

In 16 min, you'll know:

- Why the Q provision problem accelerates system transformation
- How 24/7 Q could contribute to making it safe & efficient, even in MV
- What we could do to make it happen

Efficient concertation of reactive power (Q) resources

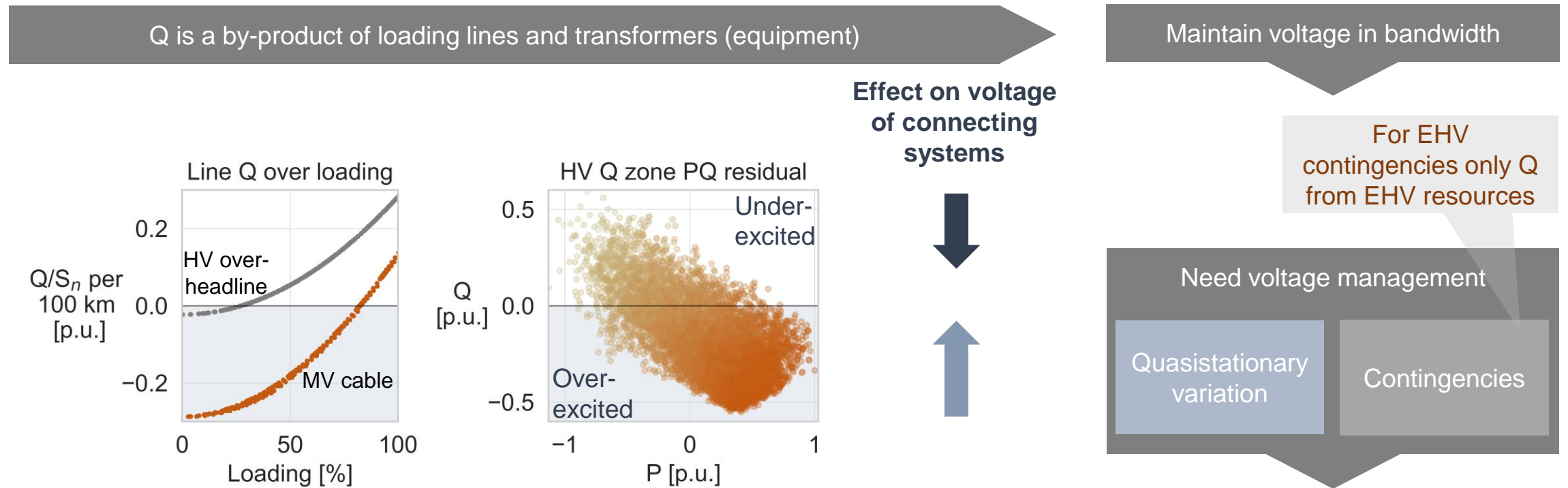
Overview of potential, solutions and requirements for leveraging 24/7 reliable capacity

Focus on MV

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Q (reactive power) in AC power systems

System transformation → Increase equipment loading → Quadratic increase in Q requirement



Need Q resources electrically close to requirement

Support between voltage levels possible within small ranges: Contain Q exchange & Q transport

Operational Q flexibility gap: MV Q resources could contribute to reducing it

Unprecedented Q requirement ▶ Reliable CO2 friendly operational flexibility wanted for quasistationary purposes

Network planning does by concept not cater for operational flexibility

Today last resort e. g.: voltage related redispatch at EHV level

Relevant flexibility magnitudes**) can be obtained when going down to NL 5

Requirement scen 2035 B NEP v 2019

From transient analyses (MUST from EHV resources)

45 – 69 Gvar

From quasistationary analyses

Overexcited	Underexcited
11 - 31 Gvar	4 - 15 Gvar
22 – 28 Gvar controllable	

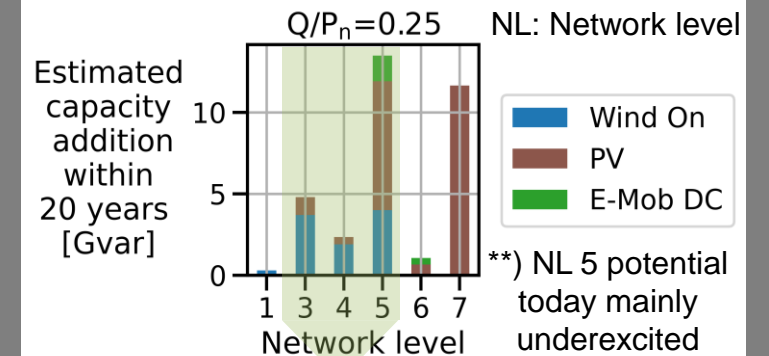
**In total only for EHV:
277 to 478 Q compensators
@ 300 Mvar**

