UIUC Capstone

Ensemble Learning and Reinforcement Learning for Energy Demand Prediction

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Mentor: Julio Massignan,
Mentor: Ashmin Mansingh

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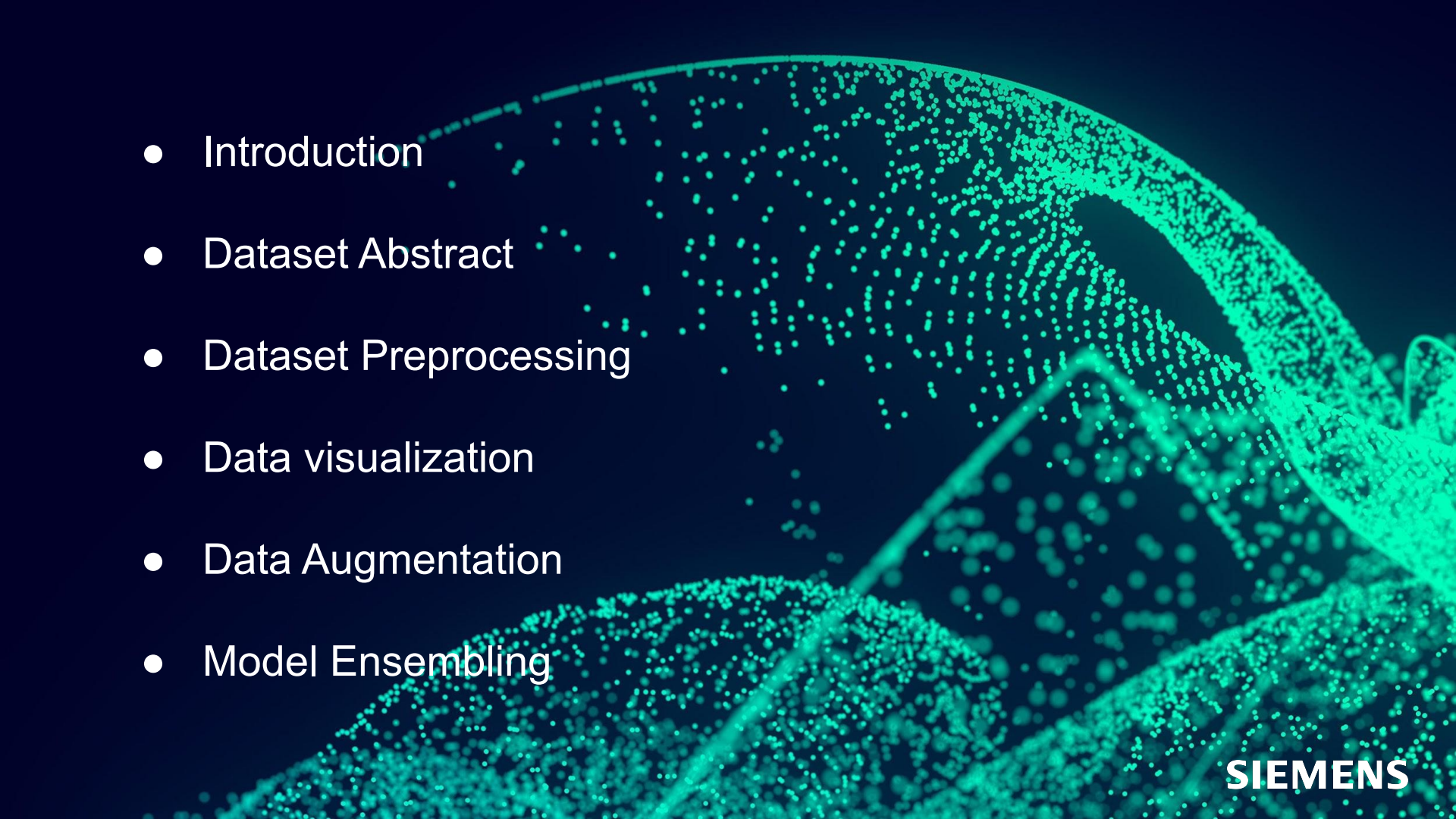
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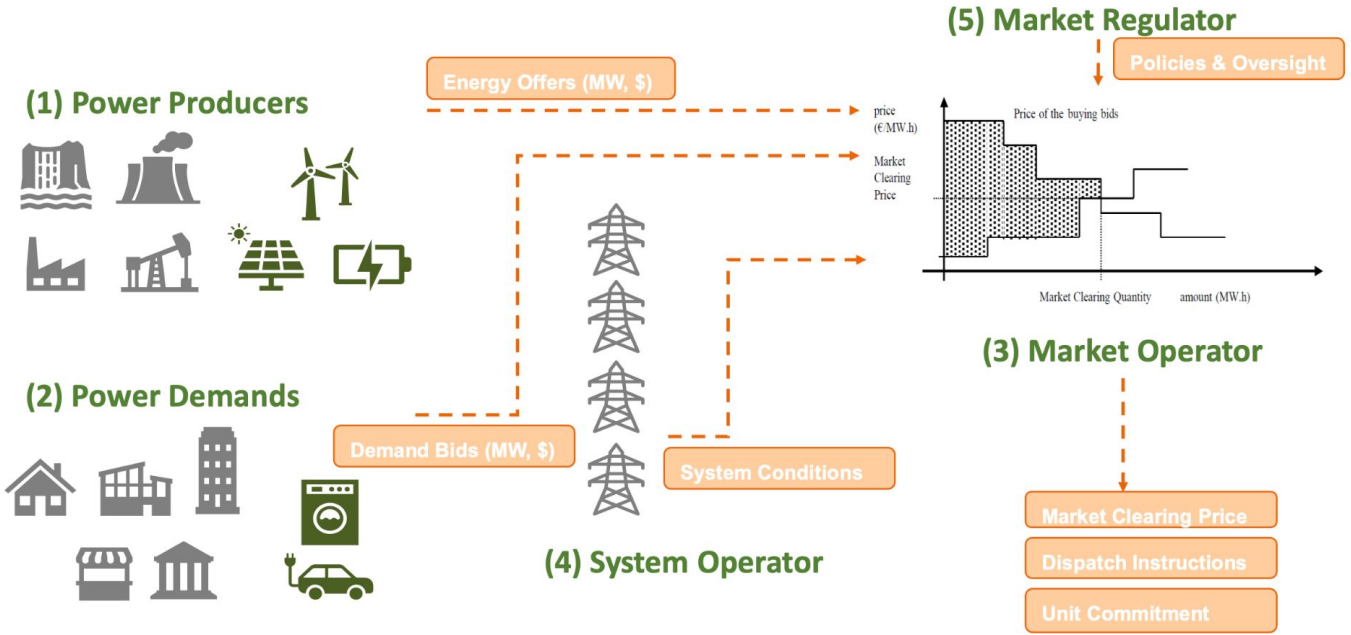
CAISO (California Independent System Operator)

Basic Concepts from Energy Markets
The role of resources optimization



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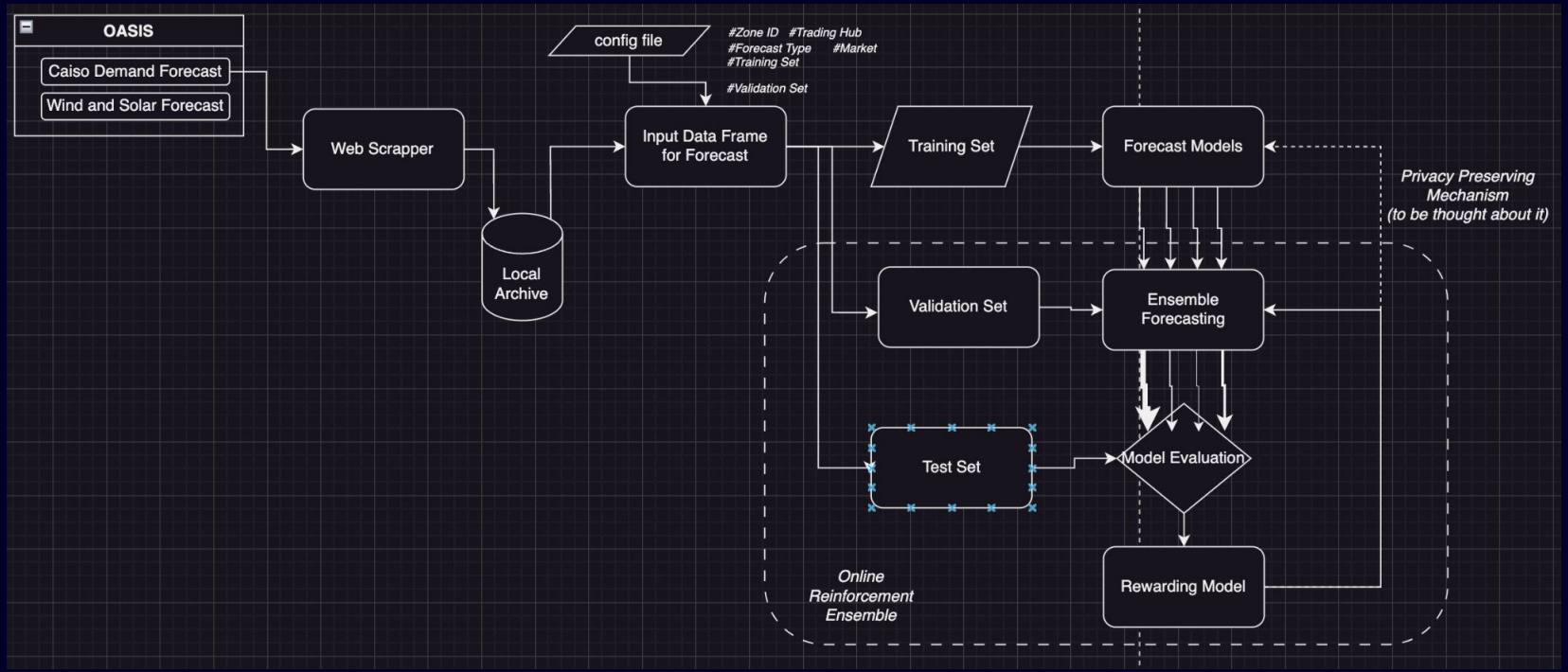
Overall Plan for demand forecasting



