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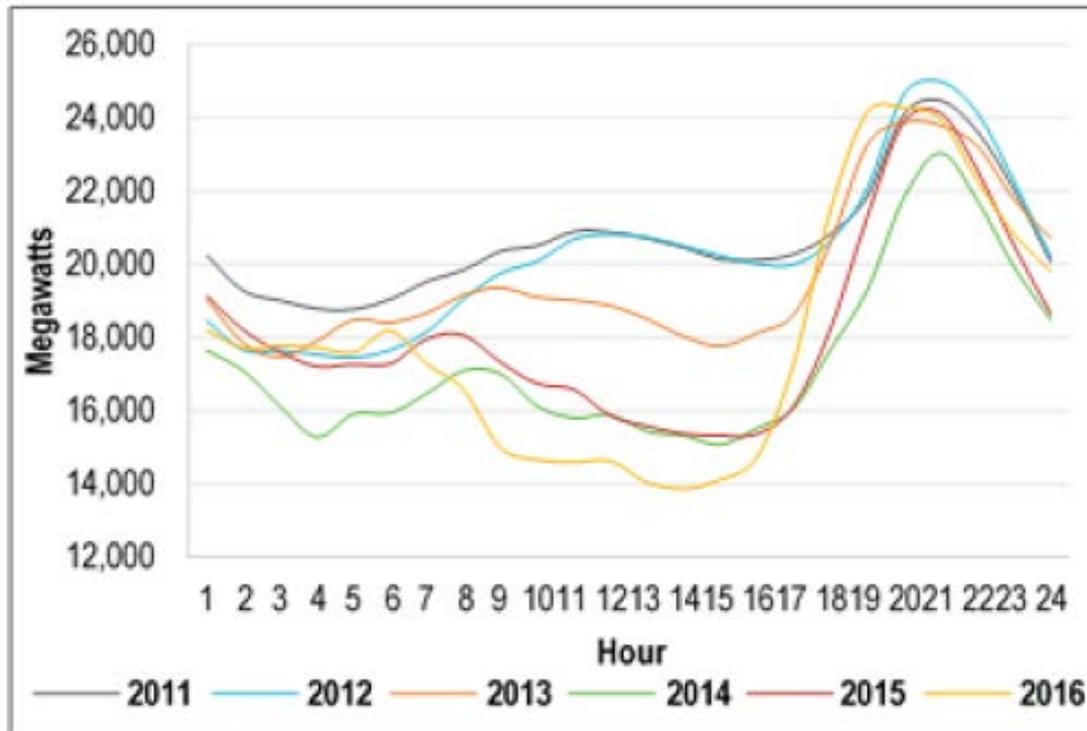
# Integration of retail and wholesale markets: Architectures and analysis

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# Motivation

**Question:** Can the introduction of demand-side flexibility into the market clearing process introduce instabilities in price, generation dispatch, etc.?

