Energy Supply Risk Due to Selling Over the Physical Generation Capacity

Anderson Rodrigo de Queiroz	**MC&E**
Verônica Etchebehere Santiago	**UNIFEI**
Luana M. Marangon Lima	**MC&E**
José Wanderley Marangon Lima	**UNIFEI**

October 14th, 2012 – Phoenix AZ

Outline

- Introduction
- ANN-based Risk Simulator
- Electricity Demand Forecasting
- Simulations Results
- Final Remarks and Future Steps

Introduction

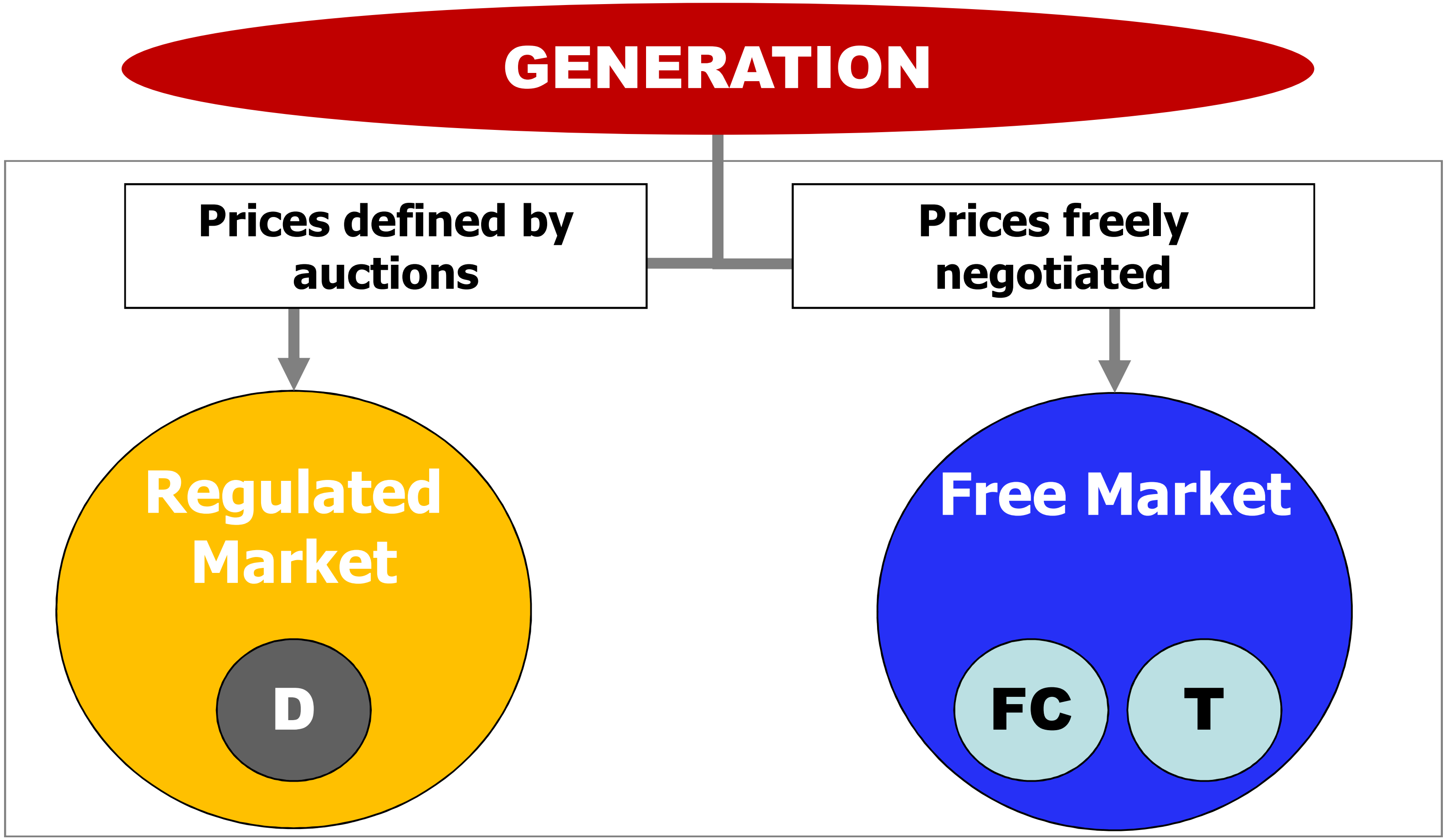
Introduction

- We consider an environment where **agents** have to present full **physical generation coverage**
- Only the generator's **assured energy** can be **negotiated**
- This work explores the possibility of **financial leverage** in terms of **energy**
- Allow the **negotiation of contracts** that **extrapolates** the assured energy

Introduction (*cont.*)

- **In 2001**, Brazil suffered one of the **biggest blackouts** in the history of the country. Losses ≈ US$ 27 Billions
- Some sources claims that this is one of the main causes of the change of parties in the government
- **In 2004** it was **created a new model** for the electricity **power system**
- Free and regulated market living toghter

The Electricity Power Market in Brazil



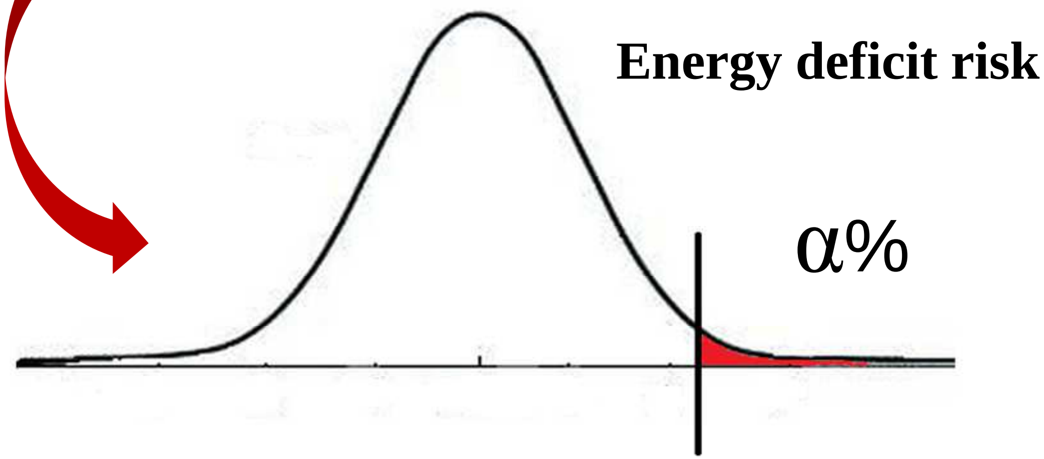
The new model **enforced the agents to contract 100%** of its **assured energy** or of its demand

