# Values and Impacts of Incorporating Local Flexibility Services in Transmission Expansion Planning

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# 1. Agenda

- Background & Motivation
  - Research Questions
    - Objectives
- Model Formulation
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  - Dispatch of Local Flexible
    - Allocation and amount of flexibility
      - Values of flexibility
        - Impact of local FSs on TEP
- Conclusions

# 1. Background and Motivation

- Transmission expansion planning (TEP), local flexibility services (FSs)
- Coordination: TSO, DSO, FSs providers → microgrids (MGs)

Research Questions

*How does the…*

1. TSO-DSO coordination affect dispatch of MG resources?
2. TSO-DSO coordination affect flexibility (amount, allocation, values)?
3. Provision of FSs affect the transmission grid expansion?

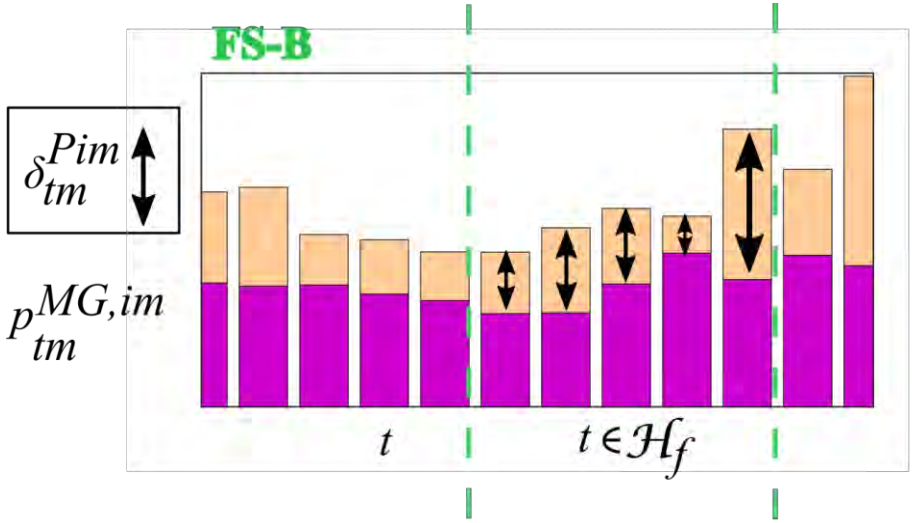
# 1. Objectives

- To develop a TSO-DSO operation coordination model
- To control power exchanges at all grid interfaces
- To integrate grid operation and local FSs into TEP
- To quantify flexibility value for all connected systems

