Investment in the Integrated Biorefinery: Research, Demonstration, Development and Deployment
(...and a whole lot of other stuff)

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IEA Task 38 Greenhouse Gas Emissions

IEA Biofuels & Bioenergy
Vancouver, Canada **25 August, 2009**

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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5 topics

- DOE Office of the Biomass Program
- Integrated Biorefineries
- Oak Ridge National Laboratory Bioenergy Program
- Landscape Design and Land use
- National Environmental Policy Act (NEPA)

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Biomass Program Mission

Develop and transform our renewable and abundant biomass resources into cost-competitive, high-performance biofuels, bioproducts, and biopower.

Focus on targeted research, development, and demonstration

- Support through public and private partnerships
- Deploy in integrated biorefineries

DOE Office of the Biomass Program Overview

- ***Program's Goals***
  - **Short Term:** Foster breakthrough technologies needed to make cellulosic ethanol cost competitive by 2012
  - **Mid Term:** Help create an environment conducive to maximizing the sustainable production of biofuels by 2017, including cost-effective technology, sufficient infrastructure, appropriate policies, and supportive consumers
  - **Long Term:** Increase the supply of renewable fuels to 36 billion gallons by 2022 - especially contributing to the 21 billion gallons of cellulosic and advanced biofuels (EISA, RFS)

Strategic Focus: Sustainable Biofuels

Feedstock Production → Feedstock Logistics → Biofuels Production → Biofuels Distribution → Biofuels End Use




- **Cellulosic Ethanol**: Historical focus of program.
- **Alternative Light-Duty and Diesel Replacement Fuels:** Expanded strategy includes advanced biofuels that require governmental support and can significantly contribute to meeting the RFS2. Update to *Multi-Year Plan* by December 2009.

2009 Program Priorities and Goals

Advancing Presidential Objectives

Science & Discovery

- Connecting basic and applied bioscience
- Conducting breakthrough R&D at universities and national labs:
  - Advances in enzymes and catalysis
  - Engineering of new microorganisms
  - Novel sustainability indicators

Clean, Secure Energy

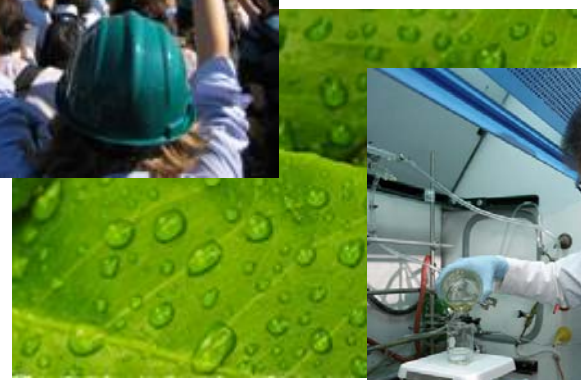
- Developing & demonstrating cellulosic and advanced biofuels to meet RFS

Economic Prosperity

- Creating 50 to 75 jobs per new biorefinery
- Creating major new energy crop markets
- Reinvigorating rural economies

Climate Change

- Reducing GHG emissions by up to 90% with advanced biofuels (compared to gasoline)
  - LCA/climate change models still being defined



Future Needs for Biofuels and Bioenergy

Technology Advances

- Diverse feedstocks in all regions
- Flexible, bio-powered conversion
  - Mix of biochemical (advanced enzymes), thermochemical (pyrolysis, gasification, etc.), and other conversion technologies
- Increased yields and efficiency
- Lower production costs
- Efficient logistics and deployment
- Modular systems to reduce capital costs

Other National Benefits

- Sustainable domestic energy
- Strong economic growth (new technology markets and jobs)
- Positive impact on climate and air quality

New & High-Yield Feedstocks

- **Energy crops**
- Wastes
- Algae

Advanced Biofuels

- Algal Based Biofuels
- Higher Alcohols
- Green Gasoline
- Renewable Diesel
- Renewable Jet Fuel Formulations

Value-added Bioproducts/Coproducts, and Biomass Power

Carbon Mitigation

- Potential role in future carbon legislation

Stimulate/Leverage Scientific Progress

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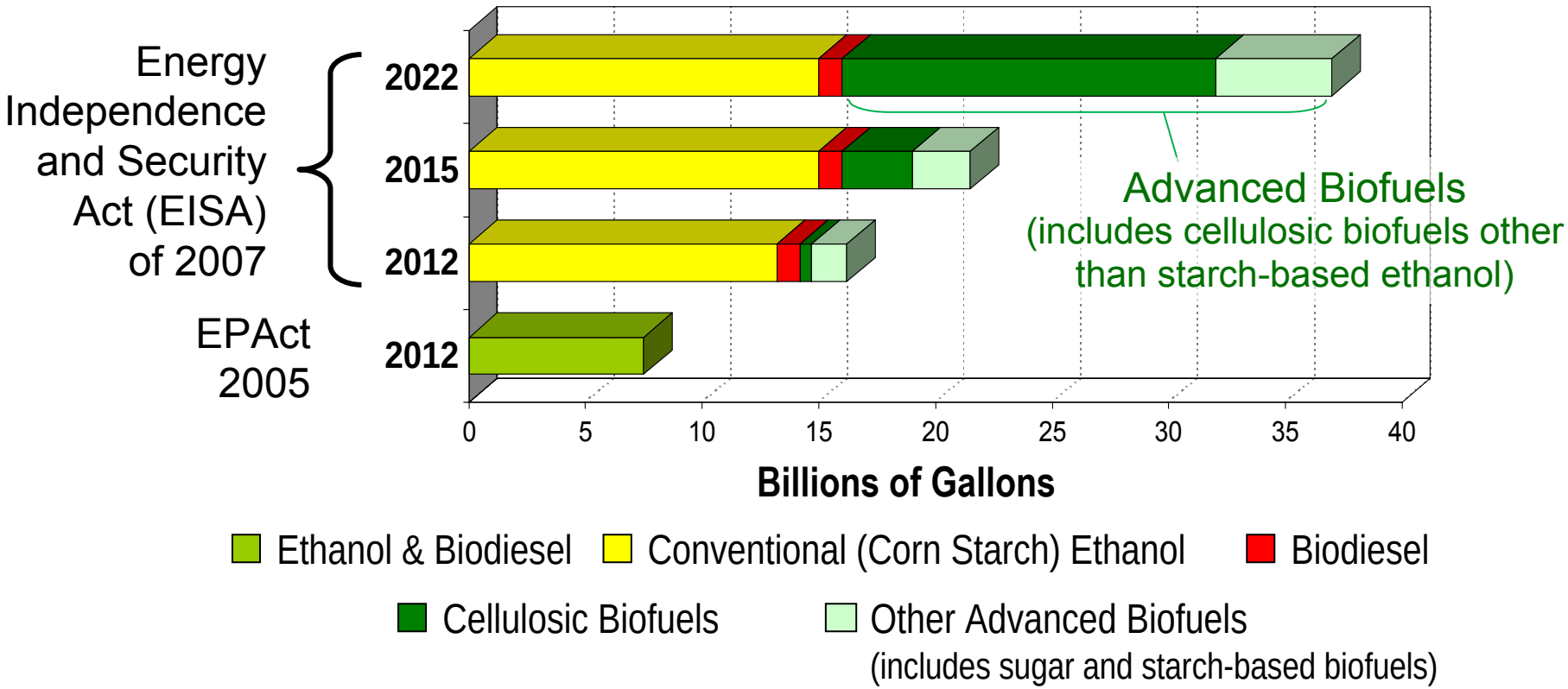
Overcoming Barriers to Commercial Use

