Development of Marine Thermoelectric Heat Recovery Systems

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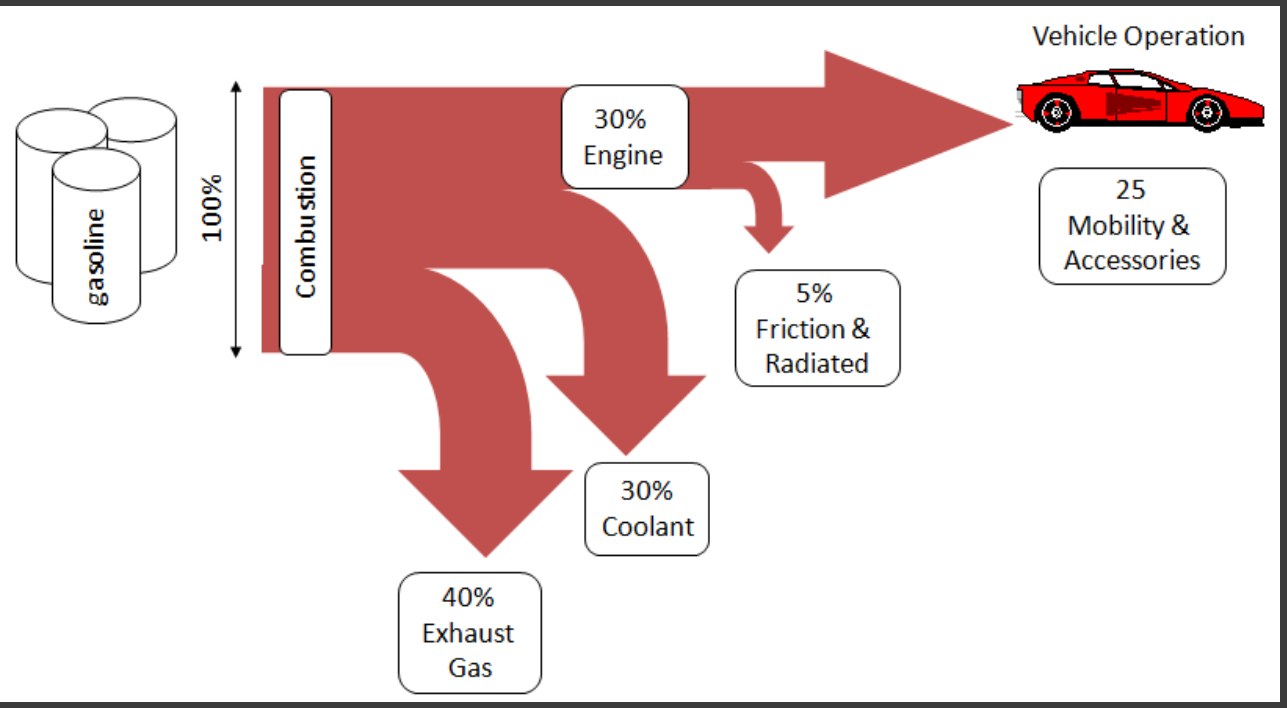
Topics of Discussion

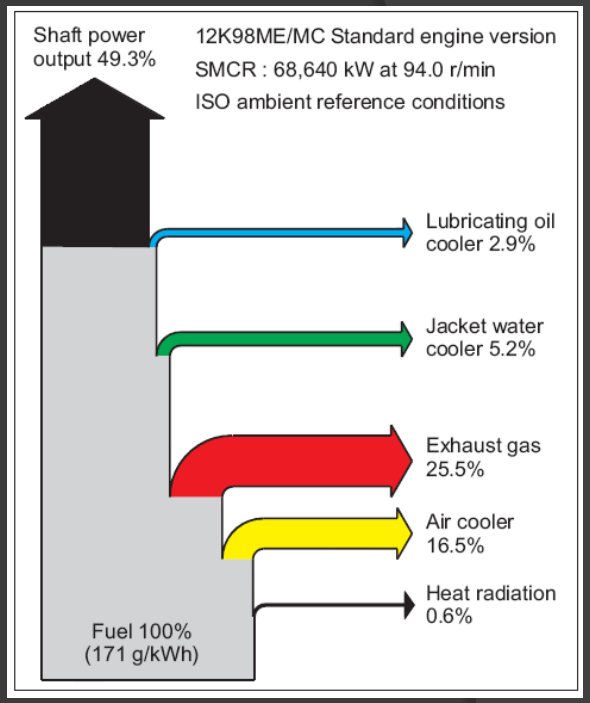
- **The expansion of thermoelectric applications to other industrial sectors, such as the marine industry, a potential significant beneficiary**
- **Societal and political need for thermoelectric materials in the marine industry today.**
- **Potential applications for thermoelectric devices on marine vessels.**
- **Achievements accomplished by our research program**

