ENCOURAGED

Energy Corridor Optimisation for the European Markets of Gas, Electricity and Hydrogen

Analysis of the optimal gas corridors and infrastructure to secure supply in Europe in the long term - Model based analysis-

Wietze LİSE and Frits van OOSTVOORN

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Overview

Scope of the analysis:

- Convergence towards liberalized market with few players in the long run,
- Prices established via demand/supply equilibrium,
- Seasonal flexibility and sectoral demand,
- Production capacity is exogenous,
- Investment in transport corridors (pipelines, LNG, storage) is endogenous.

Main conclusion:

- Substantial investments needed in corridors towards EU,
- Especially the East–West route influence future gas prices.

Outline:

1. GASTALE model presentation,
2. Results.

GASTALE model presentation

The GASTALE model version 4.4
Overview of actors in GASTALE 4.4
Supply and demand side
Model calibration
Gas corridors: transmission
Investment considerations and dynamics

The GASTALE model version 4.4

GASTALE distinguishes between:

Producers with market power: decide on production, transport to country border, earning a border price.

Transmission system operators (TSO): regulates transport through pipeline network & LNG shipping.

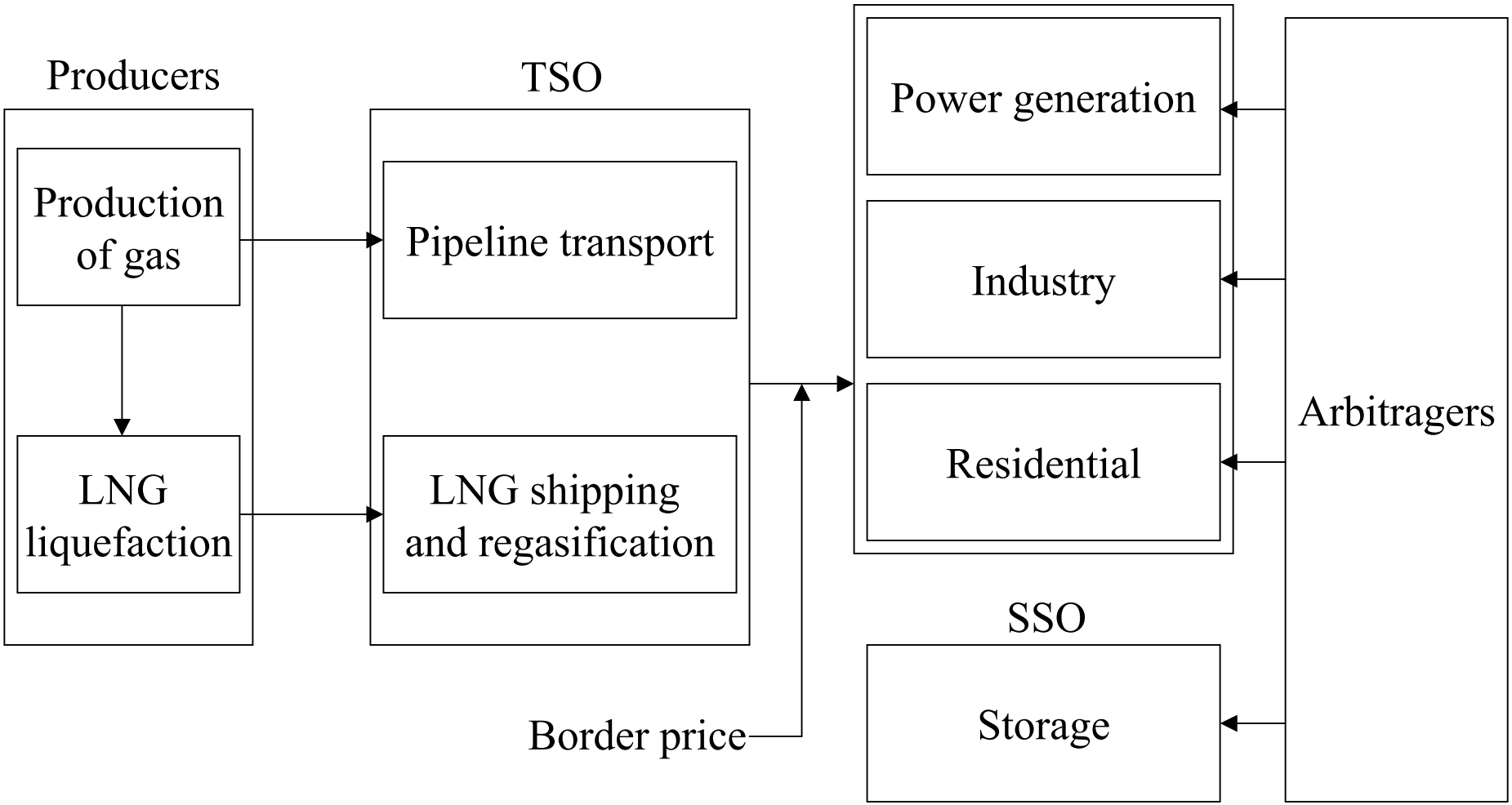
Arbitragers without market power: trade gas among power generation, industries, residents & storage.

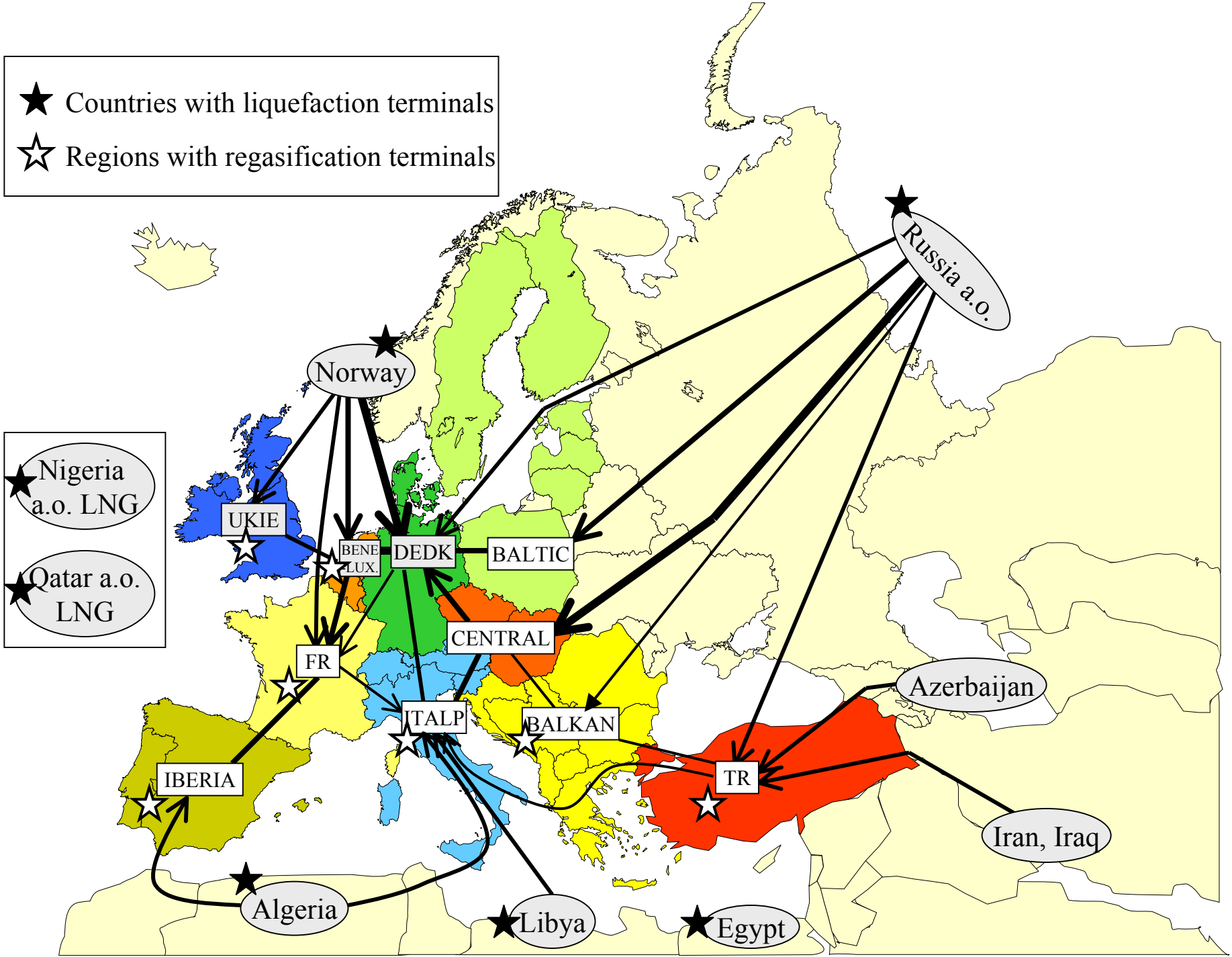
Storage system operators (SSO): regulates injection during the warm season and extraction from storage facilities during the cold season.

Consumer prices clear the market.

Investments in storage, pipeline, liquefaction and regasification, capacities.

Overview of actors in GASTALE 4.4




Countries with liquefaction terminals
Regions with regasification terminals
Nigeria a.o. LNG
Qatar a.o. LNG
Russia a.o.
Norway
UKIE
BENE LUX.
DEDK
BALTIC
CENTRAL
FR
ITALP
BALKAN
Azerbaijan
IBERIA
TR
Iran, Iraq
Algeria
Libya
Egypt

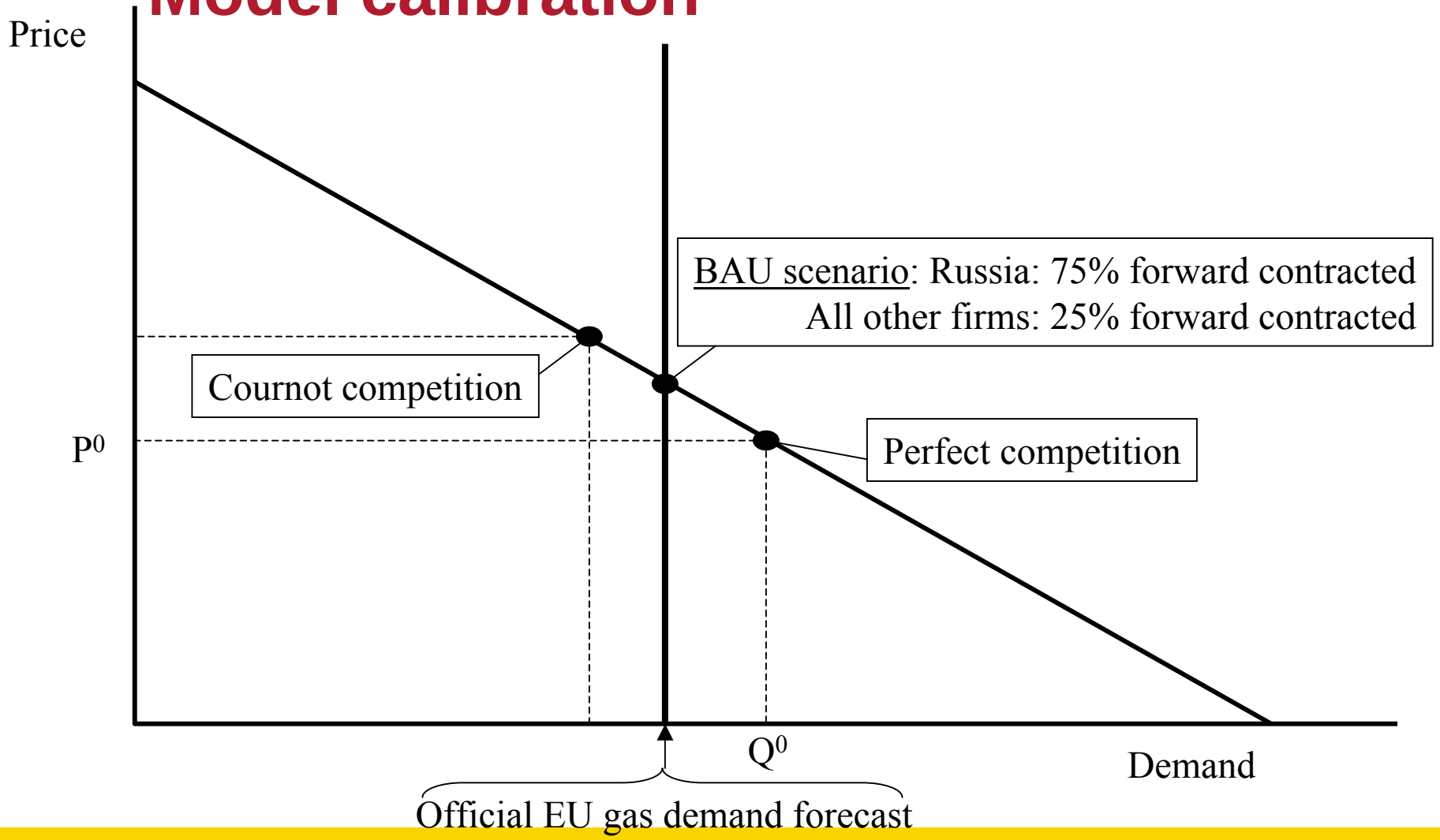
Supply and demand side

GASTALE has **twelve producers**: Algeria, Caspian, Egypt, Iran, Libya, Nigeria, Norway, Qatar, Russia, UKIE, BENELUX, DEDK

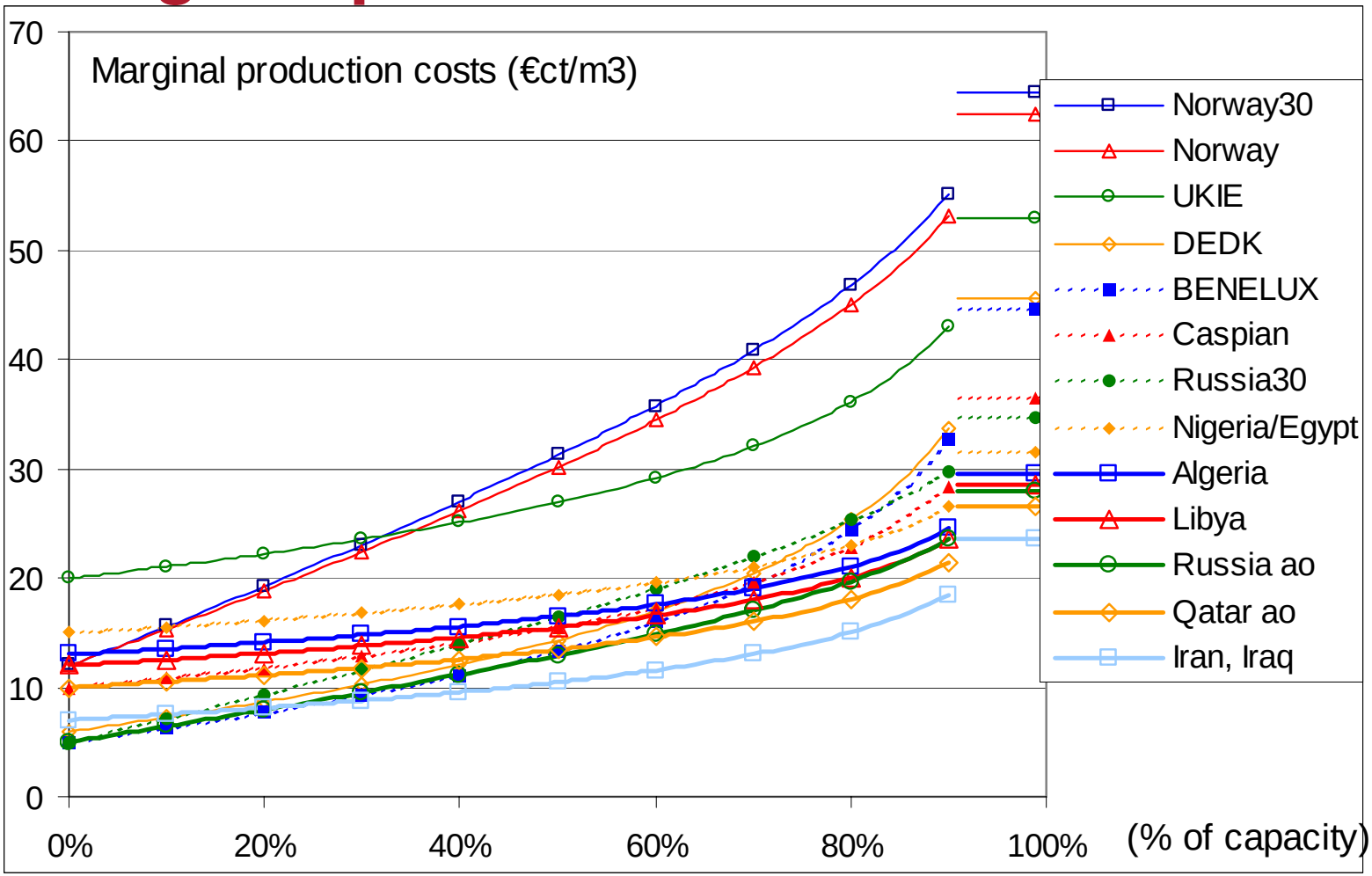
GASTALE has **ten consumers**: UKIE, BENELUX, DEDK, BALKAN, BALTIC, CENTRAL, FR, IBERIA, ITALP, TR

- Model is calibrated to a fixed level of demand in 2005 (+12%) under **perfect competition**
- Market power mark-ups are set to realistic values to derive the **BAU case** to match desired level of demand.
- Demand is elastic and the demand curve is linear

Model calibration



Marginal production costs



Gas corridors: transmission

Transmission of gas can take place in two manners from producers to consumers:

1. **Pipeline network**: involves transport costs and pipeline capacity.
   - Throughput is a possibility, for instance from Russia via CENTRAL to DEDK.
2. **LNG shipping**: involves transport costs, liquefaction and regasification capacities

Investment considerations & dynamics

We also made assumptions on the value of capital:

- The additional investment cost of pipeline transport, liquefaction and regasification capacity, and storage capacity is assumed to be 20% on top of the LRMC.
- Economic lifetime of pipeline, liquefaction and regasification capacity is 30 years, while storage has a lifetime of 60 years.
- The effective interest rate (for new investments) is set at 10% (real) per year.

