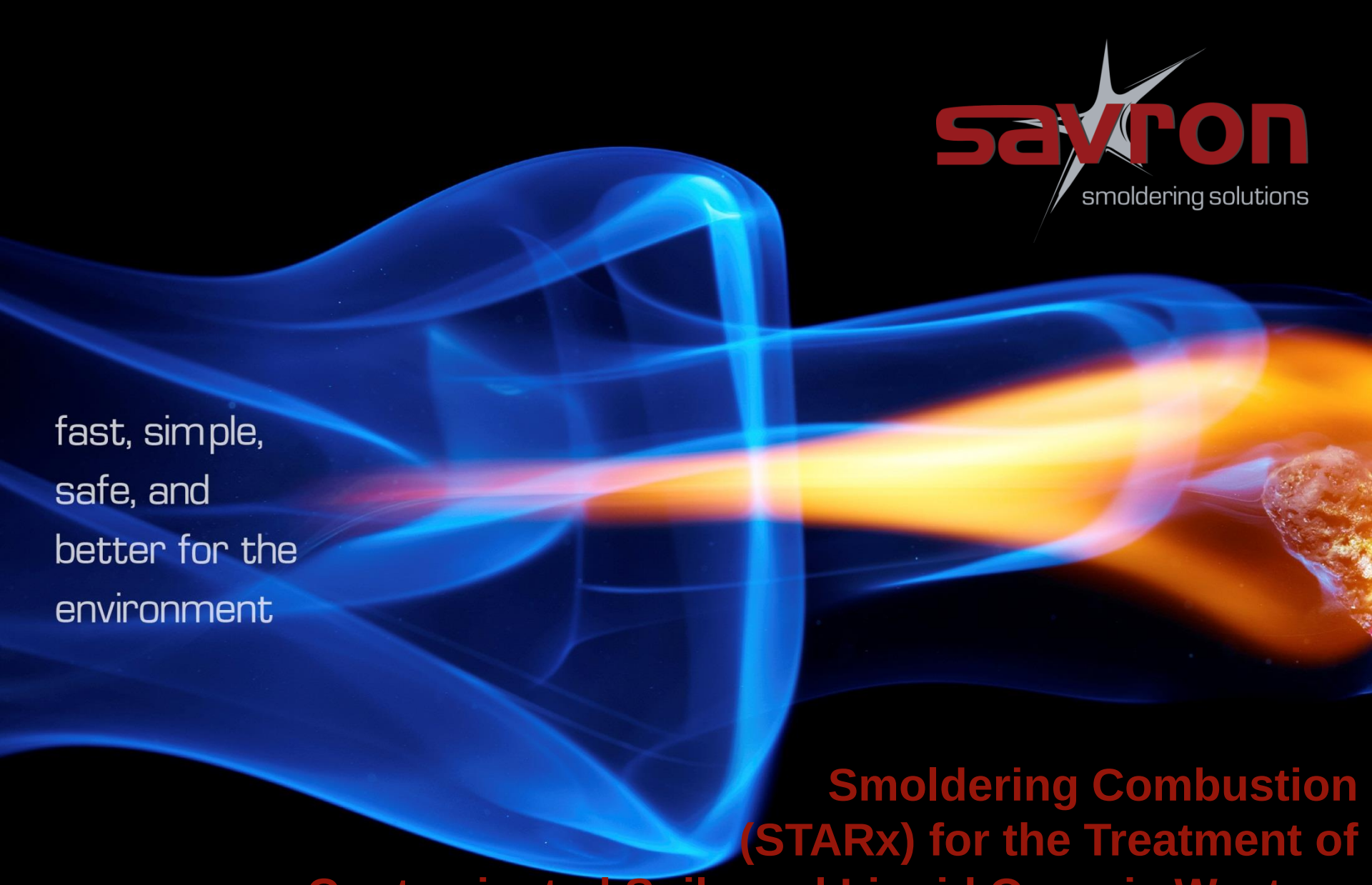

Smoldering Combustion (STARx) for the Treatment of Contaminated Soils and Liquid Organic Wastes– From Prototype to Full Scale Application

Presented by: Grant Scholes, M.E.Sc., P.Eng.

Overview

- **Smoldering Combustion Basics**
- **Modes of Application**
- **Case Study**
  - STARx from prototype to full scale
- **Summary**

