An expert elicitation on flow models for wind farm control

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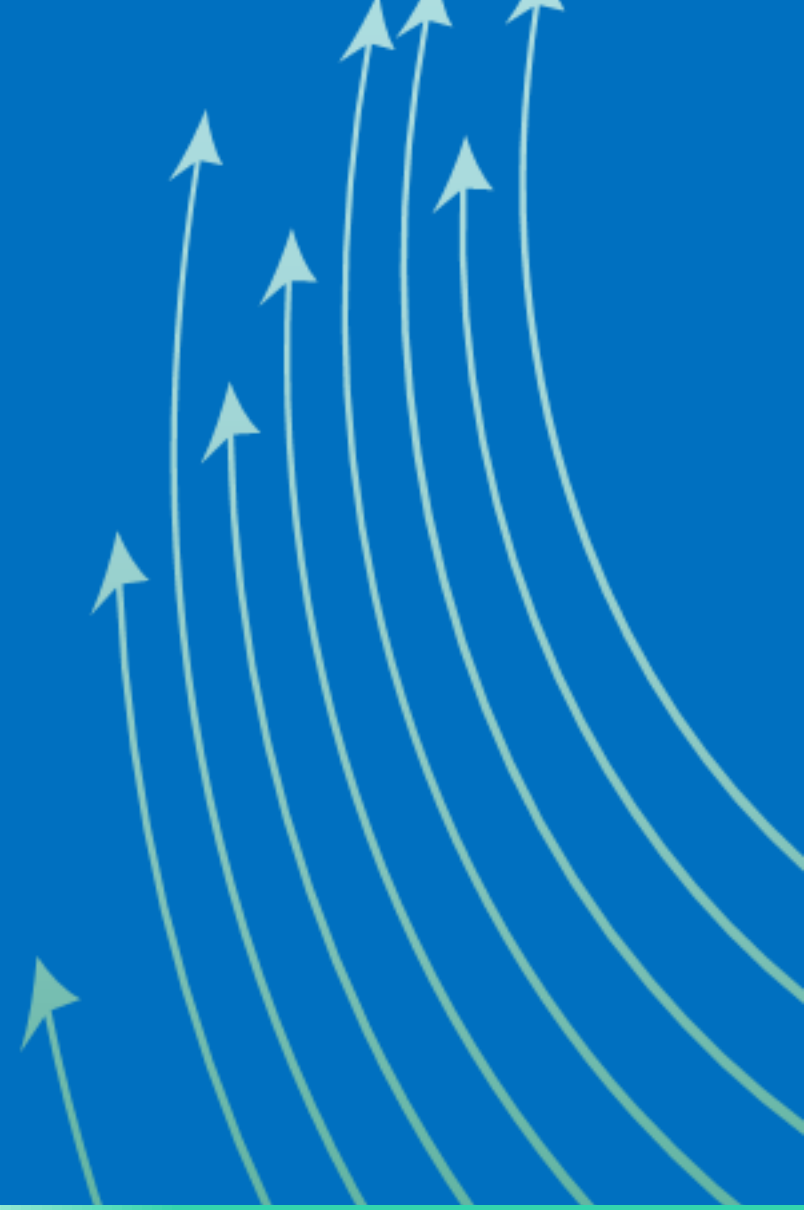
01 Elicitation Introduction



Overview

- Objective of eliciting the relative importance of model inputs for the analysis of wind farm flow control.
- Wake steering and induction control were the two methods considered.
- The model aims were restricted to low and high frequency power and fatigue load investigation under each control method.

