Cellulosic Bioethanol Plant Simulator:

Managing Uncertainty in Complex Business Environments

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14:15 – 15:00 The Waterloo

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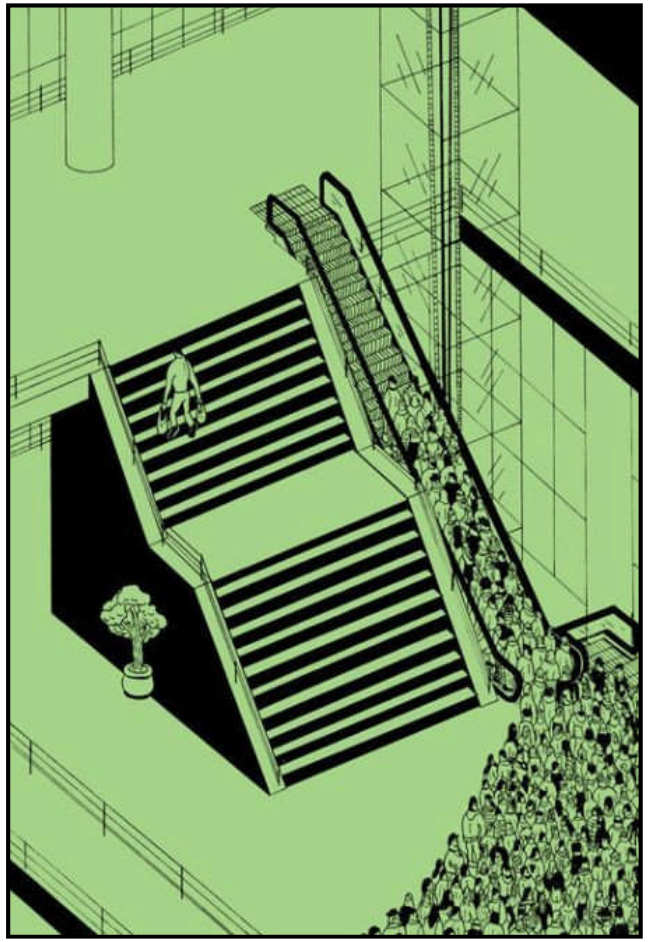
Orientation

- **Scope**
  - Orientation
  - Model composition & logistics
  - Demonstration & analysis
  - Real Options Analysis
  - Next steps
  - Questions / comments



- **Background**
  - Biomatica BV => Biotech: IT / Finance / RISK Mgmt / Bus Dev
  - Erasmus RSM Finance internship: European materials conglomerate
  - Biofuel project: Decision Making via Real Options & simulation

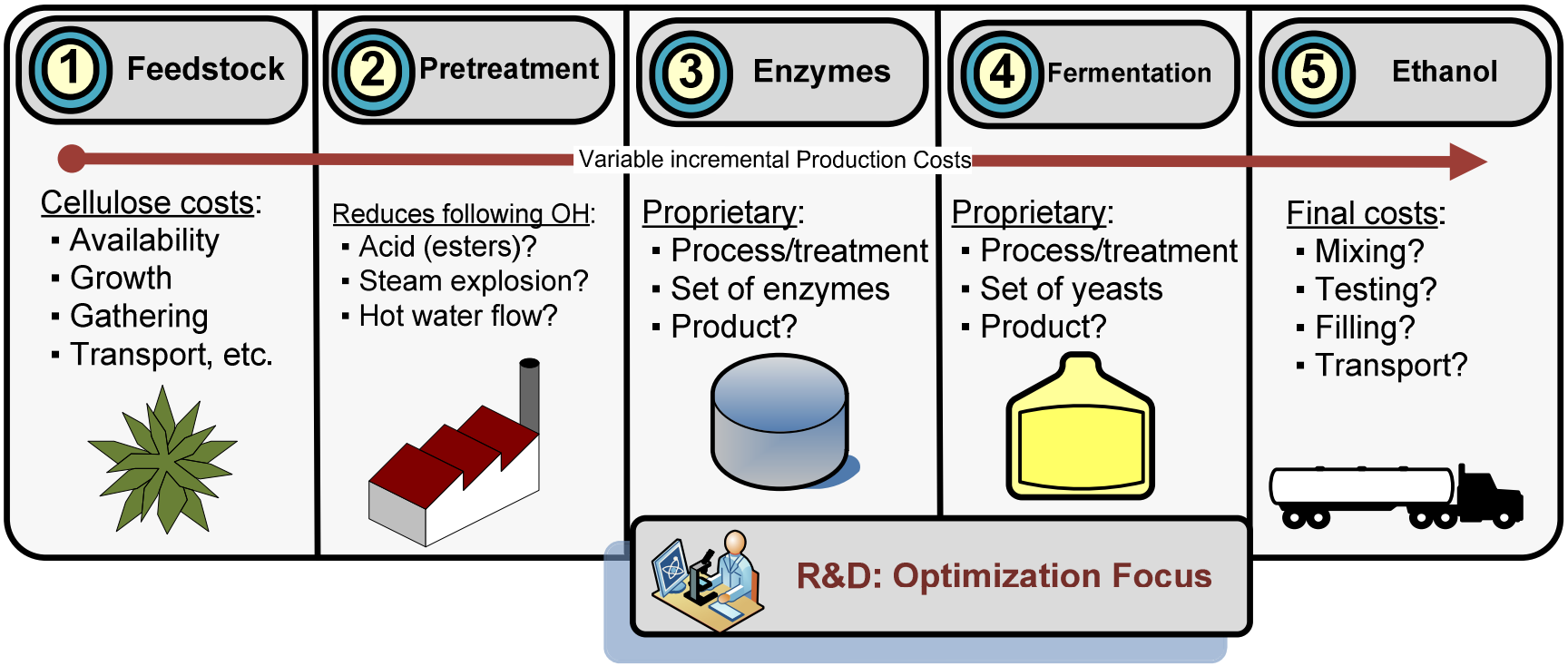
Sustainability: Biofuel Industry

- Long standing
- Tight margins
- New technologies (rapidly changing)
- Complex engineering
- Intertwined private and public aspect
- High risk investment
- Management of uncertainty
- i.e. ‘extreme’ oil industry projects
- ‘Doing good’?!

