# Greenhouse gas emissions from oil production: Insights from an open-source modeling effort

Kourosh Vafi, Adam R. Brandt

Department of Energy Resources Engineering
Stanford University

Acknowledgements: Hassan El-Houjeiri, Jim Duffy, Scott McNally

2013 CRC Life Cycle Analysis of Transportation Fuels Workshop
Argonne National Laboratory
October 15-17th, 2013

# Outline

1. Introduction
2. Work to date and initial results
3. Current work: model verification and cross-comparison
4. Future applications

# Introduction

- Goal: Build an open-source, fully public LCA tool for the estimation of GHG emissions from oil production operations
  - Funded by California Air Resources Board
- Developed the ***Oil Production Greenhouse Gas Emissions Estimator (OPGEE)***

# OPGEE modeling goals

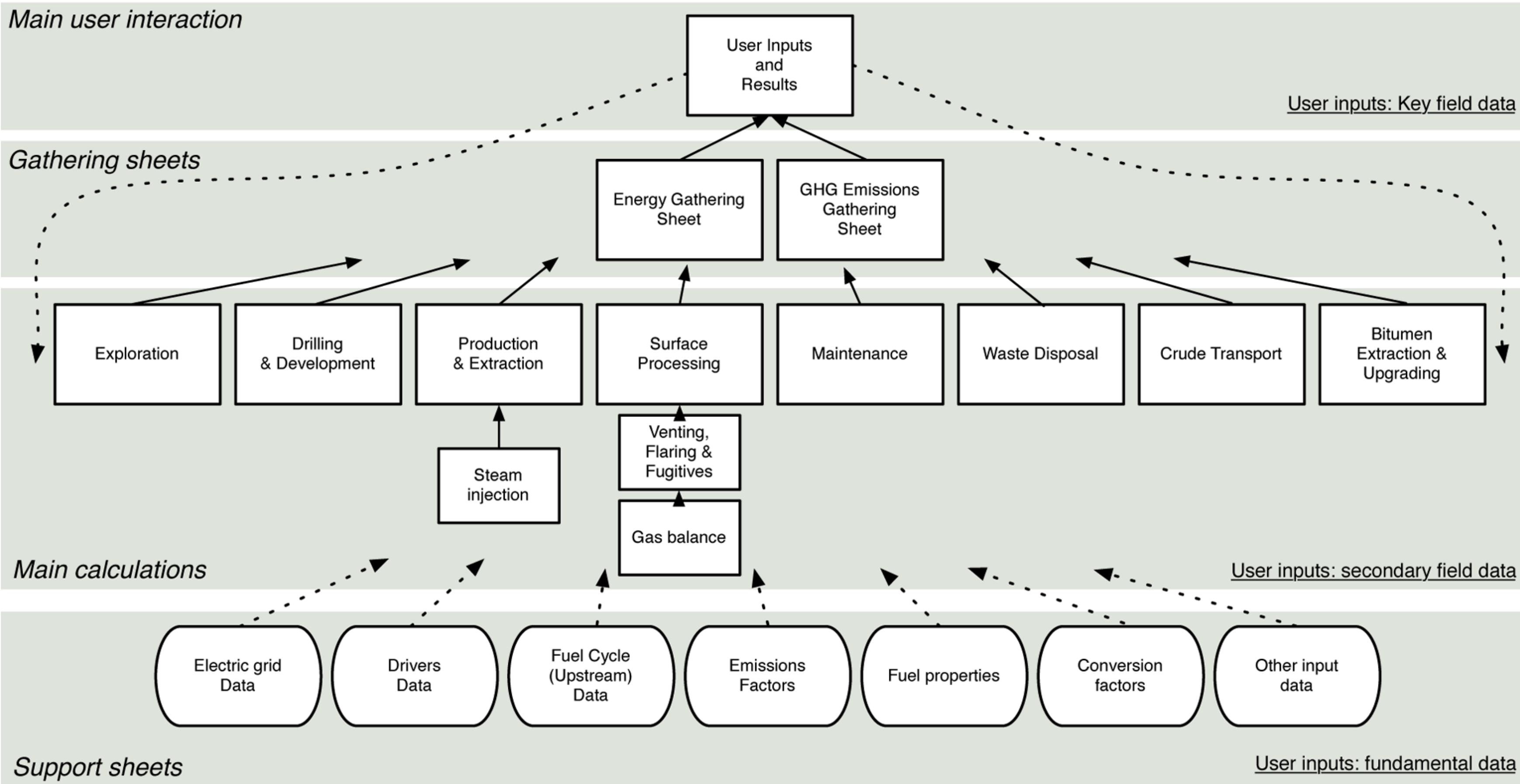
Improve crude oil GHG modeling in 5 ways:

1. Build a rigorous, engineering-based model of GHG emissions from oil production operations
2. Use disaggregated data for accuracy and flexibility
3. Use public data where possible
4. Document sources for all equations, parameters, assumptions
5. Maintain model as free to access, use, and modify by any interested party

# Work to date

| | |
|---|---|
| November 2011 | Scoping plan released for comment |
| July 2012 | OPGEE Draft version 1.0a released and public workshop |
| September 2012 | Public commenting |
| November 2012 | OPGEE version 1.0 adopted in LCFS rulemaking |
| March 2013 | Release of OPGEE v1.1 Draft A, public workshop |
| March 2013 | Release of draft baseline CI for California crude mix |

