Benefits Analysis for DOE Energy Technology Portfolio Assessment

Background

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The Context: Advancing Four, Broad National Energy Goals

1. **Diversify our energy mix and reduce dependence on foreign petroleum,** thereby reducing vulnerability to disruption and increasing the flexibility of the market to meet U.S. needs.

2. **Reduce greenhouse gas emissions and other environmental impacts** (water use, land use, criteria pollutants) from our energy production and use.

3. **Create a more flexible, more reliable and higher capacity U.S. energy infrastructure,** thereby: improving energy services throughout the economy; enabling use of diverse sources; and improving robustness against disruption.

4. **Improve the energy productivity** (or energy efficiency) of the U.S. economy.

Using Benefits Analysis to Inform the Budget Process

- DOE uses integrated benefits analysis to understand how DOE R&D is likely to advance these goals.
- This understanding is then used to inform Program, DOE, and Presidential budget requests.
- Integrated benefits analysis provides a framework for:
  - DOE technologies to interact and compete with each other as well as improvements to existing technology;
  - Economic competition due to changes in cost, supply, demand and substitution;
  - Energy system physical constraints and capital stock turnover; and
  - Alternative scenarios can be easily constructed to look at benefits of R&D portfolios under alternative conditions.
- Integrated benefits analysis has been recommended by NAS and called for by OMB and Undersecretary Garman.
- Integrated benefits analysis also helps ESE programs identify and focus on the R&D challenges that will provide the largest benefits to the public.

Peer Review Panel's Context

- **DOE has brought its best resources to implementing integrated benefits analysis during the last year.**
- **Much has been accomplished.**
- **We would like your help in reviewing these accomplishments and improving our approach.**
- **To help focus your efforts on the areas we most want help on, we prepared the following charge questions:**

Peer Review Charge

- Does the documentation clearly describe the basis for benefits forecasts so that all assumptions and calculations are understood?
- Are the assumptions associated with the benefits forecast plausible or believable? (For example: Are assumptions data driven? Are sources cited? Is there clear linkage between R&D budgets and assumptions?)
- Was the methodological guidance for benefits forecasts followed?
- Is the baseline used an appropriate representation of the future without federal funding?
- Are the DOE program goals used in the benefits forecast appropriately represented in NEMS, MARKAL, and any additional calculation tools used?
- Are the scenarios used adequate to test the robustness of the DOE portfolio?
- Do the metrics used sufficiently capture the spectrum of benefits attributable to the DOE portfolio?
- Does the benefits methodology produce results that could be useful to decision makers?
- What are the most important changes to the methodology to improve the credibility and usefulness of DOE benefits forecasts?

Benefits Analysis for DOE Energy Technology Portfolio Assessment

Common Approach and Results

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December 20, 2006

Prior Approach

- Historically, each program office within DOE undertook its own benefits analyses.
- Little centralization and management of analytical efforts.
- Small degree of coordination amongst DOE offices on analyses.
- Differing methodologies, different assumptions, different metrics.
- Different baselines against which to measure benefits.

Goals for DOE's Integrated Benefits Assessment Process

- **To achieve goal of ESE-wide integrated benefits assessment, ESE offices have agreed to use:**
  - **Common metrics**
  - **Common modeling platforms**
  - **Common baselines and scenarios**
  - **Common methodologies**

- **This presentation will summarize the status of each area.**

DOE Energy, Science, and Environment (ESE) Program Offices

- Office of Electricity Delivery and Energy Reliability (OE)
- Office of Energy Efficiency and Renewable Energy (EE)
- Office of Fossil Energy (FE)
- Office of Nuclear Energy (NE)
- Office of Science

Common Metrics

Metrics Ground Rules

- Metrics should be definitionally the same across all programs and offices.
- Metrics should be tied to DOE strategic goals, office strategic goals, and consistent with the NAS/NRC framework wherever possible.
- Metrics should be viewed by all offices as benefits.
- There should be a set of small core metrics for all programs and offices, but a larger set that is more specific to individual programs, as long as they are not in violation of ground rule 3.
- The set of metrics must show the value of DOE programs as a whole under different scenarios, not the value of each individual program under all scenarios.
- Not all metrics may be possible to extract from MARKAL and NEMS runs, and thus other tools may be used, but the underlying methods and assumptions need to be consistent with those runs.
- Metrics should represent fundamental benefits that represent societal value, i.e., to the extent possible, the phenomena measured should be of intrinsic value (or avoided intrinsic harm), rather than proxies for the phenomena.

DOE Benefits Metrics

NAS Categories	DOE Themes	Core Benefits Metrics: Impacts on …
Environmental	**Clean**	1. Annual and cumulative greenhouse gas emissions 2. Cost of pollutant control 3. Cost of carbon control under carbon constrained case
Economic	**Affordable**	4. Net consumer expenditures 5. Electricity system cost 6. Average household energy expenditure as a % of income 7. Energy intensity of economy (E/GDP) 8. Net energy system cost
Security	**Reliable**	10. Annual and cumulative foreign oil imports 11. Vehicle miles traveled per gallon of oil 12. Transportation fuel diversity index

DOE Benefits Analysis Process: Measuring what matters

FY 2007 Budget Metrics	FY 2008 Budget Metrics
Energy Displaced **•Primary non-renewable Energy**	Eliminated
Economic **•Energy expenditure savings** **•Energy system cost savings**	Economic **•Natural gas price reduction** **•Energy system cost savings** **•Consumer savings (annual, cumul)** **•Electric power savings (Annual, cumul)** **•Reduced household income spending** **•Energy Intensity of the economy**
Environmental **•GHG emission reductions (annual, cumul)**	Environmental **•GHG emission reductions (annual, cumul)** **•Reduced pollution control cost** **•Value of carbon allowances (if applicable)**
Security **•Oil savings, total (annual)** **•Natural gas savings**	Security **•Oil savings, imports (annual, cumul)** **•Security fuel economy (miles per gal oil)** **•Transportation fuel diversity index** **•Oil intensity of economy**

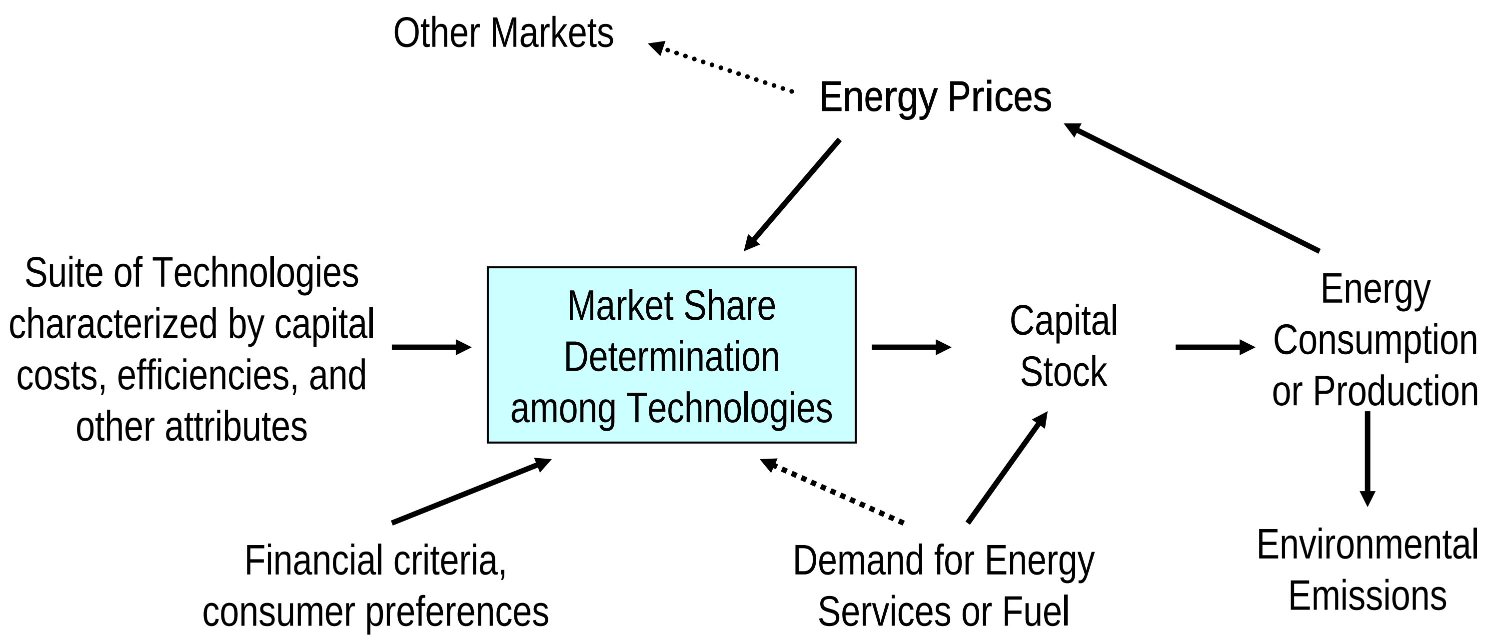
Common Modeling Platforms

Why Use Energy System Models?

- **NEMS and MARKAL provide consistent economic frameworks for assessing program impacts.**
- **Important for determining individual program and portfolio benefits.**
- **Scenarios can be easily constructed to forecast benefits of R&D portfolios under alternative conditions (energy prices, environmental policies).**
- **NEMS has greater detail for modeling through 2030; while MARKAL provides a broader, longer-term view to 2050.**

Core Model Methodology

- **Despite different specific structures, both models have at their core the projection of technology market shares based primarily on *economic* criteria.**



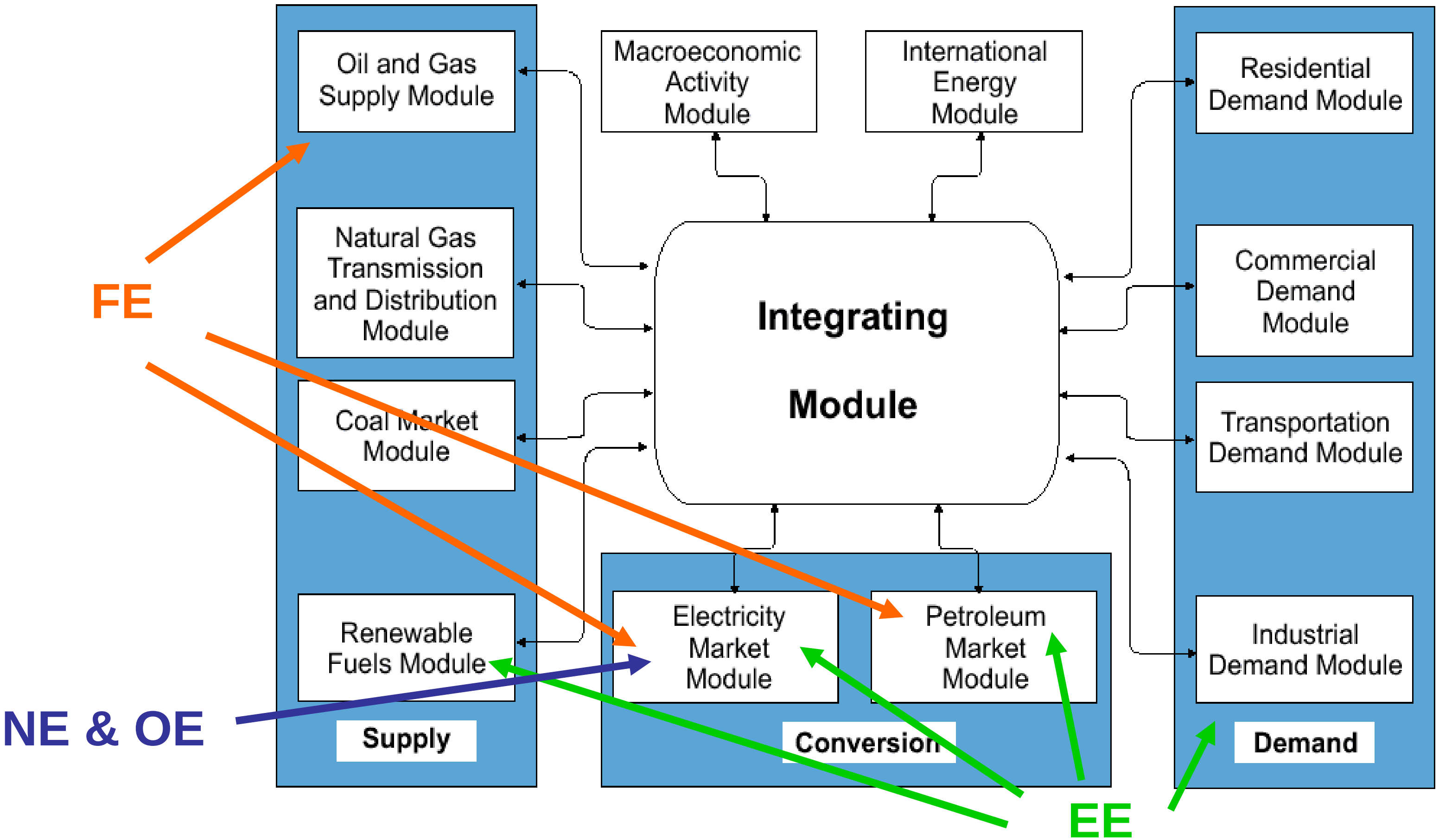
NEMS Overview

- **National Energy Modeling System (NEMS) was developed by EIA.**
  - Annual Energy Outlook projections
  - Congressional as well as agency requests
- **NEMS has also been used by others.**
  - Various National Laboratories
  - National Commission on Energy Policy
  - DOE Offices for GPRA benefit estimation
- **Modular structure allows each sector to be represented by methodology and data that fit it best, including behavioral factors.**
- **Technology representation in most sectors of interest for DOE R&D programs – residential, commercial, and transportation demand sectors, industrial heat and power, electricity supply and renewable energy.**

For information see: http://www.eia.doe.gov/oiaf/aeo/index.html

NEMS Overview (Continued)

- **NEMS is a simulation model organized by energy producing, consuming, and conversion sectors.**



Arrows are Illustrative, not exhaustive.

