Pak-IEM Team

Addressing the Critical Need for Longer Term Energy Planning in Pakistan

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Presentation Outline

Pak-IEM Team

- Policy Context
- In-country Capacity Building
- Model Development
- Scenario Analysis
- Conclusions

Policy Context

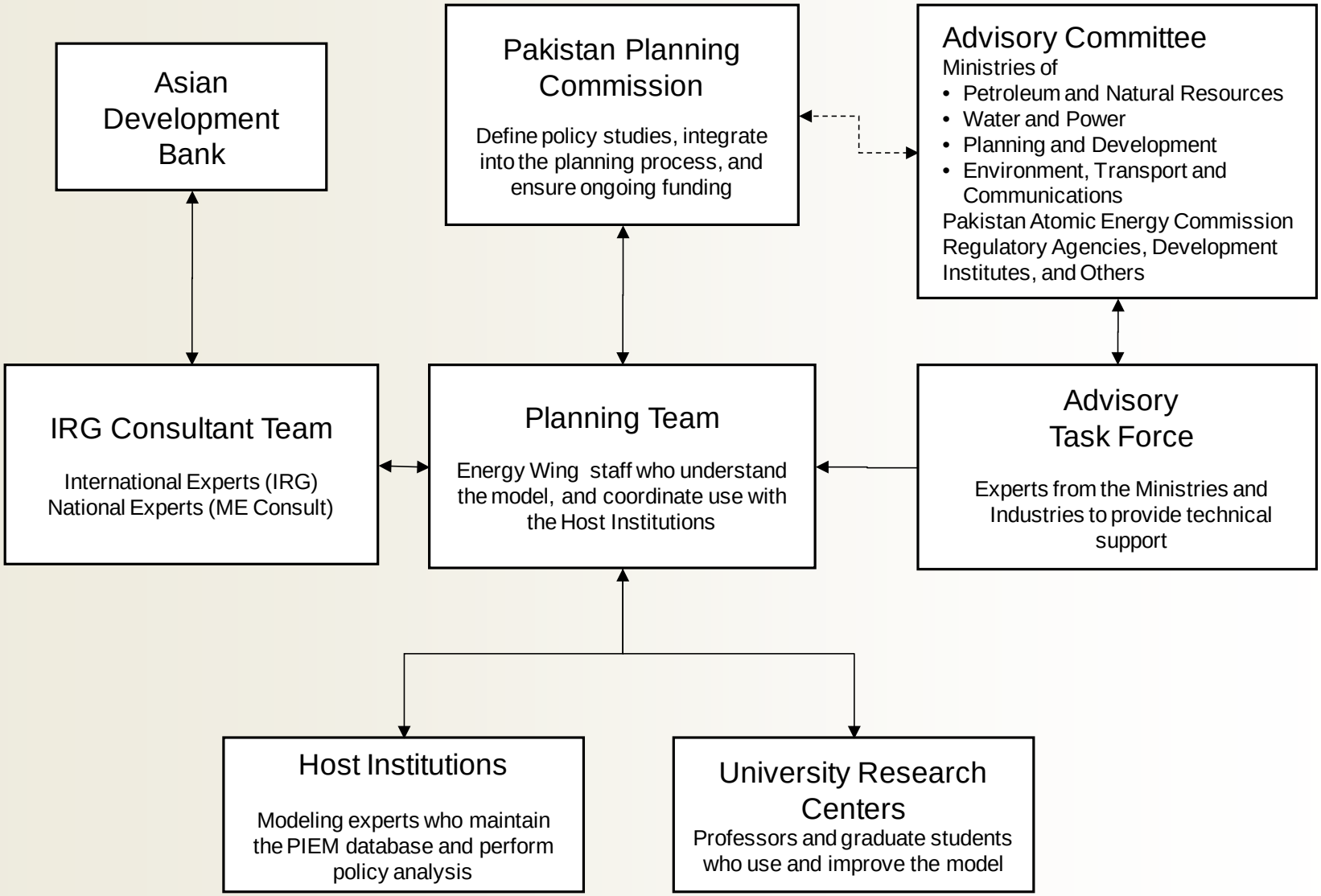
- Energy sector lacks strategic planning guided by analysis of societal costs and benefits to support decision-making
- Energy planning currently focused on individual energy sub-sectors such as gas, oil, coal and electricity
- No ability to optimize energy supply & demand investments
- Allocation of scarce resources are not optimized
  - Natural gas for industry, power sector, residential or transportation
  - Transporting imported oil upcountry for power plants versus building coastal power plants and transmitting electricity or building refineries versus importing refined oil products
- Poor understanding of relationships between the energy sector and the national economy
- All the above factors inhibit optimum decision making

ADB TA Project Goal

*To develop a **sustainable planning capability** employing an integrated **energy system model** that will enable a national team of experts to **assess impacts** of various strategies for meeting **future energy requirements** in an optimal manner*

Pak-IEM Project Institutional Structure

Pak-IEM Team



Contributing Stakeholders

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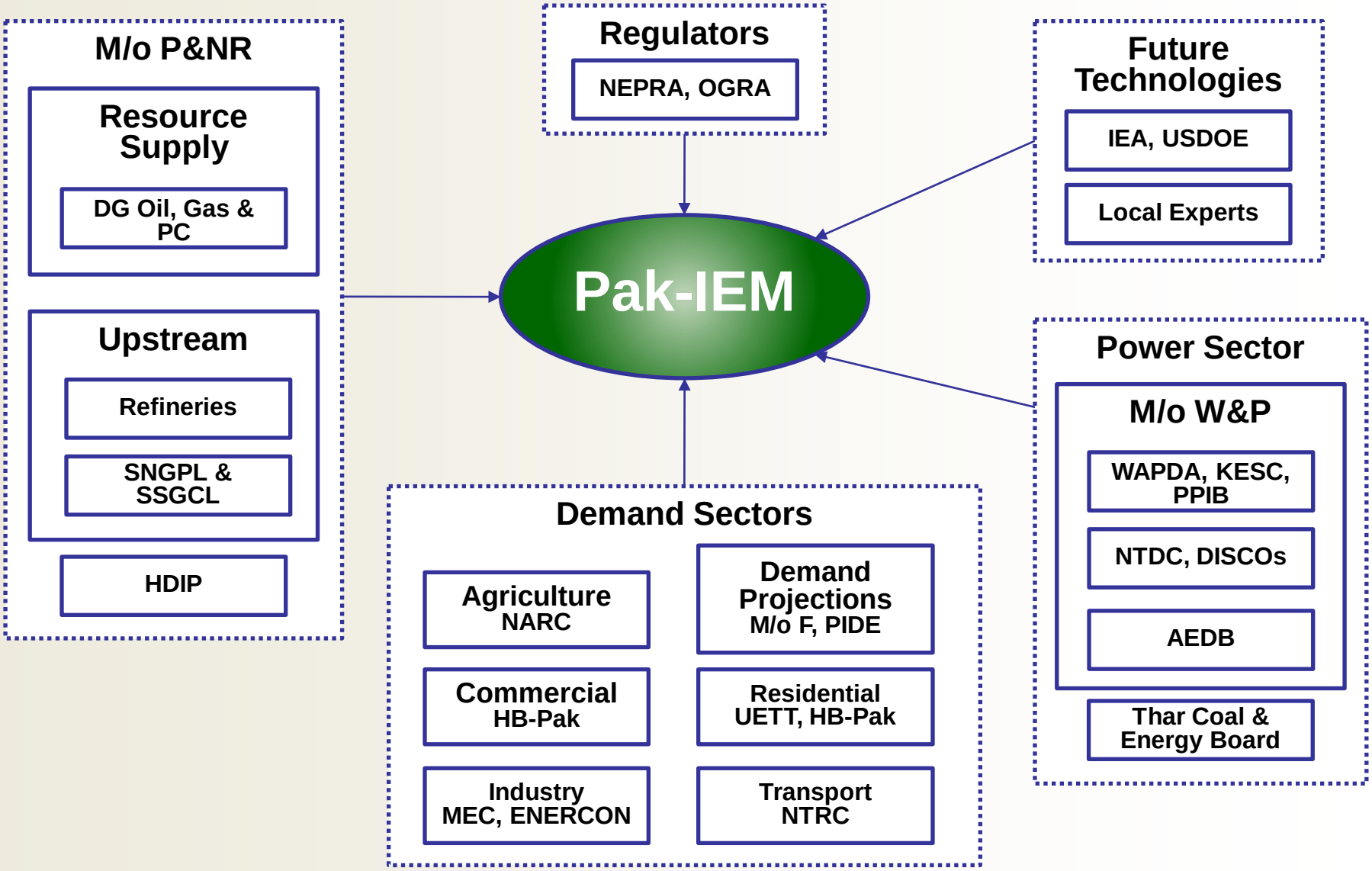

Reference Scenario Key Assumptions

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- Official projection of average economic growth of 5.6% over the planning horizon of 2007 to 2030
- Domestic Oil & Gas reserves and prices from Ministry of Petroleum
- Imported Oil &Gas prices from IEA
- Annual capacity addition limits on new power plant types
- New technology costs from WAPDA, PAEC, AEDB and IEA
- Thar coal mining cost and power costs based on Development Board Studies
- Penetration limits on energy efficiency devices (10% in 2030)
- Limits on the degree of fuel switching in demand sectors

Analytical Findings

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- **Achieving 5.6% average GDP Growth requires by 2030**
  - Four-fold increase in electricity consumption
    - 94,000 GWh to 410,000 GWh
  - 82,000 MW of new power generation capacity
  - Three-fold increase in high value petroleum products
    - 6.2 Mtoe to 18 Mtoe
- **Energy Security Alert – by 2030**
  - Proven oil and gas reserves run out
  - Energy imports jump from 27% to over 45% of total supply
- **Annual Savings from Smart Policies**
  - Eliminating load shedding avoids $44 billion in economic losses
  - Reducing T&D losses by 7% saves $2.6 billion (gross)
  - Increasing energy efficiency saves $14.5 billion (net)
  - Exploration to deliver 20% more gas saves an additional $16 billion (gross)

Primary Energy

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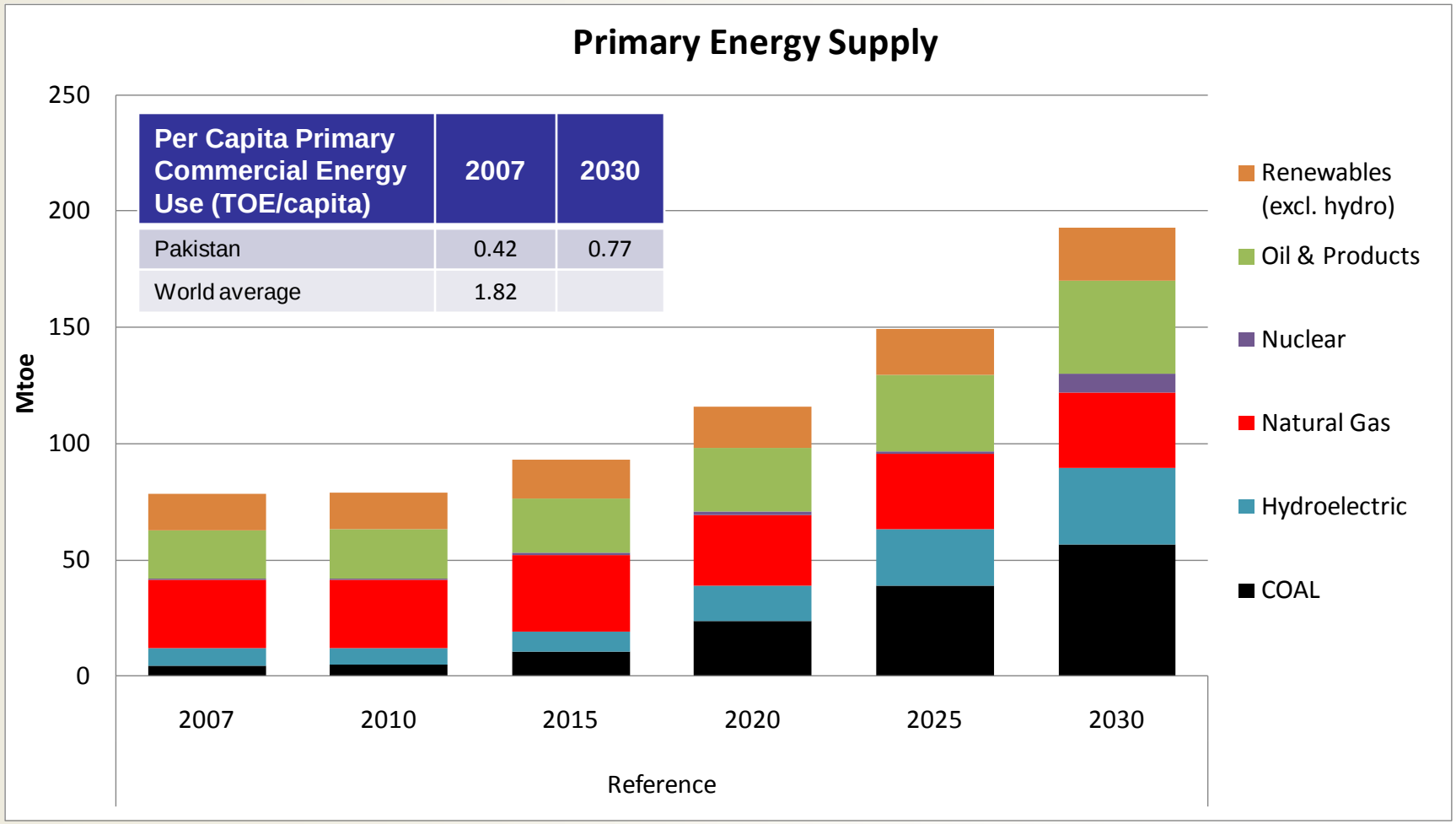
- Modest near-term primary energy growth
- Longer term growth dominated by coal and hydropower, along with transportation fuels



Power Plant Electricity Output

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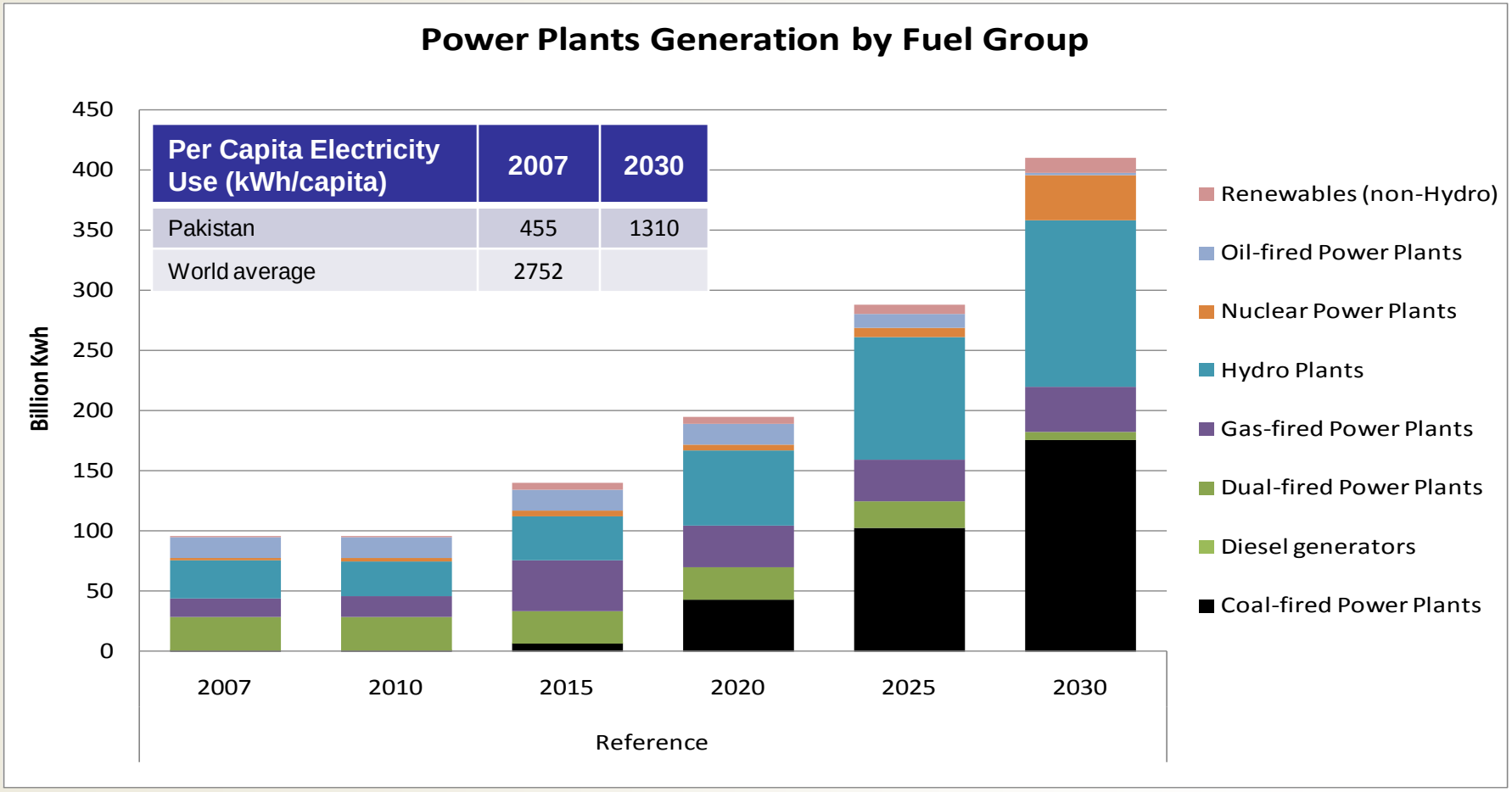
- Hydro and coal dominate, with new nuclear entering in later years
- Other fossil generation is strictly for peaking



Per Capita Electricity Use (kWh/capita)	2007	2030
Pakistan	455	1310
World average	2752	

