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Electricity demand forecasting
and the problem of embedded generation



John Young
6th March 2013

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Operating the system

- Electricity National Control Centre

Operating the system

Generation **Demand**

50.0 Hz

50.0	Normal operating frequency
50.5	Upper statutory limit
52.0	Generators tripping
49.5	Lower statutory limit
48.8	Demand disconnection starts
47.0	Demand disconnection complete

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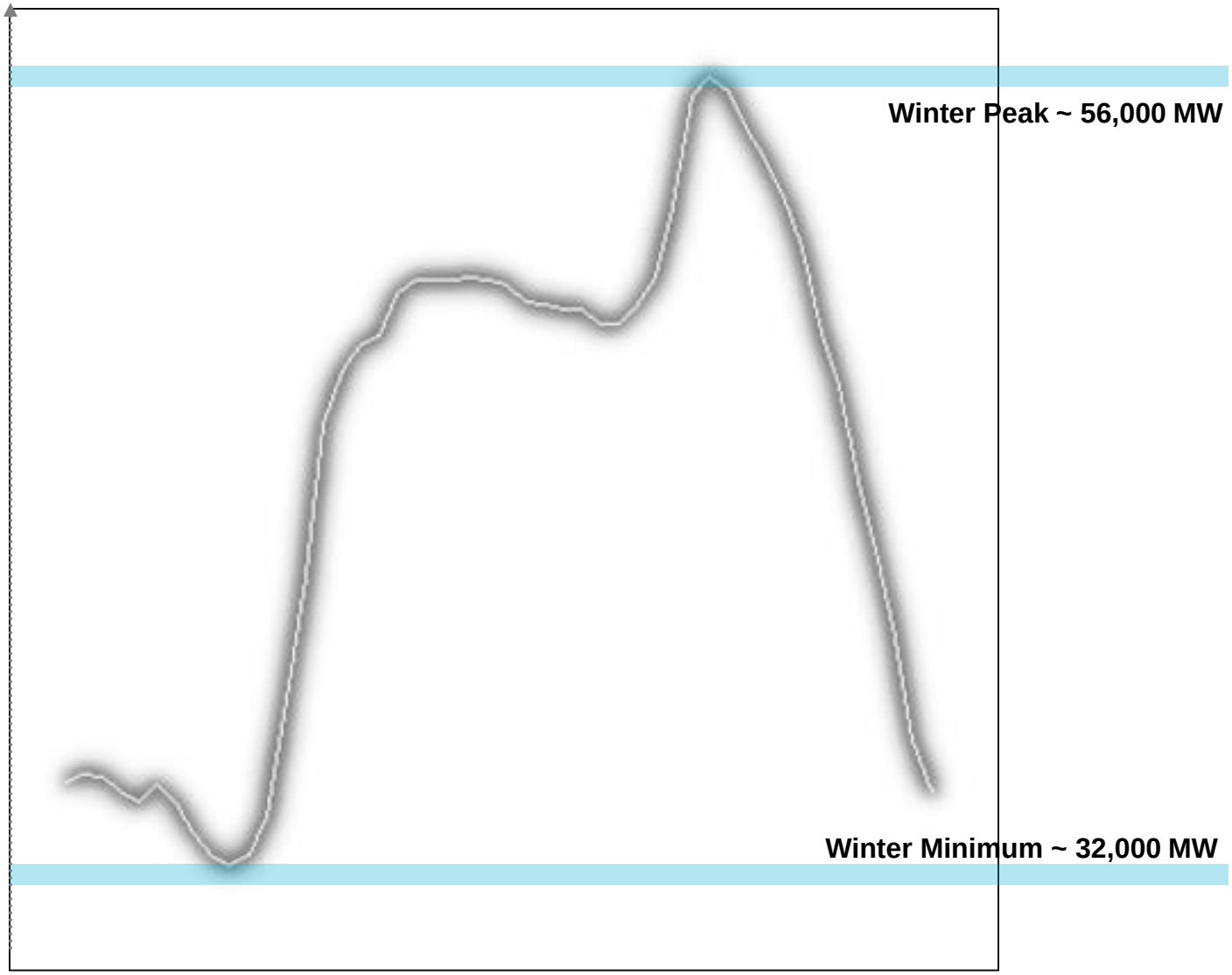
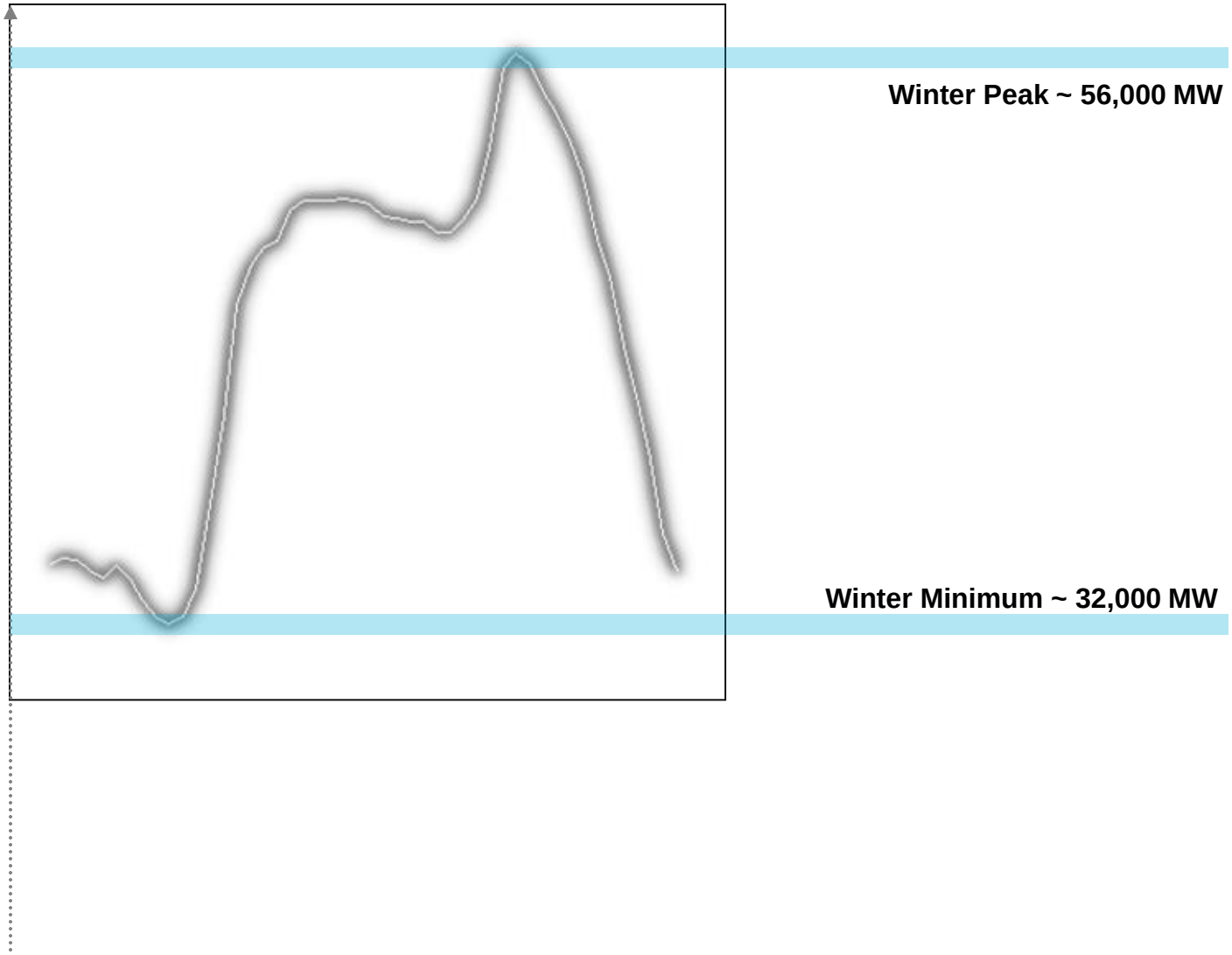
Demand profile shapes

- Shape of demand curves – in terms of turning points and points of inflections - remains **fairly constant from day to day**
- Exact position of turning points, both in vertical (Demand) and horizontal (Time) directions varies, at least partially because of weather and non-weather variables
- Shape evolves slowly over time, with some abrupt discontinuities

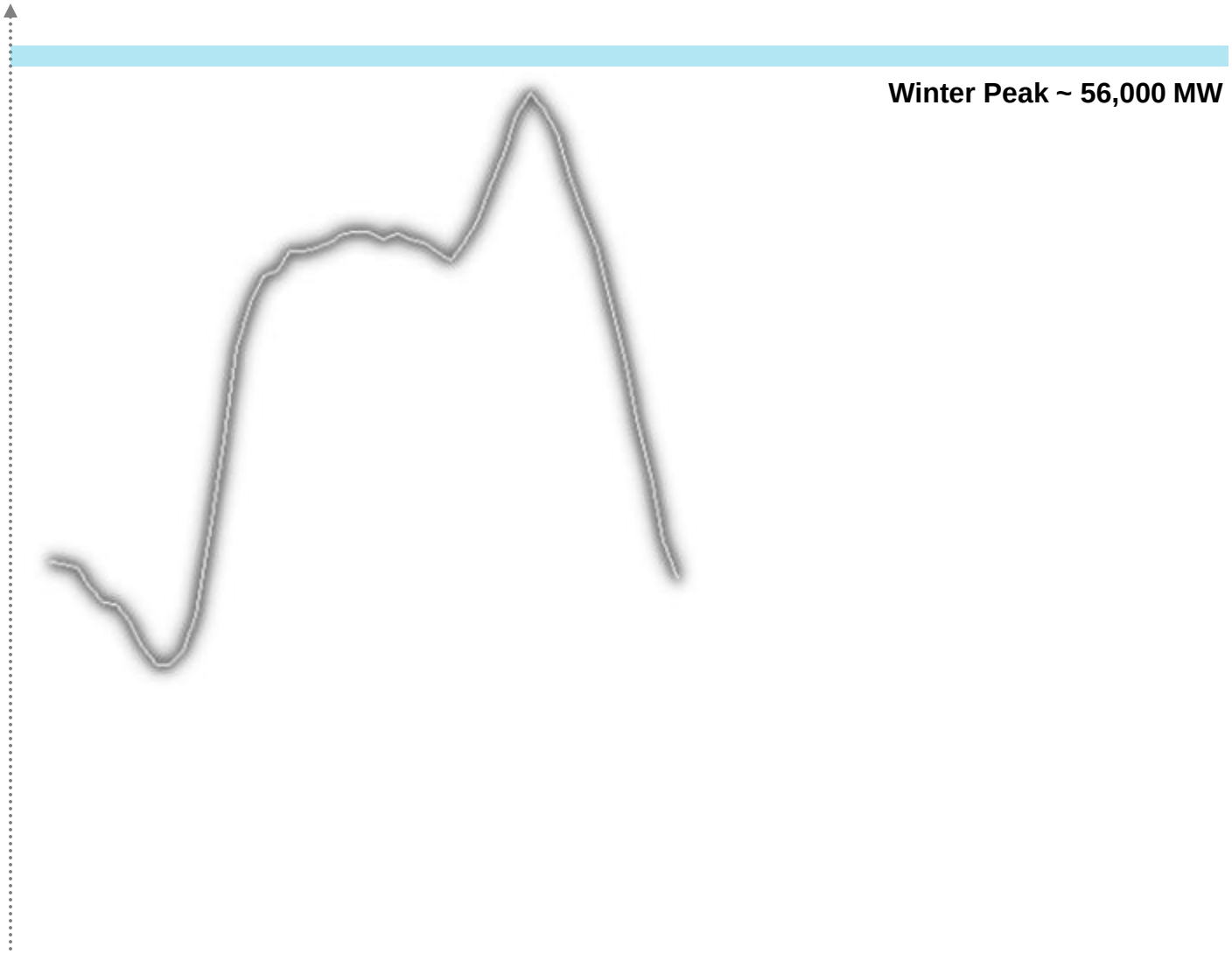
GB National Demand
A Typical Daily Profile: January



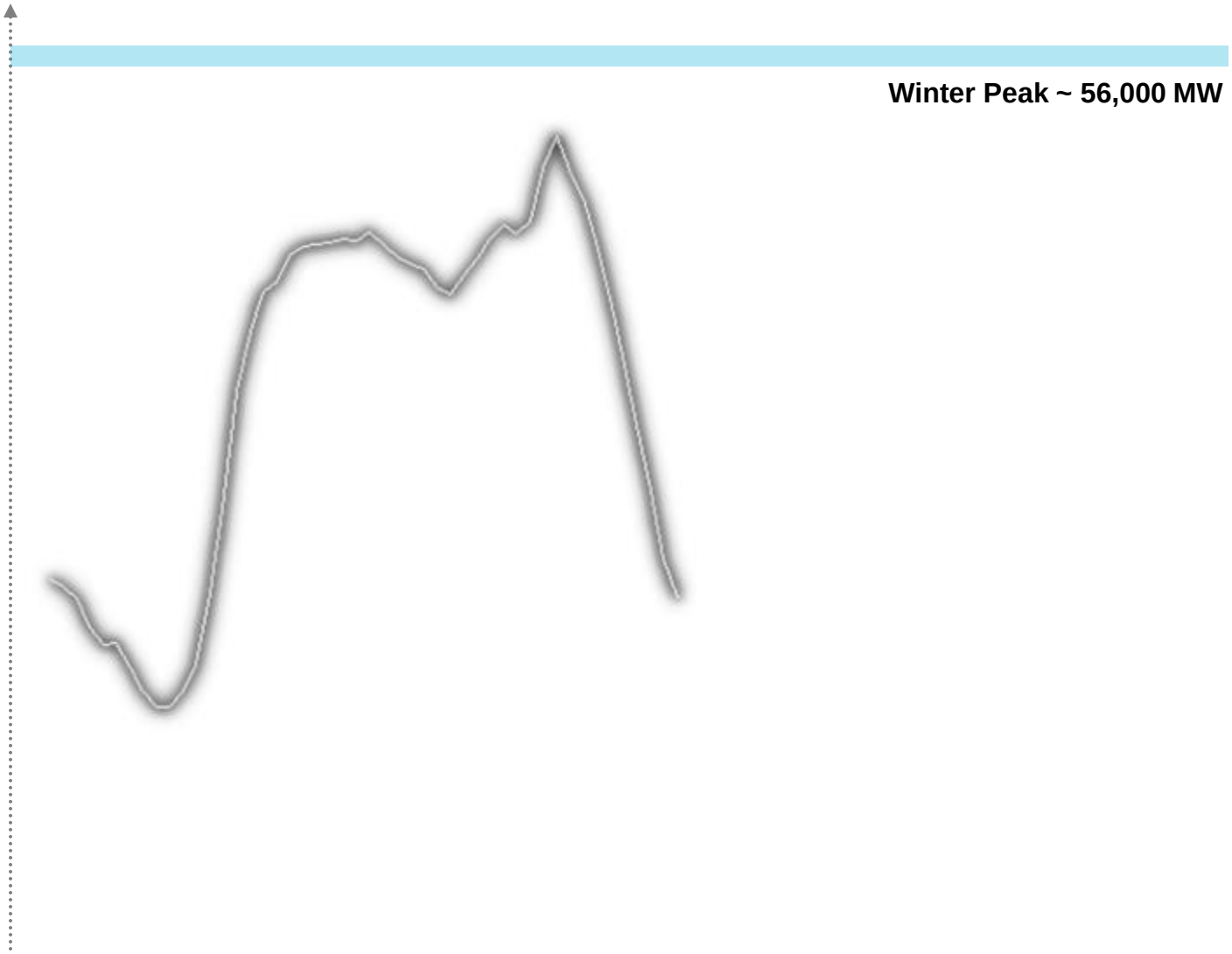
GB National Demand
A Typical Daily Profile: January



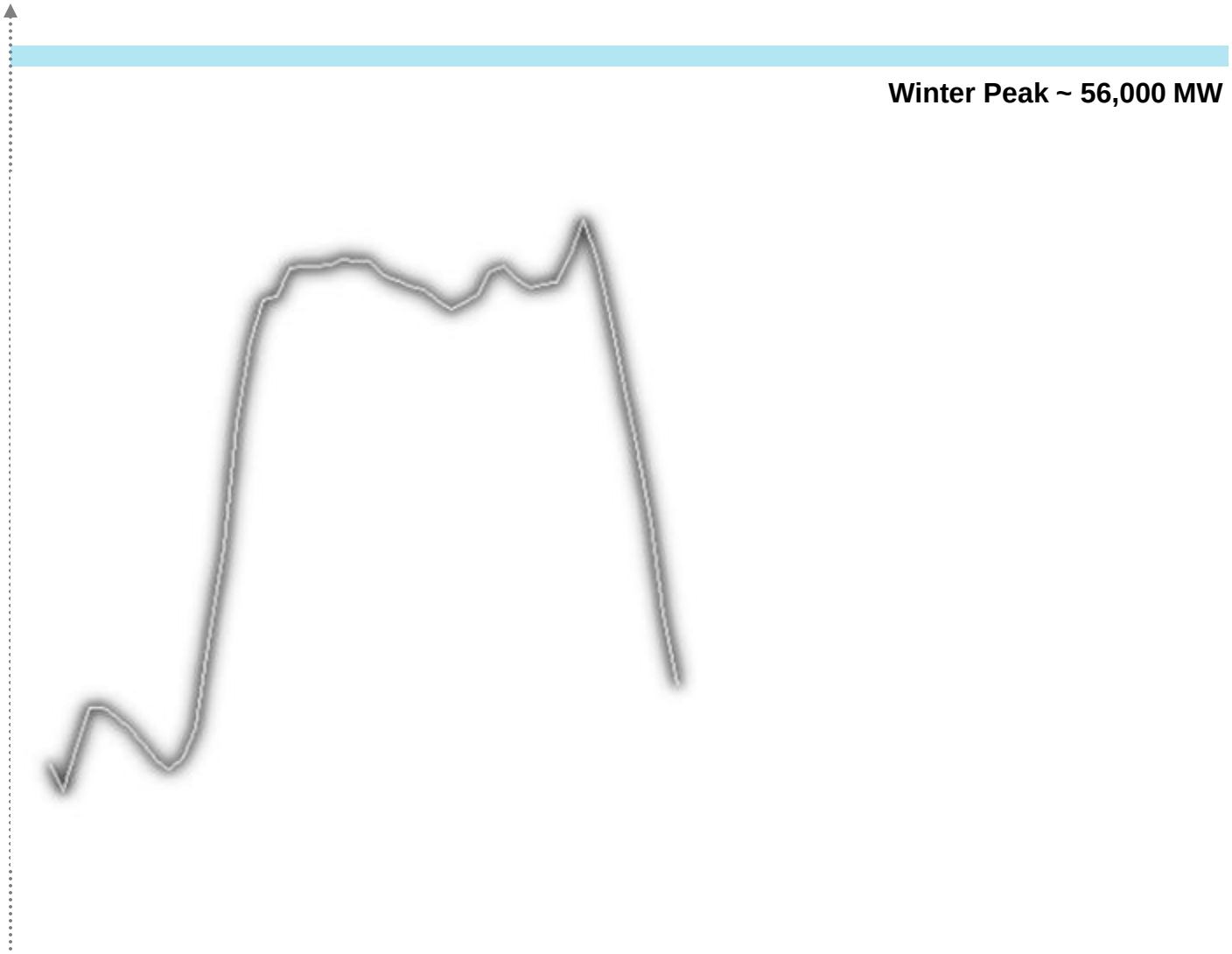
GB National Demand
A Typical Daily Profile: February



