Electric Motors for MIT Crew

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Proposed by

UA Sustainability - Special Projects

MIT Environmental Solutions Initiative

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Dear Reader:

In 1902, eight freshmen from the class of 1905 borrowed a shell from the Union Boat Club to venture out onto the Charles for a practice row. Ever since, rowing has been an integral part of MIT's identity. Being the only Division 1 sport on campus and hosting one of the oldest and largest Fall Regattas, the Head of the Charles Regatta, rowing has become an integral part of MIT's culture and identity. With the threat of climate change, the electrification of MIT Crew's Launch Fleet program was conceived to lead a shift towards renewables within MIT crew, and hopefully spark a similar change in other facets of the MIT community.

We are proposing conversion of one safety motor boat, commonly referred to as launches, to an electric motor as a pilot program primarily between MIT Crew, UA Sustainability, and the MIT Environmental Solutions Initiative. The potential benefits of this trial are numerous. Electric launches are substantially quieter than their gasoline counterparts, reducing noise pollution for coaches, athletes, and those living on the river. Additionally, zero emissions means said groups aren't subject to toxic fuels, especially coaches and athletes who spend multiple hours each day in close proximity. However, converting to electric does not also mean a weaker engine--electric engines outperform gas engines on almost every metric.

Implementing motors are extremely easy and can be installed on any of the existing MIT Crew launches without modification. These new motors would be powered by MIT's cogeneration plant, which provides cheaper and cleaner electricity than the city's grid. With fewer moving parts, the motor is advertised as needing zero maintenance, and comes with a lifetime warranty as well as on demand in person technical support. Although all of these benefits come with a larger upfront cost, MIT will ultimately save money over the course of 25 years. With our group's subsidy, this motor becomes even more financially viable.

MIT Rowing pursues excellence and is a leader in the rowing community in terms of sporting and technology. To adhere to and advance our mission, our goal is to send a clear message to our team, school, and community that MIT cares about the environment, and it is willing to make the same forward thinking changes as many other programs on the Charles River. We hope that with your help, we can make this possible.

Yours Truly,

Christopher Noga ('23), Max von Franque ('22), Kabir Mohan ('24), Joshua Masuda ('24)

I. Coaching, Athletic, and Operational Benefits

Electric launch motors provide numerous benefits to almost everyone around the river. First and foremost, they are quiet. Although one may not think that gas outboards are that loud, at cruising speeds, MIT's current gas outboards can reach around 80 dbA, just shy of the Occupational Safety and Health Administration (OHSA)'s legal workplace limit for 8 hours of 90 dbA. Furthermore, precise communication is integral for a team's success--gas motors' noise is a high barrier against achieving this goal. By going electric, coaches will be able to concentrate and think in a much softer environment for the first time. They'll be able to make technical and safety calls without yelling over engine noise, as well as hear athletes speaking at a normal volume. With hundreds of athletes and recreational boaters on the river when MIT trains, being able to hear important safety information is crucial to ensure the safety of all on the river. Additionally, implementing quieter motors directly benefit those who live and work on or near the river.

Moreover, electric motors also have zero emissions. Standard engines are not currently required to have catalytic converters that would normally deal with harmful carcinogens, meaning that athletes, coaches, and others in its proximity inhale the toxic exhaust. Carcinogens are believed to cause cancer and contribute to such problems as asthma, heart disease, birth defects, and eye irritation. Gas motors, in some instances, emit the same amount of cancer-causing pollution as 125 passenger cars[1].

