# Dynamics of cost-resource curves for RES-E

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# Content

1. **Introduction**
   - Modelling of the future development of RES-E
   - Toolbox Green-X: Dynamic cost-resource curves
2. **'Static' cost-resource curves for RES-E**
   - Definitions
   - Existing plant – achieved potential
   - New plant – additional mid-term potential
   - Costs of electricity
3. **Dynamic Parameter Assessment**
   - Dynamic cost development
   - Dynamic restrictions
4. **Conclusions**
   - Potentials vs. targets for RES-E
   - Concluding remarks

# 1. Introduction: Modelling of the future development for RES-E

*Remark: RES-E … Renewable energy sources for electricity generation*

**What are the important aspects? How to implement them into a model?**

- Energy Policy: Promotions strategies for RES-E

  → Modelling of policy instruments
  *(see presentation "the dynamic computer-model Green-X")*

- Potentials (achieved & future potentials)

  → Inclusion of limitations, described by cost-resource curves

- Economics – Costs of electricity for RES-E

  → Cost assessment, e.g. done by cost-resource curves

- Dynamic development (of costs & potentials)

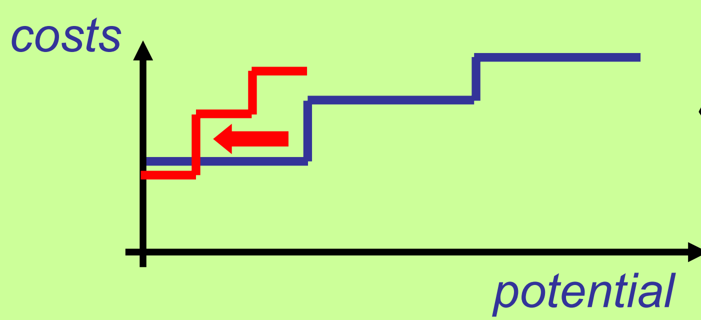
  → Costs: "learning curve – approach" or expert forecast
  → Potentials: Dynamic restrictions

# 1. Introduction: *The Green-X approach – Dynamic cost-resource curves*

**Potentials**
- by RES-E technology
- by country

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

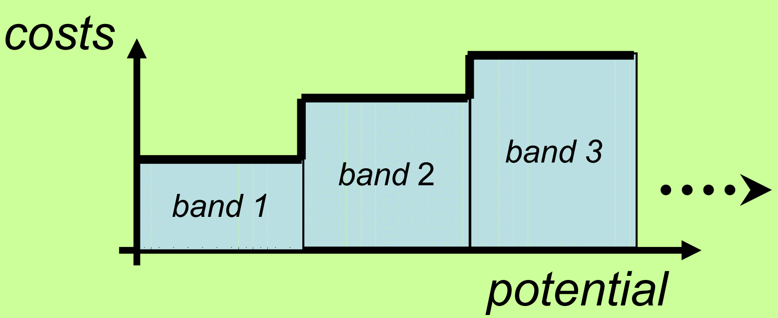
**DYNAMIC**
**COST-RESOURCE CURVES**
- by RES-E technology
- by country
- by year




**Dynamic aspects**
- Costs: Dynamic cost assessment
- Potentials: Dynamic restrictions

## 2. 'Static' cost-resource curves: Definitons

**- static cost-resource curve** … combines information on the *potential* and the according *costs of electricity* for a specific energy source




all *costs/potentials-bands* are arranged according to costs, i.e. cheapest first, and most expensive last

**- costs of electricity** …

$$C = \frac{I \cdot \alpha}{T} + C_{Var}$$

$$\alpha = \frac{z \cdot (1+z)^{LT}}{(1+z)^{LT} - 1}$$

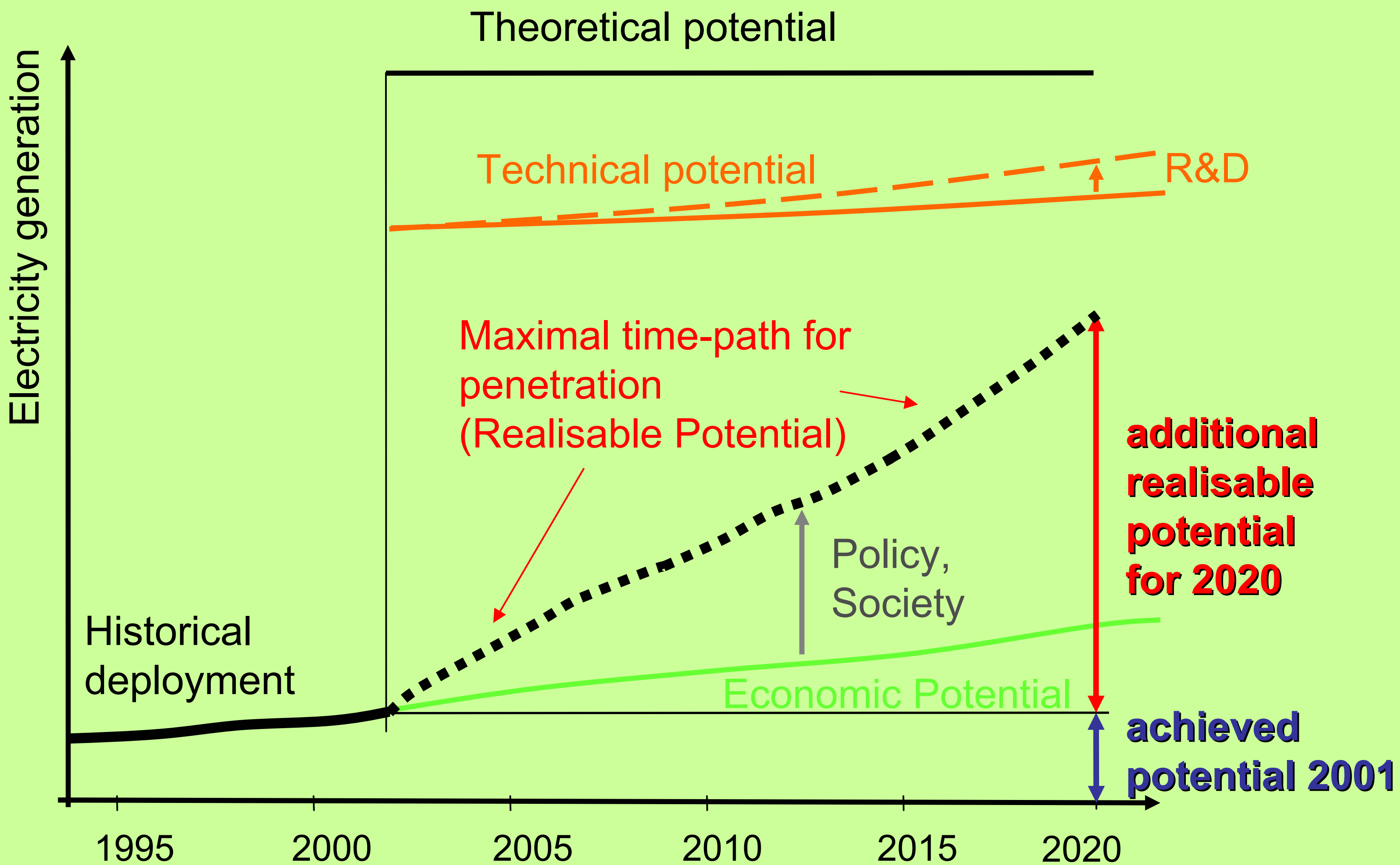
C .... Costs of electricity per unit [€/MWh]
= LONG-TERM MARGINAL COSTS

I .... Investment costs per kW [€/kW]
α .... Capital Recovery Factor [1]
T .... Full load hours [h/a]
z .... Interest rate [1]
LT .... Lifetime / depreciation time [a]

$C_{Var}$ .... Variable costs per unit [€/MWh] (incl. O&M, fuel costs)
= SHORT-TERM MARGINAL COSTS

