Grid investment for renewable energy use – cost of VRE network integration

IRENA Workshop *"Addressing the Geo-Spatial Aspects of Variable Renewable Energy in Long-Term Planning"*

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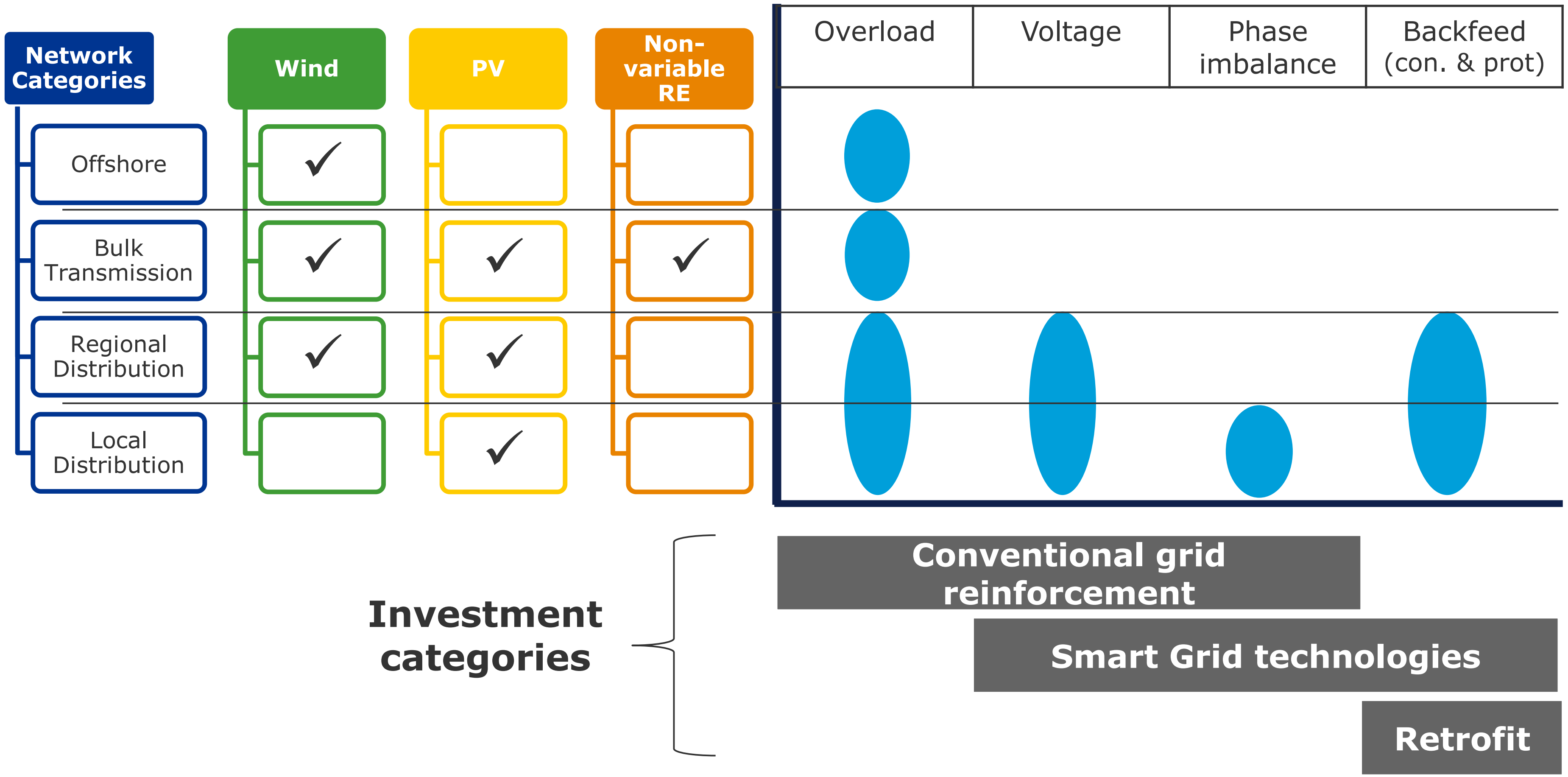
DNV GL estimation approach
VRE expansion & network integration

