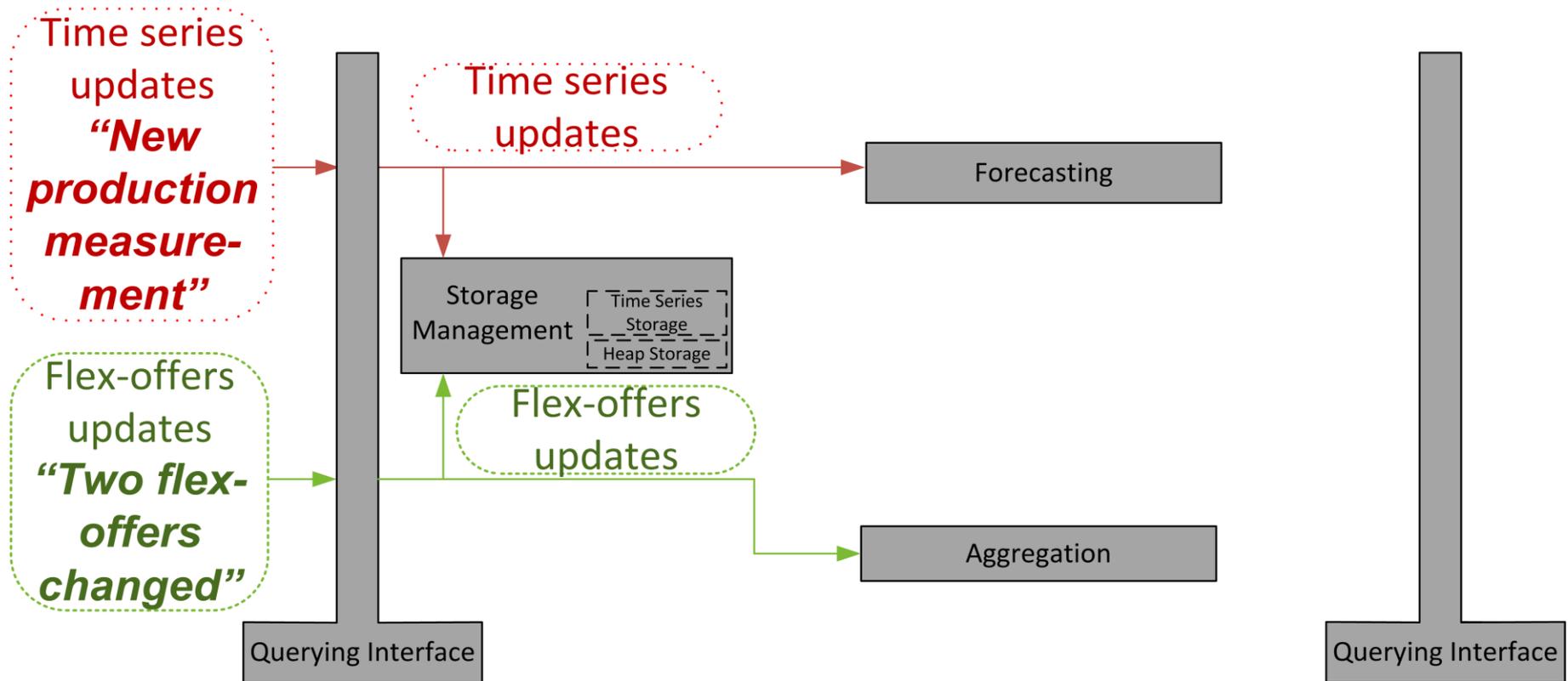MIRABEL energy
Balancing energy supply and demand

- Update queries: time series and flex-offers

Time series updates **"New production measure-ment"**

Time series updates

Forecasting

Storage Management | Time Series Storage | Heap Storage

Flex-offers updates **"Two flex-offers changed"**

Flex-offers updates

Aggregation

Querying Interface

Querying Interface

- ## Subscription queries

Subscribe for *"Notify me when flex-offer energy changes more than 10MWh"*

Subscribe for *"Notify me when forecast changes by more than 10%"*

Querying Interface

Subscriptions

Subscription Processor

Forecasting

Aggregation

Notifi-cations

Querying Interface

"Flex-offers total energy changed"

"Fore-casts changed by 11%"

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- ## Analytical queries:
  - Exact analytical queries
  - Approximate analytical queries

| Storage Management | Time Series Storage |
| | Heap Storage |

Forecasting

Approxi-mate query results

Approximate:
"Show balance for past and future 2 hours"

Model-based Query Processor

Exact query results

Standard Query Processor (PostgreSQL)

