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GLOBAL SHALE GAS DEVELOPMENT

Water Availability and Business Risks

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WRI.ORG

EXECUTIVE SUMMARY



FOREWORD

For many nations around the world, shale gas represents an opportunity to strengthen energy security while cutting emissions. In fact, shale gas adds 47 percent to the world's natural gas reserves. But as governments and businesses explore this new and abundant resource, freshwater availability is a key challenge they must address. In this study WRI provides unprecedented global information on freshwater availability for governments and businesses considering shale development.

Extracting oil or natural gas from shale poses a number of risks to the environment and requires large quantities of nearby water. Much of this water is needed for fracturing the shale to allow hydrocarbons to flow to the surface. Yet shale resources are not always located where water is abundant. Our analysis shows that China, India, South Africa, and Mexico, for example, have large quantities of shale gas but limited supplies of freshwater. It also shows that roughly 38 percent of the area where shale resources are located is arid or under significant water stress; plus, 386 million people live above these areas. These factors pose significant social, environmental, and financial challenges to accessing water and could limit shale development.

With growing energy demands and attractive financial and employment opportunities for hydrocarbon development, how can regulators and companies determine if enough freshwater exists in a given area to extract natural gas and oil from shale while not degrading the environment?

This report draws on WRI's Aqueduct Water Risk Atlas to identify the key locations, globally and with a special focus on 11 countries, where shale gas and tight oil extraction might face the greatest water challenges. In these areas government policies will be needed to guarantee water security, protect the environment, and avoid business risks, if shale energy is developed.

With interest in shale gas growing, the time is ripe to understand its constraints. This report will be an invaluable resource to businesses, policymakers, and civil society in ensuring water for people and the planet.



Andrew Steer
President
World Resources Institute



EXECUTIVE SUMMARY

Limited availability of freshwater could become a stumbling block for rapid development of shale resources through hydraulic fracturing. Using information from the Aqueduct Water Risk Atlas, WRI provides the first global and country-specific resource to help stakeholders evaluate freshwater availability across shale plays worldwide.

Innovation in hydraulic fracturing and horizontal drilling techniques is driving the rapid development of shale resources (which include shale gas, natural gas liquids, and tight oil) across the United States and Canada.¹ Already, known shale deposits worldwide have significantly increased the volume of the world's natural gas and oil resources. Governments from Argentina and the United Kingdom, to Mexico and China, have started to explore the commercial viability of their shale reserves.

The potential for expansion is huge: known shale gas deposits worldwide add 47 percent to the global technically recoverable natural gas resources, and underground stores of tight oil add 11 percent to the world's technically recoverable oil.

But as countries escalate their shale exploration, limited availability of freshwater could become a stumbling block. Extracting shale resources requires large amounts of water for drilling and hydraulic fracturing. In most cases, these demands are met by freshwater, making companies developing shale significant users and managers of water at local and regional levels, often in competition with farms, households, and other industries.

Although experts agree that critical environmental risks and impacts are associated with developing shale, the risks and impacts specific to surface and groundwater availability have been thinly documented. With *Global Shale Gas Development: Water Availability and Business Risks*, the World Resources Institute (WRI) fills this gap, providing

the first publicly available, global and country-specific analysis to help evaluate freshwater availability across shale resources worldwide. Using geospatial analysis to combine indicators from WRI's Aqueduct Water Risk Atlas and other sources (Table ES1) with the locations of shale resources globally from West Virginia University and the National Energy Technology Laboratory, the report:

- Identifies locations most in need of government oversight and robust corporate policies to properly manage freshwater availability in the context of shale development; and
- Informs companies of potential business risks associated with freshwater availability, and builds the case for corporate water stewardship and early source water assessment.

In addition to examining water availability and shale resource development from a global perspective (Figure ES1), this report analyzes for the first time water availability in each shale play (prospective areas within the shale formation where gas and oil could be commercially extracted) for 11 countries: Algeria, Argentina, Australia, Canada, China, Mexico, Poland, Saudi Arabia, South Africa, the United Kingdom, and the United States. WRI selected these countries based on the size of their technically recoverable shale resources (as estimated by the U.S. Energy Information Administration), current exploratory and production activity, likelihood of future development, and feedback from industry, academia, and nongovernmental organization (NGO) experts.



