Estimating the Potential for Oil Production and CO_2 Storage from CO_2 EOR Using the FE/NETL CO_2 EOR Storage Cost Model

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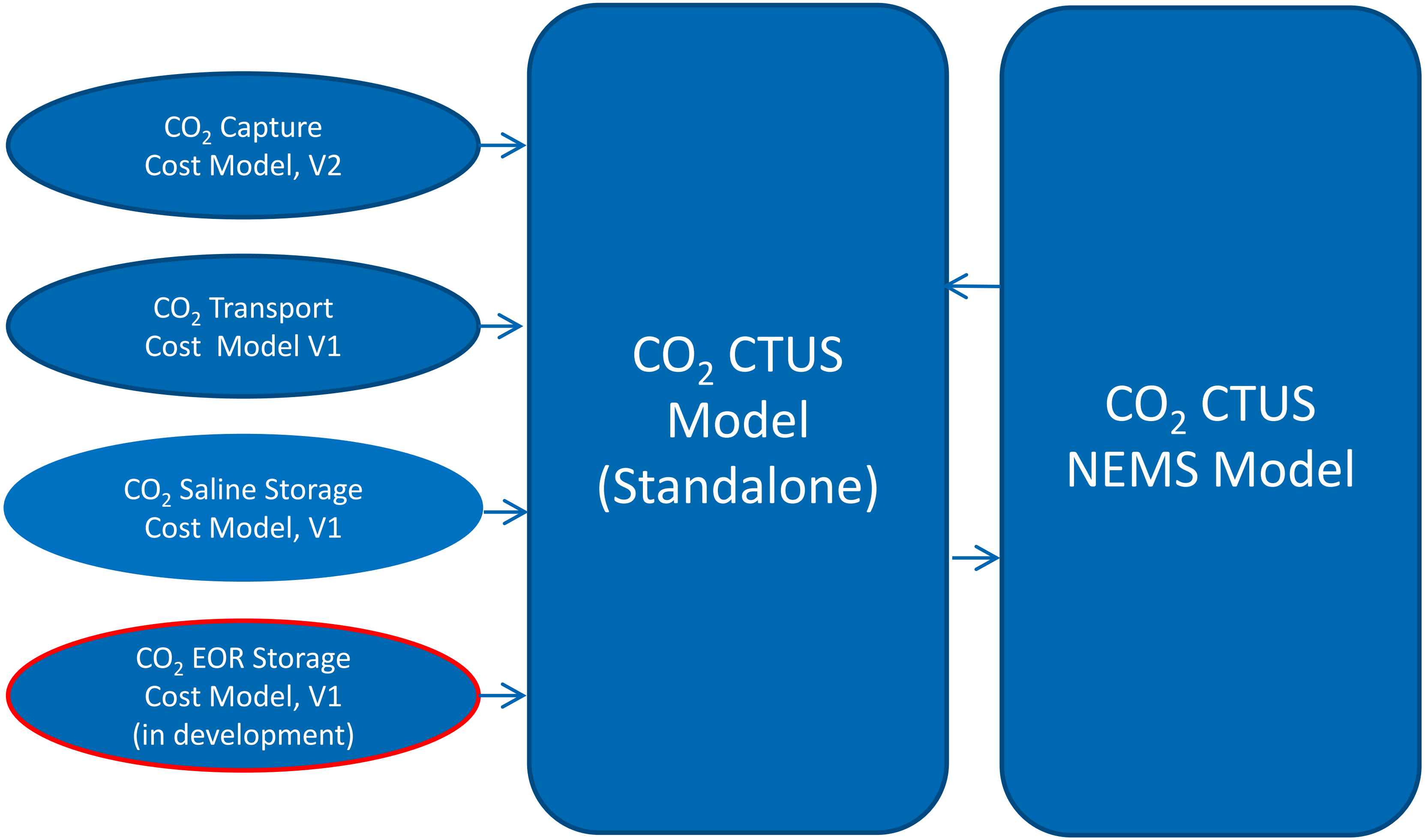
FE/NETL CO_2 EOR Storage Cost Model

Integration with Additional FE/NETL Models



What the CO_2 EOR Storage Cost Model Does

- **Estimates costs, revenues and cash flow to owners for a CO_2 EOR site for specified prices of oil ($/ST Bbl) and CO_2 ($/tonne)**
- **Determines break-even price of oil (for fixed price of CO_2) and break-even price of CO_2 (for fixed price of oil)**
- **Includes costs for complying with subpart UU and (optionally) subparts RR and Class VI well regulations**
- **Identifies cost drivers for CO_2 EOR**
- **Estimates the mass of CO_2 stored using CO_2 EOR**

CO_2 EOR Storage Cost Model Comprised of Four Modules

- **Project management module**
- **Geology module**
- **Activity cost module**
- **Financial module**

Project Management Module

- **Main user interface**
- **Specifies oil reservoir, pattern size, pattern type, pattern implementation schedule, injection schedule, financial parameters, etc.**
- **Presents key results: costs, revenues, net present value, internal rate of return, break-even price for oil, break-even price for CO_2**

