MARKAL-Georgia Energy System Model

Data Requirements and Reference Scenario

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Presentation Outline

- Establishment of a MARKAL Energy System Model for Georgia
- Reference Scenario Data, Assumptions and Guidance
- Reference Scenario Evolution of the Georgia Energy System
- Conclusions and Next Steps

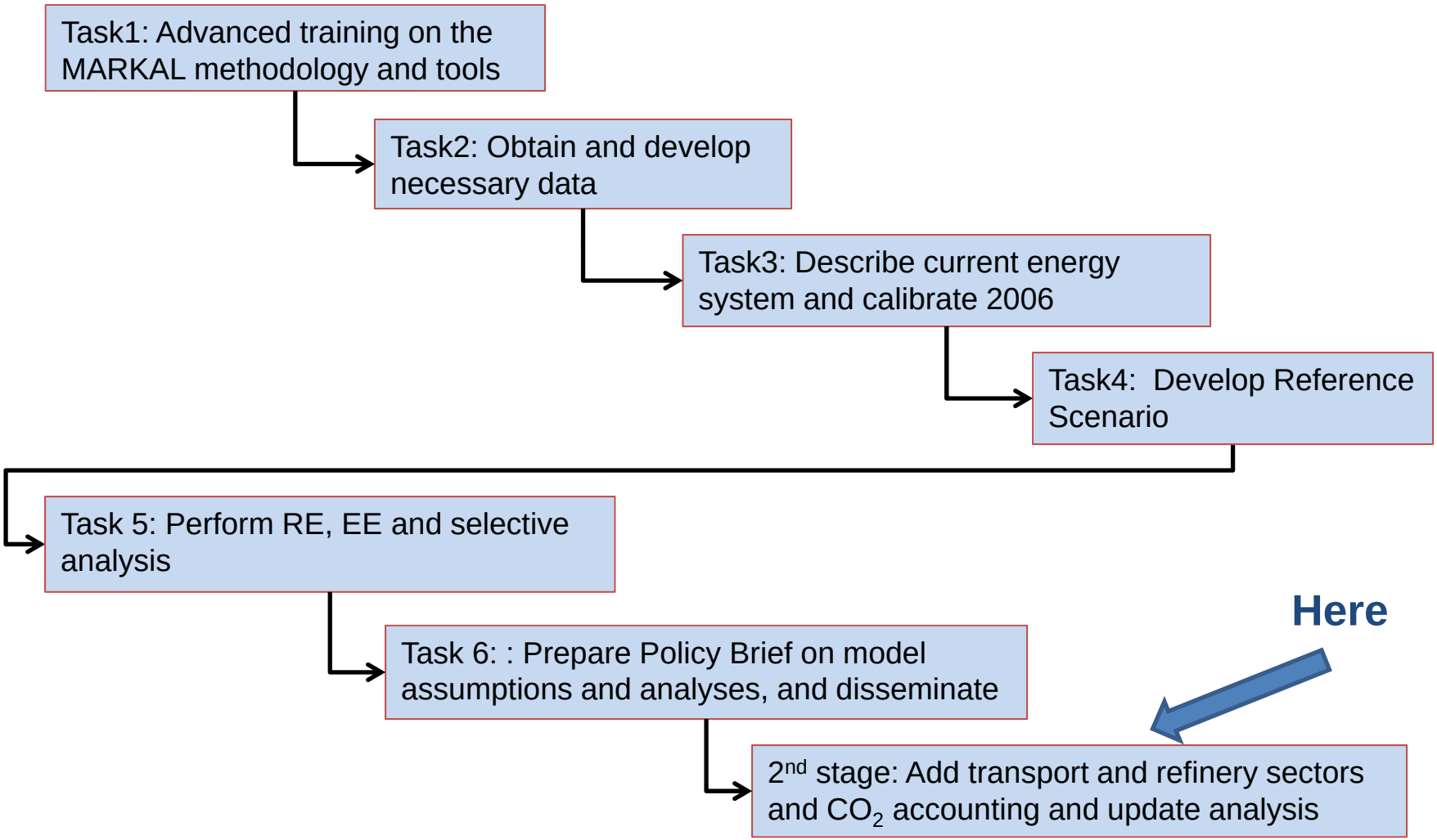
Figures in this presentation are based on a number of assumptions and the results are only indicative.

Establishment of a MARKAL Energy System Model for Georgia

Development of MARKAL-Georgia

- Work on MARKAL-Georgia started in 2009, after joining USAID/Hellenic Aid SYNENERGY Project, with guidance from IRG and CRES experts and in cooperation with MENR (coordinators).
- The model is calibrated to a base year of 2006, with 2009 reflecting the impact of the world economic crisis.
- The structure of the model is similar to other countries participating in SYNENERGY project with some country-specific modifications, particularly with respect to modeling the seasonal nature of hydro power and electricity trade.
- Available information from various sources comprise the core model data, supplemented by additional analysis where required.