## *2. 'Static' cost-resource curves:* Definitons

### - (additional) realisable mid-term potential



## 2. 'Static' cost-resource curves: Definitons

# *RES-E technologies considered:*

| | | | | |
|---|---|---|---|---|
| E & C | 1. | *Biogas* | | |
| E & C | 2. | *Biomass* | *Forestry products,*<br>*Forestry residues,*<br>*Agricultural products*<br>*Agricultural residues*<br>*Biodegradable fraction of waste* | |
| E & C | 3. | *Geothermal electricity* | | |
| E | 4. | *Hydro power* | *Small scale hydro power (<10 MW)*<br>*Large scale hydro power (>10 MW)* | |
| E & C | 5. | *Landfill gas* | | |
| E & C | 6. | *Sewage gas* | | |
| E | 7. | *Solar* | *Photovoltaics*<br>*Solar thermal electricity* | |
| E | 8. | *Tidal (stream) energy* | | |
| E | 9. | *Wave energy* | | |
| E | 10. | *Wind* | *Wind on-shore*<br>*Wind off-shore* | |

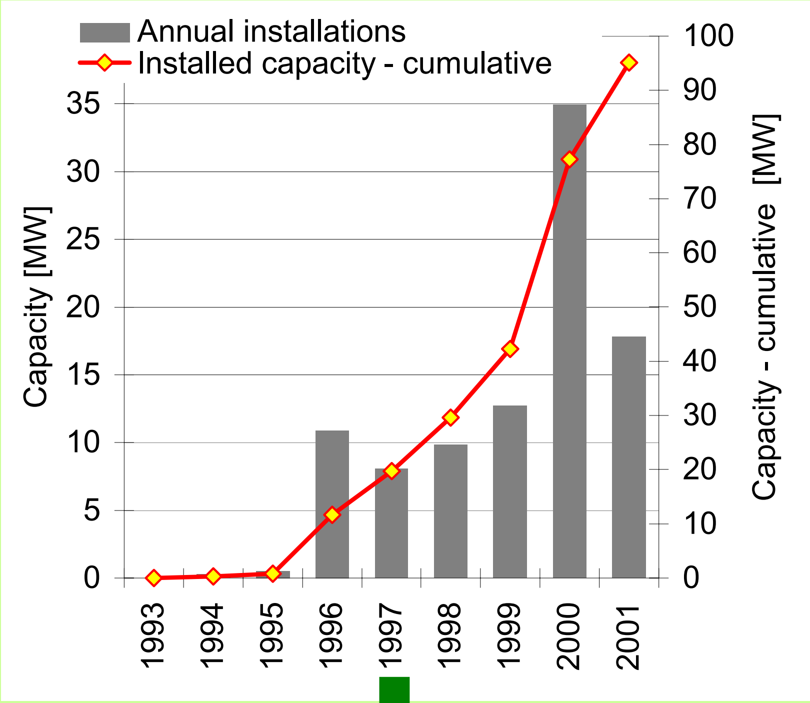
Abbreviation:

