# MULTI-MARKET MODELING IN SINTEF PART 1

Marte Fodstad

# Outline

- Multi-market – what and why?
- Main projects on the topic
- Uncertainty
- SHARM day-ahead bidding
- Multi-market modeling

# The Norwegian short-term power markets

| | | | | October | Thursday | Thursday | Friday | Day-1 | Day-1 | Hour-1 | Hour-0:45 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 10:00 | 12:00 | 12:00 | 12:00 | 18:00 | | |
| **Market** | **Period** | **Resolution** | **Commodity** | | | | | | | | |
| RKOM season | Winter | Season | Capacity | ✓ | | | | | | | |
| FRR-A | Week | N/D/E | Capacity | | ✓ | | | | | | |
| FCR-N week | Weekend | N/D/E | Capacity | | | ✓ | | | | | |
| RKOM week | Week | N/D | Capacity | | | | ✓ | | | | |
| FCR-N week | Weekday | N/D/E | Capacity | | | | ✓ | | | | |
| ELSPOT | Day | Hour | Energy | | | | | ✓ | | | |
| FCR-N/D day | Day | Hour | Capacity | | | | | | ✓ | | |
| ELBAS | Cont. | Hour | Energy | | | | | | | ✓ | |
| RKM | Hour | Hour | Energy | | | | | | | | ✓ |

# Short-term markets

- Two products: energy and capacity (reserve)
- Increasing variability
  - Intermittent renewable energy supply (wind, solar, run-of-river hydro)
  - Demand variability (electric vehicles, etc)
  - Strengthened by cables to Europe
- Back-up capacity to handle unforeseen variations
- Trade closer to operation to reduce forecast period

# SINTEF projects on multi-market modeling

**IBM**

- Integrating Balancing Markets in Hydropower Scheduling Methods
- Influence on water values

**MultiSHARM**

- Day-ahead Bidding with Multiple Short-term Markets
- Short-term bidding and scheduling

**PRIBAS**

- Pricing Balancing Services in the Future Nordic Power Market
- Fundamental market modelling