Establishing Georgia's MARKAL Capacity



Full Representation of the Georgian Energy System - Energy Supply

- **All types of fuels**
  - Electricity
  - Natural gas
  - Oil and oil products
  - Coal
  - Wood
  - LPG
  - Renewables
  - Etc.
- **Supply sector**
  - Domestic Production
  - Imports
  - Transformation
    - Power plants
    - Refineries
  - Electricity Transmission and Gas Pipelines
  - Electricity and Gas Distribution

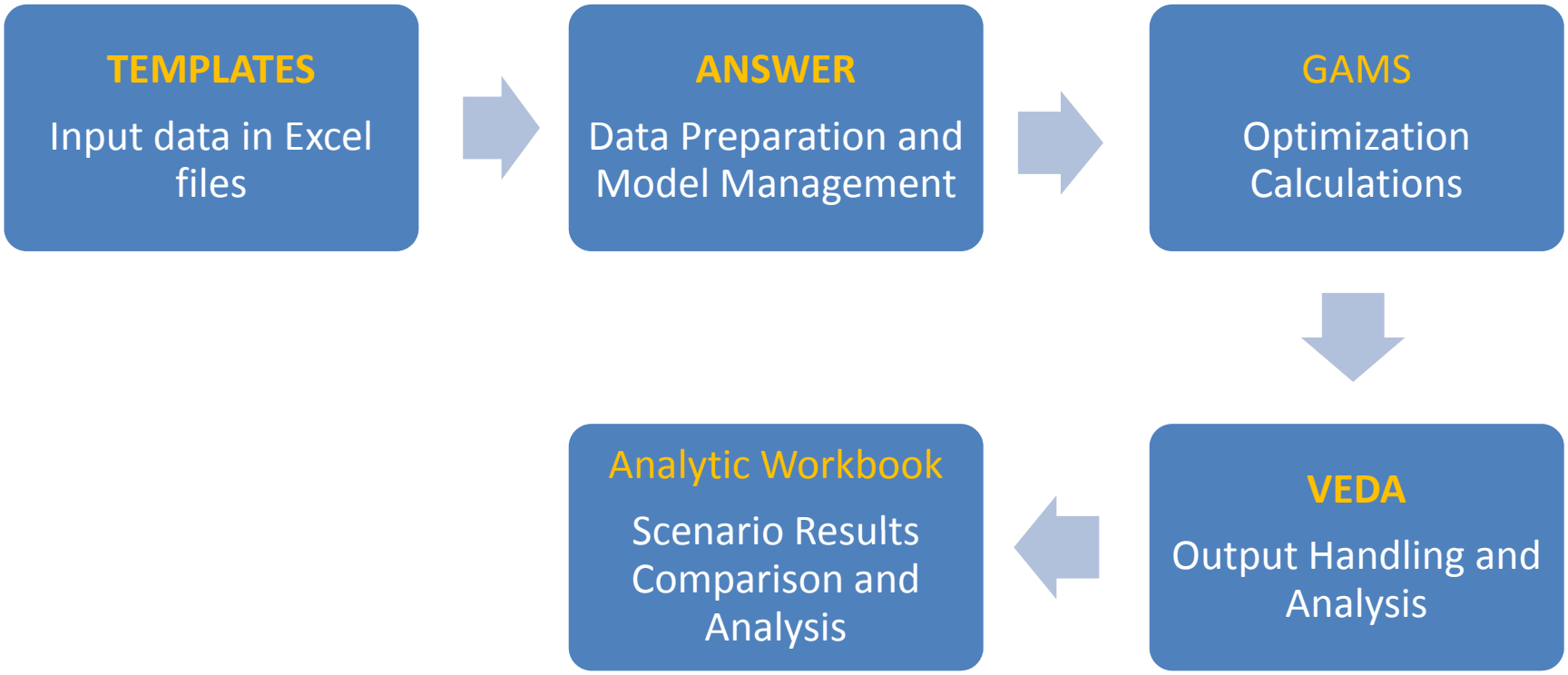
Full Representation of the Georgian Energy System - Final Energy Consumption

- **Demand Sectors**
  - **Residential**
  - **Industry**
    - Chemical
    - Iron and steel
    - Food, Beverages and Tobacco
    - Non-ferrous metals
    - Non-metallic minerals
    - Other manufacturing
    - Construction
  - **Commercial** (education, commercial, health care, public agencies etc.)
  - **Agriculture**
  - **Transport** (metro and railway – road transport added recently)

- **Energy Services**
  - Heating
  - Cooling
  - Lighting
  - Hot water
  - Refrigeration
  - Industrial heat
  - Motion power
  - Cooking
  - Others

