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TRANSPORTATION
TECHNOLOGY R&D CENTER

Energy Storage System Requirements for Fuel Cell Vehicles

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Fuel Cell Vehicle Fuel Economy Optimum

- Study Scope
- Hybridization Degree
- Energy Storage Technology
- Control Strategy
- Perspectives

FreedomCAR FCV Energy Storage Proposed Goals Spring 2003

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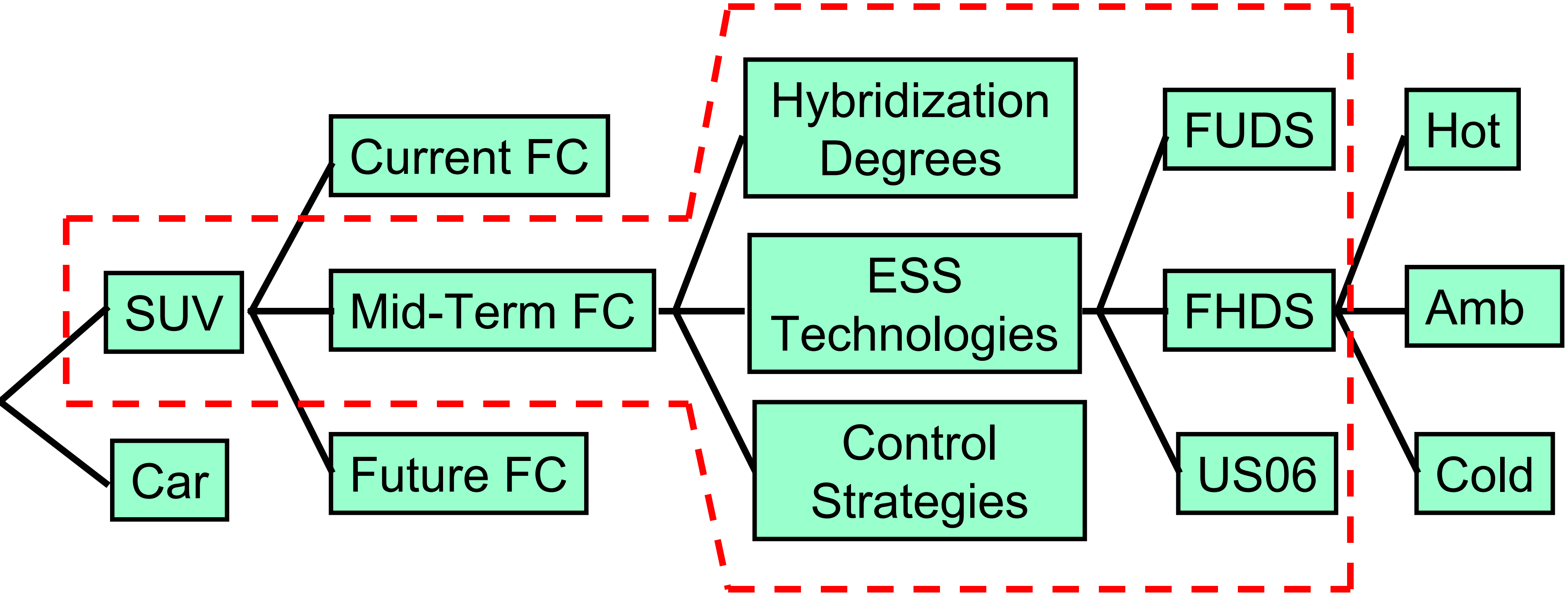
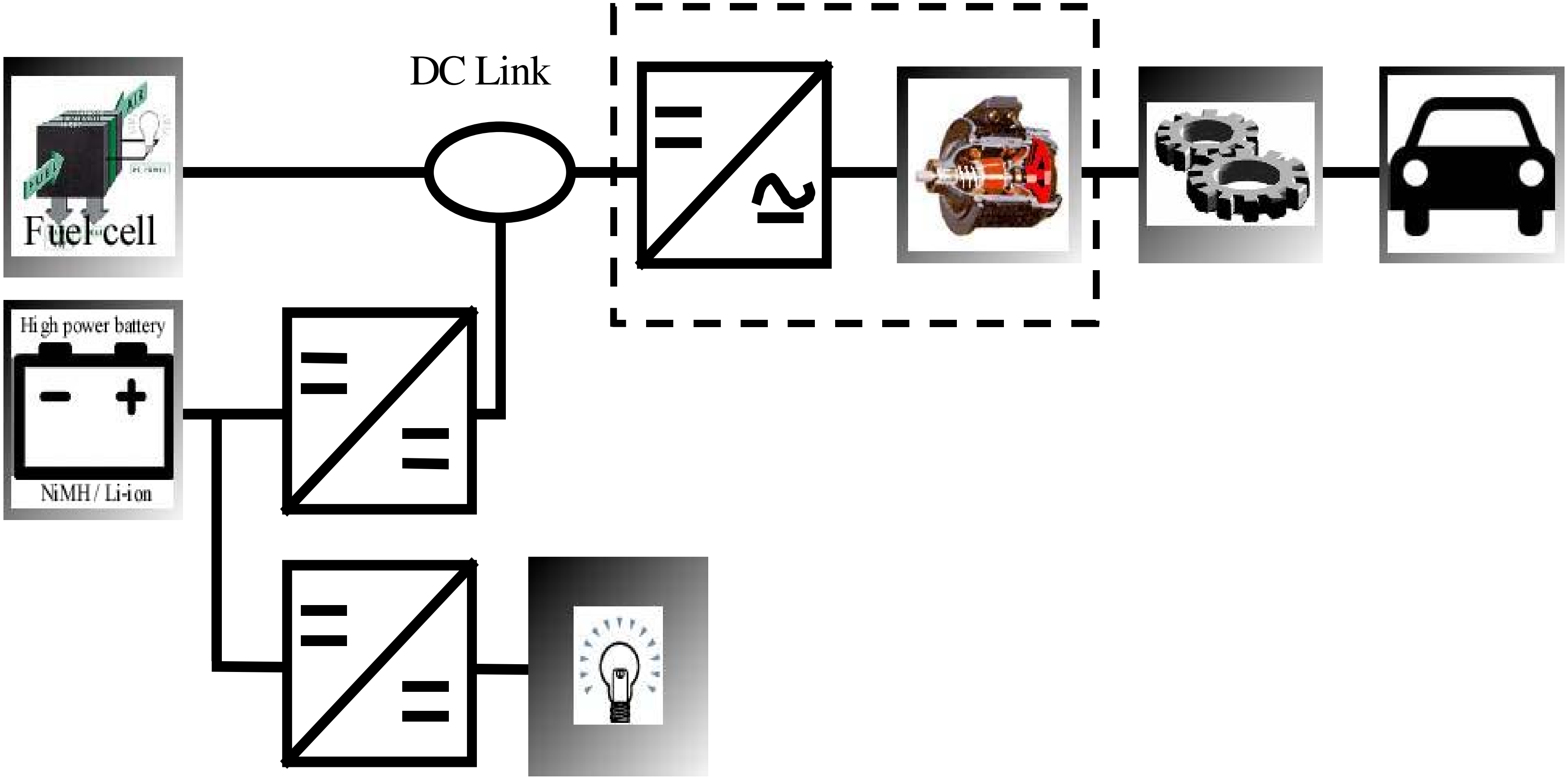
FreedomCAR

