Customers' Willingness to Pay and Willingness to Accept

Norwegian survey and experiences

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Content of presentation

- Introduction – Norwegian customer surveys
- Purpose and scope of survey 2001 – 2003
- Cost valuation methodology
- Sectors, responses and questionnaires
- Normalization and estimation of cost data
- Main results and conclusions

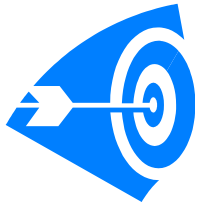
Introduction – Costs of interruptions – methodology

- Indirect analytical methods
- Case studies (blackouts)
- Customer surveys – consumer valuation
  - Direct worth
  - Willingness to pay (WTP)/ willingness to accept (WTA)
  - Indirect methods (preparatory action method (PAM), imputation)
  - Advantages:
    - Can be tailored to seek information related to specific needs
    - Provision of cost data for purposes in planning and operation
  - Disadvantage:
    - Costs and efforts may be significantly higher than for the other approaches

Introduction – Norwegian customer surveys

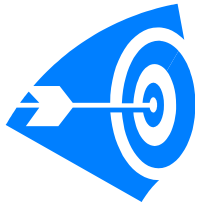
- 1979
  - Rather limited extent – selected end-users – costs of interruptions
  - Residential, agriculture, industry, offices
  - Study, questionnaire and expert evaluations
  - Objective: Provide consumer valuation of quality of supply (QoS)
- 1989 – 1991
  - Nationwide – 4 sectors – costs of interruptions
  - Residential, agriculture, industry, commercial
  - Questionnaires, analyses
  - Input to Nordic survey in 1993
  - Objective: Provide consumer valuation of quality of supply (QoS)
- 2001 – 2003
  - Nationwide – 6 sectors – costs of interruptions and voltage dips
  - Residential, agriculture, industry, commercial, large industry, public sector
  - Questionnaires, analyses

Purpose and scope of survey 2001 - 2003



- Objective:
  - To contribute to increased knowledge about socioeconomic costs related to interruptions and voltage disturbances
  - To generate quantitative indicators to enable effective regulation of QoS and for planning purposes, providing the necessary basis and incentives for authorities, system operators, network companies
- Choice of survey approach:
  - Need for comparison with previous studies and data for various purposes:
- QoS regulation, planning, operation and maintenance, load-shedding etc.

Purpose and scope of survey 2001 - 2003



- Data needed to serve the purposes:
  - Costs of long (> 3 min.) and short (≤ 3 min.) interruptions
  - Costs related to voltage disturbances (voltage dips 50 %, 1 sec)
  - Costs related to partial interruptions/ load shedding
  - Customers perceived QoS
  - Consumer flexibility regarding price vs QoS
- Considering:
  - Customer characteristics (type of customer and load/ use)
  - Interruption characteristics (duration, time, advance warning etc.)
- Aggregating collected data to six customer groups:
  - Industry, commercial, large industry (energy-intensive), public sector, agriculture, residential

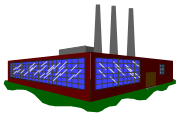
Cost valuation methodology

- The aim was to develop methodology for empirical estimation through customer surveys, providing:
  - Costs of interruptions and voltage dips reflecting consumer valuation of QoS in a market-based power system

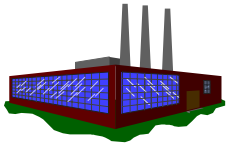
- Contingent valuation through postal customer survey

- Triangulization of research to handle strategic response:
  - Test a variable directly or indirectly using other variables
  - Examination of results via other questions and variables
  - A mix of methods was chosen: DW, WTP/ WTA and PAM

Sectors and responses





Customer sector	Resi-dential	Industry	Com-mercial	Agri-culture	Public sector	Large industry
Sample size	1000	2400	1800	800	800	220
Repeal	56	141	122	53	31	44
Real sample	944	2259	1678	747	769	176
Response rate	45 %	27 %	25 %	43 %	45 %	45 %
Incentive (lottery tickets)	40			40		

7000 randomly sampled based on Standard Industrial Classification (NACE-codes)

Questionnaires – content

I. Information about the respondent and electricity consumption
II. Costs of interruptions and voltage dips (DW)
III. Changes in costs from reference time
IV. Cost reducing actions (WTP)
V. Consumer flexibility (WTA, WTP)

Reference time for interruption scenarios:

Industry	Commer-cial	Large industry	Public sector	Agriculture	Residential
Thursday in January at 10 a.m.	Thursday in January at 10 a.m.	Thursday in January at 10 a.m.	Working day in January at 10 a.m.	Thursday in January at 6 a.m.	Working day in January at 4 p.m.