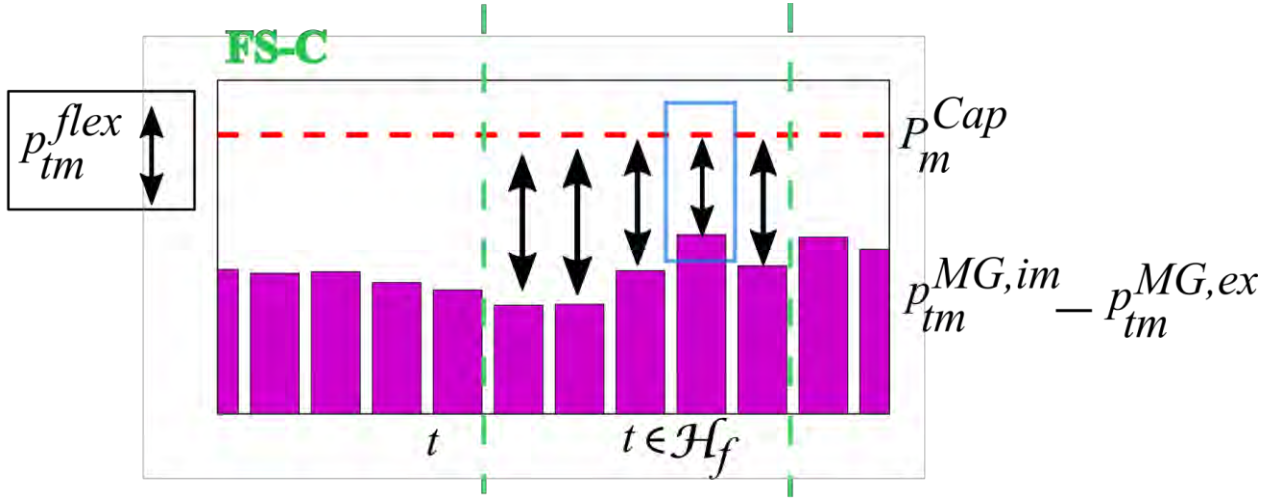
# 2. Model Formulation

| Optimization model | Objective function (minimization) | Constraints |
|---|---|---|
| TSO | Investment costs<br>+ operation costs<br>(generation dispatch, load shedding) | • DC OPF<br>• Investment decisions<br>• Transmission and generation bounds |
| DSO | Peak power cost<br>+ purchase cost FSs | • AC OPF<br>• FSs |
| MGs | Cost of energy purchase<br>– Revenue from selling energy<br>– Revenue from selling FSs | • Energy balance<br>• BES model<br>• FSs |

# 2. Models of Flexibility Services




*Baseline*




*Capacity limitation*

# 2. Coordinated operation model

Bilevel optimization

Upper level (leader): DSO

Lower level (followers): MGs

Equivalent single-level optimization model solved by DSO

(MILP)

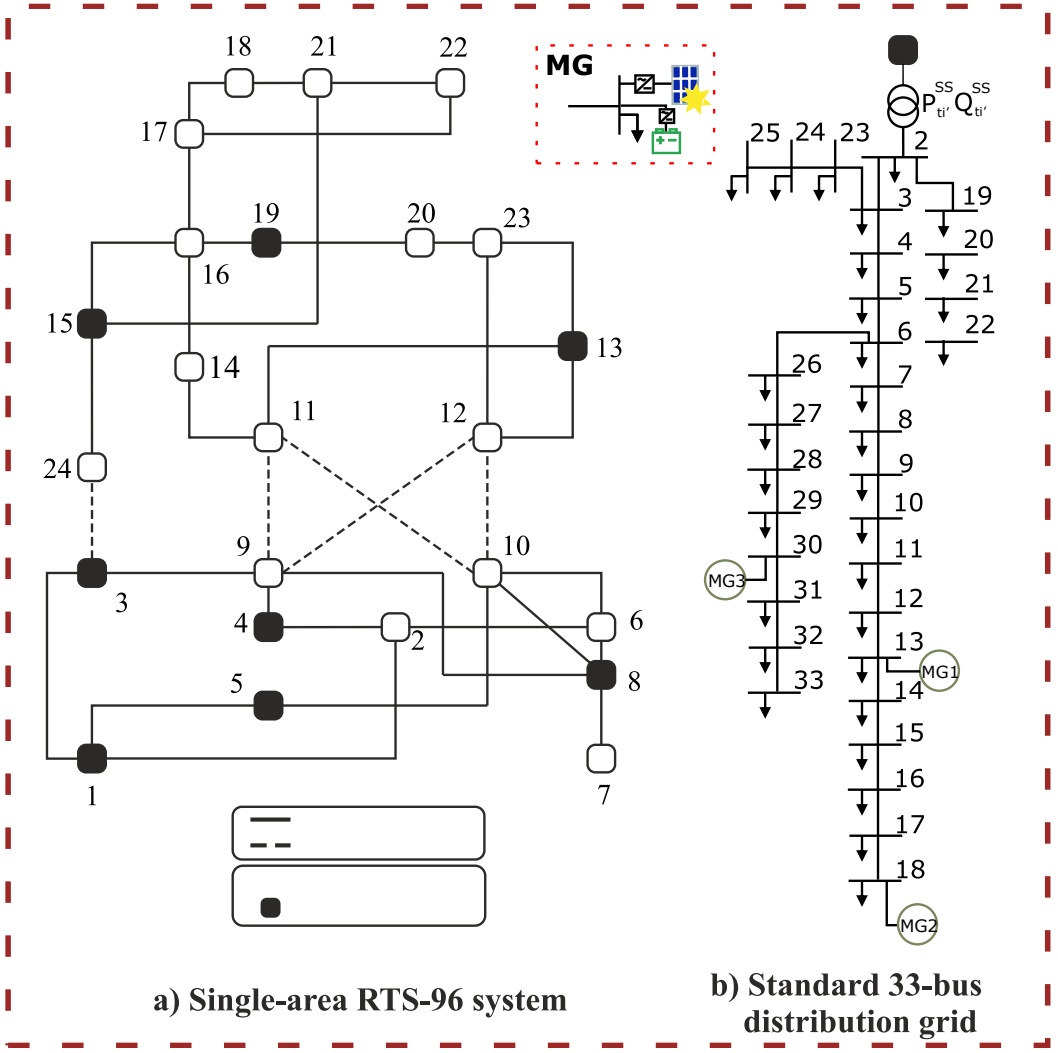
DSO's objective function (equivalent single-level)

