



Dynamics of cost-resource curves for RES-E

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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



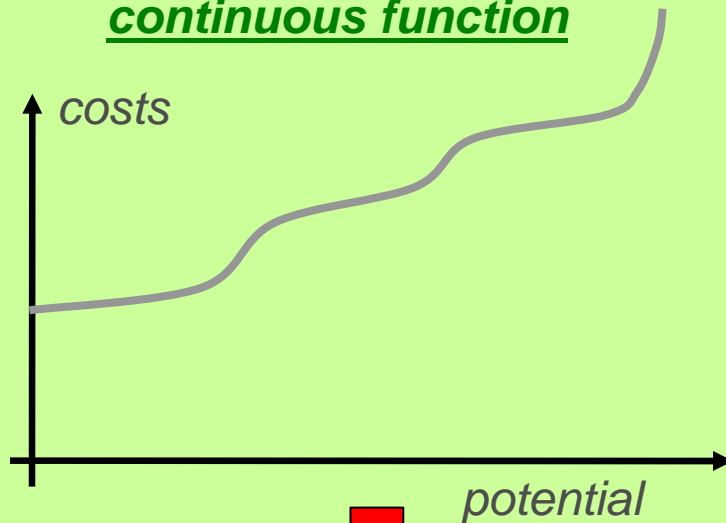
2. Basic principles:

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**.

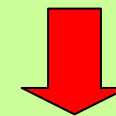
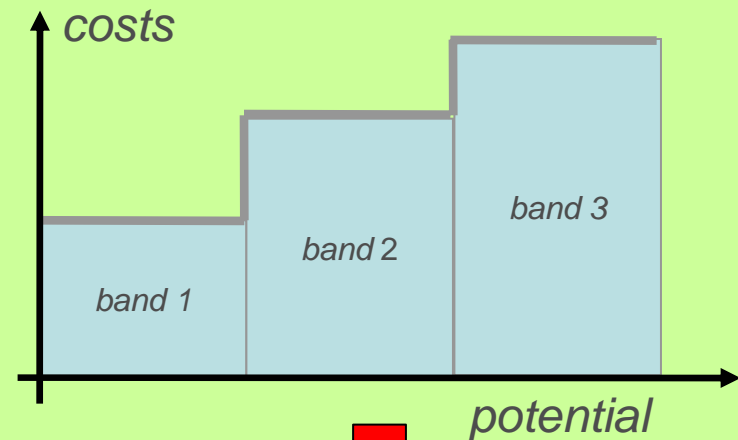
$$\text{costs} = f(\text{potential}); t = \text{constant}$$

