The Milligan School on Cost Causation

25.5.2021
EERA/ESIG Joint Webinar:
Towards a Common Understanding of Energy System Costs

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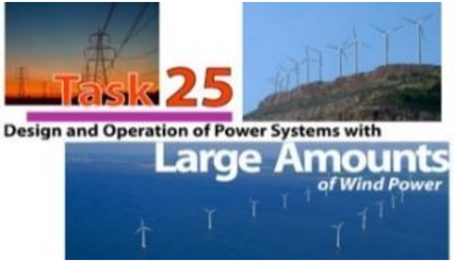
Sources of inspiration

- Michael Milligan et. al
  - E.g. Michael Milligan, Erik Ela, Bri-Mathias Hodge, Brendan Kirby, Debra Lew, Charlton Clark, Jennifer DeCesaro, Kevin Lynn. “Integration of Variable Generation, Cost-Causation, and Integration Costs”, The Electricity Journal, Volume 24, Issue 9, 2011, Pages 51-63
- Lennart Söder
  - Upcoming report: System and integration costs – Definitions and analysis
- Discussions with many others (e.g. IEA Wind Task 25)
- Own ponderings
  - E.g. Sampo Soimakallio, Juha Kiviluoma, Laura Saikku. “The complexity and challenges of determining GHG (greenhouse gas) emissions from grid electricity consumption and conservation in LCA (life cycle assessment) – A methodological review”, Energy, Volume 36, Issue 12, 2011, Pages 6705-6713.



First remarks about integration cost

- Typical interpretation: An additional cost that should be added when comparing e.g. generation technologies
  - LCOE + Integ. Cost
- May include
  - 'profile costs'
    - Compare scenarios: technology vs. without technology
      - Flat-block or load profile or alternative technology
      - Rest of the system may stay constant or be optimized
  - 'balancing / reserve costs' – if not endogenous, then add from literature
  - 'grid costs' – same thing
- Danger of double counting

A very simple case study

- No investments
- Power and heat – both single node
- Only ‘profile cost’
- Comparing operational costs of different scenario runs
  - Against ‘flat block generator’ with zero O&M cost
- Using IRENA FlexTool

- The absolute values are not the point – they are driven by assumptions as always

IRENA FlexTool

https://www.irena.org/energytransition/Energy-System-Models-and-Data/IRENA-FlexTool