  - and Exports

MARKAL Modeling Mechanics



Data Assembly Templates – National Energy Balance

Base Year Energy Supply [2006]	**GEORGIA**			
	Base-year energy consumption (PJ)			
Primary energy balance	Fuel Wood	Electricity	Natural Gas	Diesel Oil
Production (mining)	17.6		0.7	0.0
Import	0.0	2.7	67.0	15.8
Export + Stock change	0.0	0.3		
Total energy supply	17.6	29.8	67.7	15.8
Checking total demand	17.6	29.8	67.7	15.8
Total energy consumption	Fuel Wood	Electricity	Natural Gas	Diesel Oil
Transformation input, Energy consumption and losses				
Net Energy Consumption electricity sector + losses	0.0	3.8	25.6	0.0
Final energy consumption	17.6	26.1	42.1	15.8
Total energy consumption	17.6	29.8	67.7	15.8
	Energy demand (PJ)			
Final energy demand - sector Templates	Fuel Wood	Electricity	Natural Gas	Diesel Oil
Industry	0.5	8.3	17.7	0.0
Transport		1.4	2.6	15.8
Households	15.0	7.1	14.5	0.0
Commercial&Services	1.1	4.4	4.1	0.0
Agriculture	0.9	0.6	2.4	0.0
Non energy consumption			0.7	
TED		4.3		
Total	17.6	26.1	42.1	15.8
Transformation input	Fuel Wood	Electricity	Natural Gas	Diesel Oil
Electricity only Power Plants	0.0	0.0	23.1	
Couple heat&power large plants	0.0	0.0	0.0	
Cogeneration plants (small)	0.0	0.0	0.0	
District Heating plants	0.0	0.0	0.0	

Reference Scenario Data, Assumptions and Guidance

Main Sources of Data

- Ministry of Energy and Natural Resources
- Electricity and natural gas distribution companies
- Statistical yearbooks and Department of Statistics
- Georgian Oil and Gas Corporation
- Georgian National Energy and Water Supply Regulatory Commission (GNERC)
- Customs Department
- Ministry of Agriculture
- Energy Sector related studies
- And other sources

- Plus additional detailed analysis to address data holes as needed

Reference Scenario Key Assumptions

- Moderate growth of the economy and population
- Gasification of most of the territory
- Electricity consumer TED (Abkhazia)
- Uniform growth of economy subsectors
- Load curves represented as 4 seasons and 3 daily blocks (day, peak, night)
- Seasonal and daily patterns of electricity export/import
- Continuing increase of electricity export and decrease of electricity imports

GDP and Population Growth

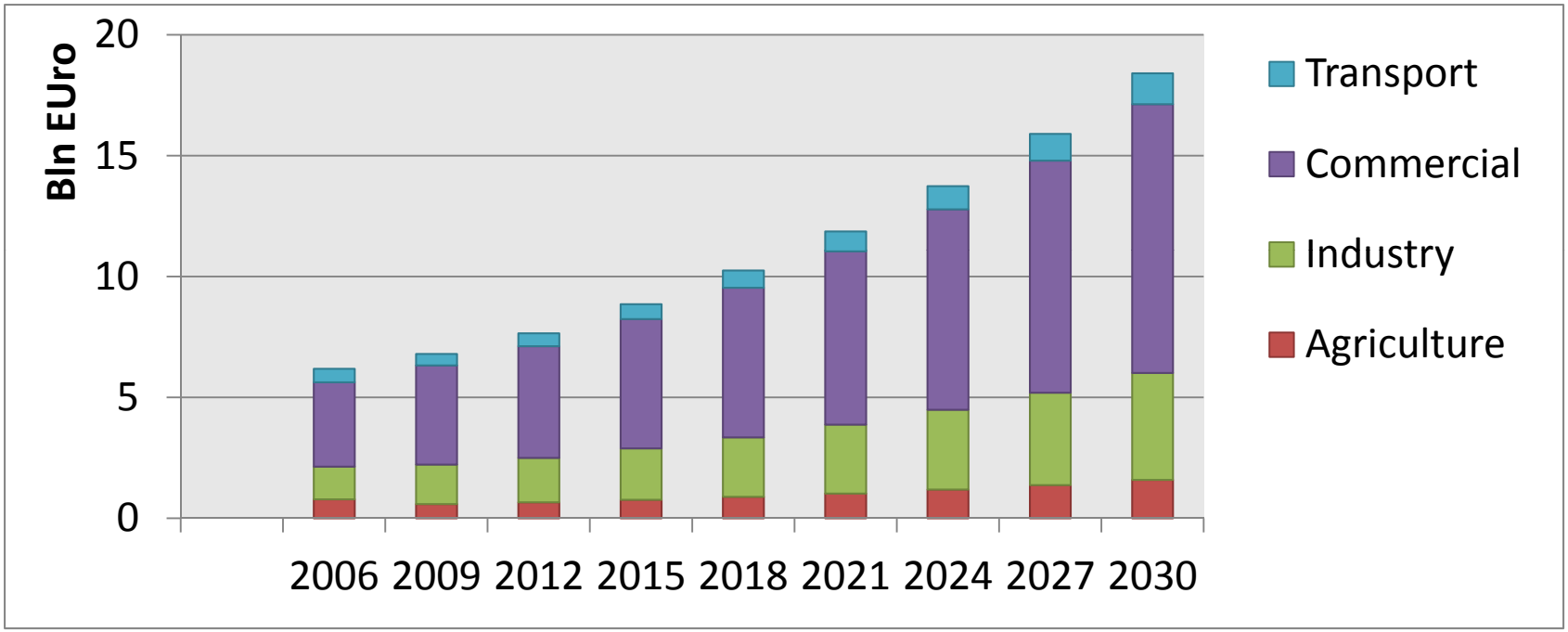
GDP growth assumption

	2006	2009	2012	2015	2018	2021	2024	2027	2030
GDP Growth (%)		3.2%	4.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
GDP(2006 €M)	6187	6800	7649	8855	10251	11867	13737	15902	18409

Population Growth assumption

	2006	2009	2012	2015	2018	2021	2024	2027	2030
Population Growth (%)		0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Population (1000 person	4400	4400	4467	4534	4602	4672	4742	4814	4886

Growth of GDP from Sectors of Economy



Sectors of economy are projected to grow with same rate as total country GDP retaining the same general shares for Commercial (56%), Industry (22%), Agriculture (13%), and transport (9%).