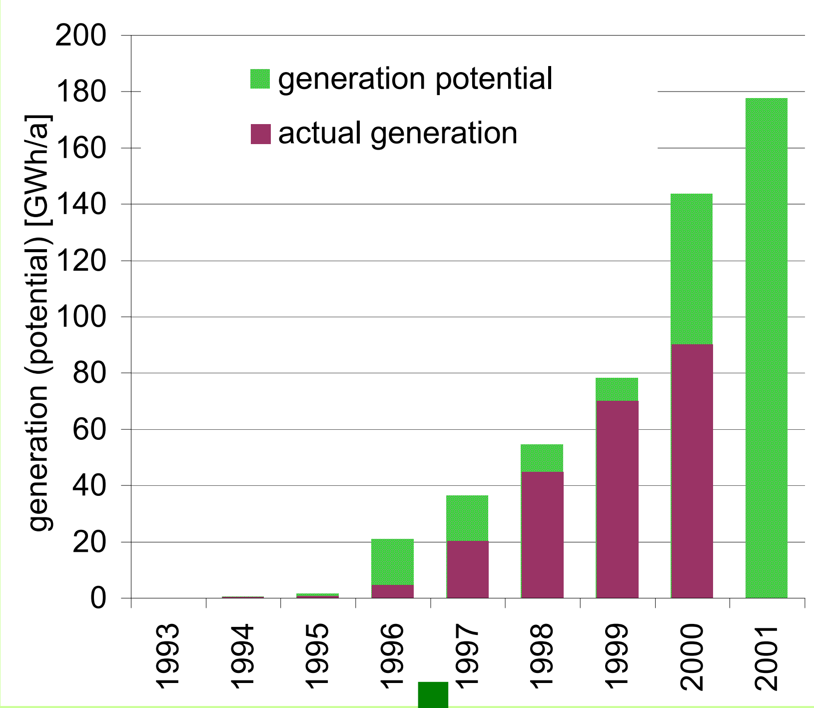
E … Electricity

C … CHP

## 2. 'Static' cost-resource curves: Existing plant – achieved potential

### Example: Wind onshore in Austria

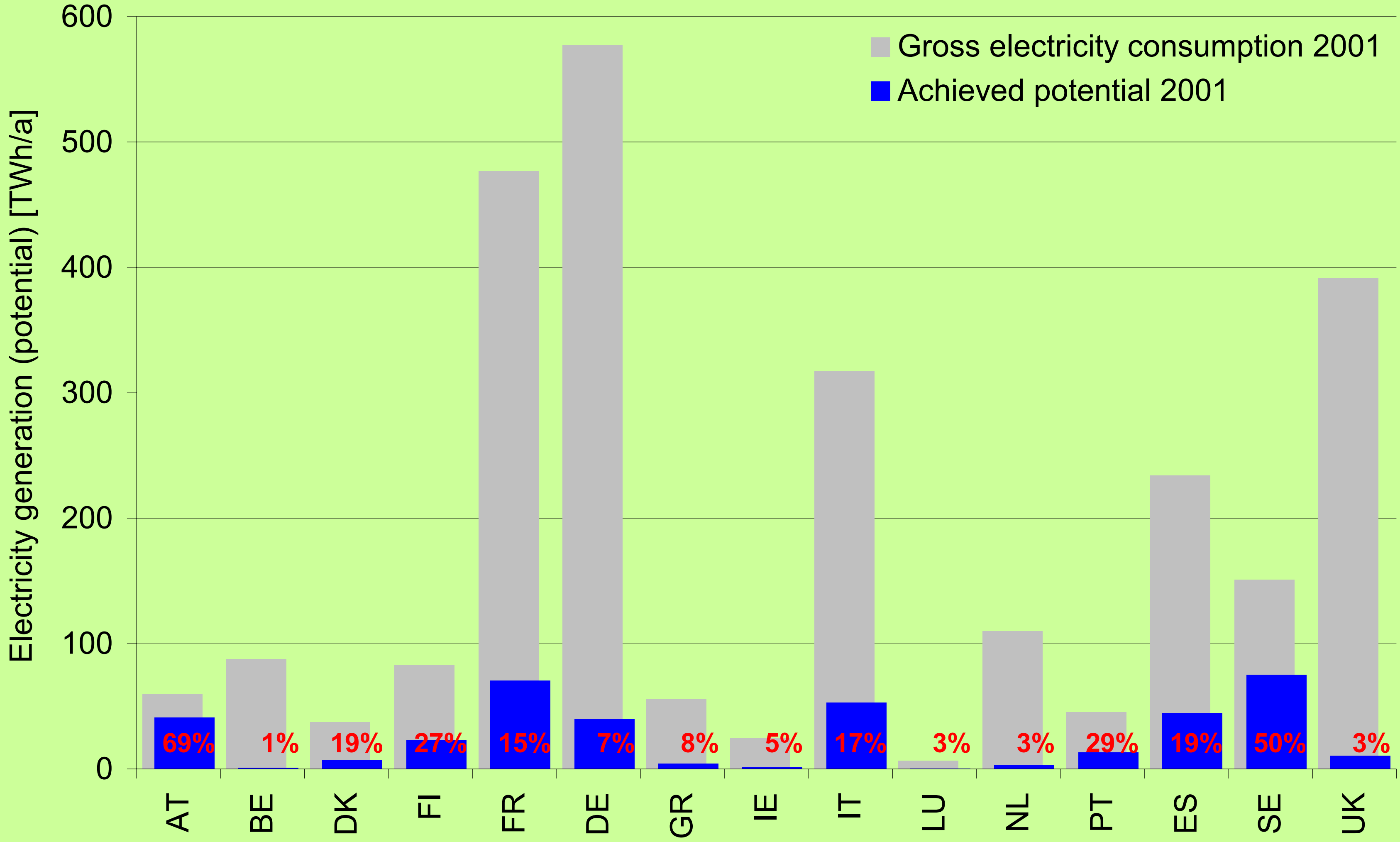



| Band name | Constr. year | Base(B)/ Peak(P) load | Potential [GWh] | Load hours ele [h/a] | Load hours heat [h/a] | Efficiency ele [1] | Efficiency heat [1] | O+M costs [€/kWinst.] | Fuel category | Investment costs [€/kWinst.] |
|---|---|---|---|---|---|---|---|---|---|---|
| AT-E-RES-X-WI-ON-1 | 1993 | B | 0,02 | 1850 | 0 | 1 | 0 | 45 | 0 | 1511 |
| AT-E-RES-X-WI-ON-2 | 1994 | B | 0,54 | 1850 | 0 | 1 | 0 | 45 | 0 | 1337 |
| AT-E-RES-X-WI-ON-3 | 1995 | B | 0,88 | 1850 | 0 | 1 | 0 | 45 | 0 | 1299 |
| AT-E-RES-X-WI-ON-4 | 1996 | B | 20,21 | 1850 | 0 | 1 | 0 | 45 | 0 | 1245 |
| AT-E-RES-X-WI-ON-5 | 1997 | B | 14,80 | 1850 | 0 | 1 | 0 | 45 | 0 | 1172 |
| AT-E-RES-X-WI-ON-6 | 1998 | B | 18,32 | 1850 | 0 | 1 | 0 | 45 | 0 | 1144 |
| AT-E-RES-X-WI-ON-7 | 1999 | B | 9,99 | 1850 | 0 | 1 | 0 | 45 | 0 | 1076 |
| AT-E-RES-X-WI-ON-8 | 2000 | B | 77,70 | 1850 | 0 | 1 | 0 | 45 | 0 | 1028 |
| AT-E-RES-X-WI-ON-9 | 2001 | B | 32,38 | 1850 | 0 | 1 | 0 | 45 | 0 | 1010 |

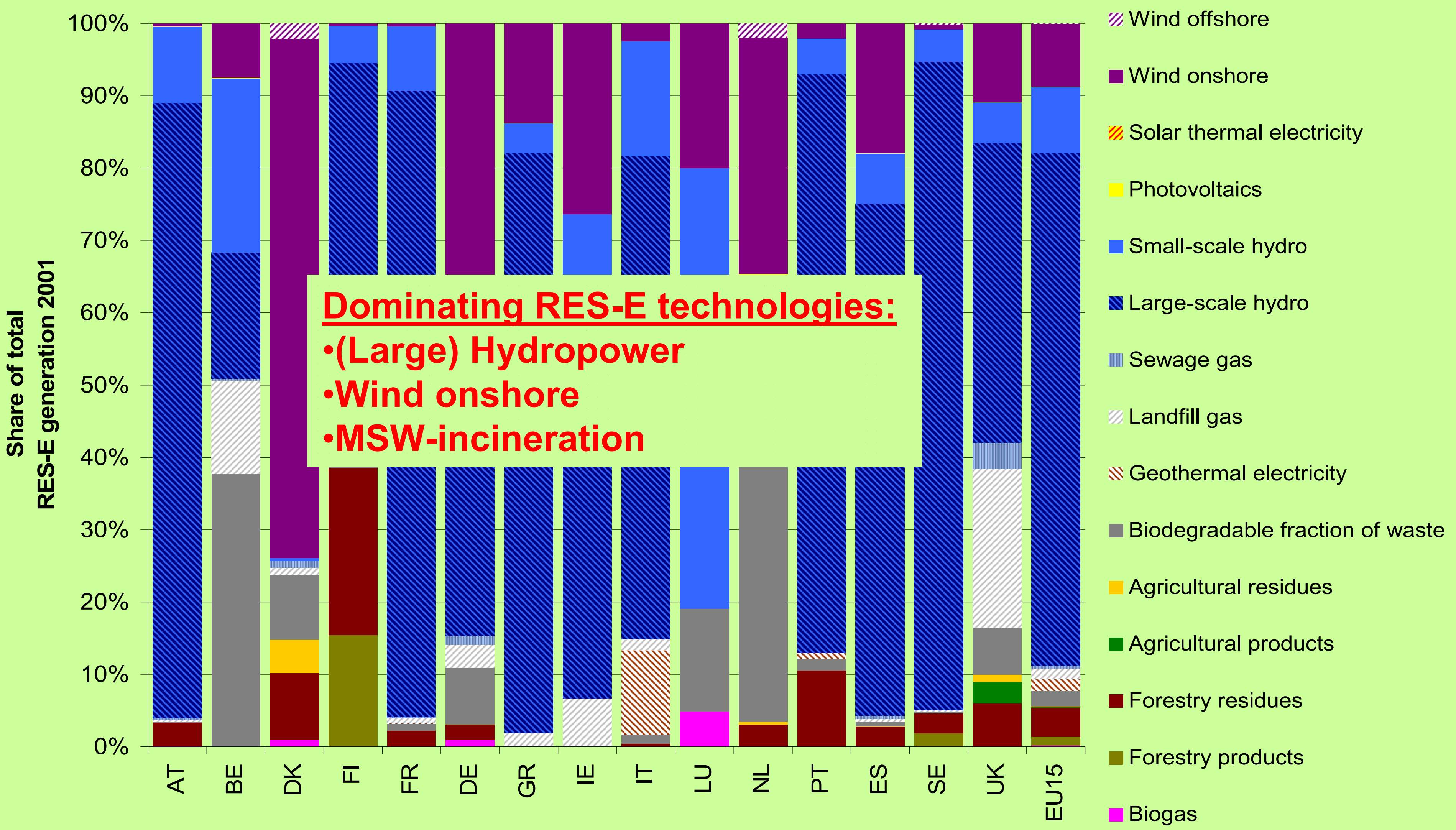
## 2. 'Static' cost-resource curves: Existing plant – achieved potential

