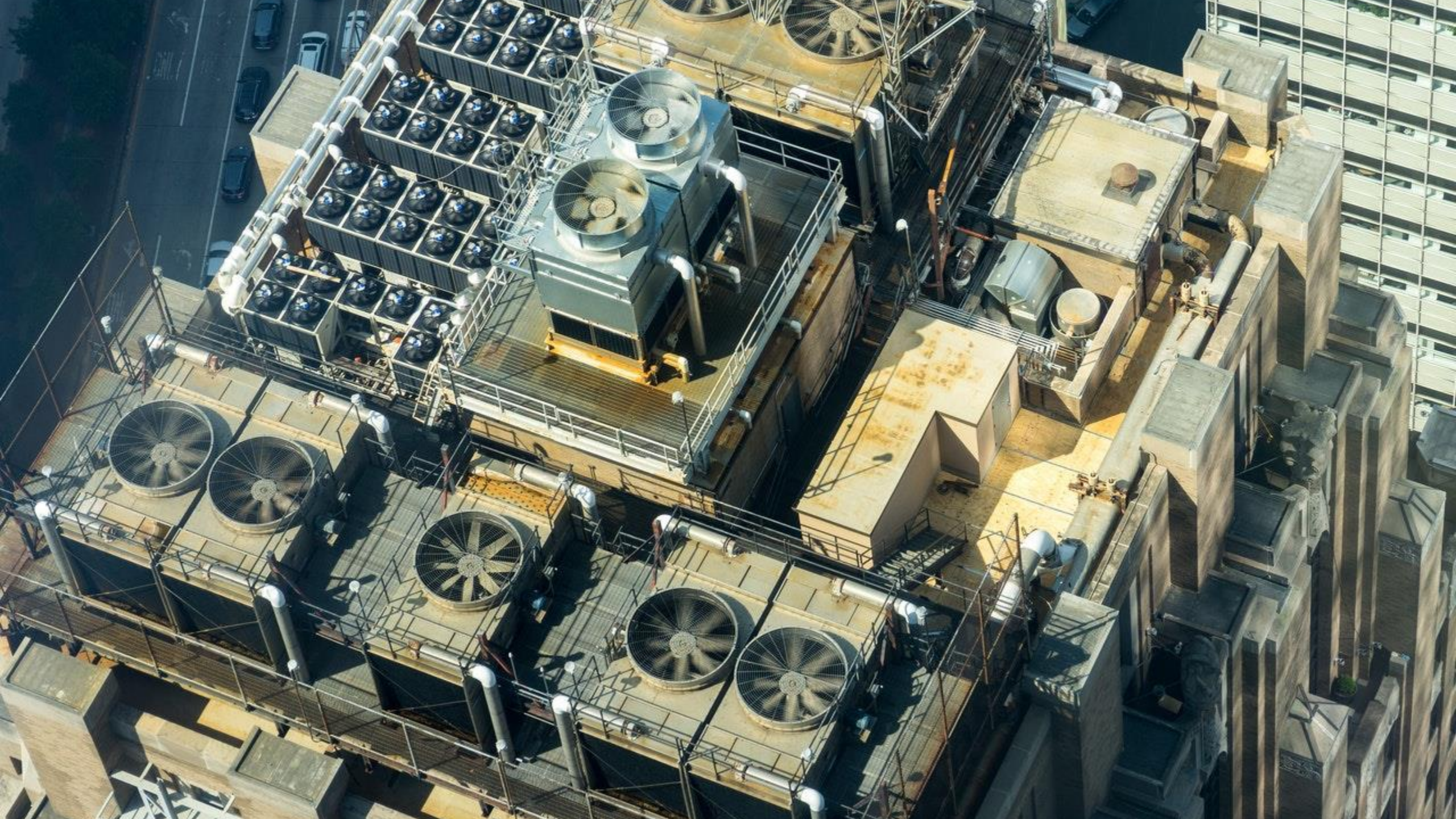
University of Antwerp

Are we really future-proofing our high energy performance buildings?

Charlotte Verhaeghe

Stijn Verbeke, Amaryllis Audenaert



Inleiding

EXISTING BUILDING STOCK

LOW ENERGY BUILDINGS

ENERGY-RENOVATION DECISIONS UNDER **UNCERTAINTY**

Dynamic context:

- **S**ocial
- **T**echnological
- **E**conomic
- **E**nvironmental
- **P**olitical

FUTURE-PROOF,
HIGH-PERFORMANCE BUILDINGS

-Dealing with doubts about the future

-Impact assessment

-Future-proof concepts

Research Question(s)

Are we really future-proofing our high energy performance buildings?

Subquestion 1: Doubts about the future?
Subquestion 2: What is “future-proofing” in theory?
Subquestion 3: Consistency and importance of “future-proofness” in practice
Subquestion 4: “Future-proofing” in energetic renovations

Doubts about the future?

