UNIVERSITY OF TORONTO

Motion+

AMPHIBIOUS YACHT AND FUELING STATION

Matthew Chen
Yuri Savguira
Jessica MacInnis
Bryan James

Faculty Advisor:
Steven J. Thorpe

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Undergraduate Education

"Re-imagine and reinvent undergraduate education at a research-intensive university, in light of current economic and social challenges, and taking advantage of emerging opportunities, including new pedagogical technologies."

-Three Priorities, President Gertler 2015

MSE458: "Nanotechnology in Alternate Energy Systems"

- **H_2 annual design competition since 2005**
- **Open to undergraduate and graduate students**
- **Emphasis on all-around design**
- **TEAL room utilization to enhance learning experience**

U of T Resources: TEAL Rooms

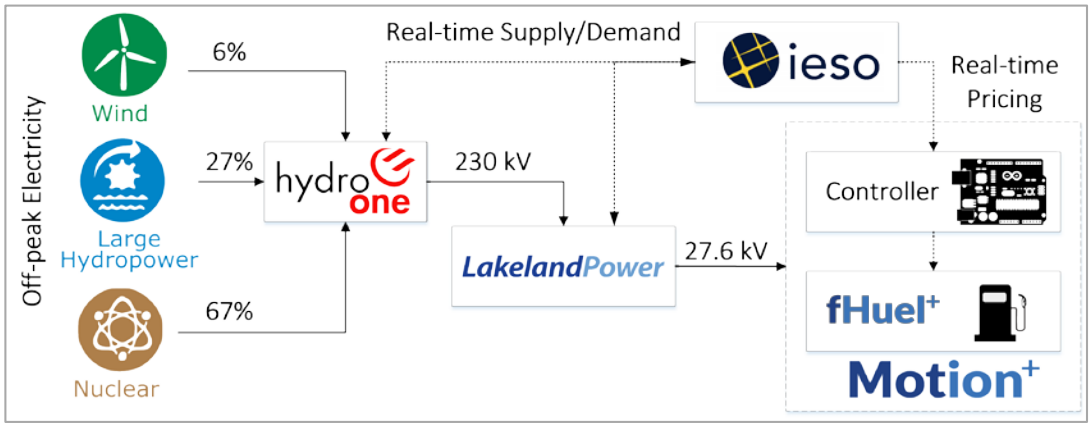
- **Dynamic space that increases educational capabilities for both small and large scale activities:**
  - **Small pods: collaborative group work**
  - **Main podium: class wide activities**
- **This project was facilitated in the pilot TEAL room in the Sanford Fleming building.**
- **Many more TEAL rooms are now available in the Myhal Centre for Engineering Innovation & Entrepreneurship**

Competition Profile

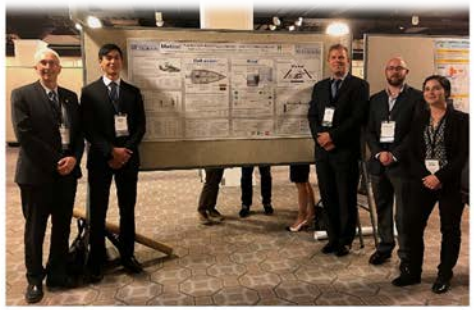
- **Host:**
  - **Department's of Energy (DOE) Hydrogen Education Foundation (HEF)**
- **2017-2018 theme:**
  - **Designing a Power-to-Gas System**
- **Competitors:**
  - **34 teams from around the world**
- **Prior history:**
  - **It is the University's third HEF award and first Grand Prize win.**
- **Grand Prize:**
  - **Presentation of the design at DOE's Annual Merit Review and Peer Evaluation Meeting (AMR).**

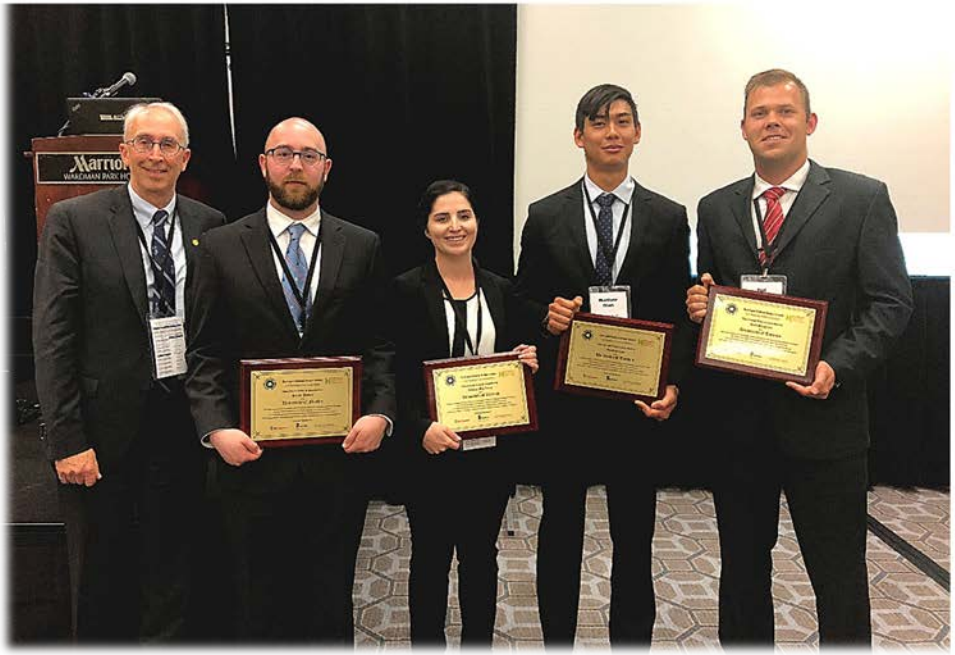
Redesigning the Iguana E-29 to Run on H_2

