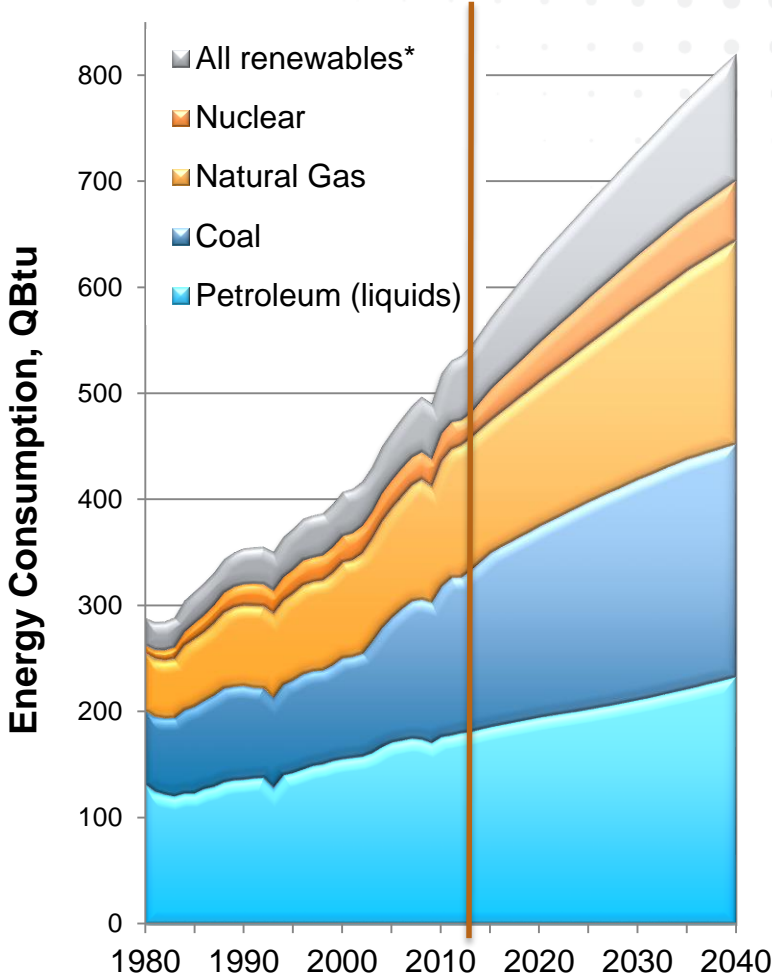
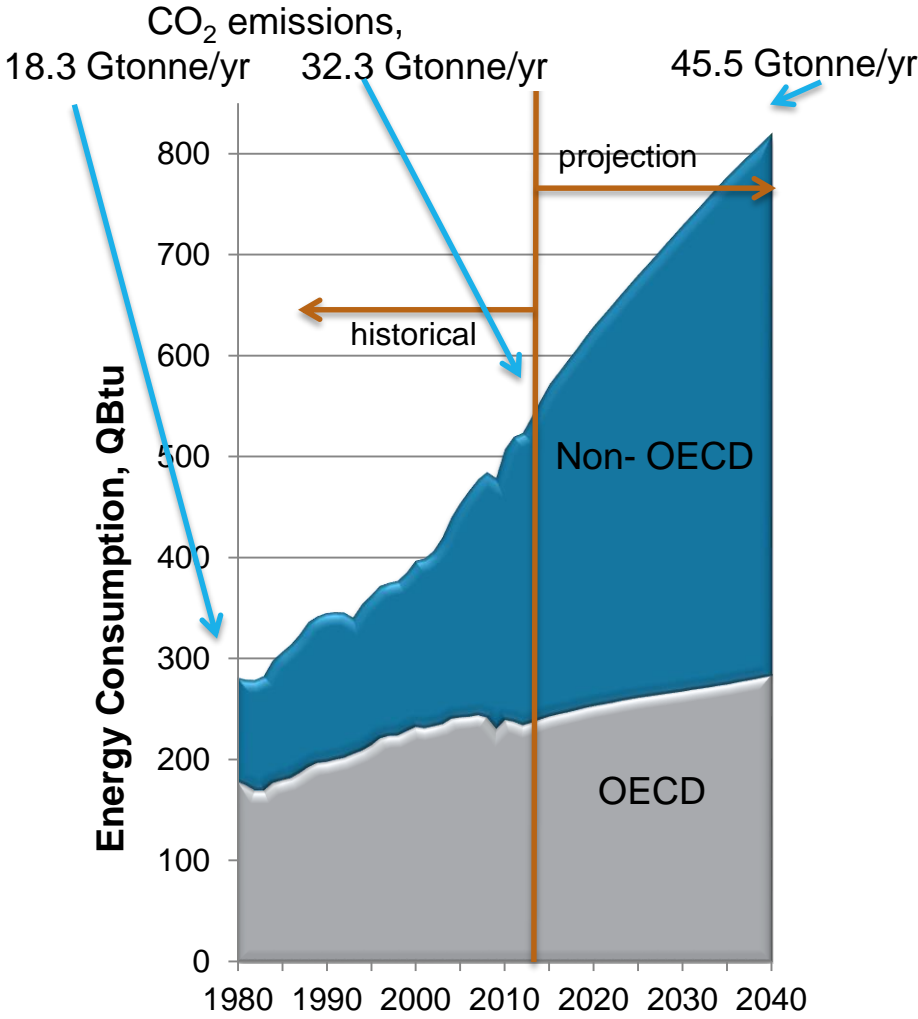


