyRAM, Hazards Analysis, Threat & Vulnerability Assessment, etc.) to large-scale hydrogen storage, production, and compression. Three hydrogen storage technologies (compressed hydrogen, liquified hydrogen, and liquid organic hydrogen carriers—LOHC) will be analyzed, and the Port will be used as a test case. This assessment is key for obtaining industry, public and City support for large-scale H<sub>2</sub> use and storage.

- 2) The near-term hydrogen uses under consideration by SCL and the Port include vehicle and harbor vessel fueling, energy storage, power generation, arbitrage, and resiliency of port operations. These operation modes will be analyzed to determine how they might affect the storage risk assessment. This includes the effects of storage system cycling (i.e. multiple discharges and recharges of hydrogen). We will assess the risk posed by hydrogen infrastructure development, both physical and cyber, to the local electric grid and make recommendations on safety as well as cyber security requirements.
- 3) Hydrogen use for future port needs beyond the scope identified in tasks one and two will be analyzed. This includes fueling of ships, natural gas pipeline injection, etc. These activities require very large amounts of hydrogen. This analysis will investigate the scalability of the risk assessment, to very large-scale hydrogen storage.
- 4) Local stakeholder acceptance of large-scale hydrogen will be key for any deployment. This task will examine how the risk assessment may be used for stakeholder engagement.

In addition to applying existing risk assessment methodologies for hydrogen storage risk, this study will examine the very large-scale storage necessitated by port operations and grid scale deployment of hydrogen systems. Various hydrogen storage forms will be analyzed for large-scale urban and industrial deployment. This includes compressed hydrogen, liquified hydrogen, and liquid organic hydrogen carriers (LOHC) such as formic acid, ammonia, and methanol. Each method will have different storage requirements; thus, the risk analysis may be substantially different for each. In addition, the risk analysis may identify what hydrogen storage form is appropriate for a wide range of capacities and applications. The successful completion of the work described in this document will accelerate the use of hydrogen at the Port.

### **Benefit to US Taxpayer**

SCL is a municipal utility and the Port of Seattle is a port facility. This risk analysis will be a key resource for future planning and can be used to guide other large scale hydrogen deployments, directly benefiting the taxpayers serviced by SCL and the Port. In addition, the deployment of hydrogen technology will reduce emissions around the port.

## **II. APPROACH**

PNNL, SNL SCL, and the Port will execute the project over two years to attain the benefits previously described. The project work is divided into five tasks. Task 1 will perform a risk assessment for three hydrogen storage technologies and the generation and compression infrastructure necessary to support them. Task 2 examines the various operating states proposed for the hydrogen deployed at the Port and examines how these might affect the storage risk assessment. Task 3 examines the scalability of the risk assessment for future uses by the Port and SCL. Task 4 will perform a cybersecurity risk assessment. Task 5 will investigate how the risk assessment can be used to gain stakeholder support for deployed large-scale hydrogen. Successful completion of this project will be a major proof of concept of foundational building blocks that will allow SCL and the Port to accelerate their plans and provide a template for others to use hydrogen at scale.

### **Task 1: Large-scale Hydrogen Risk Assessment**

Multiple technologies exist for large-scale hydrogen storage. Three that are of interest to this study are compressed hydrogen, liquified hydrogen, and LOHC. We propose to perform a preliminary risk



assessment of these three storage technologies and the accompanying generation and compression infrastructure, as it applies to storage at the Port.

It is anticipated that the stored hydrogen would be utilized for port operations and other tasks. For example, a 25MW electrolyzer can produce approximately 10 mt H<sub>2</sub> per day (assuming 90% utilization and 65% system efficiency). It is estimated that this could be used to fill approximately 200 drayage trucks per day. The system under consideration will likely be used for multiple functions, though. If the system was used to store 30 mt, it could be used to generate 60MWh of electricity (assuming 60% efficiency). This could be used by the Port for emergency backup power, or for energy storage by SCL. These are just a small subset of the proposed uses for hydrogen at the Port. As discussed herein, the opportunity for hydrogen deployed at a port will likely require significantly more hydrogen than this. The risk assessment will also investigate the many uses for hydrogen at the port, beyond an initial deployment. In the future, many hydrogen nodes may be deployed across the port area to meet all the demand. Initial discussions have estimated greater than 80mt storage may be needed. This risk assessment will investigate the array of options including multiple nodes, generation technology, storage, power production, fueling, etc.

