

Energy Sector for Economists

Session 3

Energy Resources and Energy Reserves

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Energy Resources and Energy Reserves

- What is this about?
 - Predicting future energy needs
 - Predicting available future energy resources
- and:
 - Matching these to fit
 - Economist would call it:
- Balancing constrained supply and demand

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Economic Systems 101

- Economic digression on constraints:
 - Resource constrained vs. Demand constrained system
 - Resources
 - Physical and technical nature of the constraint
 - Demand
 - Sales cannot exceed demand
 - Budget
 - Expenses cannot exceed initial budget plus proceedings from the sales

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Kornai

- Capitalism (as defined by Marx ☺),
- or Market economy
 - Demand constrained
- Socialist economy (or CPE)
 - Resource constrained
 - This does not imply 100% usage of resources
 - Nor efficient usage of resources
- Socialist or market economy:
 - Soft budget constraints (vs. Hard budget constraint)
 - Banking aid
 - Subsidies
 - Bailouts

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Energy and Future

- Demand constraints
 - The producers can't sell more than markets buy
 - Need to estimate future demand
- Resource constraint
 - Production can be limited by natural resources available, capacity limits or technologies
 - Need to check resource balance both total and in time
 - Not all resources are storable
 - Limited transformation can exist
- HBC
 - Can we do it w/o subsidies?
 - Economic viability checks

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Politics and Energy

- Policymakers worries about energy sector:
 - In modern society perceived as a basic need
 - Security of resources
 - Crucial economic input factor
 - State responsibility?
 - Role of the market?
 - Often network industries with natural monopoly element
 - World imbalance of resources and use
 - Environmental issues?

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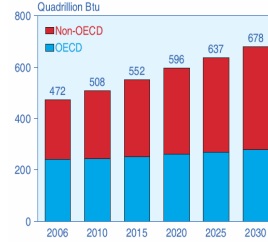
Predicting Demand

- How to predict future energy demand?
1. Wild Guess
 2. Expert Guess
 3. Modeling
 - **Physical energy models**
 - Various types of energy analyzed separately
 - Typically primary energy plus electricity
 - **Technology advances**
 - How "greedy" will be the future technologies? For production? Heating? Illumination? Transport?
 - **Economic models**
 - **Local vs. Global**
 - **Self-sustainable systems vs. open economy**

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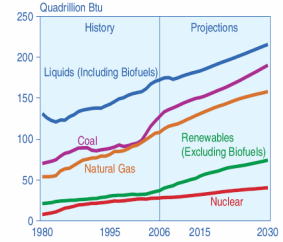
World Energy Outlook Highlights

Figure 1. World Marketed Energy Consumption, 2006-2030



Sources: 2006: Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2009).

Figure 2. World Marketed Energy Use by Fuel Type, 1980-2030

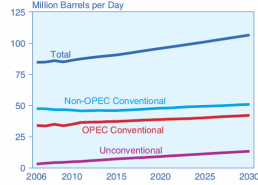


Sources: 2006: Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2009).

Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oi/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oi/ieo/pdf/0484(2009).pdf) CERGE-EI

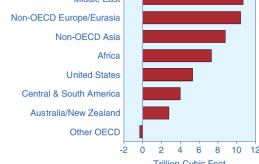
World Energy Outlook Highlights

Figure 4. World Liquids Production, 2006-2030



Sources: 2006: Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, Generate World Oil Balance Model (2009).

Figure 5. Net Change in World Natural Gas Production, 2006-2030

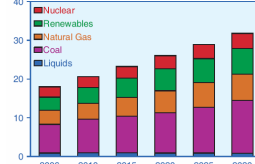


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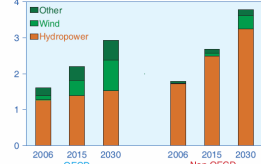
World Energy Outlook Highlights

Figure 6. World Electricity Generation by Fuel, 2006-2030



Sources: 2006: Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2009).

Figure 7. World Renewable Electricity Generation by Energy Source, 2006, 2015, and 2030

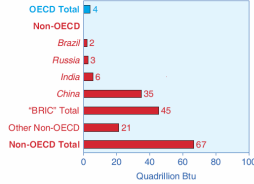


Sources: 2006: Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2009).

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World Energy Outlook Highlights

Figure 8. Net Increase in Industrial Energy Use by Region, 2006-2030

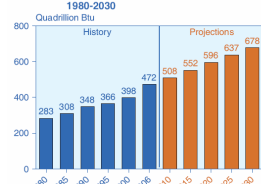


Sources: 2006: Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2009).

Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oi/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oi/ieo/pdf/0484(2009).pdf) CERGE-EI

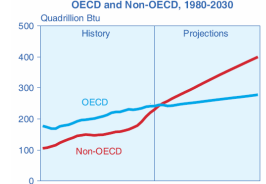
WEO – Energy Demand

Figure 10. World Marketed Energy Consumption, 1980-2030



Sources: History: Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2009).

Figure 11. World Marketed Energy Consumption: OECD and Non-OECD, 1980-2030

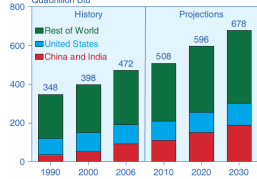


Sources: History: Energy Information Administration (EIA), International Energy Annual 2006 (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2009).

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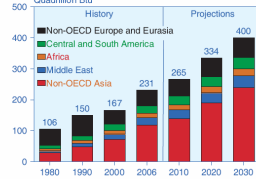
World Energy Outlook - Electricity

Figure 12. Marketed Energy Use by Region, 1990-2030



Sources: History: Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2006), web site www.eia.doe.gov/iea. Projections: EIA, *World Energy Projections Plus* (2009).

Figure 13. Marketed Energy Use in the Non-OECD Economies by Region, 1980-2030

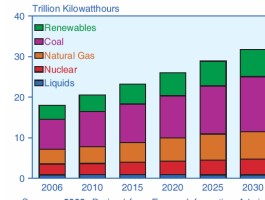


Sources: History: Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2006), web site www.eia.doe.gov/iea. Projections: EIA, *World Energy Projections Plus* (2009).

Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oi/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oi/ieo/pdf/0484(2009).pdf) CERGE-EI

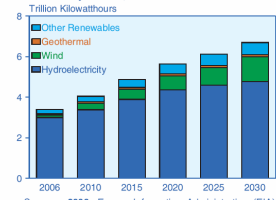
World Energy Outlook - Electricity

Figure 16. World Electricity Generation by Fuel, 2006-2030



Sources: 2006: Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2006), web site www.eia.doe.gov/iea. Projections: EIA, *World Energy Projections Plus* (2009).

Figure 17. World Renewable Electricity Generation by Source, 2006-2030

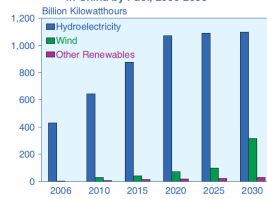


Sources: 2006: Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2006), web site www.eia.doe.gov/iea. Projections: EIA, *World Energy Projections Plus* (2009).

Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oi/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oi/ieo/pdf/0484(2009).pdf) CERGE-EI

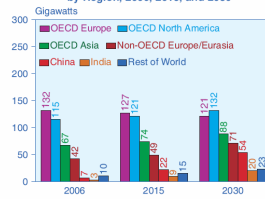
World Energy Outlook - Electricity

Figure 18. Renewable Electricity Generation in China by Fuel, 2006-2030



Sources: 2006: Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2006), web site www.eia.doe.gov/iea. Projections: EIA, *World Energy Projections Plus* (2009).

Figure 19. World Nuclear Generating Capacity by Region, 2006, 2015, and 2030

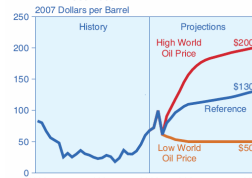


Sources: 2006: Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2006), web site www.eia.doe.gov/iea. 2015 and 2030: EIA, *World Energy Projections Plus* (2009).

Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oi/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oi/ieo/pdf/0484(2009).pdf) CERGE-EI

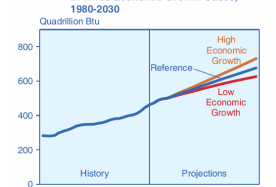
World Energy Outlook - Uncertainty

Figure 21. World Oil Prices in Three Price Cases, 1980-2030



Source: Energy Information Administration (EIA), *Annual Energy Outlook 2009*, DOE/EIA-0383(2009) (Washington, DC, June 2009), web site www.eia.doe.gov/oi/aeo.

Figure 20. World Marketed Energy Consumption in Three Economic Growth Cases, 1980-2030

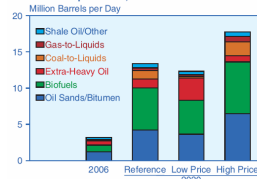


Sources: History: Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2006), web site www.eia.doe.gov/iea. Projections: EIA, *World Energy Projections Plus* (2009).

Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oi/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oi/ieo/pdf/0484(2009).pdf) CERGE-EI

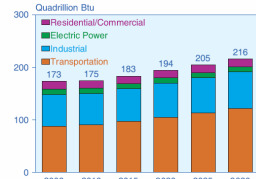
World Energy Outlook - Oil

Figure 27. World Production of Unconventional Liquid Fuels, 2006-2030



Sources: 2006: Energy Information Administration (EIA), Office of Energy Markets and End Use, 2030: EIA, *General World Oil Balance Model* (2009).

Figure 28. World Liquids Consumption by Sector, 2006-2030

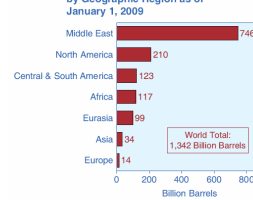


Sources: 2006: Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2006), web site www.eia.doe.gov/iea. Projections: EIA, *World Energy Projections Plus* (2009).

Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oi/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oi/ieo/pdf/0484(2009).pdf) CERGE-EI

World Energy Outlook - Oil

Figure 32. World Proved Oil Reserves by Geographic Region as of January 1, 2009

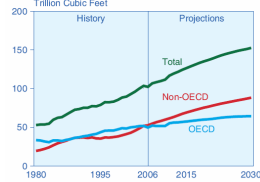


Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 106, No. 48 (December 22, 2008), pp. 23-24.

Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oi/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oi/ieo/pdf/0484(2009).pdf) CERGE-EI

World Energy Outlook - Gas

Figure 33. World Natural Gas Consumption, 1980-2030

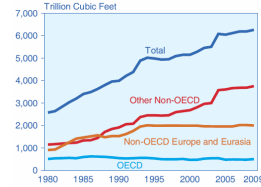


Sources: History: Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, *World Energy Projections Plus* (2009).

Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oiat/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oiat/ieo/pdf/0484(2009).pdf) **CERGE-EI**

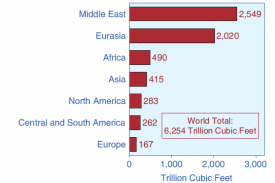
World Energy Outlook - Gas

Figure 40. World Natural Gas Reserves by Country Grouping, 1980-2008



Sources: 1988-1993: "Worldwide Oil and Gas at a Glance," *International Petroleum Encyclopedia* (Tulsa, OK: PennWell Publishing, various issues). 1994-2009: *Oil & Gas Journal* (various issues).

Figure 41. World Natural Gas Reserves by Geographic Region as of January 1, 2009

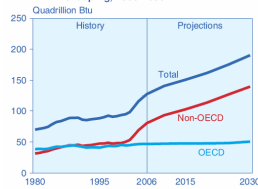


Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 106, No. 48 (December 22, 2008), pp. 22-23.

Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oiat/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oiat/ieo/pdf/0484(2009).pdf) **CERGE-EI**

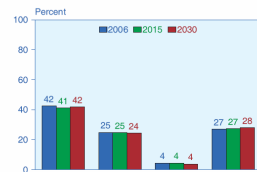
World Energy Outlook - Coal

Figure 42. World Coal Consumption by Country Grouping, 1980-2030



Sources: History: Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, *World Energy Projections Plus* (2009).

Figure 43. Coal Share of World Energy Consumption by Sector, 2006, 2015, and 2030

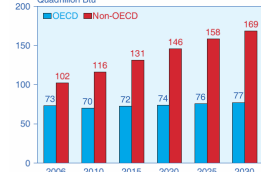


Sources: 2006: Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. 2015 and 2030: EIA, *World Energy Projections Plus* (2009).

Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oiat/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oiat/ieo/pdf/0484(2009).pdf) **CERGE-EI**

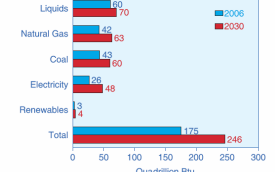
World Energy Outlook - Industry

Figure 63. OECD and Non-OECD Industrial Sector Energy Consumption, 2006-2030



Sources: 2006: Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, *World Energy Projections Plus* (2009).

Figure 64. World Industrial Sector Energy Consumption by Fuel, 2006 and 2030

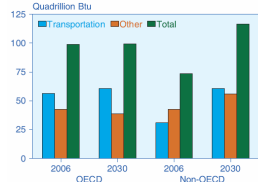


Sources: 2006: Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. 2030: EIA, *World Energy Projections Plus* (2009).

Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oiat/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oiat/ieo/pdf/0484(2009).pdf) **CERGE-EI**

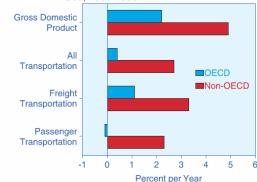
World Energy Outlook - Transport

Figure 71. OECD and Non-OECD Liquids Consumption by End-Use Sector, 2006 and 2030



Sources: 2006: Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. 2030: EIA, *World Energy Projections Plus* (2009).