Table ES1 | **Indicators Selected to Evaluate Freshwater Availability and Associated Business Risks**

INDICATOR	DEFINITION
Baseline water stress	The ratio of total water withdrawals from municipal, industrial, and agricultural users relative to the available renewable surface water. Higher values may indicate more competition among users and greater depletion of water resources.
Seasonal variability	The variation in water supply between months of the year. Higher values indicate more variation in water supply within a given year, leading to situations of temporary depletion or excess of water.
Drought severity	The average length of droughts multiplied by the dryness of the droughts from 1901 to 2008. Higher values indicate areas subject to periods of more severe drought.
Groundwater stress	The ratio of groundwater withdrawal to its recharge rate over a given aquifer. Values above one indicate where unsustainable groundwater consumption could impact groundwater availability and groundwater-dependent ecosystems.
Dominant water user	The sector (agricultural, municipal, or industrial) with the largest annual water withdrawals.
Population density	The average number of people per square kilometer.
Reserve depth interval	The range of depths of the prospective shale area. Deeper formations generally require more water for drilling.

This report does not attempt to identify or address risks to water quality associated with the development of shale resources. Nor does it assess the performance of the oil and gas industry in managing water. Instead, it aims to share information that can help increase the dialog among water users from industry, government, and civil society

in river basins worldwide. The report results are available online (<http://www.wri.org/resources/maps/water-for-shale>), providing open access to the underlying information and enabling updates as new data are made available.

