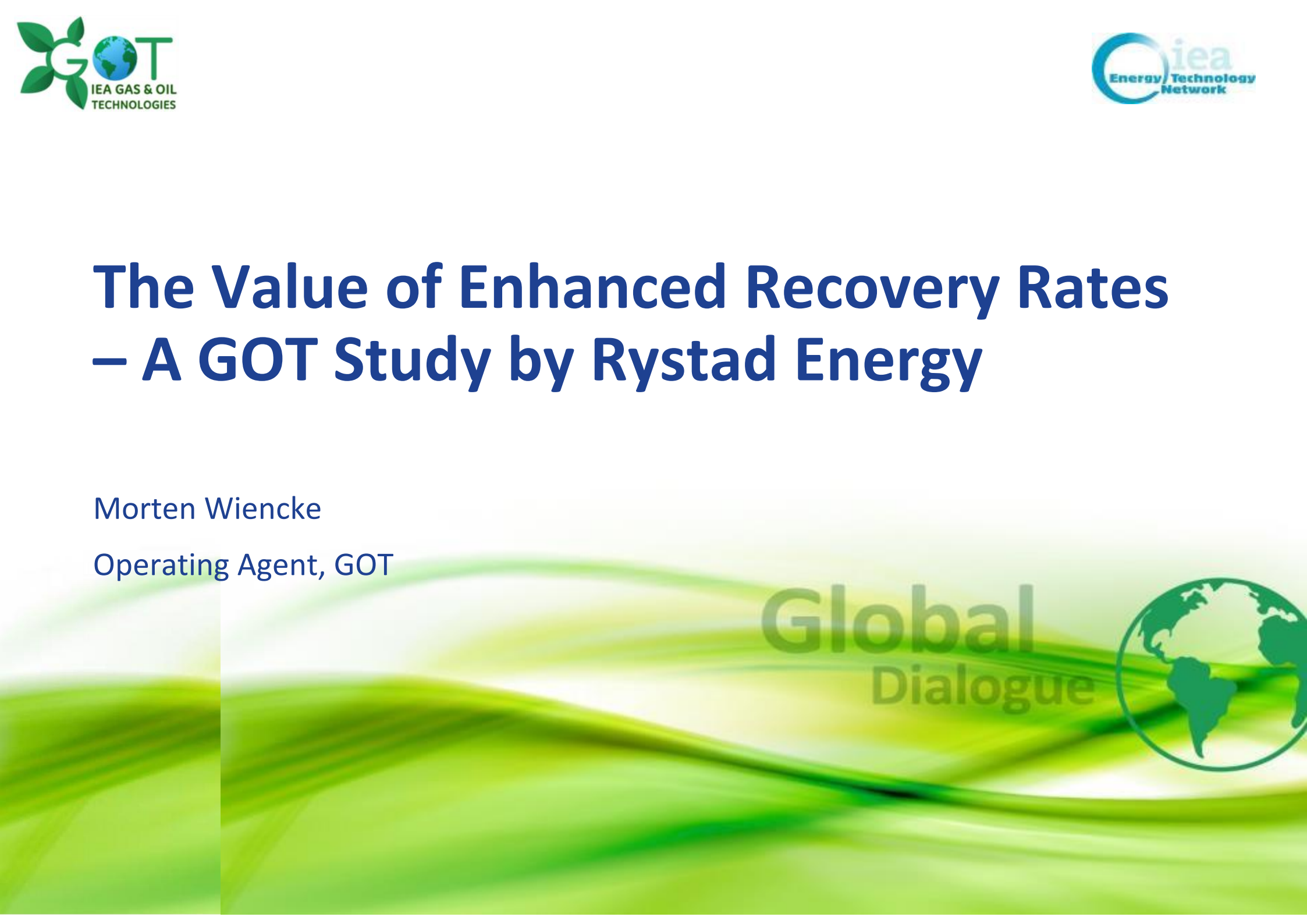
The Value of Enhanced Recovery Rates – A GOT Study by Rystad Energy

Morten Wiencke

Operating Agent, GOT



Gas & Oil Technologies –

The Value of Closing Technology Gaps

Morten Wiencke, GOT Operating Agent

SHALE

RYSTAD ENERGY

Technical resource estimates for shale globally is 1800 Billion boe, of which 75% is outside North America. Technology gaps to reduce break-even cost (wells, drilling, manufacturing), ensure license to operate (water, seismicity, local impact), enhance recovery (deeper fracking, CO_2 injection, reservoir modelling) are highlighted.

CONVENTIONALS

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"Easy" oil is gone. The 2020-2040 scenario implies that a major part of global oil & gas **supply** must come from "**demanding**" or "**challenging**" resources. The technology gaps to reduce cost and unlock reserves in **deeper** and **remote waters** are assessed, including unmanned facilities, automated drilling, composite risers, and complete subsea factory solutions.

Mapping study scope to main classes of industry challenges

Challenge	Conventional Greenfields	Conventional Brownfields	Shale/tight oil and gas
Reduce break-even costs	General cost level Deep water Small fields Stranded gas	Increased Oil Recovery Lifetime extension	Efficiency of drilling and fracking Regional cost drivers
Unlock resources	Arctic Deepwater 3000m+	Enhanced oil recovery	Recovery rate Subsurface understanding
Ensure long term social license to operate	Oil spill detection and response Arctic and deepwater	Flaring Energy use during tail end production	Water issues Air pollution Induced seismicity Community impact Climate impact