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

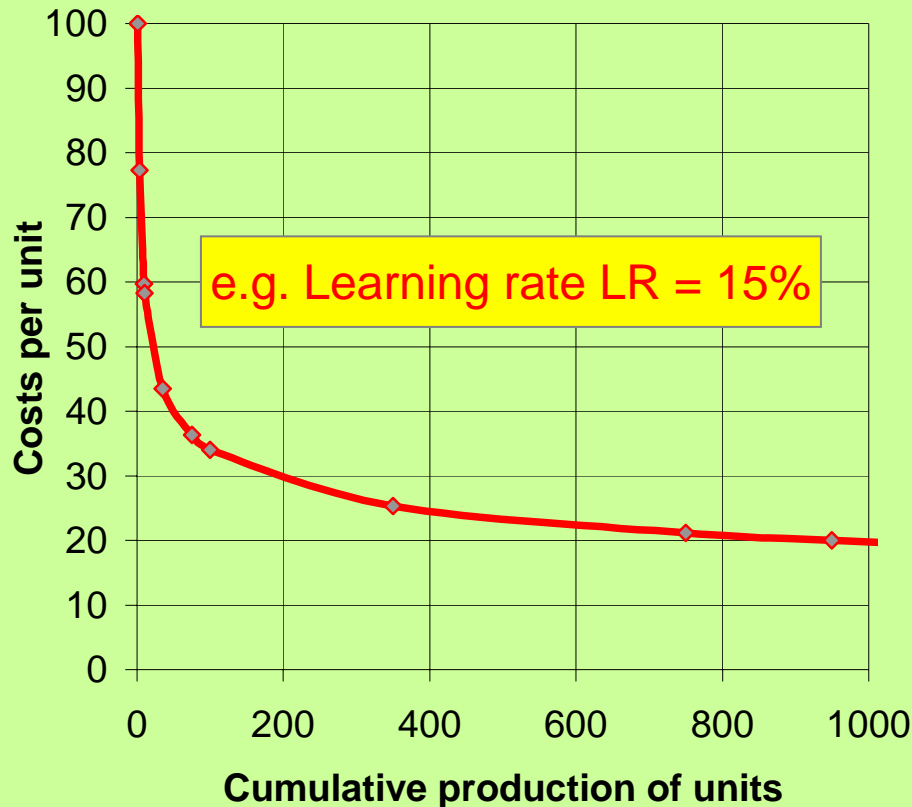
C_0 Costs of the first unit

CUM Cumulative production

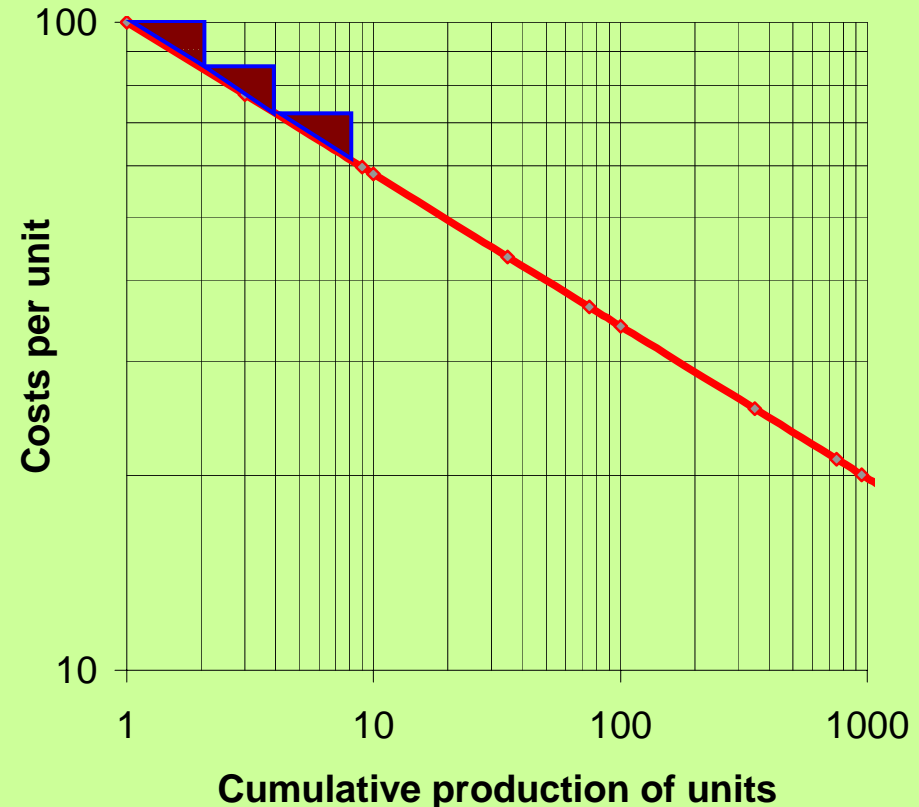
b Experience index

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

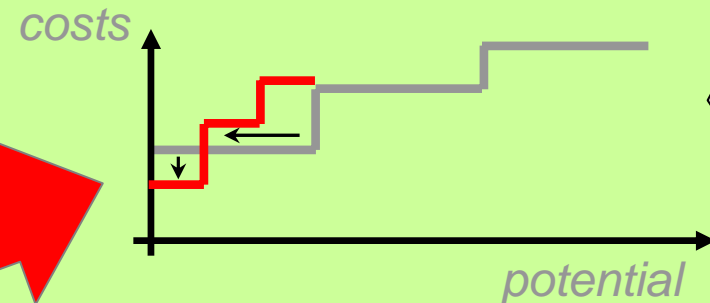
DYNAMIC

COST-RESOURCE CURVES

- by RES-E technology
- by country
- by year**

Dynamic aspects

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

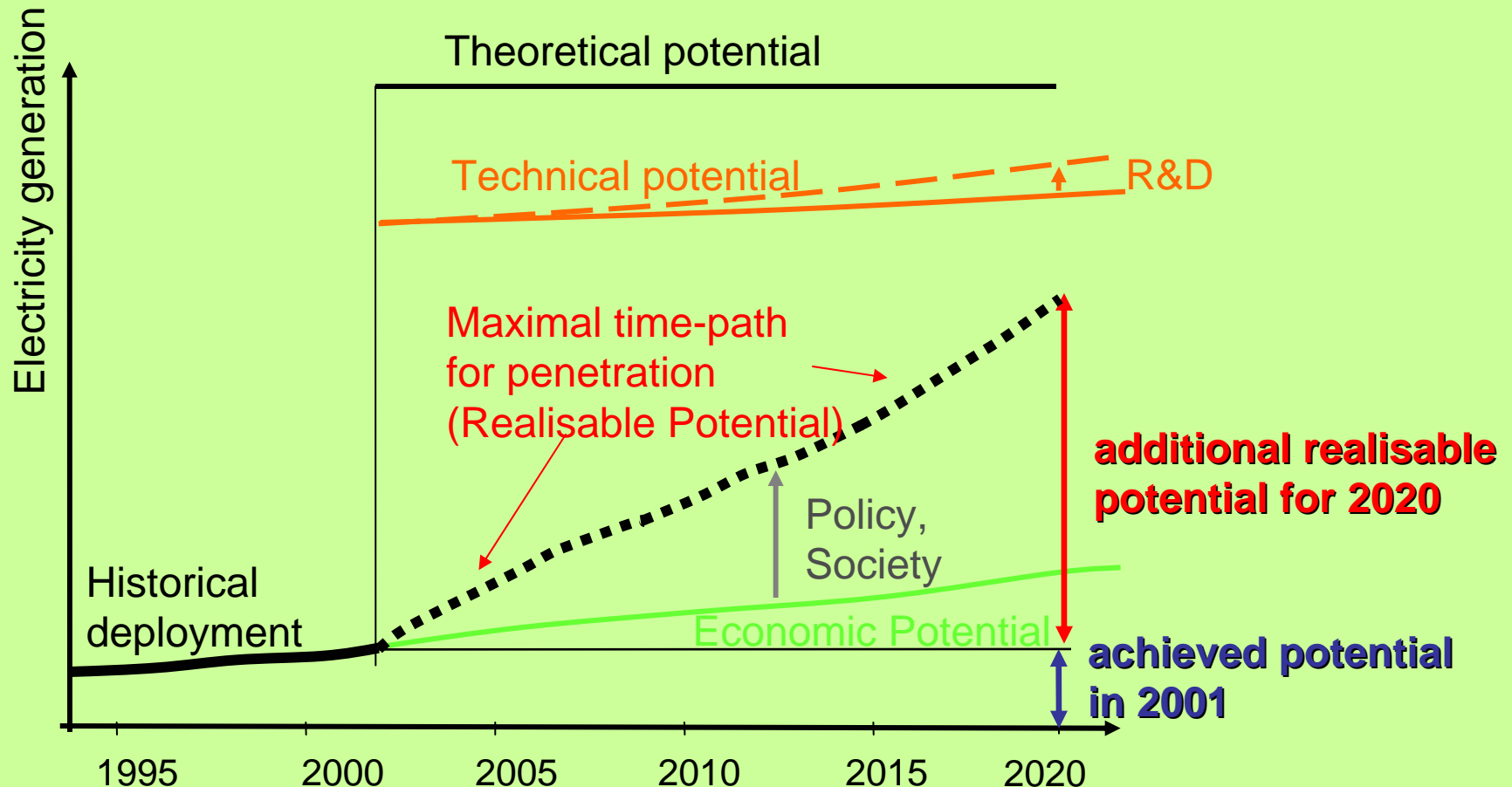




2. Basic principles: *Dynamic cost-resource curves*

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 restrictions & 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

