Cars, Homes, Renewables – Tuning them as a System

Bert Bras

George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0405
USA
www.me.gatech.edu

Georgia Institute of Technology

Systems Design: Traditional Car + Home

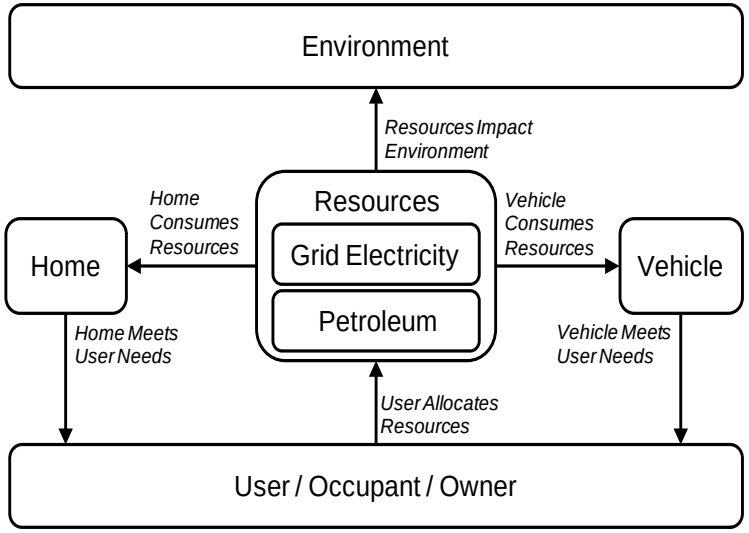
- Car and Home only share the garage (and occupants)

A little less traditional home…

- But still the same concept…

Home of the Future: Systems Connect

MyEnergiLifeStyle



Car and Home are connected. Literally.

Collaborative project between Engineering and Architecture

Lee et al., The Integrated Electric Lifestyle: The Economic and Environmental Benefits of an Efficient Home-Vehicle System, SAE Paper 2013-01-0495, SAE World Congress, April 16-18, Detroit, MI

Scenario Investigation

House location: San Jose, CA

Data came from various industrial partners and public domain sources

- Scenario 1: Baseline
  - Mid 1990's appliances
  - 2 Gasoline vehicles
  - Flat rate electricity
- No Electric Vehicle
  - Scenario 2: Add 5 kW-rated PV system (to South roof)
  - Scenario 3: Replace Vintage appliances with New
  - Scenario 4: Add Smart Control (TOU)
- Electric Vehicle Included (replace 1 Gasoline Vehicle)
  - Scenario 5: Add 5 kW-rated PV system
  - Scenario 6: Replace Vintage appliances with New
  - Scenario 7: Add Smart Control (TOU)