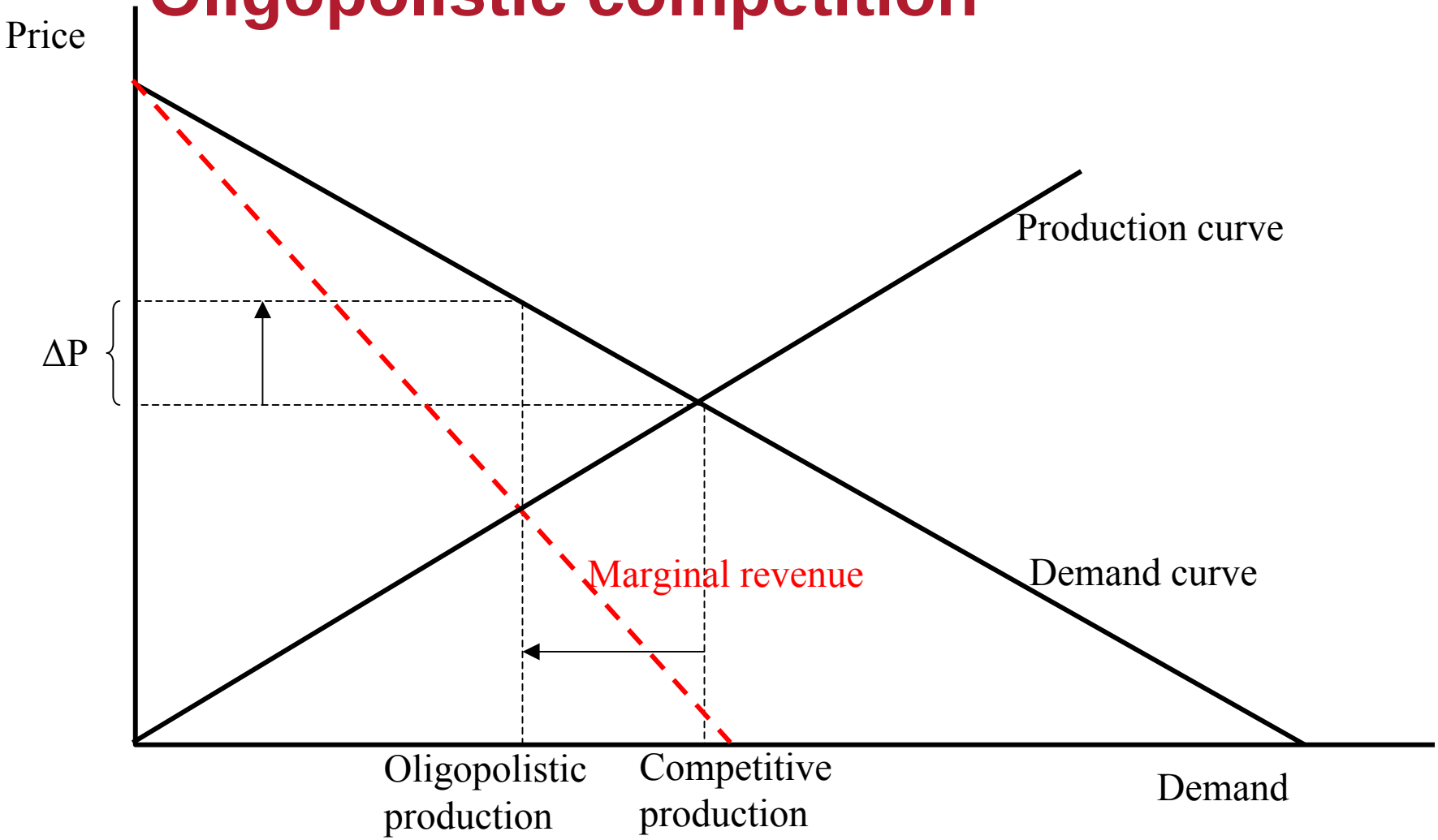
Producer behavior in liberalized market

Depending upon size, producers can follow different behaviors:

1. Small producers generally follow price taking behavior, where marginal costs equal marginal revenues
2. For medium sized producers it can become attractive to follow strategic behavior, where marginal revenues >> marginal costs, this is achieved by reducing the level of production.
3. For very large producers, full strategic behavior may not be optimal and they may maximize their profits by reducing the level of production only partially.

Game theoretic model of a liberalised market generally follows option 2, which lead to a fairly good approximation of observed market outcomes, especially when forward contracts are corrected for.

Oligopolistic competition



Results

Four policy scenarios
Prices
Demand
Investments
Flexibility

Four policy scenarios

BAU case:

driven by official EU gas demand/supply/prices forecasts,

Forward contracts: Russia 75%, other countries 25%

Low demand case:

driven by high oil prices etc.,

demand more elastic +20%, World LNG export –20%

High demand case:

driven by low oil prices etc.,

demand less elastic –20%, World LNG export +20%

Deferral case:

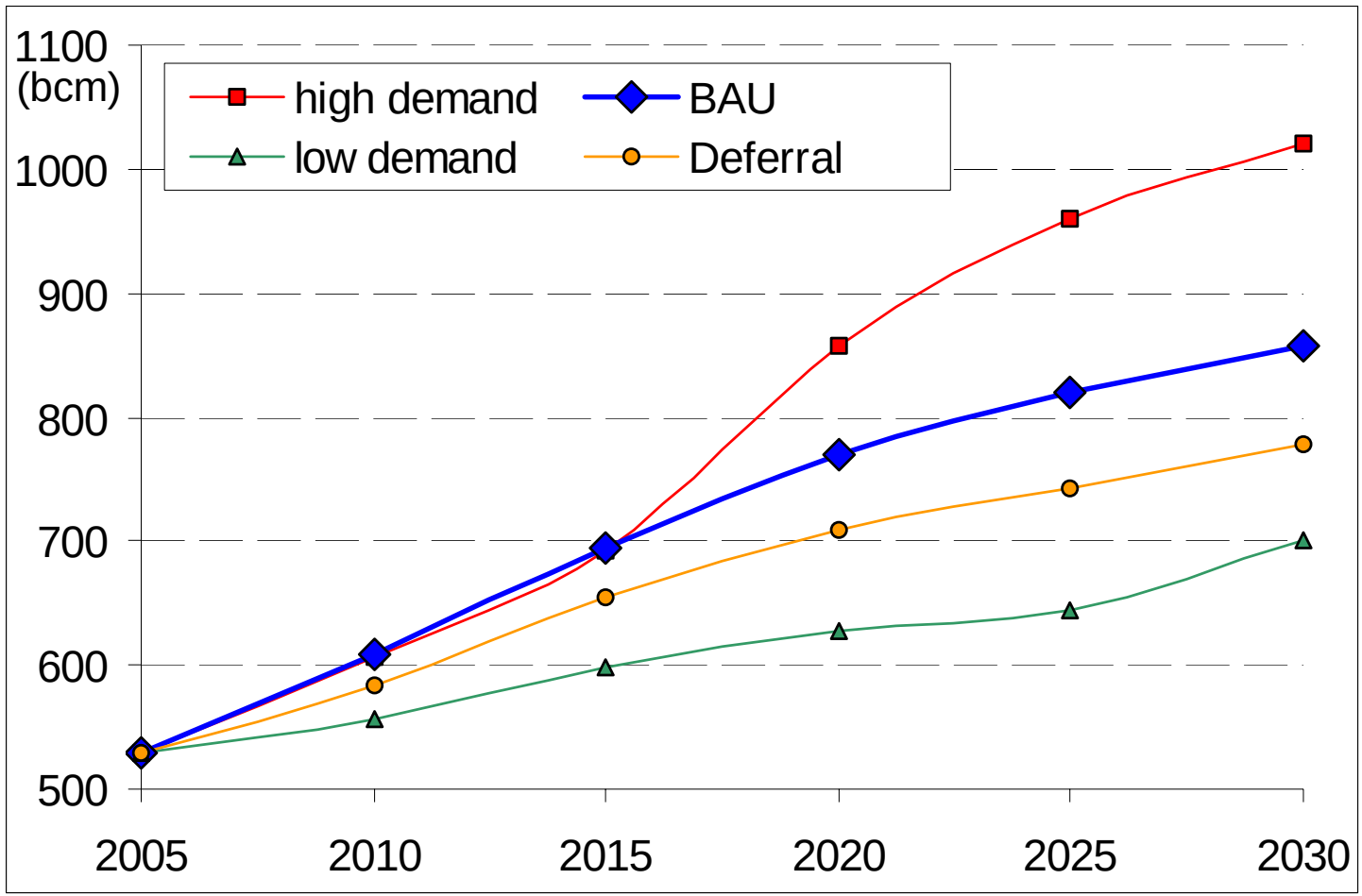
driven by increased market risks for banks etc.,

resulting in 30% additional investment costs

Expected European demand in 4 cases:

Relatively low demand in the deferral case:

Slower investments →higher prices →lower demand.



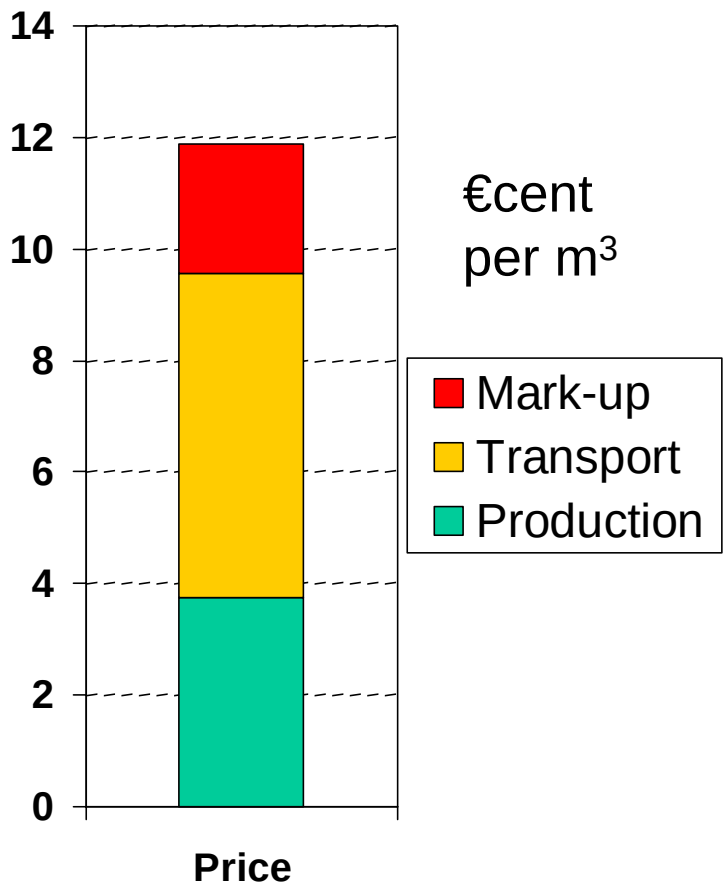
Market equilibrium gas prices

Upstream gas price is based on **long-term marginal costs**:

- Production costs (30%)
- Transport costs (50%)
- Mark-up (20%)

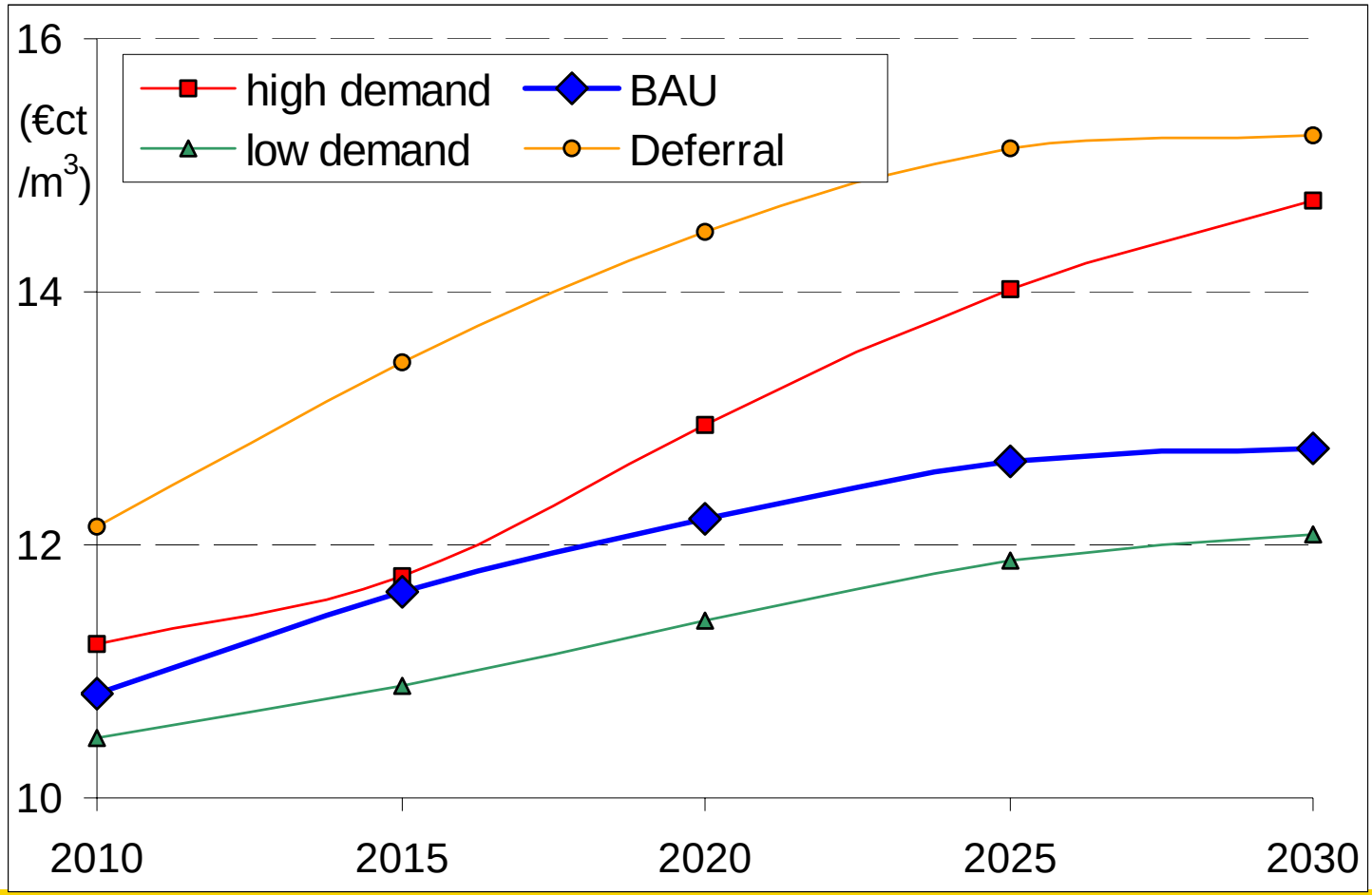
Characteristics:

- Approximation of **spot prices** at important EU gas hubs
- Exclusive of **downstream** distribution costs and taxes
- Representative for average long-run price development following EU projections



Projected gas prices at EU border in 4 cases:

- Prices are strictly increasing from 2010 onwards.
- High demand prices higher than BAU prices in 2010/2015, due to assumed lower elasticity.