# Model structure



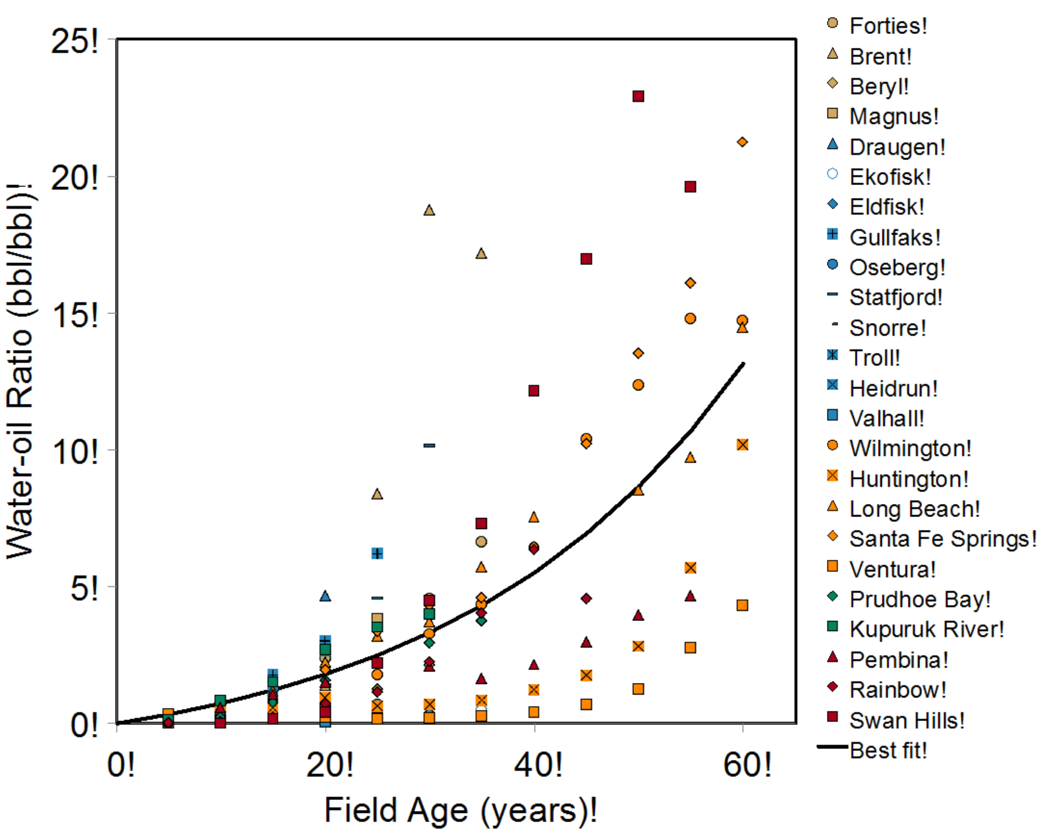

**Key structure:**

Front sheet for ease of use

Full details accessible in back sheets

# Modeling example: Smart defaults (WOR)

- OPGEE built to function with limited data
- All inputs are given defaults – Some smart defaults




Geographical coverage

- UK North Sea
- Norway North Sea
- California
- Alaska
- Alberta

Only largest fields are included

- >= 100 M $m^3$ (630 M bbl)
- Fields are likely to export internationally

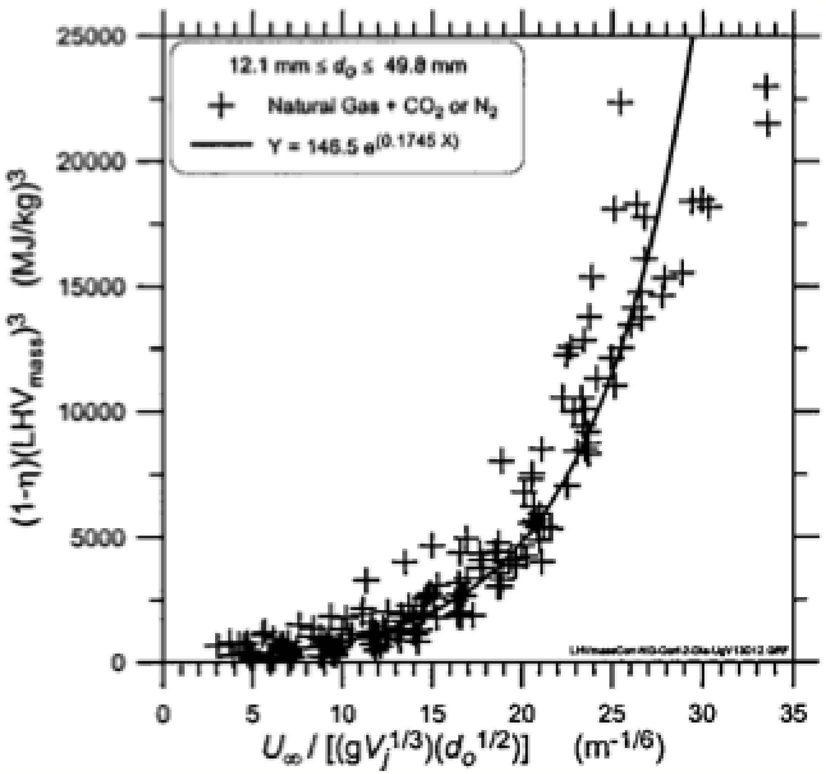
Long tail effects eliminated

- Data from old California fields is excluded

$$WOR(t) = a_{WOR} \exp[b_{WOR}(t - t_0)] - a_{WOR} \quad \left[\frac{\text{bbl water}}{\text{bbl oil}}\right]$$

