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MARIE CURIE ACTIONS

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ELECTRICITY CONSUMPTION ANALYSIS & ENERGY EFFICIENCY

INSTITUTO POLITÉCNICO DO PORTO

gecad

Knowledge Engineering and Decision Support Research Center

First ELECON Workshop
Towards Efficient European and Brazilian Electricity Markets

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ISEP, Porto, Portugal

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ELECTRICITY CONSUMPTION ANALYSIS & ENERGY EFFICIENCY

INSTITUTO POLITÉCNICO DO PORTO

Knowledge Engineering and Decision Support Research Center

Demand Response – Opportunities and Challenges

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Outline

- **XXXX management**
- **Problem formulation**
- **Programming tools**
- **Case study**

DR concepts

- **Definition [USDE-2006]:**

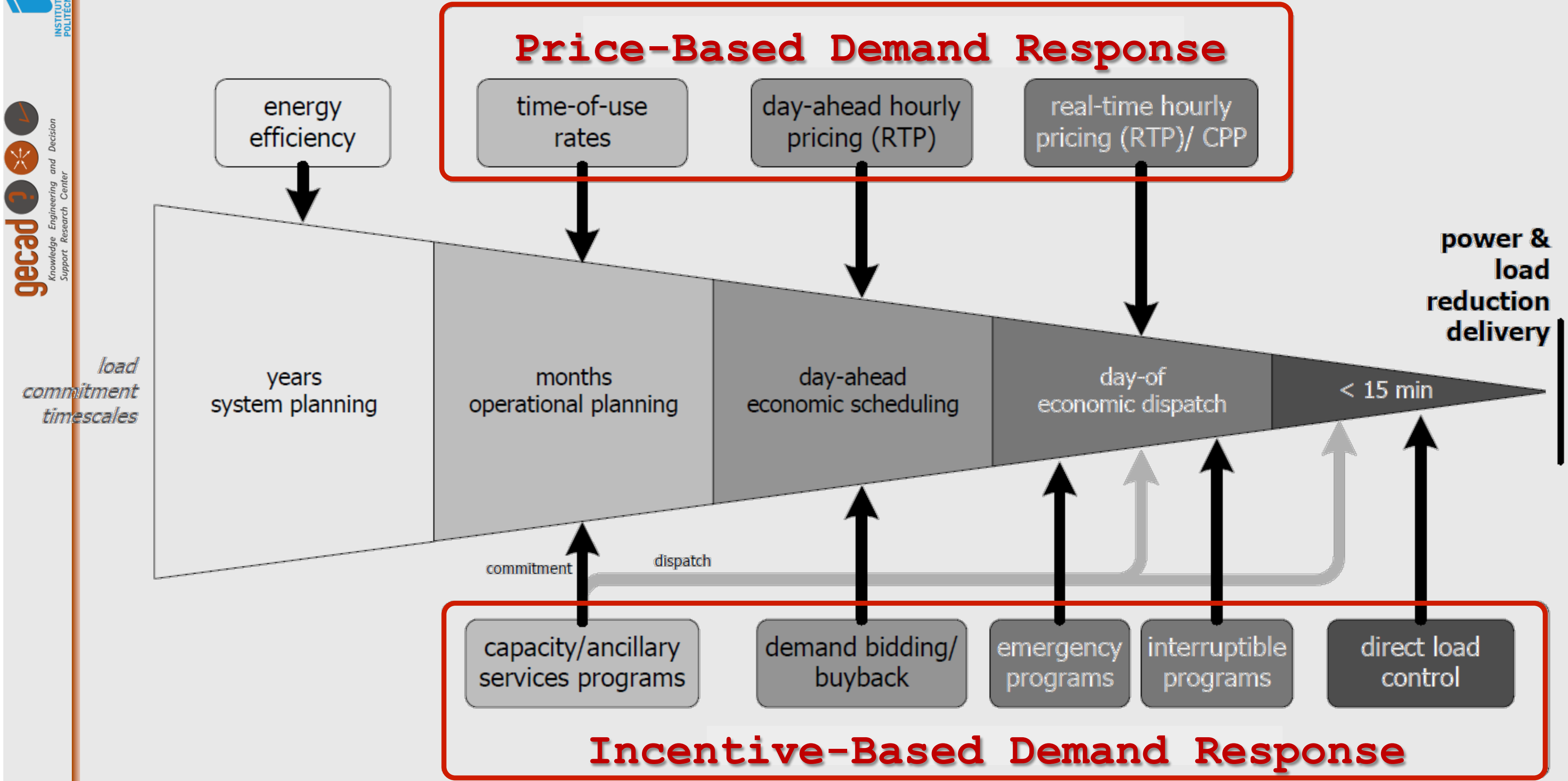
  "Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized."