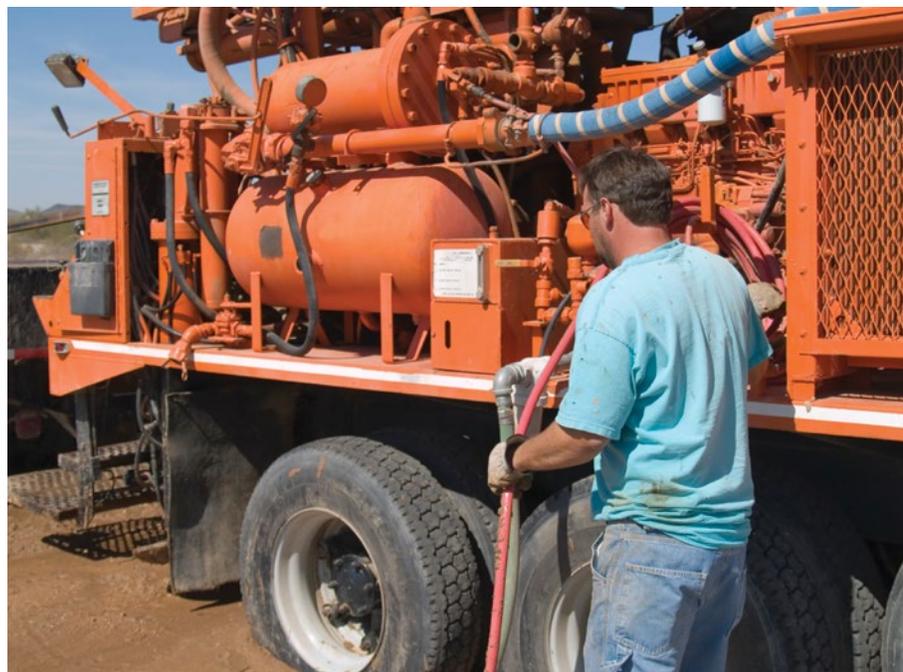
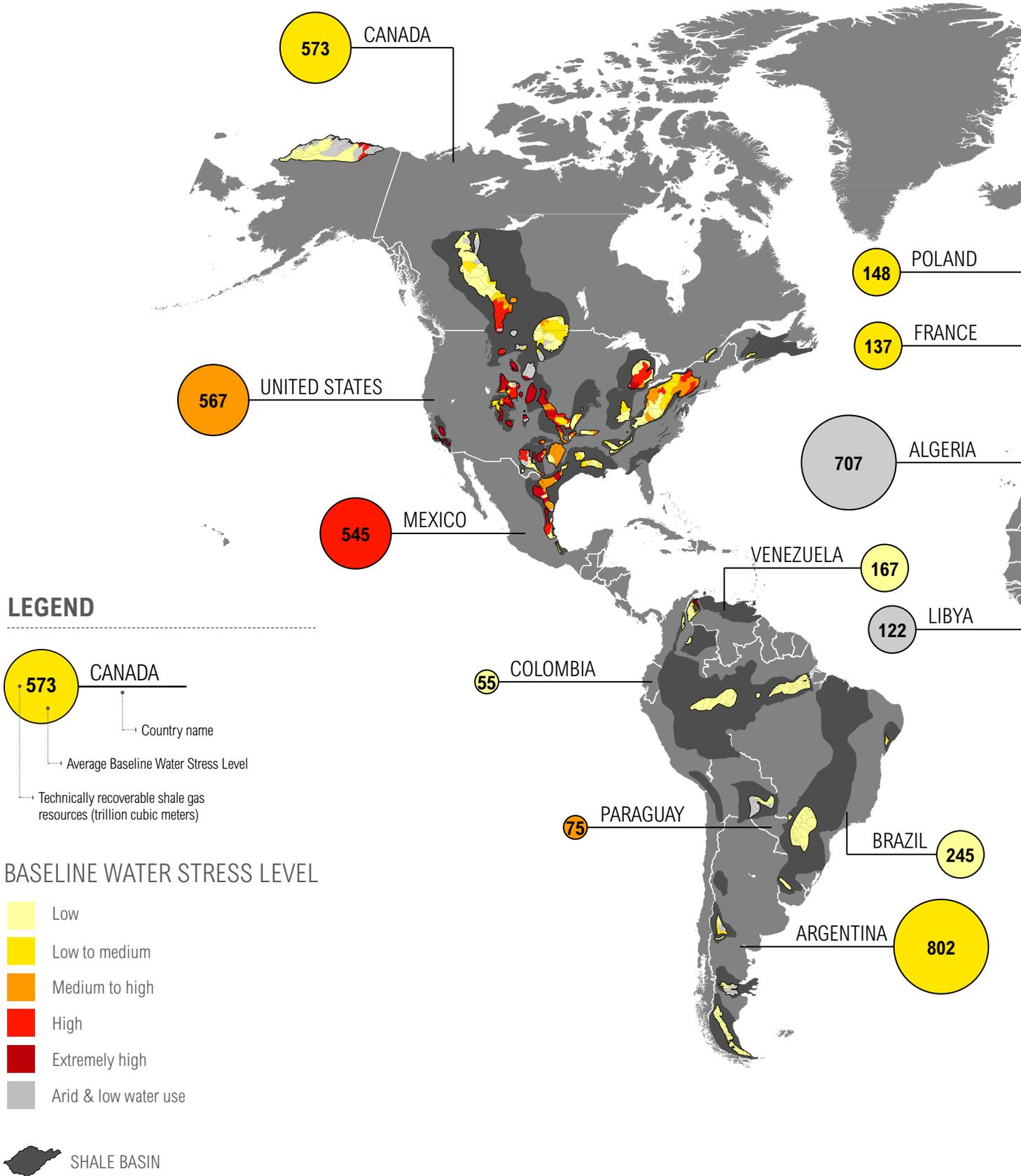
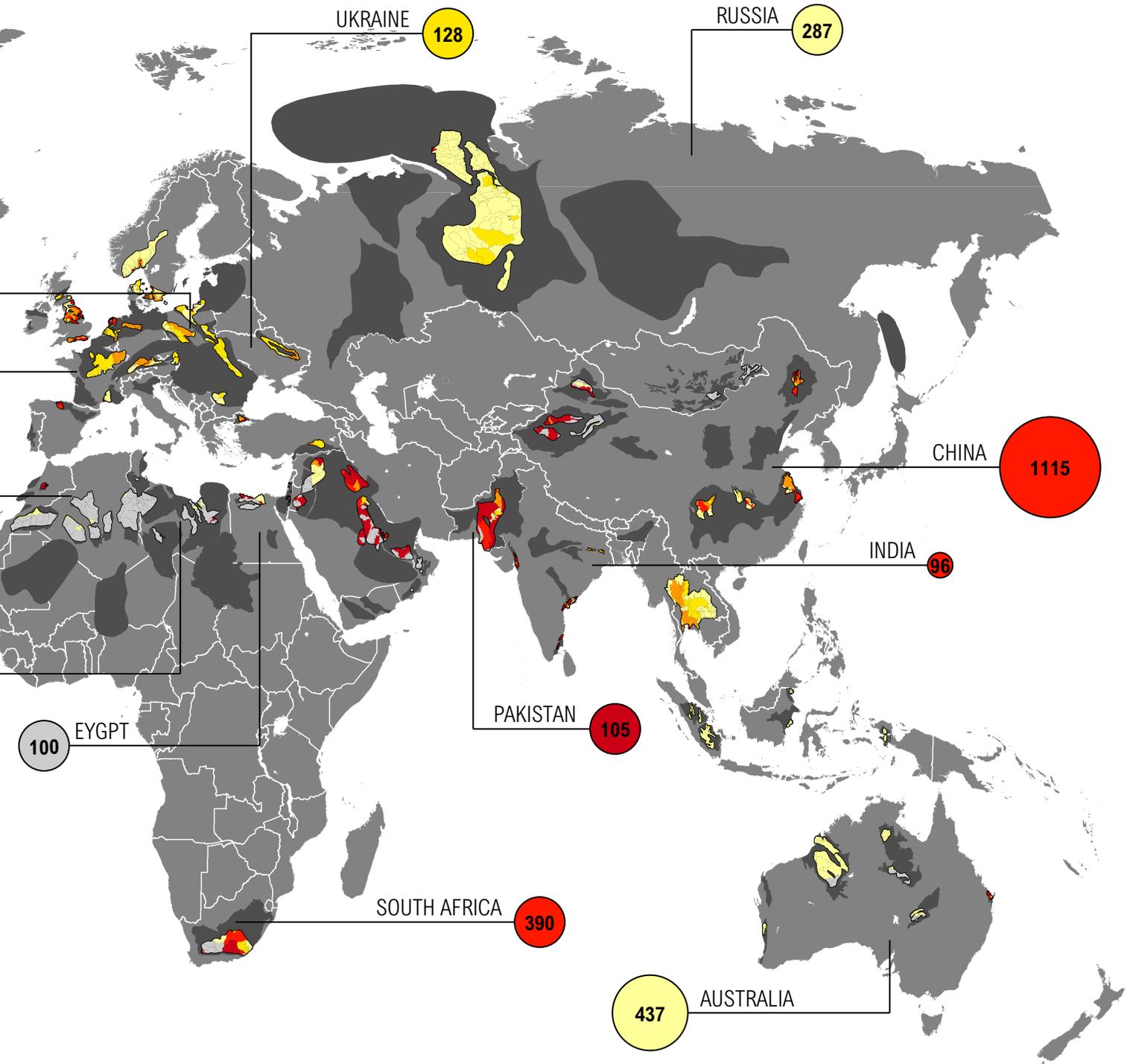