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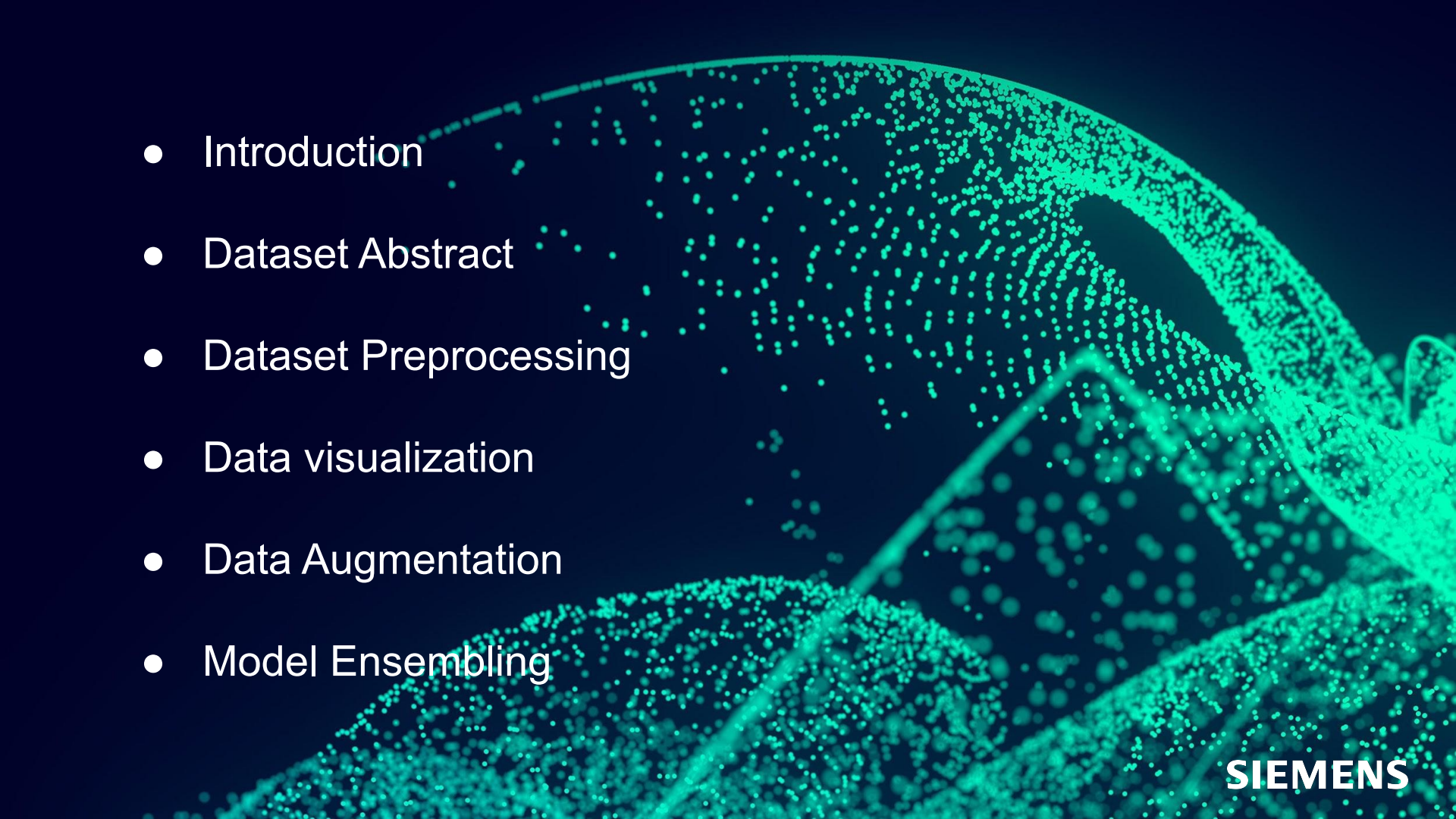
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CAISO Dataset

DAM: Day Ahead Market

ACTUAL: Ground Truth Data

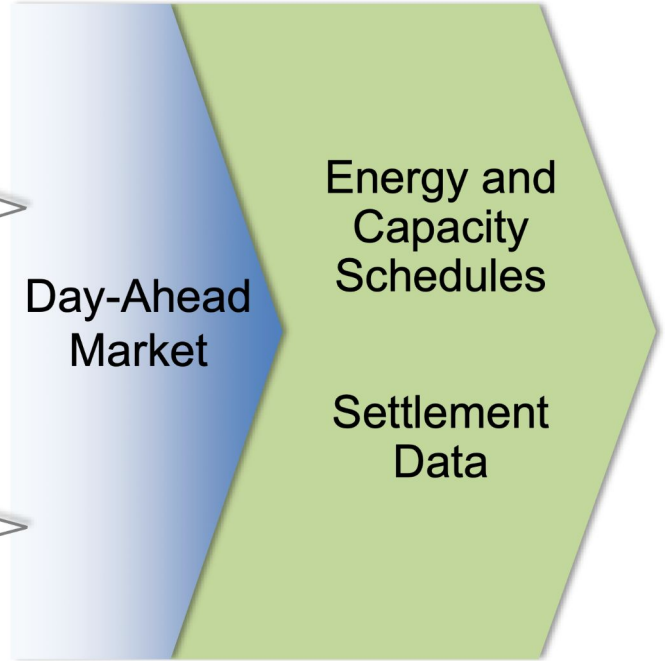
RTD: Real Time Dispatch

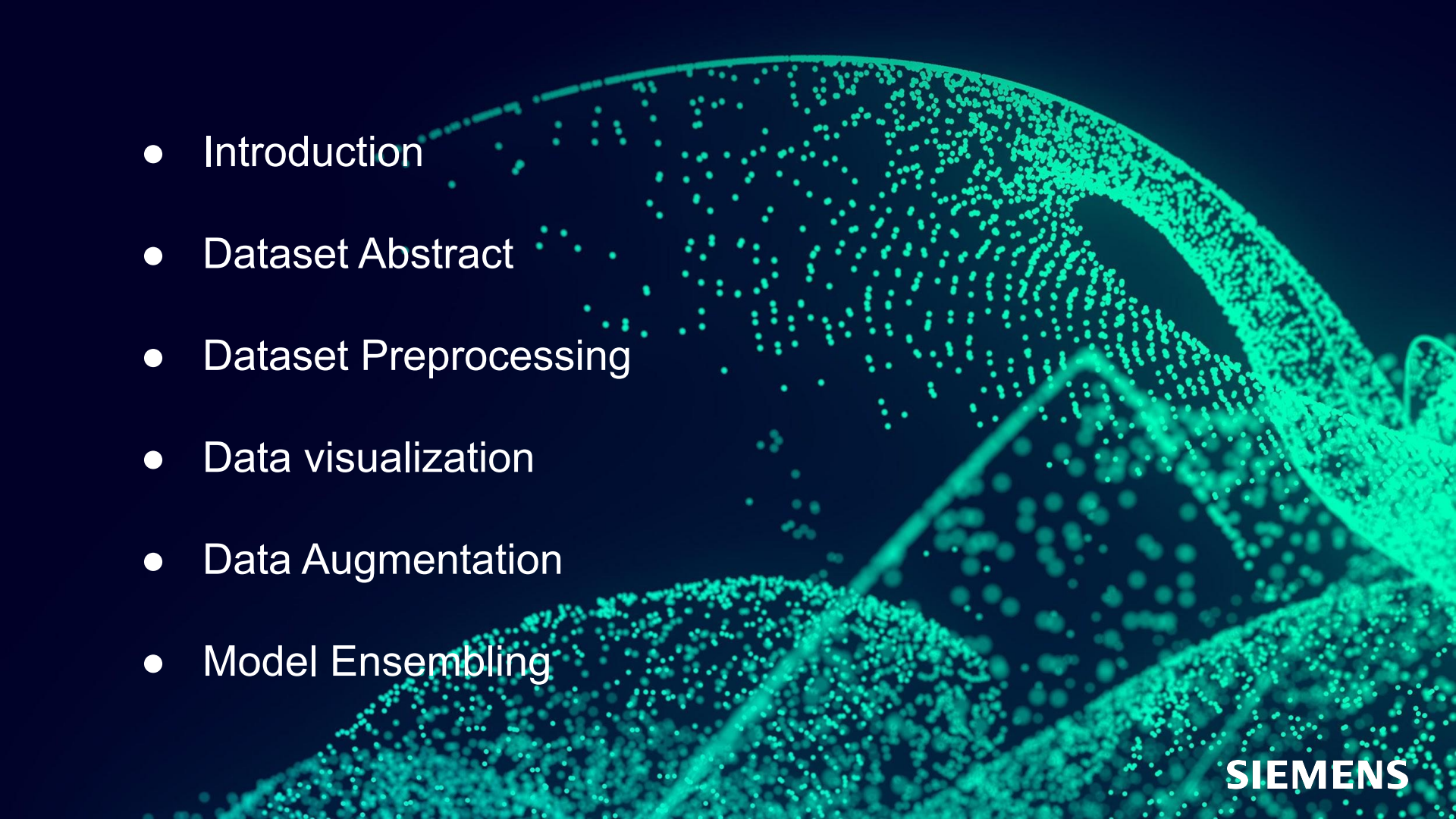
RTPD: Read Time Pre-Dispatch

Inputs and outputs of the **day-ahead** market

Data:
- System parameters
- Resource parameters
- Outage information
- Bid information
- ISO forecast of demand
- Transmission interface limits

Requirements:
- Reserves
- Residual unit commitment
- Energy to serve demand

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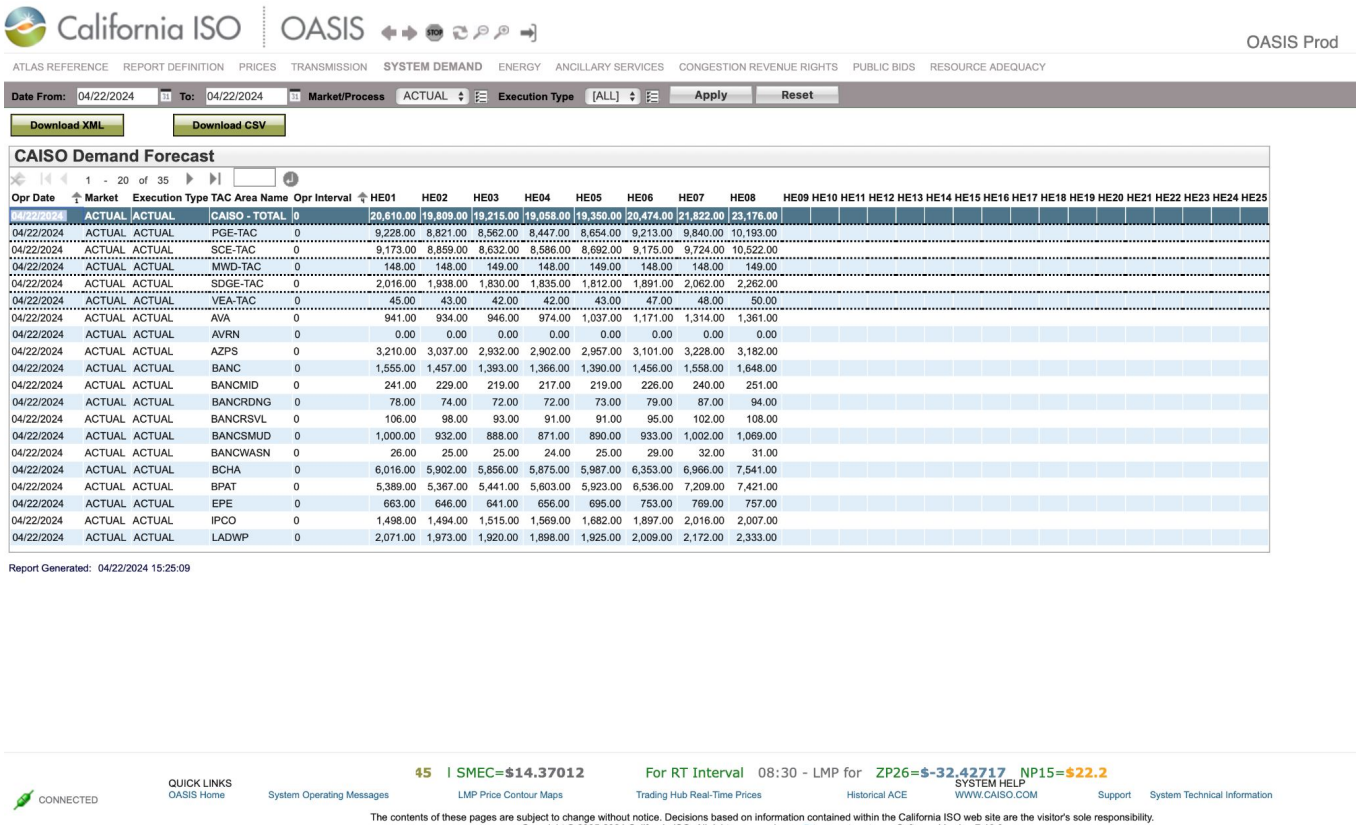

