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Workshop on Next Generation of Unit Commitment Models
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DEMAND-SIDE BIDDING

IN A COMPETITIVE ELECTRICITY MARKET

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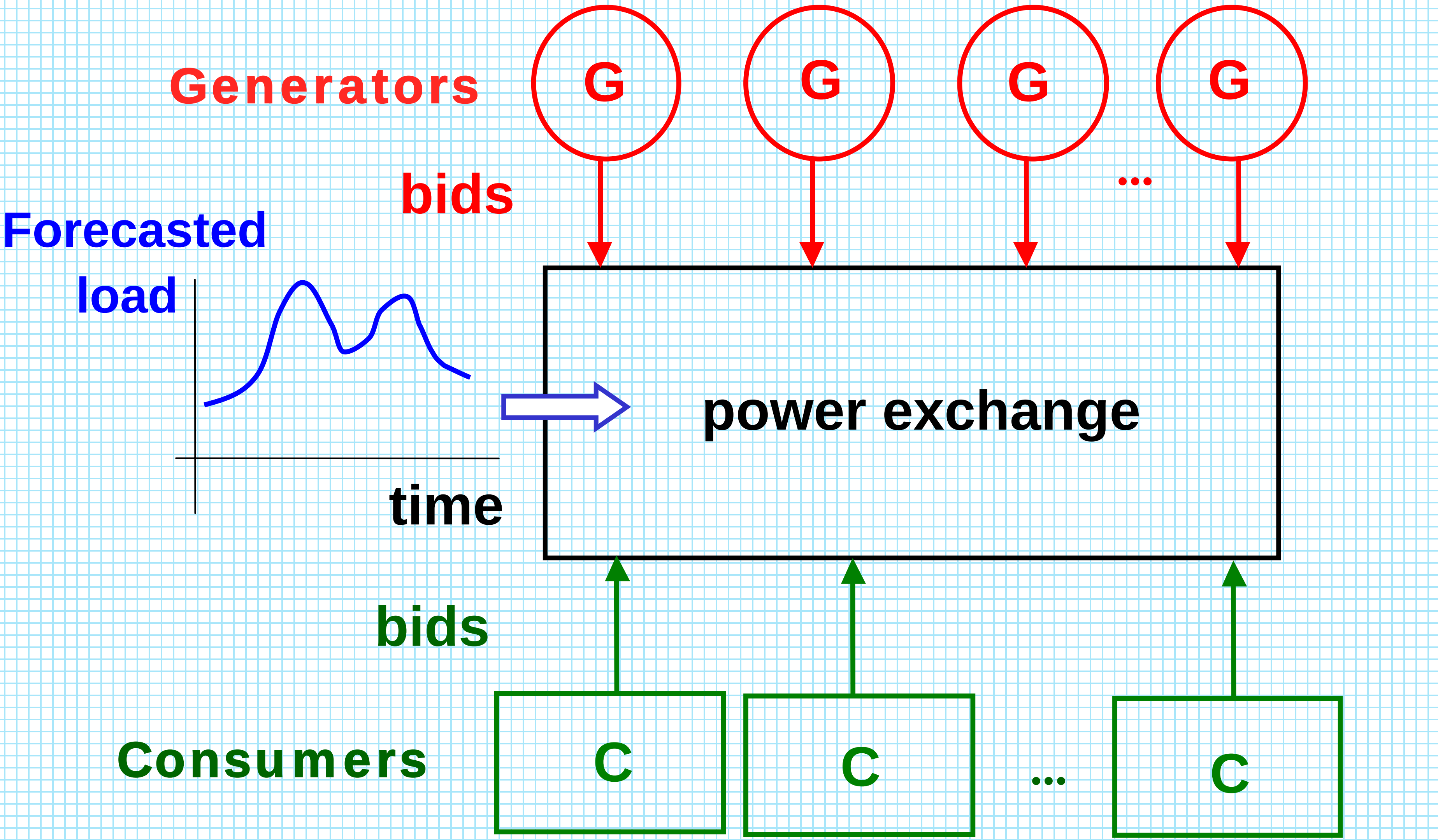
The presentation is based on work carried out as part of a collaborative project between
the University of Illinois at Urbana-Champaign (G. Gross)
and the University of Bologna (C. A. Nucci)

