PBL Netherlands Environmental Assessment Agency

Capacity vs Energy Subsidies for Renewables: Benefits and costs for the 2030 EU Power Market?

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Outline

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Introduction

- The European Union set a binding renewable target for 2030
  - at least 27% share of renewable energy in total energy consumption (January, 2014)
  - revised to 32% (New renewable energy directive, December, 2018)
  - the electricity sector will continue to contribute a significant share
- Unlike 2020 targets, 2030 targets explicitly ruled out binding national RES targets.
  - Individual countries are putting in place national policies to achieve their own RES targets
  - How will Member States meet the overall target?
- Renewable support schemes: Capacity (MW) vs. energy (MWh) mechanisms
  - The goals of cost-effectiveness and promoting technology improvement
  - Is learning best achieved by producing energy (MWh) or by installing capacity (MW)?
    - If the latter then renewable portfolio standards (MWh) may be inefficient way to achieve goals

Research question:

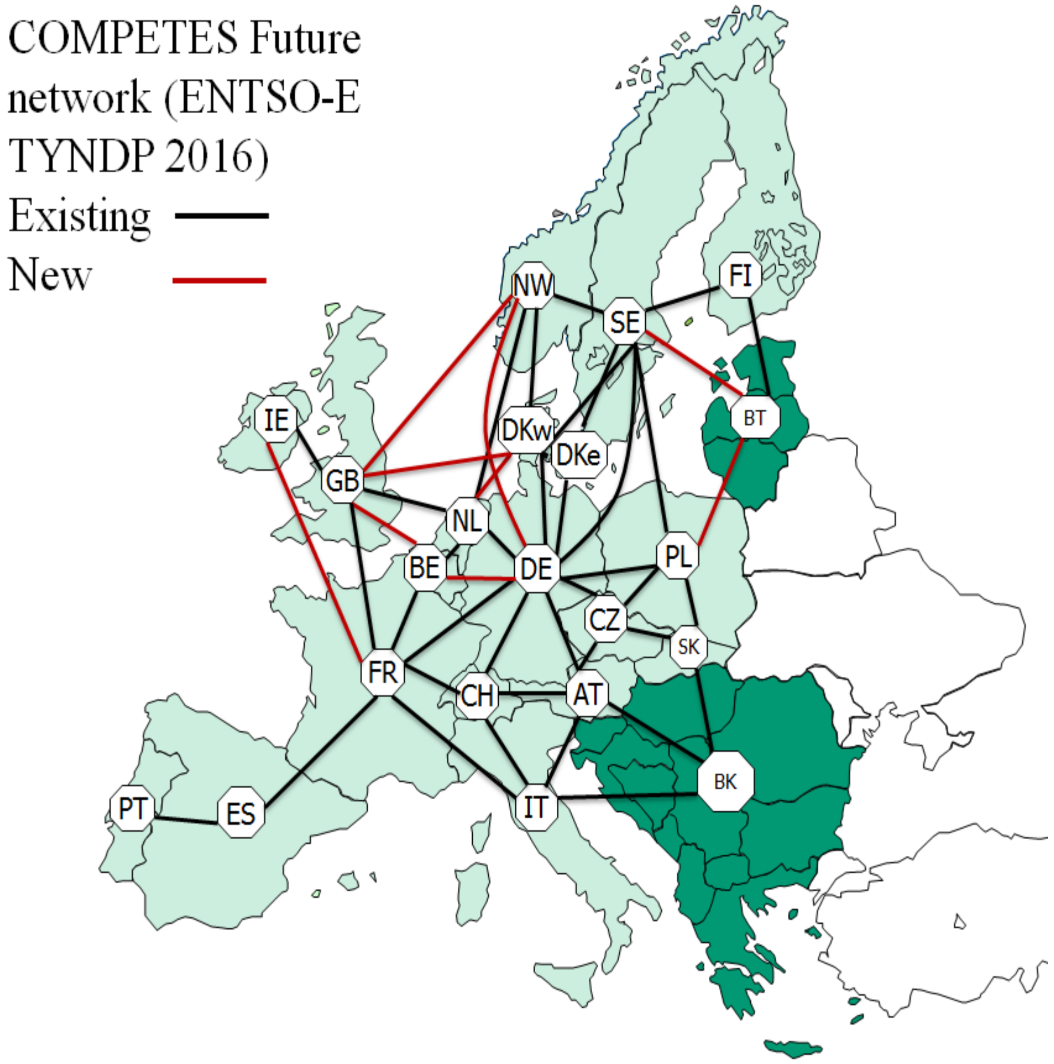
How do policies that subsidize renewable *energy* vs *capacity* impact the type and location of renewable investments, renewable share, electricity costs and the amount of subsidies in the EU power market?

