Short characterisation of the model

Green-X

Year of implementation:	2002-2004
Client:	European Commission, DG Research; FP5 Programme (ENG2-CT-2002-00607)
Consortium:	Project co-ordinator: EEG - Energy Economics Group at Vienna University of Technology, Institute of Power Systems and Energy Economics Project partners: IT Power, United Kingdom KEMA - KEMA Nederland B.V., The Netherlands RISOE - Risoe National Laboratory, Denmark CSIC - The Spanish Council for Scientific Research (Institute of Economy and Geography), Spain FhG-ISI - Fraunhofer Institute for Systems and Innovation Research, Germany WIENSTROM GmbH, Austria EGL - Elektrizitäts-Gesellschaft Laufenburg AG, Switzerland EREC - European Renewable Energy Council, Belgium
Publications / Web:	Huber et al. (2004): *Action plan for deriving dynamic RES-E policies* and *Green-X deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market* Huber et al. (2004): *Final report of the project Green-X,* Web page: www.green-x.at.

Reference projects (selected)

"Deriving a future European Policy for Renewable Electricity (futures-e)"; Project funded by the European Commission (Intelligent Energy for Europe 2006 – DG TREN, Contract No. EIE/06/143/SI2.444285); Project coordinator: EEG; Status: on-going; Duration: December 2006 – November 2008.

"Promotion and growth of renewable energy sources and systems (PROGRESS)"; Project funded by the European Commission, DG TREN (TENDER No. TREN/D1/42-2005/S07.56988); Project participation; Status: on-going; Duration: February 2006 – January 2008.

"Economic Analysis of reaching a 20% share of renewable energy sources in 2020"; Project funded by the European Commission, DG Environment (Service Contract on "Renewables Work Programme 2005", Reference: ENV.C.2/SER/2005/0080r); Project consortium with Fraunhofer ISI and Ecofys; Status: completed; Duration: December 2005 – May 2006.

"Assessment and optimisation of renewable support schemes in the European electricity market (OPTRES); Project funded by the European Commission (Intelligent Energy - Europe 2004 – DG TREN, Proposal No. EIE/04/073/S07. 38567); Project participation; Status: completed; Duration: January 2005 – December 2006.

"Bestimmung der Potenziale und Ausarbeitung von Strategien zur verstärkten Nutzung von erneuerbaren Energien in Luxemburg" (in German); Project funded by Agence de l'Energie (AEL) Luxembourg; Project consortium with Fraunhofer ISI; Status: completed; Duration: January 2006 – March 2007.

"Acceleration of European Grid-integration by ensuring an attractive business environment for key stakeholders realising RES-E projects (RE-XPANSION)"; Project funded by the European Commission (ALTENER 2002 – DG TREN, Proposal No. ALTENER-2002-054); Project coordinator: European Wind Energy Associaton (EWEA); Status: completed; Duration: April 2003 – March 2005.

"Analysis of the Renewable Energy Sources' evolution up to 2020 (FORRES 2020)"; Project funded by the European Commission (TENDER No. TREN/D2/10–2002 – LOT 8); Project participation; Status: completed; Duration: January 2003 – December 2004.

"Study on the Economic Analysis of RE Support Mechanisms", Project funded by Sustainable Energy Ireland, SEI, (reference number RDSV000192), Project coordinator: EEG, Status: completed, Duration: September 2003 – March 2004.

"Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market (Green-X)"; Project funded by the European Commission (5th FWP – DG Research, Contract No: ENG2-CT-2002-00607); Project coordinator: EEG; Status: completed; Duration: October 2002 – September 2004.