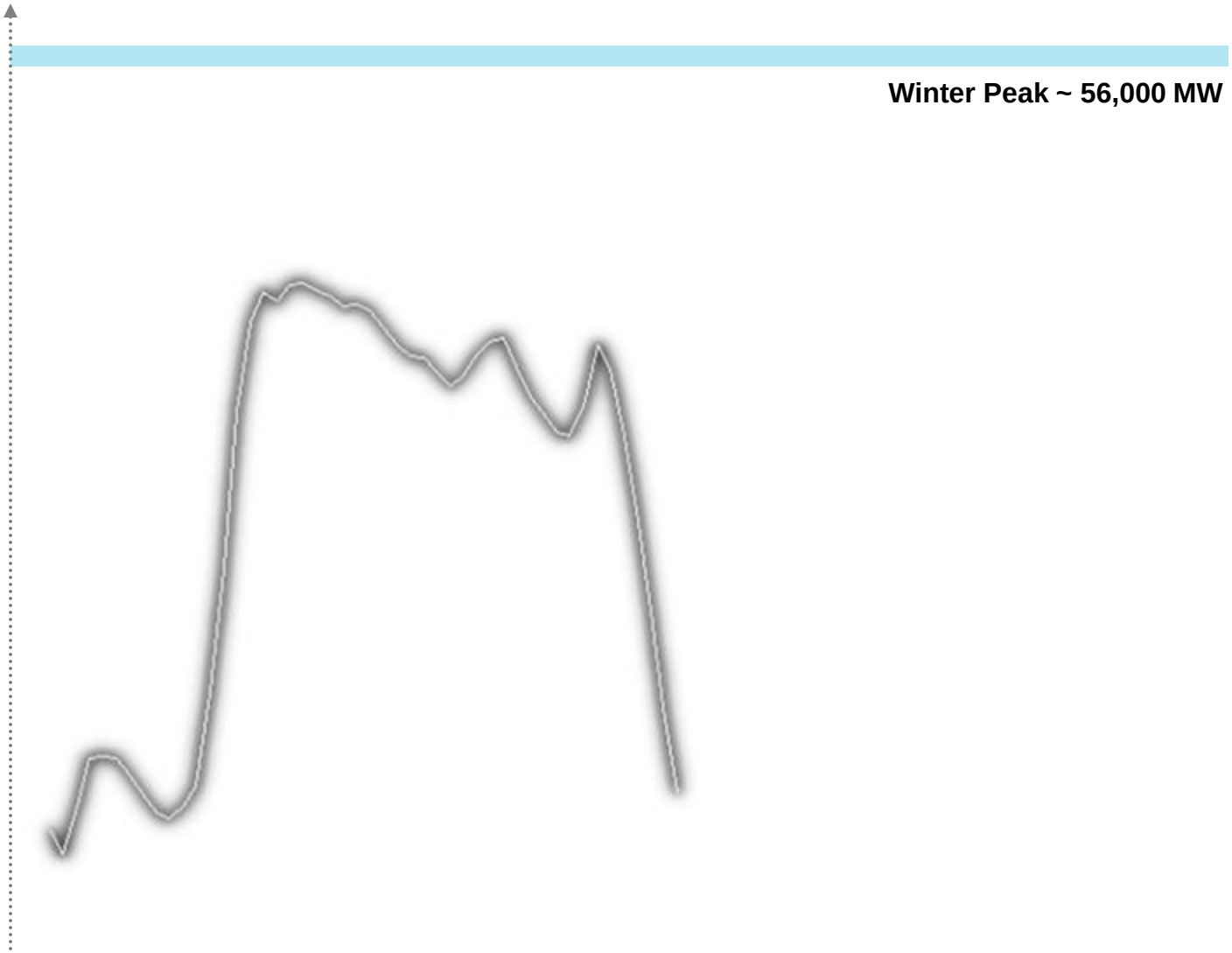
GB National Demand
A Typical Daily Profile: March



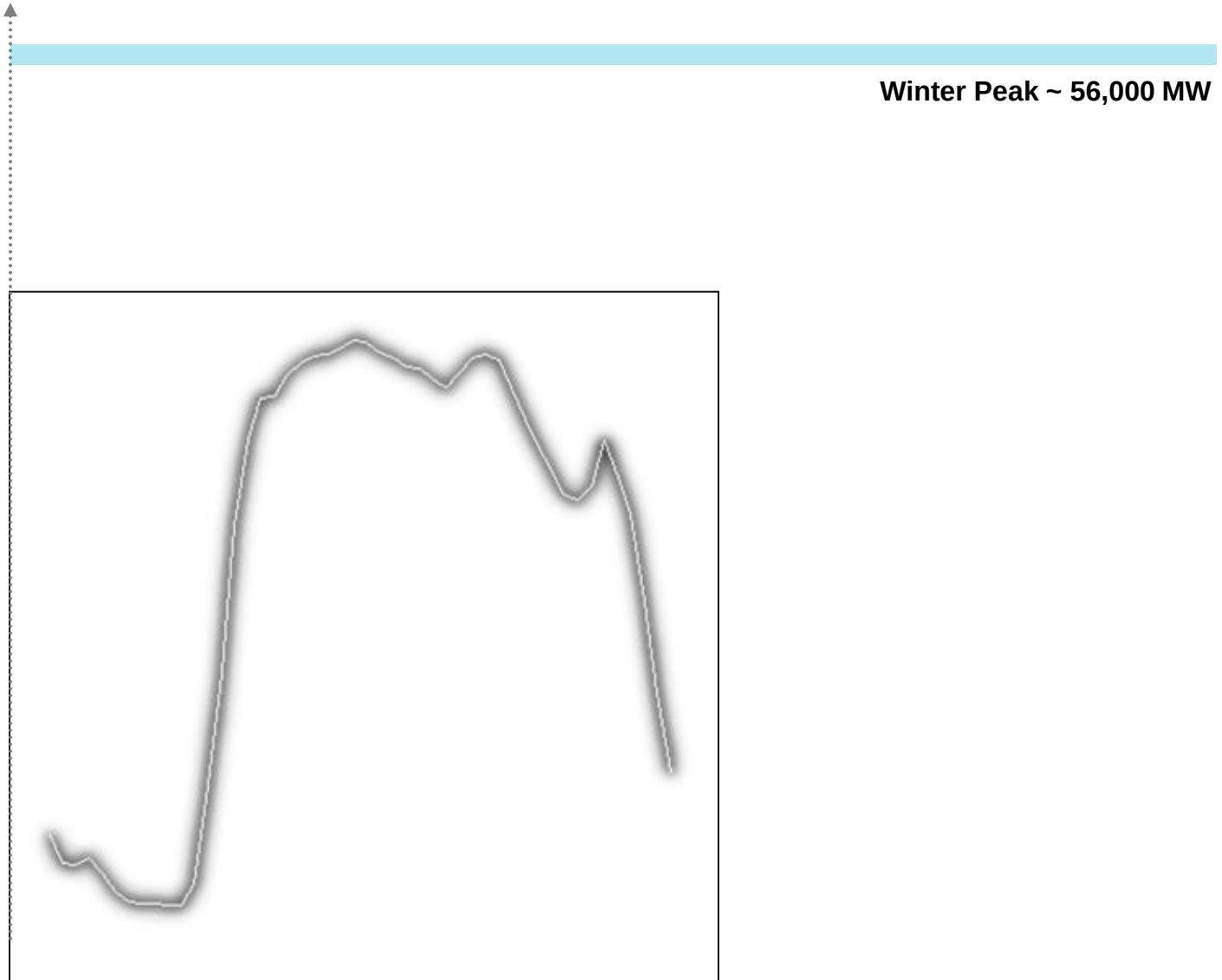
GB National Demand
A Typical Daily Profile: April



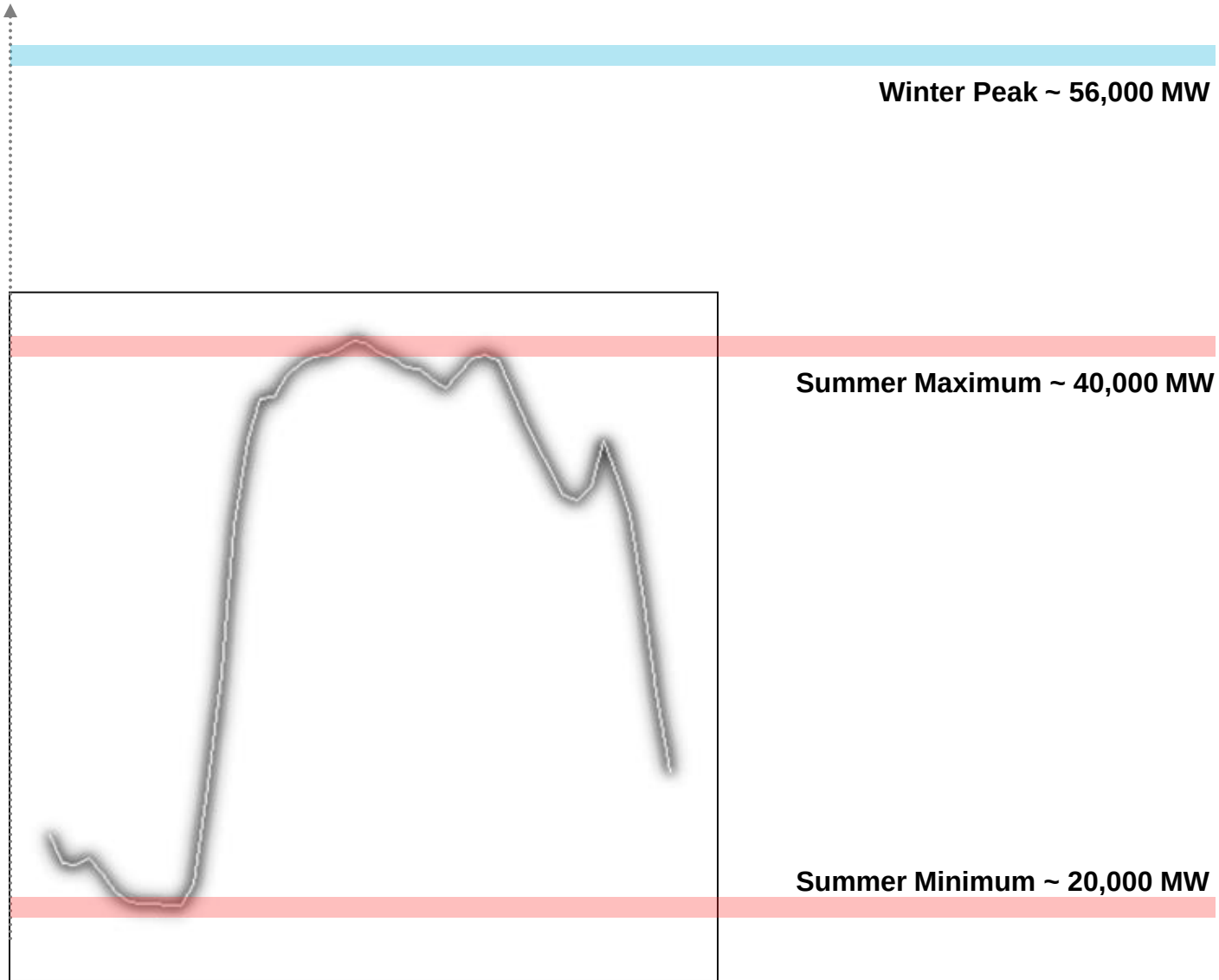
GB National Demand
A Typical Daily Profile: May



GB National Demand
A Typical Daily Profile: June



GB National Demand
A Typical Daily Profile: June



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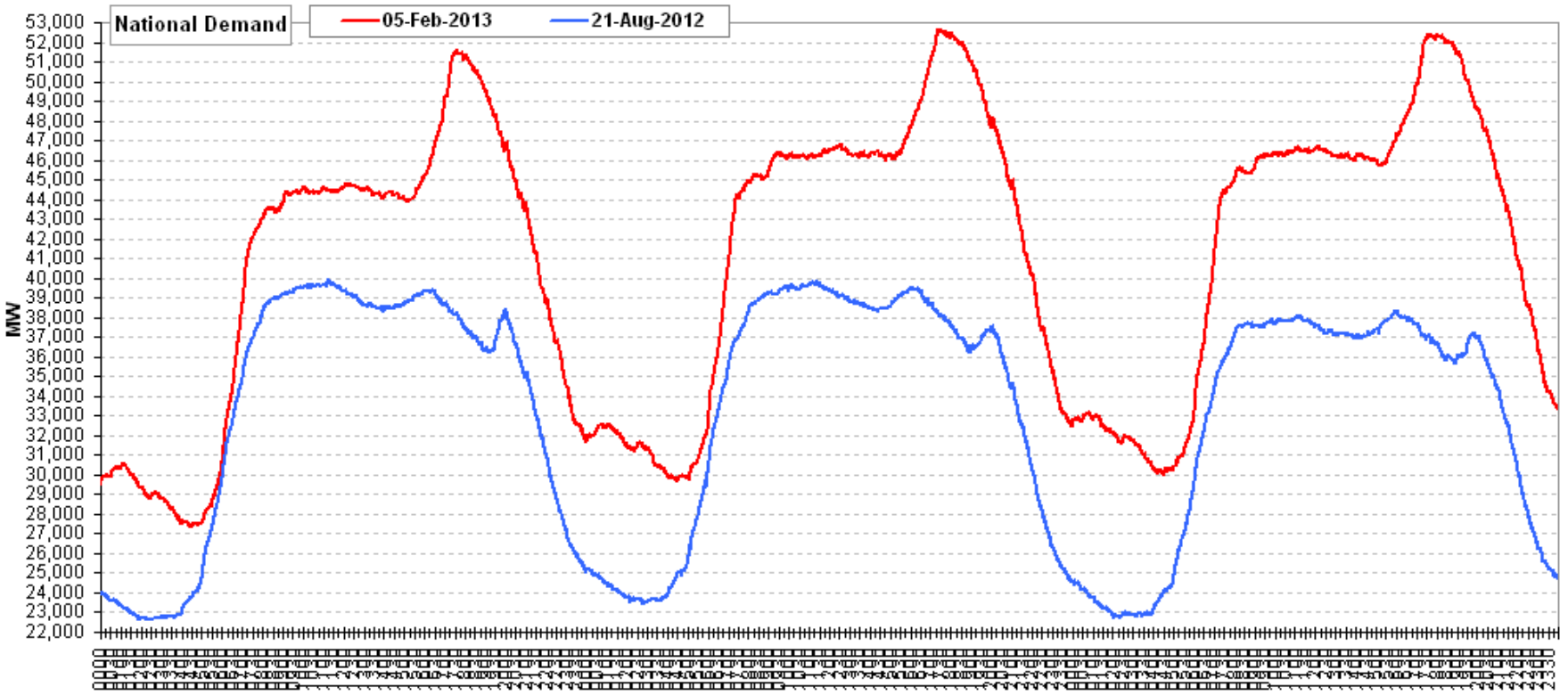
Forecasting electricity demand

- Typical demand profile shape



- 2 distinct shapes: GMT and BST

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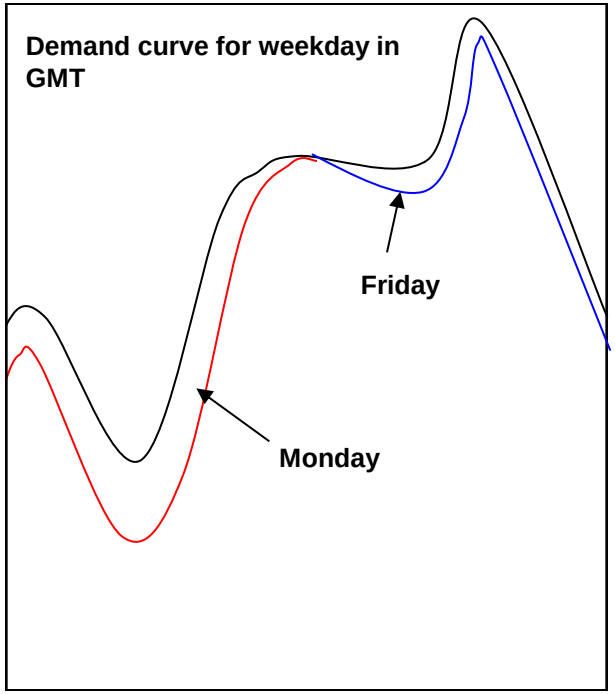
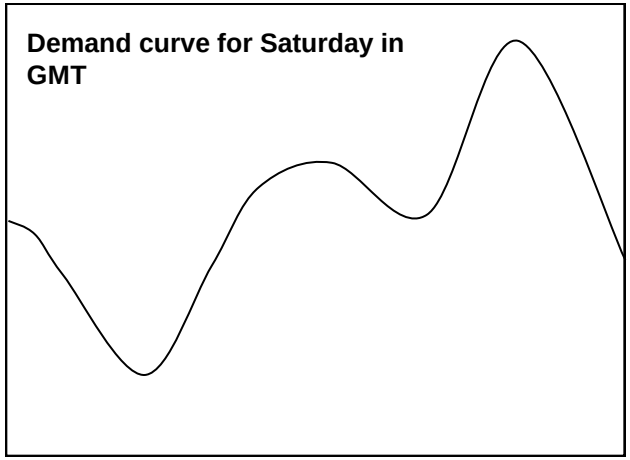
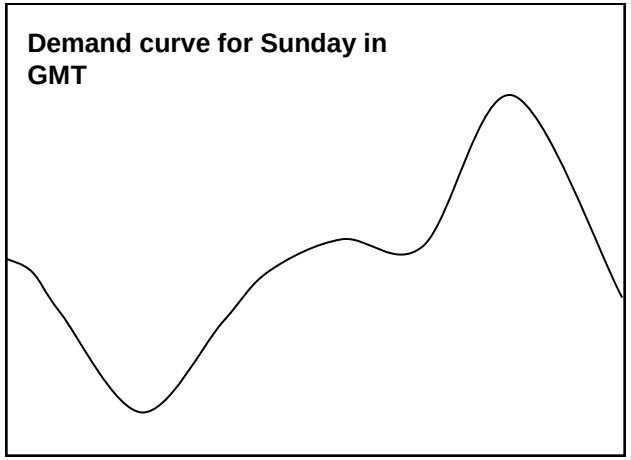
What Else Affects Demand?

- Time of Day
- Bank Holidays
- School Holidays
- **Day of Week**

Day of week impact







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What Else Affects Demand?

- Time of Day
- Day of Week
- Bank Holidays
- School Holidays
- **Weather**
- Special Events
- TV

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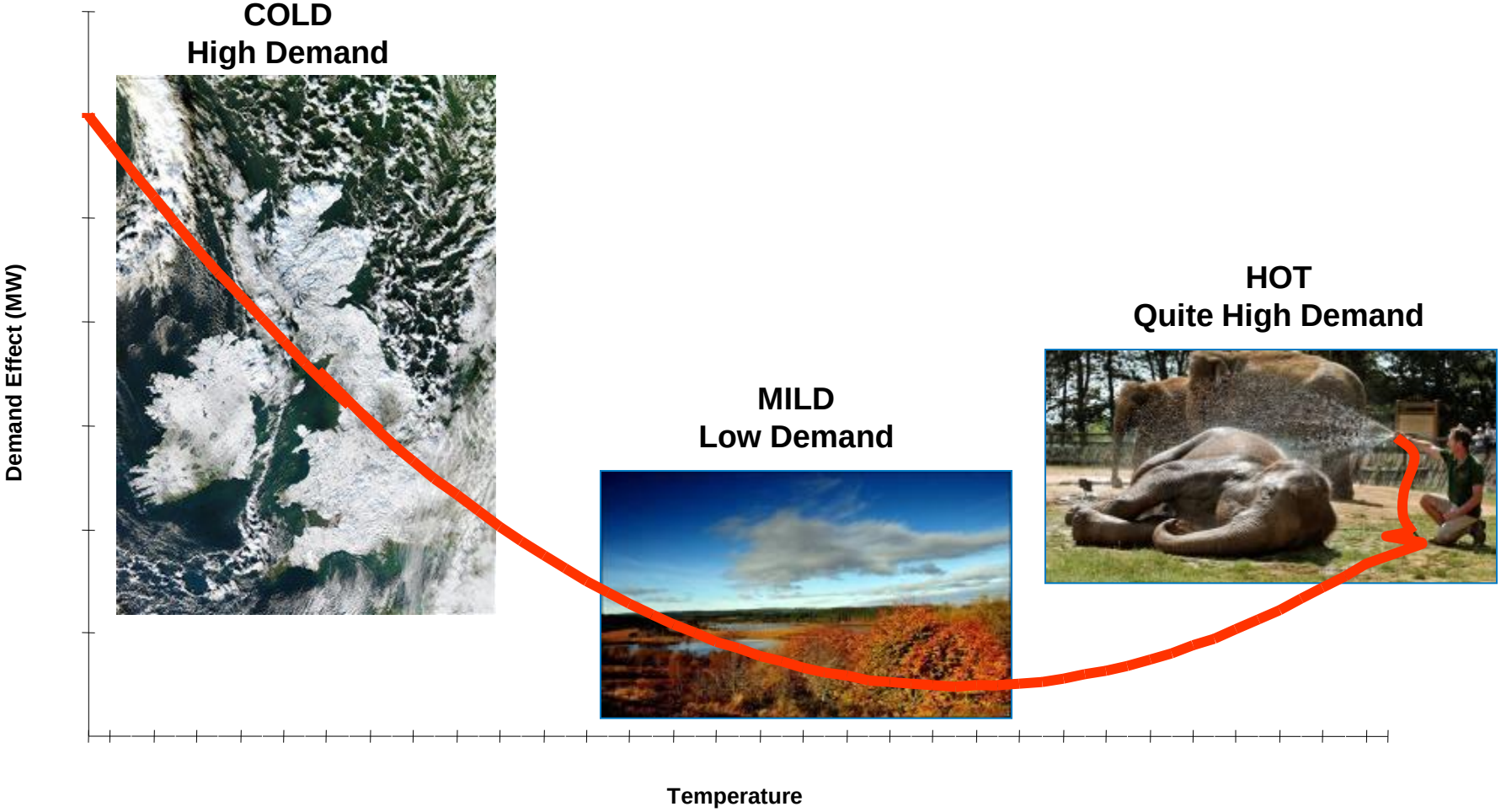
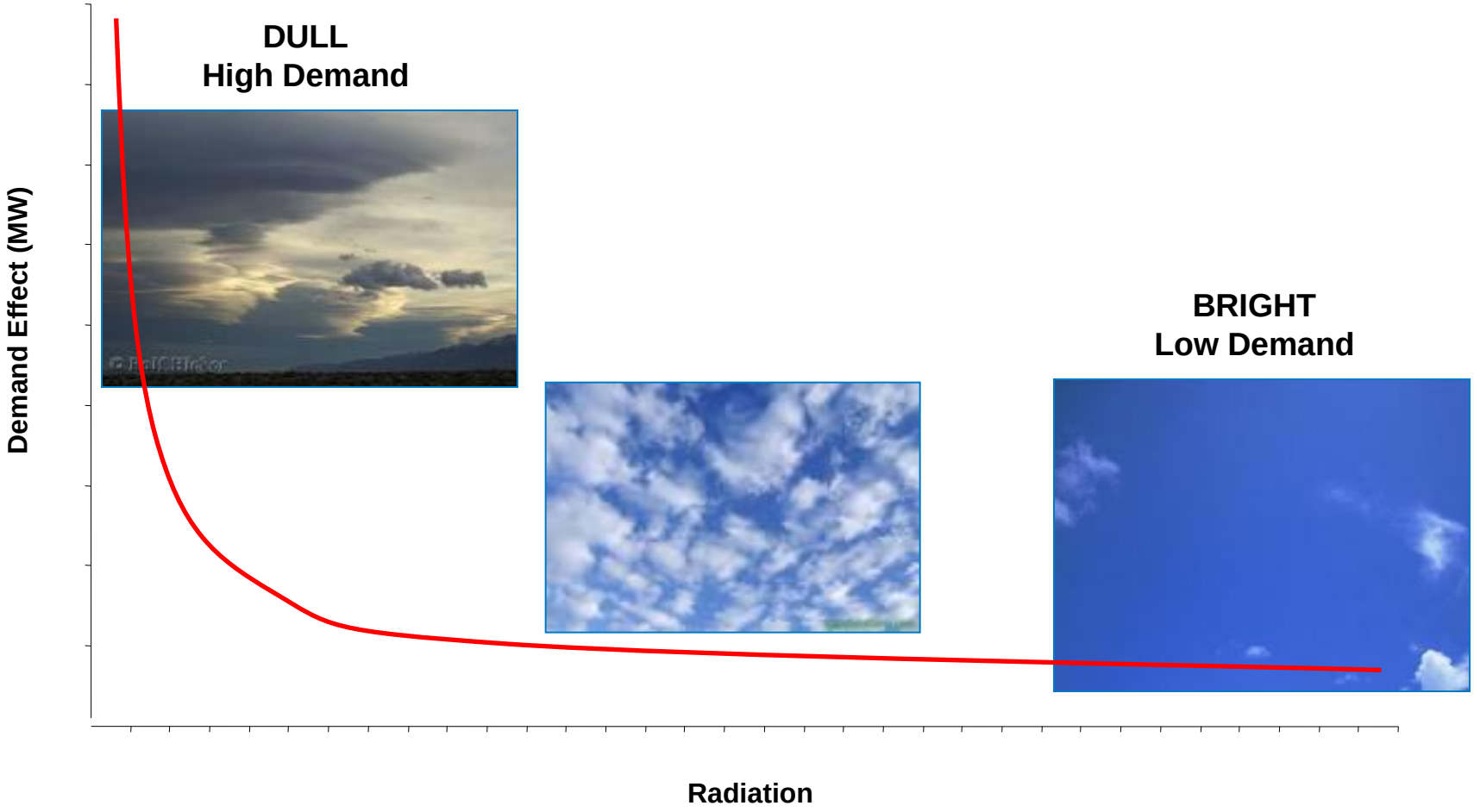
Temperature