Analytical queries

Exact: *"Show energy balance"*

Aggregation

Querying Interface

Querying Interface
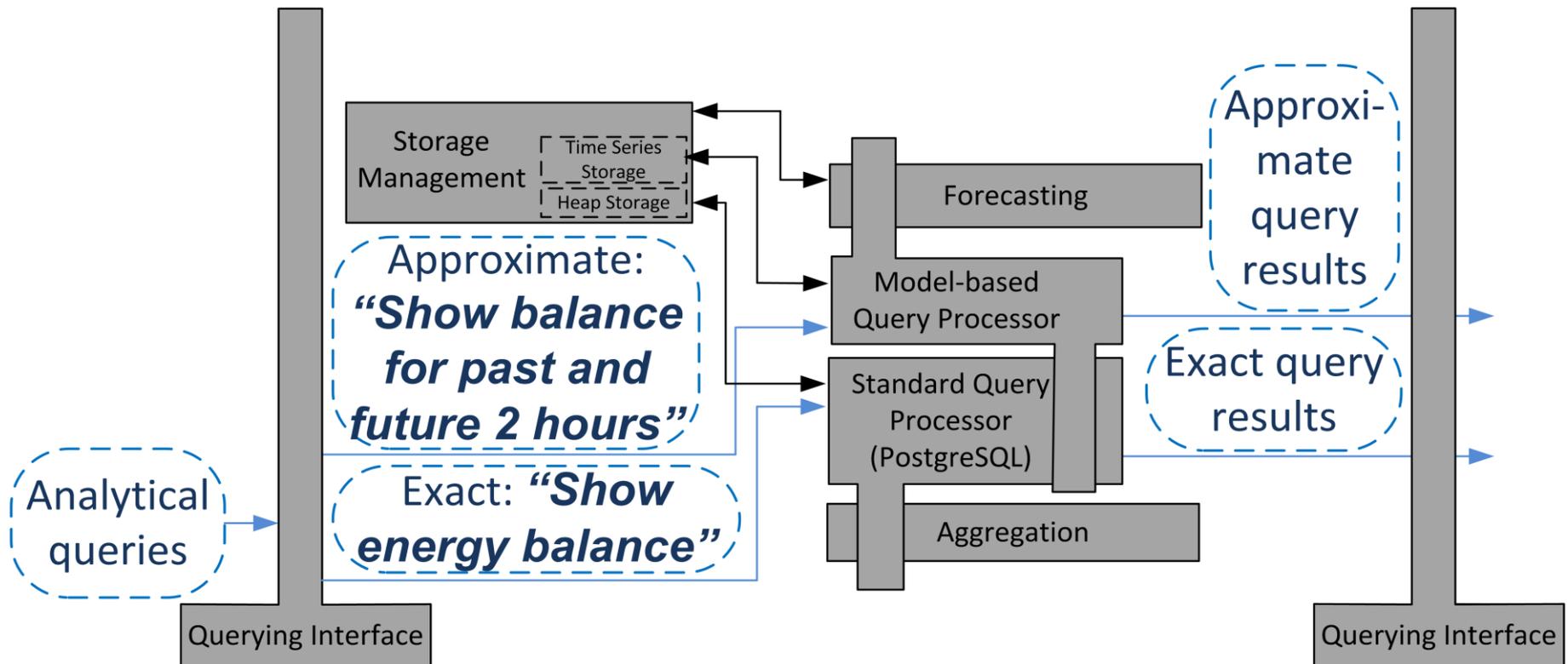
# Component Interaction Overview
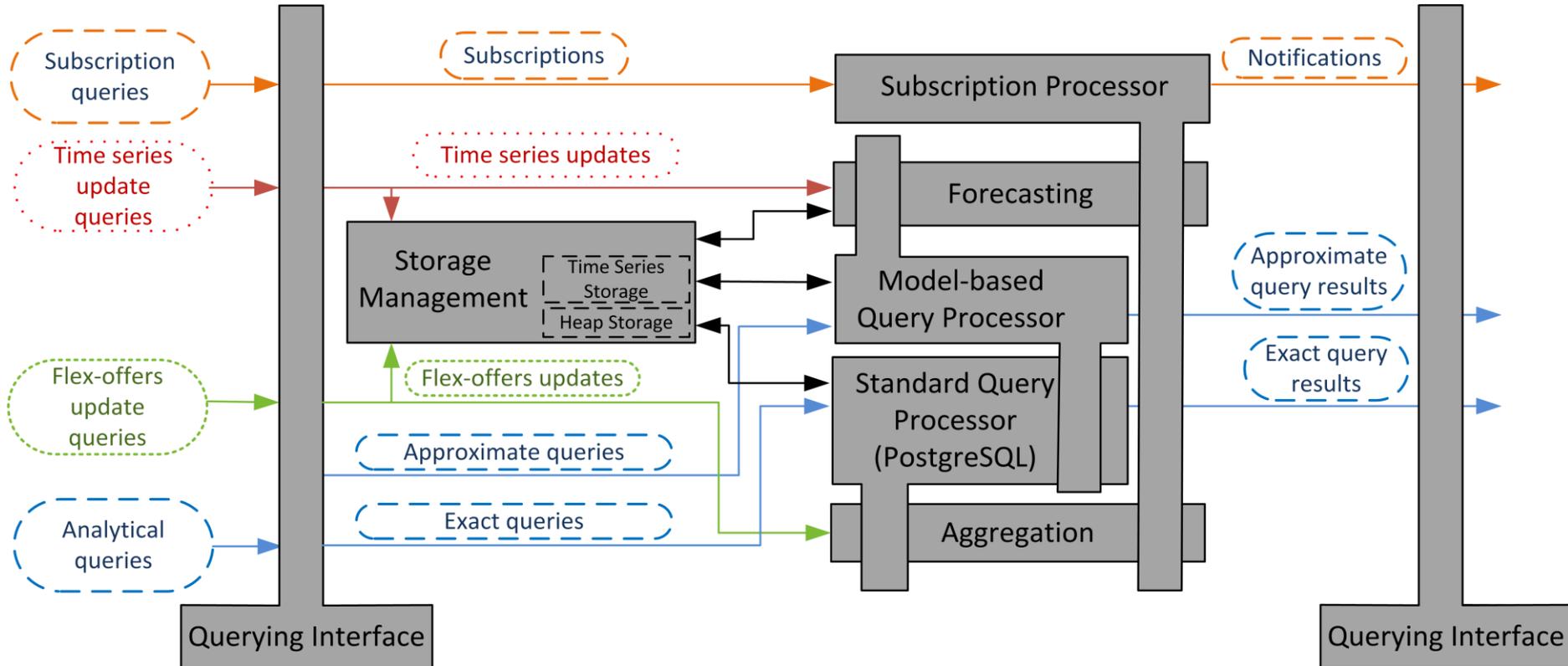
- What is MIRABEL project about?