Electricity Load-shedding

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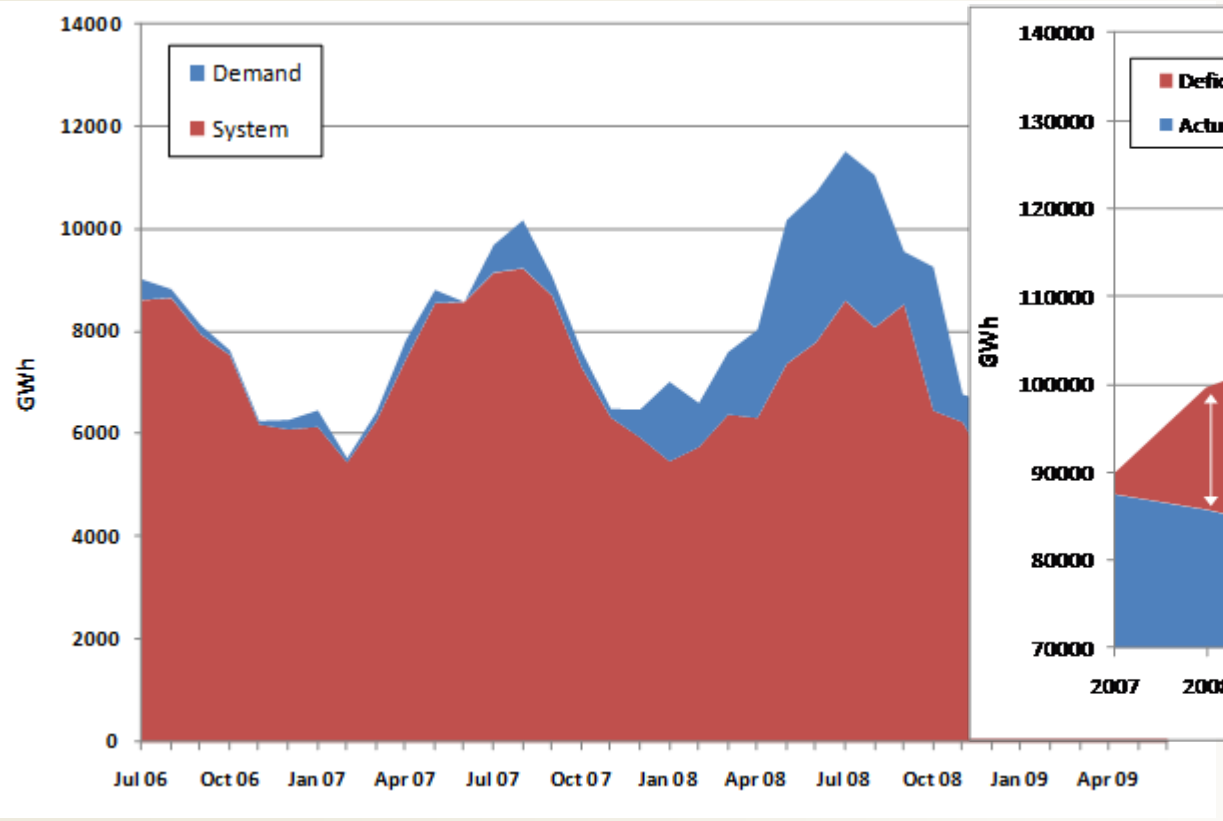
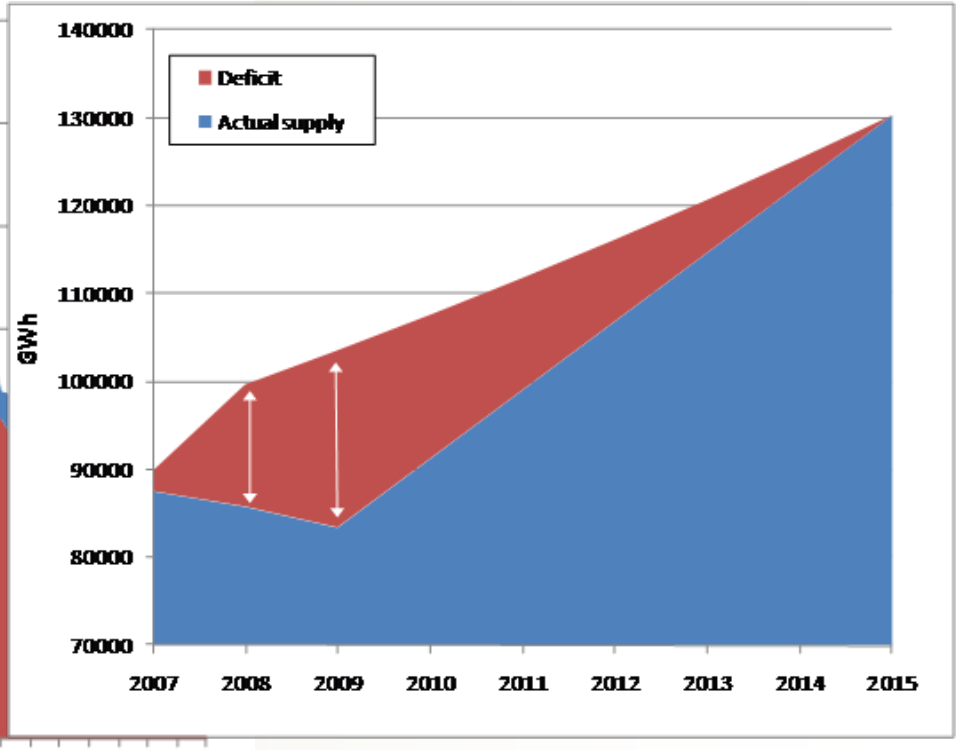
- $3.16 billion of additional investment in new power plants is required to eliminate load-shedding by 2015
- Eliminating load shedding by 2015 would avoid $44 billion in economic losses*





* "Power Outages in the Industrial Sector of Pakistan," 1989, adjusted to $0.6 /kWh on a $2006 basis.

Power Generating Capacity Additions

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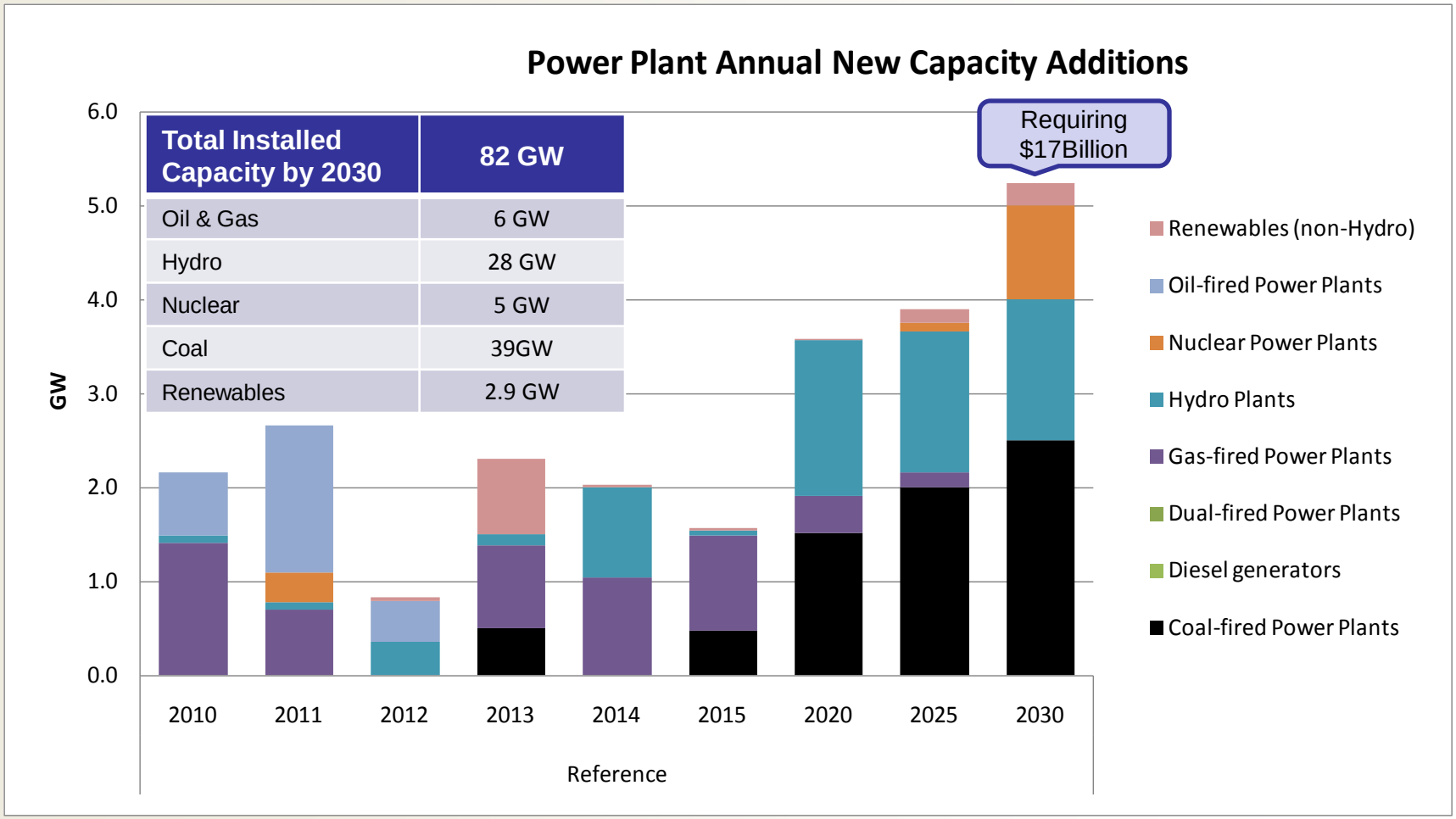
- Near-term is mostly planned builds through 2012, plus MSW
- Long-term hydro and Thar coal grow at their limits, with later nuclear additions also to its limit
- Renewable growth is MSW early, then primarily wind at its limit



CO_2 Emissions

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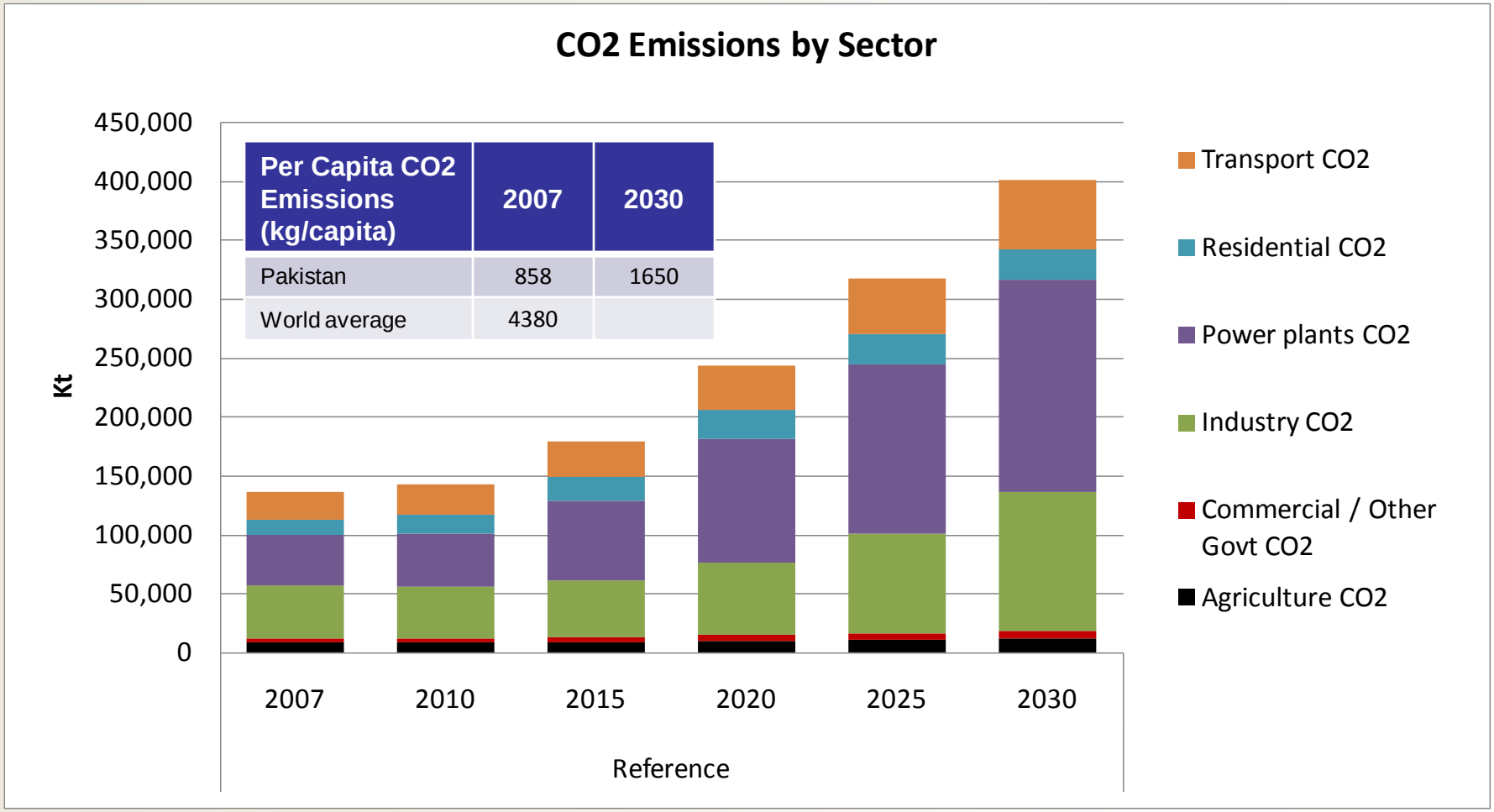
- Power sector emissions increase four fold due to new coal power plants
- Industry and transport also grow significantly



PAK-IEM SCENARIO ANALYSIS

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- **Pursue best practices**
  - Reduction of electric system losses by 7% in 2020
  - Promote power sector renewables
  - Encourage energy efficiency in demand sectors
  - Increase investment in oil & gas exploration
- **Challenges persist**
  - Delay Hydro and Nuclear by 5 years and No Thar Coal
  - No Imported Coal port facilities and power plants
  - No Imported Natural Gas
- **Best practice energy policies and programs, even under continued challenges**

Pakistan Pursues Best Practices
Energy System Costs

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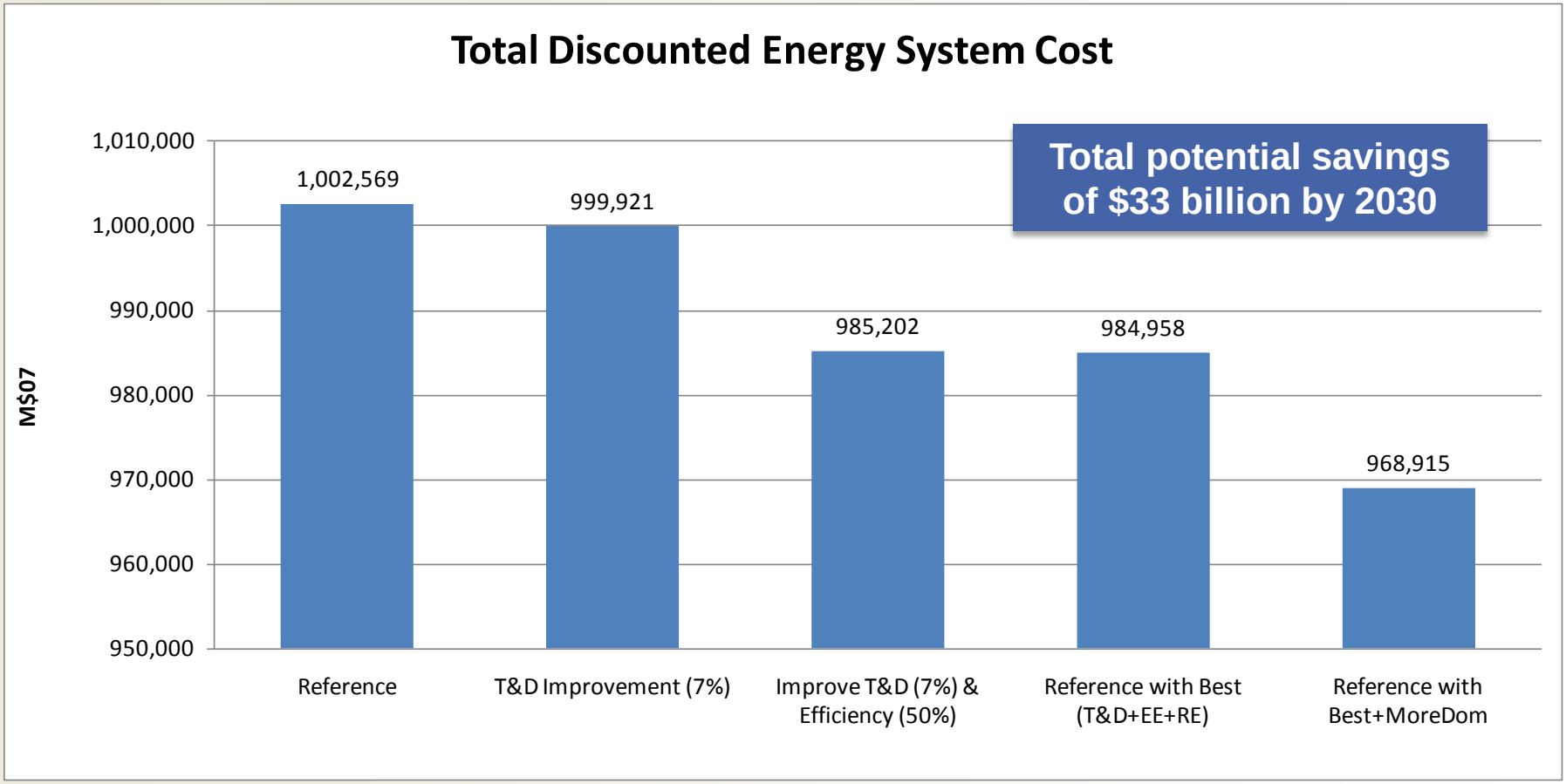
- T&D Improvements can realize $2.6 billion savings
- Energy efficiency measures can save another $14.5 billion
- Best Practice (adding renewables) does not increase cost
- Finding 20% more gas saves another $16 billion



