PROGRESSIVE AUTOMOTIVE X PRIZE

TECHNOLOGY INNOVATIONS

INNOVATION, INFORMATION AND EDUCATION: THE VALUE OF THE PROGRESSIVE INSURANCE AUTOMOTIVE X PRIZE

It is sometimes hard to remember where electric drive technology really stands when it comes to real-world vehicles. The very first production vehicle to use lithium batteries went into production earlier this year. ***All*** the electric drive vehicles in the Progressive Insurance Automotive X PRIZE competition used lithium chemistry batteries more advanced than used in that Mercedes-Benz production vehicle – sometimes two generations advanced. An array of the most efficient electric motors available was utilized by the cars in this competition, and if power inverters were not at the absolute cutting edge of power density, they were close to it. Readers should keep in mind the development cycle of these vehicles was barely over two years – a very short time for a project as complicated as an automobile. No major OEM can bring a car to a production-ready state in two years.

The competition showed that the teams in the Progressive Insurance Automotive X PRIZE used the very best components that are current available and built them into vehicles that were innovative in many ways: in lightweight design, in reducing aerodynamic drag, in unique passenger packaging and appearance, and by pushing the efficiency of energy conversion and storage to the practical limits of current technology. With DOE support, the competition has examined and tested the lightest four passenger vehicle on record, the lowest drag coefficient ever measured for a four-wheeled vehicle and the lowest drag coefficient for a three-wheeled vehicle. Energy efficiency approaching 200 MPGe has been measured under realistic driving conditions and above 200 MPGe on the chassis dynamometer on standard vehicle test cycles. Effective BEV ranges in excess of 130 miles and vehicle efficiency using renewable fuel alone in excess of 100 MPGe were also shown. A number of BEVs in the Progressive Insurance Automotive X PRIZE competition have shown a total overall efficiency (AC in to the wheels) in excess of 60% -- a very high efficiency that any OEM would be delighted to demonstrate – and none have to date.

The value of this competition is that it empowered teams to construct innovative vehicles that do not rely on conventional vehicle preconceptions or technology; familiar concepts are combined in different ways using the full range of advanced vehicle technologies available. Some truly innovative vehicles were built, tested, and validated – far more ambitious than any vehicle yet in production employing features that are only now being contemplated by some OEMs.

From an educational perspective, the Progressive Insurance Automotive X PRIZE has already paid dividends. The web presence, learning modules for secondary schools, and DASH competition were all very successful and will have life beyond the competition itself.

In addition, a great benefit for vehicle designers, policy analysts, and future scholars is the large amount of data collected from test track and laboratory conditions on these cars under rigorous and nearly identical conditions. “Real World” evaluations, through the use of established certification drive cycles, gradability requirements, dynamic safety and handling tests (conducted by Consumers Union), and FMVSS safety equipment requirements (or their univalent weight in ballast) were used to produce data that is relevant and realistic. Both a Ford Fusion Hybrid and a Gen 3 Prius were used as control vehicles to validate track testing procedures.

The results from this competition comprise a gold mine of technical data that define this moment in the evolution of transportation technologies and allow comparisons between them. It is a snapshot of the capabilities of many of the latest electrification and charging technologies, lightweight materials, vehicle design, and powertrain integration practices of this decade. Especially because

of the rigor of both the on-track testing and the dynamometer-based validation testing conducted at DOE's premier vehicle systems national laboratory, a large amount of unbiased data on the very latest automotive technologies will be made available to the public. This treasure-trove of data may well be the most important legacy of the Progressive Insurance Automotive X PRIZE.

Finally, it must be noted that without the financial and technical support of DOE that the Progressive Insurance Automotive X PRIZE could not have taken place. Much of the content of the safety procedures, technical rules, and competition operations flowed from the more than twenty years of successful collegiate Advanced Technology Vehicle Competitions. It is a major accomplishment that an international competition such as this one that attracted over 100 vehicles with a huge range of technologies was successfully operated without any incident of any kind, safety or track-related. It is a tribute to the technical team assembled by the Progressive Insurance Automotive X PRIZE, the active participation of DOE staff, and the experience of its national laboratory technical experts that this competition produced the noteworthy and valuable results it did.

What follows are some brief descriptions of the cars that are in contention for the Grand Prize awards as well as some notable other vehicles that were eliminated earlier in the competition. The results presented below are from the track phase of the competition and the Validation phase of dynamometer testing. It is important to note that the story of the Progressive Insurance Automotive X PRIZE is not only the winning teams but all the other teams that demonstrated innovative technology, gained experience in the very difficult task of vehicle design and construction, and were recognized for their efforts. There are countless stories of teams learning from each other because of the community atmosphere and synergies created by the competition. Individuals with talents in the new powertrain technologies were discovered and will help feed the growing needs of this industry. Suppliers of batteries, motors, etc. were pushed by the demands of the teams, and timing of the competition, to speed up development. Already volume applications of some of the technologies shown in the Progressive Insurance Automotive X PRIZE are being planned. Regardless of whether these are successful, the positive outcomes of the competition have already returned DOE's $5.5M investment in the competition.

