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# DRAFT SUMMARY OF THE INTEGRATED PLANNING MODEL STRUCTURE AND RESULTS FOR THE JEAS

**NIS Institutional Based Services Under the Energy Efficiency and Market Reform Project**
**Contract No CCN-Q-00-93-00152-00**

**Joint Russian-American Energy Alternatives Study**

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*Presentation*

*Prepared for*

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Office of Environment, Energy and Urban Development
Energy and Infrastructure Division

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# Draft Summary of the Integrated Planning Model Structure and Results for the JEAS

January 20, 1995

Presented By

ICF Kaiser International

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Model Structure and Assumptions

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# The Model Used For This Analysis Is ICF's Integrated Planning Model

- The Integrated Planning Model (IPM©) uses a linear programming approach to develop true least-cost resource plans while also performing accurate system dispatch and operations simulation

- IPM is a dynamic optimization model that accurately evaluates intertemporal tradeoffs

- Each resource's unique characteristics are explicitly modeled

  -- Conventional resources are dispatchable and provide capacity equal to their net dependable rating
  -- Some renewables are intermittent, providing less than rated capacity
  -- DSM options have fixed load alteration patterns and complex relationships between energy and capacity
  -- Limits on penetration and timing considerations affect the value of DSM and renewable options

- IPM takes these characteristics into account and determines least-cost resource plans over the time frame under consideration

# Regional Structure Represented in IPM©

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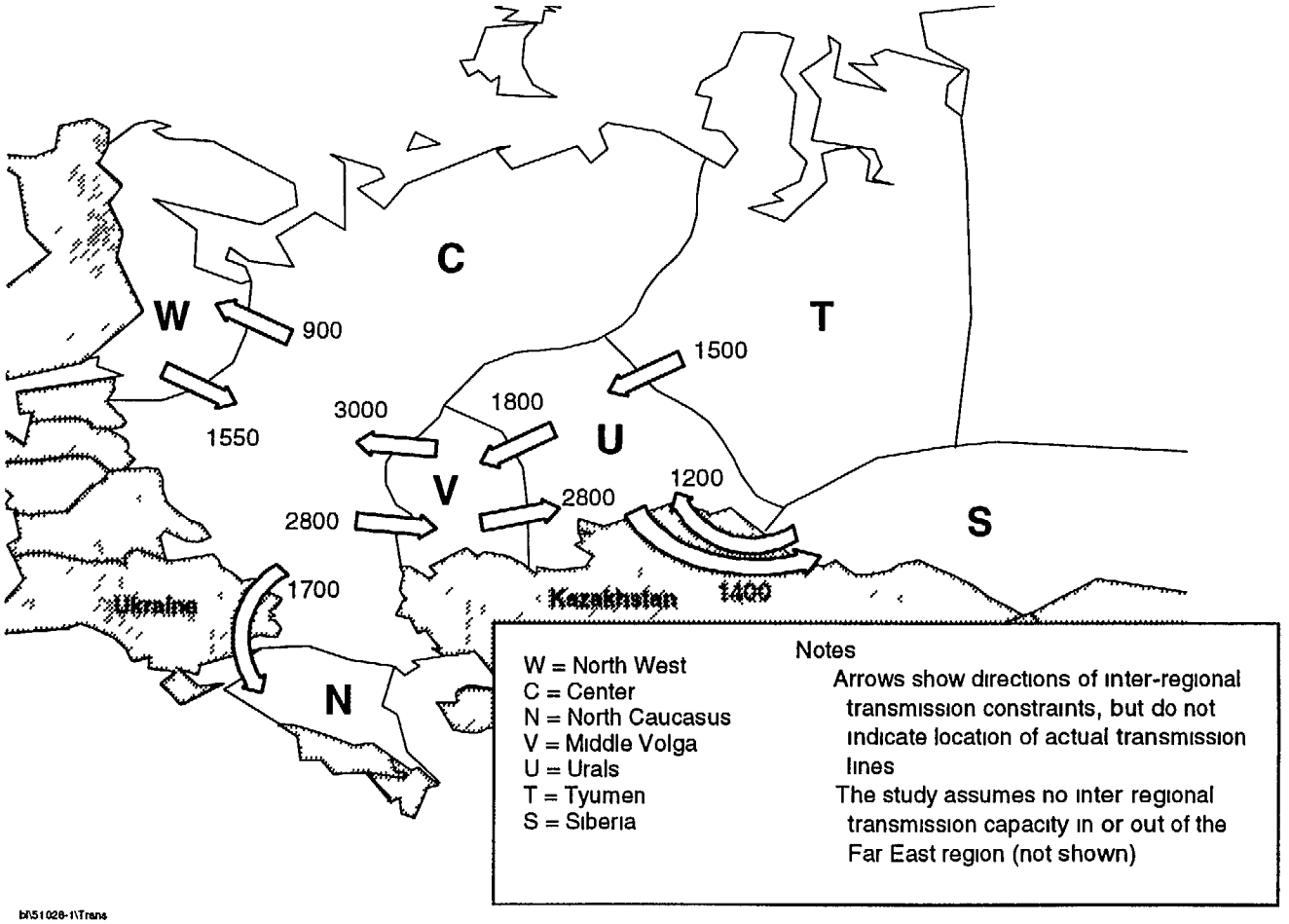
# The Version of IPM Developed for the JEAS Represents Russia As Eight Distinct Regions

- Electricity demand and supply is modeled for each of the eight regions
- For this purpose, the year is divided into three seasons
  - -- Winter (November - February)
  - -- Spring/Fall (March, April, September, October)
  - -- Summer (May - August)
- Regional demand is projected as the sum of industrial, residential, commercial, and agricultural hourly electricity use
- Heat demand is modeled as a requirement that can be satisfied by existing or new Combined Heat and Power (CHP) plants or new stand-alone boilers
- Electricity supply is represented by generation options with unique performance and operational characteristics and costs

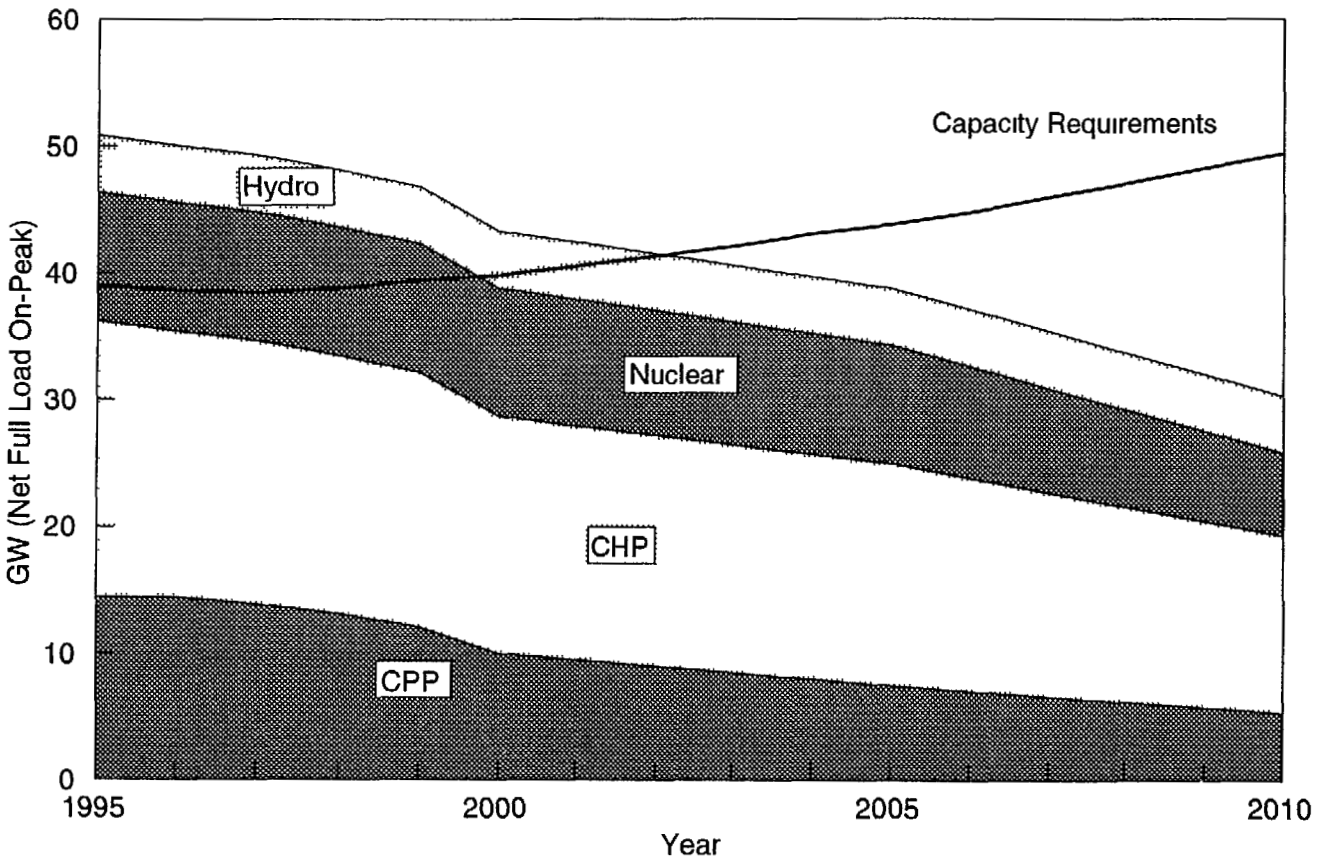
# Reference Case Transmission Capacity Represented in IPM©



# Existing Inter-Regional Transmission Capacity Is Modeled Without Political Constraints

- The transmission capacity from the Center to the North Caucasus, which runs through Ukraine is assumed to be available in the Reference Cases
- Similarly, the transmission linkage between Siberia and the Urals regions, which runs through Kazakhstan, is included in the Reference cases
- Firm electricity import and export assumptions were provided by ERI
- New transmission options are not included in the Reference Cases

# Capacity Requirements in the Center Region




Nuclear capacity does not account for outage periods for upgrades or channel replacement
Capacity requirements are defined as peak demand for the pessimistic scenario
plus a reserve margin of 13 percent