FreedomCAR Goals Characteristics	Units	Low Power Energy Storage	High Power Energy Storage
Pulse Discharge Power (10s)	kW	25	50
Max Regen Pulse (5s)	kW	30	60
Total Available Energy	kWh	1.5	3
Round Trip Efficiency	%	>90	>90
Cycle Life	Cyc.	TBD (15 year life equiv.)	TBD (15 year life equiv.)
Cold-start at -30°C (TBD kW for TBD min.)	kW	5	5
Calendar Life	Yrs	15	15
Max Weight	kg	40	65
Max Volume	liters	32	50
Production Price @ 100k units/yr	$	500	1,000
Maximum Operating Voltage	Vdc	</= 440 max	</= 440 max
Minimum Operating Voltage	Vdc	>/= 0.5 x Vmax	>/= 0.5 x Vmax
Maximum Self Discharge	Wh/d	50	50
Operating Temperature	°C	-30 to +52	-30 to +52
Survival Temperature	°C	-46 to +66	-46 to +66

Structure of the Study



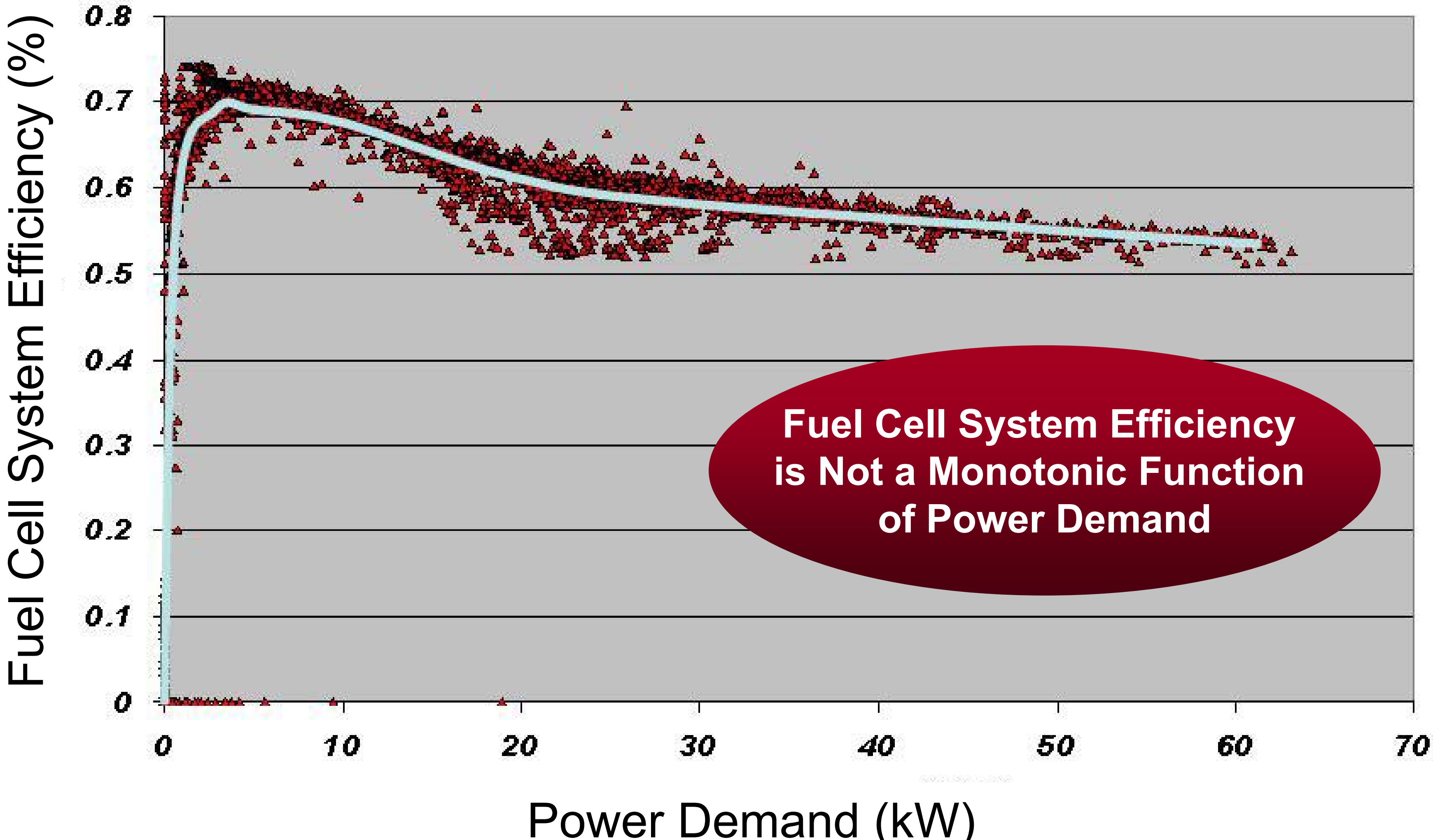
Fuel Cell HEV Configuration



