NHH


# Regulation of electricity networks and implications for integration of distributed (renewable) generation

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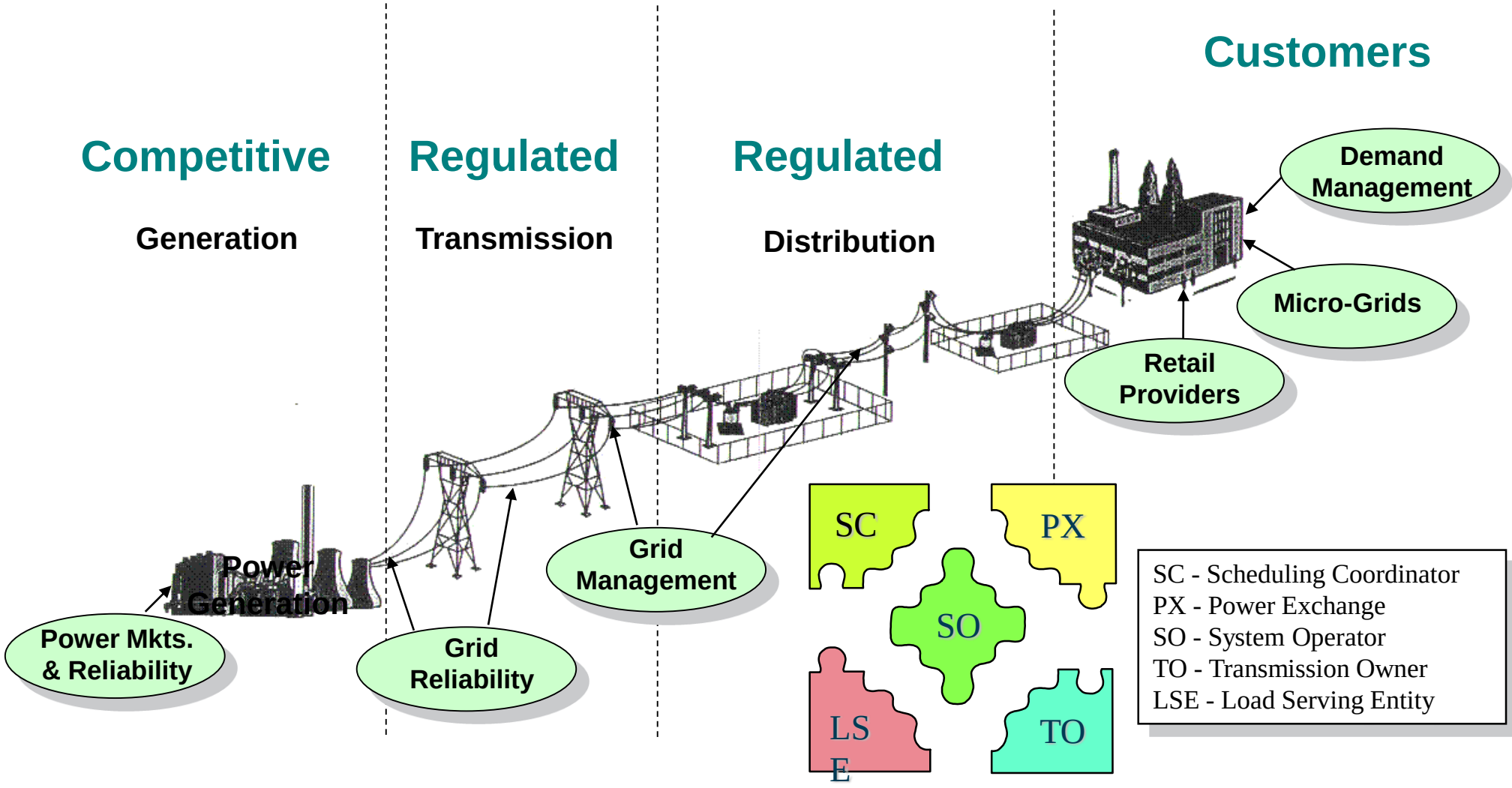
# Outline

- Revenue cap regulation of network companies
  - Sufficient compensation for additional costs arising from DG integration?
- Tariff structures
  - Prosumers and load defection

