

Changing the Game?

Industry and Macro Implications of New Natural Gas Supplies

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Roadmap

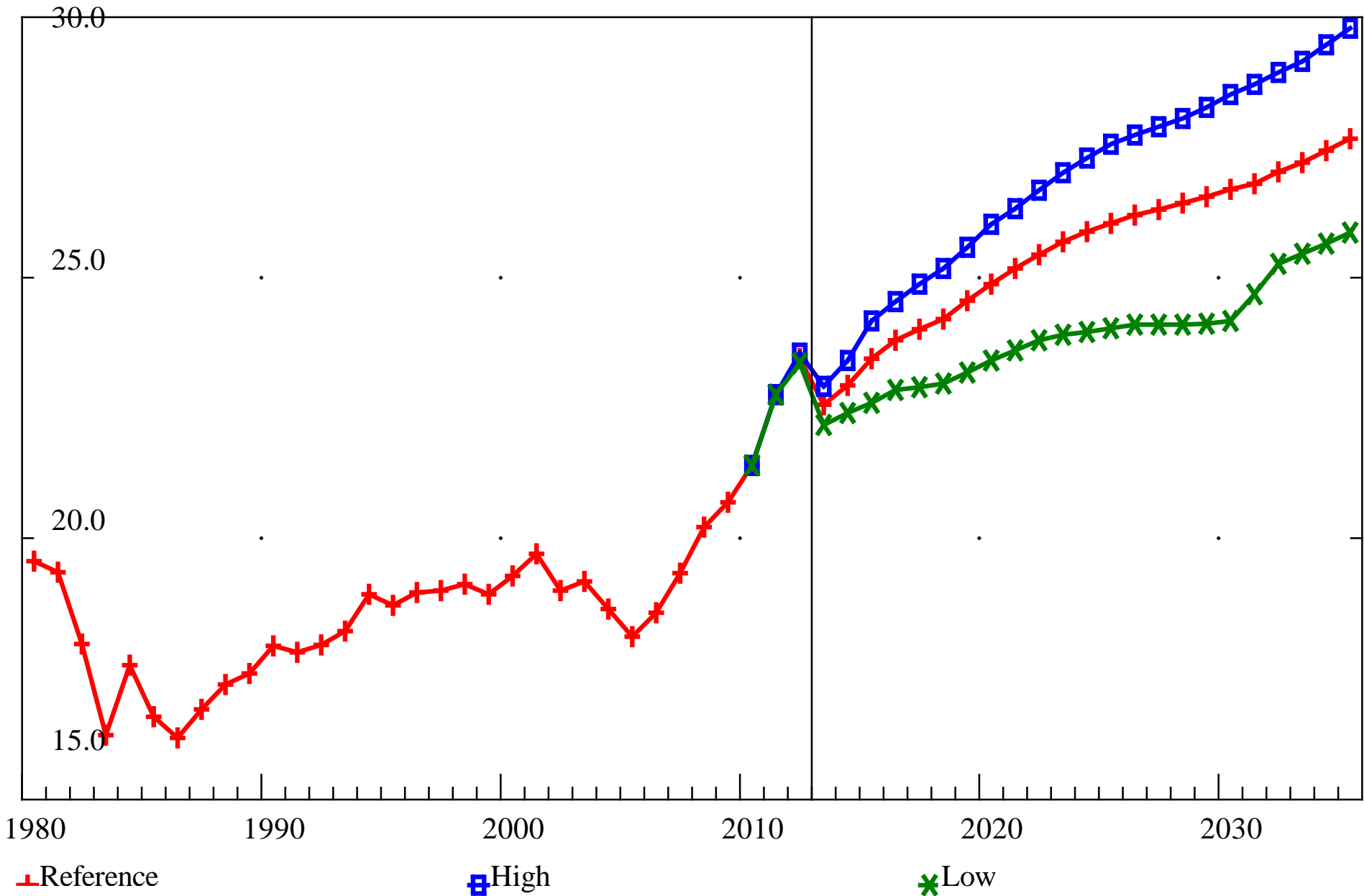
- ▣ The Shale Gas Revolution
- ▣ Energy Modeling Forum 26
- ▣ LIFT + MARKAL
- ▣ Overview of Scenarios
- ▣ Advanced Demand Scenario
- ▣ Scenario Comparisons – Highlights
- ▣ Summary and Main Conclusions

The Shale Gas Revolution

- Horizontal drilling and hydraulic fracturing have greatly increased the estimates of economical gas formations.
- US shale “plays” are extensive, but the estimates of economically recoverable reserves vary widely.
(AEO2012: shale resources = 542 trillion cubic feet, with total US resources = 2203 tcf)
- International resources in China, Brazil and Central Asia also look promising, but await the application of the new technologies.
- Environmental and other constraints add to the uncertainties in supply.

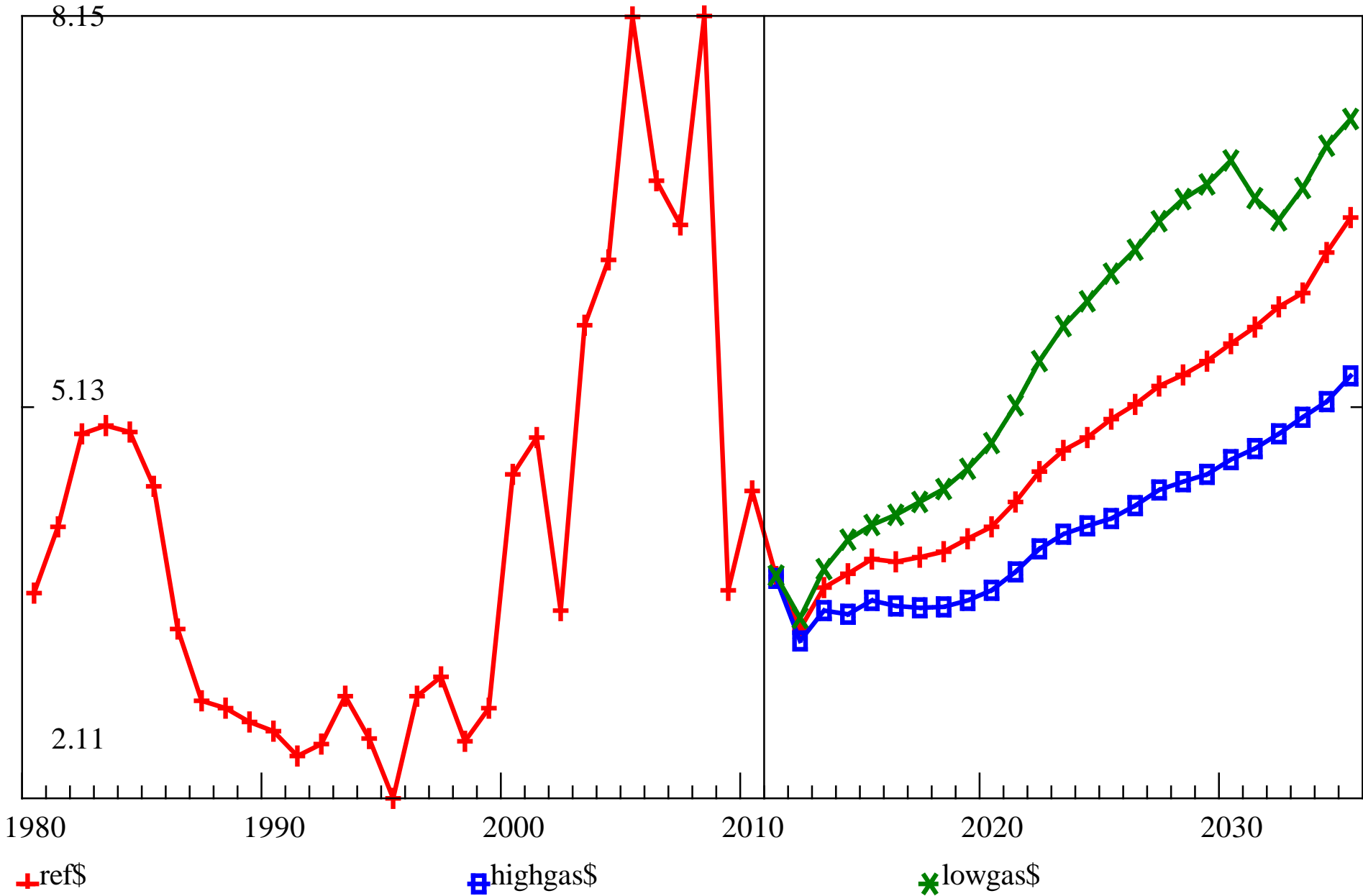
Natural Gas Production: EIA History and Projections