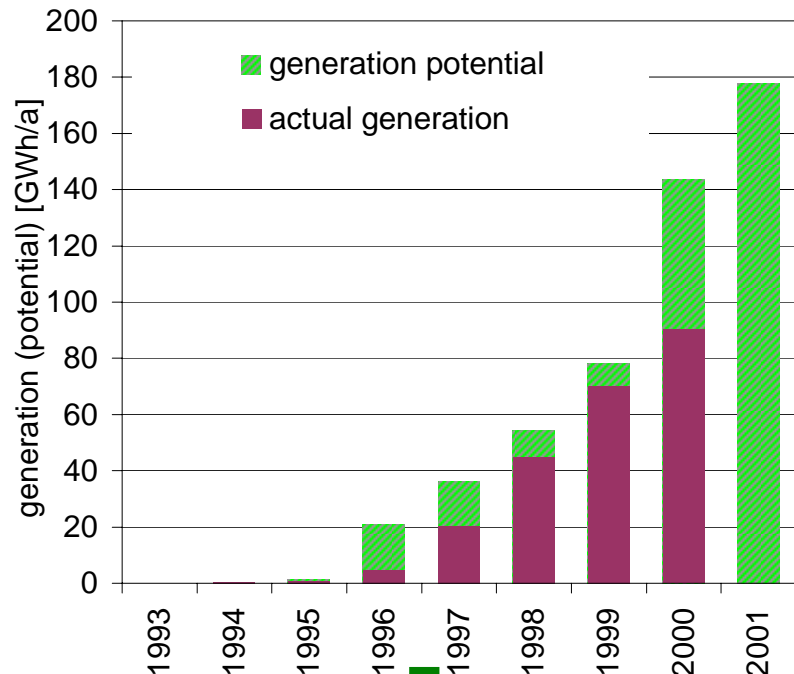
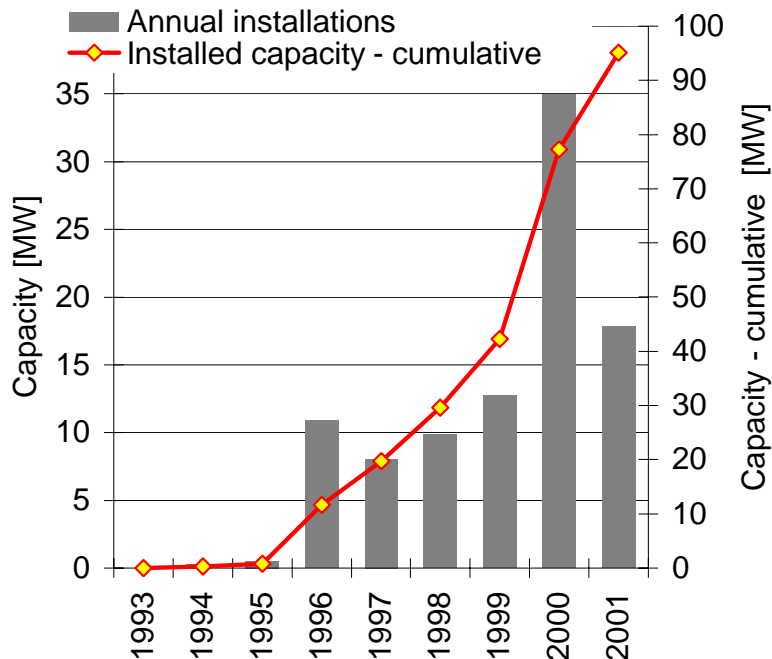
- | | | | |
|------------------|-----|------------------------|---|
| E & C | 1. | Biogas | |
| E & C | 2. | Biomass | Forestry products,
Forestry residues,
Agricultural products
Agricultural residues
Biodegradable fraction of waste |
| E & C | 3. | Geothermal electricity | |
| E | 4. | Hydro power | 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



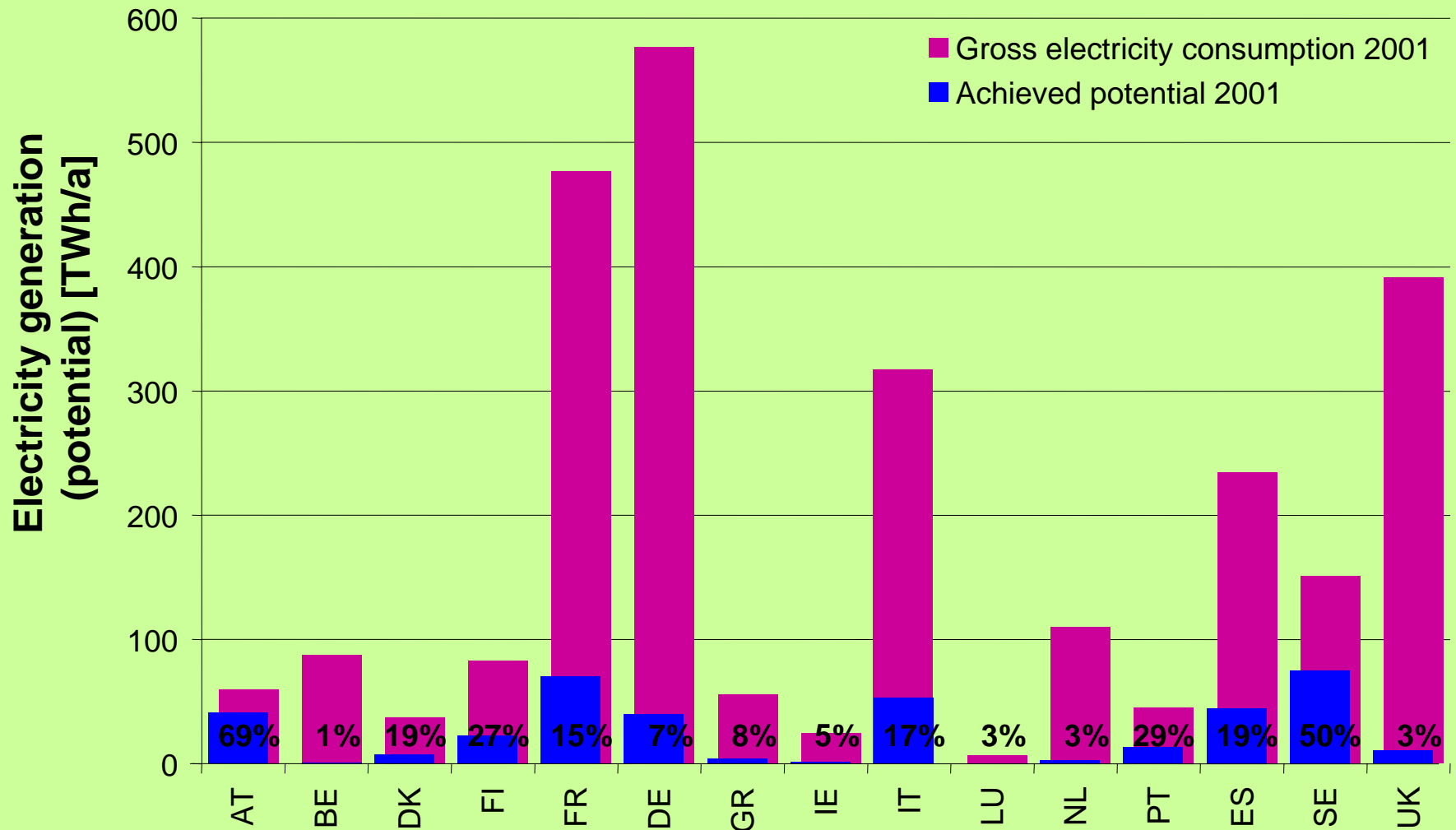
Band name	Constr. year	Base(B)/ Peak(P) load	Potential [GWh]	Load hours ele [h/a]	Load hours heat [h/a]	Efficiency ele [1]	Efficiency heat [1]	O+M costs [€/kWinst.]	Fuel category	Investment costs [€/kWinst.]
AT-E-RES-X-WI-ON-1	1993	B	0,02	1850	0	1	0	45	0	1511
AT-E-RES-X-WI-ON-2	1994	B	0,54	1850	0	1	0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