Geology Module: Overview

- **Uses a database of oil reservoir properties, wleor.txt, developed by the Energy Information Agency (EIA) for use in the National Energy Modeling System (NEMS)**
- **Exploits an oil reservoir by installing oil production patterns over time**
- **Simulates inputs and outputs from a single pattern using the CO_2 Prophet program**
- **Pattern shuts off after cumulative net operating revenue is maximized**
- **Results from CO_2 Prophet are applied across the reservoir by:**
  - Installing patterns over time
  - Performing mass balance calculations on water, CO_2, oil and hydrocarbon gas for the entire reservoir
  - Water and CO_2, being both inputs and outputs for a pattern, are recycled as part of the mass balance calculations

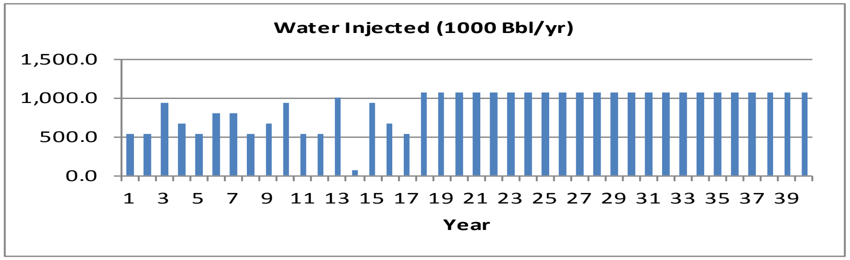
Geology Module: EIA Reservoir Database (wleor.txt)

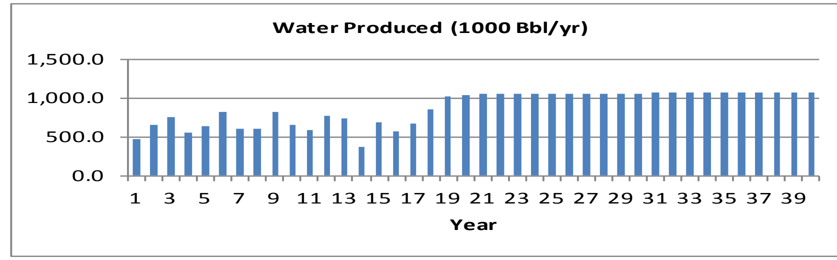
- **Provides basic geologic data:**
  - Depth to reservoir, net pay, porosity, permeability, Dykstra-Parsons coefficient
- **Provides data needed to estimate original oil in place and current oil in place:**
  - Initial oil saturation, current oil saturation, net pay, surface area of reservoir
- **Provides oil properties:**
  - API gravity, viscosity, residual oil saturation, formation volume factor for oil, ratio of hydrocarbon gas to oil
- **States included in database:**
  - AL, AR, CA, CO, KS, LA, MI, MS, MT, ND, NE, NM, OK, SD, TX, UT, WY

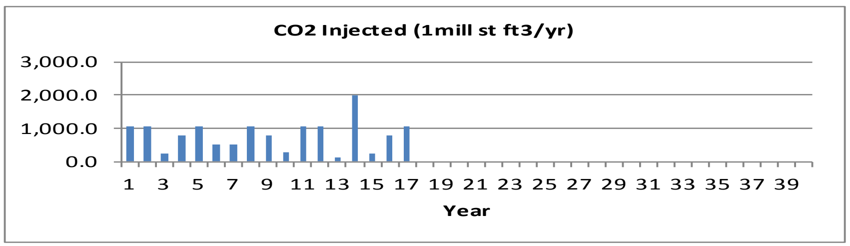
Geology Module: CO_2 Prophet

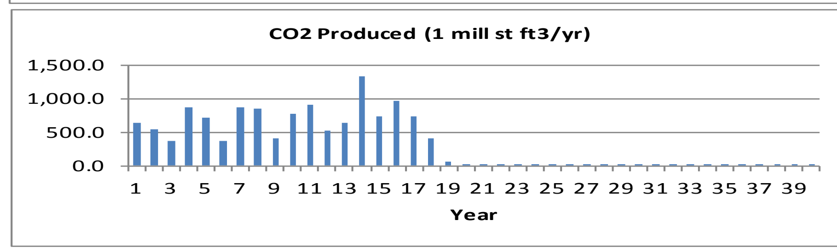
- Three phase (oil, water and solvent/CO_2), incompressible, immiscible flow equations solved using streamline/stream-tube method
- Relative permeability and viscosity of oil and solvent/CO_2 adjusted to mimic miscible phase flow
- Up to 10 layers of equal thickness with layer permeability varying according to the Dykstra-Parsons coefficient
- Assumes entire pattern volume has inter-connected pores
- Only permeability heterogeneity prevents all oil from being produced to oil-CO_2 residual saturation if production lasts long enough

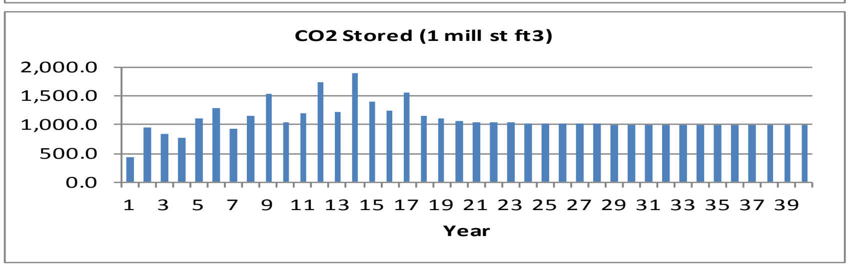
Geology Module: Example Output from CO_2 Prophet

