Title: Weather-Based Long-Term Electricity Demand Forecasting Model for Saudi Arabia: A Hybrid Approach Using End-Use And Econometric Methods for Comprehensive Demand Analysis

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WEATHER-BASED LONG-TERM ELECTRICITY DEMAND FORECASTING MODEL FOR SAUDI ARABIA: A HYBRID APPROACH USING END-USE AND ECONOMETRIC METHODS FOR COMPREHENSIVE DEMAND ANALYSIS

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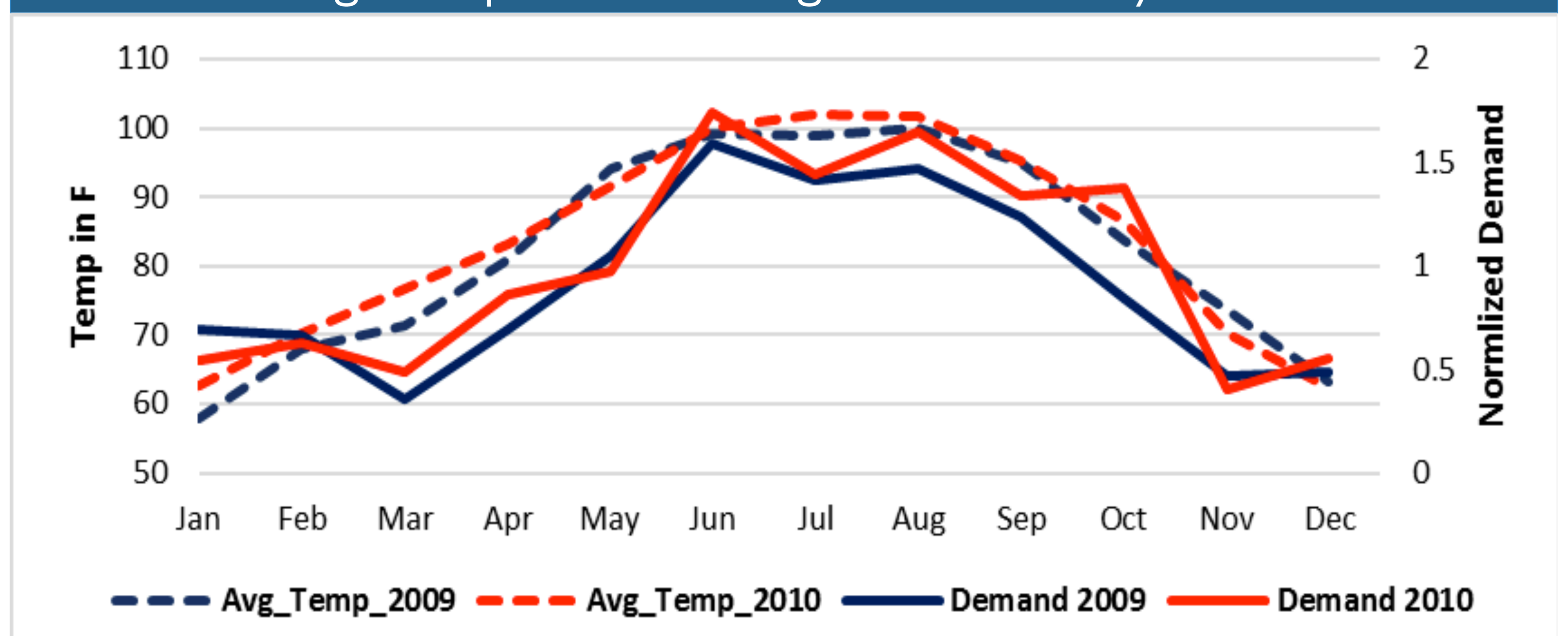
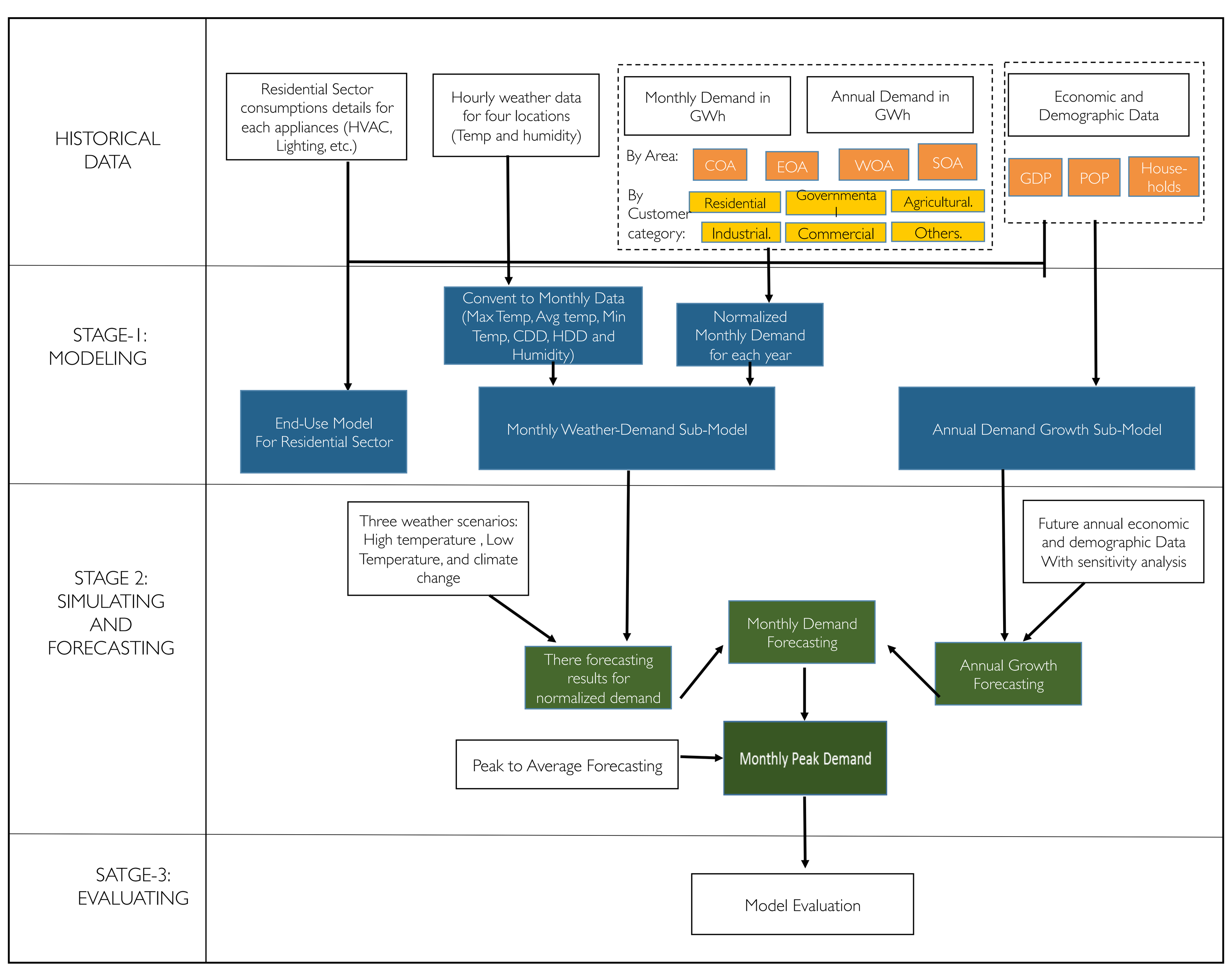
Overview and Research Summary

- Using a weather-based long-term electricity demand forecasting model, this paper primarily forecasts the electricity demand and analyzes the effects of weather on electricity demand in Saudi Arabia, up to year 2040, by adopting a hybrid approach based on end-use and econometric methods.
- In addition, the paper quantifies, technically and economically, the relationship between climate conditions and electricity consumption, that can raise awareness of climate change on future heating and cooling equipment investments.
- Also, we apply the demand forecast as a first basic step to analyzing how much new generation capacity may be needed, which generation resources are applicable, how transmission and distribution systems should be expanded, and in which customer groups or geographic regions these requirements will be concentrated.
- Using the results of this forecast, the paper identifies which DSM and efficiency programs are worth pursuing and when, as well as in which sectors and end-uses they should be implemented to realize optimal economic, environmental, and social benefits.