Opr Date	Market	Execution Type	TAC Area Name	Opr Interval	HE01	HE02	HE03	HE04	HE05	HE06	HE07	HE08	HE09	HE10	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20	HE21	HE22	HE23	HE24	HE25
04/22/2024	ACTUAL	ACTUAL	CAISO - TOTAL	0	20,610.00	19,809.00	19,215.00	19,058.00	19,350.00	20,474.00	21,822.00	23,176.00																	
04/22/2024	ACTUAL	ACTUAL	PGE-TAC	0	9,228.00	8,821.00	8,562.00	8,447.00	8,654.00	9,213.00	9,840.00	10,193.00																	
04/22/2024	ACTUAL	ACTUAL	SCE-TAC	0	9,173.00	8,859.00	8,632.00	8,586.00	8,692.00	9,175.00	9,724.00	10,522.00																	
04/22/2024	ACTUAL	ACTUAL	MWD-TAC	0	148.00	148.00	149.00	148.00	149.00	148.00	148.00	149.00																	
04/22/2024	ACTUAL	ACTUAL	SDGE-TAC	0	2,016.00	1,938.00	1,830.00	1,835.00	1,812.00	1,891.00	2,062.00	2,262.00																	
04/22/2024	ACTUAL	ACTUAL	VEA-TAC	0	45.00	43.00	42.00	42.00	43.00	47.00	48.00	50.00																	
04/22/2024	ACTUAL	ACTUAL	AVA	0	941.00	934.00	946.00	974.00	1,037.00	1,171.00	1,314.00	1,361.00																	
04/22/2024	ACTUAL	ACTUAL	AVRN	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00																	
04/22/2024	ACTUAL	ACTUAL	AZPS	0	3,210.00	3,037.00	2,932.00	2,902.00	2,957.00	3,101.00	3,228.00	3,182.00																	
04/22/2024	ACTUAL	ACTUAL	BANC	0	1,555.00	1,457.00	1,393.00	1,366.00	1,390.00	1,456.00	1,558.00	1,648.00																	
04/22/2024	ACTUAL	ACTUAL	BANCMID	0	241.00	229.00	219.00	217.00	219.00	226.00	240.00	251.00																	
04/22/2024	ACTUAL	ACTUAL	BANCRDNG	0	78.00	74.00	72.00	72.00	73.00	79.00	87.00	94.00																	
04/22/2024	ACTUAL	ACTUAL	BANCRSVL	0	106.00	98.00	93.00	91.00	91.00	95.00	102.00	108.00																	
04/22/2024	ACTUAL	ACTUAL	BANCSMUD	0	1,000.00	932.00	888.00	871.00	890.00	933.00	1,002.00	1,069.00																	
04/22/2024	ACTUAL	ACTUAL	BANCWASN	0	26.00	25.00	25.00	24.00	25.00	29.00	32.00	31.00																	
04/22/2024	ACTUAL	ACTUAL	BCHA	0	6,016.00	5,902.00	5,856.00	5,875.00	5,987.00	6,353.00	6,966.00	7,541.00																	
04/22/2024	ACTUAL	ACTUAL	BPAT	0	5,389.00	5,367.00	5,441.00	5,603.00	5,923.00	6,536.00	7,209.00	7,421.00																	
04/22/2024	ACTUAL	ACTUAL	EPE	0	663.00	646.00	641.00	656.00	695.00	753.00	769.00	757.00																	
04/22/2024	ACTUAL	ACTUAL	IPCO	0	1,498.00	1,494.00	1,515.00	1,569.00	1,682.00	1,897.00	2,016.00	2,007.00																	
04/22/2024	ACTUAL	ACTUAL	LADWP	0	2,071.00	1,973.00	1,920.00	1,898.00	1,925.00	2,009.00	2,172.00	2,333.00																	

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INTERVALST/	INTERVALEN	LOAD_TYPE	OPR_DT	OPR_HR	OPR_INTERV	MARKET_RUI	TAC_AREA_N	LABEL	XML_DATA_I	POS	MW
2023-01-01T2	2023-01-01T2	1	2023-01-01	15	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1426.98
2023-01-01T1	2023-01-01T1	1	2023-01-01	10	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1461.02
2023-01-01T1	2023-01-01T1	1	2023-01-01	9	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1423.28
2023-01-01T0	2023-01-01T1	1	2023-01-01	2	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1164.2
2023-01-02T0	2023-01-02T0	1	2023-01-01	22	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1424.59
2023-01-02T0	2023-01-02T0	1	2023-01-01	18	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1597.37
2023-01-01T2	2023-01-02T0	1	2023-01-01	16	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1446.45
2023-01-01T1	2023-01-01T2	1	2023-01-01	12	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1462.8
2023-01-01T1	2023-01-01T1	1	2023-01-01	11	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1466.69
2023-01-01T1	2023-01-01T1	1	2023-01-01	8	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1362.17
2023-01-01T2	2023-01-01T2	1	2023-01-01	13	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1452.11
2023-01-01T1	2023-01-01T1	1	2023-01-01	5	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1187.78
2023-01-02T0	2023-01-02T0	1	2023-01-01	24	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1270.49
2023-01-01T1	2023-01-01T1	1	2023-01-01	4	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1164.94
2023-01-01T1	2023-01-01T1	1	2023-01-01	3	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1157.8
2023-01-01T0	2023-01-01T0	1	2023-01-01	1	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1183.83
2023-01-02T0	2023-01-02T0	1	2023-01-01	19	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1580.71
2023-01-02T0	2023-01-02T0	1	2023-01-01	17	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1526.89
2023-01-01T1	2023-01-01T1	1	2023-01-01	6	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1230.45
2023-01-01T1	2023-01-01T1	1	2023-01-01	7	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1290.14
2023-01-02T0	2023-01-02T0	1	2023-01-01	23	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1336.41
2023-01-02T0	2023-01-02T0	1	2023-01-01	21	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1501.16
2023-01-02T0	2023-01-02T0	1	2023-01-01	20	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1549.48
2023-01-01T2	2023-01-01T2	1	2023-01-01	14	0	DAM	AVA	Demand Forec	SYS_FCST_DA	2.8	1435.78
2023-01-02T0	2023-01-02T0	1	2023-01-01	21	0	DAM	AZPS	Demand Forec	SYS_FCST_DA	2.8	3218.27
2023-01-01T2	2023-01-01T2	1	2023-01-01	13	0	DAM	AZPS	Demand Forec	SYS_FCST_DA	2.8	2319.39
2023-01-01T0	2023-01-01T0	1	2023-01-01	1	0	DAM	AZPS	Demand Forec	SYS_FCST_DA	2.8	2708.88

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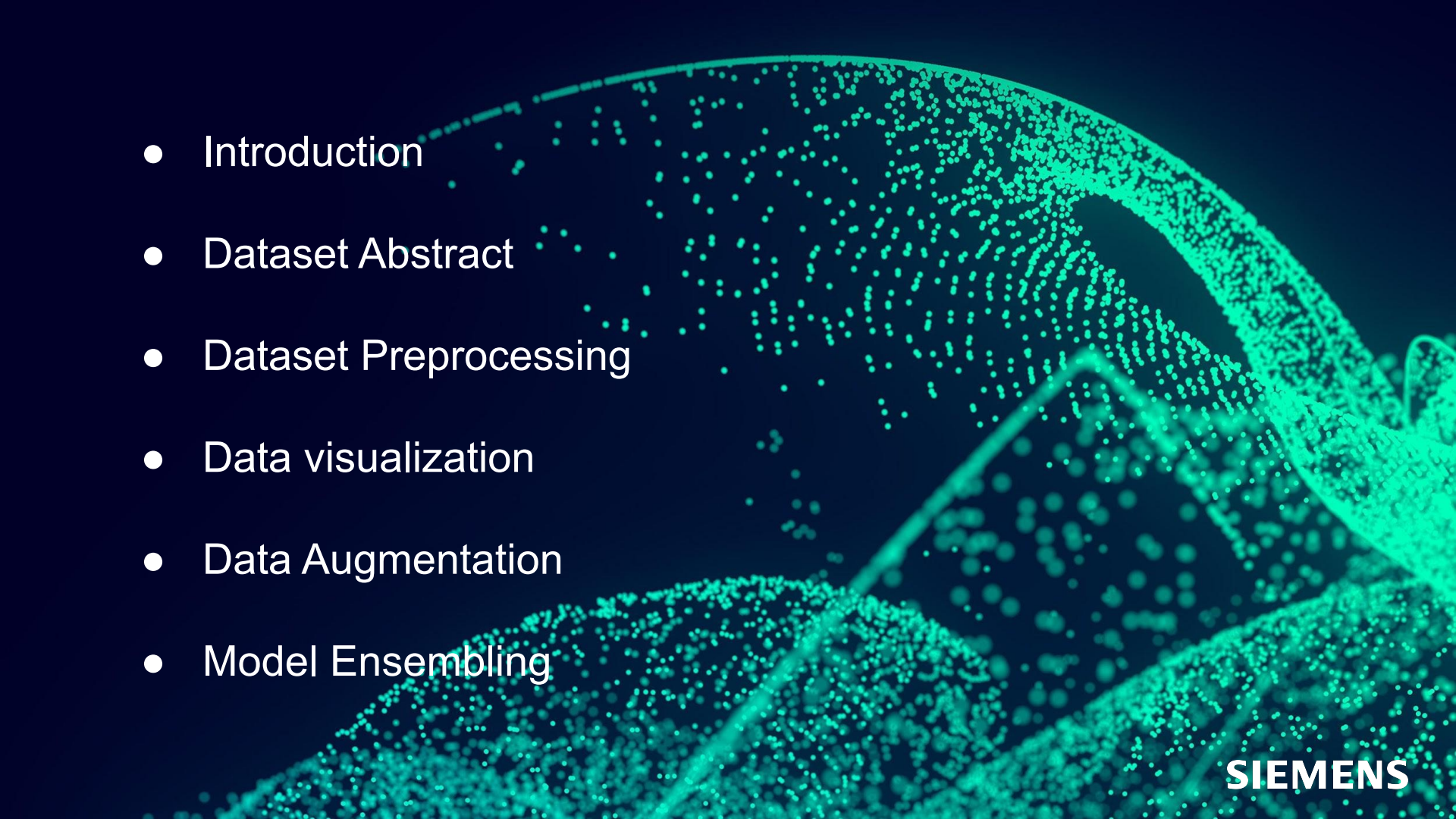
Dataset split