Questionnaires – examples

II. Costs of hypothetical interruptions and voltage dip (DW):

A. Damage of equipment, spoiled goods or raw material etc.

B. Loss of production

C. Extra costs for lost hours of work

D. Starting costs, and other costs.

IV. Cost reducing actions (WTP):

”*Assume an available reserve supply covering the whole demand during an interruption”. How much is your company/ are you) willing to pay for such a service*?” (Per interruption for different scenarios)

Questionnaires – examples

V. Consumer flexibility (WTA, WTP):

Disconnection of loads (space/ water heating, cooling/ freezing processes etc):

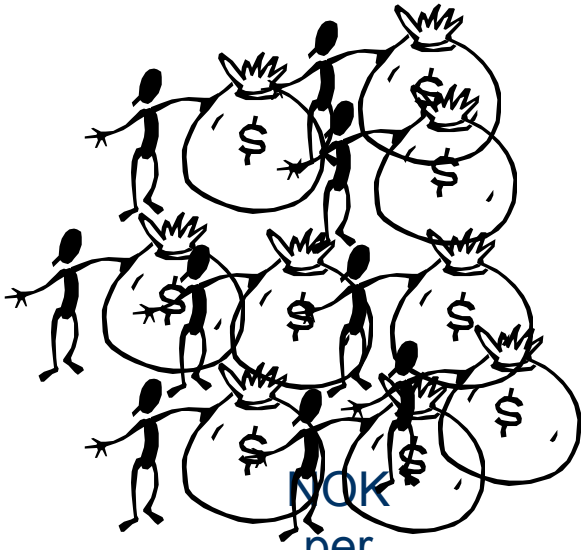
”*Assume that the network company will pay a compensation for disconnected loads when requested. Which annual compensation would your company be willing to accept for such disconnection*?”

Reserve supply:

”Assume available reserve supply covering partial loads upon reduced supply from the network. How much is your company willing to pay per year for such a service?” (For space/ water heating, cooling/ freezing processes etc.)

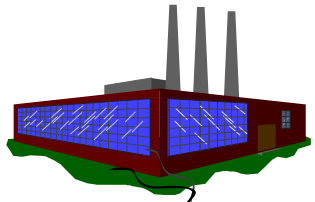
Normalization of cost data: From survey to specific interruption costs

Respondents



NOK per respondent per interru

Customer categories



NOK/kWh per customer category per interrupt

Applications

- QoS regulation
- Planning
- O&M
- Tariffs

etc.

NOK per customer or customer category per interrupt.

Normalization factor: Energy not supplied (ENS) (kWh) or interrupted power (P_{int}) (kW)

Normalization procedure

$$c_{SCDF}(r,t) = \frac{1}{m}\sum_{i=1}^{m} c_{N,i}(r,t)$$

SCDF – per sector

where

$$c_{N,i}(r,t) = \frac{C_i(r,t)}{N_i(r,t)}$$

Contingent valuation from survey per respondent

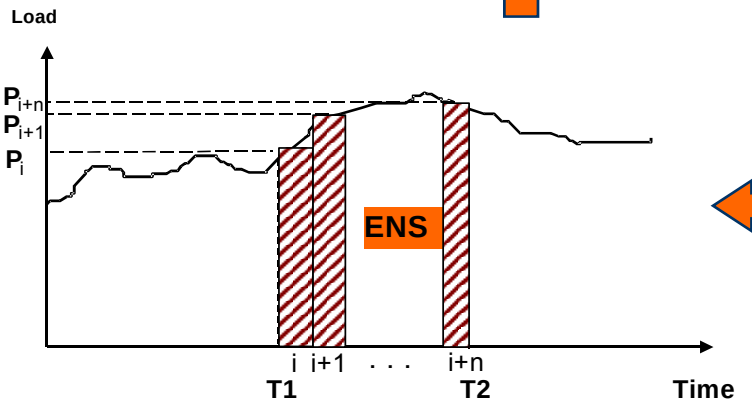
Electricity consumption information from survey

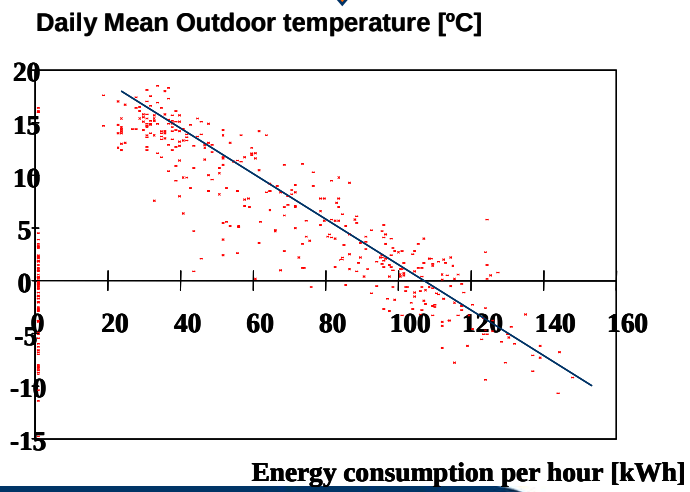
Estimated energy that would have been supplied if the interruption did not occur