Georgia Institute of Technology

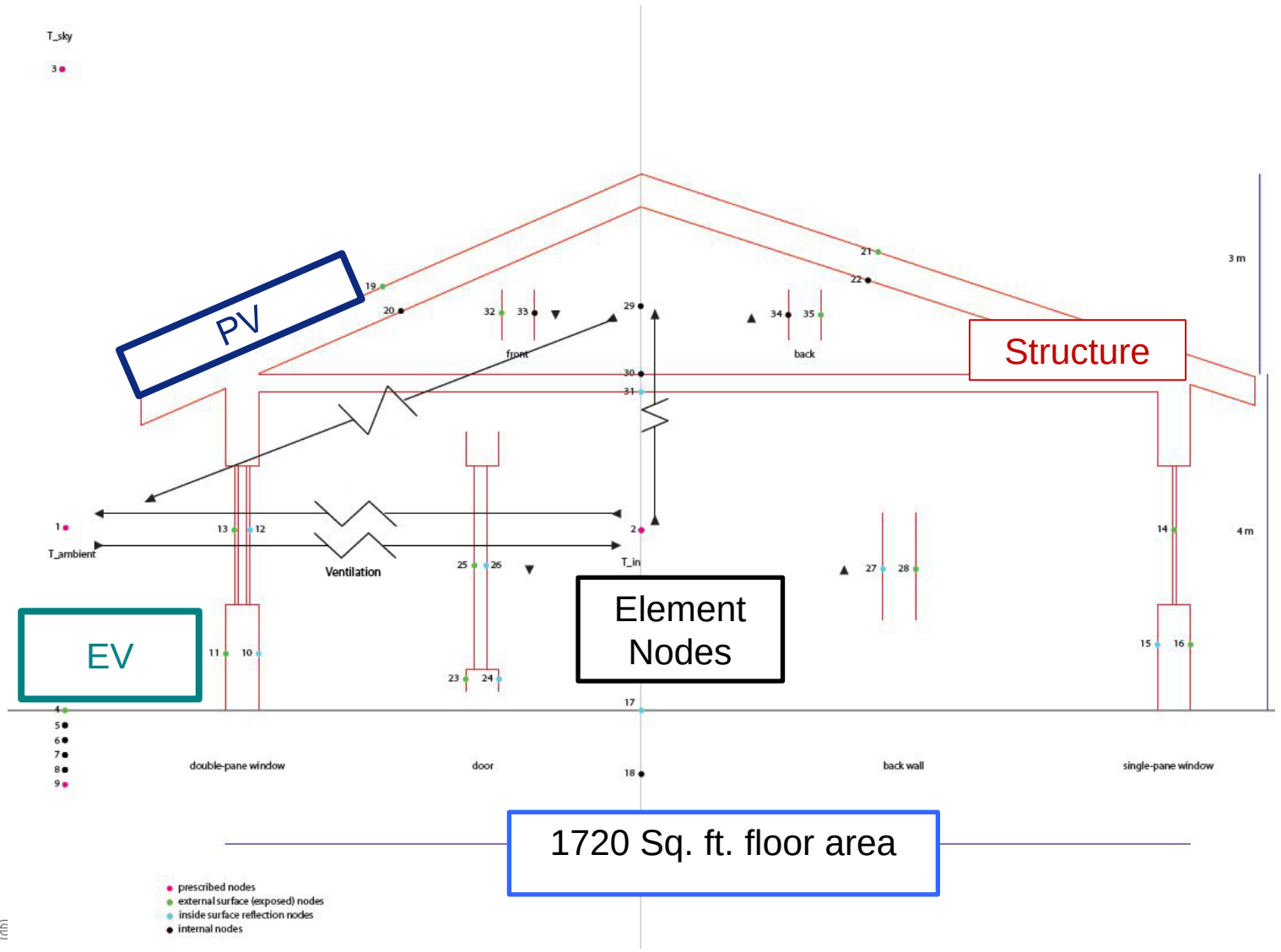
“Simple House” Simulation Model

Heat Flows
- *Conduction*
- *Convection*
- *Radiation*
- *Infiltration*
- *Ventilation*

Appliances
- *Refrigerator*
- *Laundry*
- *Dishwasher*
- *Lighting*
- *Water Heater*
- *Miscellaneous*