Training set: Jan 1st, 2023 – July 1st, 2023

Validation set: July 1st, 2023 – August 1st, 2023

Test set: August 1st, 2023 – August 20th, 2023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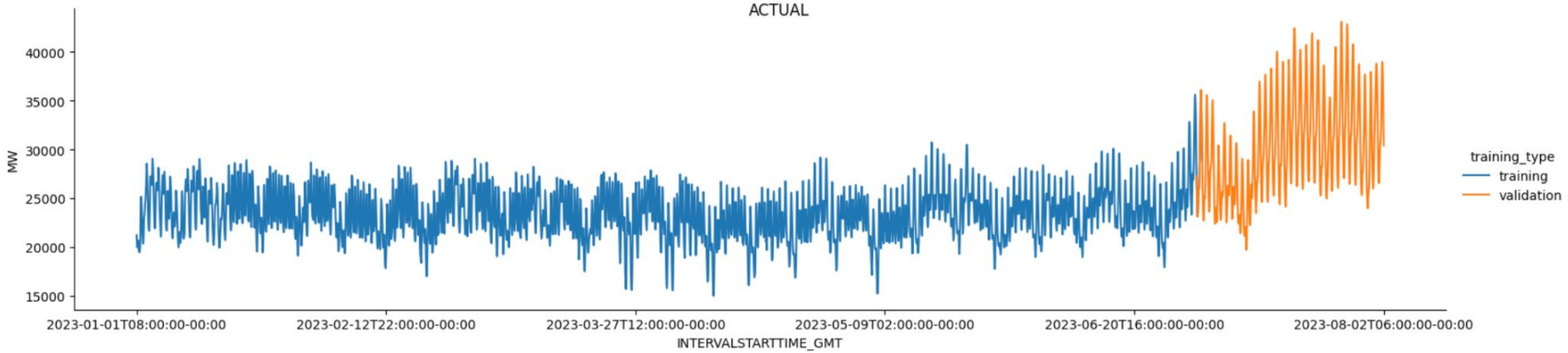
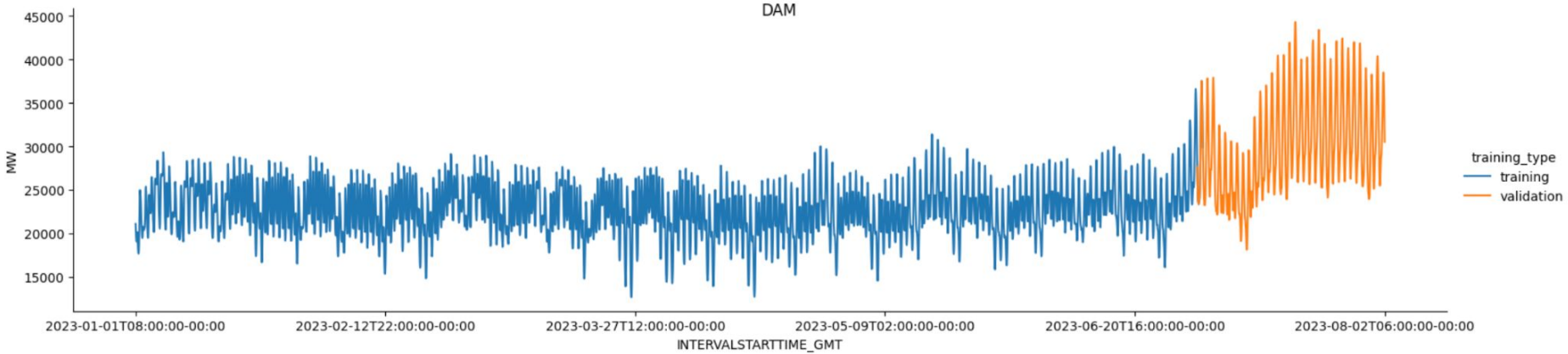
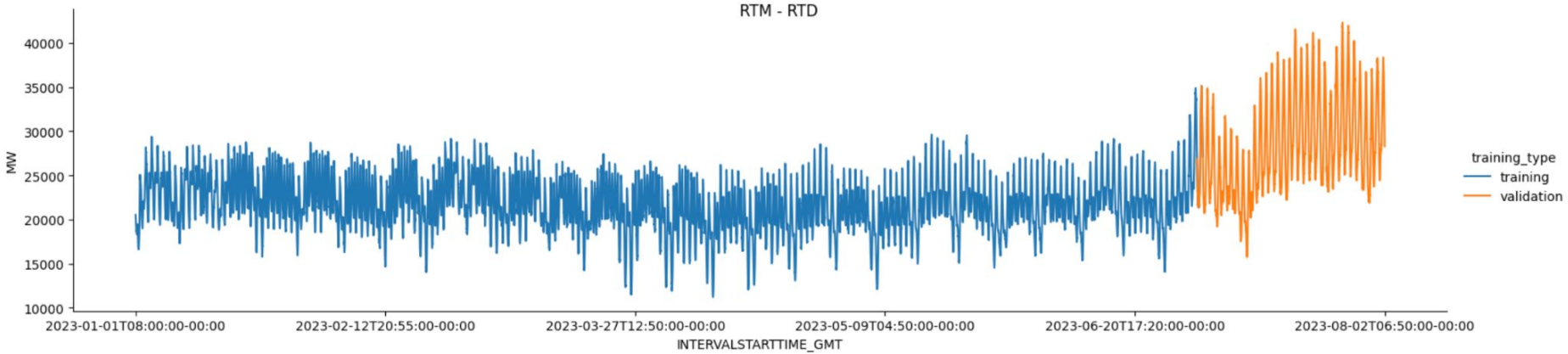
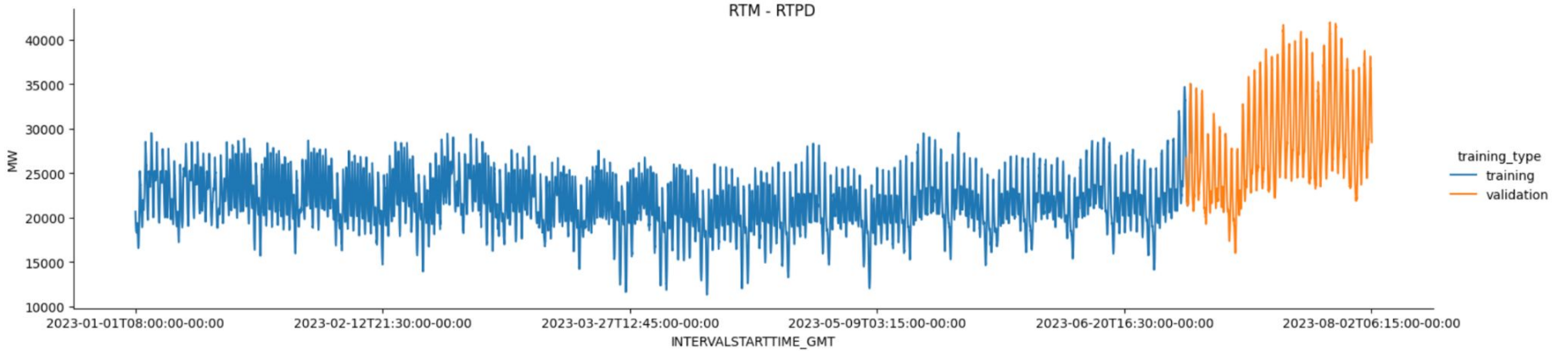
Day Ahead Market



