Quadrennial Technology Review-2015

Chapter 3: Energy Systems and Strategies

Public Webinar

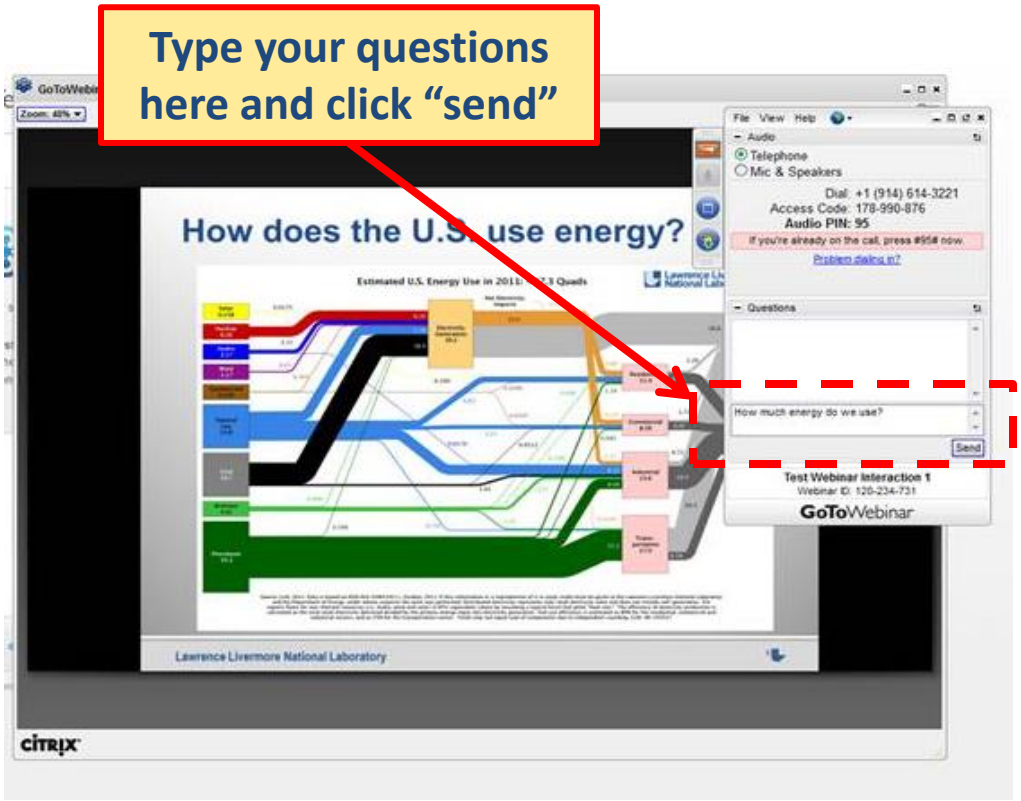
Chapter Leads:
A.J. Simon
Jeffery Greenblatt

2015-03-04

Webinar Logistics

- Due to the large number of expected participants, the audio and video portions of this webinar will be a “one way” broadcast. Only the organizers and QTR authors will be allowed to speak.

- Submit clarifying questions using the GoToWebinar control panel. Moderators will respond to as many questions as time allows. Substantial input regarding chapter content should be submitted by email to: DOE-QTR2015@hq.doe.gov



QTR 2015 Chapter Outline

Introduction

1. Energy Challenges
2. What has changed since QTR 2011
3. **Energy Systems and Strategies**

Assessments

4. Advancing Systems and Technologies to Produce Cleaner Fuels
5. Enabling Modernization of Electric Power Systems
6. Advancing Clean Electric Power Technologies
7. Increasing Efficiency of Buildings Systems and Technologies
8. Increasing Efficiency and Effectiveness of Industry and Manufacturing
9. Advancing Clean Transportation and Vehicle Systems and Technologies
10. Enabling Capabilities for Science and Energy

Integrated Analysis

11. U.S. Competitiveness
12. Integrated Analysis
13. Accelerating Science and Energy RDD&D
14. Action Agenda and Conclusions; Web-Appendices

Web Appendices

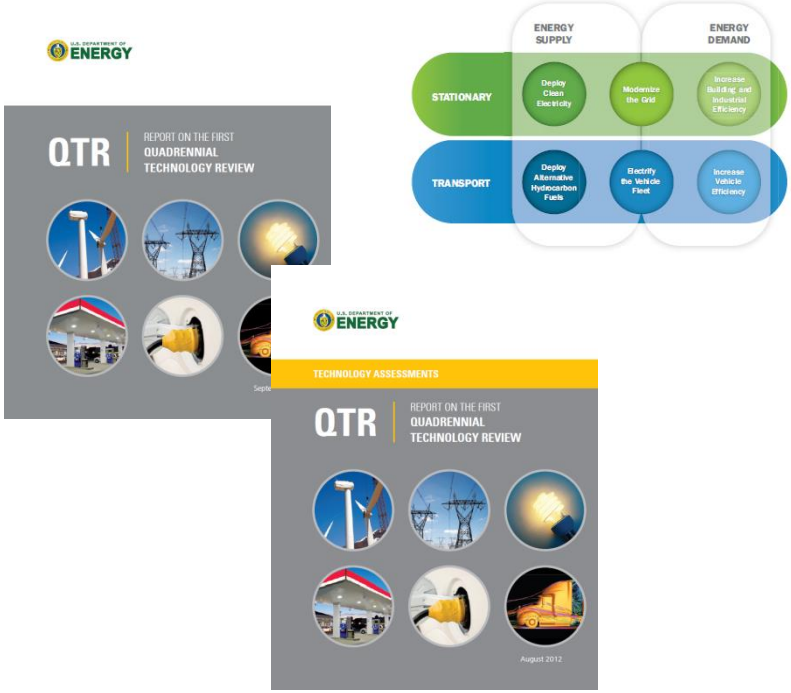
Chapter Overview

- **Energy Systems Overview**
- **Systems Integration** (*potentially includes: Systems-of-Systems, Interdependency, Digital Transition, Hybrid Systems)*
- **Complicated and Complex Energy Systems** (*potentially includes: Electric Grid, Transportation Networks, Urban Systems, Biological Systems, Manufacturing Systems, Buildings*)
- **QTR-2015 Systems Approaches**
  - **Fuels**
  - **Electric Grid**
  - **Power Generation**
  - **Buildings**
  - **Manufacturing**
  - **Transportation**

