ON MODELING THE FUTURE OF RENEWABLE ENERGY SOURCES IN EUROPE FROM A TECHNO– INSTITUTIONAL PERSPECTIVE

Reinhard Haas, Gustav Resch, Thomas Faber

Energy Economics Group, Vienna University of Technology

SEVILLA, 21st March 2007
1. Introduction
2. Political-Institutional background
3. Current state and potentials
4. Method of approach: Cost curves
5. The issue of transfer costs
6. The model GREEN-X
7. Some results from GREEN-X
8. Success of promotion strategies
9. Competitive markets?
10. Conclusions
Associated benefits of RES beyond power production:

- reduced energy import dependence and provision of a more diversified resource base;
- increases in local employment and income;
- hedge against volatile fossil fuel prices as well as avoided risks of disruption in fossil fuel supply;
- the potential to greatly reduce, and perhaps eventually eliminate pollution and greenhouse gas emissions associated with current electricity generation.
1 INTRODUCTION

CORE MOTIVATION:

Policy targets for an INCREASE of RES-E!

(e.g. currently discussed targets of 20% for 2020)
2 THE POLITICAL–INSTITUTIONAL BACKGROUND
# What is the problem?

## SURVEY ON INSTRUMENTS TO PROMOTE ELECTRICITY FROM RENEWABLES

<table>
<thead>
<tr>
<th>Capacity-driven strategies</th>
<th>REGULATORY</th>
<th>VOLUNTARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation-based</td>
<td></td>
<td>• National generation targets</td>
</tr>
<tr>
<td>Investment focused</td>
<td>• RPS</td>
<td>• National installation or capacity targets</td>
</tr>
<tr>
<td></td>
<td>• Quota-based TGCs</td>
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<tr>
<td>Price-driven strategies</td>
<td></td>
<td>• Green Power Marketing</td>
</tr>
<tr>
<td>Generation-based</td>
<td>• feed-in tariffs,</td>
<td>• Green tariffs</td>
</tr>
<tr>
<td>Investment focused</td>
<td>• Rate-based incentives</td>
<td>• Solar stock exchange</td>
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<td></td>
<td>• Net metering</td>
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<tr>
<td>Other</td>
<td></td>
<td>• Contracting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Shareholder progr.</td>
</tr>
<tr>
<td></td>
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<td>• Contribution</td>
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<td></td>
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<td>• Bidding</td>
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<tr>
<td></td>
<td></td>
<td>• NGO-marketing</td>
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<tr>
<td></td>
<td></td>
<td>• Selling green buildings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Retailer progr.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Financing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Public building prog.</td>
</tr>
</tbody>
</table>
What is the problem? Which instrument fits best?

- Should RES-E technologies be promoted on broad scale?
- Should an ambitious RES-E target be met in the short and long-term?
- Should it reflect the external costs?
- Should it be compatible with the conventional electricity market?
- How should the premium costs / burden for consumer be distributed over time?
- Is international burden sharing for consumer an important goal?
- Should the system be implemented on a national or international level?

Answer depends on POLICY OBJECTIVE

Source: GREEN-X
MAJOR PROBLEM: Correct design of policy
• with respect to:
  • renewable targets
  • Financial incentives
  • Credibility for investors
• Consideration of external costs?
3. THE CURRENT SITUATION OF RENEWABLES IN EUROPE
PRIMARY ENERGY FROM RES

- **Biomass**
- **Hydro**
- **Wind**
- **Solar**
- **Geothermal**
- **Percent RES in PE**

<table>
<thead>
<tr>
<th>Year</th>
<th>EU 15</th>
<th>EU 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TOTAL ELECTRICITY GENERATION FROM RENEWABLES IN EUROPE

1997: 12.9%
2005: 13.6%

150
100
50
0


TWh/yr

Large-scale hydro  Small-scale hydro  New RES-E excl. hydro
ELECTRICITY GENERATION FROM „NEW“ RENEWABLES IN EUROPE

1997: 1.4 %

2005: 4.5 %

0 20 40 60 80 100 120 140

TWh/y


Biogas
Solid biomass
Biowaste
Geothermal electricity
Photovoltaics
Wind on-shore
Wind off-shore
PRIMARY ENERGY POTENTIAL 2020

EE - Ausbau 2004
(Produktionspotential)