The Port will serve as a test case for this risk assessment methodology, in that port infrastructure and site-specific characteristics will be included for multiple sites across the port complex. Port operations may introduce safety issues that are not always present in a public fueling station and have different requirements because they are not accessible to the public. This work is necessary because it will provide much needed information concerning risk assessment of large-scale storage in urban and industrial areas. This work will use the Hydrogen Risk Assessment Model (HYRAM) developed by SNL. The HyRAM toolkit integrates deterministic and probabilistic models for quantifying accident scenarios, predicting physical effects, and characterizing hydrogen hazards' impact on people and structures. HyRAM incorporates generic probabilities for equipment failures and probabilistic models for heat-flux impact on humans and structures, with computationally and experimentally validated models of hydrogen release and flame physics.

### **Task 2: Operational Considerations for Storage Risk Assessment**

One of the advantages to the deployment of a modular hydrogen system at the Port is that it provides the infrastructure necessary to address other infrastructure challenges in the area. This includes vehicle fueling, power storage and generation, arbitrage, transmission upgrade deferment, and port resiliency. However, using hydrogen for this wide variety of applications may introduce risks that are not accounted for in existing risk assessments. The total storage capacity necessary for all these operating states must be understood. Also, the wide variety of operating states may introduce high cyclic loading on the storage system. This task will assess the impact of operational modes and their interactions on the storage technologies listed above.

### **Task 3: Risk Assessment Scalability for Future Port Needs**

Port operations include cruise terminal operations, grain terminal, fishing fleet, marinas, and all the port-owned equipment, as well as operations associated with the Northwest Seaport Alliance (NWSA) which manages cargo operations, (container, breakbulk, auto and bulk) in both the Port of Tacoma (aka South Harbor) and Port of Seattle (aka North Harbor). The work in this proposal focuses on the Port of Seattle.

The use-cases currently being examined by SCL and the Port include normal and abnormal operations. The hydrogen storage capacity utilized in Tasks 1 and 2 will be sized for:

- 1) Fueling of class 8 drayage trucks
- 2) Support of electrical load shifting to minimize peak feeder loading, deferring the need for infrastructure upgrades, particularly in areas with significant challenges for upgrades.
- 3) Support of electrical arbitrage to maximize revenue generation
- 4) Port resiliency of operations

Future uses of hydrogen by the Port and SCL include fueling of a significant portion of the existing drayage fleet, rail vehicles, ocean-going vessels, harbor vessels (such as tugboats, ferries, water taxis, and commercial fishing vessels) and rail. To accomplish this, it is estimated that converting all equipment at the Port to hydrogen would require over 8 million kg of H<sub>2</sub>/year. In addition, other novel concepts such as converting all port material handling equipment to hydrogen, supplying nearby cement and steel manufacturing, and natural gas pipeline injection are also under consideration. All of these concepts will require a major expansion of hydrogen storage capacity.

This task will examine the scalability of the risk assessment performed in Tasks 1 and 2 to the very large-scale storage concepts under consideration by the Port and SCL. This effort will examine the three storage technologies discussed above and will utilize the same risk assessment methodologies as used in Task 1 to evaluate their scalability.