Smoldering Combustion

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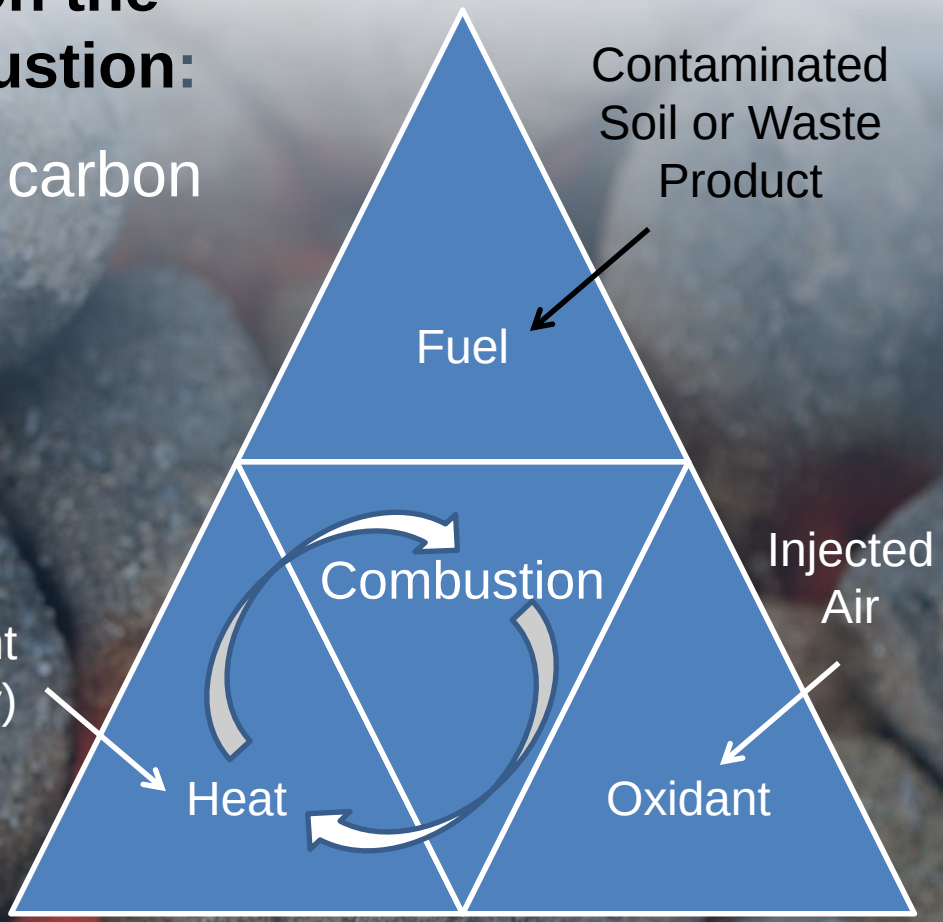
Smoldering Combustion

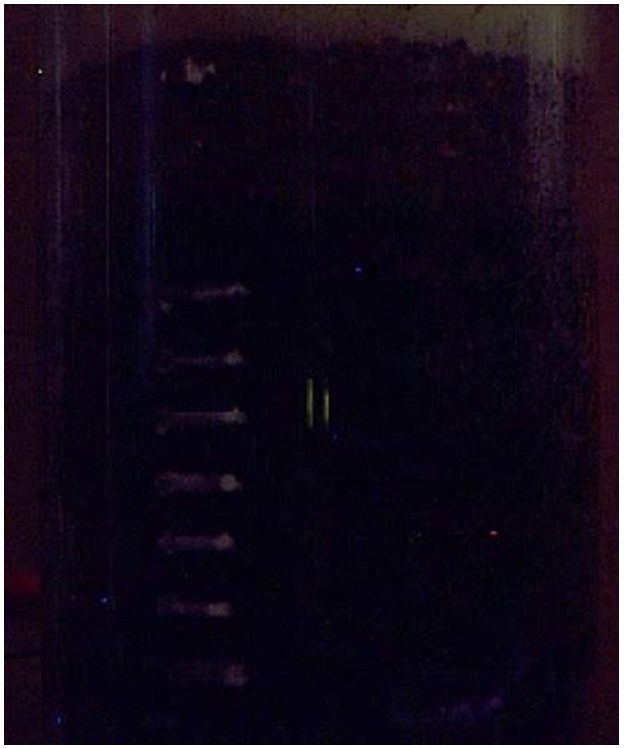
STAR and STARx are based on the process of smoldering combustion:

Exothermic reaction converting carbon compounds to $CO_2 + H_2O$



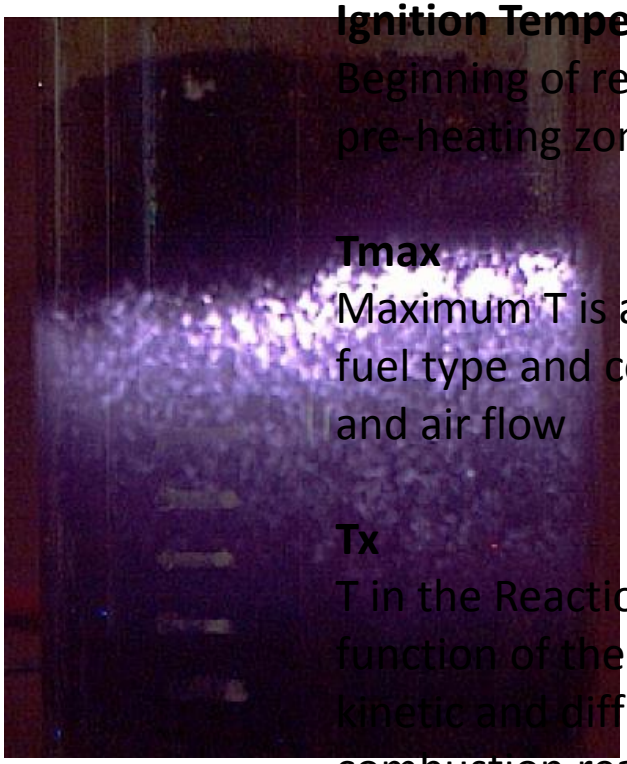
Smoldering possible due to large surface area of organic liquids (e.g., NAPL) within the presence of a porous matrix (e.g., aquifer)

Smouldering Combustion



Video accelerated 50 times

Smouldering Combustion



Ignition Temperature (Ts)
Beginning of reaction zone vs pre-heating zone

Tmax
Maximum T is a function of fuel type and concentration and air flow

Tx
T in the Reaction Zone is a function of the position of the kinetic and diffusion-limited combustion reactions