EV
- *Only Charge*

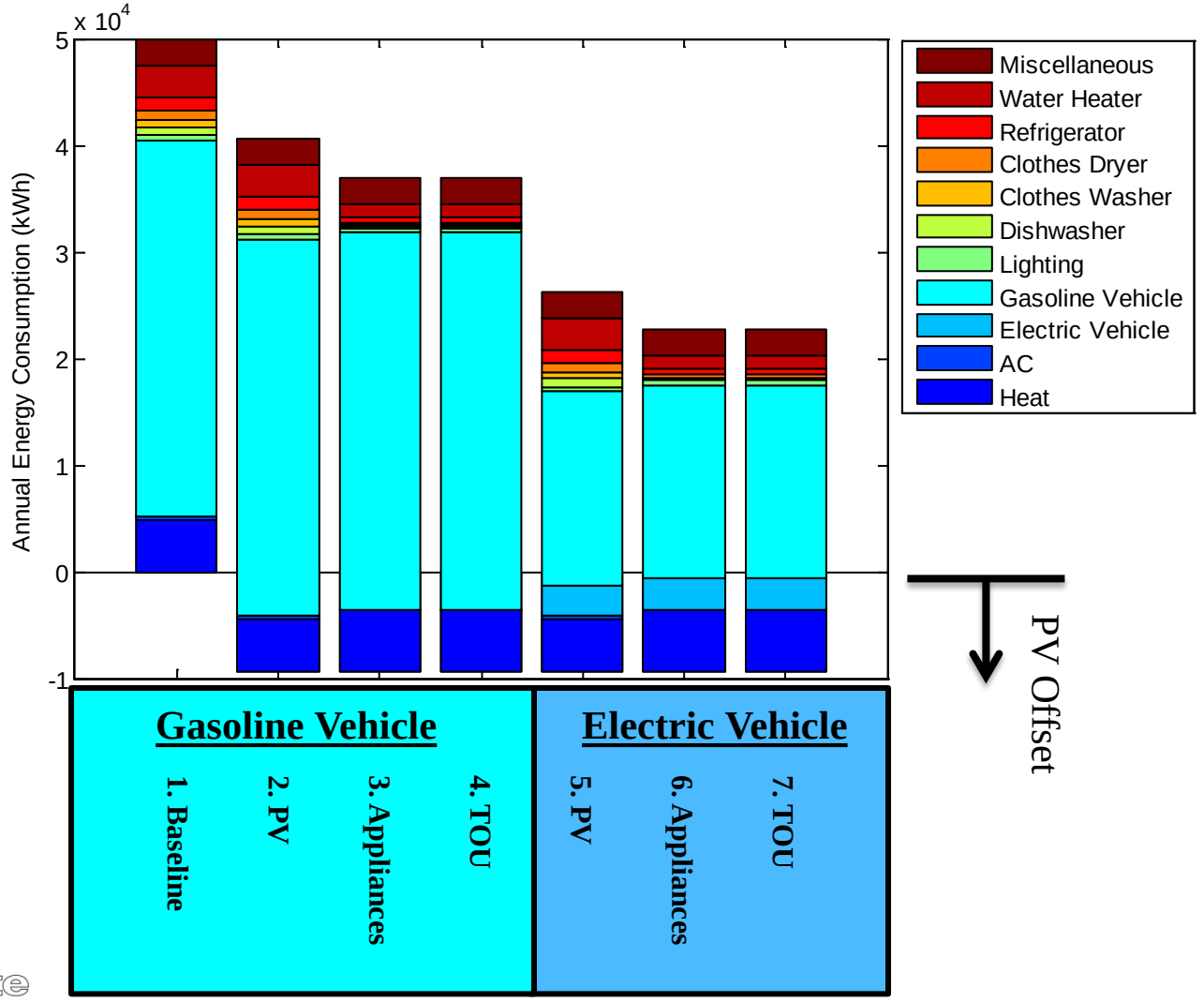
PV
- Facing South



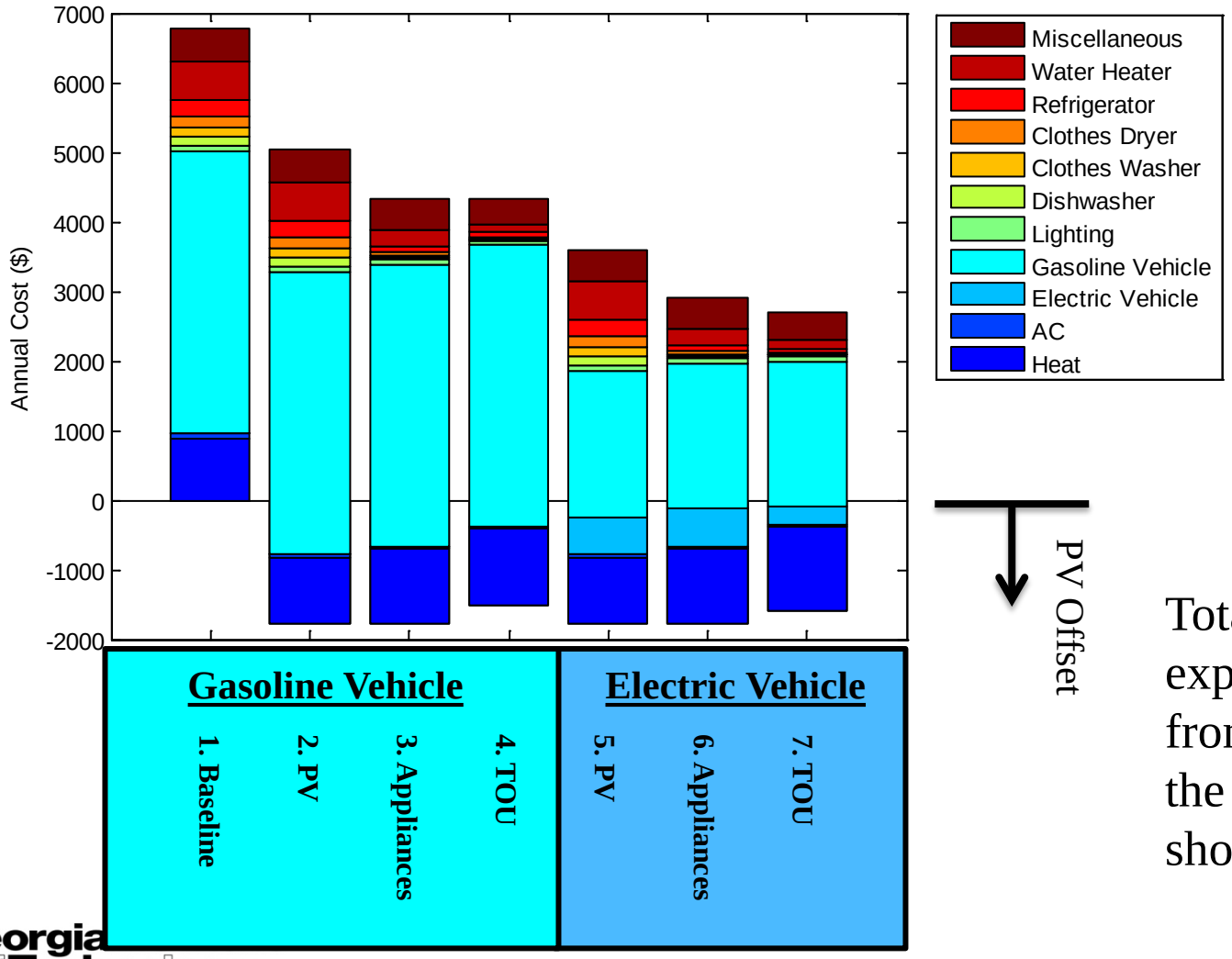
Georgia Institute of Technology

Annual Energy Consumption (kWh)

*Including energy in gasoline and electricity



Annual Cost ($)