- System architecture
    - Typical queries
    - MIRABEL use case
    - **Individual components**

- Future challenges

- Conclusions

Storage Management for Time Series

- ## Exact time series in Heap Storage

- ## Models in Time Series Storage
  - Models for past and future periods
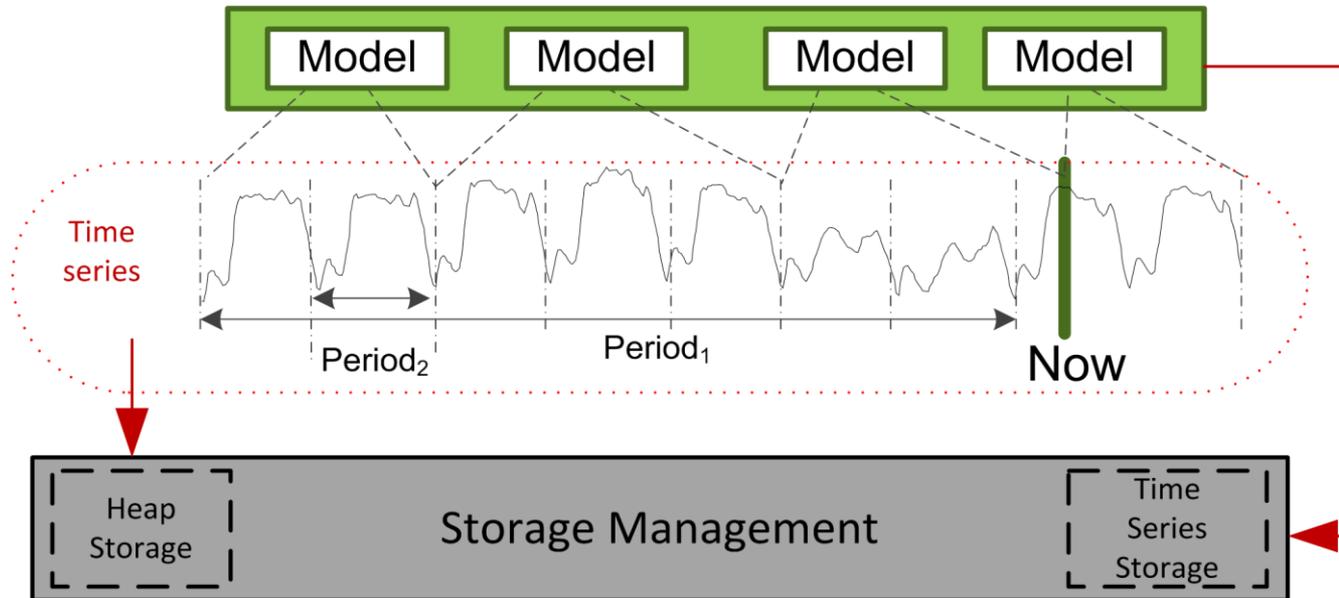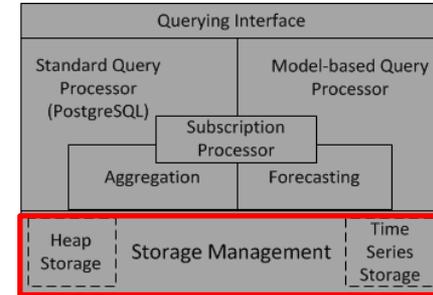
More information in Khalefa et.al "Model-based Integration of Past & Future in TimeTravel (demo)", in PVLDB, 2012

