Universidad Pontificia Comillas Madrid
ICAI ICADE
Escuela Técnica Superior de Ingeniería
Instituto de Investigación Tecnológica (IIT)

Modelos Económicos de Regulación de la Distribución Eléctrica

Tomás Gómez

II Encuentro Internacional de Regulación 2009

Ciudad de Lima, Perú. 21 y 22 de septiembre 2009.

Contents

- Distribution regulation
- Distribution costs & revenues
- RPI-X experiences
  - Great Britain
  - Norway
  - Spain
- Quality of service regulation
- Incentives to reduce energy losses
- Regulatory tools

New regulatory approach

- Before restructuring
  - generation, transmission, distribution, and retailing where bundled in one single company (vertical integration)
- After restructuring
  - generation and energy retail are unbundled as competitive businesses
  - transmission and distribution networks still continue regulated as natural monopolies

Distribution

- Distribution networks to transmit the electricity to final customers (HV, MV and LV networks)
- Distribution companies are regulated
- European Directive 2003/54/EC mandates:
  - Legal separation of DSOs
  - Regulated Third Party Access (TPA)
- Distribution activities are
  - Investment and maintenance of network infrastructures
  - Provision of network services to final customers
  - Retail to still regulated customers (changing nowadays – July 2009 was the deadline for Spain)

Distribution regulation

- Natural monopoly that must be regulated
  - Duplicate networks in the same area is inefficient
  - Regulation of: revenues, quality of service, access, obligation of supply, territorial franchise
  - A small risk business (typically)
- Distribution must be regulated separately from transmission

Remuneration of distribution (1)

- Distribution is a regulated monopoly: remuneration based on allowed costs
  - Investment costs (CAPEX)
    - network infrastructure
    - general plant: buildings, office equipment
  - Operating costs (OPEX)
    - operation and maintenance of facilities
    - commercial services, i.e., metering and billing

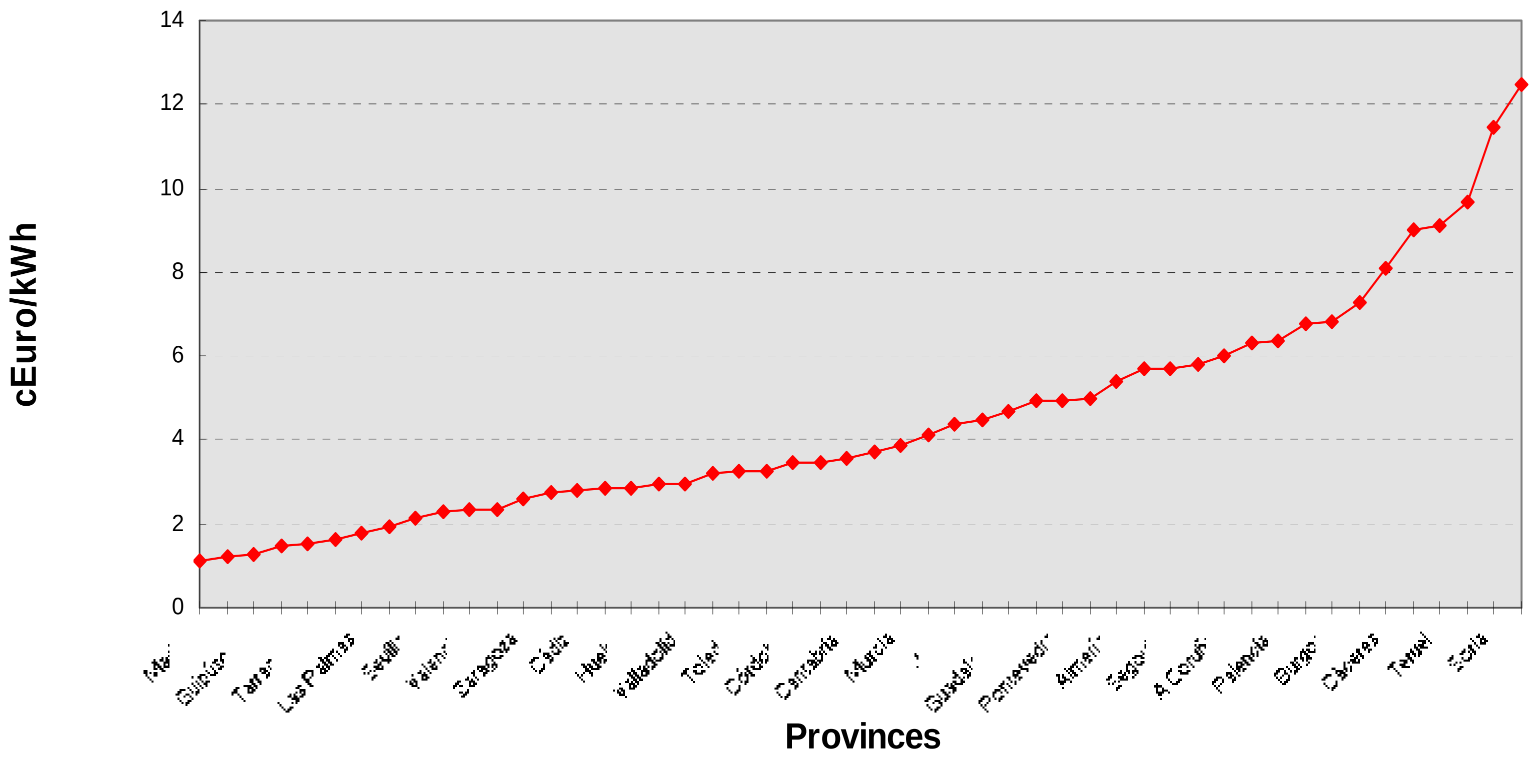
TOTAL COSTS (t) = OPEX (t) + CAPEX (t) + TAXES (t) =
*OPEX (t) + DEPRECIATION (t) + ASSET_BASE (t)*WACC + TAXES (t)*

Remuneration of distribution (2)

- The regulator should observe these principles:
  - ensure firm´s financial viability vs. low customer tariffs
  - Recognize the zonal differences in distribution costs
  - Basic remuneration : **minimum cost** to meet **quality of service** & **losses** standards (zonal differences)

Case example: Spain. Differences between regions

Based on the results of a study of HC



Remuneration schemes

- The Regulator sets the annual allowed revenues
- There is no widely accepted approach
- Two main approaches:
  - – Cost-of-service or rate-of-return
  - – Incentive regulation RPI-X
    - Price cap
    - Revenue cap

Cost-of-service remuneration (pros/cons)

- Advantages
  - financial stability
  - cost of capital should be low (low risk)
  - optimal investment levels & quality of service (caution: Averch-Johnson effect, overinvestment if the rate of return is high)
- Disadvantages
  - no incentives to keep costs down
  - based on utility´s audited records: administrative burden, cumbersome to follow in detail (information asymmetry)
  - Regulatory involvement in the daily business of the firm

RPI-X remuneration

- Formalized regulatory lag (4 or 5 years) between price reviews
- Companies incentives to reduce costs and earn profits
- Two approaches
  - **"Price cap":** trajectory of maximum prices

$$\overline{P_{m,t}} = \overline{P_{m,t-1}} \times (1 + I - X) \pm Z$$

  - **"Revenue cap",** also called revenue-yield control: trajectory of maximum revenues

$$\overline{R_t} = (\overline{R_{t-1}} + CGA \times \Delta Cust) \times (1 + I - X) \pm Z$$

Revenue vs. price caps

- With a revenue cap scheme
  - it is possible to adjust X so that the net present value of the revenues and the costs over the price control period are equal
  - The firm also has an incentive to increase the cost driver (e.g. total sales), but now the expression has a better fit to the actual costs
  - Prices change in advance, but revenues can only be checked a posteriori ➔ correction term

Contents

- Distribution regulation
- Distribution costs & revenues
- RPI-X experiences
  - Great Britain
  - Norway
  - Spain
- Quality of service regulation
- Incentives to reduce energy losses
- Regulatory tools

Distribution Costs

- Capital expenditure (CAPEX)
  - Investment, depreciation, and return
- Operational expenditure (OPEX)
  - Personnel, maintenance, operations
- Non controllable costs
  - Taxes, upstream fees, exceptional items

Regulator can adjust the X factor so that the present value of revenues should equal the present value of estimated efficient costs (a different regulatory scheme can be applied to each cost category).

General framework: network costs

- The regulator has to assess the efficient network costs in order to set the company revenues
- No matter the selected remuneration scheme (cost of service, price or revenue cap), in each rate case or price review the regulator has to determine which are the allowed costs to be remunerated
- The net present value of the allowed revenues should be equal to the net present value of the efficient costs along the next regulatory period (4 or 5 years)
- The cost concepts to be evaluated and set are:
  - Projected Investment and asset base } CAPEX
  - Rate of return on equity and debt (WACC) } CAPEX
  - Operating costs OPEX

General framework: CAPEX

- The CAPEX are calculated as the efficient asset base times the allowed rate of return plus the annual depreciation & annual investment

- The asset base is equal to the net assets. By the accounting method, the net assets are calculated as the gross assets minus the accumulated depreciation depending on the life of the assets

- Another alternative method to calculate the CAPEX is to compute the annuity of the total assets calculated as the Replacement Cost of a network adapted to supply the actual demand (VNR in Latin America). The discount rate is the allowed rate of return (WACC)

The asset base (rate base)

- Alternative evaluation procedures
  - Book value (historic cost valuation)
  - Reproduction cost (current cost of reconstructing the same infrastructures)
  - Replacement cost (replace existing infrastructures with the newest technology that is able to perform the same functionality)