# Modeling example: Scientific basis (flaring)

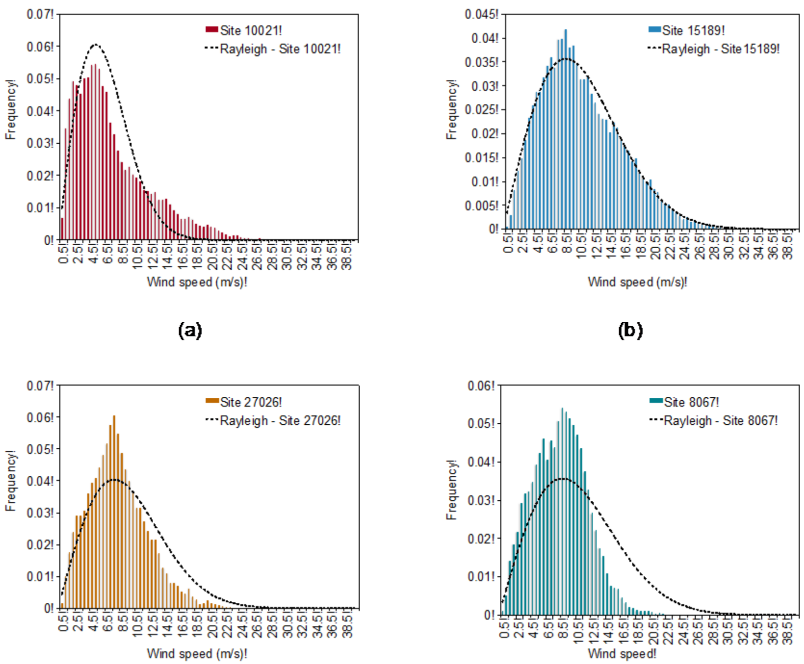
Parametric model of Johnson et al. (2002):



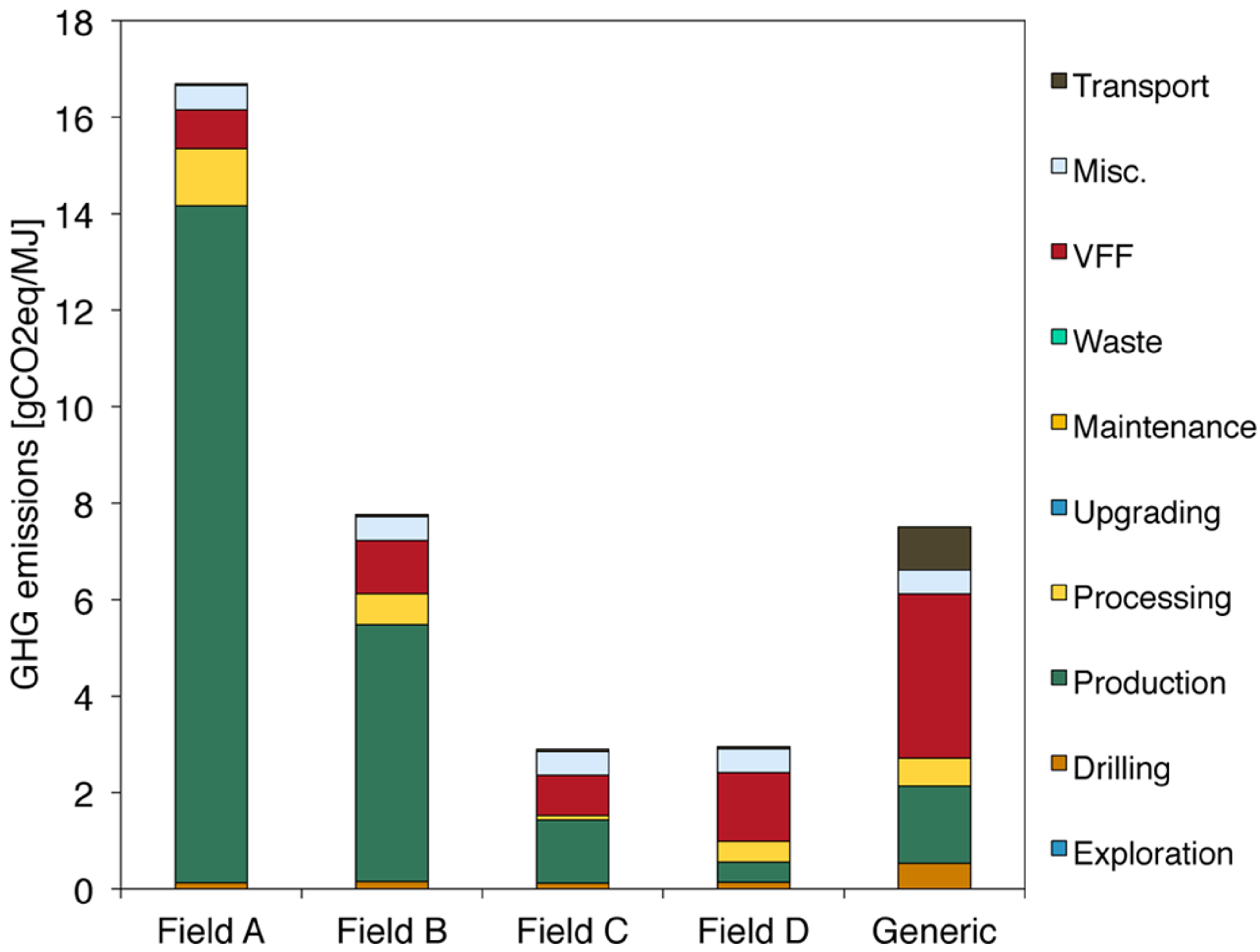

Rayleigh wind speed dist:

$$m_U = \frac{\mu_U}{\sqrt{\frac{\pi}{2}}}$$

$$p(U) = \frac{U}{m_U}\exp\left[-\frac{1}{2}\left(\frac{U^2}{m_U^2}\right)\right]$$



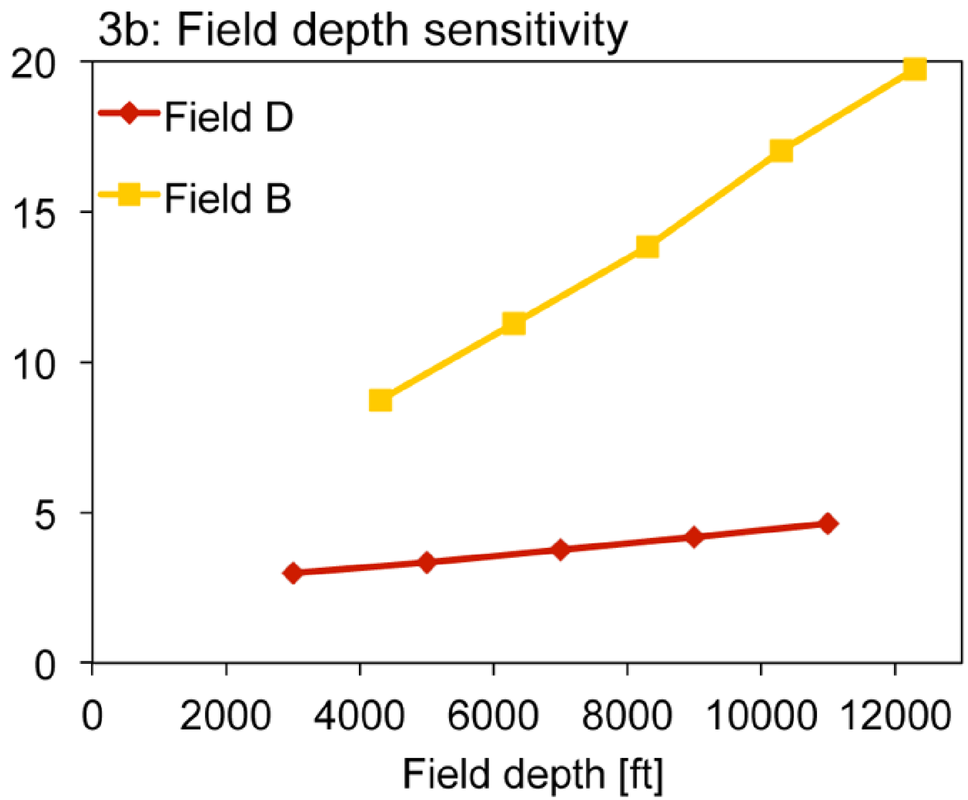
# Examples of results




Source: El-Houjeiri et al. (2013)