	Iguana	Motion+
Weight	2900 kg	1900 kg
Maximum Speed	74 km/hr	74 km/hr
Travel Range	135 km	450 km
Charge Time	6 hours	4 minutes
Operating Emissions	1063 tonnes	0 emissions



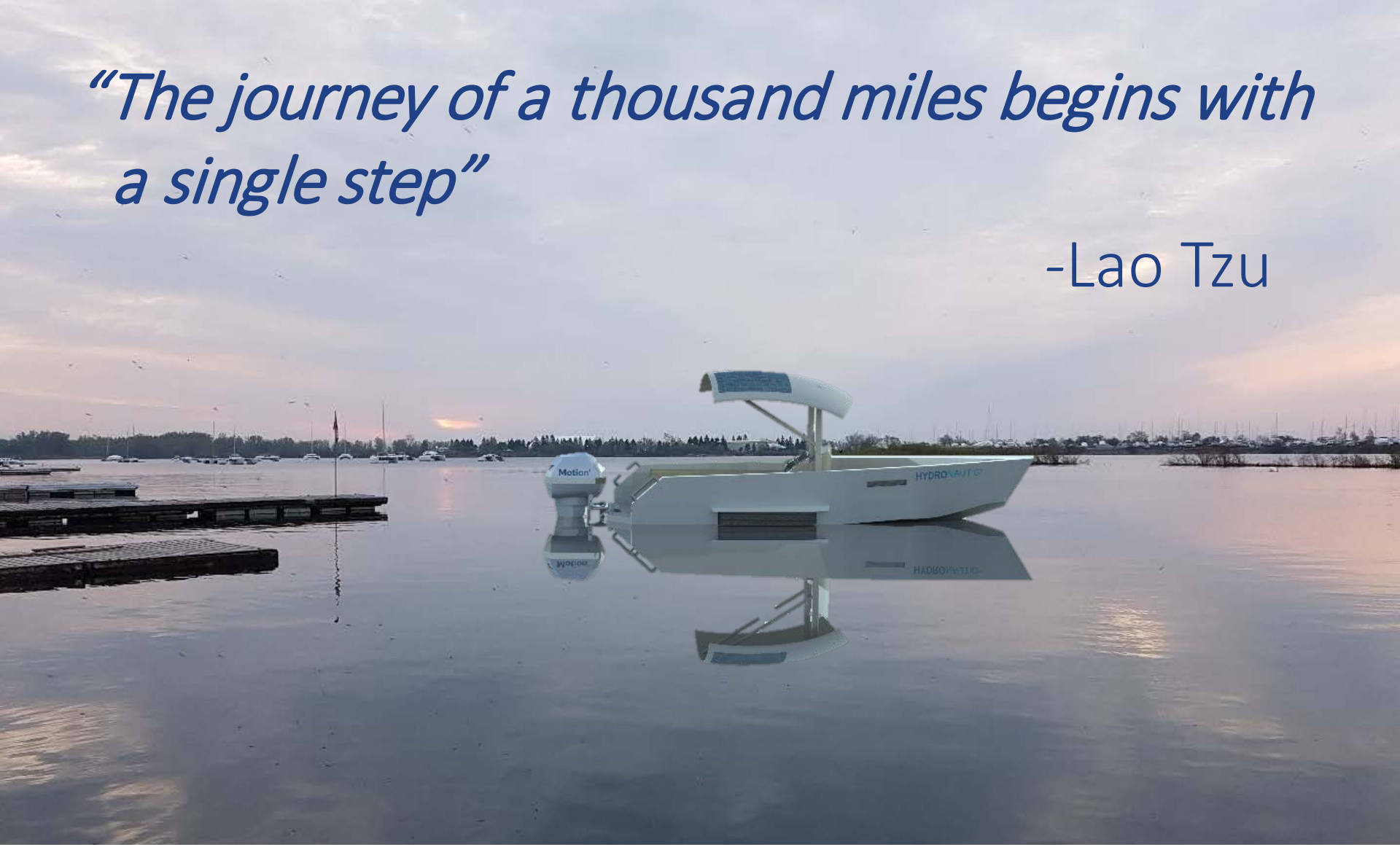
DOE's Annual Merit Review





"The journey of a thousand miles begins with a single step"

-Lao Tzu



The Hydrogen Education Foundation's Hydrogen Student Design Contest 2017: Designing a Power-to-Gas System www.HydrogenContest.org

UNIVERSITY OF TORONTO FACULTY OF APPLIED SCIENCE & ENGINEERING

Materials Science & Engineering UNIVERSITY OF TORONTO

Supplementary Slides

Recreational Boating Market

- **Market Size:**
  $125 billion/year
- **Opportunity:**
  Lack of zero emission options
- **Goal:**
  Design a zero emissions boat with a power-to-gas fueling station that utilizes off peak electricity from the grid
- **Approach:**
  Target the luxury yacht market that is able to sustain higher prices in return for improved performance

Redesigning the Iguana E-29 to Run on H_2

	Iguana	Motion+
Weight	2900 kg	1900 kg
Maximum Payload	800 kg	800 kg
Capacity	8 persons	8 persons
Maximum Speed	74 km/hr	74 km/hr
Travel Range	135 km	450 km
Charge Time	Battery: 6 hr Fuel: 1-2 minutes	4 minutes
Maximum ground speed	7 km/hr	7 km/hr
Operating emissions	1063 tonnes	0 emissions