The rate of return

- The rate of return is a key variable in price control, since it directly affects present value analysis
  - WACC is the average remuneration of the firm's capital
  - The discount factor d is used in present value calculations d=1/(1+WACC)
- Weighted average cost of capital

$$WACC_{before\_taxes} = (RF+ß.(MR-RF)+CR).(1/(1-t)).(E/(E+D))+ + (RF+CR).(D/(E+D))$$

$$WACC_{after\_taxes} = (1-t).WACC_{before\_taxes}$$

RF: risk-free rate
MR: market risk rate
CR: country risk rate

E: equity
D: debt
t: tax rate

General framework: OPEX

- The annual OPEX are calculated as the sum of efficient:
  - Operation and maintenance costs of network installations
  - Commercial management costs of customers
  - Administrative costs associated with general plant (headquarters and offices) and corporative services

Regulatory tools

- Regulators use different tools to set an efficient pattern for CAPEX & OPEX
  - Regulatory accounting (costs accounting related to activities and physical installations)
  - Benchmarking techniques (comparison of efficiency between several firms): Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA)
  - Network models (optimize the investment and operating costs to supply the distribution area with an efficient network)

Contents

- Distribution regulation
- Distribution costs & revenues
- RPI-X experiences
  - Great Britain
  - Norway
  - Spain
- Quality of service regulation
- Incentives to reduce energy losses
- Regulatory tools

Distribution business in Great Britain

- Since privatization in 1990, In England and Wales there are 12 private distribution companies (Regional Electricity Companies RECs), two vertically integrated in Scotland (Hydro-electric and Scottish Power) and Northern Ireland Electricity in Nord Ireland
- After merger adquisitions, the number of owners has been reduced to seven.
- With the Utilities Act 2000 and since October 2001, there is accounting and legal unbundling of distribution network operators (DNOs) from supplier companies. They need different licenses.

Distribution remuneration in GB

- Price control (RPI-X) in each regulatory period of five years. The last price control has been for the period 2006-2010.
- Fist period from the privatization process to 1995, second period 1996-2000, third period 2001-2005.
- Price control structure:
  - The base remuneration is associated with a revenue driver. A weighted average of distributed energy and number of customers is used.
  - Incentives for:
    - Energy losses reduction and energy efficiency promotion
    - Improvement of the quality of service (supply interruptions and customer services through phone calls)
  - Pass-through of transmission connection costs and other non-controllable distribution costs
  - Revenue correction due to revenue deviations (positive or negative) in previous periods

2005/10 Price review in GB (CAPEX)

- **Valuation of assets**: companies provide accounting values of investment and depreciations in the last period. The regulator sets the regulatory asset value (RAV).
- **Cost of capital**: OFGEM set a rate of return at 6.9 % (4.8% after taxes). Debt cost was 4.1% and equity 7.5%.
- **New investments**: Matrix for DSOs incentives related to CAPEX (allowed vs. actual) [OFGEM]

DNO:PB Power Ratio	100	105	110	115	120	125	130	135	140
Efficiency Incentive	40%	38%	35%	33%	30%	28%	25%	23%	20%
Additional income	2.5	2.1	1.6	1.1	0.6	-0.1	-0.8	-1.6	-2.4
as pre-tax rate of return	0.200%	0.168%	0.130%	0.090%	0.046%	-0.004%	-0.062%	-0.124%	-0.192%
Rewards & Penalties									
Allowed expenditure	105	106.25	107.5	108.75	110	111.25	112.5	113.75	115
Actual Exp									
70	16.5	15.7	14.8	13.7	12.6	11.3	9.9	8.3	6.6
80	12.5	11.9	11.3	10.5	9.6	8.5	7.4	6.0	4.6
90	8.5	8.2	7.8	7.2	6.6	5.8	4.9	3.8	2.6
100	4.5	4.4	4.3	4.0	3.6	3.0	2.4	1.5	0.6
105	2.5	2.6	2.5	2.3	2.1	1.7	1.1	0.4	-0.4
110	0.5	0.7	0.8	0.7	0.6	0.3	-0.1	-0.7	-1.4
115	-1.5	-1.2	-1.0	-0.9	-0.9	-1.1	-1.4	-1.8	-2.4
120	-3.5	-3.1	-2.7	-2.5	-2.4	-2.5	-2.6	-3.0	-3.4
125	-5.5	-4.9	-4.5	-4.2	-3.9	-3.8	-3.9	-4.1	-4.4
130	-7.5	-6.8	-6.2	-5.8	-5.4	-5.2	-5.1	-5.2	-5.4
135	-9.5	-8.7	-8.0	-7.4	-6.9	-6.6	-6.4	-6.3	-6.4
140	-11.5	-10.6	-9.7	-9.0	-8.4	-8.0	-7.6	-7.5	-7.4

2005/10 price review in GB (OPEX)

- Operating costs evaluation (benchmarking):
  - operating costs reported by DNOs
  - regression analysis (Ordinary Least Squares) as a function of the outputs:
    - Length of the distribution network
    - Number of customers
    - Number of distribution substations
  - Setting of the frontier selecting the 25% most efficient DNOs (Corrected ordinary least squares)

Revenue cap in Norway

- In 1991 a new Energy Act became effective
- Wholesale generation and customer retail became in competitive businesses
- There are 190 distribution companies
- Cost-of-service remuneration was applied to distribution between 1991-1996
- A revenue cap formula: 1997-2001, 2002-06, 2007-11

$$IT_{e,n+1} = IT_{e,n} \cdot \left(\frac{KPI_{n+1}}{KPI_n} \right) \cdot \left(1 - EFK_{n+1}\right) \cdot \left(1 + 0.5 \cdot \Delta LE\right)$$

Revenue cap in Norway. Efficiency comparison

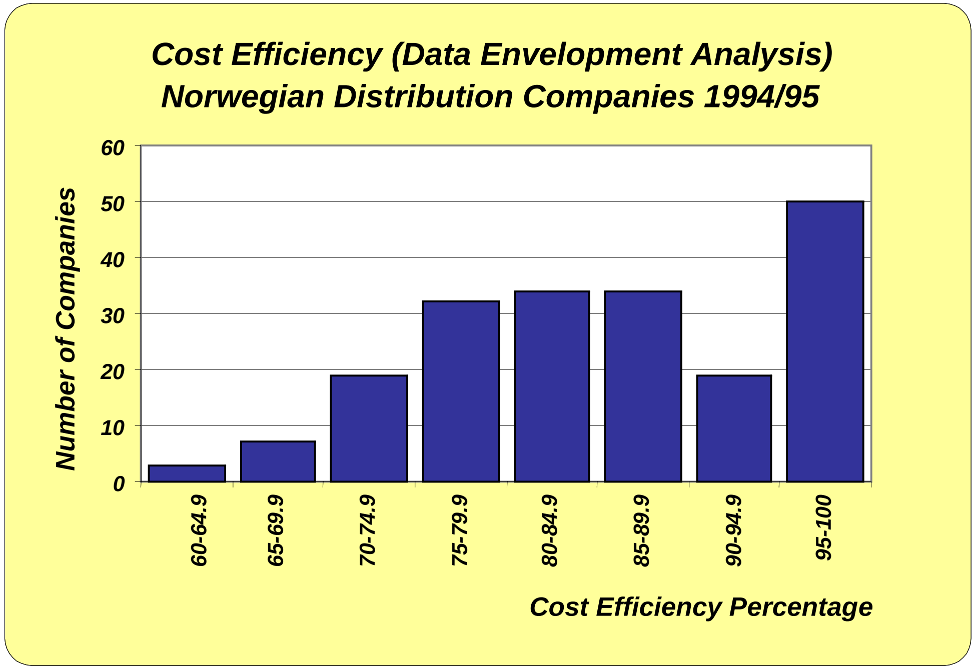
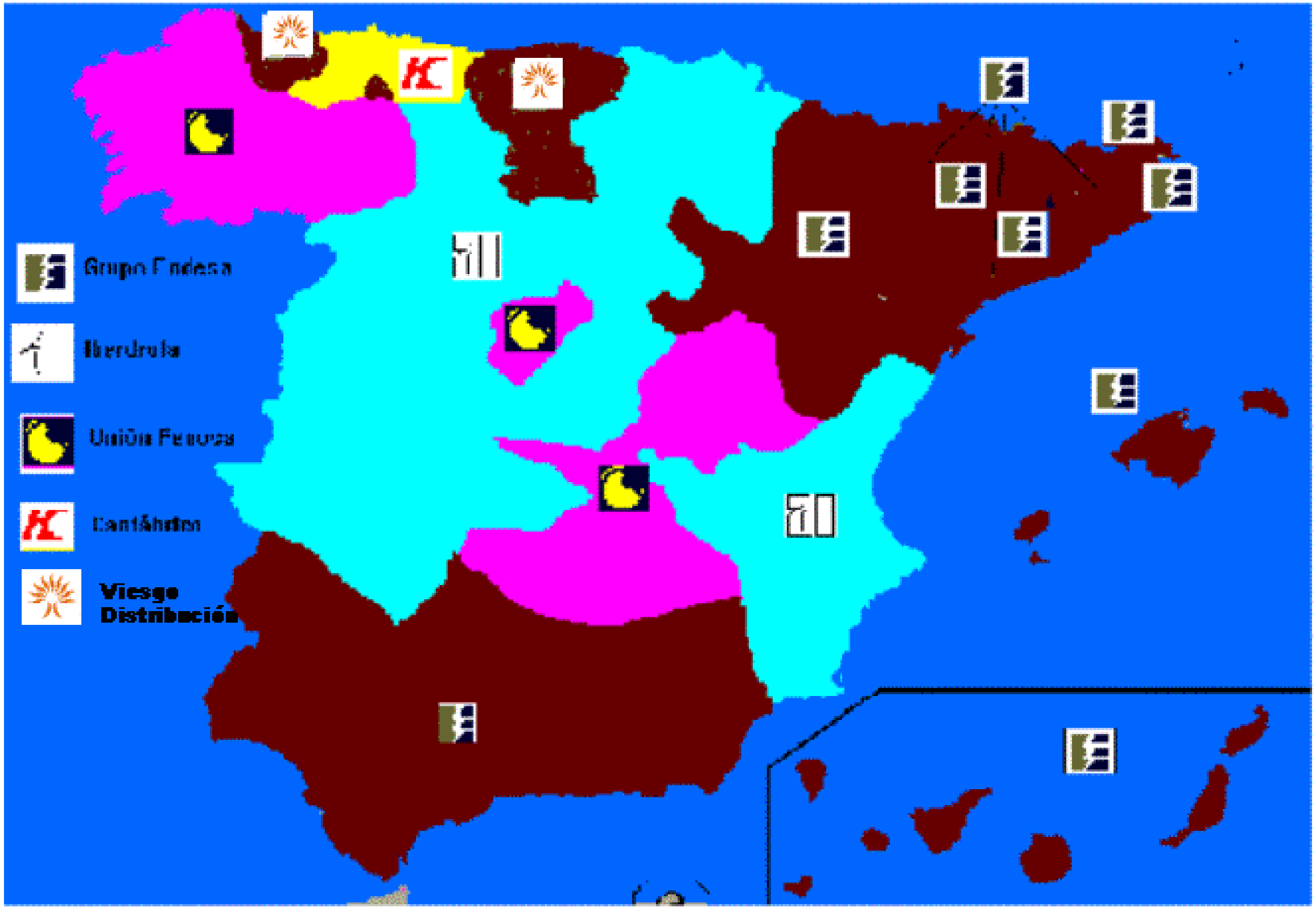


