

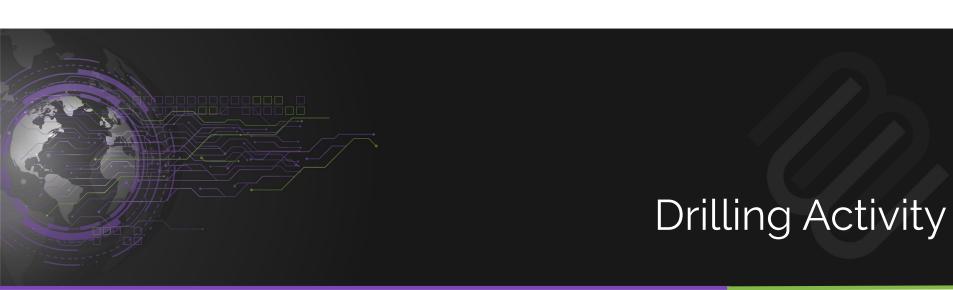


#### \_\_ Overview

### Appalachia Water & Waste - A data-driven review of produced volumes

- Drilling Rig Activity
  - Review of weekly rig activity
  - Locations spud
  - Vertical well activity
- Production Volumes
  - Brief overview of gas and oil rates
  - Unconventional water production
    - Split by formation, state, and operator
    - Water rate vs production rate
  - PA conventional water production
    - Split by operator
    - Water rate vs production rate

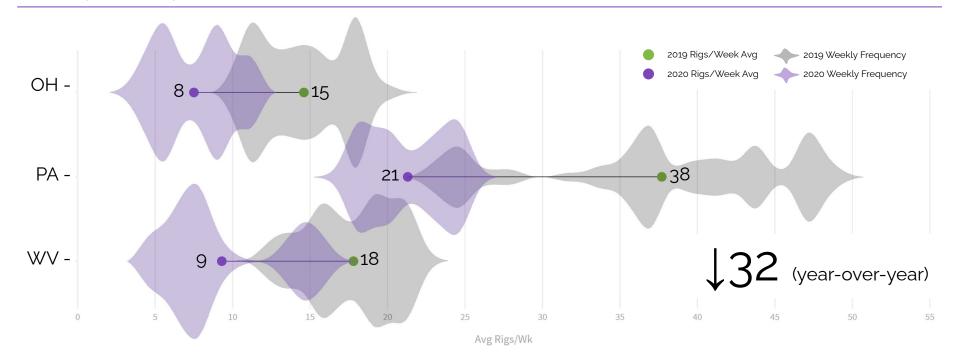
- PA Water & Waste Flow
  - Water usage
  - Example water network
  - Drill cuttings
  - Example waste networks



# Appalachia - All Rigs

## Weekly Activity 2020 vs 2019



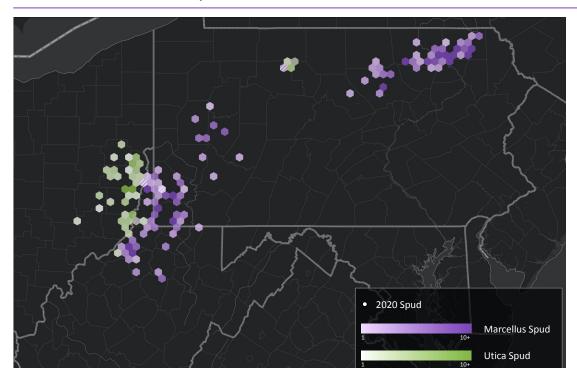


Source - Baker Hughes, Mudrock Energy

Note - Values rounded to the closest integer (YOY value calculated from basin total, not from rounded integers)

## Horizontal Wells

### 2020 Locations Spud





### - Marcellus Top 5 Counties

- Susquehanna, PA (17%)
- Bradford, PA ----- (15%)
- Washington, PA --- (11%)
- Tyler, WV ----- (11%)
- Greene, PA ----- (11%)

### - Utica Top 5 Counties

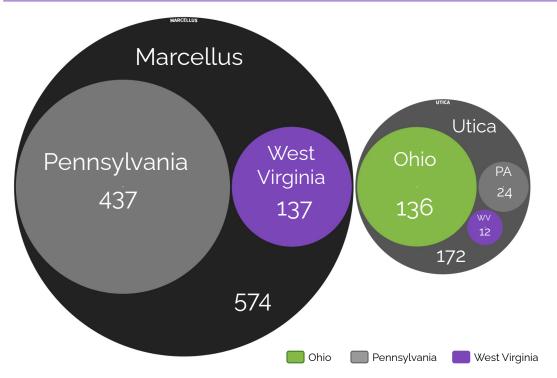
- Jefferson, OH ---- (23%)
- Belmont, OH ----- (22%)
- Harrison, OH ----- (16%)
- Monroe, OH ----- (10%)
- Cameron, PA ----- (10%)