# Power market players

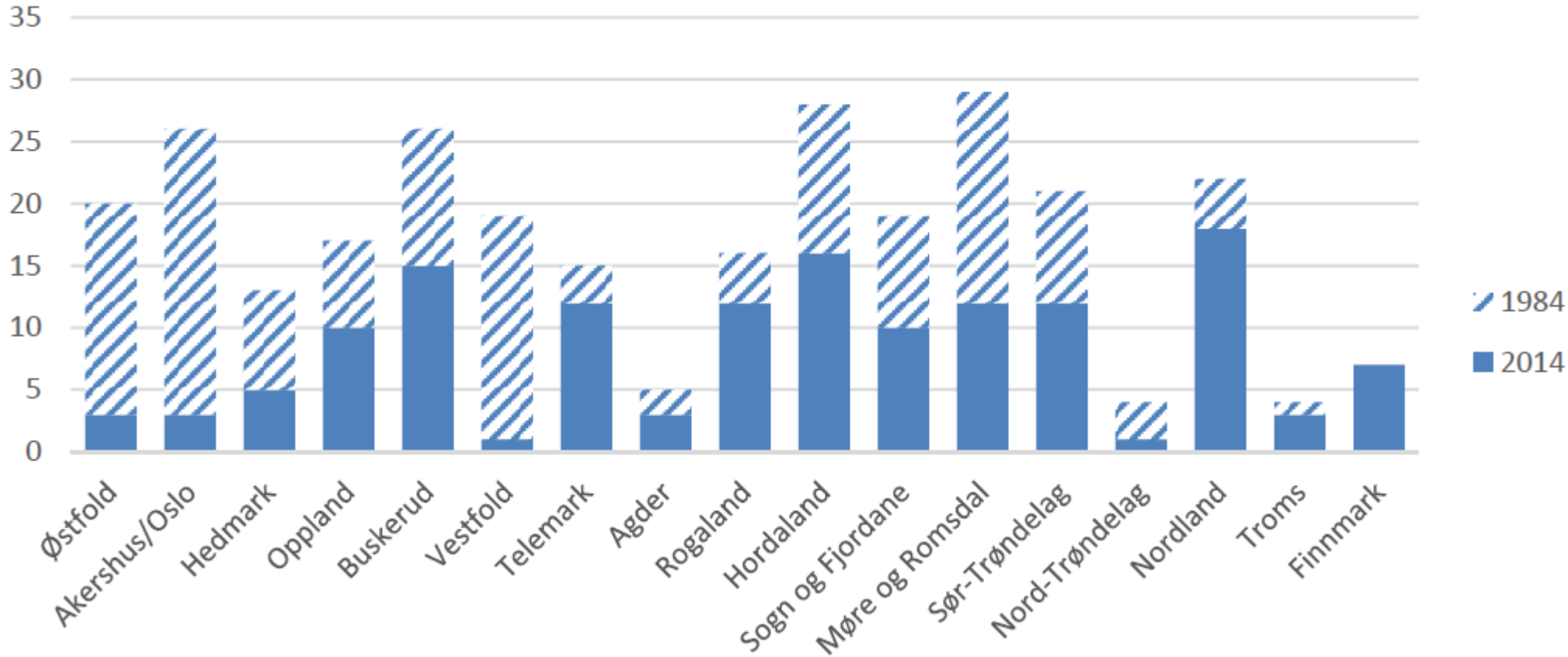



Source: S. Oren

# Norwegian and Nordic electricity market

- One of the first deregulated electricity markets
  - Nordic countries (excl. Iceland): 400 TWh / population 25 mill.
- Energy is traded in the Nordic market
  - Power Exchange: Nord Pool Spot / Part of European market coupling
  - Financial Market: NASDAQ OMX Commodities (from 2010)
- Vertical separation of transmission/distribution and generation
  - By separation of accounts (except for Statkraft / Statnett)
- Competitive supply and demand for power
  - Choose energy supplier
  - No price caps (not even for households)
- Transmission and distribution are regulated
  - RoR regulation from 1993
  - Incentive regulation from 1997

