Onshore Lower 48 Oil & Gas Supply Submodule

Methodology Peer Review

December 6 – 7, 2006
Vienna, VA

Peer Review Agenda
Wednesday, December 6, 2006

Time	Topic	Presenter
8:30-8:45 AM	Welcoming Remarks	Dana Van Wagener/Philip Budzik
8:45-9:15	Overview of NEMS –Reason for New Model –Expectation of Peer Review –New NEM Design	Dana Van Wagener/Philip Budzik
9:15-10:15	Overall System Logic –Logic Flow –Envisioned Product –New Enhancements	INTEK, Inc./Serco
10:15-10:30	Coffee Break	--
10:30-11:30	Resource Module –Data Description & Sources ◦Discovered ◦Undiscovered ◦Production ◦Reserves –Future Updates	INTEK, Inc./Serco
11:30-12:00	Technology Screening Module	INTEK, Inc/Serco

Peer Review Agenda
Wednesday, December 6, 2006

Time	Topic	Presenter
12:00-1:00 PM	Lunch	--
1:00-1:45	Process Module –Type Curves	INTEK, Inc./Serco
1:45-2:45	Technology Levers/User Options	INTEK, Inc./Serco
2:45-3:00	Coffee Break	--
3:00-5:00	Economic Module –Model Description/Logic Flow –Economics –Ranking of Projects –Selection of Projects	INTEK, Inc./Serco

Peer Review Agenda
Thursday, December 7, 2006

Time	Topic	Presenter
8:30-10:15 AM	Development Economic & Constraints	INTEK, Inc./Serco
10:15-10:30	Coffee Break	--
10:30-11:30	Open Discussions	All
11:30-12:00	Summary of Comments & Concluding Remarks	INTEK, Inc./Serco
12:15 PM	Meeting Adjourned	Dana Van Wagener

Overview of NEMS

Dana Van Wagener
Oil and Gas Modeling Specialist
Energy Information Administration
US Department of Energy

NEMS Overview

- Functional model for many analytical needs
- Extensively developed and adapted to maintain relevancy beyond simple updates and periodic extensions of the forecast horizon
- Unnecessary and impractical to start from scratch

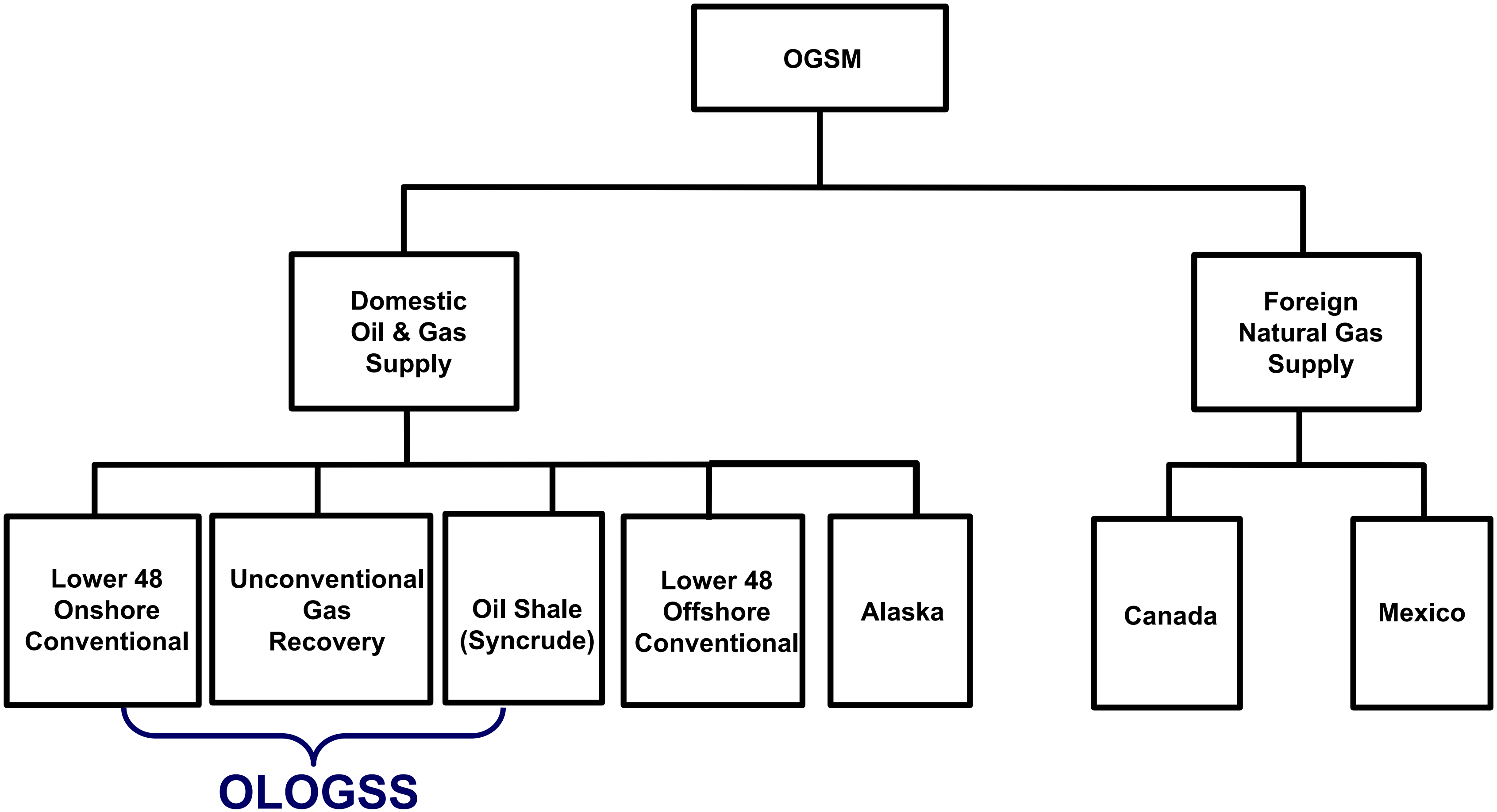
NEMS Redesign

- Initial outreach efforts
- Interest varies throughout DOE
- General Feedback
  - Extend the horizon to 2050 or later
  - Add significant technological and program detail
  - Enhance integration of U.S. energy markets with both the macro economy and world markets
  - Add representations of energy infrastructure
  - Drill down dynamically to more regional detail
  - Add uncertainty analysis and stochastic scenarios
  - Add automatic diagnostics
  - Add transparency
  - And … by the way, solve in less than one hour

NEMS – Next Steps

- Expect further discussions with DOE and external stakeholders on projects and priorities
- Initiated testing of alternative optimization software
- Initiated review and redesign of several NEMS modules in FY06 and proposed for FY07
- Expect to initiate review on technology choice by sector and foresight used in consumer decision making in the Spring of 2007
- Additional module reviews to be done in priority order and as funds become available

OGSM Overview



Characteristics of the Proposed Onshore component of OGSM

- Capability to address more policy and financial issues that affect the profitability of oil and natural gas drilling
- More technology levers
- Easy to maintain & update
- Fast execution time

Purpose of Peer Review

- Solicit input on modeling and analytic issues related to onshore oil and natural gas supply
- Identify/discuss limitations of proposed methodology
- Evaluate/discuss issues raised by the peer review panel

Onshore Lower 48 Oil & Gas Supply Submodule

Methodology Peer Review

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Onshore Lower 48 Oil & Gas Supply Submodule

System Overview

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Agenda

- Goal of OLOGSS
- OLOGSS Interaction with NEMS
- Overall System Logic
- Capabilities

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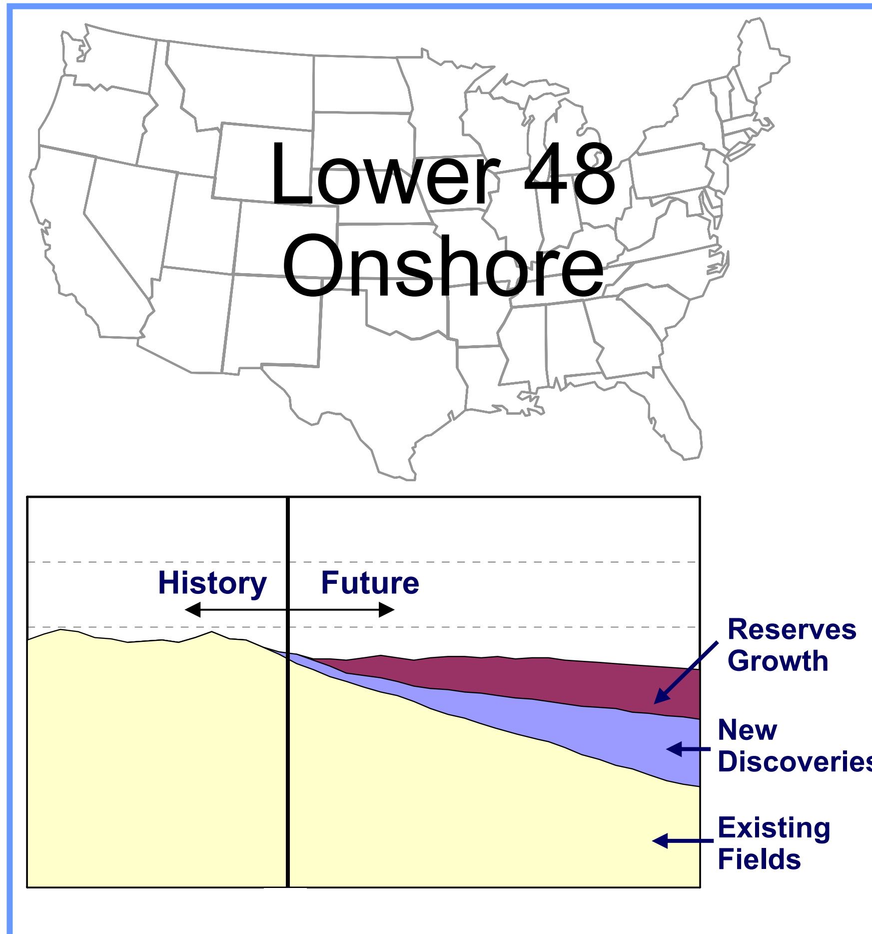
Goal of OLOGSS

- To forecast Oil & Gas supply from Lower 48 Onshore
- Existing Fields/Reservoirs
- New Discoveries
- Reserves Growth
  - EOR / ASR
  - Improved Technology



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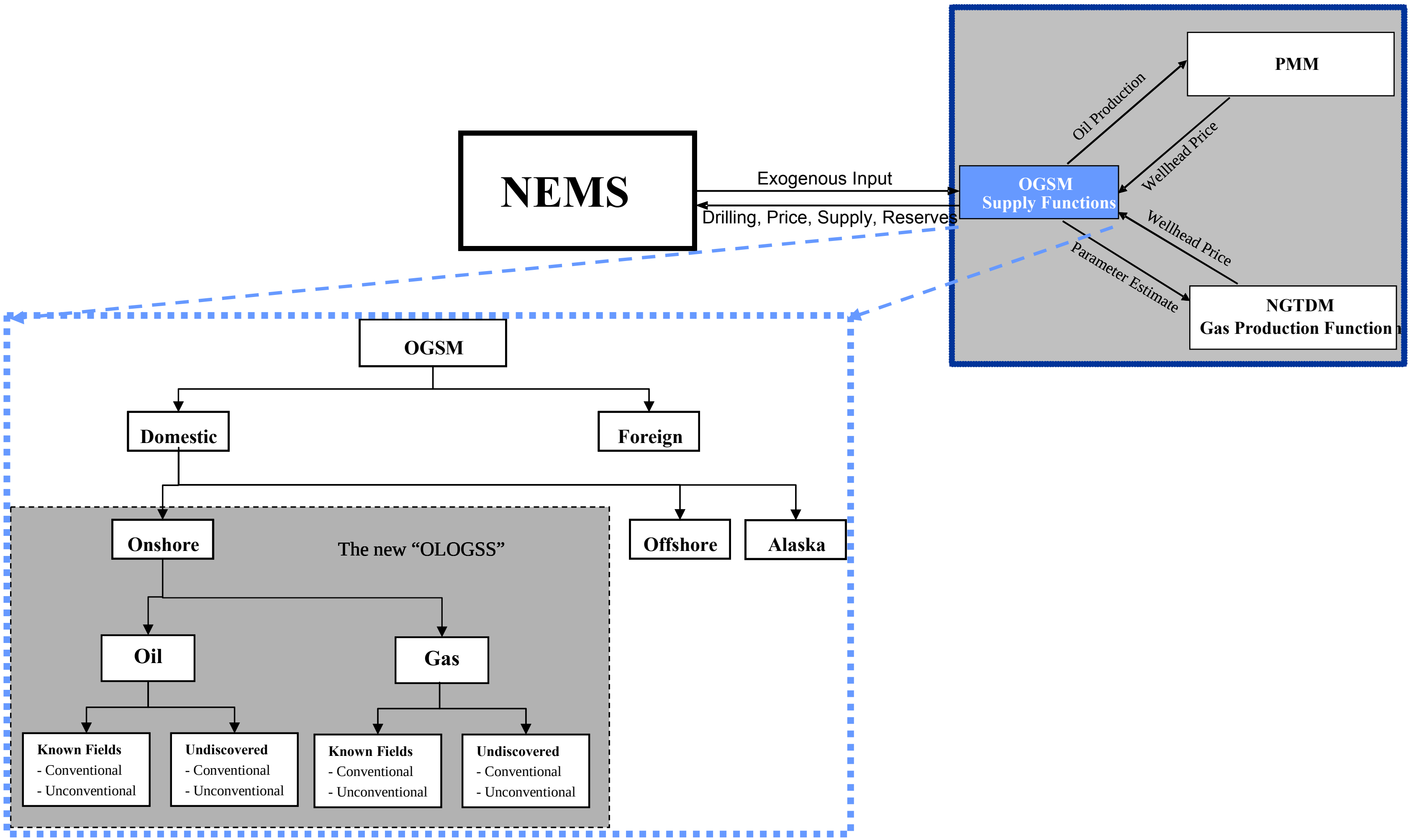
Interaction of OLOGSS with NEMS



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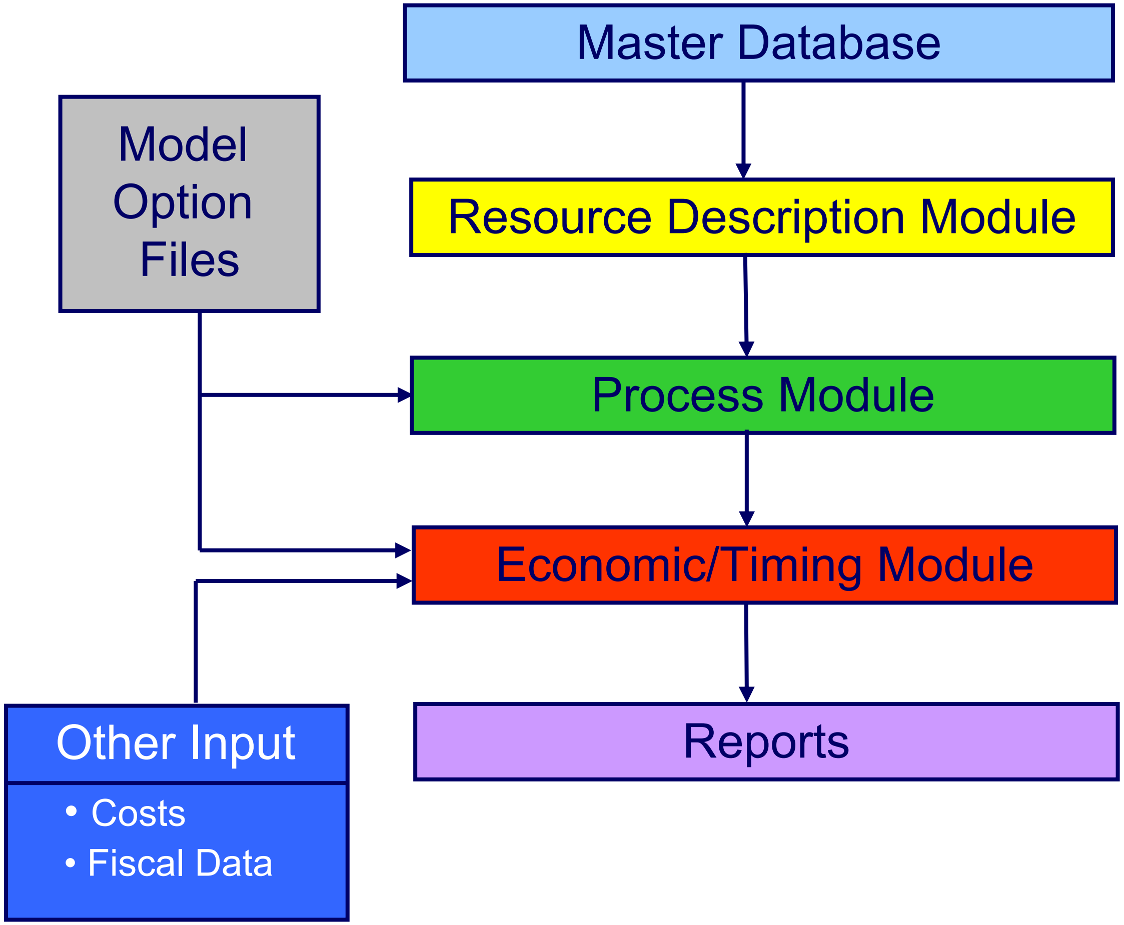
Overall System Logic Flow



Highlights

- **Plug and Play**
- **Modular**
- **User Friendly**

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Overall System Logic Flow

Master Database

- “Data Warehouse” - Master Database of Oil and Gas Resources in Lower 48 Onshore
  - Discovered (NRG Associates, HPDI, etc)
  - Undiscovered (USGS, MMS)
  - Secondary Sources (COGAM, EIA, Others)

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Overall System Logic Flow

Master Database

↓

Resource Description Module

- Compiles Raw Data to Create Input Files For Use in the Model
- Check for Quality, Consistency, Completeness
- Aggregate and Process Data Based on "Unit of Analysis"
- Allocate Resources per OLOGSS Regions

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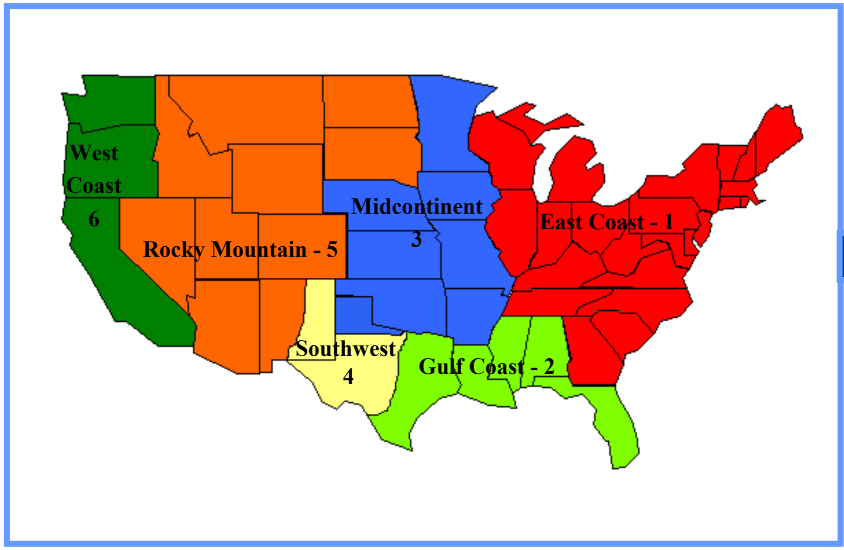
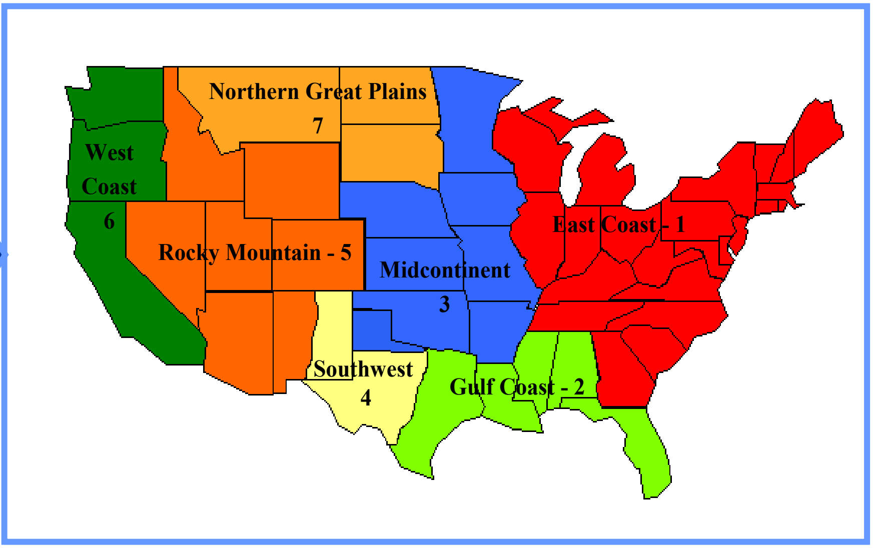
Proposed OLOGSS Regions

Original Onshore OGSM Regions



New OLOGSS Regions



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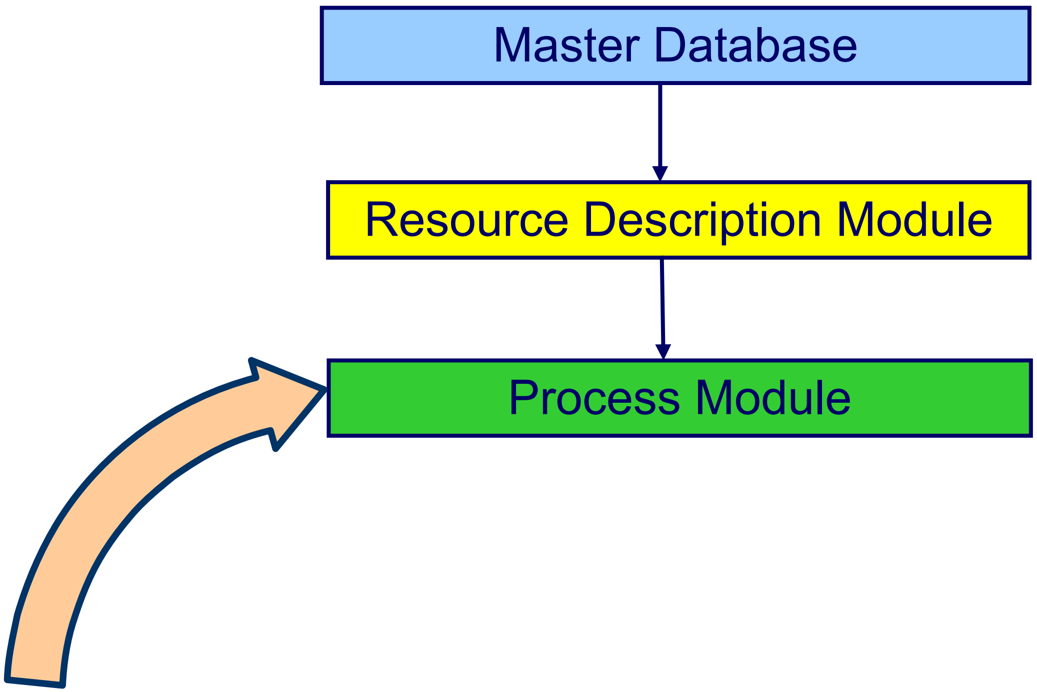
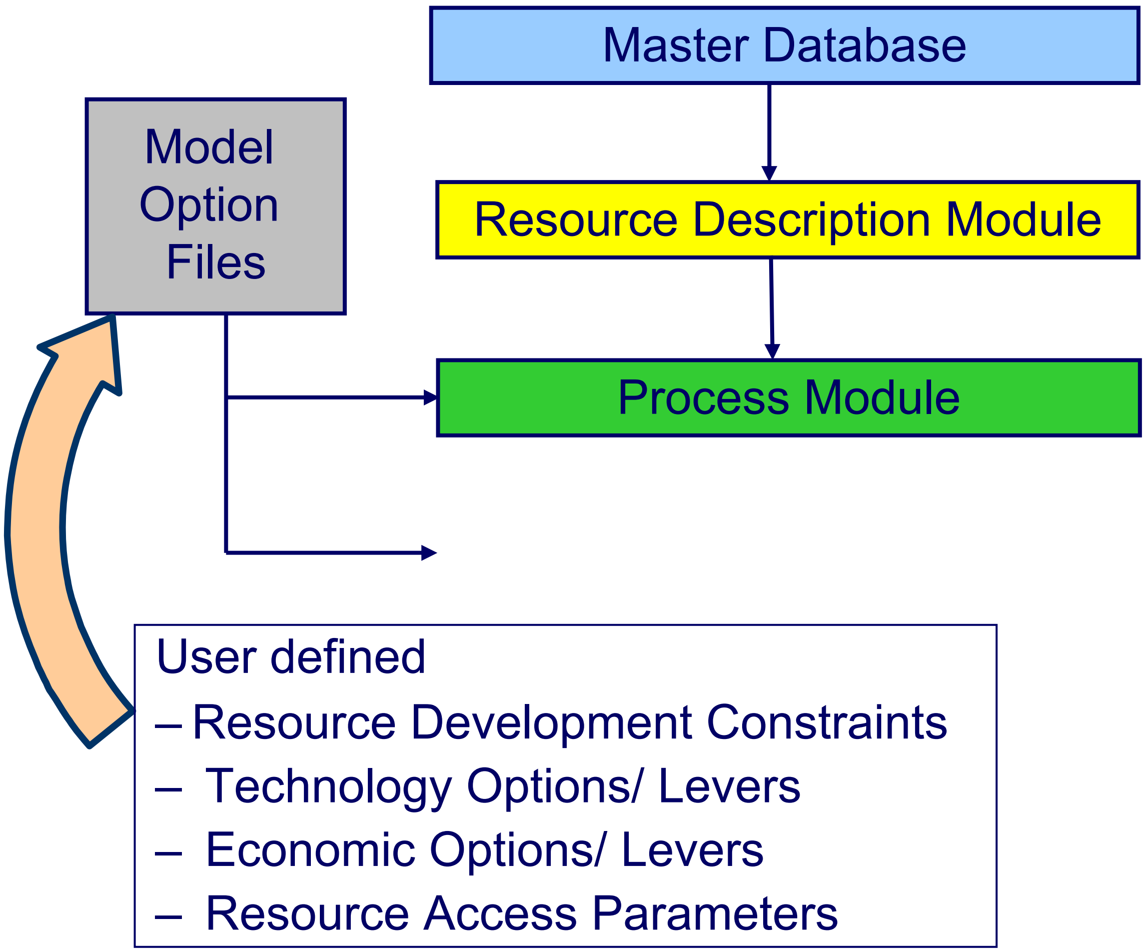
Overall System Logic Flow