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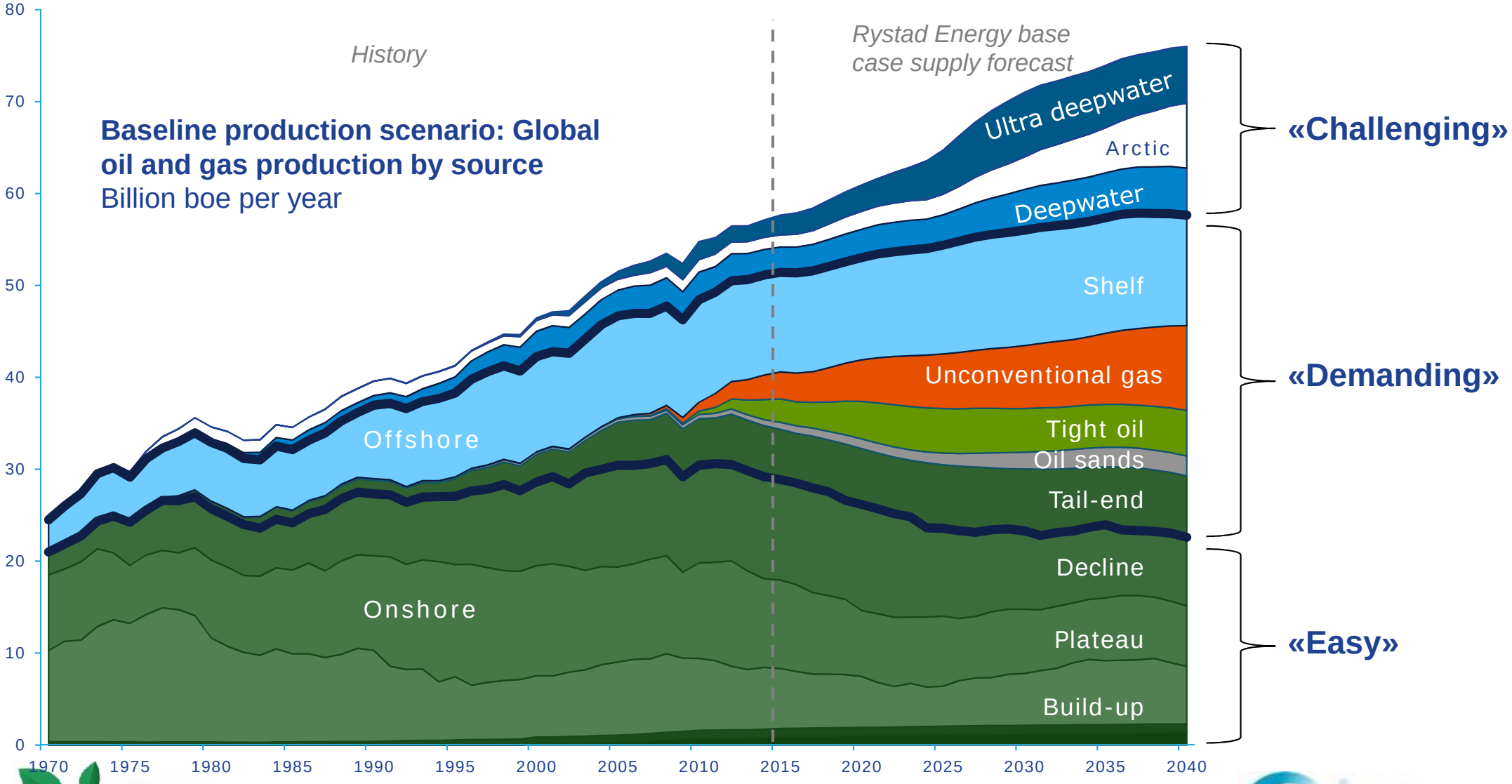
Main industry challenge: Increasingly difficult to ensure affordable, reliable and clean energy



Source: Rystad Energy UCube

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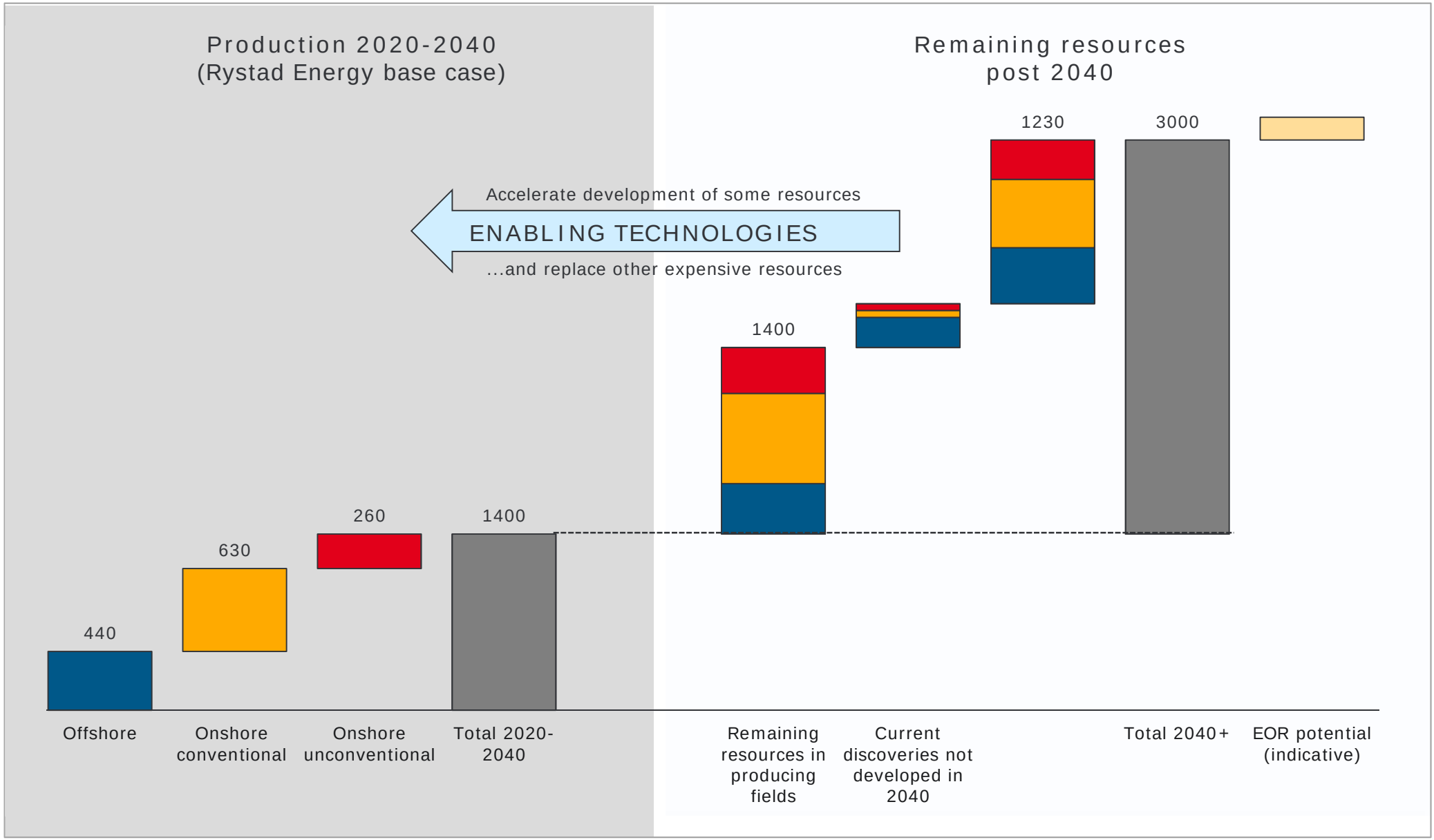
Overview of remaining oil and gas resources 2020-2100 (Source: Rystad Energy UCube). Expected ultimate recovery (EUR) of the fields based on reported 1P and 2P numbers (Trillion boe)



