AUTONOMIE

Impact of Future Vehicle System Improvements on Battery Size, Usage and Cost

AABA4 Conference
September 2011

Aymeric Rousseau
Argonne National Laboratory

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Study Objectives

- What are the benefits of the FreedomCAR & Fuel Partnership in terms of petroleum displacement?
- Assess technology potential to guide future research and development
- What is the impact of new technologies on
  - Battery power and energy requirements?
  - Energy efficiency?
  - Overall vehicle manufacturing cost?

Process & Assumptions

Study Process

Large Number of Technologies…

Vehicle Classes

⊗

Timeframes

Current

2015

2020

2030

2045

⊗

Powertrain Configurations

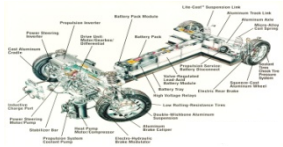
Conventional

ICE HEV

PHEV

Fuel Cell

Electric



⊗

Fuels

Gasoline

Diesel

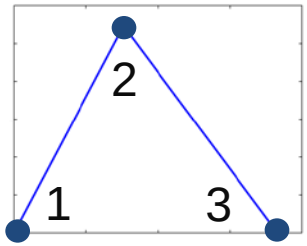
Ethanol

H_2

⊗

Risk Analysis

Triangular Uncertainty



1 = 10%
2 = 50%
3 = 90%

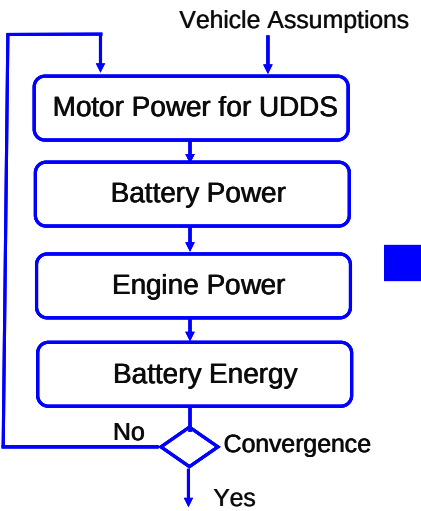
> 1800 Vehicles

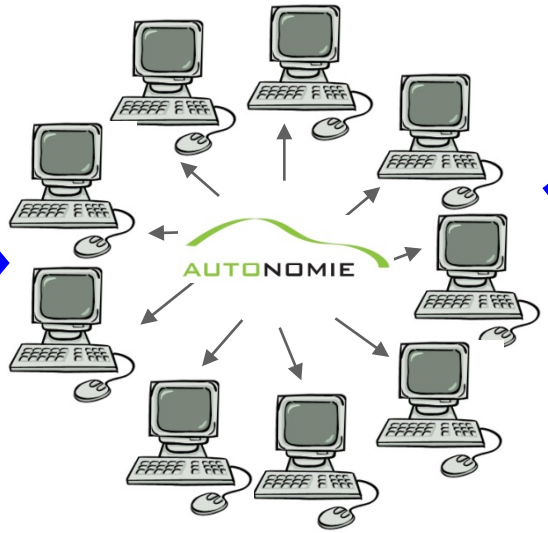
… Requires Development of Process

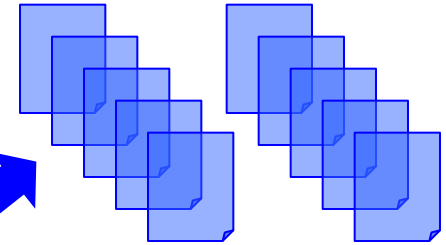
Vehicles Automatically Sized

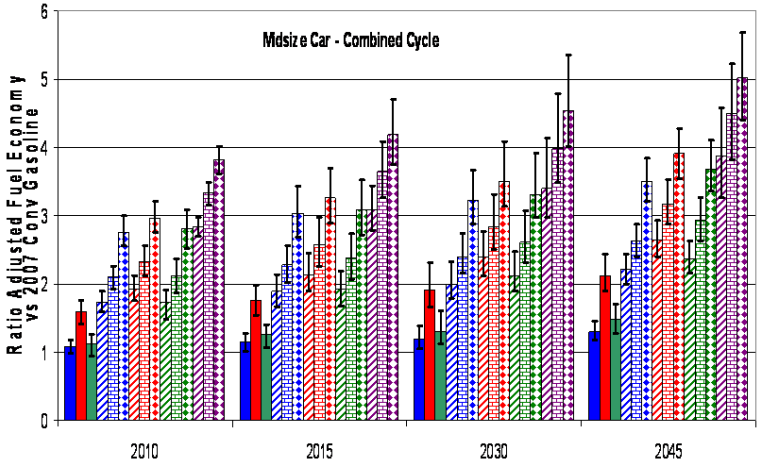
Distributed Computing

Automated Post-processing

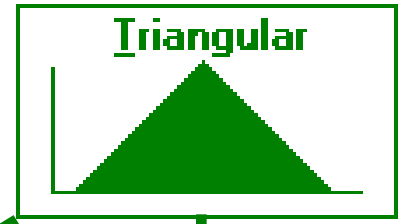






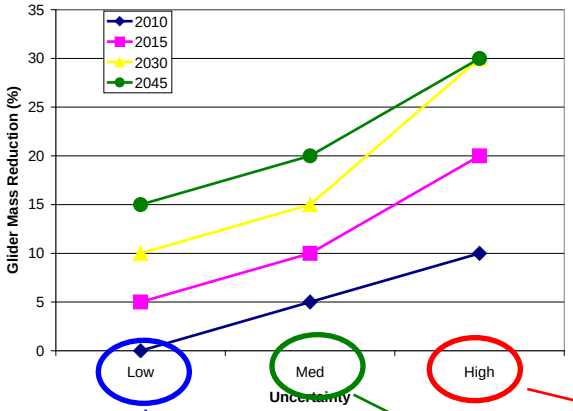


Uncertainty Process