Pakistan Pursues Best Practices
Power Generation

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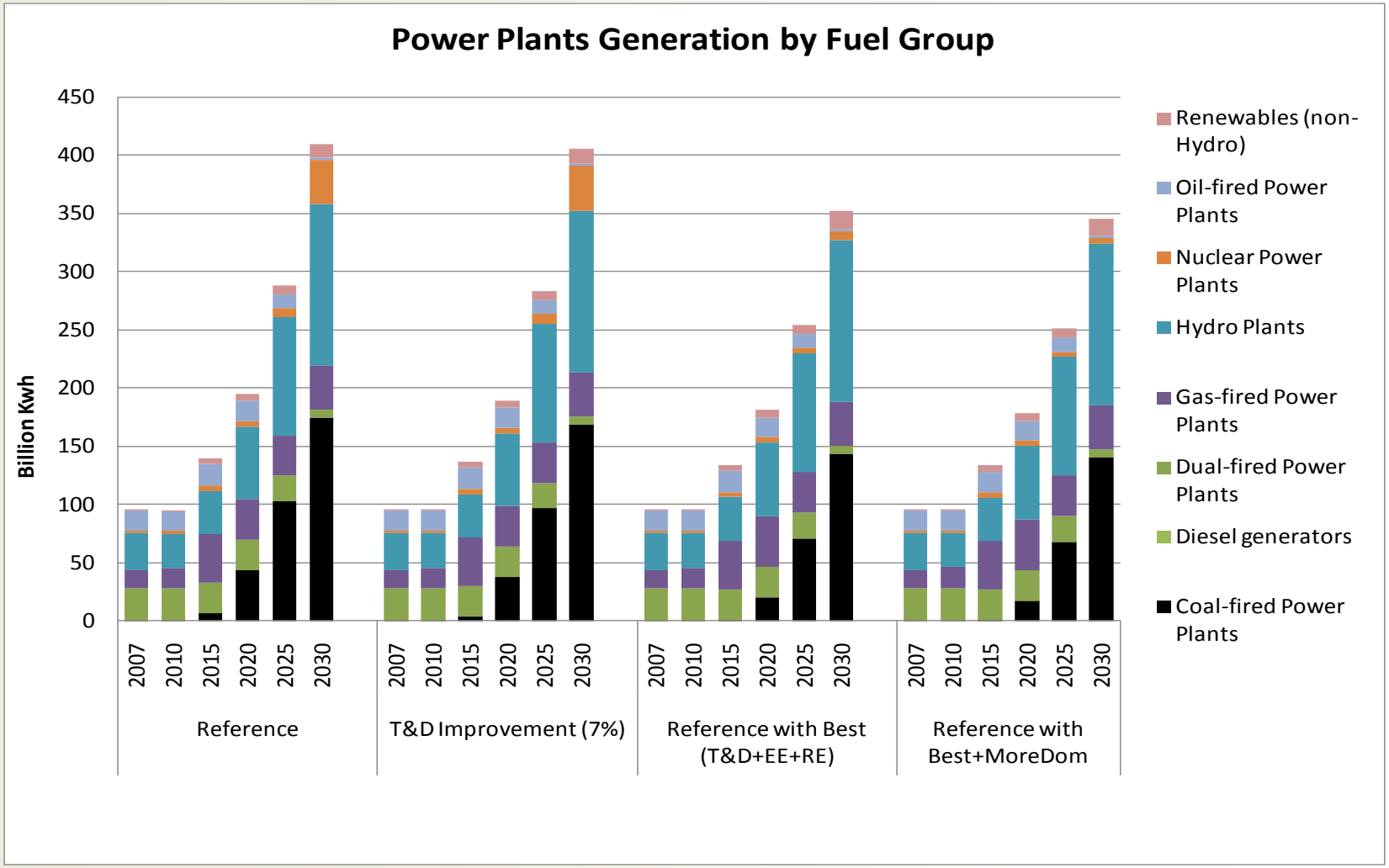
- Best practice and more gas result in less coal and nuclear generation, saving about 50-60 billion kWh annually by 2030



Pakistan Pursues Best Practices
Natural Gas Consumption

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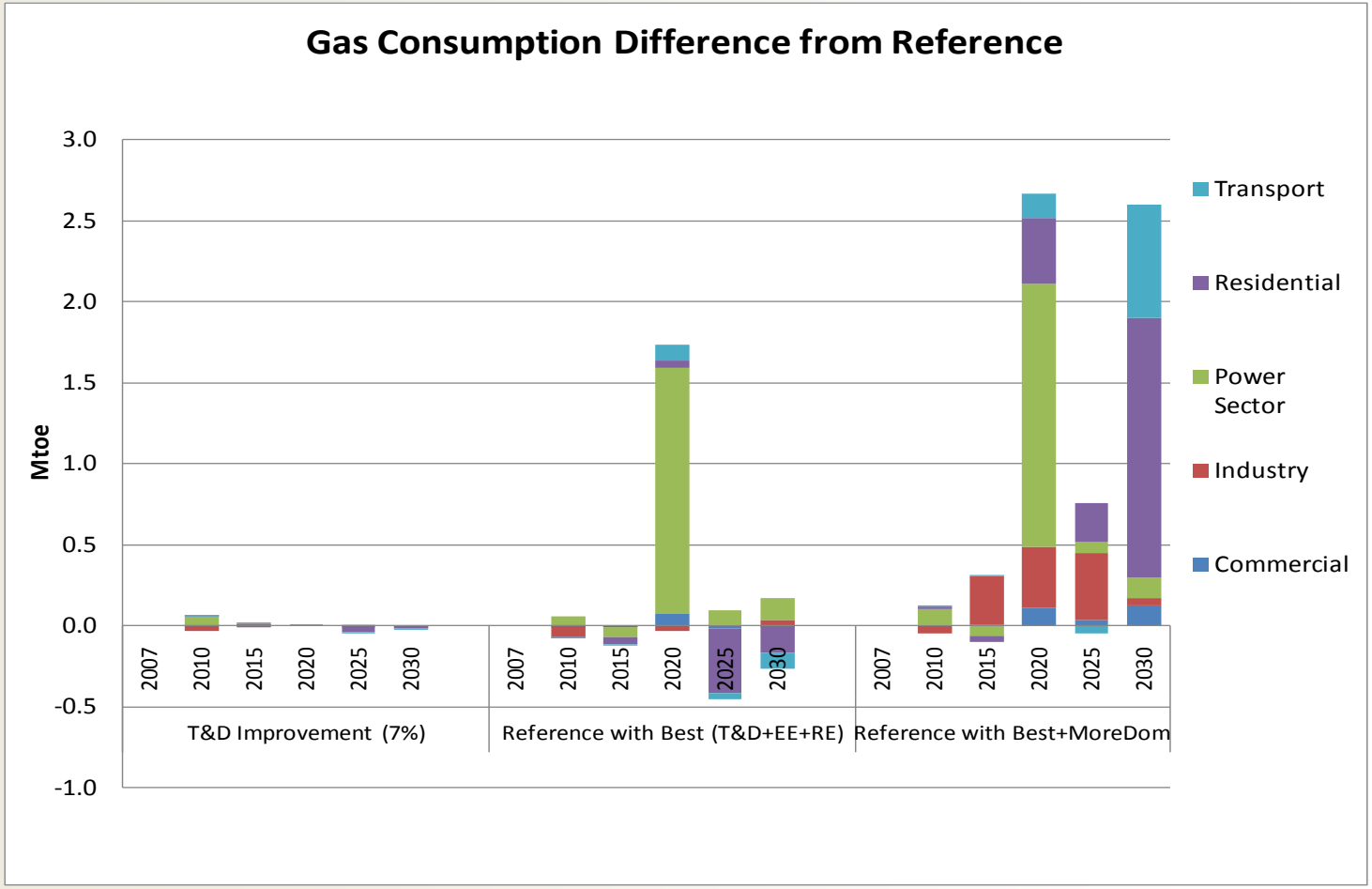
- Best Practice has LNG imported for the power sector, which encourages less direct use in residential
- Exploiting more conventional domestic gas encourages structural changes encouraging increased gas use in residential, industry and transport sectors



Challenges Persist
Energy System Costs

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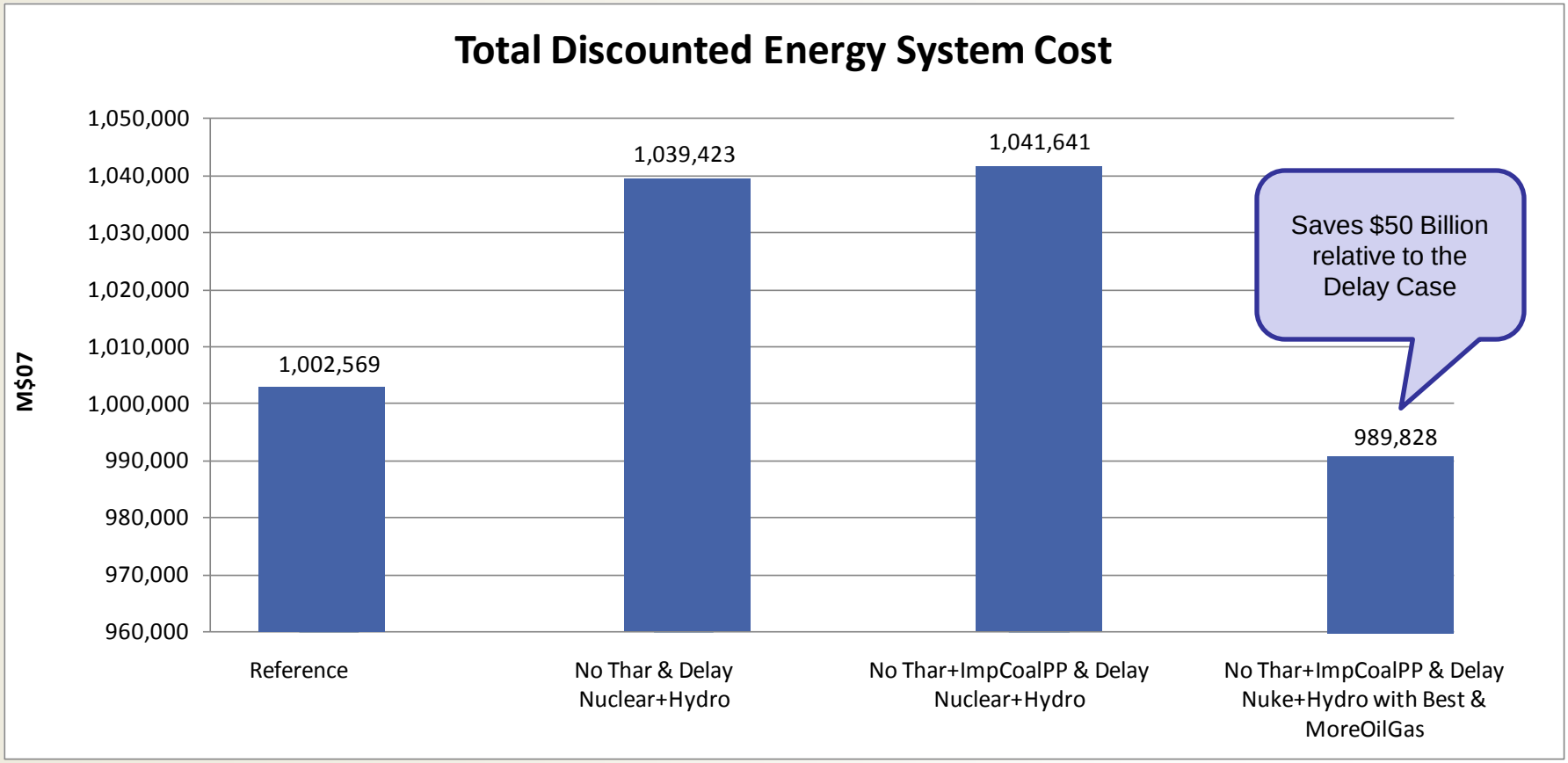
- No investment for Thar coal and delays to hydro and nuclear increase system cost by about $37 billion
- Implementing best practices plus finding more gas reduces the system cost $12.5 billion below the Reference case.



Challenges Persist
Energy System Expenditures

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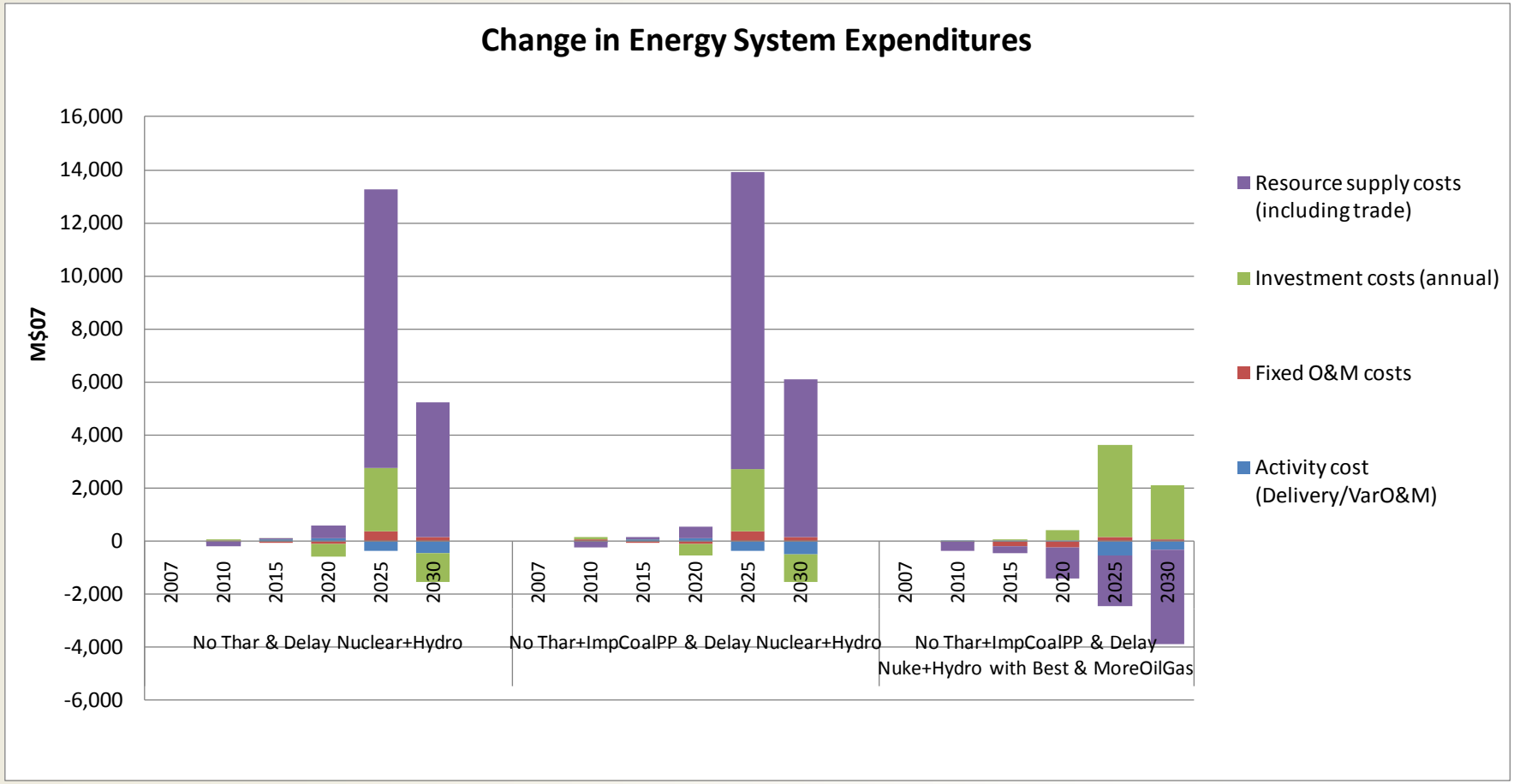
- The increased costs for lack of investment in Thar coal, hydro and nuclear mostly result from higher fuel costs; first for imported coal then for imported gas.



Challenges Persist
Power Generation

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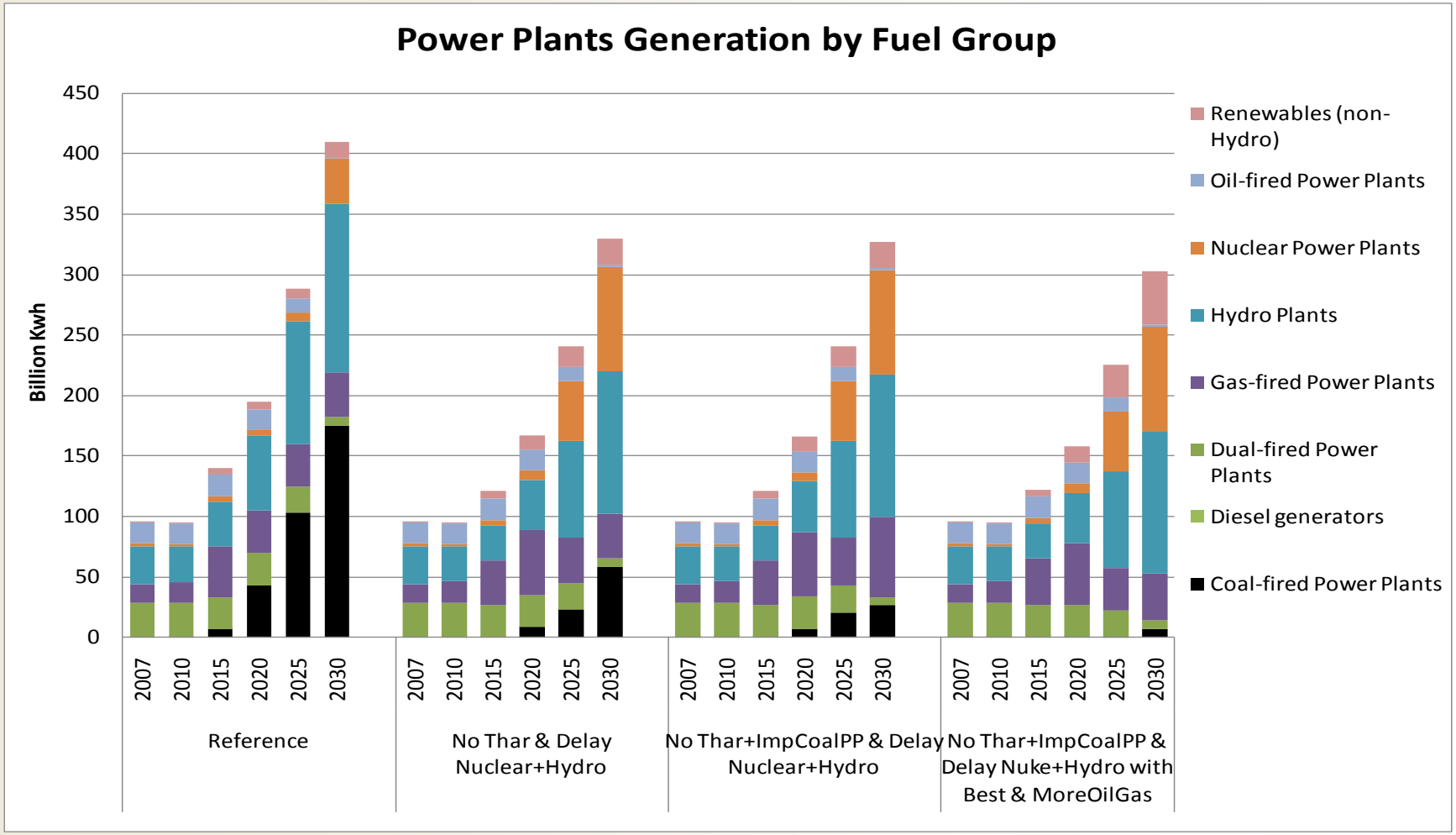
- No Thar coal increases nuclear generation, although it is delayed.
- Best practices and more gas reduce the total electricity generation through investments in efficiency.



