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MECHANICAL ENERGY SYSTEM SIMULATION OPTIMISATION

Performance Potential for Ventilative Cooling: Renewable Status and Design Stage Assessment in Ireland

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AIVC & Venticool Webinar | Design and Performance Assessment of Ventilative Cooling | Mar 2024

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Background and context

Renewable VC – Previous Work and Challenges

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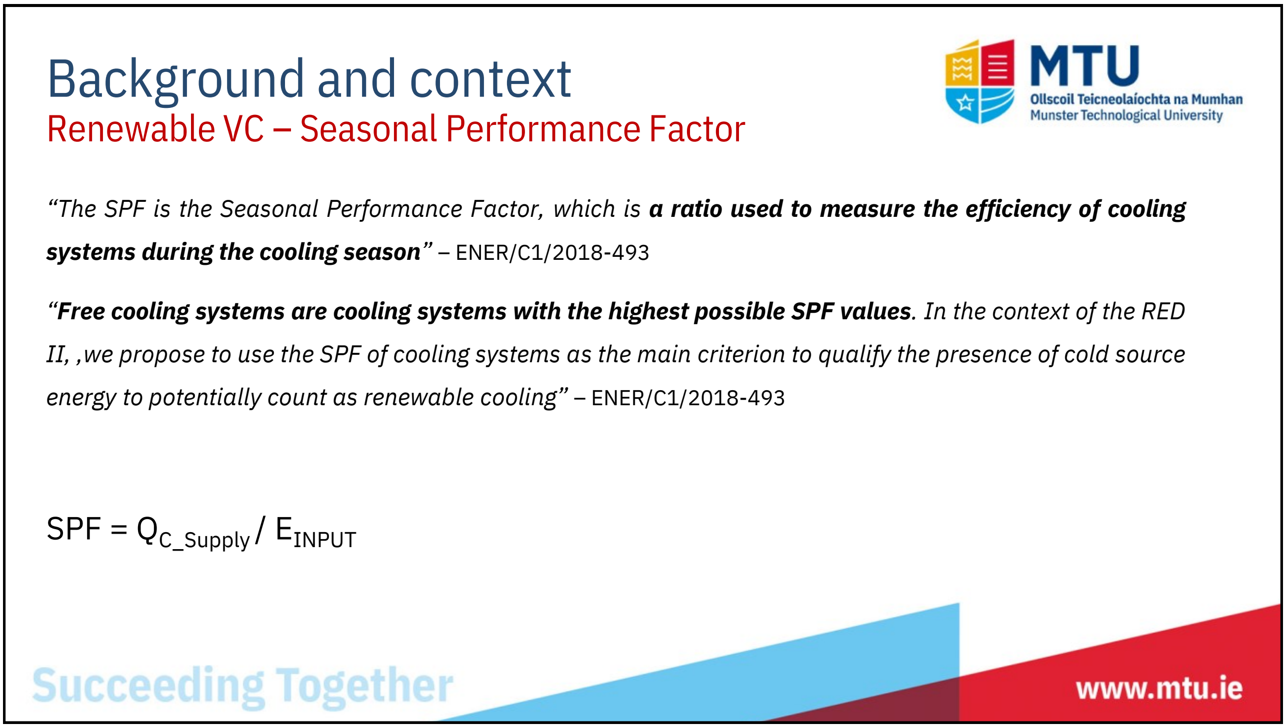
- Limited work focusing directly on the SPF of VC systems (O'Donovan et al. 2023, Yan et al. 2022, Holzer and Stern. 2019, Cremers et al. 2018)
- The scope of renewables should be outside of reversible heat pumps (Krazl et al. 2021).
- VC as a renewable **had** to overcome:
  1. Cannot be a passive cooling (building insulation, green roof, vegetal wall, shading, thermal mass) – **not attenuation or demand reduction** (section 2.6.2.1)
  2. Cooling without fans or pumps – this **excludes natural ventilation** (section 2.6.2.2)
  3. Has to exclude ventilation for hygienic purposes cooling is **not intentional** (section 2.6.2.3)