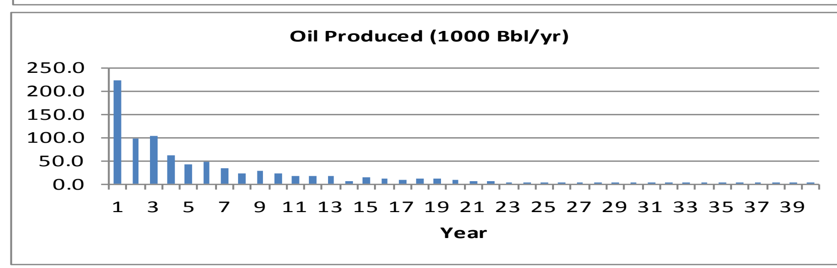


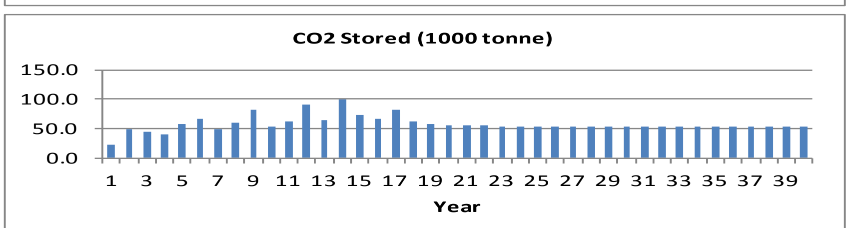


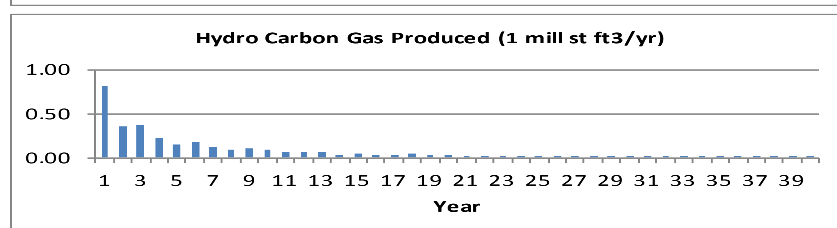








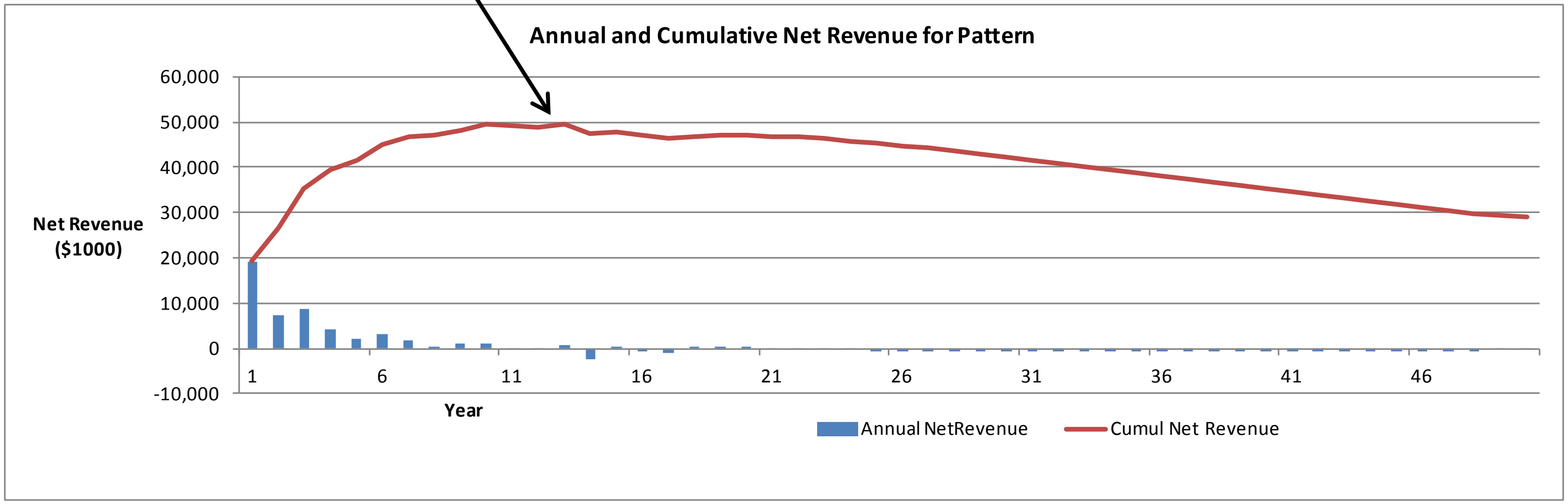




Geology Module: Stopping the Pattern

- **Pattern shut off after cumulative net operating revenue is maximized**
  - Net operating revenue = revenue from oil – cost of operating pattern and processing produced fluid (plus some contingencies)