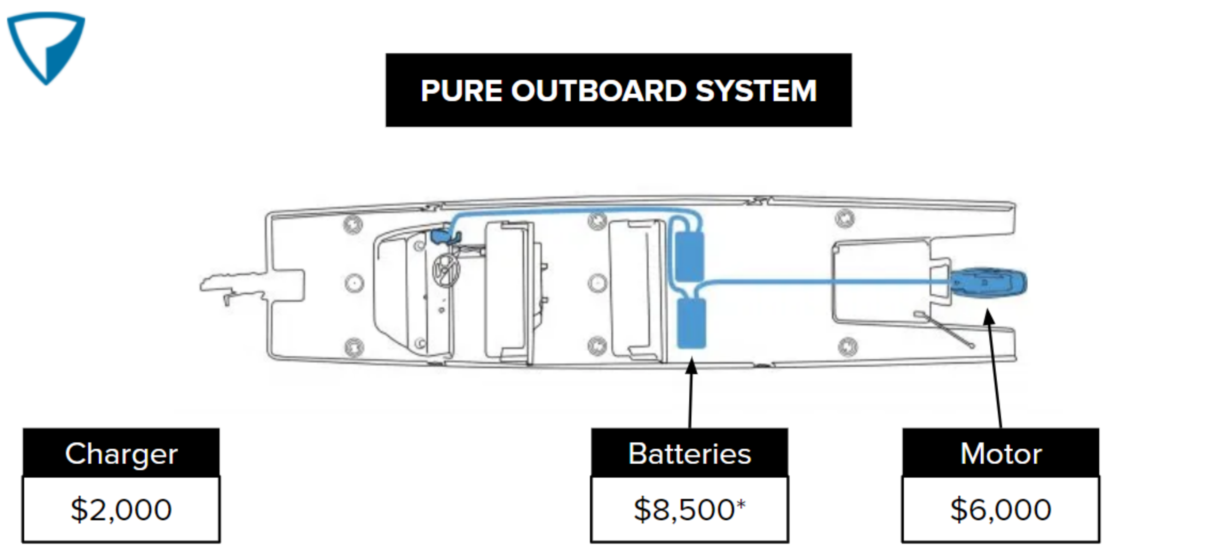
Performance wise, these motors have 40 HP, which is a significant upgrade to many of the motors used at MIT Crew (15hp). These motors are more than capable of keeping pace with a fast Collegiate V8 2K race. With fewer moving parts, electric motors are more reliable and require little to no maintenance by coaches or boatmen. If a part does break, the company has a technician on standby that can either help troubleshoot or come in person to fix any issues. Pure Watercraft is also hoping to add a local technician in the Boston area assuming enough colleges convert to their engines in the next few years. Lastly, these motors are built to last--they are good for 25 years, compared to the 8 year lifetime of a gas motor.

[1] Pure Watercraft

II. Technical Specs & Warranty

Pure Watercraft (PWC), the preferred company for this pilot, sells an entire electric launch setup. This includes an electric motor, 1-2 batteries, a throttle, and charging cable. While the entire system works with one battery, range can be extended with an additional battery. As we'll discuss later, we believe that 1 battery is sufficient for MIT. Battery levels and motor performances are displayed on the throttle at all times.

UA Sustain Special Projects in partnership with MIT ESI is working with electric launch frontrunner, Pure Watercraft brand electric outboards. Founded by MIT Sloan alum (and former coach at MIT Rowing), Andy Rebele, and employing other MIT grads, Pure Watercraft is a Seattle company based in South Lake Union that distributed its first round of electric outboards in the Spring of 2019. They design electric motors specifically for rowing and are considered the highest quality motors in the industry.



**Not including battery salvage*

The Pure Watercraft Electric launch system, configured with 1 battery, weighs 223 lbs, which is lighter than a typical 30 hp Mercury engine weighing in at 252 lbs. A two battery launch only weighs about 50 lbs more than a gas motor setup. If a hoist cannot sustain an additional 50 lbs safely, the batteries can be moved onto the dock and the launch hoisted safely without them. This motor works with any Stillwater Duo or Stillwater XL.

Furthermore, the launch's seakeeping ability will not be negatively impacted by this weight either. In fact, the battery placement can actually ballast the boat better than a typical stern heavy gas outboard set up, leading to safer and more stable operations in both calm and choppy waters. The battery can also be easily secured or free sitting on any typical launch deck.

With active thermal management, the batteries can easily withstand both Cambridge's rough and cold winters and hot summers. This technology alerts the system to warm up the battery during cold weather or cool the battery during warm weather, keeping it at the ideal operating temperature and increasing the battery's expected lifespan by almost 100%. All electrical components are watersafe.

The chargers are designed to operate between 90-250V. For the pilot, we recommend using existing 120V outlets, which can fully charge an entire battery in 8 hours. A 220V connection, which can be patched through the laundry machines or a separate connection, can fully charge the battery in 3 to 4 hours. We estimate that a full charge will be sufficient for both an AM and PM session, without charging in between. The University of Washington uses about 50% per long practice. Based on our practice schedule, even if the battery was empty after an AM session, there would still be sufficient time to fully charge the battery to full on 120V before the PM practice.

