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"The DPRK Energy Sector: Demand and Supply Overview, and Key Areas for Assistance"

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Prepared for the DPRK Energy and Minerals Experts Working Group Meeting

September 21, 2010

Tsinghua University, Beijing, PRC

OUTLINE OF PRESENTATION:

- History of the DPRK Energy Sector
- Nautilus Approach to Estimating DPRK Energy Balance
  - Approach to Analysis
  - Selected Results
  - Next Steps
- Impacts of Energy Problems in the DPRK
- Assistance Approaches to Address DPRK Energy Problems
- Conclusions: Key Lessons for Providing Energy Sector Assistance in the DPRK

History of the DPRK Energy Sector

- Decline in the supply of imported crude oil in early 1990s (~stable since 2000, imports from China)
  - Basically no domestic crude oil production, though resources have attracted some attention by foreign companies
  - Two main refineries, one working at present
- Continuing degradation of electricity generation, T&D infrastructure
  - Some modest local rehabilitation of power plants and T&D systems, and some additions of new hydro facilities
- Continuing degradation of industrial, district heating facilities
- International trade in magnesite, expanding trade with China in coal/ores, ROK investments (until recently)

History of the DPRK Energy Sector

- Difficulties with transport of all goods, especially coal
- Coal production problems related to lack of electricity, flooding
  - Some reports of recent improvements in coal production, possibly through Chinese investment
- Sporadic, highly localized economic revival
  - Mostly in non-energy intensive sectors (markets, restaurants, small agriculture)
- End of KEDO Heavy Fuel Oil (HFO) deliveries
  - New HFO under 6 PT in more recent years
- Construction of small power plants (often not connected to main grid)
- Significant fuelwood/biomass use in rural (and some urban) areas (ongoing deforestation)

Introduction and Background: Nautilus Institute DPRK Energy Analysis

OVERALL APPROACH

- Obtain as much **information** as possible about the DPRK economy, energy sector from media sources, visitors to the DPRK, other sources
- Use available information, comparative analysis, and judgment to **assemble a coherent and consistent picture** of the DPRK energy sector
- Think about **possible future paths** for DPRK energy sector/economy, what changes (national, regional, global) might bring those paths about, implication of changes for end-use, infrastructure

DPRK ENERGY BALANCE UPDATE: OVERALL APPROACH

- Start with demand/supply estimates prepared for 1990, 1996, 2000, 2005
- Modification of 1990/96/2000/2005 estimates of demand for fuels to reflect reports of recent changes in conditions in the DPRK
- Revision of 2005 electricity supply estimates to meet 2008/9 demand, reflect thermal/hydro capacity/availability changes
- Estimation of 2008/9 oil supply reflecting available information (including “official” and "unofficial" trades)

DPRK ENERGY BALANCE UPDATE: OVERALL APPROACH

- Revision of oil products demand to meet the overall supply for major oil products
- Set level of coal and biomass supply to meet demand
  - Consistent with information about coal infrastructure, forest productivity
- Re-adjust supply/demand of other fuels as necessary to produce rough balance
- Overall, approach: Obtain all information germane to DPRK energy sector
  - Sift, fit with other data, prepare internally consistent energy balance

DPRK ENERGY BALANCE UPDATE: OVERALL APPROACH

- **Information collected from:**
  - Reports by others
  - Media reports
  - Official statistics of DPRK trading partners
  - Information on the DPRK from ROK government agencies
  - Reports of visitors to and observers of the DPRK
  - DPRK Energy Experts Working Group Meetings (June 2006, Stanford, CA, USA; March 2008, Beijing; September 2010, Beijing)

DPRK ENERGY BALANCE UPDATE: OVERALL APPROACH

- **Energy Balance Elements--Rows**
  - **Domestic resources extraction, imports, exports**
  - **Energy "transformation processes"– refining, electricity production, losses…**
  - **Energy demand sectors – industrial, residential, transport…**
- **Energy Balance Elements– Columns**
  - **Fuel/resource categories – in DPRK Energy Analysis work, general and by refined product**
- **For each fuel/resource considered, demand and supply must balance**
  - **Iterative analysis to balance columns**

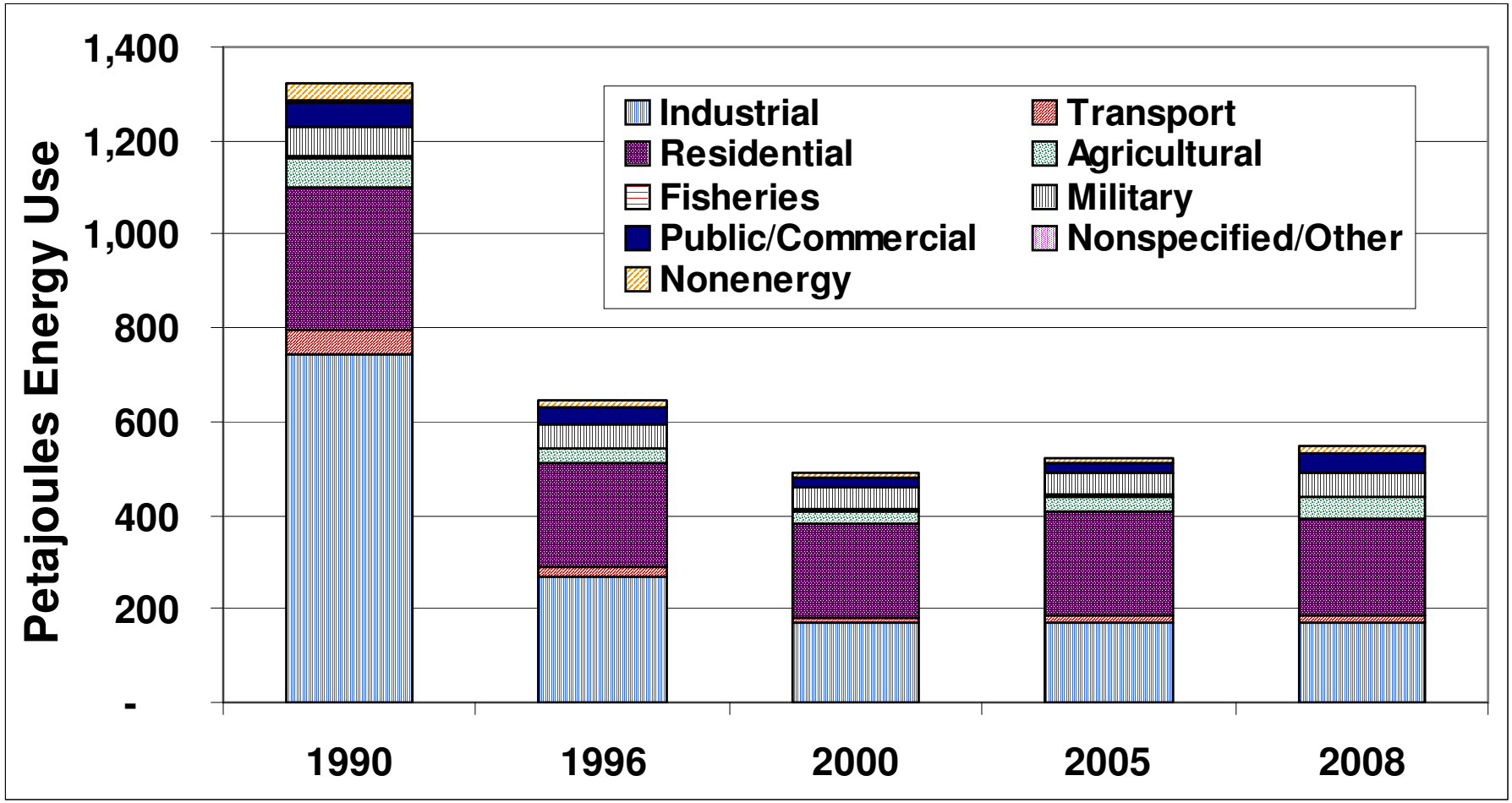
DPRK Energy Balance Update: Selected Results

UNITS: PETAJOULES (PJ)	COAL & COKE	CRUDE OIL	REF. PROD	HYDRO/ NUCL.	WOOD/ BIOMASS	CHAR-COAL	ELEC.	**TOTAL**
ENERGY SUPPLY	405	24	17	33	162	-	(0)	642
Domestic Production	480	1	-	33	150	-	-	665
Imports	5	22	17	-	12	-	0	57
Exports	80	-	0	-	0	-	0	80
Stock Changes	-	-	-	-	-	-	-	-
ENERGY TRANSF.	(117)	(24)	17	(33)	(4)	1	37	(121)
Electricity Generation	(88)	-	(5)	(33)	-	-	60	(66)
Petroleum Refining	-	(24)	24	-	-	-	-	(0)
Coal Prod./Prep.	(23)	-	-	-	-	-	(3)	(26)
Charcoal Production	-	-	-	-	(4)	1	-	(3)
Own Use	-	-	(1)	-	-	-	(4)	(5)
Losses	(6)	-	-	-	-	-	(16)	(21)
FUELS FOR FINAL CONS.	289	-	35	0	158	1	37	520
ENERGY DEMAND	289	-	35	-	158	1	37	520
INDUSTRIAL	150	-	8	-	0	-	14	172
TRANSPORT	-	-	9	-	1	-	4	14
RESIDENTIAL	94	-	3	-	118	1	4	220
AGRICULTURAL	8	-	1	-	25	-	1	35
FISHERIES	0	-	1	-	-	-	0	2
MILITARY	22	-	12	-	4	-	9	46
PUBLIC/COMML	14	-	0	-	4	-	5	23
NON-SPECIFIED			-					-
NON-ENERGY	2		1		6			9
Elect. Gen. (Gr. TWhe)	5.23	-	0.17	11.15	-	-	-	16.55

**Note: Gross terawatt-hours for coal-fired plants includes output for plants co-fired with coal and heavy fuel oil.*

Notes: 1 PJ is 10^{15} joules, ~ to energy in 24752 tonnes HFO; a 642 PJ/y economy is ~ of 15.5 million tonnes of HFO/yr
6-700000 tonnes HFO = ~ 4% DPRK annual energy use in 2005
~22 million North Koreans currently use about 3 * energy as ½ million Washington DC residents

DPRK Energy Balance Update: Selected Results (2008 results here preliminary)



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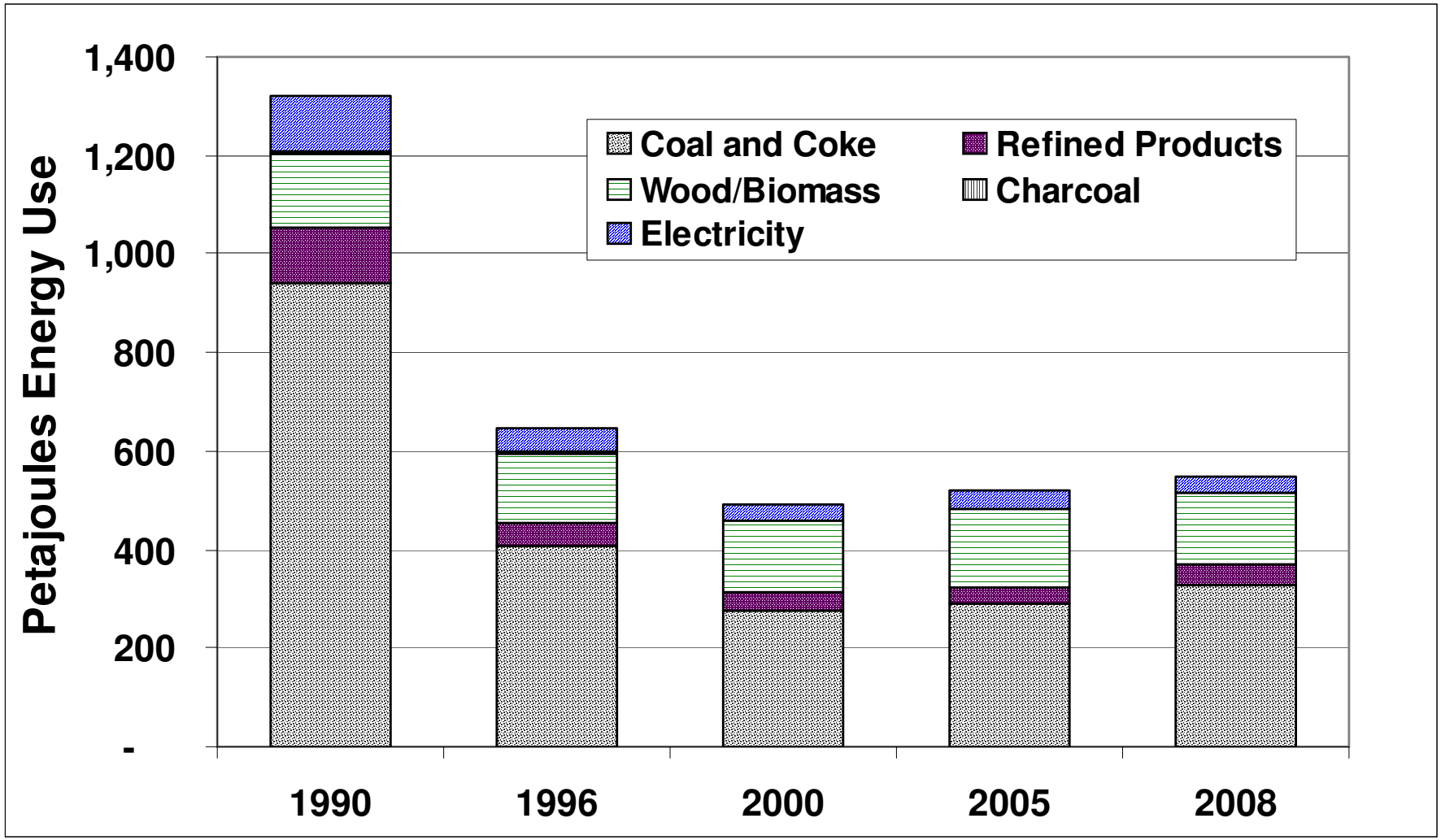
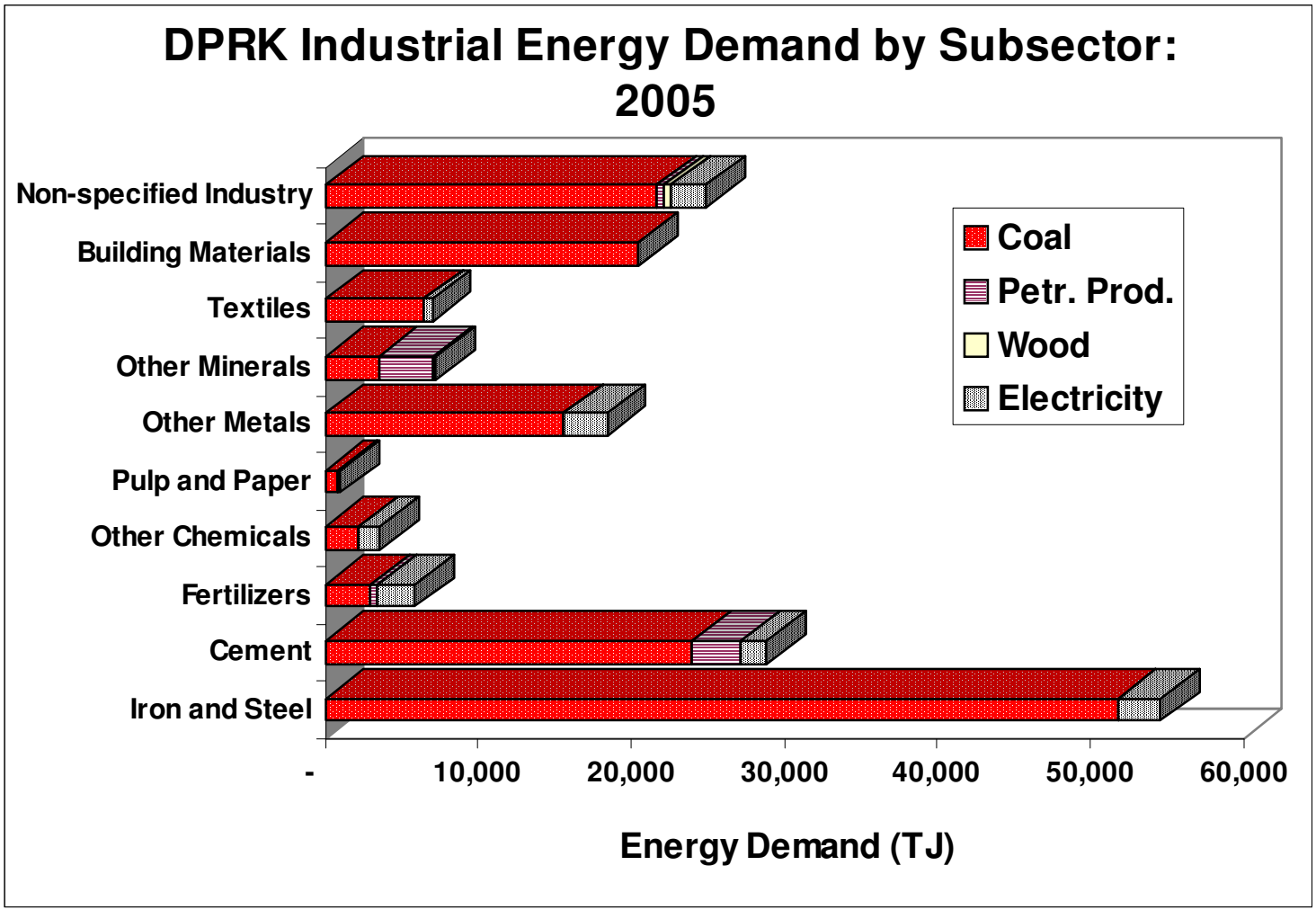


