DESIGN OF A BATCH FERMENTATION PROCESS

DESIGN OPTIMISATION OF A BATCH FERMENTATION PROCESS IN A CONTINUOUS INFANT MILK PLANT

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DANONE NUTRICIA
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NUTRICIA RESEARCH

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OUTLINE

Information Nutricia Research

Project background

Modelling setup and results

CURRENT GROUP DANONE

“Bringing health through food to as many people as possible”

€4.3 billion
+3.6% growth in 2013
Early Life Nutrition

€ 3.9 billion
+11.2% growth in 2013
Waters

€11.8 billion
+3.2% growth in 2013
Fresh Dairy Products

€1.3 billion
+5.8% growth in 2013
Medical Nutrition

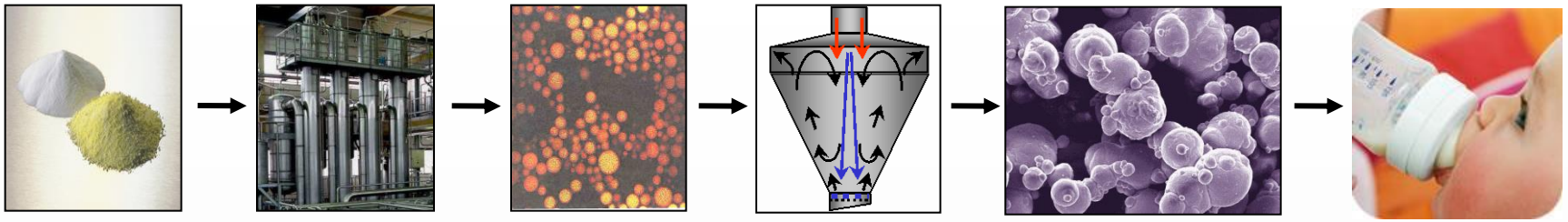
PROCESSING & NEW TECHNOLOGIES PLATFORM: POWDER PROCESSING TEAM

Team mission:

- Process development for new products
- Obtaining mechanistic process understanding
- Process optimisation projects
- Supporting supply points worldwide
- Supporting Food Science & Technology lab and Pilot Plant

THE JOURNEY FROM INGREDIENTS TO CUSTOMER

Continuous production process



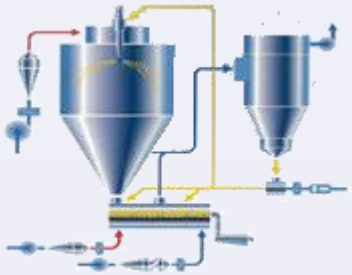
ingredients → evaporation & heating → emulsion → spray drying → powder → customer

Mastering production process is key for superior quality (safety, nutrition and easy-of-use) at acceptable costs

PROBLEM DESCRIPTION

CONTINUOUS

BATCH



CONTINUOUS

UNIQUENESS OF CASE

Normally gPROMS used to optimise single batch process

- Controlling reaction kinetics
- Finding rate limiting steps

Nutricia case:

- Optimising several batch process running in parallel
- Fit in batch process to allow continuous up stream and down stream processes
- Check operability / robustness of process design
- Evaluate usefulness of gPROMS for business
  - R & D
  - Operations / engineering

MORE DETAILS

CONTINUOUS
Fixed flow rate

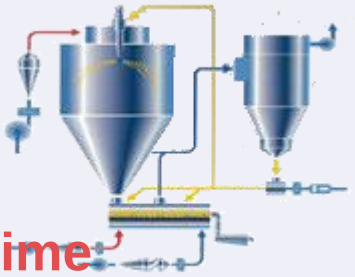
Fixed filling time

Fixed fermentation time

Fixed storage time

Fixed emptying time

BATCH



CONTINUOUS
Fixed flow rate

filling flow rate > emptying flow rate

QUESTIONS

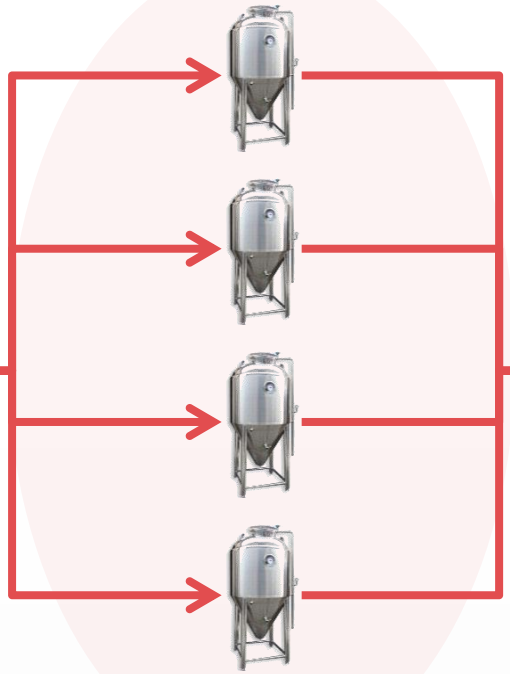
How many fermenters of which size are needed to maintain continuous flow to spray dryer?

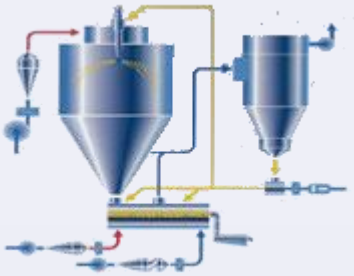
When to switch evaporator on/off for cleaning?

- Minimise number of on/off cycles
- Limited uptime of single evaporator before cleaning required

What is available redundancy / sensitivity to disturbances?

CONSTRAINTS





evaporator running:
fermenter available

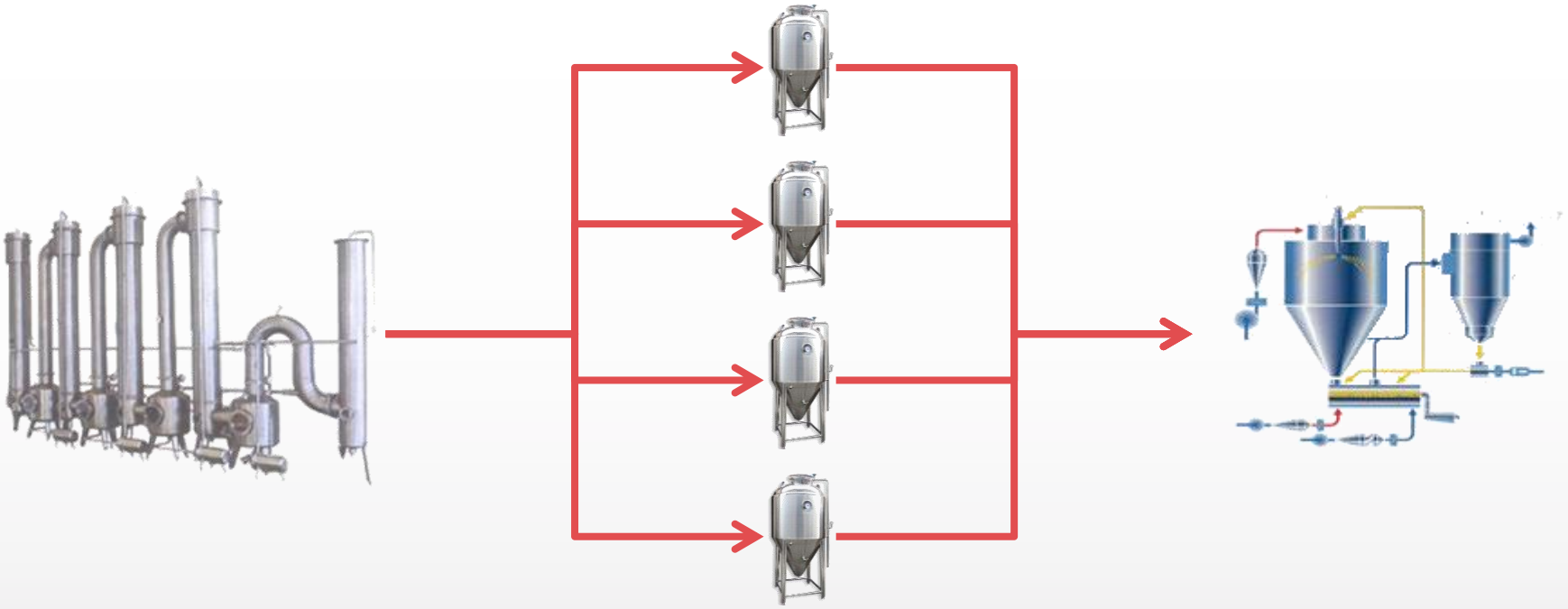
evaporator must run
until fermenter is full

