Dynamics of cost-resource curves for RES-E

Gustav Resch, Claus Huber, Thomas Faber, Reinhard Haas,
Energy Economics Group (EEG)

Content

1. **Introduction**
   - Modelling aspects
2. **Basic principles**
   - Static cost-resource curves
   - Experience curves
   - Dynamic cost-resource curves
3. **Overview: RES-E in EU-15 countries**
   - Achieved vs. additional realisable potentials
   - Costs of electricity
   - Cost-resource curves
4. **Comparison**
   - Potentials vs. future targets
   - Concluding remark

1. Introduction: The computer model Green-X

- has been developed within the EU-project „Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market - Green-X“ funded by the EC DG RESEARCH
- Objective of ***Green*-X:**
  - To facilitate a significant increased RES-E generation in a liberalised electricity market with minimal costs to European citizen.
  - To find a set of efficient, sustainable and integrated strategies for RES-E, conventional electricity production (incl. CHP), DSM activities and GHG-reduction

1. Introduction: The computer model Green-X

- Within **Green-X** the most important energy policy instruments can be simulated and their effects analysed in a dynamic framework:
  - RES-E (e.g. feed-in tariff, quota system, tendering systems)
  - Conventional technologies (e.g. nuclear phase-out)
  - Combined heat and power production (e.g. quota system)
  - Demand side activities (e.g. investment subsidies, tax relief)
  - GHG-emission strategies (certificate trade, taxes)
- All RES-E technologies in every country are described by dynamic cost-resource curves for the EU-15 member states.

1. Introduction: Forecasting RES-E deployment within Green-X

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)

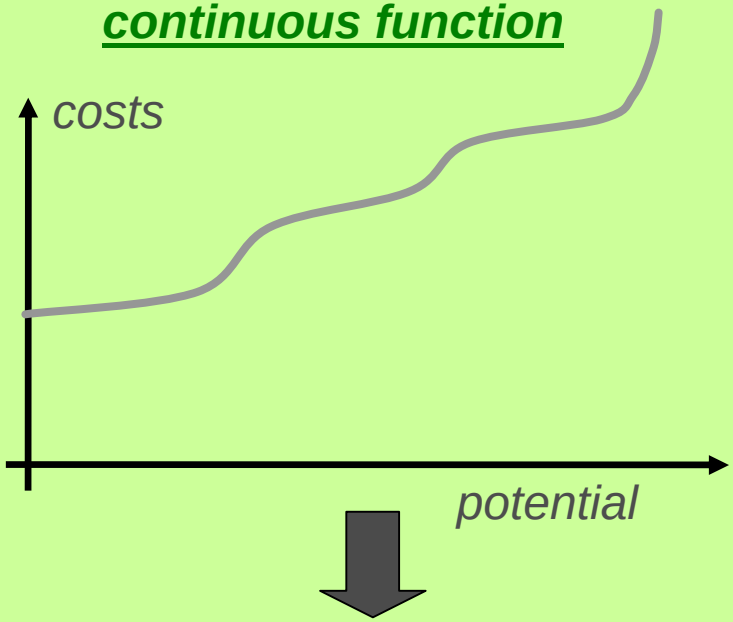
  → Costs: "learning curve – approach" or expert forecast
  → Potentials: Dynamic restrictions

2. Basic principles: Static cost-resource curves

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

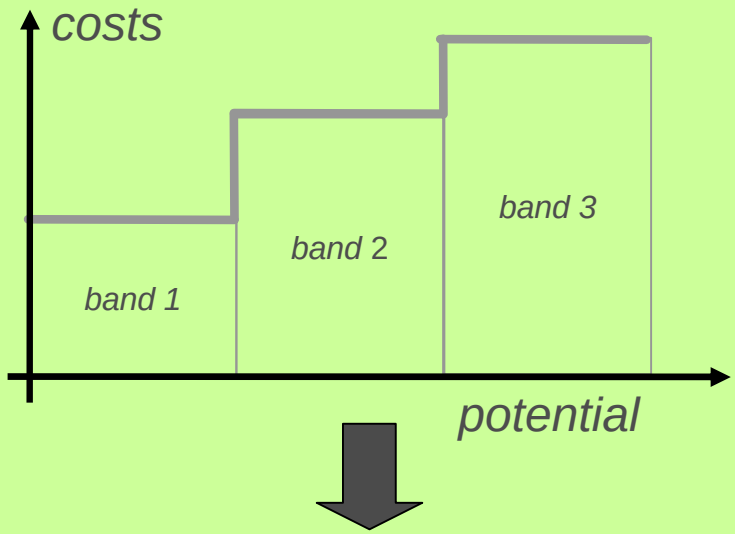
costs = f (potential); t = constant

continuous function



„…every location is slightly different“

stepped (discrete) function



Practical approach: Sites with similar characteristics described by one band

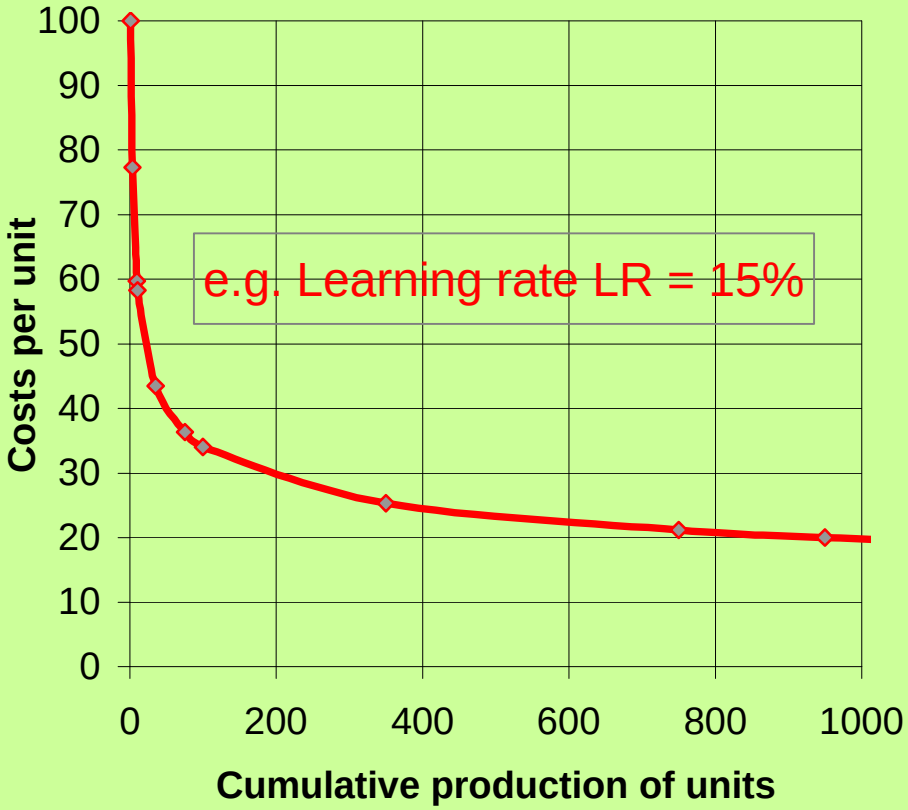
2. Basic principles: Experience curves

- describe **how costs decline with cumulative production**.
- costs decline by a **constant percentage with each doubling** of the units produced or applied.