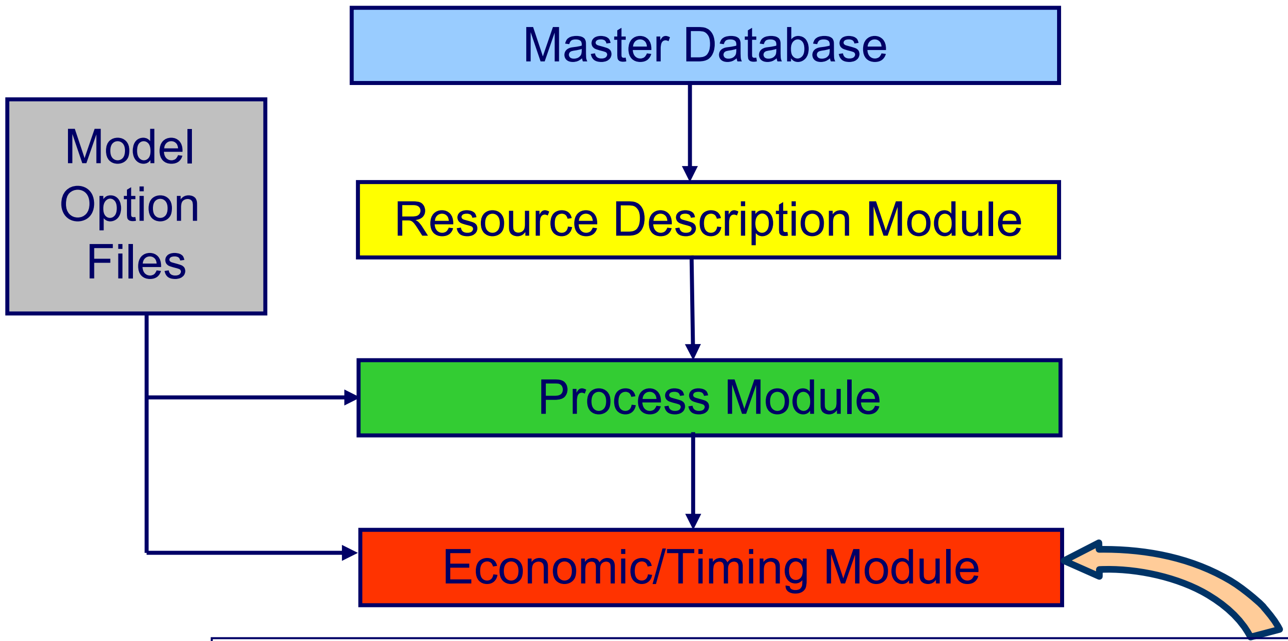


- Estimates Production Profile for Each Resource Type Based on Production Profile Functions
- Screens Technically Viable Process for Each Resource

Overall System Logic Flow



Overall System Logic Flow



Performs Economic Evaluation and Timing of Oil and Gas Resources

– Discovered and Undiscovered

– Rank and Select Resources based on Constraints

– Provides Supply Curves for NEMS

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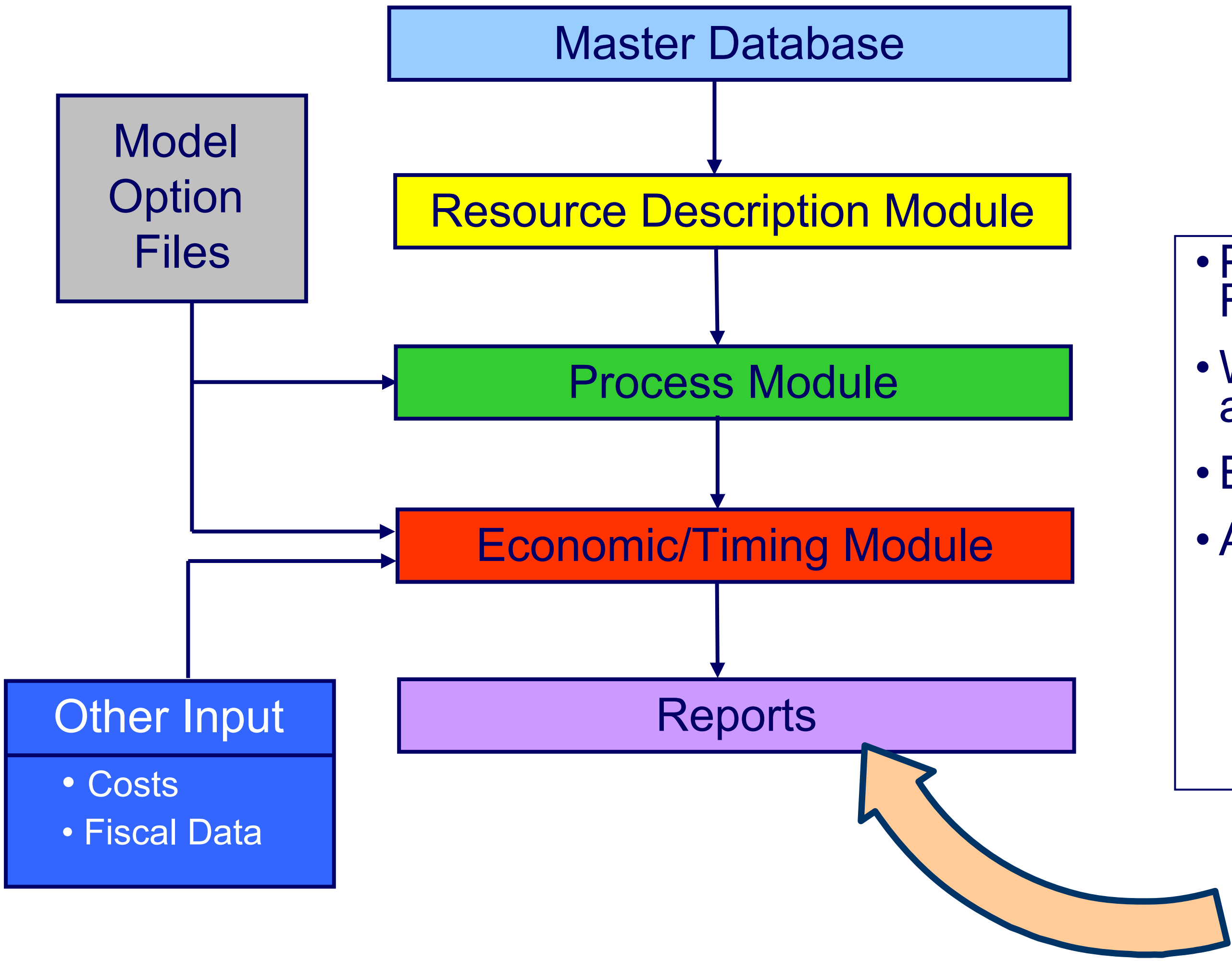
Overall System Logic Flow



- Production and Reserves
- Wells – Active and Drilled
- Economic results
- Aggregated at:
  - Play
  - Basin
  - State/Regional
  - National

Capabilities of Proposed OLOGSS

- Model Entire Oil & Gas Resource in Lower 48
  - Conventional
  - Unconventional
    - Tight Sand
    - Oil Shale
    - Continuous Formations, etc
- Ability to Model
  - Technology Change / Improvements
  - Land Access Issues
  - Legislative Policy Issues (Royalty Relief, Tax Credits, etc…)
- Easy to Maintain and Update

Onshore Lower 48 Oil & Gas Supply Submodule

Master Database & Resource Module

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Agenda

- Goal and Objective
- Description of the Master Database
- Description of the Resource Module
- Unit of Analysis

Goal and Objective

- To Process Raw Data for Use in the Process and Timing Modules

- Resource Data has:
  - Enough Checks & Balances for Quality Control
  - Internally Consistent
  - Complete with no Missing Values
  - All Resources are Accounted

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Overall System Logic Flow

Master Database

- "Data Warehouse" - Master Database of Oil and Gas Resources in Lower 48 Onshore
  - Discovered (NRG Associates, EIA, HPDI, etc)
  - Undiscovered (USGS, MMS)
  - Secondary Sources (COGAM, EIA, Others)

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Summary of Sources of Resource Data

Required Data	Source
Production Data	HPDI, EIA
Field/Reservoir Properties	NRG data *
Undiscovered Resource Estimates	USGS, MMS
Regional/Play Level Reserves Estimates	EIA

* Supplemented by COGAM Databases

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Overall System Logic Flow

Master Database

↓

Resource Description Module

↑

- Compiles Raw Data to Create Input Files For Use in the Model
- Check for Quality, Consistency, Completeness
- Aggregate and Process Data Based on “Unit of Analysis”
- Allocate Resources per OLOGSS Regions

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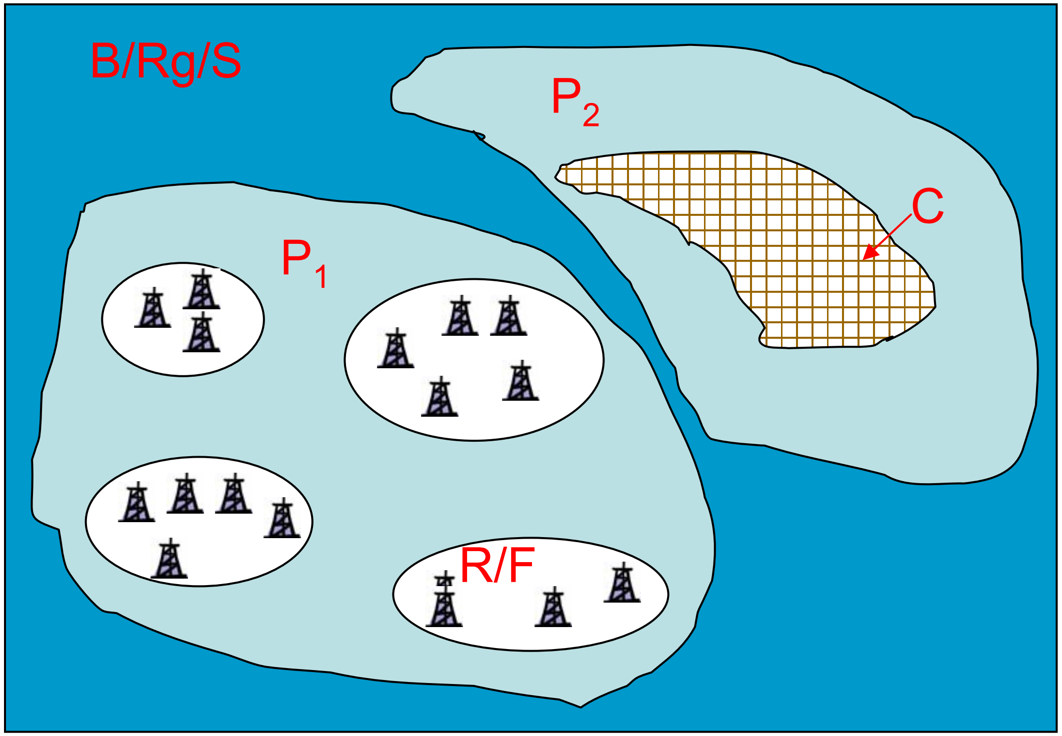
What is the Unit of Analysis

- Well (W)?
- Cell (C)?
- Reservoir (R)?
- Field (F)?
- Play (P)
- Basin (B)?
- State (S)?
- Region (Rg) ?



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Important Definitions

- Reservoir: Occurrence of Reservoir Rocks of Sufficient Quantity and Quality to Permit the Containment of Oil and Gas in Volumes Sufficient for an Accumulation of the Minimum Size
- Field: An Individual Producing Unit Consisting of a Single Pool or Multiple Pools of Hydrocarbons Grouped on, or Related to, a Single Structural or Stratigraphic Feature
- Accumulation: An Accumulation is Defined by the USGS as a Discrete Field or Pool of Hydrocarbon Localized in a Structural or Stratigraphic Trap by The Buoyancy of Oil or Gas in Water
- Cell: A cell is a quarter of a square mile of land surface in continuous formations. These are coded by USGS as predominantly oil producing, gas producing, both oil and gas producing or dry. The resource in each cell is characterized by its estimated ultimate recovery based on geologic characteristics of the continuous formation/accumulation
- Play: A play is defined as a set of known or postulated oil and/or gas accumulations sharing similar geologic, geographic, and temporal properties, such as source rock, migration pathways, timing, trapping mechanism, and hydrocarbon type.

Unit of Analysis
Is
Resource Specific

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Proposed Unit of Analysis

Resource Type			Sources of Data	Unit of Analysis
Discovered	Oil	Conventional	NRG HPDI / IHS EIA	Well Aggregated to Play Level
		Unconventional		
	Gas	Conventional		
		Unconventional		
Undiscovered	Oil	Conventional	USGS Reserves Estimates MMS Play Level Properties (NRG)	Conventional: Accumulation Unconventional - Cells Aggregated to Play Level
		Unconventional		
	Gas	Conventional		
		Unconventional		

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Role of Resource Description Module

- Defining the Play Level Resource Estimates
  - Both Oil & Gas
  - Both Discovered & Undiscovered
- Identifying the Number of Wells for Each Play (Active)
- Assigning Average Geologic Properties to Each Play/Well
- Creating the Play/Resource Specific Data Files

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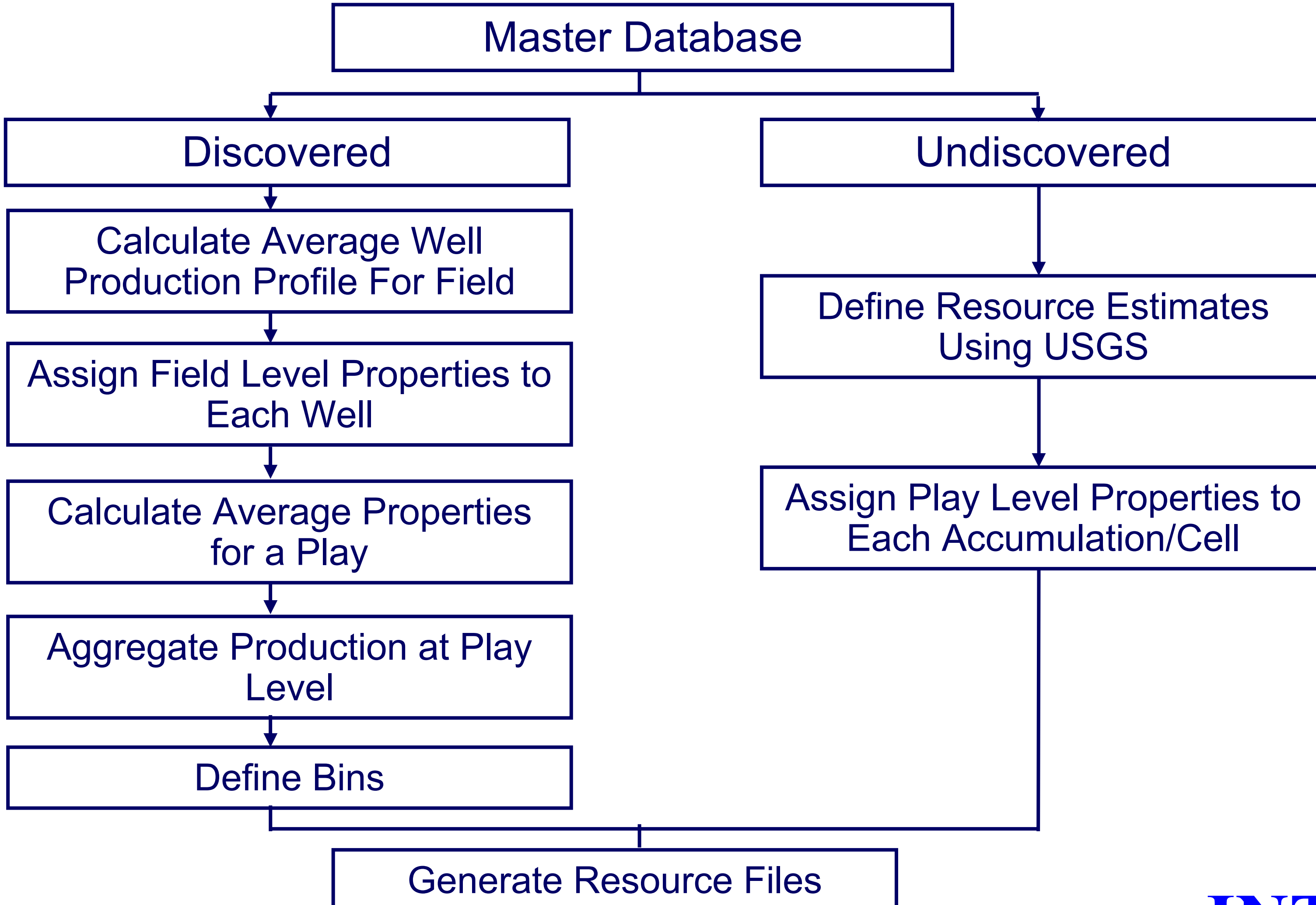
Resource Description Module Flowchart



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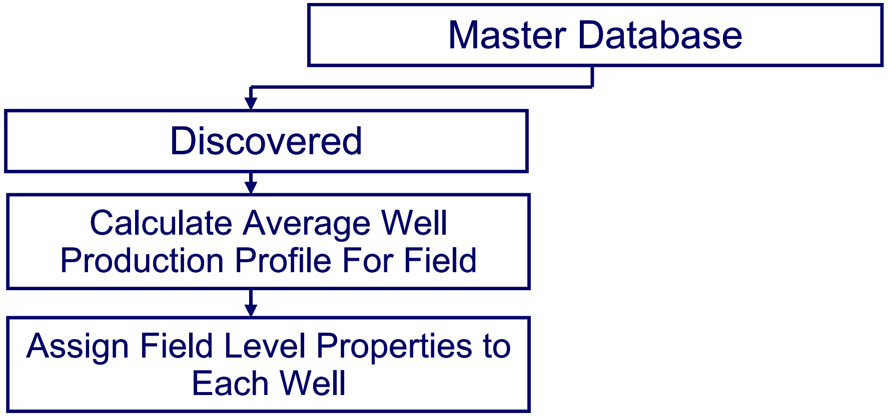
Discovered Resources – Define Well Profile



- Map NRG Database to EIA database using a crosswalk table
- Calculate average well production profile for each active well
- Assign reservoir properties to each well

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Reservoir/Field Properties Used for Analysis

Original Volumetrics
- Original-Oil-In-Place
- Reservoir Area
- Net Thickness
- Porosity
- Average Initial Water Saturation
- Average Initial Oil Saturation
- Average Initial Gas Saturation
- Average Formation Volume Factor

Current Volumetrics
- Current Oil Saturation (Swept Zone)
- Current Oil Formation Volume Factor

Development and Performance Data
- Recovery Efficiency
- Well Spacing

Geologic Data
- Lithology
- Depth
- Temperature
- Original and Current Pressure
- Permeability
- Gross Thickness
- Dip Angle
- Geologic Age Code
- Geologic Play, Depositional System, Trap Type

Fluid Data
- Average Oil Gravity and Viscosity
- Initial GOR
- Current GOR
- Gas Impurities

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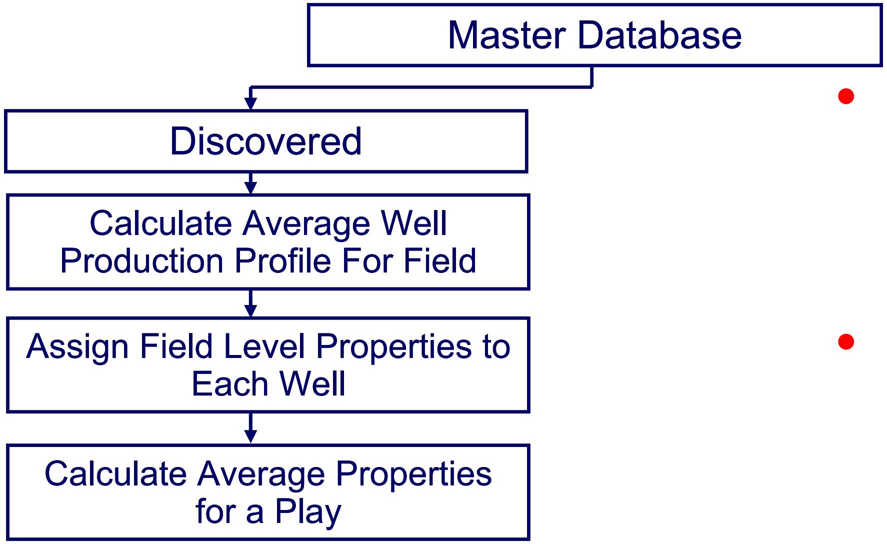
Discovered Resources - Average Play Level Properties



- Assign each reservoir to USGS defined size class
- Calculate average properties for each size class
  - When no discovered field is in a size class, assign play level properties

Example: Assigning Average Porosity --(Raw Data)--

Accumulation Distribution for Play 401:

Play No.	Oil/ Gas	Number of Accumulations	Size Class Distribution from 1 to 15														
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
401	**Oil**	**25**	1	2	3	4	5	3	4	2	1	0	0	0	0	0	0

6 known reservoirs belong to play 401:

Known Reservoir	Field Name	Recoverable (MMBL)	Porosity
A	AA	8.5	34%
B	CC	3.6	28%
C	AA	5.4	31%
D	BB	11.3	33%
E	CC	7.4	27%
F	AA	6.1	26%

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Example: Assigning Average Porosity --(Calculations Contd…)--

Step 1: Group known reservoirs by field name, and determine size class

Group No	Field Name	Reservoirs	Recoverable (MMBBL)	Total Recoverable (MMBBL)	Size Class
1	AA	A, C, F	8.5, 5.4, 6.1	20.0	5
2	BB	D	11.3	11.3	3
3	CC	B, E	3.6, 7.4	11.0	4

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Example: Assigning Average Porosity --(Calculations Contd…)--

Step 2: Calculate recoverable weighted average porosity for each group

Weighted Average Porosity = Sum(Porosity*Recoverable)/Sum(Recoverable)

Group No	Reservoir	Porosity	Recoverable (MMBBL)	Product	Weighted Average Porosity
1	A	34%	8.5	2.89	
	C	31%	5.4	1.674	
	F	26%	6.1	1.586	
	Total		20.0	6.15	**30.8%**
2	D	33%	11.3	3.730	
	Total		11.3	3.730	**33.0%**
3	B	28%	3.6	1.01	
	E	27%	7.4	1.998	
	Total		11.0	3.008	**27.4%**

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Example: Assigning Average Porosity --(Calculations Contd…)--

Step 3: Calculate play average porosity

Play Average Porosity = sum(Weighted Average Porosity for each Group*Total Recoverable)/ sum(Total Recoverable)

Group No	Weighted Average Porosity	Total Recoverable (MMBBL)	Product	Play Average Porosity
1	30.8%	20.0	6.16	
2	33.0%	11.3	3.72	
3	27.4%	11.0	3.0096	
Total		42.3	12.889	**30.5%**

Play 401 Average Porosity: 0.2990

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Example: Assigning Average Porosity --(Calculations Contd…)--

Step 4: Assign average porosity to size classes without known reservoir data

Size class	Accumulation	Average Porosity	Explanation
1	**1**	**30.5%**	**Play Average**
2	**2**	**30.5%**	**Play Average**
3	3	33.0%	Known Reservoir Average
4	4	27.5%	Known Reservoir Average
5	5	30.3%	Known Reservoir Average
6	**3**	**30.5%**	**Play Average**
7	**4**	**30.5%**	**Play Average**
8	**2**	**30.5%**	**Play Average**
9	**1**	**30.5%**	**Play Average**

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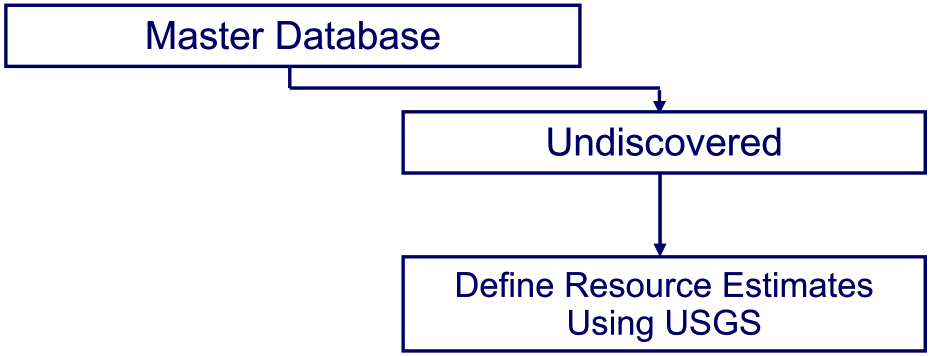
Undiscovered Resources – Resource Estimates



- Conventional
  - Use 2005 Update for Resource Estimates
  - Determine Number of Accumulations in Each Size Class
- Unconventional
  - Use 2005 USGS Update for Resource Estimate
  - Assign Number of Cells to Each Play Based on Size Class

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What are the Size Classes?