Estimated power that would have been supplied at the time of interruption or voltage dip if it did not occur

ENS or P_{int}

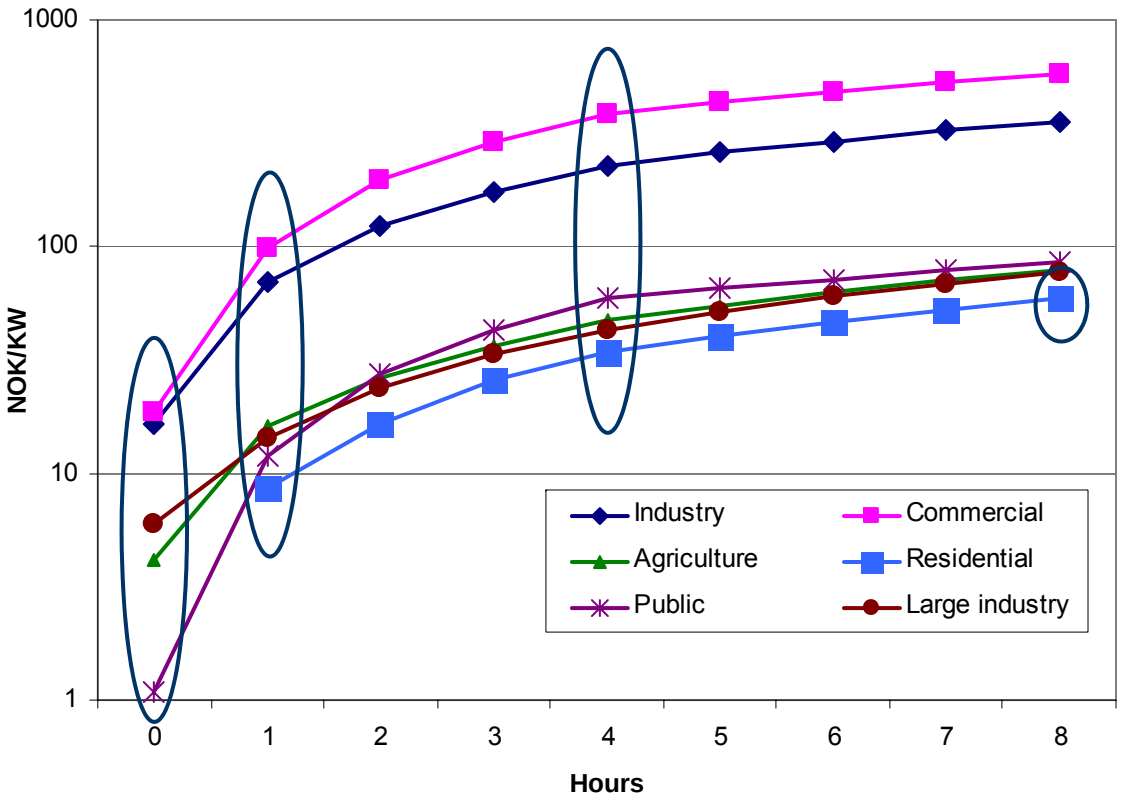
Hourly load data per sector and climate zone





Main results – Interruption costs (2002): Estimated willingness-to-pay (*M*)