Figure 72. Average Annual Growth in OECD and Non-OECD Gross Domestic Product and Transportation Sector Delivered Energy Use, 2006-2030



Sources: 2006: Derived from Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. Projections: EIA, *World Energy Projections Plus* (2009).

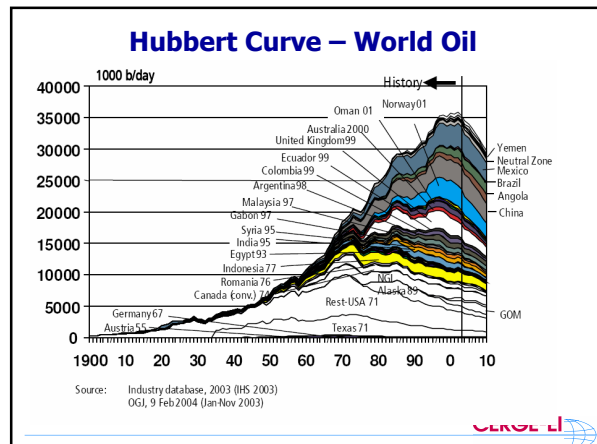
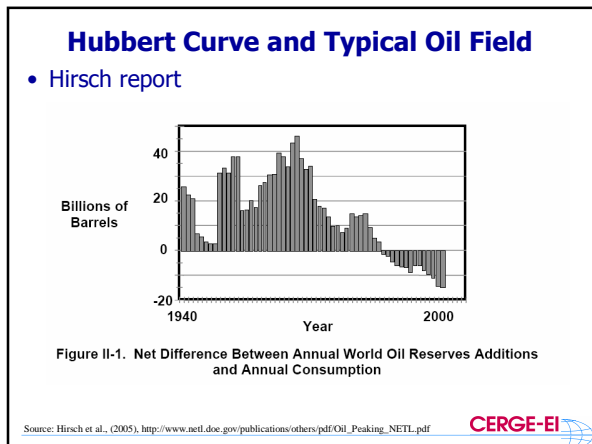
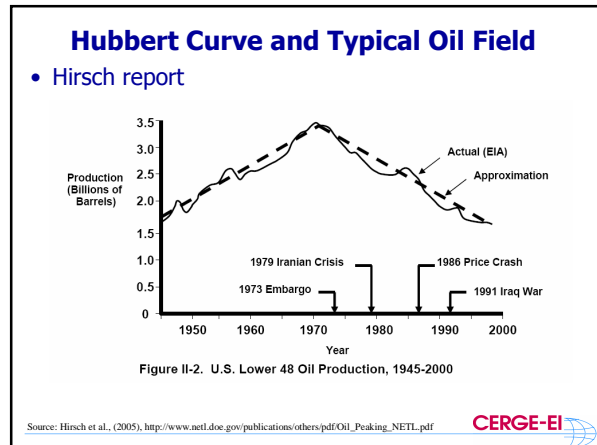
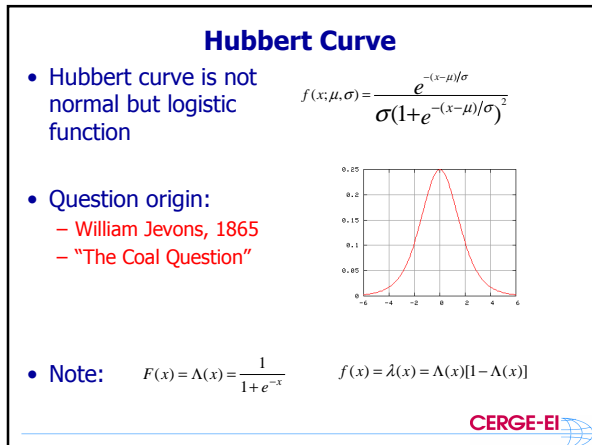
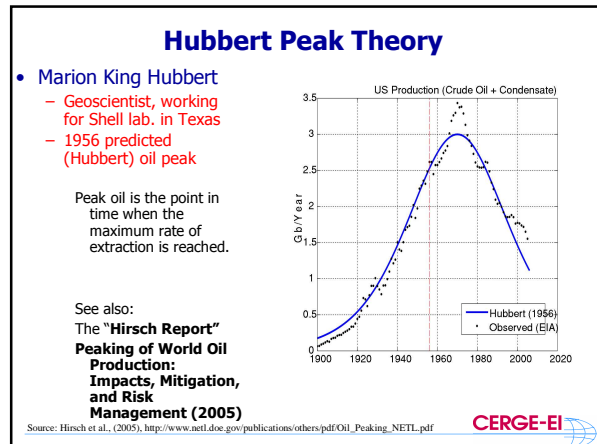
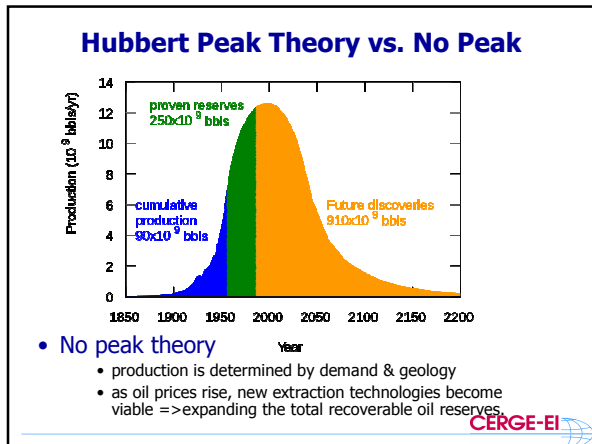
Source: International Energy Outlook 2009 (IEO2009), [http://www.eia.doe.gov/oiat/ieo/pdf/0484\(2009\).pdf](http://www.eia.doe.gov/oiat/ieo/pdf/0484(2009).pdf) **CERGE-EI**