always flow from
fermenter to spray dryer

spray dryer is expensive:
must be rate limiting

START UP

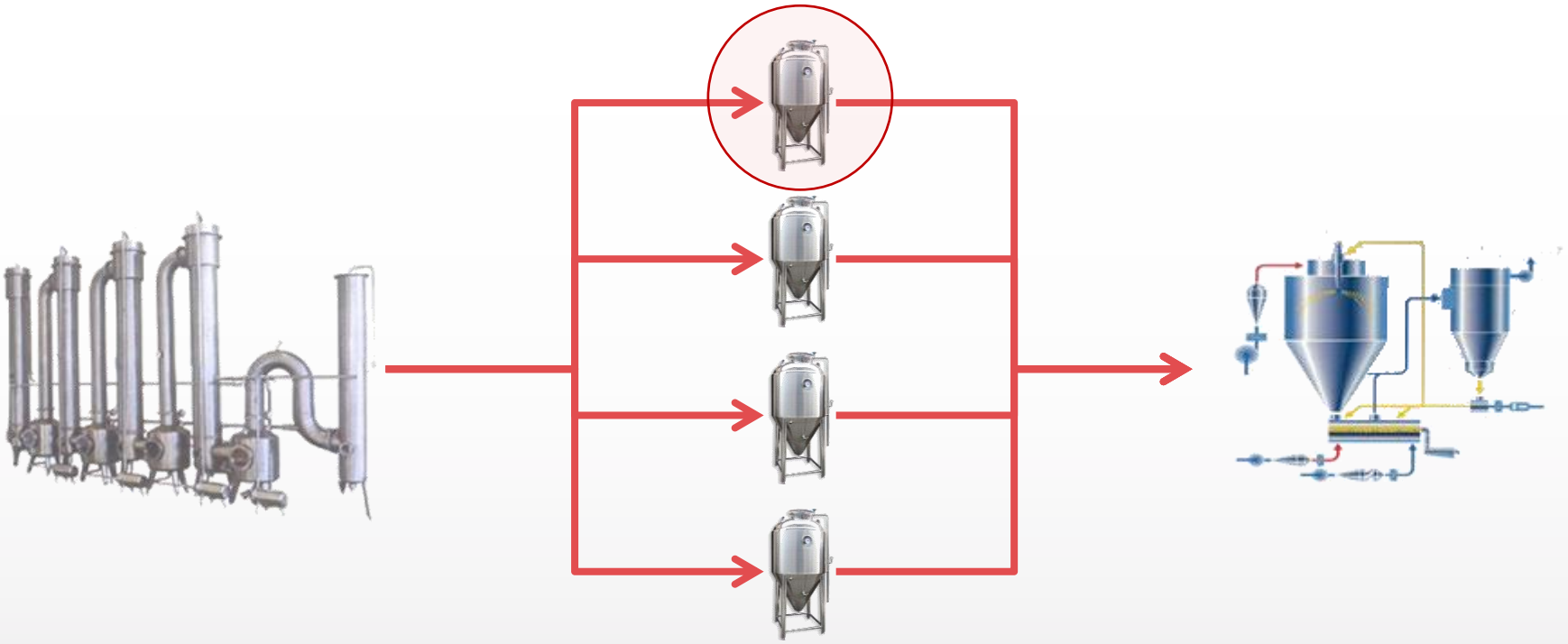
- No flow from evaporator
- No flow to spray dryer
- All fermenters empty