Trillion Cubic Feet



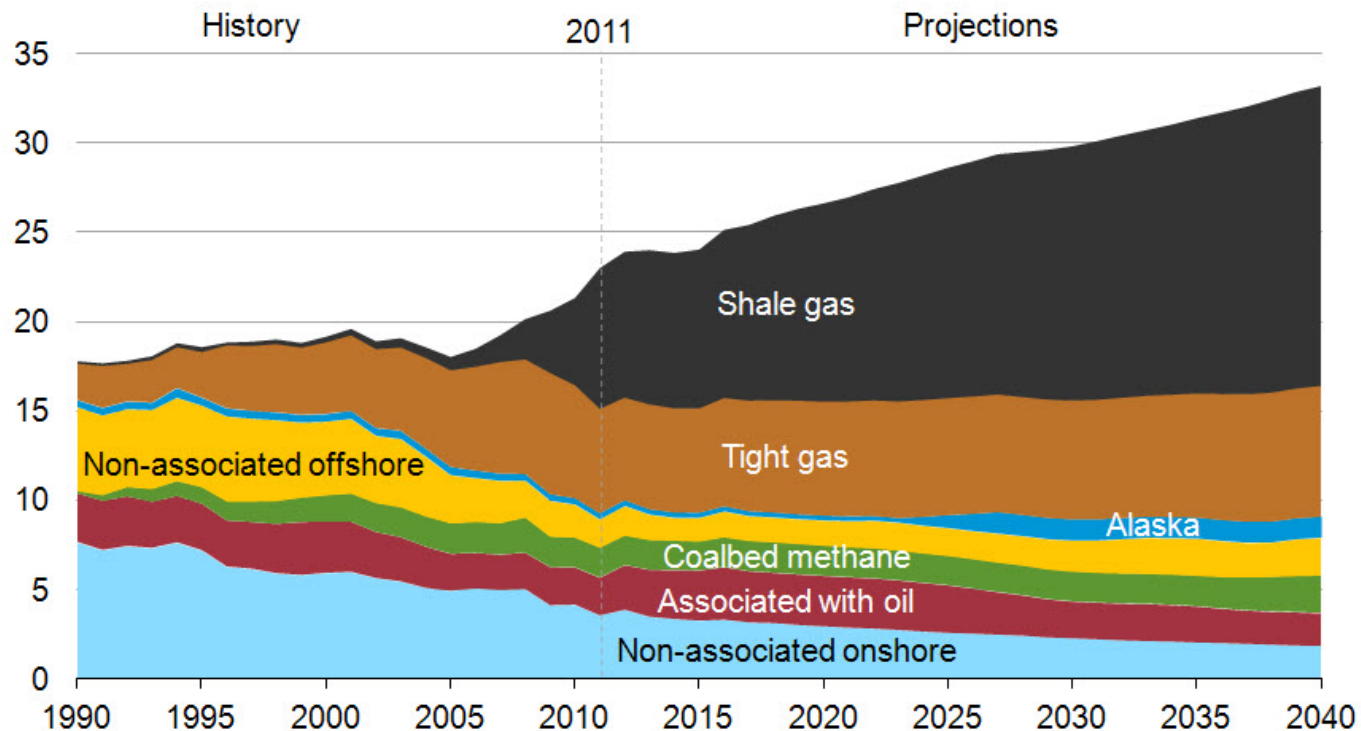
Natural Gas Price: EIA History and Projections

2010\$/thousand cu. ft.



AEO 2013 Gas: History and Projections

U.S. dry natural gas production
trillion cubic feet



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2013 Early Release*

Energy Modeling Forum (EMF) 26

- EMF (emf.stanford.edu) is an ad-hoc working group, organized to examine a single energy topic, to which many existing models can be applied.
- EMF 26 seeks to understand the market implications of the new natural gas supplies, primarily shale gas.
- The study brings together about a dozen models to investigate up to 9 alternative scenarios, including a reference case, similar to AEO 2012.
- EMF 26 scenarios include: Reference, High Shale Supply, Low Shale Supply, High GDP Growth, Advanced Demand, High Supply/High GDP Growth, Carbon Constraint, High Shale/Carbon Constraint, and High Exports.

LIFT/MARKAL Modeling Team

- ▣ Mitre and Inforum have collaborated in EMF 25 and EMF26 using the Inforum LIFT and EPA MARKAL model.
- ▣ Both LIFT and MARKAL have been calibrated to have a reference case based on the AEO 2012.
- ▣ For various alternative scenarios involving changes in supply, in macroeconomic growth or in technology, both models are integrated or coupled, as described below.

Modeling Approach: LIFT

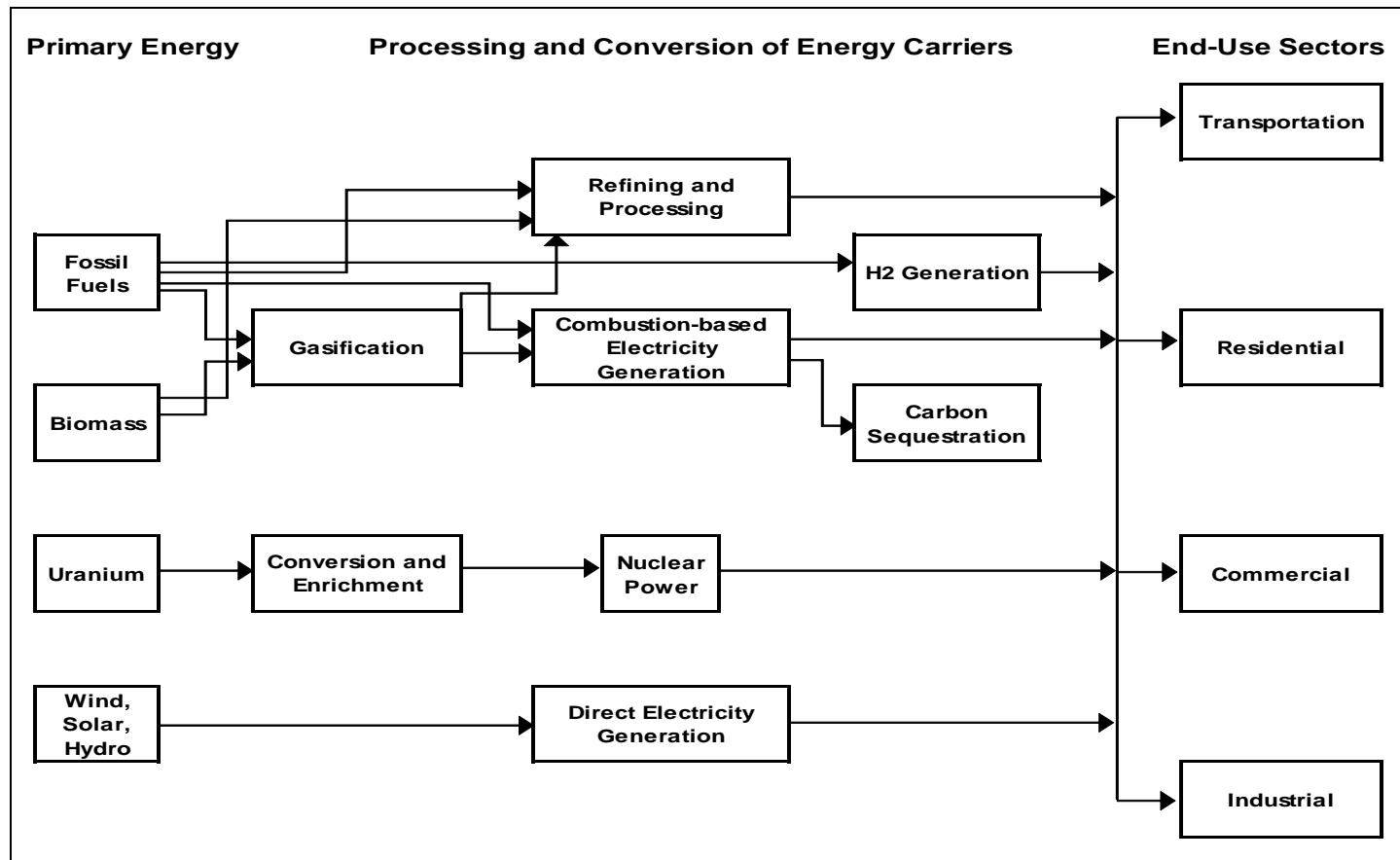
- LIFT: Large-scale model of the U.S. Economy with input-output core that builds macroeconomic forecasts from sector level data
- Key parameters informed by Annual Energy Outlook 2012 or MARKAL
 - ▣ Energy prices
 - ▣ Energy IO coefficients that determine the type and amount of energy used in the producing sectors
- LIFT endogenously determines
 - ▣ Consumer demand for 92 goods & services based on prices and incomes
 - ▣ Export/Import levels based on relative prices
- Economy wide energy use is then derived from consumer demand, government demand, imports, exports, and the interactions between the producing sectors (which include 8 energy supply sectors)