Battery Technical Overview and Safety Precautions

The batteries are made of lithium ion small cylindrical 18650 cells, which are also used in the Tesla Model S and X vehicles. PWC uses Panasonic's NCR18650bd series. All components are rated for IP 67 - which means they could be submerged up to a meter deep and stay waterproof for up to half an hour. The system has 2 redundant ways to check for safety through software and mechanical design. The software checks to make sure all connections are made before the system turns on high voltage, either in run more or charging modes. It also constantly monitors any changes based on resistance multiple times per second. For example, if a cable was unplugged, it would immediately shut down high voltage so the user is safe. There are automated switches inside the battery and outboard that control the flow of electricity, similar to the breakers in an electrical panel. Overall, the system and charger will not send any voltage or power through a system if it's not completely plugged in or if something goes wrong. This ensures the safety of both athletes and coaches.

Throttle

The throttle is shown in the image below. The display in the image shows a two battery setup. The information on the throttle screen will include percent charge left, time out on water, time remaining before empty, cardinal directions, and speed.

Warranty

PWC stands behind their product, with a warranty that will last the given lifetime of each of their products. While no official warranty is currently in place (the company is still figuring it out), PWC expects the warranty to last the length of the expected lifetime. They are committed to helping customers and will not leave MIT or any others without help. Their warranty will also be better than any gas motor warranty currently on the market, many of which don't offer a warranty at all. The quoted plan for warranties on their products are the following:

- Charger - 25 years
- Motor - 25 years
- Battery - 8 years or 1500 cycles

PWC will train coaches and boatmen in the installation, maintenance, and running of the motors. Installation is extremely easy, requiring at most a couple of hours. The new motor can simply be placed where the gas motor usually goes, and the cabling connected. In the event that an issue arises, PWC will stand by either by telephone or send their dedicated east coast technician to MIT to fix any issues. This is a direct service that does not require any third parties. Since the motors and parts are all easily shipped, replacement parts can arrive in a matter of days instead of the number of weeks it takes for gas motor parts. The service and dependability of PWC has been vouched for by Head Coach Sauer of the University of Virginia, with whom PWC has been testing their product with.

By directly working with the designer and supplier, MIT can eliminate costs and hassle associated with motor dealerships, cutting costs and out of service time. This also frees up time for the MIT Boatmen to focus their efforts on other items.

III. Coaching Testimonials

Kevin Sauer, Women's Head Coach
University of Virginia

University of Virginia (UVA) Rowing is actively testing out multiple different non gasoline motors in hopes of converting their fleet. During a brief phone call with Kevin Sauer in Spring 2020, the head women's coach at UVA, we discussed his experiences with PWC's electric motors. UVA was one of two teams (the University of Washington was the other) that was given a Beta version of the PWC system to test.

In over 4 years of research and working with PWC, Coach Sauer has found PWC's motor to be the best option available. Since PWC's owner was a former rower, Coach Sauer believes they understand what crew teams need from their motors every day. He believes that the company is highly motivated to create an excellent, dependable product because of the large demand for electric motors from the bass fishing industry.

The biggest issue he has had with the motor so far is the software. Since the product is still in testing, technical issues are to be expected. As of Spring 2021, many of these issues have been resolved. He appreciated that all the issues he highlighted were received, worked on, and fixed by PWC. Much of the software fixes can be done remotely and updated via the internet, similar to a Tesla car updating firmware.

According to Coach Sauer, the hardware, including the motor, battery, and charger, work great. With a solid foundation in hardware, PWC is working to add outlets to the battery, allowing lights, cox box batteries, and phones to be charged on launch. Combining this with the power and speed provided by the motor makes PWC's current setup vastly superior to its gas powered counterparts.

During testing, Coach Sauer found that a large Stillwater XL launch can hold five people and still travel at 18 mph. With 3 people, they could travel at around 22 mph. All this was achieved with one battery instead of the recommended two battery setup. The range is great-- the team is able to get through two practices a day while charging in between and overnight on a 120V charger. UVA is investing resources in upgrading to 220V hopefully by the upcoming fall season, and Coach Sauer has recommended that we aim to do the same.

Despite the few software issues that PWC was actively working on fixing before releasing their product, Coach Sauer spoke extremely highly of the company and the product.

