Data Lakes and Data Intelligence for Future Energy Systems

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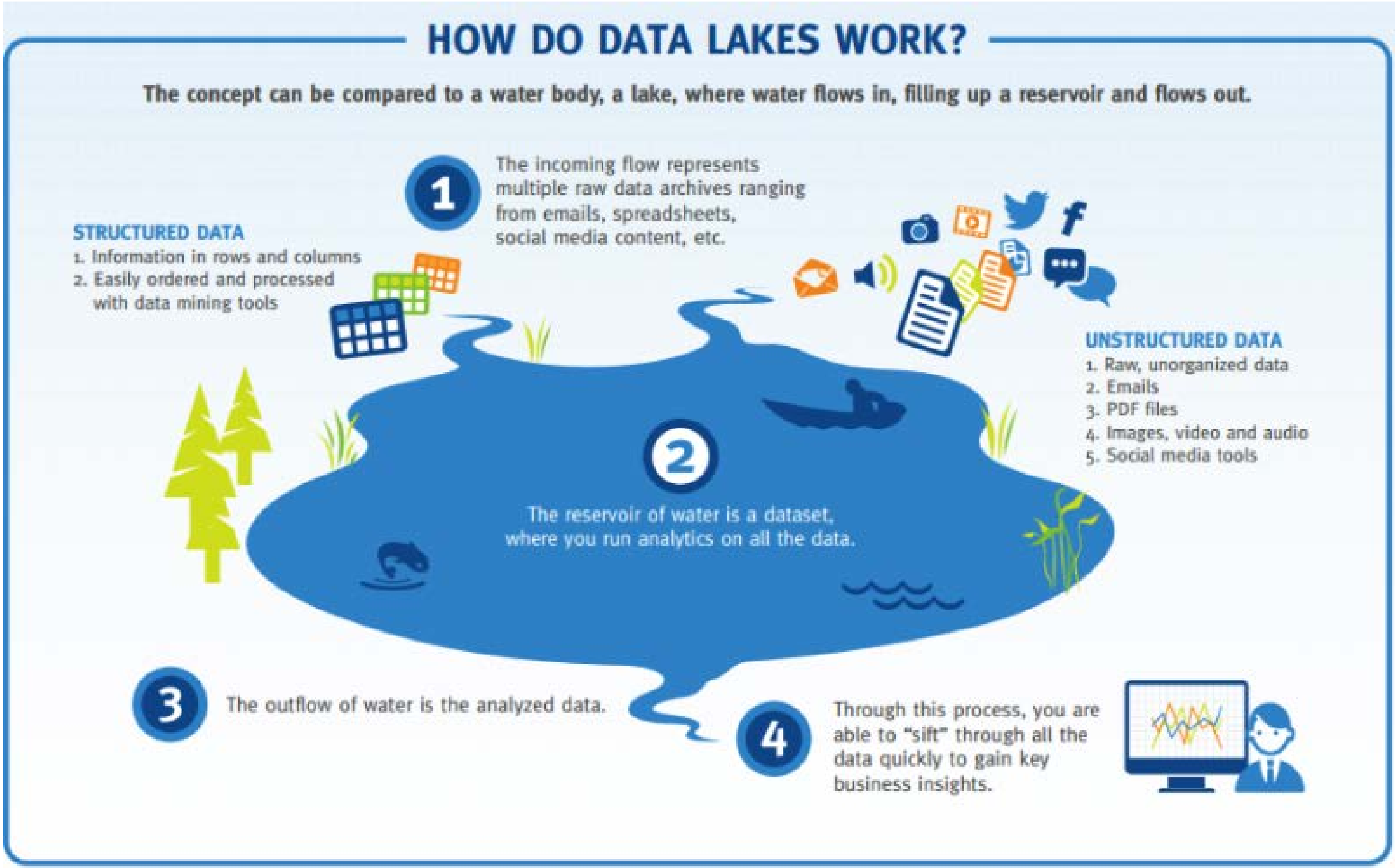
What is a Data Lake?