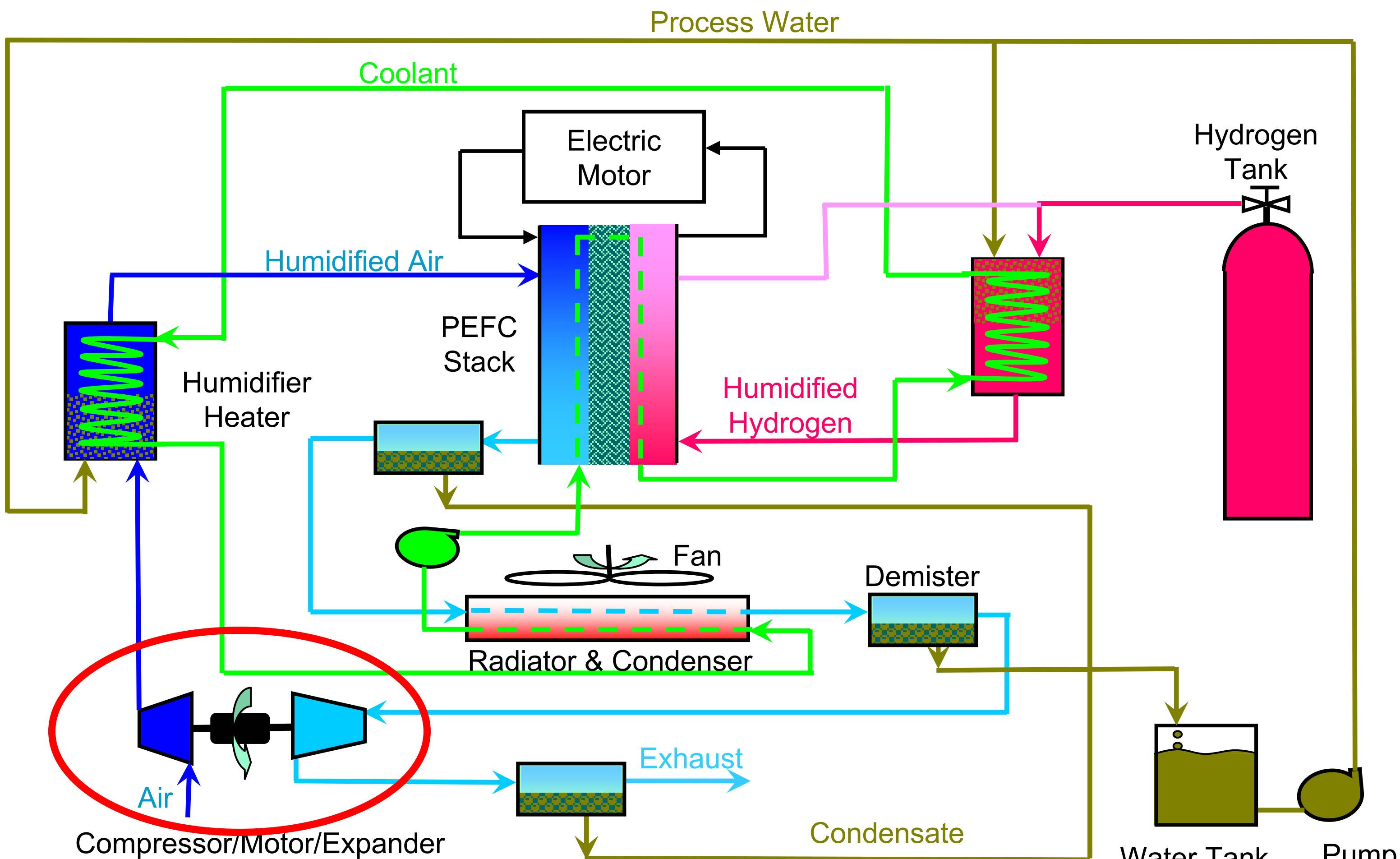
Major Assumptions

- Vehicle and Performance
  - Mid-size SUV (Explorer, Durango, Blazer)
  - Target 0-60 mph acceleration in 10.2 s
  - 55 mph at grade of 6.5% continuous (a least 20 minutes)
  - Top speed of 100 mph
- Fuel Cell System Requirements
  - Fuel cell should be sized to provide a least power for top speed and grade performance
  - FCS must have 1-s transient response time for 10% to 90% power.
  - FCS should reach maximum power in 15 s for cold start from 20C ambient temperature and in 30 s for cold start from -20C ambient temperature
- Power Requirements (based on PSAT simulations)
  - 160kW peak power for 0-60 mph acceleration
  - Minimum fuel cell power of 80kW for achieving speed at 6.5% grade
- Default: tight SOC control, lithium-ion, FUDS