Josh Gautreau, Women's Rowing Assistant Coach
University of Washington

Coach Gautreau has been testing the motor for the University of Washington. He has tested various electric motors, including Torqeedo, for a little over a year, and has concluded that PWC's motor is by far the best in terms of performance and reliability. In a call with Coach Gautreau during Spring 2020, he noted that PWC's motor "is absolutely perfect for coaching". He found that the Stillwater XL 25 launch with the electric motor and wakeless hull is a perfect pairing and a game changer when it comes to the experience for both the athletes and the coaches on the water.

Charging the launches has been simple and quick, even with their 120V charging source. The battery lasts for a 2 hour 20-24 km session. They have also tested the launch in very rough water and windy conditions, and it performed great. In his experience, every other electric setup he has used had trouble functioning in rough water and windy conditions.

There were some issues that Coach Gautreau highlighted. The one he uses has a tendency to "fault" once or twice every outing. When it faults, it requires a restart which is fairly simple, and takes 3-5 seconds**.** He describes this more as an inconvenience than something that affects practice. PWC has data recorded from all of their sessions and error codes for why faults are happening. They found that the "faults" stemmed from software issues and have been using this data to update the programming of the motor (As of Spring 2021, this is fixed). PWC has expressed a desire to have a fully dependable engine before releasing the final version to the public. In his experience, one of the common faults is tripping the torque sensor, which happened only during big wakes while under power or suddenly turning under power. This is clearly a safety parameter on the engine that is being adjusted.

Another concern was the throttle design. It was light thin plastic, did not feel durable, and small throttle adjustments are very jerky. This is another issue that PWC has been working very hard on and the design has since changed.

Aside from these issues with PWC software and finishing touches, he is very happy with the motor's performance and with PWC.

IV. Environmental Benefits

MIT Crew is one of the biggest polluters of all sports at MIT. Each year, we estimate that MIT Crew's launch fleet consumes 784 gallons of fuel per year[2] and releases 6.97 metric tons of CO_2[3] per year. That's not including the variety of other harmful emissions that these gas burning motors produce. Switching to electric motors would drastically reduce MIT's amount of Greenhouse Gas (GHG) emissions per year. On average, a single MWh distributed in Cambridge, MA produces 861 lbs of Greenhouse Gases (GHG)[4], which is well below the national 1220 lbs / MWh average in the United States[5]. However, the electricity that would be used to charge our zero emissions fleet would be much cleaner, since it would come from the MIT Central Utility Plant (CUP) and not from the local grid. The MIT CUP is a cogeneration plant, meaning that it produces both electricity and heat. Cogeneration operates at 65-75% efficiency, a large improvement over the national average of ~50% for these services when separately provided[6]. Currently, electricity produced at the MIT CUP emits around 687 lbs / MWh[7]. After its upgrade is completed, the MIT CUP expects this number to fall below 550 lbs / MWh in 2022[8]. It is anticipated that MIT-generated electricity will continue to be less carbon intensive than grid-supplied electricity for the entire planned life of the new power plant, even given the required state increases in the grid renewable energy standards over the next 20 years. This means that for the next 20 years, the electricity powering our launches will be cleaner than the state's, reducing the environmental impact.

Fueling launches also have the potential to have drastic negative effects on the environment. While an oil spill has not happened at MIT Crew yet, it is always a possibility. This can happen if there is a loose fuel cap on the movable fuel tanks that are frequently swapped on each launch. According to the MIT Environmental Health and Safety (EHS), spilling just a single drop of fuel requires thousands of dollars to clean up and requires multiple third-party companies to be hired

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2 EPA Gas Equivalency Calculator
3 0.25 gallon = 1 kWh (Assumption B16)
4 ISO New England https://www.iso-ne.com/static-assets/documents/2019/04/2017_emissions_report.pdf
5 US Energy Information Administration *https://www.eia.gov/state/?sid=MA*
6 Office of Energy Efficiency & Renewable Energy https://www.energy.gov/eere/amo/combined-heat-and-power-basics
7 Single Environmental Impact Report – MIT Central Utilities Plant Second Century Project
8 Single Environmental Impact Report – MIT Central Utilities Plant Second Century Project

and clean the spill, regardless of how small a spill might be. That means every time a fuel can is moved or swapped, MIT is vulnerable to huge amounts of environmental and financial damage.