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## Horizontal Wells

## Spud per Formation - 2020





- Marcellus Wells Spud
  - 76% in Pennsylvania
  - 24% in West Virginia

- Utica Wells Spud
  - 79% in Ohio
  - 14% in Pennsylvania
  - 7% in West Virginia

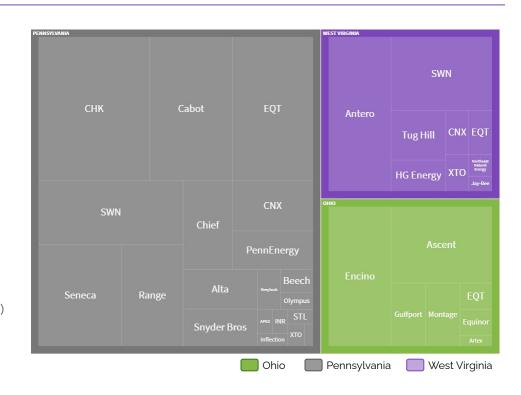
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## Horizontal Wells

## Spud per Operator - 2020



- Top Hz Drillers Appalachia
  - SWN ---- (13%)
  - CHK ----- (12%)
  - EQT ----- (10%)
  - Cabot ---- (9%)
  - Antero --- (8%)
- Top Hz Drillers per State
  - Ohio
    - Encino (38%), Ascent (34%),
      Gulfport (10%), Montage (10%)
  - Pennsylvania
    - CHK (19%), Cabot (14%), EQT (14%)
  - West Virginia
    - Antero (38%), SWN (30%), Tug Hill (11%)
- Record Length Marcellus Well
  - Olympus Energy Midas 6M 20,060 ft completed lateral

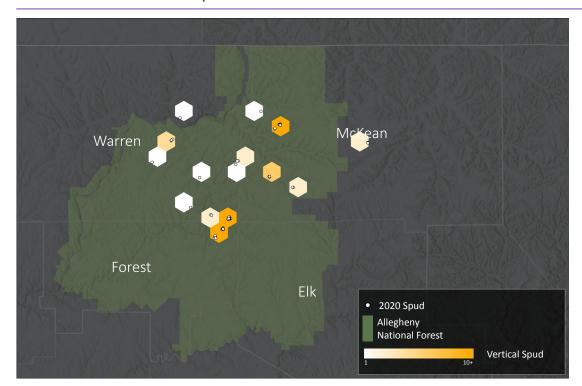


Source - IHS Markit, Mudrock Energy, Olympus Energy

# Vertical Wells

### 2020 Locations Spud





### - PA Top Counties

- Warren, PA ----- (44%)
- McKean, PA ---- (31%)
- Forest, PA ----- (21%)

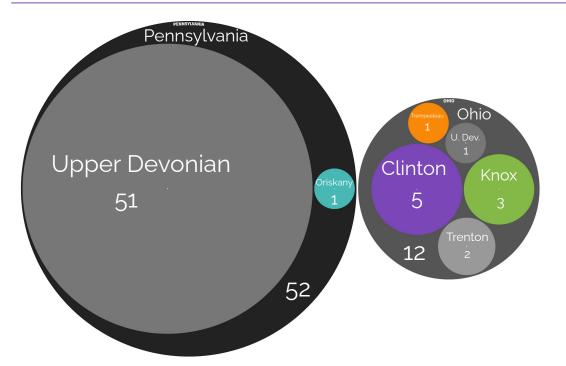
### Ohio Top Counties

- Cuyahoga, OH -- (25%)
- Summit, OH ---- (17%)
- Auglaize, OH ---- (17%)

## Vertical Wells



Spud per Formation - 2020



### Pennsylvania Wells Spud

- Focused on Upper Devonian sandstone formations
- Oriskany well listed as a development well
  - Likely associated with a storage field

### Ohio Wells Spud

Scattered throughout the state targeting various reservoirs

# Vertical Wells

## Spud per Operator - 2020



- Top Vt Drillers Appalachia
  - Cameron (27%)
  - MSL ---- (14%)
  - Mead ---- (6%)
  - Pennhills (6%)
  - Curtis ---- (5%)
- Top Vt Drillers per State
  - Ohio
    - EOS (25%), Discovery (17%), Myers (17%)
  - Pennsylvania
    - Cameron (33%), MSL (17%), (8%), Pennhills (8%)
  - West Virginia
    - No Vertical Wells Spud



# **Drilling Activity**

## Summary



- Drilling focused in Northeast PA & Southwest Tri-state Region
- Most active operators are Southwestern, Chesapeake, and EQT
- Vertical drilling focused on shallow oil
  - Most activity within Allegheny National Forest

