Energy Economics Group

TECHNISCHE UNIVERSITÄT WIEN
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RES in SEERMAP … some key inputs to the analysis

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… developed initially in the period 2002 to 2004 within the research project

Green-X (5th framework programme of the European Commission, DG RESEARCH)

www.green-x.at

Content

➢ RES modelling in SEERMAP:

- **Our approach: the Green-X model**
- **Key assumptions in our modelling exercise on SEE countries**

  … potentials of renewables …

  … financing conditions …

  … a regional approach to support renewables …

1. Introduction: Objective

The core objective of the project *Green*-X was

to develop a computer model allowing an assessment of the future deployment of RES-E in the 'real world'.

Derived objectives are:

- to **describe the potential & the accompanying cost of the various RES-E options** in a brief and suitable manner for model implementation;
- to **model the impact of policy instruments**;
- to **address dynamic aspects in a proper way**, including:
  - Future **technological changes** – e.g. a reduction of investment costs or efficiency improvements due to technological learning
  - **Technology diffusion** – i.e. the impact of non-economic barriers for RES-E

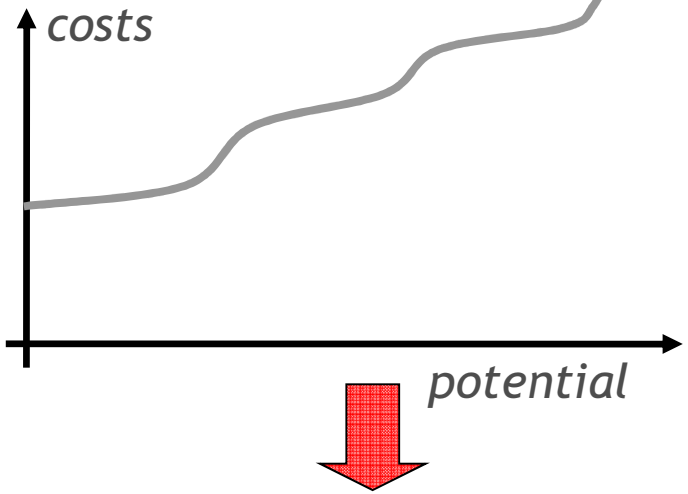
… to derive a picture of a likely future as close as possible to reality …

2. Basic principles: Static cost-resource curves

- Combines information on the ***potential*** and the according ***costs*** (of electricity/heat/fuel 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***

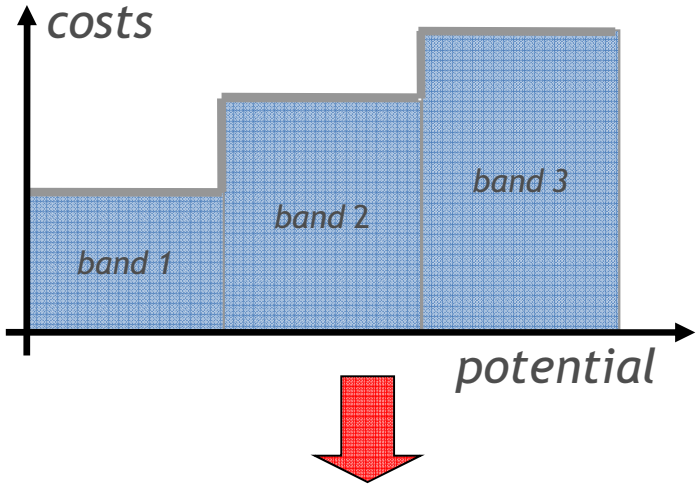
costs = f (potential); t = constant

continuous function



„…every location is slightly different“

stepped (discrete) function



Practical approach: Sites with similar characteristics described by one band

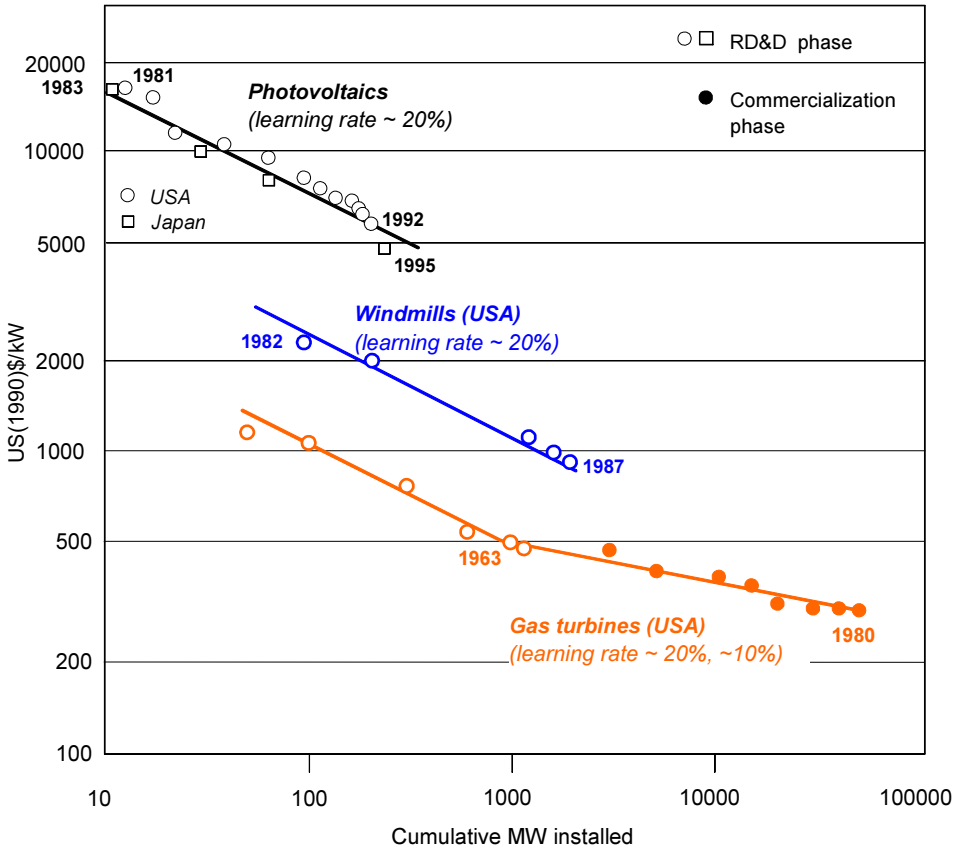
2. Basic principles: Experience curves

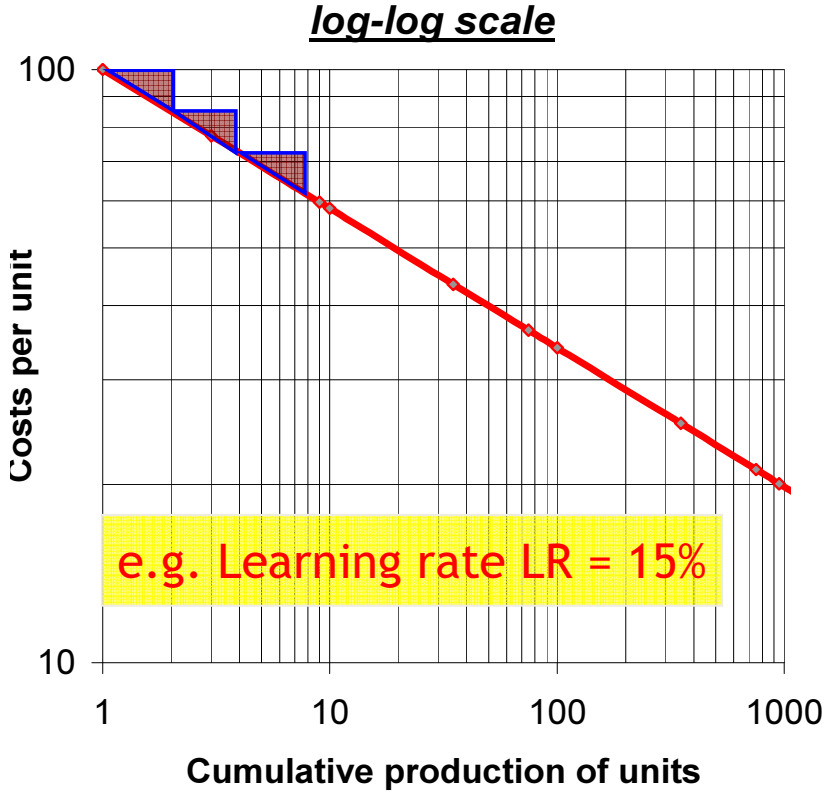
▶describe ***how costs decline with cumulative production.***

▶Empirical observations … 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)





2. Basic principles: Technology diffusion

➢… in accordance with general diffusion theory, penetration of a market by any new commodity typically follows an **'S-curve' pattern**