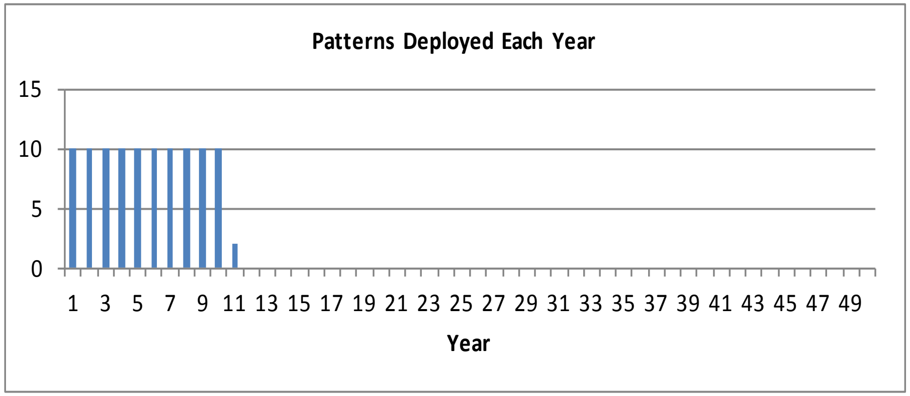
Maximum net operating revenue

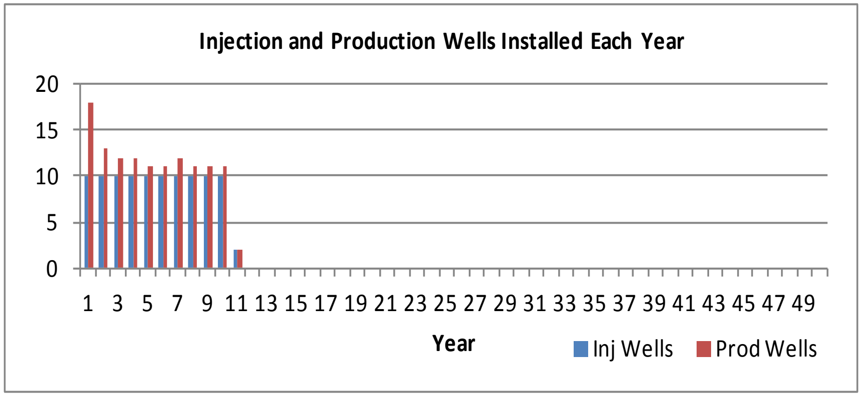


NETL

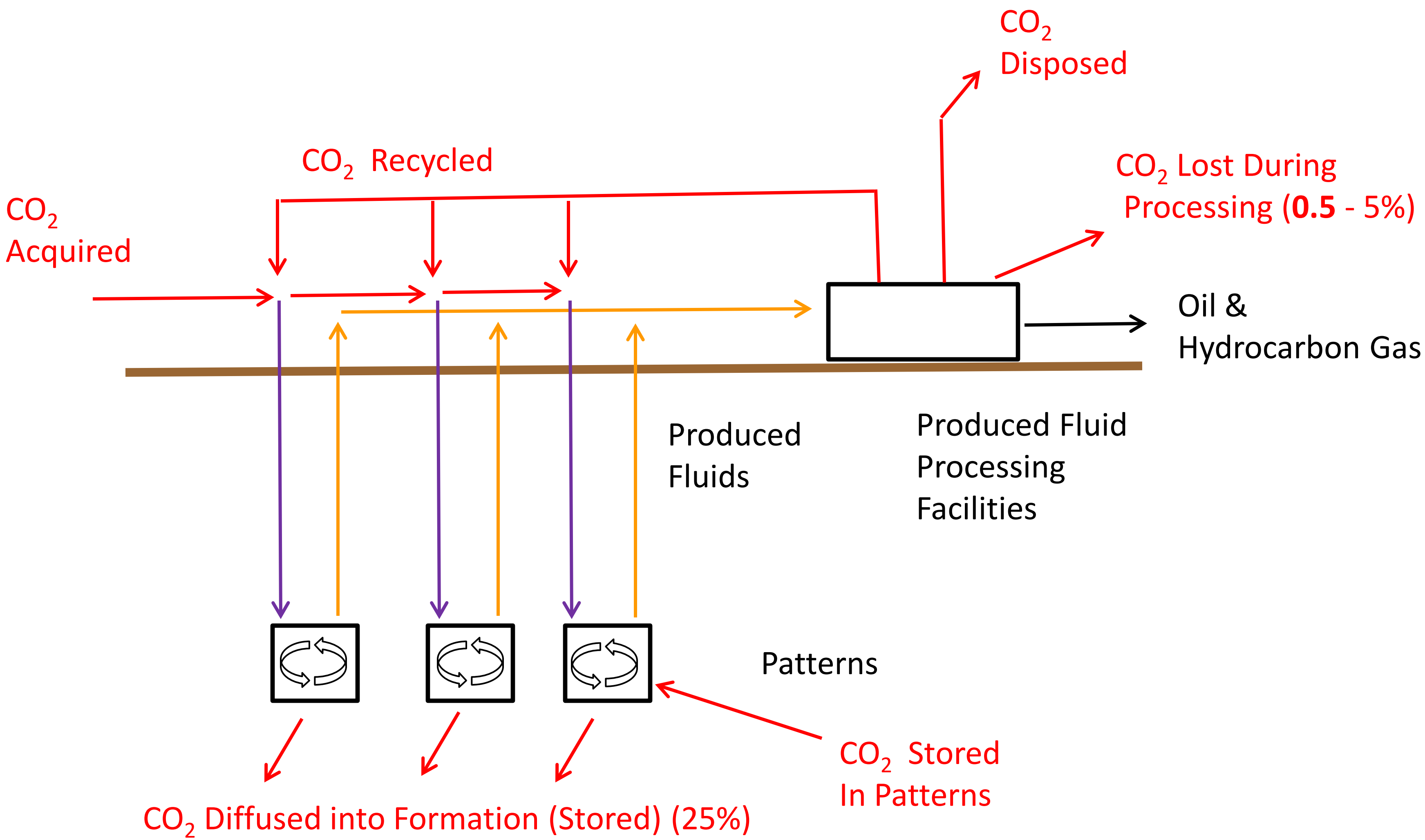
Geology Module: Development of Reservoir