Same Problem, Greater Magnitude

- Have similar propulsion means, but marine has a much larger scale
- Larger Economies of Scale
- Heightened Port Restrictions and Engine Emissions Standards Imminent
- 90% of International Cargo Transported via ships

Comparing the Gasoline and Diesel Engine





Total Energy to Propulsion:

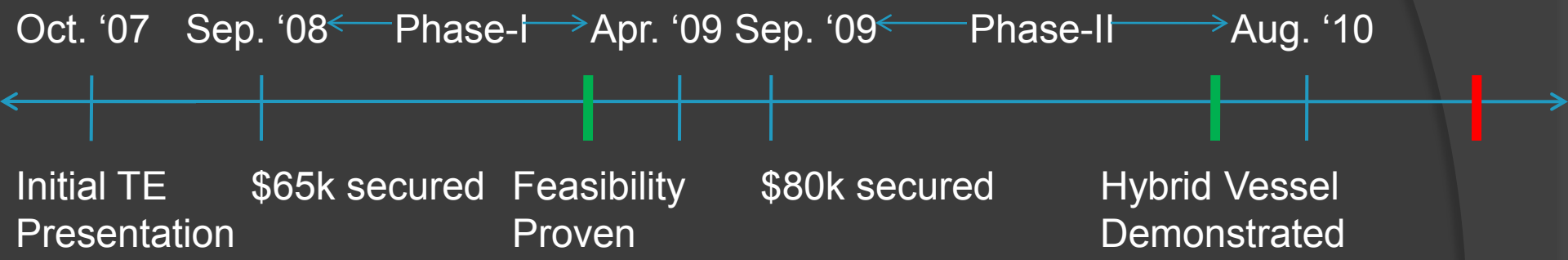
Automotive: 25%

Marine: 50%

Advantages of the Marine Industry

- Has the greatest consistent temperature differential
  - Exhaust and Sea Water
- The equipment is much larger and has greater throughputs
- No limitations on weight and space
- Has a myriad of potential waste heat recovery locations
- The ability to retrofit every vessel easily
  - Regardless of use of conventional waste heat recovery

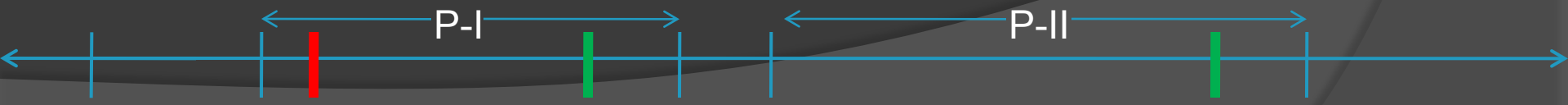
Project Timeline



- This bar shows the timeline our program has followed. It will appear throughout the presentation to demonstrate our progress.
- The green lines designate the milestone achievements in each phase
- The red line indicates date of milestone throughout the presentation

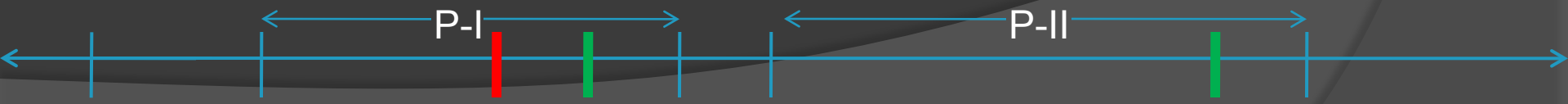
Phase-I Results

- Phase-I research began in 2008 to demonstrate feasibility of utilizing a thermoelectric generator in a marine diesel exhaust system
- A 180 Watt bismuth telluride thermoelectric generator was utilized during testing & evaluation producing saturated TEG output
- Our goal was to increase the overall plant efficiency
- Applied the technology on two prevalent propulsion systems in the marine environment; a diesel engine and a gas turbine

