Modeling China's Energy Future

A coordinated analysis between
Tsinghua Global Climate Change Institute
Princeton Environmental Institute and
Clean Energy Commercialization

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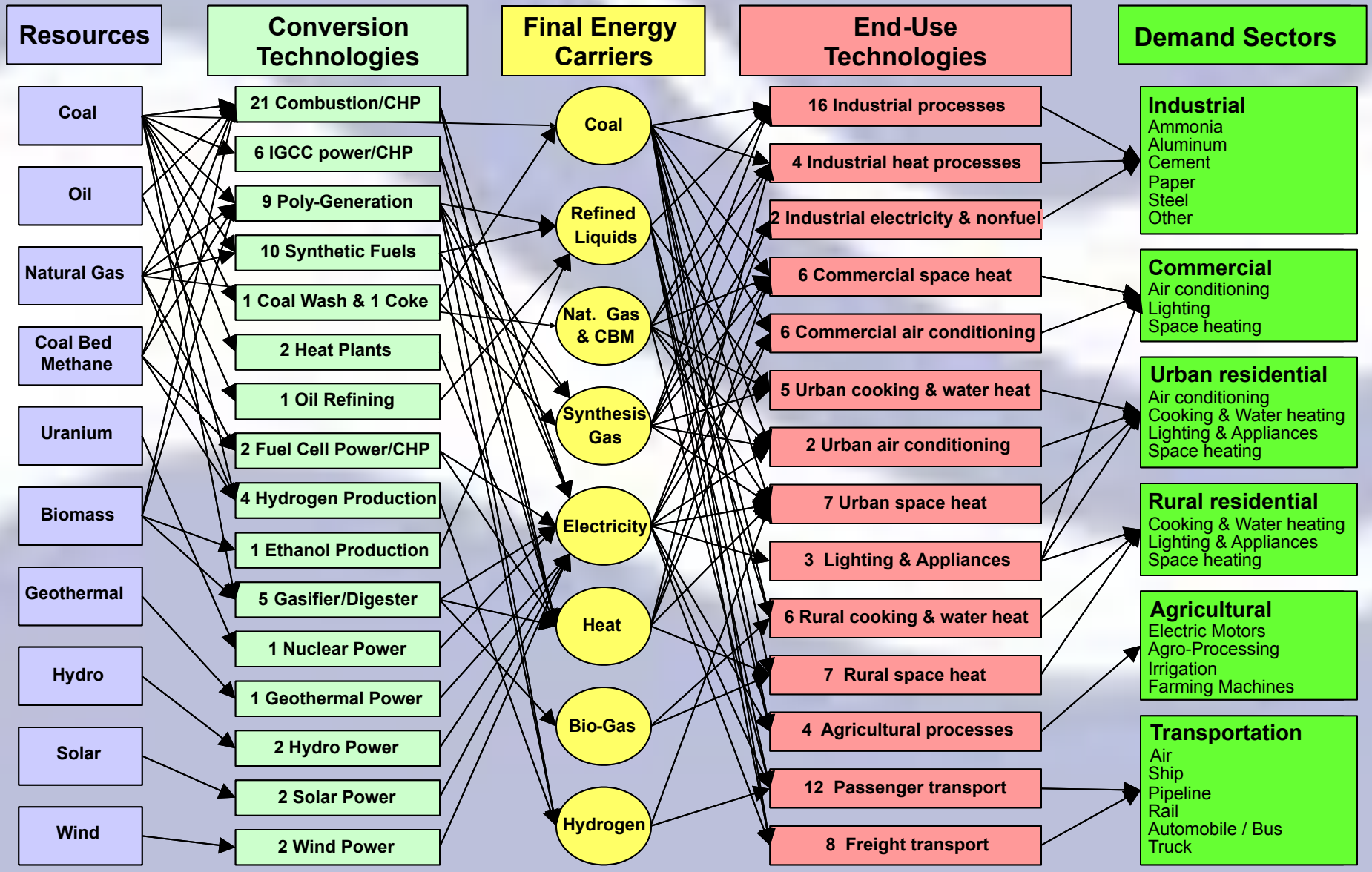
CCICED Addressed Four Key Questions:
How can China

- **Meet its projected demand for energy services? (Quadruple GDP by 2020)**
- **Meet projected liquid fuel needs, especially for transportation, while not becoming over-dependent on imported energy?**
- **Reduce urban and rural air pollution while meeting its projected demands for energy services?**
- **Meet requirements for lower carbon emissions that may be implemented due to global warming concerns?**