THE DPRK ENERGY SECTOR: Selected Results



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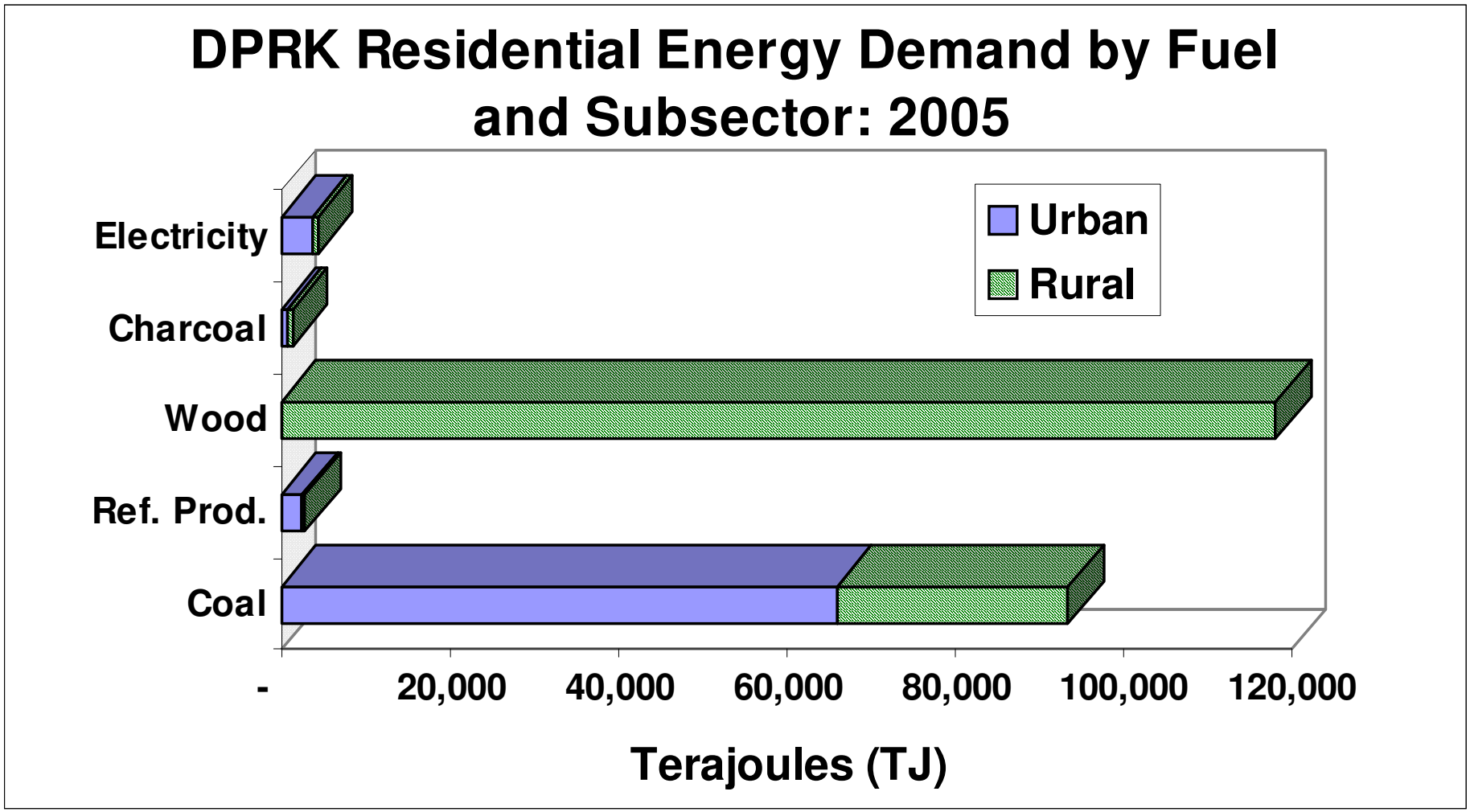

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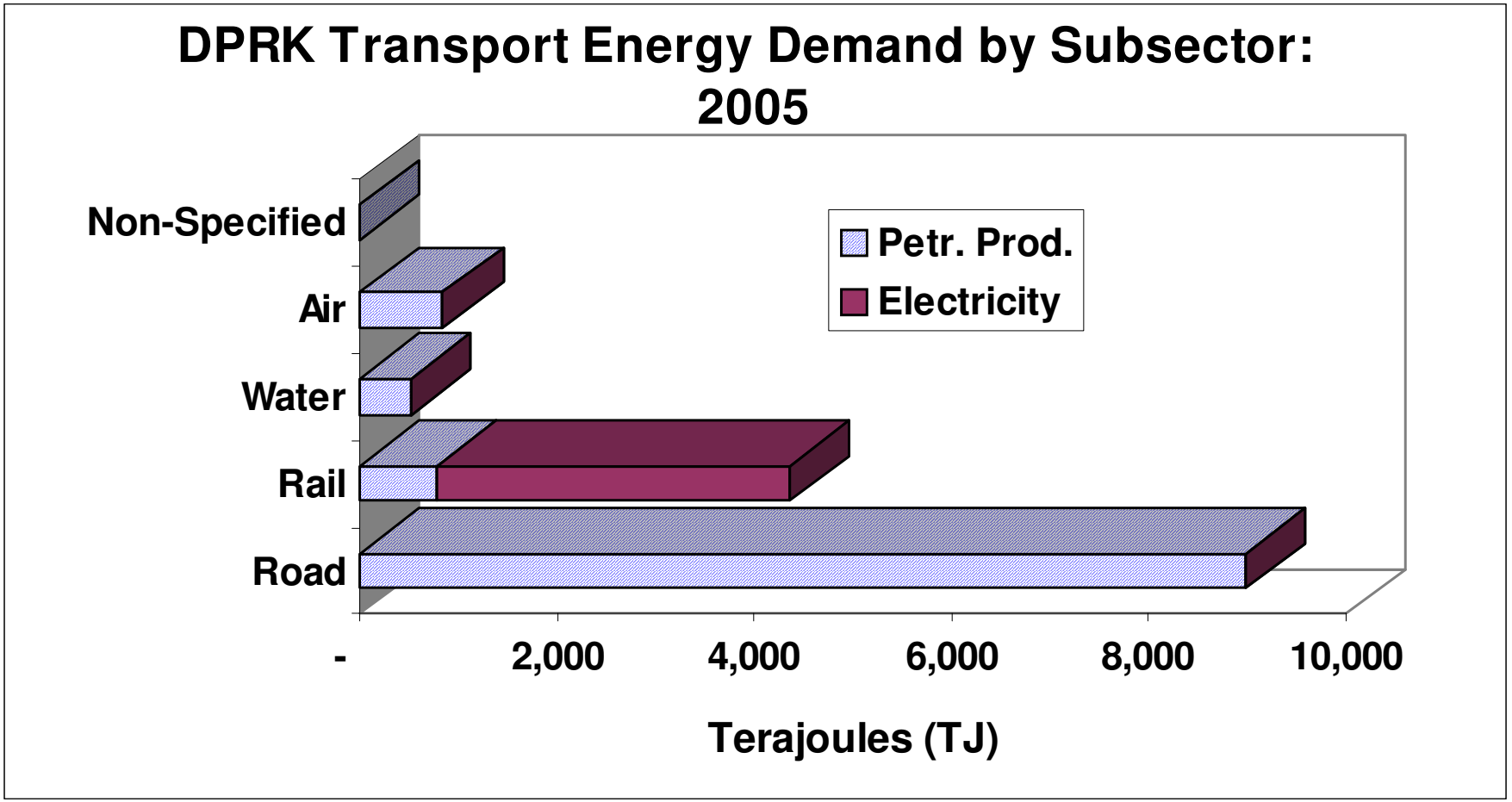

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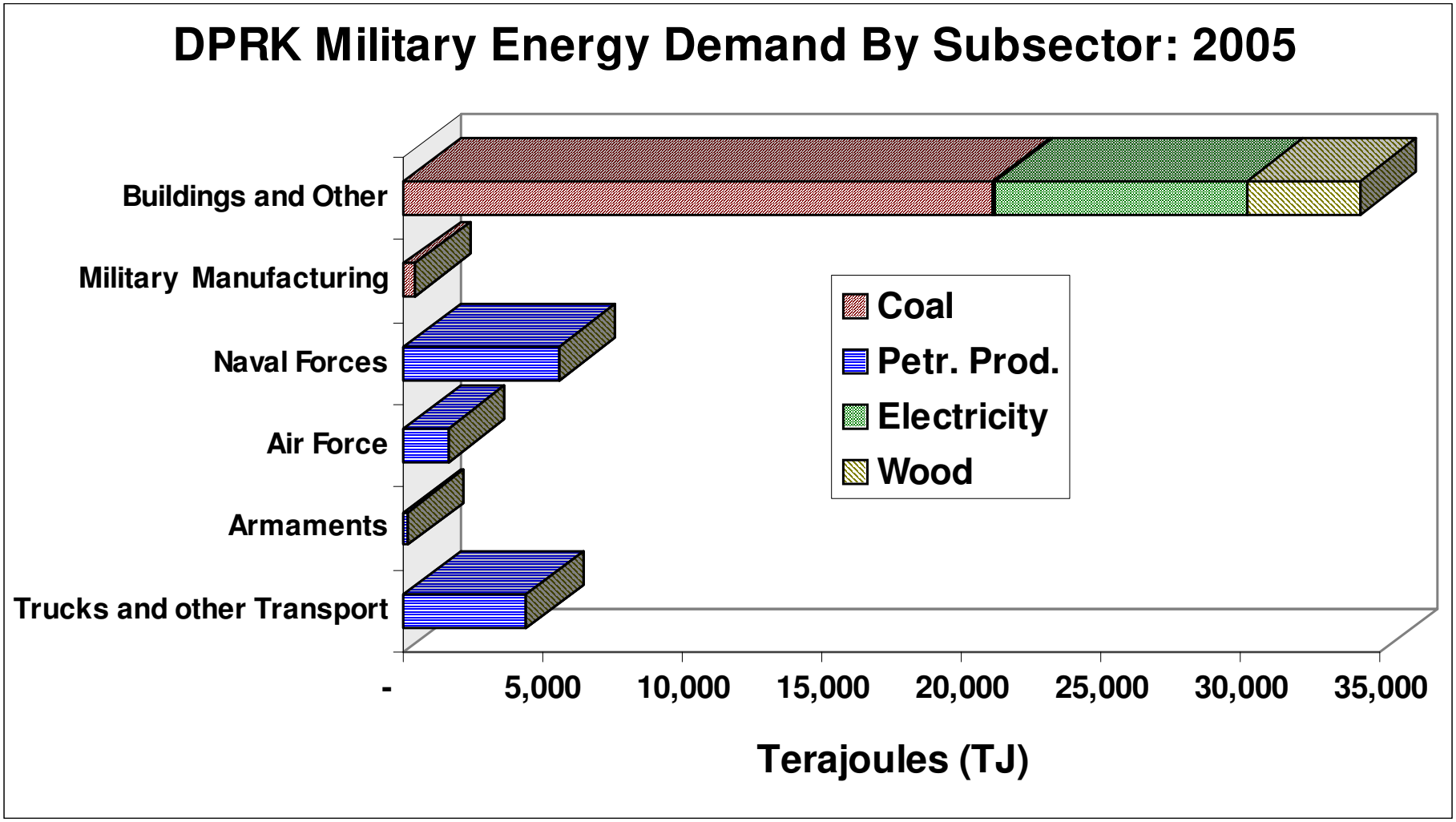