An Amphibious Luxury Experience

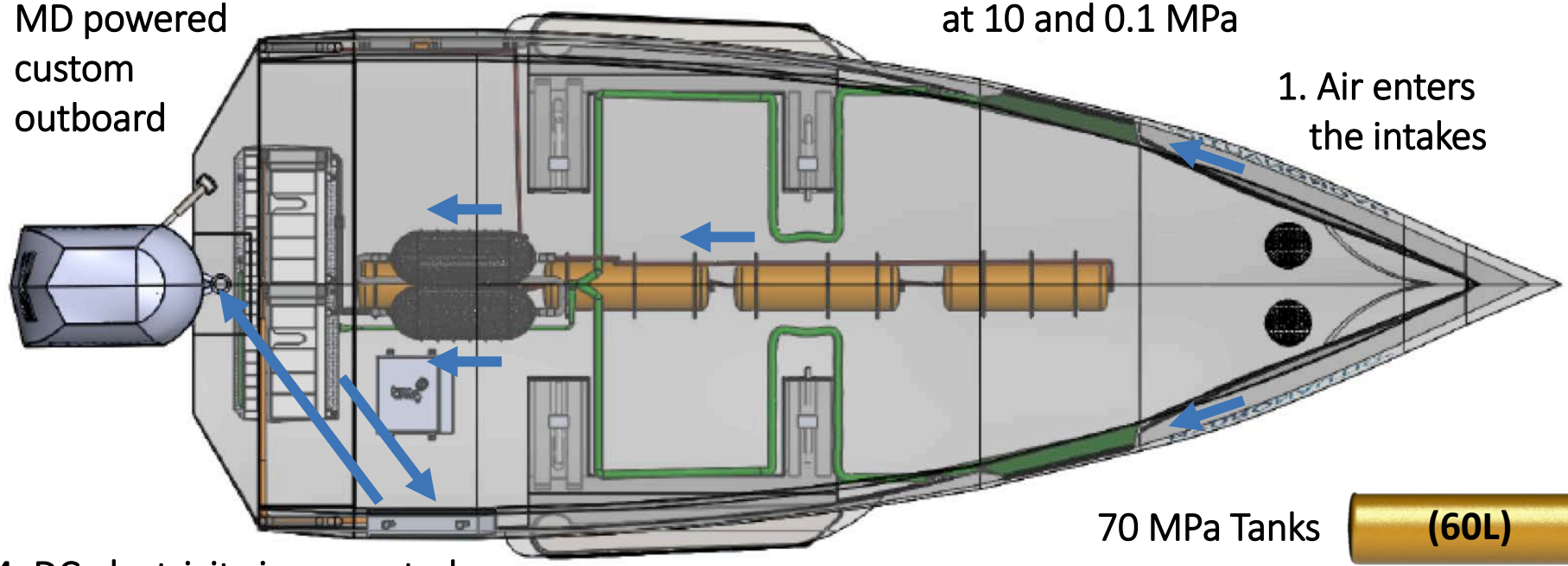
Hydronautic+

5. Driving the TM4 SUMO MD powered custom outboard

3. H_2 and air enter two Toyota Mirai fuel cells

2. H_2 flows from the 70 MPa to the fuel cells through a cascade at 10 and 0.1 MPa

1. Air enters the intakes

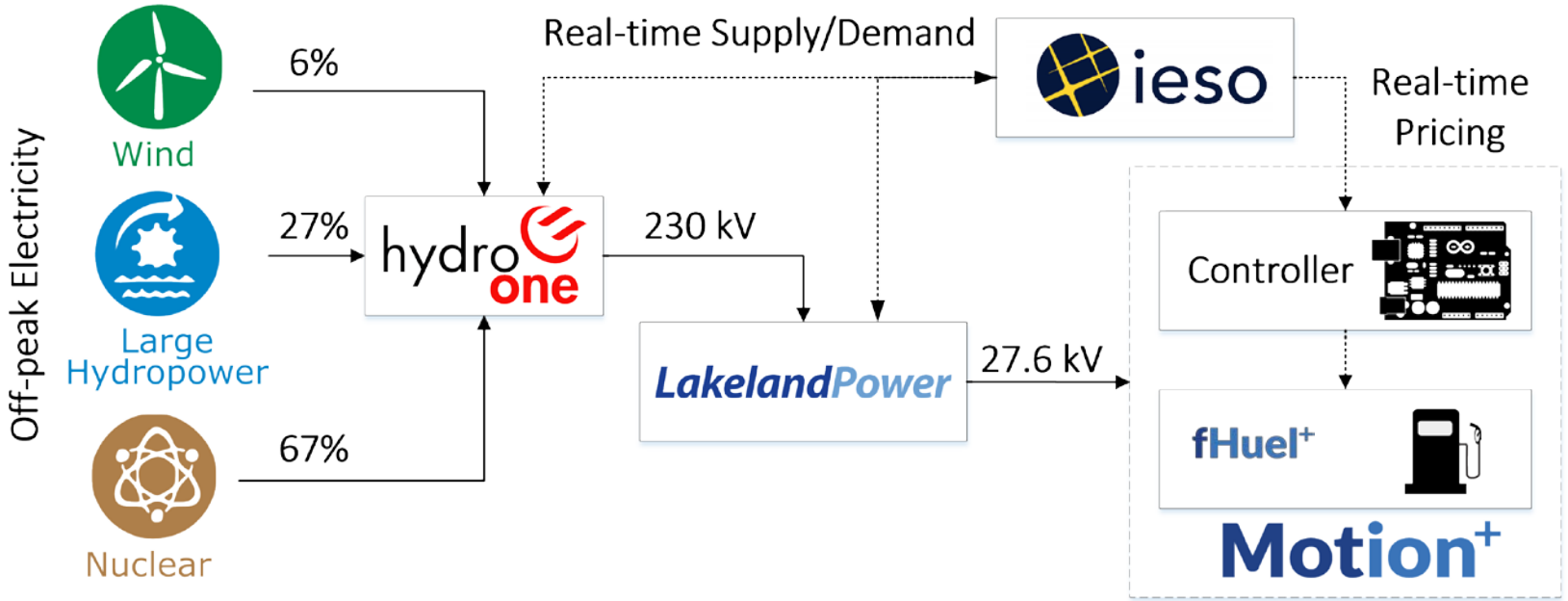


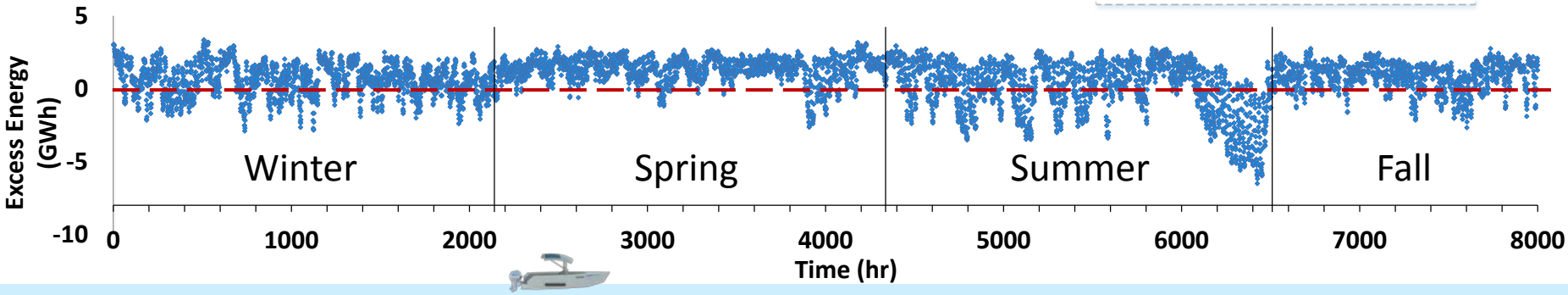
4. DC electricity is converted to AC by the TM4 Inverter

70 MPa Tanks (60L)