Barriers	Solutions
• High cost of enzymatic conversion for cellulosic ethanol	• R&D to improve effectiveness and reduce costs of enzymatic conversion
• High cost of organisms for producing ethanol from complex sugars within cellulosic biomass	• R&D on advanced micro-organisms for fermentation of sugars
• Limitations of thermochemical conversion processes	• Re-establish thermochemical conversion as a path to success
• Demonstration/integration of technology in biorefineries	• Fund loan guarantees, commercial biorefinery demonstrations, 10% scale validation, and advanced biofuel projects
• Inadequate feedstock and distribution infrastructure	• Form interagency infrastructure and feedstock teams
• Sustainability issues	• Develop detailed LCAs, tools, and models to ensure sustainable production

Future efforts address obstacles to biochemical and thermochemical routes to biofuels, support demonstrations, and resolve infrastructure issues.

Legislative Mandates (Selected Years)



EISA defines ***Advanced Biofuel*** as "renewable fuel, other than ethanol derived from corn starch, that has lifecycle greenhouse gas emissions…that are *at least 50 percent less* than baseline lifecycle greenhouse gas emissions."

EPA issued GHG Notice of Proposed Rule Making on May 5, 2009.

Biomass Program Deployment Highlights

The response to the executive and legislative mandates includes

2005: EPACT

•Awarded $385 million via competitive solicitations for six full scale Integrated Biorefineries. **(4 currently in development)**

2007: EISA

Awarded $240 million via competitive solicitations for a total of nine small-scale biorefineries using range of feedstocks to test conversion technologies for the production of cellulosic biofuels **(8 currently in development)**

2008: FCEA

•Offering $200 million via competitive solicitations for pilot and demonstration-scale biorefineries to produce biofuels

- including algal feedstocks and the production of advanced biofuels such as bio-butanol and green gasoline. **(FOA revamped for recovery funds)**

2009: ARRA

•$480 Million Solicitation for Integrated Pilot- and Demonstration-Scale Biorefineries **($200 million FOA reissued)**

- $176.5 Million for Commercial-Scale Biorefinery Projects **(Enhancing Projects Awarded under EPAct 932(d))**

Solicitations: Leveraging Partnerships to Achieve Goals

Commercial-Scale Biorefineries (up to $272 million)

- Four cost-shared, integrated biorefinery demonstration projects to produce 130 million gallons of cellulosic ethanol in 5 years using variety of conversion technologies and cellulosic feedstocks

10%-Scale Biorefinery Validation (up to $210 million)

- Cost-shared, integrated biorefinery demonstrations using cellulosic feedstocks to produce renewable fuels; one-tenth of commercial scale
- Eight selectees announced for a total investment of $210 million

Ethanologen Solicitation (up to $23 million)

- Five selected research teams working on microorganisms

Enzyme Solicitation (up to $33.8 million)

- Four selected research teams working on inexpensive enzyme systems for commercial biomass hydrolysis

Thermochemical Solicitation (up to $16.7 million)

- Integration of gasification and catalyst development
- Pyrolysis oil stabilization