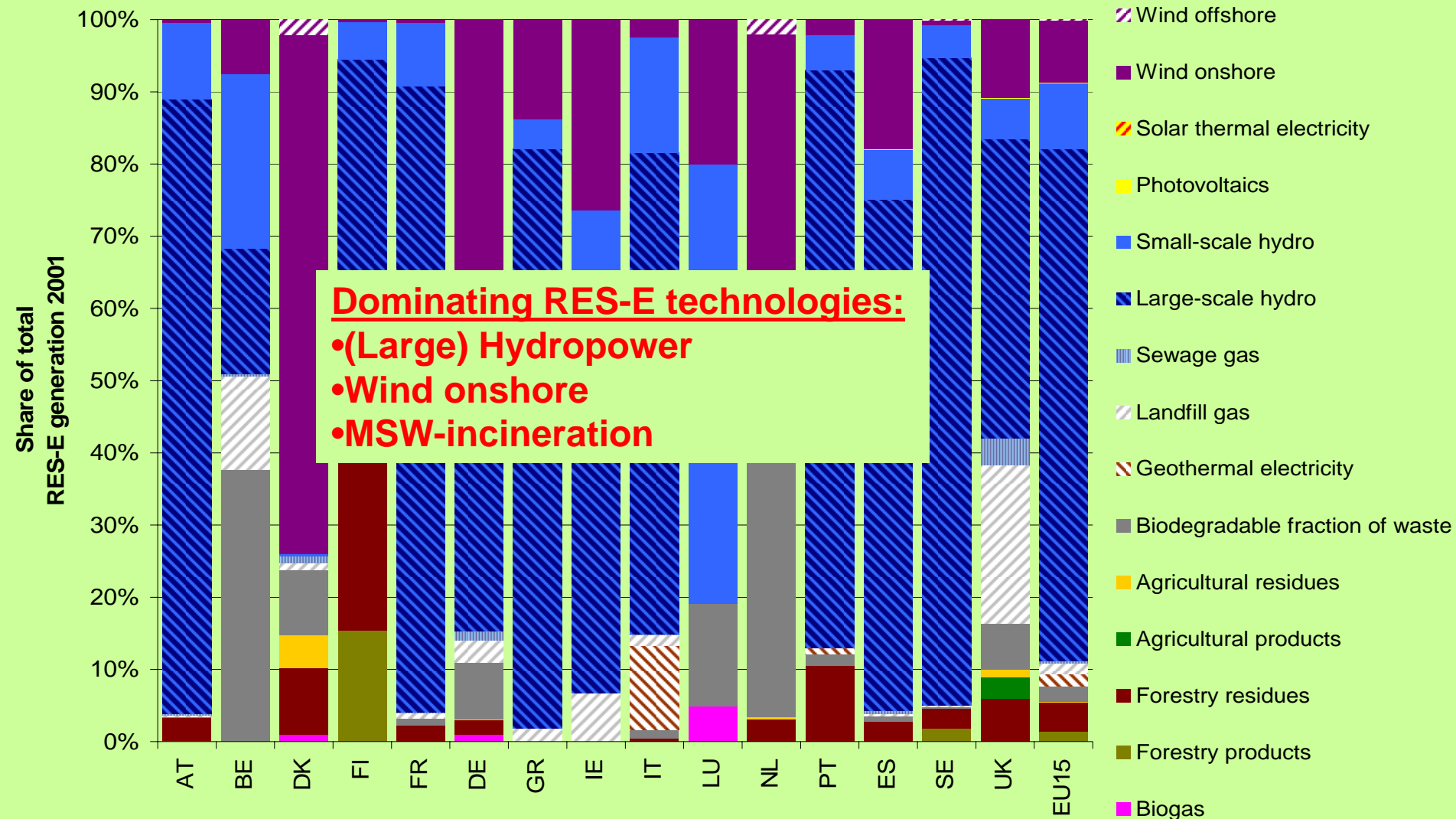




3. Overview – RES-E in EU-15 :

Existing plant – achieved potential

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

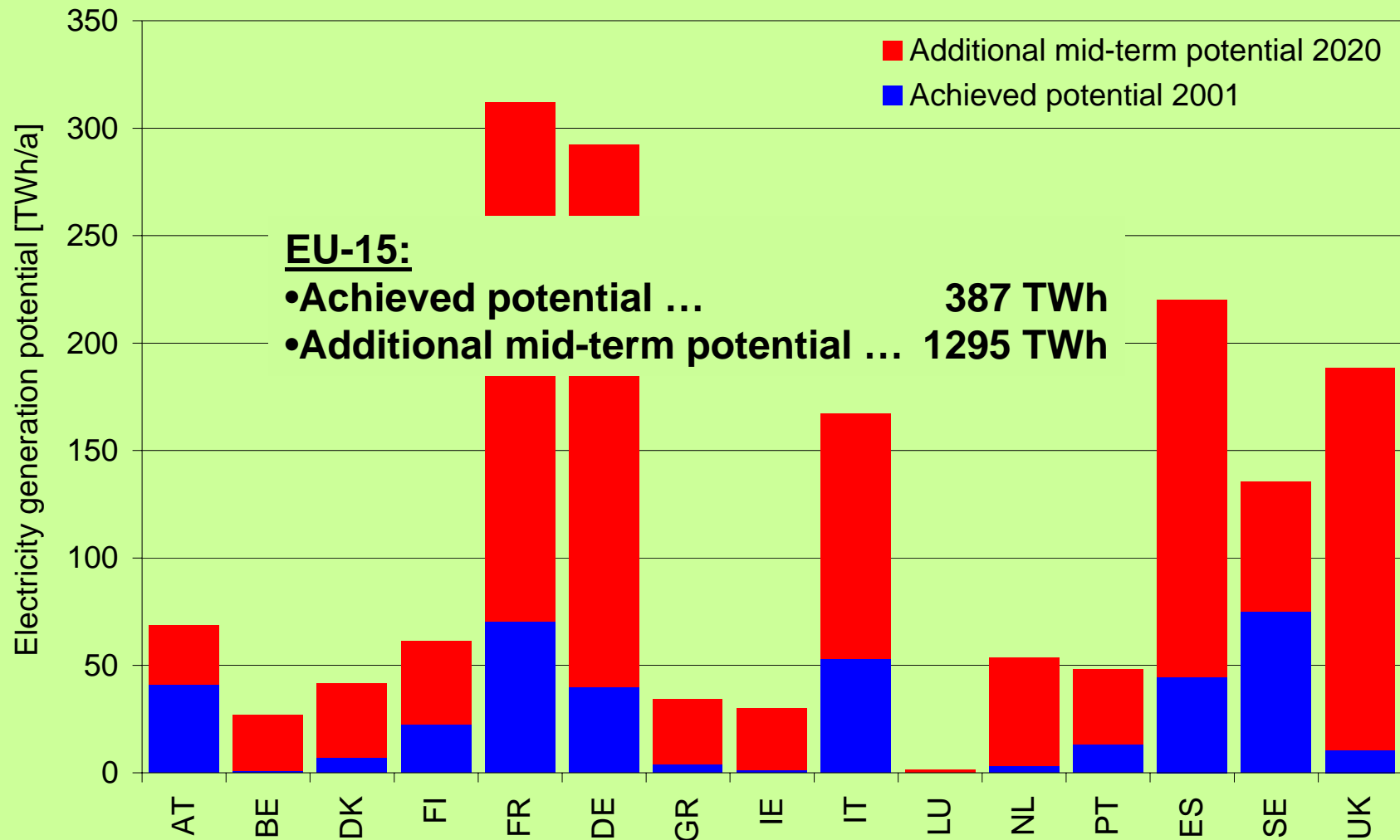




3. Overview – RES-E in EU-15 :

New plant – additional mid-term potential