+ TSO's objective function

(MILP)

# 3. Test system

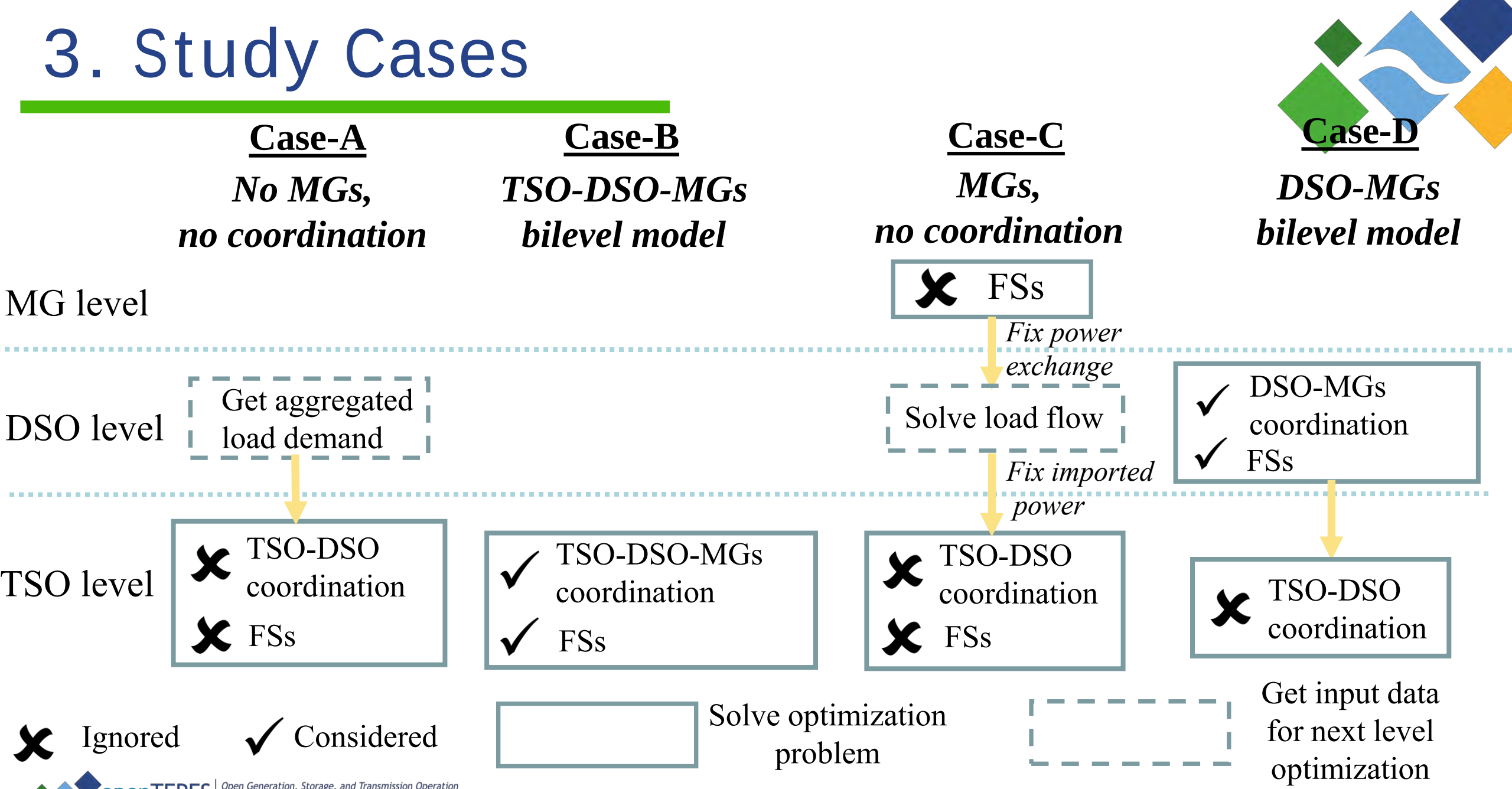
- Generation technologies: coal, gas, hydro, solar, and wind
- BES energy-to-power ratio: 17.2kWh/14.4kW, 25.9kWh/21.6kW, and 134.9kWh/111.76kW
- In total: 80 distribution networks and 240 grid-connected MGs
- Total system load: 6783.37 MW (10% at distribution)




