Demand Response Modeling Development for Urban Customers in a Smart Grid Electricity Market

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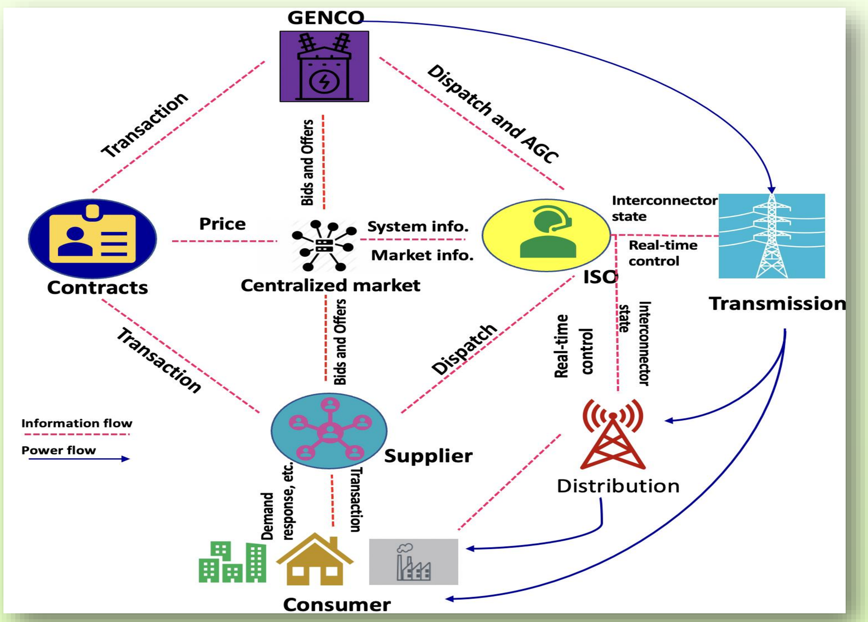
1. Introduction



Why Demand Response?

- ❑ Electricity price reduction
- ❑ Improving loads with demand flexibility
- ❑ Enhancing security through the interaction between customers and the market

Maintaining the profits of the utility sector and the customer and balancing their benefits are the most critical factors for DRPs.

- Aversion of the CUs to the risk of choosing the DPRS
- Dynamic price elasticity of demand

2. Methodology

Maximizing the welfare of the price responsive customers (CUs) using the concept of the expected utility function.

✓ Maximize: $W_{CU}=\sum_{h=1}^{H}\lambda_h U_h - E_h p_h$

Subject to :

- demand : $E_h = E_h^0\left[1+\varepsilon_{i,i}\frac{p_h-p_h^0}{p_h^0}+\sum_{h=1}^{24}\varepsilon_{i,j}\frac{p_h-p_h^0}{p_h^0}\right]$
- Price : $p_{h,Min} \le p_h \le p_{h,Max}$