# Sensitivity of variability to field characterisitcs

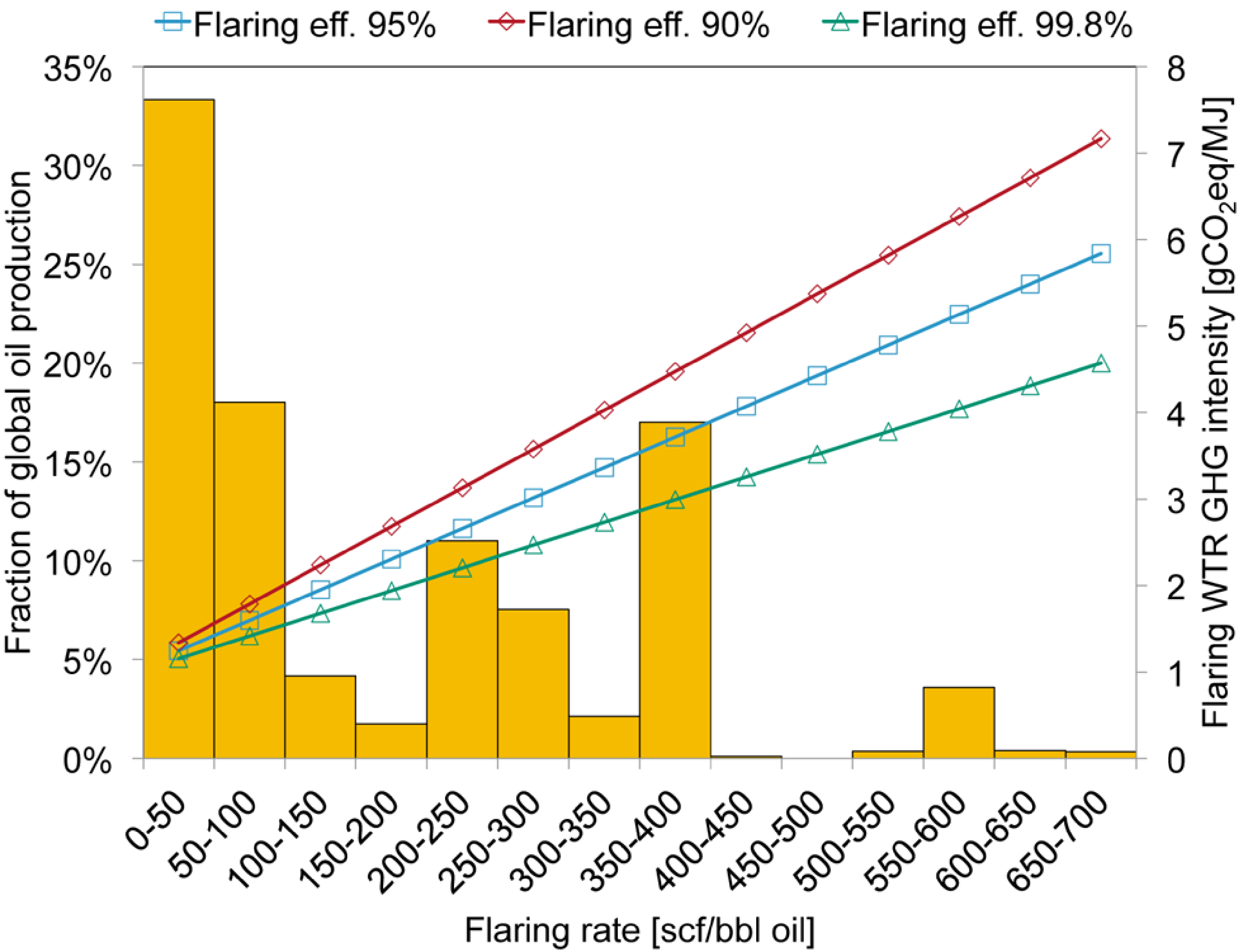
Q: Is oilfield depth a significant driver of emissions?
A: It depends.




Field B has WOR of 40 bbl water/bbl oil

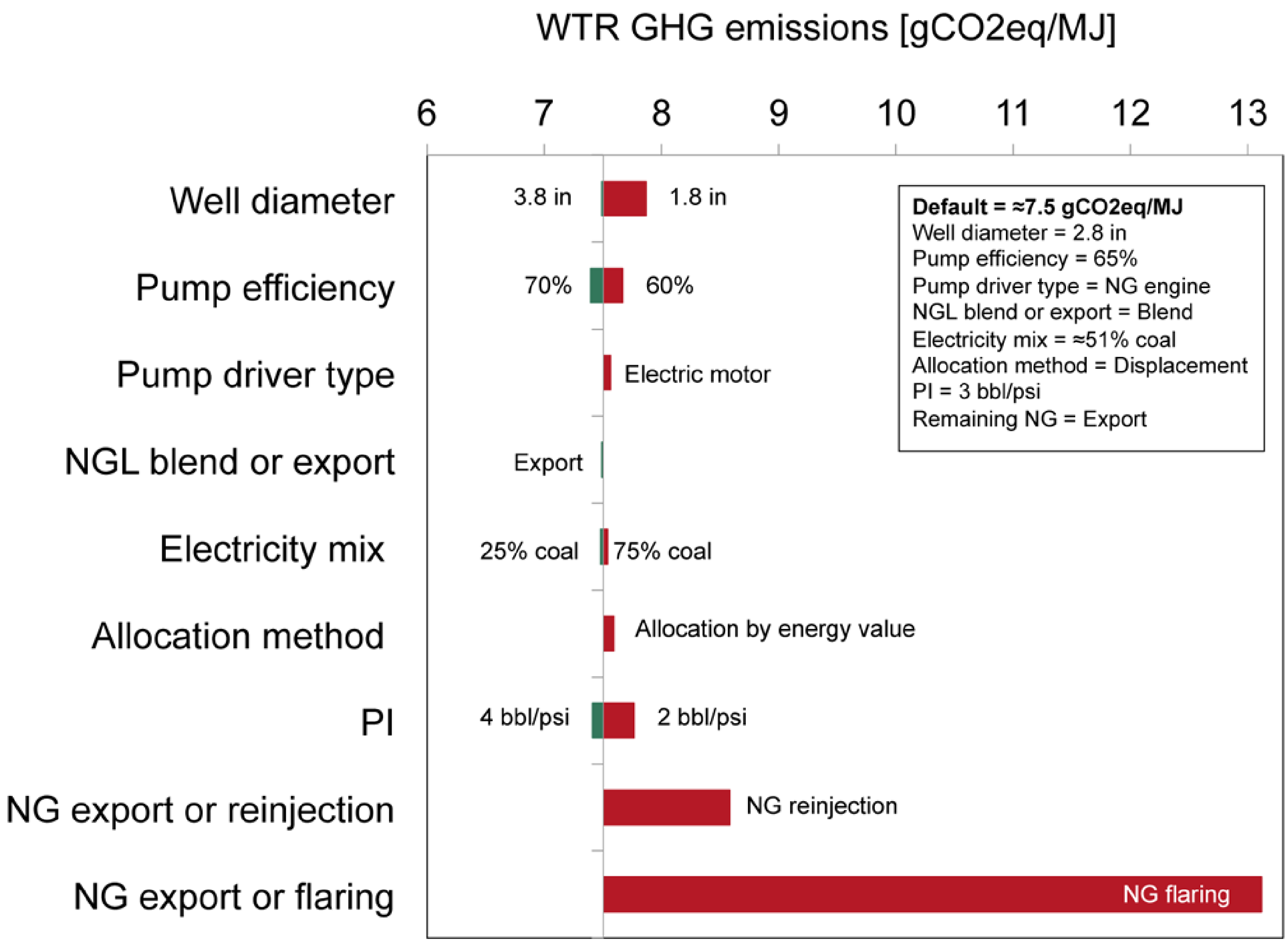
Source: El-Houjeiri et al. (2013)