Format

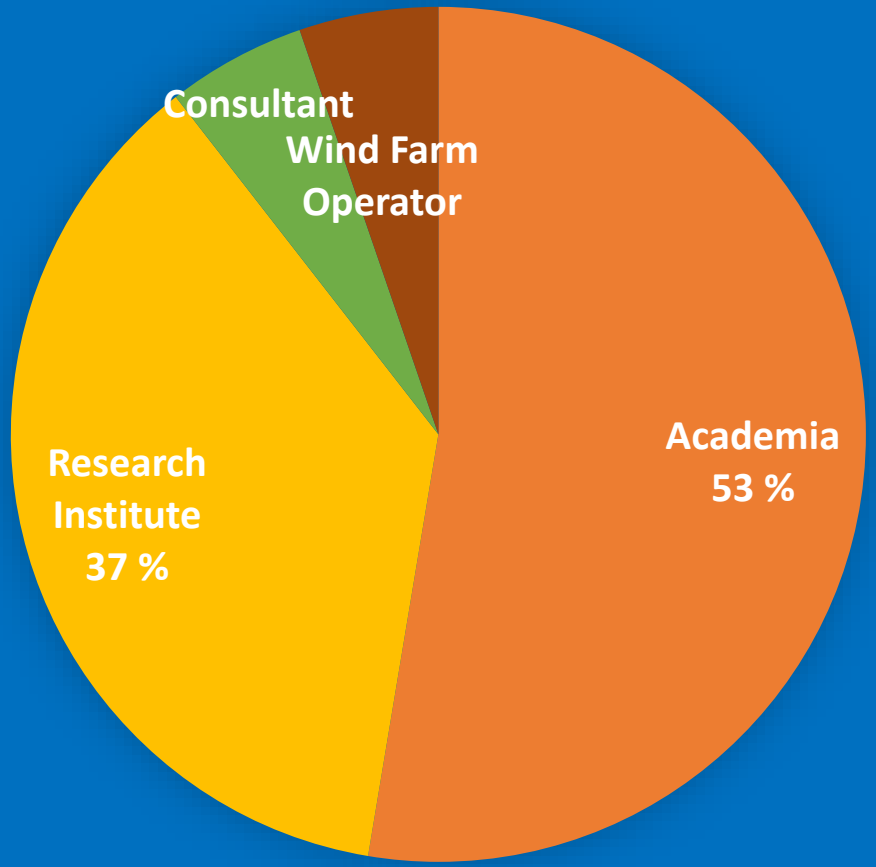
	Wind Speed	Direction
Wake Steering		
Low Frequency Power Investigation	☐	☐
High Frequency Power Investigation	☐	☐

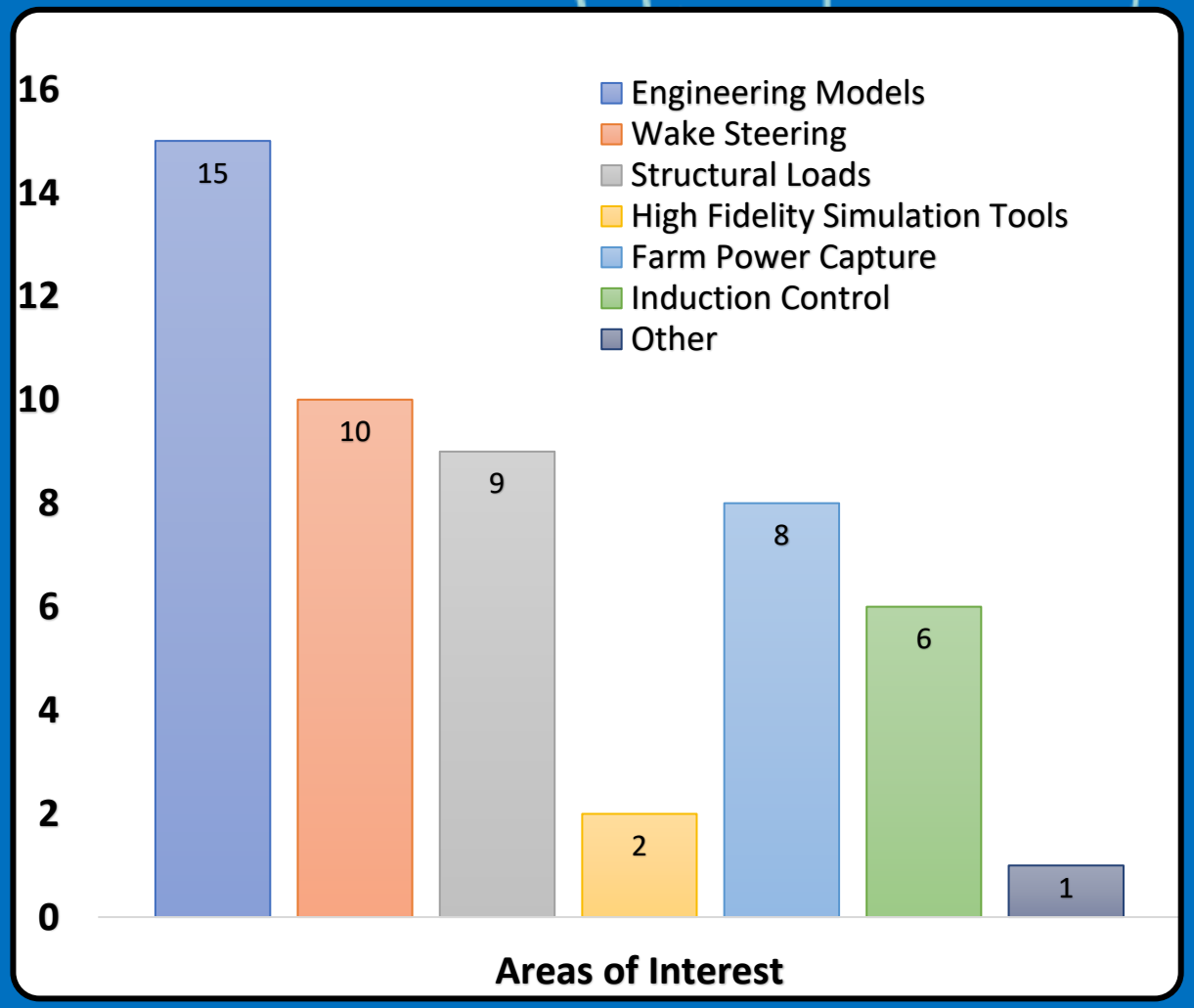
- **Each question asked respondents to rank model inputs from 1 to 4 in terms of importance towards the desired investigation:**