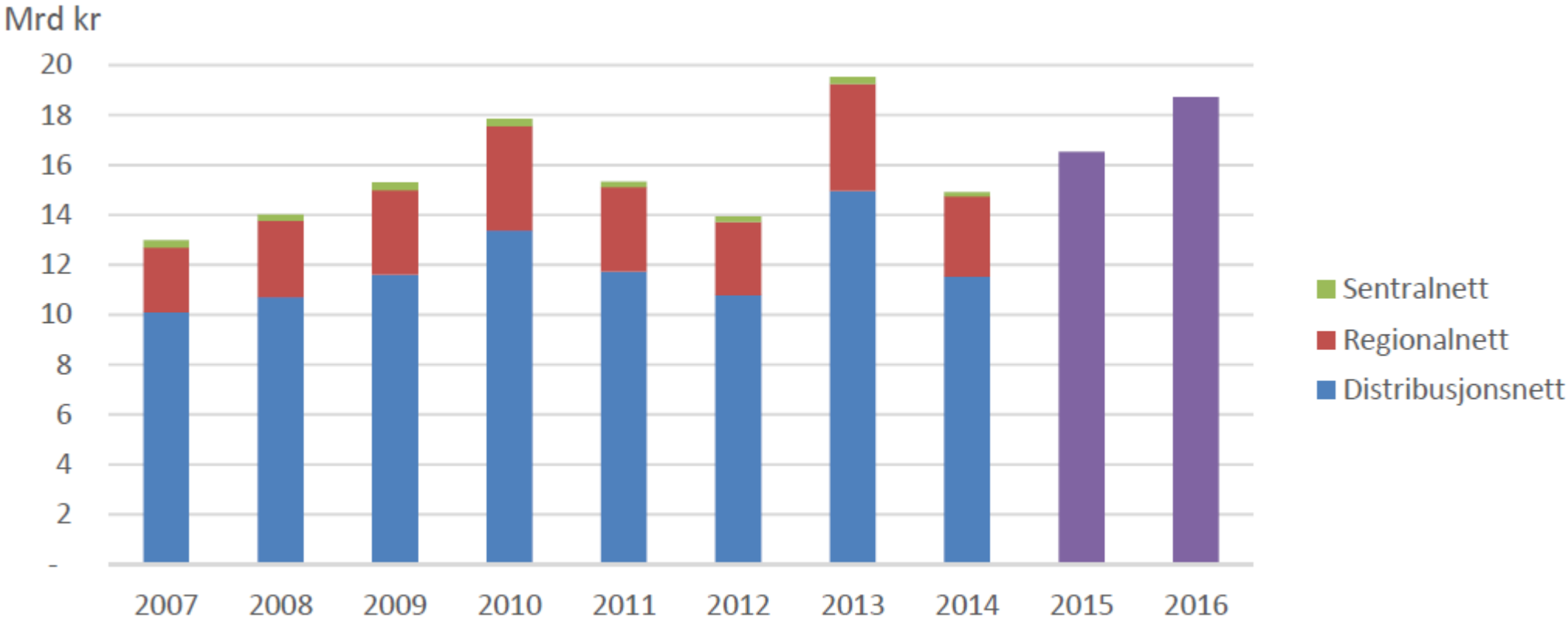
# 144 network companies (excl. Statnett) in 2014






Source: NVE (2016)

# Industry costs




Source: NVE (2016)

# Incentive regulation

- Incentives for efficient organization, operation, and investments
  - Revenue should be independent of the regulated company's own cost
    - Revenue = cost of the "marginal" company, given the company's "output" (volume and quality)
    - Profit depends also on the company's efficiency and cost
- Sufficient revenue level to attract both financial and human capital
  - Competitive rate of return on invested capital
  - Accept continual efficiency differences and "super-profits"
- Long asset life times and time profiles

# NVEs yardstick model (since 2007)

- Company specific revenue caps calculated every year:

$$Rcap_i = 0{,}6 \cdot C_i^* + 0{,}4 \cdot C_i$$

- C based on reported / calculated costs
  - Includes KILE (Kostnad ved Ikke Levert Energi)
  - Capital cost is based on regulated rate of return
- C* based on benchmarking analysis
  1. Every company is compared to a best-practice (DEA) frontier
  2. Control for local conditions
  3. Results are calibrated so that $\sum C^* = \sum C$
- Separate models for transmission and distribution

