Extending Shale Gas Well Life with Low Grade Geothermal Power

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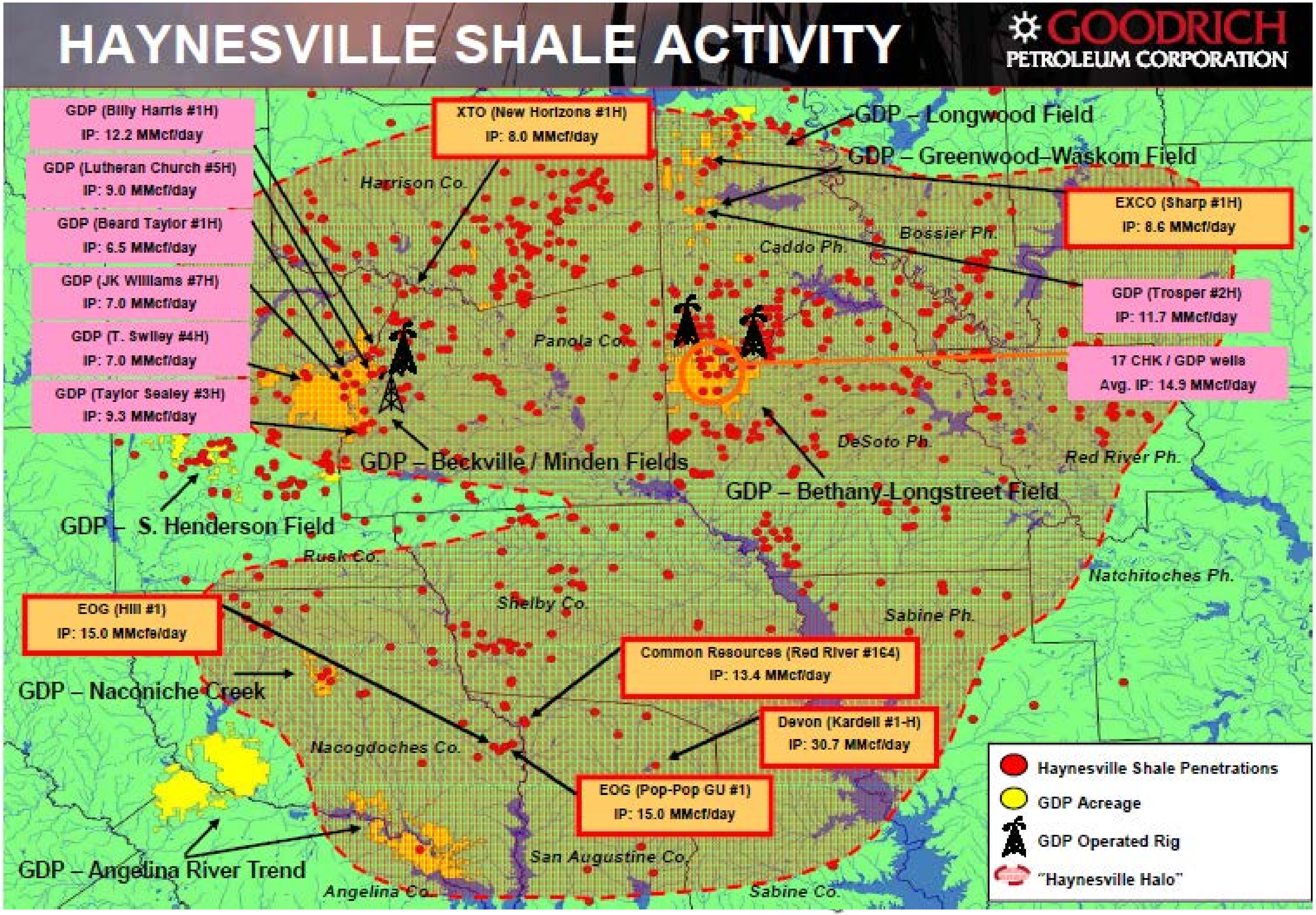
Agenda

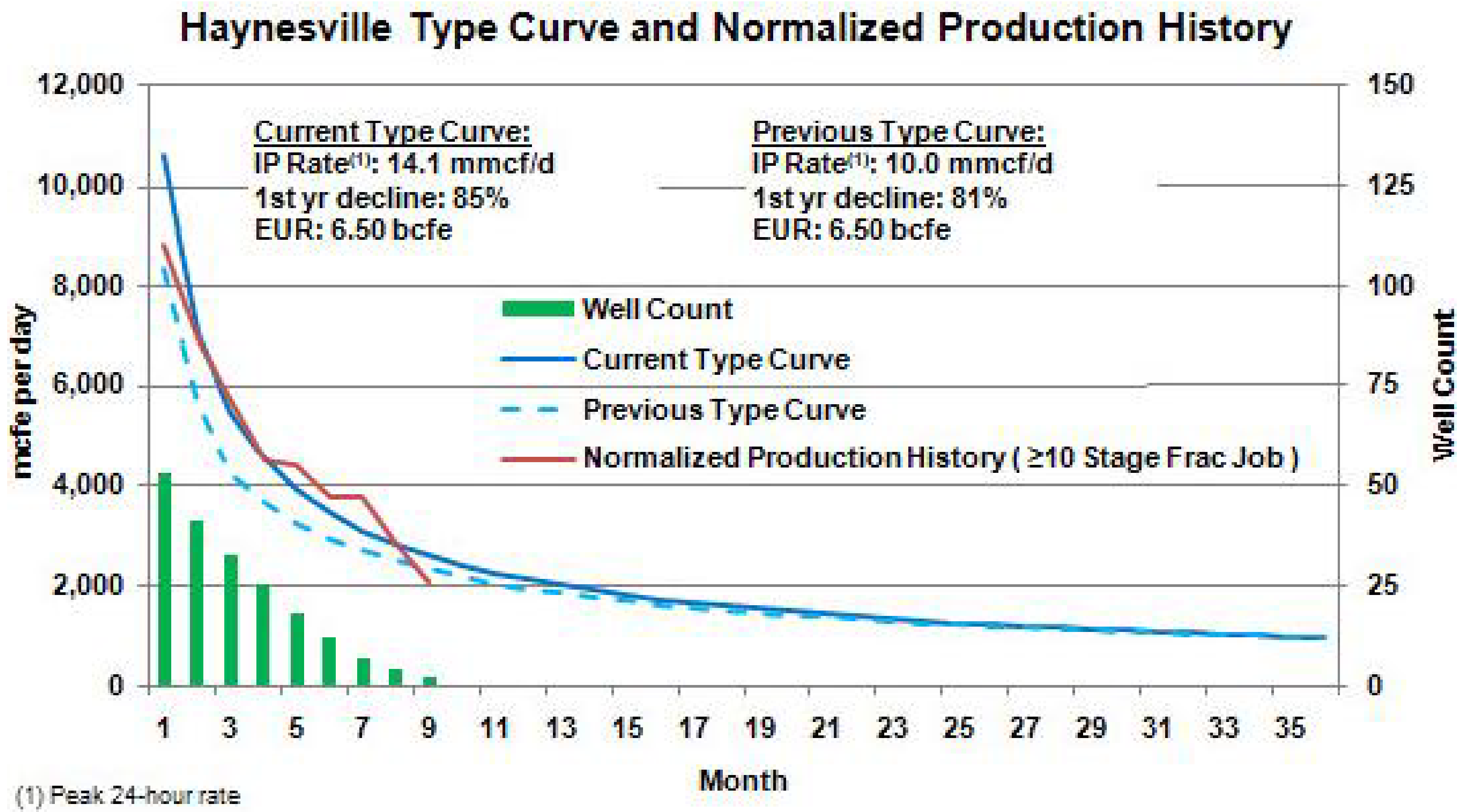
- Introduction
- Models for geothermal heat extraction
- Geothermal Power Plant
- Project Economics
- Conclusions and recommendations
- Future work

Haynesville Shale



Source: DrillingInfo

Haynesville Production Behavior



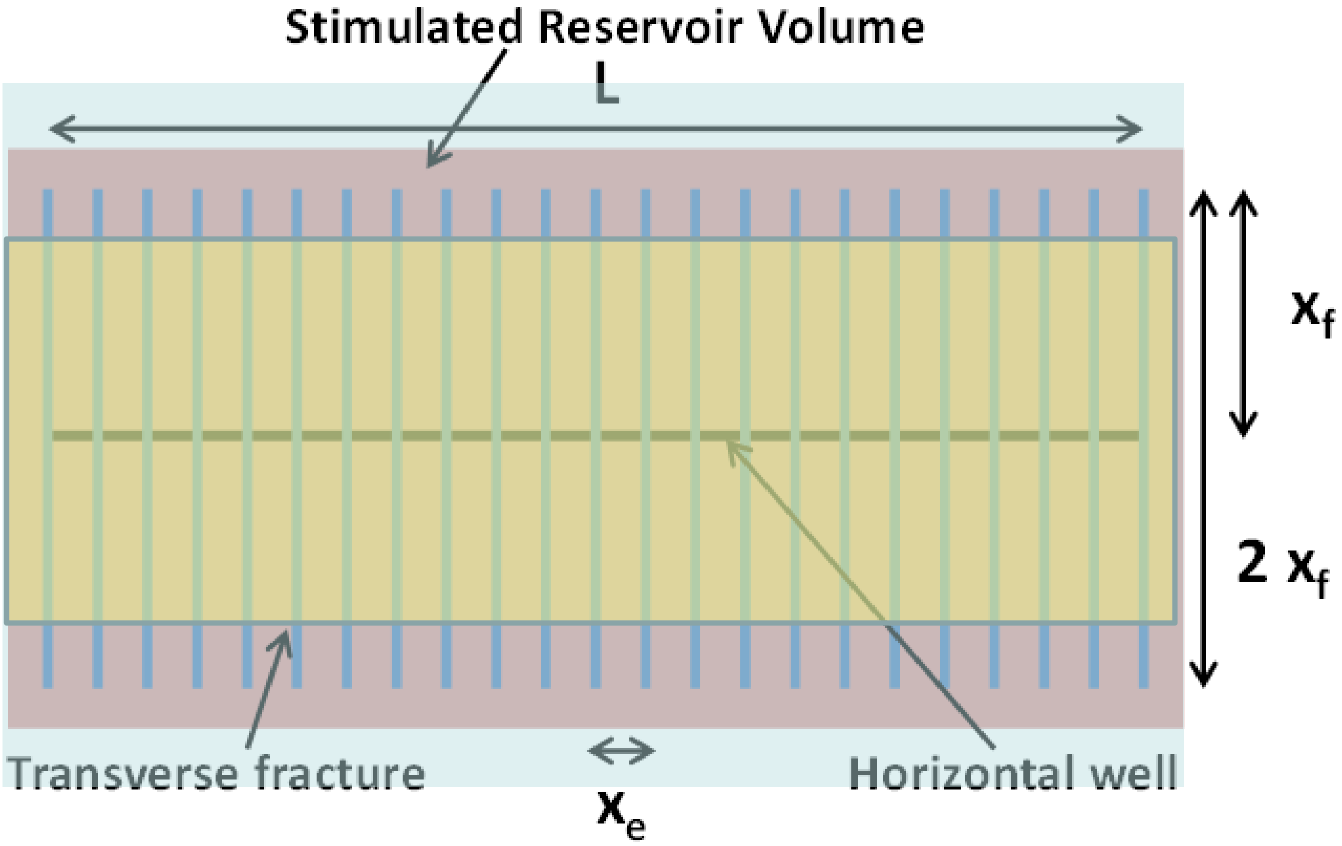
Haynesville Type Curve and Normalized Production History