1	Not required/Not adequate	2	Beneficial to have	3	Required (low fidelity/resolution)	4	Required (high fidelity/resolution)

02 Elicitation Process and Details

Demographics





03 Results Section

3.1 Ambient Wind

3.2 Disturbed Flow

3.3 Simulation Properties

Visualisation

Unalikeability Coefficient

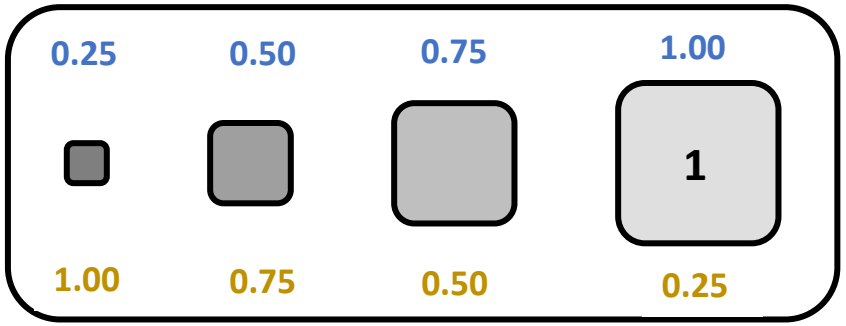
$$u = \frac{\sum c(x_i, x_j)}{n^2 - n}, \quad i \neq j$$

where,

$$c(x_i, x_j) = \begin{cases} 1, & x_i \neq x_j \\ 0, & x_i = x_j \end{cases}$$

$$n = total\,participants.$$

Area = unalikeability across each category squared.



Mode

Opacity = unalikeability in binary category.