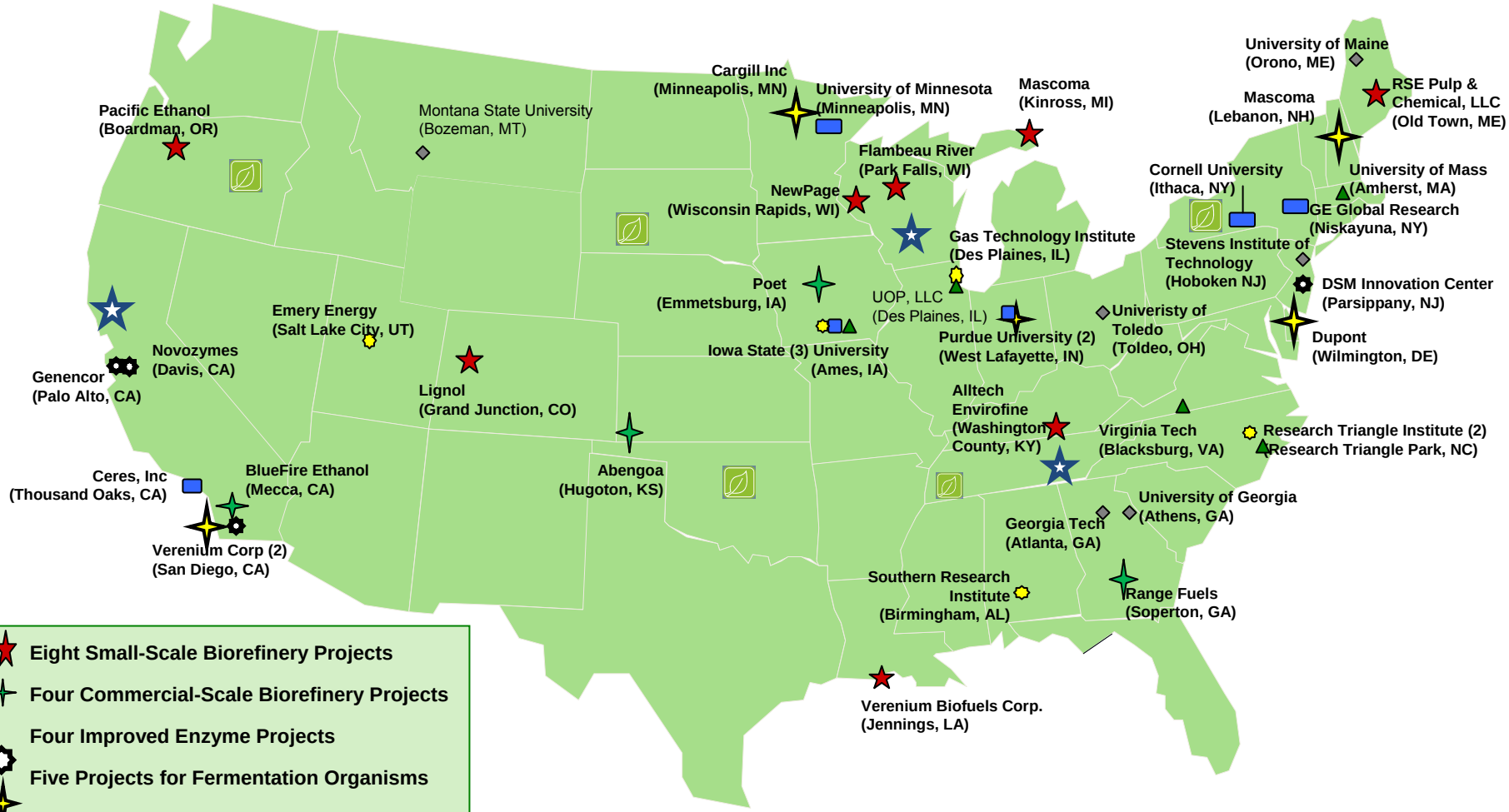
Joint DOE-USDA Solicitation ($5.2 million of $18 million funded by DOE)

- Biomass R&D Initiative: 20 awards announced March 2008

Current Solicitations

- **Integrated Demonstration / Pilot Scale Biorefinery**
- Annual USDA/DOE Joint Solicitation
- Feedstock Logistics Solicitation

Major DOE Biofuels Project Locations



- Eight Small-Scale Biorefinery Projects
- Four Commercial-Scale Biorefinery Projects
- Four Improved Enzyme Projects
- Five Projects for Fermentation Organisms
- Five Thermochemical Syngas Projects
- DOE Joint Solicitation Biomass Projects
- Five Thermochemical Bio-Oil Projects
- Six University Conversion Projects

Office of Science Bioenergy Centers

DOE Great Lakes, Madison, WI
DOE Joint Bioenergy Institute, Berkeley, CA
DOE Bioenergy Science Center, Oak Ridge, TN

Regional Partnerships

South Dakota State Univ., Brookings, SD
Cornell University, Ithaca, NY
Univ. of Tennessee, Knoxville, TN
Oklahoma State Univ., Stillwater, OK
Oregon State Univ., Corvallis, OR

EPACT Section 932 "Commercial-Scale" Biorefineries

DOE investments in cellulosic biofuels will accelerate commercialization and help create a biofuels market based on non-food feedstocks.

Performers	Feedstock Type	Conversion Technology	Location	Status
Bluefire	Sorted MSW	Biochemical- Concentrated Acid Hydrolysis	Mecca, CA	Lease and NEPA issues being resolved. Anticipate an Award 2 for construction in FY09.
Poet	Corn Cob Corn Fiber	Biochemical	Emmetsburg, IA	Award 2 TIA issued, engineering and construction in progress.
Range Fuels	**Woody Waste**	Gasification + Mixed Alcohol synthesis	Soperton, GA	Award 2 TIA issued, engineering and construction in progress.
Abengoa	Agricultural Residue	Biochemical	Hugoton, KS	NEPA EIS process initiated. Award 2 anticipated in FY09.

Demonstration-Scale Biorefineries Selected in FY08 Award One's Under Negotiation

Performers	Feedstock Type	Conversion Technology	Location
Alltech-Envirofine	Corn Cobs, Corn Fiber	Biochemical-Solid State Fermentation	Washington County, KY
Lignol Innovations	**Woody Biomass**	Biochemical-Organisolve	Grand Junction, CO
Mascoma	**Woody Biomass**	Biochemical	Upper Peninsula, MI
NewPage	**Woody Biomass - Mill Residue**	Thermochemical-Fischer-Tropsch	Wisconsin Rapids, WI
Pacific Ethanol	Wheat Straw, Stover, **Poplar Residuals**	Biochemical-Biogasol	Boardman, OR
RSE	**Woody Biomass - mill residues**	Biochemical-Pentose Extraction	Old Town, ME
Verenium Biofuels Corp.	Energy Cane and Bagasse	Biochemical Process	Jennings, LA
Flambeau River Biofuels LLC	**Forest residues and wood waste**	Thermochem to Fischer-Tropsch	Park Falls, WI

Major DOE Biorefinery Project Locations

Geographic, Feedstock, and Technology Diversity

Eight Small-Scale Biorefinery Projects

Four Commercial-Scale Biorefinery Projects

Modified 2/12/09

Integrated Demonstration Biorefineries

Topic Area Descriptions

Topic Area 1

- Operate an integrated **pilot-scale** biorefinery
- Feedstock – **Algae, lignocellulosic biomass**
- Primary Product **- Biofuel**
- Throughput of no less than one (1) dry tonne of feedstock per day.
- Legislative Authority – **EPAct 2005, Section 932**
- GHG Reduction requirements: No minimum but must provide analysis
- Ceiling for DOE funds - **$25,000,000** per award
- Cost Share – **20%** (special circumstances may apply)