Table 5.1 Output and input variables used in the Norwegian DEA for distribution companies.

Output Variables	Input Variables
• Number of customers • Energy delivered [MWh] • Length of higher voltage cables [km] • Length of sea cables [km] • Length of lower voltage cables [km]	• Number of annual labor hours • Network losses [MWh] • Capital investments [NOK 1,000] • Services and goods [NOK 1,000]

Source: NVE, 2000

Major DSOs in Spain

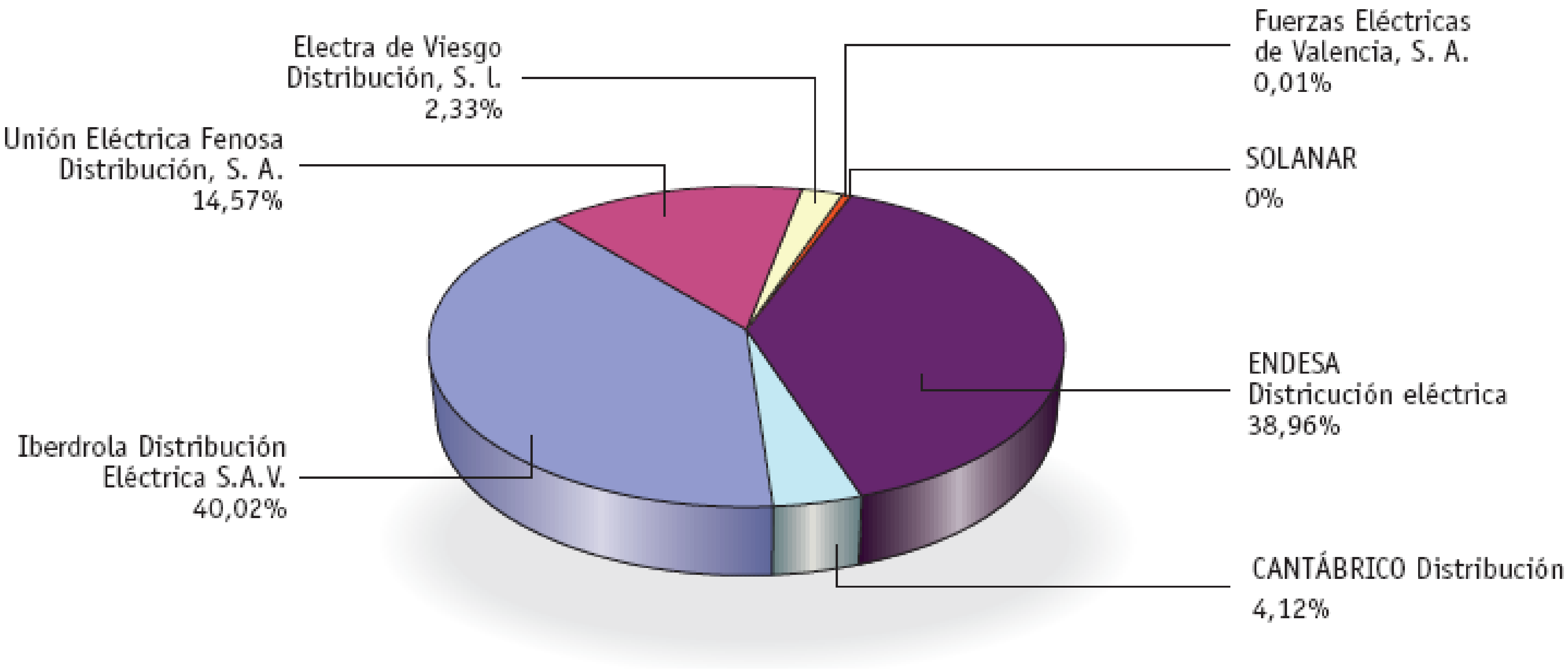


Source: CNE

Note: In addition, there are more than 300 small DSOs

Revenue cap in Spain

- Distributed energy in 2006 in the peninsula: 231 TWh



Source: CNE. Información básica de los sectores de energía, 2007

Revenue cap in Spain

- Basic principles (RD222/2008):
  - A revenue cap for each individual DSO
  - Regulatory period: 4 years
  - Baseline updated taking into account actual DSO investment and OPEX but using as benchmark a **network reference model (NRM)**
  - Annual increment of revenues calculated as a function of the annual market (demand and new connections) increments
  - Benchmarking and Efficiency improvement factors of OPEX unitary costs
  - Incentives and penalties associated with meeting continuity of supply targets (TIEPI and NIEPI in urban, semi-urban, and rural areas)
  - Incentives to energy losses reductions

Revenue cap in Spain

- With the new Electricity Act, since 1998, the whole distribution was regulated by a revenue control formula
- In 2008, the RD222/2008 set a revenue formula for each DSO:

$$R_0^i = R_{base}^i (1 + IA_0)$$

$$R_1^i = R_0^i (1 + IA_1) + Y_0^i + Q_0^i + P_0^i$$

$$R_2^i = (R_1^i - Q_0^i - P_0^i)(1 + IA_2) + Y_1^i + Q_1^i + P_1^i$$

$$R_{n+1}^i = (R_n^i - Q_{n-1}^i - P_{n-1}^i)(1 + IA_{n+1}) + Y_n^i + Q_n^i + P_n^i ; n = 2, 3$$

i: DSO i

n: year n

Y: revenue increment to remunerate incremental costs for supplying the incremental demand (and new DG connections)

Q: incentives/penalty for continuity of supply results

P: incentives/penalties for energy losses reductions

$$IA_n = 0.2 \cdot (IPC_{n-1} - x) + 0.8 \cdot (IPRI_{n-1} - y)$$

$x = 80$; $y = 40$ points

The base remuneration: RD222/2008

- Every four years for each company *i* the Regulator will calculate the base remuneration

$$R_{base}^{i} = CI_{base}^{i} + COM_{base}^{i} + OCD_{base}^{i}$$

CI_{base}^{i}	Are the capital costs calculated as the annual depreciation of assets and the rate of return on investment (WACC * rate base).
COM_{base}^{i}	Are the operation and maintenance costs. They are calculated by applying standard efficient costs (benchmarking) to existing installations. (For LV the NRM will be used.)
OCD_{base}^{i}	Other distribution costs: customer services (billing and metering, new connections), planning and energy management. Standard costs from actual costs (benchmarking). Municipal taxes.

The incremental annual remuneration: RD222/2008

Y_{n-1}^{i}

In every year *n* the remuneration of company *i* will be updated according to the increment of activity occurred in year *n-1*.

This is calculated as the increment of CAPEX and OPEX due to supply the annual incremental demand. A network reference model (NRM) will be used.