3.1 Ambient Wind

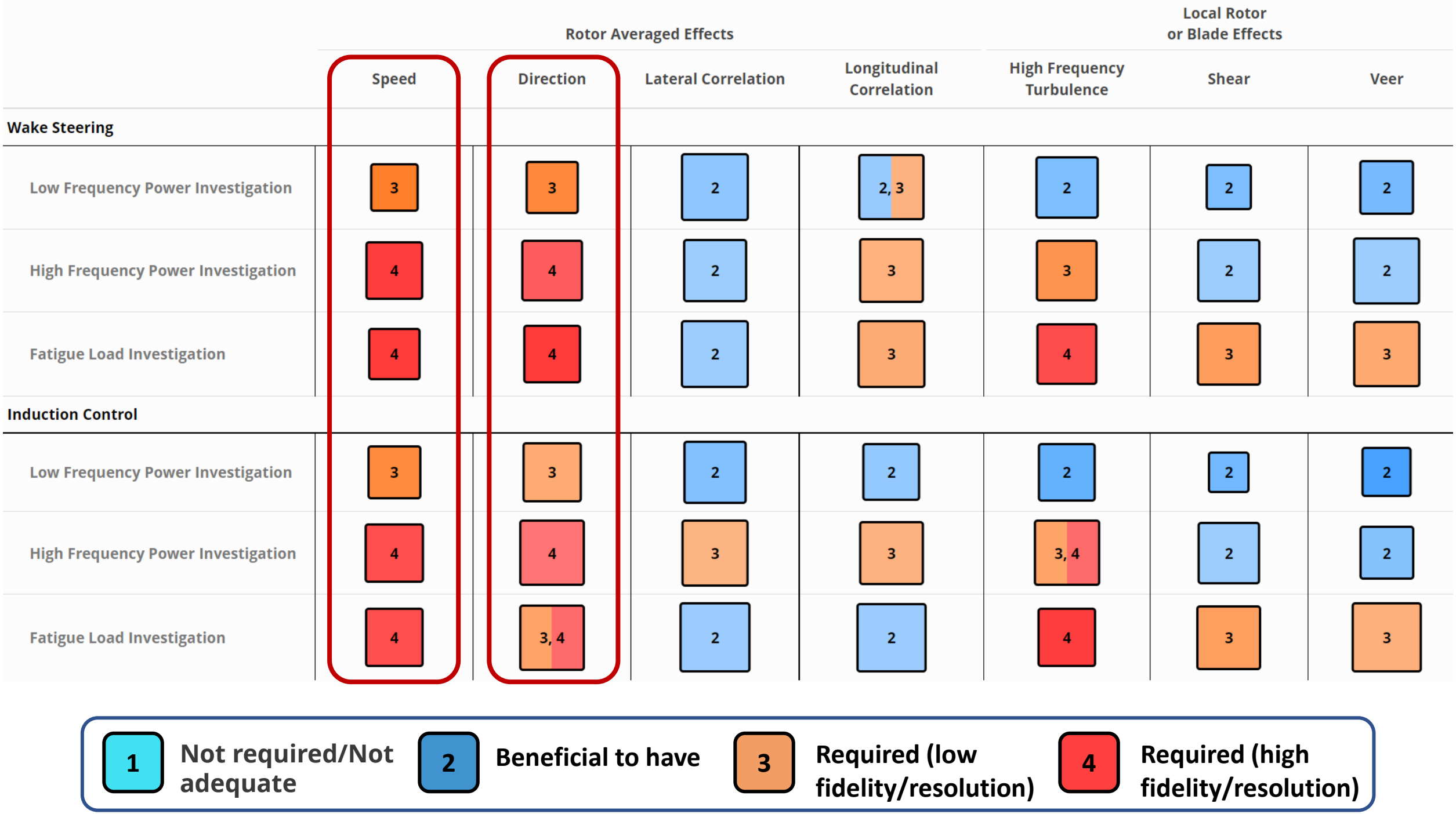
	Rotor Averaged Effects				Local Rotor or Blade Effects		
	Speed	Direction	Lateral Correlation	Longitudinal Correlation	High Frequency Turbulence	Shear	Veer
Wake Steering							
Low Frequency Power Investigation	3	3	2	2, 3	2	2	2
High Frequency Power Investigation	4	4	2	3	3	2	2
Fatigue Load Investigation	4	4	2	3	4	3	3
Induction Control							
Low Frequency Power Investigation	3	3	2	2	2	2	2
High Frequency Power Investigation	4	4	3	3	3, 4	2	2
Fatigue Load Investigation	4	3, 4	2	2	4	3	3