### Overview: Achieved potential vs. Gross electricity consumption (EU-15)



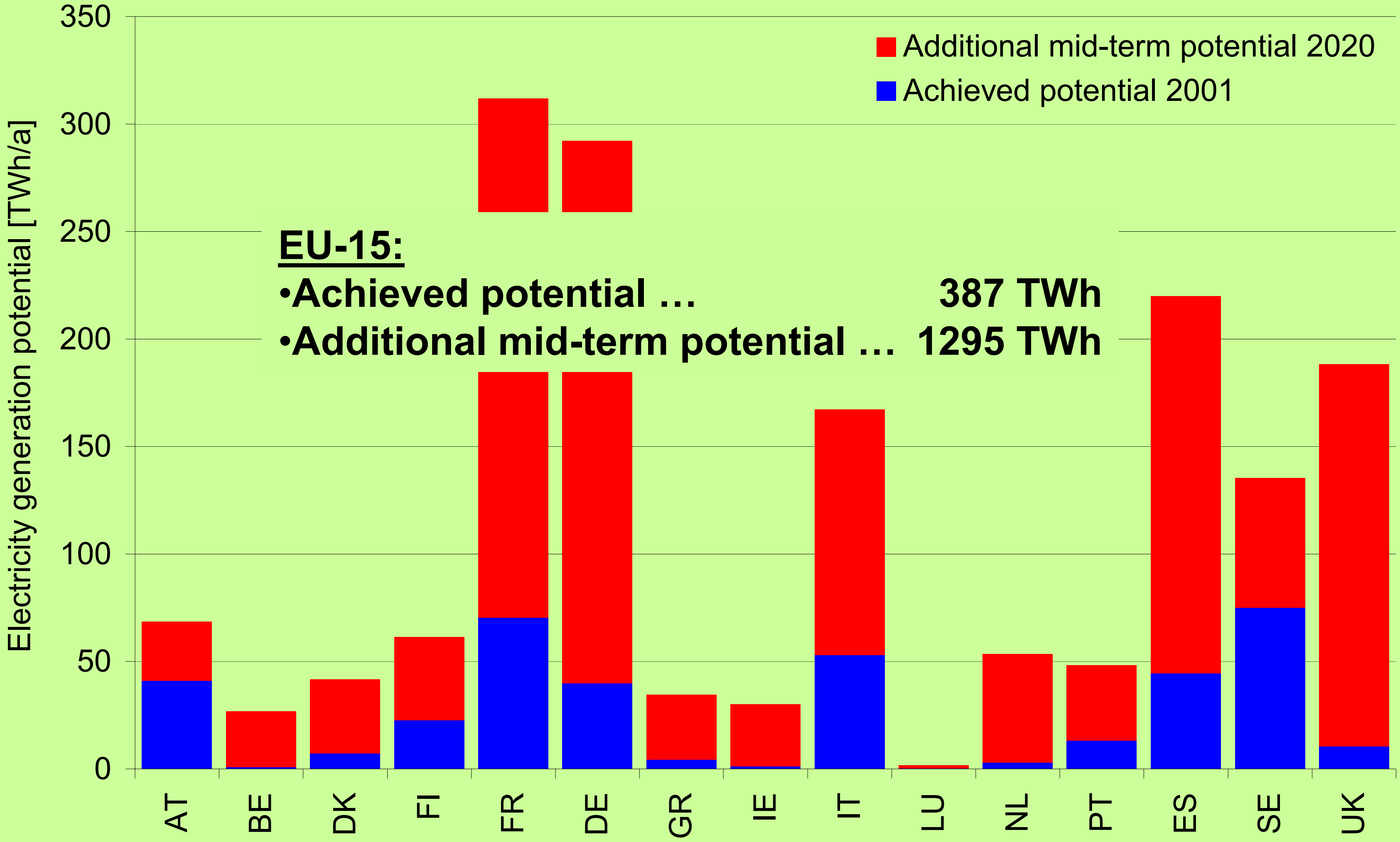
## 2. 'Static' cost-resource curves: Existing plant – achieved potential

### Overview: RES-E technologies as share of total achieved potential (EU-15)



## 2. 'Static' cost-resource curves: New plant – additional mid-term potential

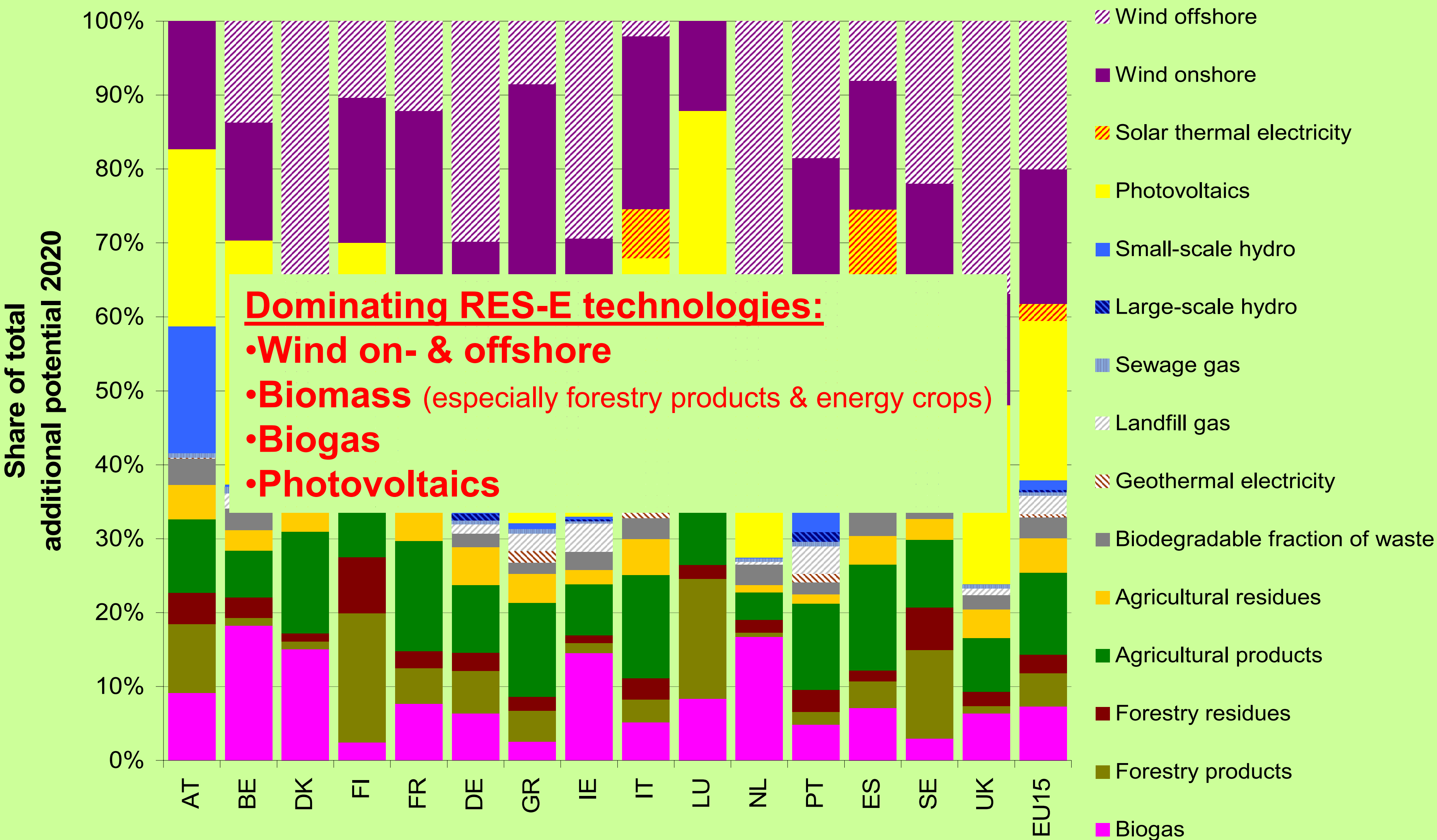
**Overview: Achieved (2001) and additional mid-term (2020) potential (EU-15)**




**EU-15:**
- **Achieved potential … 387 TWh**
- **Additional mid-term potential … 1295 TWh**

## 2. 'Static' cost-resource curves: New plant – additional mid-term potential

### Overview: RES-E technologies as share of total additional potential (EU-15)




**Dominating RES-E technologies:**

- **Wind on- & offshore**
- **Biomass** (especially forestry products & energy crops)
- **Biogas**
- **Photovoltaics**

# 2. 'Static' cost-resource curves: Costs of electricity
## - Model implementation -

## Band specific parameter:
***(i.e. included in the database for potentials & costs!!!)***

- Investment costs
- O&M costs
- Fuel costs (→Biomass)