## Spud Year-over-year



- Marcellus 135%

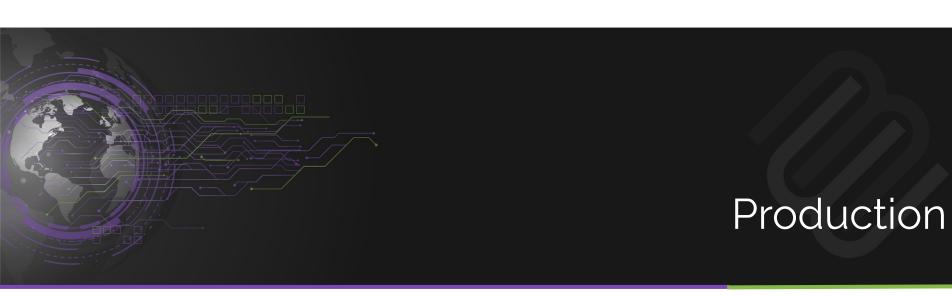


- Utica ↓42%



Vertical Wells ↓73%

Source - Baker Hughes, IHS Markit, Mudrock Energy

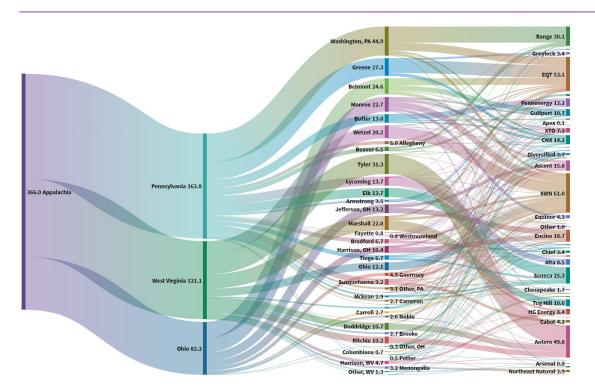


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## All Unconventional Water Production

#### 2020 Exit Rate (Mbbl/d)





 Appalachia All Unconventional

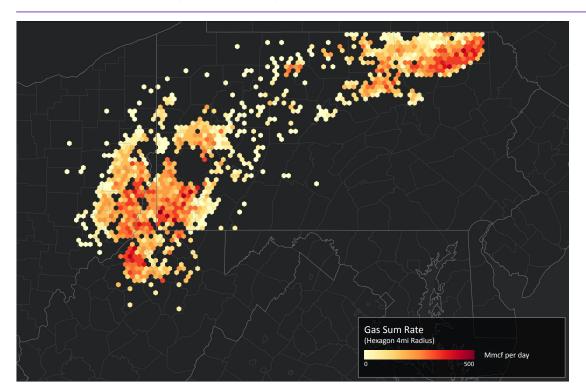
- 366 mbbl/d (\1%)
- Higher volumes of water production typically indicate areas of recent activity
  - Need to first understand oil & gas production

- Source PA DEP, ODNR, WV DEP, IHS Markit, Mudrock Energy
- 2020 Exit Rate based on reports OH 4Q 2020, PA 12/2020, WV 12/2020

## All Unconventional Gas Production

#### 2020 Exit Rate (Mmcf/d)





Appalachia All
 Unconventional

- 34.0 bcf/d (↑4%)
- Ohio ----- 6.4 (↓ 13%)
- Pennsylvania --- 20.7 (↑ 7%)
- West Virginia ---- 6.9 (↑ 15%)

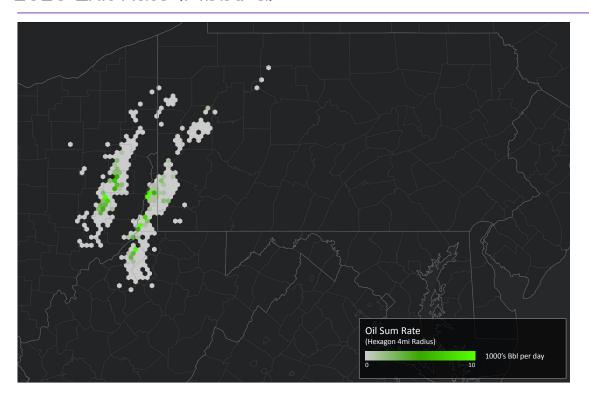
- Source PA DEP, ODNR, WV DEP, IHS Markit, Mudrock Energy
- 2020 Exit Rate based on reports OH 4Q 2020, PA 12/2020, WV 12/2020

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## All Unconventional Oil Production