Cellulosic BioEthanol (CEtOH)

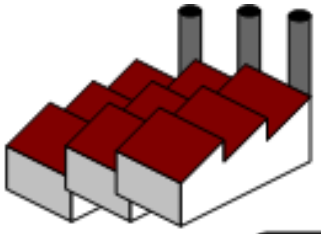
- **Cellulose**
  - Cell structural component in green plants & algae
  - Approx 33% of all plant matter
  - Most common existing organic compound
  - Indigestible by humans
- **Ethanol (EtOH)**
  - Blended into petrol (most autos can run on 10% blend)
  - 5.4% ethanol in global gasoline (2008)
  - 90% produced between US & Brazil
  - Increasingly target of mandates & subsidies
  - Trading market forming
  - Process similar to beer brewing

CEtOH Production Process



Processing/transformation of cellulosic-rich feedstock (i.e.: switchgrass, wood pulp, algae) into simple sugars suitable for subsequent fermentation

Operating Biofuel Plant Context



Market revenue

- **Plant revenue**
  - **Yield per plant**
    - **Plant capacity**
    - **Productivity per capacity unit**
  - **Profit margin**
- **Number of plants**

Global Factors:

- Productivity range
- Overhead/COGS
- Global oil prices
- Global supply costs

Productivity Factors
(variable activity based costing):

- Yield rates
- Yeast strain yields
- Enzymatic techniques
- Pre-processing effects
- Relative supply costs

Regional Factors:

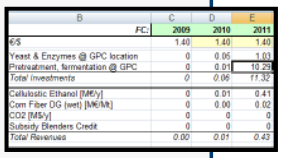
- Blend rates
- Tax rates
- Inflation
- GDP growth
- Material costs
- Labor costs
- Transport costs
- Productivity
- Political risk premium
- Cost of capital
- Subsidy factor
- Local biofuel prices

Managing Uncertainty → Analysis Process

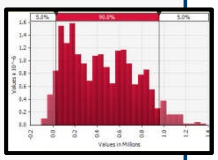
Uncertainties Categorized

1. Target process(es) to employ
   - Associated costs?
2. Product strategy
   - Associated revenues?
3. Revenue forecasting
   - Competition, economic factors?
4. Process cost analysis
   - Productivity variability?
5. R&D planning / decision making
   - What decisions, made when?

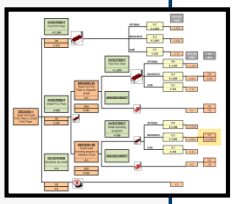
Process Defined



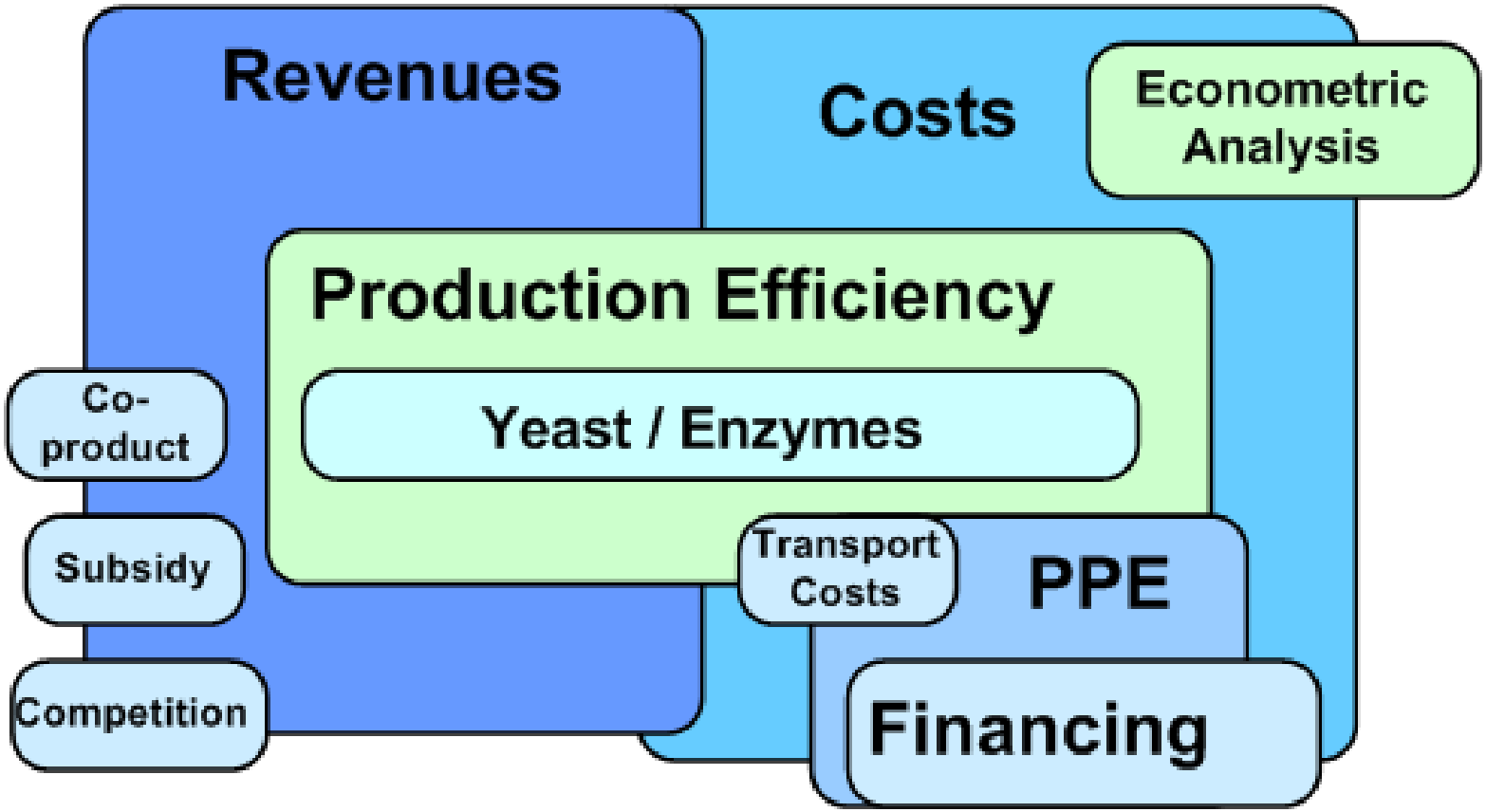
1. **NPV analysis**
   - Three processes
   - Product strategies
2. **Volatility simulation**
   - Monte-Carlo simulation



3. **Real Options Analysis**
   - Use range of NPV end-points
   - Add volatility (probability)
   - Add key decision points