Critical Factors for Success

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- Formalization of a Planning Institution
  - Create and support a Planning Institution through a Public Private Partnership to steward Pak-IEM
- Greater involvement of the key Ministries, agencies and private sector for improved data development
- Integration of Pak-IEM into the decision making process
  - Government of Pakistan
  - Donor agencies
  - Private energy sector stakeholders
- Mandates and requests of the PPP to perform both regular and special planning analyses
- Wider dissemination of the model and results of it's use

Potential New Policy Evaluations

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- Transition plan for removal of energy sector subsidies
- Sectoral gas allocation – most economic utilization
- Power and energy infrastructure priorities under funding constraints
- Short-term potential for energy efficiency
  - DISCO-level T&D improvement
  - Power plant rehab and upgrades
  - Gas processing and pipeline improvements
  - Residential and commercial buildings and appliances
  - Industrial processes and captive power generation
  - Transport mode shifts
- Strategic energy security (reducing imports & supply diversification)
- Support for climate change negotiations

THANK YOU

MORE INFO

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ADDITIONAL SLIDES

Developing a Reference Case

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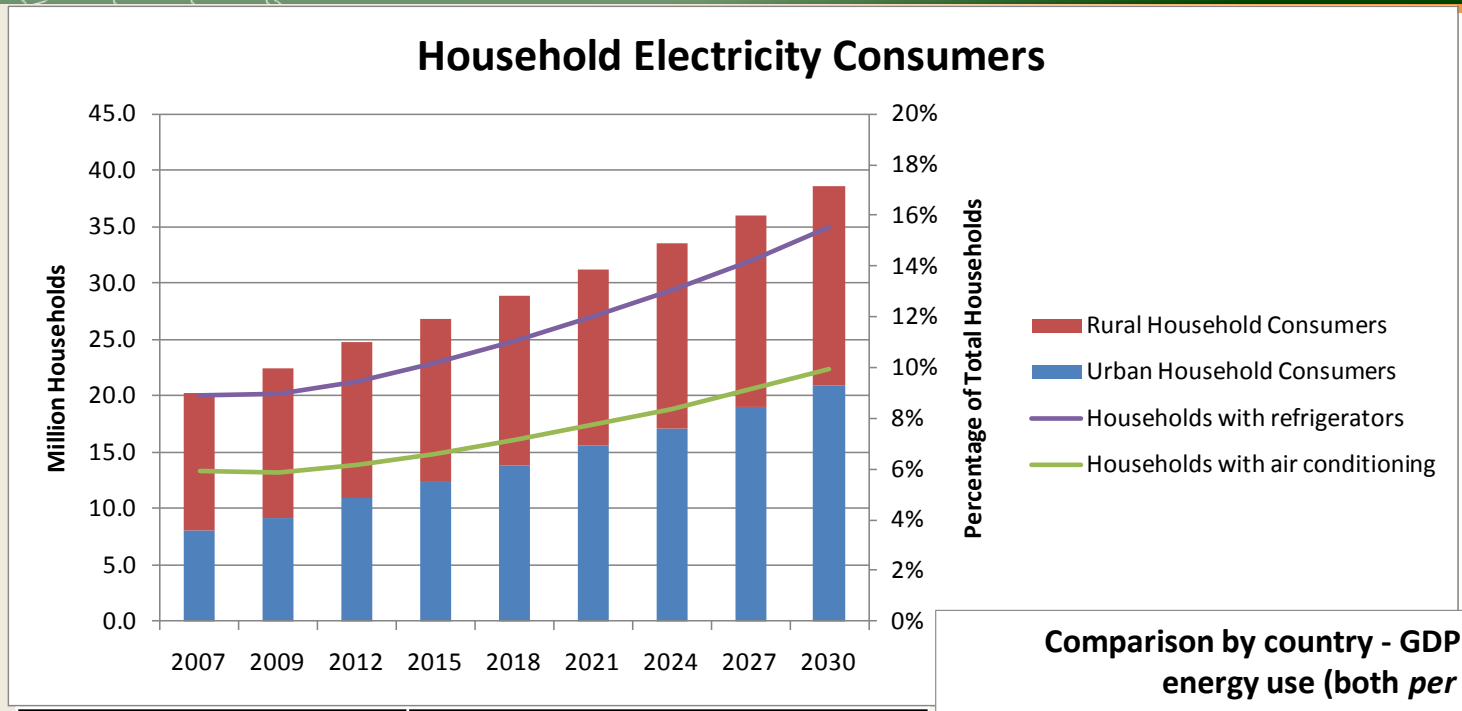
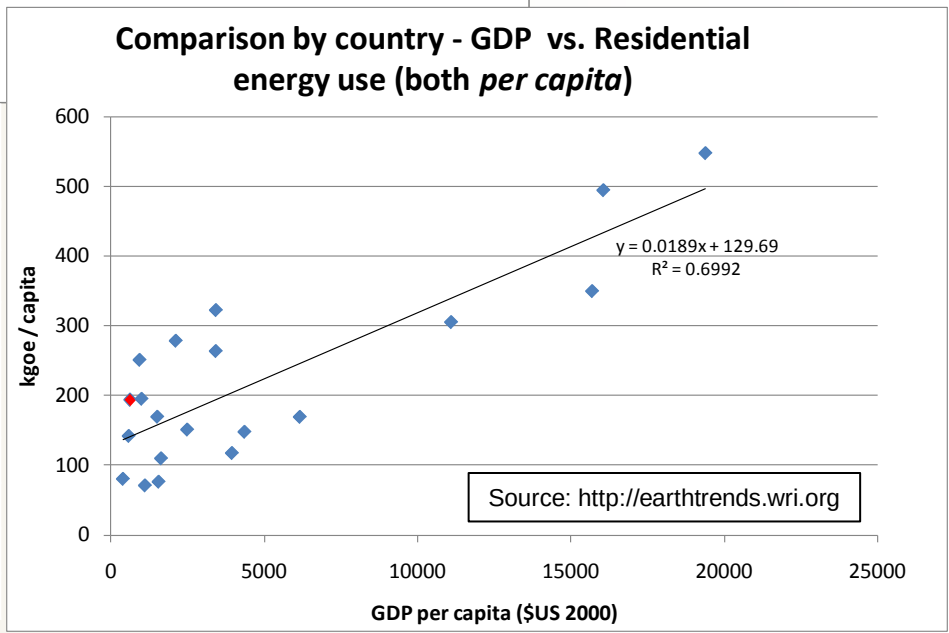


Residential projections based on GDP & household energy use

Demand	Average Household Energy Use (kgoe)	
	Urban	Rural
Space Heating	42.7	67.0
Water Heating	145.7	76.9
Space Cooling (Fans and Coolers)	51.6	39.2
Space Cooling (AC)	16.5	3.6
Lighting	45.7	42.8
Cooking	542.4	581.4
Refrigeration	22.8	6.4
Miscellaneous Electric	22.3	12.0
Other	10.6	14.1



INDUSTRY PROJECTIONS
BASED ON INDUSTRIAL GDP & SUBSECTOR FACTORS

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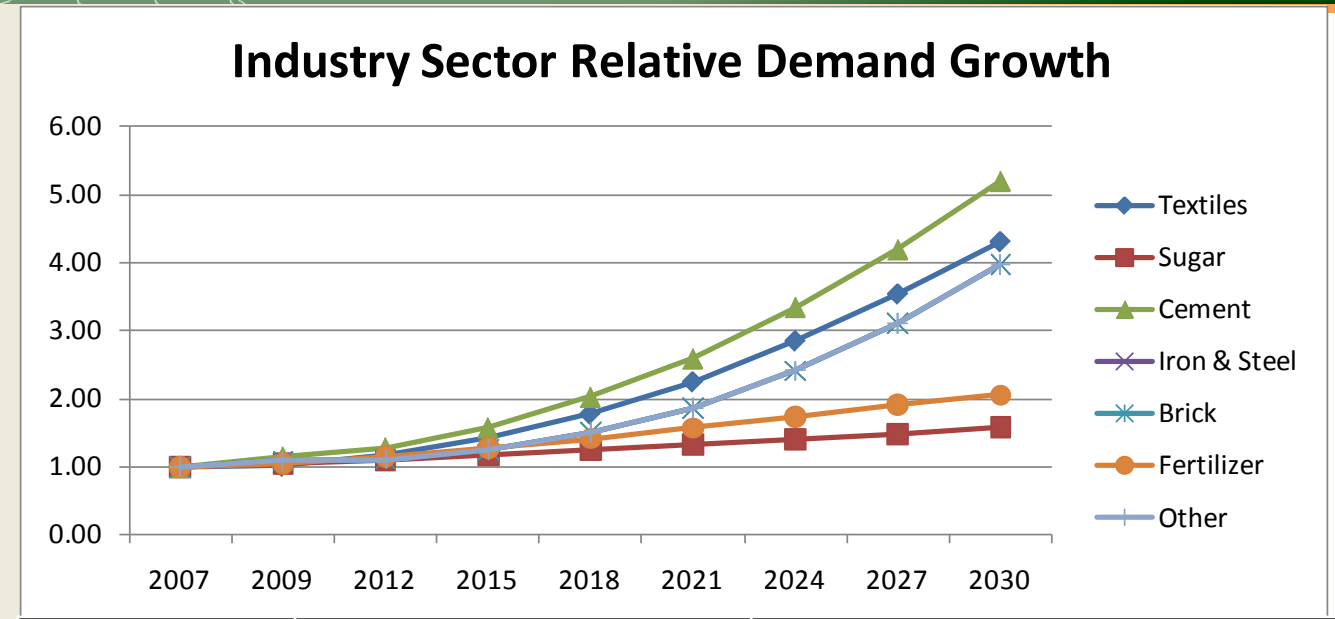

Demand	Driver	Energy Intensity Factor
Textiles	Specific growth factors for yarn (5.1%), cloth (7.7%) & garments (6.4%) based on 2010 Economic Survey data	
Sugar	Sugar Cane Production growth of 2%	
Cement	Construction component of GDP	Increase by 2.0% per annum near term due to export potential
Iron & Steel	Industrial GDP	Decrease by 1.0% per annum (21% by 2030)
Brick	Construction component of GDP	Decrease by 1.0% per annum (21% by 2030)
Fertilizer	Agricultural GDP	Decrease by 0.5% per annum (21% by 2030)
Other	Industrial GDP	Decrease by 1.0% per annum (21% by 2030)

PASSENGER TRANSPORT PROJECTIONS
BASED ON TOTAL GDP & INTENSITY FACTOR

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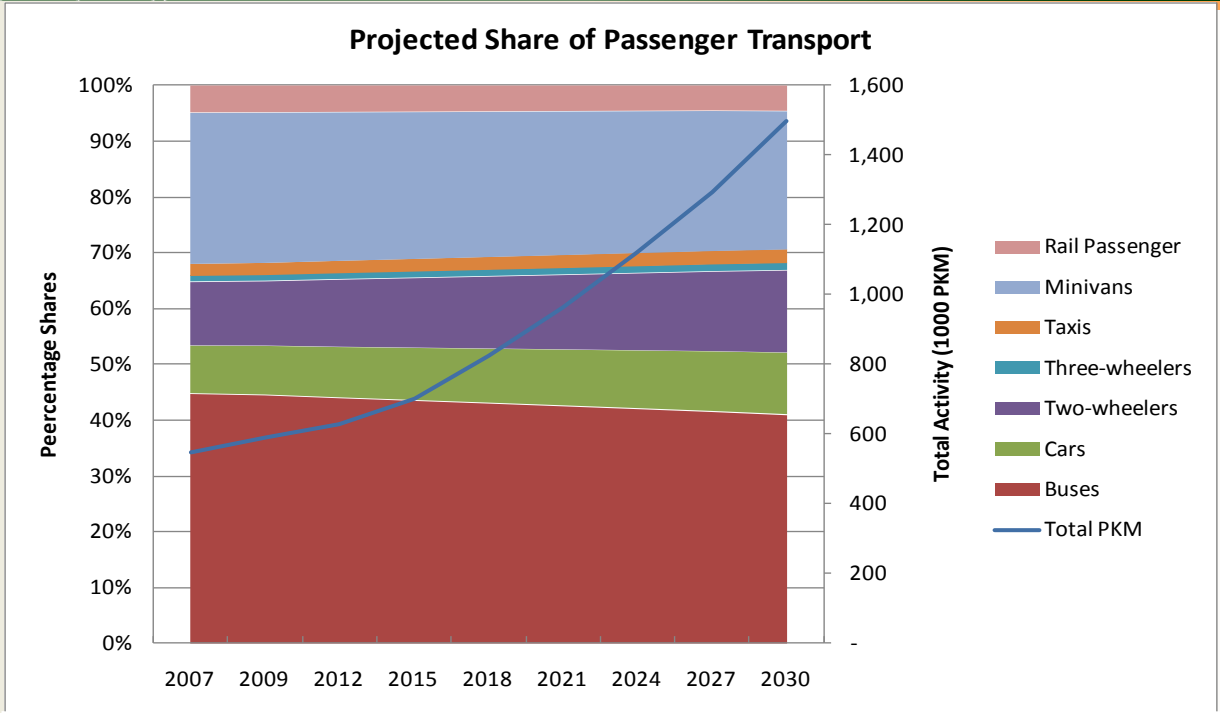

Based on Pakistan Transport Plan Study, JICA 2006

Per Capita Passenger Transport goes from 3500 km/yr to 6500 km/yr

Demand	Intensity (Change in Transport Activity Relative to GDP)
Buses	Decrease by 1.5% per annum (29% by 2030)
Cars	No change relative to GDP
Two-wheelers	Decrease by 0.5% per annum (11% by 2030)
Three-wheelers	Decrease by 0.5% per annum (11% by 2030)
Taxis	Decrease by 0.5% per annum (11% by 2030)
Minivans	Decrease by 1.5% per annum (29% by 2030)
Rail Passenger	No change relative to GDP

Reference Scenario Key Assumptions-1

Pak-IEM Team

- Official projection of average economic growth of 5.6% over the planning horizon of 2007 to 2030
- Oil & Gas Supply Reserves from Ministry of Petroleum
- Annual capacity addition limits (GW) on new power plant types

Type	2020	2030
Nuclear	1	1
Oil	2.5	2.5
Gas	2.5	2.5
Coal	2.5	2.5
Hydro	1.5	1.5
Solar	0.002	0.005
Wind	0.2	0.2

- Limits on the degree of fuel switching in demand sectors

Reference Scenario Key Assumptions -2

Pak-IEM Team

- Thar coal mining cost based on Shenhua Study of 2004 which predicted $130/tonne investment with operating costs of $3.7/million Btu
- Penetration limits on energy efficiency devices (10% in 2030)
- Oil and gas prices, $/million Btu

Type	2008	2020	2030
Crude Oil	10.3	17.2	19.9
Domestic gas	2.5	3.8	4.4
Imported pipeline gas	11.7	12.8	14.7
Imported LNG	12.6	13.7	15.9
Imported heavy fuel oil	10.9	18.2	20.9

- T&D investment costs and losses need further research
- Economic cost of load shedding estimated at $0.60/KWh

New Power Plant Characteristics

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New Power Plant Option	Total Investment Cost (2007 $/kW)	Fixed O&M ($2007/kW)	Variable O&M ($2007 mills/kWh)	Efficiency	Start Date	Lead Time (Years)
Gas Turbine Open Cycle - Gas or Fuel Oil	709	11.79	3.47	32.7%	2011	2
Heavy Oil Reciprocating engines Combined cycle	1200	16.92	6.20	48.0%	2010	3
Heavy Oil Steam turbine with Reheat Cycle	1000	17.52	2.40	40.0%	2010	3
Coal Integrated Gasification Combined Cycle	2898	37.63	2.84	45.8%	2016	4
Gas turbine Combined Cycle - Natural gas and diesel	1063	12.15	2.01	47.4%	2011	3
Gas turbine Combined Cycle with Reheat - Natural gas and diesel	1200	15.84	3.00	54.0%	2011	3
Nuclear Power Plant	4501	87.60	0.48	34.1%	2011	6
Coal Supercritical Steam turbine Power Plant	2560	26.79	4.47	37.1%	2010	3
Hydro Power	1911	53.19	5.15	34.1%	2016	4
Solar Photovoltaic Systems	6390	11.37	0.00	34.1%	2011	1
Solar Thermal Power Systems	3500	19.08	2.40	34.1%	2011	3
On Shore Wind Turbines-Classification 4-5	2500	63.24	0.40	34.1%	2012	2
On Shore Wind Turbines-	2750	63.24	0.40	34.1%	2012	2