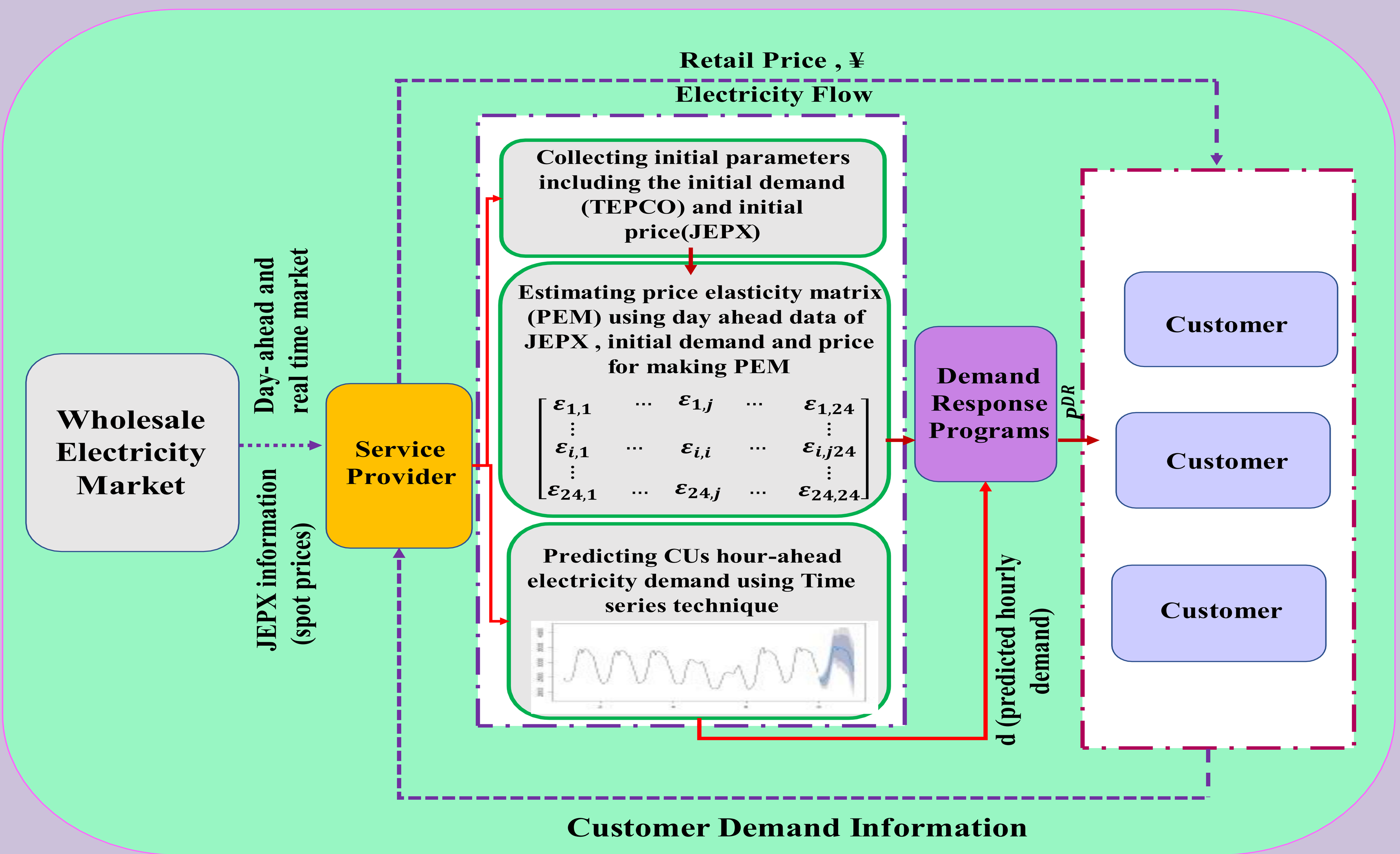
✓ Expected Utility Function:

$U_H = 1 - e^{-Rf(E)}e^{-R\mu+\frac{R^2\sigma^2}{2}}$

λ_h: multiplier used to calibrate
U_h : customer utility
E_h : electricity demand
p_h : electricity price
$f(E)$: the function of the electricity consumption
R: risk aversion coefficient
σ : variance
μ: mean