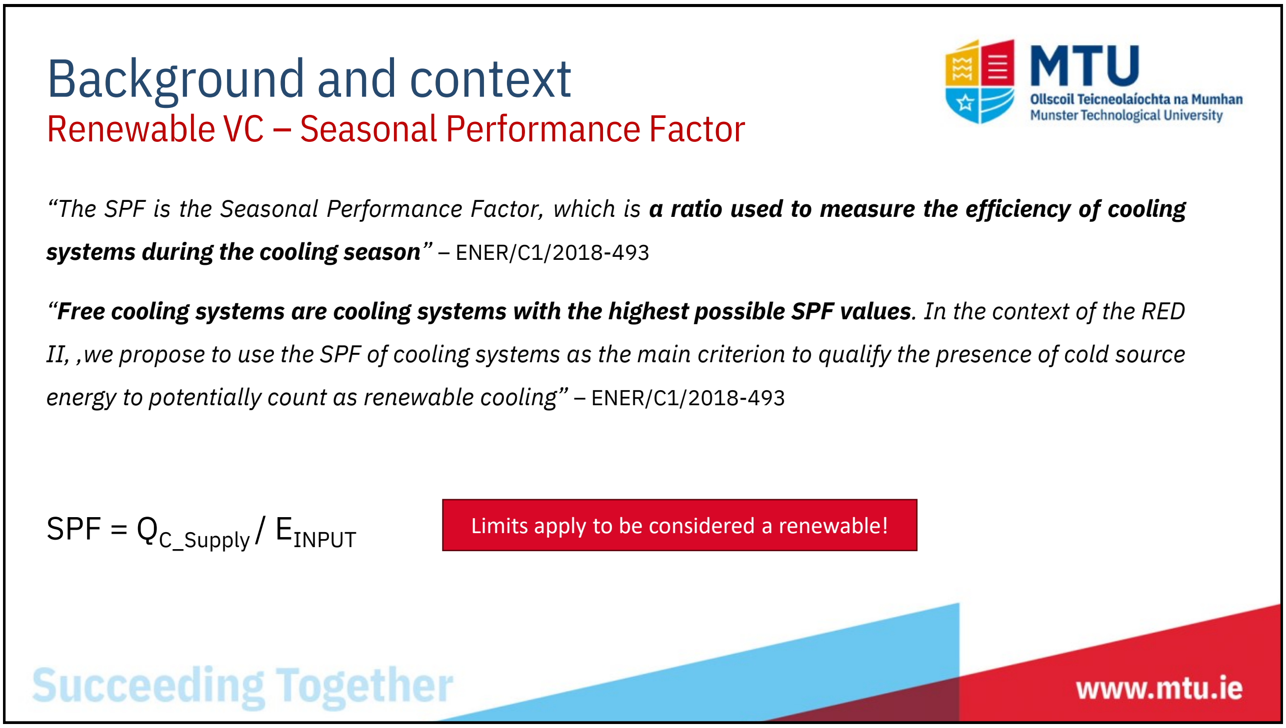
Background and context

Renewable VC – Seasonal Performance Factor

"The SPF is the Seasonal Performance Factor, which is ***a ratio used to measure the efficiency of cooling systems during the cooling season****"* – ENER/C1/2018-493

*"**Free cooling systems are cooling systems with the highest possible SPF values**. In the context of the RED II, ,we propose to use the SPF of cooling systems as the main criterion to qualify the presence of cold source energy to potentially count as renewable cooling"* – ENER/C1/2018-493

$SPF = Q_{C\_Supply} / E_{INPUT}$



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$SPF = Q_{C\_Supply} / E_{INPUT}$

Limits apply to be considered a renewable!

Background and context

Ventilative Cooling as a Renewable

Policy background

*"Where **ventilation air is used as a heat transport medium for cooling**, the corresponding cooling supply, which can be supplied either **by a cooling generator or by free cooling** is part of renewable cooling calculation." – Regulation (EU) 2022/759 (Venticool.eu)*

Literature review

Table 1: Reported efficiency values from literature

Author	Year	Ventilation Type	Metric	Value
Cremers et al.	2018	MVC	SPF	3.7 to 9.8
Holtzer and Stern et al.	2019	MVC	COP	24
Yan et al.	2022	NVC plus heat pumps	COP	18.3
O' Donovan et al.	2023	NVC	SPF	63
		MVC	SPF	23

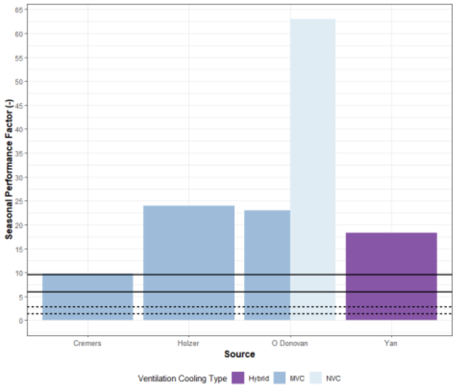


Figure 1: Maximum SPF values achieved in literature (Lines show thresholds according to Renewable Energy Directive EU and Ireland)

Background and context

Aim and objectives – Renewable NVC and MVC

A: To present an example of renewable NVC and MVC in a non-residential building using a **dynamic simulation approach.**

- **O1:** Present cooling demand and **feasibility**
- **O2:** Present **actual performance** using design summer year (DSY) data (2021 and 2071).
- **O3:** Calculate seasonal performance factor (**SPF**) for NVC and MVC systems
- **O4:** Discuss **implications, future work and direction**