Base scenario: 10 TWh electricity load
10 TWh heat load

Profiles from Finland
Interest rate 8%

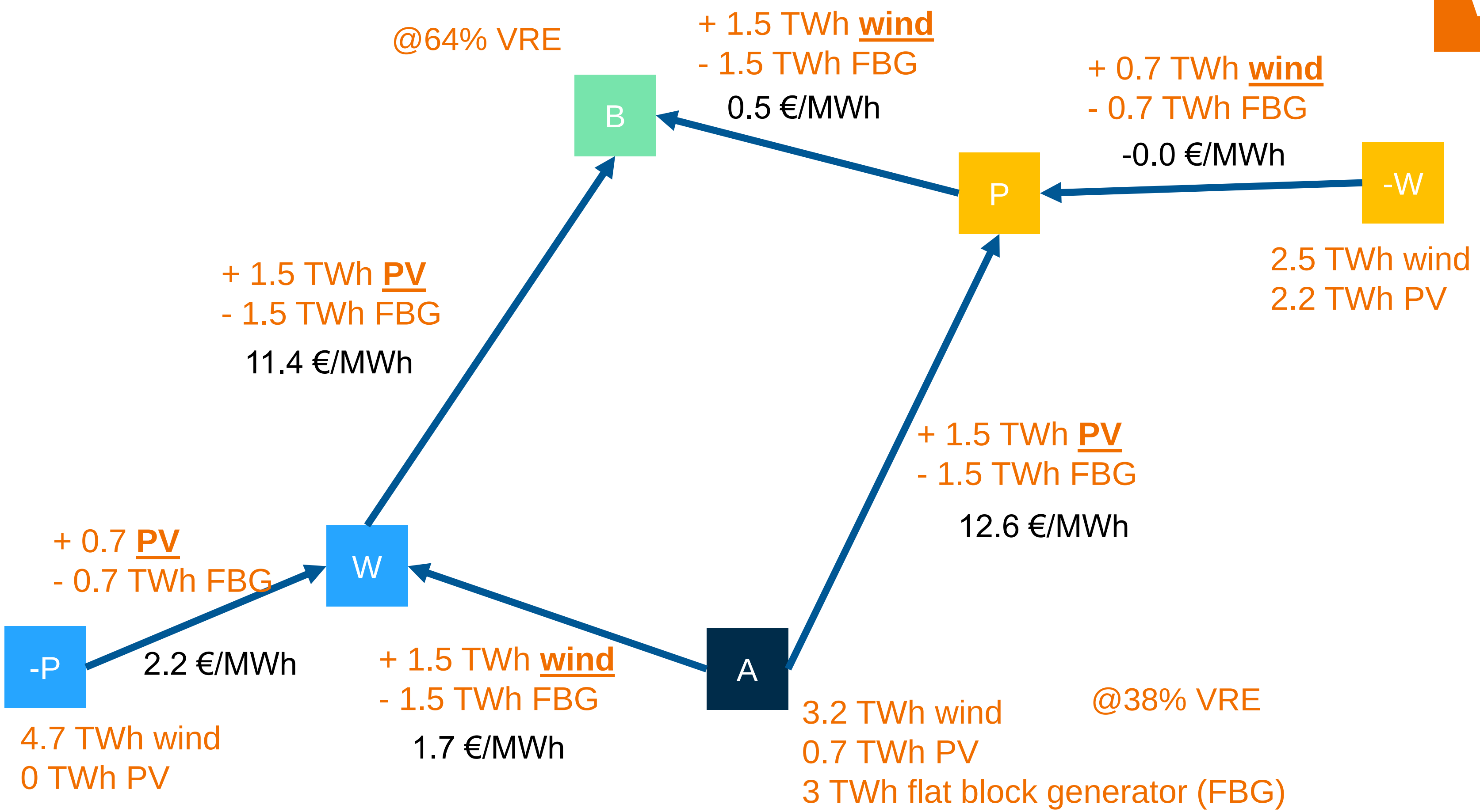
VTT

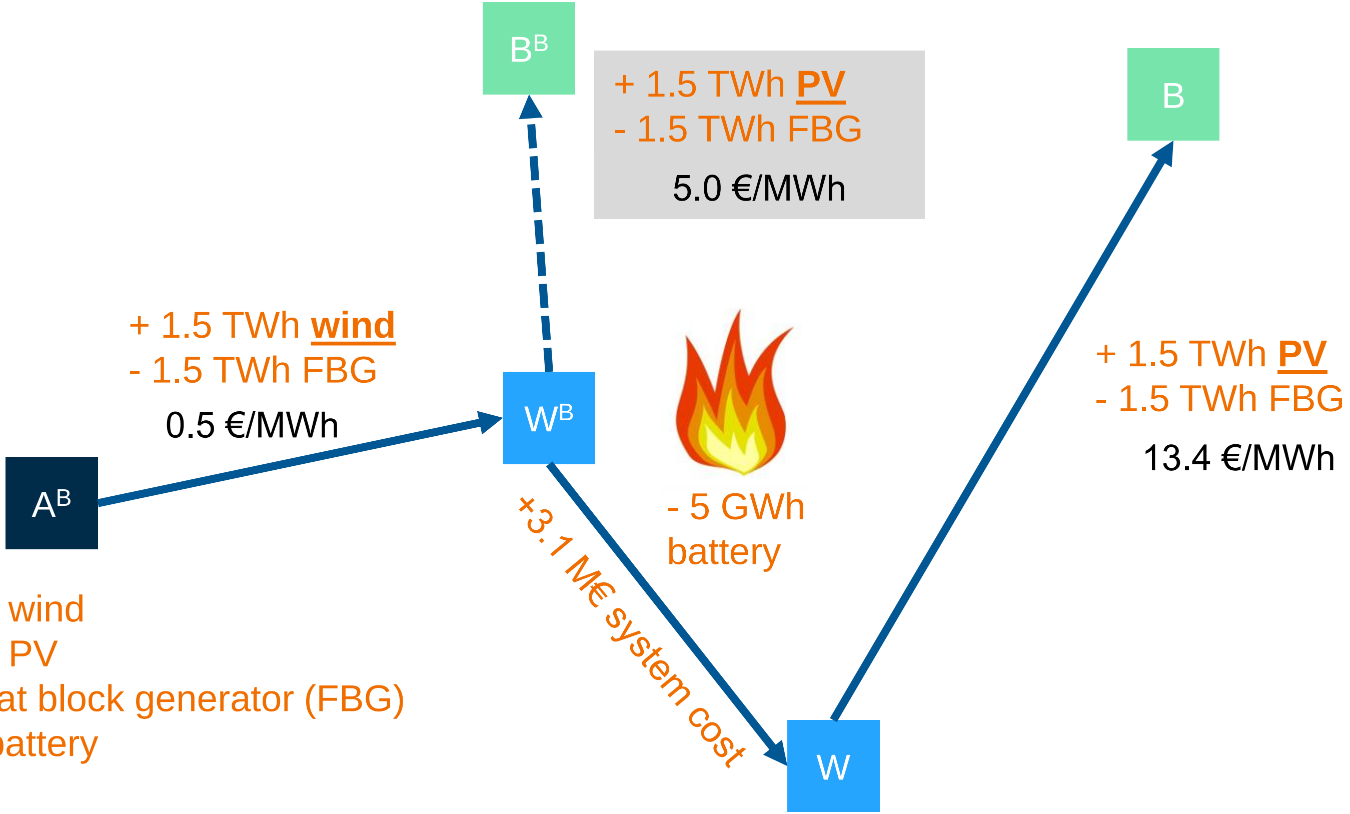
	MW	var. cost / cf / eff	Inv. cost (€/kW)	Lifetime
Cond. coal	500	37.5 €/MWh	2000	40
Gas engine	1000	41.1 €/MWh	600	35
Wind	1000	CF: 0.38	1200	20
PV	1701.7	CF: 0.11	400	30
Battery	0	Eff: 81%	70[x]	10
Oil boiler	1500	24.6 €/MWh	300	30
Heat pump	500	COP: 1 – 3.5	700	40
Heat storage	0	Eff: 98%	10[x]	40

[x] Investment cost as €/kWh

‘Integration cost’ is system dependent

- 10 TWh electricity demand
- Existing: ~3.2 TWh wind, ~0.7 TWh PV (before curtailment)
- Add ~1.5 TWh PV
- Without battery in the system
  - PV ‘profile cost’: 12.6 €/MWh (against flat block generator)
- With battery (500 MW, 10 hour battery)
  - PV ‘profile cost’: 5.0 €/MWh (against flat block generator)


@64% VRE
B
+ 1.5 TWh wind
- 1.5 TWh FBG
0.5 €/MWh
+ 0.7 TWh wind
- 0.7 TWh FBG
-0.0 €/MWh
P
-W
2.5 TWh wind
2.2 TWh PV
+ 1.5 TWh PV
- 1.5 TWh FBG
11.4 €/MWh
+ 1.5 TWh PV
- 1.5 TWh FBG
12.6 €/MWh
+ 0.7 PV
- 0.7 TWh FBG
W
-P
2.2 €/MWh
+ 1.5 TWh wind
- 1.5 TWh FBG
1.7 €/MWh
A
4.7 TWh wind
0 TWh PV
3.2 TWh wind
0.7 TWh PV
3 TWh flat block generator (FBG)
@38% VRE