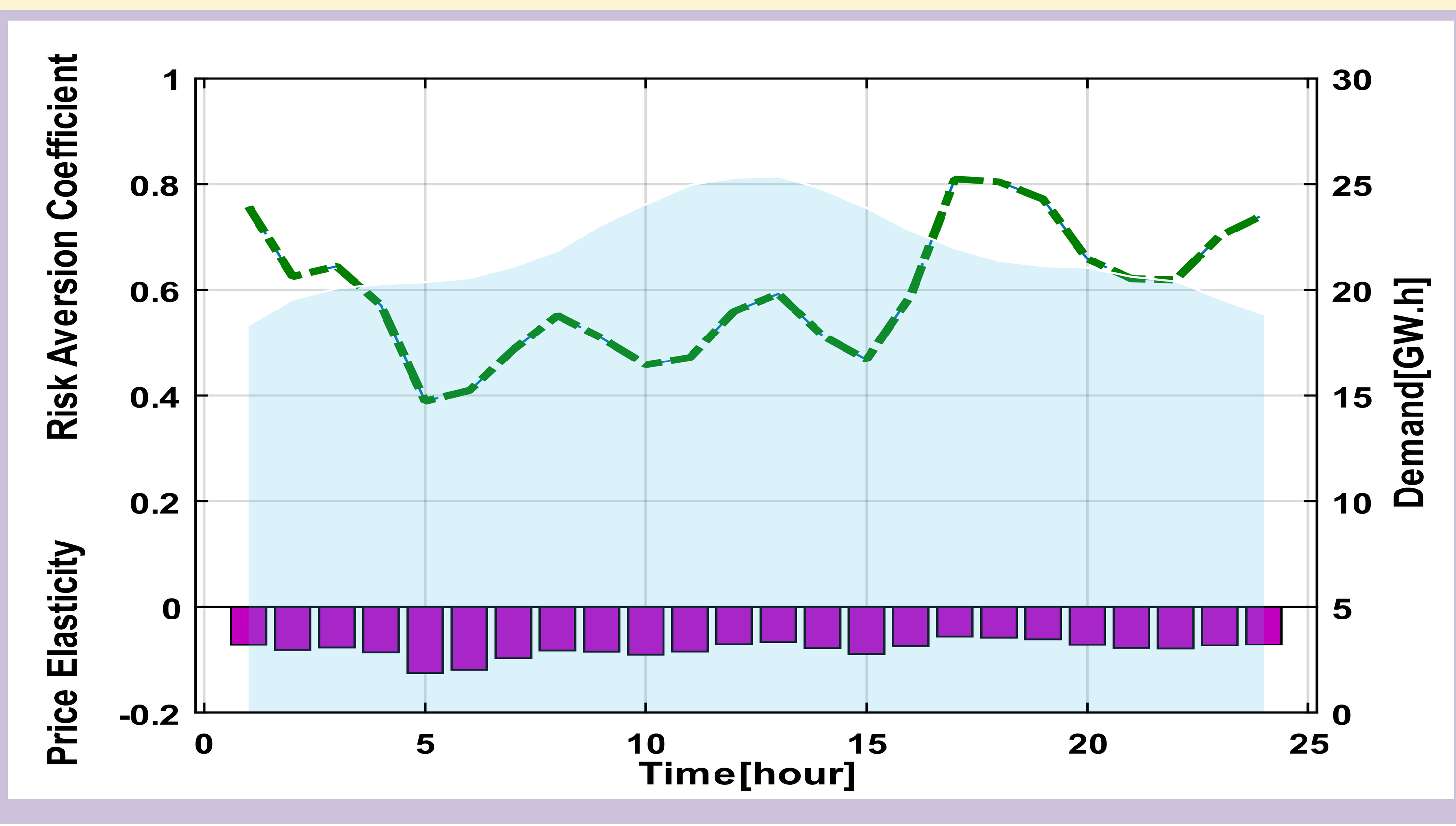
1. Time series forecasting of the day-ahead hourly electricity demand using the Seasonal Autoregressive Integrated Moving Average (SARIMA) model .
2. Estimation hourly price elasticity of the electricity demand (panel data analysis technique).
3. Using the estimated price elasticities to establish the elasticity matrix of demand (PEMD).
4. Analyzing the CUs' behaviors with different demand response strategies in the JEPX market in Tokyo.