- **Patterns implemented over time (10% of total number of patterns each year)**
  - Minimum number each year: 3
  - Maximum number in one year: 40
- **Number of injection and production wells needed each year to implement these patterns**
- **Number of active injection and production wells each year**

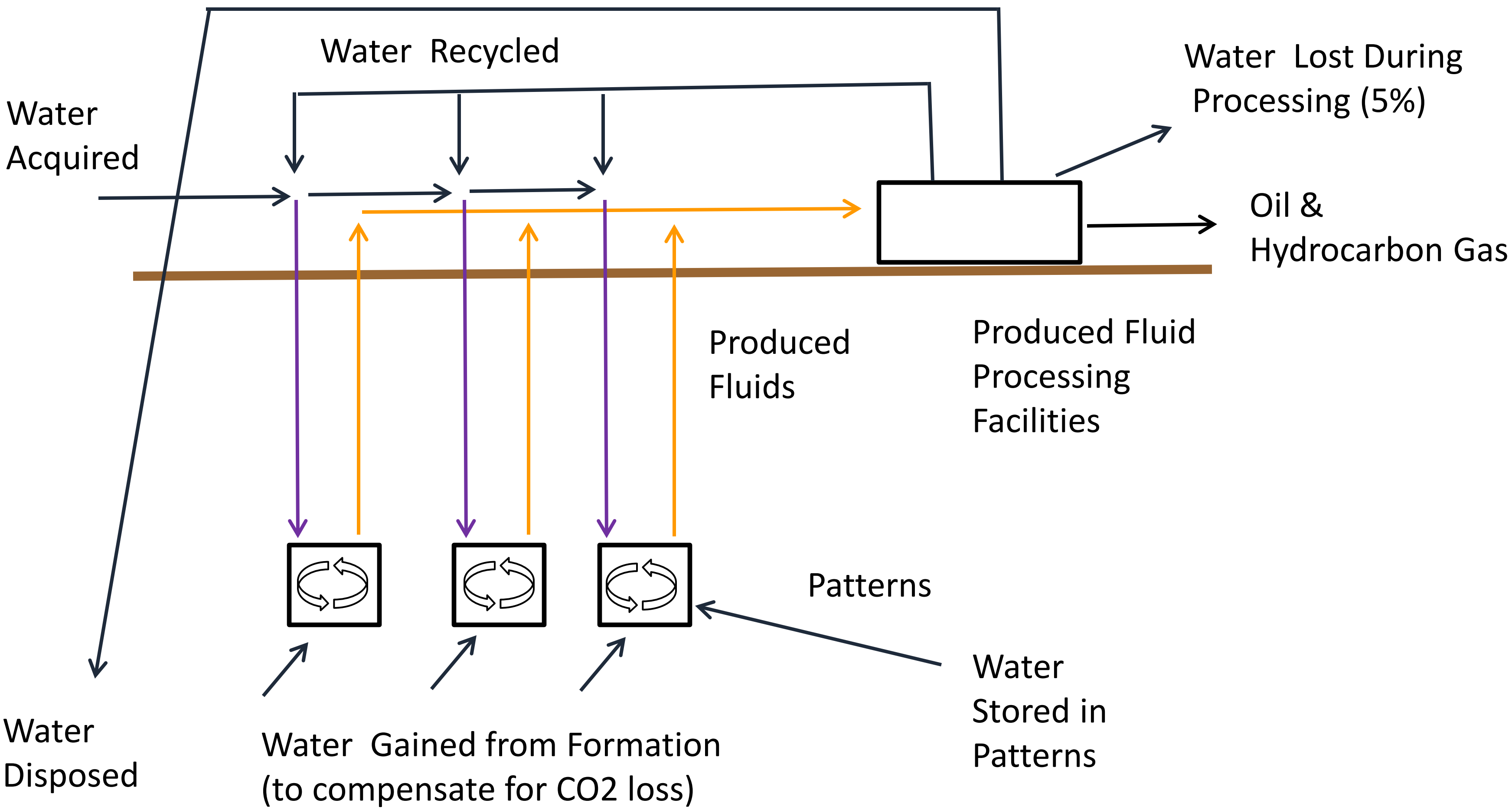