QTR 2011 vs. 2015

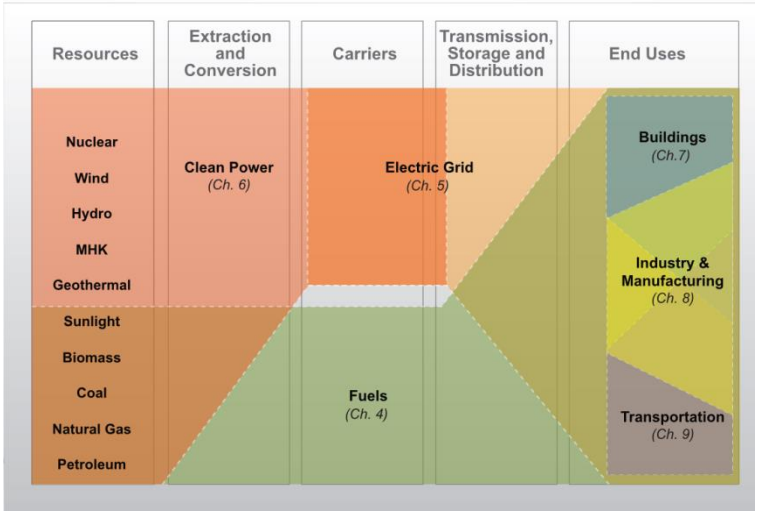
2011

- 6 Strategies + 3 Supporting Chapters
- 17 Technology Assessments
- **Snapshot of Technology and DOE Operations**

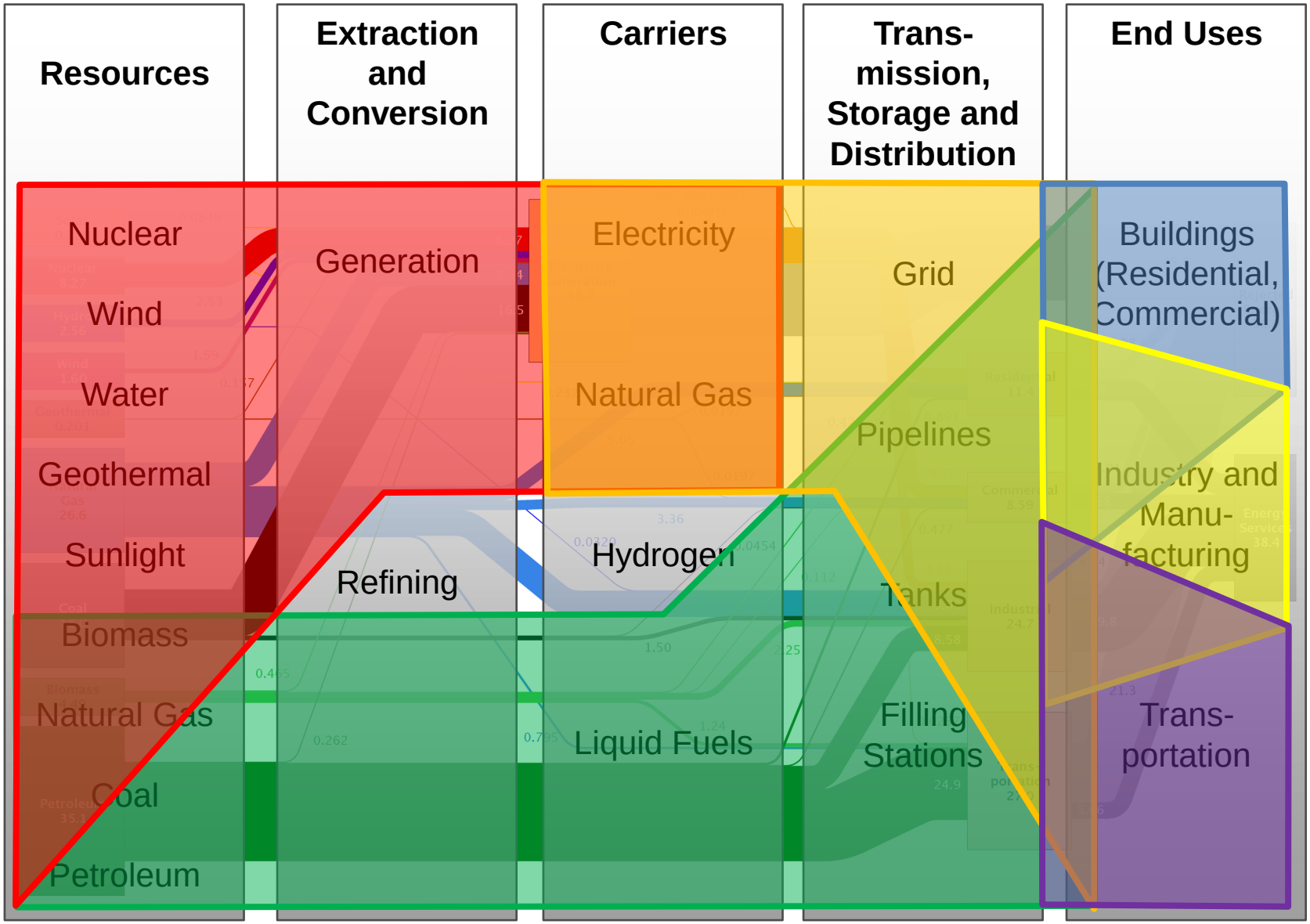


2015

- 6 Technical Chapters + 7 Supporting Chapters
- 50+ Technology Assessments
- **Systems-oriented**
- Surveys Opportunity Space