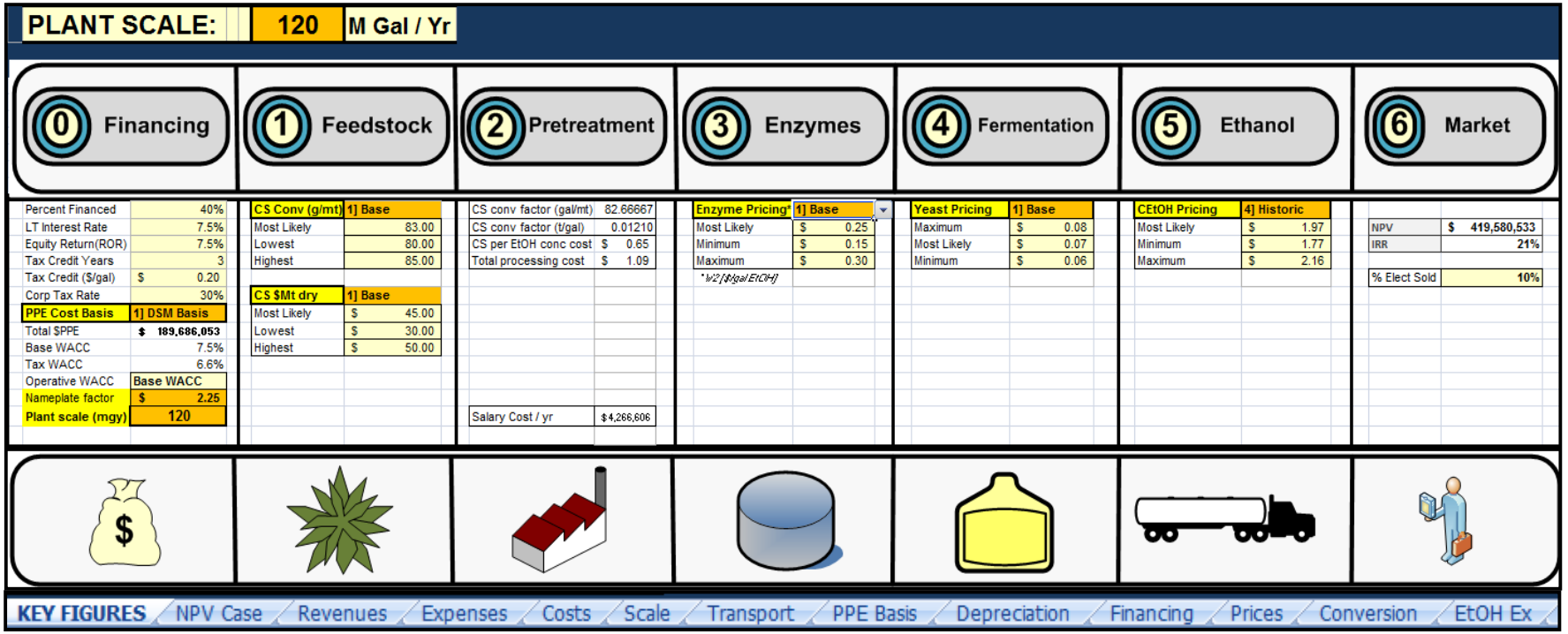


ViBeS: Virtual Bioethanol Simulator



- US NREL research
- U of Oklahoma – CEtOH calculator
- Iterative development working with industry experts

ViBeS: Virtual Bioethanol-plant Simulator

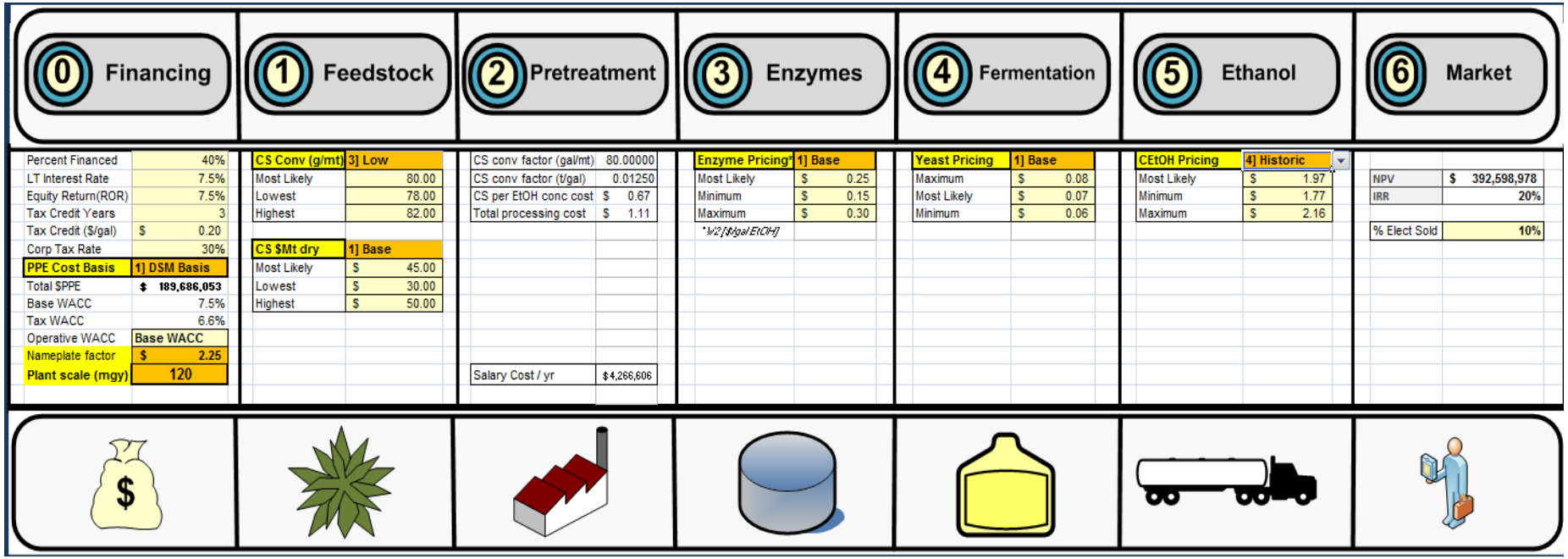


- NPV
- Revenues
- Expenses (OPEX)
- Scale
- Transport
- PPE (CAPEX)
- Depreciation
- Financing
- Econometrics