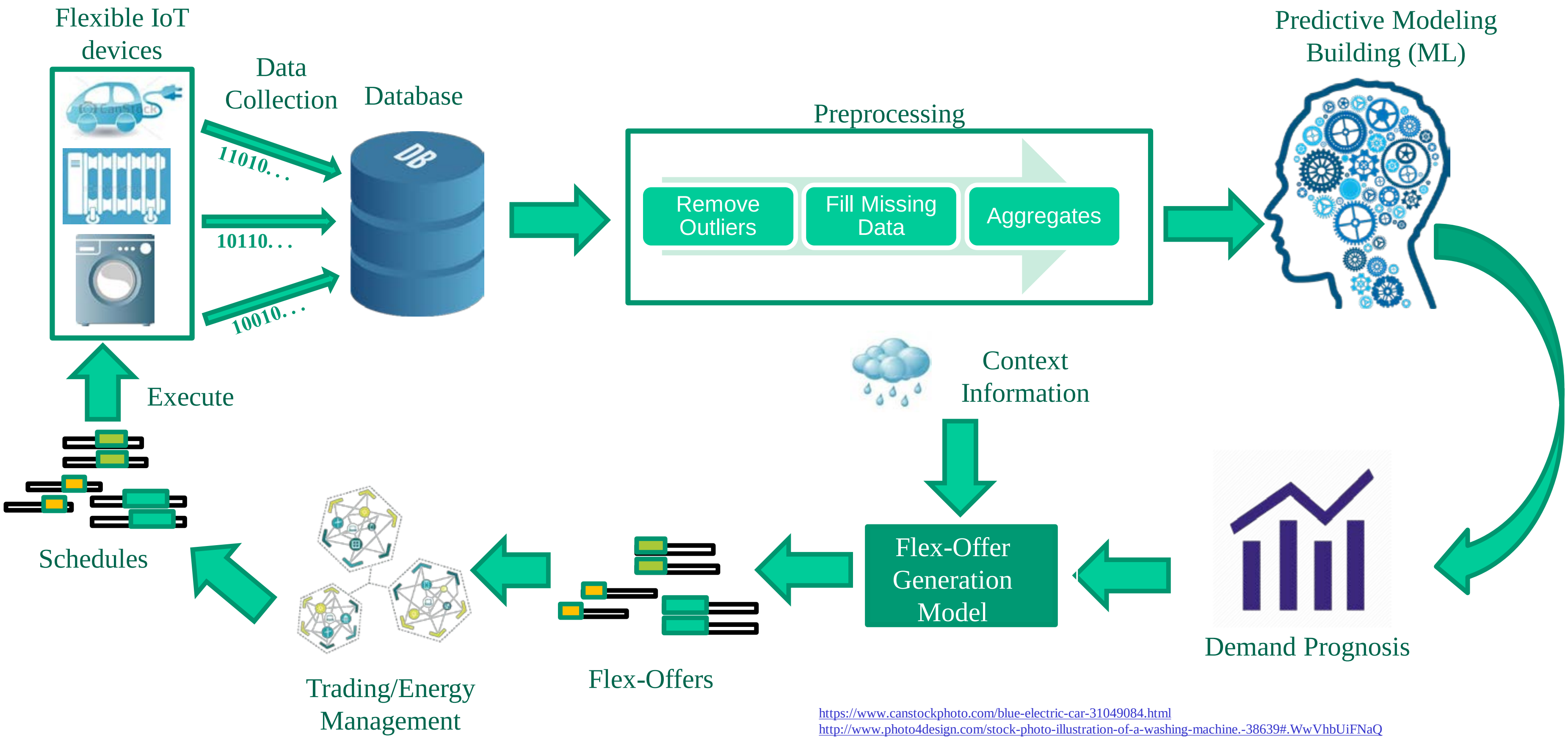
[https://www.linkedin.com/pulse/building-data-lake-using-open-source-technologies-aneel/]

DW Versus Data Lake

DATA WAREHOUSE	vs.	DATA LAKE
structured, processed	DATA	structured / semi-structured / unstructured, raw
schema-on-write	PROCESSING	schema-on-read
expensive for large data volumes	STORAGE	designed for low-cost storage
less agile, fixed configuration	AGILITY	highly agile, configure and reconfigure as needed
mature	SECURITY	maturing
business professionals	USERS	data scientists et. al.