EE - realisierbares Potenzial 2020

EE-Strom, gesamt - ohne Biomasse

EE-Wärme, gesamt - ohne Biomasse

Biomasse (inländisch)

Biomasseimporte
POTENTIALS CURRENT AND 2020

... by country (left)

... by technology (right)
GENERATION COSTS BY TECHNOLOGY

- Wind offshore
- Wind onshore
- Tide & Wave
- Solar thermal electricity
- Photovoltaics
- Hydro small-scale
- Hydro large-scale
- Geothermal electricity
- Biowaste
- (Solid) Biomass
- (Solid) Biomass co-firing
- Biogas

Costs of electricity (LRMC - Payback time: 15 years) [€/MWh]

Current market price

PV: 430 to 1640 €/MWh
4. METHOD OF APPROACH: STATIC COST RESOURCE CURVES

- Cheapest capacities
- More expensive capacities

predicted

Uncertainty

EURO/kWh vs kWh
Static cost-resource curves

- Combines information on the **potential** and the according **costs** (of electricity for a specific energy source).
- For **limited resources** (as RES-E) costs rise with increased utilization.
- All costs/potentials-bands are **sorted in a least cost way**

\[
\text{costs} = f(\text{potential}); \ t = \text{constant}
\]

**continuous function**

**stepped (discrete) function**

"...every location is slightly different"

Practical approach: Sites with similar characteristics described by one band
Potentials
• by RES-E technology (by band)
• by country

Costs of electricity
• by RES-E technology (by band)
• by country

DYNAMIC COST-RESOURCE CURVES
• by RES-E technology
• by country
• by year

Dynamic aspects
• Costs: Dynamic cost assessment
• Potentials: Dynamic restrictions

(costs)
(potential)

(technological change)
(technology diffusion)
(7) Results

Reduction of investment cost within the BAU-scenario due to technological learning

Resulting cost reduction for RES-E technologies

Cost reduction - share of initial investment costs (as in the year 2005) [%]


BAU scenario
5. THE ISSUE OF TRANSFER COSTS AND EXTERNALITIES

All regulatory promotion schemes (Quota-based TGC systems, tendering systems, Feed-in tariffs) create an artificial market and cause transfer costs (additional costs)
It is important to minimize these additional transfer costs. Why?

These additional costs have finally to be paid by the electricity customers (regardless which promotion scheme is chosen)
Method of approach
(EU-project **GREEN-X**)

Minimise additional costs for consumers = Producer Surplus + Generation costs - Revenues electricity market

( - Avoided External costs)

**Price, costs [Euro/MWh]**

- $p_{MC}$ - marginal generation costs
- $p_{ele}$ - market price for (conventional) electricity
- $p_{MC}$ - Marginal price for green electricity (due to quota obligation)

**Producer surplus (PS)**

**Avoided External costs**

**Generation Costs (GC)**

**Quota Q**

**Quantity kWh**
Transfer costs vs avoided costs

Example: Promotion of wind in Germany 2005

Source: Krewitt/Schloemann: Externe Kosten ... (2006)
The lower the additional costs (=transfer costs) are which have finally to be paid by electricity customers, the higher will be public acceptance. The larger will be the amount of additional electricity generated from RES.
An example from the conventional electricity market:

in several countries (e.g. Germany, Belgium) customers are fed up with the high profits the large incumbent utilities make in the “free” market they request a re-regulation of electricity prices!
IMPACT OF THE SHAPE OF THE COST CURVE

Producers' Surplus

P_{Zert}

Biomass

Quota

Loc. B

Costs

[cent/kWh]

[GWh/year]
IMPACT OF THE SHAPE OF THE COST CURVE

- Producer Surplus
- Costs
- Munic. waste
- Grass cofiring
- Wind
- Biomass pure
- Small Hydro

[cent/kWh]

P_Zert

[Q] [GWh/year]
6. The simulation tool Green-X

This research project is supported by the European Commission, DG Research under the 6th Framework Programme and contributes to the implementation of the Key Action “Socio-economic aspects of energy within the perspective of sustainable development. Methodologies for global systems analysis” within the thematic programme “Energy, Environment and Sustainable Development.”

