Infrastructure and Forecasting Models for Integrating Natural Gas Grid within Smart Grids

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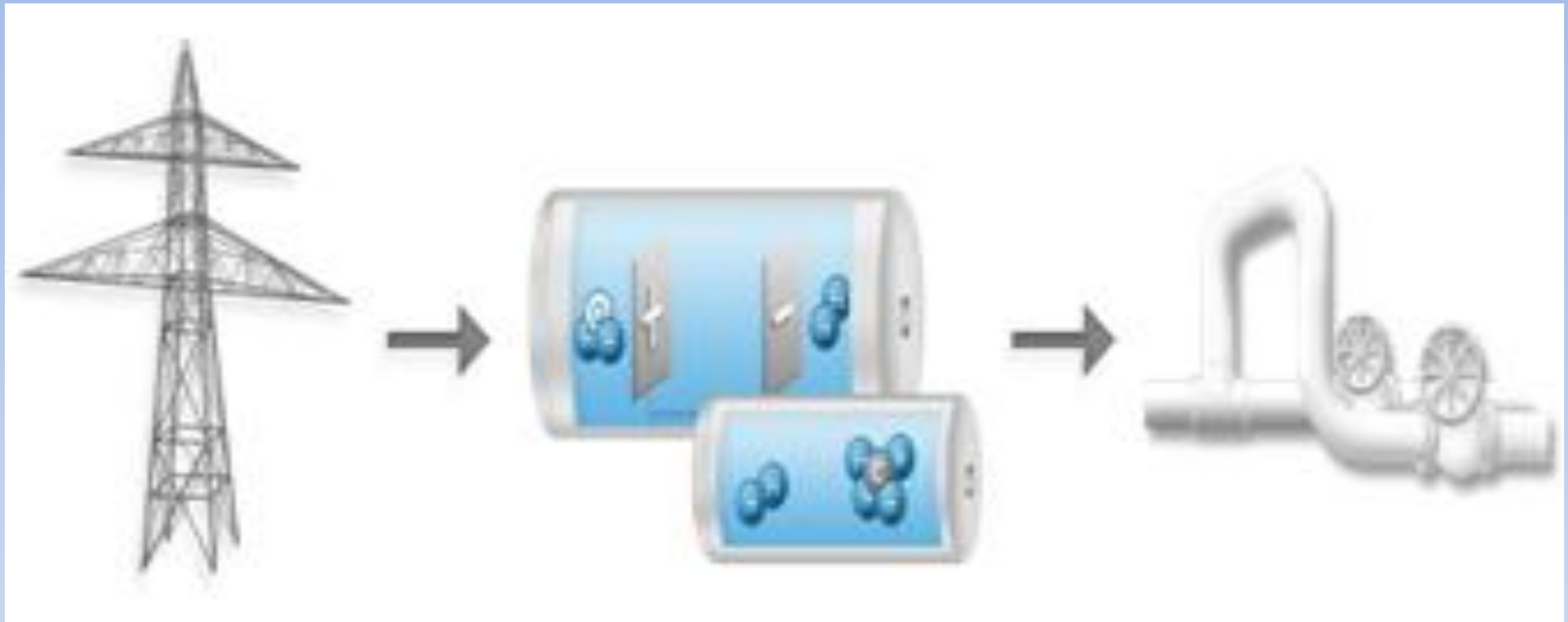
Energy Hub Model

$$\begin{bmatrix} L_{\infty} \\ L_{\beta} \\ \vdots \\ L_{\omega} \end{bmatrix} = \begin{bmatrix} C_{\alpha\alpha} & C_{\alpha\beta} & \cdots C_{\omega\alpha} \\ C_{\alpha\beta} & C_{\beta\beta} & \cdots C_{\omega\beta} \\ \vdots & \vdots & \ddots & \vdots \\ C_{\alpha\omega} & C_{\beta\omega} & & C_{\omega\omega} \end{bmatrix}$$

$$\alpha, \beta, \cdots \in \varepsilon = \{electricity, natural\ gas, hydrogen, \cdots\}$$