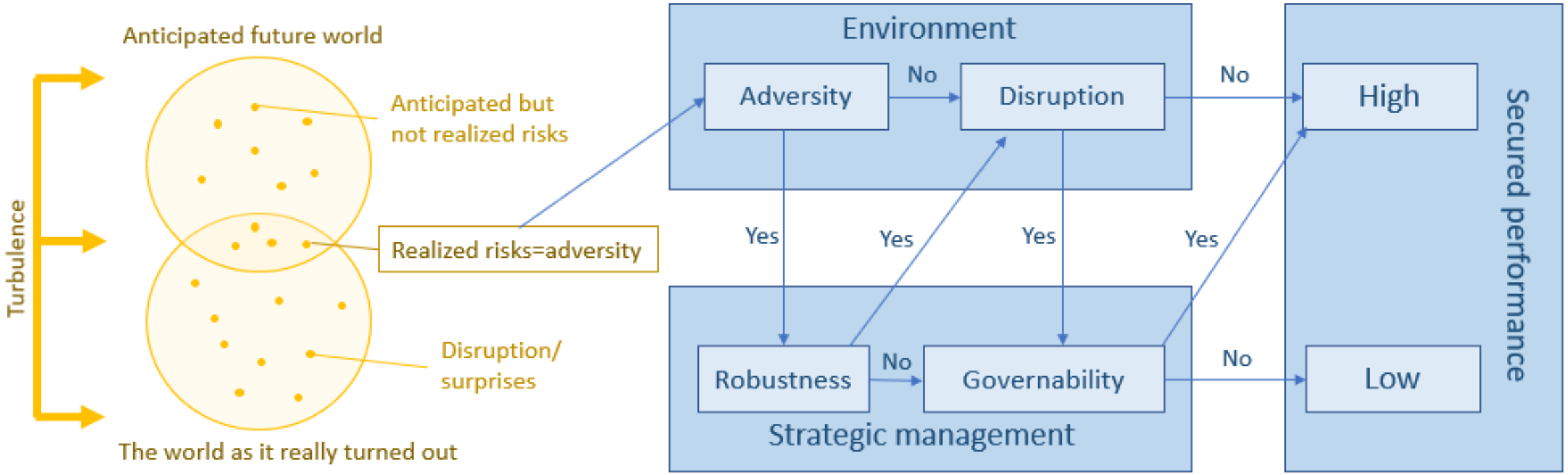
SQ1: What are doubts about the future?
SQ2: What is “future-proof”?
SQ3: Consistency of “future-proofing” in practice
SQ4: “Future-proofing” in energetic renovations

STEEP

Social	Lifestyle changes (housing unit types, occupant behaviour schemes, new working and living patterns, energy poverty, etc.) Demographic changes (age, gender, race, household sizes, privacy protection issues etc.)
Technological	(Maturity of) innovations (novel energy efficiency measures, RES, construction practices, accuracy in energy consumption data, etc.) Durability (frequency of repair, maintenance, accessibility, building management, construction quality, etc.) New manners of collaboration (e.g. energy communities, privacy protection, etc.)
Economic	Energy prices and energy tariff structures Scarcity of non-renewable energy resources Technology prices (RES, storage, etc.) Revenue models (e.g. performance contracting, etc.) Economic downturn (e.g. being influenced by taxation changes)
Environmental	Climate change (hotter and drier summers, overheating, urban heat island effect, etc.) Market and customer values towards environment (e.g. engagement towards the environment)
Political	Funding (grants, initiatives, etc.) Trading policies Energy security Energy and environmental targets (e.g. resulting in building regulations and standards)