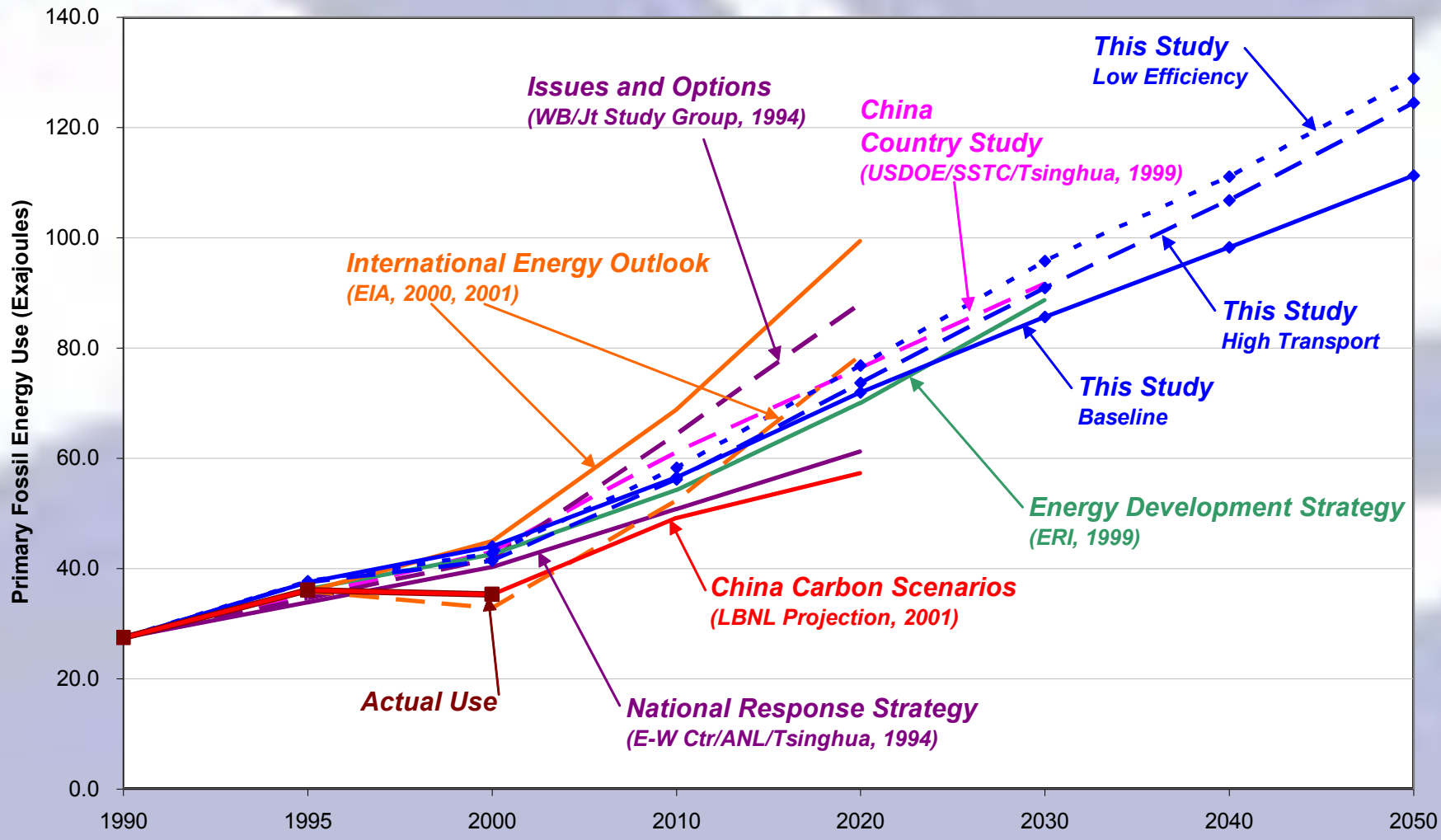
China MARKAL Model Structure



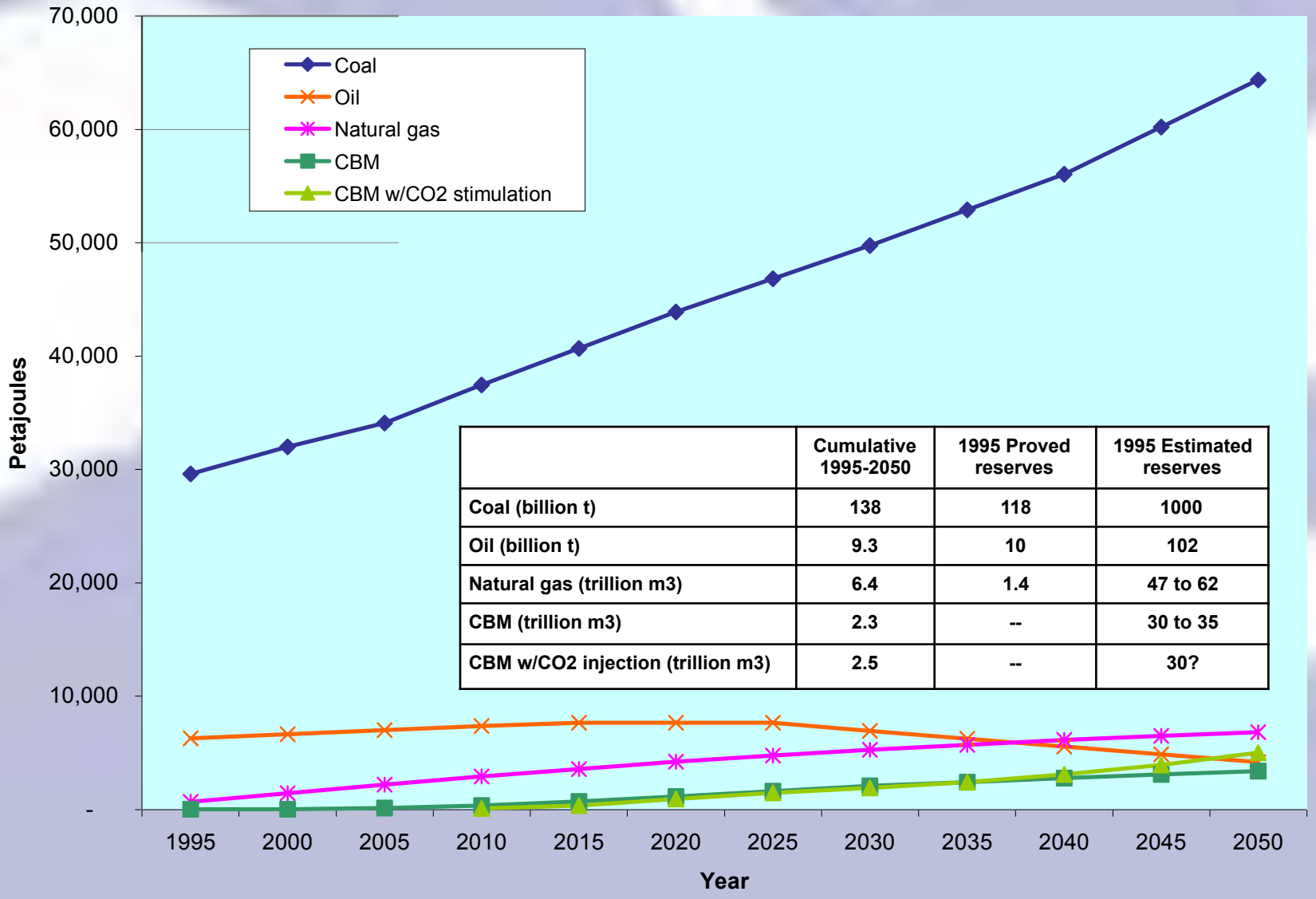
Methodology for Projecting Energy Service Demands