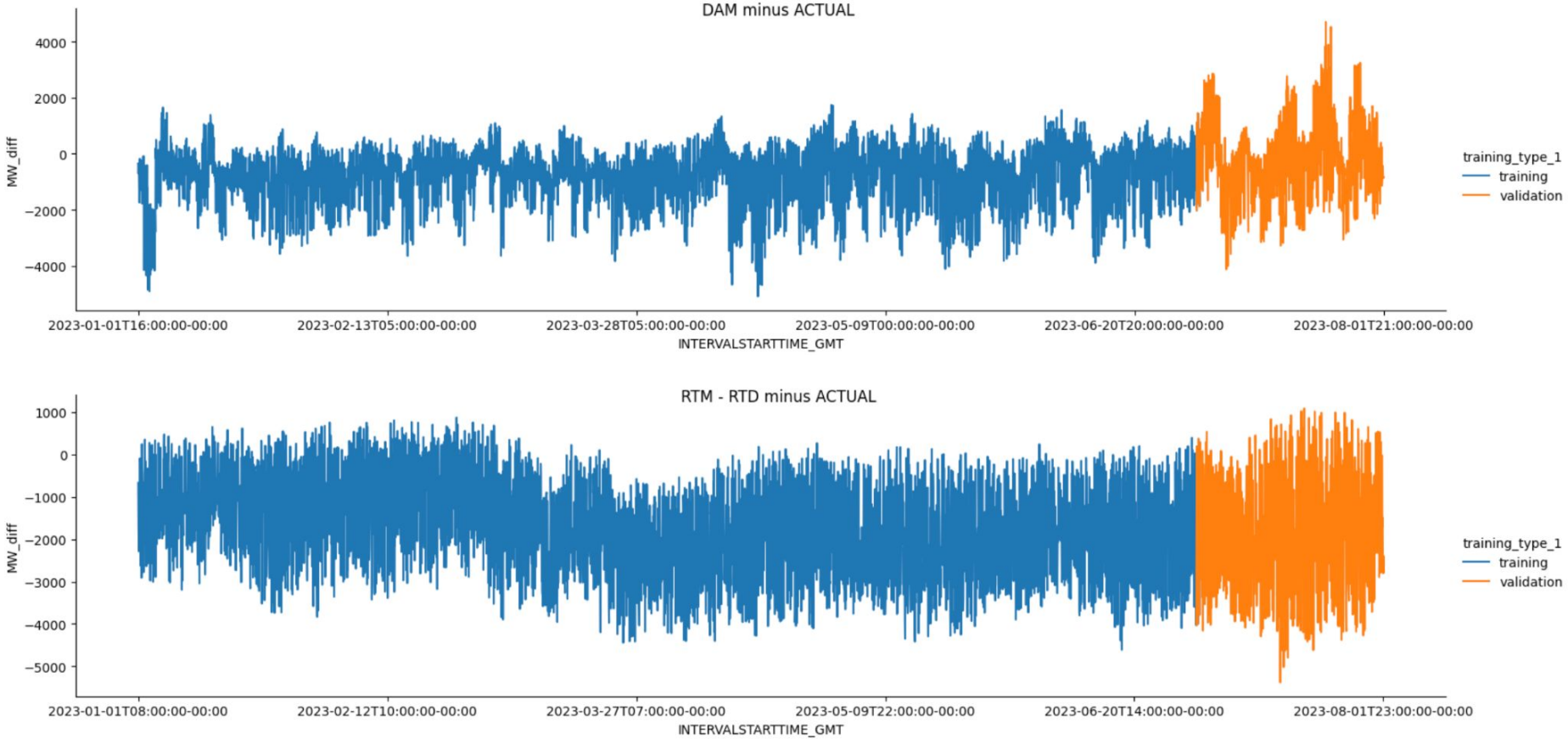


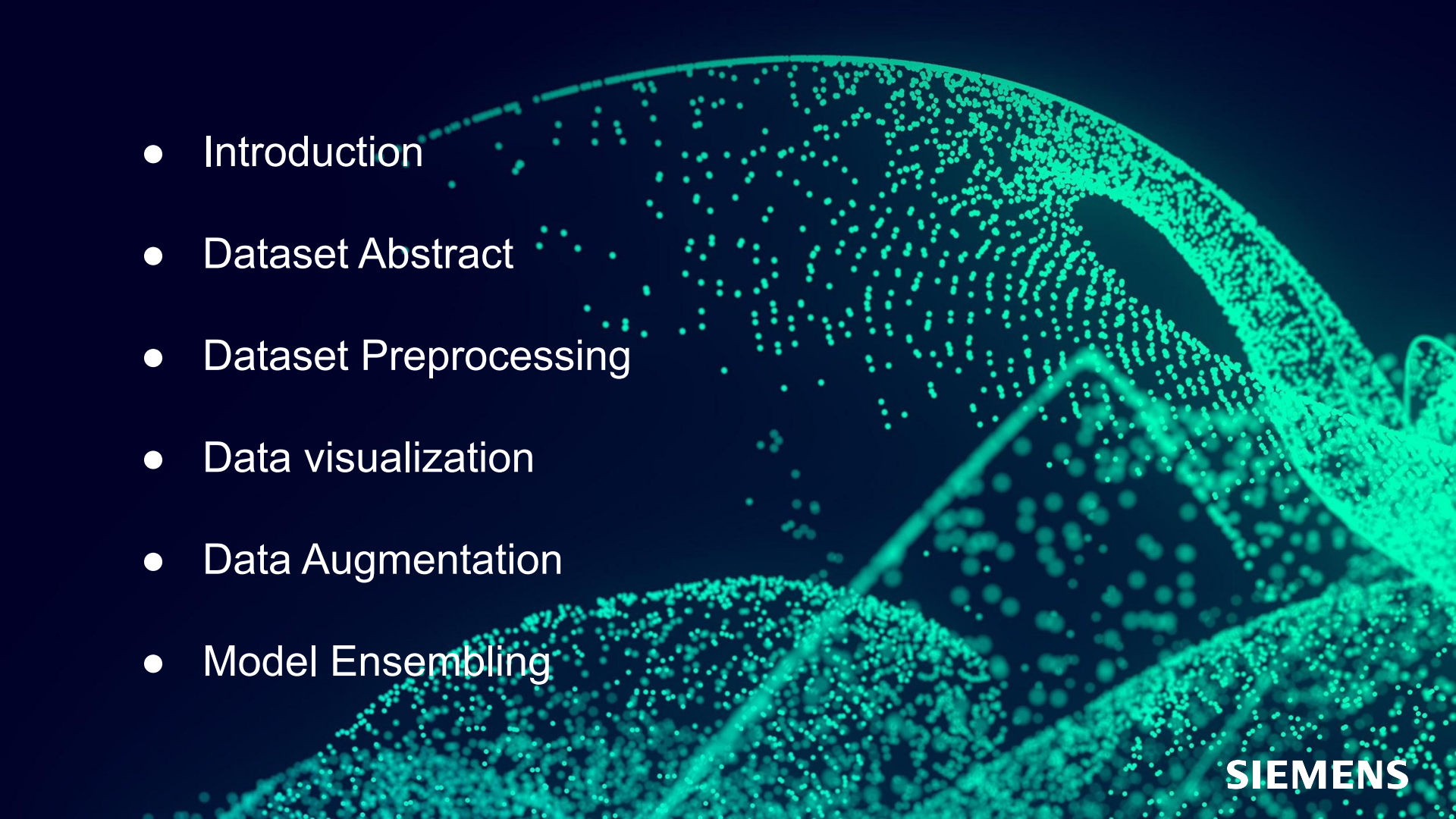
Real Time Market





CAISO Prediction Bias

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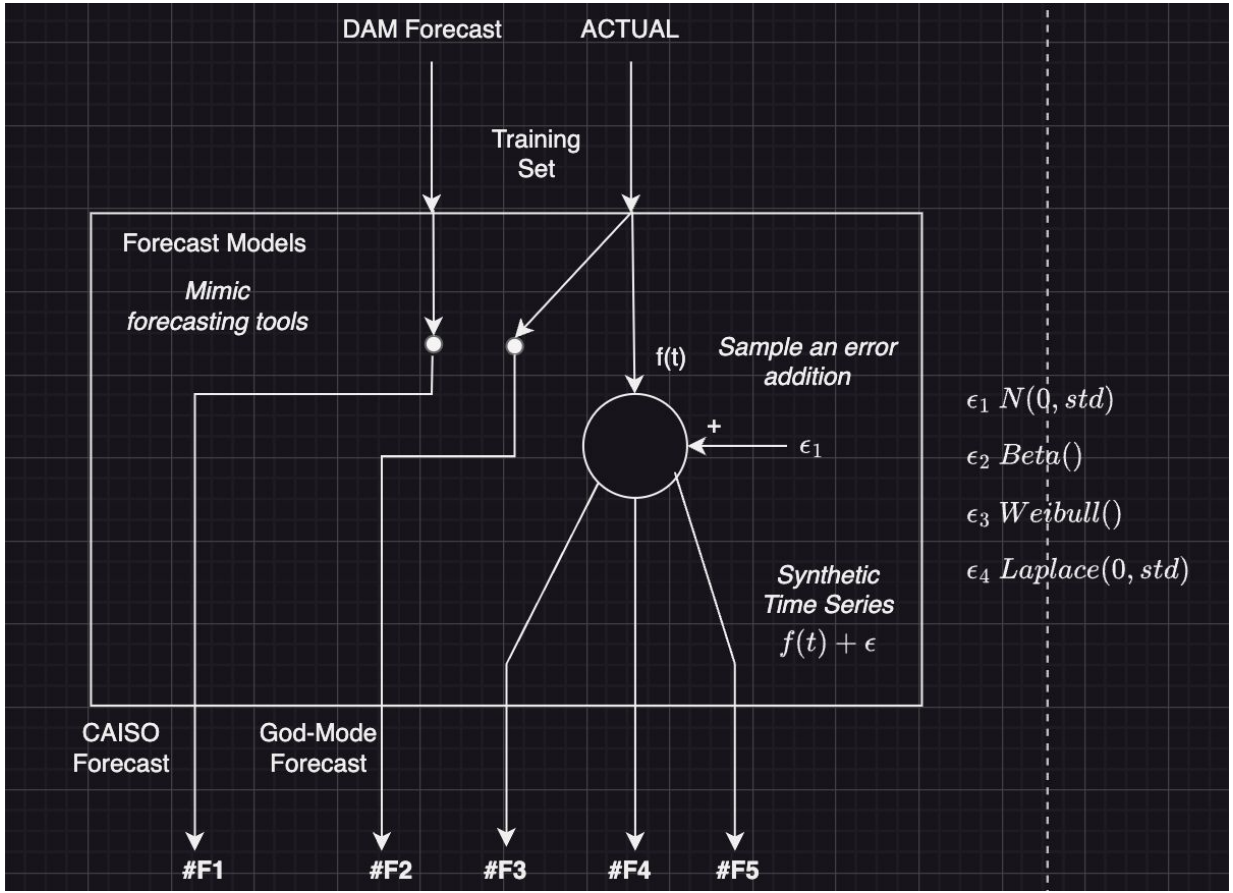

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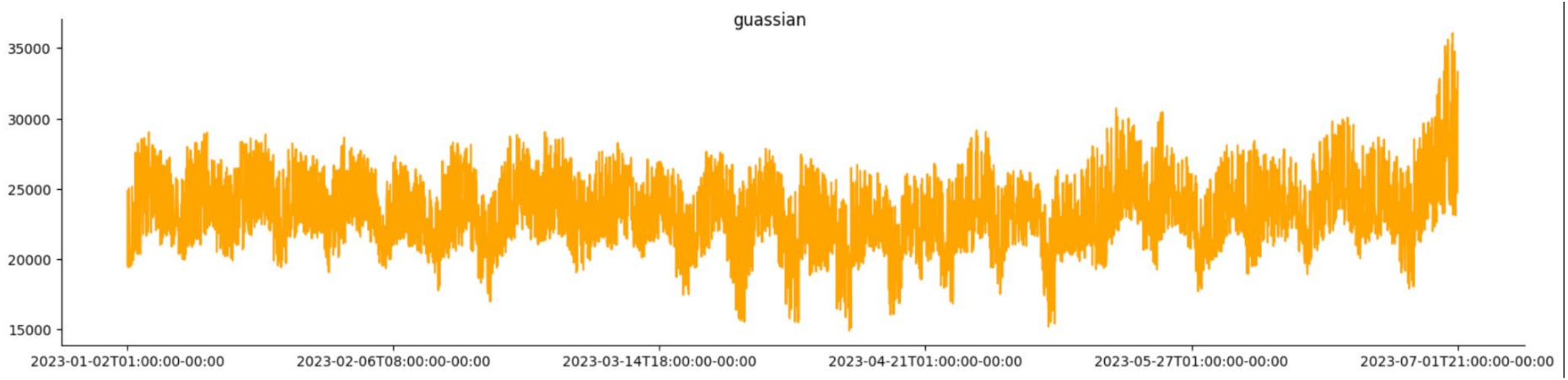
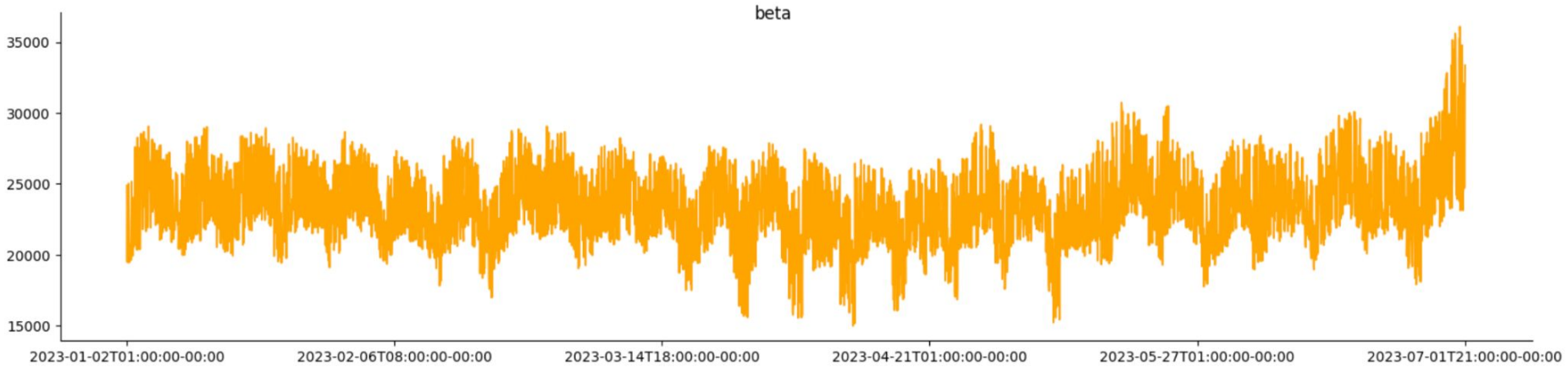
Data Augmentation: Gaussian Noise



Data Augmentation: Beta Noise



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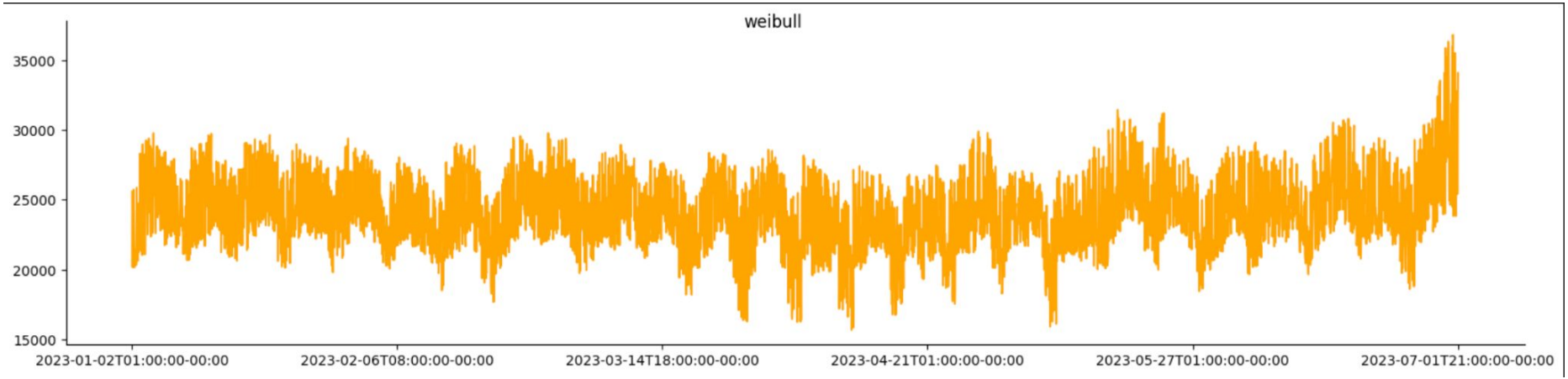
Data Augmentation: Weibull Noise



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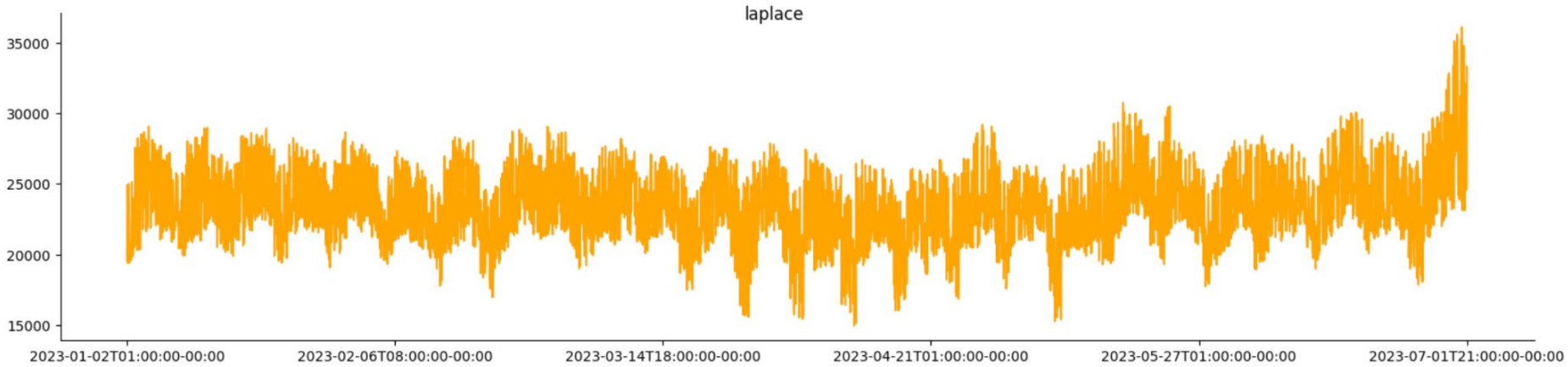
Data Augmentation: Laplace Noise