Current Type Curve:
IP Rate(1): 14.1 mmcf/d
1st yr decline: 85%
EUR: 6.50 bcfe

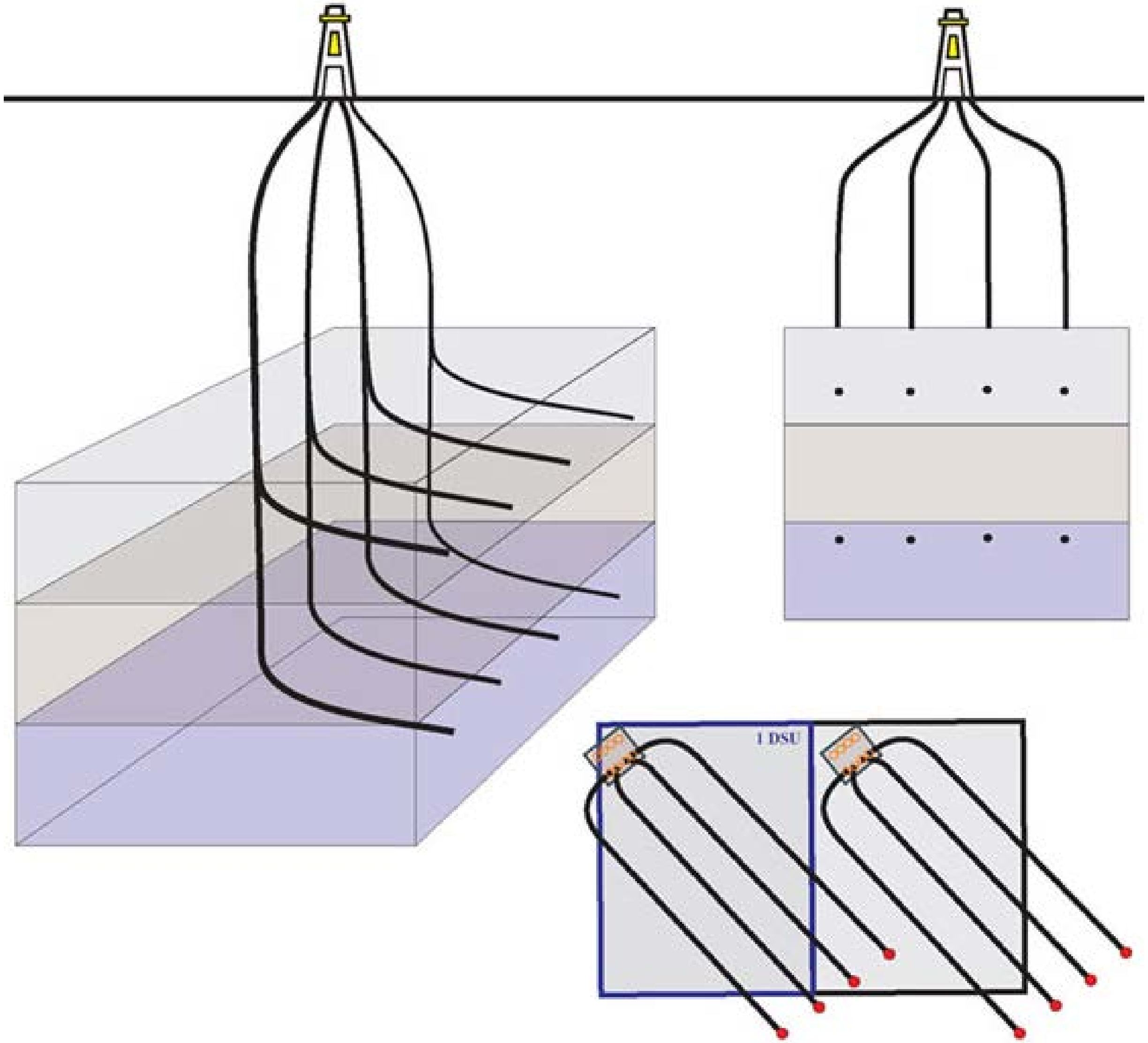
Previous Type Curve:
IP Rate(1): 10.0 mmcf/d
1st yr decline: 81%
EUR: 6.50 bcfe

(1) Peak 24-hour rate

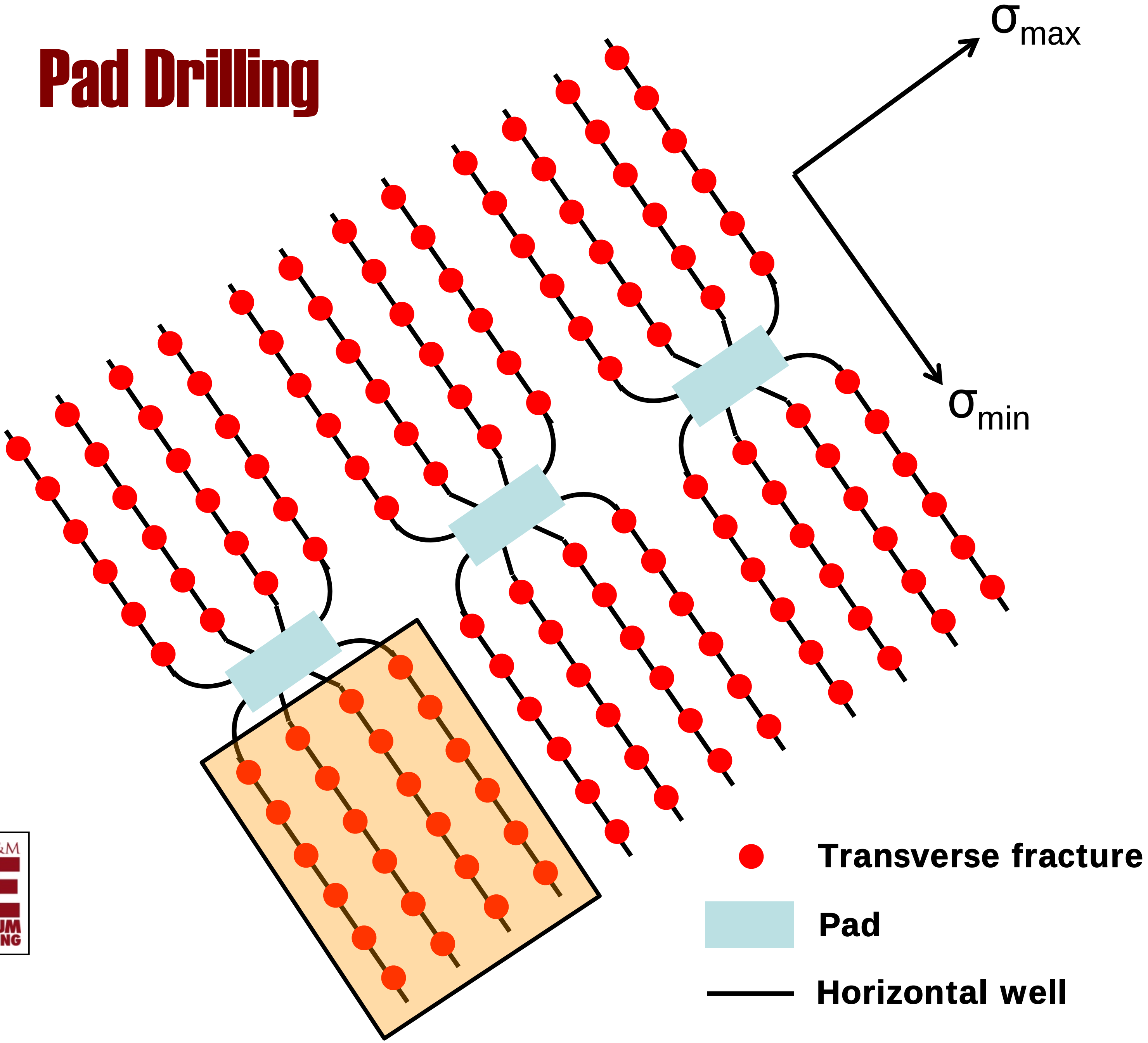
Planar view of the Stimulated Reservoir Volume