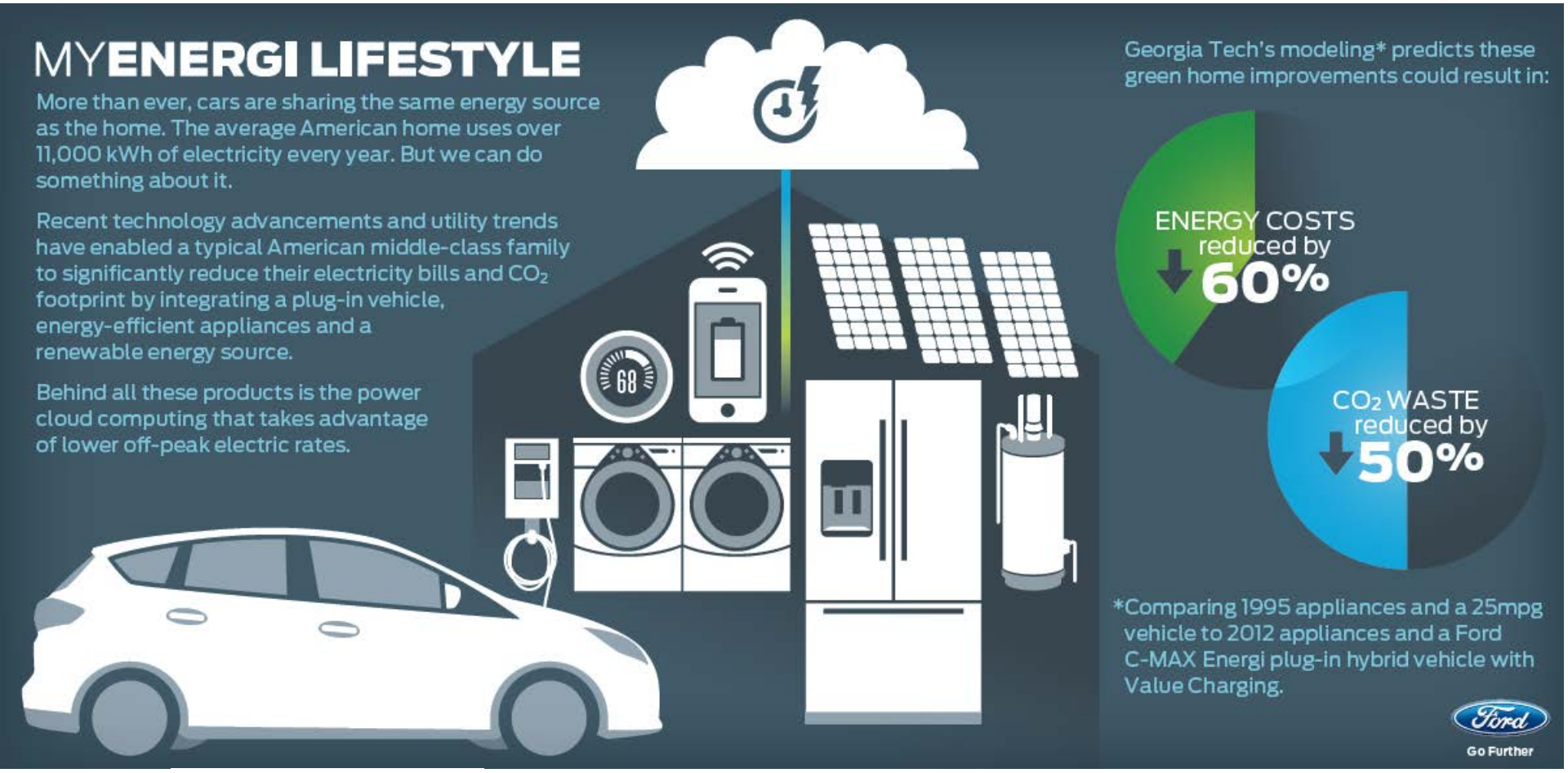


In TOU, the electric vehicle can make other house systems more expensive to operate.

Total increase in utility expenditures resulting from the introduction of the electric vehicle should be considered

Georgia of Technology

MyEnergi Lifestyle – New Collaborations, New Business



Ford SUNPOWER EATON Powering Business Worldwide Infineon Whirlpool Corporation

Georgia Institute of Technology

MyEnergi Lifestyle (MEL) versions

- MEL 1.0: Single house retrofit.
  - Simulation model verified with data from actual retrofits in CA and CO
- MEL 2.0: MEL 1.0 house plus home battery storage
  - 5 & 10 kWh systems (external to car)
- MEL 3.0: Updated MEL 1.0 plus new home technologies
  - LED lighting, full DC house, etc.
- MEL China: MEL 1.0 for Chinese market and consumer
  - Electric car without renewables can be worse than IC engine car in China
- MEL 4.0: Updated MEL 2.0 homes plus micro-grid

Conclusions: MEL 1.0 provides largest single reduction, but ROI is problematic – especially for MEL 2.0 and 4.0

(e.g., $5,000-$9,000 battery with, say, 5000 duty cycles)

Georgia Institute of Technology

EV on Renewables: Ford C-Max Solar Energi Concept

Can you recharge an electric vehicle with renewables without plugging it in?

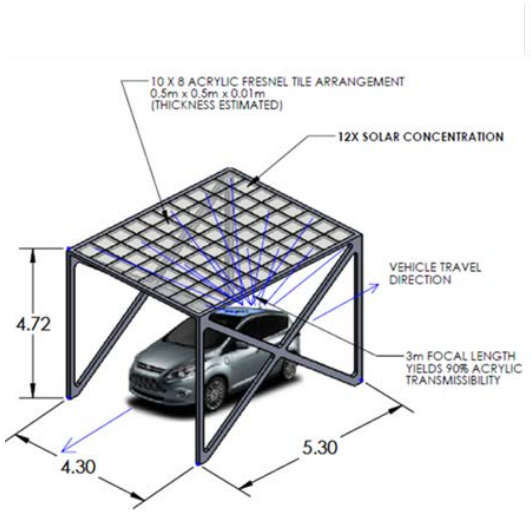
Ford C-MAX Solar Energi Plug-in Hybrid Electric Vehicle (PHEV) at 2014 CES