- Future energy demands projections were based on comparisons with historical data for various OECD countries at similar levels of GDP per capita
- Key assumption was that by 2050 China as a whole will have developed to the levels of energy services that are characterized key OECD countries in the mid-1990s
- Cross-country comparisons were selected to minimize the differences in economic structure, demographics, geography, culture, development path, etc.
- The methodology ties the projection of energy service demands to the level of economic development toward which China aspires in the future

Projections for Primary Fossil Energy Demand in China



Potential Domestic Fossil Fuel Supplies

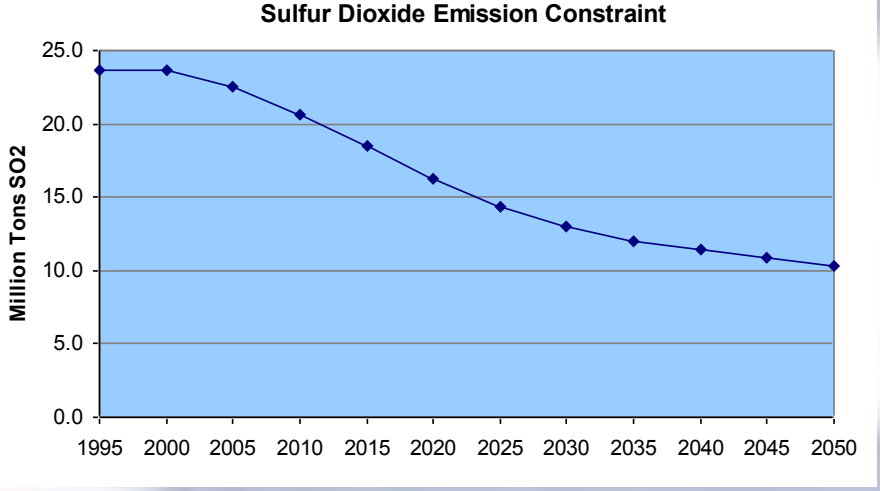


	Cumulative 1995-2050	1995 Proved reserves	1995 Estimated reserves
Coal (billion t)	138	118	1000
Oil (billion t)	9.3	10	102
Natural gas (trillion m3)	6.4	1.4	47 to 62
CBM (trillion m3)	2.3	--	30 to 35
CBM w/CO2 injection (trillion m3)	2.5	--	30?

Environmental and Energy- Security Constraints

Sulfur Emissions Constraint

- SO_2 emission level for 2020 is government target of 16.5 Mt
- 2050 constraint of 10.4 Mt brings China to same level of SO_2 emission per GJ of coal consumption as US in 2000



Energy Security Constraints

- Imported oil and natural gas constrained to be 30% to 50% of total oil and gas fuel consumption in any given year.

Carbon Emissions Constraints

WRE emissions scenario		Cumulative CO_2, 1990-2100 (Gt C)		China's allowable C emissions, 1995-2050 (Gt C)
	Stable CO_2 (ppmv)	Global	China's "allowance"	
High	750	1400	301	89
Medium	550	1100	237	80
Low	450	750	161	66
Very low	350	380	82	46

Two Technology Scenarios

BASE TECHNOLOGIES

- Coal used primarily by existing or advanced direct combustion technologies
- Energy end-use technologies include current best energy-efficiency options
- Renewable energy technology limited to those currently commercial
- Carbon sequestration options are not available
- Available starting in 1995 or 2000