- Energy subsidy: Renewable portfolio standards (RPS)
- Capacity subsidy: Capacity auction
- A mixed investment/output subsidy (Newbery et al., 2018)
  - MW auction
  - Payments made per MWh up to a maximum MWh/MW
- National vs EU-wide targets

METHODOLOGY

COMPETES Model

- COMPETES is a network constrained model of the European electricity market
  - 22 node pan-European network
- Transmission mimics integrated EU network limited by Net Transfer Capabilities
- Wide-range of RES and conventional generation technologies
- Hourly resolution per node
  - Hourly profiles of demand
  - Hourly profiles for wind, solar, and hydro



Model Structure (Ozdemir et al. 2019)

- Optimization Problem
  - *Minimize*

    Generation Investment Costs + Fixed and variable O&M Costs+ Fuel Costs+ CO_2 Costs +Load shedding costs

  Subject to:
    - Generation capacity constraints (by technology/unit)
    - Feasible investments (e.g., potentials for RES)
    - Variable wind/solar generation
    - Operation of storage (e.g., hydro pump storage, hydro availability within season)
    - Cross-border transmission flow limits
    - Electricity balance by country
    - Renewable MWh or MW target (EU-wide or by country)

- Solution (Perfect competition equilibrium)
  - (Dis)investments, electricity dispatch, flows, electricity prices, renewable subsidies