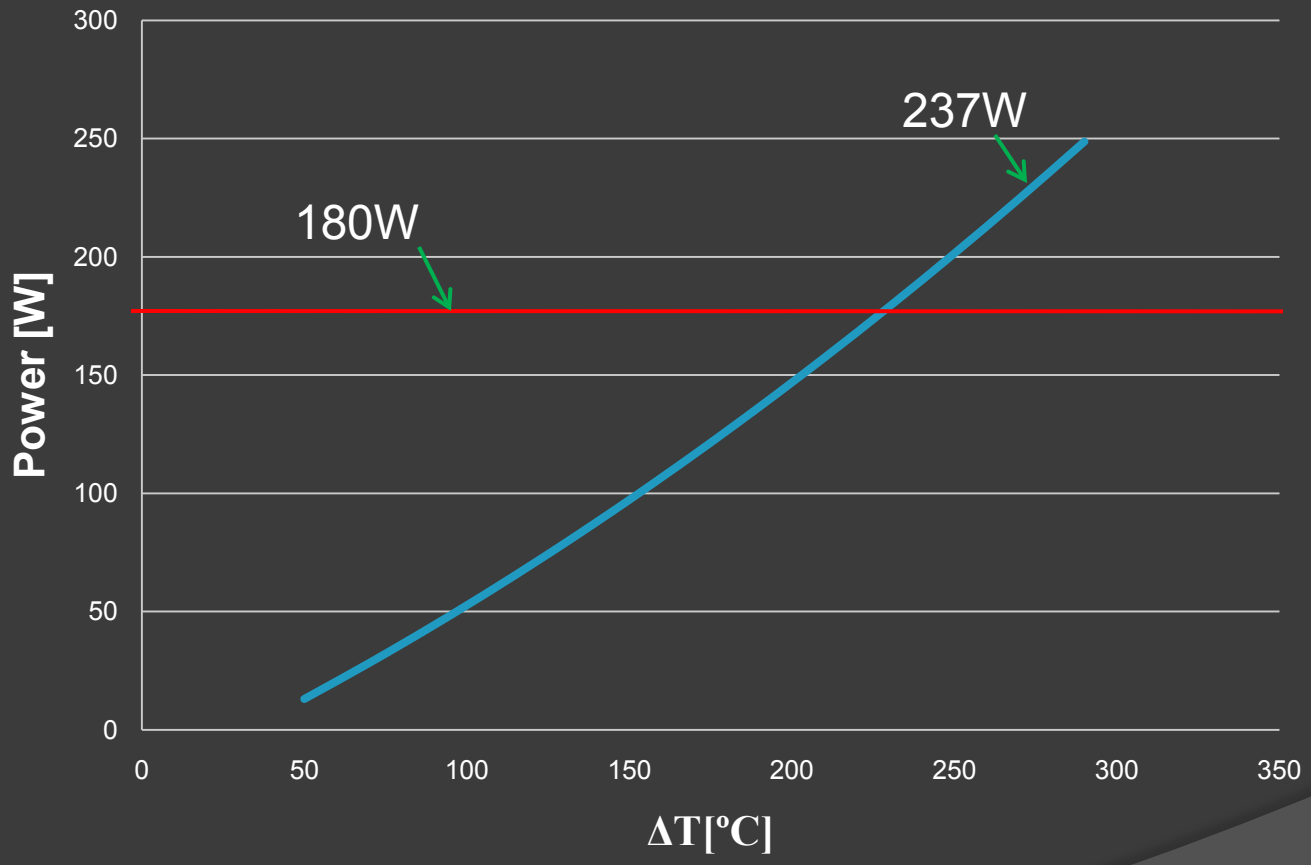


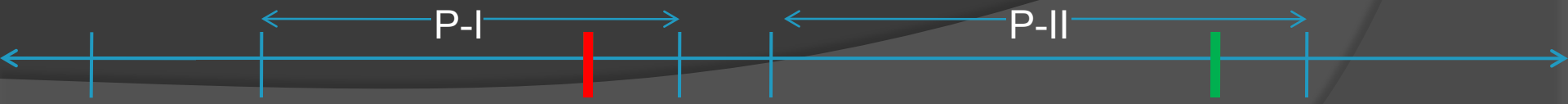
Phase-I Application
R/V *Friendship*

- R/V Friendship
  - 47’ Length (14 m)
  - 52 Gross Tons
  - Cummins NIC855 350hp (261 kW) Diesel Engine
- Engine comparable to semi-truck