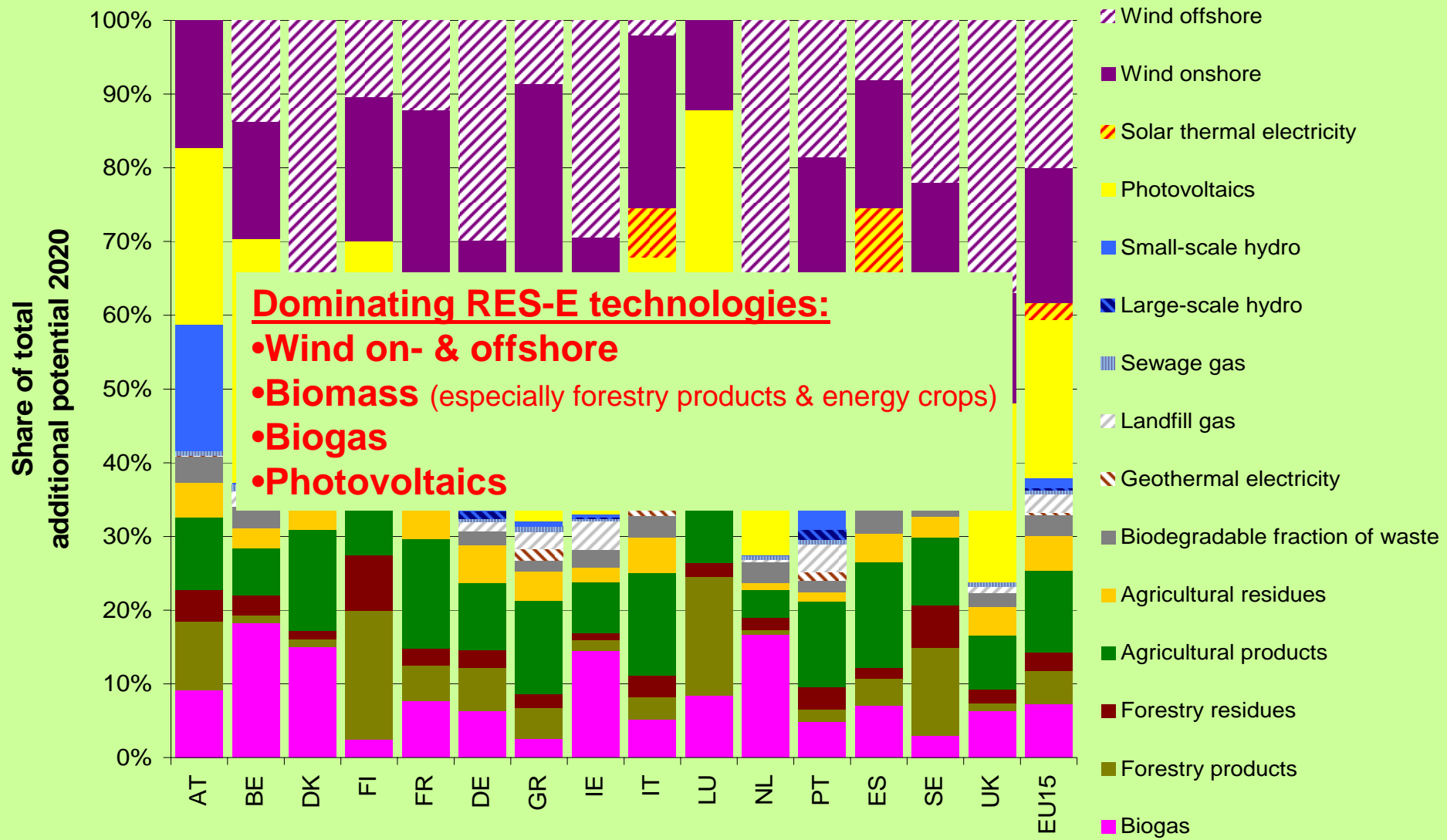
Overview: Achieved (2001) and additional mid-term (2020) potential (EU-15)



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)

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

Strategy-/Setting-specific parameter:

(i.e. internalised into model-calculation)