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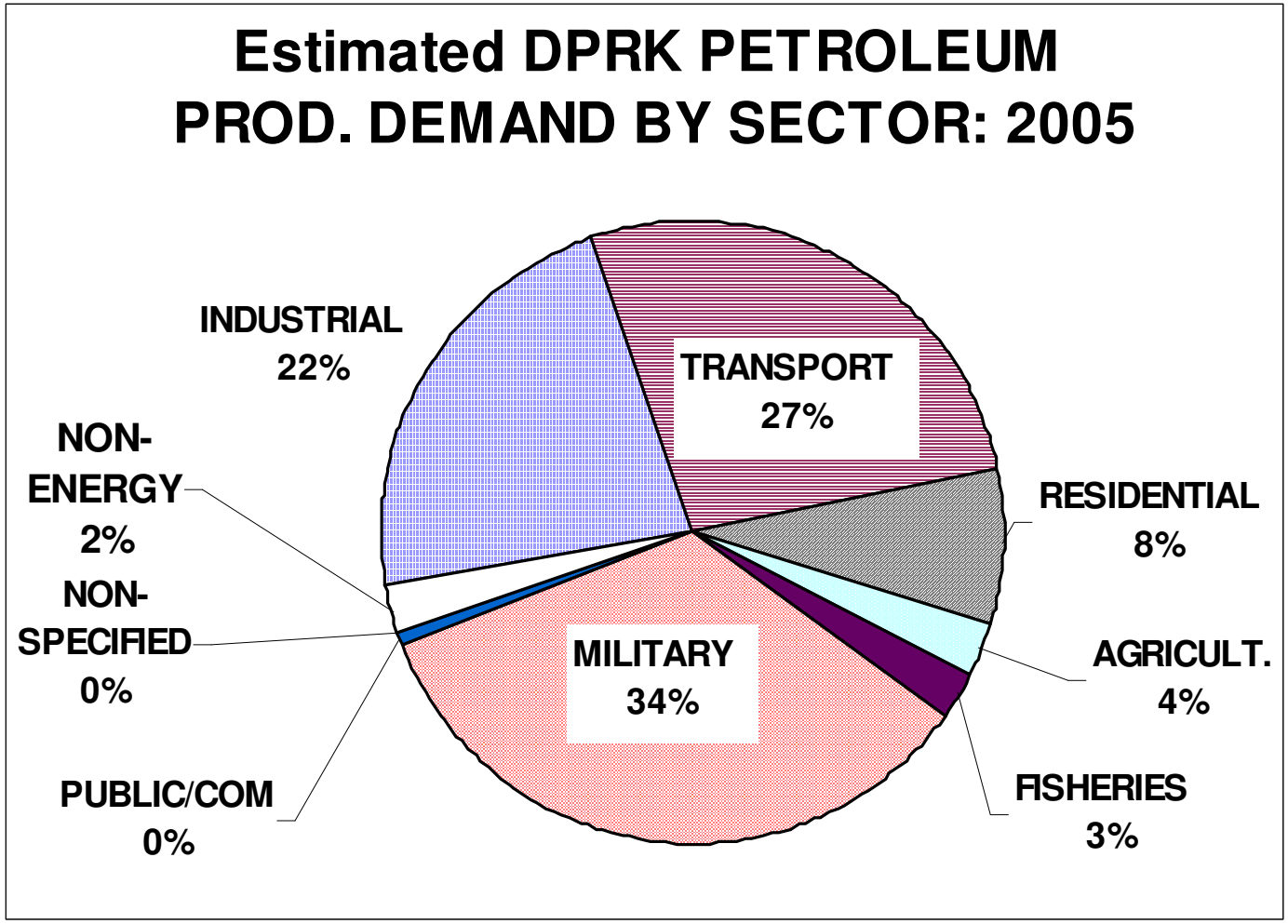

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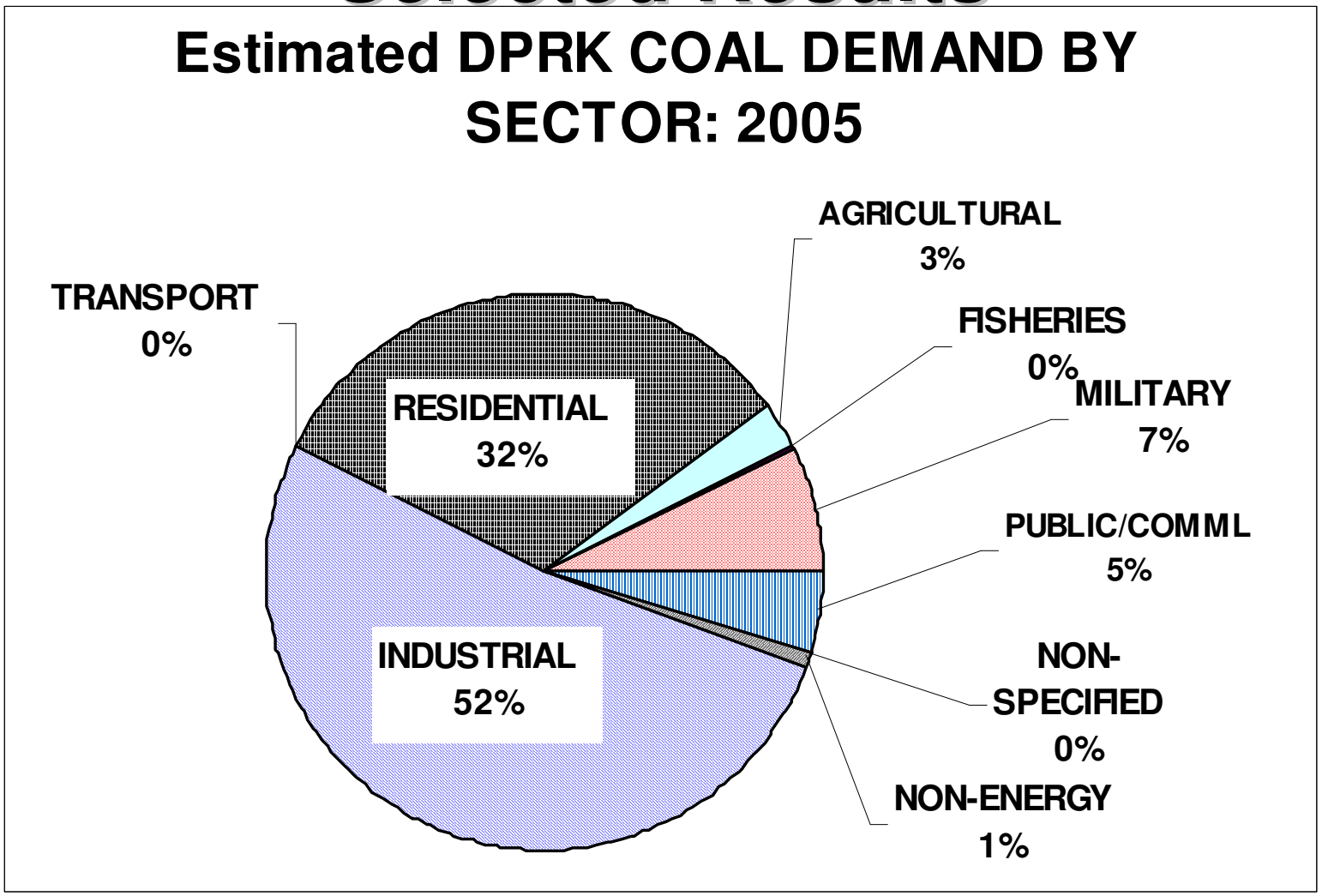
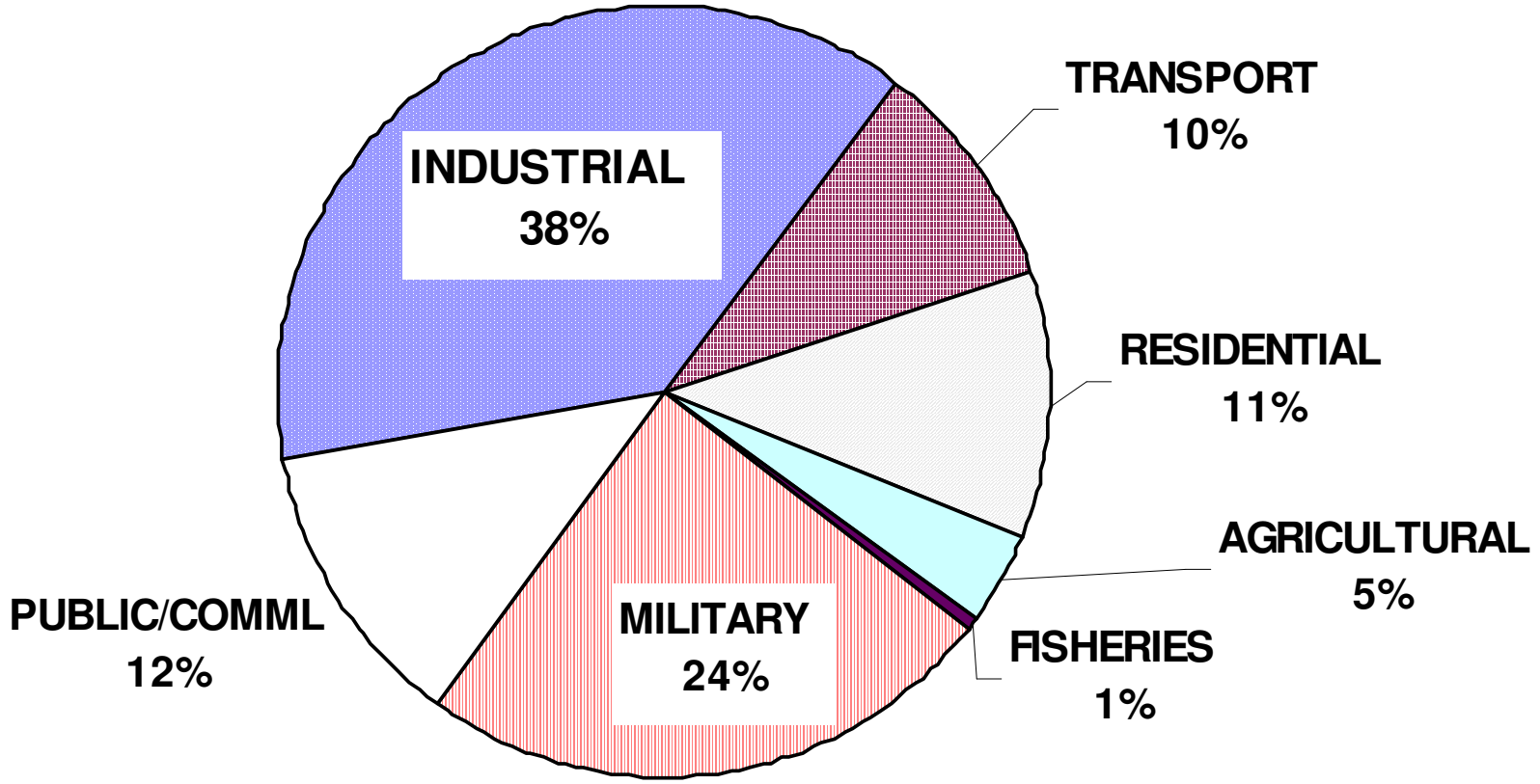


THE DPRK ENERGY SECTOR: Selected Results

Estimated DPRK ELECTRICITY DEMAND BY SECTOR: 2005



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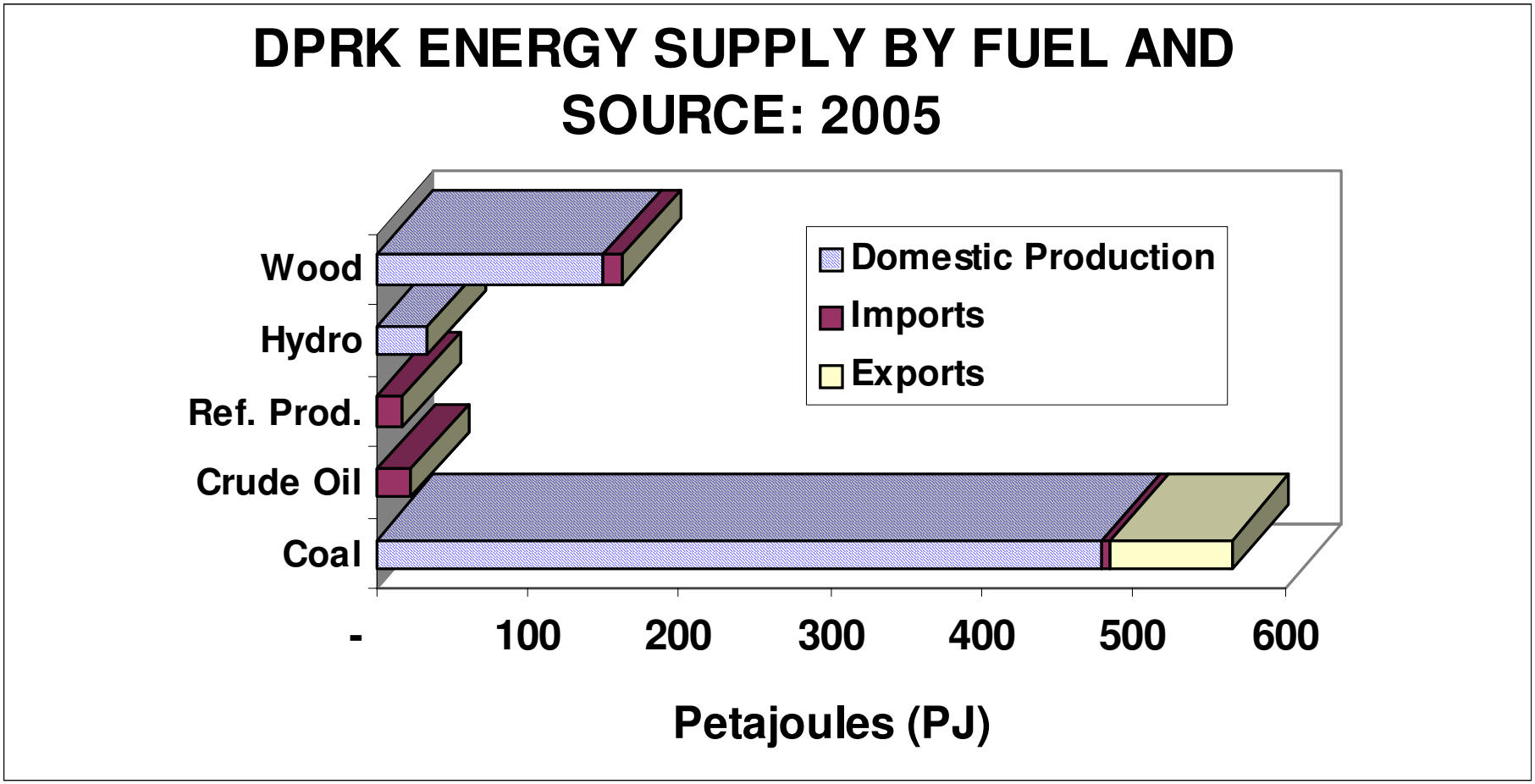