# Advanced Research Projects Agency - Energy

Ellen D Williams  
Columbia University  
May 24, 2016



# Energy and Emissions - World



\* Includes both traditional and modern uses of biomass

# ARPA-E Mission

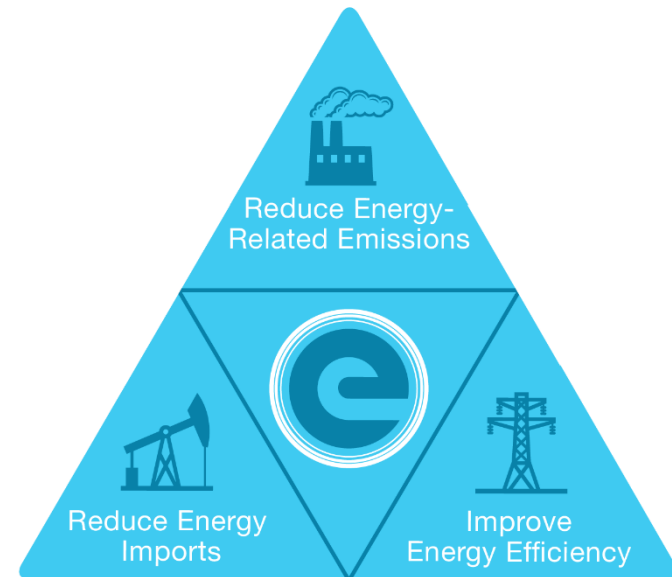
**Mission:** To overcome long-term and high-risk technological barriers in the development of energy technologies

**Goals: Ensure America's**







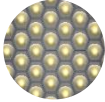







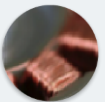

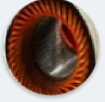






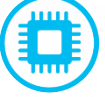
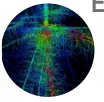


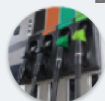
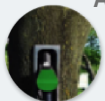



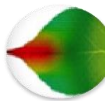



- Economic Security
- Energy Security
- Technological Lead in Advanced Energy Technologies

**Means:**

- Identify and promote revolutionary advances in fundamental and applied sciences
- Translate scientific discoveries and cutting-edge inventions into technological innovations
- Accelerate transformational technological advances in areas that industry by itself is not likely to undertake because of technical and financial uncertainty



# Focused Program Portfolio

ELECTRICITY GENERATION	 IMPACCT  SOLAR ADEPT	 FOCUS  REBELS	 ALPHA  GENSETS  MOSAIC	
ELECTRICAL GRID & STORAGE	 GRIDS  HEATS  GENI		 CHARGES  NODES	 GRID DATA  IONICS
EFFICIENCY & EMISSIONS	 ADEPT  BEETIT  REACT	 METALS  SWITCHES  DELTA  MONITOR	 ARID	 SHIELD  ENLITENED  ROOTS
TRANSPORTATION & STORAGE	 BEEST  AMPED  ELECTROFUELS  PETRO  MOVE	 RANGE  REMOTE	 TERRA  TRANSNET	 NEXTCAR  REFUEL
	2010 - 2012	2013-2014	2015	2016

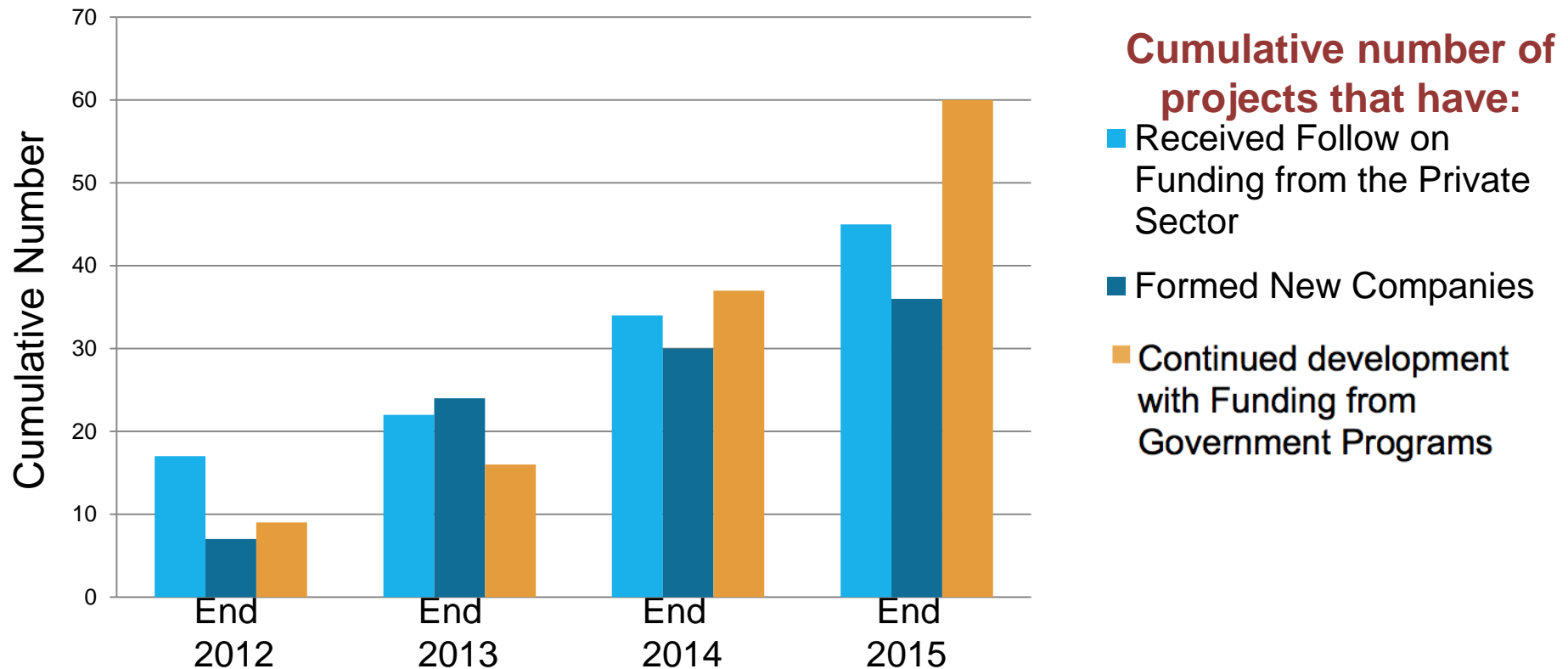
If it works...