ADVANCED TECHNOLOGIES

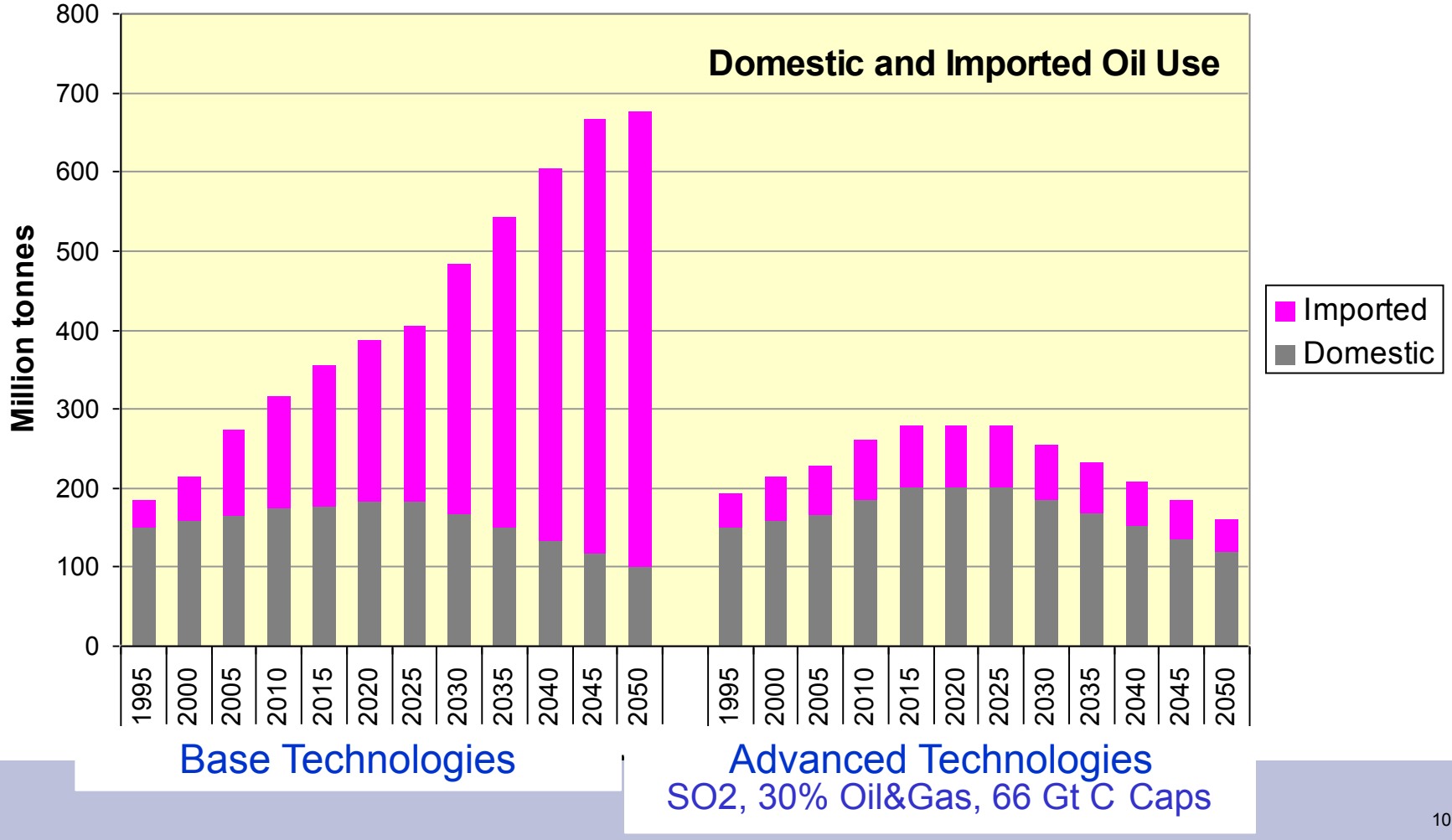
- Advanced poly-generation technologies based on gasification of coal and biomass
- Advanced high-efficiency industrial processes
- Advanced renewable energy technologies
- Urban residential demand technologies
- Hybrid-electric and fuel cell vehicles
- Carbon capture and sequestration options
- Available starting between 2005 and 2015