➢… applied within the model to describe **the impact of non-economic barriers on RES-E deployment**

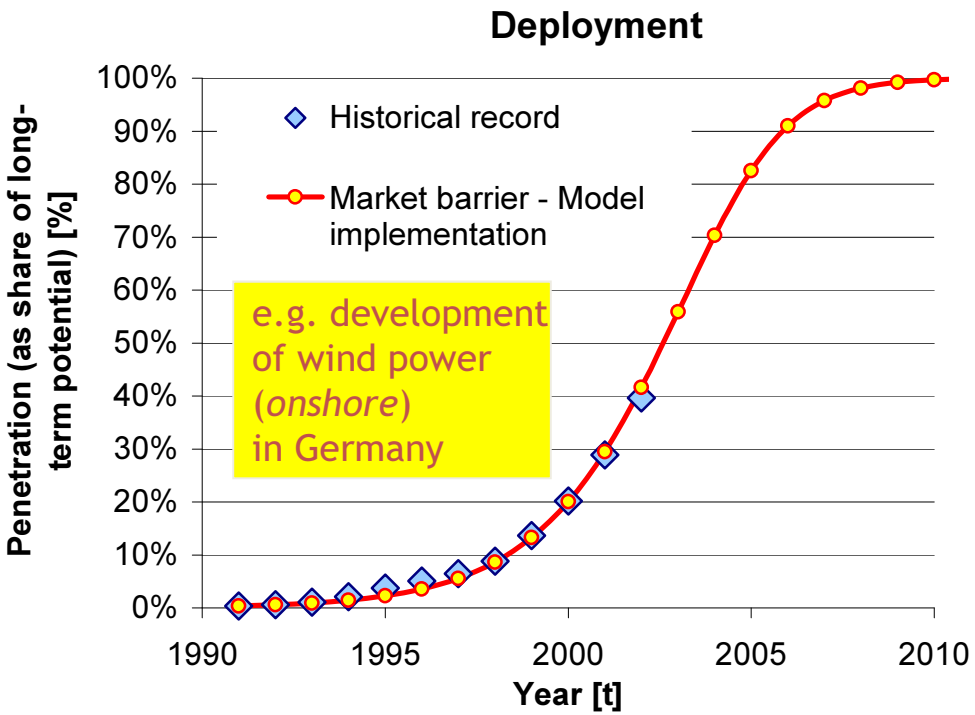
General diffusion theory

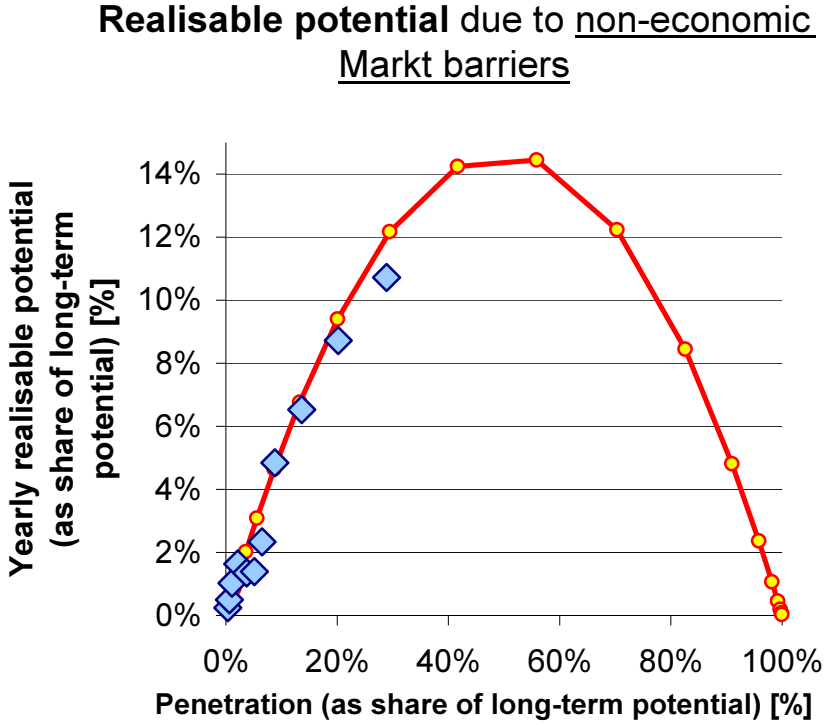
$$F = \frac{1}{1+e^{-d*(t-t_0)}}$$

F	Markt penetration
d	Diffusion rate
ΔP_{Mn}	Yearly realisble potential (according to market barrier)
P	Long-term realisable potential

Model implementation of dynamic non-economic market barriers

$$\Delta P_{Mn} = P * d * F * (1-F)$$

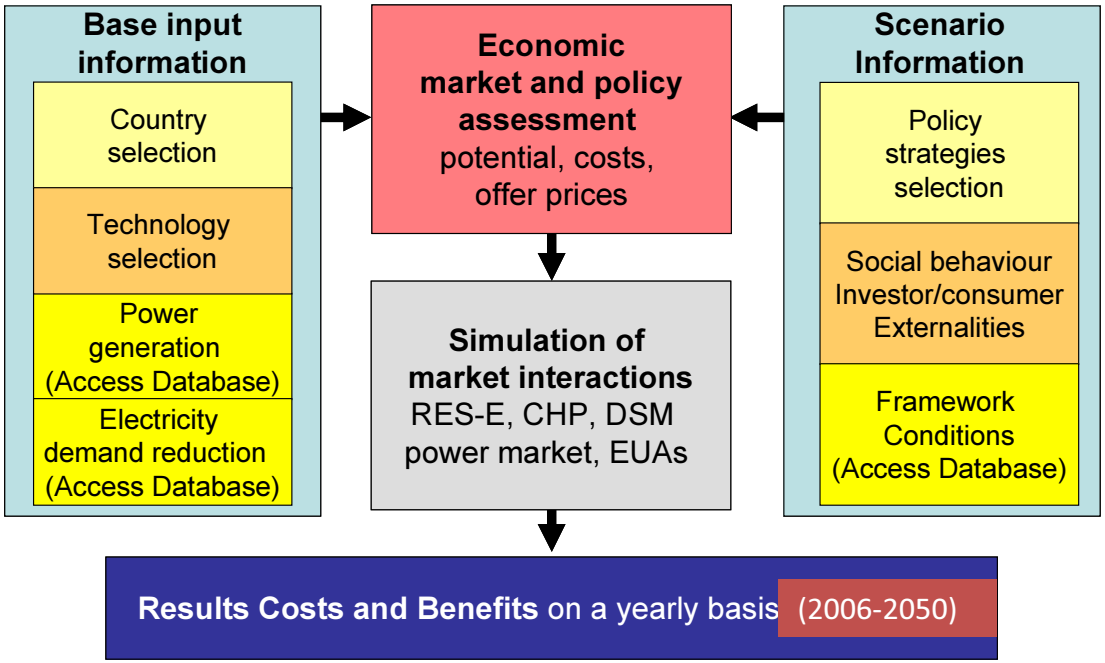


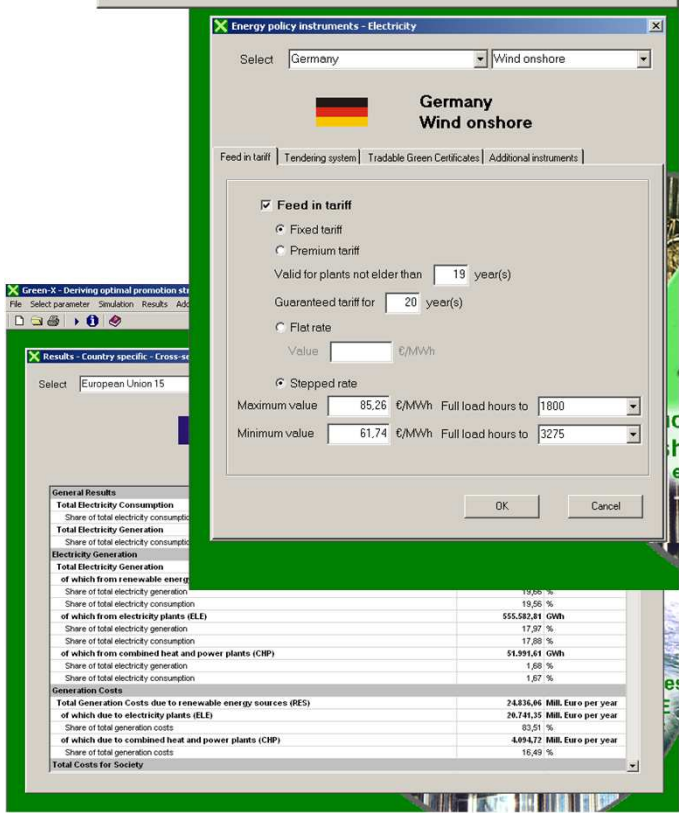


The *Green*-X model

Simulation model for energy policy instruments in the European energy market

- RES-E, RES-H, RES-T and CHP, conventional power
- Based on the concept of dynamic cost-resource curves
- Allowing forecasts up to 2030(2050) on national / EU level



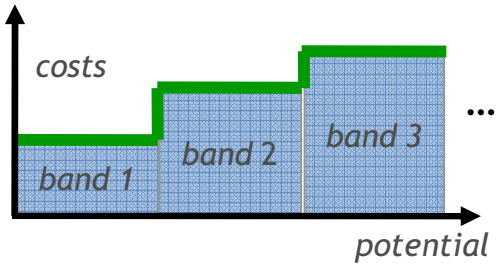


Reference clients: European Commission (DG RESEARCH, DG TREN, DG ENV, DG ENER), Sustainable Energy Ireland, German Ministry for Environment, European Environmental Agency, Consultation to Ministries in Serbia, Luxembourg, Morocco, etc.

