Blowing Hot and Cold –

advanced high efficiency heating and cooling technologies.

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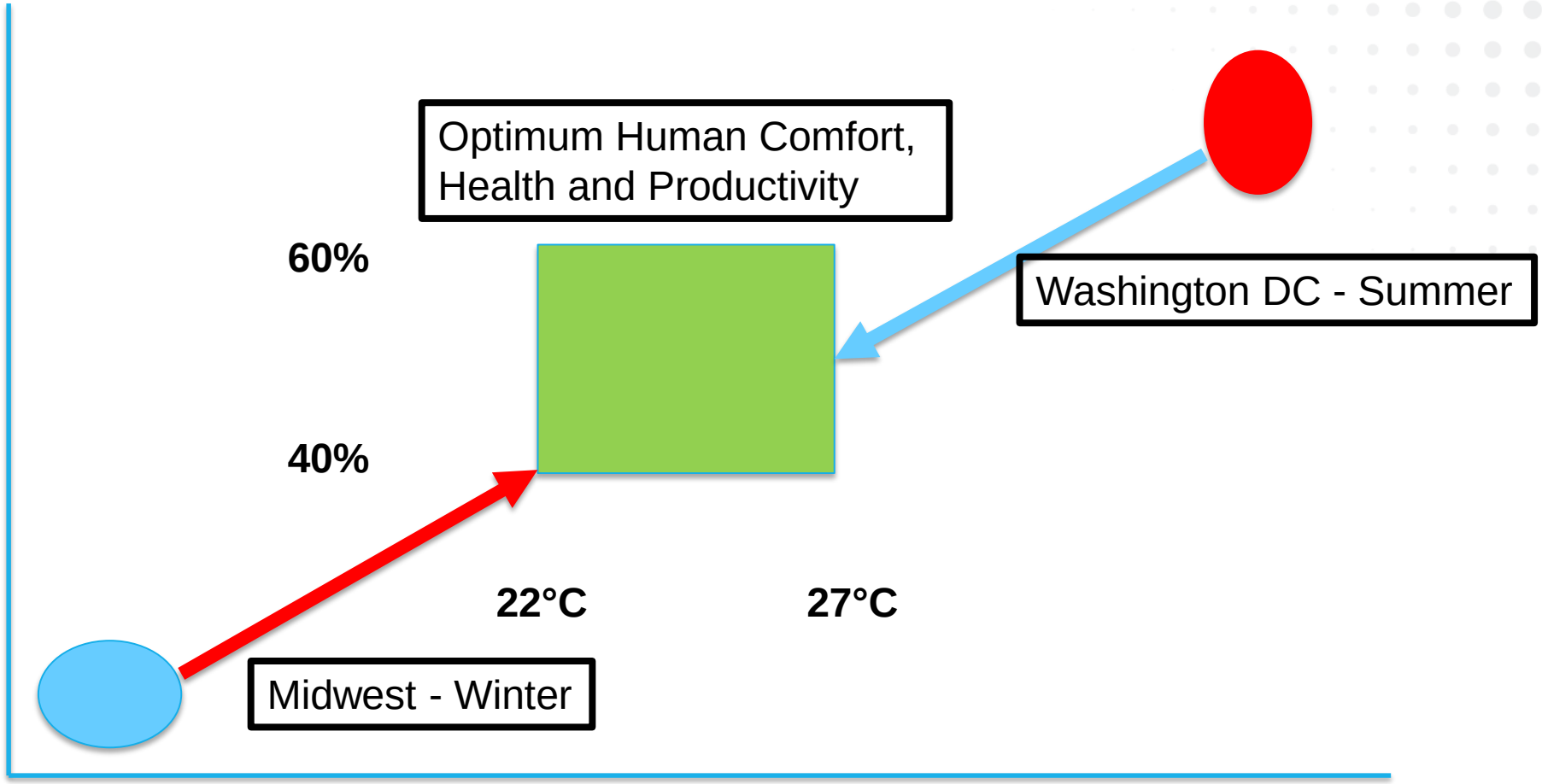
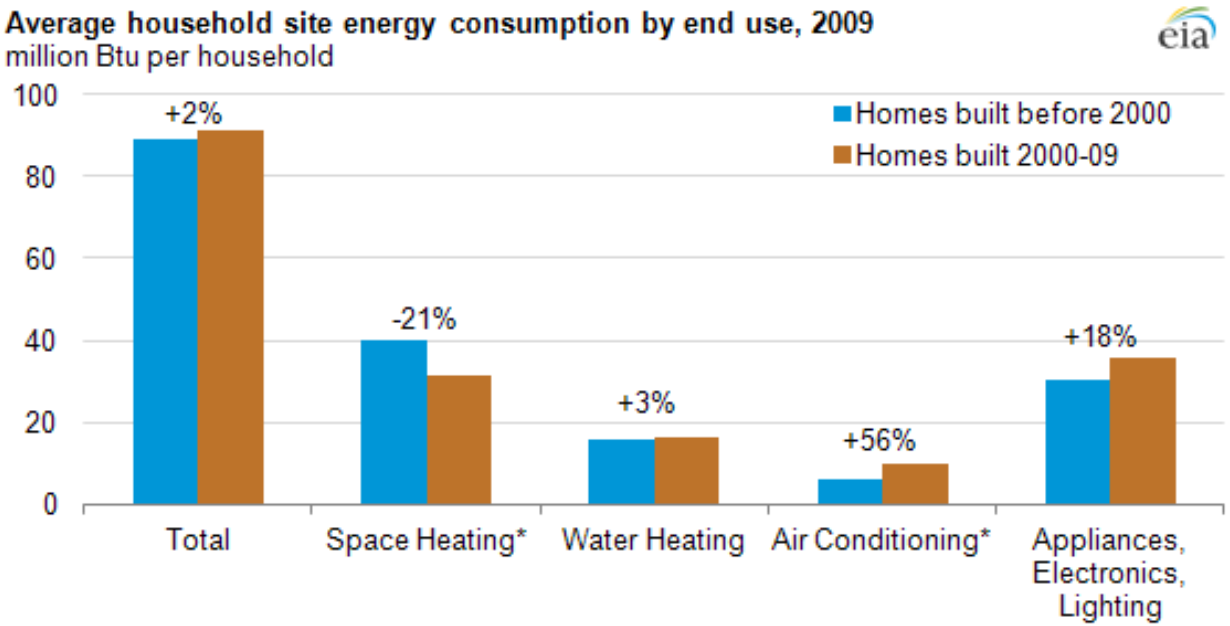
Program Director