MARKAL Overview

- **MARKAL is a technology rich, dynamic linear programming model that solves for sector specific, fuel and technology choice over 5-year intervals.**
- **MARKAL model structure is generic; based on reference energy system concept that can easily accommodate any set of demand specifications and technologies.**
- **Model solves for combination of energy technologies that satisfies energy service demands at minimum cost.**
- **Model has long history of use for energy system analysis and is used by 90 research institutions and universities in over 50 countries.**
- **Multi-region global MARKAL model variants include:**
  - System for Analysis of Global Energy Markets (SAGE) – EIA
  - Energy Technology Perspective (ETP) – IEA

For information: http://www.etsap.org/documentation.asp

MARKAL Reference Energy System

Primary Energy Supply	Conversion Technologies	End-Use Technologies	Demand for Energy Service
	(Final Energy)	(Useful Energy)	

Primary Energy Supply

<u>Renewables</u> e.g.
- -Biomass
- -Hydro

<u>Mining</u> e.g.
- -Crude oil
- -Natural gas
- -Coal

<u>Imports</u> e.g.
- -Crude oil
- -Oil products

<u>Exports</u> e.g.
- -Oil products
- -Coal

<u>Stock changes</u>

Conversion Technologies

<u>Fuel Processing Plants</u> e.g.
- -Oil refineries
- -Hydrogen prod.
- -Ethanol prod.

<u>Power plants</u> e.g.
- -Coal Steam
- -IGCC
- -IGCC with Seq.
- -CCGT
- -Solar
- -Wind
- -Nuclear
- -Fuel Cells
- -Combined Heat and Power

End-Use Technologies

<u>Industry,</u> e.g.
- -Steam boilers
- -Machinery

<u>Services,</u> e.g.
- -Air conditioners
- -Light bulbs

<u>Households,</u> e.g.
- -Space heaters
- -Refrigerators

<u>Agriculture,</u> e.g.
- -Irrigation pumps

<u>Transport,</u> e.g.
- -Gasoline Car
- -Fuel Cell Bus

Demand for Energy Service

<u>Industry,</u> e.g.
- -Process steam
- -Motive power

<u>Services,</u> e.g.
- -Cooling
- -Lighting

<u>Households,</u> e.g.
- -Space heat
- -Refrigeration

<u>Agriculture,</u> e.g.
- -Water supply

<u>Transport,</u> e.g.
- -Person-km

NEMS and MARKAL Key Attributes

Attribute	NEMS	MARKAL
Methodology	Simulation/Optimization hybrid	Optimization
Timeframe	To 2030 annually	To 2050 in 5-year steps
Geographic Aggregation	Regional	National
Energy Demand Aggregation	Residential: 16 end-uses and 3 building types; Commercial: 10 end-uses and 11 building types; Industry: 7 energy-intensive industries, 8 non-energy-intensive industries, CHP, motors; Transportation: 12 car and truck classes	Residential: 8 end-uses; Commercial: 7 end-uses; Industry: 7 end-uses; Transportation: 2 car and truck classes
Behavioral Assumptions	Consumer hurdle rates; risk premiums, economic and other consumer choice parameters	Consumer hurdle rates
Electricity Aggregation	Database of individual plants Seasonal and multiple time-block representation	"Typical" plants Day/Night and season time blocks

Common Baseline and Scenarios

The Baseline Case: The world ***without*** DOE funding

- **Purpose of a common baseline.**
  - Assure same initial forecasts for economic growth, energy prices, and levels of energy demand
  - Provide basis for assessing how well DOE technologies might be able to compete against future, rather than current, conventional energy technologies
  - Assure that underlying improvements in existing energy technology are not counted as part of benefits of DOE programs

The Baseline Case:
The world ***without*** DOE funding

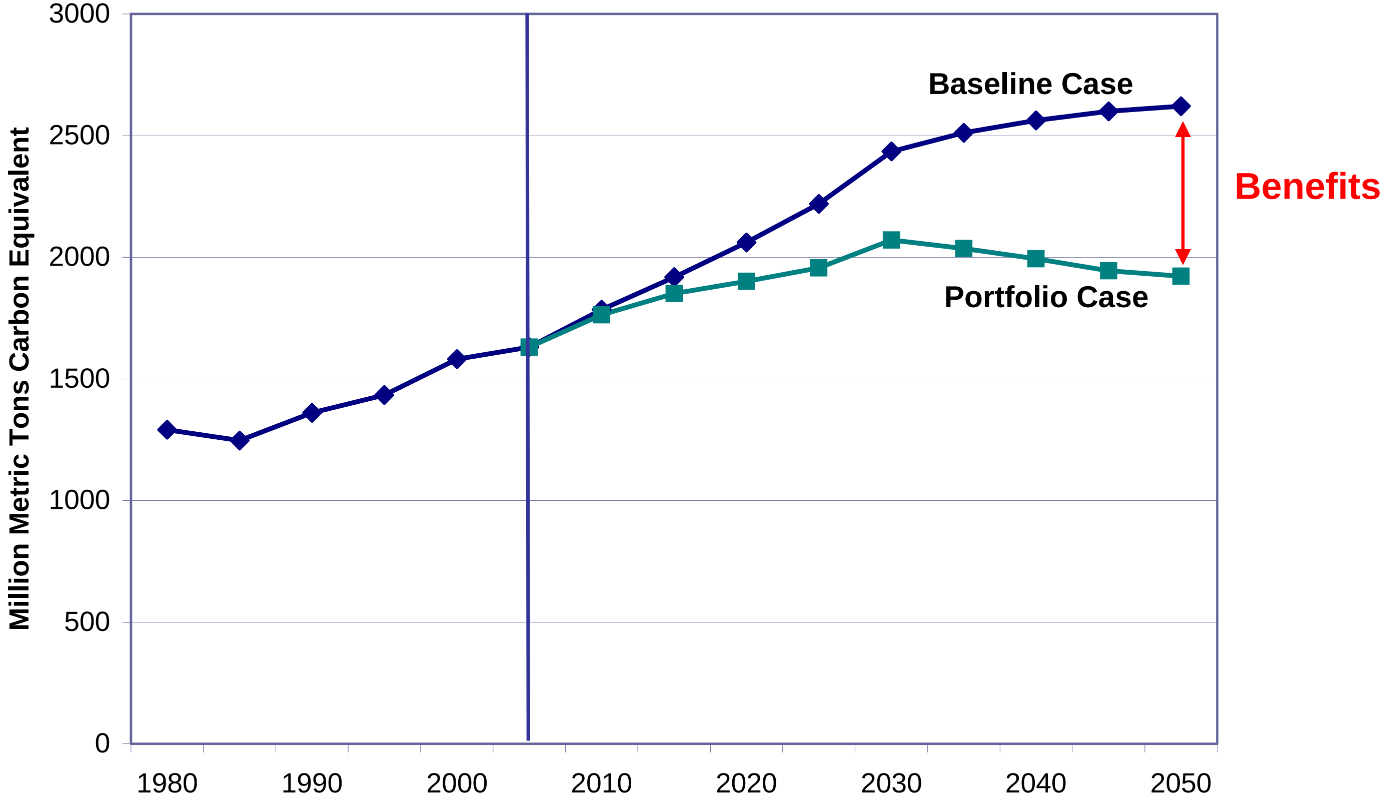
- **Adjustments are made to official AEO 2006 reference case.**
- **Four types of changes.**
  1. Removal of any DOE program effects
  2. Adjustment for greater or less technology improvement in baseline than represented by AEO reference case
  3. Energy market updates
  4. Structural changes
- **Technology improvements to EIA baseline diminish net impact of DOE programs.**

The Portfolio Case: The world *with* DOE funding

- **Use input values describing projected program outputs (goals) for each DOE program.**
- **Program goals are typically translated into inputs to integrated energy models in the form of projected technology cost and performance improvements.**
- **DOE portfolio cases (one for each scenario) depict all DOE program outcomes.**

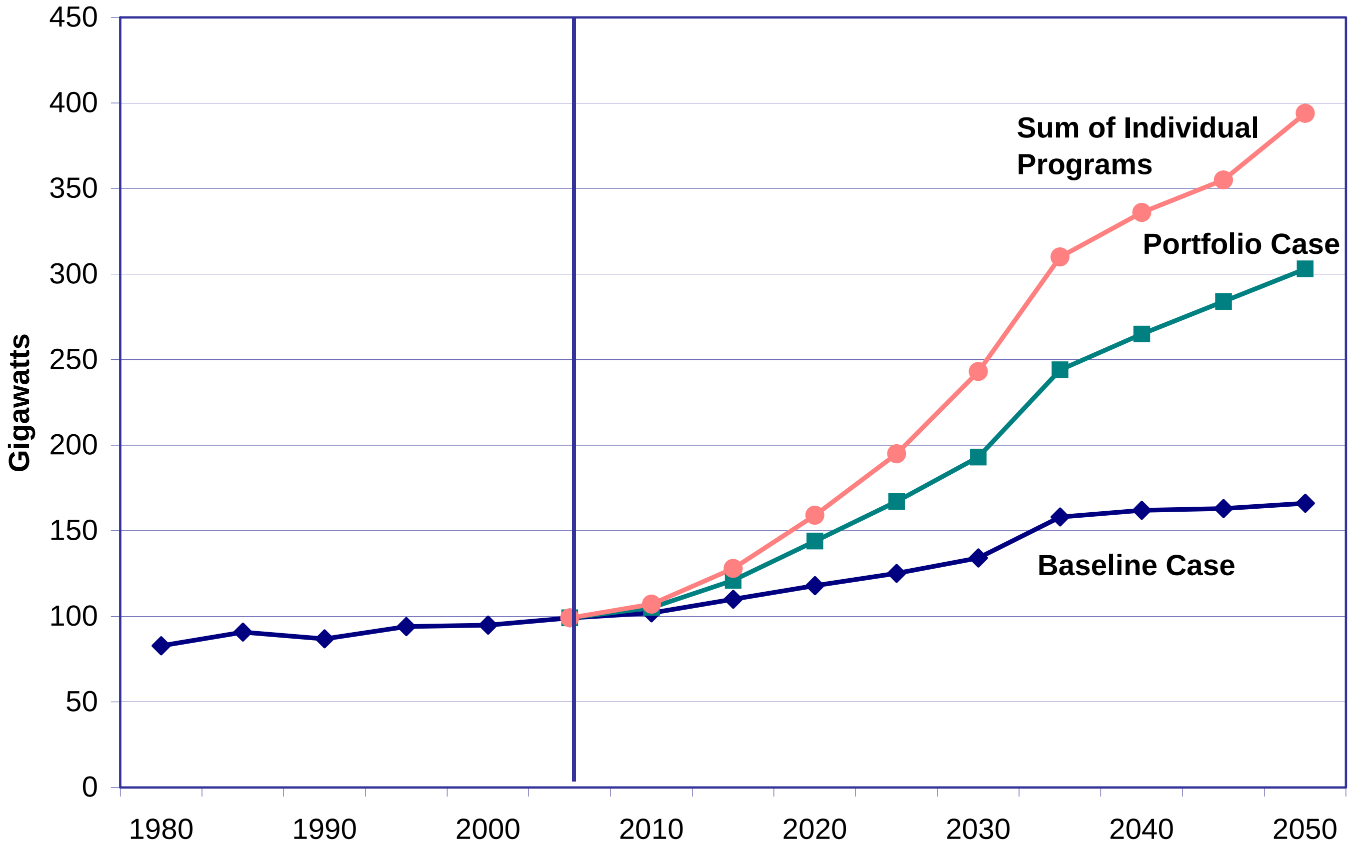
Benefits Estimates

- **Benefits are determined by the difference in projections *with* and *without* the R&D programs.**



Portfolio Effects

- **Due to interactive effects, the portfolio impact is not necessarily the same as the sum of individual programs.**