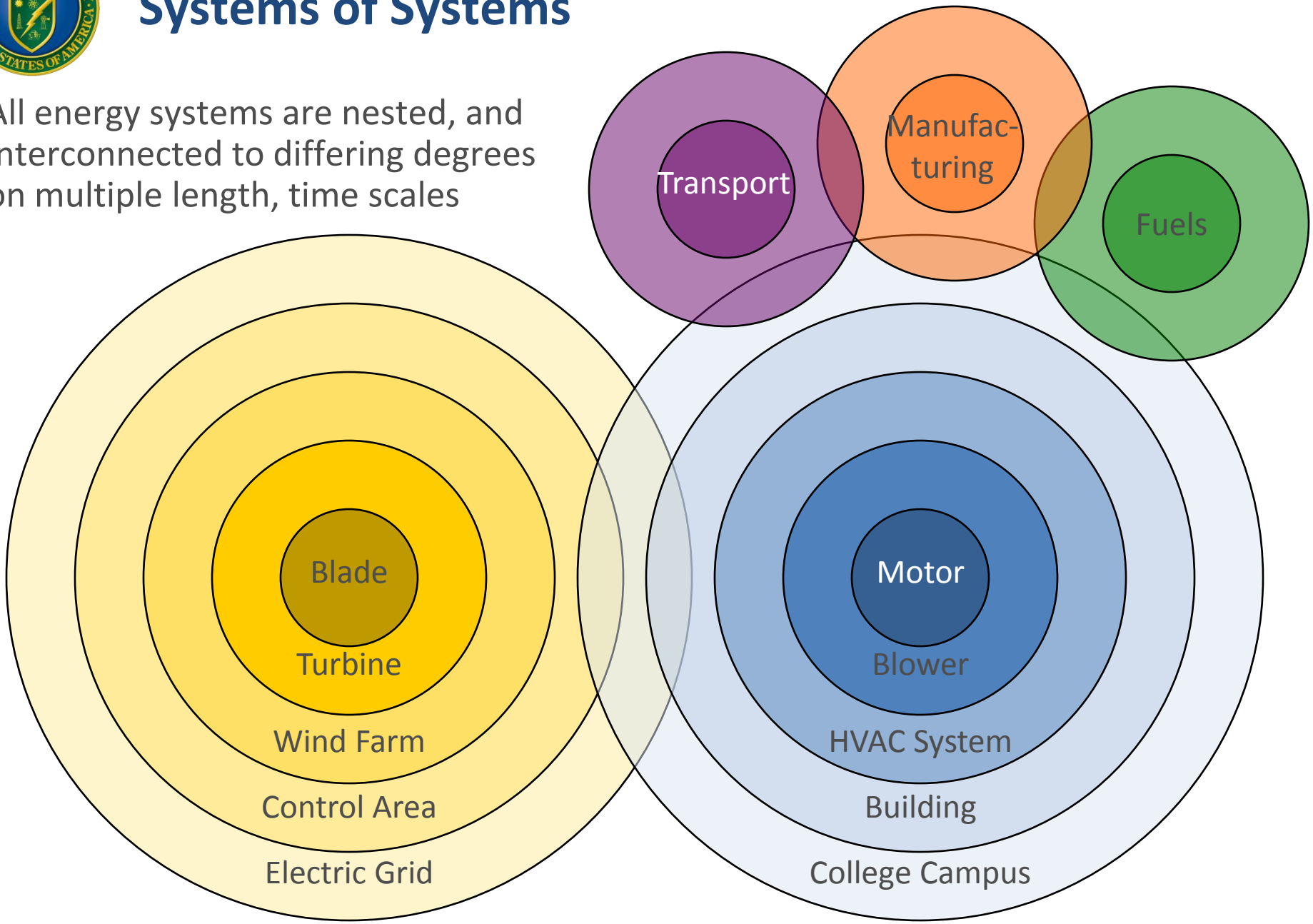


Energy Systems



Systems of Systems

All energy systems are nested, and interconnected to differing degrees on multiple length, time scales



Interdependency

Energy systems: increasingly interconnected

Earth systems

- Energy-water nexus: energy requires water, water requires energy
- Climate: energy systems must adapt to changing climate
- Resources: Current energy system depends on fossil resources, clean energy depends on materials too, including critical materials

Financial markets

- Time-of-day rates, end user participation in markets important?

Information Technology (IT) and the Digital Transitions

- Energy systems rapidly becoming digital and internet-accessible

Transportation systems

- Increasingly dependent on electricity, IT, collective decision making?

Human systems

- Political vulnerabilities, internet/social media: important effects?

Hybrid Systems: Examples

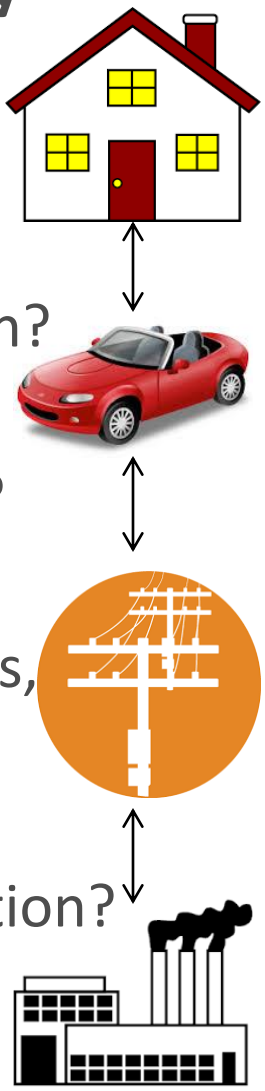
Opportunities for savings, challenges of increased complexity

Within sector hybrids:

- Buildings: Combined HVAC and water heating systems?
- Vehicles: Gasoline-electric hybrids, links to public transit?
- Fuels: Gasoline-ethanol blends, coal-biomass co-gasification?
- Industry: Waste product utilization (industrial ecology)?
- Grid: Dual-fuel combustion turbines, wind-storage hybrids?

Cross-sector hybrids:

- Building-Grid: Demand response, grid-connected appliances, cogeneration?
- Vehicle-Grid: 1- and 2-way EV charging?
- Fuel-Grid: Fossil/CCS (or biomass) fuel-electricity cogeneration?
- Industry-Fuel-Grid: Above with co-product chemicals?



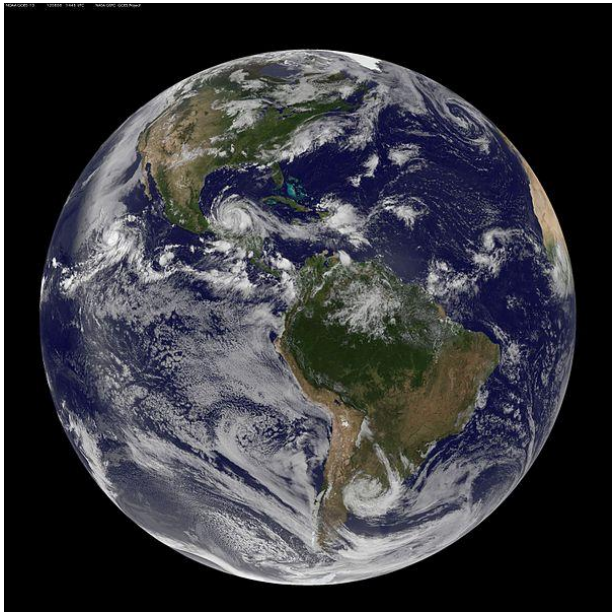
Complicated and Complex Systems

Complicated Systems

- Multi-component, multi-domain, multi-scale and/or multi-dimensional
- Challenging to simulate and/or control

Complex Systems

- Many individual components
- Non-linear interactions
- Emergent Properties/Behaviors