*will it matter?*

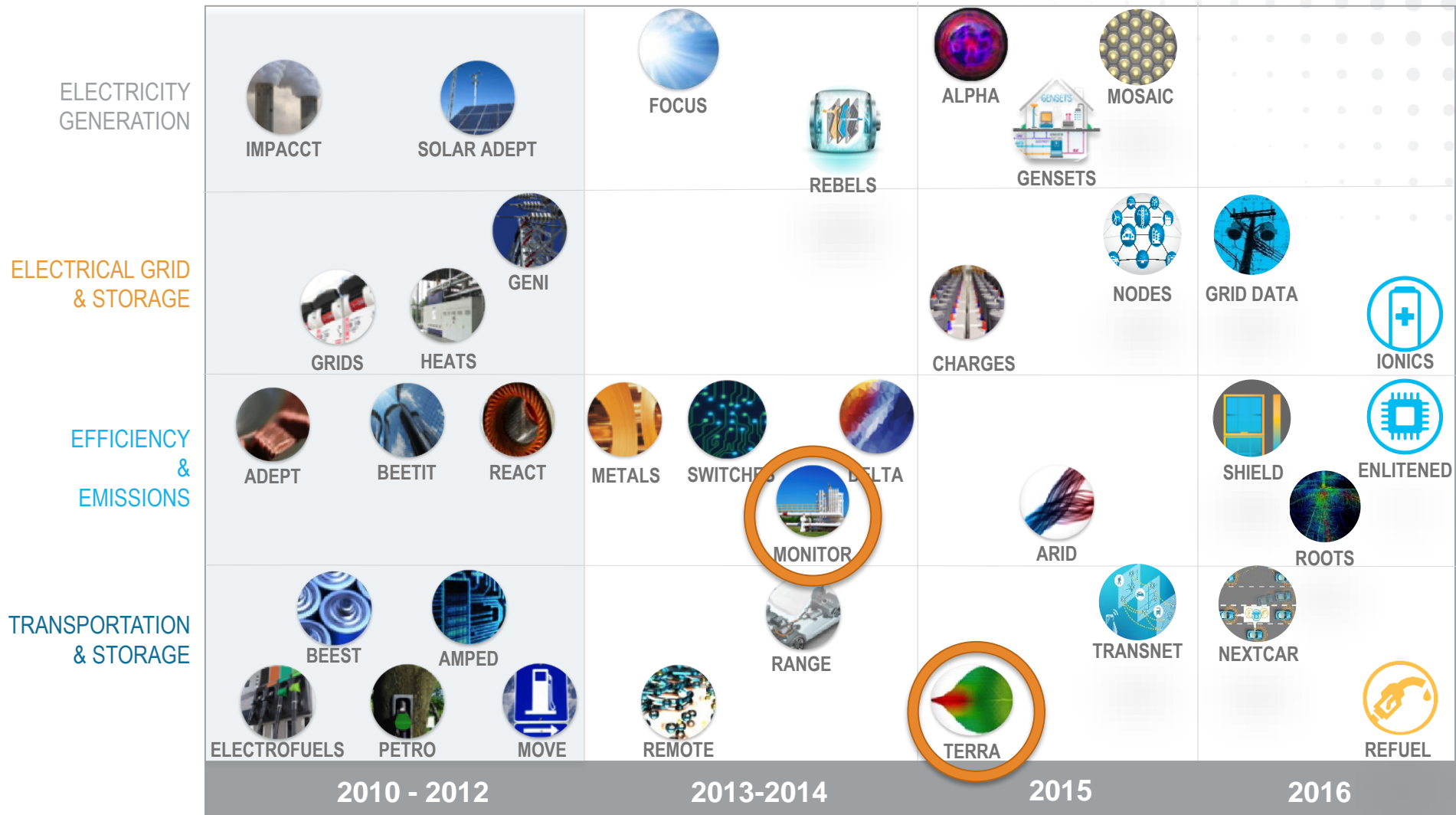
# Metrics of Transition Toward Market\*

Since 2009 ARPA-E has invested approximately \$1.3 billion across more than 475 projects. Of those, 206 are alumni projects.

45 ARPA-E projects have attracted more than \$1.25 billion in private-sector follow-on funding\*



# Focused Program Portfolio



# MONITOR

Methane Observation Networks with Innovative Technology to Obtain Reductions



## Mission

Develop innovative, cost-effective technologies that can accurately detect and measure methane emissions associated with natural gas production and distribution.