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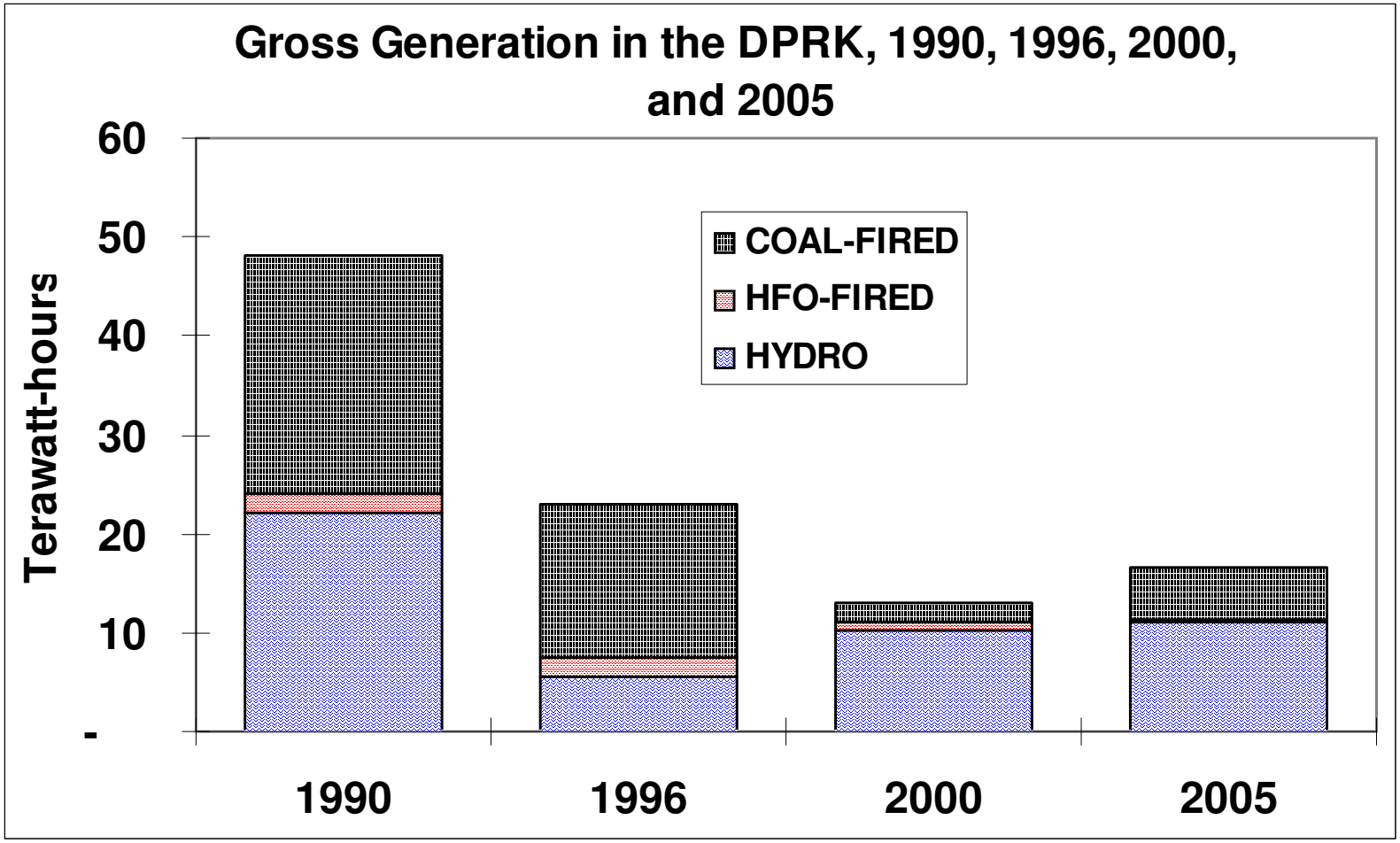
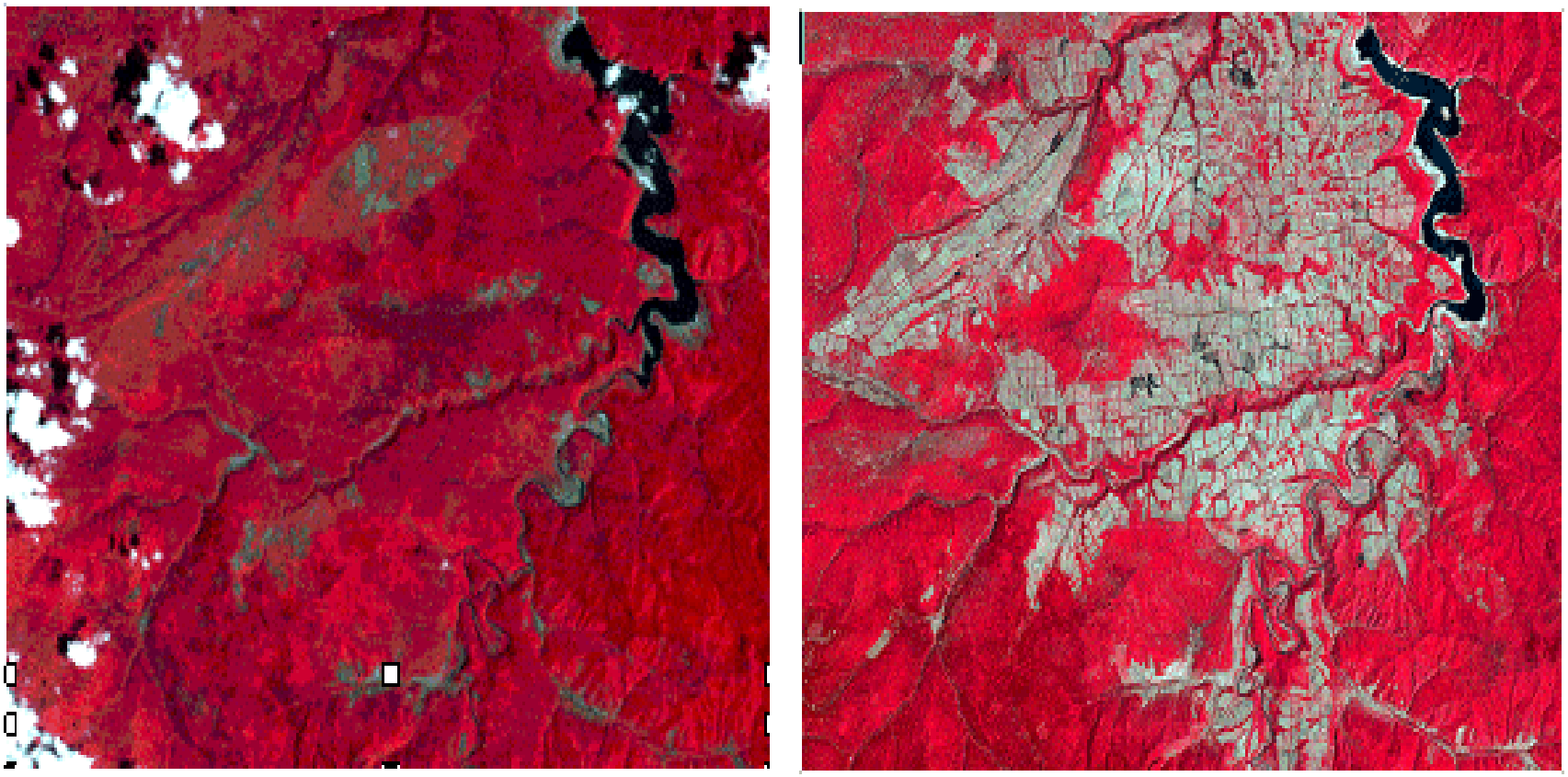


THE DPRK ENERGY SECTOR: RECENT TRENDS, FORESTRY

Landsat Images of an Area in the DPRK taken in 1981 (left) and 1993 (right)



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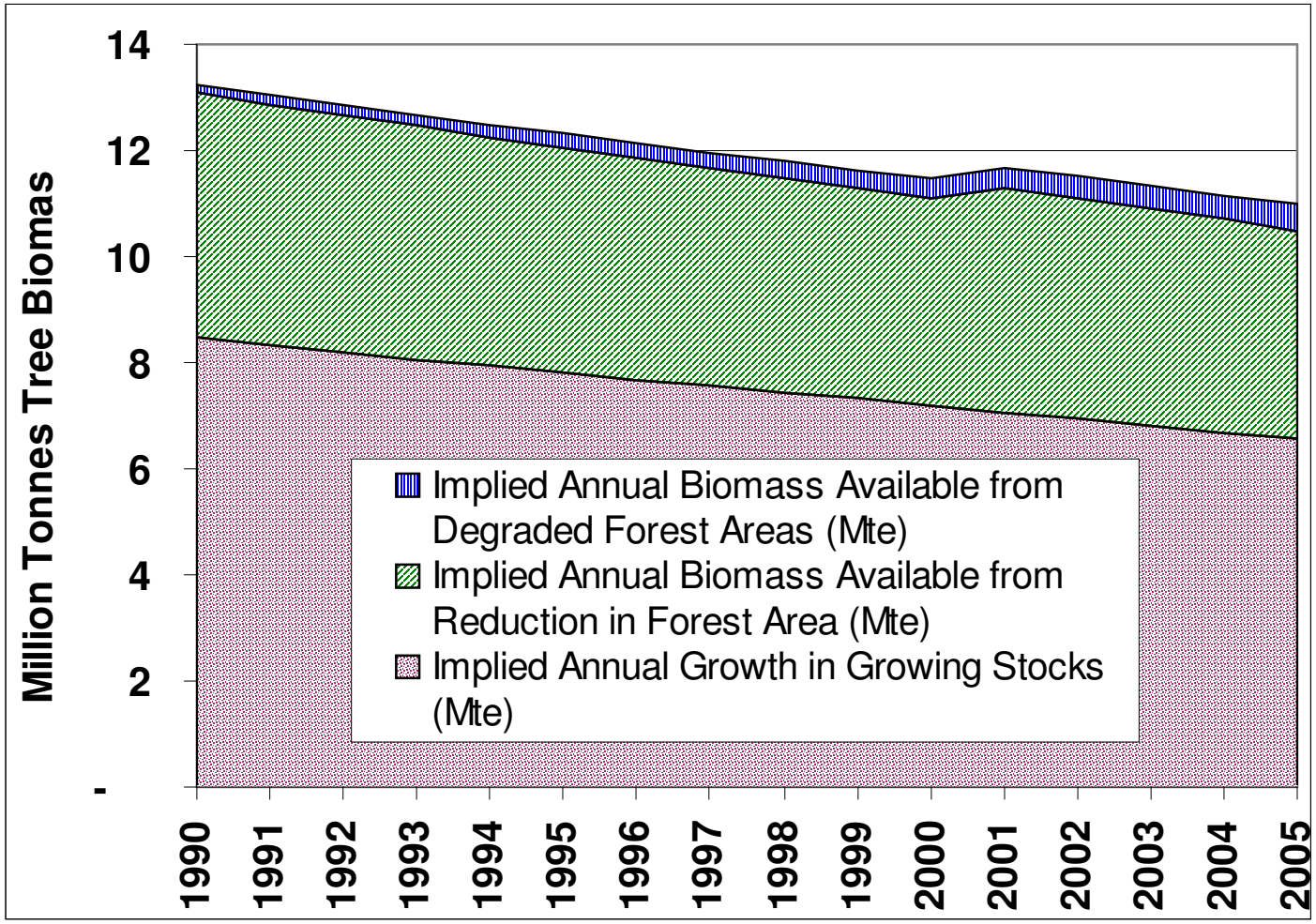


DPRK ENERGY DATABASE UPDATES: NEXT STEPS

- Continue review of available DPRK literature
- Evaluate information from 2010 Energy Experts Working Group meeting and to collect additional input
- Review what is known about DPRK resources, energy/industrial infrastructure, including talking with visitors
- Revise/rebalance analysis to produce 2008/2009 Energy Supply/Demand tables and related results
- Partially revise database/Report as appropriate
- Use Report results, other materials/ideas collected to work with others to identify and elaborate possible sets of activities to assist DPRK energy sector redevelopment

Impacts of Energy Problems in the DPRK

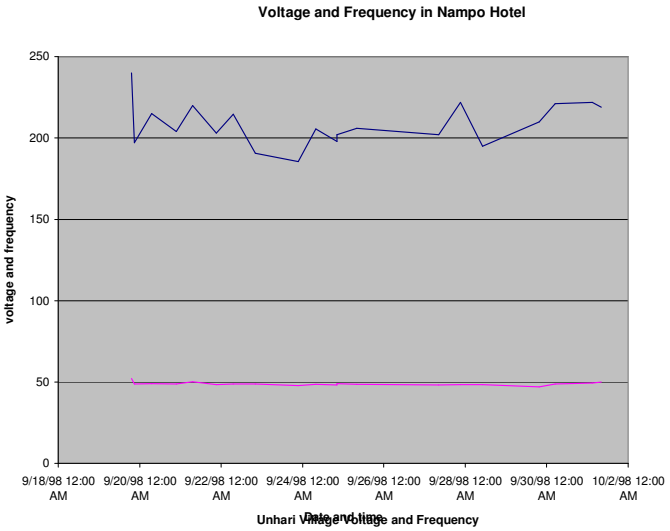
- Lack of fuels in many sectors of the DPRK economy has caused demand for energy services to go unmet
  - When and if supply constraints are removed there is likely to be a surge in energy (probably particularly electricity) use
  - The magnitude of such a surge will depend on the DPRK developing an economy that can pay for fuel supplies.
- The DPRK Electricity Sector
  - Status of electricity sector had/has/will have important political implications related to Simpo LWR project, regional electricity grid interconnection options
  - Thermal power generation system has been eroding significantly; only some boilers and turbines per plant operating, usually at low efficiency due to maintenance problems, sometimes lack of fuel
  - Hydroelectric plants important, but output limited by maintenance problems, seasonal nature of river flows in the DPRK
  - Construction of hydroelectric plants of various sizes (small/local, and a few larger plants) is a recent focus of DPRK energy policies
- Total estimated electricity supply: 1990: 46 TWh→1996: 23 TWh → 2000: 13 TWh →2005: 16.6 TWh, probably similar in 2008/2009