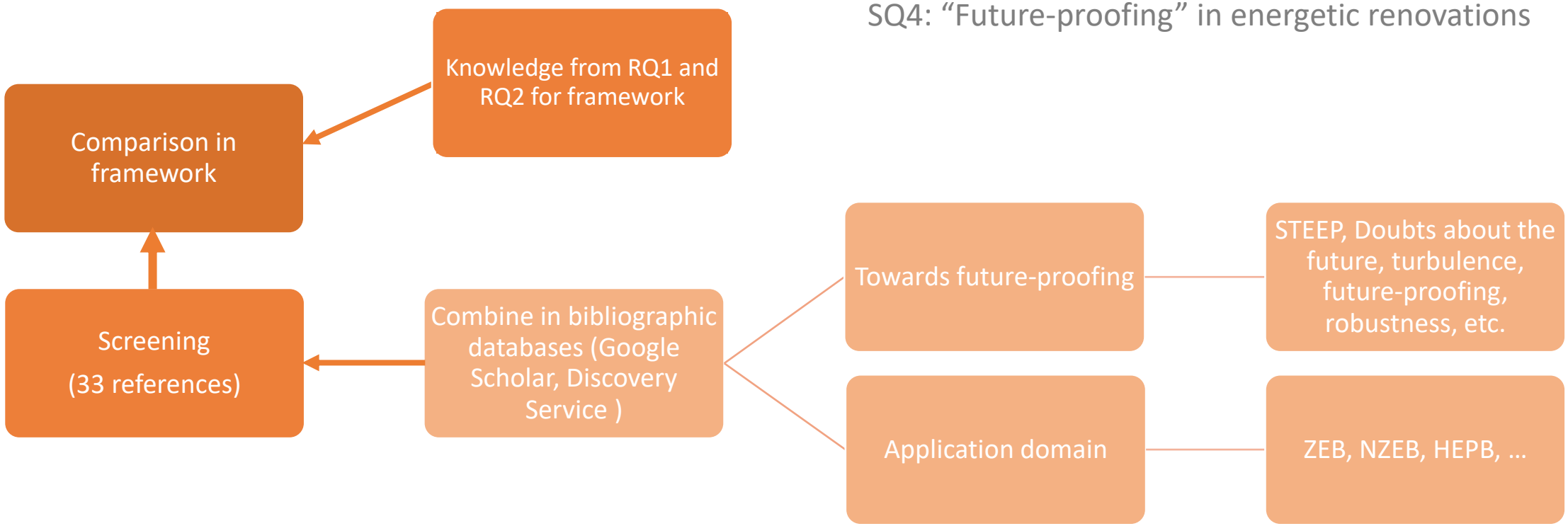
Future-proofing in theory

SQ1: What are doubts about the future?
SQ2: What is "future-proof"?
SQ3: Consistency of "future-proofing" in practice
SQ4: "Future-proofing" in energetic renovations



Theory versus practice…

SQ1: What are doubts about the future?
SQ2: What is “future-proof”?
SQ3: Consistency of “future-proofing” in practice
SQ4: “Future-proofing” in energetic renovations



Perception of future-proofing

	Author(s)	(Coley, Kershaw, and Eames 2012)	(Nik, Mata and Sasic Kalagasidis 2015)	(Shen and Sun 2016)	(Galimshina, Moustapha and	(Yu, Chen and Sun 2016)	(Buckner, Lafrenie and Denommée 2016)	(Li and Wang 2021)	(Lu, Wang and Yan 2017)	(Huang, Huang, and Sun 2018)	(Hopfe 2009)	(Floricel and Miller 2001)	(Moazami, Salvatore and Vahid 2019)	(Galle, Poppe and Cambier 2019)	(Hensen 2021)	(Zhou, Cao, and Evins 2021)	(Westermann and Evins 2021)	(Ji, Liang and Xei 2021)	(Wang, Qi and Ren 2021)	(Chang, Rivera, and Wanielista 2011)	(Li, Wang, and Tang 2019)	(Li and Wang 2020)	(Kotireddy, Hoes, and Hensen, 2017)	(Georgiadou, Hacking, and Guthrie 2012)	(Alawirad, Mohammadi and Hoes 2022)	(Kotireddy, Hoes, and Hensen 2018)	(Kotireddy, Hoes, and Hensen 2015)	(Rysanek and Choudhary 2013)	(Cheng, Wang and Yan 2017)	(Leyten and Kurvers 2006)	(Lu, Shengwei and Chengchu 2017)	(Ramon 2021)	(Howlett, Malevitt, and Hacking 2012)	(De Wilde 2014)	(Bean, Volt and Dorizas 2019)
DaF	Social	a		a	a		a	a	a	a	a	x	a	a	a	a	a		a		a	a	a	a	a	a	a	a	a		a		a	X
	Technological				d,c		c			d,c		c		d	c,d,e						d	d		c		x		c	c	d				c	X
	Economic				f,h	d	f,h					h			f,j			f	f	f				f,h		f		f,h				f			X
	Environmental	k	k	k	k	k	k	k	k	k	k	x	k				k		k	k	k	k	k	k	k	k	k	k	k		k	k	k	X	X
	Political											x						p						o,p		m		m					p		X
Keyword/naming		Future-proof against higher temperatures	Robust against climate change	..under uncertainties	Robust	...under uncertainties	Future-proof	Risk-benefit-based	Robust	Robust	Robust	Robust, flexible	Climate-robust	Robust	Robust	Uncertainty-aware, robust	Uncertainty-based optimal	Uncertainty-based optimal	Uncertainty-based optimal	Uncertainty-based optimal	Robust	Robust	Robust	Future-proof, robust	Future-proof, robust	Robust	Robust	Robust, optimum under uncertainty	Uncertainty-based optimal	Robust		Future-proof, climate-robust, robust	Future-oriented, future-proof	Robust, occupant-proof, climate-change-proof, performance based buildings	Future-proof
Type of source		Journal	Journal	Journal	Journal	Journal	Book	Journal	Journal	Journal	Book (PhD)	Journal	Journal	Report	Journal	Journal	Journal	Journal	Journal	Journal	Journal	Journal	Conference	Journal	Journal	Journal	Conference	Journal	Journal	Journal	Journal	Book (PhD)	Journal	Journal	EPBD
With Case study		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X	
Focus on	Epistemic			X				X	X	X	X	X				X	X			X	X	X							X	X	X		X	X
	Aleatory	X	X		X	X	X	X	X	X	X	X	X	X	X				X		X	X	X	X	X	X	X	X	X	X		X	X		X
	Error											X												X				X	X				X		
	Linguistic																																		
	Decisoin											X		X	X													X							X
	ST/LT uncertainty	LT	LT	ST	LT	LT	LT	ST	ST/LT	ST/LT	ST/LT	LT	LT	LT	LT	ST	ST	ST	LT	ST	ST/LT	ST/LT	LT	LT	LT	LT	LT	LT	ST/LT	ST/LT	ST	LT	LT	ST	LT
	|Impact [%]|	/	≤78	≤14.4	≤30	≤20	/	≤40	≤45,6	≤13	≤75	/	≤14.4	/	≤77	≤30	≤71	≤14.2	≤70	≤36.8	≤54	/	/	≤100	/	/	≤50	≤17,7	≤50	/	≤67	/	≤30	/

