# Operating the power market

## Optimisation of a Dutch power plant portfolio

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# Outline

- Electricity
- Energy market
  - Different parties
  - Supply and demand
  - Price setting
- Optimisation
  - Plant level
  - Operating the market
- Conclusions and discussion

# Electricity

Electricity can not be stored

Although…


# Electricity

Electricity can not be stored

Although…

…not on a “serious” scale

Hence at every moment:

Supply = Demand

So… energy market? →

System operation

TenneT

Generation

Supply

NV Nuon

Wholesale market

Fuel sourcing

Customers

# System operation (TenneT)

Netherlands:

- TenneT: HV grid
- Smaller network companies

- Maintain grid
- Balance supply / demand

- Split production and infrastructure
- See also: railways

# Generation

## Mostly fossil fuels

- Coal, Lignite
- Oil
- Natural Gas
- Uranium

## Renewable generation

- Wind
- Hydro
- Biomass
- Solar

# Generation

Introducing: *Riverbank*

Coal-fired power plant
Capacity: 200 – 500 MW
Efficiency: 40%

$CO_2$ production per GJ Coal:
94.6 kg

# Wholesale market

Forward market: 1 day to 3 years ahead

- Power
- Fuels
  - Coal, Natural Gas, Oil, etc.
- Emission rights
  - $CO_2$

# Some definitions

- Marginal cost
  - (Fuel + Emission rights) / MWh
  - Non-marginal cost (capital investment, maintenance, fuel handling facilities, etc.)
- Spark spread
  - Power revenues – Marginal (fuel) cost

# Some definitions: example

*Riverbank*

Efficiency: 40%

Prices:

- Power: 60 €/MWh
- Coal: 2.50 €/GJ
- CO2: 20 €/tonne

**Spark spread** =

Power revenues – Marginal cost

Fuel cost:

2.50 €/GJ → 22.50 €/MWh

(GJ → MWh, apply efficiency)

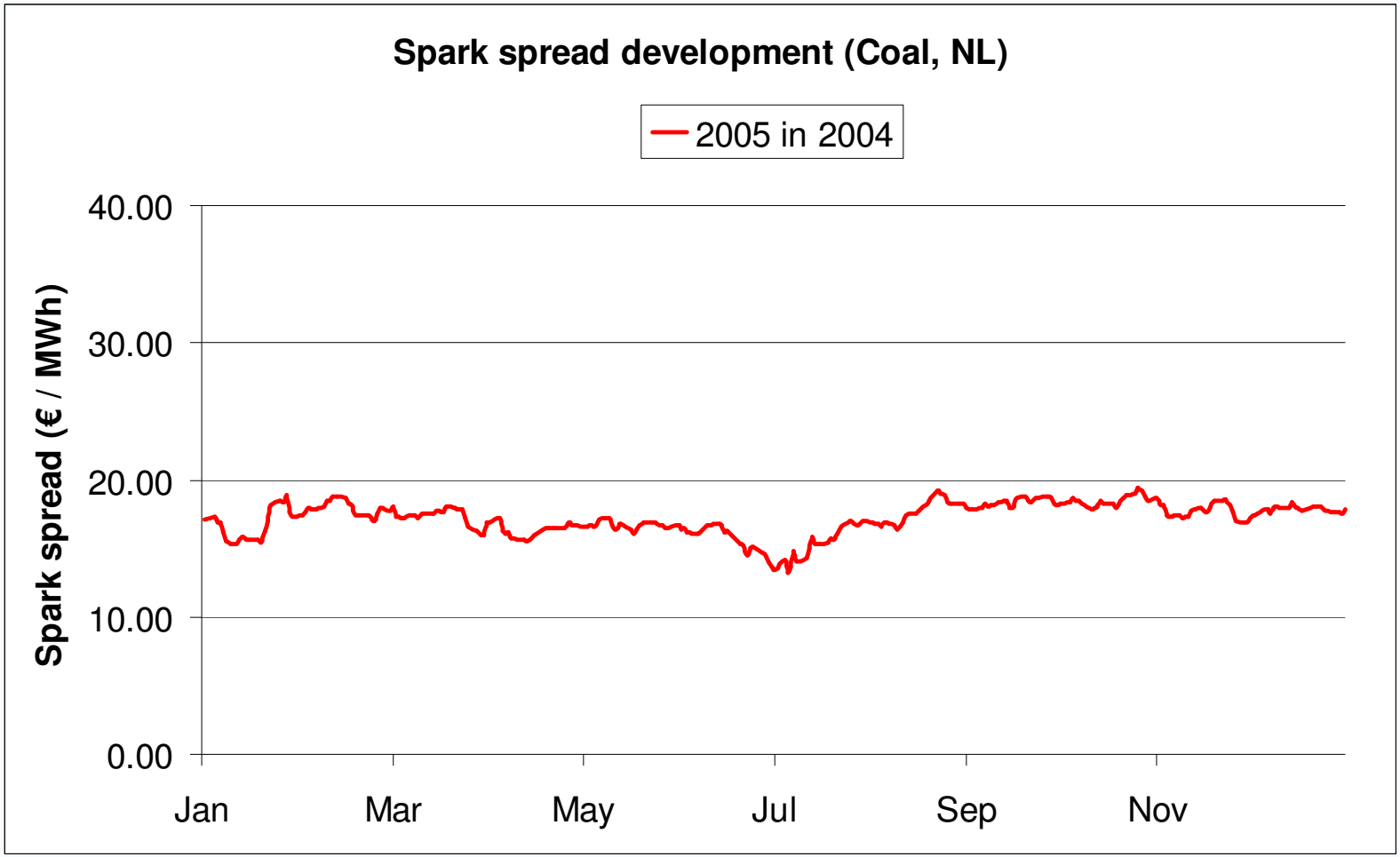
CO2 cost:

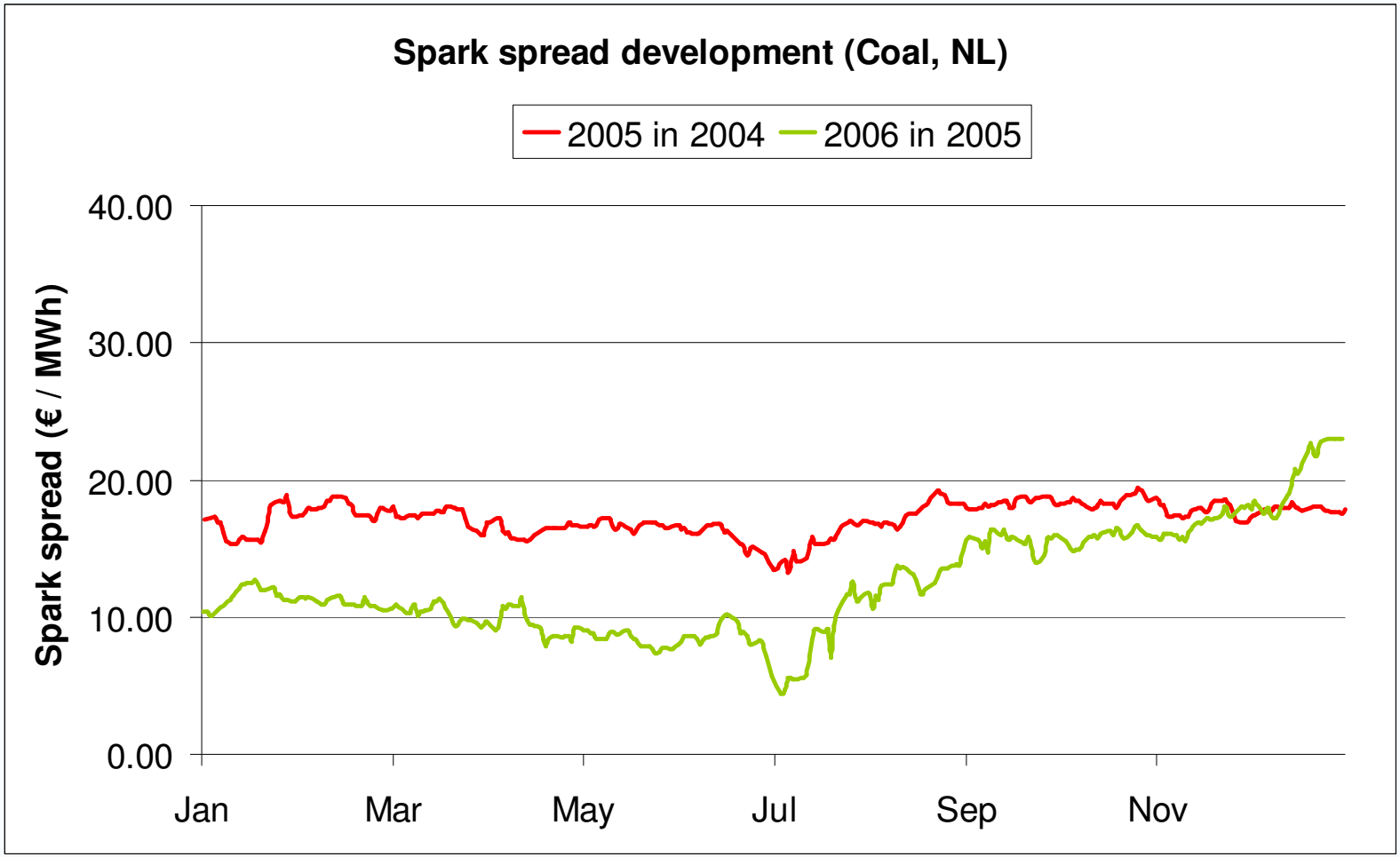
20 €/tonne → 17.03 €/MWh

(CO2 production coal: 94.6 kg/GJ)