Optimal corridors according to model's economic principles

Some connection would not be built:

- The Baltic line between Russia and Germany

This connection is exogenous in analysis

Some connections would be expanded beyond reality:

- Norway – UK, would by-pass other Norway-EU connections
- Algeria – Spain
- Algeria – Italy
- Libya – Italy

These connections are restricted → Algeria/Libya use second best option, LNG.

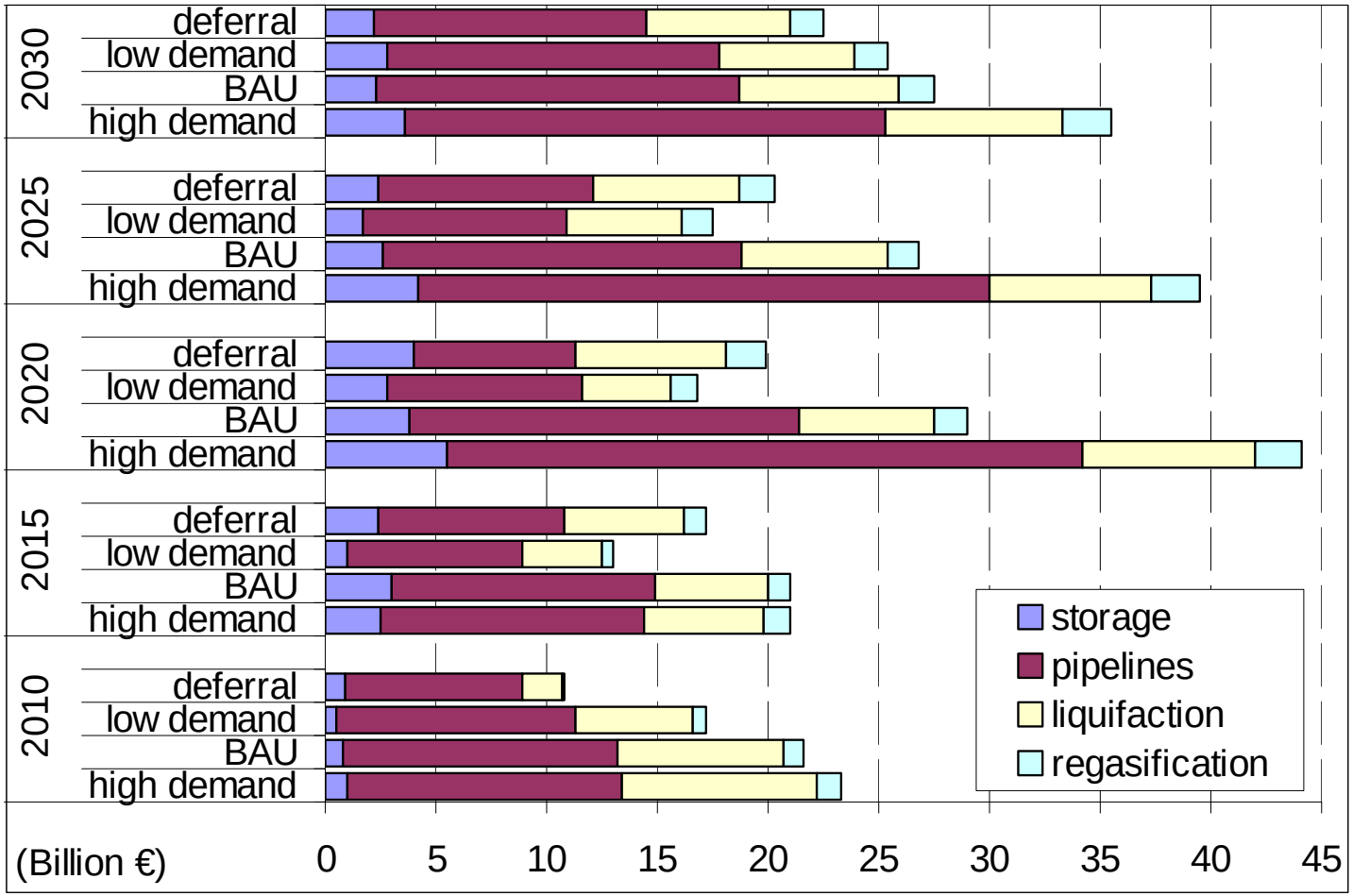
LNG to Europe from Russia is attractive option; binding restriction in analysis.

Total yearly investment costs in 4 cases:

Highest for pipeline connections,

High pipeline costs from 2020 onwards in high demand case,

Low costs in 2010 deferral case, low costs in 2015 low demand case



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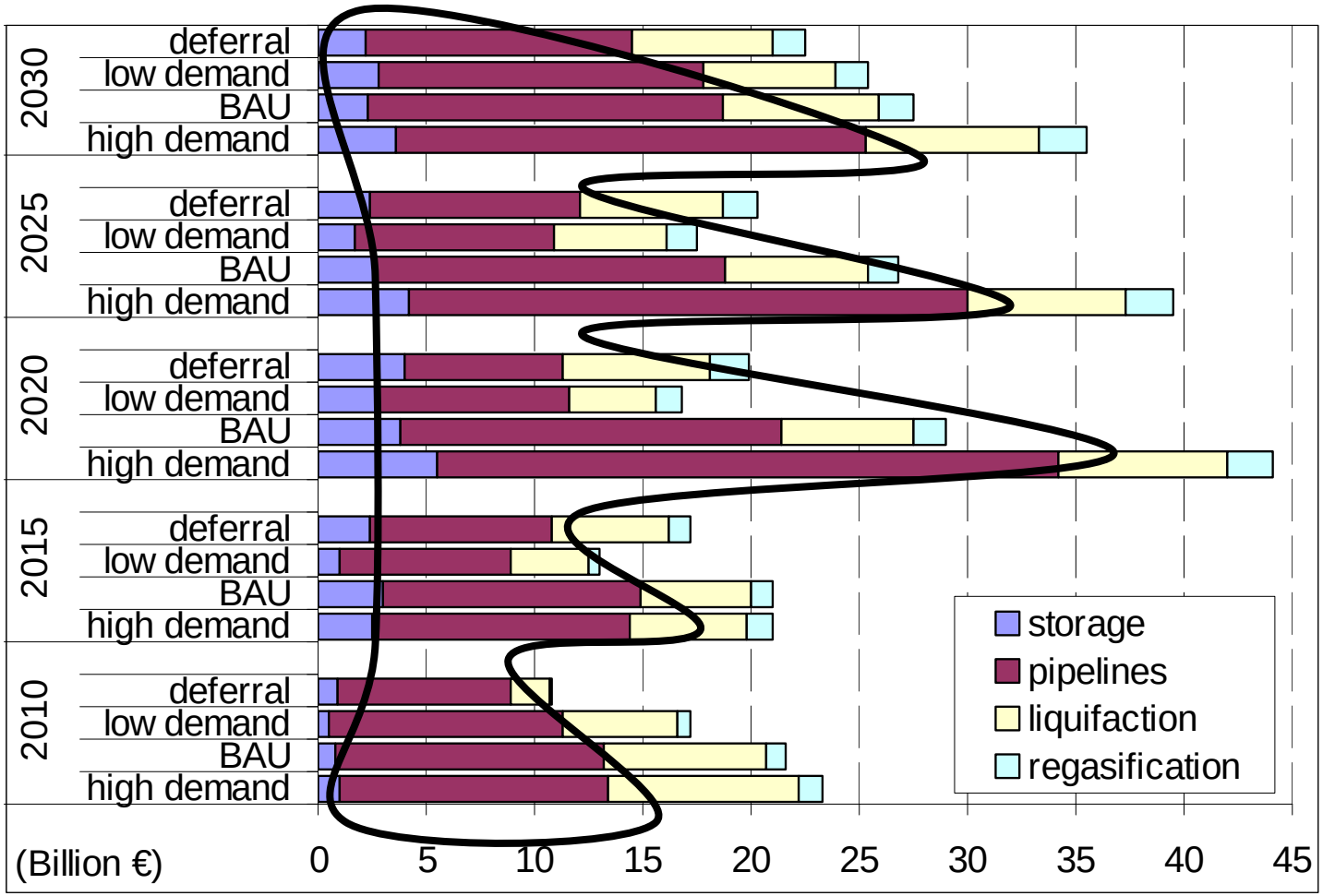

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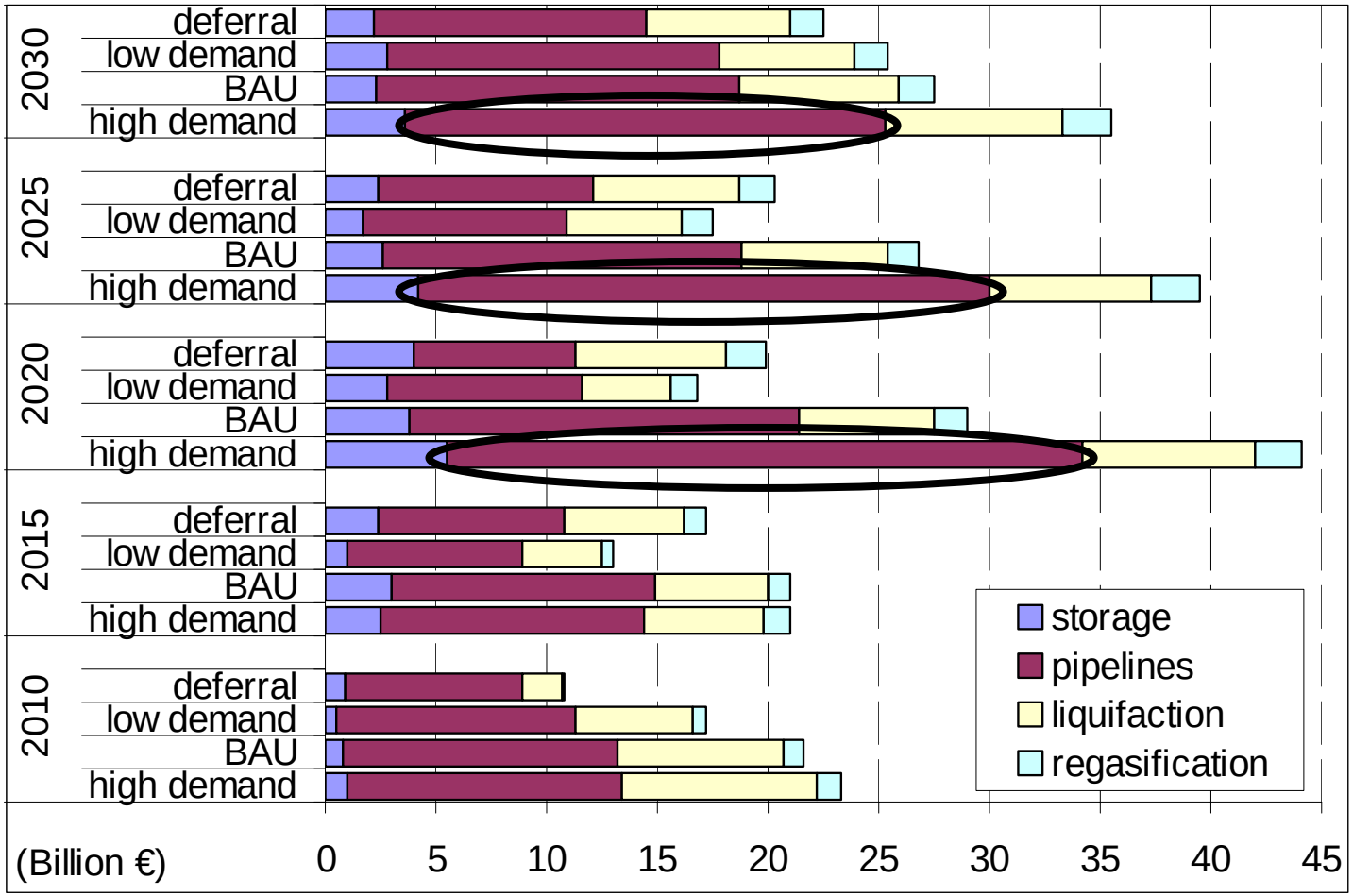

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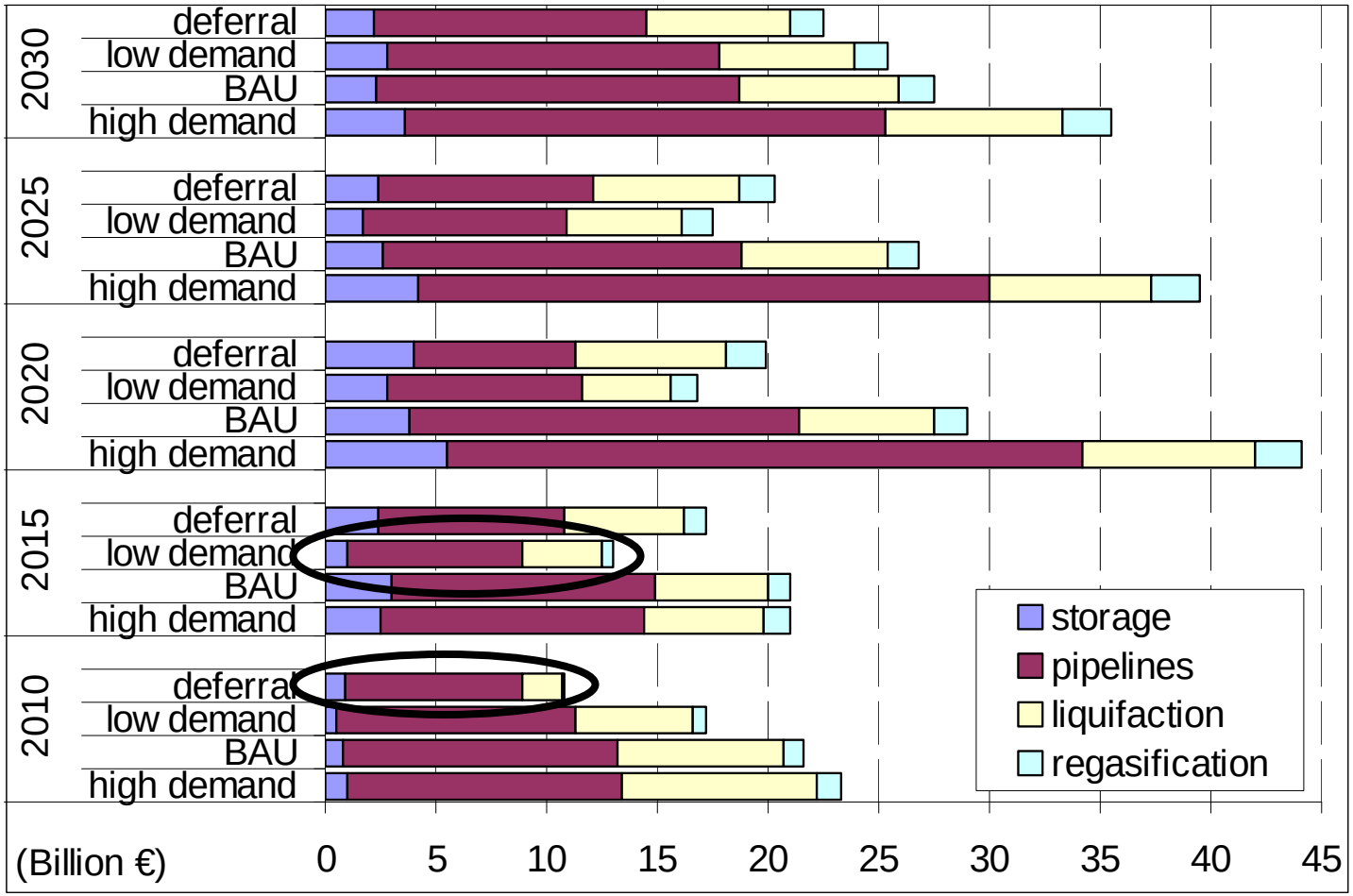
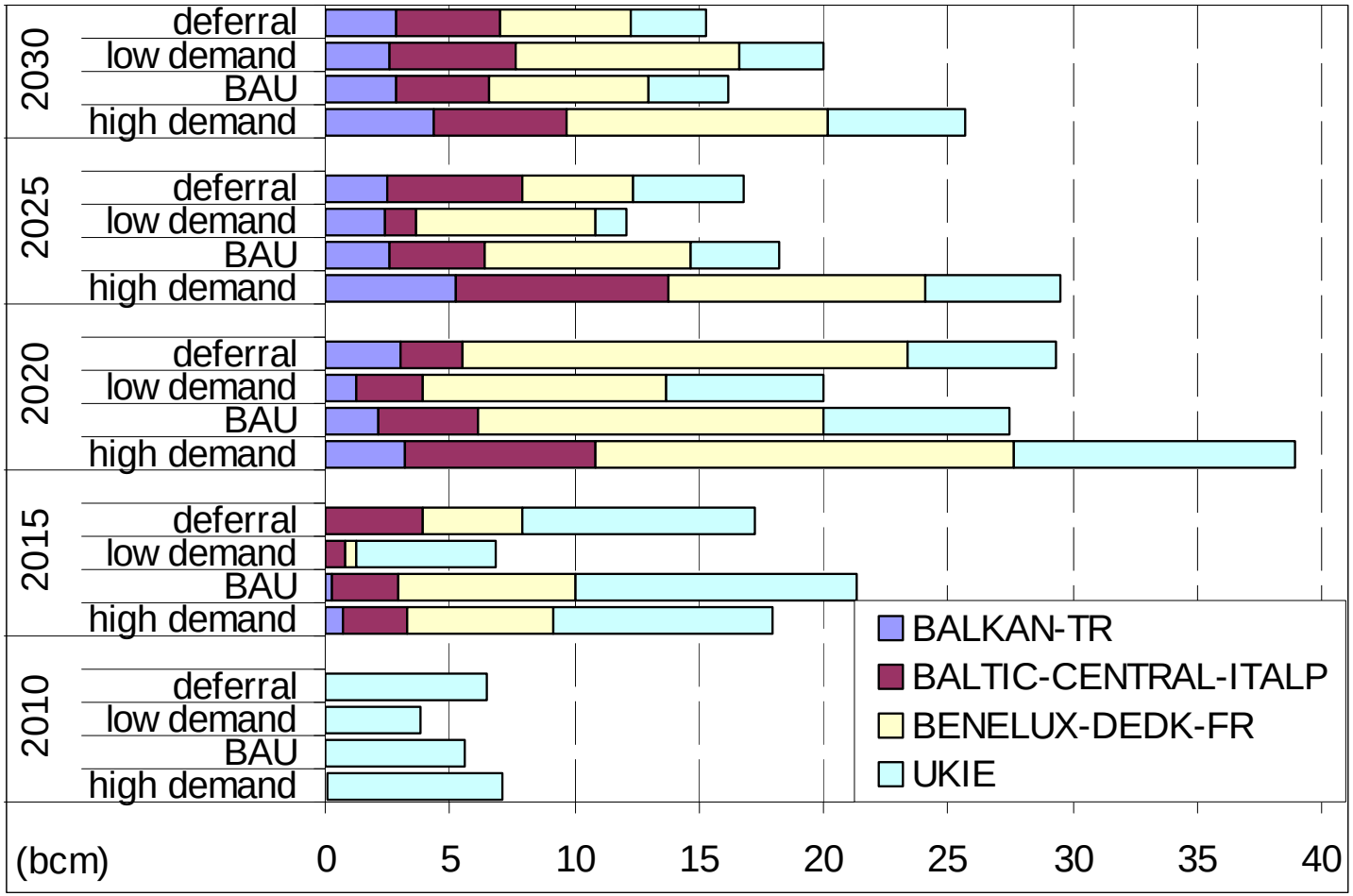