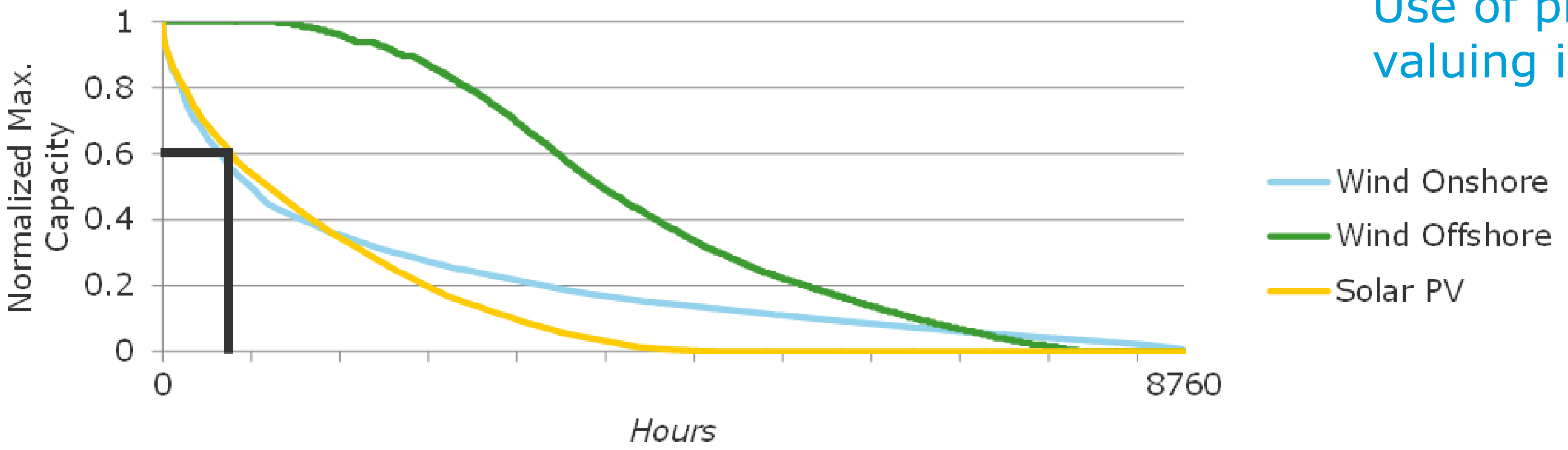
VRE expansion leads to problems in existing networks resp. needs for grid expansion / alternative measures

- Figure shows network problems arising from VRE expansion
- DNV GL approach allows for structured link between and clustering of different areas, causes and types of investment needs in transmission and distribution networks



Transmission networks
First step: moving from annual VRE to capacity needs

Methodology needs to start with the derivation of need for transmission network expansion from VRE expansion, based on specific RE assets & (weather-dependent) generation profiles



Use of production duration curves for valuing incremental grid capacity

Source:
DNV GL, based on 2013 data from German TSOs

Approach for determining the value of incremental transmission capacity for different types of RE:

1. Use (standardized) production duration curves (alt.: chronological profile)
2. Determine value contribution of incremental "transport" capacity, based on (average) production costs or market prices in "remote" area
3. Identify level of transport capacity, for which additional network investments are equal to opportunity costs of curtailment

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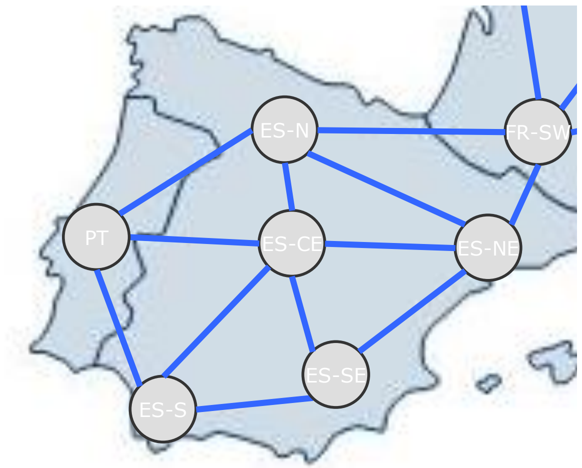
Transmission networks
Second & Third step: estimating cost of VRE driven network expansion