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GOT key actions - Conventionals

Greenfield

- Design to cost – Out-of-the-box solutions that make marginal field development feasible @ 30$
- Standardization – subsea, floaters, etc
- Drill & produce @ 3000m WD – New well control rule, reduce BOP weight and payload, all electric, composite risers
- Remote fields 300kms offshore – Subsea compression, subsea gas/CO2 separation and reinjection, all electric subsea to shore

Brownfield

- Robotic drilling, unmanned platforms
- Changing market landscape – newcomers taking over old fields (may need more help)
- The water issue. Enormous amounts of water to be handled
- Light subsea well intervention faster and cheaper
- Help operators build confidence in business cases for CAPEX decisions in late life

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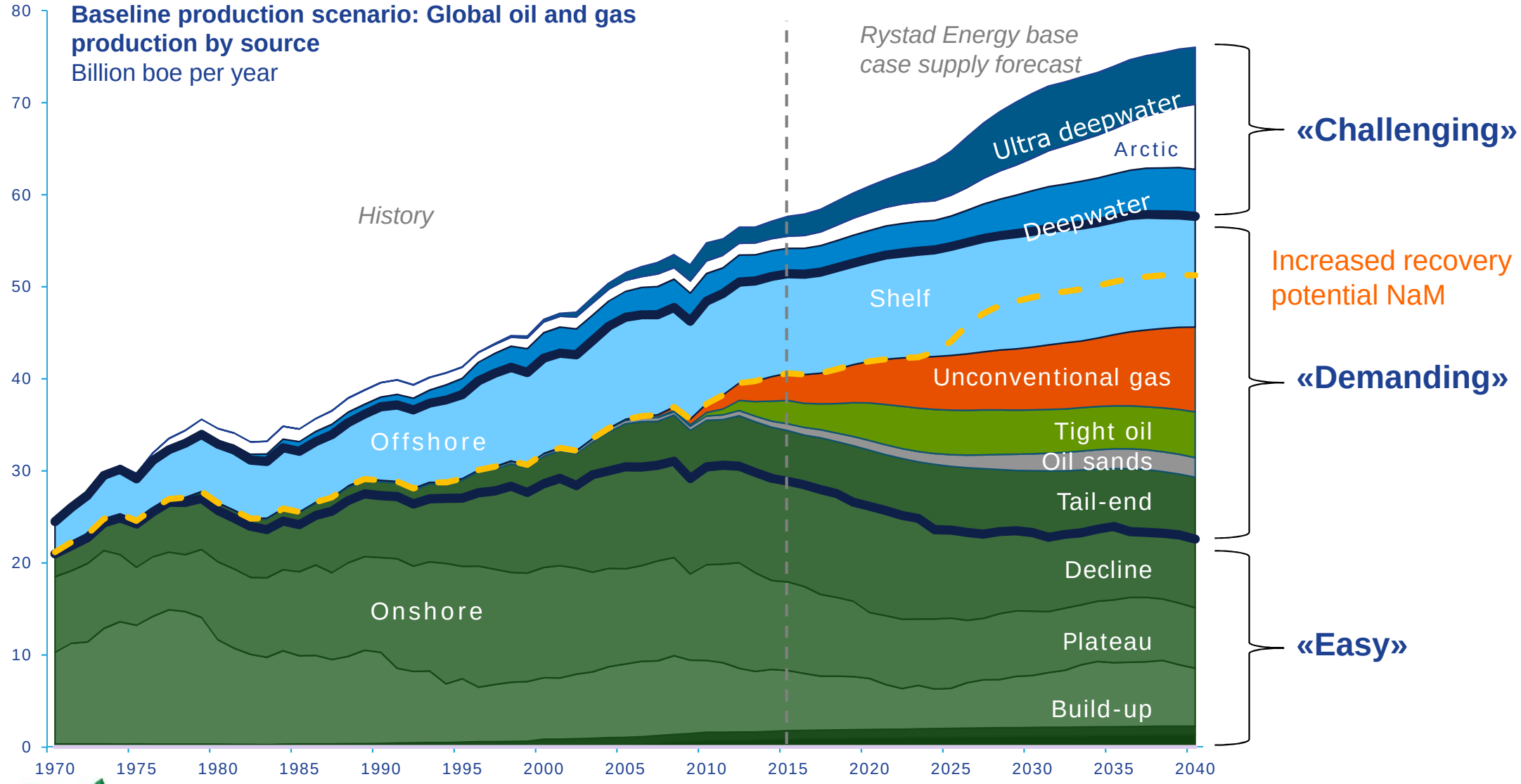
From a greenfield development perspective: Easy oil and gas is mostly gone