1 Not required/Not adequate

2 Beneficial to have

3 Required (low fidelity/resolution)

4 Required (high fidelity/resolution)


Rotor Averaged Effects
Local Rotor or Blade Effects
Speed
Direction
Lateral Correlation
Longitudinal Correlation
High Frequency Turbulence
Shear
Veer
Wake Steering
Low Frequency Power Investigation
3
3
2
2, 3
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High Frequency Power Investigation
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4
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Fatigue Load Investigation
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Induction Control
Low Frequency Power Investigation
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High Frequency Power Investigation
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3, 4
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Fatigue Load Investigation
4
3, 4
2
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3
3
1 Not required/Not adequate
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	Rotor Averaged Effects				Local Rotor or Blade Effects		
	Speed	Direction	Lateral Correlation	Longitudinal Correlation	High Frequency Turbulence	Shear	Veer
Wake Steering							
Low Frequency Power Investigation	3	3	2	2, 3	2	2	2
High Frequency Power Investigation	4	4	2	3	3	2	2
Fatigue Load Investigation	4	4	2	3	4	3	3
Induction Control							
Low Frequency Power Investigation	3	3	2	2	2	2	2
High Frequency Power Investigation	4	4	3	3	3, 4	2	2
Fatigue Load Investigation	4	3, 4	2	2	4	3	3

1 Not required/Not adequate

2 Beneficial to have

3 Required (low fidelity/resolution)

4 Required (high fidelity/resolution)

3.2 Disturbed Flow

	Wake Effects					ABL Effects	
	Turbulence	Deflection	Meandering	Advection	Profile, Shape and Diffusion	Vertical Distribution	Longitudinal
Wake Steering							
Low Frequency Power Investigation	2	3	2	2	3	2	2
High Frequency Power Investigation	2, 3, 4	4	3	3	3	2	2
Fatigue Load Investigation	3, 4	3	4	2	3	2	2
Induction Control							
Low Frequency Power Investigation	2	1	2	2, 3	3	2	2
High Frequency Power Investigation	3	3	3	3	3	2	2
Fatigue Load Investigation	4	1, 3	4	3	3	2	2

1 Not required/Not adequate

2 Beneficial to have

3 Required (low fidelity/resolution)

4 Required (high fidelity/resolution)

	Wake Effects					ABL Effects	
	Turbulence	Deflection	Meandering	Advection	Profile, Shape and Diffusion	Vertical Distribution	Longitudinal
Wake Steering							
Low Frequency Power Investigation	2	3	2	2	3	2	2
High Frequency Power Investigation	2, 3, 4	4	3	3	3	2	2
Fatigue Load Investigation	3, 4	3	4	2	3	2	2
Induction Control							
Low Frequency Power Investigation	2	1	2	2, 3	3	2	2
High Frequency Power Investigation	3	3	3	3	3	2	2
Fatigue Load Investigation	4	1, 3	4	3	3	2	2