10 MPa Tanks (37L)

Motion+ Powered by Excess Renewable Energy

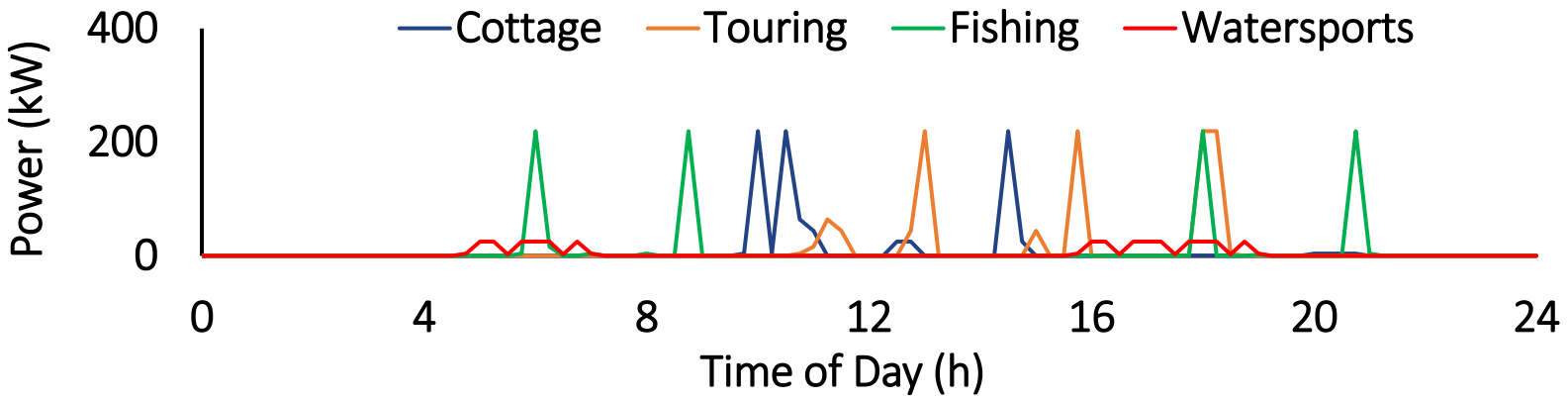




Energy Requirements per Day

Activity	Electronics Daily Energy Usage (kWh)	Motor Daily Energy Usage (kWh)	Total Daily Energy Usage (kWh)	Weight*	Weighted Usage (kWh)
Cottage	3.00	217.09	220.09	0.5	110.05
Touring	2.17	275.79	277.95	0.1	27.80
Fishing	2.39	229.35	231.74	0.2	46.35
Watersports	2.96	101.47	104.43	0.2	20.89
				Total	205.08