Source: Rystad Energy UCube

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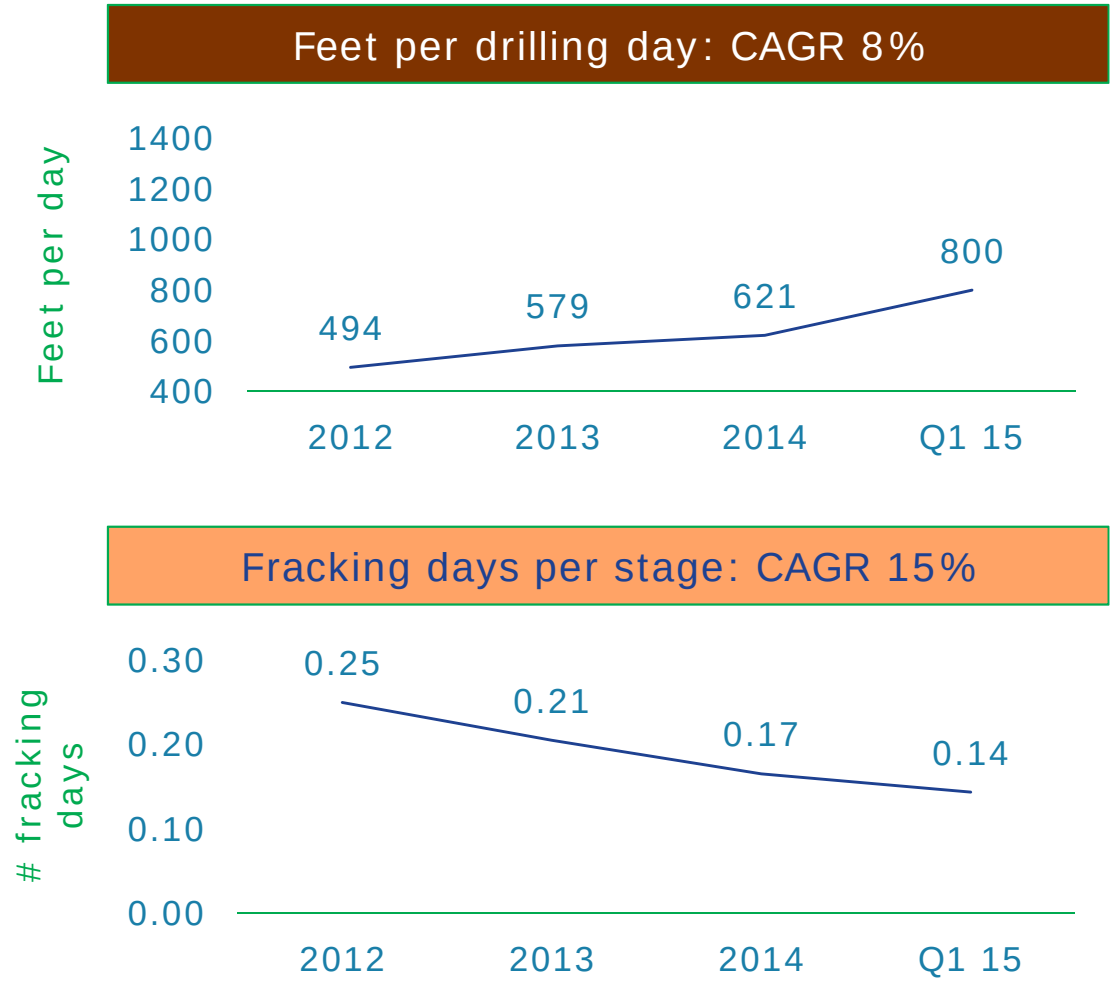
Shale productivity up 11% per year over the period 2010-2015 (excluding price effects)

Productivity is defined as increased output per activity input (adjusted for price effects).

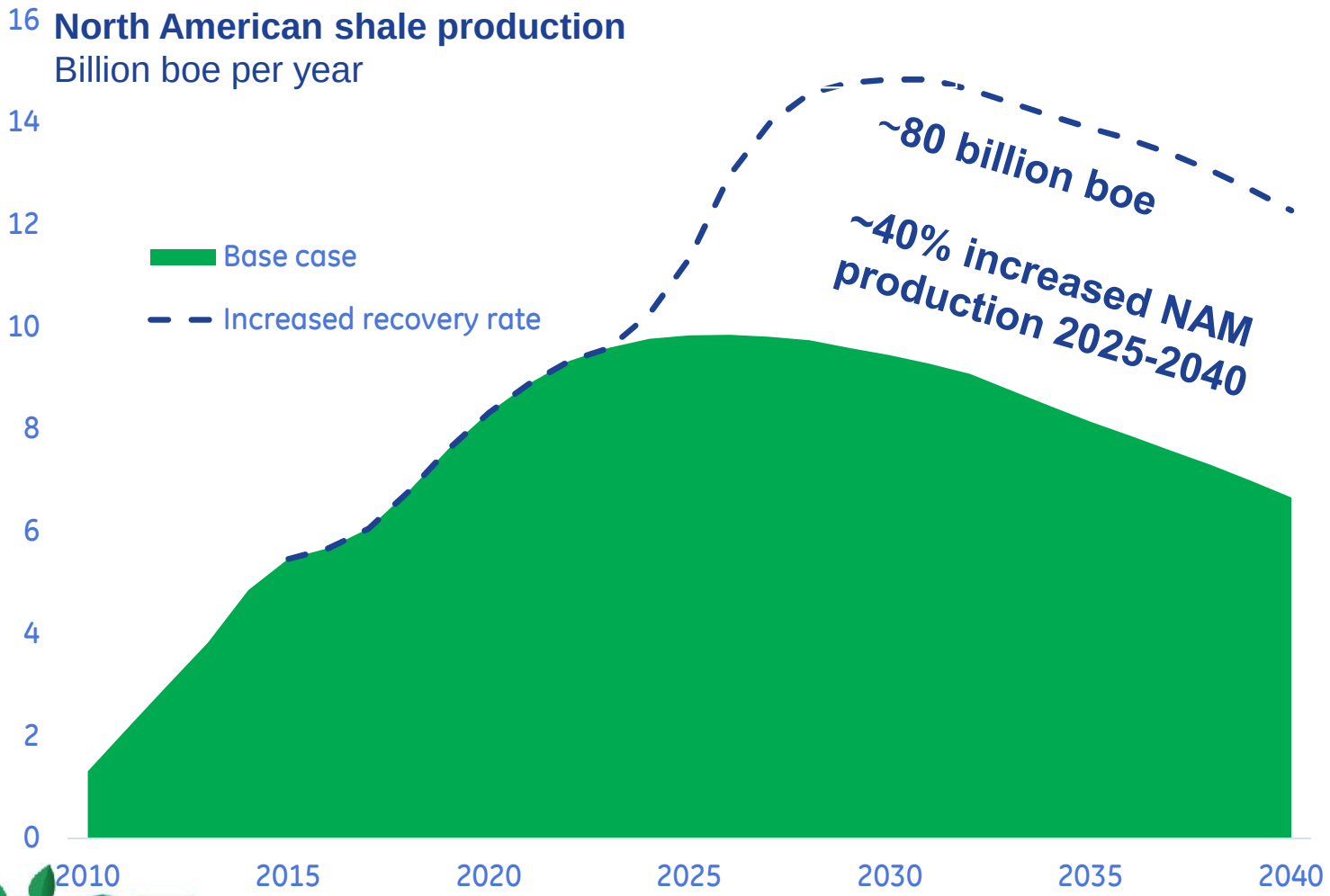
The productivity gains are indicated by faster drilling, shorter time per frac stages and smaller rig crews per rig.

Shale productivity indicators



Source: Rystad Energy research and analysis

Improved subsurface understanding is key to enable increased recovery from shale



Source: Rystad Energy research and analysis

- Current recovery rate is ~5-8%, more than 90% of the resources left in the ground
- Better subsurface understanding is considered key to enable future increase in recovery rate
- Doubling the technically recoverable global shale resources globally is equivalent to ~ 30 years of current global oil and gas production.