❖ The schematic of the customer-based demand response model in the wholesale market in this study



3. Results and Discussion

❖ The variation of the hourly price elasticity of demand and the risk aversion coefficient with hourly average electricity demand in the JEPX market

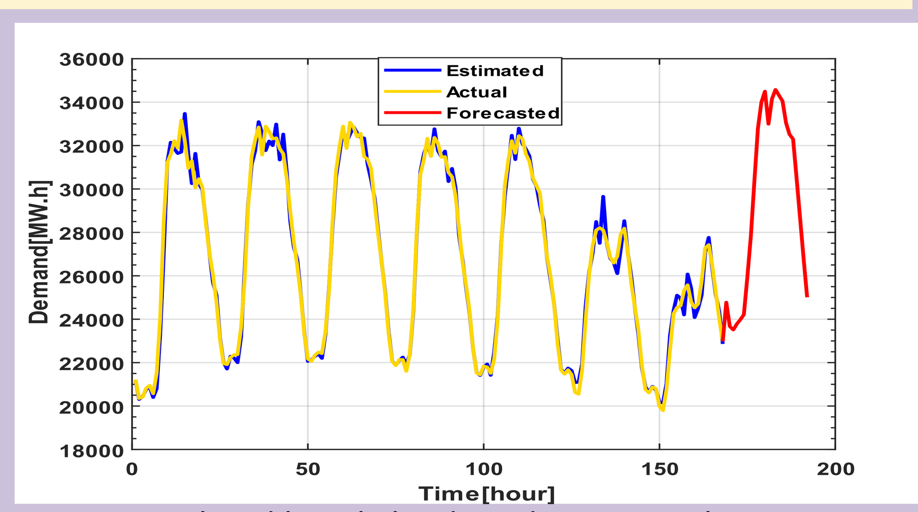


❖ Structure of the time series forecasting model in this study

Model Identification
Multi-seasonal Time series data
- Data preparation
- Seasonal decomposition to daily Seseonality
- Model selection (Testing stationary)

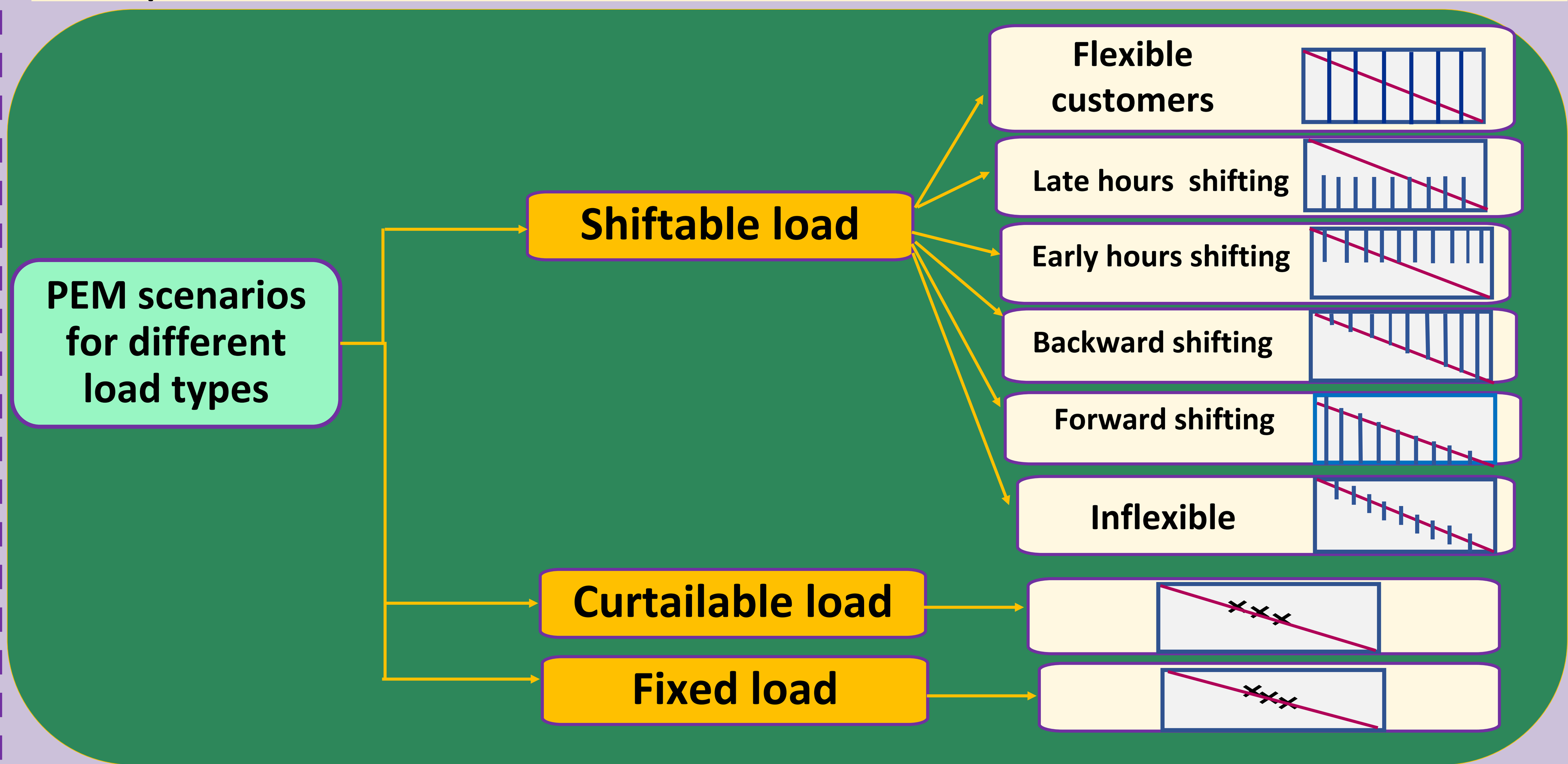
Model Estimation & Testing
- Identify potential SARIMA models
- Select best model using suitable criterion
- Check ACF/PACF of residuals …. White noise
- Testing the distribution of errors, using Box-Ljung