FIRST CYCLE

FERMENTER 1

fill fermenter



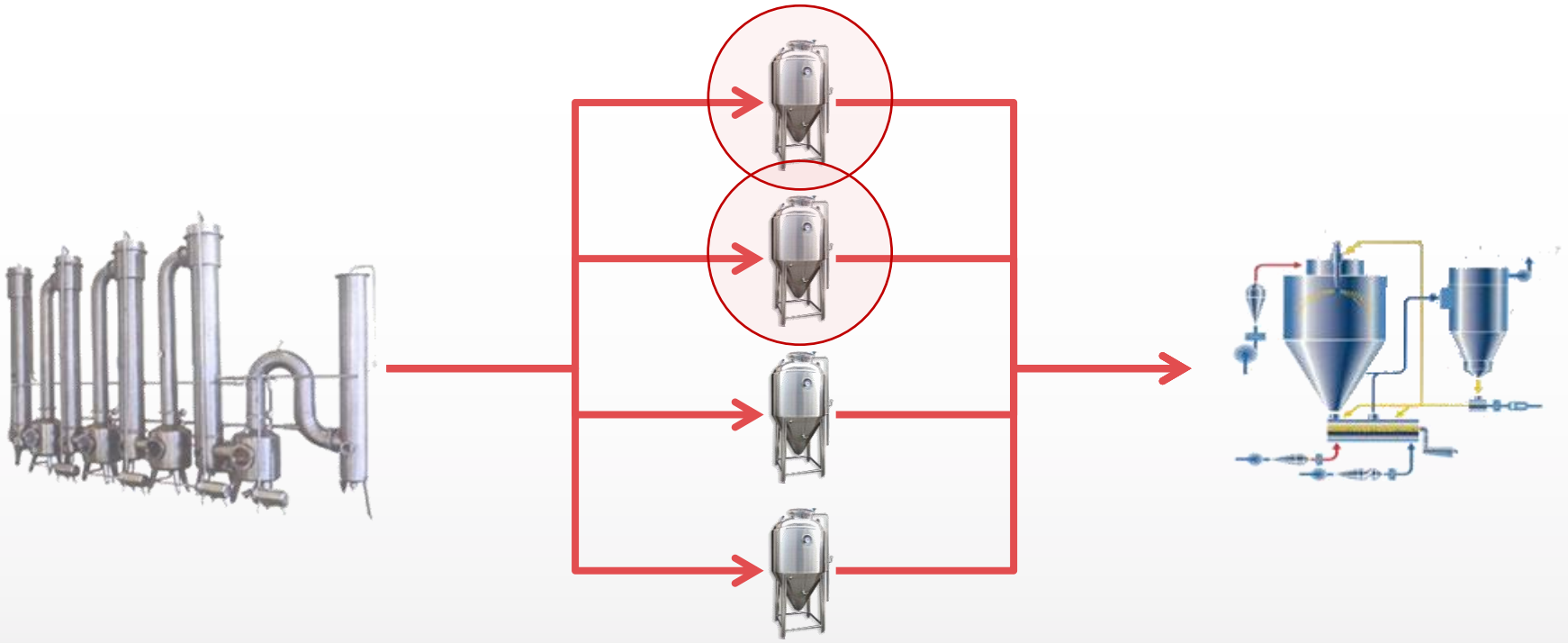
FIRST CYCLE

FERMENTER 1

ferment fermenter

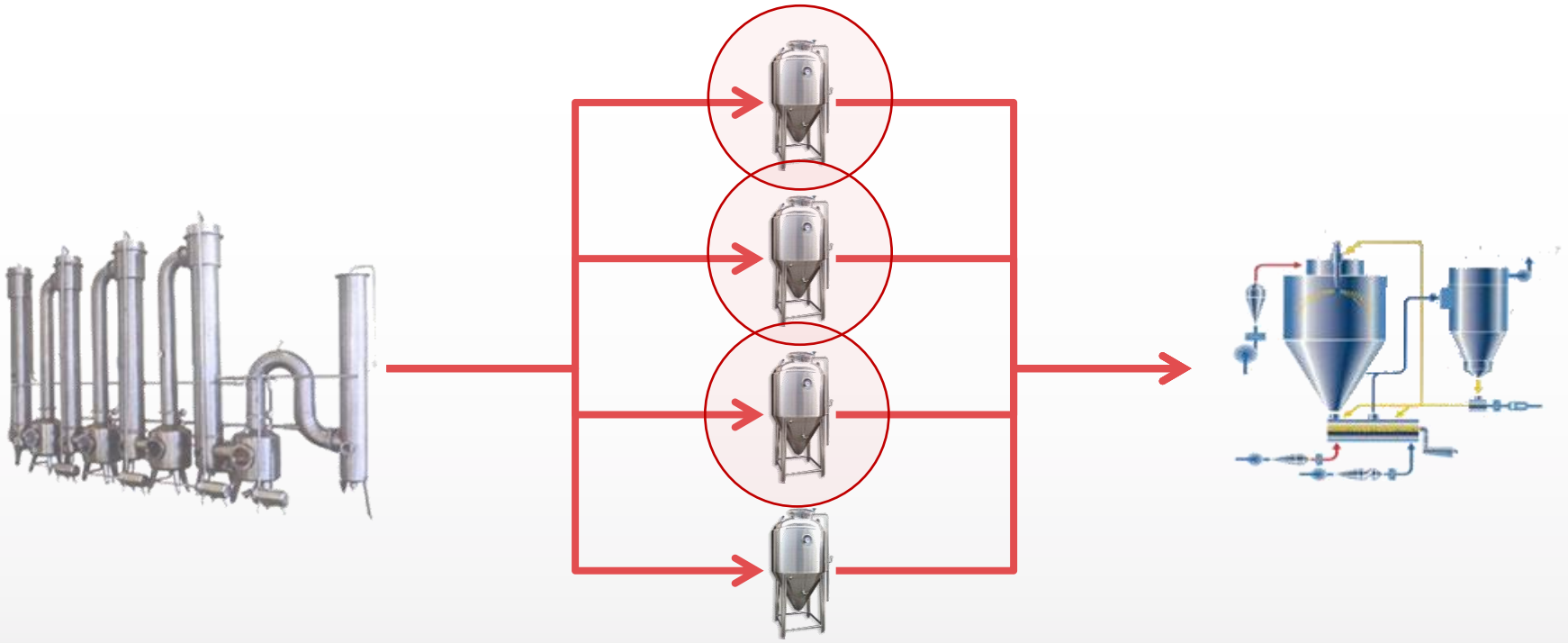
FERMENTER 2

fill fermenter



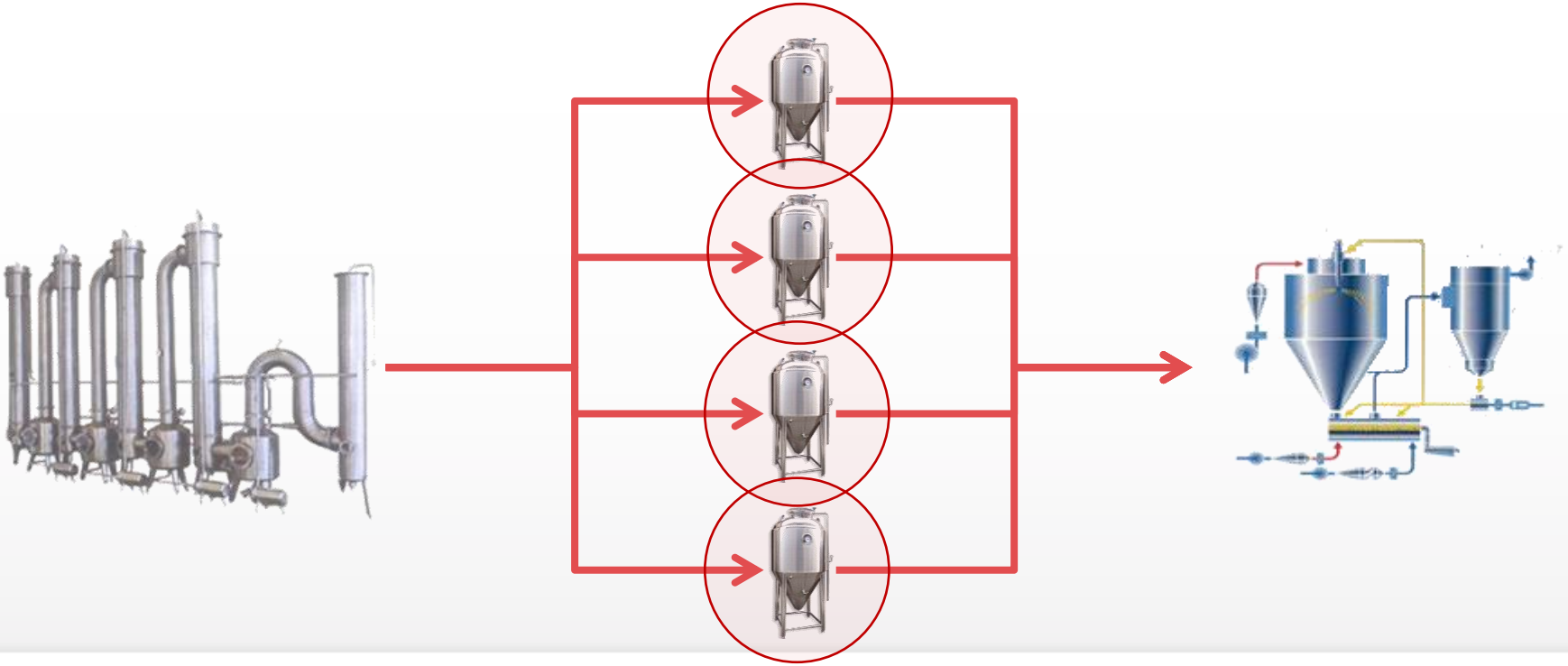
FIRST CYCLE

FERMENTER 1	FERMENTER 2	FERMENTER 3
empty fermenter	ferment fermenter	fill fermenter