Modeling Approach: MARKAL (1/2)

- MARKAL (MARKet ALlocation) developed in the late 1970's by international teams at Brookhaven National Laboratory and Kernforschungsanlage-Juelich and sponsored by DOE and the International Energy Agency (IEA)
- Bottom-up energy technology and systems model
 - Models specific energy flows and detailed energy technologies
- Determines lowest cost technology, infrastructure, and energy mix meeting energy service demands (sq. ft. heated, sq. ft. lighted, vehicle miles, etc.)
 - Outputs include technology mix, use of energy carriers, emissions, and estimates of marginal energy prices
- For this study we use a database developed by the U.S. EPA's Office of Research and Development

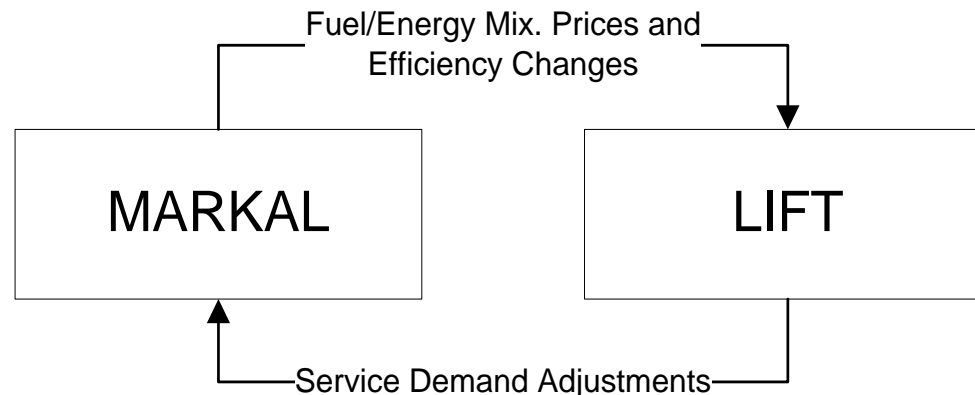
Modeling Approach: MARKAL (2/2)

- The MARKAL Modeling Framework: The Reference Energy System



MARKAL+LIFT

- MARKAL is initiated with resource supply curves, technology cost & performance, energy service demands, and constraints
- MARKAL determines mix of energy carriers (fuels) used and the efficiency with which they are used, for electric power, residential, commercial, industrial and transportation sectors
- MARKAL provides these assumptions to the LIFT model.
- LIFT provides MARKAL service demands, based on macroeconomic and industry projections.



Selected EMF Scenarios

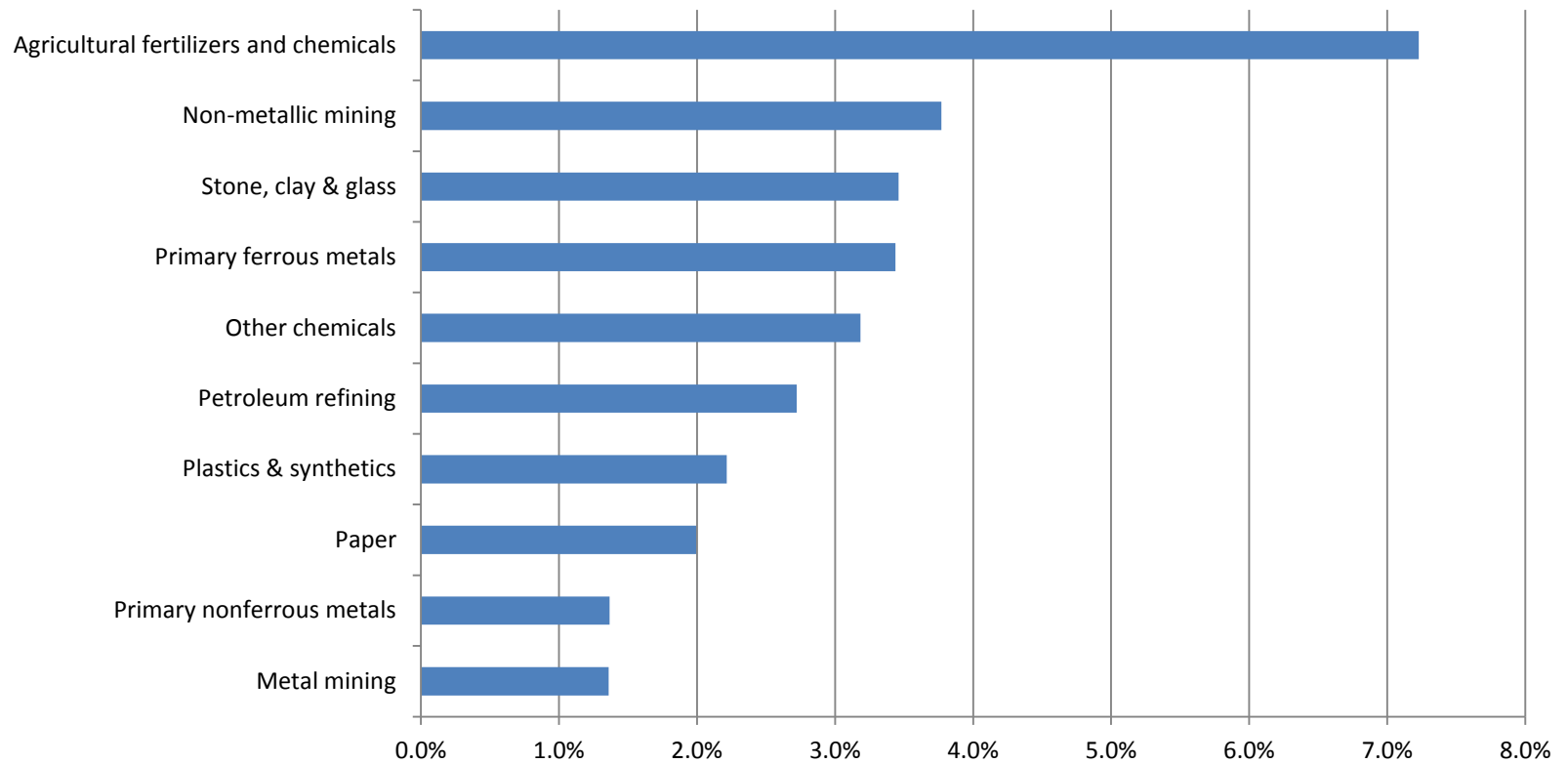
- ▣ **Reference Case** – LIFT and MARKAL calibrated to the AEO 2012 Reference, 2.6% annual GDP growth.
- ▣ **High Shale Supply** – Based on EIA estimates of high estimated ultimate recovery (EUR). Higher use of natural gas in all sectors, especially electric power.
- ▣ **High GDP Growth** – Faster average GDP growth (3.1%), with corresponding increases in energy use and emissions.
- ▣ **Advanced Demand** – Combine high shale supply with increased industrial demand from gas-to-liquids (GTL) and expanded ethylene production.

High Gas Supply Scenario

- ▣ **Motivation:** To explore the implications of increased gas supply and lower prices.
- ▣ **Trade effects:** How much are exports stimulated? What sectors?
- ▣ **Price Effects** – What are impacts on other sectors' prices?
- ▣ **Electric Power Sector** – How much does the gas share of electric power generation increase?