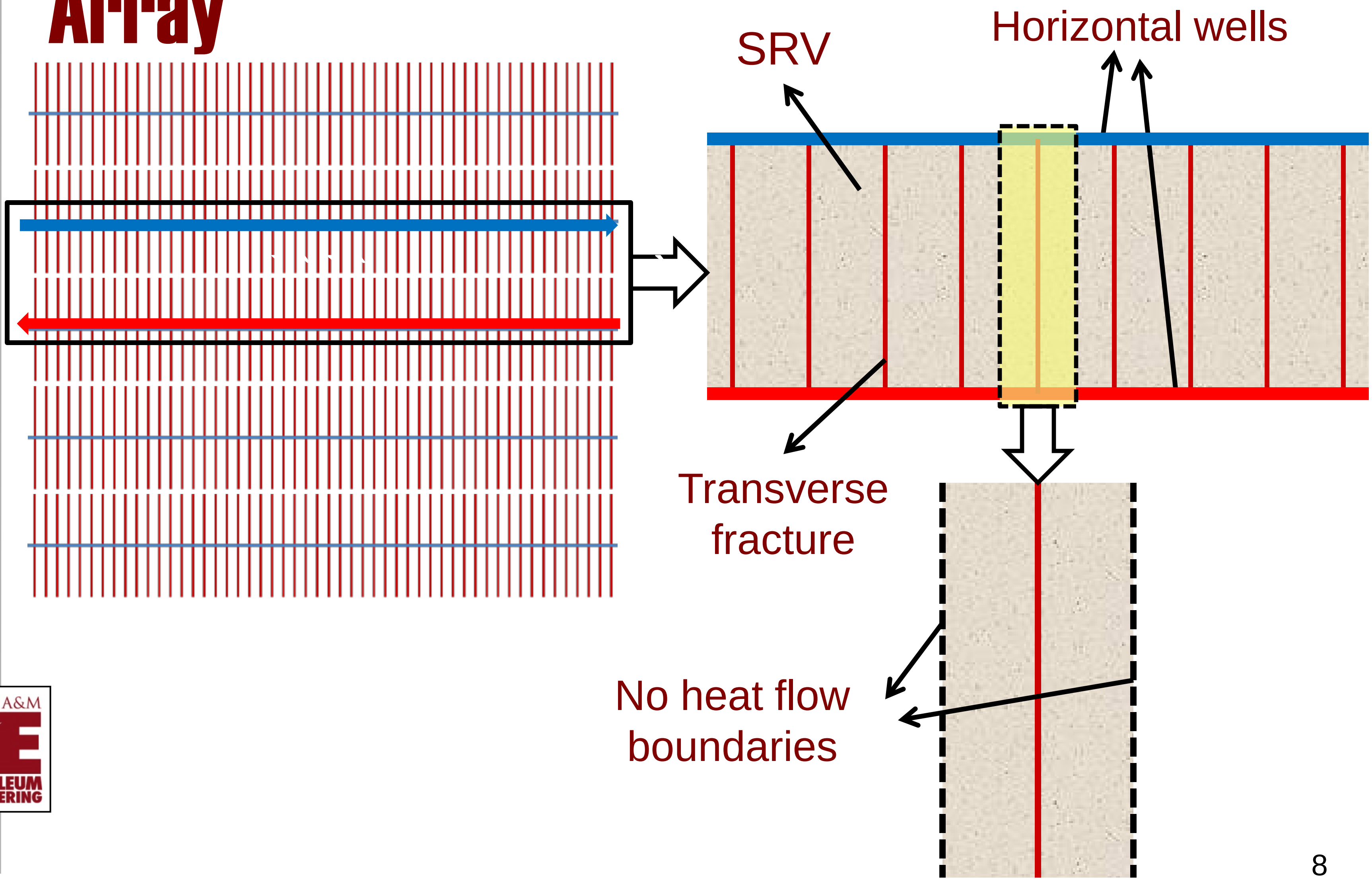
Pad Drilling



Pad Drilling



Idealization of Haynesville Shale Gas Well Array



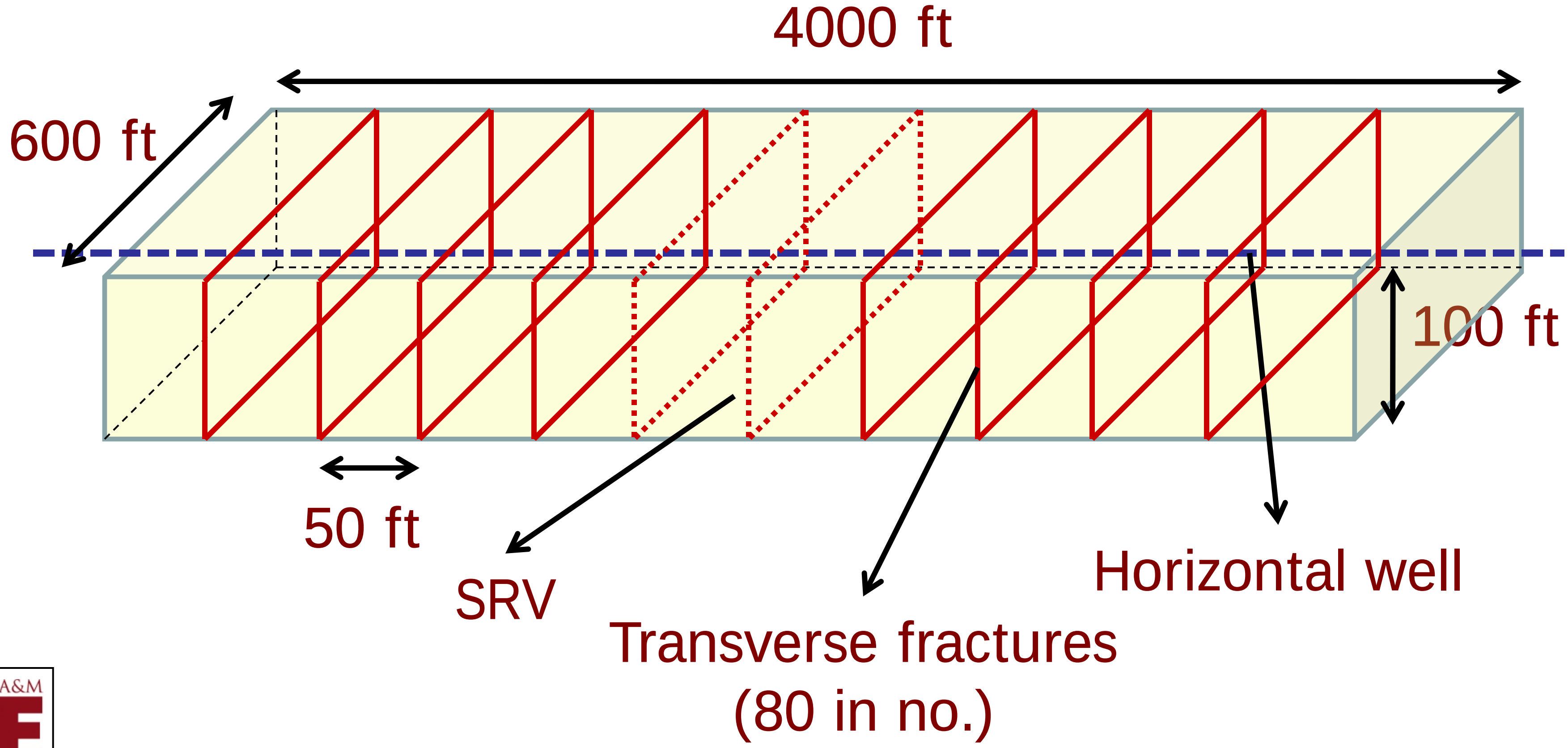
SRV

Horizontal wells

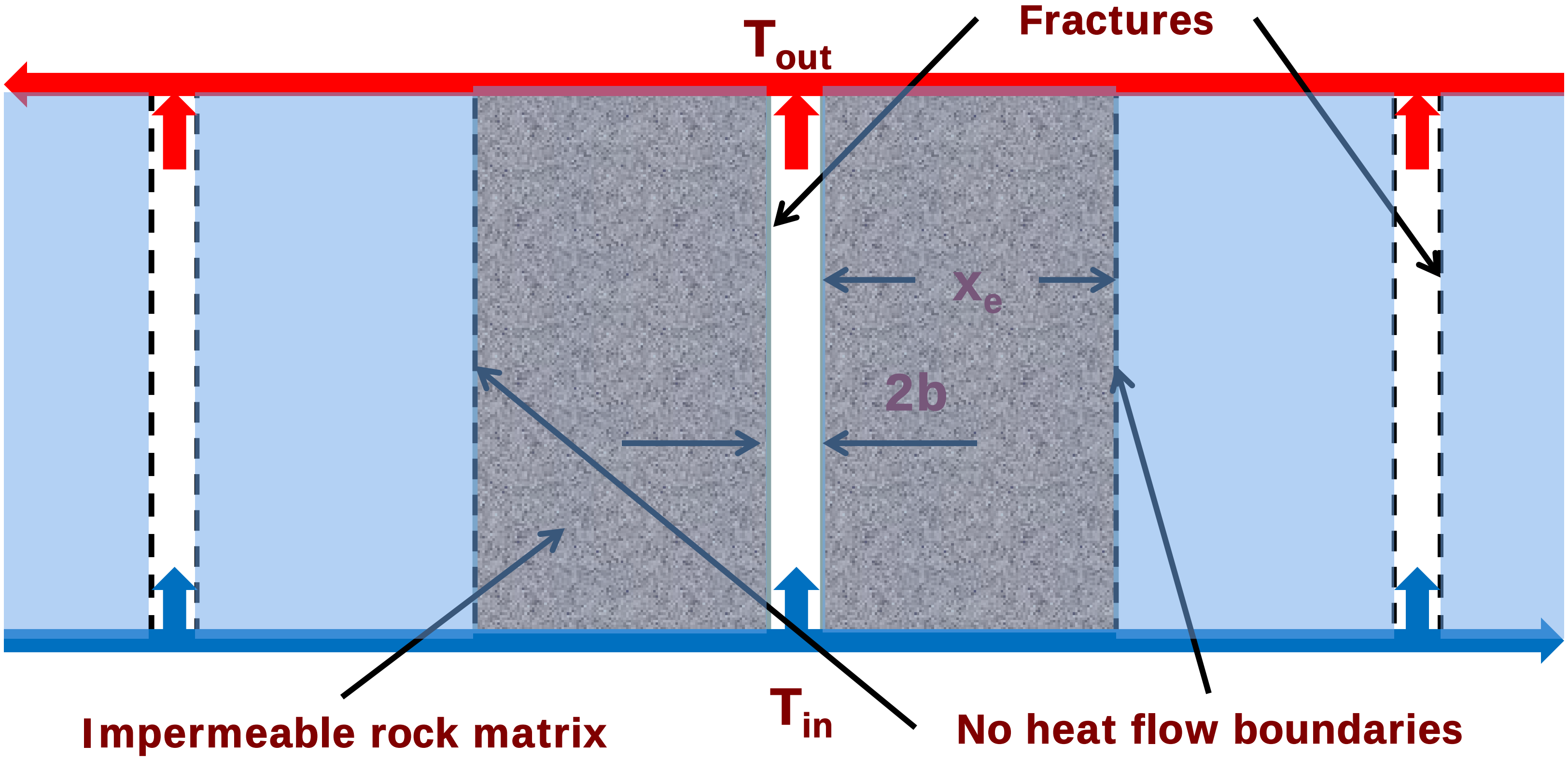
Transverse fracture

No heat flow boundaries

Typical SRV dimensions of a Shale Gas well in Haynesville



Analytical Model



Analytical Model

Heat conduction in rock matrix

$$\frac{\partial^2 T_r(x,y,t)}{\partial x^2} = \frac{\rho_r c_r}{k_r} \frac{\partial T_r(x,y,t)}{\partial t}$$