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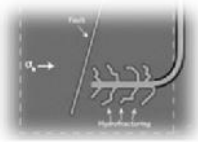
Key challenge: Environmental issues related to shale drilling and production

Type of environmental impact		Indicator
Scarcity of water		Population density & Water stress level
Induced seismicity		Population density & geomechanical stress
Water contamination		Population density
Damage on nature		Population density
Other impacts on local community		Population density
Air pollution		CO2 and methane emissions per barrel

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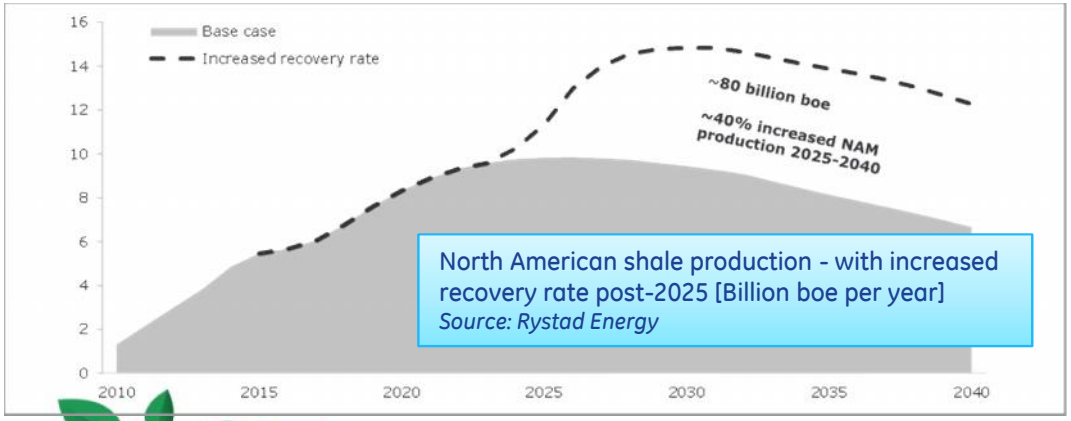
Key points from the Rystad Energy report on Unconventionals

Unlock Shale Resources

- **Increase shale recovery rate**
  - Current recovery rate ~5-8% of in-place – Enormous potential for increased recovery
  - Better understanding of subsurface properties
  - Area development, drainage strategy, well pattern
- **Improve subsurface understanding and modelling**
  - Good reservoir modelling for well spacing optimization, fracture design, proppant injection strategy
  - Static subsurface model – tectonics, faults, heterogeneity, thermal maturity, natural fracture patterns, identify sweet spots
  - Fracture growth patterns and proppant distribution – grow effectively propped rock volume, tracers, monitoring
  - Dynamic modelling – fluid flow simulations in permability/fracture environment, real time history updating, IOR/EOR predictions



North American shale production - with increased recovery rate post-2025 [Billion boe per year]
Source: Rystad Energy

Social License to Operate

- **Regulatory framework, compliance with best practice**
  - 2015 report (Porte, Gee, Pope) on non-technical measures to accelerate local environmental improvement
  - ANSI hydraulic fracturing standards
  - The Texas Railroad Commission regulations
- **Regional environmental stress level key indicators**
  - Population density, water stress, geomechanical stress

	Type of environmental impact		Description	Stress indicator
Regional impact	Scarcity of water		Large volumes of fresh water are used during hydraulic fracking, withdrawn from surface and groundwater sources.	*Water stress level*
	Induced seismicity		Induced earthquakes due to hydraulic fracturing and waste water disposal wells (fracturing fluid and produced water)	*Population density & geomechanical stress*
	Water contamination		Large volumes of flowback water or produced water must be handled. Methods used can cause contamination of fresh water sources.	*Population density*
	Damage on nature		Valuable natural areas can be affected by drilling and production activity, including construction of infrastructure	*Population density*
	Other impacts on local community		Other impact on local communities, including trucking, construction of pipelines and local air pollution	*Population density*
Global impact	Greenhouse gas emission		Greenhouse gas emissions throughout the lifecycle, primarily CO2 and methane	

New technology needed to reduce flaring, monitor and inhibit methane emissions, enable water re-use etc

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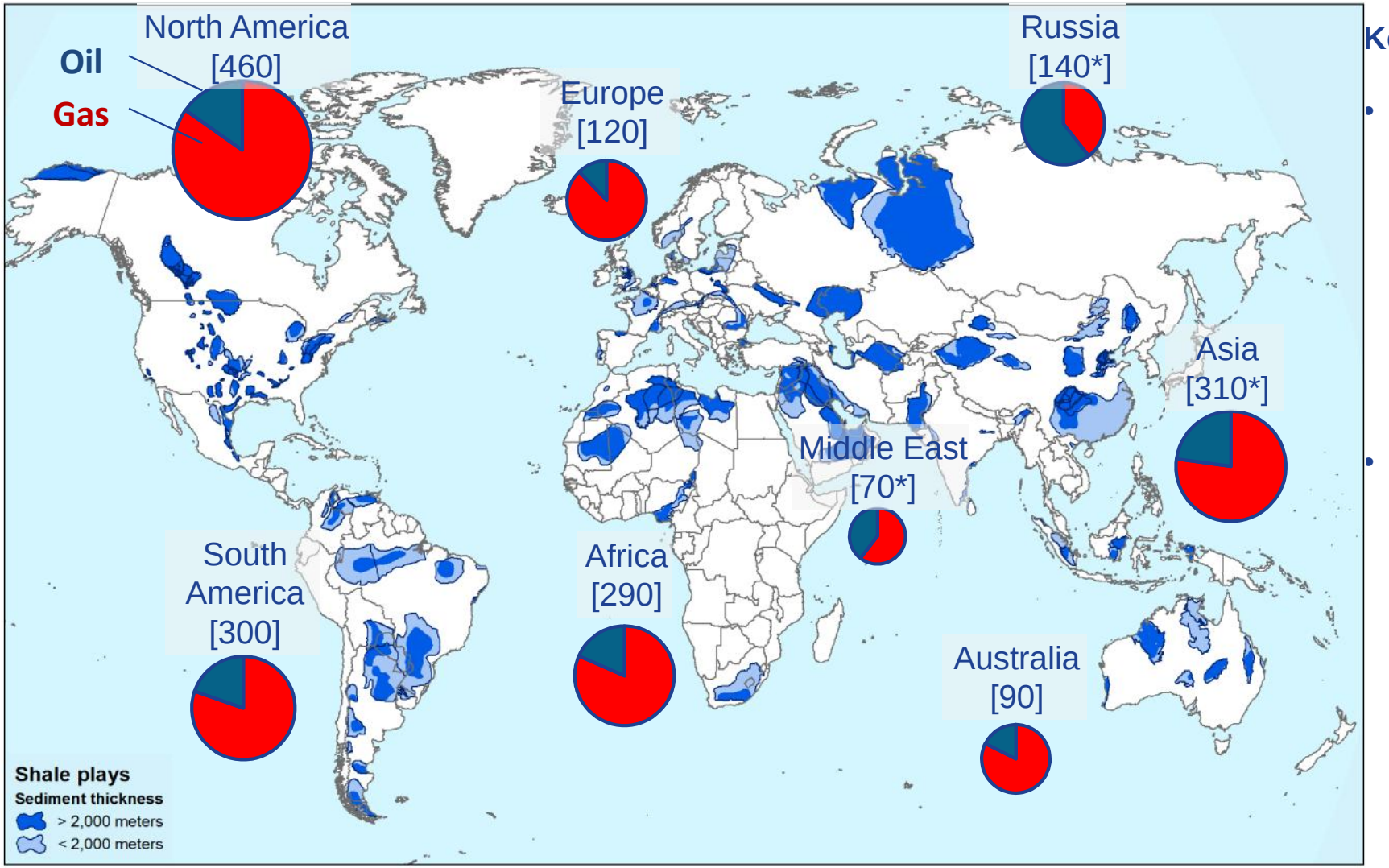
Global shale potential of ~1800 billion boe - how to enable production outside North America?