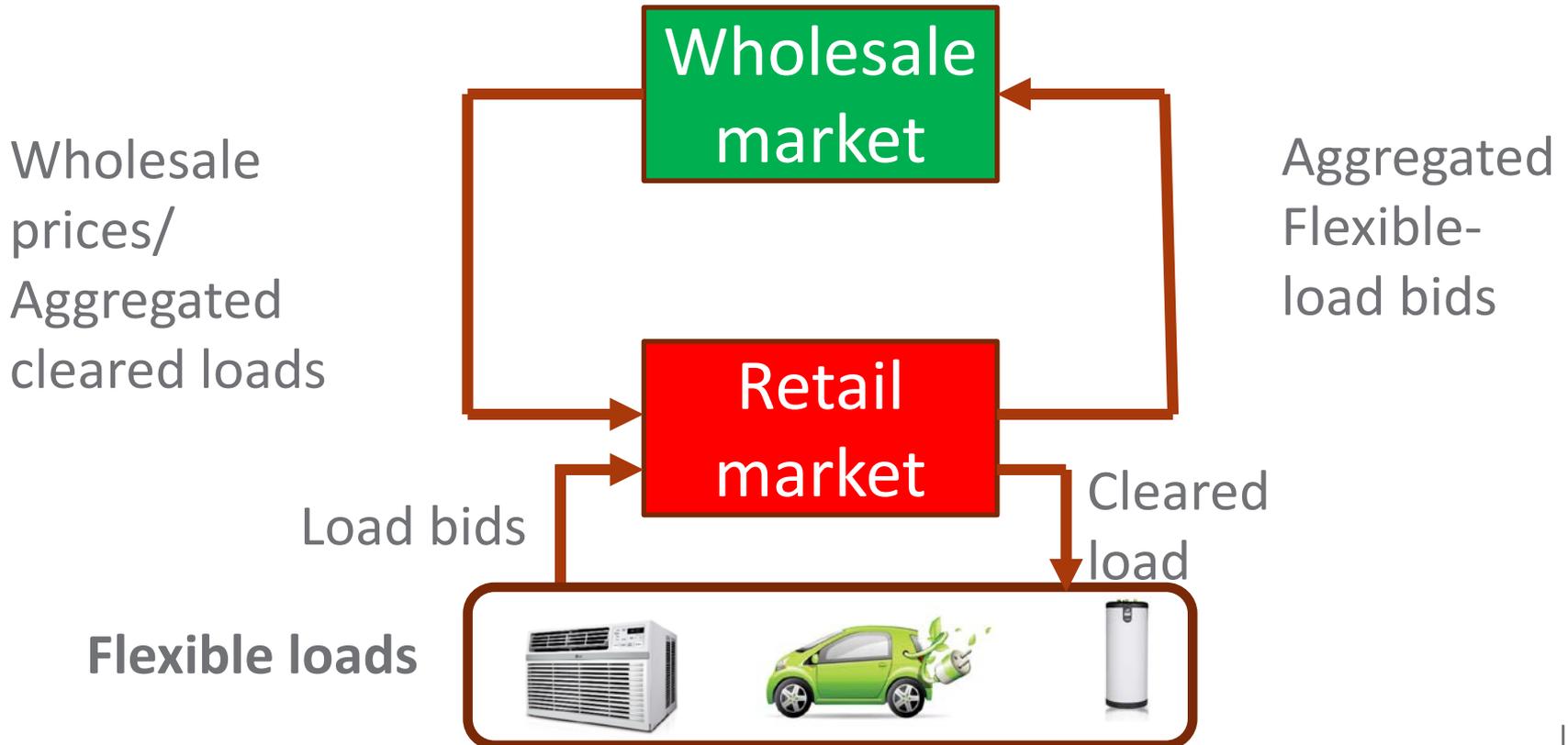
**Figure 2: Lowest March Daytime Net Load, 2011–2016**



# Two-layer market architecture

## Focus of our work:

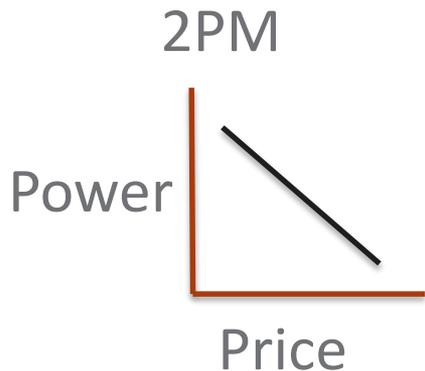
A theoretical framework to model the retail-wholesale interface in the two-layer market architecture and analyze stability of this interconnection