Investments needs determined for equivalent capacity needs between "centers of gravity", based on specific costs of "typical network mix"

Network represented by "centers of gravity"



Consideration of equivalent capacity and specific costs of "typical network mix"

Transmission capacity: X MW ✖ Distance: Y km ✖ Transmission mix / Specific investment cost:

Share*	Category	Specific Cost* [$/kWkm]
60%	AC-OHL	500
10%	AC-cable	2000
20%	DC-OHL	1000
10%	DC-cable	4000

*Country-specific assumptions

✖ Environmental conditions: Routing factor, Topology factor = Z $

- Analysis limited to connection between different "centers of gravity"
- Flexible approach, allowing for consideration of capacity needs, typical technology mix, country-specific cost levels and other environmental factors

Transmission networks
Example Morocco: VRE extension & transmission capacity needs

1000 MW wind program 2020

2000 MW solar power by 2020

Residual load duration curve based on Spanish wind, solar and load profiles

	Investment cost [mUS$]	Until 2020	Until 2030
LINE 1	Boudjour - Laayoune	9	19
	Layonne - Agadir	126	252
	Agadir - Essaouira	36	73
	Essaouira - Casablanca	143	290
	Casablanca - Tanger	190	385
LINE 2	Midelt - Taza	15	32
	Taza - Tanger	61	131
LINE 3	Tanger - Gibraltar	10	8
	TOTAL	591	1,190

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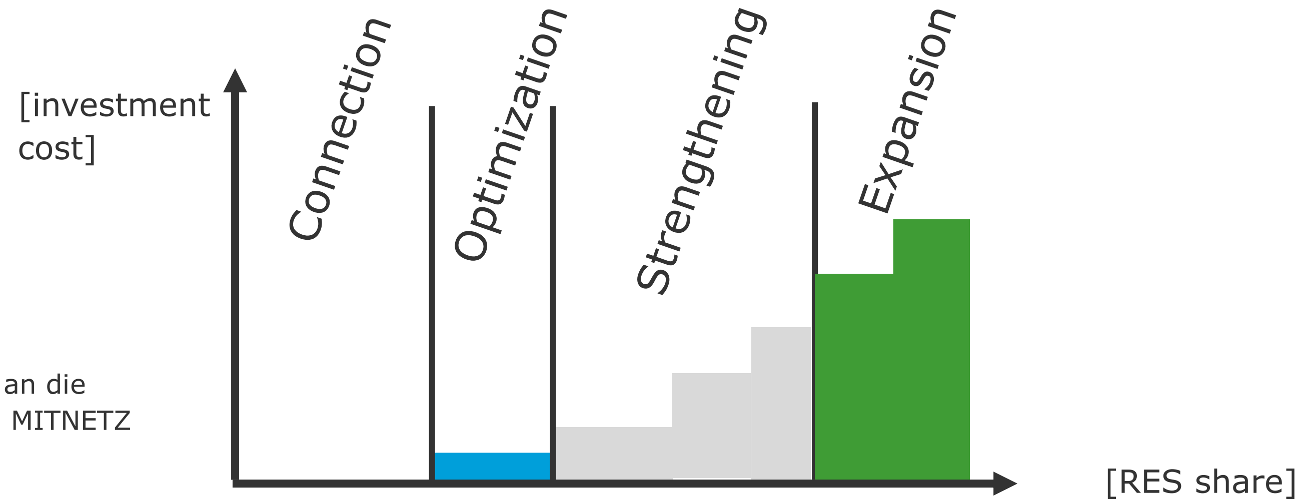
Distribution networks
Basic structure: different stages of network expansion

Network operators can take various measures to deal with increasing levels of distributed RES, but it is not possible to account for each stage in this project



Based on: “Anforderungen an die Energienetze der Zukunft”, MITNETZ Strom, 24.10.2012