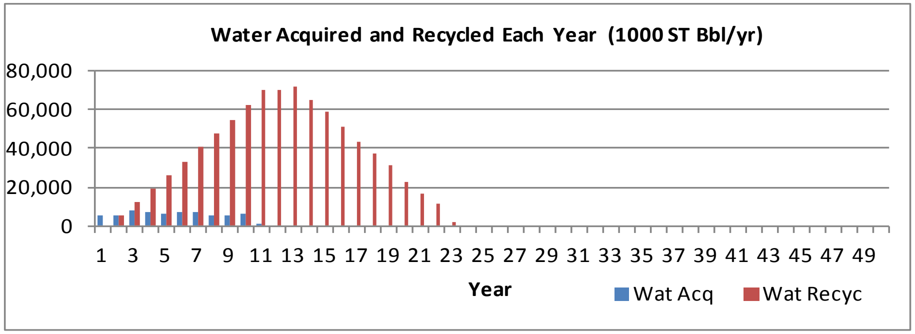
Geology Module: CO_2 Flows in Reservoir

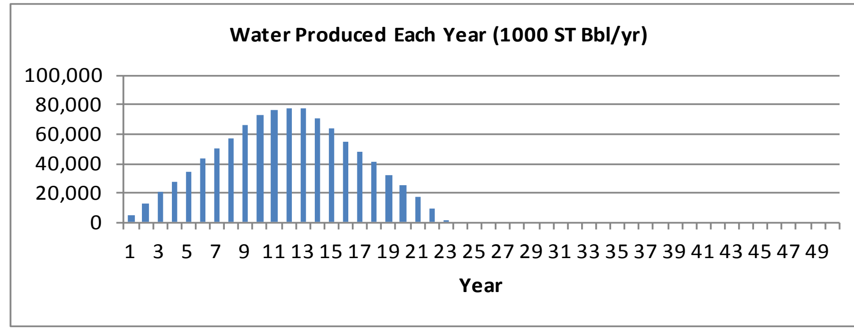


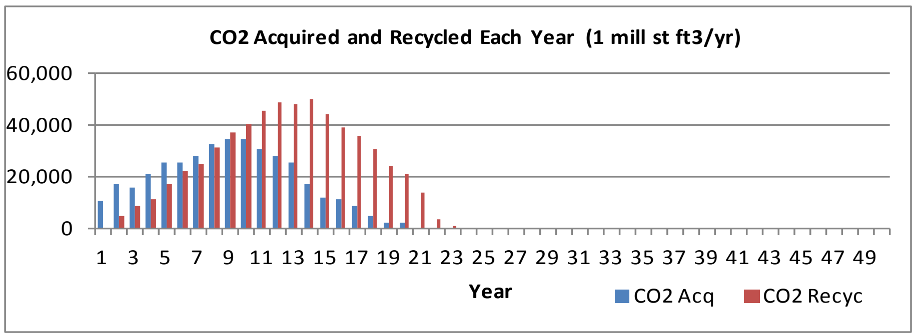
Geology Module: Water Flows in Reservoir

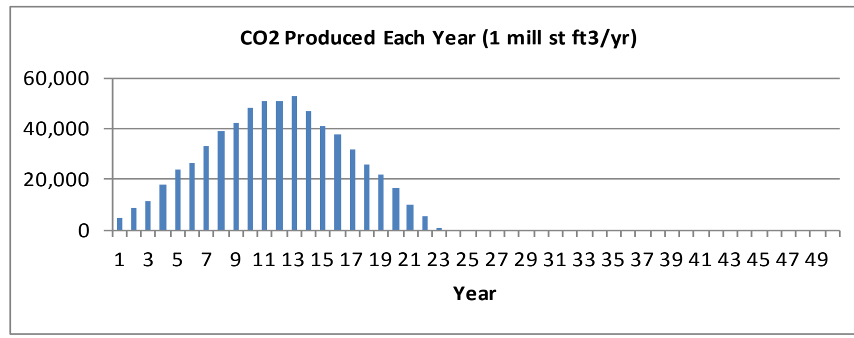


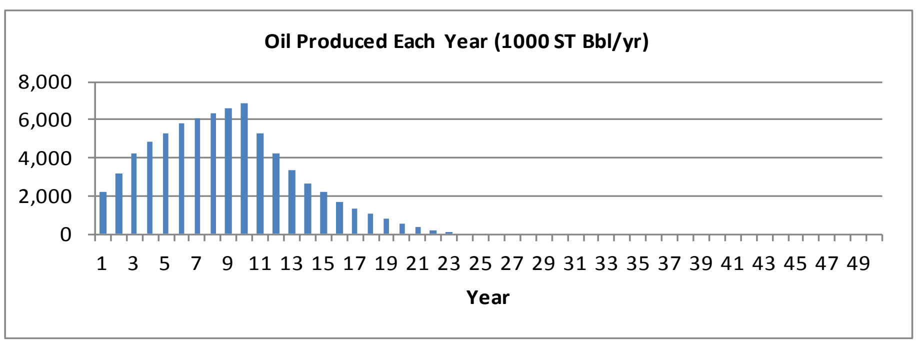
Geology Module: Example Results for Reservoir