Supported by The Research Council of Norway

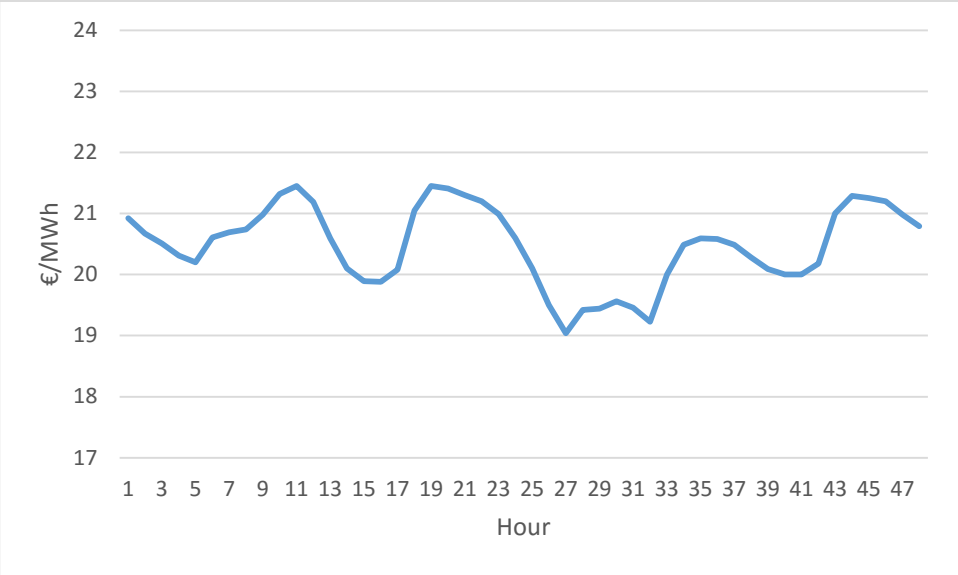
# Uncertainty and multiple markets

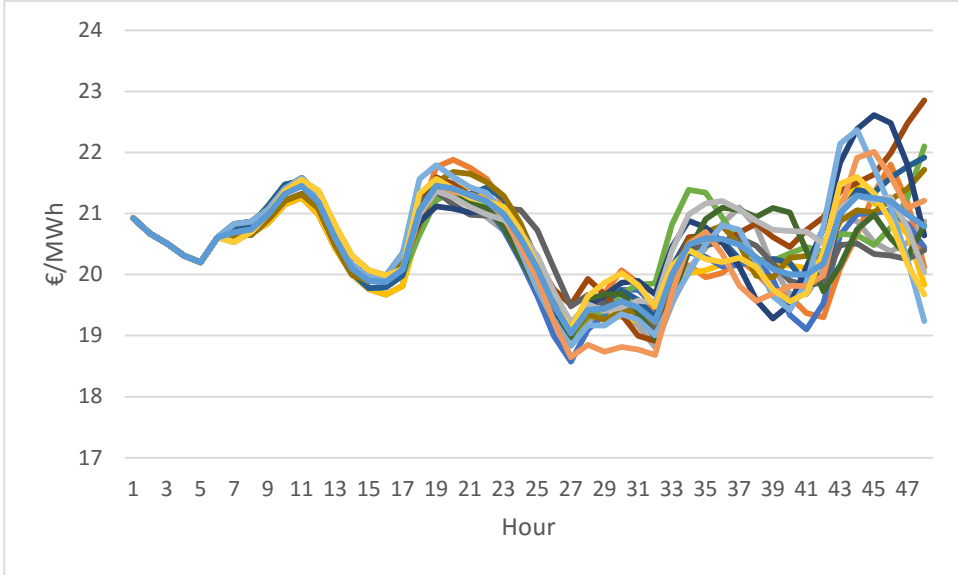
What it the distinction between 1 MWh in Elspot and 1 MWh in Elbas?

- Physically the same product
- Different timing -> different knowledge -> different uncertainty

- Increased focus on description of uncertainty in multi-market modeling

# SHOP + uncertainty = SHARM



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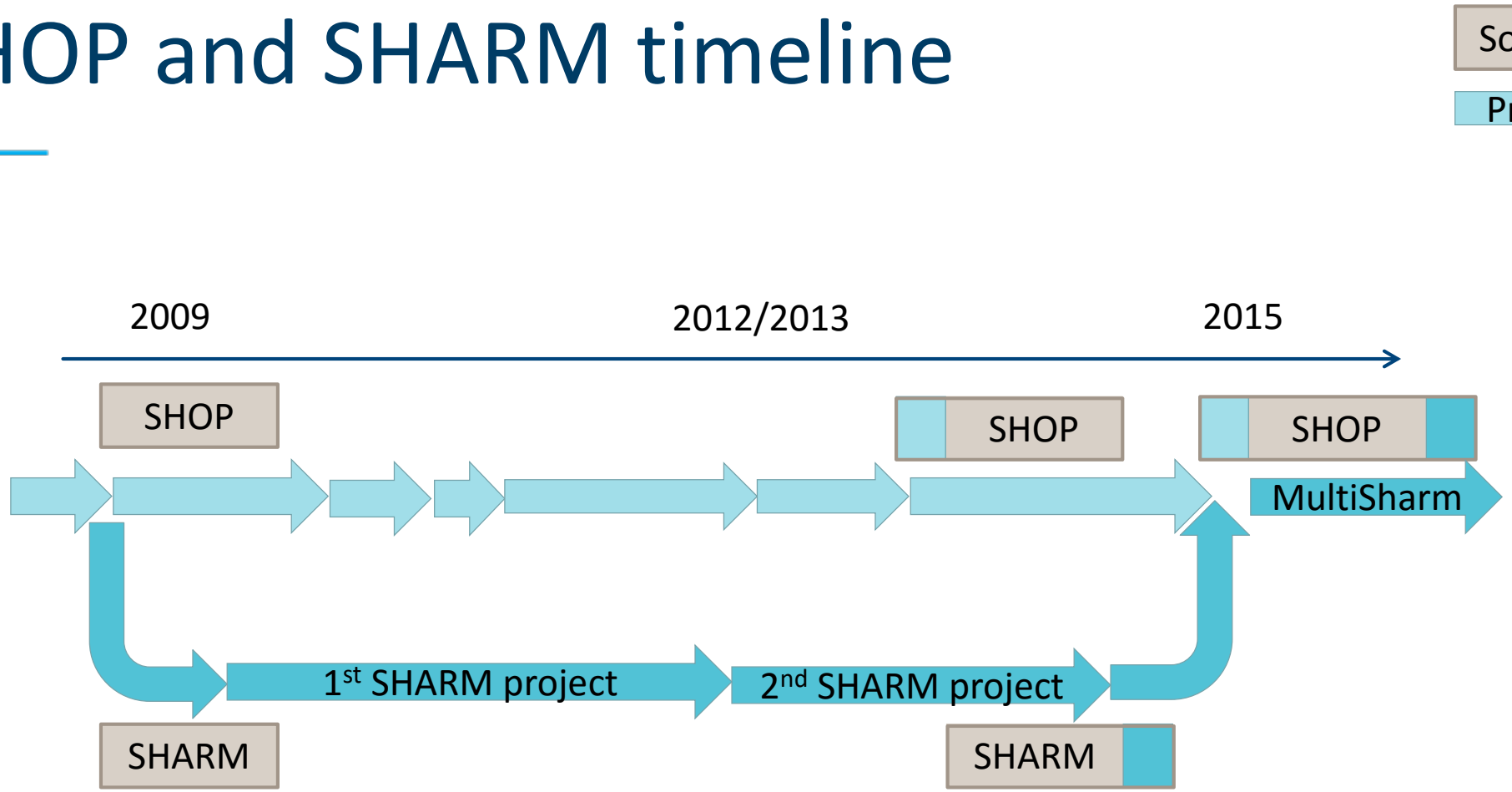
# SHOP and SHARM timeline



