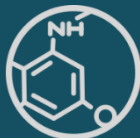




ADVANCED PROCESS  
MODELLING FORUM 2017  
London 25–26 April

# New developments for integrated asset optimisation

Javier Rodriguez – Senior Consultant



# Integrated asset optimisation (to be completed)



- Summary of benefits (from Malcolm)
- Summary of challenges (from Malcolm)
- Why gPROMS is well positioned (from James)

# Case study – Production network and facilities

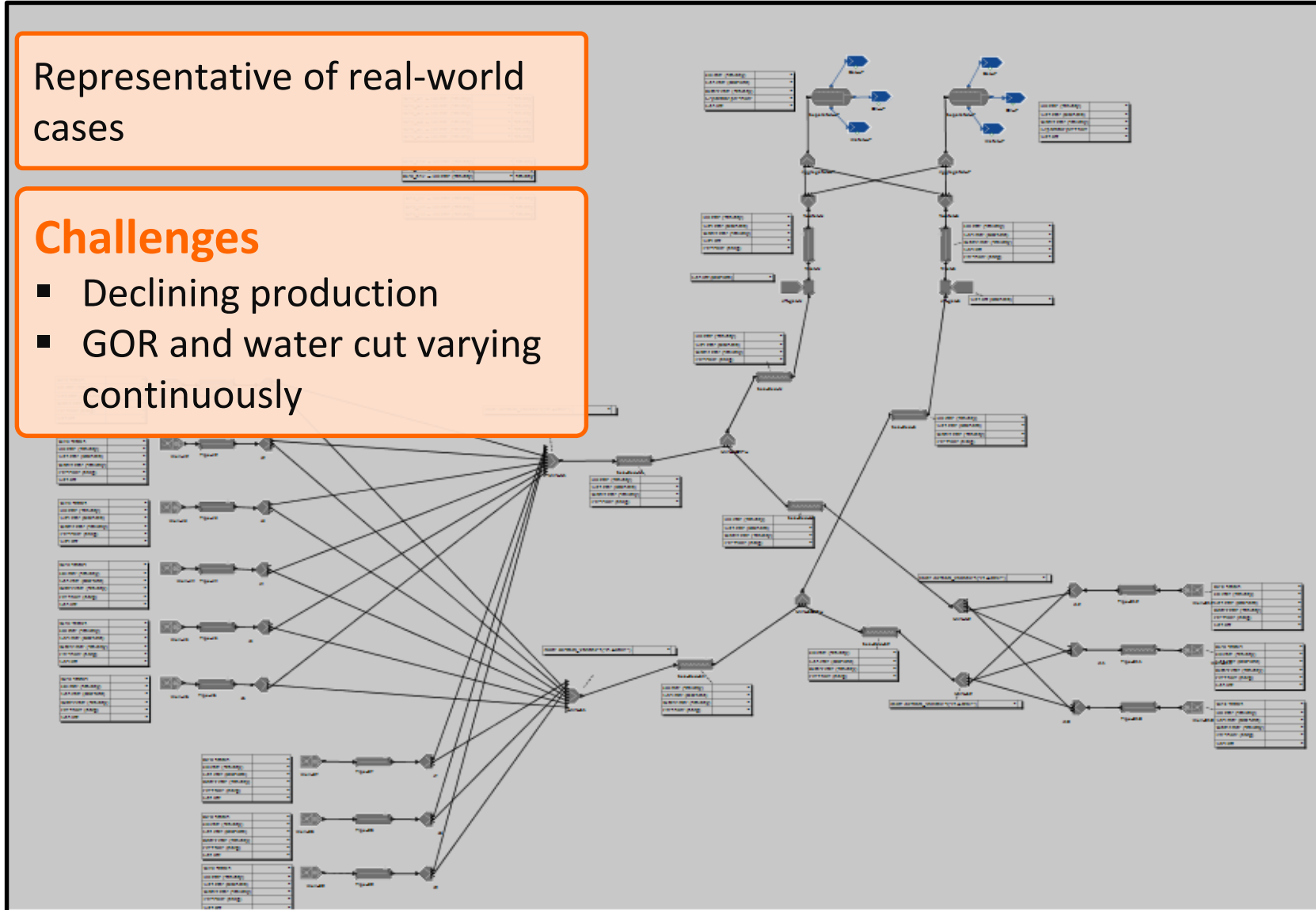


New developments for integrated asset  
optimisation

Representative of real-world cases

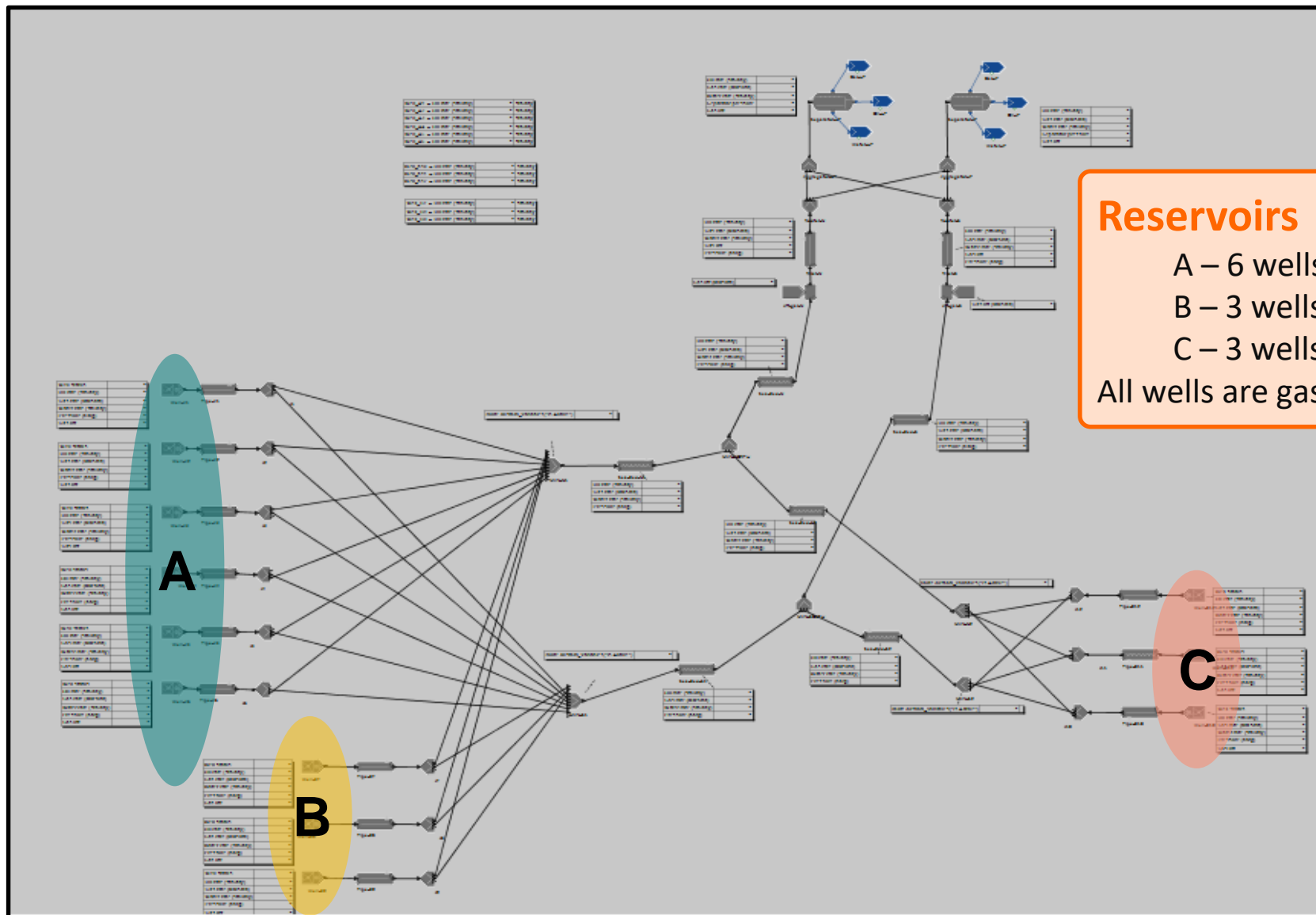
### Challenges

- Declining production
- GOR and water cut varying continuously