Global technically recoverable shale potential by region – Billion boe



Key observations:

- Technical recoverable hydrocarbon potential is estimated based on volumetric estimation of shale formation in place, shale characteristics, and risked recovery rate.
- Current estimates of the global technically recoverable shale potential of ~1800 billion boe.

*Some plays without assessed resource estimates, mainly in the Middle East, Russia and Asia
Source: Rystad Energy Ucube, EIA

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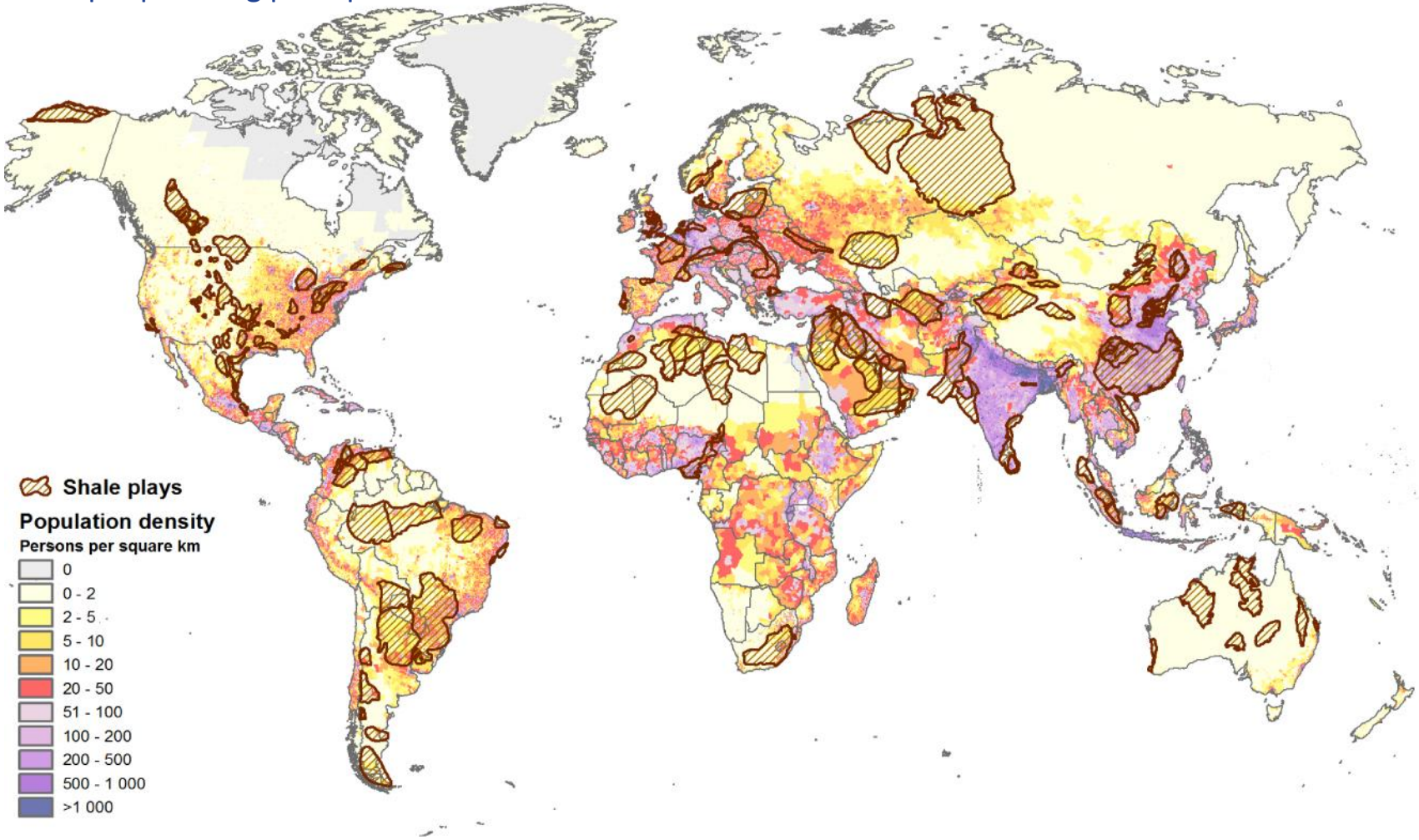
All environmental stress indicators have been assessed per play

Global population density for global shale plays

No of people living per square kilometer



Key observations on population density:

- The population density viewed as one of the key factors influencing decisions on whether to pursue exploration and development in shale plays
- The highest population density within shale plays is found in Europe and in the south and eastern parts of Asia.
- Average density within the different shale plays in the US varies from 3 persons/sq.km in the Bakken play (North Dakota) to close to 150 in the Utica shale play (mainly Ohio).

