A young child with light hair, wearing a blue jacket, is crouching on a large, smooth rock in a body of water. The child is looking down at something in the water. In the background, a line of wind turbines stretches across the horizon under a clear blue sky. The water is calm, reflecting the sky and the turbines.

Variationshantering i elsystemet med 100 % förnybart

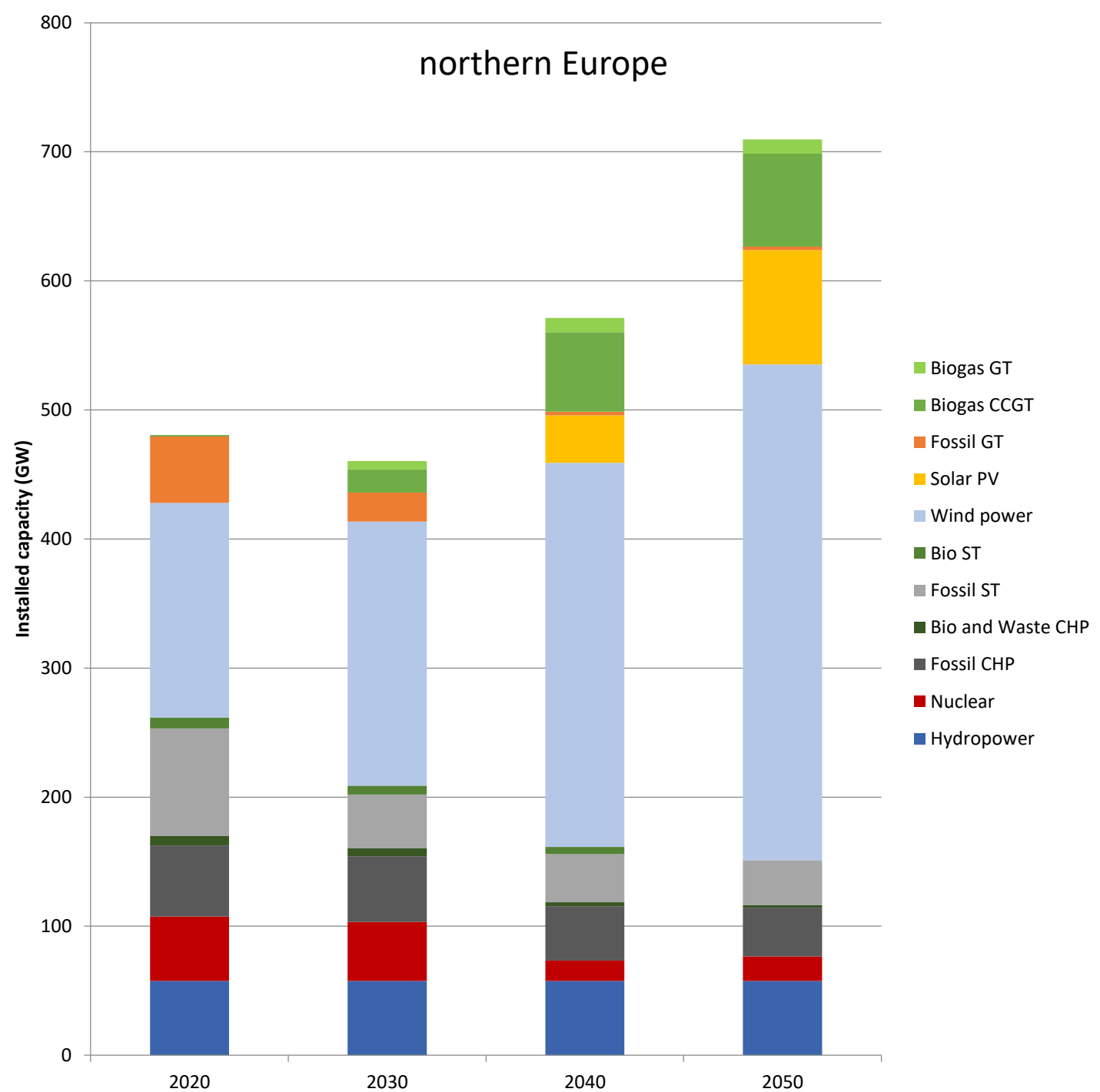
Lisa Göransson, Chalmers

I korthet

- Variationshantering banar väg för mer vindkraft
 - Reducerar behovet av resursbegränsad biomassa
 - Vindkraft + VMS kan vara billigare än alternativen
- Olika variationshantering för olika systemkontext
- Nät för variationshantering
 - Öppnar upp för tillgång till variationshanteringsåtgärder
 - Geografiska utjämnings effekter