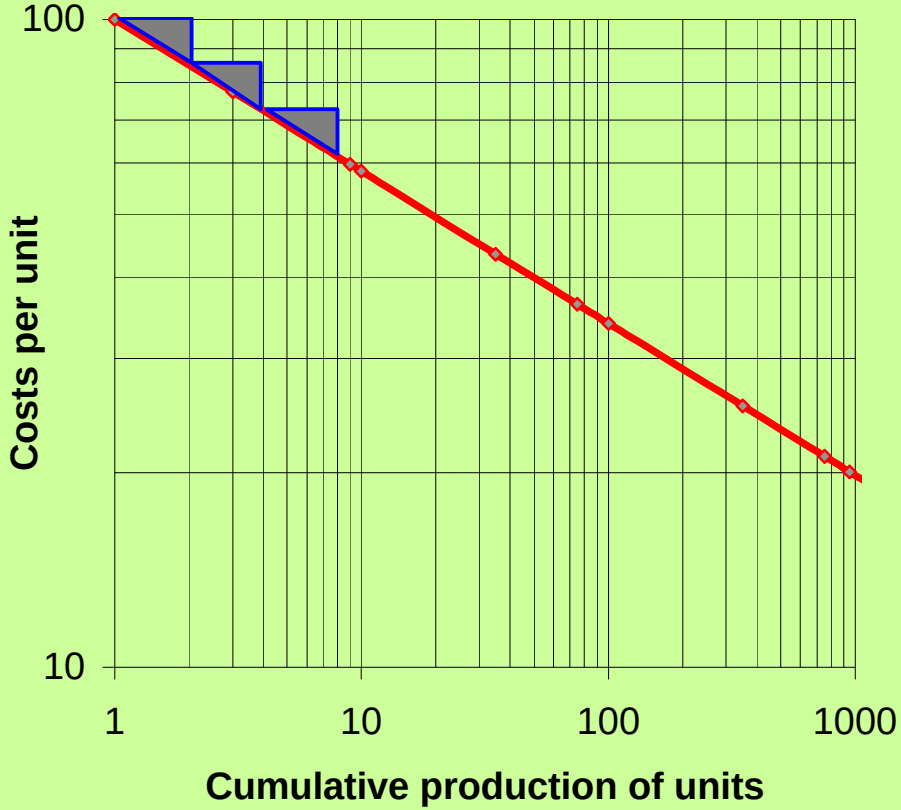
$$C_{CUM} = C_0 * CUM^b$$

C_{CUM}	Costs per unit
C_0	Costs of the first unit
CUM	Cumulative production
b	Experience index
LR	Learning rate (LR=1-2^b)

linear scale



log-log scale



2. Basic principles: Dynamic cost-resource curves

A *dynamic cost-resource curve*
represents a tool to **provide the linkage** between both approaches described before,
i.e. the dynamic cost assessment as e.g. done by application of **experience curves**
and the formal description of costs and potentials by means of **static cost-resource curves**.

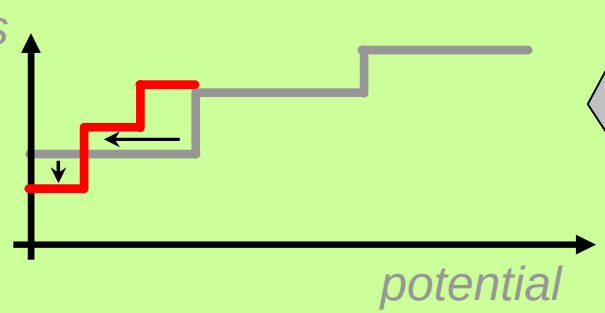
The Green-X approach:

Dynamic cost-resource curves

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***

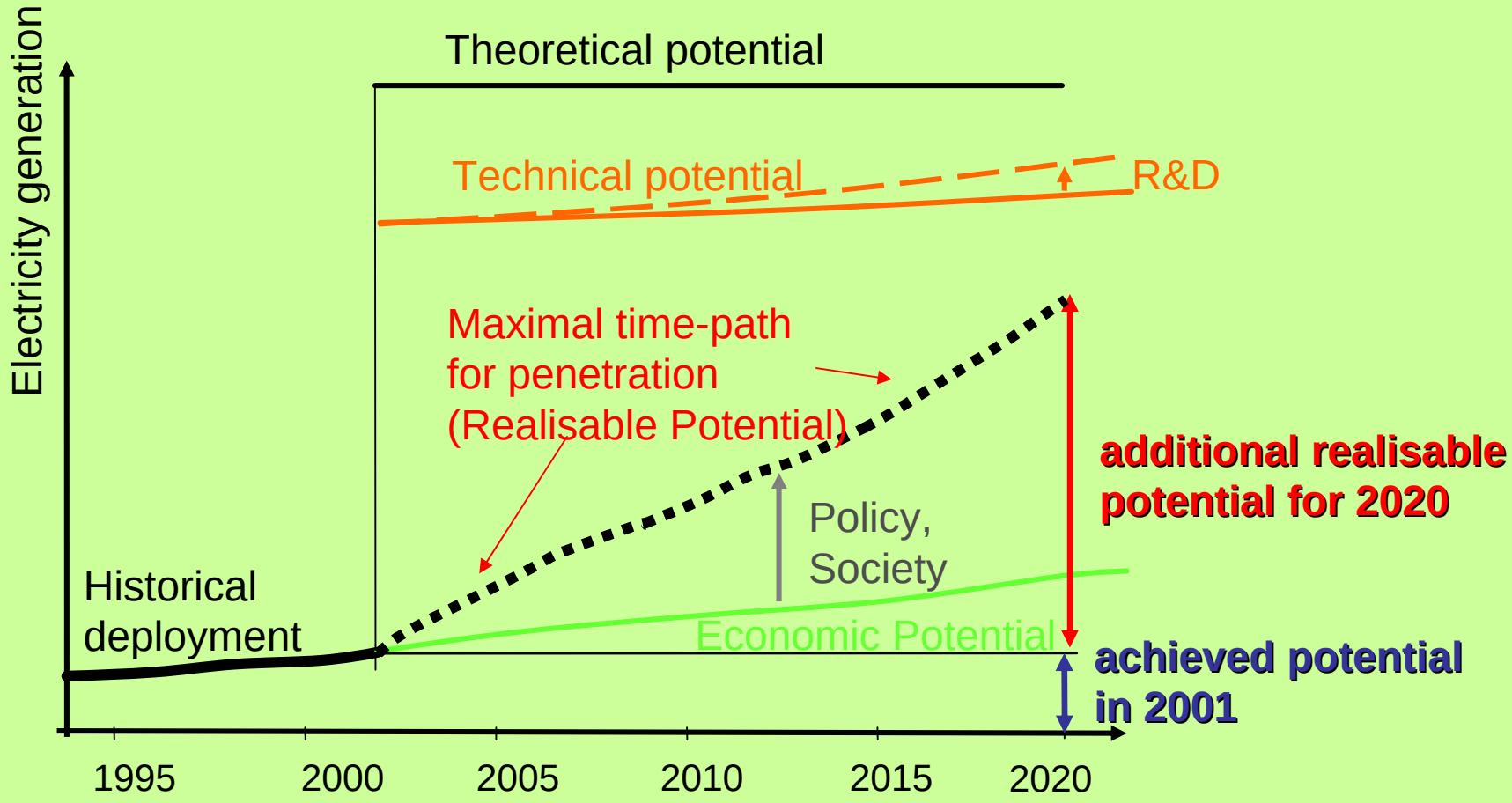


Dynamic aspects
- *Costs:* ***Dynamic cost assessment***
- *Potentials:* ***Dynamic restrictions***