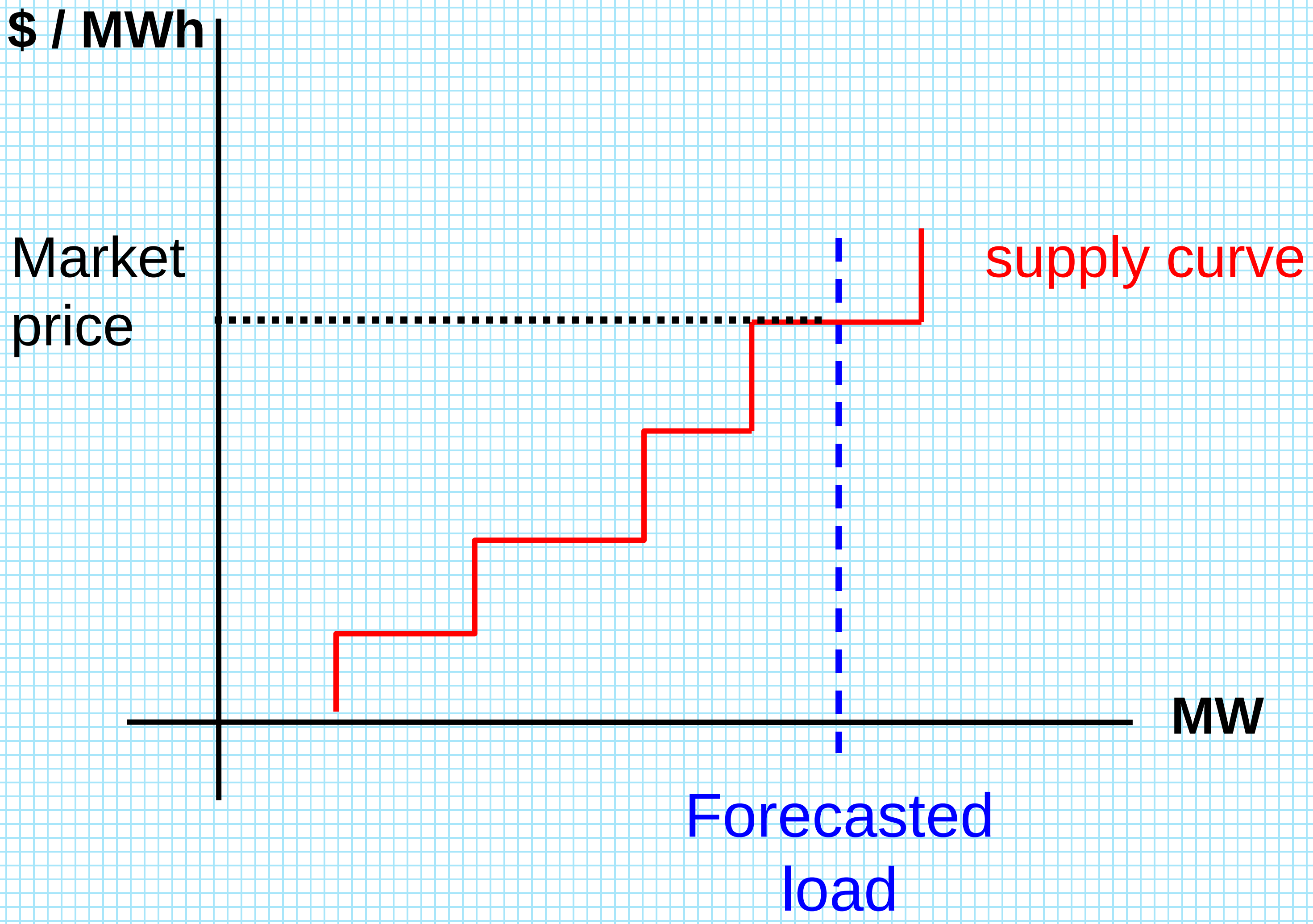
OUTLINE

- Generalized model for competitive power pool
- Characteristics of DSB incorporation
- Solution methodology
- Implementation aspects
- Numerical results
- Conclusions

