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Setting the scene >> Technology >> Examples
Electromagnetics can immediately support Climate Change battle



- **What are KEY applications?**
 - Support EV change over– battery material - mining
 - GREEN energy – geothermal
 - Reducing carbon footprint via CO₂ sequestration
- Others not shown here:
 - EOR → higher recovery factor → lower carbon footprint/barrel
 - Sub-basalt & subsalt imaging → lower environmental impact

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- From key to EM
- Picture 3D cube with geothermal and minerals
- Hardware and sensors
- Lithium example
- Geothermal Hungary
- ND
- Summary

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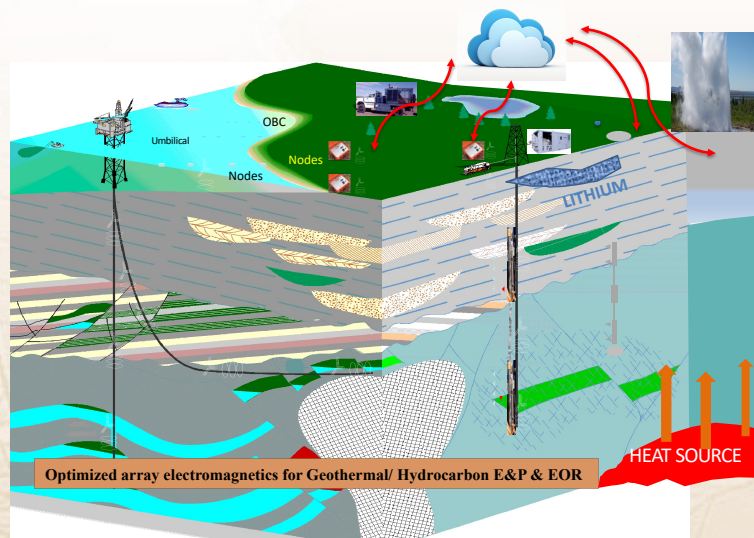
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Setting the scene >> Technology >> Examples
KEY: Lithium, Geothermal, & CO₂ storage in reservoirs