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- ## Flex-offer storage
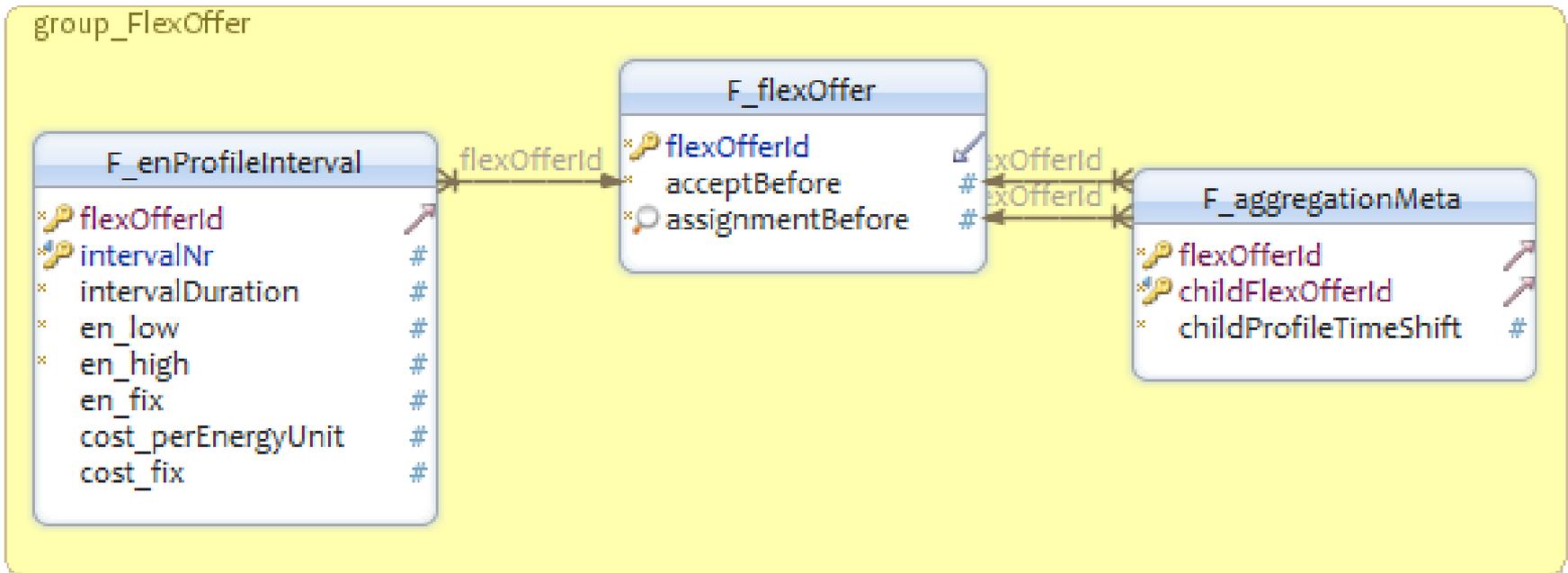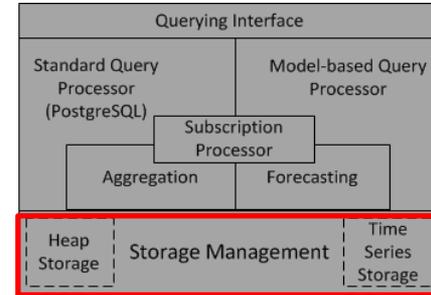
Generated using DbSchema

More information in Šikšnys et.al. "MIRABEL DW: Managing Complex Energy Data in a Smart Grid", in Proc. of DaWaK, 2012