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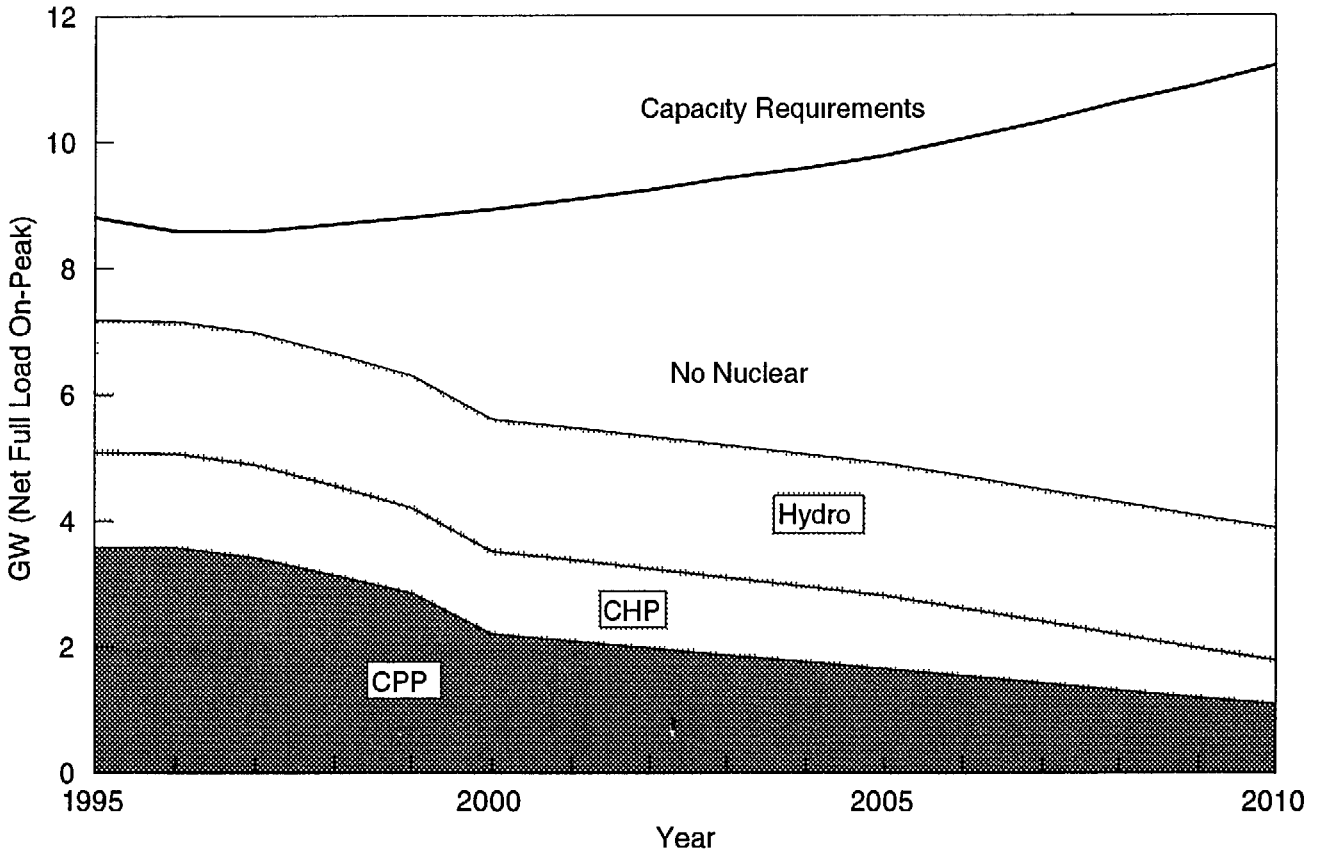
# Demand Projections and Capacity Retirement Schedules Indicate Some Regions Currently Have Surplus Generation Capacity

- IPM develops a least cost plan for meeting capacity requirements
- Capacity requirements are estimated as peak demand plus reserve margin requirements
- The demand projections and reserve margin requirements used in IPM were developed by ERI
- Retirement schedules for existing capacity were developed by Working Groups 2, 3, and 4
- The combination of the demand projections, reserve margins, and retirement schedules determine the need for capacity additions
- Many regions, including the Center, Northwest, Middle Volga, Tyumen, Siberia, and the Far East currently have generation capacity in excess of estimated requirements

# Capacity Requirements in the North Caucasus Region




Capacity requirements are defined as peak demand for the pessimistic scenario plus a reserve margin of 13 percent

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# Some Regions Are in Need of Capacity Additions In the Immediate future

- Based on ERI demand projections and the capacity retirement schedules provided by the Working Groups, the North Caucasus and the Urals are currently faced with capacity deficits
- Given this immediate need for capacity and the time needed to construct new capacity, retirement dates were postponed by a few years for some plants in these two regions in order to obtain a feasible solution
- Even with these limited plant life extensions, capacity additions are still projected to be needed in the near future in these regions

# Fossil and Nuclear Options Represented in IPM©
# Resource Costs

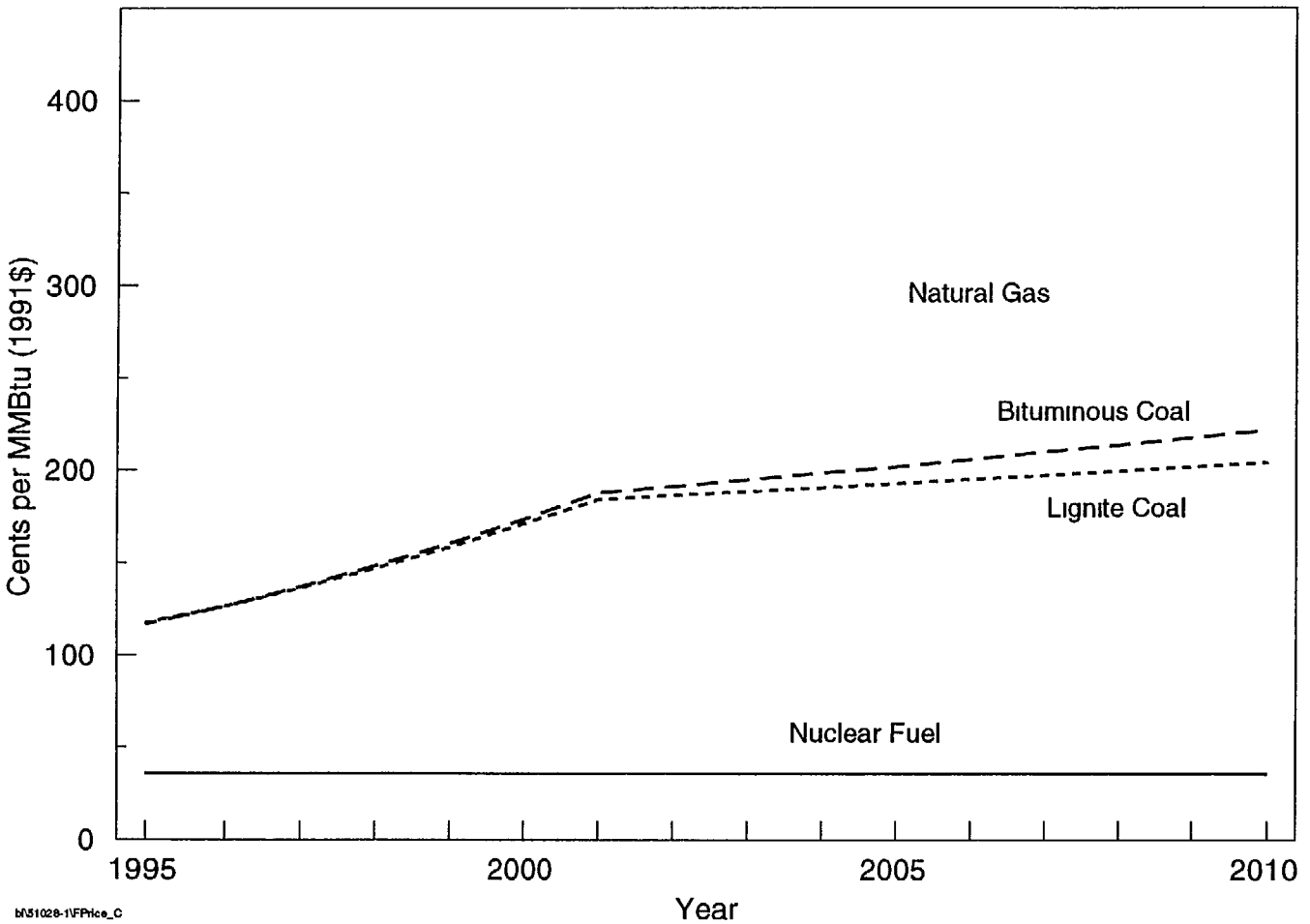
| | 1995 | | | 2000 | | | 2010 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Capital $/Kw | FO&M $/kW-yr | VO&M $/Mwh | Capital $/Kw | FO&M $/Kw-yr | VO&M $/Mwh | Capital $/Kw | FO&M $/kW-yr | VO&M $/MWh |
| Pulverized Coal | 942 | 14 | 1.9 | 1083 | 22 | 2 2 | 1486 | 34 | 2.4 |
| Combined Cycle | 682 | 7 | 0.3 | 782 | 11 | 0.3 | 988 | 17 | 0.4 |
| Nuclear | 1144 | 17 | 0.3 | 1281 | 27 | 0.3 | 1970 | 42 | 0.3 |
| Modernizations | | | | | | | | | |
| CPP (Oil/Gas) | 552 | 6 | 0.3 | 623 | 10 | 0.3 | 787 | 16 | 0.4 |
| CPP (Coal) | 552 | 21 | 2.6 | 661 | 34 | 3 1 | 938 | 52 | 3.3 |
| CHP (Oil/Gas) | 455 | 32 | 1.3 | 545 | 51 | 1.5 | 747 | 79 | 1.6 |
| CHP (Coal) | 619 | 40 | 7.9 | 776 | 64 | 9 3 | 1121 | 99 | 9.8 |
| Nuclear | 53 | 35 | 0.6 | 112 | 56 | 0.6 | 219 | 86 | 0.7 |

*All Costs are expressed in January 1994 U S Dollars*
*Modernization options were characterized by typical options available in the Center Region.*
*Nuclear upgrades costs are for plant continuation with confinement and jet condenser, with Russian decommissioning*

# IPM Selects From Approximately 300 Power Plant Options To Develop a Least Cost Solution for Capacity Requirements

- New resource options in the Reference Case include
  - -- Nuclear Upgrades, Completion and Repowering
  - -- New nuclear - NP500
  - -- Fossil modernization - CHP and CPP units are included
  - -- Greenfield fossil options
    - Combined Cycle CPP
    - Pulverized coal
    - Atmospheric fluidized bed (AFBC)
    - Combined cycle CHP units
    - New pulverized coal CHP
    - Simple cycle combustion turbines are *not* included as options
  - -- Hydro completion
  - -- Committed - Included without cost (fossil and hydro) for 1995-1997

# Fuel Prices In the Center Region



# Fuel Price Assumptions Affect IPM's Selection of the Optimal Capacity Mix

- Fuel prices for the Reference cases were developed by ERI based on the estimated full cost of production
- In most regions, natural gas prices are higher than coal
- Fossil fuel prices are substantially higher than nuclear fuel prices in all regions
- The price differential among the fuels depends on the region reflecting the differences in the source of fuel and transportation costs

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# Two Reference Cases Are Simulated in IPM

- The principal difference in assumptions between the two Reference Cases is the rate of growth in electricity demand
  - -- Reference Case A has electricity demand dropping until 1996, and reaching levels about 20% higher than 1990 in 2010
  - -- Reference Case B has electricity demand dropping until 1997, and then slowly increasing to approximately 1990 levels by 2010
- The two reference cases also differ in following
  - -- The level of heat demand
  - -- Interregional imports and exports of electric capacity
  - -- The extent to which life extension is required over the next two years to meet demand in the Urals and North Caucasus regions
- Other assumptions are common to both cases

# A Total of 27 Different Cases Have Been Analyzed

- In addition to the two Reference Cases, Change Cases were also simulated for the following categories

  -- Scenario cases, which are designed to analyze alternative assumptions about such factors as fuel prices, nuclear capital costs, and energy efficiency

  -- Nuclear Decision cases, which are designed to evaluate alternative policies concerning such factors nuclear safety upgrade options, nuclear decommissioning costs, and the nuclear share of total generation capacity

  -- Non-Nuclear Decision cases, which are designed to evaluate policies concerning such factors as air pollution control and transmission capacity

- Each of these Change Cases is modeled for both Reference Case sets of assumptions

# Scenario Change Cases

- 20% Lower Nuclear Capital Costs
- Fossil Fuel Price Sensitivity
- High and Low Uranium Prices
- The Value of Energy Efficiency Gains