# Case study – Production network and facilities

## Asset overview – production network



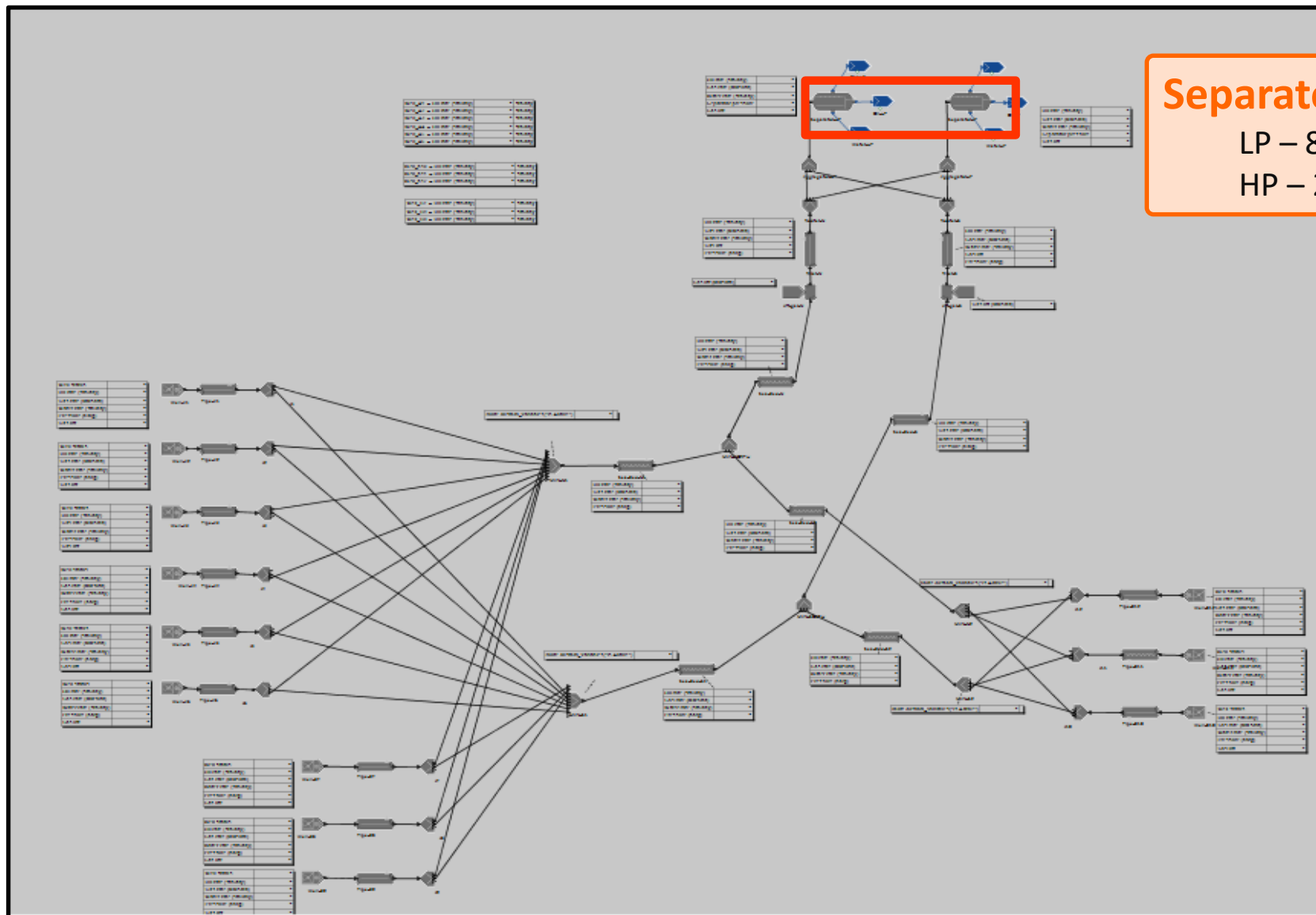
### Reservoirs

A – 6 wells

B – 3 wells

C – 3 wells

All wells are gas-lifted



## Separators

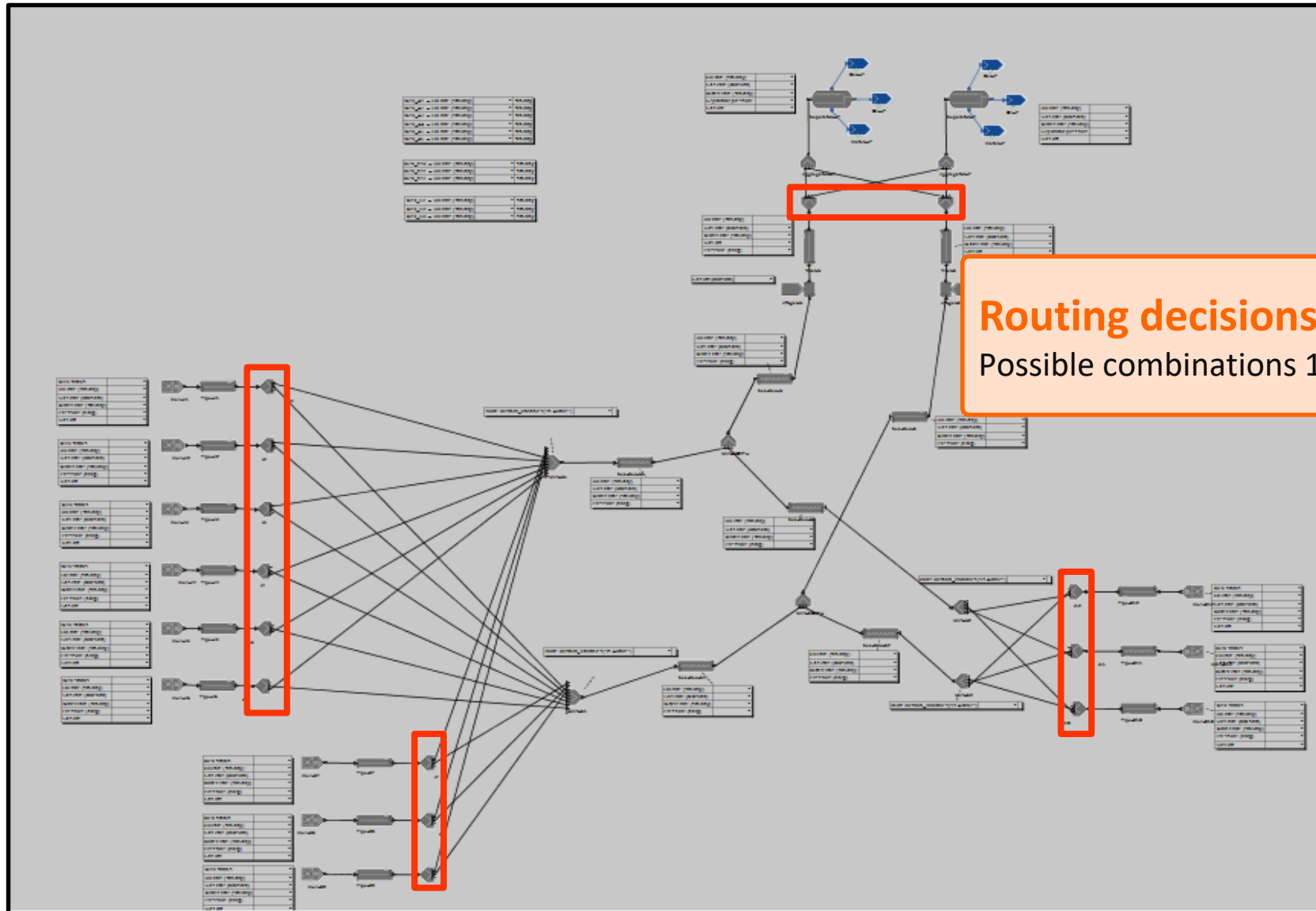
LP – 8 barg

HP – 20 barg



# Case study

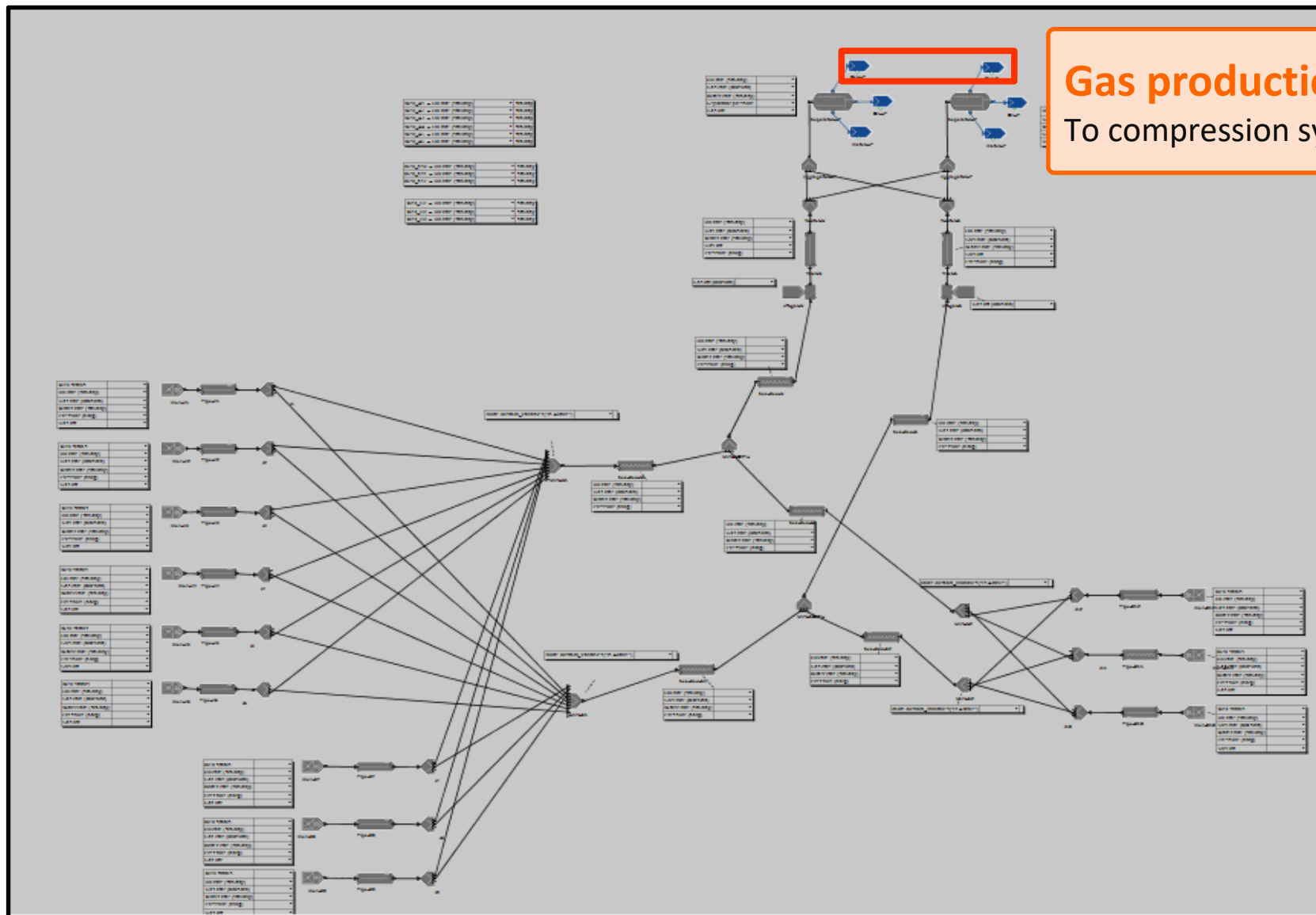
## Asset overview – production network



**Routing decisions - 14**  
Possible combinations 16,384