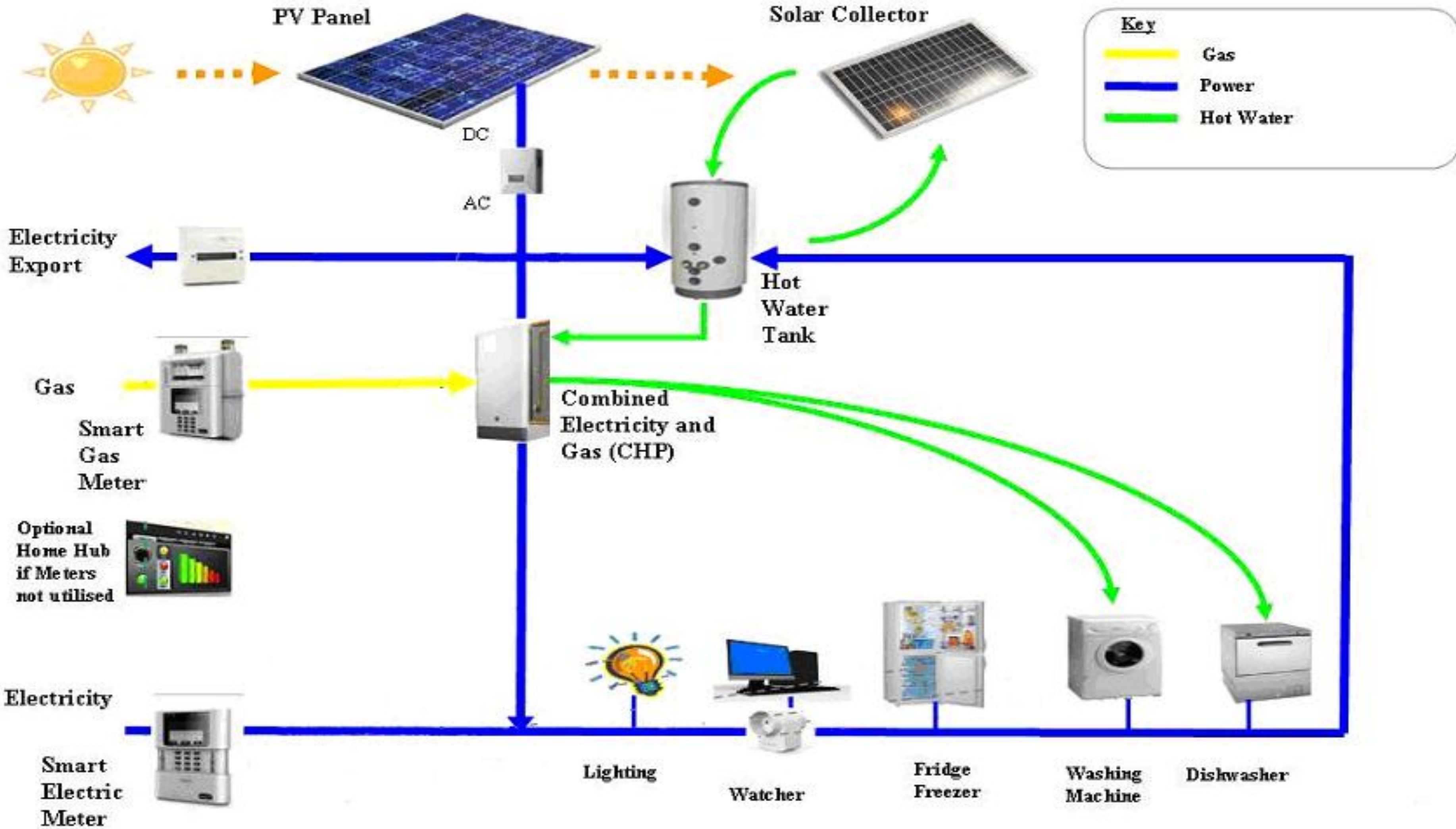
where L,C denote loads, coupling matrix and input powers, respectively. Coupling factors $C\alpha\beta$ denote the conversion from one energy carrier α to another carrier β.