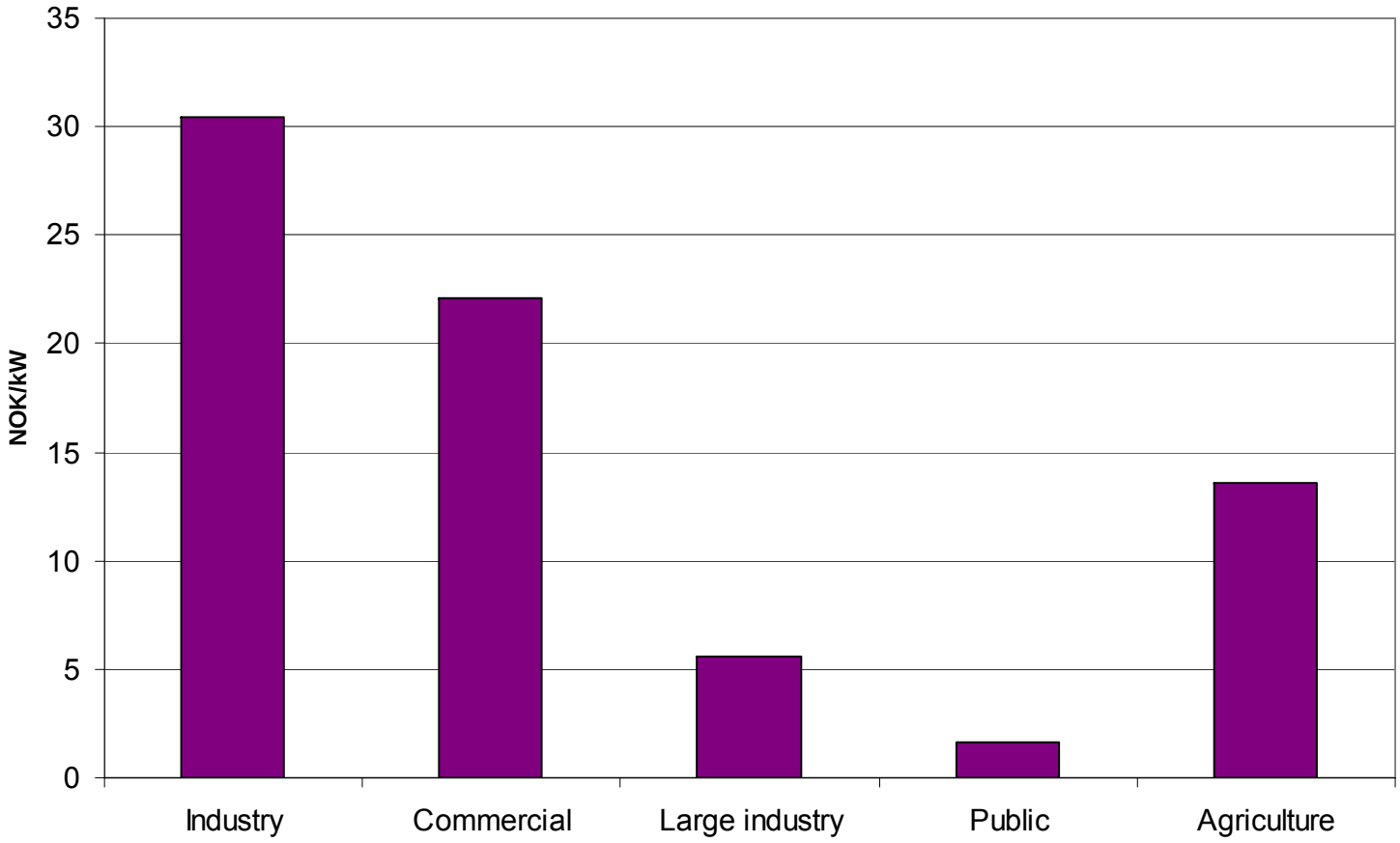
Interruption scenarios:
1 minute
1 hour
4 hours
24 hours