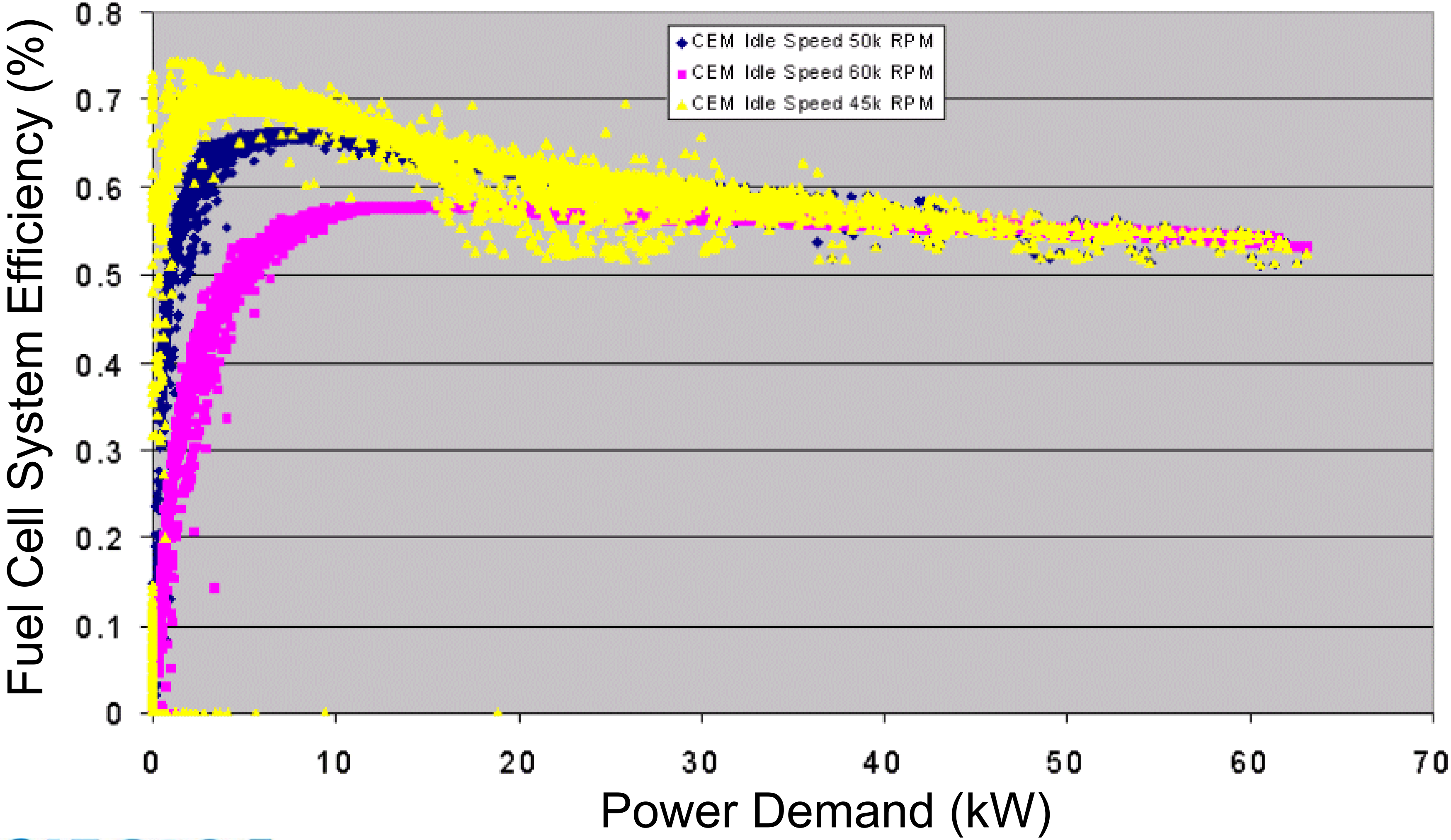
Detailed Models Necessary for Realistic Behavior



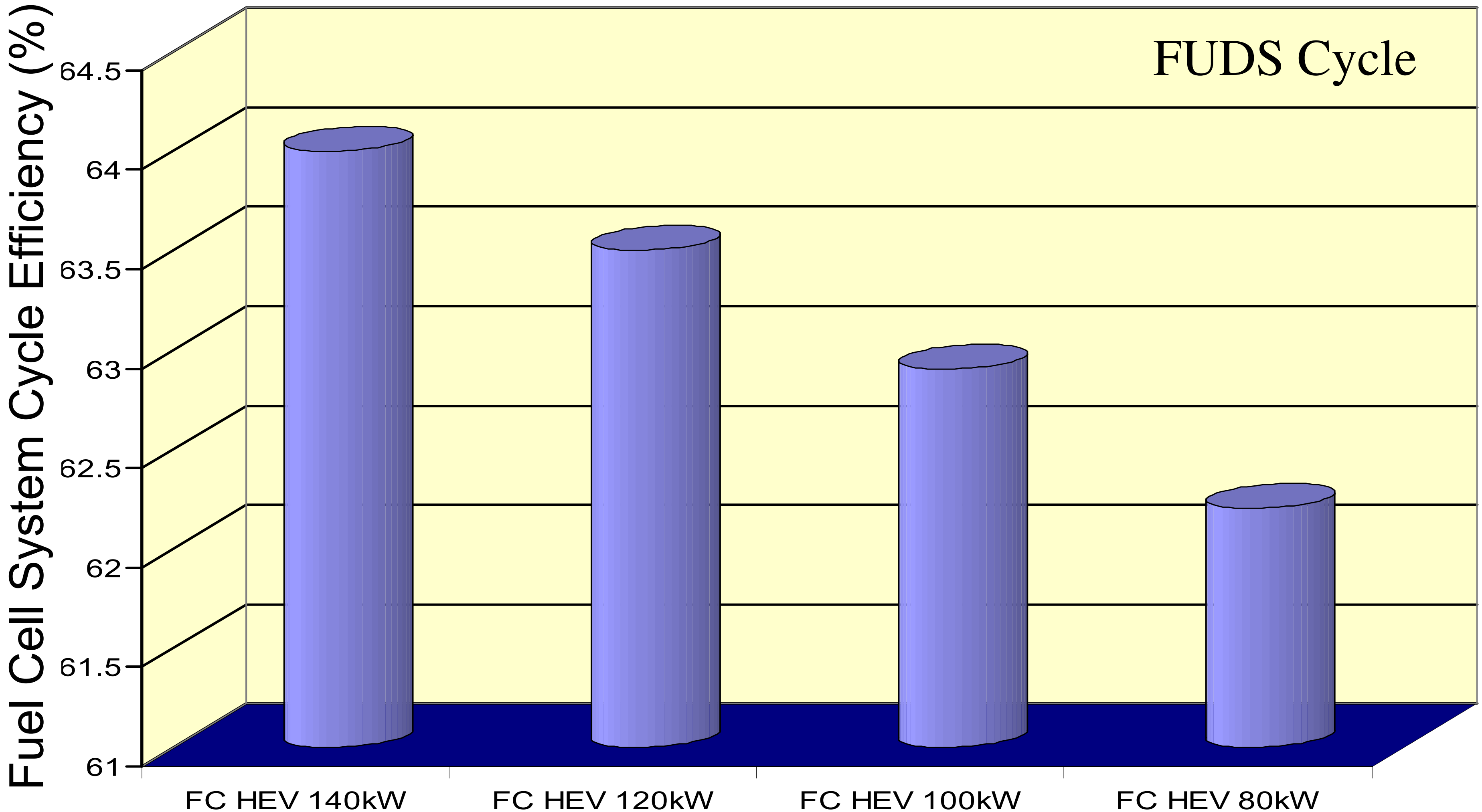
Design-Specific FC System Modeling Required to Assess Component Impact