Further down the line, we hope to install solar panels on top of the boathouse. These panels would both reduce the cost of electricity, and be significantly cleaner. With the boathouse being on the river, there is little shade and ample sunlight. While this would require extensive funding and be a separate project altogether, it is the logical next step.

V. Economic Analysis

Overview: Single battery electric launches cost less over 25 years and are cheaper than gas engines in under 8 years with the stipend proposed. UA Special Projects is looking at the following two options based on available funding. We recommend Option A .

Option	Range	# of launches	Includes	Cost
A	Short	1	Motor (1), Battery (1), Charger (1)	$16,500
B	Long	1	Motor (1), Battery (2), Charger (1)	$25,000

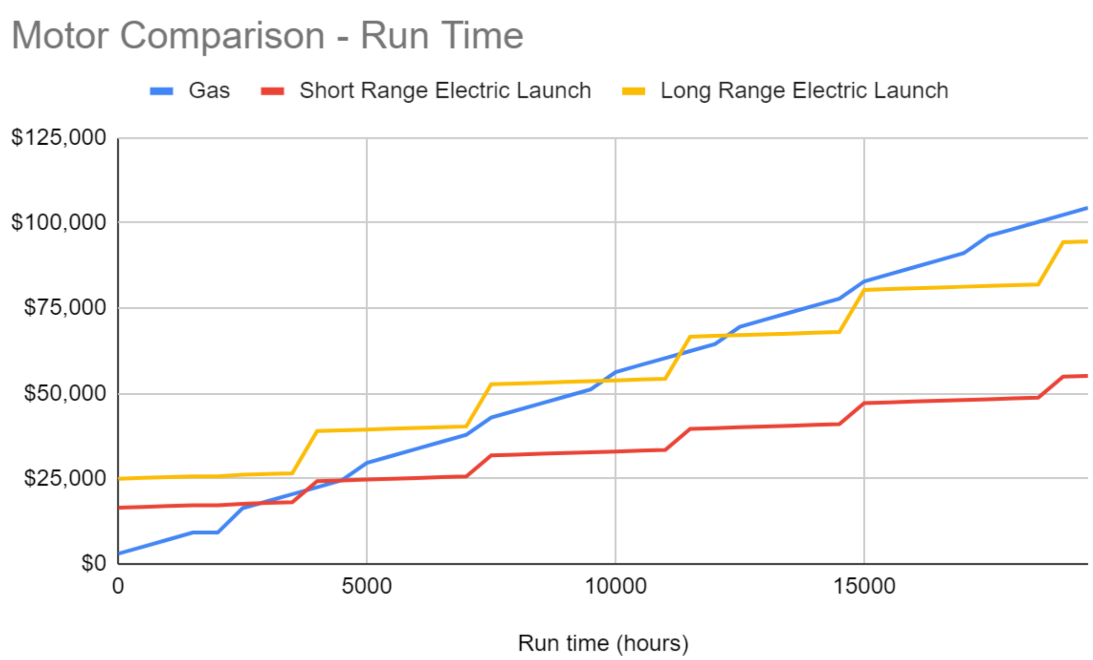
These costs break down to $6,000 for a 40hp Outboard Motor, $8,500 for a single 8.8 kW Battery, and $2,000 for a charger[9]. An XL requires two batteries for more reliable operation, but can also function for less time on a single battery as noted by the testimonial from Head Coach at Virginia. One charger can charge multiple batteries.

We ran two comparisons to test gas motors against a single motor with 1 battery (Option A) and a single motor with 2 batteries (Option B). The first comparison considers motor hours as our time metric, the second considers years as our time metric. In both scenarios, without our provided subsidy, our electric motors are cheaper over 25 years. Adding in our subsidy, our electric motors save substantially more money.

[9] Pure Watercraft, Assumptions A9, A10, A11

Time Based Method

Comparing motor hours as a time metric essentially shows what happens if we ran both gas and electric motors against each other continuously. This only factors in the cost of replacing either a gas or electric engine, replacement (without salvage refund) of a battery, and price of gas ($2.75 / Gallon) and electricity ($0.13 / kWh[10]). This does not take into consideration any maintenance and parts required to maintain a gas motor. This also does not consider a boatman's time fixing gas motors, or driving to get gas. We define short range launch as having one battery and a long range launch having two batteries.