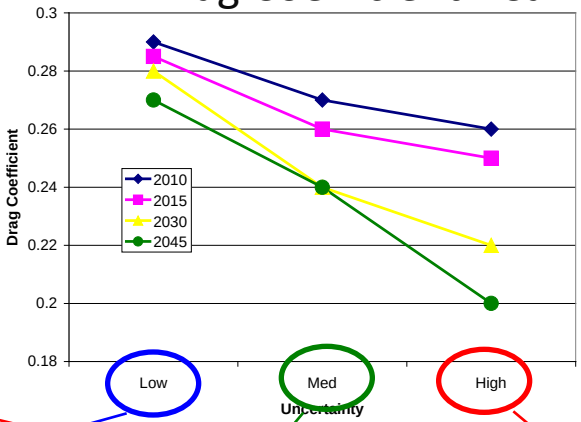


Triangular analysis was used for each assumption

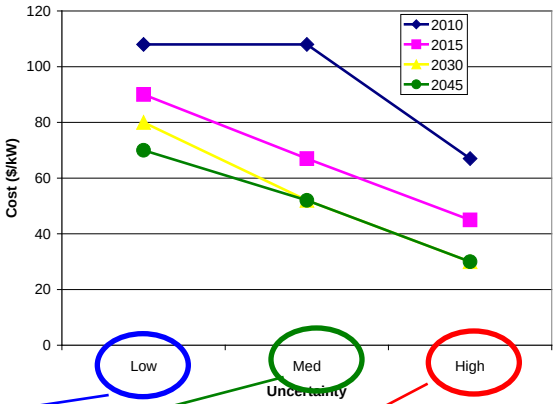
Glider Mass Reduction



Drag Coefficient - Car



Fuel Cell System Cost



90% vehicle

50% vehicle

10% vehicle

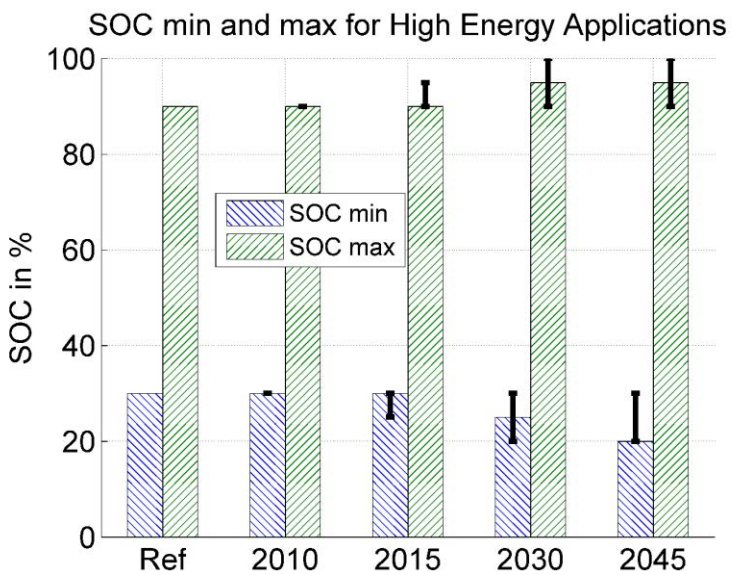
Main Study Assumptions

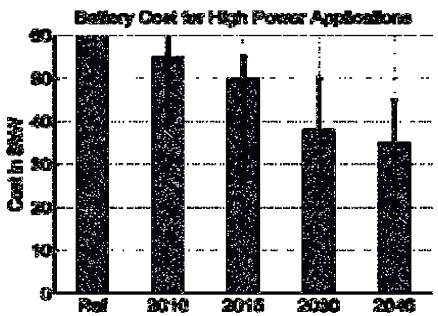
- All the main component assumptions are predicted with their uncertainties (i.e., engine, electric machine, energy storage, fuel cell, transmission, light weighting…)
- All vehicles are sized to meet the following Vehicle Technical Specifications:
  - 0-100kmph in 9sec
  - Maximum vehicle speed > 160 kmph
  - 6% grade at 55 mph at GVW
- Battery power sizing:
  - HEVs are sized to capture all the regenerative braking from the UDDS
  - PHEVs 10&20 are sized to be able to follow the UDDS in EV mode
  - PHEVs 30&40 are sized to be able to follow the US06 in EV mode
- Battery energy is always sized on the UDDS.

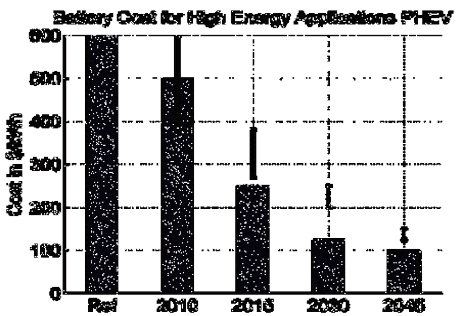
Main Battery Assumptions

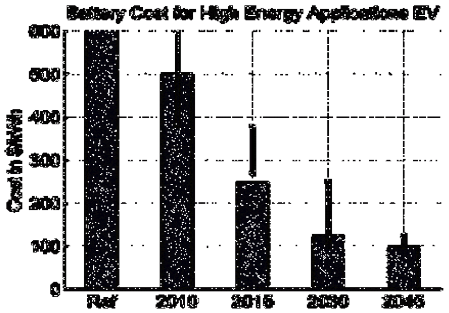
	Source	Technology	Reference Cell Capacity
HEV	Idaho Nat lab Battery manufacturer	NiMH Li-ion	6.5 6
PHEV	Argonne Nat Lab	Li-ion	41

		2010			2015			2030			2045	
	Ref /Low	avg	high	low	avg	high	low	avg	high	low	avg	high
HEV	**NiMH**	**NiMH**	**NiMH**	**NiMH**	**Li-ion**			**Li-ion**			**Li-ion**	