- **DLC, guaranteed load reduction, firm service level**

- **Shifting, foregoing, on-site generation**

DR concepts

- **Programs**



U.S. Department of Energy, "Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them", USA, February, 2006. Available from: http://eetd.lbl.gov

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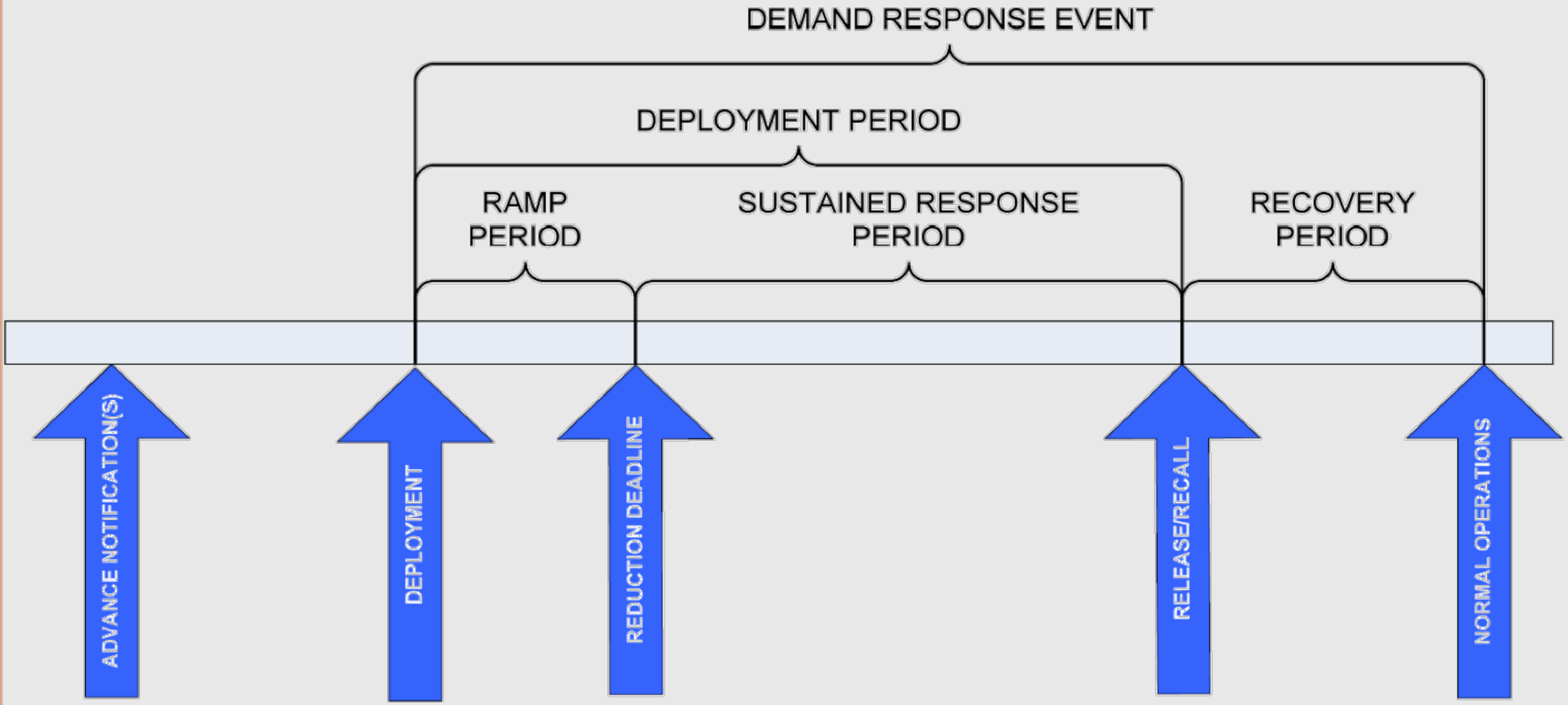
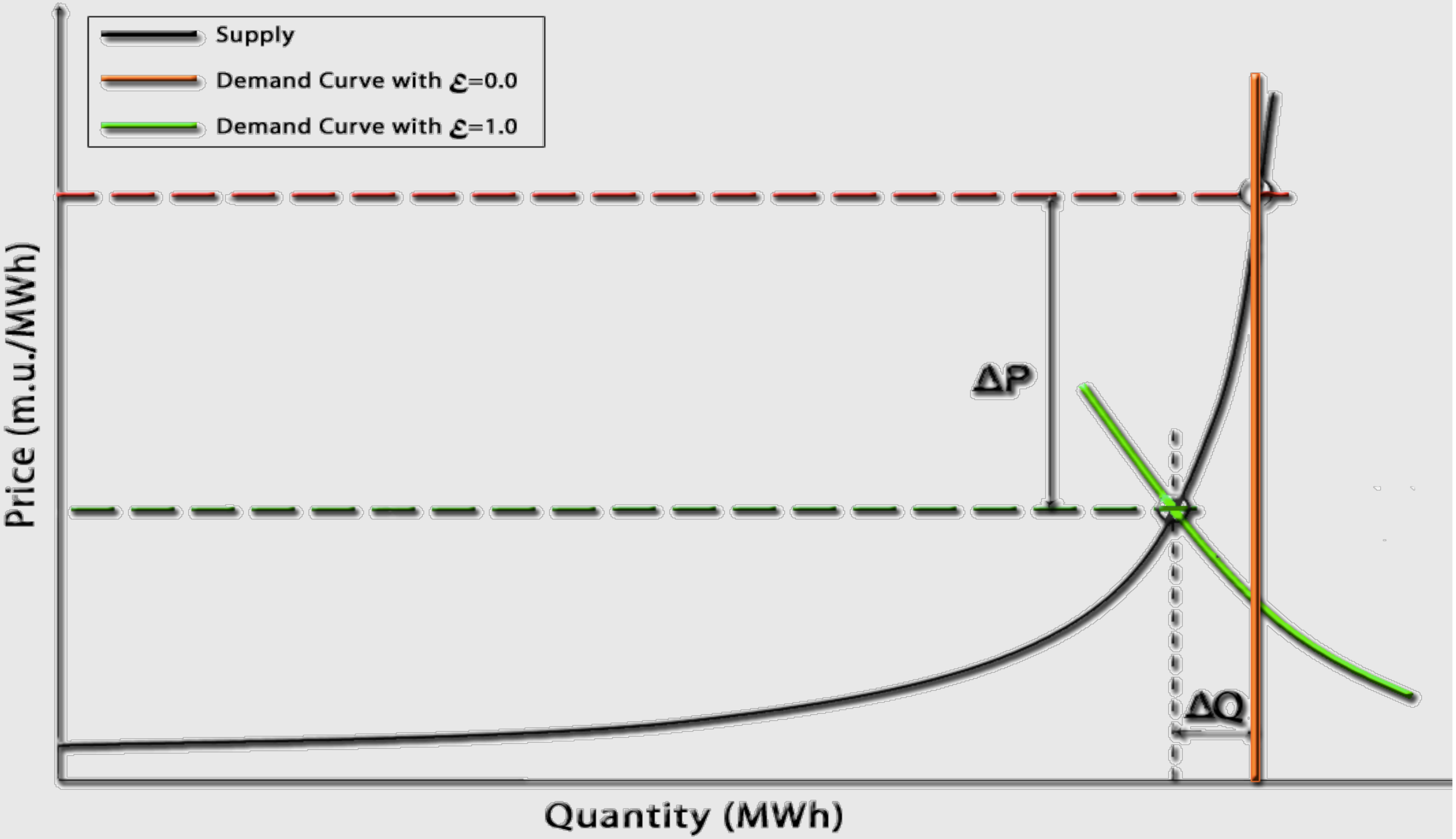
DR concepts

