GE Energy

Power-Water Nexus

Nexus for economic and environmental sustainability

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European Energy Forum
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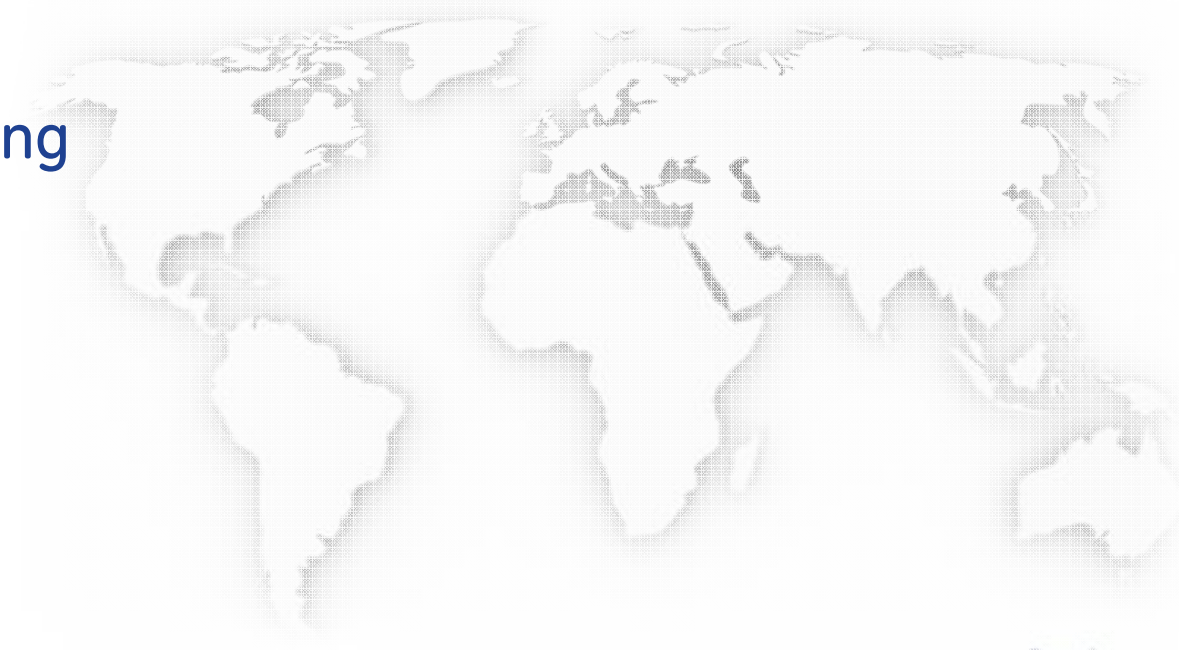

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Looking ahead...

What the world can expect by 2025

1B	Expected increase in world population... up from our current 7 billion
60%	Emerging markets share of the global economy... up from approximately 48 percent today
80%	Primary energy consumption will be hydrocarbon based
70%	Power-related carbon emissions will come from developing countries
30x	Increase in volume of annual electronic data generated
28%	Amount the world's water needs will exceed freshwater supply

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Source: GE Energy, Global Strategy and Planning, 2012

Unconventional fuels

Unconventionals…next wave of E&P

Over next 25 years…

34%
of incremental oil demand growth*

40%
of incremental gas demand growth

Unconventional Oil

Unconventional Gas

Oil Sands

Extra-heavy oil

Shale Gas

Coal Bed Methane

* Includes oil sands, extra heavy oil, and oil shale

Source: GE Energy, GSP and IEA, "Are We Entering a Golden Age of Gas? World Energy Outlook,, 2011

