



Passive and Active Electromagnetic Instrumentation Applied to Carbon Footprint Reduction

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


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OUTLINE



-  **Energy Transition Phase**
-  **Passive and Active EM Instrumentation**
-  **Supporting Technology for Remote EM Data QA/QC**
-  **Applications in the Energy Sector**
-  **Summary**

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Energy Transition Phase



- Aims to provide a sustainable energy **switch from traditional fossil energy sources to renewable energies** to reduce greenhouse gases (GHS) emissions.
- Hydrocarbon and Geothermal plays are **analogous** through their ratio of porosity and permeability. **Possible to transfer knowledge/technology** from hydrocarbon plays to geothermal plays and vice versa.
- **Geophysical monitoring is required.**
- **Passive and Active Electromagnetic (EM)** instrumentation/methods support the current and new workflows required to enable the integration, analysis, and data needed to reduce GHG emissions in the energy sector.



+ other renewable energies

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Passive and Active EM Instrumentation



Where is EM equipment deployed?
on land, boreholes, and marine settings.

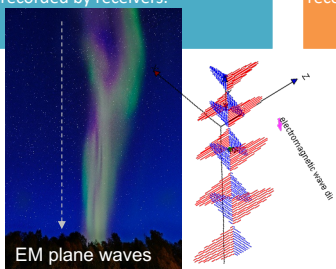
What do EM methods measure?
the magnetic and electric fields associated with natural or artificially generated subsurface currents.

Energy source type?
The nature of the energy source defines whether an EM method is passive or active.

What are Passive EM methods?
employ natural incoming plane waves as the energy source recorded by receivers.

What are Active EM methods?
require a controlled or artificial energy source (transmitter) and receivers.

Passive and Active EM instrumentation can mix and matched in a **modular fashion.**



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Passive and Active EM Instrumentation

Passive EM instrumentation (AMT & MT)

Layout (AMT station or MT station)

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- **Passive EM** uses natural EM plane waves as energy source recorded by receivers (LEMI-118, LEMI 120).
- **Passive Methods:**
 - **AMT (Audio-Magnetotelluric)**
 - ✓ operates at 1-70 kHz band
 - ✓ investigation depth: 50 m to ~1 km
 - **MT (Magnetotelluric)**
 - ✓ operates at 0.0001-1 kHz and 0.0001-10 kHz
 - ✓ investigation depth: 0.3-200 km and 1-200 km
- **Near real-time Remote EM Data QA/QC** is possible
- **Multi-station AMT/MT arrays** deployable for conventional 1D/2D/3D or Time-Lapse 2D and 3D surveys.

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Passive and Active EM Instrumentation

TRANSMITTER STATION

RECEIVER STATION

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Active EM instrumentation Layout (CSEM)

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Supporting Technology for Remote EM Data QA/QC

- Layered-cloud solution (station components)
- Works for **Active** and **Passive** surveys worldwide!

Remote Access EM Station Setup

TOOLS:
 AI – Artificial Intelligence: Some form of neural Net (NN) delivering INSTANT results
 Deep Learning – feedback & continued learning of the AI

IMAGE LAYER:
 Deep learning 3D images

OPERATIONS:
 Analytics, Operations

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Applications in the Energy Sector

Carbon Capture Utilization, Storage & Monitoring (CCUSM)

SOURCE: Vattenfall / World Coal Institute

Enhanced Oil Recovery (EOR)

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Geothermal Exploration

Geothermal Energy Production

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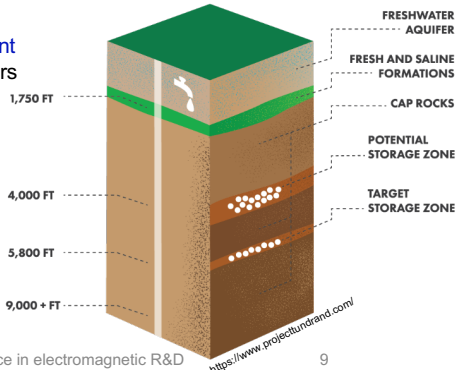
Applications in the Energy Sector

***Permanent CCUSM at coal-based power plant in North Dakota, USA**

- Designed to capture 90% of CO₂ produced
- Capture rate ≈ ~4 million metric tons/year ≈ removing 800K gasoline-fueled cars off the road
- Now in Phase III (site charact. & permitting)**

Phase III:

- Purpose:** Drilling another exploratory well and conducting geophysical surveys around power plant
- Goal:** to gather geologic data on 3 sandstone layers 1.5 to 3 km below the surface; needed to address CO₂ injection and storage
- Geophysical surveys:**
 - Seismic + Gravity
 - Electromagnetics (EM):**
 - ✓ LOTEM survey established electrical conductivity baseline for future CO₂ injection and monitoring



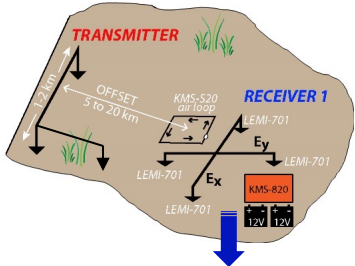

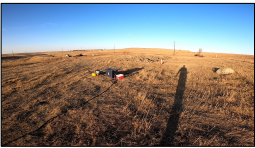


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Applications in the Energy Sector

Active EM Survey: CCUSM at coal-based power plant

Goal: LOTEM survey to establish electrical conductivity baseline for future CO₂ storage and monitoring

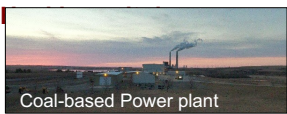








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Background & physics >> Methods >> Example >> issues & path forward

CarbonSAFE III: Field operations – field test



Coal-based Power plant



Receiver station set up for Data Collection (video)

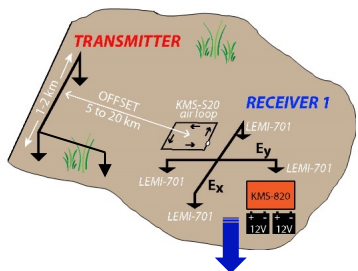



Diagram illustrating the receiver station setup. It shows a transmitter and receiver (RECEIVER 1) separated by an offset of 5 to 20 km. The receiver station includes a KMS-820 unit and two 12V batteries. The diagram also labels the transmitter, receiver, and various components like LEMI-701, KMS-520 air loop, and field components Ex and Ey.



Receiver station set up


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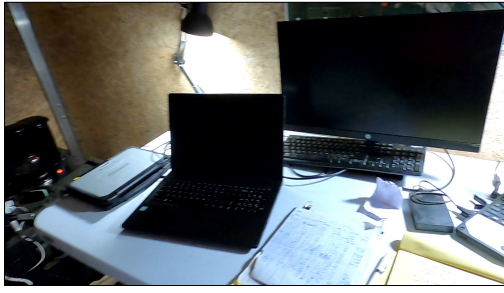
Applications in the Energy Sector

Active EM Survey: [CCUSM](#) at coal-based power plant

Goal: LOTEM survey to establish electrical conductivity baseline for future CO₂ storage and monitoring



Transmitter station set up



Indoors: Transmitter station (video)

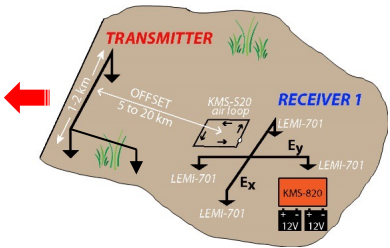



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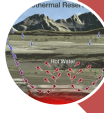
Transmitter station set up

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Applications in the Energy Sector





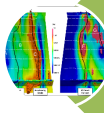
Geothermal Exploration

- Shallow (< 2 km)
- Deep (2-6 km)
- Any Tectonic Setting
- Any Geothermal Play Type (geology)



In Developing and Producing Geothermal Fields

- Porosity mapping within carbonate reservoirs
- Image hot/cold section of reservoir
- Monitoring purposes
 - ✓ Flood front (steam, water, and CO₂)
 - ✓ Fluid injection and migration in reservoir
 - ✓ Induced-seismicity




EM Methods Complement Traditional Deep Exploration Techniques


- Seismic
- Gravity
- Magnetics
- Borehole geophysics

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Summary







In the energy transition phase, and beyond, **EM geophysics** will be incrementally used for **carbon footprint reduction** while simultaneously supporting the exploration and development of geothermal energy.




CCS and EOR operations store carbon underground; however, their life-cycles require customized **geophysical monitoring workflows**.



EM methods have a superior sensitivity to the **bulk resistivity/conductivity** resulting from changes in the reservoir fluid (hydrocarbon and geothermal) than any other geophysical method.



Passive (AMT, MT) and Active (LOTEM) EM instrumentation can monitor fluids' injection and propagation patterns in a carbon-storing formations or in a geothermal producing field.



In areas w/ high cultural noise, **Active EM methods are more efficient** than Passive EM methods.

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