a) Single-area RTS-96 system

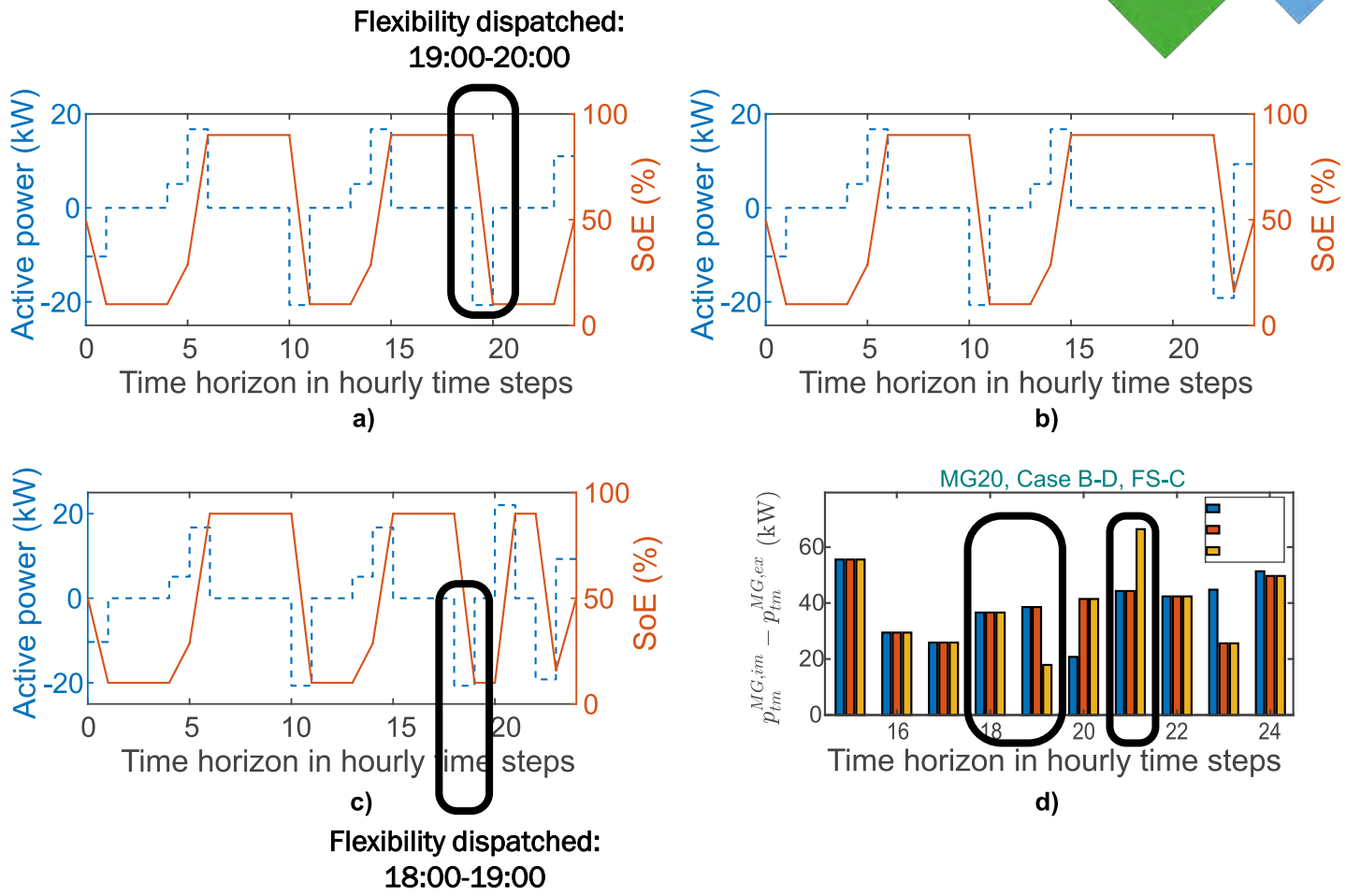
b) Standard 33-bus distribution grid

# 3. Study Cases



# 3. Results

Dispatch of Local Flexible Resources




*Case-B: TSO-DSO-MGs bilevel model*
*Case-C: MGs, no coordination*
*Case-D: DSO-MGs bilevel model*
SoE: State-of-energy

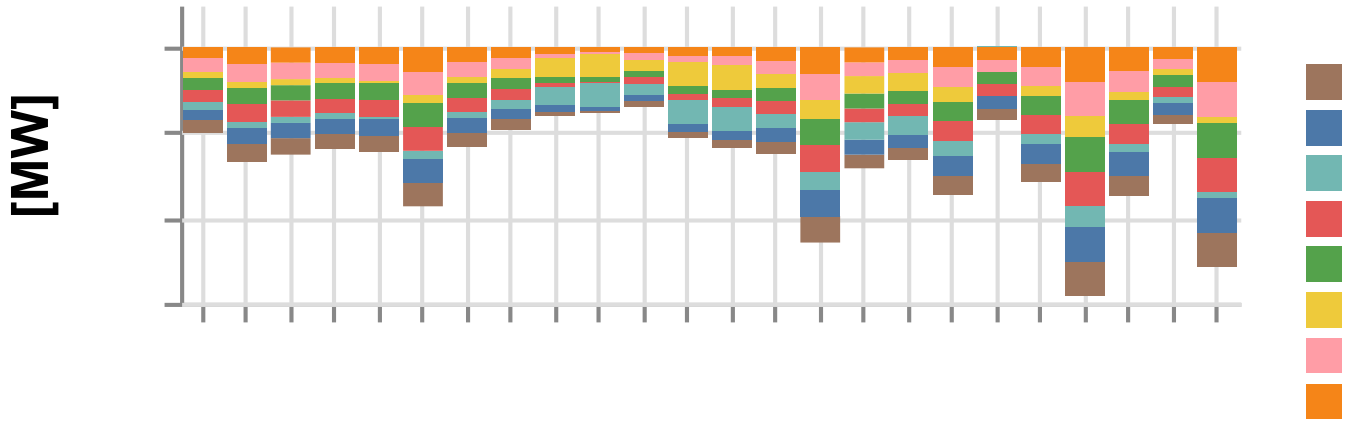
- *The TSO-DSO coordination scheme can change the output profile of the flexibility resources.*
- *Right after the flexibility period in Case D, there is large increase in the imported power.*

# 3. Results

Allocation and Amount of Flexibility

*Case-A: No MGs, no coordination*
*Case-B: TSO-DSO-MGs bilevel model*

Case A vs Case B




*a notable difference in the net load amount in the transmission nodes with distribution grid*