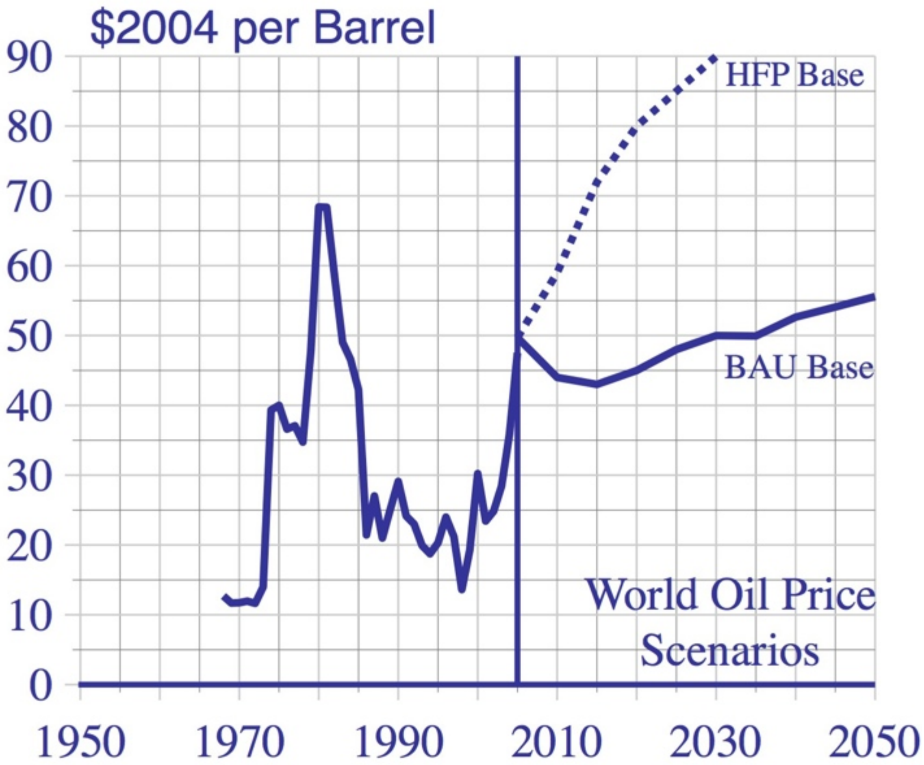


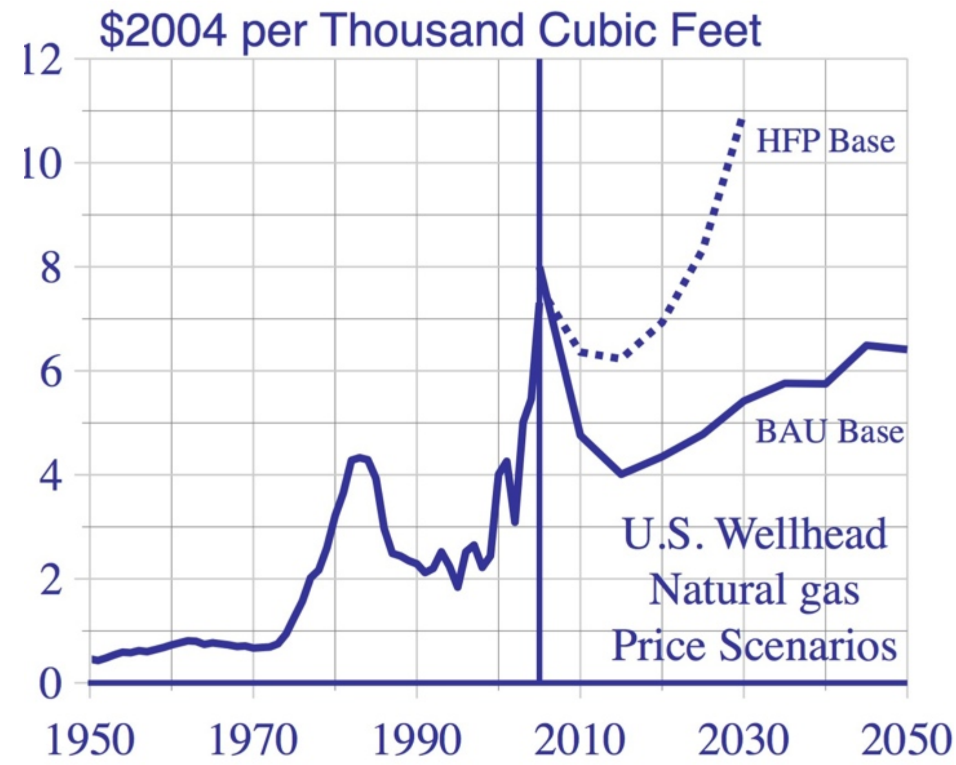
Three Scenarios

- **Business-as-Usual (BAU)**
  - Same assumptions as used in AEO 2006 Reference Case
  - Only current laws and regulations are considered
- **Highly Constrained Carbon (HCC)**
  - Carbon constraints imposed to coincide with "high control" (lower PPM) scenario developed by Climate Change Science Program through 2050
  - Meets Administration's "Global Climate Change Initiative" goal in 2012
  - Further reductions… by 2020: 1,640 mmtce; by 2030: 1,490 mmtce; by 2050: 1,200 mmtce
- **High Fuels Prices (HFP)**
  - Start with AEO 2006 High World Oil Price Case (oil prices rising to $90 per barrel in 2030)
  - No New U.S. LNG terminals; limits on LNG expansion
  - Construction of Alaskan natural gas pipeline delayed beyond NEMS horizon
  - Allow only initial construction of a pipeline from McKenzie Delta
  - Reduction of Canadian imports by approximately 25 % relative to AEO 2006 reference case
  - Maintain exports of natural gas to Mexico at AEO 2006 reference case level

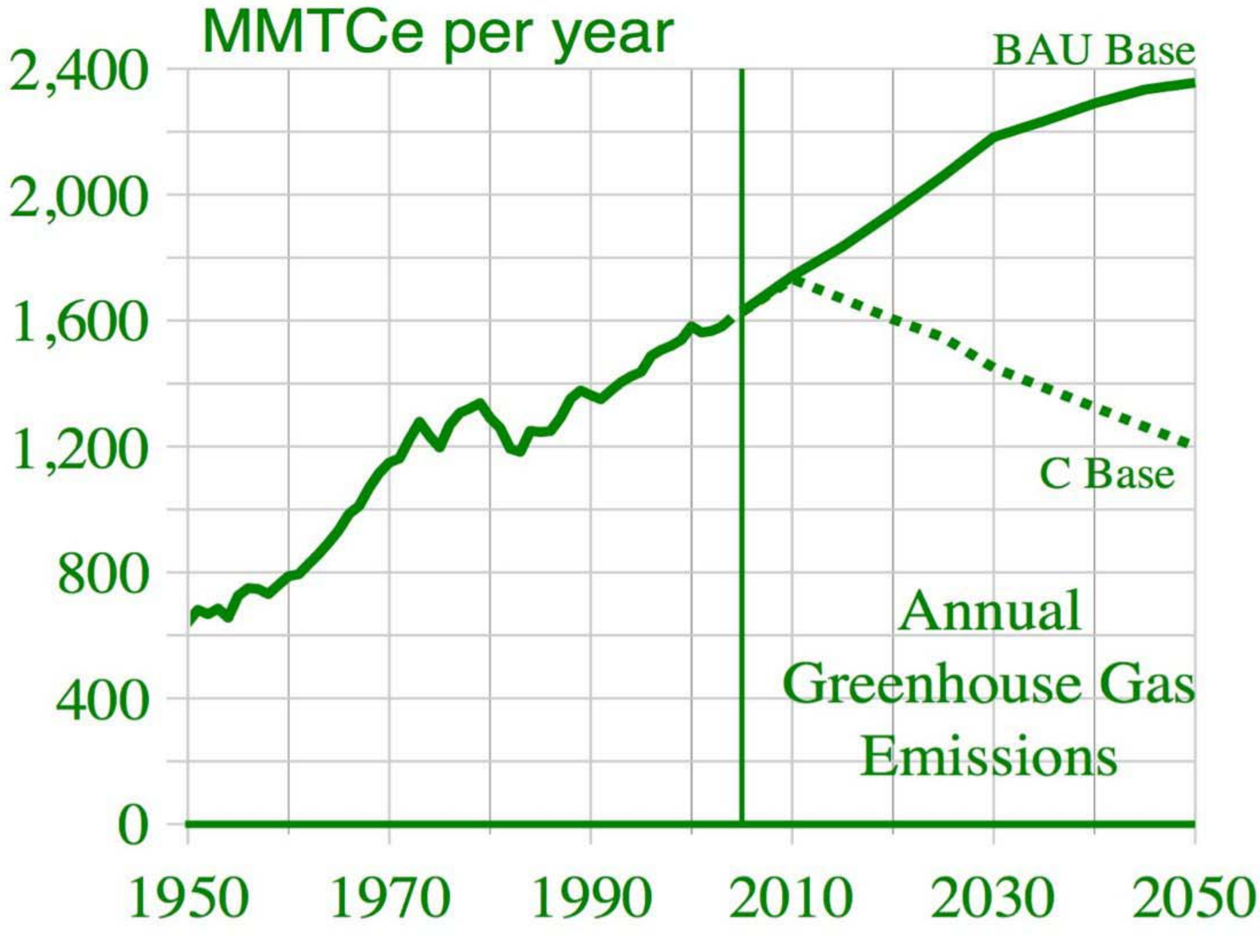
	World Oil Price	Wellhead Natural Gas Price
2015	$72/bbl	$6.21/thousand cu. ft.
2020	$80/bbl	$6.86/thousand cu. ft.
2030	$90/bbl	$10.96/thousand cu. ft.

Scenarios: High Fuel Prices



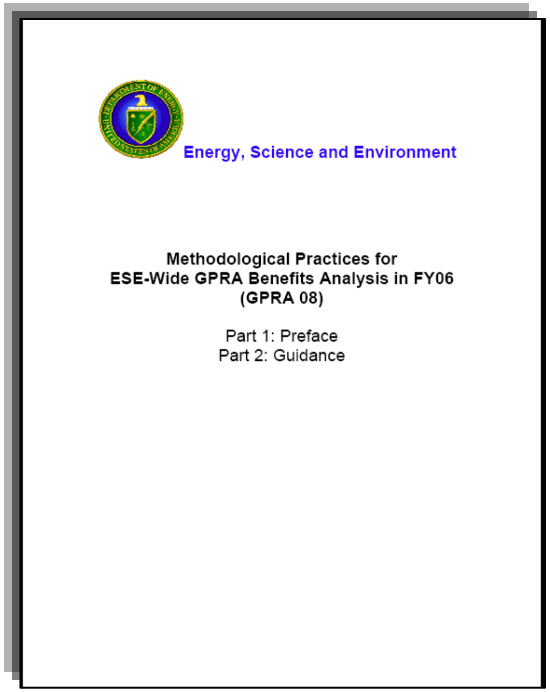


Scenarios:
Highly Constrained Carbon



Common Methodologies

Methodological Guidance


Energy, Science and Environment

Methodological Practices for
ESE-Wide GPRA Benefits Analysis in FY06
(GPRA 08)

Part 1: Preface
Part 2: Guidance

General Guidance Themes	
1	**Document All Assumptions**
2	**Assure that GPRA Targets, Milestones, and Outputs are In-line with Programmatic Vision and Budget Planning**
3	**Understand AEO Baseline (consult with EIA)**
4	**Provide a Data-Driven and Intuitive "Storyline" for any Departures from AEO Forecast of Technological Change in Absence of DOE Programs**
5	**Provide a Data-Driven and Intuitive "Storyline" for Technological Change, Attributable to and Driven by DOE Technology Programs**
6	**Provide a Data-Driven and Intuitive "Storyline" for Technology Adoption and Diffusion, Attributable to and Driven by DOE Deployment Programs**
7	**Ensure that Offline Analyses are – to the Degree Possible – Standardized with Results Generated "Endogenously" by Integrated Models**
8	**Ensure that Calculation Rules and Assumptions Provided to Modelers are Clear**

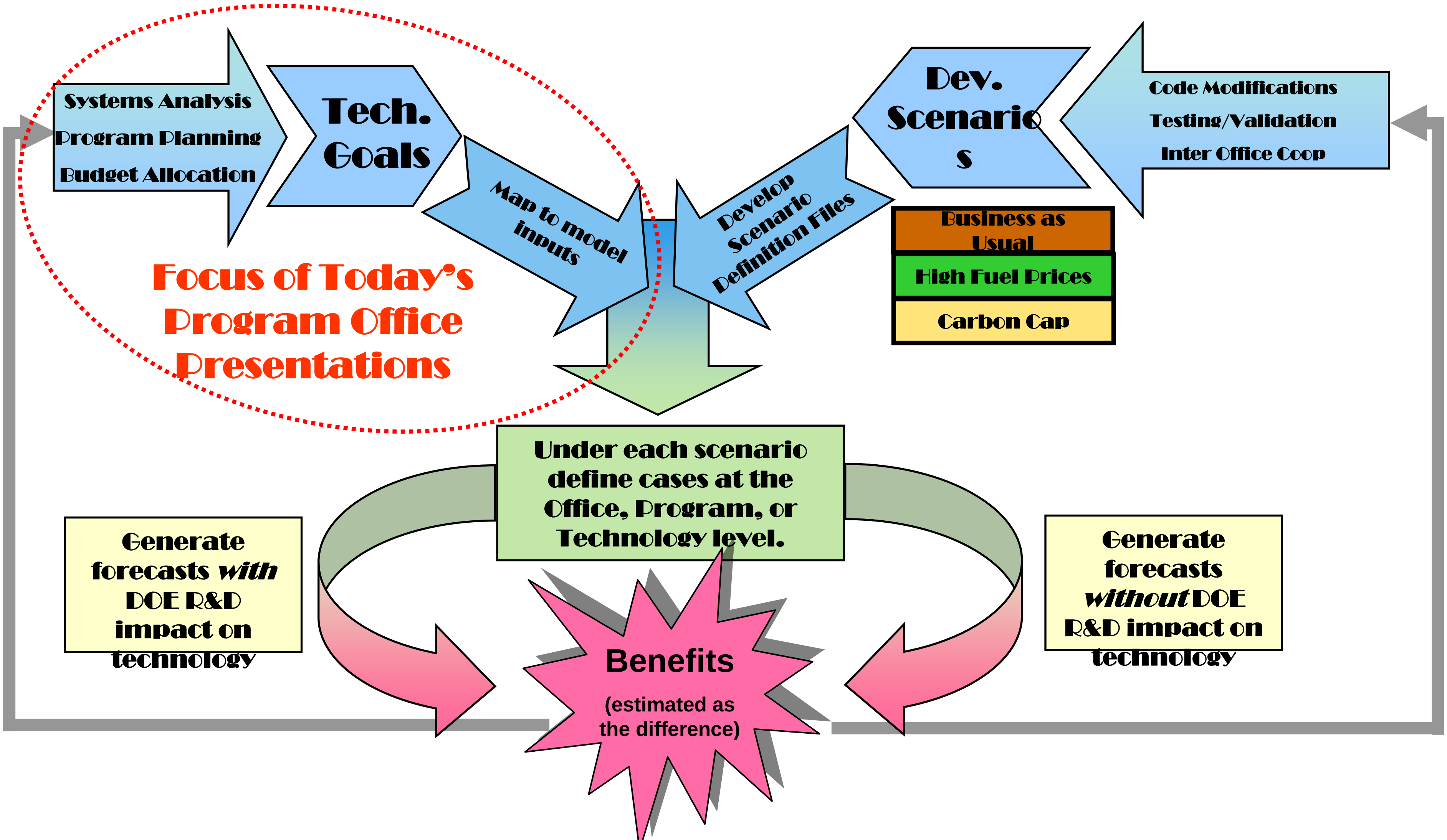
Methodological Guidance (Continued)