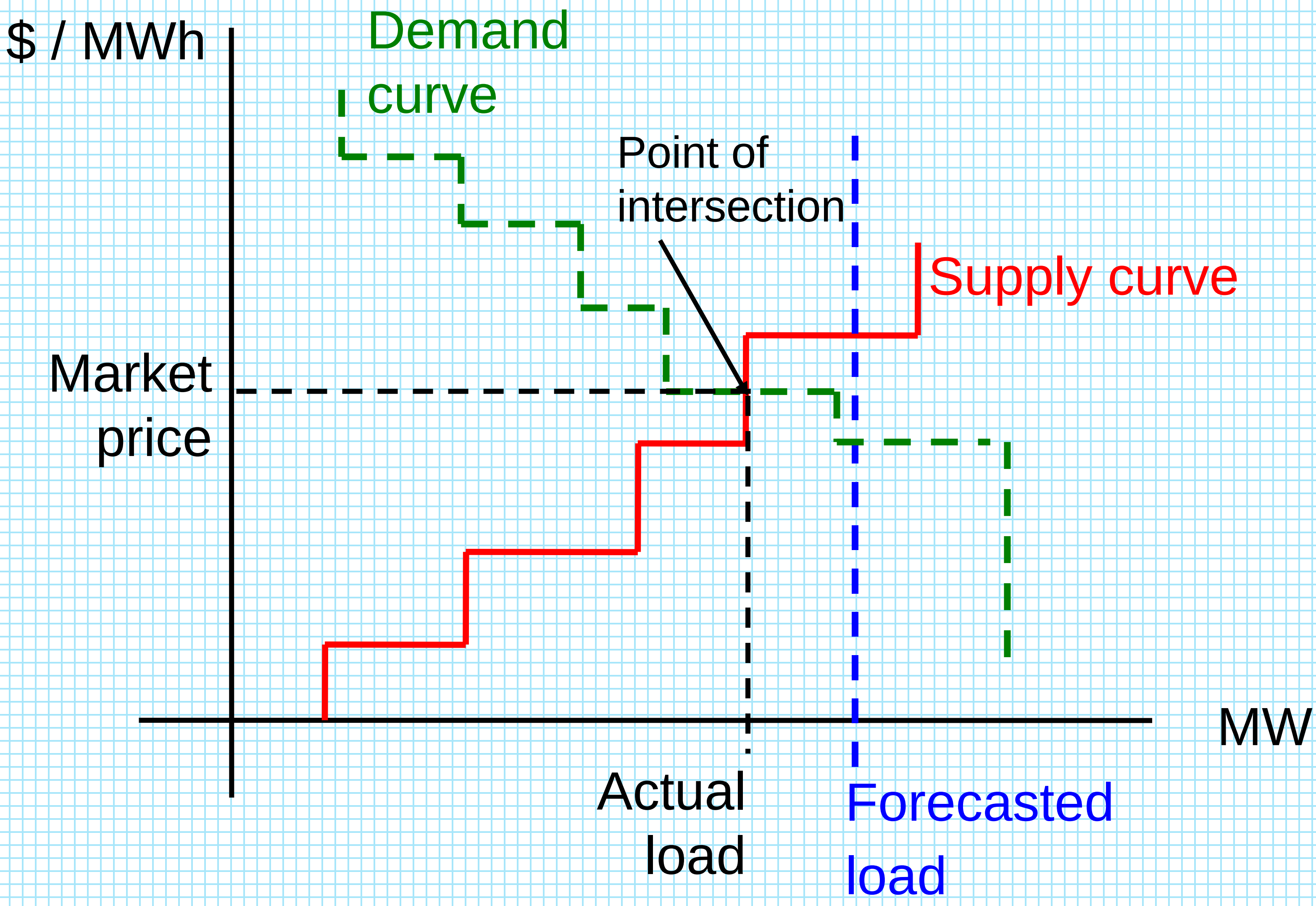
COMPETITIVE POWER POOL INCLUDING DEMAND-SIDE BIDDING



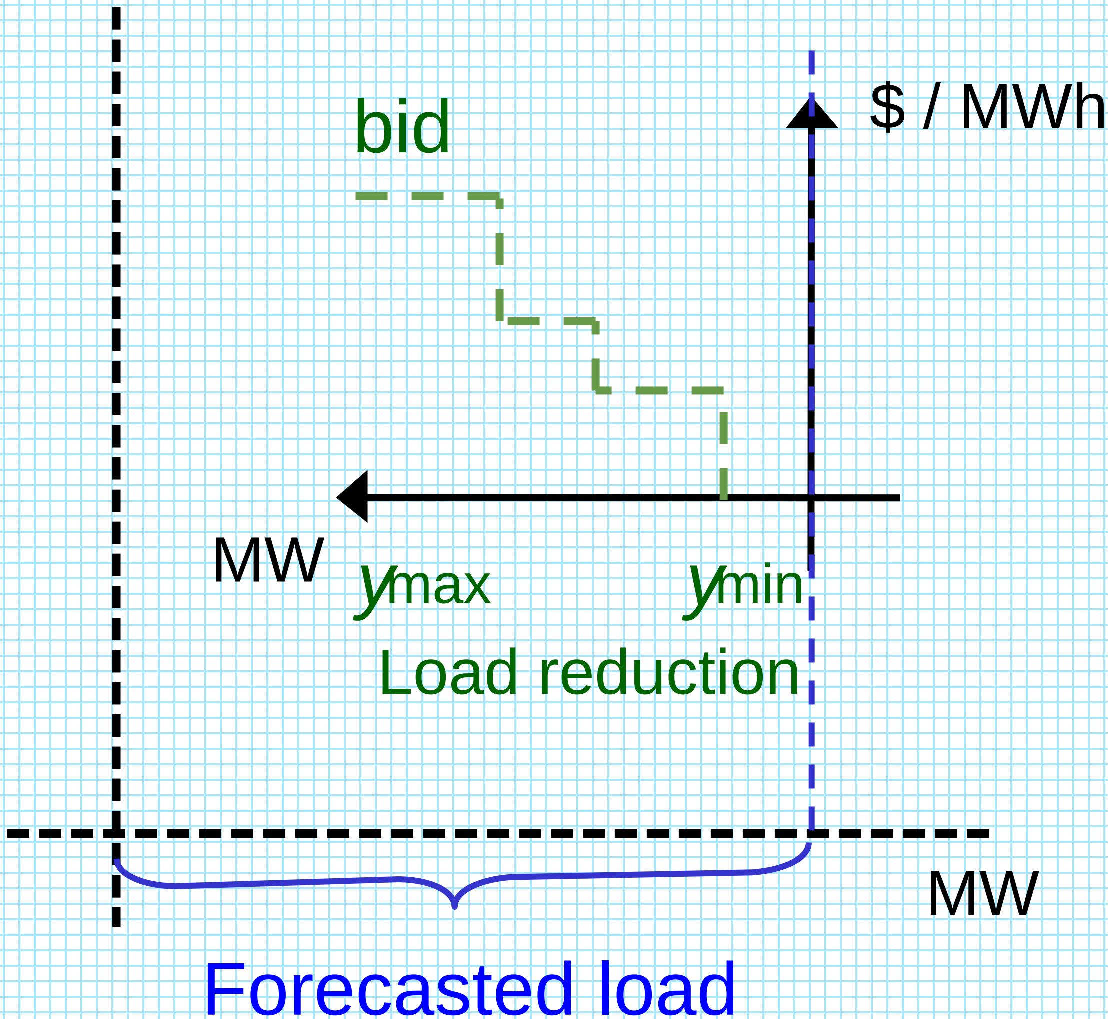
SUPPLY CURVE and price determination



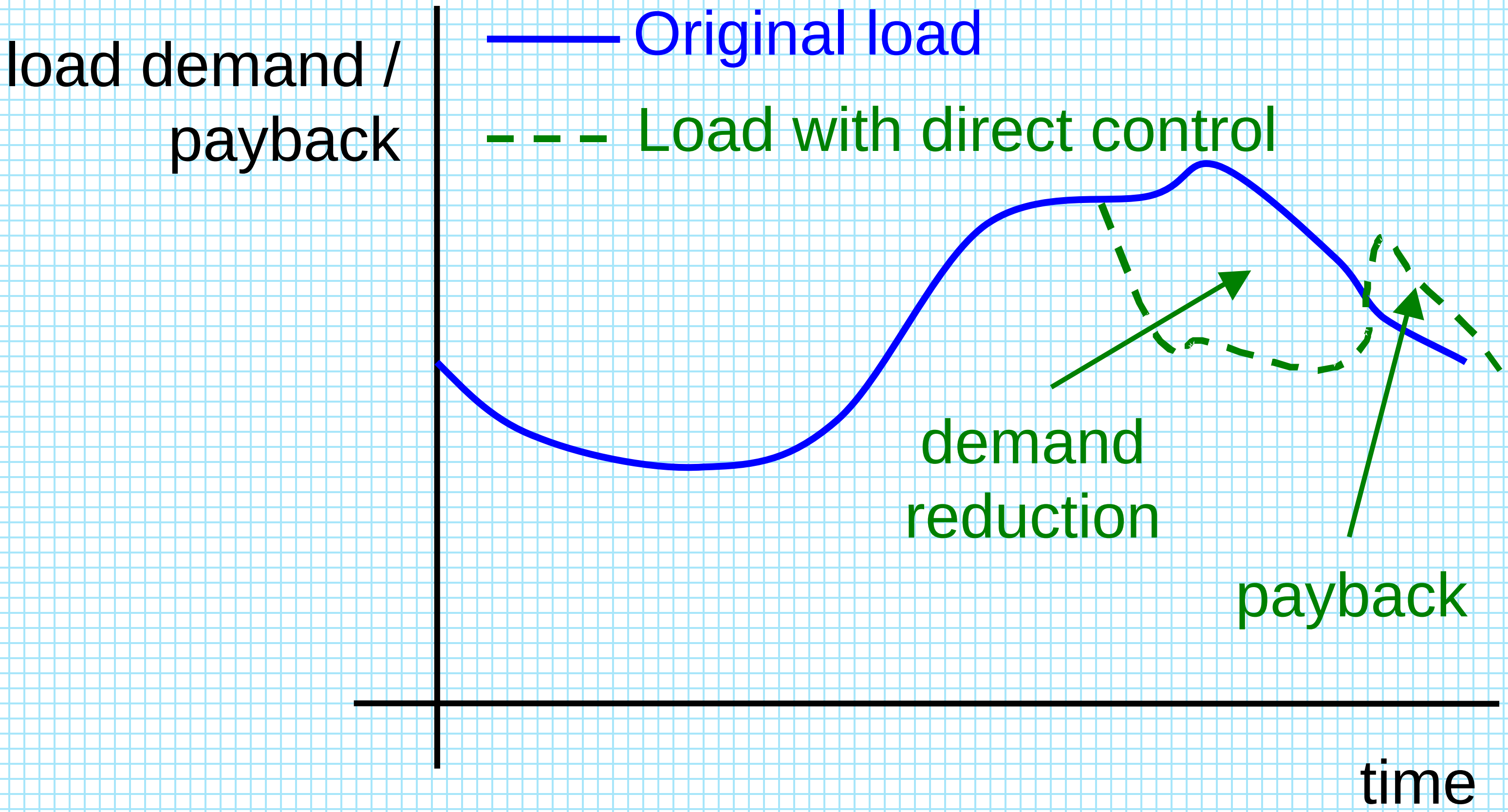
SUPPLY / DEMAND CURVES
and price determination



DEMAND-SIDE BIDDING



DIRECT LOAD CONTROL



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COMPETITIVE POWER POOL MODEL

Supply-side bid definition (of generator *i*)

control variables

- u_t zero-one decision variable at time *t*
  constraints: minimum up/down times
- p_t dispatched output at time *t*
  constraints: upper/lower limits

inputs

- b^f bid price function of MW provided
- b^s start-up price function

COMPETITIVE POWER POOL MODEL INCLUDING DEMAND SIDE BIDDING

Demand-side bid definition (of consumer *j*)

control variables

- w_t decision variable at time *t*
  constraints: min. times and control period
- y_t load reduction dispatched at time *t*
  constraints: upper/lower reduction limits

inputs

- b^f bid function of MW reduced
- b^s start-up function
- z_t^h ratio of the payback at time *t* due to a reduction at time *h*

PAYBACK

$$r_t = \sum_{h \in d} z_t^h \cdot y_h$$

for consumer *j*

where

r_t payback at time *t* due to a dispatched reduction at time *h* (y_h)

d reduction control period

Adapted from Strbac, Farmer and Cory, IEE Proc., 1996

OBJECTIVE FUNCTION