# Benchmarking variables

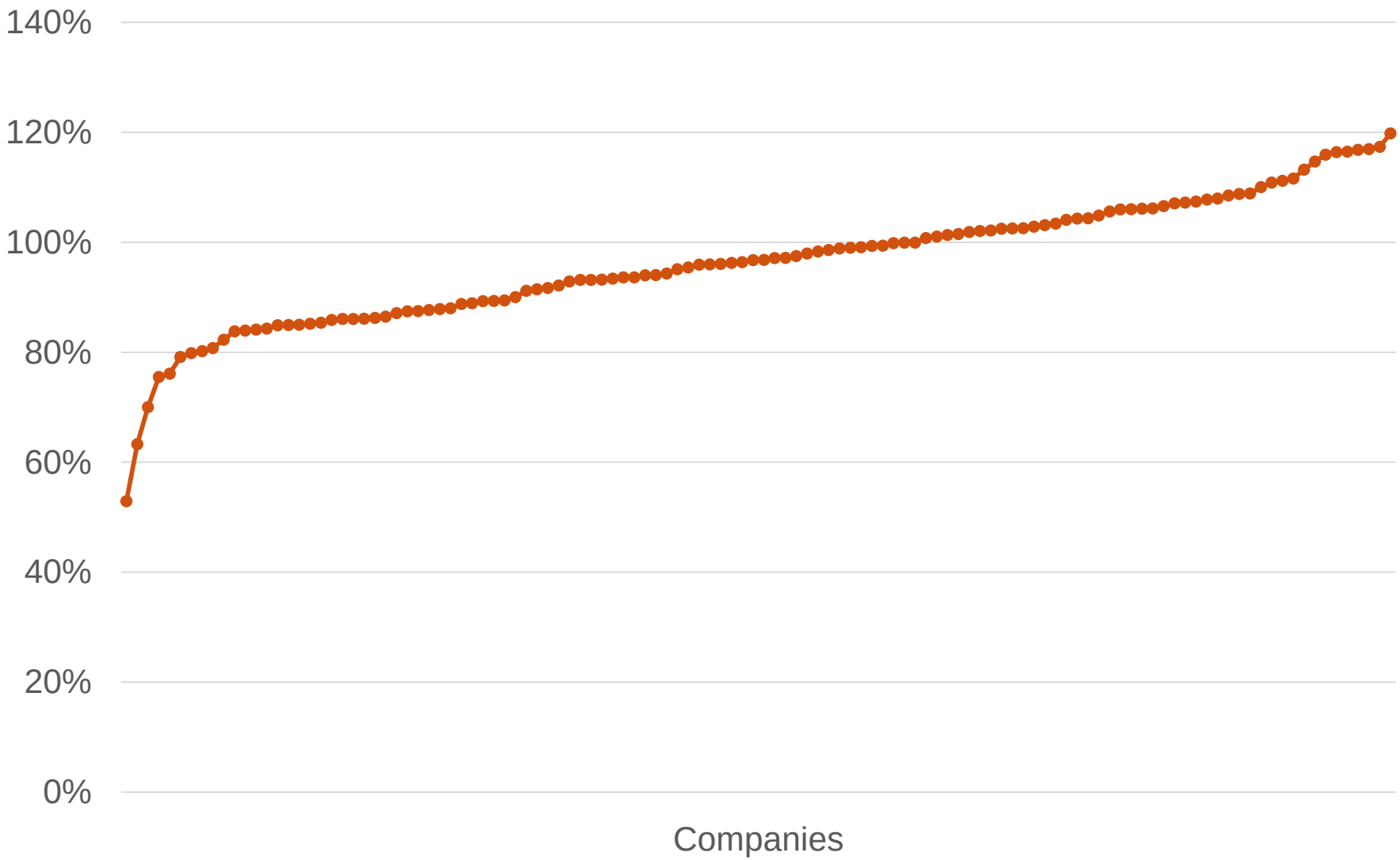
## Distribution

- Input
  - Total cost
- Output
  - Customers
  - High voltage lines
  - Network stations
- Geography
  - Share of underground cables
  - Coniferous forest
  - Slope
  - Small-scale hydro
  - Desiduous forest
  - Wind speed / distance to coast
  - Islands
  - Share of sea cables

## Transmission

- Input
  - Total cost
- Output
  - Overhead lines (weighted)
  - Underground lines (weighted)
  - Sea cables (weighted)
  - Interface (weighted)
- Geography
  - Slope
  - Forest

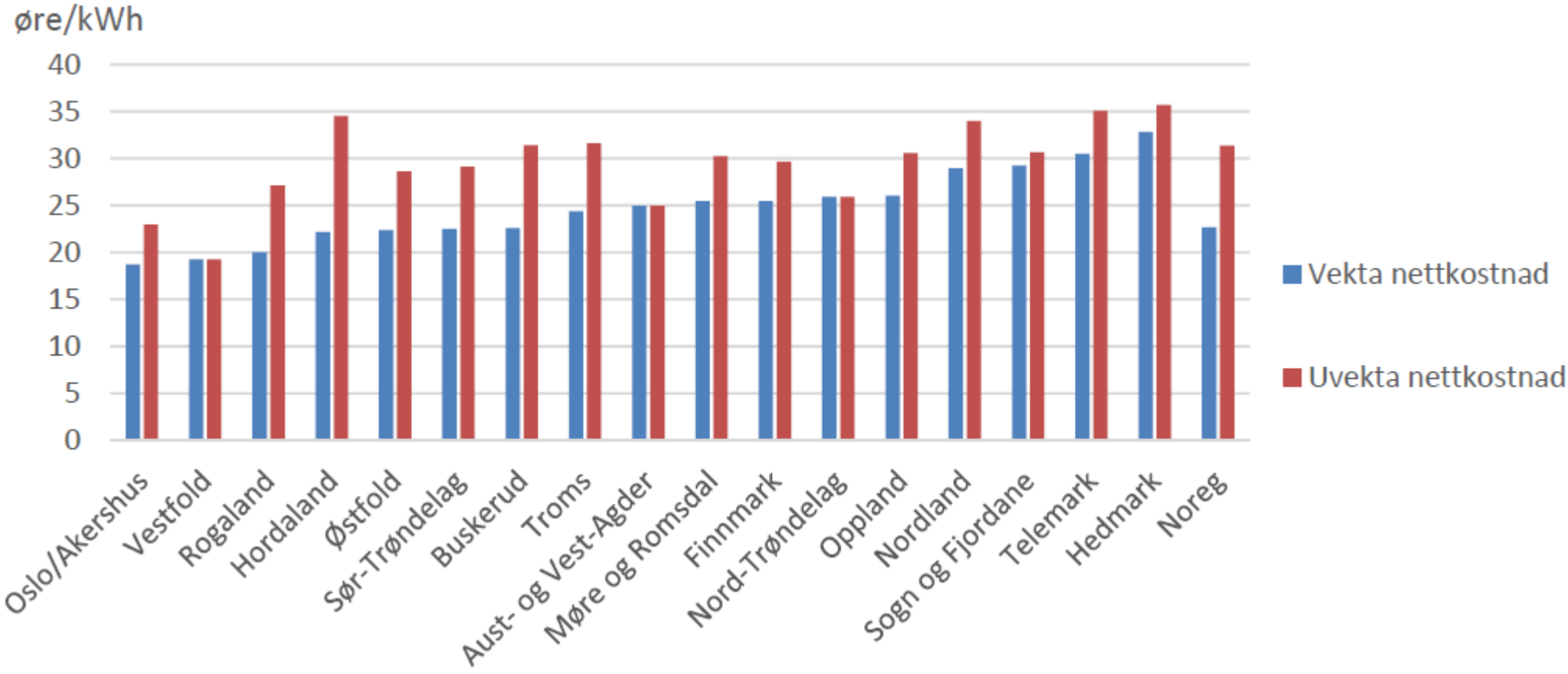
# NVEs efficiency adjustment of distribution companies in 2016