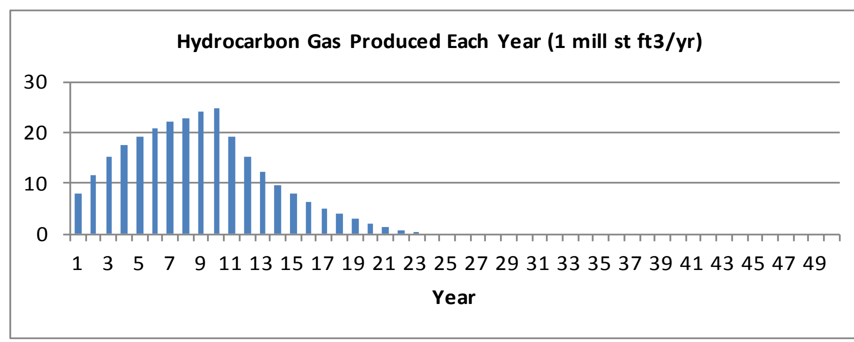












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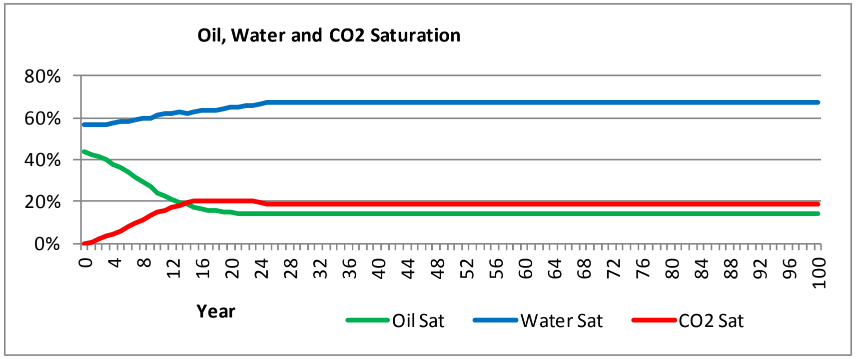
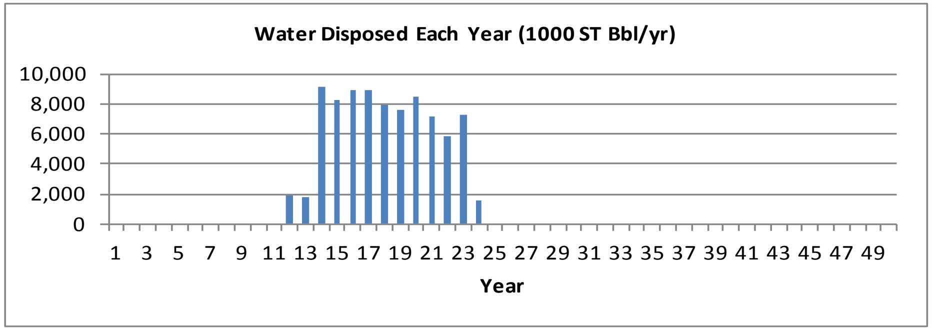
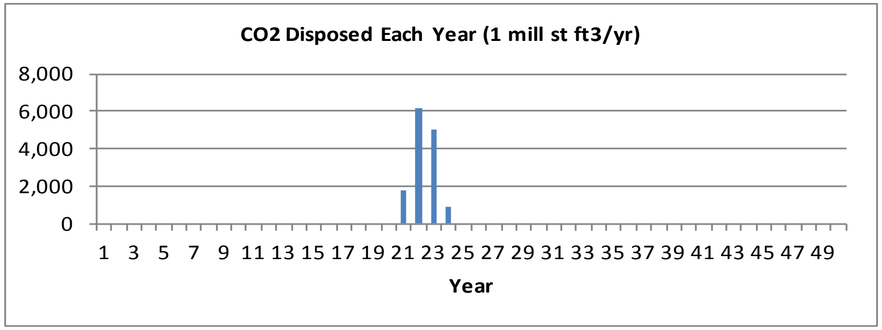
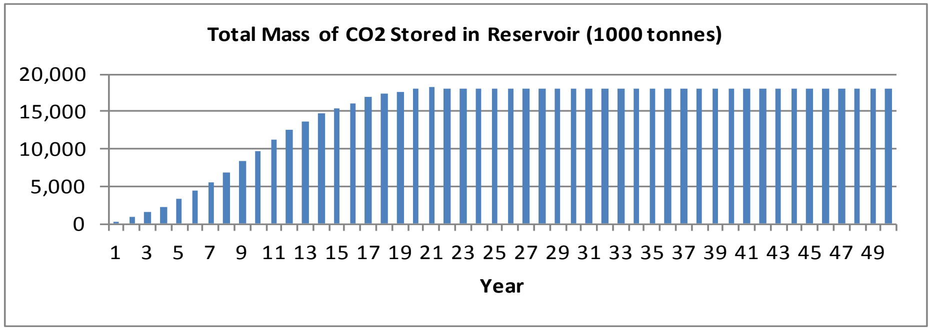
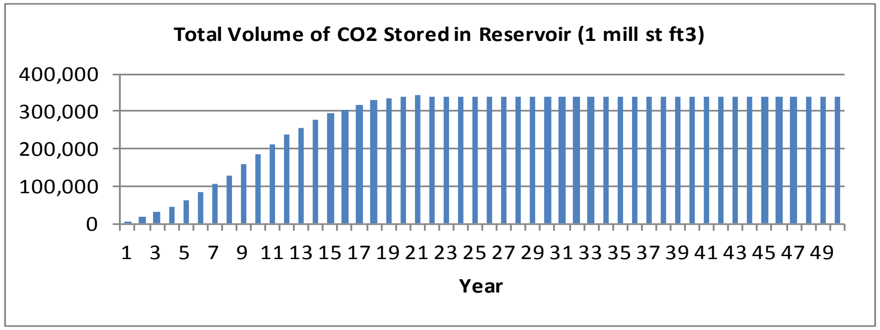