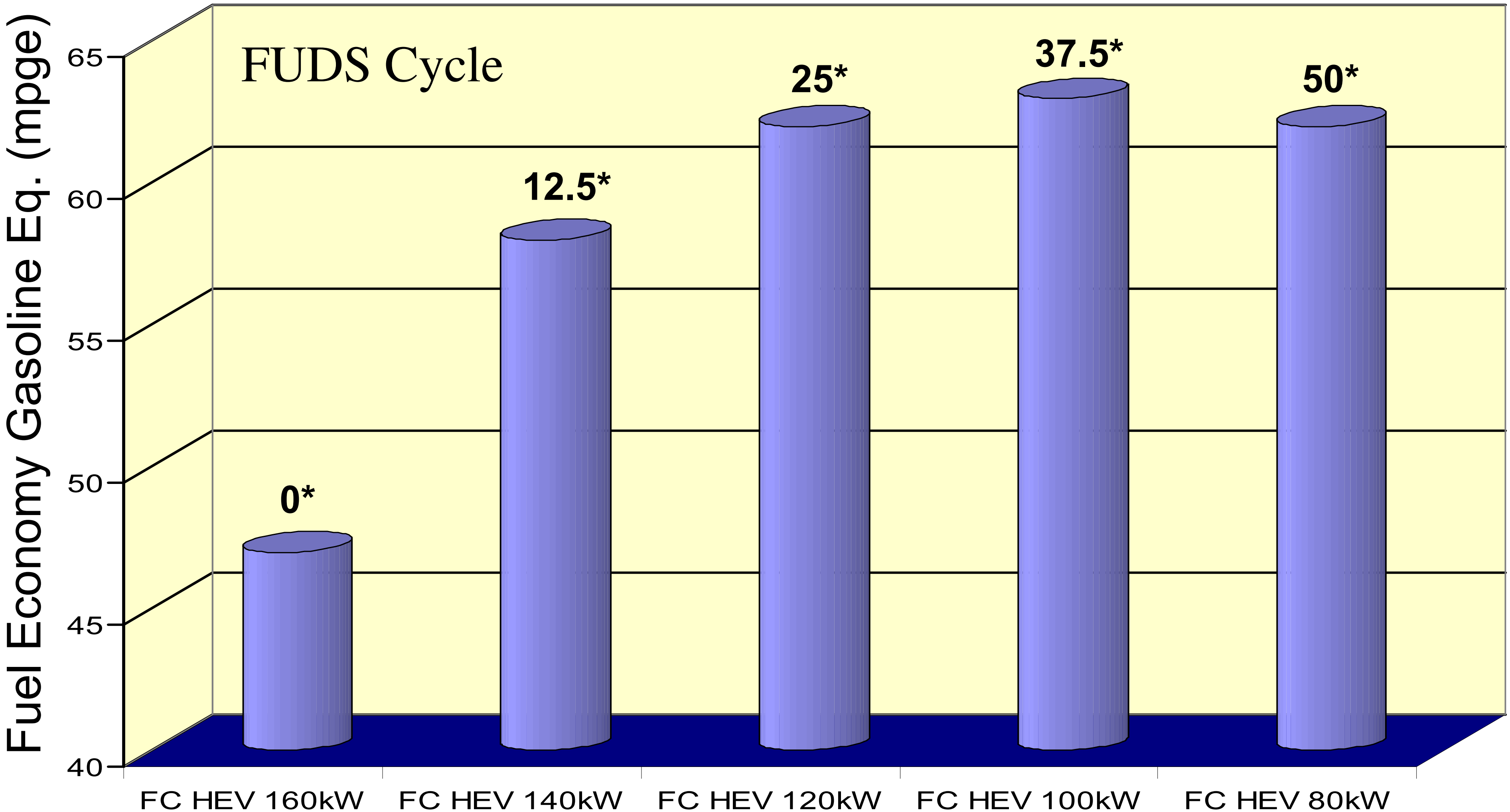
Small Differences in Components Can Have Large System Implications