Video accelerated 50 times

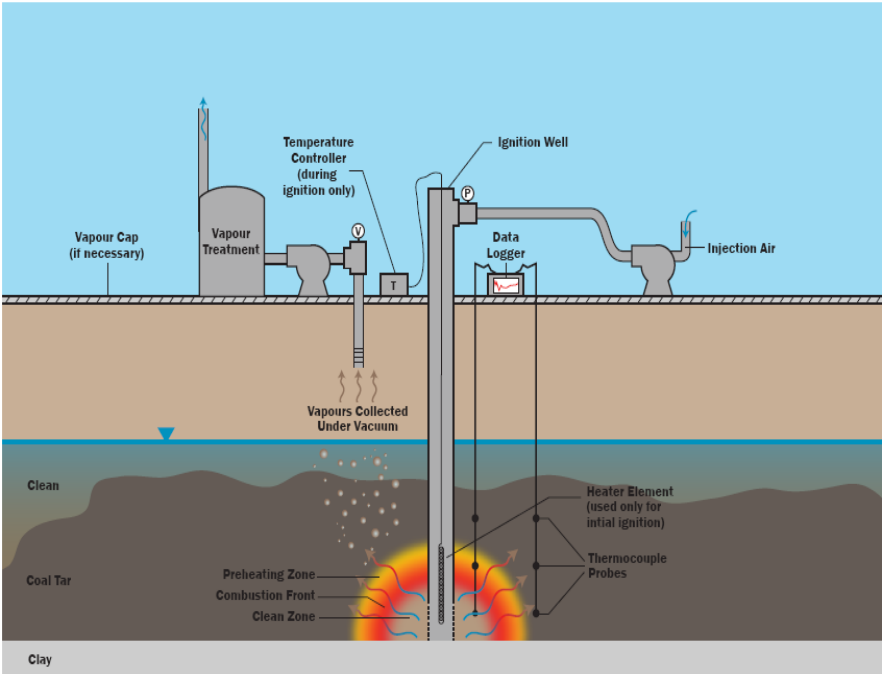
Smoldering Combustion

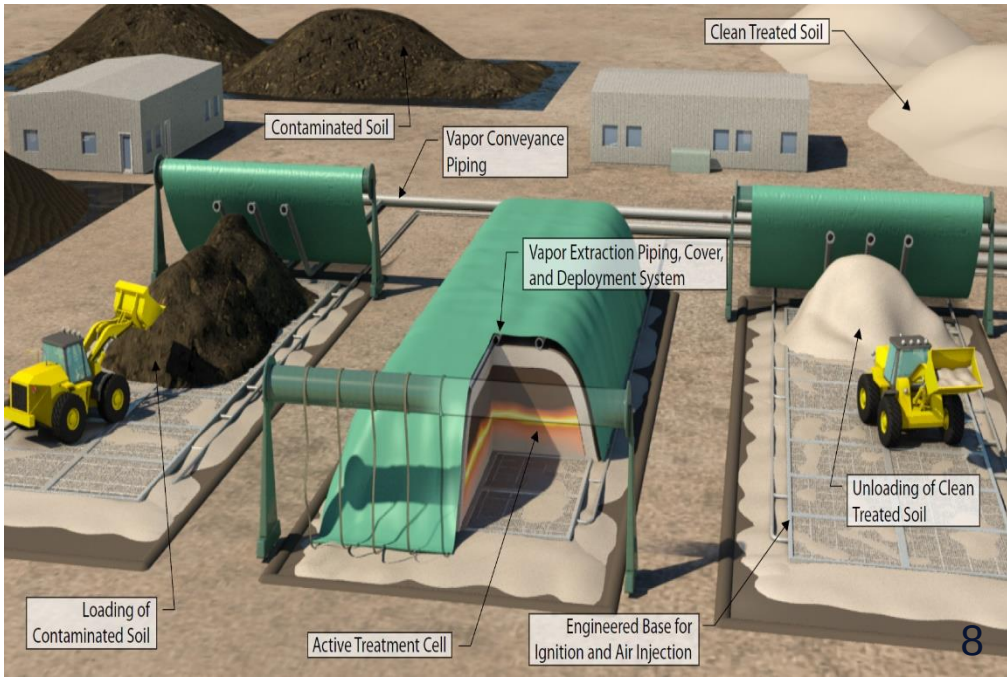
Typical transformation of soil undergoing STARx process:

Modes of Application

- **In situ (below water table)**
  - Applied via wells in portable in-well heaters

- **Ex situ (above ground)**
  - Soil piles placed on “Hottpad” system





STARx

Case Study: “Hottpad” System for the treatment of oil-water separator sludge

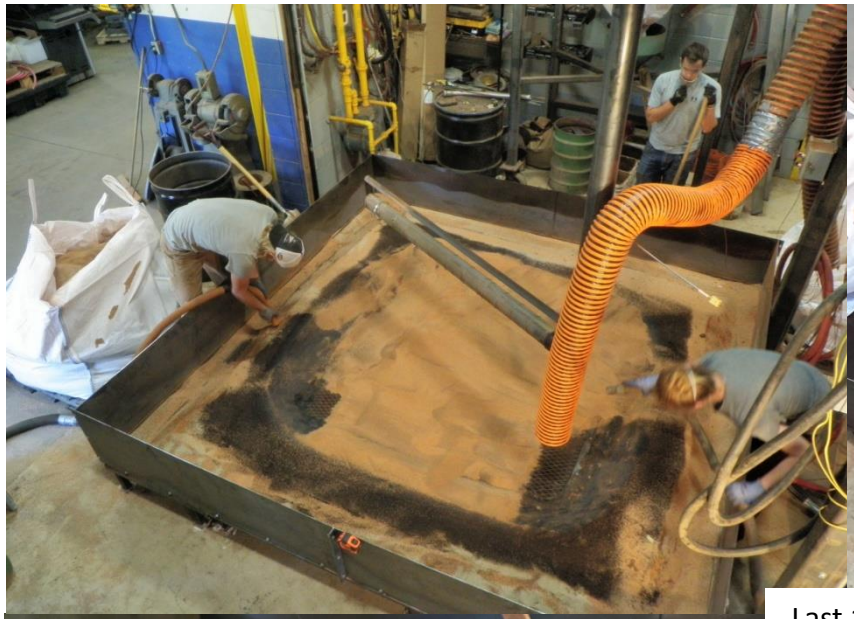
with Dave Thomas and
Gabriel Sabadell, Chevron ETC