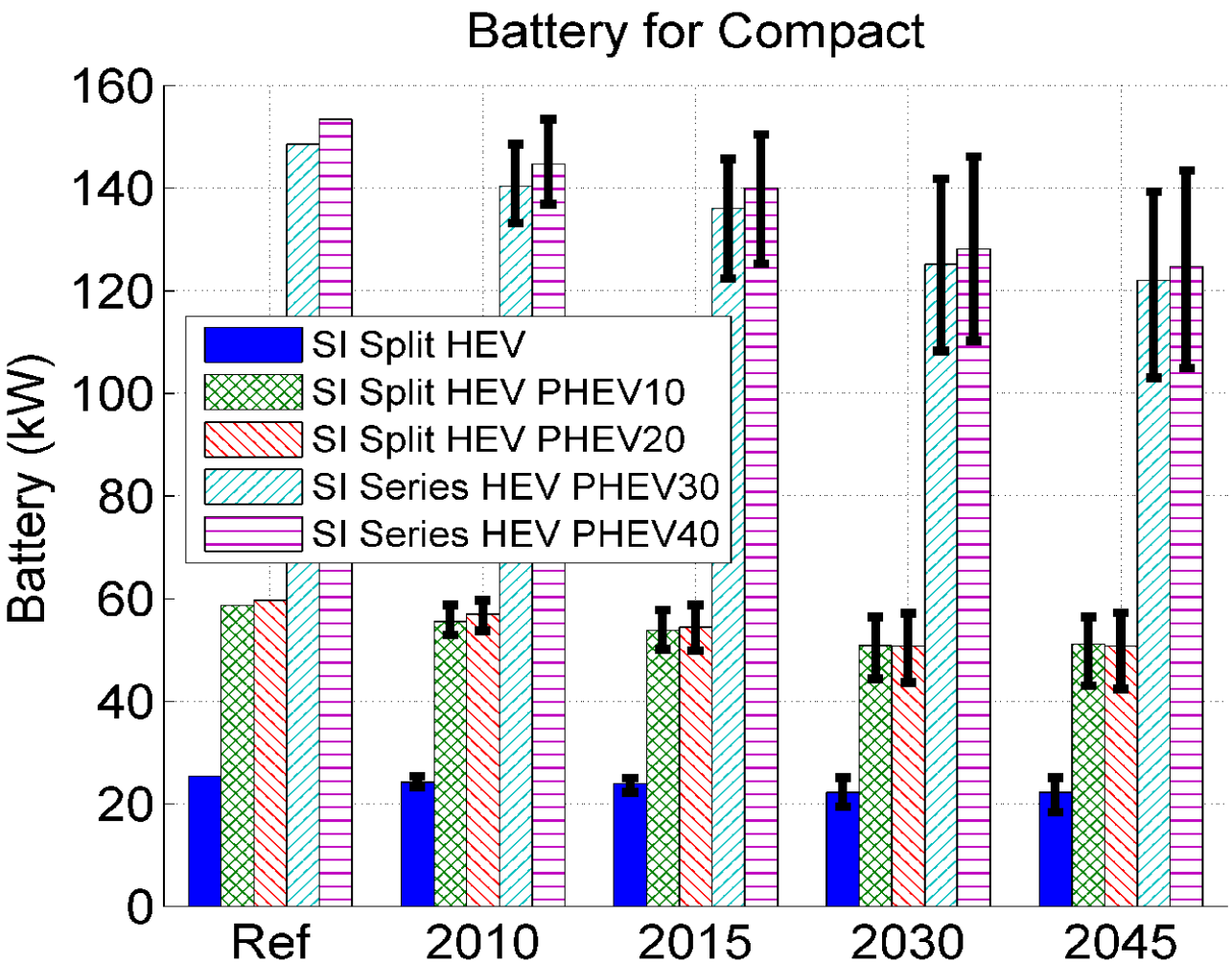




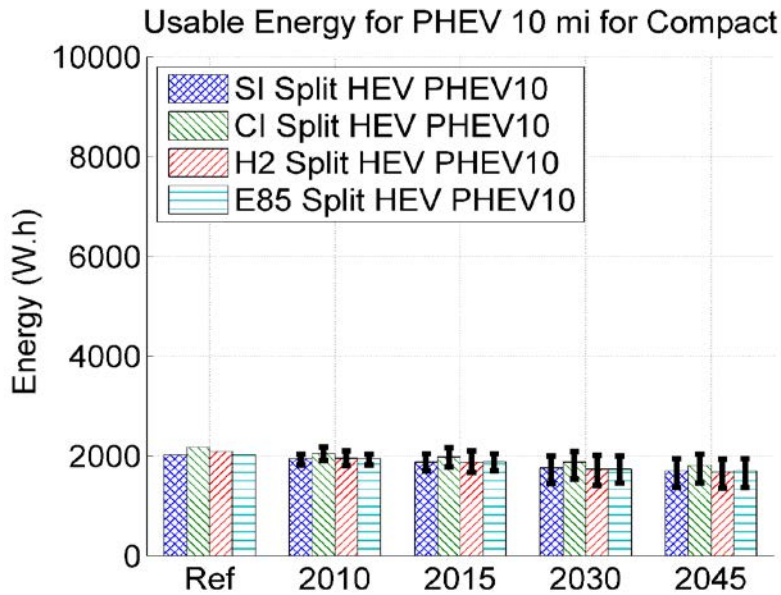


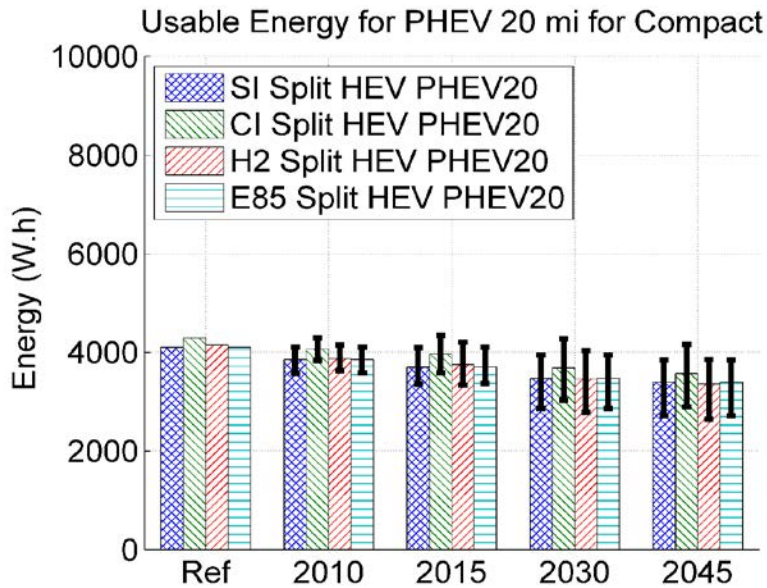
Component Sizing Evolution

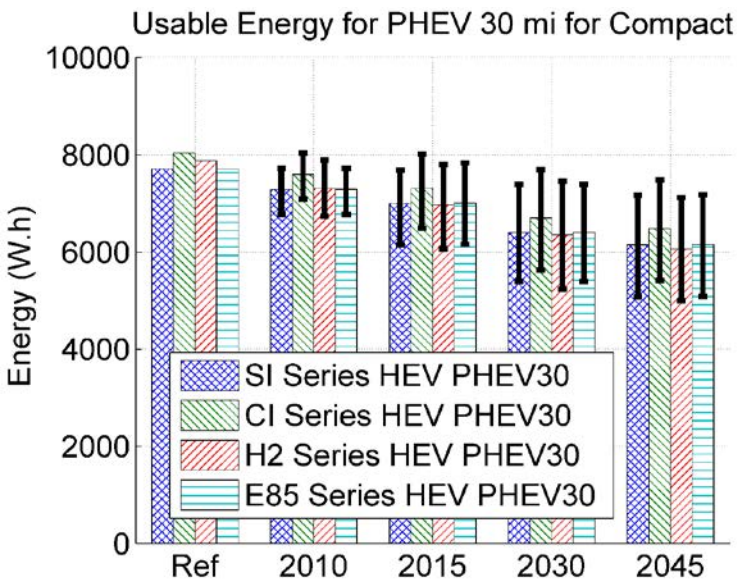
Battery Peak Power Requirement Could Significantly Decrease Over Time