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

- energy output by sector (RES-E, RES-H, RES-T), by country, by technology
- installed capacity & corresponding capital expenditures by sector, by country, by technology
- share on gross domestic electricity / heat / transport fuel demand
- (average) (additional) generation costs by sector, by country, by technology
- avoided (fossil) primary energy and CO_2 emissions due to additional RES deployment by sector, by country, by technology
- impact of selected energy policy instruments on supply portfolio, costs & benefits to the society (consumer)
  - e.g. consumer expenditures due to RES support

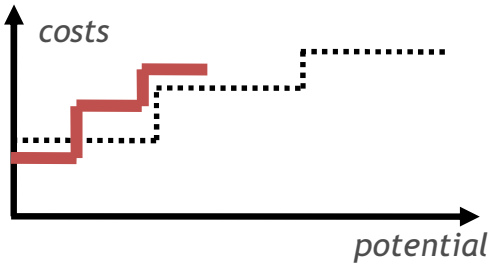
Mid-term (up to 2020)
realisable potentials in year n
& corresponding costs for RES at country level
by RES technology *(subdivided into several bands)*



Potential
Cost (efficiency)

Technology diffusion *('S-curve')*
(non-economic barriers by technology/country)

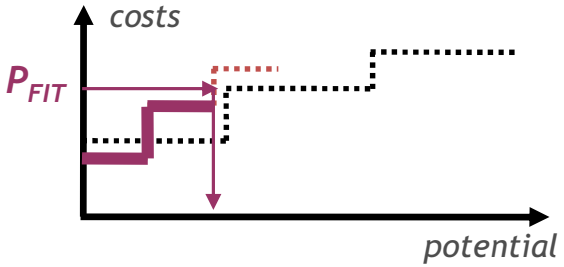
Technological change
((global) learning curves by technology)



Realisable yearly potentials in year n

Energy policy
(energy prices, RES support)

e.g. Feed-in tariffs,
Investment incentives,
Tendering schemes,
Quotas with tradable green certificates



Deployment in year n
and corresponding costs & benefits

The *Green*-X approach:

Dynamic cost-resource curves

&

a detailed energy policy representation

▸ *Key assumptions*

To ensure maximum consistency with existing EU scenarios and projections the key input parameters of the Green-X scenarios are (as default) based on **PRIMES modelling** and the (updates of the) **Green-X database**.

Based on PRIMES*	***Defined for this study***
Energy demand by sector	RES policy framework
Primary energy prices	Reference electricity prices
Conventional supply portfolio and conversion efficiencies	RES cost & learning rates (Green-X database, incl. biomass)
CO_2 intensity of sectors	**RES potential** (Green-X database)
	Biomass trade specification
	Technology diffusion
	Financing conditions

Main input sources for scenario parameters

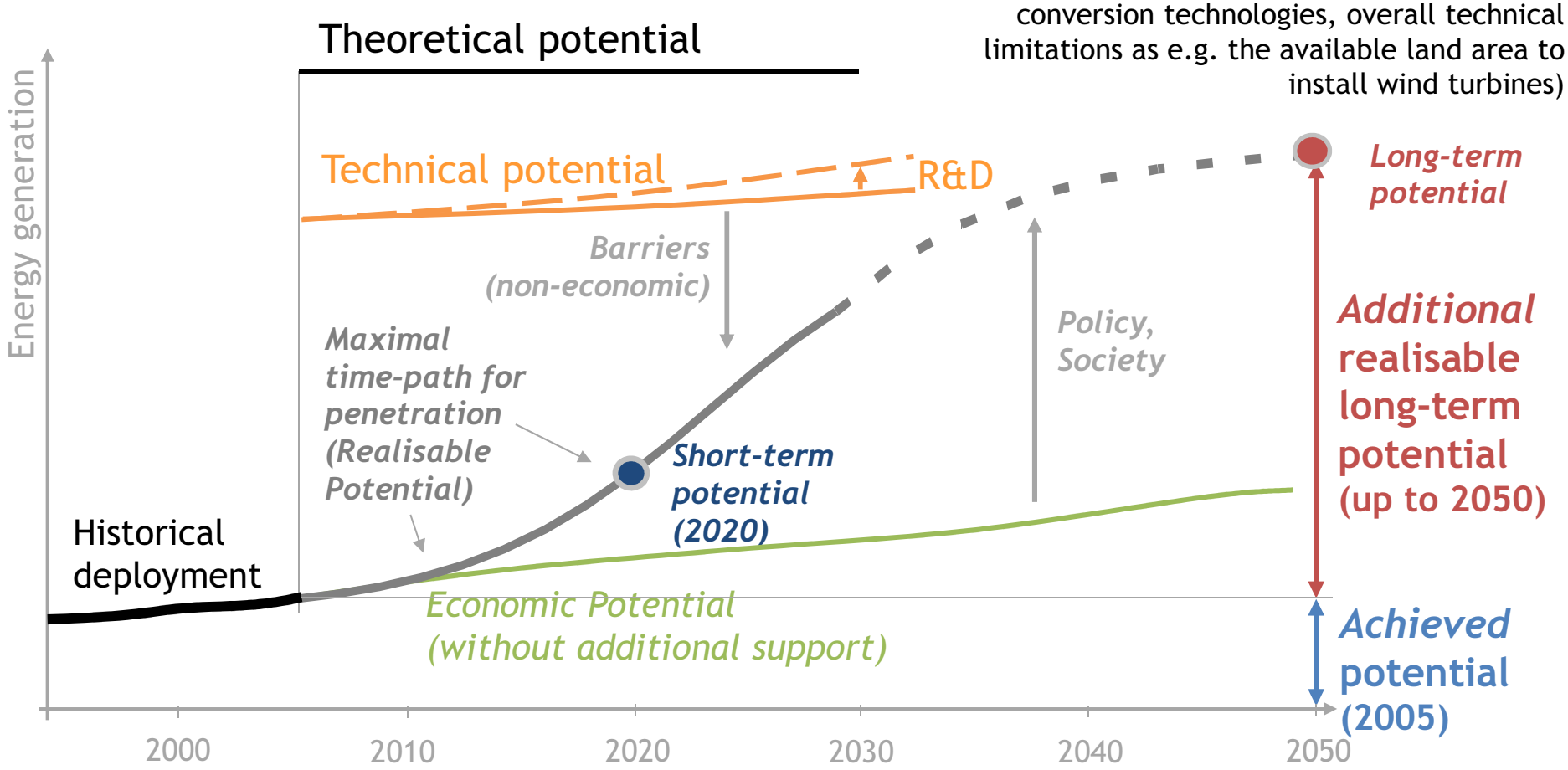
**Primes scenario used subsequently: Reference case (as of 2015/2016)*

Definition of the (additional) realisable mid-term potential (up to 2020/2030/2050)

