WA MARKET REFORM PROGRAM

REAL TIME MARKET FORUM – MEETING 2

22 NOVEMBER 2016

AGENDA

1. Welcome and confirm agenda
2. Recap on actions from previous meeting
3. Introduction to constraints
4. Introduction to Ancillary Services
5. Lunch
6. Constraints in dispatch
7. Ancillary Services in dispatch
8. Approach to registration
9. Next meeting and closing

RECAP ON ACTIONS FROM PREVIOUS MEETING

TOPICS COVERED

- Introduction to real time dispatch
- Dispatch and pricing
- Bidding and offers
- Market information
- Wholesale market systems

KEY OUTCOMES AND ACTIONS

- Key actions:
  - None
- Stakeholders requested more information in the following areas:
  - Constraints
  - Ancillary services
  - Different generator scenarios, and examples of trading
- Notes from the meeting are located at: http://www.aemo.com.au/Stakeholder-Consultation/Industry-forums-and-working-groups/WA-Forums/WAMRP-Real-Time-Market-Forum

INTRODUCTION TO OPTIMISATION AND CONSTRAINTS

SESSION OBJECTIVES

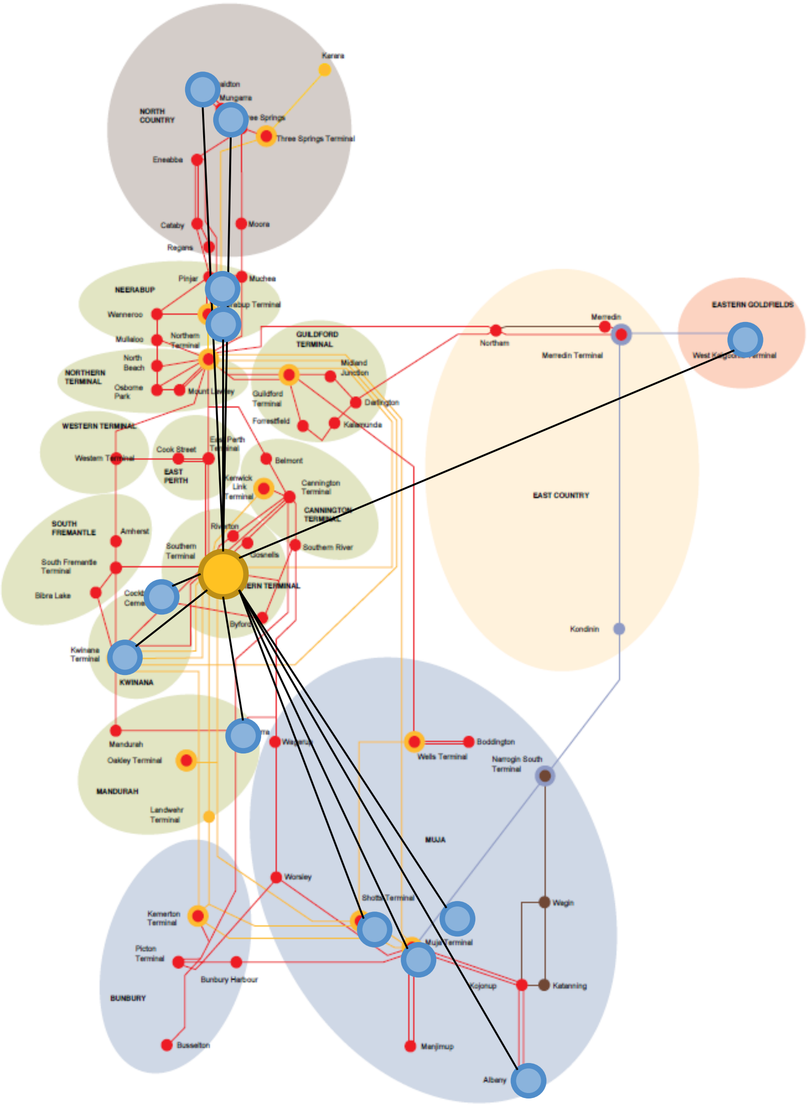
1. Constraint Principles
2. Optimisation Principles
3. Optimisation Example

CONSTRAINT PRINCIPLES

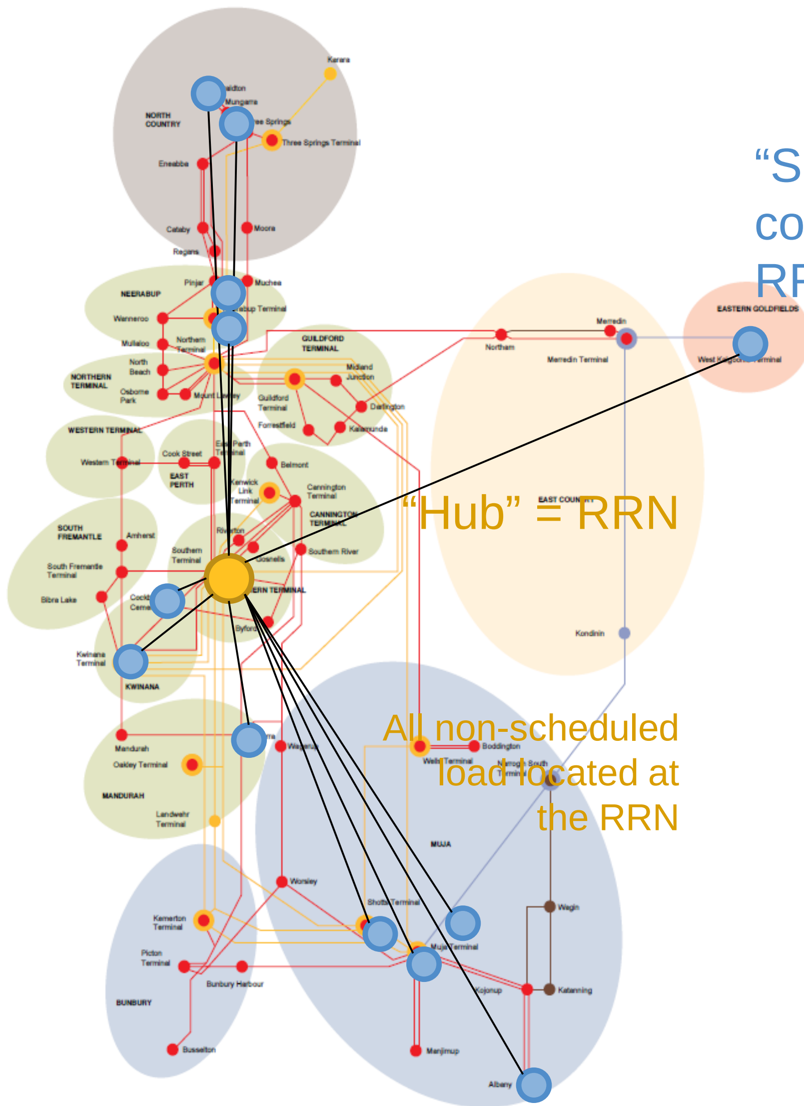
CONSTRAINT PRINCIPLES SUMMARY

- The central dispatch process is economically-*optimised* and security-*constrained*
- The “hub-and-spoke” model used in dispatch is simple, but the physical power system is complicated
- Accurate dispatch requires the dispatch model to recognise the physical complexity of the power system
- Physical complexity is transferred to the dispatch model via constraints: network, FCAS, “intrinsic”
- A constraint is a mathematical equation
- Constraints are the most complicated aspect of dispatch that most people encounter

CONSTRAINT PRINCIPLES
WHY WE NEED CONSTRAINTS 1



CONSTRAINT PRINCIPLES
WHY WE NEED CONSTRAINTS 2



"Spokes" = radial connections to RRN

All scheduled generation able to supply load at the RRN (with prices modified by MLF)

OPTIMISATION PRINCIPLES

AEMO

- The prerequisites for optimisation:
  - One or more variables

    e.g. x, y
  - One or more constraints

    e.g. $4x + 2y \leq 24$, $x + y \leq 8$, $x \geq 0$, $y \geq 0$
  - An objective function

    e.g. $\max(10x + 6y)$
  - The ability to express the objective and constraints as functions of the variables i.e. mathematical equations

OPTIMISATION PRINCIPLES
SOLVING THE PROBLEM

- The prerequisites for solution:
  - For small problems
    - a set of simultaneous equations
    - graph paper + pencils
  - For most real-world, non-trivial problems
    - a computer with optimisation software

OPTIMISATION EXAMPLE

OPTIMISATION EXAMPLE 1

- Two products: wine and beer (variables)
- Two types of worker: fermenter and bottler
  - Three fermenters (constraints)
  - One bottler (constraints)
  - Each worker works 8 hours a day (constraints)
  - Wine and beer take different times to make (constraints)
- Aim to maximise profits (objective function)
  - Wine and beer have different profits

Example based on *Management Science* by Pinney & McWilliams

OPTIMISATION EXAMPLE 2

	Wine	Beer
Profit	$10	$6
Ferment Time	4 hr	2 hr
Bottling Time	1 hr	1 hr

OPTIMISATION EXAMPLE 3

Define variables

- X = bottles of wine per day
- Y = bottles of beer per day

Define constraints

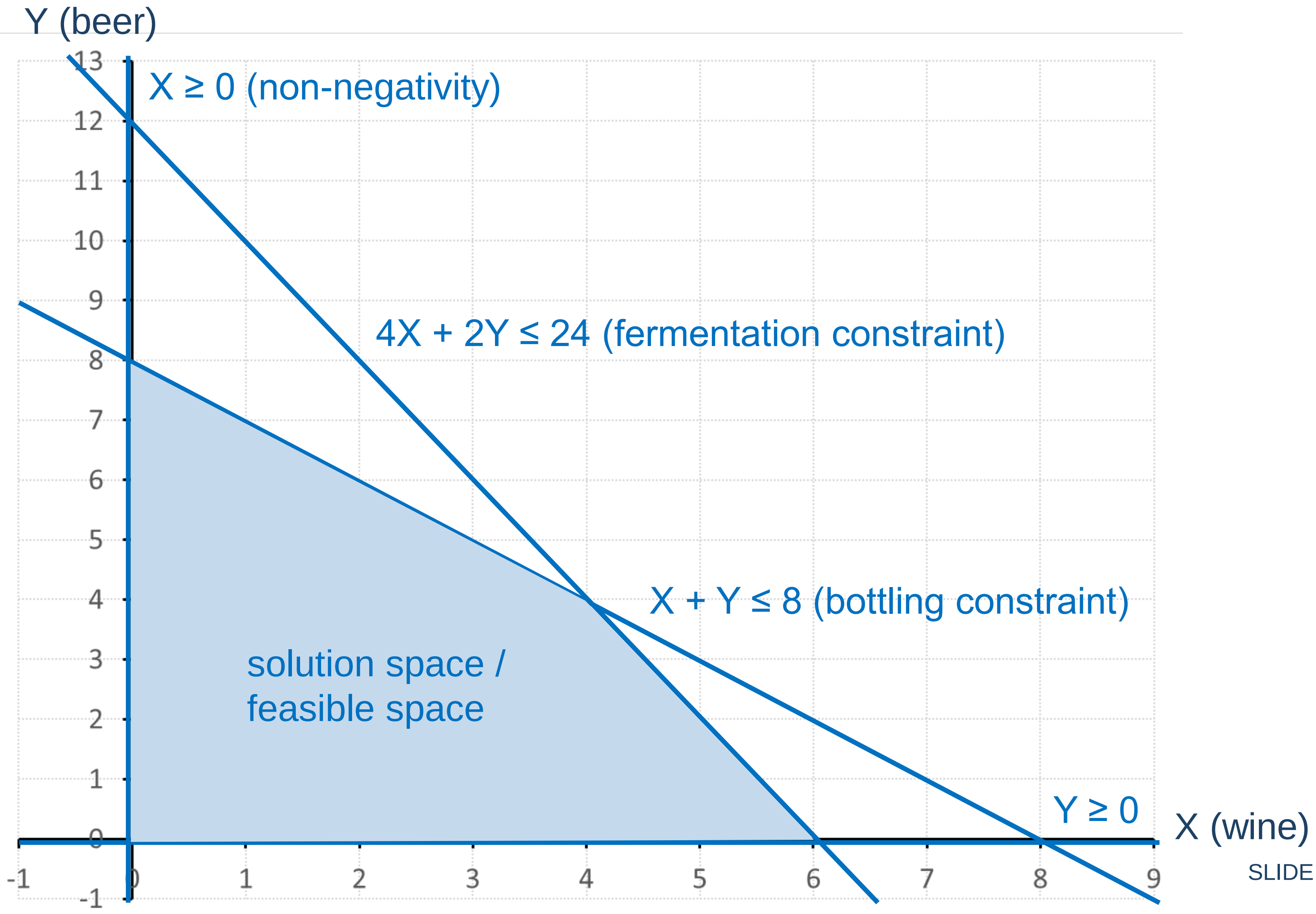
- 3 fermenters working 8 hour days
- $4X + 2Y \leq 24$
- 1 bottler working 8 hour day
- $X + Y \leq 8$
- non-negativity constraints
- $X \geq 0, Y \geq 0$