$$\min_{\underline{u},\,\underline{p},\,\underline{w},\,\underline{y}} \left\{ \begin{array}{l} \sum_{i=1}^{I}\sum_{t=1}^{T}\left[b_i^f\left(p_{i,t}\right)u_{i,t} + b_i^s(\tau)\left(1-u_{i,t-1}\right)u_{i,t}\right] \\ + \sum_{j=1}^{J}\sum_{t=1}^{T}\left[b_j^f\left(y_{j,t}\right)w_{j,t} + b_j^s(\tau)\left(1-w_{j,t-1}\right)w_{j,t}\right] \end{array} \right\}$$

DEMAND CONSTRAINT

$$D_t - \sum_{i=1}^{I} p_{i,t} \cdot u_{i,t} - \sum_{j=1}^{J} y_{j,t} \cdot w_{j,t}$$

$$+ \sum_{j=1}^{J} \sum_{h \in d} z_{j,t}^{h} \cdot y_{j,h} \cdot w_{j,h} \leq 0$$

$$t = 1 \cdots T$$

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DEMAND-SIDE BIDDING IN THE LR ALGORITHM

De-coupled dual problem (of consumer *j*)

$$\vartheta_j(\underline{\lambda}) = \min_{\underline{w},\,\underline{y}} \left\{ \sum_{t=1}^{T} \left[\begin{array}{l} b_j^f\left(y_{j,t}\right)\cdot w_{i,t} + b_j^s(t)\left(1 - w_{j,t-1}\right)\cdot w_{i,t} - \\ -\lambda_t\left(y_{j,t}\cdot w_{i,t} - \sum_{h\in d} z_{j,t}^h \cdot y_{j,h}\cdot w_{j,h} \right) \end{array} \right] \right\}$$

Ampl

Dual problem

SOFTWARE IMPLEMENTATION

Relaxed local problem solution: dynamic program

Additional term to the on-state Bellman values at period *t* for consumer *j*:

$$\sum_{h=1}^{T} \lambda_h \cdot z^t_{j,h} \cdot y_{j,t}$$

PD

Iteration

Development environment: AMPL
(a modeling language for mathematical programming)