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

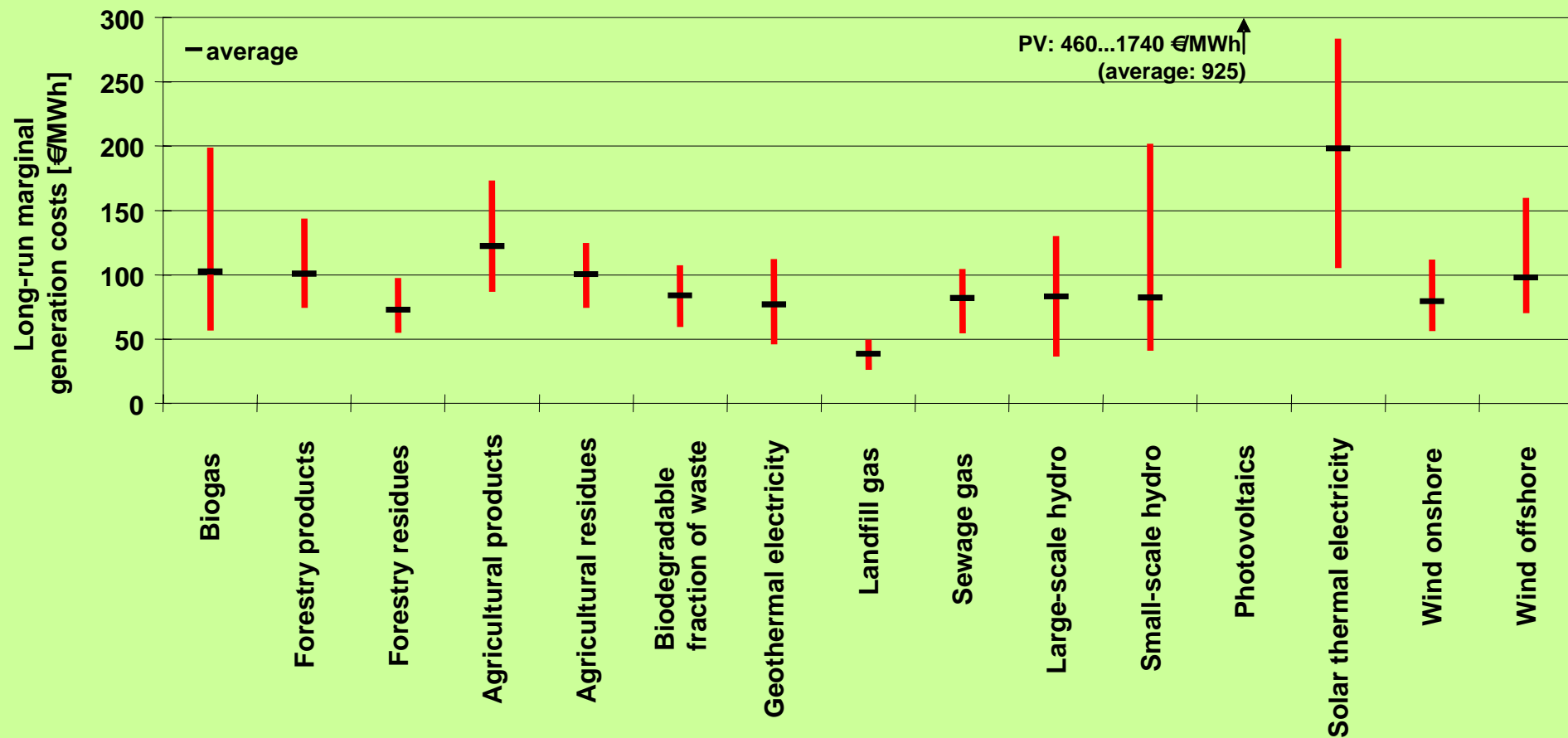
➔ The following **overview on electricity generation costs** is based on default figures for **interest rate** (i.e. 6,5%) & **depreciation time** (i.e. 15 years)!!!