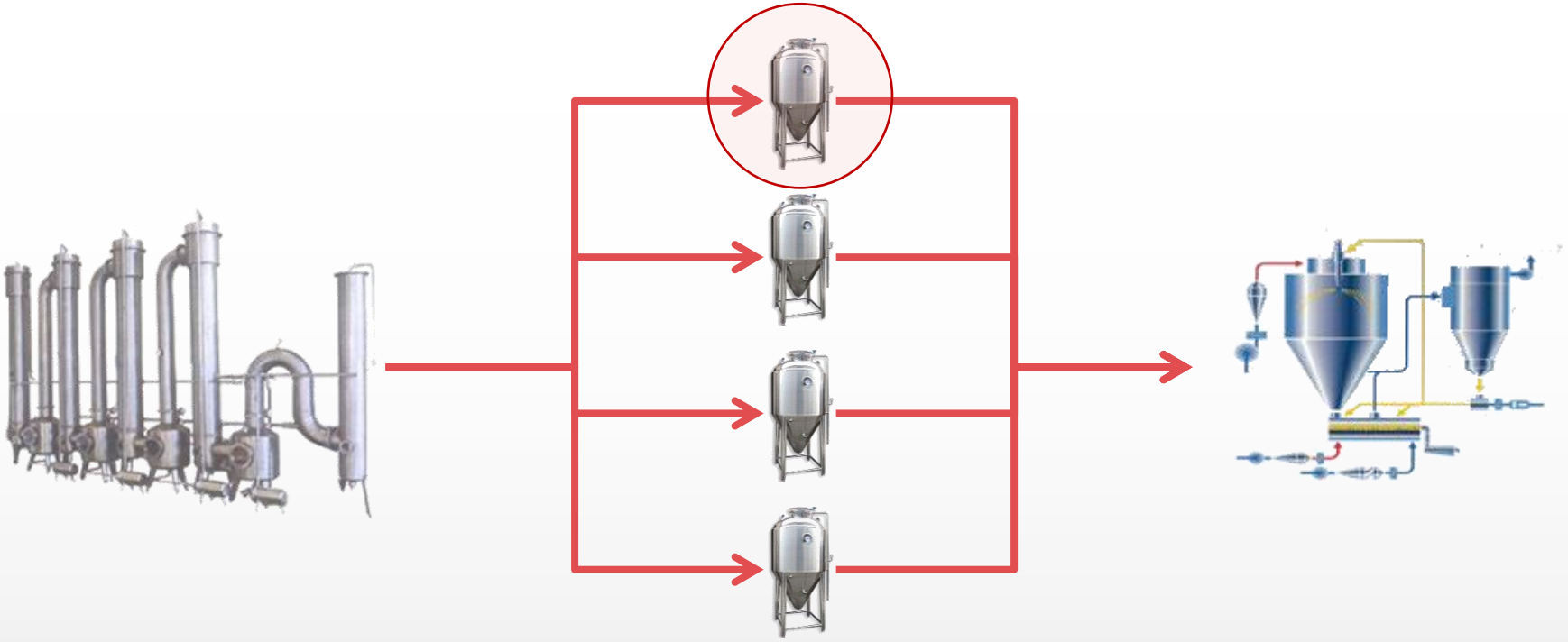
FIRST CYCLE

FERMENTER 1	FERMENTER 2	FERMENTER 3	FERMENTER 4
clean fermenter	empty fermenter	ferment fermenter	fill fermenter



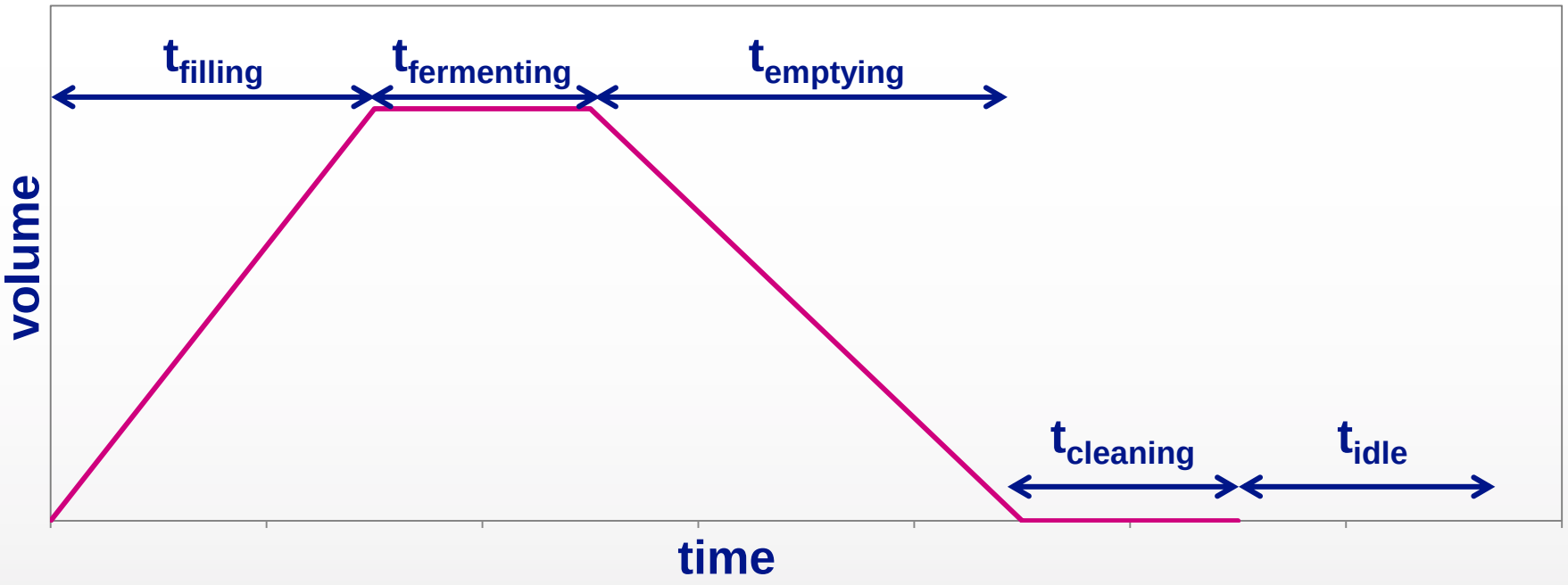
FIRST CYCLE

FERMENTER 1	FERMENTER 2	FERMENTER 3	FERMENTER 4
Ready for next round	clean fermenter	empty fermenter	ferment fermenter