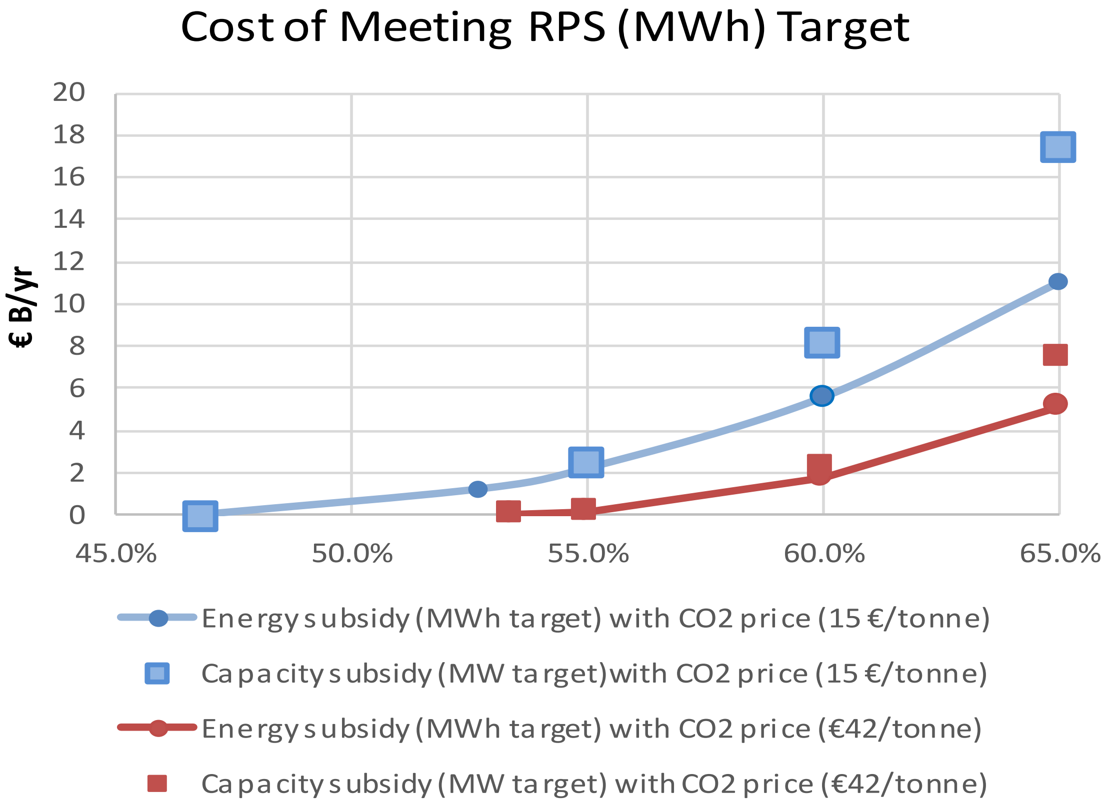
Assumptions for EU 2030

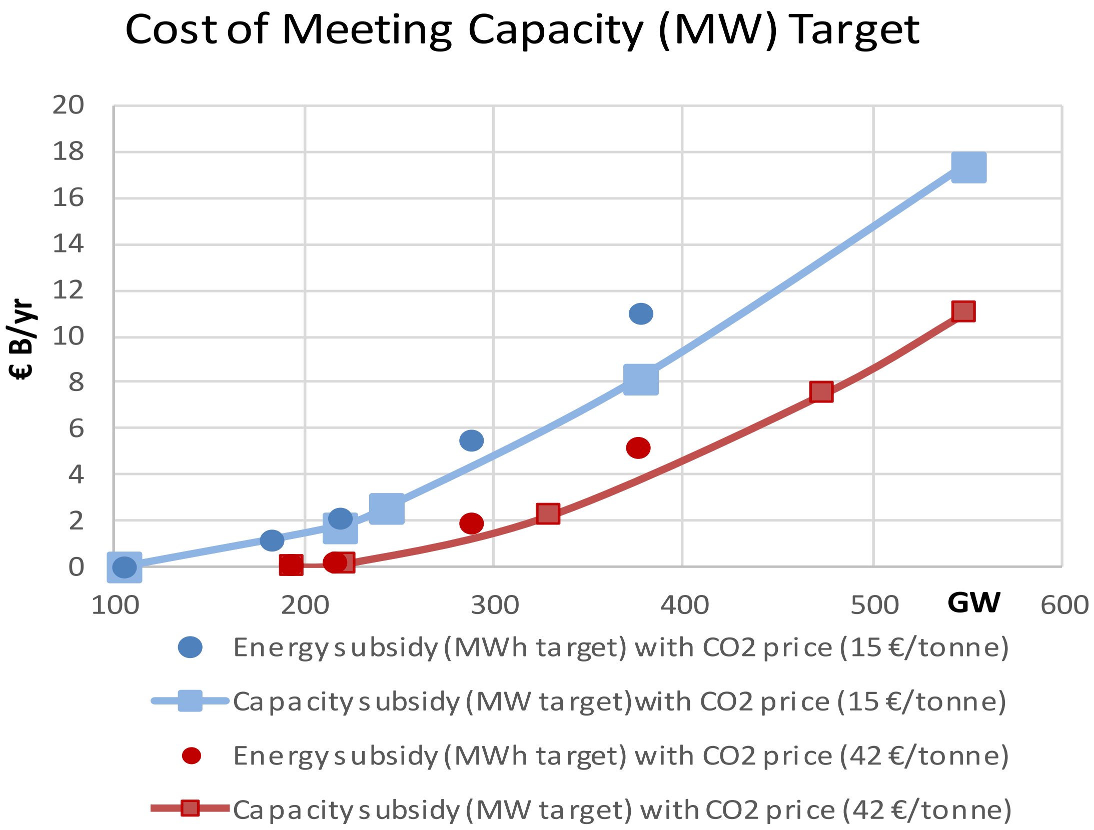
- Renewables:
  - Renewable policies EU+UK until 2020
  - Cost and potentials (PRIMES-2013, Green-x, Resolve-E)
- Conventional Generators
  - Fuel prices WEO 2016
  - ENTSO-E Mid-Term Adequacy scenario up to 2020
  - Policy-driven retirements
- Load
  - perfectly inelastic
  - ENTSO-E Vision 1, 2016
- Transmission
  - ENTSO-E TYNDP2016
- Load and VRE variability
  - 50 representative days of a year (1200 hours)
  - Sampled from 8 years of data from Gorm et al., 2015

RES support policy scenarios		CO_2 price €/tonne	Target variations
EU-wide policy and targets	Baseline (No subsidy)	• *15 vs. 42*	• *No target*
	Energy subsidy (RPS)	• *15 vs. 42*	• *Energy target up to 65%* • *Technology neutral vs. tech specific*
	Capacity subsidy (Capacity auction)	• *15 vs. 42*	• *Capacity target up to 550 GW* • *Technology neutral vs. tech specific*
	The mixed investment/output subsidy	• *15 vs. 42*	• *MWh/MW target achieving up to 65%*
National targets	Country specific targets	• *15*	• Based on *renewable capacities in 2030 reported by ENTSO-E's Sustainable Transition (ST) scenario (ENTSO-E, 2018).*

RESULTS

Incremental Costs of meeting MWh vs. MW targets





- *Energy-based subsidy:* the cost-effective way to reach a certain Mwh target
- *Capacity-based subsidy:* the cost-effective way of reaching a certain capacity level
- *The mixed investment/output subsidy:* falls between these two cases as it has characteristics of both capacity and energy policies
- *Higher carbon price*
  - motivates a greater penetration of renewables without the need for subsidies
  - the inefficiency resulting from choosing one type of policy to meet a different type of goal is diminished.

Capacity installed under MWh vs MW targets

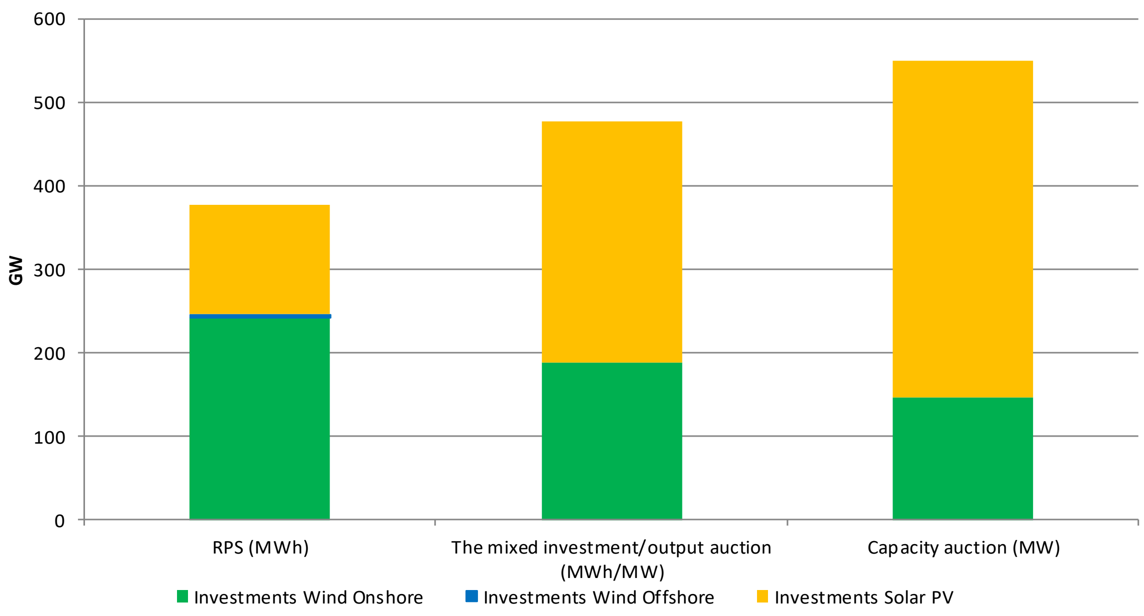
- *An energy-based subs*idy boosts technologies with higher capacity factors (e.g., wind)