2. Overview – RES-E in EU-15 :

Costs of electricity

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

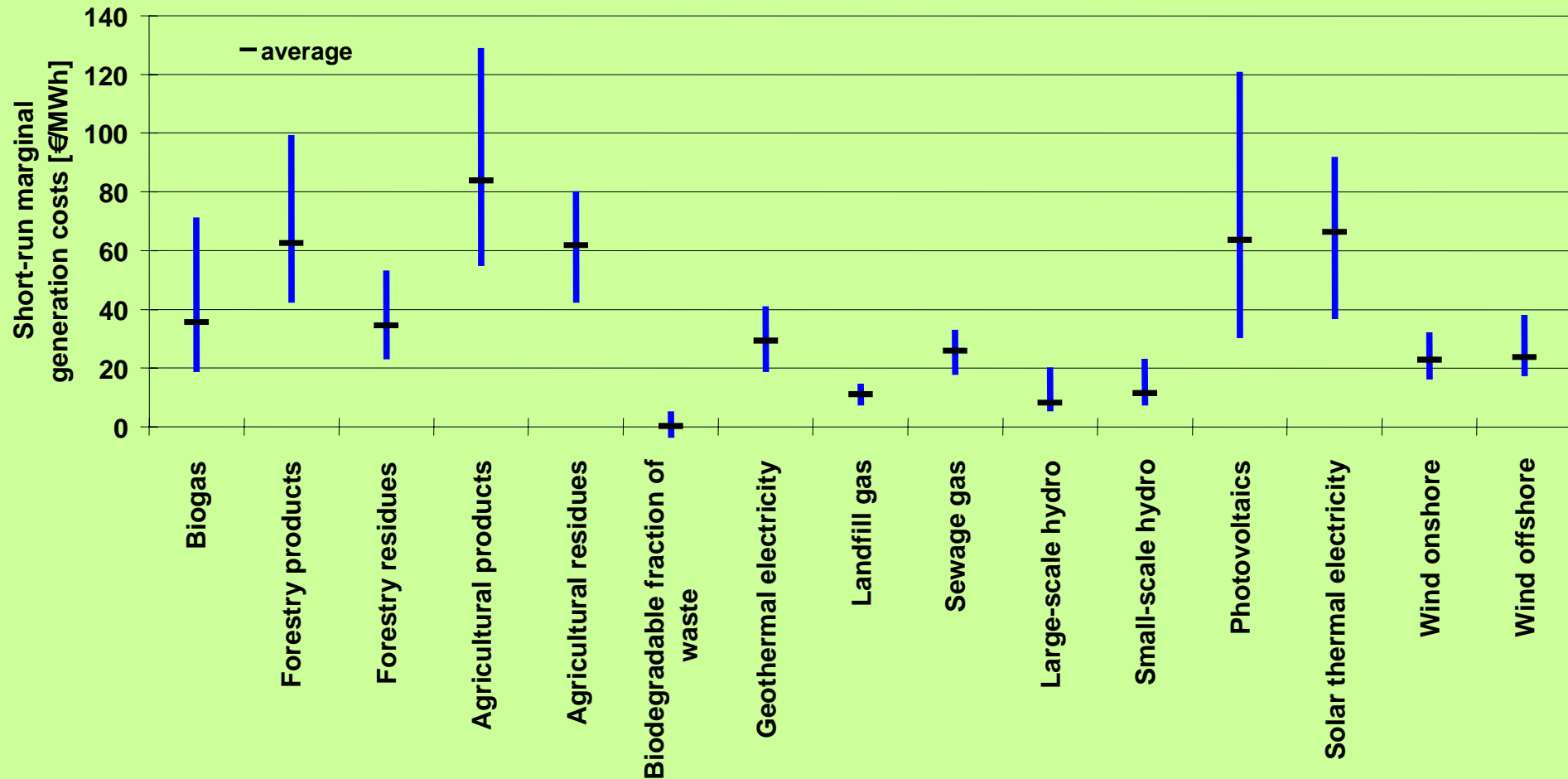




3. Overview – RES-E in EU-15 :

Costs of electricity

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



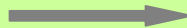


3. Overview – RES-E in EU-15 :

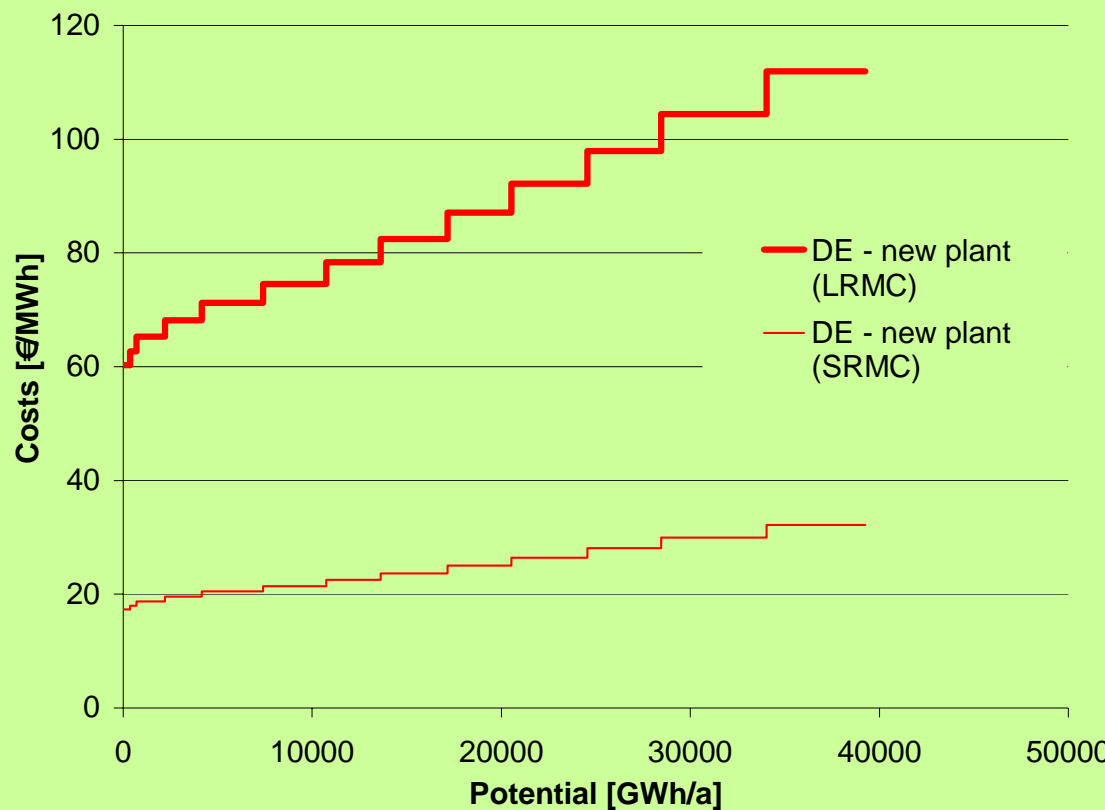
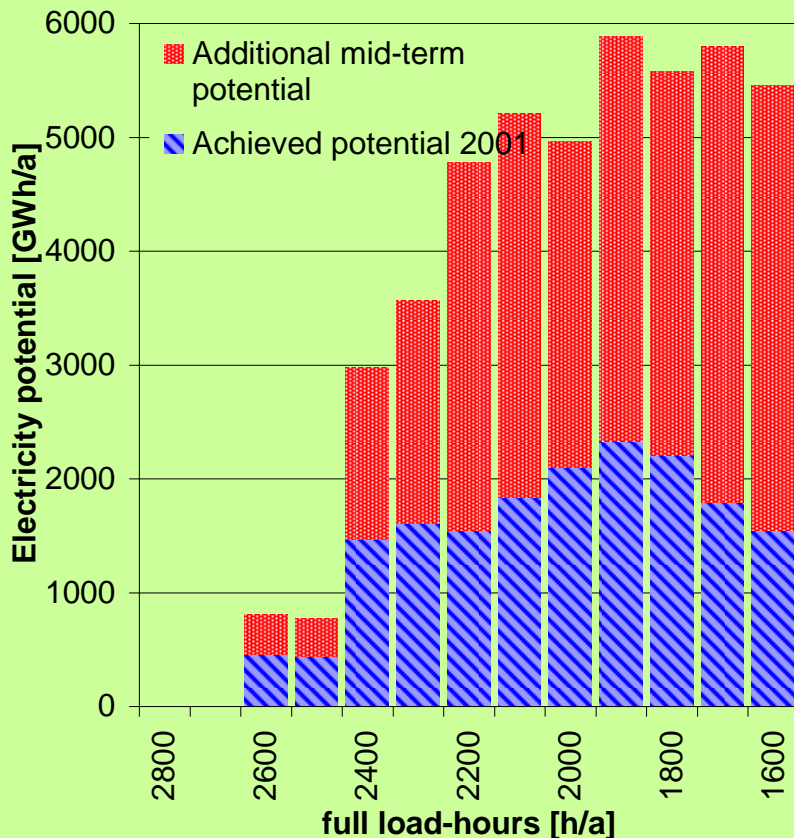
Cost-resource curves