#### 2020 Exit Rate (Mbbl/d)





 Appalachia All Unconventional

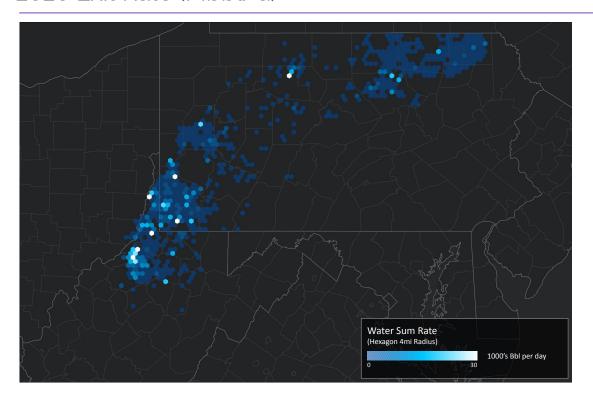
- 118 mbbl/d (↓ 16%)
- Ohio ----- 50.3 (↓ 32%)
- Pennsylvania --- 14.2 (↓ 1%)
- West Virginia --- 53.3 (↑ 3%)

- Source PA DEP, ODNR, WV DEP, IHS Markit, Mudrock Energy
- 2020 Exit Rate based on reports OH 4Q 2020, PA 12/2020, WV 12/2020 (Oil Production includes reported Oil and Condensate)

## Marcellus Water Production

#### 2020 Exit Rate (Mbbl/d)





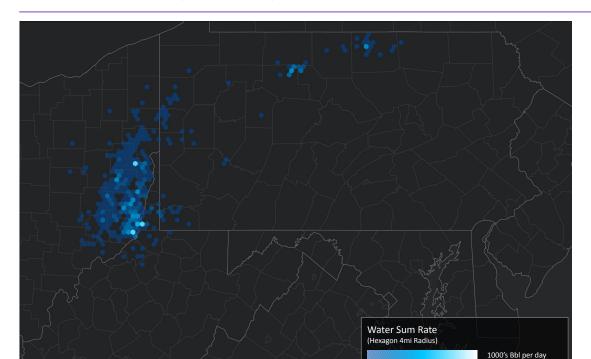
- Highest VolumesProduced SouthwestTri-state Region
- Marcellus Top 5 Gas
  Producing Counties
  - Washington, PA
  - Tyler, WV
  - Greene, PA
  - Wetzel, WV
  - Marshall, WV

- Source PA DEP, ODNR, WV DEP, IHS Markit, Mudrock Energy
- 2020 Exit Rate based on reports OH 4Q 2020, PA 12/2020, WV 12/2020

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## **Utica Water Production**

#### 2020 Exit Rate (Mbbl/d)





- Highest Volumes
  Produced in Eastern OH
- Utica Top 5 GasProducing Counties
  - Belmont, OH
  - Monroe, OH
  - Jefferson, OH
  - Harrison, OH
  - Marshall, WV

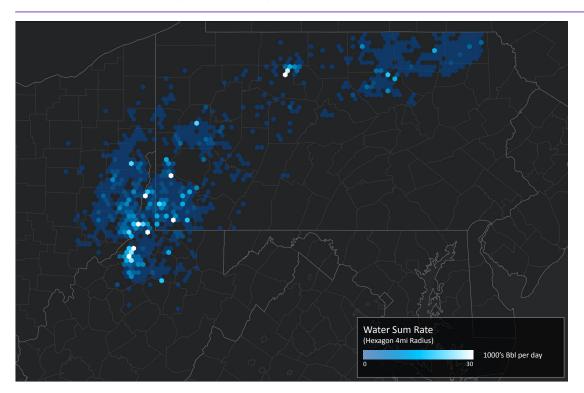
2020 Exit Rate based on reports - OH 4Q 2020, PA 12/2020, WV 12/2020

Source - PA DEP, ODNR, WV DEP, IHS Markit, Mudrock Energy

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## All Unconventional Water Production

2020 Exit Rate (Mbbl/d)



 Appalachia All Unconventional

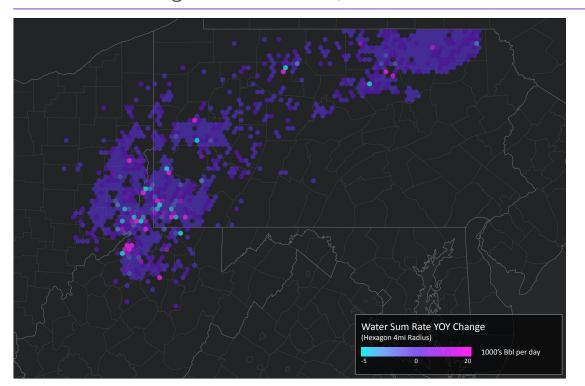
- 366 mbbl/d (↓1%)
- Ohio ----- 82.2 (↓ 14%)
- Pennsylvania --- 162.8 (↓ 2%)
- West Virginia ---- 121.1 (↑ 11%)