Source: Rystad Energy research and analysis, NASA Earth Observations (NEO), the World Bank

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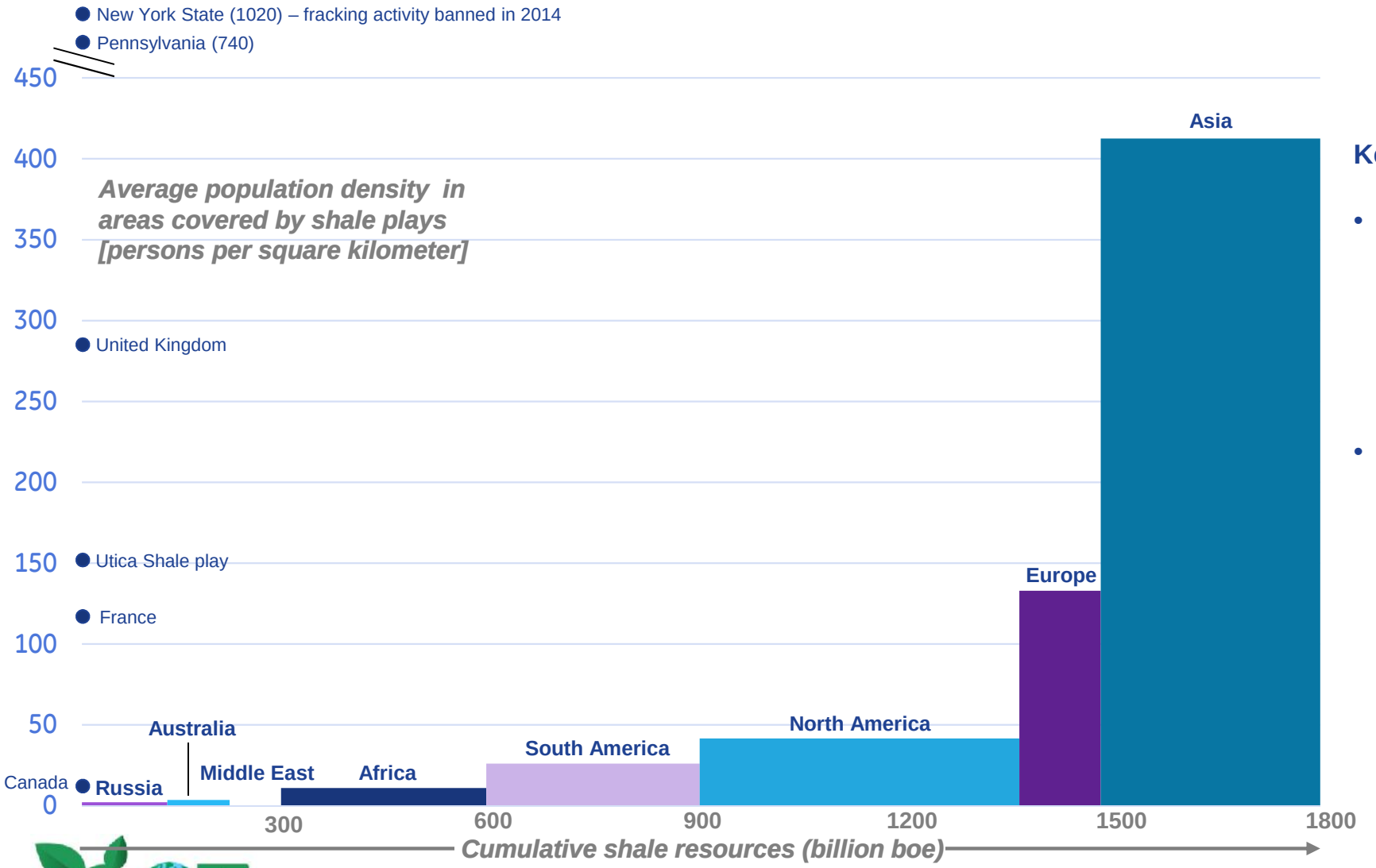
High population density in Europe and Asia – more challenging to obtain public acceptance

Cumulative shale resources and average population density



*Some plays without assessed resource estimates, mainly in the Middle East, Russia and Asia
Source: Rystad Energy research and analysis, EIA, NASA Earth Observations (NEO), the World Bank

Key observations:

- Asian shale resources located in areas with very high population density, an average above 400 people per square kilometer
- The Sichuan basin lies in a highly populated area with density above 700 people/sq.km and accounts for around 30% of the total Asian resources.

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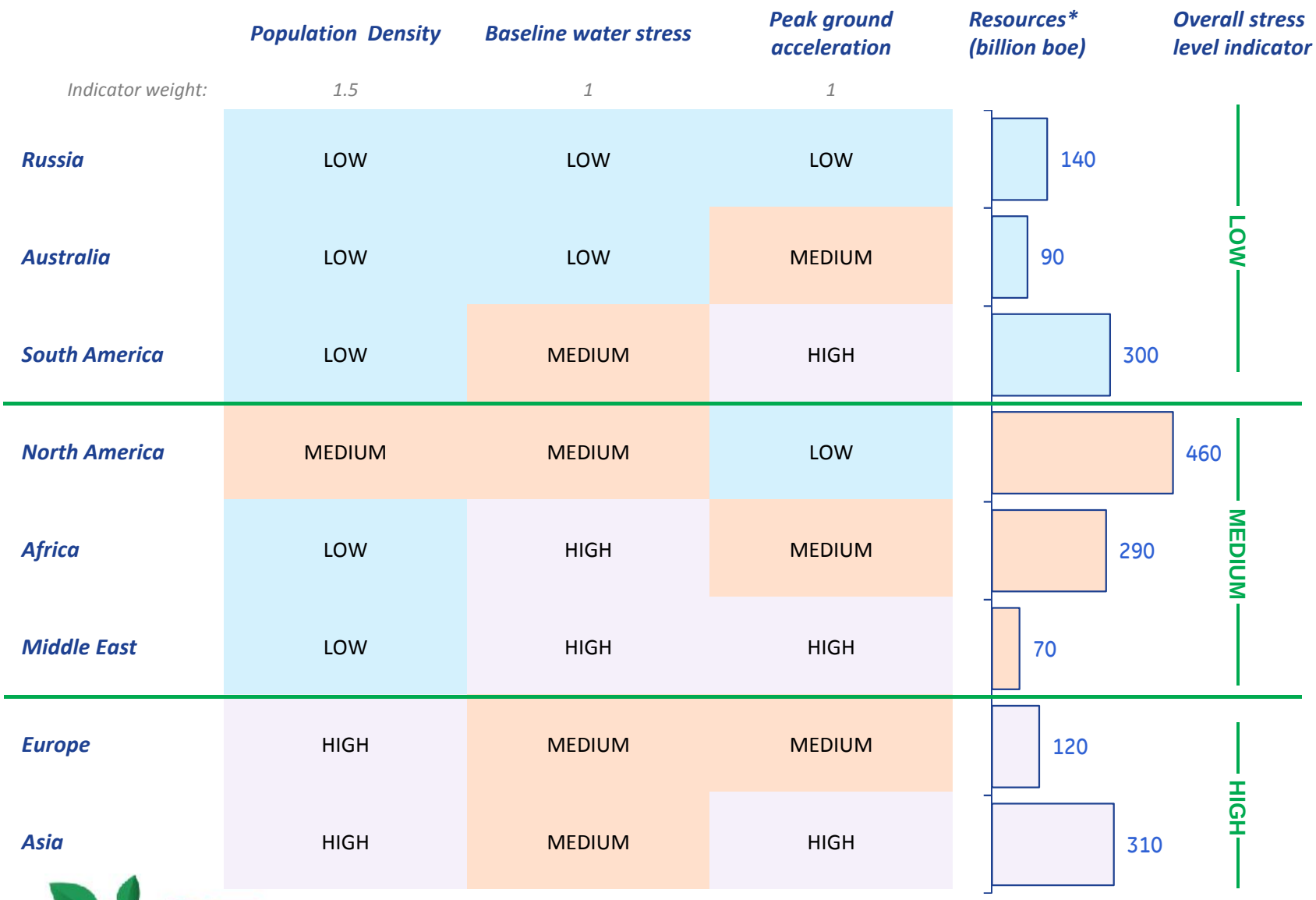
Global assessment of environmental stress level – shale play by shale play