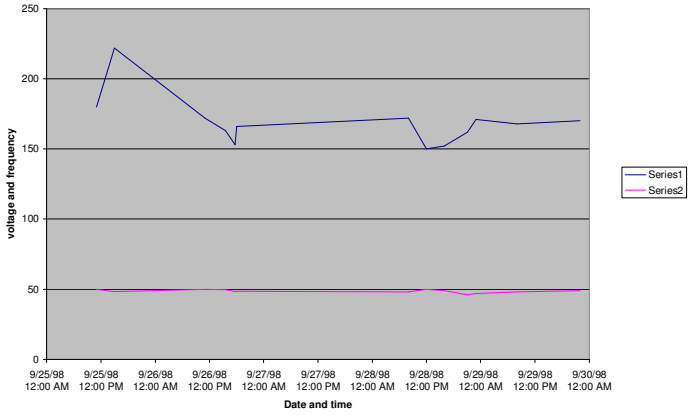
DPRK Energy Sector Problems

Continuing degradation of electricity generation, T&D infrastructure (Nautilus observations)

Frequency 50 Hz +/- 4 Hz

Voltage 230 V +/- 35%





Impacts of Energy Problems in the DPRK

- **Industry**
  - **Lack of consistent supplies of coal and electricity for industry have idled many, perhaps most of DPRK's industrial capacity, leaving workers also idled (though they may still have jobs)**
  - **Interconnections between energy supplies, lack of markets, parts for Soviet-built factories/power plants key complicating factors, requiring an integrated energy/economy solution**
- **Transport**
  - **Lack of gasoline, diesel fuel for trucks, buses, and cars, and electricity for trains and trams**
  - **Energy-related problems with obtaining spare parts for vehicles and transport systems**
  - **Affects agriculture, electricity generation as well**
  - **Lack of transportation fuels, especially in rural areas means most North Koreans are obliged to walk, ride bicycles, or use animal carts, hitch rides on (mostly military) trucks**

Scrapped DPRK Industrial Infrastructure (2000)

DPRK Transport: Images (rural/Pyongyang)

Impacts of Energy Problems in the DPRK

- **Agriculture**
  - **Lack of commercial fuels (electricity, diesel fuel) increases need for human, animal labor**
  - **More use of urban workers to help in agricultural activities**
  - **Lack of energy and equipment for proper and timely post-harvest processing cause crop losses (~15%)**
  - **Lack of energy in industrial sector has resulted in shortages of fertilizer, which have further depressed crop yields, and shortages of spare parts for agricultural equipment**
  - **Problem of lack of availability of electricity for irrigation has been improved somewhat by new major irrigation canals (in some areas)**
  - **Erosion of agricultural soils caused by deforestation due to use of biomass/wood as a substitute residential fuel**

Agricultural Energy Demand: Images

Impacts of Energy Problems in the DPRK

- **Residential/Institutional/Office/Military Units**
  - **Lack of availability of commercial fuel, largely coal, for cooking/space heating results (vary by region) in increased wood/biomass fuels use →deforestation, erosion, reduced soil fertility**
  - **In cities, lack of central heating plants/spare parts for plants means reduced/no heat to apartment blocks, offices, leaving buildings without heat and/or using small amounts of other fuels for heat (sometimes with indoor air pollution impacts)**
  - **In turn, lack of heat in the winter combined with other factors, increases illness, reduces productivity**
  - **Electricity outages reduce availability of light for study, other productive/social activities**
  - **Reduced availability of heat, electricity reduces services that can be offered in clinics, hospitals, schools, nurseries…**

Impacts of Energy Problems in the DPRK

- **Further Indirect "Political" Impacts**
  - **Lack of domestic oil and shortages of other fuels, coupled with limited opportunities to earn hard currencies to pay for imported fuel, are a factor in DPRK weapons sales/barter, weapons, other, sometimes allegedly illicit, activities, to earn hard currency**
  - **Lacking fuels to run a modern economy, the DPRK uses threat of military action to coerce**
  - **Lack of energy supplies affects DPRK's military security through shortage of fuels for military sector—substitution of nuclear for conventional deterrence may be one result**
  - **Lack of fuel supply to DPRK military also implies dependence on strategies other than prolonged battle to prevail in any conflict, namely overwhelming first-strike capability in conventional or nuclear weapons, or use of "nuclear umbrella" to support deterrence of attack by adversaries**

Assistance Approaches to Address DPRK Energy Problems

- **Assistance for internal policy and legal reforms to stimulate, sustain energy sector rebuilding, open opportunities for private companies**
  - **Capacity-building for reform of energy pricing practices, energy planning, training for energy sector actors, regulatory agencies, educational/research institutions, legal and financial sector**
- **Rebuilding of electricity transmission and distribution (T&D) system**
  - **Start by working collaboratively to define priorities, and with pilot installations in limited areas (associated with economic investments)**
- **Rehabilitation of power plants and other coal-using infrastructure**
  - **Small and medium boilers, power plants, steam lines**

Assistance Approaches to Address DPRK Energy Problems

- **Rehabilitation of coal supply and coal transport systems**
  - **Required for short- and medium-term economic improvement**
- **Development of alternative sources of small-scale energy, energy-efficiency measure implementation**
  - **Emphasis on fast, small and cheap, agricultural and humanitarian applications, support for economic development in specific areas. Energy efficiency is key to expanding availability of energy services**
- **Rehabilitation of rural infrastructure to improve agricultural production**
- **Begin transition to gas use with Liquid Petroleum Gas (LPG) networks**
  - **Clean burning, limited military diversion potential, modest investment costs**

Conclusions: Key Lessons for Providing Energy Sector Assistance in the DPRK

- A complex combination of historical economic dependencies, resource endowment, policy choices by the North Korean regime, and international responses to those policy choices → DPRK energy problems
- Impacts of energy problems in the DPRK affect every sector, human welfare
- Challenges for the international community in working with the DPRK to address its energy security problems are many, thus…
- Carefully considered energy assistance to DPRK in a broad suite of areas is needed, coordinated both with steps in addressing DPRK's nuclear weapons issue and with economic assistance of various types

Conclusions: Key Lessons for Providing Energy Sector Assistance in the DPRK

- Energy aid options for DPRK require consideration from many perspectives, or risk unintended consequences
  - Internally coordinate and phase aid projects to work well together, make sure DPRK's human, organizational capacity is developed to support sustainable, peaceful economy
- Help DPRK re-engage in regional energy/economic fora, complementing grassroots-level projects
  - Consider energy import/export needs, goals of regional players → integrate DPRK into regional energy economy
- Larger-scale options that contribute to regional (and Korean) economic integration are longer-term candidates
  - Set up by smaller, cheaper, quicker local projects, extensive human capacity-building
- Addressing DPRK's underlying needs for energy services required to sustainably solve nuclear weapons issue

THANK YOU!

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Additional Slides for Reference: Energy Efficiency Analysis and DPRK Energy Paths (~2007 results--not yet updated to 2008/9 base year)

THE DPRK ENERGY SECTOR: Energy Efficiency Analysis

MEASURES TO SAVE COAL:

Measure	Estimated Energy Energy Savings Potential, TJ/yr		Total Estimated Investment Cost, $US 2005
TOTALS	115,000	TJ/yr	$ 529,300,000
Avoided Losses of Coal During Transport:	1,200	TJ/yr	
TOTAL COAL SUPPLY SAVINGS	116,000	TJ/yr	
Fraction of 2005 Total Coal Supply	28.7%		
Investment required, $ per GJ/yr of Coal Supply Savings			**$ 4.55**
Investment required, $ per tce/yr of Coal Supply Savings			**$ 133**

MEASURES TO SAVE/GENERATE ELECTRICITY:

Measure	Estimated Energy Energy Savings Potential, TJ/yr		Total Estimated Investment Cost, $US 2005
TOTALS	15,240	TJ/yr	$ 844,000,000
Additional Avoided T&D Losses (based on 2005 Rates)	1,490	TJ/yr	
TOTAL ELECTRICITY SUPPLY SAVINGS/GENERATION	16,720	TJ/yr	
Fraction of 2005 Total Electricity Generation	28.1%		
Investment required, $ per GJ/yr of Electricity Supply Savings/Generation			**$ 50.47**
Investment required, $ per MWh/yr of Electricity Supply Savings/Generation			**$ 182**

PREPARATION AND ANALYSIS OF ENERGY PATHS FOR THE DPRK

- Goals/Philosophy of Paths Analysis
  - **Assemble** plausible, potentially achievable, internally-consistent alternative energy paths for the DPRK, based on best information available—**not judgments** on what **would** or **should** happen
  - **Explore**, quantitatively/qualitatively, relative energy security implications of different paths, including the implications of energy sector cooperation between countries of Northeast Asia
  - Use energy paths as **focus, starting point** to talk about how to **assist in sustainable re-development** of DPRK energy sector
  - Hope to **work with DPRK colleagues** to improve analysis, make more applicable

PREPARATION AND ANALYSIS OF ENERGY PATHS FOR THE DPRK

- Overall Approach in Paths Preparation/Evaluation
  - Start with older DPRK LEAP dataset that includes several paths evaluated briefly in previous work
  - Update data set to reflect most recent Nautilus estimates of 1996, 2000, 2005 DPRK energy use (overall analysis period for paths, 1990 to 2030)
  - Develop overall “themes” for paths to be evaluated
  - Identify specific assumptions for use in implementing the themes within LEAP
  - Modify paths so that all paths have the same 2005/2007 energy picture

PREPARATION AND ANALYSIS OF ENERGY PATHS FOR THE DPRK

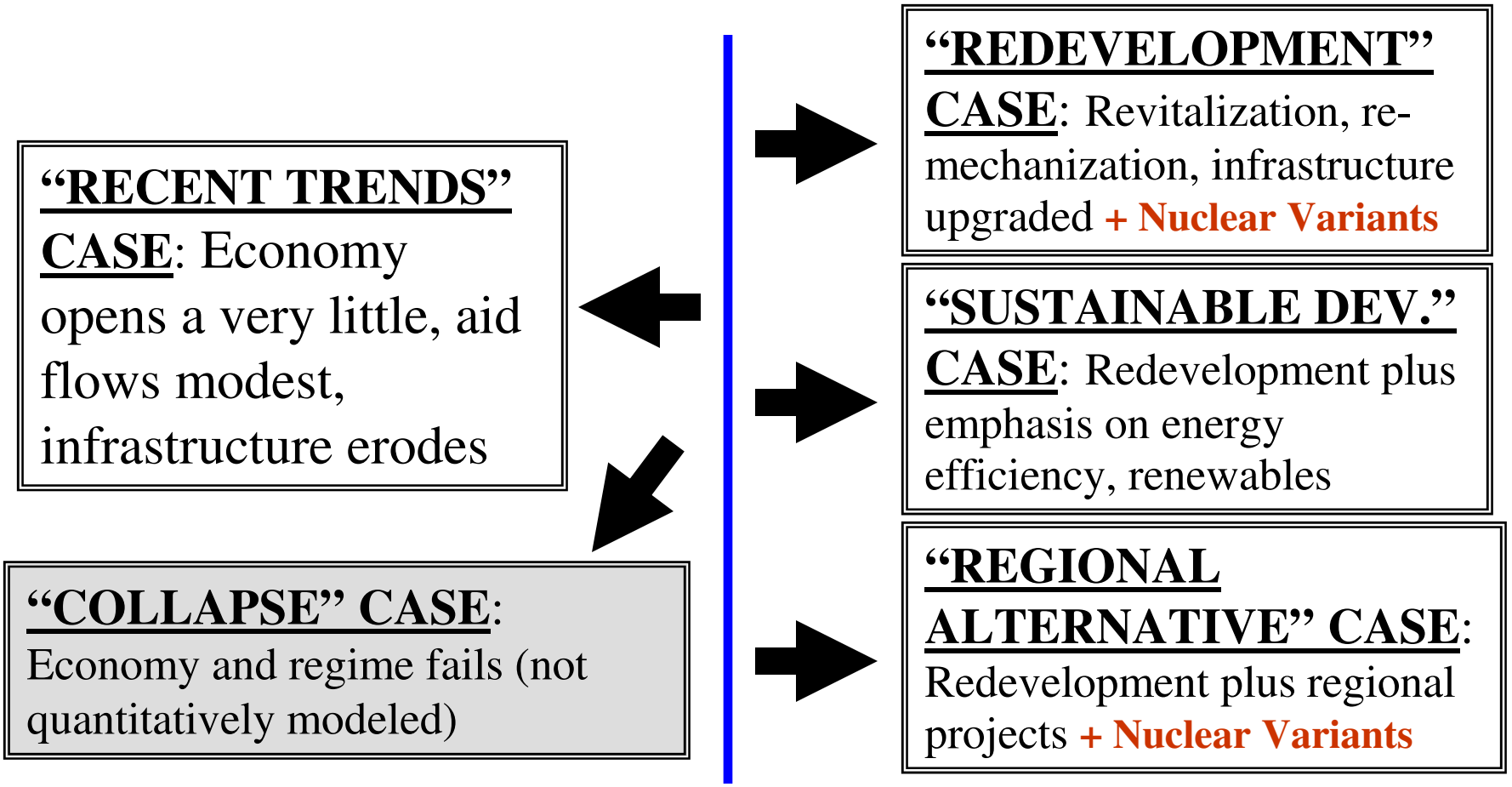
- Overall Approach in Paths Preparation/Evaluation
  - Prepare demand-side data entries (and document assumptions in Excel workbook)
  - Enter demand-side assumptions in LEAP
  - De-bug demand-side datasets
  - Prepare approximate supply-side data entries (and document in Excel workbook)
  - Enter supply-side assumptions in LEAP (including nuclear energy path variants), calculate, and modify parameters so that supply and demand balance
  - Enter cost and environmental data for all paths
  - Run all paths, check results, debug, re-run, and evaluate relative demand, transformation, cost, environmental results of paths
  - Do off-line calculations (including, for example, spent fuel estimates) using LEAP results in Excel as needed

DPRK Energy Paths Considered

POLITICAL STALEMATE IS….