1 Not required/Not adequate

2 Beneficial to have

3 Required (low fidelity/resolution)

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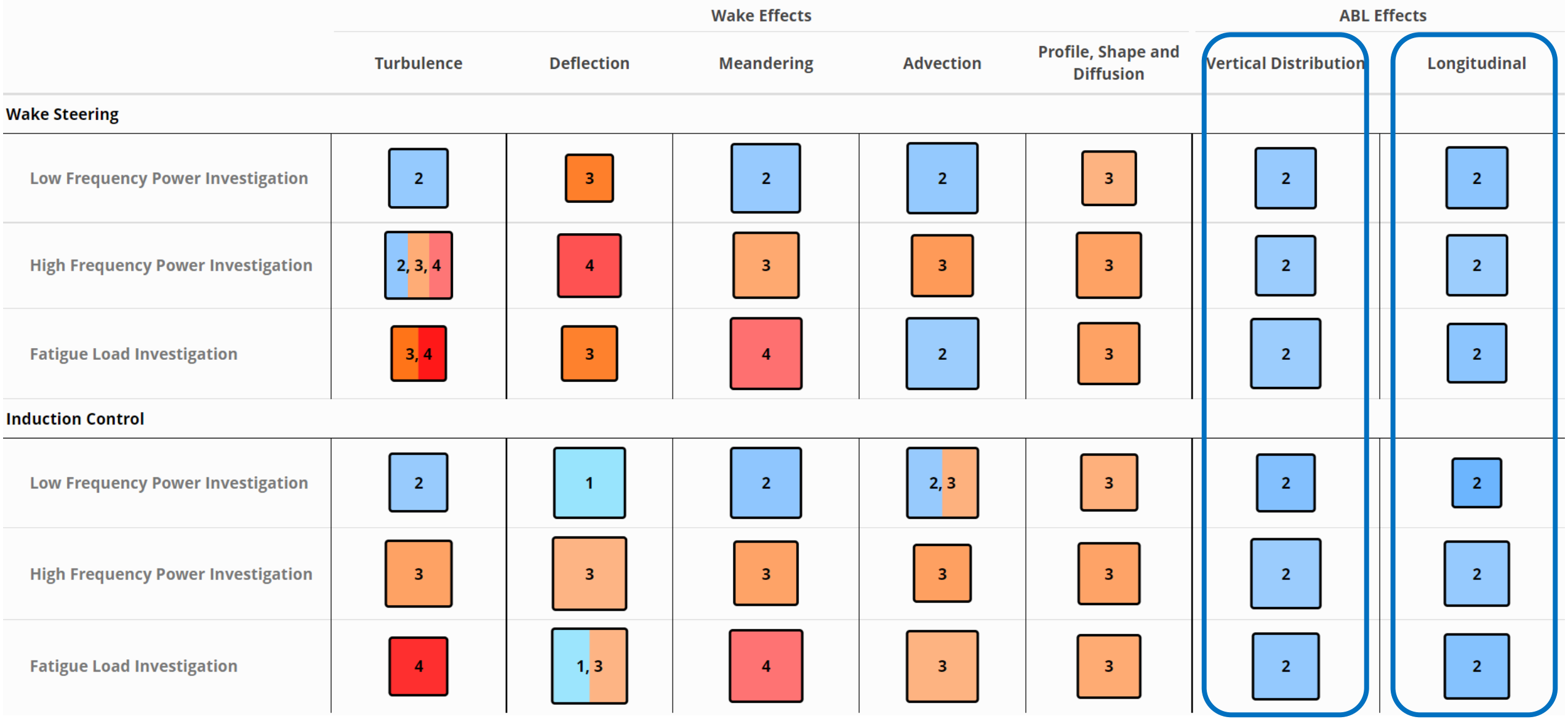
Wake Effects
ABL Effects
Turbulence
Deflection
Meandering
Advection
Profile, Shape and Diffusion
Vertical Distribution
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Wake Steering
Low Frequency Power Investigation
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High Frequency Power Investigation
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Fatigue Load Investigation