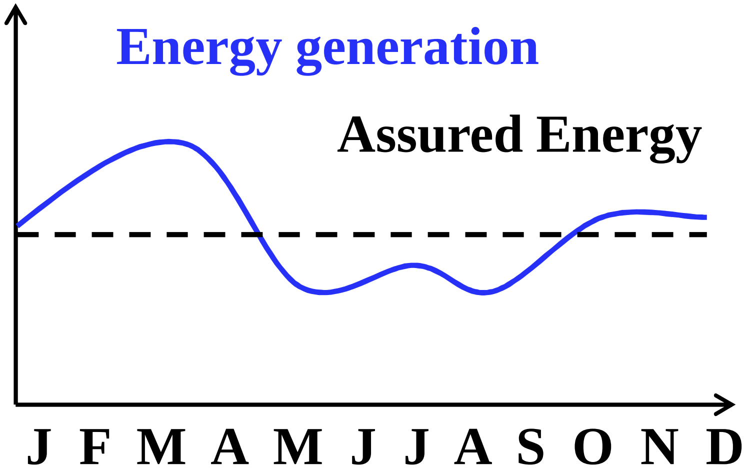
Assured Energy

- The AE is **computed** considering a certain level of energy **deficit risk** to the power generation system
- Solve the hydrothermal scheduling problem

and define

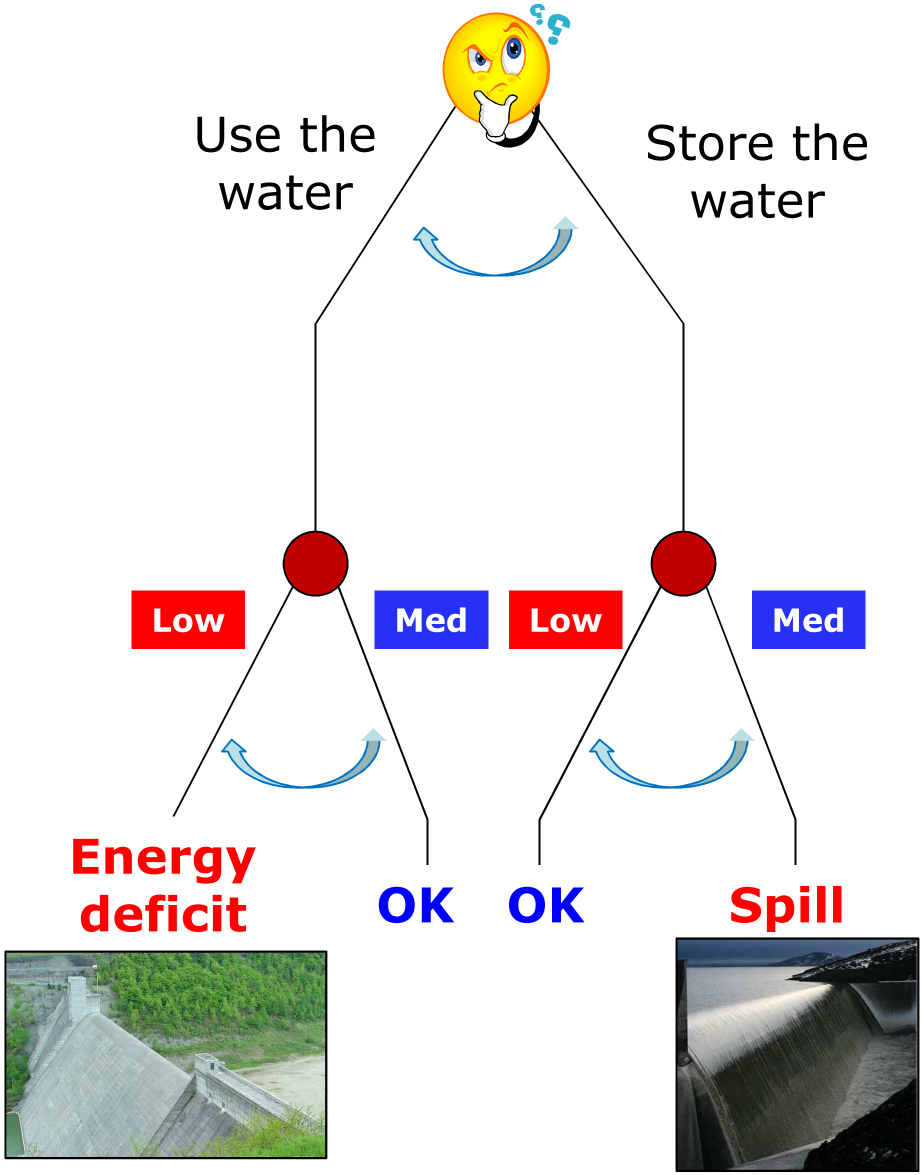
To obtain





Hydro-thermal Scheduling Problem

- **Find** a sequence of **hydro** releases and **thermal** plant **dispatches** for a planning horizon in order to **match system demand**
  - Resource management
  - Input variable forecasting
  - Operational aspects
  - Present decisions affect the future conditions
  - Multi-stage large scale stochastic optimization problem
  - NEWAVE used in Brazil to deal with the problem

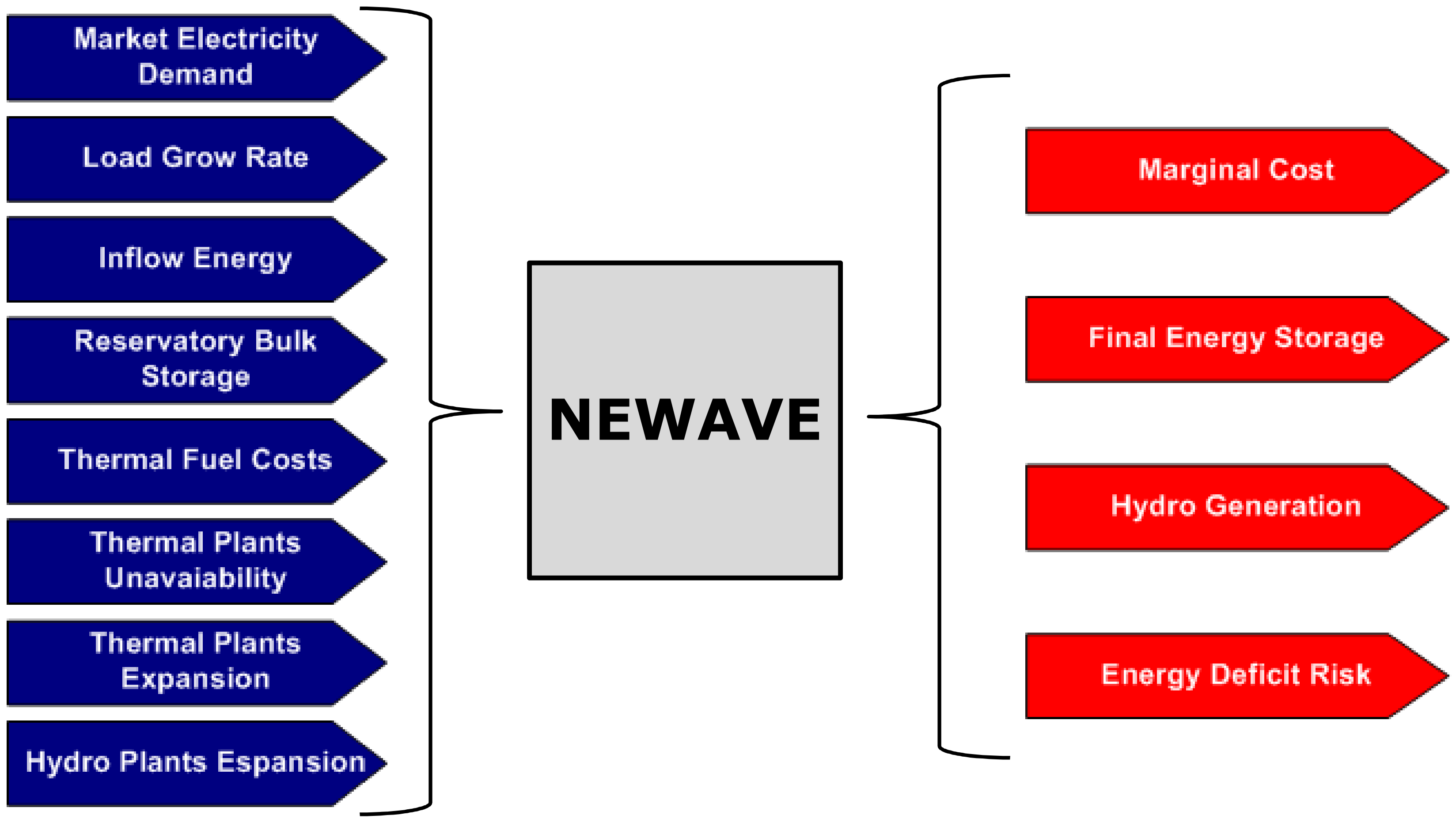


What We Want to Know?