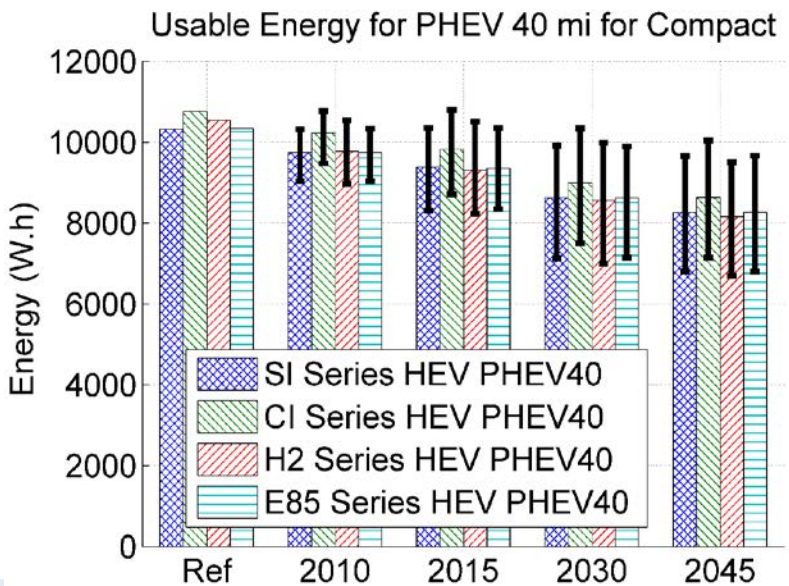


So Would Energy Storage Usable Energy

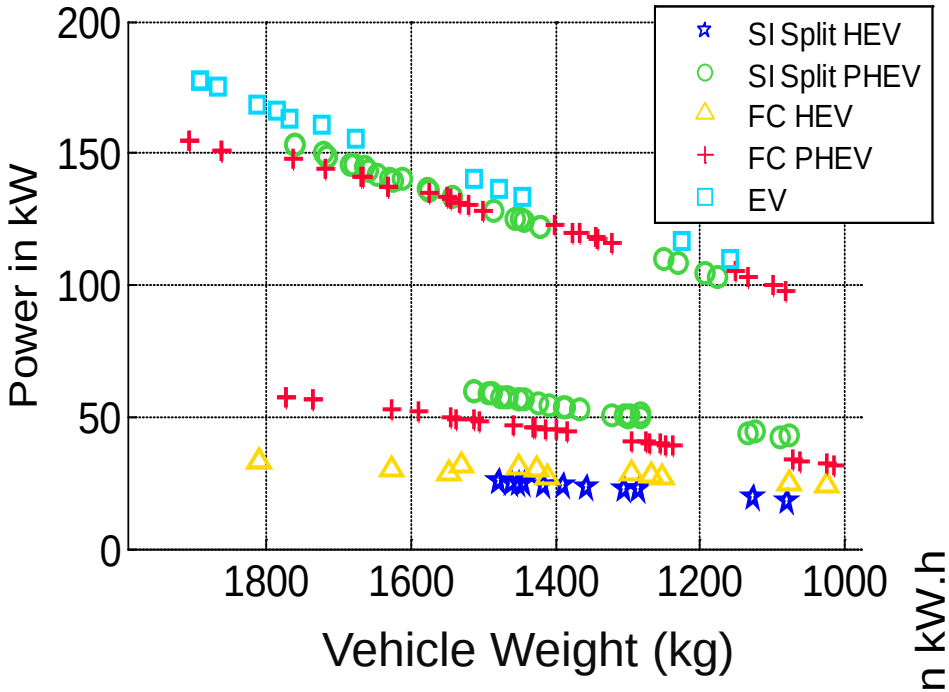


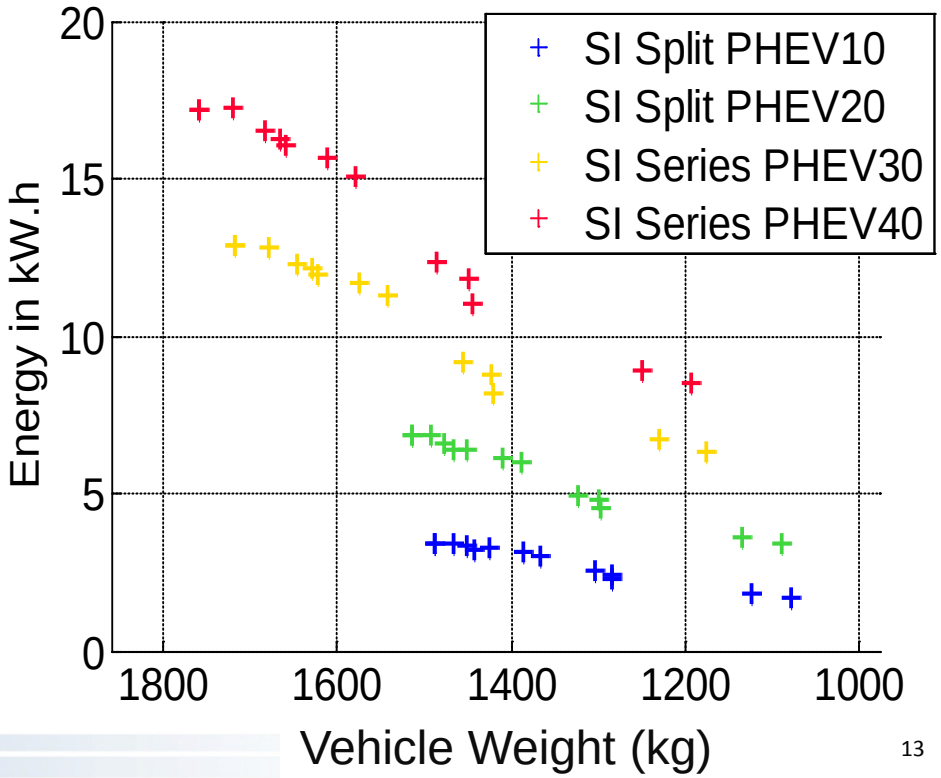




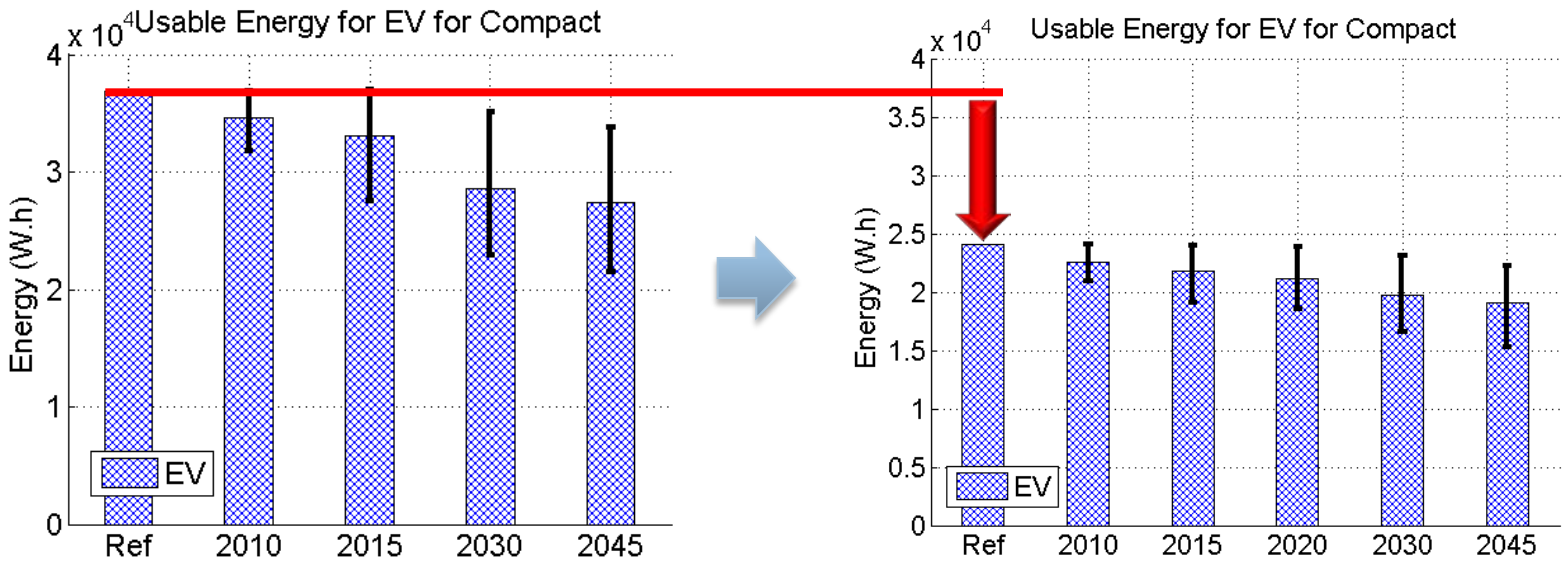


Vehicle Light Weighting is the Principal Reason For Lower Peak Power and Energy Requirements





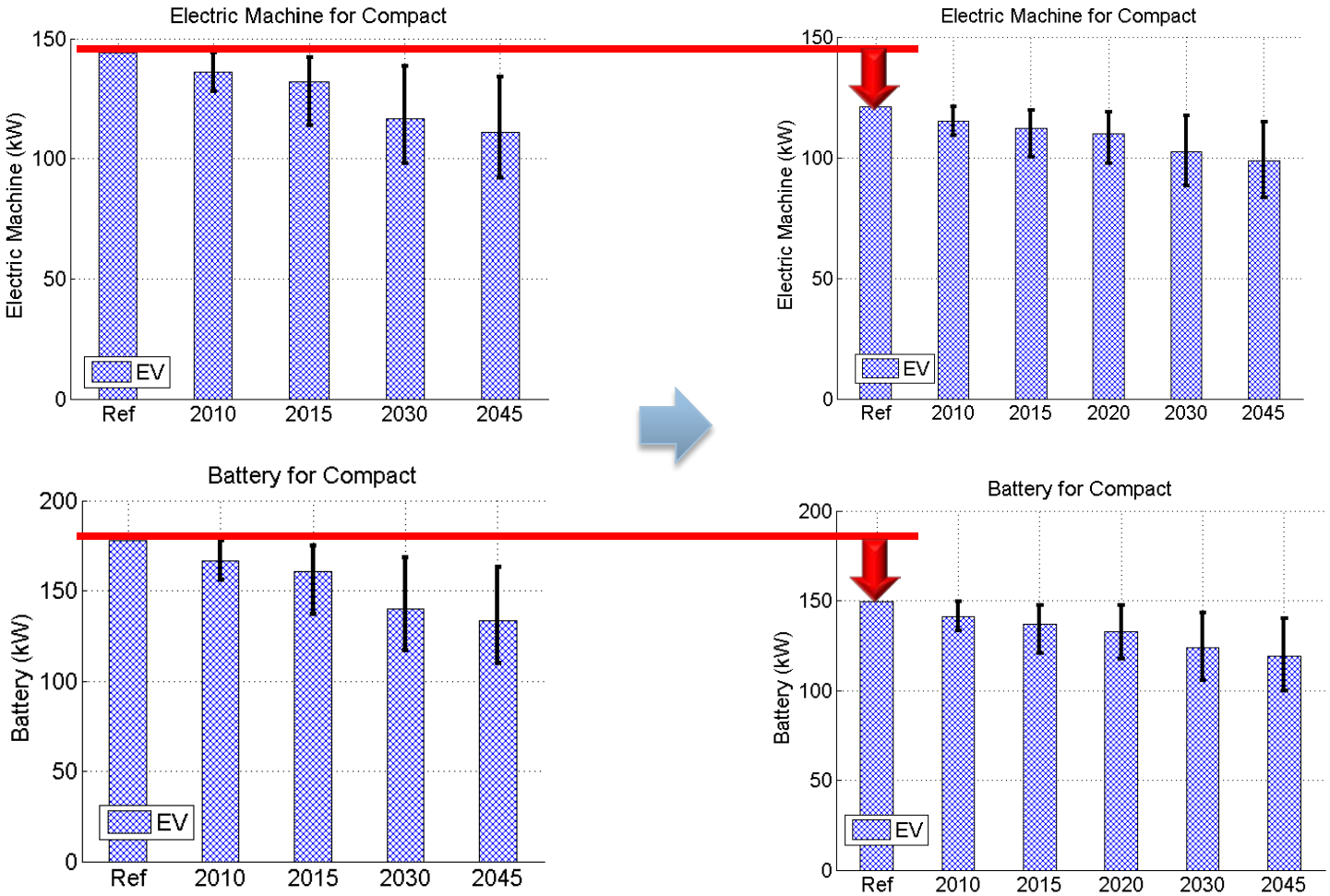
Decreasing EV Range by 50% Contributes to a 34% Decrease in Useable Energy