- *A capacity-based subsidy* boosts technologies with lower investment costs (e.g., solar PV)

- *The mixed investment/output subsidy* falls in between

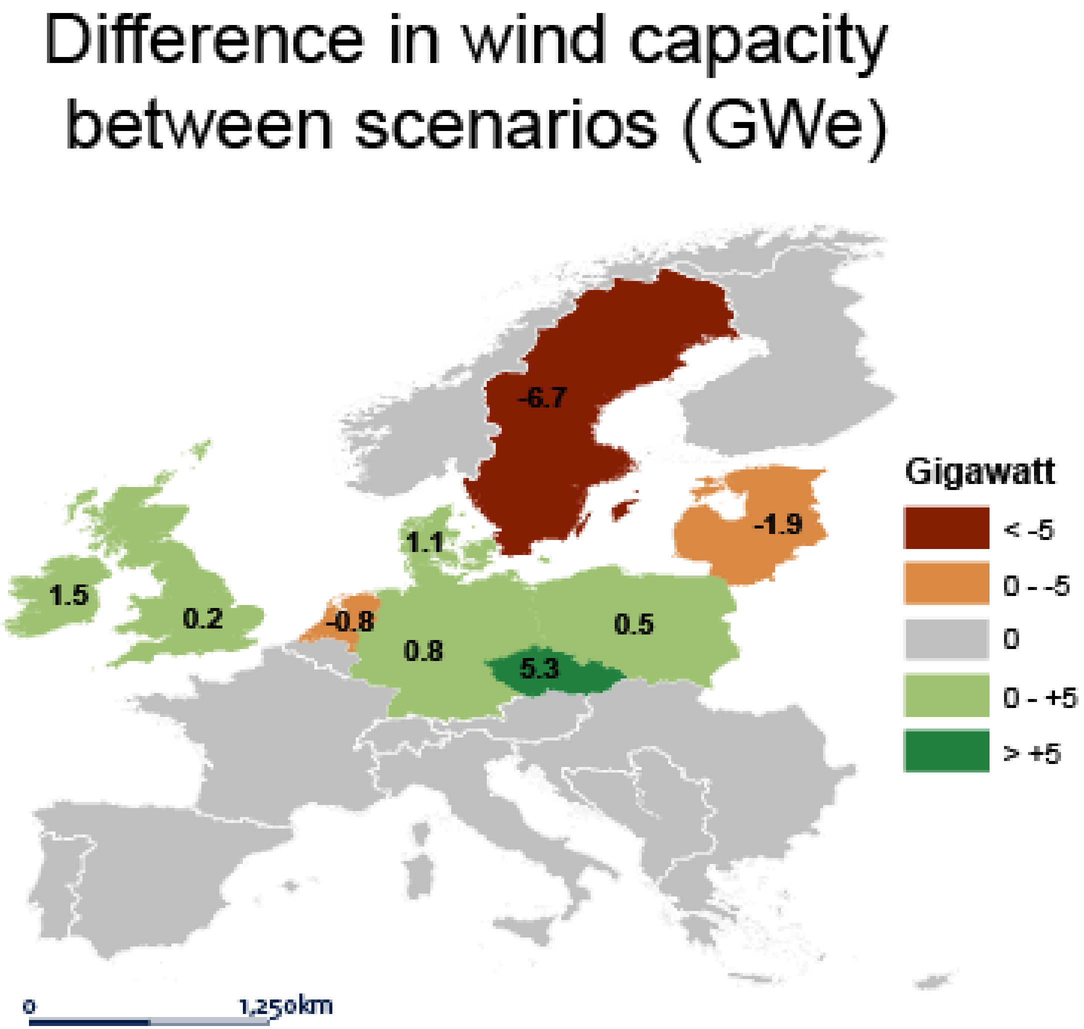
- Trade-off:
    - A capacity-based subsidy is a more expensive way to achieve an implicit energy goal
    - But in exchange for that added expense, much more capacity might be built and more learning achieved
    - ***Ex for 65% renewable share:*** 46% more total renewable investments with capacity subsidy compared to an RPS while increasing the cost of the incremental renewables by 50%.