2. Basic principles: Dynamic cost-resource curves

PART 1: STATIC cost-resource curves

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



2. Basic principles: Dynamic cost-resource curves

PART 2: Dynamic assessment

- Dynamic **cost assessment** done **by experience curves** or expert forecast
- Dynamic **limitation of annual realisable potential…**

Dynamic restricitons & 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 & administr. constraints	Market transparency	X	X				X	…
	„bureaucracy“	X	X		X	(X)	X	…
	…							
Societal constraints	‘Willingness to accept‘	X	X	X	X		X	(Band-specific) limitation of annual realisable potential
	…							

3. Overview – RES-E in EU-15: Definitons

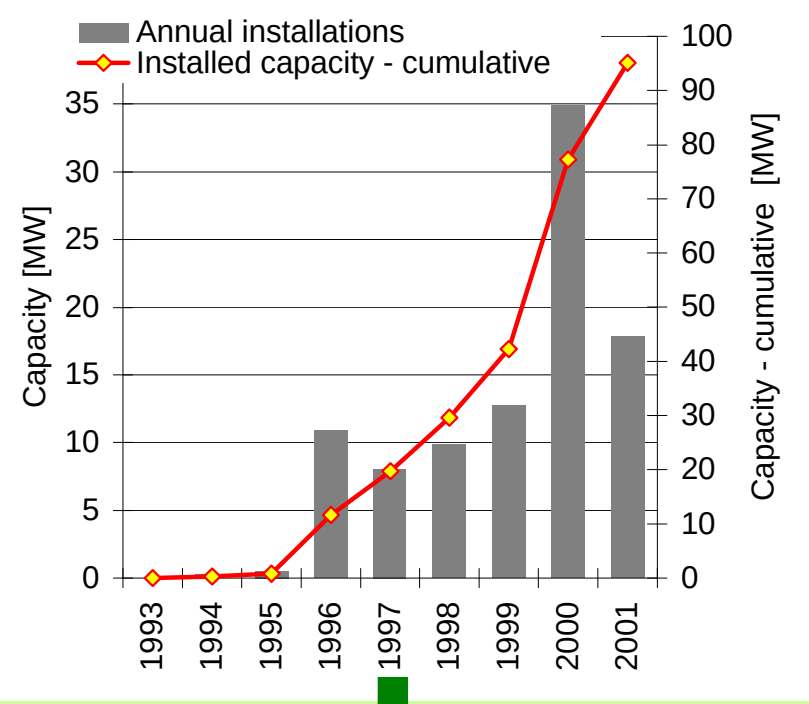
RES-E technologies considered:

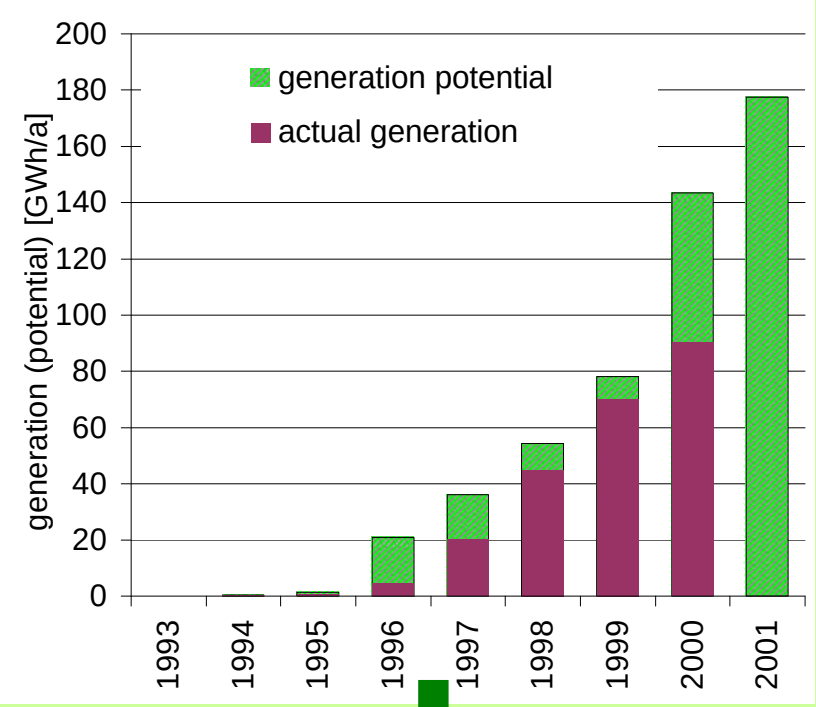
Abbreviation:
E … Electricity
C … CHP

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

3. Overview – RES-E in EU-15 : Existing plant – achieved potential

Example: Wind onshore in Austria

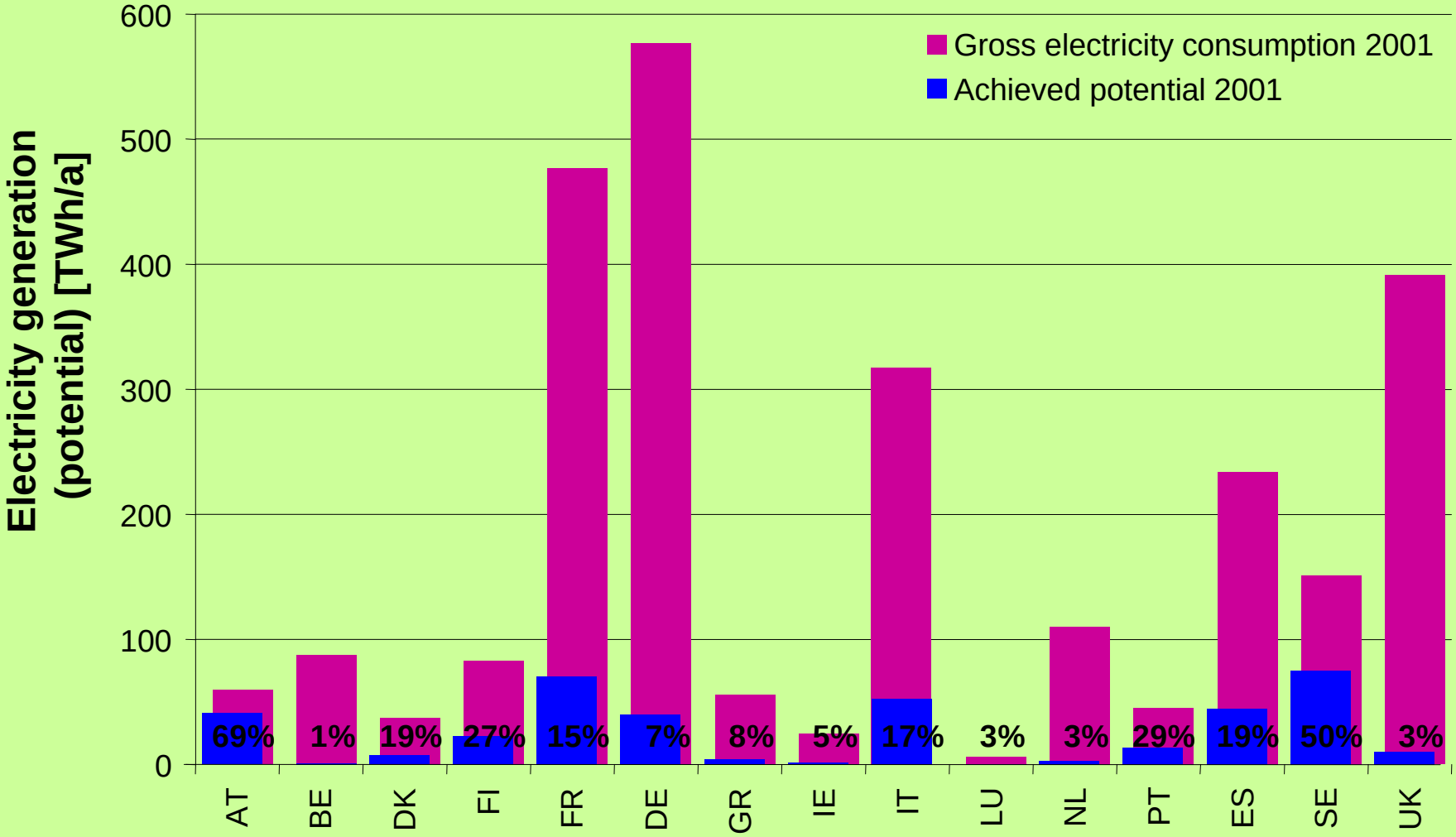




Band name	Constr. year	Base(B)/ Peak(P) load	Potential [GWh]	Load hours ele [h/a]	Load hours heat [h/a]	Efficiency ele [1]	Efficiency heat [1]	O+M costs [€/kWinst.]	Fuel category	Investment costs [€/kWinst.]
AT-E-RES-X-WI-ON-1	1993	B	0,02	1850	0	1	0	45	0	1511
AT-E-RES-X-WI-ON-2	1994	B	0,54	1850	0	1	0	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

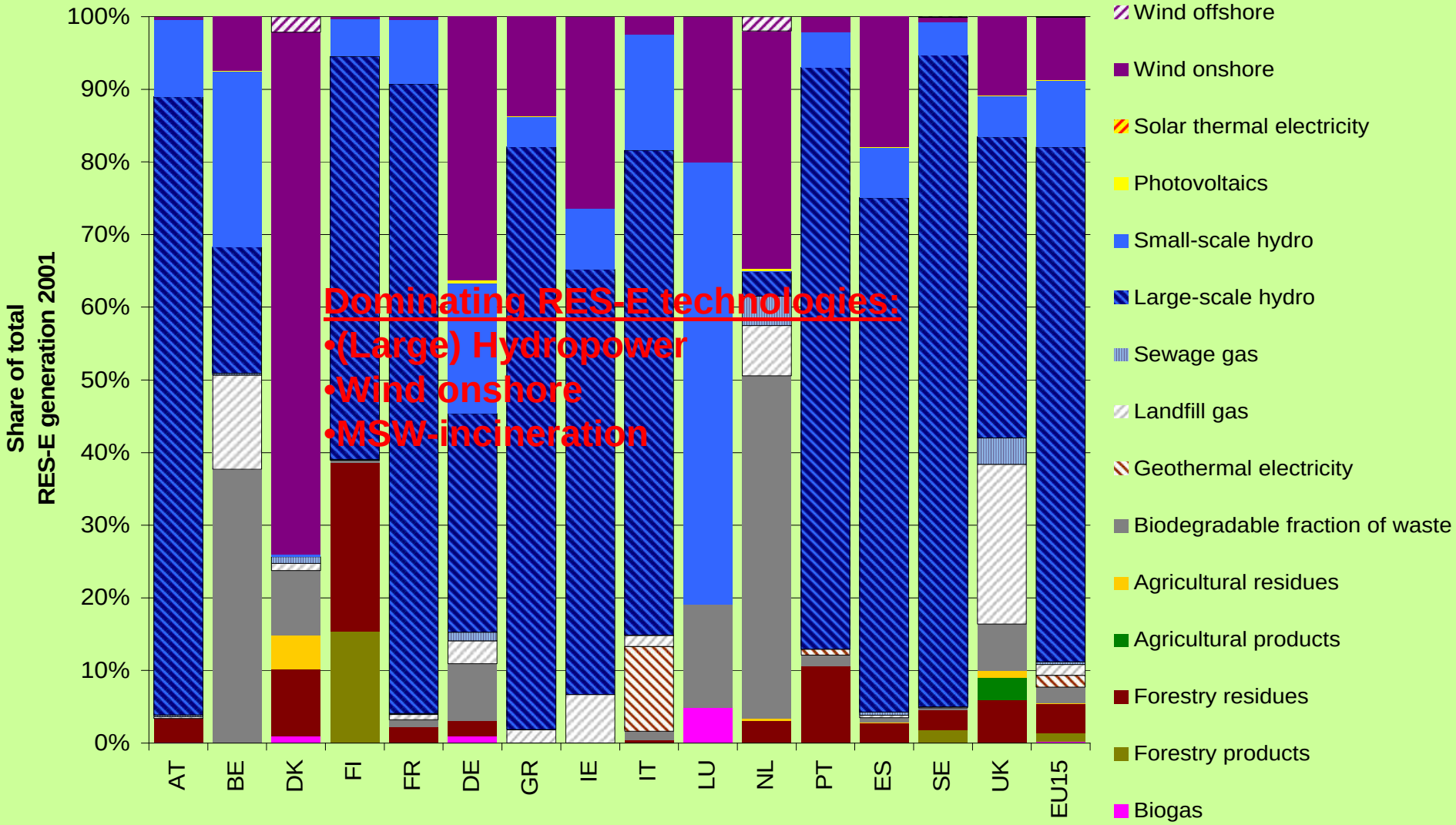
3. Overview – RES-E in EU-15 : *Existing plant – achieved potential*