Marginal cost: 39.53 €/MWh

Spark spread: 20.47 €/MWh


Spark spread development (Coal, NL)
2005 in 2004
Spark spread (€ / MWh)
40.00
30.00
20.00
10.00
0.00
Jan
Mar
May
Jul
Sep
Nov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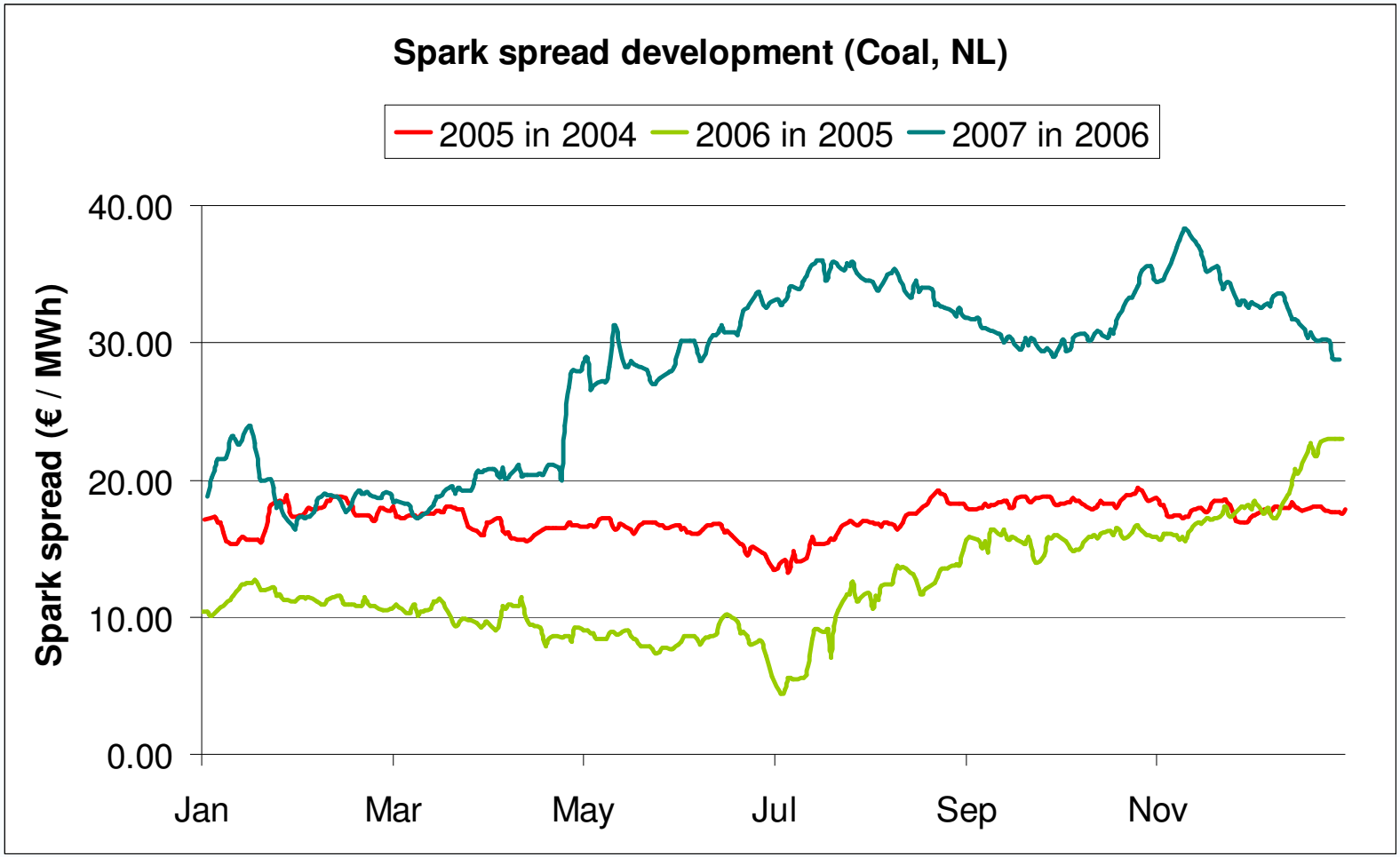
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Jan
Mar
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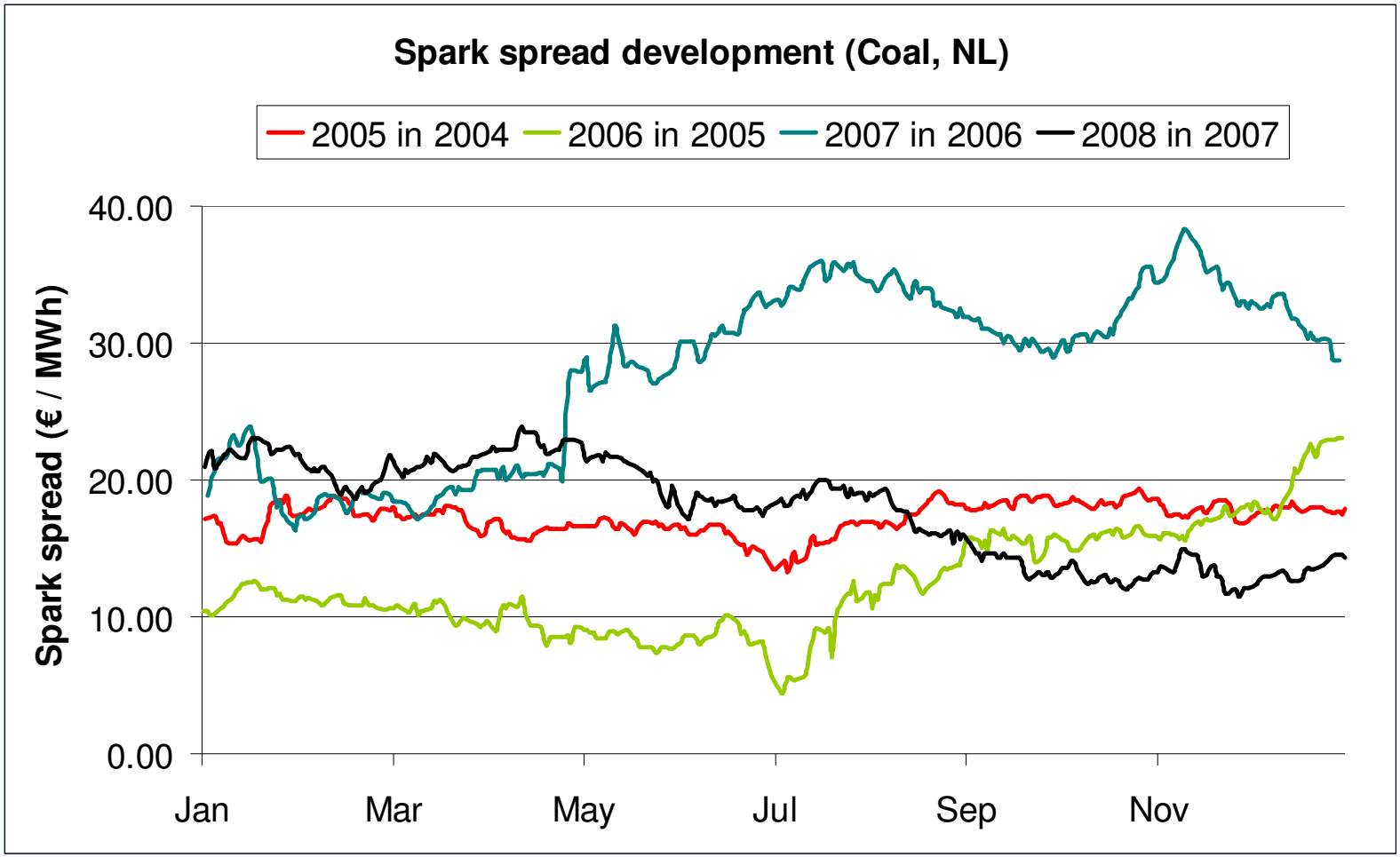
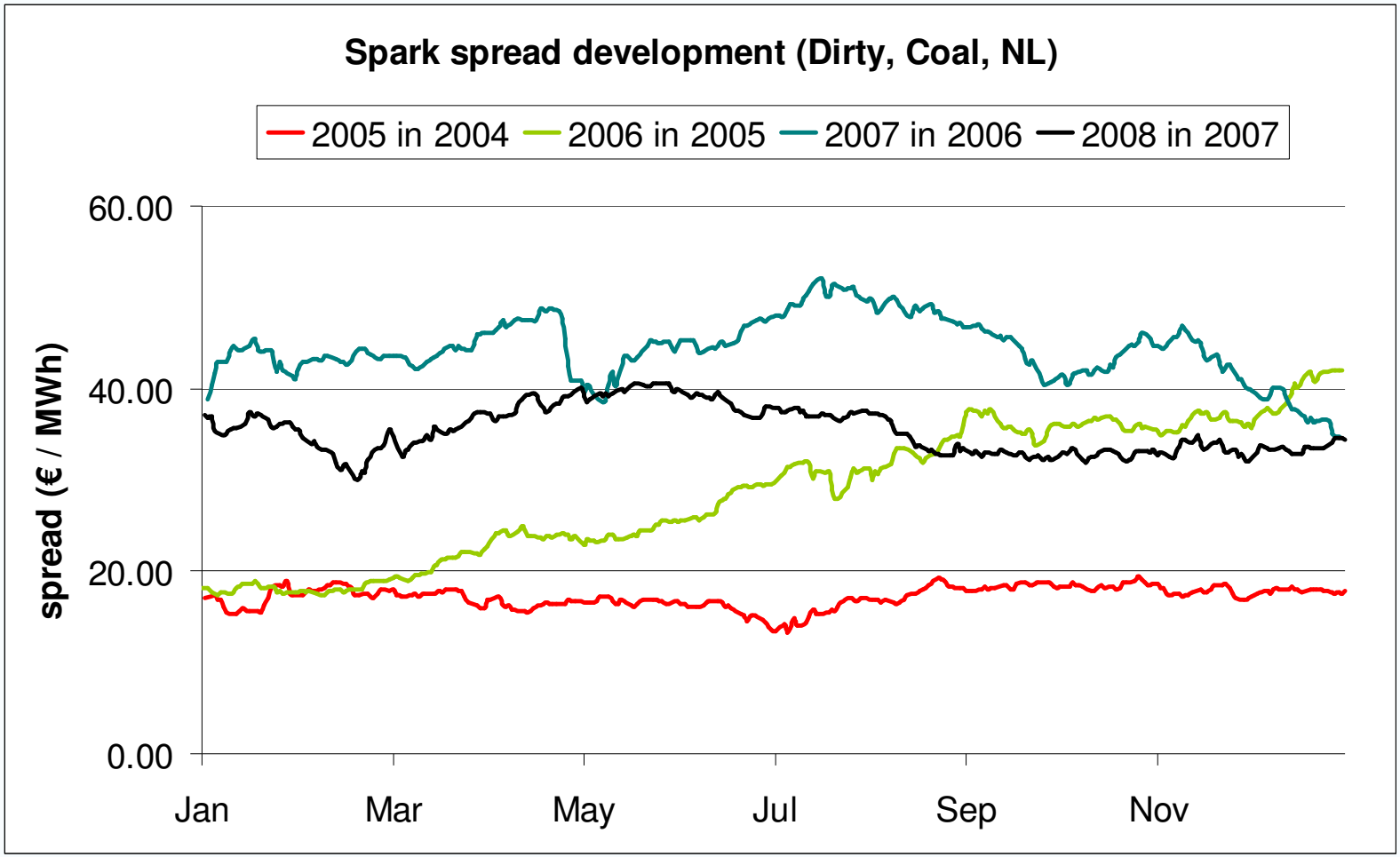