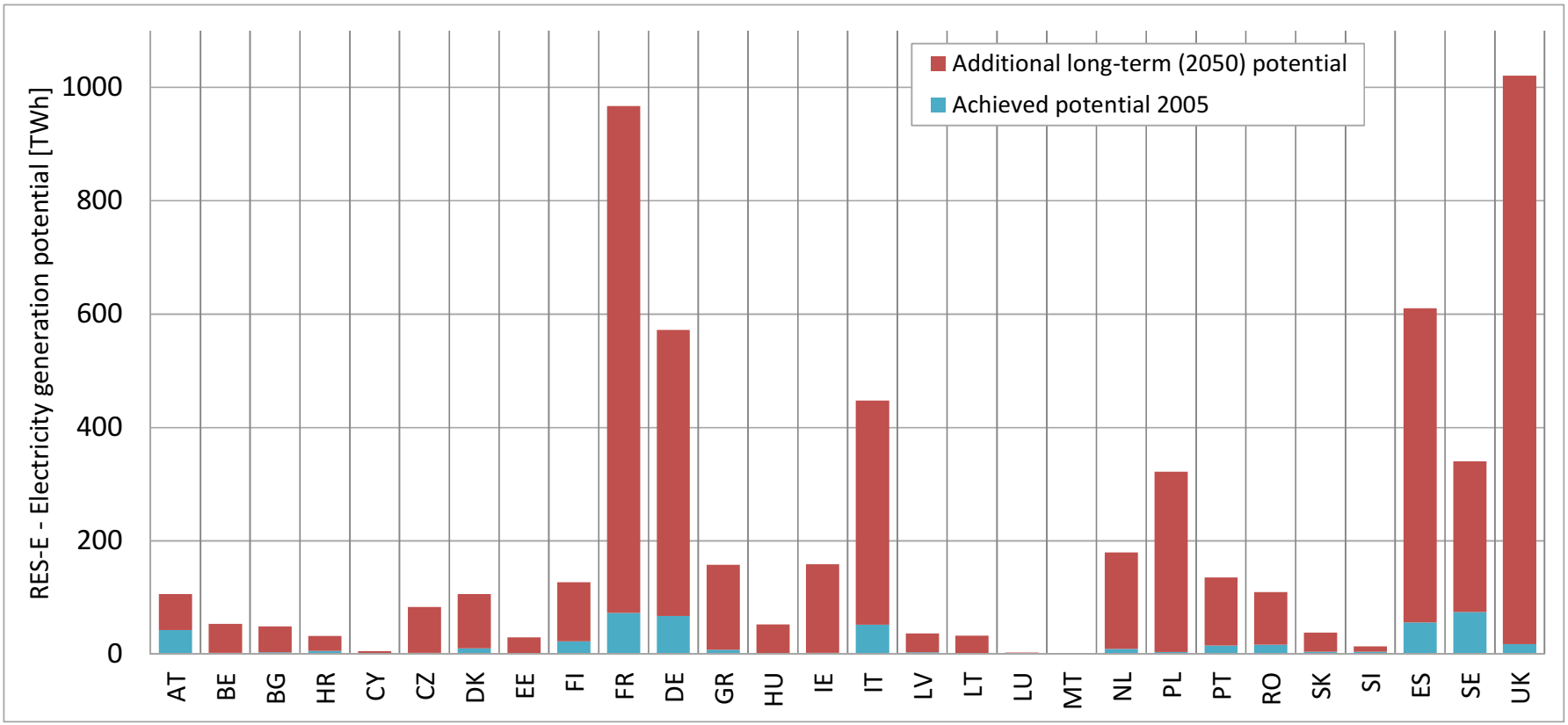
Definition of potential terms

Theoretical potential ... based on the determination of the energy flow.

Technical potential ... based on technical boundary conditions (i.e. efficiencies of conversion technologies, overall technical limitations as e.g. the available land area to install wind turbines)

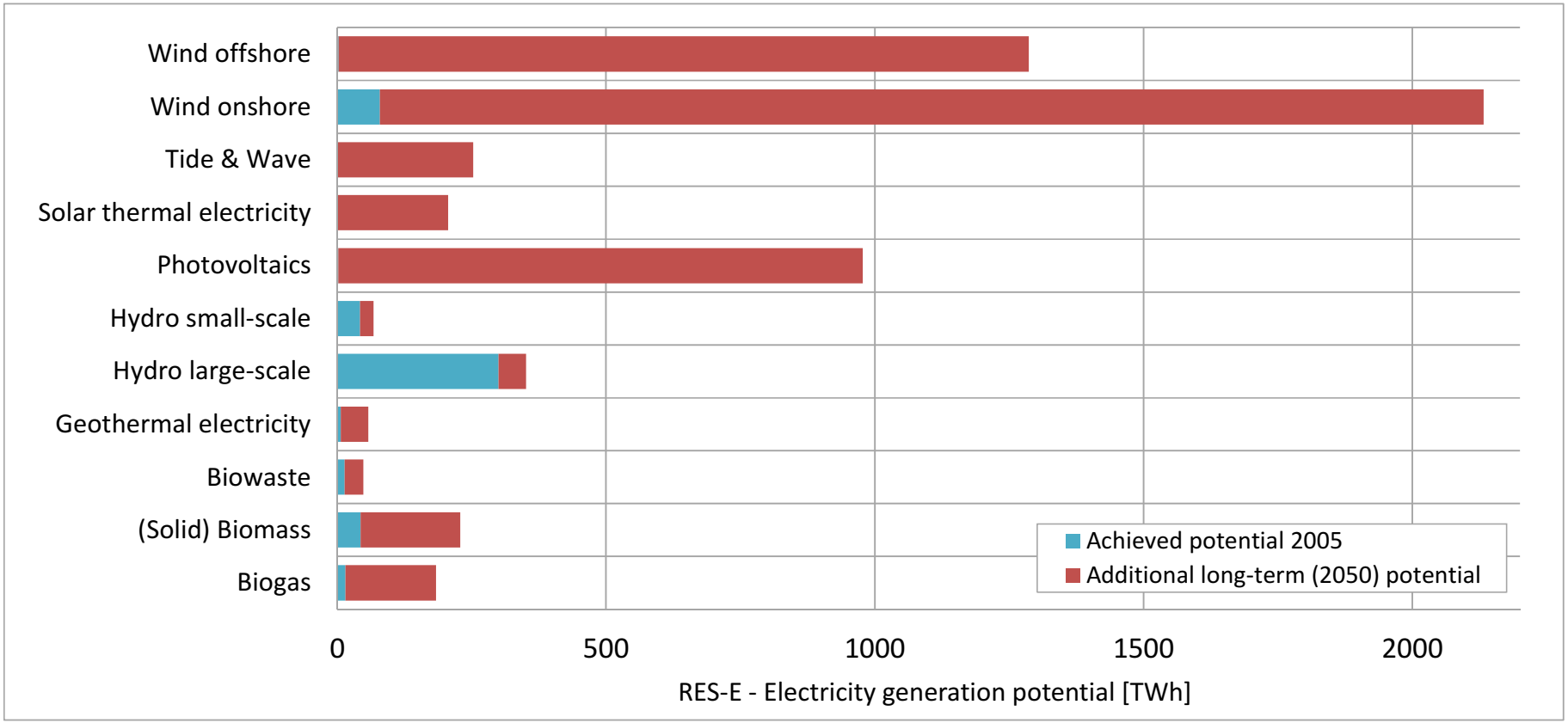


Green-X database on RES potentials



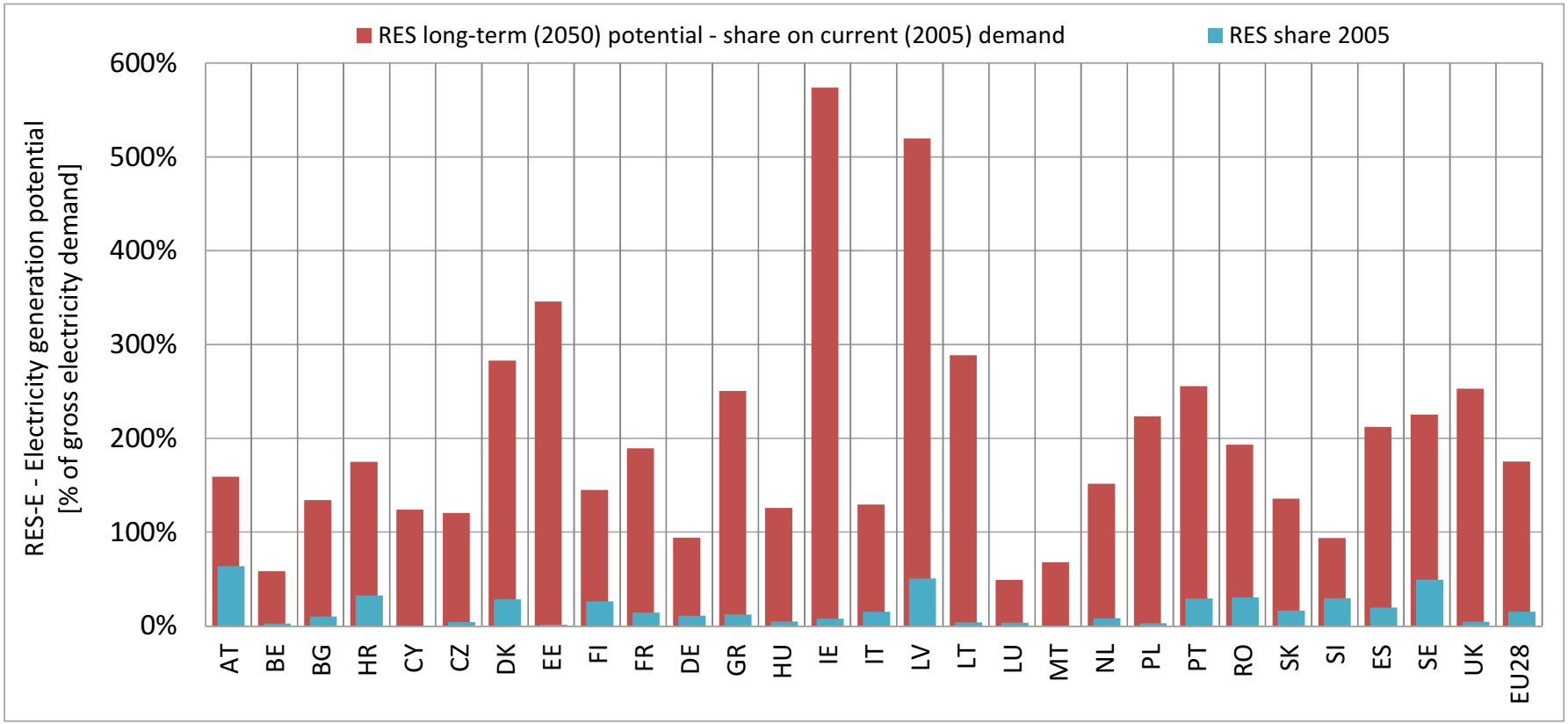
Long-term (2050) potentials for RES-electricity in EU28 countries
(in absolute terms [TWh])