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



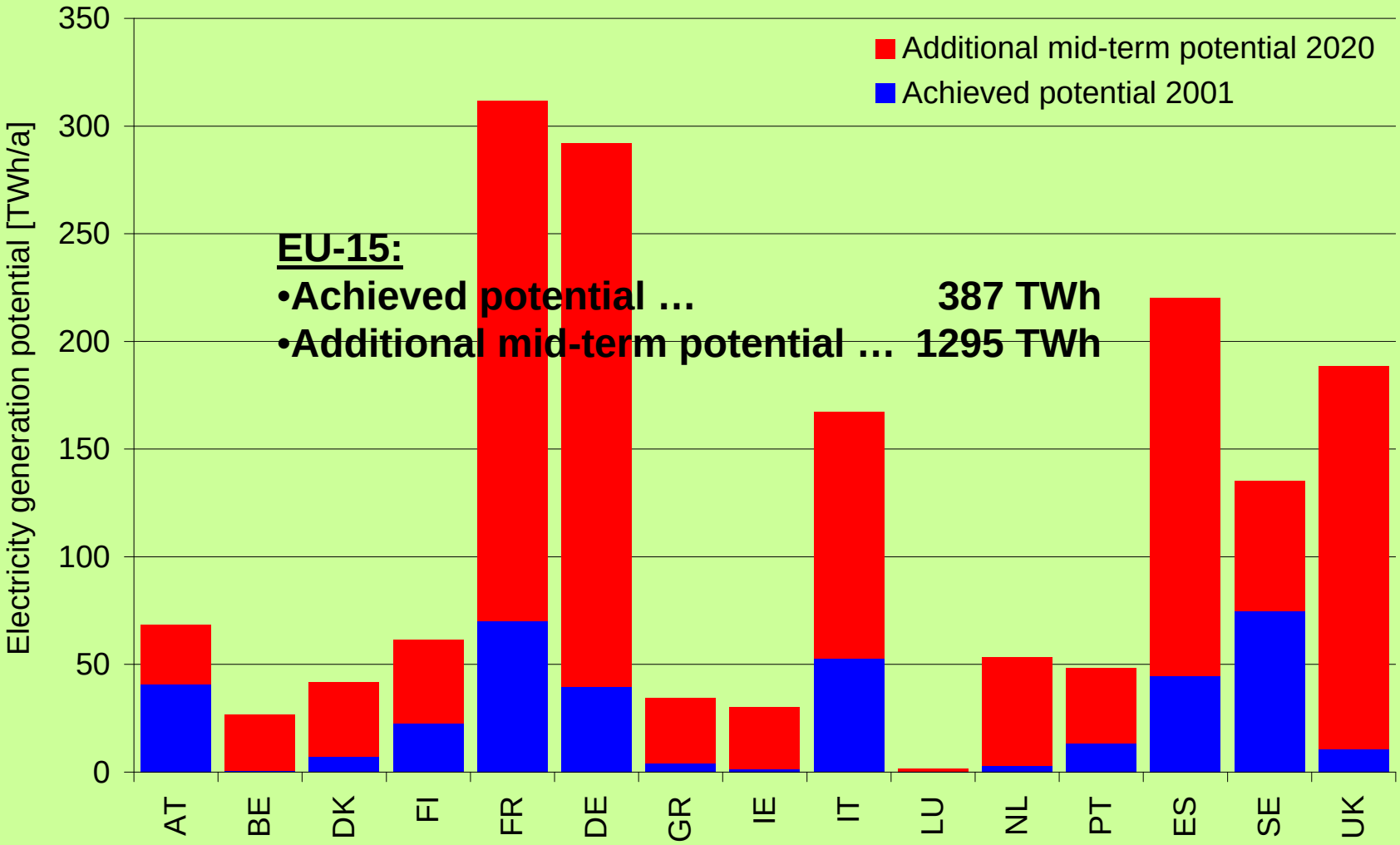
3. Overview – RES-E in EU-15 : Existing plant – achieved potential

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



3. Overview – RES-E in EU-15 : ***New plant*** *– additional mid-term potential*

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

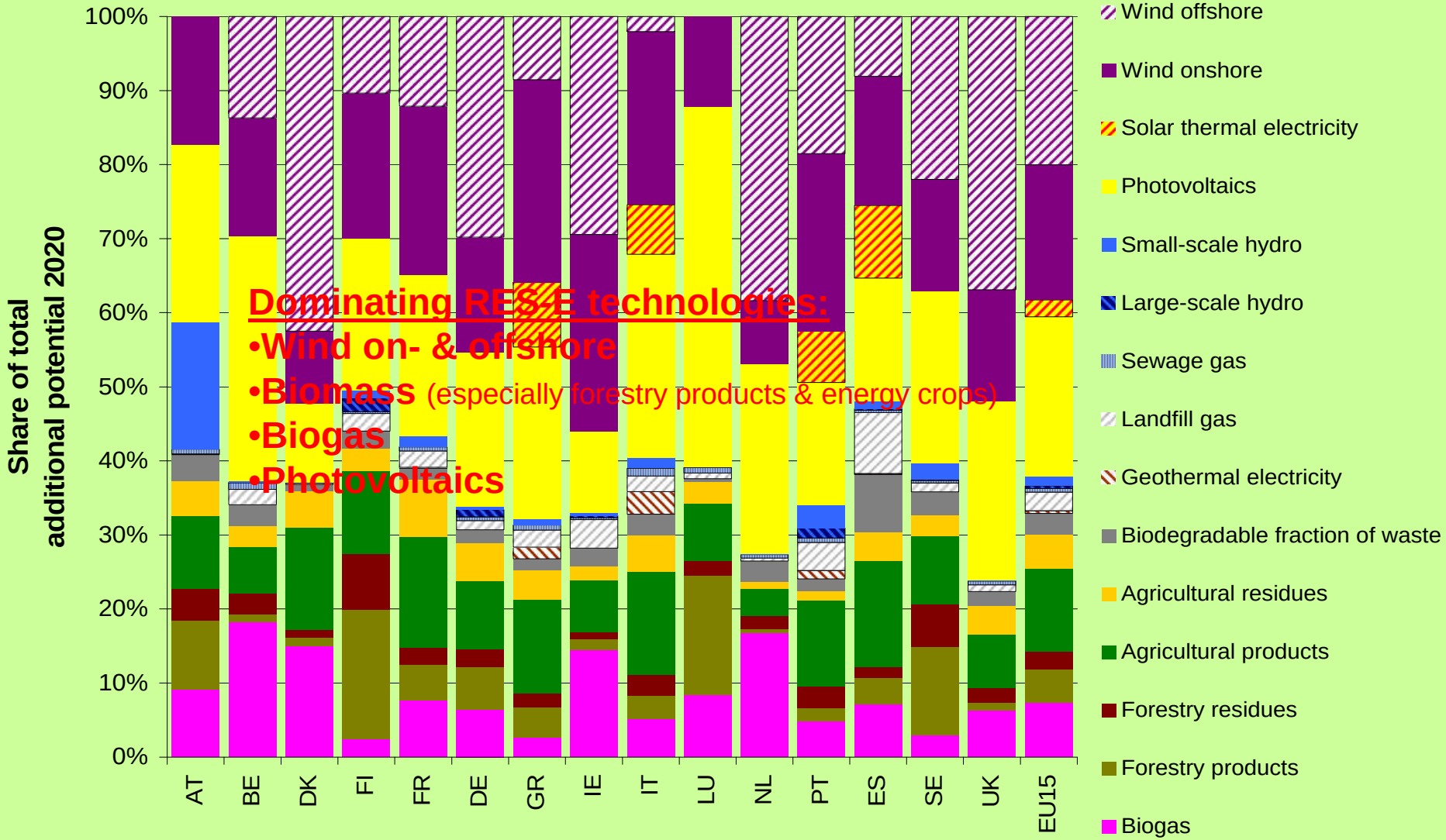


EU-15:

- **Achieved potential … 387 TWh**
- **Additional mid-term potential … 1295 TWh**

3. Overview – RES-E in EU-15 : ***New plant*** *– additional mid-term potential*

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



3. Overview – RES-E in EU-15 : 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)

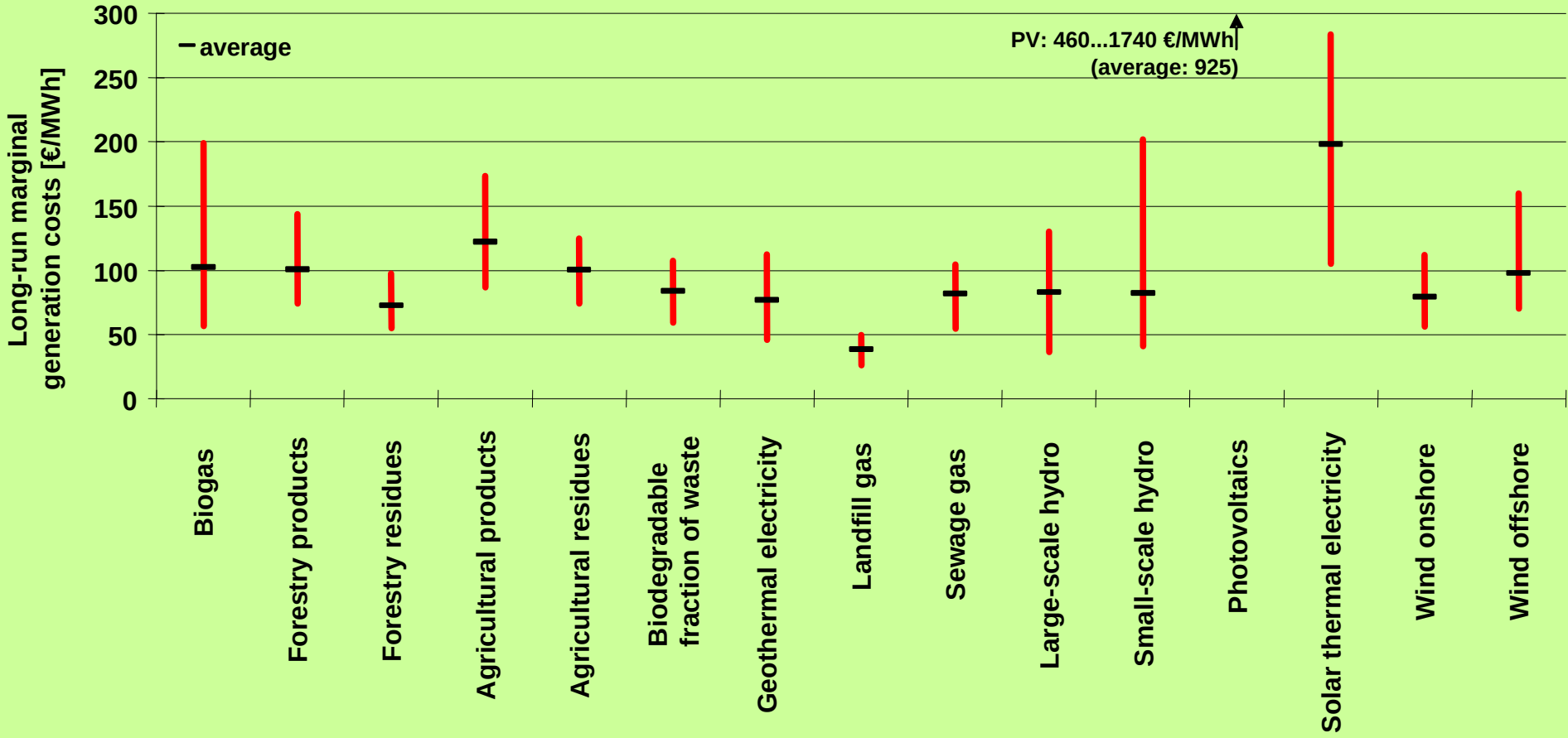
Strategy-/Setting-specific parameter:
(i.e. internalised into model-calculation)

- 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)!!!

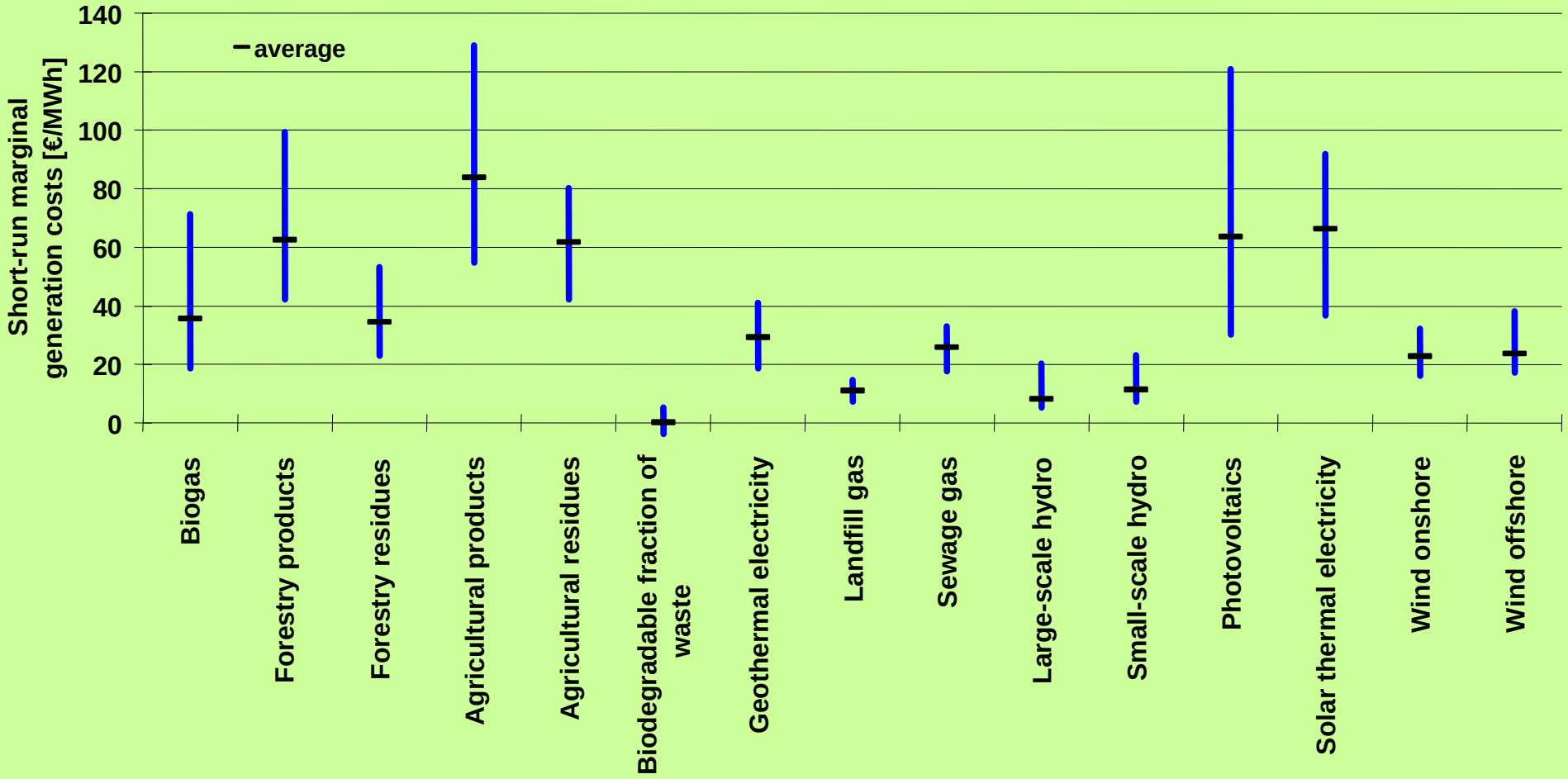
2. Overview – RES-E in EU-15 : *Costs of electricity*