#### **Task 4: Cyber security risk assessment**

Cybersecurity is as strong as the weakest link. PNNL will use their cutting-edge cyber security capabilities to assess vulnerabilities associated with the envisioned the Port hydrogen infrastructure and make recommendations for what cybersecurity measures should be used. Specifically, we will use PNNL's Proactive Adaptive Cybersecurity for Control (PACiFiC). PACiFiC delivers five technologies that work independently or in combination to sense, alert, determine threats, defend, create deceptions, or isolate systems to prevent access (<https://www.pnnl.gov/projects/pacific-cyber>). It is designed for use for grid and energy storage that connects to the grid. The five technologies include: Cyber Isolets (prevents attackers from jumping between applications), Shadow Figment (patent pending deception platform which deploys decoys that mimic real devices), Threat Model-based Response (machine learning-based approach to malware triage allowing for continuous improvement), and Unified Operating Picture (an "intelligent dashboard" baseline profile that presents expected behavior of an industrial control system. This baseline enables defenders to observe and flag deviations and make appropriate operational decisions in real time). We will work with SCL and the Port to identify which measures should be applied and how to improve the cyber security of the whole.

Recent advancements in cyber process hazard analysis (PHA) methodologies facilitate a systematic process for linking cyber events to challenges of the system processes. Cyber PHA methodologies are top-down methods which model the data/information flow in the system, identify unsafe control actions between operators, controllers, & process components, and link unsafe control actions to hazards and consequences of the system. Utilizing top-down methods help bound and prioritize cybersecurity plans by focusing on cyber events that result in physical hazards and consequences, such as system equipment damage and loss of power generation, respectively. Cyber PHA methods

have been applied to many diverse systems across various industrial sectors to identify emergent system properties. For novel applications such as hydrogen interactions with the electric grid, identifying emergent system properties and protecting against cyber-induced hazards and consequences will ensure safe and secure operations for future operators.

#### Task 5: Risk Assessment for Stakeholder Engagement

Deploying large-scale hydrogen energy systems will require the acceptance of local stakeholders. This will be key for any future deployment at the Port. This work will examine using the risk assessment developed by Tasks 1-4 as means to engage local stakeholders and gain acceptance. PNNL has extensive experience in engaging stakeholders and communicating risk for large-scale energy projects. This experience will be leveraged for this effort.

### III. SCHEDULE, MILESTONES AND DELIVERABLES

Project Milestones and Deliverables		
Milestone	Description	Milestone Type
<b>Year 1</b>		
Y1Q1	Complete initial data collection from SCL and Port of Seattle (Port, SCL, PNNL, and SNL)	Progress
Y1Q2	Conceptualization of initial risk models, identification of additional data needs, and the development of the strategy we will use to close any knowledge gaps. (PNNL, SNL)	Progress
Y1Q3	Complete initial risk model and HYRAM integration (PNNL, SNL)	Progress
Y1Q4 -1	Complete status report on risk model progress and initial model results (PNNL, SNL)	Progress/deliverable
Y1Q4 -2	Complete workshop with stakeholders presenting methods (PNNL, SNL, SCL, Port)	Annual & Go/No-Go
<b>Year 2</b>		
Y2Q1	Integration of workshop feedback into risk model (PNNL, SNL)	Progress
Y2Q2	Complete preliminary risk analyses for all tasks (PNNL, SNL)	Progress
Y2Q3	Presentation of initial results to SCL/Port of Seattle for all tasks and project integration (PNNL, SNL)	Progress
Y2Q4	Finalize report for OSTI distribution, per the requirements of CRADA Article X Reports and Publications. (PNNL, SNL, SCL, Port)	Annual & Final Deliverable

## IV. TOTAL COST AND RESOURCE CONTRIBUTIONS

	Federal Funds	Cost share	Federal Funds	Cost share	Federal Funds	Cost share
	Year 1		Year 2		Total Project	
PNNL	\$200,000		\$200,000		\$400,000	
SNL	\$185,000		\$185,000		\$370,000	
SCL (in kind)		\$55,000		\$55,000		\$110,000
SCL (cash)		\$37,500		\$37,500		\$75,000
Port (in kind)		\$55,000		\$55,000		\$110,000
Port (cash)		\$17,500		\$17,500		\$35,000
<b>Total</b>					\$1,100,000	

SCL will provide an in-kind contribution to this project.