- CO2 intensive

- Inefficient at times of negative market prices

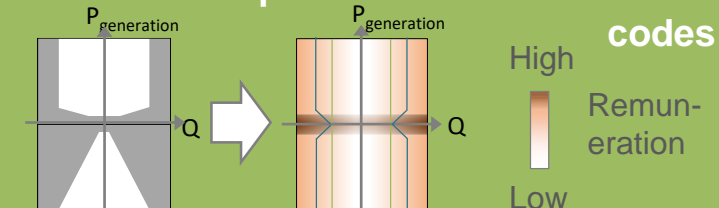


Wanted: Increase in operational flexibility that reflects increase in expected challenges & uncertainty



**Imaginable from MV & HV
5 to 10 Gvar 24/7 Q in 2035**

Standardize optional 24/7 in connection codes



Leverage Q potential and 24/7 Q capability at ~ 0 CAPEX

A growing number of Q resources can provide **24/7 Q on demand at negligible added CAPEX**

Resource OPEX is competitive, mostly at low utilization frequencies
→ Consider OPEX in dispatch

From TSO perspective, perceivable benefit is not likely to start before 2030
Even if some TSOs might have completed their addition of underexcited capacity till then:

Design requirement

(Limited) reliable Q flexibility to EHV is possible (see today EU SysFlex; see Kämpf 2014)
by joint contingency constrained optimization of EHV/HV tap positions and Q resources:
E. g. 100 Mvar overexcited Q from NL 3 and NL 4 in a constrained real EHV/HV system

Offer standardized remuneration solutions → Leverage potential

**No regret option:
No call, no cost!**

Chance: Increased resilience & flexibility on distribution level

If needed, also to EHV in limited amount & utilization frequency

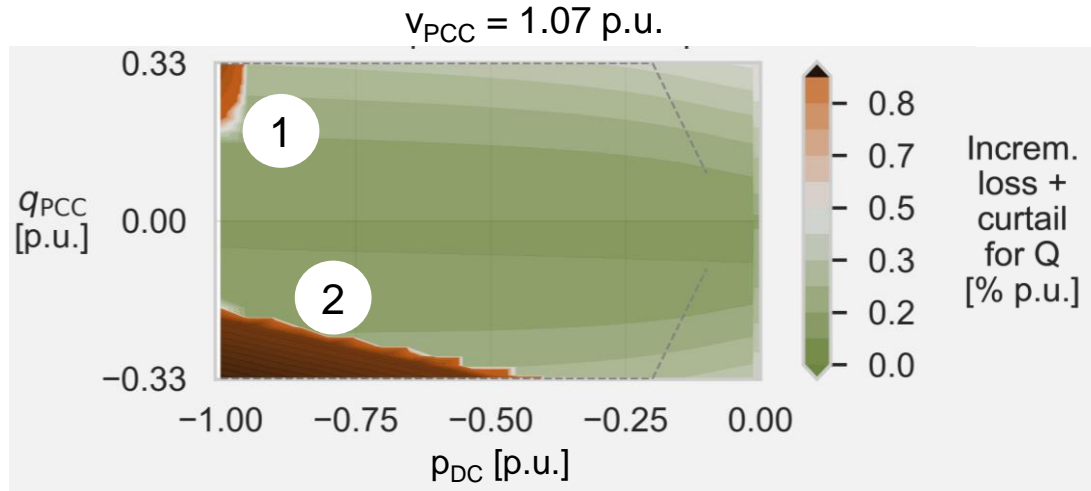
EnWG § 12 h (Dec 2020): To be developed mechanisms
 "...must ensure that ... no curtailment of feed-in from privileged electricity is caused by market-based procurement"