- **Strong Emphasis on Documentation.**
  – Enable peer review
  – Force analysts to think through and provide rationale for targets and goals
- **Focus on distinguishing—through data and storylines—effect of DOE programs from baseline improvements.**
- **Aim to harmonize as much as possible, including "off-line" analyses.**

Current DOE Benefits Assessment Capabilities

- **Common methodologies.**
  - **"harmonized, not uniform"**
    - **Methodologies are the same, but some underlying assumptions may still differ (e.g., degree of technical optimism, financing structures, "N-year" rule, etc.)**
- **Common baselines.**
- **Common metrics.**
- **Common scenarios.**
- **Common modeling platforms.**
- **Based on "OMB Target" funding levels.**
- **Focused on applied energy R&D portfolio.**

General Benefits Methodology Overview



Representation of Programs Goals in Models

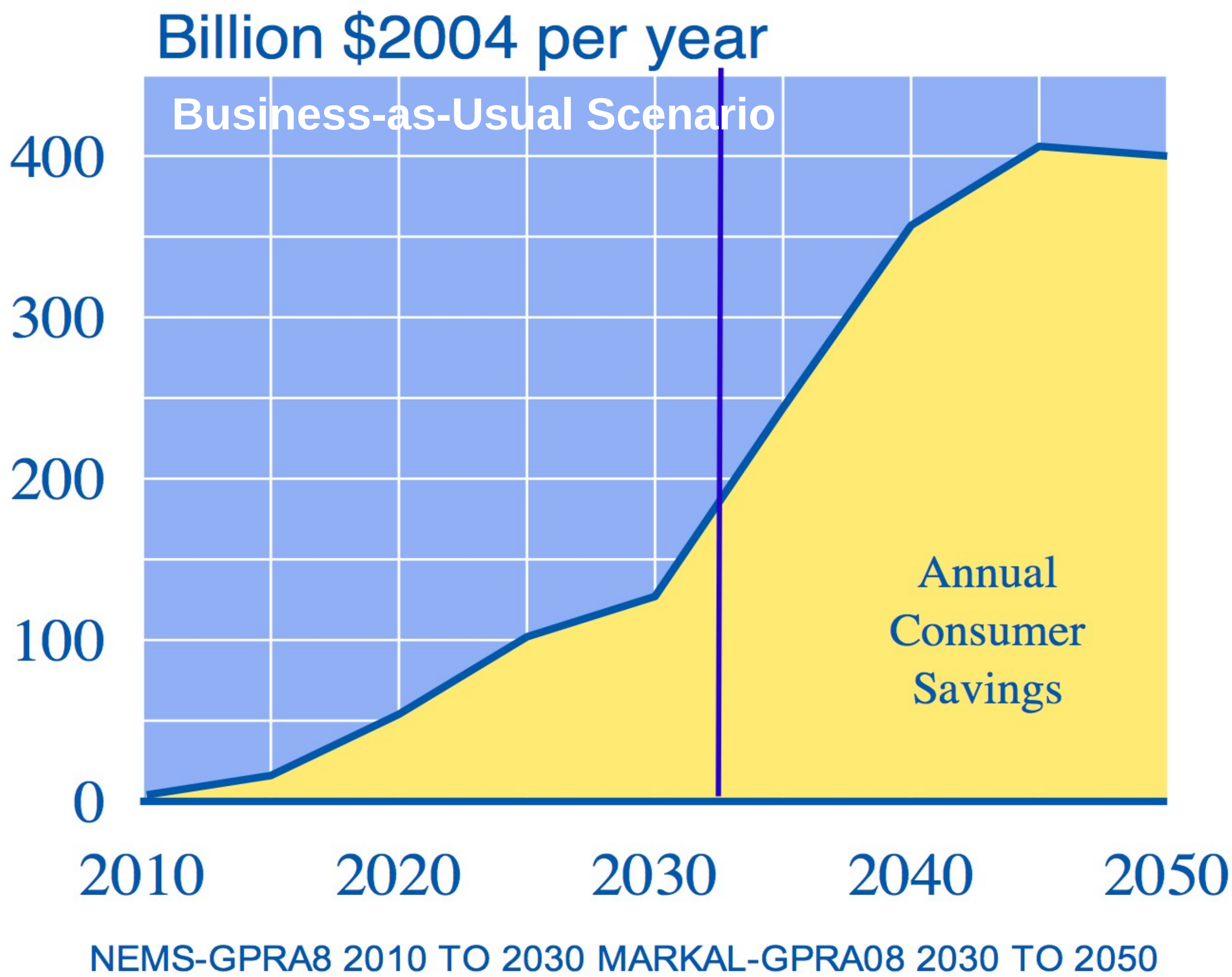
- **Most R&D programs are represented by changing technology cost and performance characteristics (e.g., $/kW and conversion efficiency) to reflect program goals.**
  - Examples include: nuclear technologies, wind turbines, hybrid vehicles, IGCC power plants, CO_2 sequestration
- **Deployment programs are generally represented by lowering consumer hurdle rates for targeted end uses to achieve program adoption goals.**
  - Examples include Energy Star, residential lighting, refrigerators, and water heaters

Offline Analysis

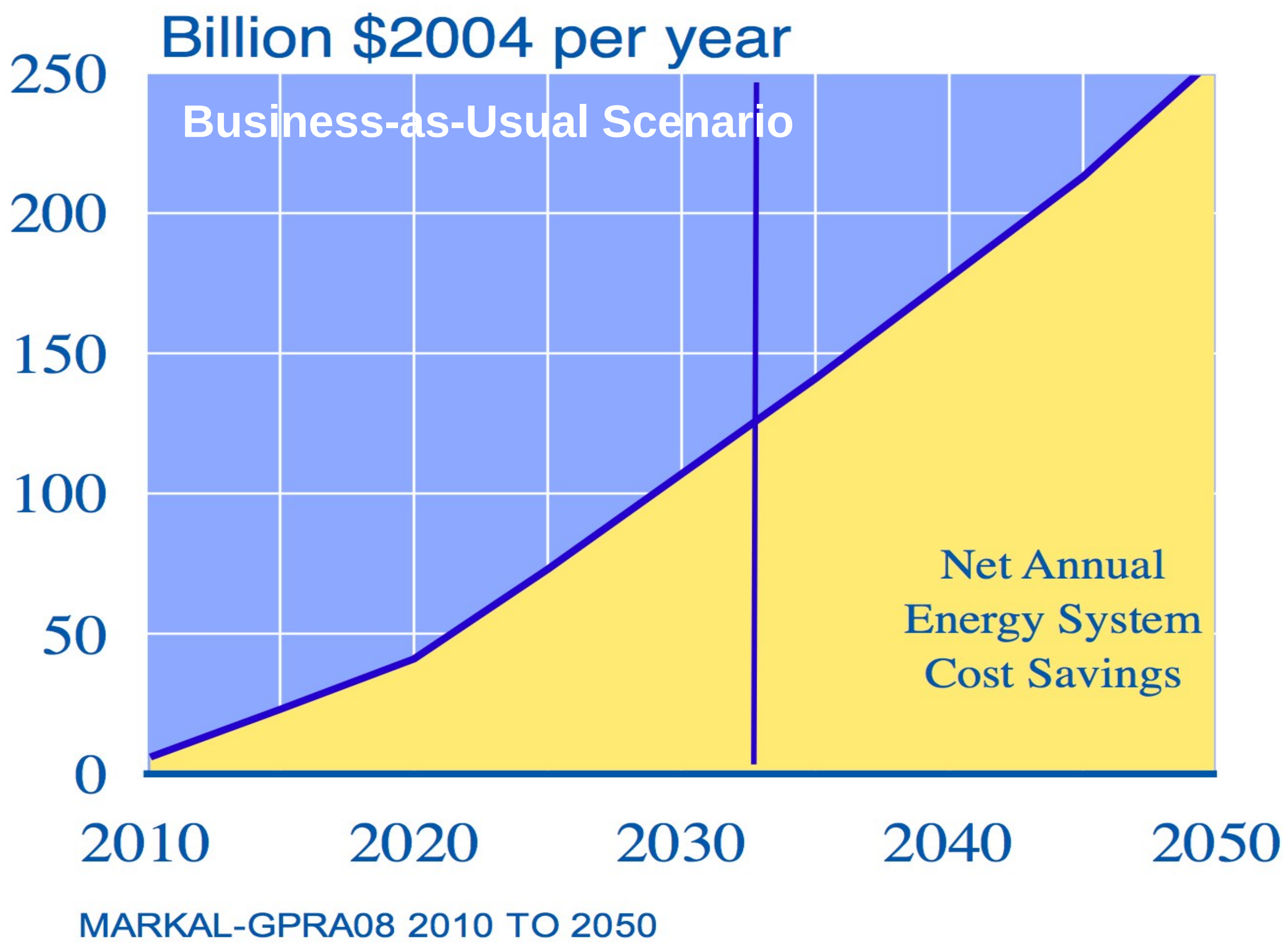
- **Some programs must be analyzed offline**
  – Technologies are extremely heterogeneous
  – Program outcomes are budget driven
  – Selection is influenced by non-price factors not represented in models
  – Models do not have required technology representation
  – Models cannot measure metric of interest (e.g., reliability)
- **Offline results are discounted if significant interactions among components are expected.**
- **Offline results are put into integrated models, either by subtracting energy consumption, using offline penetration rate estimates, or modifying model econometric parameters.**
- **Integrated models then calculate aggregate portfolio case outcome.**
  – Except for electricity reliability and security benefits that cannot be measured by integrated models (these are estimated separately).