OPTIMISATION EXAMPLE 5

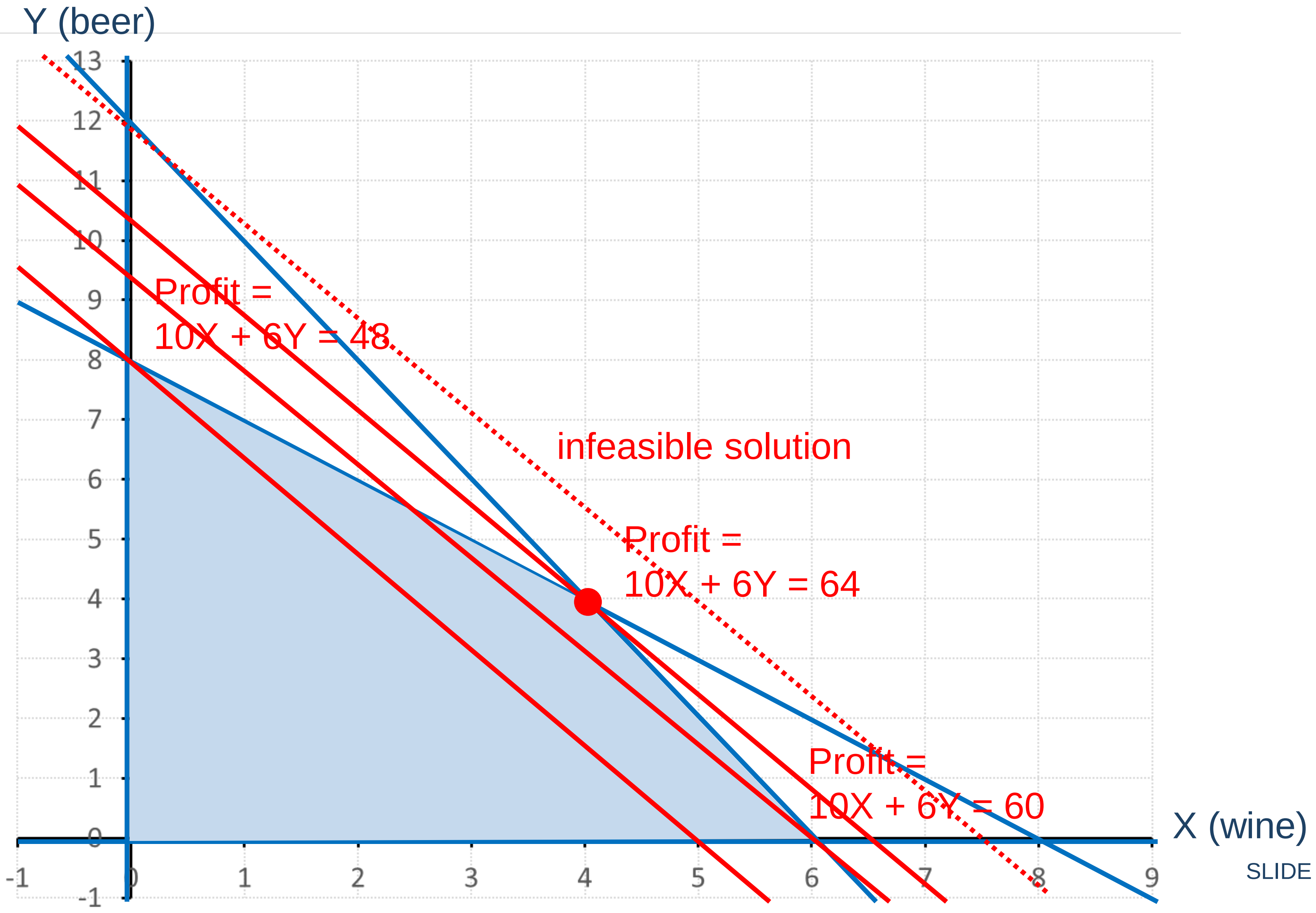
Define objective function

- Profit: $Z = 10X + 6Y$
- Aim to maximise Z

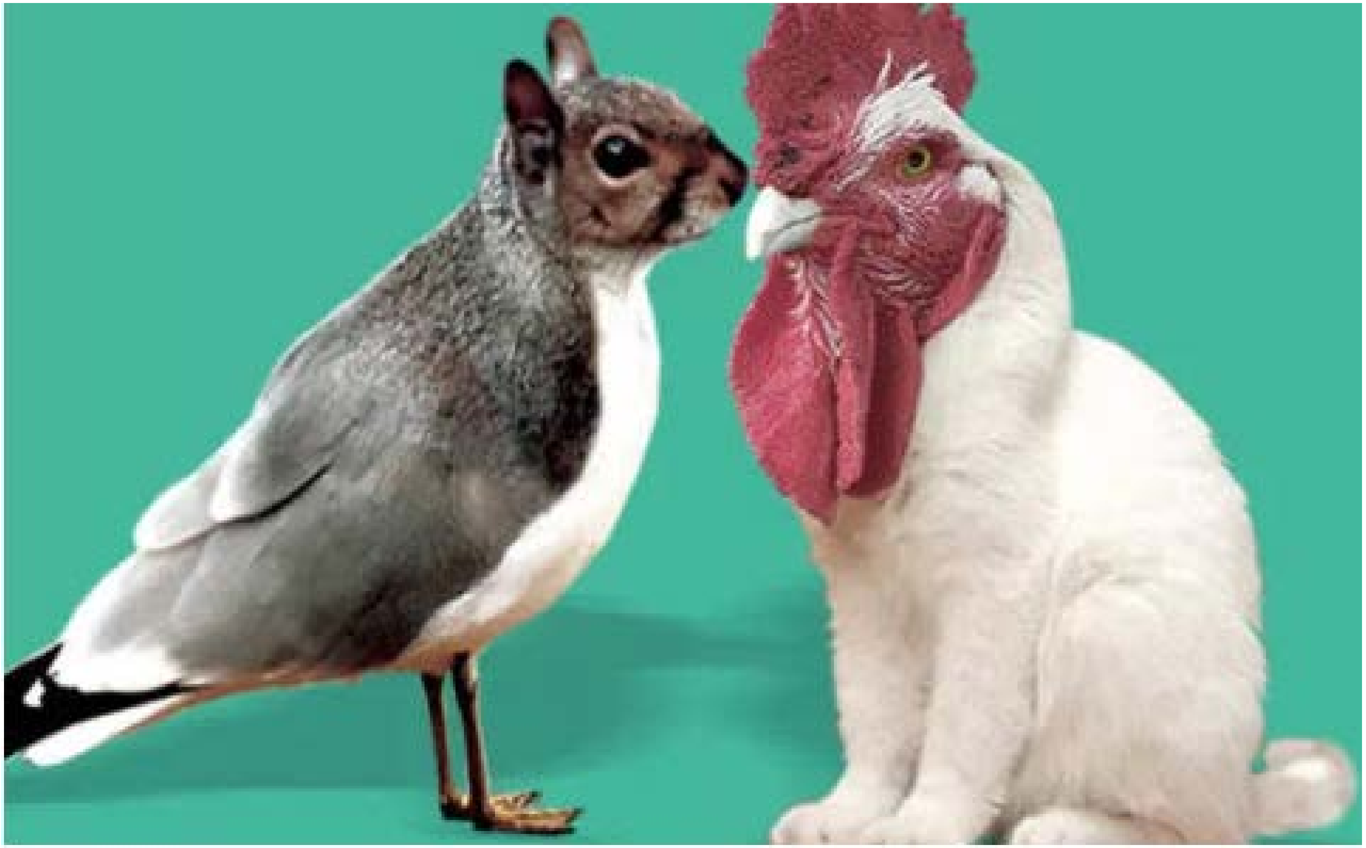
OPTIMISATION EXAMPLE 6



OPTIMISATION EXAMPLE 7



QUESTIONS?



INTRODUCTION TO ANCILLARY SERVICES

SESSION OBJECTIVES

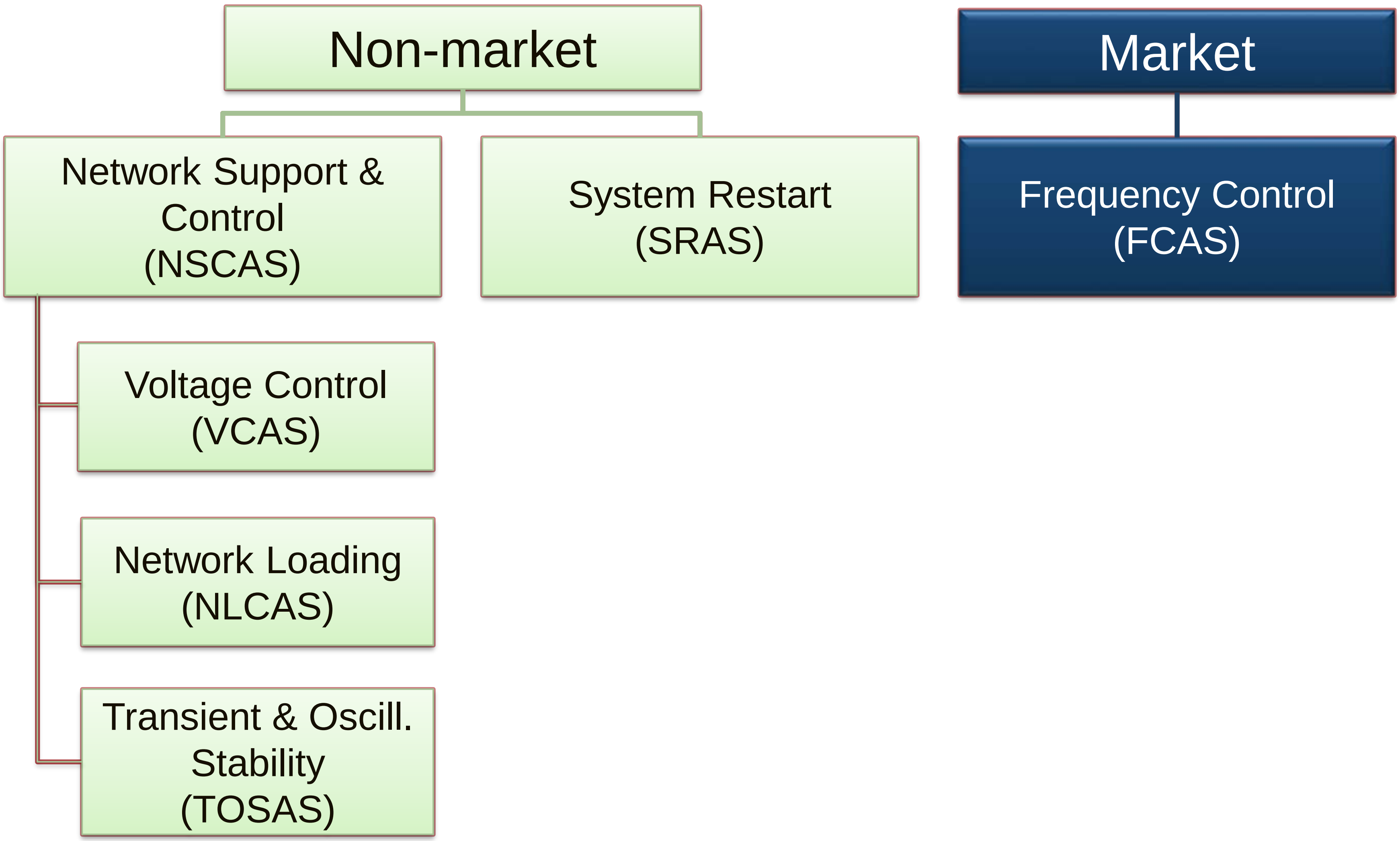
1. Define ancillary services and why we need them
2. Non-market and market ancillary services
3. Types of FCAS
4. FCAS bids

WHY DO WE NEED THEM AND WHAT ARE THEY?

- Enable AEMO to manage the power system safely, securely and reliably
- To manage:
  - Frequency
  - Voltage
  - Network Loading
  - Power system stability
  - System Restart processes

Guide to Ancillary Services in the National Electricity Market (http://aemo.com.au/-/media/Files/PDF/Guide-to-Ancillary-Services-in-the-National-Electricity-Market.pdf)

ANCILLARY SERVICES



NON-MARKET - CONTRACTED SERVICES

NSCAS – VCAS, NLAS, TOSAS

- Requirement determined by AEMO

SRAS

- To maintain System Restart Standard (SRS)

NON-MARKET: NSCAS - VCAS

- Help control voltage supplying/absorb reactive power at certain network points within specified tolerances.

- Required if insufficient non-contracted voltage control resources are available.

  e.g. Two VCASs manage high voltage issue in southern NSW.

  - Generator contracted to provide MVar generation or absorption capability, high costs involved.

  - TNSP contracted to provide MVar absorption capability, reduced costs.

NON-MARKET: NSCAS - NLAS & TOSAS

Network Loading Ancillary Service (NLAS):

- Services that are used to reduce active power flow on lines to within their short-term limits following a credible contingency.

  e.g. One service procured in the past – Contracted with a major load in Victoria to reduce load, if VIC-NSW interconnector flow reached 5 minute rating following credible contingency.

- No services currently procured in the NEM.

Transient and Oscillatory Stability Ancillary Service (TOSAS):

- Services that help to maintain transient and oscillatory stability within the power system following faults on major lines, loss of key generators etc.

  e.g. PSS, Fast regulating voltage services (synchronous condensers, SVCs, generators), Inertia support services etc.

- No services currently procured in the NEM

NON-MARKET: SRAS

- Generators with the capability to black-start i.e. ability to start without power supply from grid.
- System restart services enable the power system to be restarted following complete or partial black-out.
- Services are procured to meet the System Restart Standard

MARKET: FCAS
FREQUENCY CONTROL

- Maintaining system security is one of AEMO's main responsibilities.

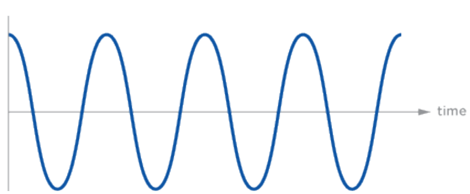
  - ➢ Voltage levels
  - ➢ Line flows
  - ➢ Equipment loadings

  Local problems

  - ➢ Frequency

  It has the same value in every part of the system.

  Indicates System Generation = System Demand.



FREQUENCY CONTROL

- Power system frequency needs to be maintained close to 50 Hz at all times – Reliability Standard.
- Load varies continuously, generation needs to be varied correspondingly to maintain 50 Hz frequency.

Demand > Generation = Frequency ↓

Generation > Demand = Frequency ↑

- FCAS helps to maintain power system frequency close to 50 Hz.