Censored data, mean values

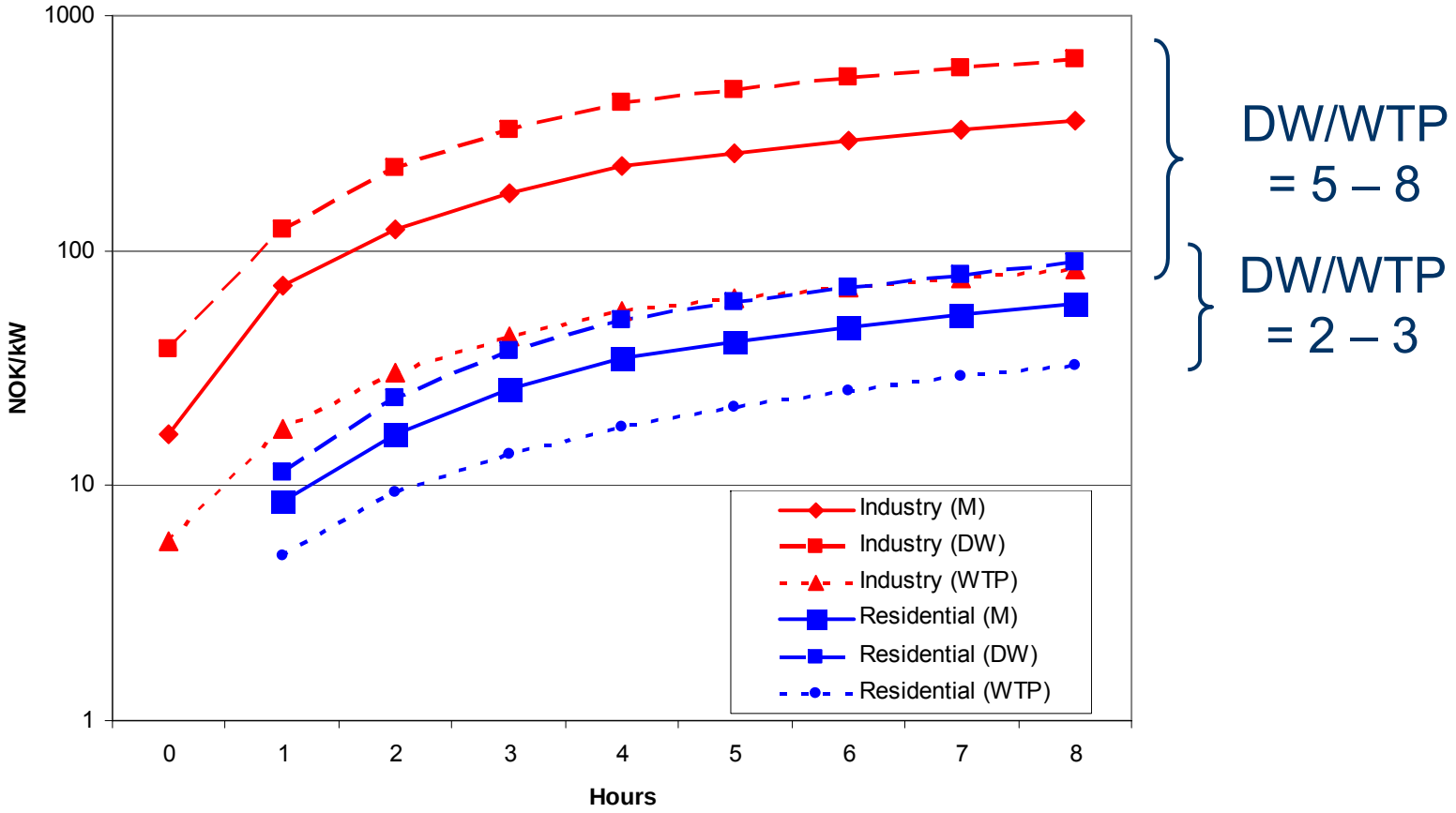
$$M = (DW + WTP)/2$$

Main results: Voltage dip (50 %,1 s) (2002): Direct worth (*DW*)