# Flaring is a significant driver of emissions




Source: El-Houjeiri et al. (2013)

# Sensitivity of results to input assumptions



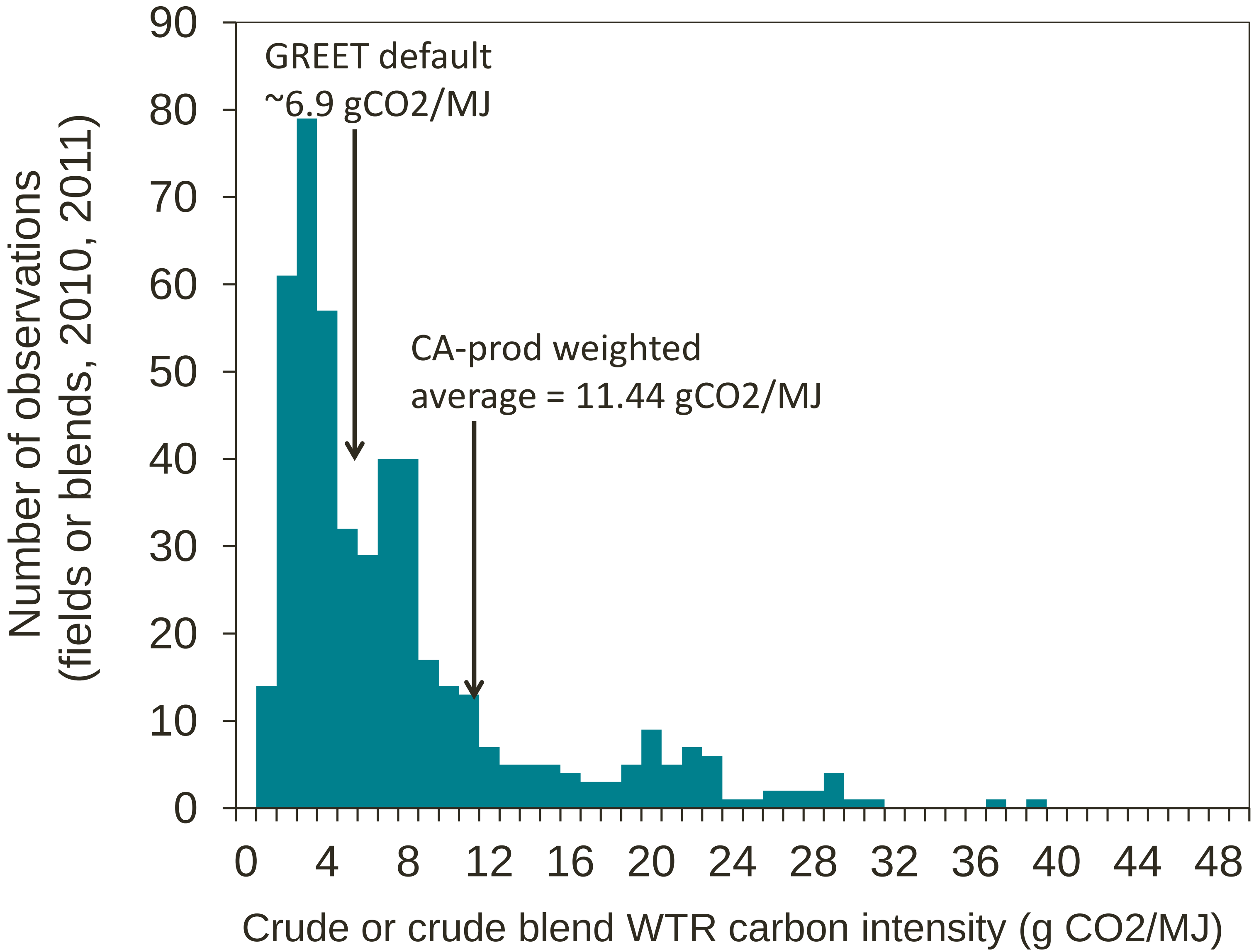

Source: El-Houjeiri et al. (2013)

# Application to regulation – CA LCFS

- OPGEE was applied to calculating California baseline GHG intensity for crude oil
- ~270 crude oil producing fields and crude blends modeled using OPGEE
  - Detailed data on California fields
  - Mixed data sources on global fields
- First ever effort to build a field- or blend-specific average CI for the crude oil consumed in a region

Source: Duffy et al. (2013)

# Results of California LCFS baseline analysis




Source: Based on data from Duffy et al. (2013)

# Current work: Model verification

- Post-doctoral researcher Kourosh Vafi has been building rigorous comparison of OPGEE to other models
- Assess the variety of LCA and LCA-like models
- Questions:
  - How do results differ between OPGEE and others when modeling same crude?
  - If we norm system boundaries and inputs, do we get more agreement in results?