COMPLICATION… SINGLE FERMENTER

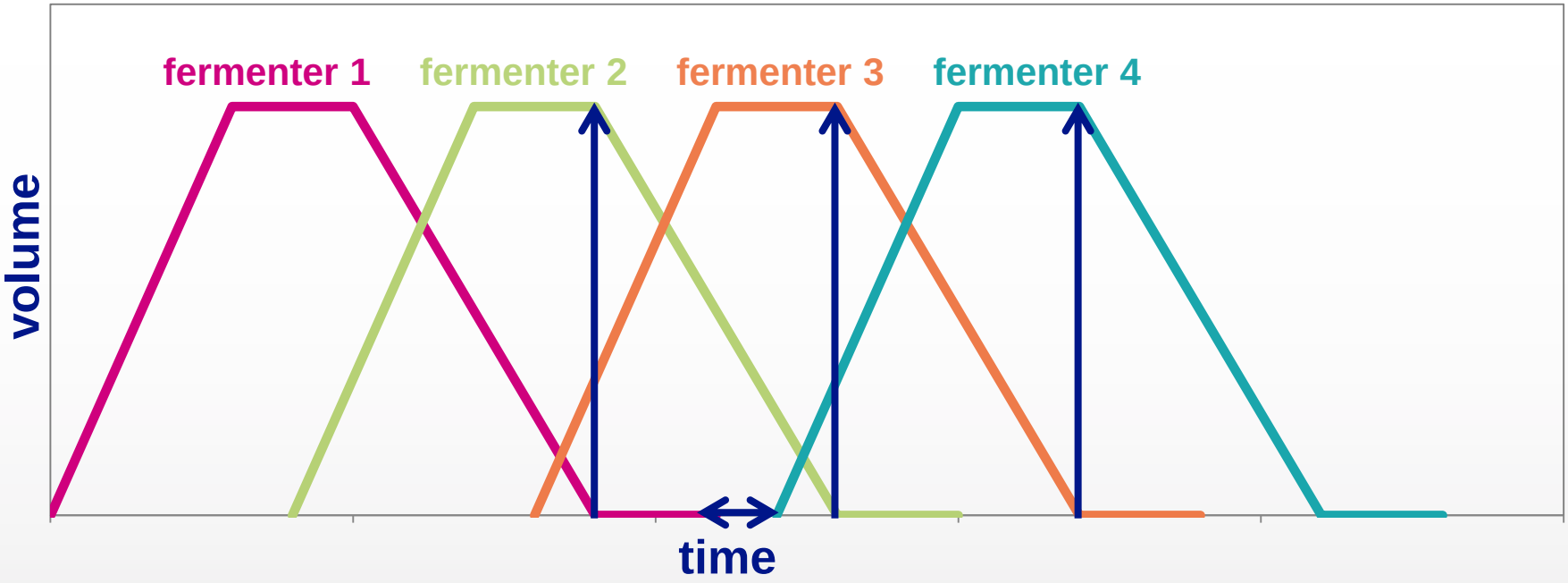
$t_{filling} \neq t_{fermenting} \neq t_{emptying} \neq t_{cleaning}$



COMPLICATIONS… MULTIPLE FERMENTERS

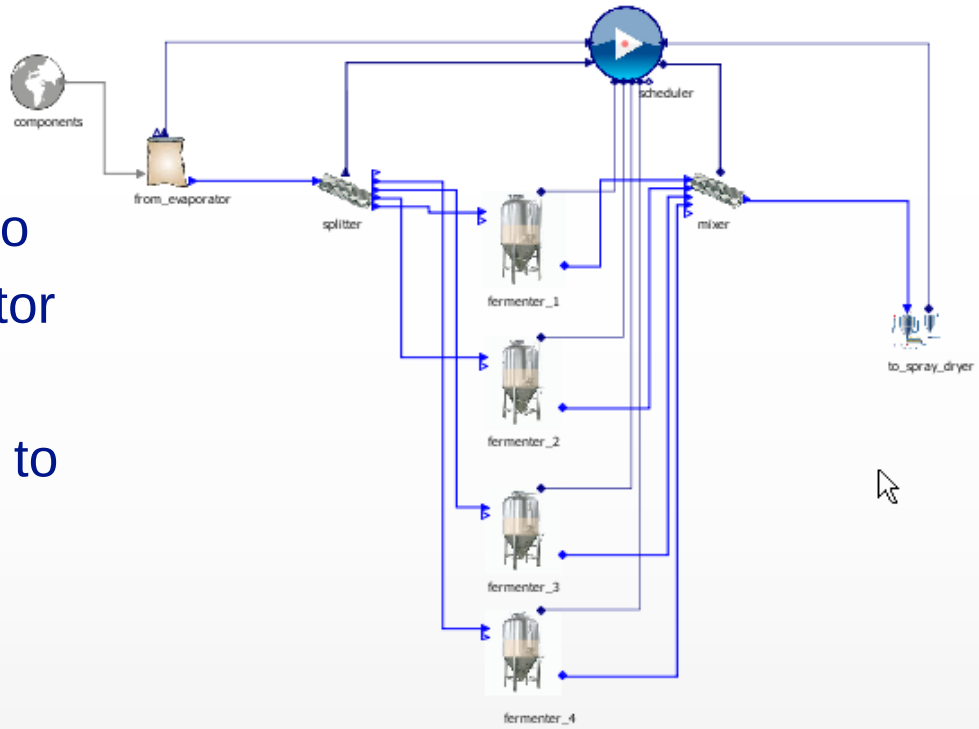
Complicated batch scheduling

- Batch process itself does not need to be optimised (fixed)
- Scheduling of several batch process simultaneous needs to be optimised



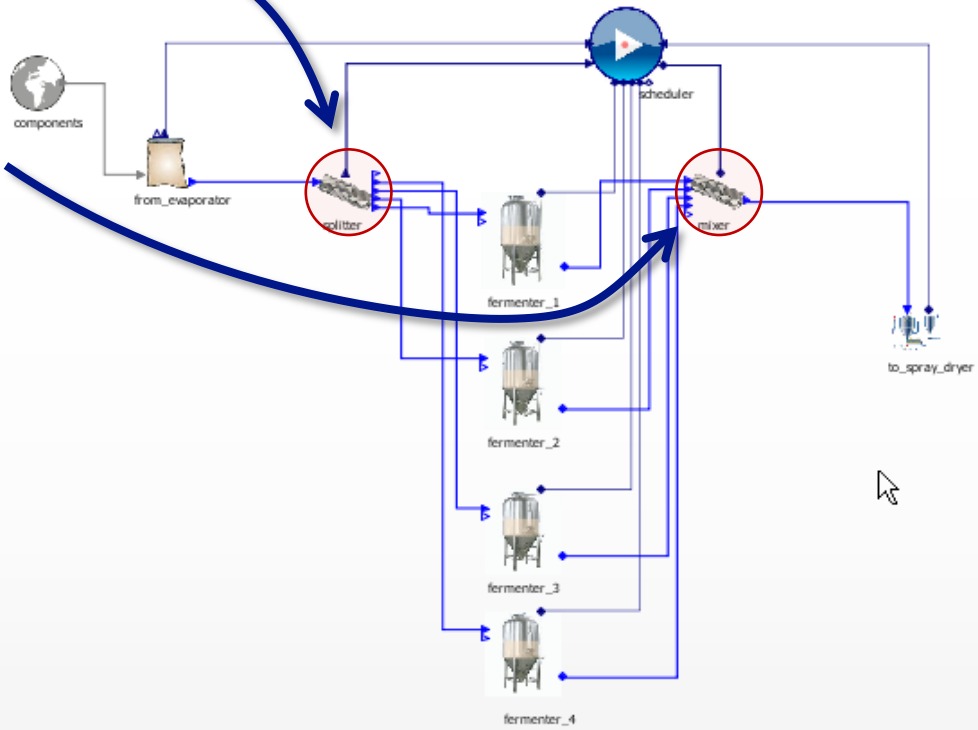
MODELLING APPROACH

- Introduce ‘Scheduler’ model
  - Allocates resources based on ‘state’ of each fermenter
- Use gPROMS tasks in parallel to control fermenters and evaporator
- Simulate over long time horizon to capture many cycles