Common Benefits Projections

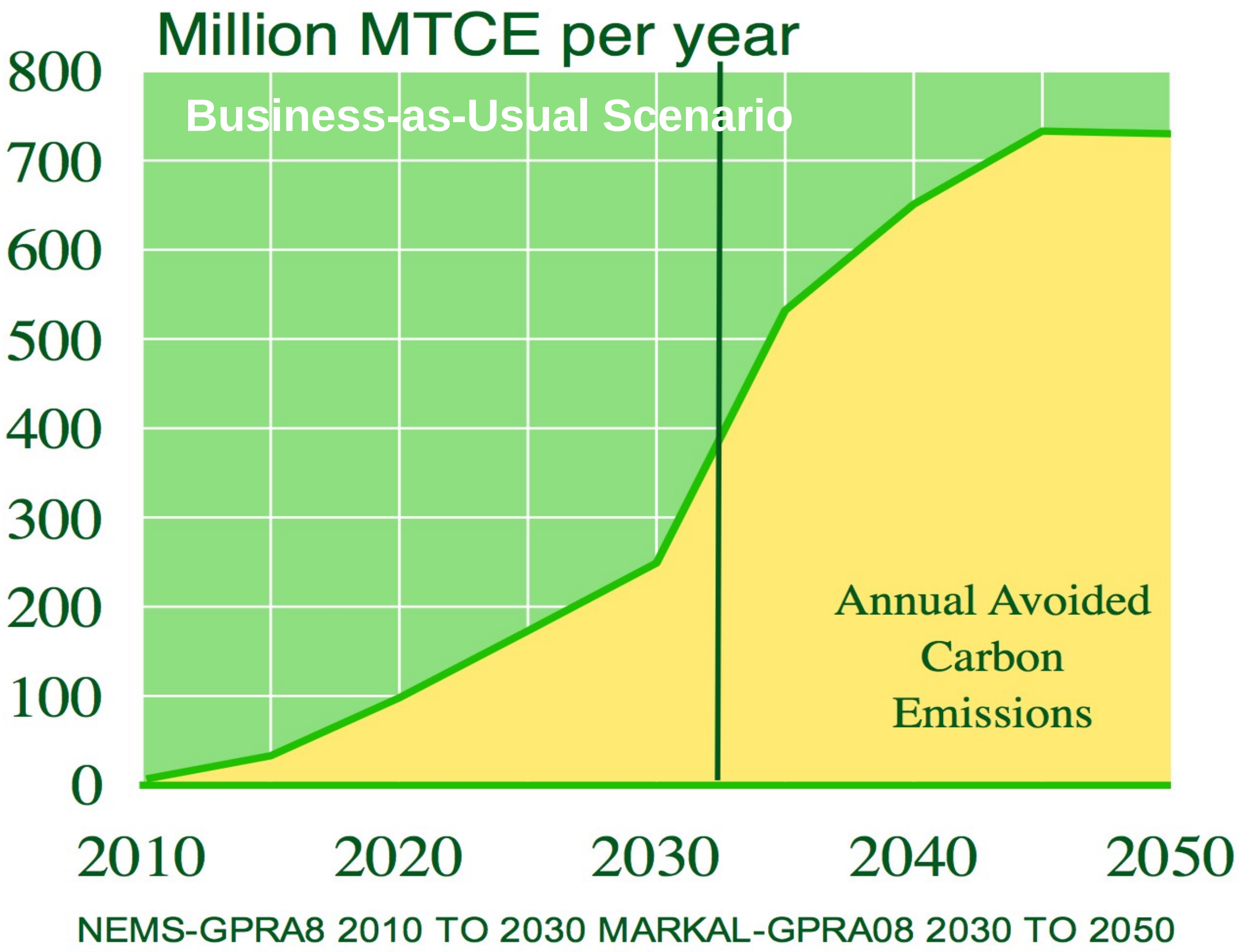
Economic Benefits: Consumer Savings



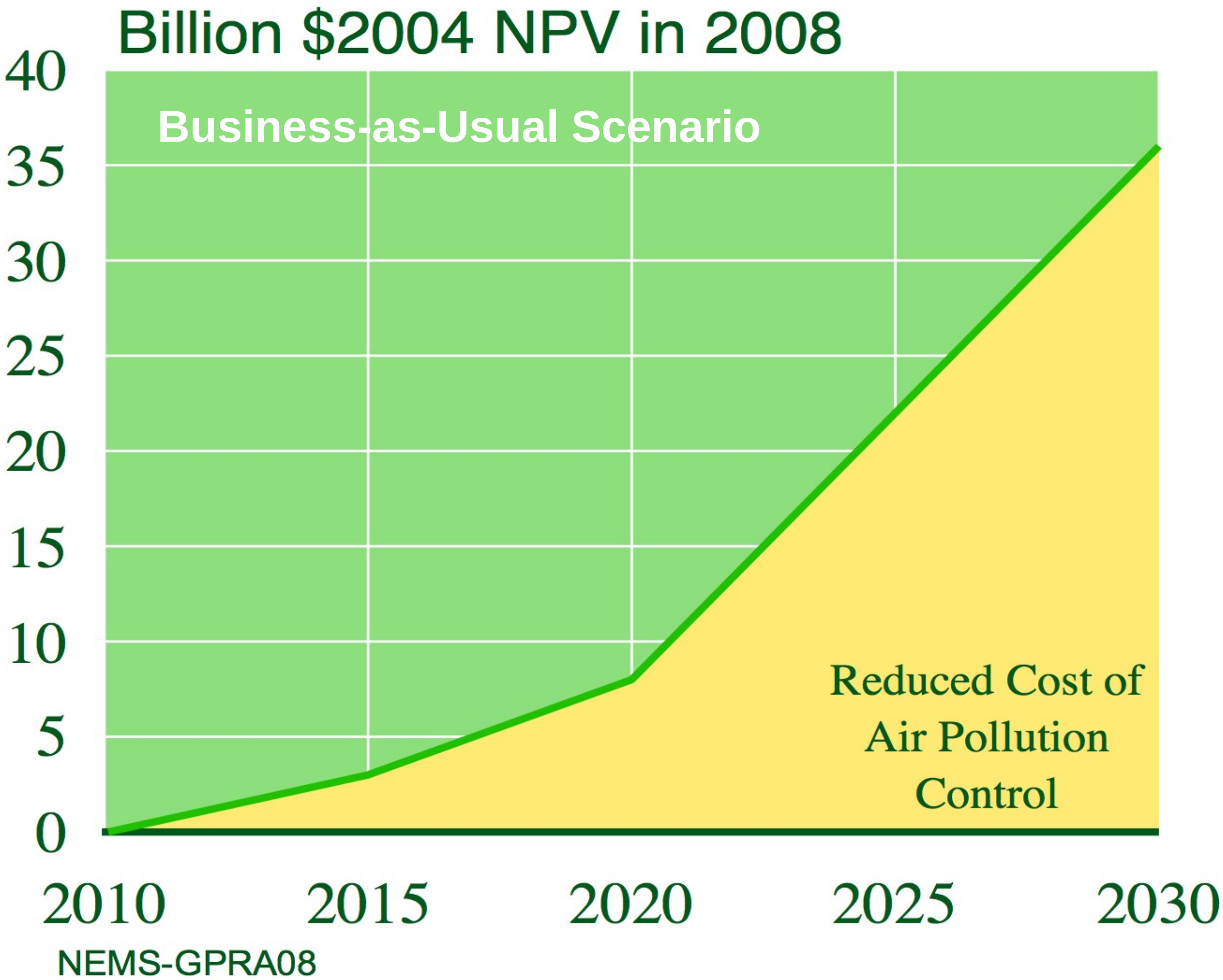
Economic Benefits: Energy System Cost Savings



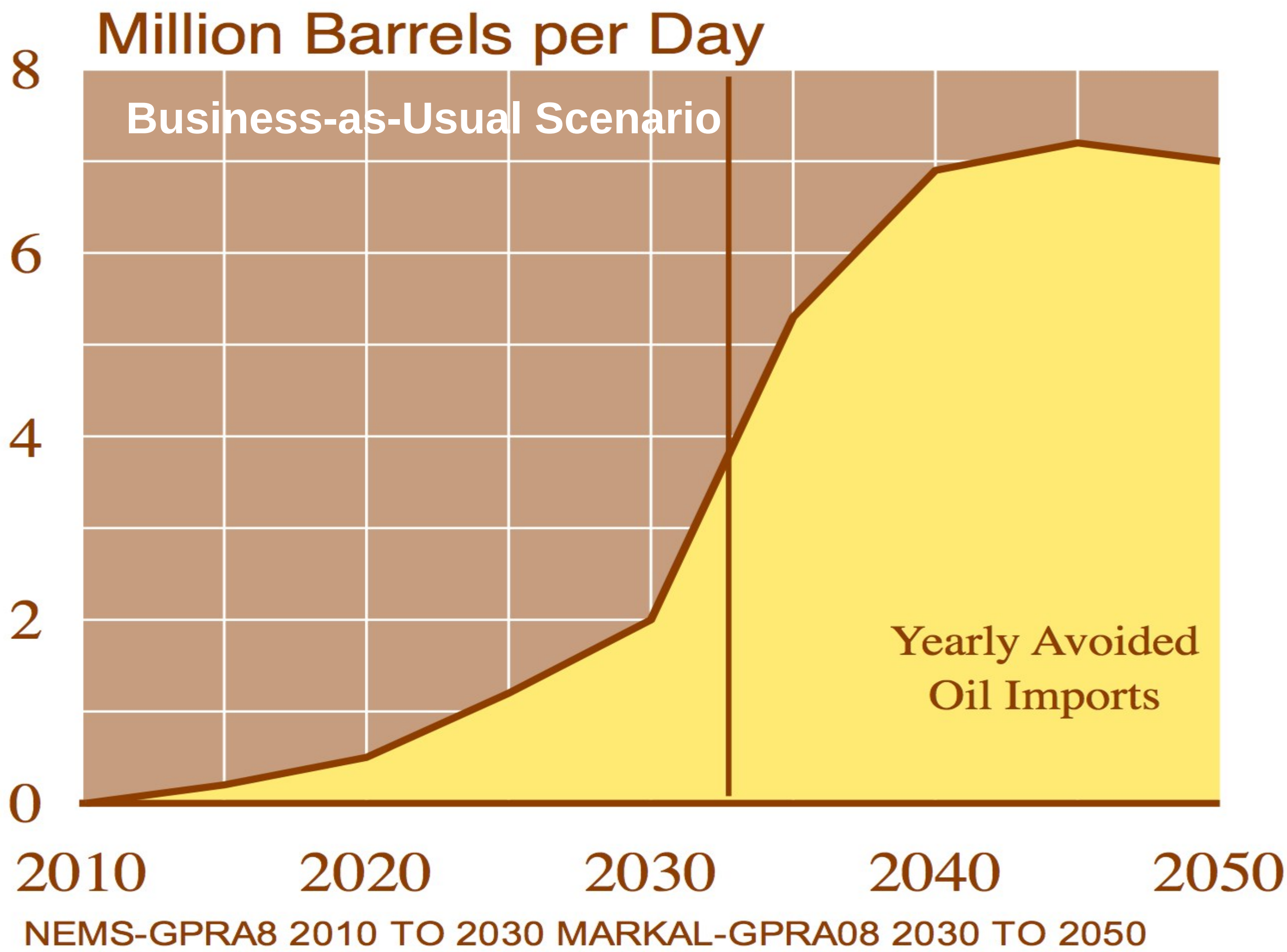
Environmental Benefits: Avoided GHG Emissions (Annual)



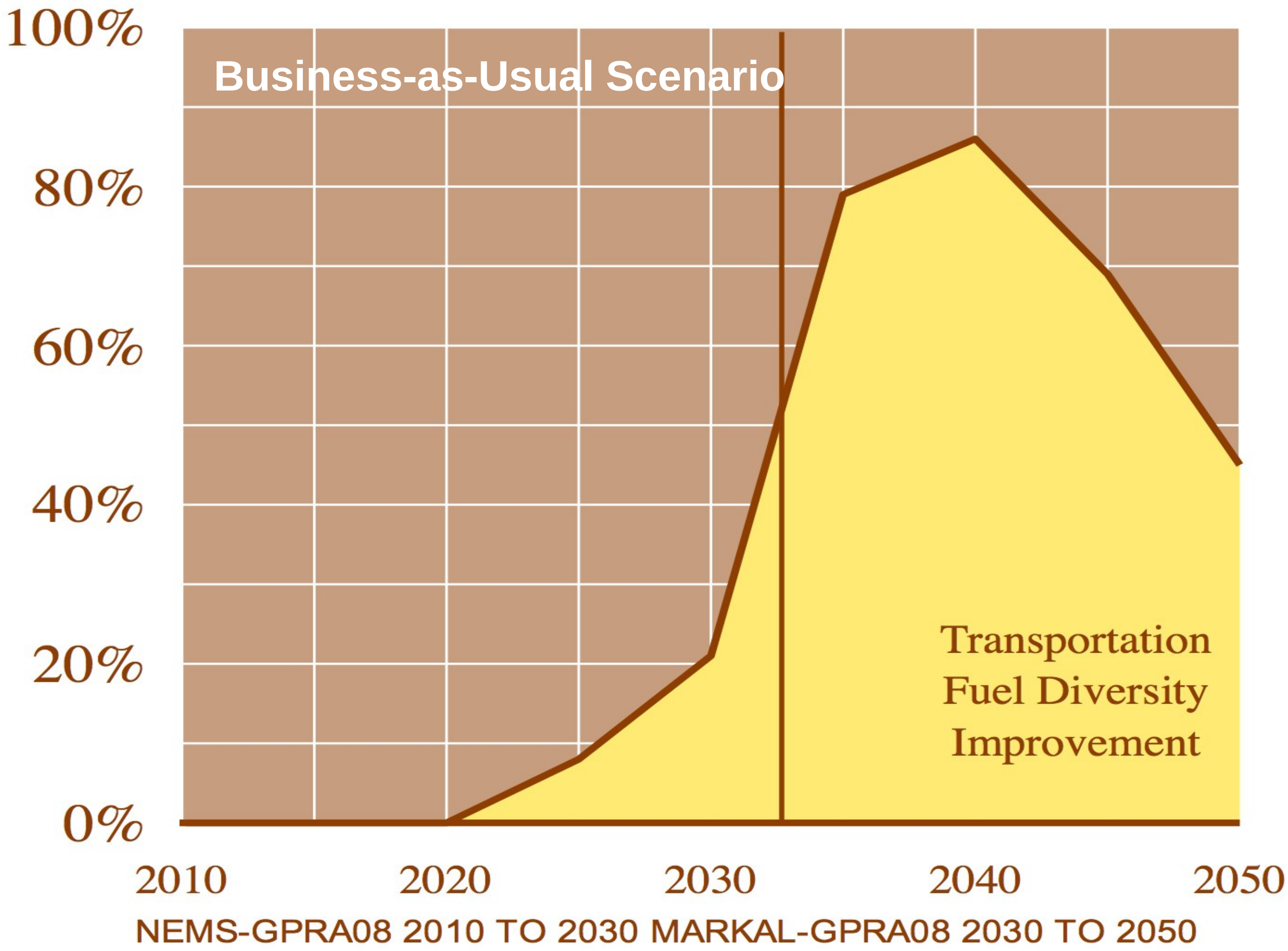
Environmental Benefits: Reduced Air Pollution Control Costs