[https://media.licdn.com/mpr/mpr/shrinknp_800_800/AAEAAQAAAAAAAARFAAAAJGFlMWEyOGU4LWJhMWYtNGYwYi1hZjk0LTFlZWNiMmI3NjNkOQ.png]

Data Intelligence: Energy Example



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https://www.123rf.com/photo_12496301_abstract-cognitive-intelligence.html
https://clip-art-guru.info/weather-clip-art-for-preschoolers/weather-clip-art-for-preschoolers-clip-art-weather-forecast-clipart-clipart-kid/

Data Intelligence: Many Steps…

- **Model** the data
  - What data is available, how is it structured and connected?
- **Collect** the data
  - Using IoT (Internet of Things) devices, etc.
- **Cleanse** the data
  - Correct/tag errors, missing data, outliers
- **Integrate** the data
  - Connect different datasets, match (pseudo) keys, achieve consensus…
- **Store** the data
  - In a **data lake…**
- **Understand** the data
  - Query, analyze, visualize,
- **Predict** the data
  - Build+test machine learning models to predict the future
- **Optimize** given **certain** objectives
  - Based on data and predictions
- **Make decisions and act**
  - Manual or (semi-)automated, what-if,
- **Control/Actuate** to put the decision into action
  - IoT works both ways

What are the challenges?

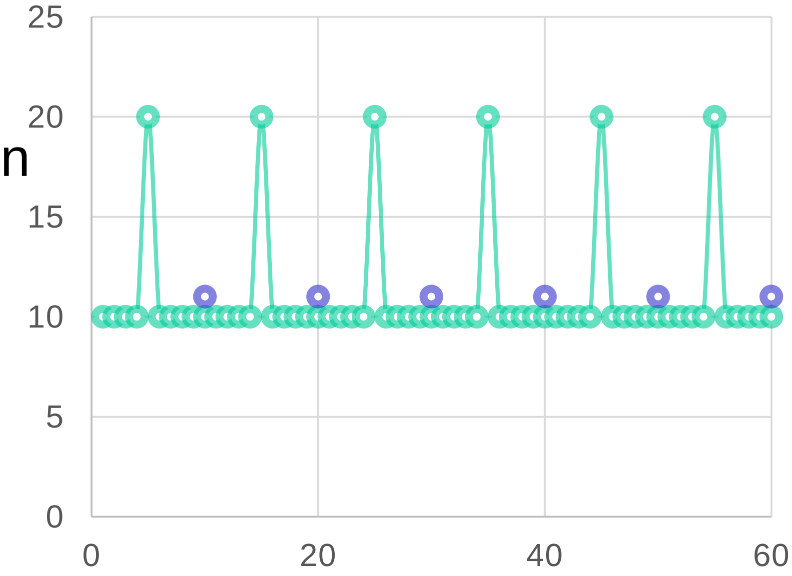
- **Many** challenges in **each** step
- I will talk about 2 specific data management challenges

- Storing and querying massive amounts of fast sensor data
  - Model-based storage and querying
  - **ModelarDB**

- Integrating data+models+optimization
  - Prescriptive analytics
  - Tool that does this **efficiently** and with high programmer **productivity**
  - **SolveDB**

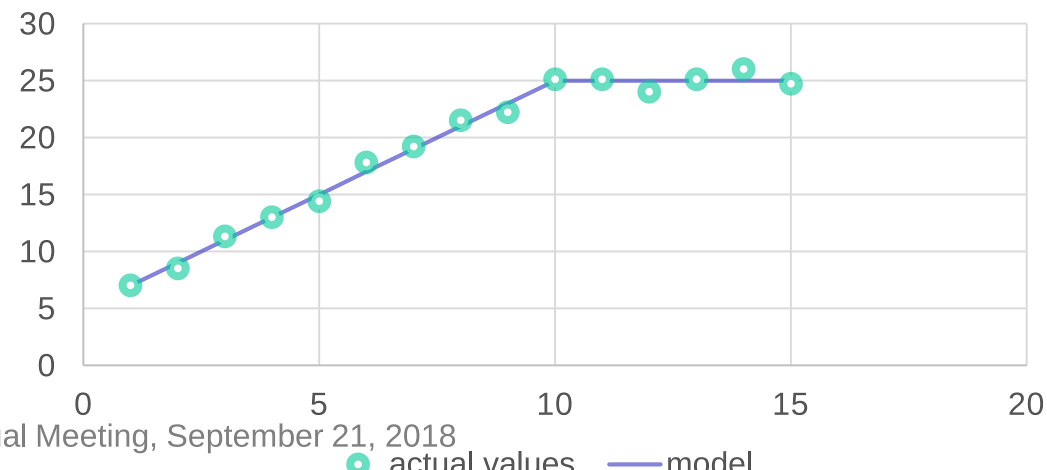
Massive, Fast Sensor Data

- Wind turbines/solar panels: 100s of sensors read subsec
  - A modern wind turbine has up to 15,000 streams
- This generates a lot of data
  - 10 reads/second, 4 bytes, 15000 streams ➔ ~50 GiB/day/turbine. 100s in a park, 1000s of parks, 20 years…
- Currently not fully exploited/stored
- Typical setup:
  - Consider few (~100) streams
  - Store single avg value every 5-15 min
- Fast variations not seen