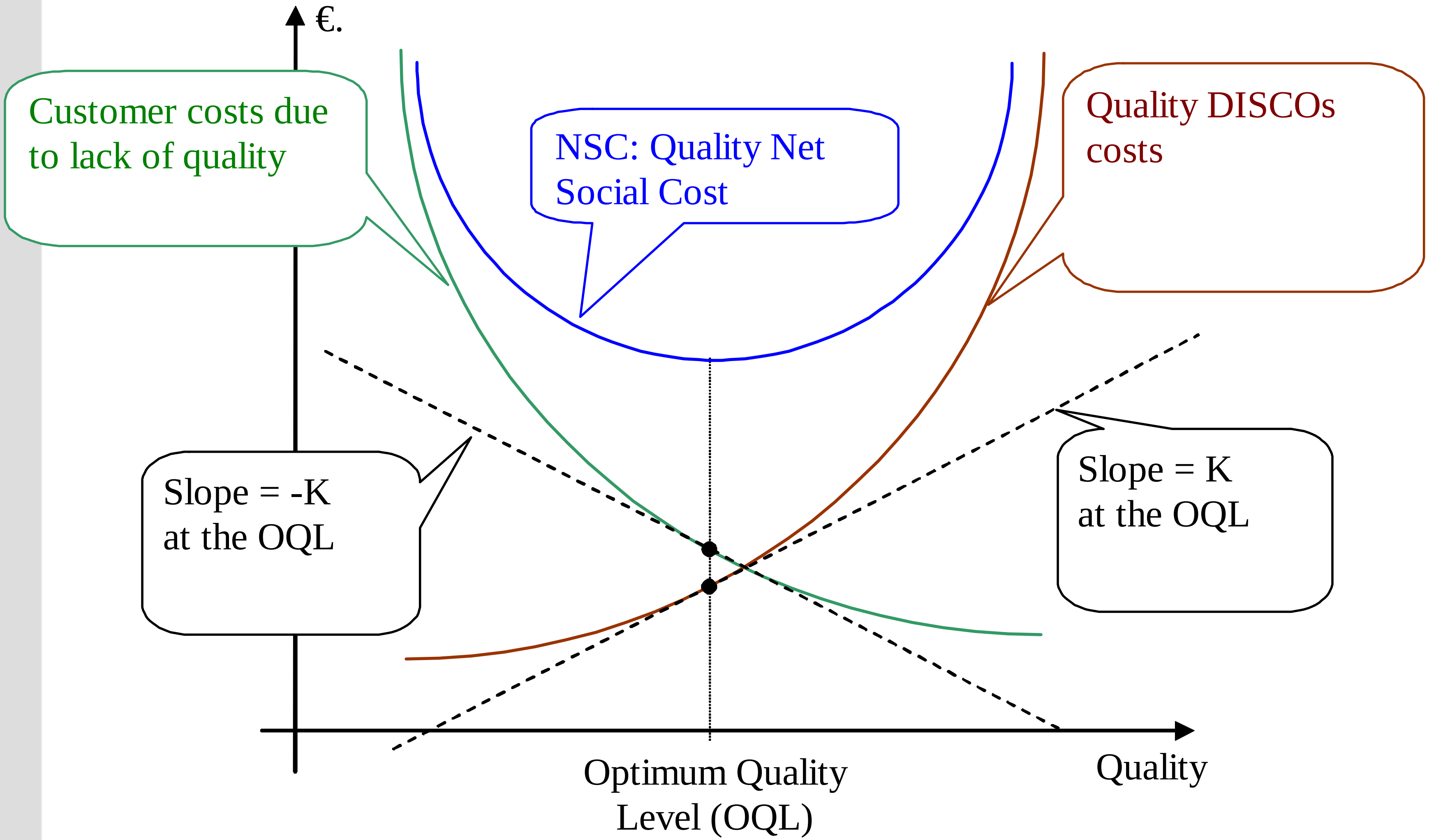
Contents

- Distribution regulation
- Distribution costs & revenues
- RPI-X experiences
  - Great Britain
  - Norway
  - Spain
- Quality of service regulation
- Incentives to reduce energy losses
- Regulatory tools

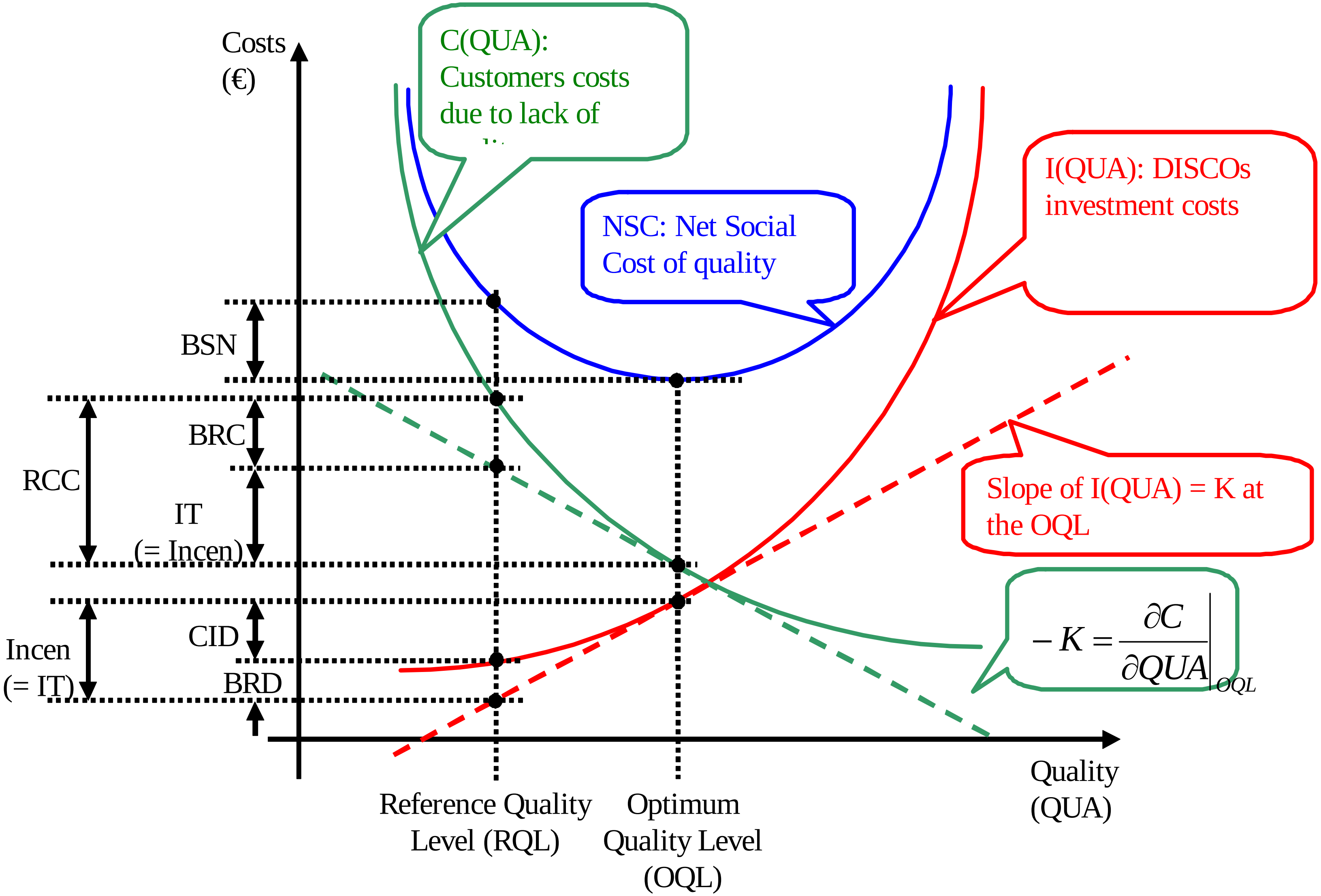
Quality of service control

- Cost reduction incentives can lead to quality degradation => regulation and control
- Distribution companies are responsible for :
  - reliability (interruptions)
  - voltage quality (voltage levels and disturbances)
  - customer services
- The regulator can implement penalty mechanisms to ensure that distribution companies meet specific quality requirements
- SAIDI & SAIFI are measured and controlled
- European standard EN – 50160 on voltage quality