Raise Services = Increase MW output (Generators)/ Reduce MW demand (Loads)

Lower Services = Reduce MW output (Generators)/ Increase MW demand (Loads)

FREQUENCY STANDARD

NEM frequency operating standards

- Set by the Reliability Panel of the AEMC

Condition	Containment	Stabilisation	Recovery
Accumulated time error	5 seconds		
Non-contingency event or load event	49.75 to 50.25 Hz 49.85 to 50.15 Hz 99% of the time	49.85 to 50.15 Hz within 5 minutes	
Generation event or load event	49.5 to 50.5 Hz	49.85 to 50.15 Hz within 5 minutes	49.85 to 50.15 Hz within 5 minutes
Network event	49 to 51 Hz	49.5 to 50.5 Hz within 1 minutes	49.85 to 50.15 Hz within 5 minutes
Separation event	49 to 51 Hz	49.5 to 50.5 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
Multiple contingency event	47 to 52 Hz	49.5 to 50.5 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes

TYPES OF FCAS

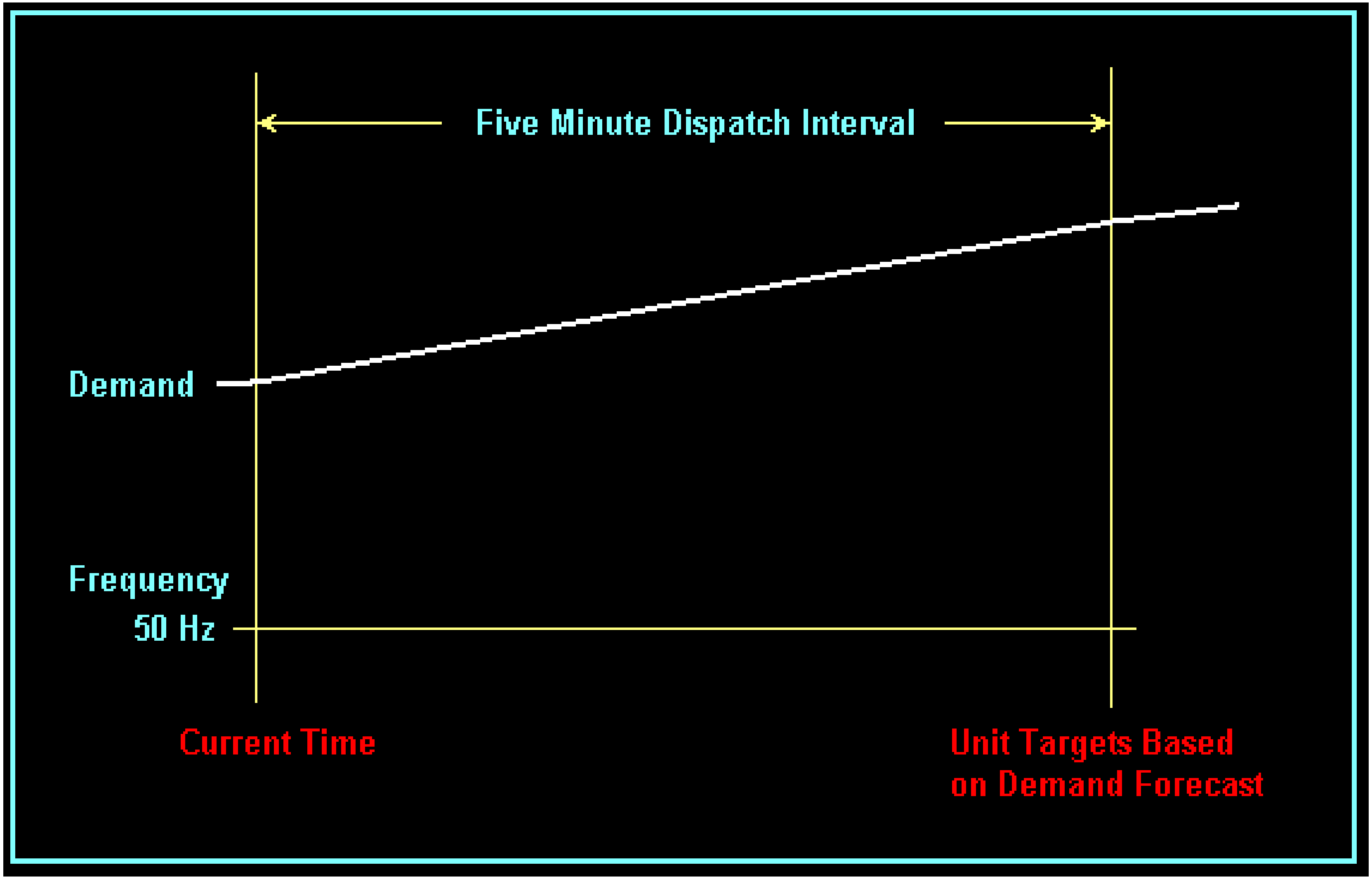
NEM		
Regulation	Raise	
	Lower	
Contingency	Raise 6sec	
	Raise 60sec	
	Raise 5min	
	Lower 6sec	
	Lower 60sec	
	Lower 5min	

WEM
LFAS
Spinning Reserve
Load Rejection

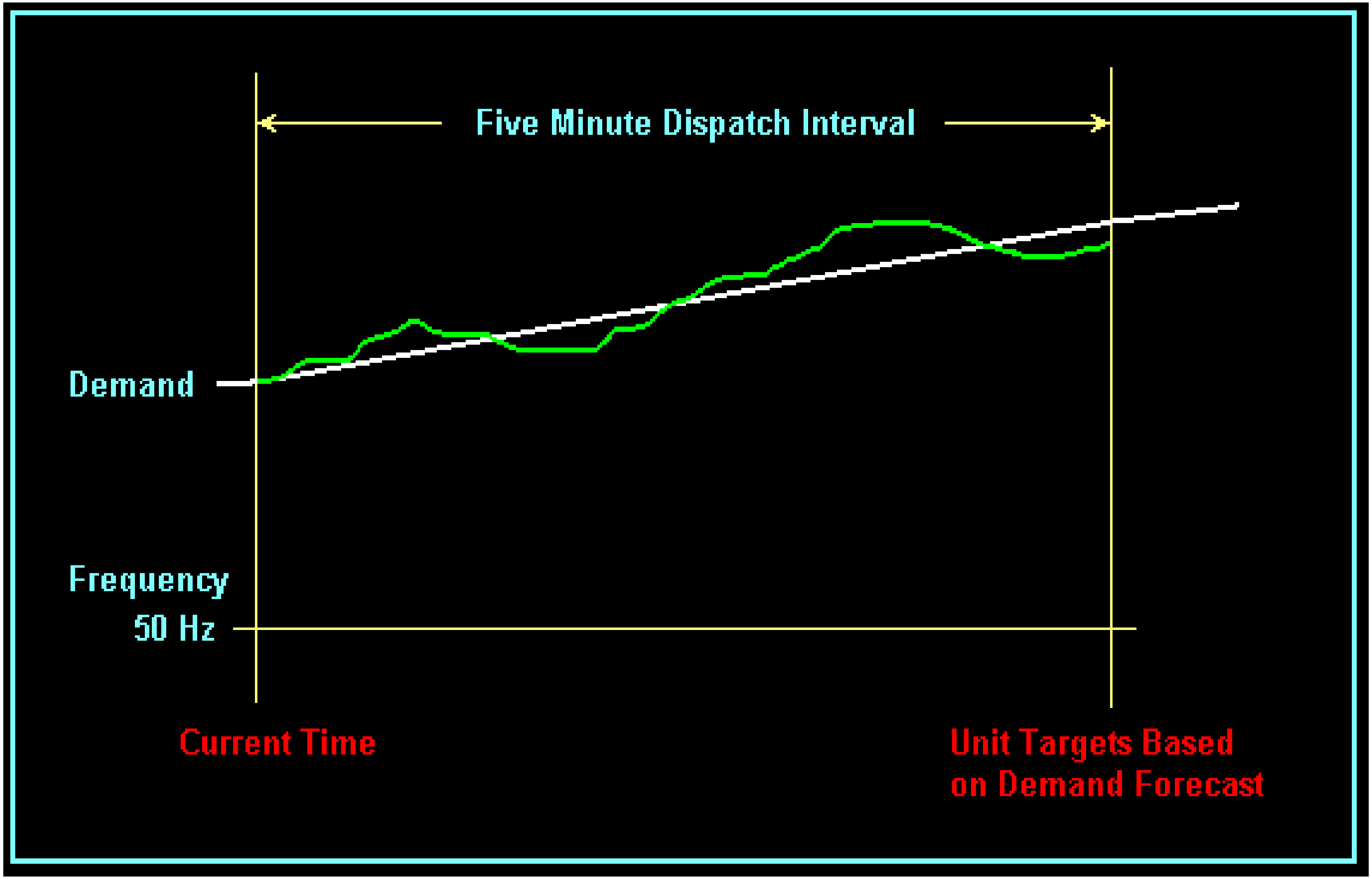
TYPES OF FCAS

- **Regulation FCAS (Raise and Lower):**
  - Corrects minor deviations in frequency (within normal operating band).
  - Centrally-controlled by AEMO using Automatic Generation Control (AGC).
- **Contingency FCAS (Raise and Lower):**
  - Corrects major deviations in frequency following a contingency event (outside normal operating band).
  - Locally controlled. Examples: Governor response, Load shedding.
  - Three (3) types:
    1. 6 sec Raise/Lower (Fast service): <u>Arrests</u> the immediate frequency deviation.
    2. 60 sec Raise/Lower (Slow service): <u>Stabilises</u> the frequency within the contingency band.
    3. 5 min Raise/Lower (Delayed Service): <u>Restores</u> the frequency back to normal operating band.

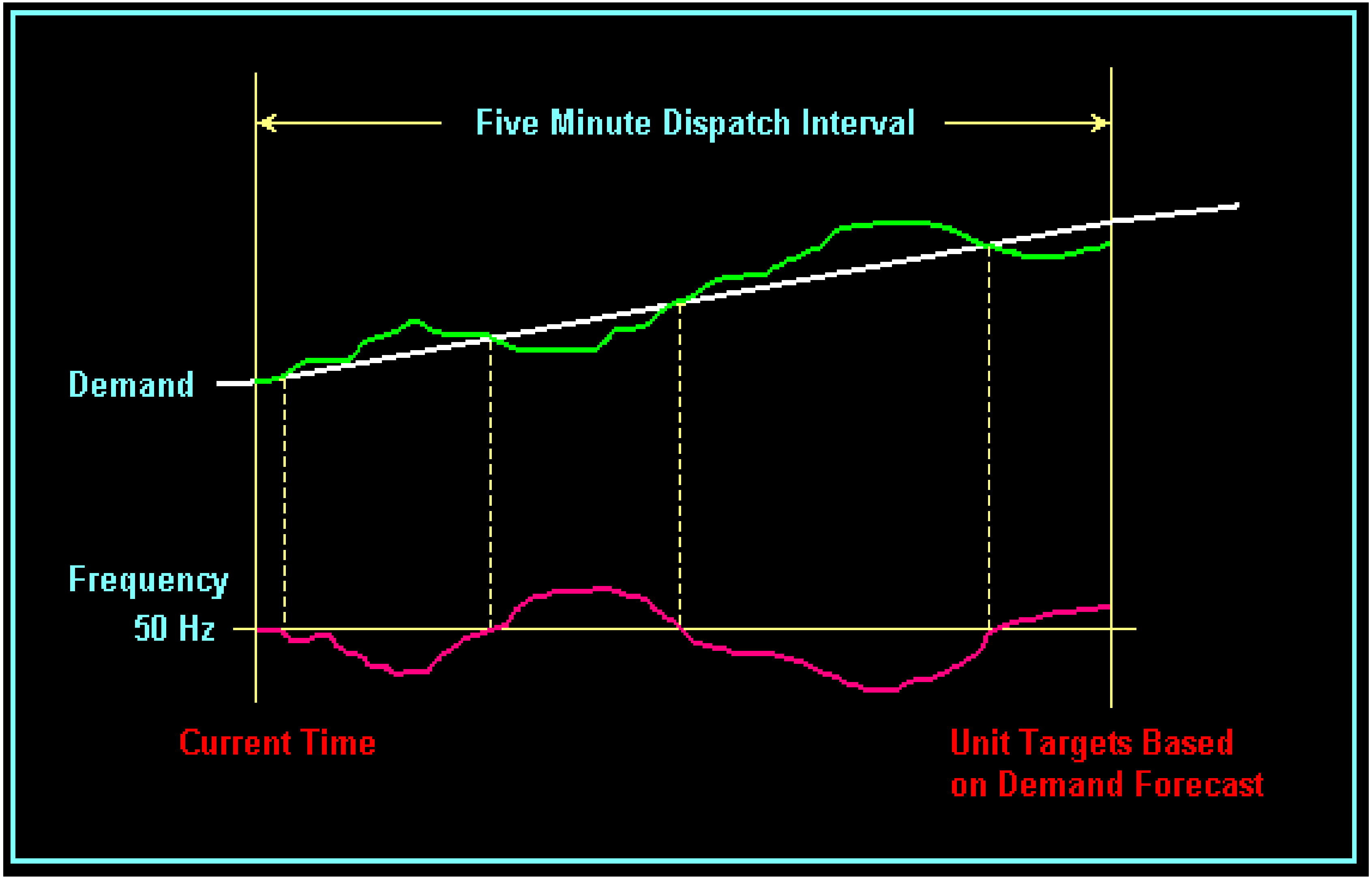
IDEAL LINEAR DEMAND



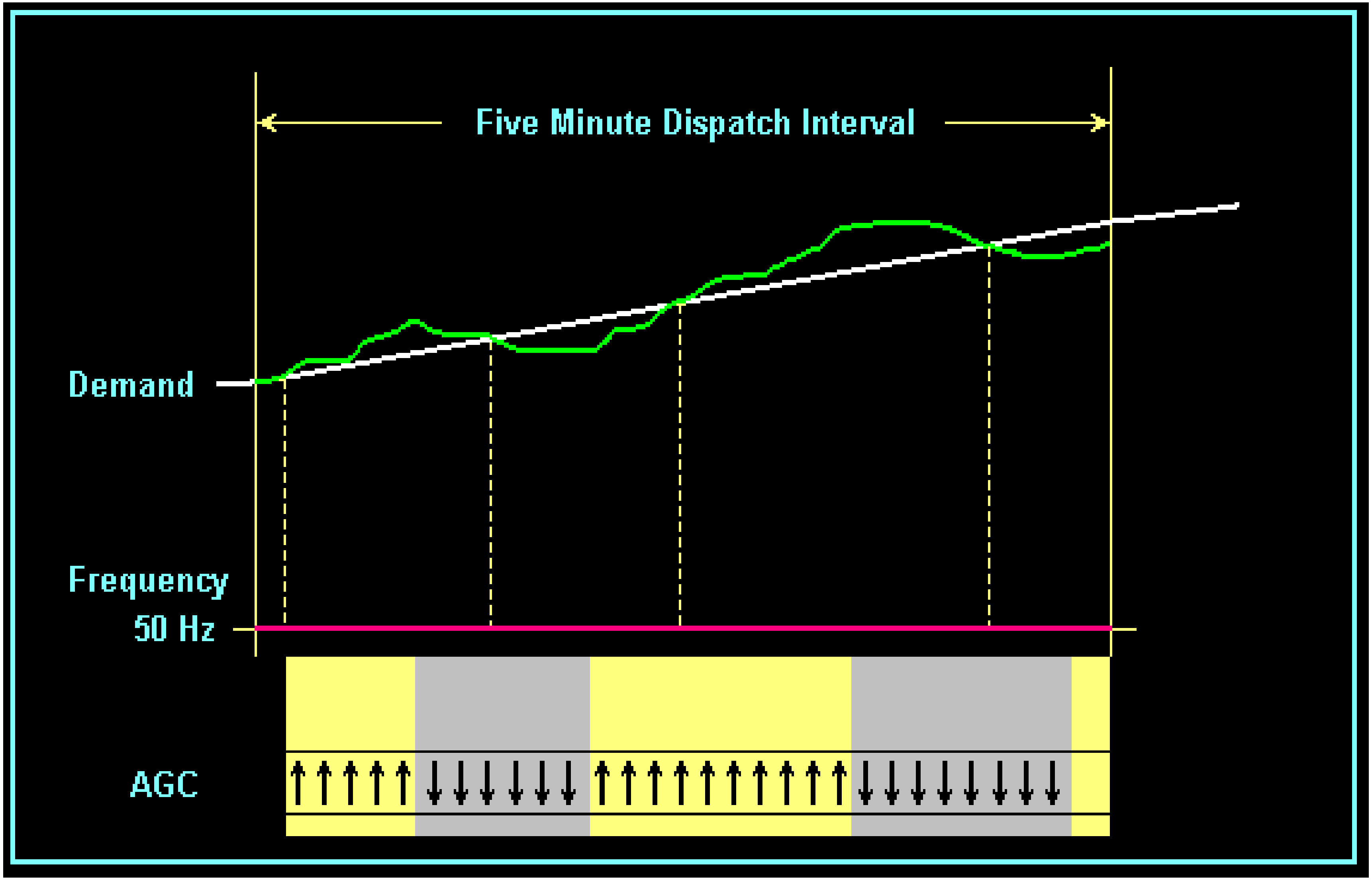
REAL DEMAND


Five Minute Dispatch Interval
Demand
Frequency
50 Hz
Current Time
Unit Targets Based
on Demand Forecast