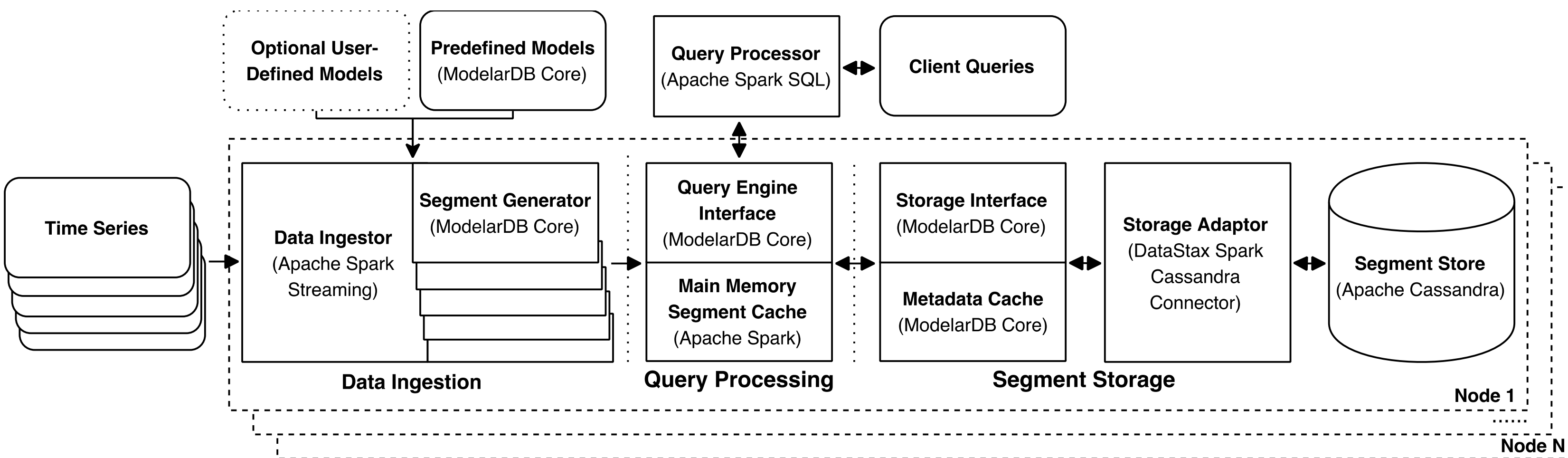
Model-Based Data Storage

- Want store and use **all** available sensor data
- Support efficient aggregate queries on historical data
- Streaming analysis of data while it is being ingested
  - Detect underperformance and other problems immediately
  - Enable predictive maintenance
  - Detect and fix a problem before the wind turbine breaks
- Represent data by **models**
  - Store model **parameters** rather than data values
  - User-defined error (0,1,5%) allowed



ModelarDB

- ***ModelarDB*** uses models to store time series data
- Time series functionality in a system-agnostic library
- Some built-in model types, user can add user-def model
- ModelarDB will automatically pick the best
- Query processing and storage by (Spark & Cassandra)