Fossil Energy Supply

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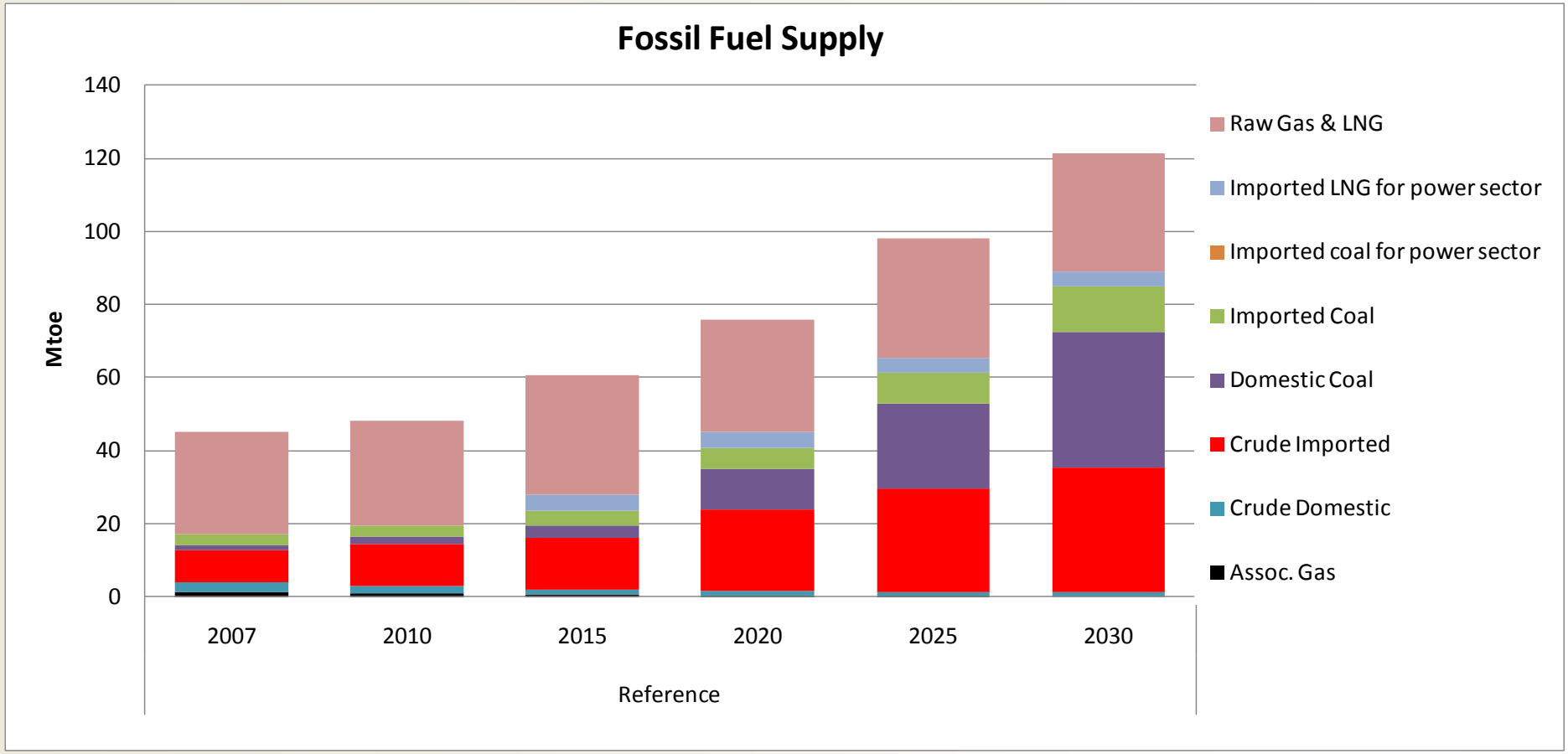
Long-term fossil supply is dominated by imports of oil and increasingly gas, with Thar coal making a growing contribution



Natural Gas Supply

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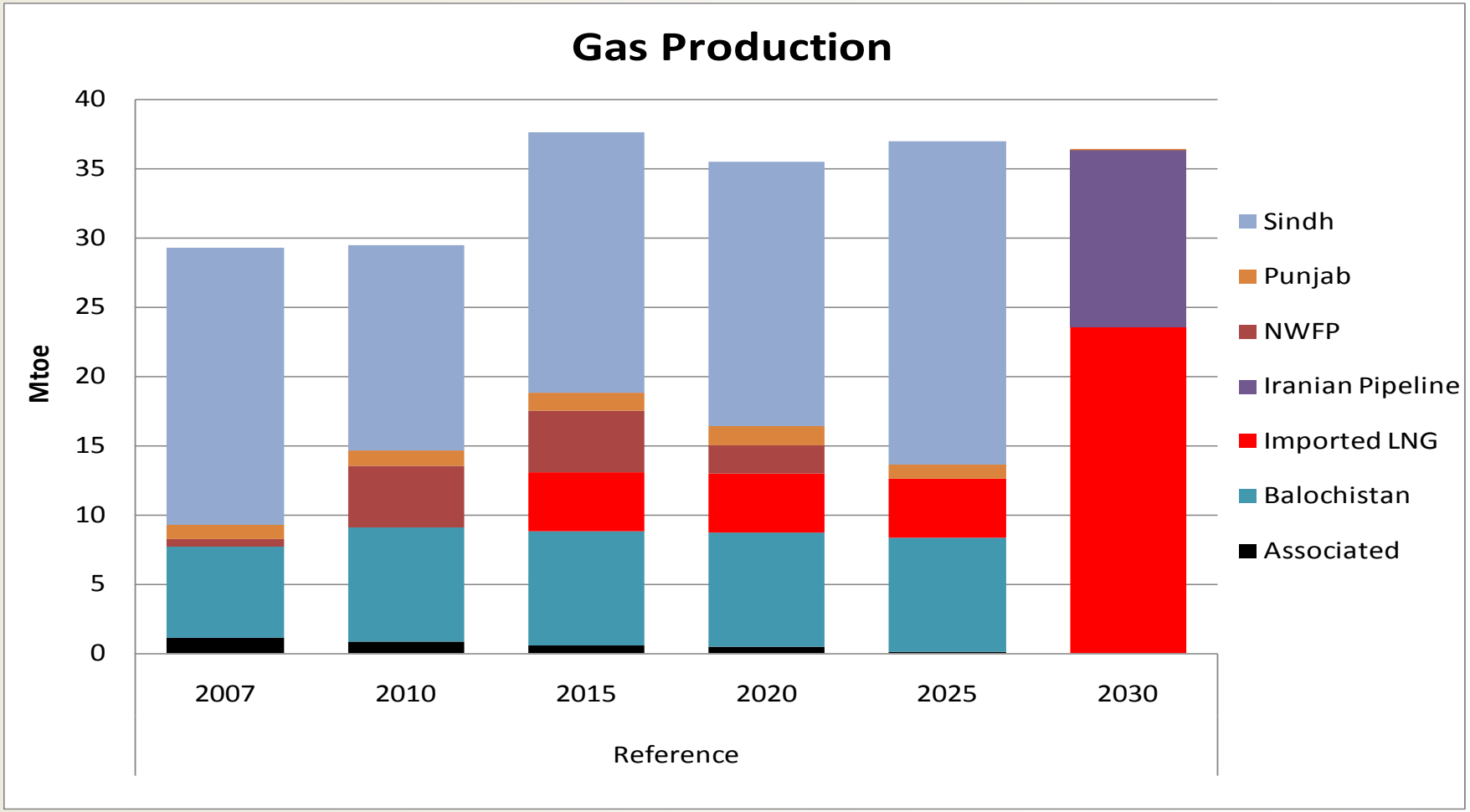
Current gas reserves are depleted by 2030 and supply transitions to Iranian pipelines and LNG imports



Refined Oil Products

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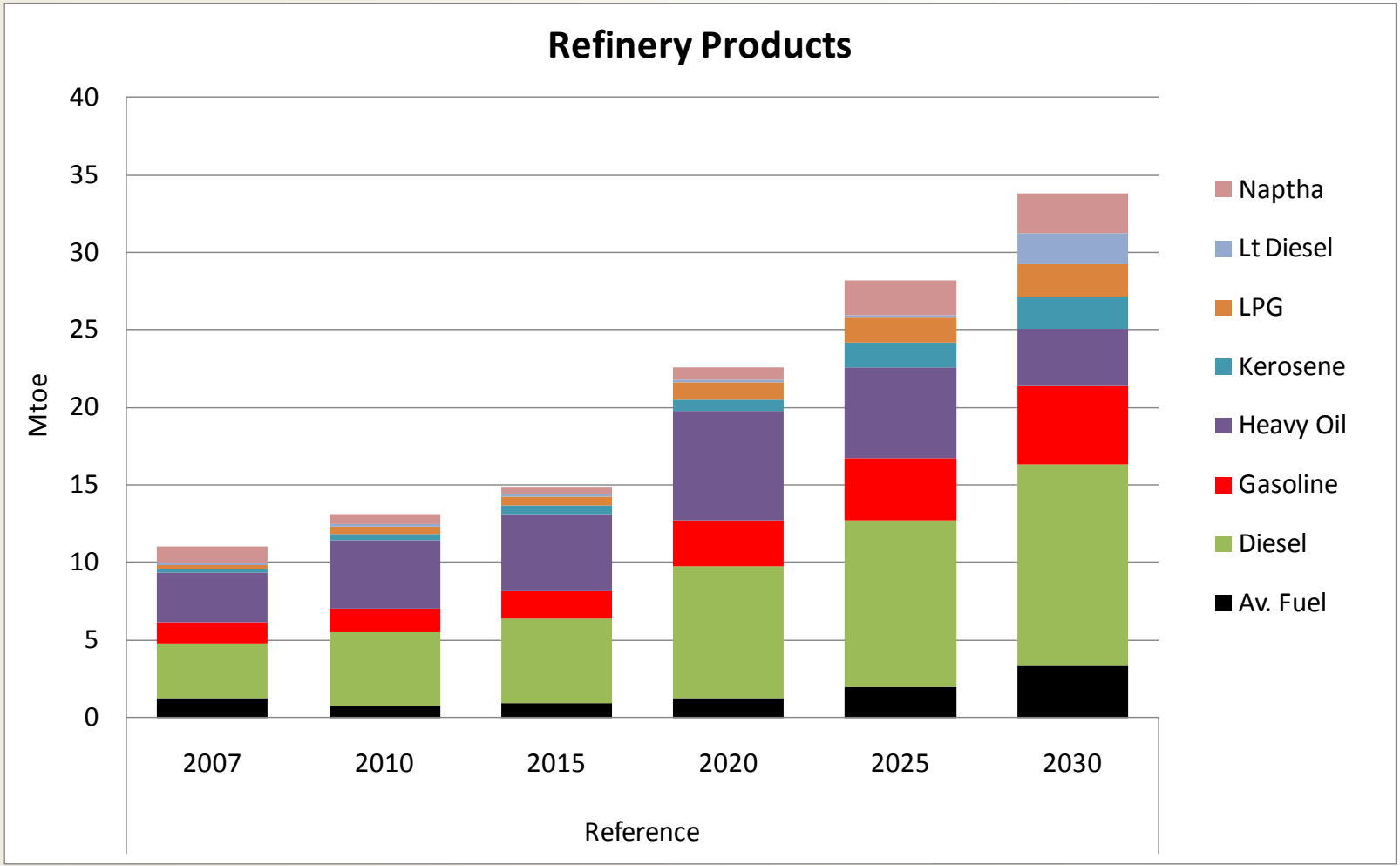
Refineries will need to triple output by 2030, or imported oil products will need to rise dramatically
Demand shift towards high-value added products



IMPORT DEPENDENCY

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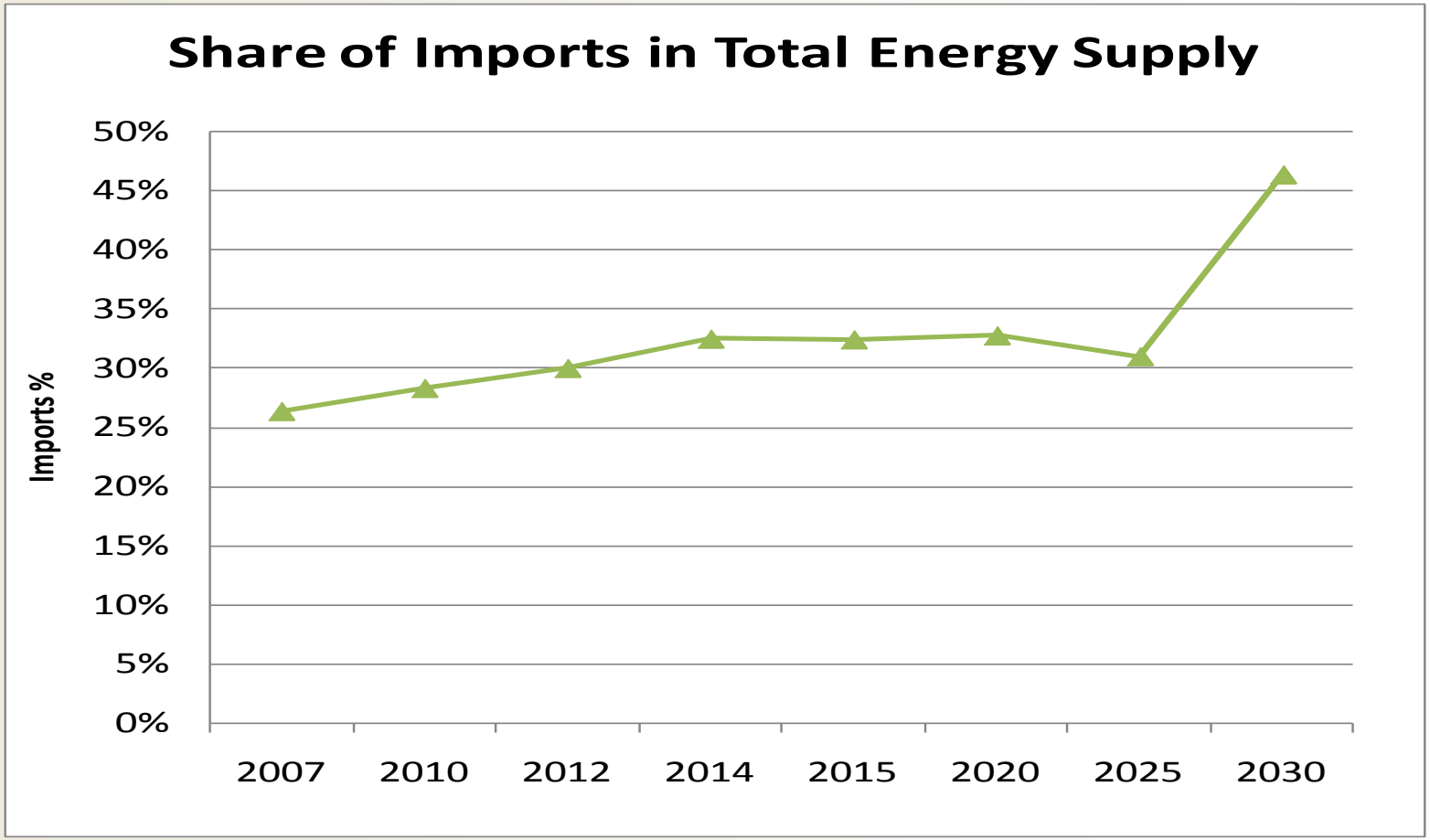
Imports grow to over 45% of total supply by 2030 as the Iranian pipeline and LNG imports come on line



Final Energy Consumption by Fuel

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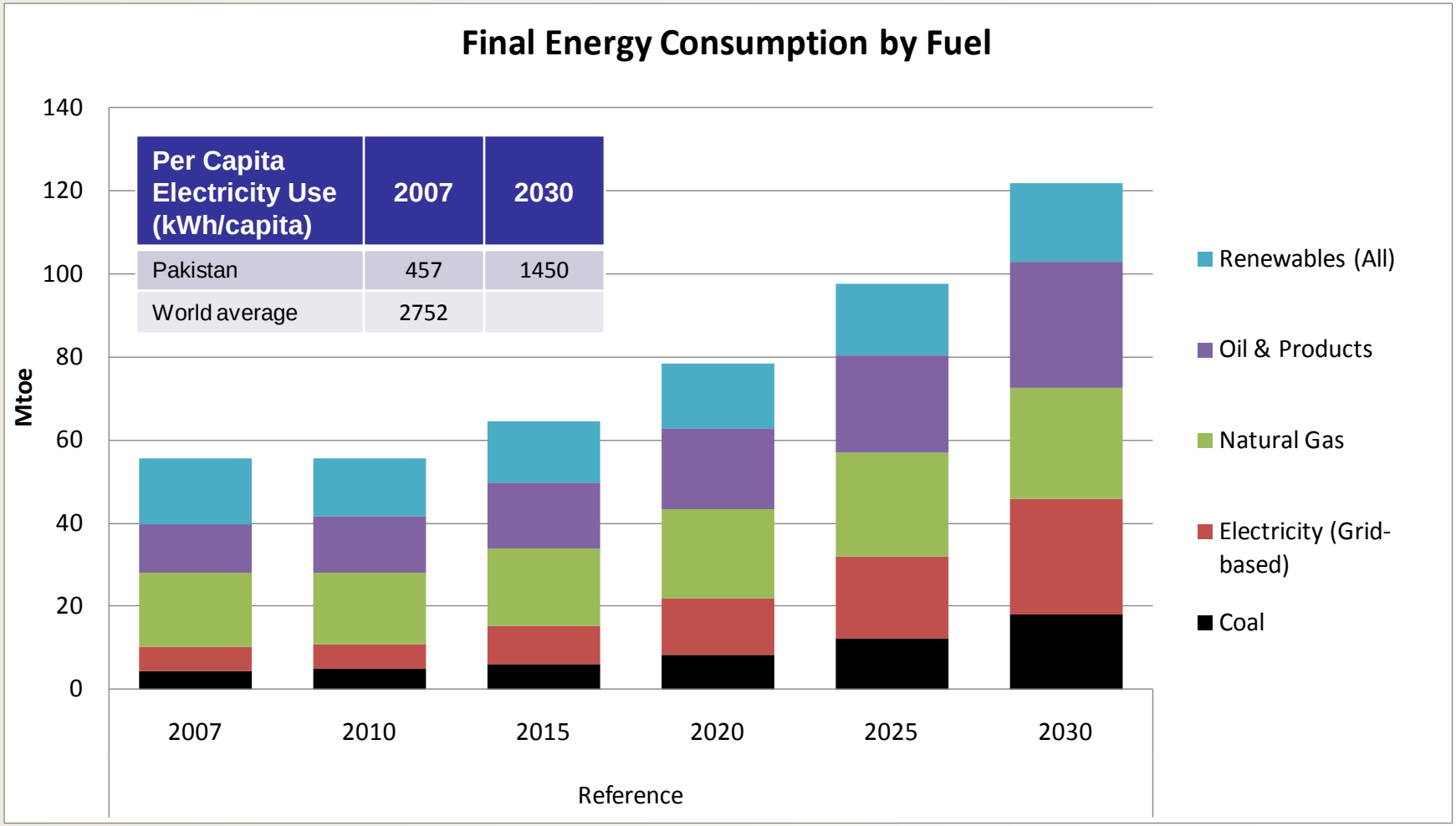
Near term growth is from natural gas