Topic Area 2

- Operate an integrated **pilot-scale** biorefinery
- Feedstock – **Algae, lignocellulosic biomass**
- Primary Product **- Bioproduct**
- Throughput - no less than one (1) dry tonne of feedstock per day.
- Legislative Authority – **EPAct 2005, Section 932**
- GHG Reduction requirements: No minimum but must provide analysis
- Ceiling for DOE funds - **$25,000,000** per award
- Cost Share – **20%** (special circumstances may apply)

Integrated Demonstration Biorefineries

Topic Area Descriptions (continued)

Topic Area 3

- Design, Construct and Operate an integrated **demonstration-scale** biorefinery
- Feedstock – **Algae, lignocellulosic biomass**
- Primary Product **- Biofuel**
- Throughput - at least fifty (50) dry tonnes of feedstock per day
- Legislative Authority – **EPAct 2005, Section 932**
- GHG Reduction requirements: No minimum but must provide analysis
- Ceiling for DOE funds - **$50,000,000** per award
- Cost Share – **50%** (special circumstances may apply)

Topic Area 4

- Design, Construct and Operate an integrated **demonstration-scale** biorefinery
- Feedstock – **Algae, lignocellulosic biomass**
- Primary Product **- Bioproduct**
- Throughput - at least fifty (50) dry tonnes of feedstock per day
- Legislative Authority – **EPAct 2005, Section 932**
- GHG Reduction requirements: No minimum but must provide analysis
- Ceiling for DOE funds - **$50,000,000** per award
- Cost Share – **20%** (special circumstances may apply)

Integrated Demonstration Biorefineries

Topic Area Descriptions (continued)

Topic Area 5

- Operate an integrated **pilot-scale** biorefinery
- Feedstock – **Any renewable biomass feedstock except corn starch**
- Primary Product **- Biofuel**
- Throughput of no less than one (1) dry tonne of feedstock per day.
- Legislative Authority – **EISA 2007, Section 207**
- GHG Reduction requirements: **Minimum 80% reduction**
- Ceiling for DOE funds - **$25,000,000** per award
- Cost Share – **20%** (special circumstances may apply)

Topic Area 6

- Design, Construct and Operate an integrated **demonstration-scale** biorefinery
- Feedstock – **Any renewable biomass feedstock except corn starch**
- Primary Product **- Biofuel**
- Throughput - at least fifty (50) dry tonnes of feedstock per day
- Legislative Authority –**EISA 2007, Section 207**
- GHG Reduction requirements: **Minimum 80% reduction**
- Ceiling for DOE funds - **$50,000,000** per award
- Cost Share – **50%** (special circumstances may apply)

Information Resources

- Office of Biomass Program - http://www1.eere.energy.gov/biomass/
- EERE Info Center - www1.eere.energy.gov/informationcenter
- Alternative Fuels Data Center - http://www.eere.energy.gov/afdc/fuels/ethanol.html
- Bioenergy Feedstock Information Network - http://bioenergy.ornl.gov/
- Grant Solicitations - www.grants.gov
- Office of Science - http://www.er.doe.gov/
- Loan Guarantee Program Office - http://www.lgprogram.energy.gov

- DOE Office of the Biomass Program
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ORNL is DOE's largest science and energy laboratory

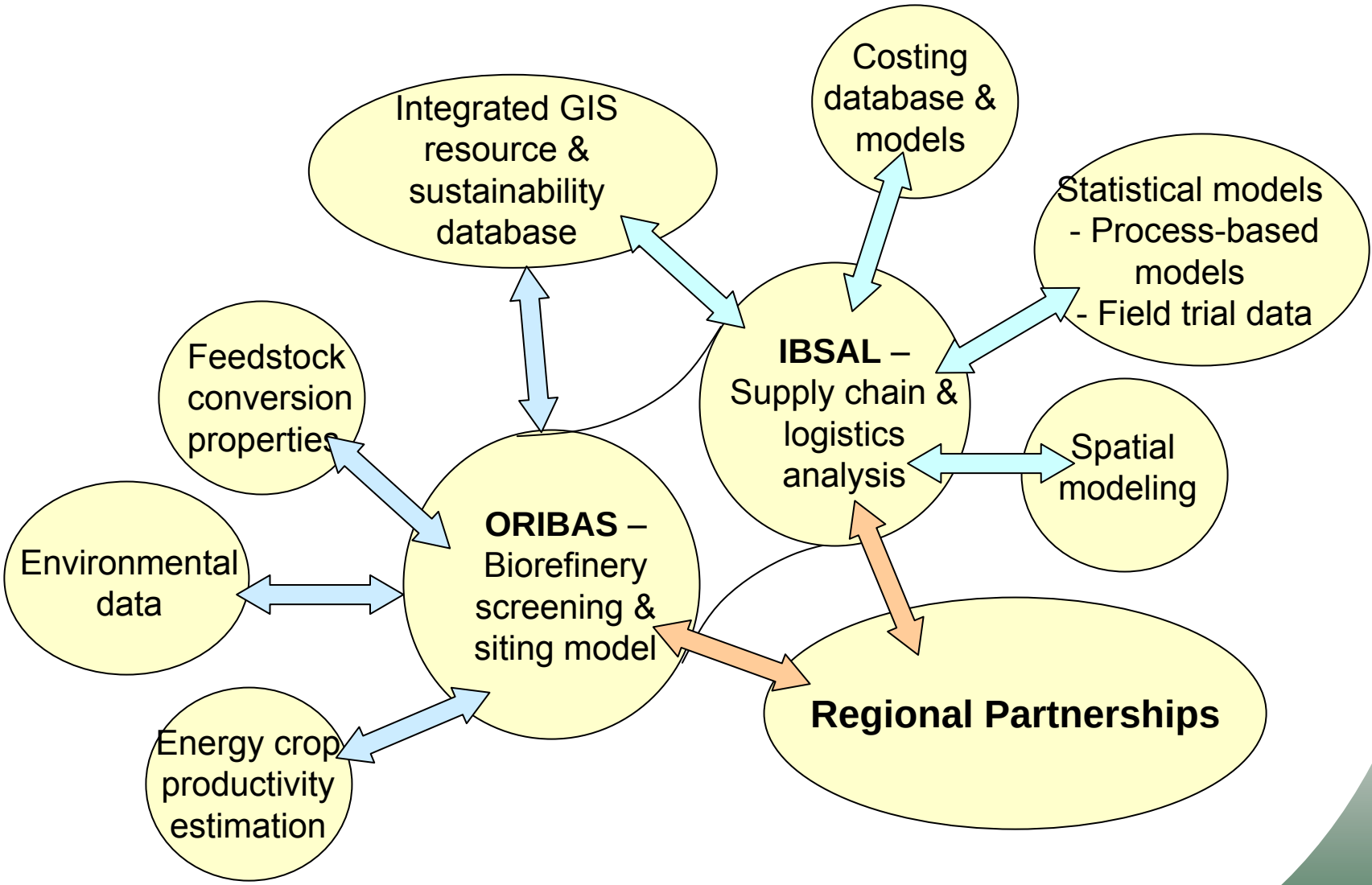
- **$1.3B budget**
- **4,300 employees**
- **3,900 research guests annually**
- **$350 million invested in modernization**