Conventional

Size Class Number	Gas Accumulation Size MMCF		Oil Accumulation Size MMBbl	
	Minimum	Maximum	Minimum	Maximum
0	> 3	6	> 0.5	1
1	> 6	12	> 1	2
2	> 12	24	> 2	4
3	> 24	48	> 4	8
4	> 48	96	> 8	16
5	> 96	192	> 16	32
6	> 192	384	> 32	64
7	> 384	768	> 64	128
8	> 768	1,536	> 128	256
9	> 1,536	3,072	> 256	512
10	> 3,072	6,144	> 512	1,024
11	> 6,144	12,228	> 1,024	2,048
12	> 12,228	24,576	> 2,048	4,096
13	> 24,576	49,152	> 4,096	8,192
14	> 49,152	98,304	> 8,192	16,384
15	> 98,304	196,608	> 16,384	32,768

Unconventional

Size Class Number	Gas EUR Volume MMCF		Oil EUR Volume MBbl	
	Minimum	Maximum	Minimum	Maximum
1	> 0	36	> 0	6
2	> 36	72	> 6	12
3	> 72	120	> 12	20
4	> 120	180	> 20	30
5	> 180	300	> 30	50
6	> 300	450	> 50	75
7	> 450	600	> 75	100
8	> 600	1,200	> 100	200
9	> 1,200	1,800	> 200	300
10	> 1,800	3,000	> 300	500

Defined by USGS

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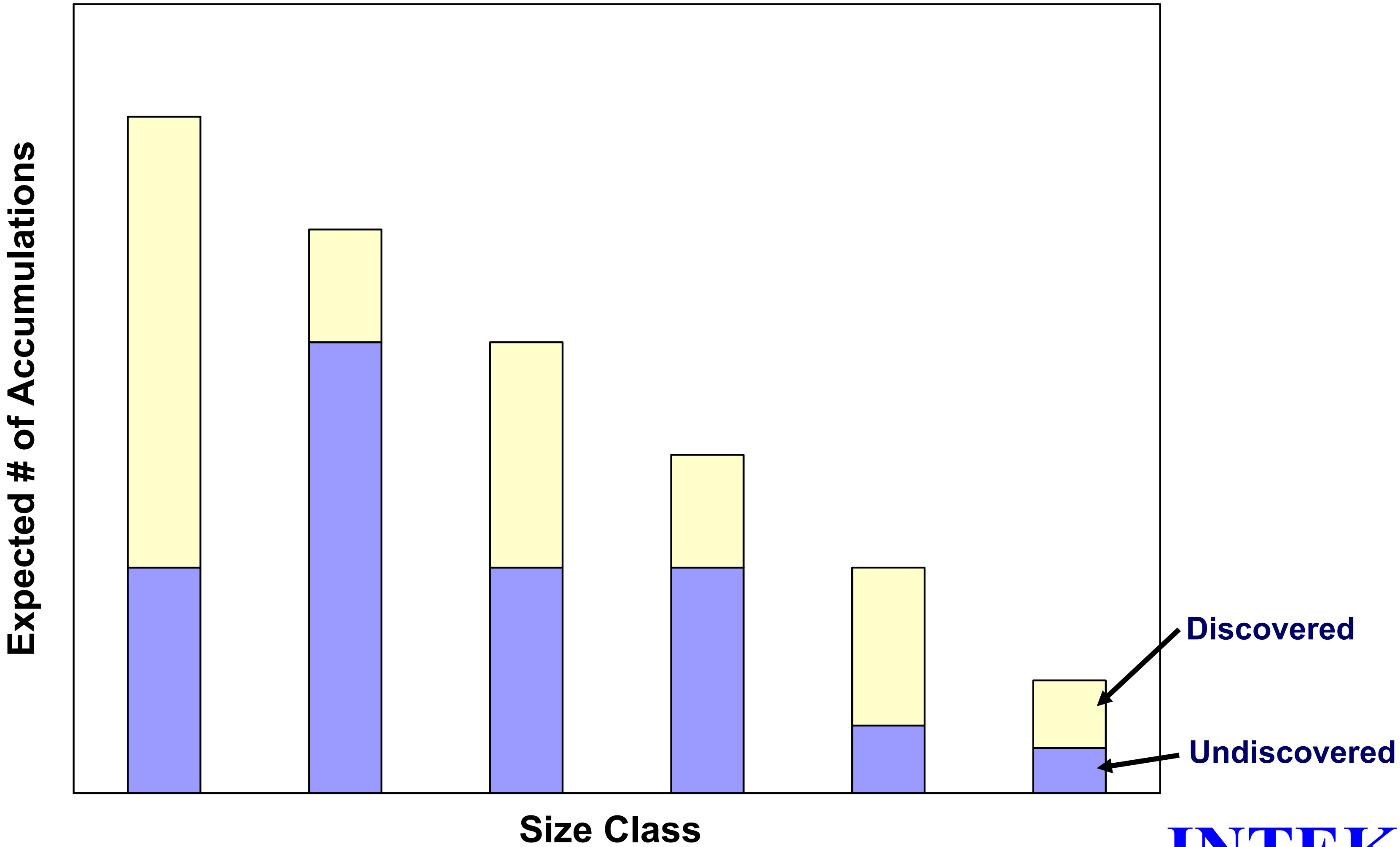
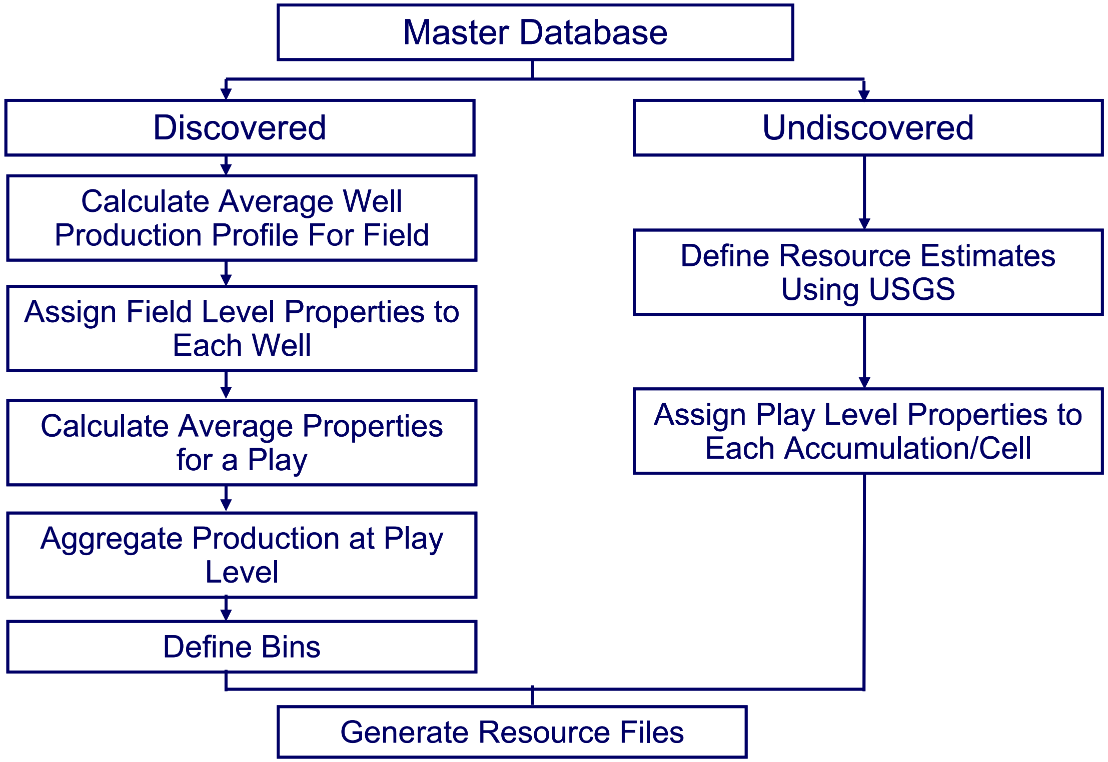
Number of Accumulations by Size Class



Undiscovered Resource – Assign Properties



- For Each Accumulation / Cell
- Assign Play Level Properties Based on
  - Size Class
  - Play Average

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Binning of Resource Data

- Due to the Proprietary Nature of the Resource Data, the Discovered Resource Will be Classified in Pseudo-Bins Based on its Production Volumes and Depth
- Each Well is Assigned a Size and Depth Bin Category

Size (BOE/Day)

Size Range	Depth
0-10	
>10-15	
>15-50	
>50-100	
>100	

for each size bin

Depth of Producing Zone (Feet)

Depth Range	Number of Wells
0-2000	
>2000-4000	
>4000-8000	
>8000-12000	
>12000-15000	
>15000	

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Example of Binning Wells

Well Number	Average Production (BOE)	Average Depth (FT)	Size Category	Depth Category
1	9	4500	1	3
2	8	4350	1	3
3	15	3700	2	2
4	25	4500	3	3
5	25	2900	3	2
6	30	5100	3	3
7	45	4625	3	3
8	7	3975	1	2
9	12	4150	2	3
10	18	4300	3	3
11	13	4450	2	3
12	5	4750	1	3
13	9	4950	1	3
14	38	4600	3	3
15	40	5150	3	3

- Assume 15 Wells in a Hypothetical Play
- The Size Category and Depth Category Are Determined for Each Well

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Example of Binning Wells (Cont)

Size Category	Depth Category	Bin Population
1	2	1
1	3	3
2	2	2
2	3	2
3	2	1
3	3	6

- The Bin Population Is the Total Number of Wells in Each Size and Depth Category Combination
- The Empty Bins Are Not Shown

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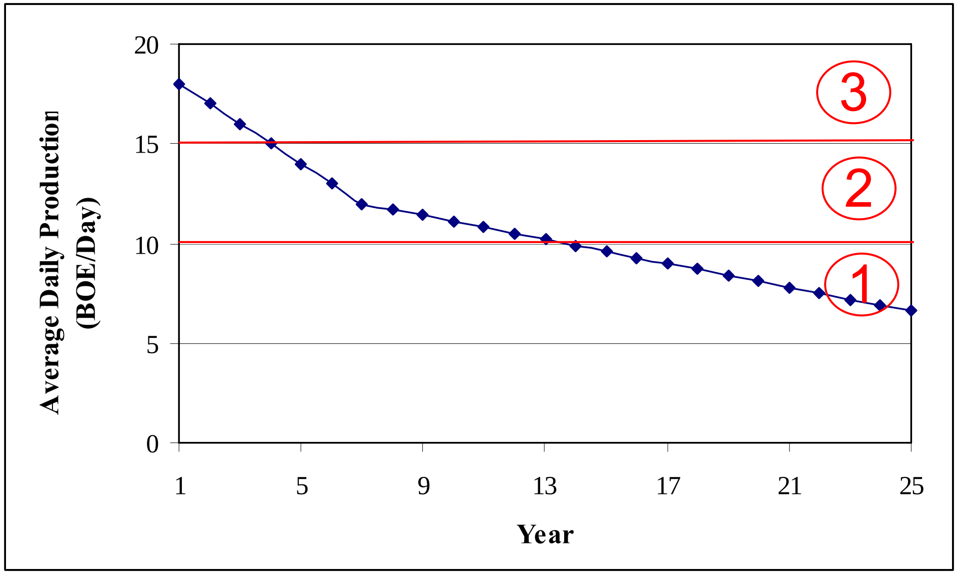
Example of Well Binning (Cont)



- Decline Curve Analysis is Used to Determine the Size Category of Each Well in Subsequent Years

  (for Future Technology Advancements)

- This Well is in:
  - Bin 3 Year 1 – 4
  - Bin 2 Year 5 – 14
  - Bin 1 Year 15 - 25

Summary

- Resource Description Module will Process and Create the Data Required for the Following Resources
  - Oil
    - Conventional
    - Unconventional
  - Gas
    - Conventional
    - Unconventional

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Onshore Lower 48 Oil & Gas Supply Submodule

Process Module

&

Technical Screening

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Discussion Items

- Goal
- Process Model
- Production Profile Function Approach
- Technology Screening Criteria

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Goal & Objective

- To Forecast Future Production Potential from Oil & Gas Fields Based on their
  - Geologic Properties
  - Petrophysical Properties

Bin/Play Level

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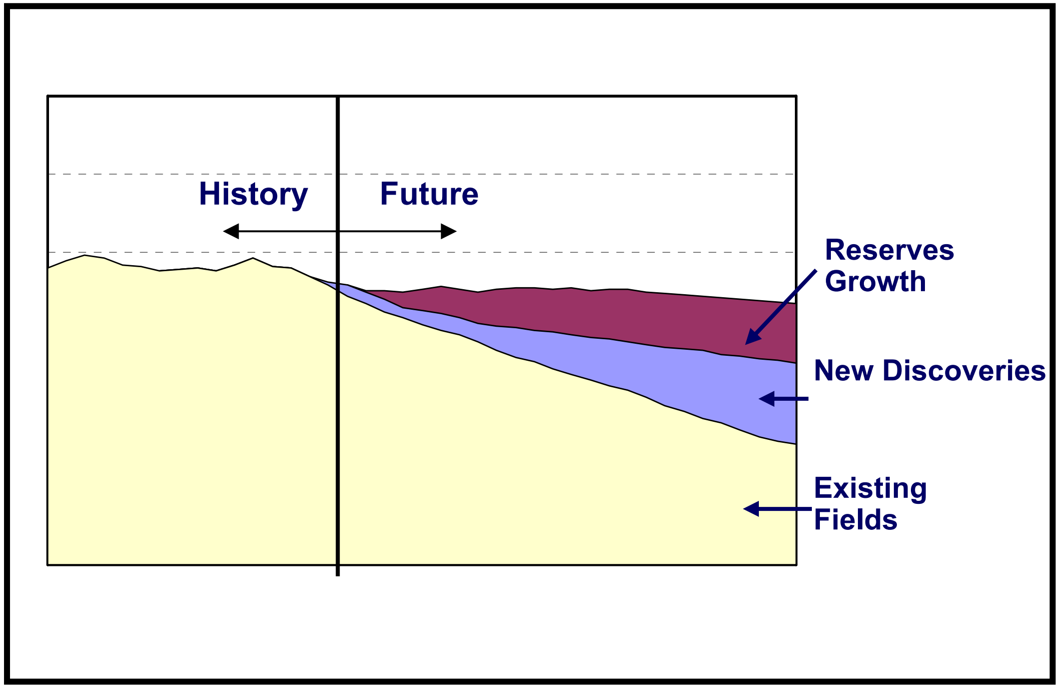
Three Phases of Future Production

- Existing Production
  - From Currently Producing Oil & Gas Fields
- Reserves Growth
  - ASR / EOR
  - Infill Drilling
- Undiscovered Resource



Existing Production

- Use Production Profile Function Approach for Both
  - Oil
  - Gas
- QA/QC Process
  - Perform Back Casting Analysis to Validate Decline Curve

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Reserves Growth

- Production Profile Functions for Estimating Reserves Growth
  - Oil
    - Advanced Secondary Recovery
    - Enhanced Oil Recovery
    - Infill Drilling
  - Gas
    - Infill Drilling

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Processes Modeled

Oil	Gas
- Water Flooding	- Conventional
- Polymer Flooding	- Water Drive
- CO2 Flooding	- Tight Sands
- Steam Flooding	- Coal / Shale
- Infill Drilling	
- Profile Modification	
- Horizontal Wells	

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Production Profile Development Procedure

- Identify predictive model for a specific process
- Identify variables critical to the process (4-5 / process)
- Run predictive model by changing one variable at a time
  - Number of runs = "n" variables X "m" changes
- Generate a production profile equation as a function of n variables

$$\text{Prod}_{\text{iyr}} = f(var_1, var_2, \ldots, var_n)_{\text{iyr}}$$

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Example: Generic Production Profile Curves for CO_2 Flooding

- Critical Variables
  - Depth
  - Minimum Miscibility Pressure (mmp)
  - WAG
  - CO_2 Pore Volume Injected
  - Permeability (k)
  - Porosity (Φ)

$$\text{Production Profile} = f(\mathit{Depth},\ \mathit{mmp}, k, \Phi)$$

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Technology Screening

- Every Size Class Oil Bin will be Assigned to One Or More Possible Processes for ASR/EOR
- For Gas Bins, Technology Screening will be Applied Based on Lithology, Drive Mechanism, and Geologic Properties

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Existing Screening Criteria for EOR Processes

	Alkaline	MCP	CO_2 Miscible Flooding	Imp. Steam Flooding	Adv. Steam Flooding	In-situ Combustion
Oil Gravity, API	< 30		≥ 25	10 to 34		10 to 35
In-situ Oil Viscosity, cp	<90	< 40		≤ 15,000		≤ 5, 000
Depth, ft				≤ 3,000	≤ 5,000	≤ 11,500
Net Pay, ft				≥ 20	≥ 15	≥ 20
Reservoir Temp. (°F)	< 200	< 200				
Porosity, Φ				≥ 20*	≥ 15*	≥ 20*
Avg. Perm., md	> 20	> 40		≥ 250	≥ 10	≥ 35
Transmissibility, md-ft/cp				≥ 5		≥ 5
Reservoir Pressure, psi			≥ MMP	≤ 1,500	≤ 2,000	≤ 2,000
Minimum Oil Content at Start (So*Φ)				≥ 0.10	≥ 0.08	≥ 0.08
Salinity of Formation Brine, ppm	< 100,000	< 100,000				
Rock Type	Sandstone	Sandstone	Sandstone or Carbonate	Sandstone or Carbonate	Sandstone or Carbonate	Sandstone or Carbonate

*Ignore if Soi*Por. is satisfied

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Gas Technology Screening

	Lithology	Permeability	Depth	Drive	Other TBD
Conventional	Sandstone Carbonates		All Depths		
Tight Sands	Sandstone Carbonates	<= 0.1	All Depths		
Coal/Shale	Coal/Shale		All Depths		
Water Drive	Sandstone Carbonates		All Depths	Water Drive	

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Onshore Lower 48 Oil & Gas Supply Submodule

Modeling & Technology Options

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Discussion Items

- Phases of Technology Development
- Uncertainty
- How We Account for Uncertainty
- The Technology Penetration Curve

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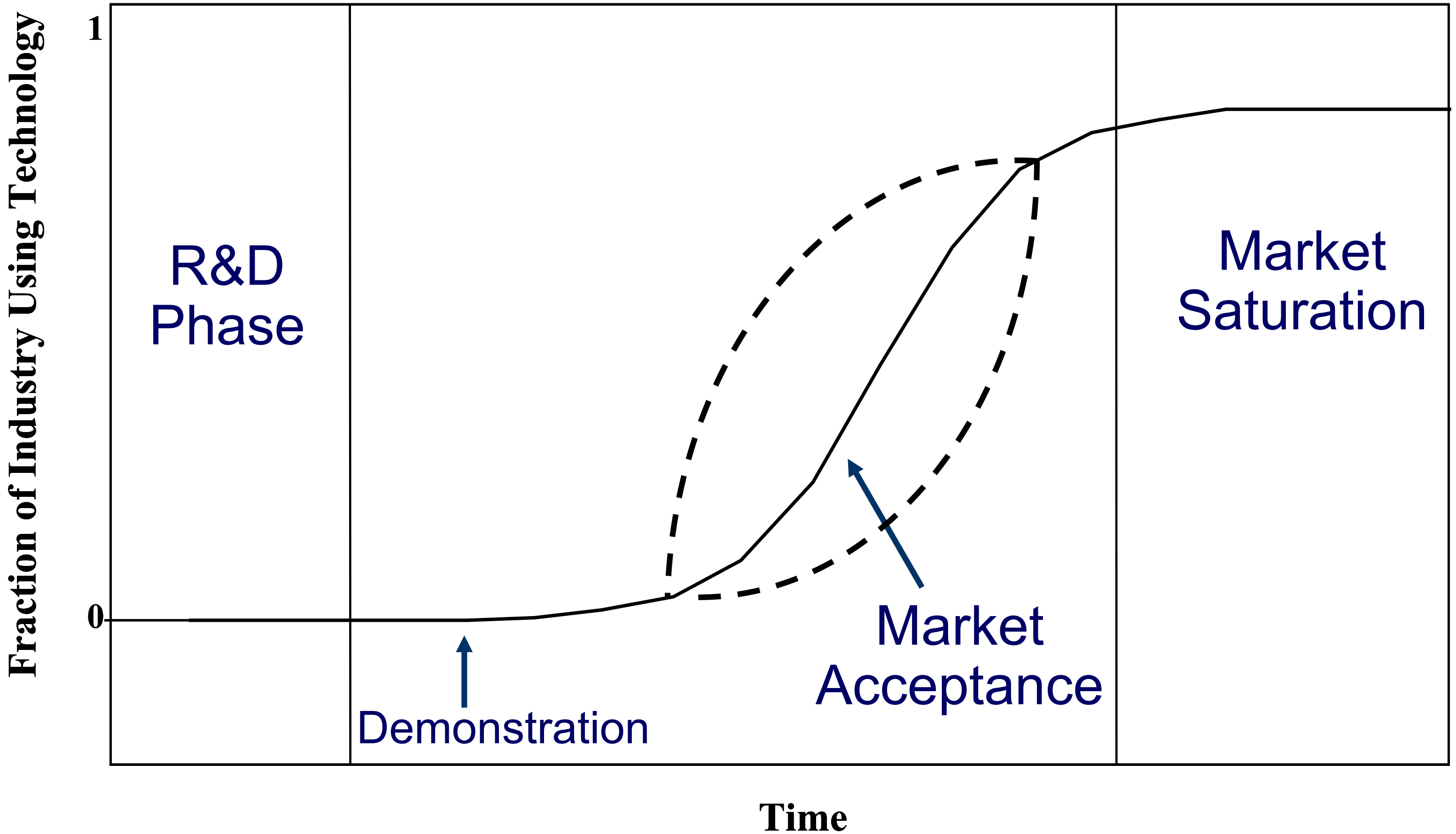
Three Phases of Technology Development



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Three Phases of Technology Development

- RD&D Phase (Outcome)
  - Technology May be a Success
  - Technology May be Unsuccessful
  - Performance May Be a Fraction of Targeted Goals

Chances of Success

- Implementation Phase
  - Effective or Not Effective
  - Lack of Understanding
  - Lack of Access to Technology

Market Acceptance

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Summary of Uncertainties

	Technology	Economic	Market
Existing Technology		✓	✓
Advanced Technology	✓	✓	✓
New Technology	✓✓	✓✓	✓✓

To be discussed later

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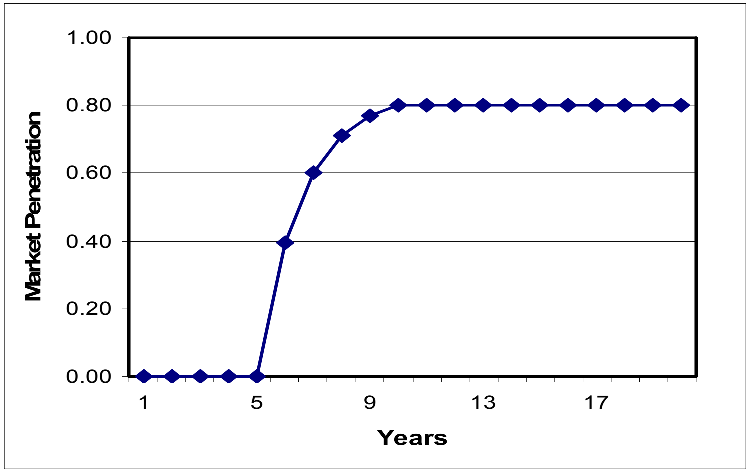
Modeling Uncertainty & Risk