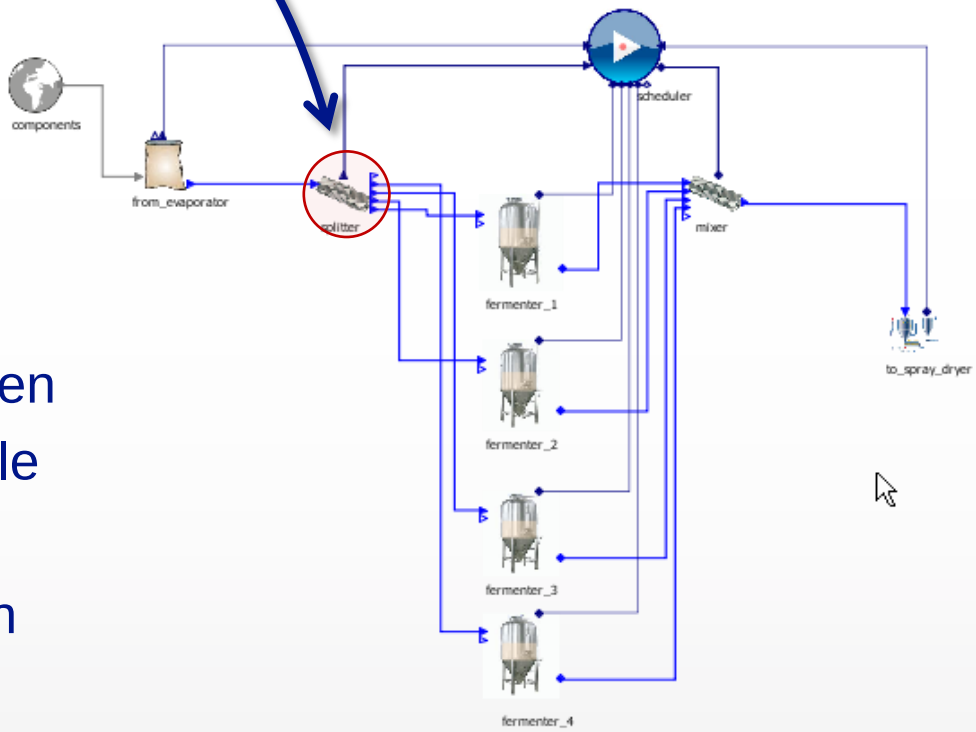
MODELLING APPROACH

- Flow to fermenters directed by Splitter model
- Flow to spray dryer directed by Mixer model
- Only allowed inlet/outlet from a single fermenter



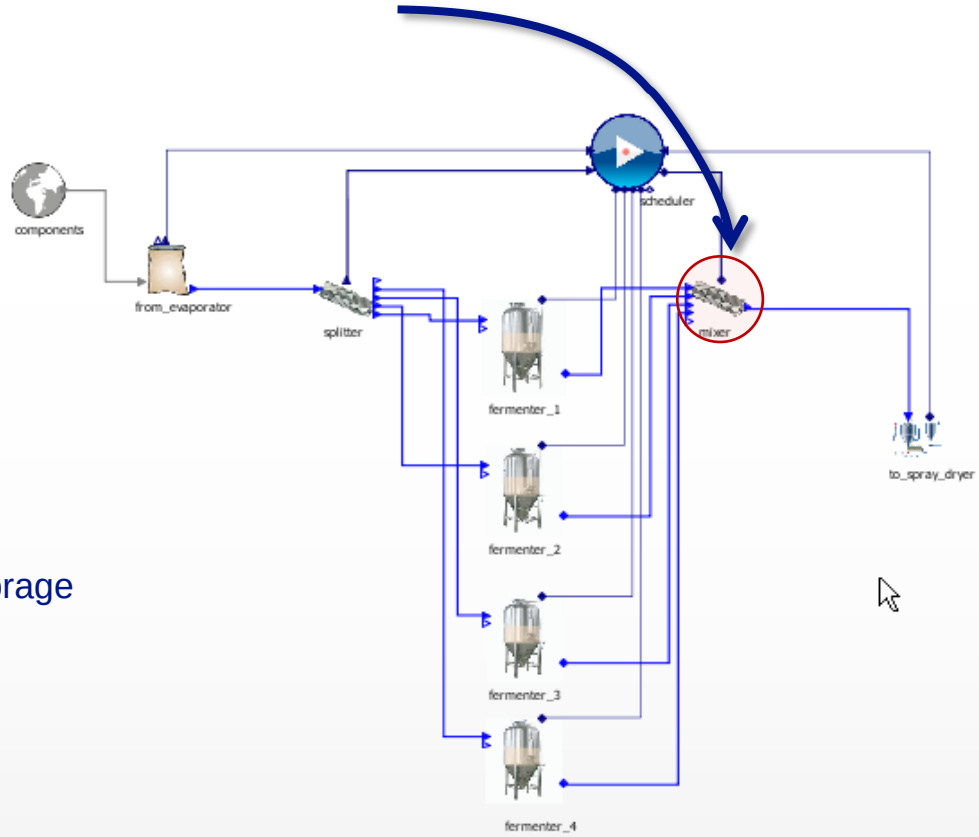
MODELLING APPROACH - SPLITTER

- Only allowed to fill one fermenter at a time
- If no fermenter is idle then the evaporator will be stopped
- If multiple fermenters are idle then will fill vessel which has been idle shortest amount of time
  - Some fermenters could remain unused



MODELLING APPROACH - MIXER

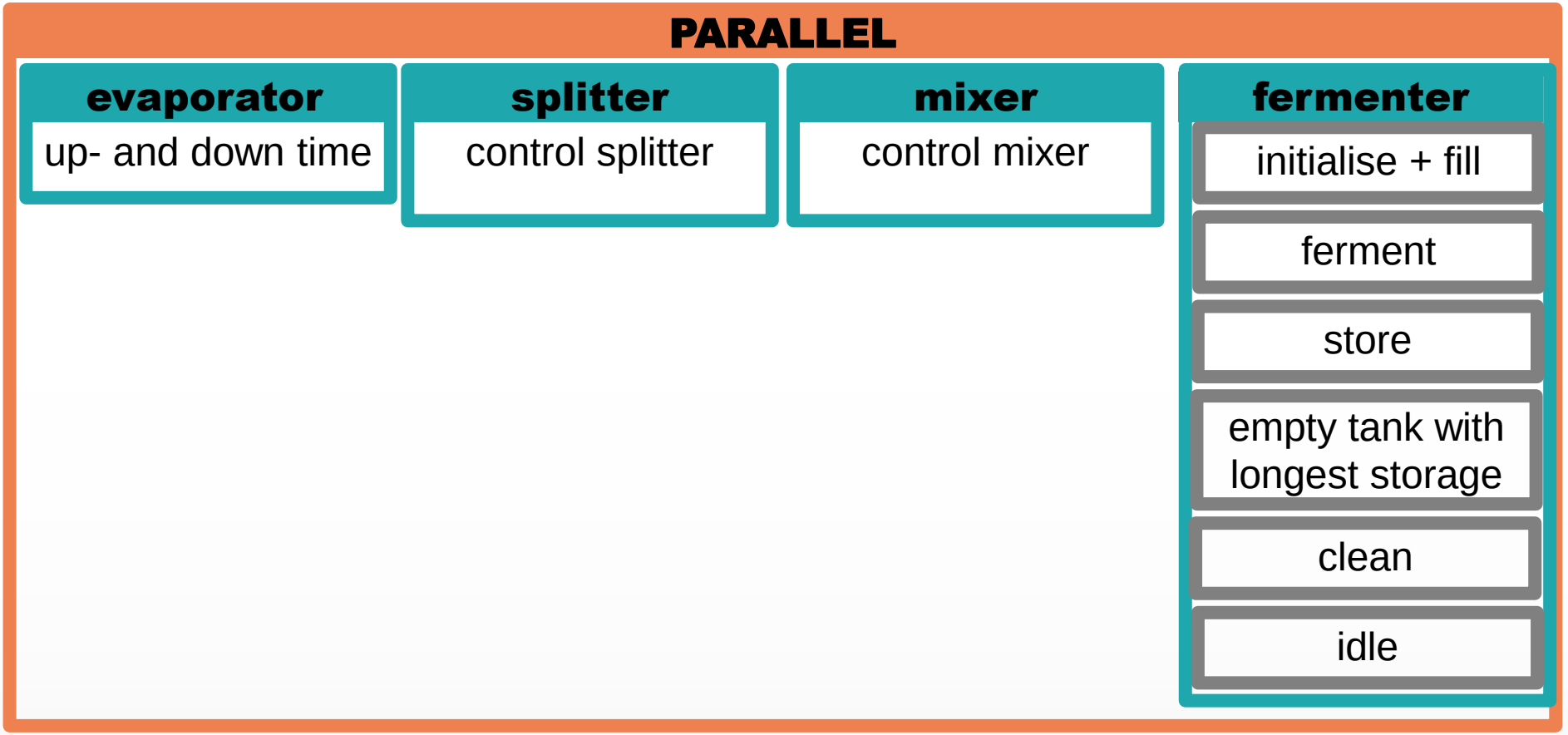
- Only allowed inlet from a single fermenter
- If no fermenter is ready
  - stop spray dryer
- If multiple fermenters are ready
  - choose vessel with longest $t_{storage}$