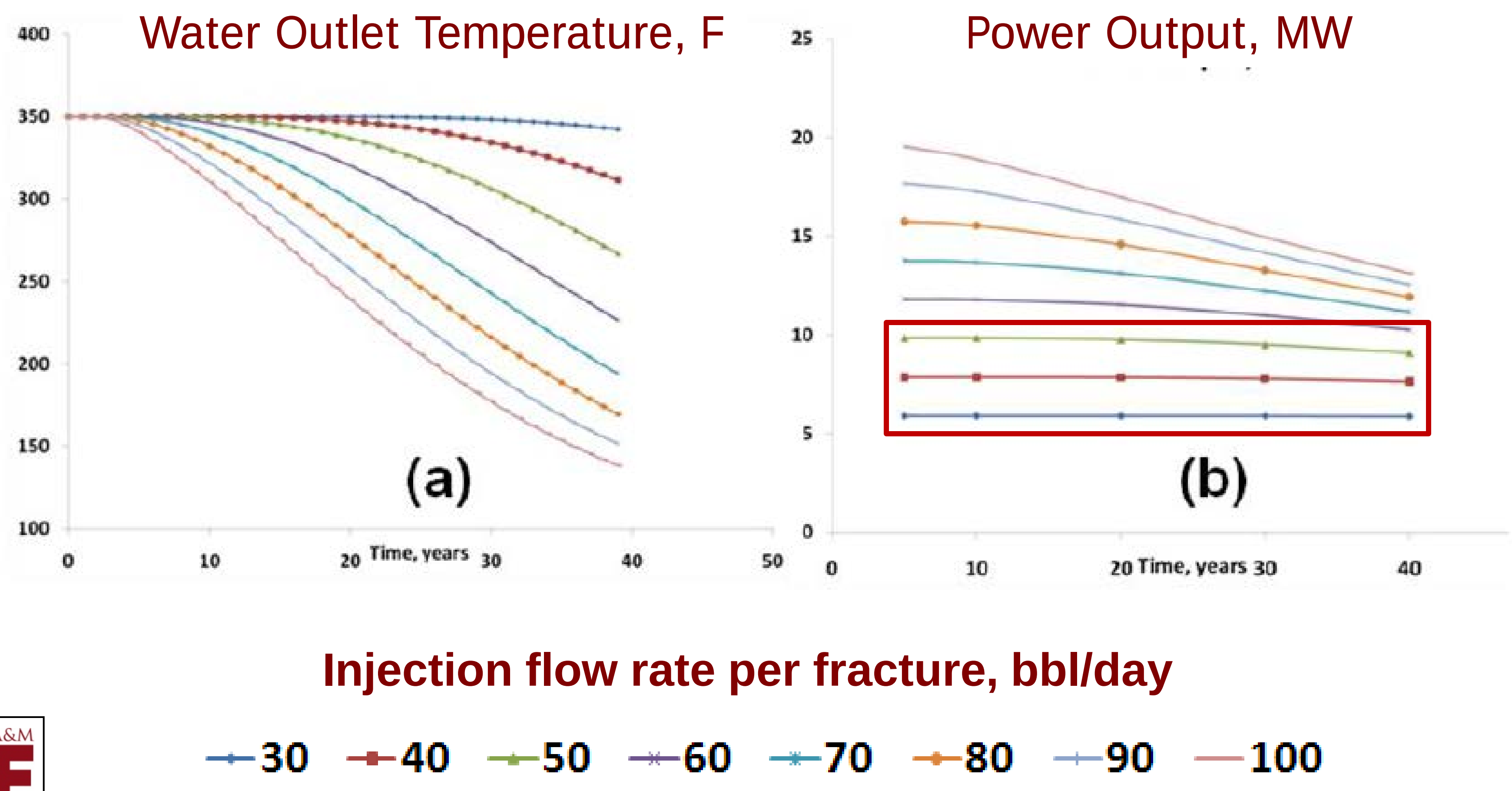
Heat conduction and convection for water in fracture

$$b\rho_w c_w \left[\frac{\partial T_w(y,t)}{\partial t} + v \frac{\partial T_w(y,t)}{\partial y}\right] = k_r \frac{\partial T_r(x,y,t)}{\partial x}_{(\,at\; x=b)}$$

Laplace transform solution

$$T_{wD}(y_D,s) = \frac{1}{s}\, Exp[-y_D s^{\frac{1}{2}} \tanh\left(\frac{Q\rho_w c_w x_e}{2\, k_r y_f}\right) s^{\frac{1}{2}}$$

Sensitivity to injection rate per fracture



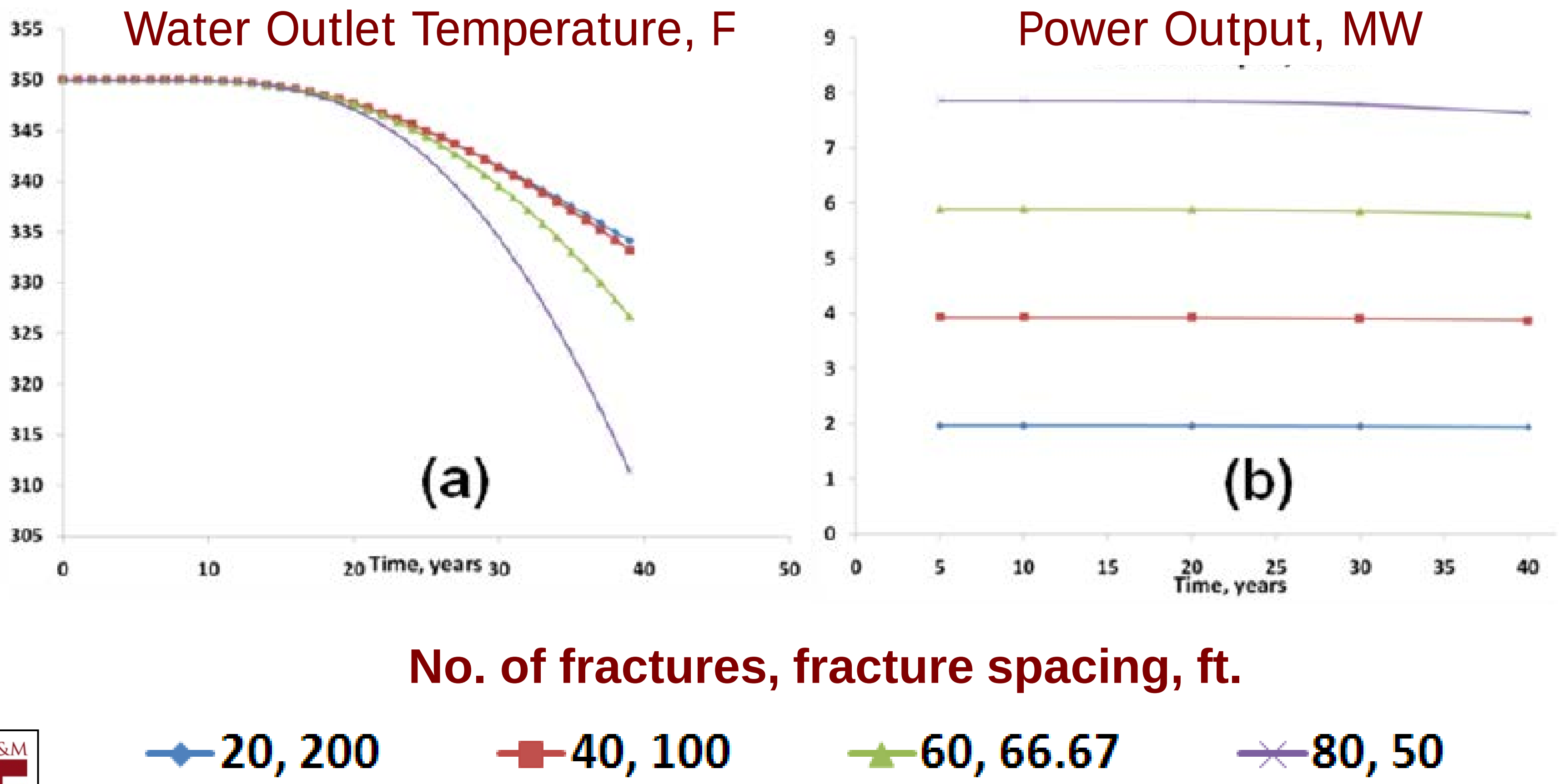
Water Outlet Temperature, F

Power Output, MW

Injection flow rate per fracture, bbl/day

80 fractures, 50 ft. spacing

Sensitivity to number of fractures

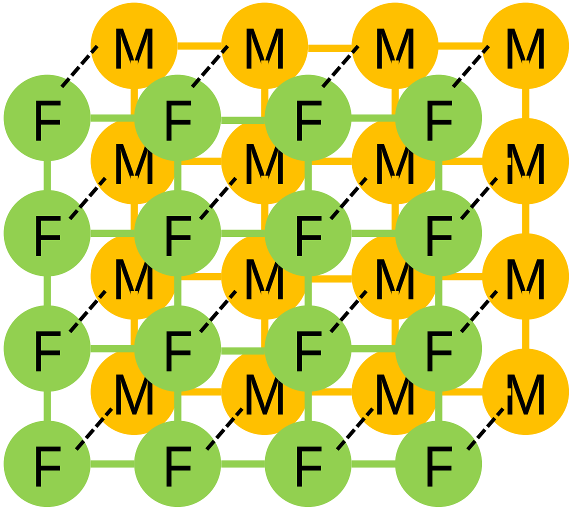

Water Outlet Temperature, F

Power Output, MW

No. of fractures, fracture spacing, ft.

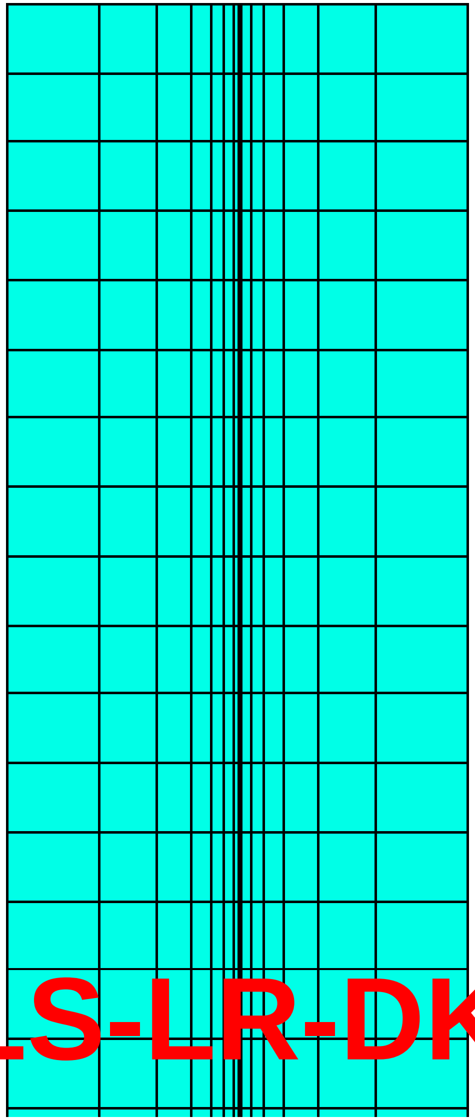
Injection flow rate per fracture = 40 bbl/day