Source: NVE

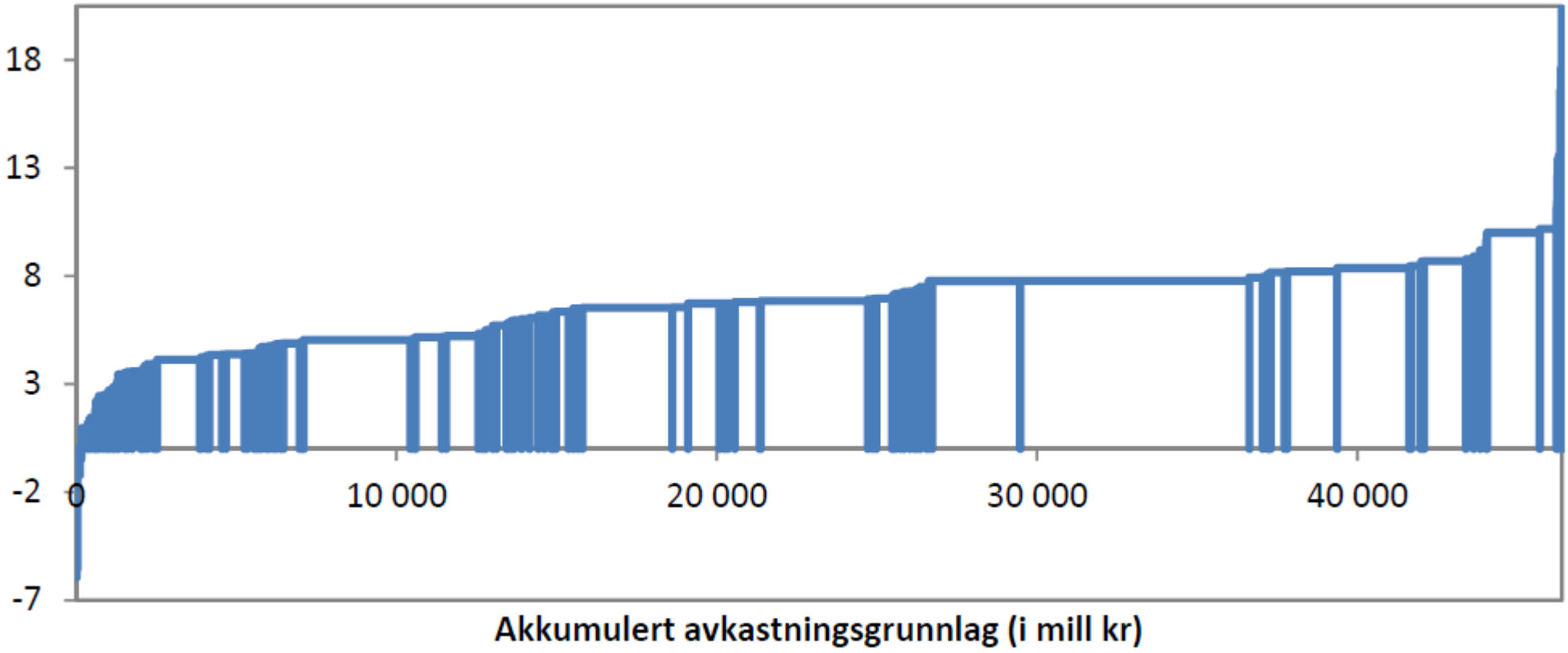
# Locational variation in tariffs (2014)






Source: NVE (2016)