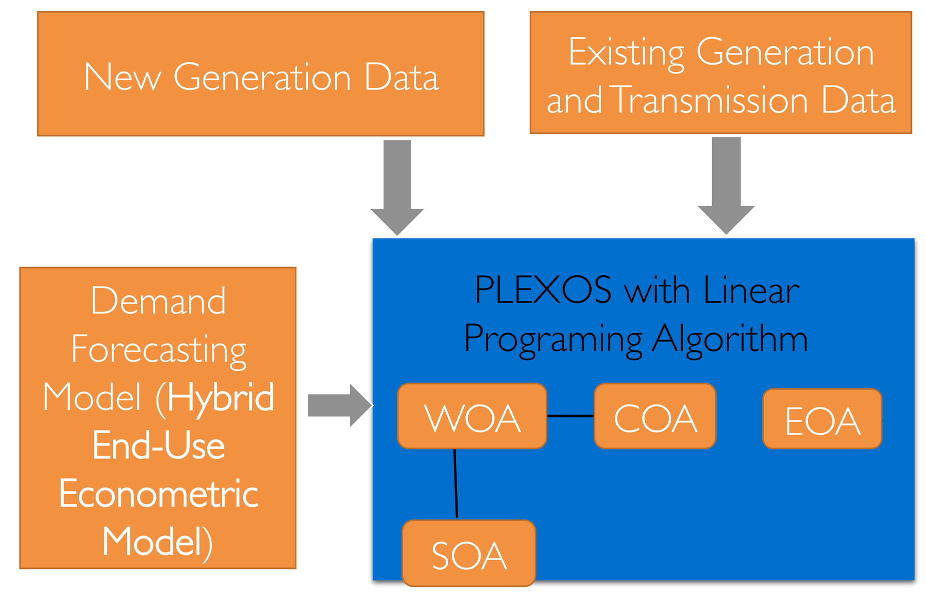
Effect of Average Temperature Changes on Electricity Demand

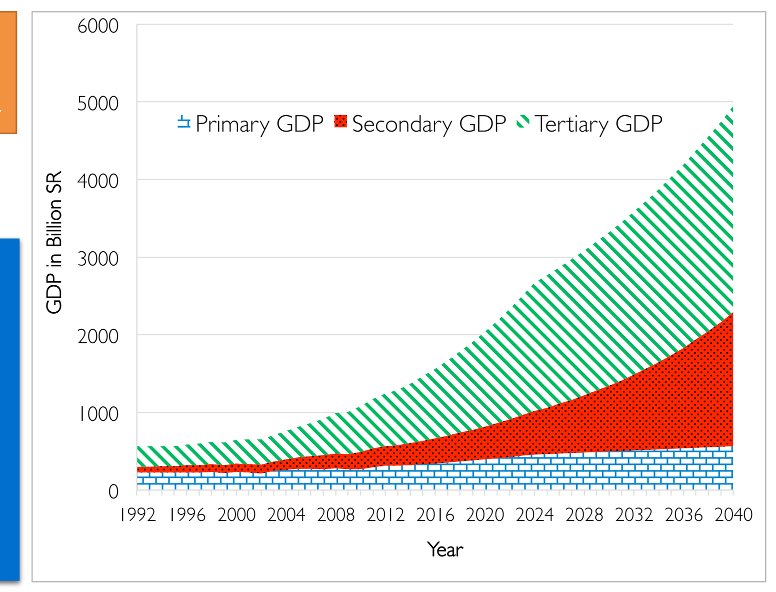


Demand Forecasting Methodology



Optimal System Modeling





Model Descriptions

Forecasting model consists of two econometric sub-models: annual demand growth sub-model based on economic and demographic variables, and monthly weather-demand sub-model based on weather variables. Following the same approach used by Hyndman & Fan (2009), the model can be written as follows:

$$y_{t,p} = f_p(w_t) + \sum_{j=1}^{j} c_j z_{j,t} + n_t$$

Denotes monthly electricity sales on year t (measured in GWh) during month period (p=1, 2, 3,……12)

Models all weather effects within each network operating area using econometric analysis.