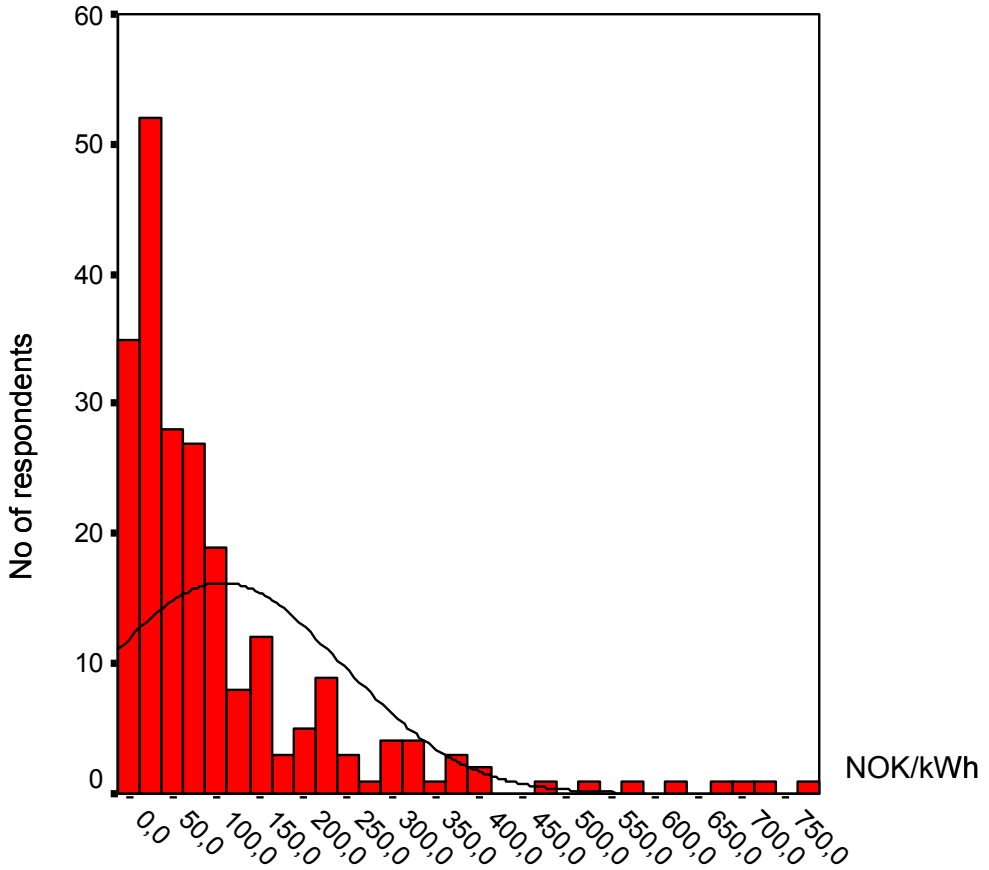
Censored data, mean values

Main results: Interruption costs (2002): *DW / WTA* versus *WTP* – examples



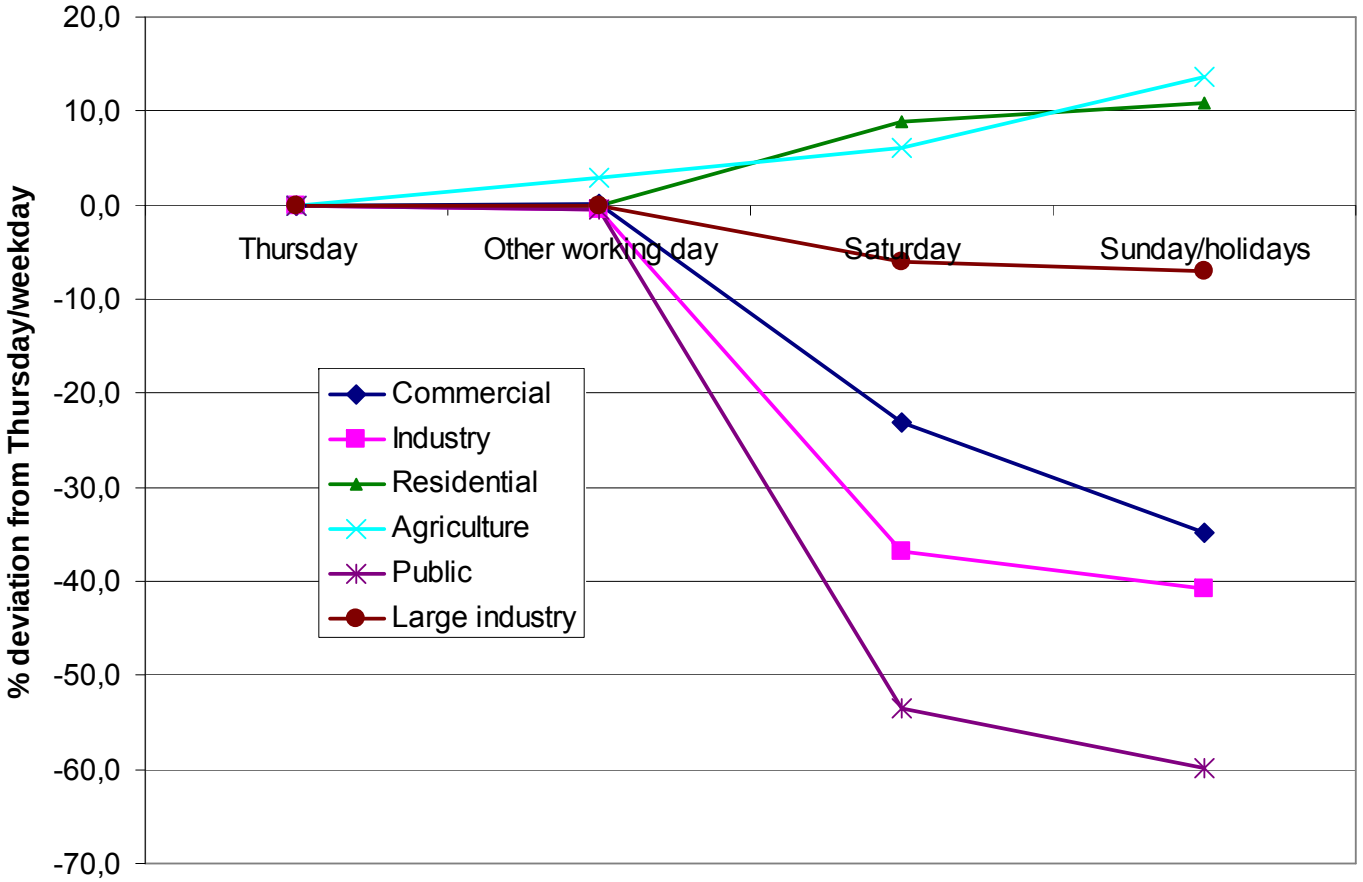
Censored data, mean values

Main results: Large dispersion in costs: Cost of 4 h interruption – Industry



Std. deviations 1 – 2 times mean (2 – 5 times for uncensored data)

Main results: Time dependency in costs: Deviation (%) in cost from reference time