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# Multi-market extensions in SHOP

- SHOP structure ready for multi-market modeling!
  - Input multiple prices and trade limits
  - Optimize trade in multiple markets
    - Energy and reserves
  - MULTI_MARKET-tag
- Available for all SHOP users

Market index

Market index

```
# Elspot
MULTI_MARKET price_sale 1 1
0 0 20170508120000 HOUR 8760 1 NOK 1
20170508120000 297.25

MULTI_MARKET max_sale 1 1
0 0 20170508120000 HOUR 8760 1 MW 1
20170508120000 1000

# FRR_UP
MULTI_MARKET price_sale 2 1
0 0 20170508120000 HOUR 8760 1 NOK 1
20170508120000 43.00

MULTI_MARKET max_sale 2 1
0 0 20170508120000 HOUR 8760 1 MW 1
20170508120000 105

MULTI_MARKET market_type 2 FRR_UP

MULTI_MARKET reserve_group 2 1
```



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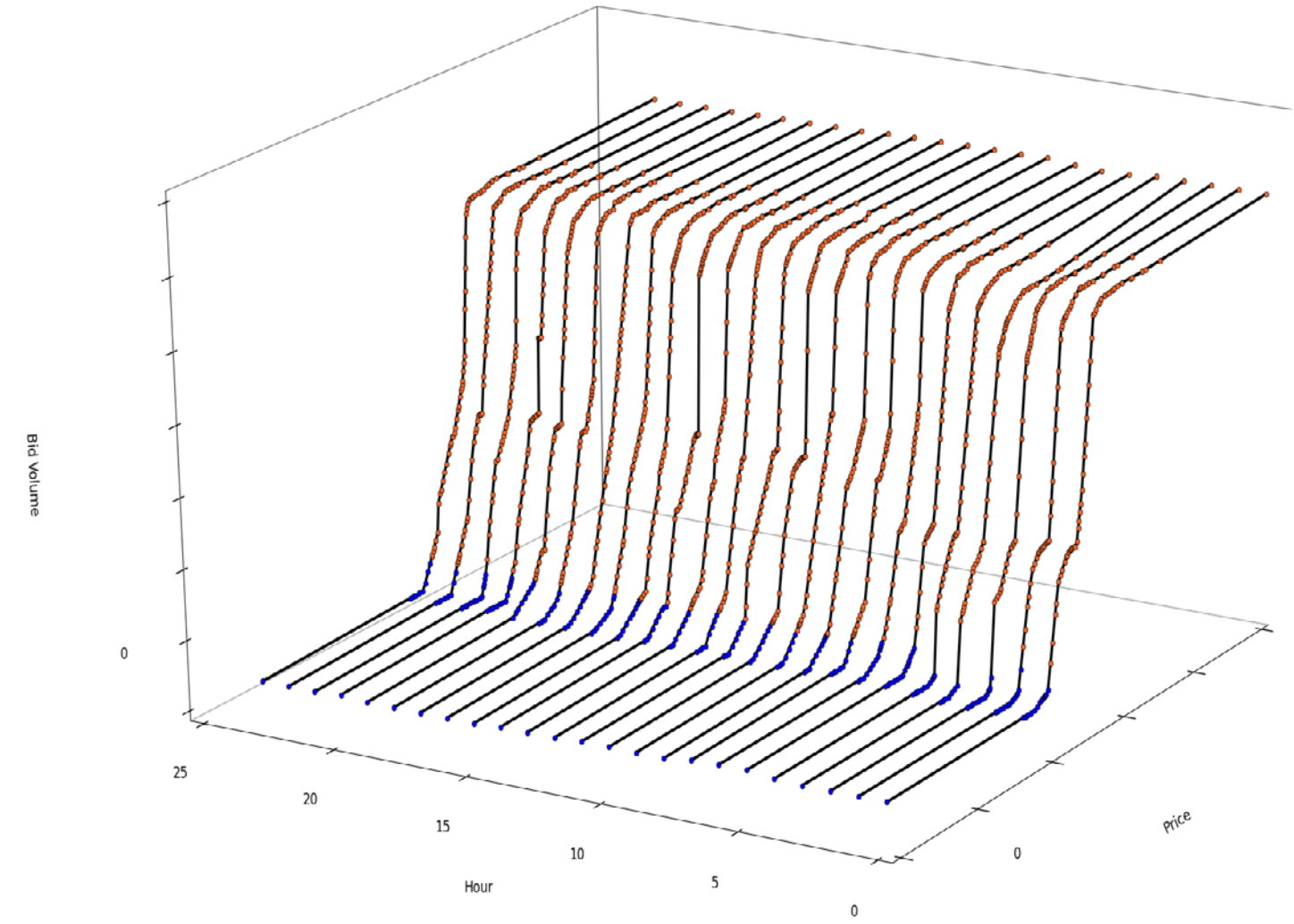
# Bidding in SHARM