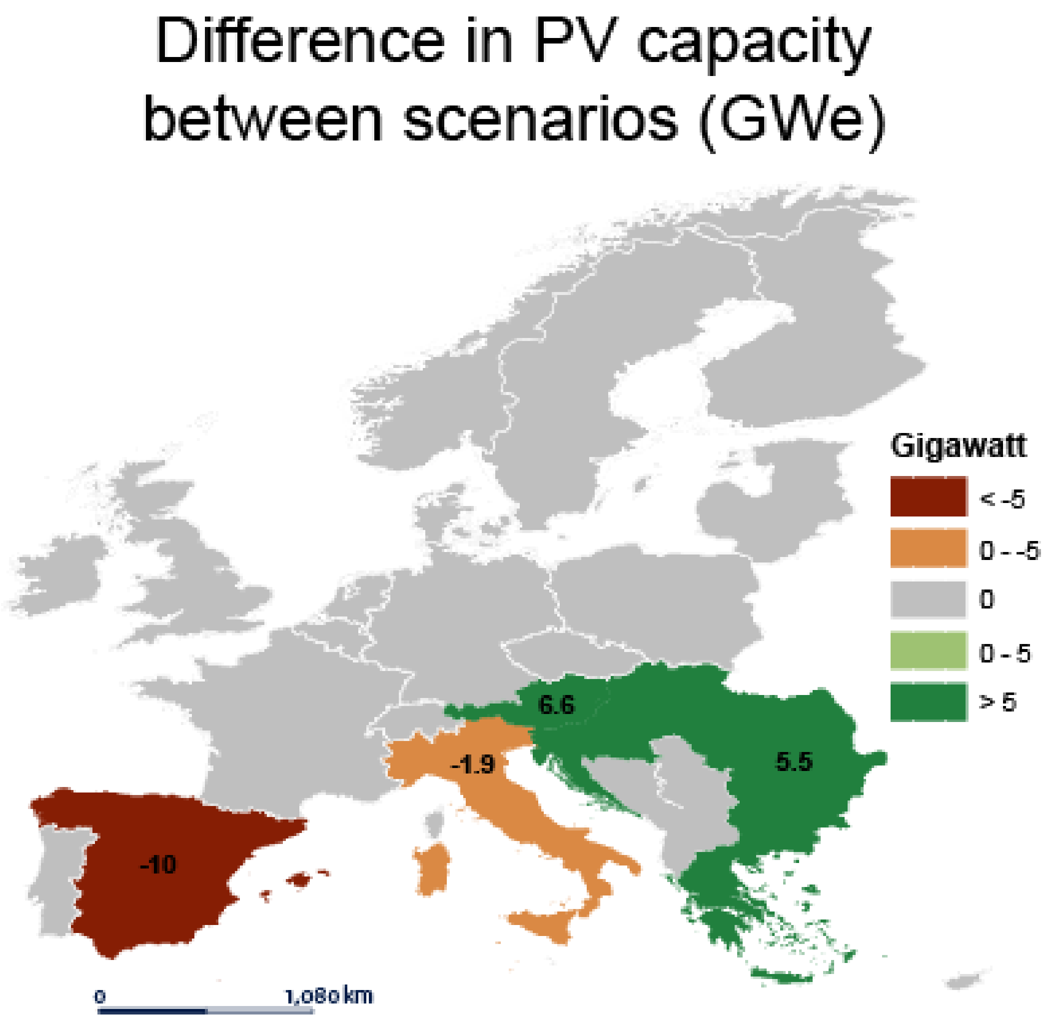
Incremental investments compared to base case: wind and solar under energy and capacity-focused subsidies achieving 65% renewable share: Technology neutral case



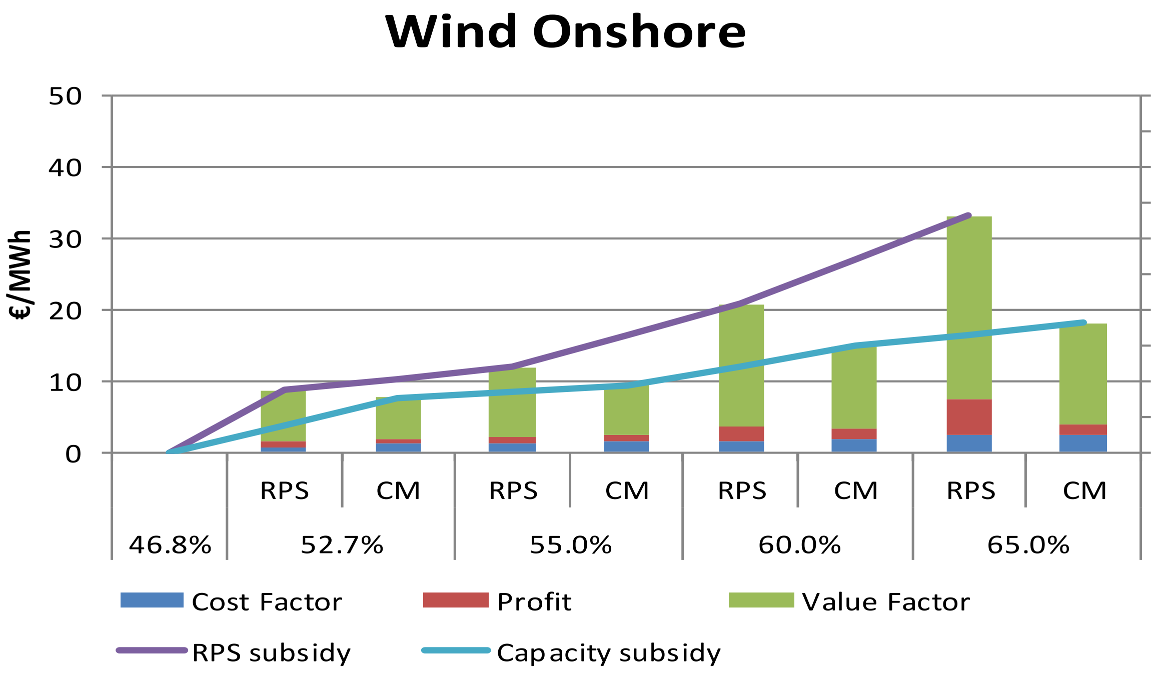
Locational Impact under MWh vs MW targets