- Identify Critical Parameters Affecting Each Technology
- Generate Technology/Market Penetration Curve

$$Imp_x = f\,(Y_d, Y_c, Y_a, U_P, P_s, P_i,)$$

Name	Parameter
Yd	Number of years required to develop technology
Yc	First year of commercialization
Ya	Number of years to fully penetrate the market
UP	Ultimate market penetration (%)
Ps	Probability of success
Pi	Probability of Implementation
Impx	Percent of industry implementing the technology in a given year x



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Effect of Market Penetration Curve on Technologies

Three Major Effects:

- Effect on Overall Production Profile of the Resource
- Effect on Economics of the Resource
- Combination of Both

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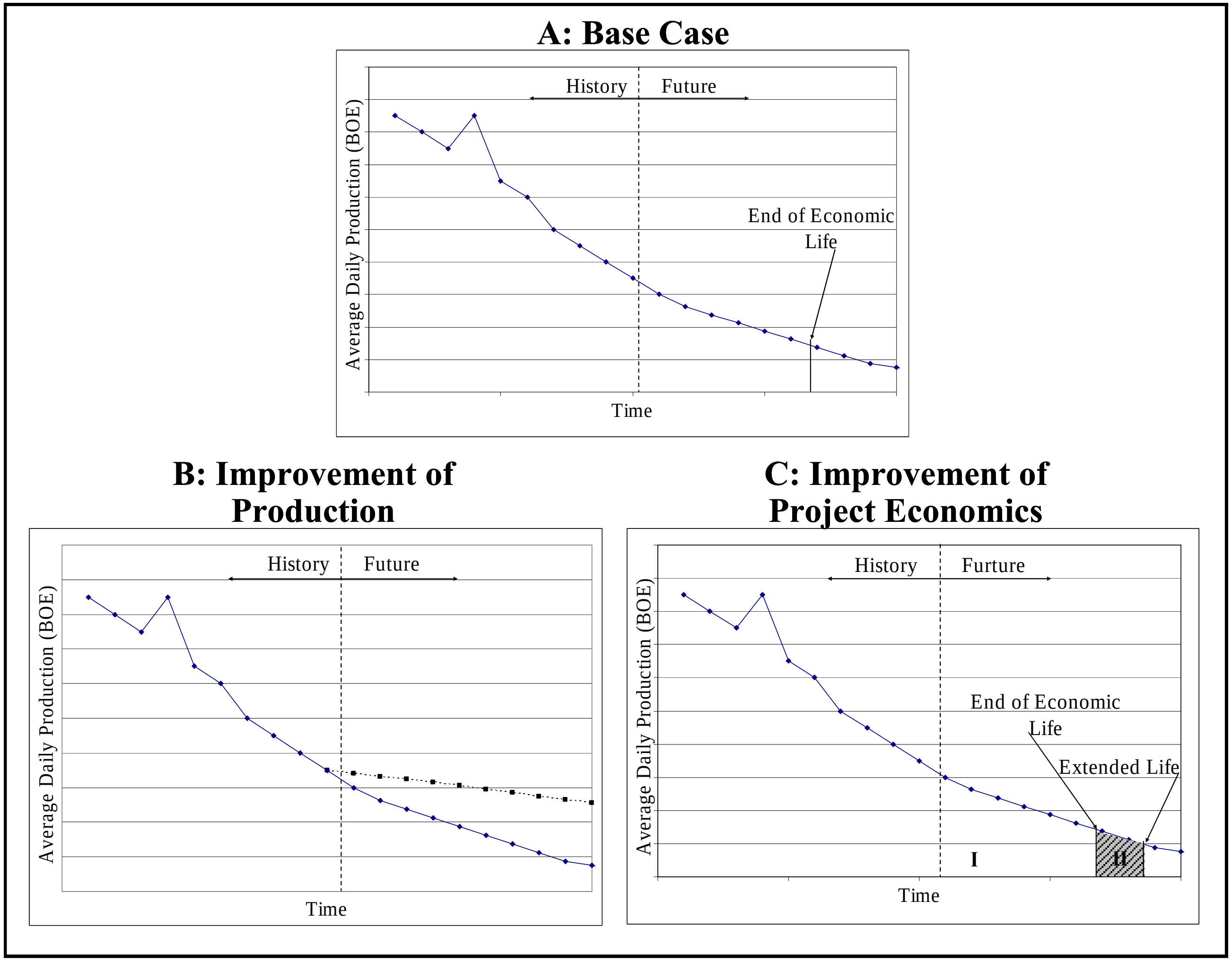
Effects of Technology Development



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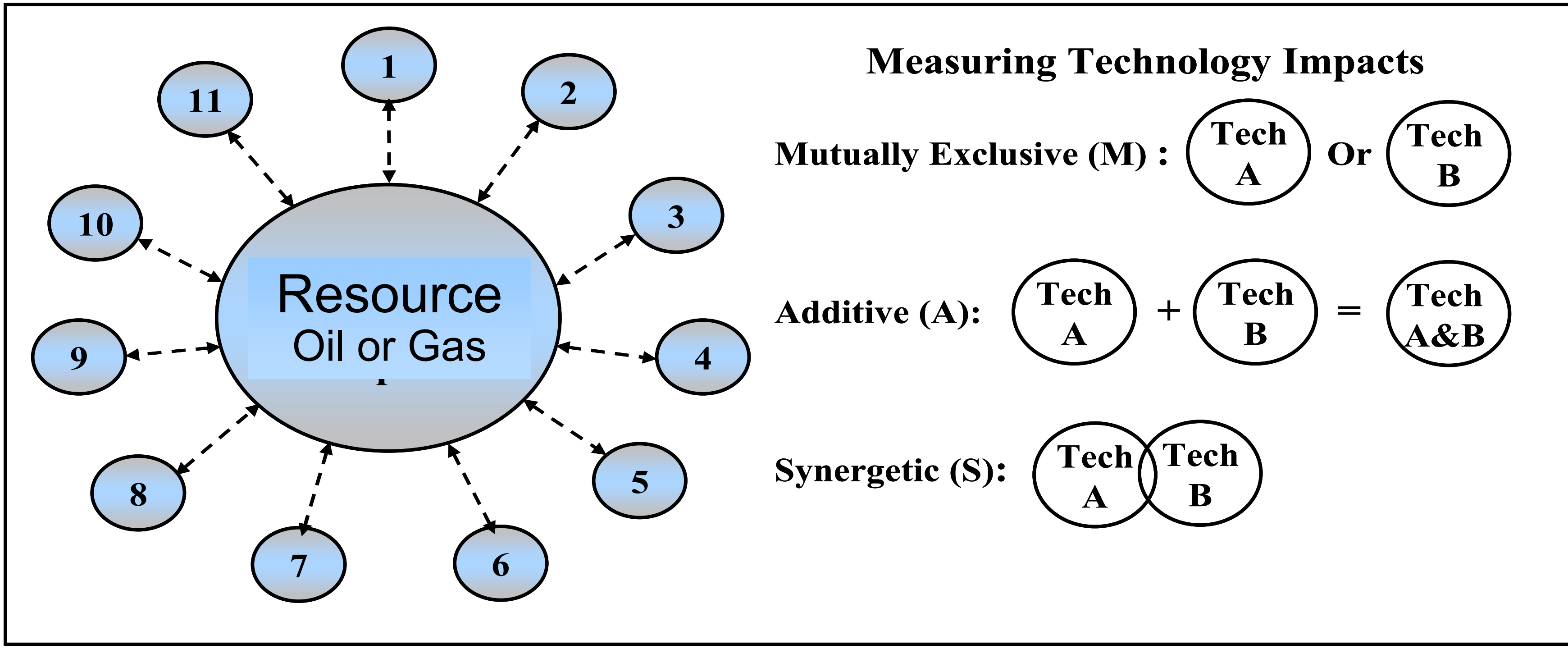
Impacts of Multiple Technologies



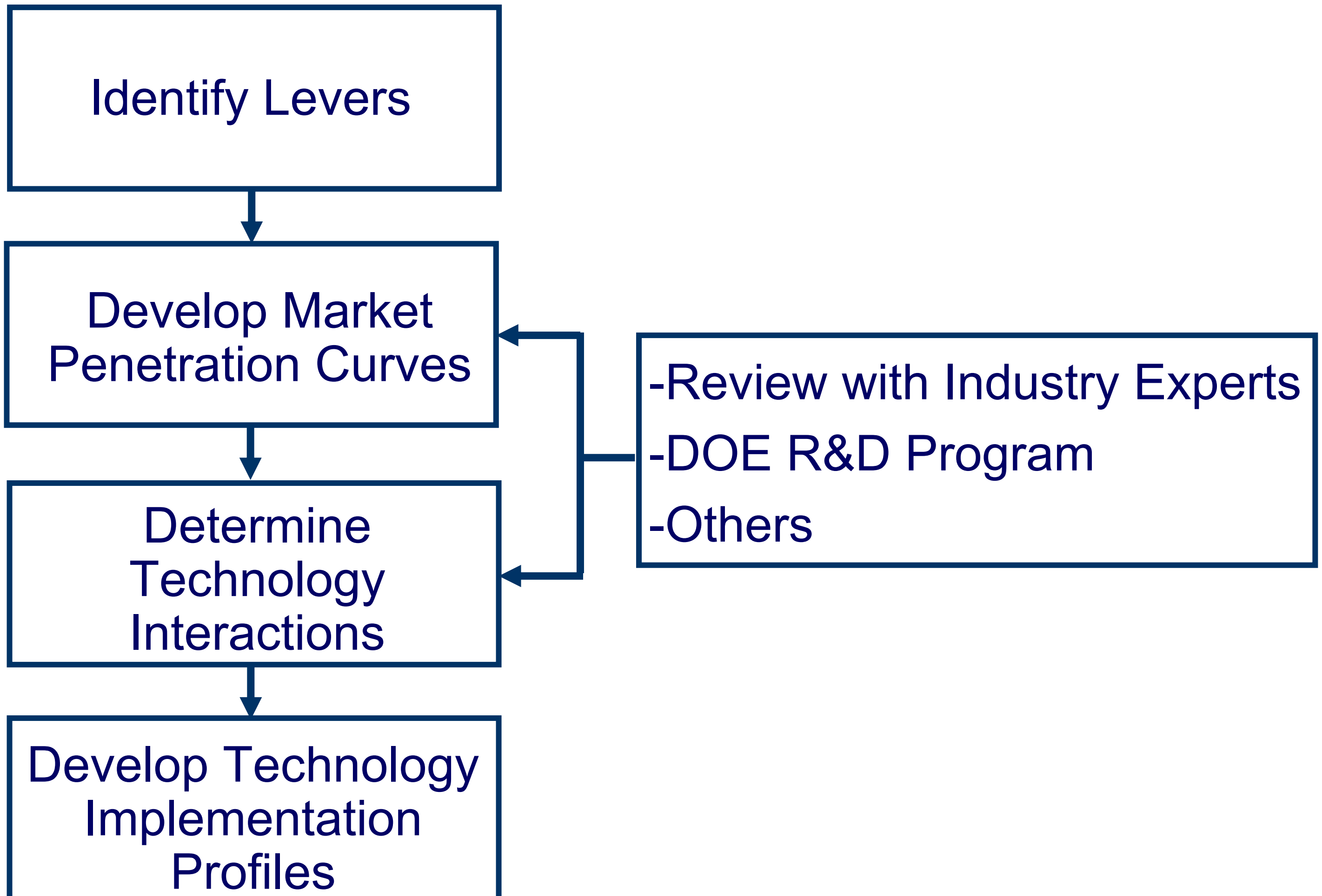
Rules will be Developed to Identify Interactions

Example

- Reservoir Characteristics Help Improve Production by 15%
- Drilling Bit Improvements Help Reduce Drilling Cost by 10%

These Technologies are Mutually Exclusive, Additive, or Synergetic

Implementation of Technology Options



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Onshore Lower 48 Oil & Gas Supply Submodule

Economic/Timing Module

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Discussion Items

- Role of Timing/Economic Module

- Overall Logic
  - System / Timing Module

- Components of Timing Module
  - Input Data
  - Exploration – Conventional & Unconventional
  - Discovered Resource
  - Selection & Ranking
  - Resource Development Constraints

- Model Applications

- Reports

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Role of Timing/Economic Module

- Projects Future Oil & Gas Supply at Play Level
  - Production from Existing Fields/Reservoirs
  - Reserves Growth in Existing Fields/Reservoirs
  - Exploration in Undiscovered Fields/Reservoirs

- Development of Resources is Subject to the Following Constraints:
  - Access to Resource
  - Technology
  - Economics
  - Infrastructure
    - Drilling
    - CO_2 Availability
    - Pipeline
    - Others

Processes Modeled

Oil	Gas
- Water Flooding	- Conventional
- Polymer Flooding	- Water Drive
- CO2 Flooding	- Tight Sands
- Steam Flooding	- Coal / Shale
- Infill Drilling	
- Profile Modification	
- Horizontal Wells	

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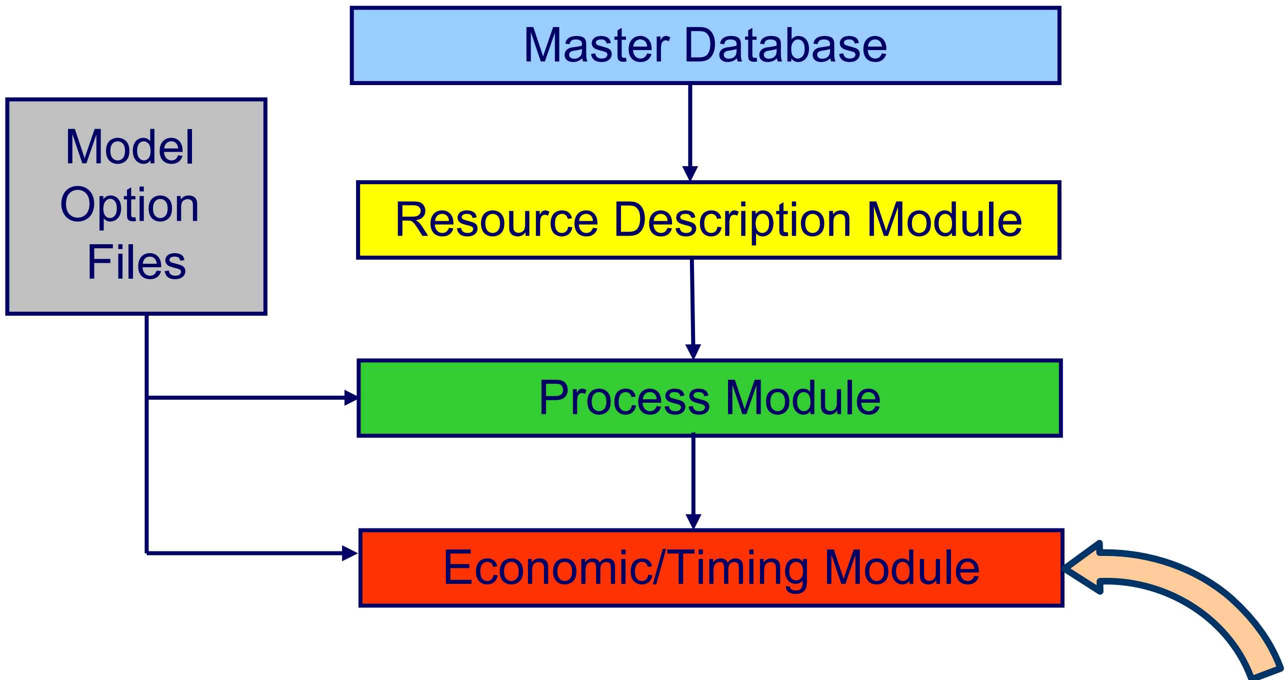
Overall System Logic Flow



Performs Economic Evaluation of Oil and Gas Resources

– Discovered and Undiscovered

– Rank and Select Resources for Development

– Provides Supply Curves for NEMS

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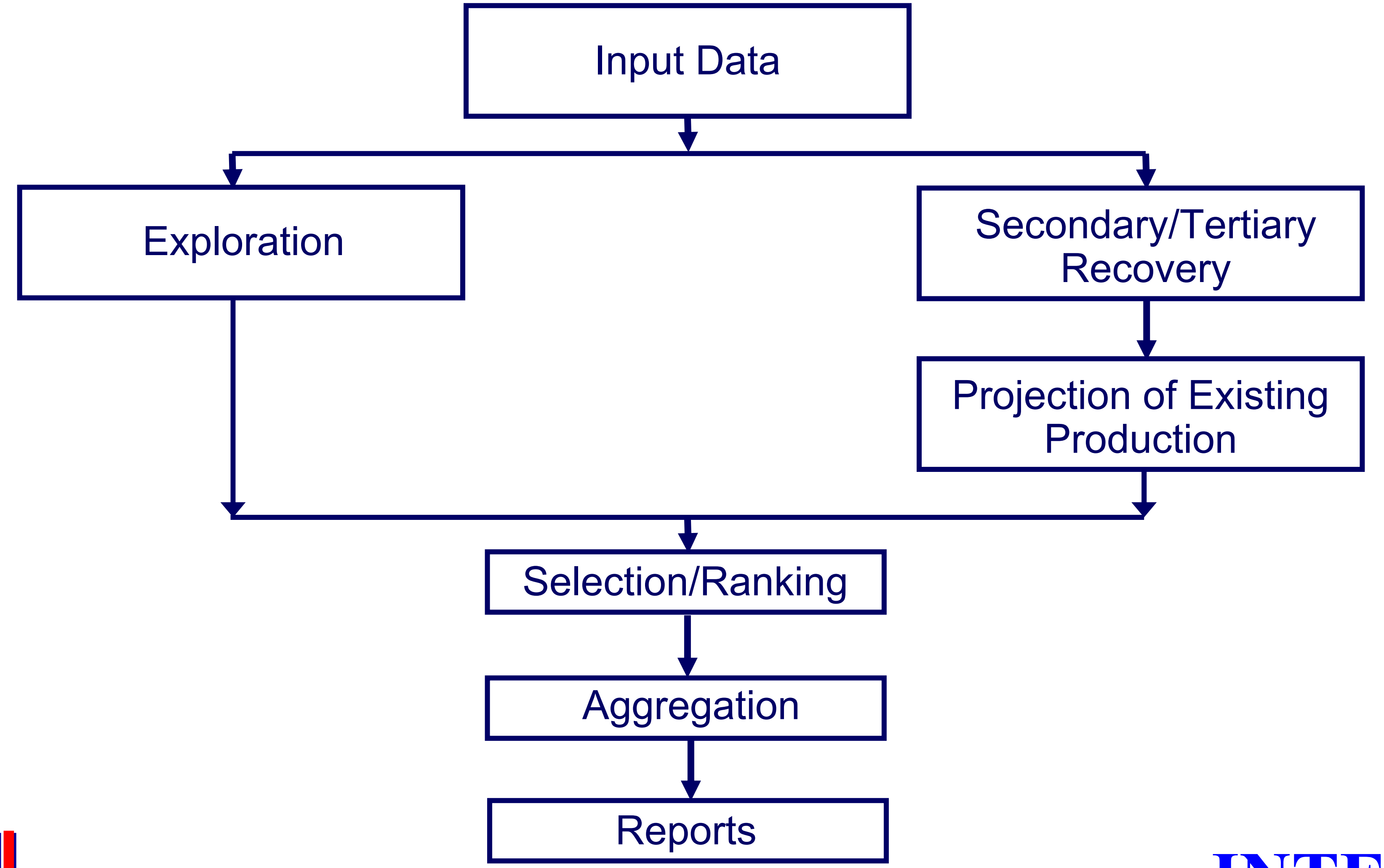
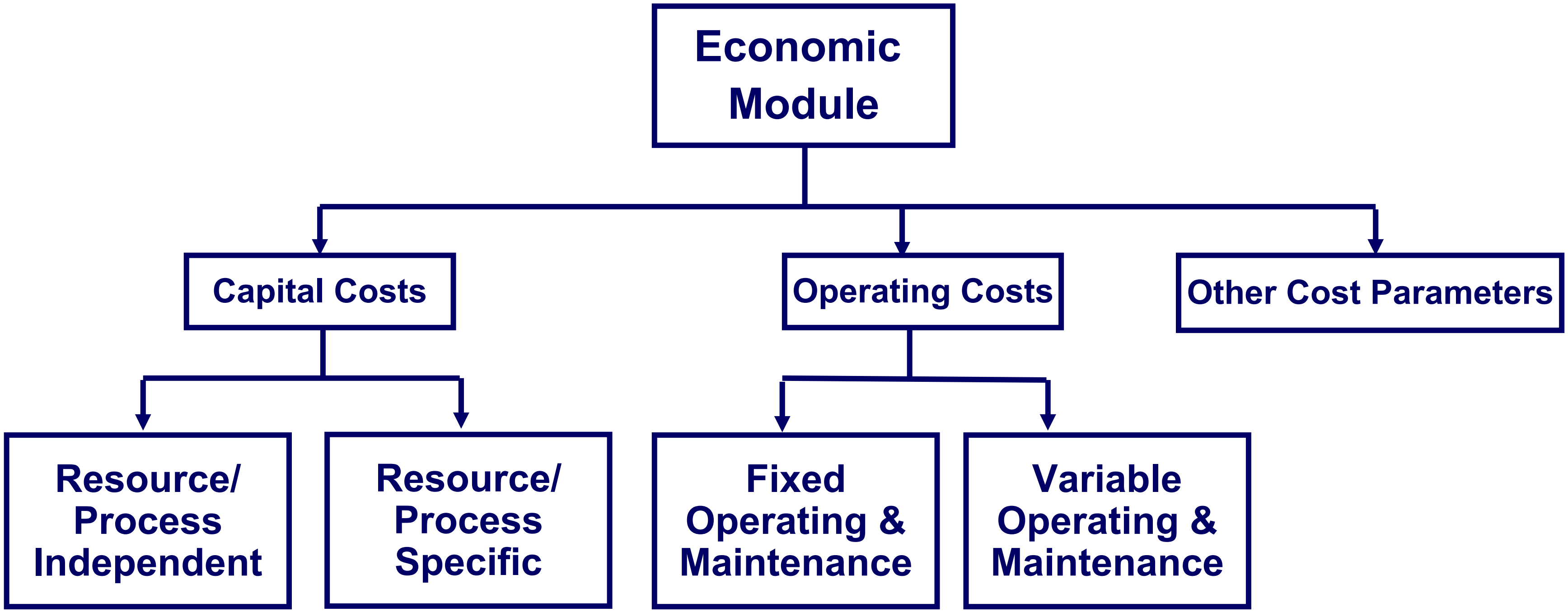
Components of Timing Module



A- Input Data

- Resource Data √
  - Discovered
  - Undiscovered
- Process Production Profile Parameters √
- Cost Data ☐
- Constraints ☐
- Economic Parameters (Price, ROR, etc…) ☐
- Fiscal Data ☐
- User Defined ☐
  - Technology Levers
  - Economic Levers
  - Control Variables

Types of Cost Data



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Capital Cost Data

- Resource/process independent:
  - Drilling & completion
  - Workover
  - Surface and Subsurface facilities

  } $f(depth)_{region}$

- Resource/process dependent:
  - Gas processing facilities
  - CO_2 injection plants — $f(CO_2$ injection volume)
  - Steam generators — f (*steam* injection volume)
  - Environmental costs

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Operating Cost Data

- Fixed operating costs:
  - Direct annual operating costs *f(depth)* region
  - Secondary production costs
- Variable operating costs:
  - Lifting cost (*$/Bbl, $/Mcf*)
  - Gas processing cost (*$/Bbl, $/Mcf*)
  - CO_2 cost (*$/Mcf*)
  - Chemical (*$/Bbl*)
  - Recycling (*$/Bbl, $/Mcf*)
  - Environmental costs (*$/Bbl, $/Mcf*)
  - G&A on Capital and Operating Costs factors

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Developing Cost Equations

- Determine historical cost data
- Determine corresponding oil price
- Normalize all costs data to a fixed oil price ($30/bbl)
- Develop regional cost equations as a function of critical parameters :
  - Depth
  - Production Rate
  - Injection Rate
  - Others (TBD)

- Test cost equation for validity

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Cost Adjustment Factors

- Capital and operating costs vary with supply & demand and also oil price
- Cost adjustment multipliers will be used to capture the impact of oil price changes
- Use National Petroleum Council (NPC) methodology for price impacts

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NPC Methodology For Price Impacts

- Determine the ratio of the change between the current oil price and the fixed price

$$\text{Term} = \frac{(\text{Oil Price}_{current} - \text{Fixed Price})}{\text{Fixed Price}}$$

- Apply adjustment multipliers for various cost categories:

$$(\text{Cost Multiplier})_x = 1 + (\text{Factor})_x\ (\text{Term})$$

Cost Category	Factor_x
Tangible Investments	0.2
Intangible Investments	0.4
Operating Costs - Fixed	0.2
CO_2	0.39
Polymer	0.3913
Other Costs	0.25

Source: COGAM

To be validated against current data

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Resource Development Constraint Files

- Drilling Constraints
  - Total number of rigs
  - Rig depth rating
  - Total development & exploration drilling (footage)