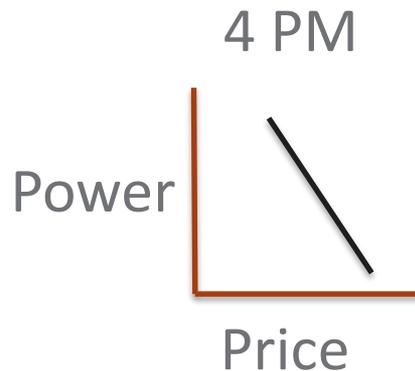
# Modeling load flexibility

## Load flexibility:

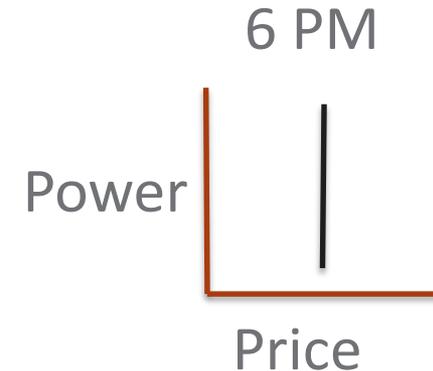
The flexibility of loads is characterized by its price elasticity. Price elasticity varies over time depending on the need of the flexible loads.



Time left to charge  
deadline >>  
Min. charge time



Time left to charge  
deadline >  
Min. charge time



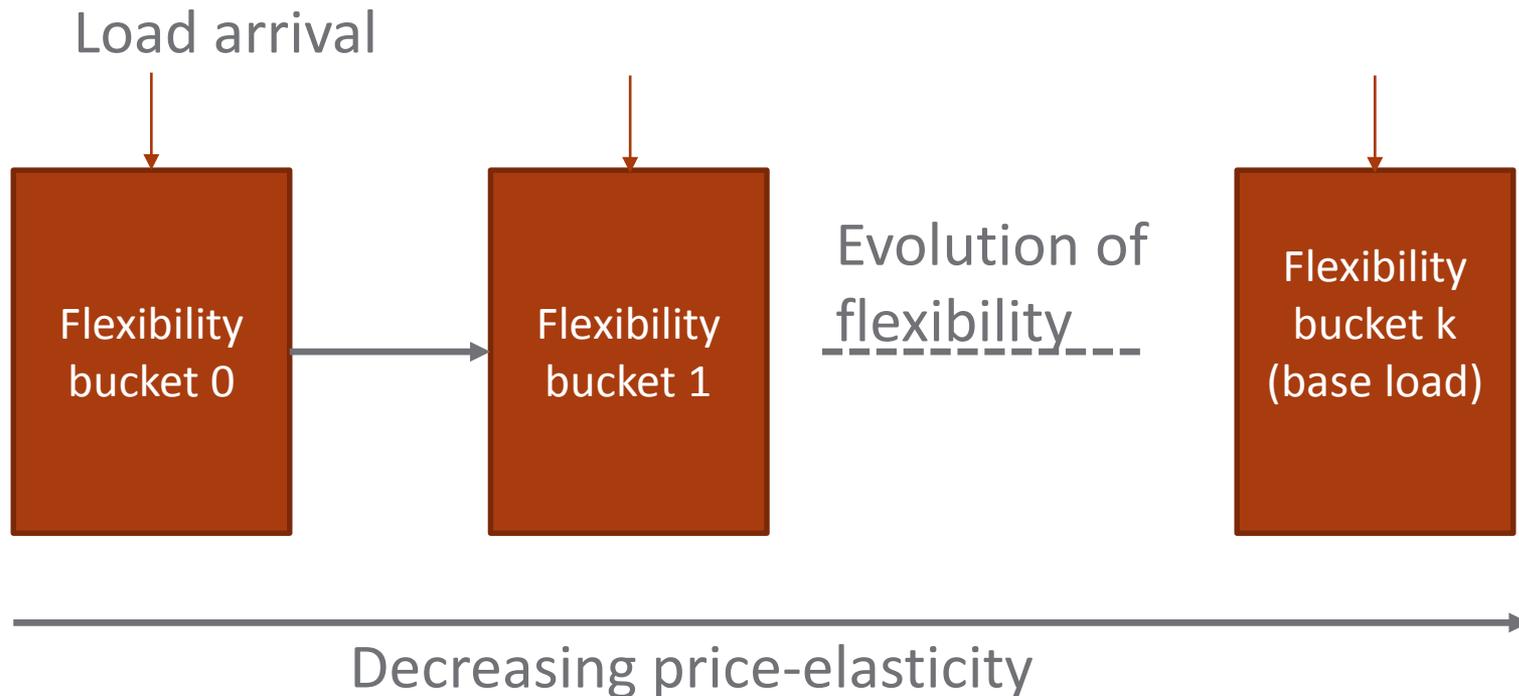
Time left to charge  
deadline =  
Min. charge time