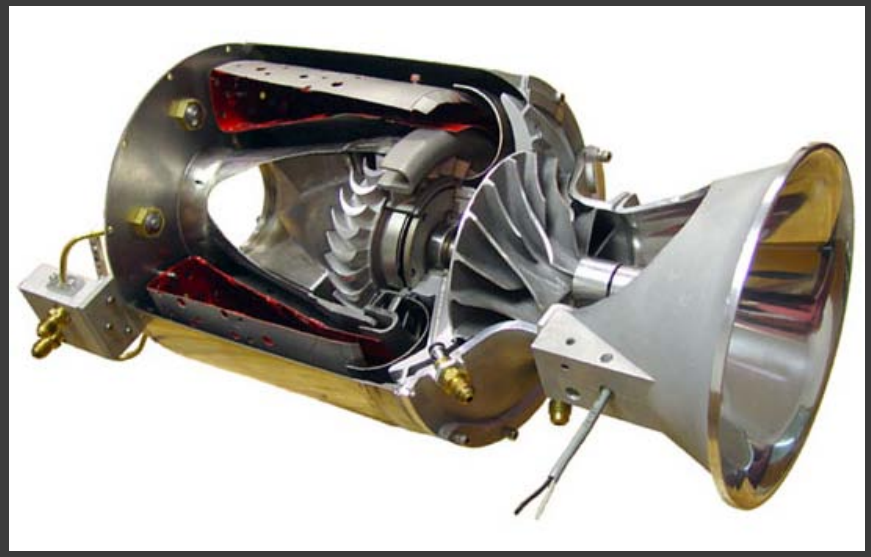


Marine Diesel Results



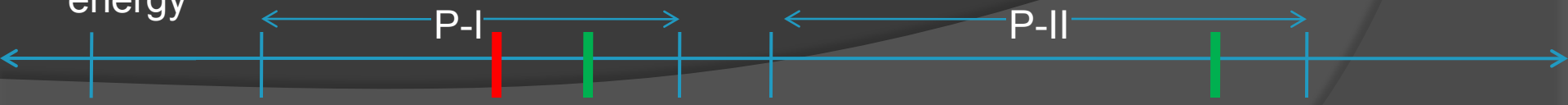


Phase-I Application
SR30 Microturbine

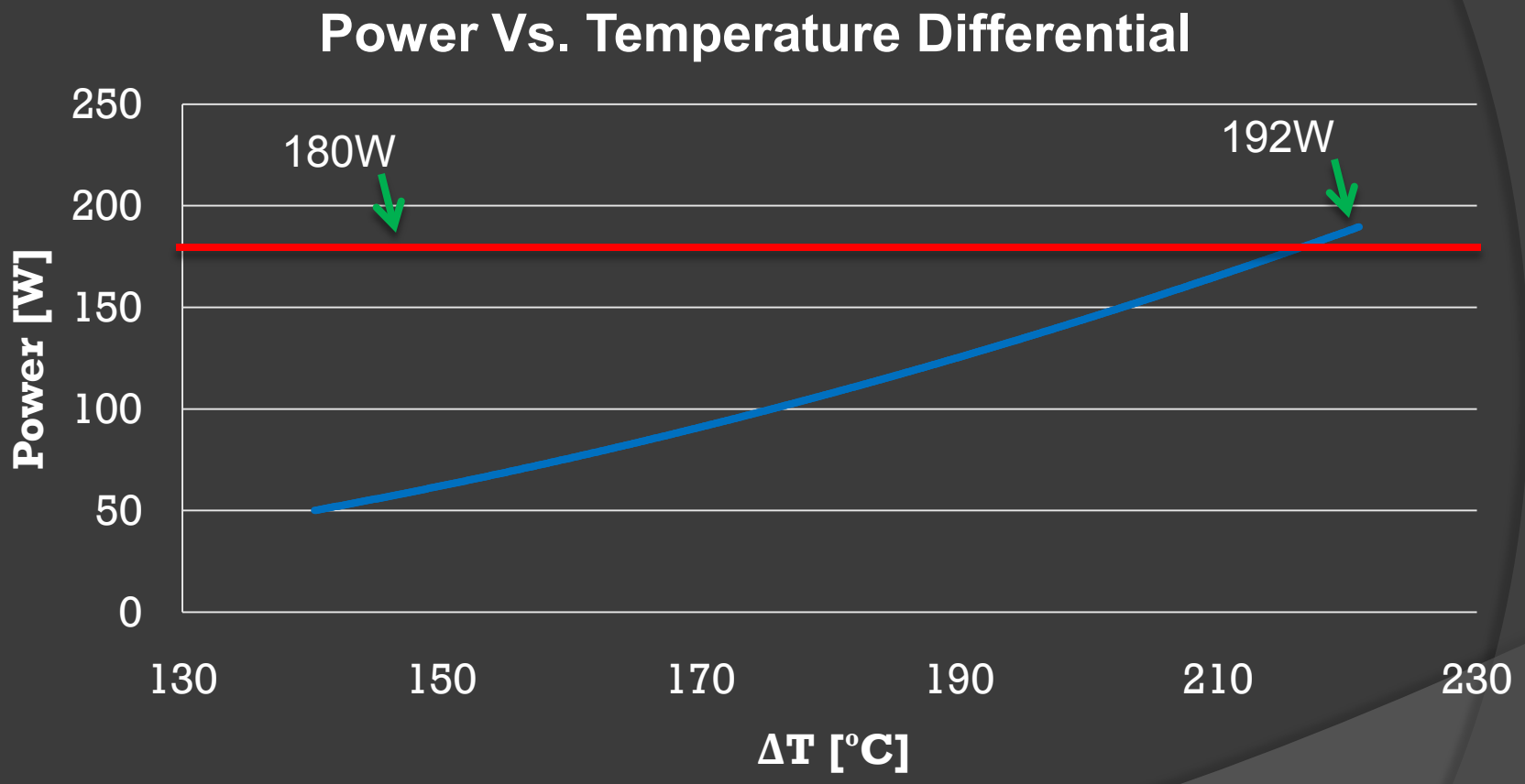


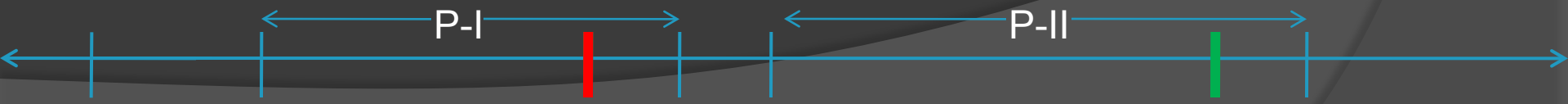
May not be many GTs in commercial ships, but almost exclusively used onboard modern military vessels

The thermal efficiency of a GT is much less than a diesel engine when used in a simple cycle, therefore has the potential of recovering a significant amount of waste energy