*Refering to the start year of the simulation (i.e. 2002)*

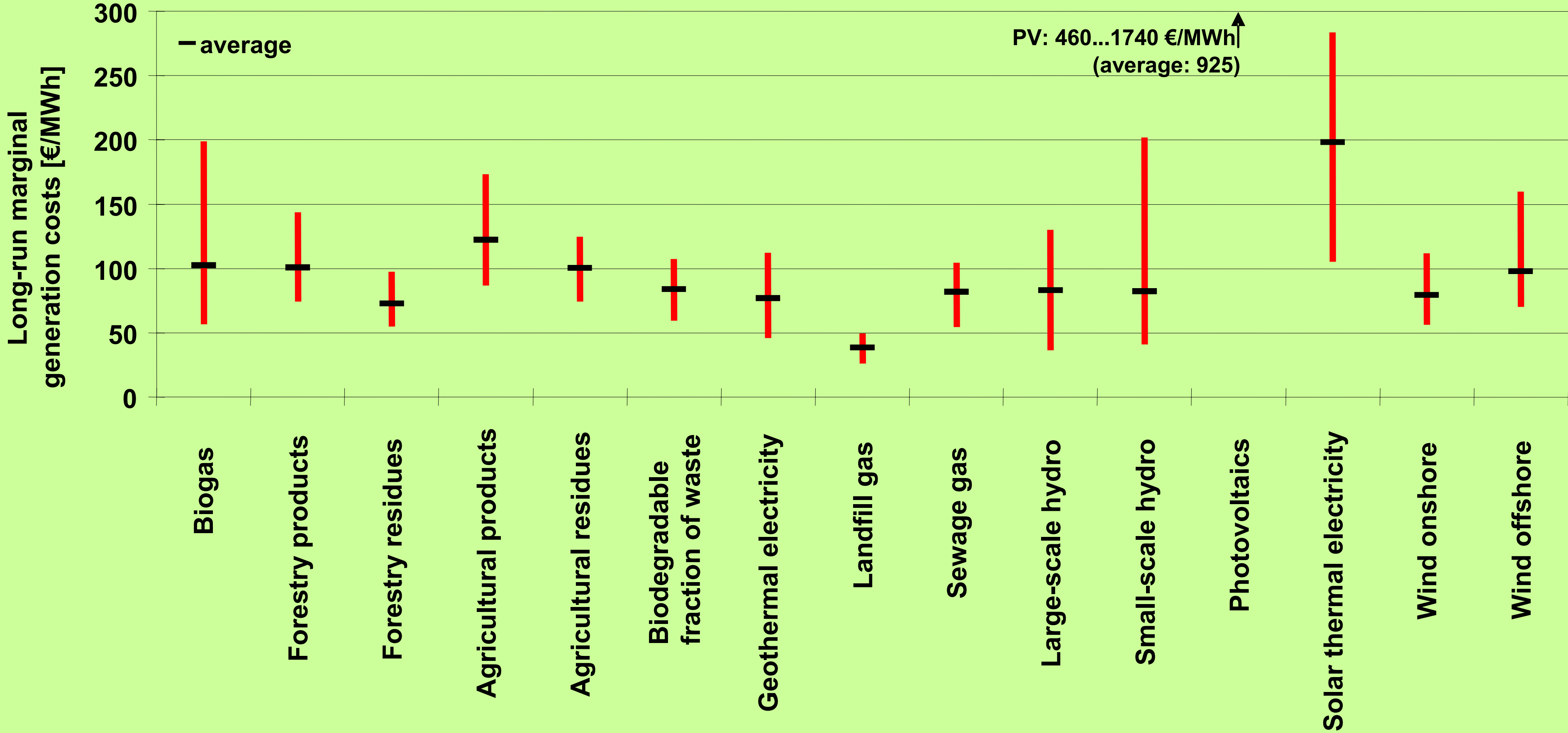
## Strategy-/Setting-specific parameter:
***(i.e. internalised into model-calculation)***

- Depreciation time
- Interest rate
- Electrcity market price (peak/base)

➡ The following **overview on electricity generation costs** is based on default figures for **interest rate** (i.e. 6,5%) & **depreciation time** (i.e. 15 years)!!!

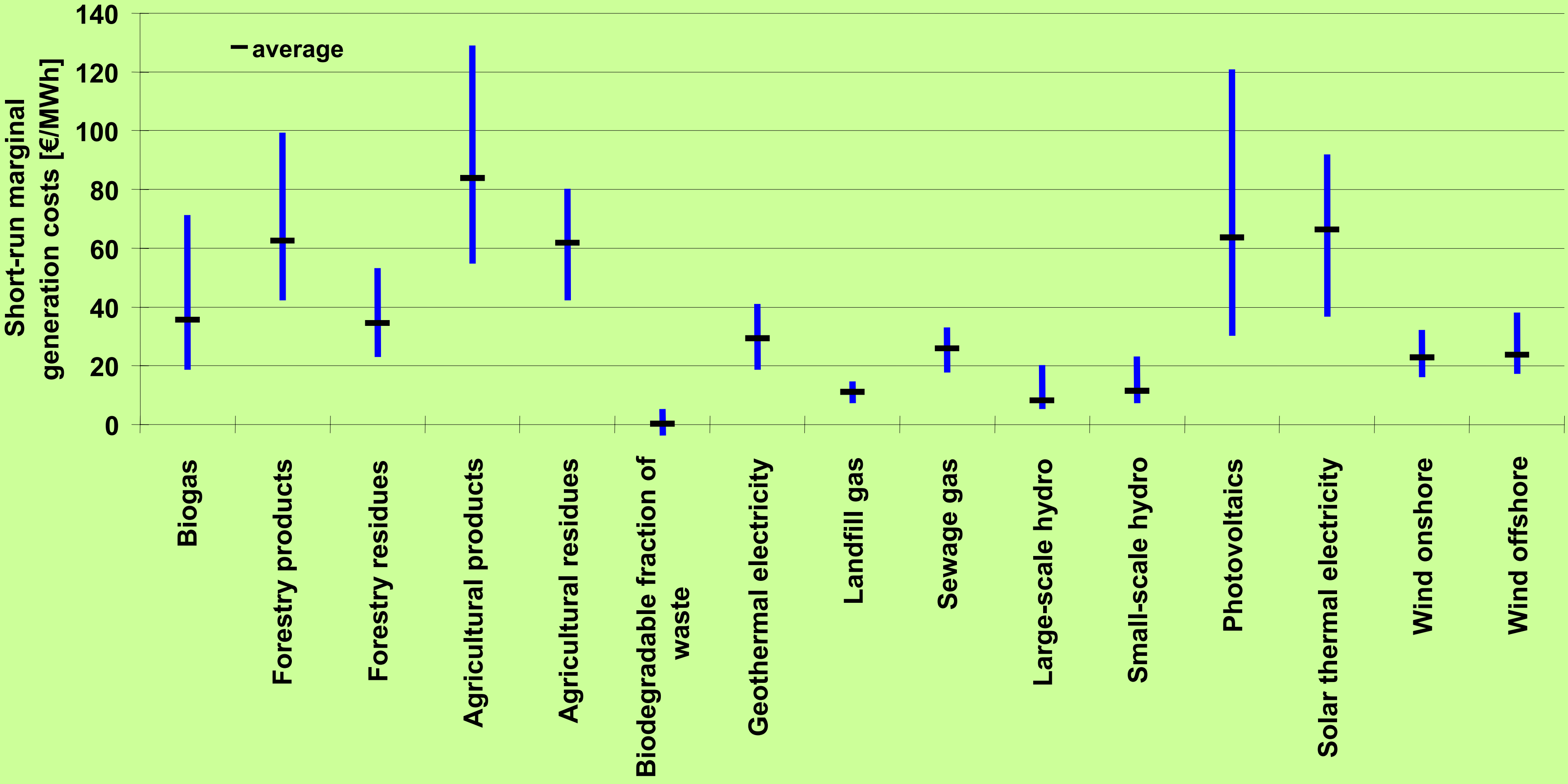
## 2. 'Static' cost-resource curves: Costs of electricity

