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Benefits of Early-Stage Systems Engineering for Complex Energy Decarbonisation Projects

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Overview

- Context for Decarbonisation
- Complex Energy Dearbonisation (CED) Systems
- CED System Modelling & Analysis
  - Approach
  - Skills
  - Environment
- Examples of Austere DE Approach to CED Systems
- Conclusion

Context

- Challenge of Climate Change
- Australia has mandated for Net-Zero greenhouse gas emissions by 2050
- This will require a major investment
  - Estimated at $100s of billion up to $7 Trillion [1]
  - i.e. 10% of GDP for next 25 years
- Large and growing number of CED projects
  - Ranging from $10s of millions to $10s of billions
- Projects often undertaken
  - With limited whole-of-system understanding
  - Using overly optimistic assumptions
  - With a focus on subsidies
- High potential for wasted time, effort and resources

[1] Net-Zero Australia, 2023

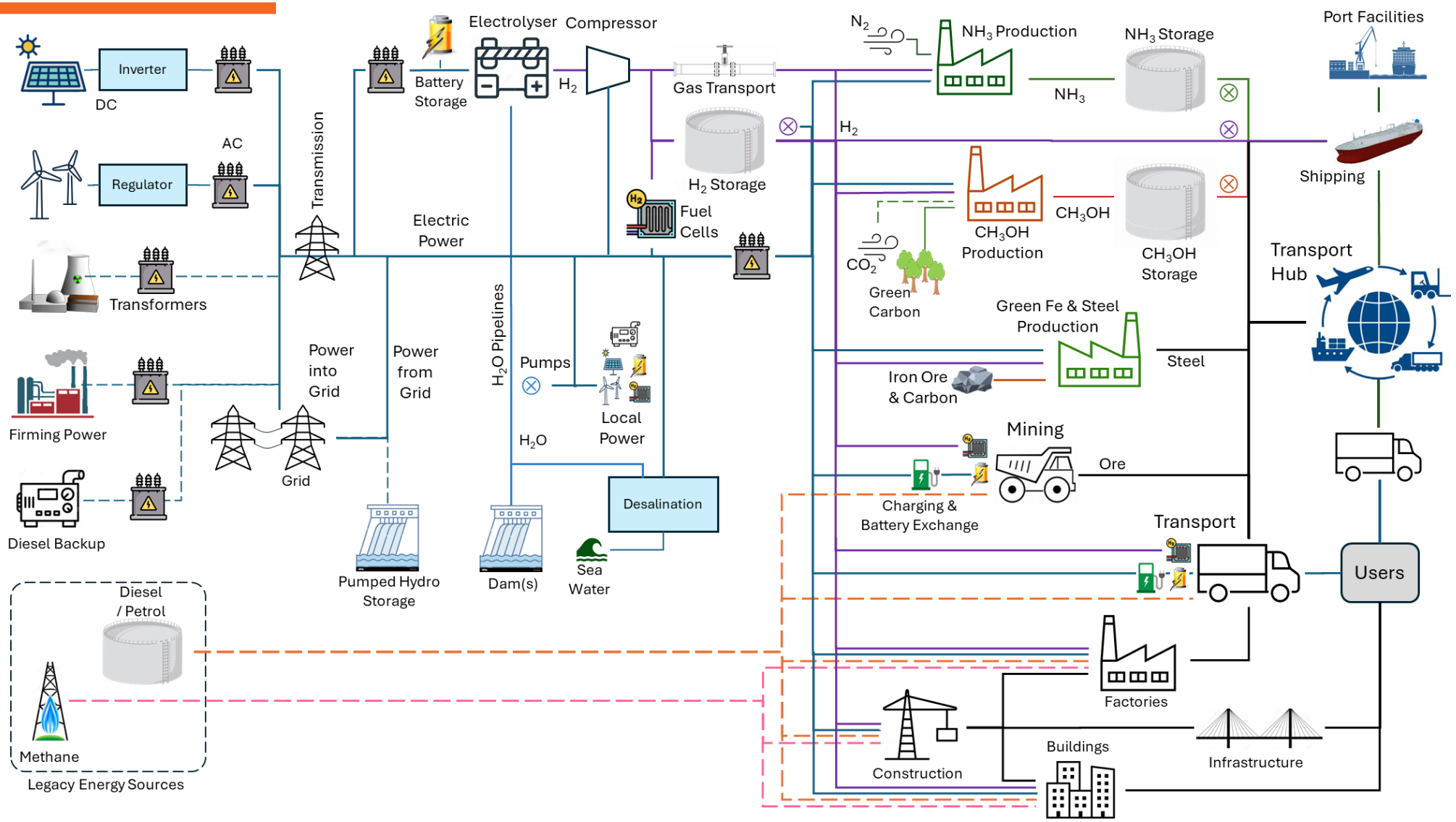
Opportunity for Systems Engineering (SE)