Residential sector growth is tied to population and other demographics, as well as end-use saturation rates.

Gas Prices and Availability

Natural Gas Availability (mln cub.m)

	2006	2009	2012	2015	2018	2021	2024	2027	2030
Azeri gas at market price	24.5	575.6							
Russian gas at Russian price	1685.4	490.6	260.8	260.8	260.8	260.8	260.8	260.8	260.8
Transit fee for Armenia transit (10%) - free	171.6	202.0	240.6	278.5	322.4	362.7	407.9	445.8	487.1
Additional gas from SCP	0.0	266.8	433.3	500.0	500.0	500.0	500.0	500.0	500.0
Option gas from SCP	0.0	12.4	22.0	325.0	325.0	325.0	325.0	325.0	325.0
total	**1881**	**1547**	**1686**	**2118**	**2162**	**2202**	**2248**	**2286**	**2327**

Natural Gas Price (USD/1000 cub.m)

	2006	2009	2012	2015	2018	2021	2024	2027	2030
Azeri gas at market price	250.00	250.00	255.00	250.00	255.00	270.00	270.00	270.00	270.00
Russian gas at russian price	200.00	250.00	280.00	300.00	300.00	300.00	300.00	300.00	300.00
Transit fee for Armenia transit (10%) - free	0	0	0	0	0	0	0	0	0
Additional gas from SCP	0	55.00	57.51	60.14	62.89	65.76	68.76	71.90	75.19
Option gas from SCP	0	50.00	53.06	56.31	59.75	63.41	67.29	71.41	75.78

Current Average gas price 160 USD/1000 cub.m

Existing Power Plants

Plant	Fuel	Capacity [MW]	Efficiency	Availability Factor %	Decommission Date
Enguri/Vardnili HPP	Hydro	1640	100	Seasonal	2035
Other reservoir hydro plants	Hydro	435	100	Seasonal	2035
Run-off river HPPs	Hydro	605	100	Seasonal	2035
Mtkvari unit 9	Natural Gas	270	36.7	52%	2025
EnergyInvest	Natural Gas	90	33.5	37%	2030
Tbilsresi units #3,4	Natural Gas	255	32.1	32%	2015

Hydro Power Plants - Capacity Expansion Options

HPP NAME	Start	Investment Cost ($/KW)	Capacity (MW)
Khudoni	2017	930	750-702
Khobi HPP2	2014	1740	39.5-44.6
Khobi HPP1	2017	1650	46.5
Namakhvani cascade	2017	2200	450
Zoti	2015	2200	36
Paravani	2013	1600	78
Mtkvari	2015	1500	43
7 Mini-HPP (less than 15 MW)	2012	1620	49.5
3 Small HPP (more than 15 MW)	2012	1400	70.4

Besides these, up to 500MWs of additional small hydro, as well as any amount of combined cycle natural gas plants may be built.