Dual permeability (DK) and MINC models

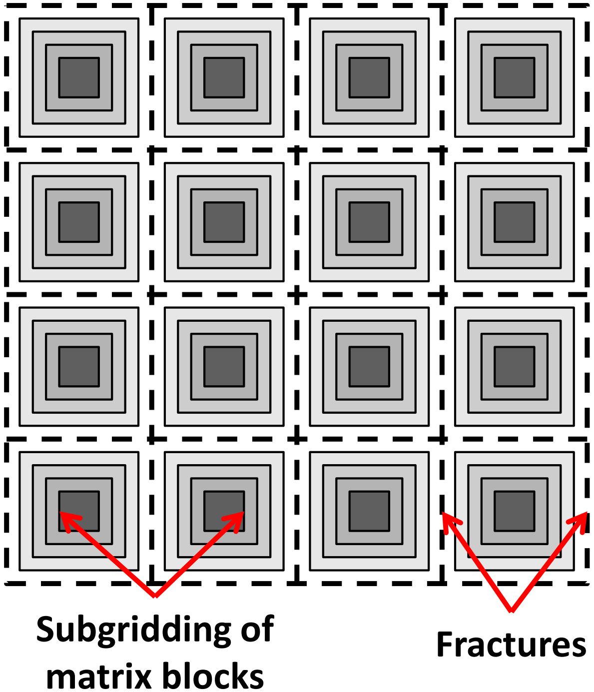


- F Fracture block
- M Matrix block

DK



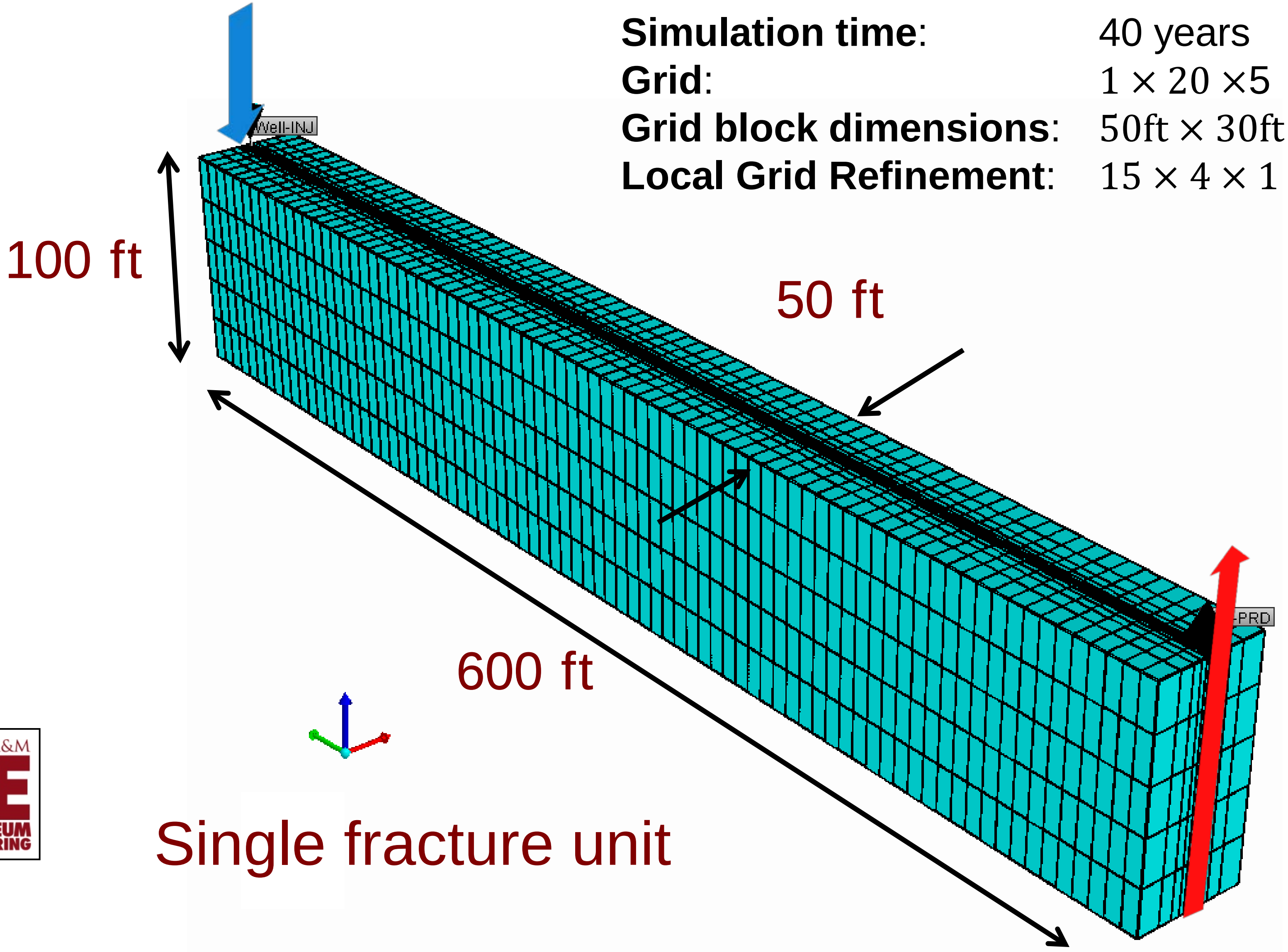
LS-LR-DK



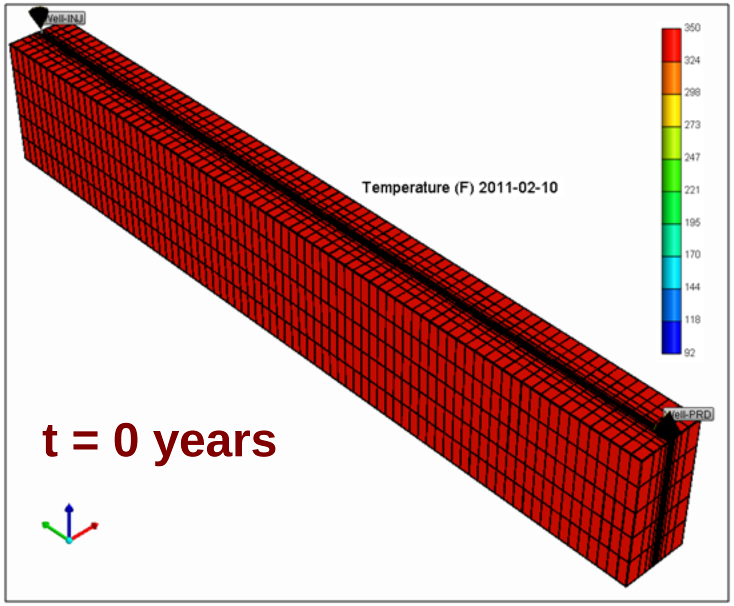
MINC

Numerical Model – CMG

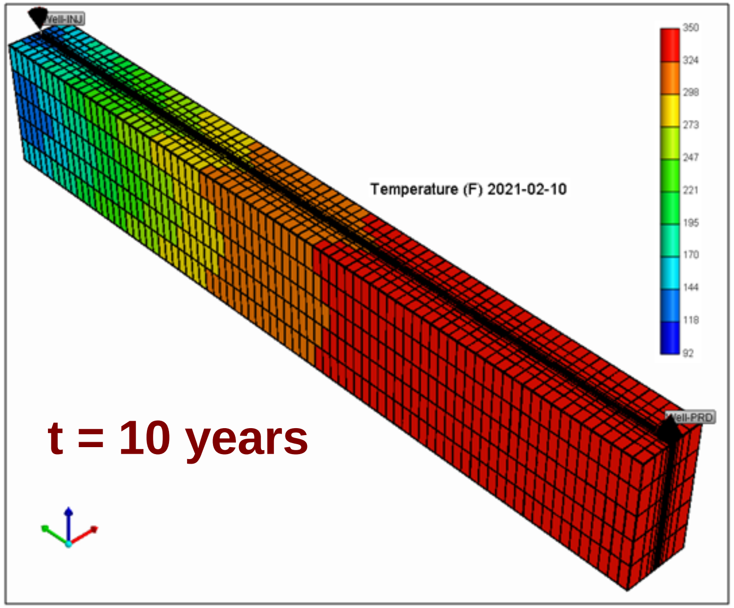
Simulation time:	40 years
Grid:	$1 \times 20 \times 5$
Grid block dimensions:	$50\text{ft} \times 30\text{ft} \times 20\text{ft}$
Local Grid Refinement:	$15 \times 4 \times 1$