## Goals

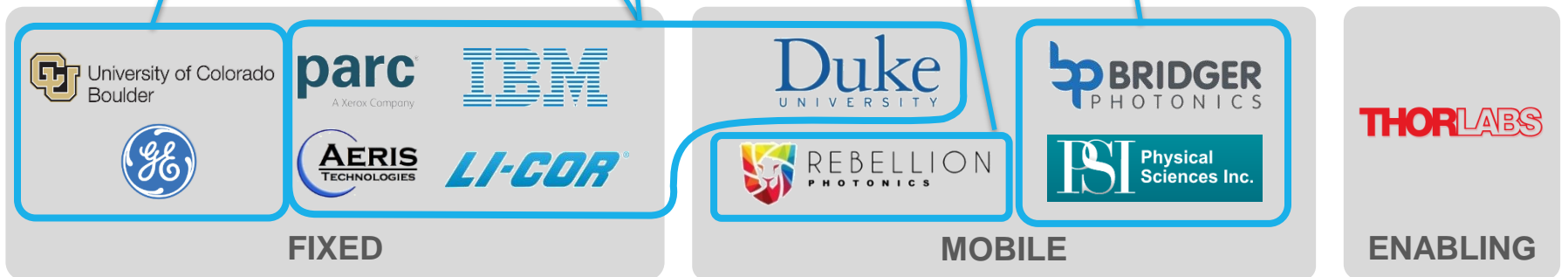
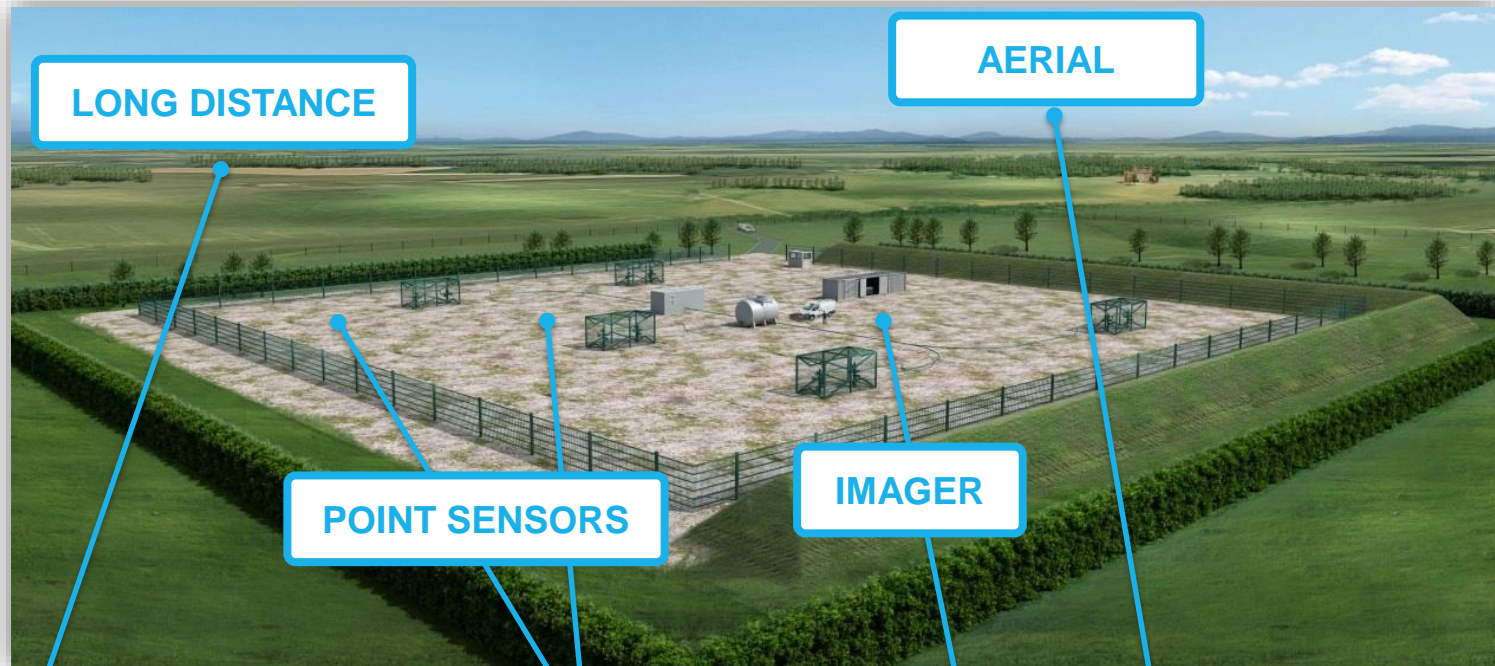
- Detect a methane leak of at least 6 SCFH, locate the leak within 1 meter, and quantify the flow rate
- Significantly decrease the cost of methane detection, yielding a system cost less than \$3,000/year/wellhead
- Improve the sustainability of domestic natural gas production



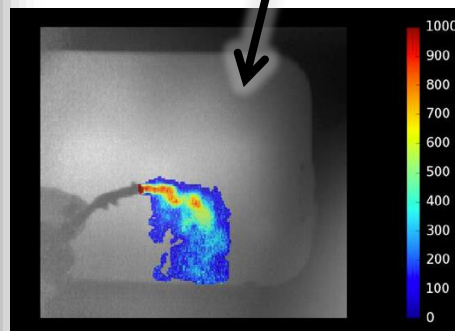
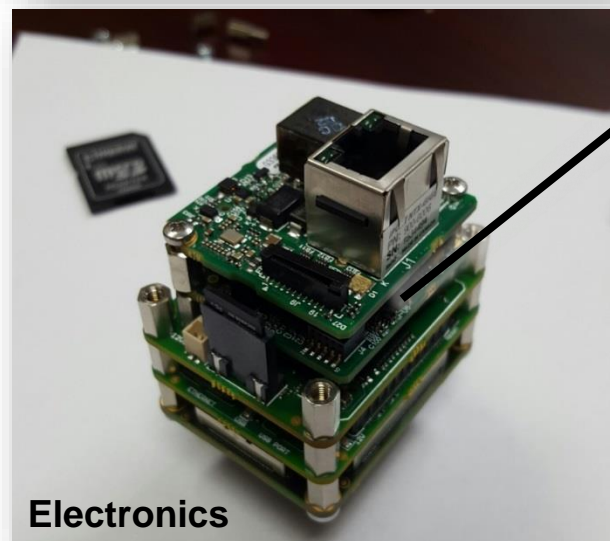
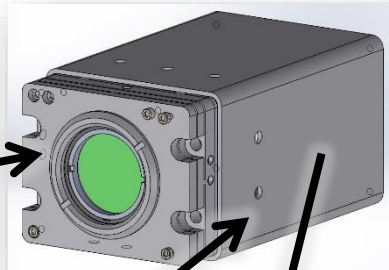
<b>Program Director</b>	Dr. Bryan Willson
<b>Year</b>	2014
<b>Projects</b>	11
<b>Total Investment</b>	\$31 million