Key observations:

- Resource-weighted average stress level indicator in each region.
- The combination of relatively low stress values place Russia, Australia and South America at a low overall stress indicator.
- North America, Africa and Middle East viewed to be in the middle of the interval
- Europe and Asia are both regions with shale plays located in areas with high population density, in combination with water- and seismic stress in the medium-high range.

*Some plays without assessed resource estimates, mainly in the Middle East, Russia and Asia
Source: Rystad Energy research and analysis, EIA, NASA Earth Observations (NEO), the World Bank

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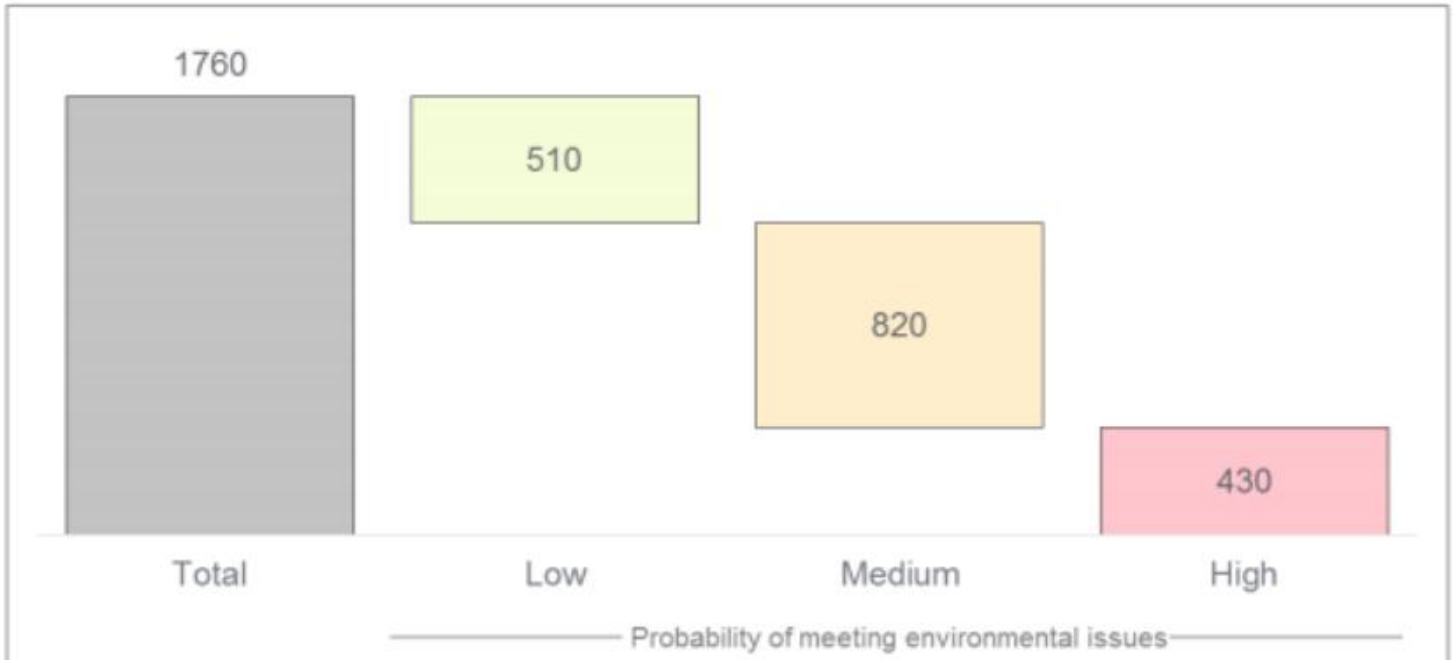
Global shale resources by regional environmental stress level



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Offshore deepwater and NAM Shale have complimentary technology development strengths

		Offshore	*Shale*
Innovation Characteristics	**Wells drilled per year (2014)**	Low: 650	High: 23 000
	Oilfields service market	Concentrated High barriers of en	Diverse Low barri
	Resource size of fields/leases	Large	Small/On
	Technology piloting environment	High risk, limited te	Low risk,
	Traditional technology focus	Enable volumes	Efficient production
Step-wise improvements	**Historical productivity**	0%	11% (Avg. annual increase 2008-2015)
	Technology development focus	Operational efficiency Standardization Industrialization	Further efficiency gains Potential: 30% Trial and error
	Challenges	Technology adoption Risk averseness Access to pilot tes es Volume-focused cul Technical versus functional specifications	Adoption of existing te Optimization of fracture Cheaper materials Environmental footprint redu driven by individual companies
Long term R&D	**Technology development focus**	From possible to affordable: Achieve step-changing productivity improvements Enable production from deepw Enable exploration and pro Arctic.	Step-changing efficiency increases Achieve conventional-type rec Requires optimization of d area/play level
	Challenges	Cost level Few sanctioned project than drive development	Improved portfol Improved long term p between E&P companies and servic iders

Long term R&D

Step-wise improvements

Networking

Good results

Good results

Open Innovation

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Unconventional summary

Challenges	Technologies/Solutions	Impact assessment
Reduce break-even costs	Reduce cost drilling and well completion Low cost exploration Low cost infrastructure Technology and knowledge transfer	NAM potential of further cost reduction of ~30% ~3/4 of global shale resource potential outside North America
Unlock resources	Subsurface understanding to enable increased recovery	One percentage point of increased recovery yields 10-20% increase in recoverable resources.
Ensure long term social license to operate	Seismic monitoring and induced seismicity models Water treatment technologies Local use of natural gas Methane leakage monitoring	Significant shale resources in regions with high environmental stress level, including Europe and Asia holding ~ 25% of global shale resources

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Thank You

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