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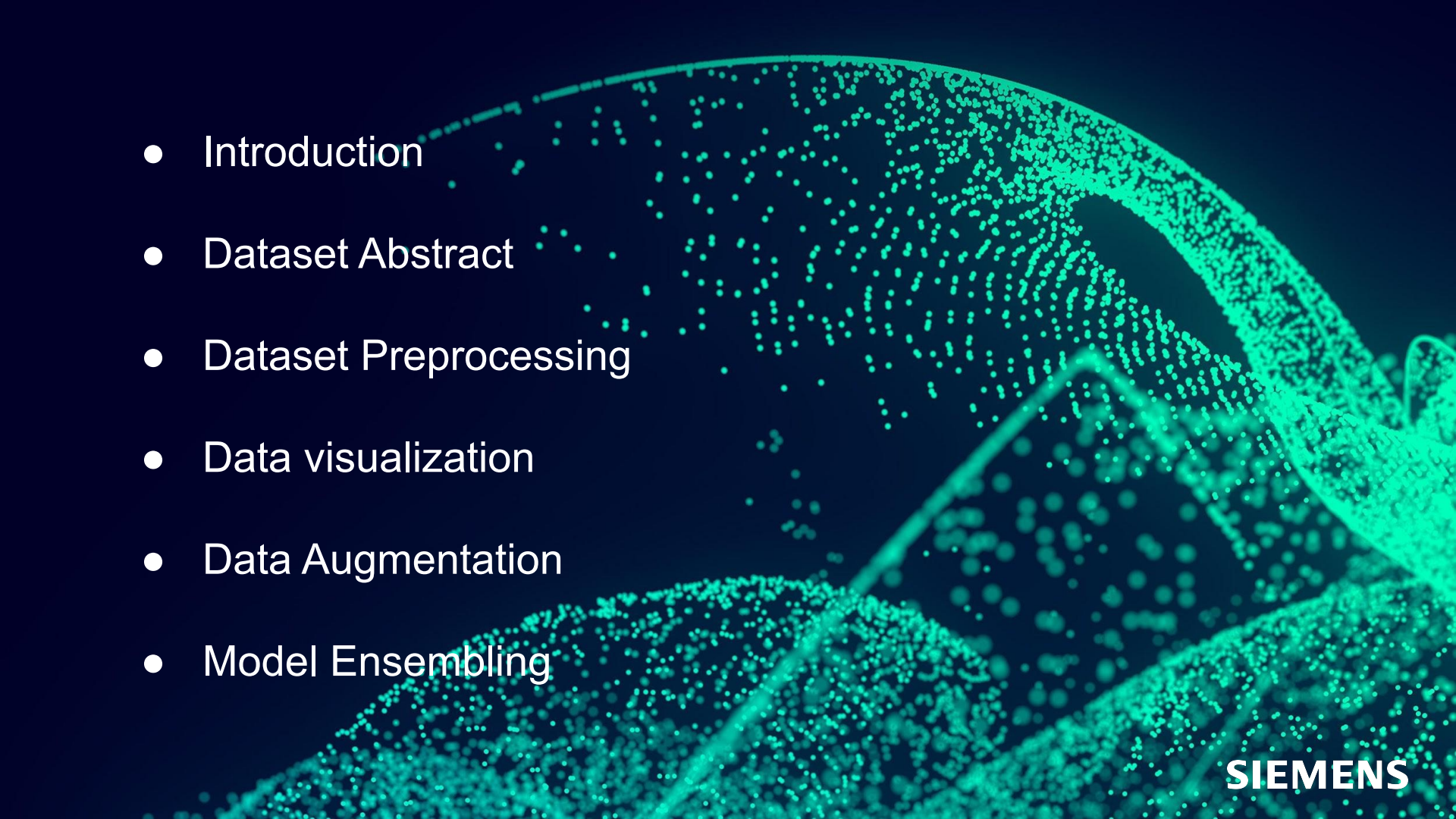
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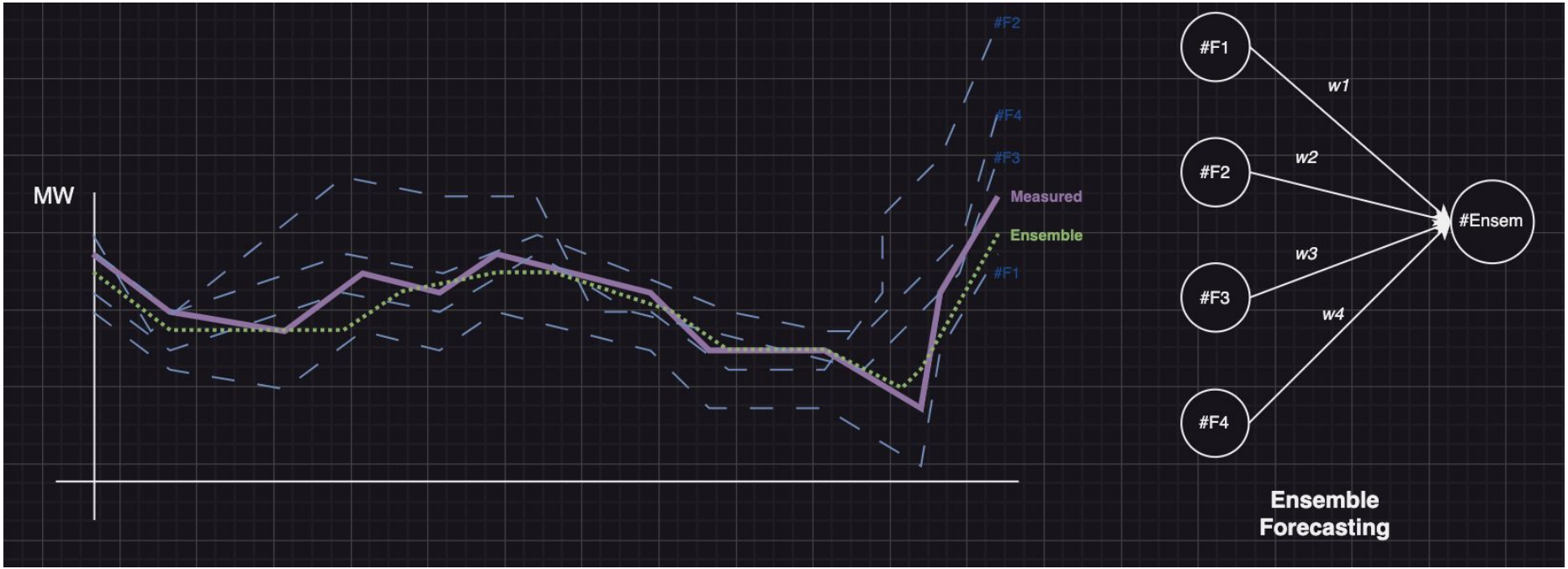

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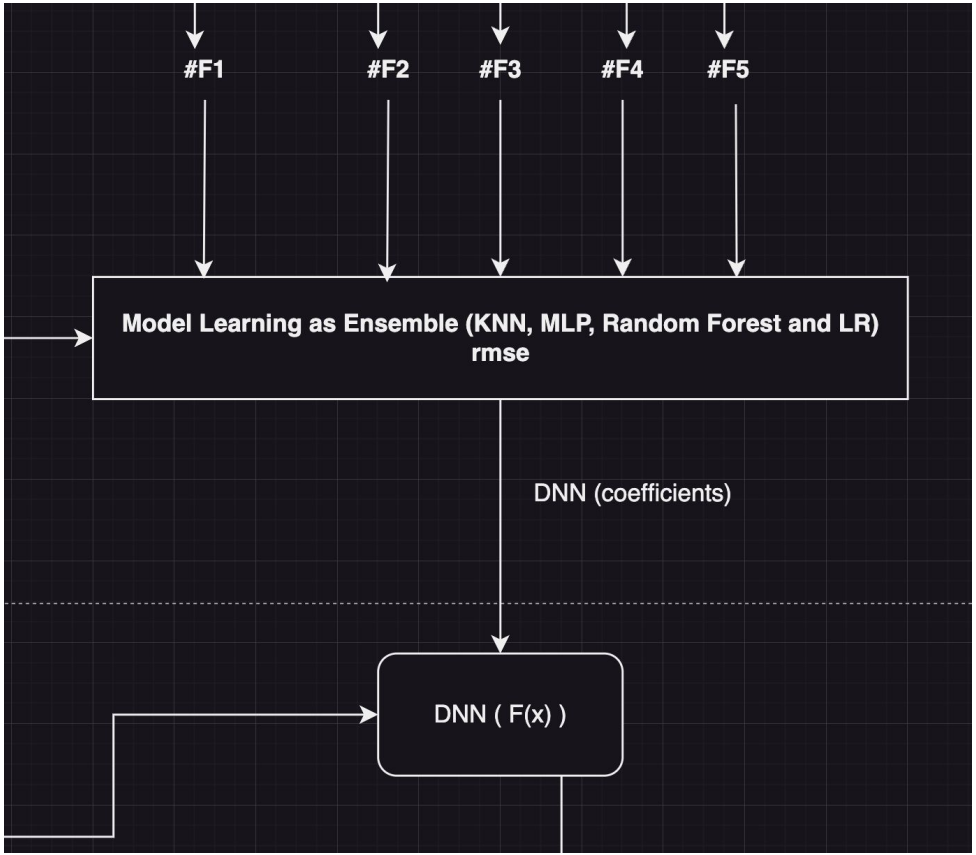
Model Ensembling



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Linear Regression with Actual Values as a feature: Parameters

```
Intercept: 3.637978807091713e-12
Coefficients: [-1.56102205e-16 -5.55111512e-17 -5.07042306e-17 -1.15643556e-16
 -6.97027300e-17  1.00000000e+00]
LR: 2.7630033906398518e-12
```