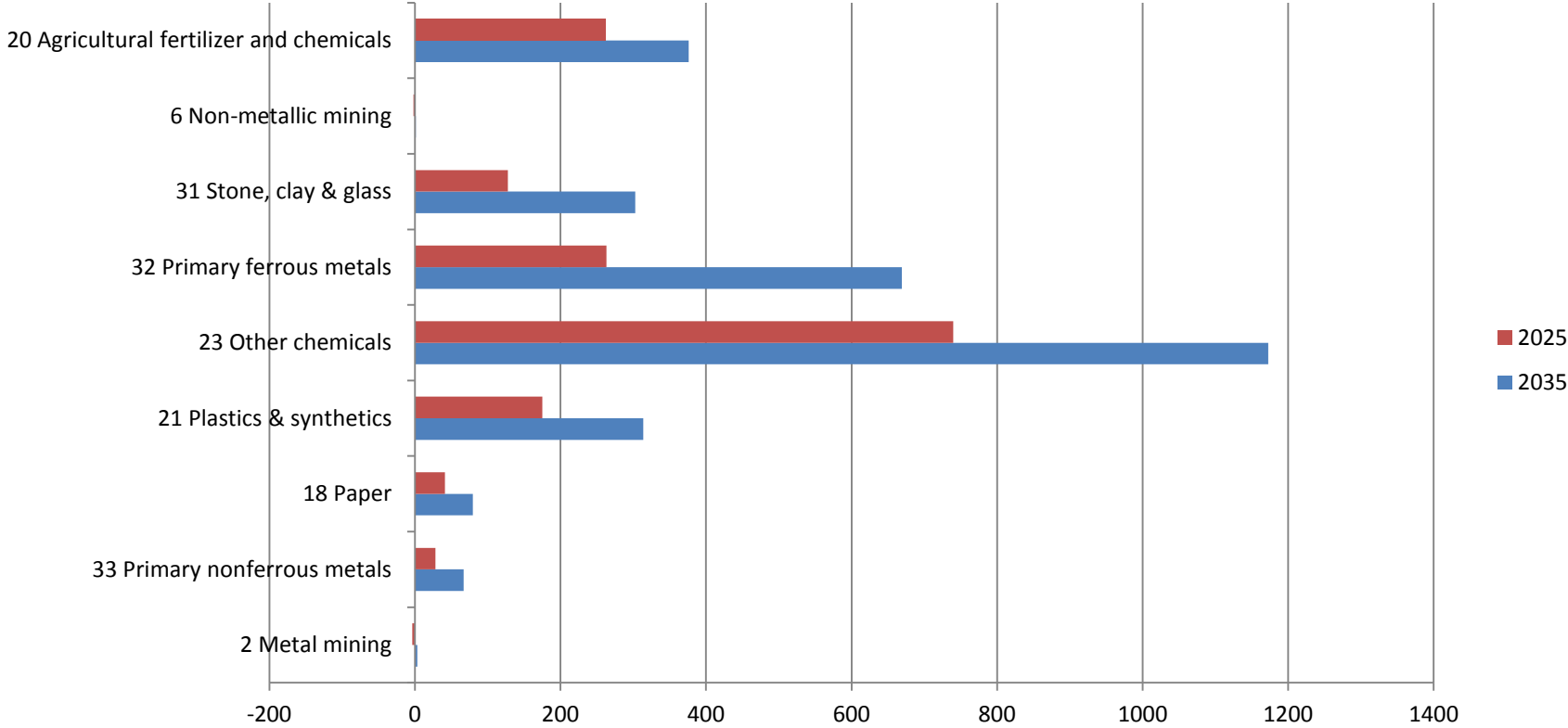
Gas Intensive Sectors

Top 10 Industries in Natural Gas Input



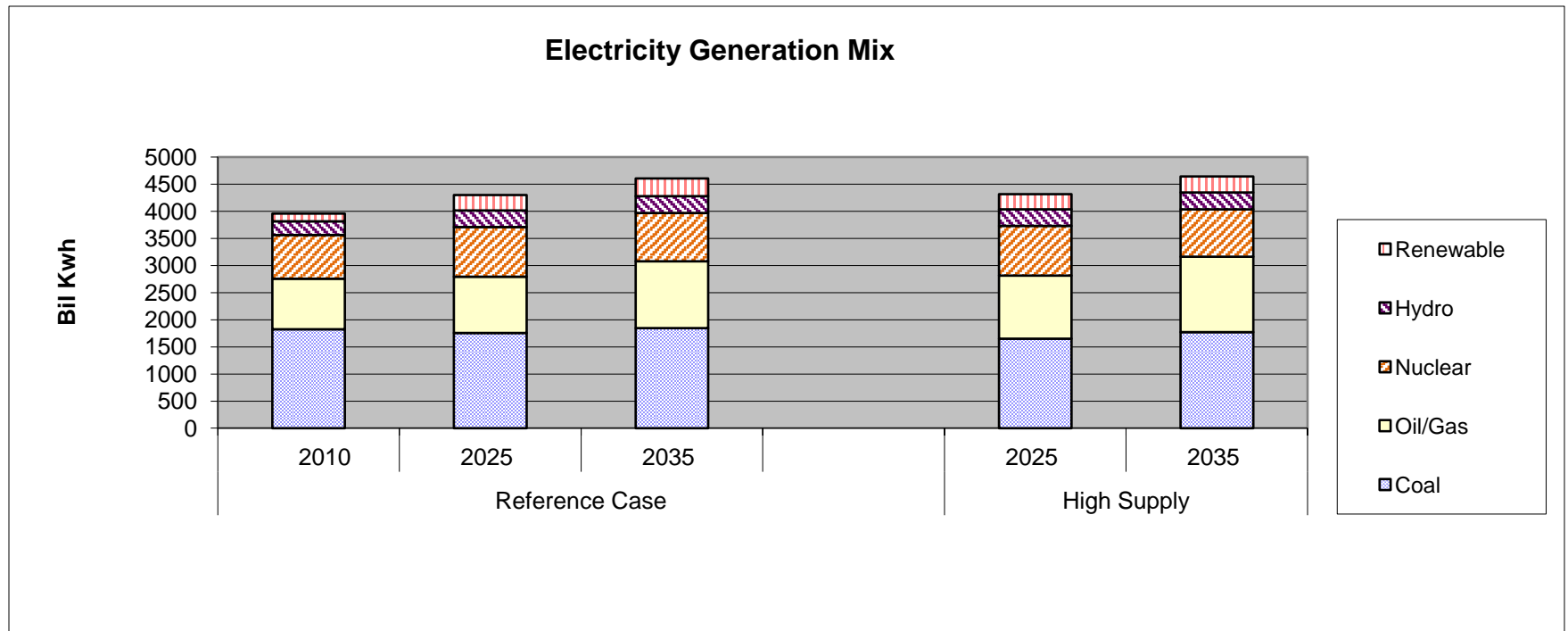
Expand Exports

Exports Changes for Selected Gas Intensive Sectors



Electric Power Sector

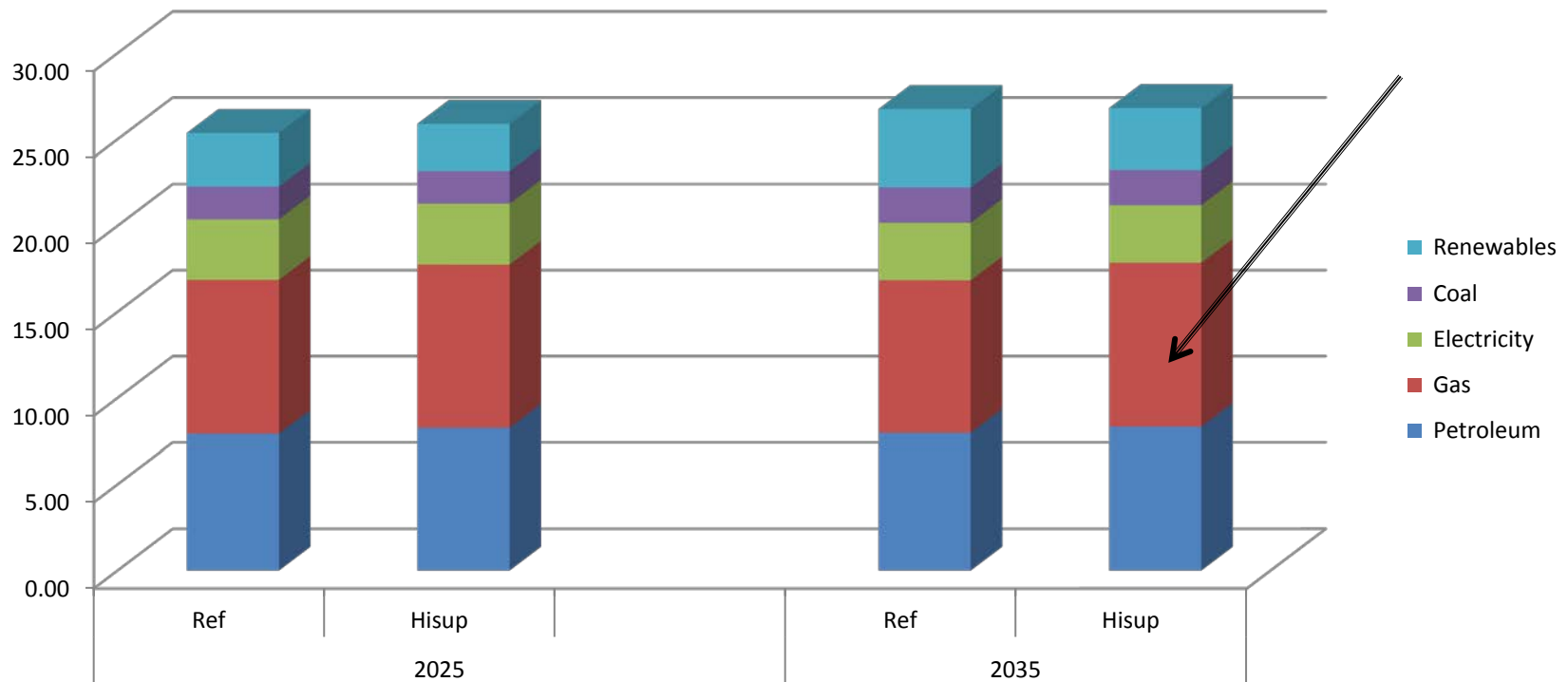
- ▣ Increased use of natural gas
- ▣ Less coal, renewables



Industrial Sector

- Gas-intensive sectors stimulated from exports
- Some substitution => +.67 quad increase by 2035

Industrial Energy Use by Source



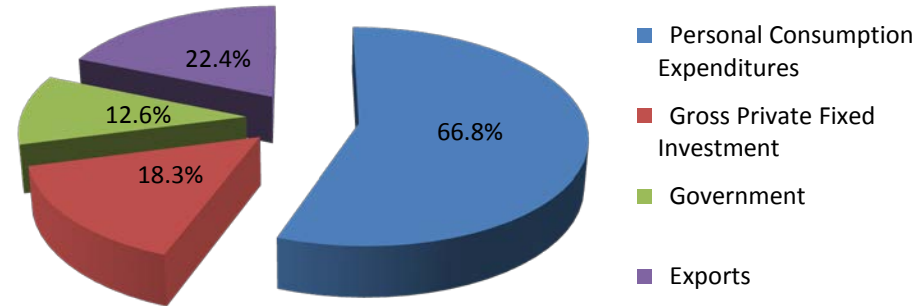
High GDP Growth Scenario

- ▣ **Motivation:** Set a reasonable upper bound to expected GDP, energy and emissions growth.
- ▣ **Supply Factors:** Labor force growth is .1% faster than reference, productivity growth is .4% faster.
- ▣ **Demand Factors:** Higher exports and investment growth, incomes and personal consumption also grow faster. Investment and exports increase as a share of GDP, personal consumption and government are slightly lower shares than reference.