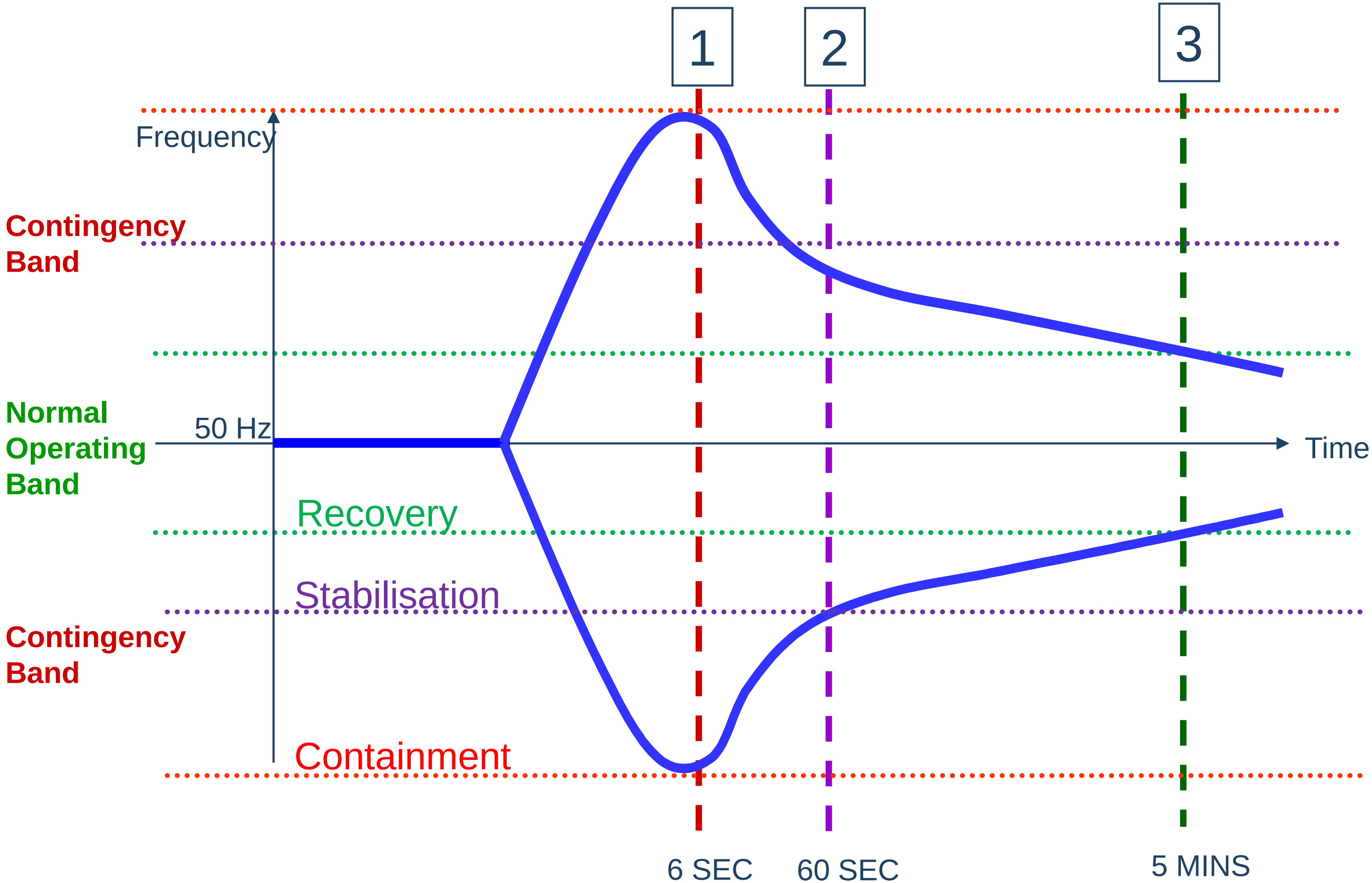
EFFECT OF DEMAND ON FREQUENCY



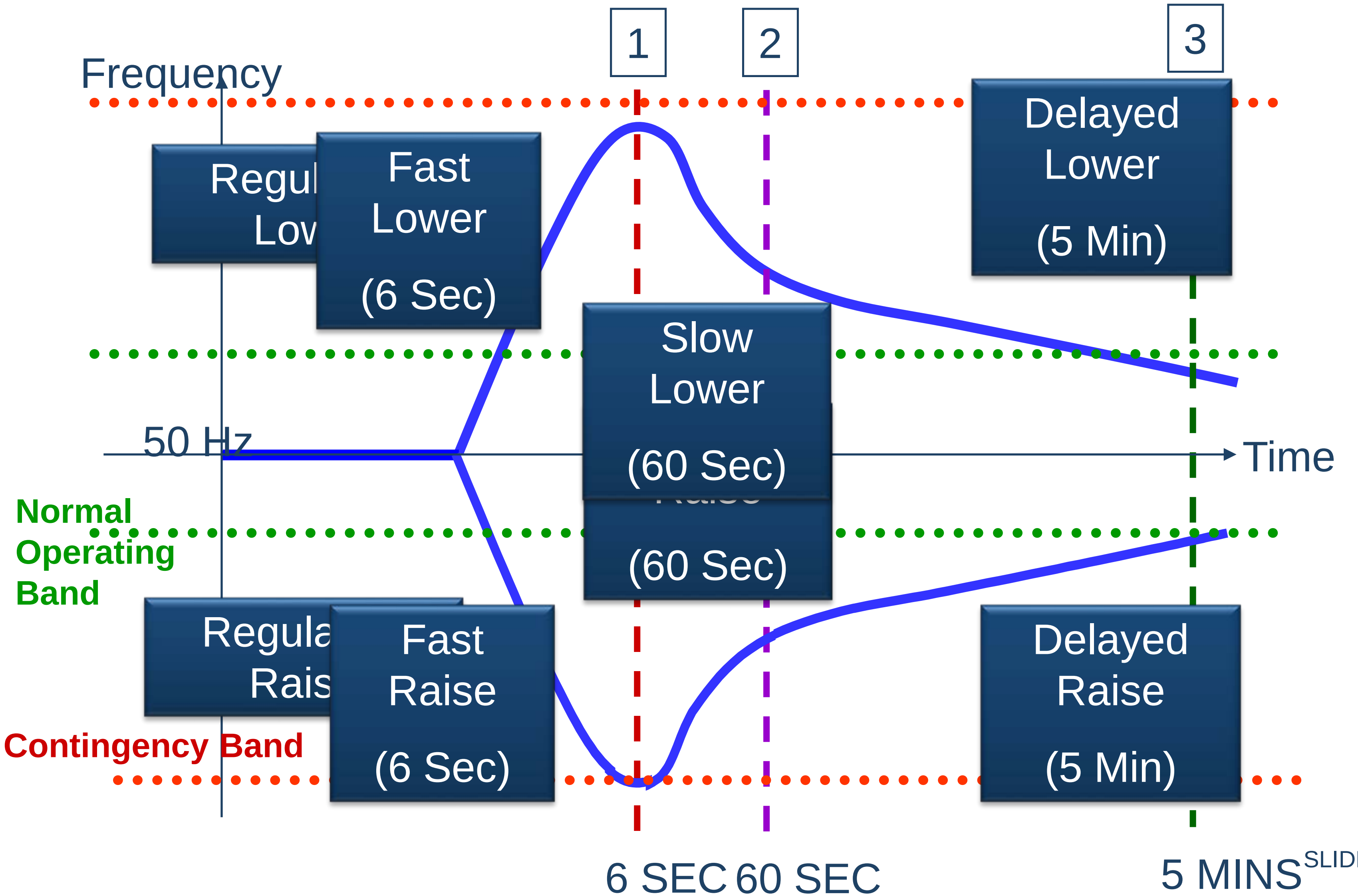
REGULAITON FREQUENCY CONTROL



CONTINGENCY STANDARDS



FCAS MARKETS



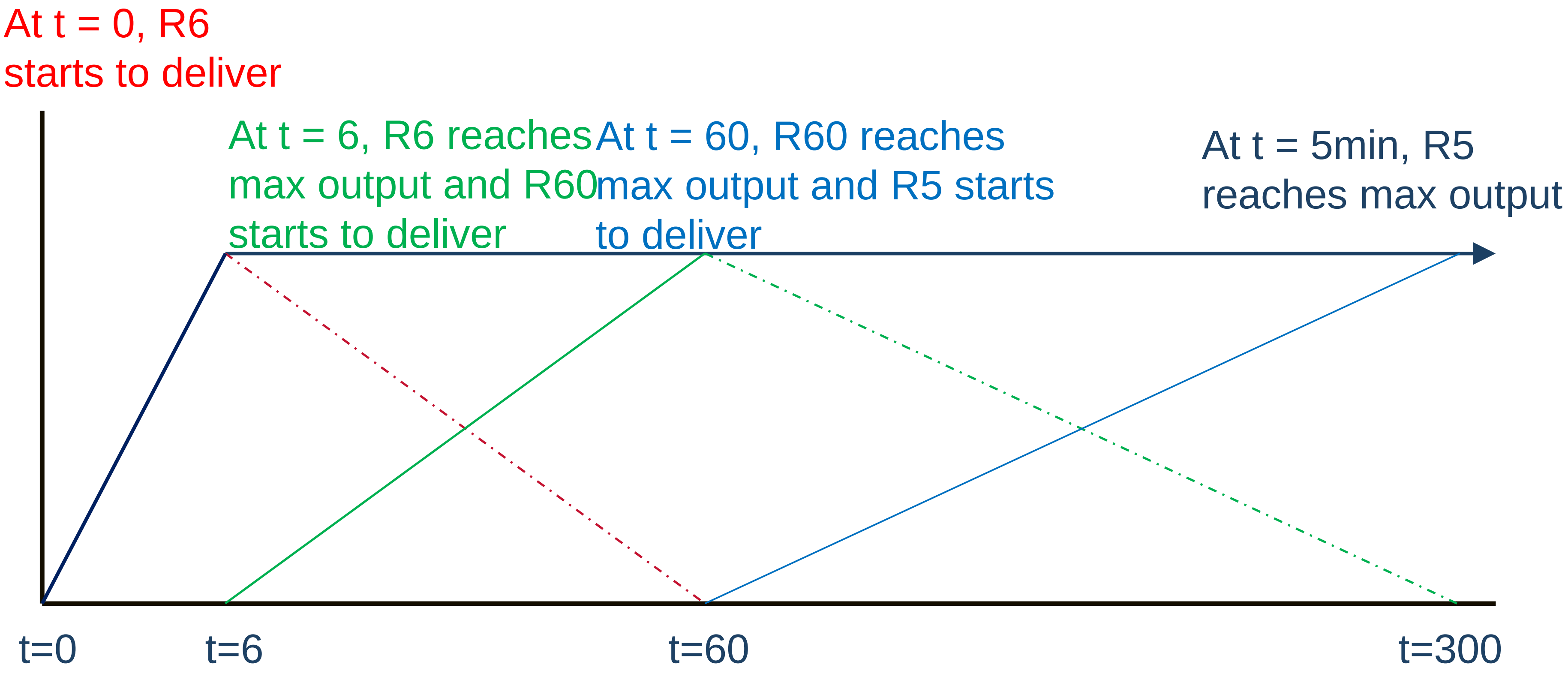
PARTICIPATE IN MORE THAN ONE FCAS MARKET?

Contingency FCAS

- Fast Raise/Lower (6s)
  - Between 0 and 6s to respond, and
  - Between 6s and 60s to sustain the response
- Slow Raise/Lower (60s)
  - Between 6 and 60s to respond, and
  - Between 60s and 5mins to sustain the response
- Delayed Raise/Lower (5min)
  - Between 1 and 5mins to respond, and
  - Between 5mins and 10mins to sustain the response

Details: Market Ancillary Service Specification (MASS)
https://www.aemo.com.au/-/media/Files/PDF/01600136pdf.pdf

HOW DOES IT WORK?



FCAS BID STRUCTURE

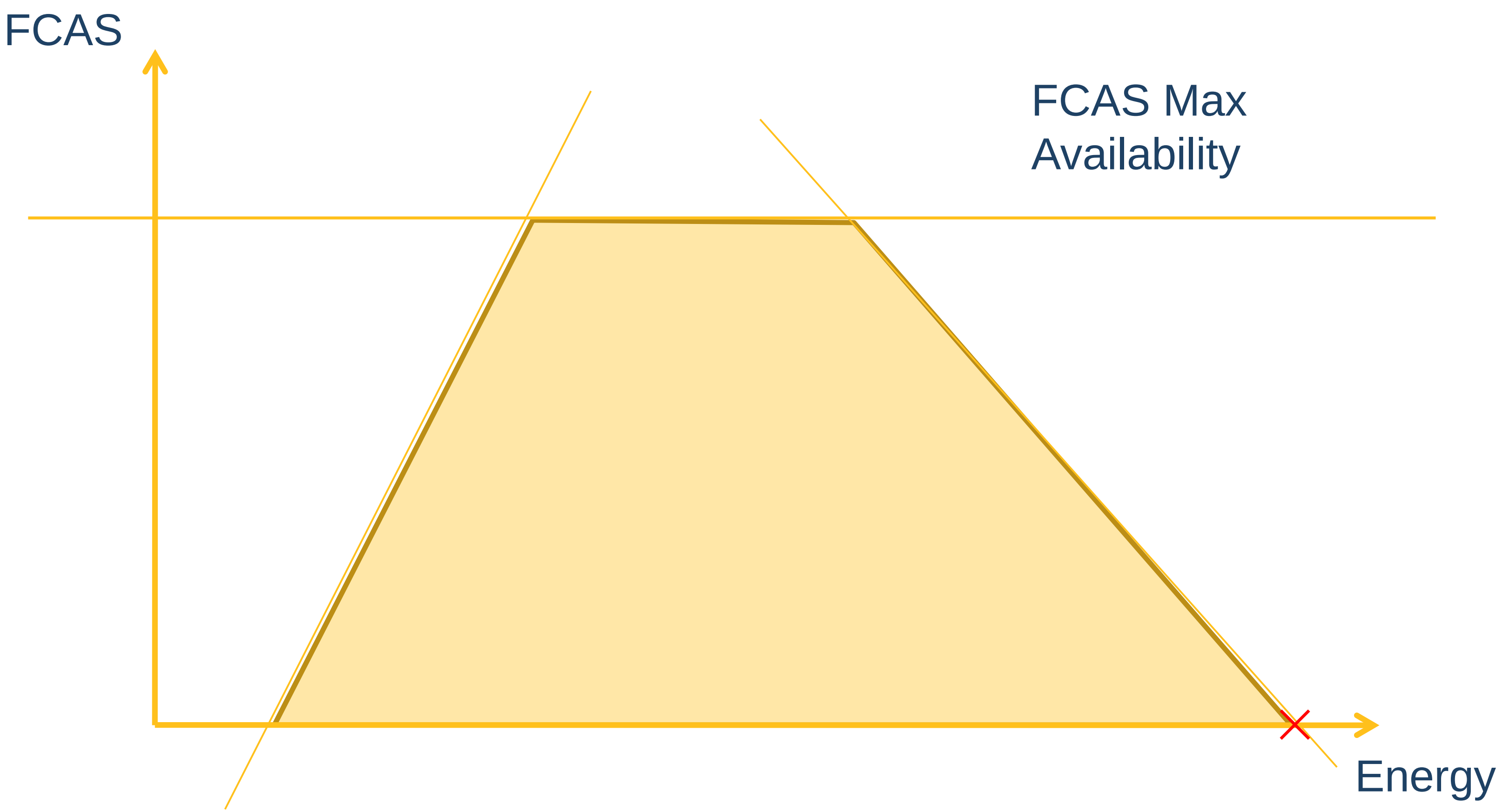
Band	1	2	3	4	5	6	7	8	9	10
Price ($/MW per hour)	0.01	0.35	0.50	6.80	20.80	48	618	1118	7198	12000
Quantity (MW)	13	8	4	12	4	4	4	6	6	5