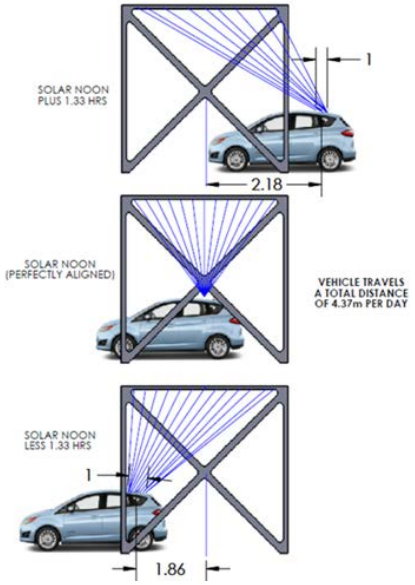
Georgia Institute of Technology

Problem of Charging (PH)EV with on-car Solar

- **Problem:** You need at least 8kWh to recharge and you have about 1 square meter of roof, which only gives you (at best) 1 kW of sunlight

- **Solutions:**
  - Bigger collection area (m^2)
  - Longer charging (hours)
  - More intense sun (magnification)
  - All of the above





- Obviously easier to do off-car (as charging infrastructure) than on-car, but you need (new) infrastructure (= expensive) and you are back to square one

Georgia Institute of Technology

Vehicle to Grid & Home (V2G & V2H)

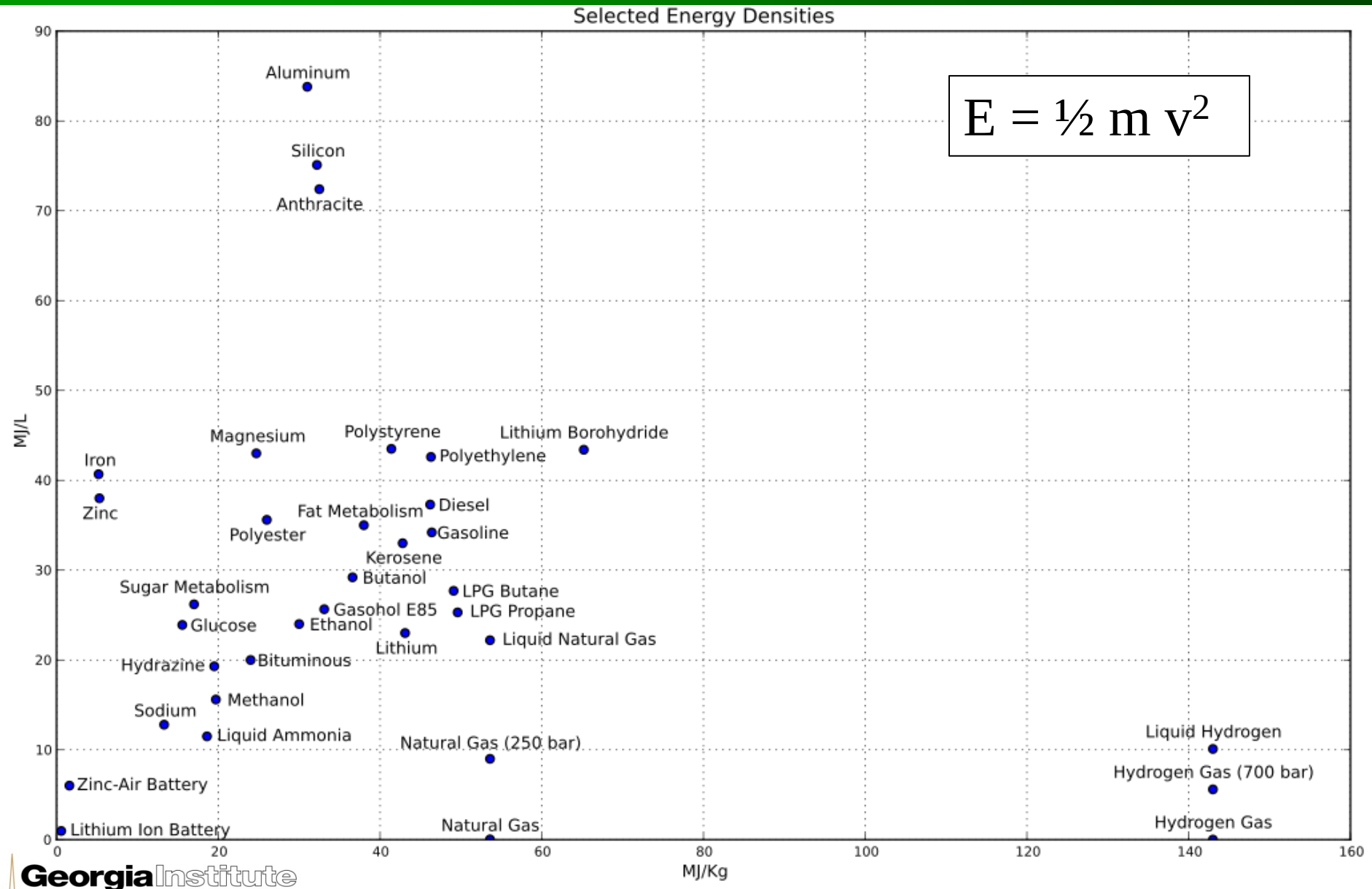
Opportunities:

- 8 kWh (PHEV) to 80 kWh (BEV) batteries can help stabilize fluctuations in renewables

Some challenges:

- Car needs to be "grid enabled" – charging parts need to allow backflow to grid or EVSE in home (only recently being considered/done)
- Number of EVs is (still) too low for large scale V2G
  - V2H is easier (like in MEL)
- Inefficiencies in conversions
  - DC-AC
- V2G & V2H discharges will degrade the (expensive) battery faster
  - Batteries have finite number of discharge cycles (Tesla Powerwall lasts 5000 cycles)
- ***Who "owns" the battery? (Who gets the benefits and what are they?)***

The Fundamental Problem: Energy Densities



Georgia Institute of Technology

Ships and Planes

Bio-diesel and fuels probably only option for ship & planes

- Moving ships and planes requires serious power
  - Most “renewables” are employed for auxiliary power
- Trains can run on PV and wind but require electrification (lots of infrastructure)

Georgia Institute of Technology

Transportation on 100% Renewables – How?

- First, “renewable” does not just mean wind and solar
- Gasoline is also “renewable” (bio-diesel, synthetic fuel, etc.)
- Liquid fuels (gas, diesel, etc.) are almost impossible to beat based on energy per unit mass (energy density)
- Electric batteries are heavy, charge slowly, don’t pack as much energy, are expensive and have finite life time (~7 yrs)
- Best thing to do is drive less (or not at all – bike!)
- Personally, right now I would buy a Plug in Hybrid Electric Vehicle which gives the option of pure electric for short (20 mile) ranges and regular (hybrid) driving for long distances
- Class 8 trucks are a whole other story.
- In short, it’ll be a while…

PV & Wind Save Water

Energy Type	Cooling Configuration	Boiler Type	Water Consumed (l/kWh)	Ref.
Coal	Once-Through	Subcritical	0.522	[12-14]
		Supercritical	0.428	
	Cooling Tower	Subcritical	0.269	
		Supercritical	0.469	
	Cooling Pond	Subcritical	0.390	
		Supercritical	0.242	
Energy Type	**Cooling Configuration**		**Water Consumed (l/kWh)**	
Oil or Natural Gas	Once-Through		0.341	[12-14]
	Cooling Tower		0.606	
	Cooling Pond		0.420	
Nuclear	Once-Through		0.519	[12-14]
	Cooling Tower		2.362	
	Cooling Pond		1.700	
Energy Type	**Location**		**Water Consumed (l/kWh)**	
Hydro	United States Average		17	[14]
PV Solar	United States Average		**0.023**	[14, 46]
Wind	United States Average		**0.004**	

- Lots of water is consumed in electricity production
- Only water that PV and wind need are for cleaning and maintenance
- Hydropower is a problem though – depending on how you draw the boundary

Georgia Institute of Technology

Some Closing Thoughts

- Convenience may still trump good sense
  - 100% renewables will not get you to Florida for vacation, unless you can crack synthetic or bio-fuel problem
  - Are we going to get rid of natural gas heating infrastructure for homes?
- Devil is in the details
  - Maintenance? Ownership? Reliability? (In)Convenience?
  - Costs are still high for consumer & businesses
  - Technical issues like frequency regulation remain to be solved/hardened
- Getting transportation on renewables will likely require synthetic and/or bio-based fuels of some sort

Any opinions, findings, and conclusions or recommendations expressed are those of the authors and do not necessarily reflect the views of the US government and/or the authors' parent institutions and sponsors.

Georgia Institute of Technology