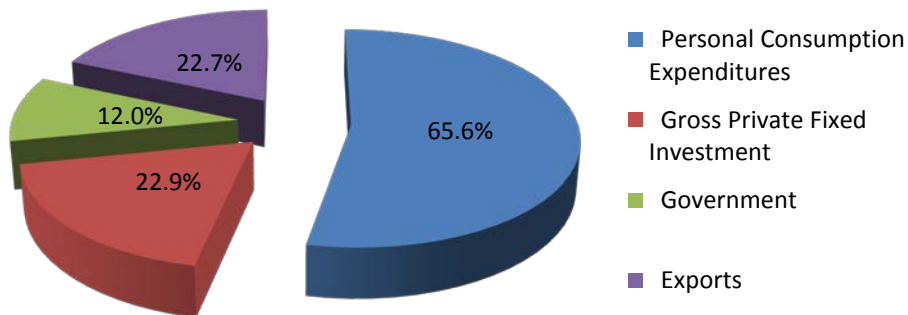
High GDP Growth: Macro Composition

- This scenario is one of export and investment-led growth.
- By 2035, exports and investment are a higher share in the High Growth Case.
- This has implications for the distribution of industry output.

Reference Case: 2035 GDP



High GDP Growth: 2035 GDP



Takeaways: High Shale Supply and High GDP

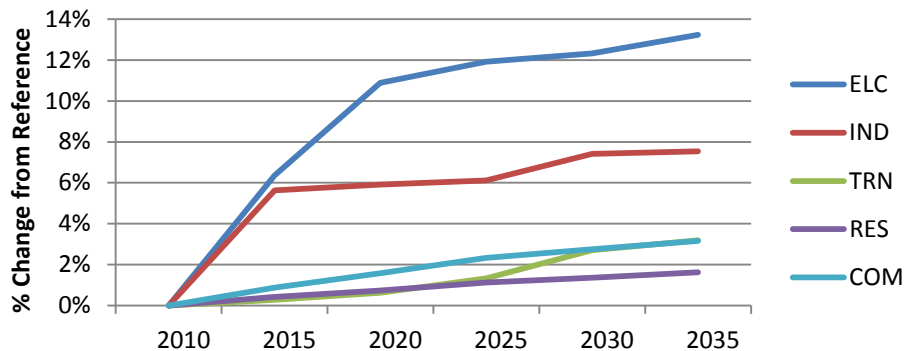
□ High Shale Supply

- Small increase in both manufacturing and chemical exports
- Uptake of natural gas in all sectors, but the electric sector uptake was particularly strong

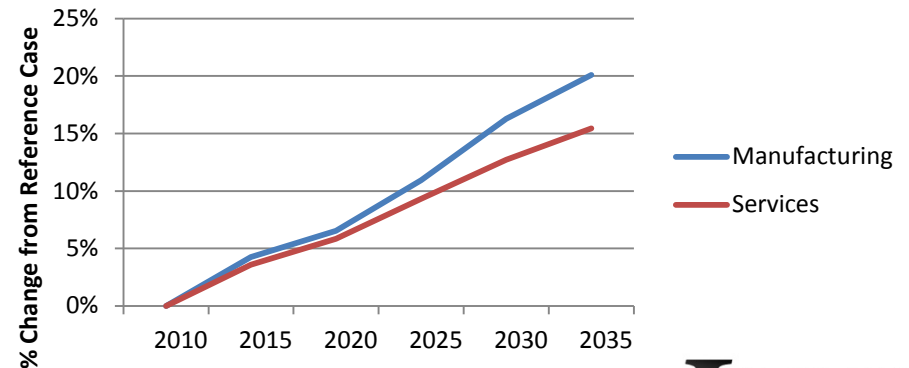
□ High GDP Growth

- Not seeing significant increases in energy efficiency
- Manufacturing growth outstrips service industry growth