Green-X database on RES potentials



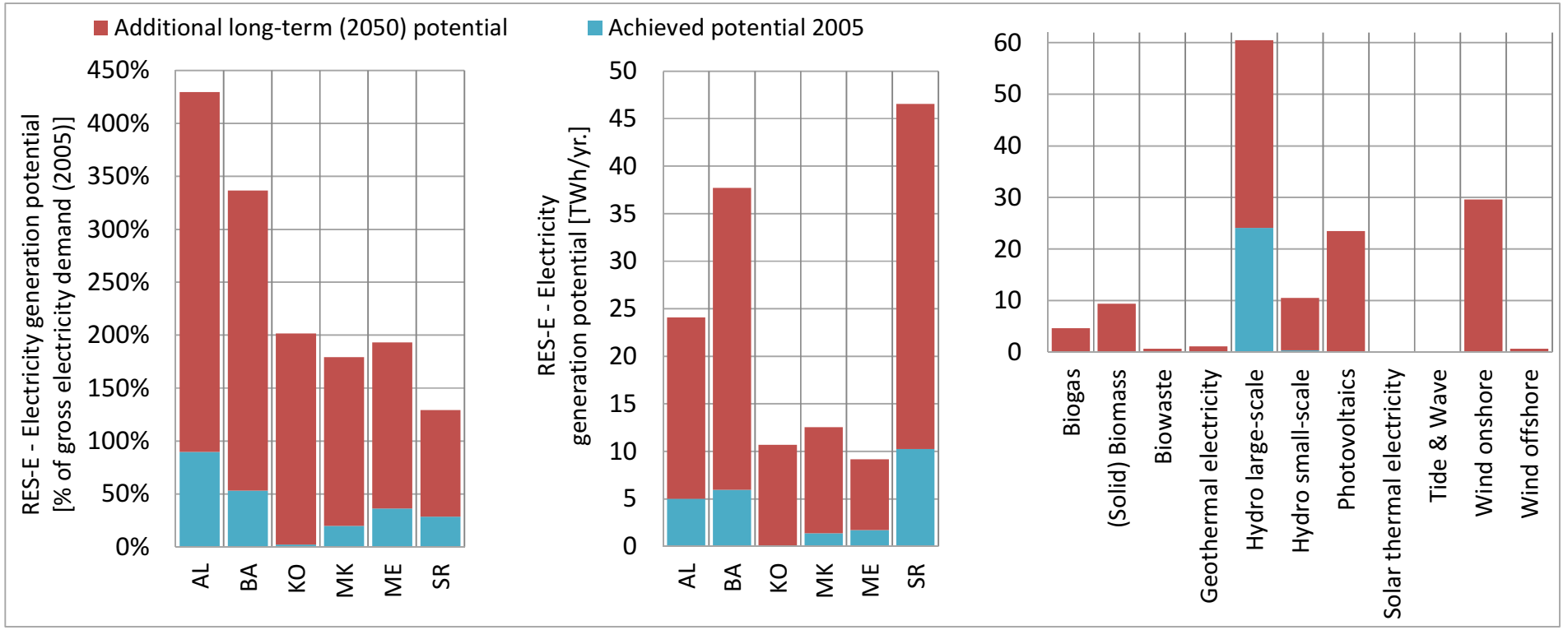
Long-term (2050) potentials for RES-electricity in EU28 countries
(in absolute terms [TWh] by technology)

Green-X database on RES potentials



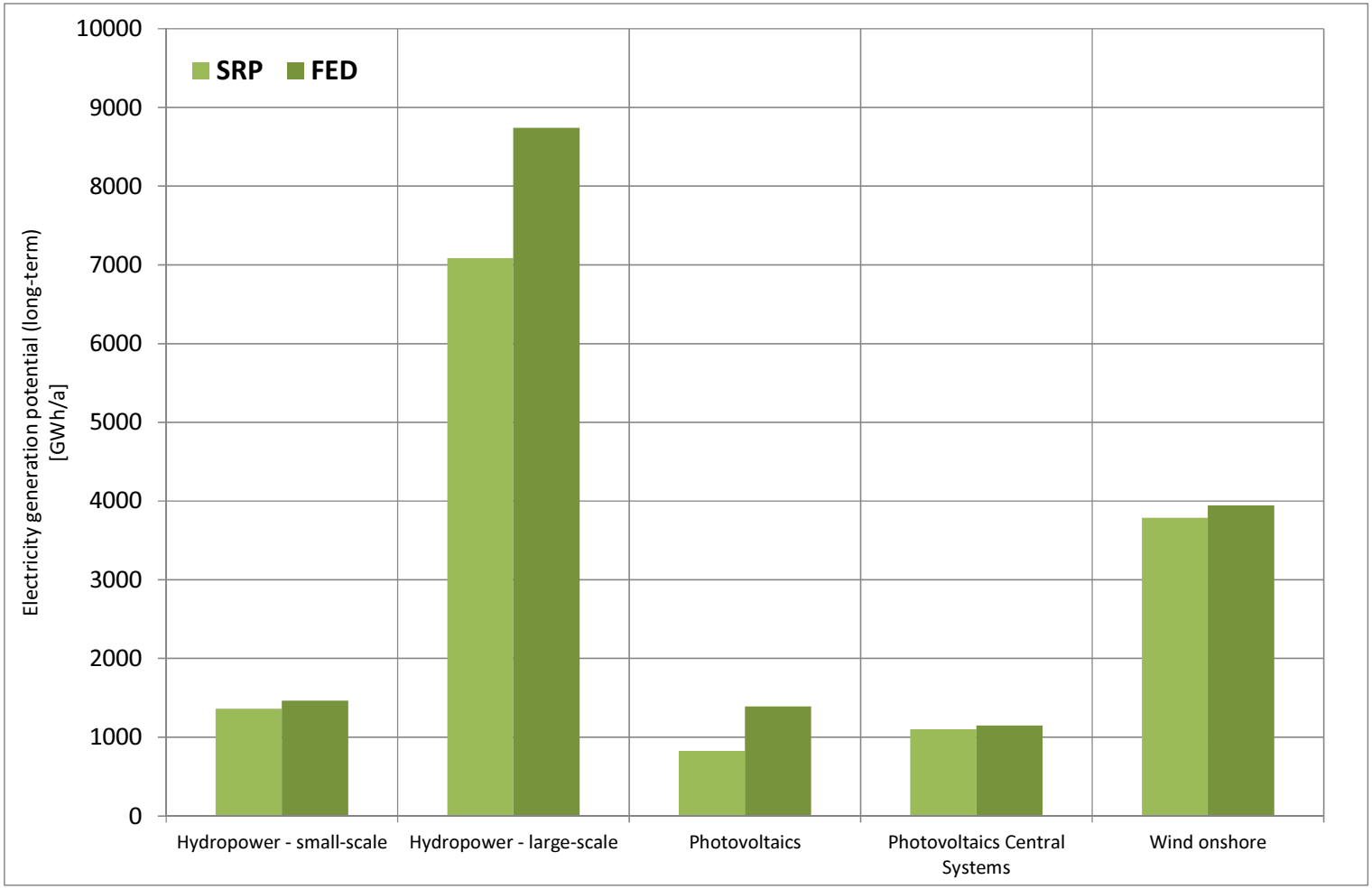
Long-term (2050) potentials for RES-electricity in EU28 countries
(in relative terms [% - share of gross electricity demand])

Green-X database on RES potentials



Long-term (2050) potentials for RES-electricity in Western Balkan countries
(in absolute & relative terms)