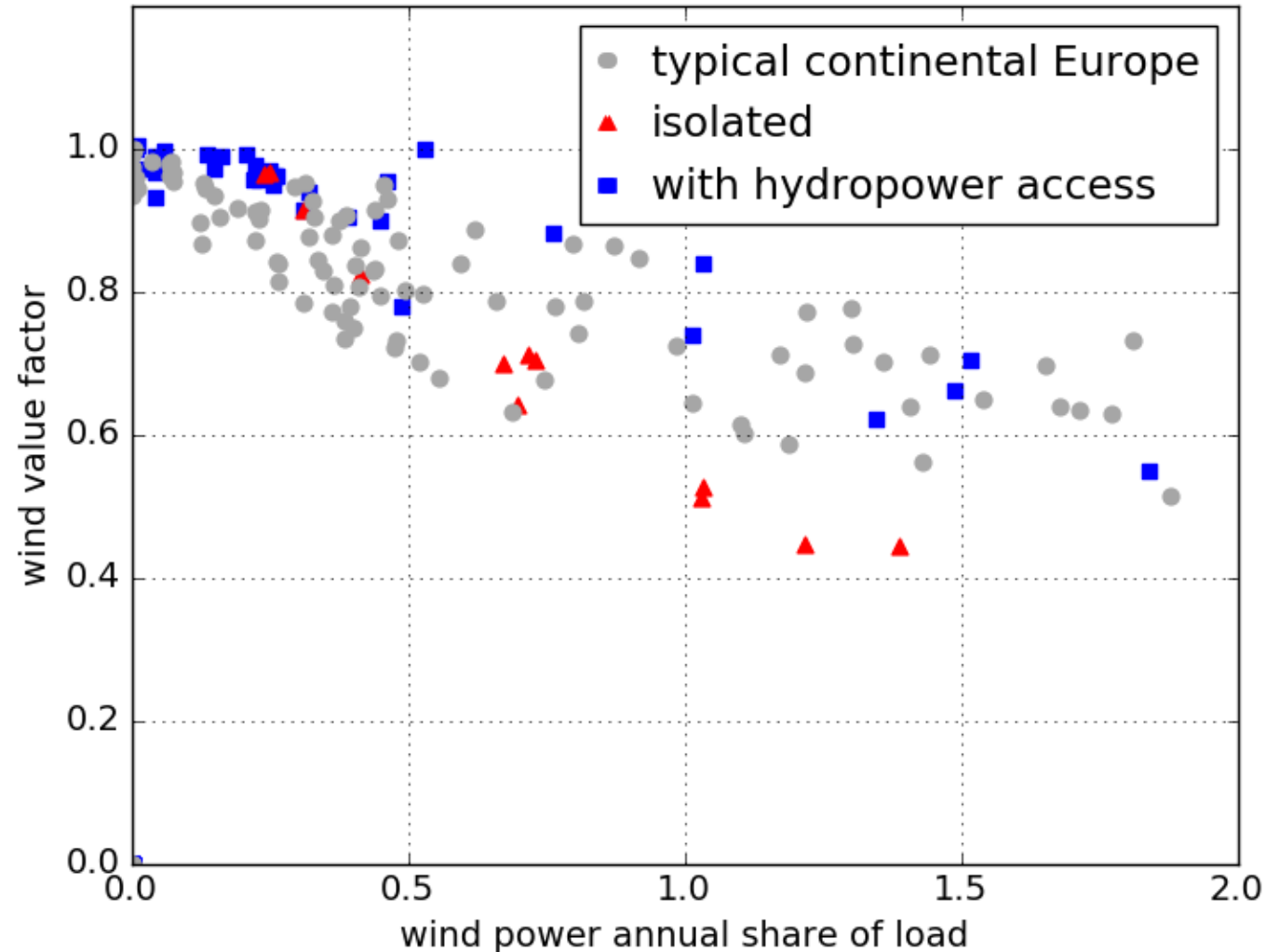


Wind power is a low cost option for CO₂ free electricity in northern Europe



The value of wind power

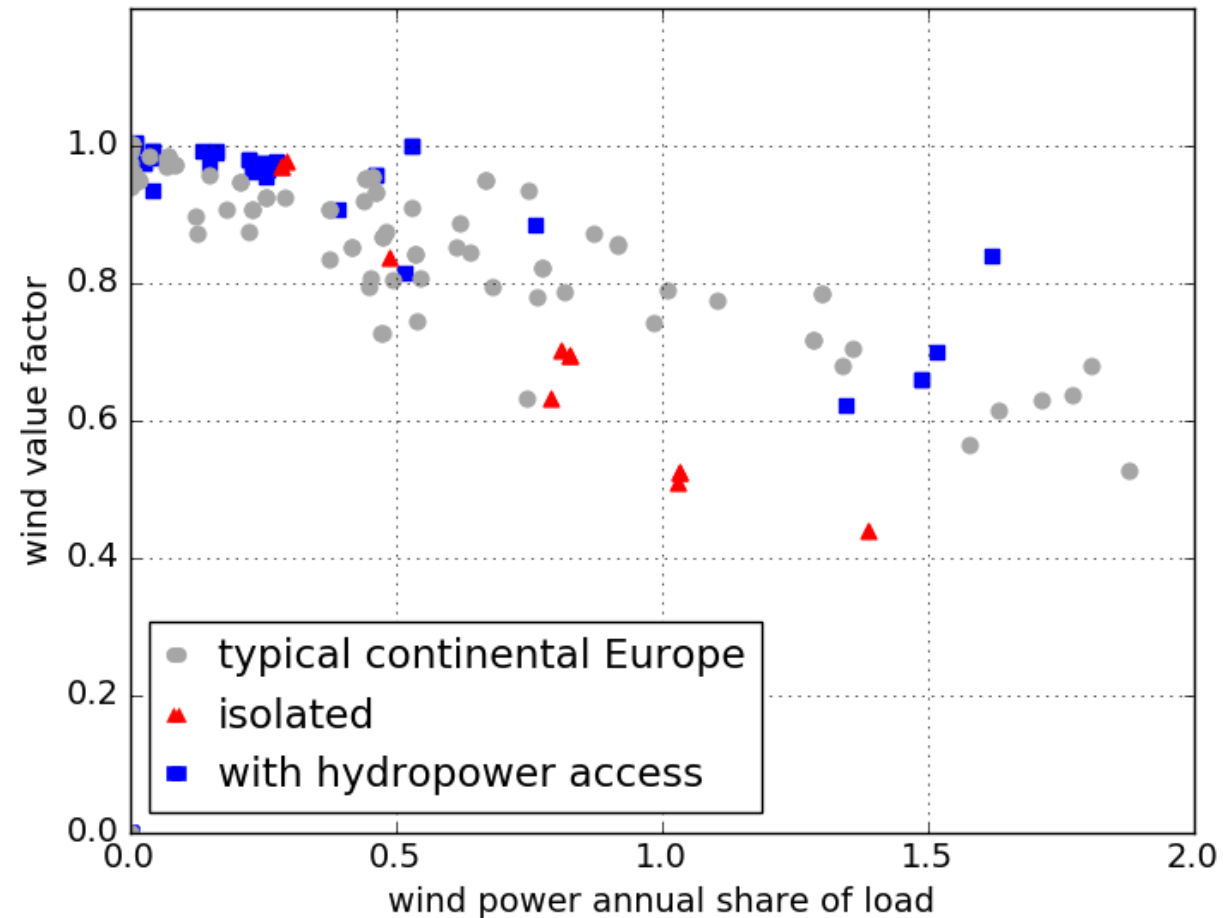
- Penetration level vRE
- System composition
 - Access to hydropower / complements
 - Presence of inflexible generation
- Ability to trade
- Technology design
 - Specific power of wind turbines