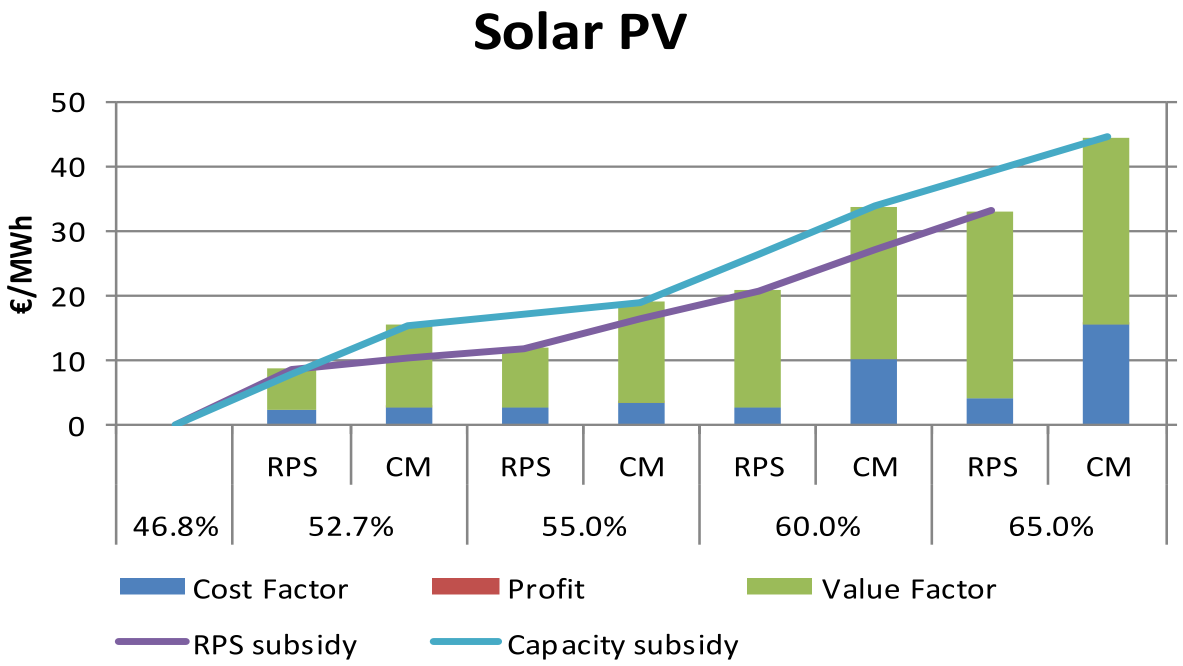
- Consider MW of On-S, Off-S Wind and Solar based on 65% RPS. Then instead use capacity auction to get those same MW





Where Does the Subsidy Go?





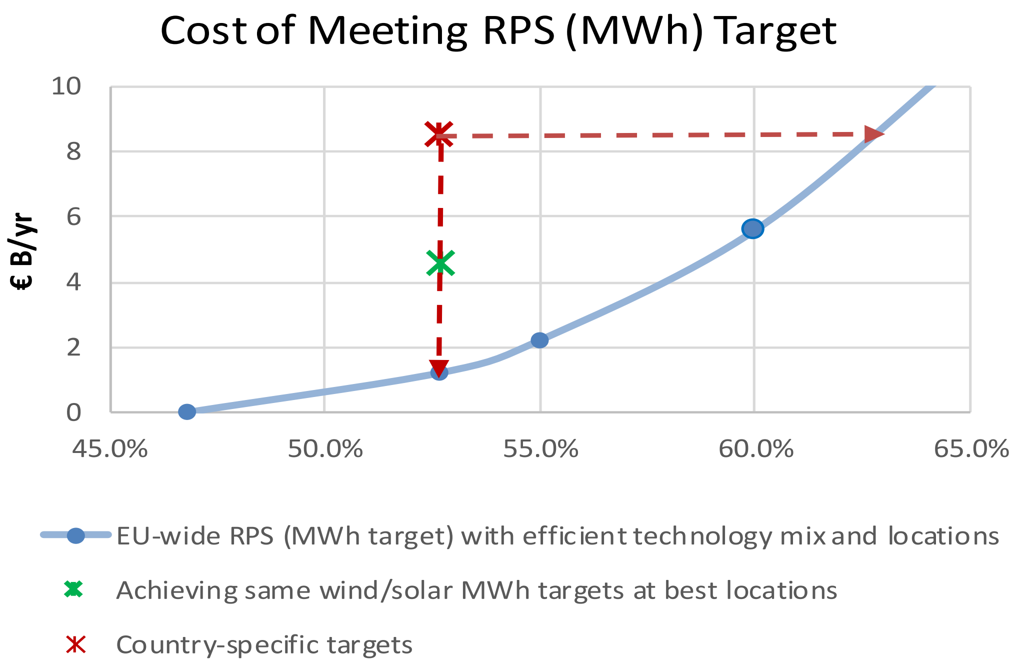
- Wind receives higher subsidy under energy-based policy than capacity-based policy while the reverse is the case for solar PV
- Under both cases, the subsidy rises as renewable targets increase, and is mostly devoted to compensating for the decreasing market value of the renewables