Spark spread development (Coal, NL)
2005 in 2004
2006 in 2005
2007 in 2006
2008 in 2007
Spark spread (€ / MWh)
40.00
30.00
20.00
10.00
0.00
Jan
Mar
May
Jul
Sep
Nov

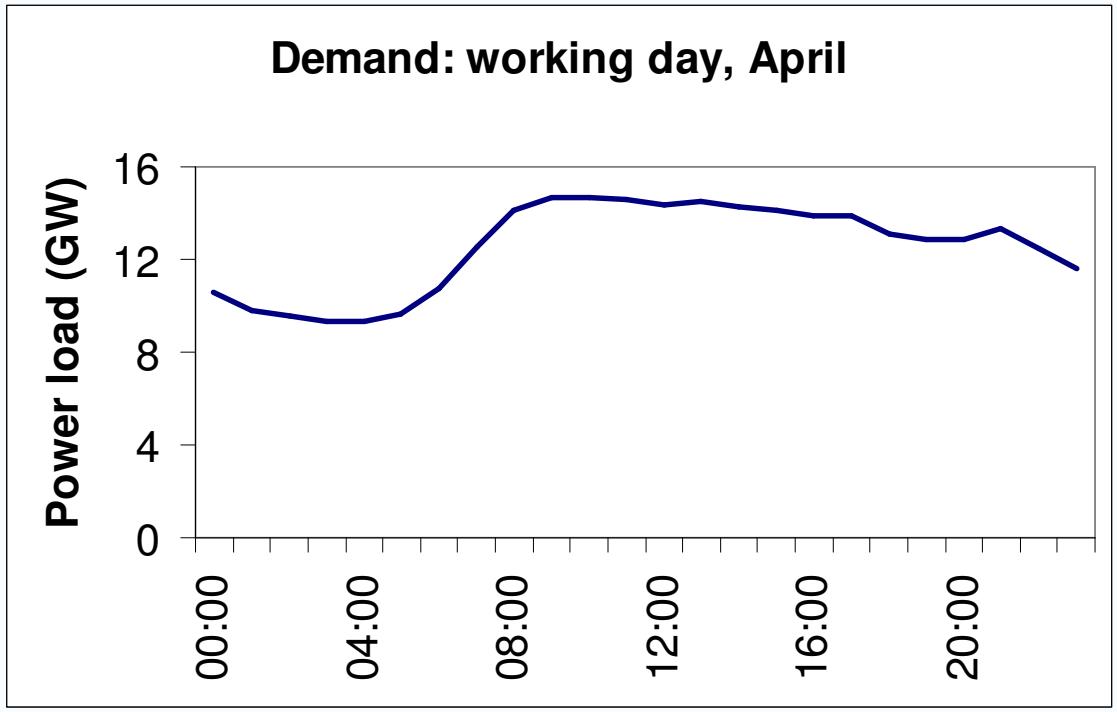

Spark spread development (Dirty, Coal, NL)
2005 in 2004
2006 in 2005
2007 in 2006
2008 in 2007
spread (€ / MWh)
60.00
40.00
20.00
0.00
Jan
Mar
May
Jul
Sep
Nov

# Supply and demand

Now we know what the market looks like…

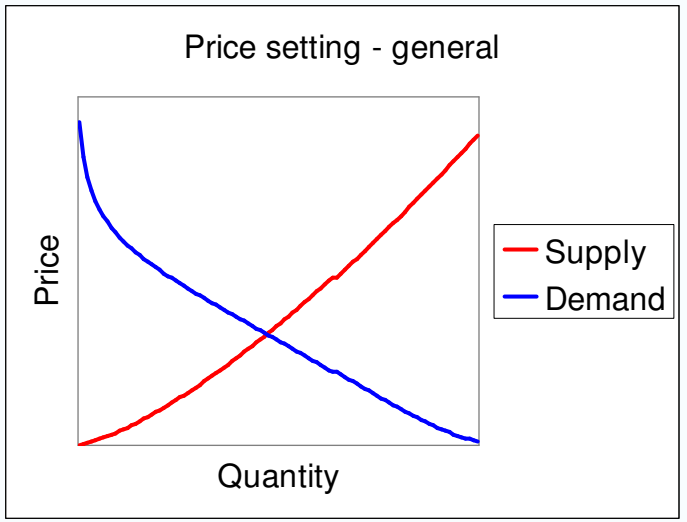
…let's take a look at its dynamics

# Supply and demand



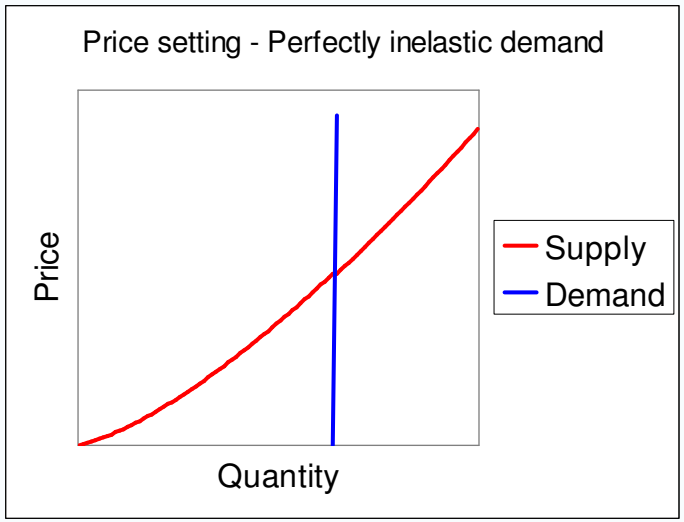
# Supply and demand

- Perfect market around a "typical" product
- Elastic supply
- Elastic demand
- Equilibrium price