- **World's most powerful open scientific computing facility**
- **Nation's largest concentration of open source materials research**

- **Nation's most diverse energy portfolio**
- **Operating the world's most intense pulsed neutron source**
- **Managing the billion-dollar U.S. ITER project**

ORNL Bioenergy Program

- **Resource and Economic Analysis**
- **Feedstock Logistics and Engineering Modeling**
- **Environmental Effects Research**
- **International Resource Analysis and Environmental Effects Research**
- **GIS Data Management and Analysis**
- **NEPA support to DOE for the Integrated Biorefinery**
- **Support to DOE Office of the Biomass Program**
- **Support to Sun Grant/DOE Regional Feedstock Partnerships**



ORNL Bioenergy Program

- **Resource and Economic Analysis**
  - **Development of revised regional supply curves based on POLYSYS modeling, and other crop production estimates and costs**
  - **Leverage numerous spatially-explicit datasets (e.g., soils, land-cover, crop management) and remote-sensing data developed under projects funded by NASA, NOAA, and DOE/BER**
  - **Work with Regional Partnerships and Sun Grant to collect actual field data and develop standardization for data layers**

ORNL Bioenergy Program

- **Resource and Economic Analysis**

Needs and uses:

- **Estimate energy crop yields over space and time**
- **Estimate moisture content and amenability to wet and dry collection systems**
- **Biorefinery plant siting and logistics evaluation**
- **Monitor changes in soil carbon and greenhouse gas emissions**
- **Monitor ecosystem health and sustainability**

EISA 2007

- **Energy Independence and Security Act of 2007 requires increased biofuel production and additional funds to promote cellulosic and advanced biofuel production.**
- **The Renewable Fuel Standard (RFS) is going up from 7.5 billion gallons by 2012 to 36 billion by 2022. The minimum requirements of the new mandate must be from advanced biofuels, cellulosic biofuels, and biodiesel.**

ORNL Bioenergy Program

- **Feedstock Logistics and Engineering Modeling**
  - Regional logistical characteristics for stover collection and supply; development for other crops and cropping systems
  - Techno economic analysis of stover: An initial design for depot/regional center
  - Modeling of biomass wet storage processes & logistics
  - Cost data base and standardized costing procedure for analysis for BFIN website
  - Large scale production, harvest and transport of switchgrass - current technology and visioning a mature technology
  - Active coordination with Idaho National Laboratory

ORNL Bioenergy Program

- **Environmental Effects Research**
  - **Coordination and leadership for data collection protocols for Regional Feedstock Partnerships for hydrology, water quality, and soil carbon**
  - **Development of standard ecological indicators so qualitative and quantitative measures are consistent**
  - **Coordinating with International Analysis Task to provide consistency for standards measurements**

ORNL Bioenergy Program

- **Environmental Effects Research**
  - **Examining technology shifts that drive land-use changes**
  - **Identification of real vs. perceived environmental benefits and costs (increments and decrements)**
  - **What do we know about effects, and what do we need to know**

ORNL Bioenergy Program

- **International Resource Analysis and Environmental Effects Research**
  - **Provide consistent assessment of feedstock resources available and currently used by country**
  - **Provide assessment of ethanol potential for producing countries**
  - **Assess ethanol supply and demand scenarios for individual countries**

ORNL Bioenergy Program

- **International Resource and Environmental Effects Research**
  - **An overall goal is to assess the degree to which foreign supplies of biofuels could contribute to meeting future U.S. targets to reduce dependence on imported oil. Given limited time and resources, the first step involved a screening process to focus effort on priority countries using the following criteria related to future biofuel export potential:**
  - **Current feedstock and biofuel production**
  - **Export infrastructure**
  - **Processing capacity**
  - **Proximity to the U.S.**
  - **Forecast production potential**
  - **Need for more information**