Materials and Methods

Materials and Methods

General Methodology

Case Study Classroom

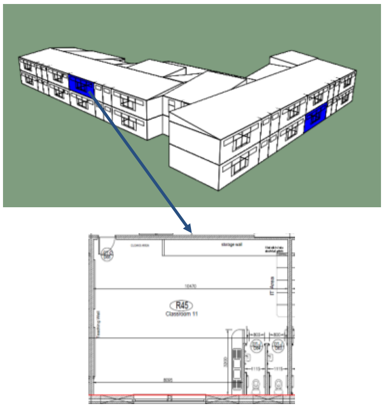
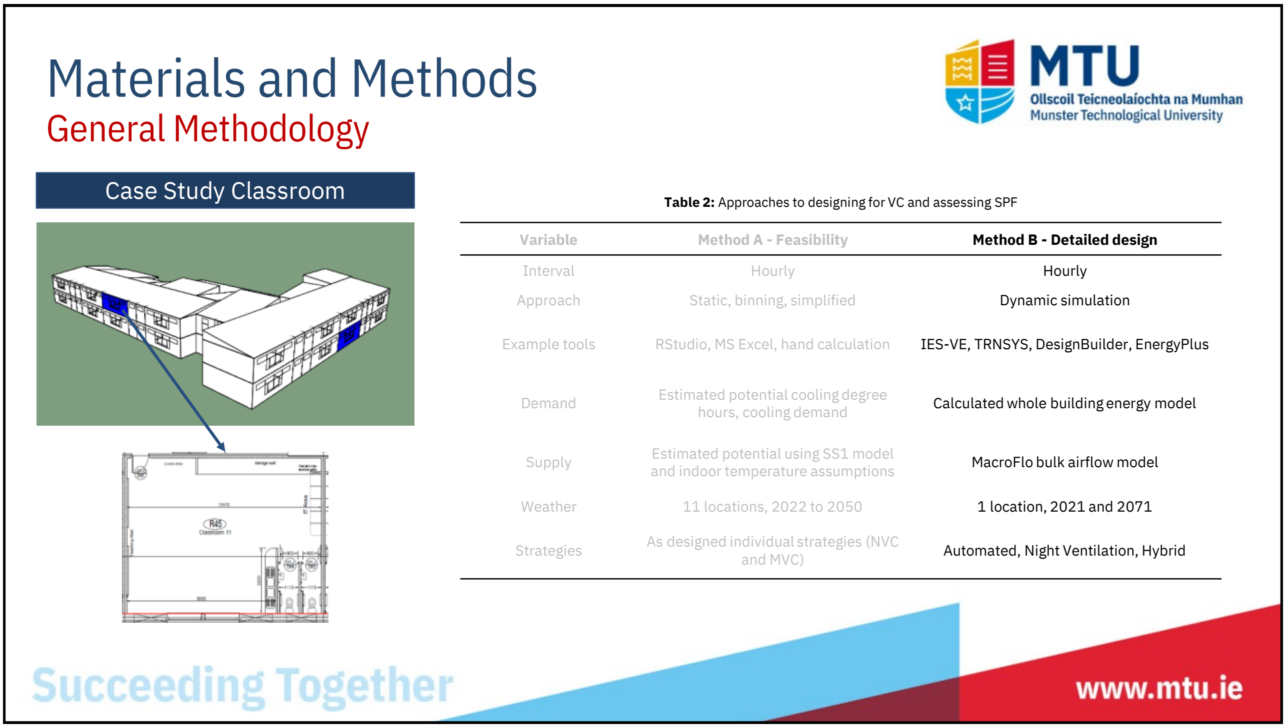


Table 2: Approaches to designing for VC and assessing SPF

Variable	**Method A - Feasibility**	**Method B - Detailed design**
Interval	Hourly	Hourly
Approach	Static, binning, simplified	Dynamic simulation
Example tools	RStudio, MS Excel, hand calculation	IES-VE, TRNSYS, DesignBuilder, EnergyPlus
Demand	Estimated potential cooling degree hours, cooling demand	Calculated whole building energy model
Supply	Estimated potential using SS1 model and indoor temperature assumptions	MacroFlo bulk airflow model
Weather	11 locations, 2022 to 2050	1 location, 2021 and 2071
Strategies	As designed individual strategies (NVC and MVC)	Automated, Night Ventilation, Hybrid