# Case study

## Asset overview – production network

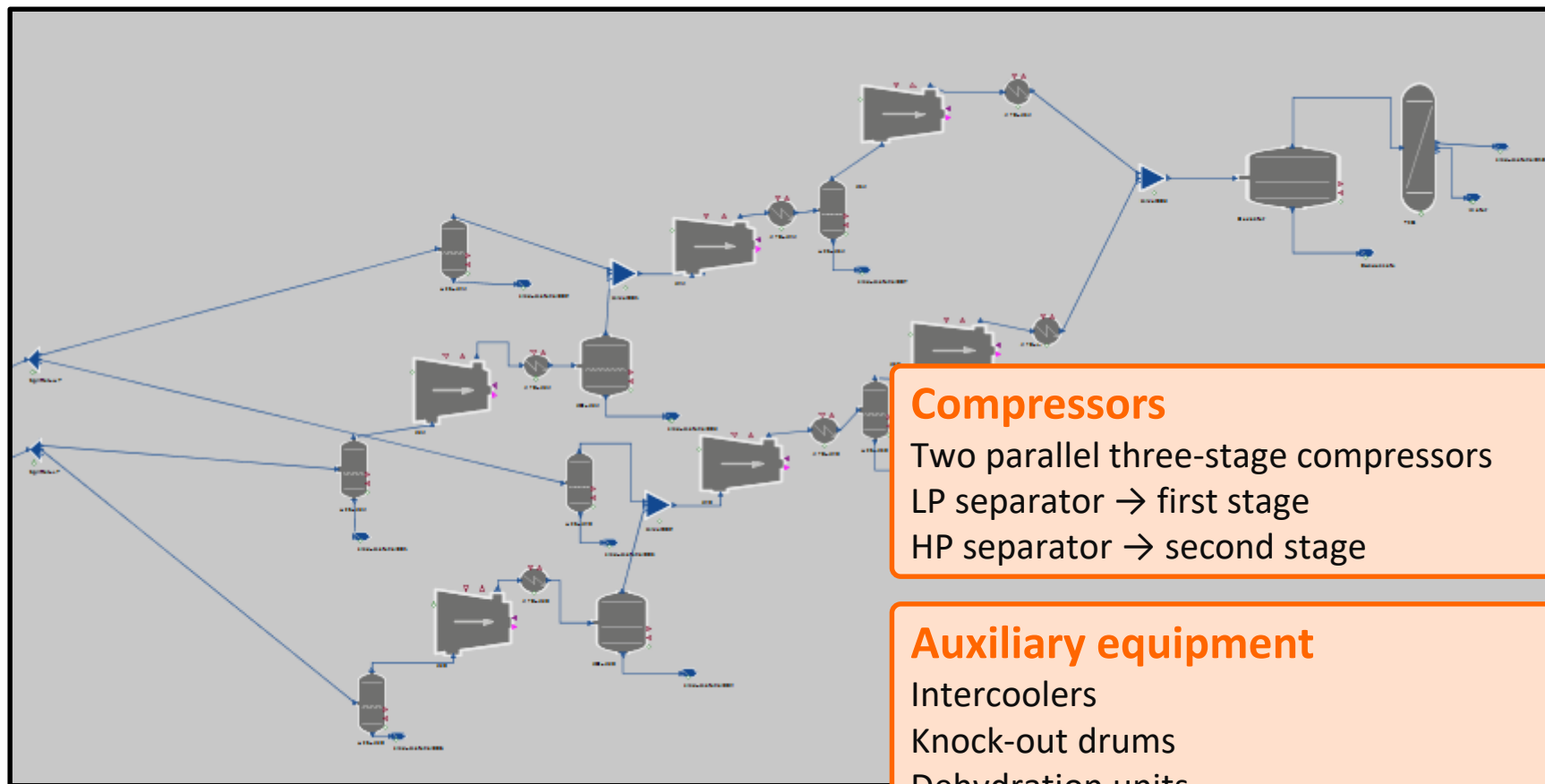


**Gas production**  
To compression system



# Case study

## Asset overview – compression system



### Compressors

Two parallel three-stage compressors  
LP separator → first stage  
HP separator → second stage