Total five-yearly investments in storage capacity:

In 2005–2010 only new storage capacity in UKIE,

From 2015 onwards storage becomes important in BENELUX-DEDK-FR,

Lower need for storage in the low demand case.



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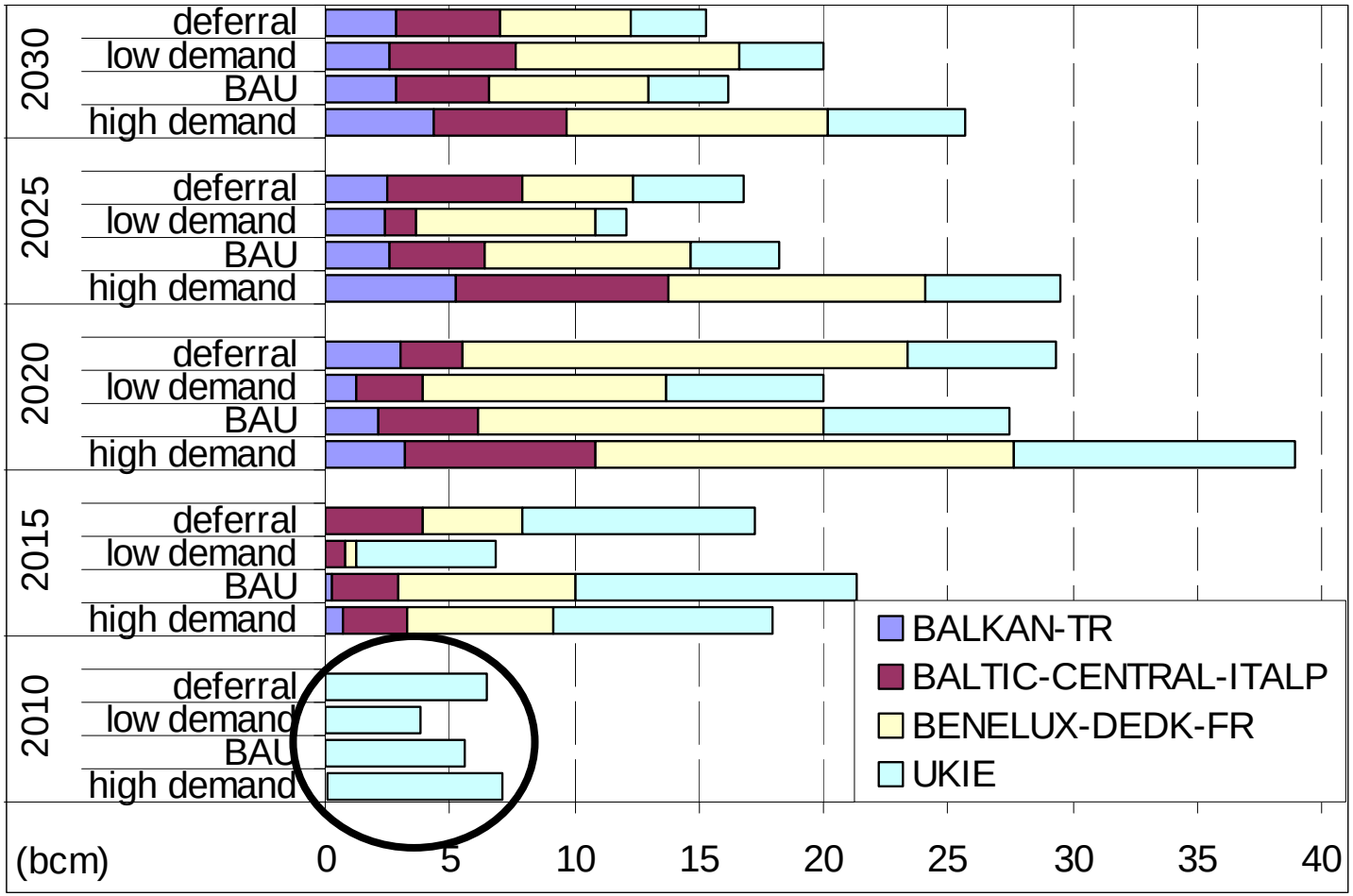

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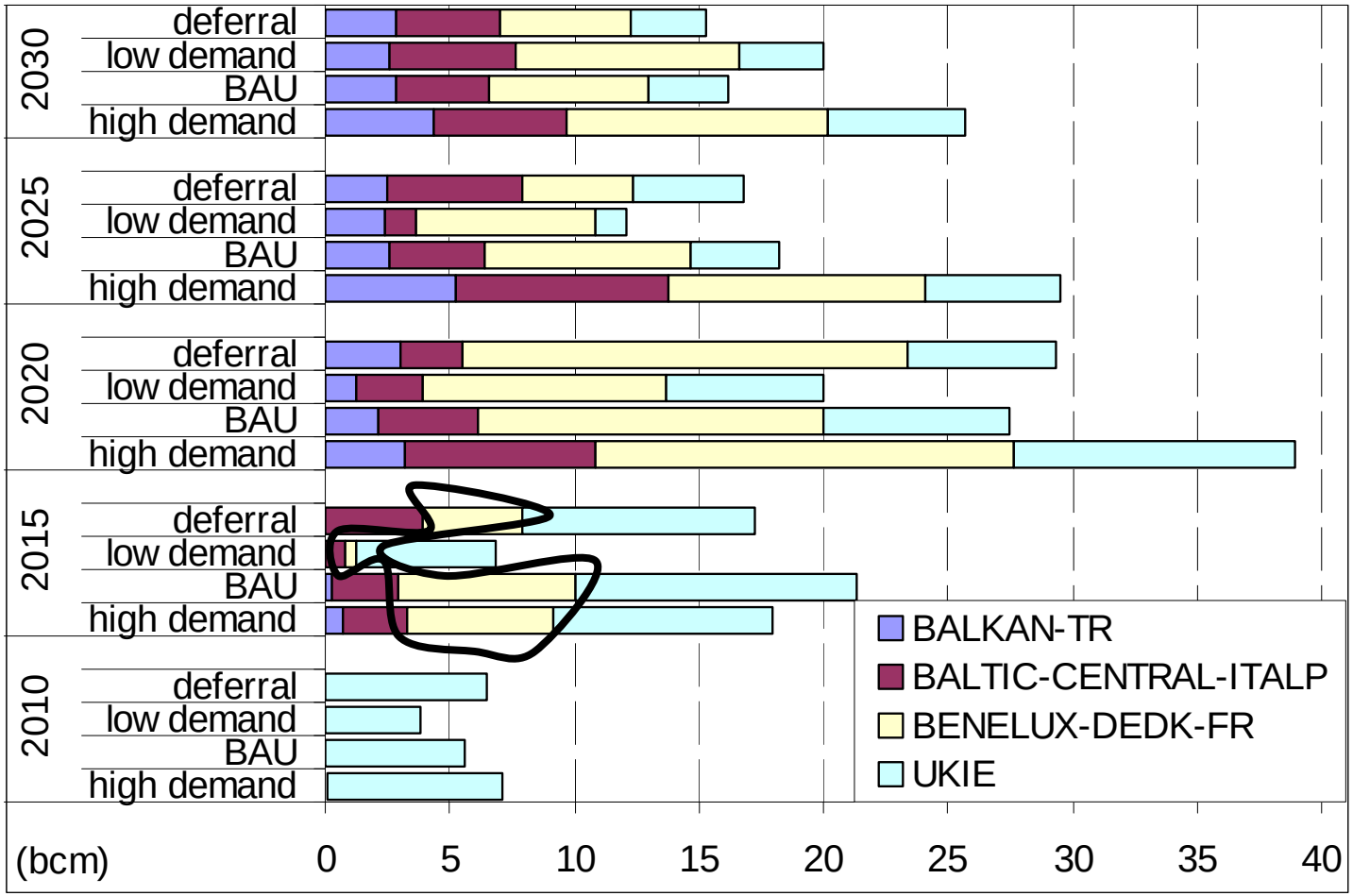

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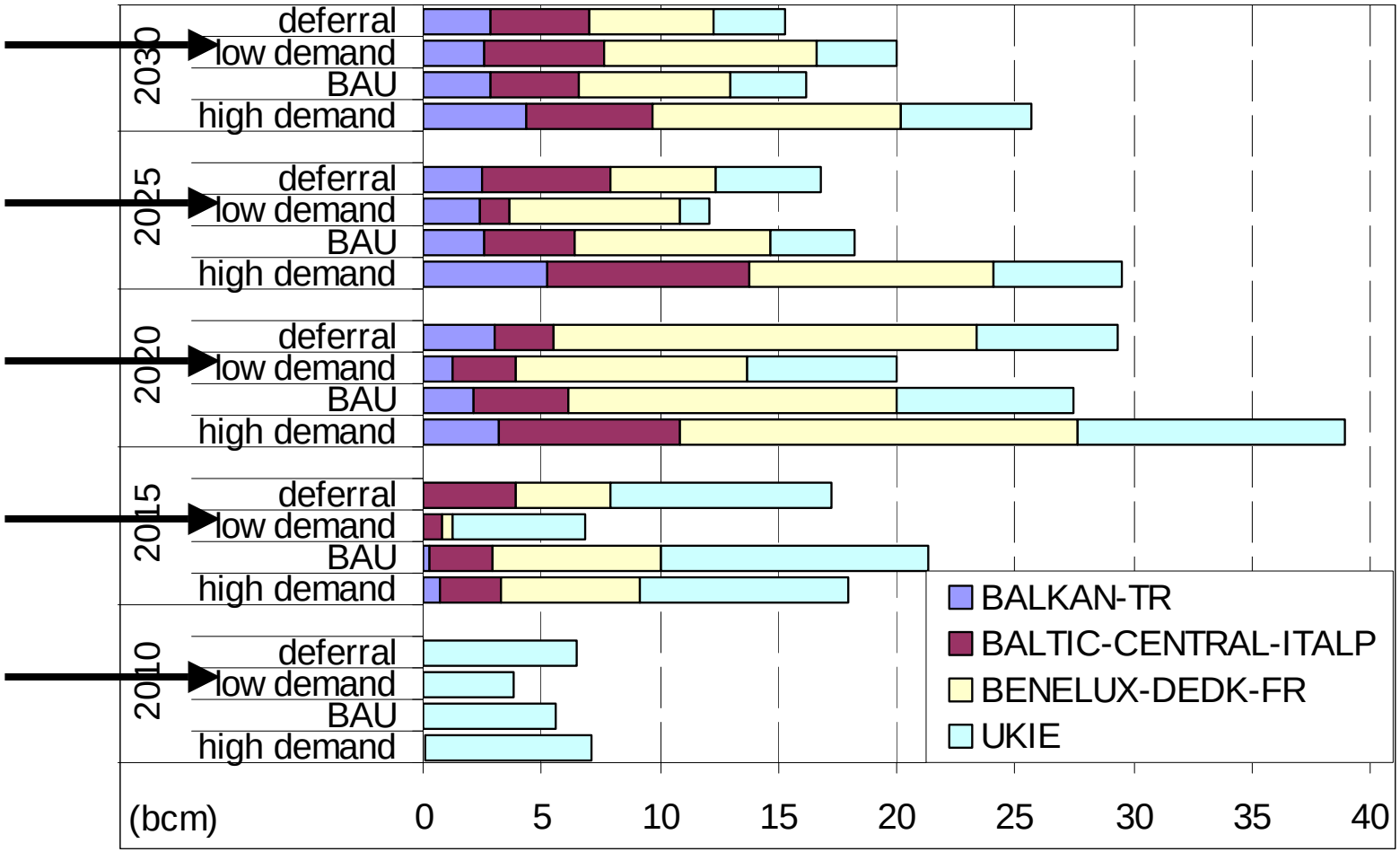
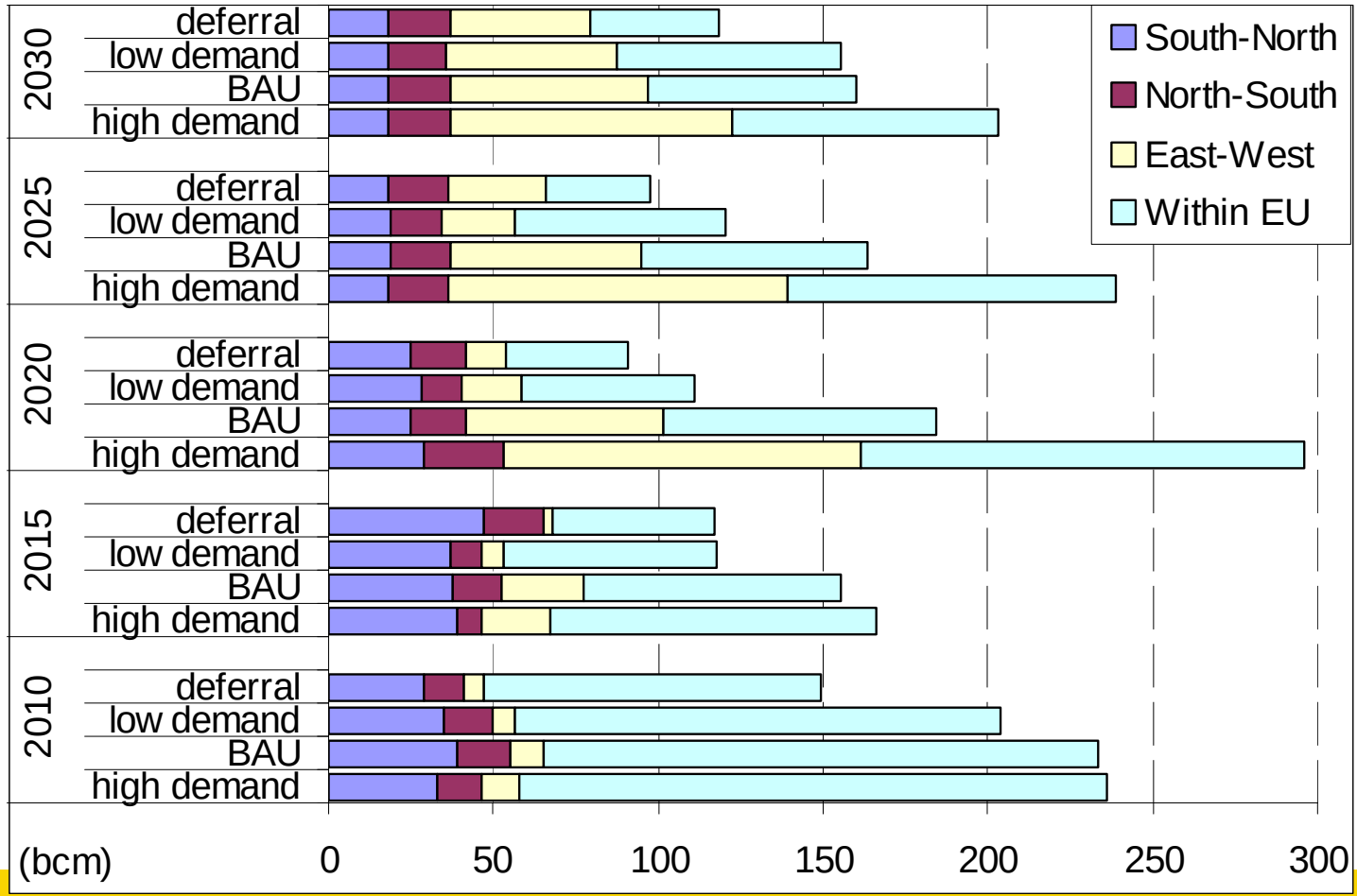