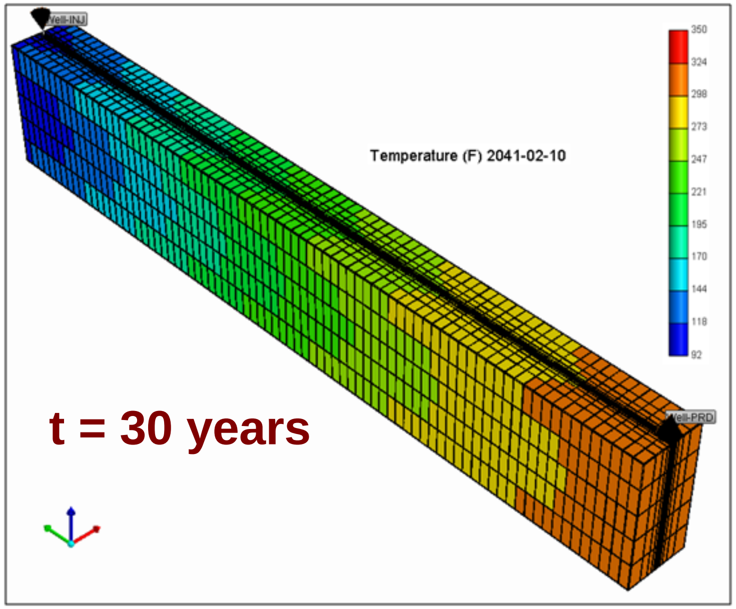
Single fracture unit



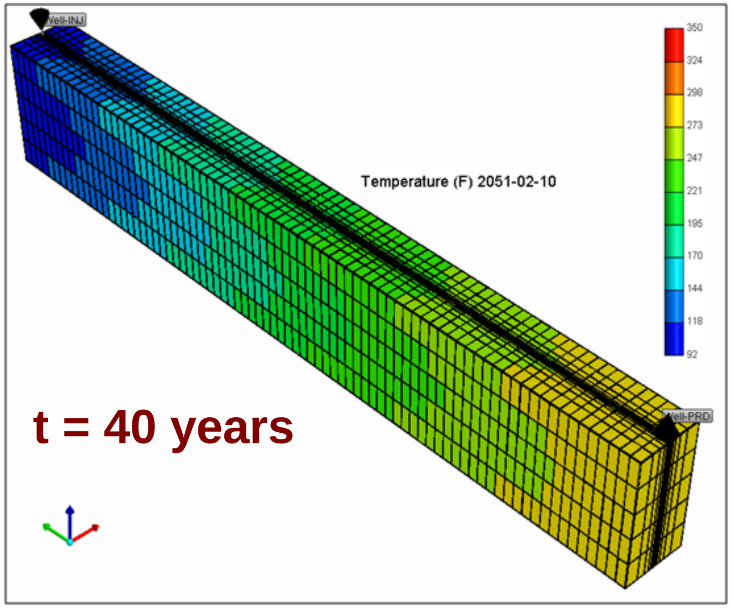
t = 0 years



t = 10 years



t = 30 years



t = 40 years

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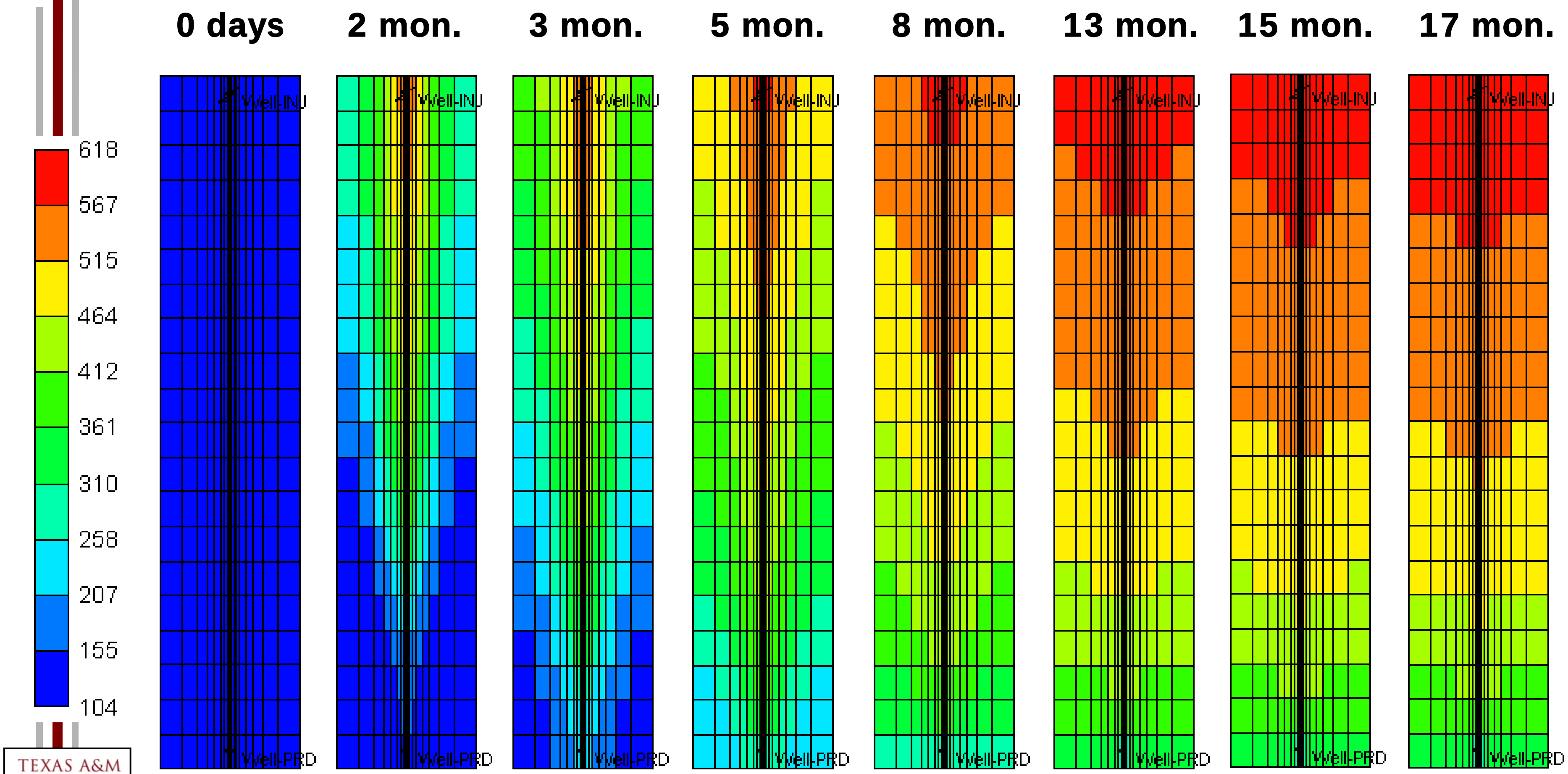
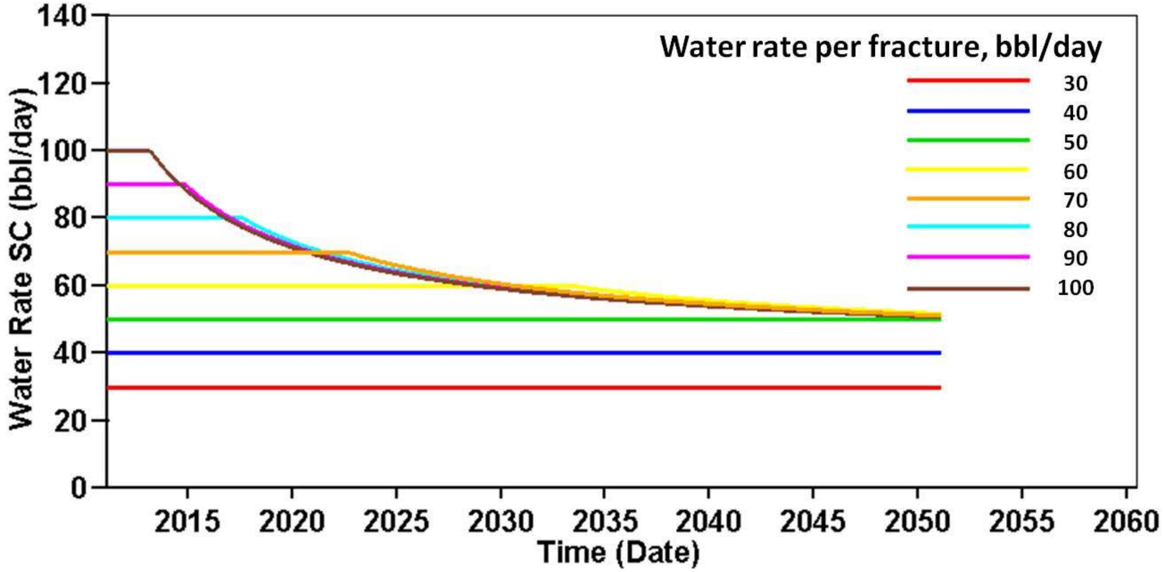
PETROLEUM
ENGINEERING