### Overview: Long-run marginal generation costs by RES-E (for EU-15)



## *2. 'Static' cost-resource curves:* *Costs of electricity*

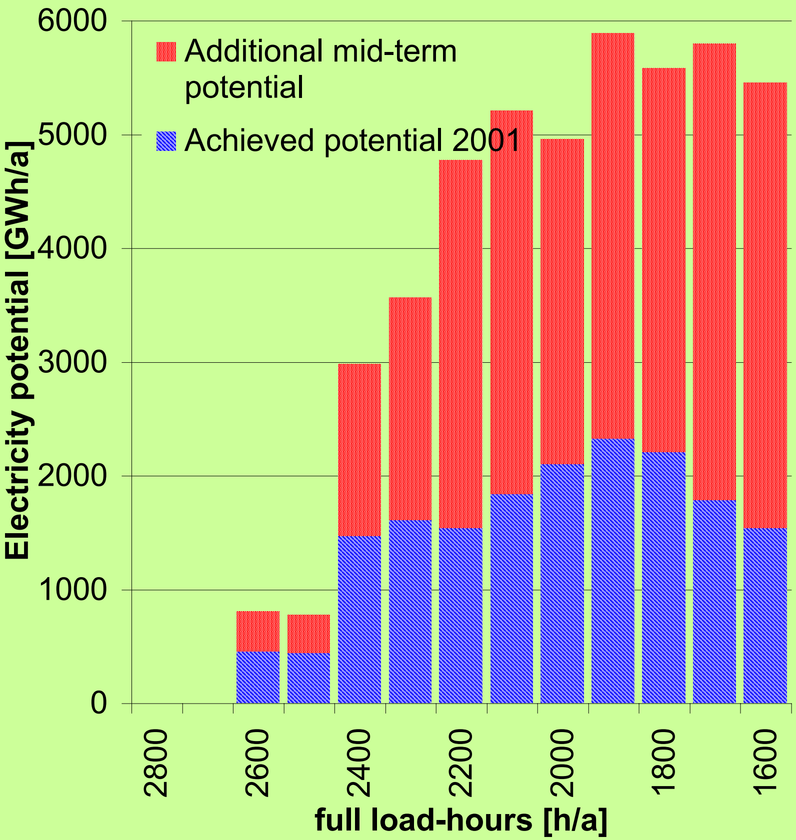
**Overview: Short-run marginal generation costs by RES-E (for EU-15)**

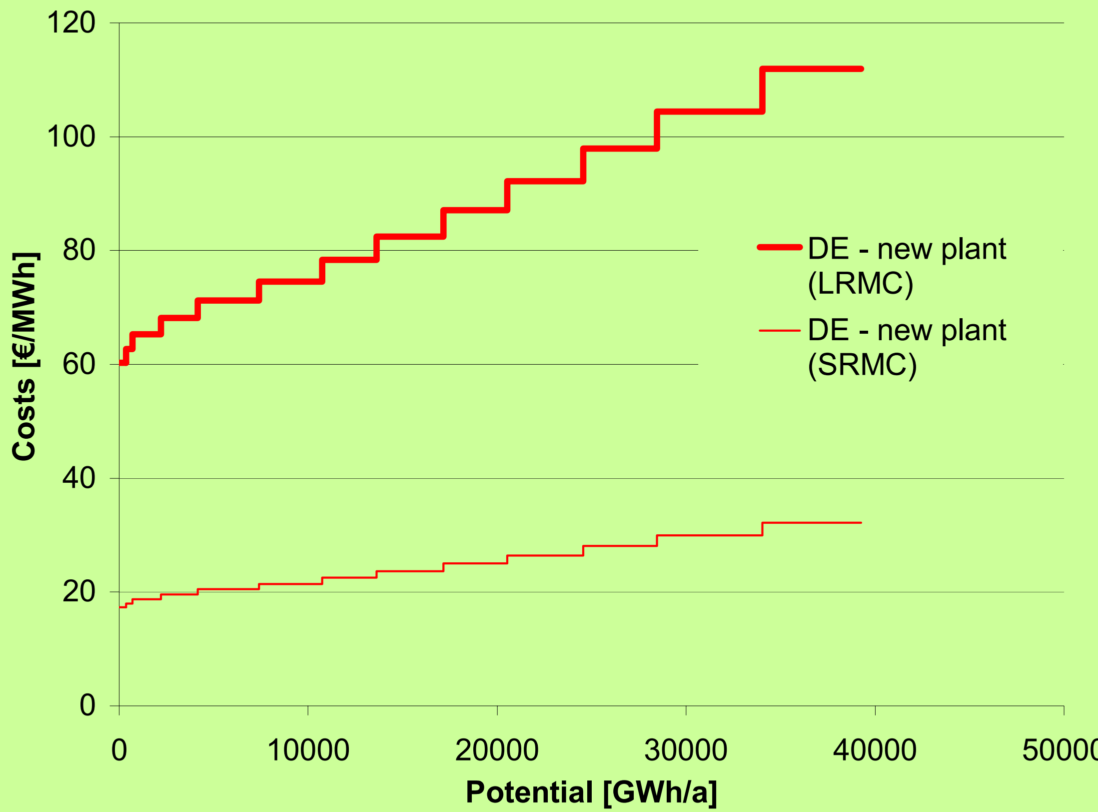


## 2. 'Static' cost-resource curves: Cost-resource curves

### Example: Wind onshore in Germany

**Distribution of potential on full-load hours** → **Resulting cost-resource curve (for new plant)**



## 3. Dynamic parameter assessment: Dynamic cost development
### – investment costs –

- *E.g. done by* **„Learning curve“-approach** → future cost development

$$C_n = C_0 * \left( \frac{P_n}{P_0} \right)^b$$

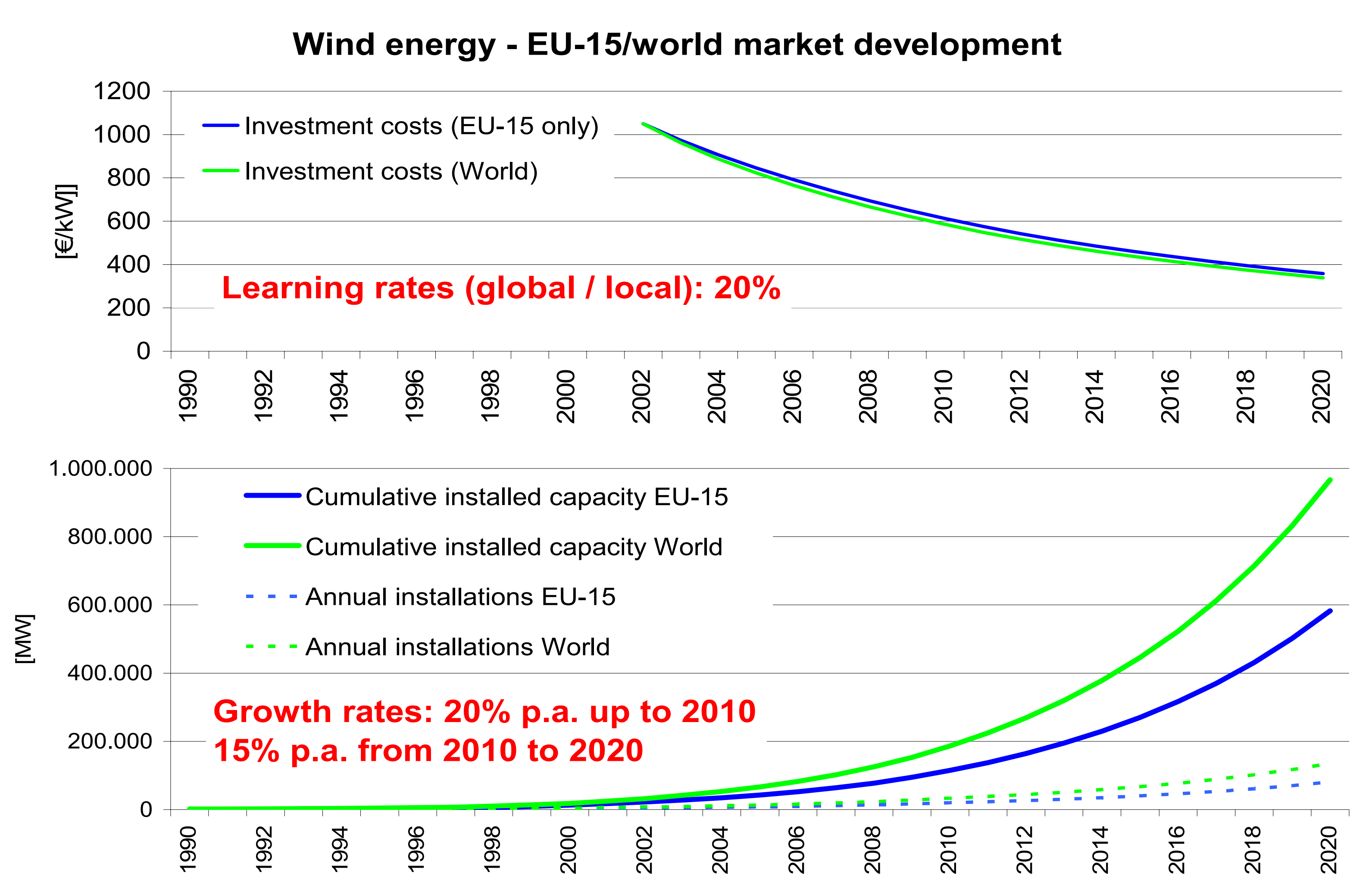
$$1 - LR = 2^b$$

$C_n$ … Investment costs in year n
$C_0$ … Investment costs in start year (0)
$P_n$ … Installed capacity in year n
$P_0$ … Installed capacity in start year (0)
LR … Learning rate %