Total five-yearly investments in pipeline capacity:

In bcm terms the largest expansion is needed among EU countries.

1st decade most investments on South-North route.

2nd decade most investments on East-West route in BAU/ high demand cases.



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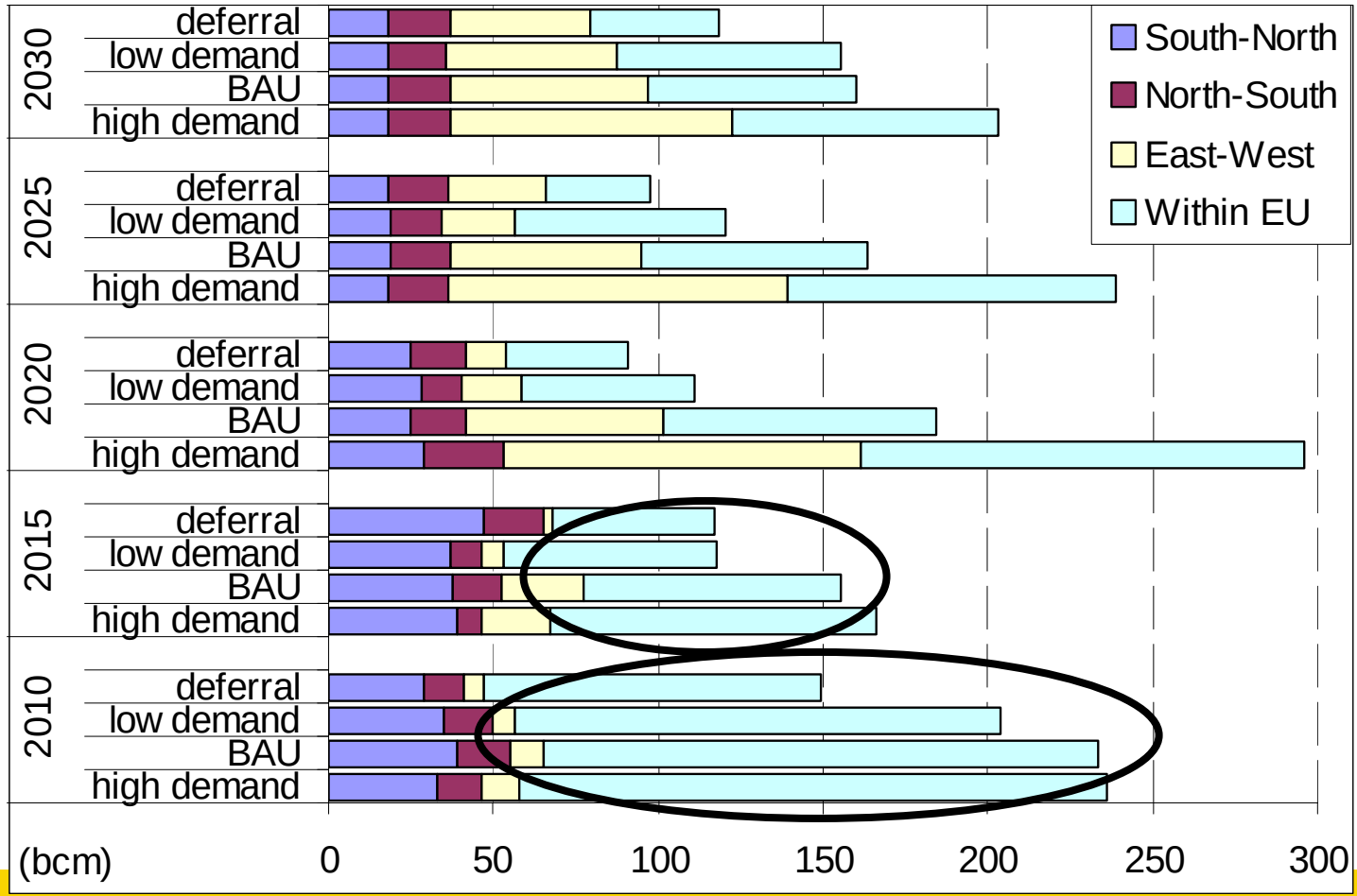

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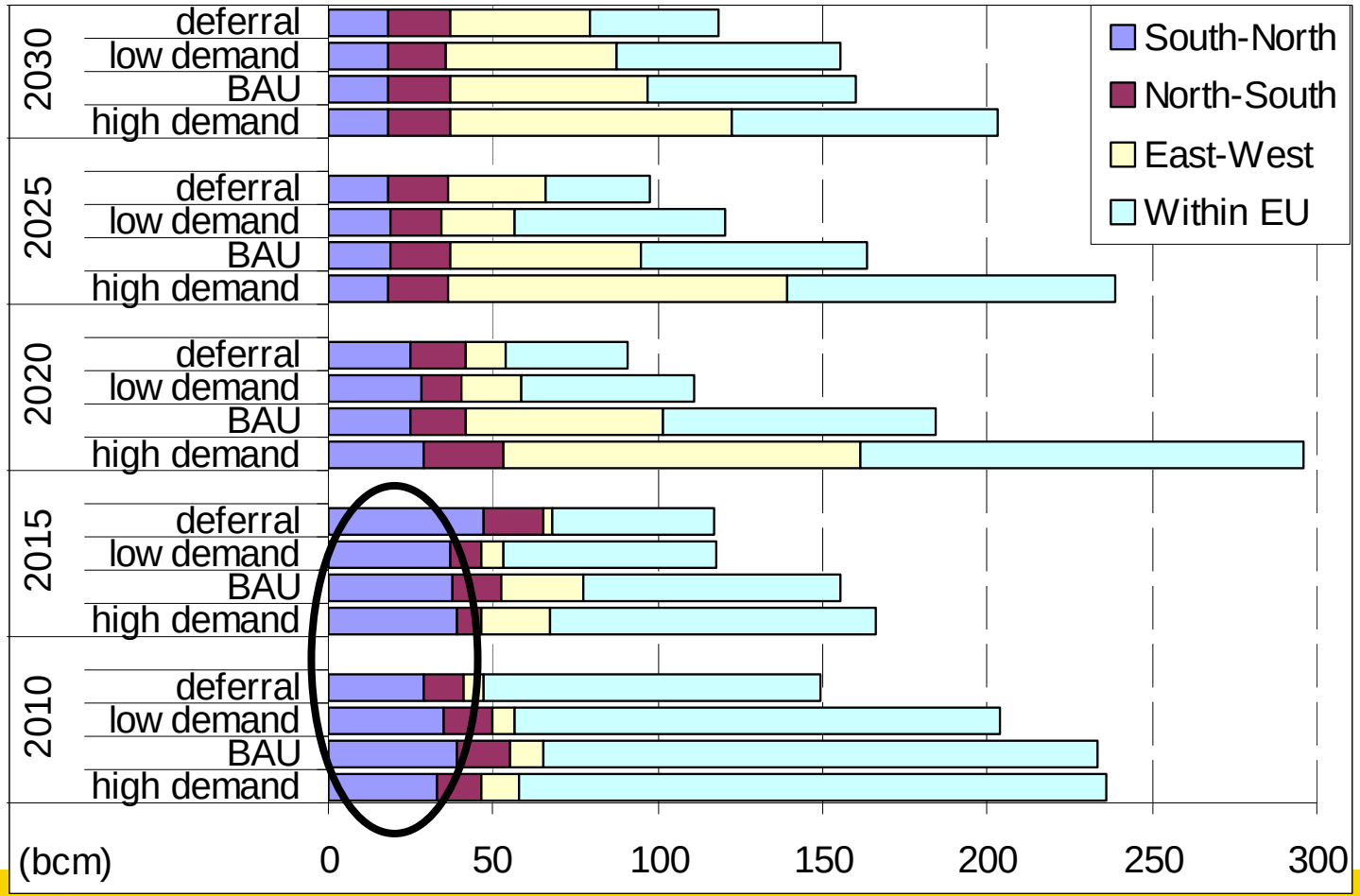

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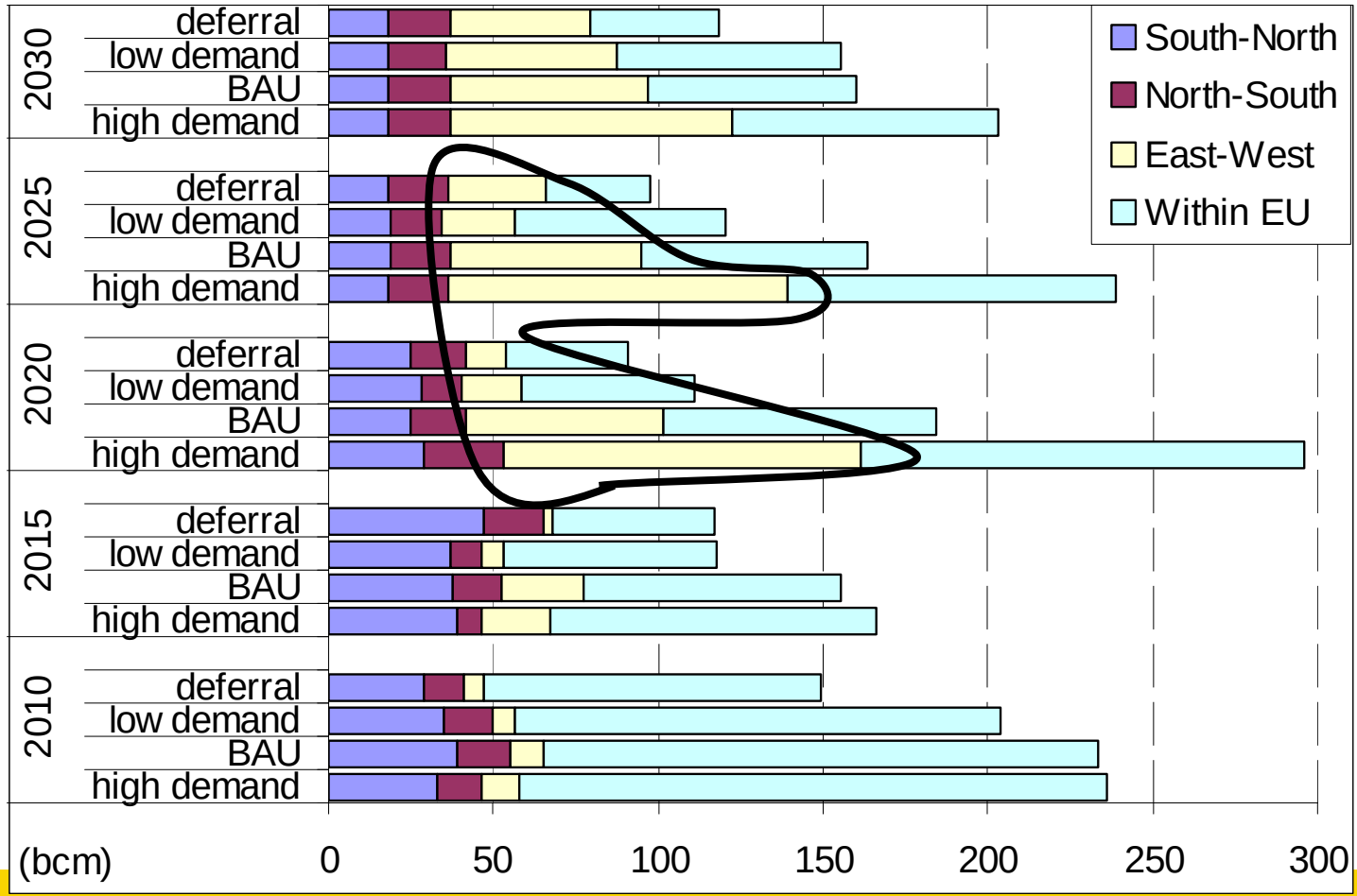
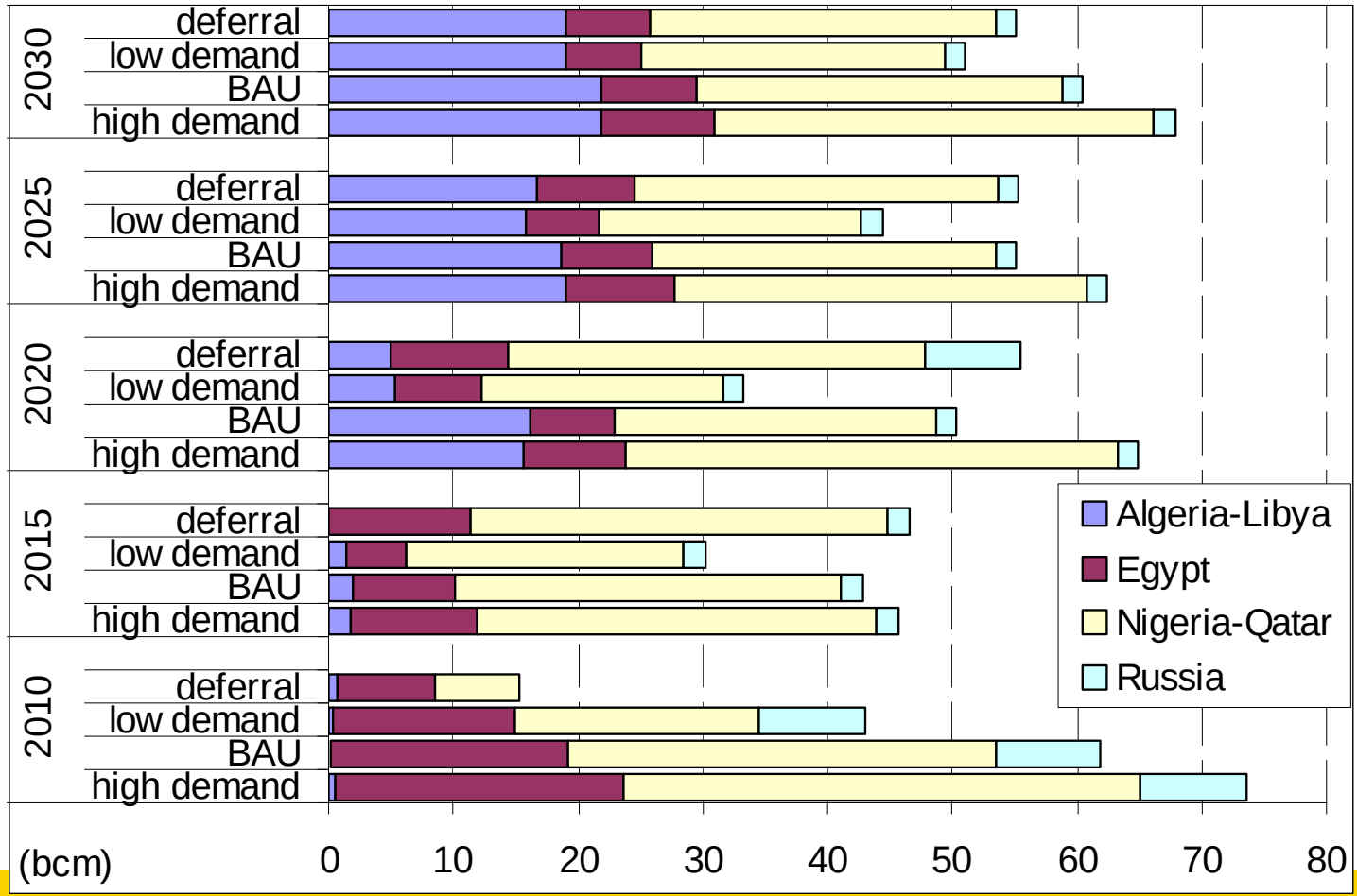


Total five-yearly investments in liquefaction capacity:

New in Nigeria-Qatar (56%), Algeria-Libya (20%), Egypt (19%), Russia (6%).