# The Portfolio: 3 Technology Categories



# Portable Imaging Spectrometer for Methane Leak Detection



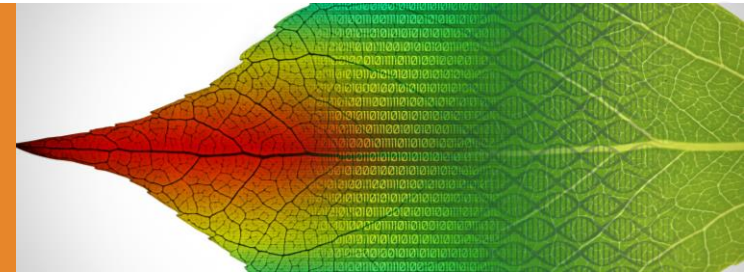
## PROJECT HIGHLIGHTS

- ▶ Miniaturization of Rebellion's Gas Cloud Imager (GCI), a long-wave infrared imaging spectrometer
- ▶ Camera will be lightweight and portable – the size of a Red Bull can - and capable of being incorporated into personal protective equipment
- ▶ Data processing uses cloud-based computing architecture that streams results to mobile device

AWARD AMOUNT: \$4.3 million

# TERRA

## Transportation Energy Resources from Renewable Agriculture



### Mission

Facilitate development of improved varieties of sorghum as climate resilient bioenergy feedstocks that place lower demands on land use, water use and fertilizer use.

### Goals

- Develop autonomous robotic sensor systems capable of high-throughput assessment of plant growth and development in the field.
- Develop advanced 'big data' algorithms to construct 3-D models that predict crop performance and response to environment.
- Create sophisticated bioinformatics tools and genomics resources for gene and trait discovery that accelerate breeding of improved crops.

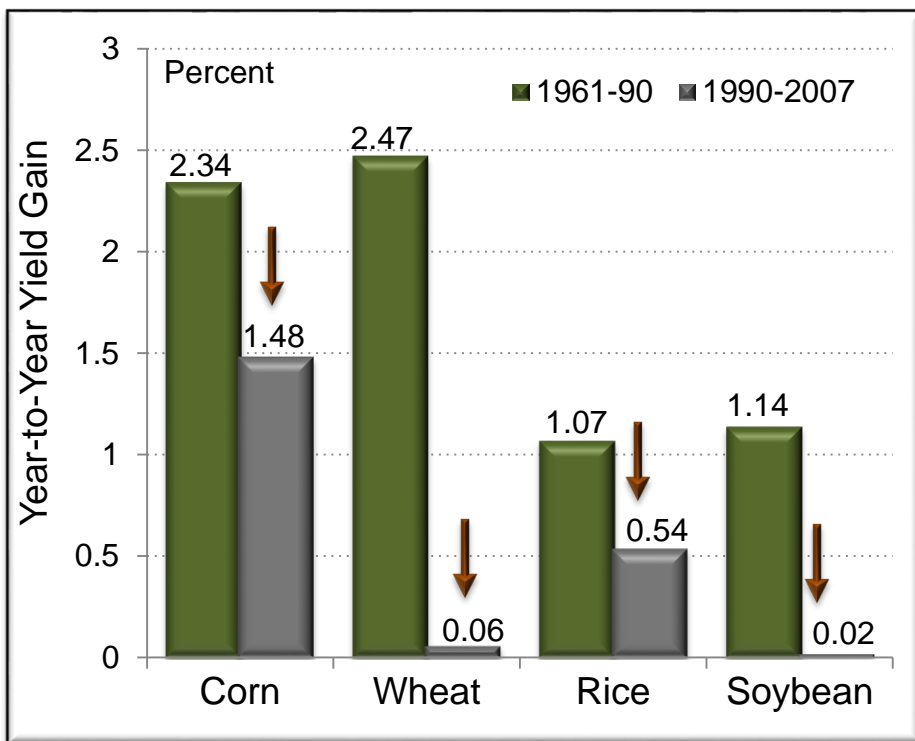
### Highlights

- Program Kickoff November 15, 2015
- Public x Private Sector collaborations established

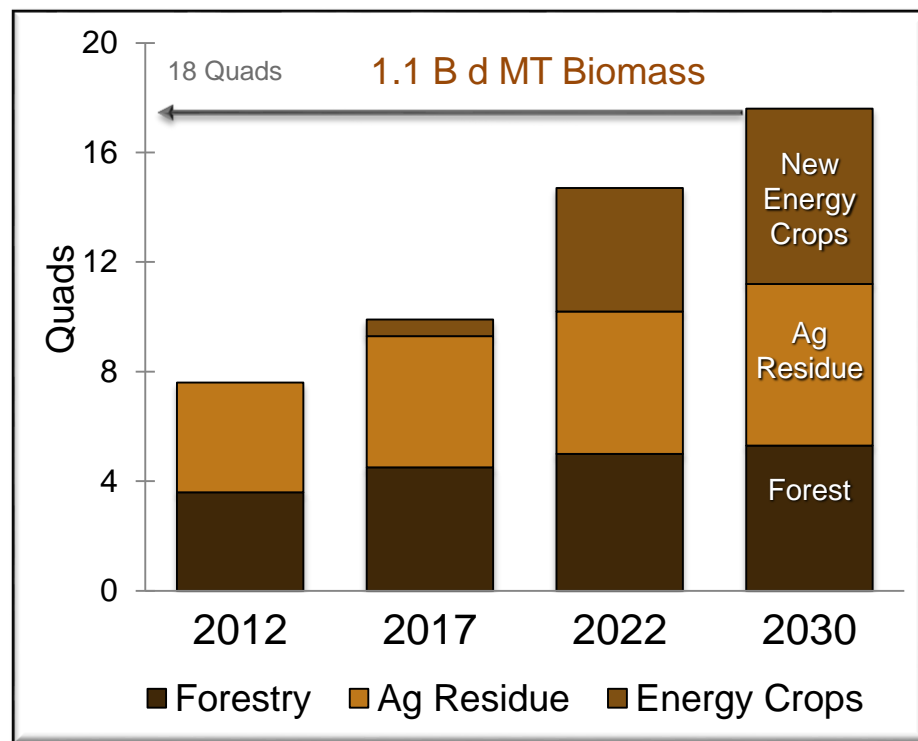
<b>Program Director</b>	Dr. Joe Cornelius
<b>Year</b>	2015
<b>Projects</b>	7
<b>Total Investment</b>	\$32.7 million