Figure ES1 | **Location of World's Shale Plays, Volume of Technically Recoverable Shale Gas in the 20 Countries with the Largest Resources, and the Level of Baseline Water Stress**





Notes

1. Colored polygons are areas that have been identified as shale plays: shale deposits that are viable for commercial production.
2. Dark grey polygons are shale basins. While shale plays fall within basins, other shale resources within basins may not be commercially viable.
3. Circle size denotes the country's total technically recoverable shale gas resources (trillion cubic meters).
4. Circle color denotes the area-weighted average of baseline water stress levels over all shale plays within a country. If more than half of the country's shale play area is in arid and low water use regions, the circle is colored in light grey.

Sources: Location of world's shale basins and plays from West Virginia University and The National Energy Technology Laboratory. Estimates of total technically recoverable shale gas resources from the U.S. Energy Information Administration. Estimates of baseline water stress from WRI's Aqueduct Water Risk Atlas.

Key findings

Shale resources are unevenly distributed worldwide and, for the most part, not located where freshwater is abundant. For example, China, Mexico (Figure ES2), and South Africa have some of the largest technically recoverable shale gas resources (based on estimates from the U.S. Energy Information Administration), but face high to extremely high water stress where the shale is located.

This report reveals that lack of water availability could curtail shale development in many places around the world:

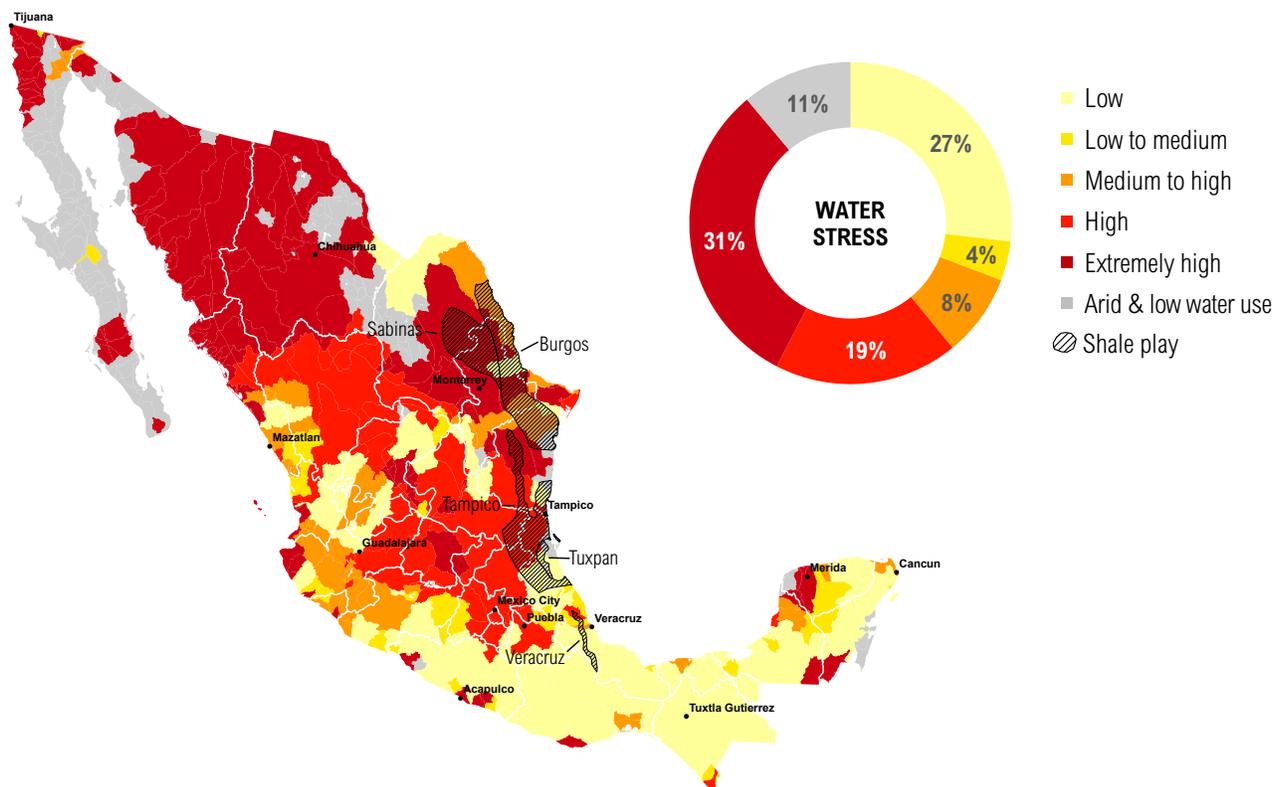
- 38 percent of shale resources are in areas that are either arid or under high to extremely high levels of water stress;
- 19 percent are in areas of high or extremely high seasonal variability; and
- 15 percent are in locations exposed to high or extremely high drought severity.

Furthermore, 386 million people live on the land over these shale plays, and in 40 percent of the shale plays, irrigated agriculture is the largest water user. Thus drilling and hydraulic fracturing often compete with other demands for freshwater, which can result in conflicts with other water users. This is particularly true in areas of high baseline water stress, where over 40 percent of the available water supplies are already being withdrawn for agricultural, municipal, or industrial purposes.

The 20 countries with the largest shale gas or tight oil resources that are recoverable using currently available technology are shown in Table ES2.

- Eight of the top 20 countries with the largest shale gas resources² face arid conditions or high to extremely high baseline water stress where the shale resources are located; this includes China, Algeria, Mexico, South Africa, Libya, Pakistan, Egypt, and India.

Figure ES2 | **Mexico's Shale Plays Often Overlap with Areas with High Baseline Water Stress**



Sources: Location of shale plays from West Virginia University and The National Energy Technology Laboratory. Estimates of baseline water stress from WRI's Aqueduct Water Risk Atlas.