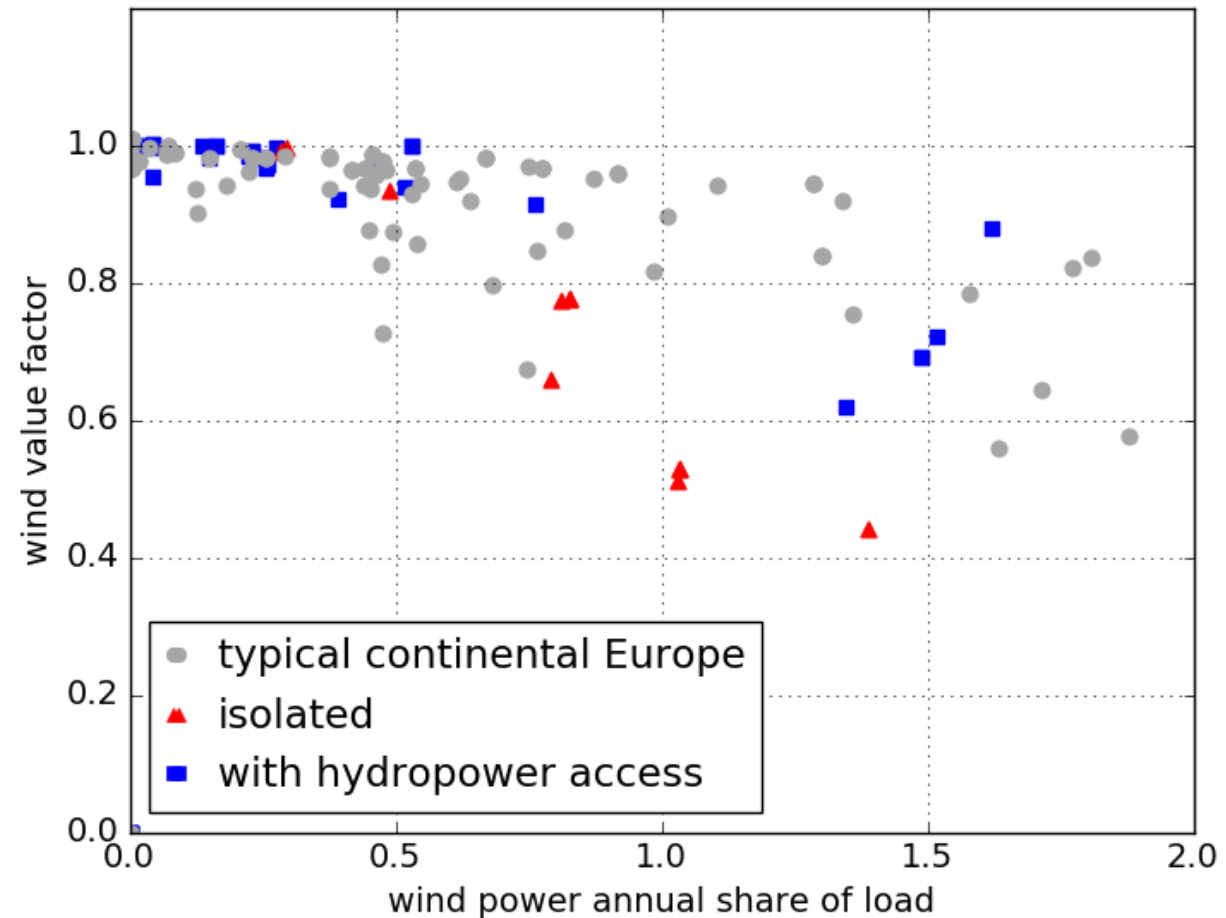
Source: Göransson and Johnsson, 2018

Variation management increase the system value of wind power

Without hydrogen storage



With 7 day hydrogen storage



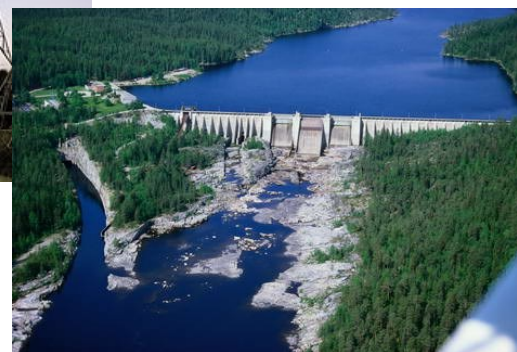
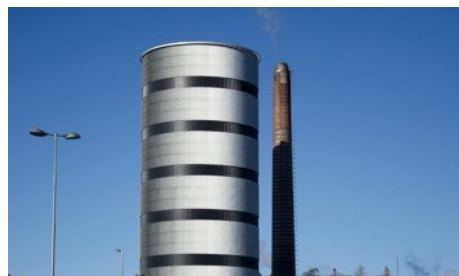
Vi behöver alla!



Den här löser allt!