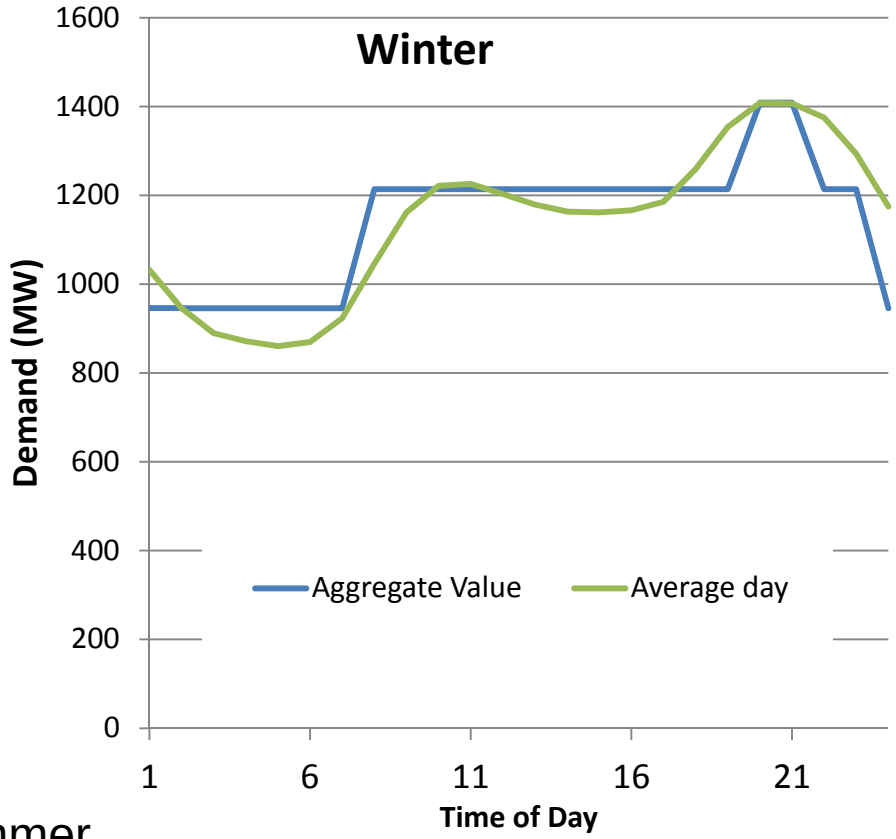
Seasonal / Time-of-Day Load Curves

Spring
April, May, June July

Summer:
August, September

Fall:
October, November

Winter:
December, January, February, March



Time-of-Day Hours
- Day: 8:00-23:00
- Night : 24:00-7:00
- Peak : 21:00-22:00 in spring-summer, 20:00-21:00 in fall-winter

Minimum capacity reserve 10%

Reference Scenario Evolution of the Georgia Energy System

Aspects Shaping the Reference Scenario

- How will the energy sector develop under business-as-usual conditions to meet the projected economic growth?
- What levels of imports are required?
- What technology and fuel mix is expected in this Reference scenario?
- What is anticipated structure of the power sector to meet increased electricity demand?
- How much investment will be required and what will be the impact on the price of energy?
- Reference scenario is not a forecast!

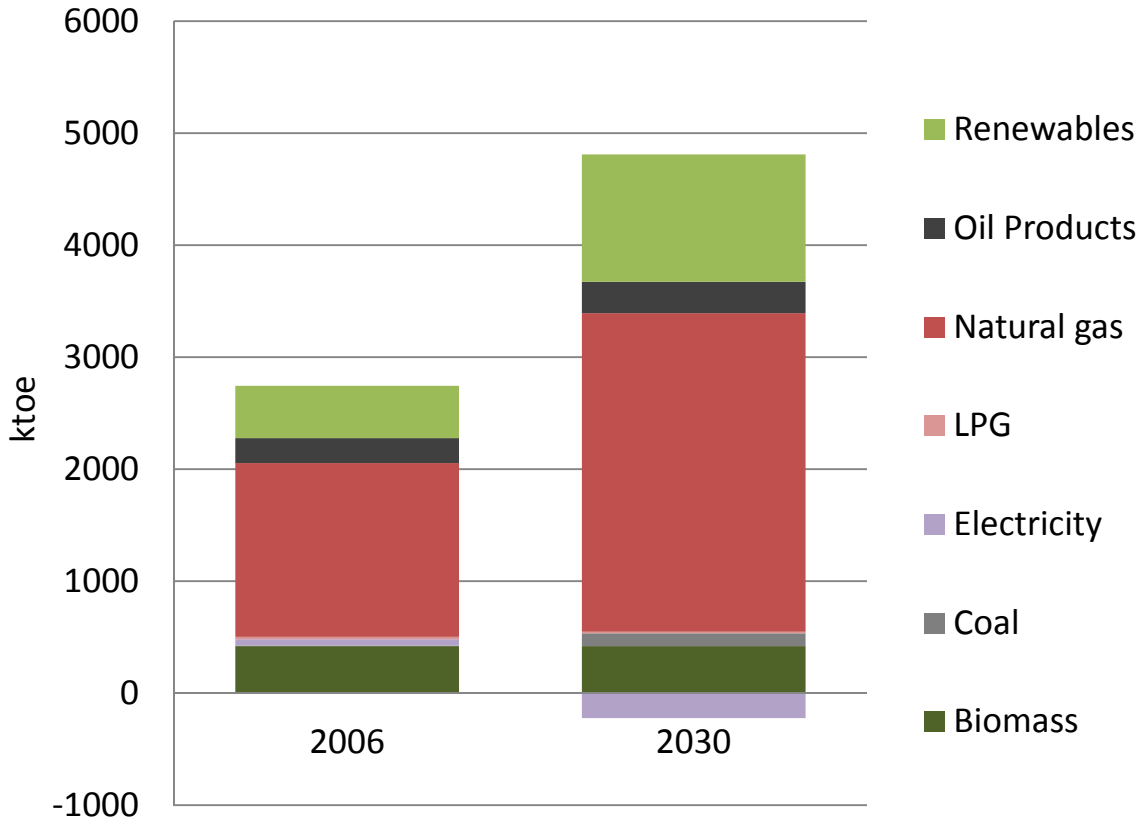
Key Indicators from the Reference Scenario

Indicator	2006	2030	Annual growth rate (%)	Overall growth (%)
Primary Energy (Ktoe)	2743	4588	2.2%	67.2%
Final Energy (Ktoe)	2226	4288	2.8%	92.6%
Power plant capacity (GW)	3.30	4.62	1.4%	40.2%
Imports (Ktoe)	1845	3263	2.4%	76.8%
CO_2 emissions (Kt)[1]	4291	7884	2.6%	83.7%
GDP (€ Mill.)	6187	18409	4.6%	197.5%
Population (000s)	4400	4886	0.4%	11.1%
Final Energy intensity (toe/€000 GDP)	0.360	0.233	-1.8%	-35.3%
Final Energy intensity (toe/Capita)	0.506	0.877	2.3%	73.5%
CO_2 emissions intensity (t/capita)	0.98	1.61	2.1%	65.5%

[1] Accounts for only energy sector CO_2 emissions, without transportation.