- CED systems and projects need SE for:
  - Advice to government departments
    - Whole-of-system understanding
  - Advice to investors
    - Understanding risks and opportunities
    - Support to decision-making
  - Through-life support
    - Early-stage design and trade-off analysis
    - Realisation of CED system
    - Whole-of-life consideration

- Government agencies and large corporation undertake internal modelling and analysis
- SE support by SMEs is currently emergent
- **Creates a business opportunity for SMEs – if cost effective**
  - Supporting the large number of CED projects
  - Harnessing and realising opportunities
  - Reducing risk and wasted resources

Complex Energy Decarbonisation Systems

Scope of CED Systems



CED Project Stages

- Key stages in CED Project
  1. **Feasibility Studies**
  2. **Conceptual Design**
  3. **Pre-FEED**
  4. **FEED**
     - Front End Engineering Design
  5. Detailed Design
  6. Procurement and Fabrication
  7. Construction and Installation
  8. Pre-Comm
  9. Handover
- Mapped on standard lifecycle models
- Focus of work is up to FEED stage

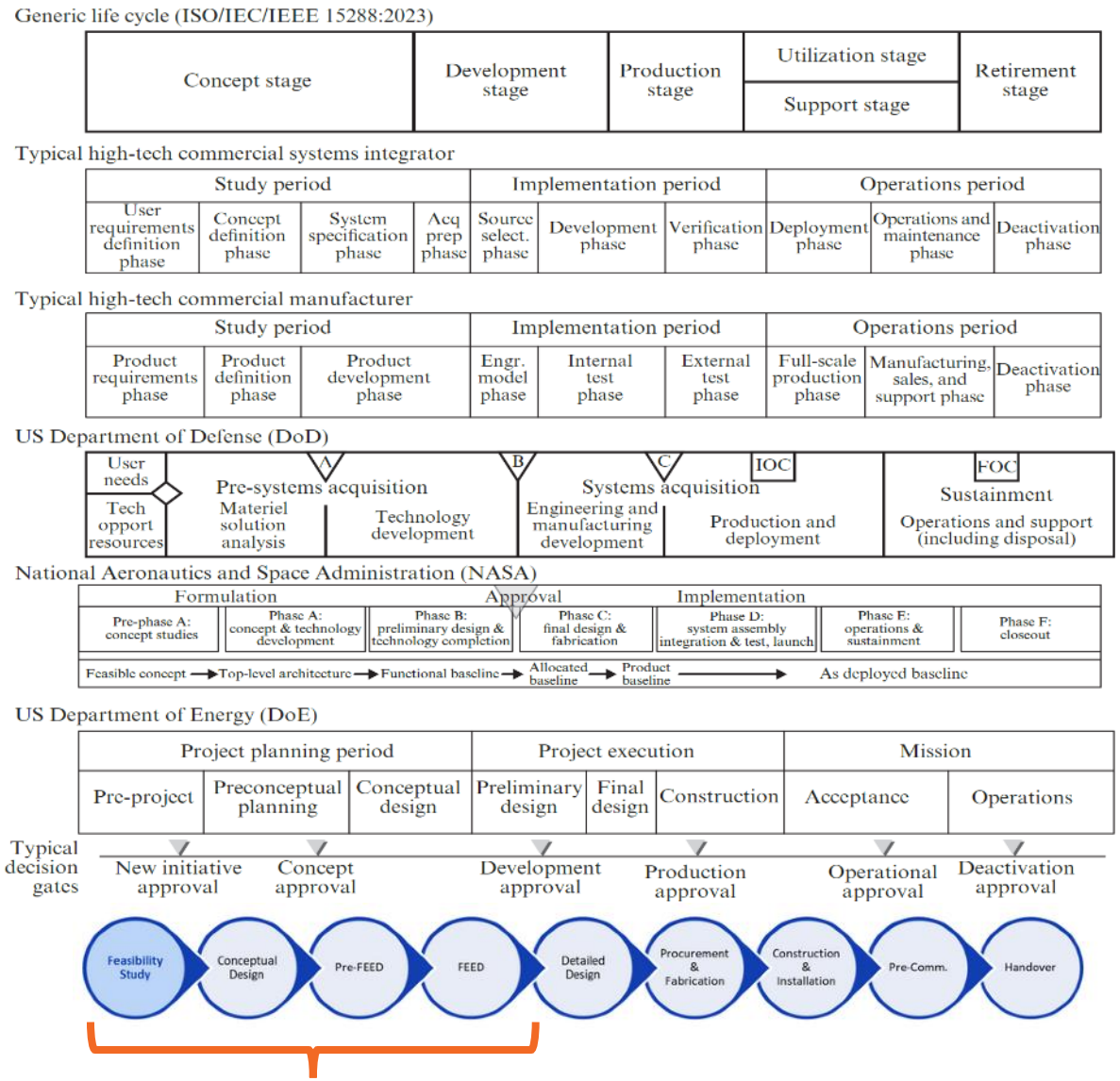
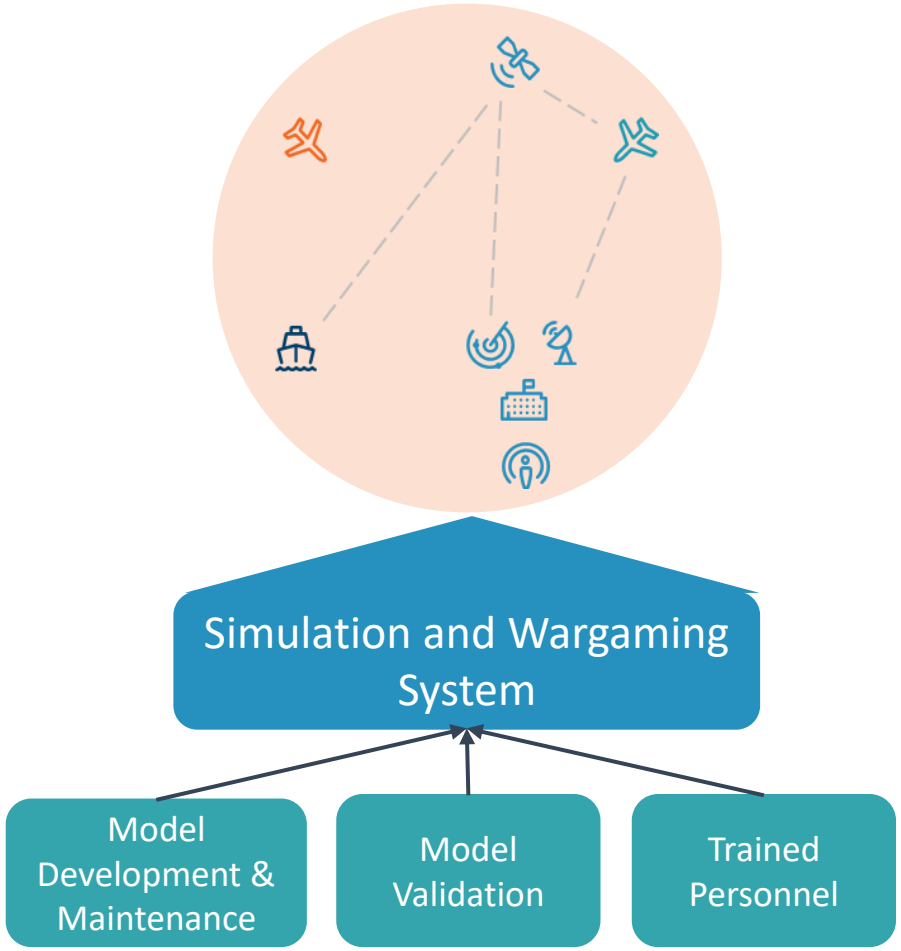