LNG for Libya and Algeria after 2015.

Russian LNG at full capacity in all cases except deferral



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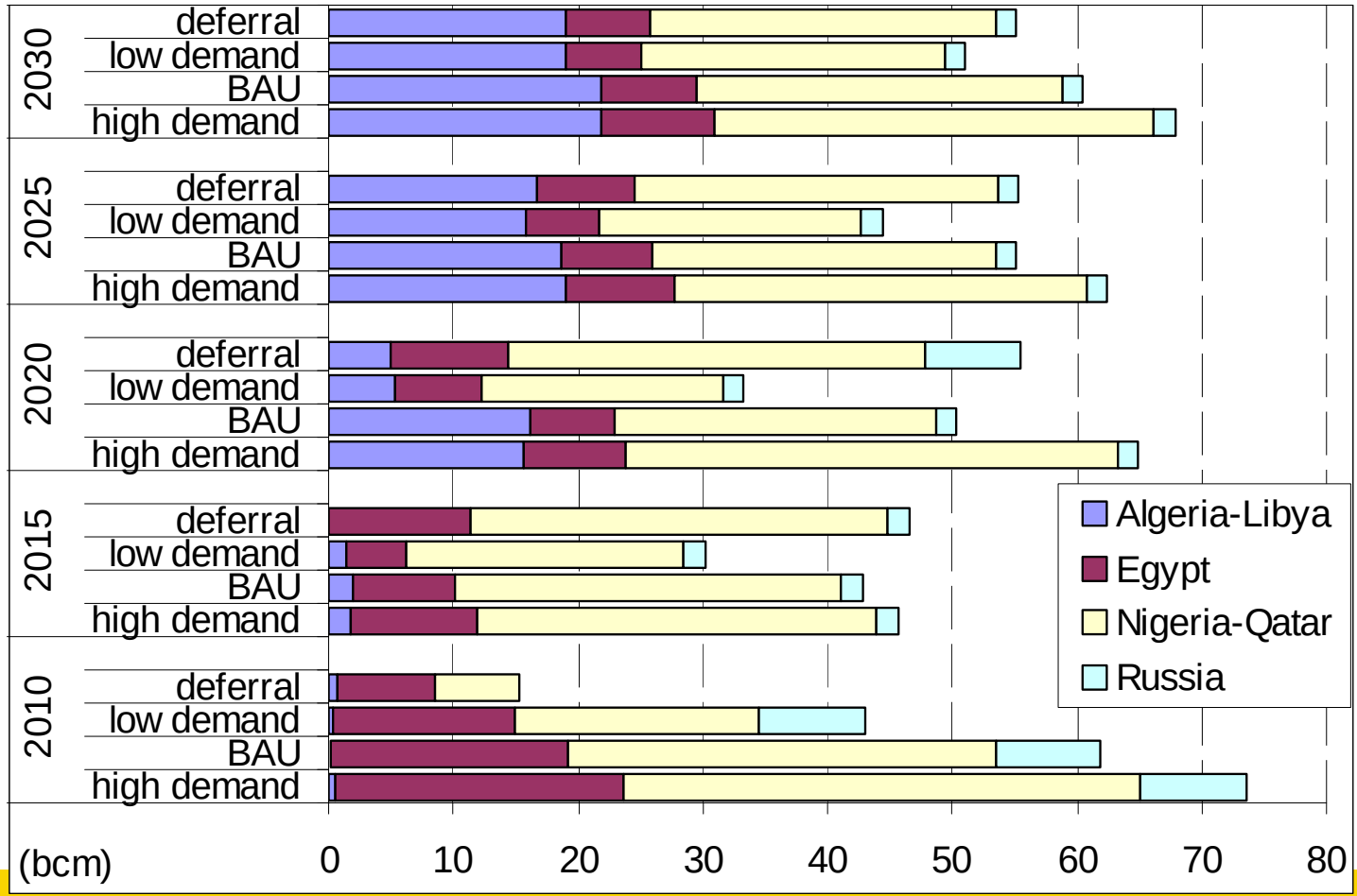

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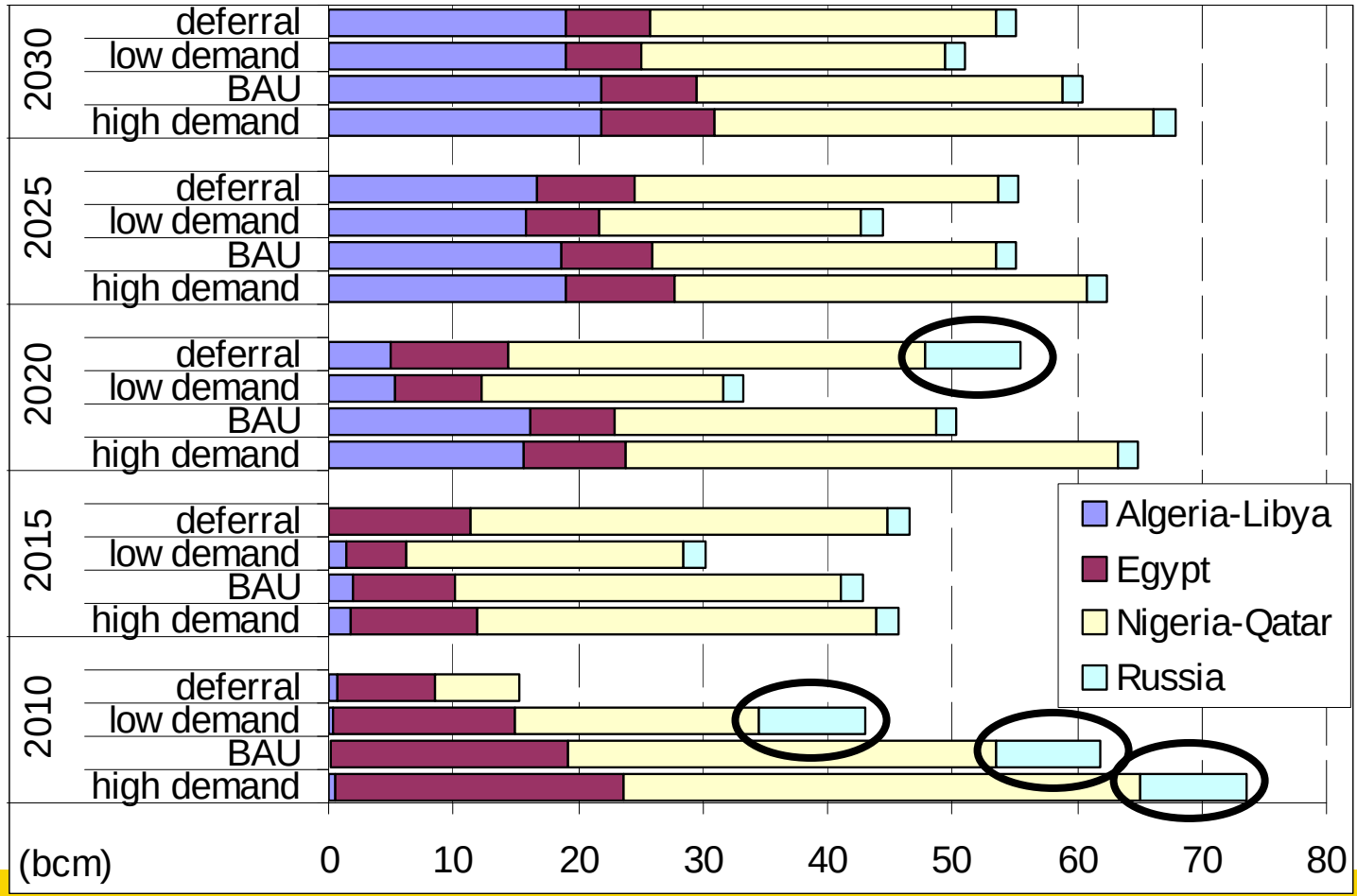
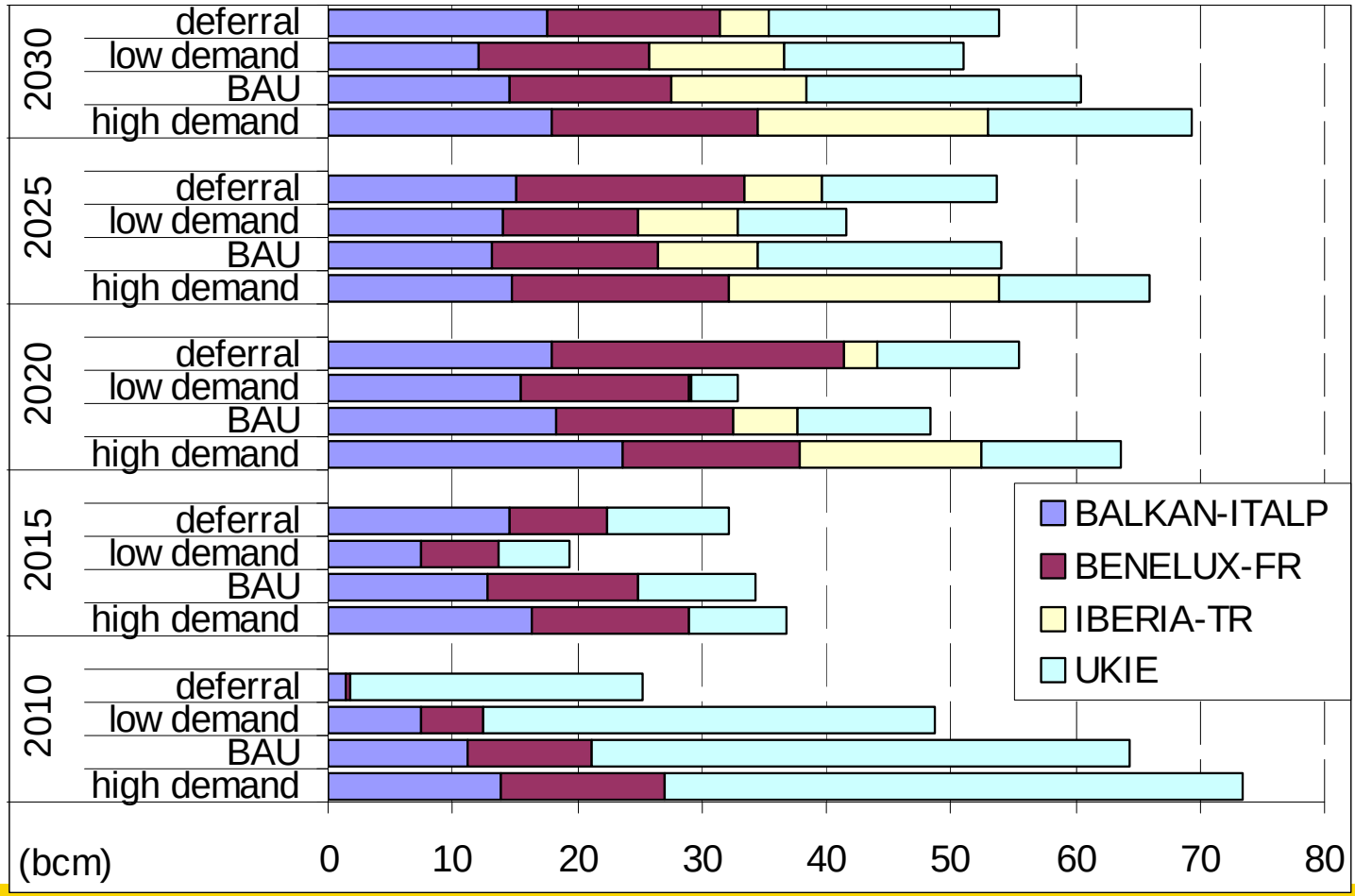


Total five-yearly investments in regasification capacity:

By 2010 regasification capacity mainly added in UKIE → flexibility.

After 2010 regasification capacity additions to BENELUX-FR/BALKAN-ITALP.

After 2015 regasification capacity additions to IBERIA-TR LNG.



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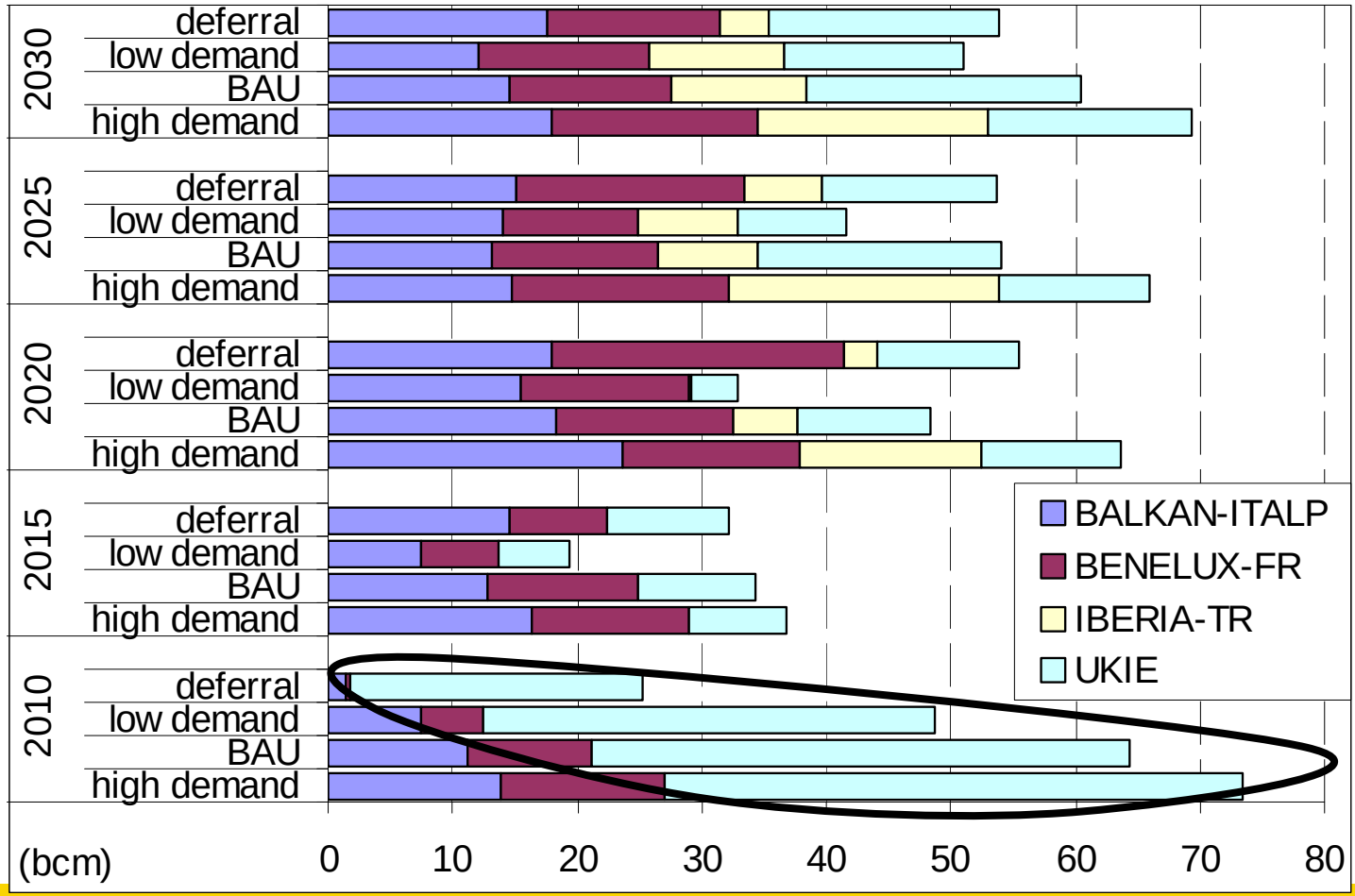