Each doubling of installed capacity → costs drop by (LR)%

## 3. Dynamic parameter assessment: Dynamic cost development
## – investment costs –

•*Example:* ***„Learning curve"-approach*** *in case of wind energy*



# 3. Dynamic parameter assessment: Dynamic restrictions – Overview –

| **Dynamic parameter & their characterization** | | **Techn.-specific** | **Country-specific** | **Band-specific** | **Linkage to policy** | **Impact on Costs** | **Impact on Potentials** | **Methodology to implement** |
|---|---|---|---|---|---|---|---|---|
| **Industrial constraints** | Growth rate of industry | X | | | | | X | EU-wide limitation of annual installations… |
| | ... | | | | | | | |
| **Technical constraints** | Grid constraints (i.e. extension necessary) | X | X | X | | X | (X) | Band-specific limitation of annual installations, additional costs for grid extension… |
| | ... | | | | | | | |
| **Market constraints** | Market transparency | X | X | | | | X | … |
| | Investors behaviour | X | X | | X | | X | … |
| | ... | | | | | | | |
| **Societal constraints** | 'Willingness to accept' | X | X | X | X | | X | (Band-specific) limitation of annual realisable potential |
| | ... | | | | | | | |

# 3. Dynamic parameter assessment: Dynamic restrictions – Model implementation –

**Technical constraints:**
Grid connection / Grid extension … → Dynamic limitation of potential

**Industrial contraint (growth rate of industry):**
Limitation of available additional potential in year n / EU-wide

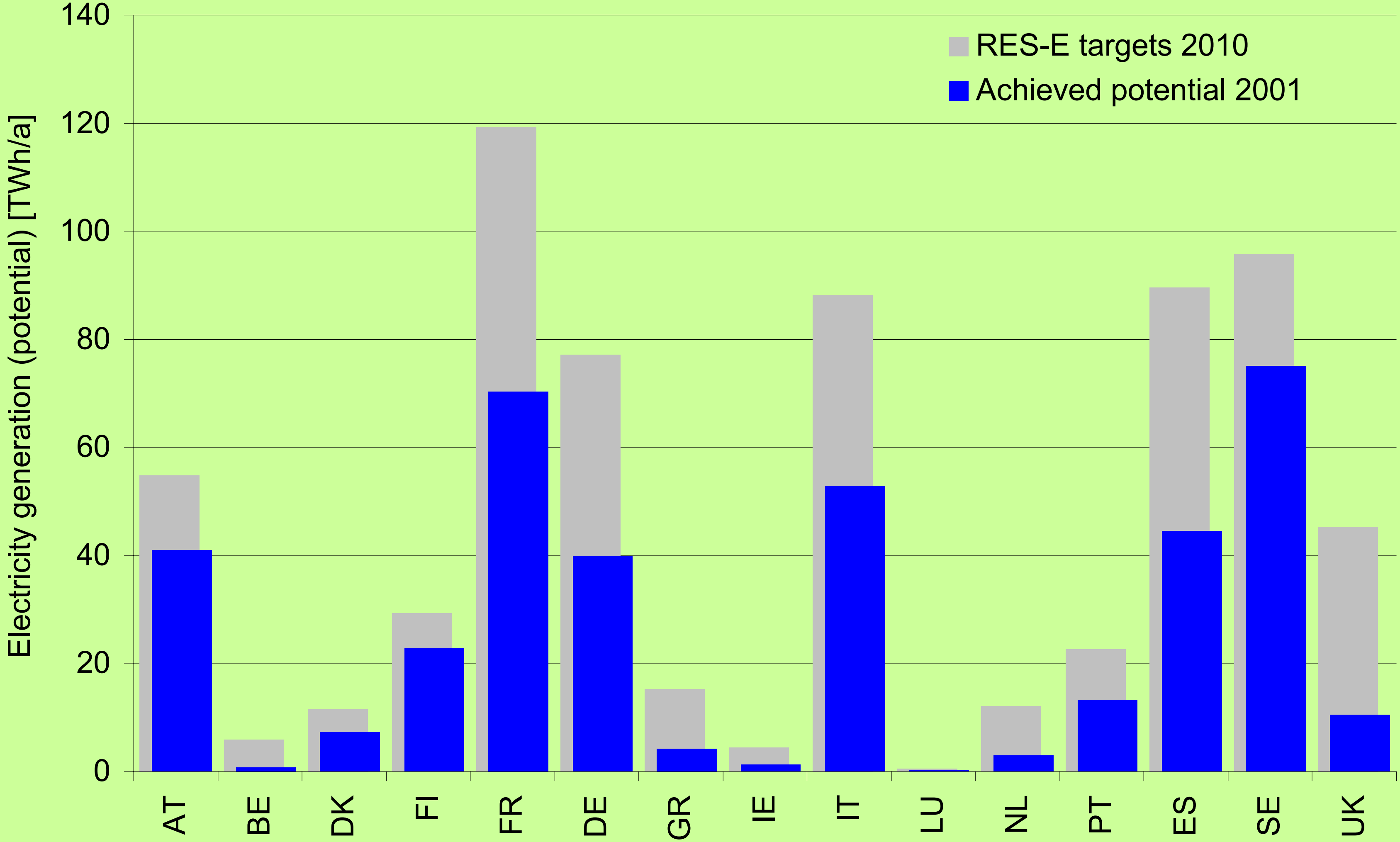
**Market constraints ((Missing) Market transparency):**
Limitation of potential of technology X (in Country Y)
to z% of additional potential

**Social constraints ((Missing) Public acceptance):**
Limitation of potential of technology X (in Country Y)
to z% of additional potential

**Administrative constraints (Implementation delay due to administrative barriers)**
Delay (leap time) → translate to potential limitation in year n