Technology Characteristics

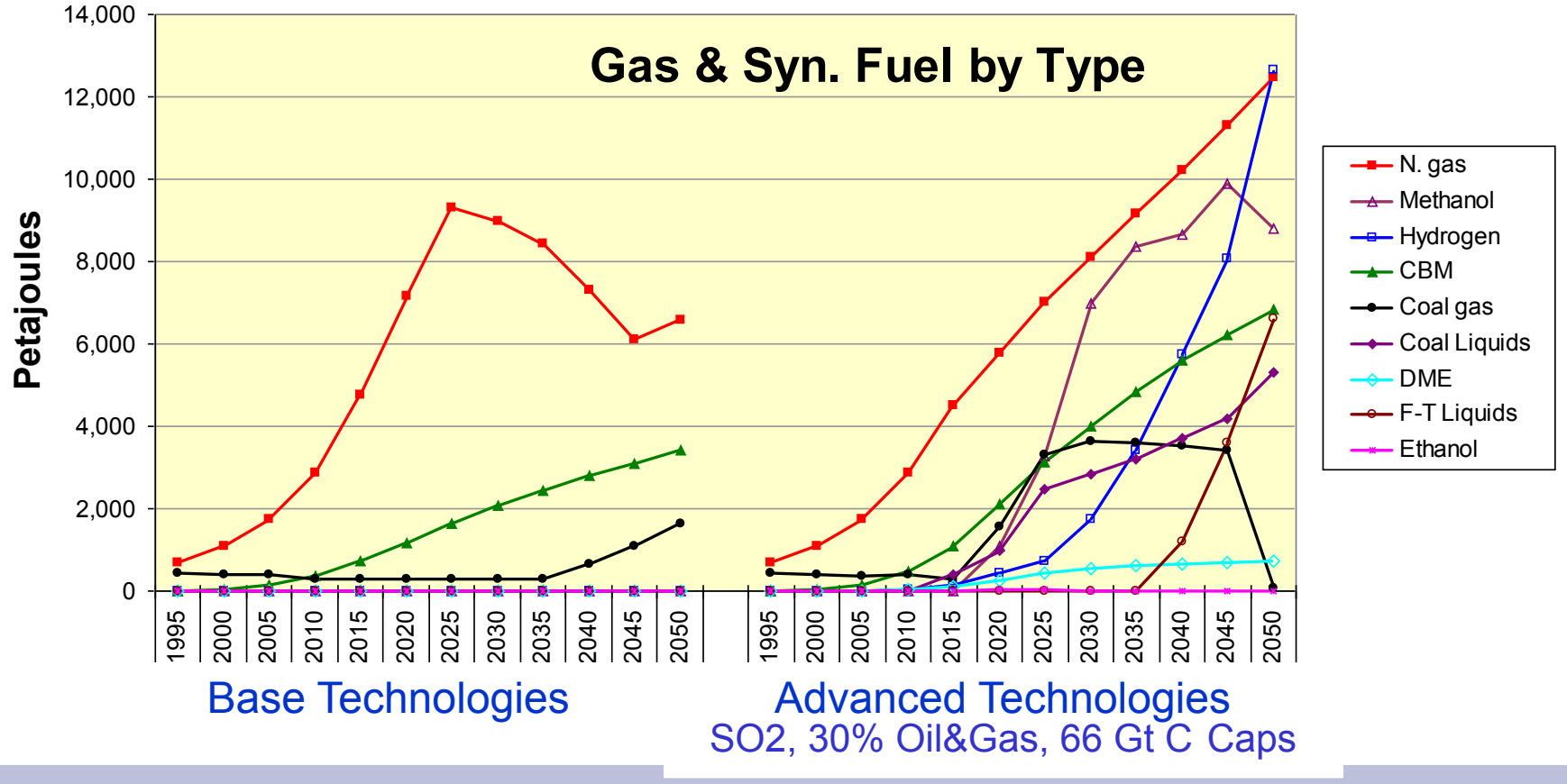
Advanced Techs were phased in over 3, 5-year periods at 1.5, 1.25 and 1.1 times their mature plant cost

	Efficiency (% LHV)	Capital Cost ($/kW)	Fixed O&M ($/kW-yr)	Variable O&M ($/kWh)	SO_2 (gr/kWh)
BASE Technologies					
Coal, steam plant with FGD (500 MW)	36.4	1,090	16.1	0.0020	0.46
Natural gas, gas turbine combined cycle	58.1	600	16.1	0.0015	0
Nuclear	33.0	2,000	40.0	0.0086	0
Wind, large-scale with long-dist. transmission	-	580	5.0	0.0020	0
ADVANCED Technologies					
Coal, integrated gasification/combined cycle	43.0	1,068	21.4	0.0024	0.075
Coal, gasification-based, with CO_2 capture	36.8	1,383	27.7	0.0031	0
Natural gas, combined cycle with CO_2 capture	50.8	1,008	18.1	0.0026	0
H_2, distributed fuel cell combined heat/power	41.0	250	10.0	0	0
Biomass, electricity and DME co-production	16.3	2,141	44.8	0.0064	0