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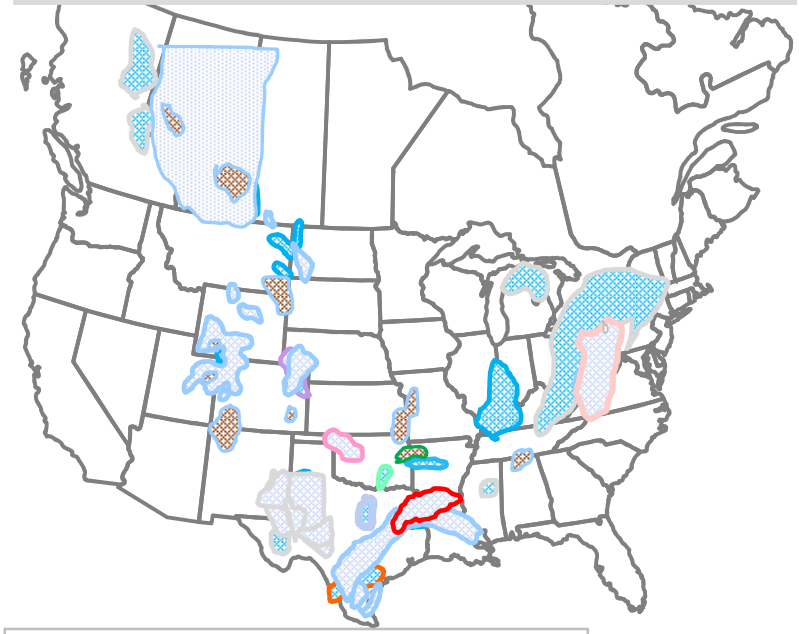
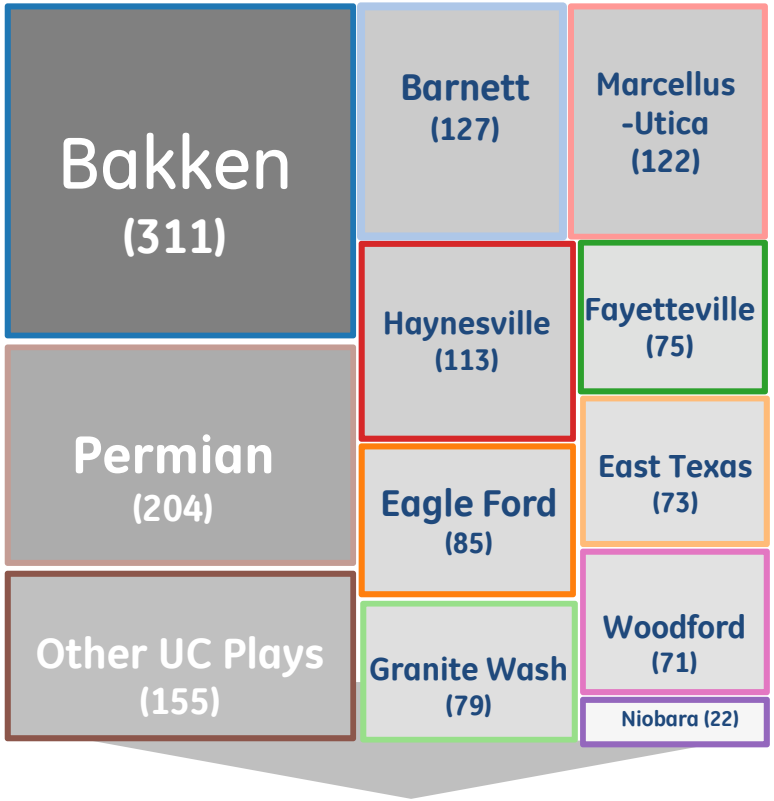
US water requirements for frac fuels

Million barrels per year (MMB/y), 2010

Frac Fuels:

Unconventional fuels (gas and oil) that require hydraulic fracturing





Average Requirements* **120 MMB/yr**

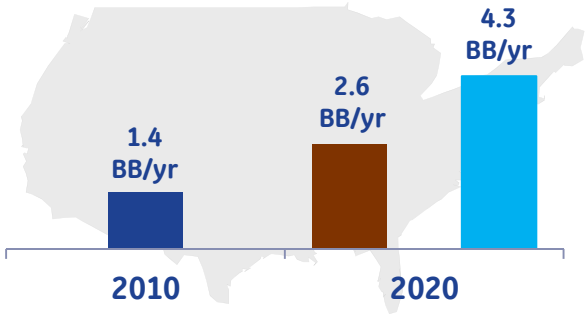
* By frac gas/oil play

Source: Global Strategy & Planning,, 2012

Frac fuels: how much water?

Water requirements, Billion barrels per year (BB/yr)

US Injection Water Requirements for Key Frac O&G Plays [1]



Avg. water use per frac stage = 9,500 BBLs

2020	Low Case	High Case
Frac Oil Production	1.94 MMb/d	2.82 MMb/d
Frac Gas Production	33.3 Bcf/d	47.2 Bcf/d
Horizontal Rig Count	1,009	1,779
Fracturing Stages (annual)	241,813	407,392

Equivalent to what share of New York City's annual withdrawals? [2]

Today	2020
11%	20%-33%
Percent of NYC annual use	Percent of NYC annual use

Source: Global Strategy & Planning, 2012 Scenarios; NY Dept. of Env. Conservation
[1] Key drilling plays include Marcellus, Eagle Ford, Bakkan, Granite Wash, Haynesville, Barnett etc.; [2] Based on NY City at a peak demand of 1.5 BGD.