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Induction Control
Low Frequency Power Investigation
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High Frequency Power Investigation
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Fatigue Load Investigation
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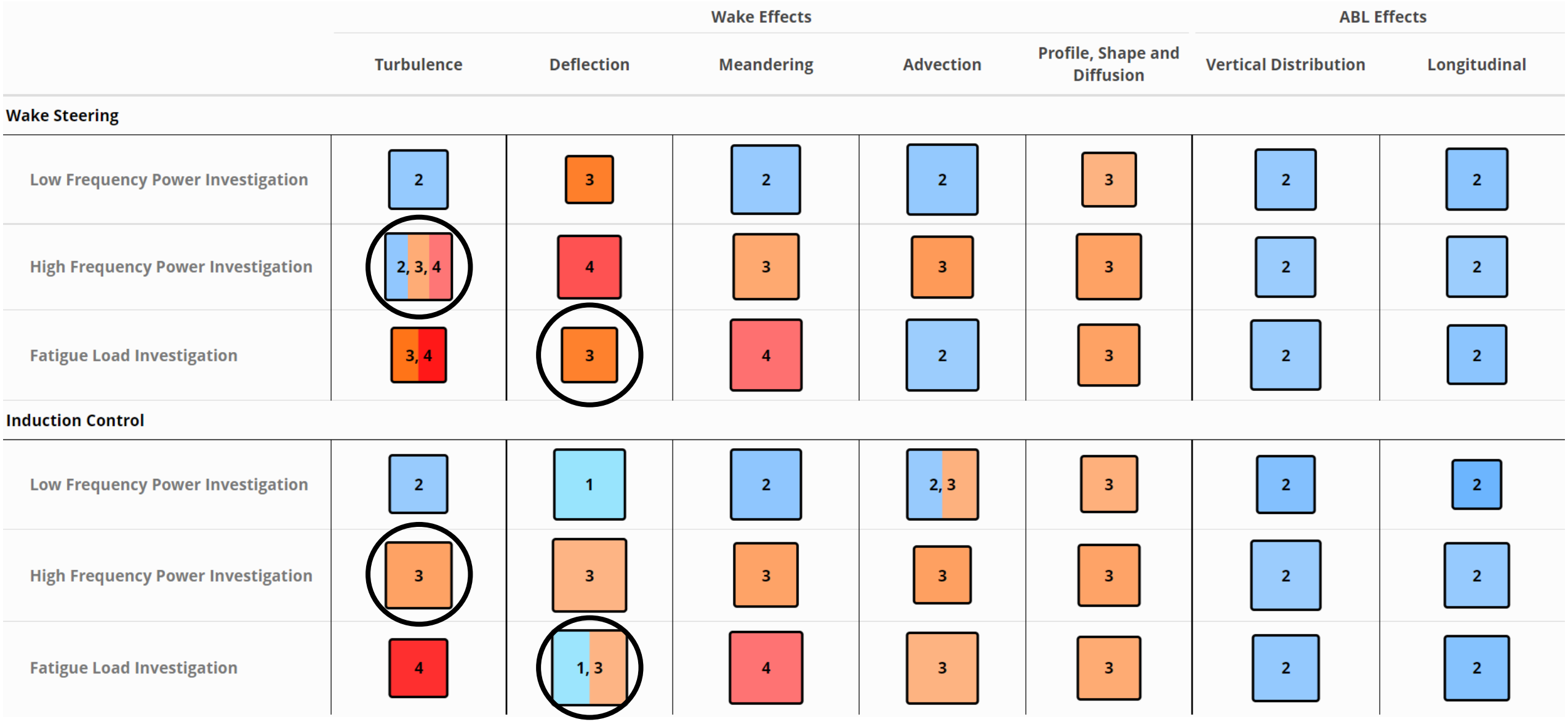
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Fatigue Load Investigation
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1
Not required/Not adequate
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3.3 Simulation Properties