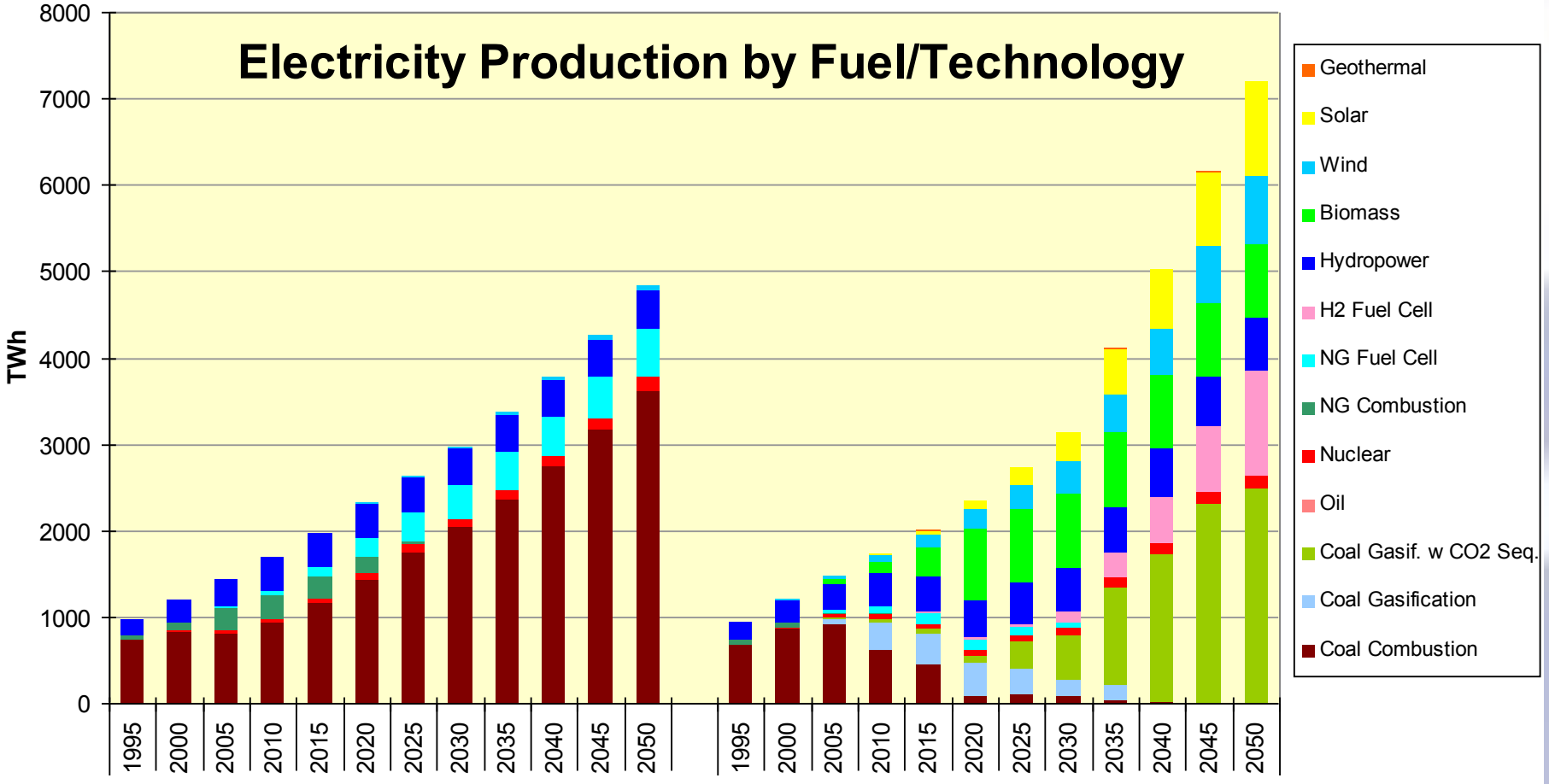
Base case oil imports are 435 Mt/yr in 2050 while AdvTech oil imports peak at about 75 Mt/yr in 2025. Transport drives Base case oil demand. Natural gas imports are reduced from 120 bcm (Base) to 70 bcm (AdvTech).



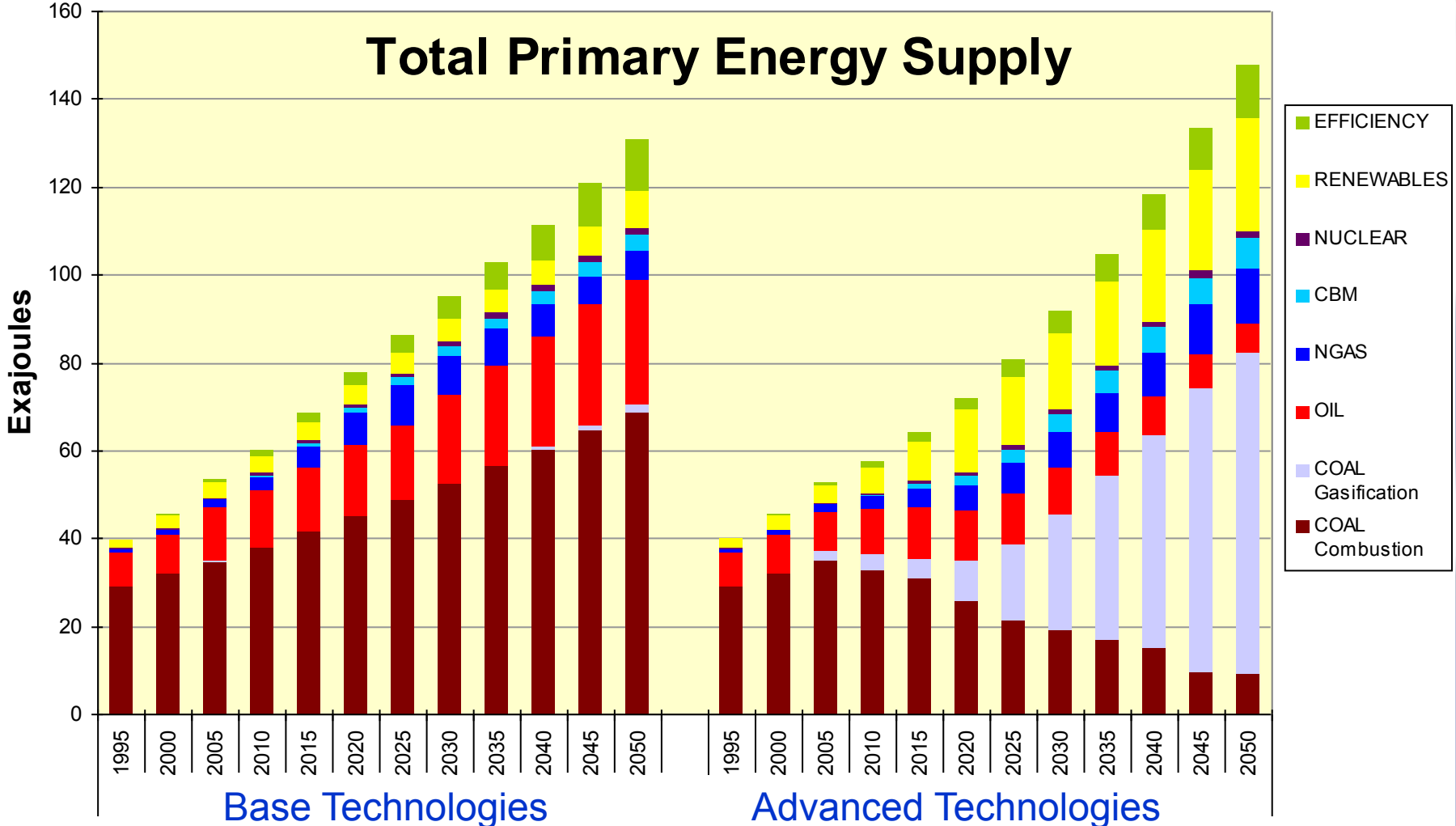
AdvTech scenario employs a variety of synthetic fuels: coal gas for urban heating and cooking; methanol, F-T liquids and later hydrogen for transportation; DME from biomass for rural heating & cooking