# Return (%) on capital (2010-2014)



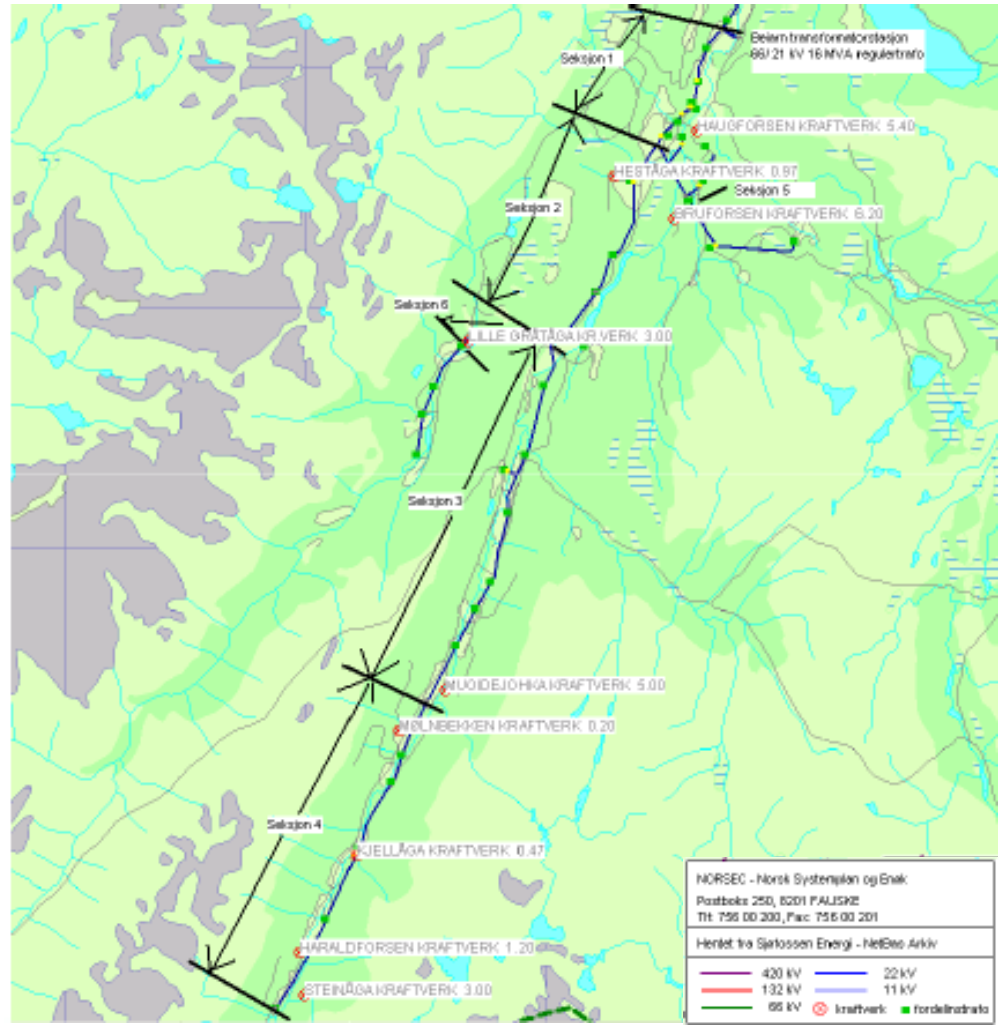

Regulated rate of return:
2014: 6,61 %
2013: 6,9 %
2012: 4,2 %
2011: 5,31 %
2010: 5,62 %



Source: NVE (2016)

# Investment incentive example – effect of distributed generation

- Extension/reinforcement of network caused by 8 new small scale hydro power plants in the Beiarn valley
  - 26.67 km lines
- New generation capacity
  - 25 MW
- Network investments
  - 13.013 MNOK (with project)
  - 3.933 MNOK (w/o project)

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# Consequences for network owner

- Mandatory connection
  - Obligation for network owner
- Network owner can choose to charge investment contribution from the power plant owner(s)
  - Most companies charge maximal investment contribution
    - 13.013 – 3.933 = 9.08 MNOK in the example
  - Optimal decision will depend on the network owner's efficiency score

# Revenue effects

| BE Nett AS | | Lyse Nett AS | | Dalane Energi IKS | |
|---|---|---|---|---|---|
| Company | Δ IR2 | Company | Δ IR2 | Company | Δ IR2 |
| SFE Nett AS | -207 | SFE Nett AS | -55 | SFE Nett AS | -107 |
| Tussa Nett AS | -187 | Tussa Nett AS | -44 | Tussa Nett AS | -93 |
| Sunnfjord Energi AS | -171 | Sunnfjord Energi AS | -37 | Sunnfjord Energi AS | -85 |
| Stranda Energiverk AS | -82 | BKK Nett AS | -20 | Agder Energi Nett AS | -68 |
| x | x | x | x | x | x |
| x | x | x | x | x | x |
| Fortum Distribution AS | 78 | Trondheim Energiverk Nett AS | 8 | Trondheim Energiverk Nett AS | 21 |
| Skagerak Nett AS | 116 | Fortum Distribution AS | 14 | Fortum Distribution AS | 33 |
| Hafslund Nett AS | 438 | Hafslund Nett AS | 53 | Hafslund Nett AS | 135 |
| BE Nett AS | 714 | Lyse Nett AS | 785 | Dalane Energi IKS | 881 |
| Sum | 389 | Sum | 389 | Sum | 389 |