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



3. Overview – RES-E in EU-15 : *Costs of electricity*

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

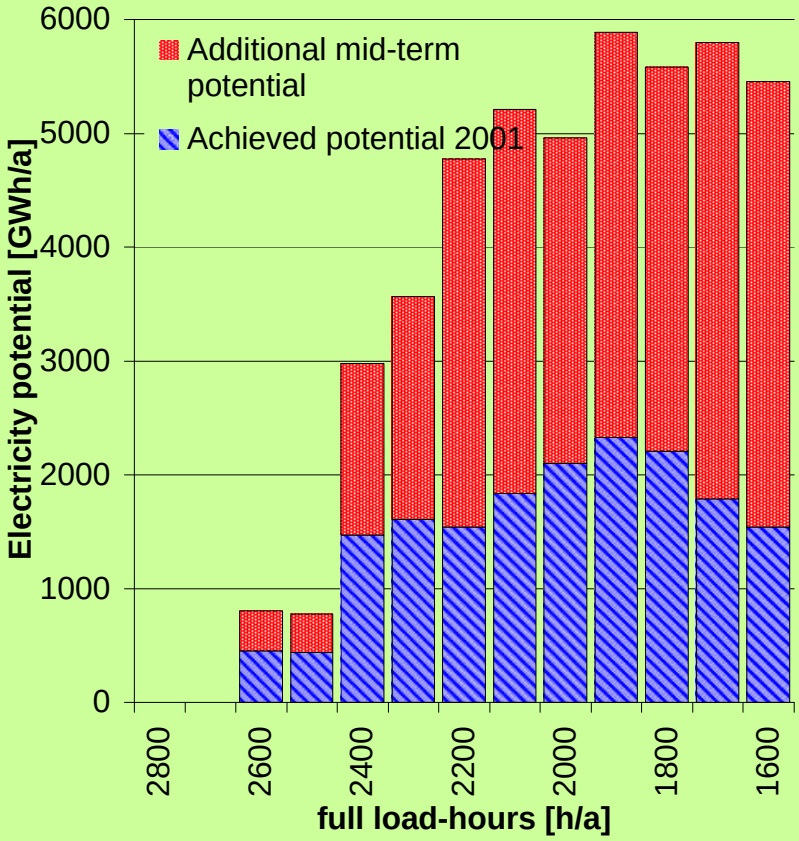


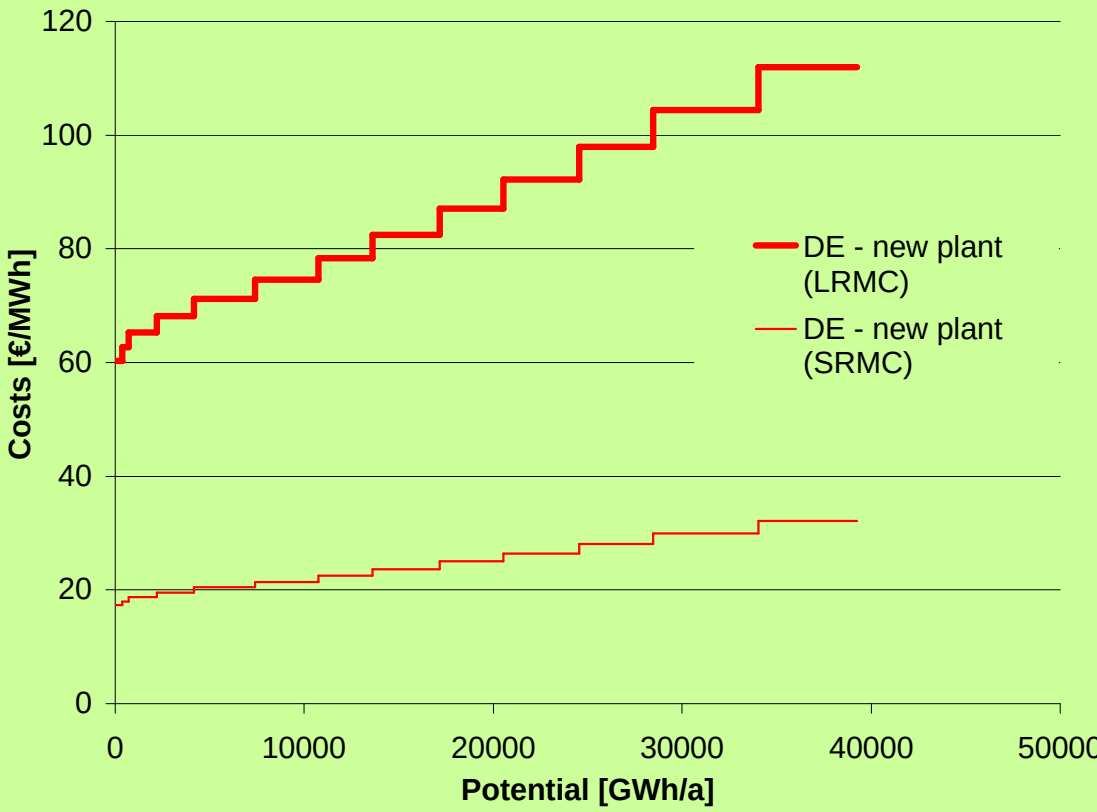
3. Overview – RES-E in EU-15 : Cost-resource curves