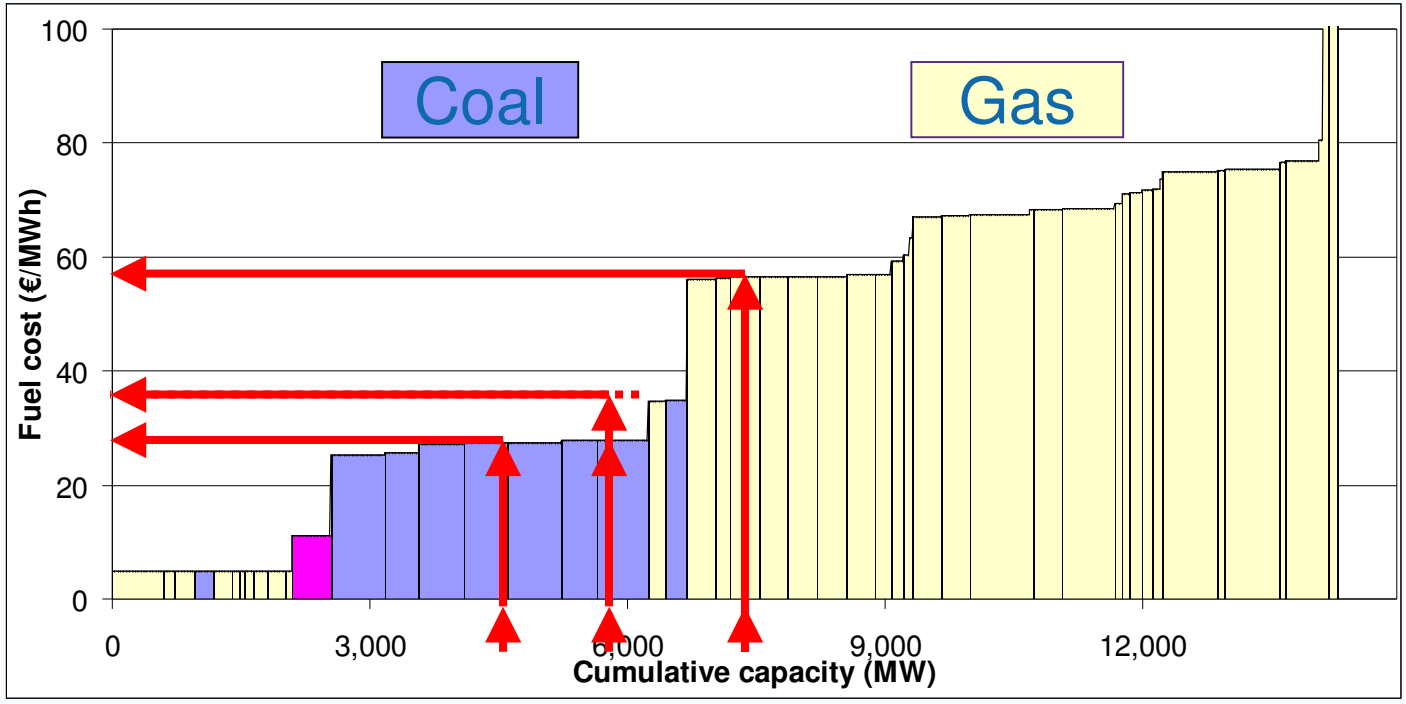


# Supply and demand

- Power demand is (almost) perfectly price-inelastic
- Zoom-in on supply curve →



# Supply: merit order Dutch power plants



# Optimisation in different time horizons

- Strategic
  - More than 3 years ahead
  - Market developments
  - Political / Regulatory developments
- Tactical
  - 1 to 3 years ahead
  - Price (=market)
- Operational
  - Day ahead – Months ahead
  - Demand, commitment, price

# Optimisation forward market

- We have power plants (**supply**)
- Market (quite liquid)
  - quoted **prices**
  - indirectly representing **demand**
- So we can trade power / fuels, backed up by our own power plants
- Let's optimise this!

# Optimisation forward market

Sell power in long term market or in spot market?

+ Forward - Spot
  - After selling power / buying fuel, profit is secured (risk avoiding)
  - Market not liquid enough for large volumes at once

+ Spot - Forward
  - Spreads might go up → lost opportunities
  - Plant might break down → buyback risk

Practice: a bit of both

# Optimisation forward market

- Basic idea…
- Market prices + Plant efficiency → Spark spread
- Spark spread positive?
  - **Sell** power + **Buy** fuel
- Spark spread turns negative?
  - **Buy** power + **Sell** fuel
- Other players have roughly the same options!

# Optimisation forward market: example

*Riverbank*

Efficiency: 40%

Capacity: 200 – 500 MW

Prices:

- Power: 60 €/MWh
- Coal: 2.50 €/GJ
- CO2: 20 €/tonne

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**Spark spread** =

Power revenues – Marginal cost

Fuel cost:

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CO2 cost:

20 €/tonne → 17.03 €/MWh

Spark spread: 20.47 €/MWh

# Optimisation forward market: example

*Riverbank*

Efficiency: 40%

Capacity: 200 – 500 MW

Prices:

- Power day: 60 €/MWh
- Power night: 35 €/MWh
- Coal: 2.50 €/GJ
- CO2: 20 €/tonne

Spark spread day:

20.47 €/MWh

Spark spread night:

-4.53 €/MWh

Turn off the plant?