FCAS offers can be up to 10 bands

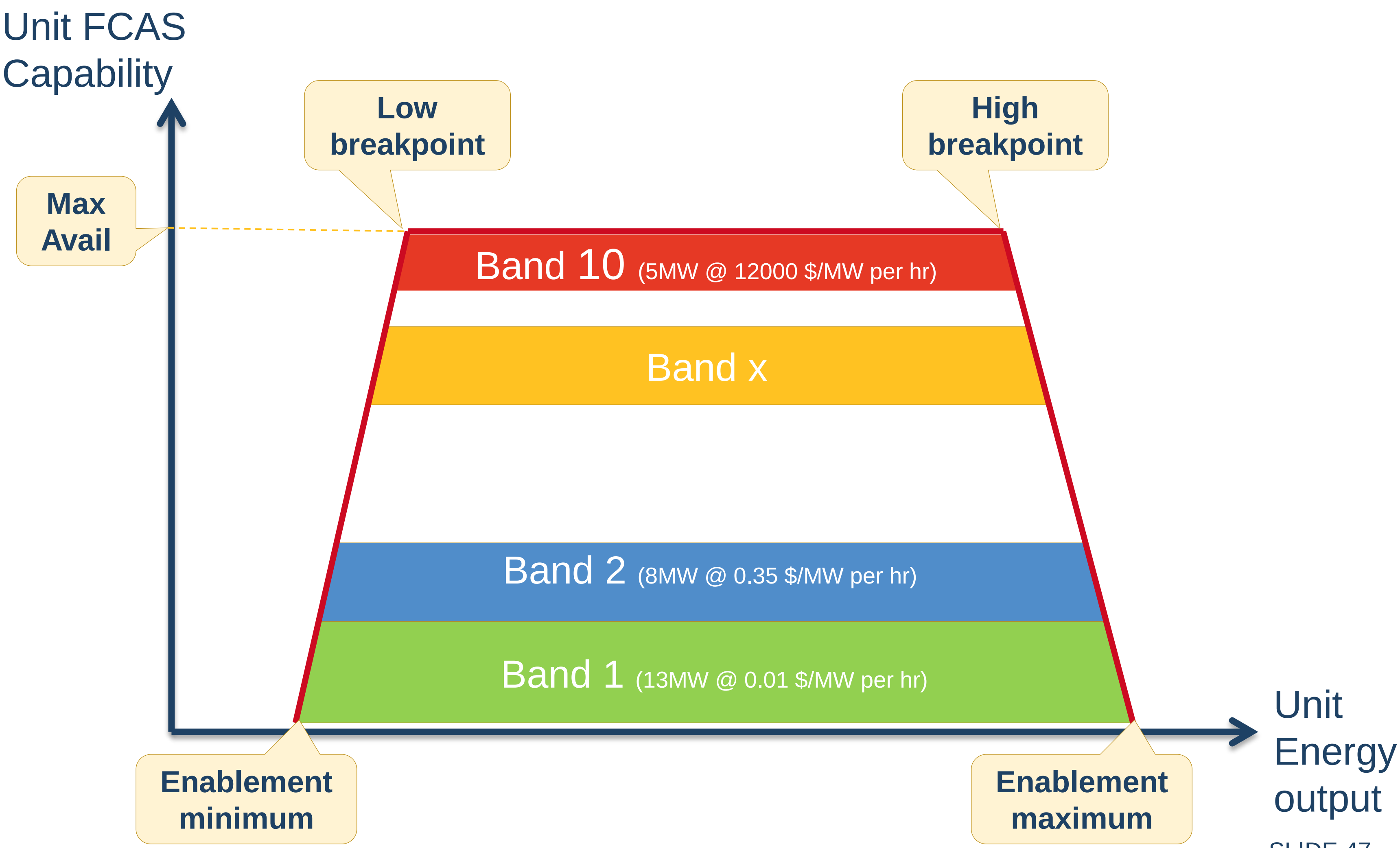
FCAS trapezium defines the FCAS-Energy capability curve

Max Availability	Enable Minimum	Enable Maximum	Low Break Point	High Break Point
66	234	690	300	581

UNIT FCAS CAPABILITY DIAGRAM: FCAS TRAPEZIUM

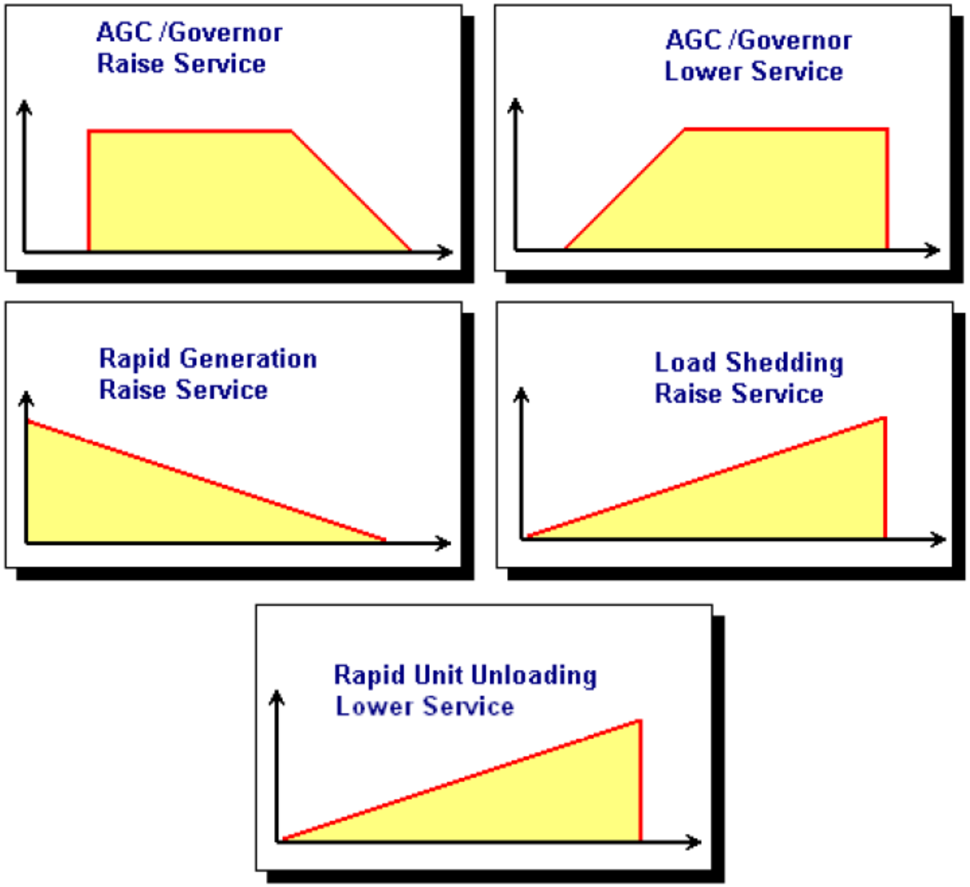


FCAS SUPPLY BIDS



FCAS TRAPEZIUM

Participants may provide multiple trapeziums for different services



LUNCH

OPTIMISATION AND CONSTRAINTS IN DISPATCH

SESSION OBJECTIVES

1. Optimisation in Dispatch
2. Constraint Types in Dispatch
3. Network Constraint Example

OPTIMISATION IN DISPATCH

OPTIMISATION IN DISPATCH
INTRODUCTION

- Objective function:
  - Cost of meeting forecast demand at lowest available cost
- Controllable variables:
  - Generation
- Complexity:
  - Multivariate solution space

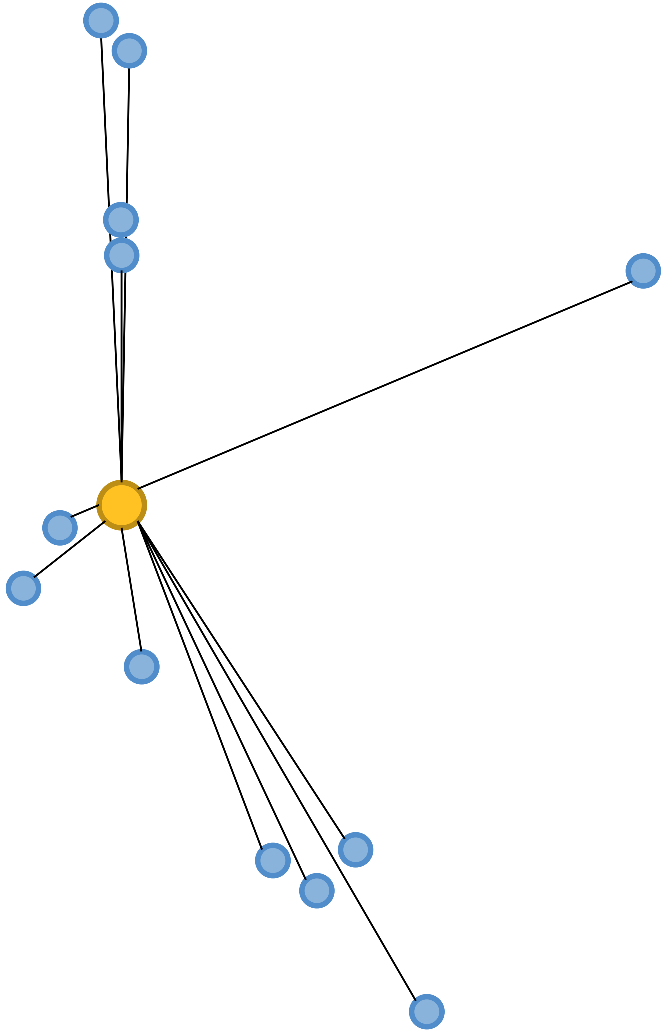
OPTIMISATION IN DISPATCH OBJECTIVE FUNCTION

- Cost of meeting demand at lowest available cost
  - Costs based on bids and offers
  - Losses in supplying demand at RRN
  - Must also meet FCAS requirements
  - Subject to network constraints

$$min\left\{\sum TraderVolumes * TraderPrices\right\}$$

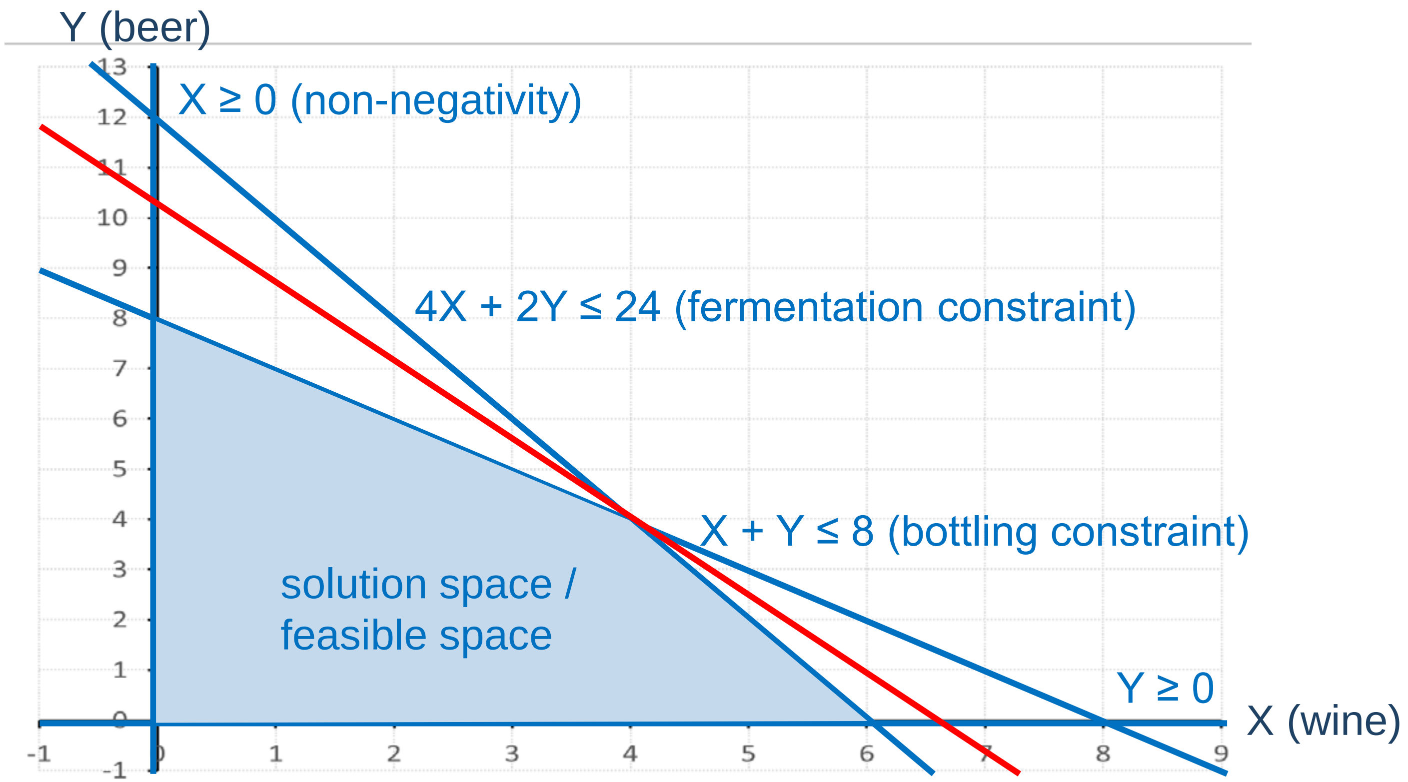
OPTIMISATION IN DISPATCH CONTROLLABLE VARIABLES