Table ES2 | **Average Exposure to Water Stress across Shale Plays**

A. TWENTY COUNTRIES WITH THE LARGEST TECHNICALLY RECOVERABLE SHALE GAS RESOURCES

RANK ^a	COUNTRY	AVERAGE EXPOSURE TO WATER STRESS OVER SHALE PLAY AREA
1	China	High
2	Argentina	Low to Medium
3	Algeria	Arid & Low Water Use
4	Canada	Low to Medium
5	United States	Medium to High
6	Mexico	High
7	Australia	Low
8	South Africa	High
9	Russian Federation	Low
10	Brazil	Low
11	Venezuela	Low
12	Poland	Low to Medium
13	France	Low to Medium
14	Ukraine	Low to Medium
15	Libya	Arid & Low Water Use
16	Pakistan	Extremely High
17	Egypt, Arab Rep.	Arid & Low Water Use
18	India	High
19	Paraguay	Medium to High
20	Colombia	Low

a. Based on size of estimated shale gas technically recoverable resources

B. TWENTY COUNTRIES WITH THE LARGEST TECHNICALLY RECOVERABLE TIGHT OIL RESOURCES

RANK ^a	COUNTRY	AVERAGE EXPOSURE TO WATER STRESS OVER SHALE PLAY AREA
1	Russian Federation	Low
2	United States	Medium to High
3	China	High
4	Argentina	Low to Medium
5	Libya	Arid & Low Water Use
6	Australia	Low
7	Venezuela, RB	Low
8	Mexico	High
9	Pakistan	Extremely High
10	Canada	Low to Medium
11	Indonesia	Low
12	Colombia	Low
13	Algeria	Arid & Low Water Use
14	Brazil	Low
15	Turkey	Medium to High
16	Egypt, Arab Rep.	Arid & Low Water Use
17	India	High
18	Paraguay	Medium to High
19	Mongolia	Extremely High
20	Poland	Low to Medium

a. Based on size of estimated tight oil technically recoverable resources

Sources: Estimates of total technically recoverable shale gas and tight oil resources from the U.S. Energy Information Administration. Estimates of baseline water stress from WRI's Aqueduct Water Risk Atlas.

- Eight of the top 20 countries with the largest tight oil resources³ face arid conditions or high to extremely high baseline water stress where the shale resources are located; this includes China, Libya, Mexico, Pakistan, Algeria, Egypt, India, and Mongolia.

Hydrological conditions vary spatially and seasonally across shale plays, with variation among plays, within plays, and throughout the year. This variation makes companies' ability to meet the freshwater demands for hydraulic fracturing and drilling highly unpredictable, and estimates based on previous experience not always accurate in new shale formations. This high level of uncertainty can lead to business risks for companies exploring new areas for development. Furthermore, public concern over increased competition and impacts on freshwater availability can threaten a company's social license to operate and lead to changes in government regulations that could impact both short- and long-term investments.