Image source: INCOSE SE Handbook 5th Edition

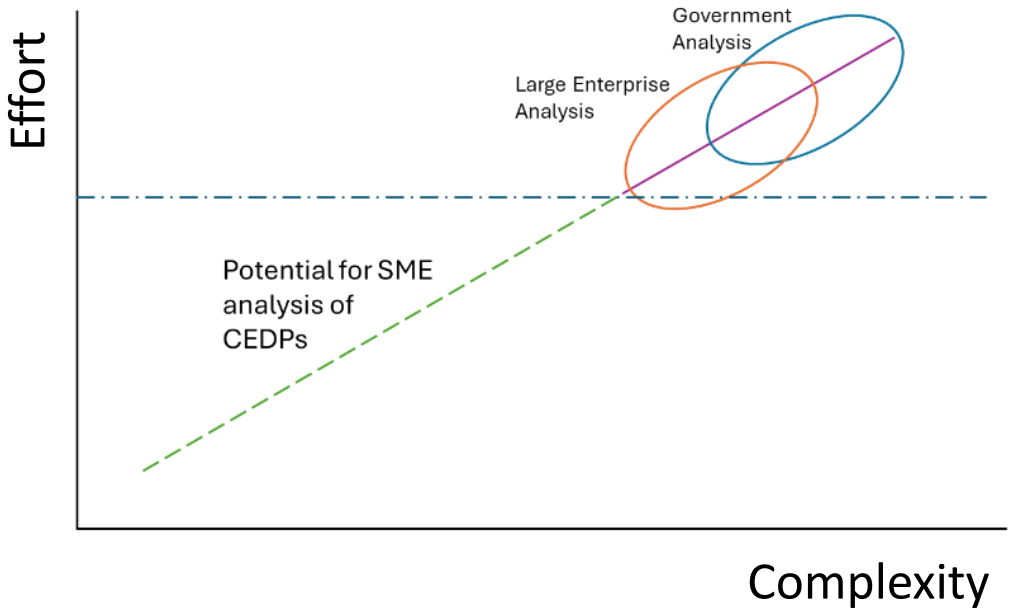
Large Scale Modelling, Simulation and OR

- Defence has long used modelling and simulation (M&S) + operations research to analyse military operations
- Modern tools are effective but require numerous highly-capable personnel and significant resources
- Similar modelling is undertaken by large corporations
- Such M&S is beyond most SMEs



Opportunity for SE SMEs

- SE-based analysis scales with complexity
- Very complex systems (e.g. warfighting) undertaken by governments & large corporations
- There are a range of moderately complex CED systems that will need support
- Opportunity for SMEs
  - If it can be undertaken at SME scale