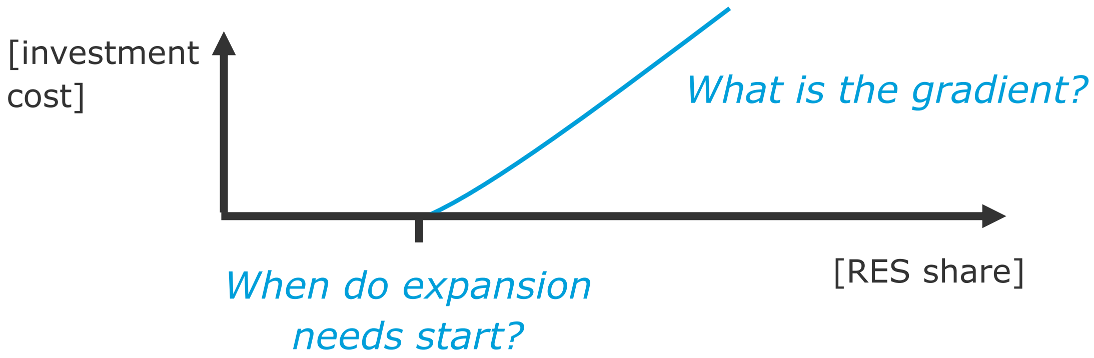
- Distributed RE can initially be integrated without major efforts
- With penetration increases, different measures required, to facilitate VRE integration
- Major reinforcements often required only once substantial penetration of VRE has been exceeded

Distribution networks
Quantification: key questions and factors

Simple linear model, which uses two major parameters to estimate the need for (RE-driven) network expansion

- Due to large number & variety of distribution networks, standardized approach required
  - Should be based on typical assumptions and networks
- Review of different studies & reports suggests similar pattern for VRE driven network expansion
  - No need for network expansion up to certain VRE penetration (ranging between 10% & 40% of peak load)
  - Somewhat linear growth of incremental costs as RES penetration grows

Illustration of basic concept

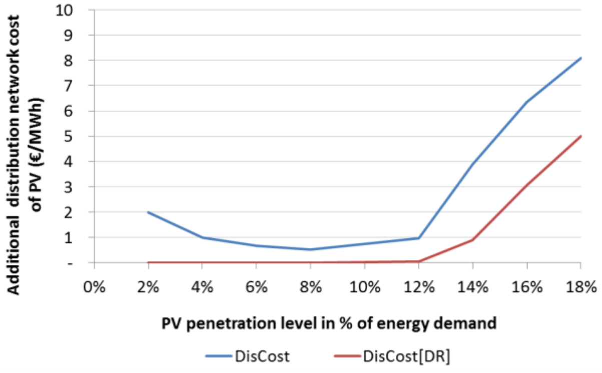


Distribution networks
Example of Germany & Spain: evolution of investments

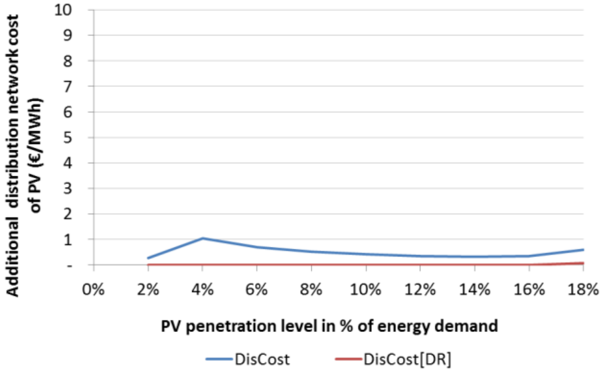
Study on solar PV indicates similar impacts for 11 European countries, although threshold for investments varies

- Study analyzed costs of system integration (balancing and back-up) and distribution network expansion for PV generation for 11 European countries
  - Cost curves vary considerably initially, but show largely linear trend once a certain threshold is exceeded
  - Differences mainly due to simultaneity of load and generation, i.e. assumed coincidence of PV generation and local demand in Southern Europe