NOT RESOLVED

RESOLVED



DPRK ENERGY PATHS CONSIDERED

"Redevelopment" Path

- Used as National **Reference** path for DPRK
- Current political stalemate solved within next few years, DPRK receives international assistance/cooperation in redevelopment
- Industrial sector is revitalized, but mostly not rebuilt as it was before
  - More iron and steel from scrap, efficiency improvements in iron and steel, cement
  - Most industry 50% of 1990 output by 2015, growth at 1.5%/yr thereafter; textiles, fertilizer higher
  - Natural gas begins to be used in industry ~2015

DPRK ENERGY PATHS CONSIDERED

"Redevelopment" Path (continued)

- Considerable increase in new light-industrial production (IT, auto parts, joint ventures…)
  - Increase in diesel, electricity use for light industry
- Agricultural sector re-mechanized
  - Cropped area decreases, but electricity, oil use in agriculture increases (coal/biomass use decreases)
- Increase in residential electricity consumption
  - Fraction of population in urban areas increase
  - Consumption of electricity, LPG, kerosene increase, NG use begins, coal use declines
- Commercial sector expands rapidly

DPRK ENERGY PATHS CONSIDERED

"Redevelopment" Path (continued)

- Transport use, particularly personal transport, expands
  - Civilian auto, plane, train, bus transport per person rise
  - Efficiency improvements in road, rail transport modes
- Investment in new electricity infrastructure
  - New coal, gas CC, some rehabilitation, particularly hydro, new small hydro, existing coal plants retired, Simpo reactors completed 2013 (export power) in one variant of path
- Re-investment in East Coast refinery
  - Back on line by 2012, expanded 2015 (including power plant)
- Natural gas, first as LNG, begins to play a role in powering industry, electricity generation, urban residences starting in about 2012-2015
  - Smaller LNG terminal built (Nampo?), part of output exported

DPRK ENERGY PATHS CONSIDERED

"Recent Trends" Path

- Assumes that current political difficulties remain, or are addressed only very slowly
- DPRK economy opens a very little, aid flows modest, infrastructure erodes
- Very gradual increase in industrial output relative to 2000 (after 2005), intensities remain high
- Transport activity increases slowly
- Residential energy demand increases slowly
  - Continued emphasis on coal, electricity gradually more available
- Some modernization/re-mechanization of agriculture
- Commercial sector floorspace, electricity/coal use grow somewhat

DPRK ENERGY PATHS CONSIDERED

"Recent Trends" Path (continued)

- Transmission and distribution losses remain high through 2015, decrease slightly after 2015
- 10 MW of small hydro power plants are added each year from 2005 on
- Total capacity at existing hydro and oil-fired power plants does not change over time
- Simpo nuclear reactors not completed
- Oil products (except KEDO HFO) continue to be imported at year 2000 levels
- West Coast refineries continue to operate

DPRK ENERGY PATHS CONSIDERED

"Sustainable Development" Path

- Same energy services as "Redevelopment" Path—with same demographic assumptions, economic output—but…
- Applies energy efficiency, renewable energy, other measures, in an aggressive fashion
  - Upgrading of industrial infrastructure goes above average standards to high-efficiency international standards
  - Rapid phase-out of existing coal-fired power plants.
  - Earlier addition of LNG (liquefied natural gas) terminal and gas CC (combined cycle) generating plants

DPRK ENERGY PATHS CONSIDERED

"Sustainable Development" Path (continued)

- Costs
  - **Cost estimates** included for all demand end-uses, transformation processes, and fuels whose use changes relative to the Redevelopment case

DPRK ENERGY PATHS CONSIDERED

"Regional Alternative" Path

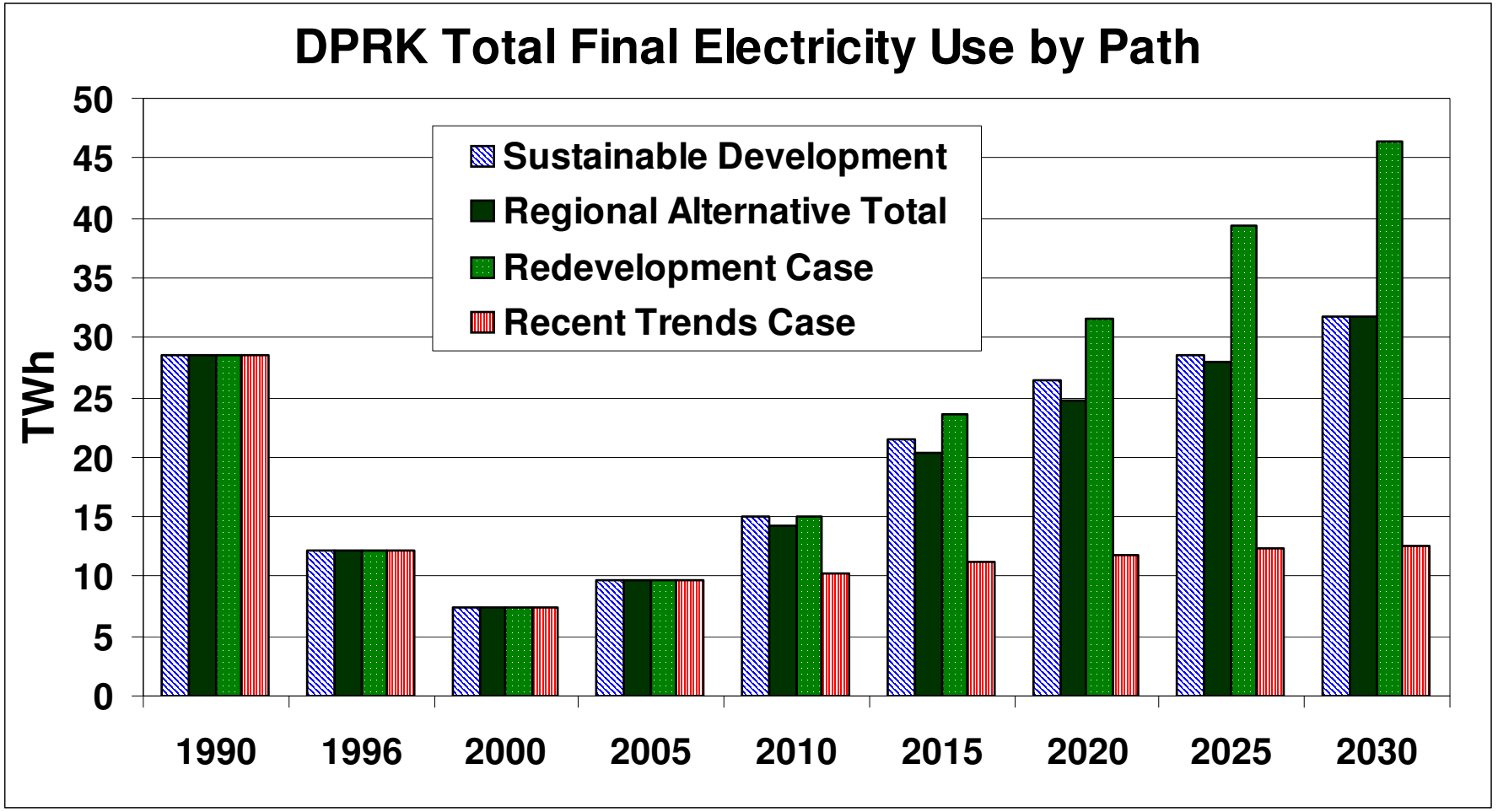
- Demand-sector Modifications
  - As a result of regional cooperation, efficiency improvement targets reached two years earlier at costs 10% less than in Sustainable Development path
- Transformation-sector Modifications
  - Gas pipeline from RFE begins operation in 2011; 3% of gas used in DPRK initially, 10% by 2020, 15% by 2030
  - DPRK gets $10 million/yr "rent" for hosting the pipeline
  - Larger LNG facility installed (also shared with ROK)
  - Power line from the Russian Far East through the
  - Participation in regional cooperative activities in energy

DPRK ENERGY PATHS CONSIDERED

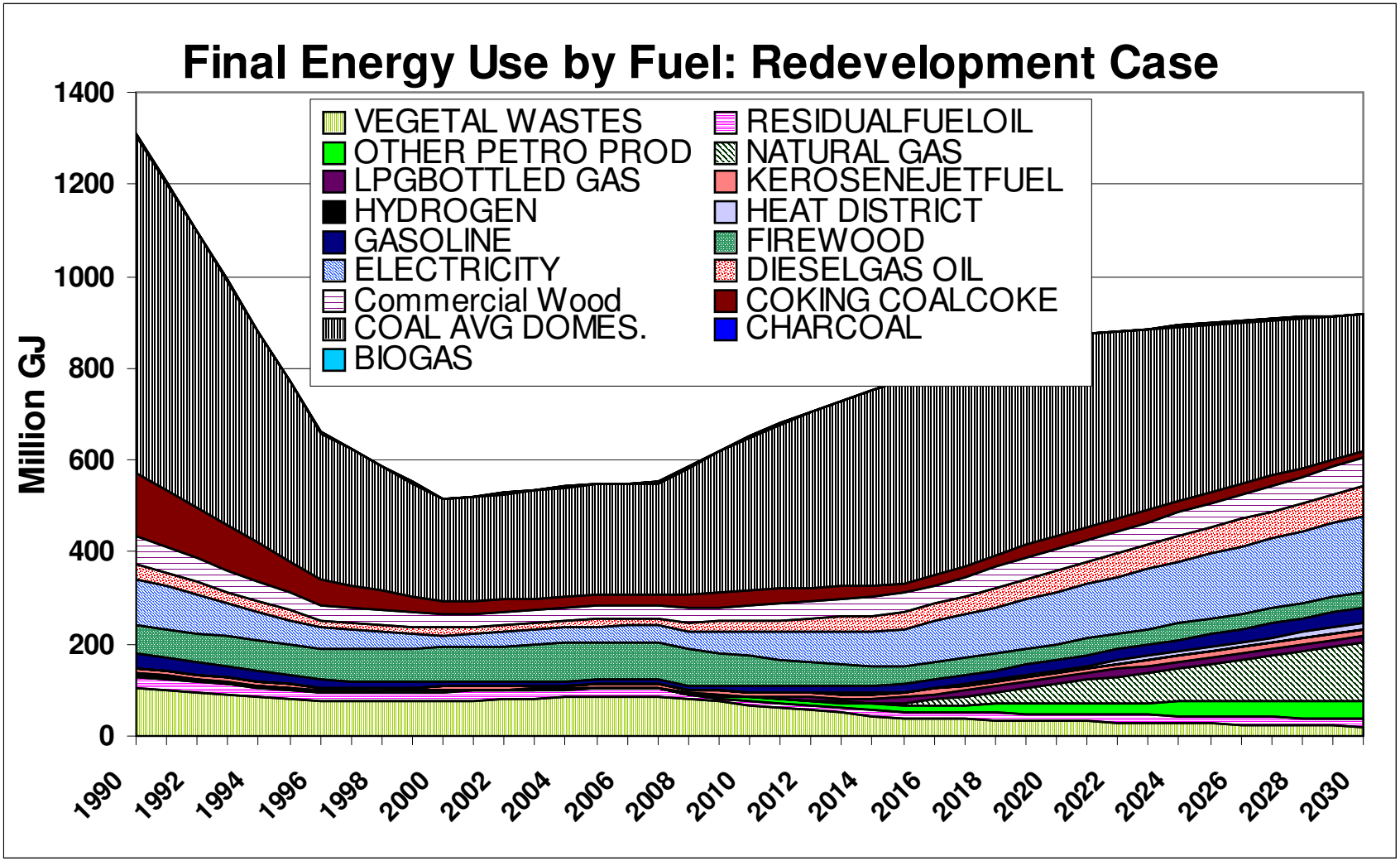
"Regional Alternative" Path (continued)

- Transformation-sector Modifications (continued)
  - Cooperation in renewable energy technologies yield earlier deployment,10% reduction in cost of wind, small hydro technologies
  - Last of existing coal-fired plants retired by 2020
- Sustainable Development/Regional Alternative Path Costs
  - **Cost estimates** included for all demand end-uses, transformation processes, and fuels whose use changes relative to the Redevelopment case

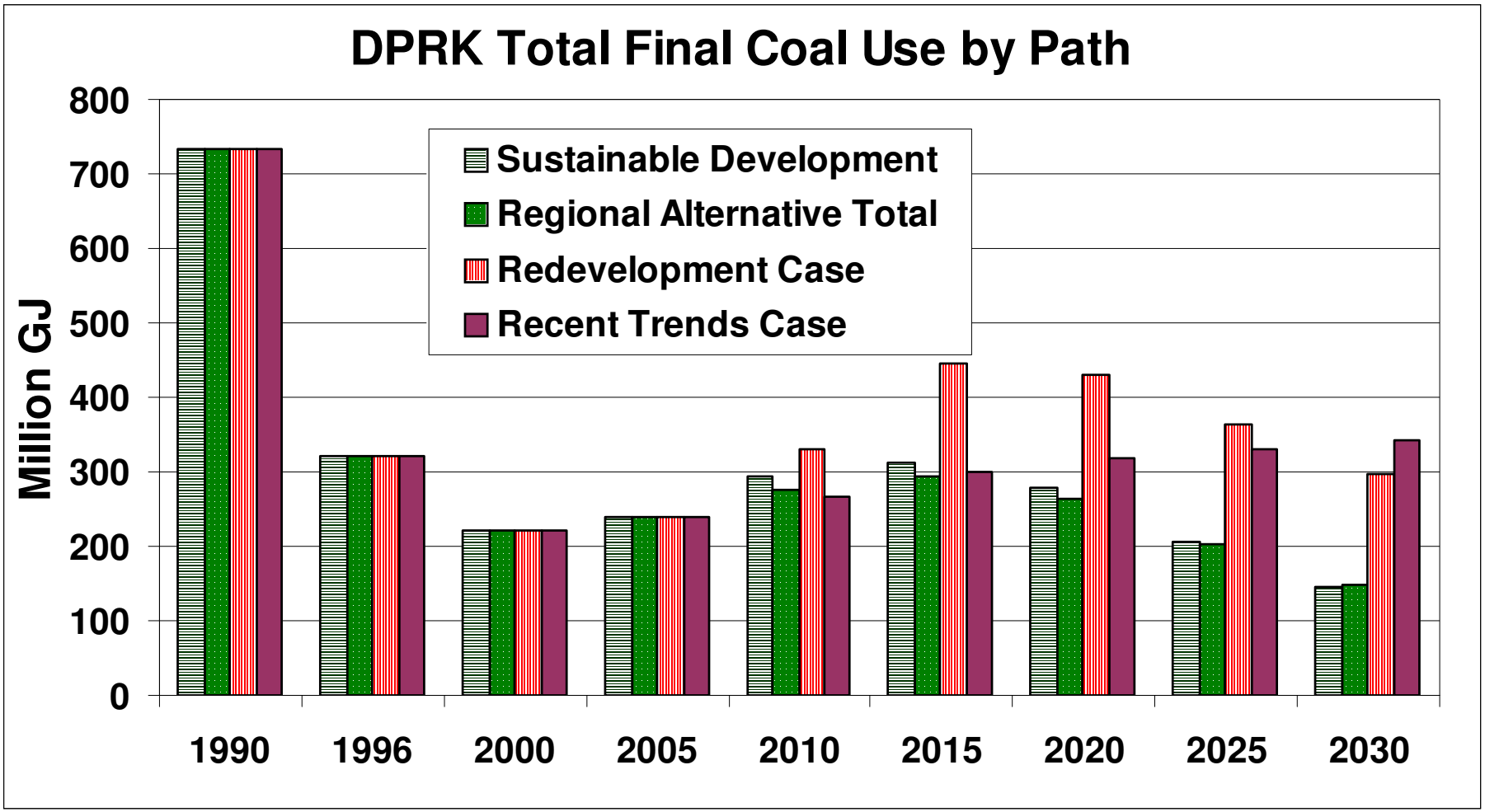
DPRK ENERGY PATHS: SELECTED DRAFT RESULTS