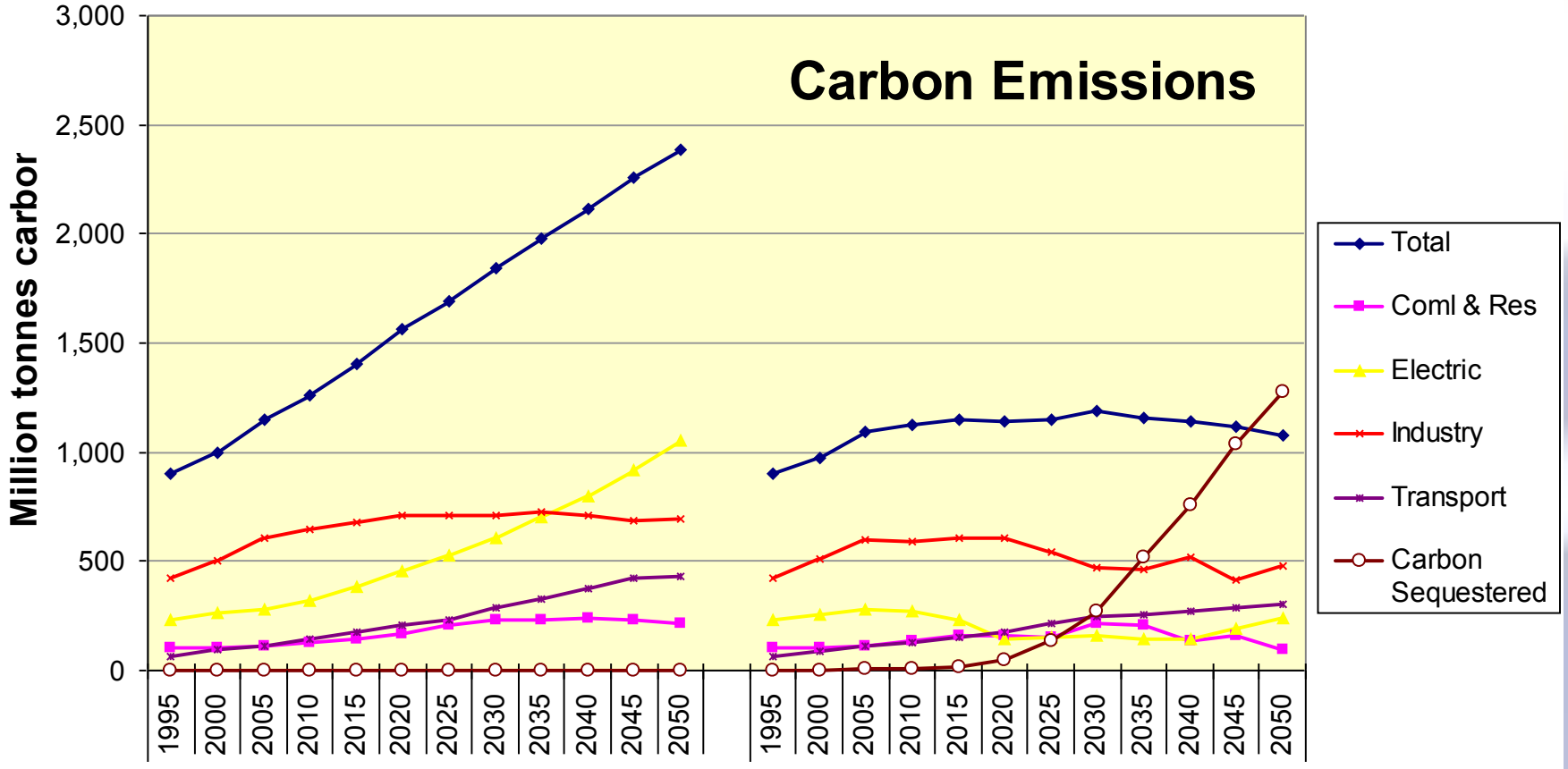
In AdvTech scenario, coal combustion is replaced by coal gasification and CO_2 sequestration. Biomass and wind power plants make significant contributions. CO_2 used for enhanced resource recovery of CBM.