Example: Wind onshore in Germany

Distribution of potential on full-load hours

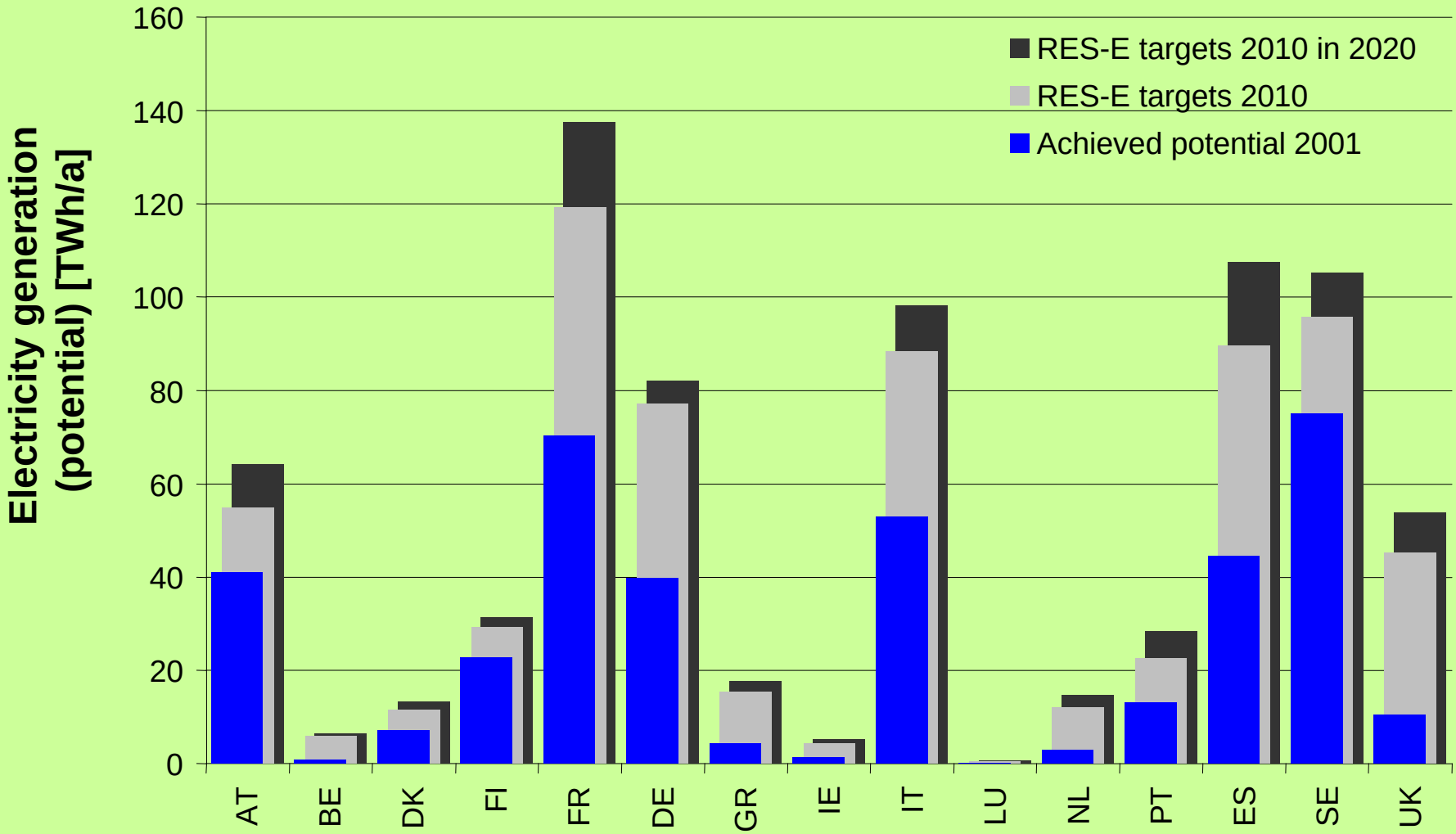
Resulting cost-resource curve (for new plant)





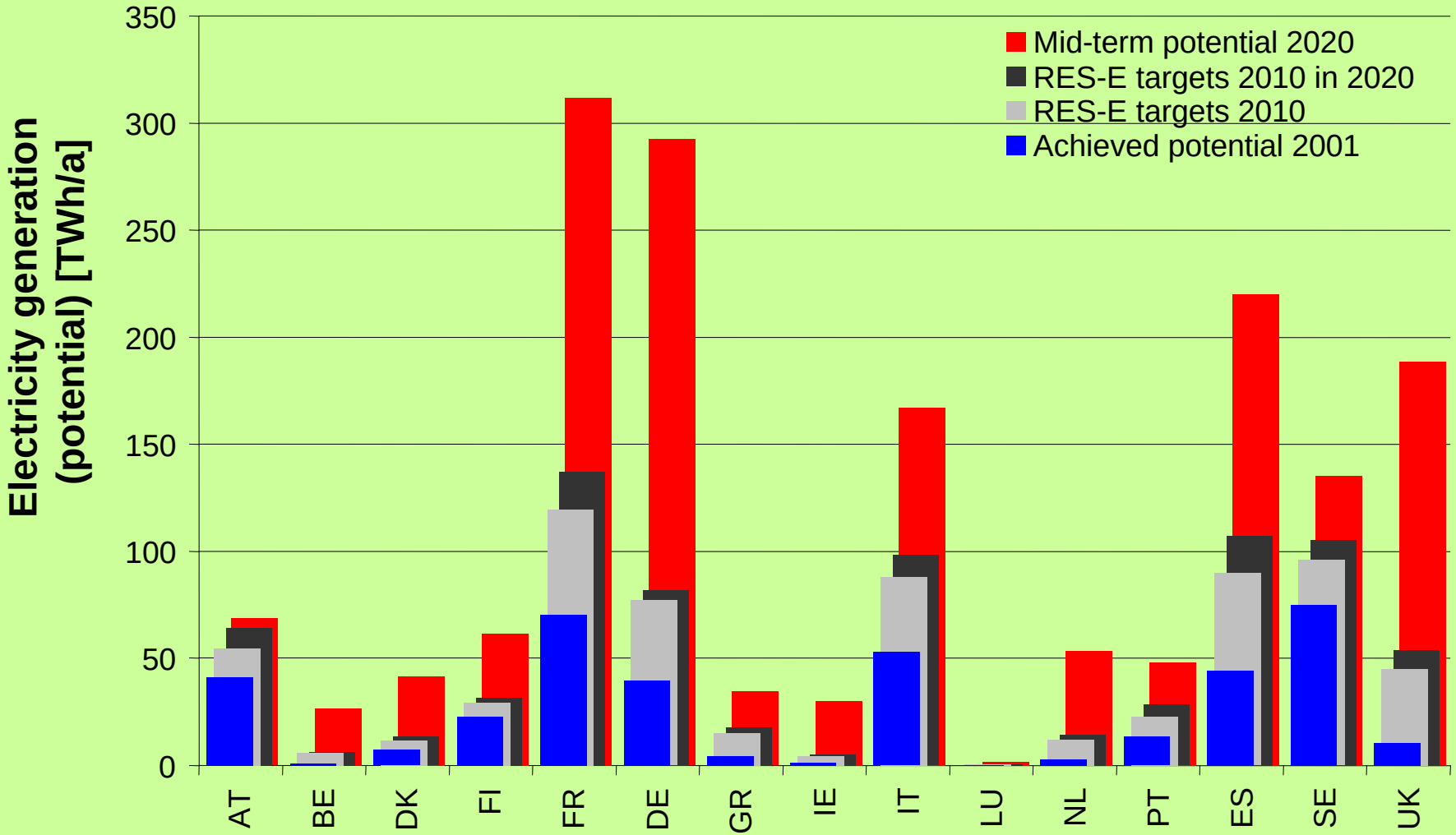
4. Comparison : Potentials vs. targets

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



4. Comparison : Potentials vs. targets

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



4. Comparison: Concluding remark

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!