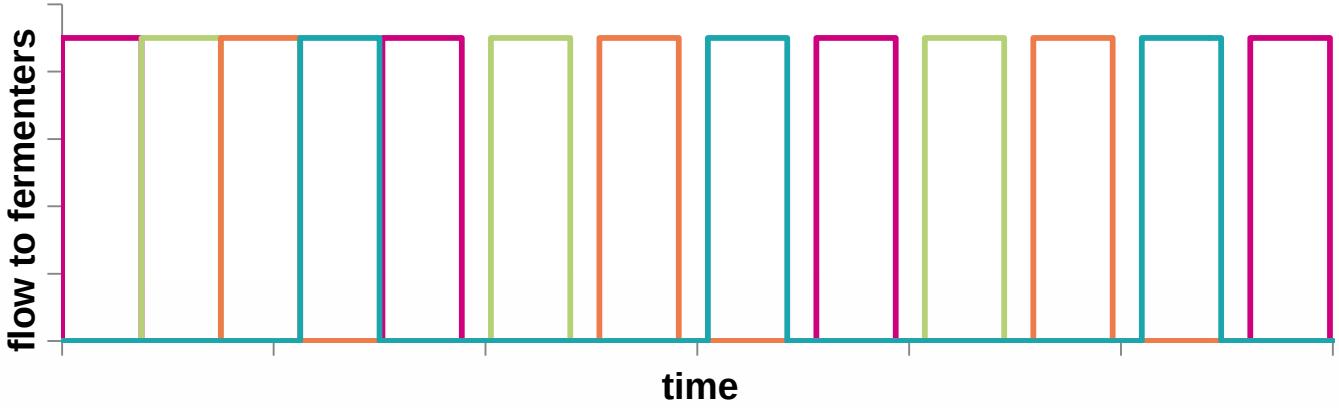
MODELLING APPROACH - FERMENTER

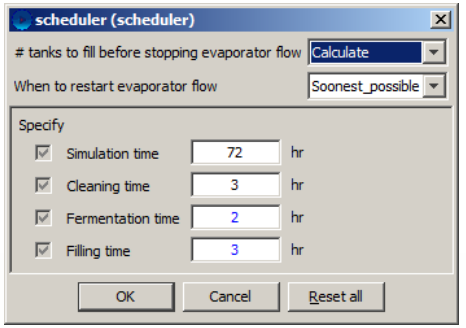
- Fermenter model has dynamic mass holdup
- Can be in one of six states
  - Idle
  - Filling
  - Fermenting
  - Storing
  - Emptying
  - Cleaning
- State changed by tasks
- Model tracks length of time for which it has been storing a given load

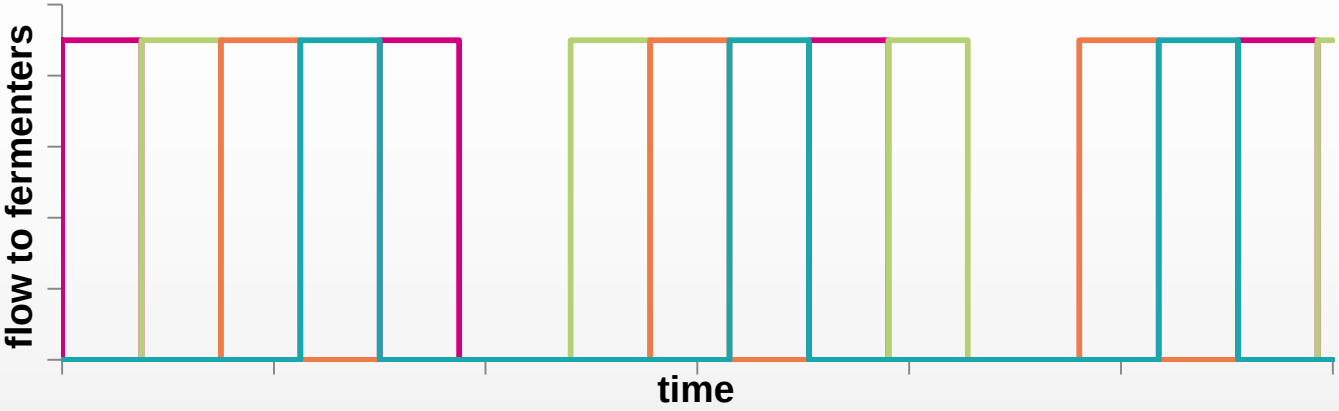
MODEL OVERVIEW

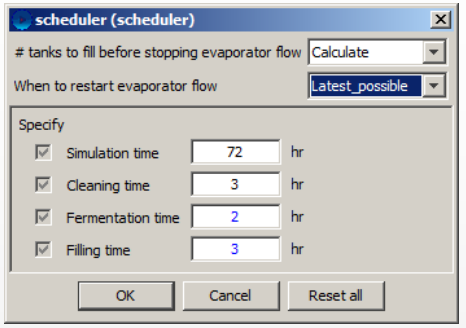


MODELLING RESULTS - EVAPORATOR









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EVAPORATOR RUN TIME OPTIMISATION