### Auxiliary equipment

Intercoolers  
Knock-out drums  
Dehydration units

### Delivery pressure

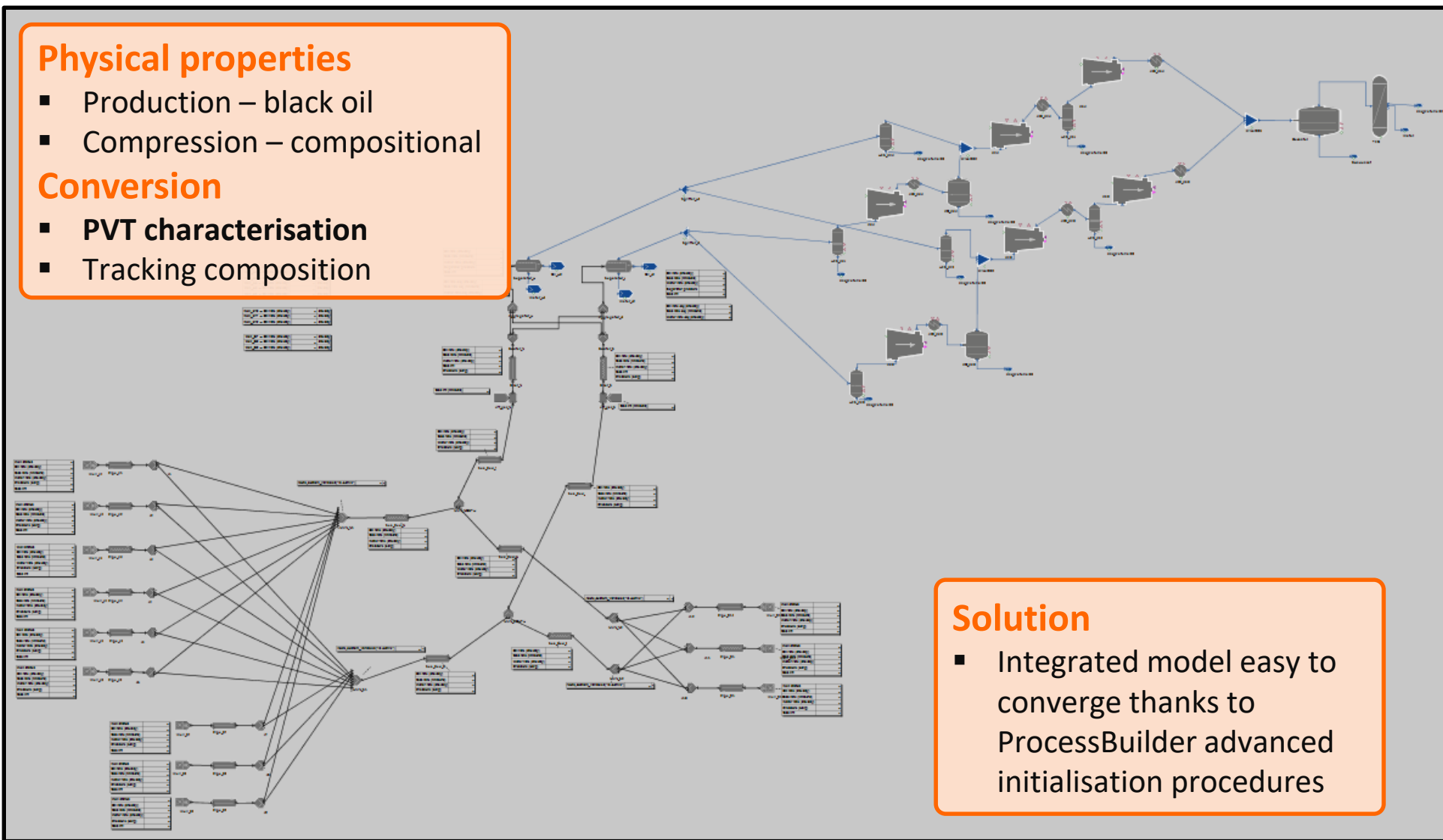
Min 80 barg – transmission network

## Physical properties

- Production – black oil
- Compression – compositional

## Conversion

- PVT characterisation
- Tracking composition



## Solution

- Integrated model easy to converge thanks to ProcessBuilder advanced initialisation procedures

- Simulation of current operation
- Production network optimisation
  - Gas lift injection rate
  - Choke pressure drop
  - Separator pressure
- Integrated asset optimisation
  - Gas lift injection rate
  - Choke pressure drop
  - Separator pressure
  - Compressor speed
  - Discrete: Field configuration

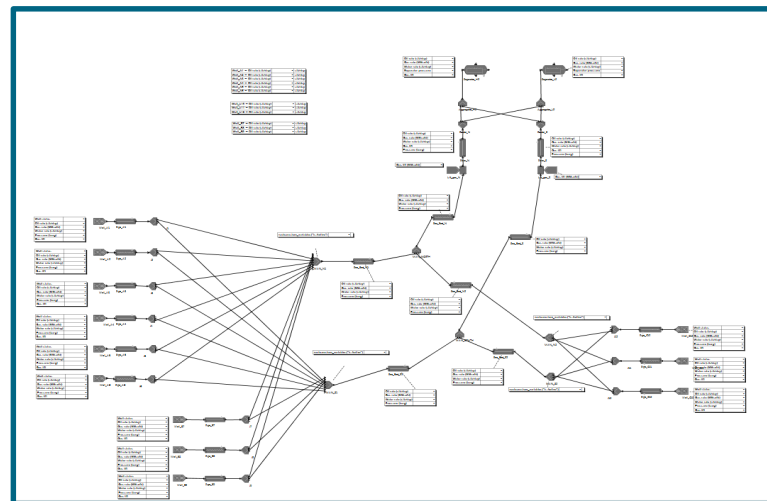
- Simulation of current operation
- Production network optimisation
  - Gas lift injection rate
  - Choke pressure drop
  - Separator pressure
- Integrated asset optimisation
  - Gas lift injection rate
  - Choke pressure drop
  - Separator pressure
  - Compressor speed
  - Discrete: Field configuration

## Challenges

- Declining production
- GOR and water cut varying continuously

Oil production  
[STB/day]

23,073



## Control variables

Well	A1	A2	A3	A4	A5	A6	B7	B8	B9	C10	C11	C12
Choke [bar]	13.3	28.7	17.3	0	0	0	4.6	3.7	9.7	0	0	0
Gas lift [MMscf/day]	0	0	0	0	0	0	0.7	0.5	0	0	0	0

Margin constraints						
Well	DHGP [bar]	Well	DHGP [bar]	Separator	Gas rate [MMscf/day]	Water rate [STB/day]
A1	2.93	B7	7.65	HP max gas rate=12 max water rate=10k	2.91	1,761
A2	30.83	B8	4.85	LP max gas rate=12 max water rate=7.5k	2.98	1,119
A3	1.95	B9	15.20	Total max gas rate=20	1.89	-
A4	27.01	C10	11.63			
A5	48.66	C11	5.22			
A6	10.35	C12	8.31			

- Margin constraints – satisfied as expected
- Field in production decline results in spare gas handling capacity
  - Separators capacity originally sized based on compression design and operating experience
- Opportunity for optimisation