Power to Gas

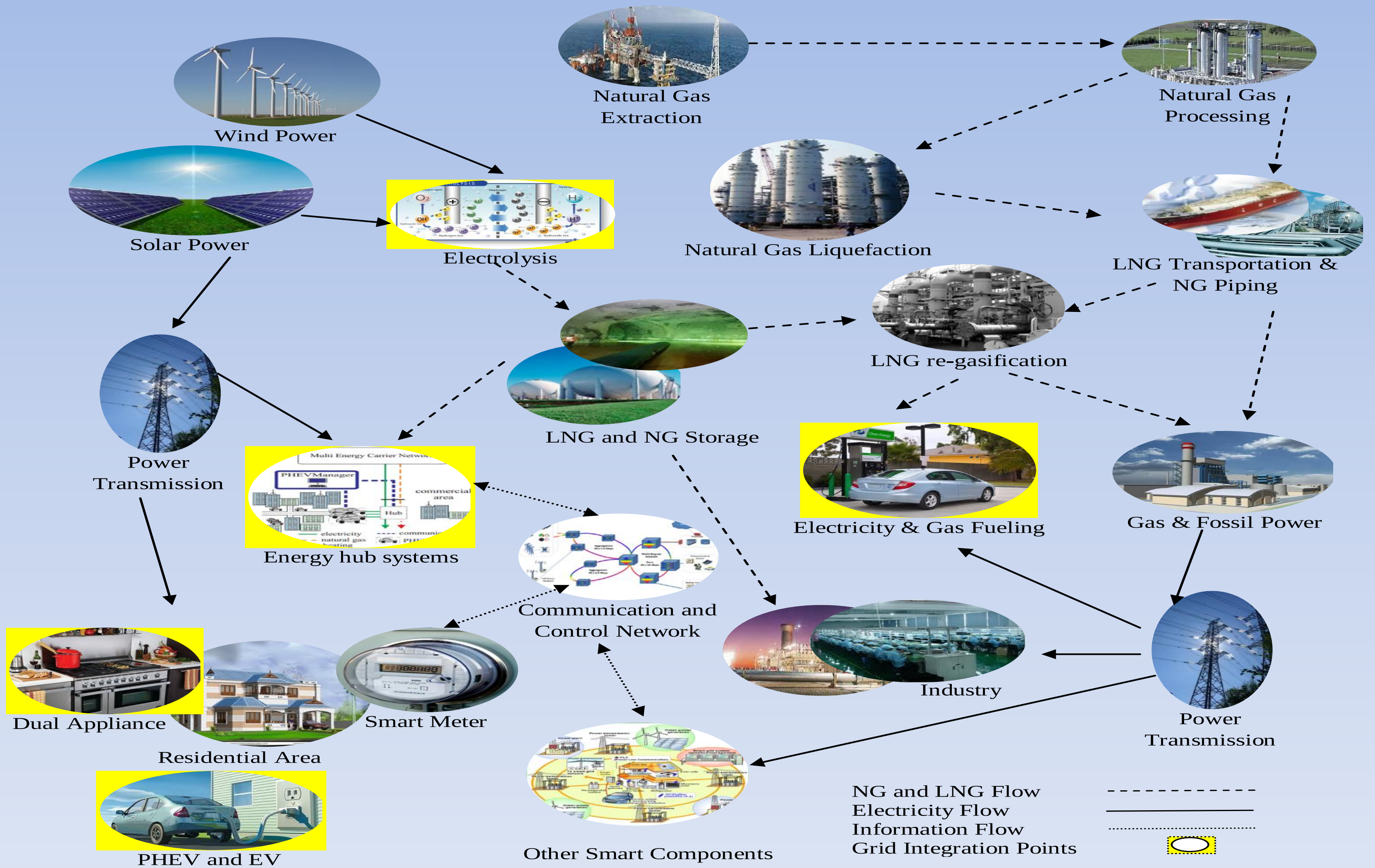


- German Example

Dual Fuel Appliances



Proposed Energy Grid Architecture



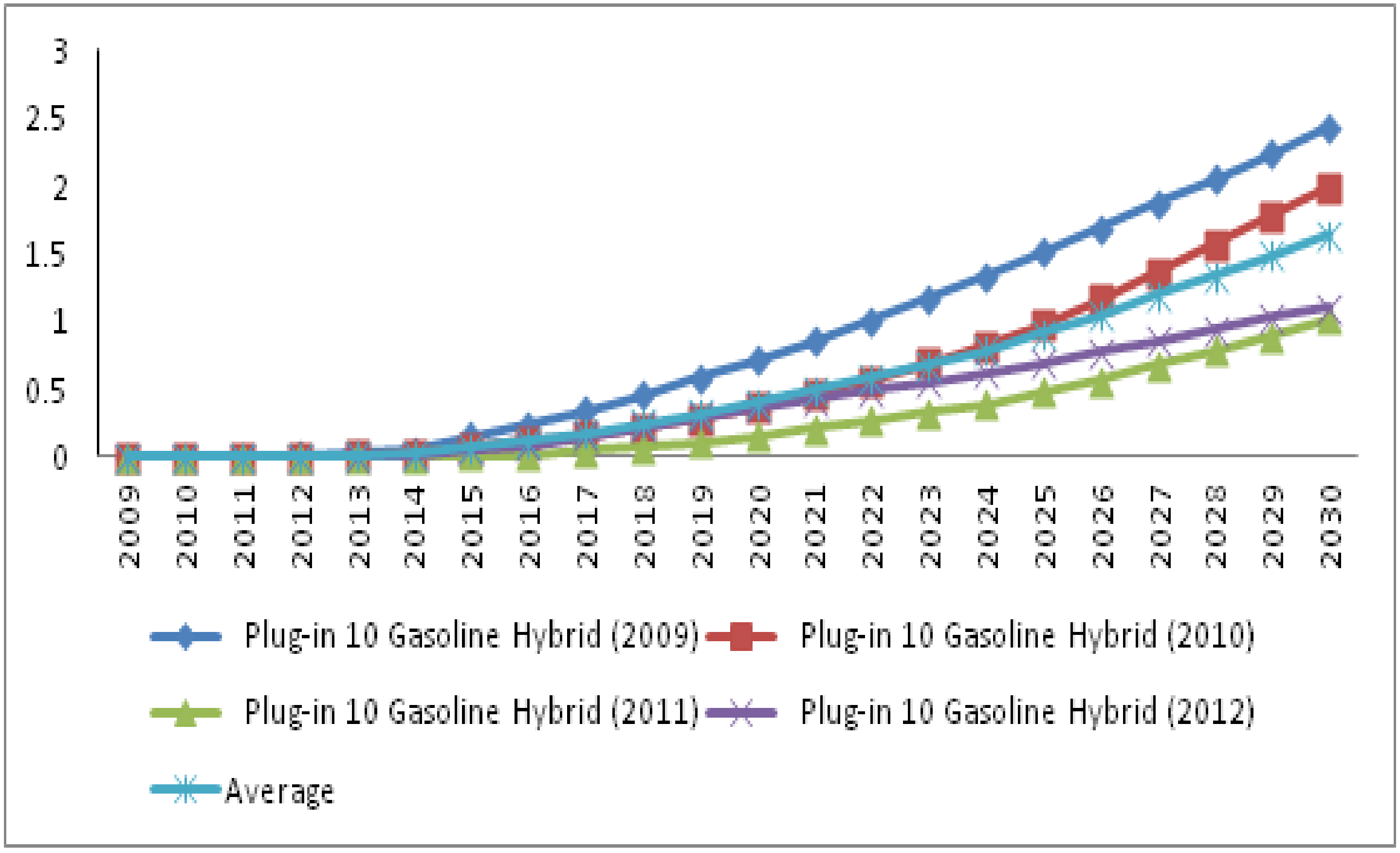
Grid Performance Indicators

- Target grid is operated based on performance optimization.
- The performance is defined locally for each model block as well as for the overall grid architecture by defining key performance indicators (KPI's) for each grid model element.
- The definition of KPI's will enable the optimization of overall grid performance based on desired ranking of KPI's.
- Typical KPI's are defined based on the ratio of outputs versus inputs.
- The KPI's are formulated using model elements based on physical, dynamic, and control model elements to allow dynamic estimation of the grid in real time and with respect to grid operation and control.