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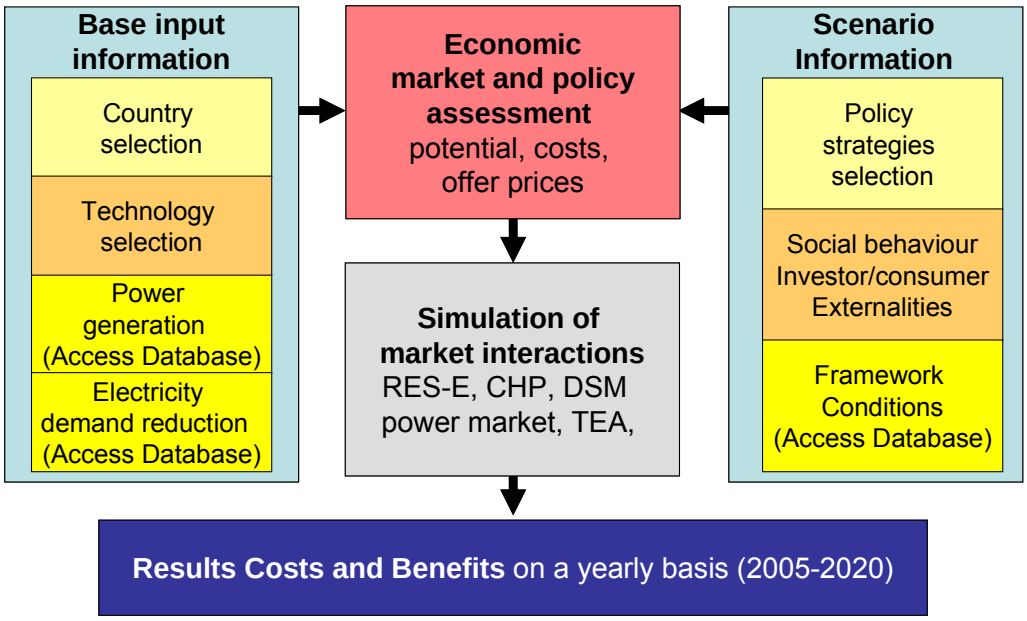

*Figure 1 Overview of the computer model **Green-X** (electricity sector)*

The computer model ***Green-X*** is an independent software tool developed under Microsoft Windows by EEG in the EC-funded project Green-X (5th FWP – DG Research, Contract N°: ENG2-CT-2002-00607).[1]

Two major variants of the ***Green-X*** model are currently available:

- An extended variant with respect to the **intra-sectoral** coverage was developed, which **includes** besides RES-E **endogenous modelling of all conventional power generation options of the electricity sector** (incl. interconnections and according restrictions) as illustrated in Figure 1. Geographically this variant covers solely **the EU-15**. It allows a comparative, quantitative analysis of interactions between RES-E, conventional electricity and CHP generation, demand-side activities and GHG-reduction in the electricity sector, both within the EU-15 as a whole, as well as for individual member states.

- An extended variant with regard to the **geographical and sectoral coverage for RES**. It **covers** besides the EU-15 **all new member states (EU-10) as well as Bulgaria, Romania and Croatia**. It enables a comparative and quantitative analysis of the future deployment of RES in all energy sectors (i.e. electricity, (grid-connected and non-grid) heat and transport) based on applied energy policy strategies in a dynamic context. In this context, the impact of the conventional supply portfolio within each sector is described by exogenous forecasts of reference energy prices and corresponding CO2 emission-factors etc., all set on country level.

  For the purpose of the study "Economic Analysis of reaching a 20% share of renewable energy sources in 2020", the modelling approach has been extended by the concept of a cross-sectoral quota: The key approach in the calculations is that the European

1 For more details see: http://www.green-x.at

energy market optimizes the additional generation costs for RES against the background of a RES target which can be set on a yearly base up to the year 2020. This overall optimization is modelled by comparing the difference between RES generation costs and conventional reference prices across all sectors (heat, electricity and biofuels), all technologies and all countries. Results are presented in terms of additional costs, that is, the total costs of generation per energy output minus the reference cost of energy production per unit of energy output. To avoid underestimation of the resulting cost with regard to an enhanced RES-deployment, negative additional cost are not counted – i.e. set to zero. The optimisation is conducted across all three sectors (RES-E, RES-H and RES-T). As biomass may play a role in all sectors, the allocation of biomass resources is a key issue. Consequently the overall optimization across sectors includes an integrated optimization of the distribution of biomass among the sectors.

Within the model ***Green-X***, the most important RES-E (e.g. biogas, biomass, biowaste, wind on- & offshore, hydropower large- & small-scale, solar thermal electricity, photovoltaics, tidal & wave energy, geothermal electricity), RES-H technologies (e.g. biomass – subdivided into log wood, wood chips, pellets, district heating - , geothermal and solar heat) and RES-T options (e.g. traditional biofuels such as biodiesel and bioethanol, advanced biofuels as well as the impact of biofuel imports) are described for each investigated country by means of *dynamic cost-resource curves*. Dynamic cost curves are characterised by the fact that the costs as well as the potential for electricity generation / demand reduction can change each year. The magnitude of these changes is given endogenously in the model, i.e. the difference in the values compared to the previous year depends on the outcome of this year and the (policy) framework conditions set for the simulation year.