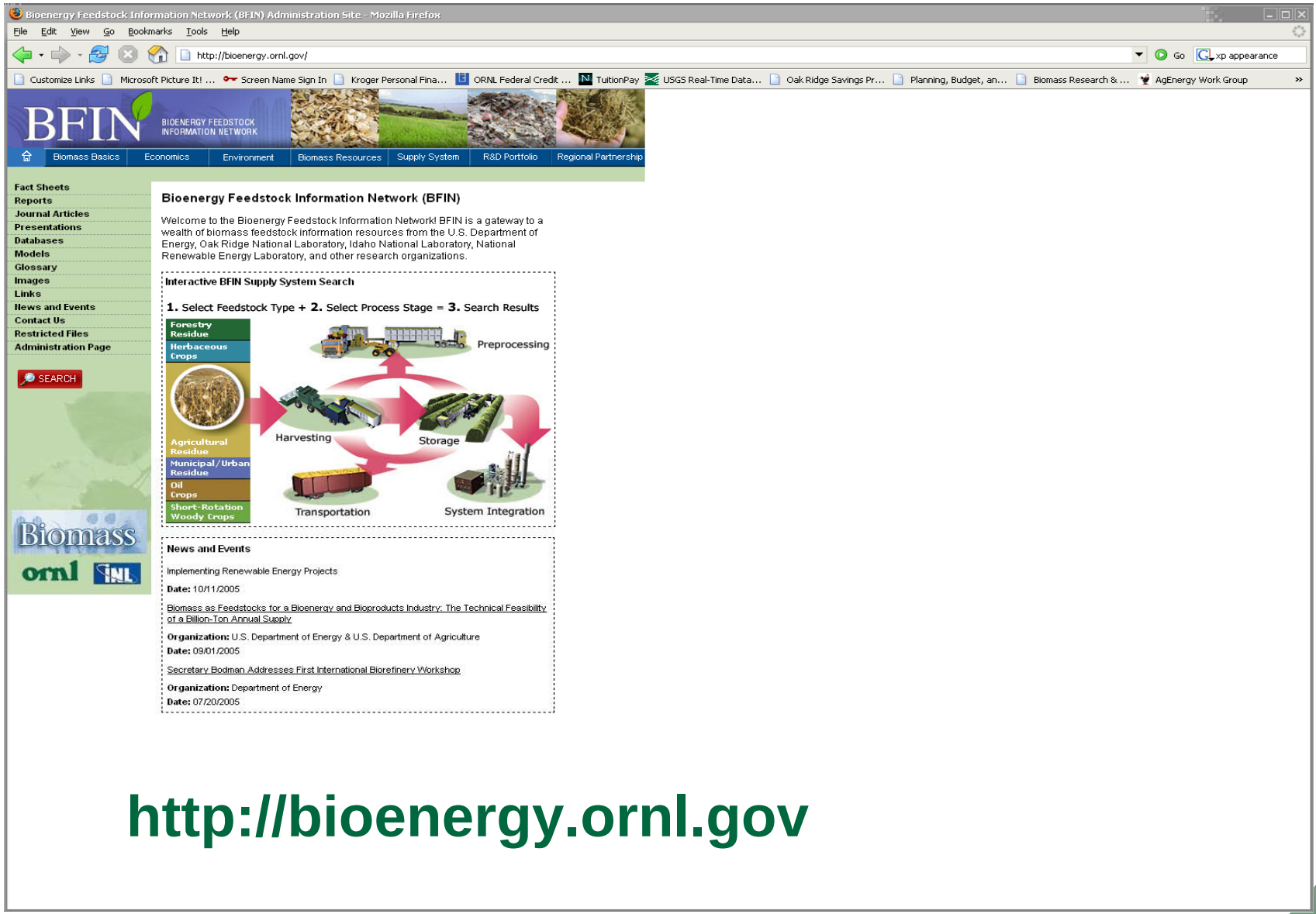
ORNL Bioenergy Program

- **GIS Data Management and Analysis**
  - **This task is in direct support to Regional Feedstock Partnership and other data management activities and links closely with the Resource Analysis Task**
  - **http://cdiac3.ornl.gov established for uploading data in the interim in preparation for development of the Knowledge Discovery Framework (KDF)**
  - **Integration with NASA as proof-of-concept for their agency through use of biomass cropping systems**

ORNL Bioenergy Program

- **NEPA support to DOE for the Integrated Biorefinery**

ORNL Bioenergy Program



http://bioenergy.ornl.gov

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The 4 F words

- **Food, Feed, Fiber, Fuel**
- **Agriculture and forestry cropping systems are endorsed by farm and forestry programs and policies**
- **Bioeconomics and systems for production or use of these for energy is not clearly defined (at a scale we are asking to have provided)**
- **Need to separate food and feed and fiber stocks from those used for energy**
- **Lignocellulosic cropping systems will assist us in developing enhanced support programs and policies which would enjoy similar benefits as agriculture and forestry**

Point of singular benefit

(simplistic linear thinking) Downing, drivel not published in 2009

- **Instead of: Max Σ(π(a…n)**

  subject to: Σ min α…ß

Where: π is profit or net revenue

a…n are the individual energy crops produced

α…ß are factor costs of inputs

System of multiple benefits

(maximizing a submodular function set subject to a matroid constraint)

Calinescu, et al. 2007

We propose: Max $\Sigma(\alpha \ldots \eta)^t$

subject to: Σ minimum level π

Σ minimum $\alpha \ldots \beta$

Σ minimum y

Where: $(\alpha \ldots \eta)^t$ is a series of quantifiable environmental amenities or ecosystem services received over time t

π is profit or net revenue as a floor

$\alpha \ldots \beta$ are input factor and costs of production

y is a minimum yield permissible (floor)

Baseline measurements

- **Necessary because we want to measure the deviation from the current state of the world (at some relevant scale and in some relevant region)**
- **Need more extensive measures than we may have experienced (four dimensional)**
- **Need to be measured intensively (lots of observations with lots of variability)**
- **Need long term reporting for perennial cropping systems (not just each year)**
- **Need to probably decide what to measure…and at what scale… (what is really important and to whom?)**