How to deal with MV Q resources that curtail P for Q

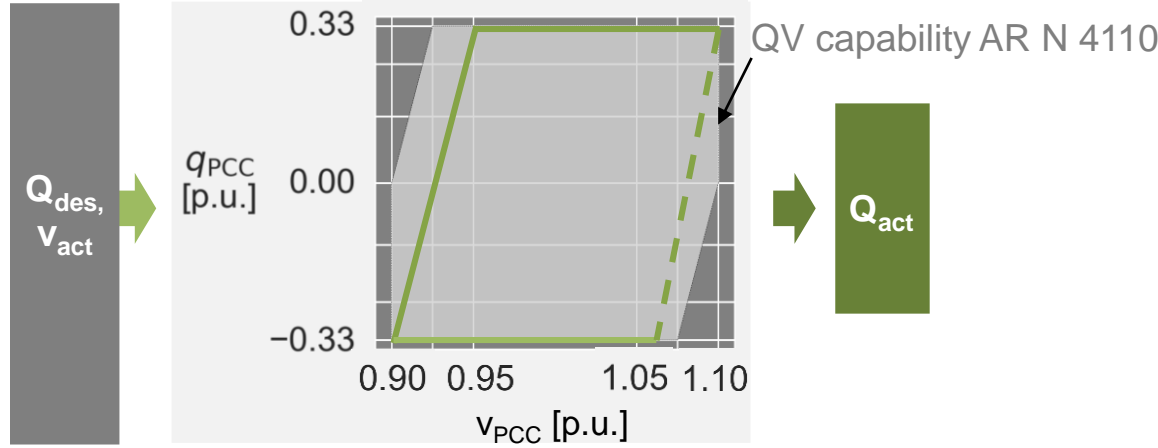
P curtailment for Q: An efficient measure for reducing Q-related CAPEX Permitted for MV in Germany since 2018

1 Curtailment for Q due to restrictive sizing (apparent power limitation at high P: up to ~ 5 %)

2 ~ up to 100 % if overexcited operation requested at high v_{PCC}



Concept: ‚Setpoint for Q management + limitation from grid perspective‘.
 Introduced in: Wang et al. (2015): Zentrales Blindleistungsmanagement für die Netzverknüpfungspunkte HS/MS der Bayernwerk AG.



1 Should not be subject to redispatch mechanisms

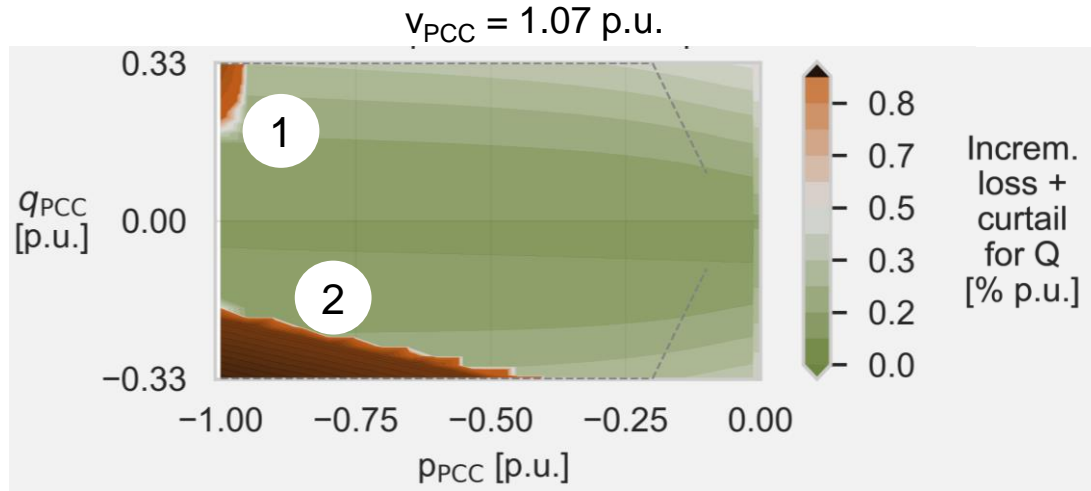
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How to deal with MV Q resources that curtail P for Q