*Weights to account for the frequency of each scenario for a user



Refueling Dockside at the fHuel+ Station

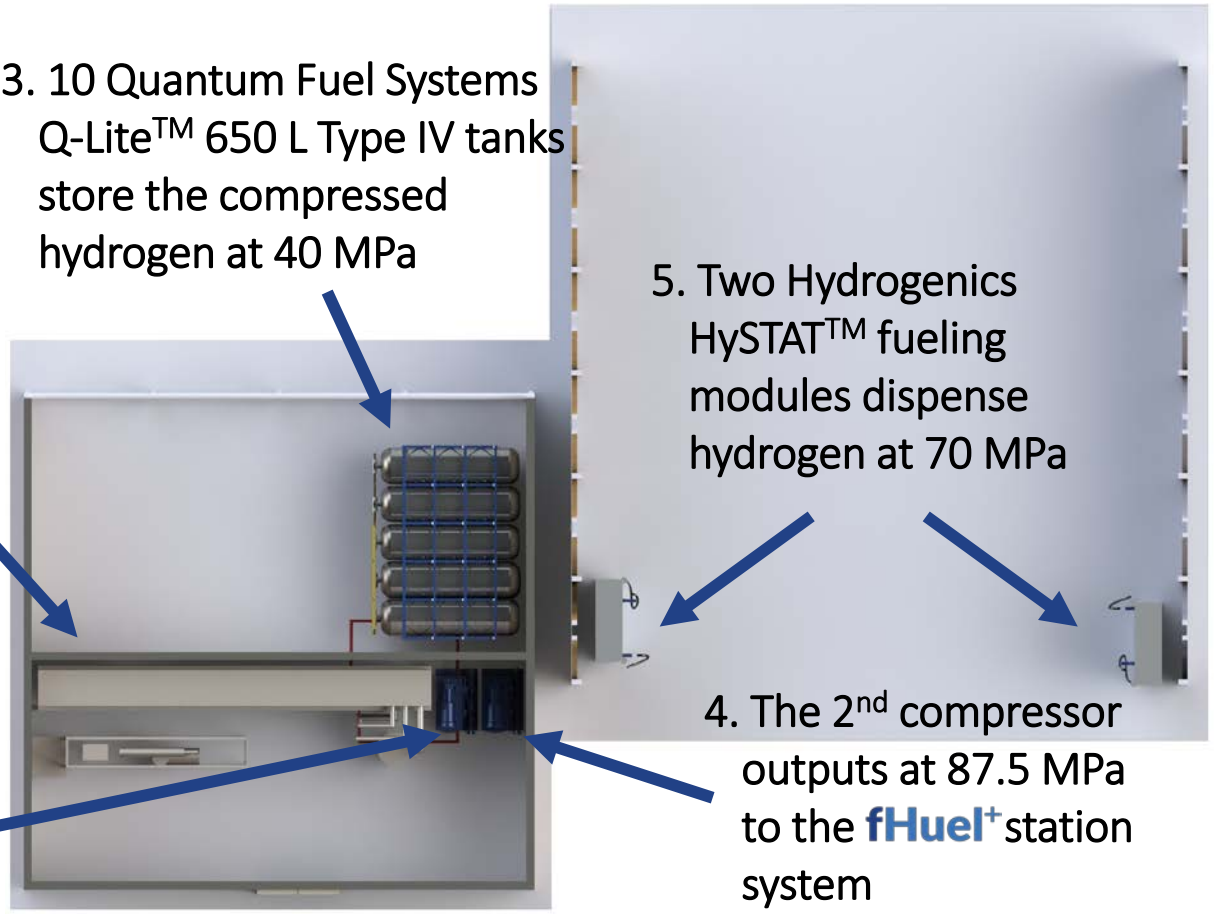
1. Proton On-Site M100 PEM Electrolyzer produces H_2 at 3 MPa

2. The 1st compressor outputs at 40 MPa to the tanks

3. 10 Quantum Fuel Systems Q-Lite™ 650 L Type IV tanks store the compressed hydrogen at 40 MPa