# Modeling load flexibility at an aggregate level

## Retail market model:

Organize loads into a collection of “flexibility buckets” aggregating loads with similar price elasticity. As loads wait longer to be cleared, they transition into buckets with lower elasticity.

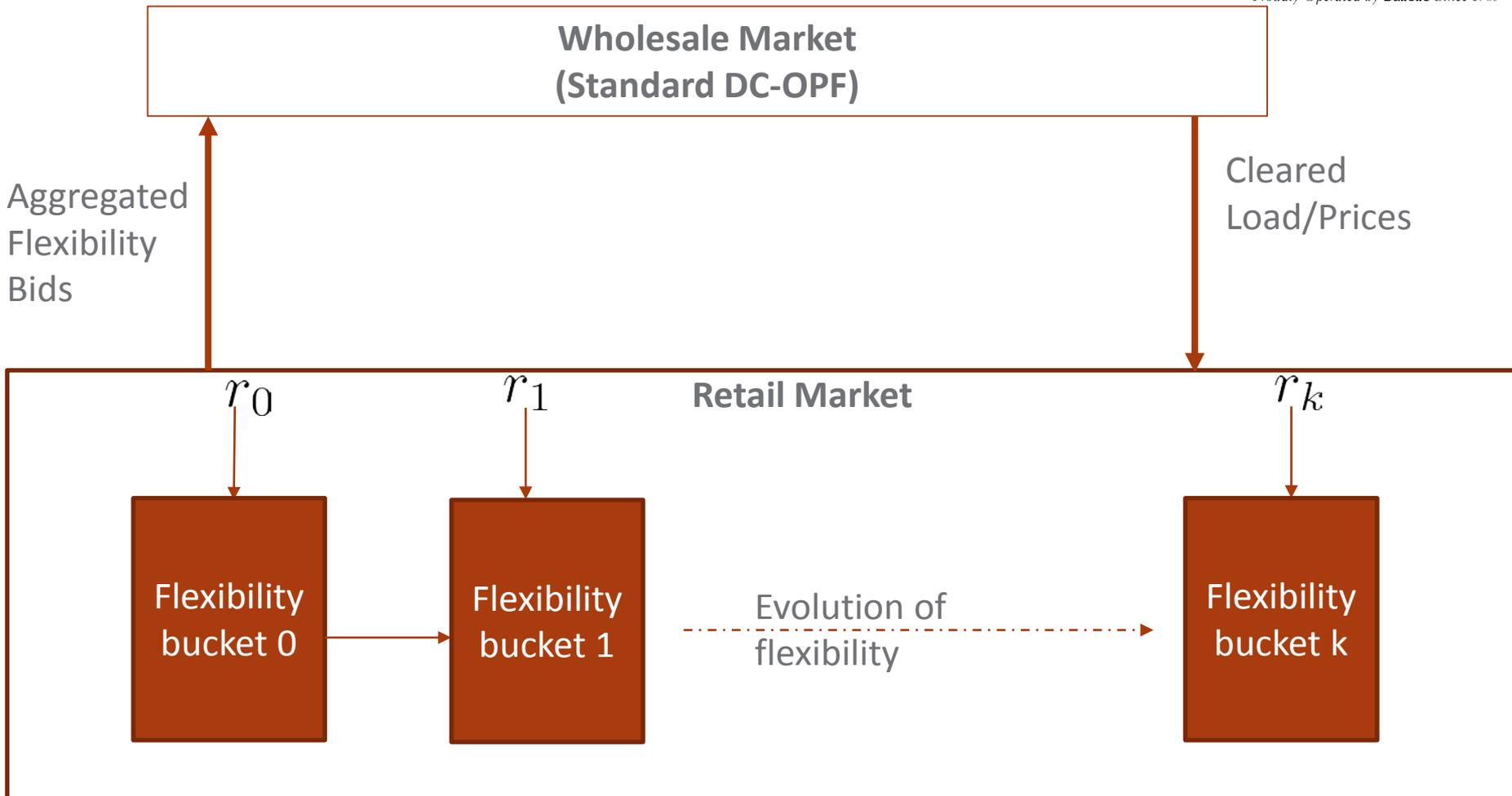


# A wholesale-retail dynamical system



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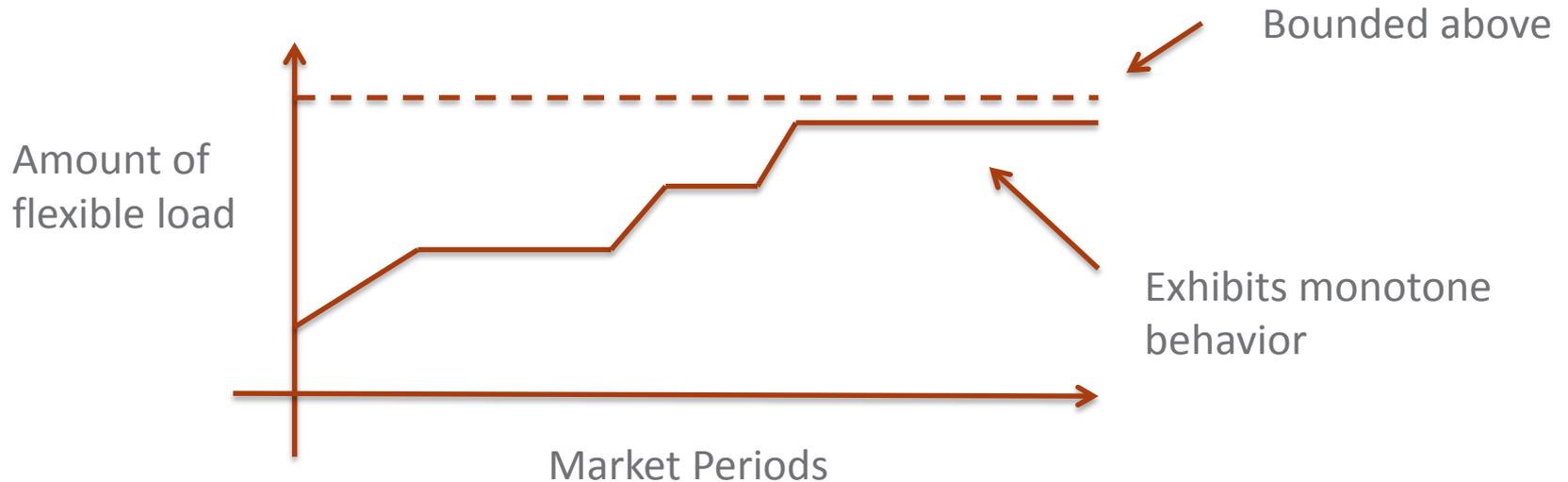


## Questions:

Is this system stable? Can we see oscillations in price or physical quantities? Can we see state growing unbounded?

# Main theoretical result and insight

**Theorem 1.** *The amount of load contained in each of the flexibility buckets converge monotonically (no oscillation) to steady state equilibrium values.*



## Conclusion:

Retail-wholesale dynamical system is stable (under the bucket model of retail markets) and does not exhibit volatile behavior.



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# Questions?

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# Thank You

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