Long-term growth is based on electricity and oil products



Final Energy Consumption by Sector

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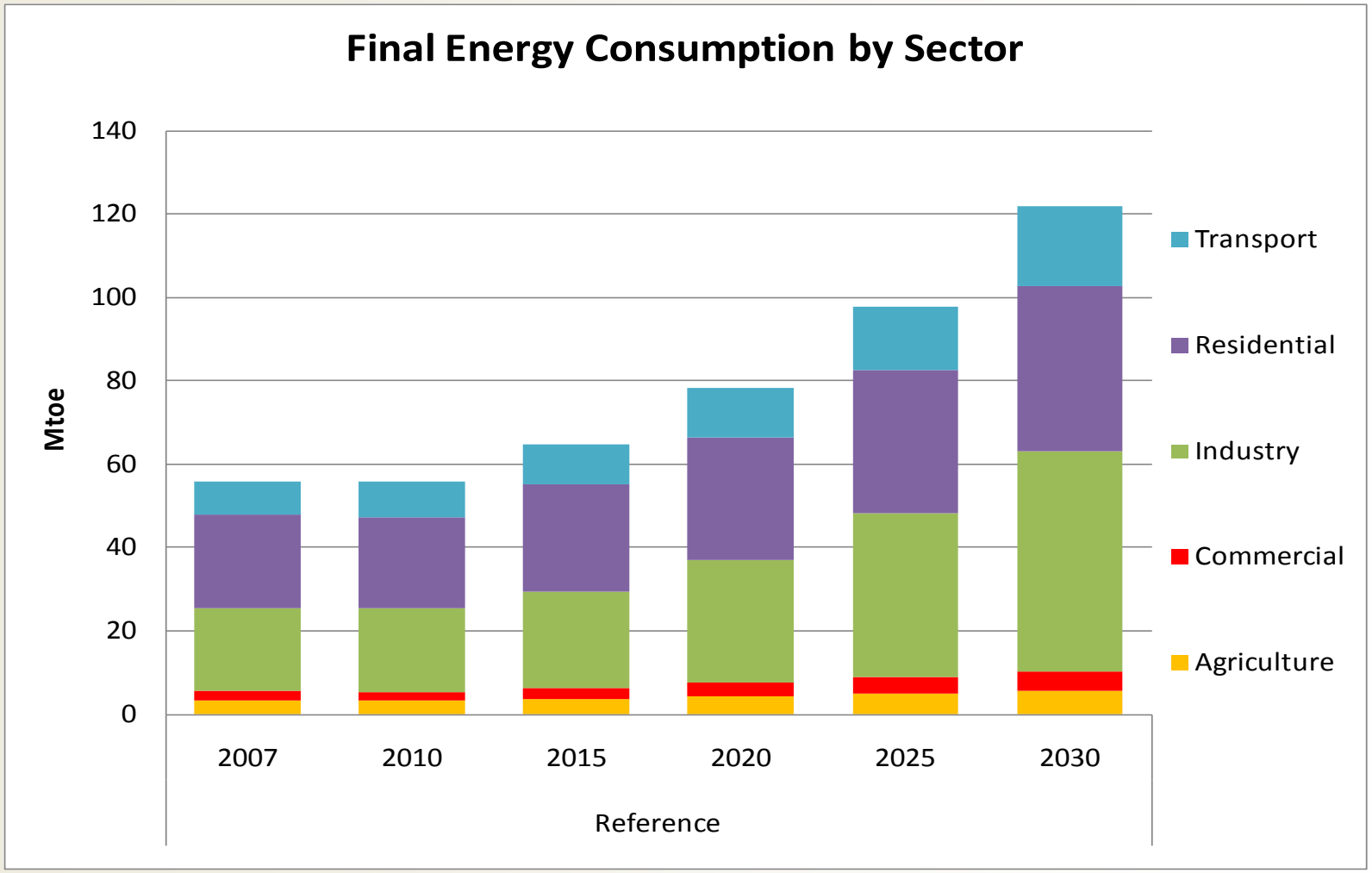
Overall final energy use doubles, while Industrial energy use increases 2.5 times



Energy System Costs

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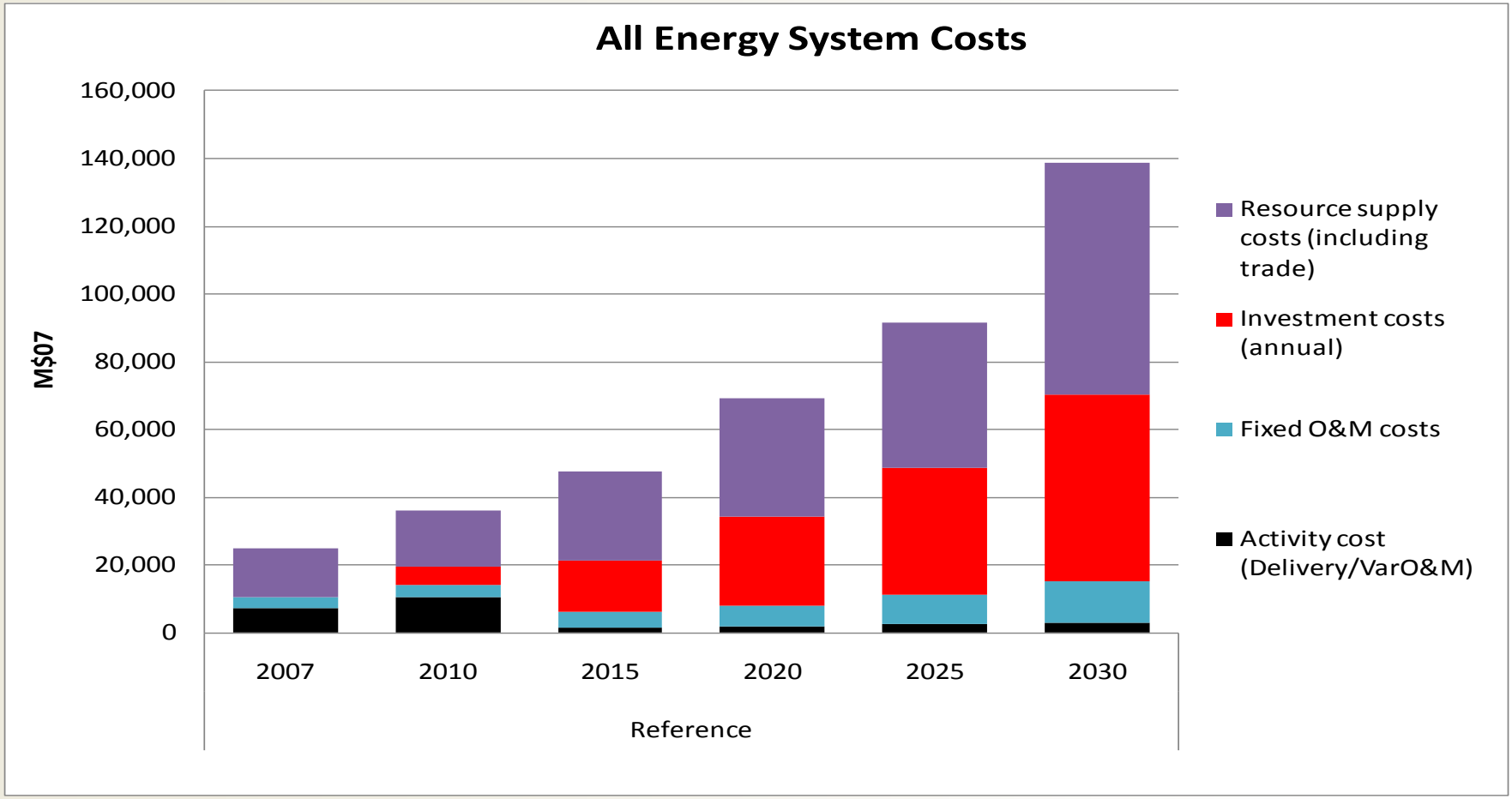
Cost of load shedding is estimated at $37B from 2007 till 2013
Annual payments for fuels increase four fold. Investment expenditures for all energy sector devices rise to $45B annually



Storyline 1: Pakistan Pursues Best Practices
Energy System Investments

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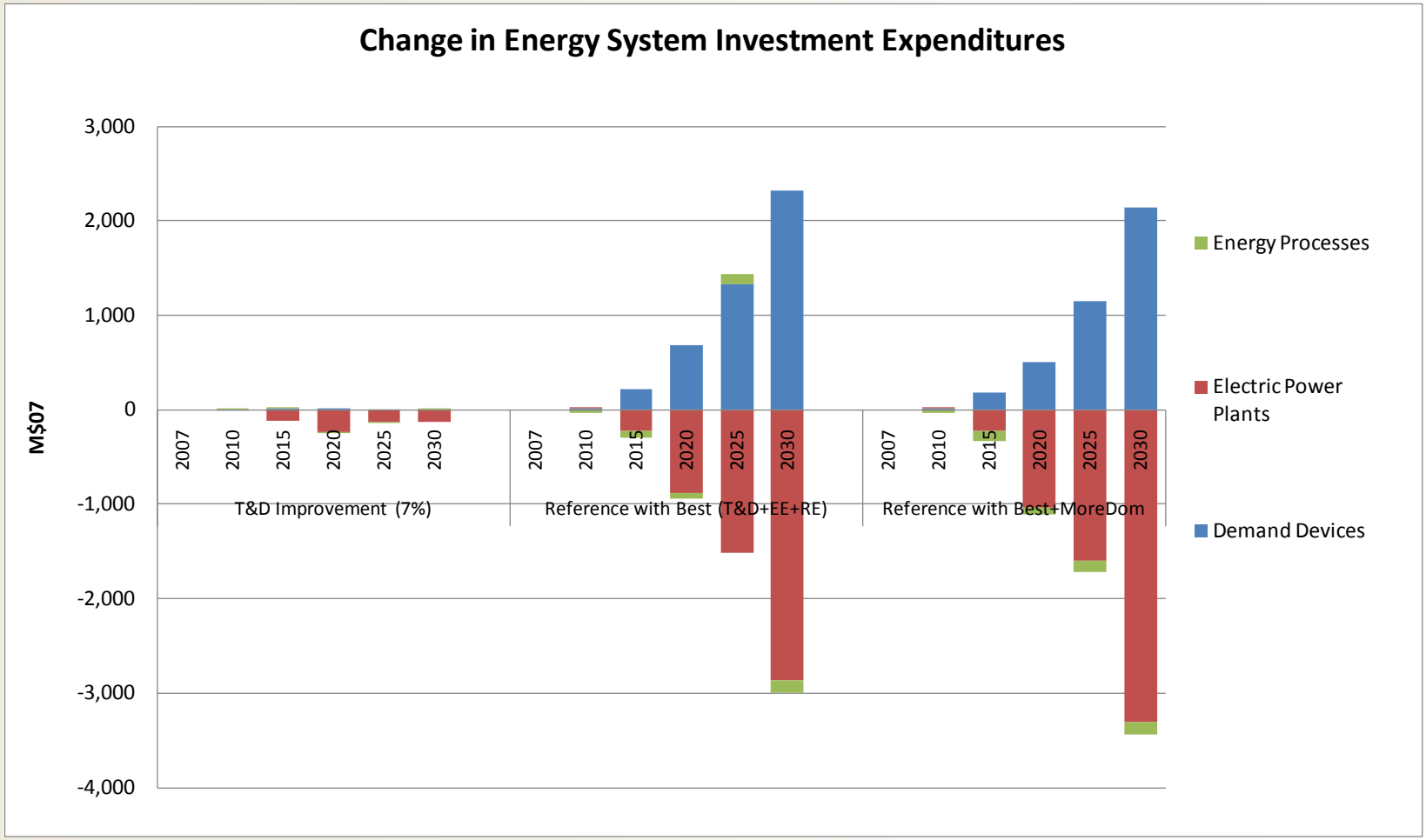
- T&D improvements reduce power plant investments
- While efficiency measures require investment in demand more expensive devices, but offset by lower power plant requirements (as well as large reductions in fuel expenditures – not shown)



Storyline 1: Pakistan Pursues Best Practices

Natural Gas Production

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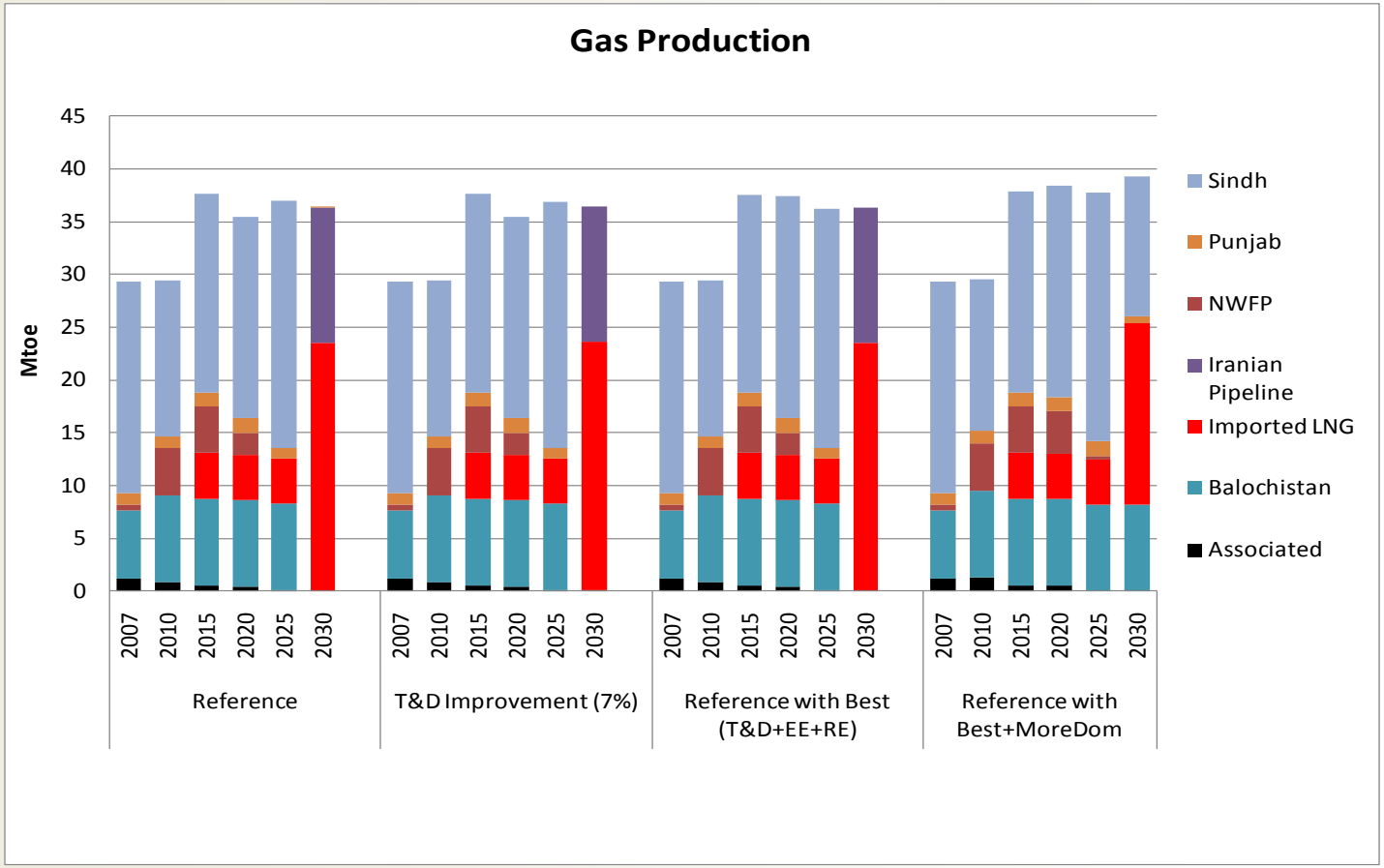
Without additional finds domestic gas reserves run out, even with FoDP recommended LNG (for power plants initially). Exploiting more conventional domestic gas delays the need for the Iranian pipeline. LNG results in more overall gas consumption, but at a higher cost than 1st depleting all domestic reserves – forcing Tight Gas or earlier Iranian pipeline show similar behavior.



Storyline 1: Pakistan Pursues Best Practices

Final Energy by Sector

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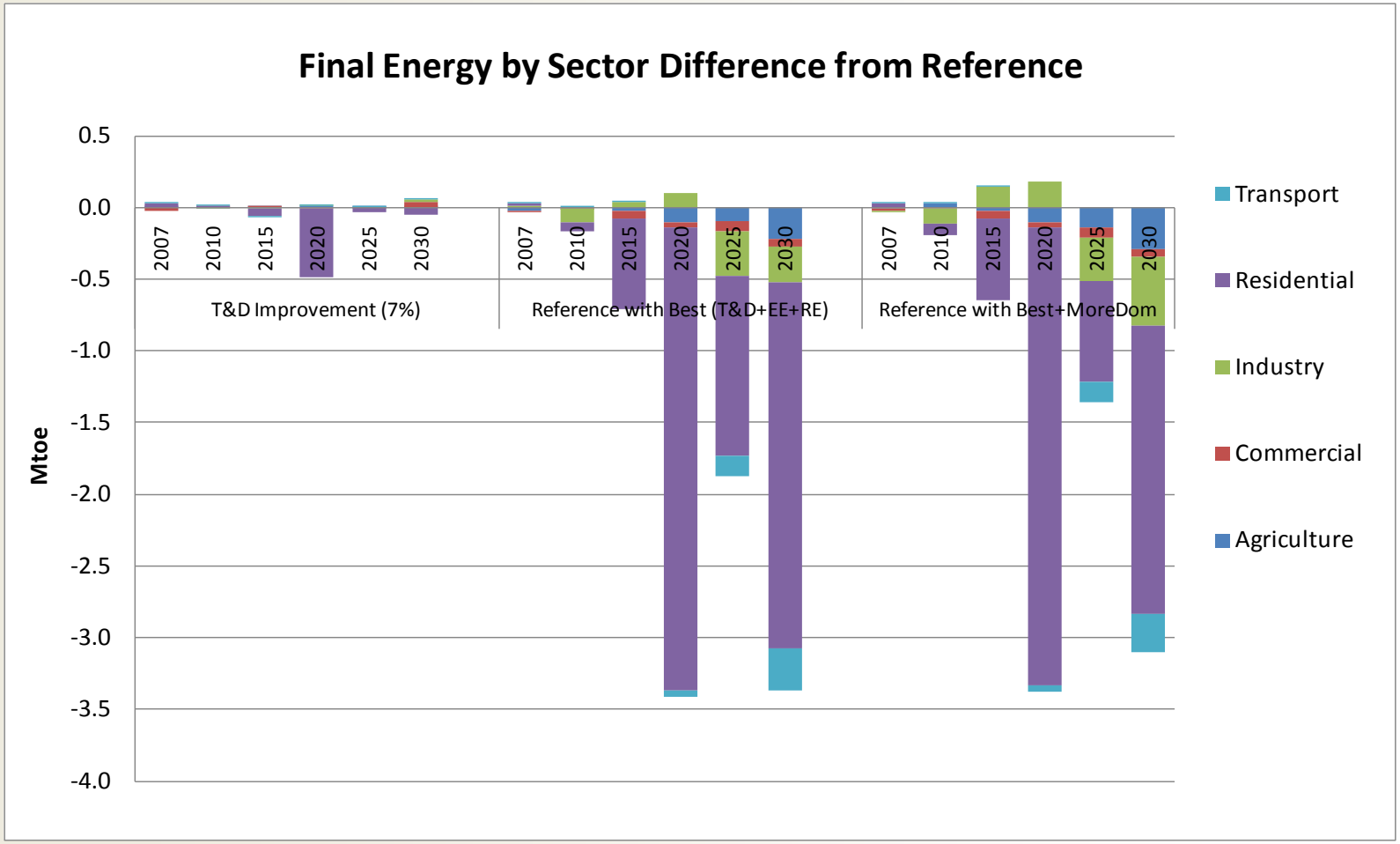
- End use efficiency reduces electricity demand for residential lighting and cooling, agriculture irrigation, industrial processes; biomass for cooking; gasoline for cars
- More gas allows expanded direct consumption, including for captive power, and fuel switching from oil products