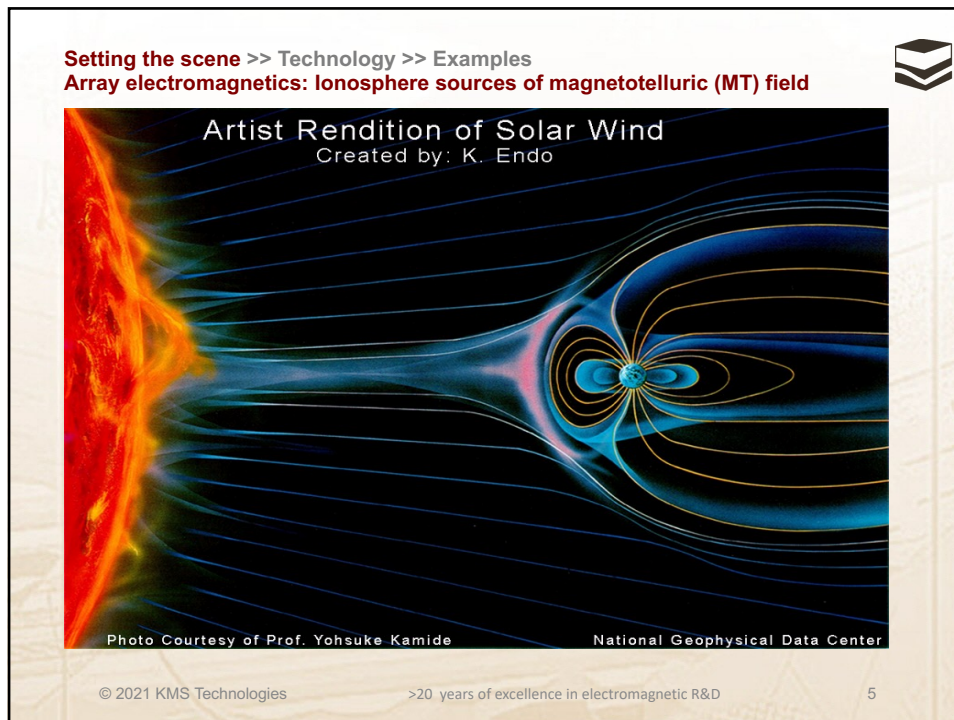


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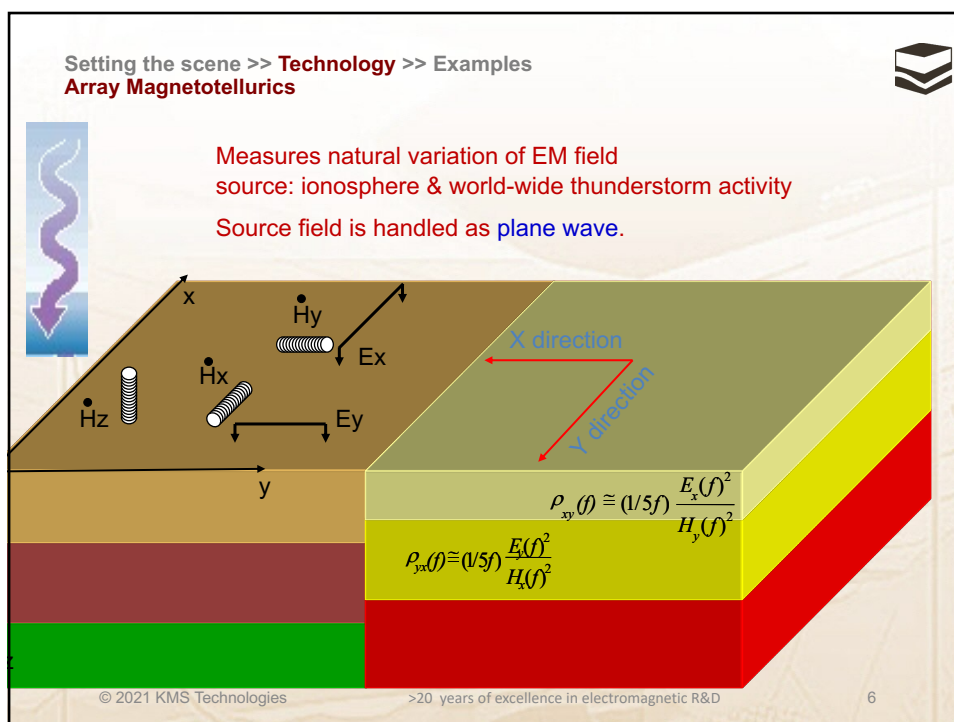
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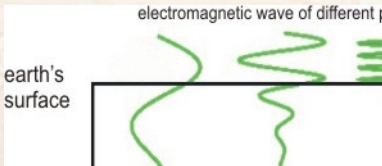
Setting the scene >> **Technology** >> Examples

Array Magnetotellurics: Skin depth



$$\text{Skin depth} = 503 \sqrt{\rho / f} \text{ [m]}$$

resistivity
frequency



Low frequencies: Ionosphere

High frequencies: thunderstorm

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Setting the scene >> **Technology** >> Examples

Controlled source EM improves accuracy

Shallow borehole tool

Transmitter

Receiver

Downhole receivers

Modified after Hoertt

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Setting the scene >> **Technology** >> Examples
Controlled source EM improves accuracy II

MT

CSEM

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Setting the scene >> **Technology** >> Examples
New array acquisition hardware

- Wireless (long range & WIFI)
- True array system
- Large dynamic range (up to 32 bits)
- High bandwidth (DC to 50 kHz)

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Setting the scene >> **Technology** >> Examples
New array acquisition hardware

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Setting the scene >> **Technology** >> Examples
Smaller, lower cost sensors: DC - 200 KHz