ViBeS: Virtual Bioethanol Simulator – Key Figures

- PPE cost basis
- Nameplate (CAPEX $/gal output)
- Feedstock conversion factor (gal/mt)
- Feedstock cost
- Enzyme and yeast pricing
- EtOH market price
- Byproduct / subsidy

- 90 distributions
- 10 year project
- Terminal & non-terminal values
- Normal, triangle & trend distributions



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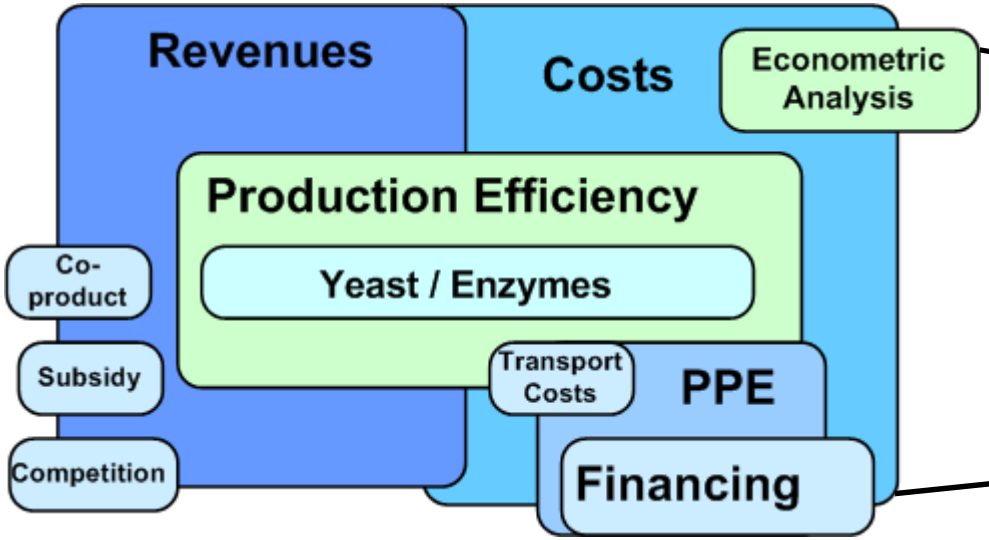
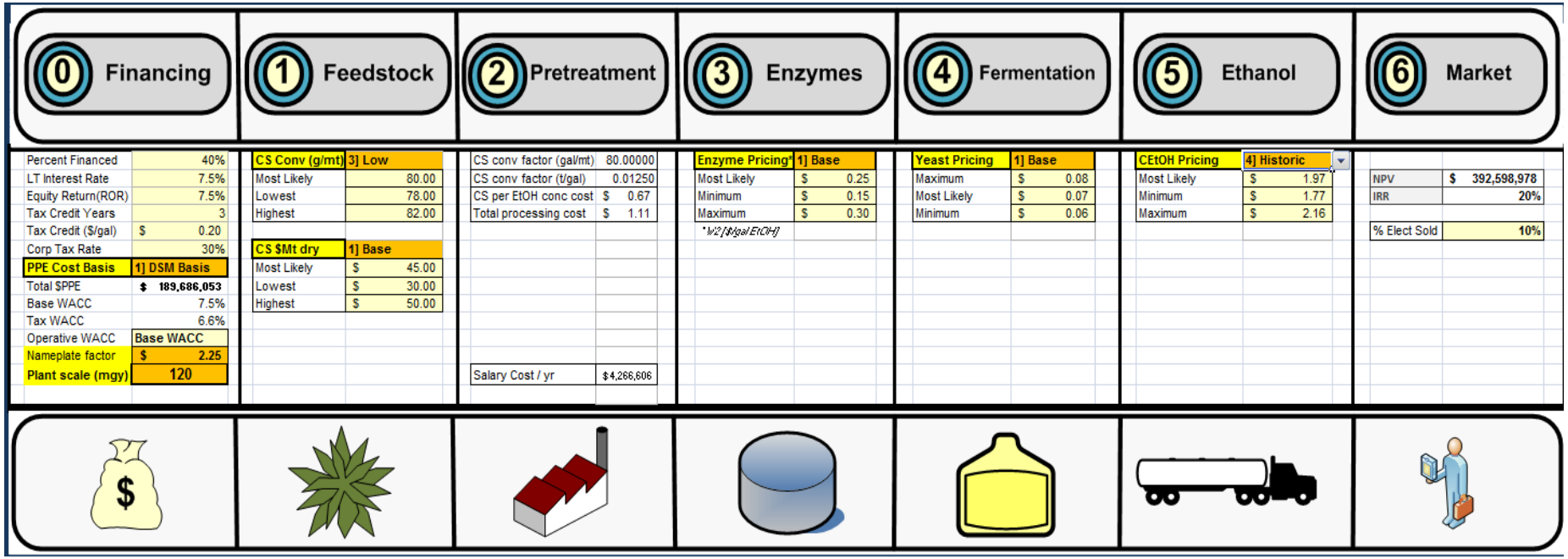