TESV
STORAGE

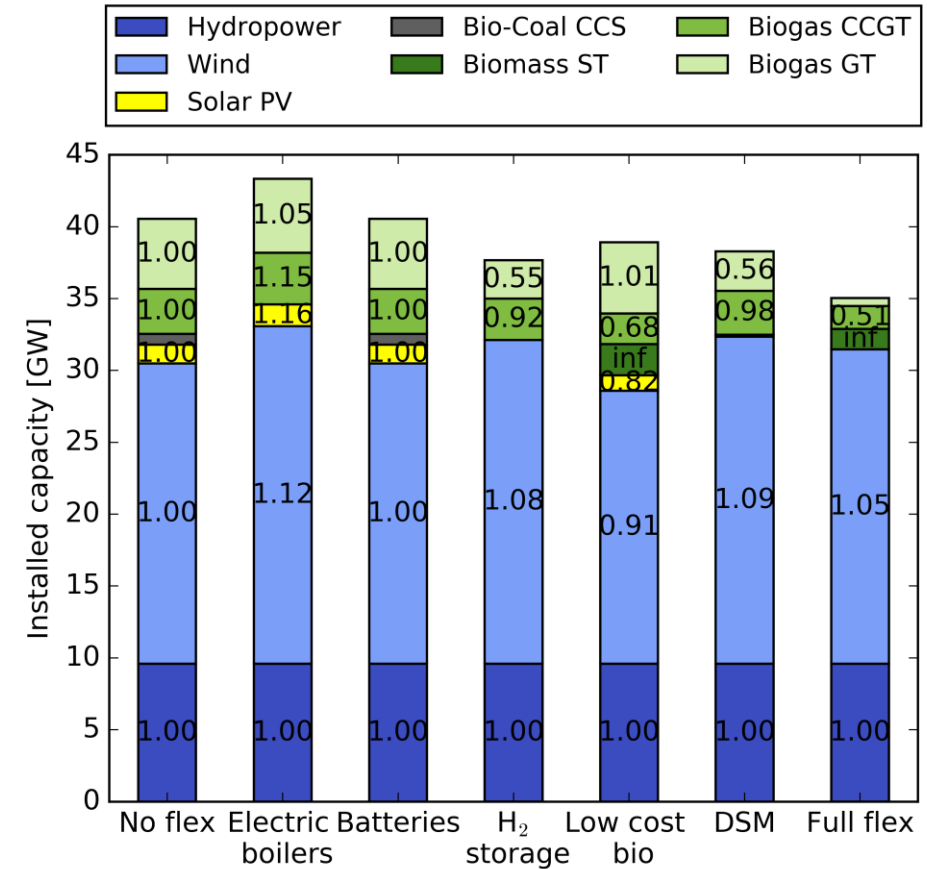
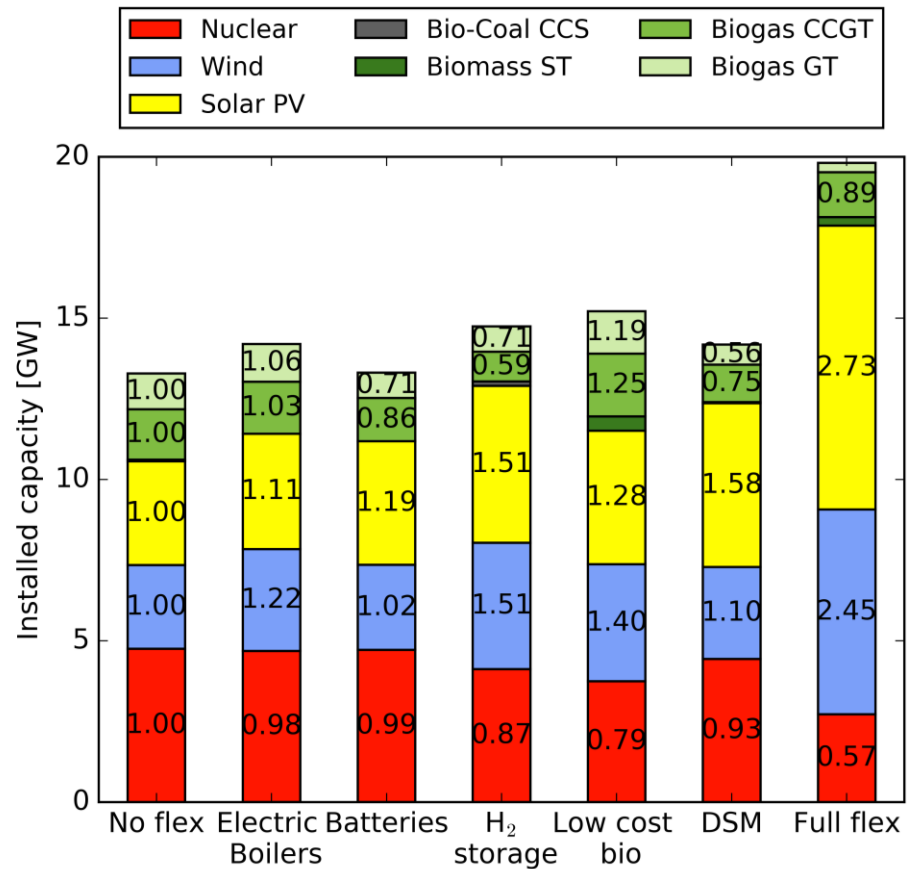


Shifting	Absorbing	Complementing
<p>Electricity ⇒ Electricity</p> <ul style="list-style-type: none"> • Reduce curtailment and peak power • More even costs on diurnal basis 	<p>Electricity ⇒ Fuel and heat</p> <ul style="list-style-type: none"> • Reduce curtailment • Fewer low cost events 	<p>Fuel ⇒ Electricity</p> <ul style="list-style-type: none"> • Reduce peak power • More even costs on yearly basis
Batteries	Power-to-heat	Flexible thermal generation
Load shifting	Electrofuels	Reservoir hydropower
Pumped hydro	Power-to-gas (hydrogen)	