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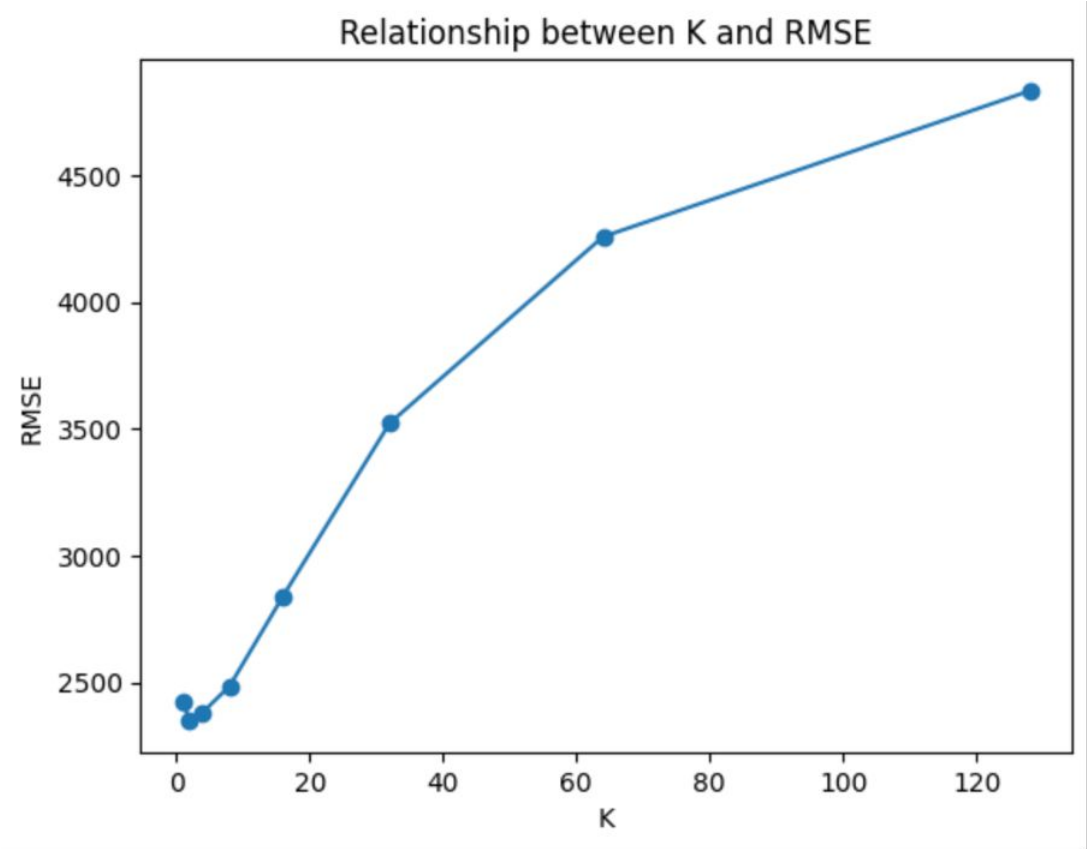
K Nearest Neighbors: Tuning Hyperparameters



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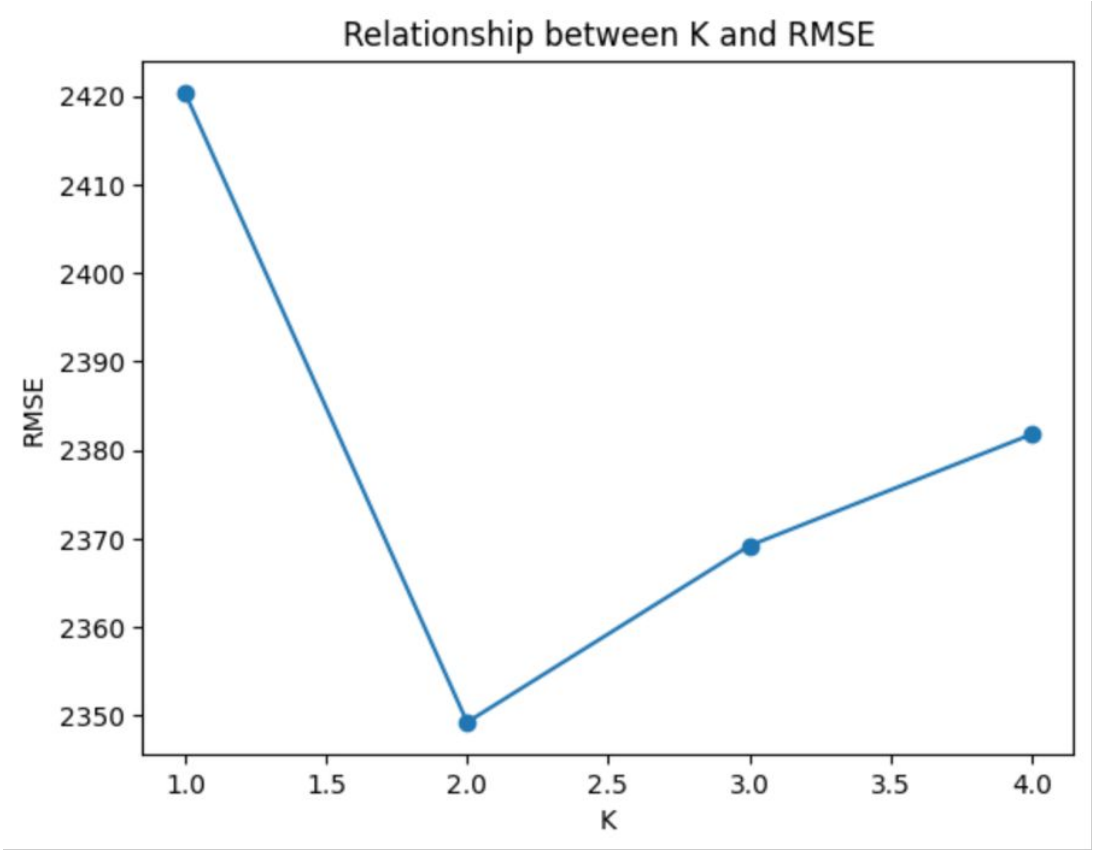
K Nearest Neighbors: Tuning Hyperparameters



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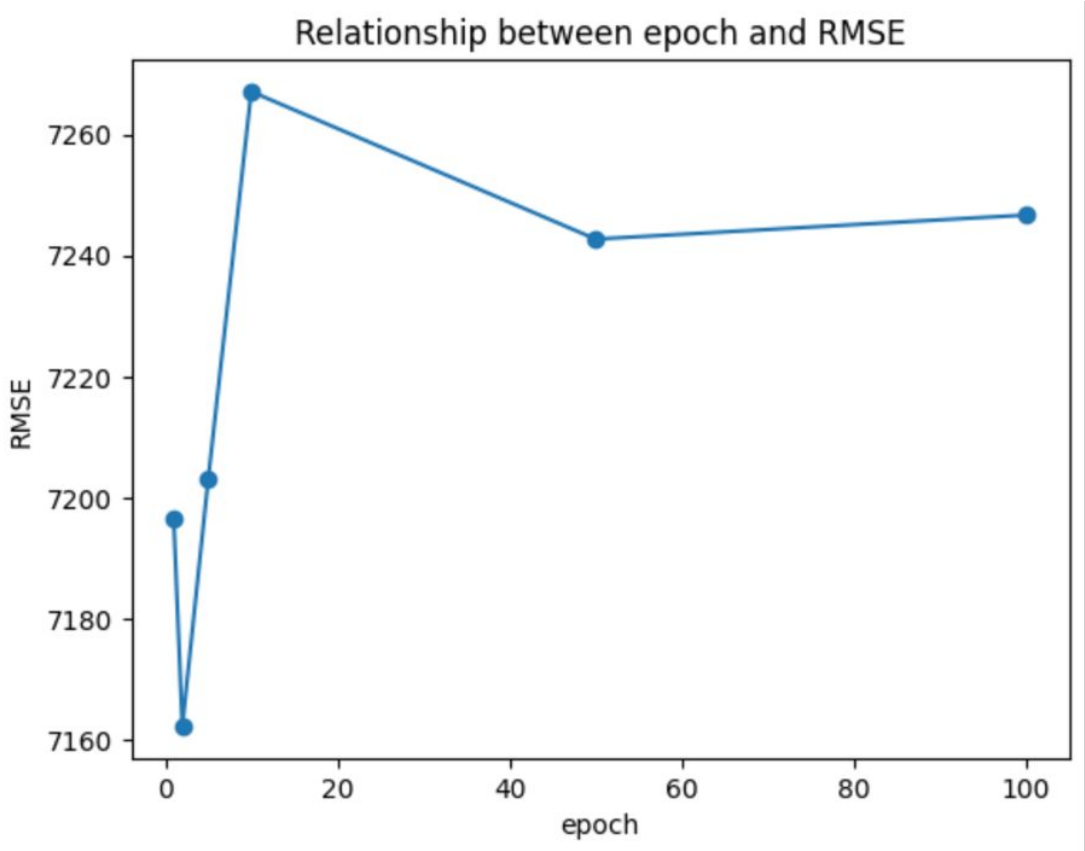
Multilayer Perceptron: Tuning Hyperparameters



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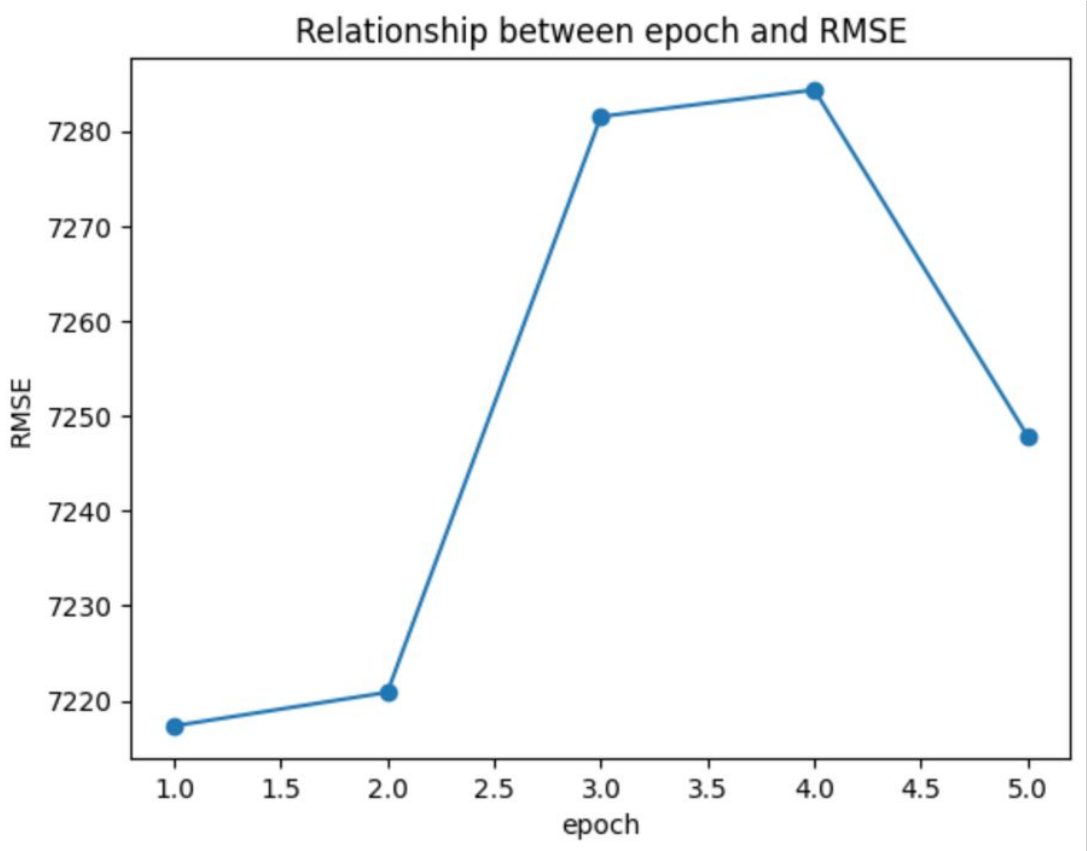
Multilayer Perceptron: Tuning Hyperparameters