The requirement for heating, cooling & air conditioning

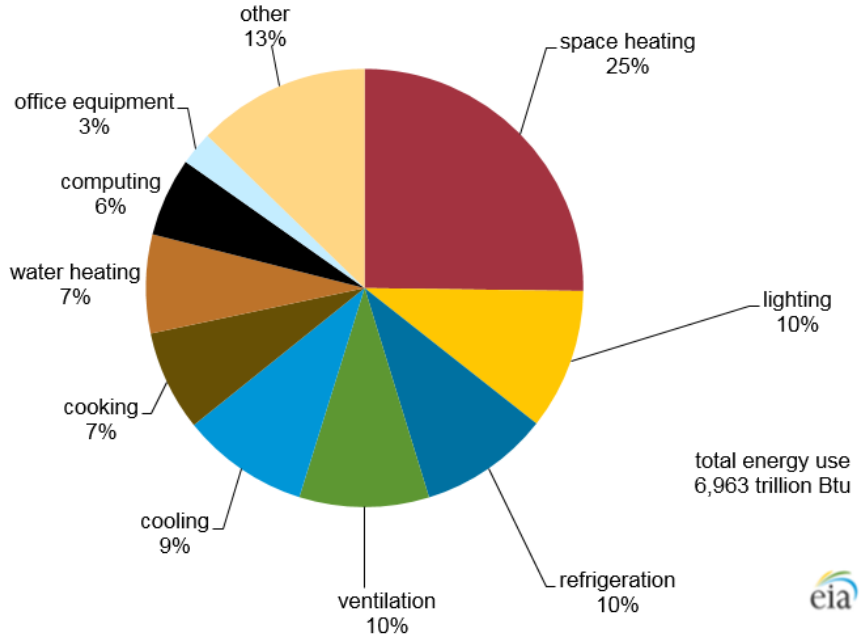


US energy consumption for heating and cooling



EIA, 2009 – 113.6 million residential units, (with 72 million detached).
Total energy usage 10.2 quads/year.
48% of energy used for heating/cooling or **4.9 quads/year**.