Design-Specific Models Required for Realistic FC Cycle Efficiency

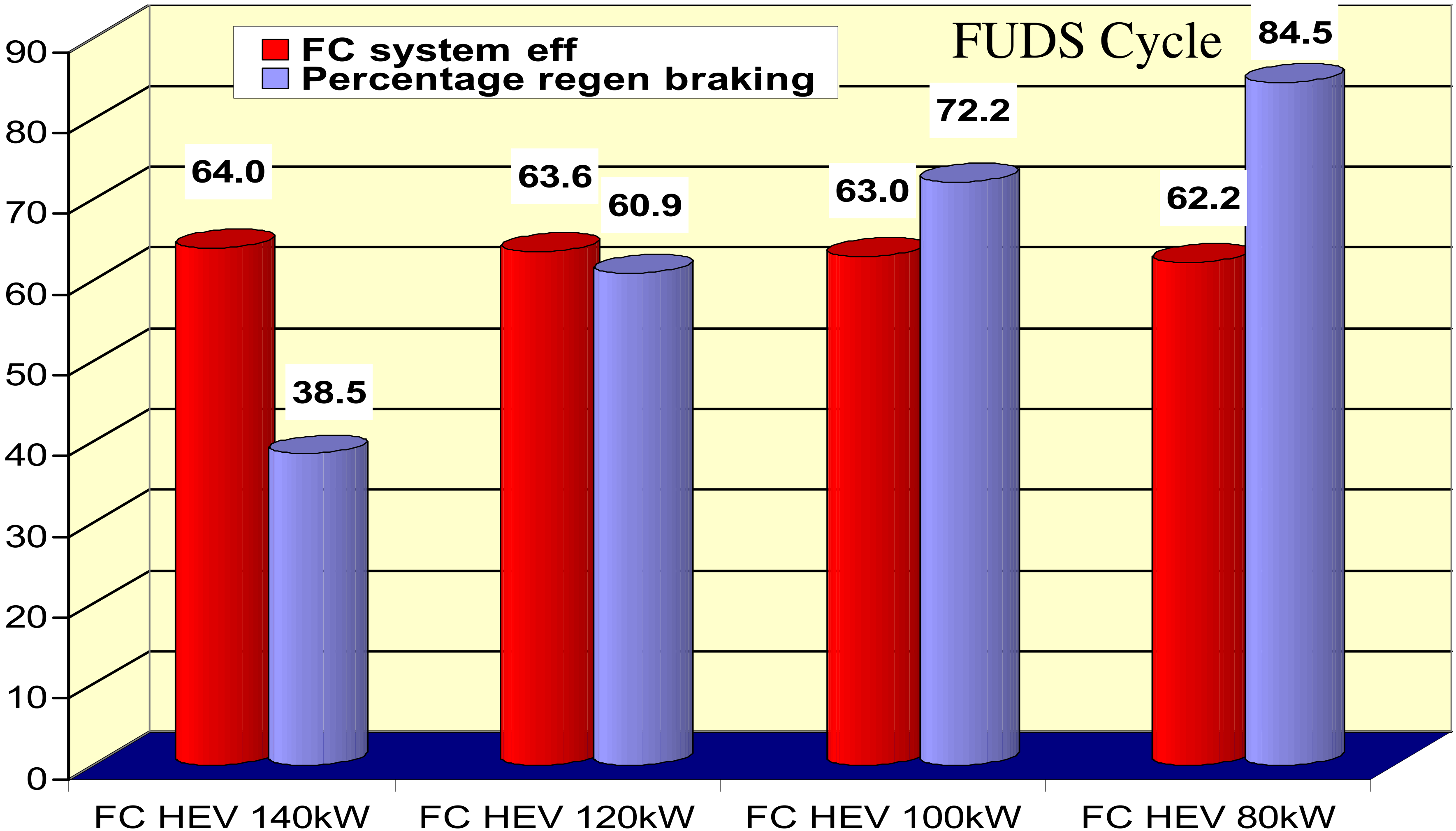


Increase in Hybridization Degree Can Lead to Decrease in Fuel Economy

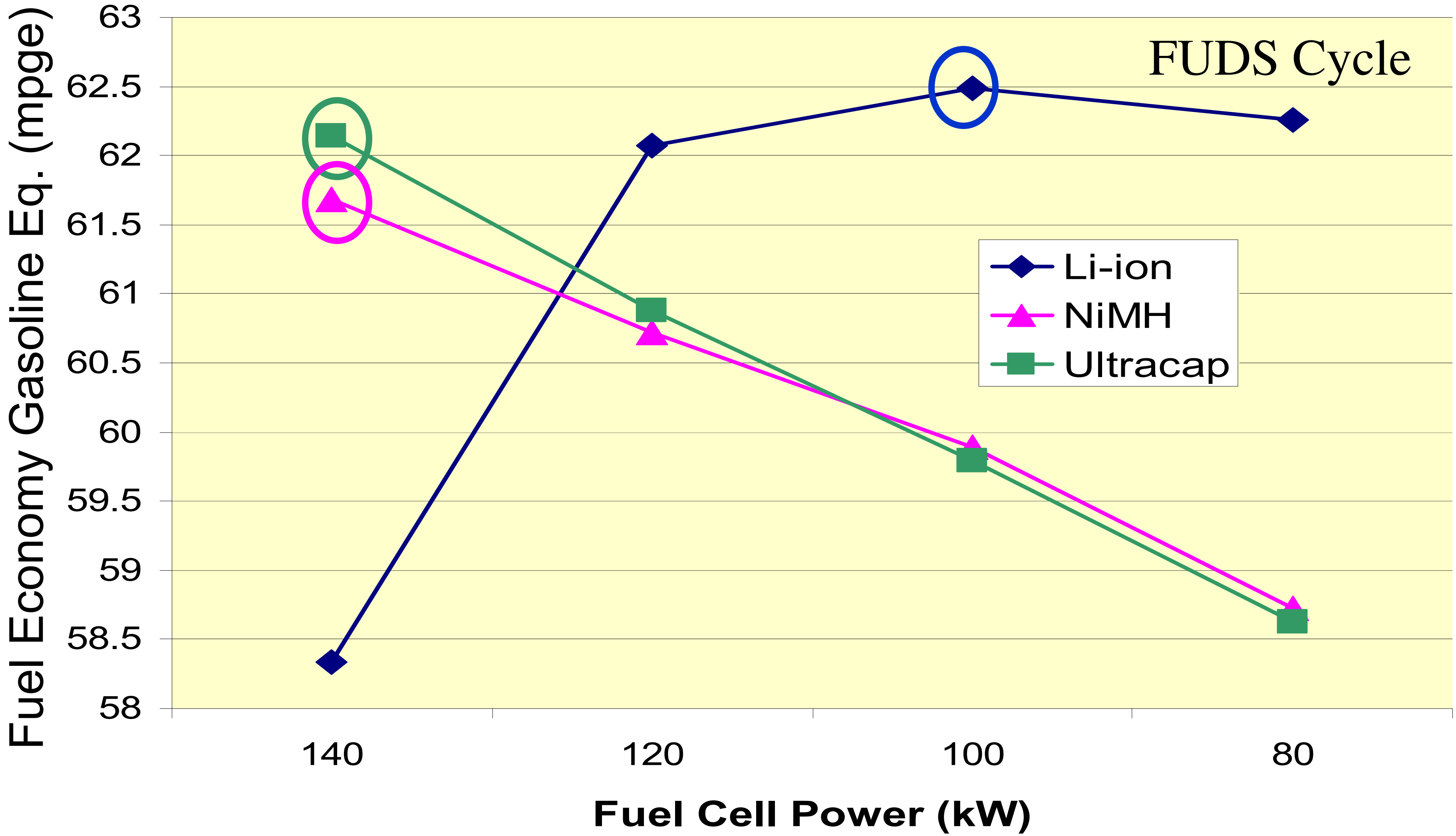


*Hybridization Degree

Because the Regen Energy Increase is Nullified by the FC Efficiency Decrease



Optimum Hybridization Degree Depends upon the ESS Technology



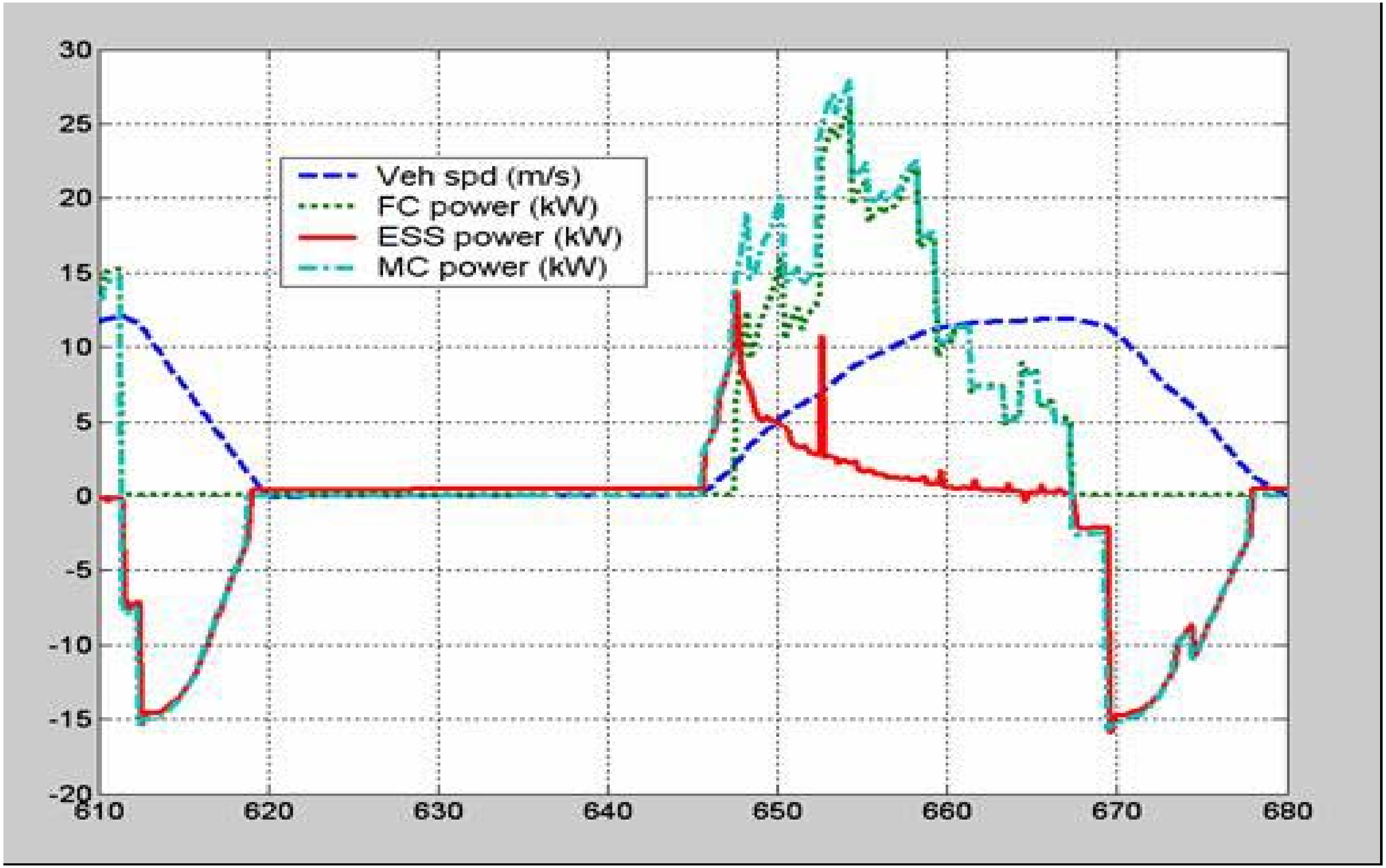
Numerous Control Strategies Options Were Considered

- Use the fuel cell as main power source
  - SOCtarget = 0.7
    - Min fuel cell power demand = 0 (Default Control)
    - Min fuel cell power demand = 5kW
    - Min fuel cell power demand = 15kW
  - SOCtarget = 0.5
    - Min fuel cell power demand = 0
    - Min fuel cell power demand = 15kW
- Use the battery as main power source
  - SOCtarget = 0.7
  - SOCtarget = 0.5