System integrated

Marine seismic/EM node

Borehole seismic/EM node

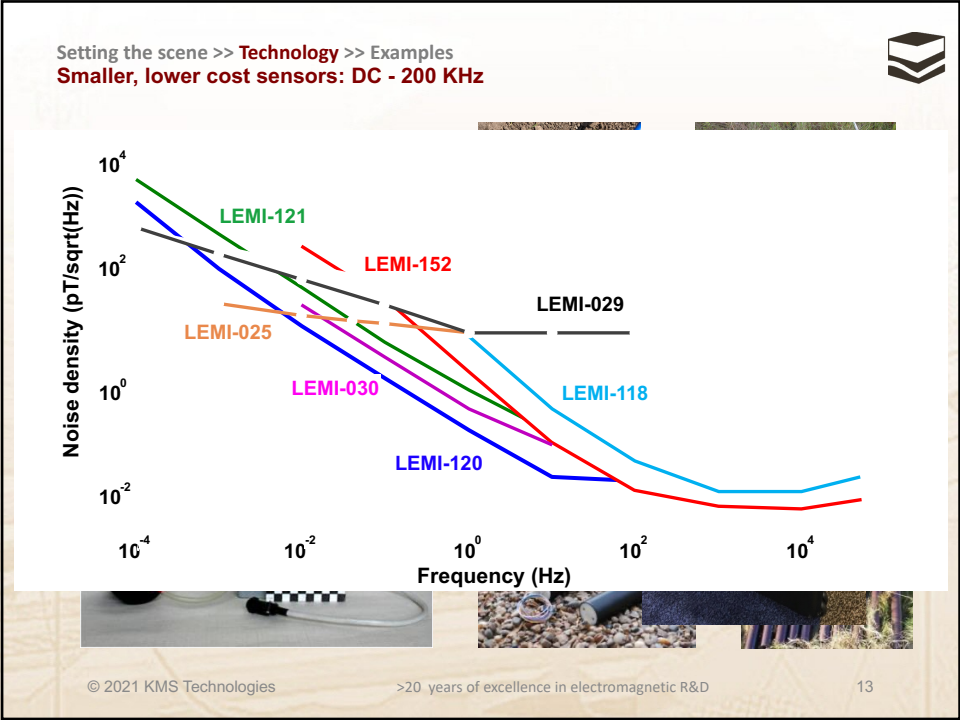
Fluxgates – 3 components

Induction coils – T & F domain

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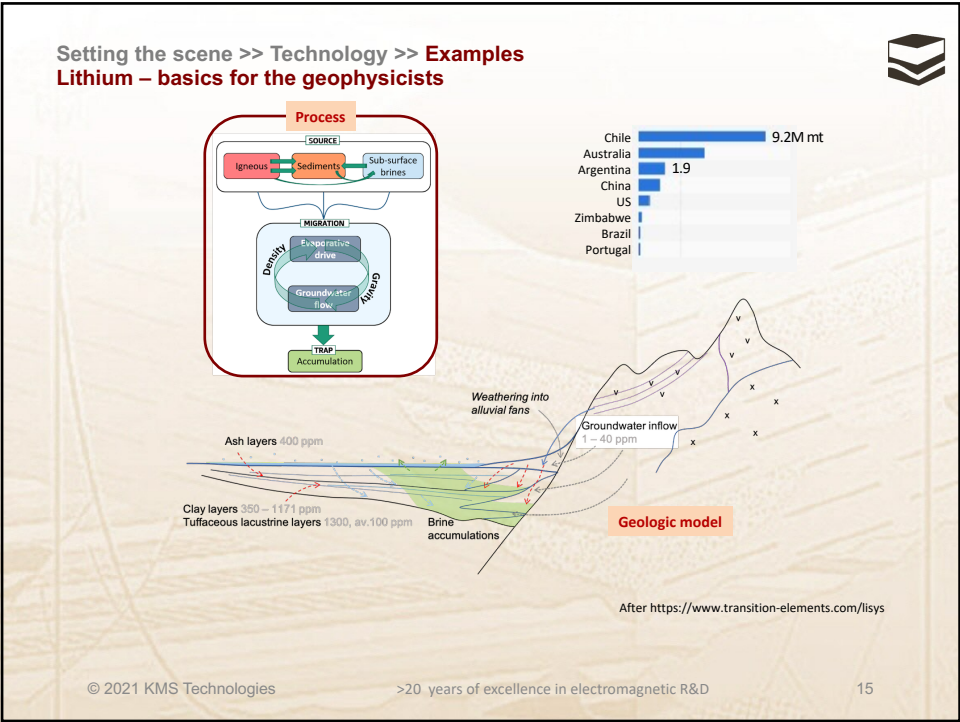