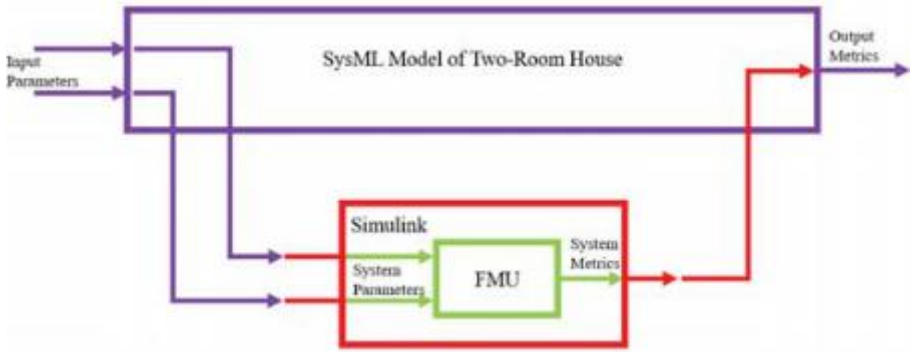


CED System Modelling & Analysis

Approach
Skilled personnel
Development Environment

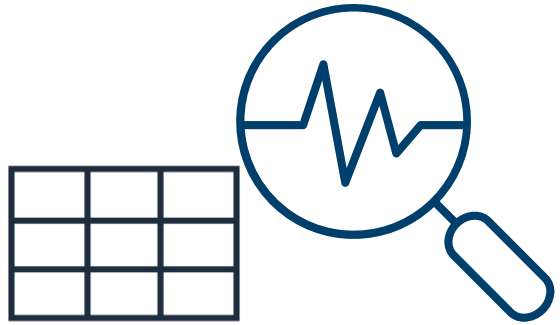
Approach – Modular Digital Engineering

- Leverages similarities between many CED systems
- Build tailorable modules:
  - Systems architecture modules (SysML / UAF)
    - Designed for reuse
  - Analytical models
    - Excel-based, OpenModelica, MatCAD etc.
    - Imbed into SysML models as FMUs as appropriate



Cawasji and Baras (2018)

- **Keep the analytical models as simple as possible**
- Construct CED system model from modules
- Analyse CED system using model
  - e.g. Electric Vehicle as a system
- Use OR to examine larger scale behaviours
  - e.g. Fleet of vehicles

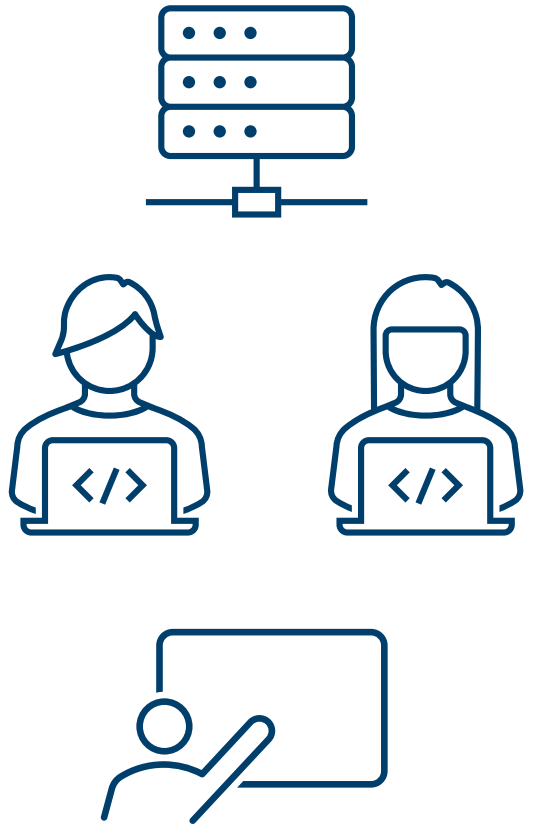


Skilled Personnel

- The effort of skilled personnel is the dominant cost
- Build on existing skills of personnel
- Choose tools that suit the personnel
- Align with skills of university graduates
- Shoal's skills build on:
  - MBSE – SysML / UAF
  - Modelling and simulation using a range of tools
  - OR experience
- Extensive experience across:
  - Defence, Space, Transport, Infrastructure