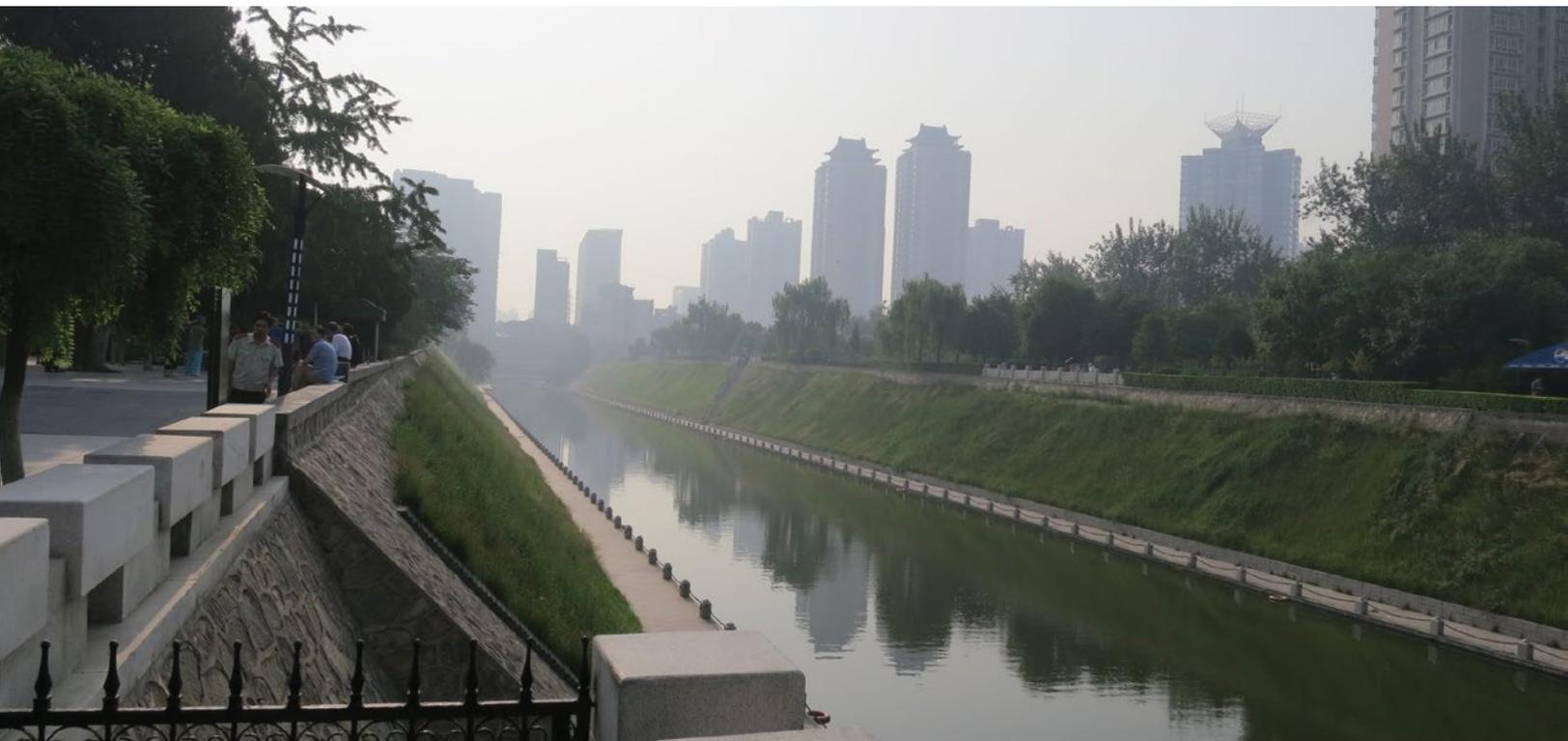
WRI's findings indicate that companies developing shale resources internationally are likely to face serious challenges to accessing freshwater in many parts of the world. These challenges highlight a strong business case for strategic company engagement in sustainable water management at local and regional levels. They also point to a need for companies to work with governments and other sectors to minimize environmental impacts and water resources depletion.

Recommendations

Based on the report's analysis, WRI offers a set of practical recommendations for how governments, businesses, and civil society can continue to evaluate and sustainably manage freshwater availability if shale resources are developed.

1. **Conduct water risk assessments to understand local water availability and reduce business risk.**

- 1.1. *Companies can evaluate water-related risks.* Using a combination of publicly available global and asset-level tools, companies should identify water-related business risks and prioritize areas to engage with regulators, communities, and industry to increase water security.
- 1.2. *Governments can increase investments in collecting and monitoring water supply and demand information.* Robust baseline information and estimates of future water supply and demand and environmental conditions can help build a strong, shared knowledge base to inform the development of effective water policies and science-based targets and goals.



2. Increase transparency and engage with local regulators, communities, and industry to minimize uncertainty.

2.1. *Companies can increase corporate water disclosure.* By disclosing and communicating their water use and management approach, companies can build trust with financial and river basin stakeholders as they investigate water risks and opportunities. Ongoing disclosure will reduce reputational risks.

2.2. *Governments and companies can engage with local and regional industry, agriculture, and communities.* Companies should closely collaborate with local government, industry, NGOs, and civil society to understand the hydrological conditions and regulatory frameworks within the river basin. This information allows for more accurate estimates of the cost, technology, and processes required to access water for shale development without displacing other users or degrading the environment.

3. Ensure adequate water governance to guarantee water security and reduce regulatory and reputational risks.

3.1. *Companies can engage in public water policy.* Adequate water governance and environmental protection standards, coupled with predictable implementation and effective enforcement, can minimize environmental degradation and ensure fair water allocation and pricing. A stable regulatory environment allows companies and investors to evaluate long-term opportunities and minimize business risks.

3.2. *Governments and companies, through collective action, can develop source water protection and management plans.* Governments and businesses in the early stages of developing shale resources have a unique opportunity to work collectively with key river basin stakeholders to develop source water protection and management plans that help reduce business risks; promote a shared water sourcing and recycling infrastructure; and improve the sustainable management of watersheds and aquifers.



4. Minimize freshwater use and engage in corporate water stewardship to reduce impacts on water availability.

4.1. *Companies can minimize freshwater use.* Using publicly available guidelines, companies can evaluate their potential for using non-freshwater sources and build a business case for investing in technology to recycle or reuse water, use brackish water, or otherwise significantly reduce freshwater withdrawals.