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Advanced technology exists

Produced water

Water Treatment Chemistry

Filtration and Membranes

Evaporators and Zero Liquid Discharge Equipment

Thermal Evaporation and Crystallizers

Mobile Evaporator

Beneficial reuse

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Global power generation

Benchmark to measure water volumes

Water requirements in terms of megacities

New York City peak water demand

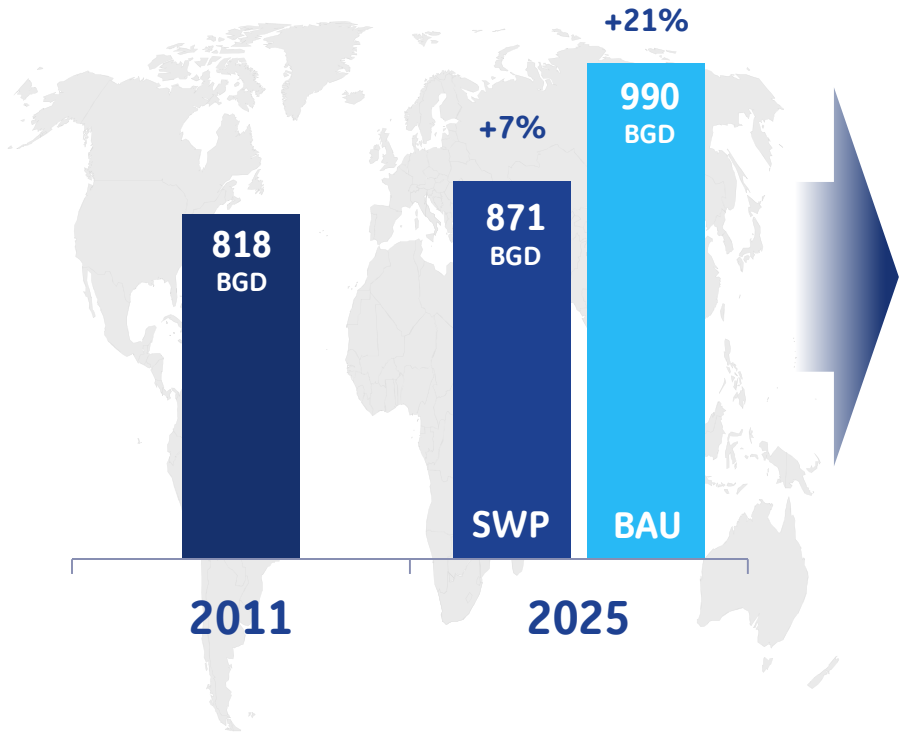
= 1.5 billion gallons per day

Source: Water System Safe Yield Calculation 2011, New York City Department of Environmental Protection, November 30, 2011.

Global power-water footprint

How could it evolve?

Global Thermoelectric Power Water Withdrawals (BGD)



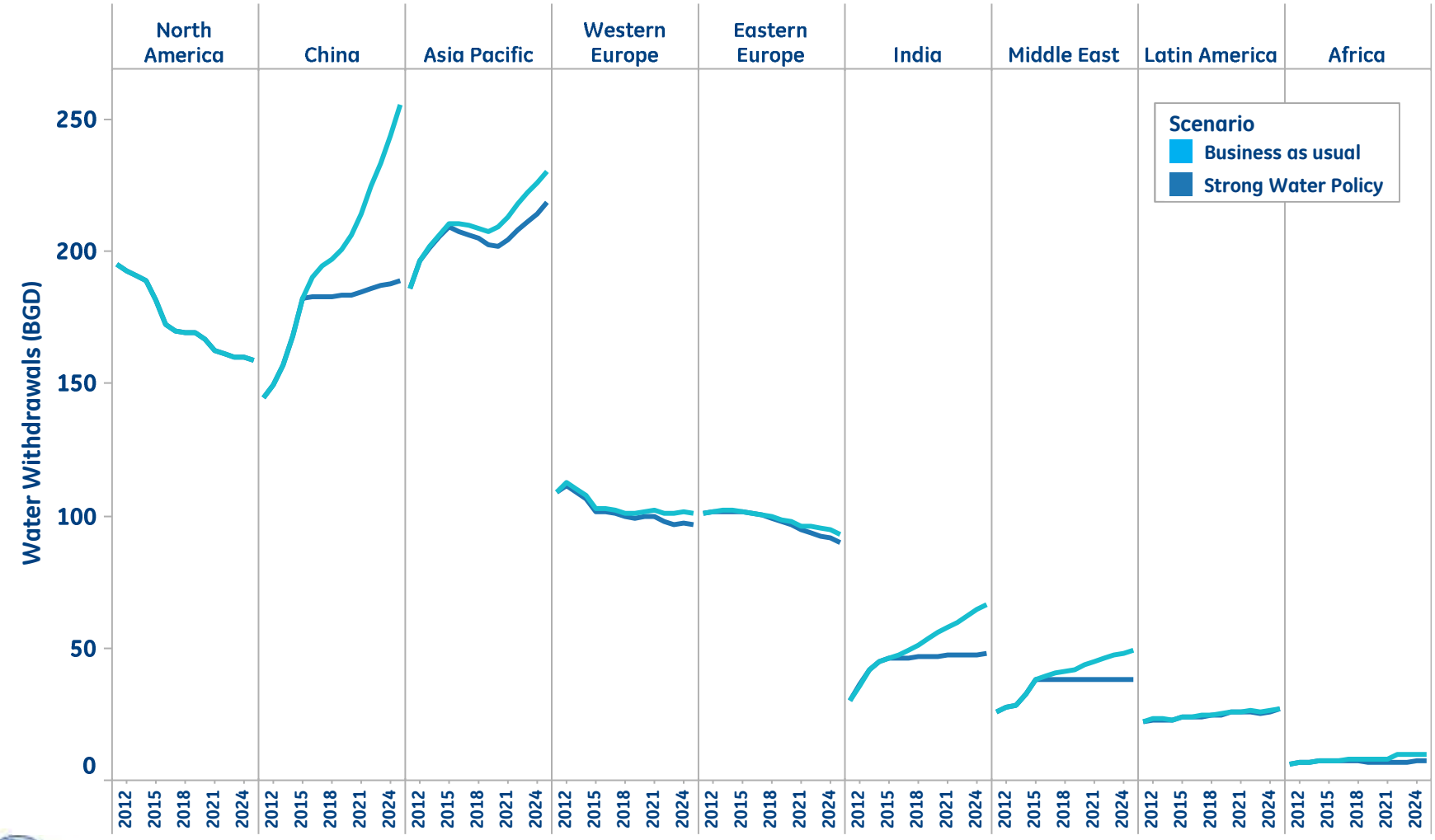
Today	2025
545 megacities	+36 581 megacities
	vs.
	+115 660 megacities