  Function of oil & gas prices

- CO_2 Availability
  - Sources of CO_2 :Type, State, Region
  - Volume of CO_2 available by source
- Capital Constraints
  - Total capital available for E&P activity
  - Resource Access

  Function of oil & gas prices

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Other Economic Parameters

- Other economic parameters includes:
  - Depreciation schedule
  - Depletion rate
  - Amortization schedule
  - Environmental costs
  - Lease acquisition costs
  - Geological & geophysical costs

- Oil & Gas prices:
  - Annual oil & gas prices
  - Fixed or variable

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Model Levers

- Technology levers
  - Value of all levers
  - Implementation & market penetration curves
  - Interaction of Technologies
- Economic Levers
  - ROR
  - Risk
- User defined run controls
  - Types of Output
  - Single or Multiple Cases
  - Other
- Resource access parameters

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Economic Risk

- Economic Risk is Modeled Using Rate of Return
- Two Components of Rate of Return
  - Cost of Capital – 6% to 8%(historical average)
  - Technology Risk – Varies with Technology

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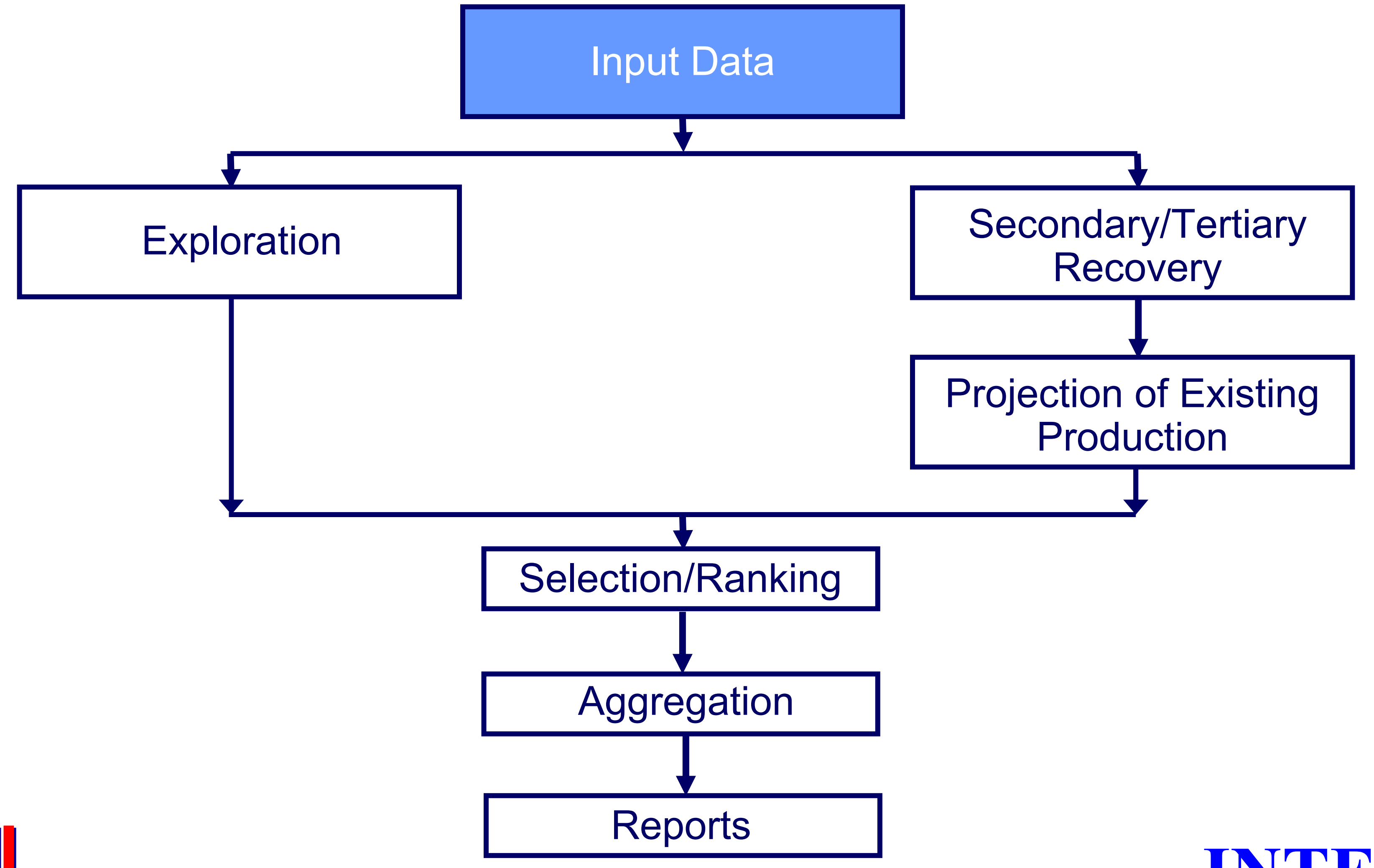
Components of Timing Module



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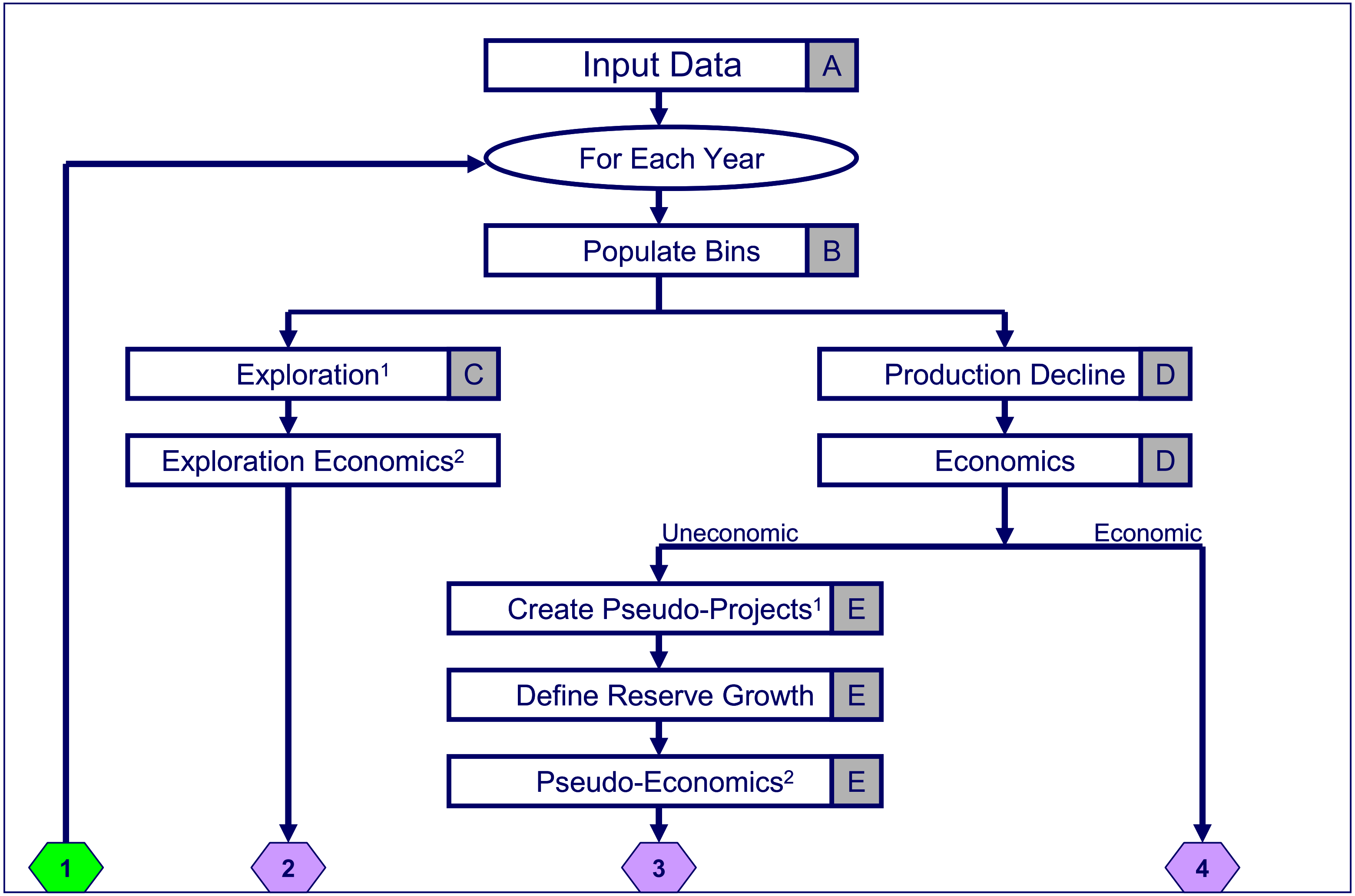
Detailed Timing/Economic Module Flowchart



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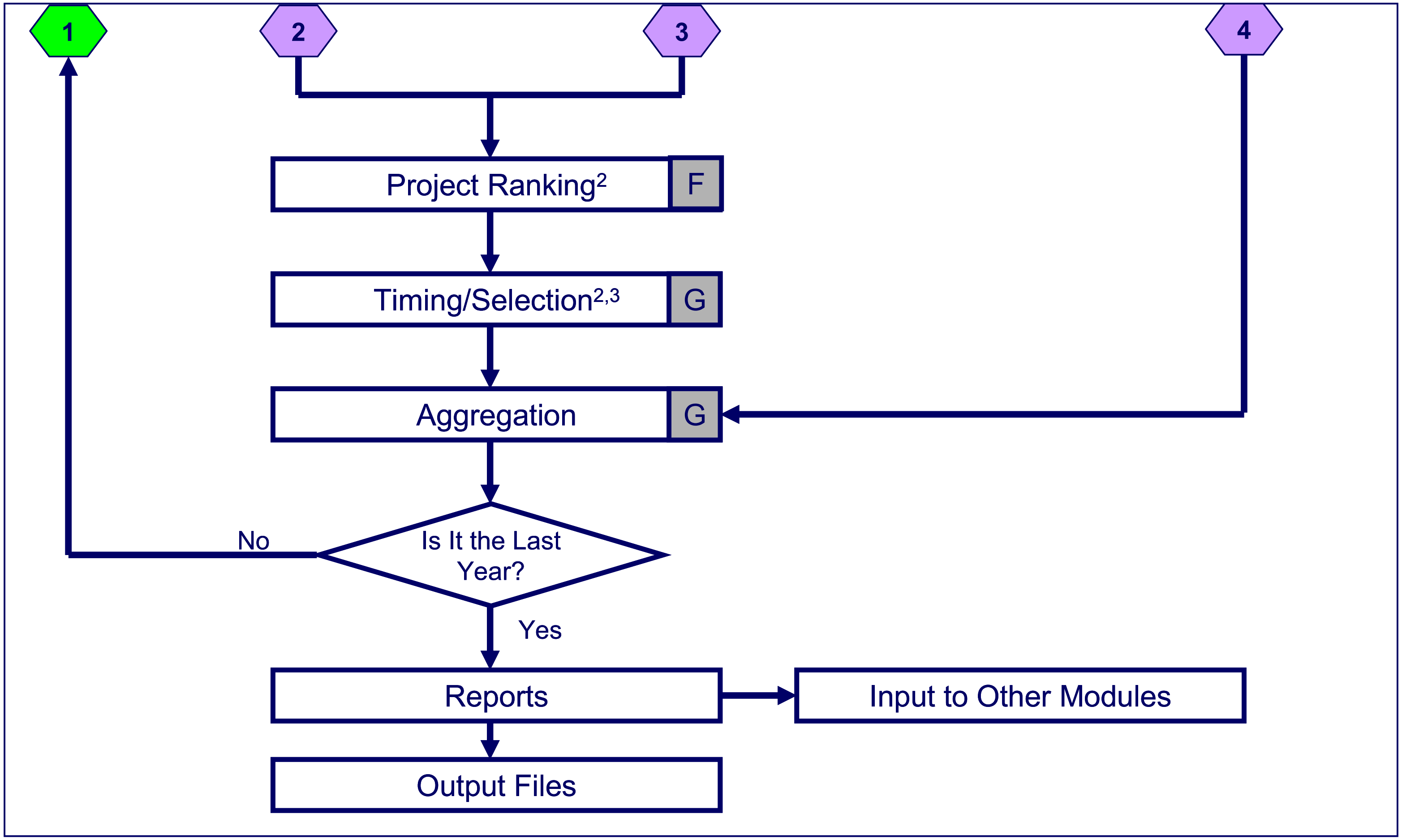
Detailed Timing/Economic Module Flowchart (Contd…)



1: Step Where Technology Levers Will Be Used
2: Step Where Economic Levers Will Be Used
3: Step Where Resource Access Levers Will Be Used

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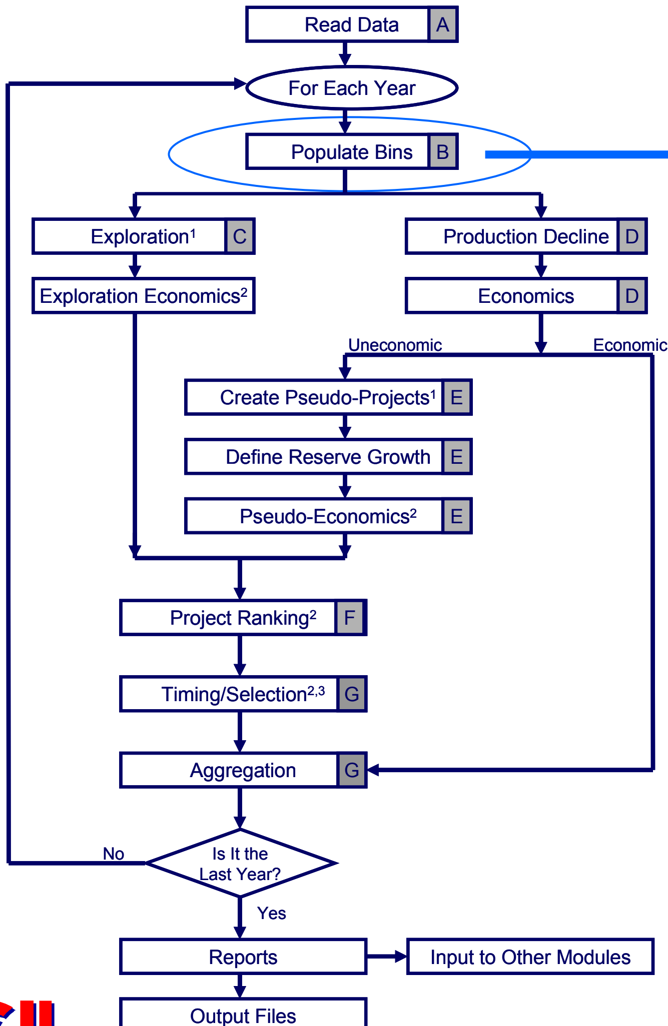
B: Populate Bins



- Read Resource Files
- Populate Bins for Each Play Based on Size Class & Depth

Size (BOE/Day)

Size Range	Depth
0-10	
>10-15	
>15-50	
>50-100	
>100	

for each size bin

Depth of Producing Zone (Feet)

Depth Range	Number of Wells
0-2000	
>2000-4000	
>4000-8000	
>8000-12000	
>12000-15000	
>15000	

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An Example of Bin Populations

The population of bins in YEAR I at the beginning of the YEAR loop for a play:

Size Bin	Depth Bin	Number of Wells
1	1	10
2	2	11
3	4	6
2	3	4
3	2	7
4	1	3

Note: Only bins with data are shown in this example

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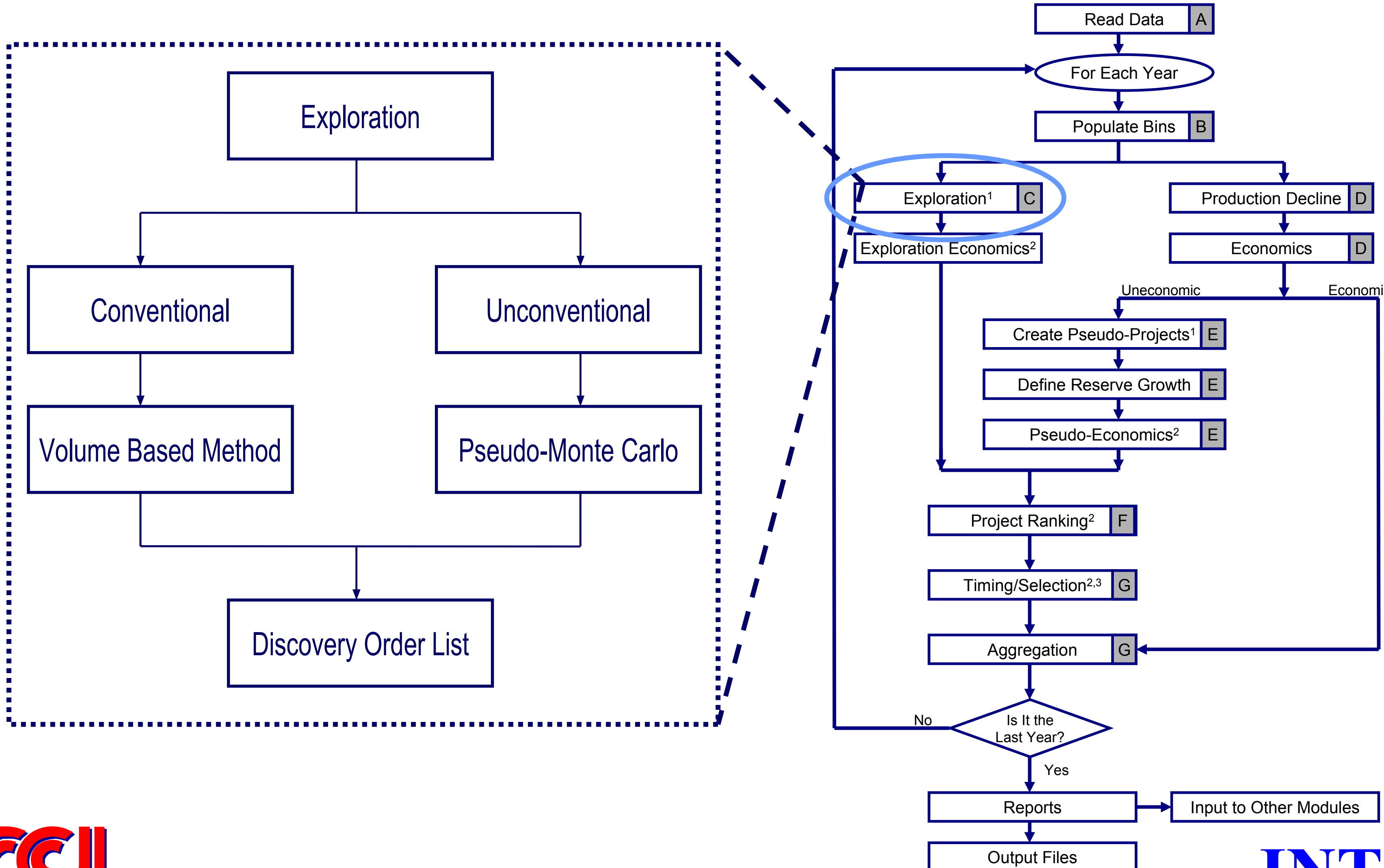
C: Exploration in Timing Module



Exploration Sub Module

- Objective: to Evaluate Economic Potential For Undiscovered Oil & Gas Resources
    - Conventional
    - Unconventional
- Based on Undiscovered Resource Estimates

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Ultimate Goal of the Exploration Model

- To Determine the Discovery Order of Accumulation/Cell within a Region/Play

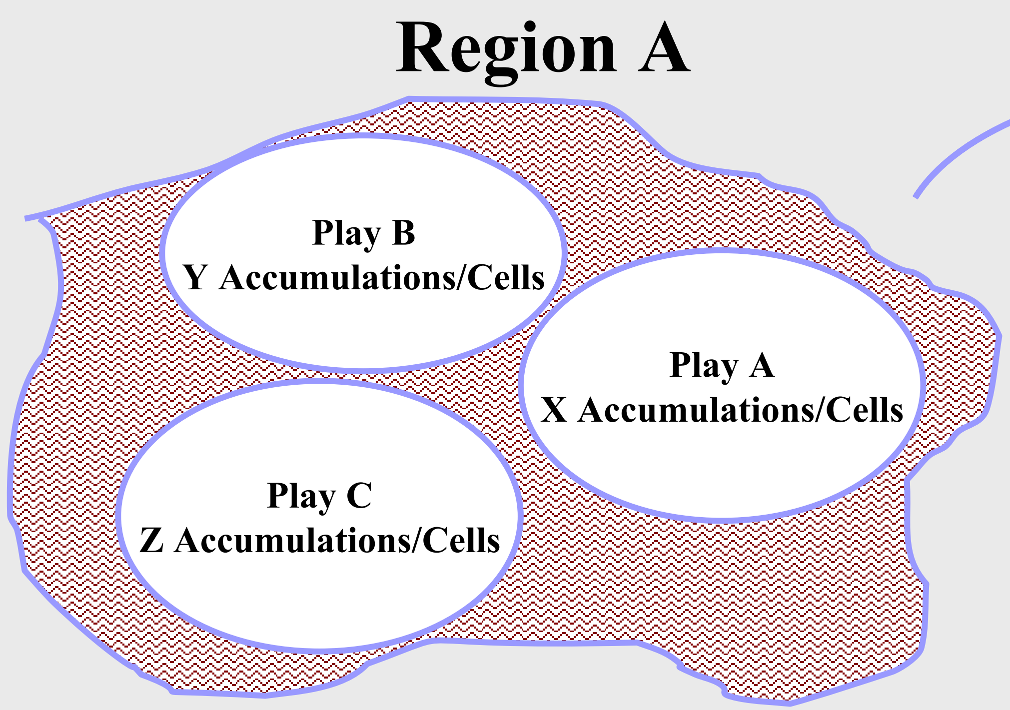

Table to Fill

Discovery Order	Play No.	Accumulation /Cell ID
1 2 • • • n		

Exploration

-Conventional Resource-

Exploration: Conventional Resource

- Proposed Method to Calculate Probability
  - Volume based
- Exploration effectiveness is modeled using :
  - Technology factors
  - Favorability factors (such as resource access)

Methodology Accommodates Theories & Methods Developed by Industry/Government

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Modeling Conventional Exploration

- Rules for Exploration:
  - First explore the plays with the largest remaining reserves
  - Use the volume to calculate the probability of discovery of each class in the play
  - Aggregate and normalize the class discovery probabilities to determine the discovery probability of the play
  - Make selections using the cumulative probabilities and a pseudo-random number

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Modeling Conventional Exploration (Cont.)

- Adjust probabilities using:
  - Technology levers
  - Resource access levers
- Add to list for competition with other resources

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Adjusting Probabilities for Conventional Exploration

- Technology Factor:
  - Drilling
  - Resource description
- Resource Access Factor:
  - Resource is available
  - Resource is unavailable

Example

Play	Technology Factor	Resource Access
401	0.95	1.00
403	1.05	1.00
450	1.00	1.15
451	1.00	0.85
503	0.85	0.95
1001	1.10	1.00
1007	1.00	1.00
1102	0.90	1.10
1301	0.85	0.95
1804	1.00	0.10
2005	1.10	1.00
2057	0.85	0.85
2206	1.00	1.05
2503	1.00	1.20
2801	0.90	1.00

Resource is unavailable

No Resource Access Constraints

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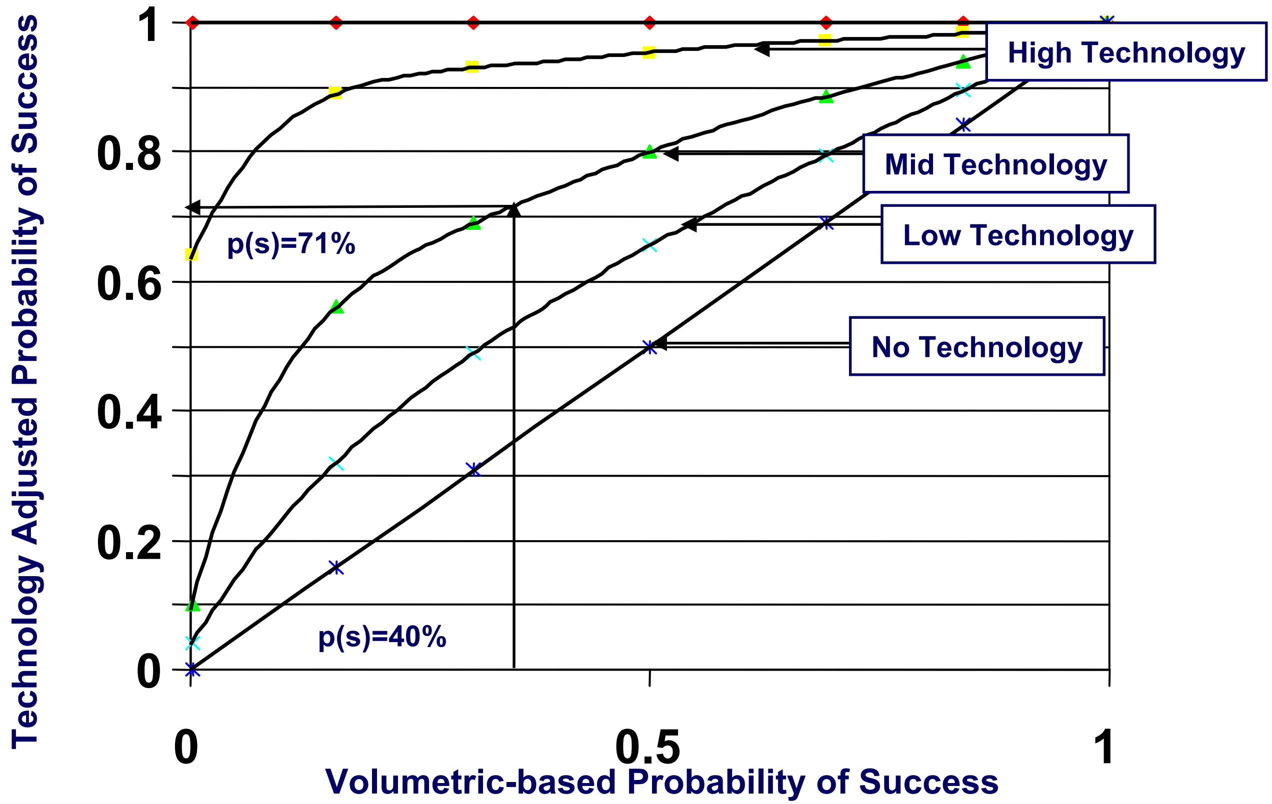
Exploration Technology Factor

How Do We Model the Effects of Exploration Technologies?