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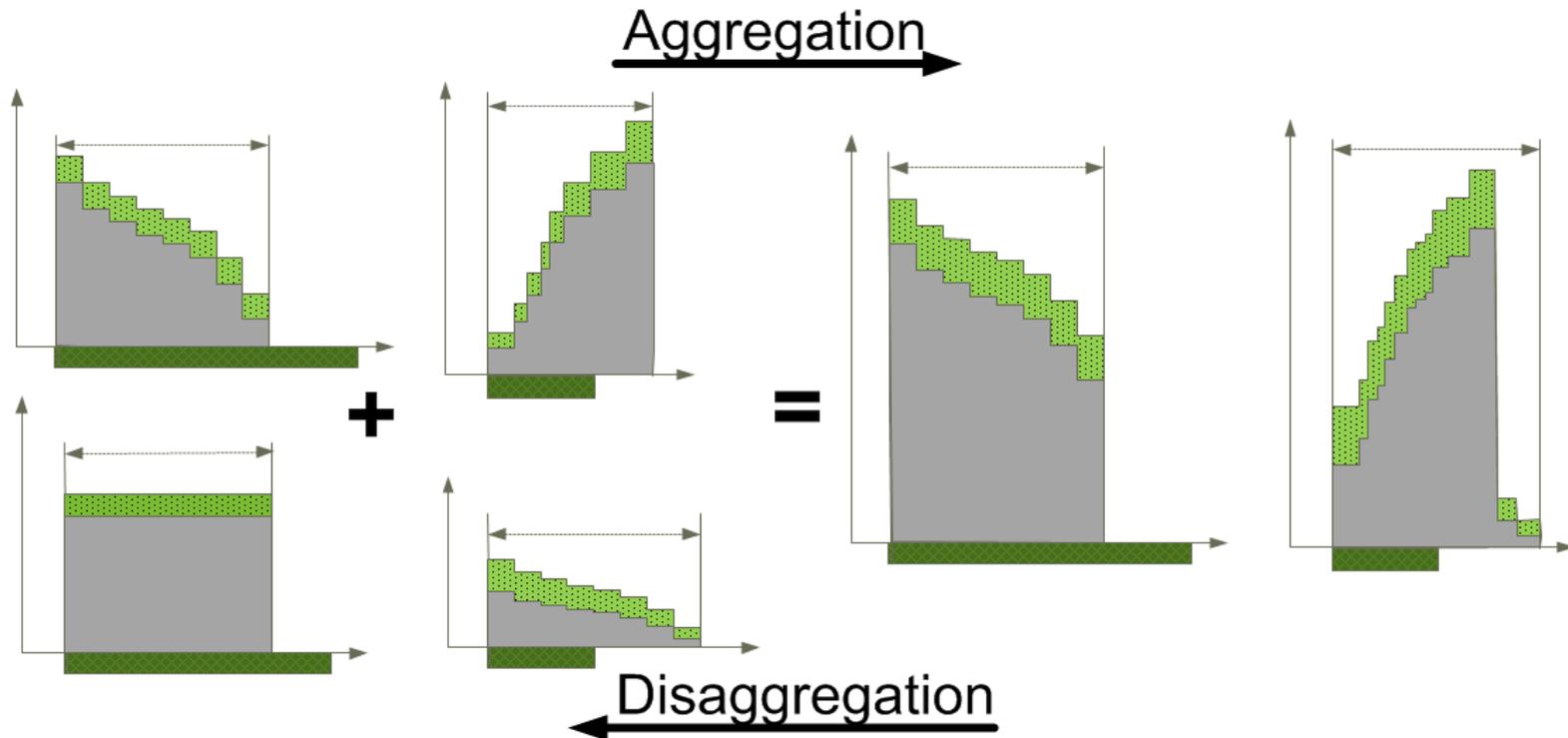
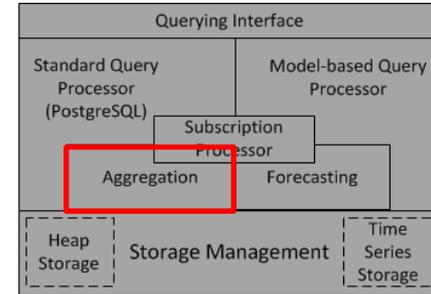- ## Data bulk loading approach:
  – Intermediate store in main memory
  – Available for queries
 – Materialized in bulks
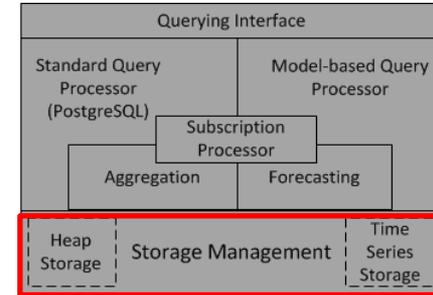
- ## For flex-offers and time series

- ## For high update rate – only check if time series value influences forecasts

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- Combine set of flex-offers into smaller set of flex-offers

- Preserve flexibilities!