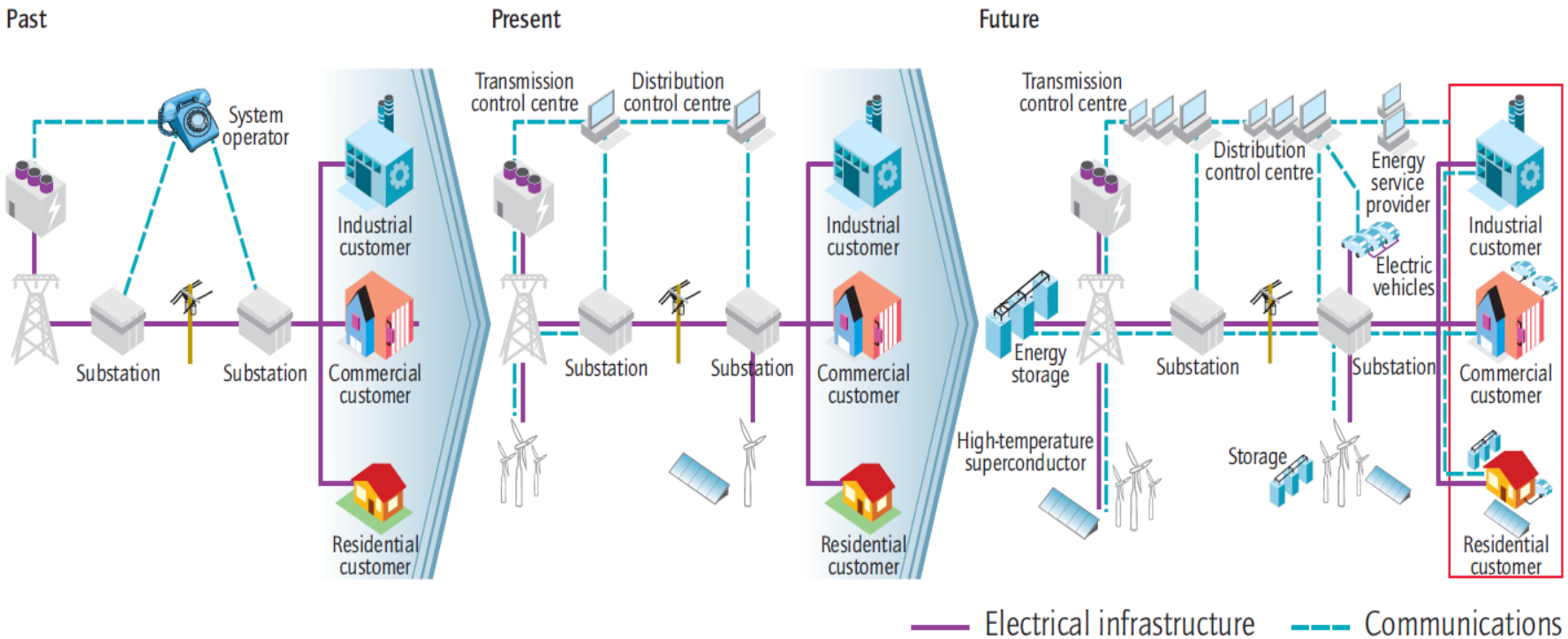
Example: Electric Grid

Complicated

- Thousands of generators
- Millions of customers
- Sub-second *physical* balance

Complex?

- Interacting autonomous controllers
- Cascading failure
- Simultaneous *physical, computational, market* balance



Example: Transportation Systems

Conventional Vehicles (Complicated)

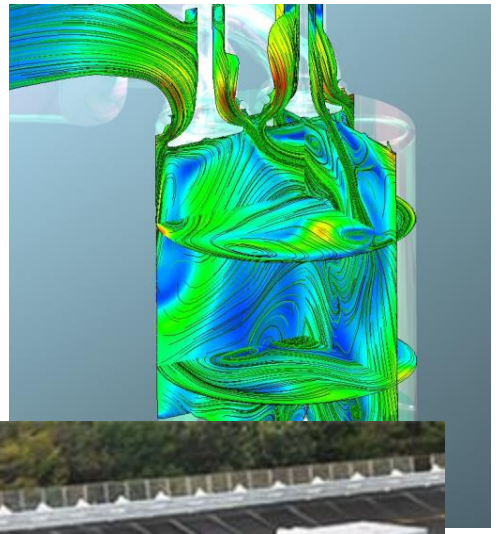
- Prime Mover (physics of combustion, electrochemistry, etc.)
- Human Behavior / Traffic Flow
- Freight Shipment / Logistics

Connected Vehicles (?)

- Route Optimization
- Platooning

Autonomous Vehicles (Complex?)

- Collision Avoidance
- Shared Use / Logistics



Potential Example: Urban Systems

Overlapping Infrastructures

- Transportation (private, public, multi-mode)
- Energy (electricity, fuels)
- Communications, Food, Water, Finance, …

Multi-scale

- Minutes (emergency response) to multi-decades (planning)

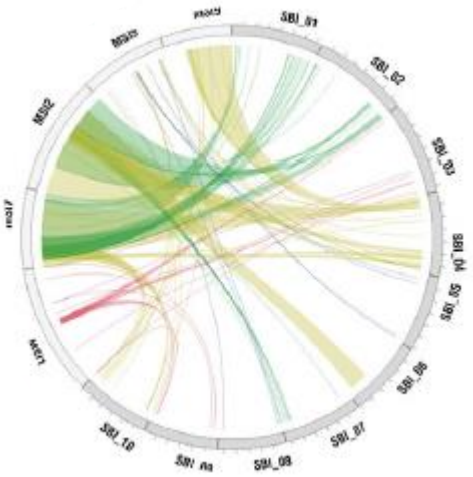
Competing Objectives

- Energy / Emissions
- Sustainability
- Quality of Life

Potential Example: Biological Systems

Organism Level

- Genetic Transcription / Translation networks
- Genotype / Phenotype
- Environmental Interactions (drought tolerance, etc.)



Biota Communities

- Polycultures
- Microbial community

Potential Example: Manufacturing Systems

Unit Operations

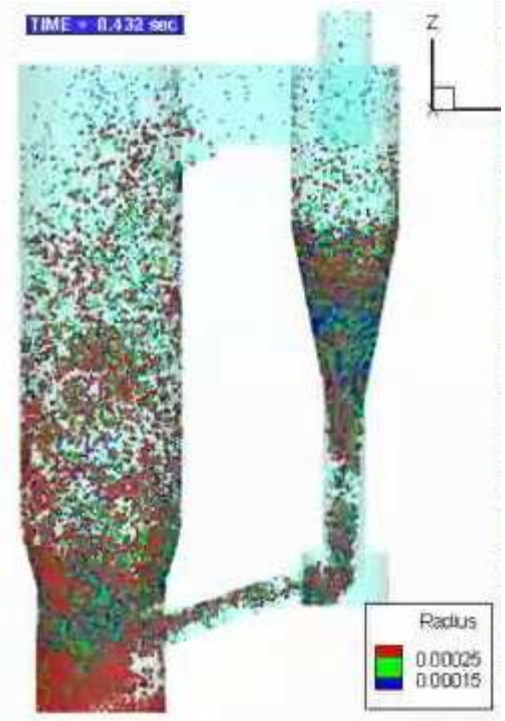
- Multi-scale, multi-physics (eg. fluidized bed reactors)