Technology Enhances the Probability of Exploratory Success for Applicable Resources

Source: COGAM

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Exploration

-Unconventional Resource-

Exploration: Unconventional Resource

- Modeled using a two step process
- Step 1: Determine probable exploration/ development schedule for all cells in each play
  - Use pseudo Monte Carlo methodology
  - Run every year
- Step 2: Determine the development order for all plays while incorporating:
  - Technology
  - Resource access

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Important Definitions

- Unit of Analysis: **Play**

- Exploration Unit: **Cell (as defined by USGS)**

- Annual Drilling Package:

  - In a play

  - Randomly selected set of cells

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Modeling Unconventional Exploration

- Calculate probability of discovery of Each cell bin as a function of EUR
- Create drilling packages using pseudo random methodology
- Select first package
- Run economics
  - If economic: Select next package
  - If not economics: Add next package for next year and run economics
- Repeat process for next package
- Determine discovery order using probabilities
- Add to list for competition with other resources

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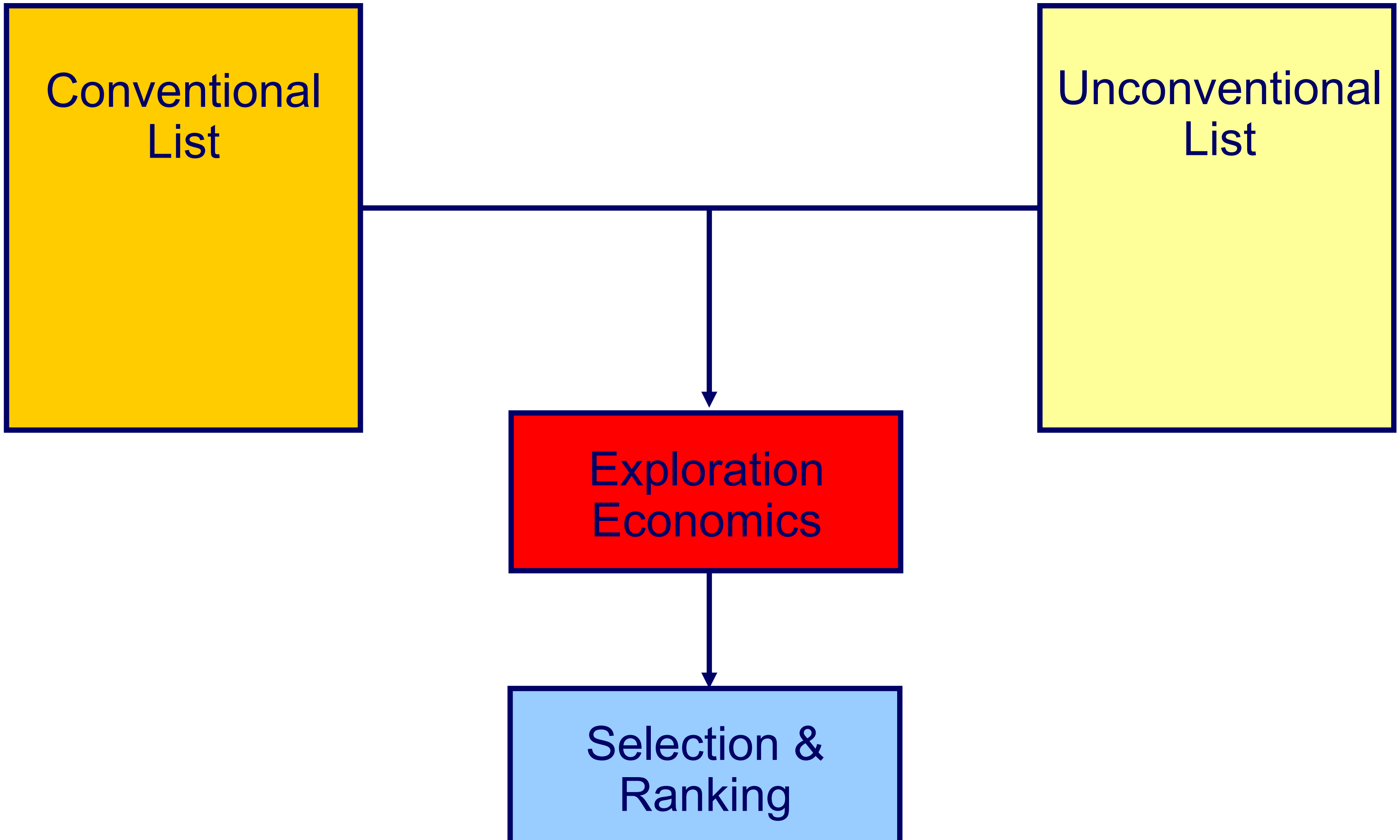
Exploration: Discovered Order



Exploration Economics

- All Exploration Costs are Assumed to be Sunk Costs
- Full Development Economics is Performed on Each Accumulation/Cell
  - Development Drilling Costs
  - Lease Acquisition Cost
  - Capital Equipment Cost for New Producers
  - Fixed and Variable Operating Costs
  - Only Primary Production is Considered for Economic Calculation

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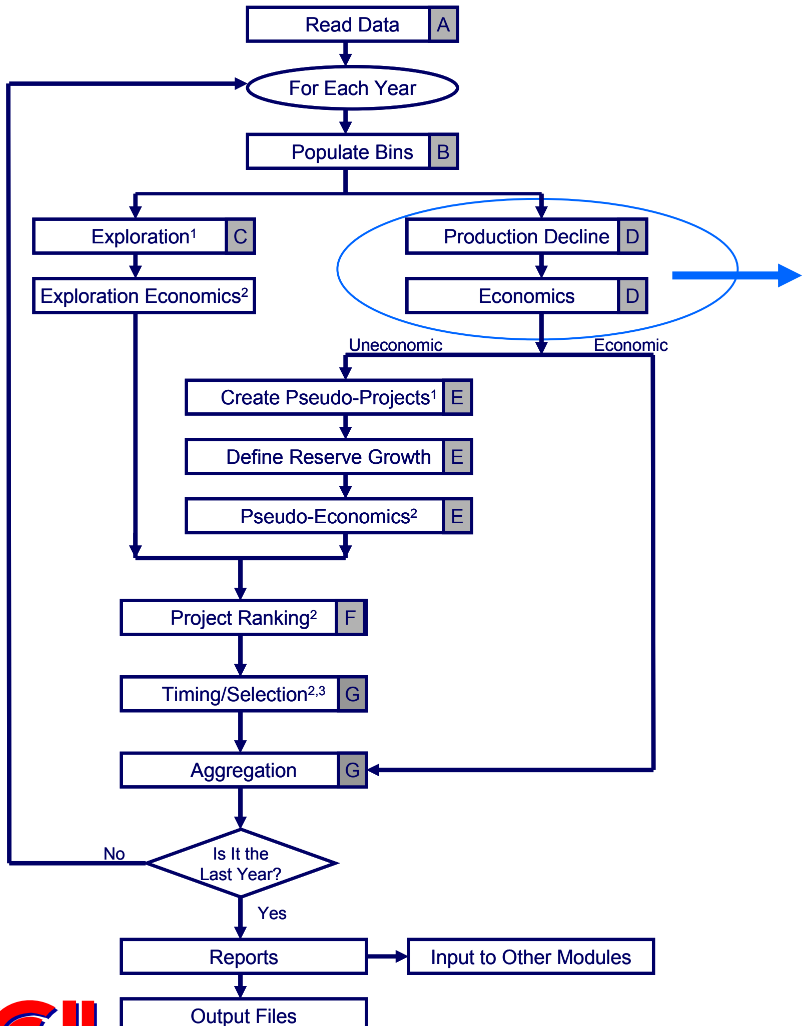
Exploration

-Discovered Resource-

D: Production Decline Submodule



- For each play & bin:
  - Assign & calculate average historical production profile
  - Perform decline curve analysis at bin level using bin size/depth as one of the production profile parameters
  - Perform economics of the future profile

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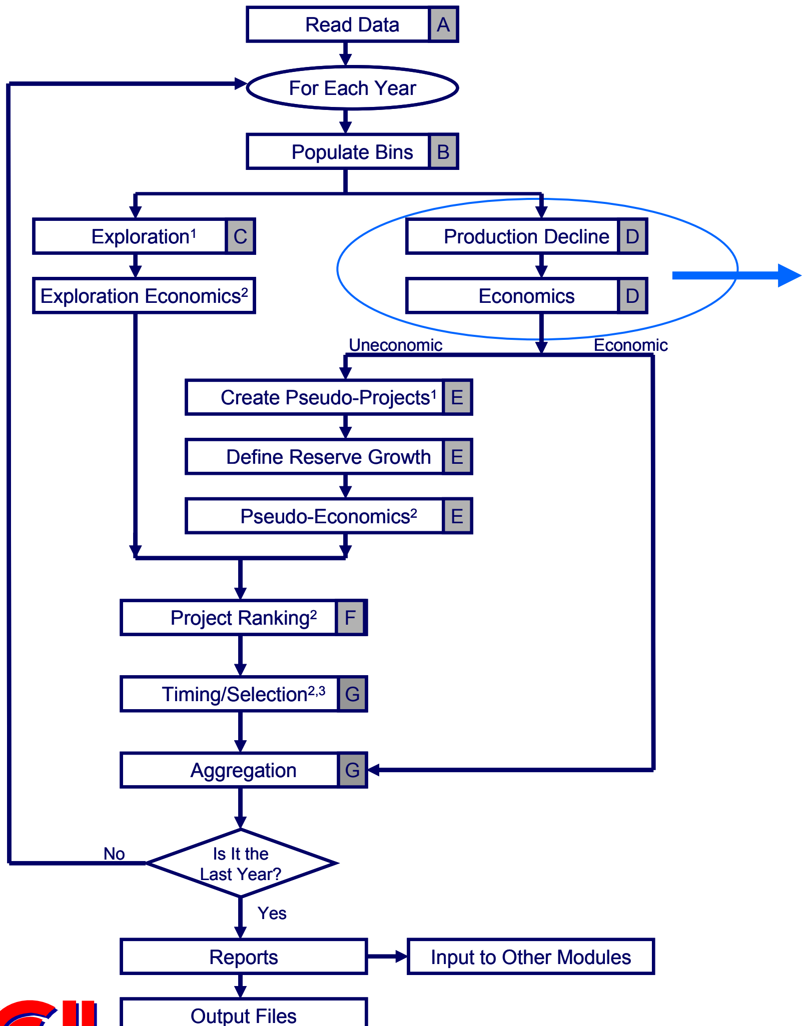
D: Production Decline Submodule (Cont.)



- If economic:
  - Scale economics and production from one well to the number of wells in the bin
  - Aggregate the production from that bin
  - Tag the bin as economic (section G)
- If uneconomic:
  - Tag the uneconomic bin for reserves growth (section E)
- Repeat for each bin and each play

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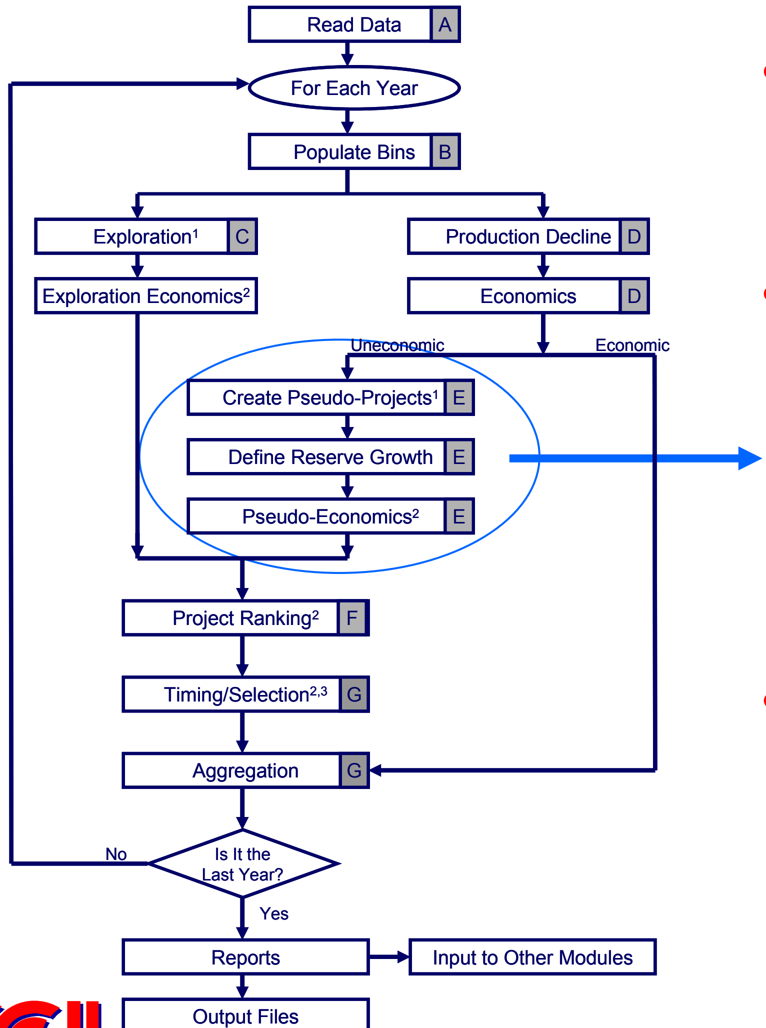
E: Reserve Growth Submodule



- Aggregate the wells in uneconomic bins
- Determine which bins can not be combined in pseudo-projects due to:
  - Depth
  - Average play properties
- Create pseudo-projects by selecting wells using pseudo-random methodology

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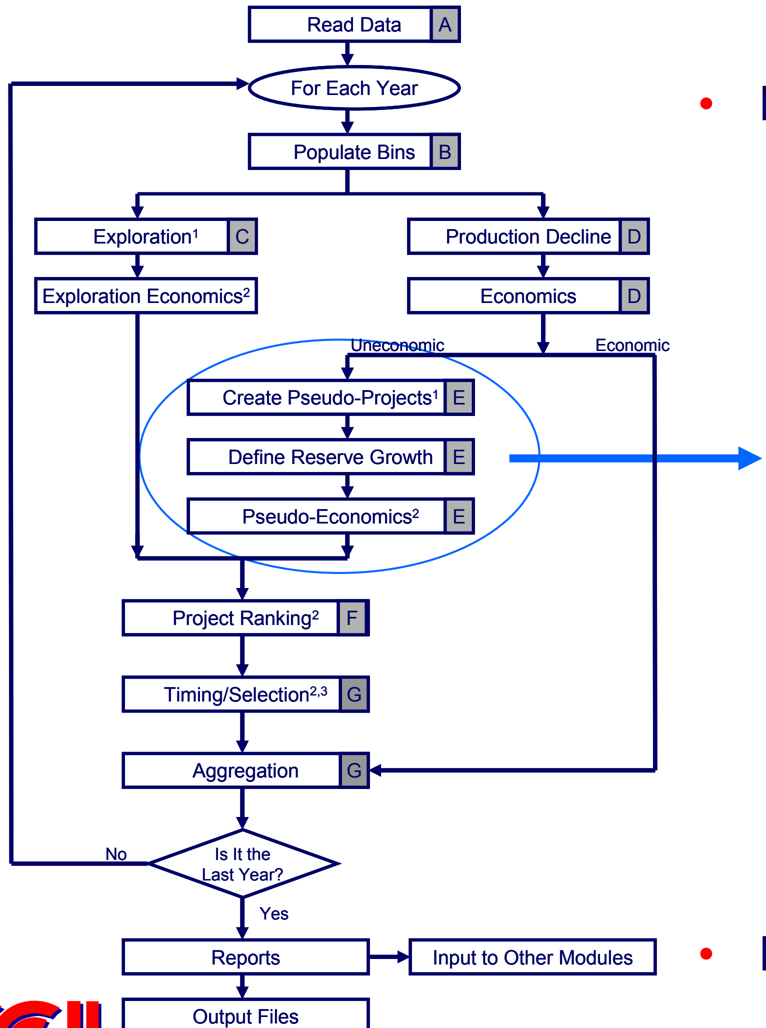
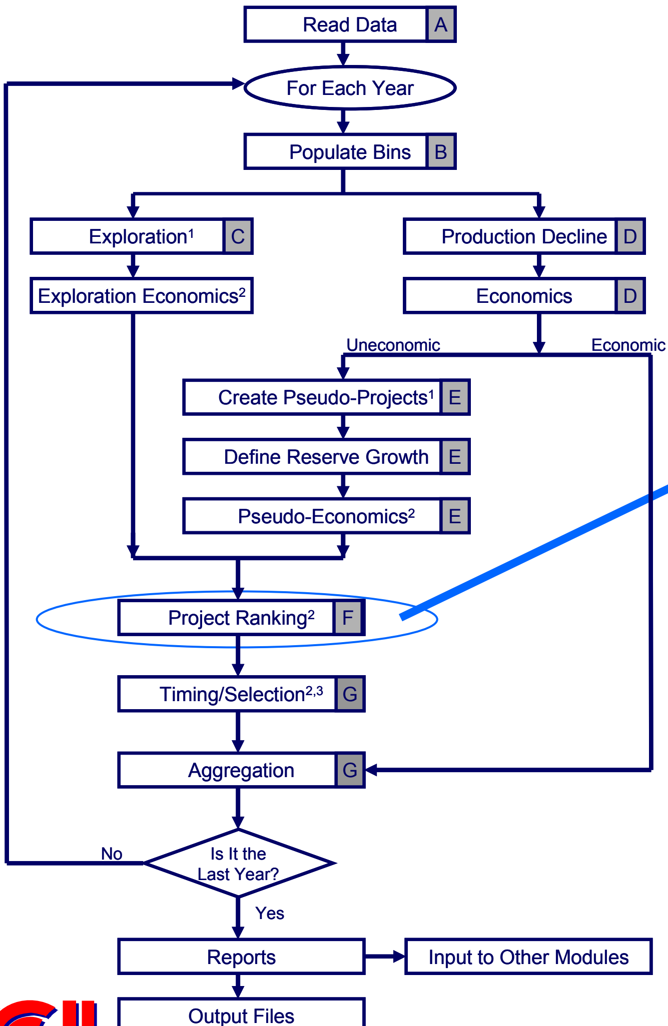
E: Reserve Growth Submodule (Cont.)



- **For each pseudo-project:**
  - Determine, using screening criteria applied to the play average properties, which reserve growth processes are applicable
  - Using process specific type curves, and model levers, determine the potential additional production from EACH reserve growth process
  - Apply technology levers as applicable
  - Calculate life cycle economics on pseudo projects using process specific costs & schedule
  - Calculate investment efficiency
  - Store the project for ranking

- **Repeat this process for all pseudo projects**

F: Project Ranking Submodule



- Read the list of projects
  - Reserve growth projects from step E
  - Exploration projects from step C
- Read YEAR
- For Every Region:
- Rank projects by:
  - Investment efficiency (reserves growth)
  - Probability of discovery (exploration)
- If YEAR >1:
  - Add the "Economic Undeveloped" projects from YEAR – 1 to the top of the list
- Transfer list of potential projects to Timing/Selection (step G)

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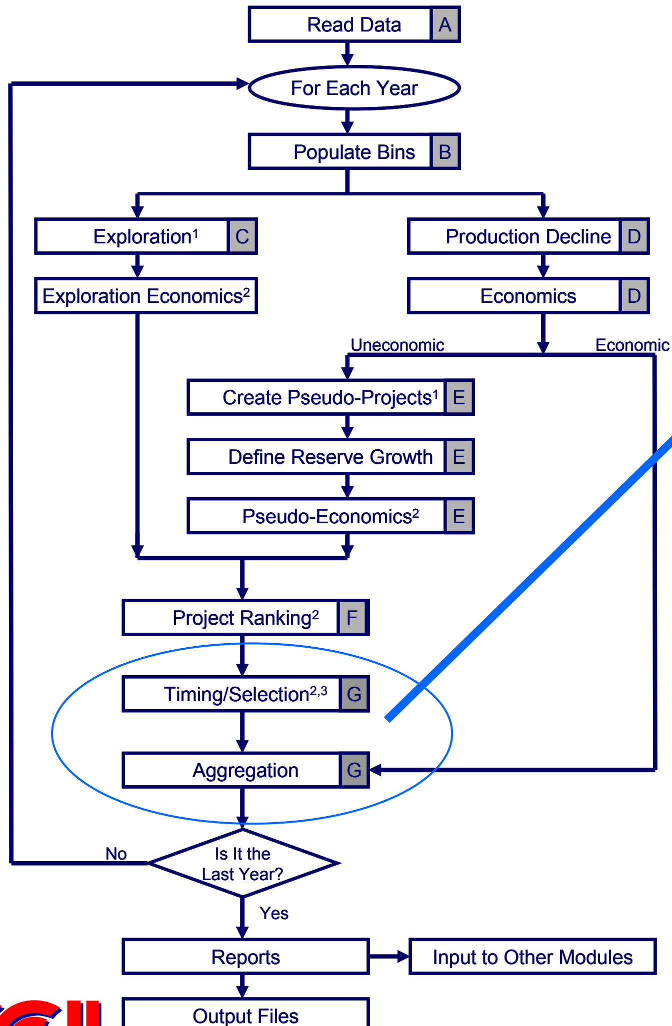
G: Timing & Aggregation Submodule



- Read list of ranked projects
- Read constraint data and model levers
- For every region:
  - Check project at top of the list
  - Determine if sufficient constraints are available
  - Determine project's resource access category
  - Check that development of project would not exceed play level estimates

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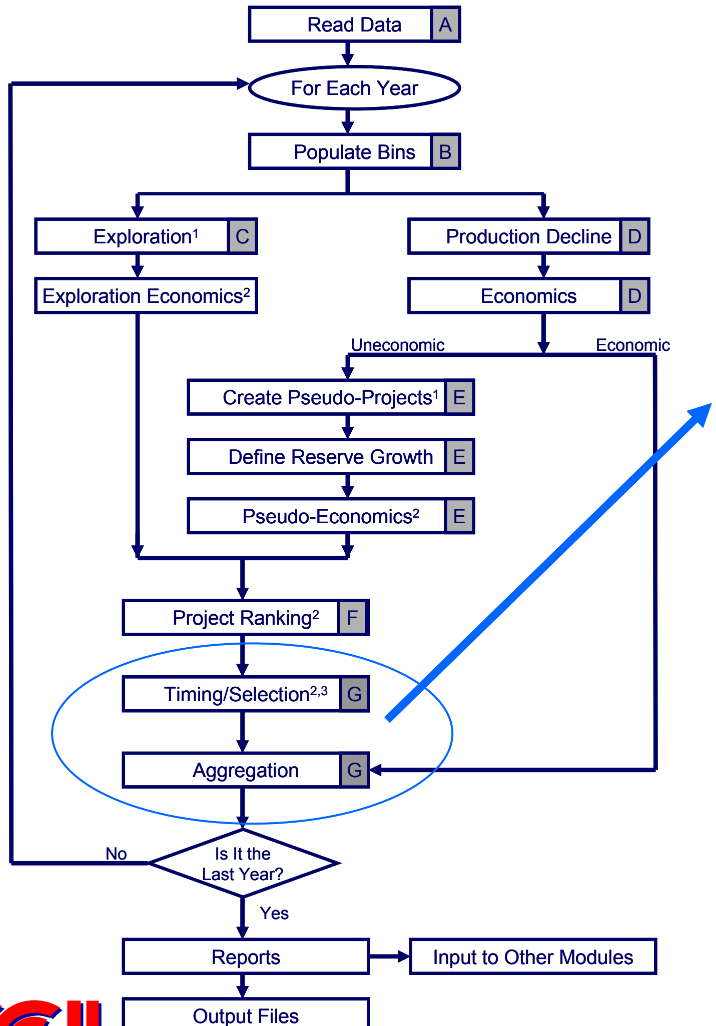
G: Timing & Aggregation Submodule (Cont.)