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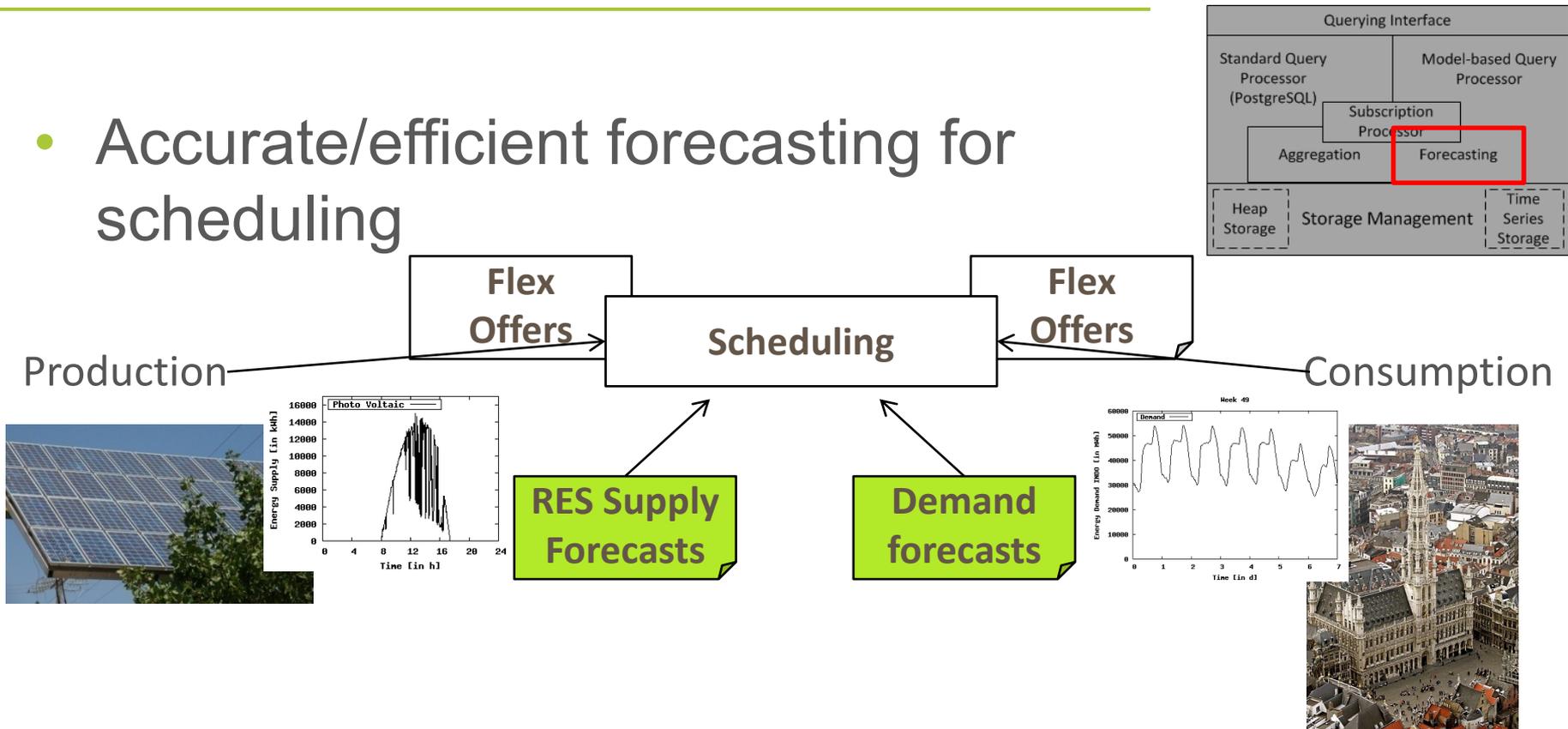
- ## Incremental aggregation solution
  - Grouping (similar)
  - Bin Packing (ensure constraints)
  - Aggregation (sum up energy)
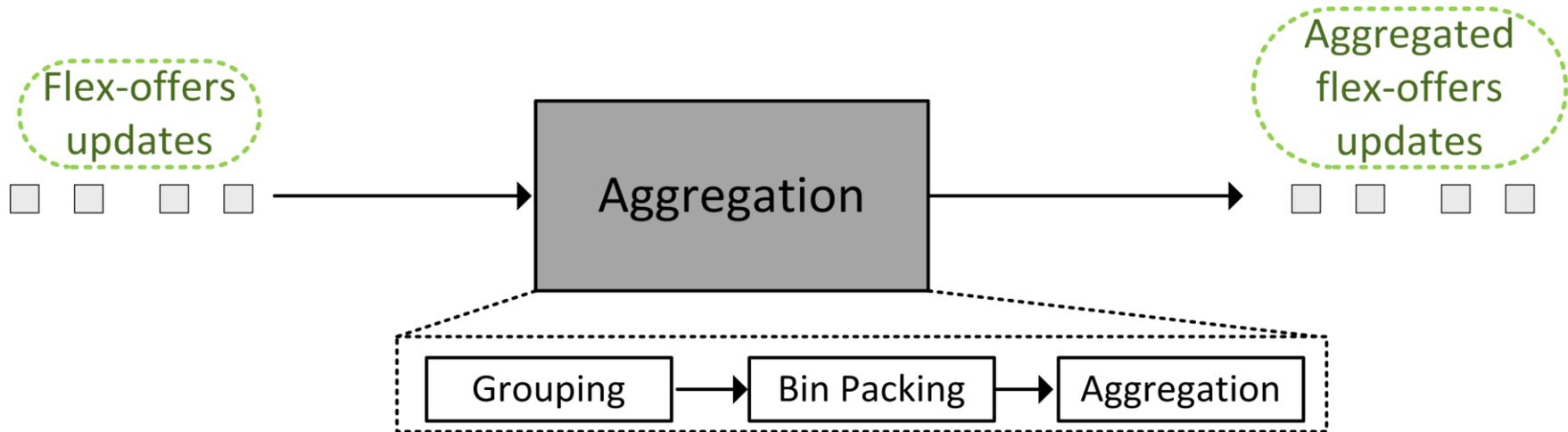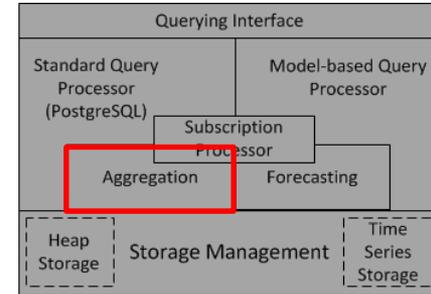
More information in Šikšnys et.al. "Aggregating and Disaggregating flexibility objects", in Proc. of SSDBM, 2012