Is it possible for the system agents to **afford certain level of** financial **leverage** in terms of energy (i.e., liberate the agents to sell contracts with values that are larger than the AE) **without harming** the energy deficit risk for **the whole system?**

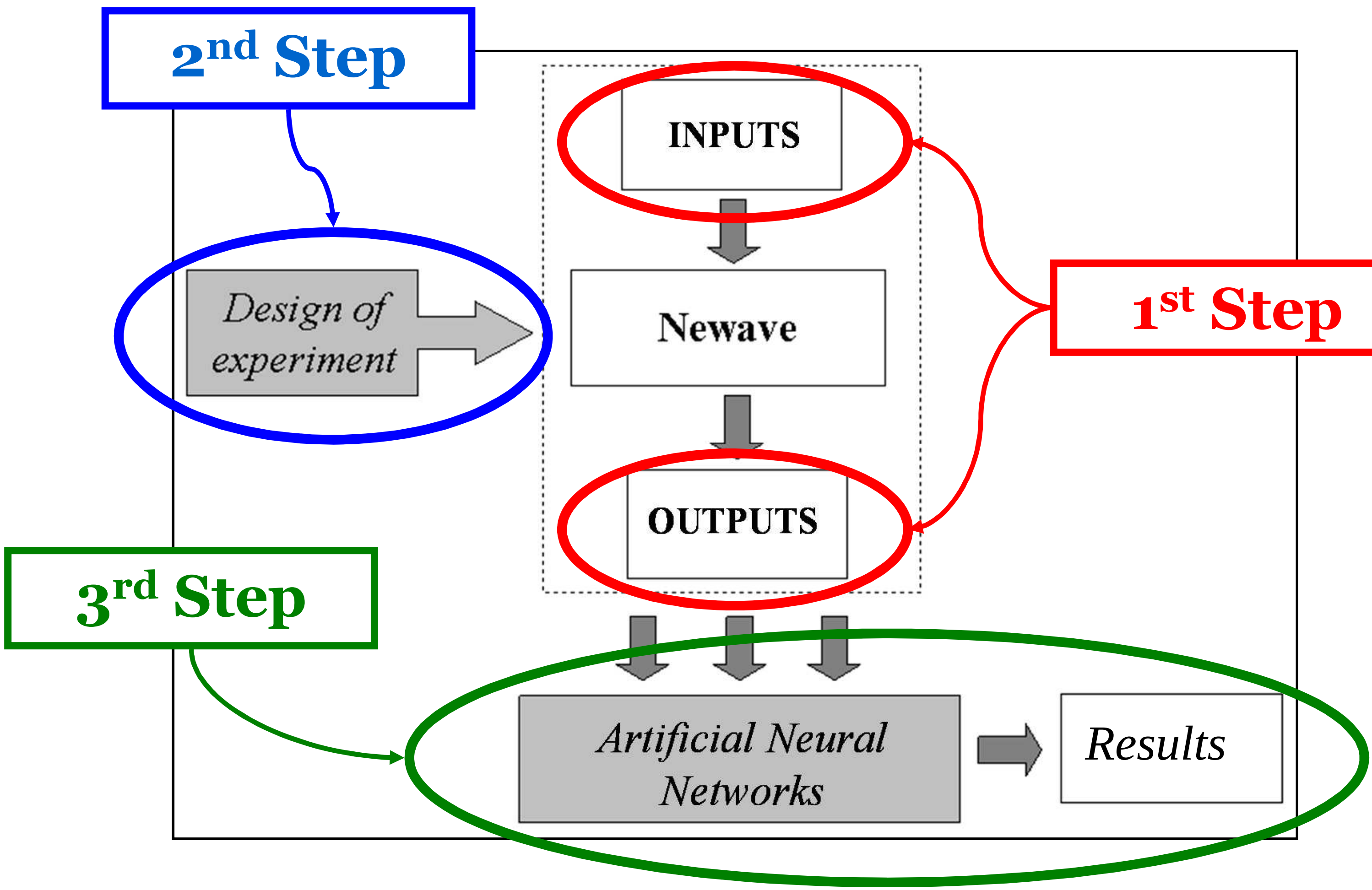
ANN-based Simulator

Model Inputs and Outputs



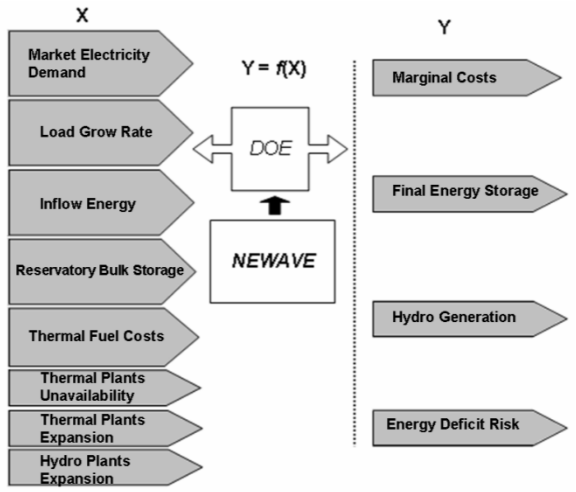
Multi-stage problem with many decision variables and constraints, representation of stochastic inflows → Time consuming!