Modeling Components

• Demand According Type

- Liquid fuels
 - Oil, Biofuels, Ethanol...
- Natural gas
- Coal
 - Hard coal
 - Lignite
- Electricity
 - Coal, gas, and oil power plants -> link to above
 - Hydro
 - Nuclear
 - Other (solar, wind, tide, geothermal,...)

CERGE-EI



Hubbert Curve and Typical Oil Field

- Hirsch Report – Oil Consumption Mix

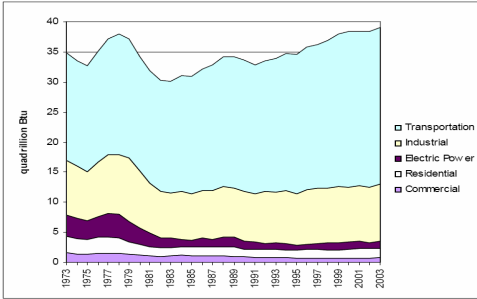


Figure III-1. U.S. Petroleum Consumption by Sector, 1973-2003²⁵

Source: Hirsch et al., (2005), http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf



Hirsch Report – Can Technology Help?

- Better Field Utilization

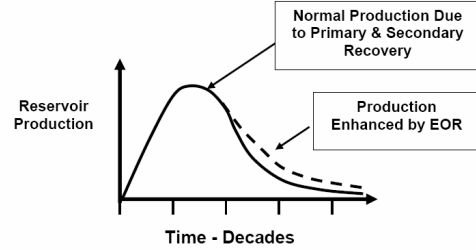


Figure VI-1. The Timing of EOR Applications

Source: Hirsch et al., (2005), http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf



Hirsch Report – Can Technology Help?

- Better Cars

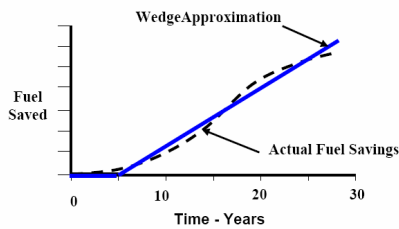


Figure VII-2. The delayed wedge approximation in the case of major changes in transportation fuel consumption

Source: Hirsch et al., (2005), http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf



Hirsch Report – Can Technology Help?

- Better Everything
 1. Enhanced Oil Recovery is applicable worldwide.
 2. Heavy oil / Oil sands is currently commercial in Canada and Venezuela.
 3. Coal liquefaction is a well-developed, near-commercial technology.
 4. Gas-To-Liquids is commercially applicable where natural gas is remote from markets.
 5. Fuel-efficient cars



Hirsch Report – Can Technology Help?

- Better Everything

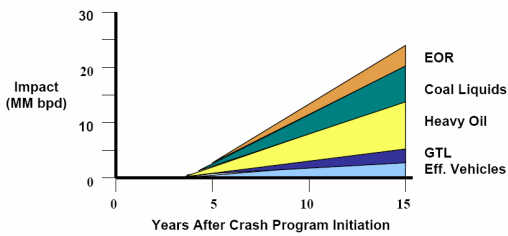


Figure VIII-3. Assumed wedges

Source: Hirsch et al., (2005), http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf



Hirsch Report – Can Technology Help?