Authors

Reference type

Perception of future-proofing

STEEP Doubts about the future

	Author(s)	(Coley, Kershaw, and Eames 2012)	(Nik, Mata and Sasic Kalagasidis 2015)	(Shen and Sun 2016)	(Galimshina, Moustapha and Hellweg 2021)	(Yu, Chen and Sun 2016)	(Buckner, Lafrenie and Denommée 2016)	(Li and Wang 2021)	(Lu, Wang and Yan 2017)	(Huang, Huang, and Sun 2018)	(Hopfe 2009)	(Floricel and Miller 2001)	(Moazami, Salvatore and Vahidi 2019)	(Galle, Poppe and Cambier 2019)	(Zhou, Cao, and Hensen 2021)	(Westermann and Evins 2021)	(Ji, Liang and Xei 2021)	(Wang, Qi and Ren 2021)	(Chang, Rivera, and Wanielista 2011)	(Li, Wang, and Tang 2019)	(Li and Wang 2020)	(Kotireddy, Hoes, and Hensen, 2017)	(Georgiadou, Hacking, and Guthrie 2012)	(Alavirad, Mohammadi and Hoes 2022)	(Kotireddy, Hoes, and Hensen 2018)	(Kotireddy, Hoes, and Hensen 2015)	(Rysanek and Choudhary 2013)	(Cheng, Wang and Yan 2017)	(Leyten and Kurvers 2006)	(Lu, Shengwei and Chengchu 2017)	(Ramon 2021)	(Howlett, Malevitz, and Hacking 2012)	(De Wilde 2014)	(Bean, Volt and Dorizas 2019)
DaF	Social	a		a	a		a	a	a	a	a	x	a	a	a	a		a		a	a	a	a,b	a	a	a	a	a		a		a	a	X
	Technological				d,c		c			d,c		c		d	c,d,e					d	d		c		x		c	c	d			c		X
	Economic				f,h	d	f,h					h			f,j		f	f	f				f,h		f		f,h				f			X
	Environmental	k	k	k	k	k	k	k	k	k	k	x	k			k		k	k	k	k	k	k	k	k	k	k	k	k	k	k	X	X	X
	Political											x					p						o,p		m		m				p		X
Keyword/naming		Future-proof against higher temperatures	Robust against climate change	..under uncertainties	Robust	...under uncertainties	Future-proof	Risk-benefit-based	Robust	Robust	Robust	Robust, flexible	Climate-robust	Robust	Robust	Uncertainty-aware, robust	Uncertainty-based optimal	Uncertainty-based optimal	Uncertainty-based optimal	Uncertainty-based optimal	Robust	Robust	Future-proof, robust	Future-proof, robust	Robust	Robust	Robust, optimum under uncertainty	Uncertainty-based optimal	Robust		Future-proof, climate-robust, robust	Future-oriented, future-proof	Robust, occupant-proof, climate-change-proof, performance based buildings	Future-proof
Type of source		Journal	Journal	Journal	Journal	Journal	Book	Journal	Journal	Journal	Book (PhD)	Journal	Journal	Report	Journal	Journal	Journal	Journal	Journal	Journal	Journal	Conference	Journal	Journal	Journal	Conference	Journal	Journal	Journal	Book (PhD)	Journal	Journal	EPBD
With Case study		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	
Focus on	Epistemic			X				X	X	X	X	X				X	X		X	X	X							X	X	X		X	X	X
	Aleatory	X	X		X	X	X	X	X	X	X	X	X	X	X				X		X	X	X	X	X	X	X	X	X	X	X	X		X
	Error											X											X				X	X					X	
	Linguistic																																	
	Decisoin											X		X	X												X							X
	ST/LT uncertainty	LT	LT	ST	LT	LT	LT	ST	ST/LT	ST/LT	ST/LT	LT	LT	LT	LT	ST	ST	LT	ST	ST/LT	ST/LT	LT	LT	LT	LT	LT	LT	ST/LT	ST/LT	ST	LT	LT	ST	LT
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DaF	Social	a		a	a		a	a	a	a	a	x	a	a	a	a	a		a		a	a	a	a	a,b	a	a	a	a	a	a	a	a	a		a		a	a	X
	Technological				d,c		c			d,c		c		d	c,d,e						d	d		c			x		c	c	d				c			X
	Economic				f,h	d	f,h					h			f,j		f	f	f	f				f,h		f		f,h				f			f			X
	Environmental	k	k	k	k	k	k	k	k	k	k	x	k			k		k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	X	X
	Political											x						p						o,p		m		m						p			X
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With Case study		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	
Focus on	Epistemic			X				X	X	X	X	X				X	X			X	X	X						X	X	X			X	X	X
	Aleatory	X	X		X	X	X	X	X	X	X	X	X	X	X				X		X	X	X	X	X	X	X	X	X	X		X	X		X
	Error											X												X				X	X				X		
	Linguistic																																		
	Decisoin											X		X	X													X							X
	ST/LT uncertainty	LT	LT	ST	LT	LT	LT	ST	ST/LT	ST/LT	ST/LT	LT	LT	LT	LT	ST	ST	ST	LT	ST	ST/LT	ST/LT	LT	LT	LT	LT	LT	ST/LT	ST/LT	ST	LT	LT	ST	LT	LT
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Category of doubts about the future