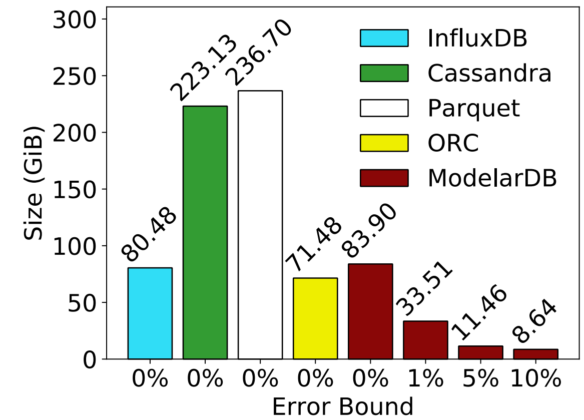


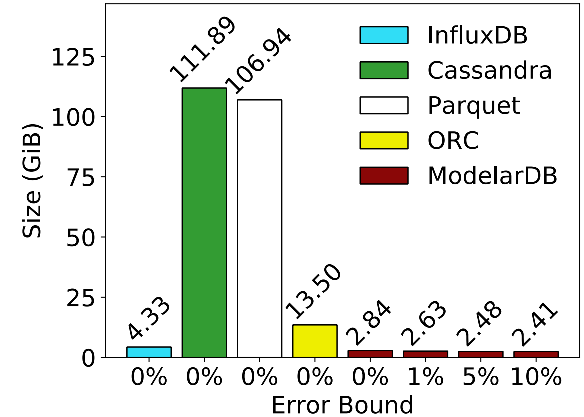
Performance/storage results

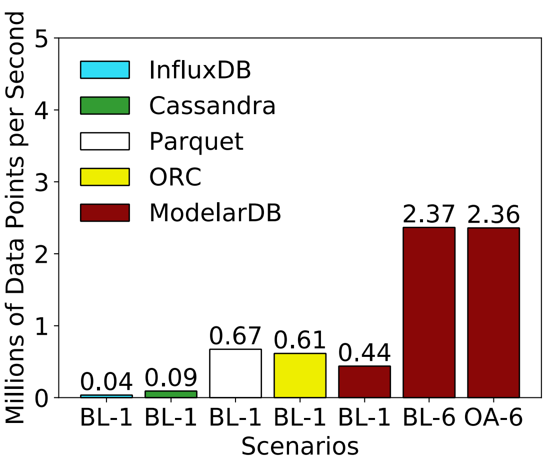
- High ingestion rates
  - Allows **online** analytics unlike ORC/Parquet
- Better compression than competitors, even InfluxDB/ORC
  - Achieved by **adaptively using multiple models**
- Low average errors, much lower than error bounds
  - Degrades gracefully as outliers are added
- Close to linear scalability up to 32 nodes
- Effective query optimizations
- Better performance for large aggregate queries
  - Comparable for small aggregate and point-range
- Provides unique **"sweet spot"**
  - Fast ingestion+good compression+fast, scalable online aggregate query processing

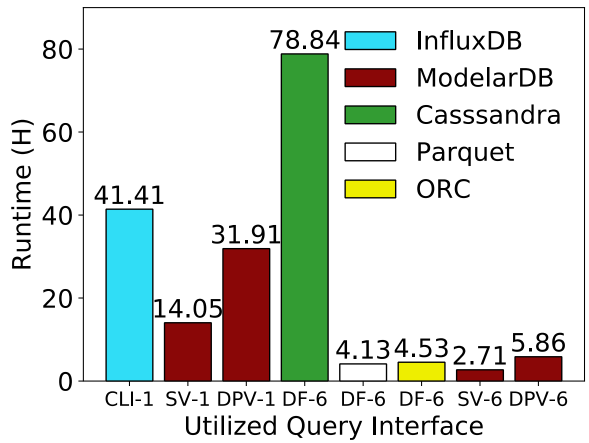
ModelarDB Evaluation Summary

- Provides unique **"sweet spot"**
  - Best compression
  - Fast ingestion
  - Fast, scalable online aggregate query processing









What is Prescriptive Analytics?