Security Benefits: Avoided Oil Imports



Security Benefits: Transportation Fuel Diversity



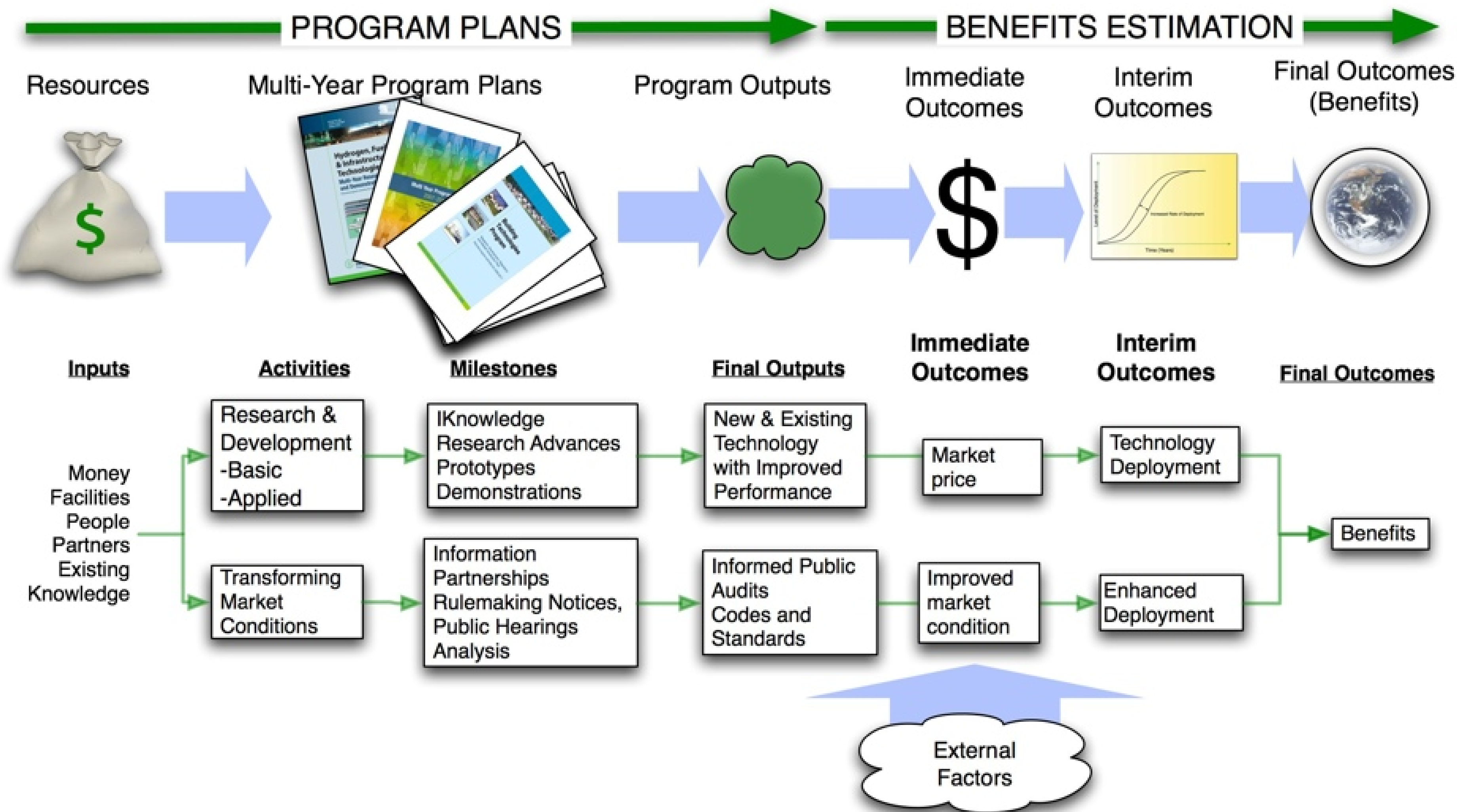
Closing Comments

Next Steps for DOE Benefits Analysis

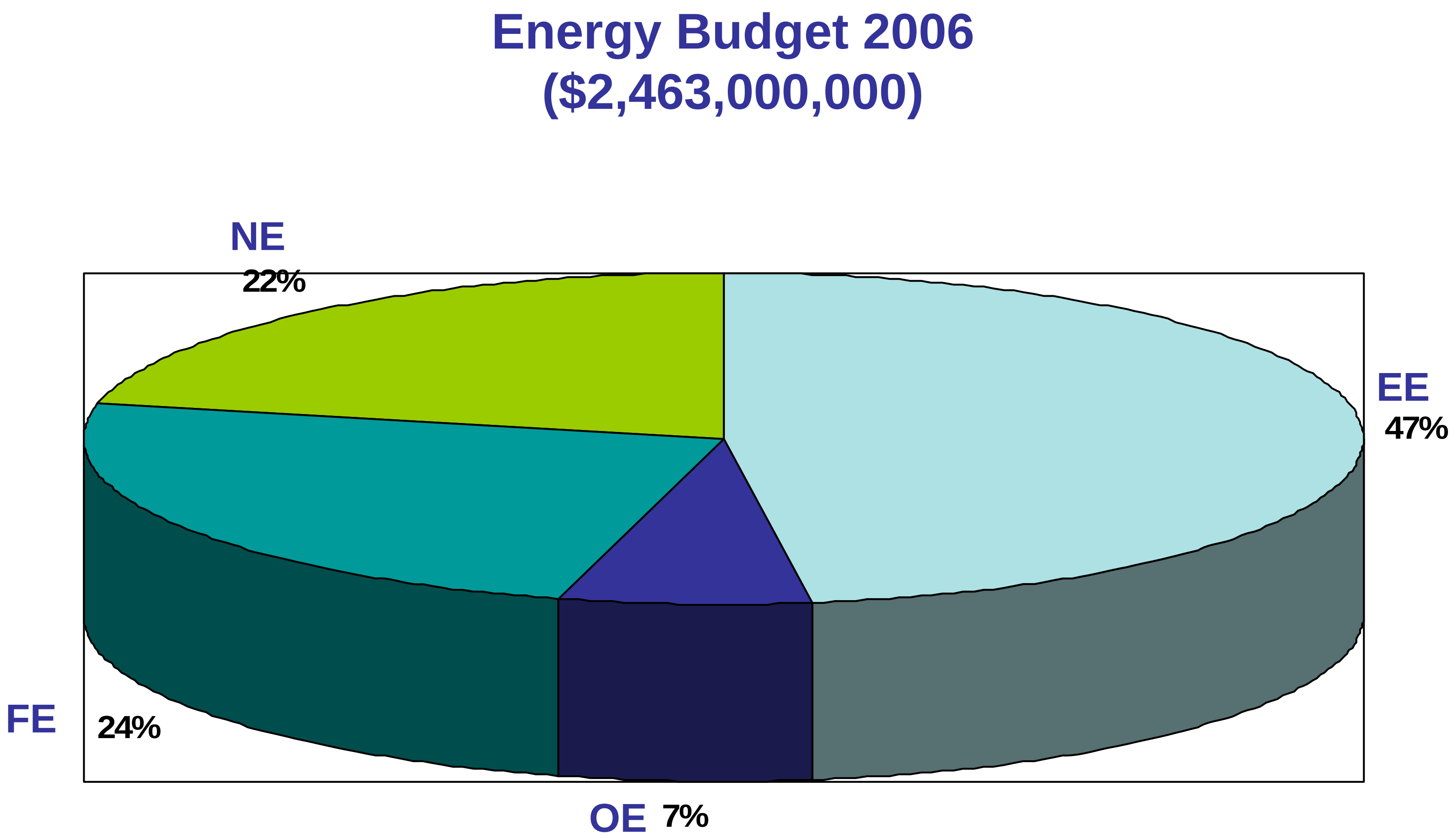
- **Fully implementing integrated common and consistent benefits analysis across DOE remains a multi-year process.**
- **This peer review is an important step in the process.**
- **DOE is actively working on:**
  - **Developing an explicit way to recognize and account for technological risk, uncertainty, and its many complicating factors.**
    - **DOE expects NAS to provide a 2nd report on this topic soon.**
  - **Closer linkages to budgeting and planning.**
  - **Method for allocating benefits from portfolio.**
- **We look forward to your thoughts on the charge questions so we can consider how to improve our efforts and provide better information to DOE decision-makers.**
- **Next… Program presentations on how each office implemented "Methodological Guidance"**

Backup Slides

DOE Benefits Analysis Process: Logic model



Relative Size of Programs Examined



Economic Benefits of the DOE Portfolio—BAU Scenario

	2015	2020	2025	2030	2040	2050
Consumer Savings, Annual (billion 2004$)	16	54	102	127	357	400
Consumer Savings, NPV (billion 2004$)	62	204	476	802	2,094	3,359
Electric Power Industry Savings, Annual (billion 2004$)	6	16	26	36	80	86
Electric Power Industry Savings, NPV (billion 2004$)	17	59	126	210	441	721
Reduced Household Energy Expenses (Percent)	0.8%	2.2%	3.9%	5.1%	10.1%	10.4%
Reduced Energy Intensity of Economy (Percent)	1.7%	3.8%	5.9%	7.3%	13.3%	16.2%

Economic Benefits of the DOE Portfolio—HFP Scenario

	2015	2020	2025	2030	2040	2050
Consumer Savings, Annual (billion 2004$)	27	62	152	213	597	613
Consumer Savings, NPV (billion 2004$)	90	262	613	1,141	4,145	6,197
Electric Power Industry Savings, Annual (billion 2004$)	8	15	29	36	104	82
Electric Power Industry Savings, NPV (billion 2004$)	26	68	138	225	741	1,049
Reduced Household Energy Expenses (Percent)	1.1%	2.7%	5.4%	7.0%	15.2%	15.2%
Reduced Energy Intensity of Economy (Percent)	1.9%	3.8%	5.6%	6.2%	16.6%	13.6%

Economic Benefits of the DOE Portfolio—HCC Scenario

	2015	2020	2025	2030	2040	2050
Consumer Savings, Annual (billion 2004$)	32	89	165	301	812	720
Consumer Savings, NPV (billion 2004$)	99	340	761	1,420	6,274	8,822
Electric Power Industry Savings, Annual (billion 2004$)	17	37	58	86	126	105
Electric Power Industry Savings, NPV (billion 2004$)	54	162	312	514	1,418	1,800
Reduced Household Energy Expenses (Percent)	1.3%	3.2%	5.3%	8.8%	16.9%	13.0%
Reduced Energy Intensity of Economy (Percent)	1.7%	3.1%	4.9%	5.9%	12.8%	14.5%

Environmental Benefits of the DOE Portfolio—BAU Scenario

	2015	2020	2025	2030	2040	2050
Avoided Carbon Emissions, Annual (MMTCE)	33	98	173	249	651	730
Avoided Carbon Emissions, Cumulative (MMTCE)	118	486	1,163	2,259	8,235	15,391
Reduced Cost of Criteria Pollutant Control, NPV (billion 2004$)	3	8	22	36	na	na

Note: na = not available.

Environmental Benefits of the DOE Portfolio—HFP Scenario

	2015	2020	2025	2030	2040	2050
Avoided Carbon Emissions, Annual (MMTCE)	43	114	181	252	786	611
Avoided Carbon Emissions, Cumulative (MMTCE)	151	572	1,346	2,465	9,924	16,961
Reduced Cost of Criteria Pollutant Control, NPV (billion 2004$)	2	9	19	35	na	na

Note: na = not available.

Environmental Benefits of the DOE Portfolio—HCC Scenario

	2015	2020	2025	2030	2040	2050
Avoided Carbon Emissions, Annual (MMTCE)	na	na	na	na	na	na
Avoided Carbon Emissions, Cumulative (MMTCE)	na	na	na	na	na	na
Reduced Cost of Criteria Pollutant Control, NPV (billion 2004$)	2	3	3	3	na	na
Reduced Cost of CO_2 Allowances, NPV (billion 2004$)	51	185	373	667	na	na

Note: na = not available.

Security Benefits of the DOE Portfolio—BAU Scenario

	2015	2020	2025	2030	2040	2050
Avoided Oil Imports, Annual (mbpd)	0.2	0.5	1.2	2.0	6.9	7.0
Avoided Oil Imports, Cumulative (billion barrels)	0.3	1.0	2.6	5.7	28.5	54.5
Reduction in Oil Intensity (percent)	1 %	3 %	5 %	9 %	na	na
Increase in Vehicle Miles Traveled per Gallon of Oil (percent)	0.5 %	1.3 %	2.7 %	5.2 %	139%	195%
Transportation Fuel Diversity Improvement (percent)	ns	ns	8 %	21 %	86%	45%

Note: ns = not significant. na = not available.

Security Benefits of the DOE Portfolio—HFP Scenario

	2015	2020	2025	2030	2040	2050
Avoided Oil Imports, Annual (mbpd)	0.2	0.5	1.0	1.8	7.8	6.0
Avoided Oil Imports, Cumulative (billion barrels)	0.2	0.9	2.2	4.9	32.0	57.4
Reduction in Oil Intensity (percent)	1 %	3 %	5 %	9 %	na	na
Increase in Vehicle Miles Traveled per Gallon of Oil (percent)	0.5 %	1.3 %	2.8 %	5.7 %	398%	498%
Transportation Fuel Diversity Improvement (percent)	ns	6 %	8 %	16 %	90%	48 %

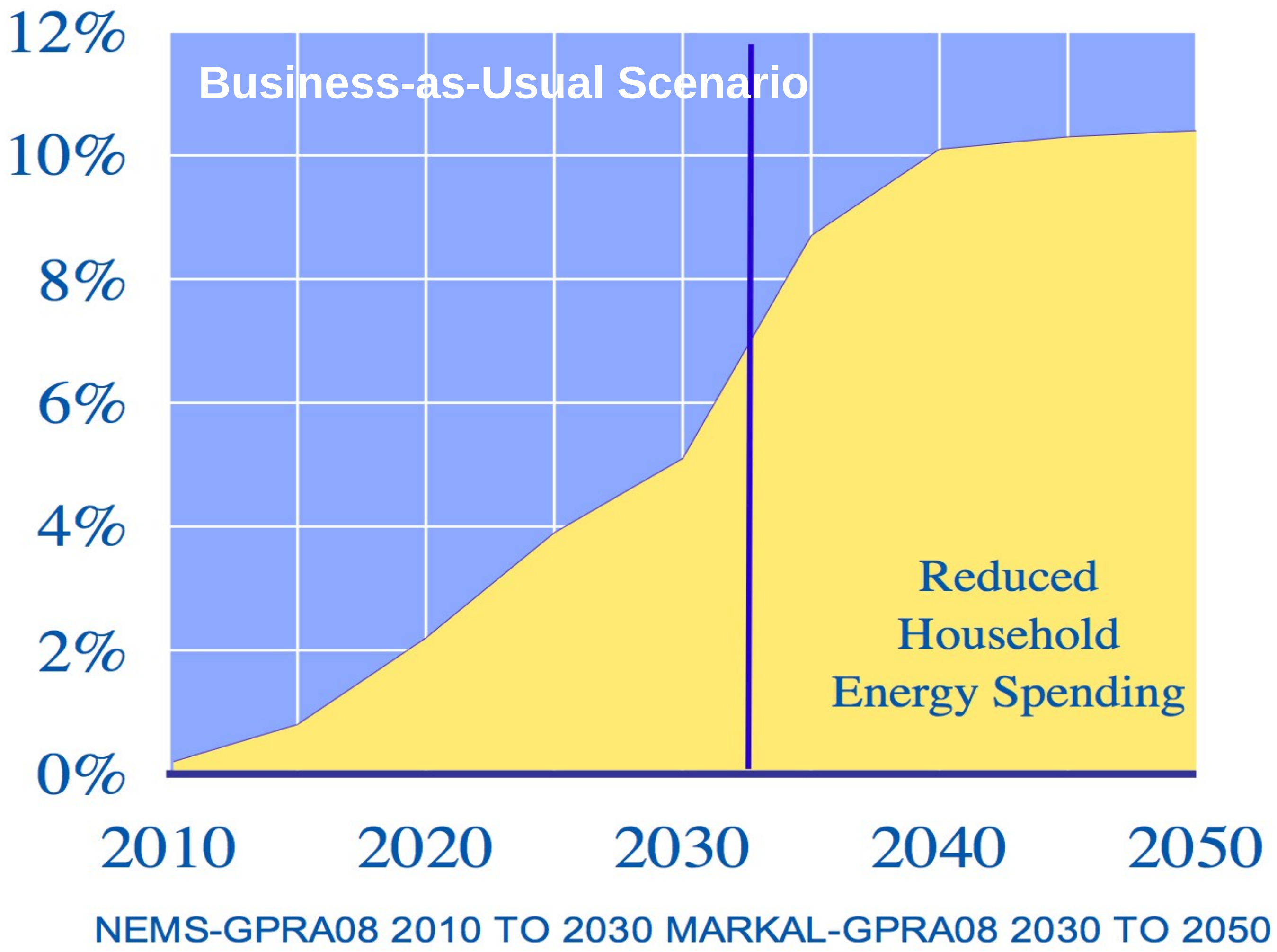
Note: ns = not significant. na = not available.