ANN Simulator Modeling Process



ANN Simulator Modeling Process *(cont.)*

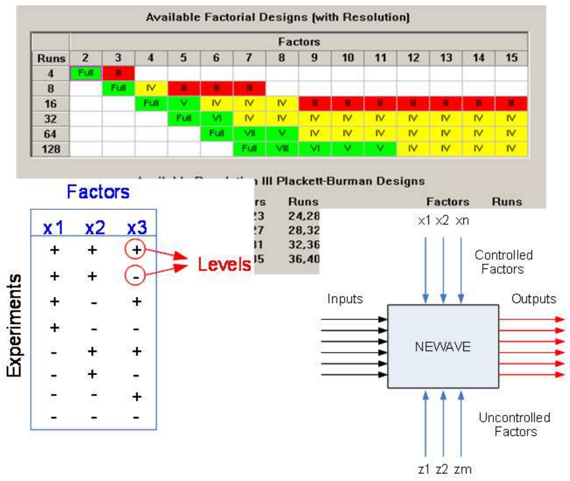
1st Step



Input variables selection

- ***27 Input Variables***
- ***32 Output Variables***

2nd Step



DOE procedure

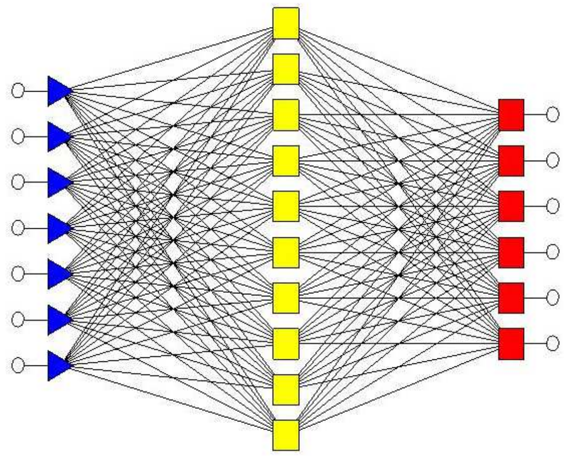
- ***Plackett-Burman* DOE**

  Select the main factors
- **Fractional Factorial DOE**

  Verify interactions between factors
- **Combinatorial DOE**

  Create a sample for ANN training

3rd Step

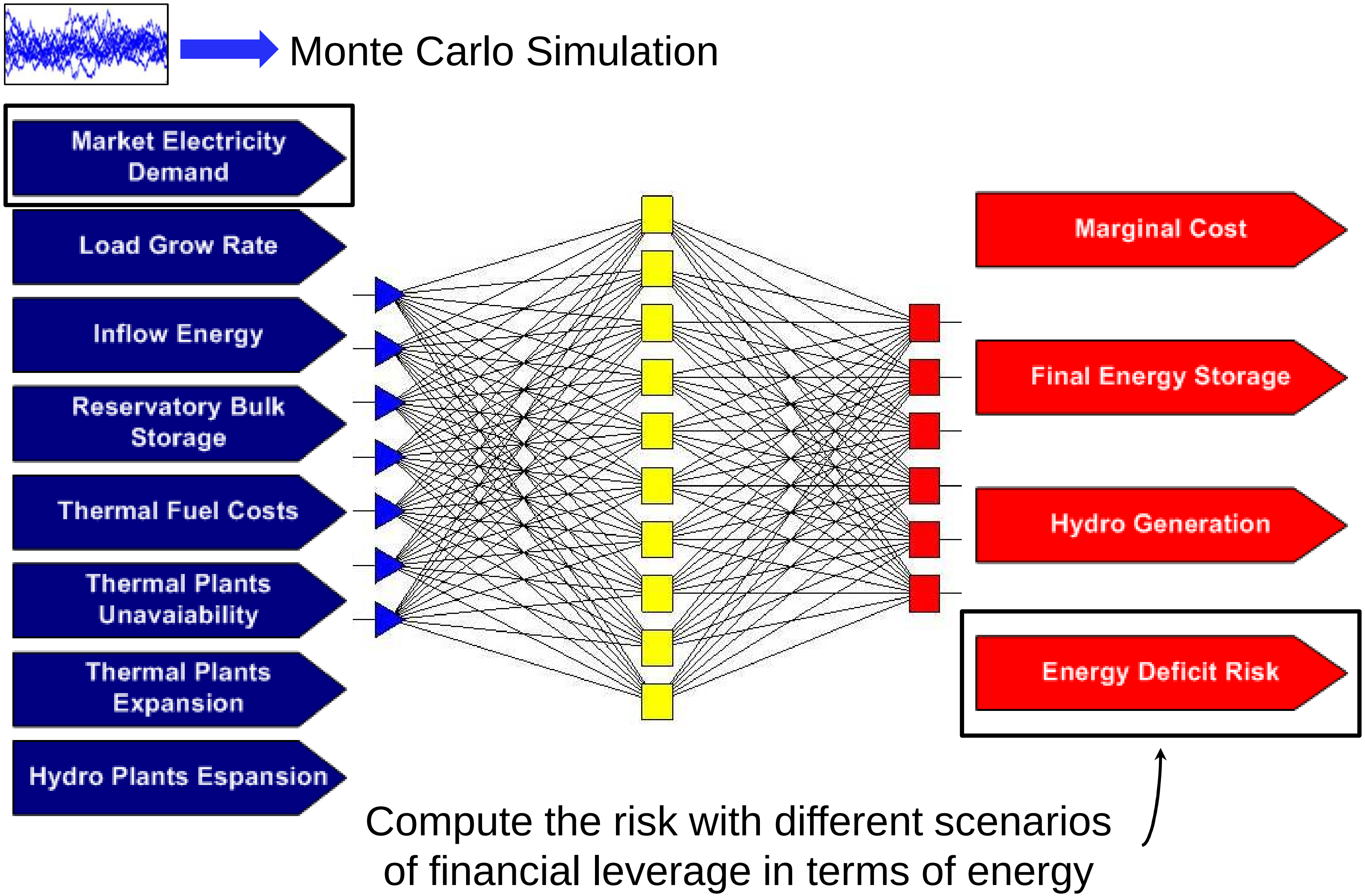


ANN training

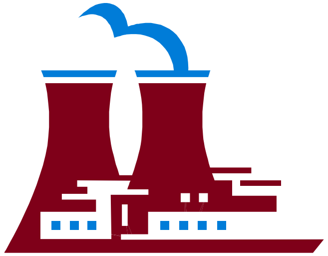
- ***MLP network***

  Superior to other types of ANN for the problem addressed

ANN-based Energy Supply Risk Simulator

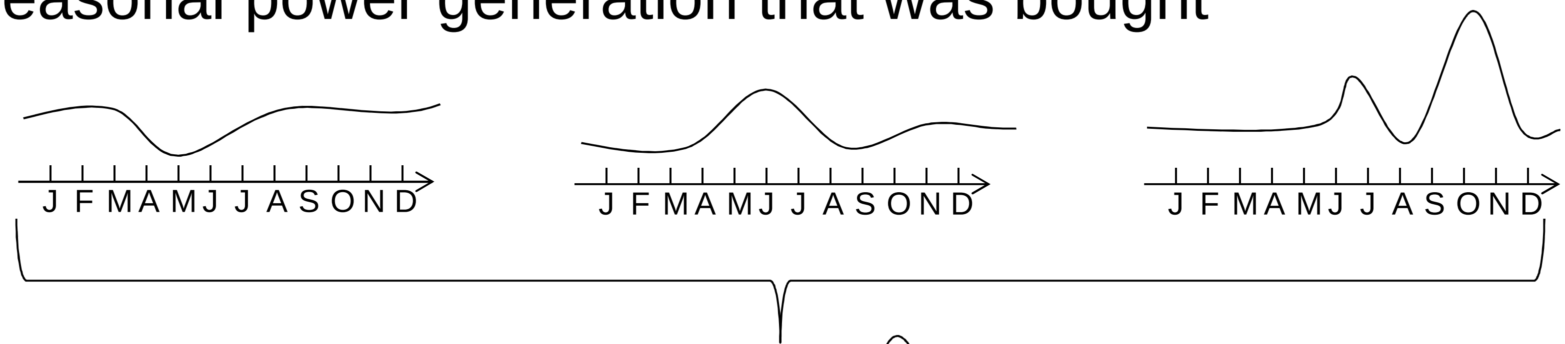


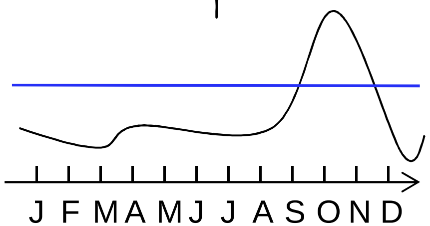
Buying Contracts in the Market



80MW **30MW** **150MW** **Total = 260 MW (avg.)**

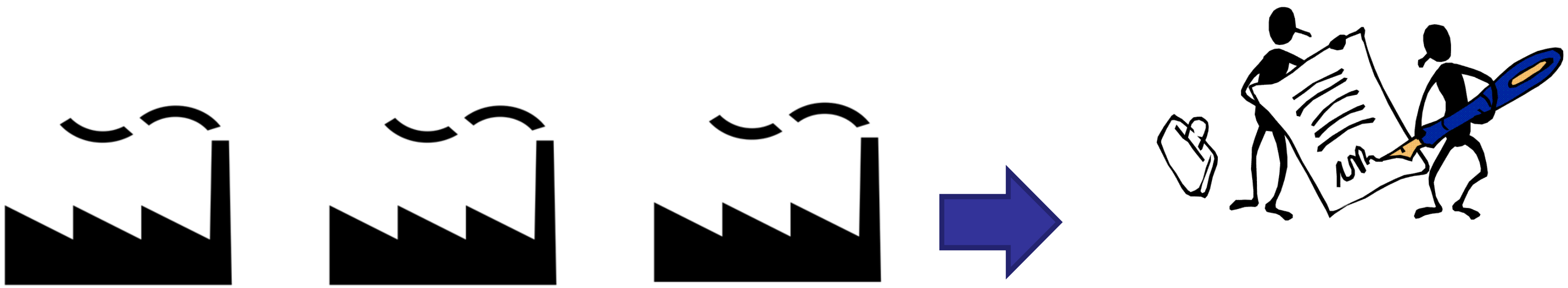
Seasonal power generation that was bought