- Optimized bidding matrix
- Main elements in method
  - Scenario tree prices are bid price points
  - Optimized non-decreasing bid volumes
  - Heuristic to compress matrix to 64 bid points
- Bids per group of plants
- So far tested on Elspot



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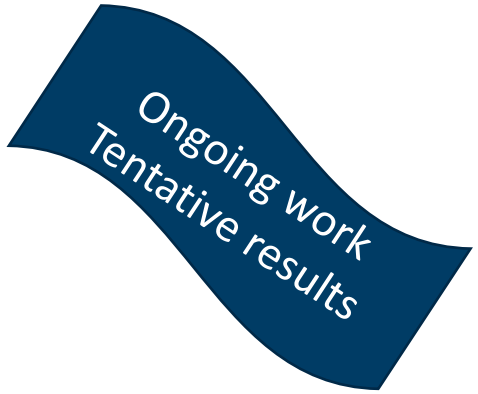
# Where are the added values? – Case study




- Approach: start out simple - add complexity step-wise
- Perfect foresight, one year
- Stylized production system
  - Observed inflow: 1000 MWh
  - Max prod.: 10MW
  - Max storage: 550MWh
  - Start storage level = end level
- Markets
  - Day-ahead (DA)
  - Intra-day (ID)
  - Balancing market (RK=BM)
- Observed prices NO5 2015
- Trade limits from observed trades/activation