Security Benefits of the DOE Portfolio—HCC Scenario

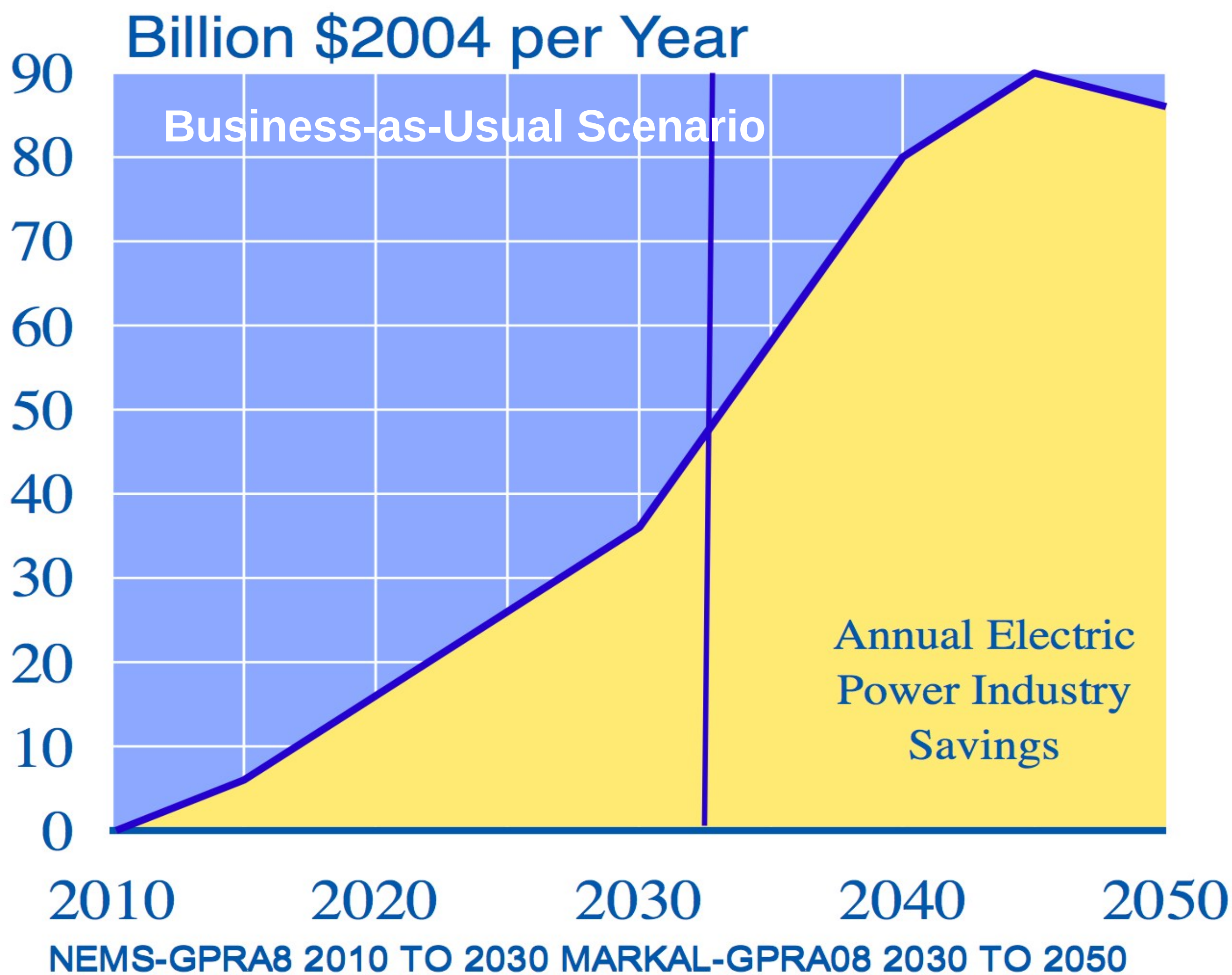
	2015	2020	2025	2030	2040	2050
Avoided Oil Imports, Annual (mbpd)	0.1	0.4	1.0	1.5	8.9	8.0
Avoided Oil Imports, Cumulative (billion barrels)	0.2	0.7	2.0	4.3	39.2	70.4
Reduction in Oil Intensity (percent)	1%	2%	5%	7%	na	na
Increase in Vehicle Miles Traveled per Gallon of Oil (percent)	0.5%	1.3%	2.6%	4.6%	245%	302%
Transportation Fuel Diversity Improvement (percent)	ns	ns	6%	16%	184%	113%

Note: ns = not significant. na = not available.

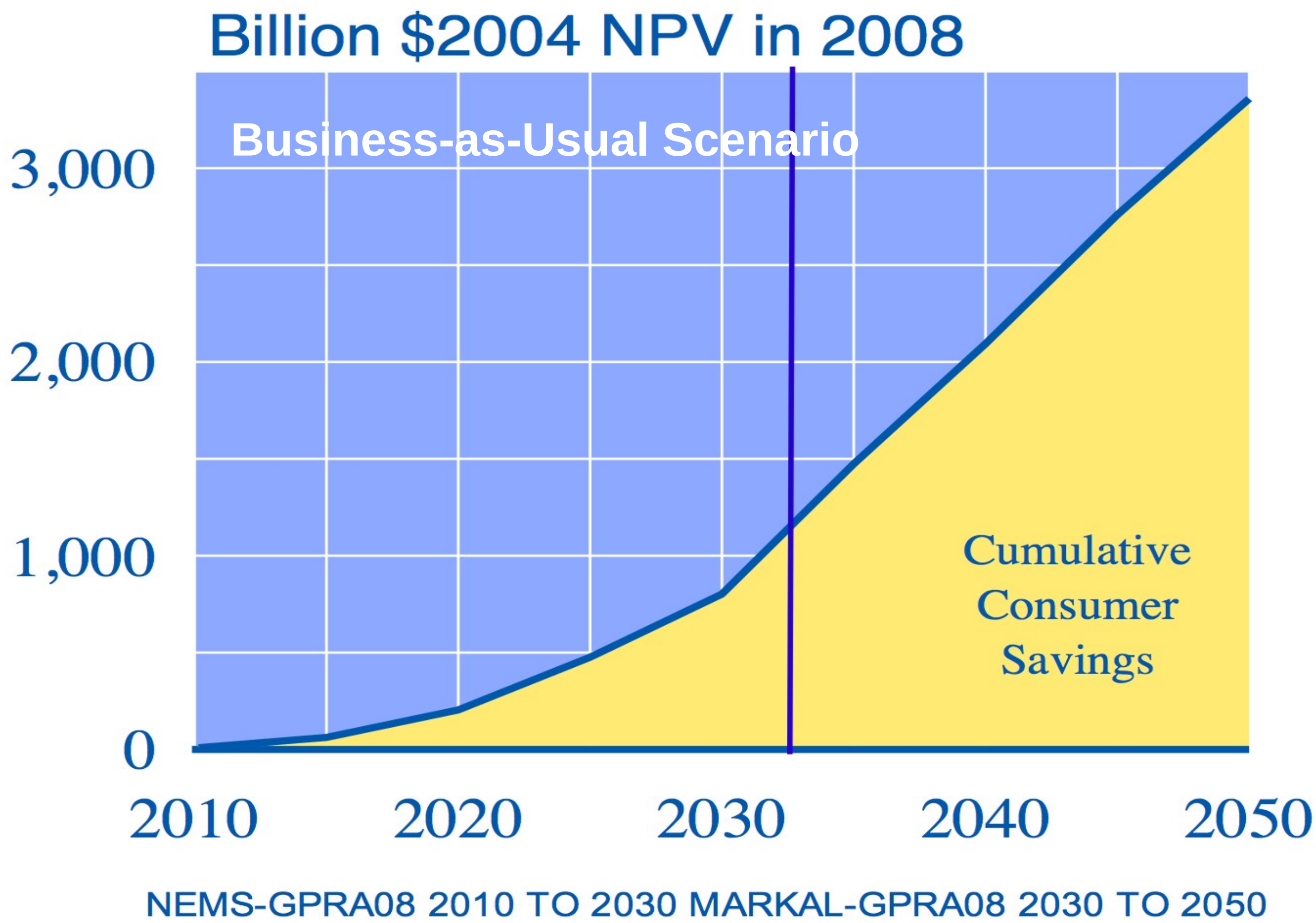
Economic Benefits:
Reduced Household Energy Spending



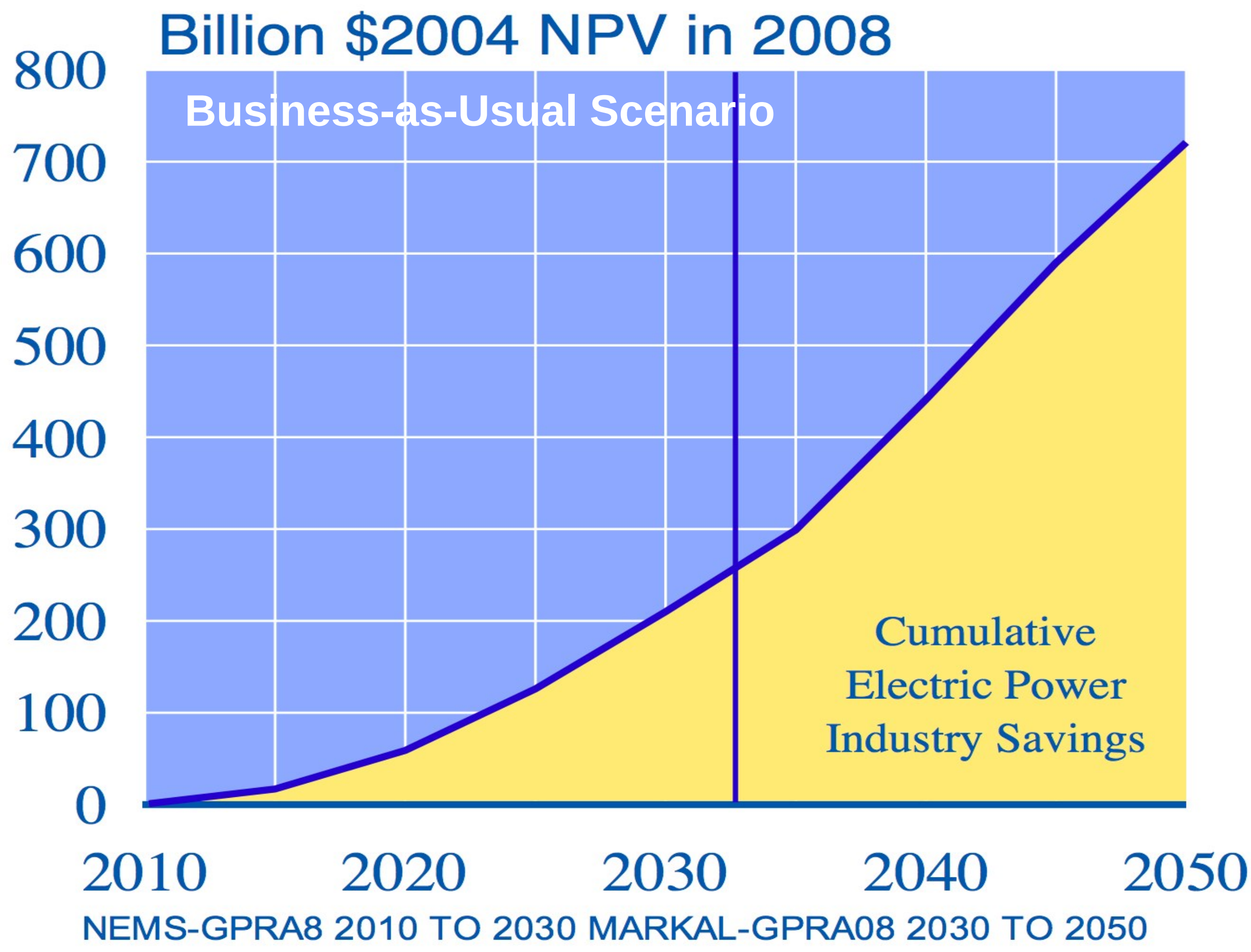
Economic Benefits:
Electric Power Industry Savings