Is the annual demographic and economic variable at time t and its impact on monthly demand via the coefficient *cj* (these terms do not depend on the period *p*) using multivariable econometric analysis.

Denotes the demand which is left unexplained by the model (the model residuals) at time *t*.

To estimate the weather factor $f_p(w_t)$ we can use the following regression model: $f_p(w_t) = \beta_0 + \sum_{p=1}^{12} \beta_p w_{p,t}$

Are explanatory weather variables which are nonlinear functions of historical weather parameters

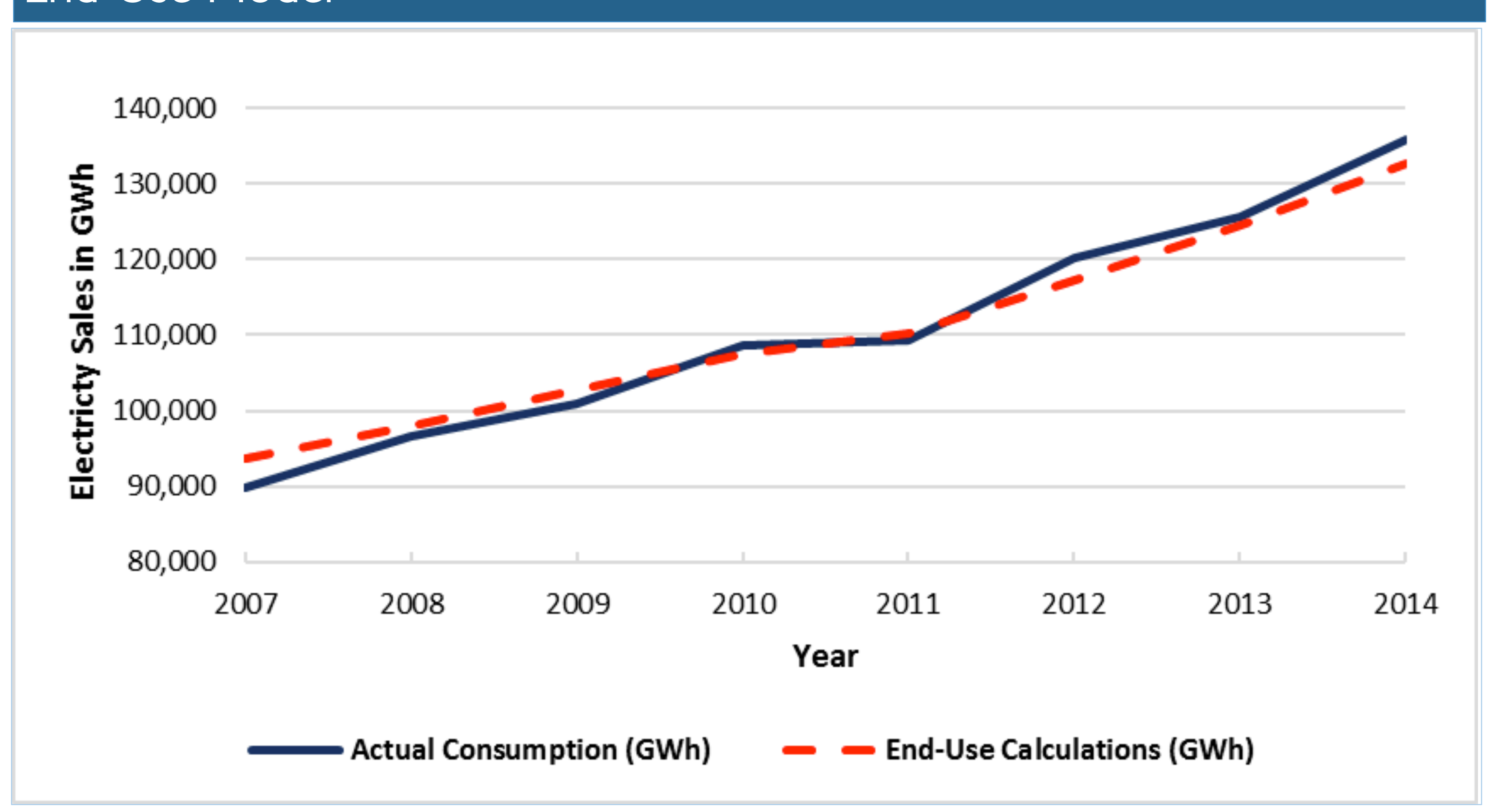
β_0, β_p are the regression coefficients.