Based on the derivation of the dynamic cost curve, an economic assessment takes place considering scenario-specific conditions like selected policy strategies, investor and consumer behaviour as well as primary energy and demand forecasts.

Within this step, a transition takes place from generation and saving *costs* to bids, offers and switch *prices*. It is worth mentioning that the policy setting influences the effective support, e.g. the guaranteed duration and the stability of the planning horizon or the kind of policy instrument to be applied.

Policies that can be selected are the most important price-driven strategies (feed-in tariffs, tax incentives, investment subsidies, subsidies on fuel input) and demand-driven strategies (quota obligations based on tradable green certificates (including international trade), tendering schemes). All the instruments can be applied to all RES technologies (and conventional options within the EU-15) separately for the various energy sectors. In addition, general taxes can be adjusted and the effects simulated. These include energy taxes (to be applied to all primary energy carriers as well as to electricity and heat) and environmental taxes on CO_2-emission as well as policies supporting demand-side measures. As ***Green-X*** is a dynamic simulation tool, the user has the possibility to change policy and parameter settings within a simulation run (i.e. by year). Furthermore, each instrument can be set for each country individually.

The results are derived on a yearly basis by determining the equilibrium level of supply and demand within each considered market segment – e.g. tradable green certificate market (TGC, both national and international), electricity power market and tradable emissions allowance market. This means that the supply for the different technologies is summed up within each market and the point of equilibrium varies with the demand calculated.

A broad set of results with respect to RES can be gained on country and technology-level:

- total energy output by sector (RES-E, RES-H, RES-T), by country, by technology
- total installed capacity by sector (RES-E, RES-H, RES-T), by country, by technology
- share on gross domestic electricity / heat / transport fuel production or demand,
- average generation costs by sector (RES-E, RES-H, RES-T), by country, by technology
- import / export balance for the power sector (only for EU-15 countries),
- avoided (fossil) primary energy and CO_2 emissions due to additional RES deployment by sector (RES-E, RES-H, RES-T), by country, by technology
- impact of simulated energy policy instruments on supply portfolio, generation costs, etc.
- impact of selected energy policy instruments on total costs and benefits to the society (consumer) – premium price due to RES-E / RES-H / RES-T strategy.

For illustration of the modelling tool, some screen shots are copied in Figure 2 to Figure 6.