- Very good compensation for local network owner
  - 19 % p.a. return on the investment
- Other companies loose

# Tariffs

- How to collect the revenues from network customers?
  - Energy charge (€ / kWh)
    - Time-of-use?
    - Gross or net metering?
  - Capacity charge (€ / kW)
    - Flat or variable?
    - Time-of-use?
  - Fixed charge (€ / period)

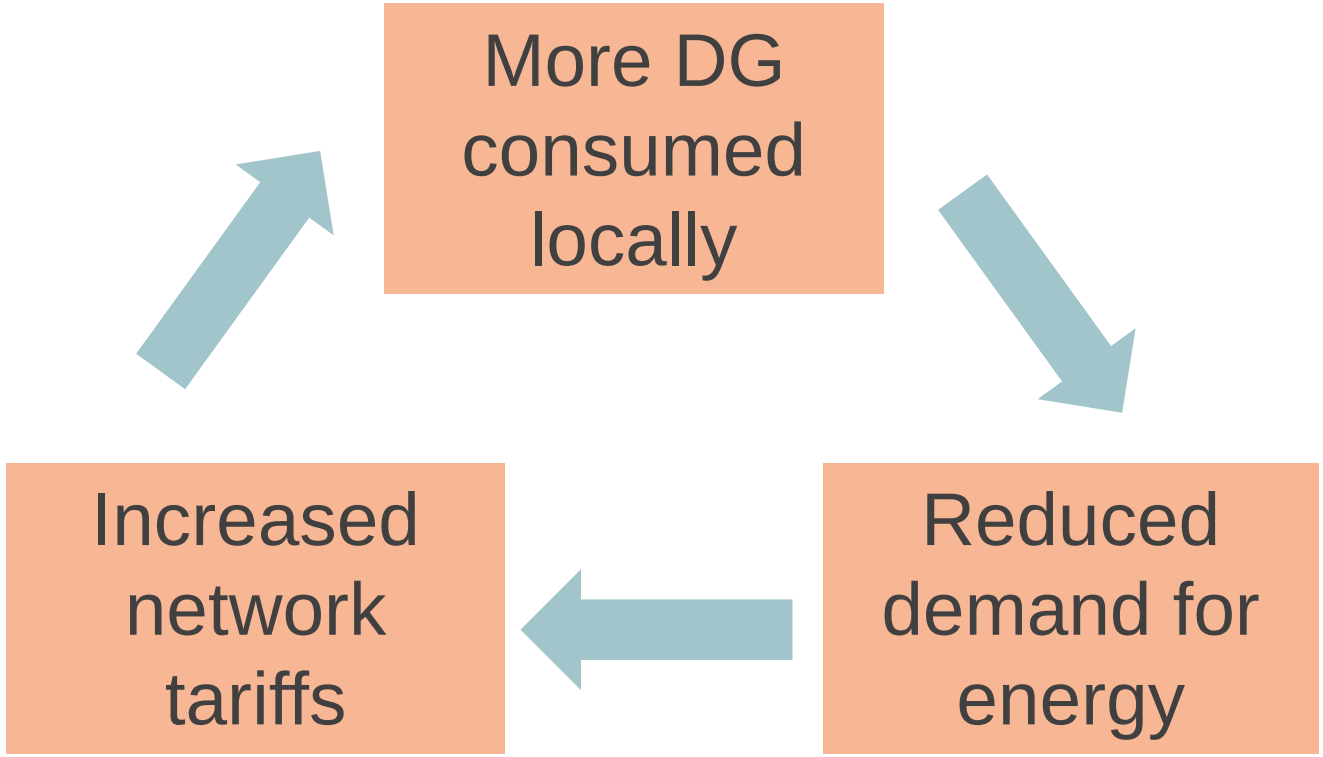
# Bonbright's tariff principles (1961)

- Tariffs should be **practical**: simple, understandable, acceptable to the public, feasible to apply, and free from controversy as to their interpretation.
- Tariffs should keep the utility **viable**, effectively yielding the total revenue requirement and resulting in relatively stable cash flow and revenues from year to year.
- Rates should be relatively **stable** such that customers experience only minimal unexpected changes that are seriously adverse.
- Tariffs should **fairly** apportion the utility's cost of service among consumers and should not unduly discriminate against any customer or group of customers.
- Tariffs should promote economic **efficiency** in the use of energy as well as competing products and services while ensuring the level of reliability desired by customers.