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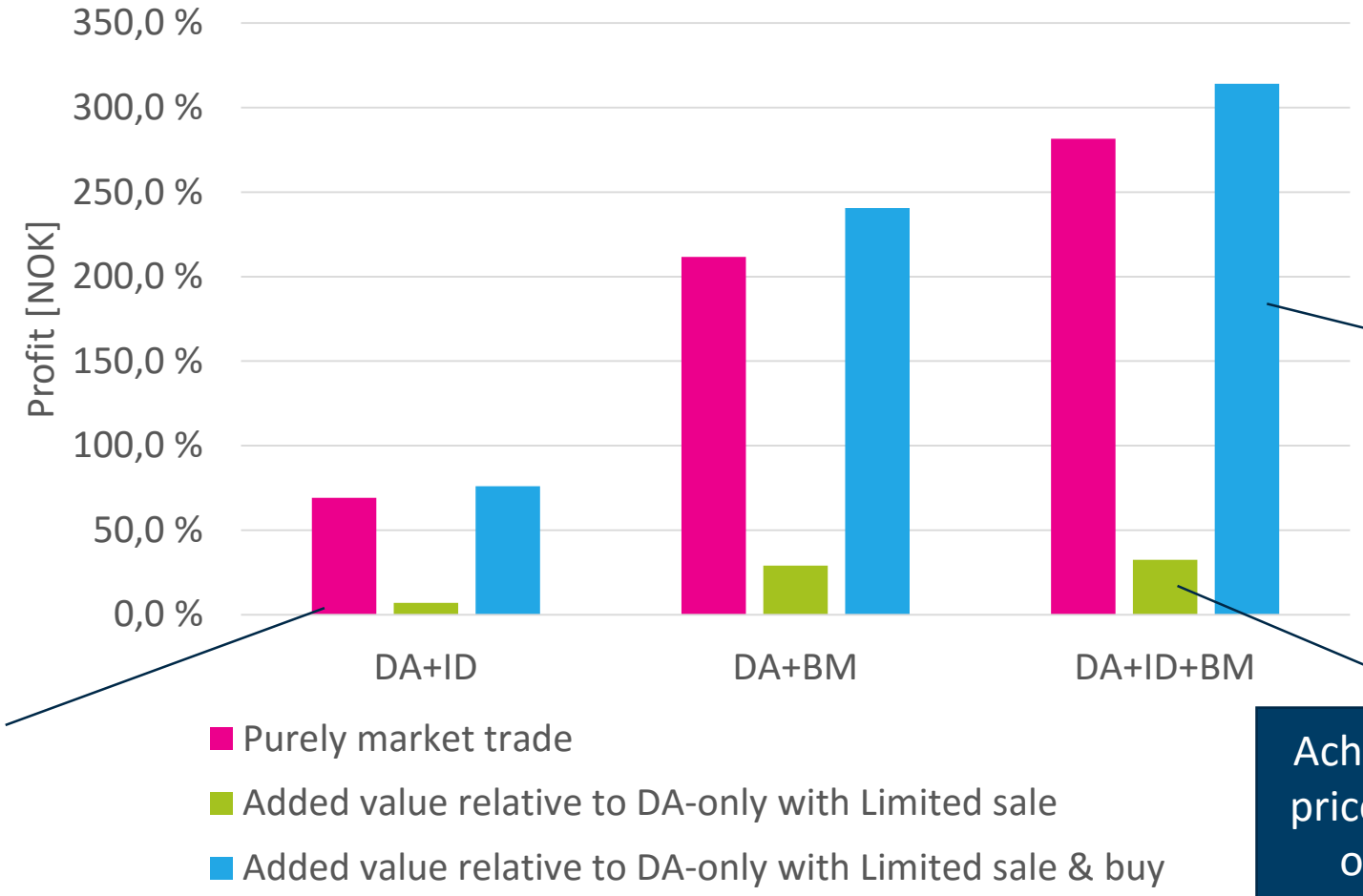
# Case study
# – Added profits relative to DA sale

Ongoing work
Tentative results




Independent of production system

Both market trade and better prices

Achieves better prices. Depends on storage capacity

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# Case study
# - Sequential vs coordinated planning

Ongoing work
Tentative results

To be continued…
- Production system characteristics
- Limited foresight
- Uncertainty
- Other prices (SE3, Germany?)



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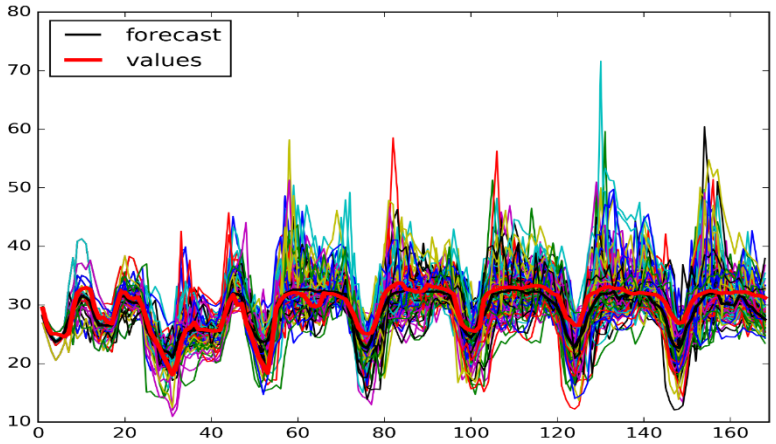
# Related activities

- Market and inflow data
  - Prices with uncertainty, correlations, trade limits
  - Different methods for scenario tree generation and reduction




- Computation time for stochastic model
- Long-term simulation
  - Extend evaluation period for short-term analysis
  - Further develop interaction between short-term and long-term models



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