# Nuclear Decision Change Cases

- No New Nuclear
- Full Containment With Russian Decommissioning
- Early Nuclear Decommissioning
- American Decommissioning Costs
- Constant Nuclear Share
- Decommission Kursk 1

# Non-Nuclear Decision Change Cases

- Air Pollution Control Not Required on New Capacity and Modernizations
- Transmission Capacity Additions

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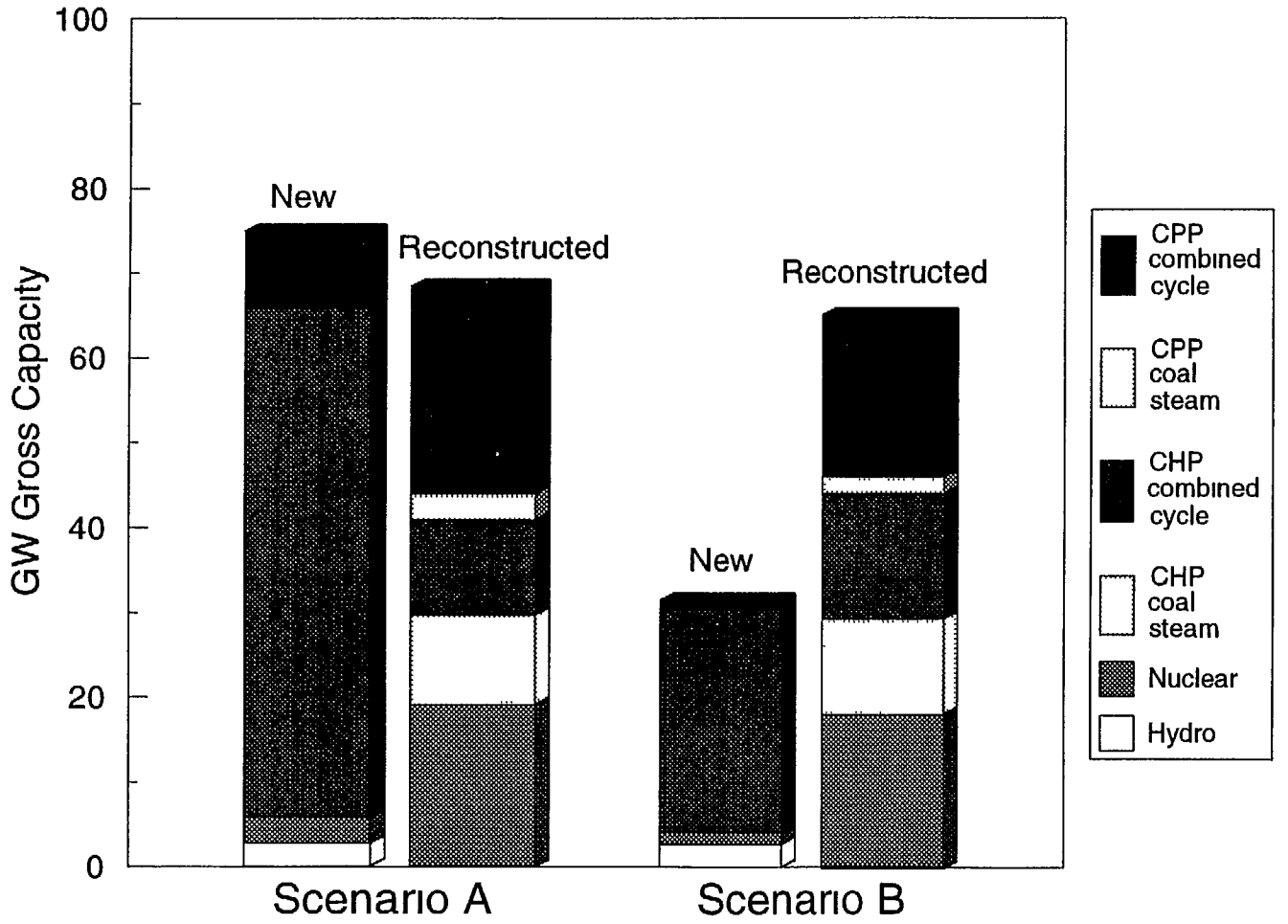
# Projected Capacity Additions for the Reference Cases



# Capacity Additions Are Projected for a Broad Mix of New, Reconstructed, and Upgraded Power Plant Options

- The differing assumptions about the growth of electric and heat demand lead to a large range in projected capacity additions In Reference Case A, capacity additions total 143 4 GW In contrast, total capacity additions are projected to be 96 7 GW in Reference Case B

- The amount of capacity additions coming from modernization of thermal power plants and upgrade of nuclear power plants is similar for both Reference Cases

- However, additions of new power plants are much higher in Reference Case A New power plants account for over half of total capacity additions in this case In contrast, in Reference Case B, new power plants account for only 33 percent of total capacity additions

## REFERENCE CASE A
## NUCI EAR UNITS SELECTED FOR SAFETY UPGRADE

| NUCLEAR PLANT | UPGRADE | COMMENT |
|---|---|---|
| BALAKOVO<br>1 VVER 1000<br>2 VVER 1000<br>3 VVER 1000<br>4 VVER 1000 | <br>YES<br>YES<br>YES<br>YES | ALL UNITS ARE ASSUMED TO BE MODERNIZED BECAUSE THEY ARE RELA TIVELY NEW UPGRADING THESE UNITS IS NOT SUBJECT TO MODEL SE LECTION |
| BELOYARSKAYA<br>3 BN 600 | <br>NA | UPGRADE NOT MODELED |
| KALININ<br>1 VVER 1000<br>2 VVER 1000<br>3 VVER 1000 | <br>YES<br>YES<br>YES | UNITS 1 & 2 ARE ASSUMED TO BE MODERNIZED BECAUSE THEY ARE RELA TIVELY NEW UPGRADING THESE UNITS IS NOT SUBJECT TO MODEL SE LECTION<br>UNIT 3 IS SELECTED FOR COMPLETION IN THE YEAR 2000 |
| KOLA<br>1 VVER-440<br>2 VVER-440<br>3 VVER-440<br>4 VVER-440 | <br>NO<br>NO<br>YES<br>YES | UNITS 3&4 ARE 440 213 S WITH LOW SAFETY UPGRADE COSTS<br>UNITS 1&2 HAVE LESS REMAINING LIFE RETIRING IN 2004 |
| KURSK<br>1 RBMK 1000<br>2 RBMK 1000<br>3 RBMK 1000<br>4 RBMK 1000 | <br>YES<br>YES<br>YES<br>YES | |
| LENINGRAD<br>1 RBMK 1000<br>2 RBMK 1000<br>3 RBMK 1000<br>4 RBMK 1000 | <br>YES<br>YES<br>YES<br>YES | |
| NOVOVORONEZH<br>3 VVER-440<br>4 VVER-440<br>5 VVER 1000 | <br>NO<br>NO<br>YES | UNIT 5 IS ASSUMED TO BE MODERNIZED UPGRADING THIS UNIT IS NOT SUBJECT TO MODEL SELECTION<br>UNITS 3 & 4 HAVE LESS REMAINING LIFE RETIRING IN 2002 AND 2003 |
| SMOLENSK<br>1 RBMK 1000<br>2 RBMK 1000<br>3 RBMK 1000 | <br>YES<br>YES<br>YES | |
| ROSTOV<br>1 VVER 1000 | <br>NO | NOT SELECTED FOR CONVERSION TO COAL PLANT |
| NEW GENERATION<br>1 NP 500 | <br>YES | A TOTAL OF 3 1 OF NEW NUCLEAR CAPACITY ADDED IN BY 2010 IN CENTER FAR EAST N CAUCASUS AND THE NORTHWEST |

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# Most Existing Nuclear Plants Are Upgraded in Reference Case A

- Nuclear units not selected for upgrading were generally those with limited remaining lifetimes Units not selected for upgrade include Kola 1 & 2, and Novovoronezh 3 & 4

- Kalinin 1 and 2, Novovoronezh 5 and Balakovo 1-4 are assumed to be upgraded because these units are relatively new Upgrading these units is not subject to model selection

- In addition, 3 1 GW of new nuclear capacity is projected to be brought on line by 2010 New nuclear capacity is projected to be added in the following regions

  -- Center - 1 0 GW Kalinin 3
  -- Far East - 2 7 GW, 1 2 by 2010
  -- North Caucasus - 0 6 GW in 2002
  -- N WEST - 0 3 GW in 2002

- The Rostov plant, which was included as a coal completion option, was not selected in this case