Figure 2 *Starting page* **Green-X**

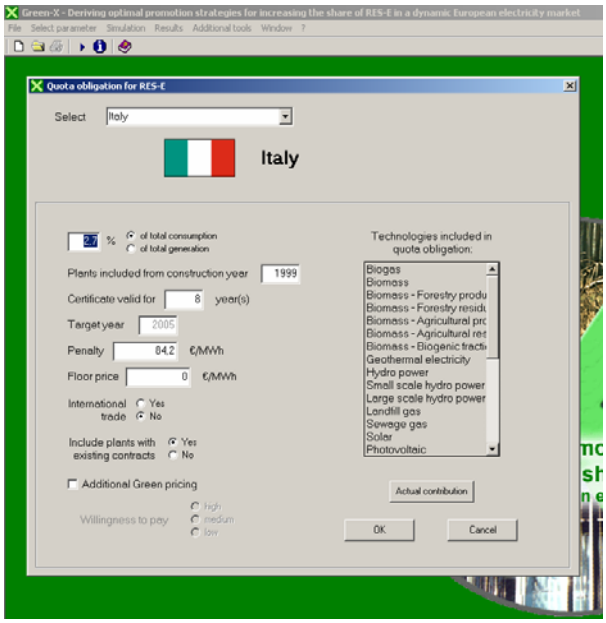

Figure 3 *Design options in case of a quota obligation*

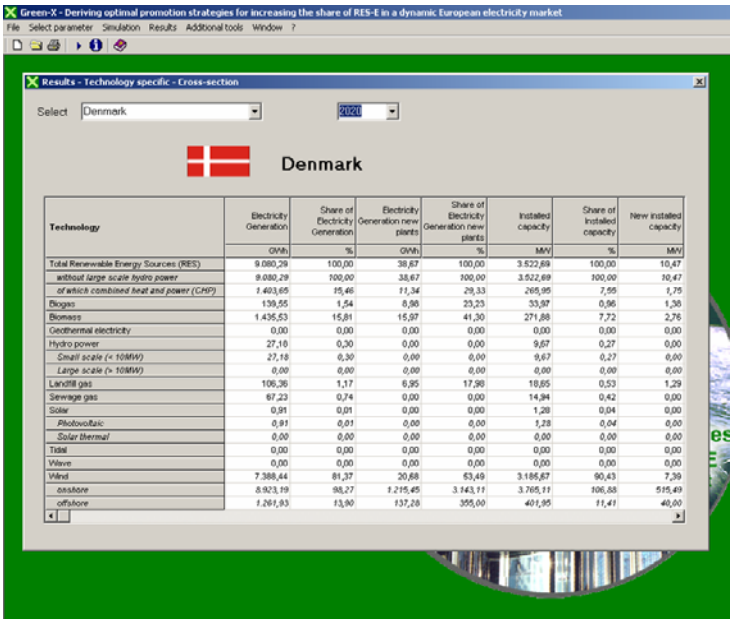

Figure 4 *Result table - technology specific results on country level*

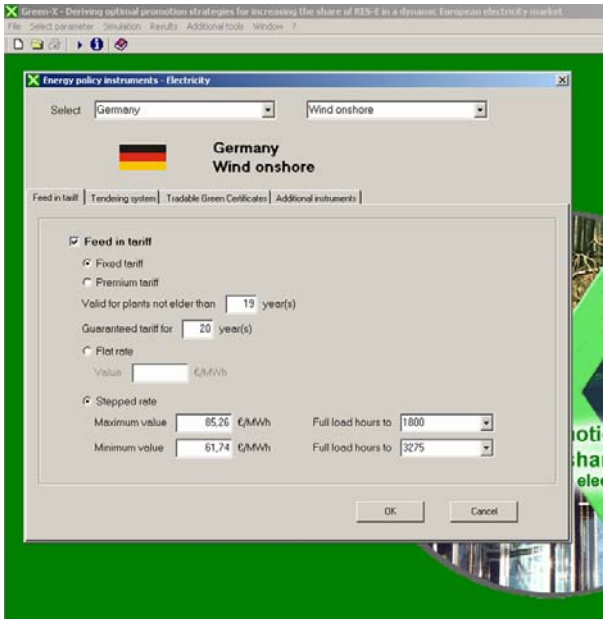

Figure 5 *Design options in case of a feed-in tariff*

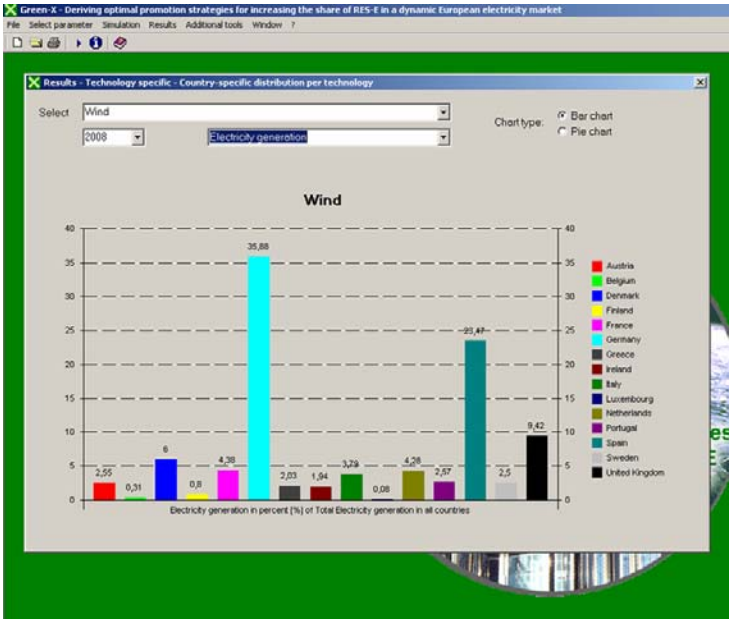

Figure 6 *Result figure – technology specific distribution per country*

For further information … Web links …

www.green-x.at – Web page of the Green-X project - providing model description, project specific information, etc..

www.optres.fhg.de – Web page referring to the (recently completed) IEE-project OPTRES – offering latest news on European RES-E policies, analysing the effectiveness & efficiency of support instruments.

www.futures-e.org – Web page of the ongoing IEE-project futures-e – stimulating an in-depth discussion of national optimisation vs. coordination of European RES-E support policies with focus on national viewpoints.