Perception of future-proofing

Keywords for future-proofing variants

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DaF	Social	a		a	a		a	a	a	a	a	x	a	a	a	a		a		a	a	a	a,b	a	a	a	a	a		a		a	a	X
	Technological				d,c		c			d,c		c		d	c,d,e					d	d		c		x		c	c	d			c		X
	Economic				f,h	d	f,h					h			f,j		f	f	f				f,h		f		f,h				f			X
	Environmental	k	k	k	k	k	k	k	k	k	k	x	k			k		k	k	k	k	k	k	k	k	k	k	k		k	k	k	X	X
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	With Case study	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X		X	
Focus on	Epistemic			X				X	X	X	X	X				X	X		X	X	X							X	X	X			X	X
	Aleatory	X	X		X	X	X	X	X	X	X	X	X	X	X			X		X	X	X	X	X	X	X	X	X	X		X	X		X
	Error											X											X				X	X					X	
	Linguistic																																	
	Decisoin											X		X	X												X							X
	ST/LT uncertainty	LT	LT	ST	LT	LT	LT	ST	ST/LT	ST/LT	ST/LT	LT	LT	LT	LT	ST	ST	LT	ST	ST/LT	ST/LT	LT	LT	LT	LT	LT	LT	ST/LT	ST/LT	ST	LT	LT	ST	LT
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Perception of future-proofing

+ casestudy?

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DaF	Social	a		a	a		a	a	a	a	a	x	a	a	a		a		a	a	a	a,b	a	a	a	a	a		a		a	a	X
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	Economic				f,h	d	f,h					h			f,j	f	f	f				f,h		f		f,h				f				X
	Environmental	k	k	k	k	k	k	k	k	k	k	x	k			k	k	k	k	k	k	k	k	k	k	k	k		k	k	k	X	X
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	With Case study	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X		X	
Focus on	Epistemic			X				X	X	X	X	X				X	X		X	X	X						X	X	X			X	X
	Aleatory	X	X		X	X	X	X	X	X	X	X	X	X	X			X		X	X	X	X	X	X	X	X	X	X	X	X	X		X
	Error											X											X				X	X				X		
	Linguistic																																	
	Decisoin											X		X	X												X							X
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+ casestudy