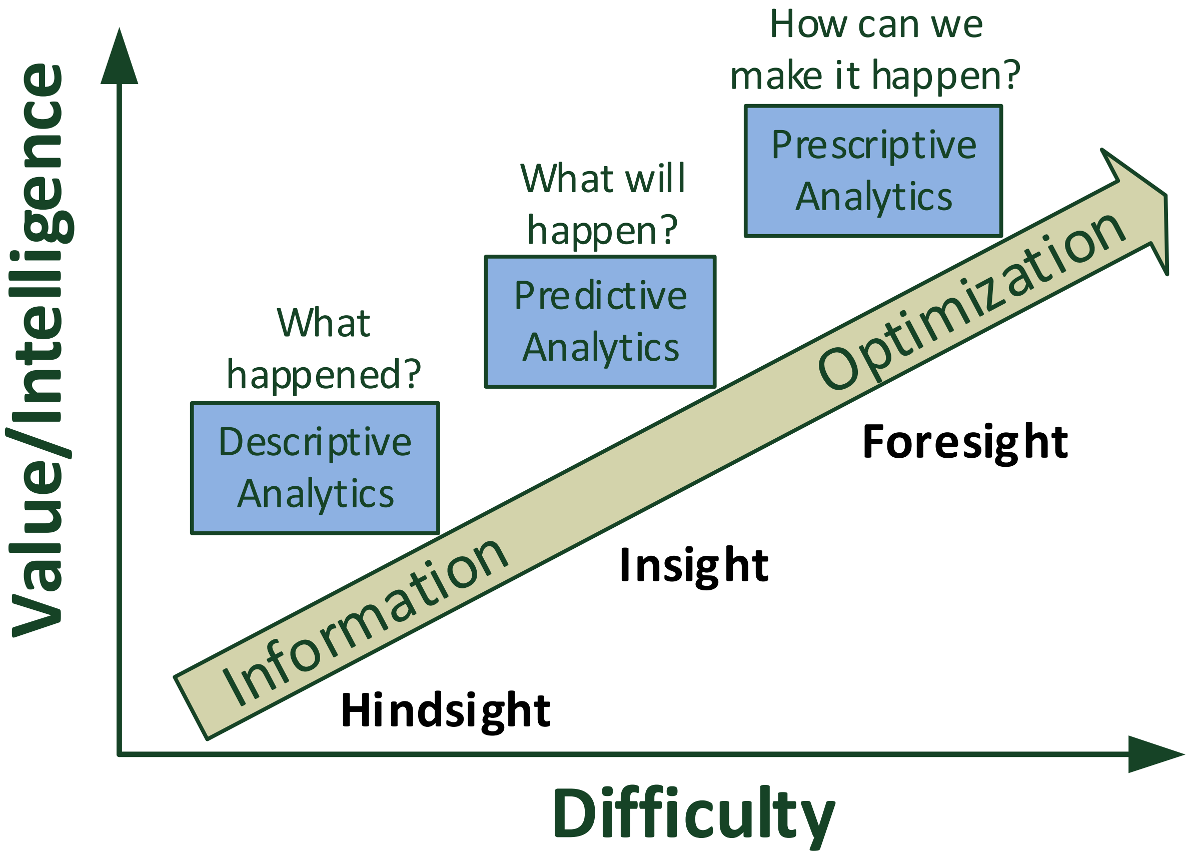
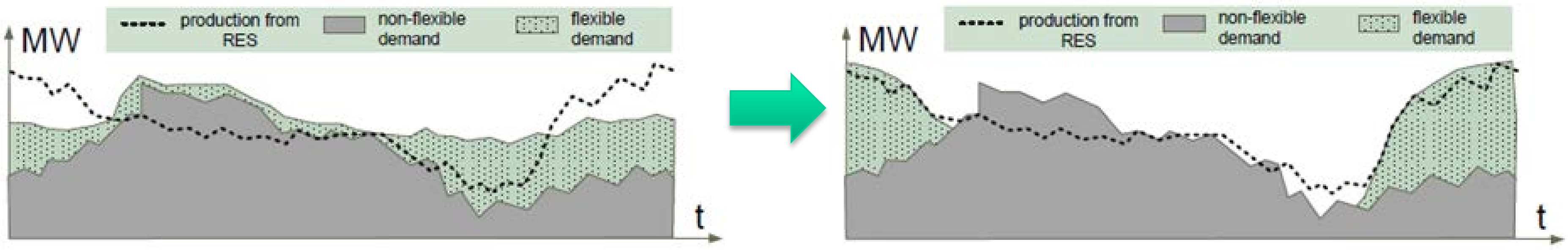


Figure 1: Three stages of business analytics (source "Gartner Inc.")