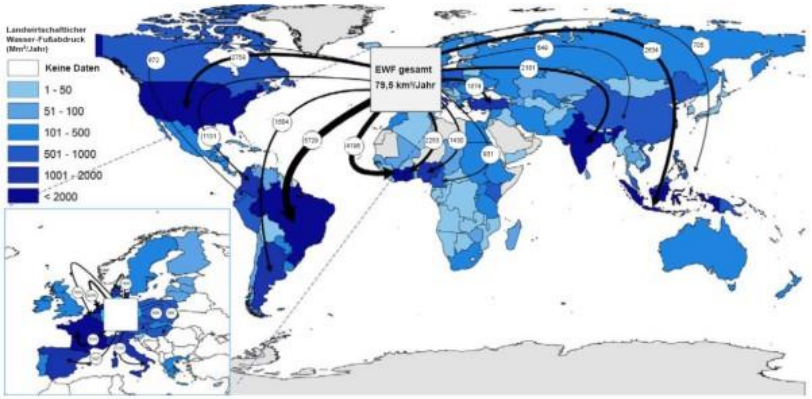
Facility Systems

- Heat and materials integration
- Dynamic Operations
- Process Intensification

Industrial Ecosystems (Supply Chain)

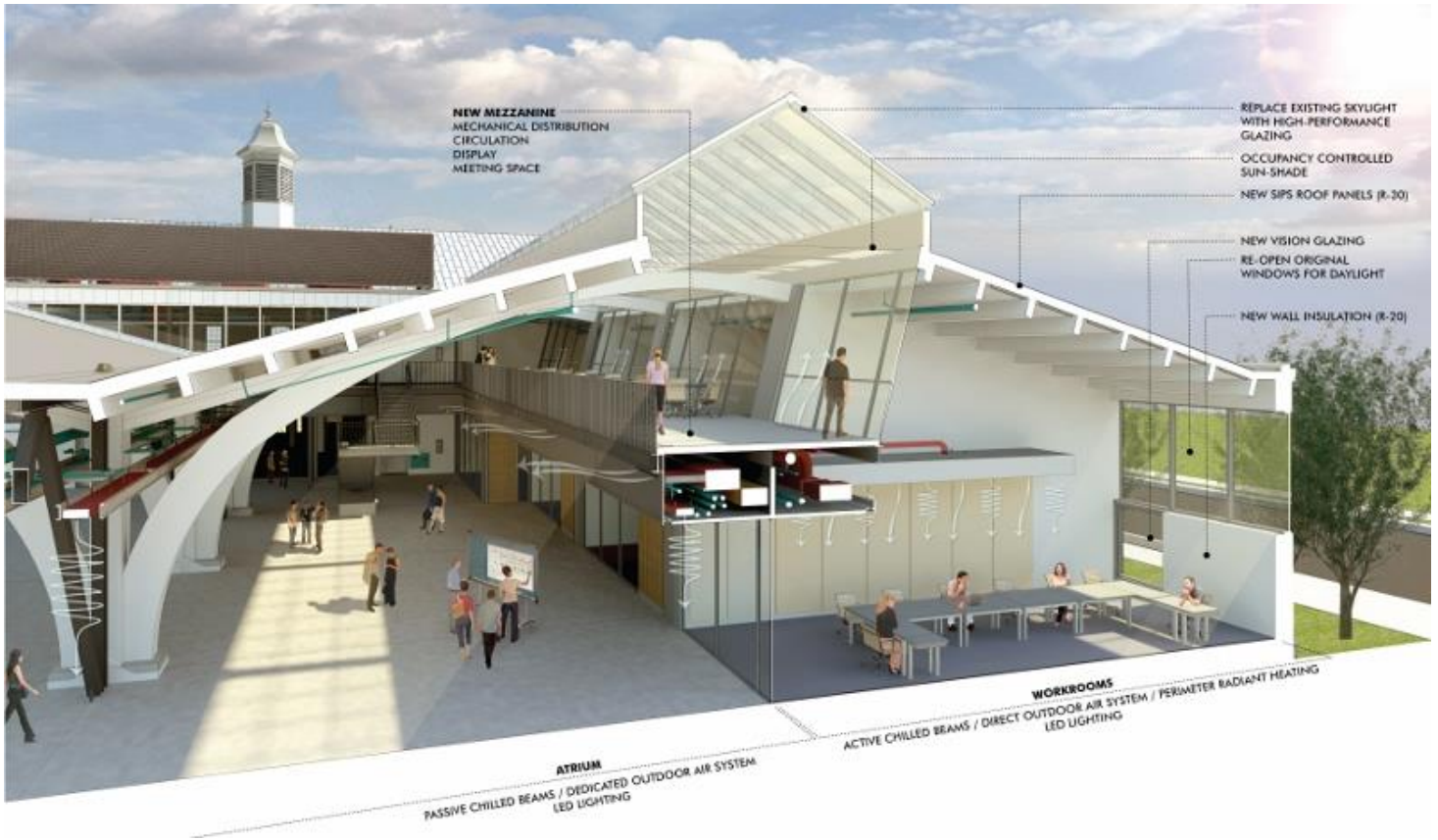
- Just-in-time vs. resilience
- Interdependence with other systems (transportation, communications, financial)
- Sustainability (virtual or displaced energy, emissions, water, etc.)





Potential Example: Buildings

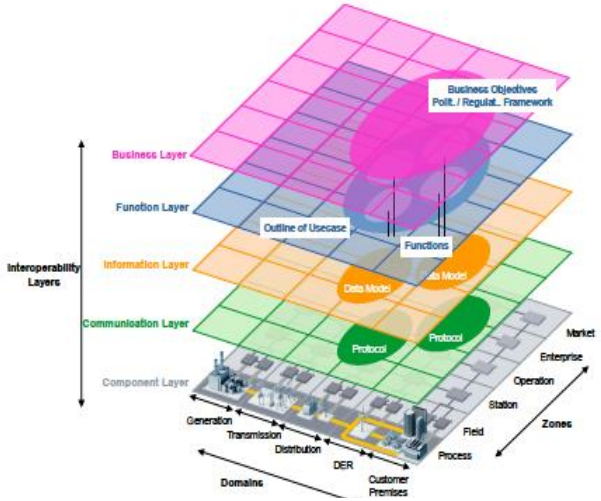
- Dynamic: Diurnal, Seasonal, Extremes
- Multi-objective, highly sensitive, human factors (*multi-occupant, air flow and quality, lighting*)
- Increasingly automated and connected