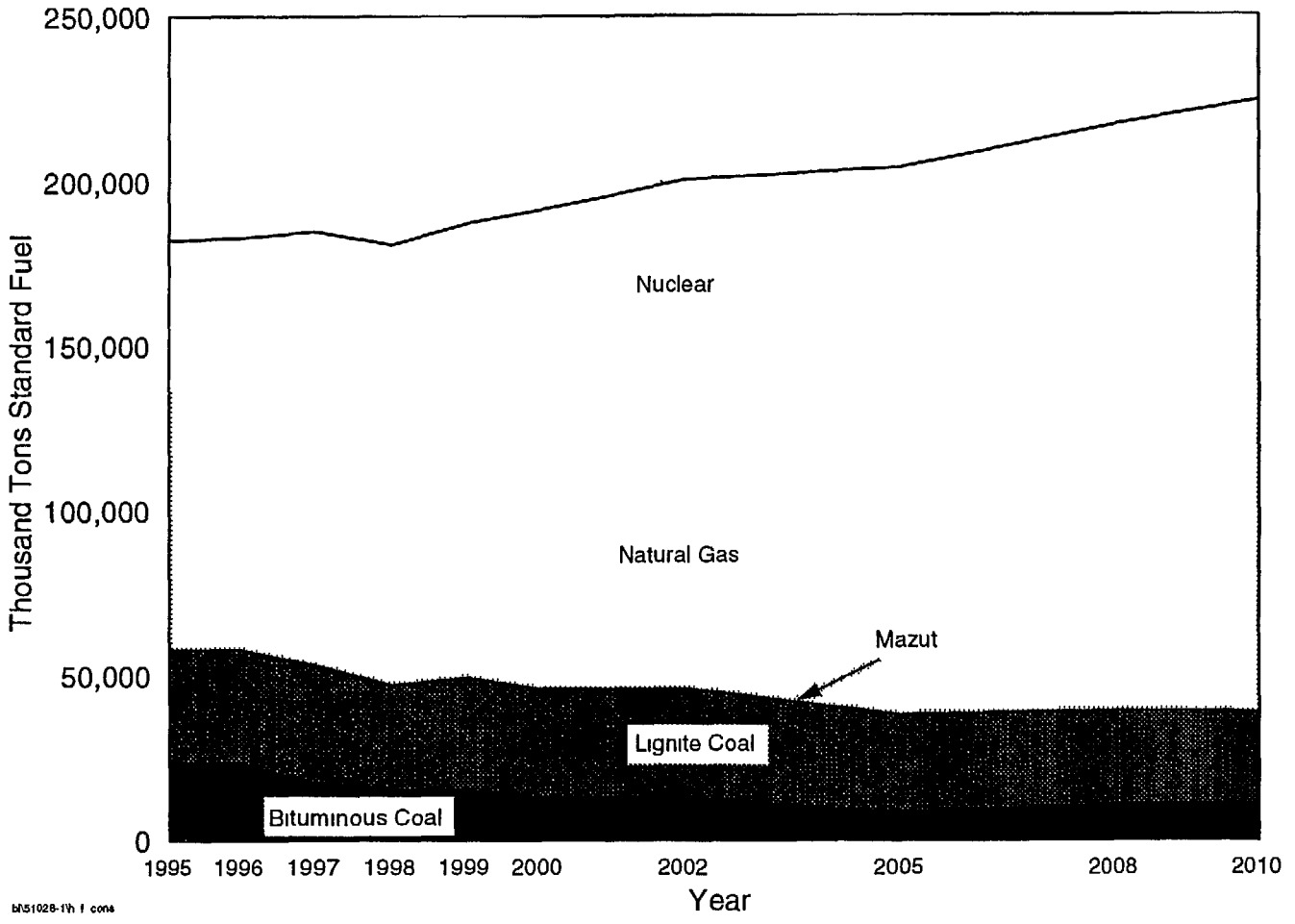
## REFERENCE CASE B
## NUCLEAR UNITS SELECTED FOR SAFETY UPGRADE

| NUCLEAR PLANT | UPGRADE | COMMENT |
|---|---|---|
| BALAKOVO<br>1 VVER 1000<br>2 VVER 1000<br>3 VVER 1000<br>4 VVER 1000 | <br>YES<br>YES<br>YES<br>YES | ALL UNITS ARE ASSUMED TO BE MODERNIZED BECAUSE THEY ARE RELA TIVELY NEW UPGRADING THESE UNITS IS NOT SUBJECT TO MODEL SE LECTION |
| BELOYARSKAYA<br>3 BN 600 | <br>NA | UPGRADE NOT MODELED |
| KALININ<br>1 VVER 1000<br>2 VVER 1000<br>3 VVER 1000 | <br>YES<br>YES<br>YES | UNITS 1 & 2 ARE ASSUMED TO BE MODERNIZED BECAUSE THEY ARE RELA TIVELY NEW UPGRADING THESE UNITS IS NOT SUBJECT TO MODEL SE LECTION UNIT 3 IS SELECTED FOR COMPLETION NEAR THE END OF THE STUDY TIME FRAME |
| KOLA<br>1 VVER-440<br>2 VVER-440<br>3 VVER-440<br>4 VVER-440 | <br>NO<br>NO<br>YES<br>YES | UNITS 3&4 ARE 440 213 S WITH LOW SAFETY UPGRADE COSTS<br>UNITS 1&2 HAVE LESS REMAINING LIFE RETIRING IN 2004 |
| KURSK<br>1 RBMK 1000<br>2 RBMK 1000<br>3 RBMK 1000<br>4 RBMK 1000 | <br>YES<br>YES<br>YES<br>YES | |
| LENINGRAD<br>1 RBMK 1000<br>2 RBMK 1000<br>3 RBMK 1000<br>4 RBMK 1000 | <br>NO<br>YES<br>YES<br>YES | |
| NOVOVORONEZH<br>3 VVER-440<br>4 VVER-440<br>5 VVER 1000 | <br>NO<br>NO<br>YES | UNIT 5 IS ASSUMED TO BE MODERNIZED UPGRADING THIS UNIT IS NOT SUBJECT TO MODEL SELECTION<br>UNITS 3 & 4 HAVE LESS REMAINING LIFE RETIRING IN 2002 AND 2003 |
| SMOLENSK<br>1 RBMK 1000<br>2 RBMK 1000<br>3 RBMK 1000 | <br>YES<br>YES<br>YES | |
| ROSTOV<br>1 VVER 1000 | <br>NO | NOT SELECTED FOR CONVERSION TO COAL PLANT |
| NEW GENERATION<br>1 NP 500 | <br>YES | KALININ 3 COMPLETED IN CENTER REGION 400 MW ADDED IN THE NORTH CAUCASUS IN 2002 |

# Most Existing Nuclear Plants Are Also Upgraded in Reference Case B

- Upgrade decisions in Reference Case B match those projected for Reference Case B with the exception of Leningrad 1 which is not upgraded
- 400 Mw of new nuclear capacity is added in the North Caucasus in 2002
- Kalinin 3 is also completed
- As in Reference Case A, the Rostov power plant was not selected for completion as a coal plant

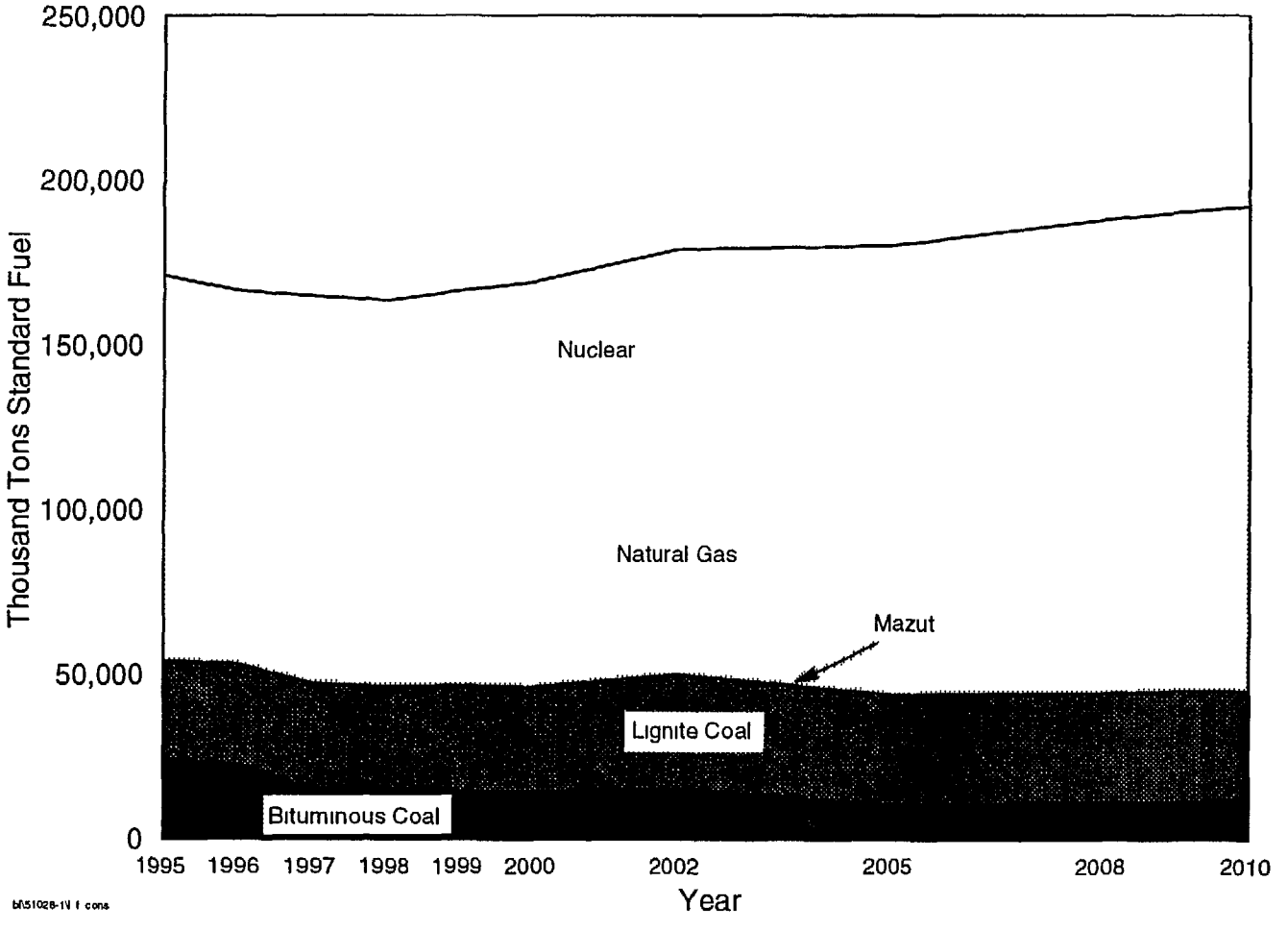
# Projected Fuel Use For Electric Generation for Reference Case A



# Natural Gas Use Increases Sharply in Reference Case A

- Total fuel use for electric generation is projected to increase from 182 million TSF in 1995 to 224 million TSF in 2010
- Natural gas use increases by 85 percent over the fifteen year period the gas share of total fuel use for generation increases from 41 percent in 1995 to 61 percent in 2010
- Coal use for electric generation declines over the projection period with bituminous coal use declining more than lignite use Bituminous coal use declines by 54 percent, while lignite use declines by a smaller 18 percent
- Fuel use for nuclear electric generation increases by 23 percent over the period 1995 through 2002 before declining back to 1995 levels by 2010

# Projected Fuel Use For Electric Generation for Reference Case B



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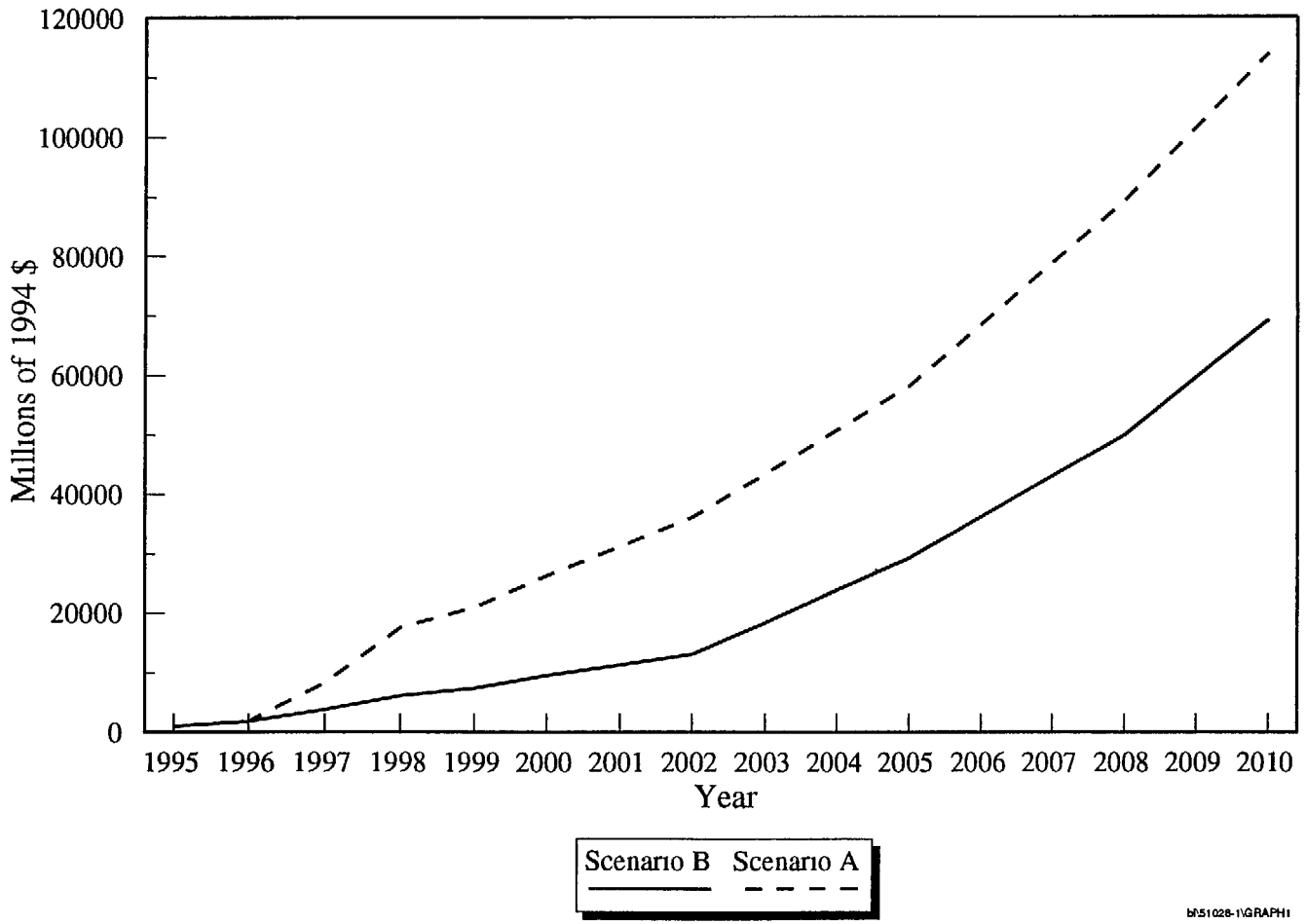
# Natural Gas Use Increases at a Slower Rate in Reference Case B