Source: Vafi et al. (2013)

# Models compared to OPGEE

| Model | Data | Calculations | Boundaries |
|---|---|---|---|
| OPGEE | Open literature and public datasets. | Engineering-based, mechanistic and empirical | Oil production process (WTR) |
| EcoInvent | Reported data from operators (QC). | Matrix-based calculation of emissions (direct and indirect) | All processes in economy. |
| GEMIS | Open literature | Direct and indirect emissions | All processes in economy. |
| GREET | Open literature and estimates. Data accessible. | Iterative calculation of all emissions from a pathway | All transportation fuel pathways (WTW) |
| GHGenius | Open literature and public datasets. Data accessible. | Iterative calculation of all emissions from a pathway | All transportation fuel pathways (WTW) |
| TIAX | Public data sources | Simple engineering-based calculations based on public data | Oil production pathways (WTW) |
| Energy-Redefined | Proprietary industry data sources at field level. | Methods not clearly defined. | Oil production processes (W to Refinery outlet) |
| Jacobs Consultancy | Proprietary data sources. Some data reported. | Engineering-based spreadsheet model. Mechanistic and empirical. | Oil production pathways (WTW) |
| SANGEA | EPA and API emissions caculations. | Emissions calculations for compliance based on user inputs of fuel consumption. | Oil and gas production |
| OGP | Proprietary | Data aggregated and | Oil and gas |

Source: Vafi et al. (2013)