- Energy consumption is projected to grow significantly, by 93% in terms of final energy by 2030.
- Electricity generation system will require 1320MW of new capacity by 2030.
- Total investment of 2.2€Billion will be required for capacity additions in generation sector.
- Natural gas imports will almost double by 2030, increasing CO_2 emissions 84%.
- Annual payments for primary fuels will almost double by 2030.

Total Primary Energy



Primary Energy Supply - 2006/2030

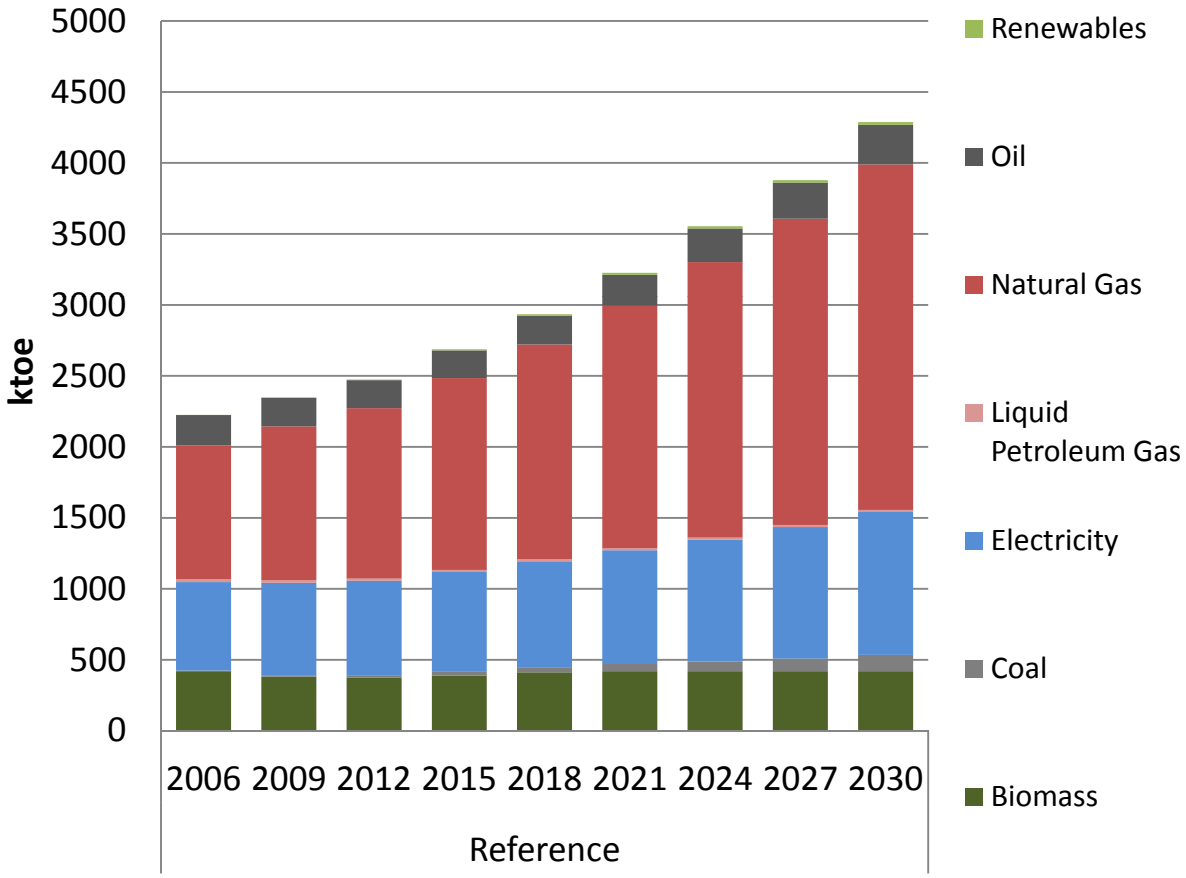
- Primary energy supply will grow to 4588ktoe in 2030, an increase of over 67% on 2006 levels.
- However, energy consumption per unit GDP is estimated to be 0.233toe/1000€, which is almost 35% lower than 2006 owing to anticipated improvements in technologies.
- Primary energy supply mix remains broadly similar between 2006 and 2030.
- Share of renewable energy increases from 17% in 2006 to **25% ?**in 2030 as additional hydro power plants are added.
- Relative importance of imported gas for end use energy remains high, going up to 62% in 2030 compared to 57% in 2006.