Thermal front movement

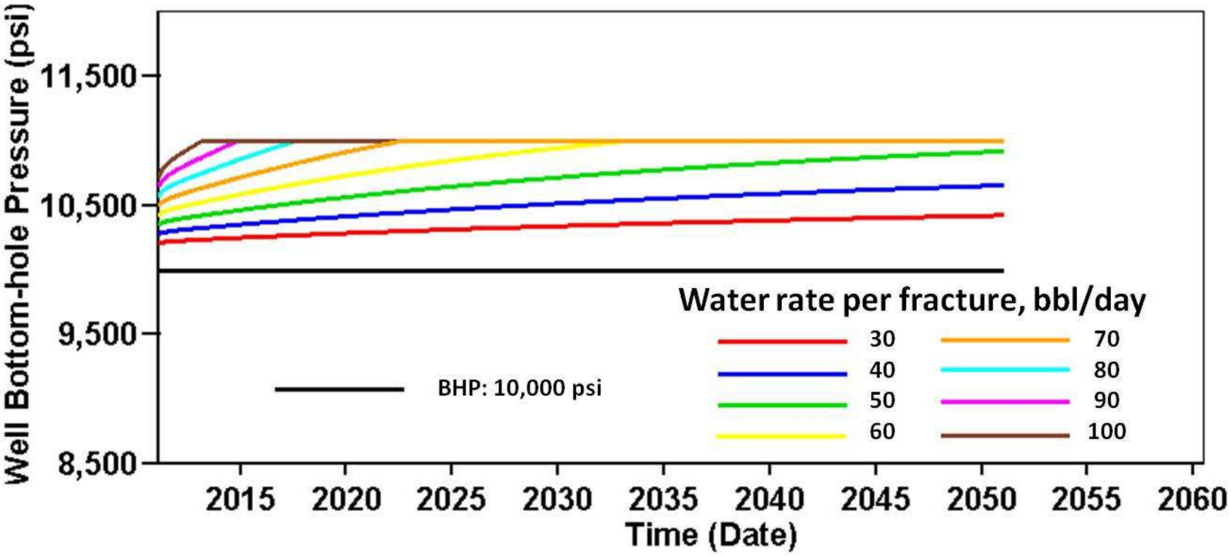


Simulation Results

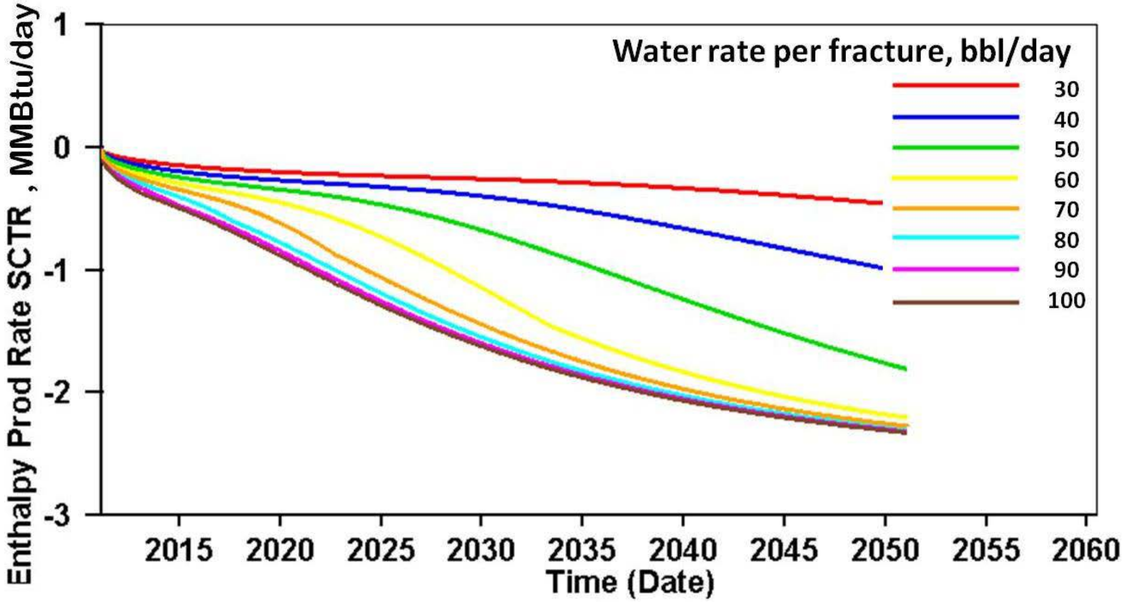
Injection rate per fracture, bbl/day



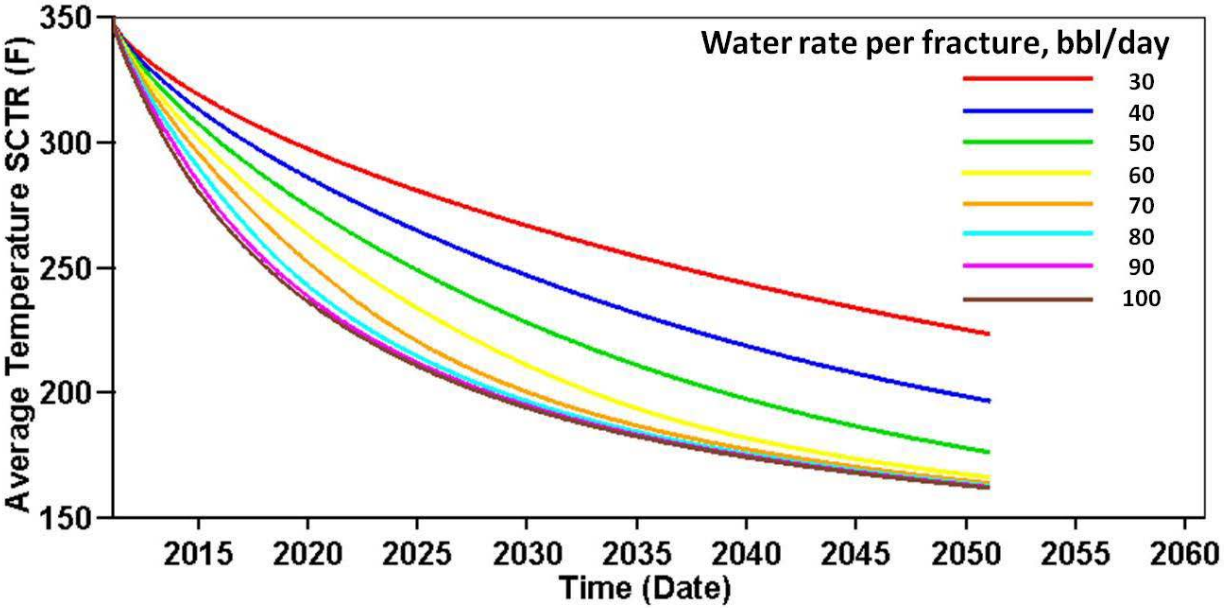
Well Bottom-hole Pressure, psia



Enthalpy Production Rate, MMBtu/day

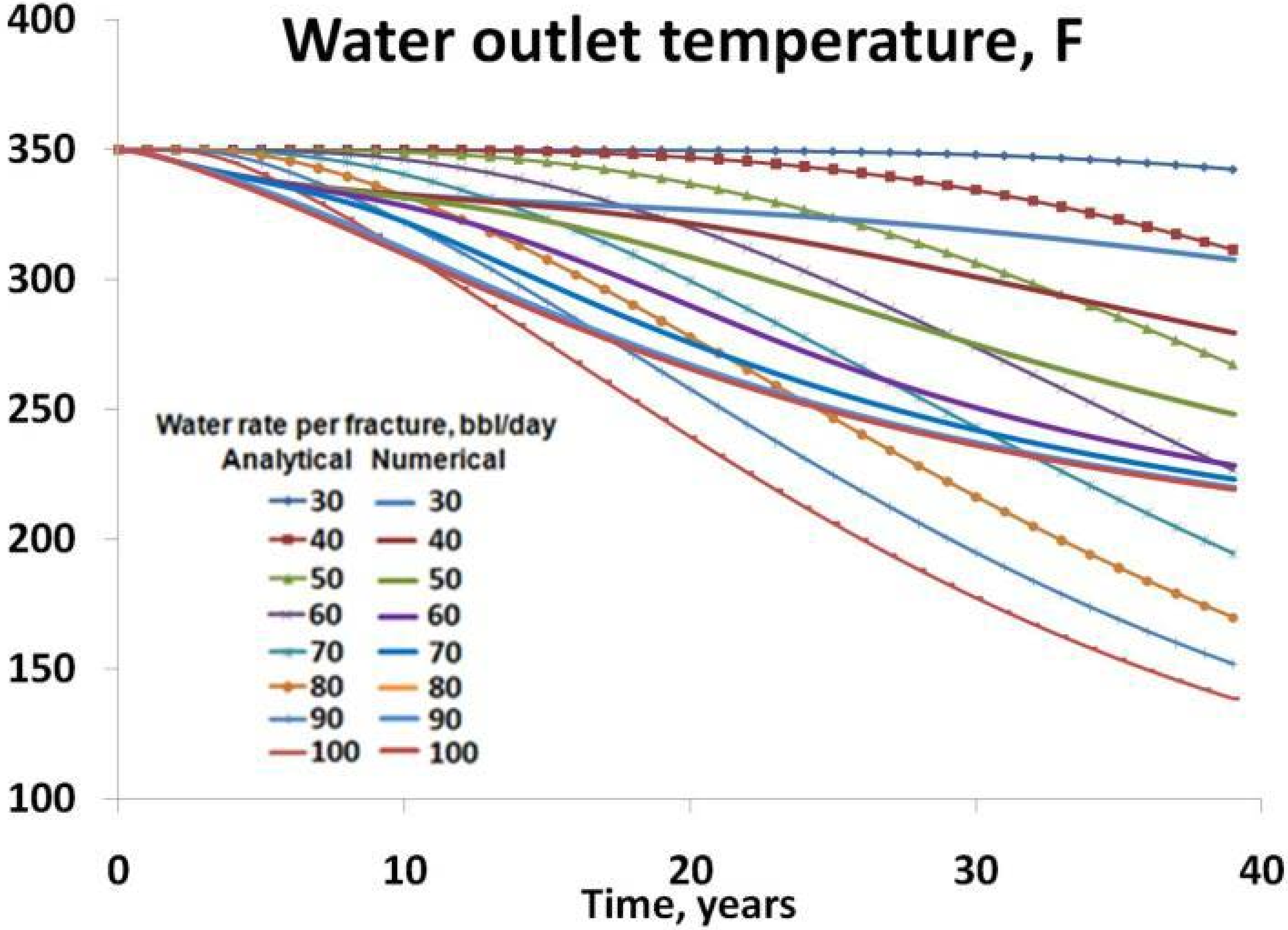


Average Formation Temperature, F



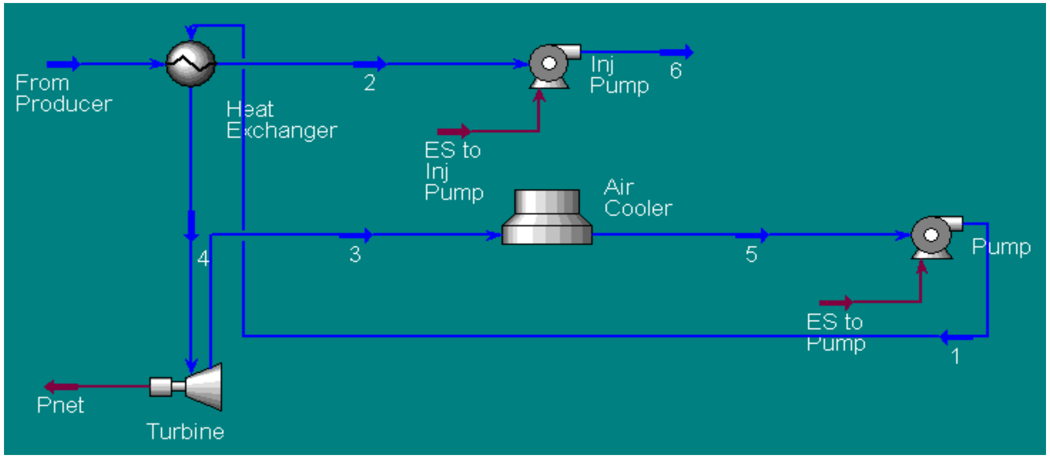
TEXAS A&M PETROLEUM ENGINEERING

Water outlet temperature

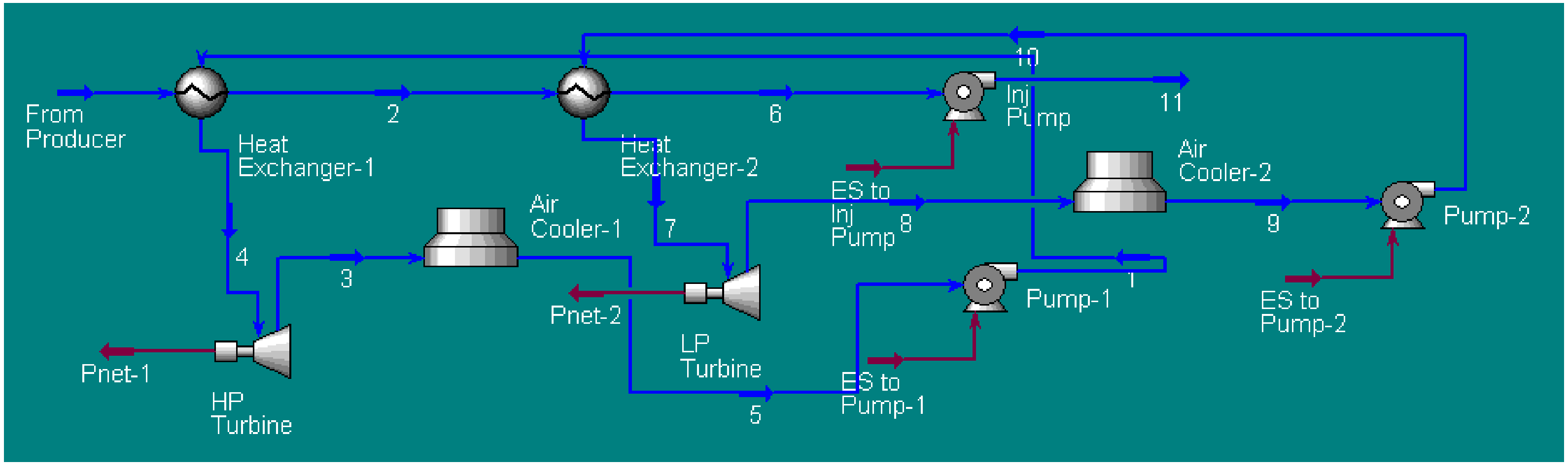


Binary Cycle Power Plant

AspenHYSYS

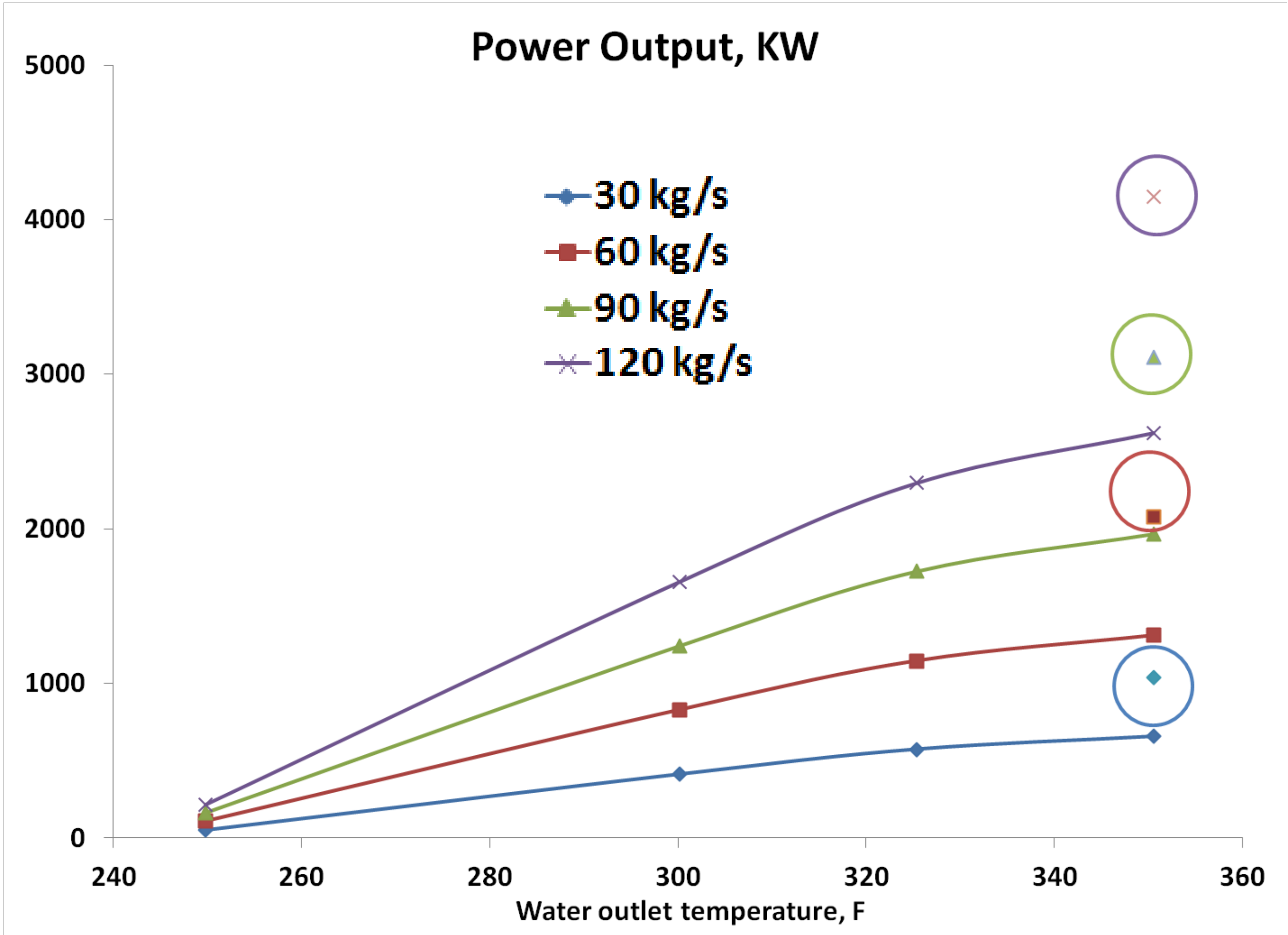


Basic Binary Power Plant

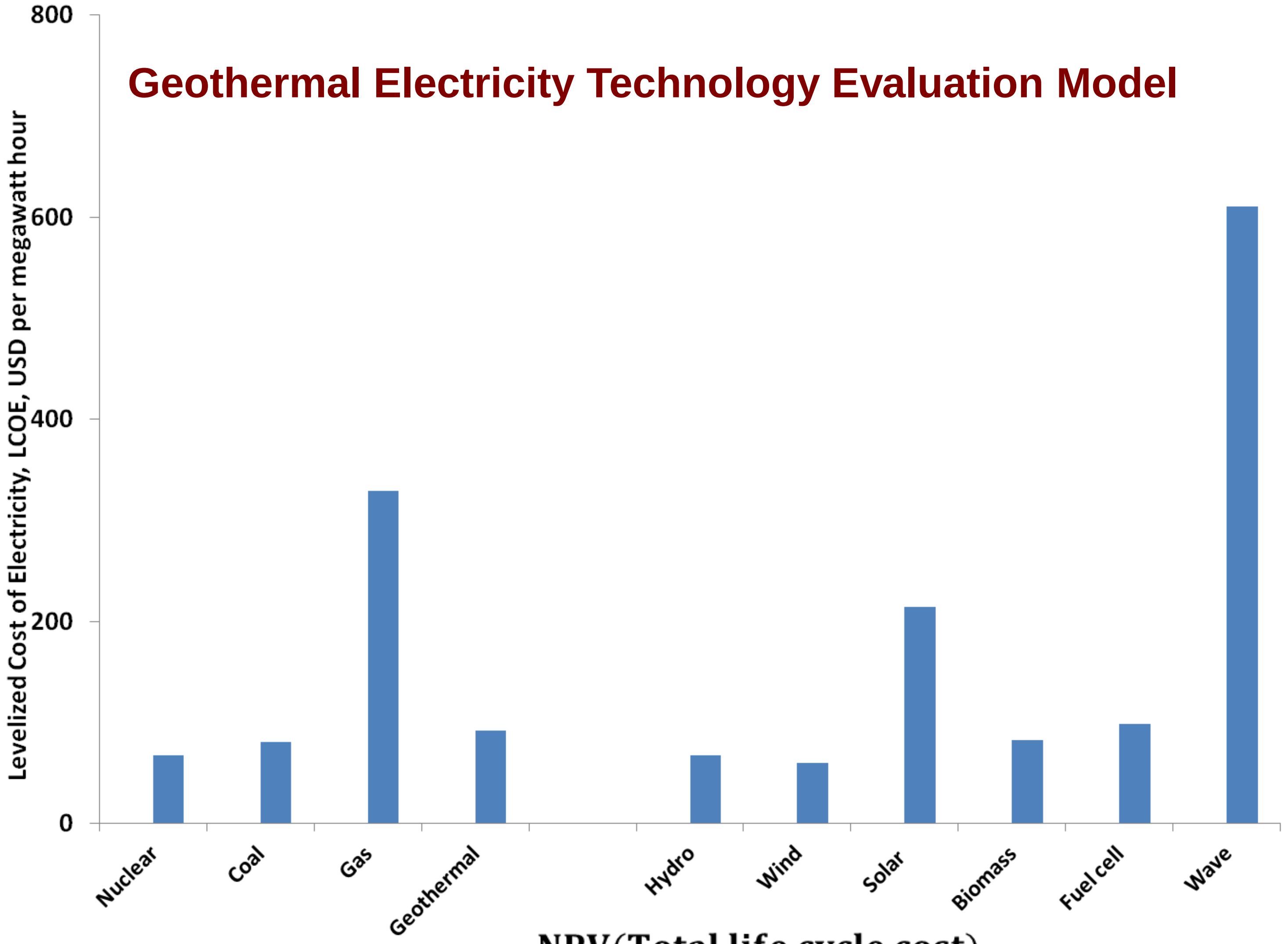


Dual Pressure Binary Cycle Power Plant

Net Power comparison for different water flow rates



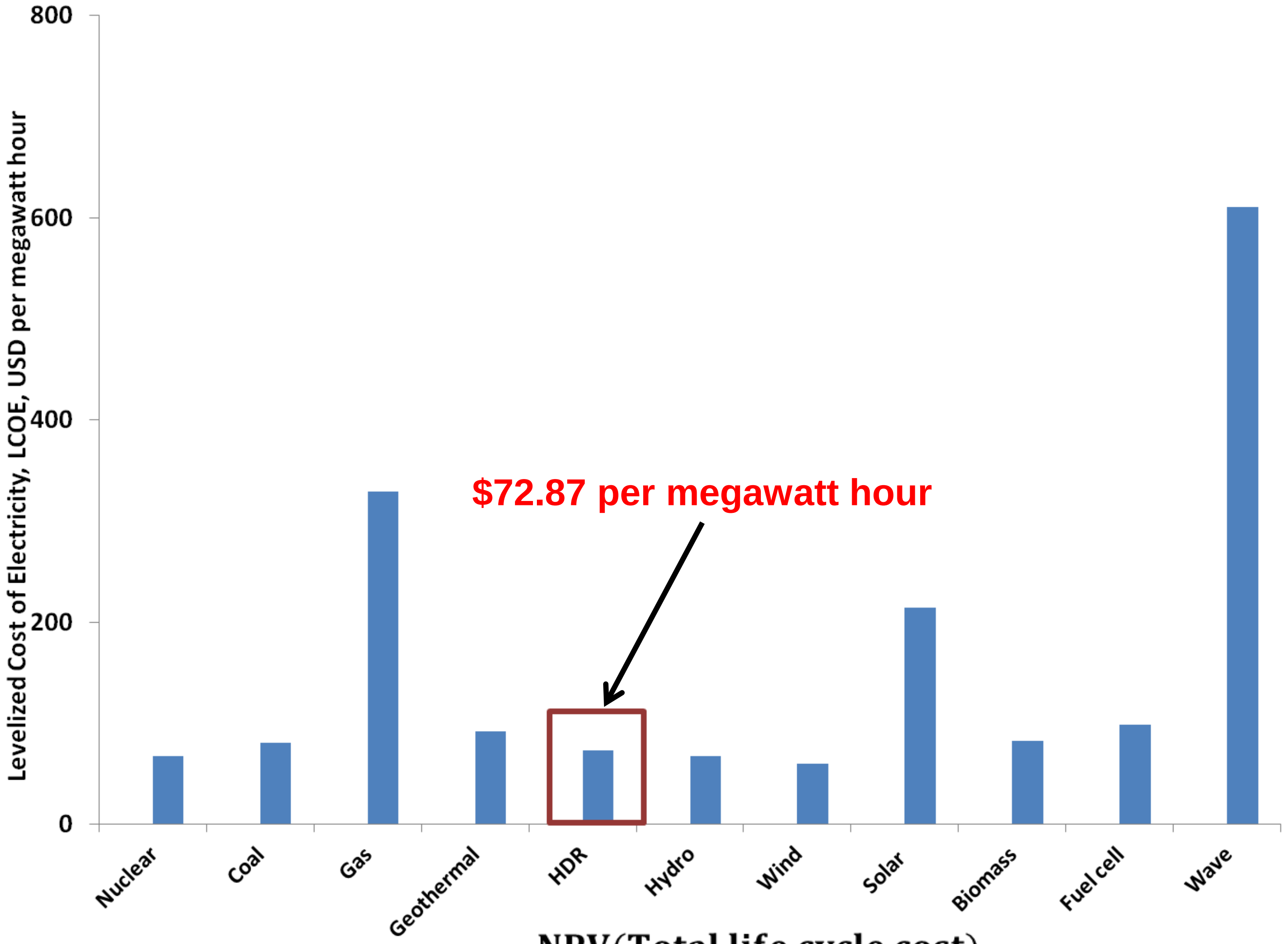
Economics – LCOE Comparison



Geothermal Electricity Technology Evaluation Model

$$\text{LCOE} = \frac{\text{NPV(Total life cycle cost)}}{\text{Total lifetime energy production}}$$

Economics – GETEM Model



$72.87 per megawatt hour

$$\mathrm{LCOE} = \frac{\mathrm{NPV}(\text{Total life cycle cost})}{\text{Total lifetime energy production}}$$

Conclusions & Recommendations

- Coupling models with a surface binary cycle power plant suggests that reuse of Haynesville shale gas production wells for low grade geothermal heat extraction after gas production is depleted appears feasible both technically and economically.

- Sufficient connectivity between adjacent wells can greatly aid to project economics by eliminating well drilling and completion costs.

Conclusions & Recommendations

- Dual pressure binary plant is more efficient and results in higher power output.
- Estimated LCOE of $73 per megawatt hour compares favorably to a natural gas power plant.

Future work

- Develop generalized intergranular thermo-geomechanical-chemical coupled model.
- Thermal contraction of the rock results in increased power output and should be incorporated into the model.