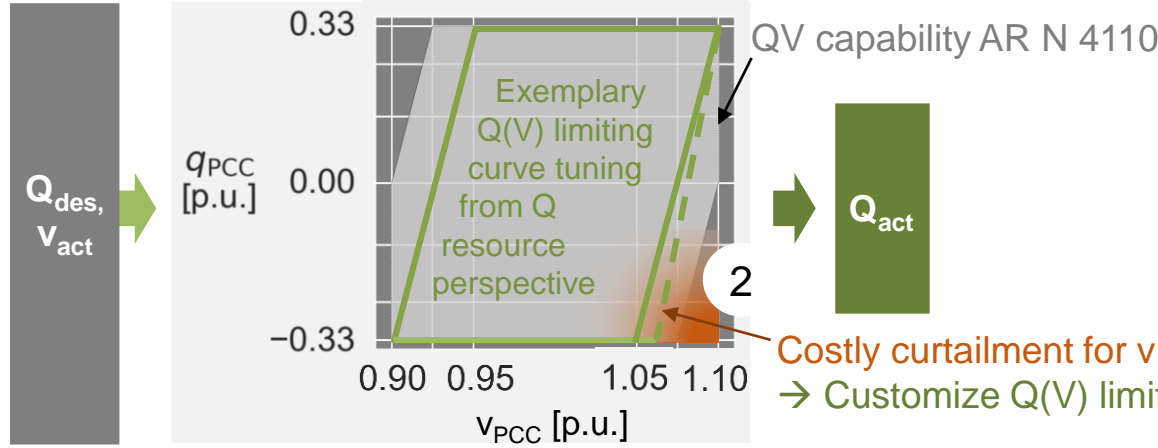
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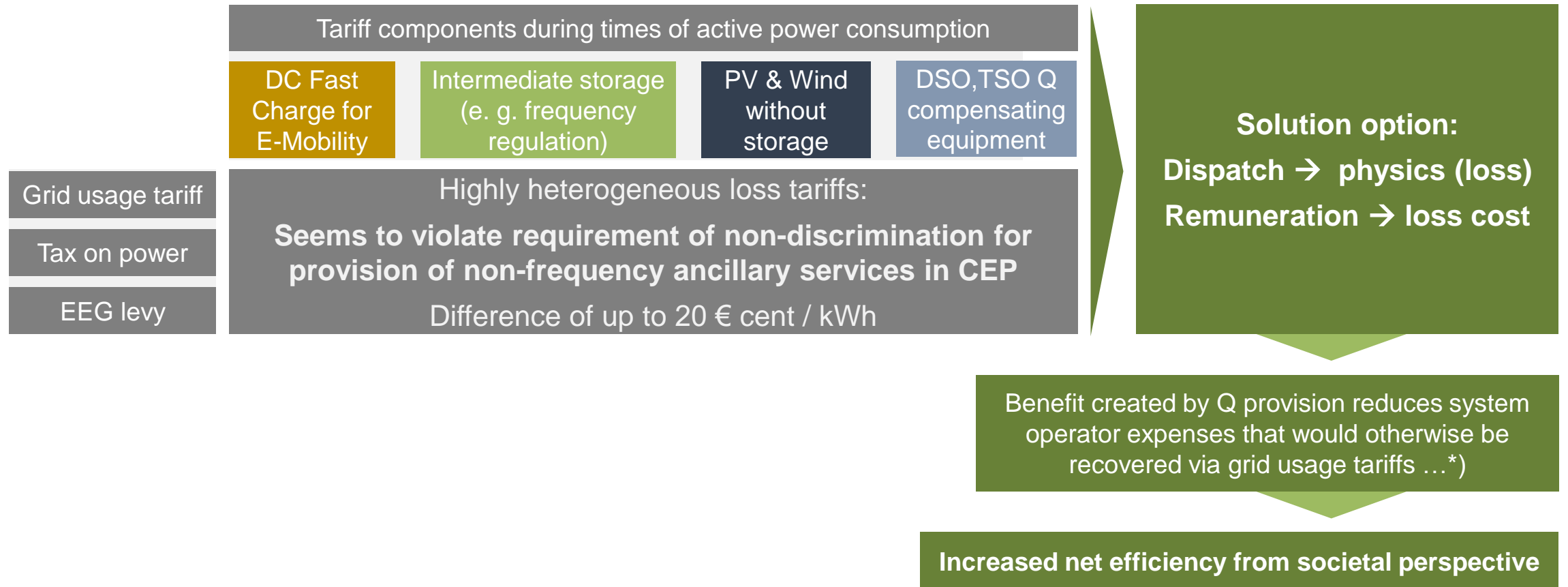
1 Should not be subject to redispatch mechanisms

2 Via (de-) central Q setpoint + Q(v) limitation, high curtailment regions can be elegantly avoided

How to deal with high & heterogenous consumption tariffs faced by some Q resources