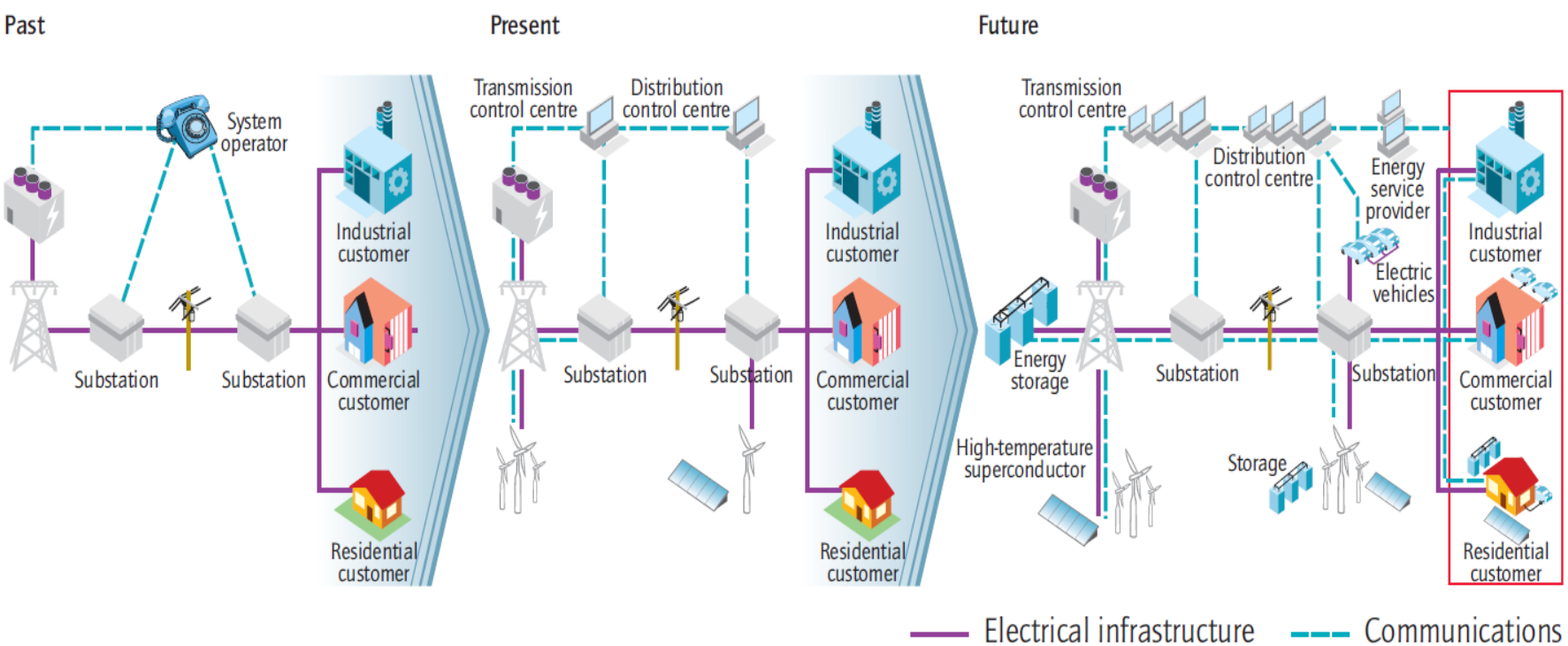


Systems Approach: Fuels

	Resources	Extraction and Transport	Conversion and Synthesis	Distribution and Use
Fossil				
Biological				
Hydrogen				
Other				
	Environmental Impacts			

Systems Approach: Grid





Systems Approach: Clean Power

		Siting Characteristics				Environmental Criteria				Electric System		
		Traditional Pollutants	Local Resources	Transmission Connection	Water Availability	GHG Footprint	Land Use	Water Impacts	Waste	Load Following	Dispatch-ability	Security
System Requirements	Reliability											
	Resiliency											
	Safety											
	Minimal Environmental Footprint											
	Flexibility											
	Affordability											

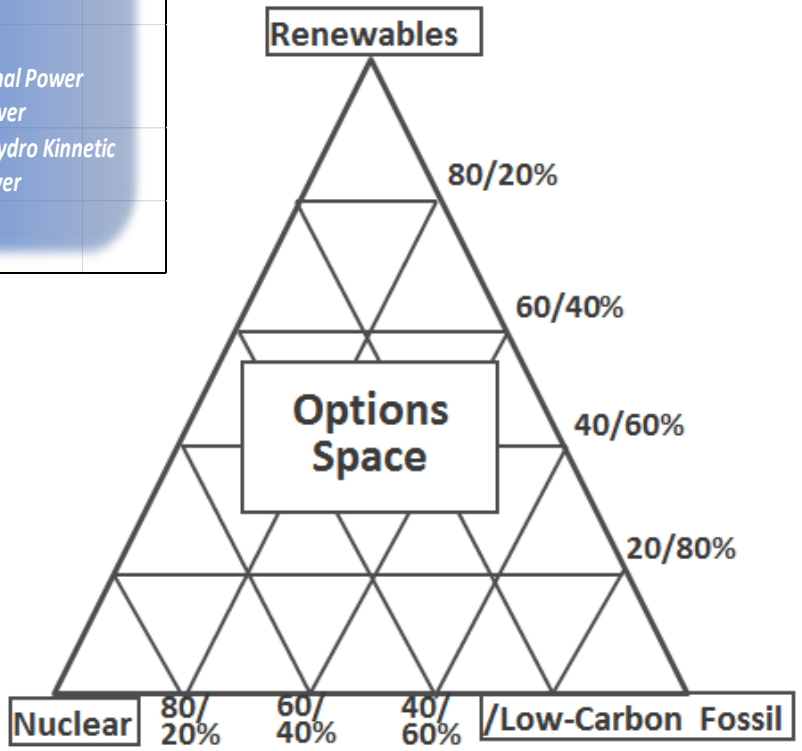
Historical Electric Generation

Evolving Criteria Require a Balanced System Approach

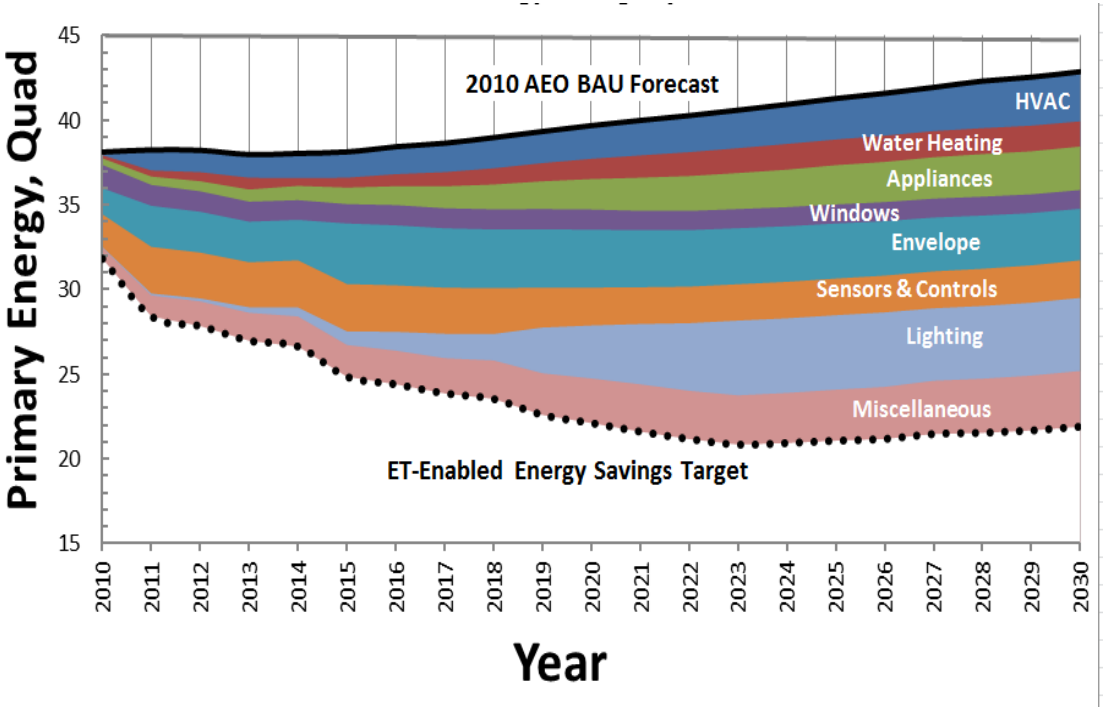
Future Electrical Power Generation System Addressing Multiple Criteria