- Timing Matters

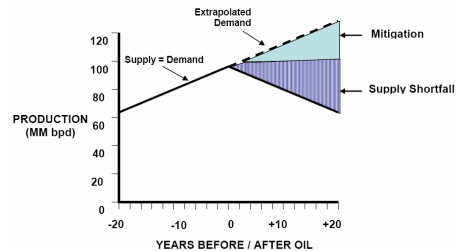


Figure VIII-4. Mitigation crash programs started at the time of world oil peaking: A significant supply shortfall occurs over the forecast period.

Source: Hirsch et al., (2005), http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf



Hirsch Report – Can Technology Help?

- Timing Matters

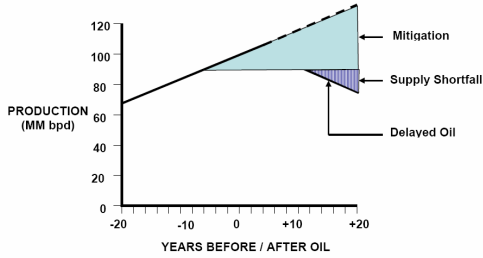


Figure VIII-5. Mitigation crash programs started 10 years before world oil peaking: A moderate supply shortfall occurs after roughly 10 years.

Source: Hirsch et al., (2005), http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf



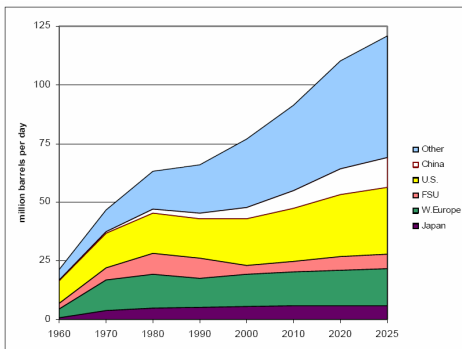
Hirsch Report – Can Technology Help?

- Timing Problem

1. Waiting until world oil production peaks before taking crash program action leaves the world with a significant liquid fuel deficit for more than two decades.
2. Initiating a mitigation crash program 10 years before world oil peaking helps considerably but still leaves a liquid fuels shortfall roughly a decade after the time that oil would have peaked.
3. Initiating a mitigation crash program 20 years before peaking appears to offer the possibility of avoiding a world liquid fuels shortfall for the forecast period.
4. Mitigation actions initiated prematurely will be costly and could result in a poor use of resources.
5. Late initiation of mitigation may result in severe consequences.



Hirsch Report – The World



Source: Hirsch et al., (2005), http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf

Figure A-4. World Petroleum Consumption, 1960-2025



Hirsch Report – Two Scenarios

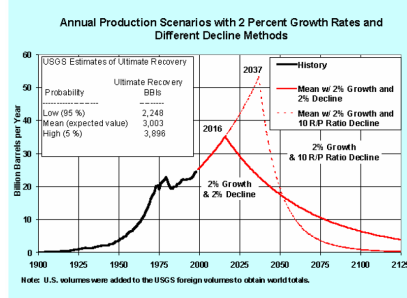


Figure A-1. Two EIA oil production scenarios based on expected ultimate world-recoverable oil of 3,003 billion barrels and a 2 percent annual world oil demand escalation

Source: Hirsch et al., (2005), http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf



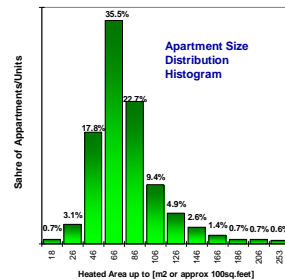
Modeling Components

- Demand According Use

- Industries
 - Energy intensive
 - other
- Transport
 - Freight vs. Passenger
 - Mode:
 - Ground
 - Rail
 - Air
 - Sea
 - Space...
- Heating
 - Industries
 - Households