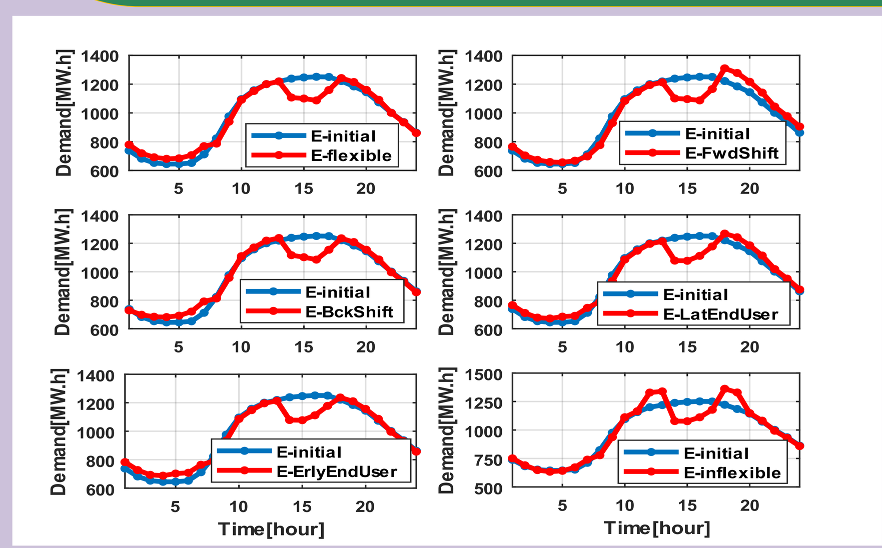
Model Application
- Use selected model to forecast