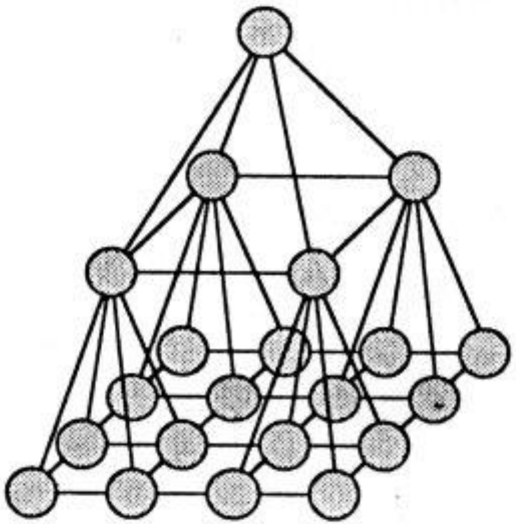


3.2 TWh wind
0.7 TWh PV
3 TWh flat block generator (FBG)
5 GWh battery

Who is to blame (attribute)?

- The previously built wind?
- The next to be built PV plant? (It's 5 kW)
- A highly variable load?

Fair attribution is not possible



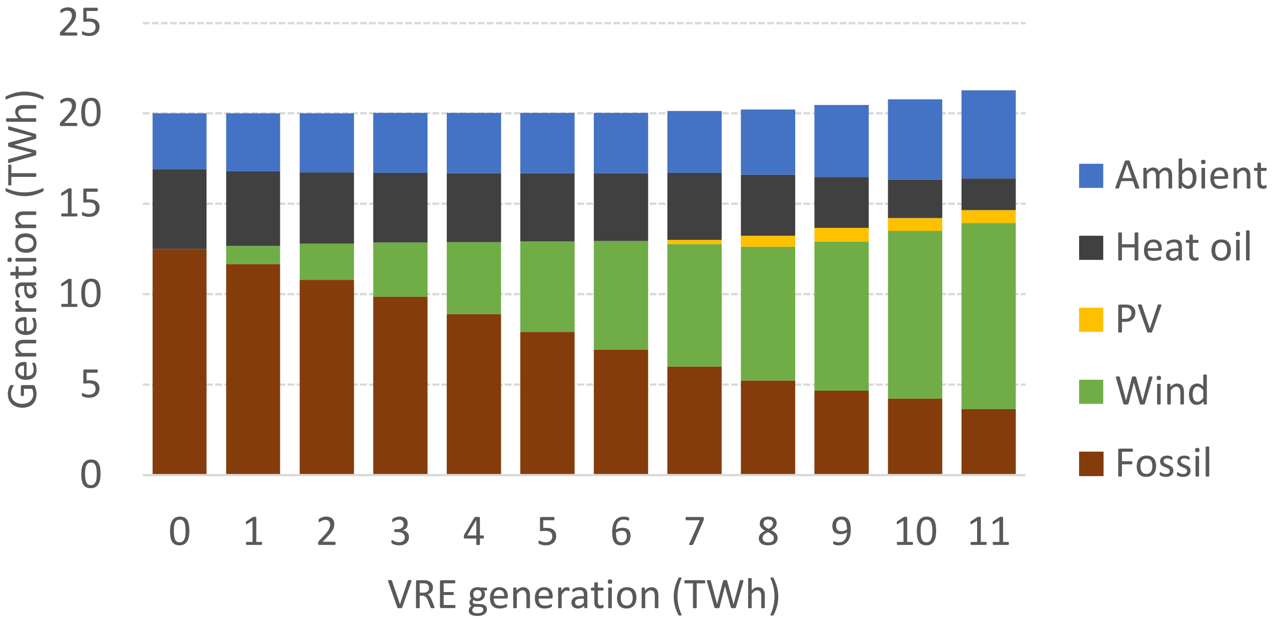
Da-Ren Chen, Chiun-Chieh Hus, “Fault-tolerant routing for pyramid networks using the least level minimal routing method”, January 2003, Computer Systems Science and Engineering 18(1):35-44.