- Generation



OPTIMISATION IN DISPATCH COMPLEXITY

- Multivariate solution space



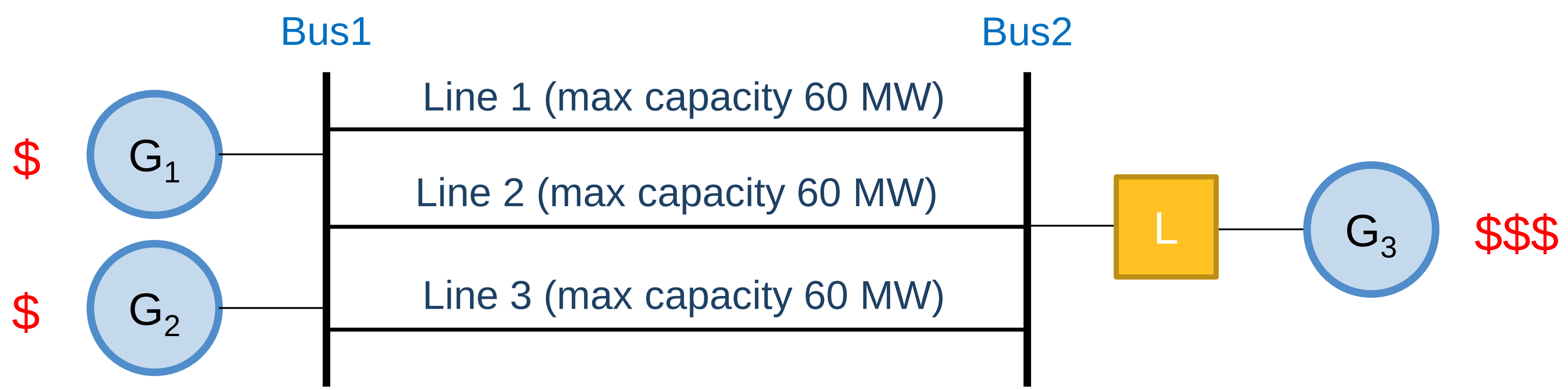
CONSTRAINT TYPES

CONSTRAINT TYPES IN DISPATCH OVERVIEW

- Network
  - Example
- FCAS
  - (Next session)
- “Intrinsic”
  - Maximum availability
  - Ramp rates
  - Non-negative generation

NETWORK CONSTRAINT EXAMPLE

NETWORK CONSTRAINT EXAMPLE



- Thermal network limits
- Security-constrained dispatch → manage failure of one line → maximum transfer from Bus1 to Bus2 of 120 MW
- Network constraint equation:

$$G_1 + G_2 \leq 120$$

IMPLICATIONS OF CONSTRAINTS

- Constrained on
  - A generator is dispatched in bands that are above the clearing price
- Constrained off
  - A generator is restricted even though bands are below the clearing pricing

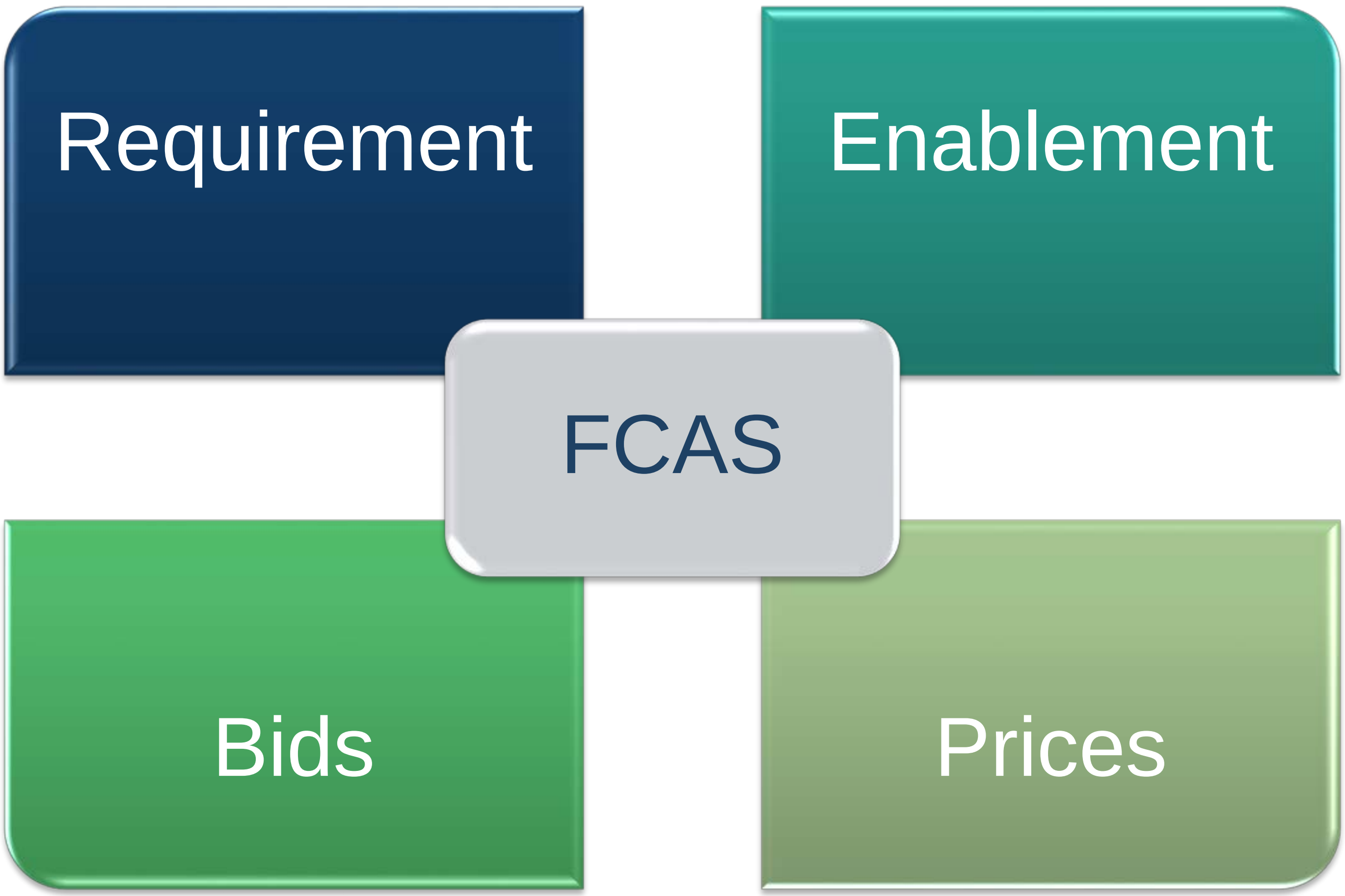
QUESTIONS?

ANCILLARY SERVICES IN DISPATCH

OBJECTIVES

1. FCAS requirements by constraints
2. FCAS dispatch and pricing
3. FCAS-Energy trade-off

FCAS MARKETS - BASICS



NEMDE

$$\text{Objective Function} = \sum_{\text{Generators Offers}} (\text{Dispatched Band MW} \times \text{Band Offer Price})$$
$$- \sum_{\text{Dispatchable Load Bids}} (\text{Dispatched Band MW} \times \text{Band Bid Price})$$
$$+ \sum_{\text{Ancillary Service Offers}} (\text{Dispatched Band MW} \times \text{Band Offer Price})$$

To maximise the value of spot market trade, NEMDE must minimise the objective function each time it runs.

NEMDE will choose the lowest priced available FCAS offers for dispatch first (*subjected to constraints*)

NEMDE CO-OPTIMISATION

- **All markets are optimised simultaneously**
  - No priority for energy
  - Sum of all costs are minimised
- **Generator can offer the same capacity in multiple markets**
  - With the capability information
  - Dispatch engine ensures the solution is technically feasible
- **Regulation can substitute for Delayed Contingency**
- **Dispatch engine may reduce the energy output to increase the headroom**
  - Increased FCAS availability from the unit
  - FCAS price calculation take the opportunity cost in the energy market into the consideration

FCAS REQUIREMENT

- Regulation – generally 130MW /120MW raise / lower in the NEM, 50MW for raise/lower in TAS
  - Linked to time error

- Contingency – to cover the largest credible contingency
  - Raise – loss of largest single generating unit
  - Lower - loss of largest single load
  - Special requirements - Loss of transmission lines under reclassification
  - Adjusted for load relief

FCAS REQUIREMENT CONSTRAINT

- Determine size of largest single generator/load that could be lost

- For each type of service (6 sec,60 sec,5 min) determine the amount of load relief available from the system based on the permissible frequency for that service.

- Subtracting the load relief obtained from the largest generator/load value gives the required amount of FCAS that will need to be procured in each timeframe.

- EXAMPLE:

  WEM(R6SEC) >= Largest Gen – Load Relief

NETWORK VS. FCAS CONSTRAINTS

Network Constraints

LIMITATIONS OF
THE NETWORK

CONSTRAINTS USED
TO ENSURE NETWORK LIMITS
ARE NOT SURPASSED

FCAS Constraints

REQUIREMENTS OF
THE POWER SYSTEM

CONSTRAINTS USED
TO ENSURE MINIMUM
FREQUENCY REQUIREMENTS
ARE MET

***The Marginal Price* for a market ancillary service** **=** Change in Objective Function resulting from a 1MW increase in the requirement

For Market Ancillary Services there is a difference between Regional Service Prices and Constraint Marginal Prices

FCAS PRICING

- The ancillary service price is set by a regional increment in requirement (as opposed to the constraint based increment)
- Sum of different price components set the regional FCAS prices

The price in a region for any FCAS is equal to the sum of the marginal prices of all constraints for that service encompassing that region

EFFICIENT DISPATCH OF REGULATION AND DELAYED CONTINGENCY

For Regulation requirement of X

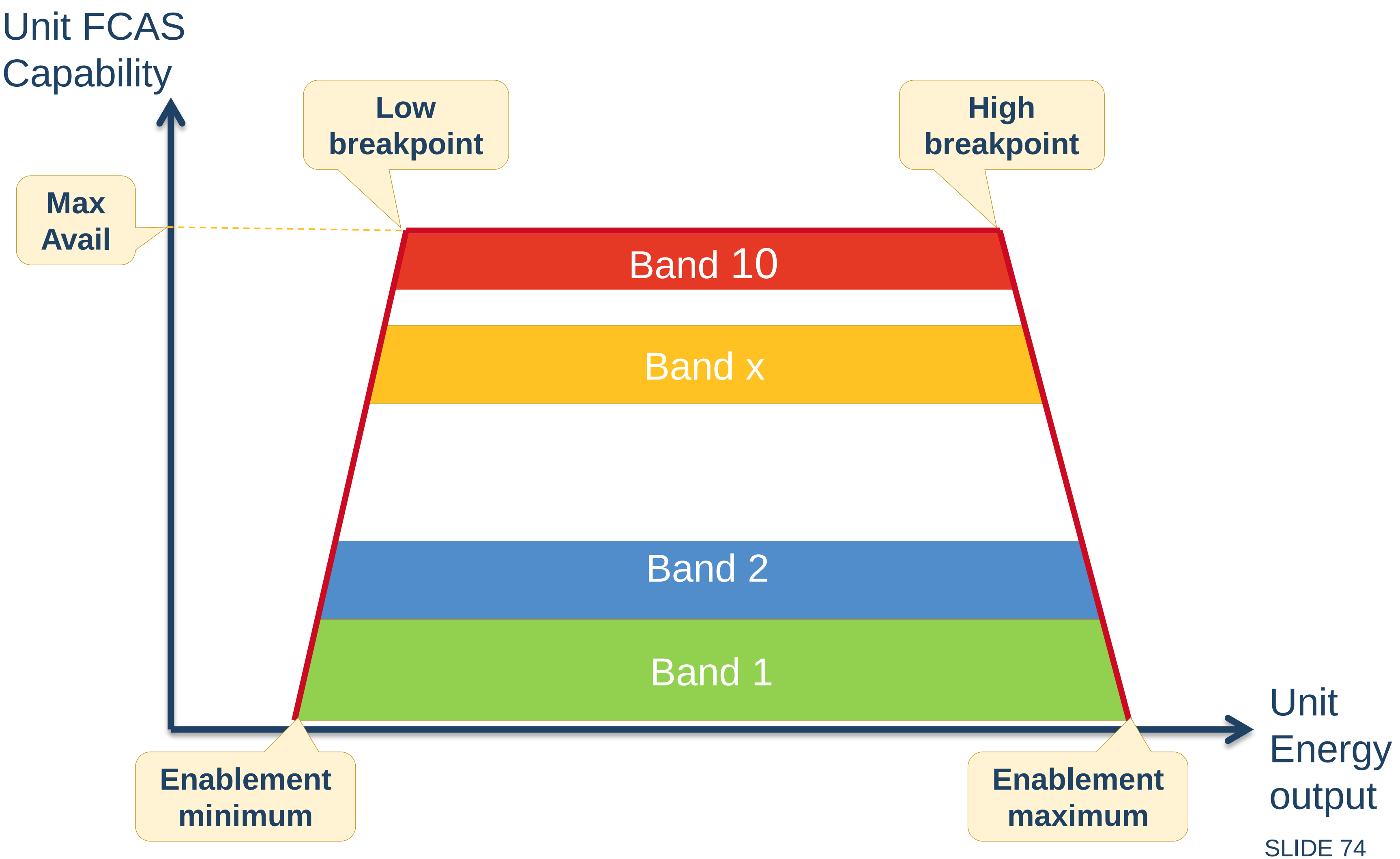
and Delayed Contingency requirement of Y