Regulation: Optimum Quality Level



Regulation: incentives/penalizations



Incentivos zonales y penalizaciones individuales

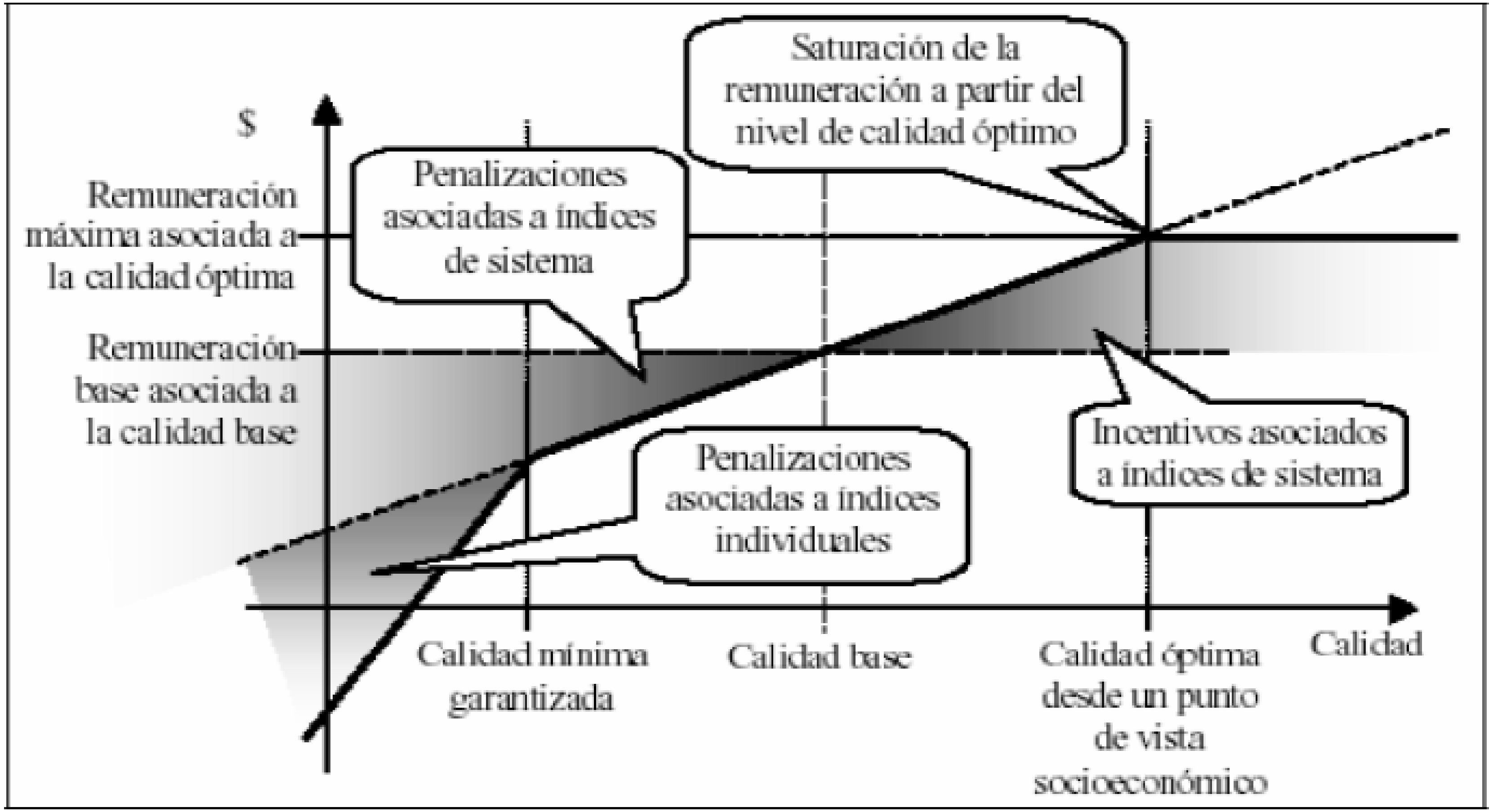
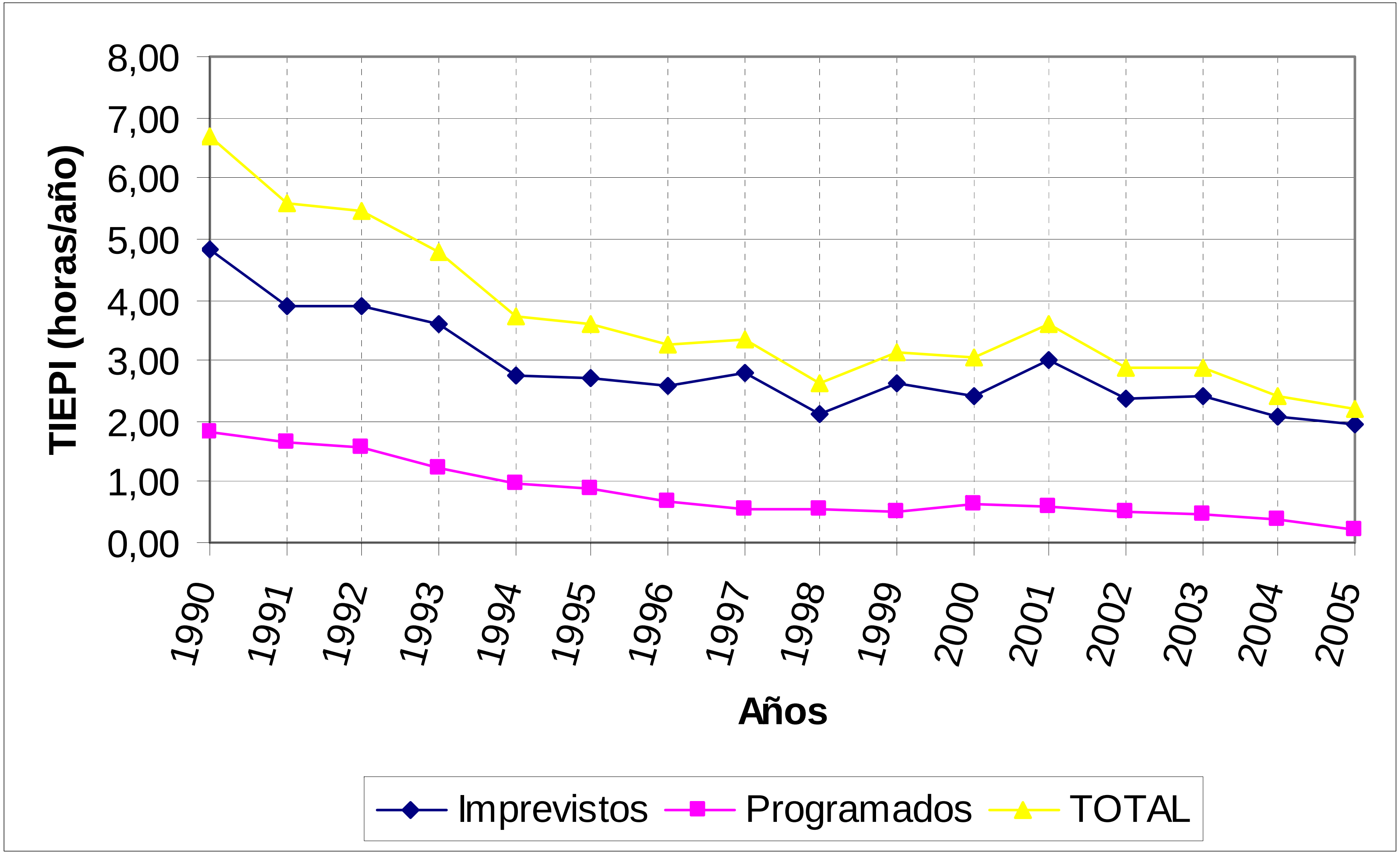


Figura 24. Mecanismos para incentivar la calidad de servicio

Quality of service in Great Britain

- OFGEM asks for measurement of continuity of supply indices
  - SAIDI (average number of supply interruption minutes per customer)
  - SAIFI (number of interruptions per 100 customers)
- The SAIFI decreased from 112.6 in 90/91 to 81.4 in 99/00
- In the same period the SAIDI decreased from 227.4 to 70.8.
- Target values for SAIFI and SAIDI in the period 2005-10
- Target for SAIFI: 77.1 interruptions per 100 customers (year 1) to 74.5 (year 5).
- Target for SAIDI: 71.8 minutes per customer (year 1) to 63.8 (year 5)
- There are incentives or penalties up to 3% of the total yearly revenues
- The incentives or penalties are £*150,000* per each point in interruptions, and £*190,000* per each point in minutes

Quality of supply in Spain



Source: CNE

Incentives to improve continuity of supply in Spain

- Continuity of supply indices are controlled in urban, semi-urban and rural areas
  - TIEPI: zonal average interruption duration index per installed MV/LV transformer kVA
  - NIEPI: zonal average interruption frequency index per installed MV/LV transformer kVA
- Incentives as a percentage of the total remuneration, in the range (3%, -3%)
- Current Targets (RD 1634/2006)

ZONES	TIEPI (hours)	NIEPI (Number)
Urban (U)	1,5	3
Semi-urban (SU)	3,5	5
Rural (concentrated) (RC)	6	8
Rural (dispersed) (RD)	9	12

Incentives to improve continuity of supply in Spain

- Formula for incentives/penalties (RD222/2008):

$$Q^i_{n-1} = 0.03 \cdot R^i_{n-1}(\beta^i_U \cdot X^i_{U,n-1} + \beta^i_{SU} \cdot X^i_{SU,n-1} + \beta^i_{RC} \cdot X^i_{RC,n-1} + \beta^i_{RD} \cdot X^i_{RD,n-1})$$

$$X^i_{\alpha,n-1} = \left(1 - \frac{TIEPI^i_{\alpha-ACTUAL,n-1}}{TIEPI_{\alpha-REFERENCE,n-1}}\right) + \left(1 - \frac{NIEPI^i_{\alpha-ACTUAL,n-1}}{NIEPI_{\alpha-REFERENCE,n-1}}\right)$$

β^i_α are weighting coefficients

Quality of supply: individual compensations

- Customer are compensated about five times the cost of the tariff for Non Supplied Energy when the interruptions in one year last longer than or show higher frequency than (RD 1634/2006):

ZONES	LV customer (hours)	LV customer (number)	MV customer (hours)	MV customer (number)
Urban	5	10	3,5	7
Semi-urban	9	13	7	11
Rural (concentrated)	14	16	11	14
Rural (dispersed)	19	22	15	19

Contents

- Distribution regulation
- Distribution costs & revenues
- RPI-X experiences
  - Great Britain
  - Norway
  - Spain
- Quality of service regulation
- Incentives to reduce energy losses
- Regulatory tools

Energy losses

- DNOs should have incentives to reduce energy losses (technical and commercial losses)
- The regulator set target or reference losses levels (different for voltage levels)
- If actual losses are higher than target values then there is an economic penalty and vice versa
- Implementation schemes:

DSO incentive/penalty = ($/MWh) (Elosses_ref - Elosses_act)

Incomes associated with the losses reference values → Distribution company → Payments for actual losses in the energy market

Energy losses in Great Britain

- In the period 2005-10:
  - The reference losses for distribution companies range from 4.94% to 8.73%.
  - The incentive or penalty to reduce energy losses with respect to the reference values is £48/MWh of reduction or increase in energy losses

Incentives to reduce energy losses in Spain

- Each company *i* has an incentive to reduce losses below a reference. Note that the reference losses value is the one for which the base remuneration has been set. The incenitve can be as much as (+1% / -1%) of the total remuneration (RD222/2008).

$$P^i_{n-1} = 0.8 \cdot \mathrm{Pr}_{losses} \cdot (Elosses^i_{REFERENCE,n-1} - Elosses^i_{ACTUAL,n-1})(E^i_{input} + E^i_g)$$

The actual energy losses are calculated as:

$$Elosses^i_{ACTUAL,n-1} = \frac{(E^i_{input} + E^i_g) - E^i_{billed}}{(E^i_{input} + E^i_g)}$$

Pr_{losses}	Is the price of the energy losses deviations in Euros/MWh

Contents

Regulatory tools

- In each rate case or price review, every four years, the regulator in Spain will use mainly two basic tools to compute the basic model parameters

•Regulatory accounting systems
•Network reference models

- These tools will reduce the problem of **information asymmetry**

Regulatory tools

Regulatory accounting
Historic record of OPEX, investment, and DSO assets

→ Economic Efficiency

Network reference models
Development of efficient networks
Targets for quality of supply levels and energy losses

→ Technical Efficiency

Regulatory accounting: OPEX accounts

- Network planning and development
- Network operation and control
- Network maintenance
- Energy management: purchases and settlements
- Power quality and environmental improvements
- Customer management and commercial activities
- Management of new customer connections and meters
- Costs for R&D, general services, other costs

Regulatory accounting: DSO assets

- The standardized asset base is divided into assets depending on the type of installations and voltage levels
- Depreciation on standardized asset base
- Regulated return on standardized asset base