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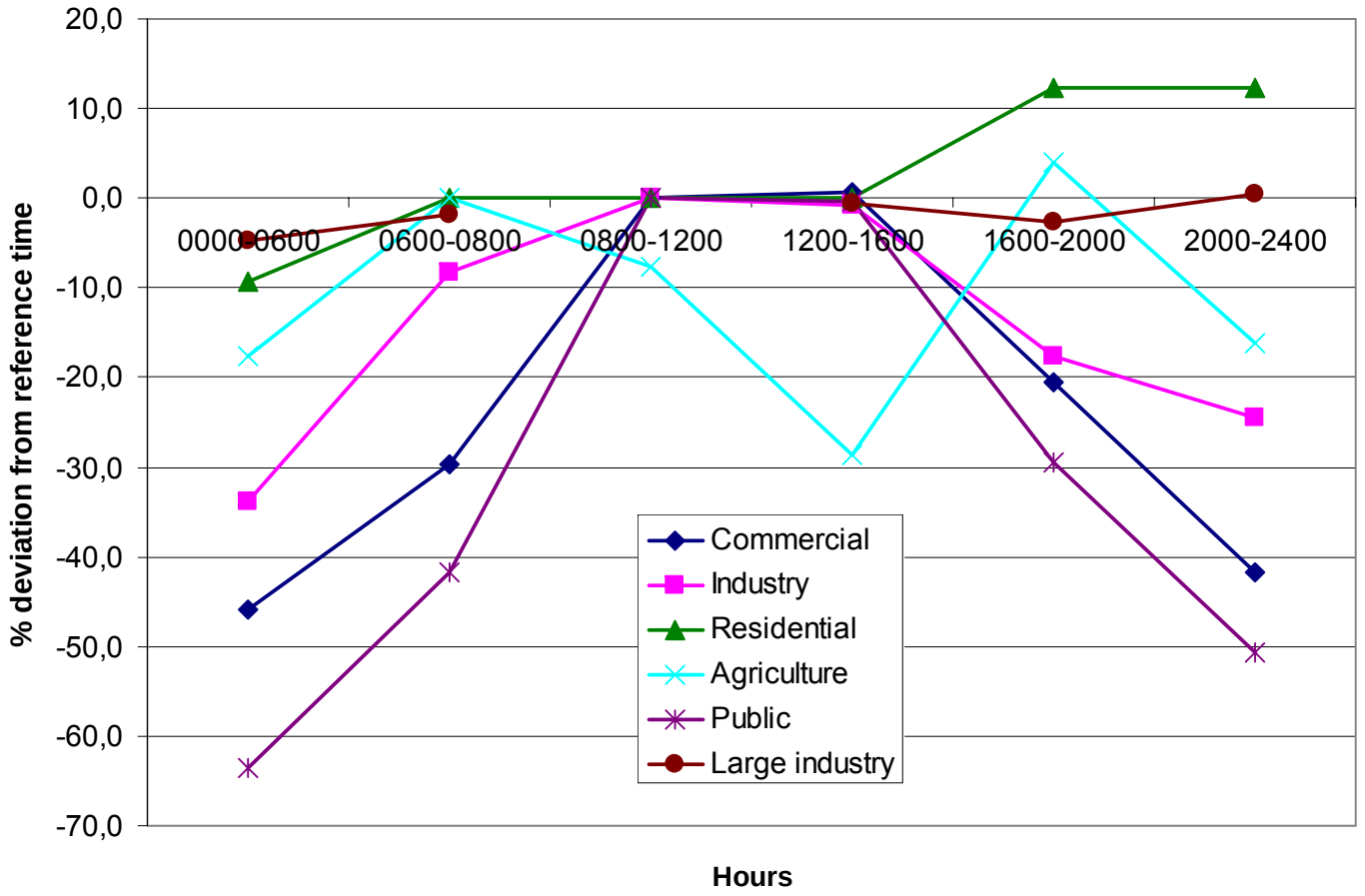


Results basis for Cost of Energy not Supplied arrangement (CENS) (2002):

Customer category	Non-notified interruption (1.3 h) NOK/kWh ENS	Notified interruption (min 1 day) (2.85 h) NOK/kWh ENS
Industry	66	46
Commercial	99	68
Agriculture	15	10
Household	8	7
Public sector	13	10
Large industry	13	11

CENS about 400 - 500 mill NOK per year 2001 - 2006

1 Euro approx. 8 NOK

Conclusions

- Methodology and main results from Norwegian survey 2001 – 2003 presented, for six customer groups
- Based on a combination of DW and WTP
- Raw data normalized by energy not supplied and interrupted power
- The DW/WTP ratio in the order of 2 – 12
- Large dispersions in normalized cost data
- Significant time dependency in cost (day, week)
- Cost estimates incorporated in QoS regulation

End of presentation

- Reference:

  - Kjølle. G. H., Samdal, K. Singh, B., Kvitastein, O.:
    Customer costs related to interruptions and voltage problems: Methodology and results,
    IEEE Transactions on Power Systems, Vol. 23, No. 3, Aug. 2008

Additional slides

Uncertainties in cost estimates from customer surveys (aim is socioecon. cost)

- Customer surveys:
  - Subjective valuations (partly objective) – calculation of costs not standardized, strategic response may occur (triangulization however partly built in the questionnaire)
  - Time consuming and competence demanding to answer
  - The costs are relative, depending on QoS level and perceived QoS
  - Large dispersions in costs within and between sectors
- Applications:
  - Cost estimates reflect average of individual respondents' valuations
  - Extra costs due to geographical extent of interruption, unavailability of other infrastructures and distributional effects among companies not covered
  - Costs change with societal changes (electricity dependency, markets etc)
  - Specific costs should be used with care, with special regard to the normalization factor (ENS vs P_{int} vs annual consumption etc.)