Variables Selections Criteria

Annual Demand Growth Econometric (Long-run) Sub-Model	
Dependent Variables	Independent Variables
• Commercial Electricity Sales • Governmental Electricity Sales • Agricultural electricity Sales • Others Sales	• Population • Total GDP or other GDP categories

Monthly Demand Weather Econometric (Short-run) Sub-Model	
Dependent Variables	Independent Variables
• Residential Normalized Electricity Sales • Commercial Normalized Electricity Sales	• Monthly Maximum Temperature • Monthly Minimum Temperature • Monthly Average Temperature • Monthly CDD • Monthly HDD • Monthly Average Humidity

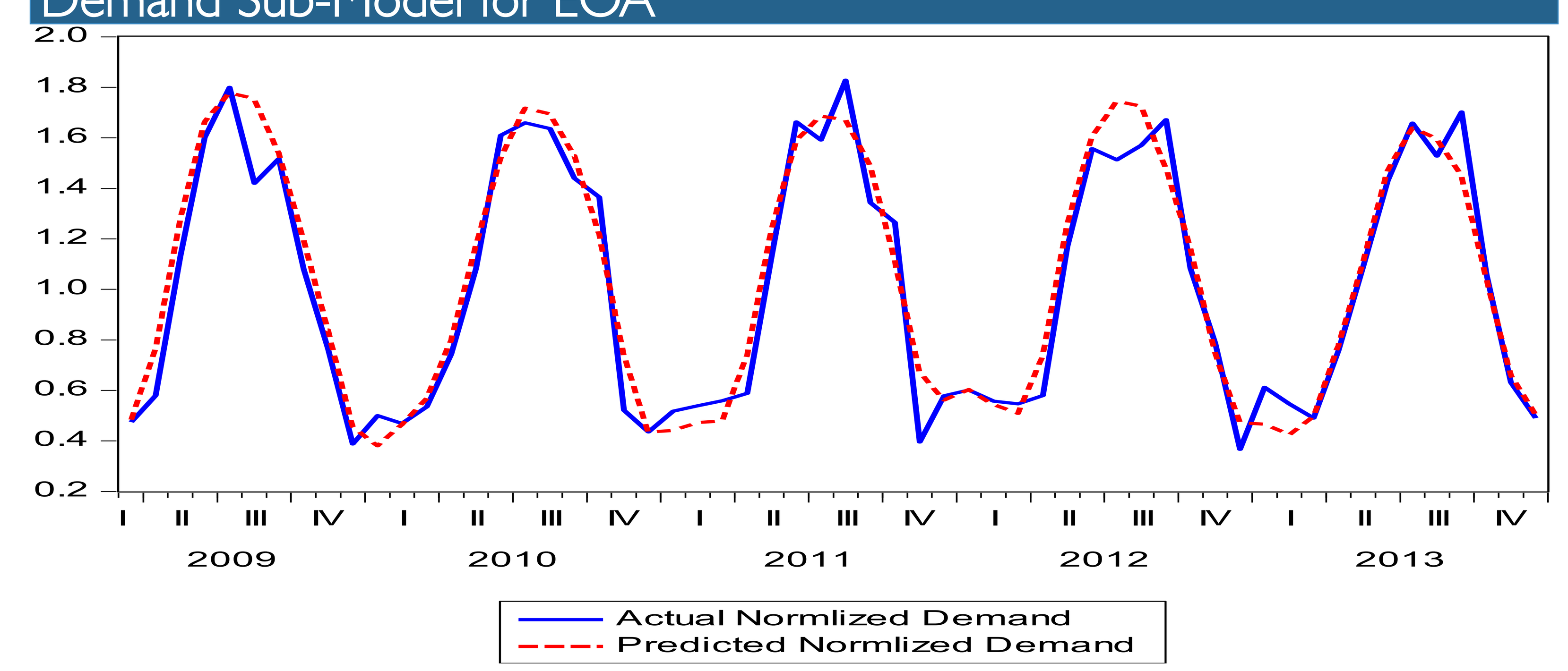
Actual Annual Electricity Sales and Calculated Annual Demand from the End-Use Model