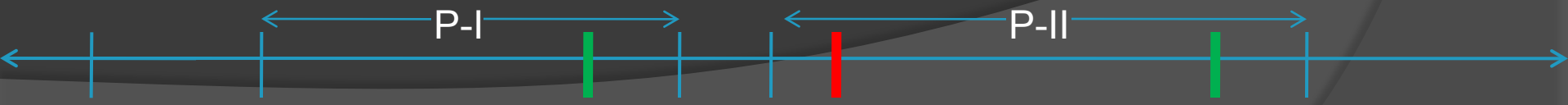
SR30 Results



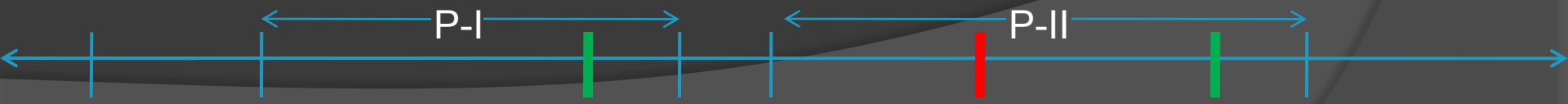


Phase-II Accomplishments

- In 2010 research expanded to include development of a first-of-its-kind marine diesel electric hybrid test platform
- Simulated and demonstrated a small scale diesel electric propulsion system while utilizing a 180 Watt TEG in parallel with a 27 kW diesel generator
- Converted a MARAD encapsulated lifeboat in Spring of 2010
- Resolved inverting DC voltage from TEG into AC and distribution onto the electric drive system