Storyline 1: Pakistan Pursues Best Practices

Summary Metrics

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Energy efficiency and developing more domestic gas provide the biggest potential for driving the economy by reducing expenditures on the energy system by about $15Billion each

Pakistan will benefit on the energy security and environmental front as well

Scenario	System Cost		PP Builds		Fuel Supply		Imports		Final Consumption		CO2 Emissions	
	M$07	% Diff	GW	% Diff	Mtoe	% Diff	Mtoe	% Diff	Mtoe	% Diff	Mt	% Diff
Reference	1,002,569		135		5,933		2,290		3,899		12,099	
T&D Improvement (7%)	-2,648	-0.26%	0.88	0.65%	-23	-0.39%	4	0.16%	0	0.00%	-145	-1.21%
T&D Improve (7%) & Efficiency (50%)	-17,366	-1.73%	-12.90	-9.57%	-318	-5.36%	-40	-1.75%	-144	-3.68%	-854	-7.06%
Reference with Best (T&D+EE+RE)	-17,610	-1.76%	-7.05	-5.23%	-310	-5.22%	-38	-1.67%	-145	-3.73%	-894	-7.40%
Reference with Best+MoreDom	-33,653	-3.36%	-7.56	-5.61%	-311	-5.25%	-157	-6.86%	-137	-3.52%	-922	-7.62%

Storyline 1: Pakistan Pursues Best Practices
Energy System Costs

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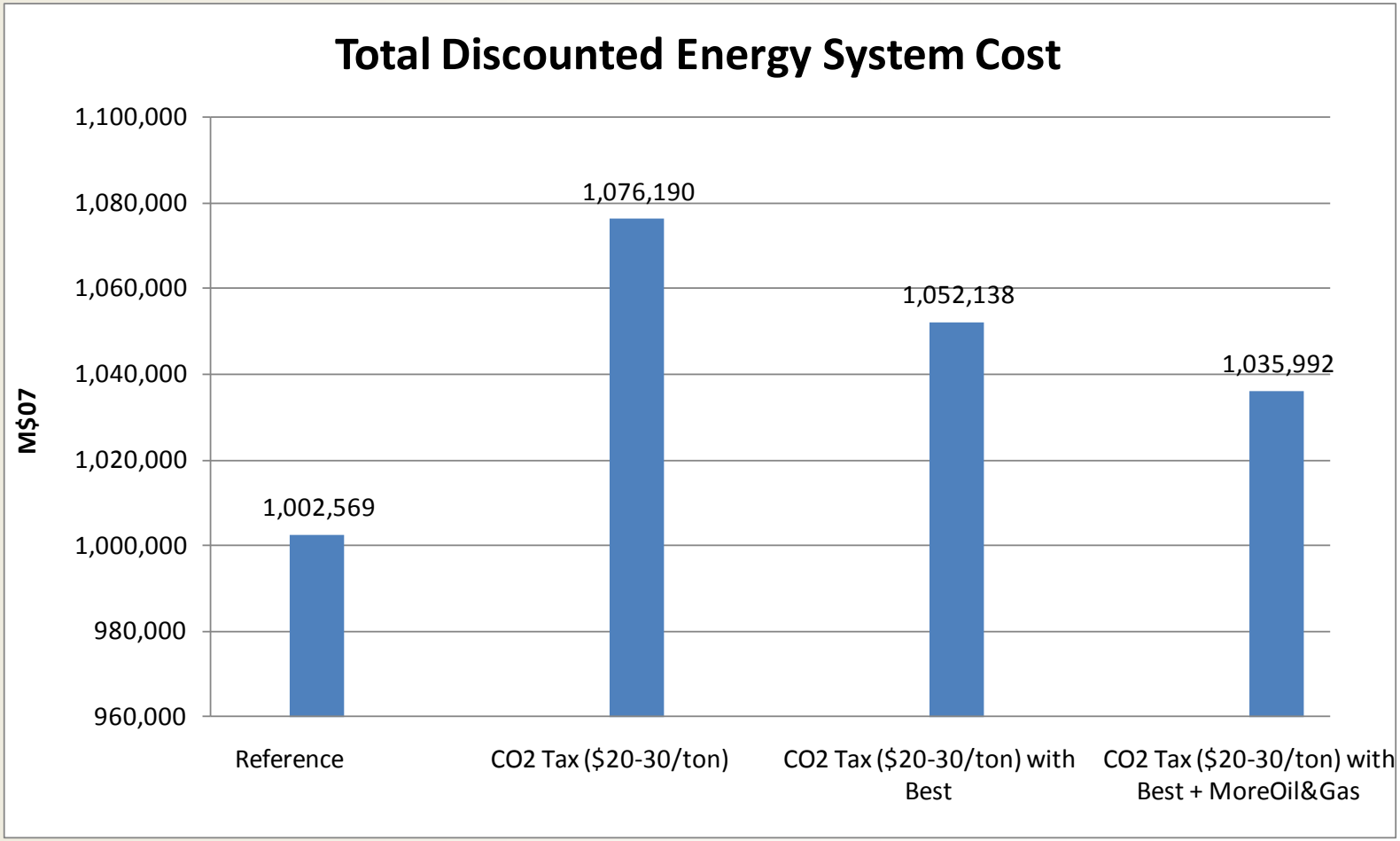
The impact of a CO_2 tax is about $70B, but implementing the best practices plus exploiting domestic gas reserves could reduce this impact in half

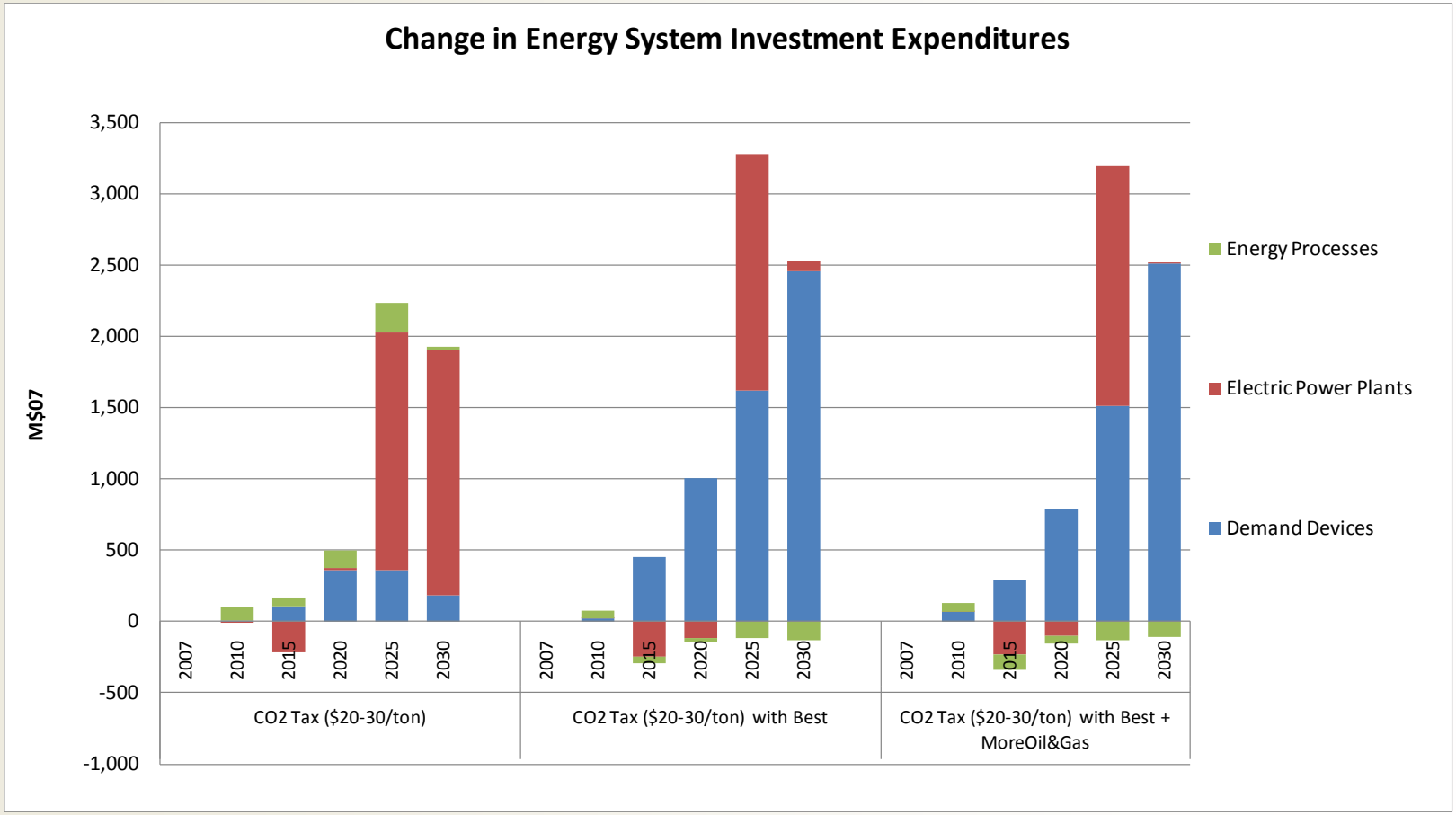


Storyline 1: Pakistan Pursues Best Practices
Energy System Investments

Pak-IEM Team

CO_2 tax incentives the expensive clean power plants, while best practices encourages efficient end-use device purchases

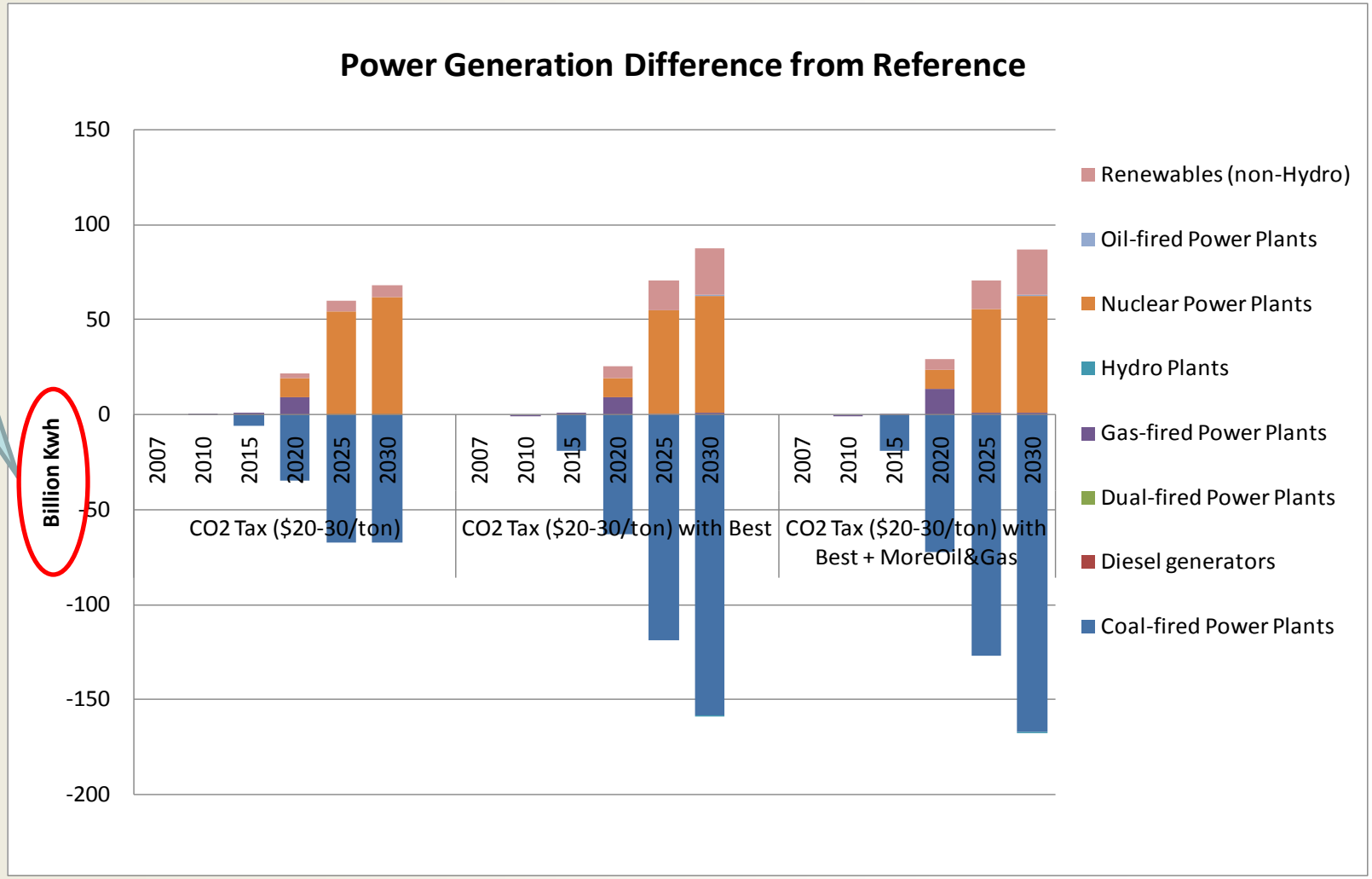
More gas further reduces power plant investments due to increased direction consumption



Storyline 1: Pakistan Pursues Best Practices
Power Generation

Pak-IEM Team

CO_2 tax results nuclear and renewables to their build limits to replace coal, and more gas further reduces coal generation

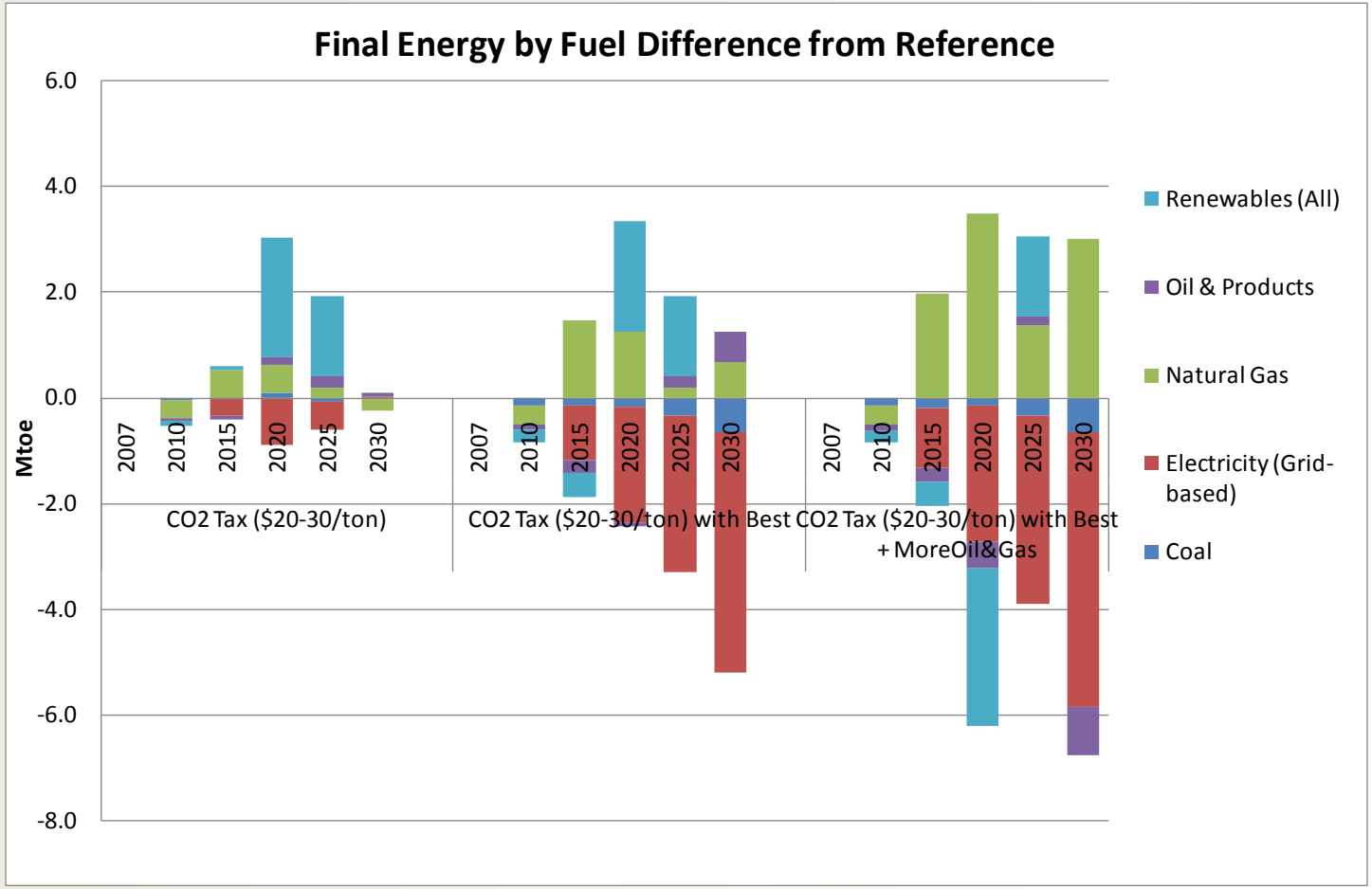


Storyline 1: Pakistan Pursues Best Practices

Final Energy by Fuel Type

Pak-IEM Team

CO_2 tax increases use of commercial biomass fuels in residential, which are pushed out when more gas is available. More gas is largely used directly by industry. Efficiency devices and fuel switching reduce electricity consumption