Comparison of vehicle mass of electric vehicles – average 2010 case

	Vehicle's Curb Weight (kg)		% Mass Decrease
	150 miles EV Range	100 miles EV Range	
Compact	1786	1589	- 11.0 %
Midsize	2029	1810	- 10.8 %
Small SUV	2159	1912	- 11.4 %
Midsize SUV	2577	2276	- 11.7 %
Pickup	3011	2639	- 12.4 %

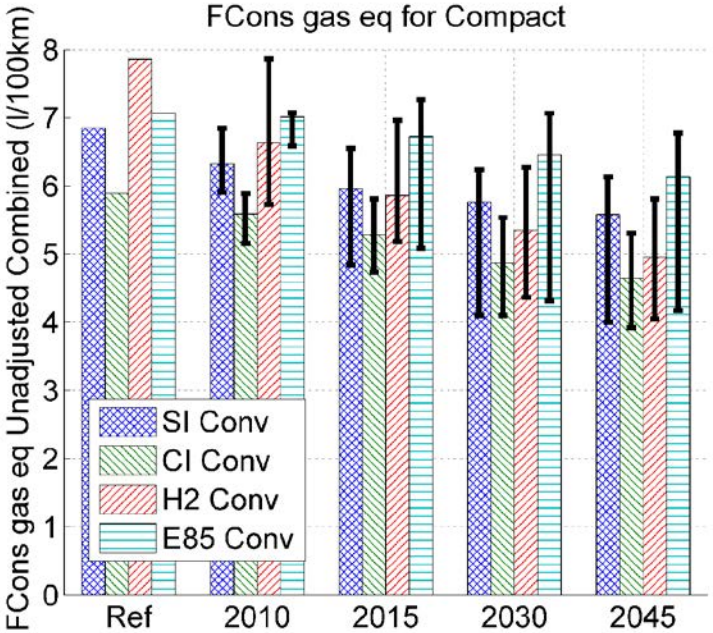
Decreasing EV range by 50% Contributes to a 15% Decrease in Power of EM and Battery