Site Background

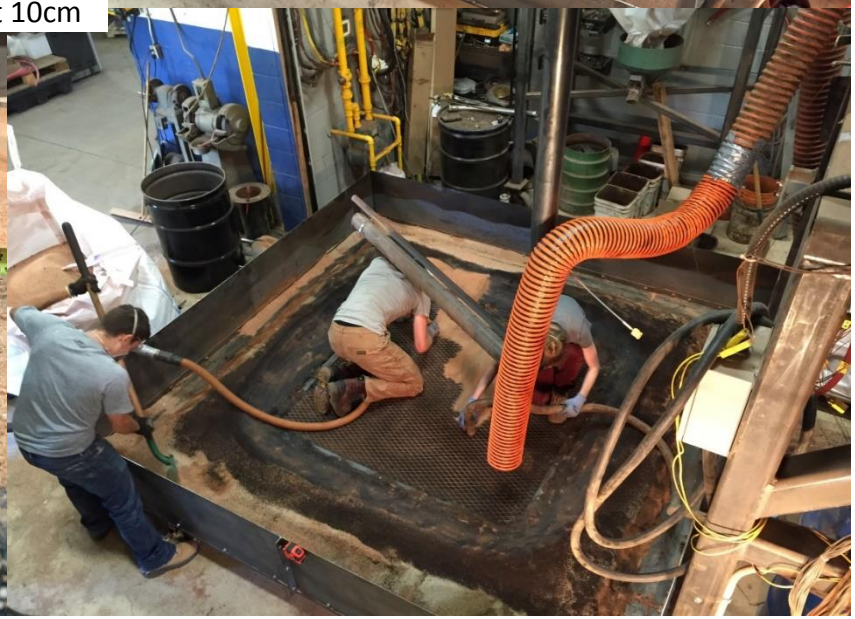
- Active terminal facility in south east Asia
- Designed to treat for 3,500 m^3 of stockpiled API separator sludge
- Co-treatment with Petroleum hydrocarbon-impacted site soils