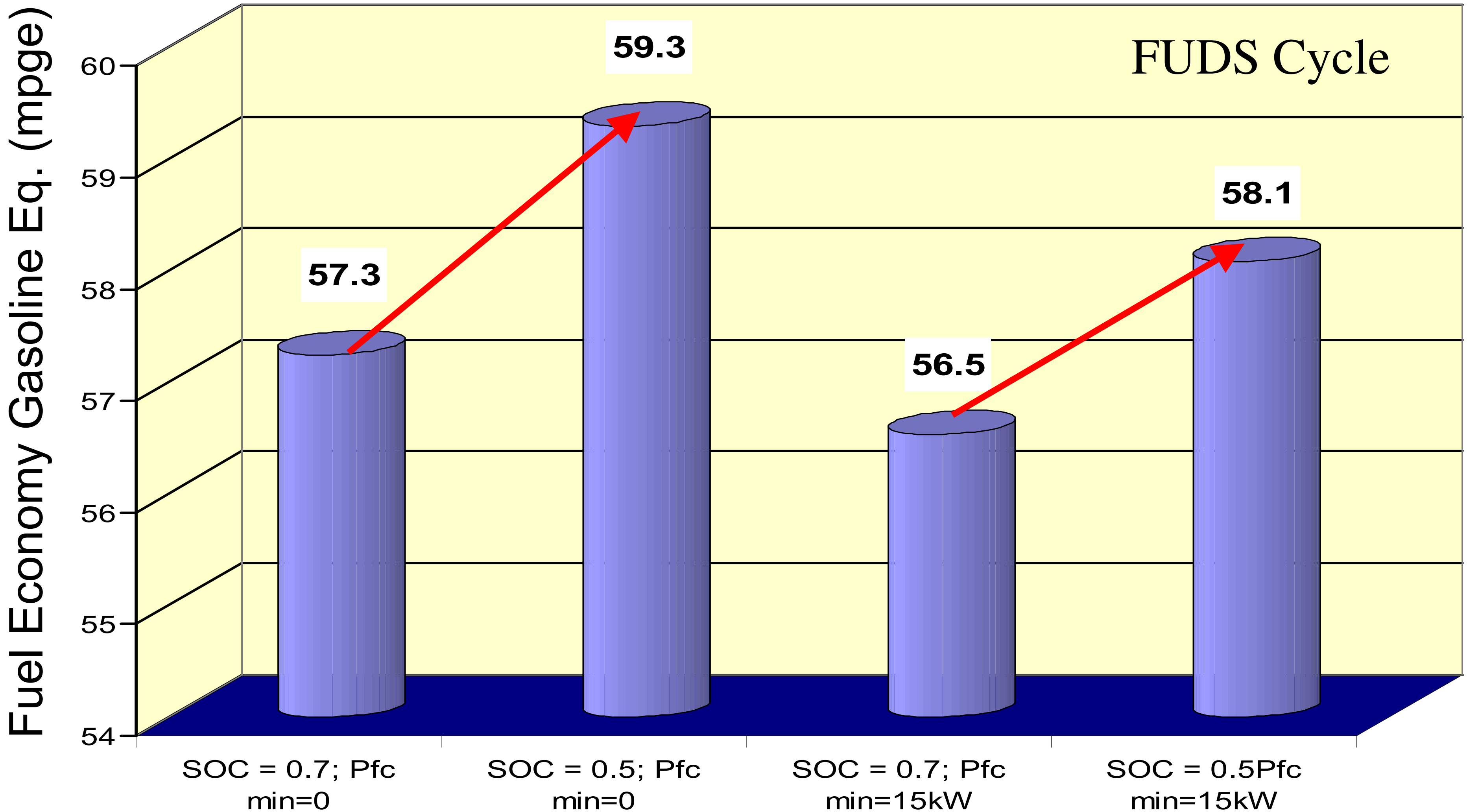
different ways to increase SOC window

With min fuel cell power demand = Pwheel + P(SOC)

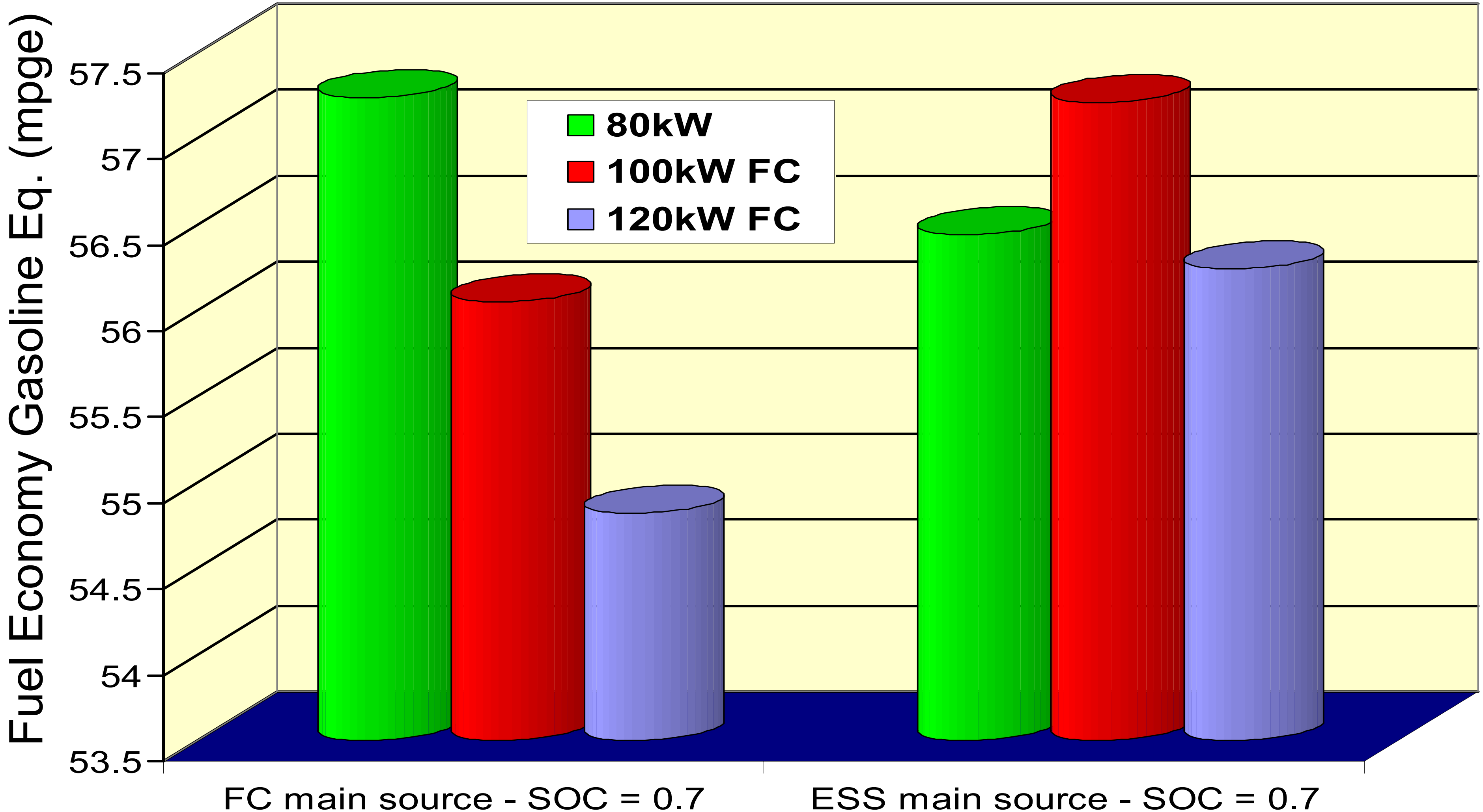
Default Control Strategy Maximizes Fuel Cell System Use



Smaller Target SOC (0.5) Leads to Fuel Economy Benefits



US06 Cycle Could Benefit From Using More The Battery



System Approach is Needed to Achieve Optimum Fuel Economy

- Key benefit of hybridization is fuel economy increase for FUDS thanks to regenerative braking
- Optimum hybridization degree is energy storage technology dependant
- Fuel cell system efficiency and regenerative braking trade-off is key to optimum fuel economy
  - Increasing hybridization degree and SOC window can lower fuel economy
  - Minimizing SOC target is a good way to increase the regenerative braking

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