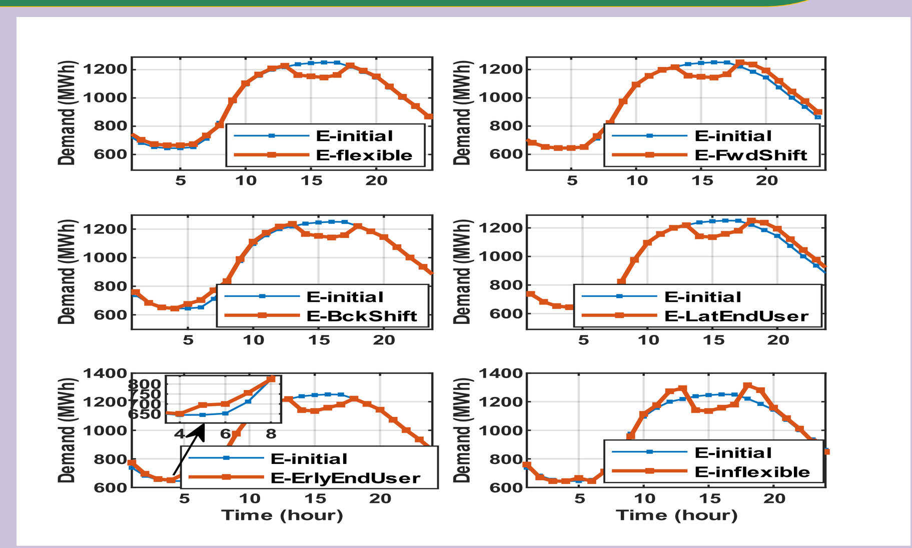
Day-ahead hourly load prediction in Tokyo
(First day of June 2020)

❖ Applying TOU and RTP with different PEMs to the shiftable loads .It can be observed that, the flexible CUs reschedule their demand throughout the day by shifting demand from peak to off-peak hours.