*Based on NY City requiring a water supply of 1.5 BGD in 2005

Source: Global Strategy & Planning, 2012 Scenarios; NY Dept. of Env. Conservation

Water withdrawals by region

Billion gallons per day, 2011-2025



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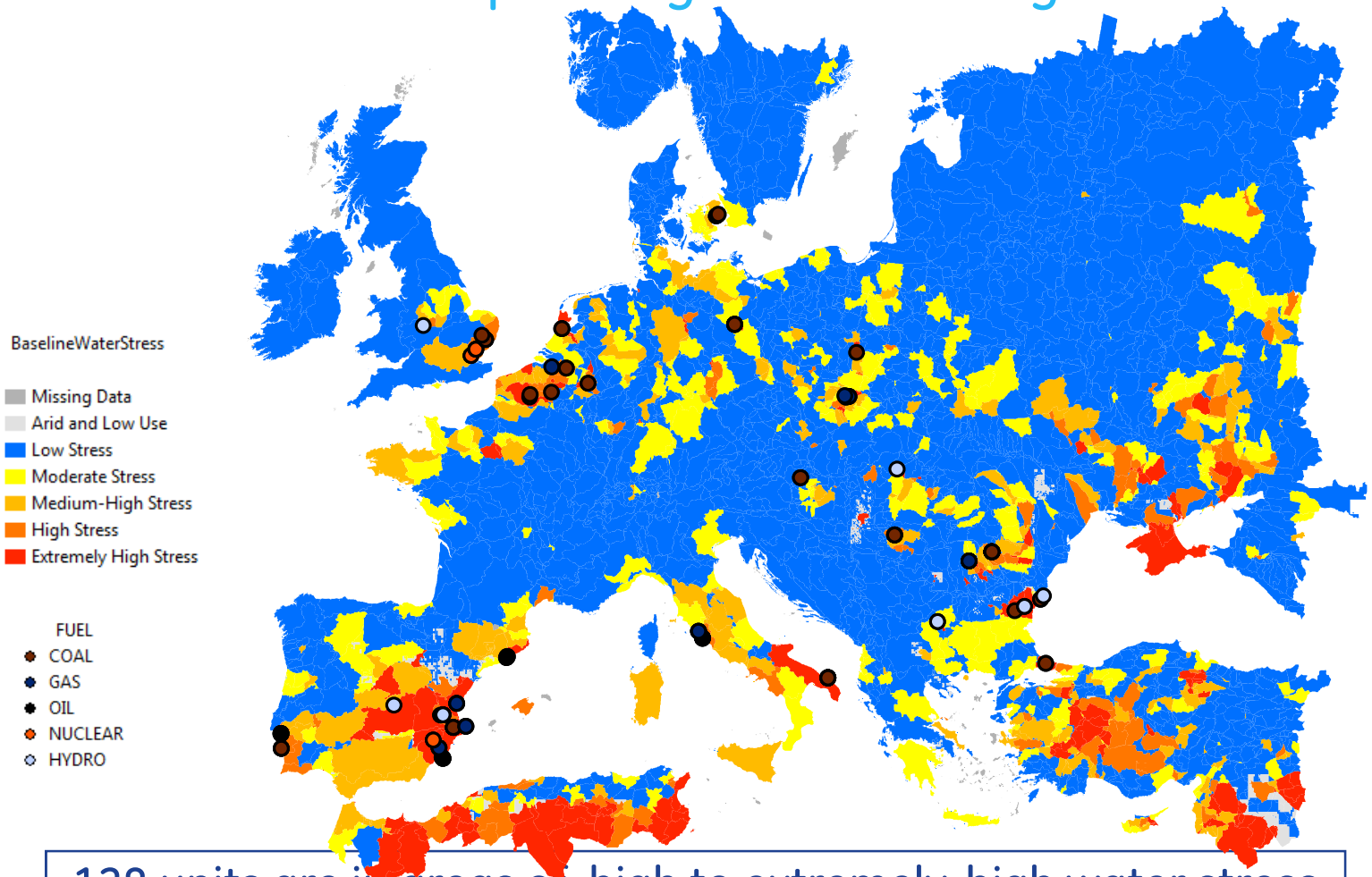
Source: GE Energy, Global Strategy & Planning 2012