Impact

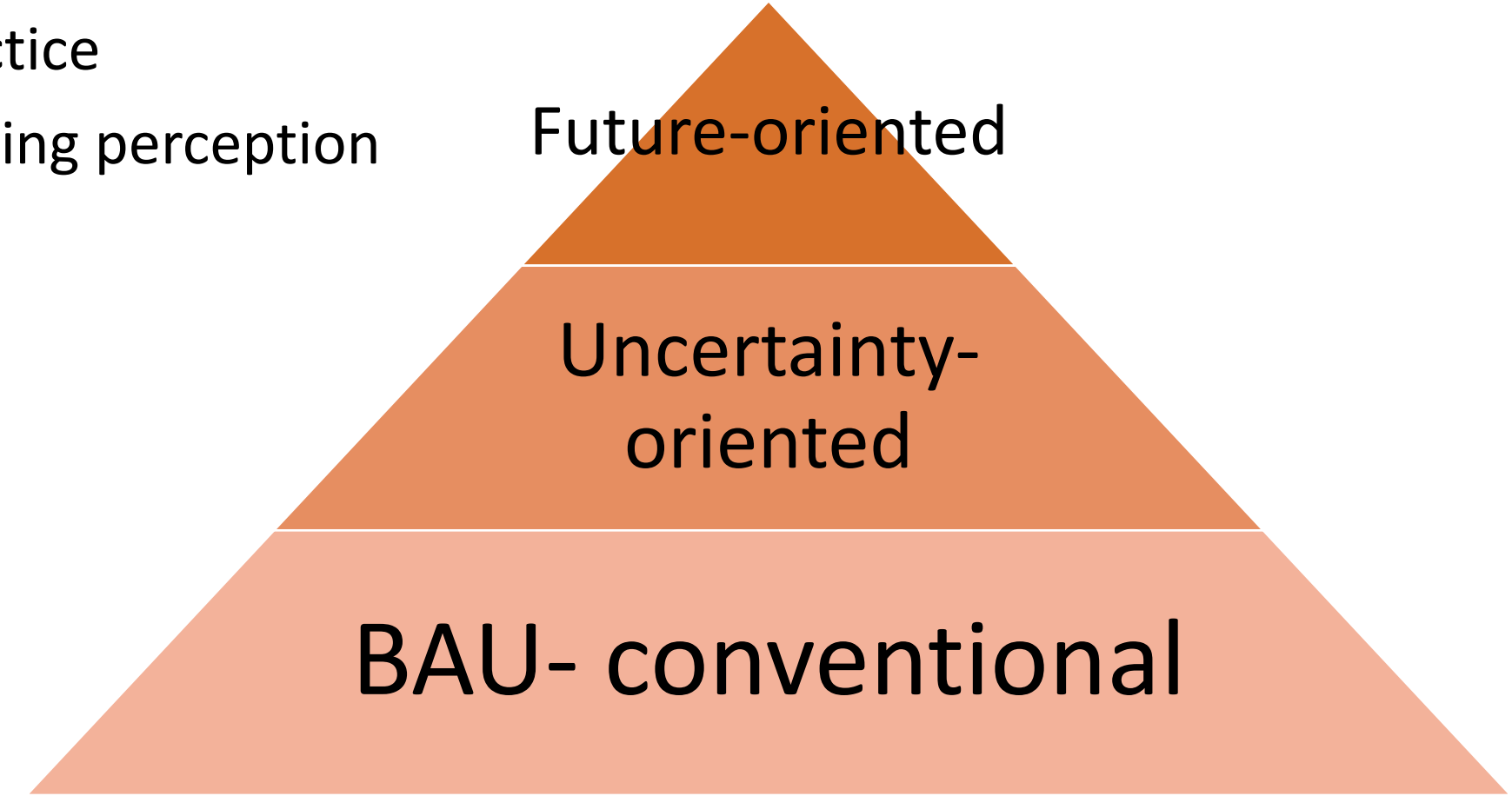
	Author(s)	(Coley, Kershaw, and Eames 2012)	(Nik, Mata and Sasic Kalagasidis 2015)	(Shen and Sun 2016)	(Galimshina, Moustapha and	(Yu, Chen and Sun 2016)	(Buckner, Lafrenie and Denommée 2016)	(Li and Wang 2021)	(Lu, Wang and Yan 2017)	(Huang, Huang, and Sun 2018)	(Hopfe 2009)	(Floricel and Miller 2001)	(Moazami, Salvatore and Vahid 2019)	(Gallé, Poppe and Cambier 2019)	(Zhou, Cao, and Hensen 2021)	(Westermann and Evins 2021)	(Ji, Liang and Xei 2021)	(Wang, Qi and Ren 2021)	(Chang, Rivera, and Wanielista 2011)	(Li, Wang, and Tang 2019)	(Li and Wang 2020)	(Kotireddy, Hoes, and Hensen, 2017)	(Georgiadou, Hacking, and Guthrie 2012)	(Alavirad, Mohammadi and Hoes 2022)	(Kotireddy, Hoes, and Hensen 2018)	(Kotireddy, Hoes, and Hensen 2015)	(Rysanek and Choudhary 2013)	(Cheng, Wang and Yan 2017)	(Leyten and Kurvers 2006)	(Lu, Shengwei and Chengchu 2017)	(Ramon 2021)	(Howlett, Malevitt, and Hacking 2012)	(De Wilde 2014)	(Bean, Volt and Dorizas 2019)
DaF	Social	a		a	a		a	a	a	a	a	x	a	a	a	a		a		a	a	a	a,b	a	a	a	a	a		a		a	a	X
	Technological				d,c		c			d,c		c		d	c,d,e					d	d		c		x		c	c	d			c		X
	Economic				f,h	d	f,h					h			f,j		f	f	f				f,h		f		f,h				f			X
	Environmental	k	k	k	k	k	k	k	k	k	k	x	k			k		k	k	k	k	k	k	k	k	k	k	k		k	k	k	X	X
	Political											x					p						o,p		m		m					p		X
Keyword/naming		Future-proof against higher temperatures	Robust against climate change	..under uncertainties	Robust	...under uncertainties	Future-proof	Risk-benefit-based	Robust	Robust	Robust	Robust, flexible	Climate-robust	Robust	Robust	Uncertainty-aware, robust	Uncertainty-based optimal	Uncertainty-based optimal	Uncertainty-based optimal	Uncertainty-based optimal	Robust	Robust	Future-proof, robust	Future-proof, robust	Robust	Robust	Robust, optimum under uncertainty	Uncertainty-based optimal	Robust		Future-proof, climate-robust, robust	Future-oriented, future-proof	Robust, occupant-proof, climate-change-proof, performance based buildings	Future-proof
Type of source		Journal	Journal	Journal	Journal	Journal	Book	Journal	Journal	Journal	Book (PhD)	Journal	Journal	Report	Journal	Journal	Journal	Journal	Journal	Journal	Journal	Conference	Journal	Journal	Journal	Conference	Journal	Journal	Journal	Book (PhD)	Journal	Journal	EPBD
With Case study		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X		X	X	
Focus on	Epistemic			X				X	X	X	X	X				X	X		X	X	X							X	X	X		X	X	X
	Aleatory	X	X		X	X	X	X	X	X	X	X	X	X	X			X		X	X	X	X	X	X	X	X	X	X		X	X		X
	Error											X											X				X	X					X	
	Linguistic																																	
	Decisoin											X		X	X												X							X
	ST/LT uncertainty	LT	LT	ST	LT	LT	LT	ST	ST/LT	ST/LT	ST/LT	LT	LT	LT	LT	ST	ST	LT	ST	ST/LT	ST/LT	LT	LT	LT	LT	LT	LT	ST/LT	ST/LT	ST	LT	LT	ST	LT
	|Impact [%]|	/	≤78	≤14.4	≤30	≤20	/	≤40	≤45,6	≤13	≤75	/	≤14.4	/	≤77	≤30	≤71	≤14.2	≤70	≤36.8	≤54	/	/	≤100	/	/	≤50	≤17,7	≤50	/	≤67	/	≤30	/