Illumination



The Impact of Weather
Cooling Power of the Wind

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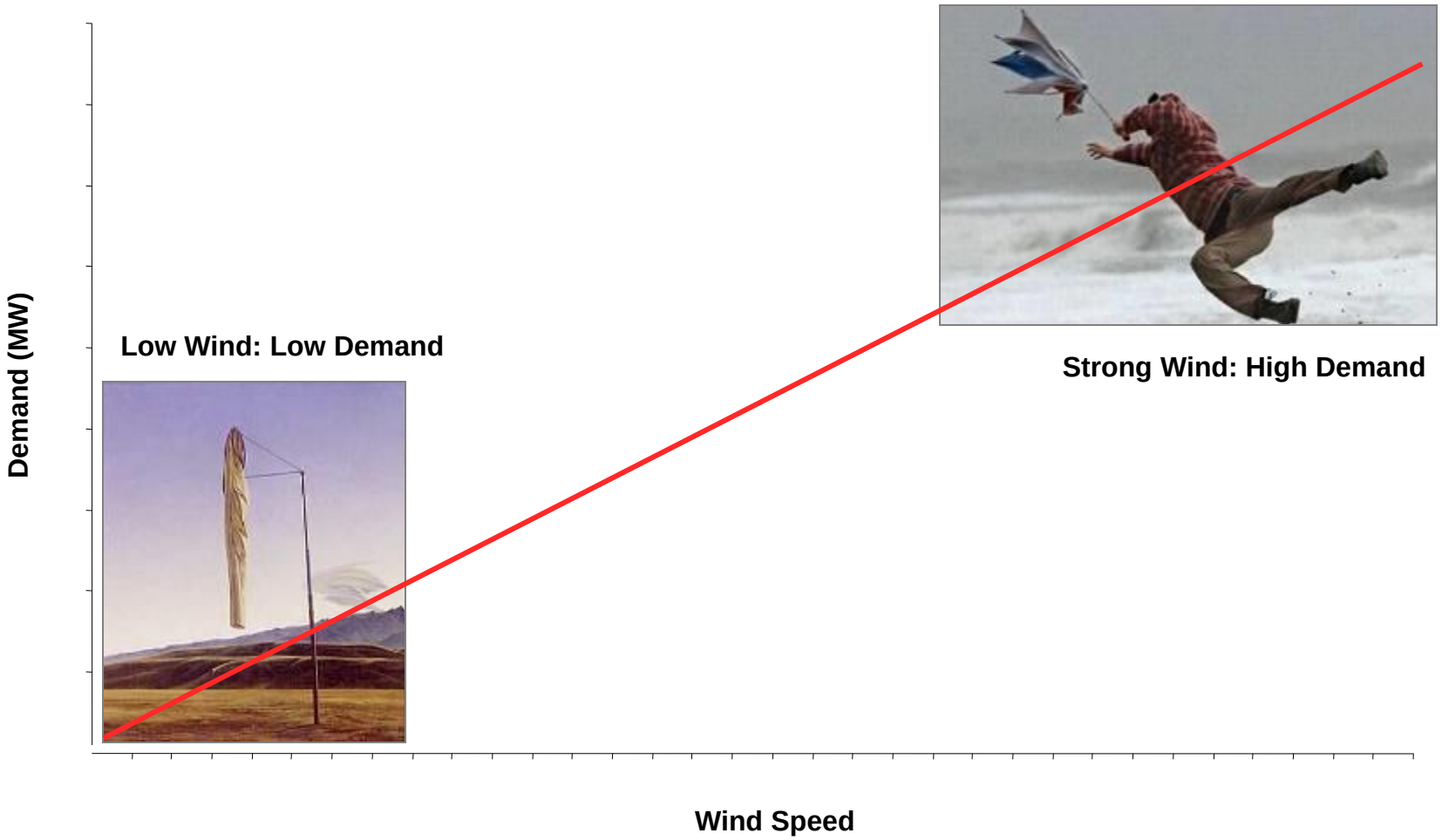
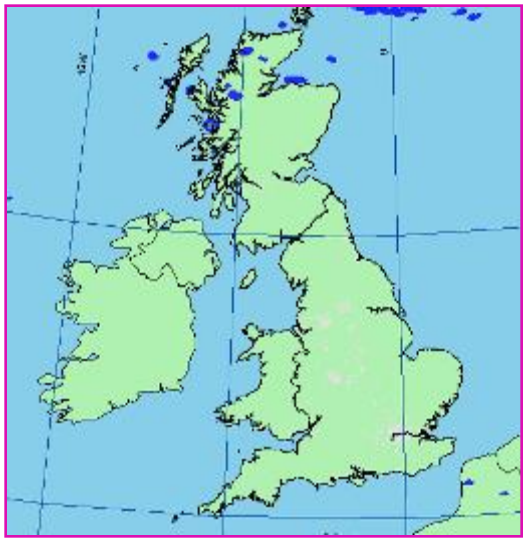
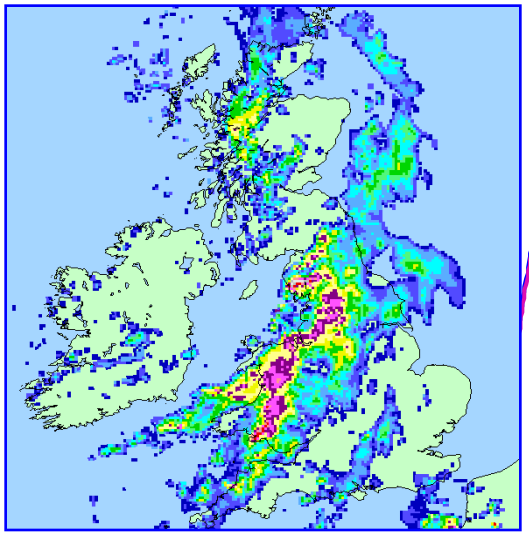
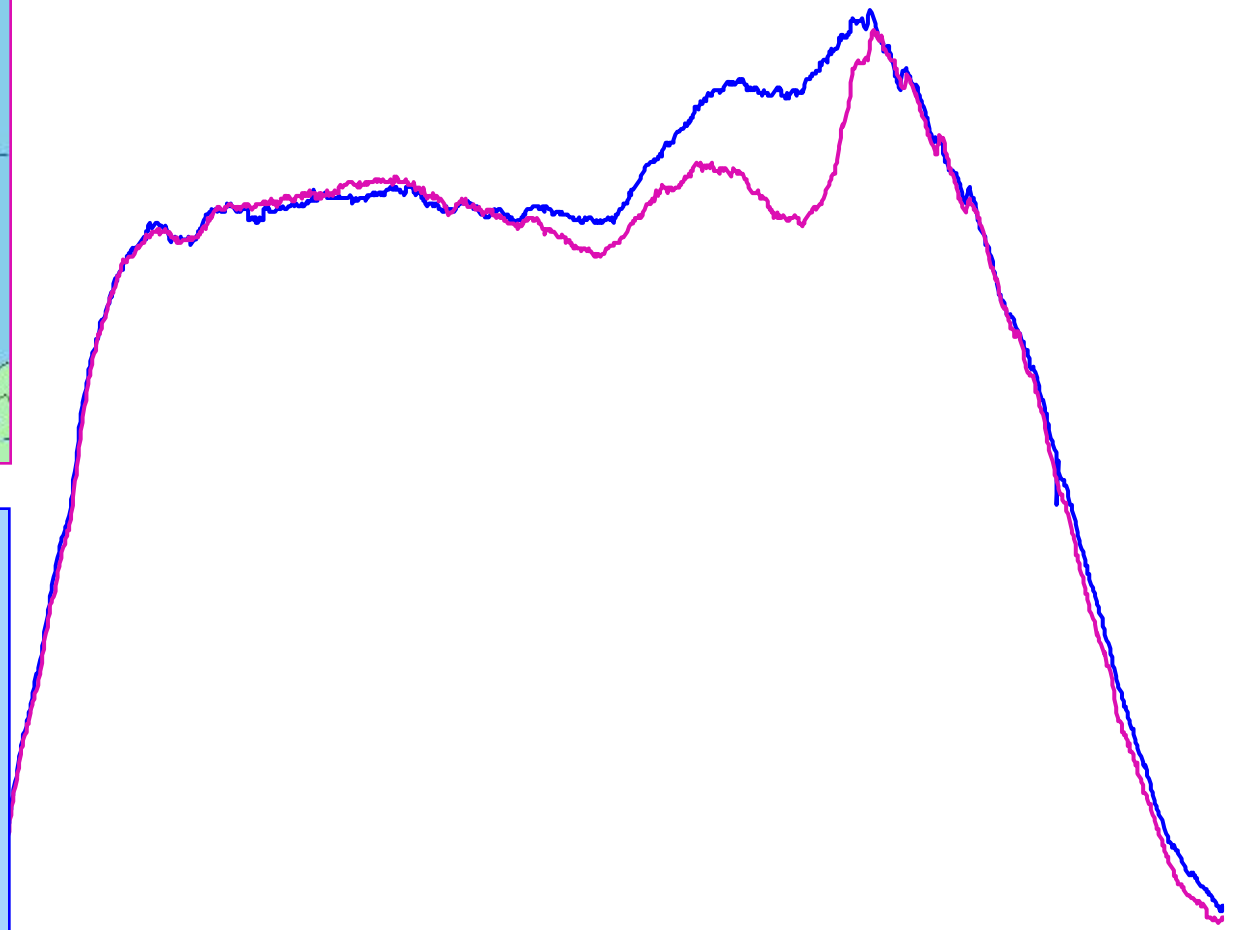


The Impact of Weather
Rain







The Impact of Weather
Some Numbers

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Temperature
(1˚ C fall in cold conditions)

Cloud cover
(clear sky to thick cloud)

Precipitation
(no rain to heavy rain)

Temperature
(1˚ C rise in hot conditions)

Cooling power
(10 mph rise in cold conditions)

+ 500 MW

+ 1,500 MW

+ 1,000 MW

+ 500 MW

+ 1,000 MW

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Weather Variables

- **4-Hourly Average Temperature [TO]**
- **Effective temperature [TE]**
- **Wind Speed [WS]**
- **Cooling Power of the Wind [CP]** – a function of Wind Speed and Temperature (TO)
- **Effective illumination of the Sky [EI]** - A derived quantity calculated from radiation levels and measurements of cloud type and cover

Non-weather variables

- **Day of week**
- **Year Effect** – indicator variable for different years: mostly owing to different economic conditions
- **Time of year** – seasonality
- **Time of Sunrise and Sunset**
- **School Holidays** - % of schools on holiday
- **Annual Holidays** – indicator variable from common August holiday weeks
- **Bank Holidays** – excluded from data set for purposes of modelling, then deal with on an ad hoc basis

GB National Demand Cardinal Points

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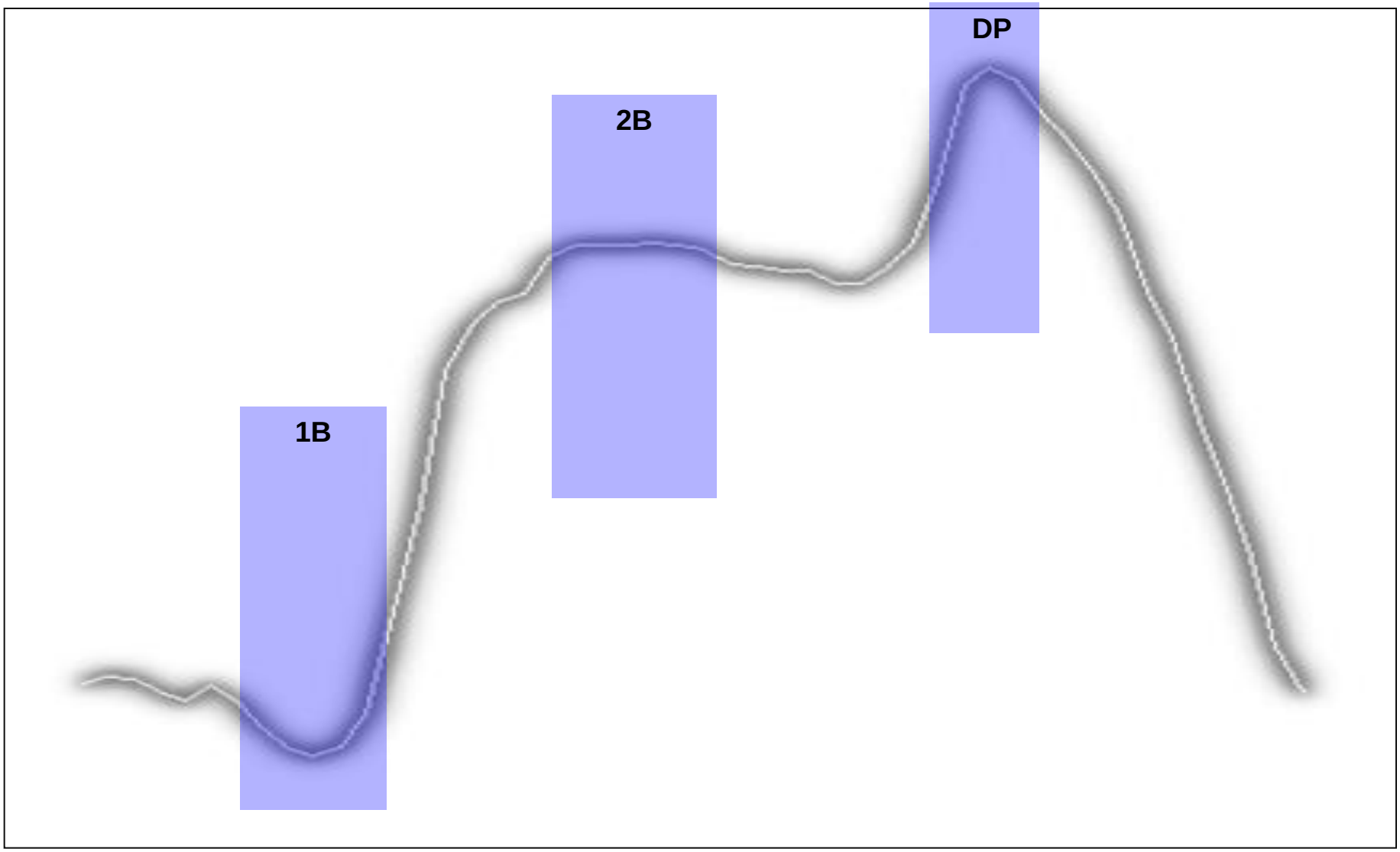

Standard Linear Regression Conventional Models

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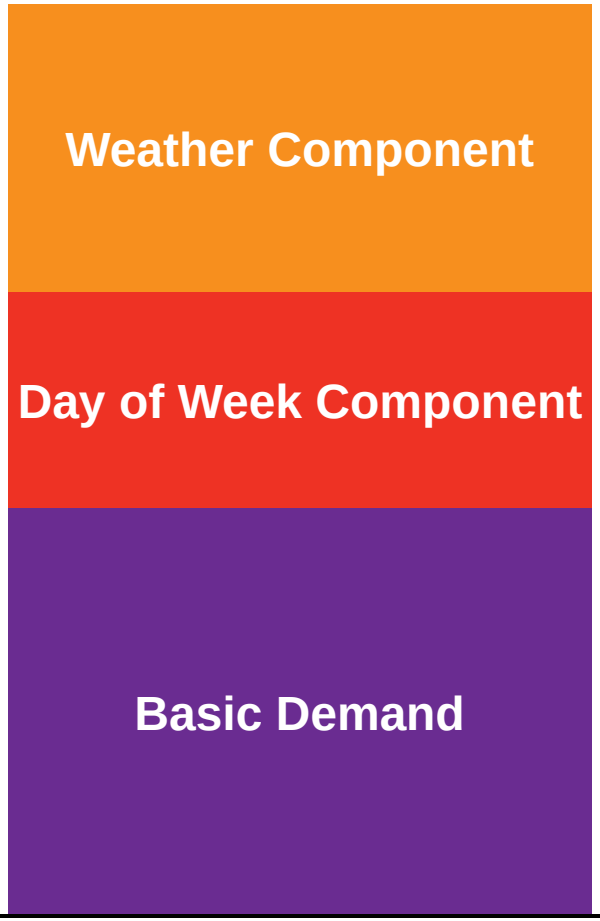
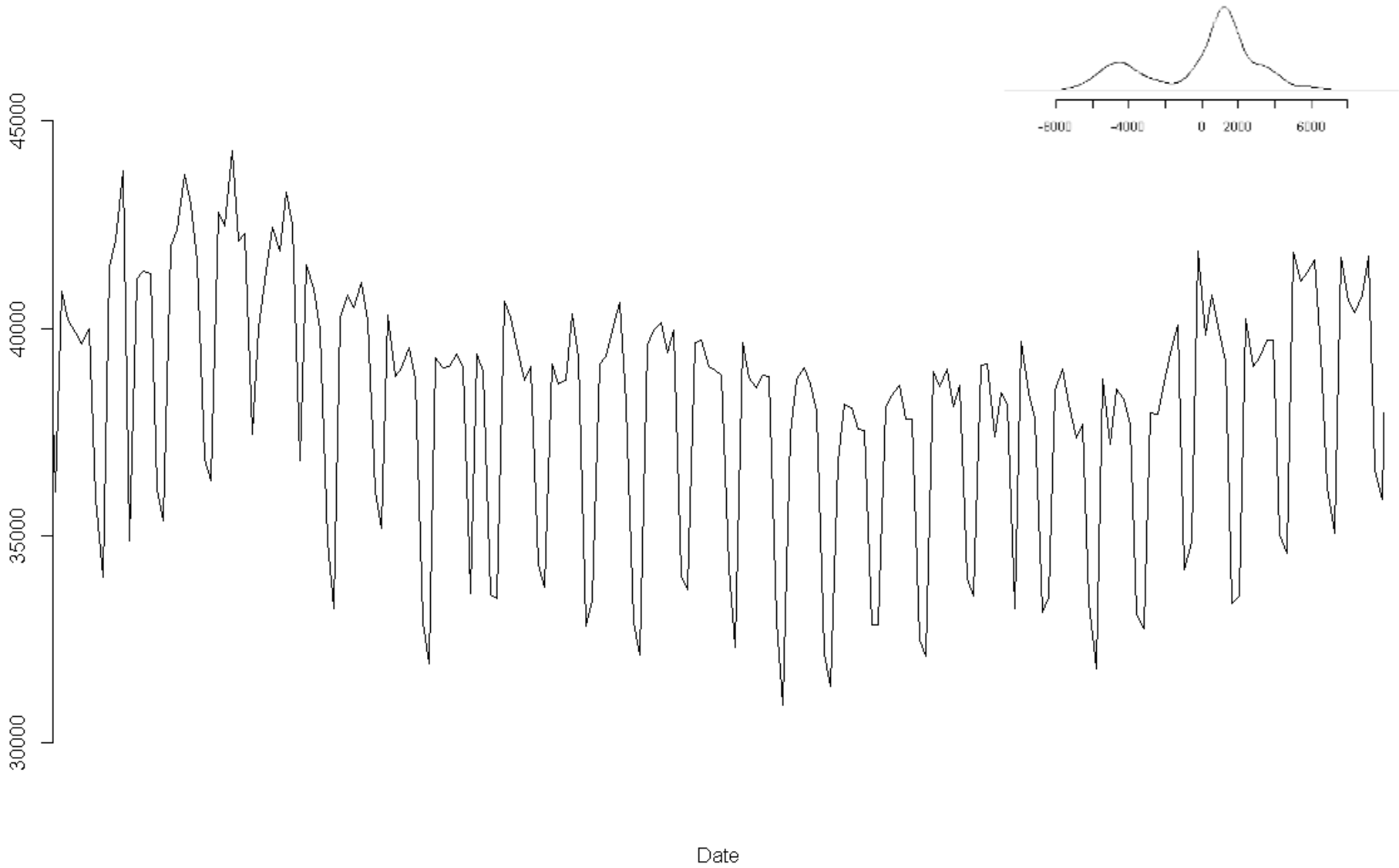