- It is a system of dependencies
- Multiple changes that accrue over time cannot be fairly attributed into any single change
- Not even if it is the latest one
  - As changes stack on top of it, it’s contribution/attribution is not clear
  - …and it wasn’t clear in the first place

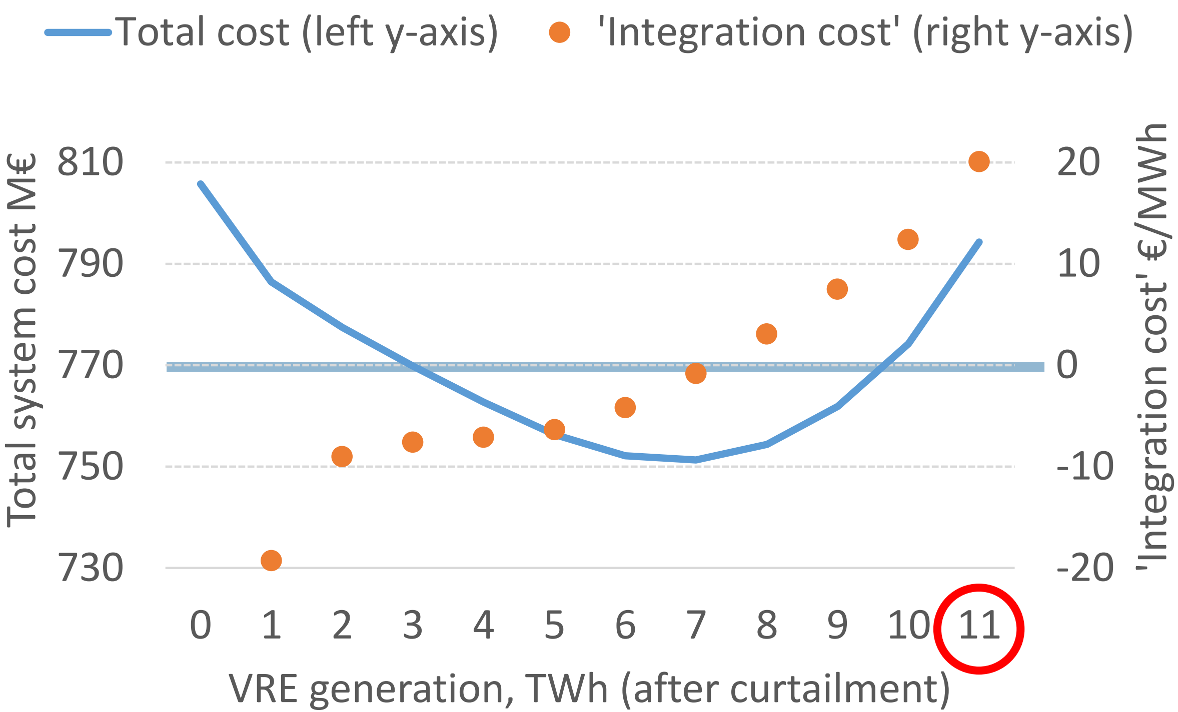
Simple case study with investments

- Previous assumptions
- Force X amount of VRE in TWh (after curtailments)
- Integration cost: Total system cost before - total system cost after
- Again, the system is 10 TWh electricity and 10 TWh heat