# Optimisation forward market: example

*Riverbank*

Efficiency: 40%

Capacity: 200 – 500 MW

Spark spreads:

- Day: 20.47 €/MWh
- Night: -4.53 €/MWh

Start cost: 20 000 €

Day

- 16 hours
- 500 MW
- Margin: € 163 760

Night

- 8 hours
- 200 MW
- Margin: € -14 496

# Optimisation forward market

Basic idea…

…but there are constraints

High level

- District heating
- Industrial contracts

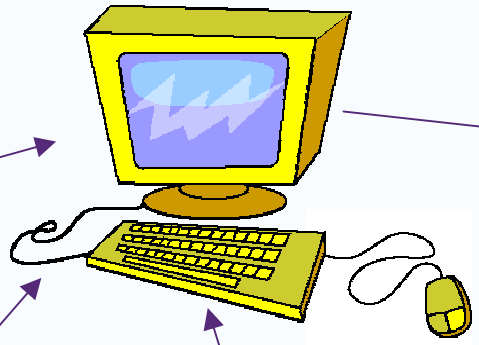
Plant level

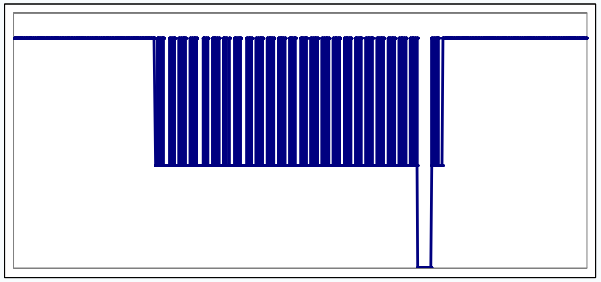
- Minimum up/down time
- Ramp up/down rate
- Fuel contracts
- Cooling water constraints