Perception of future-proofing

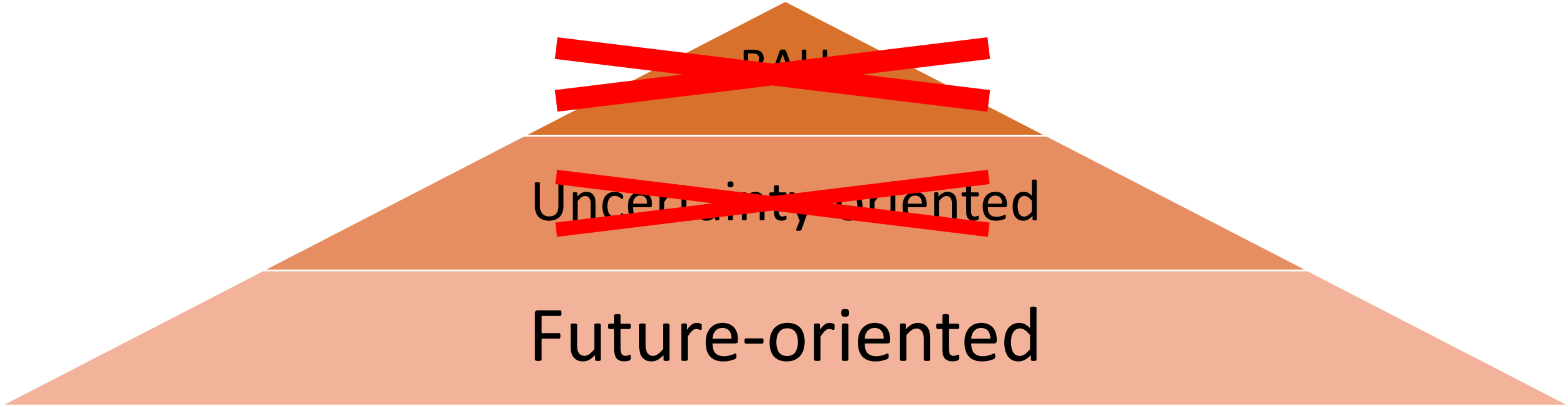
SQ1: What are doubts about the future?
SQ2: What is “future-proof”?
SQ3: Consistency of “future-proofing” in practice
SQ4: “Future-proofing” in energetic renovations

In practice

→varying perception



Perception of future-proofing



SQ1: What are doubts about the future?
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SQ4: “Future-proofing” in energetic renovations

Design practice

Focus on **energy technology** for residential buildings

Cohesion

Shared responsibility (circular bussiness models, e.g. shared ownership, partnerships, ESCO, etc.)
Accessibility, readability
Holistic design approach (in relation to SDGs, intigration with surroundings, etc.)