Increments and decrements

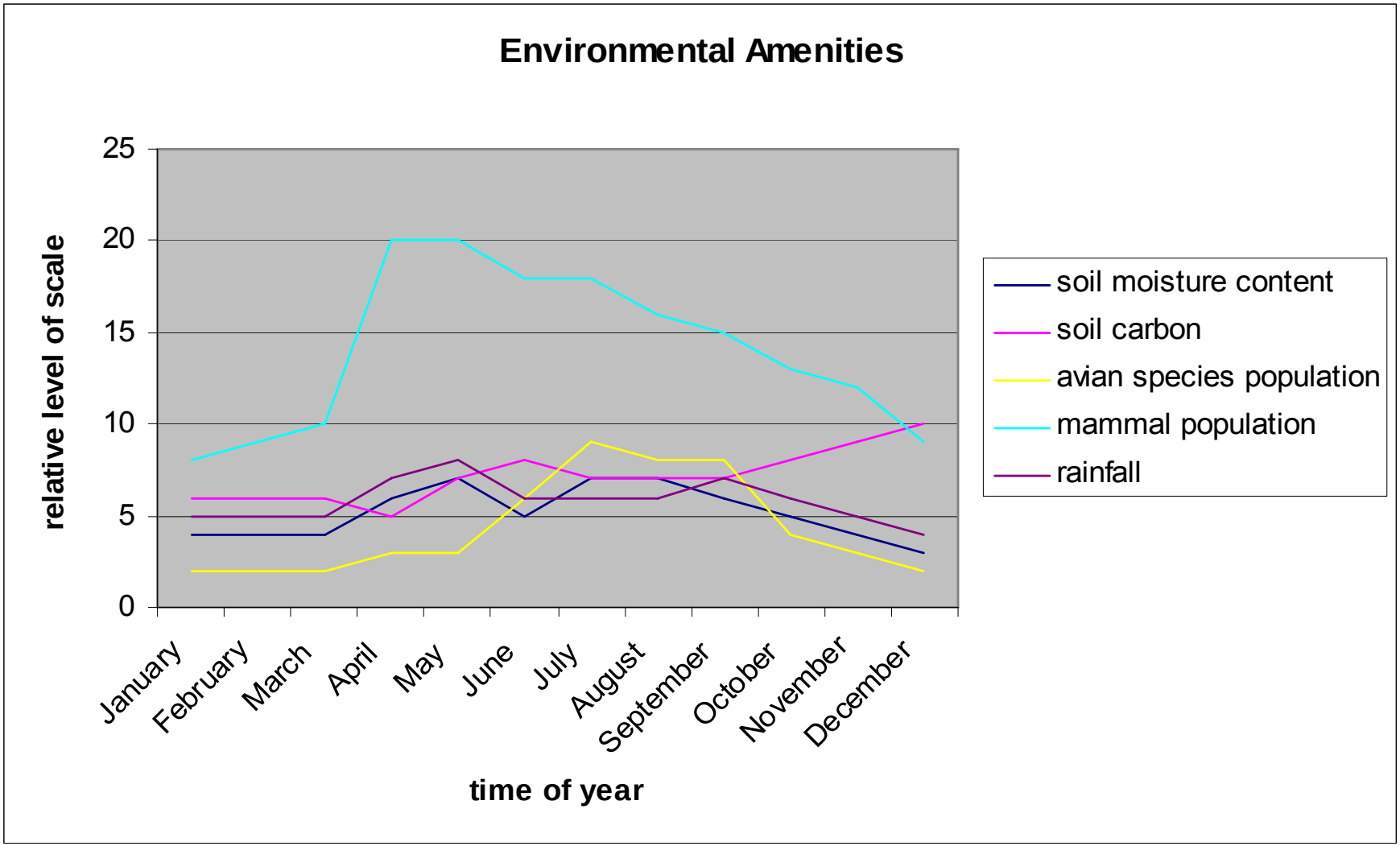
- **We will be assuming some change but we don't know the direction of that change**
- **Previous literature and research indicative of suggested scenarios of perennial cropping systems of herbaceous grasses that are native, non-irrigated, and familiar to farmer-producers**
- **Assumption: we will be experiencing something more generally environmentally favorable than annual row-cropping systems, but less environmentally favorable than natural forest systems**

Magnitude and quantification of the change

- **This is as simple as suggesting that quantifying the changes may be indicative that there are either minor or major implications on the overall ecological and environmental health of a region as a result of the magnitude of the environmental increment or decrement**
- **These implications should be set in a risk sensitivity analysis framework**
- **We need to answer the question about how far we are actually moving the needle (are we simply inserting "blips" on a screen)**
- **Example: we cannot risk the loss of production, nor sacrifice of net revenues, but we need to know how close we are to the edge of world before we fall off!**

Relative changes over time

(dynamic modeling of environmental amenities inter-temporally, and inter- and intra-regionally)



According to the previous graph:

- **Are we sacrificing one amenity for another at a given time of year?**
- **Is this really a system of dynamic trade-offs?**
- **Should we be disturbed about Jan and Dec?**
- **Which amenity interacts and contributes to the increase in another amenity?**
- **Do the monetary values matter, or does the Σ of environmental amenities really matter?**
- **Did we assume that the 5 indicators in the previous slide are REALLY indicators? Or are they the RESULT of some action (or lack thereof) that we should have taken or should not have taken?**

Valuation of environmental amenities

- **Controversial concept**
- **Still no solution for damage and payment estimates**
- **No method of enforcement**
- **Complex system of property rights presents difficulties in policy solutions based on private and public goods, and private and public property assumptions**
- **Non-transferable across amenities or regions, nor over time**
- **Great as an understanding of relative values given our ability to estimate willingness-to-pay (amenities), or willingness-to-accept (decrements)**

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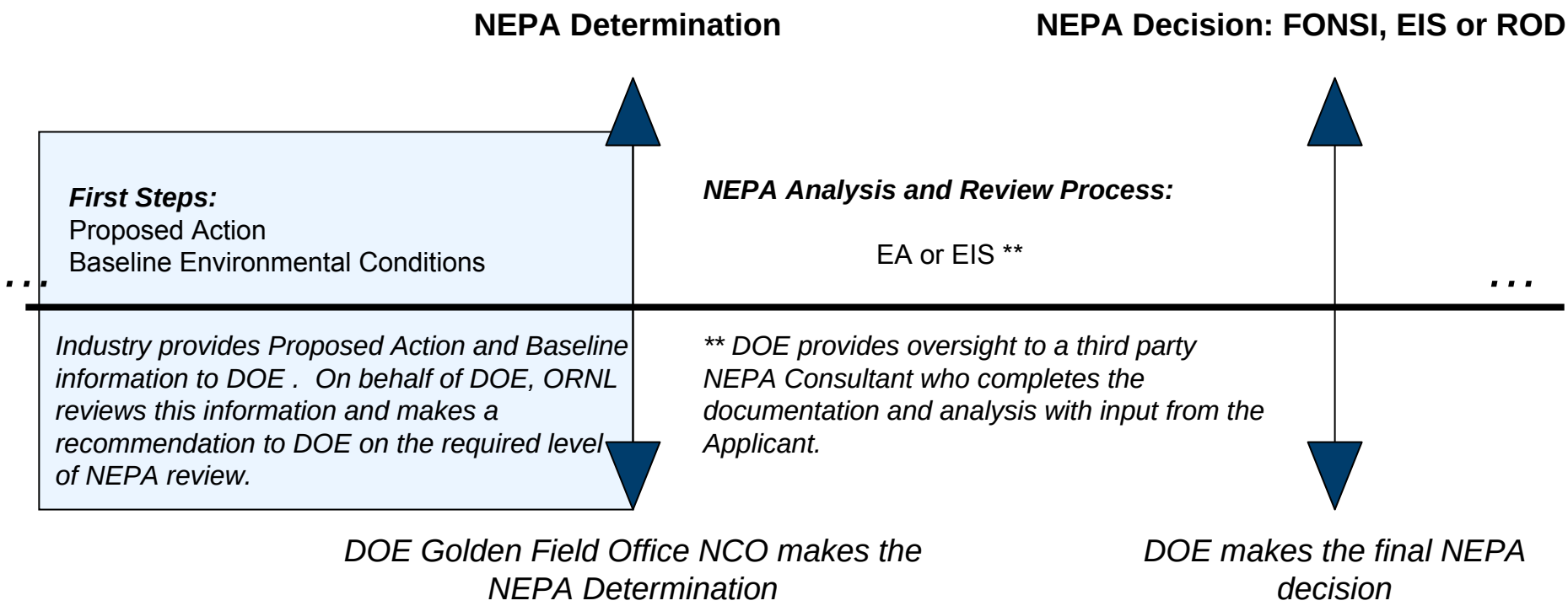
NEPA Determination: Process Overview