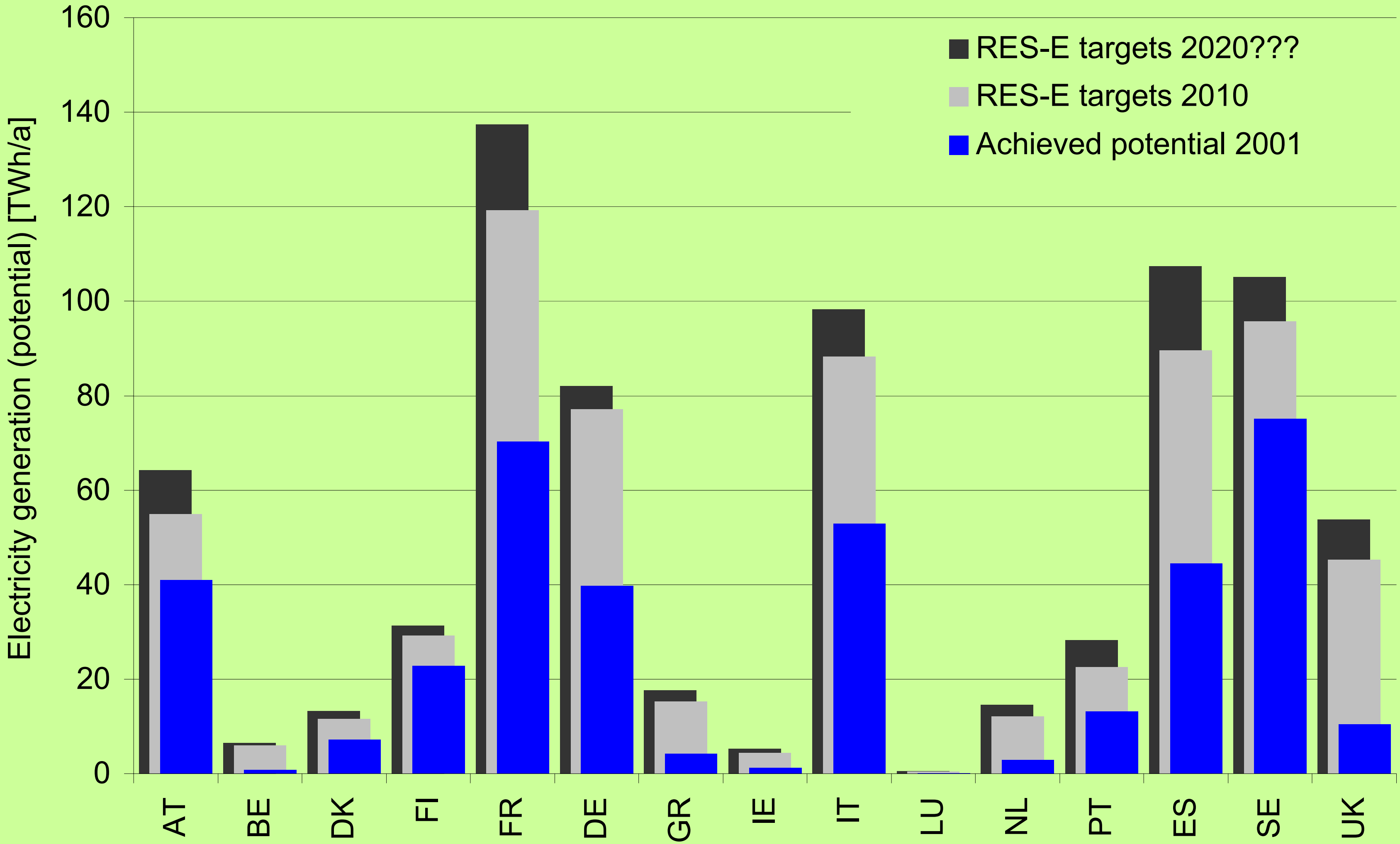
# 4. Conclusions: Potentials vs. targets

## Overview: Achieved potential vs. RES-E targets by country (for EU-15)



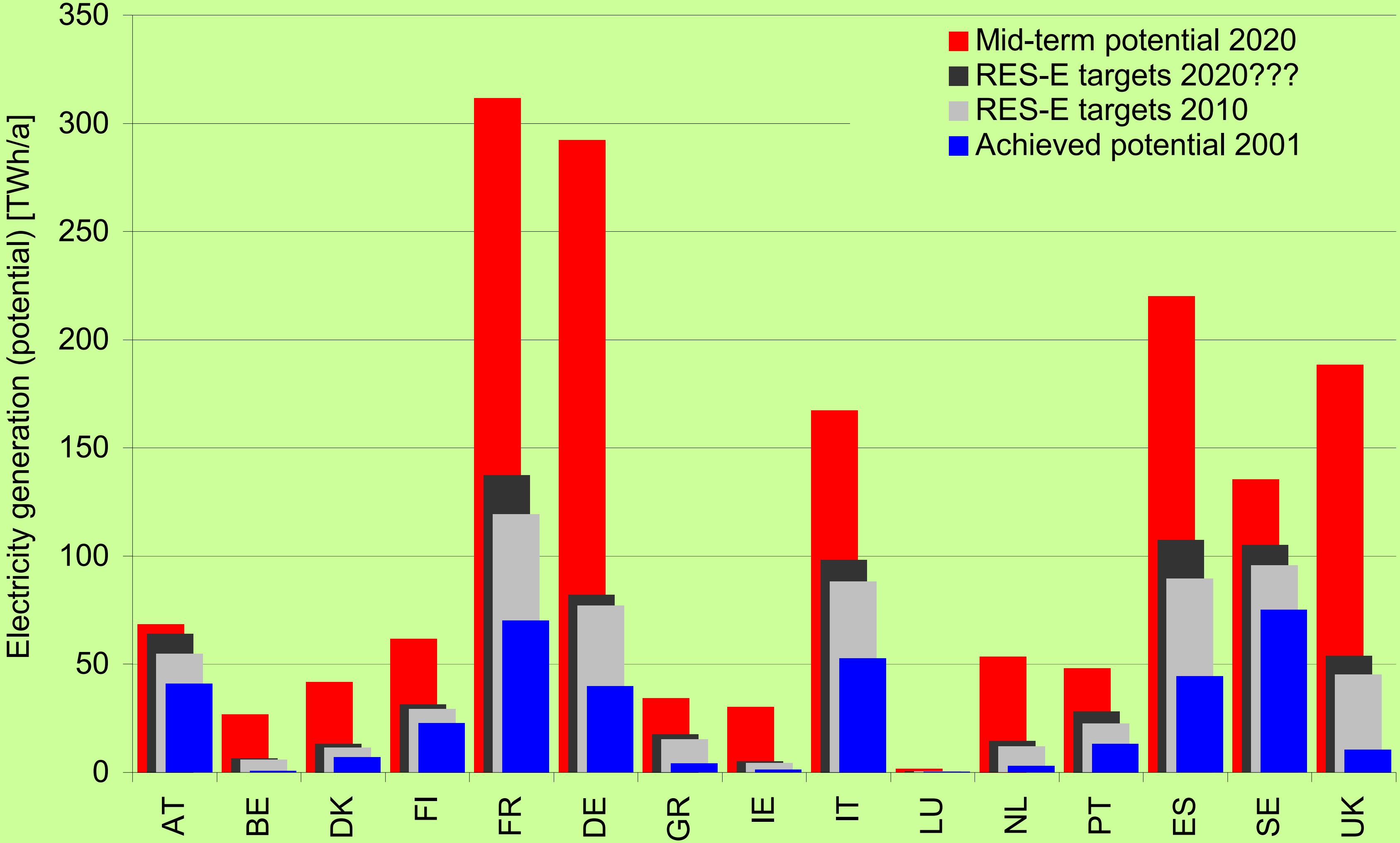
# 4. Conclusions: Potentials vs. targets

## Overview: Achieved potential vs. RES-E targets by country (for EU-15)



# 4. Conclusions: Potentials vs. targets

## Overview: Mid-term potential vs. RES-E targets by country (for EU-15)



# 4. Conclusions: Potentials vs. targets

## Overview: Mid-term potential vs. Targets (& Consumption) by country (for EU-15)

| Potential vs. RES-E targets | Mid-term potential as share of gross electricity consumption | Mid-term potential as share of RES-E target 2010 | Mid-term potential as share of RES-E target 2020 |
|---|---|---|---|
| Austria | 83% | 125% | 107% |
| Belgium | 25% | 454% | 416% |
| Denmark | 91% | 360% | 315% |
| Finland | 62% | 211% | 197% |
| France | 48% | 261% | 227% |
| Germany | 44% | 379% | 356% |
| Greece | 39% | 226% | 195% |
| Ireland | 76% | 690% | 575% |
| Italy | 43% | 190% | 170% |
| Luxembourg | 18% | 348% | 320% |
| Netherlands | 33% | 443% | 367% |
| Portugal | 66% | 213% | 170% |
| Spain | 60% | 246% | 205% |
| Sweden | 77% | 141% | 129% |
| United Kingdom | 35% | 416% | 350% |
| European Union (15) | **48%** | **250%** | **220%** |

# 4. Conclusions: Concluding remarks

The **derived database on RES-E potentials & costs** – done by **dynamic cost-resource curves** – provides a comprehensive picture of the EU-wide situation & is ready to start in-depth analysis!

**Preliminary conclusions:**

*– based on a rough comparison of potentials, targets & electricity demand –*

- The EU(-15)-wide mid-term potential for RES-E is in size to meet e.g. the 2010-targets given by the 'RES-E directive' (EC, 2001);
- Nevertheless, - beside policies - the future **development of electricity demand is of crucial importance** regarding target-achievment;
- On a country-level large differences regarding RES-E potentials occur
- In general, by considering potentials & costs, **wind (on- & offshore) and biomass** will be the most important RES-E options;
- Of course, to achieve targets **all RES-E options have to be considered**.