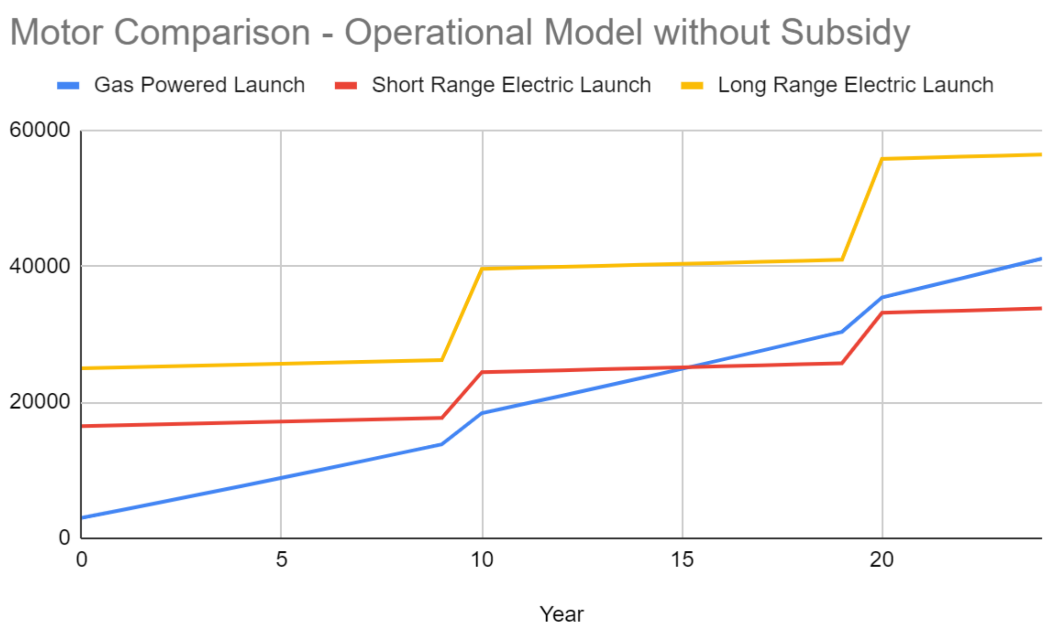


Here, we see that overtime, both a short and long range launch cost less to operate. The large jumps represent purchasing new gas motors or new batteries.

[10] MIT Central Utilities Plant

Operational Method - Without Subsidy

More relevantly, we look at gas versus the two electric motor configurations during normal operations at MIT. Again, we are only considering the cost of motors and batteries. We are not considering battery salvage, parts, maintenance, or salary. Here, we add a few more assumptions, including a typical practice is 2 hours and a team practices approximately 140 times per year[11]. Based on our previous assumptions, this means that a gas motor costs approximately $4.13 per hour, while an electric motor costs $0.46 / outing. Graphically, it looks as follows:

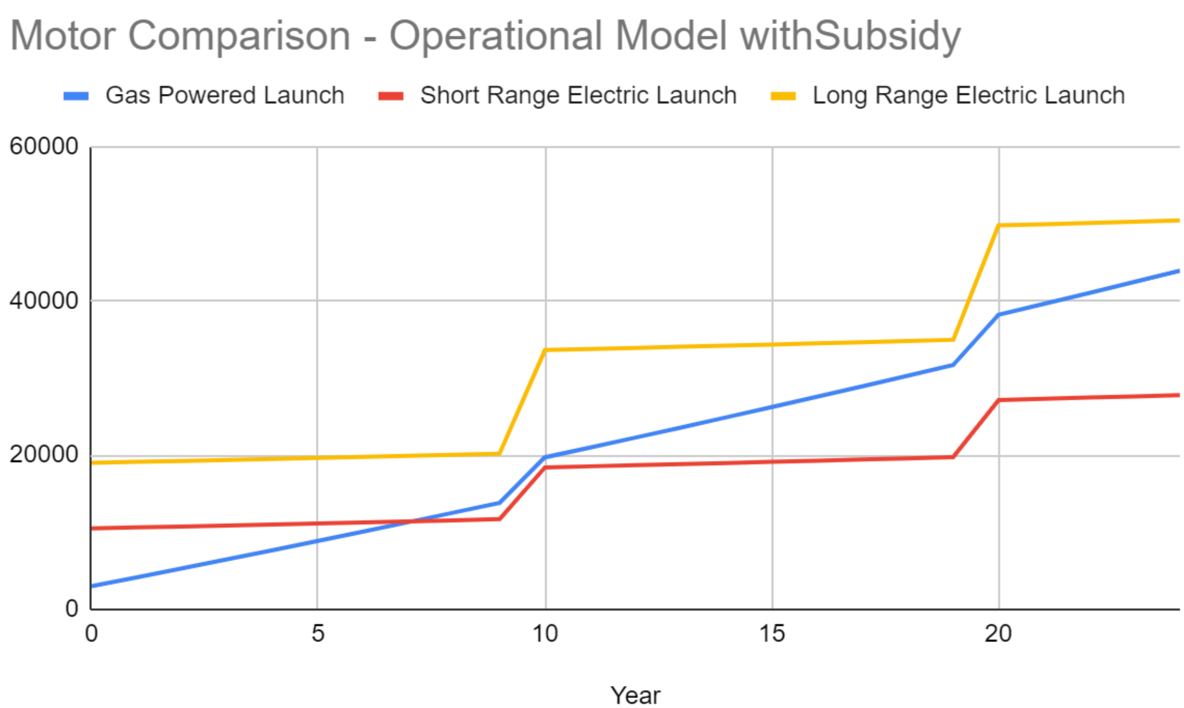


We see that after 15 years, a short range launch costs the program less money.

[11] Based on the MIT Heavyweight Crew Training Plan 2019-2020

Operational Model - With Subsidy and Salvage

UA Special Projects has been hard at work fundraising to help offset the cost of the initiation motor. So far, $8,000 has been raised (see Fundraising specifics), which will be used to purchase the charger and motor. The remaining $8,500 for the battery is still unfunded. With this subsidy, and now considering battery salvage[12], we see the following:



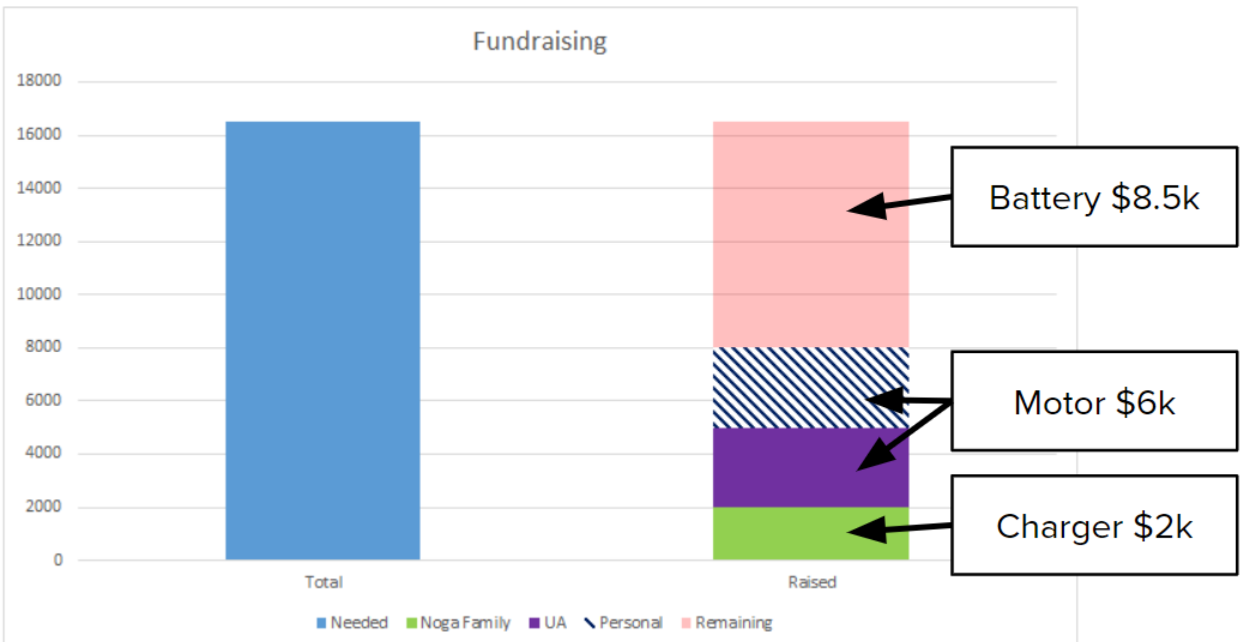
Here, we see that after 7 years, the short range launch becomes cheaper.