Natural Gas Consumption by Sector (%)
Scenario: High Shale Supply



Total Manufacturing and Service Dollar Output (%)
Scenario: High GDP Growth



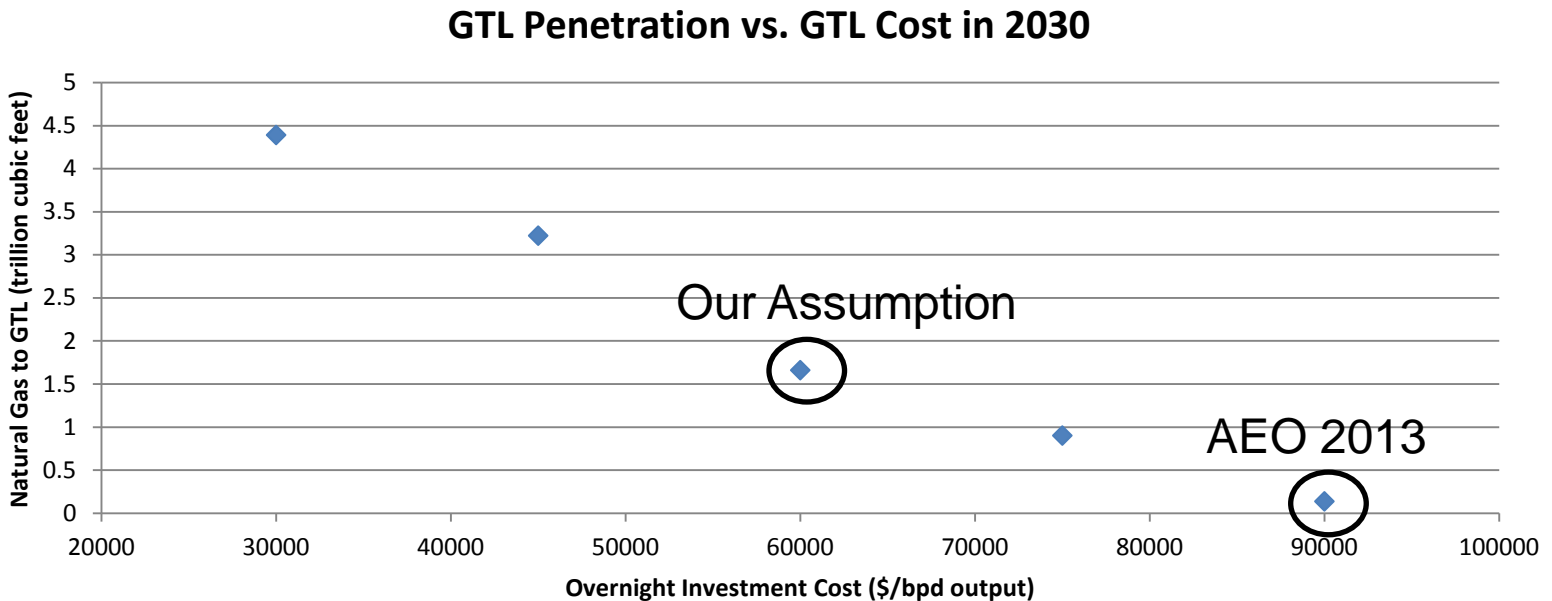
Advanced Demand Scenario

- ▣ **Motivation:** Explore impacts of more optimistic growth in natural gas demand.
- ▣ **Gas to Liquids (GTL)** – Assumed aggressive penetration of this technology.
- ▣ **Ethylene** – Assumed 25 percent increase in ethylene production over the reference case.

GTL Technology Penetration:

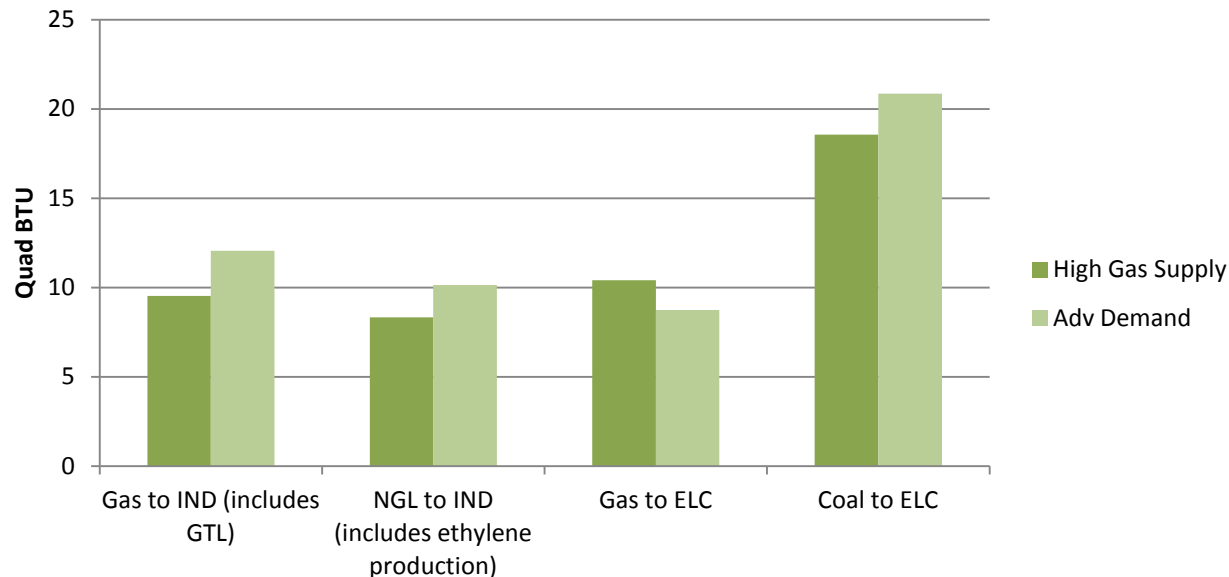
Gas to Liquids as a Function of Investment Cost

- Used MARKAL to determine sensitivity of GTL penetration to investment cost
- For reference



Energy Sector Dynamics

- By 2035 the sum of natural gas and natural gas liquids in the Advanced Demand scenario is up 15% over the Reference scenario and 7% over the High Gas Supply scenario
- Compared to the High Gas Supply scenario
 - GTL drives increase in gas to the industrial sector
 - Ethylene increases drives increase in natural gas liquids to the industrial sector
 - Decrease in natural gas to the electric sector

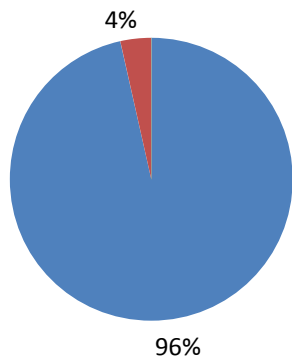


Impacts on Diesel and Chemical Exports

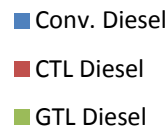
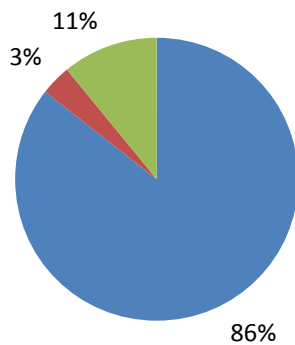
- In Advanced Demand Scenario, 11% of diesel is generated from GTL
- Increased ethylene production drives up chemical sector exports

Diesel by Source (Year 2035)