- Check if project has passed the "shut in" window
- If project has passed "shut in":
  - Calculate shut-in costs
  - Calculate environmental costs
  - Tag as "Shut in"
  - Examine next project
- If project has not passed "shut in" window:

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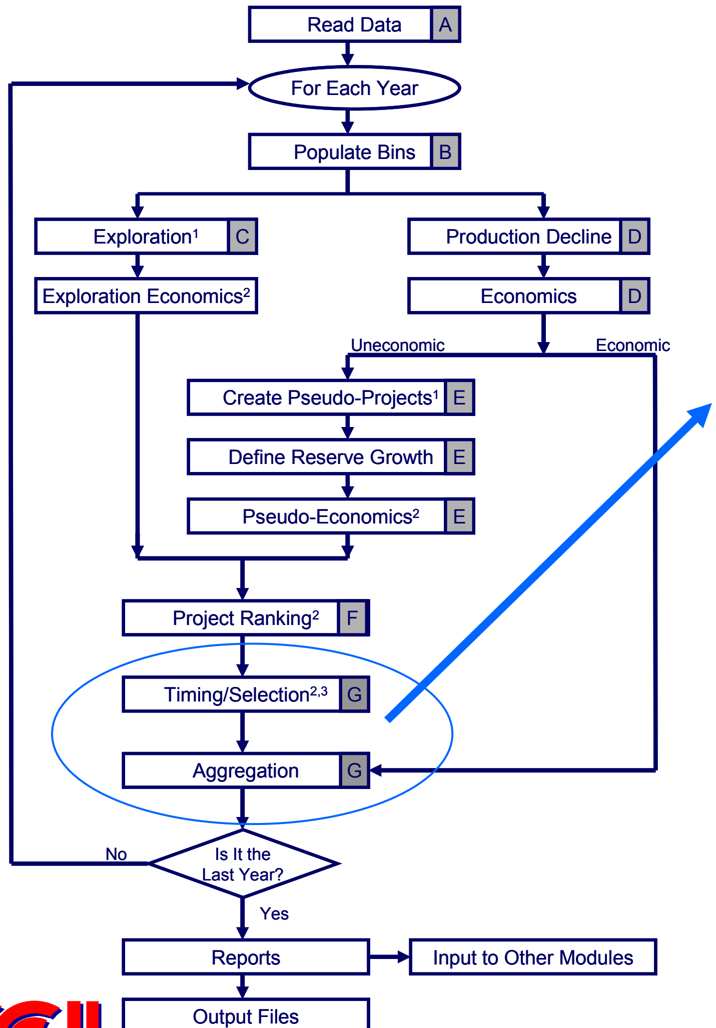
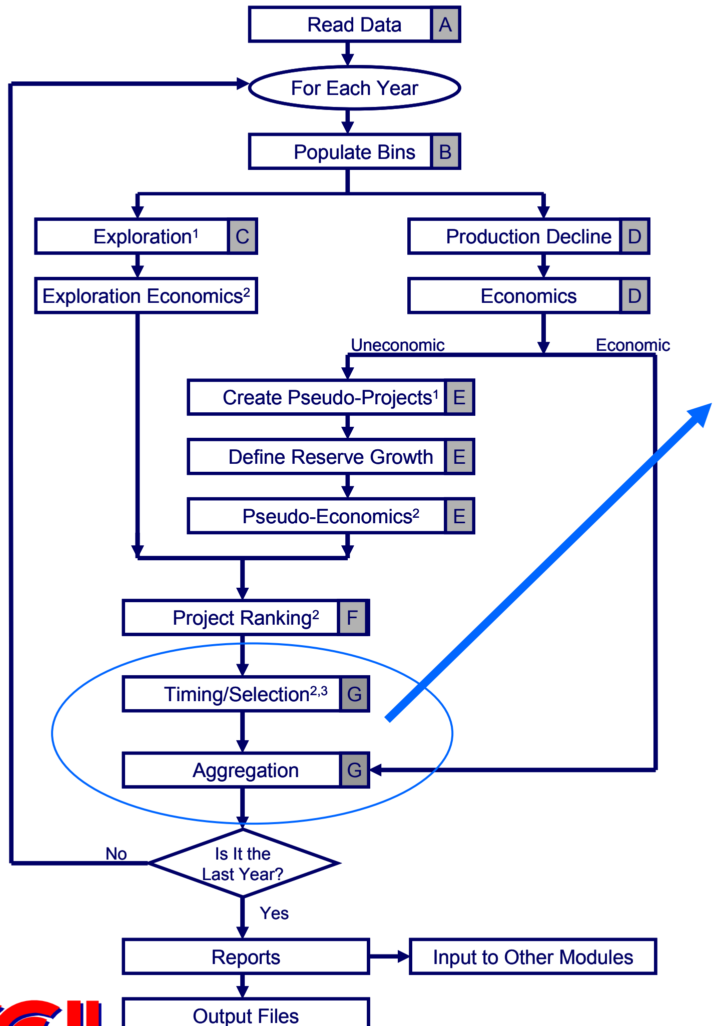
G: Timing & Aggregation Submodule (Cont.)



- If constraints are available:
  - Time in project
  - Tag as "Economic Developed"
  - Remove from list
  - Remove duplicate projects
  - Calculate remaining constraints
  - Check next project
- If constraints are not available:
  - Read remaining projects for that region
  - Tag the economic projects as "Economic Undeveloped"
  - Tag the project, for potential shut in, in YEAR + 1
  - Delete uneconomic projects

G: Timing & Aggregation Submodule (Cont.)



- End the reading and evaluation of projects
- Repeat for all projects/regions and run aggregation

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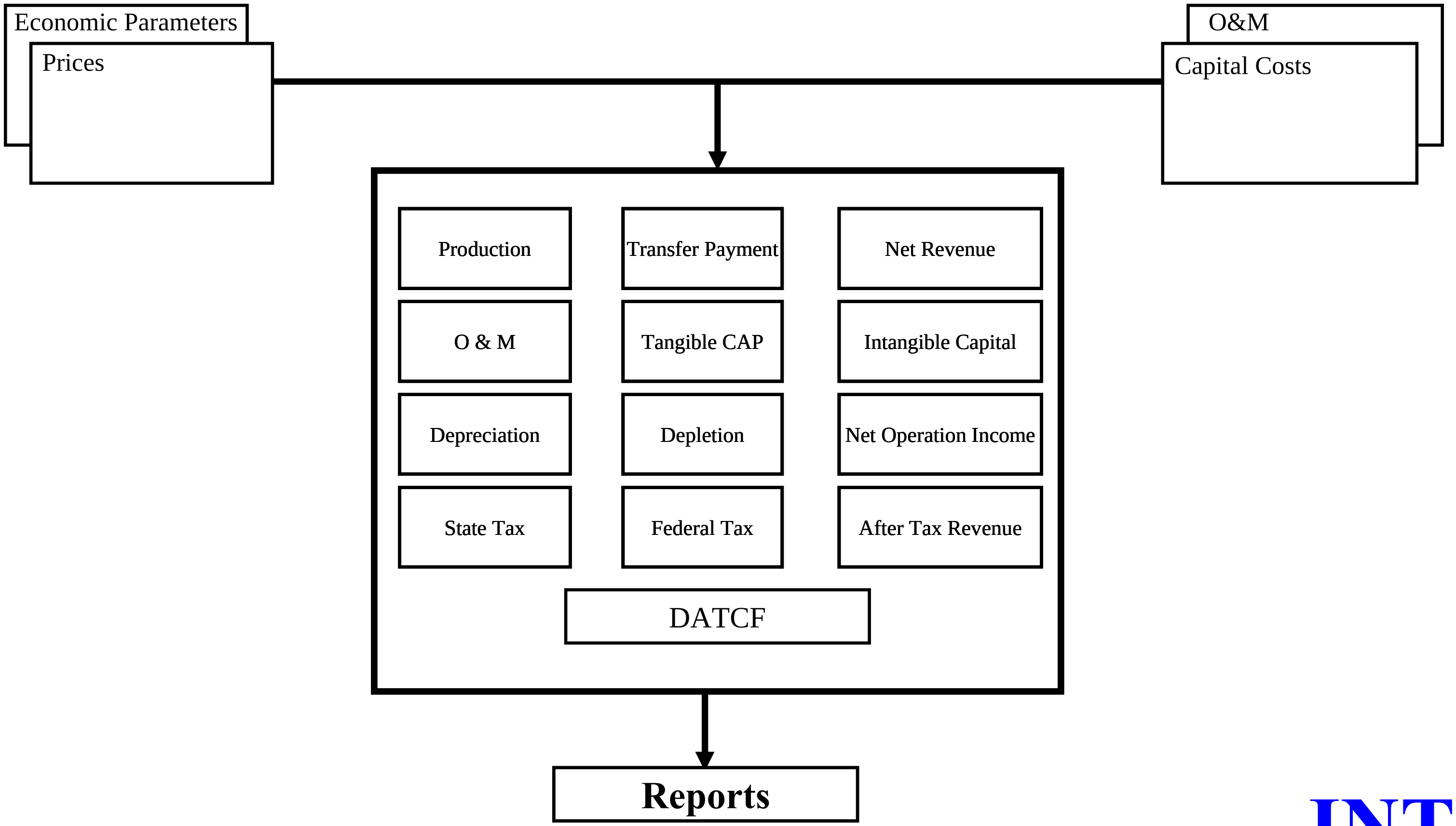
Economics

- Each Project will be Subject to Detailed Full Cycle Cashflow Analysis



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Onshore Lower 48 Oil & Gas Supply Submodule

Resource Development Constraints

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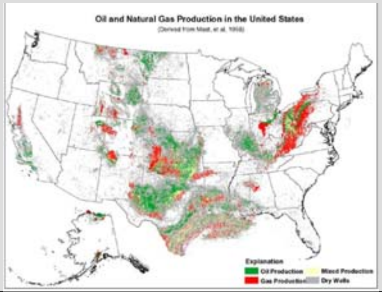
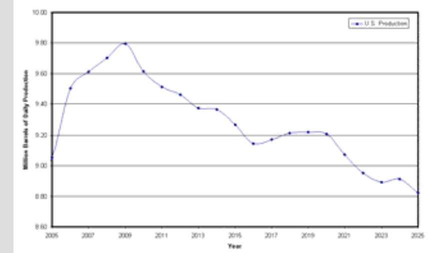
Resource Development Constraint Data

Resource Data



Production Data



Cost Data

Development Constraint Data

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Resource Development Constraints

- Constraints will be Used for Future Development of Various Resources
  - Drilling
    - Number of Rigs
    - Depth Rating
  - Capital Constraints
    - E&P Capital
    - Others
  - CO_2 Availability
  - Access to Land – Federal/State
  - Others to be Defined

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Sources of Resource Development Constraints

Resource Development Constraint	Data Source
Drilling Constraints	
Number of Rigs	API, Baker Hughes, Smith Bits
Rig Depth Rating	API, Baker Hughes, Smith Bits
Development Drilling	EIA, API, IPAA, OGJ
Exploratory Drilling	EIA, API, IPAA, OGJ
Capital Expenditures	EIA, API
Other Constraints	
CO_2 Availability/Pipeline capacity	OGJ, Kinder Morgan, NATCARB

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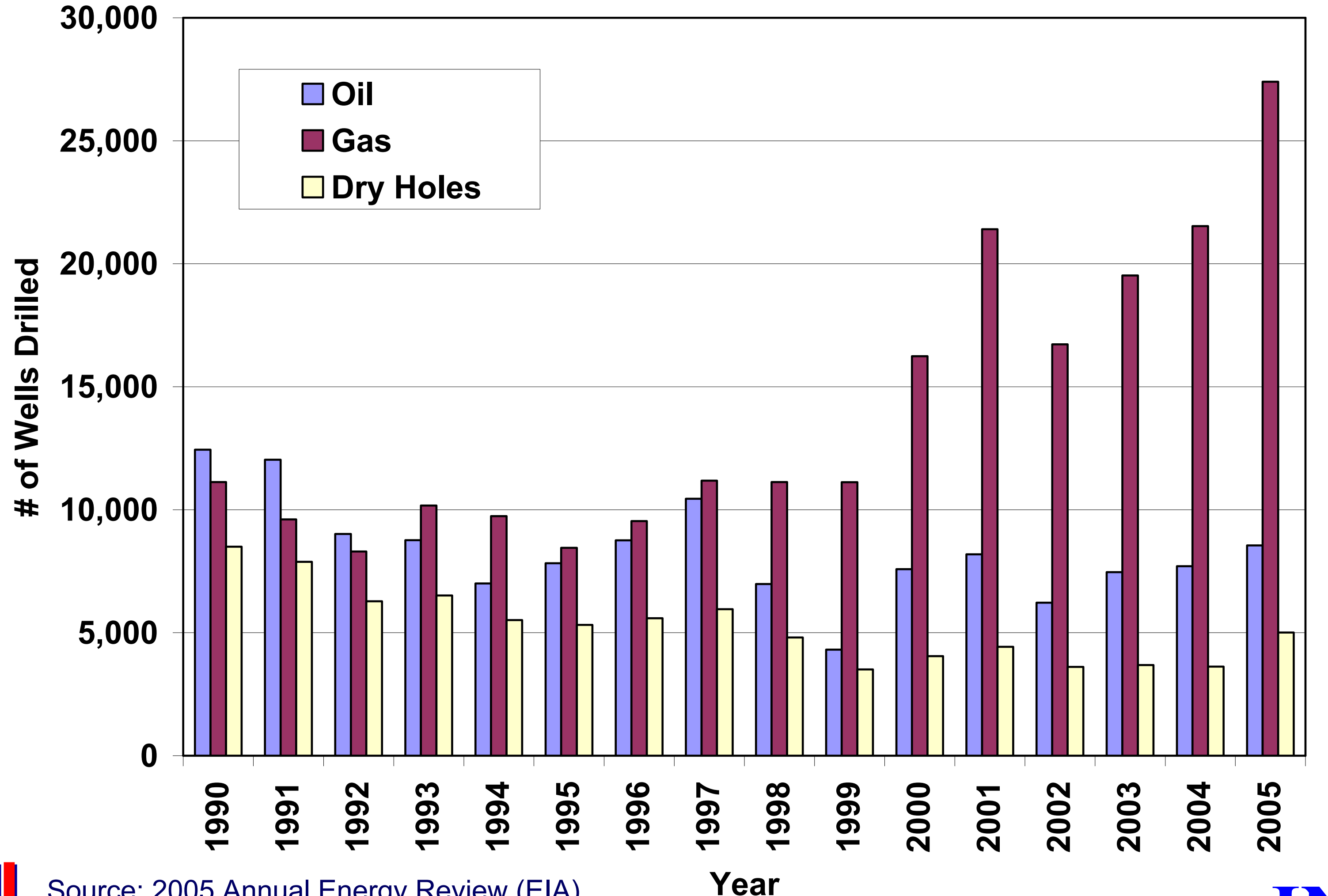
US Historical Drilling Activity



Source: 2005 Annual Energy Review (EIA)

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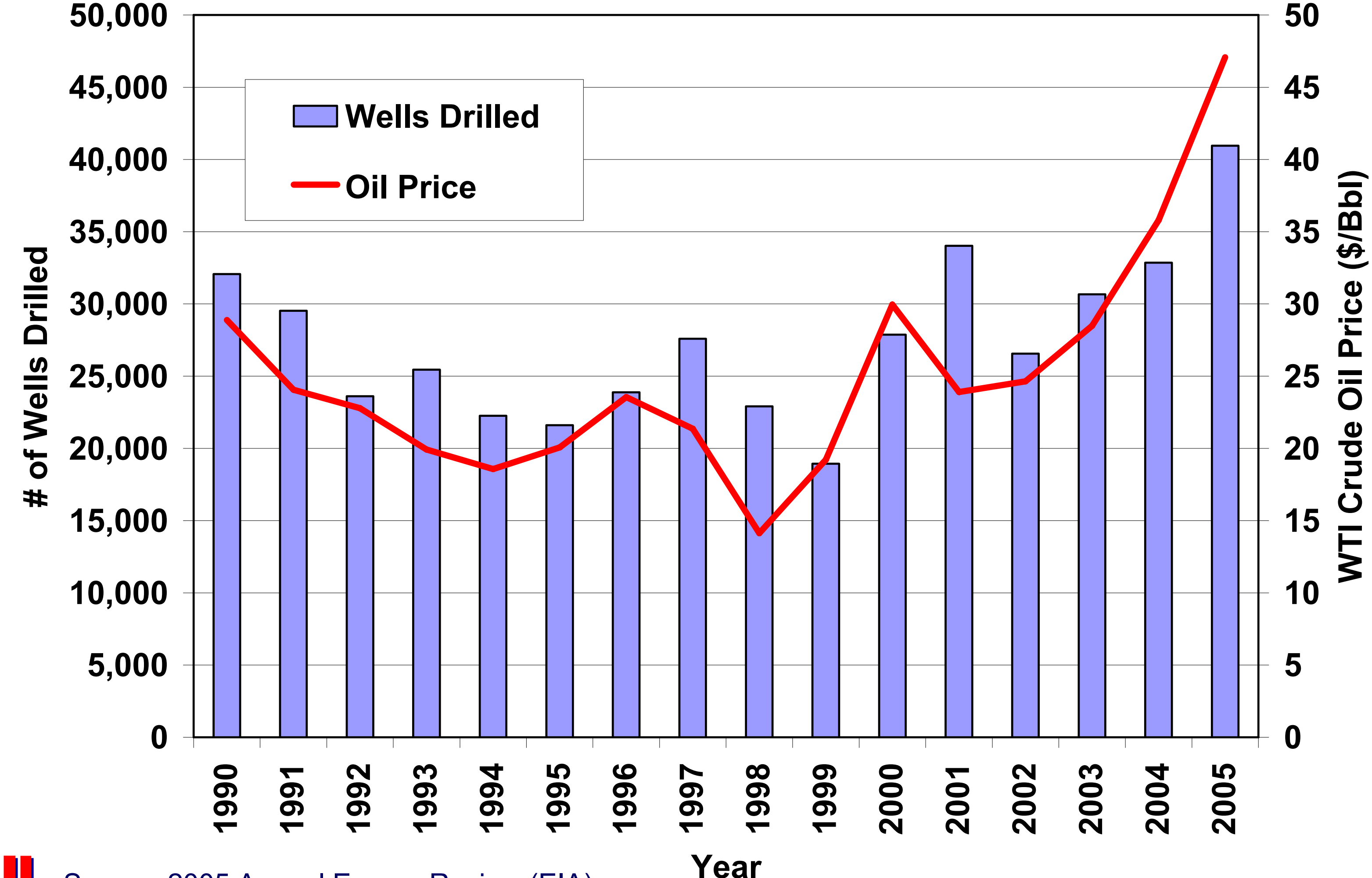
Wells Drilled Annually is Function of Oil Price



Source: 2005 Annual Energy Review (EIA)

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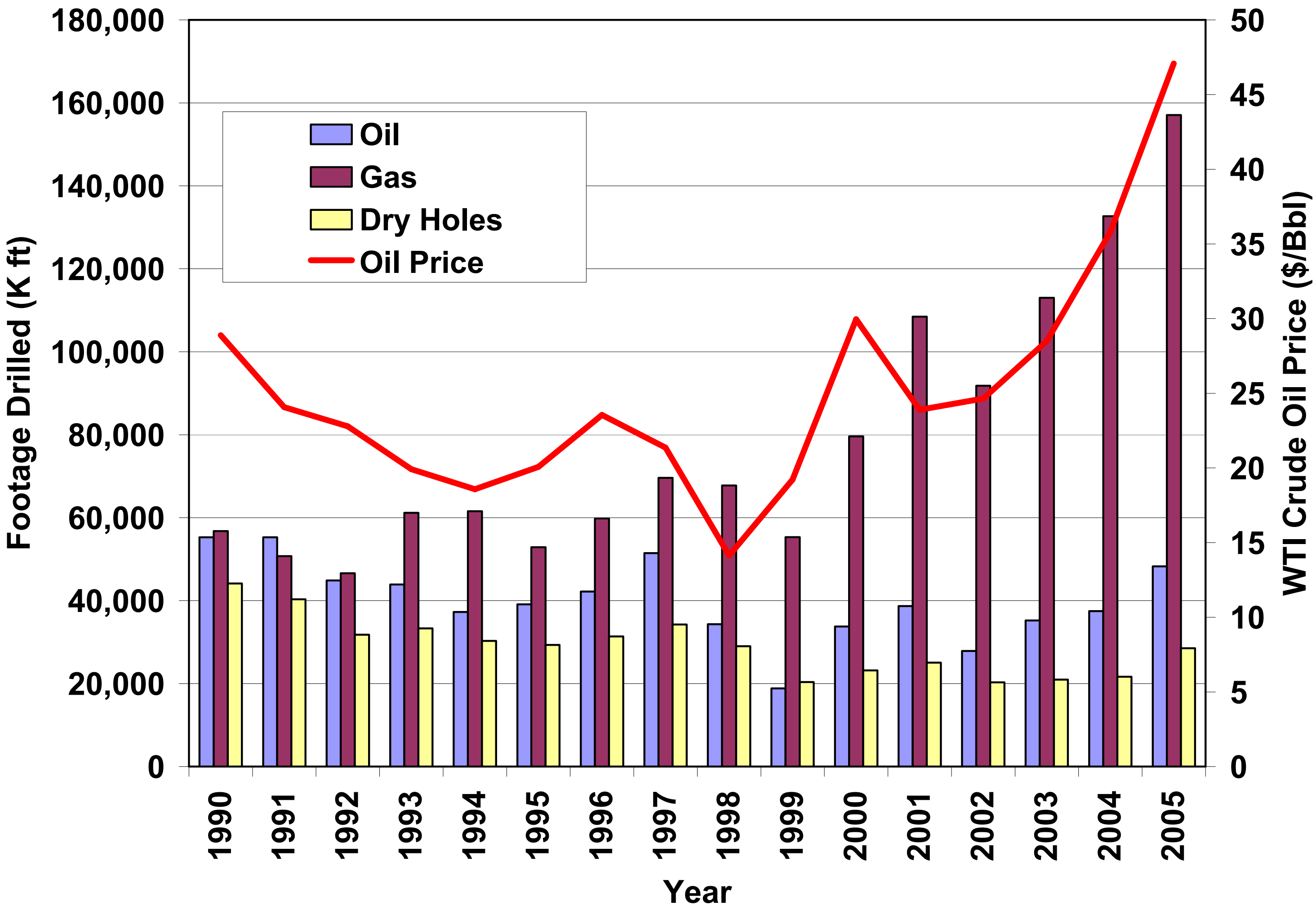
So is Footage Drilled



Source: 2005 Annual Energy Review (EIA)

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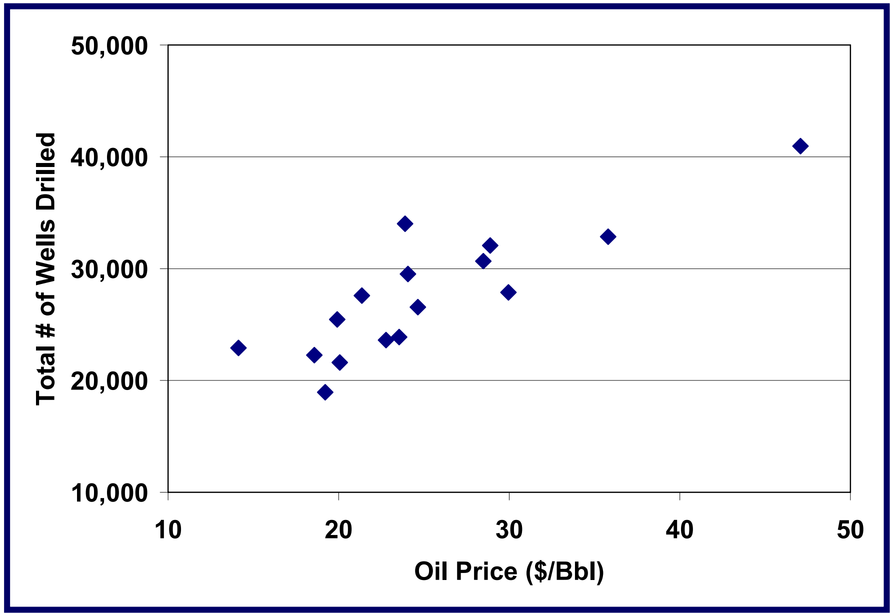
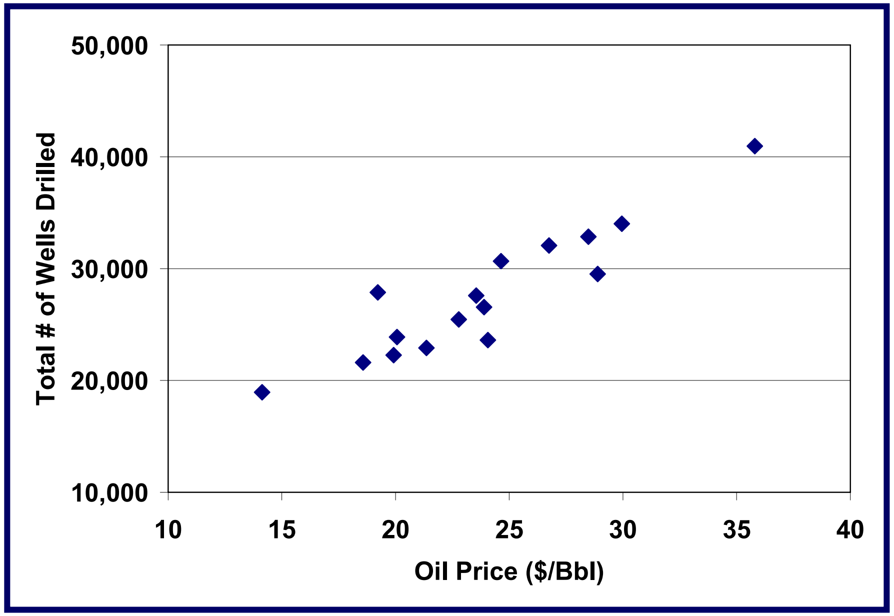
Relationship between Oil Price and Drilling