Example: **Wind onshore in Germany**

Distribution of potential on
full-load hours



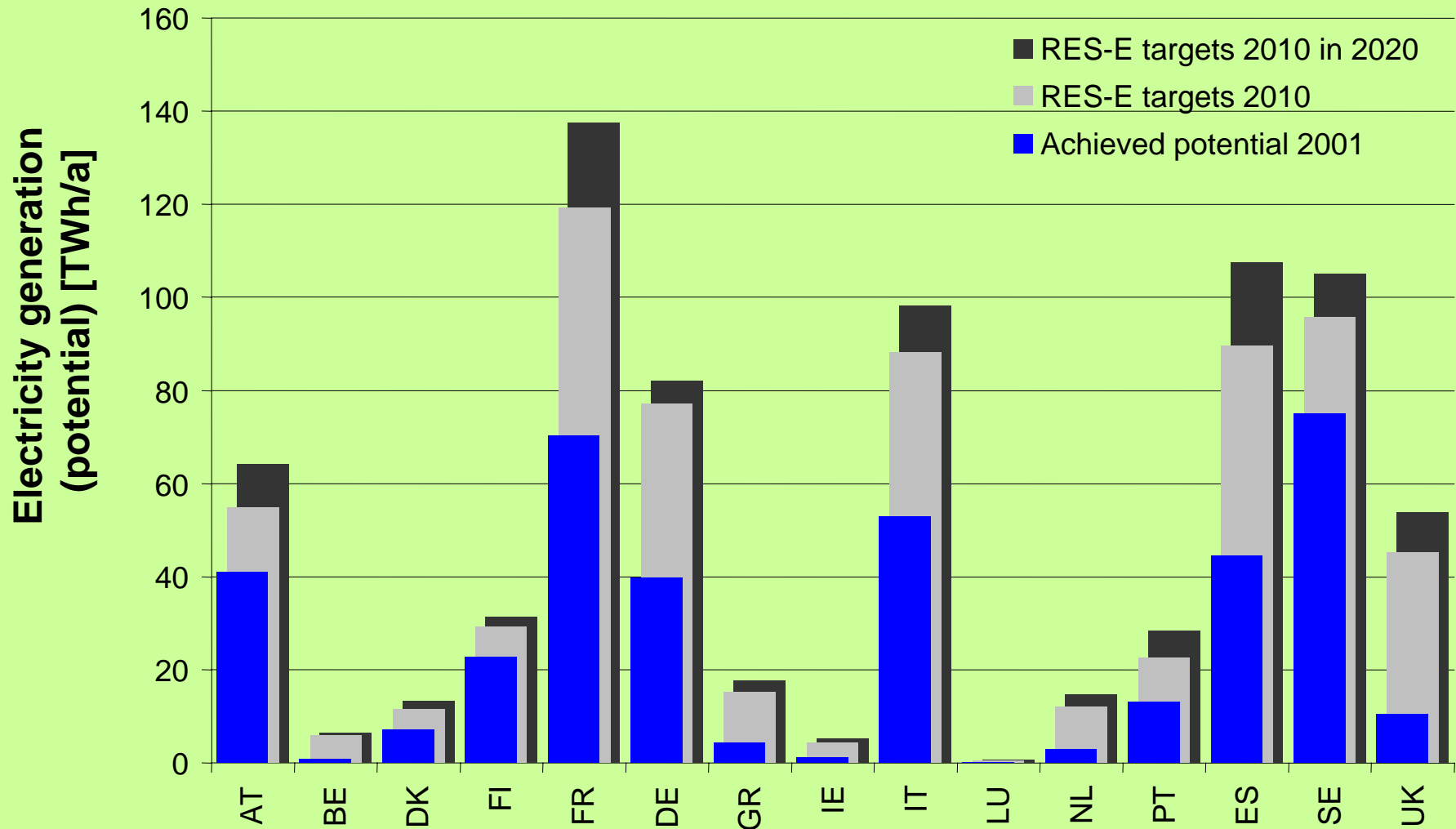
Resulting cost-resource curve
(for new plant)





4. Comparison : *Potentials vs. targets*

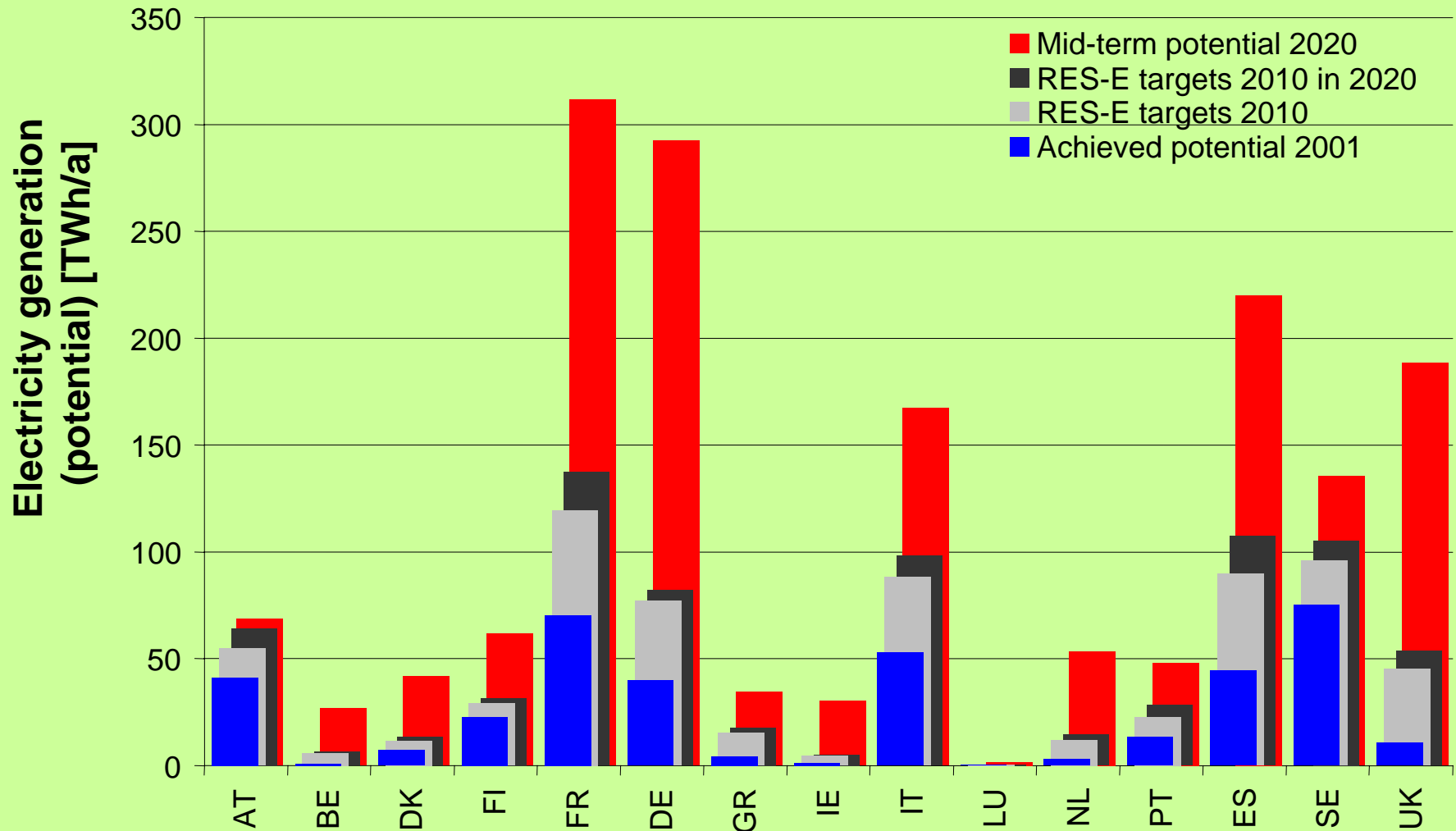
Overview: **Achieved potential vs. RES-E targets**
by country (for EU-15)





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!