Figure 5. Space heating demanded the most overall energy use in commercial buildings in 2012, followed by other uses

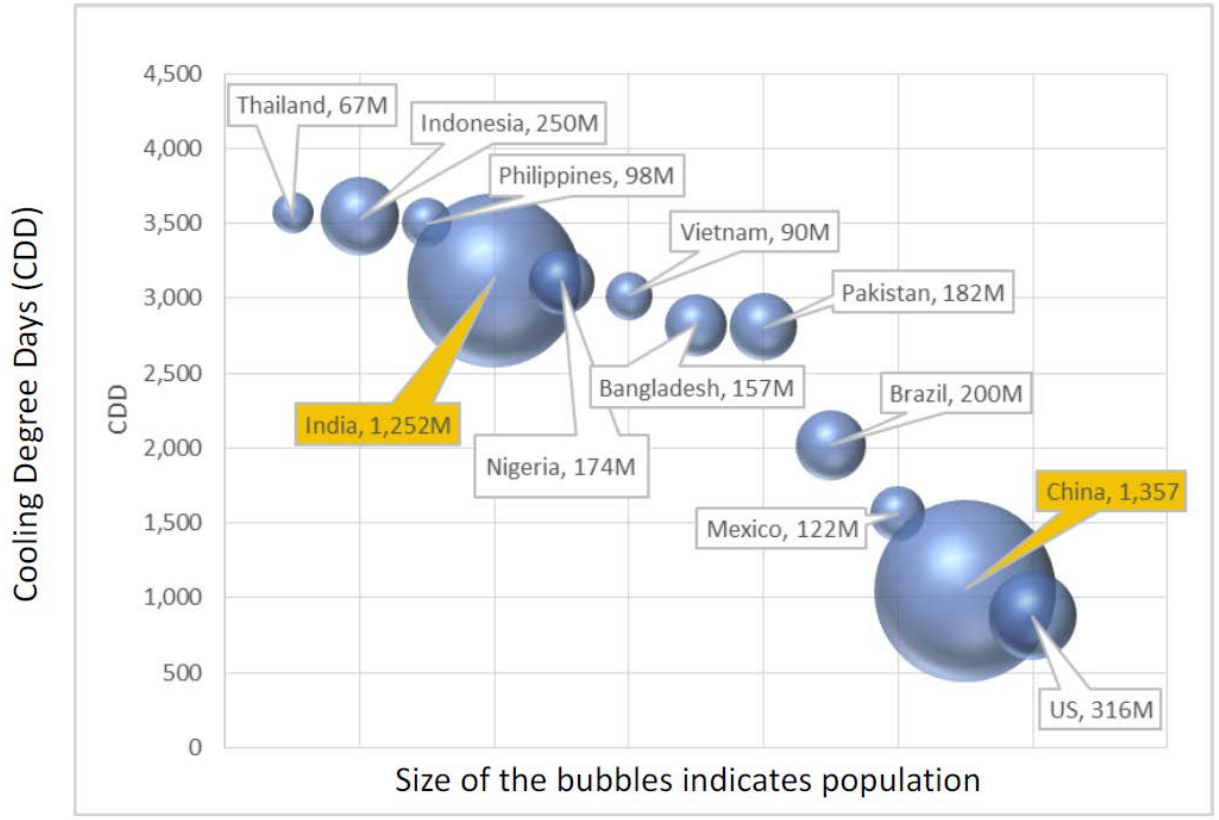


Source: U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey.

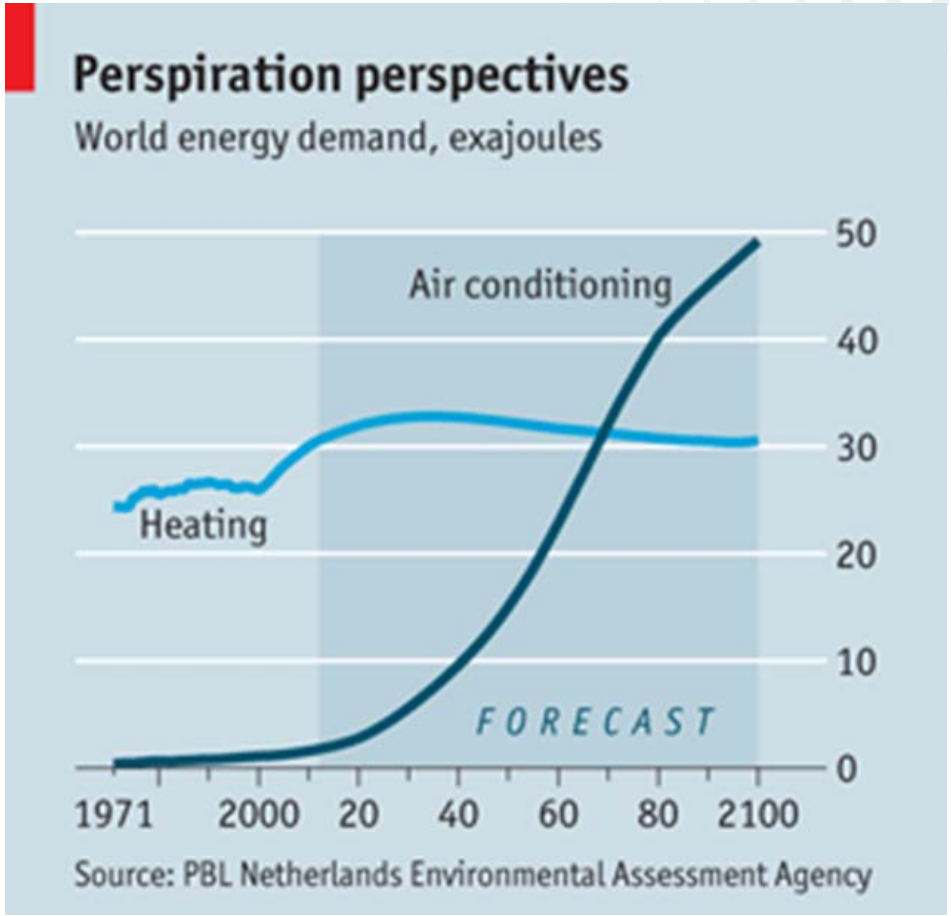
EIA, 2012 – 5.6 million commercial buildings.
Total energy usage ~7.0 quads/year.
44% of energy used for HVAC, or **3.06 quads/year**.