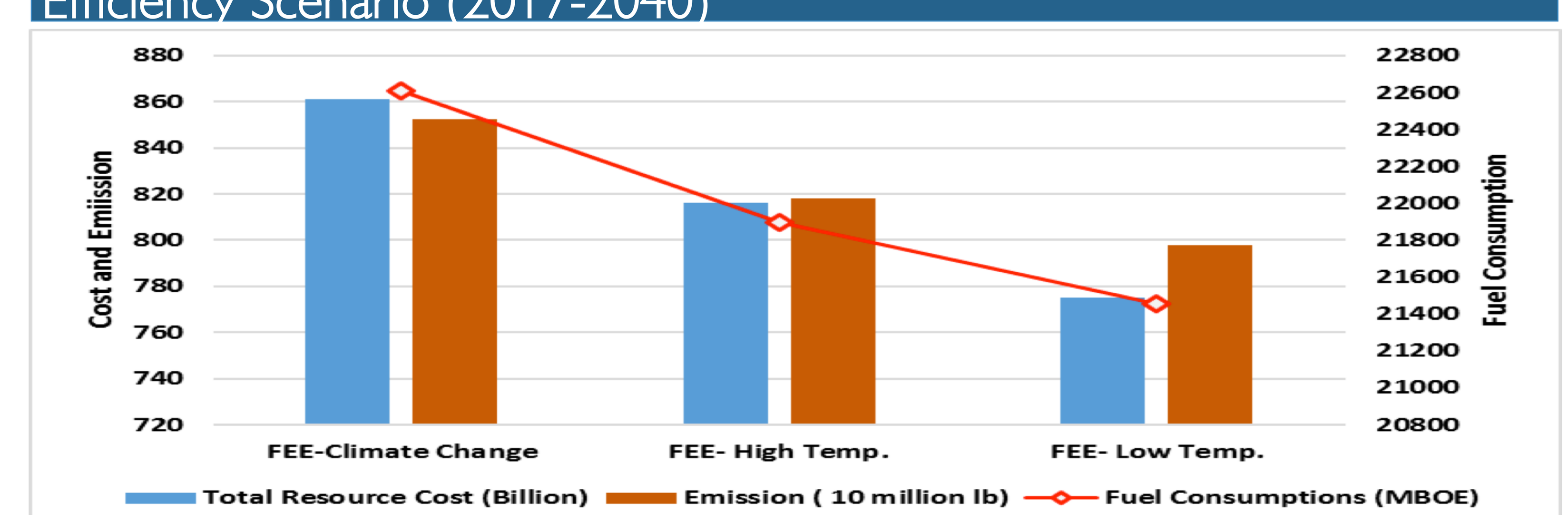
Monthly Demand Weather Models Fitted to the Available Data Using Average Temp., HDD & Humidity Variables in EOA Residential Sector