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- ## Accurate/efficient forecasting for scheduling

Production → Flex Offers → **Scheduling** ← Flex Offers ← Consumption

RES Supply Forecasts → Scheduling
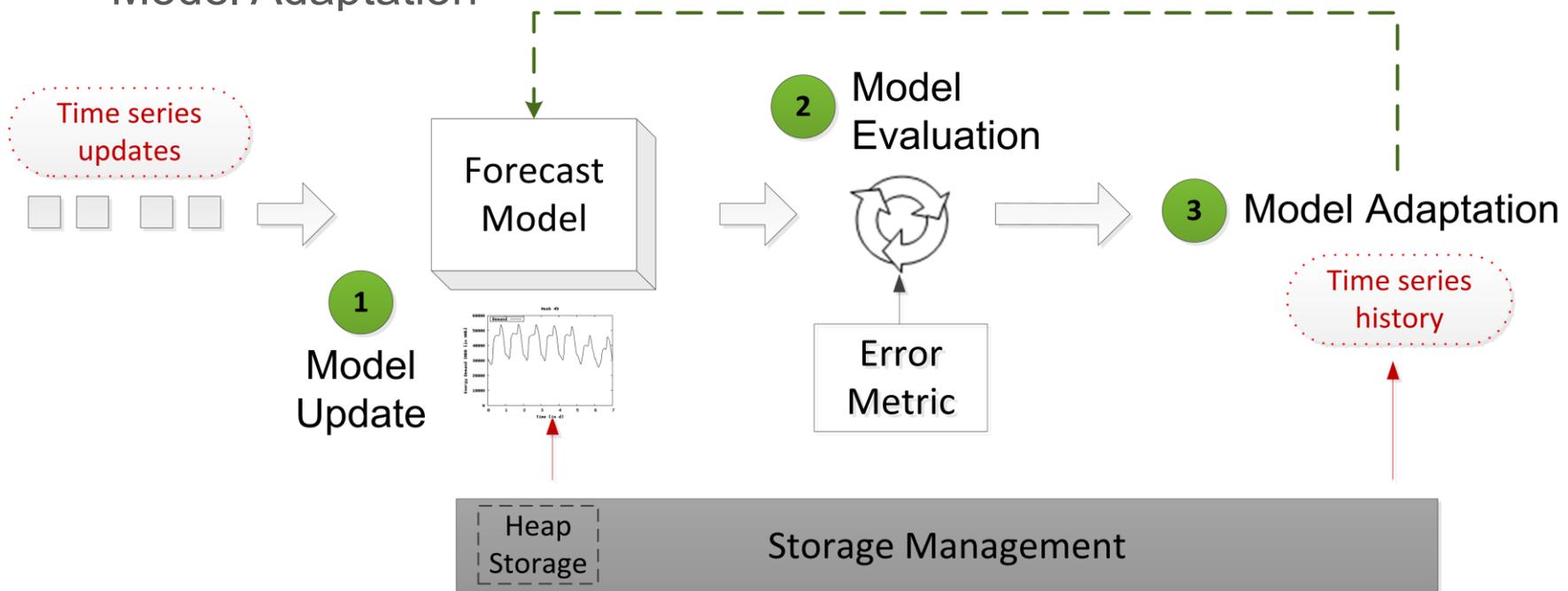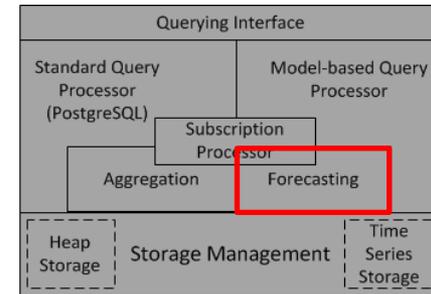
Scheduling ← **Demand forecasts**

- ## Objectives

  – Accurate forecasting of energy demand and supply

  – System architecture integration

  – Efficiency, robustness, scalability
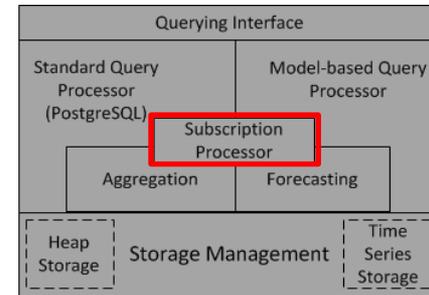
Forecasting – Model Maintenance

- ## Overview Maintenance Loop
  - Model Update
  - Model Evaluation
  - Model Adaptation

More information in Fischer et.al. "Offline Design Tuning for hierarchies of forecast models", in Proc. of BWT, 2011

**MIRABEL energy**
Balancing energy supply and demand

- ## Notifies subscribers on **substantial** changes in:
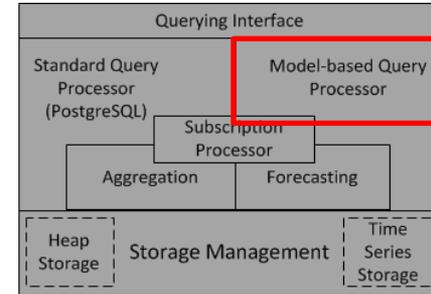 - Flex-offers
  - Forecasts

```
SELECT hour, energy_per_hour
FROM ..
FORECAST energy_per_hour ON hour
NOTIFY ON MIN HORIZON '12 hours' AND THRESHOLD 0.1
```