Split-up of (revised) RES potentials for Bosnia &Herzegovina by entity



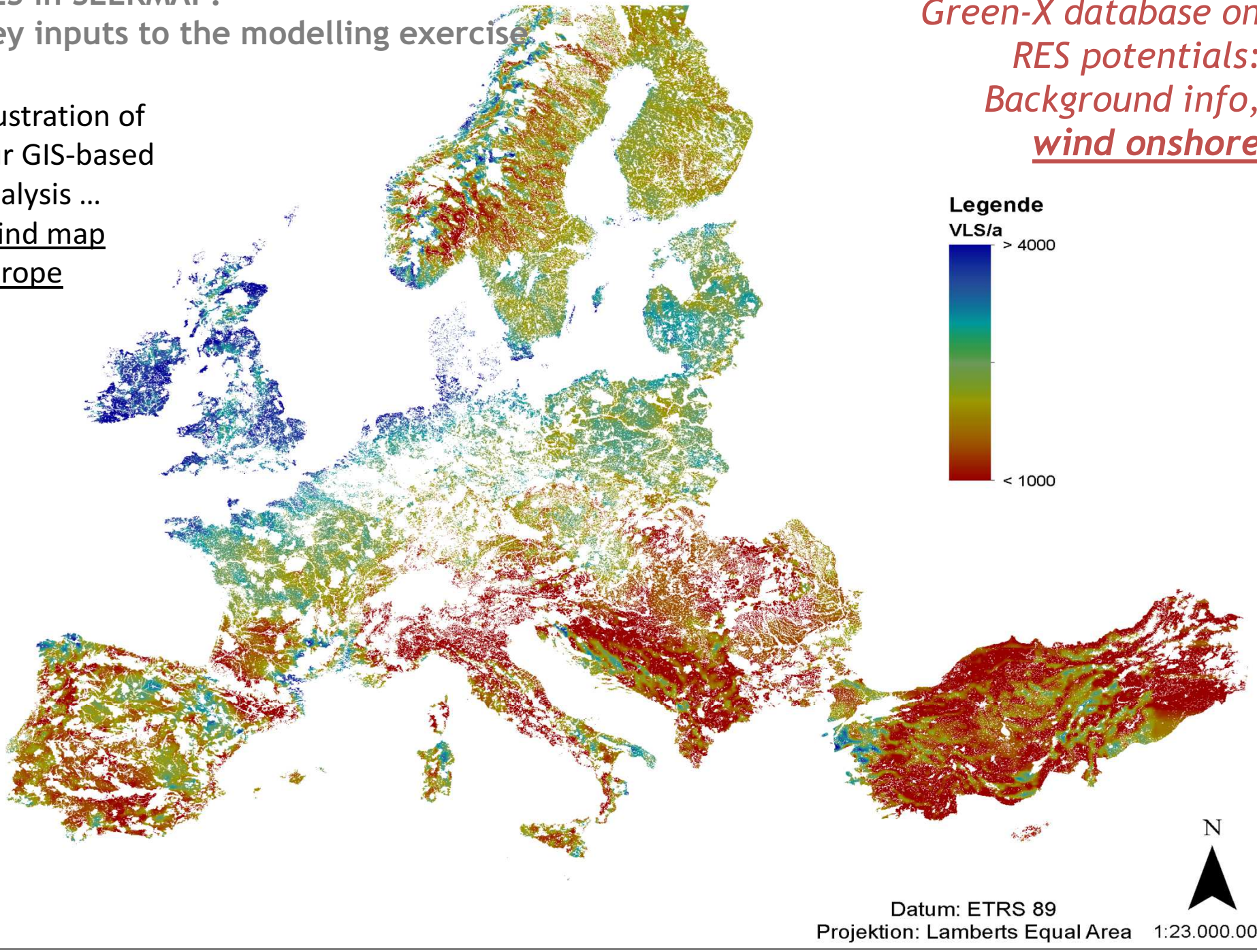
Bosnia & Herzegovina

RES in SEERMAP:
Key inputs to the modelling exercise

Green-X database on RES potentials: Background info, ***wind onshore***

Illustration of our GIS-based analysis …

Wind map Europe



Artifical surfaces	0%
Arable land	25.0%
Permanent crops	15.0%
Pastures	20.0%
Heterogeneous agricultural areas 1	10.0%
Heterogeneous agricultural areas 2	10.0%
Heterogeneous agricultural areas 3 (agro-forestry)	5.0%
Forests	5.0%
Natural grasslands, moors	22.5%
Sclerophyllous vegetation & Transitional woodland-shrub	22.5%
Beaches, dunes, sands	10.0%
Bare rocks	0.0%
Sparsely vegetated areas	30.0%
Burnt areas & glaciers	0.0%
Inland wetlands	5.0%
Maritime wetlands	5.0%
Inland waters	0%
Marine waters	0%

Applied Land use constraints: Suitability for wind power plants

*Green-X database on RES potentials: Background info, **wind onshore***

	GR	BG	RO	AL	BA	KO	ME	MK	SR
	Greece	Bulgaria	Romania	Albania	Bosnia H.	Kosovo*	Montenegro	FYR of Macedonia	Serbia
TOTAL POTENTIAL **with land use restrictions**, without power system constraints (Capacity potential) [MW]	54,754	16,412	57,427	9,707	15,983	2,114	6,242	5,386	31,593
RESTRICTED POTENTIAL **with land use restrictions, with default power system constraints** (Capacity potential) [MW]	36,976	10,110	17,922	2,423	4,243	2,023	1,064	1,587	7,293

Long-term (2050) potentials for **Wind Onshore** in SEE countries

▸ *Key assumptions*

To ensure maximum consistency with existing EU scenarios and projections the key input parameters of the Green-X scenarios are (as default) based on **PRIMES modelling** and the (updates of the) **Green-X database**.

Based on PRIMES*	***Defined for this study***
Energy demand by sector	RES policy framework
Primary energy prices	Reference electricity prices
Conventional supply portfolio and conversion efficiencies	RES cost & learning rates (Green-X database, incl. biomass)
CO_2 intensity of sectors	RES potential (Green-X database)
	Biomass trade specification
	Technology diffusion
	Financing conditions

Main input sources for scenario parameters

**Primes scenario used subsequently:*
Reference case
(as of 2015/2016)

WACC – risk elements

WACC assumptions and the impact of risk (policy, technology, country)

$$WACC_{c,t,p} = WACC_{default} * f_c * f_t * f_p$$

Default assumptions concerning energy technologies in Austria

WACC (in Austria)	default (real)	ideal
posttax (nominal)	6.5%	4.9%
pretax (nominal)	8.7%	6.5%
pretax (real)	**7.4%**	**5.3%**

Note: Through complementary measures the investor risk can be reduced, from „real“ to „ideal“ (according to an assessment conducted in the DIA-CORE project)

Source: Dia-Core project (www.diacore.eu)

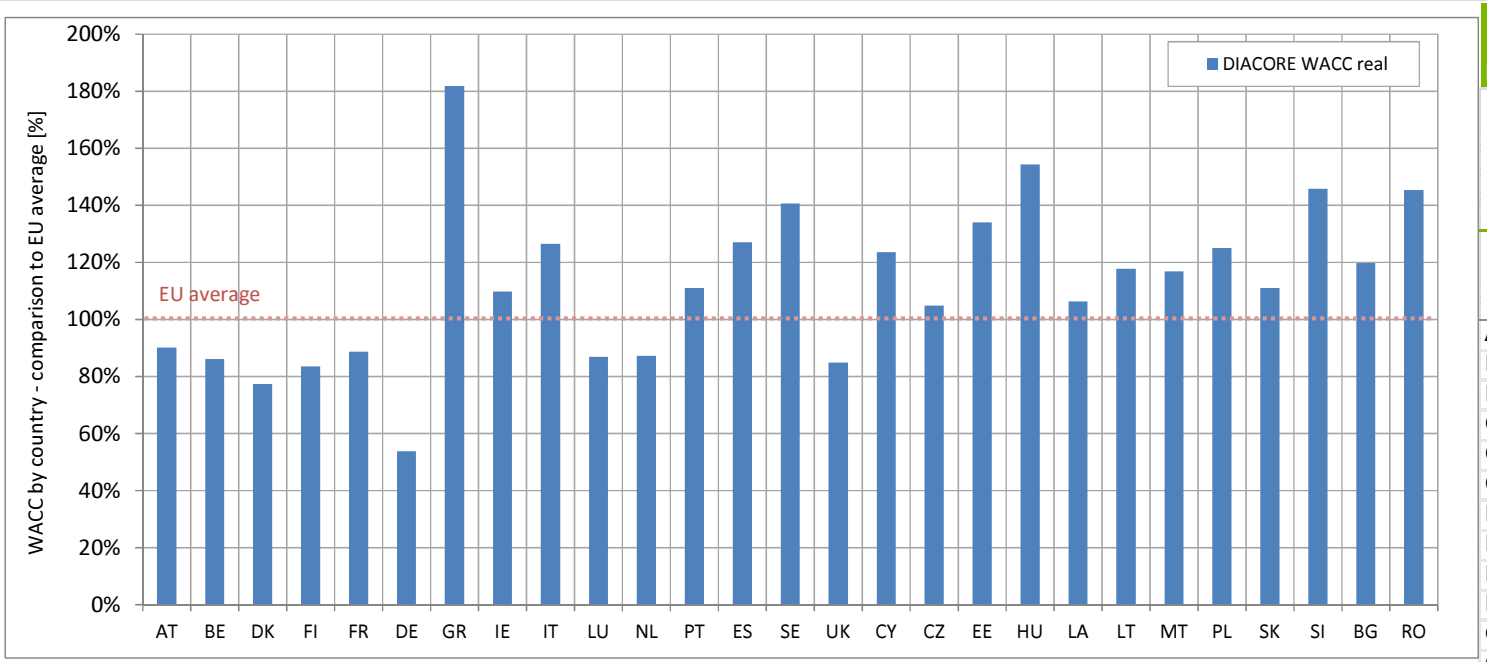
Technology-specific risk factor (i.e. multiplier of default WACC)	
RES-electricity	
Biogas	1.00-1.05
Solid biomass	1.05
Biowaste	1.05
Geothermal electricity	1.1
Hydro large-scale	0.95
Hydro small-scale	0.95
Photovoltaics	0.85-0.90
Solar thermal electricity	1.1 (1.0)
Tide & wave	1.4 (1.2)
Wind onshore	0.95
Wind offshore	1.4 (1.15)