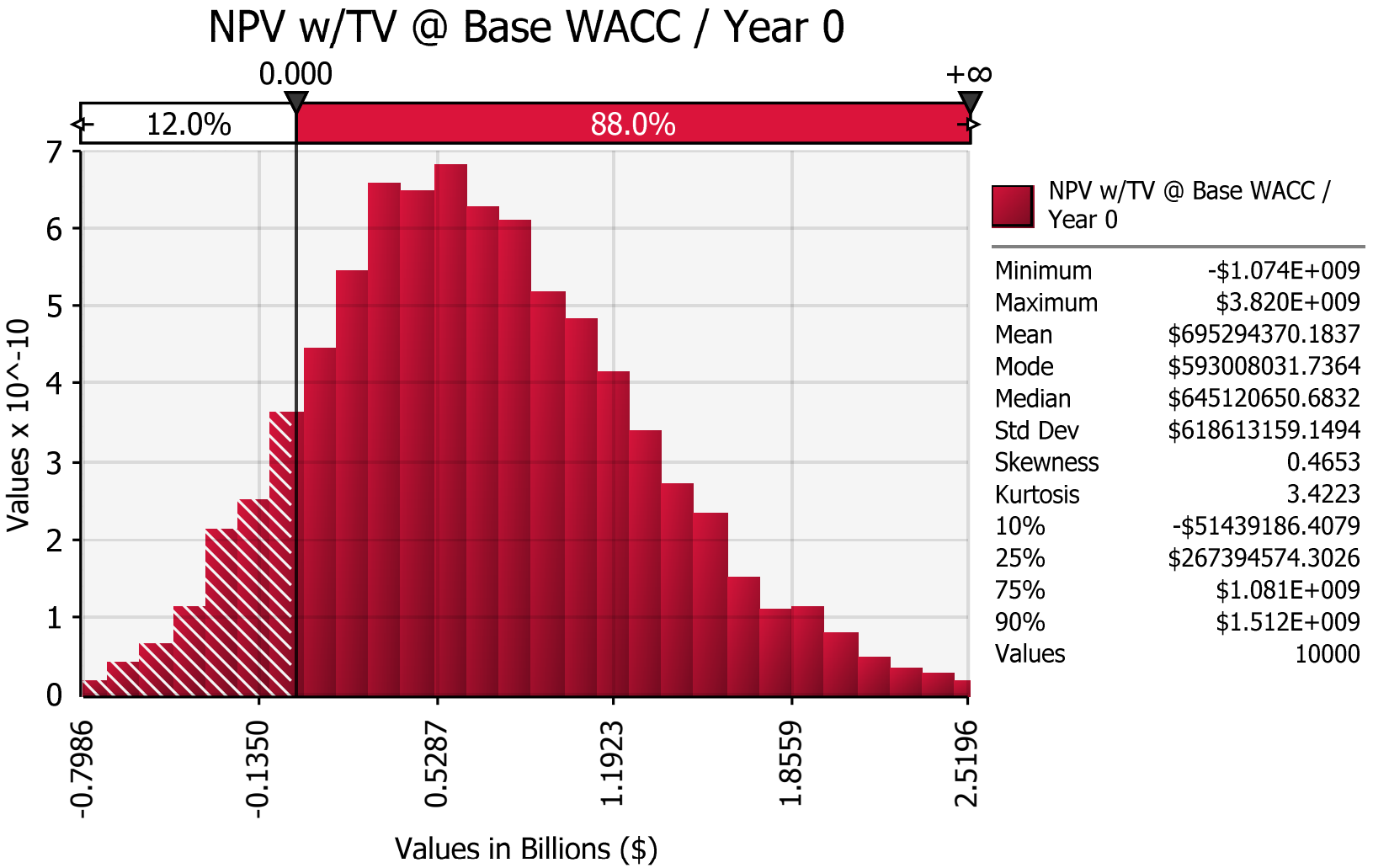
END-TO-END OPTIMIZATION
(OPEX & CAPEX)
- How do innovations effect process and plant productivity across PPE, efficiency, material / processing costs?
-What risk assurance value adds can be wrapped?
- What is 'educated basis' for investment?



Model Development Process

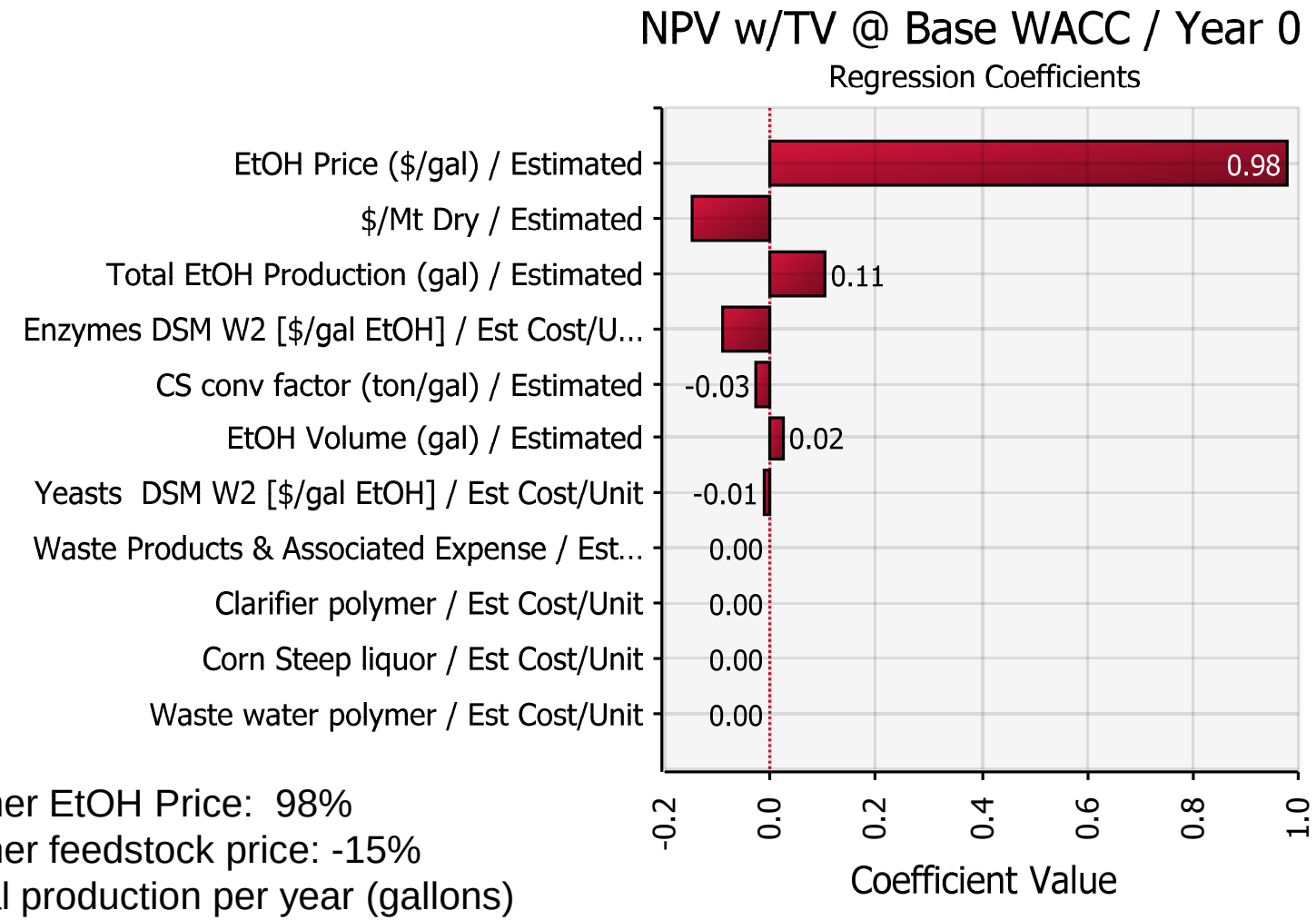
- Interviews of scientists & engineers
- Reductive, appreciate complexity & ‘completeness’
- Iterative development (cycles of ‘review and revise’)
- Education concerning model mechanics
- Tendency to speculate concerning econometrics
- Organizational considerations:
  - Risk appetite
  - Available corporate functionality (i.e.: advanced hedging)