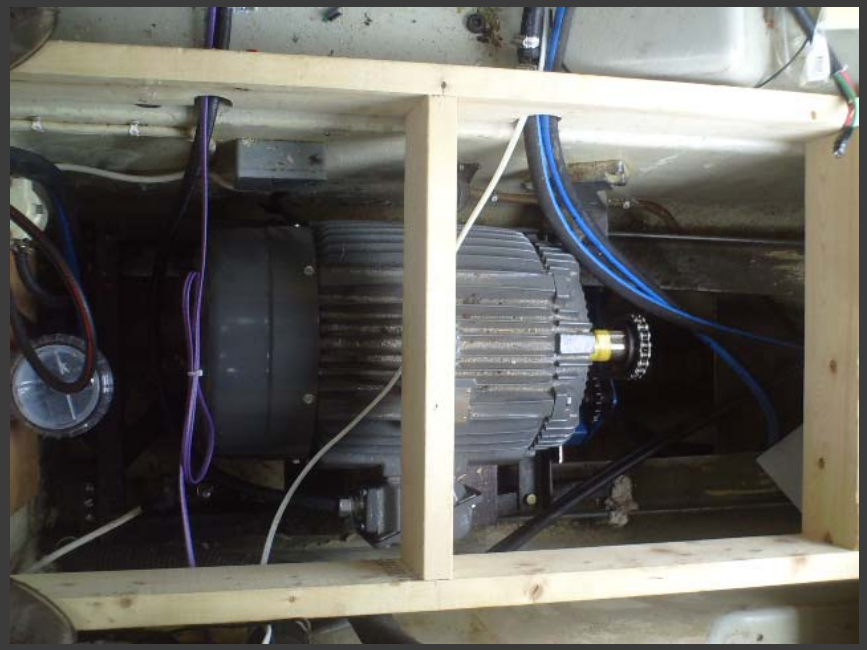


Phase-II Results

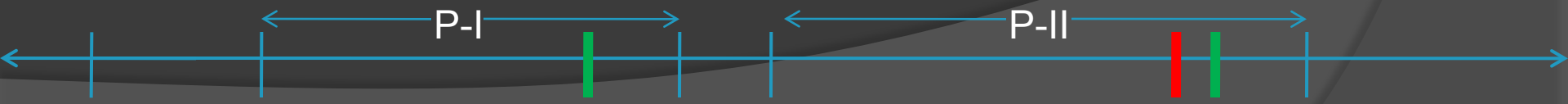


Main Components

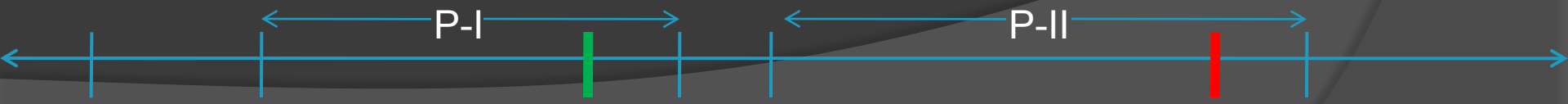
36 Hp (27 kW)
Caterpillar C2.2 Marine Genset



30hp (22 kW)
Induction Motor

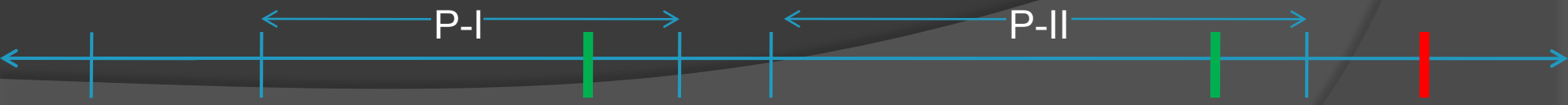

P-I
P-II

Project Success



Conclusions and Future Work

- Developed a hybrid vessel to serve as a dedicated test platform to evaluate effectiveness of TEGs
- Design and optimize a high power density TEG for the marine environment
- Using newer materials, test and evaluate optimized marine TEGs
- TPS intends to actively collaborate with engine manufacturers and leaders in TE field to expand TEGs into the marine environment



Slide Media Acknowledgments

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Acknowledgments

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