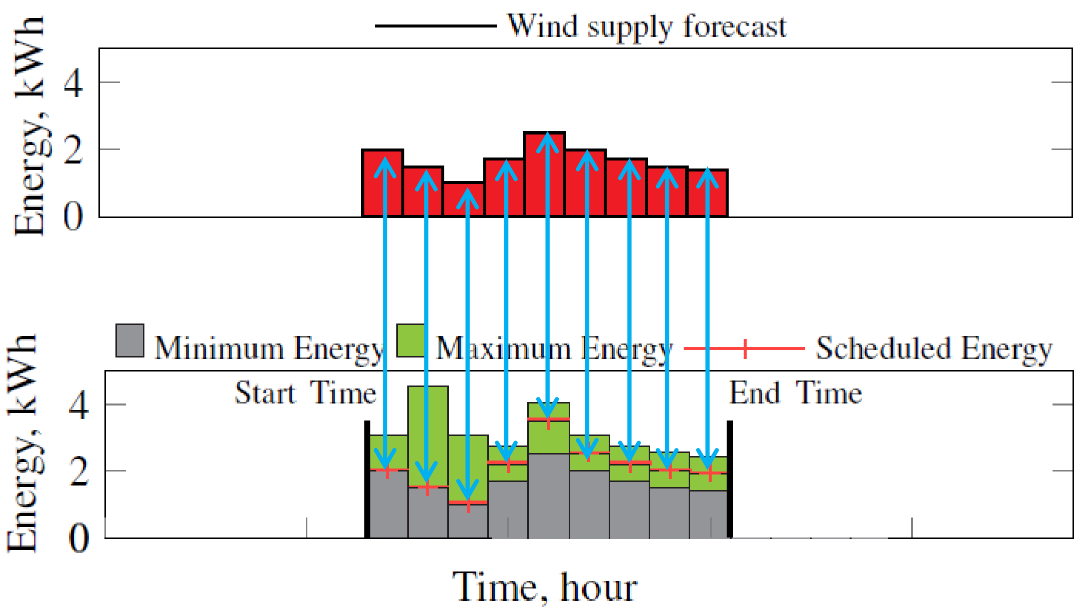
An Example from Smart Energy

- Balancing demand and supply



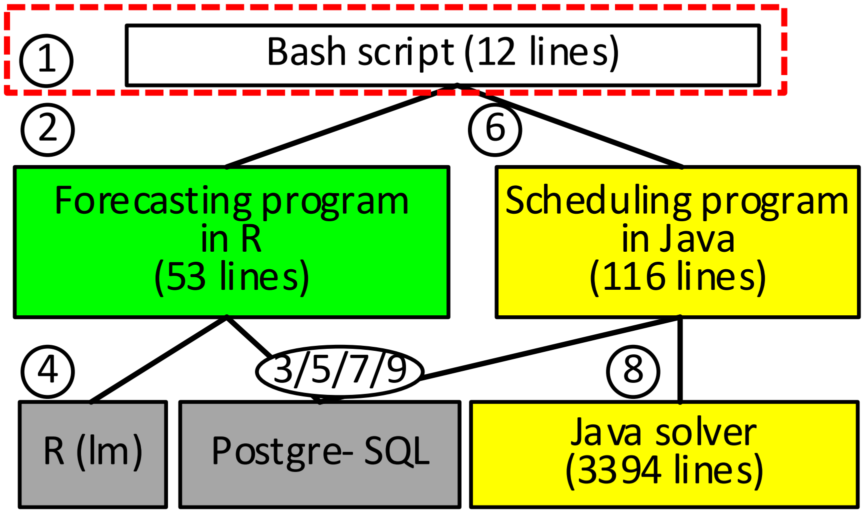
Step 1: Forecast RES production

Step 2: Generate demand FlexOffers



Traditional Solution

- Implementation based on RDBMS + R + Java solver

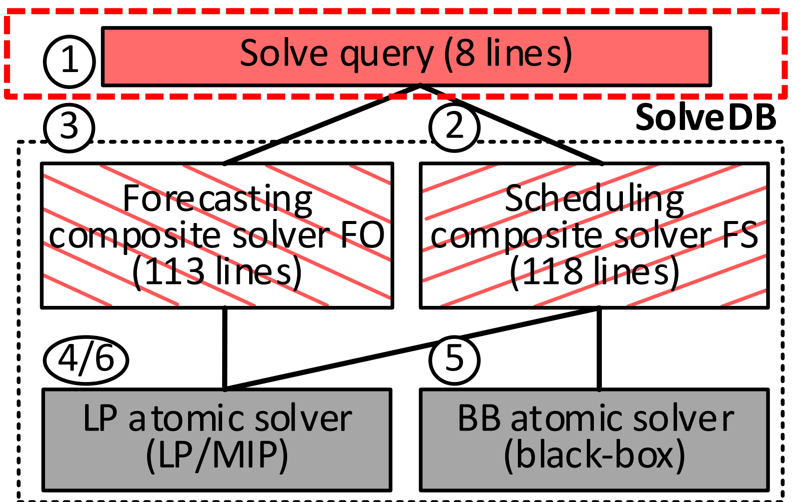



```
#!/bin/bash
export mirabelDbUrl="jdbc:postgresql://localhost/postgres";
export mirabelDbUsername="postgres";
export mirabelDbPassword="";
export mirabelRoot="`pwd`";
export CLASSPATH="$CLASSPATH:.:../FlexOffers/Implementation/SDB-
scheduling-experiments/target/sdb-scheduling-experiments-0.9.9-
SNAPSHOT.jar:../FlexOffers/Implementation/SDB-scheduling-
experiments/target/dependency/*"

# Run forecasting
(time Rscript ergv_forecast.R) &> output_fc_r.txt

# Check for the forecasting error
fcerror=`psql -d postgres -c "SELECT * FROM forecast_error"
-Ptuples_only`

echo "Forecasting error (MAPE): " $fcerror

# Run scheduling
(time java -Xmx1000m -Xss10m
org.mirabel.aggregation.experiments.AggSchExperiment) &>
output_sch_c.txt

# Check for imbalance
schImb=`psql -d postgres -c "SELECT * FROM scheduling_imbalances;"
-Ptuples_only`

echo "Scheduling remaining imbalance (kWh): " $schImb
```