# Distributed generation (DG) and challenges for tariff design

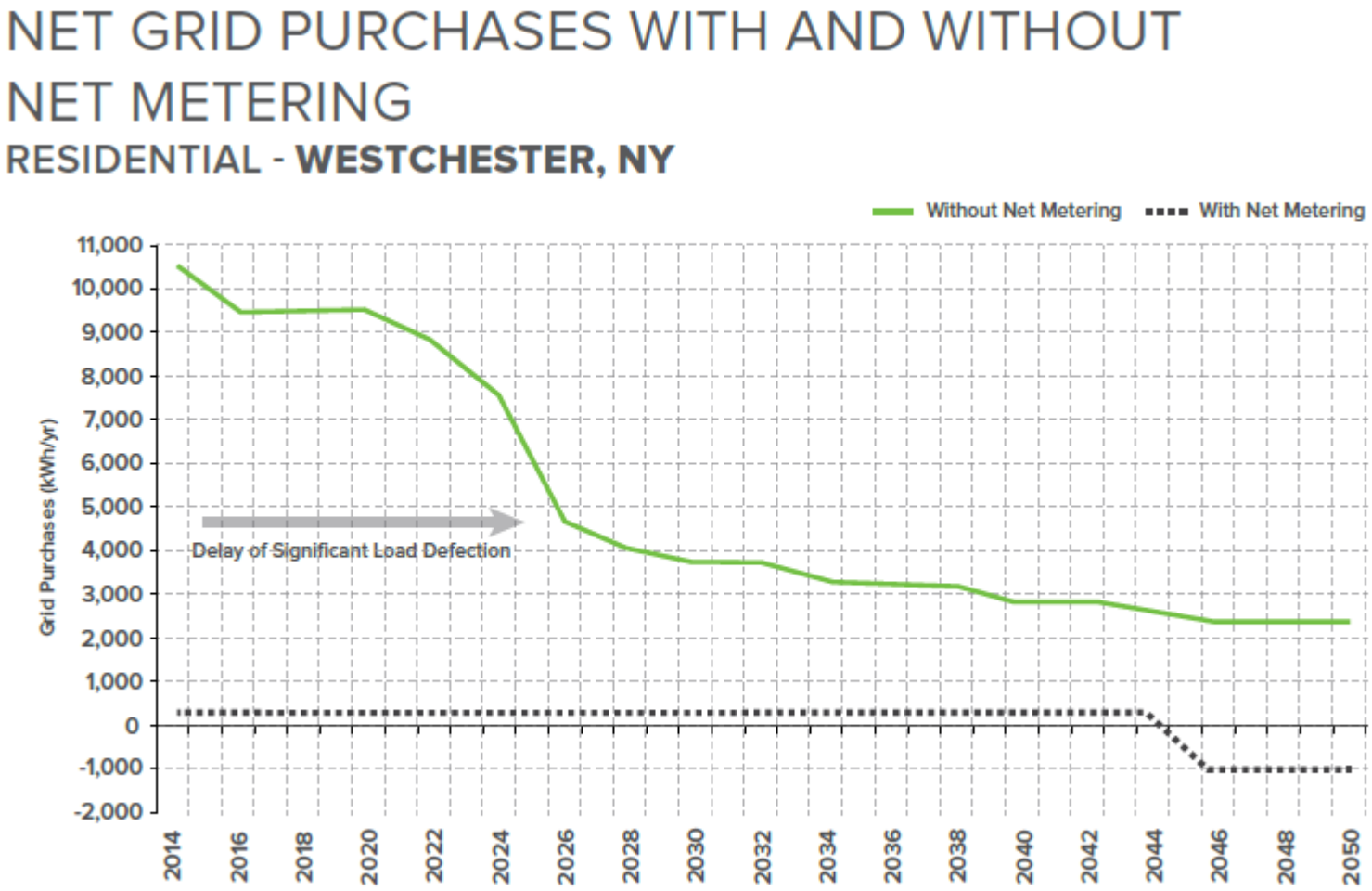
(Picciariello et al., 2015)

- DG exempt from distribution tariffs in many countries
- Load-tailored tariff schemes applied to DG
  - E.g. energy-based tariffs with net metering



# The Economics of Load Defection

(Rocky Mountain Institute, 2015)



# Conclusions

- The Norwegian regulation of electricity network companies aims to create incentives for efficient organization, operation, and investments
- Revenue caps are established via a yardstick regulation formula with relies on benchmarking analysis in order to determine an efficient cost level (C*)
- Network owners are obliged to connect distributed generation (DG), but they have some discretion to ask for investment contributions (anleggsbidrag)
- Profitability of network reinforcements due to DG connections depends on the (imperfect) signals form the regulation model
- DG can pose challenges for designing viable and fair tariff structures