## WTW LCA models

GREET, GHGenius

## General LCA models

GaBi, EcoInvent, GEMIS

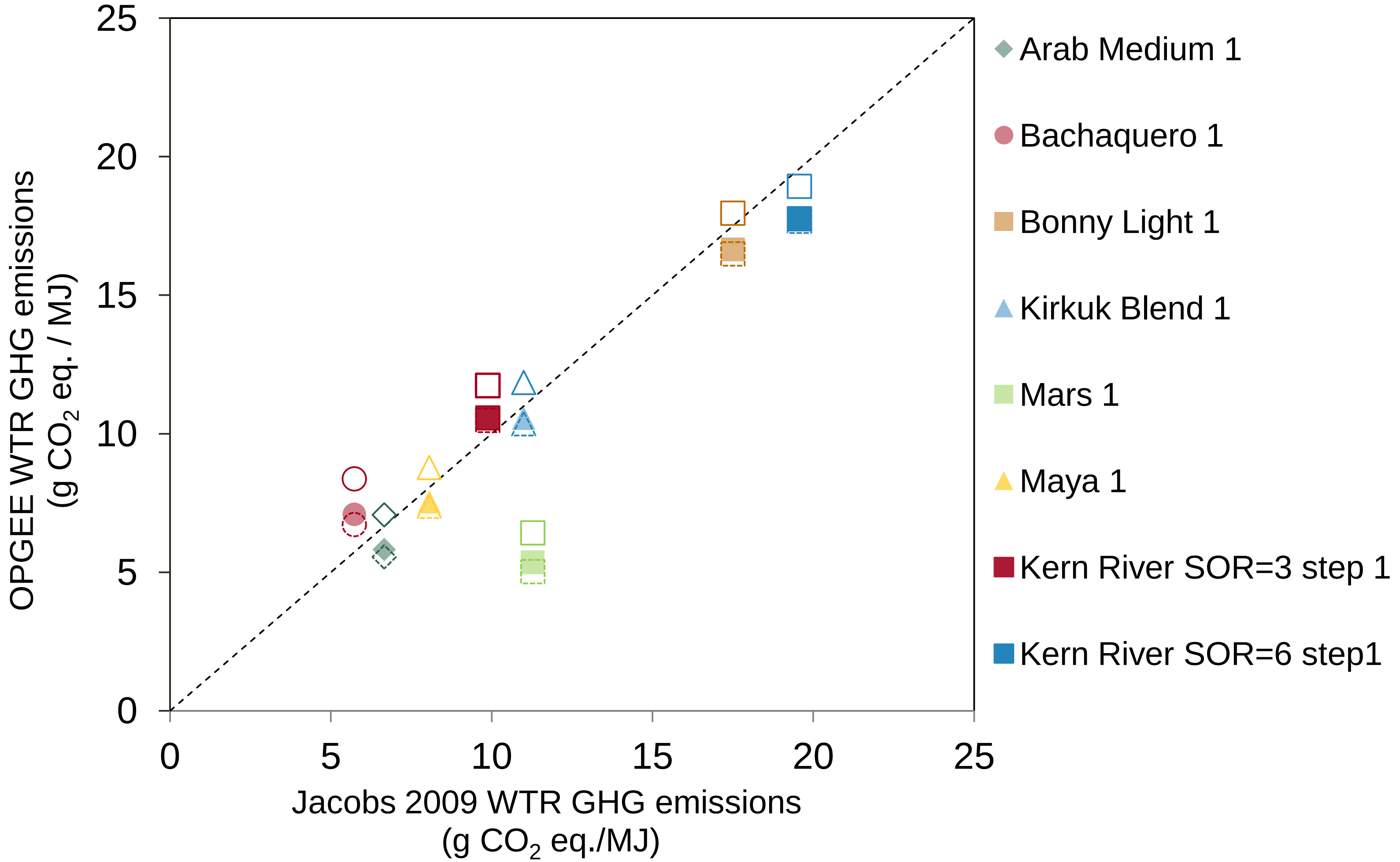
## Engineering-based oil models

Jacobs, TIAX, Energy-Redefined

## Other

OGP, SANGEA

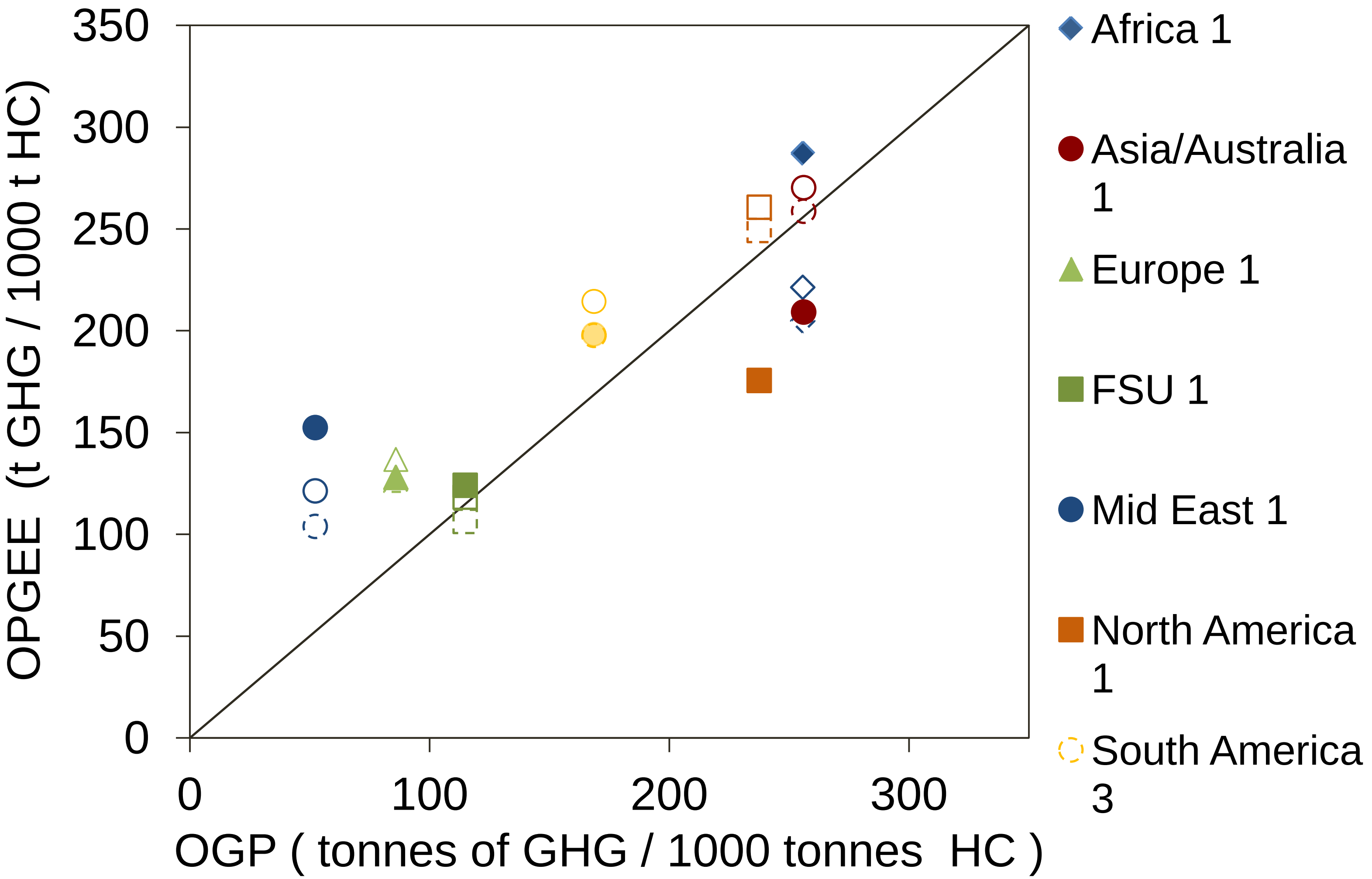
# Example results: Jacobs Consultancy




Source: Vafi et al. (2013)

# Example results: OGP sustainability report

Operator reported emissions for ~30% of global production




Source: Vafi et al. (2013)

# Model comparison – A significant challenge

- In most cases, it is **very difficult** to determine why OPGEE results differ from other studies
  - Months of work to reverse-engineer other studies, limited by reported data
- Transparency in methods and data is a major concern for most studies
- Modeling in this area will progress slowly without more availability of competing models and data

Source: Vafi et al. (2013)

# Moving forward

- Uncertainty analysis
  - Monte carlo analysis using range of inputs from literature
- Model extensions and applications to new oil resources
  - Tight oil in Bakken, deep offshore, arctic resources
- Extensions to model other processes
  - $CO_2$ EOR/CCS, Oil sands

Thank you