4. The 2nd compressor outputs at 87.5 MPa to the fHuel+ station system

5. Two Hydrogenics HySTAT™ fueling modules dispense hydrogen at 70 MPa

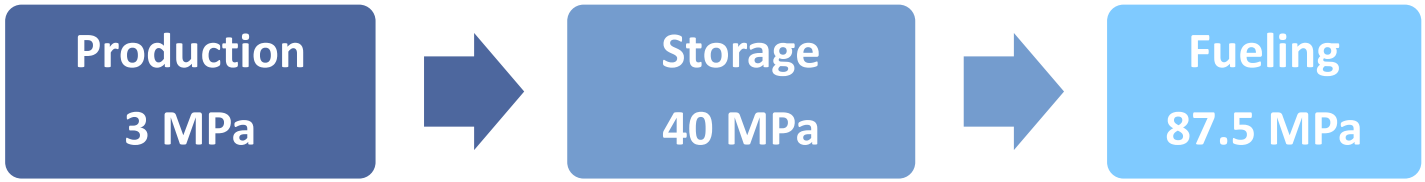


Refueling Dockside at the fHuel+ Station

Proton On-Site M100 PEM Electrolyzer

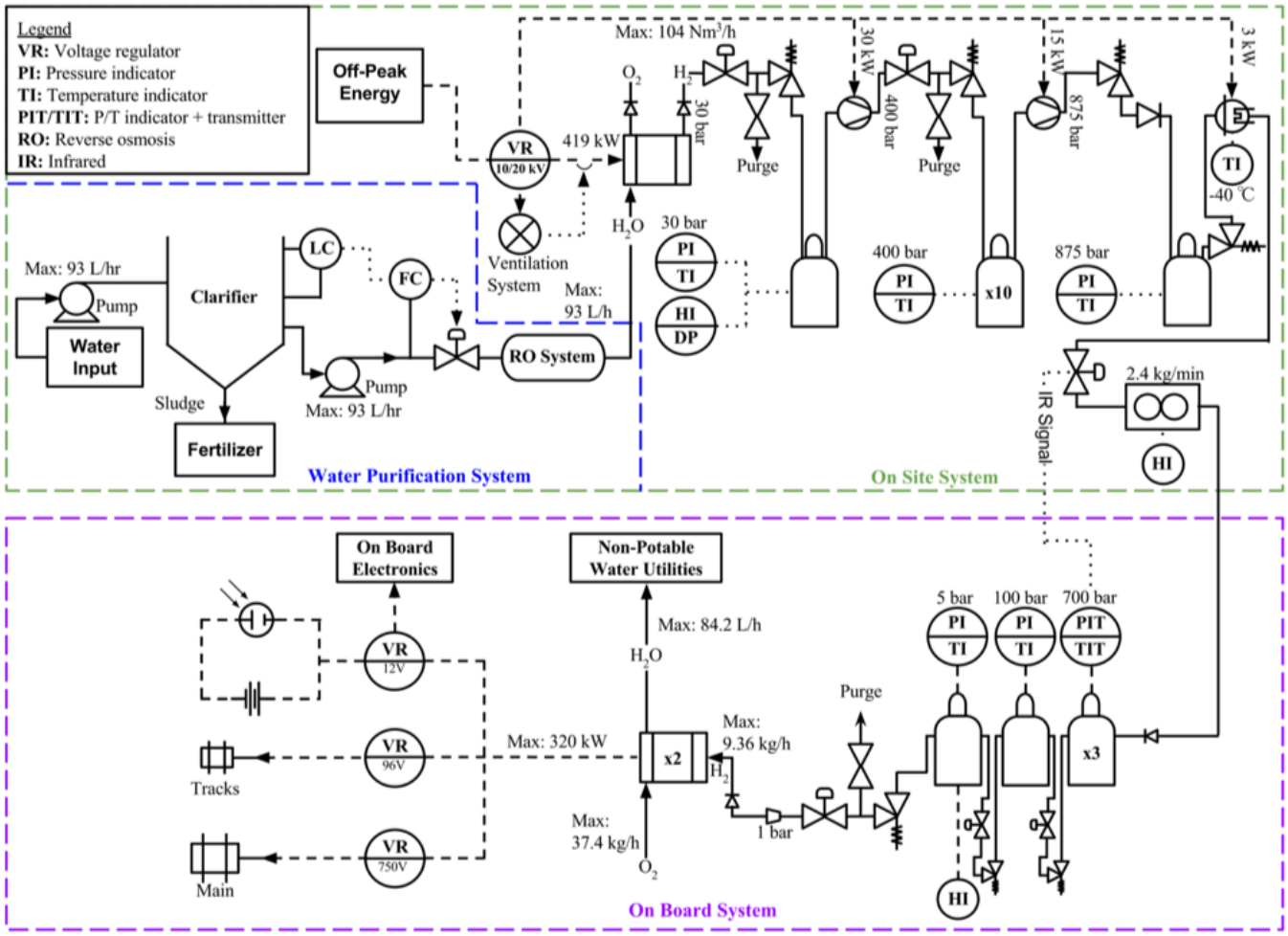
- **Enhanced with the FC-2178-HPA PEM membrane**
- **Power consumption improved from 59 to 45 kWh/kg**