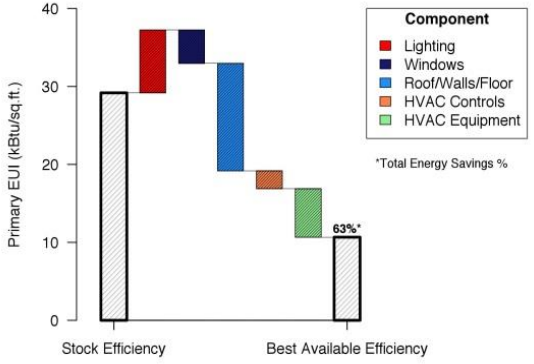
Technology Portfolio Options:

- Fossil Fuels w CCS
- Nuclear Power
- Biopower
- Fuel Cells
- Wind Power
- Geothermal Power
- Hydropower
- Marine Hydro Kinnetic
- Solar Power



Systems Approach: Buildings





Systems Approach: Industry

Energy Production

Energy Delivery

U.S. Energy Economy
95 quads

Transportation Sector 27 quads	Industrial Sector 31 quads
Residential Sector 20 quads	Commercial Sector 17 quads

Energy-efficient technologies reduce the 58 quads lost throughout the U.S. Energy Economy

Manufacturing, facility, and supply-chain improvements reduce the 12 quads lost within the industrial sector

Industrial Systems
31 quads

Supply-Chain Systems

Network of facilities and operations involved in moving materials through industry, from extraction of raw materials to the production of finished goods.

Example: Petroleum Refining

Refining Industry ~4 quads

Production/Facility Systems

Equipment, process flow, and energy strategies that comprise a goods-producing facility

- Petroleum Refinery ~26 TBtu
- Facility Steam ~5 TBtu

Manufacturing Systems/ Unit Operations

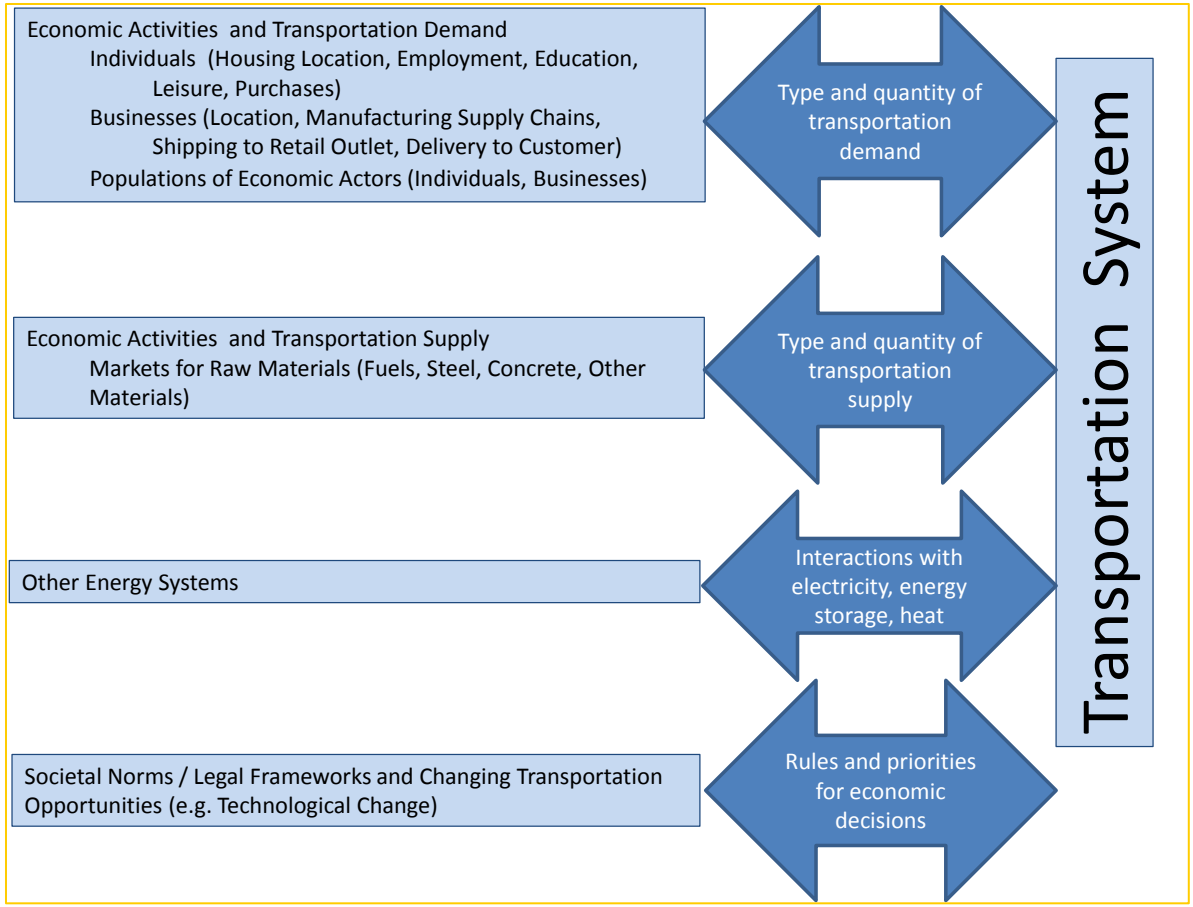
Equipment used for manufacturing process and nonprocess unit operations

- Atmospheric Distillation Unit ~4 TBtu
- Hydro-cracker ~2 TBtu
- Catalytic Reformer ~3 TBtu

Technologies for clean & efficient manufacturing
Technologies to improve energy use in transportation
Technologies to improve energy use in buildings
Technologies to improve energy production and delivery