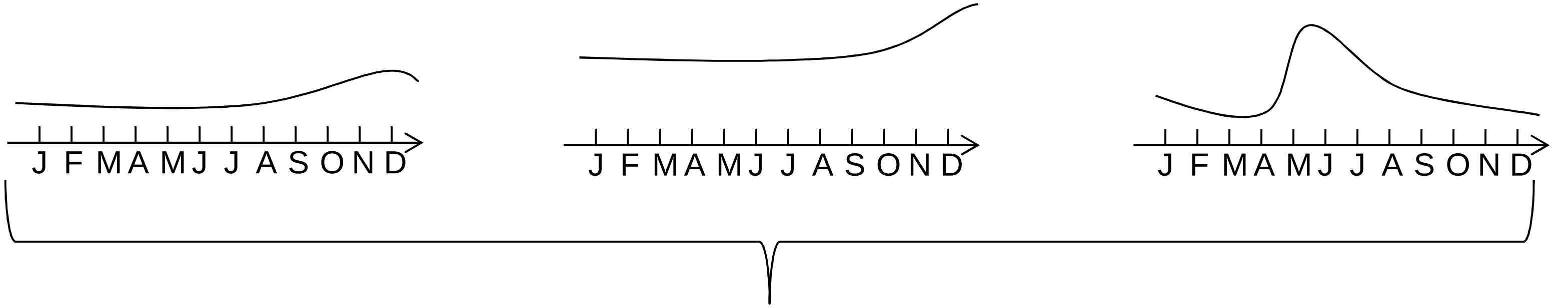
Total power generation bought per month

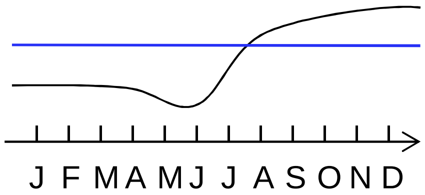
Selling Contracts in the Market



70MW **100MW** **90MW** **Total = 260 MW (avg.)**

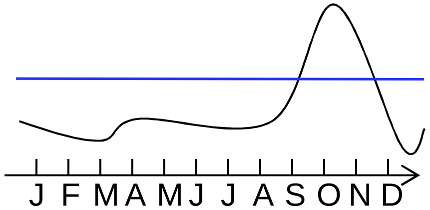
Seasonal power generation that was sold



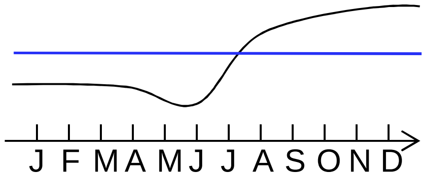


Total power generation sold per month

Buying and Selling Contracts in the Market



260 MW (avg.) bought



260 MW (avg.) sold

Suppose that the first buyer expands its plant and needs to buy 100 MW of energy instead of 70 MW

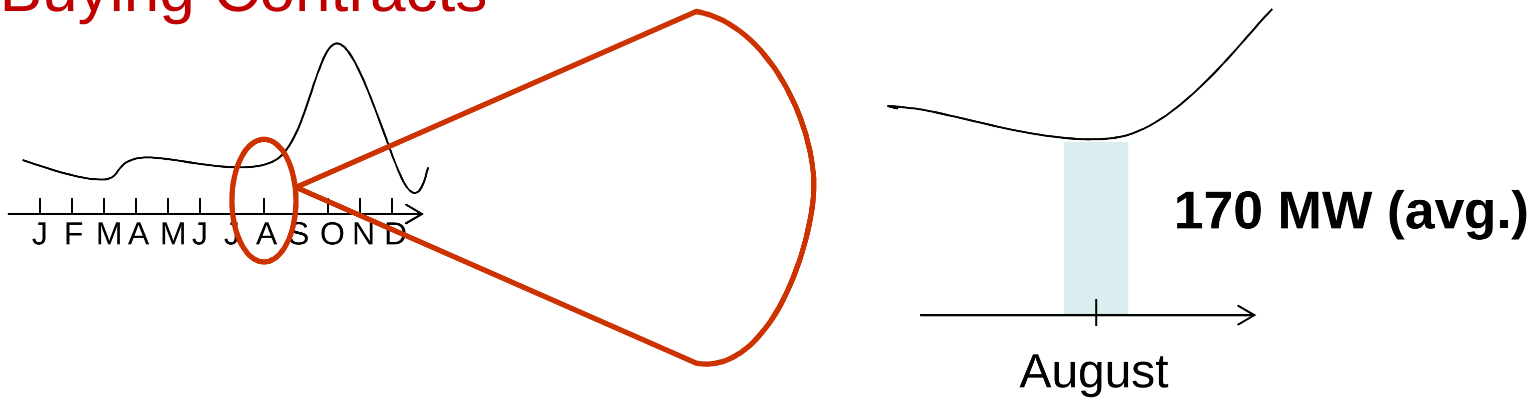
100MW

11% of leverage in the contract

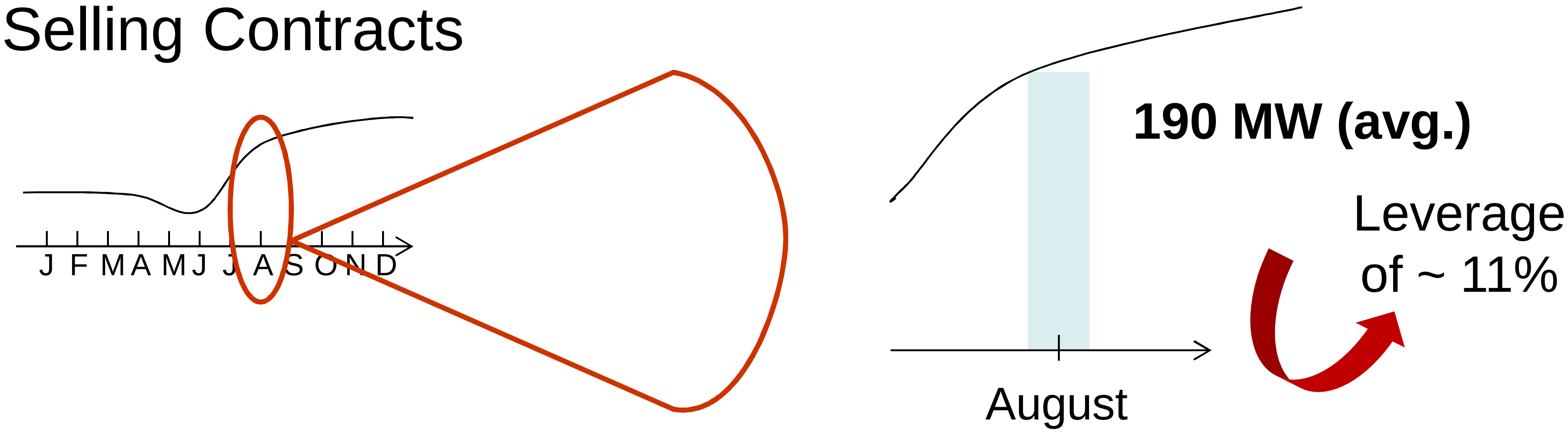
Is there a possibility to sell this new contract?