- **Timeline**



- **Price elasticity of demand**



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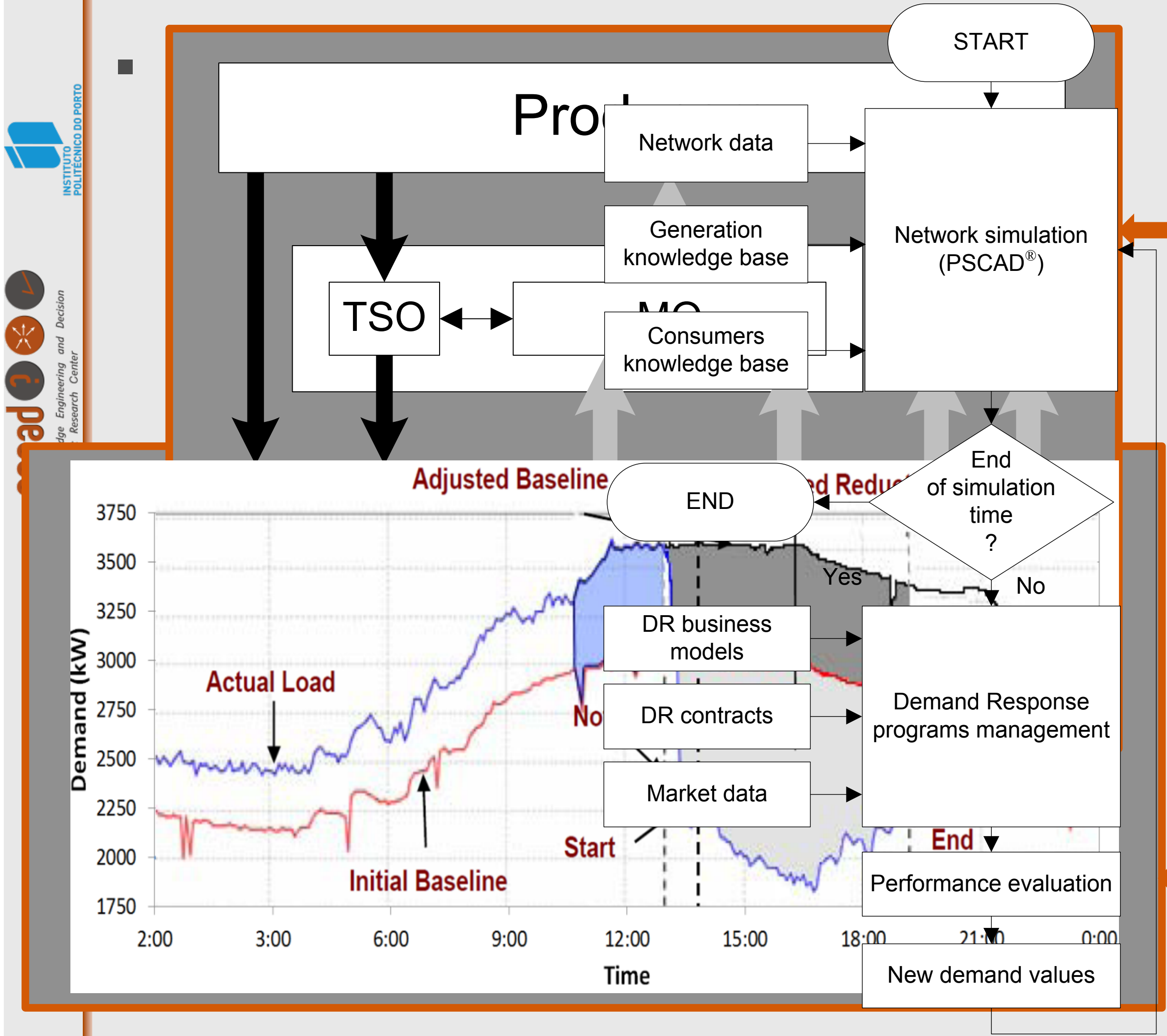
DR concepts