Development Environment

- An effective development environment is essential to deliver cost effective analysis of CED systems
- Information management
  - Models
  - Underpinning data
  - Analysis results
- Knowledge management
  - Processes and lessons
  - Rapid integration of new team members
- Appropriate tools
  - Spreadsheets for initial modelling
  - MBSE
  - Modelling and simulation
  - Operations Research
  - Visualisation



Modular DE Modelling & Analysis Examples

Decarbonised Haulage Operations

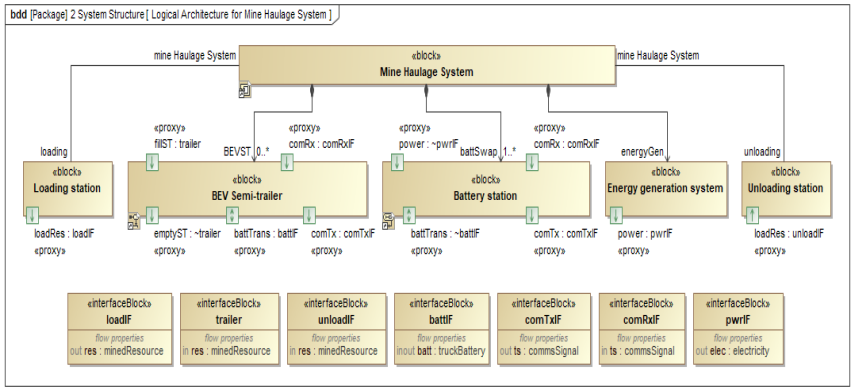
- Diesel ➔ Green haulage operations
  - Efficient green (e.g. electric) transport of bulk materials
  - Trucks to use, Operations,
  - Throughput, energy usage …
- Support to Solarh2e transport decarbonisation
  - Inter-city haulage (Melbourne to Sydney)
    - Fast battery exchange system (using SANY technologies)
  - Regional to city haulage
  - Intra-city haulage
  - Mining haulage to processing centre or port