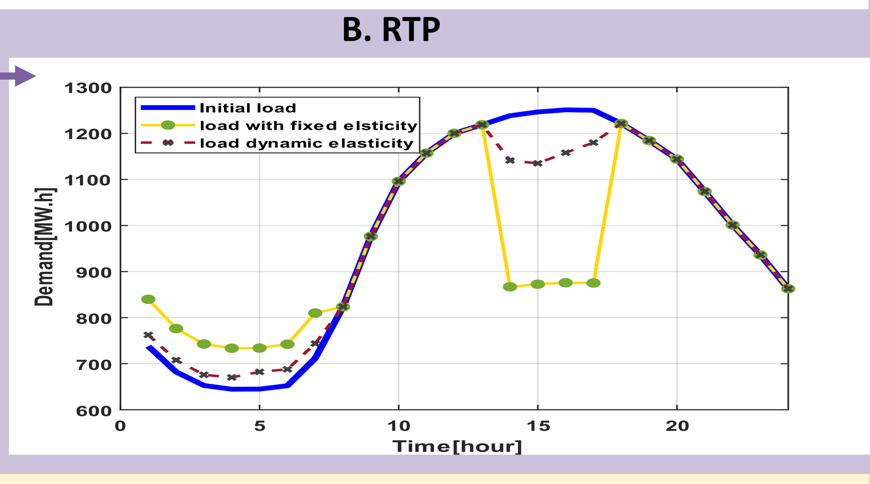


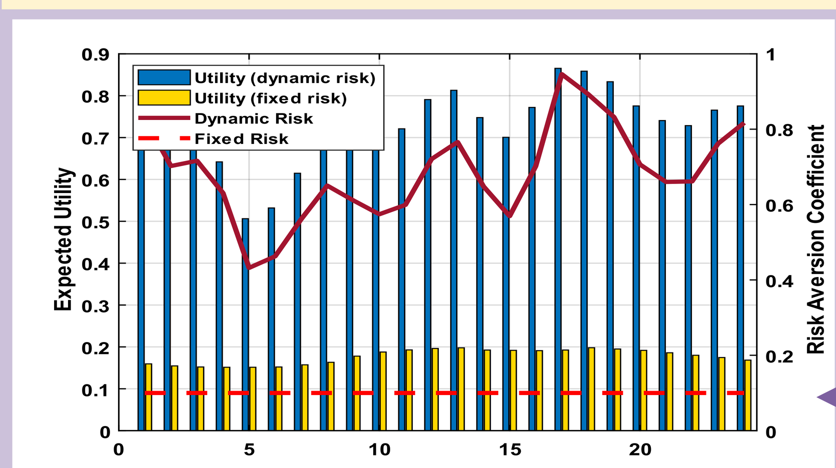
A. TOU



B. RTP

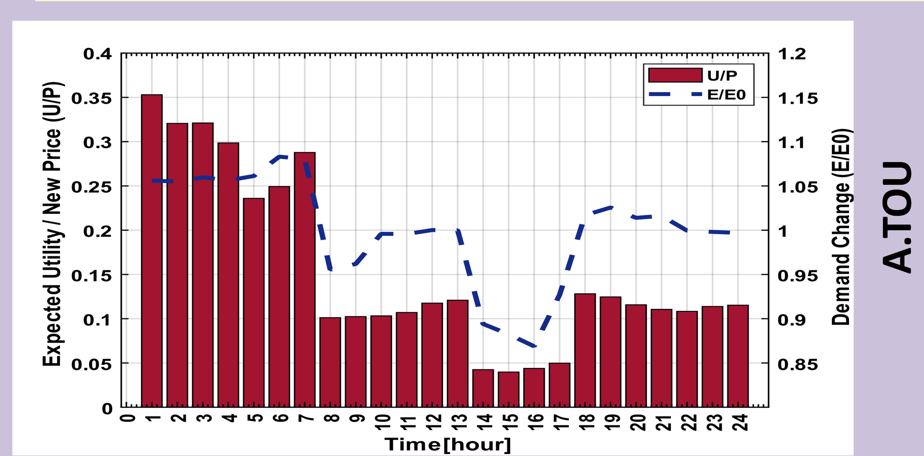
❖ Comparison the result of the dynamic self-elasticity estimated in this study and the the fixed self-elasticity in unrealistic anticipation of the peak reduction

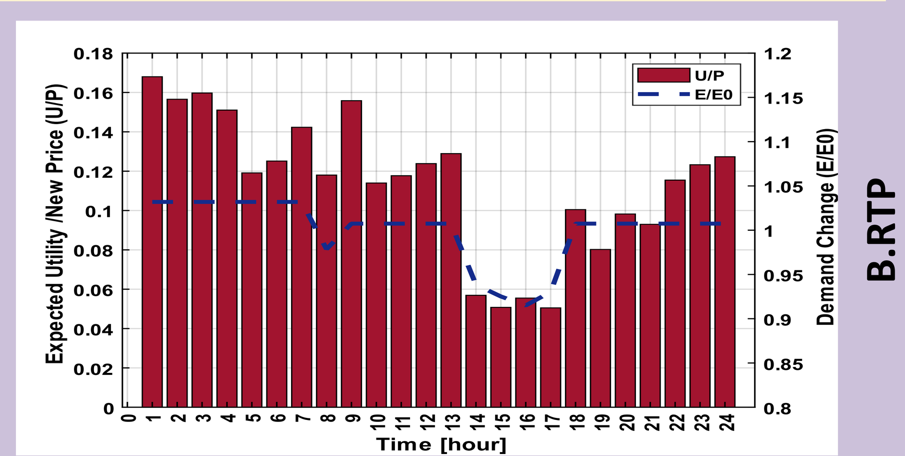




❖ The comparison between the expected utility of two different customers, including a risk-averse CU this study) and a risk-neutral CU (with a constant value of risk aversion coefficient

❖ the change in the CU's expected utility due to different consumption levels





4. Conclusion

A mathematical modeling approach was developed based on maximizing the CU's welfare by considering a price-responsive demand response system in the wholesale market in Japan .In order to precisely reflect the CUs' behavior in responding to the DRPs, the PEMD was developed based on identifying the hourly self-and cross-price elasticities of demand. An hourly day-ahead electricity demand model was developed using the time series forecasting method to predict an hour-ahead demand . From an economic viewpoint, the TOU is the best DPR, as the CU can save more electricity with the TOU program. However, from the customer's view, the CU is more satisfied with the price change in the RTP program as its expected utility is affected less by the price changes.

5. Future work

The next step of this study will focus on determining the optimal interaction between the service providers and customers through maximizing their profits from selling and buying electricity from a wholesale electricity market.