Network reference models

- Two models:
  - **Basic model (Greenfield)**: develops the efficient distribution network from scratch taking into account the GPS location of consumers and distributed generation
  - This model will be used as a benchmark for calculating the reference remuneration for each company in each regulatory period. The CAPEX and OPEX reported by each DSO will be adjusted taking into account the results provided by this model (*this is not clear in the RD222/2008*)
  - This model will be used to estimate the assets and the O&M costs of LV networks due to the lack of information on this type of installations

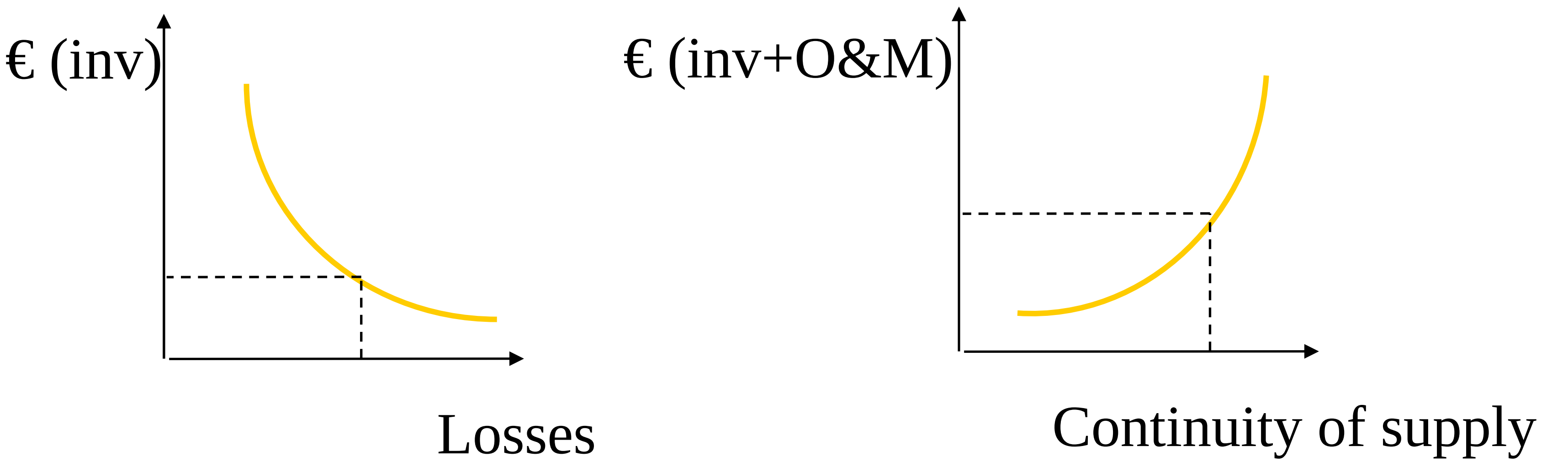
Network reference models

- Two models:
  - **Incremental model**: from the existing network adds new installations and reinforcements to supply demand increments and new connections
  - This model will be used to compute the network incremental costs (investment plus O&M) to supply annual increment of demands (Y parameter)

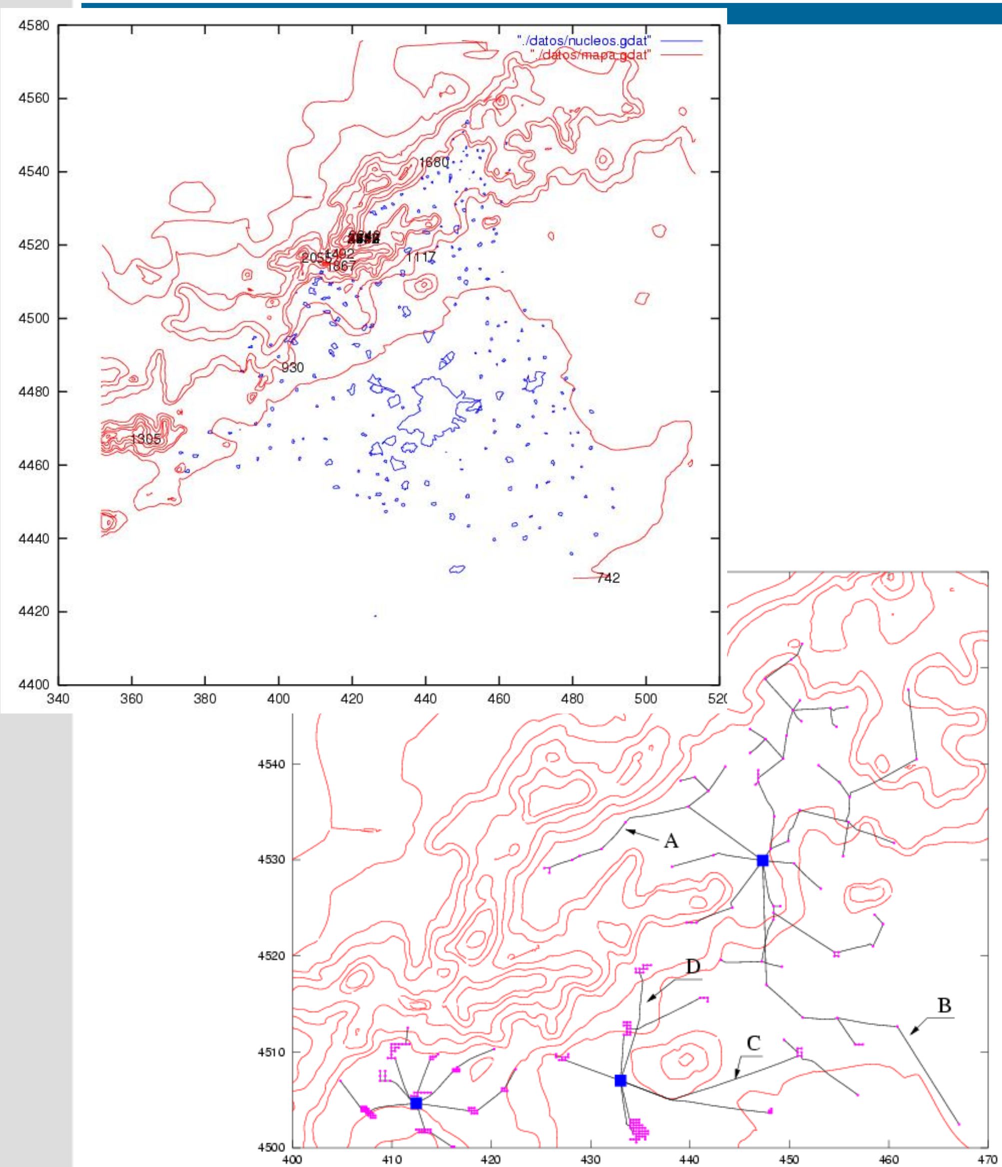
Network reference model

- The developed network minimizes
  - Investment
  - O&M costs
  - Cost of energy losses

  meeting the continuity of supply requirements in the different areas (TIEPI & NIEPI)