- Constraint Equation and Marginal Value

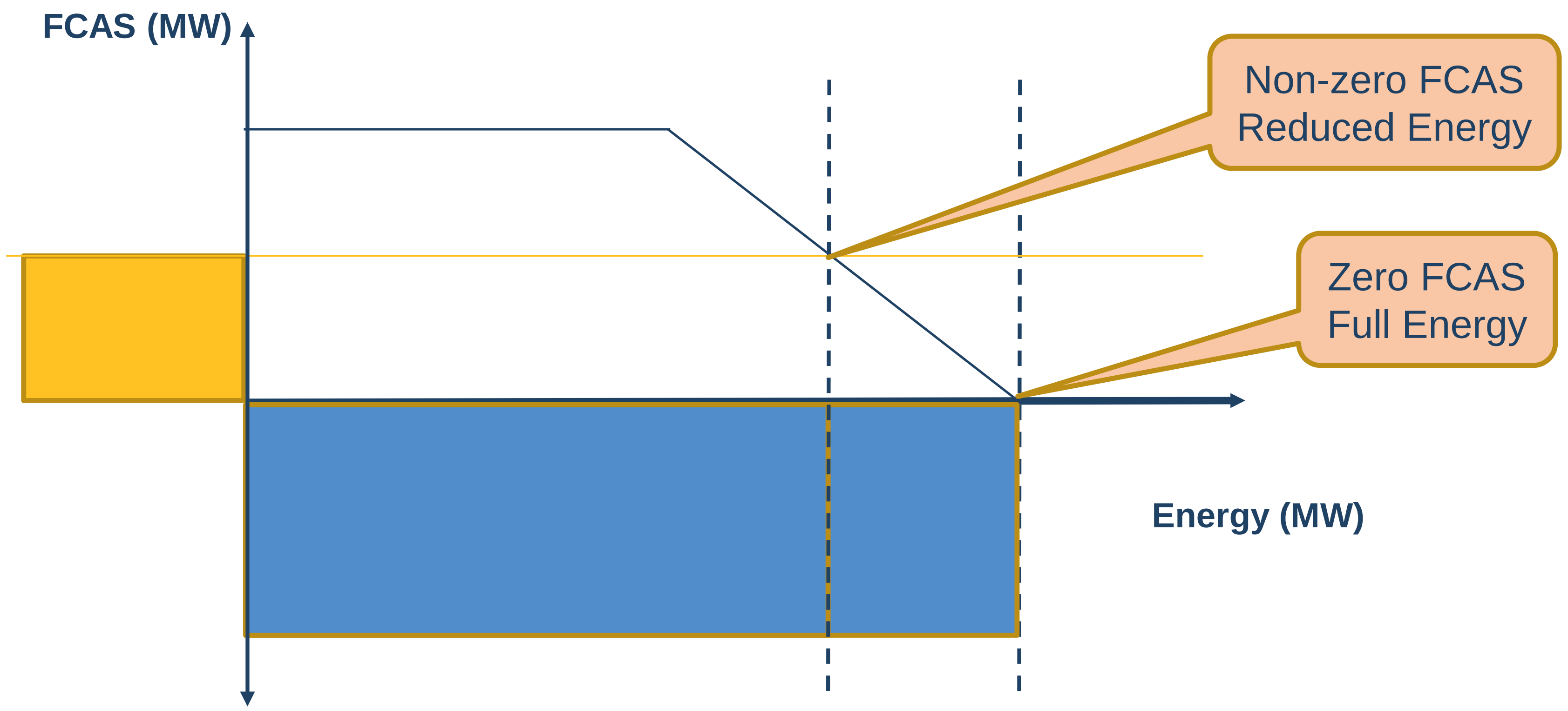
Constraint	MV
Regulation >= X	$\$ \alpha$
Regulation + Delayed Contingency >= Y	$\$ \beta$

- FCAS Prices
  - Reg Price = $\$ \alpha + \$ \beta$
  - Del Cont Price = $\$ \beta$

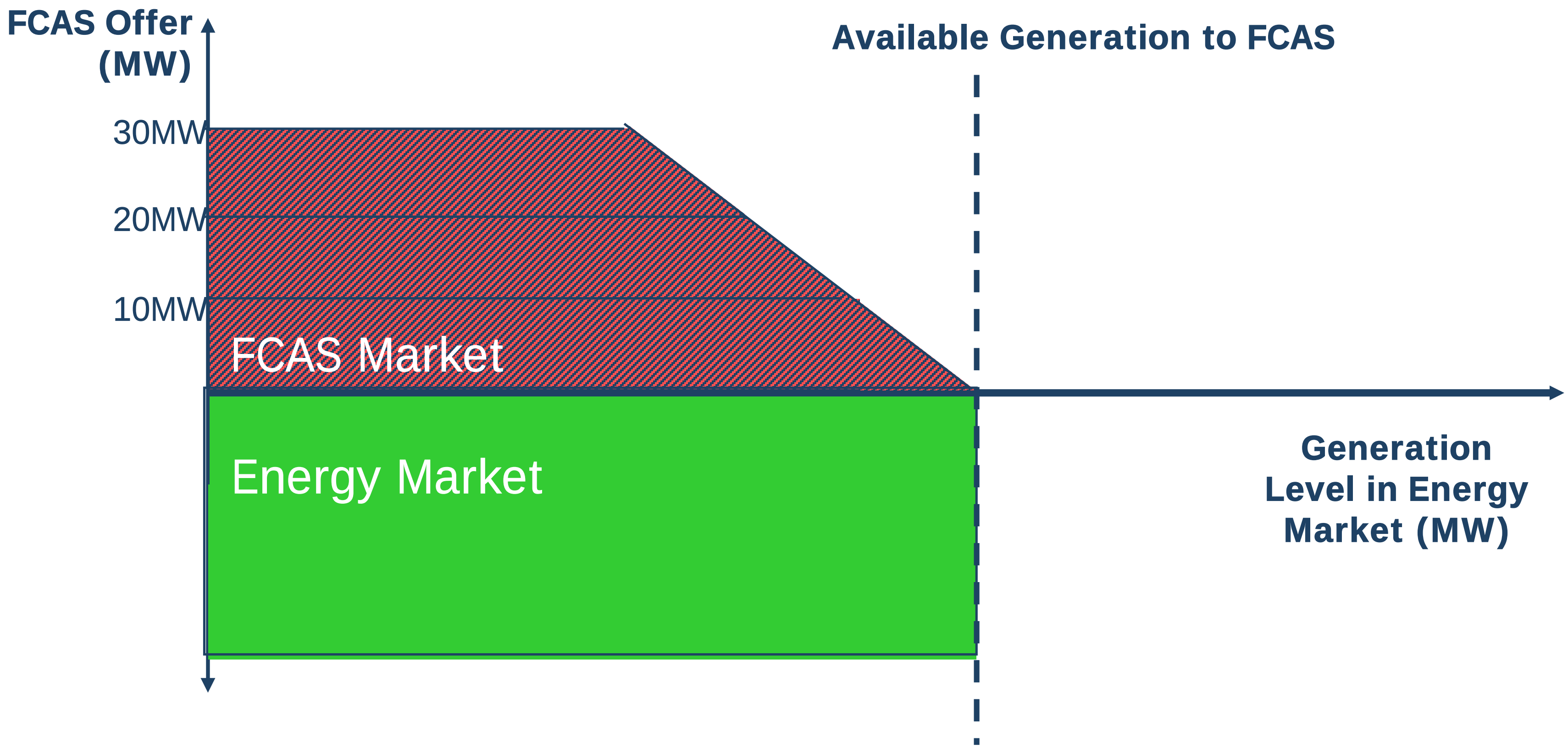
FCAS TRAPEZIUM - NEMDE INTRINSIC CONSTRAINTS