Opportunities and challenges

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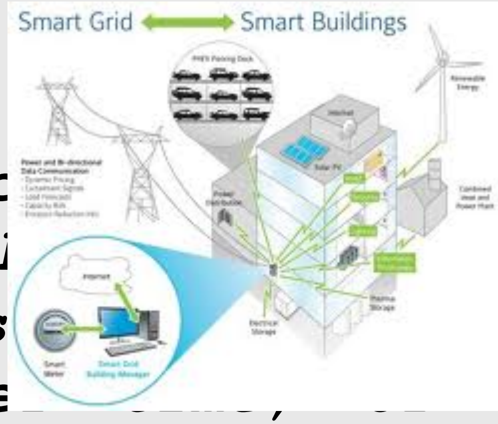
- **Definition [USDE-2006]:**



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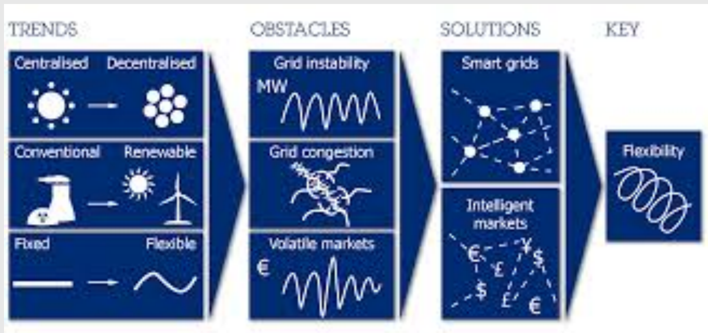


Problem formulation

- **The following mathematical formulation has been used in the SA approach**

Objective Function

$$\min f = f_1 + f_2 + f_3 + f_4$$

Operation cost of the Distributed Generation (DG)

$$f_1 = \sum_{t=1}^{T} \sum_{DG=1}^{N_{DG}} \begin{pmatrix} c_{A(DG,t)} \times X_{DG(DG,t)} + c_{B(DG,t)} \times P_{DG(DG,t)} + \\ c_{C(DG,t)} \times P_{DG(DG,t)}^2 \end{pmatrix}$$

Operation cost of the energy bought from external suppliers

$$f_2 = \sum_{t=1}^{T} \sum_{S=1}^{N_S} c_{SP(S,t)} \times P_{SP(S,t)}$$

Problem formulation

- **The following mathematical formulation has been used in the SA approach**

Objective Function

$$min\ f = f_1 + f_2 + f_3 + f_4$$

Operation cost of the energy bought from EV users

$$f_3 = \sum_{t=1}^{T} \sum_{V=1}^{N_V} c_{Dch(V,t)} \times P_{Dch(V,t)} - c_{Ch(V,t)} \times P_{Ch(V,t)}$$

Penalization cost of the excess available power and non-supplied demand

$$f_4 = \sum_{t=1}^{T} \left(\sum_{L=1}^{N_L} c_{NSD(L,t)} \times P_{NSD(L,t)} + \sum_{DG=1}^{N_{DG}} c_{EAP(DG,t)} \times P_{EAP(DG,t)} \right)$$

Problem formulation

- **Network power balance**
  - Active and reactive power balance with power loss at each bus
  - Voltage magnitude and angle limits at each bus
  - Line thermal limit at each line

- **DG and external supplier power limits**
  - Active generation limits
  - Reactive generation limits

- **EVs technical limits**
  - Energy balance in the battery of each EV
  - Minimum and maximum stored energy at each EV
  - Charge and discharge maximum limits at each EV