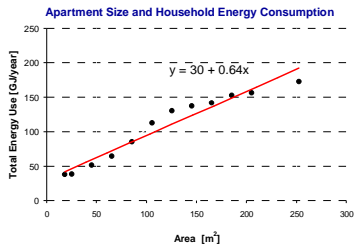
Example: Household Energy Consumption



Source: CZSO



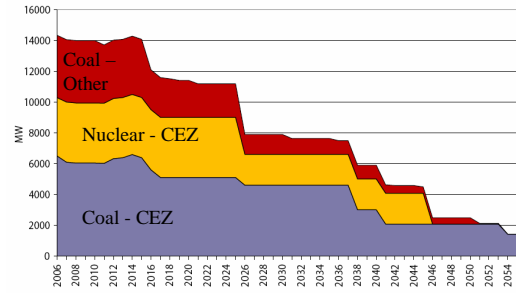
Example: Household Energy Consumption



Source: CZSO

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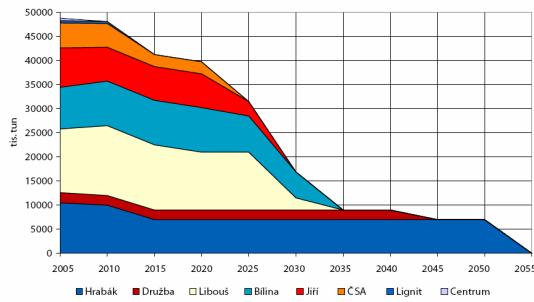
Czech Electricity - Installed



Graph: Installed Facilities, Source: NEK Report, 2008

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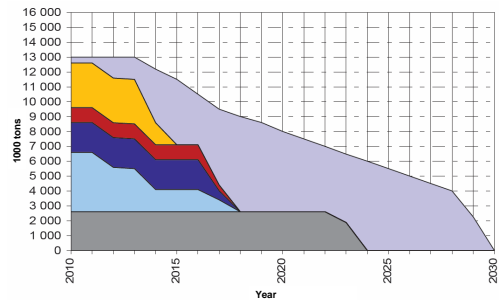
Czech Coal (Lignite) Reserves



Graph: Estimated Lifetime of Brown Coal Mines, Source: NEK Report, 2008

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Czech Hard Coal Reserves



Graph: Estimated Lifetime of Hard Coal Mines, Source: NEK Report, 2008

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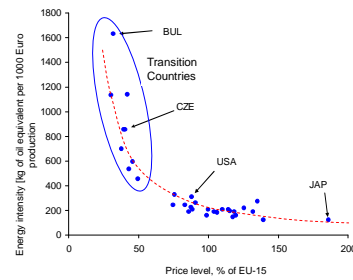
Czech Republic – Practical Example of Prediction Exercise

- Currently, the Czech Republic imports almost half of its primary energy resources (NEK, 2008, pp.153, 167) and this share is expected to continue its upward trend:

	2003	2005	2010	2015	2020	2030	2040
Import energy dependency, %	39.6	47.2	52.4	60.1	63.1	75.4	80.3

CERGE-EI

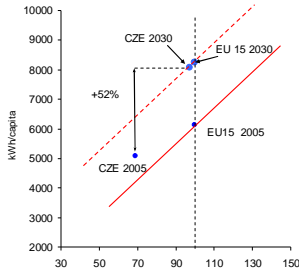
Energy Intensity – and GDP



Source: Tomšík (2007)

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Real Convergence of Czech Republic

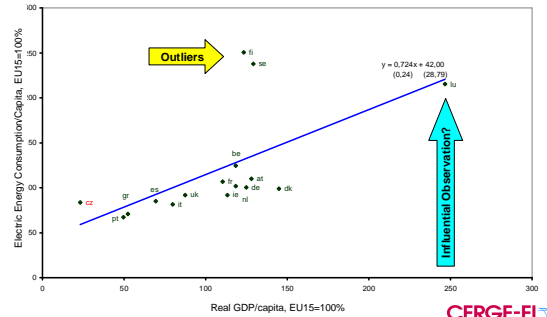


Source: Tomšik (2007)

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Predicting Future in the CZ - Electricity

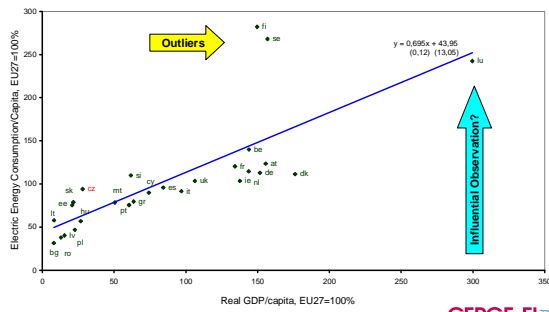
Real EU-15 GDP per capita and Energy consumption per capita



CERGE-EI

Predicting Future in the CZ - Electricity

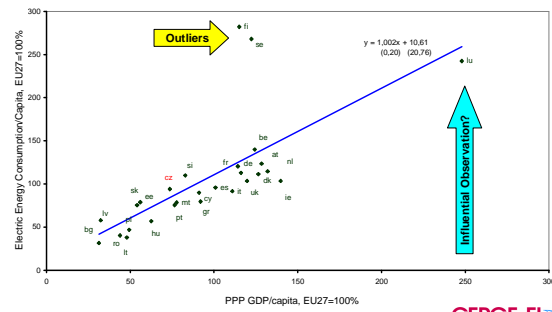
Real EU-27 GDP per capita and Energy consumption per capita