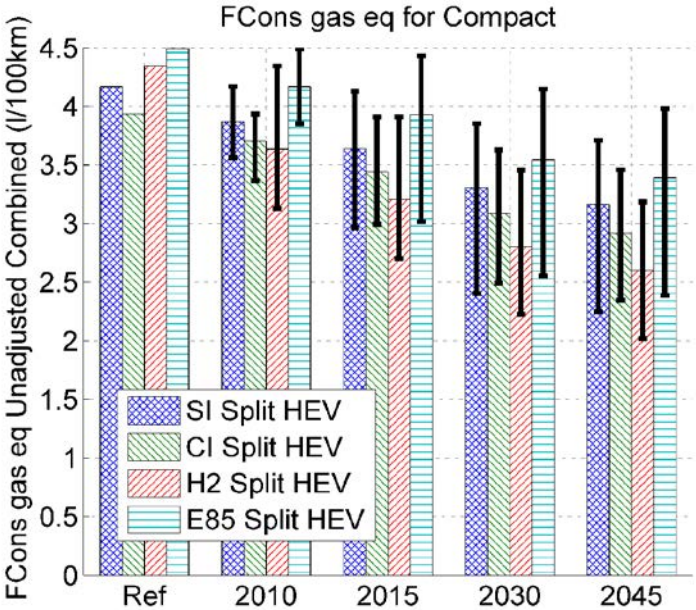


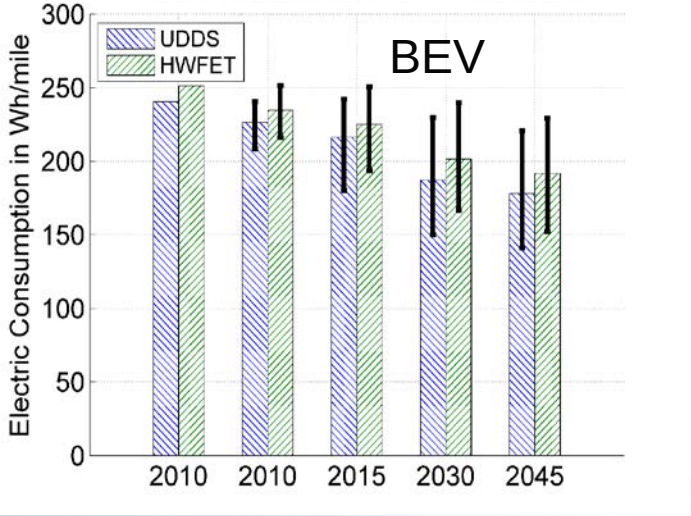
The vehicle mass affects the power of components for BEV.

Energy Consumption Evolution

Fuel Consumption is Expected to Decrease for ALL Vehicle Powertrain Technologies





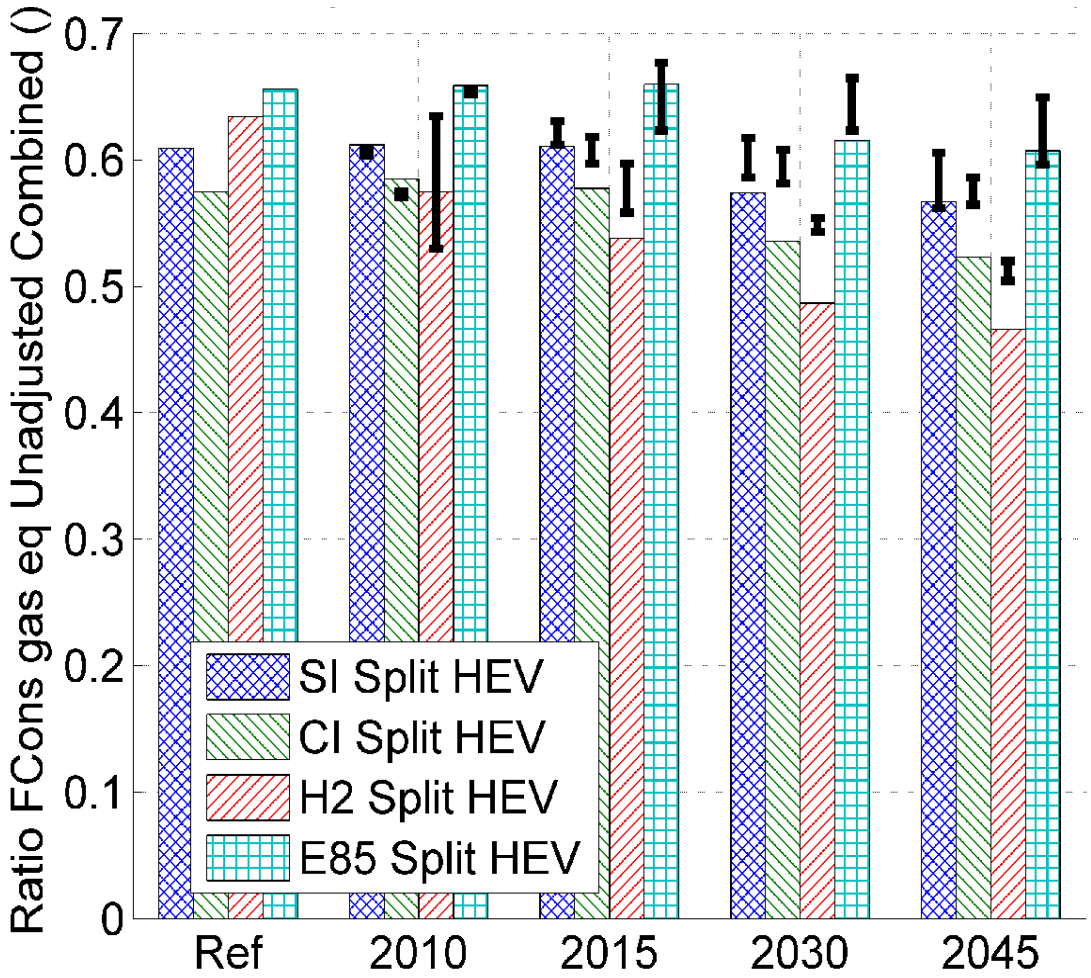


Percentage Fuel Consumption Reduction by 2045 Compared to 2010 Gasoline

Fuel\Powertrain	Conventional	HEV	PHEV10	PHEV40
Gasoline	2-43	37-64	49-70	64-81
Diesel	16-42	42-62	51-69	65-80
Hydrogen Internal Combustion Engine (ICE)	4-41	50-67	56-73	69-82
Ethanol	1-47	32-62	46-69	62-80
Fuel Cell		57-70	62-75	77-84

Electrical consumption is not taken into account for PHEVs

But Overall, Fuel Consumption Ratio Between Powertrain Technologies Remains Fairly Constant