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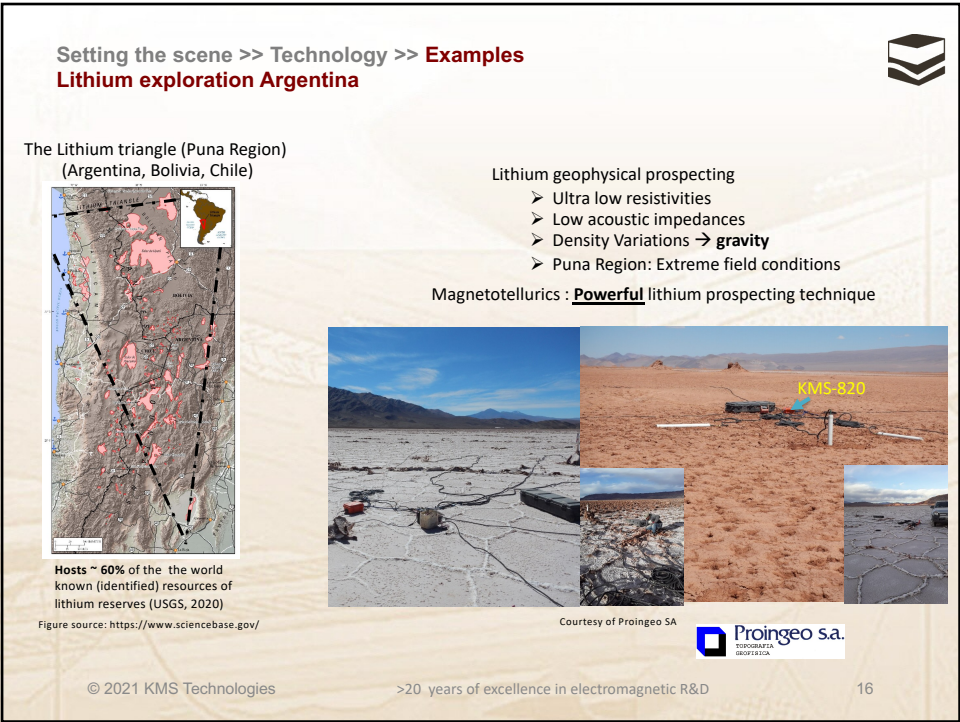
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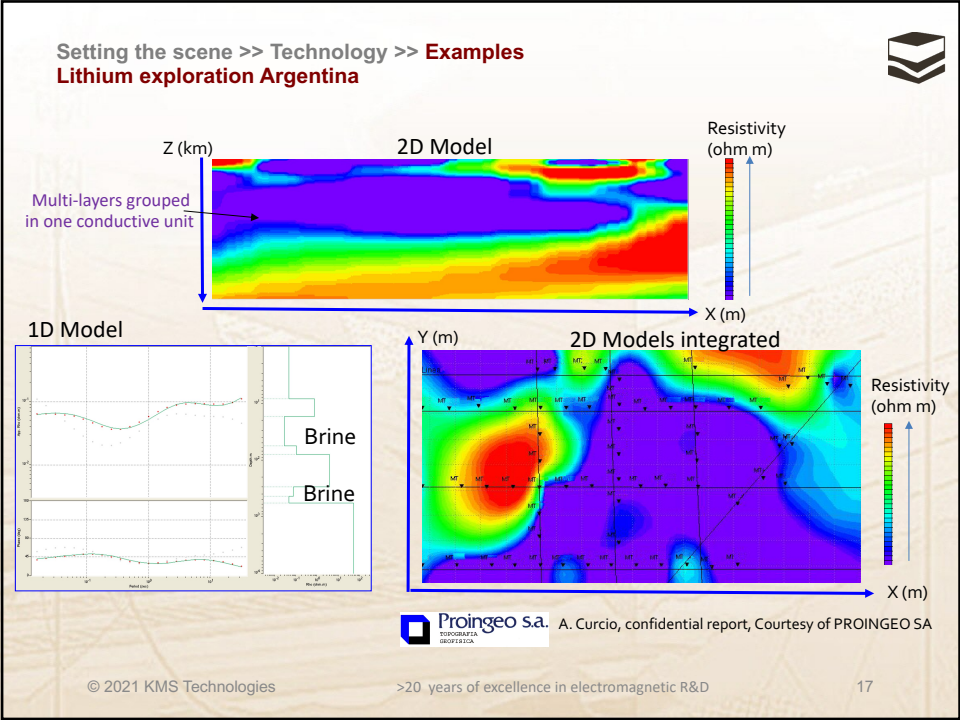
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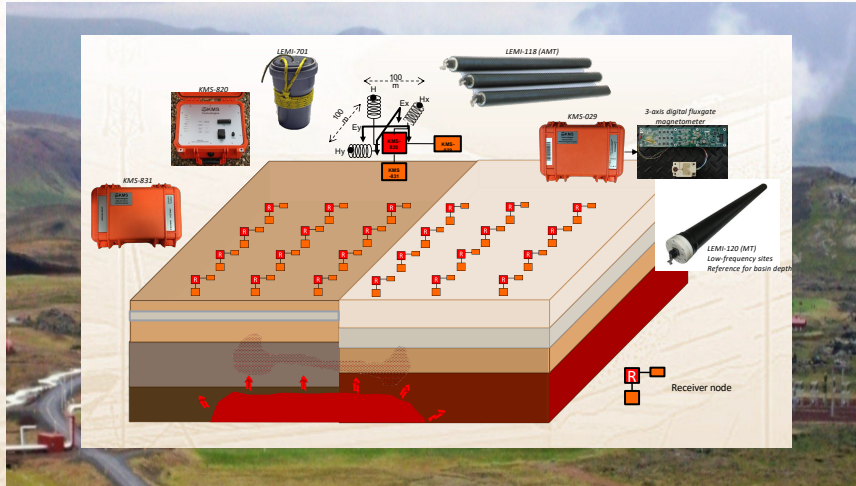