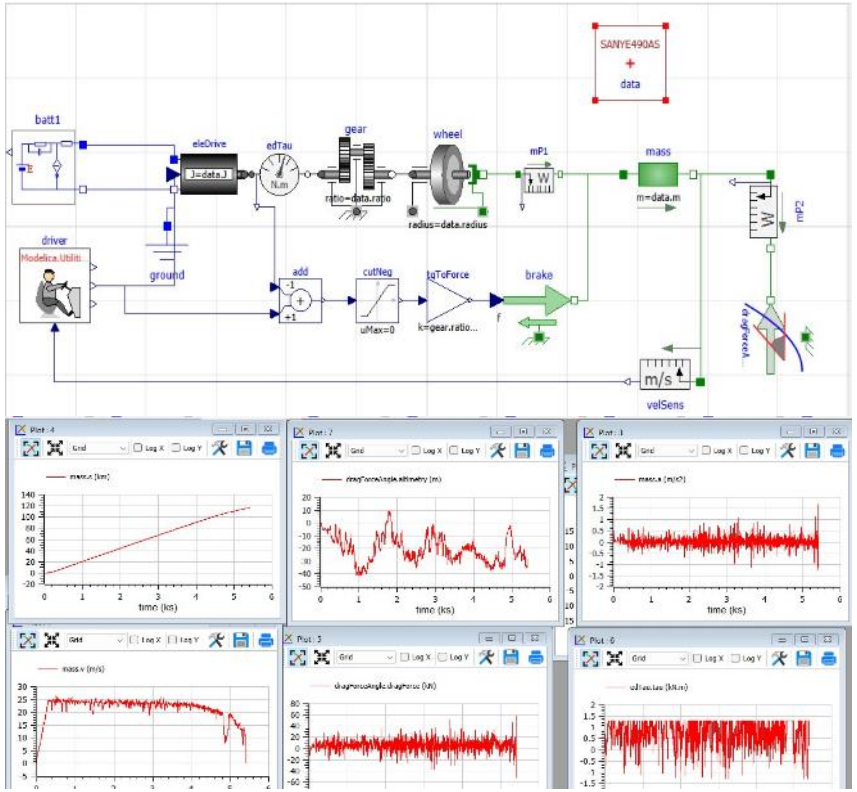
Diesel

Electric

Modelling & Simulation

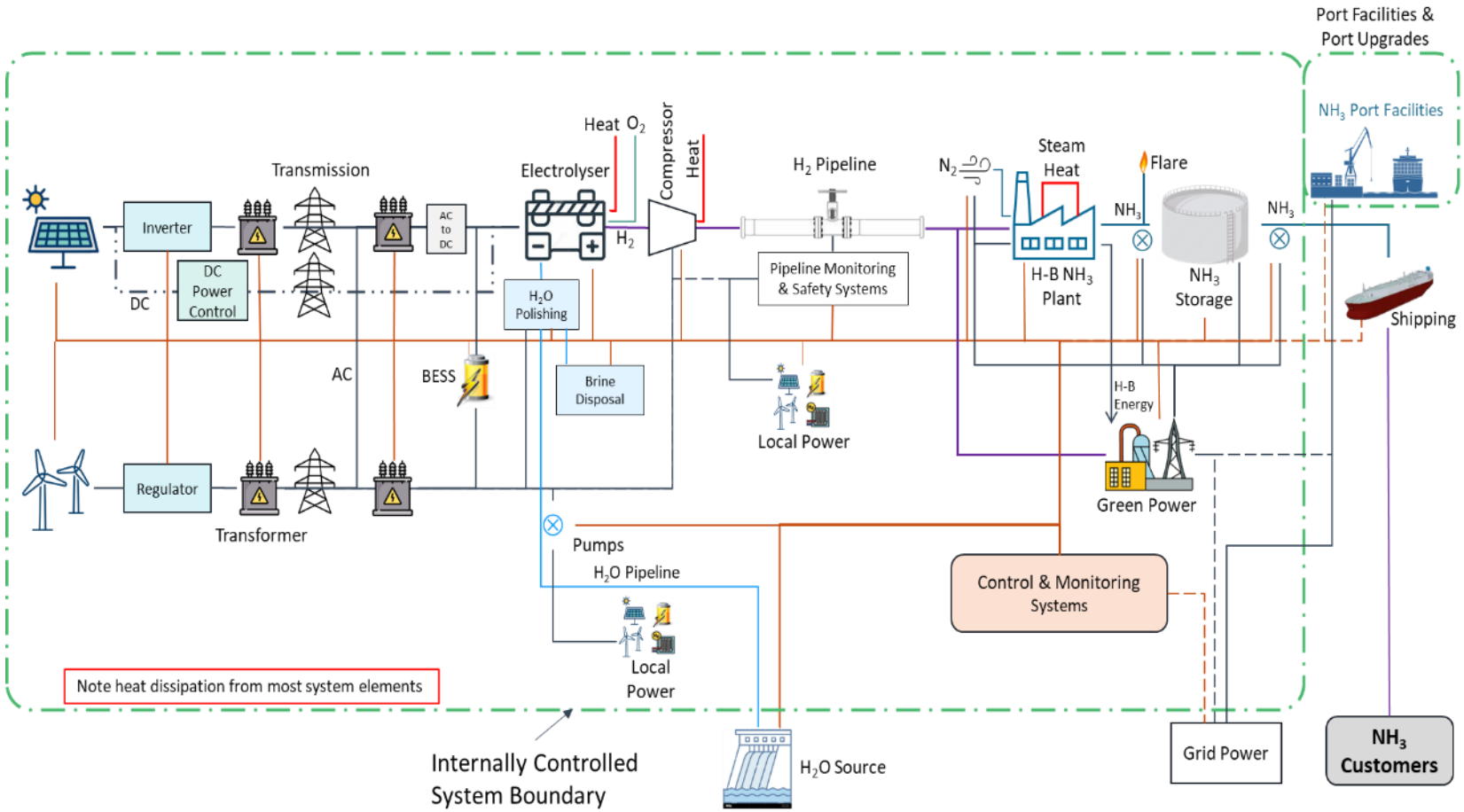
- Systems Engineering
  - Enables the whole capability to be considered and understood
  - Identifies and manages the risks and opportunities
- Digital Engineering based Modelling & Simulation
  - **Use simplest viable level of analysis and modelling**
  - Combines functional and physical modelling
  - Provides flexible modular modelling
  - Models the behaviour of the whole capability
  - Captures the design, interfaces, gaps and risks
  - Enables understanding, optimisation, and impacts of changes
- Analyse many ideas at low cost
  - Project feasibility
  - Energy requirements
  - Project risks and opportunities