Evaporator run time

- $n \cdot t_{filling}$

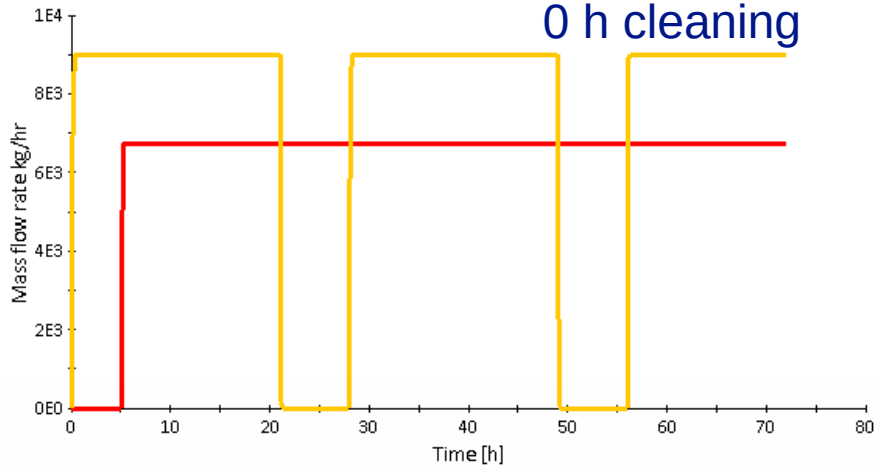
Evaporator cleaning time

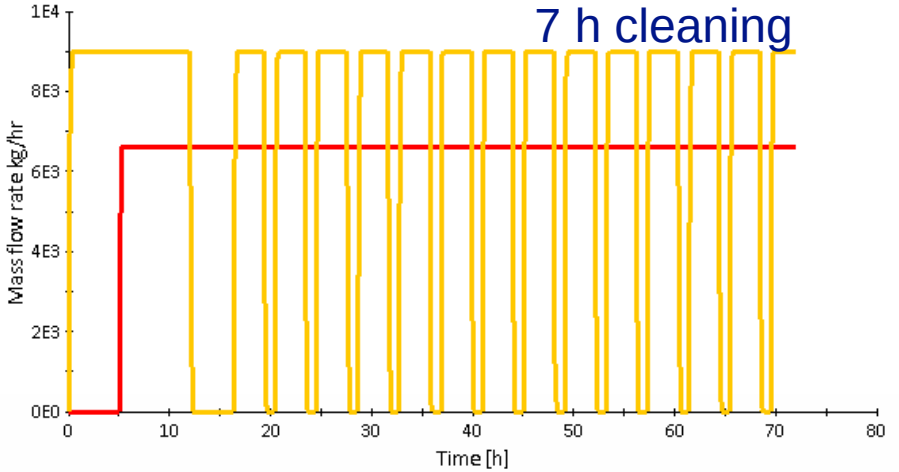
- $n \cdot (t_{emptying} - t_{filling})$

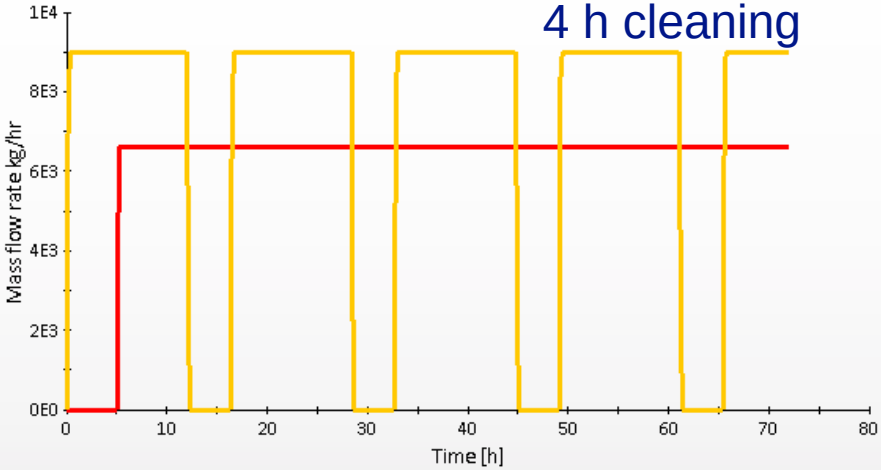
Example: 4 fermenters / cycle, Δt = 1 h, $t_{filling}$ = 3 h

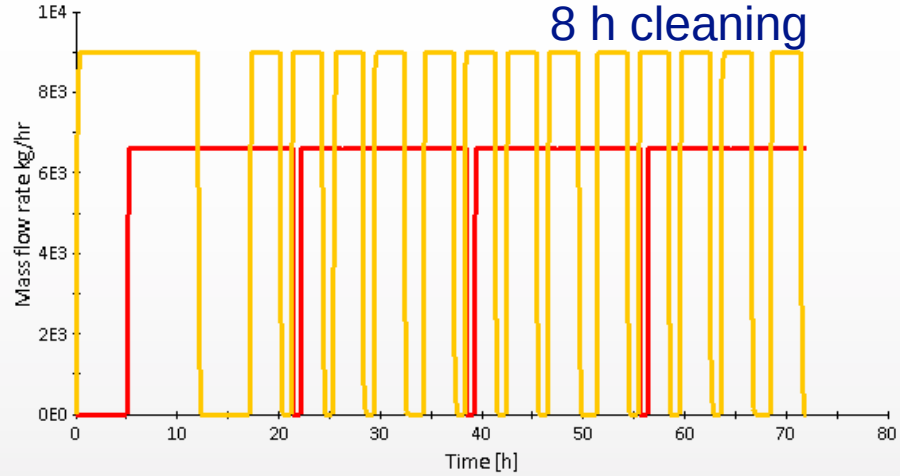
- Uptime / downtime: 12 h / 4 h
- Optimising by gProms: 15 h / 5 h

ROBUSTNESS - CLEANING TIME / DOWNTIME









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MODELLING RESULTS – # FERMENTERS

What is the minimum number of fermenters needed to run continuous?

- Only variable: cleaning time → $t_{cleaning}$ = 0 h → 4 fermenters
- No possibility to have < 4 fermenters
- Maximum cleaning time, before needing 5 fermenters: 4 h
- Longer fermenter cleaning time is possible
  - Run time evaporator decreases
  - Cleaning time evaporator decreases

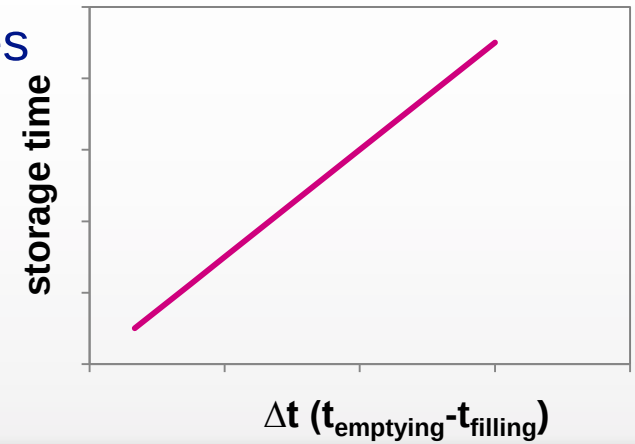
MODELLING RESULTS – STORAGE TIME

Storage time of fermented products is important

- viscosity increases over time
- storage time should be limited
- holding time = storage time (full tank) + emptying time (decreasing tank volume)

Storage time considerations

- Can be minimised by starting fermentation just in time
  - Frequent starting stopping upstream processes
- More fermentations / cycle → longer storage
  - $t_{emptying} - t_{filling} \rightarrow 0$, shorting filling



CONCLUSIONS

Using gPROMS

- We could easily calculate number and size of fermenters
- Optimise the scheduling of several batch processes in parallel
- Fit the batch fermentation process in a continuous plant

Follow up

- Make implementation plan for gPROMS
- Get budget approval to acquire licence

ACKNOWLEDGEMENTS

Frances Pereira, PSE

Sean Bermingham, PSE