- Total fuel use for electric generation increases from 171 million TSF in 1995 to 192 million TSF in 2010
- Natural gas use increases in this case, but not as much as in Reference Case A Natural gas use increases by 52 percent with the gas share of total fuel use increasing from 39 percent to 54 percent
- Total coal use is projected to decline in Reference Case B Bituminous coal use declines by 50 percent However, this decline is partially offset by an increase of 11 percent in lignite coal use

# Comparison of Cumulative Investment



# Investment Requirements Differ Greatly Between the Two Reference Cases

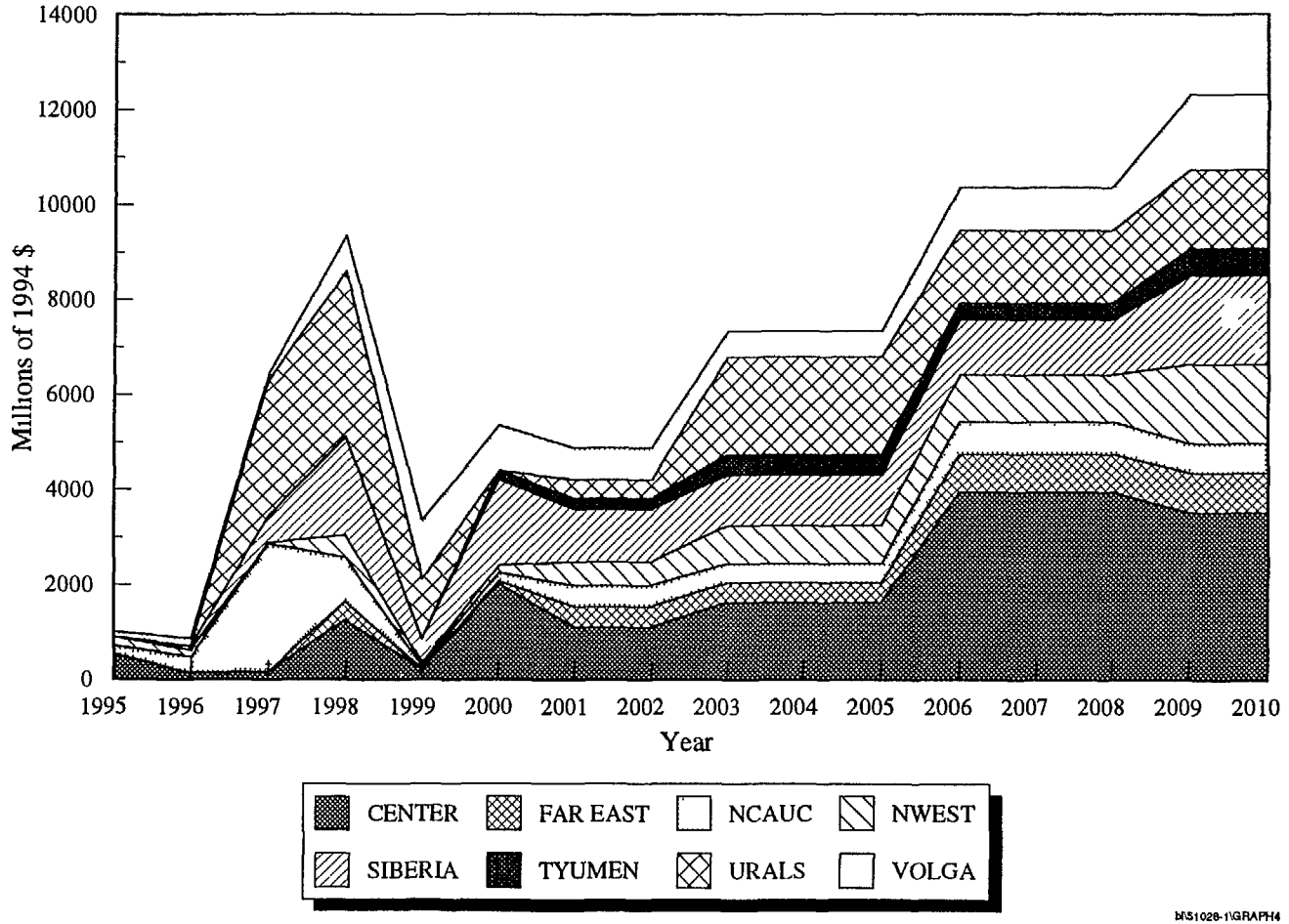
- In Reference Case A, projected cumulative investment requirements total 113 billion dollars by 2010
- In Reference Case B, cumulative investment requirements total 69 billion dollars by 2010, 39 percent below the Reference Case A level

# Comparison of Annual Investment

# The Need for Large Investment Amounts Occurs Much Sooner in Reference Case A

- Annual investment patterns also differ greatly between the two Reference Cases
- In Reference Case A, annual investment is projected to rise sharply to 9 3 billion dollars in 1998 After declining in 1999, annual investment eventually increases to 12 3 billion dollars by 2010
- In Reference Case B, annual investment is projected to range from 1 to 2 billion dollars over the period 1995 through 2002 Subsequently, annual capital costs rise sharply to as high as 9 7 billion dollars in 2010

# Regional Annual Investment for Reference Case A

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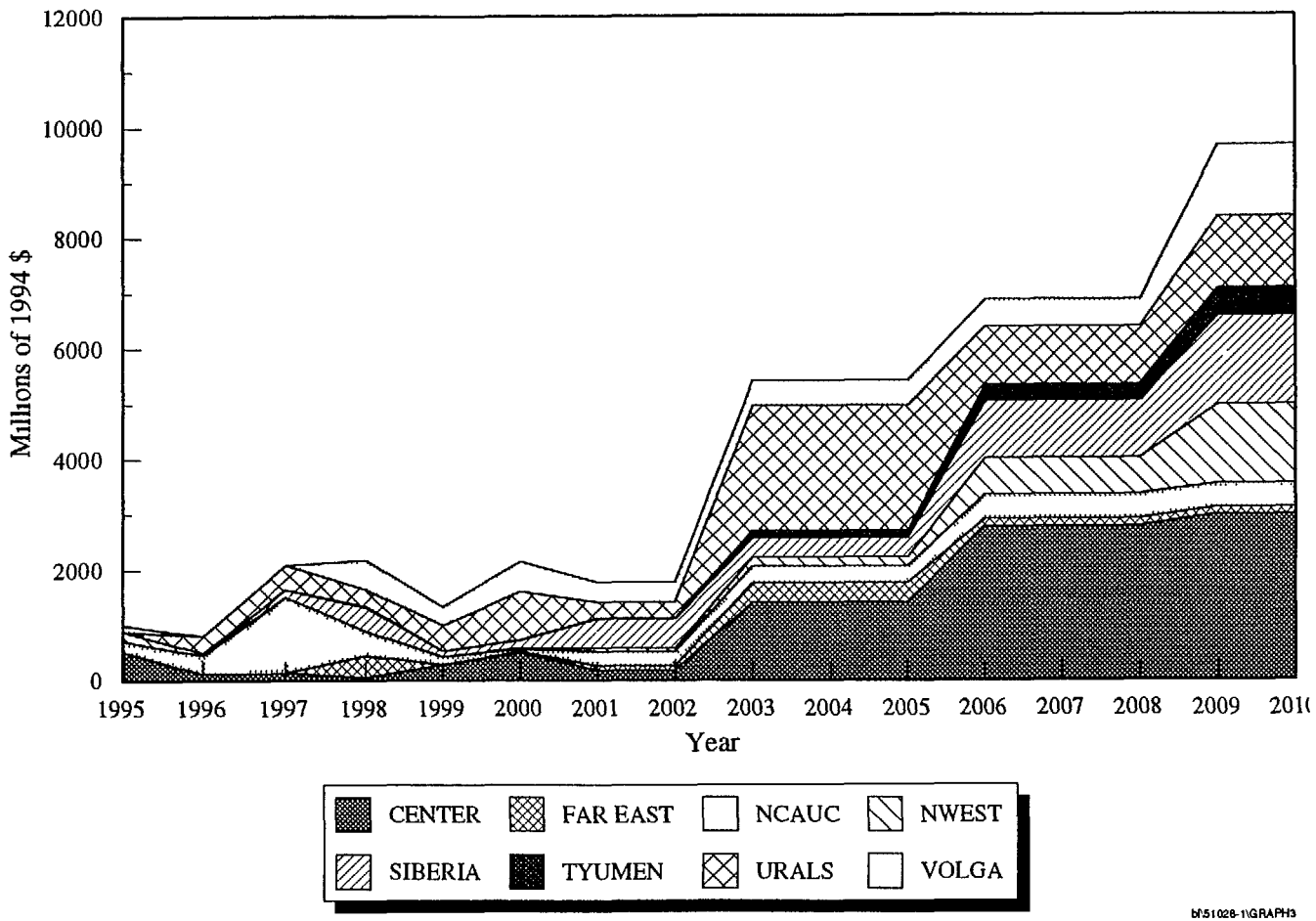
# In Reference Case A, Large Investment is Projected for the Urals and North Caucasus in the Near Future

- In 1997, investment is projected to be 2 7 billion dollars in the North Caucasus and 2 9 billion dollars in the Urals Investment is projected to be needed for both CPP and CHP plants in the North Caucasus and for CHP plants in the Urals

- In 1998, investment is projected to be highest in the Urals, totaling 3 5 billion dollars This investment is projected for CHP capacity to meet heat demand However, substantial investments are also projected for Siberia (2 1 billion), and the Center region (1 3 billion) in this year

# Regional Annual Investment for Reference Case B



# In Reference Case B, the Center and Urals Regions Account for the Highest Proportion of Investment Projections

- While electric generation investment is projected for all regions, the Center and Urals regions account for over half of the projected total investment
- However, in the earlier years investment is projected to be highest in the North Caucasus where investment is primarily needed to replace retiring CHP capacity