[12] PWC Estimates it to be 30%

VI. Fundraising

UA Special Projects have so far raised over 8.5K. This includes:

- 3K from UA Special Projectsas part of the special project's operating budget
- 2K gift from the Noga family
- $750 from Chris Noga UROP Funding
- $750 from Max von Franque UROP Funding
- $750 from Kabir Mohan UROP Funding
- $750 from Joshua Masuda UROP Funding



Because of numerous conflicts with the Alumni Fund, unfortunately none of the money could come from alumni. With MIT Crew's permission, we would be willing and excited to lead an online fundraising campaign with all alumni, not just crew alumni. We believe that our project will not necessarily detract from alumni donations and President Reif agrees with this sentiment, saying that fundraising campaigns are not zero-sum games.

VII. Student Involvement & Outreach

For the purposes of this project, the student involvement will be through the MIT Undergraduate Association - Sustainability - Special Project Division (UA Special Projects). There are two main focuses on student involvement for the project beginning with the inception and planning of the project. From the start, this project has been student run with minimal involvement from coaches and administrators except when absolutely necessary. We would like this project in the future to have a minimal impact on the coaching staff. Max von Franque and Christopher Noga will be collaboratively heading the project, with help from other resources and students. Beyond the proposal writing and research that goes into the project, the majority of student involvement will be to secure funding, evaluate the continued feasibility of the project, and be involved in outreach within the greater community. Once implemented, continued conversations with and the gathering of usage data from the coaching staff will be taken into account to help determine future feasibility of full fleet conversion. This data will be shared with head coaches of collegiate and high school programs all along the Charles as well as the wider rowing community. By sharing our data with other programs, we hope that this project will become the catalyst for change along the river. It will be the students' role to help spread the knowledge of electric launches to other rowing teams both locally and abroad.

MIT Rowing has athletes from all over the world. With this standing, we have an opportunity and a responsibility to impact the community positively. Transitioning to electric motors within our own fleet of launches is only one step in creating a positive impact in the rowing community. In addition to our own transition, we will work to educate others within the rowing community in efforts to help adapt electric launches into more clubs around the country. Our initial tests for the feasibility of this project drove us to open communication with many other collegiate programs along the Charles River and West Coast. Changing the culture of sustainability will have profound effects not only across the country but also globally. With well over 11,000 athletes from all over the world participating in the yearly Head of the Charles Regatta, the Charles River is placed in the worldview every year, providing an incredible opportunity for international outreach and to raise awareness. By converting the fleet of MIT crew, one of the major supporters and drivers of the regatta, to electric launches, we will place the issues of climate change at the forefront of attention. Educating board members, athletes and coaches of local clubs about the footprint that rowing has on the environment could spark a movement towards a more sustainable rowing community both here in Boston and globally. Eventually, we hope to expand our education efforts across the country and advise clubs all around the nation about Pure Watercraft Outboard and the positive impact the rowing community could have in the effort to aid our environment.

VIII. Concluding Statement

While electric motors may cost more for MIT Crew upfront, the small premium that must be paid is a worthwhile investment. Electric launches outperform gasoline engines on almost every metric. Their silent running allows rowers and coaches to better communicate, leading to safer and more productive practices. Their zero maintenance means less work for the hardworking staff that help maintain our fleet, allowing them to focus on other aspects of the program that need fixing. Zero emissions means that all river users are no longer breathing in toxic fumes, and MIT Crew can be proud to know that their fleet is not contributing negatively to climate change as a gas powered fleet. All these benefits are a worthwhile investment. While the goal is to convert the entire fleet to electric, right now, we are only asking for funding for one pilot launch that will be subsidized by almost 50%, to allow MIT Crew, MIT Sailing, and other schools along the river to fully test these engines, to see if this is a viable option for the future of the program, school, and the wider rowing community. After testing, MIT Crew will own the motor and utilize its benefits for long after all members of this project are gone.

With this proposal, we hope to be able to change the way we row. Rowing is a deep passion for many athletes and coaches who have committed years of their lives to better themselves within the sport. Now, UA Special Projects is striving to help the sport do the same: become better and more environmentally conscious.

IX. Acknowledgements

We would like to acknowledge the following people for their instrumental help in writing and guiding this proposal.

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