- Source PA DEP, ODNR, WV DEP, IHS Markit, Mudrock Energy
- 2020 Exit Rate based on reports OH 4Q 2020, PA 12/2020, WV 12/2020

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## All Unconventional Water Production

Exit Rate Change 2020 vs 2019 (Mbbl/d)



- Appalachia All Unconventional
  - -4.9 mbbl/d (\1%)
- Ohio
  - -13.6 mbbl/d (↓ 14%)
    - Jefferson Co., +2.1 mbbl/d
    - Belmont Co., -6.2 mbbl/d
- Pennsylvania
  - -3.4 mbbl/d (↓ 2%)
    - Washington Co., +9.0 mbbl/d
    - Greene Co., -6.2 mbbl/d
- West Virginia
  - +12.1 mbbl/d (↑ 11%)
    - Wetzel Co., +17.6 mbbl/d
    - Monongalia Co., -7.1 mbbl/d

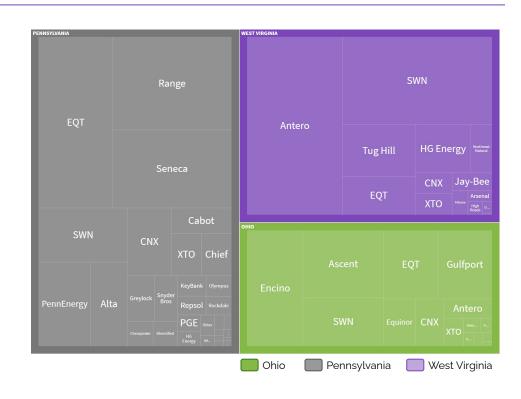
- Source PA DEP, ODNR, WV DEP, IHS Markit, Mudrock Energy
- 2020 Exit Rate based on reports OH 4Q 2020, PA 12/2020, WV 12/2020

## All Unconventional Water Production

# Operator Exit Rate 2020 (Mbbl/d)



- Top Producers Appalachia
  - SWN------ 61 († 134%)
  - EQT ----- 53 (↓ 8%)
  - Antero ----- 50 († 3%)
  - Range ----- 30 († 4%)
  - Seneca ----- 25 († 25%)
- Top Producers per State
  - Ohio
    - Encino, Ascent, SWN
  - Pennsylvania
    - EQT, Range, Seneca
  - West Virginia
    - Antero, SWN, Tug Hill



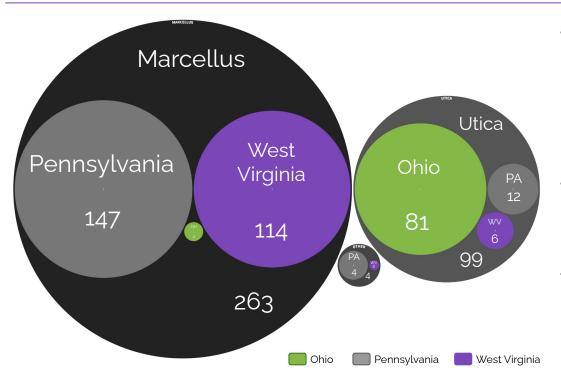
- Source PA DEP, ODNR, WV DEP, IHS Markit, Mudrock Energy
- 2020 Exit Rate based on reports OH 4Q 2020, PA 12/2020, WV 12/2020 (Pct 2020 vs 2019)

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## All Unconventional Water Production



Exit Rate 2020 (Mbbl/d) per Formation



- Marcellus continues to drive produced water volumes from the basin
  - 72% of 2020 exit rate
  - 5% YOY growth
- Utica growth slowed in 2020
  - 27% of 2020 exit rate
  - -12% YOY growth
- Other formations account for 1% of 2020 exit rate

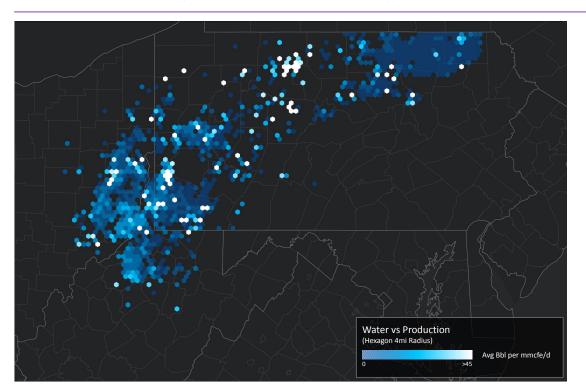
Source - PA DEP, ODNR, WV DEP, IHS Markit, Mudrock Energy

 <sup>2020</sup> Exit Rate based on reports - OH 4Q 2020, PA 12/2020, WV 12/2020 (Pct 2020 vs 2019)