European generation units

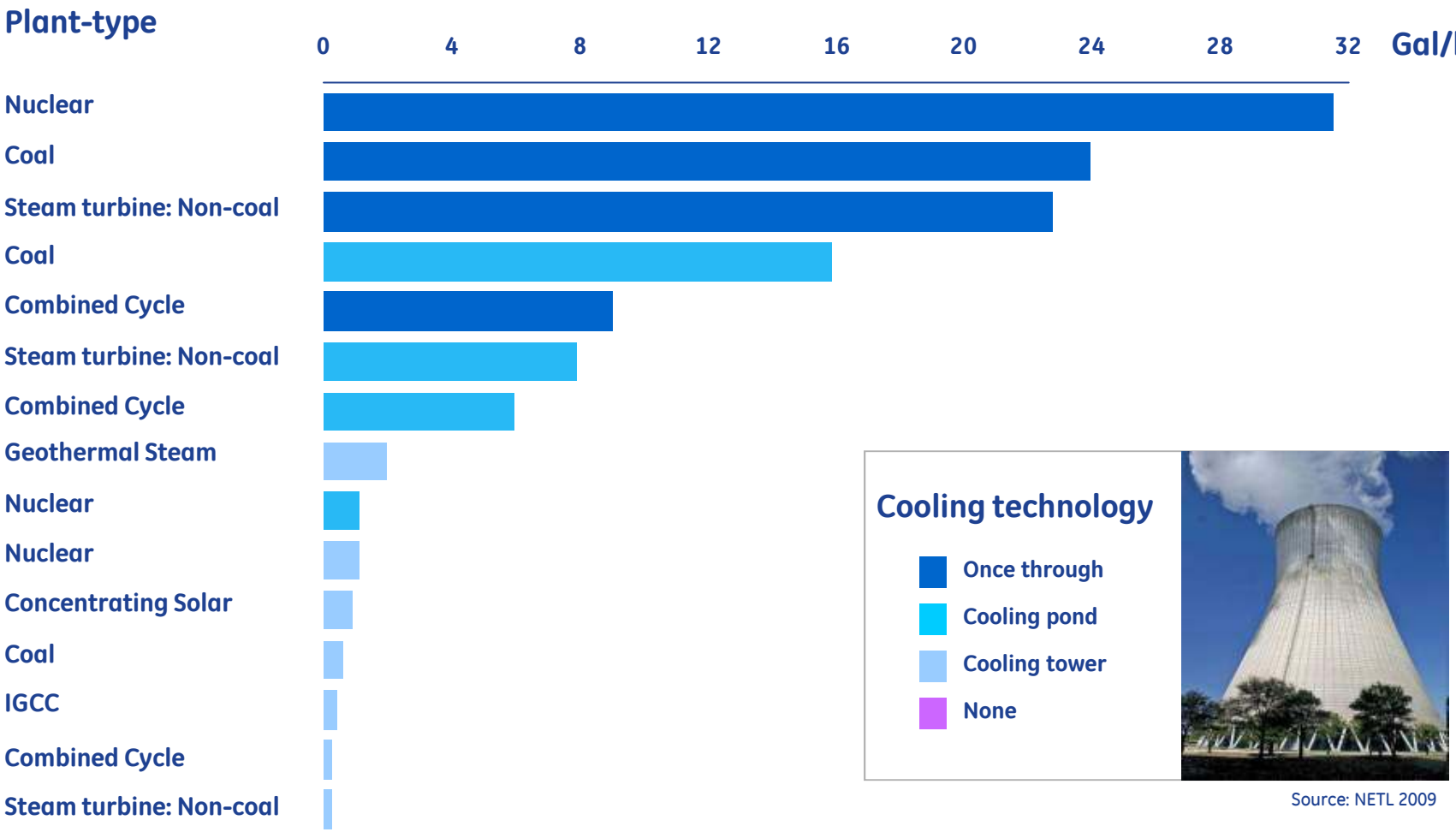
Greater than 100 MW operating in areas of high water stress



128 units are in areas of high to extremely-high water stress

Notes: Includes thermal and hydro plants
Source: Platts UDI Database 2012 and WRI Aqueduct data

Water withdrawals for power gen



Source: NETL 2009

Gas-fired plants compare favorably to coal and nuclear

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Responses to water stress

Constraints force four potential paths

Options

Shift to alternate water source… saline or brackish water

Pivot to water reduction technologies… closed-loop cooling towers and dry air- cooling

Reduce by switching to zero water use technologies… wind, solar PV, gas turbines

Grab resources away from other sectors… agriculture, domestic

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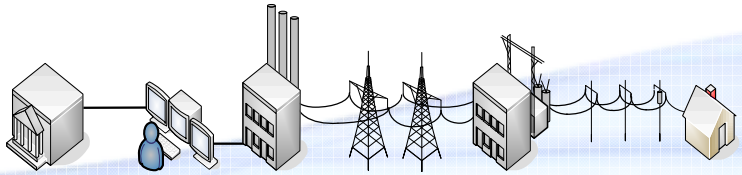
Technology integration

Building infrastructure synergies to reduce emissions + water

Electrical infrastructure



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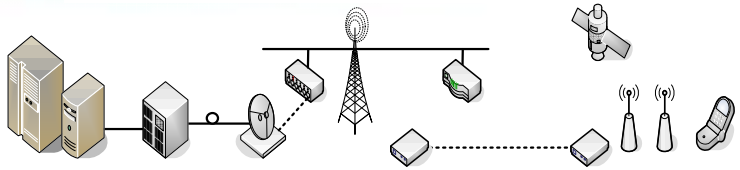
Information infrastructure