# Sustainability issues

Evidenced by Declining Rate of Genetic Gain in Core Crops



“Improvements in crop yield are below 1.16-1.31 %/y rate required to meet demand in 2050.”

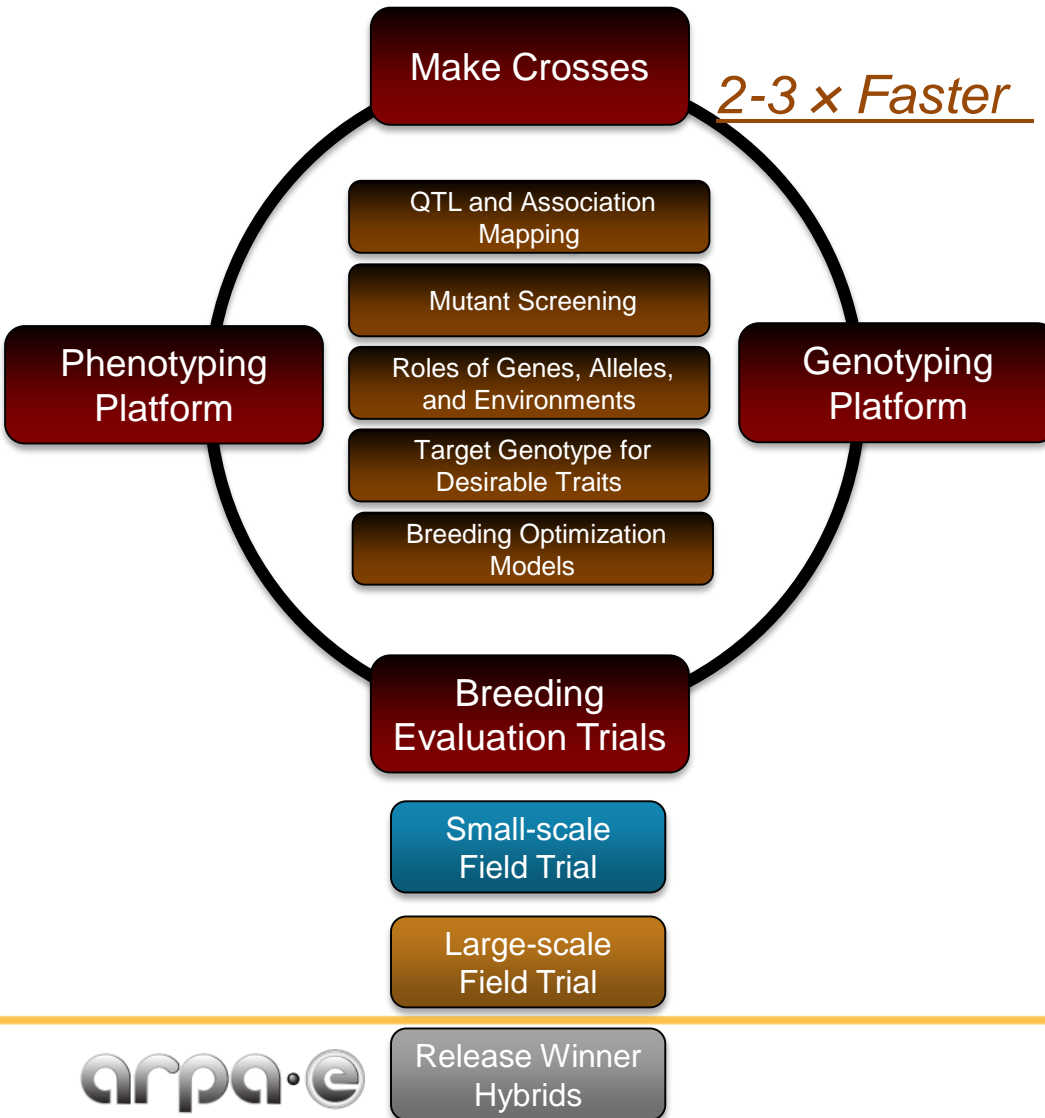


DOE bioenergy plan (Billion Ton Study) requires a 1% /year genetic gain in dedicated energy crops.

$$\Delta G \approx h^2 \sigma_p i / L$$

# TERRA Enables Better Breeding Strategies

## Advanced Genomic Selection (GS)



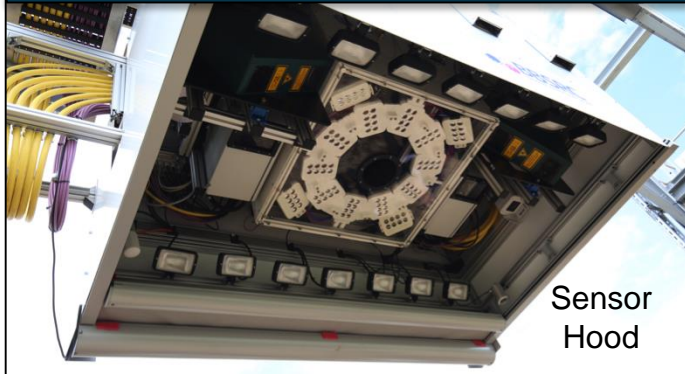
TERRA Program approach:  
Complete integrated phenotyping systems with