SCL's In-Kind Contribution		Year 1	Year 2	Total
A.	Personnel	\$50,000	\$100,000	
B.	Travel	\$5,000	\$10,000	
C.	Equipment			
D.	Supplies			
E.	Contractual			
F.	Other			
Total Direct Charges		\$55,000	\$55,000	\$110,000
Indirect Charges				
<b>Total Project Costs</b>		<b>\$55,000</b>	<b>\$55,000</b>	<b>\$110,000</b>

The Port will provide an in-kind contribution to this project.

Port's In-Kind Contribution		Year 1	Year 2	Total
A.	Personnel	\$50,000	\$50,000	\$100,000
B.	Travel	\$5,000	\$5,000	\$10,000
C.	Equipment			
D.	Supplies			
E.	Contractual			
F.	Other			
Total Direct Charges		\$55,000	\$55,000	\$110,000
Indirect Charges				
<b>Total Project Costs</b>		<b>\$55,000</b>	<b>\$55,000</b>	<b>\$110,000</b>

**DIRECT FUNDS-IN**

SCL will also be providing a funds-in contribution to this project.

<b>SCL's Funds-In Contribution</b>		<b>Year 1</b>	<b>Year 2</b>	<b>Total</b>
A.	Personnel (PNNL Labor)	\$37,500	\$37,500	\$75,000
B.	Travel			
C.	Equipment			
D.	Supplies			
E.	Contractual			
F.	Other			
Total Direct Charges		\$37,500	\$37,500	\$75,000
Indirect Charges				
<b>Total Project Costs</b>		<b>\$37,500</b>	<b>\$37,500</b>	<b>\$75,000</b>

The Port will also be providing a funds-in contribution to this project.

<b>Port's Funds-In Contribution</b>		<b>Year 1</b>	<b>Year 2</b>	<b>Total</b>
A.	Personnel (PNNL Labor)	\$17,500	\$17,500	\$35,000
B.	Travel			
C.	Equipment			
D.	Supplies			
E.	Contractual			
F.	Other			
Total Direct Charges		\$17,500	\$17,500	\$35,000
Indirect Charges				
<b>Total Project Costs</b>		<b>\$17,500</b>	<b>\$17,500</b>	<b>\$35,000</b>

ANNEX B

OPTION AGREEMENT

FOR

CRADA NO. PNNL/554

As a supplement to the above-referenced CRADA, the Parties to such CRADA have agreed that the Participants shall have the option to negotiate a semi-exclusive license (limited to the number of parties to the CRADA) in the Field of Use set forth below for any Subject Invention made solely or jointly by Battelle and NTESS as Contractors during the performance of work under this CRADA. Such option must be exercised, in writing, within three (3) months after completion of work under the CRADA, or termination of the CRADA according to Article XIII, whichever occurs first. The parties must conclude their license negotiations and execute a license agreement within six (6) months from the date Participant notifies Battelle and/or NTESS that Participant wishes to enter into a license, or this option will terminate. Any license granted pursuant to this option shall be subject to:

1. a written notice of election to exercise the option addressed to:  

Battelle Memorial Institute  
Attn: Manager, IP Transactions, MS K1-53  
902 Battelle Blvd, P.O. Box 999  
Richland, WA 99354
2. a Field of Use defined as: Hydrogen generation, storage, transportation, and delivery
3. the U.S. Government retaining a nonexclusive, nontransferable, irrevocable, paid-up license to practice the invention or have the invention practiced throughout the world by or on behalf of the U.S. Government;
4. march-in rights by the U.S. Government as defined in Article VI of the CRADA;
5. specified license and patenting fees, royalties and diligence requirements to be negotiated by the Parties.

ANNEX D

For

CRADA No. PNNL/554

List of Background Intellectual Property

**Contractor-Owned Background Intellectual Property:**

**PNNL:** None

**SNL:** SCR 1703.3 – HyRAM+ v4 – “Hydrogen Plus Other Alternative Fuels Risk Assessment Models”: Authors – Brian Ehrhart, Gregory Walkup, Eri Carrier, Alice Muna, Myra Blaylock, Katrina Grothe, Ethan Hecht, Isaac Ekoto, Benjamin Schroeder; Approved: October 6, 2021

**Participant Background Intellectual Property:**

**Seattle City Light:** None

**Port of Seattle:** None