Cars that Earned Entry into the Validation Stage

Edison2 Very Light Car: Mainstream Class/4 Passenger Car

Boasting a the lowest drag coefficient of any car tested in the GM wind tunnel or at the Chrysler Proving Grounds, this innovative Very Light Car demonstrated over 100 MPGe on the test track under stringent testing conditions using a highly innovative small displacement engine and over 104 MPGe during chassis dynamometer testing. It requires only 8 pounds of force to push this vehicle. More like an airplane than a car, the Edison2 uses highly innovative light-weight, low mass hub-mounted suspension for its aerodynamically flared four wheels contributing to its sports car-like handling and braking. Its low total mass of 830 pounds is a tribute of engineering strength and packaging utility. Using a 250cc turbocharged fuel injected single-cylinder engine fueled by E85, this light and inexpensive powerplant passed Tier 2 Bin 8 emissions testing, delivered a 14 s 0 - 60 mph acceleration, and a range of over 300 miles.

TW4XP: Alternative Class/Urban Car

This innovative side- by-side two seat city car eschews a steering wheel for outstanding visibility and ease of entry/exit instead by using two control sticks and buttons to control the speed and direction of the car. A lightweight aluminum chassis and all-electric drive using high torque motor operating a wheel speed (no transmission or gear reduction needed) with integral differential weighed in at just 1545 pounds. This car uses an 800V lithium-ion manganese battery pack and an inverter adapted from a wind turbine power generator. This unusually high vehicle voltage level reduces electrical losses and increases overall vehicle efficiency while using standard electric components. Employing a technique just now being considered by OEMs, this team charges their batteries through their motor and controller. The car demonstrated an impressive 146 MPGe on the track and 189.1 MPGe in the validation stage as well as a 100 mile range on realistic combined city and highway cycle, highlighting and its lower-than-average aerodynamic and mechanical losses.

Aptera: Alternative Class/Urban Car

This highly-regarded side-by-side two seat commuter car combines striking good looks with a low aerodynamic drag body. Already at the 95% production ready level, this BEV uses the latest generation A123 lithium-ion batteries and a high power density motor from Remy that is ready for mass production. This car demonstrated 100 miles range in realistic conditions with only 18.6 kWh energy storage and turned in an excellent 10.5 s 0-60 performance. Aptera's highway efficiency was measured at a remarkable 178 MPGe on the track and 194 MPGe on standardized testing on the dynamometer. These numbers are very impressive and demonstrate both an innovative design and an outstanding level of engineering integration in a vehicle that will enter production this year.

Li-Ion Motor's EVI Wave II: Alternative Class/Urban Car

This side-by-side two seat urban car was the sleeper of the competition. Built on a lightweight aluminum chassis and carrying 20.7 kWh of perhaps the best available lithium-ion batteries for BEV applications (Dow-Kokam), the vehicle still weighed in at only 2176 pounds. Paired with a permanent magnet electric motor of 38 kW continuous power and a 91.5% efficient battery charger, the Wave II demonstrated outstanding low mechanical and aerodynamic drag that resulted in over 182 MPGe in the combined on-track efficiency testing, a remarkable 203 MPGe on standardized dynamometer testing, a 14.7s 0 – 60 mph time, and over 100 miles range over

a realistic driving cycle.

Race About: Alternative Class/Urban Car

This side-by-side seat sports car employed an innovative configuration of four separate wheel-speed motors, custom inverters, and a special supervisory controller all designed and constructed by a team of university students from the Metropolitan University of Helsinki, Finland. Using almost 33 kWh of Altairnano lithium titanate batteries optimized for power rather than energy, this densely packaged car weighed 3770 pounds yet demonstrated 135 MPGe on track and 149 MPGe in Validation testing. Given these numbers, demonstrating 100 miles range under realistic driving conditions was easily shown. The car was quick, achieving an 8.4 s 0 – 60 acceleration performance. The students used Audi R8 supercar aluminum suspension and brakes to match the driving performance of this vehicle. Given the mass, overall size, and battery makeup of this car, its results clearly show that traditional OEMs could build a similar car with existing technology that would achieve a similar attractive blend of energy efficiency and high performance.