Intermittent renewables

Wind

Solar

+

Flexible gas turbine technology

Joining capabilities for sustainability and resilience

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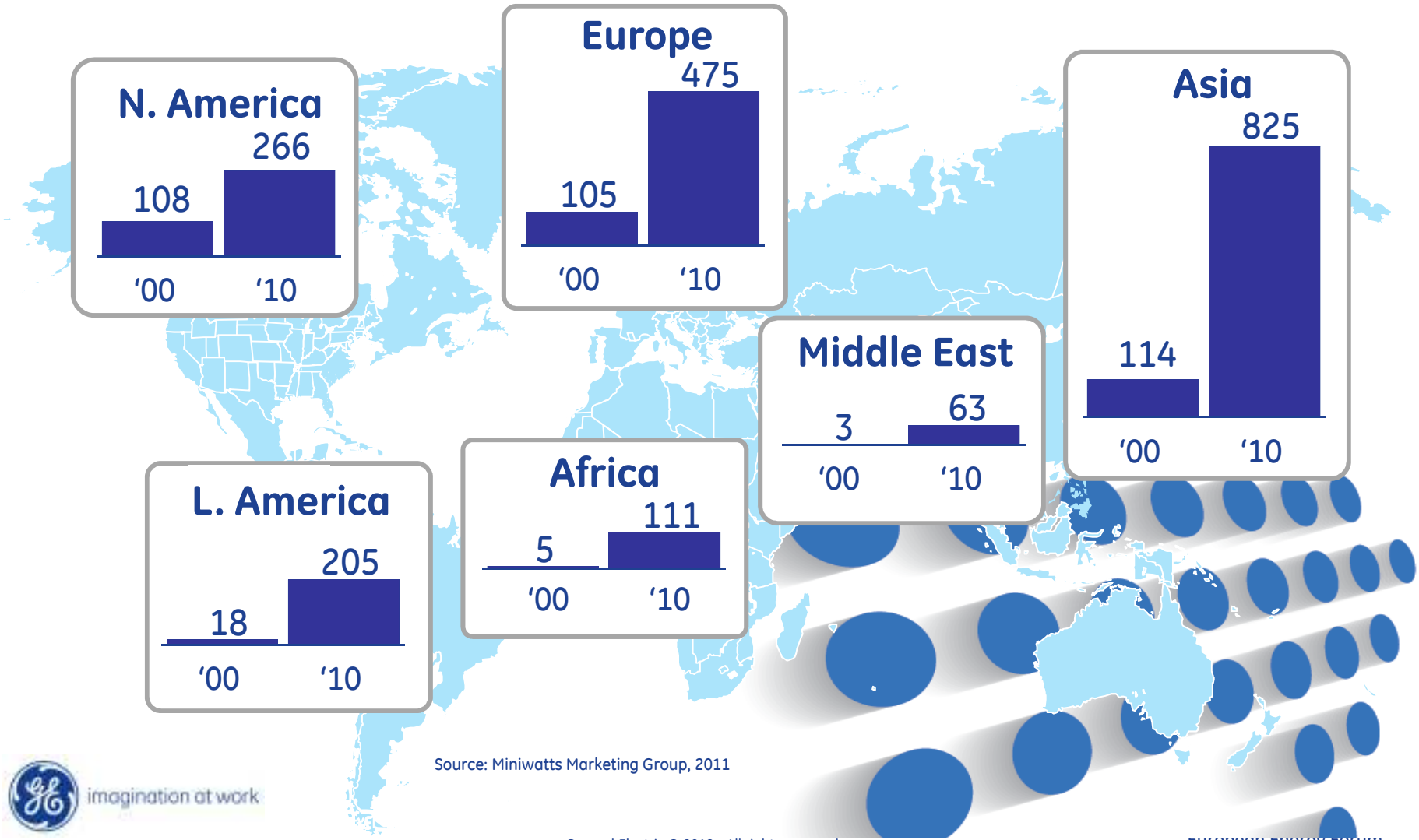
Data Centers