- Model Inputs:
  - Historic Demands
  - Historic Weather – Heathrow, Glasgow, Manchester, Bristol, Leeds, Bimingham
  - Additional Effects – School Holidays, Day of Week, Time of Year

Modelling

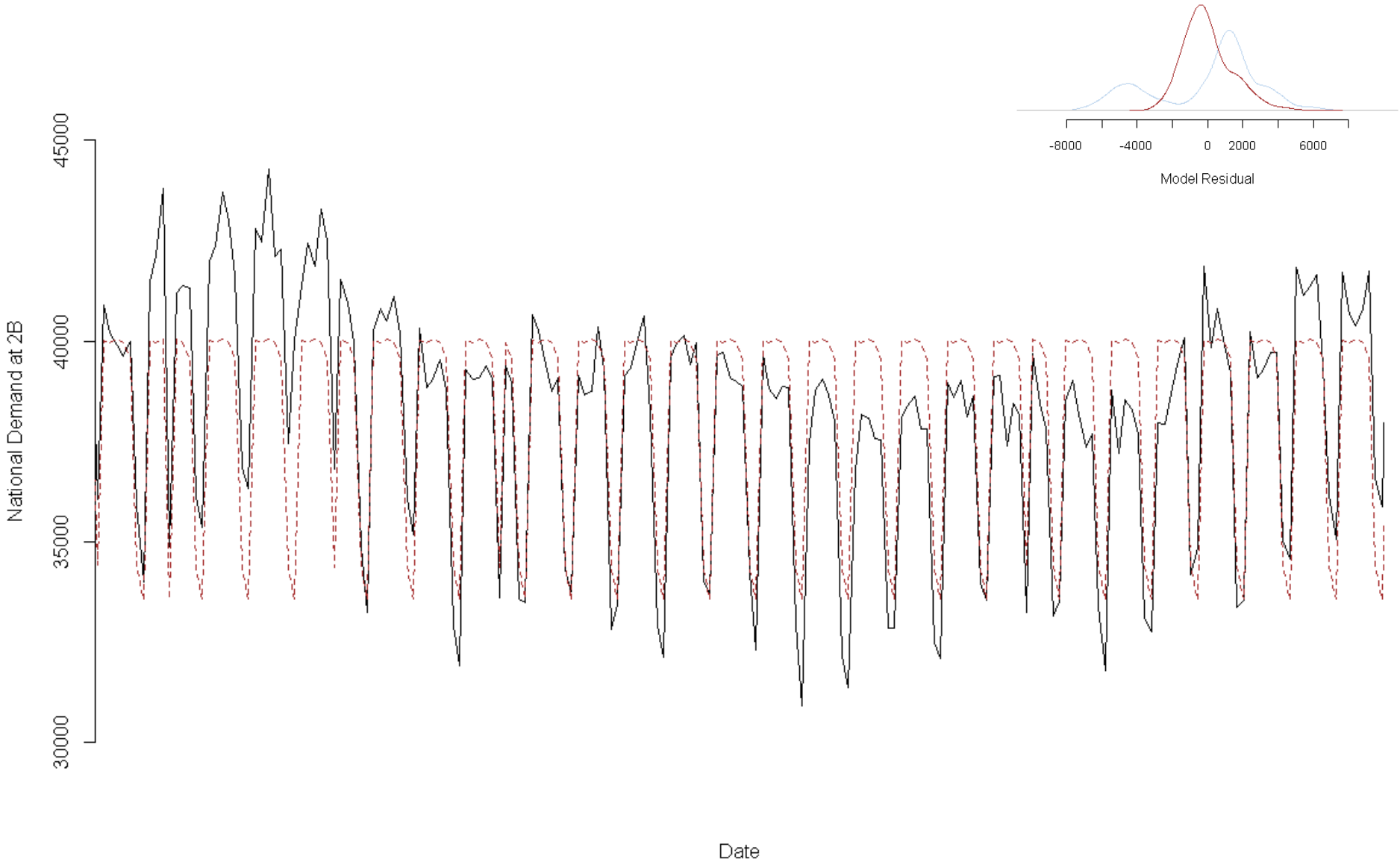
- Construct different models for each of the Cardinal Points (CPs)
- Construct different models for GMT and BST
- Construct models of two different types for each CP:
  - Standard linear regression models (Conventional Models)
  - Time series models with linear regression (Trend models)
- Depending on the CP we construct 7 day models, 5 day models, Saturday models and Sunday models
- On any day of the week there are at least two (and up to four) models that we forecast with

2B Demand (12:30)



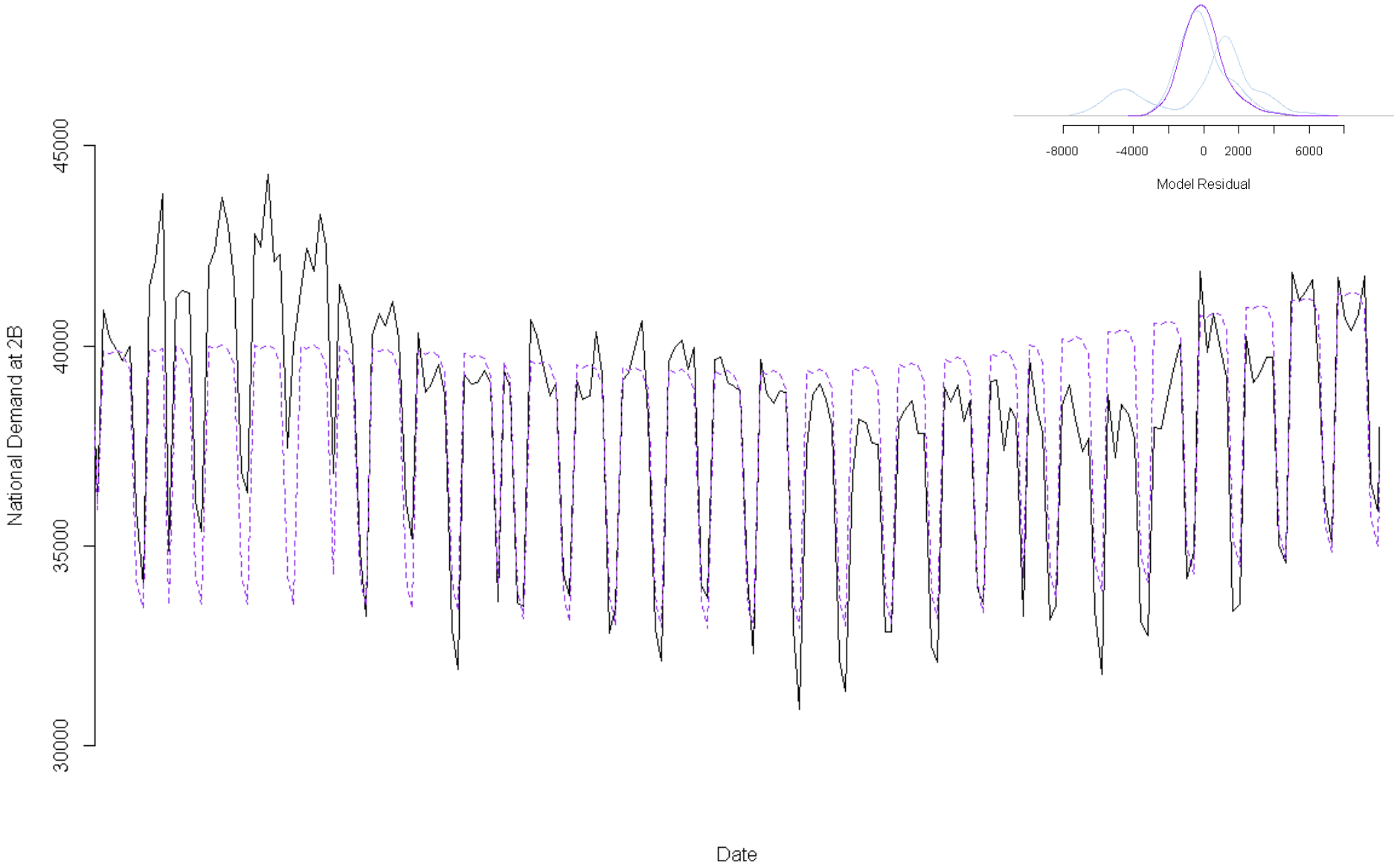
2B Model On Day Of Week Effect

Actual Demand Vs Fitted Values



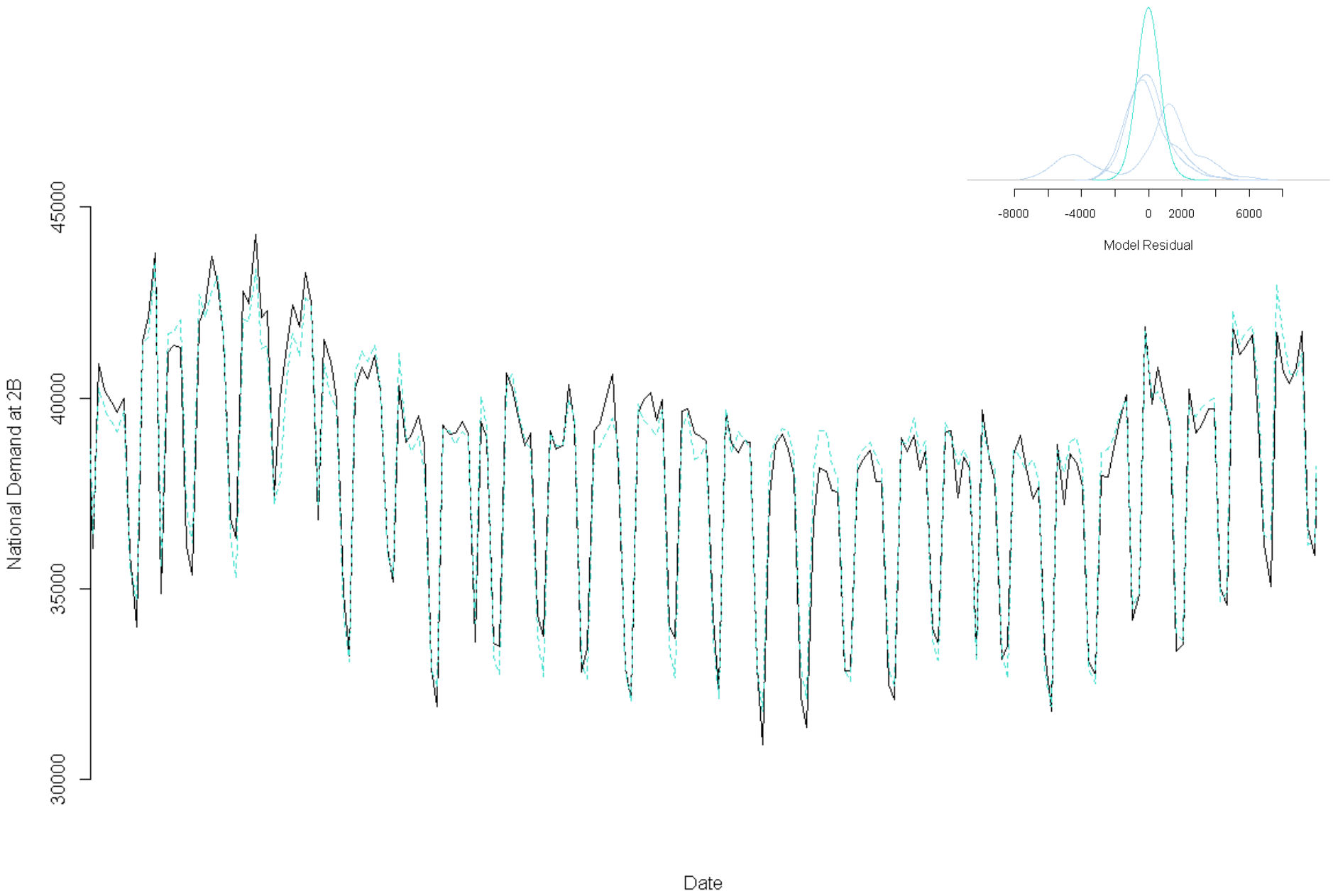
Including A Seasonal Effect

Actual Demand Vs Fitted Values



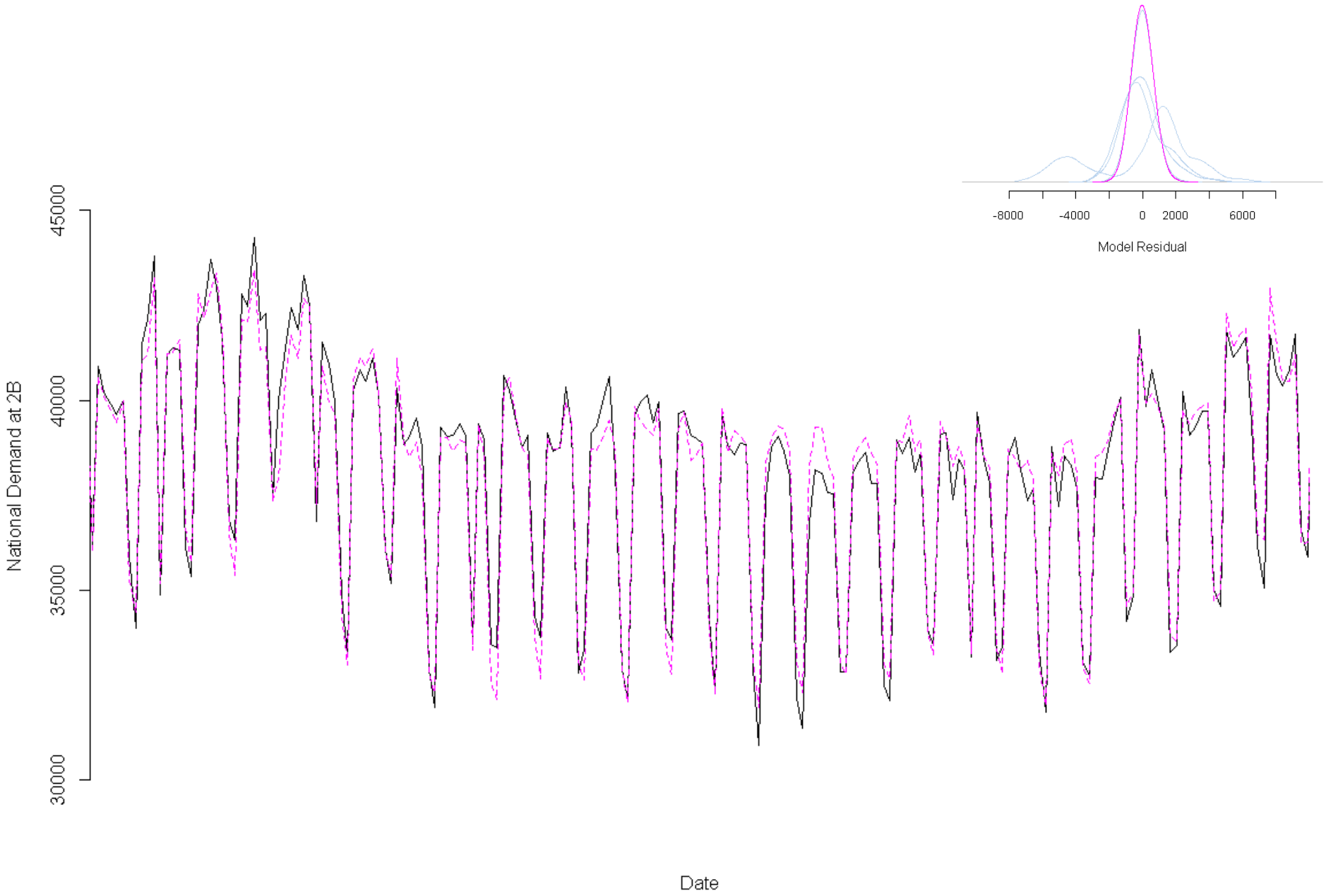
Including A Weather Effect

Actual Demand Vs Fitted Values



Including A School Holiday Effect

Actual Demand Vs Fitted Values



Time Series with Linear Regression Trend Models

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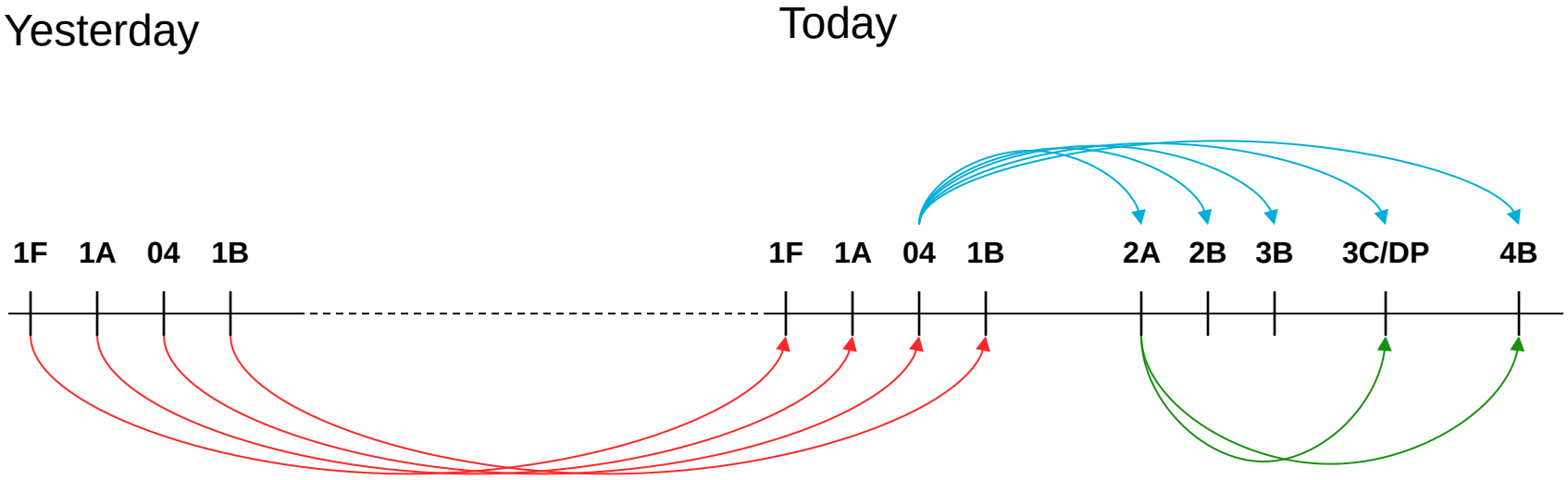
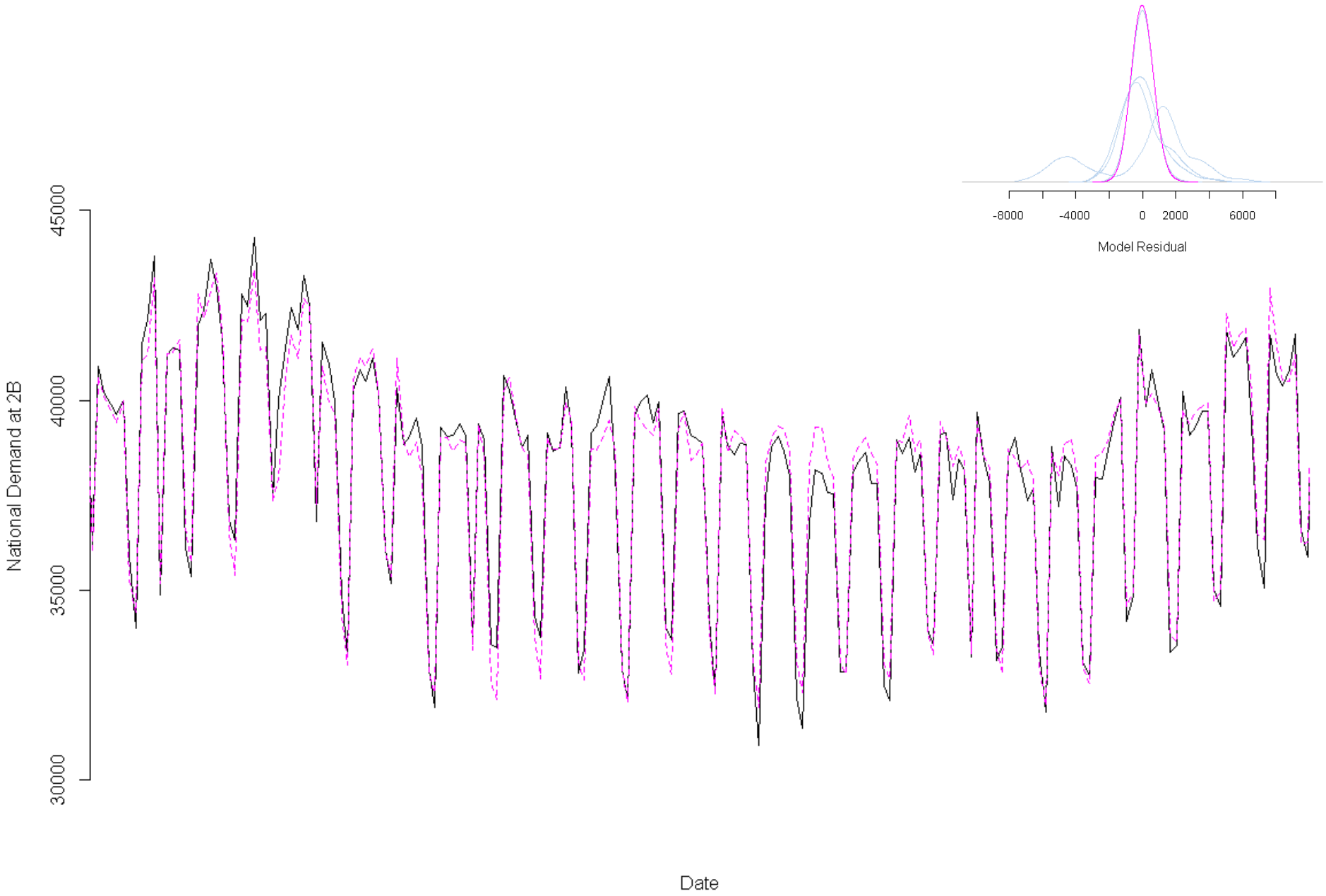