Leverage in Energy Terms for a Trader

Buying Contracts

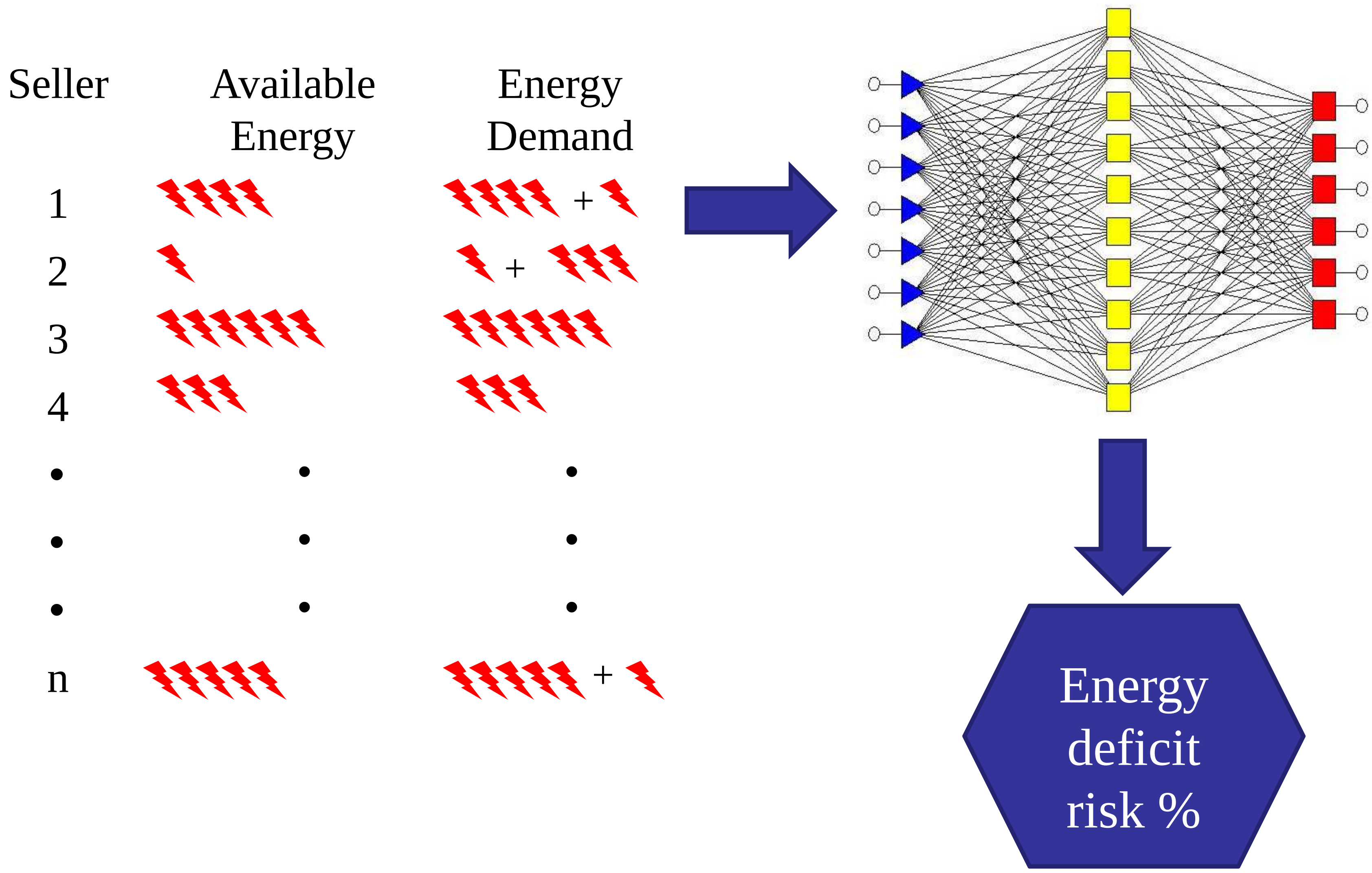


Selling Contracts



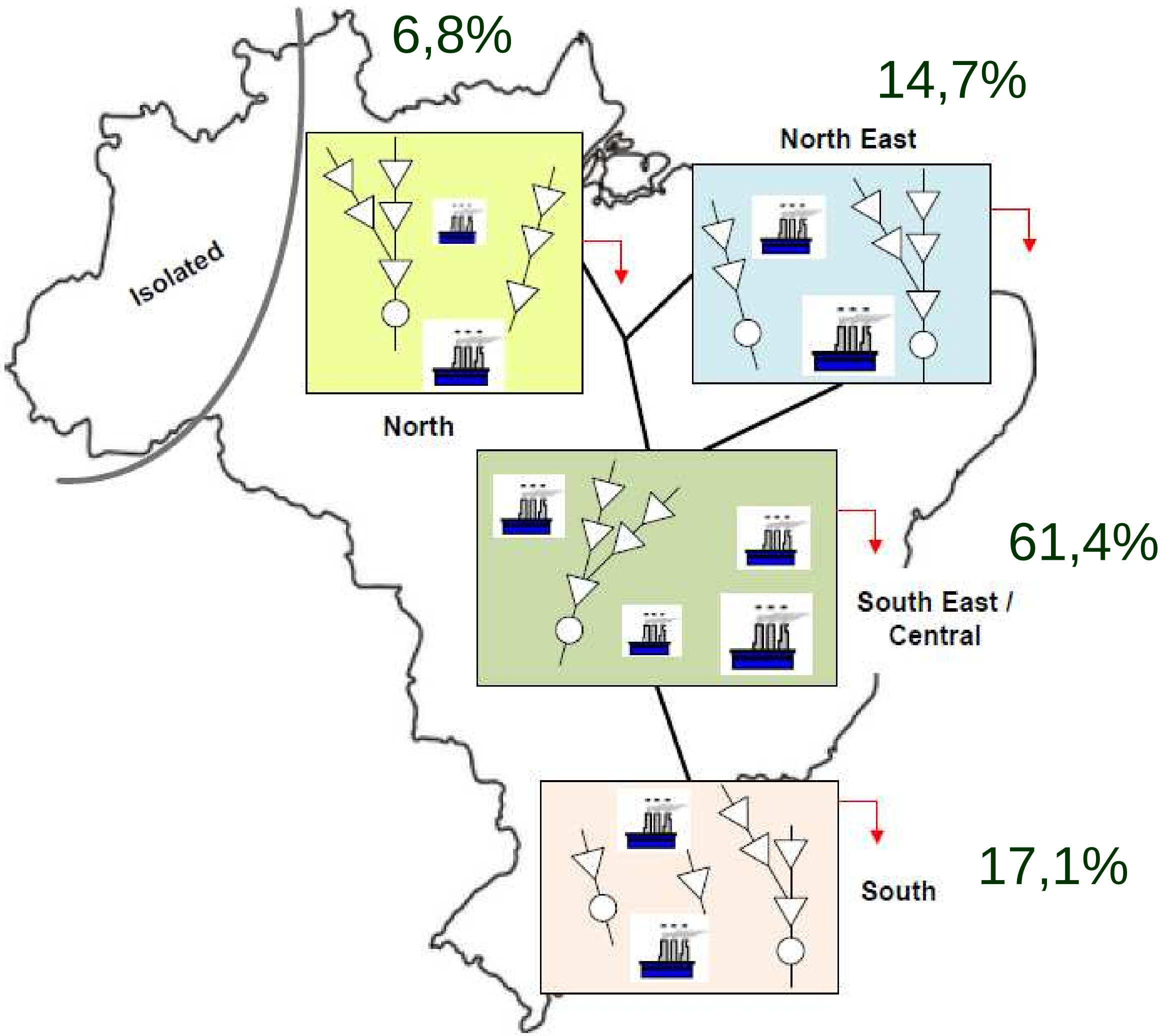
This could happen to several traders in a random way according to their clients needs or for none of them