Main features of Network Reference Models

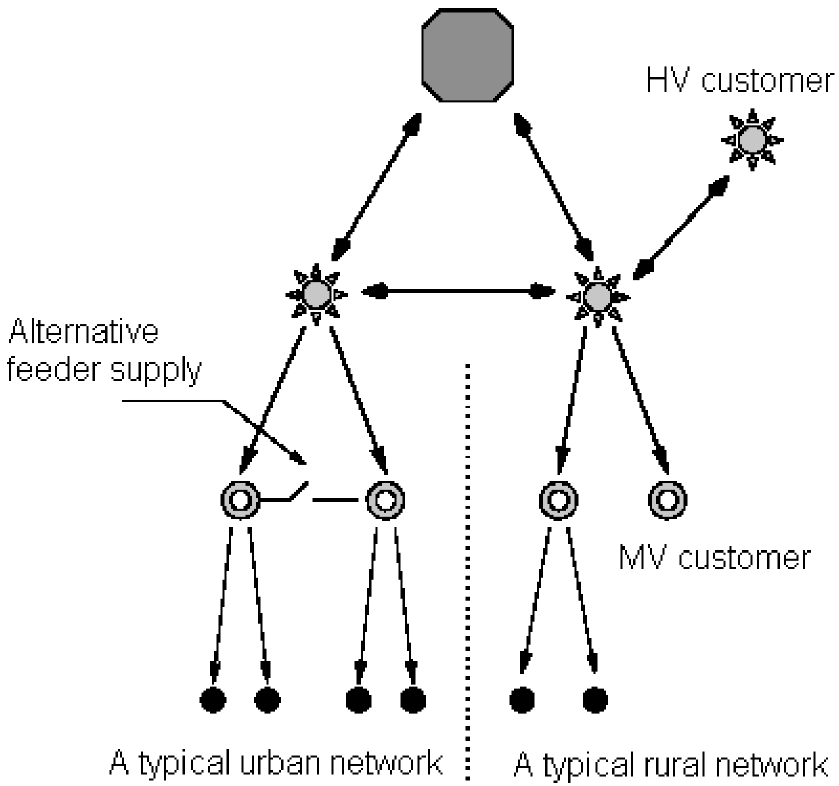


Main Features

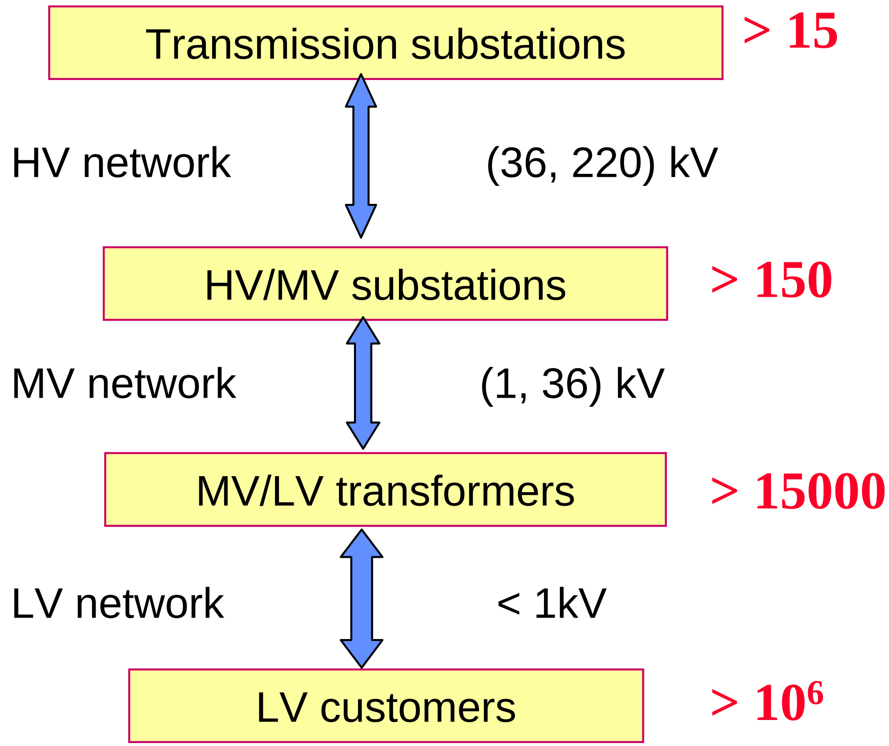
- *Large scale (> 1 million customers)*
- *Both urban & rural areas*
- *Detailed Geographical Features:*
  - *Settlements identification*
  - *Automatic street map building*
  - *Forbidden ways through*
  - *Aerial/underground areas*
- *Voltage, capacity & reliability constraints*
- *Detailed standardized equipment and parameter library*
- *Detailed reliability assessment*

Main features of Network Reference Models

Network Structure

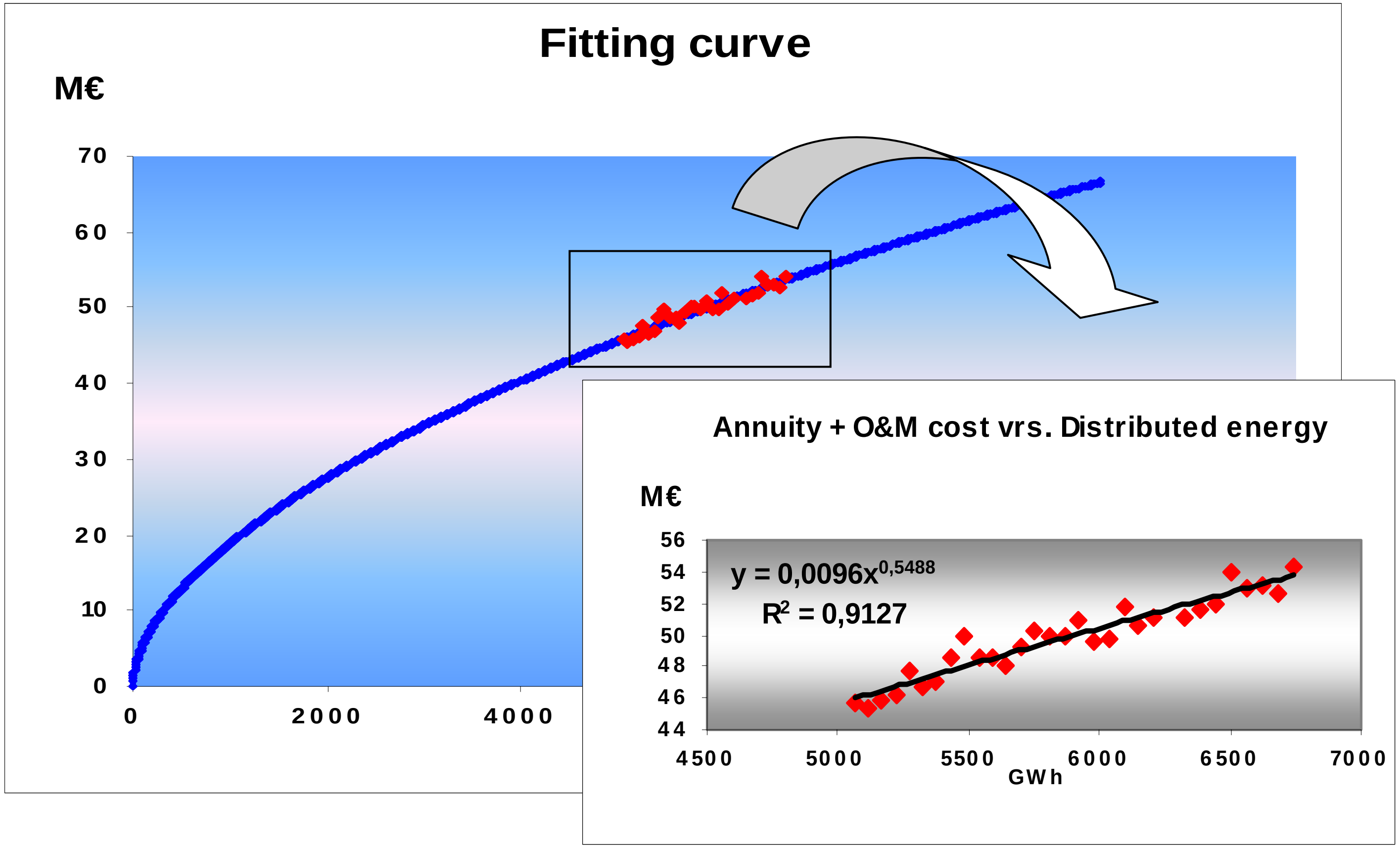


Types and number of facilities



- *Input Data: HV, MV and LV customers, and transmission substations*
- *Results of the model: LV, MV & HV network, HV/MV and MV/LV substations*

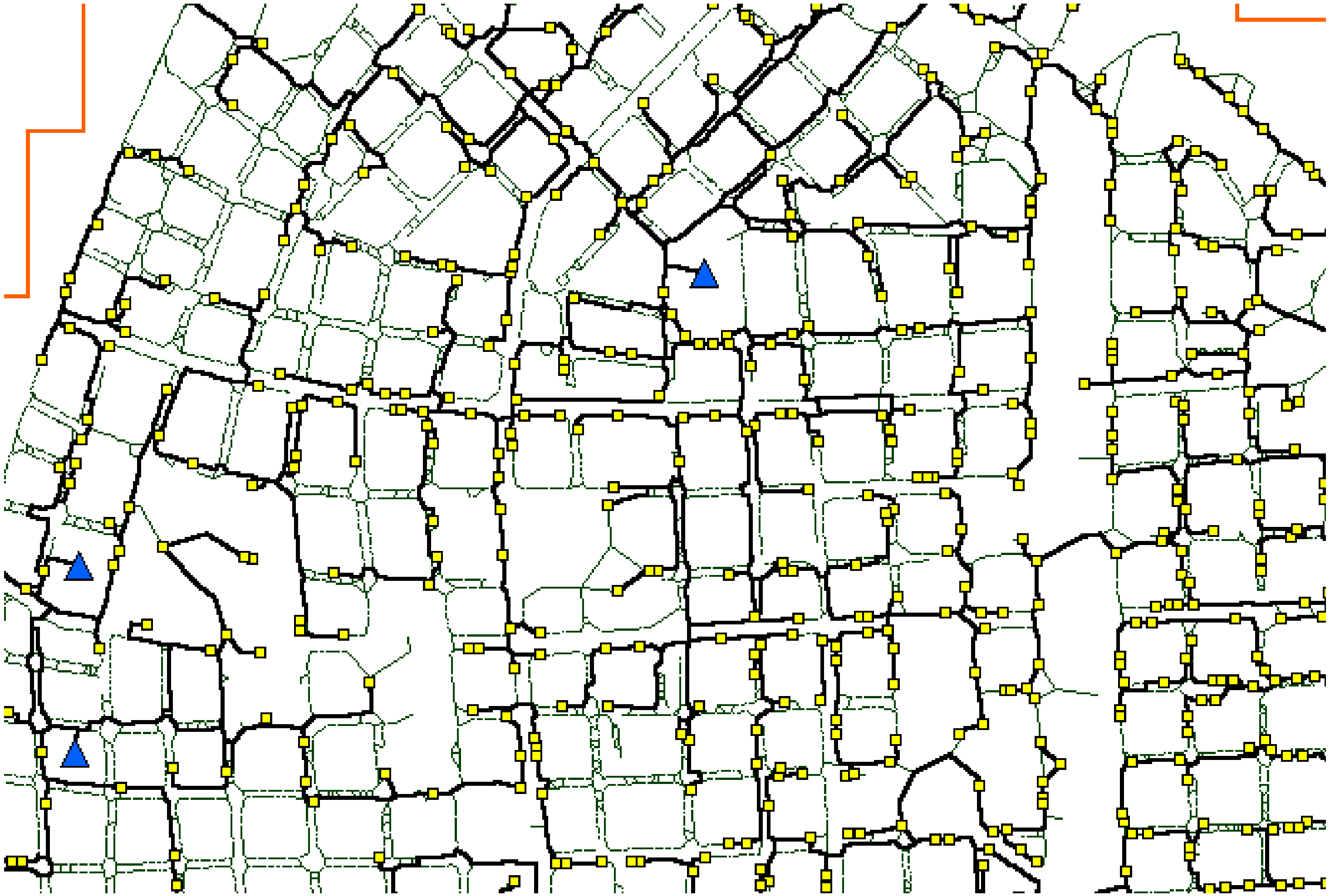
An illustrative example: incremental revenues