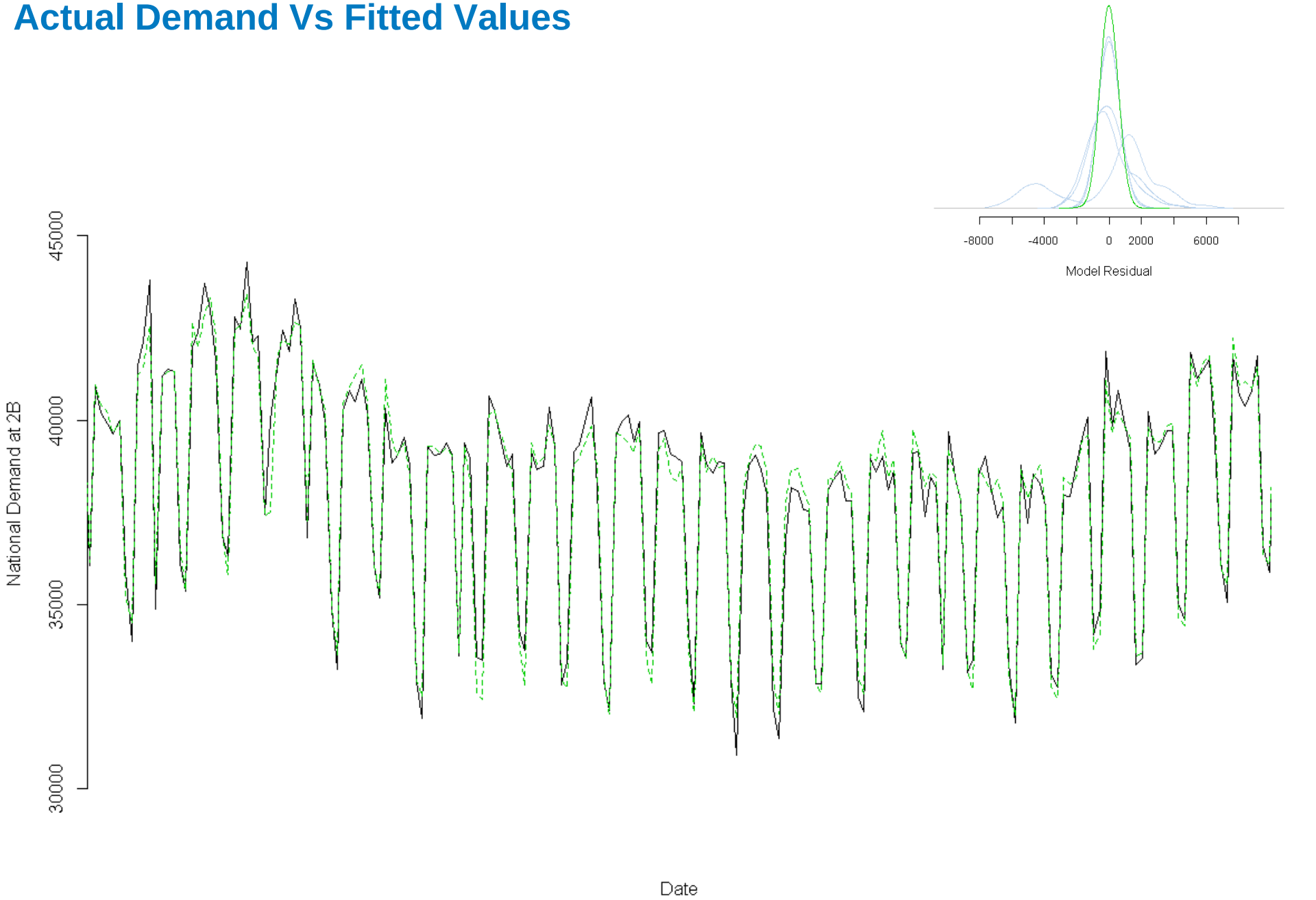
Including A School Holiday Effect

Actual Demand Vs Fitted Values



Including A Trend Component

Actual Demand Vs Fitted Values



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The Model Symbolically

$$L2B \sim L04 + DWK + SCH + EI + CP + \varepsilon$$

Trend term

Day of Week Effect

Weather Effect

Error term

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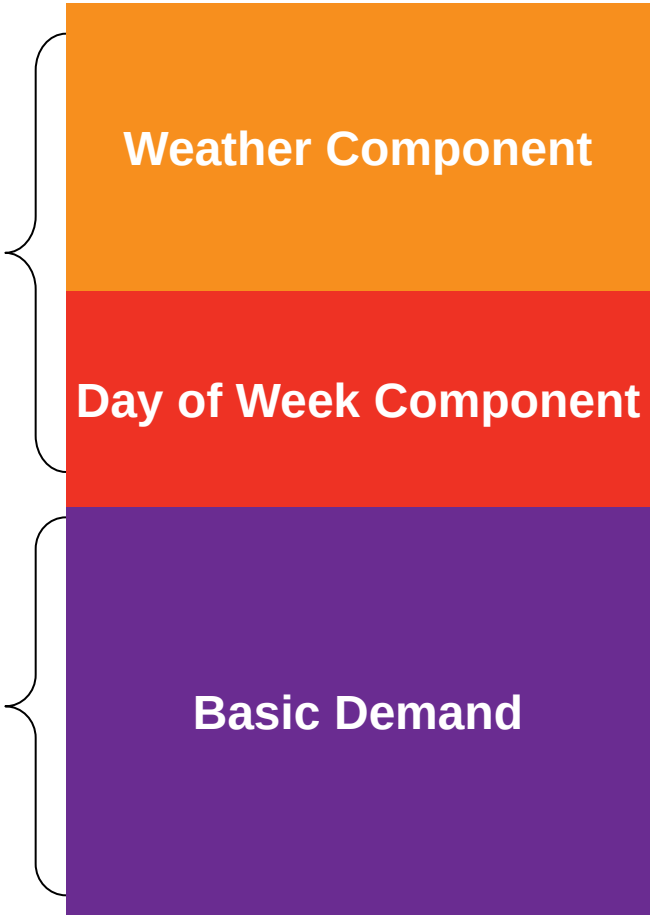
Modelling CP Demand

- Construct forecast models using variables that make sense
- Use best model possible with variables that reduce the residual error significantly

- Track ‘Basic Demand’, non-model component of demand



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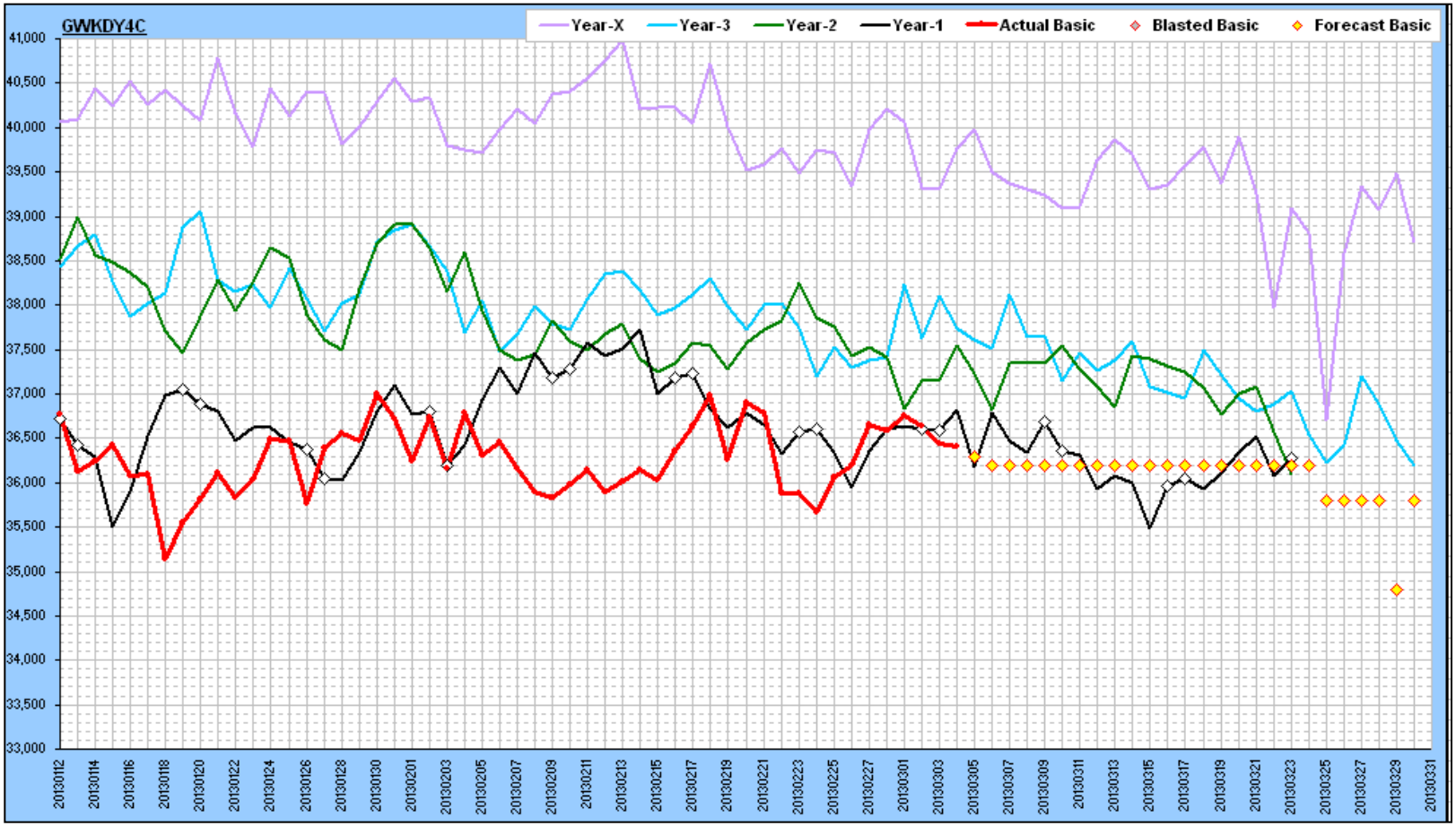
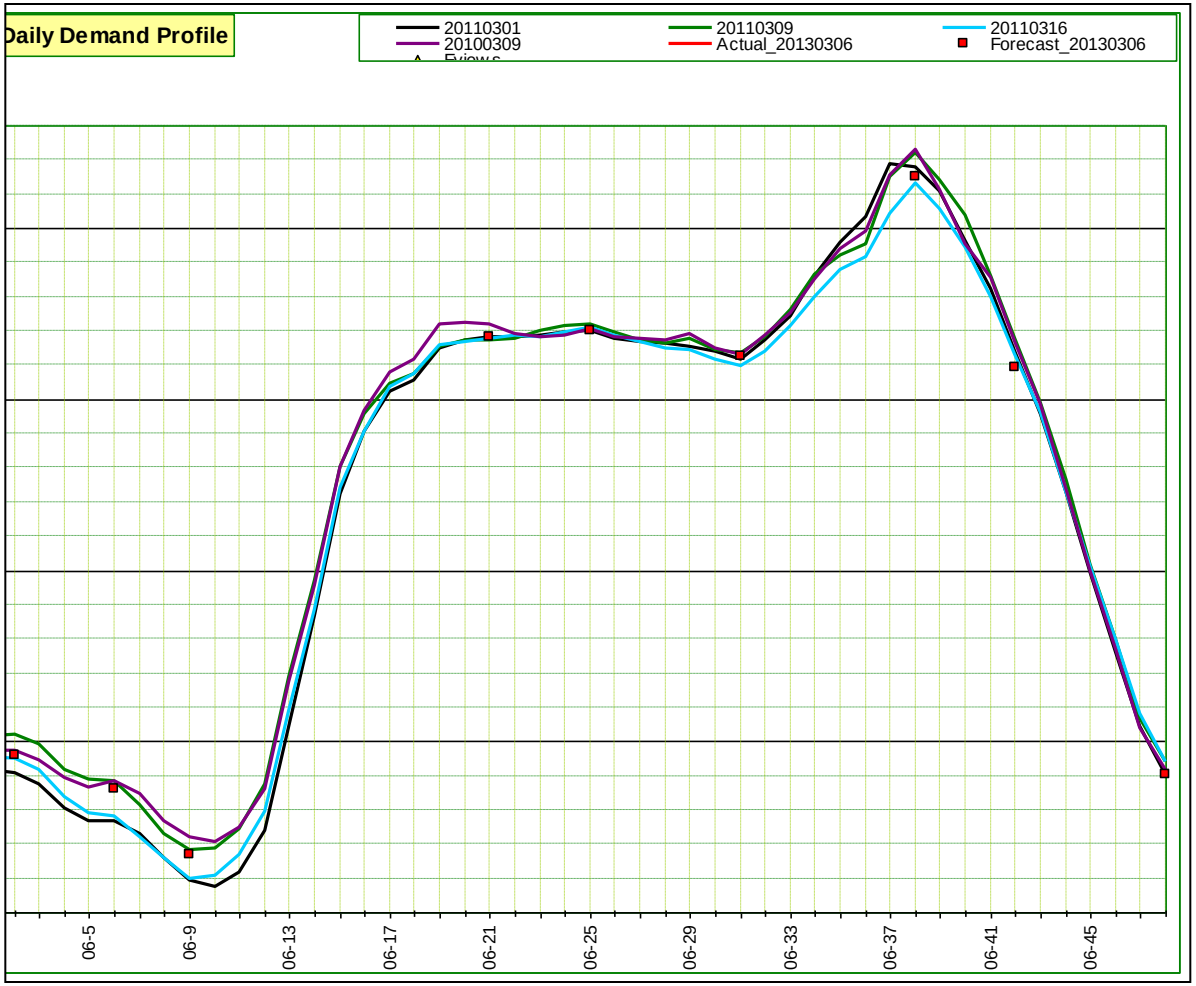
Basic Demand

- Manually track and forecast basic element of demand



Profile Matching

- Check how well CP forecasts match historic days



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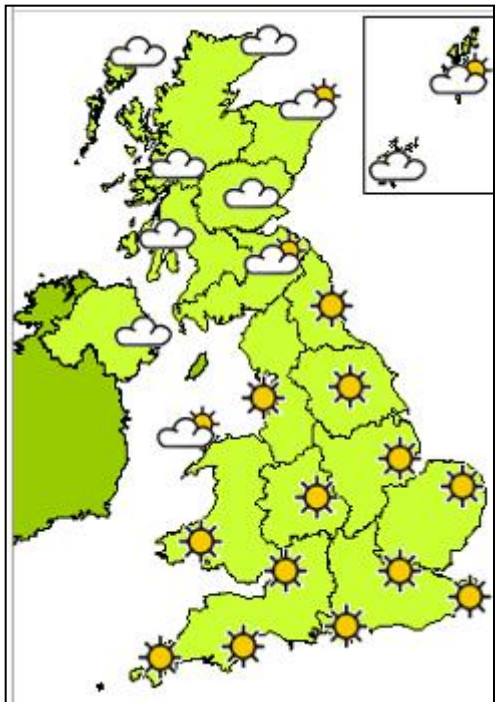
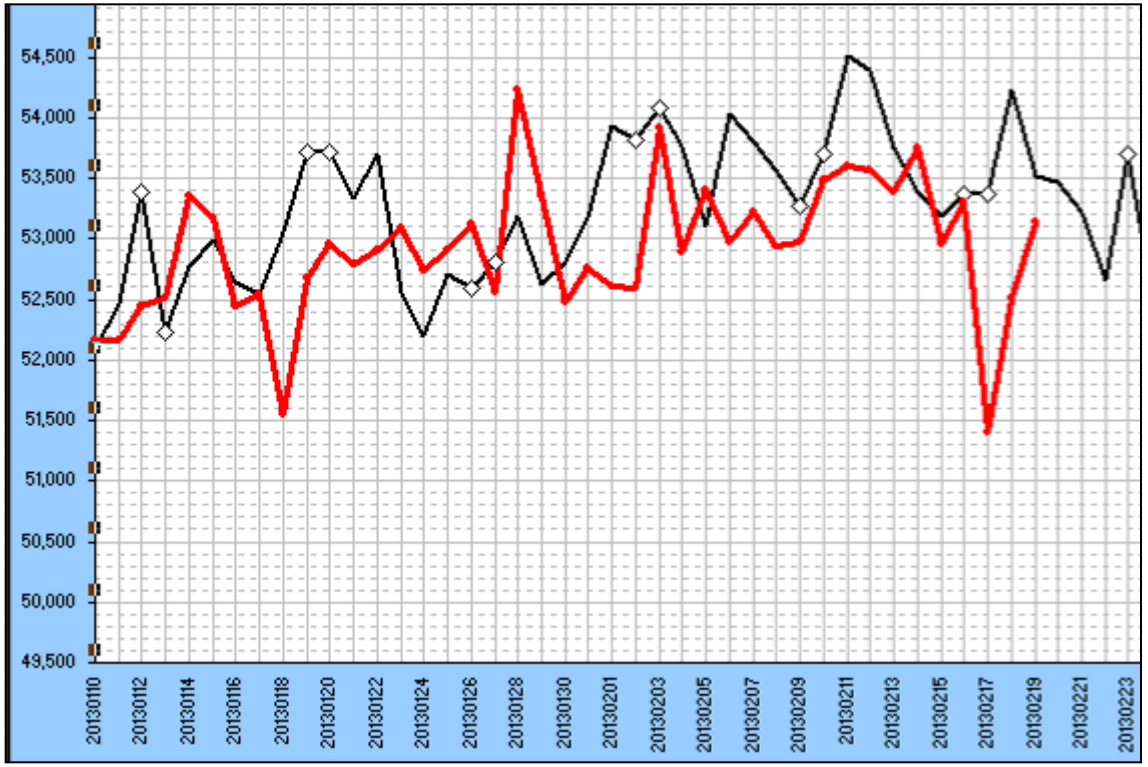
Choosing Basics