4.2. *Companies can develop a water strategy and engage in corporate water stewardship.* Companies should embed water management at the core of their business strategy to minimize exposure to risks and ensure long-term water availability for other users, the environment, and their own operations. Corporate water stewardship involves a progression of increasing improvements in water use and impact reductions across internal company operations and the rest of the value chain.⁴

ABBREVIATIONS AND ACRONYMS

EIA	U.S. Energy Information Administration
GDP	Gross domestic product
GHG	Greenhouse gas
GIS	Geographic information system
IEA	International Energy Agency
IPIECA	The global oil and gas industry association for environmental and social issues
NGLs	Natural gas liquids
NGO	Nongovernmental organization
OPEC	Organization of the Petroleum Exporting Countries
PEMEX	Petróleos Mexicanos
TRR	Technically recoverable resource
UK	United Kingdom
U.S.	United States
U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UN	United Nations
WRI	World Resources Institute
WVGISTC	West Virginia Geographic Information Systems Technical Center
WVU	West Virginia University

DEFINITIONS

Brackish water: water that is generally saltier than freshwater, but not as salty as seawater.¹²⁹

Conventional oil and gas resources: reservoirs of natural gas or oil that typically permit the oil and natural gas to flow readily into wellbores.

Flowback: water that returns to the surface directly after hydraulic fracturing. Flowback contains a mix of fracturing fluid and water originally found in the formation.

Hydraulic fracturing: treatment by which a fluid is pumped at high pressure down a wellbore to initiate and propagate cracks in low-permeability geological formations.

Natural gas liquids (NGLs): natural gas liquids are naturally occurring hydrocarbons found in natural gas or associated with crude oil that are considered a byproduct in the oil and gas industry but are increasingly being targeted for extraction.

Produced water: water that returns to the surface along with the oil or gas pumped from the well; produced water returns to the surface after the flowback and is mostly water originally found in the formation.

Recycled Water: water used a second time after undergoing treatment.

Reused Water: water used a second time with minimal treatment.

Shale basin: large shale formations defined by similar geologic characteristics.

Shale gas: natural gas deposits found in shale reservoirs, with even lower permeability than tight gas reservoirs.

ENDNOTES

1. In this report, shale resources (or more technically, shale hydrocarbons) include shale gas, natural gas liquids, and tight oil.
2. Technically recoverable resources based on estimates by the U.S. Energy Information Administration.
3. Technically recoverable resources based on estimates by the U.S. Energy Information Administration.
4. World Wildlife Fund, *Water Stewardship: Perspectives on Business Risks and Responses to Water Challenges* (Gland, Switzerland, 2013), http://awsassets.panda.org/downloads/ws_briefing_booklet_lr_spreads.pdf.

Shale play: area of a shale basin where gas and oil could be commercially extracted. Oil and gas deposits within a play usually share similar geologic and geographic properties such as source rock, migration pathways, trapping mechanisms, and hydrocarbon type.¹³⁰

Shale resource: hydrocarbon resources found in shale plays, such as natural gas, natural gas liquids, and tight oil.

Technically recoverable resource (TRR): resources that can be produced using current technology without reference to the economic viability.¹³¹

Tight gas: natural gas trapped in reservoir rock with a permeability that is a factor of 10 to thousands of times less permeable than conventional natural gas reservoirs.

Tight oil: oil trapped in fine-grained sedimentary rocks with extremely low permeability, such as shale, sandstone, or carbonate.

Unconventional oil or gas resources: reservoirs of natural gas or oil, in geological formations with often extremely low permeability, which are unable to flow readily to the wellbores. Examples include: heavy oil, oil sands or tar sands, tight oil, oil shales, tight gas, shale gas, and coalbed methane.

Water consumption: volume of surface or groundwater withdrawn that is not returned to the original water source and therefore is no longer available for reuse.

Water withdrawal: volume of water that is taken from a surface or groundwater source

Water stress: the ratio of total water withdrawals relative to the available renewable surface water

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Opinions or points of view expressed in this report are those of the authors and do not necessarily reflect the position of the External Advisory Group or the organizations they represent.

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ABOUT WRI

WRI is a global research organization that works closely with leaders to turn big ideas into action to sustain a healthy environment—the foundation of economic opportunity and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

PHOTO CREDITS

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