Hottpad Prototype Testing

Hottpad Prototype Testing



Last 10cm

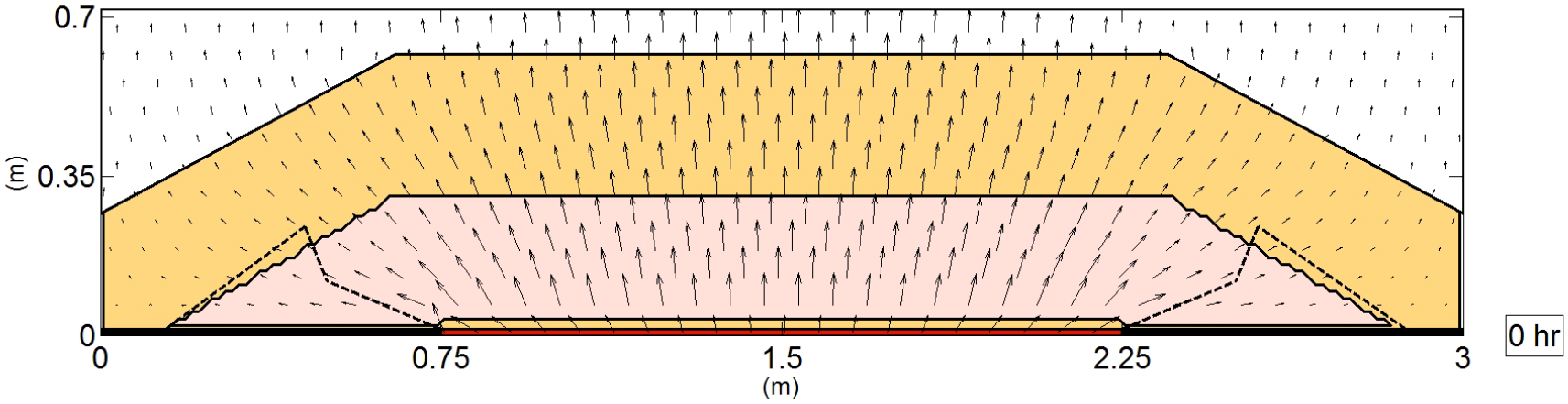


Modeling

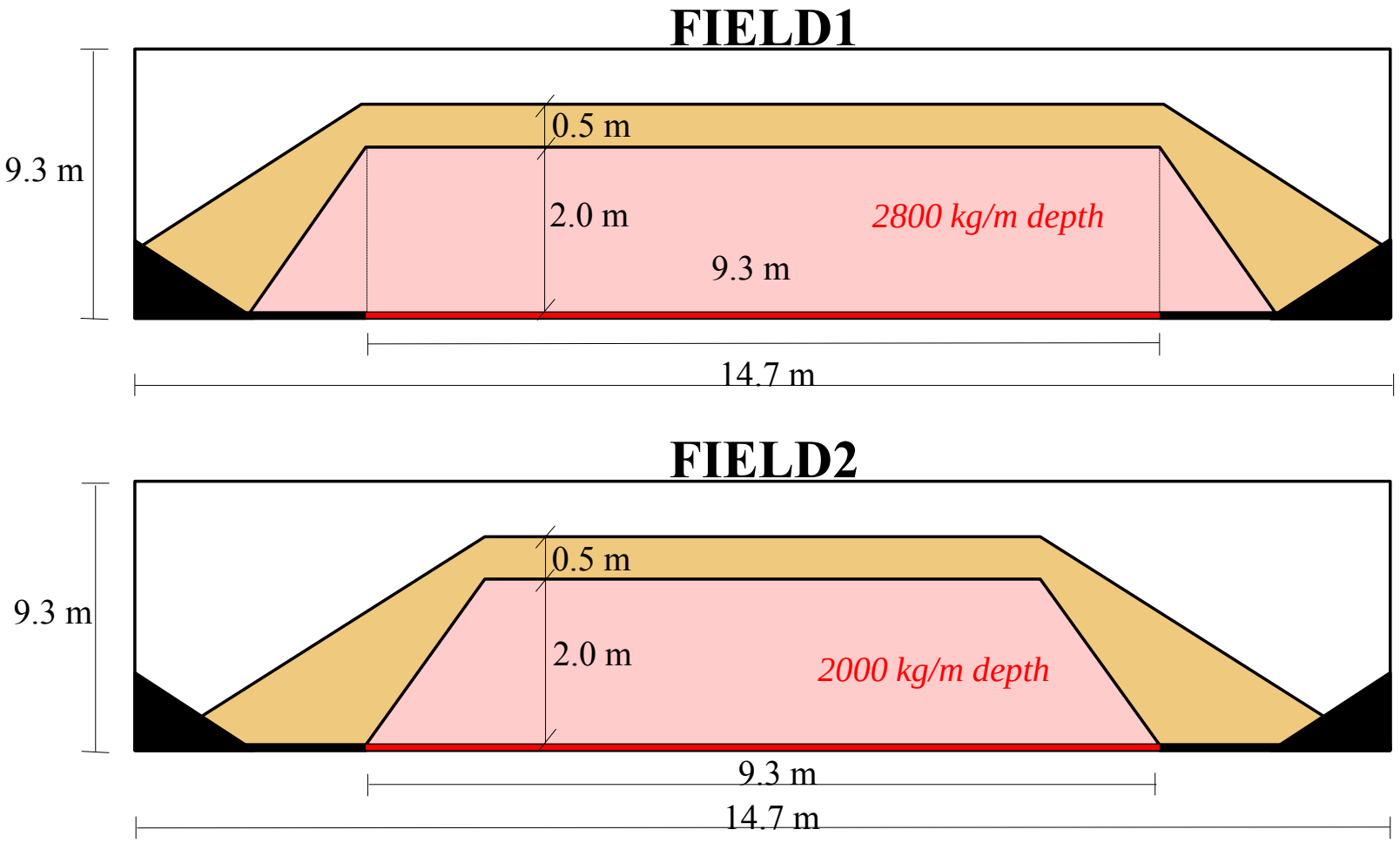
1. **Model calibration and validation against prototype tests**
2. **Predict the effects of:**
   - Injected air flux
   - Contaminant pack saturation
   - Hottpad configuration
   - Heterogeneity in contaminant saturation & soil permeability
3. **Approximate treatment masses & times expected at the field-scale for a system operated under similar conditions**

Model Calibration

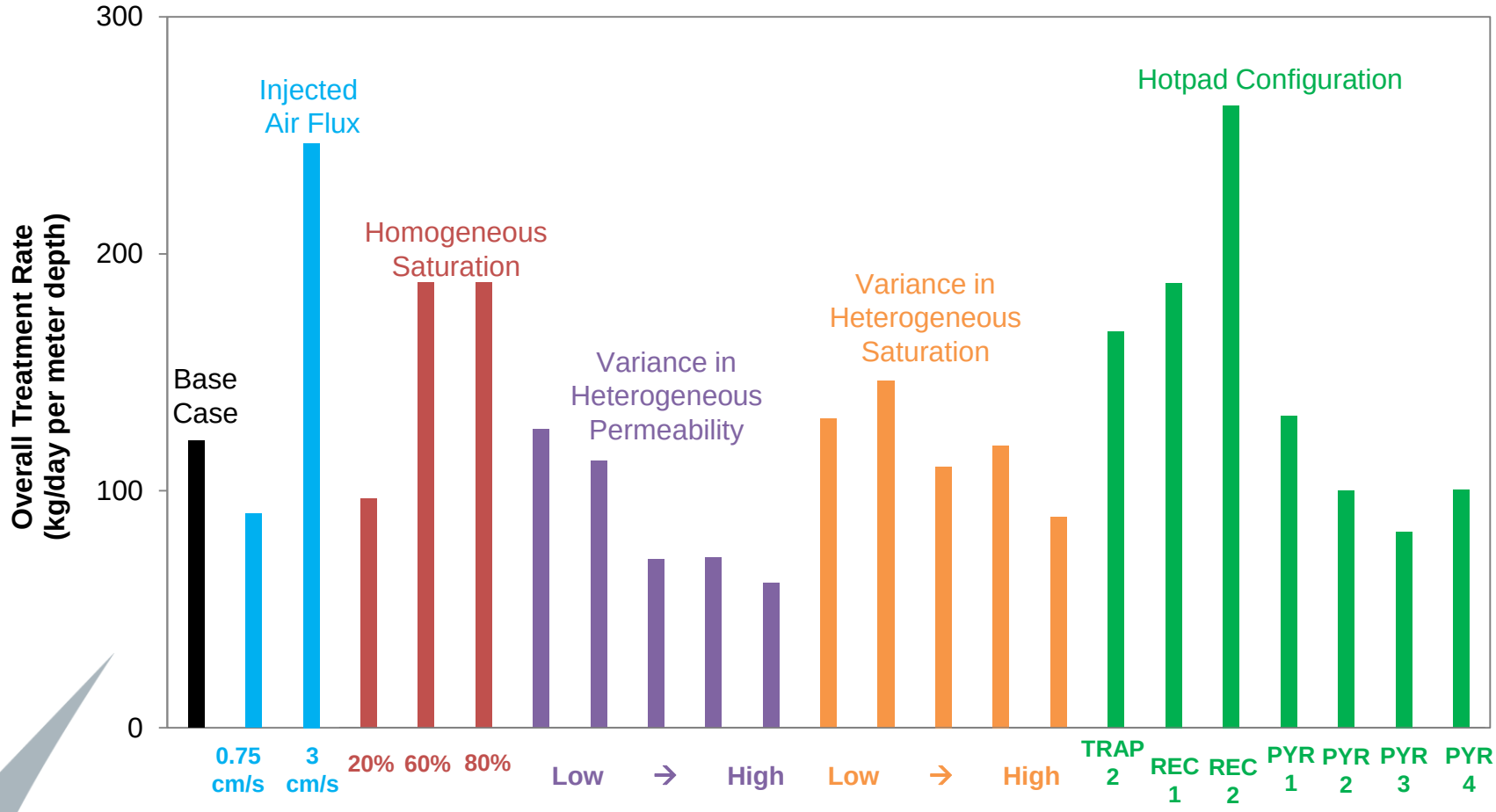
Extent of treatment ✓ **Vertical Smouldering Velocity ✓** **Time of Treatment ✓**