	Time Variability			Required Scale of Simulation		
	Steady State	Stationary	Transient	Single Turbine	2-10 Turbines	>10 Turbines
Wake Steering						
Low Frequency Power Investigation	3	3	2, 3	2	3	3
High Frequency Power Investigation	1	3	3, 4	2	3	3
Fatigue Load Investigation	3	3	4	4	4	3
Induction Control						
Low Frequency Power Investigation	3	3	2	2	3	3
High Frequency Power Investigation	1	3, 4	4	4	3	3
Fatigue Load Investigation	3	3	4	4	3	3

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	Steady State	Stationary	Transient	Single Turbine	2-10 Turbines	>10 Turbines
Wake Steering						
Low Frequency Power Investigation	3	3	2, 3	2	3	3
High Frequency Power Investigation	1	3	3, 4	2	3	3
Fatigue Load Investigation	3	3	4	4	4	3
Induction Control						
Low Frequency Power Investigation	3	3	2	2	3	3
High Frequency Power Investigation	1	3, 4	4	4	3	3
Fatigue Load Investigation	3	3	4	4	3	3

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	Time Variability			Required Scale of Simulation		
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Wake Steering						
Low Frequency Power Investigation	3	3	2, 3	2	3	3
High Frequency Power Investigation	1	3	3, 4	2	3	3
Fatigue Load Investigation	3	3	4	4	4	3
Induction Control						
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High Frequency Power Investigation	1	3, 4	4	4	3	3
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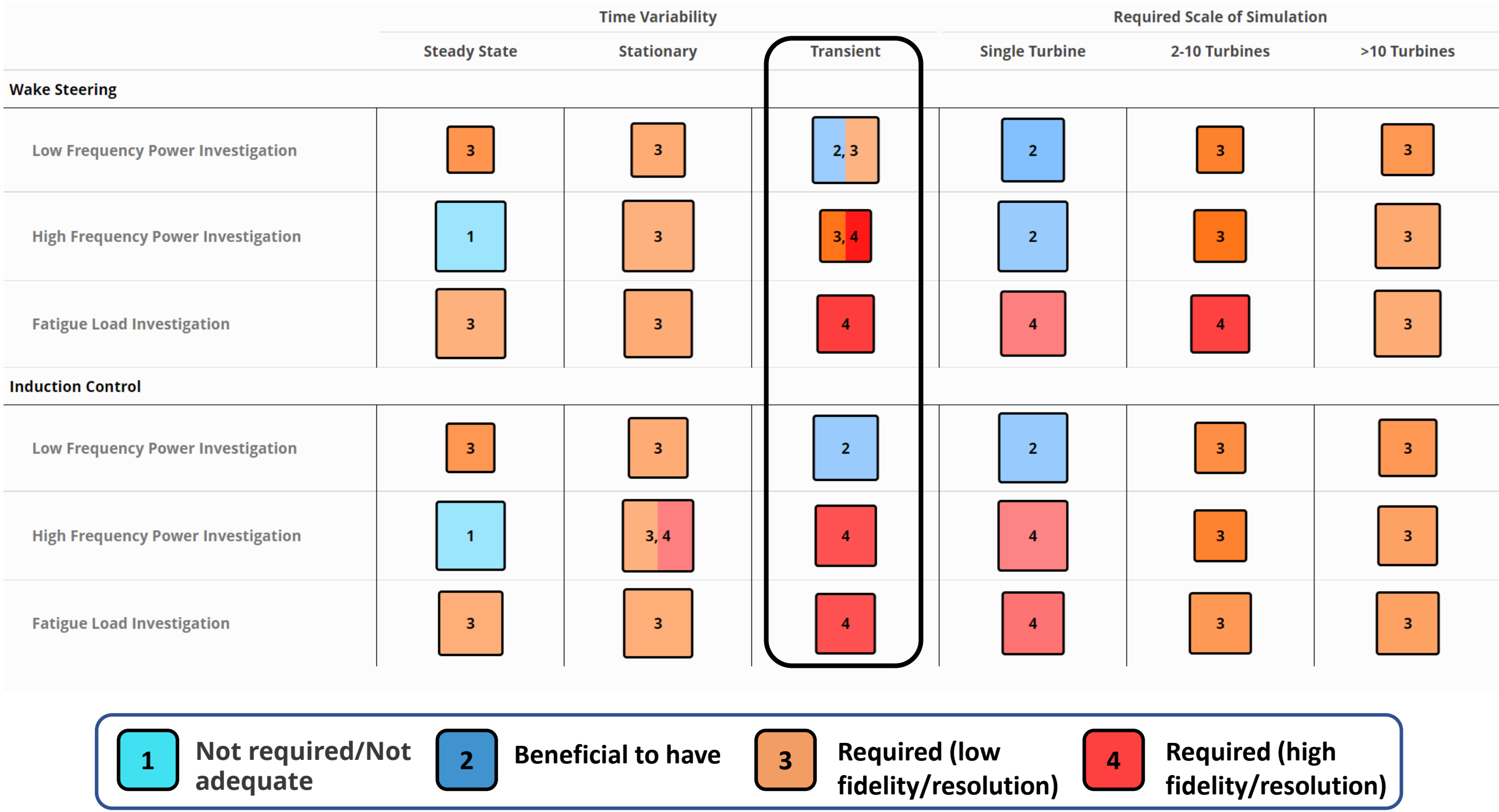
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Required Scale of Simulation
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Induction Control
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High Frequency Power Investigation
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04 Discussion and Conclusion

Limitations

- Restricted demographic set.
  - Solution: distributed through IEA task 44.
- Differences in interpretation of questions.
  - Solution: definitions provided with survey.
- Situation is more nuanced than 1-4 ranking can reflect.
  - Solution: comment boxes to allow for qualitative answers.

Achievements

- A useful guide for model input requirements and relative importance.
  - Stimulates discussion.
- Identifies areas of focus for model developments at different fidelities.
  - Future research.
- Helps to match existing software to their capabilities.
  - Next step in the process.

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Thank You!

Questions?

[Survey Link]

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