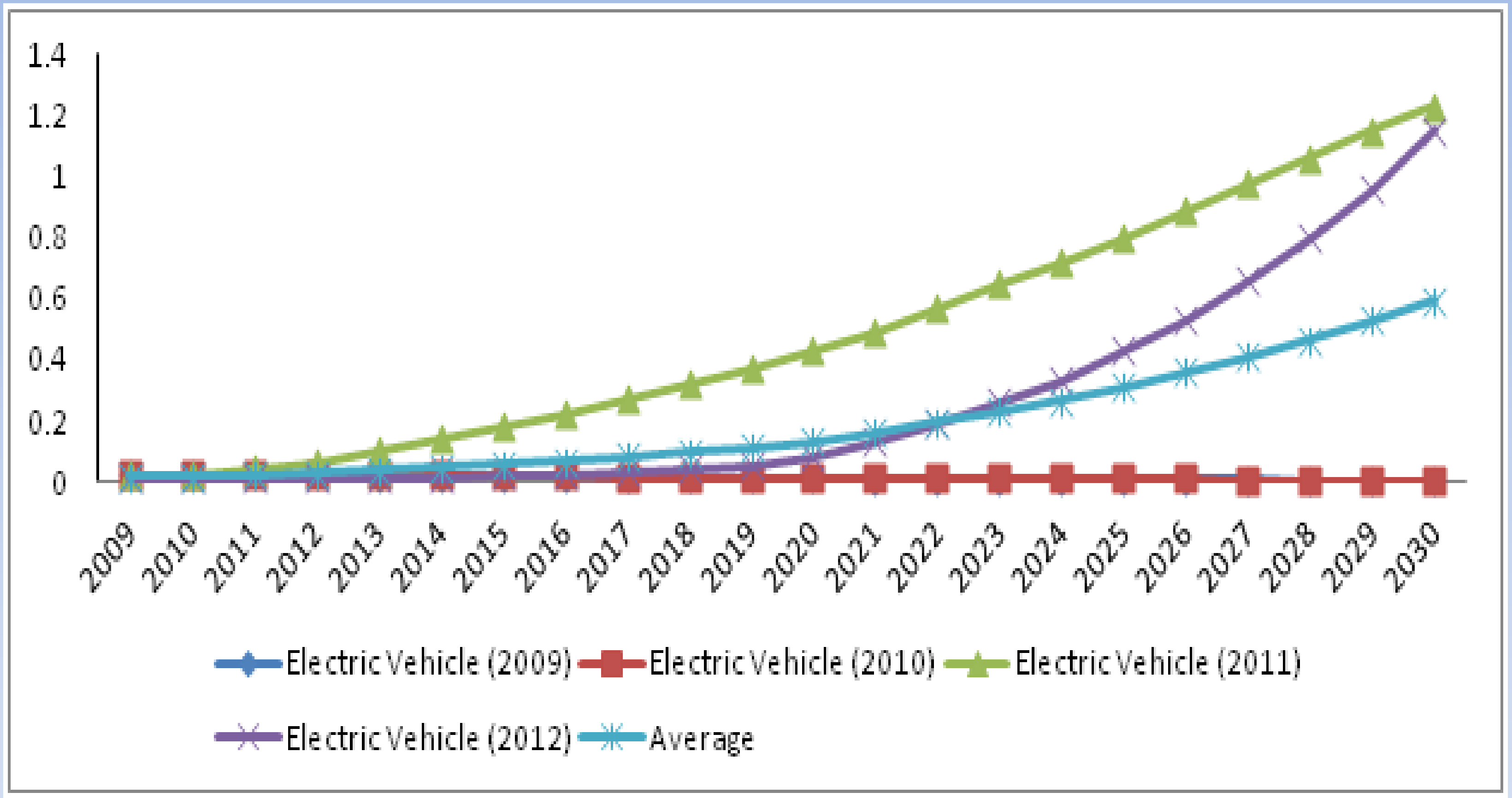
Smart Grid Infrastructure Model

- Modeling energy smart grid is a challenging task due to the complications of the relationship between its components.
- One of those challenges is controlling charging electric vehicles during peak periods that may diminish their role as a load shifting agent.
- The time of use control method was tested through cost benefit analysis which proved to be worthwhile under all of the cases they tested .