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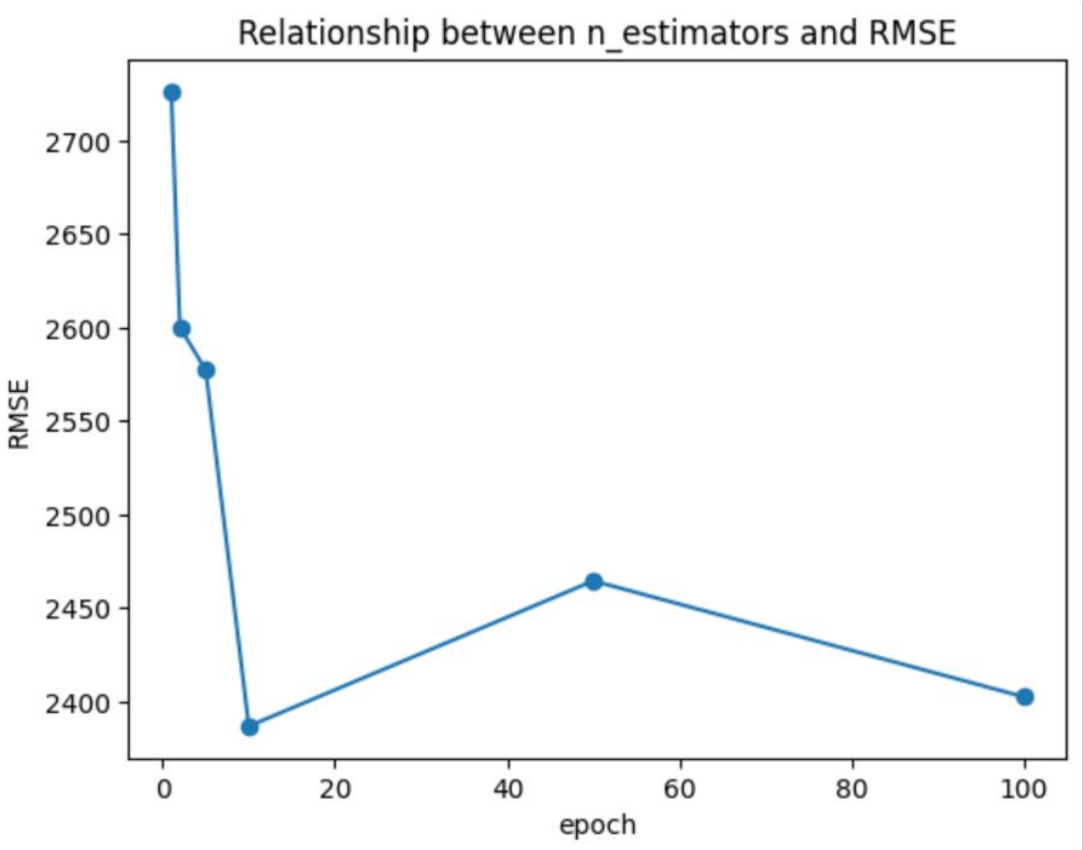
Random Forest: Tuning Hyperparameters



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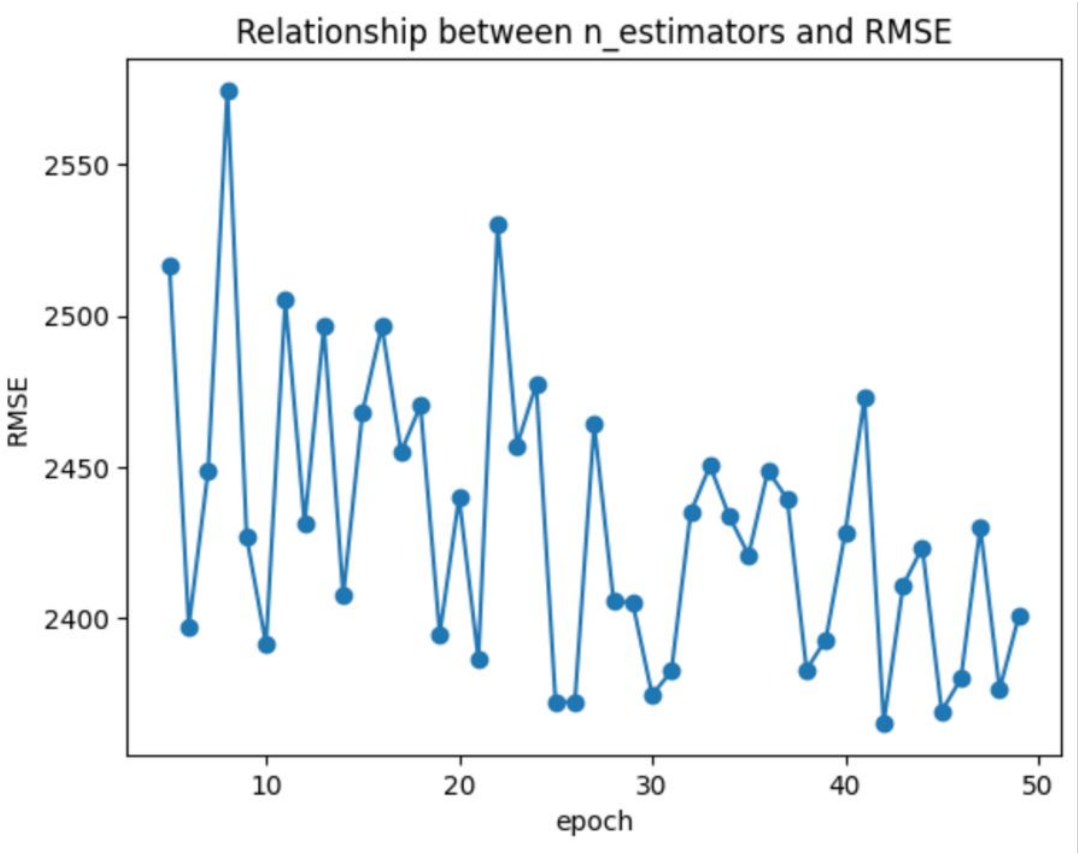
Random Forest: Tuning Hyperparameters



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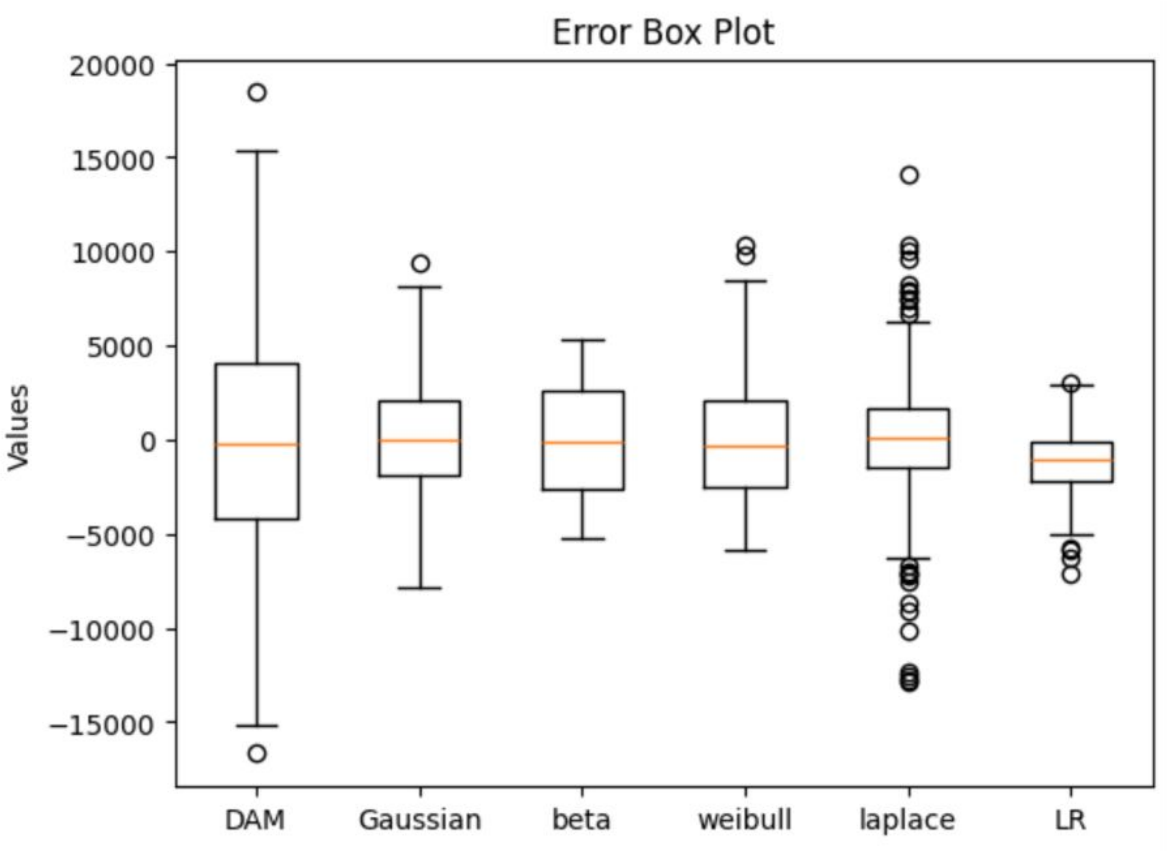
Linear Regression: Parameters

```
Intercept: 3809.3155696293616
Coefficients: [0.05976227 0.19431258 0.19846912 0.19496223 0.19161918]
LR: 1940.2586104000395
```

Error compared with single models



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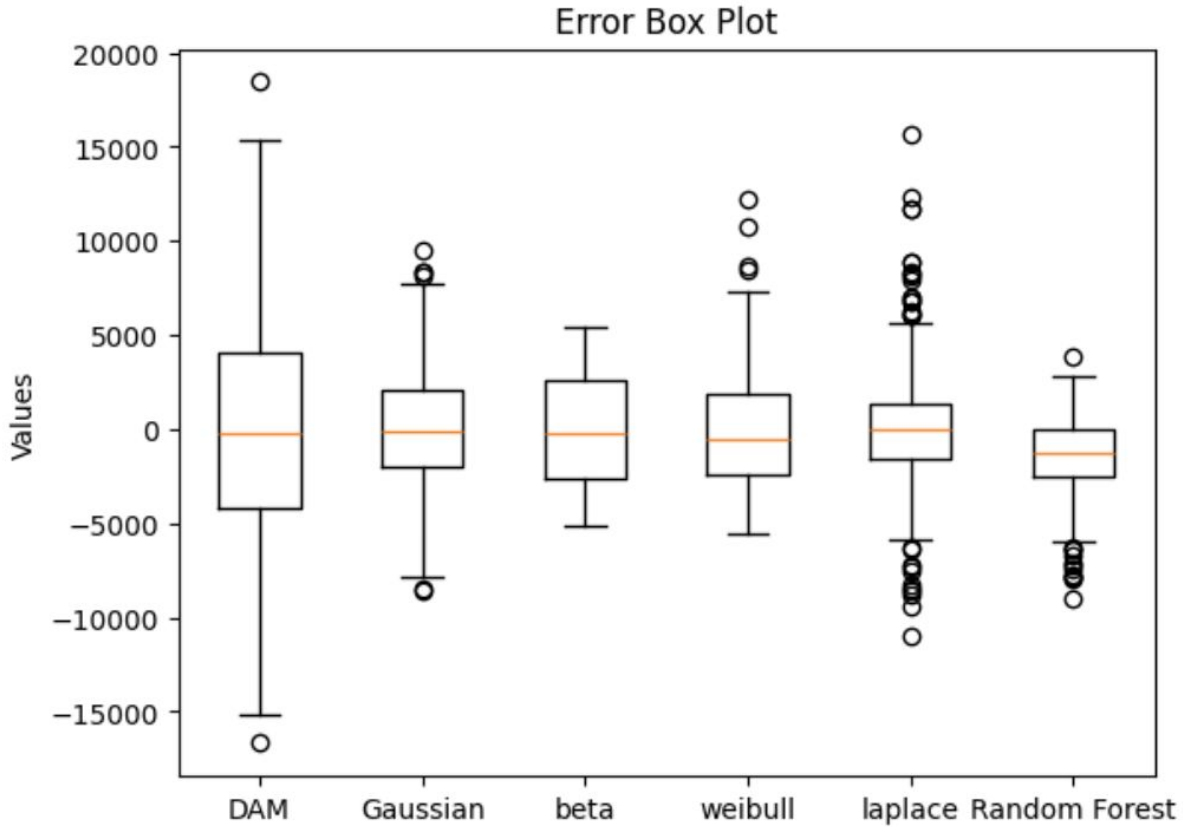
Error compared with single models



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Conclusion

In this research project, we explore the whole procedure of deploying and optimizing machine learning models for increasing prediction accuracy, by experimenting with data processing and machine learning methods, we improved the accuracy of the power demand forecasting.

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Future work

- Reinforcement learning methods
- Combining with data markets
- Real world CAISO model improvement

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Thank You
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