Note: Numbers in brackets refer to the period post 2020.

Policy risk: Instrument-specific risk factor (i.e. multiplier of default WACC)	
FIT (feed-in tariff)	1.00
FIP (feed-in premium)	1.10
QUO (quota system with uniform tradable green certificates (TGC))	**1.20**
ETS only (Emission Trading Scheme only - no dedicated RES support)	1.30
TEN (tenders for selected RES-E technologies)	**1.15**

WACC – country-specific risk

The impact of country specific risk – our initial figures… based on www.diacore.eu



MS	WACC pretax (real)	WACC pretax (real)
	Interview	Triple A policies
	Real case	Ideal situation
Austria	7.4%	5.3%
Belgium	7.1%	5.8%
Bulgaria	9.9%	6.7%
Croatia	13.8%	7.7%
Cyprus	10.2%	6.0%
Czech Republic	8.6%	6.4%
Denmark	6.4%	5.2%
Estonia	11.0%	4.8%
Finland	6.9%	4.4%
France	7.3%	6.1%
Germany	4.4%	3.7%
Greece	15.0%	9.1%
Hungary	12.7%	7.8%
Ireland	9.0%	6.2%
Italy	10.4%	8.3%
Latvia	8.8%	5.6%
Lithuania	9.7%	5.6%
Luxembourg	7.2%	6.0%
Malta	9.6%	7.4%
Netherlands	7.2%	5.6%
Poland	10.3%	6.5%
Portugal	9.1%	5.9%
Romania	12.0%	7.4%
Slovakia	9.1%	6.3%
Slovenia	12.0%	7.8%
Spain	10.5%	8.6%
Sweden	11.6%	5.3%
UK	7.0%	5.3%
	9.4%	6.3%

- Represents the (outdated?) status quo according to an assessment done in the DIACORE project (done in 2014-2015)
- For future trends: link to GDP per capita trends?
- **Problem: mixing country- and policy-related risks → take out policy risk!**
- **Problem II: how to include non-EU Western Balkan countries?**

WACC – country-specific risk

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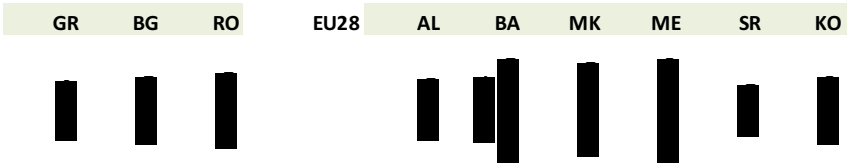
The impact of country-specific risk – our alternative approach



		GR	BG	RO	EU28	AL	BA	MK	ME	SR	KO
Alternative country risk setting											
DIA-CORE figures		182%	120%	145%							
2016 data	weighting factor										
Eurostat - long term government bond yields	**10%**	8.64	2.42	3.30	1.17						
RES deployment times risk ranking		279.6	46.9	196.9	1978.5						
Default risk multiplication factor		738%	207%	282%	100%						
National Credit Rating	**90%**	0.44	0.56	0.67	0.84	0.44	0.44	0.56	0.44	0.56	*0.56*
RES deployment times risk ranking		14.4	10.7	39.8	1418.8	0.0	0.0	0.0	0.0	0.0	0.0
Default risk multiplication factor		189%	151%	126%	100%	189%	189%	151%	189%	151%	151%
Ease of getting credit	**0%**	0.50	0.70	0.85	0.62						
RES deployment times risk ranking		16.2	13.5	50.8	1054.9						
Default risk multiplication factor		125%	89%	73%	100%						
Average risk rating		244%	157%	142%	100%	189%	189%	151%	189%	151%	151%
Smootheining factor - low	75%	208%	143%	131%	100%	167%	167%	138%	167%	138%	138%
Smootheining factor - medium (default)	50%	172%	128%	121%	100%	144%	144%	126%	144%	126%	126%
Smootheining factor - high	25%	127%	111%	108%	100%	117%	117%	110%	117%	110%	110%
Smootheining factor - very high	13%	118%	107%	105%	100%	111%	111%	106%	111%	106%	106%

- Remaining problem**:** how to make it dynamic?
  … in other words, what would be the country risk by 2030, 2050, …

Sources:

Alternative country risk setting

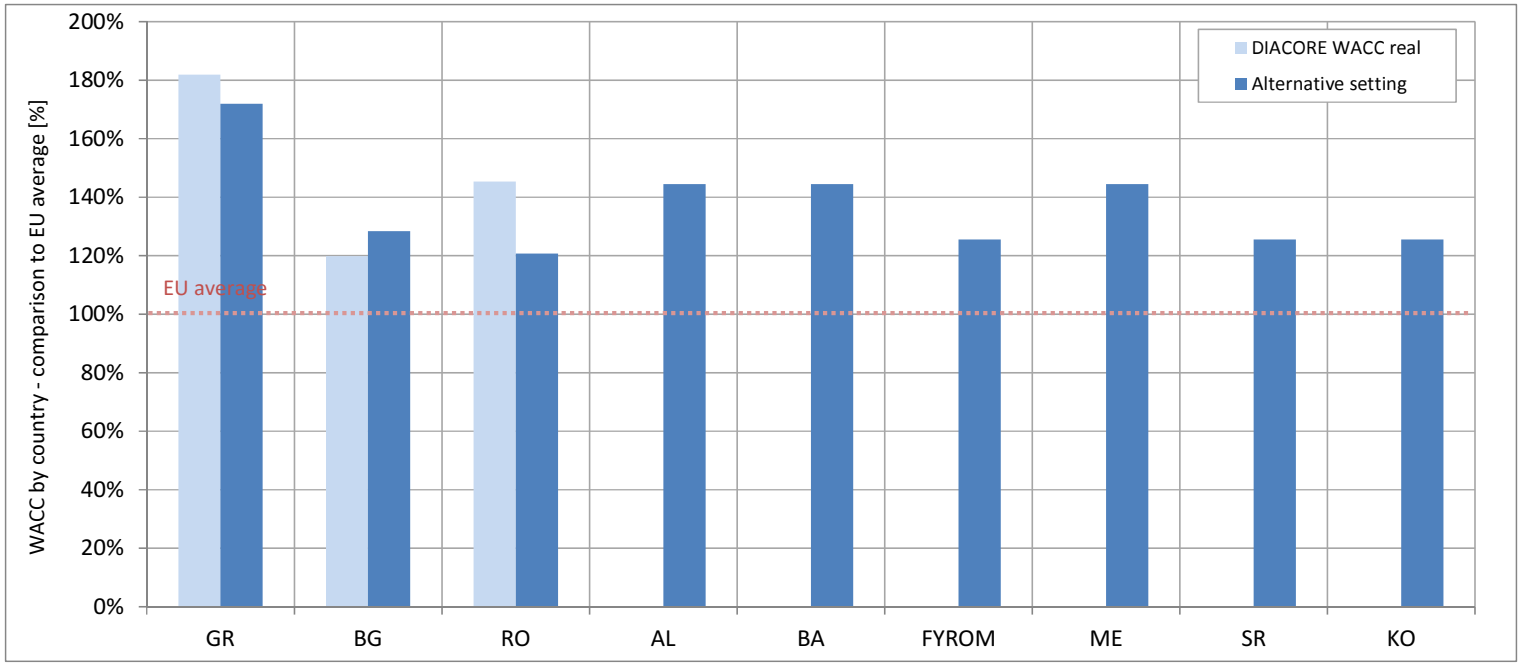
Eurostat - long term government bond yields
http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin

National Credit Rating
https://www.standardandpoors.com/en_US/web/guest/home

Ease of getting credit
http://www.doingbusiness.org/

WACC – country-specific risk

The impact of country-specific risk – our alternative approach



Remaining "problems":

- **How to make it dynamic?**
  … in other words, what would be the country risk by 2030, 2050, etc.