Energy Deficit Risk Simulation



Electricity Demand Forecasting

Electricity Demand in Brazil

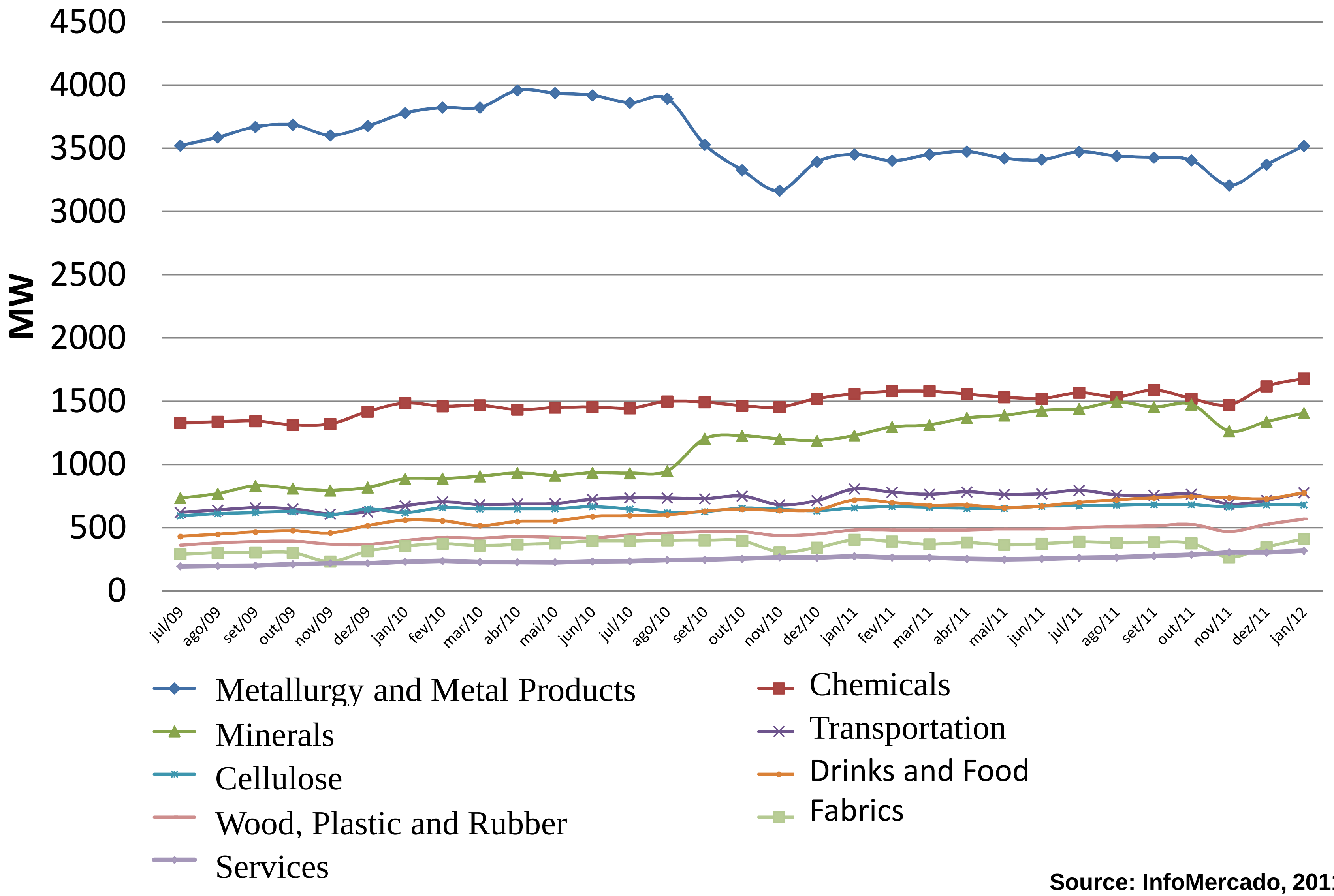


Around 26% of the total electricity demand is required by the free market in Brazil

Source: Brazilian ISO - Jan 2012

Total = 60565 MW

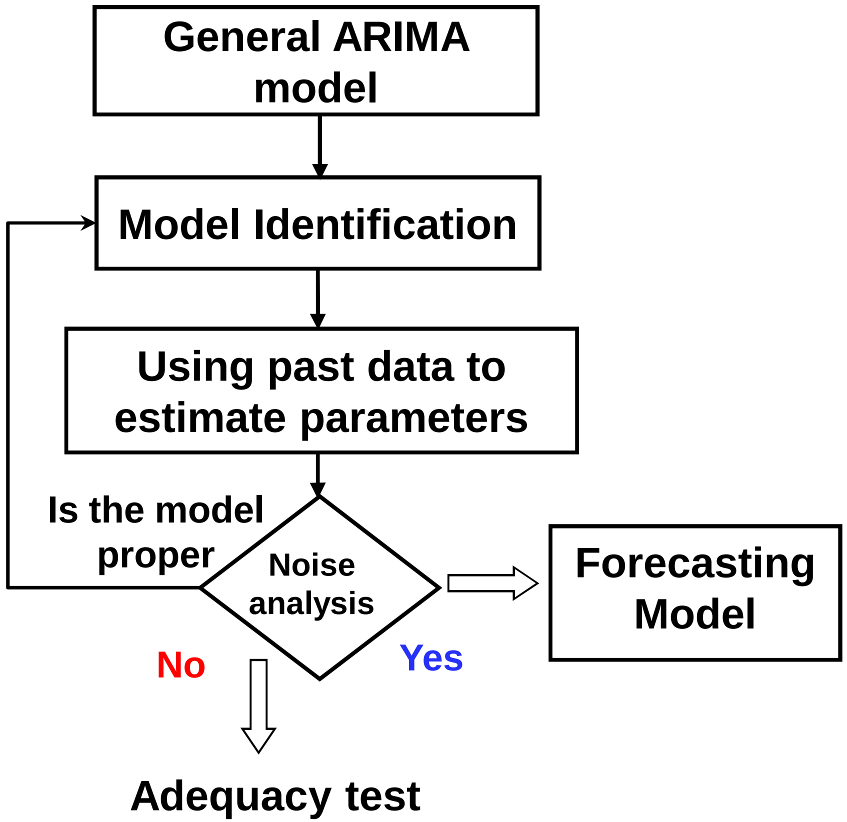
Electricity Demand Profile



Source: InfoMercado, 2011

Electricity Demand Forecasting

- We use an ARIMA model in order to forecast the electricity demand



- Autoregressive integrated moving average
- Used when a time series has time depedency in terms of mean and variance. Used for non-stationarity parameters