Reserves

Buffers (with respect to financial, technologic, and other sources, beyond prevailing regulations, etc.)
Emerging technologies (-ready)

Flexibility

Reversibility, simplicity, accessibility, grouping and information on durability of the components, decoupling (and independence), possibility to dismount, to relocate, divisibility, hierarchically system-based layers, modularity, etc.
Diversity
Smart (-ready), source control, BACS, etc.
Simplicity, passive first, etc.
Internal flexibility: open space plan, multi-purpose, multi-functional

Generativity

Qualitative
Quantitative

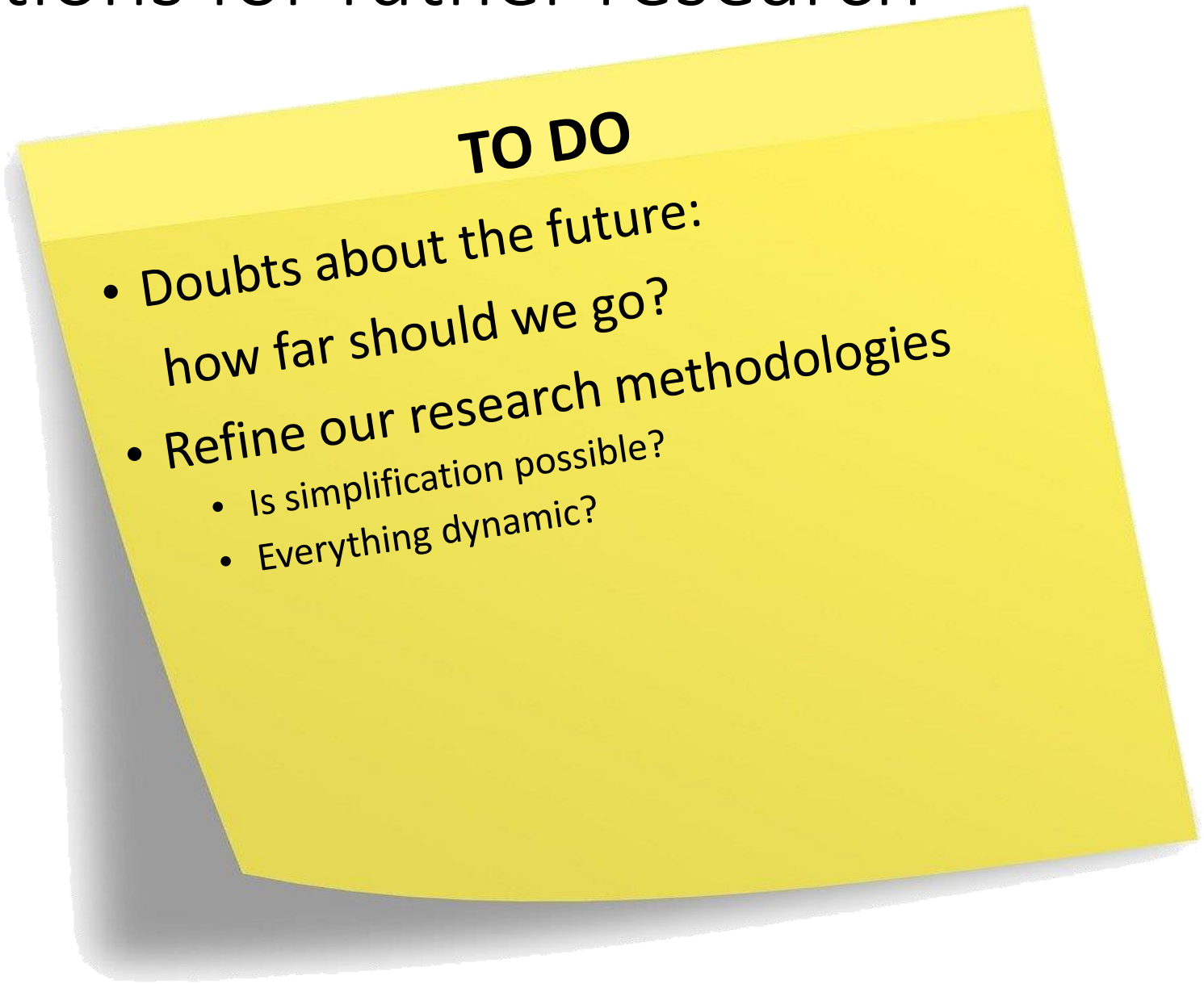
SQ1: What are doubts about the future?
SQ2: What is “future-proof”?
SQ3: Consistency of “future-proofing” in practice
SQ4: “Future-proofing” in energetic renovations

Assessment

Focus on **energy technology** for residential buildings

	↓ secured performance	**↑ secured performance**
Time steps	Static	Dynamic
Sequence of events	Linear	Sequential

Suggestions for futher research



Besluit

Subquestion 1: Doubts about the future?
Subquestion 2: What is “future-proofing” in literature?
Subquestion 3: Consistency and impact of “future-proofness” in practice
Subquestion 4: “Future-proofing” in energetic renovations

Are we really future-proofing our buildings?

"We still have **a long way to go** to make renovation designs future-proof, **there has however already been a lot of deepening and improvement** in the future-proofing-theme in recent years."