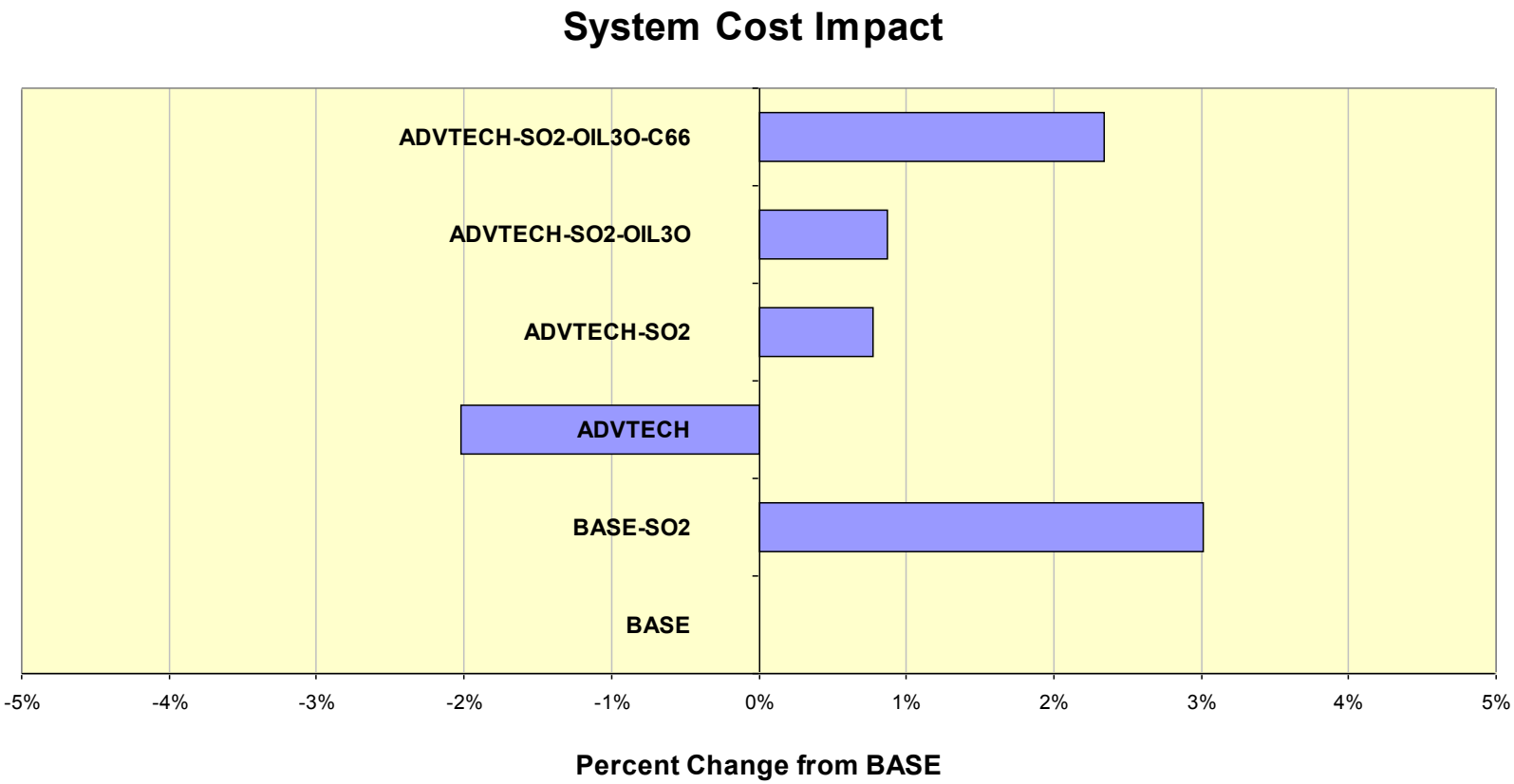
AdvTech scenario uses renewable energy in 2005-2020 period, which slows coal use. Coal gasification technologies start in 2005 but grow rapidly after 2020 when plant costs mature.



AdvTech: CO_2 emissions from electricity generation are reduced by renewables, CO_2 sequestration and by fuel-switching in the industrial, commercial and residential sectors.



AdvTech cases can achieve SO2, Oil30 and CO2 targets for lower cost than only achieving SO2 targets with the Base technologies.



Conclusions

- AdvTech strategy offers the opportunity to achieve China's sustainable development goals at lower cost than a "business-as-usual" approach
- AdvTech strategy also provides a lower-cost path to deep reductions in CO_2 emissions
- To realize the 3E's: Economic Development, Energy Security and Environmental Protection
  - Coal use must shift from combustion to gasification based technologies, which enables the production of clean synthetic liquid and gas fuels and significantly reduces the cost of CO_2 capture and sequestration
  - Gas and liquid fuels from coal and biomass need to play increasingly important roles in the energy economy
  - Energy efficiency and Renewable energy need to take on significant roles
  - Modest contributions from nuclear power can help achieve goals, but nuclear power is not essential if energy efficiency is stressed

Recent Developments in China

- Target 15% of energy consumption from renewable energies by 2020
- Commit US$185 billion investment
- Implementation of Renewable Energy Law
- Provide tax incentives for local manufacturing
- Bio-fuels
  - Corn ethanol
  - Bio-diesel
- Coal gasification-polygeneration
  - Shandong – Fischer Tropsche liquids
  - Ningsha – Dimethyl ether (DME)

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