Quadratic solver problem: MINOS

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Case study

Single bus system

10 thermoelectric generators
generator 9 non available in periods 20-42

forecasted load diagram in 48 periods

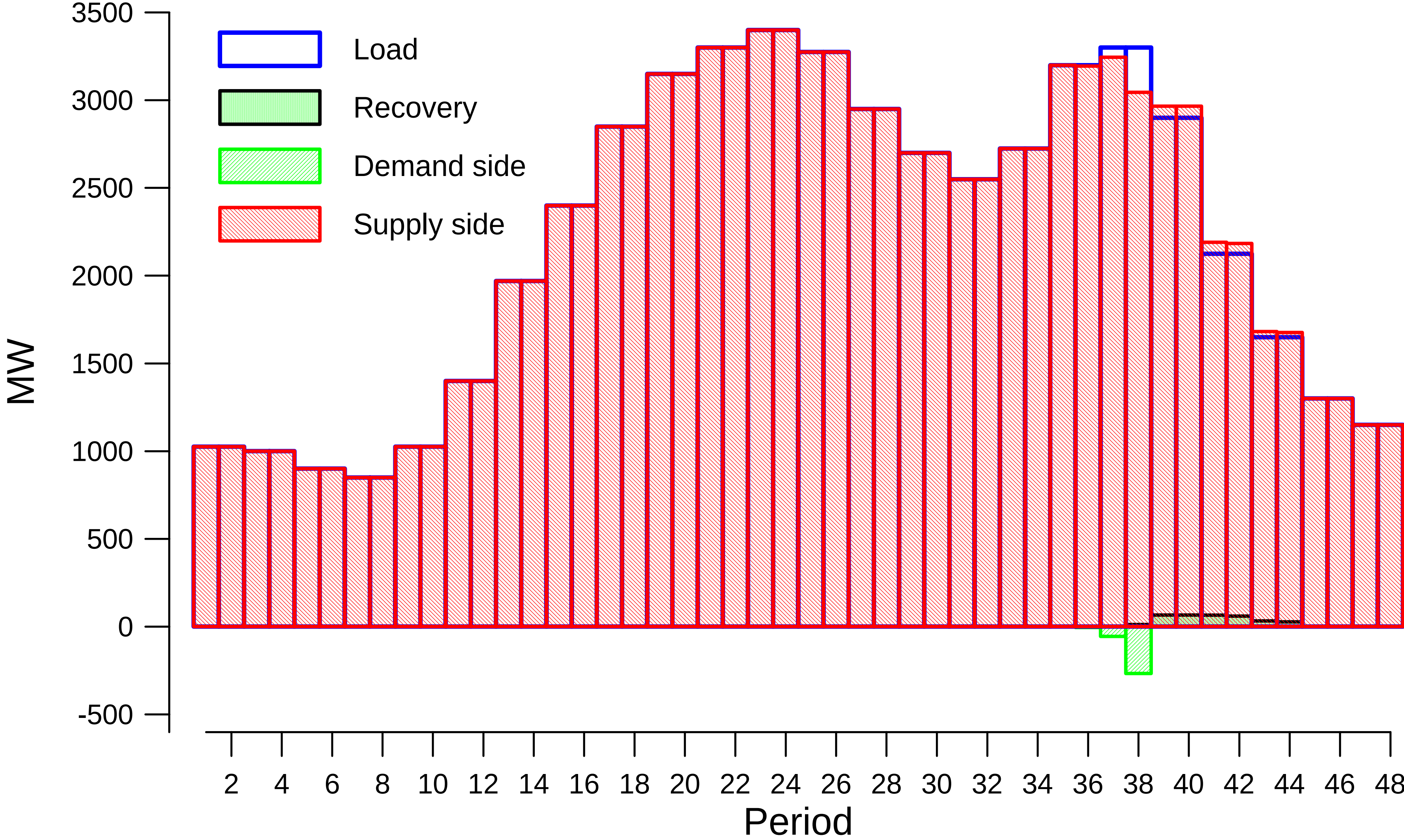
Adapted from Bard, OR 1988

2 demand side bidders

DSB	Control Period	Lower limit	Upper limit
dsb 1	19-28	5 MW	500 MW
dsb 2	33-42	5 MW	500 MW