- Forecast basic demand
- Aim is to reduce risk of error



2B model: Jan-Feb 2013



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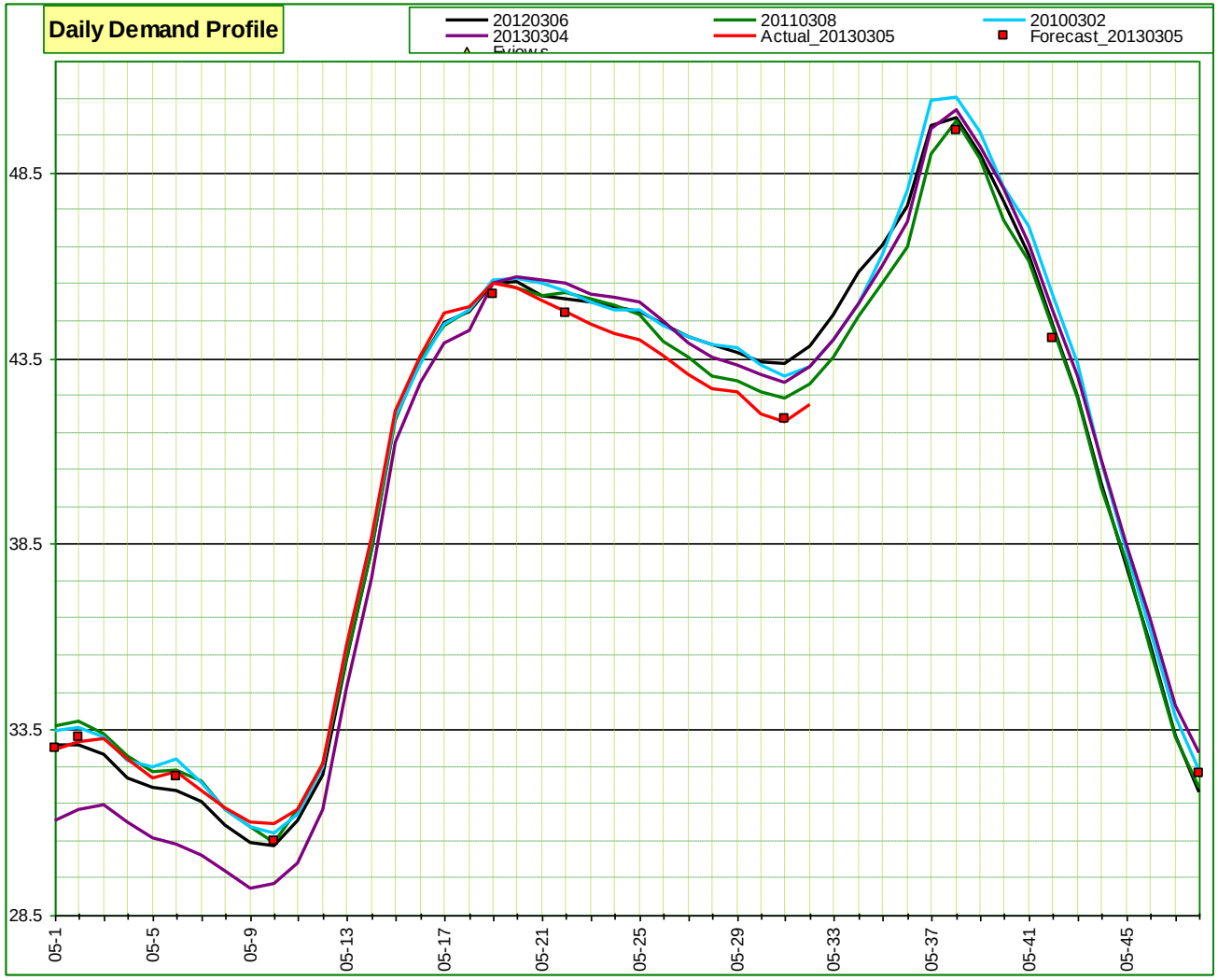
Embedded PV Generation

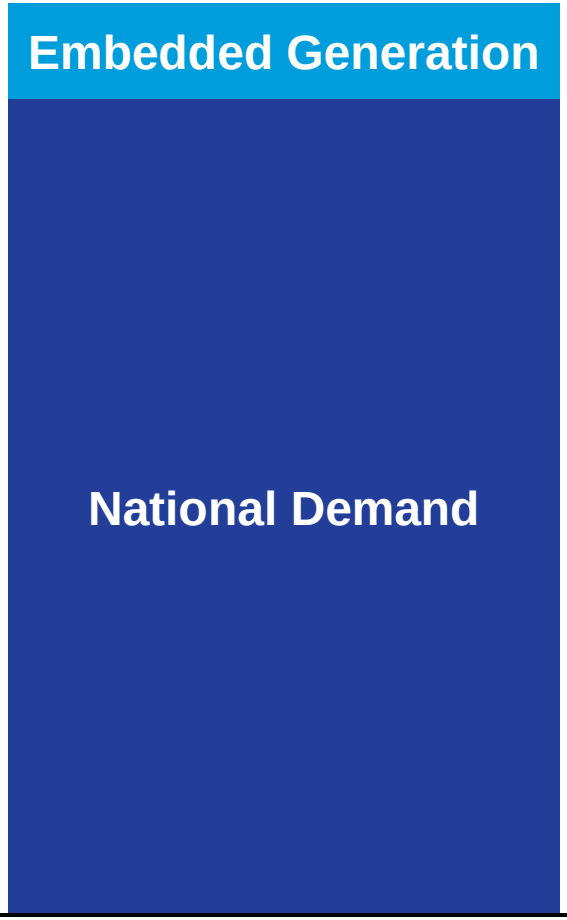
Embedded PV Generation



Embedded Generation

- ‘Invisible’, non-metered
- Connected directly into distribution networks
- Effectively reduces demand on the system
- Not just PV…

The Impact of Embedded Generation



- True GB Demand is higher than National Grid observe
- Not a new phenomenon, but an increase in more variable technologies means it is a more significant effect
  - Wind Power ~ 2,000 MW
  - Solar Power ~ 1,500 MW

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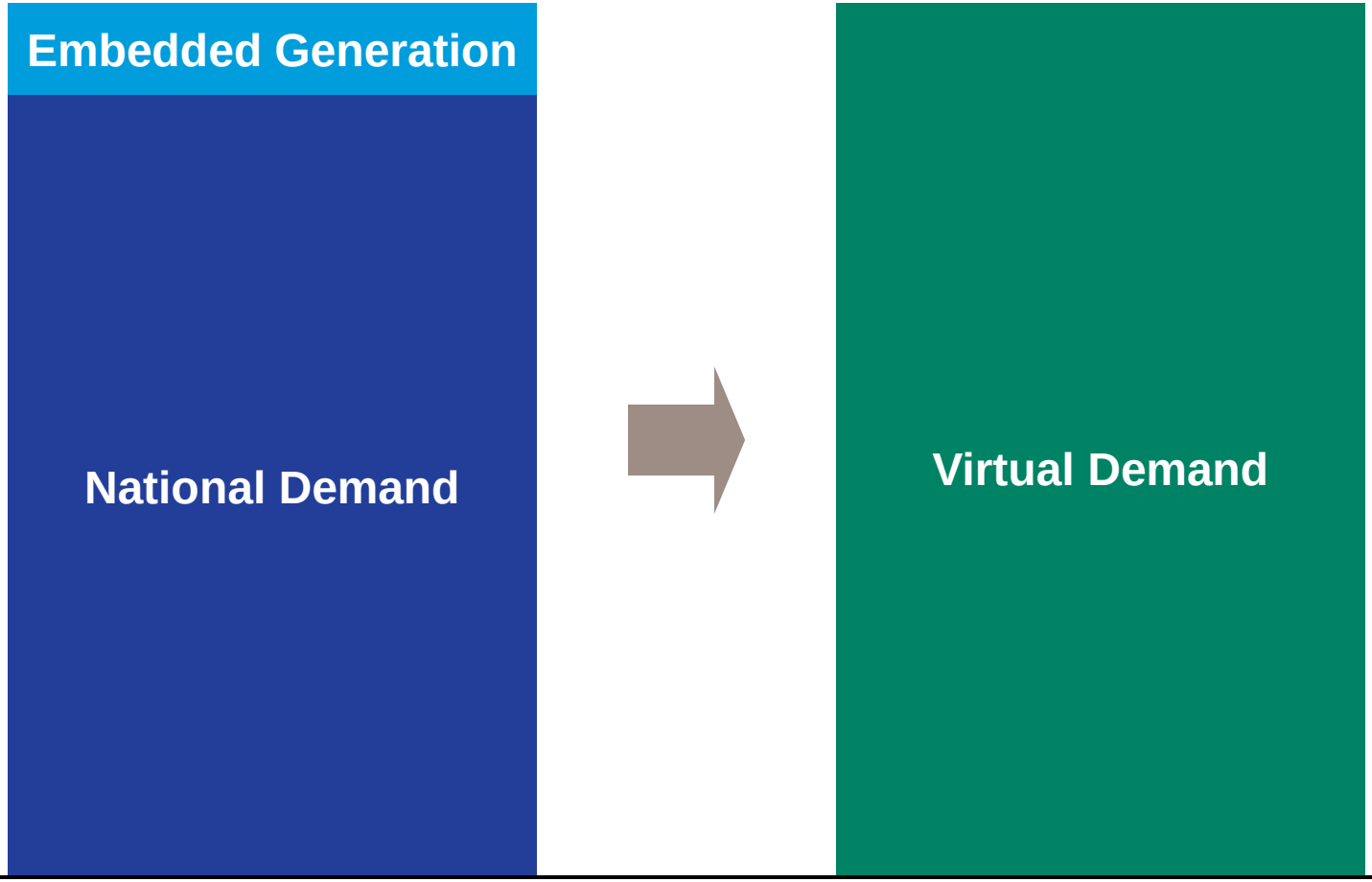
Virtual Demand: A True National Demand



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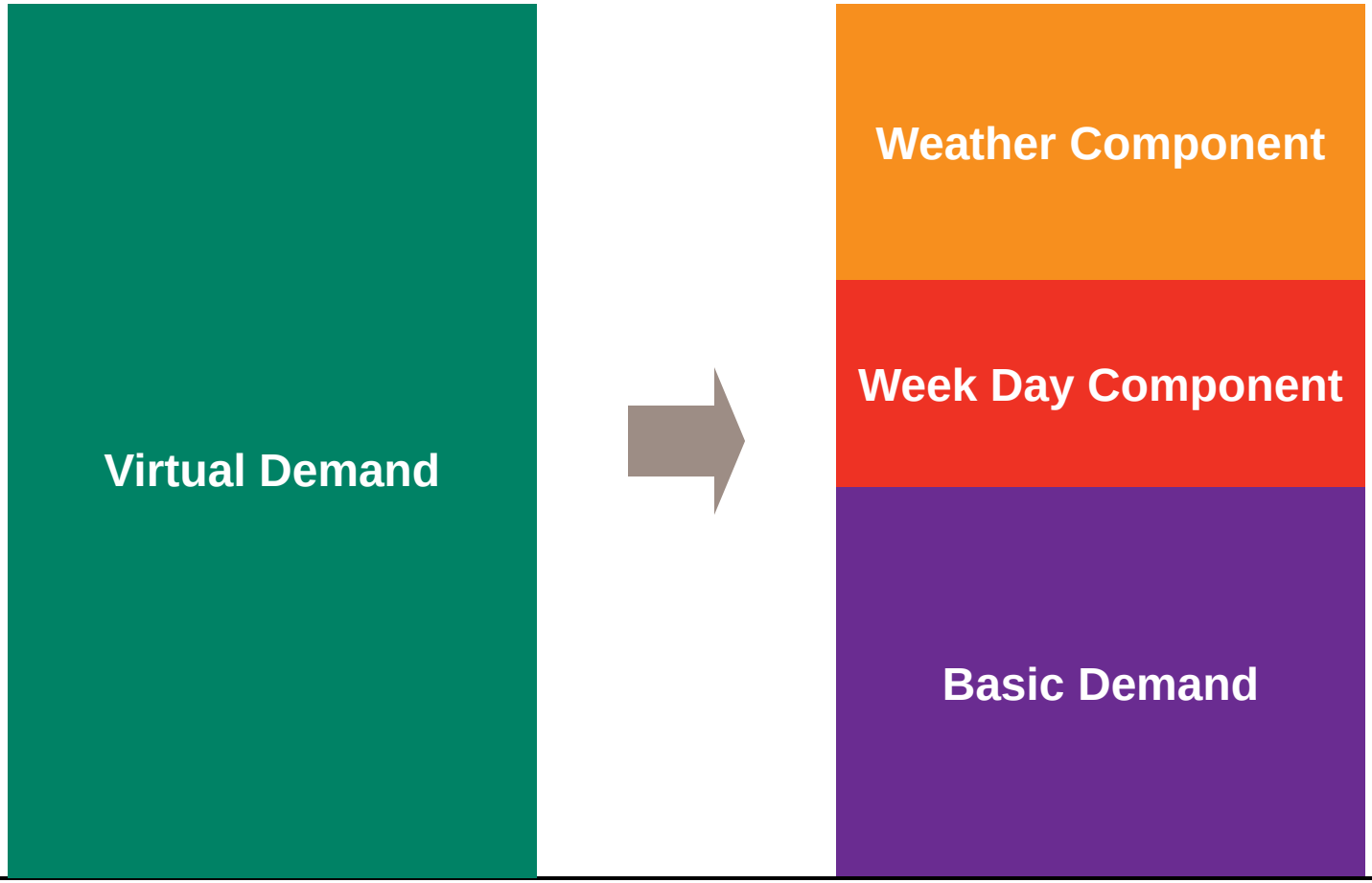
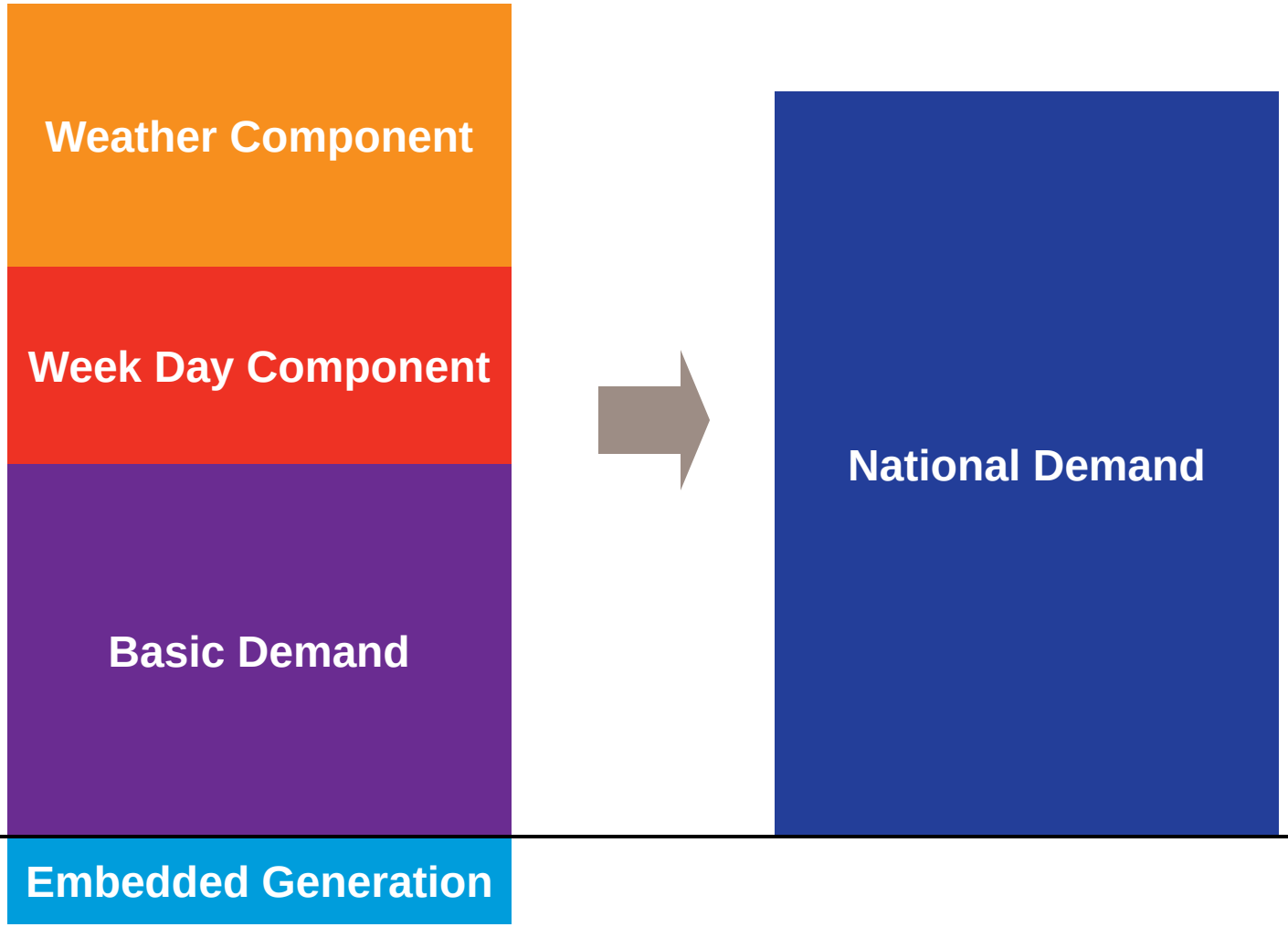
Model Using Virtual Demand

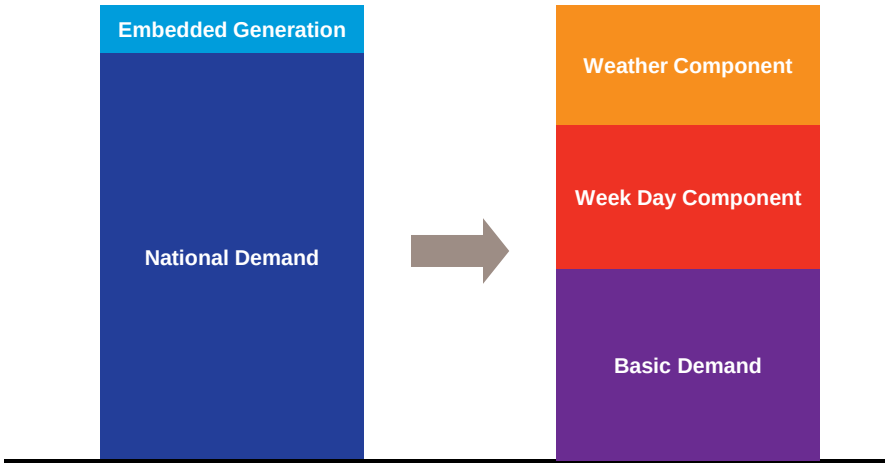


Forecast Virtual Demand; Adjust for Embedded Generation

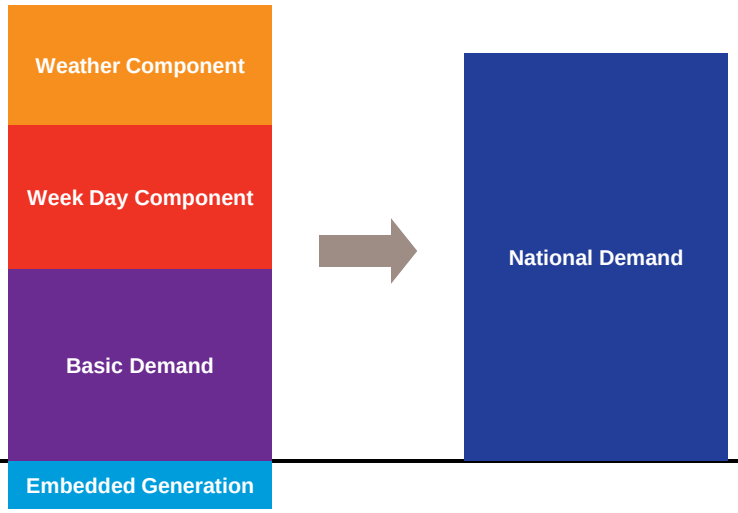


The Forecasting Process

Model using Virtual Demand



Forecast Virtual Demand; Adjust for Embedded Generation



Forecasting Embedded Wind Generation
Existing Forecasting Methods

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Wind Power Forecasting System