- full cost <\$20K/HA
- THREE YEAR PAYBACK
- High Throughput Automated Hardware & Sensing Technologies
- Computational Solutions for Selection and Prediction
- Genetics, Genomics and Bioinformatics
- Programmatic Reference Data Generation and Data Hosting

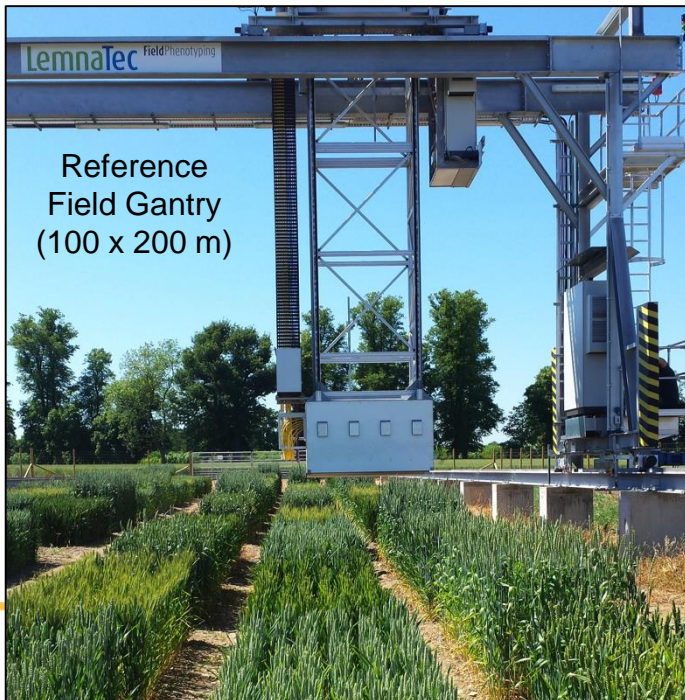
$$\Delta G \approx h^2 \sigma_p i / L$$

# Robotic Platforms are Diverse and Data Rich

Danforth Center, USDA, Lemna Tec  
Stationary Reference Field Gantry



Sensor Hood



Reference Field Gantry (100 x 200 m)

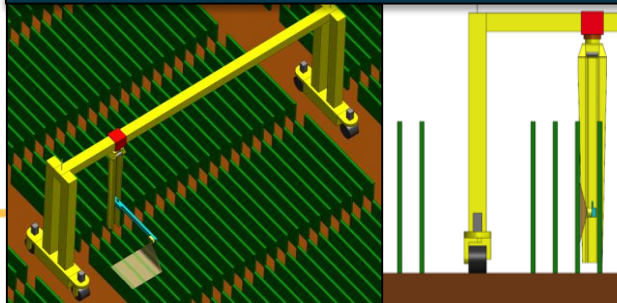
## Performance Comparison

	Current Breeding Manual	TERRA Ground & Aerial Vehicles
# Breeder Plots	1,000	1,000
# Phenotypes	10's	1000's
Resolution	1 m	1 cm
Bandwidth (nm)	400-700	100-2500
Data Collection	Bytes	Terabytes
Cycle Time	8 hrs	1 min UAV 4 hrs AGV

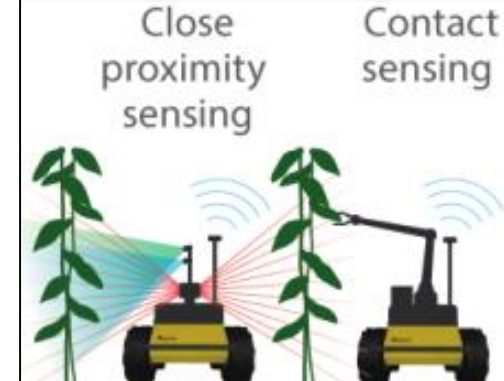
## Reference Field Gantry Sensors:

- Hyperspectral (350-2500 nm)
- Thermal infrared
- Dedicated NDVI sensor
- Dedicated PRI (photochemical reflectance)
- PAR sensor
- Color sensor
- Height Scanner
- 8 MP RGB down camera
- 2 side looking cameras
- Active reflectance in-field
- Fluorescence
- Environmental temperature, humidity, rainfall, wind, CO<sub>2</sub>

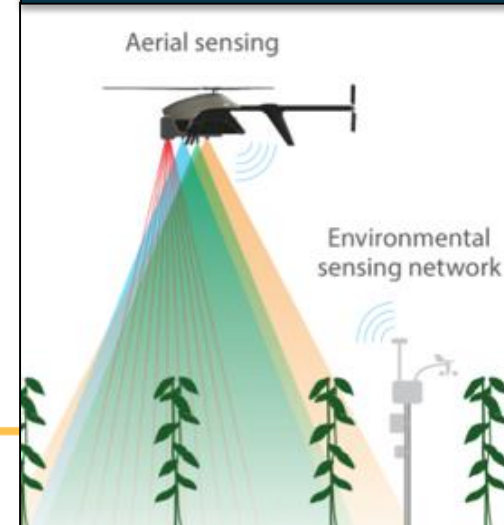
National Robotics Engineering Center  
Mobile Deployable Field Gantry