Model 1	CDD	HDD	CDD(-1)	HDD (-1)	Humidity	Avg-CDD (Last 3 Months)	Avg-CDD (Last 6 Months)	Avg-CDD (Last 12 Months)	R square	Adjusted R Square	RMSE	Results
t-satstitics	A	A	A	A	< 2	< 2	< 2	A	0.963	0.962	0.07326	Rejected
Probability	H	A	A	A	H	H	H	A				
Model 2	CDD								R square	Adjusted R Square	RMSE	Results
t-satstitics	A								0.898	0.898	0.15348	Accepeted
Probability	A											
Model 3	CDD	HDD							R square	Adjusted R Square	RMSE	Results
t-satstitics	A	A							0.92	0.92	0.1056	Accepeted
Probability	A	A										
Model 4	CDD	HDD	CDD(-1)	HDD (-1)					R square	Adjusted R Square	RMSE	Results
t-satstitics	A	A	< 2	A					0.921	0.92	0.1362	Rejected
Probability	A	A	H	A								
Model 5	CDD	HDD	CDD(-1)	HDD (-1)	Humidity				R square	Adjusted R Square	RMSE	Results
t-satstitics	A	A	A	A	A				0.931	0.93	0.12837	Accepeted
Probability	H	A	A	A	A							
Model 6	CDD	HDD	CDD(-1)			Avg-CDD (Last 3 Months)	Avg-CDD (Last 6 Months)	Avg-CDD (Last 12 Months)	R square	Adjusted R Square	RMSE	Results
t-satstitics	< 2	A	< 2			< 2	A	< 2	0.955	0.954	0.10437	Rejected
Probability	H	A	A			H	H	A				

Actual Vs. Predicted Normalized Demand for Residential Weather Demand Sub-Model for EOA



Integrated Electricity evaluation for weather cases in the Frozen Energy Efficiency Scenario (2017-2040)



Conclusion

- A major paradigm shift that includes energy efficiency and DSM investments is needed to change KSA's high dependency on crude oil and refined petroleum products for electricity generation.
- With the power sector consuming the largest energy in the country, an optimal energy system design is necessary to realize efficiency gains.
- Also, a unique weather-based systemic long-term forecasting model for KSA, accounting for weather effects using a hybrid approach of end use method and econometric analysis (based on demographic variables) is urgently required..
- Our findings demonstrate an urgent need for decarbonizing the electricity sector and mitigate climate change impacts. In addition, investing on energy efficiency would reduce the demand significantly by more than 25% and realize significant economic, social and environmental benefits. Furthermore, this would help KSA to continue in its unique role as a global energy supplier and avoid a high price volatility in the world markets.

References

- Pierru, A. & Matar, W. (2014). The Impact of Oil Price Volatility on Welfare in the Kingdom of Saudi Arabia: Implications for Public Investment Decision-making. *The Energy Journal*, Vol. 35, No. 2. DOI: http://dx.doi.org/10.5547/01956574.35.2.5
- Al-Falih, K. (2010, April 19). Saudi Aramco and its Role in Saudi Arabia's Present and Future. speech presented at MIT Club of Saudi Arabia Dinner.
- Atallah, T., Gualdi, S., & Lenza, A. (2015). A global degree days database for energy-related applications. Riyadh: King Abdullah Petroleum Studies and Research Center (KAPSARC). Retrieved July 15, 2016, from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2586960
- The Tellus Institute. (2010). Best Practices Guide: Integrated Resource Planning for Electricity. Boston, Massachusetts. Retrieved January 2015, from http://pdf.usaid.gov/pdf_docs/PNACQ960.pdf
- Crowley, C., & Joutz, F. (2005). Weather Effects on Electricity Loads: Modeling and Forecasting. The George Washington University, Department of Economics, Washington. Retrieved July 15, 2016, from http://www.ce.jhu.edu/epastar2000/epawebsrc/joutz/Final%20Report%20EPA%20Weather%20Effects%20on%20Electricity%20Loads.pdf
- Taher, N., & Hajjar, B. (2014). Energy and Environment in Saudi Arabia: Concerns and Opportunities. New York: Springer.

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