How much can WTP and WTA differ?

Theory: *Difference should be minimal*

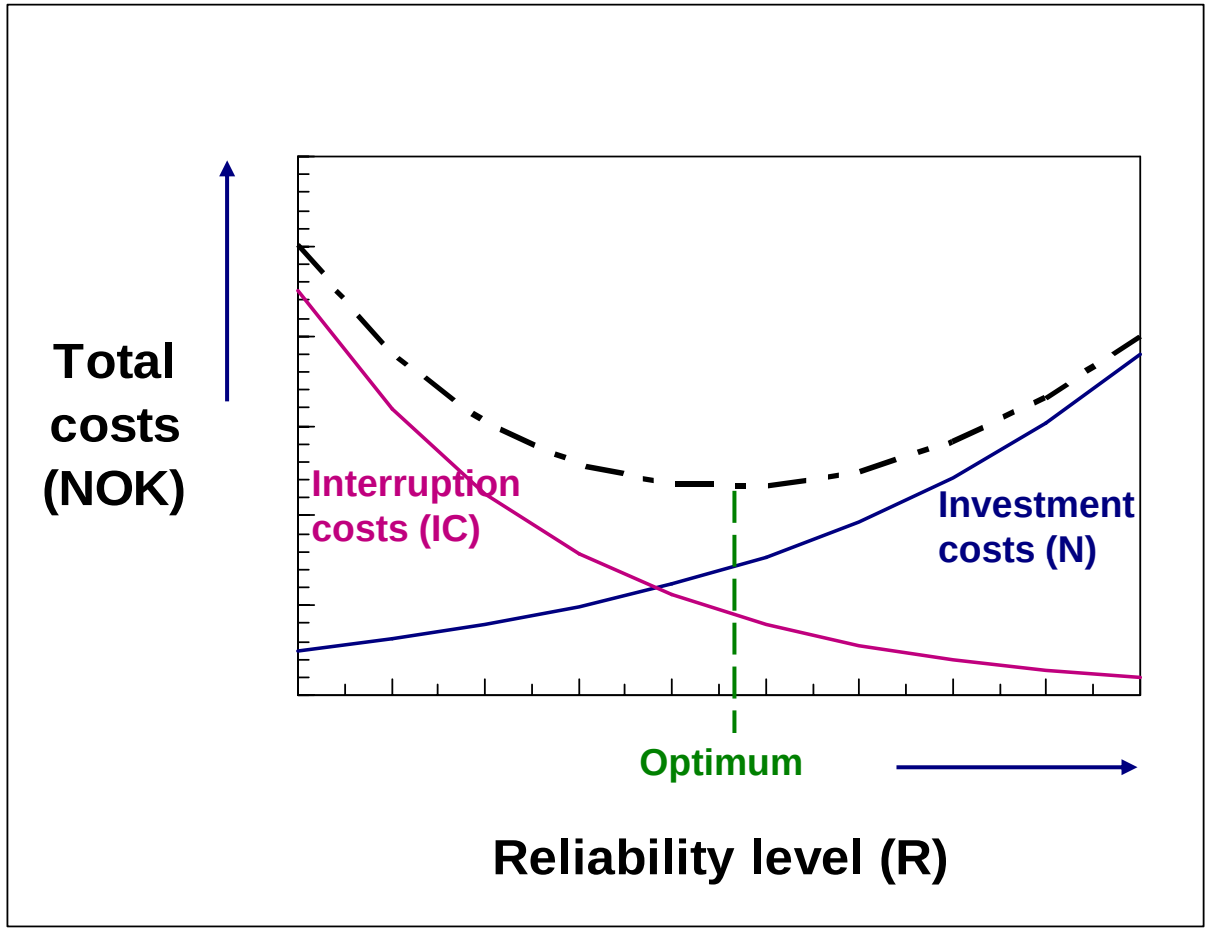
Empirical Evidence: *Large disparities*

- Cognitive dissonance
- Inexperience with valuation periphery goods
- Protest valuation
- Careful respondent
- Prospect theory
- Lack of budget constraint
- Substitution possibilities, Income effects
- Strategic response

Interpret WTP and WTA as bounds

- Use a combination – Average

Value-based planning and socio-economic costs



Optimal reliability level:

$$\frac{dN}{dR} = -\frac{dIC}{dR}$$

Total costs of interruptions and voltage dips in Norway (cost level 2002)