	Stage 1		Stage 2		Stage 3	
	Suction	Discharge	Suction	Discharge	Suction	Discharge
T [°C]	10.03	96.73	59.85	95.43	59.85	113.50
P [bar]	8	20	20	40.58	40.58	80
Compression ratio	2.50		2.03		1.97	
Current/design speed [Hz]	186.30/195					

### Compressor system operating below capacity

- Desired delivery pressure (80 barg) is achieved with compressor speed ~95% of design speed (195 Hz)

- Spare capacity in the separators and compression system
- Opportunity for production network optimisation

- Simulation of current operation
- Production network optimisation
  - Gas lift injection rate
  - Choke pressure drop
  - Separator pressure
- Integrated asset optimisation
  - Gas lift injection rate
  - Choke pressure drop
  - Separator pressure
  - Compressor speed
  - Discrete: Field configuration

## Scope

Production network

## Objective

Maximise oil production

## Control variables

Continuous

- Well choke valves
- Gas lift rates
- **Separator pressures**
  - Normally fixed in production optimisation
  - General assumption is that reducing the pressure increases production

## Constraints

- Well drawdown (DHGP)
- Total gas lift
- Water handling
- Gas handling

	Current operation	Production optimisation
Control variables	-	Gas lift Wellhead choke Separator pressures
Production [STB/day]	23,073	25,752
Increase [%]	-	12%
Time [min]	-	1

- Production optimisation can find a solution that improves on the current operation by 12%
- Running times ~ 1 minute

# Case study

## Production network optimisation



Control variables				
Well	Choke [bar]		Gas lift [MMscf/day]	
	Current operation	Production optimisation	Current operation	Production optimisation
A1	13.36	5.91	0	0
A2	28.74	10.95	0	0
A3	17.33	10.29	0	0
A4	0	0	0	0.08
A5	0	0	0	0.09
A6	0	0	0	0.04
B7	4.69	0	0.74	0.24
B8	3.78	0	0.50	0.16
B9	9.76	1.61	0	0
C10	0	<div>Separator pressures reduced To the minimum allowable value for each separator</div>		
C11	0			
C12	0			
Separator Pressure [barg]		Current operation	Production optimisation	
HP		20	16	
LP		8	7	

# Case study

## Production network optimisation



Control variables				
Well	Choke [bar]		Gas lift [MMscf/day]	
	Current operation	Production optimisation	Current operation	Production optimisation
A1	13.36	5.91	Well choke valves are open	
A2	28.74	10.95		
A3	17.33	10.29		
A4	0	0	0	0.08
A5	0	0	0	0.09
A6	0	0	0	0.04
B7	4.69	0	0.74	0.24
B8	3.78	0	0.50	0.16
B9	9.76	1.61	0	0
C10	0	0	0	0.20
C11	0	0	0	0.11
C12	0	0	0	0.14
Separator Pressure [barg]		Current operation	Production optimisation	
HP		20	16	
LP		8	7	



# Case study

## Production network optimisation



Control variables				
Well	Choke [bar]		Gas lift [MMscf/day]	
	Current operation	Production optimisation	Current operation	Production optimisation
A1	13.36	5.91	0	0
A2	28.74	10.95	0	0
A3	17.33	10.29	0	0
A4	0	Gas lift redistributed	0	0.08
A5	0		0	0.09
A6	0	0	0	0.04
B7	4.69	0	0.74	0.24
B8	3.78	0	0.50	0.16
B9	9.76	1.61	0	0
C10	0	0	0	0.20
C11	0	0	0	0.11
C12	0	0	0	0.14
Separator Pressure [barg]		Current operation	Production optimisation	
HP		20	16	
LP		8	7	

### Margin constraints

DHGP [bar]		
Well	Current operation	Production opt.
A1	2.93	0
A2	30.83	6.26
A3	1.95	0
A4	27.01	20.79
A5	48.66	34.60
A6	10.35	23.72
B7	7.65	3.49
B8	4.85	0
B9	15.20	0
C10	11.63	0.24
C11	5.22	0
C12	8.31	0

Water rate [STB/day]		
Separator	Current operation	Production opt.
HP max=10k	1,761	126
LP max=7.5k	1,119	1,067

Gas rate [MMscf/day]		
Separator	Current operation	Production opt.
HP max=12	2.91	3.02
LP max=12	2.98	0.98
Total max=20	1.89	0

- Constraints satisfied – closer to being active
- Total gas rate is the limiting constraint
- Production can be greatly increased by reducing separators pressure
- However, is this a feasible solution?

## Simulation of compression system

Inlet gas conditions given by the solution of production network optimisation

Compression system operation						
	Stage 1		Stage 2		Stage 3	
	Suction	Discharge	Suction	Discharge	Suction	Discharge
T [K]	10.05	122.87	59.85	118.42	59.85	125.34
P [barg]	7	16	16	38.55	38.55	80
Compression ratio	2.28		2.34		2.07	
Current/design speed [Hz]			227/195			

Maximum compressor speed set to 110% of design = 214.5Hz

Compression system cannot deal with the increase in volumetric flow

The speed required to achieve the desired delivery pressure is over the maximum

**Solution found by optimising the production system is not valid**

Can only be identified and addressed with an integrated model

- Simulation of current operation
- Production network optimisation
  - Gas lift injection rate
  - Choke pressure drop
  - Separator pressure
- Integrated asset optimisation
  - Gas lift injection rate
  - Choke pressure drop
  - Separator pressure
  - Compressor speed
  - Discrete: Field configuration

# Case study

## Integrated asset optimisation



### Objective

Maximise oil production

### Production network

#### Control variables

- Well choke valves
- Gas lift rates
- **Separator pressure**

#### Constraints

- Well drawdown
- Total gas lift
- Water handling
- ~~Gas handling~~

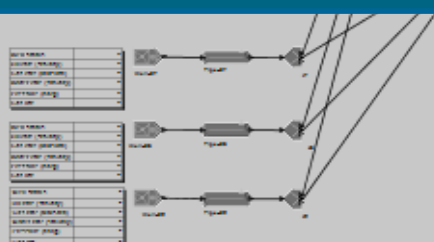
### Compression system

#### Control variables

- Compressor speed

#### Constraints

- Surge & choke margin  
Ensure high efficiency
- Transmission network delivery  
pressure (80 barg)