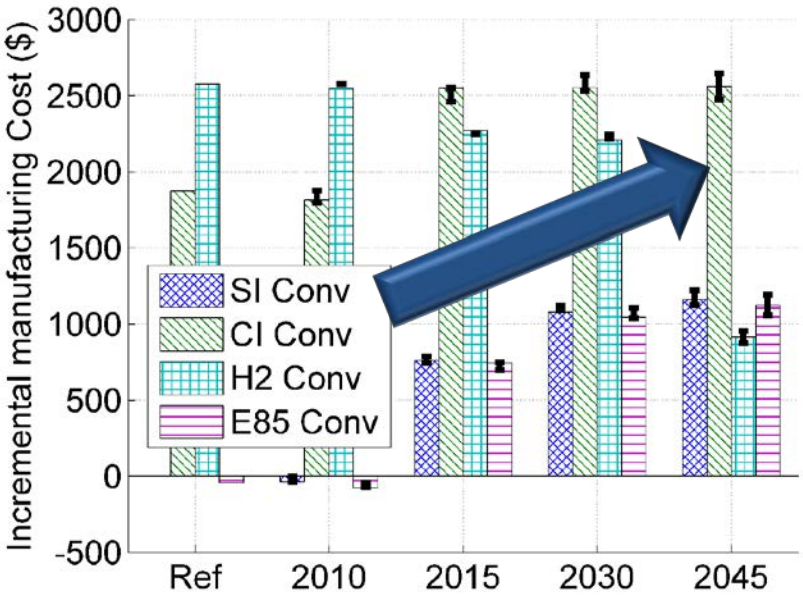
HEVs fuel consumption ratio vs Conventional of the same year

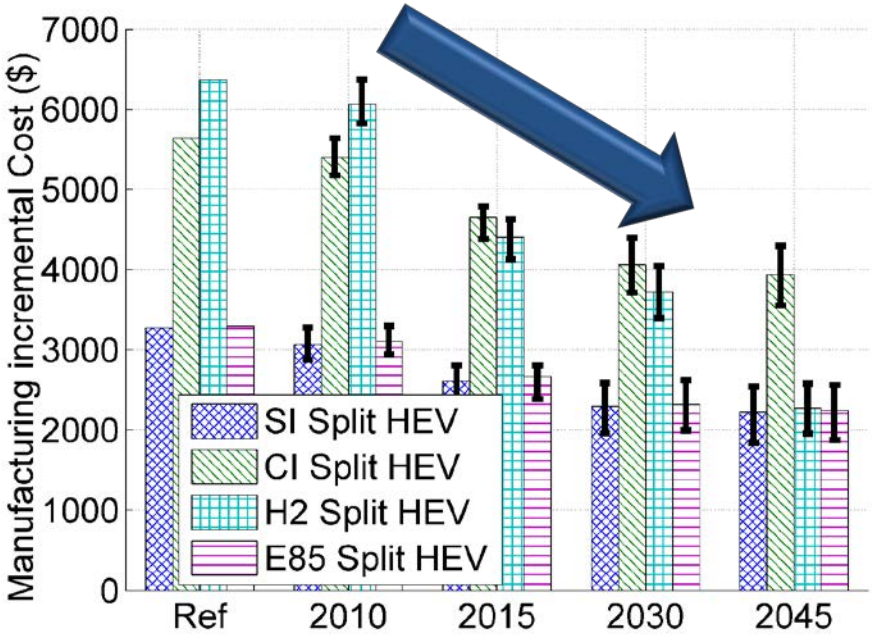
Percentage Fuel Consumption Reduction by 2045 Compared to Respective 2010 Status

Fuel\Powertrain	Conventional	HEV	PHEV10	PHEV40
Gasoline	2-43	9-45	8-43	11-49
Diesel	5-33	10-39	9-39	12-43
Hydrogen ICE	19-49	24-52	23-50	25-50
Ethanol	1-41	10-46	8-44	10-50
Fuel Cell		23-48	20-45	18-42
Electricity (BEV)	6-41			

