





# The Dynamic Computer-model Green-X

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#### **Overview**

#### Introduction

> Available versions of the simulation tool

# Overview of the computer-model Green-X (Methodology)

#### Illustration of the computer-model Green-X





## Introduction

- The dynamic toolbox Green-X represents the main product of the project Green-X
  - A database, allowing dynamic changes and calculating potentials and costs of RES-E, CHP and conventional power
  - A dynamic computer model Green-X integrating RES-E, CHP generation, conventional electricity production and the most relevant demand-side activities
- The computer model allows a comparative and quantitative analysis of interactions between RES-E, CHP, DSM activities and GHG-reduction within the liberalised electricity sector both for the EU as a whole and individual Member States over time by simulating different scenarios





## **Scenarios Output**

- Advice on policy proposals at both EU and on national level e.g. to reach targets indicated by the EU RES-E Directive
- Demonstrate the consequences of a non-harmonised approach versus a harmonised RES-E policy
- Show the effects of *linked policies* for RES-E, CHP, important DSM activities and GHG-reduction versus separated and *individually adjusted strategies* for these areas, (demonstrating especially the impact on TGCs and GHG permits).
- Estimation of costs and benefits for the EU as a whole as for all 15 member states, producers and consumers.
- Recommendation for practical implementation of efficient strategies over time for each step



Green-X

#### **Available Versions**

#### **Internal Version**

#### Aim:

- + Analysis of RES-E policy
- + Interactions of RES-E with the conventional electricity market and other policies (TEA, CHP, DSM)

#### Know-how:

Internal full version is an expert tool; detailed knowledge of the database and the applied methodology necessary

Interactive work during simulation runs necessary

#### **Public Version (CD)**

#### Aim:

 + Analysis of RES-E policy on country and EU-15 level (conventional power price exogenously given)

#### Know-how:

Public version is robust simulation tool – (rudimentary) knowledge of the RES-E system and promotion instruments necessary;

No comprehensive interactive work during simulation runs necessary, lower run-time



**Green-X** 

#### **Overview computer-tool Green-X**



Results Costs and Benefits on a yearly basis (2000-2020)





## **Country Selection**

Individual countries or whole group of countries

**EU-15 Member States** 

EU 10+ Accession Countries -- extended version

EU Candidate Countries (BU, RO, TR) -- extended version

Other European countries (CH, NO) -- extended version





# **Technology Selection**

Considered Technologies
Electricity generation
10 (17) RES-E technologies
4 (5) Thermal and nuclear power plants
Combined heat and power generation - extended version
4 (8) RES-E technologies
<i>3 (4) Thermal power plants</i>
Technological learning
Learning curves
Expert forecast





#### **Power generation (Database)**

#### **Cost-resource curve for each technology in each country**





**Green-X** 

# **Electricity demand reduction (Database)**







## **Policy strategy selection**

Considered promotion strategy
General tax
Energy tax
Environmental tax - extended version
Electricity generation
Price-driven strategies
Capacity-driven strategies
Combined heat and power
Price-driven strategies
Capacity-driven strategies
DSM instruments
Climate Policy - extended version





#### **Social Behaviour**

Individual behaviour can be selected per technology country and year

Investment decisions of investors (interest rate) - extended version

Technology

**Policy instrument** 

Planning horizon / policy design

Strategic behaviour investors (tendering, bidding)

**Dynamic non-economic barriers** 

**Technical (Grid)** 

Social

Market / administration





### Framework Conditions / Database

Different Scenarios available per country and year
Demand forecast
yearly electricity demand
yearly heat from CHP
peak demand electricity
reserve capacity
Price elasticity - extended version
Availability factor of each technology (yearly volatility)
Import / export restrictions electricity trade extended version
Dynamic parameter restrictions
Technology cost forecast / learning factors
Prices
Primary energy price

Heat price CHP





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**Externalities** 

## **Economic market and policy assessment**

**Cost-resource curves** 

for each technology in each country



**Technology / country specific support schemes** 

Incentives / Barriers Investor / consumer behaviour





#### **Dynamic aspect: Investment costs**

#### Illustration: Reduction of investment cost reduction BAUscenario due to technological learning







# **Dynamic aspect: Potential**

- Mid-term potential is be broken down to yearly available potentials. In the model the following barriers will be considered:
  - Market barriers (e.g. no matured market)
  - Social barriers (e.g. social acceptance)
  - Industrial barriers (e.g. maximum of global growth rate of a certain technology)
  - Dynamic availability of resources (e.g. biomass, landfill gas)
- Determination of dynamic parameters is based on econometric analysis and stakeholder and expert interviews





## **Dynamic aspect: Potential**

#### Modelling approach for grid restriction







## **Dynamic aspect: Potential**

#### Modelling approach for social constraints







## **Dynamic aspect: Potential**

#### Modelling approach for market constraints







### Simulation of market interactions

Analysis of various interactions between RES-E, power market, CHP support, GHG goals, and DSM activities

= > Possible market separations, clearing prices







## **Expected Results (1/3)**

Results per country and year
General Results
Installed capacity per technology [MW]
Total Fuel input [TJ]
Total energy generation [GWh]
Total electricity generation [GWh]
Electricity generation per technology [GWh]
National electricity consumption [GWh]
Import / export electricity balance [GWh, % of gen.] extended version
Total CO amigaiana IMt CO 1 avtended version

Total CO<sub>2</sub>-emissions [Mt-CO<sub>2</sub>] -- extended version





#### **Expected Results (2/3)**

Results per country and year
Impact Producer
Total generation costs [M€, €MWh]
Gen. costs electricity generation [M€, €/MWh]
Gen. costs electricity per techn. [M€, €/MWh]
Total producer surplus (PS) [M€, €/MWh]
PS electricity generation [M€, €/MWh]
PS electricity per techn. [M€, €/MWh]
Marginal generation costs per technology electricity gen. [€MWh]





## **Expected Results (3/3)**

Results per country and year
Impact Consumer
Additional costs due to RES-E strategy [M€, €MWh]
Additional costs due to CHP strategy [M€, €/MWh]
Additional costs due to DSM strategy [M€, €/MWh]
Additional costs due to CO <sub>2</sub> -strategy total [M€, €MWh, €t-CO <sub>2</sub> ] extended version
Prices
Market price electricity [€MWh] extended version
Market price Tradable Green Certificates [€MWh]

Market price Tradable Emission Allowances [€t-CO<sub>2</sub>] -- extended version





# System requirements Green-X

- Intel Pentium IV or AMD Processor with 2500 MHz frequency or more, respectively Centrino Mobile Processor with 1700 MHz frequency
- Minimum of 512 Mbyte RAM
- Minimum Screen Resolution 1024x768 (optimised for 1280x1024)
- ➢ 16 Bit Colours
- Operating system: Windows 2000, Windows XP

#### Green-X

Dissemination Workshop project Green-X September 28<sup>th</sup> 2004, Madrid



# **Illustration of the computer-model Green-X**





Green-X

#### **Contact Details**

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#### Project web-site:

#### www.green-x.at