- Metered Wind ~ 5,800 MW
- Embedded ~ 2,000 MW

Metered Wind Farms

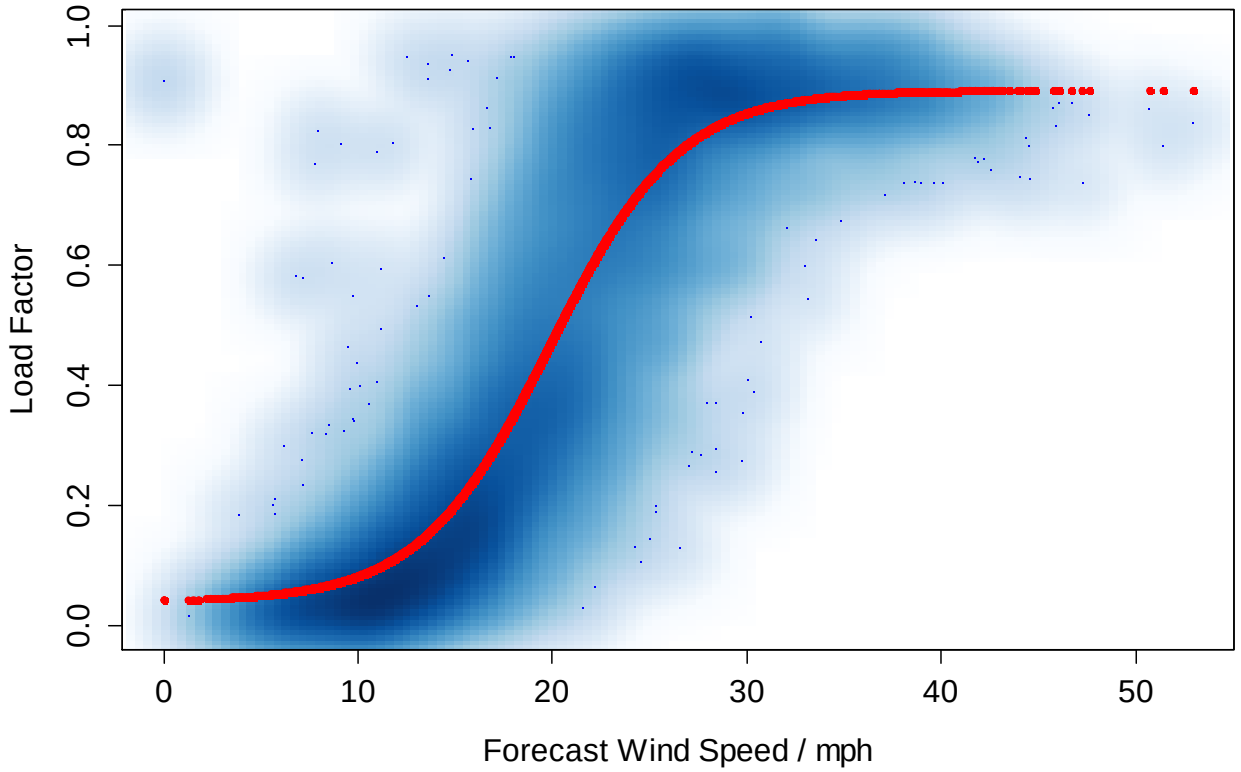
Embedded Wind Farms

Metered Wind Power Forecast

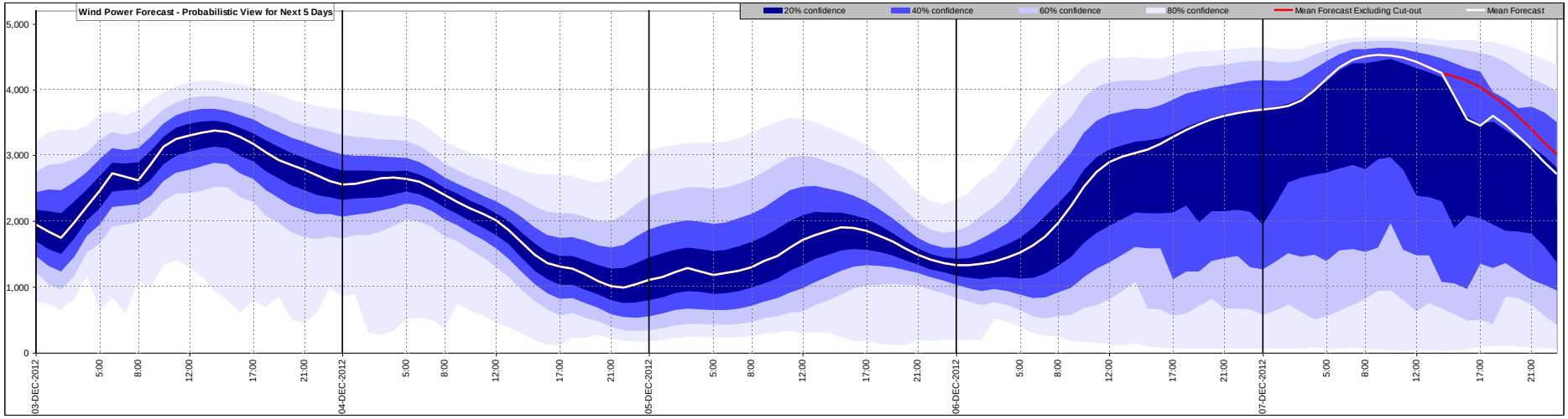
National Demand Forecast

Standard Wind Power Curve
Wind Farm

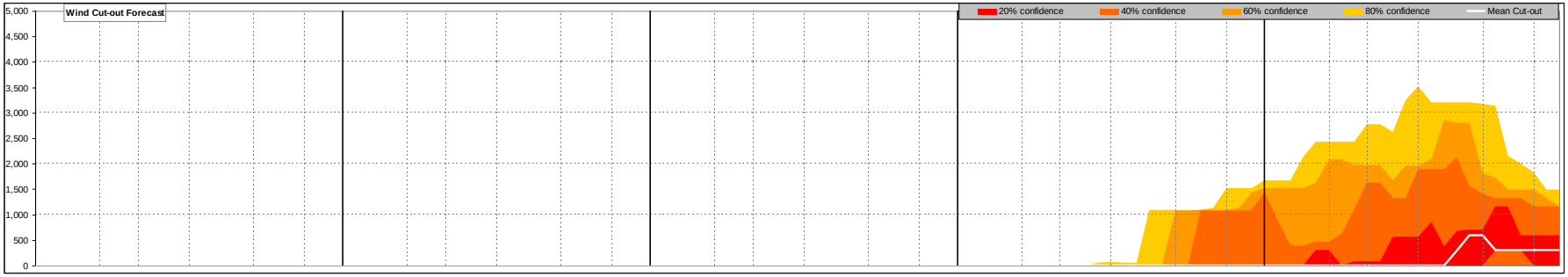
- Decile wind speed forecast applied to a load curve
- Load curves for each wind generator, optimised using actual metering



Wind Power forecast probabilistic view for next 5 days from Mon 3rd Dec 2012

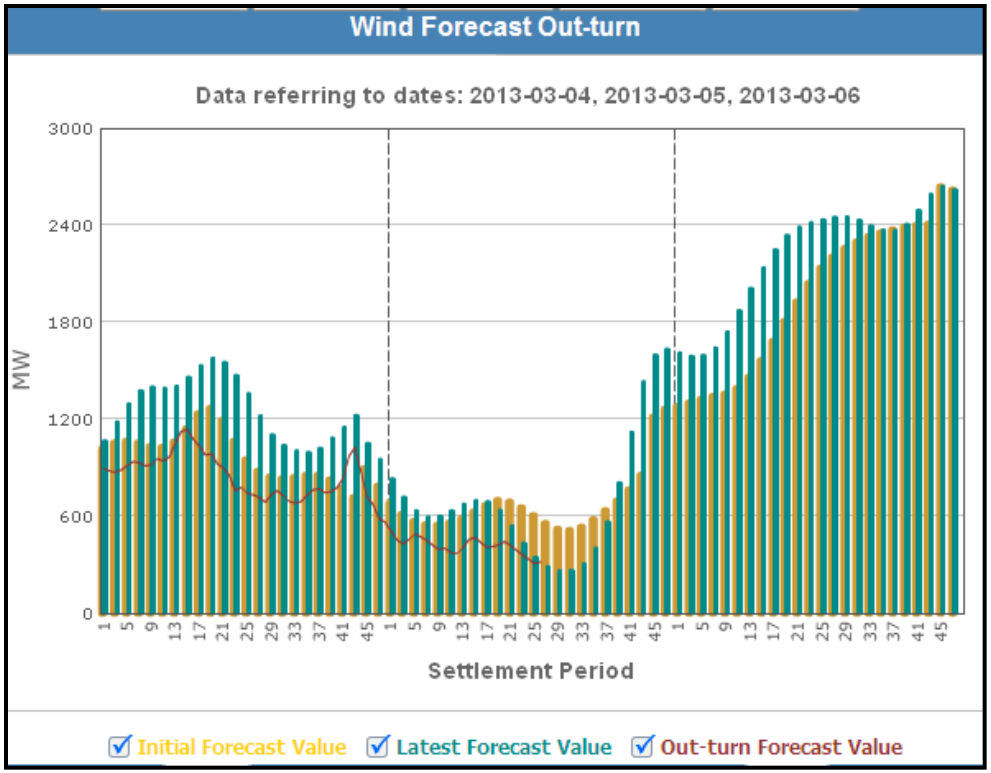


Wind cut out forecast

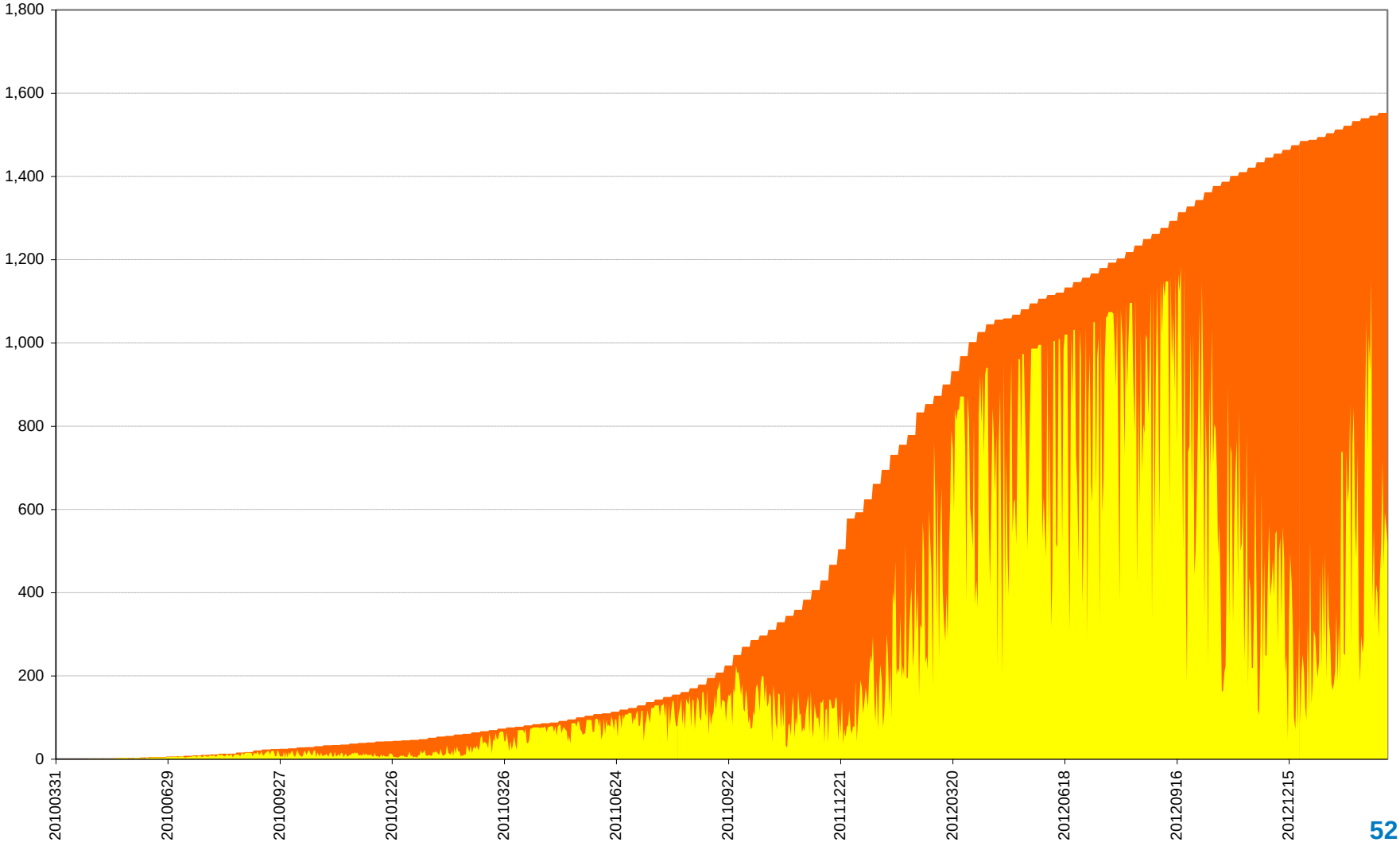


Metered wind generation forecast

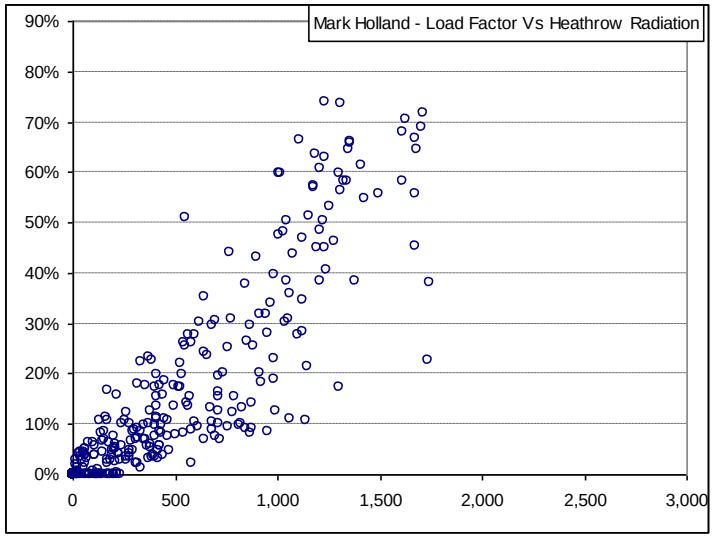
- Use same process to forecast embedded wind
- Have information on location and capacity for all embedded wind generators above 2MW

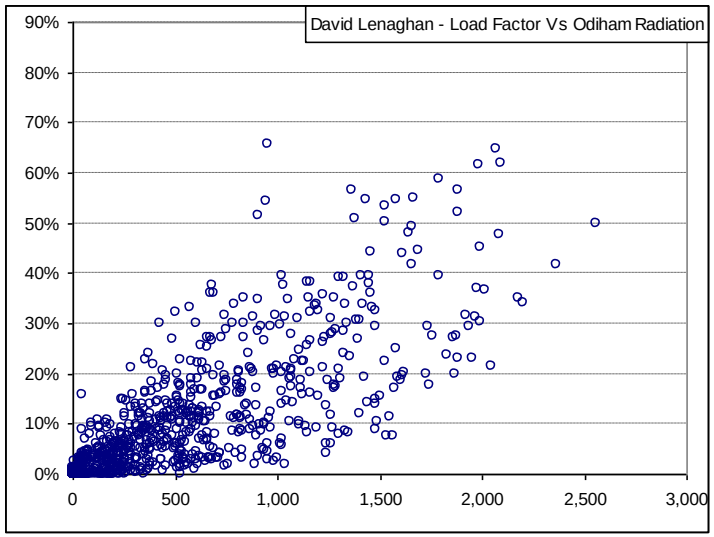


Forecasting Embedded Generation
Simulated National PV Output

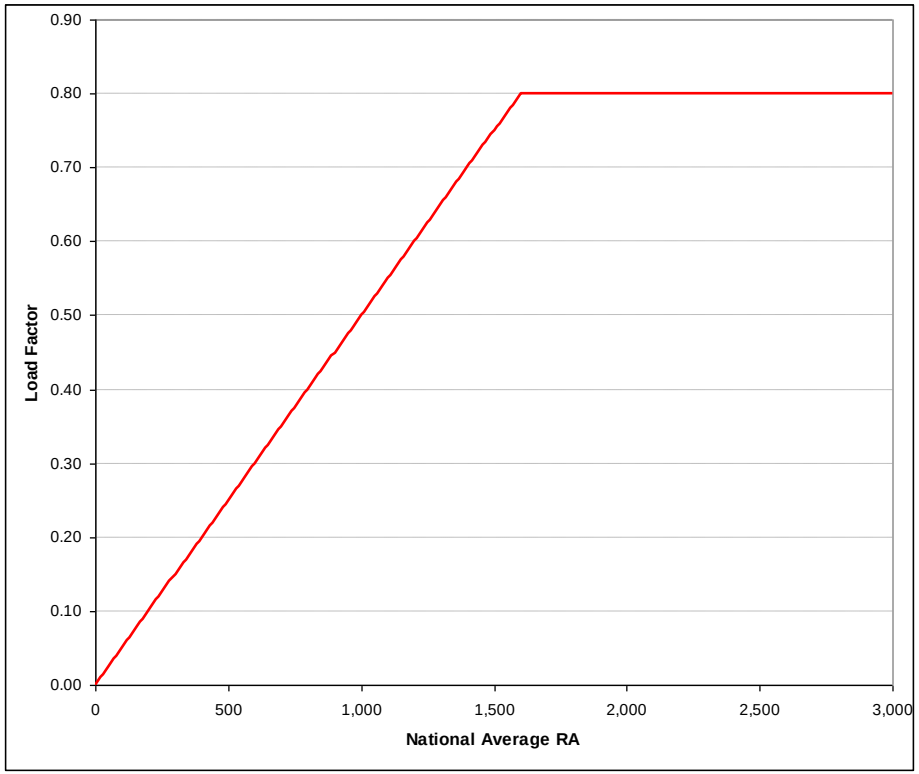


Forecasting Embedded Generation
Forecasting PV





- National average radiation forecast
- Generic power curve
- National capacity



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The challenges of PV

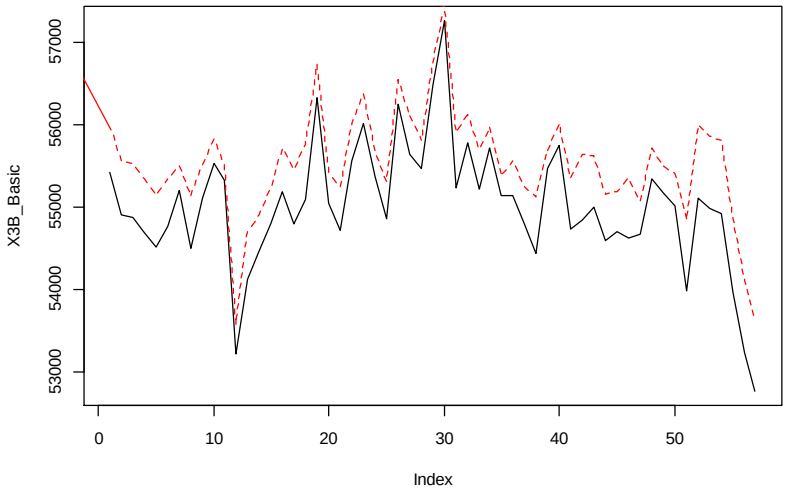
Embedded Wind

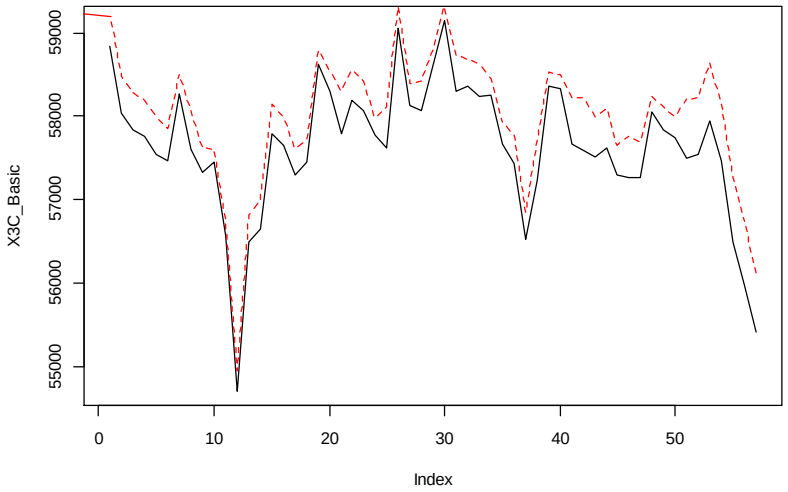
- Individual locations and capacities
- Wind speed forecasts for various locations
- Experience forecasting metered wind

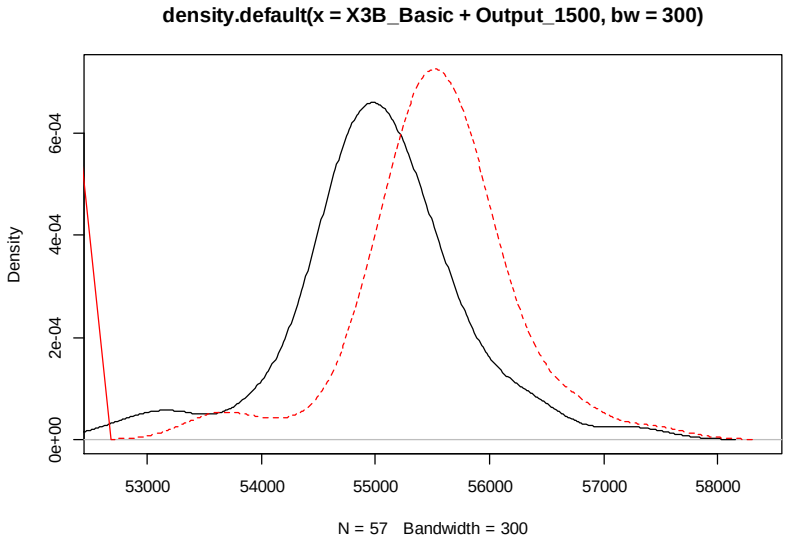
Embedded PV

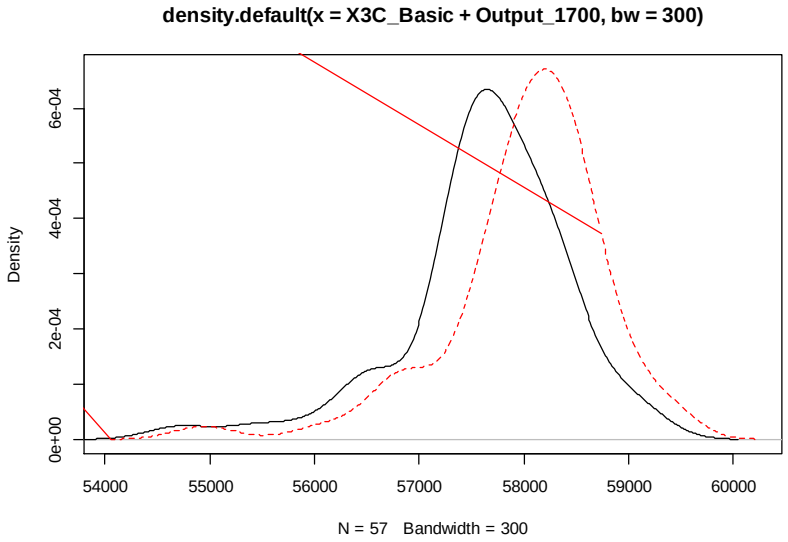
- Overall capacity for whole country
- National Average radiation
- No operational experience yet