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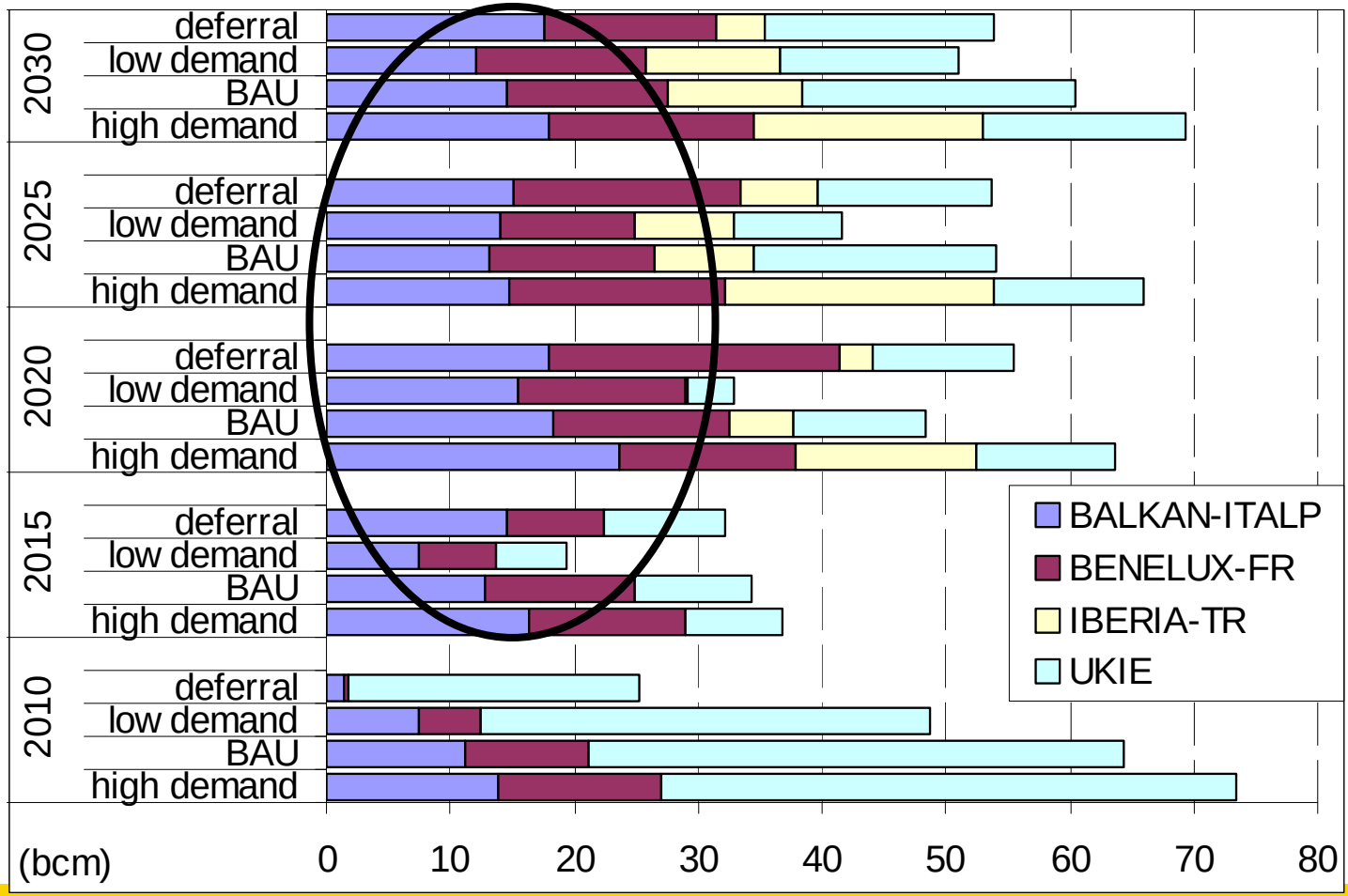

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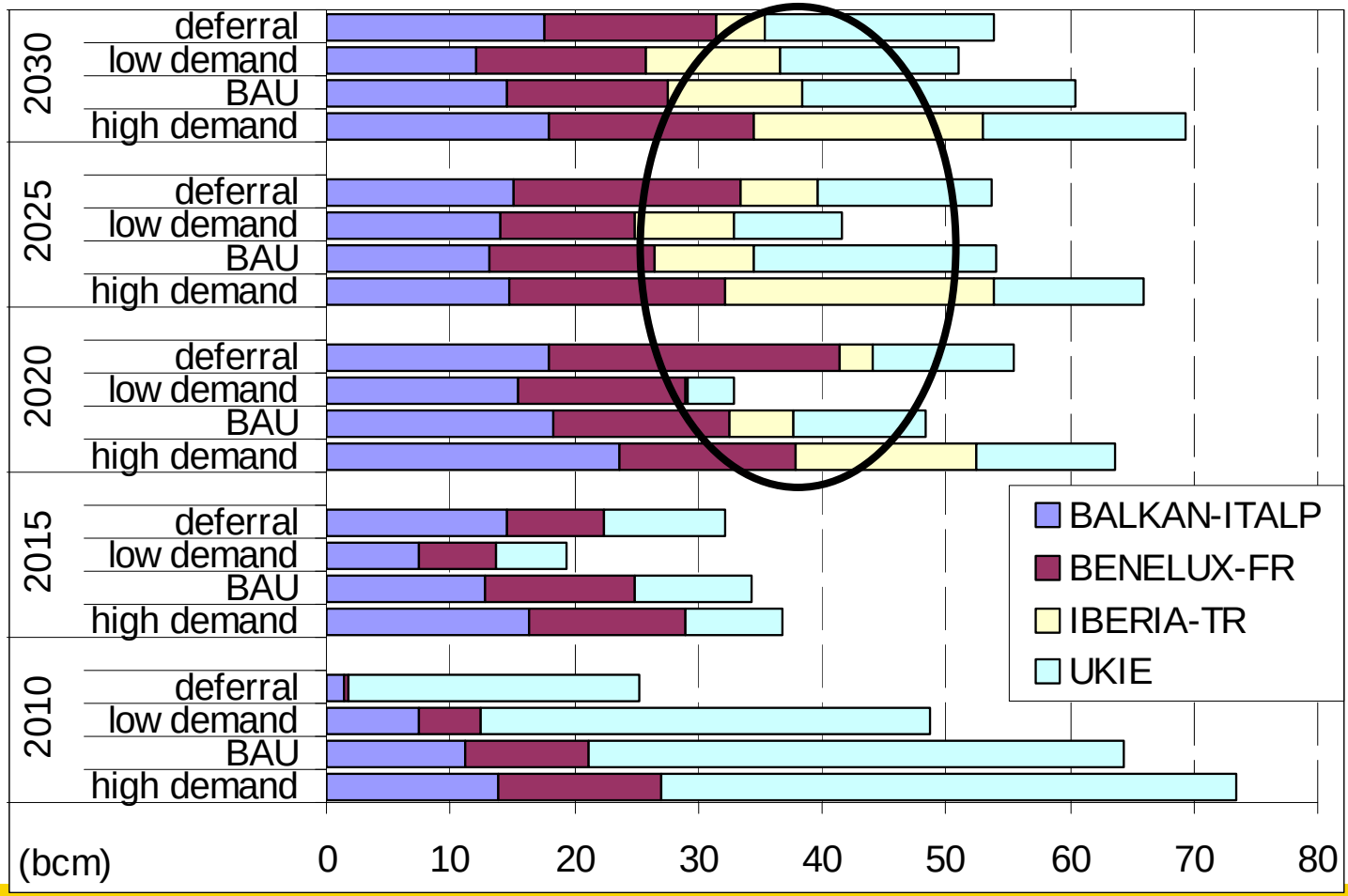
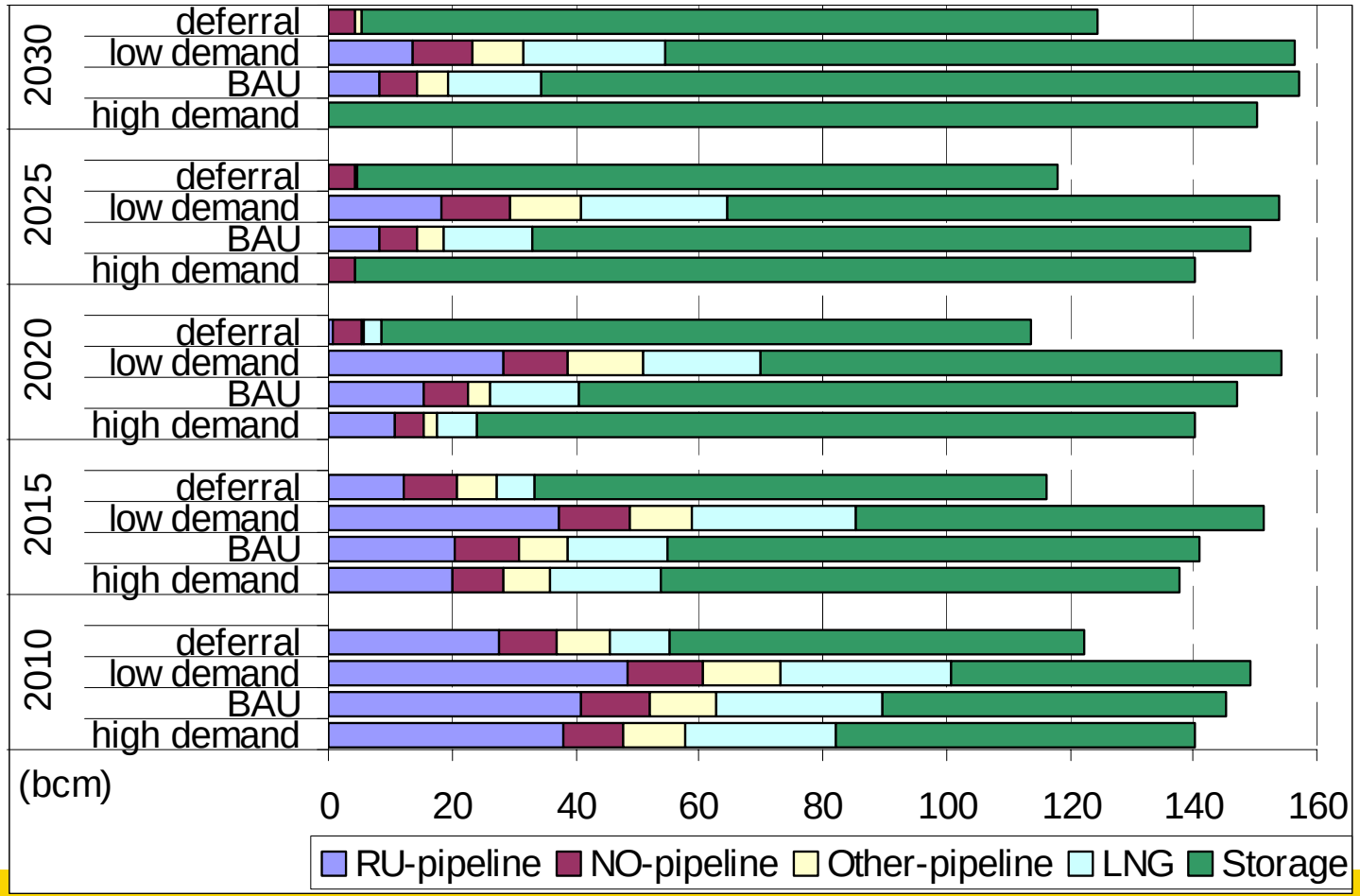


Total yearly difference between cold and warm season:

Storage gains importance in time, 100% in high demand case by 2030,

Flexibility from Russian pipelines decreases in time,

Flexibility through LNG remains important in time in low demand/BAU case.



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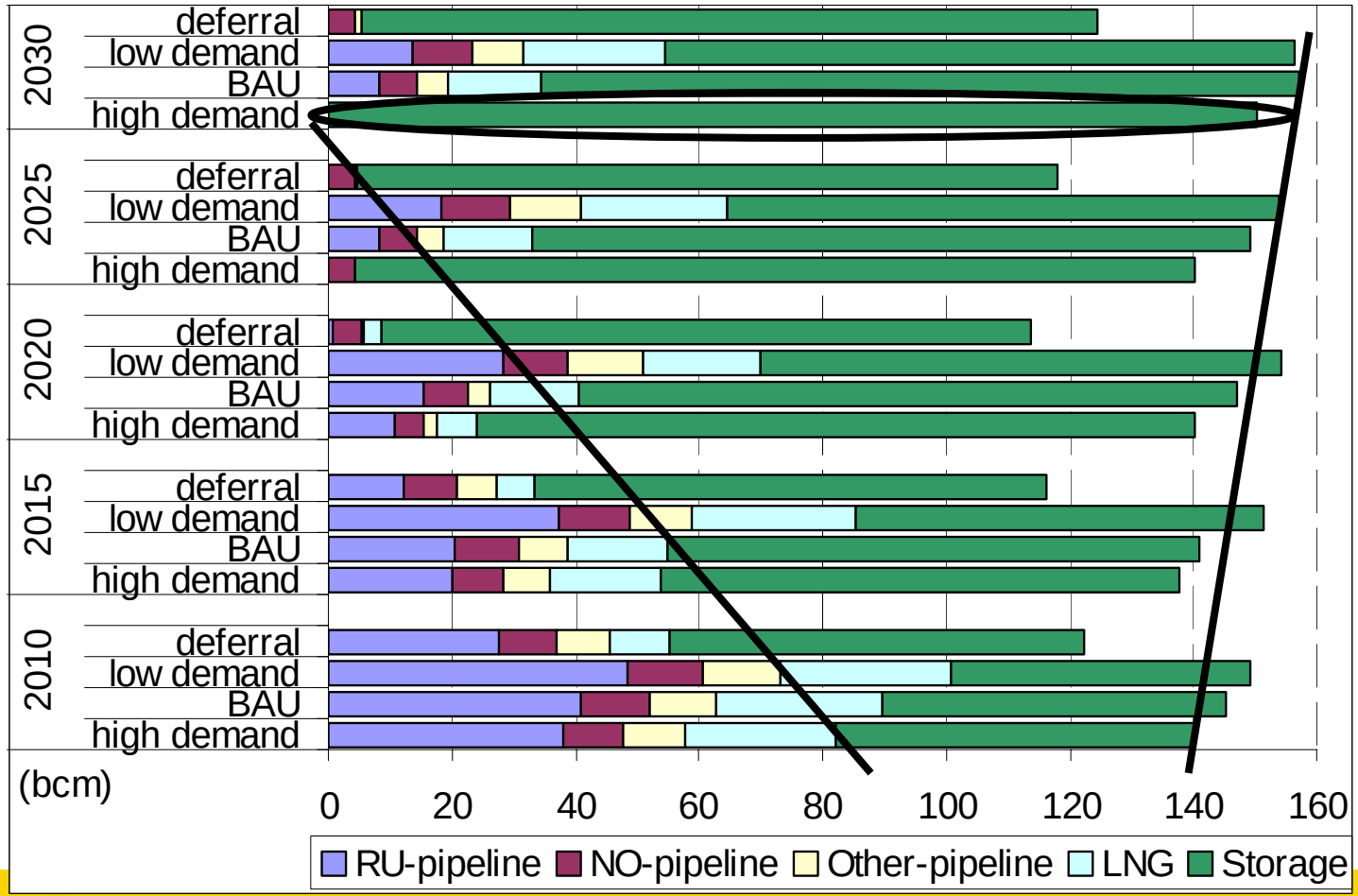