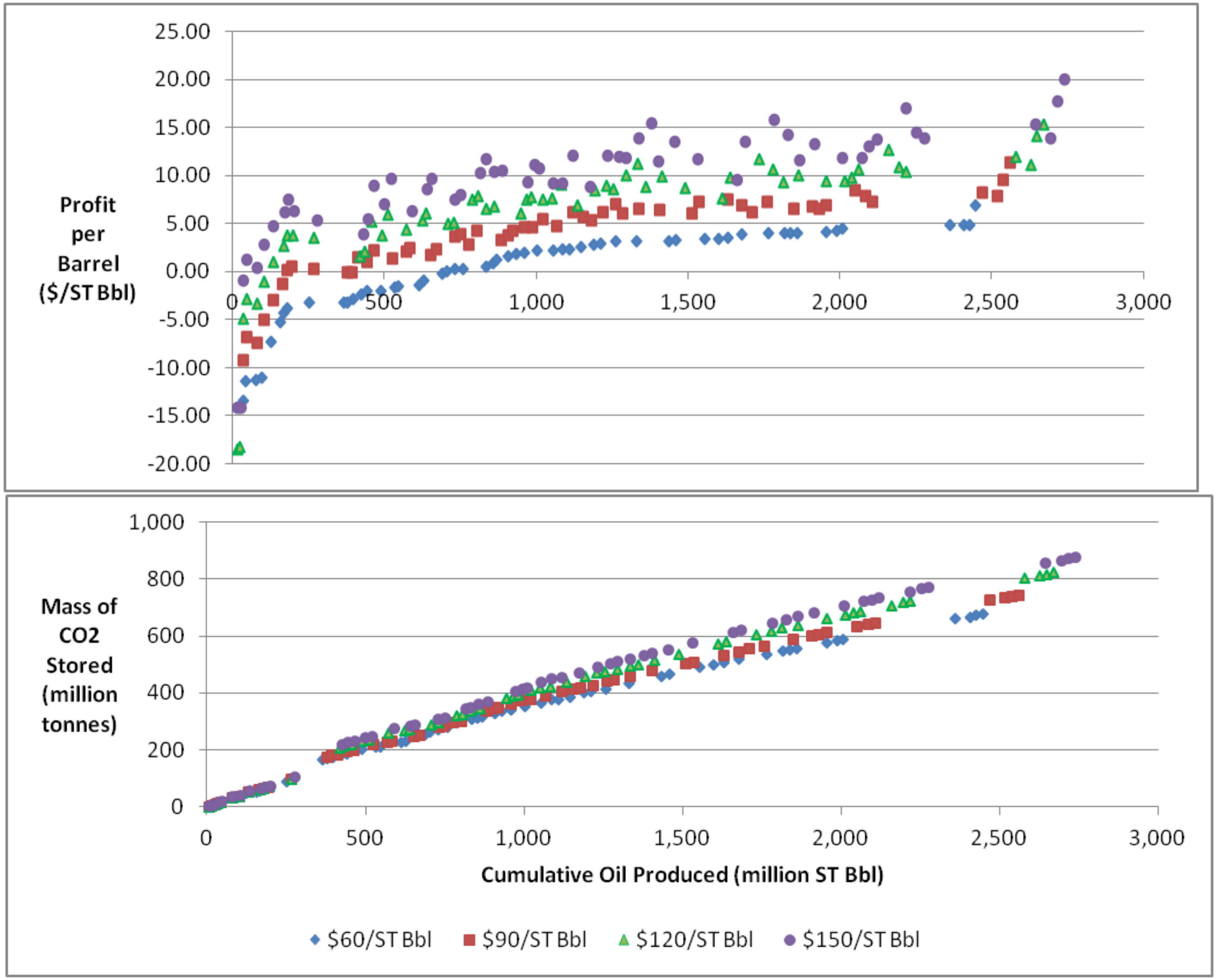




Activity Cost and Financial Modules

- **Activity cost module**
  - Costs for discrete activities (e.g., drilling wells, installing produced water processing facilities) in various stages posted in appropriate year
- **Financial module**
  - Revenue from oil is expressed in constant dollars in each applicable year
  - Total constant dollar costs of activities are reported in each year (capital costs and expenses are kept separate)
  - Revenue and costs are escalated
  - Depreciation and taxes included in financial module
  - Cash flow to owners determined in escalated and discounted dollars
  - When net present value of cash flow to owners equals zero, return on equity meets minimum desired value

Example Output from First Version of Model



- As wellhead oil price rises, profitability increases
- However, cumulative oil production does not increase dramatically
- Also, mass of CO_2 stored does not increase dramatically

Future Efforts

- Transfer EOR aspects into current FE/NETL CO_2 Saline Storage Cost Model
- Incorporate new reservoir databases (EIA's wloil.txt DB and ARI Big Oil Field DB [internal use only])
- Initialize pattern for EOR by water flooding pattern until oil production is not economical
- Incorporate new surface facilities costs developed by ARI
- Additional issue: CO_2 Prophet vs. dimensionless performance curves from reservoir simulation models

Questions