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## All Unconventional Water Production

2020 Exit Rate ((Bbl/d)/(Mmcfe/d))



- Highest volume of water typically produced following completion
- Volumes also affected by
  - Operator methods
  - Formation
  - Regional Geology
- Northeast Marcellus region appears to generally have lower values

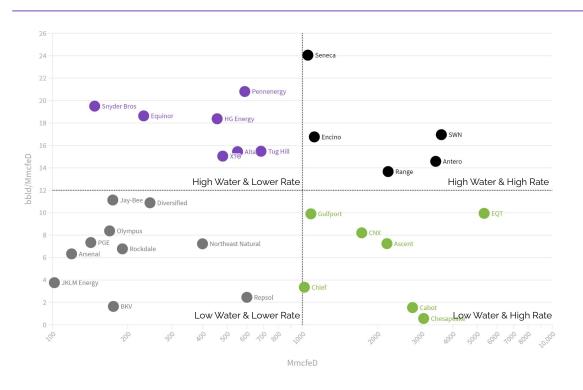
Source - PA DEP, ODNR, WV DEP, IHS Markit, Mudrock Energy

 <sup>2020</sup> Exit Rate based on reports - OH 4Q 2020, PA 12/2020, WV 12/2020

Mmcfe calculated using a 6:1 ratio of reported oil or condensate

## All Unconventional Water Production

#### 2020 Exit Rate ((Bbl/d)/(Mmcfe/d))



- Operator water cuts do not appear to be influenced by daily volumes
- Other factors likely more important

Mmcfe calculated using a 6:1 ratio of reported oil or condensate

Source - PA DEP, ODNR, WV DEP, IHS Markit, Mudrock Energy

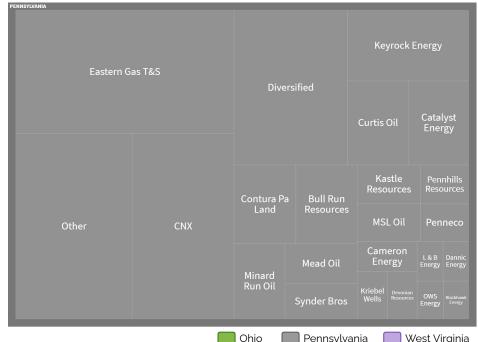
<sup>2020</sup> Exit Rate based on reports - OH 4Q 2020, PA 12/2020, WV 12/2020

# Conventional Pennsylvania Water Production



Operator Exit Rate 2020 (Bbl/d)

- Top Producers Pennsylvania
  - Eastern Gas T&S -- 726 (↑ -)
  - CNX ----- 507 († 13%)
  - Diversified ----- 472 († 85%)
  - Keyrock Energy ---- 231 (J 48%)
  - Curtis Oil ----- 138 (1 1%)



Ohio Pennsylvania

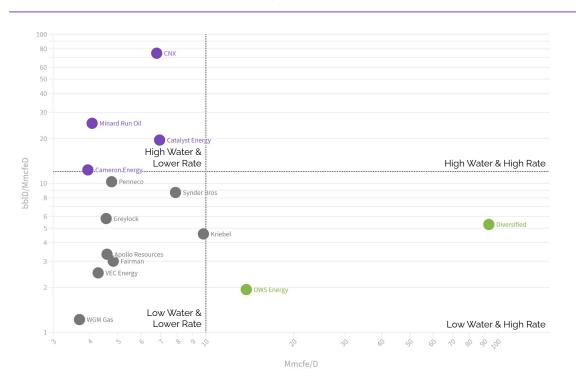
Source - PA DEP, Mudrock Energy

2020 Exit Rate based on reports - PA 12/2020 (Pct 2020 vs 2019)

# Conventional Pennsylvania Water Production



2020 Exit Rate ((Bbl/d)/(Mmcfe/d))



- Operator water cuts do not appear to be influenced by daily volumes
- Other factors likely more important

Source - PA DEP, Mudrock Energy

 <sup>2020</sup> Exit Rate based on reports - PA 12/2020 (Pct 2020 vs 2019)

Mmcfe calculated using a 6:1 ratio of reported oil or condensate

# Water Production

## Summary



- Water production held steady within the basin
  - Growth led by the Marcellus Shale
  - Utica Shale volumes shrank
- Top drillers correspond with the top producers for 2020
- Volumes often affected by operator methods, formation, and regional geology

#### Exit Volume Rates



- 366 mbbl/d (\ 1%)



- Leading Operators
  - SWN 61 mbbl/d (↑ 134%)
  - EQT 53 mbbl/d (↓ 8%)

 <sup>2020</sup> Exit Rate based on reports - OH 4Q 2020, PA 12/2020, WV 12/2020 (Pct 2020 vs 2019)