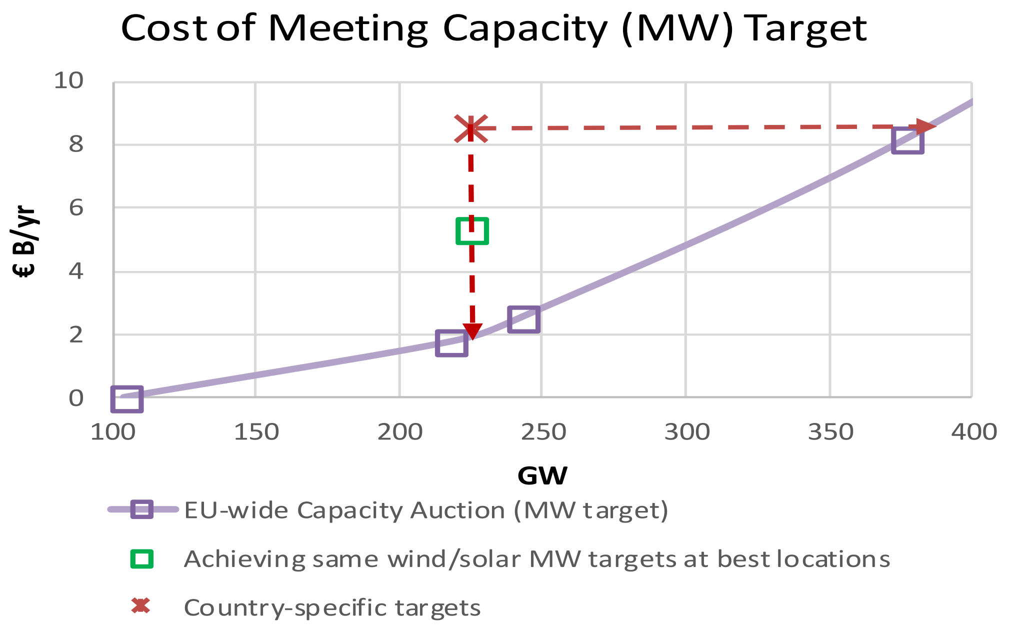
No REC trade: Country vs EU-wide targets

- Country targets: ENTSO-E's 2030 "Sustainable Transition"
  - 52.7% renewable share
  - 225 GW of new renewable capacity investments

- The incremental cost of country specific targets is 8.5B€/yr
  - *seven* times higher than the cost of achieving the same renewable share by EU-wide RPS
  - *four* times higher than the cost of achieving the same total renewable capacity by EU-wide capacity auction

- Half of the inefficiency is due to the wrong mix of technologies, and half is due to the wrong locations





Conclusions

- Trade-off between capacity vs energy subsidy mechanisms
  - To reach a certain share of renewable energy, it is more cost-effective to use an energy subsidy
  - To promote technology improvement through capacity installation, capacity subsidy mechanisms are more cost-effective
- Sensitivity of the results
  - The differences between capacity and energy subsidies increase with more ambitious targets
  - The differences decrease if targets are technology specific (i.e., wind onshore, offshore, solar)
  - The differences decrease with higher CO2 price
- The subsidy rises with more ambitious targets and is mostly devoted to compensating for the decreasing market value of the renewables
- The country-specific targets without renewable energy credit trading greatly increase the cost of renewable policies
  - Both the choice of technologies and locations are equally to blame for the cost increase resulting from country targets
  - The efficiency gains by setting an EU-wide target and REC trade is likely to be much higher than the choice between capacity vs. energy subsidies

References

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- Özdemir, Ö., Hobbs B.F., van Hout, M., Koutstaal, P., 2019. Capacity vs energy subsidies for renewables: Benefits and costs for the 2030 EU power market. Cambridge Working paper in Economics 1927, Energy Policy Group, University of Cambridge, UK. https://www.eprg.group.cam.ac.uk/wp-content/uploads/2019/03/1911-Text.pdf

Thank you for your attention!
Any questions?