New Power Plant Capacity Additions (MW)

TYPE	2012	2015	2018	2021	2024	2027	2030
Hydro	242	119	204	163	197	688	0
Natural Gas	0	0	0	0	0	83	153
Total	**242**	**119**	**204**	**163**	**197**	**772**	**153**

- Future additions in generation capacity are almost entirely hydro plants, except post 2027 when some new CCGT (combine cycle gas turbine) capacity comes online to replace gas plants that have retired.
- While hydro dominates the system, gas-fired power plants are also an important part of electricity system. They are used to meet domestic demand in winter, where it accounts for 14% of generation in 2021, 6% overall on an annual basis.

Final Energy Consumption

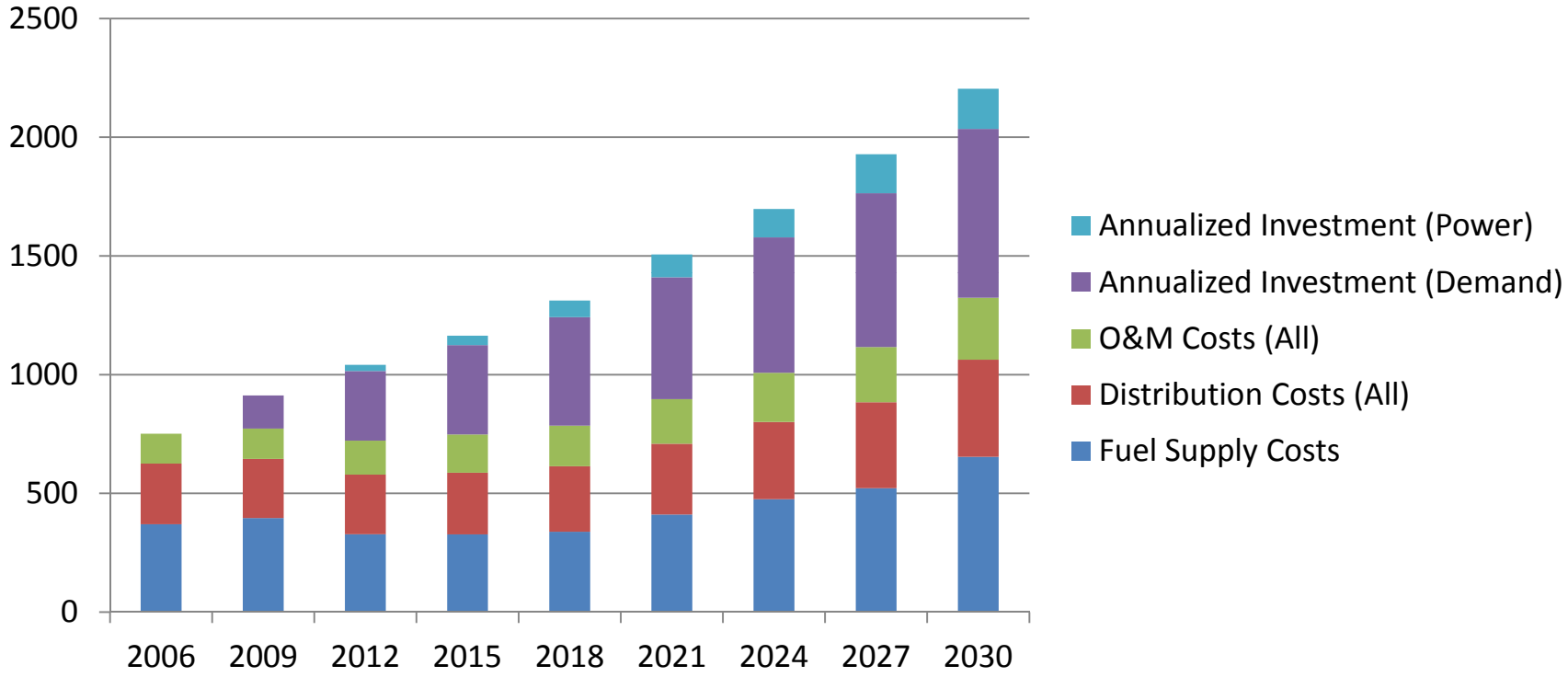


Total Final Energy Consumption (TFEC)

- Total final energy consumption grows by 93% over the planning horizon*.
- Natural gas imports more than doubled by 2030, driven by increasing demand in end use sectors, with a limited amount being used for electricity generation.
- Energy consumption in residential, commercial and industry sectors all grow significantly.
- Industry (41%) and Residential (34%) sectors comprise highest shares in energy consumption (Transport sector not included).