Forecasting Embedded Generation
Forecasting PV







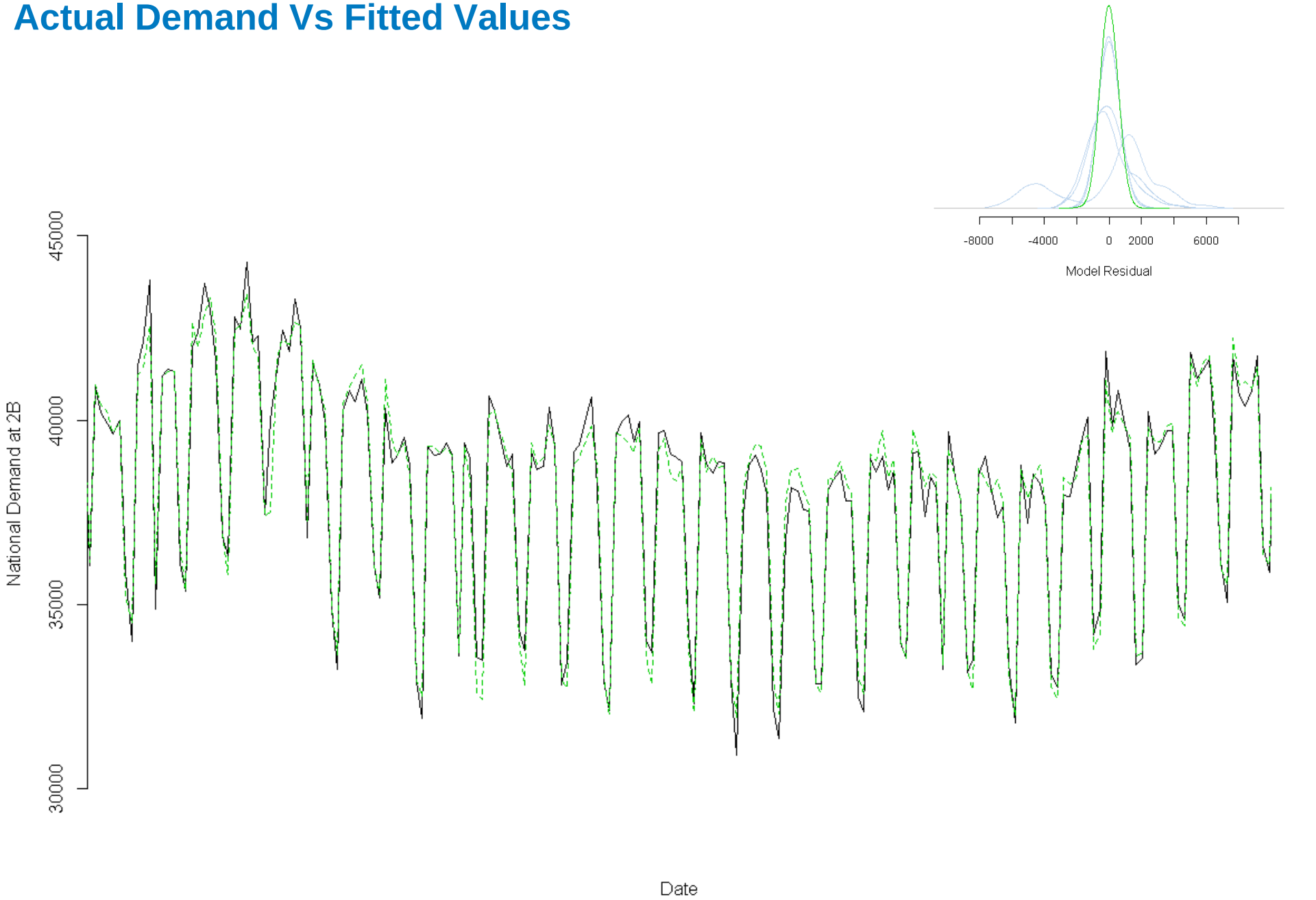


The Problem with Embedded Generation

- ~ 3,500 MW installed capacity
- Variable output dependant on weather effects
- Changing capacity levels
- Reliant on estimates of output
- No means of directly testing forecast models
- Increases the volatility of National Demand

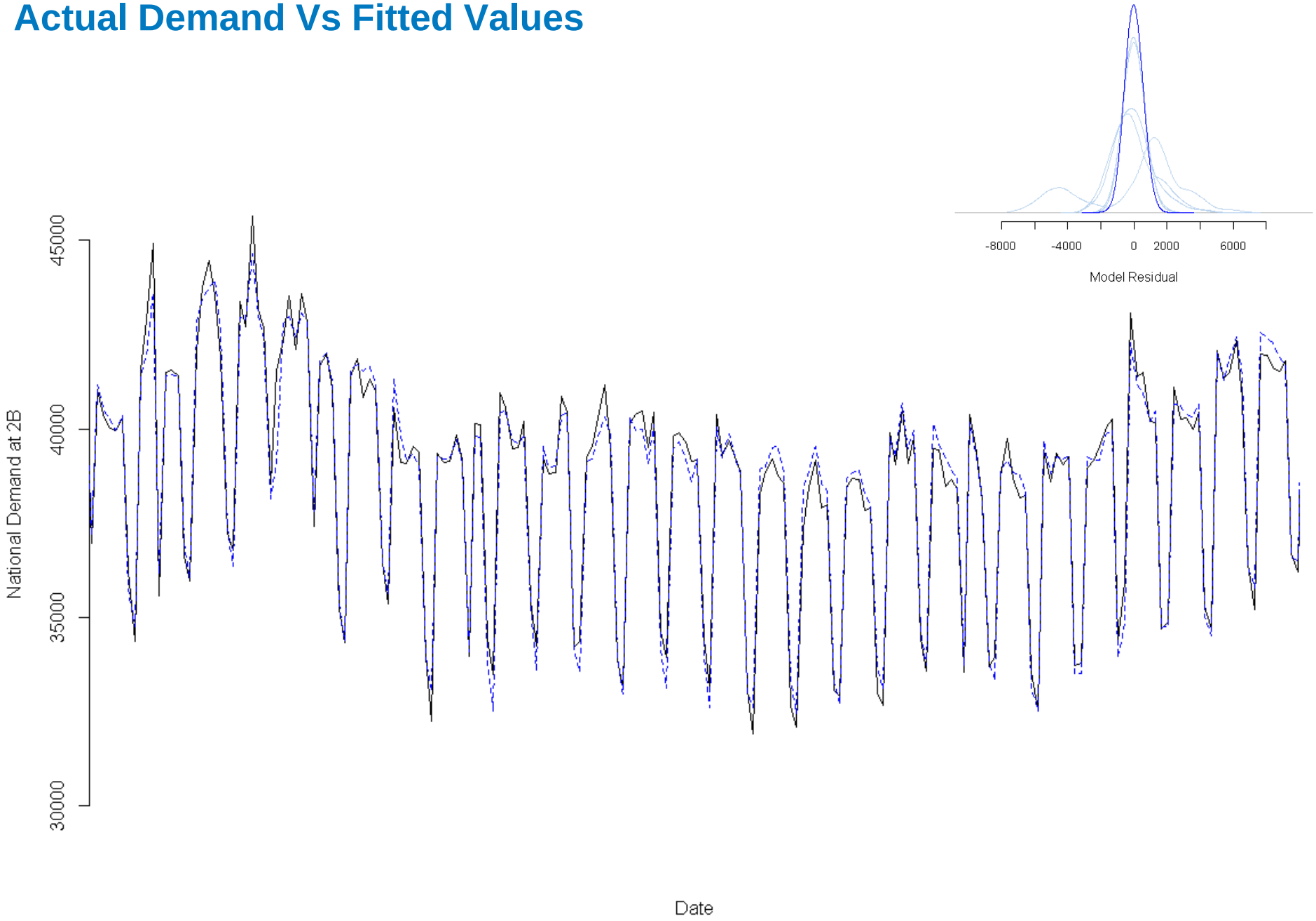
Including A Trend Component

Actual Demand Vs Fitted Values



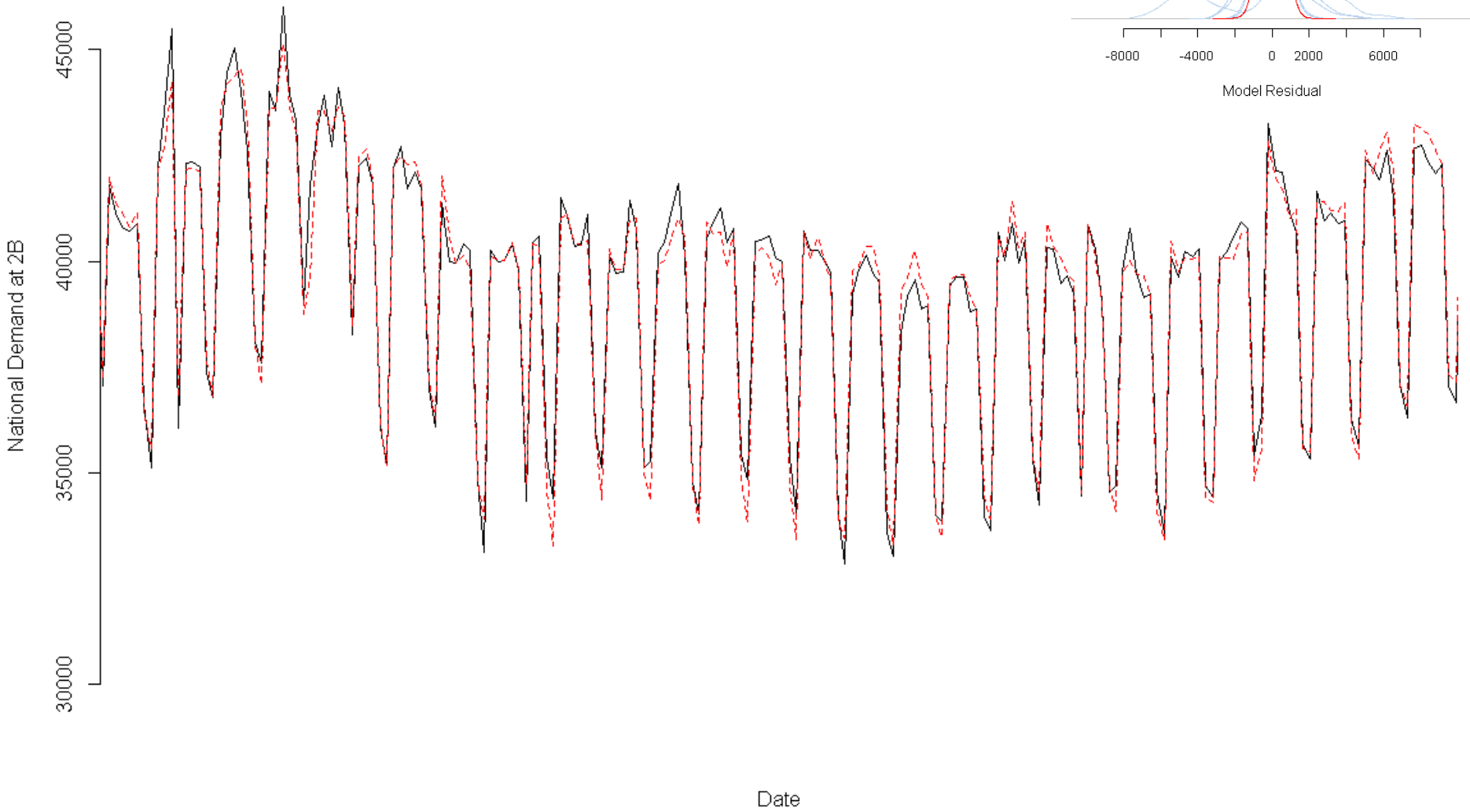
Including Embedded Wind Generation

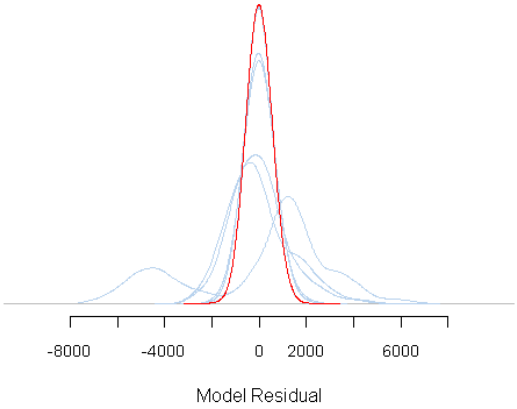
Actual Demand Vs Fitted Values

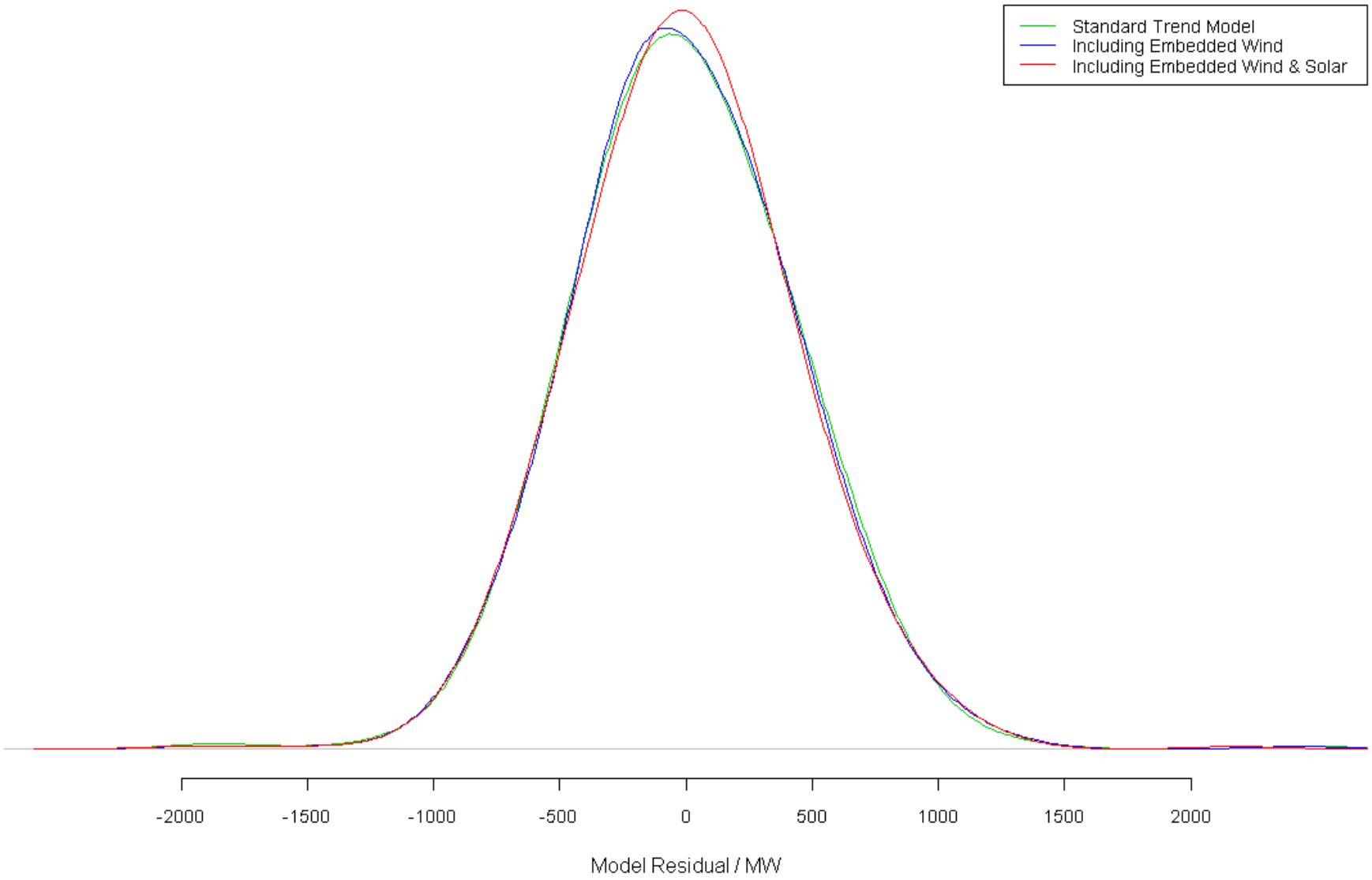


Including Embedded Solar Generation

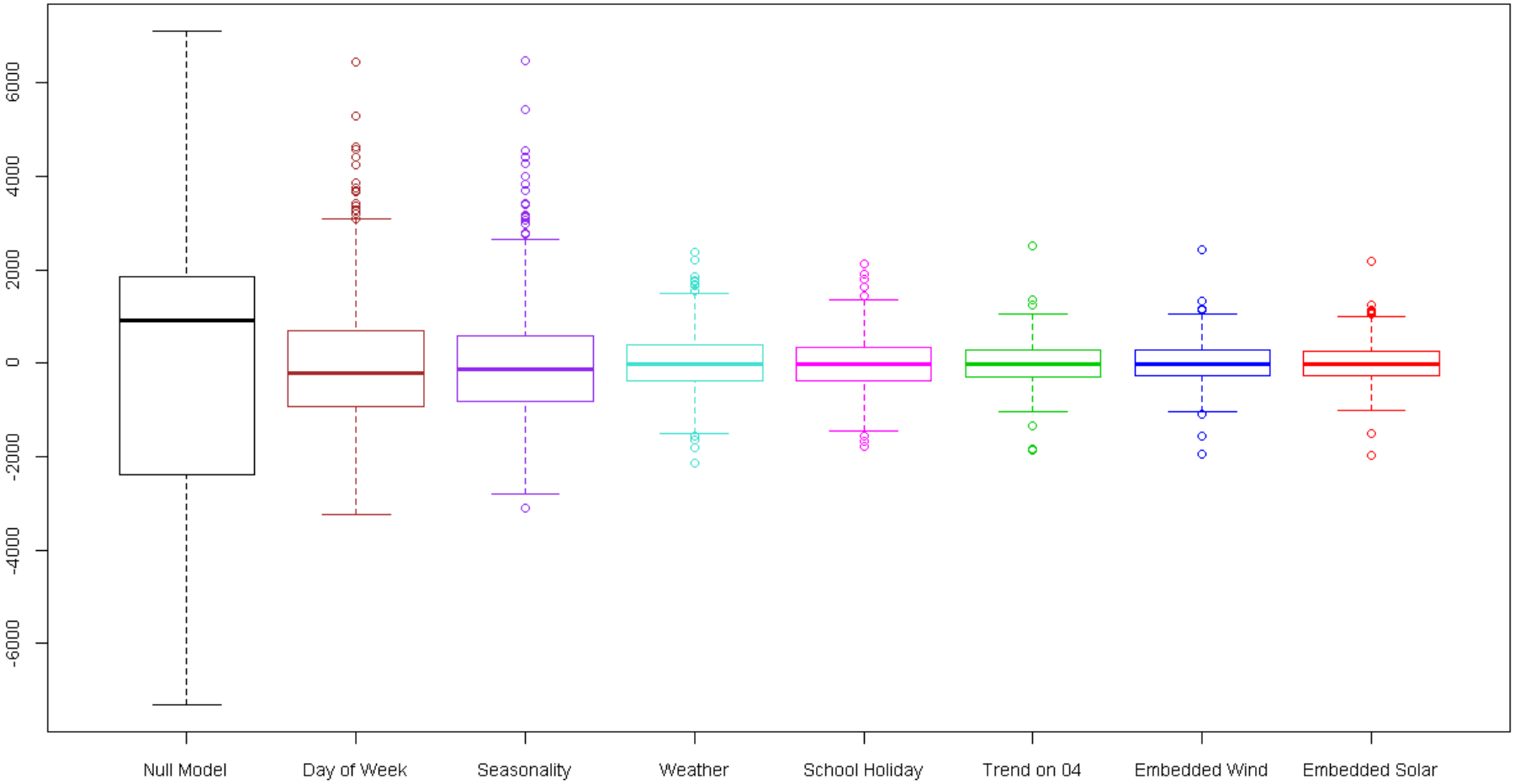
Actual Demand Vs Fitted Values






Standard Trend Model
Including Embedded Wind
Including Embedded Wind & Solar
-2000
-1500
-1000
-500
0
500
1000
1500
2000
Model Residual / MW

nationalgrid



Thanks for listening

Demand and Wind Forecasting