Mmcfe calculated using a 6:1 ratio of reported oil or condensate

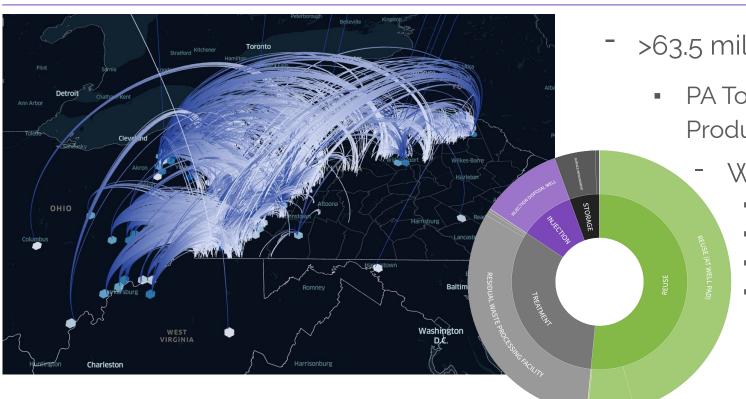


# PA Water & Waste Flow

# All Pennsylvania Water Production

## 2020 Water Usage



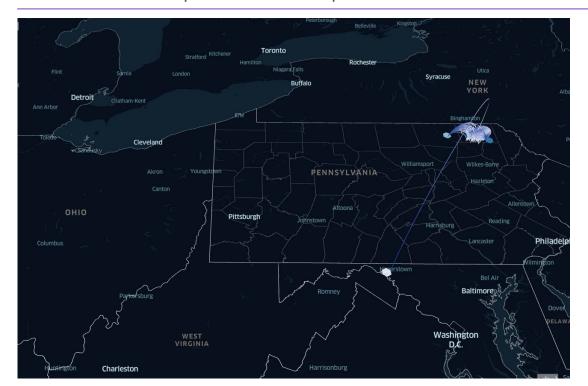


- >63.5 million bbls
  - PA Total Water Produced in 2020
    - Water Usage
      - Reuse 52%
      - Treatment 33%
      - Injection 10%
      - Storage 6%

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# All Pennsylvania Water Production

### Northeast PA Operator Example Water Flow

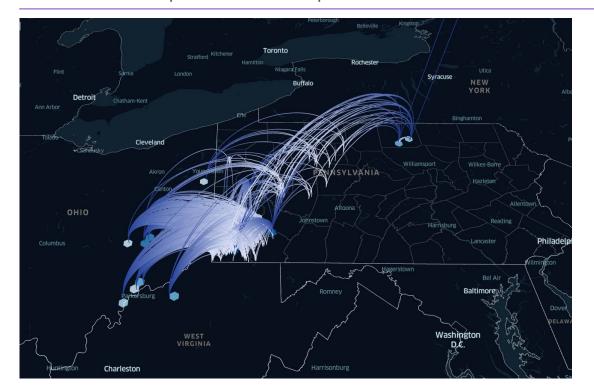




- Elaborate network of water treatment
- Geospatially connecting water flow
  - From well to facility
- NEPA Operator has a small local footprint

# All Pennsylvania Water Production

## Western PA Operator Example Water Flow



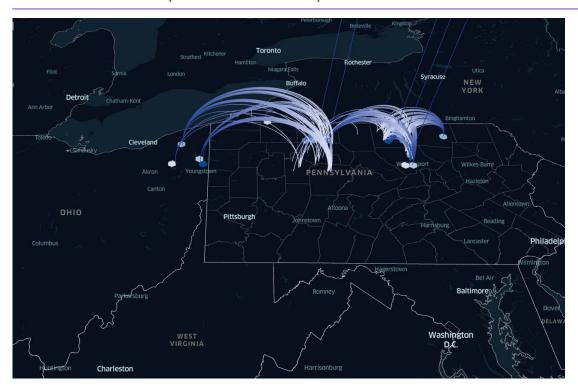


- Western PA Operator example
  - Broader operational footprint
  - Water shipped across basin into neighboring states

# All Pennsylvania Water Production

## Northern PA Operator Example Water Flow



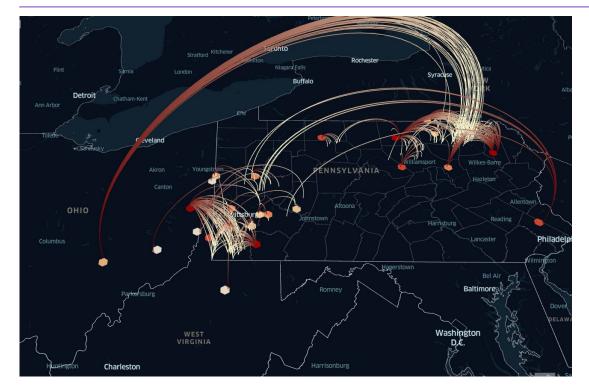


- Northern PA Operator example
  - Broader operational footprint
  - Water shipped along northern tier and I-80 corridor