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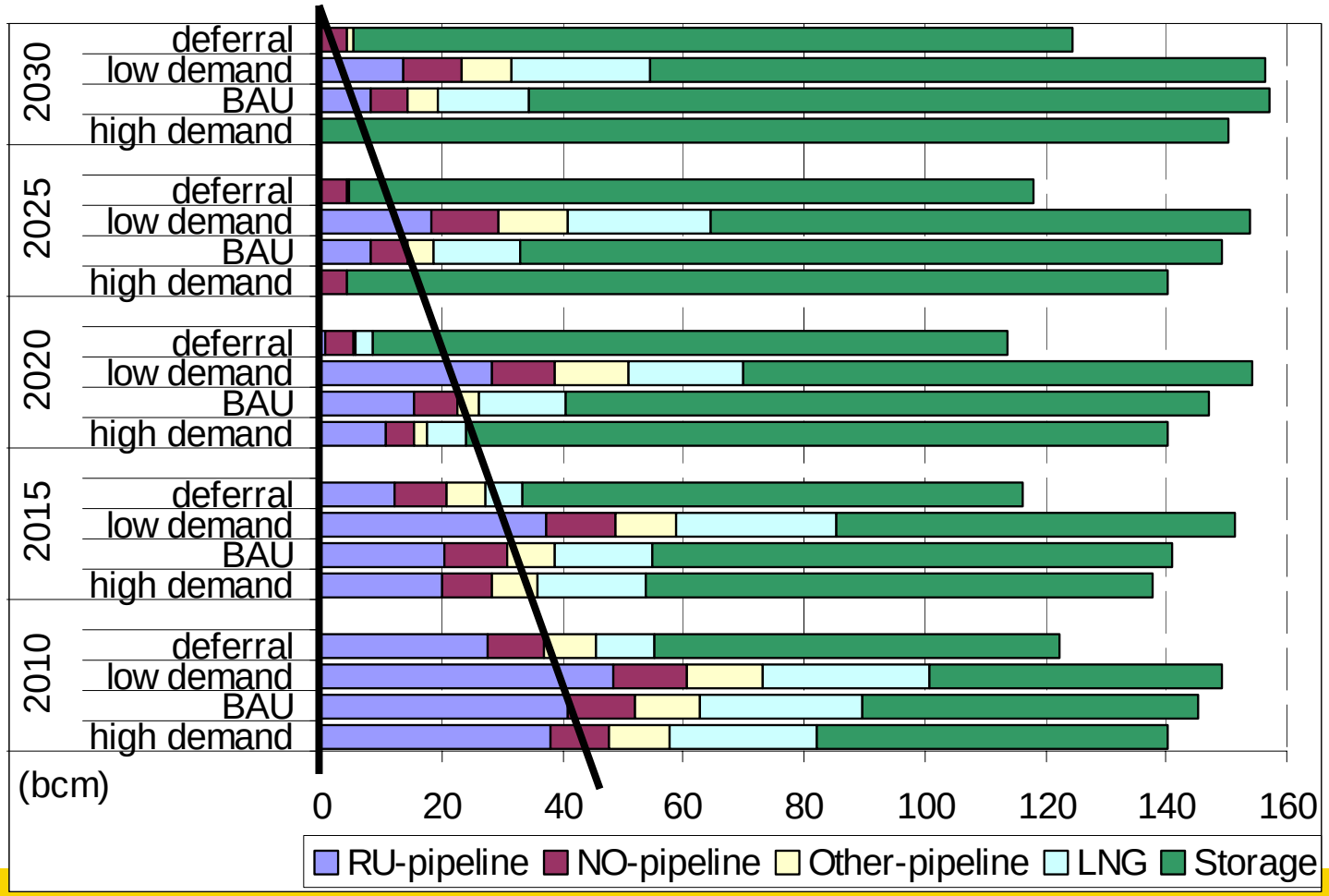

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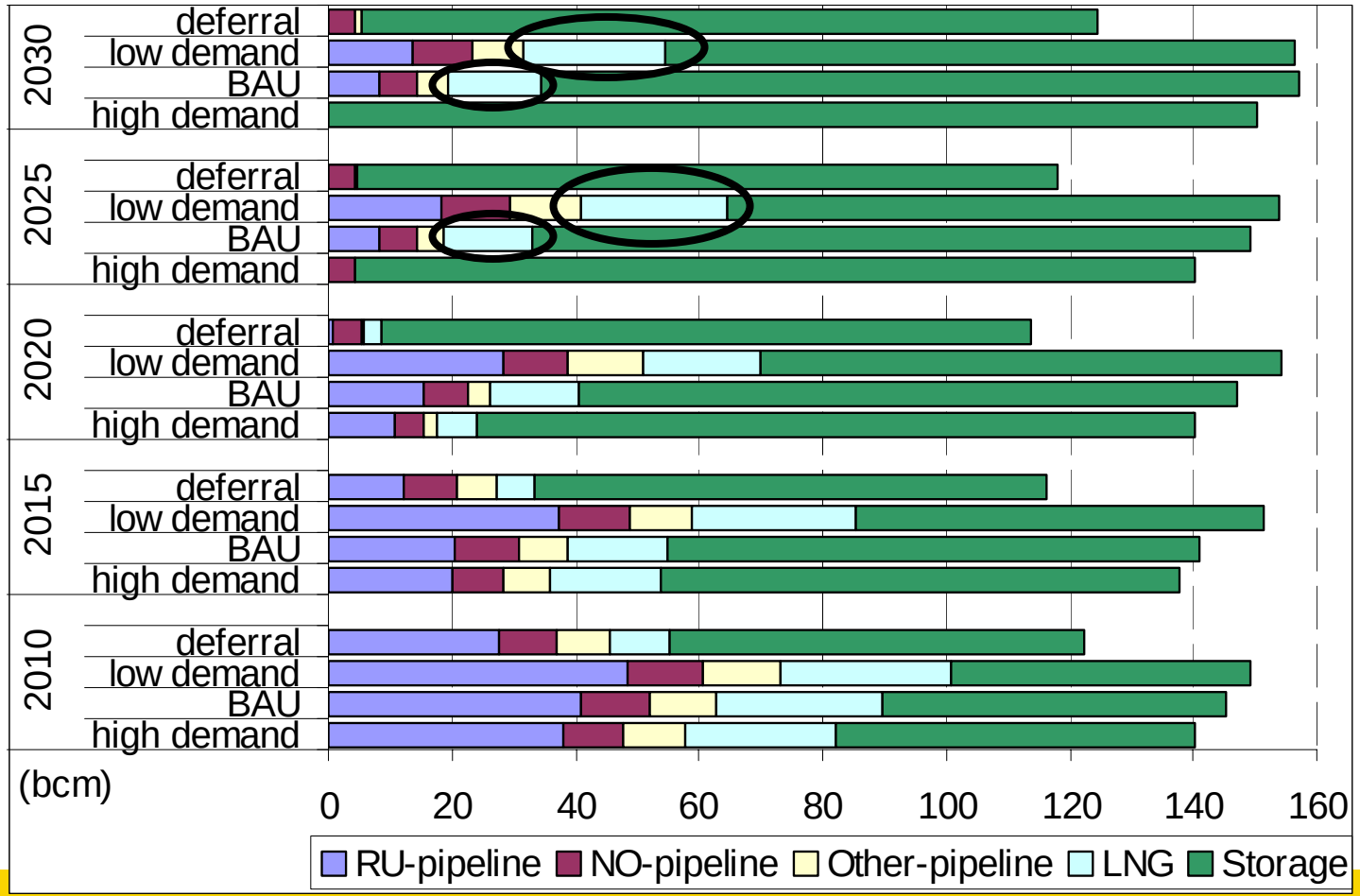
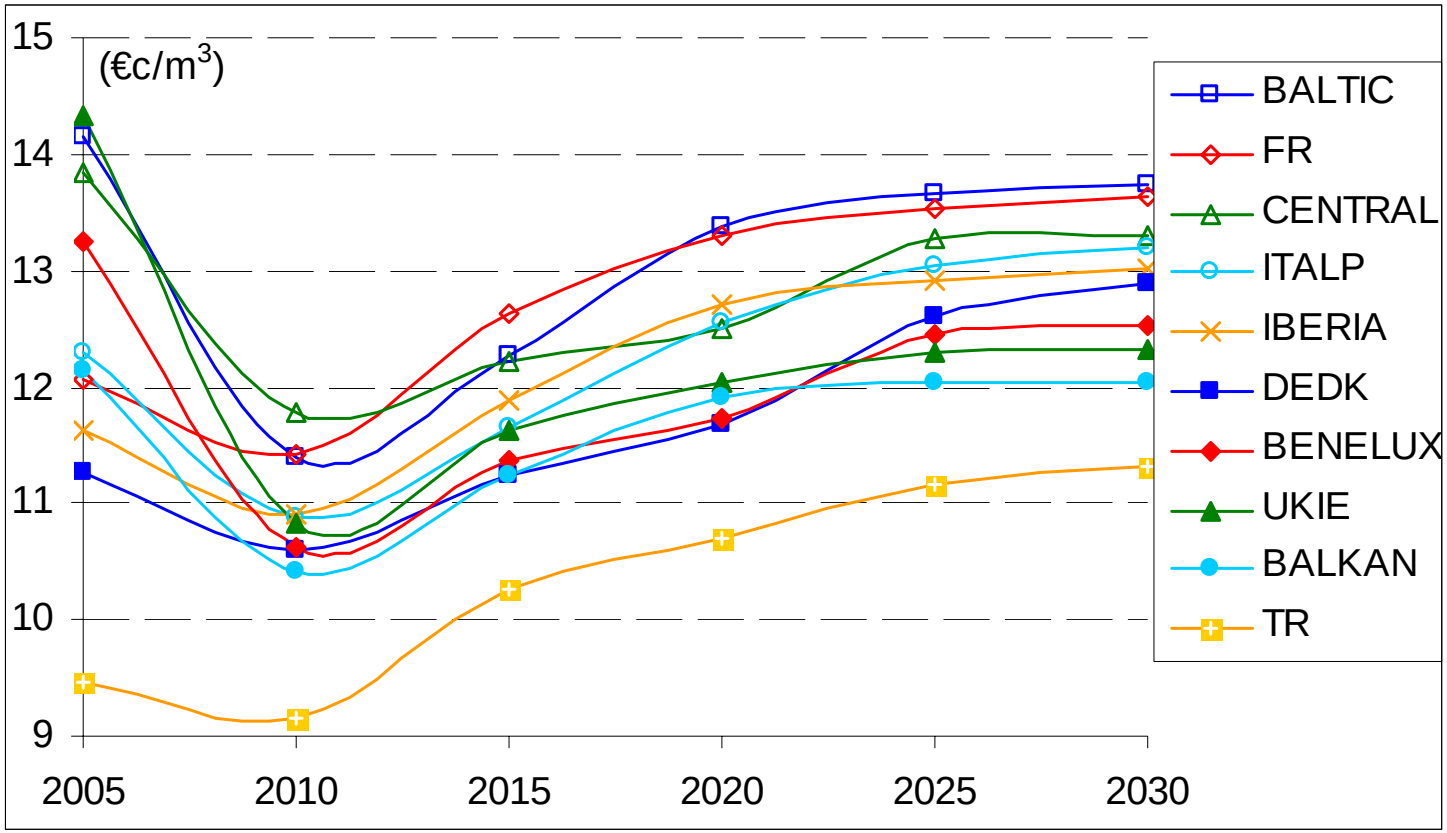


Regional prices in the BAU case:

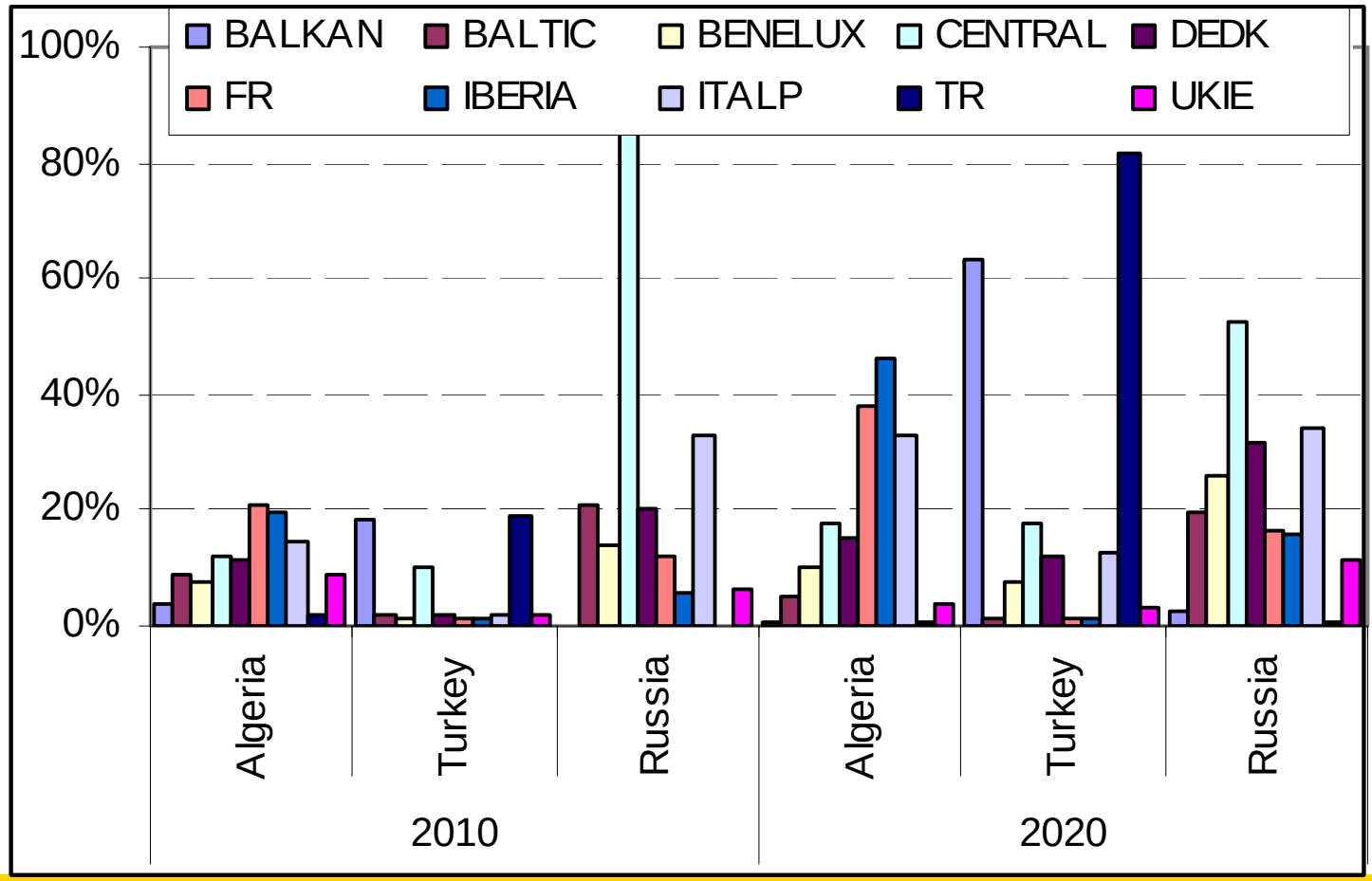
- Prices lowest in Turkey → potential transit artery to EU.
- Prices high in FR, BALTIC, CENTRAL → competition, accessibility.
- New investments reduce market power → prices ↓ from 2005 to 2010.



Price response in disruption cases:

Percent changes w.r.t. BAU prices of a full (100%) short-run (≈year) disruption of supply for 2010 and 2020 through: Algeria, Russia, Turkey.

No investment responses possible in such a short time-frame.



Conclusions

- **Price differences** due to: 1) distance from producer, 2) market power.
- **Pipelines dominant** in future: 83% (low demand), 81% (high demand & BAU) and 77% (deferral) in 2030.
- **Storage is cheapest option** for arbitrage between summer and winter demand. LNG is second best option.
- Decisions for new corridors **political**, shown by existence of expensive and absence of cheap options.
- **Disruption** leads to higher gas prices in neighboring countries. Price effect in 2020 higher for Algeria/Turkey due to higher demand Price effect in 2020 lower for Eastern Europe due to alternative supplies.
- **Substantial investments** needed in corridors towards EU, Especially the East–West route influence future gas prices.