Without Lag



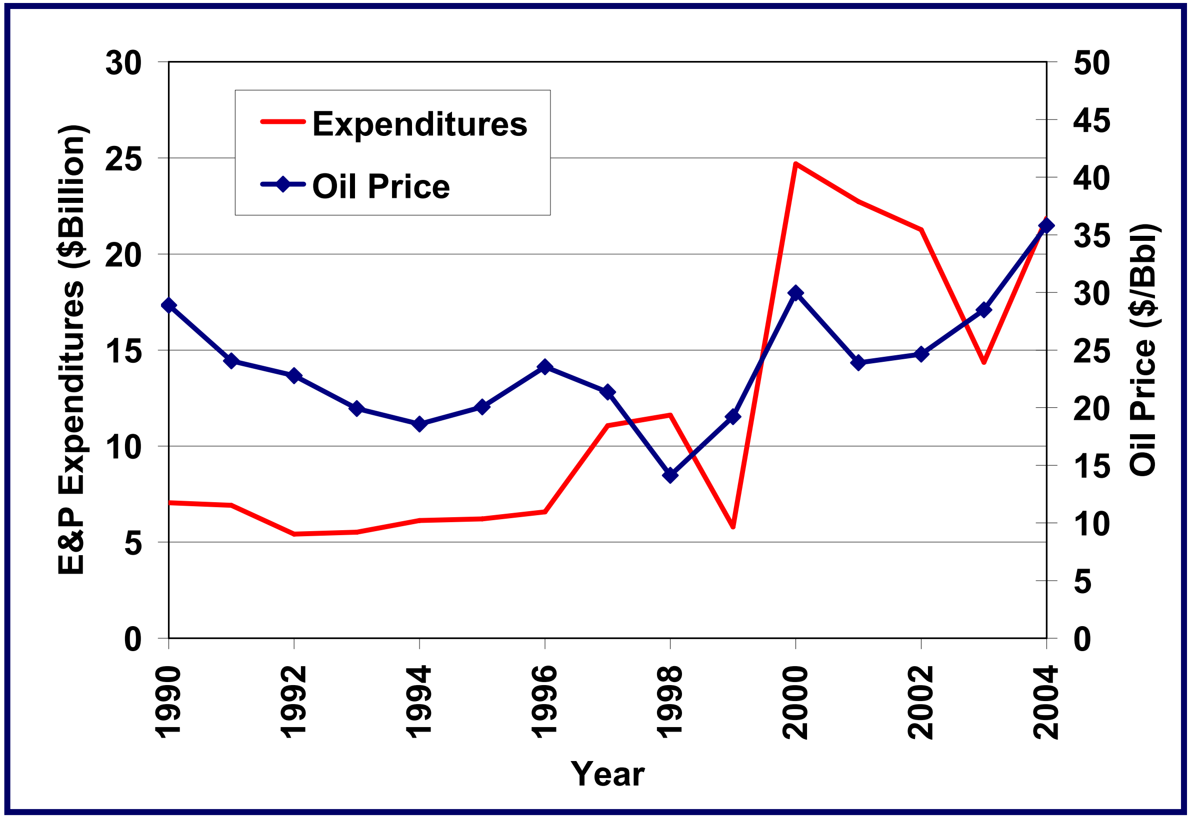
With 1 year Lag



Source: 2005 Annual Energy Review (EIA)

Capital Expenditures - Onshore

• Major U.S. Companies' Expenditures for Onshore Crude Oil and Natural Gas Exploration and Development



Source: 2005 Annual Energy Review (EIA), with prices adjusted to 2004 Dollars

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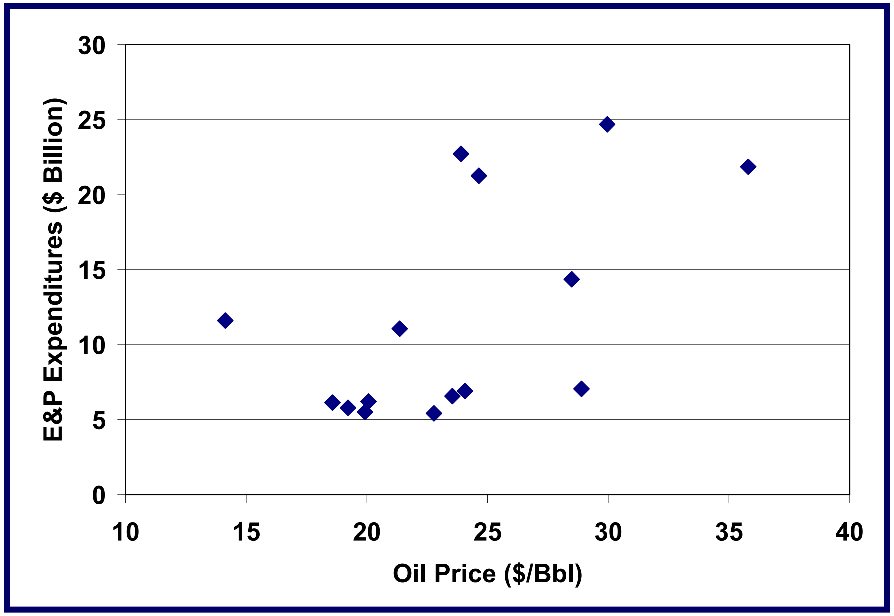
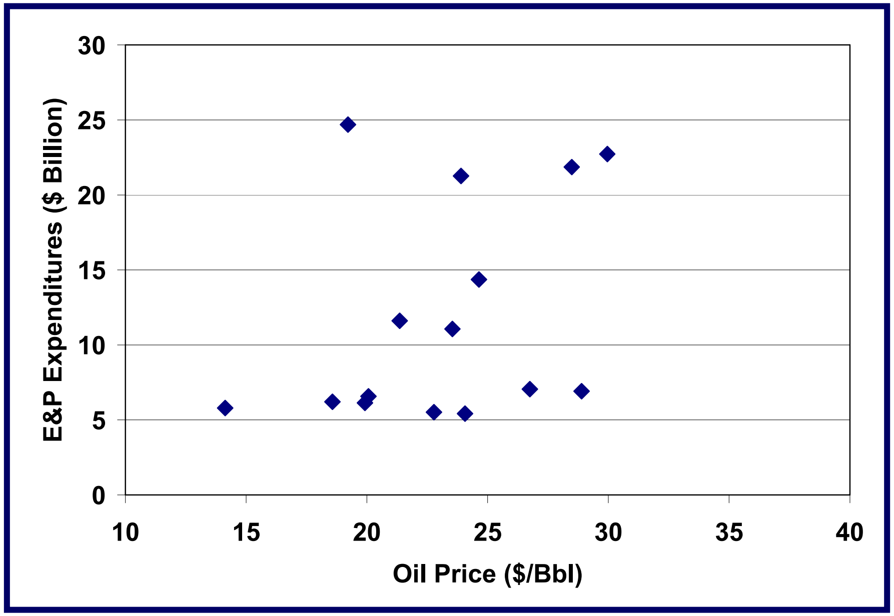
Relationship between Oil Price and Capital Expenditures

Without Lag



With 1 year Lag



Source: 2005 Annual Energy review (EIA)

Major U.S. Companies Expenditures for Onshore Oil and Natural Gas Exploration & Development

Expenditures adjusted to 2004 Dollars

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CO_2 Constraints

- Natural Sources
- Industrial Sources
  - Existing – Connected to Infrastructure
  - Existing – Not Connected to Infrastructure
  - New Sources – CTL, Power Plants, Oil Shale Retort, etc …

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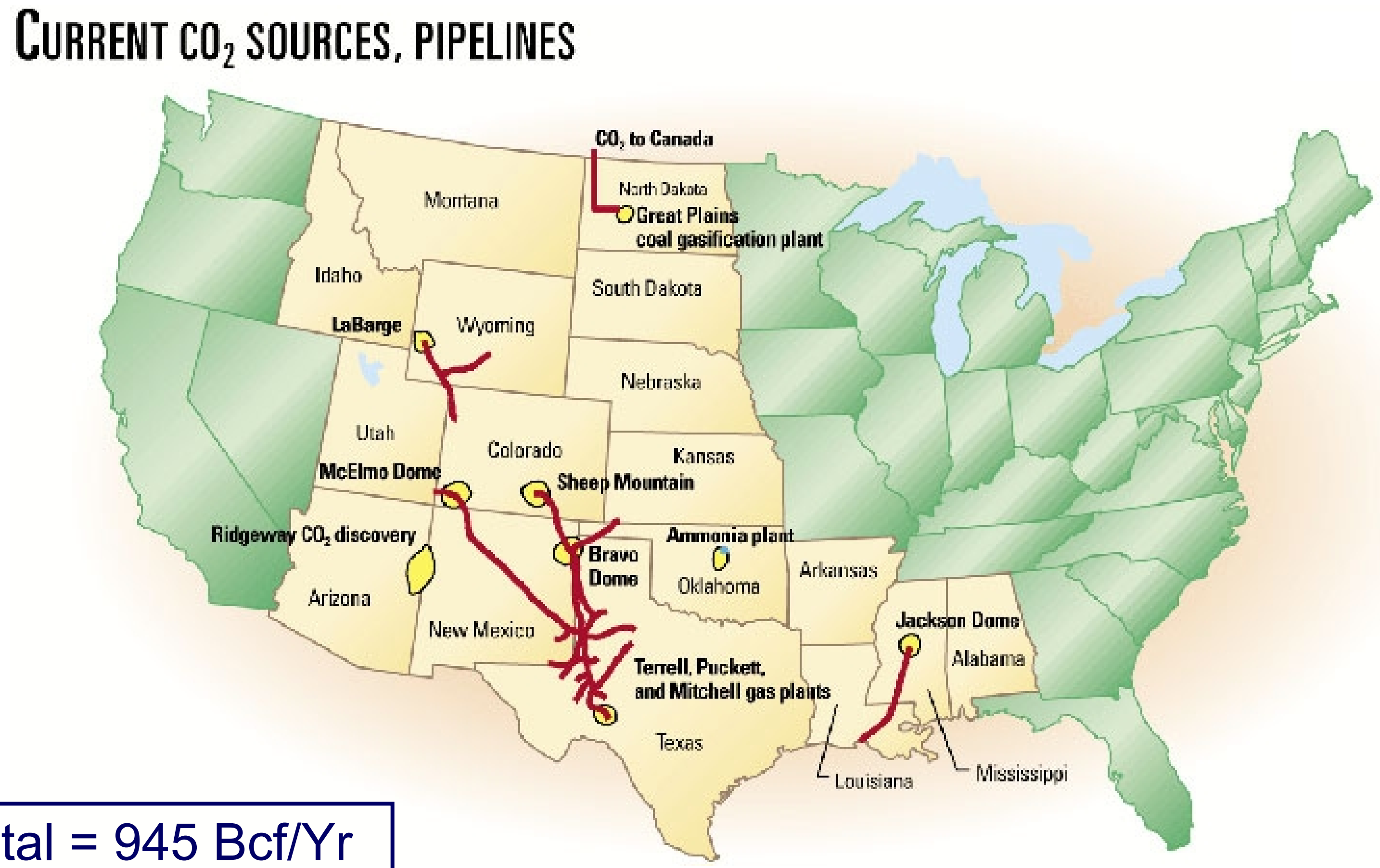
Natural CO_2 Sources – Existing Infrastructure



Total = 945 Bcf/Yr

Source: Oil & Gas Journal

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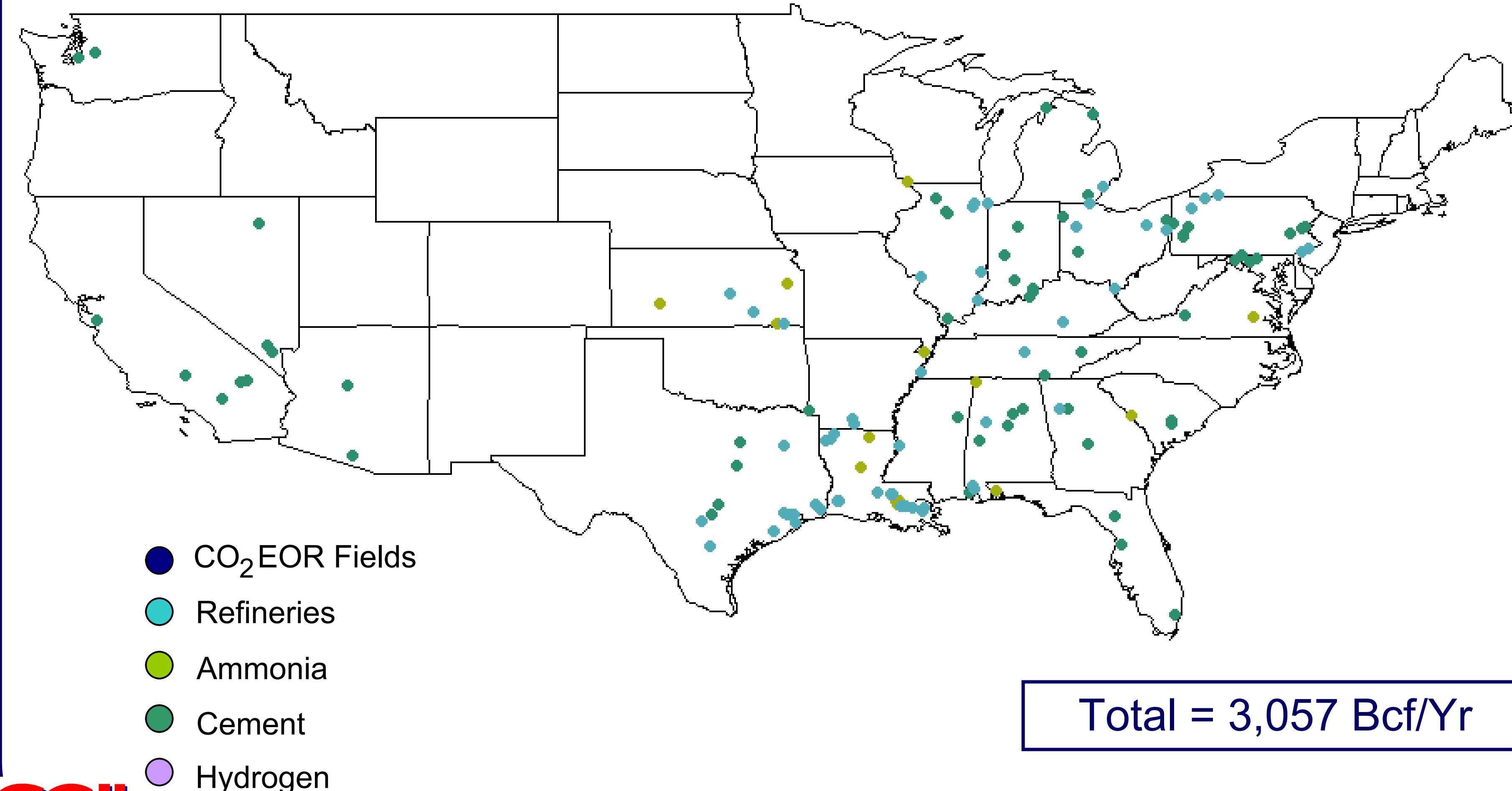
Industrial CO_2 Sources – Fossil Fuel Plants

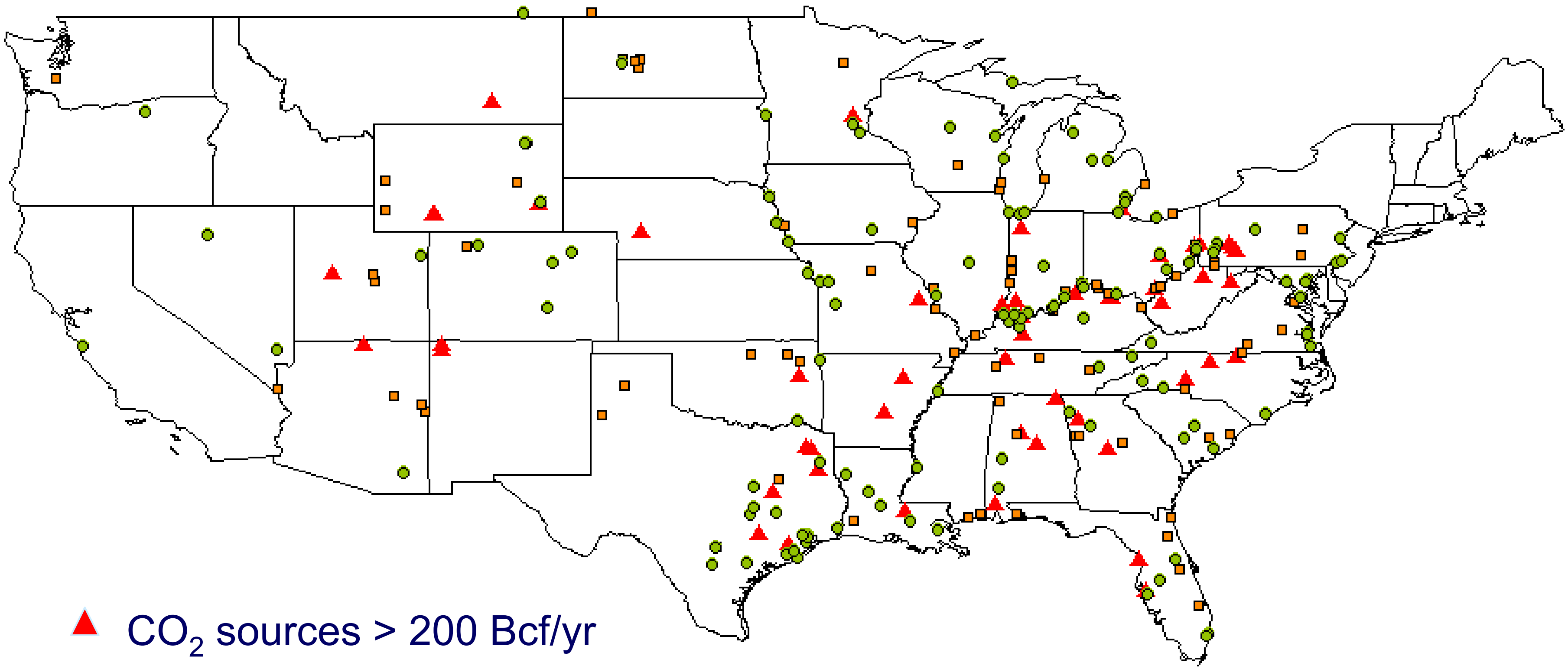


Total = 3,057 Bcf/Yr

Source: INTEK

INTEK

Industrial CO_2 Sources – Other Plant Types



▲ CO_2 sources > 200 Bcf/yr

■ CO_2 sources > 100 Bcf/yr

● CO_2 sources > 50 Bcf/yr

Total = 21,821 Bcf/Yr

Source: INTEK

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Resource Access

- Play Specific
  - % of Resource on Federal Lands Accessible for Development
  - % of Resource on Federal Lands Not Accessible for Development
- Other Limiting Factors to be Determined

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Onshore Lower 48 Oil & Gas Supply Submodule

Model Applications

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Model Applications

- Future Production Profile
  - Business As Usual (BAU) Case
  - Advanced Technology Scenario
- Different Resource Access Scenarios
- Development of New Resources

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Model Applications

- Effect on Onshore Lower 48 Oil & Gas Production as a result of:
  - New Tax Incentives
  - Environmental Regulation
  - Proposed Legislation Changes
  - Proposed Tax Law Changes
  - Other Policy Analyses

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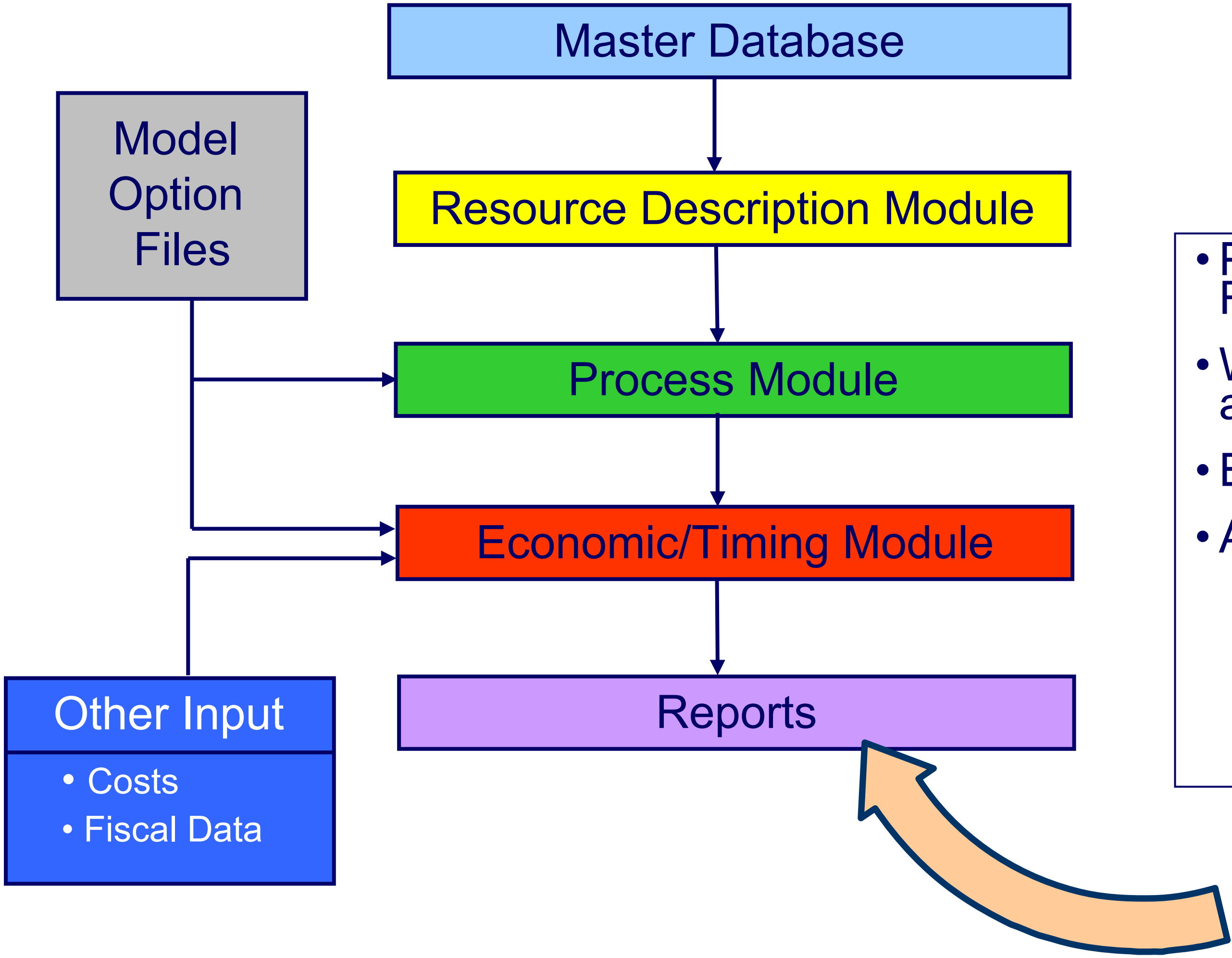
Overall System Logic Flow



- Production and Reserves
- Wells – Active and Drilled
- Economic results
- Aggregated at:
  - Play
  - Basin
  - State/Regional
  - National

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Reports Module: Role in OLOGSS

- The Reports Module transfers the results from the OLOGSS to:
  - Other OGSM modules
  - NEMS
  - User

- Allows iteration of supply and demand

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Reports Module: Summary of Outputs

- Production Price Supply Curves
  - Oil
  - Natural Gas
    - Non-associated
    - Associated-dissolved
  - Reported by
    - Resource Access Category
    - Play
    - State
    - Region
    - National

Reports Module: Summary of Outputs (Contd…)

- Drilling statistics disaggregated by
  - Exploratory
  - Developmental
  - For oil and gas
  - Reported by
    - Play
    - State
    - Region
    - National

Reports Module: Summary of Outputs (Contd…)

- Economic Reports
- Resource Development Constraints Utilized
- Detailed reports for analysis of
  - Technology
  - Changes in taxes
  - Access issues
- Other reports to be determined

OPEN DISCUSSION

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