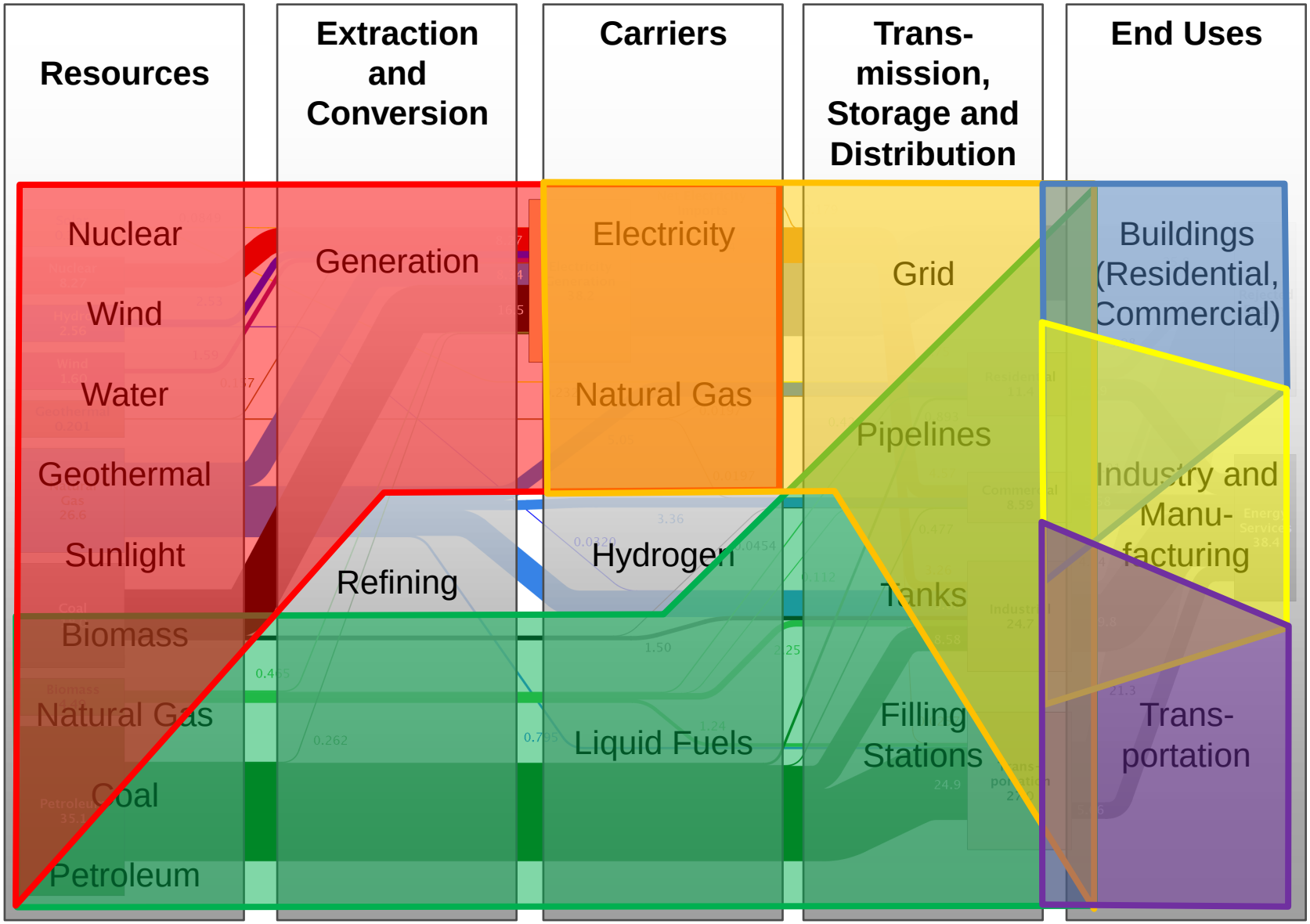
Note: 1 quad = 1,000 TBtu

Systems Approach: Transportation



$$\frac{GHG\ Emissions}{Fuel} \times \frac{Fuel}{Transport} \times \frac{Transport}{Activity} \times Activity = GHG\ Emissions$$

Energy Systems



Public Input

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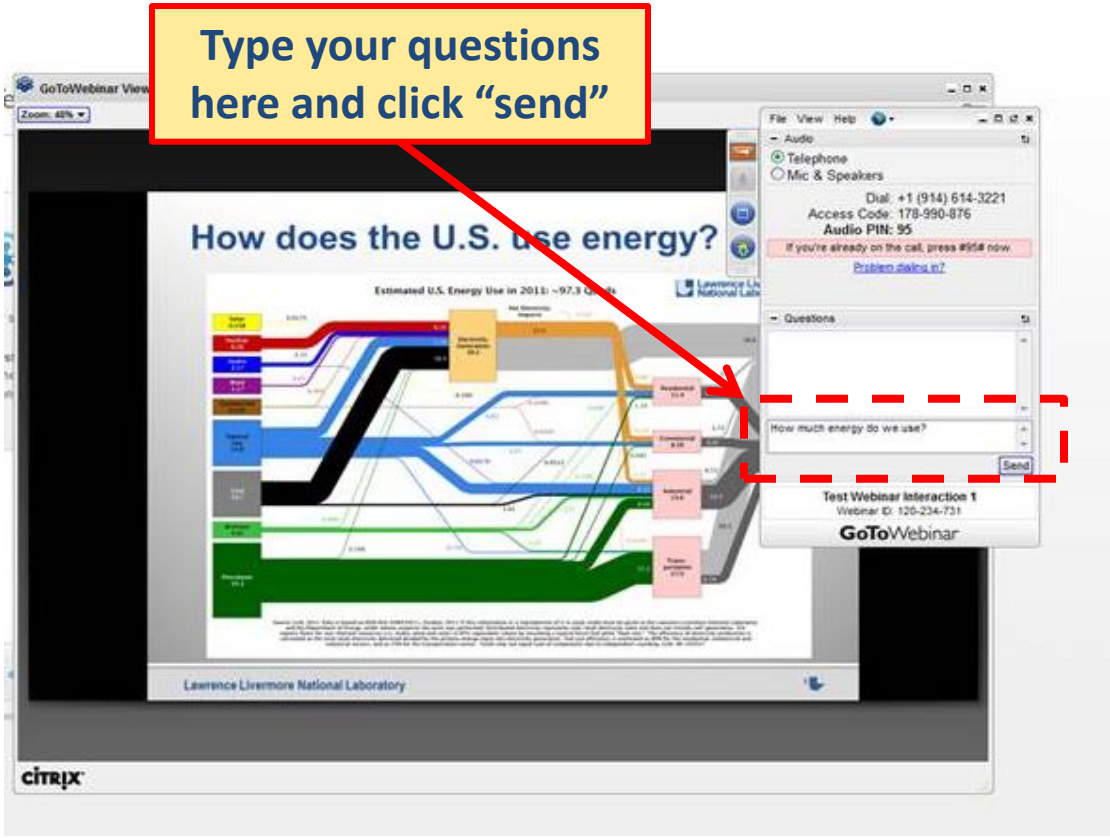

- If you have questions or comments that cannot be addressed during the webinar, email them to DOE-QTR2015@hq.doe.gov

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2015-02-18