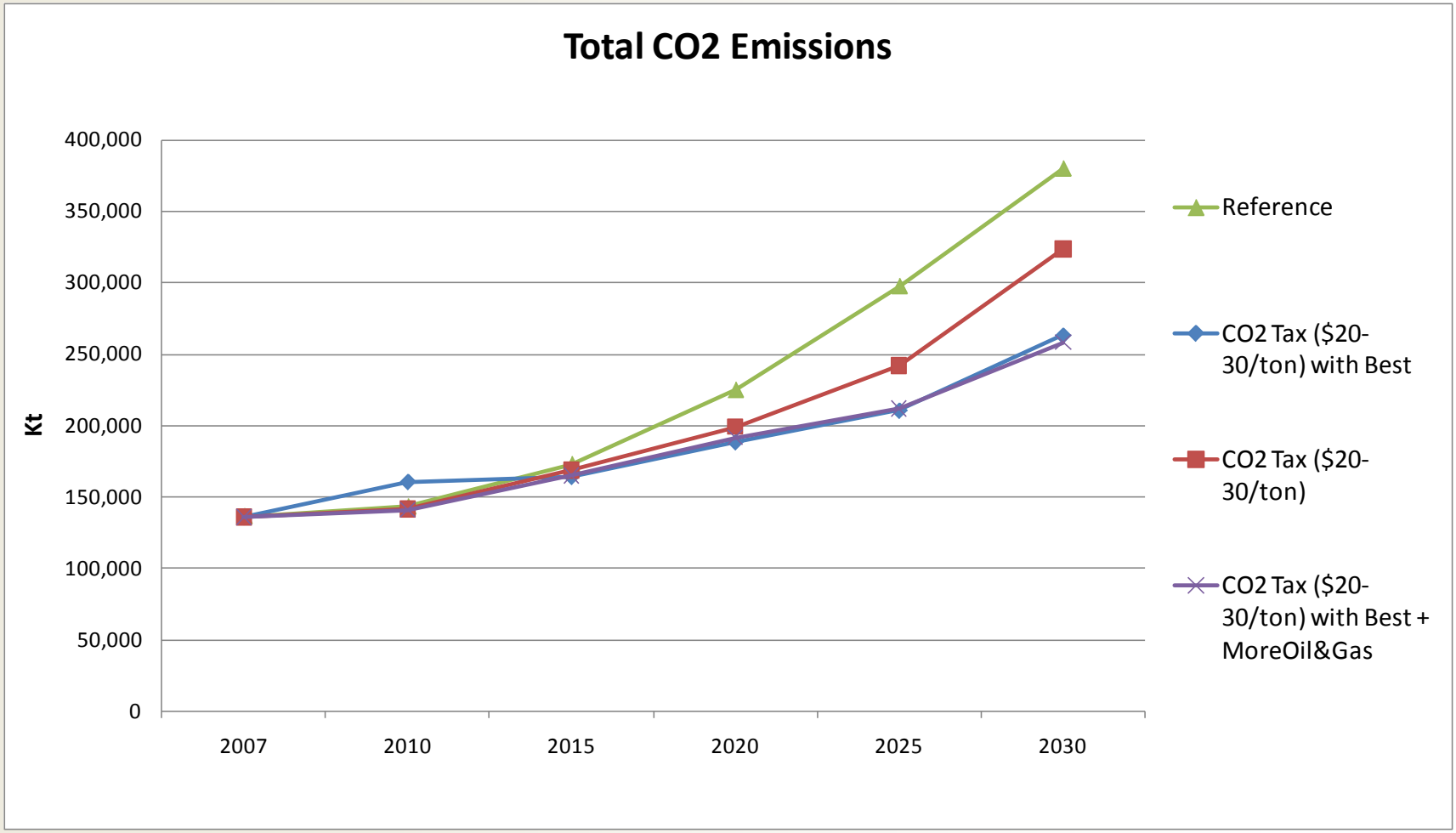


Storyline 1: Pakistan Pursues Best Practices

CO_2 Emissions

Pak-IEM Team

Best practices reduce CO_2 emissions by about 117Mt in 2030, with cumulative emissions dropping a full 22%



Storyline 1: Pakistan Pursues Best Practices

Summary Metrics (2007 to 2040)

Pak-IEM Team

CO_2 mitigation wont come cheap, but at $20-30/ton the 2.5Bt abated could generate $50-60Billion for investment in the energy sector

The main structural changed arising from a CO_2 tax occurs in the power sector where coal is replaced by nuclear and renewables, and the resulting higher electricity prices also resulting in more direct use of gas

Scenario	System Cost		PP Builds		Fuel Supply		Imports		Final Consumption		CO2 Emissions	
	M$07	% Diff	GW	% Diff	Mtoe	% Diff	Mtoe	% Diff	Mtoe	% Diff	Mt	% Diff
Reference	1,002,569		135		5,933		2,290		3,899		12,099	
CO2 Tax ($20-30/ton)	73,622	7.34%	1.53	1.14%	61	1.03%	17	0.76%	25	0.65%	-1,312	-10.84%
CO2 Tax ($20-30/ton) with Best	49,569	4.94%	-6.23	-4.62%	-186	-3.14%	-34	-1.51%	-119	-3.05%	-2,676	-22.12%
CO2 Tax ($20-30/ton) with Best + MoreOil&Gas	33,423	3.33%	-6.37	-4.73%	-214	-3.60%	-154	-6.73%	-148	-3.79%	-2,772	-22.91%

Storyline 2: Challenges Persist

Import Supply

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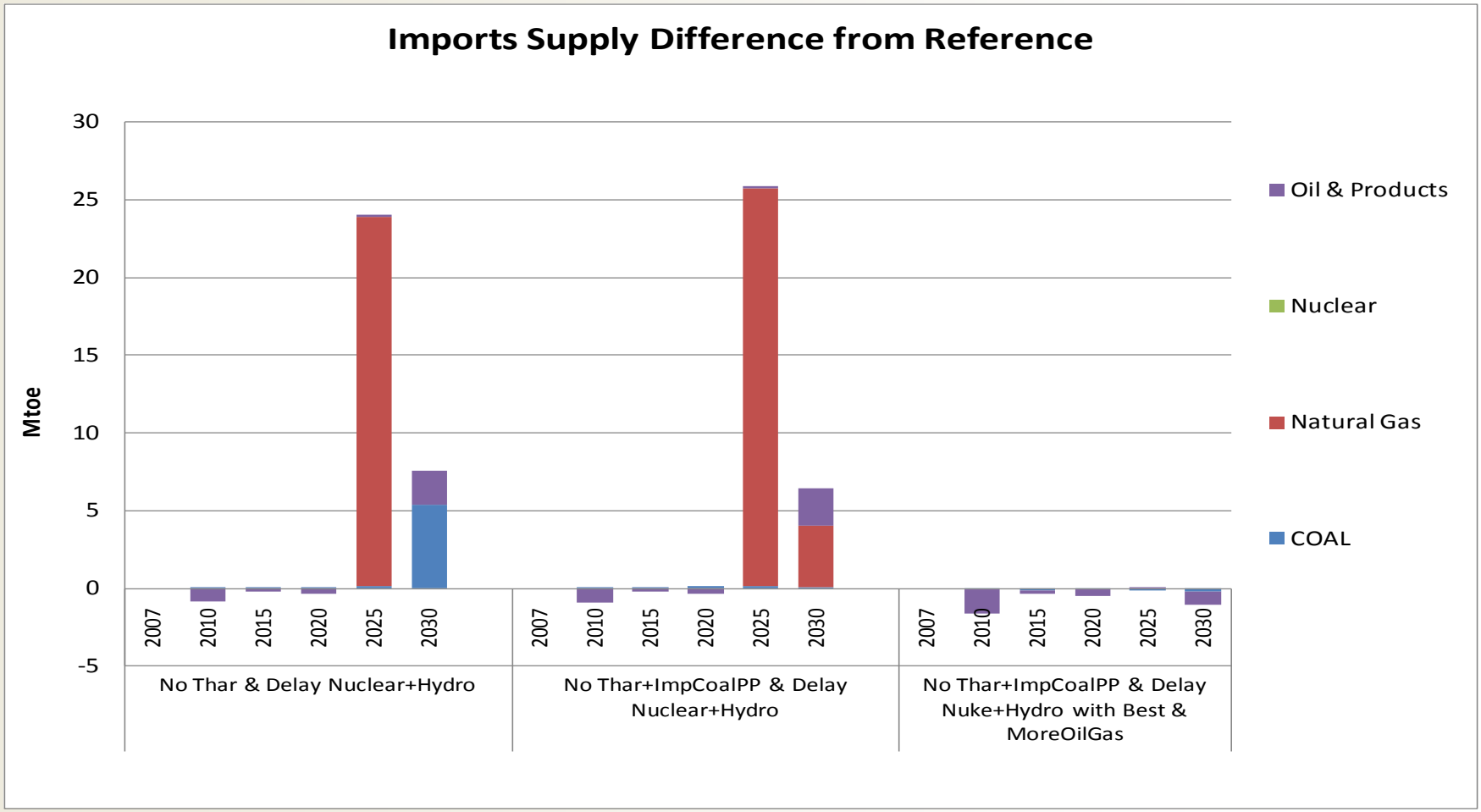
With No Thar coal and delayed hydro and nuclear, the next option is imported coal, and if that is deferred, then additional gas is imported. More gas reduced the need for the gas imports.



Storyline 2: Challenges Persist

Final Energy by Fuel Type

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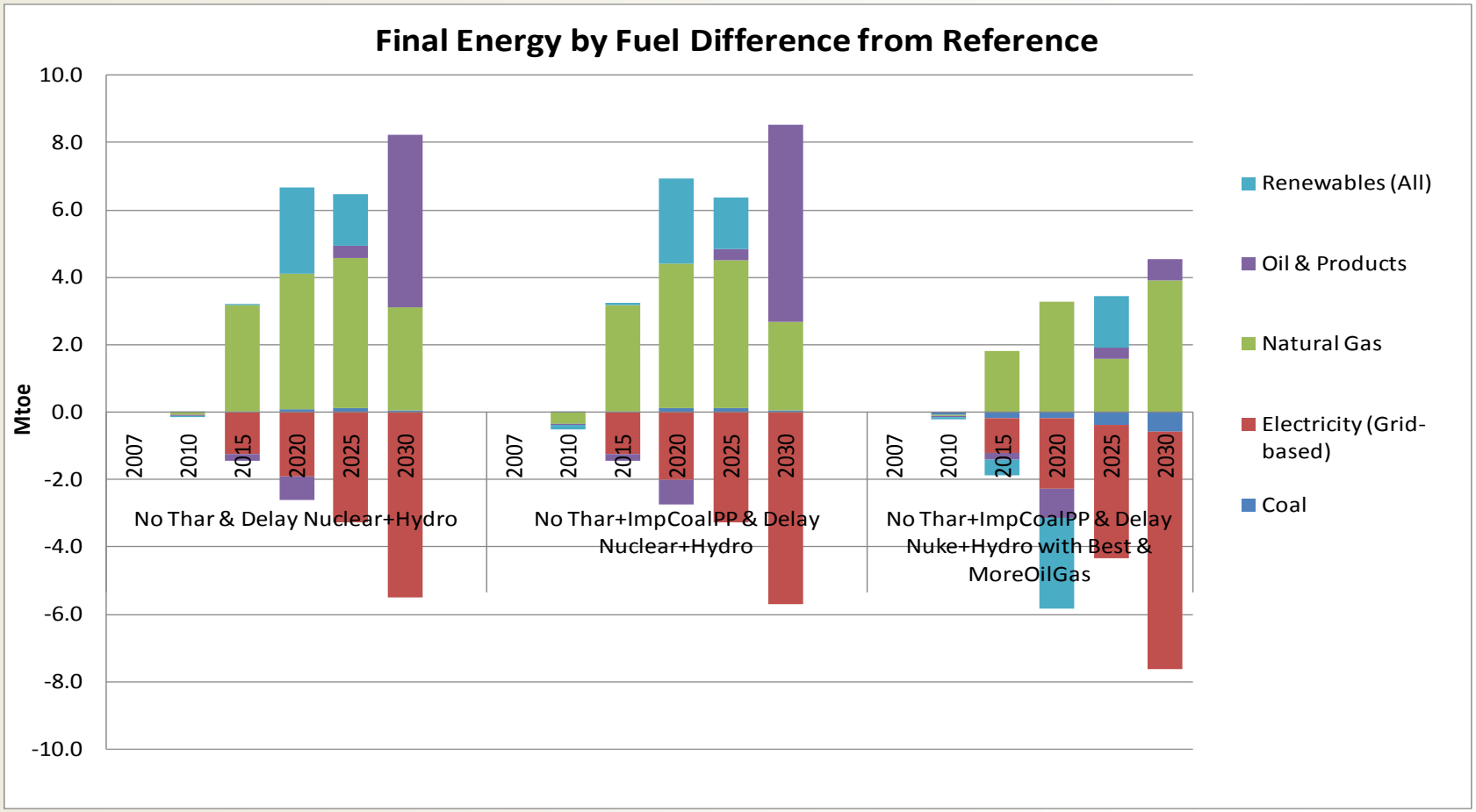
- With No Thar coal and delayed hydro and nuclear, electricity consumption is displaced by natural gas, biomass and oil products in the residential and industry sectors.
- With best practices and more gas, the there is less demand for additional biomass and oil products.

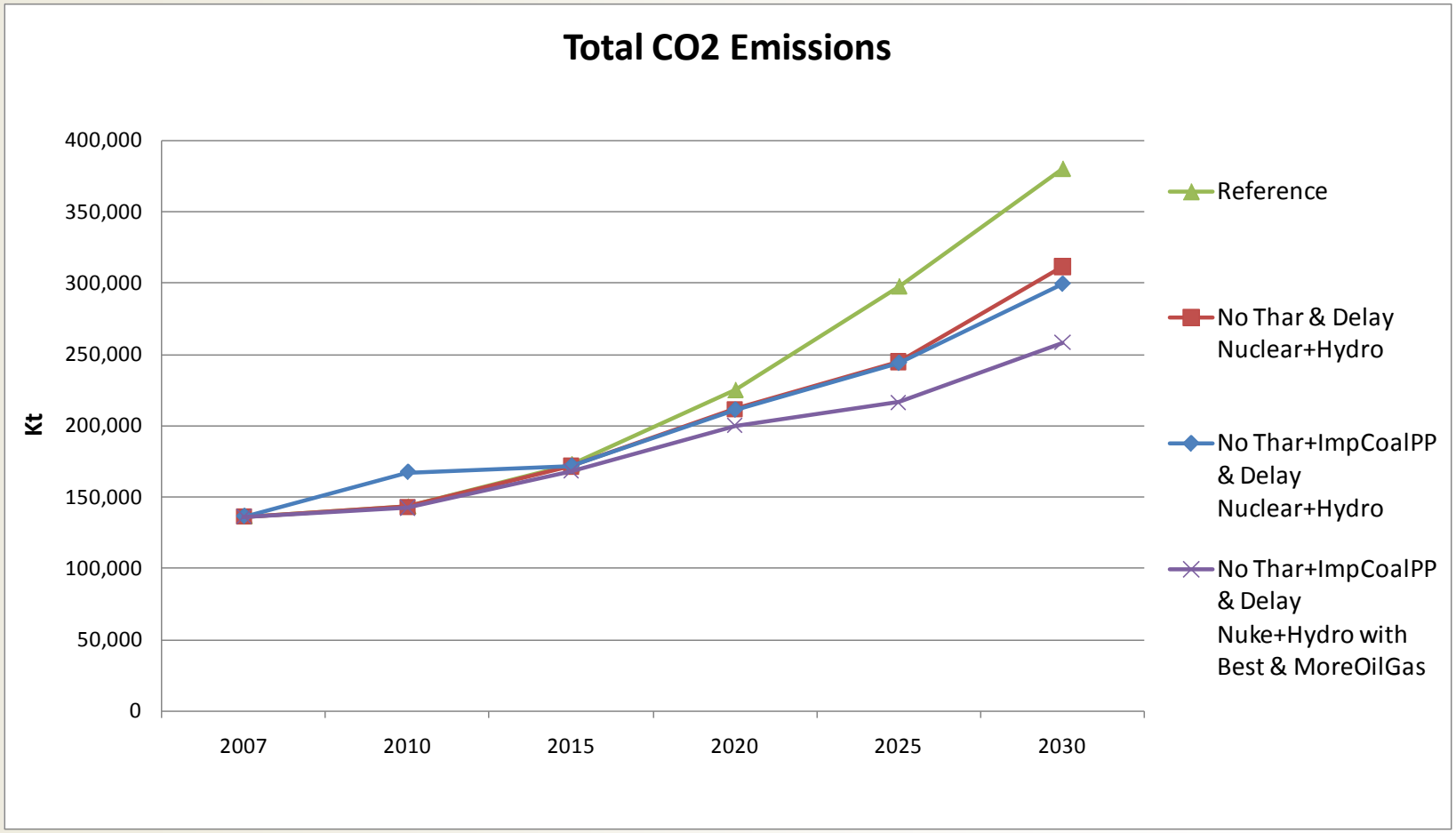


Storyline 2: Challenges Persist

CO2 Emissions

Pak-IEM Team

No Thar coal results in 80 million tons of reduced CO2 emissions in 2030, and the implementation of best practices and more gas reduces emissions by another 42 million tons



Storyline 2: Challenges Persist
Summary Metrics

Pak-IEM Team

The cost of inaction is significant, but it can be mitigated by policies that focus on efficiency, renewables and expanded gas supply.

Scenario	System Cost		PP Builds		Fuel Supply		Imports		Final Consumption		CO2 Emissions	
	M$07	% Diff	GW	% Diff	Mtoe	% Diff	Mtoe	% Diff	Mtoe	% Diff	Mt	% Diff
Reference	1,002,569		135		5,933		2,290		3,899		12,099	
No Thar & Delay Nuclear+Hydro	36,855	3.68%	9.76	7.25%	-74	-1.25%	486	21.22%	72	1.84%	-1,442	-11.92%
No Thar+ImpCoalPP & Delay Nuclear+Hydro	39,072	3.90%	-25.21	-18.71%	-195	-3.29%	367	16.02%	104	2.67%	-2,156	-17.83%
No Thar+ImpCoalPP & Delay Nuke+Hydro with Best & MoreOilGas	-12,741	-1.27%	-11.43	-8.49%	-322	-5.43%	31	1.37%	-111	-2.85%	-3,141	-25.96%