# Optimisation forward market

Power plant specs

Computer program



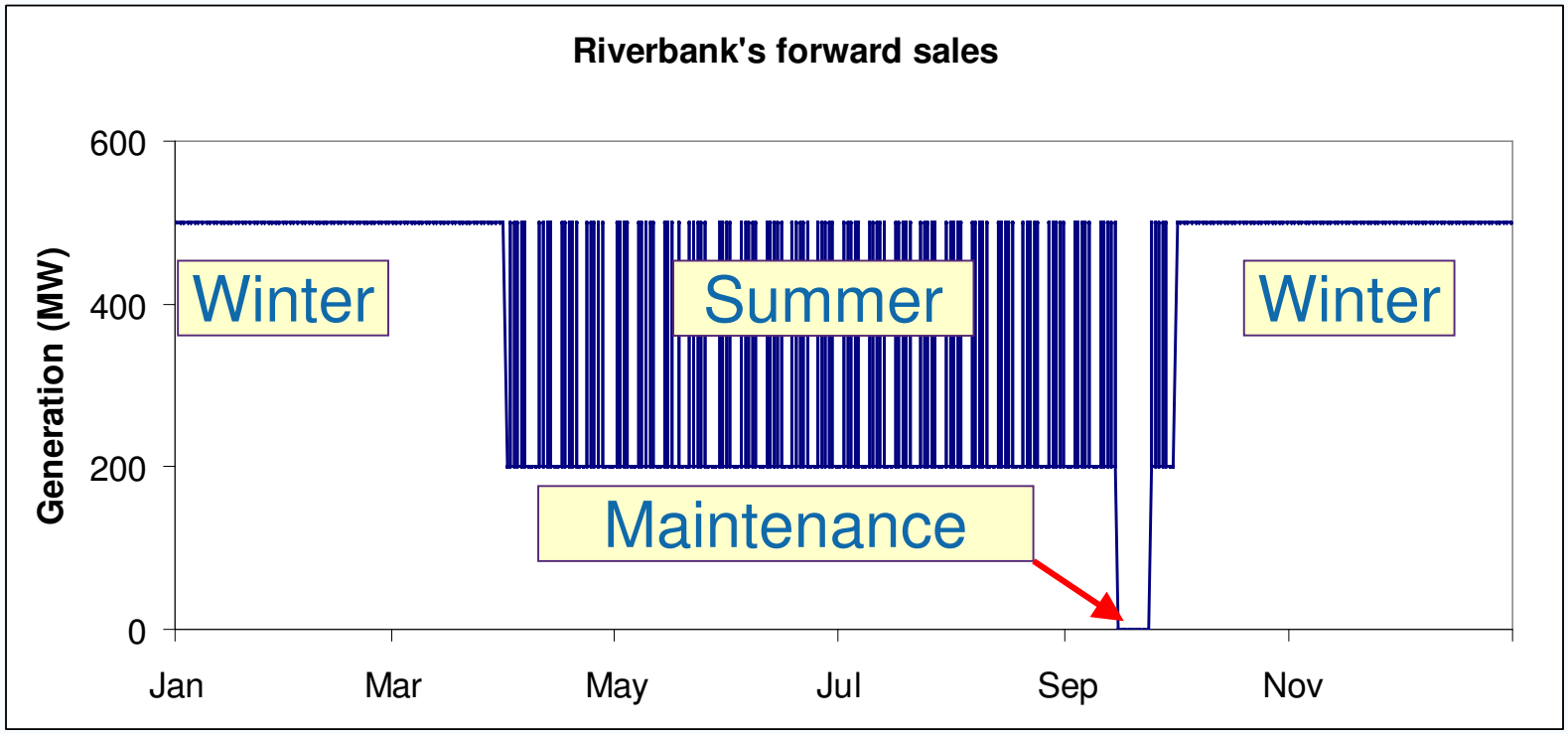


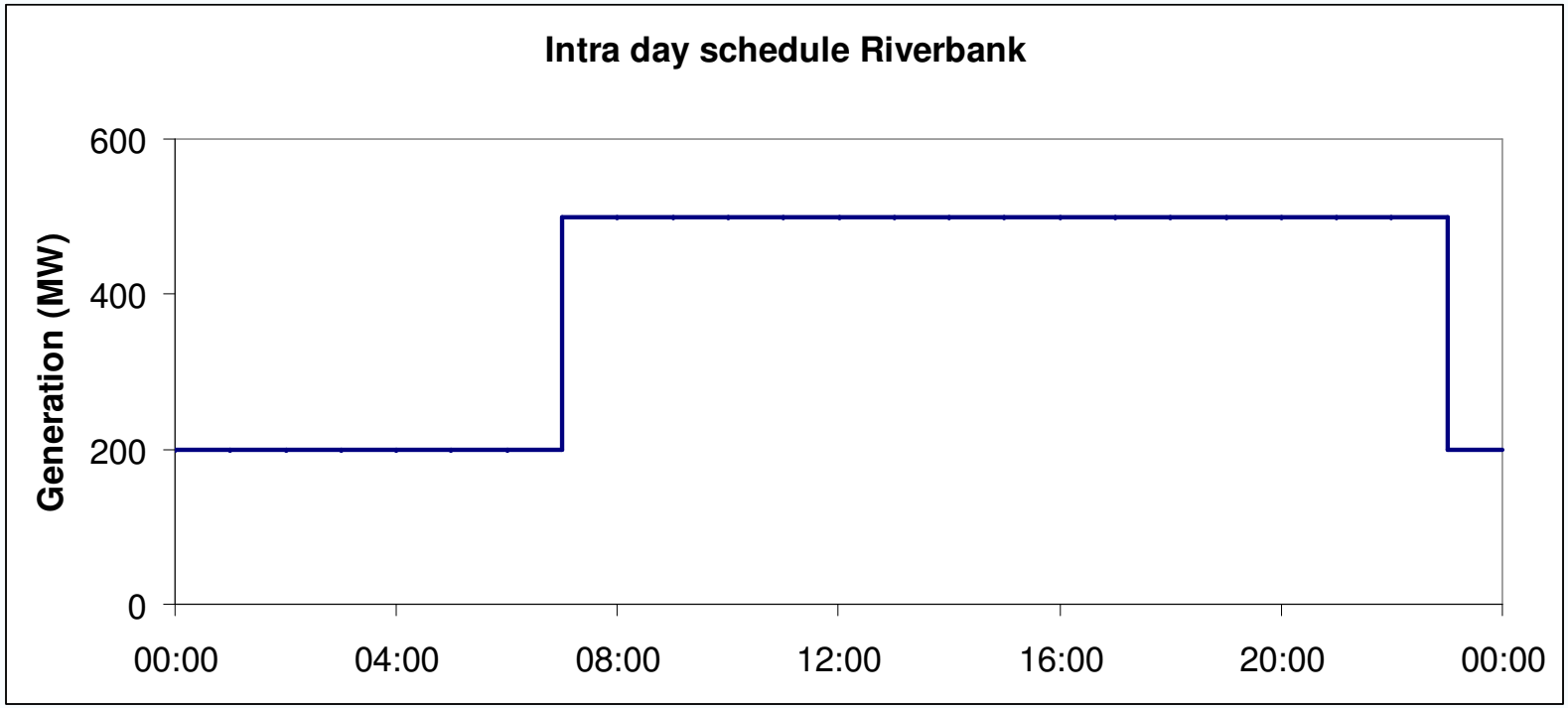
Optimal forward sales

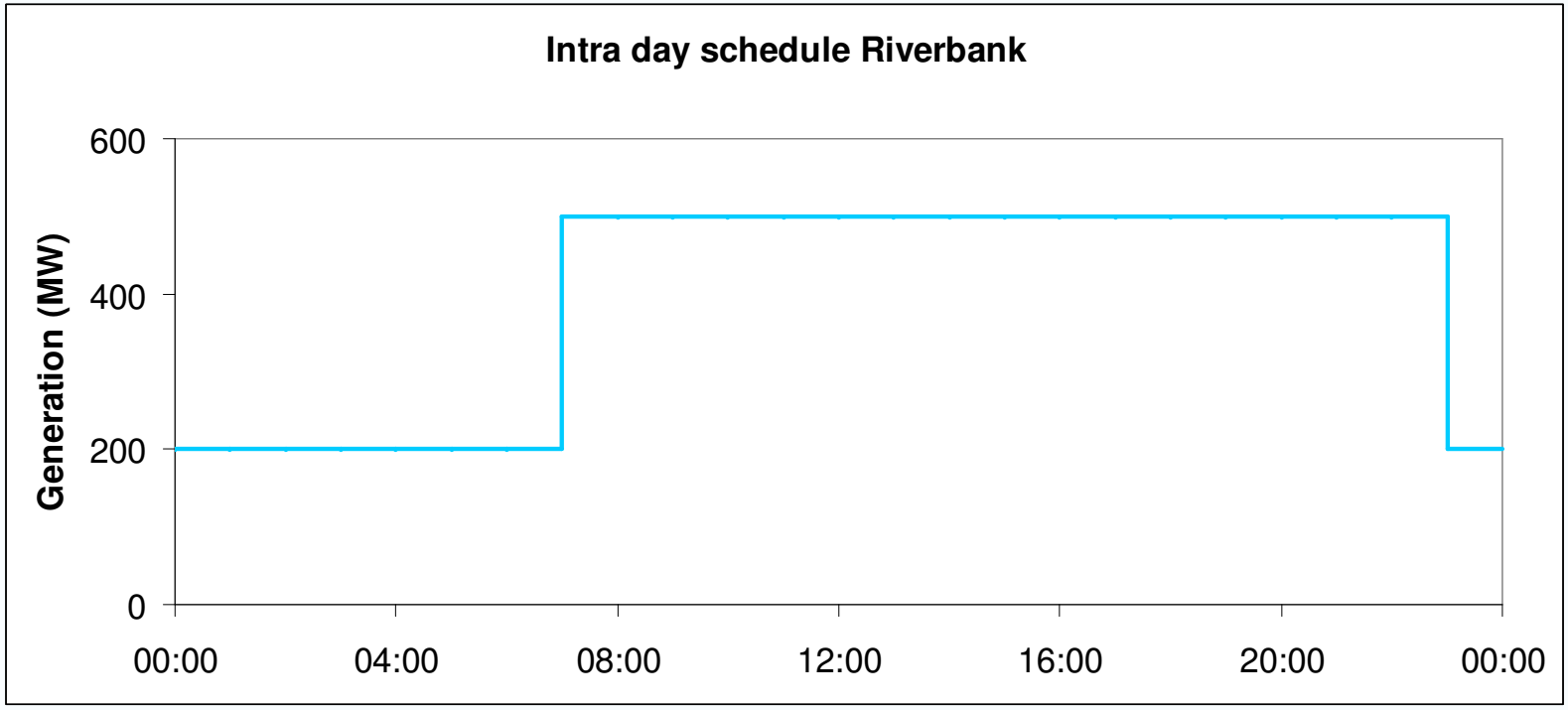
Market prices

$\Sigma x \leq \ldots$

Constraints


Riverbank's forward sales
Generation (MW)
600
400
200
0
Jan
Mar
May
Jul
Sep
Nov
Winter
Summer
Winter
Maintenance