2 stages of compression

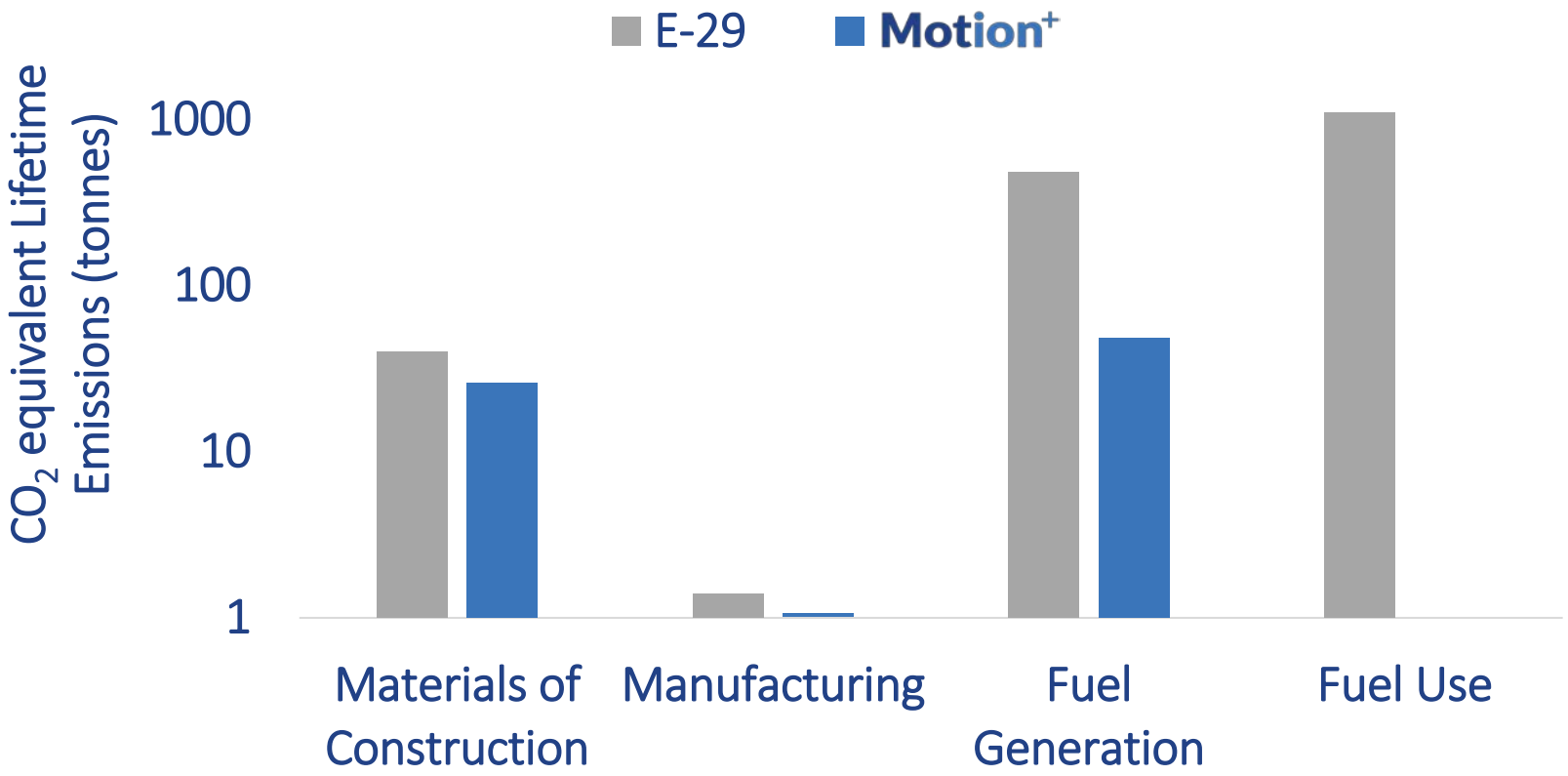


Storage in 10 Type IV Quantum Fuel Systems Tanks

Process & Instrumentation Diagram



The Hydronautic+ Reduces CO_2 Emissions Throughout its Lifetime



Key Emission Metrics for the Motion+ System Over its Lifetime

Metric	E-29	Motion+	Units
Total CO_2-eq Emissions	9,961	541	tonnes *CO_2-eq*
CO_2-eq/km Traveled	5.93	0.32	*kg CO_2-eq*/km
CO_2-eq/kWh Consumed	2.58	0.07	kg *CO_2-eq*/kWh
CO_2-eq /H_2-eq	13.40	3.42	kg *CO_2-eq*/H_2-eq