Rise of the global internet economy

From 360 million to +2 billion internet users, 2001-2011



Source: Miniwatts Marketing Group, 2011

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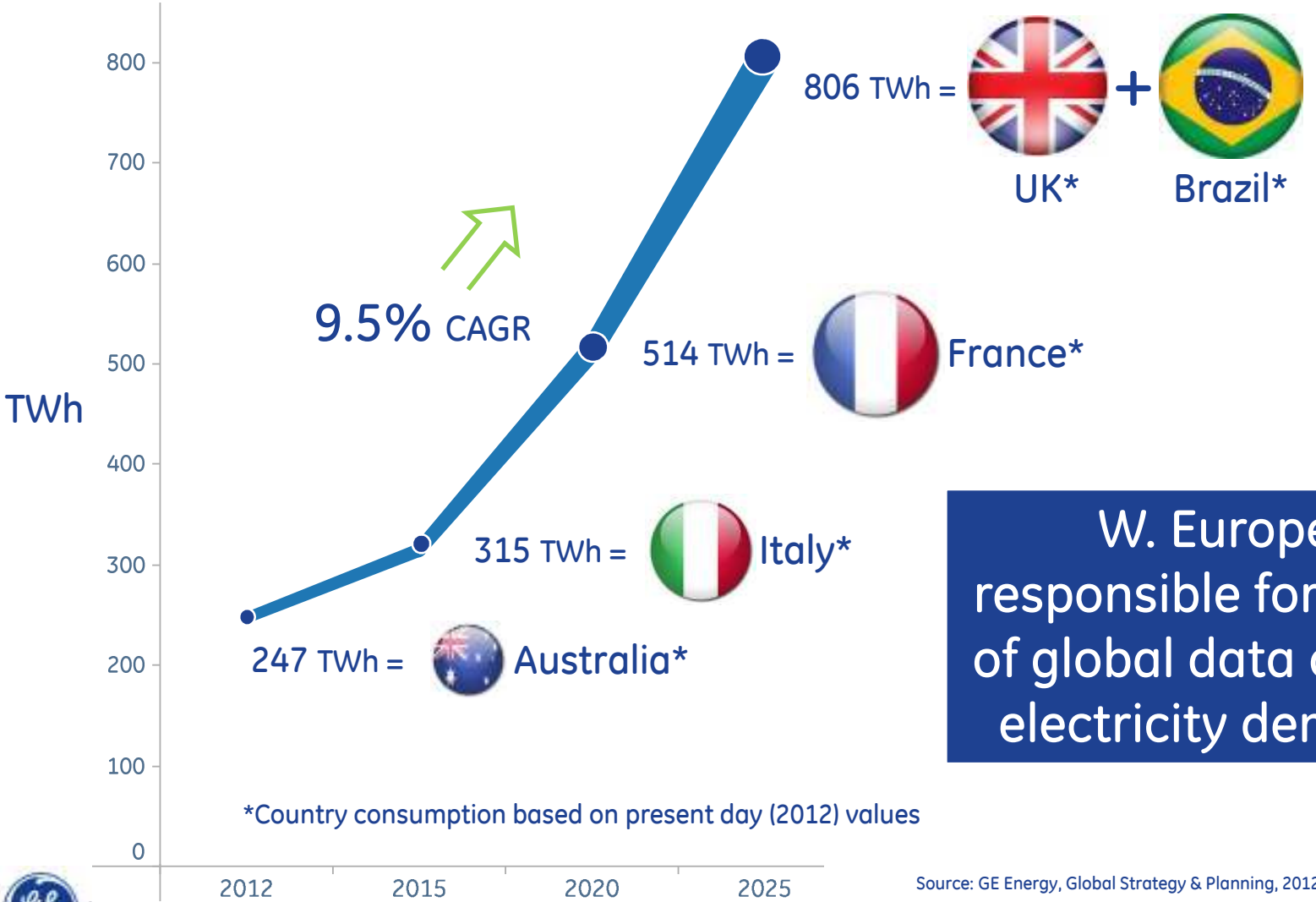
Future data center energy demand

Global electricity consumption growth, 2012-2025



W. Europe responsible for 1/4th of global data center electricity demand

Source: GE Energy, Global Strategy & Planning, 2012

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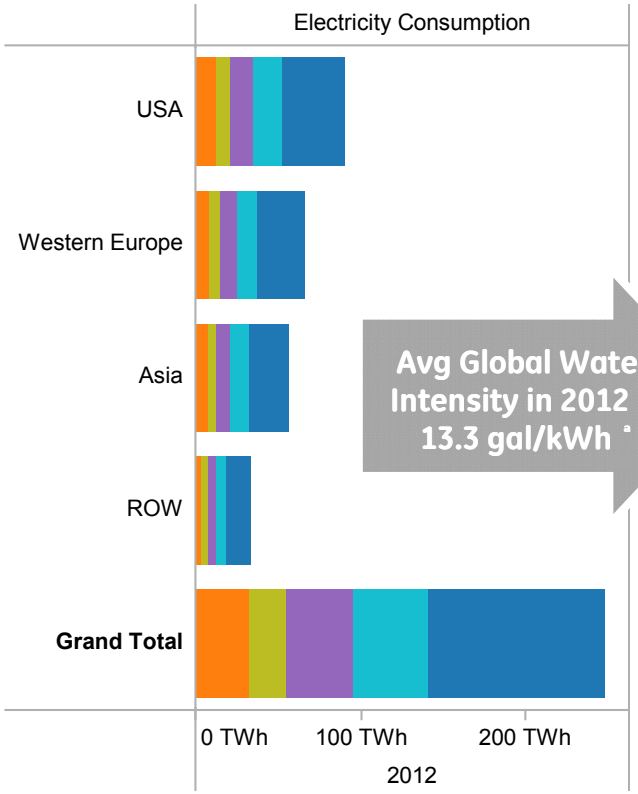
Data center water footprint