STATCOM Q cost: function of heterogenous loss tariffs **→ Enable non-discriminatory, cost-efficient dispatch**

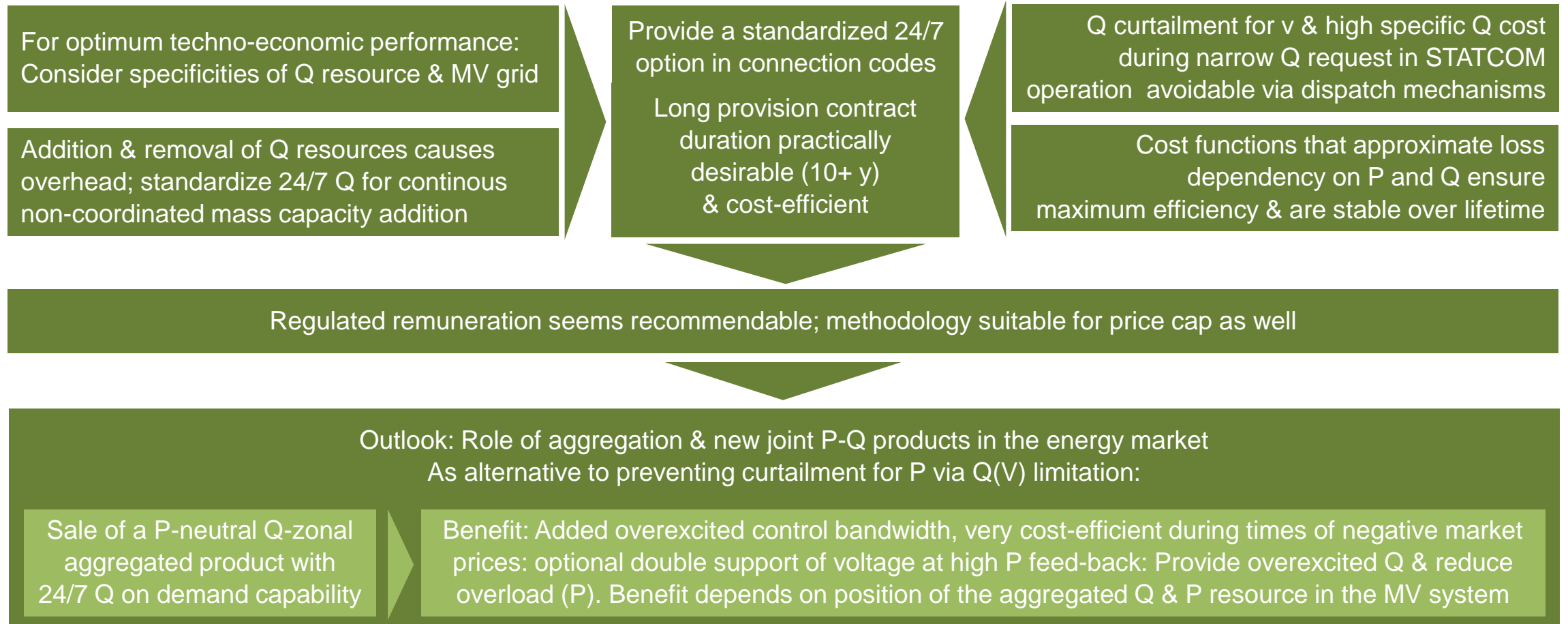
Solution also OPF friendly



*) Compromise possible, by adding slight cost penalty on physical loss in STATCOM operation

Leverage the full operational potential of new Q resource capacity additions

Efficient Q procurement from 24/7 MV resources: Summary



Leverage the full operational potential of new Q resource capacity additions

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Design requirement: Ensure ~ 0 CAPEX for Q solution

Provide a standardized 24/7 Q option in connection codes
For MV, long provision contract duration practically desirable (10+ y) & cost-efficient

Regulated remuneration seems recommendable; methodology suitable for price cap as well

Outlook: Role of aggregation & new joint P-Q products in the energy market
As alternative to preventing curtailment for P via Q(V) limitation:

Would need an update of
EnWG § 12 h

Sale of a P-neutral Q-zonal
aggregated product with
24/7 Q on demand capability

Benefit: Added overexcited control bandwidth, very cost-efficient during times of negative market prices: optional double support of voltage at high P feed-back: Provide overexcited Q & reduce overload (P). Benefit depends on position of the aggregated Q & P resource in the MV system