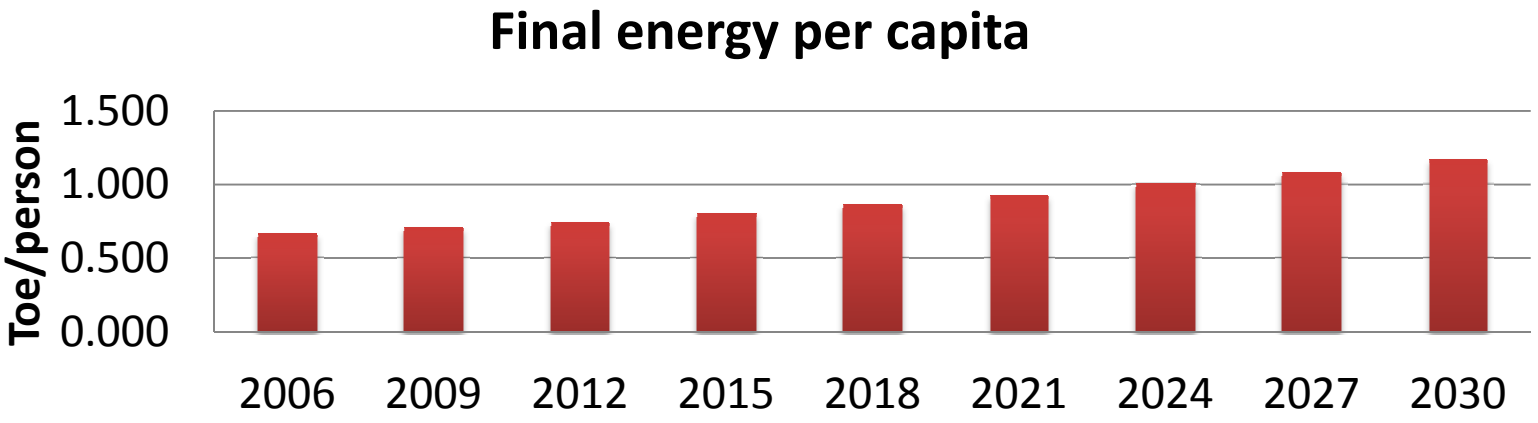
[* Note that TPES only grows by 67% due to the increased role of hydro.]

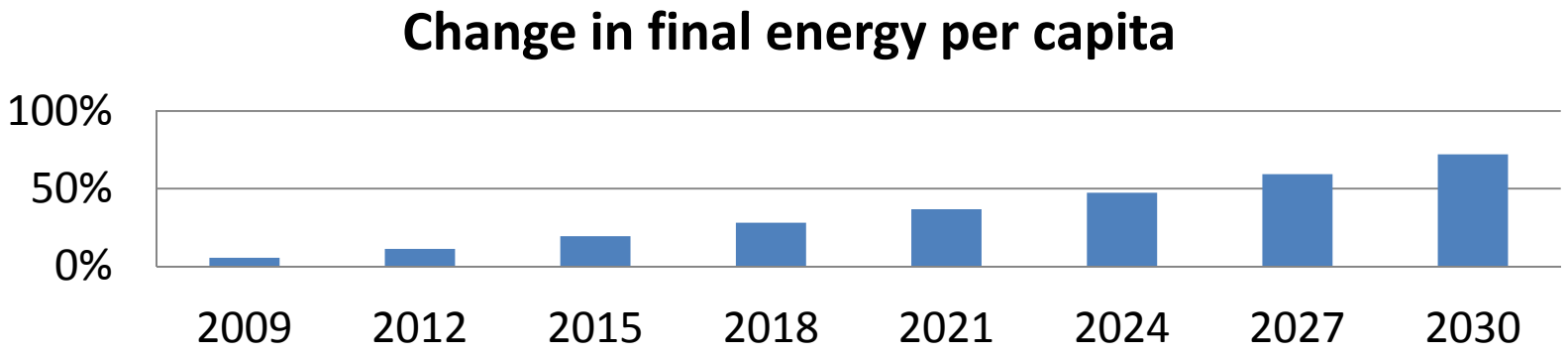
Energy System Expenditure by Cost Type (Million EUR)



- Annual payments for fuels will rise to 1.06€Billion per year in 2030, twice the current level.
- Over 700€Million annually will be required to cover the cost of new demand devices.
- A total of 1.85GW of new generation capacity is required by 2030, costing 2.2€Billion, which corresponds to capital payments on the order of 170€Million per annum in 2030.
- However, energy system expenditures are expected to absorb a smaller percentage of GDP in 2030 due to the reduced energy intensity per unit of economic output.

Growth of Energy Consumption per Capita





Energy Consumption* per capita will increase in 2030 by 76% compared to 2006 and reaches 1.2 toe per person.

* Including Transport Sector

Conclusions and Next Steps

Conclusions

- Assessing policies and completing alternatives to foster energy security, affordability and competiveness, while considering environmental goals, will be an ongoing necessity.
- Modeling energy systems is complex and challenging, requiring an ongoing commitment to sustain and improve the planning tool.
- Georgia now has in place a widely used energy system model, MARKAL-Georgia, with the expertise to use it effectively.
- In order to promote understanding and acceptance of MARKAL-Georgia a consensus building process should be undertaken engaging key stakeholders
  - Determine (a range of) values for key model assumptions, and
  - Identify alternative development options and opportunities to be considered.
- MARKAL-Georgia is ready to provide insights and analytic rigor in support of policy deliberations and formulation that will shape the evolution of Georgia's future energy system and its place in region.

Planned Enhancements to MARKAL-Georgia

- Inclusion of full transportation sector
- Sector tracking of CO_2 emissions
- Refining the model
  - Reflect the cost of transmission line expansion for new large HPPs
  - Review and revision of the characterization of consumption technologies
  - Refinement of the Reference scenario for recently available information (free industrial zones, new power plant builds, etc.)
  - Further refine export-import options as a first step towards a regional model

Thank You!

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