Contact No.: EN6-CT-2002-00697

Thomas Faber, Claus Huber, Gustav Resch
Energy Economics Group
Vienna University of Technology
GREEN-X allows

... to simulate various policy strategies for the promotion of electricity from RES in a dynamic framework on a national or international level (considering DS-effects)

(Current: EU-25, future: EU 39???)
Simulation model for energy policy instruments in the European electricity sector:

Base input information:
- Country selection
- Technology selection
- Power generation (Access Database)
- Electricity demand reduction (Access Database)

Economic market and policy assessment:
- Potential, costs, offer prices

Scenario Information:
- Policy strategies selection
- Social behaviour
- Investor/consumer
- Externalities
- Framework Conditions (Access Database)

Simulation of market interactions:
- RES-E, CHP, DSM power market, EUAs

Results Costs and Benefits on a yearly basis (2005-2020)
## General Results

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Electricity Consumption within the Country</td>
<td>349,948.63 GWh</td>
</tr>
<tr>
<td>Share of Total Electricity Consumption within the Country</td>
<td>100.00%</td>
</tr>
<tr>
<td>Total Electricity Generation within the Country</td>
<td>352,570.64 GWh</td>
</tr>
<tr>
<td>Share of Total Electricity Generation within the Country</td>
<td>100.75%</td>
</tr>
<tr>
<td>Import</td>
<td></td>
</tr>
<tr>
<td>Share of Total Electricity Generation within the Country</td>
<td></td>
</tr>
<tr>
<td>Export</td>
<td>2,620.00 GWh</td>
</tr>
<tr>
<td>Share of Total Electricity Generation within the Country</td>
<td>0.75%</td>
</tr>
<tr>
<td>Market price for Electricity</td>
<td>31.65 € per MWh</td>
</tr>
<tr>
<td>Total installed capacity</td>
<td>63,049.68 MW</td>
</tr>
<tr>
<td>New installed capacity</td>
<td>4,273.89 MW</td>
</tr>
</tbody>
</table>

## Generator/Production

### Total Outcome from National Generation

<table>
<thead>
<tr>
<th>Year</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Additional Outcome due to selected Strategy/Strategies from National Generation

<table>
<thead>
<tr>
<th>Year</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### United Kingdom

<table>
<thead>
<tr>
<th>Technology</th>
<th>Total Amount of Electricity Generation</th>
<th>Share of Total Electricity Generation</th>
<th>Total Amount of Electricity Generation new plants</th>
<th>Share of Total Electricity Generation new plants</th>
<th>Total installed capacity</th>
<th>New installed capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable power plants</td>
<td>27,832.00 GWh</td>
<td>8.24%</td>
<td>6,124.49 GWh</td>
<td>100.00%</td>
<td>20,769.55 MWh</td>
<td>4,119.19 MWh</td>
</tr>
<tr>
<td>Bioenergy</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Biogas</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Forestry products</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Forestry residues</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Agricultural products</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Agricultural residues</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Biogenic fraction of waste</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Geothermal electricity</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Hydro power</td>
<td>4,330.83 GWh</td>
<td>1.46%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>1,507.90 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Small scale (&lt; 10MW)</td>
<td>594.01 GWh</td>
<td>0.16%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>161.99 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Large scale (&gt; 10MW)</td>
<td>4,336.02 GWh</td>
<td>1.28%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>1,326.00 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Landfill gas</td>
<td>2,300.55 GWh</td>
<td>0.66%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>410.30 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Sewage gas</td>
<td>382.50 GWh</td>
<td>0.11%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>85.50 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Solar</td>
<td>9,736.54 GWh</td>
<td>2.88%</td>
<td>1,752.03 GWh</td>
<td>20.62%</td>
<td>14,666.95 MWh</td>
<td>2,540.73 MWh</td>
</tr>
<tr>
<td>Photovoltaic</td>
<td>9,736.54 GWh</td>
<td>2.88%</td>
<td>1,752.03 GWh</td>
<td>20.62%</td>
<td>24,663.95 MWh</td>
<td>2,540.73 MWh</td>
</tr>
<tr>
<td>Solar thermal</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Total</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Waste</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 GWh</td>
<td>0.00%</td>
<td>0.00 MWh</td>
<td>0.00 MWh</td>
</tr>
<tr>
<td>Wind</td>
<td>10,481.47 GWh</td>
<td>3.10%</td>
<td>4,371.65 GWh</td>
<td>71.35%</td>
<td>4,021.40 MWh</td>
<td>1,489.40 MWh</td>
</tr>
</tbody>
</table>
Example IRELAND