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Setting the scene >> Technology >> Examples
Geothermal: Hungary



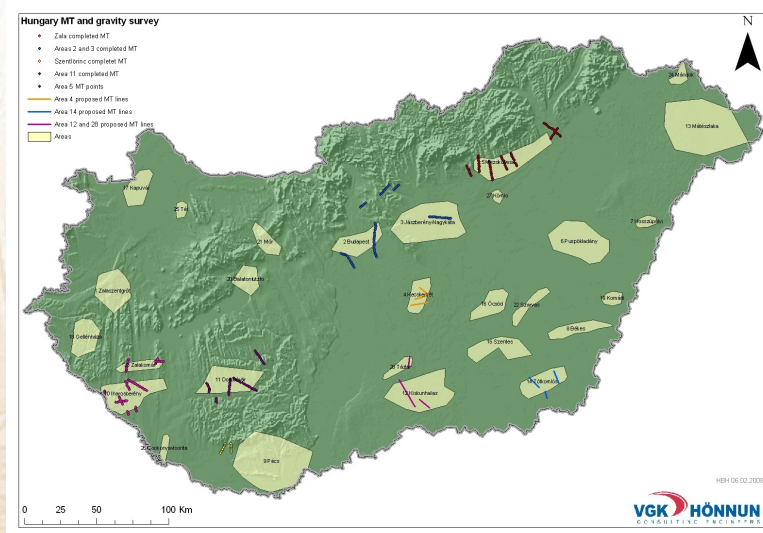
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Setting the scene >> Technology >> Examples
Geothermal: Hungary map



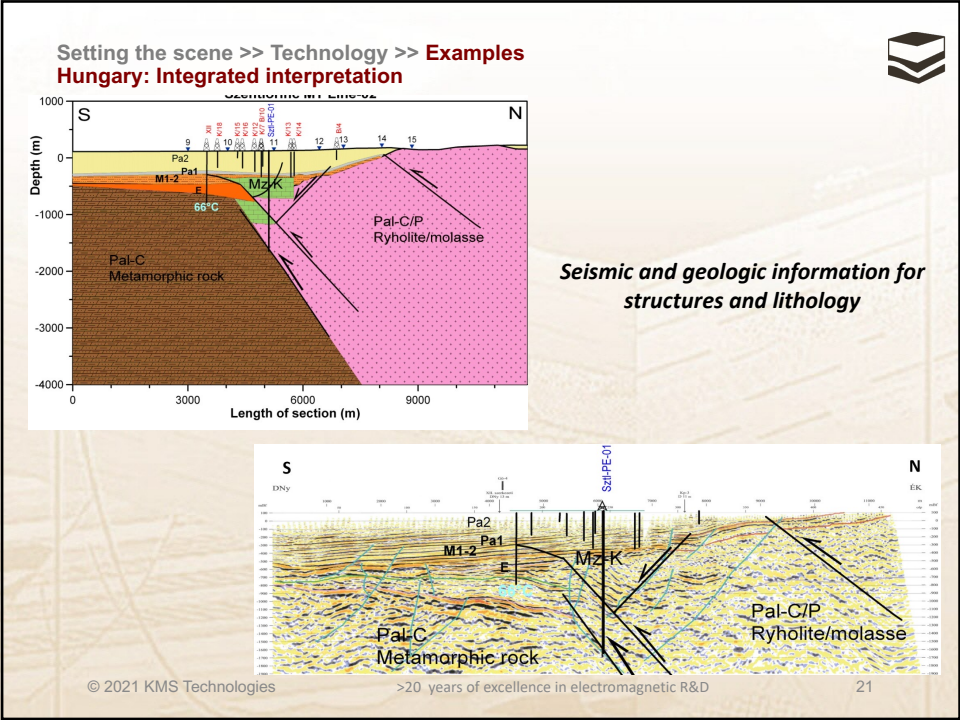
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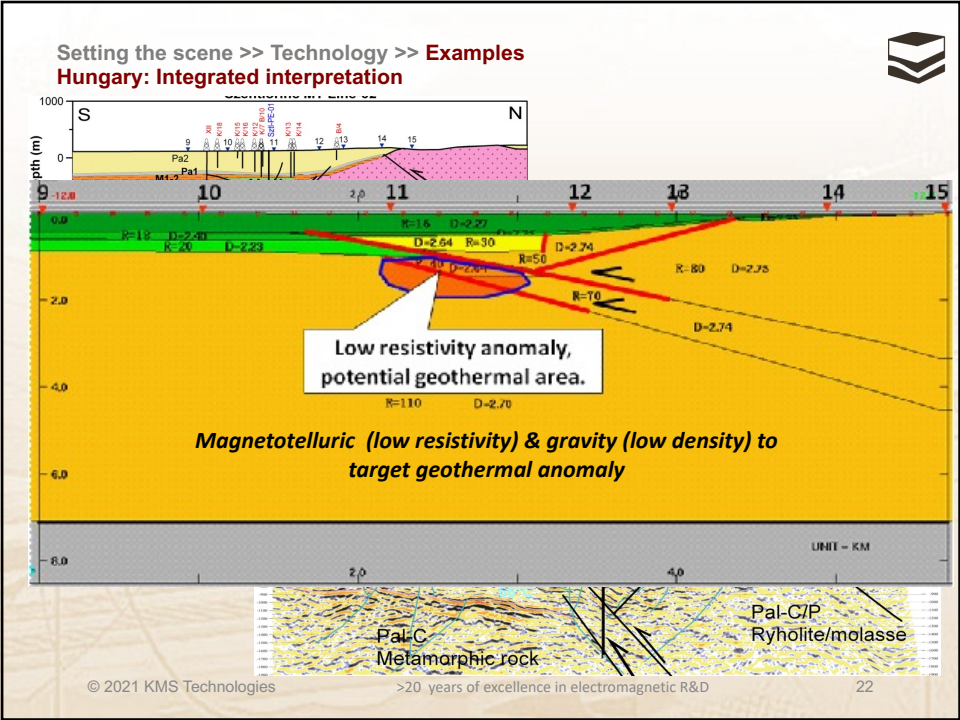
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Hungary: Drilling gives 3 MW