Primary energy usage for HVAC exceeds 13 quads/year in the US.

Global cooling energy demand – significant growth ahead



Source: Davis et al., Proceedings of the National Academy of Sciences, 2015; Sivak, Energy Policy, 2009



Source: The Economist 1/5/2013

The future global energy usage for HVAC is potentially enormous.

The heating and cooling technology problem

- Energy requirements for space heating and cooling for residential and commercial applications in the US and globally, are increasing significantly.
  - how can we make heating and cooling systems even more efficient?
  - what new systems and technologies are there to reduce energy consumption, while maintaining low lifecycle costs?
- HVACR systems have required constant re-invention due to periodic changes in regulations concerning refrigerants (Montreal, 1989; Kigali, 2016).
- This is a mature industry, driven by regulation but extremely cost-constrained.

Can we break out of this cycle of constant low-tech reinvention?

The state of the art of HVACR

- Considerations:
  - Energy efficiency of HVACR is paramount to the customer/consumer
  - Low cost and robust, long-life systems required
  - Refrigerants – zero ODP, low GWP, non-toxic, non-flammable, low cost, low leakage required
  - Indoor air quality and human health considerations becoming more critical
- US Department of Energy has a long history of funding in this area:
  - Building Technologies Office – BTO MYPP 2016-2020
  - **ARPA-E** **BEETIT** **DELTA** **OPEN** **SENSORS**