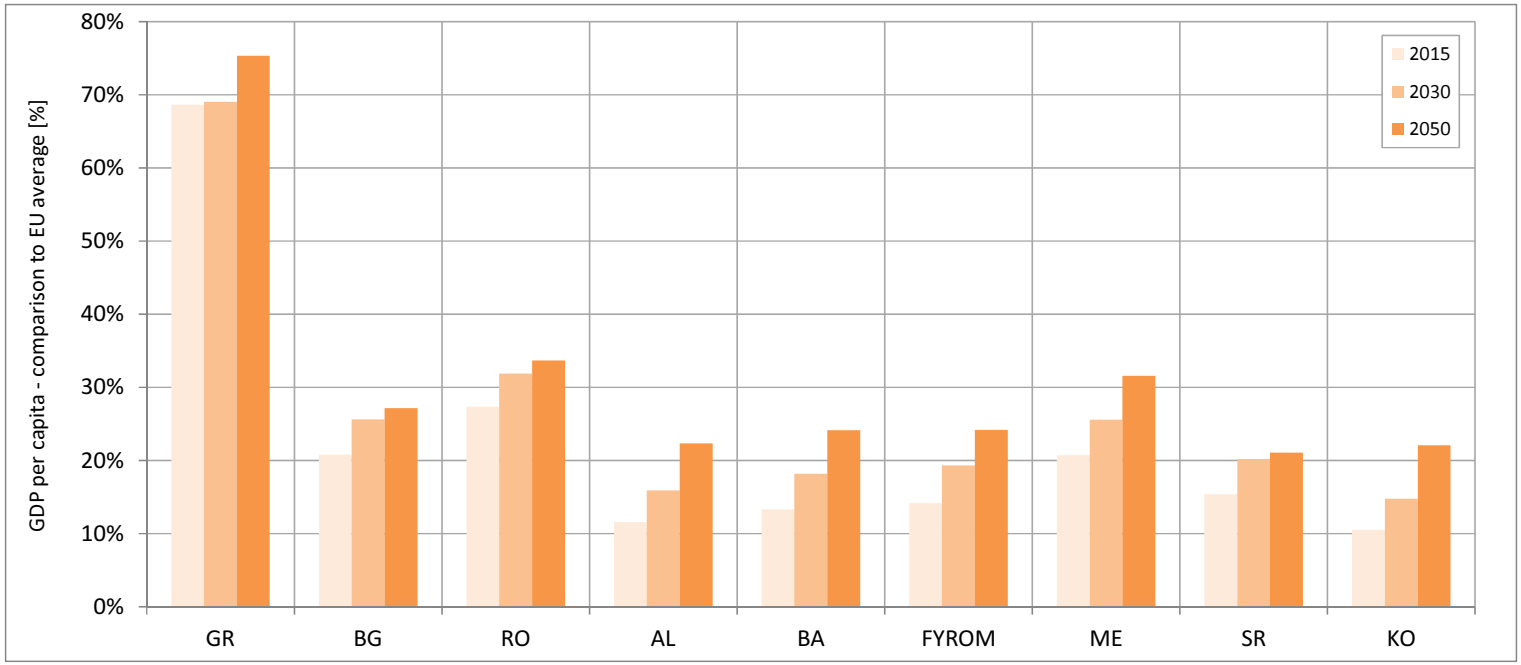
  OUR approach → Link to change (compared to today) in GDP per capita

- **How would a common (regional) policy change the picture?**

- ***→ A regional (or EU wide harmonised) policy would have an "averaging" effect:***
  OUR approach … 50% determined by default country risk, 50% by regional (average) risk

WACC – country-specific risk

The impact of country-specific risk – our alternative approach



- **How to make it dynamic?**
  … in other words, what would be the country risk by 2030, 2050, etc.

  OUR approach → Link to change (compared to today) in GDP per capita

→ **Illustration of GDP per capita trends** (Source: PRIMES, 2012, 2015)

▸ *Key assumptions*

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RES policy concept

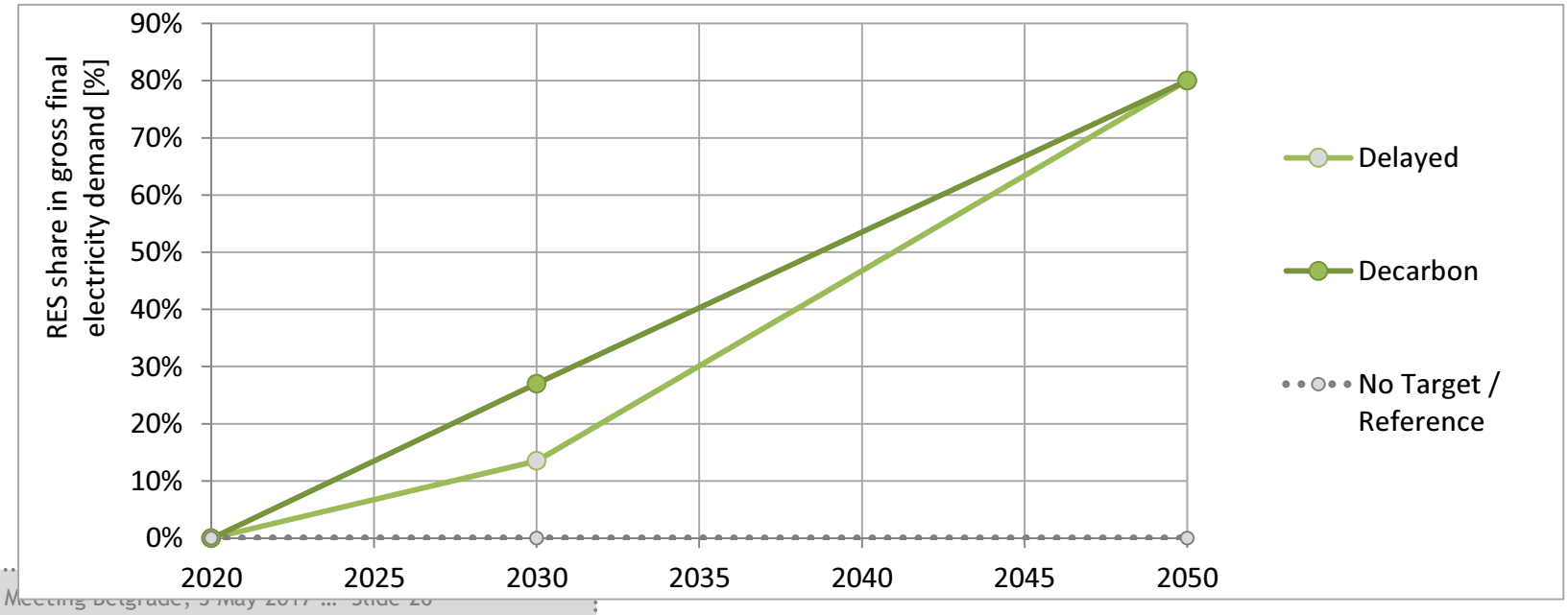
The policy concept used in our default scenarios

A regional policy approach post 2020

- As default we assumed a **regionally harmonised policy concept** for supporting new RES installations post 2020

→ with this one can take the full benefits of doing it regionally rather than purely nationally, **increasing cost-effectiveness** and **allowing to use renewables there where most beneficial / attractive from a system perspective**

The required uptake of new RES (installed post 2020) at regional level is illustrated below



RES policy concept

The policy concept used in our default scenarios

A regional policy approach post 2020

- **Different policy concepts** for supporting the uptake of RES-electricity are/will be assessed:
  - **Regionally harmonised quota scheme** with tradable green certificates … technology-neutral, uniform pricing
  - **Feed-in premium scheme with technology-specific auctions** for price determination
  - **National quota schemes with tradable green certificates** … technology-neutral, uniform pricing (to be added to the scenario calculations)

- *Are further sensitivity analyses required?* … for example on the WACC assumptions and these impacts, on energy price trends …?

Thanks for your attention!

In case of questions/remarks …

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