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Setting the scene >> Technology >> Examples

Carbon Capture, Utilization & Sequestration - CCUS

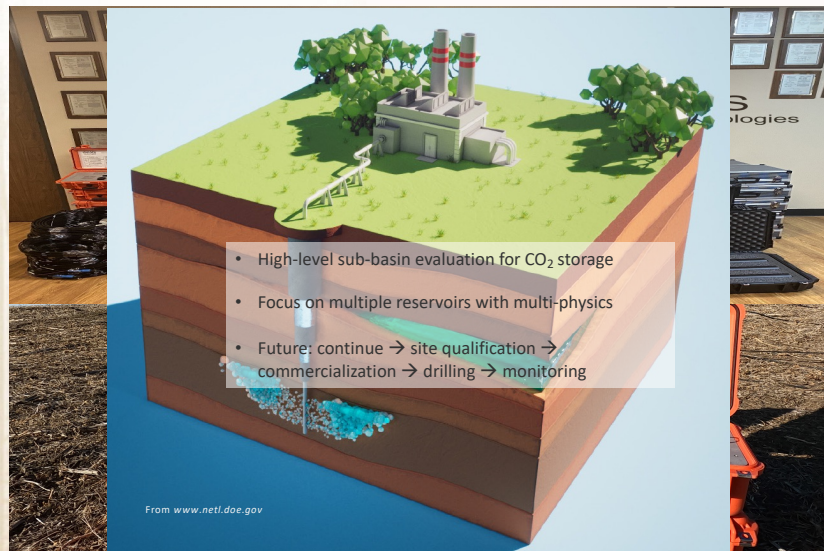
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Setting the scene >> Technology >> **Examples**
Carbon Capture, Utilization & Sequestration - CCUS



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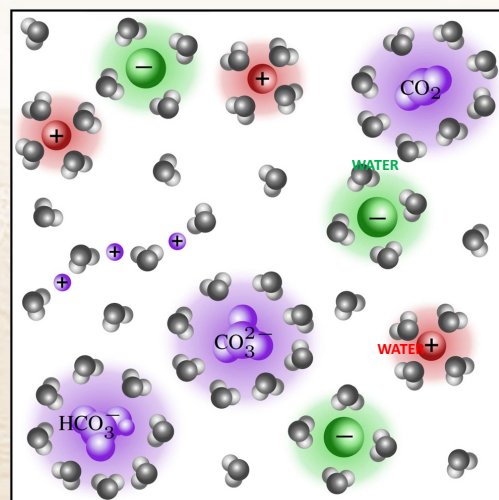
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Setting the scene >> Technology >> **Examples**
CCUS: CO2 influence on resistivity



- @ normal brine salinity → fluids are more resistive (6 -50 times)
- @ low salinity ($\leq 5,000$ ppm) → more conductive