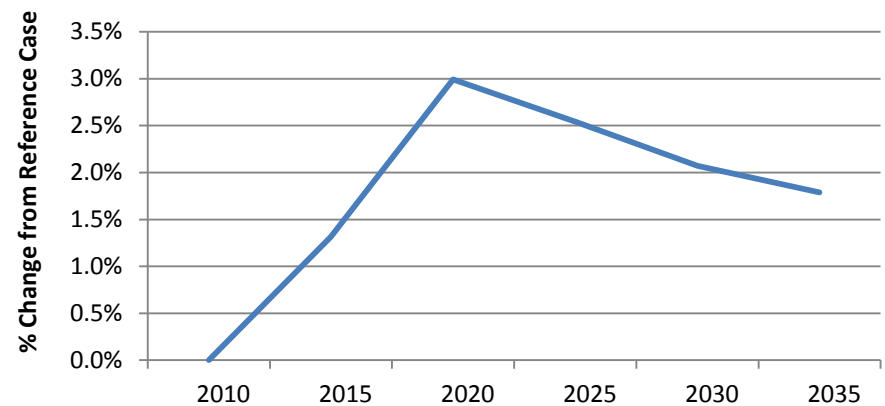
Scenario: Reference



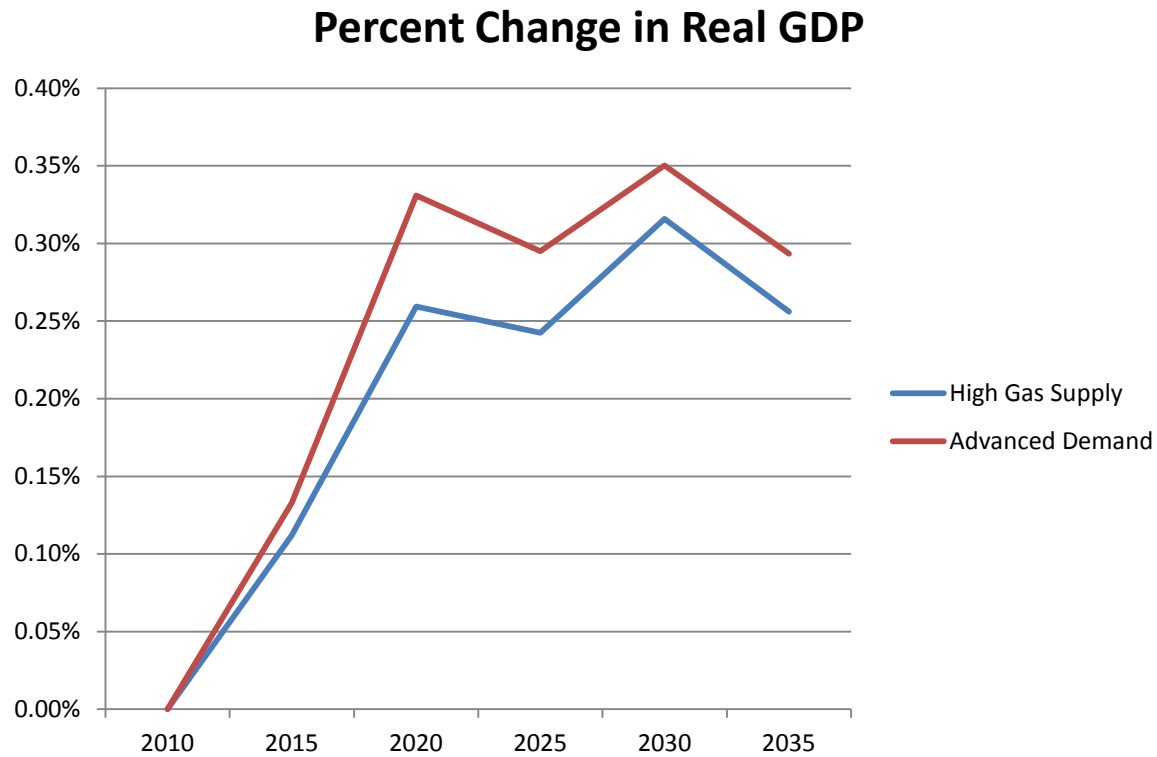
Scenario: Advanced Demand



Chemical Exports (%) Scenario: Advanced Demand

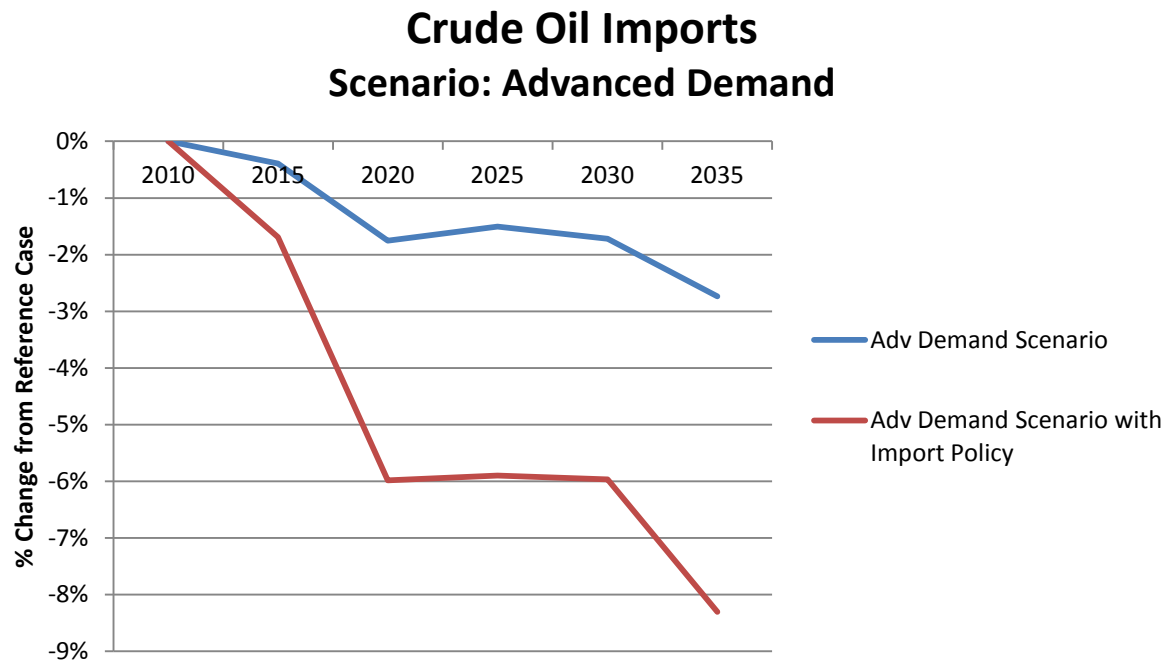


Increases to GDP



Potential GDP Gains

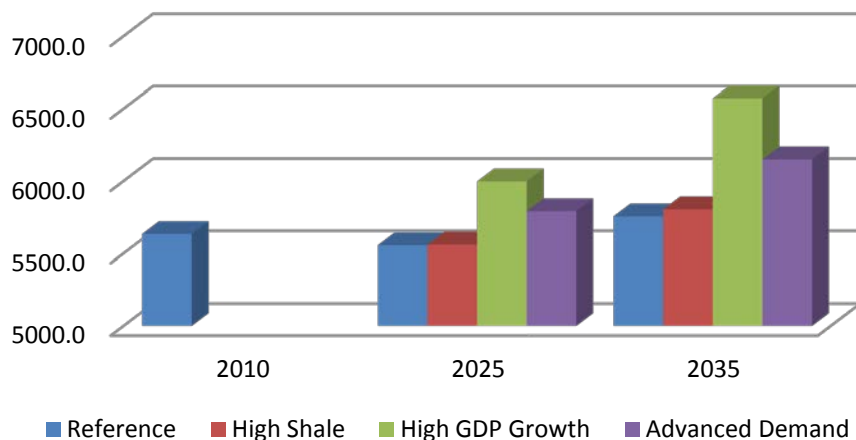
- ❑ Ethylene production spurs additional manufacturing in the United States
- ❑ Additional chemical sector growth beyond ethylene
- ❑ Enact policy to use GTL outputs to reduce oil imports



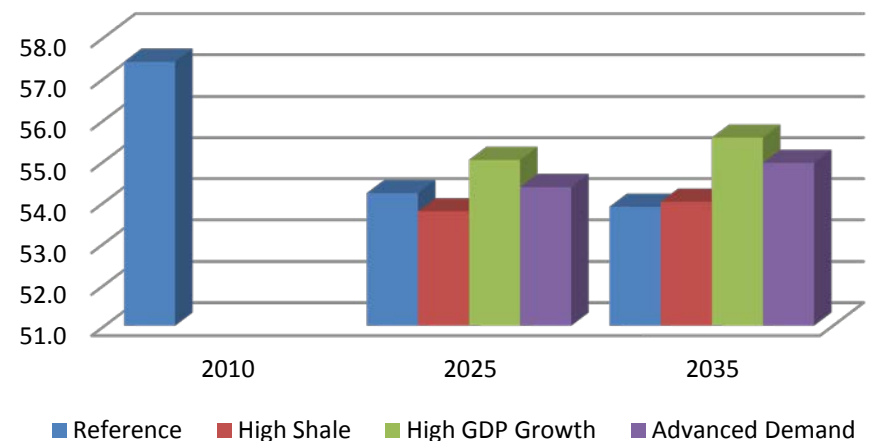
CO2 Emissions and Intensity

- Total CO2 Emissions
 - ▣ High GDP case shows probable upper bound for total emissions.
 - ▣ Advanced Demand case has high emissions due to more coal uptake in the electric sector
- CO2 Emissions / Energy
 - ▣ High Shale shows improvement over reference in 2025.
 - ▣ High GDP and Advanced Demand are pulling in more coal.