Monte-Carlo Analysis Example



Minimum	-$1.074E+009
Maximum	$3.820E+009
Mean	$695294370.1837
Mode	$593008031.7364
Median	$645120650.6832
Std Dev	$618613159.1494
Skewness	0.4653
Kurtosis	3.4223
10%	-$51439186.4079
25%	$267394574.3026
75%	$1.081E+009
90%	$1.512E+009
Values	10000

Simulation: Regression Coefficients - Identifying NPV Key Drivers



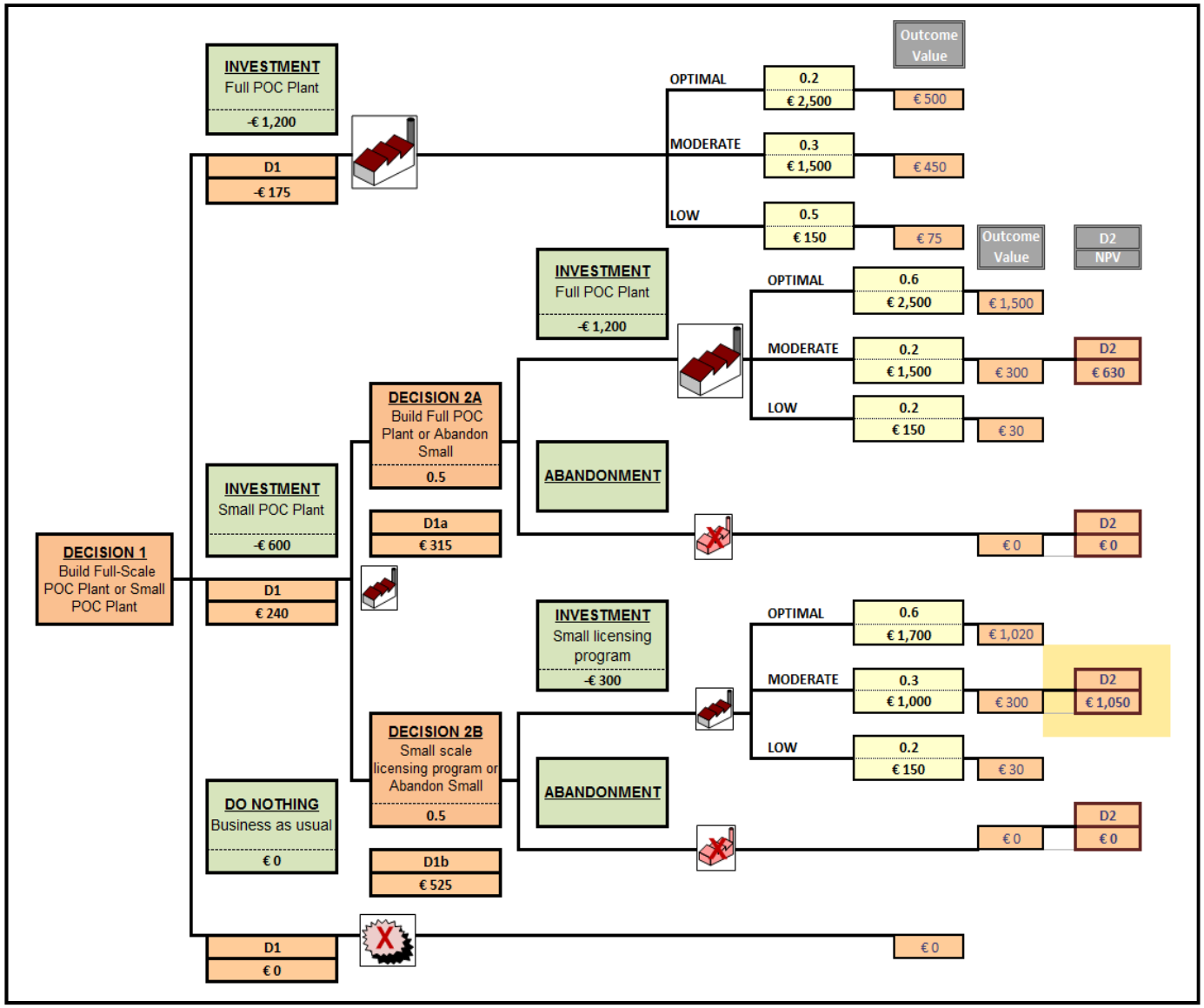
- Higher EtOH Price: 98%
- Higher feedstock price: -15%
- Total production per year (gallons)
- Euro/$ exchange rate (earlier version)
- OPEX costs (enzymes, yeasts) to productivity factor

Real Options Analysis

- Thesis project RSM MFM:

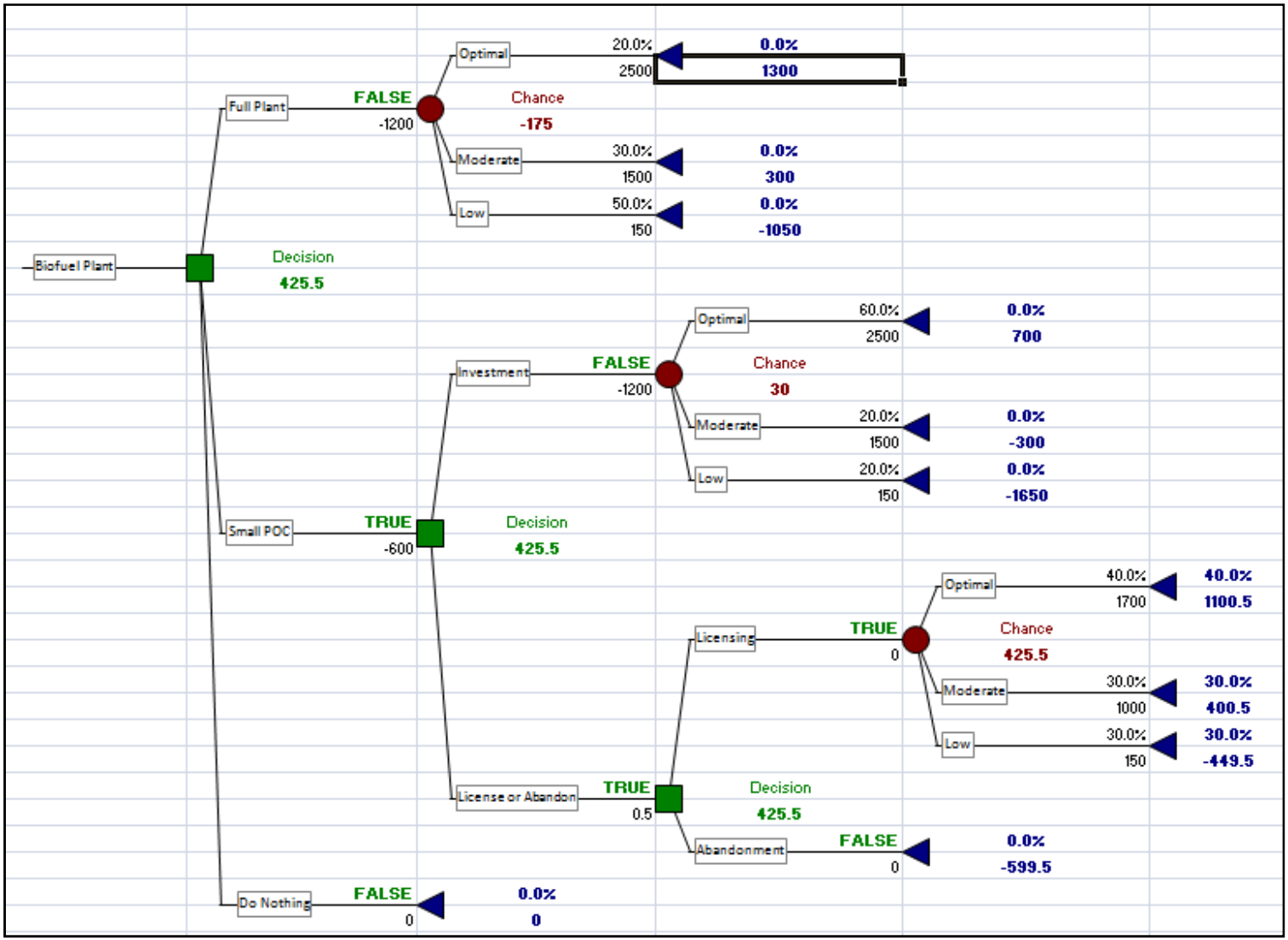
  '*Decision Support via Real Options Analysis*'
- 95% solid valuation / Monte Carlo
- ROA as a decision making process
  - Management buy-in/trust factor crucial
  - Requires 'optionality' paradigm understanding
  - Transparency
  - Agency factors
- R&D project management

Example: Biofuel Plant Decision Tree



1. Add management decision points, investments required, and probabilities
2. NPV valuation of each node in scenarios (DCF)
3. Work backwards to probabilistic ‘inherent value’ of management option to expand/contract at each step
4. Choose for highest NPV value at each decision point
5. Revise as probabilities, decisions, and values as time progresses

Precision Tree Implementation



Take-Aways

- Clarify ‘known unknowns’
  - Between CAPEX & OPEX
  - Overall profitability
  - Key CAPEX & OPEX reduction technical targets
  - Productivity
  - Value of co-product , subsidy, and recovery
- Useful for focusing discussions
  - Internal decision making
  - Partnership discussions
  - Investment analysis
  - Market dynamics

Conclusions

- CEtOH production not clearly profitable yet
  - Technology developing…
  - Sensitive to subsidies and mandates
  - Need to keep major stakeholders ‘dancing’
- Outsized concerns
  - Oil (EtOH) & feedstock costs
  - ForEx, interest rate (CoC), inflation
  - Susceptible to hedging and focused control
- Scale
  - Assumes proportional scalar CAPEX and OPEX…
  - Observable profitability benefit to scale (to 200 mgy)
  - Additional benefits of regional scale: feedstock/EtOH market-making
  - Anecdotal supporting evidence in brewery industry