# Case study

## Integrated asset optimisation



	Current operation	Production opt.	Integrated opt.
Control variables	-	Gas lift Wellhead choke Separator pressures	Gas lift Wellhead choke Separator pressure <b>Compressor speed</b>
Production [STB/day]	<b>23,073</b>	25,752	<b>26,015</b>
Increase [%]	-	12%	<b>13%</b>
Time [min]	-	1	<b>2</b>

- Integrated optimisation can find a solution that improves on the current operation by 13%, whilst still ensuring that the installed compressor system can handle the gas flow
- Running times ~ 2 minutes



# Case study

## Integrated asset optimisation



Control variables				
Well	Choke [bar]		Gas lift [MMscf/day]	
	Current operation	Integrated optimisation	Current operation	Integrated optimisation
A1	13.36	3.29	0	0
A2	28.74	18.32	0	0.38
A3	17.33	7.04	0	0.0
A4	0	0.08	0	0.28
A5	0	0	0	0.47
A6	0	0	0	0.24
B7	4.69	0.19	0.74	1.22
B8	3.78	0.04	0.50	0.70
B9	9.76			
C10	0			
C11	0			
C12	0			
Separator Pressure [barg]		Current operation	Integrated optimisation	
HP		20	19.1	
LP		8	7.2	

Separator pressures reduced  
Not by as much as in production optimisation, to ensure that the compressor system can handle them

# Case study

## Integrated asset optimisation



Control variables				
Well	Choke [bar]		Gas lift [MMscf/day]	
	Current operation	Integrated optimisation	Current operation	Integrated optimisation
A1	13.36	3.29	Well choke valves are open	
A2	28.74	18.32		
A3	17.33	7.04		
A4	0	0.08	0	0.28
A5	0	0	0	0.47
A6	0	0	0	0.24
B7	4.69	0.19	0.74	1.22
B8	3.78	0.04	0.50	0.70
B9	9.76	0.53	0	0.48
C10	0	0.07	0	0.33
C11	0	0	0	0.18
C12	0	0	0	0.22
Separator Pressure [barg]		Current operation	Integrated optimisation	
HP		20	19.1	
LP		8	7.2	

# Case study

## Integrated asset optimisation



Control variables				
Well	Choke [bar]		Gas lift [MMscf/day]	
	Current operation	Integrated optimisation	Current operation	Integrated optimisation
A1	13.36	3.29	0	0
A2	28.74	18.32	0	0.38
A3	17.33	7.04	0	0.0
A4	0	0	0	0.28
A5	0	0	0	0.47
A6	0	0	0	0.24
B7	4.69	0.19	0.74	1.22
B8	3.78	0.04	0.50	0.70
B9	9.76	0.53	0	0.48
C10	0	0.07	0	0.33
C11	0	0	0	0.18
C12	0	0	0	0.22
Separator Pressure [barg]		Current operation	Integrated optimisation	
HP		20	19.1	
LP		8	7.2	

Gas lift redistributed

# Case study

## Integrated asset optimisation



Control variables				
Well	Choke [bar]		Gas lift [MMscf/day]	
	Current operation	Integrated optimisation	Current operation	Integrated optimisation
A1	13.36	3.29	0	0
A2	28.74	18.32	0	0.38
A3	17.33	7.04	0	0.0
A4	0	0.08	0	0.28
A5	0	0	0	0.47
A6	0	0	0	0.24
B7	4.69	0.19	0.74	1.22
B8	3.78	0.04	0.50	0.70
B9	9.76	0.53	0	0.48
C10	0	0.07	0	0.33
C11	0	0	0	0.18
C12	0	0	0	0.22

Compressor speeds increased  
Not to maximum value

Compressor	Current operation	Integrated optimisation
Current/design speed [Hz]	186.3/195	199.77/195

# Case study

## Integrated asset optimisation



### Margin constraints

DHGP [bar]		
Well	Current operation	Integrated opt.

Water rate [STB/day]		
Separator	Current operation	Integrated opt.

LP separator water rate is now the limiting constraint

➤ compressor not operated at full capacity

A5	48.66	0
A6	10.35	0

HP max=10k	1,761	854
LP max=7.5k	1,119	0

### Gas rate [MMscf/day]

Separator	Current operation	Integrated opt.
HP max=12	2.91	0.91
LP max=12	2.98	-0.54
Total max=20	1.89	-3.62

*Original* gas rate constraints violated now  
At the solution separator pressures, the compressor can handle more gas than initially thought

It is possible to increase production by optimising separator conditions, but the compression system needs to be taken into account

- Simulation of current operation
- Production network optimisation
  - Gas lift injection rate
  - Choke pressure drop
  - Separator pressure
- Integrated asset optimisation
  - Gas lift injection rate
  - Choke pressure drop
  - Separator pressure
  - Compressor speed
  - Discrete: Field configuration



**Objective**

Maximise oil production

**Production network****Control variables**

Continuous

- Well choke valves
- Gas lift rates
- **Separator pressure**

Discrete

- **Well routings**
- **Riser routings**
- **Well status**

**Constraints**

- Well drawdown
- Total gas lift
- Water handling
- Gas handling

**Compression system****Control variables**

- Compressor speed

**Constraints**

- Surge & choke margin constraints  
Ensure high efficiency
- Transmission network delivery pressure

	Current operation	Integrated opt. continuous	Integrated opt. discrete
Control variables	-	Gas lift Wellhead choke Separator pressure Compressor speed	Gas lift Wellhead choke Separator pressure Compressor speed <b>Field routing</b>
Production [STB/day]	23,073	26,015	<b>27,975</b>
Increase [%]	-	13%	<b>21%</b>
Time [min]	-	2	<b>15</b>

- Integrated optimisation **including field configuration** can find a solution that improves on the current operation by 21% whilst still ensuring that the installed compressor system can handle the gas flow
- Running times ~15 min

Control variables				
Well	Choke [bar]		Gas lift [MMscf/day]	
	Current operation	Integrated optimisation	Current operation	Integrated optimisation
A1	13.36	0	0	0
A2	28.74	0	0	0.05
A3	17.33	0	0	0
A4	0	0	0	0.08
A5	0	0	0	0.40
A6	0	0	0	0.77
B7	4.69	0	0.74	1.54
B8	3.78	0	0.50	1.74
B9	9.76	0	0	0
C10	0			
C11	0			
C12	0			
Separator Pressure [barg]		Current operation	Integrated optimisation	
HP		20	19.10	
LP		8	8.30	

HP separator pressure reduced  
LP separator pressure increased

Control variables				
Well	Choke [bar]		Gas lift [MMscf/day]	
	Current operation	Integrated optimisation	Current operation	Integrated optimisation
A1	13.36	0	0	0
A2	28.74	0	0	0.05
A3	17.33	0	0	0
A4	0	0	0	0.08
A5	0	0	0	0.40
A6	0	0	0	0.77
B7	4.69	0	0.74	1.54
B8	3.78	0	0.50	1.74
B9	9.76	0	0	0
C10	0	Compressor speeds increased to the maximum 110% of design speed (195Hz)		
C11	0			
C12	0			
Compressor		Current operation		Integrated optimisation
Speed [Hz]		186.3		214.5

This is now the limiting constraint!