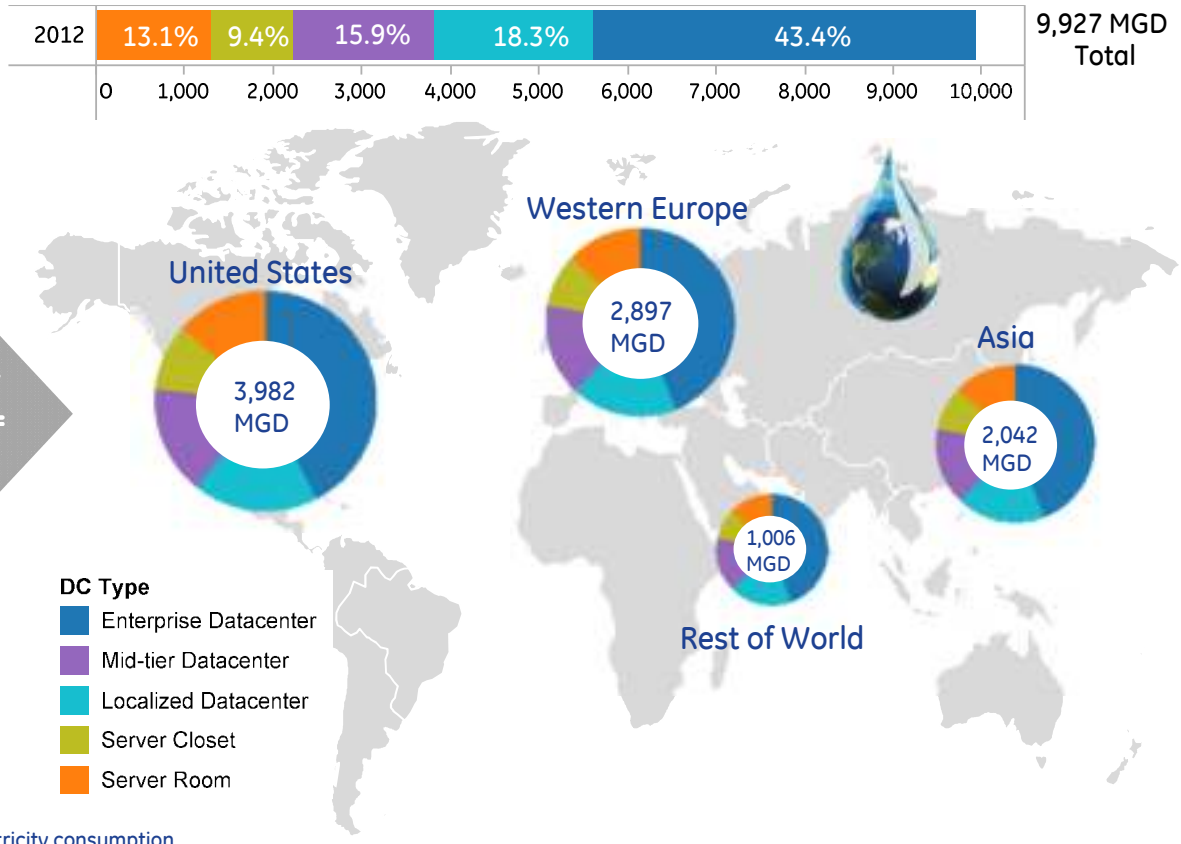
Today's demand equivalent to 7 megacities

Electricity Consumption, 2012
Trillion of Kilowatt hours



Avg Global Water Intensity in 2012 = 13.3 gal/kWh [a]

Data center water requirements, 2012*
Million gallons per day (MGD)



*Note: Analysis only includes water use from electricity consumption

[a] Average OECD water intensity = 16.0 gal/kWh,
Average Non-OECD water intensity = 10.9 gal/kWh

Source: GSP, Data Center forecast, 2012

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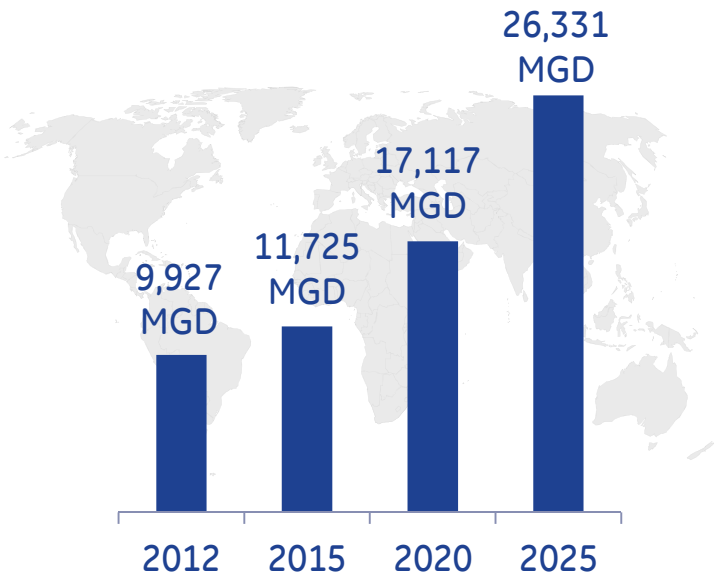
Future data center water footprint

Data center water demand, 2012-2025

World's data center power-related water withdrawals



Million gallons per day (BGD)

Equivalent to the withdrawals of how many mega cities? *

*Based on NY City requiring a water supply of 1.5 BGD in 2005.

Today	2025
7 megacities	18 megacities

World's data center water needs in next 15 years = 11 mega cities

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Source: GE, Data Center forecast, 2012

Summary

- Water stress/shocks are an under appreciated energy system risk
- The volume of water used in hydraulic fracking is within manageable scales; regulatory policy should focus on proper pricing and assuring against contamination
- Water usage in the power sector will grow dramatically world-wide over the next 15 years, but will likely hold constant in Europe given retirements of coal and introduction of low-to-zero water renewables
- Data centers will put new pressure on water resources
- Minimizing water usage in power will become increasingly important; need for less water- intensive power systems, such as combining gas and renewables

End