Static cost-resource curve for all RES-E (achieved potential up to 2005 and the additional mid-term potential)
Example AUSTRIA
Static cost-resource curve for all RES-E (achieved potential up to 2005 and the additional mid-term potential)
THE "POLICY" TRACK

1999 2001 2003 2005 2007

ELGREEN

theoretical modeling

GREEN-X

TRACK:
GREEN-NET

OPTRES

PROG-RES

FUTUR

empirical application
Total current electricity consumption: 3200 TWh

7. SOME RESULTS OF GREEN-X: CASE STUDY 2020

Investigated cases:

- **NO HARMONISATION**
  - Business-as-usual (BAU)
    - Continuation of current national policies up to 2020
  - Improved national policies
    - Efficient & effective national policies
  - Technology-specific support
    - Feed-in tariffs - harmonised

- **HARMONISATION IN 2015**
  - Non technology-specific support
    - Quota obligation based on TGCs - harmonised

Historical development
- Indicative RES-E Target (2010)
- Introduction of harmonised policies (2015)

BAU-forecast

Strengthened national policies

Technology-specific harmonised FIT scheme

Non technology-specific harmonised TGC system


951 TWh (BAU)

1156 TWh (improved national & harmonised policies)
(7) Case study - Results

**Total electricity generation from RES (EU25) as share of gross electricity demand**

**BAU scenario**

... how far will we come with current RES policies?

![Graph showing RES-E deployment](image)

- **BAU with accompanying DSM**: 27.0%
- **BAU with low energy prices**: 23.6%
- **BAU - continuation of current national RES-E policies**: 22.9%

... the impact of an **active DSM policy** and **conventional energy prices**
(7) Results

Total electricity generation from RES (EU25)

BAU scenario

Improved national policies scenario

... both cases based on purely national support schemes
Breakdown of electricity generation from new RES-E plant (installed in the period 2005 to 2020) on EU-25 level

**BAU scenario**

Breakdown of electricity generation by 2020 from new RES-E plant (installed 2005 to 2020)

- Wind onshore: 42.0%
- Wind offshore: 9.7%
- Biogas: 7.6%
- Biowaste: 3.8%
- Biowaste: 3.8%
- Solid biomass: 22.7%
- Biowaste: 3.8%
- Hydro large-scale: 5.9%
- Hydro small-scale: 1.8%
- Photovoltaics: 2.2%
- Solar thermal electricity: 2.8%
- Total: 520 TWh/year

**Improved national policies scenario**

Breakdown of electricity generation by 2020 from new RES-E plant (installed 2005 to 2020)

- Wind onshore: 31.5%
- Wind offshore: 22.8%
- Biogas: 8.7%
- Biowaste: 2.7%
- Biowaste: 2.7%
- Solid biomass: 22.7%
- Biowaste: 2.7%
- Geothermal electricity: 0.3%
- Hydro large-scale: 4.4%
- Hydro small-scale: 2.3%
- Photovoltaics: 2.2%
- Solar thermal electricity: 0.8%
- Tide & wave: 1.5%
- Total: 725 TWh/year
Breakdown of investment needs for new RES-E plant (installed in the period 2005 to 2020) on EU-25 level

**BAU scenario**

- Wind onshore: 35.3%
- Photovoltaics: 18.5%
- Solid biomass: 12.7%
- Biogas: 6.1%
- Hydro large-scale: 4.9%
- Hydro small-scale: 1.4%
- Tide & wave: 1.4%
- Solar thermal electricity: 4.4%
- Geothermal electricity: 0.2%
- Total: 234 Bill. €

**Improved national policies scenario**

- Wind onshore: 26.5%
- Photovoltaics: 18.6%
- Solid biomass: 11.8%
- Biogas: 7.6%
- Hydro large-scale: 3.7%
- Hydro small-scale: 2.3%
- Tide & wave: 1.6%
- Solar thermal electricity: 1.0%
- Geothermal electricity: 0.2%
- Total: 330 Bill. €
(7) Results

Reduction of investment cost within the BAU-scenario due to technological learning

Resulting cost reduction for RES-E technologies

Cost reduction - share of initial investment costs (as in the year 2005) [%]

- Hydropower
- Geothermal electricity
- Solid biomass - cofiring & large-scale plant
- Solid biomass - small-scale CHP
- Gaseous biomass
- Gaseous biomass CHP
- Wind energy
- Tidal & wave
- Solar thermal electricity
- Photovoltaics