# 3. Results

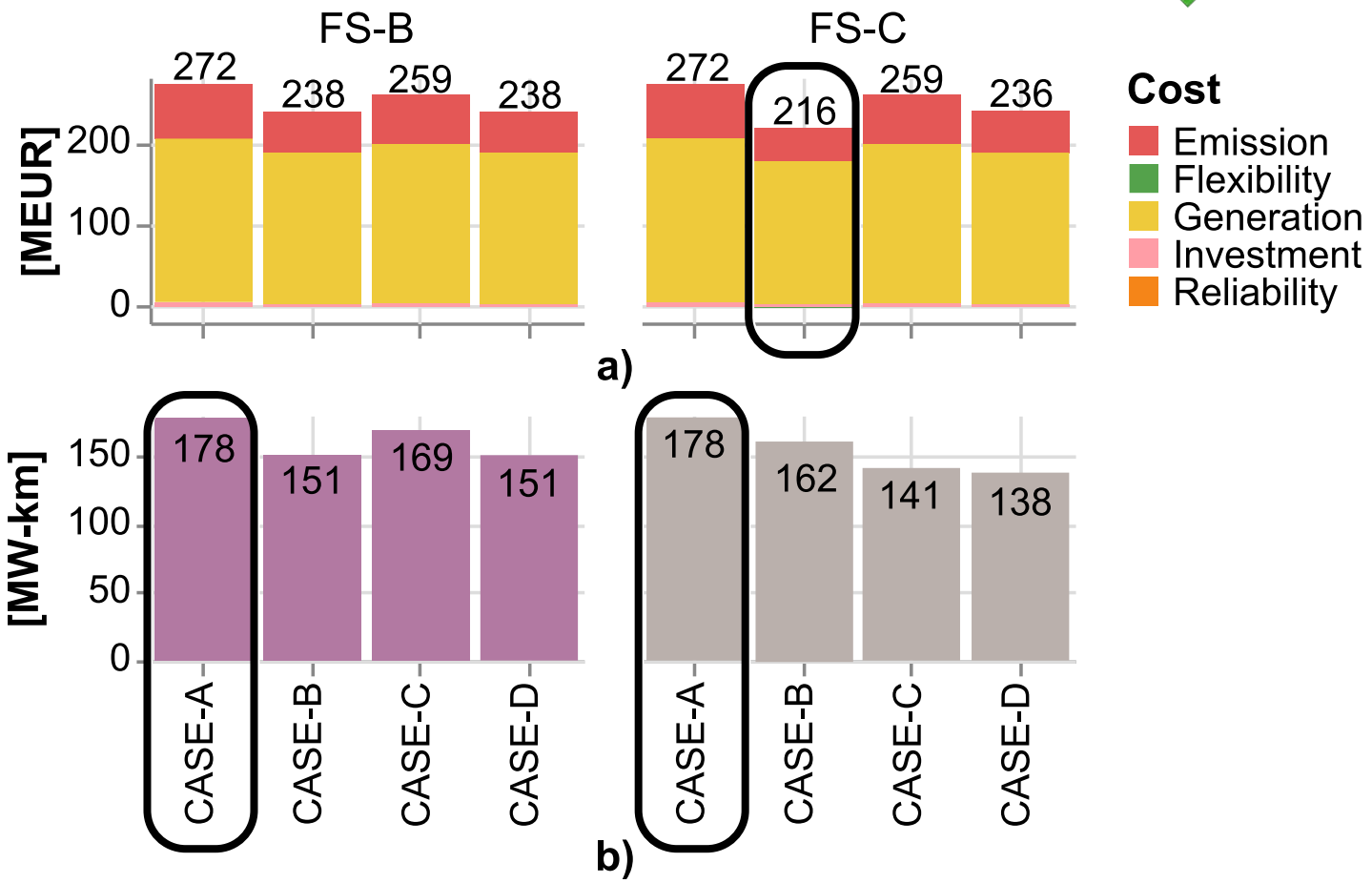
## Values of Flexibility

| | |
|---|---|
| TSO | • FS-B: cost reduction<br>• FS-C: higher cost reduction |
| DSO | • FS-B: no value, Case C cost = Case D cost<br>• FS-C: low value, depends on capacity limit |
| MGs | • FS-B: dispatch modification in Case B, no value<br>• FS-C: promising, depends on capacity limit |

*Capacity limit should be separately customized for each MG*

# 3. Results

Impact of local FSs on TEP




*Case-A: No MGs, no coordination*
*Case-B: TSO-DSO-MGs bilevel model*
*Case-C: MGs, no coordination*
*Case-D: DSO-MGs bilevel model*

*where no MGs or FSs are considered, yields higher total system costs*

# 3. Conclusions

1. Larger reduction in TEP cost achieved with FS-C.
2. FS-B benefited TSO, no value for DSO/MGs.
3. When local FSs were provided, transmission costs decreased.

# Thank you

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