Predicting Full-scale Performance



Sensitivity Analysis



Full-scale Hottpad – Base Unit

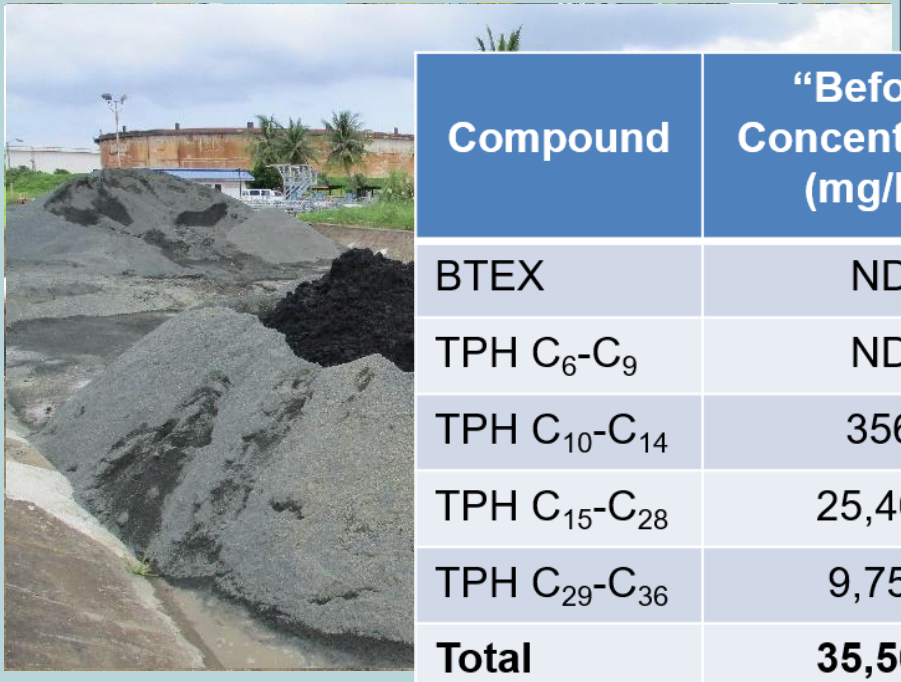
Field Deployment

Full-scale Hottpad – Field Deployment

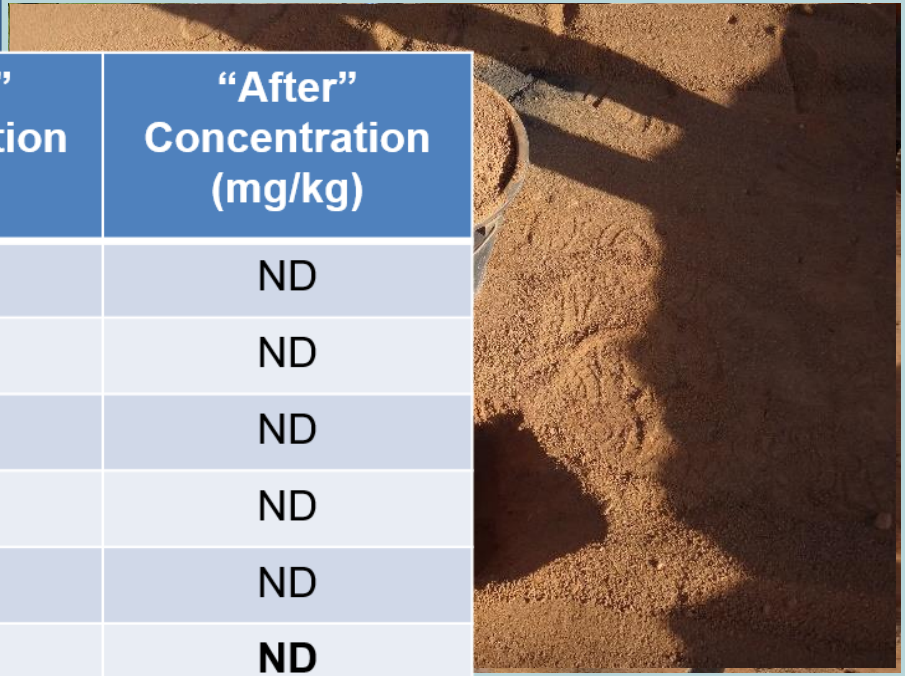
Operation and Monitoring

- **Combustion Tracking**
  - Real time thermocouple and combustion gas analysis
- **Process Equipment Monitoring**
  - Flow and pressure monitoring
  - Vapour treatment system monitoring
  - Power and control system monitoring/optimization
- **Treatment Monitoring/Efficiency**
  - Pre/post laboratory analysis
  - Economic analysis