CERGE-EI

Predicting Future in the CZ - Electricity

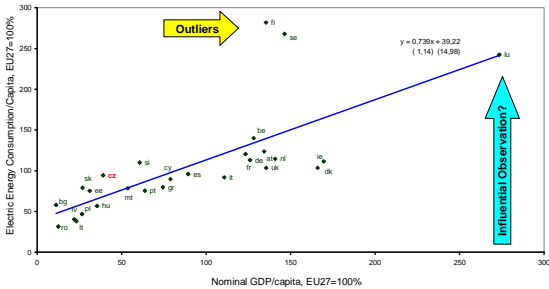
EU-27 GDP per capita in PPP and Energy consumption per capita



CERGE-EI

Predicting Future in the CZ - Electricity

Nominal EU-27 GDP per capita and Energy consumption per capita



CERGE-EI

Predicting Future in the CZ - Electricity

Weight = El. Energy Consumption

	Coeff.	St. Err.	t-stat.	P-val.	Excess cons. (%)	R ²
Constant	-17.2	60	-0.28	0.78	39	0.16
Elasticity	1.15	0.46	2.16	0.04		

Weight = Population

Constant	2.82	14	0.20	0.85	33	0.66
Elasticity	0.92	0.13	6.99	.00		

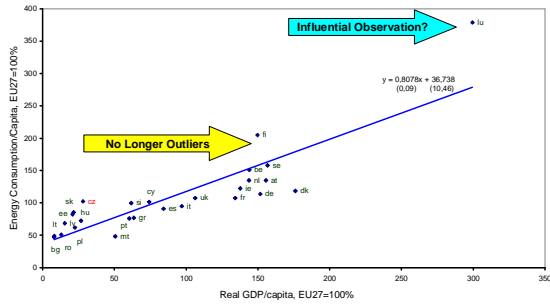
Weight = GDP PPP

Constant	2.01	32	0.06	0.95	34	0.30
Elasticity	0.93	0.28	3.28	0.00		

CERGE-EI

Predicting Future in the CZ - Energy

Real EU-27 GDP per capita and Energy consumption per capita



CERGE-EI

Predicting Future in the CZ - Energy

Weight = El. Energy Consumption

	Coeff.	St. Err	t-stat.	P-val.	Excess cons. (%)	R ²
Constant	-55	47	-1.16	0.27		
Elasticity	1.52	0.46	3.30	0.01	49	0.46

Weight = Population

	Coeff.	St. Err	t-stat.	P-val.	Excess cons. (%)	R ²
Constant	-37	32	-1.16	0.27		
Elasticity	1.34	0.32	4.22	0.00	44	0.58

Weight = GDP PPP

	Coeff.	St. Err	t-stat.	P-val.	Excess cons. (%)	R ²
Constant	-45	35	-1.28	0.22		
Elasticity	1.42	0.35	4.06	0.00	47	0.56

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Predicting Future in the CZ - Electricity

Countries	Electricity per capita consumption growth	GDP per capita growth	Income consumption elasticity
EU 27	24%	50%	0.48
EU 25	20%	42%	0.48
EU 15	36%	40%	0.90

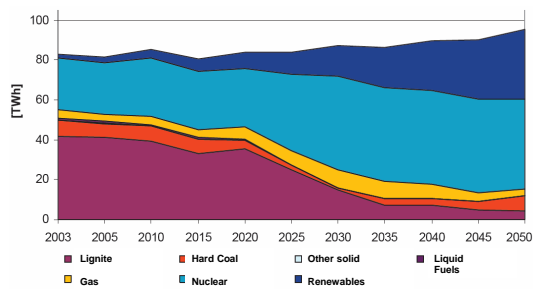
CERGE-EI

Predicting Future in the CZ - Electricity

Elasticity	Excess Consumption (%)	CZ GDP Growth (%)	CZ GDP EU 15 in 2030	EU15 increase (%)	CZ kWh per capita in 2030
0.8	0	3	1.01	134	7091
0.8	0	2.5	0.90	134	6290
0.8	15	3	1.01	134	8155
0.8	15	2.5	0.90	134	7234
1	0	3	1.01	144	7405
1	0	2.5	0.90	144	6569
1	15	3	1.01	144	8516
1	15	2.5	0.90	144	7554

CERGE-EI

Czech Republic - Forecast



Source: NEK Report, 2008

CERGE-EI