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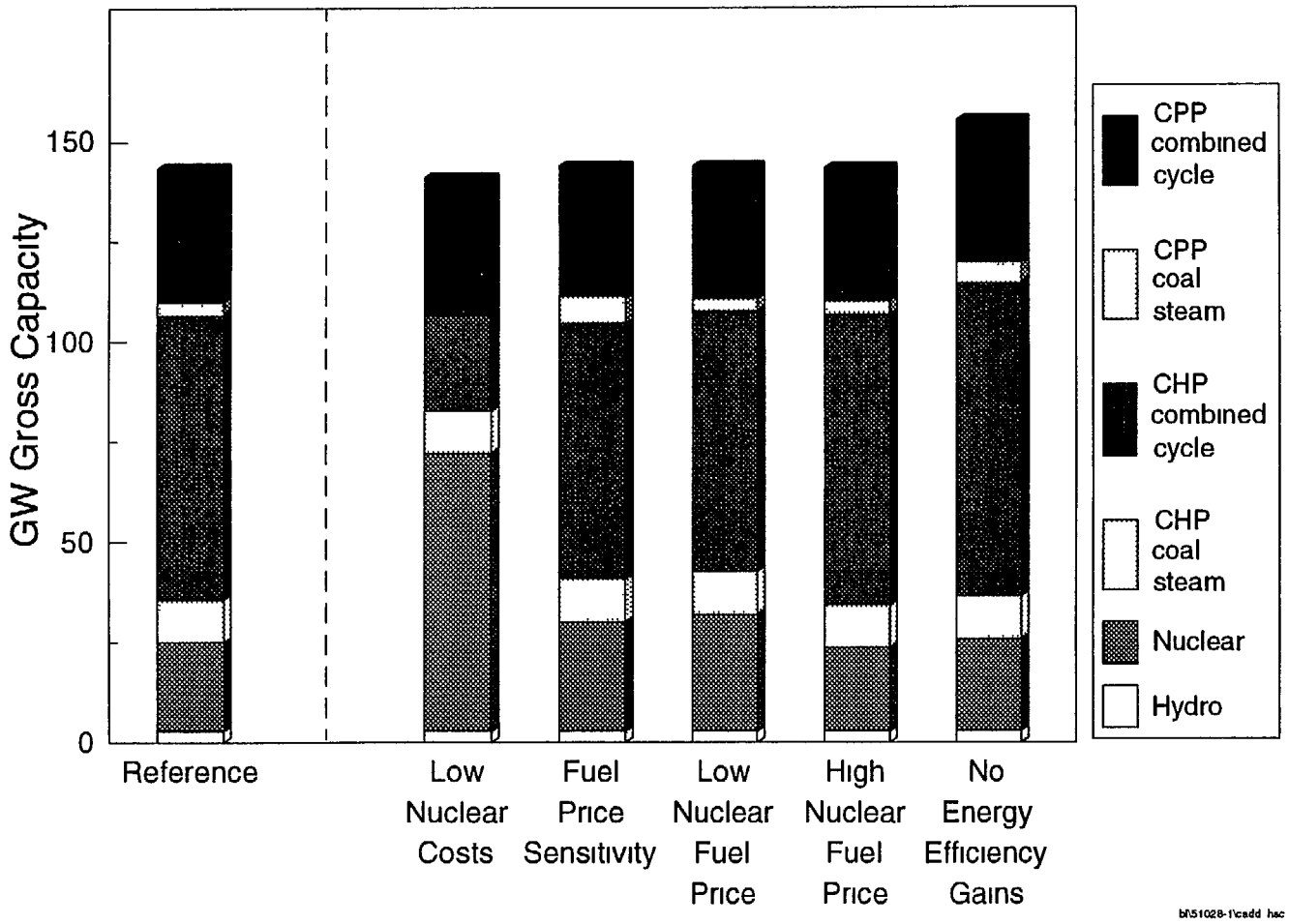
# Cumulative Capacity Additions Through 2010 For Reference Case A and Related Scenario Cases

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# Reducing Nuclear Capital Costs Has a Large Effect on the Capacity Addition Mix

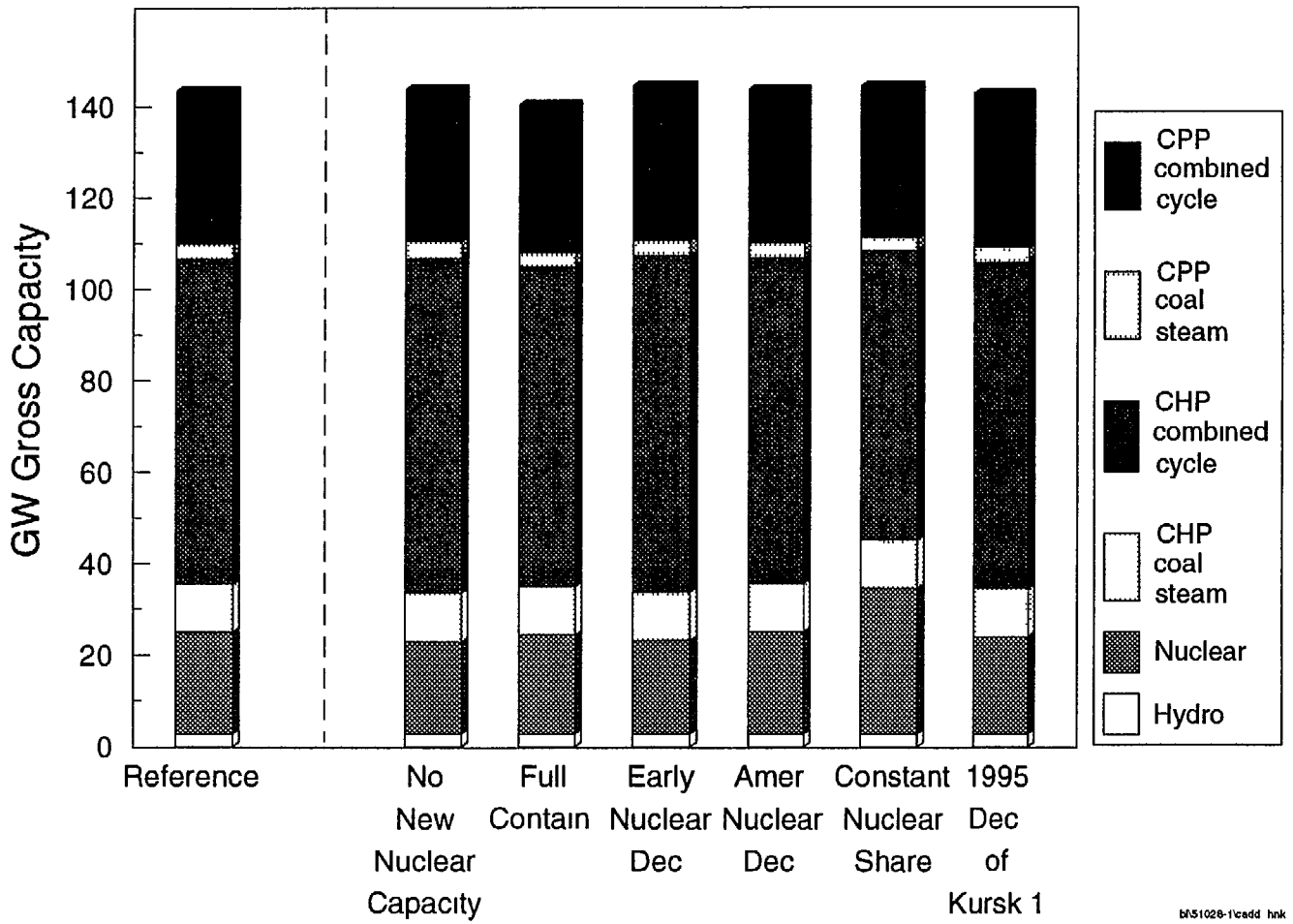
- In the Change Case in which nuclear capital costs were reduced by 20 percent, capacity additions of nuclear power plants, including safety upgrades, increased from 22 2 GW in Reference Case A to 69 5 GW In this case, the model found it to be economic to add more nuclear capacity and stand-alone boilers to meet heat demand, and correspondingly less combined cycle CHP capacity

- Changes in nuclear fuel price assumptions had a much smaller effect on nuclear capacity additions In the Low Nuclear Fuel Price Change Case, an additional 7 1 GW of nuclear capacity is added relative to the Reference Case

- In the Energy Efficiency Change Case, the model adds 11 9 GW of additional capacity relative to the Reference case, primarily combined cycle CHP capacity, combined cycle CPP and coal CPP, and to a lesser extent hydro and nuclear capacity

- The Fuel Price Change Case leads to an increase in nuclear capacity additions of 5 2 GW and a 3 4 GW increase in coal CPP capacity additions These increases are offset by declines in combined cycle CHP and CPP capacity additions

# Cumulative Capacity Additions Through 2010 For Reference Case A and Related Nuclear Decision Cases

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# The Nuclear Decision Cases Had Only Marginal Impact on the Model's Nuclear Plant Upgrade Decisions

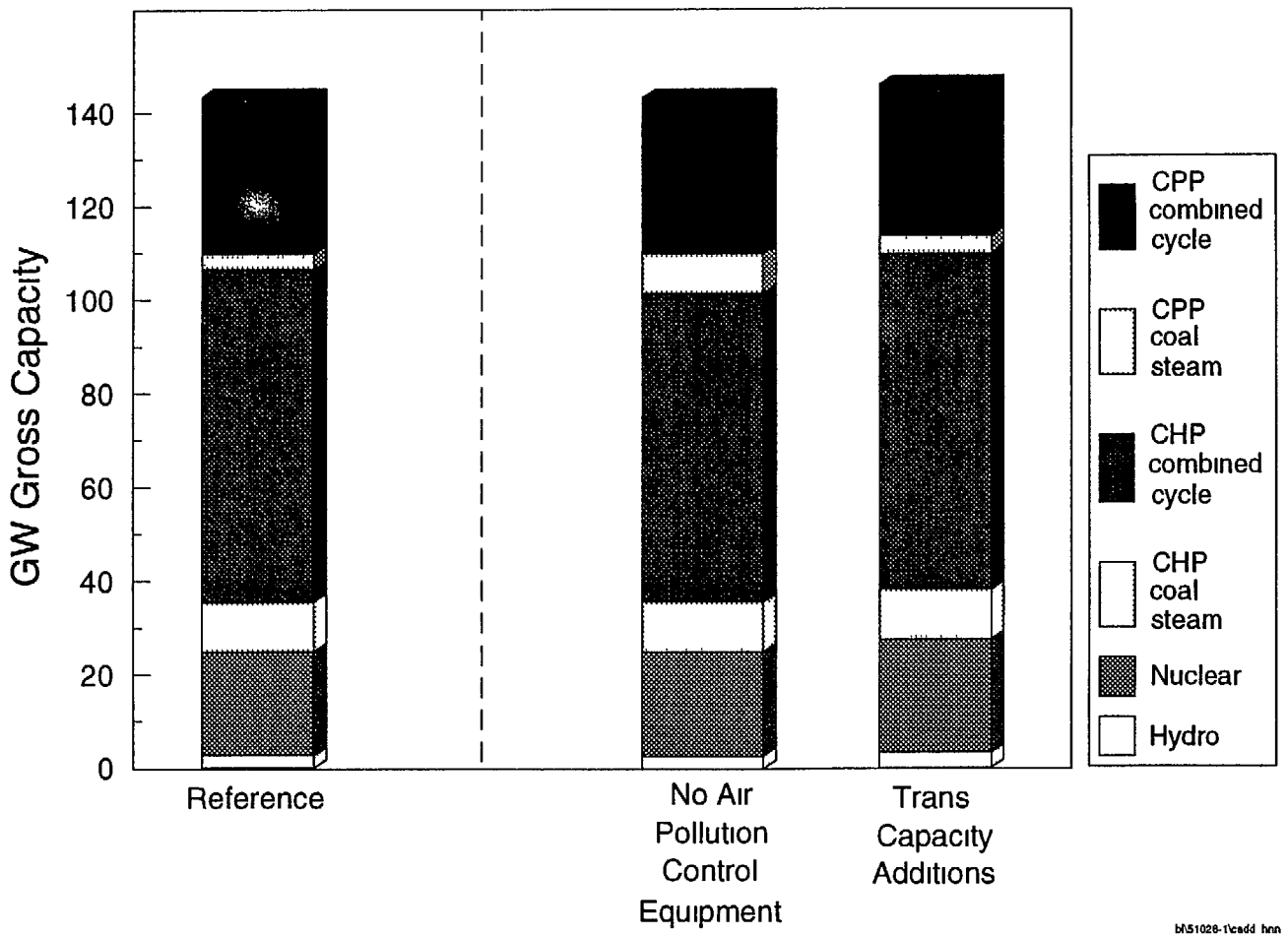
- In the Full Containment Change Case, the only change in selection of which existing nuclear plants to upgrade is at the Leningrad plant, where unit number 2 is not upgraded All other plant upgrade choices are the same as in the Reference Case

- Early Decommissioning has little effect on the model's nuclear upgrade choices, the only change relative to the Reference Case A is that Leningrad 1 is not selected for upgrading

- In the American Decommissioning Change Case, Kola 1 is selected for upgrading All other upgrading choices are the same as in Reference Case A

- In the Constant Nuclear Share Change Case all existing nuclear units are selected for upgrading In addition, 11 4 GW of new nuclear capacity is added.