Germany



Spain



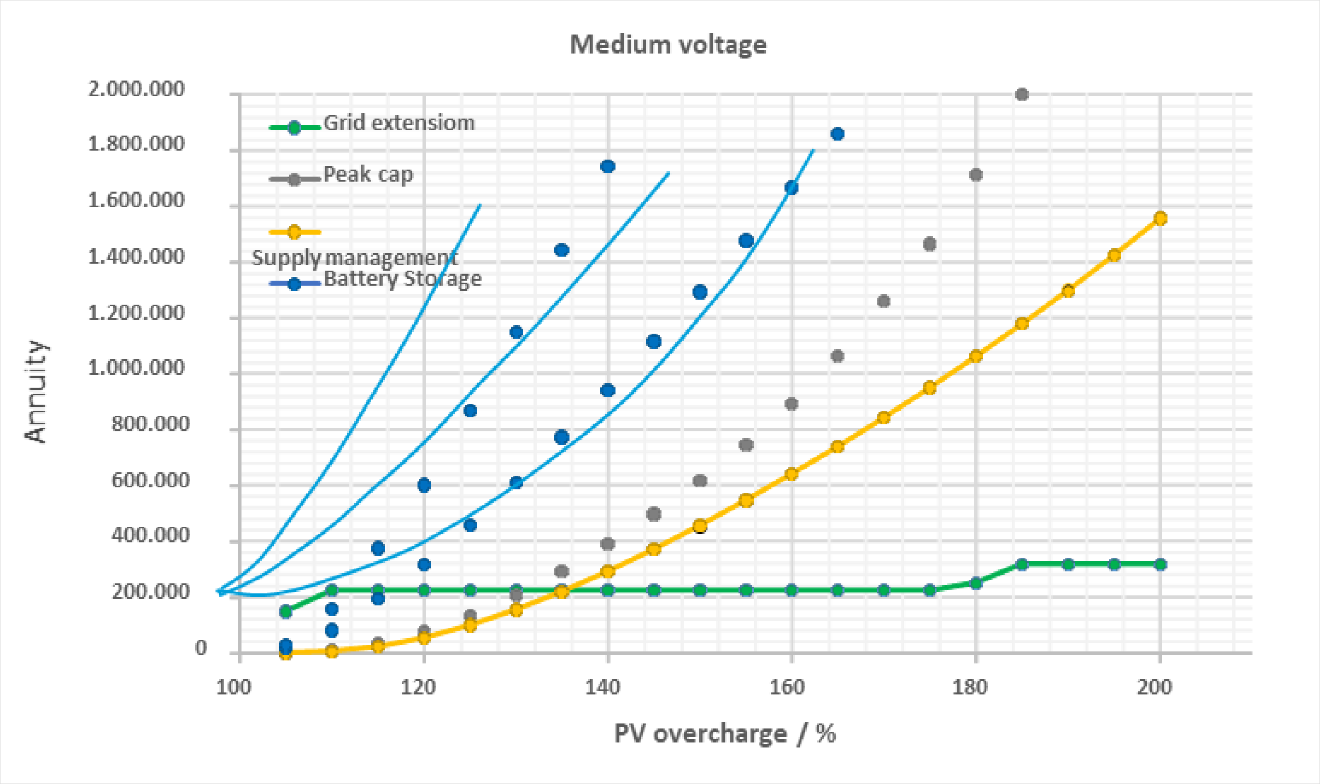
Source: Imperial College London. Grid Integration Cost of PhotoVoltaic Power Generation. PV Parity project, September 2013

Distribution networks
Technical alternatives to VRE driven expansion

Technical alternatives to grid expansion exist but –as of today- they are often more expensive

- Figure from DNV GL study shows cost of technical alternatives in case of solar PV overcharge in distribution network, including
  - Grid extension
  - Peak cap
  - Battery storage
  - Supply management

Figure: Comparison of technological options for mitigation of over-feed-in



(PV overcherge: amount of produced power that exceeds the maximum grid capacity)

Figure refers to medium voltage CIGRE network in rural area of Switzerland, low storage costs (lithium ionium battery)

Source: DNV GL study (2015) on decentralized storage commis-sioned by Swiss Federal Energy Agency (BFE)

Thank you !

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