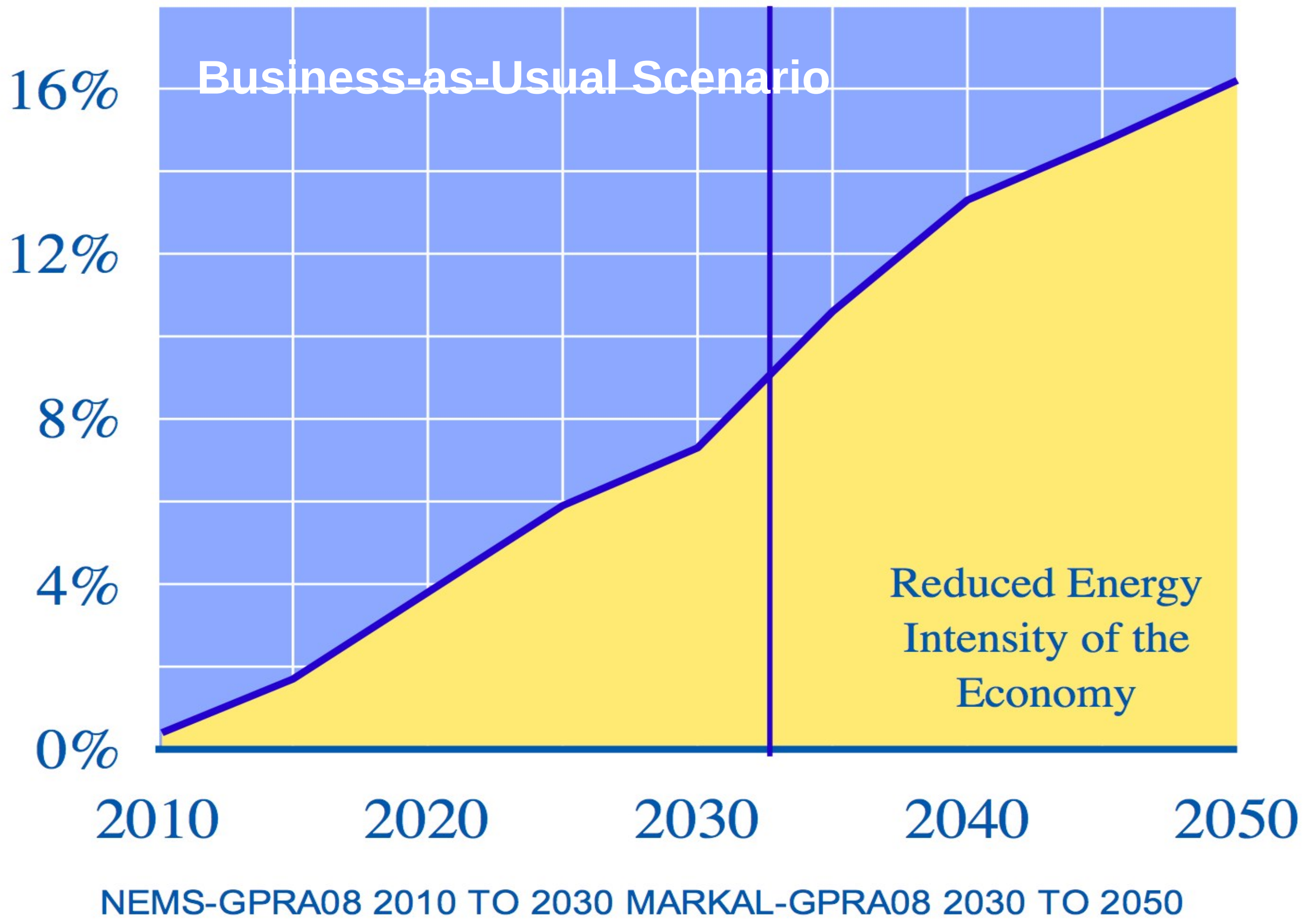
Economic Benefits: Consumer Savings



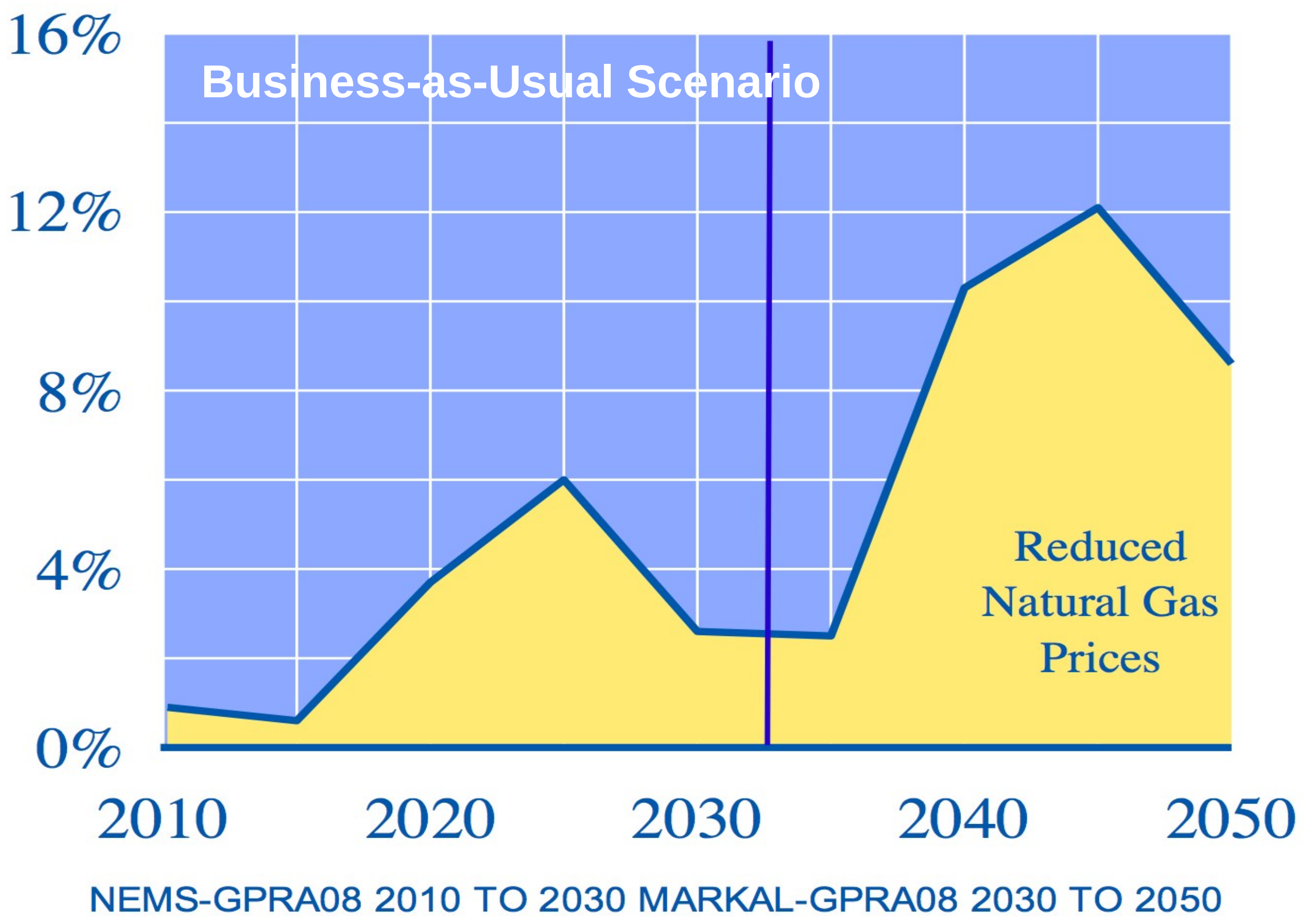
Economic Benefits: Electric Power Industry Savings



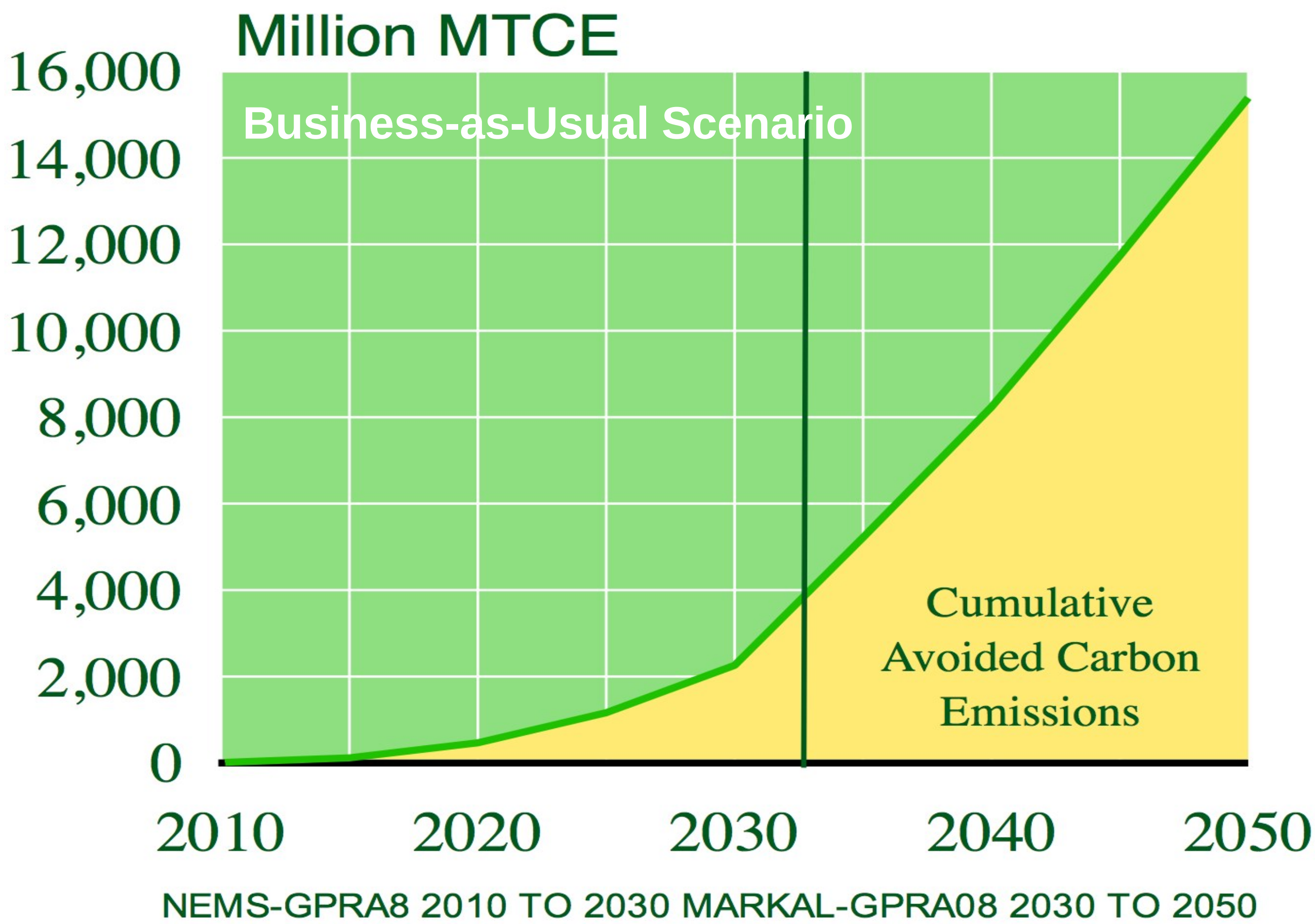
Economic Benefits: Energy Intensity of the Economy



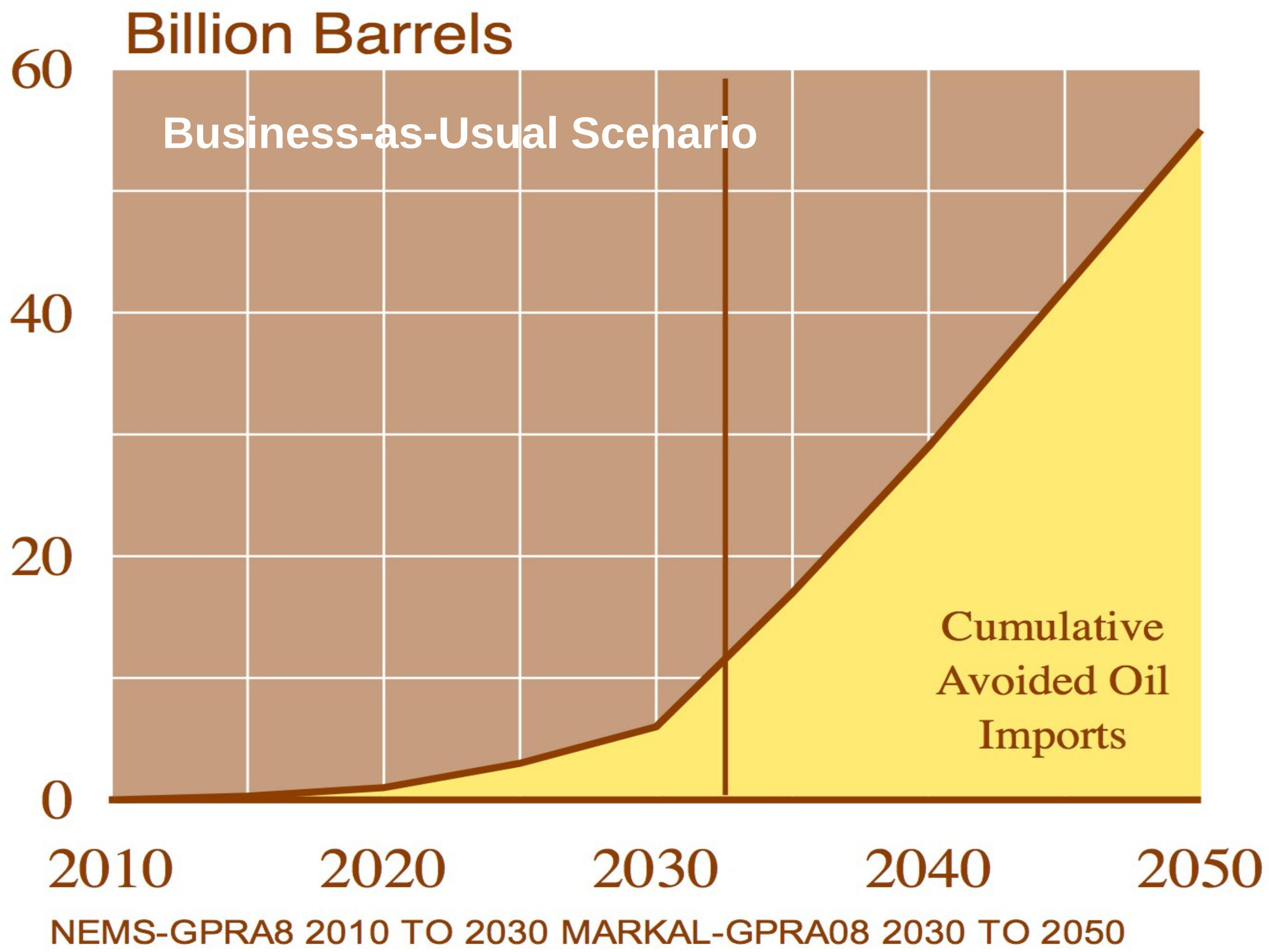
Economic Benefits: Reduced Natural Gas Prices



Environmental Benefits: Cumulative GHG Emissions



Security Benefits: Cumulative Avoided Oil Imports



Security Benefits: Security Fuel Economy