After Boerner et al., 2015

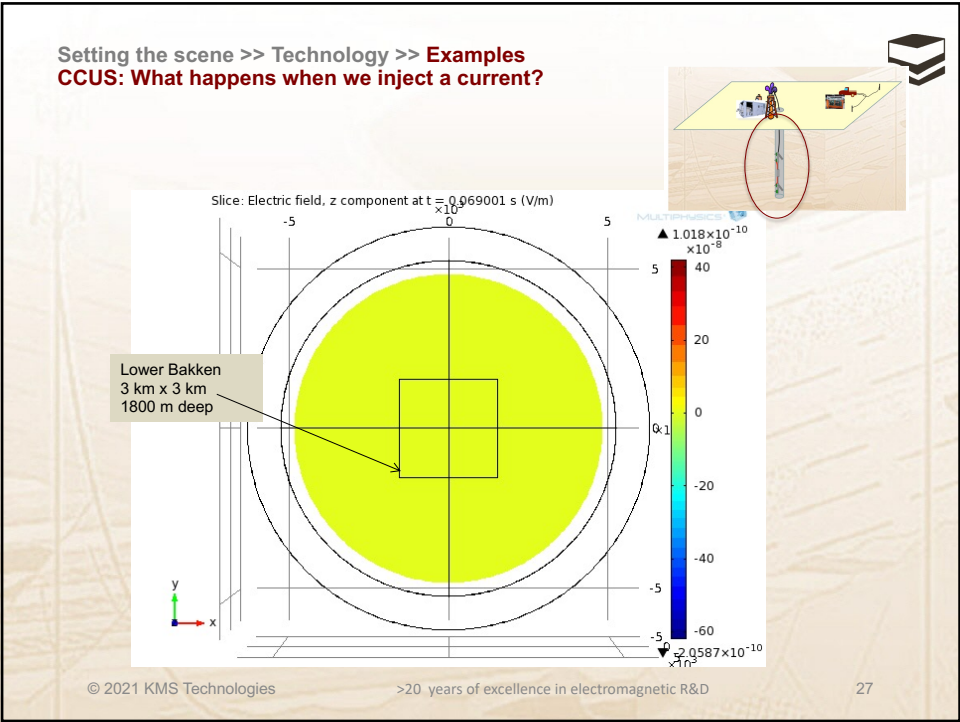
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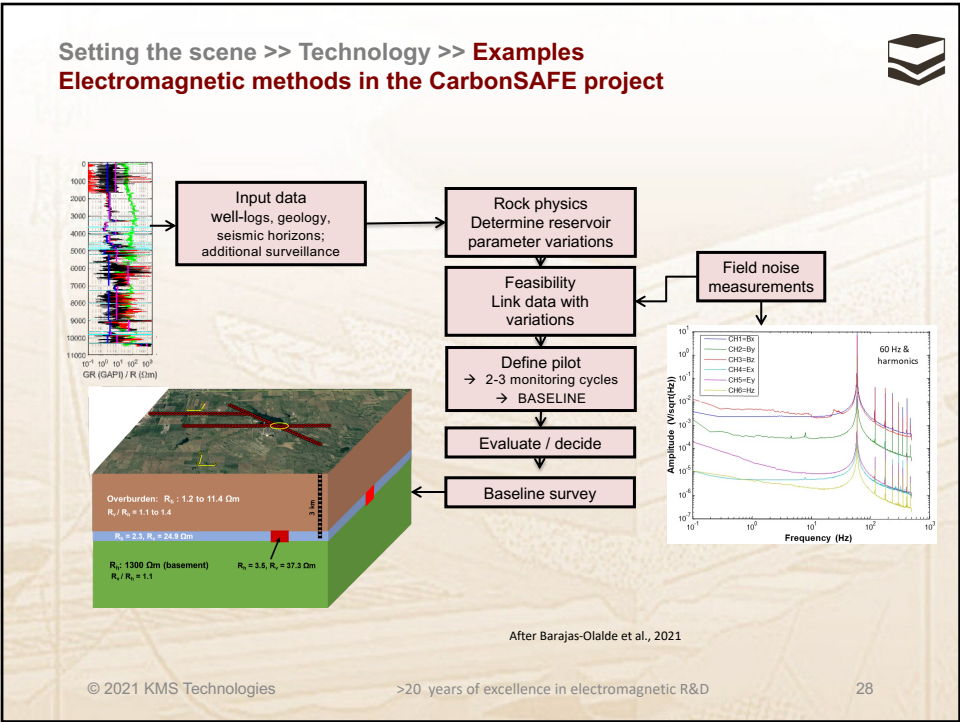
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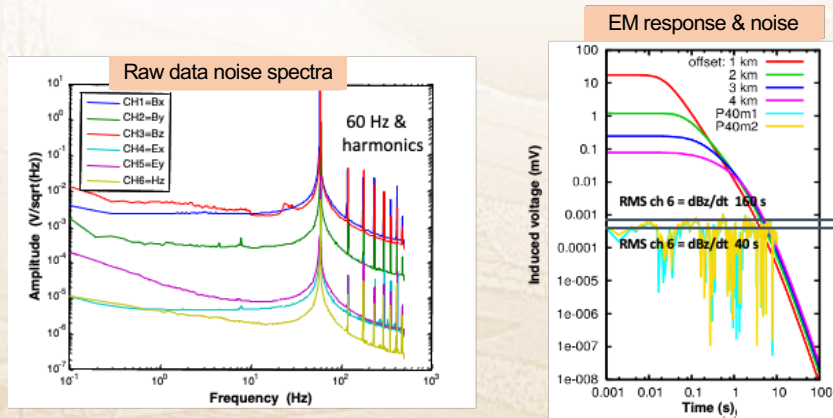


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Setting the scene >> Technology >> Examples
Field noise measurements