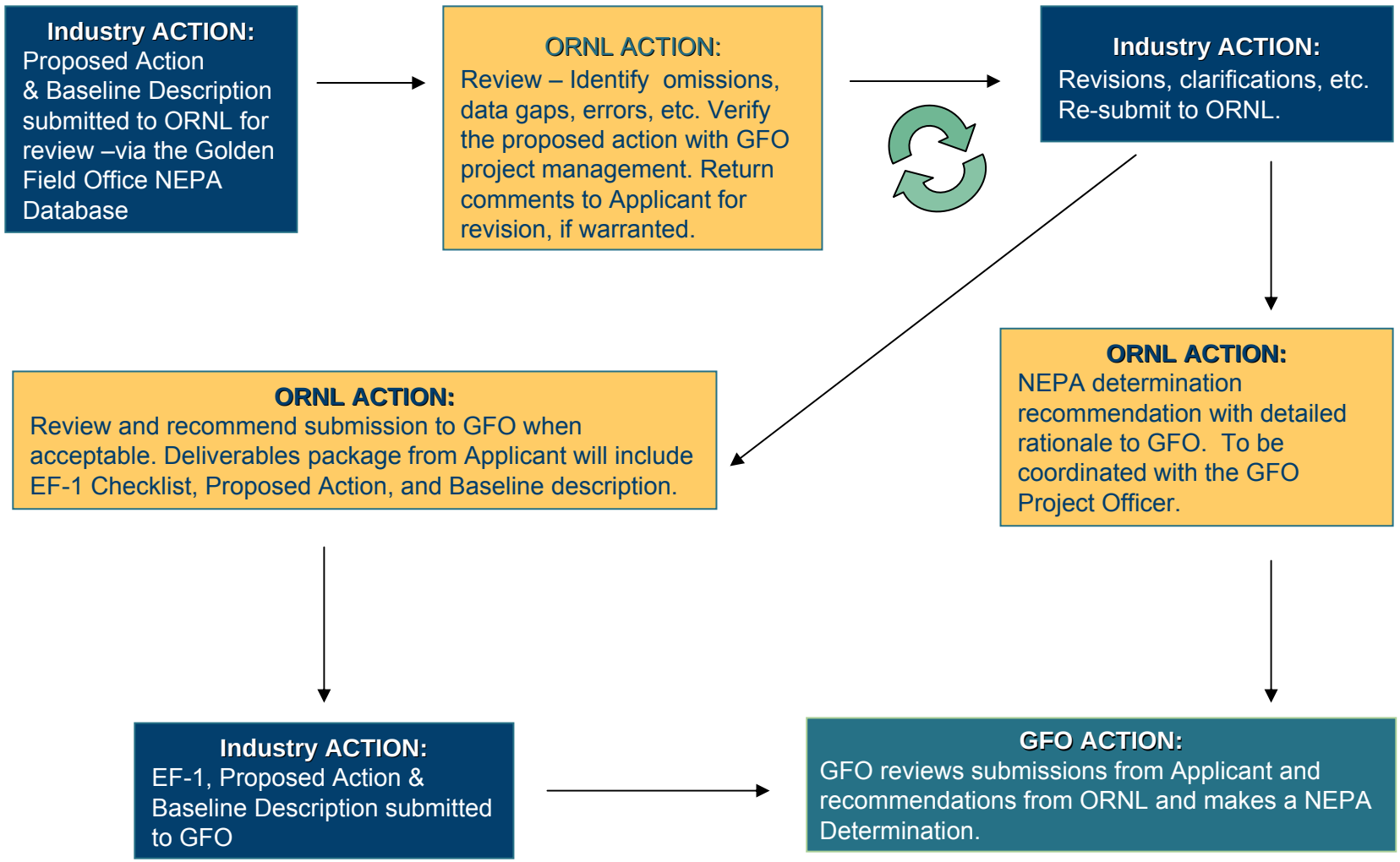
Award II EF-1 and Associated Documentation

Update from Industries

NEPA Process Overview



NEPA Determination Process Overview



Award II EF-1 Environmental Checklist

The Award II EF-1 will be submitted to the online NEPA Database.
The EF-1 for Award II should include the following information:

Proposed Action Elements

- Construction
- Operations
- Material Balance (including input, output, and waste)
- Logistics (transportation of input and output, including waste and required utilities, etc.)
- Visual Representation
- Major Plant Components
- Process Description

Baseline Data

- Location
- Aerial Photos
- General Physical Characteristics
- Air Quality and Meteorology
- Geology and Soils
- Biological Resources
- Water Resources
- Waste Management
- Infrastructure
- Cultural Resources
- Land Use
- Noise
- Aesthetics
- Socioeconomic
- Traffic
- Odor

Thank you – and for more information:

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http://www1.eere.energy.gov/biomass/program_areas.html

http://bioenergy.ornl.gov

www.sungrant.org