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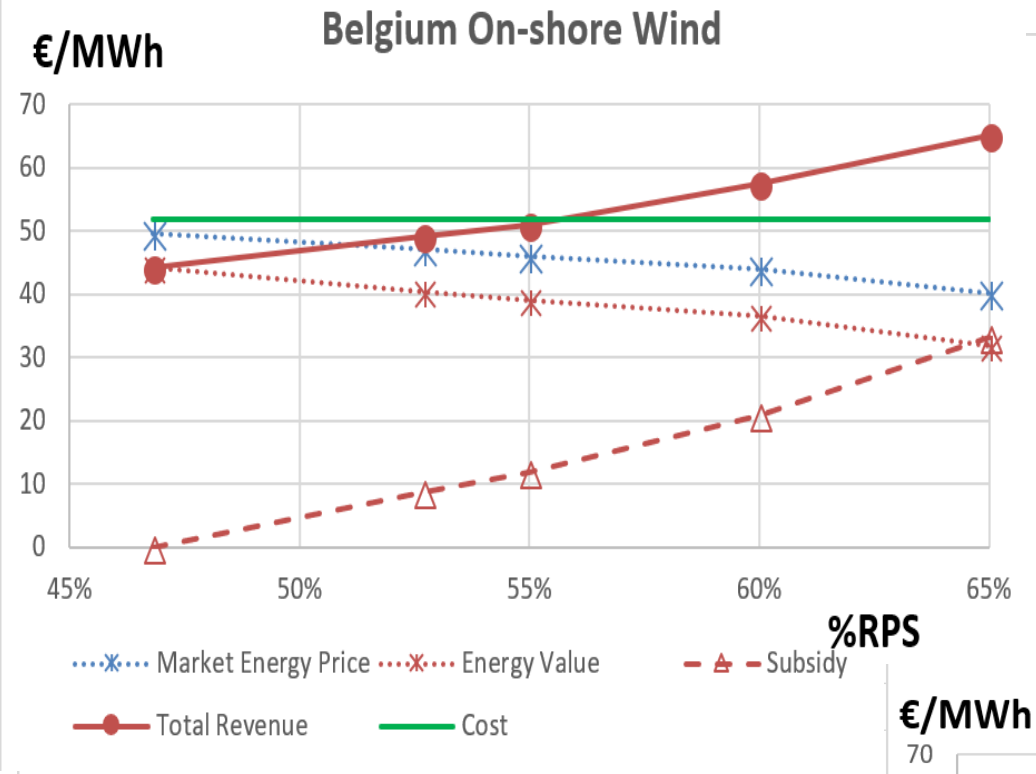
Model Structure (Ozdemir et al., IEEE TPWRS, 2016; Hobbs et al., IEEE TPWRS, 2004)

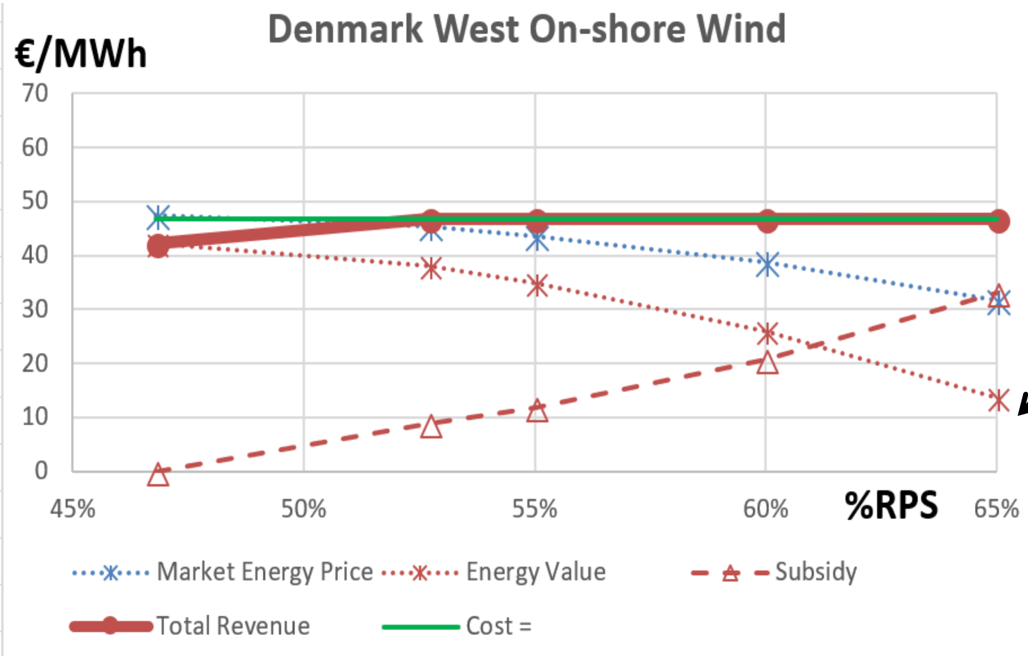
Equilibrium problem:
KKTs of parties' problems + Market clearing

- Equilibrium problem:
  - ***Generators:***
    - *Maximize* (Energy + Net Renewable Credit) – (Investment + Fuel + CO_2 Costs)
    - *Subject to:* Capacity constraints; variable wind/solar; storage operations, hydro availability within season; feasible investments
  - ***Transmission:***
    - *Maximize* Arbitrage revenues
    - *S.t.:* Transmission flow limits
  - ***Consumers:***
    - *Maximize* Consumer surplus (if demand elastic)
  - ***Market clearing:***
    - Energy balance by country
    - Renewable MWh or MW credits
- Solution
  - Solve equilibrium problem (MCP) via PATH (Dirkse, Ferris, 1995)
  - Or solve equivalent optimization problem (Samuelson, AER 1952):
    - *Maximize* (Value of Consumption – Cost of generation)
    - *S.t.* Generator, transmission constraints; market clearing
    - KKTs equivalent to equilibrium problem

Revenue vs. Cost



Mild decrease/discrepancy in energy prices



…Strong decrease/discrepancy in energy prices