After Barajas-Olalde et al., 2021

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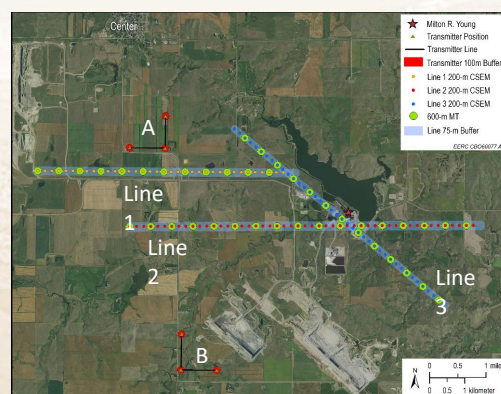
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Setting the scene >> Technology >> Examples
CarbonSAFE III: acquisition layout



- **MT**
 - To measure the model's baseline background resistivity
 - 42 Stations, 600 m spacing
 - Remote station near Grand Forks, North Dakota
- **CSEM**
 - 124 Stations, 200 m spacing
 - Two transmitter sites (A & B), 400 A
 - Time domain
- 24 hours operation – 6 weeks
- No equipment breakdowns
- Real-time data upload for QA
- Production: Pickups: 24, deployment: 16, fully recorded sites: 17 / day



After Barajas-Olalde et al., 2021

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Setting the scene >> Technology >> Examples

CarbonSAFE III: Acquisition options

- 24 hours operation for CSEM (versus Standard: Night – MT & Day CSEM)
 - More routine less operational problems
 - Generator stays warm
 - Electrode pit remain stable
 - High production rate
 - Q/A via Cloud enabled receivers
- **CON 24/7:** Processing more complex as data must be demerged by transmission cycle and then remerged with transmitter current



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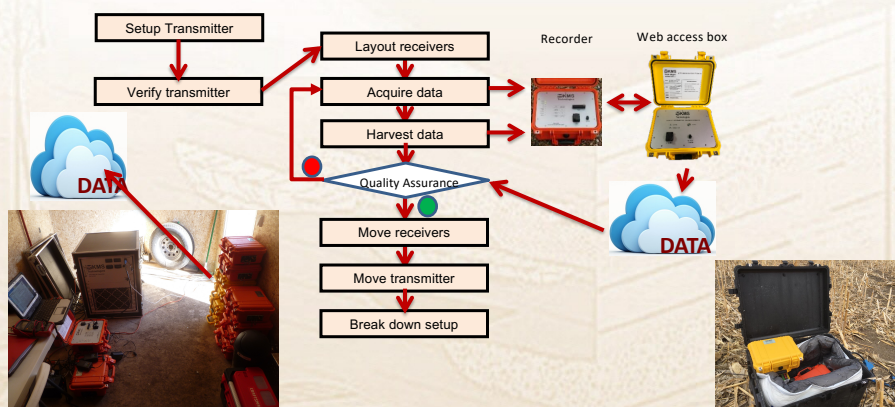
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Setting the scene >> Technology >> Examples

CarbonSAFE III: acquisition workflow



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Setting the scene >> Technology >> **Examples**
Summary



- EM technology developed from patent to interpretation
- Array system (sensors) used (MT and CSEM)
- Ideal for fluid imaging
- High contrast (Lithium) no problem
- Hoping for more use in Latin America

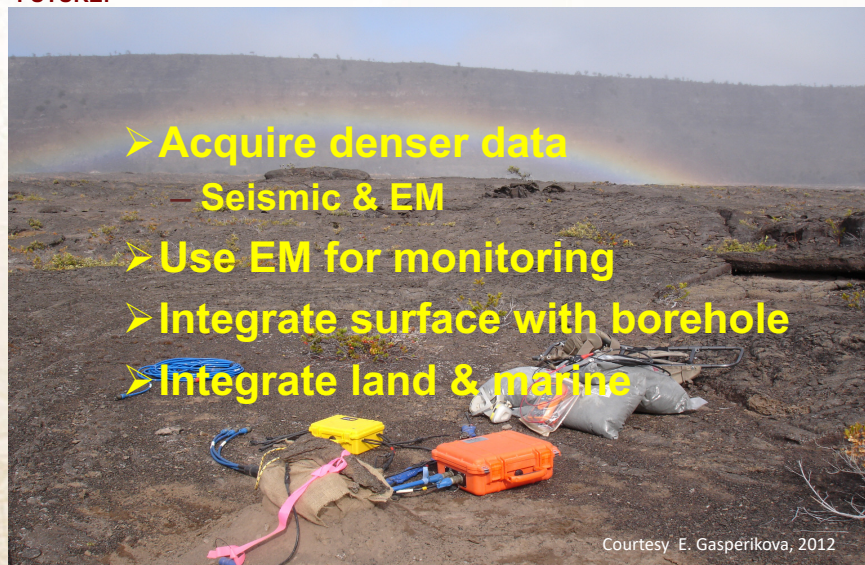
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Setting the scene >> Technology >> **Examples**
FUTURE:



- **Acquire denser data**
 - **Seismic & EM**
- **Use EM for monitoring**
- **Integrate surface with borehole**
- **Integrate land & marine**

Courtesy E. Gaspèrikova, 2012

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