Full-scale Hottpad - Results



Compound	"Before" Concentration (mg/kg)	"After" Concentration (mg/kg)
BTEX	ND	ND
TPH C_6-C_9	ND	ND
TPH C_{10}-C_{14}	356	ND
TPH C_{15}-C_{28}	25,400	ND
TPH C_{29}-C_{36}	9,750	ND
Total	**35,506**	**ND**



Before

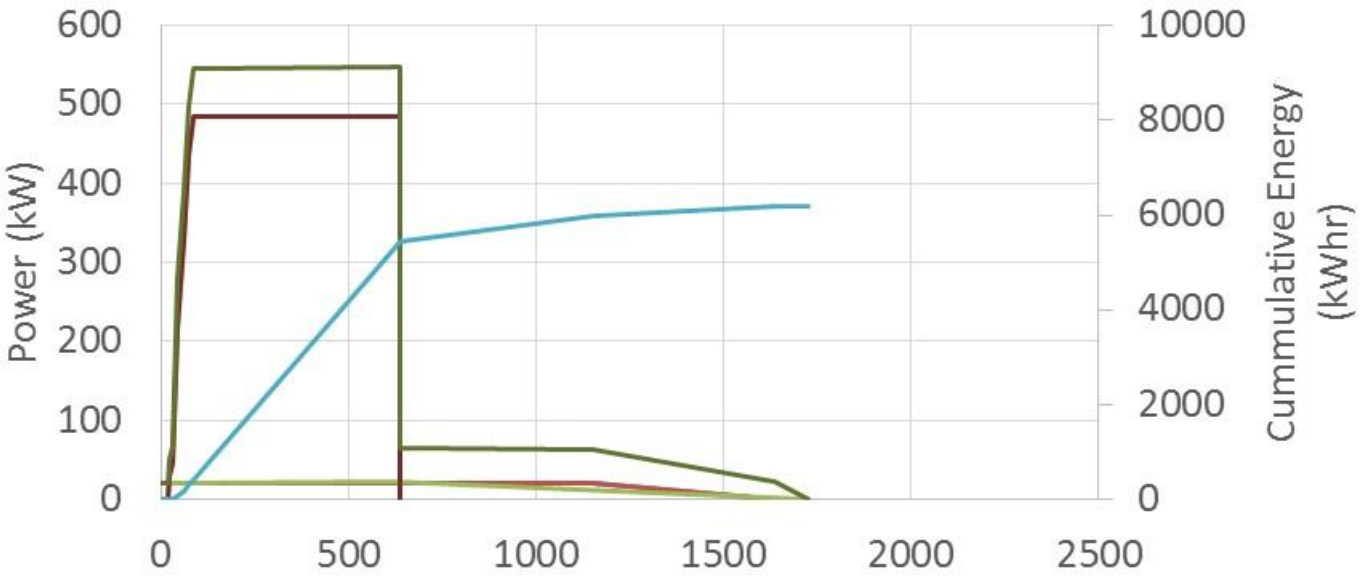
After

Example – Process Optimization

Example – Process Optimization

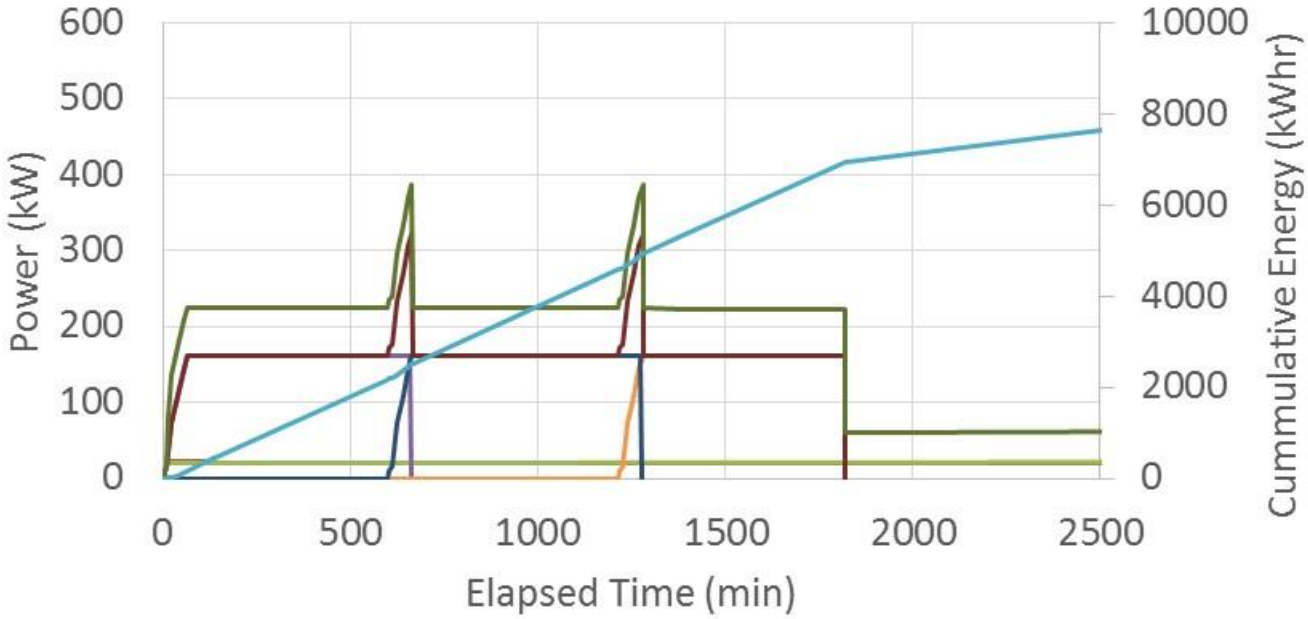
TEST 1

- Operate all pad heaters simultaneously
- High peak load during heating, followed by low demand for duration of process