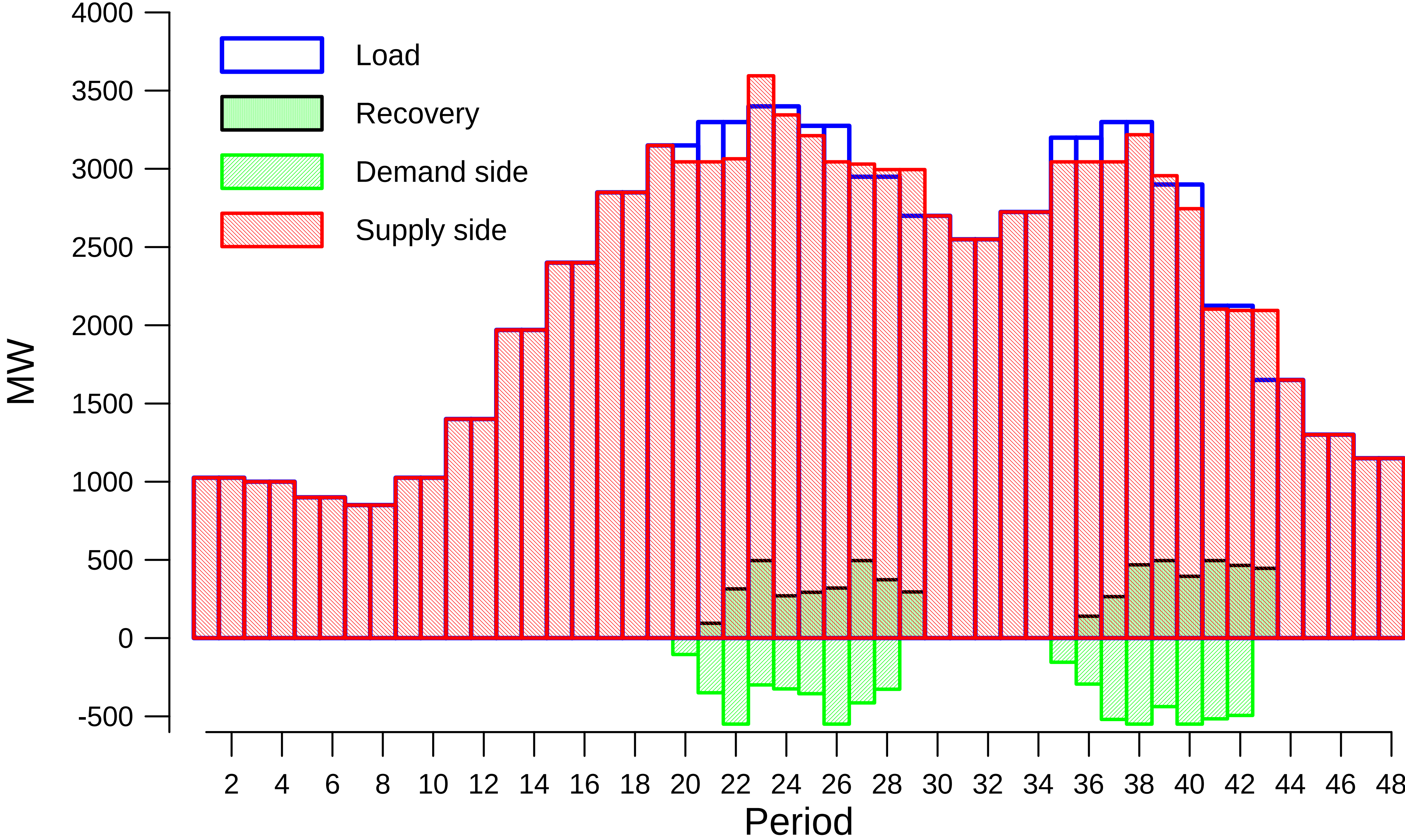
Case 1

payback pattern = 100% in the following 6 periods



Case 2

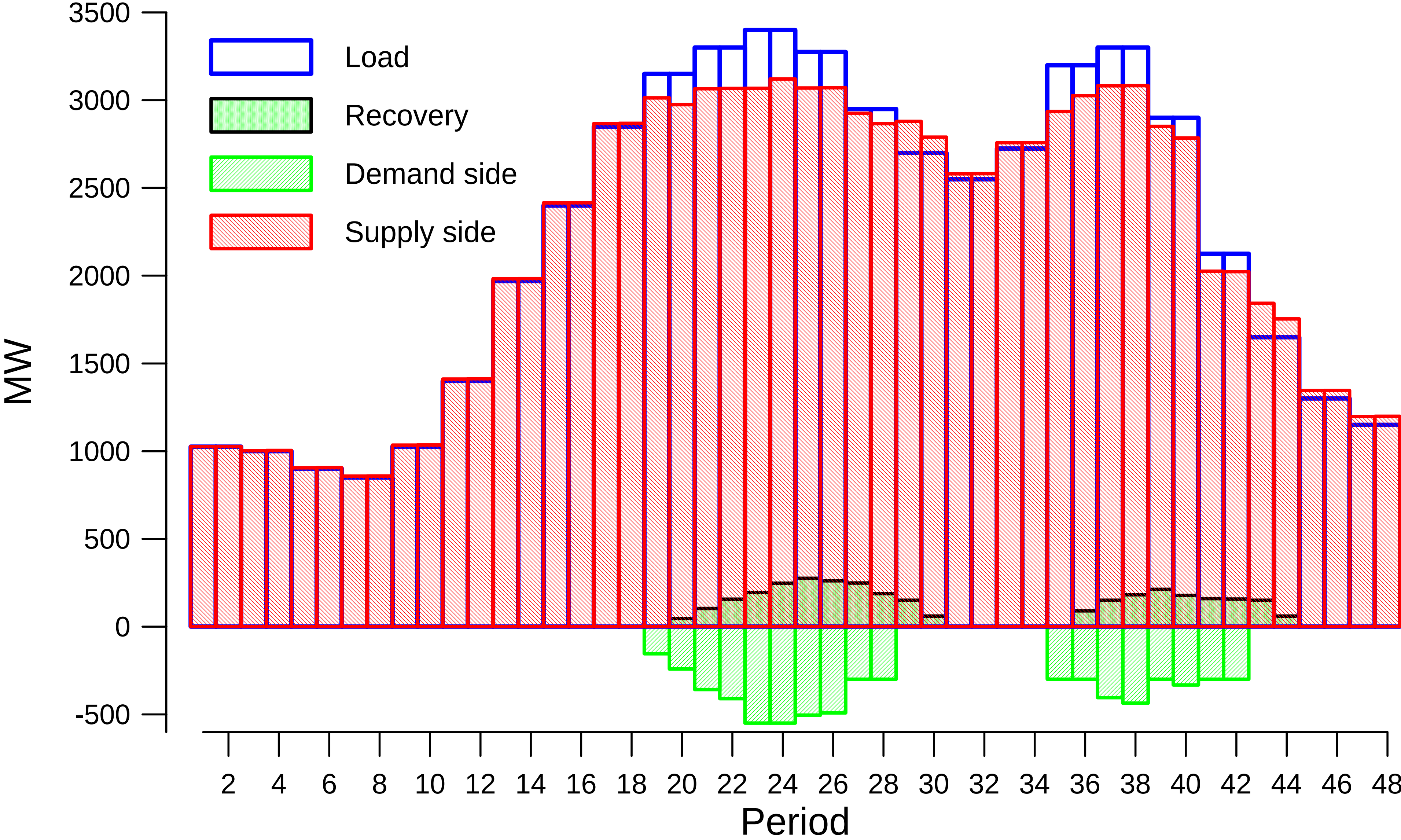
Payback pattern = 90% in the following period