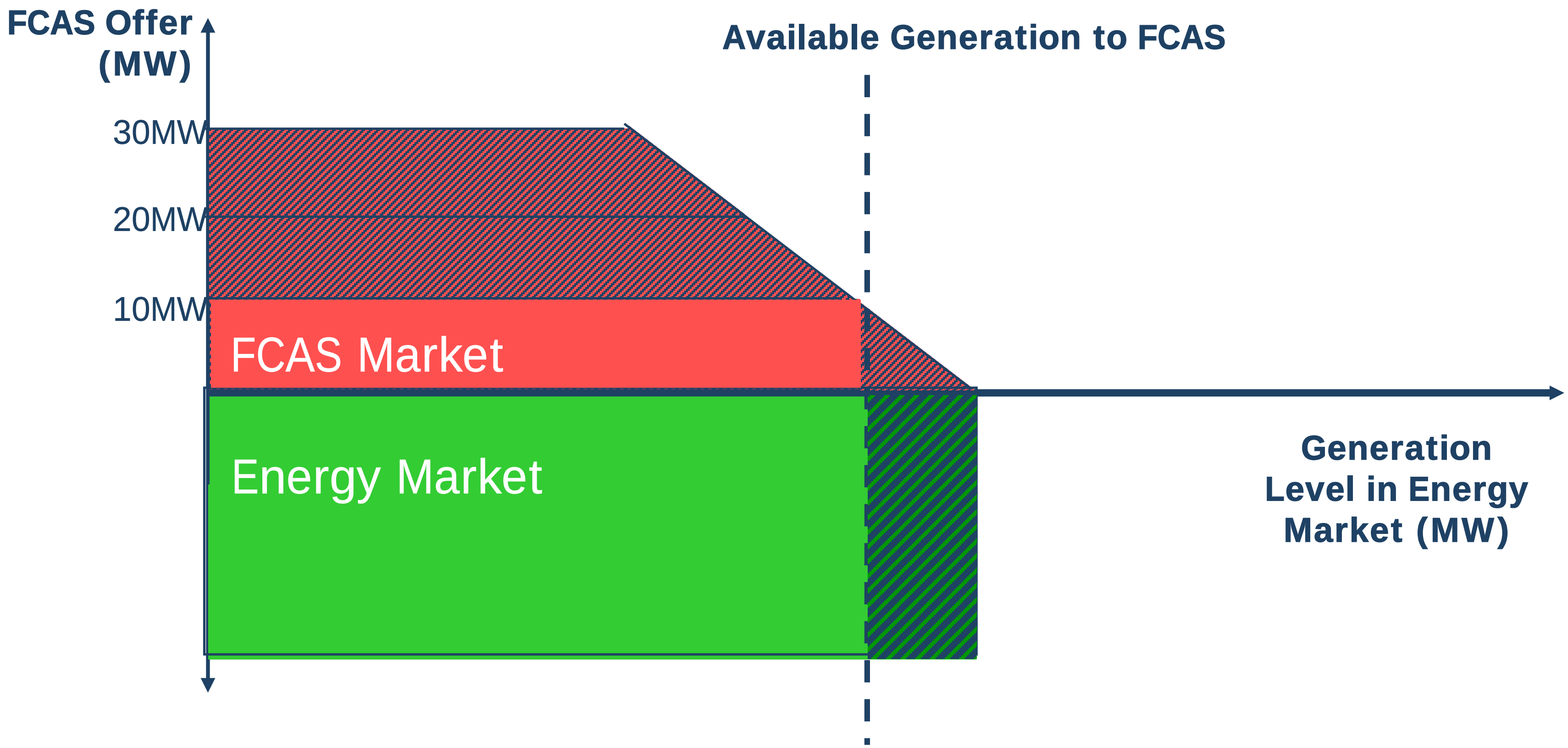
Co-optimisation of FCAS and Energy



CO-OPTIMISATION - EXAMPLE



CO-OPTIMISATION - EXAMPLE



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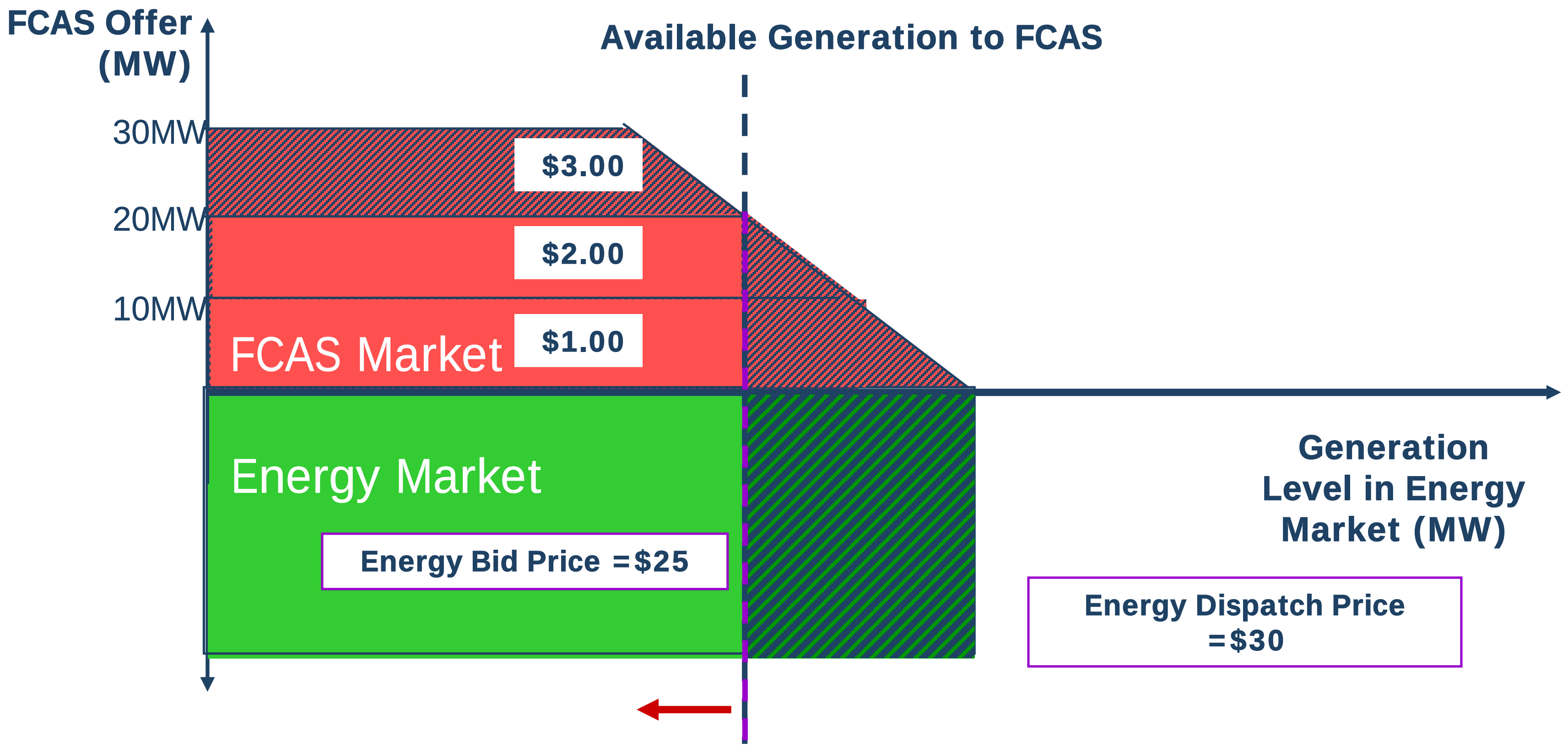
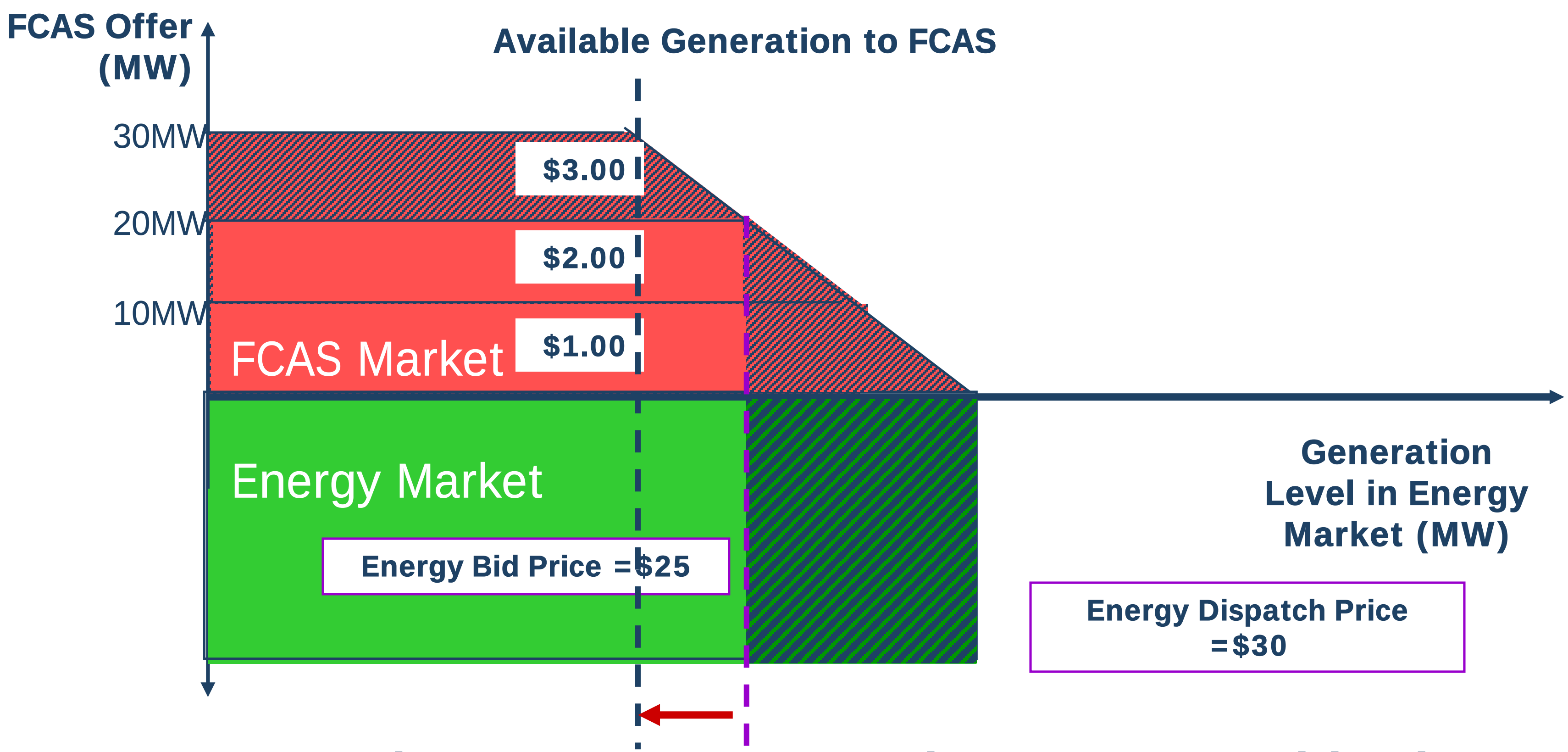
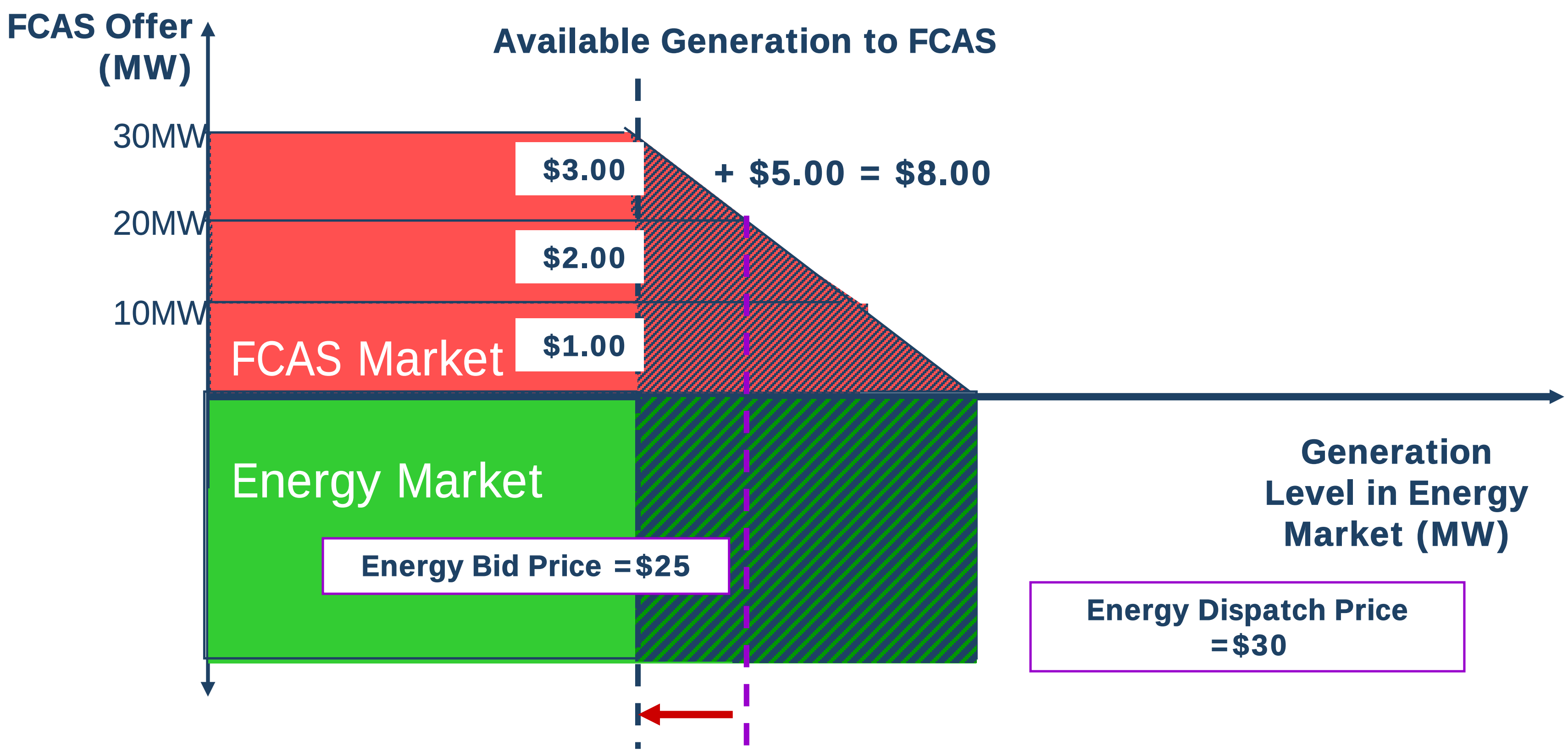


CO-OPTIMISATION - EXAMPLE



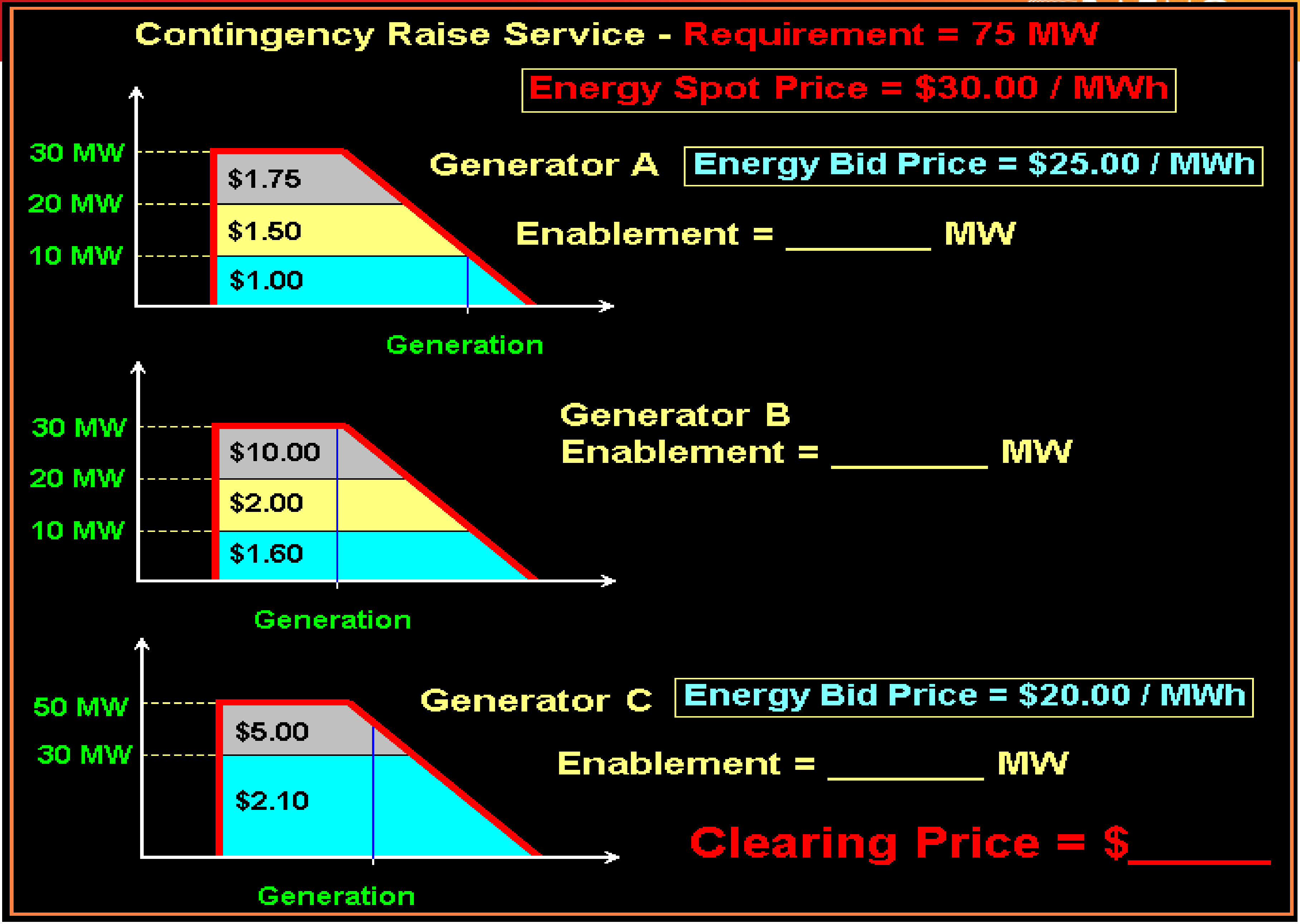
- **Compensation = Energy Spot Price – Energy Bid Price = 30 – 25 = $5**
- **Adjusted FCAS Offer Price = $3 + $5 = $8**

CO-OPTIMISATION - EXAMPLE



- **FCAS Clearing Price >= $8**

FCAS DISPATCH EXAMPLE



APPROACH TO REGISTRATION

WA WHOLESALE ELECTRICITY MARKET

Generation

- Total registered generation about 5800 MW
- Around 70 individual units and wind farms
- Expecting up to 30 registered participants
- 98.5% above the 10 MW threshold for being scheduled

Customers

- Can be retailers or end users
- Expecting about 20 registered Market Customers

Network Service Providers

- Western Power to be both TNSP and DNSP

WA Specific Categories

- Nothing concrete yet as to how these will fit into the new framework

Currently 2 WA participants also registered in the NEM

TRANSLATION

WEM	NEM
Network Operator	Network Service Provider – transmission or distribution
Market Generator	Market Generator Non-Market Generator Scheduled Generator Semi-scheduled Generator Non-scheduled Generator
Market Customer	Market Customer
Ancillary Service Provider	N/A
Rule Participant	Registered Participant
Scheduled Generator	scheduled generating unit
Non-Scheduled Generator	semi-scheduled generating unit
-	non-scheduled generating unit
Dispatchable Load	scheduled load
Interruptible load, demand side program	No direct equivalent

SOME NEM CONCEPTS

- We register ‘entities’; we classify ‘facilities’
- So:
  - XYZ Generation Pty Ltd – registered as a Market Scheduled Generator
  - Xyz Power Station Unit 1 – classified as a market scheduled generating unit
- Owner, controller and operator are required to register
  - Typically the same person, but can be different
  - Owner – company which has the asset on its balance sheet
  - Controller – company that sets targets and strategies
  - Operator – company that does the physical operation
  - Can appoint one of these as an intermediary to take on the registration obligations

NEM GOVERNANCE

- AEMO is exercising a statutory, regulatory function
- Primary eligibility test is AEMO must be satisfied an applicant can comply with the rules.
- Formal delegation of authority to a Participant Registration Committee.
- Application process requires supporting evidence…

NEM SUPPORTING EVIDENCE

Supporting Evidence

- Supporting evidence requirements are generally category specific – some common across categories e.g. eligibility
- Guidelines and checklists available on AEMO's website
- Registered Participants published on AEMO's website

Examples of Supporting Evidence that may be Required

- Letter of authority where AEMO required to liaise with consultant or other 3rd party
- Evidence of partnership status
- Copies of trust deeds
- Copies of jurisdictional licences
- Audited financial statements
- Organisation chart
- Details of non-compliances
- List of policies and procedures in place
- Brief resumes of key personnel with relevant skills
- IT systems to support NEM activities
- Austraclear Account – ASX (Can take up to 6 weeks to set up)
- Credit support
- Details of links with parent companies
- Generator Performance Standards
- Local Black Start Procedures

STAGES OF NEM ONBOARDING

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	STAGE 6
Pre-application	**Application received**	**5 Day Outstanding sent to Applicant**	**Monitor outstanding items and PRC**	**Post PRC decision activities**	**Go Live**
Applicant contemplates registration	AEMO teams commence initial assessment	AEMO provides Applicant with list of outstanding items	Applicant and AEMO interact to satisfy outstanding requirements	System changes implemented	Participant ready to commence market participation
Commences enquiries			Once final outstanding item received, 15 business days for PRC to consider	IT systems tested and in place	

WAMRP READINESS APPROACH

- Five broad stages
  - Gap analysis of WEM vs NEM data requirements
  - Translation
  - Review
  - Final review, submission, interim approval
  - Approval
- Funded through the project (no registration fee, for example).
- Participant data from the Market Participant Interface has been imported into a prototype version of the NEM central dispatch process.
- An initial straw man generation registration list has been distributed to current WA participants.

NEXT MEETING AND CLOSING

NEXT STEPS

- Next meeting: 13 December 2016
  - Topic suggestions?
- Meeting schedule for 2017
- Any other suggestions or comments?

MORE INFORMATION

- Website: http://www.aemo.com.au/Stakeholder-Consultation/Industry-forums-and-working-groups/WA-Forums/WAMRP-Real-Time-Market-Forum
- Email: WAMRPWholesale@aemo.com.au
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