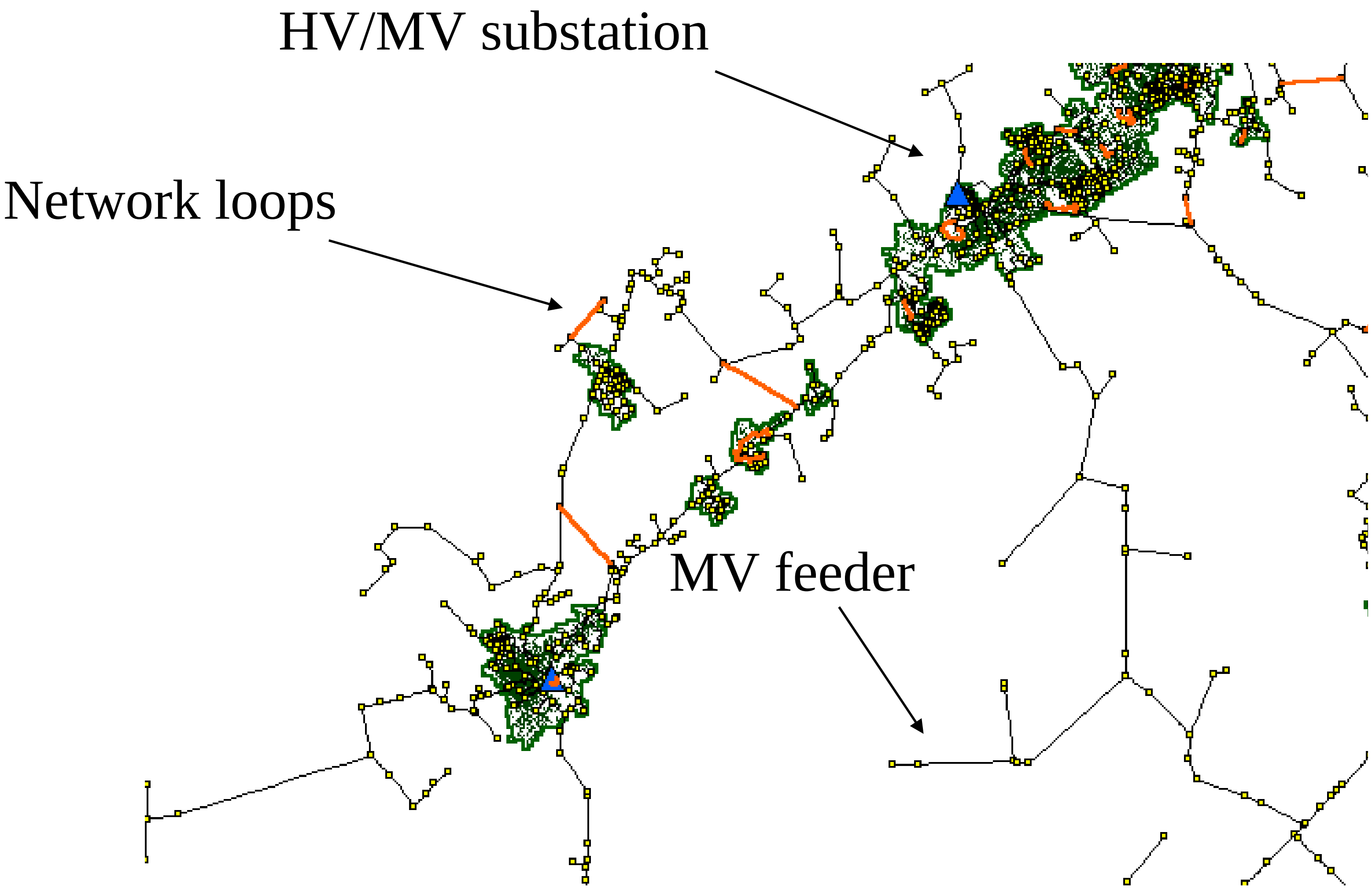
$$\frac{\Delta R}{R} = fe \times \frac{\Delta D}{D}$$

fe = 0.55

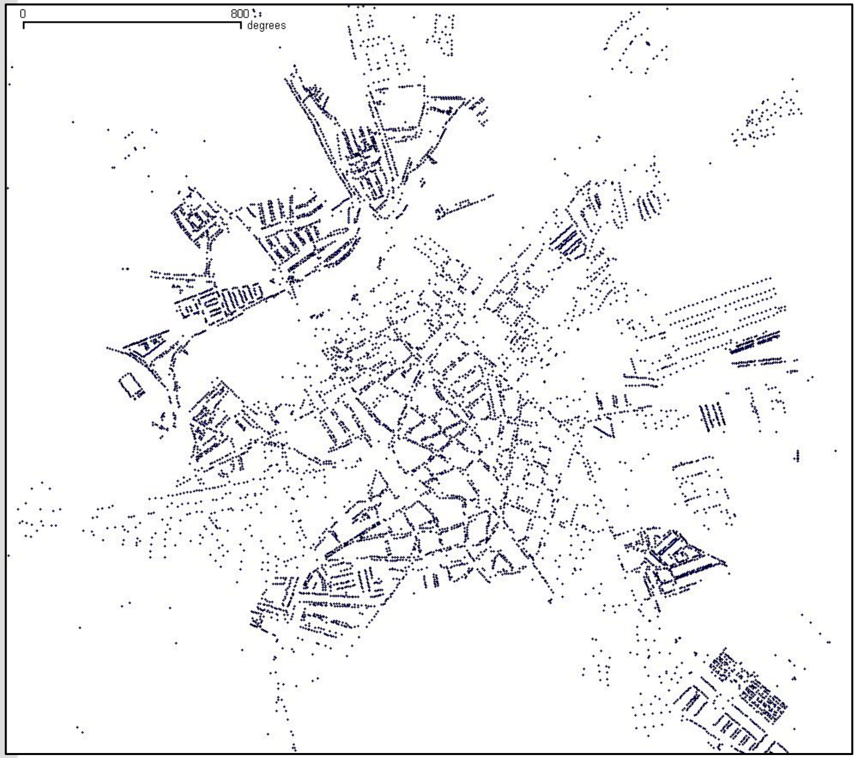
MV urban network



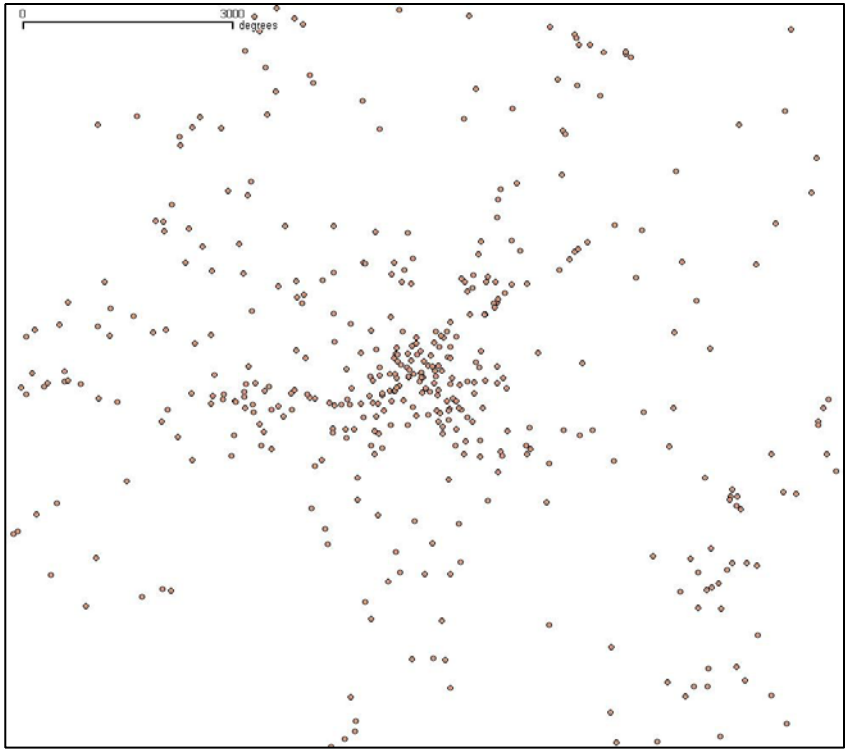
MV urban/rural network



Case study: LV networks in Spain



Location of LV customers



Location of MV/LV transformers

Case study: LV networks in Spain

Conclusions (i)

- Distribution regulation is based on setting
  - annual allowed revenues
  - quality of service requirements
- RPI-X schemes (4 or 5 years) provide an economic incentive for companies to reduce costs
- In addition the remuneration scheme should provide incentives for
  - Efficient investment for demand increments and new connections
  - Improving continuity of supply
  - Losses reductions

Conclusions (ii)

- The Regulator needs methods and tools to estimate efficient distribution costs
- Two basic regulatory tools
  - Regulatory accounting
  - Network reference models
- Network reference models provide a benchmark for investment and O&M costs taking into account continuity of supply requirements and energy losses reductions
- Great Britain and Spain two examples of practical applications

References

- T. Gomez, “Electricity distribution”, Notes for training course for energy regulators, European University Institute, Florence, 2003.
- Geoffrey Rothwell, Tomás Gómez. *Electricity Economics: Regulation and Deregulation*. IEEE-Wiley Press. 2003.
- National Audit Office. *Pipes and Wires*. 2002. Documento que se puede descargar en www.nao.gov.uk
- The Regulatory Assistance Project. *Performance-based Regulation for Distribution Utilities*. 2000.
- T. Gómez, "Regulación de la distribución de energía eléctrica en España. Principios y mecanismos de retribución," Economía Industrial, no. 364, pp. 113-124, March 2007
- OFGEM. *Electricity distribution price control review. Final proposals* DPCR4. Nov. 2004. *www.ofgem.gov.uk*
- Real Decreto 222/2008 *por el que se establece el régimen retributivo de la actividad de distribución de energía eléctrica.* Feb 2008*. www.cne.es*

End of presentation

- tomas.gomez@upcomillas.es

- http://www.iit.upcomillas.es/