Intra day schedule Riverbank
Generation (MW)
600
400
200
0
00:00
04:00
08:00
12:00
16:00
20:00
00:00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200
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00:00
04:00
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20:00
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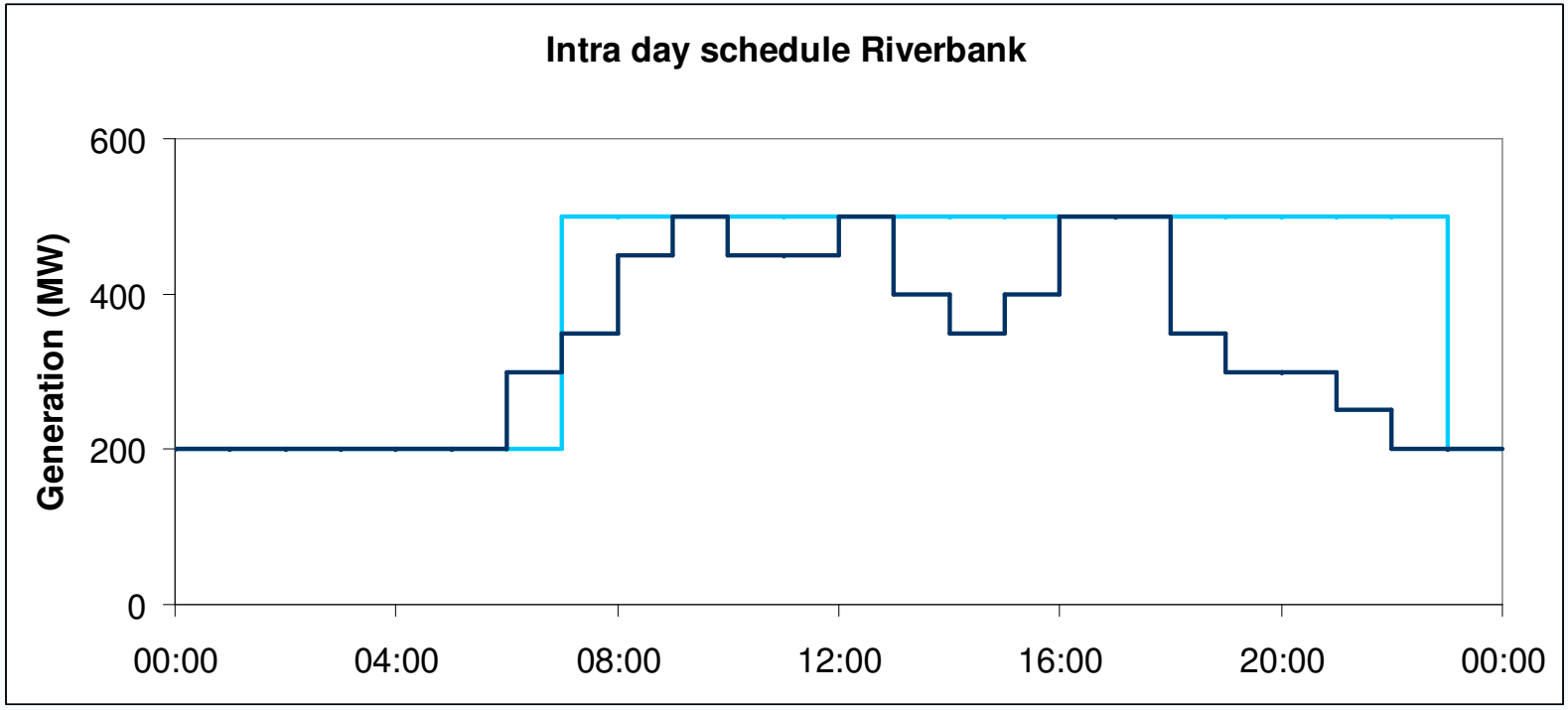
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0
00:00
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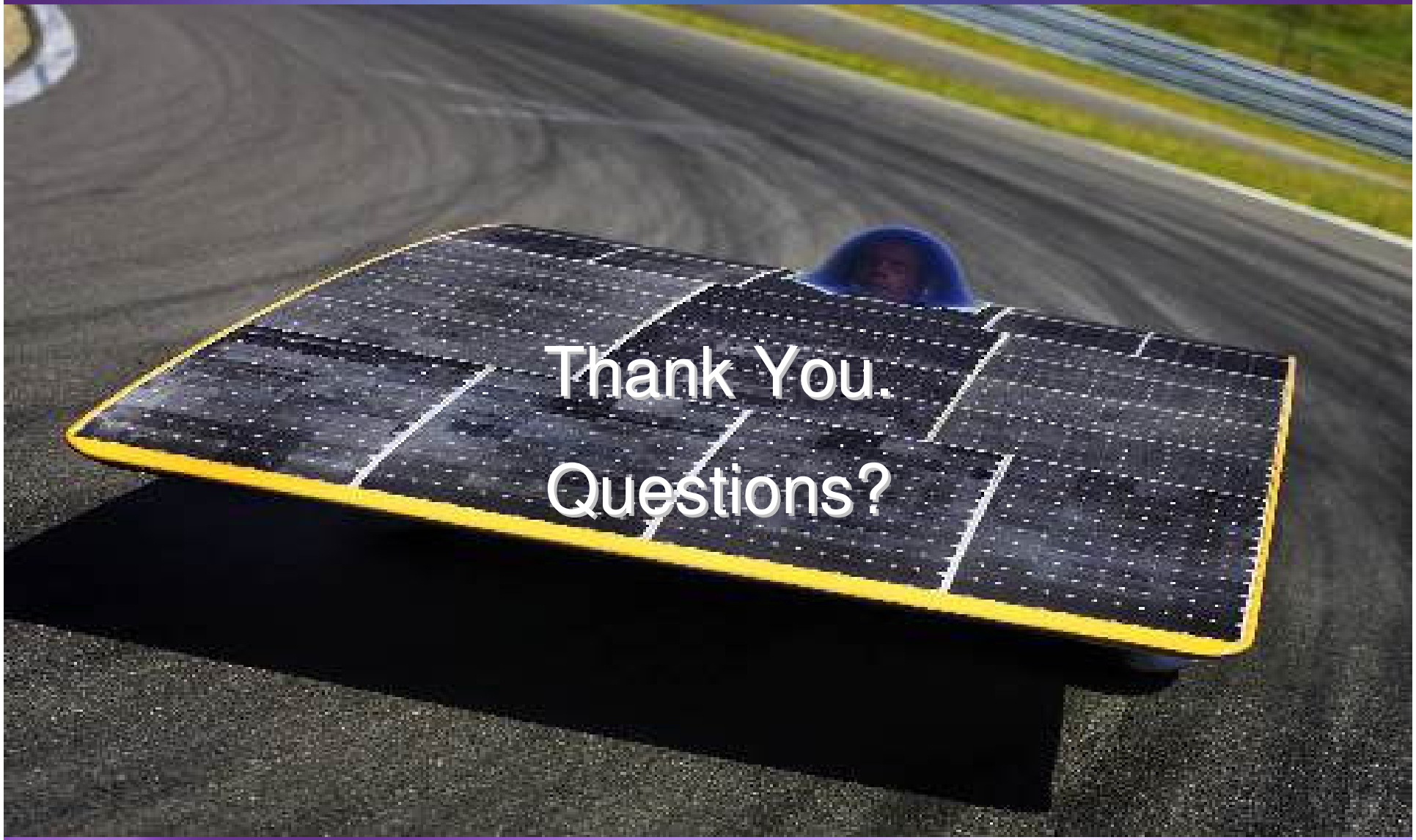
08:00
12:00
16:00
20:00
00:00

# Conclusion

- Energy: dynamic market
  - Optimal behaviour changes every day
- Different horizons, Different characteristics
- Complex optimisation
  - Constraints, chronological issues


Thank You.
Questions?