# Cumulative Capacity Additions Through 2010 For Reference Case A and Related Non-Nuclear Decision Cases

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# Removing SO2 Scrubbers from New and Modernized Coal Plants Would Increase Coal Consumption Significantly

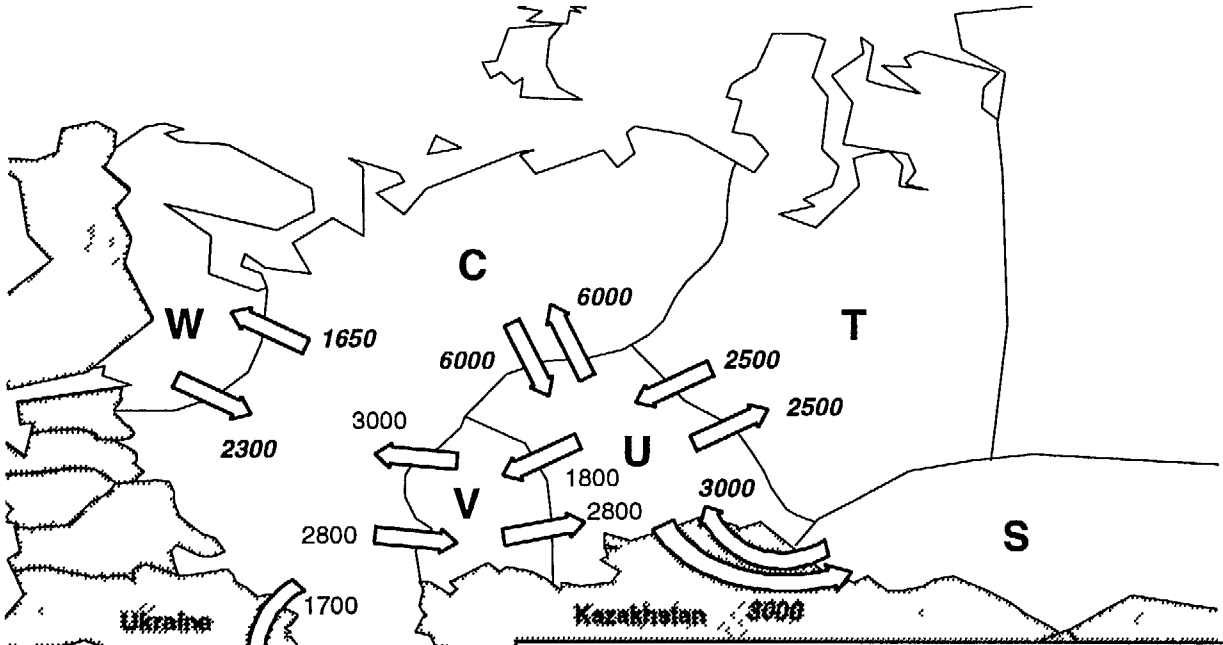
- Removing SO2 scrubbers from modernized and new coal plants is projected to increase coal CPP capacity additions by over 5 3 GW Gas CHP capacity is reduced by the same amount Thus, with lower coal capital costs, the model finds it economic to build coal CPP instead of Gas CHP CC Additional boilers are built to meet the heat demand

- In the Transmission Capacity Change Case, additional hydro capacity of 0 6 GW is constructed in Siberia

- 1 2 GW of new nuclear capacity is also added in Siberia in the transmission capacity change case

- This additional capacity is added in Siberia to meet a 1 6 GW increase in firm capacity exports as specified by ERI

# Transmission Capacity Expansion Analyzed in IPM©




W = North West
C = Center
N = North Caucasus
V = Middle Volga
U = Urals
T = Tyumen
S = Siberia

Notes
- Arrows show directions of inter regional transmission constraints, but do not indicate location of actual transmission lines
- The study assumes no inter-regional transmission capacity in or out of the Far East region (not shown)
- Capacities in bold italics are different from the Reference Case

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# Transmission Capacity Expansion Projects Were Analyzed in a Change Case in IPM©

- The transmission capacity addition from Siberia to the Ural region was fully utilized in the transmission change case
- The transmission capacity addition from the Urals to the Center was not fully utilized

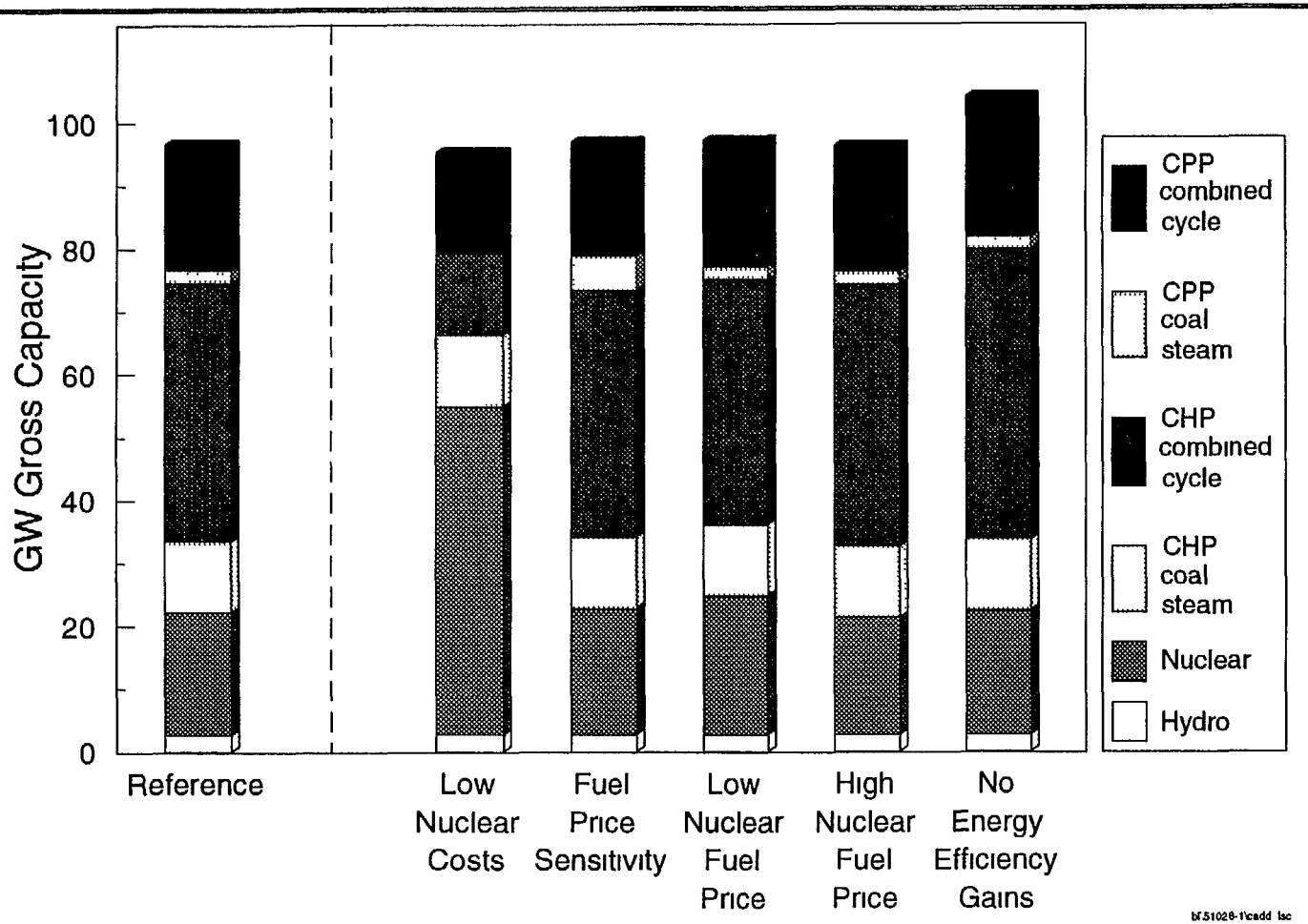
# Cumulative Investment and System Costs For Reference Case A and Change Cases

| CASE DESCRIPTION | INVESTMENT COSTS TOTAL (Billions 1994 $) | INVESTMENT COSTS CHANGE FR REF CASE (%) | SYSTEM COSTS TOTAL (Billions 1994 $) | SYSTEM COSTS CHANGE FR REF CASE (%) |
|---|---|---|---|---|
| Reference Case | 113 9 | NA | 143 6 | NA |
| 20% Reduction in Nuclear Costs | 133 6 | 17 3% | 141 5 | -1 5% |
| High Nuclear Fuel Prices | 113 2 | -0 6% | 146 2 | 1 8% |
| Fuel Price Sensitivity | 115 0 | 0 9% | 149 4 | - 4 0% |
| Energy Eff Gains Added to Demand | 125 1 | 9 8% | 149 0 | 3 7% |
| Low Nuclear Fuel Prices | 117 5 | 3 1% | 140 9 | -1 9% |
| American Nuclear Decommissioning | 114 1 | 0 2% | 143 6 | -0 0% |
| Full Containment | 113 8 | -0 1% | 146 0 | 1 7% |
| Constant Nuclear Share | 119 5 | 4 9% | 143 8 | 0 1% |
| Early Nuclear Decommissioning | 117 0 | 2 8% | 145 0 | 1 0% |
| 1995 Dec of Kursk 1 | 113 6 | -0 3% | 143 7 | 0 1% |
| No New Nuclear Capacity | 112 6 | -1 2% | 143 8 | 0 1% |
| No Air Pollution Control Equipment | 109 7 | -3 6% | 142 8 | -0 6% |
| Tran Capacity Additions | 116 7 | 2 5% | 143 6 | 0 0% |

# The Largest Change in Investments Occurs in the Lower Nuclear Capital Cost Case

- Lowering nuclear capital costs by 20 percent results in a large increase in new nuclear capacity additions
- For the most part, the model elects to build new nuclear capacity and stand-alone boilers to meet heat demand rather than Combined Cycle CHP plants
- Because nuclear capacity is capital intensive, investment increases by nearly 20 billion dollars, or 17 percent In this case, total system costs decline by 1 5 percent reflecting the lower variable cost of nuclear generation
- IPM estimates that investment would increase by 11 2 billion dollars if cost effective energy efficiency gains were not included in the Reference Case
- Removing SO2 scrubbers from new and modernized coal plants reduces capital investment by a total of 4 billion dollars