Our Business Model Involves a Strategic Partnership with the Marina

Motion+

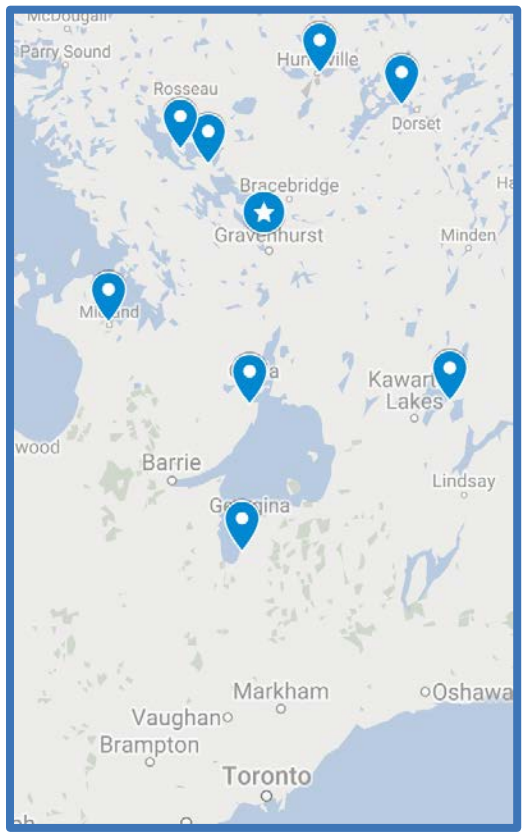
H_2 System Maintenance & Repair

Hydronautic+ fHuel+

Customer

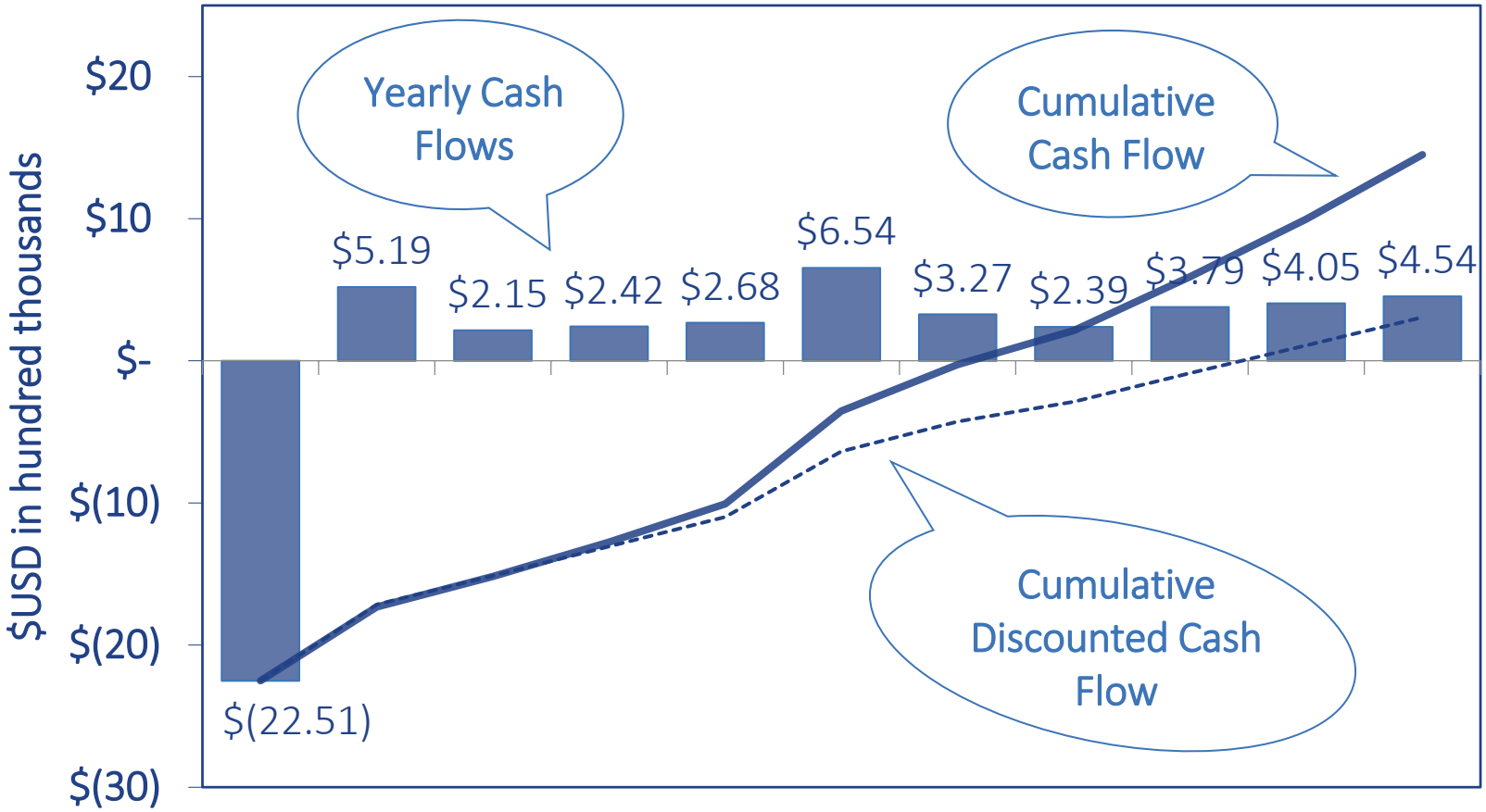
pride marine group

H_2 & Hydronautic+



Pride Marine Group locations

Payback Period: <6 Years



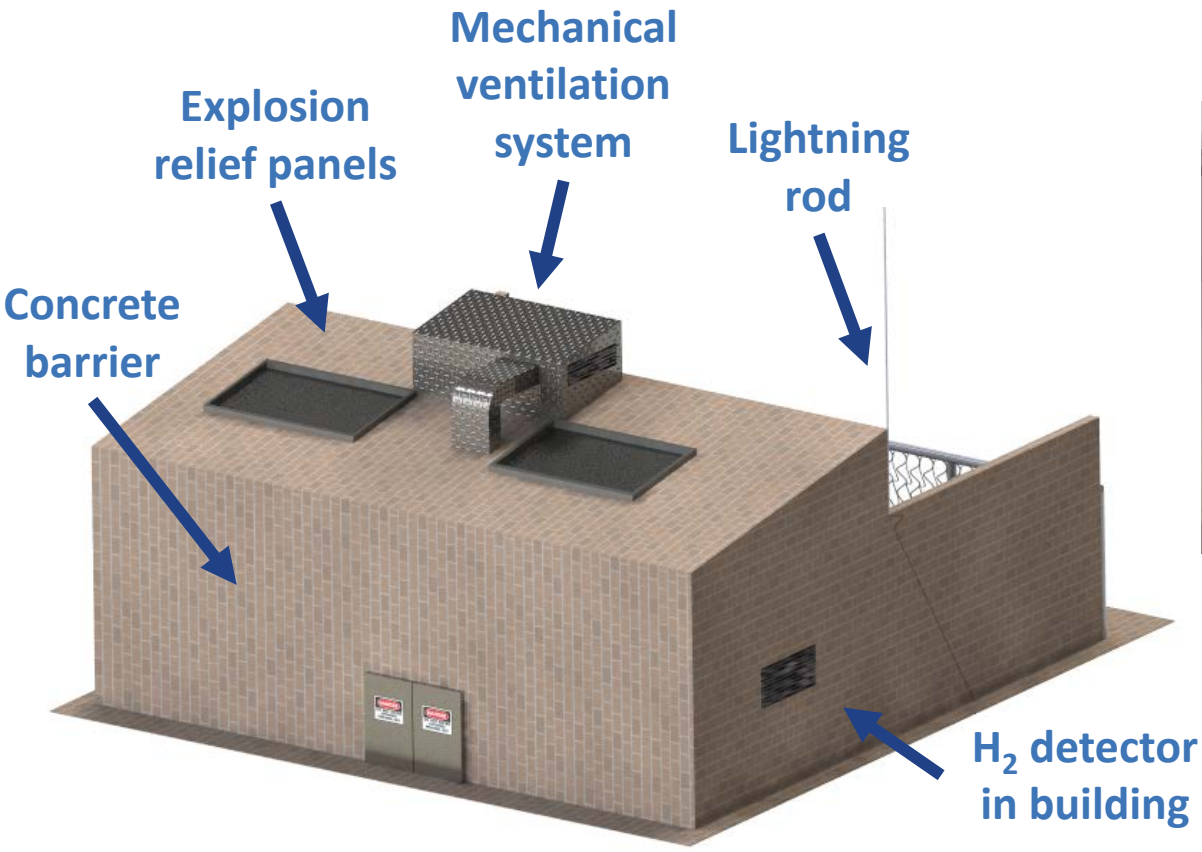
The Motion+ System is compliant with Local, Provincial, and International Regulations and Standards

Regulatory Stakeholders	Regulations/Standards
Township of Muskoka	By-law 214-14
Province of Ontario	Ontario Technical Standards and Safety Act, reg. 214/01
Fire Department	NFPA – 2; NFPA – 55
Design Standards Associations	CSA; ISO; CEC

Safety Risks – FMEA

Item	Failure Mode	Potential Effect(s) of Failure	Sev	Potential Failure Cause	Occ	Det	RPN
On-board H_2 storage	Overpressure	Release of H_2 into hull, potential fire or explosion	10	Thermal expansion of H_2	2	4	80
	Oxygen in tank	Potential explosion	10	Upstream purity affected	2	3	60
	Puncture/leak	Release of H_2 into hull, potential fire or explosion	10	Collision	1	4	40
Compressor	Leak/rupture	Release of H_2 into enclosure, potential fire or explosion	9	Mechanical failure	2	3	54
	Seal failure	Release of H_2 into enclosure, potential fire or explosion; O_2 ingress downstream	9	Mechanical failure	2	3	54

Customized Safety Features



Explosion-proof fans