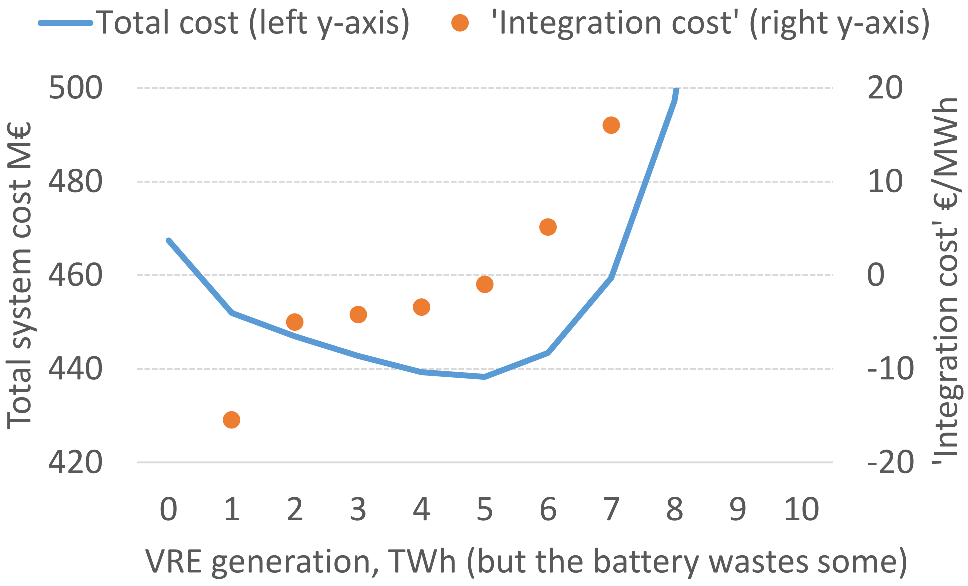
Simple case study with investments

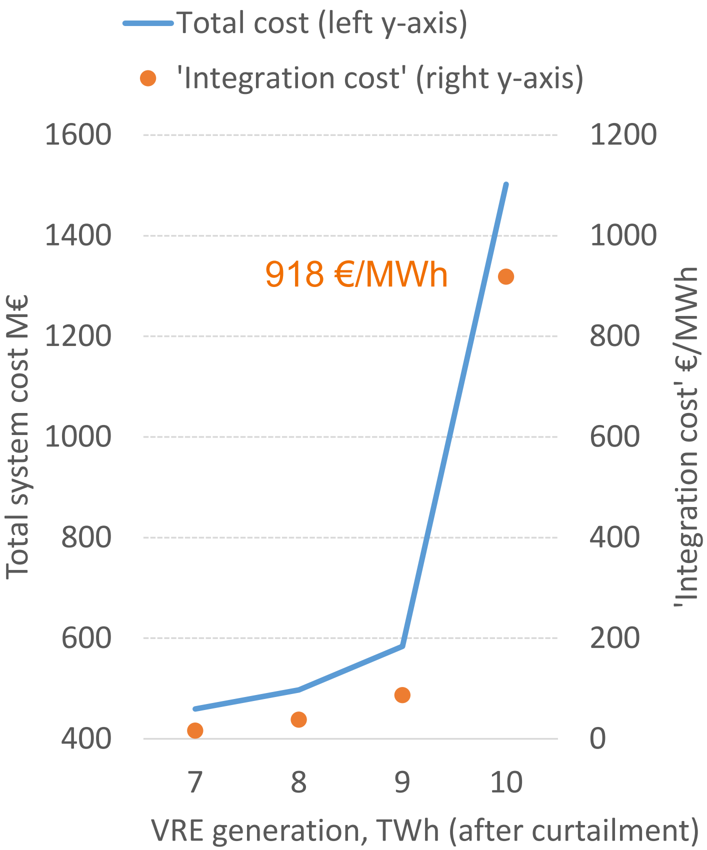


Simple case study with investments

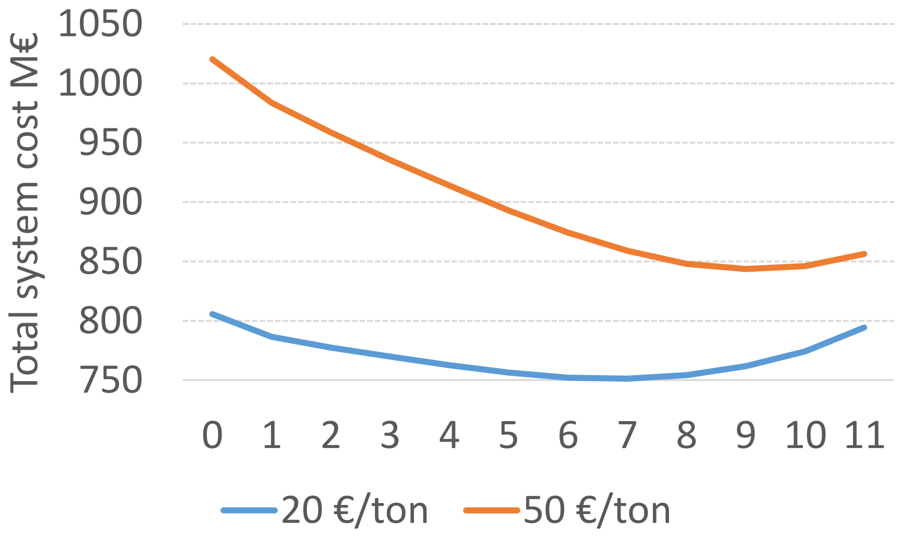


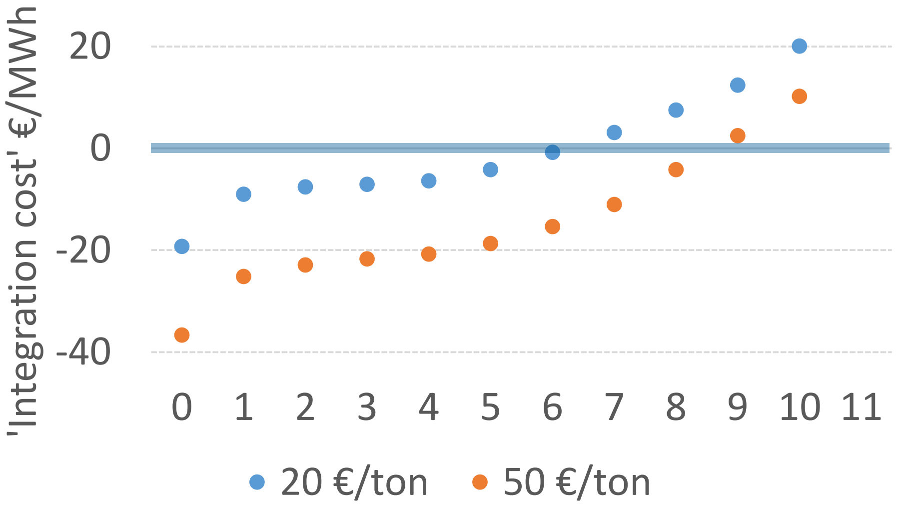
Without the heat sector





From 20 €/tCO_2 to 50 €/tCO_2





Total system cost

- Is not misleading
- The audience can immediately understand that the whole system matters
- Directs the attention to finding cost-effective solutions for fulfilling objectives (e.g. emission reductions) at least cost
  - Improve markets, transmission, flexibility, sector coupling,…
  - Analyzing the particular system
- Discuss the assumptions, modelling methodology, etc.
  - Is the sector coupling considered
  - Is VRE allowed to provide reserves
  - How many years were considered
  - …

Further comments

- Some costs are not covered by the modelling methods
  - Some ancillary service and balancing costs (especially intra-period)
  - Some grid costs
  - …
  - These should be evaluated for the system in question to ensure that the total system cost comparison is fair
- LCOE depends on the full load hours – it’s also a system property
- Market price evaluation considers short term only (no information about investment cost differences). Also has an attribution problem.

What I really want to say

- Let's focus on the important and interesting stuff
  - Finding least cost solutions for future energy systems
  - How to include operational detail in the planning problem
  - What are the solutions for operating inverter based power systems
  - Including the other energy sectors with sufficient detail
  - Using sufficient geographical scope and resolution
  - While considering different kinds of uncertainty
  - …and still being able to run the models
- Working on these:
  - Spine Toolbox is an open source software to manage data and workflows for modelling (Documentation)
  - SpineOpt is a Julia-based open source energy system modelling framework capable of planning and scheduling energy and power systems with high level of temporal, spatial and technological adaptability (Documentation)

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beyond
the obvious

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