The ideal HVAC system

Energy efficient

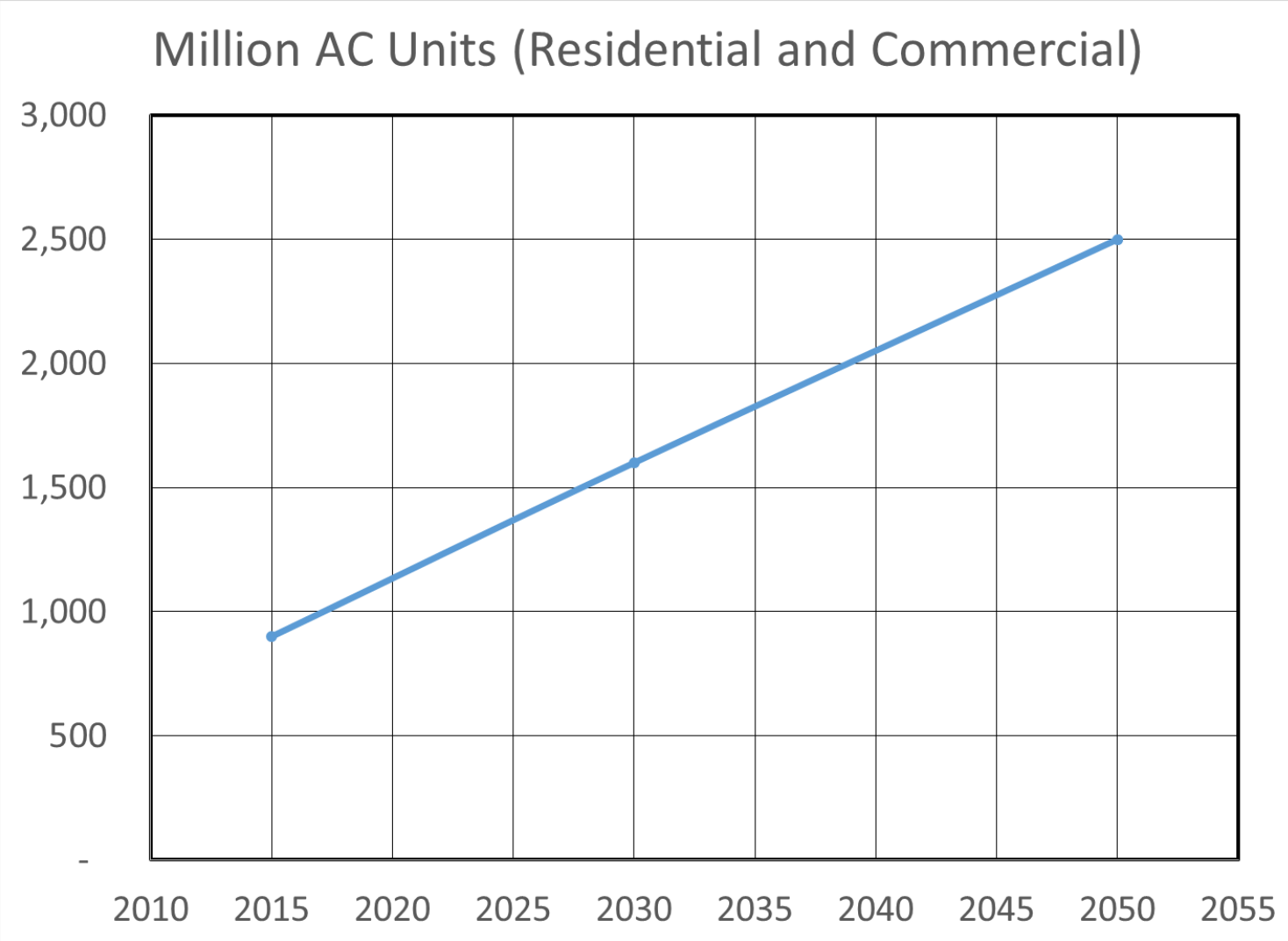
Environmentally benign

Low lifecycle costs (CAPEX & OPEX)

The ideal

The reality

The future opportunity (and the future threat)



US & OECD China India, Brazil, SE Asia

A new ARPA-E program – potential technical solutions

- **High efficiency heat pumping**
  - New vapor compression cycles
  - Binary refrigerant systems
  - New compression technologies
  - New absorption/adsorption systems
  - Solid state cooling – thermoelastic, thermoelectric, magnetocaloric….
  - Gas cycles – Stirling, thermoacoustic, supercritical CO_2
  - Enabling technologies – advanced HX manufacturing, advanced joining technologies, compressors, low-charge systems
  - Cascaded systems
  - Split systems

- **Cold climate heat pumping**
  - Air-, ground-, water-coupled systems

- **Dehumidification**
  - Desiccant systems
  - Membrane-based dehumidification

- **Heating**
  - CHP systems
  - Direct-fired systems
  - Solid state heating
  - New absorption/adsorption systems

- **Other technologies**
  - Hybrid systems
  - Thermal storage – diurnal, seasonal
  - Integration with renewable energy
  - SmartGrid integration
  - Control technologies
  - Integrated remote generation and heating/cooling

  - (underlining denotes where DOE and ARPA-E have previously invested).

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Are there any NEW breakthrough technologies that can give us the efficiency and reduced costs that we require, without the constant reinvention?

Are there any synergies among these technologies?

arpa·e
CHANGING WHAT'S POSSIBLE

There is strong technical motivation for a new ARPA-E program in this area.

Potential program targets

TARGETS

- Improved energy efficiency
- “Perfect” refrigerants (if used)
- Air quality
- Reasonable lifecycle costs
- Commercialization

Potential program metrics

TARGETS

- Improved energy efficiency
- “Perfect” refrigerants (if used)
- Air quality
- Reasonable lifecycle costs
- Commercialization

METRICS

- 2x current COP or W_{th}/W_e efficiency
- Zero ODP, low GWP, safe, non-toxic
- Applicable human health standards
- Lower than today
- Pathway to market within 3 years

If we achieve these metrics, we will have solved the problem for once and for all!

Next steps in program development

Program Development

- Request for Information (RFI)
- Technical Workshop
- Funding Opportunity Announcement (FOA)

Timeline

- Spring 2017
- Summer 2017
- Fall 2017

- Sign up for ARPA-E notifications on our website

- Contact: Chris.Atkinson@hq.doe.gov