Leverage the full operational potential of new Q resource capacity additions

THANK YOU FOR YOUR ATTENTION

To leverage solution potential of 24/7



Regulatory support beneficial



Break with the logic that more safety can only come with more CAPEX

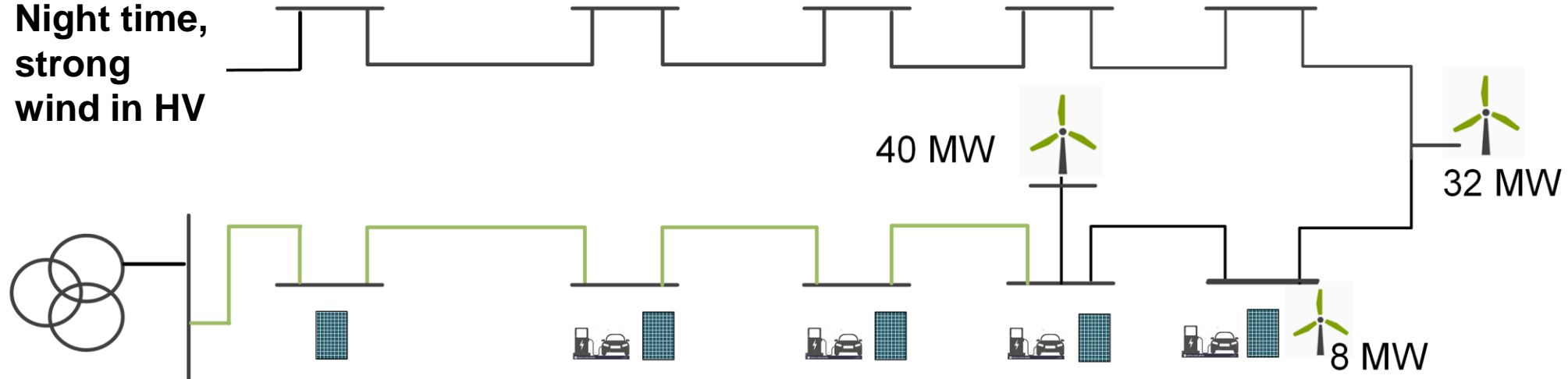


Foster Markowitz-efficient investment portfolios:
Consider uncertainty at the expense of potentially higher system operator OPEX

Variation of Q requirement in future MV systems: On the benefit of 24/7 Q from MV