- Problems:
  - Non-integrated specialized glued together in ad-hoc fashion
  - Labor-intensive, error-prone, inefficient

SolveDB Solution [SSDBM16,ICDE17]

- SolveDB (PostgreSQL + solvers)
  - Integrates RDBMS and LP/MIP, BB, and specialized solvers
  - Uses SQL extension for problems




```
SOLVESELECT sch IN (SELECT fo, NULL::schedule AS sch
                    FROM flexobject) AS t
SUBJECTTO (SELECT is_instanceof(sch, fo) FROM t),
          (SOLVESELECT load IN (SELECT time, load
                                FROM hist_load) AS s
           SUBJECTTO (SELECT time, temp
                      FROM temp_data)
           WITH solverFO)
WITH solverFS(rndseed:=12345, sn:=3176)
```

Specifies forecasting

Specifies scheduling

  - Lines of code: 3571 versus 237
    - **1-2 orders of magnitude less code** for most cases
  - I/O time: 7.3 versus 0.8 secs
    - up to **2 orders of magnitude faster I/O** for other cases

Conclusion

- Future Energy Systems
  - Lots of data from many new sensors and devices
  - Many types of data, very large volumes, very fast data
- Data Lake
  - Central repository for all the data
  - Challenge: store big and fast sensor streams
  - **ModelarDB**: model-based storage + querying of sensor streams
- Data Intelligence
  - Add **prediction and optimization** on top of the data
  - Challenge: **ease-of-use/productivitty and efficiency**
  - **SolveDB:** integrate data, prediction, and optimization with SQL
- Future work:
  - Data lakes: compression of multi time series, indexing
  - Data intelligence: SolveDB +physical models, MPC in the database

References

- S. K. Jensen, T. B. Pedersen, C. Thomsen. *Time Series Management Systems: A Survey*. IEEE TKDE, 2017.
- S. K. Jensen, T. B. Pedersen, C. Thomsen. *ModelarDB: Modular Model-Based Time Series Management with Spark and Cassandra*, PVLDB, 2018
- L. Siksnys and T. B. Pedersen*: Integrating Optimization Problem Solvers Into SQL Databases*, SSDBM 2016
- L. Siksnys and T. B. Pedersen*. Demonstrating SolveDB: An SQL-based DBMS for Optimization Applications,* ICDE 2017

- Siksnys et al. *Aggregating and Disaggregating Flexibility Objects*. TKDE 2015
- Siksnys et al. *Dependency-based FlexOffers: scalable management of flexible loads with dependencies*. *ACM e-Energy 2016*
- Neupane et al. *Generation and Evaluation of Flex-Offers from Flexible Electrical Devices,* ACM e-Energy 2017 (**Best paper award**)

Links

- http://people.cs.aau.dk/~tbp
- http://www.dicyps.dk
- https://github.com/skejserjensen/ModelarDB
- http://daisy.aau.dk/solvedb

- http://goflex-project.eu
- http://goflex-community.eu
- http://goflex-community.eu/PlayVideo.asp?Video=1505_BAUM_GOFLEX_Final.mp4
- http://www.flexshape.dk
- http://www.totalflex.dk
- http://www.arrowhead.eu