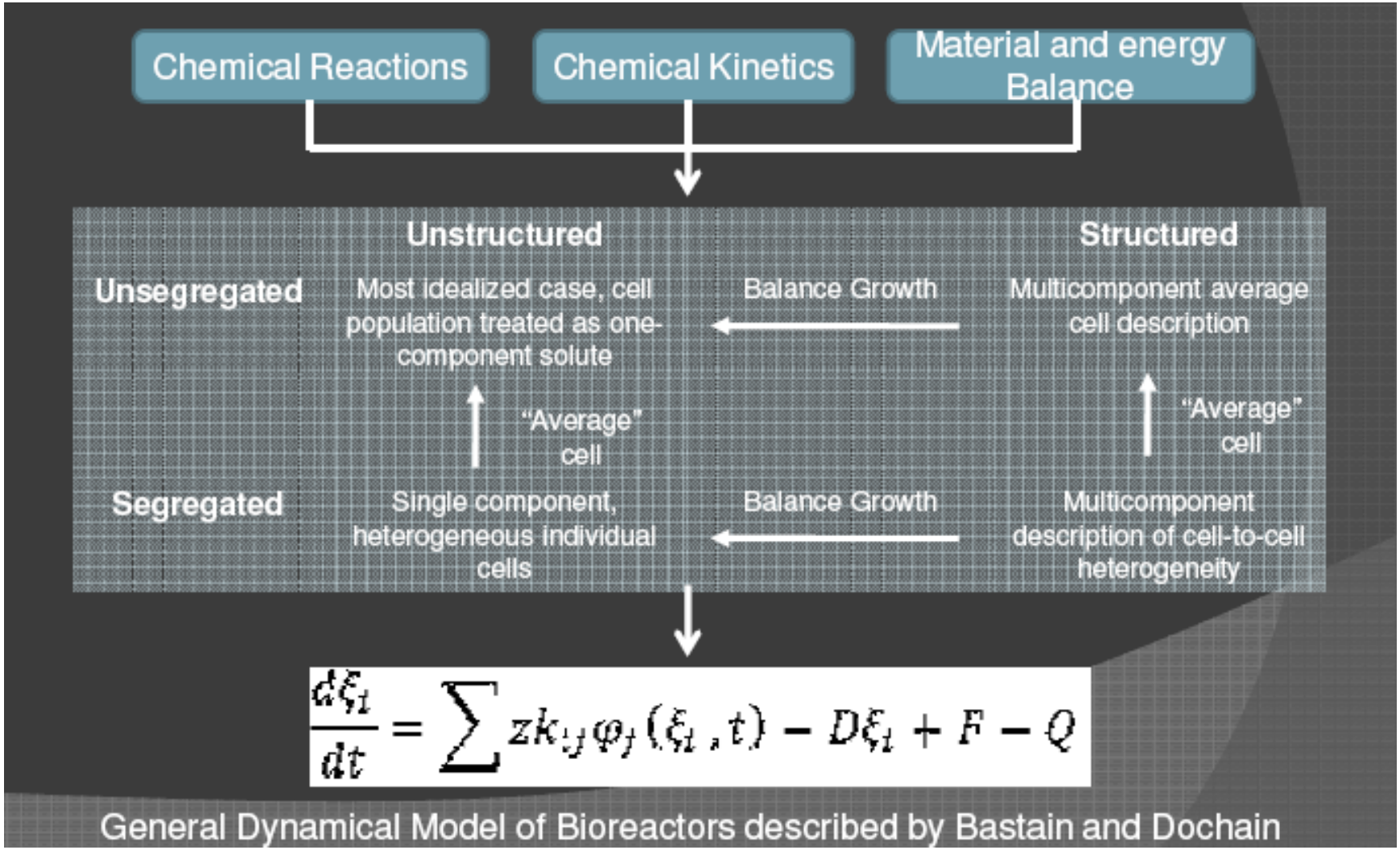
Recommendations

- Where are we today?
  - Sustainability & ‘shareholder’ business model legacy
- Difficulty bootstrapping sustainability projects
  - Marginal profits
  - Catch 22: Subsidy ⇔ R&D ⇔ Investment
  - Complex relation: CAPEX, OPEX, financing, dep…
- Advice
  - Credit crisis: insight into systemic risks…
  - Sustainability: reverse engineer & manage systemic risk
  - Bring systemic conversations together
  - Bring agency interests together (megaproject risk mgmt)
  - Organizational need for actionable risk management (RR)

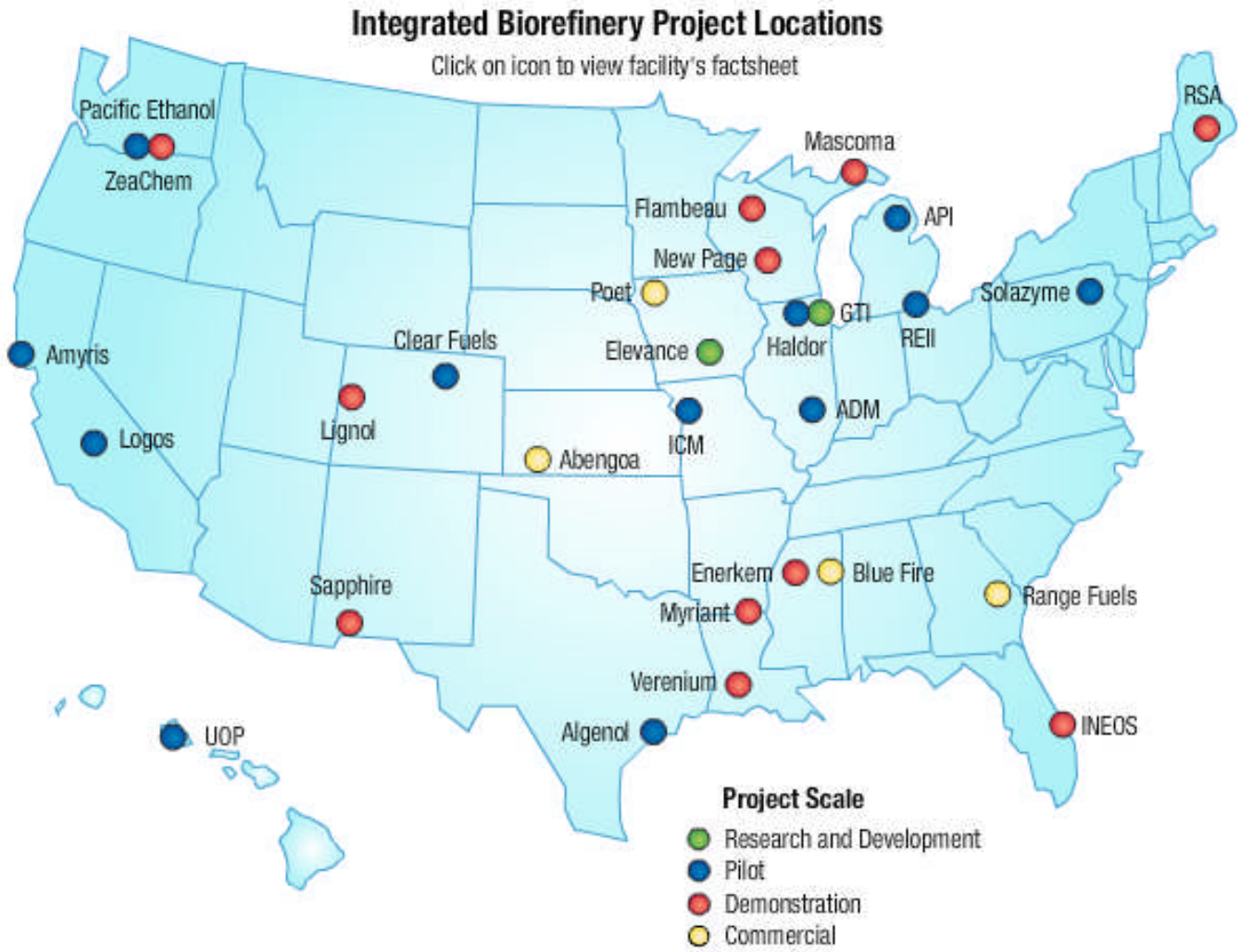
Possible Future Simulation Development

- Fermentation
- Extended market competition simulation
- Real Options Analysis process
  - R&D project decision making process
  - Project risk management
- Partnership & co-investment analysis
- Deeper economic & econometric analysis

Example: Fermentation Simulation



Example: Market Competition Simulation



Source: US Department of Energy: *http://www1.eere.energy.gov/biomass/integrated_biorefineries.html*

References

- Dr. Michael Rees, Palisade's Global Director of Training and Consulting '*Financial Modelling in Practice*' (John Wiley & Sons, 2008)
- Aden, Ruth, Ibsen, Jechura, Neeves, Sheehan, Wallace, Montague, Slayton,&Lukas '*Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover*' (NREL, 2002)

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