Analysis of Large-Scale Hydrogen & Ammonia

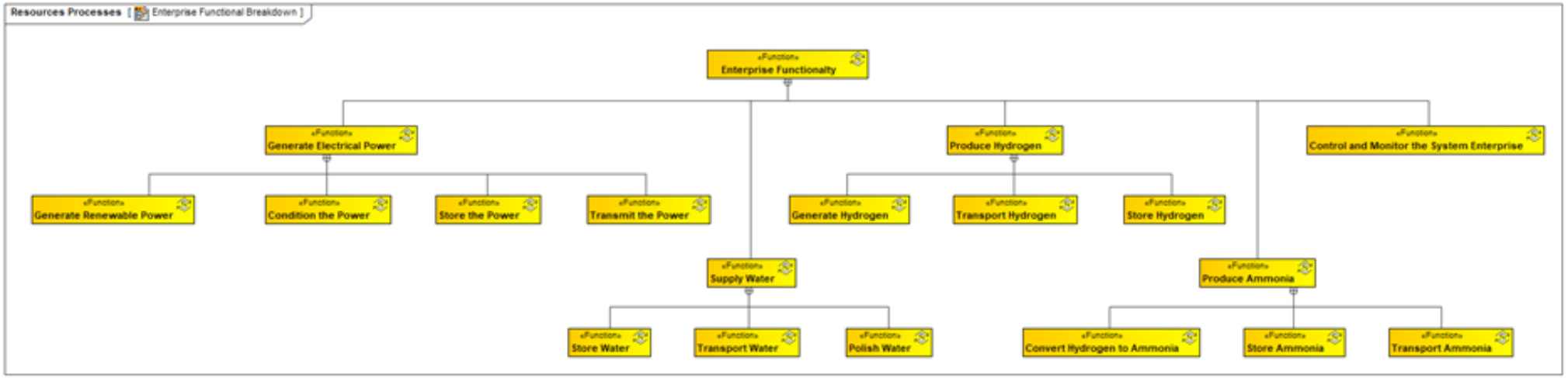
- Large scale green energy project
  - ~ US$20 B
  - Pre-FEED stage
- Northern Australia
- Solar and Wind energy
  ➔ Hydrogen
  ➔ Ammonia
- Ammonia for export



Analysis of Large-Scale Hydrogen & Ammonia

- ‘Owner’s SE’ role – quality assurance
- Underpinned by DE-based analysis
- Risk and opportunity analysis
- Sensitivity and trade-off analysis

- High-level Excel-based modelling
- Provided key insights, including:
  - Whole-of-system energy requirements
  - Hydrogen production and transport issues
  - Heat dissipation
  - System and SoS risks



Top level UAF architecture

Conclusions

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Conclusion

- Multitude of CED systems and projects
  - ~ $100s billions over next 25 years
- Critical to understand the risks and opportunities
- SMEs have an opportunity to support and de-risk these projects
- Shoal has developed an austere DE approach for CED systems
  - Analysis & modelling must match the recourses available at project stage
  - Combines MBSE, analytical modelling, plus OR
  - Modular design
  - Keep modelling as simple as possible
  - Development environment is critical
- Critical to underpin investor confidence
- Enables cost effective DE support to CED projects at SME scale

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Questions and comments

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