Electricity Demand Forecasting *(cont.)*

- We aggregate the data correlation in our analysis:
  - We do so by making stationary series following the idea of Box & Jenkings by simply differentiate the time series the number of times that is needed
  - After that we incorporate the correlation using Cholesky factorization
  - Multiply the decomposed correlation matrix by the electricity demand of each activity in matrix

$$U = DD^T = \begin{pmatrix} D_{11} & & \\ D_{21} & D_{22} & \\ D_{31} & D_{32} & D_{33} \end{pmatrix} \begin{pmatrix} D_{11} & D_{21} & D_{31} \\ & D_{22} & D_{32} \\ & & D_{33} \end{pmatrix}$$

$$Y = DX$$

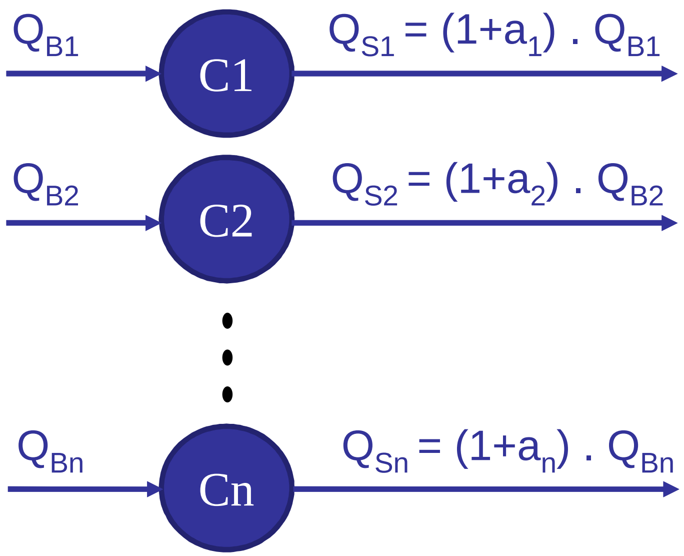
Where,

Y – is the matrix with the time series values with modified by the correlation

D – is a matrix of correlation, inferior triangular

X – is a matrix with the original time series

Electricity Demand Forecasting *(cont.)*



$$Q_S = \sum_{i=1}^{N} Q_{Si} = Q_{B1}(1 + a_1) + \cdots + Q_{Bn}(1 + a_n)$$

$$Q_S = \sum_{i=1}^{N} Q_{Bi} + \sum_{i=1}^{N} Q_{Bi} \cdot a_i$$

$$Q_S = Q_B + \sum_{i=1}^{N} Q_{Bi} \cdot a_i$$

$$Q_E = \sum_{i=1}^{N} Q_{Bi} \cdot a_i$$

Where,

Q_{Si}:	Electricity amount [MW] of selling contract i
Q_S :	Total amount of electricity sold [MW]
Q_{Bi}:	Electricity amount [MW] of buying contract i
Q_B:	Total amount of electricity bought [MW]
Q_E:	Total amount of exceding electricity in the system [MW]
a_i:	Financial leverage in terms of energy for contract i
N:	Number of contracts

Electricity Demand Forecasting - Procedure

1. Choose leverage limit for all contracts
2. Perform Monte Carlo simulation
    1. Generate each contract using a normal distribution
    2. Use this new electricity demand value as input for the energy deficit simulator to obtain the risk values
    3. Compute the energy deficit risk
3. Create the probability density function for the deficit risk
4. Choose a new limit for the leverage for all contracts. Go back to step 2

Simulation Results

Simulation Results – Energy Deficit Risk

- We **increase leverage** to verify the energy deficit risk for the system
- We generated **200 hypothetical contracts** randomly that combined would form the **electricity demand** in the **spot market**
- The **leverage percentage** was also **randomly** generated, but considering a **limit** (e.g., 2% for each contract)

Simulation Results – Energy Deficit Risk *(cont.)*

		Electricity Deficit Risk for each Region							
		Northeast		North		Southeast		South	
		Avg	Std	Avg	Std	Avg	Std	Avg	Std
Max % of leverage in the contracts	2%	5,97%	0,0054%	3,63%	0,0150%	3,44%	0,0026%	2,45%	0,0099%
	4%	5,89%	0,0086%	3,86%	0,0243%	3,41%	0,0037%	2,60%	0,0156%
	6%	5,80%	0,0148%	4,10%	0,0425%	3,37%	0,0057%	2,75%	0,0268%
	8%	5,72%	0,0123%	4,35%	0,0364%	3,34%	0,0042%	2,91%	0,0224%
	10%	5,64%	0,0224%	4,57%	0,0673%	3,32%	0,0068%	3,05%	0,0410%
	12%	5,54%	0,0239%	4,89%	0,0744%	3,29%	0,0061%	3,24%	0,0444%
	14%	5,44%	0,0293%	5,21%	0,0941%	3,26%	0,0062%	3,43%	0,0552%
	16%	5,37%	0,0227%	5,43%	0,0745%	3,25%	0,0042%	3,56%	0,0433%
	18%	5,29%	0,0400%	5,71%	0,1359%	3,24%	0,0061%	3,72%	0,0781%
	20%	5,19%	0,0331%	6,51%	0,1181%	3,22%	0,0350%	3,92%	0,0669%

Final Remarks and Future Work

Final Remarks

- We presented a way to verify the possibility to increase the **autonomy** of the free market in Brazil
- We believe that the procedure gives **more flexibility and liquidity** to the market amplifying the business possibilities
- “So, the **merchant** or trader, **moved** only by their own **selfish interest**, is led by an invisible hand to **promote something** that has never been part of his interest: **the welfare of society**.” Adam Smith – Wealth of Nations (Leal, 2012)

Future Steps

- Create an **ANN** model to deal only with the **energy deficit outputs** of the hydrothermal scheduling
- Generate hypothetical contracts that may represent in a better way the different consumer types with their demand correlation
- Try to find an **optimal leverage** percentage that would **not harm** the energy deficit for the whole **system**

References

- ANEEL, Decreto Nº 5.163 *“Regulamenta a comercialização de energia elétrica, o processo de outorga de concessões e de autorizações de geração de energia elétrica, e dá outras providências*”, Brasilia, 30 de Julho de 2004.
- ROSS, S.A.; WESTERFIELD, R.W.; JAFFE J.F. *“Corporate Finance.”* McGraw−Hill Primis. 6ª ed. 2003.
- PEREIRA, M.V.F.; PINTO, L.M.V.G. *“Multi-stage stochastic optimization applied to energy planning”*. Mathematical Programming, 52:359-375, 1991.
- QUEIROZ, A.R., MARANGON LIMA, J.W., OLIVEIRA, F.A., BALESTRASSI, P.P., QUINTANILHA FILHO, P.S., ZANFELICE, F., *“Electricity Spot Prices - Modeling and Simulation Using Design of Experiments and Artificial Neural Networks*” In: Simpósio de Especialistas em Planejamento da Operação e Expansão Elétrica, 2009, Belém. SEPOPE. 2009.
- EPE, Nº EPE-DEE-RE-099/2008 – r0. *“Metodologia de cálculo da Garantia Física das Usinas.”* Rio de Janeiro, 2008.
- TONELLI, A.V.P., “Modelo Computacional para gestão de riscos na comercialização de energia elétrica.” UNIFEI. 2006
- GUARDIA, E. C., “Metodologia para o Cálculo da Elasticidade da Tipologia de Carga Frente à Tarifa de Energia Elétrica.”UNIFEI. 2007.
- WERNER, L., RIBEIRO, J. L.D., “Previsão de Demanda: Uma Aplicação sos Modelos Box-Jenkins na Área de Assistência Técnica de Computadores Pessoais.” Gestão e Produção. v.10. 2003.
- FAVA, V. L., “Manual de econometria”. In: VASCONCELOS, M. A. S.; ALVES, D. São Paulo: Editora Atlas, 2000.
- MORRETIN, P.A., TOLOI, C.M.C., “Previsão de séries temporais”. 2. ed. São Paulo: Atual Editora,1987.
- OLIVEIRA, F.L.C., “Nova abordagem para geração de cenários de afluências no planejamento da operação energética de médio prazo”. PUC. 2010.
- LEAL, M., “Bolsas de energia europeias podem servir de exemplo para o Brasil aumentar a liquidez e a liberdade do mercado livre nacional”, Canal Energia, Setembro de 2012.
- LIMA, L.M.M.,“Modeling and Forecast of Brazilian Reservoir Inflows via Dynamic Linear Models under Climate Change Scenarios.” The University of Texas at Austin. 2011.
- BILLINTON, R., SINGH, C., “System Reliability Modelling and Evaluation”. London: Hutchinson, 1977.
- SILVA, A.M.,“Estudo de Modelos ARIMA com Variáveis Angulares para Utilização na Perfuração de Poços Petrolíferos.” UFCG. 2007.

Thank you!