DPRK ENERGY PATHS: SELECTED DRAFT RESULTS



DPRK ENERGY PATHS: SELECTED DRAFT RESULTS



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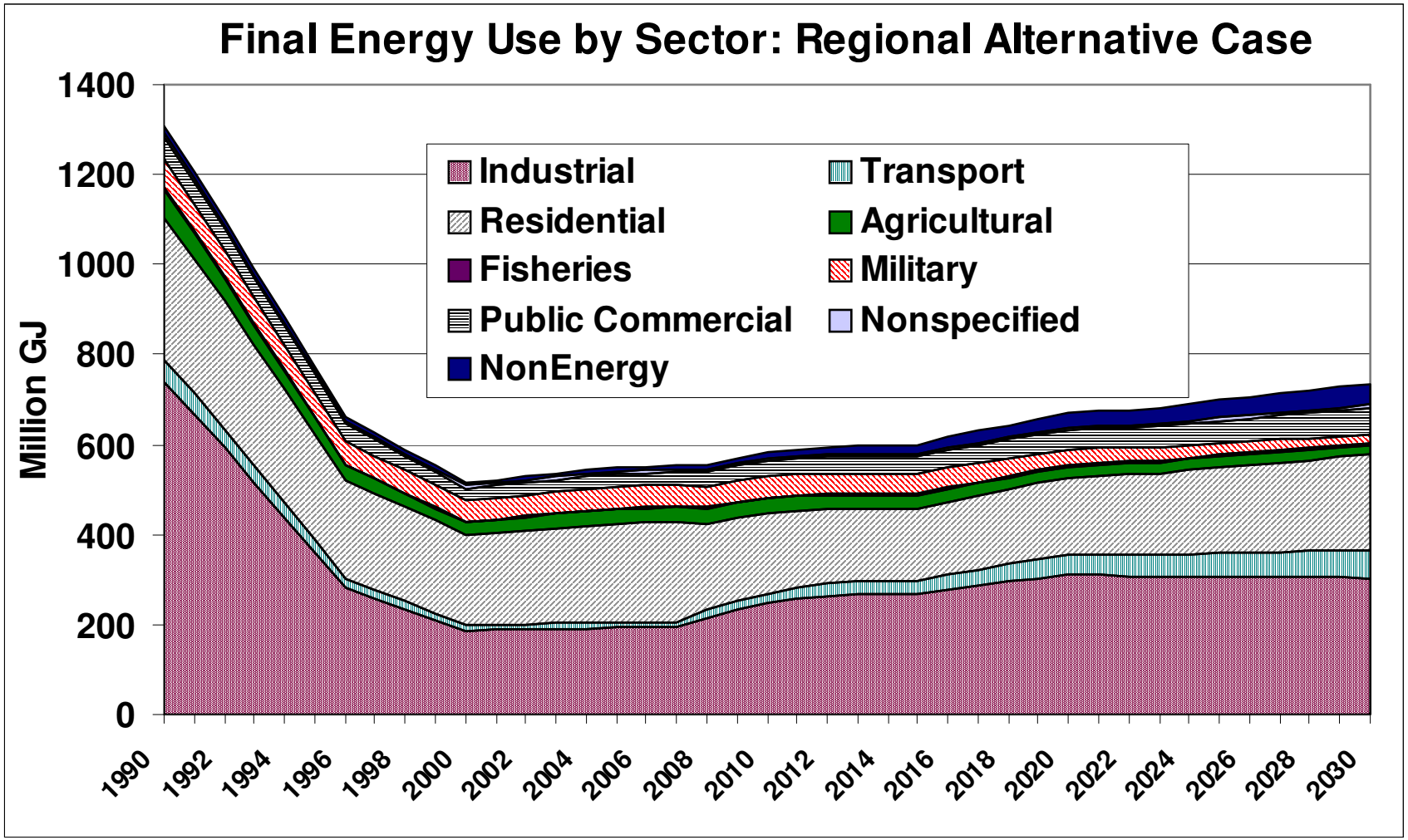

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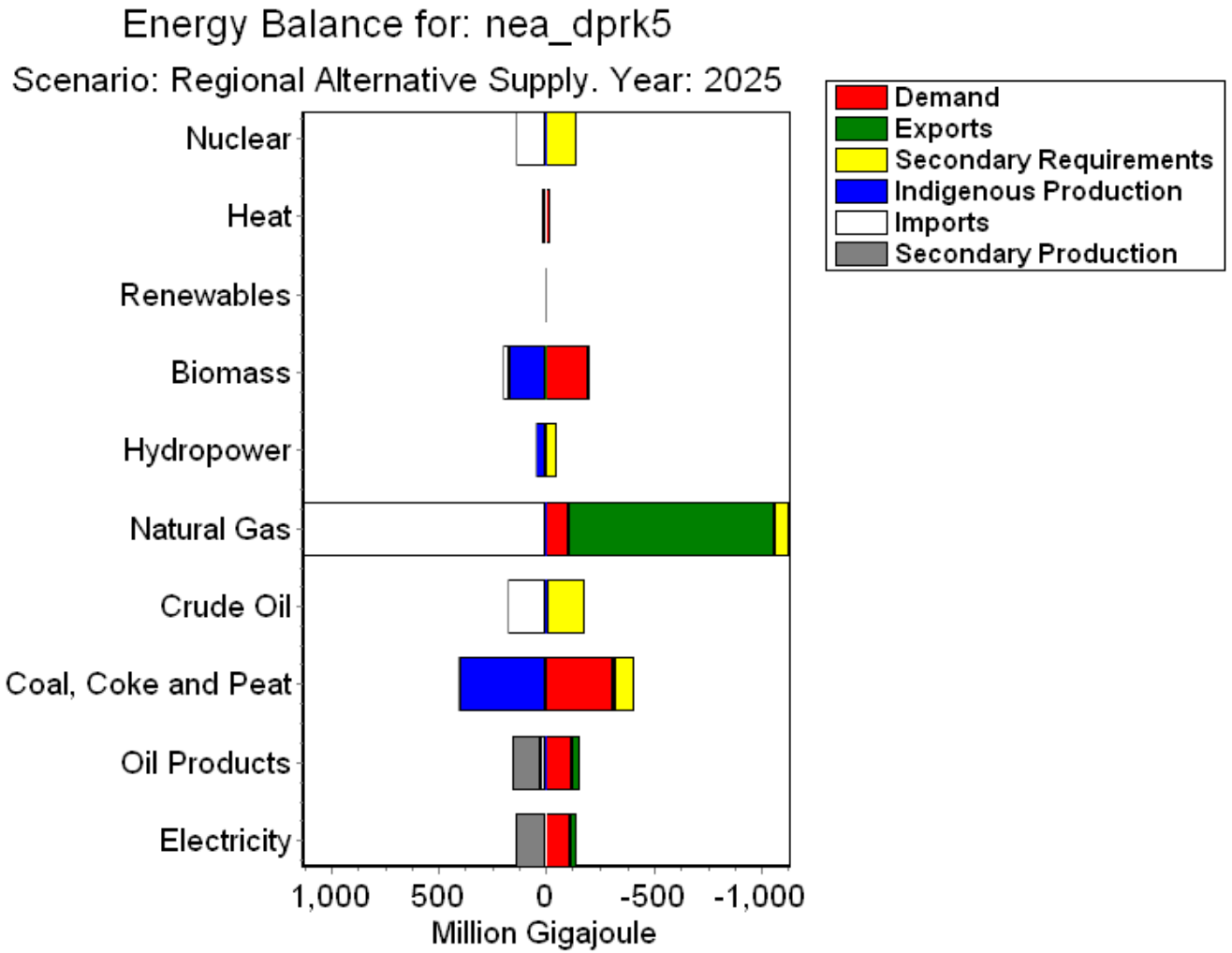

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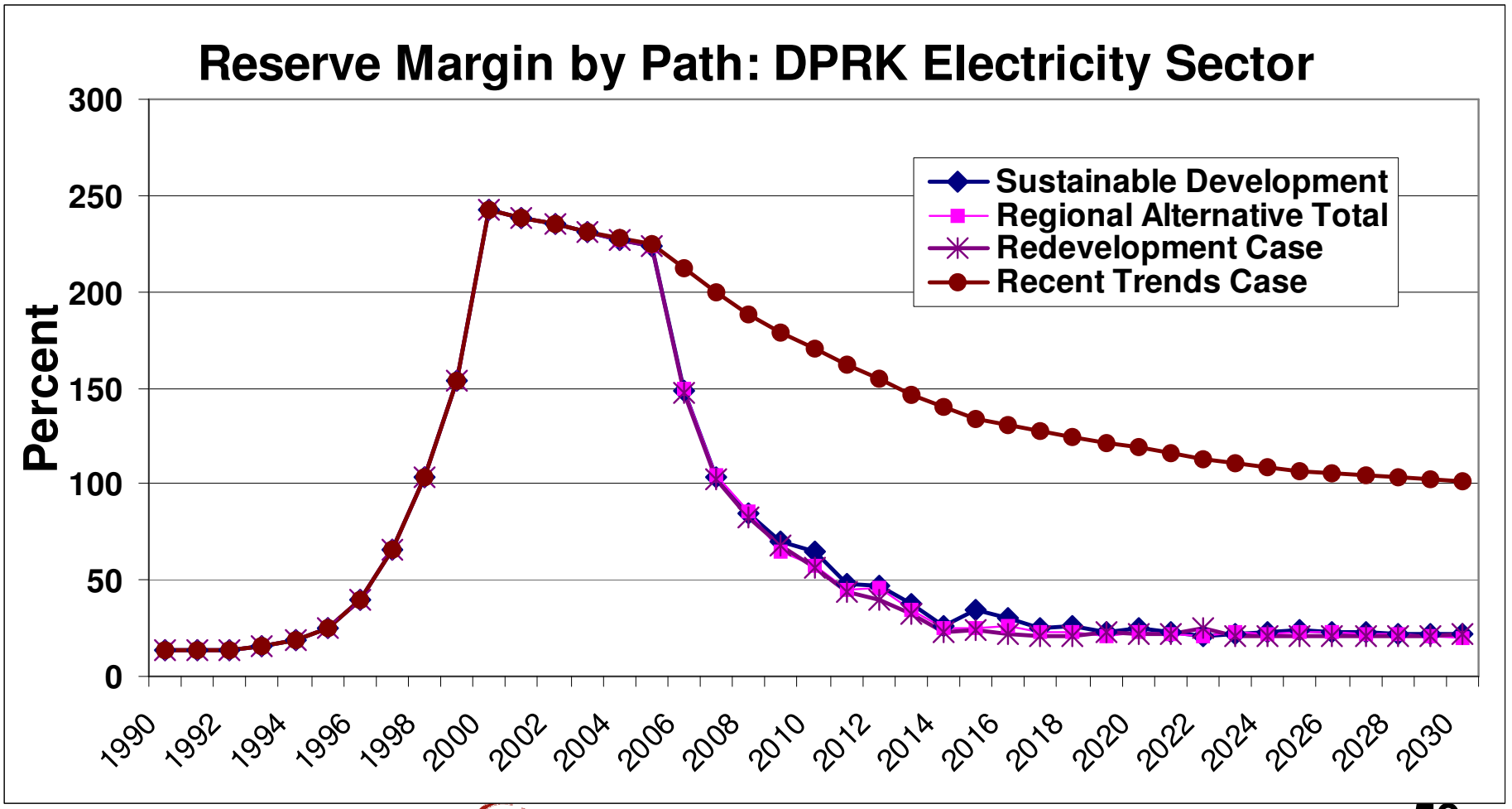