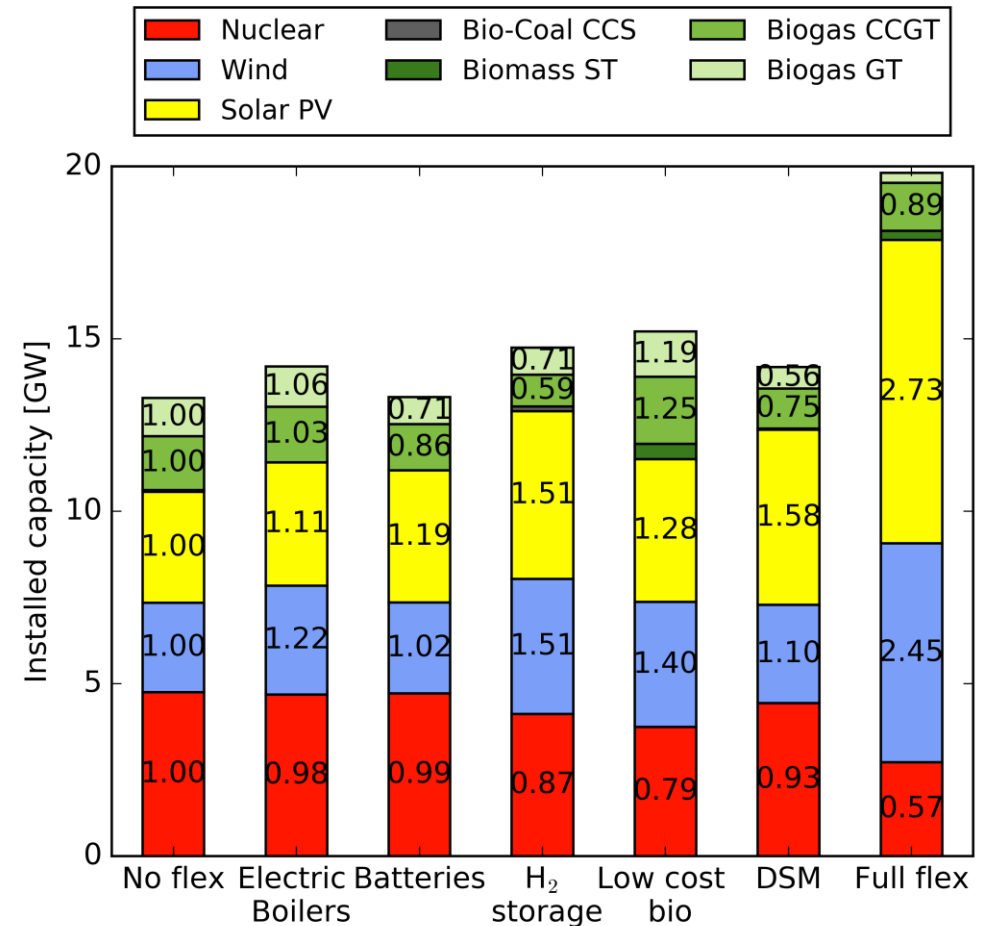


VMS impact cost-optimal investments in all types of generation

- DSM reduce need for peak generation the most
- Hydrogen storage increase wind investments the most
- Base load investments are consistently reduced



- Impact of VMS depends on vRE cost-competitiveness
 - Absorbing or shaping strategies for system limited solar
 - Absorbing strategies for system limited wind
 - Complementing strategies for resource limited wind
 - No strategies for resource limited solar
- There are synergies between VMS in different category
 - In the case of resource limited wind power and at least decent solar conditions.



Different VMS at different geographical levels



**Shifting –DSM
Shifting -Batteries**

Absorbing –District heating

**Absorbing -Hydrogen storage
Complementing -Hydropower**

Shifting -Geographical smoothening

I korthet

- Absorberande strategier viktigast i system med goda vindtillgångar
 - Koppling mellan sektorer
 - Samverkan: vätgaslager, DSM, vattenkraft
- Vindvariationer hanteras effektivast på central nivå
 - Kan behövas nätutbyggnad för tillgång till kompletterande och absorberande strategier



lisa.goransson@chalmers.se