Programming tools

- **Deterministic technique**

    GAMS

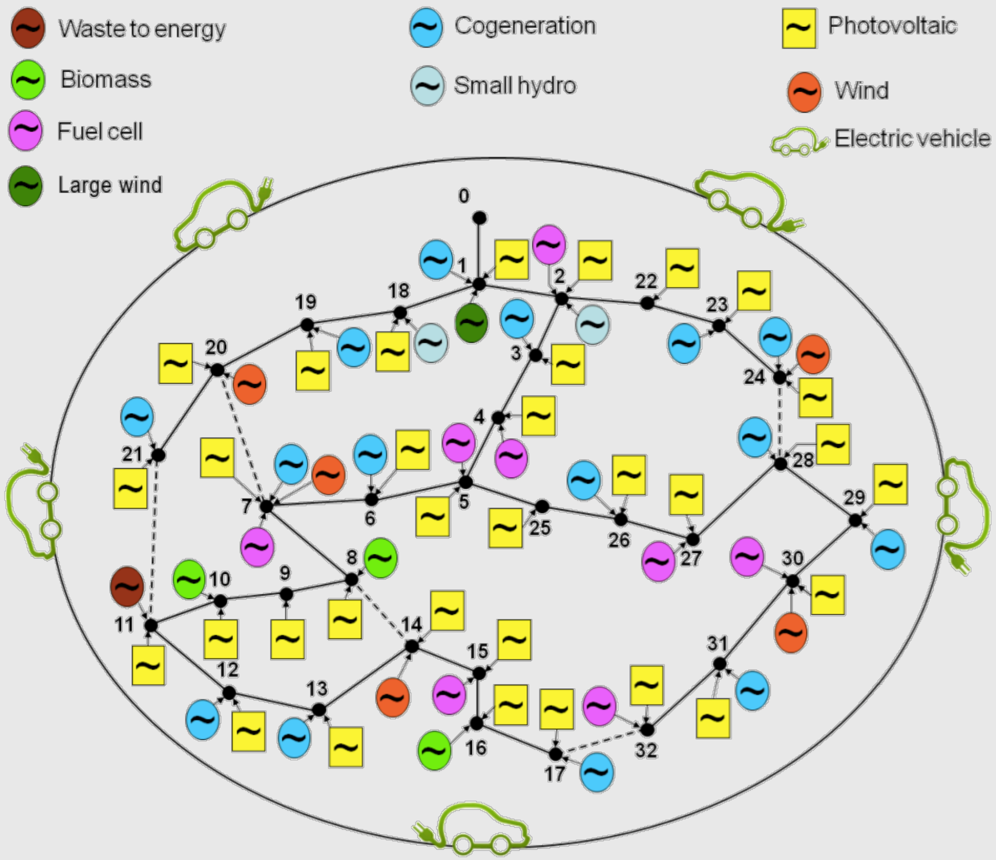
    - Mixed-Integer Non Linear Programming

- **Metaheuristic**

    MATLAB

    - Simulated Annealing

Case study



- 33 bus distribution network
- 66 DG units
- 10 external suppliers
- Electric vehicles:

Case study	Number of EVs	Optimization technique
1	1000	MINLP and SA
	2000	
	3000	

- **Case Study 1**
  - The proposed SA achieved worse operation costs than the MINLP methodology, however with a much lower execution time

Number of EVs	Approach	Operation cost (m.u.)			Execution time (s)
		Best	Worst	Mean	
1000	MINLP	6555.03	-	-	20,559.21 (5.71)
	SA	6653.62	6659.17	6657.60	9.38
2000	MINLP	6940.95	-	-	103,945.70 (28.9)
	SA	7155.93	7162.44	7159.88	23.76
3000	MINLP	7325.26	-	-	267,547.61 (74.3)
	SA	7679.73	7712.47	7698.65	82.33

  - In the 3000 EVs scenario, the SA achieves a solution around 7 % of the MINLP's execution time, and the difference in the operation cost is about 5 %

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