# Cumulative Capacity Additions Through 2010 For Reference Case B and Related Scenario Cases

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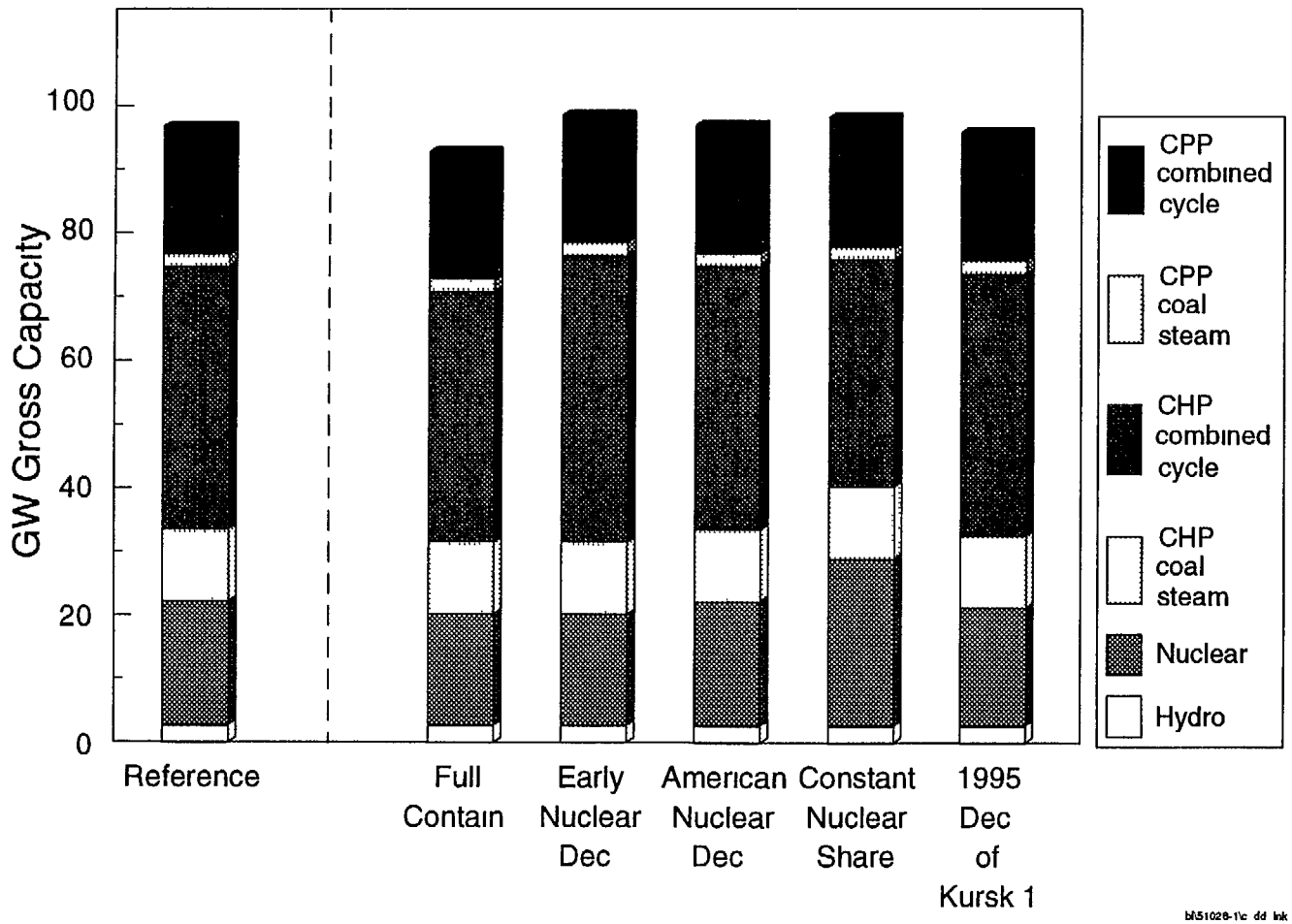
# As in Reference Case A, Reducing Nuclear Capital Costs Substantially Increases Nuclear Capacity Additions

- In the Low Nuclear Capital Cost Change Case, capacity additions of nuclear power plants, including safety upgrades, increased by 32 7 GW
- The Low Nuclear Fuel Price Change Case yields an increase of 2 5 GW of nuclear capacity additions
- In the Energy Efficiency Change Case, the model adds 7 3 GW of additional capacity relative to the Reference case The additional capacity is almost exclusively combined cycle CHP and CPP
- The Fuel Price Change Case leads to an increase in CPP coal capacity of 3 4 GW Nuclear capacity also increases by 0 6 GW

# Cumulative Capacity Additions Through 2010 For Reference Case B and Related Nuclear Decision Cases

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# The Nuclear Decision Cases Have More Impact on Upgrade Decisions under Reference Case B Assumptions

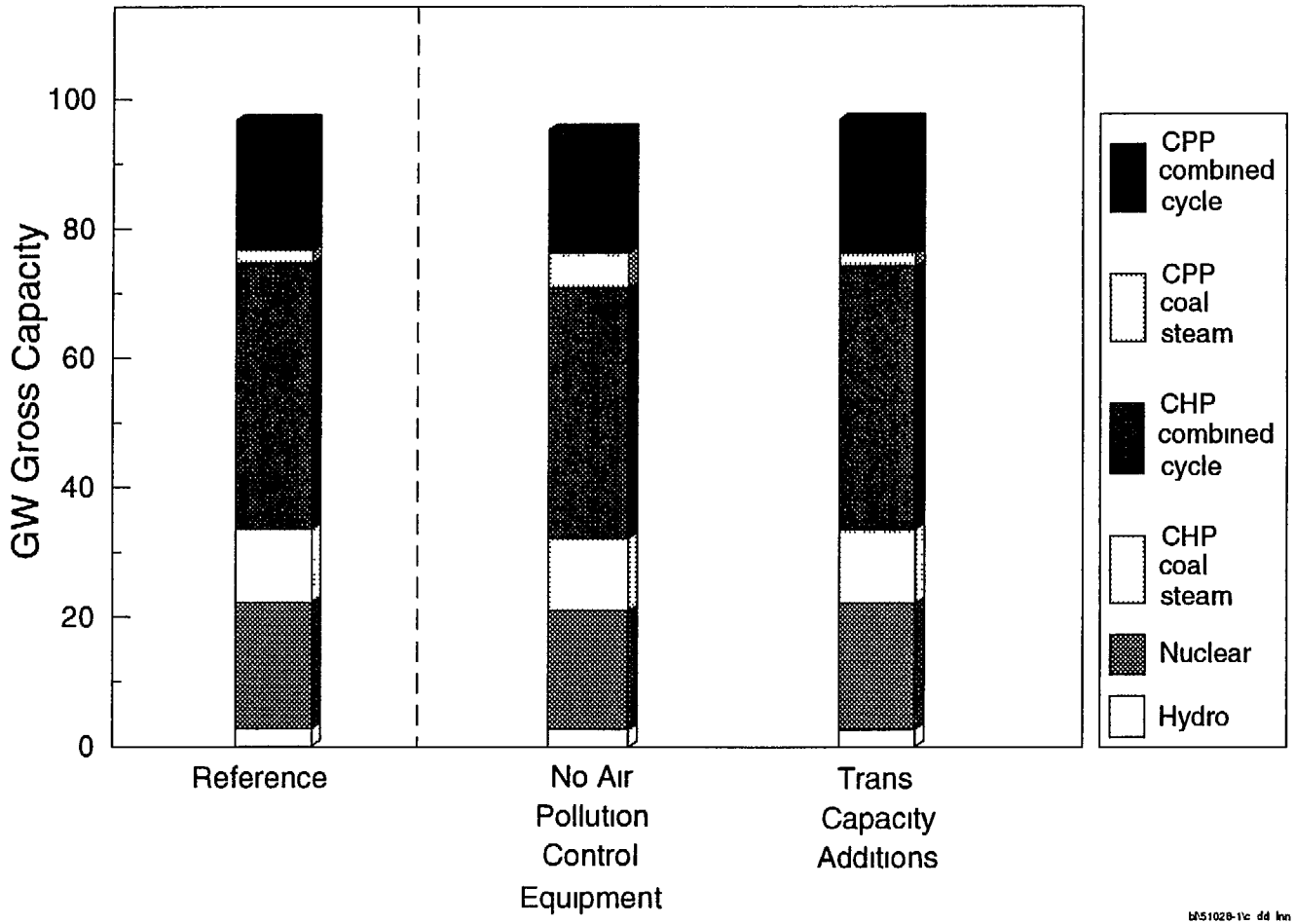
- In the Full Containment Change Case, Leningrad units 1 and 2 are not upgraded In addition, Kursk 1 is also not selected for upgrading All other upgrade choices are the same as in Reference Case B

- Early Decommissioning has the same effect as Full Containment on the model's nuclear upgrade decisions Leningrad 1 and 2 and Kursk 1 are not selected for upgrade

- In the American Decommissioning Change Case, Kursk 1 and Leningrad 2 are upgraded

- In the Constant Nuclear Share Change Case all existing nuclear units except Leningrad 1 are selected for upgrading In addition, 6 5 GW of new nuclear capacity is added

# Cumulative Capacity Additions Through 2010
# For Reference Case B and Related Non-Nuclear Decision Cases



# Removing SO2 Scrubbers from Coal Plants Would Increase Coal and Reduce CHP Additions

- Removing SO2 scrubbers from modernized and new coal plants is projected to increase coal CPP capacity additions by 3 6 GW Higher coal additions are offset by reductions in gas combined cycle capacity
- In the Transmission Capacity Change Case has little effect on capacity additions under Reference Case B assumptions

# Cumulative Investment and System Costs For Reference Case B and Change Cases

| CASE DESCRIPTION | INVESTMENT COSTS TOTAL (Billions 1994 $) | INVESTMENT COSTS CHANGE FR REF CASE (%) | SYSTEM COSTS TOTAL (Billions 1994 $) | SYSTEM COSTS CHANGE FR REF CASE (%) |
|---|---|---|---|---|
| Reference Case | 69 3 | NA | 116 7 | NA |
| 20% Reduction in Nuclear Costs | 87 4 | 26 2% | 115 4 | -1 1% |
| Low Nuclear Fuel Prices | 70 8 | 2 3% | 114 2 | -2 1% |
| Energy Eff Gains Added to Demand | 75 9 | 9 6% | 119 6 | 2 5% |
| Fuel Price Sensitivity | 68 3 | -1 5% | 121 5 | 4 2% |
| High Nuclear Fuel Prices | 69 0 | -0 4% | 119 0 | 2 0% |
| 1995 Dec of Kursk 1 | 69 0 | -0 4% | 116 7 | 0 0% |
| Constant Nuclear Share | 73 1 | 5 5% | 117 0 | 0 3% |
| Full Containment | 68 0 | -1 8% | 118 8 | 1 8% |
| American Nuclear Decommissioning | 69 3 | -0 0% | 116 6 | -0 1% |
| Early Nuclear Decommissioning | 72 1 | 4 1% | 117 7 | 0 9% |
| No Air Pollution Control Equipment | 64 8 | -6 5% | 116 0 | -0 6% |
| Transmission Capacity Additions | 69 2 | -0 1% | 116 0 | -0 6% |

# The Largest Change in Investment Again Occurs in the Lower Nuclear Capital Cost Case

- Lowering nuclear capital costs by 20 percent results in an increase in investment of 18 1 billion dollars, or 26 percent

- IPM estimates that investment would increase by 6 6 billion dollars if cost effective energy efficiency gains were not included in Reference Case B

- Removing SO2 scrubbers from new and modernized coal plants reduces capital investment by about the same amount as in Reference Case A, 4 5 billion dollars