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# All Pennsylvania Drill Cuttings

## All Operators Drill Cuttings Flow



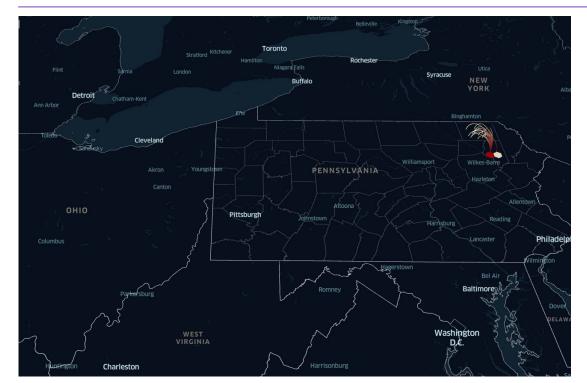


- Almost 29 million tons
  - PA Drill cuttings disposed
- Highlights recent annual activity
  - Wells transferring cuttings to solid waste facilities

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# All Pennsylvania Drill Cuttings

## Northeast PA Operator Example Drill Cuttings Flow

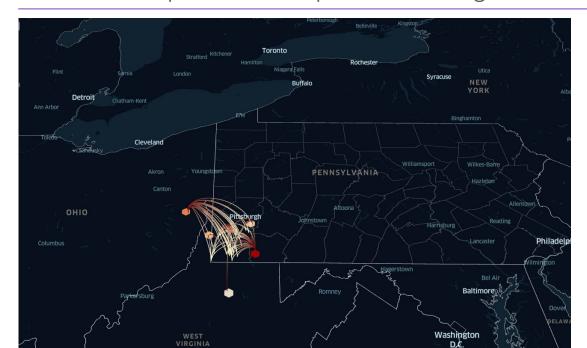




- Geospatially connecting drill cuttings shipment
  - From well to facility
- Network of solid waste facilities
- NEPA Operator has a small local footprint

# All Pennsylvania Drill Cuttings

## Western PA Operator Example Drill Cuttings Flow





- Western PA Operator example
  - 2020 drilling focused in SW region
  - Cuttings waste shipped nearby in PA and neighboring states

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# All Pennsylvania Drill Cuttings

## Northern PA Operator Example Drill Cuttings Flow



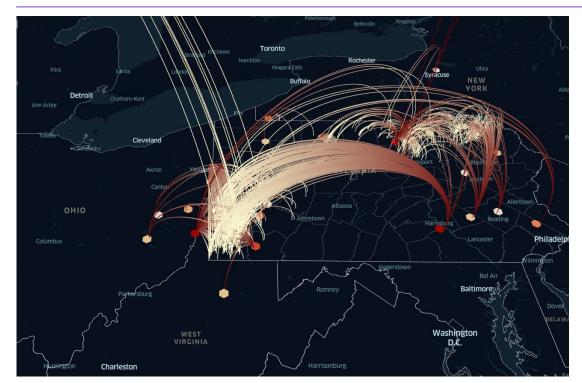


- Northern PA Operator example
  - 2020 drilling focused along northern tier
  - Cuttings waste shipped locally

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# All Pennsylvania Drill Cuttings

### All Operators Other Solids Flow





- All PA waste data can be analyzed and mapped
- Identification of facility type and state
- Highlights recent annual activity
- Example of all other solids trucked to waste facilities



Summary

## Appalachia Upstream 2020

## Summary



### Drilling

- Spuds YOY Marcellus \$\\$35\%, Utica \$\\$42\%,
  Vertical Wells \$\\$73\%

#### Production

- Gas volume rates †4%
- Oil volume rates \$\16\%
- Water volume rates \$\1\%
- Appalachia production continues to be driven by the Marcellus Shale
- 4 of the top 5 gas operators increased production

#### PA Water & Waste

- Total water >63.5 million barrels
  - Reuse 52%
  - Treatment 33%
  - Injection 10%
  - Storage 6%
- Drill cuttings contributed almost 29 million tons of waste
- All PA waste data can be analyzed and mapped
  - Highlights an elaborate network of waste shipping throughout the state

# Thank you

#### **Contact Information**



- PIOGA
- Paul Hart
- Scot Evans
- Teresa Irvin McCurdy

## MudrockEnergy.com

- Presentation & updates
- Weekly rig update
- Monthly newsletter
- Other maps & reports

### **Contact Information**



- www.MudrockEnergy.com



- dboyer@mudrockenergy.com



- www.linkedin.com/in/boyerd



- (209) MUD-ROCK