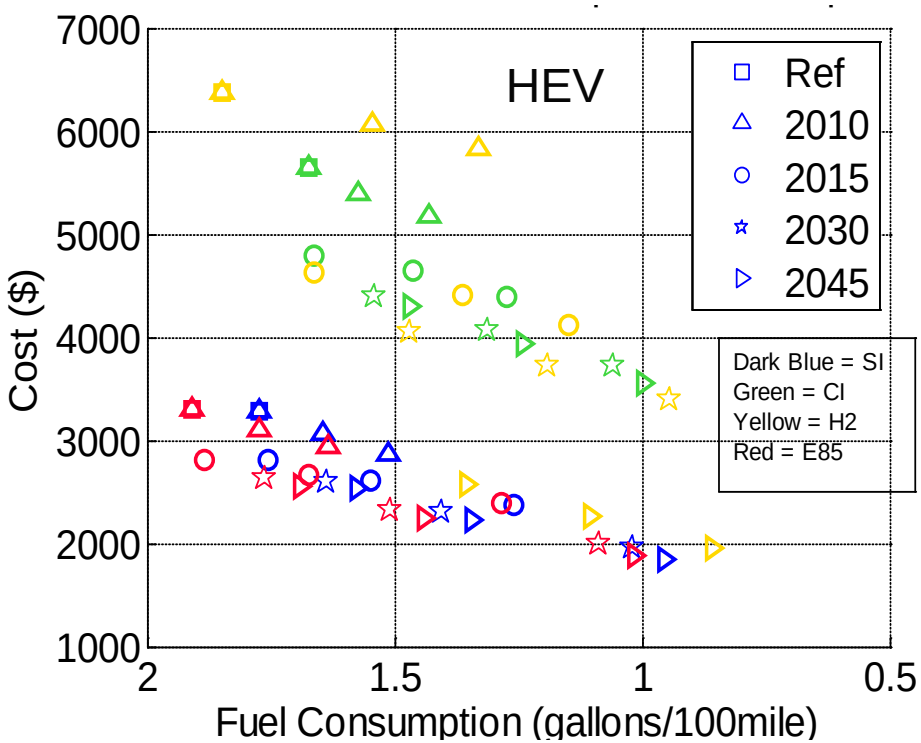
Vehicle Manufacturing Cost Evolution

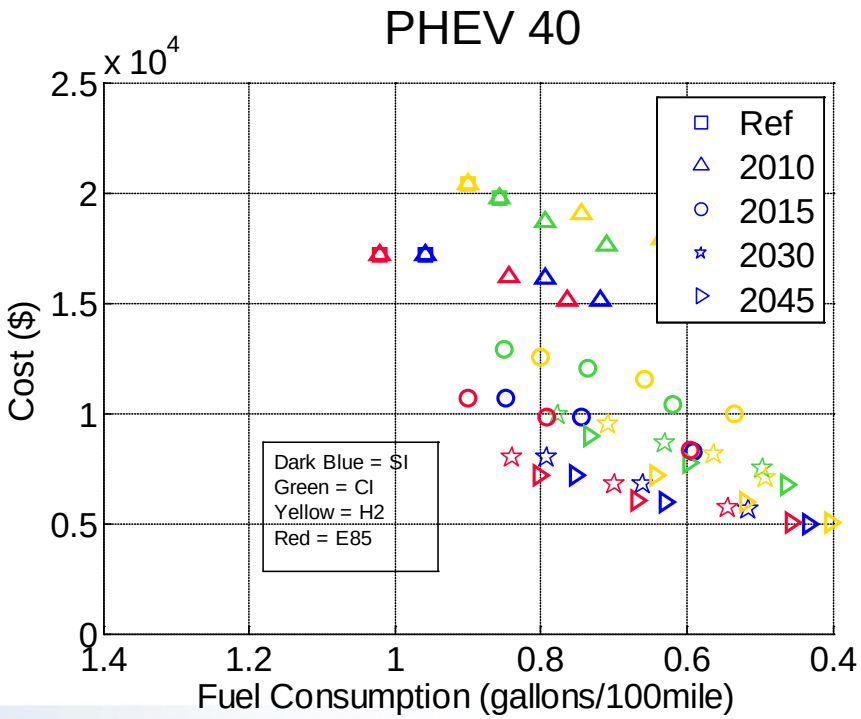
Incremental Cost of Electric Drive Powertrains Is Expected to Decrease While Conventional Will Increase



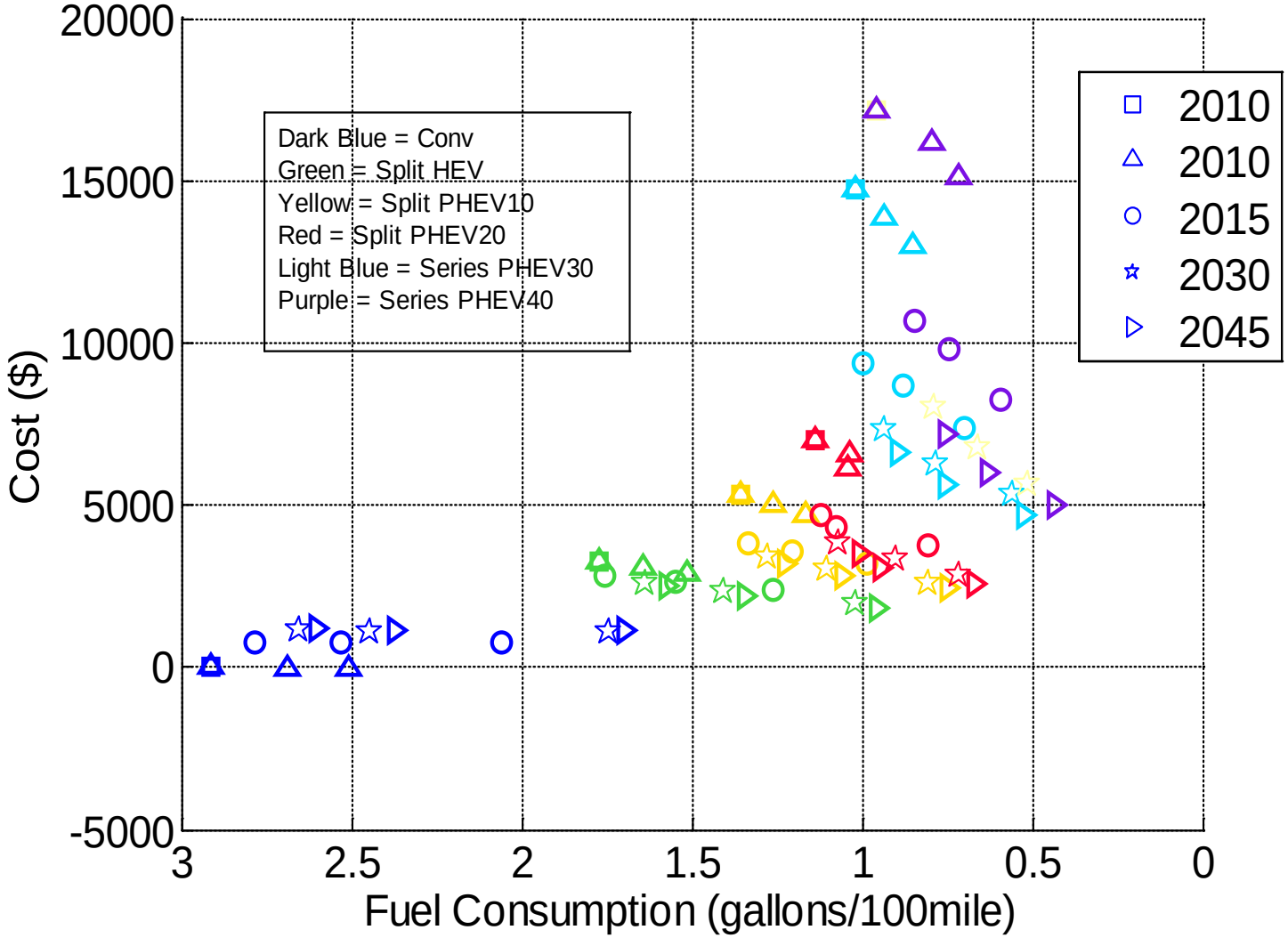


Example of Incremental Manufacturing Cost for Electric Drive Powertrains





Incremental Cost For All Powertrain Considered



Percentage Manufacturing Cost Reduction for Each Powertrain by 2045 Compared to Respective 2010 Status

Fuel\Powertrain	Conventional	HEV	PHEV10	PHEV40
Gasoline	-9 to 4	-1 to -2	-18 to -11	-41 to -32
Diesel	1 to 4	-12 to -5	-20 to -13	-40 to -33
Hydrogen ICE	-10 to 7	-21 to -5	-27 to -14	-45 to -35
Ethanol	4 to 9	-10 to -2	-18 to -11	-40 to -33
Fuel Cell		-41 to -29	-42 to -30	-45 to -35
Electricity (BEV)	-66 to -55			

Values for Compact car

Conclusion

- Battery peak power is expected to decrease over time to meet current vehicle performance: up to 34% for gasoline-engine HEVs and PHEVs and as high as 48% for fuel-cell systems.
- Battery total energy will be decreasing significantly owing to other component improvements as well as a wider usable state-of-charge range. The reduction in energy required for PHEVs and battery-powered electric vehicles (BEVs) could range from 4 to 60%.
- Vehicle technology improvements will lead to new battery requirements
- Owing to the expected improvements in batteries, the higher the battery energy, the greater will be the manufacturing cost reduction.
- PHEV40 demonstrates a larger cost reduction than PHEV10 across all fuels. PHEV40s with gasoline engines show cost reductions ranging from 32 to 41% from 2010 to 2045, while PHEV10s only show a cost reduction ranging from 11 to 18%.
- Due to expected improvements, advanced technologies are expected to have significant market penetration over the next decades.

Contacts

Aymeric Rousseau
arousseau@anl.gov

The information presented today is issued from the report entitled

"Potential of Technologies for Displacing Gasoline Consumption by Light-Duty Vehicles through 2045"

Full report can be downloaded at
http://www.autonomie.net/publications/fuel_economy_report.html