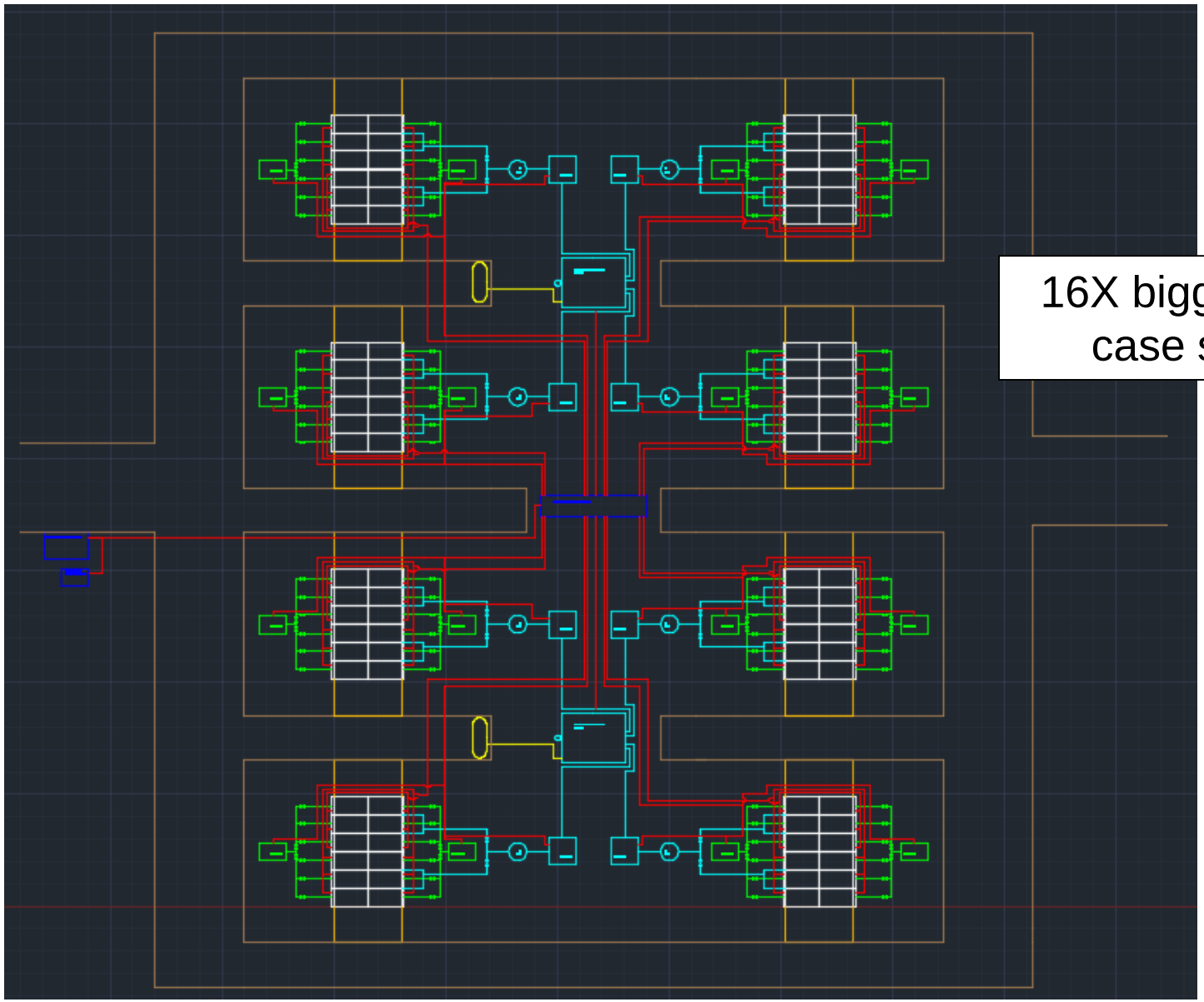


TEST 2

- 'Rolling start'system monitoring
- Reduced peak power
- More steady power load
- = smaller service demand and ultimately more efficient process



Process Optimization



16X bigger than case study

The STARx Advantage

- **Safe**
  - Controllable process
  - Stationary / small / “standard” equipment
- **Reduced cost versus other technologies**
- **Rapid and flexible**
  - Modular STARx systems fully expandable to meet target throughput
- **Complete treatment**
- **Sustainable**

Upcoming Projects

- **Waterfront Toronto – Portlands**
  - Dual STAR / STARx pilot test
- **Brazil**
  - STARx for Chloronitorbenzene compounds
- **Taiwan**
  - Just completed – STARx pilot for oil and gas site
- **South East Asia**
  - Continued full scale operations and process optimization (Case study site)
  - Pilot program and full scale design for STARx in an active oil field
- **Numerous STAR projects**
  - New Jersey, Taiwan, Canada, etc.

Acknowledgments

- Dave Thomas, Chevron ETC
- Gabriel Sabadell, Chevron ETC
- David Major, Savron
- Gavin Grant, Savron
- Cody Murray, Savron
- Warren Ferguson, Savron
- Laura Kinsman, Savron
- Ben Boulay, Savron
- Jorge Gabayet, Savron

Questions?

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