Forecasting Model Problems



Forecasting Model Problems



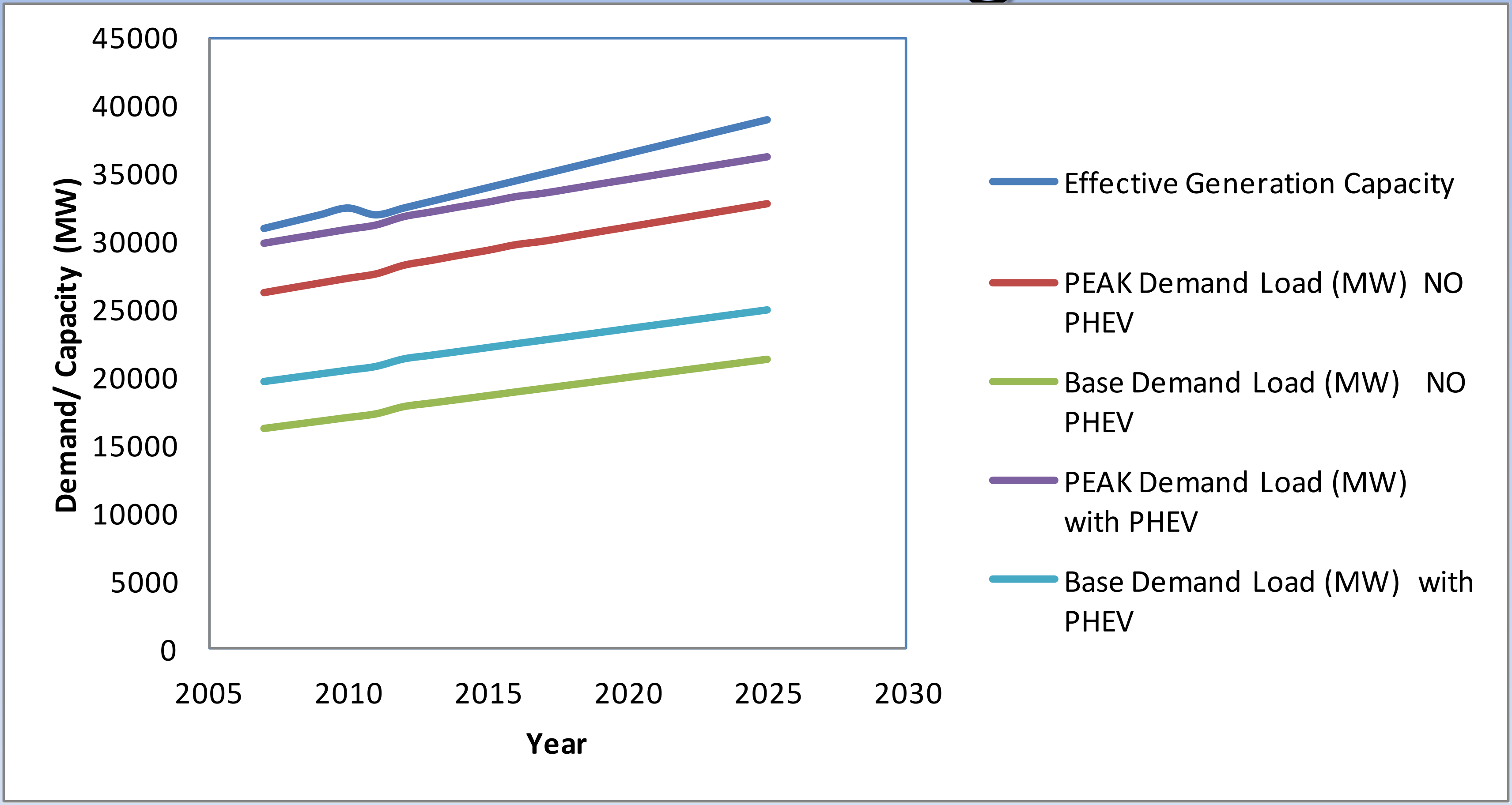
Infrastructure forecasting model

- The model idea is to improve the forecasting quality of long term models through the following sequence:
- Build a number of long -term and mid-term forecasting models using different modeling assumptions and experiences, viz., using the diffusion rate of EV in the market as high, medium, and low.
- Build strategic scenarios based on those model, viz., using ‘what-if’ strategies.
- Use midterm models to test the changes in market demands and re-adjusting plans and taking corrective action.

Mixed Long Term and Midterm Forecasting

- The Mixed Long term and Midterm Forecasting Model (LMFM) predicts the penetration rate of different vehicles to the future market and their associated infrastructure.
- The model provides accurate forecasting in the complex environment which has different demand factors.
- This hybrid statistical genetic-based demand forecasting expert system was first developed by Sayed et al, and tested for forecasting food industry supply chains.
- Using this forecasting model the statistical methods and Genetic algorithms combined with the baseline forecast is expected to give more accurate forecasts.
- The model will be compared to available statistical Long term and Midterm forecasting models and tested using the data of PHEV volumes in Japan, LPG vehicles and number of LPG fuelling stations in South Korea and PHEV penetration in Ontario.

Mixed Long Term and Midterm Forecasting



Conclusions

- To fully integrate and deploy the gas grid and other components into the smart grid are required
- A proper combination between electricity, gas delivery infrastructure, modern telecommunications and sensing technology are needed.
- This research has presented a proposal for some possible methods to link gas grid with smart power grid e.g. energy hub systems, power to gas, and dual fuel appliances, in one model.
- Using possible architectures, the key performance indicators (KPI's) for grid models will be defined to enable the optimization of the overall grid performance.
- A general explanation about the forecasting models and their common features and requirements were also presented.
- A mixed forecasting model that uses mid-term forecasts to re-align the long term forecasts was discussed

Future Work

- Various energy grid infrastructure scenarios need to be investigated to estimate their basic infrastructure estimation based on various types of forecasting models and their comparison to LMFM model including uncertainty factors.