BAU scenario
(7) Results

Transfer costs for consumer
(due to the promotion of RES-E)
Unit: M€/year or €/MWh\textsubscript{DEMAND}

Transfer costs for consumer / society (sometimes also called additional / premium costs for consumer / society) are defined as direct premium financial transfer costs from the consumer to the producer due to the RES-E policy compared to the case that consumers would purchase conventional electricity from the power market.
8. PERFORMANCE OF STRATEGIES: AN EMPIRICAL ANALYSIS
REQUIREMENTS TO SUCCESSFUL STRATEGIES

Major objectives:

- increase the amount of electricity from renewables and
- reduce costs!
HOW FEED-IN TARIFFS WORK

Costs

EURO/kWh

$P_{\text{Fix}}$

kWh

$Q_{\text{Out}}$

?
HOW QUOTA-BASED TRADABLE GREEN CERTIFICATES WORK

Costs

EURO/kWh

P_Zert

 QUOTA

kWh

?
LESSONS LEARNED: COMPARISON OF STRATEGIES

**Effectiveness:**

**Costs:**

(2000-2004)
SUCCESS CRITERIA FOR FIT’s

1 Use a stepped FIT and calculate starting values carefully

2 Identify ecological bonus

3 Decrease over time, link to conv. electr. market prices
MAJOR PITFALL OF FITs:
The example of wind

- Revenues increase!
- Profits increase!
- Costs decrease!
DYNAMICS:

- **RES-E-costs**
- **Support must decrease!**
- **Conventional electricity prices**

Diagram showing the relationship between RES-E-costs and conventional electricity prices over time.
SUCCESS CRITERIA
FOR QUOTA-BASED TGC’s

1 Penalty >> MC

2 Ensure long-term planning horizon!

3 Focus on new plants

4 Allow banking
MAJOR PITFALLS FOR QUOTA-BASED TGC’s

1. Market too small: e.g. in a small country for one technology with very limited potential -> Non-Liquid because every single plant is known (e.g. Flanders (BE))

2. Penalty is too low (e.g. UK)

3. Short planning horizon (e.g. UK 2003, Italy)

4. The problem of windfall profits for (existing) capacities (e.g. Flanders (BE), Sweden)
QUOTA: EXISTING VS NEW CAPACITY

- Market clearing price = price of certificate
- Windfall profits
- Δ Quota
- PS Total Quota
- Δ Quota
- New capacity
- Total Quota
Costs of promoted kWh vs costs of new kWh

Costs of promoted RES-E versus costs of "new" RES-E

- Costs of promoted RES-E (all plants)
- Costs of promoted RES-E (new installed plants)

Countries: SE, BE, UK, IT, ES, DE, AT
9. COMPETITION?

- conventional electricity market: To maximize profits utilities merge to avoid competition

- hard to imagine that a European-wide TGC market will work disconnected from these large incumbents

- TGC markets: Why should competition work if it does not in the conventional electricity market?

- Utilities/generators are in favour of TGC because they can make much more money and control the market, the construction of new plants much better
9. COMPETITION?

- Competition among manufacturers exist
- Most important argument for TGCs: it is assumed that they foster competition between generators
- Objective of competition -> competitive prices
- Competitive prices:
  \[ \text{Prices} = \text{marginal costs (of generation)} \]
- Currently (except Sweden): certificate prices > average feed-in-tariffs
- No indicator for real competition in many TGC markets!
10. CONCLUSIONS (1)

• Careful design of a strategies: by far the most important success criteria!

• There should be a clear focus on NEW capacities!

• IMPROVE THE CURRENT SYSTEMS!
10. CONCLUSIONS (2)

- Instead of harmonisation: Stimulate/Foster competition between promotion schemes/between countries: Which system/where provides new RES-E capacities at lowest costs for society?
- Exchange of lessons learned: Improvement of strategy design must build on learning from each other: e.g. Feed-in-cooperation DE and ES -> Why not a similar “Club” of TGC – countries?
- Currently, a well-designed (dynamic) FIT system provides a certain deployment of RES-e fastest and at lowest costs for society
- However, for sustainable policy -> parallel focus on demand-side conservation of high priority!
In the long run?

• Re-regulation?

• Priority production from renewables should persist

• Ecological bonus of the magnitude of external cost relief could prevail “eternally” (at least as long as no environmental taxes are introduced)

• However, for sustainable policy -> parallel focus on demand-side conservation of high priority!
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