More information in Fischer et.al. "Optimizing Notifications of Subscription-based Forecast queries", in Proc. of SSDBM, 2012

Standard Query Processor

- ## Exact queries

- ## Operates on:
  - Time series (from Heap Storage)
  - Flex-offers

- ## Utilizes aggregation component
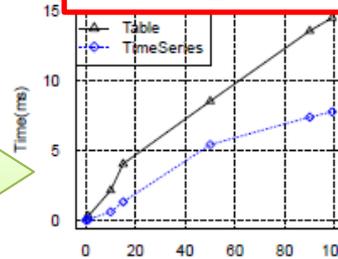
Model-based Query Processor
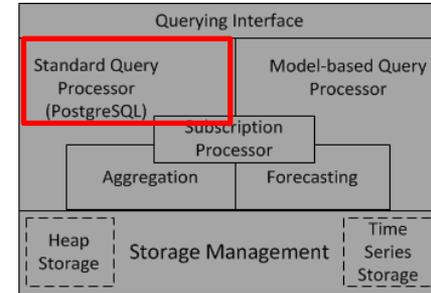
- ## Approximate queries
- ## From Time Series storage
- ## Utilizes Forecasting component
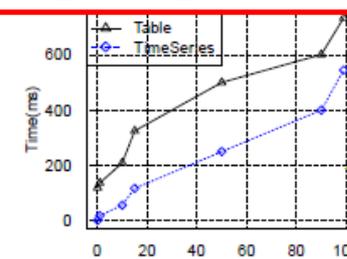
```
SELECT hour, energy_per_hour
FROM ..
WHERE time BETWEEN (now() - INTERVAL '24 hours') AND
                   (now() + INTERVAL '2 hours')
RELATIVE_ERROR 0.05
```

- ## Time Series Storage:

4.5 – 1.8 times & 100 – 1.3 times speed up

Accessing 110,000 tuples of time series

.. and building models

- ## Flex-offer Aggre-gation:

Incremental aggregation is usually better

.. and with aggrega-tion cons-traints
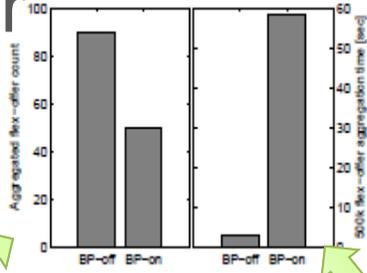
# of aggregated flex-offers

Aggregation time for 500,000 flex-offers
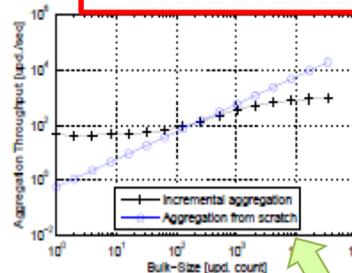
Throughput without aggregation constraints

Time/threshold update is best.

- ## Forecas-ting:

Model adap-tion

Random Restart Nedler Mead converges faster
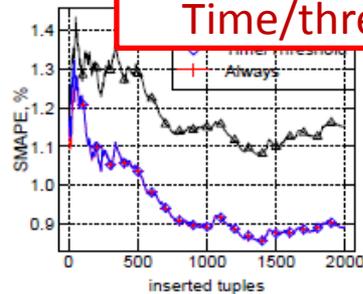
Model evaluation – forecast accuracy
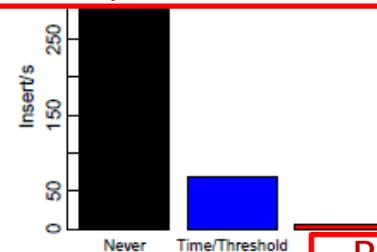
Model evaluation maintenance time

- What is MIRABEL project about?

- System architecture

  – Typical queries

  – MIRABEL use case

  – Individual components

- **Future challenges**

- Conclusions

- Distribution of EDMS nodes – consistency, efficiency, optimal communication

- More flexibilities in flex-offers – e.g., price

- Real-time DW using approximate data:
  – Build/maintain models from time series
  – Forecast future (using models)
  – New measurement: can be predicted (error < θ)?

- ## MIRABEL is unique for:

  - Flex-offer concept

  - Real-time challenges – 15 min to storing, forecasting, aggregating, scheduling

  - Analytical queries with various precision

  - Past and future time in queries

  - Distributed and hierarchical deployment architecture

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Balancing energy supply and demand

- ## Solutions:
  - Storage of flex-offers, time series + models, which enable:
    - Forecasts for future
    - Fast, approximate historical data
    - Optimize data loading
  - Aggregation using incremental approach
  - Forecasting in real-time
  - Subscription service
  - Integrated processing of approximate queries on past and future

Thank you!

Questions?