Total CO2 Emissions (MMt)



CO2/Energy Use (MMt/Quad)



Total Energy Use and Intensity

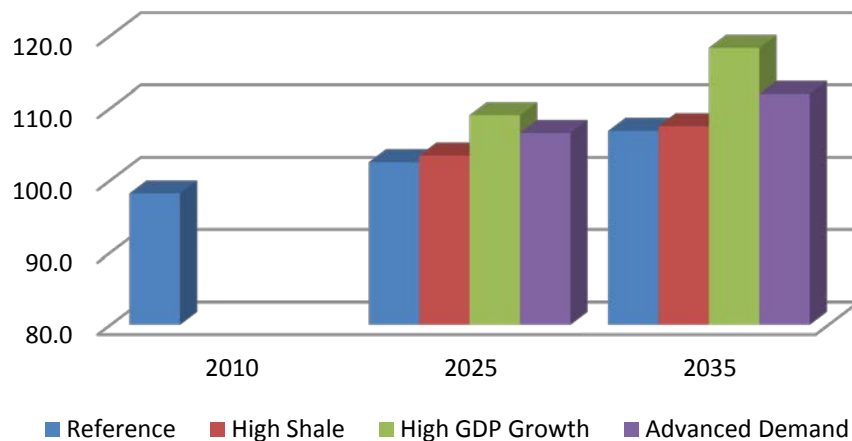
□ Total Energy Use

- High GDP case shows probable upper bound for total energy use.
- Advanced Demand case shows increased energy use relative to High Shale

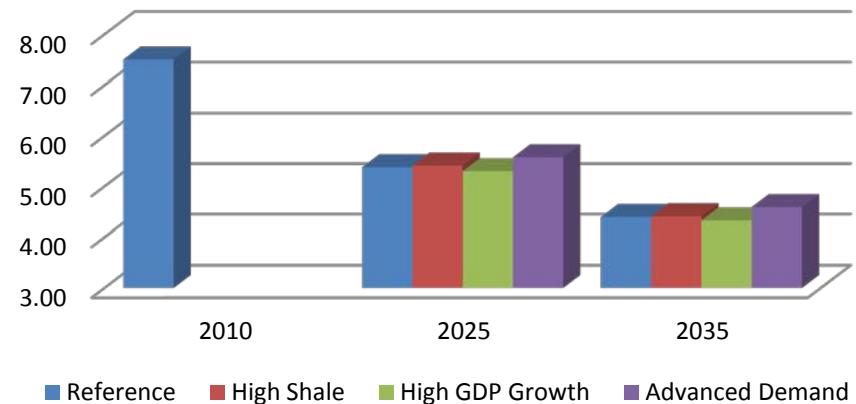
□ Energy / GDP

- High GDP case is showing slightly reduced energy intensity. Advanced Demand has greater energy intensity due to GTL and Ethylene.

Total Energy Use (Quads)



Energy / GDP (Tril Btu / Bil 2005\$)



Policy Issues and Future Analysis

- ❑ Price response: Mostly in electric power and industrial sectors. Not as much in industrial or commercial.
- ❑ Potential for increased gas use in transportation seems relatively small.
- ❑ Industrial sector response could be larger with favorable technologies for GTL and ethylene and other petrochemicals.
- ❑ Long-run shape of supply curve is not well-known -> we don't know the effect of higher demand on gas prices.
- ❑ Export potential remains a big question. This may be more favorable in the short- to mid-term horizon.



Thank You!

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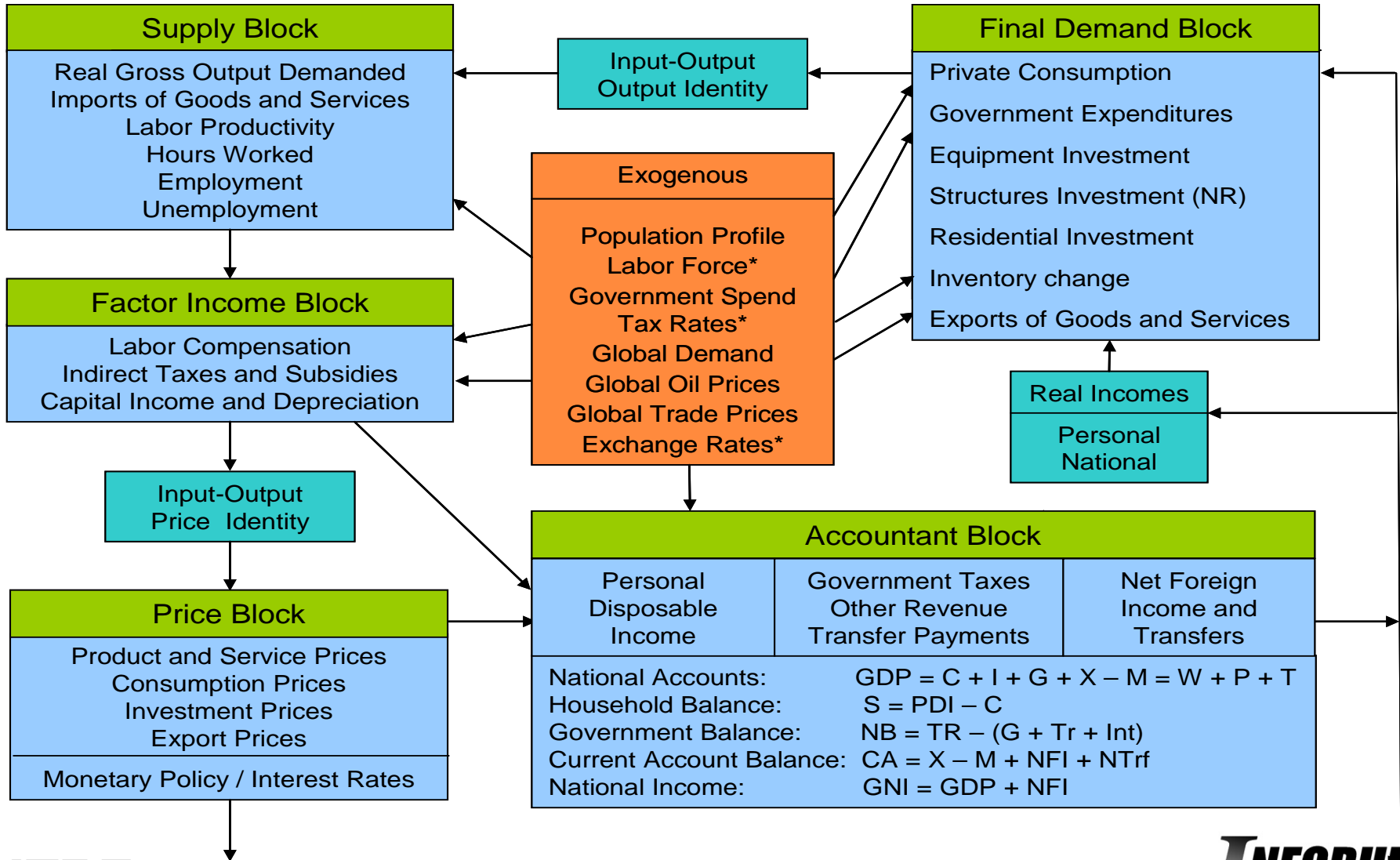
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Additional Slides

Overview of *LIFT*

- ❑ Inforum Interindustry Macro (IM) model, builds macro from bottom-up.
- ❑ 110 commodities (final demands, output and prices) and 65 industries (employment, investment, value added)
- ❑ LIFT includes a time series of IO tables from 1998-2010.
- ❑ Benchmark 2002 IO table provides the groundwork.
- ❑ This is updated with the 1998-2010 Annual IO, along with time series of detailed output, exports and imports
- ❑ Output and price are both solved using Gauss-Seidel.

LIFT Model Structure



High Supply: Electricity Generation

Electricity Generation Mix in Reference and High Supply Cases (Billions of Kwh)

	Reference Case			High Supply	
	2010	2025	2035	2025	2035
Coal	1824	1753	1846	1650	1769
Oil/Gas	929	1040	1232	1162	1393
Nuclear	807	917	887	917	875
Hydro	255	305	310	303	308
Renewable	139	280	325	283	294
Total Generation	3955	4296	4601	4315	4639

- Total generation slightly higher in high supply case by 2035.
- Cheap gas crowds coal. Renewables are also lower than the reference by 2035.

High GDP: GDP Distribution

	Reference Case					High GDP Growth Case			
	2010	2025	2035	2025	2035	2025	2035	2025	2035
Gross Domestic Product	13087	19071	24333			20583	27347		
Personal Consumption Expenditures	9221	12720	16256	66.7%	66.8%	13623	17929	66.2%	65.6%
Gross Private Fixed Investment	1714	3520	4452	18.5%	18.3%	4175	6252	20.3%	22.9%
Government	2558	2771	3061	14.5%	12.6%	2902	3284	14.1%	12.0%
Exports	1663	3687	5445	19.3%	22.4%	4057	6198	19.7%	22.7%
Imports	2085	3428	4481	18.0%	18.4%	3881	5616	18.9%	20.5%