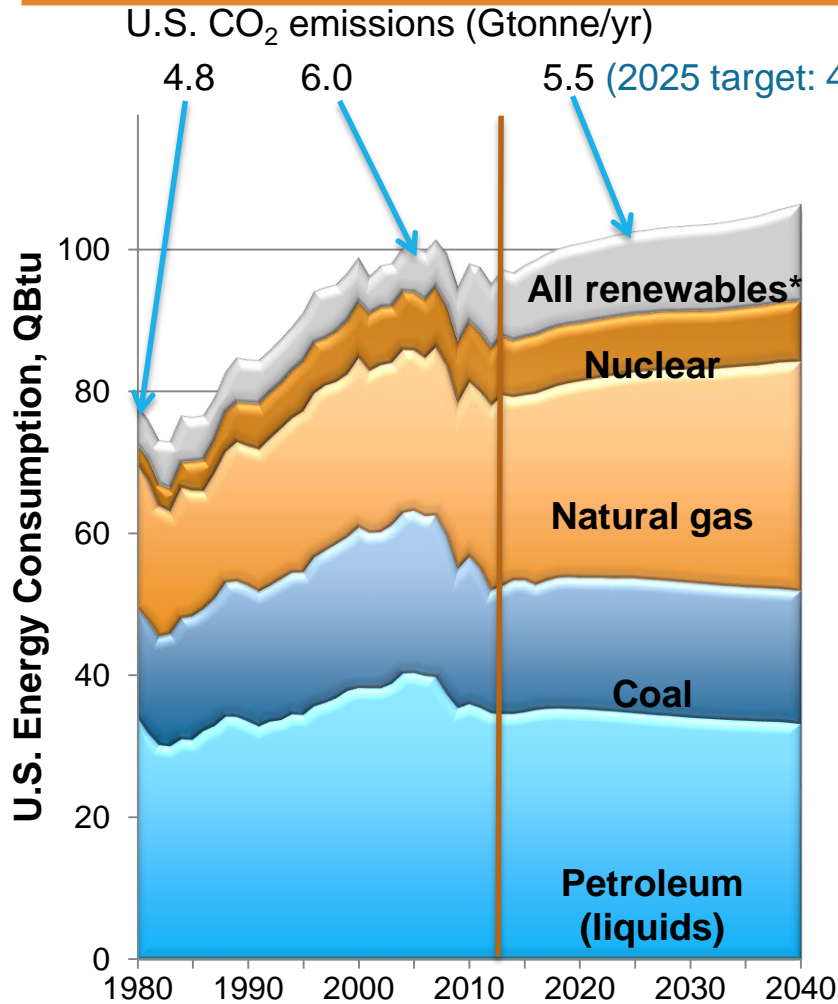
Carnegie Mellon, UIUC, Purdue  
Mobile Ground Vehicles



Near Earth, Purdue, KSU, Blue River  
Mobile Aerial Vehicles

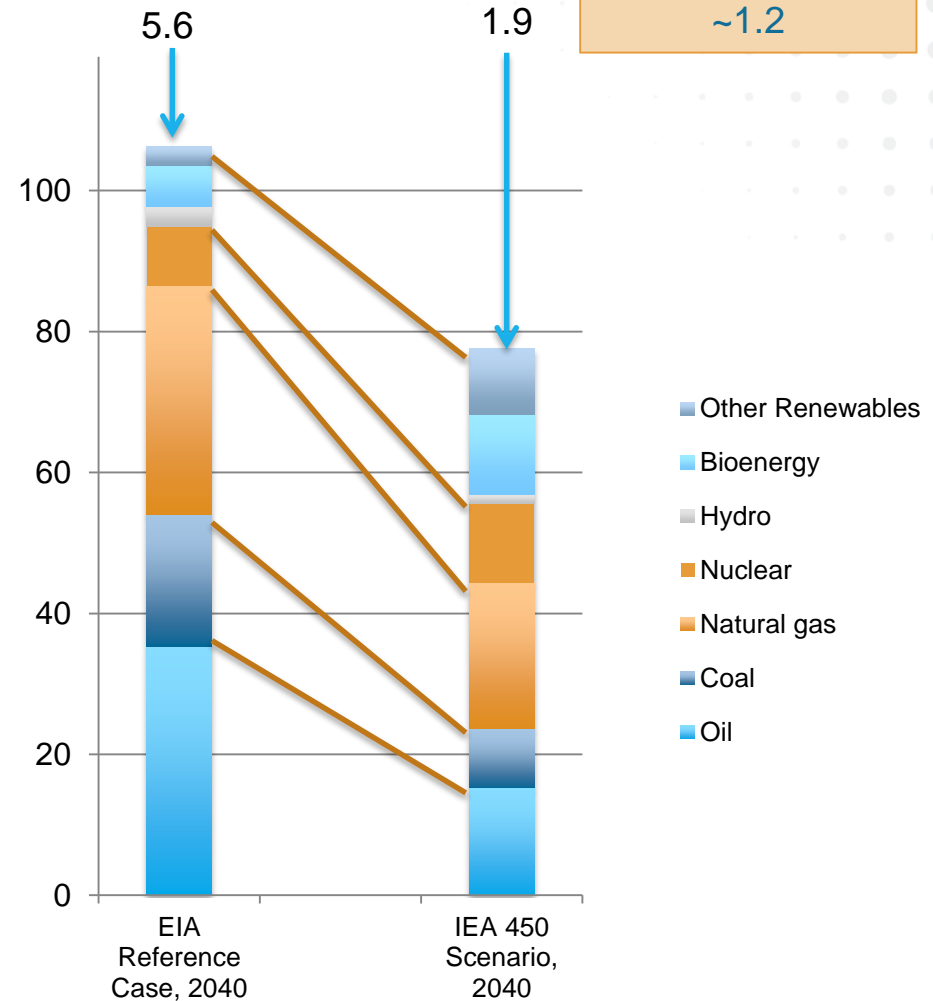


# Energy and Emissions – Changing what’s possible



\* Includes both traditional and modern uses of biomass

U.S. CO<sub>2</sub> emissions, Gtonne/yr



Left: EIA AEO Figure MT-9 (Reference Case), 2013 updated for Actual  
 Right: EIA 2014 AEO Tables A2 and 17, and IEA World Energy Outlook 2014, Table 2.1 ,  
 Note: EIA biofuels projection moved to “Bioenergy” to match IEA categorization



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