Optimising field configuration allows to run the compression system at full capacity

Control variables				
Well	Choke [bar]		Gas lift [MMscf/day]	
	Current operation	Integrated optimisation	Current operation	Integrated optimisation
A1	13.36	0	0	0
A2	28.74	0	0	0.05
A3	17.33	0	0	0.08
A4	0	0	0	0.40
A5	0	0	0	0.77
A6	0	0	0	1.54
B7	4.69	0	0.74	1.74
B8	3.78	0	0.50	0
B9	9.76	0	0	0.91
C10	0	0	0	0.89
C11	0	0	0	0.90
C12	0	0	0	
Separator Pressure [barg]		Current operation	Integrated optimisation	
HP		20	19.10	
LP		8	8.30	

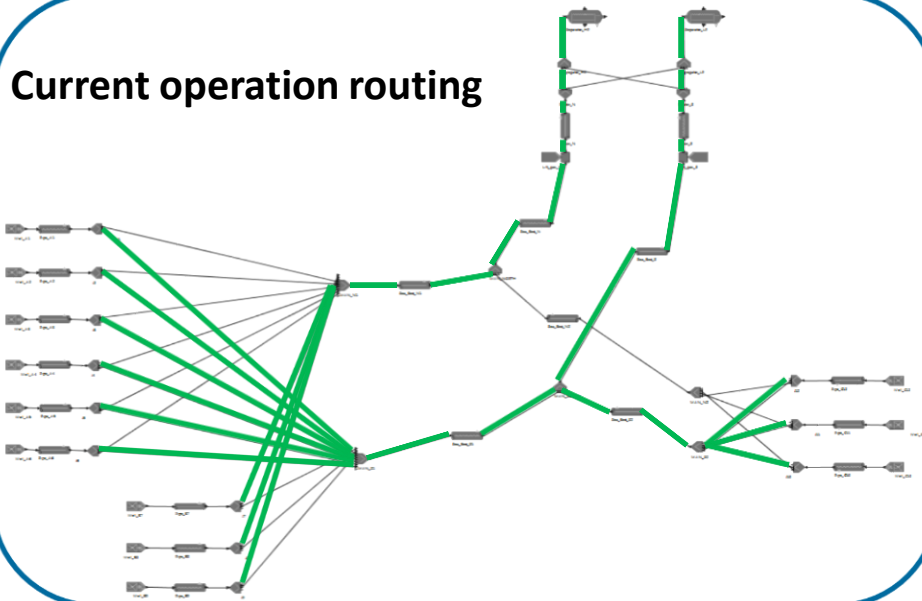
Well choke valves fully open

Control variables				
Well	Choke [bar]		Gas lift [MMscf/day]	
	Current operation	Integrated optimisation	Current operation	Integrated optimisation
A1	13.36	0	0	0
A2	28.74	0	0	0.05
A3	17.33	0	0	0
A4	0	0	0	0.08
A5	0	0	0	0.40
A6	0	0	0	0.77
B7	4.69	0	0.74	1.54
B8	3.78	0	0.50	1.74
B9	9.76	0	0	0
C10	0	0	0	0.91
C11	0	0	0	0.89
C12	0	0	0	0.90
Separator Pressure [barg]		Current operation	Integrated optimisation	
HP		20	19.10	
LP		8	8.30	

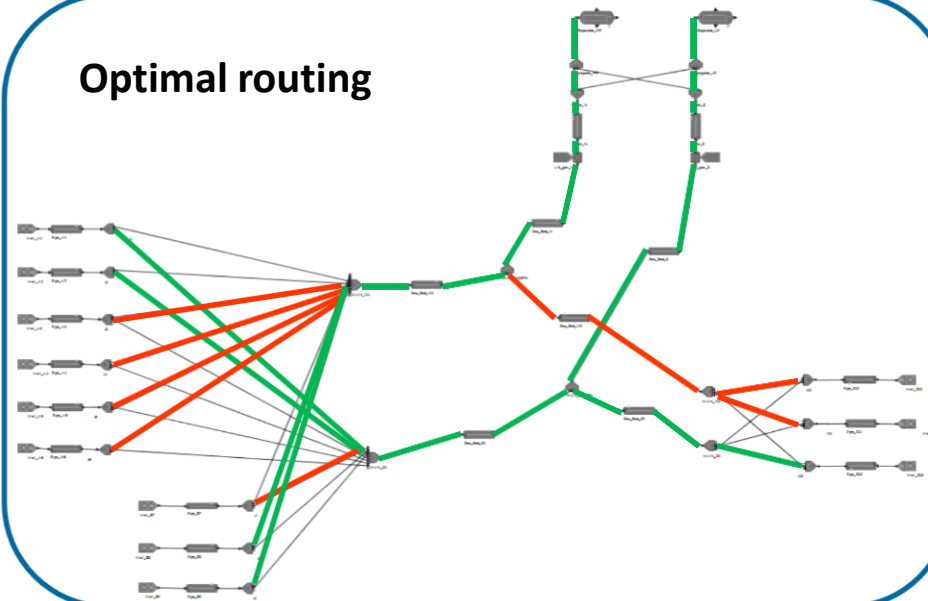
Gas lift redistributed  
More is employed

## Control variables

Current operation routing



Optimal routing



7 routing decisions are modified



- Field in decline – separator and compressor spare capacity
  - Opportunity for optimisation
  
- Limiting the scope to production optimisation results in a solution that is not implementable
  - Compressor system cannot handle the conditions
  
- Integrated asset optimisation addresses this
  - Continuous
    - Separator water rate is limiting factor
  - Discrete
    - Compressor capacity is limiting factor

Thank you