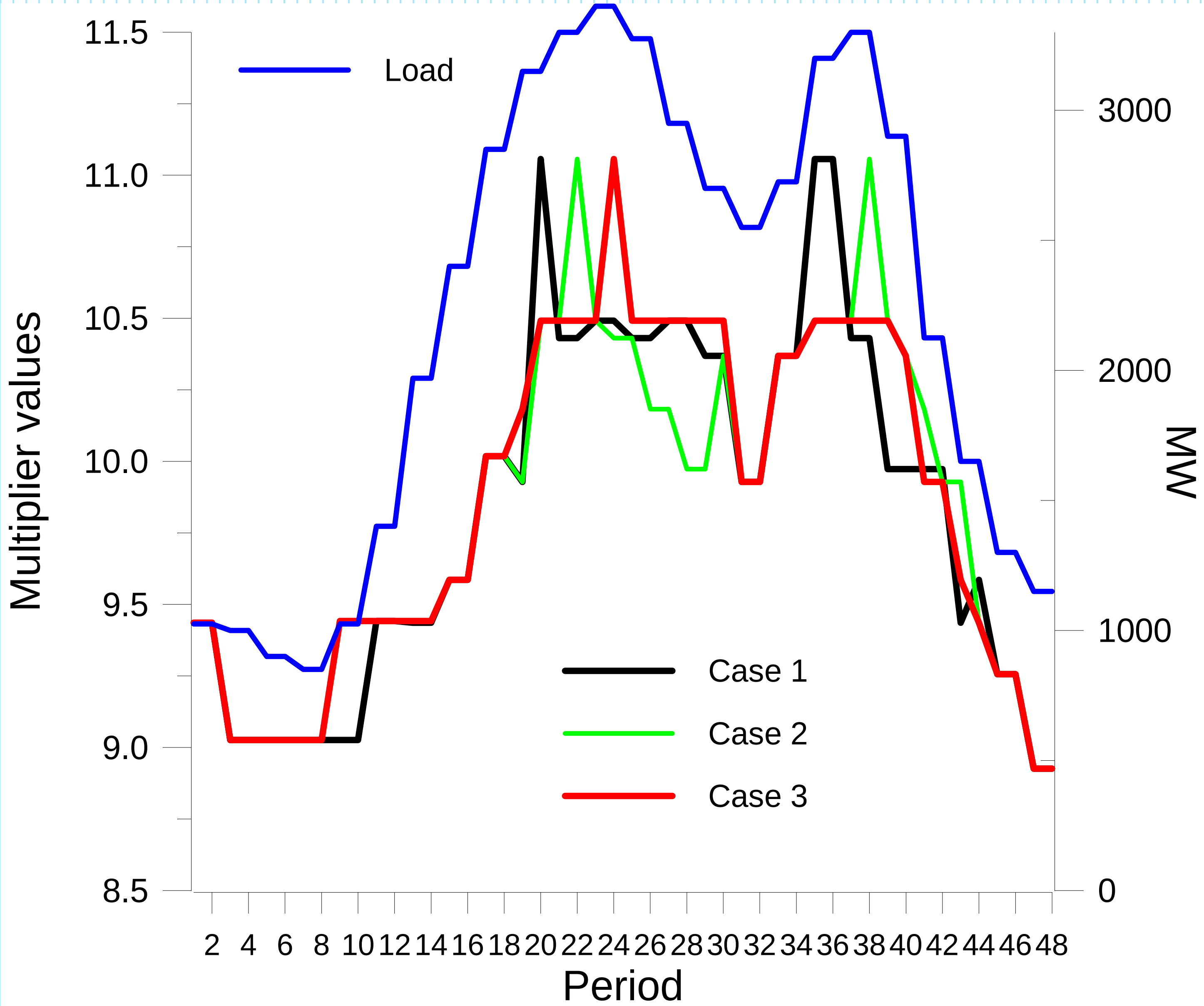
Case 3

Payback pattern = 50% in the following 2 periods

The demand-side bids are higher that the previous cases



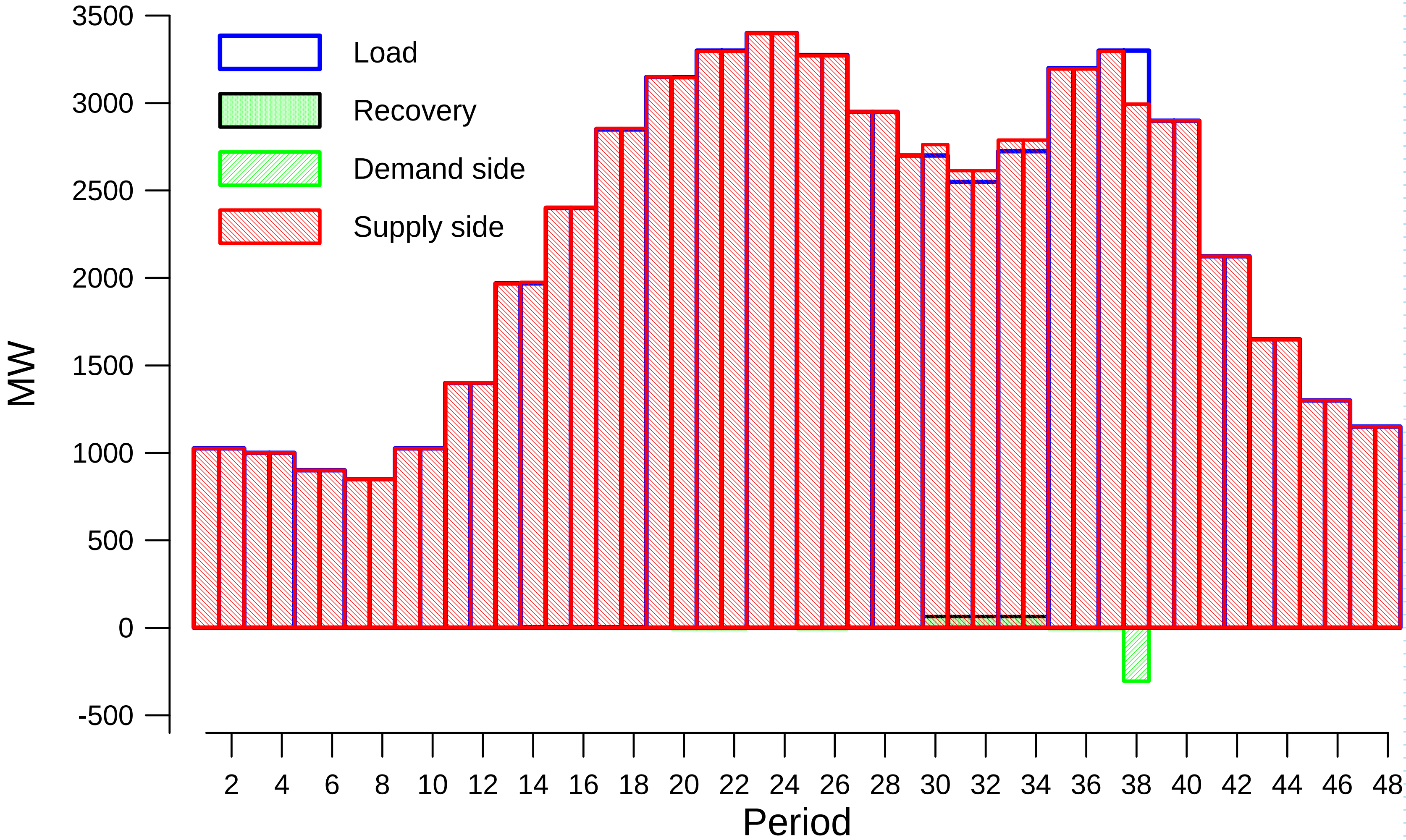
Multipliers values



Case 4

payback pattern = 100%, uniformly distributed

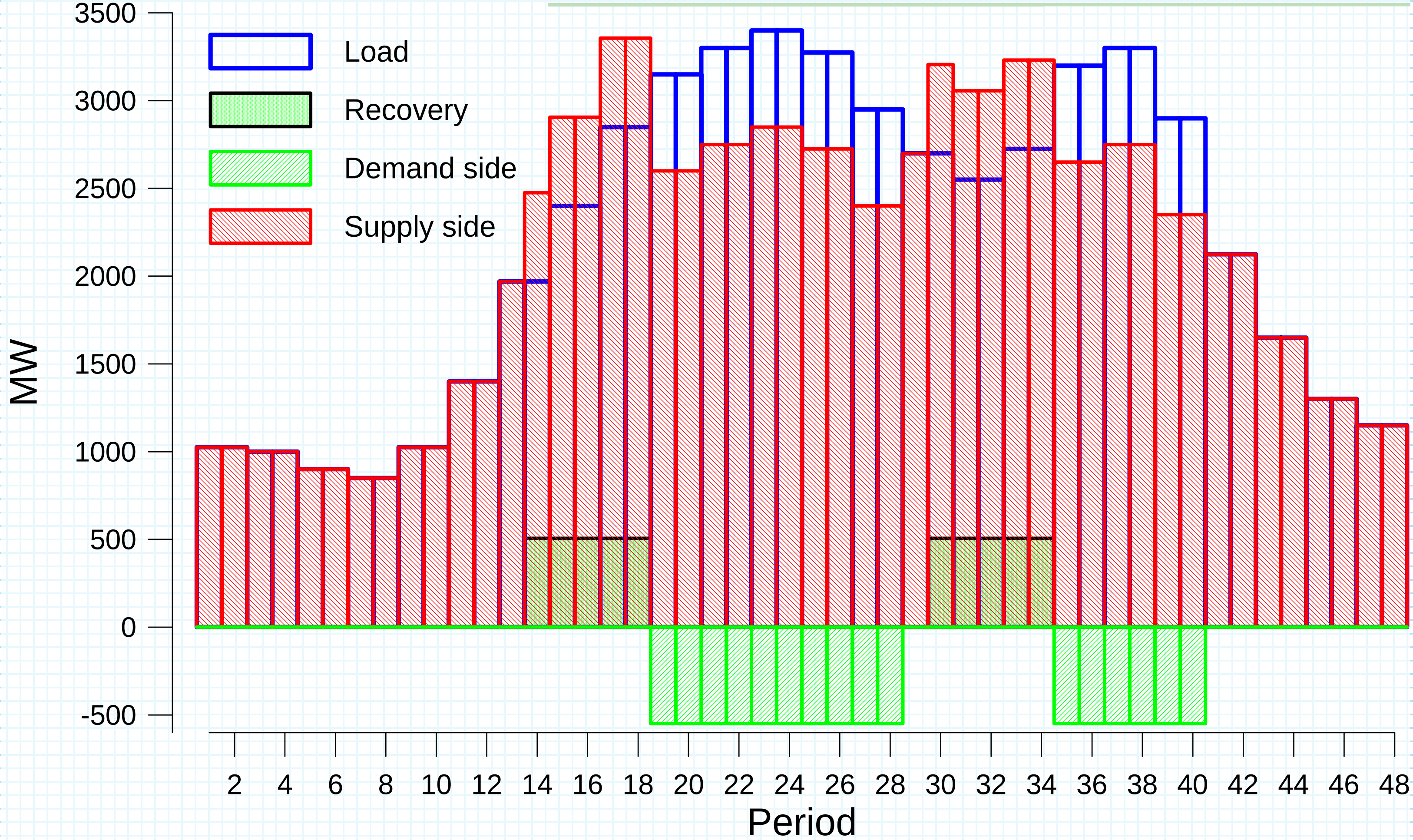
DSB	Control Period	Payback period
1	19-28	14-18
2	35-42	30-34



Case 5

payback pattern = 50% (DSB1) and 70% (DSB2), unif. distributed

DSB	Control Period	Payback period
1	19-28	14-18 and 30-34
2	35-42	14-18 and 30-34



Conclusions

- Demand-side bidding allows consumers to play a proactive role in the price determination without changing the price determination procedure

- The economic impact of DSB is that it reduces the overall costs

- By using the LR algorithm, we are allowed to disaggregate the model into separate subproblems

- The model developed permits to quantify the effects of the payback ratio as well as of the recovery period duration.