Example: Electric vehicles participate in balancing market

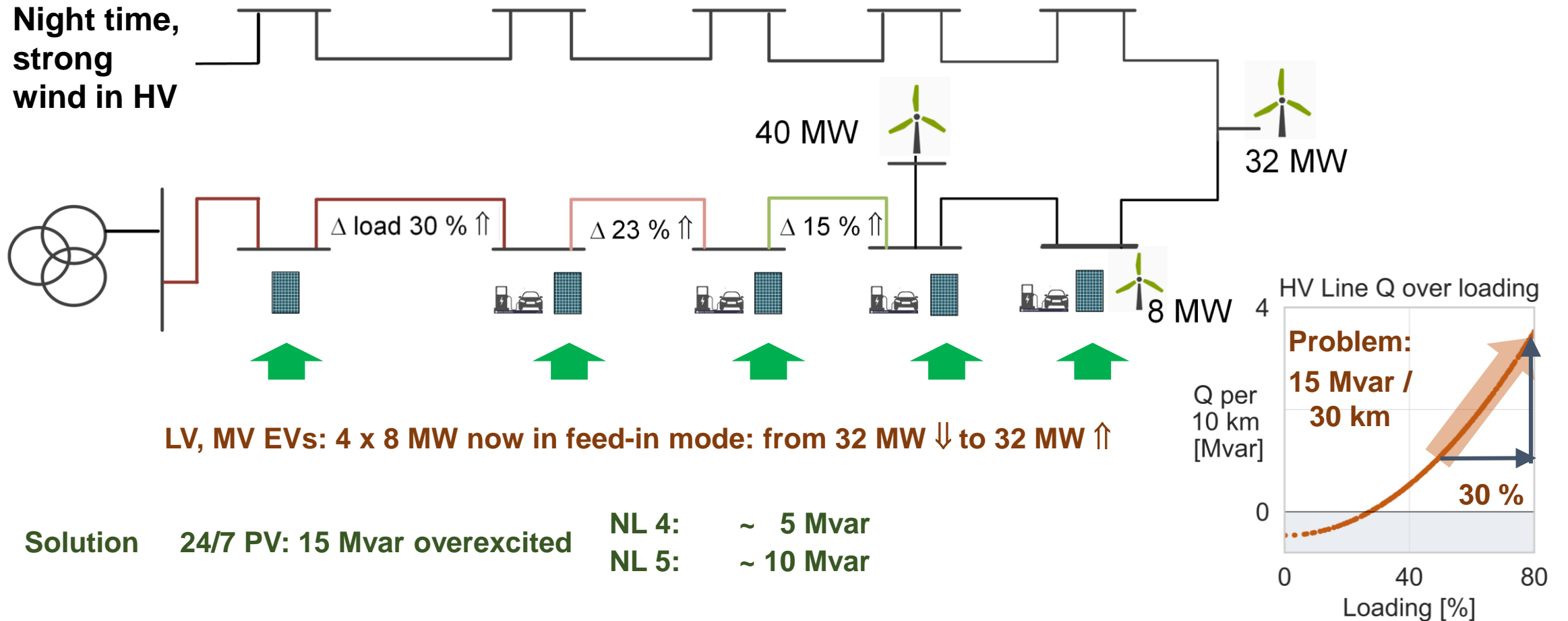
Night time,
strong
wind in HV



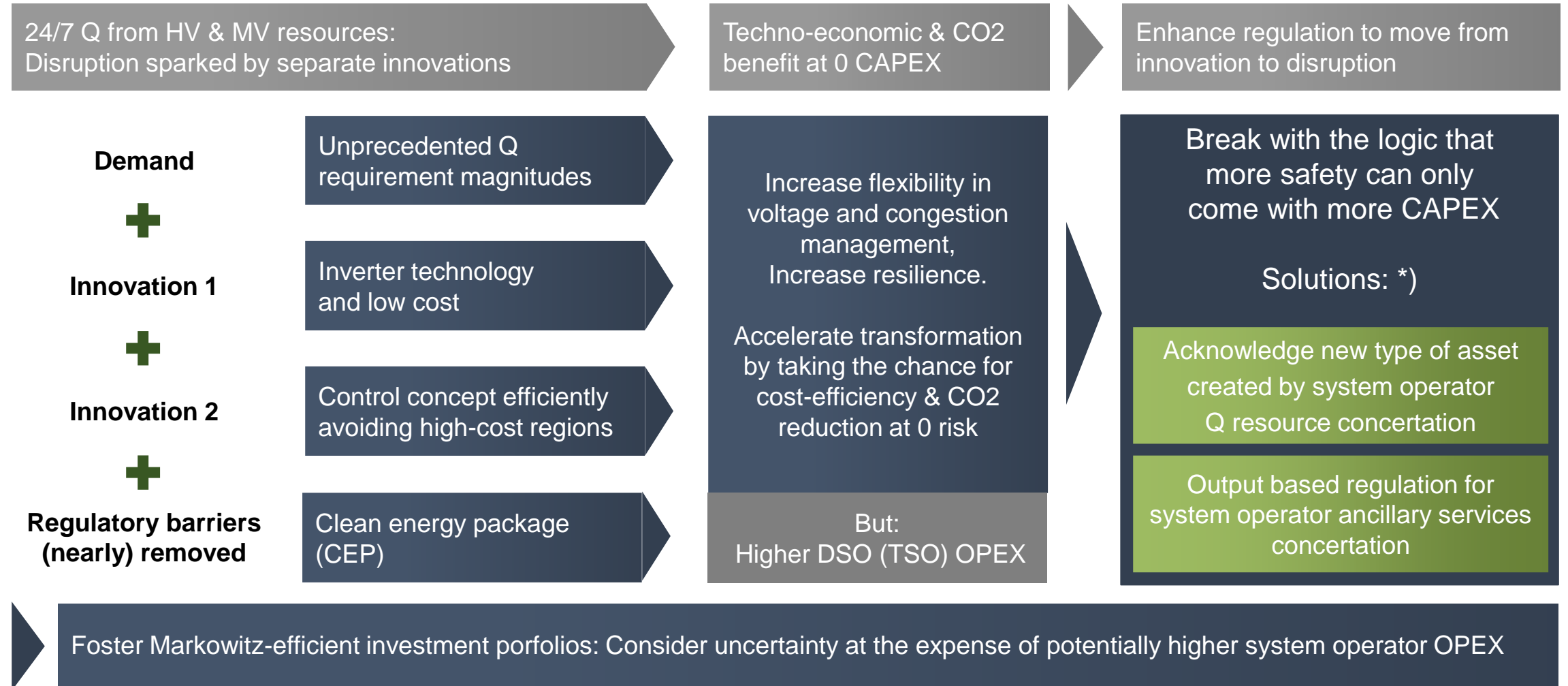
LV, MV EVs: 4 x 8 MW in charging mode

24/7 MV PV @ 0 Q

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From innovation to disruption: regulatory enhancements beneficial

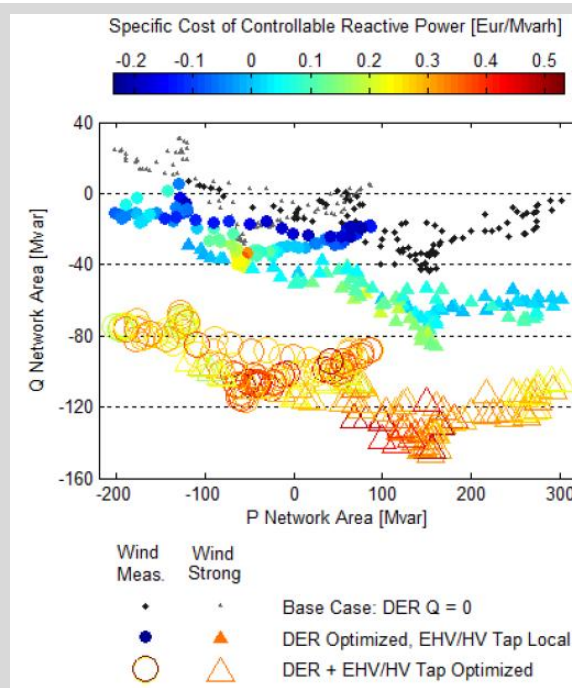


24/7 Q for EHV: technically feasible in limited amount economically minimization of total stakeholder cost desirable

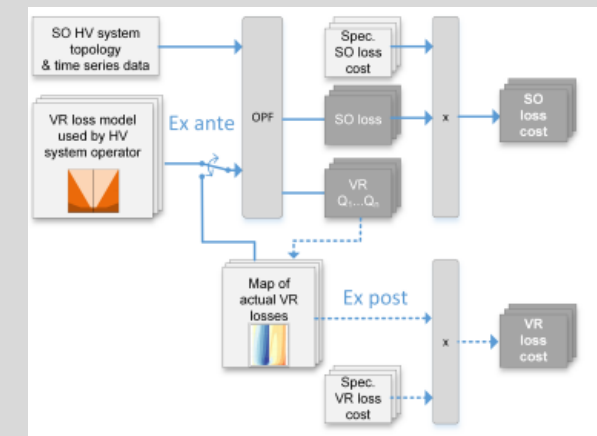
24/7 overexcited Q to EHV possible
(2015: only system operator loss considered)

Here: 100 Mvar
during 3 most constrained days of the year,
using NL 3 to NL 4 resources
Combined contingency constrained
AC OPF of EHV / HV taps & generator Q
Using real data in 15 minute resolution

Kämpf et al. (2015) 'Reliable Controllable Reactive Power for the Extra High Voltage System By High Voltage Distributed Energy Resources' Cigre Science & Engineering Journal



24/7 underexcited Q to EHV
(2017: minimize total stakeholder cost)
50 Mvar for 1 year @ total loss $\Delta \sim 25$ kW/Mvar



Kämpf. et al (2017) 'Remuneration of controllable reactive power inside so far free of charge ranges: Cost-Benefit Analysis, Solar Integration W.'

Quasistationary 24/7 Q from distribution level resources is a source of operational flexibility & resilience
Usually it is a complement of EHV Q compensating capacity (substitute for redispatch)

See also: Hinz (2016): Reactive power provision from the distribution grid and its effects on redispatch cost, Enerday.

Principles for concertation of connection code & procurement