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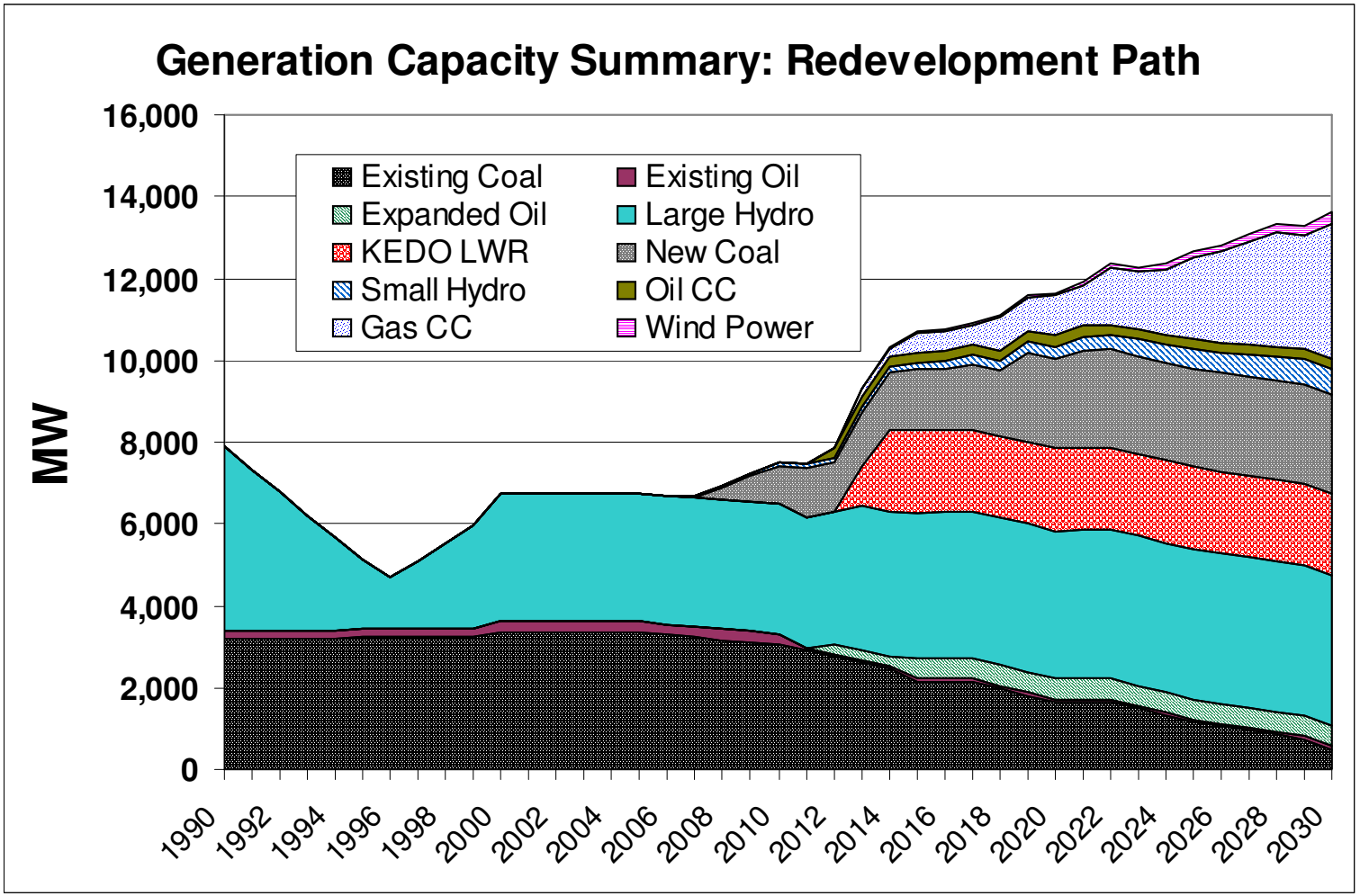

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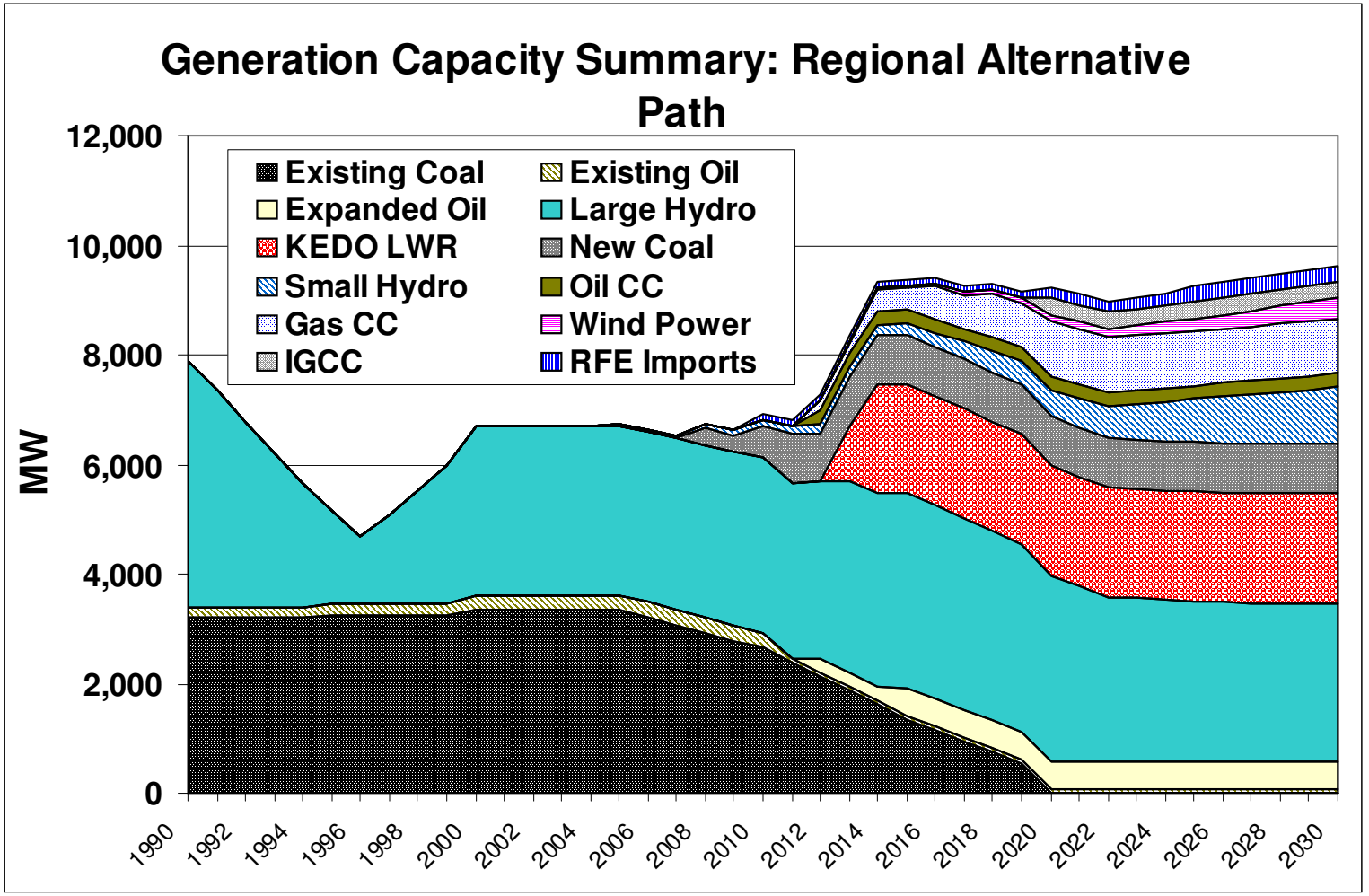

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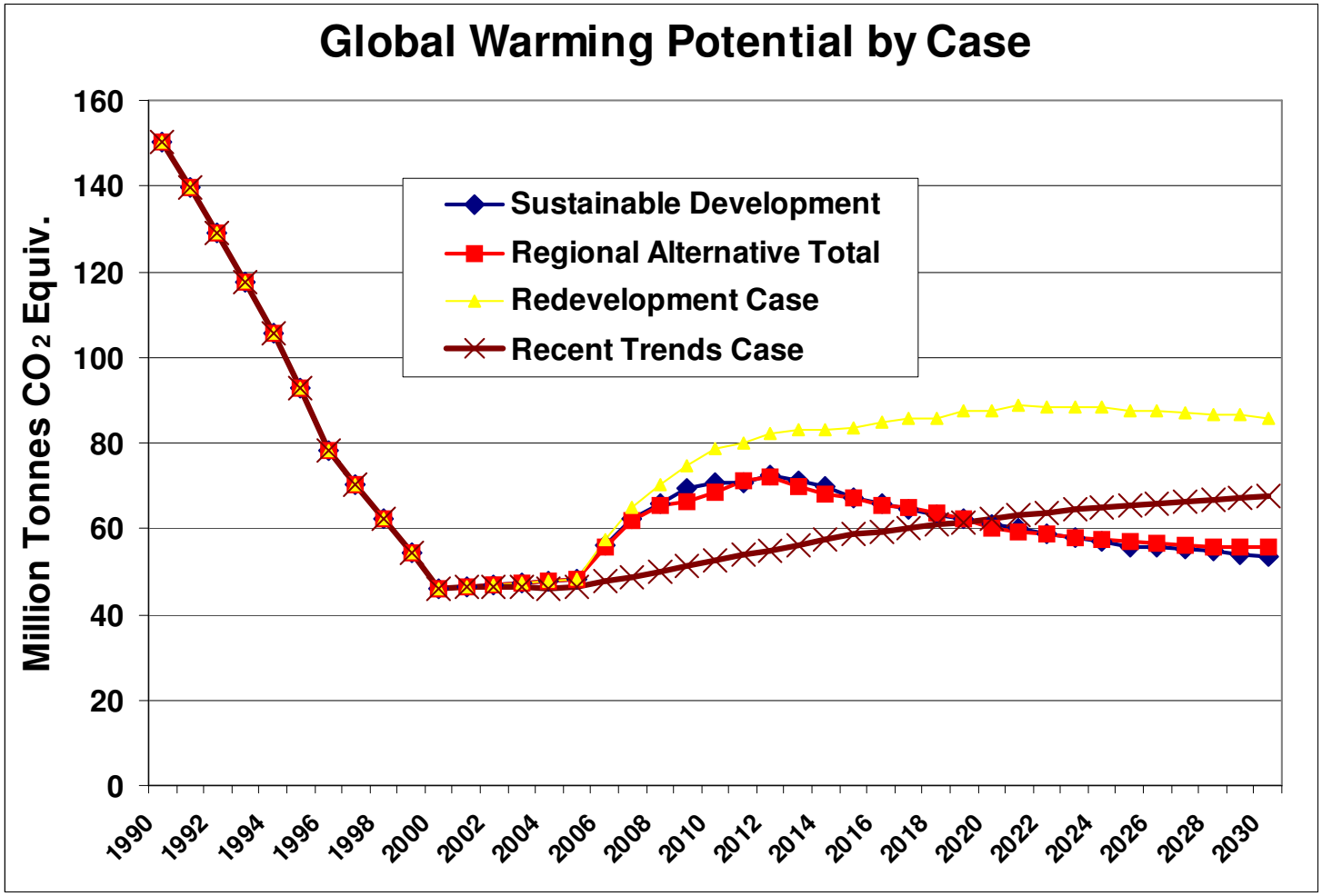

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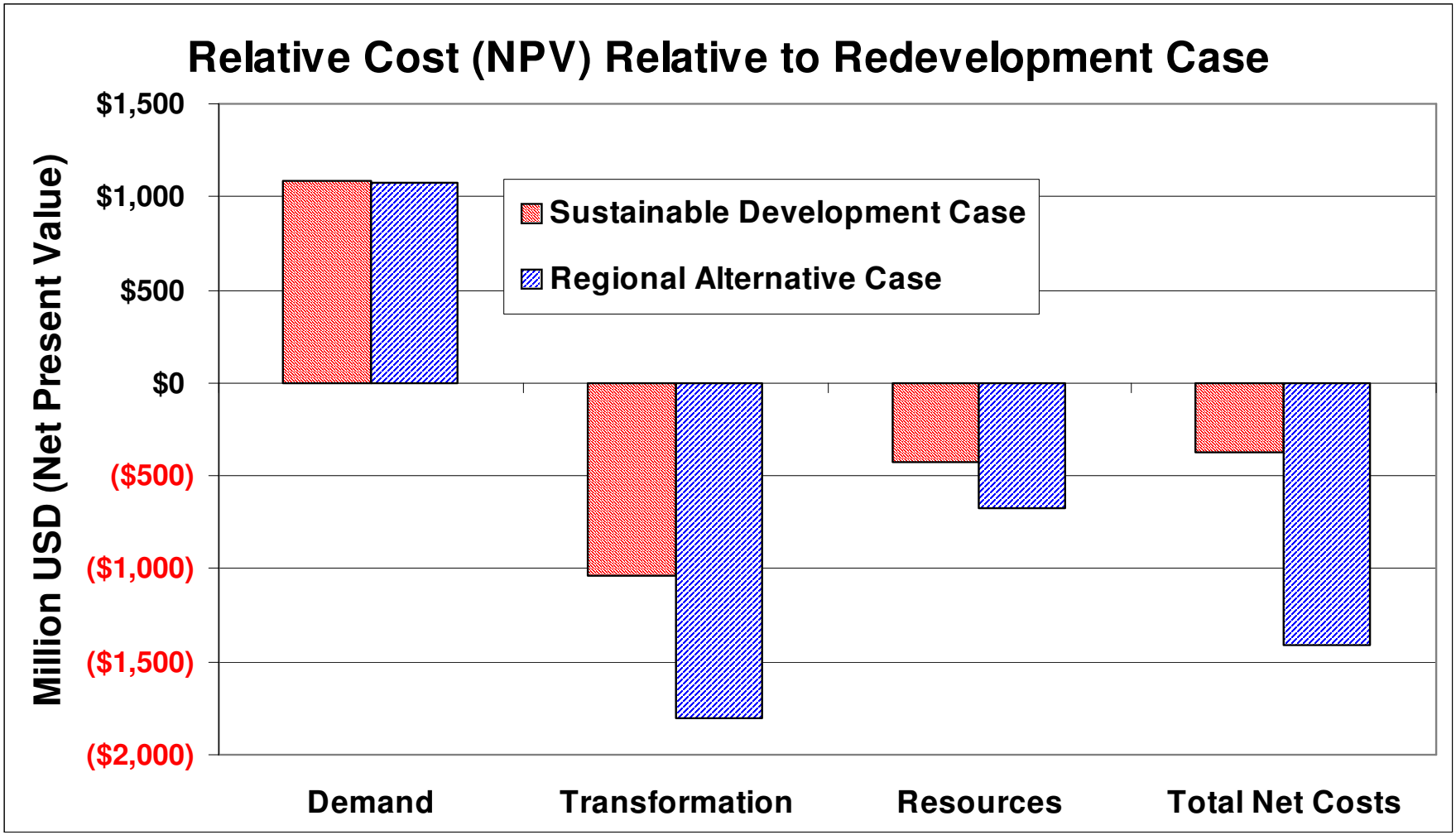

DPRK ENERGY PATHS: INITIAL CONCLUSIONS FROM RESULTS

- Sustainable Development and Regional Alternative Cases indicate significant reductions in energy use, emissions, are possible relative to Redevelopment Case, and…
- Net costs of those reductions may be relatively small or even negative
  - May offer opportunity for application of Clean Development Mechanisms to share costs, carbon credits
- **Net costs very dependent on resource prices**

NEXT STEPS IN DPRK ENERGY PATHS ANALYSIS

- Next Steps on DPRK Paths Analysis (AES2007/AES2008)
  - Refine and improve reference cost and performance assumptions, particularly on the demand side, but for transformation, resources as well (Regional Alternatives)
  - Add detail on nuclear energy, including for "maximum nuclear" path
  - Sensitivity analysis (key costs, prices)
  - Consideration of non-quantitative impacts on energy security (as part of Regional integration of RAP)
  - Consideration of other path variants
- **Work with DPRK Colleagues to Improve Analysis, Fully Implement in DPRK**