Zap Alias: Alternative Class/Urban Car

The Zap Alias won the on-line poll for the most attractive car, but this car is far more than just a pretty face. An efficient and quick three-wheeled side-by-side BEV, the Alias demonstrated 122MPGe on track, 126 MPGe on the dynamometer, and a 0 – 60 mph time of 7.5 s. Made by one of the largest BEV manufacturers in the US, it carried 32 kWh of advanced lithium-ion phosphate batteries, yet it still weighed in at a modest 2733 pounds. This car showed innovation in both its design and execution, yielding excellent performance and demonstrating a range in excess of 100 miles in realistic conditions.

X-Tracer #72: Alternative Class/Urban Car

This is one of two highly innovative tandem two seat vehicles that combine the best of motorcycles and automobiles. Looking like a large enclosed motorcycle, this clever design has two extra wheels that deploy at low speed to stabilize the vehicle. This BEV weighs in at a modest 1436 pounds even with over 16 kWh of lithium-polymer batteries. The Kelvar/carbon fiber monocoque chassis makes this roomy vehicle with such a low weight possible. This version of the X-Tracer uses a 37 kW Brusa motor and inverter to deliver over 100 miles range, a competition-leading 197 MPGe on-track energy efficiency and 213 MPGe on standardized dynamometer testing, and a fast 0 – 60 mph acceleration of 6.6 s.

X-Tracer #79: Alternative Class/Urban Car

The second of this innovated tandem two seat car uses an all-American powertrain composed of a 150 kW electric drive system made by AC Propulsion and a 19.4 kWh lithium polymer battery system from NeuEnergy in San Diego. Weighing in at a svelte 1335 pounds, this car delivered an outstanding on-track efficiency of 190 MPGe, 186 MPGe in Validation testing and a blistering 0 – 60 acceleration of 5.5 s. It easily achieved 100 miles in the range test and always pleased observers with its unique ability to change from a four-wheeler into a two-wheeler.

Cars That Were Eliminated Before the Validation Stage

Tango: Alternative Class/Urban Car

Tango is an innovative half-lane tandem two-seat commuter car with over 33 kWh of lithium-ion battery storage. This striking vehicle challenges our perception of what a vehicle can be. It demonstrated excellent performance, long range, and a respectable 88 MPGe track energy efficiency. Its inability to reach 100 MPGe was largely due to the choice of a powerful brushed DC motor that did not allow for regenerative braking. A crowd favorite, this BEV is poised to enter low-volume production.

Western Washington University Viking 27: Alternative Class/Urban Car

The WWU Viking used an innovative variant of parallel plug-in hybrid architecture and 10 kWh of lithium-ion batteries. Their design includes both a mild hybrid drivetrain based on a small gasoline engine plus a larger electric machine for all-electric operation. This lightweight side-by-side two seat car demonstrated over 100 mile range and over 97 MPGe combined on-track energy efficiency. A first-rate effort by undergraduate engineers, this car was considered the most improved vehicle in the Progressive Insurance Automotive X PRIZE.

Future Vehicle Technologies (FVT): Alternative Class/Urban Car

FVT's vehicle was a PHEV with more than a 100 mile all-electric range that demonstrated an impressive 153 MPGe on track under realistic driving conditions. It used tandem seating and a door/canopy opening system that preserved its aerodynamic profile while allowing ease of entry for both drive and passenger. Variants of this vehicle are starting limited production.

Tata Motors: Alternative Class/Urban Car

The Tata Motors entry is scheduled for production for the European market later this year. Although a four-passenger, four door vehicle, it was entered in the Alternative Class due to that class's 100 mile range requirement. This BEV version of a production subcompact, it uses 31.5 kWh of lithium-ion batteries and easily demonstrated a 100 mile range. Although a charger failure eliminated this car from the Final Stage competition, it earlier demonstrated over 134 MPGe energy efficiency on-track and a sub 12 s 0 – 60 mph acceleration.

Illuminati Motor Works SEVEN: Mainstream Class/ 4 Passenger Car

One of the most strikingly innovative vehicles in the Progressive Insurance Automotive X PRIZE, the Illuminati SEVEN BEV featured back-to-back four passenger seating surrounding a pyramidal-shaped 31 kWh lithium-ion battery pack. This vehicle demonstrated 120 MPGe on track and over 140 mile range. It had ample luggage space and likely would have met the 200 mile range minimum for the Mainstream class.

<u>West Philly EVX GT:</u> Alternative Class/Urban Car

One of two entries from West Philadelphia High School, this innovative diesel PHEV EVX GT was based on a high performance side-by-side GT car. It used a through-the-road configuration with the electric drive in the front and an efficient diesel engine and manual transaxle in the rear. A 9 kWh lithium-ion pack and a 47 kW AC motor gave it over a 20 mile electric range. An impressive effort from a high school, this vehicle demonstrated over 55 MPGe over the competition's realistic track-based driving cycles.