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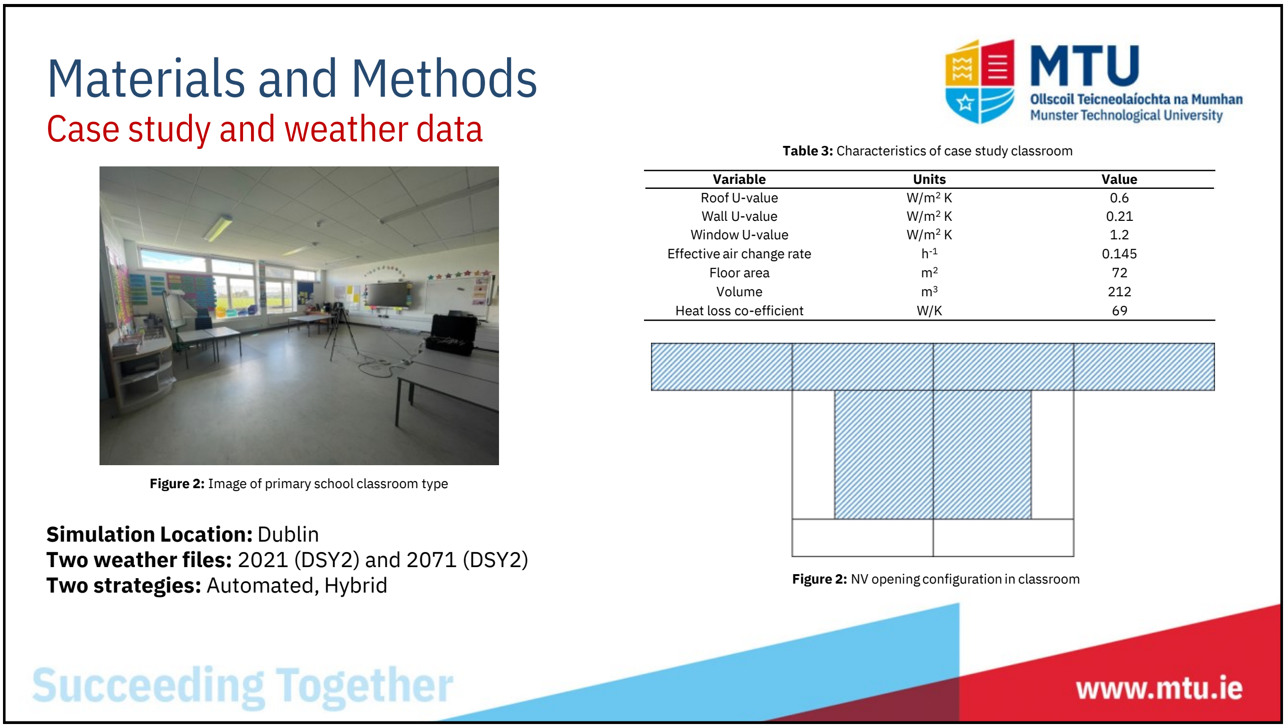

Materials and Methods

Case study and weather data

Figure 2: Image of primary school classroom type

Simulation Location: Dublin
Two weather files: 2021 (DSY2) and 2071 (DSY2)
Two strategies: Automated, Hybrid

Table 3: Characteristics of case study classroom

Variable	Units	Value
Roof U-value	W/m^2 K	0.6
Wall U-value	W/m^2 K	0.21
Window U-value	W/m^2 K	1.2
Effective air change rate	h^{-1}	0.145
Floor area	m^2	72
Volume	m^3	212
Heat loss co-efficient	W/K	69

Figure 2: NV opening configuration in classroom

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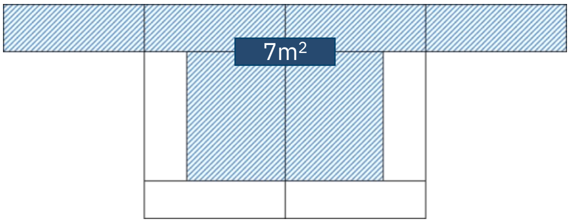

Figure 2: NV opening configuration in classroom

Materials and Methods

NVC and MVC strategies considered

Table 4: Strategies simulated in IES-VE

ID	Strategy Name	Day/Night Usage	Season	Time	Operable Windows
AV	Automated Ventilation	Day	All year	09:00 am to 02:30 pm	All windows
HV	Hybrid Ventilation	Day/ Summer Night	All year	Daytime: 9am to 2:30pm Night-time: 10pm to 7am	All windows

Table 5: E_{INPUT} values reported for NVC and MVC

Reference	System type	Units	Values reported
(Cho et al. 2021)	Hybrid systems	kWh/m²/a	0.3 – 2.8
(Agency and Programme 2018)	NVC	kWh/m²/a	~1.2
(Santos, Hopper, and Kolokotroni 2016)	NVC + phase change materials	kWh/m²/a	~0.77
(Yan et al. 2022)	NVC	kWh/m²/a	0.7-1.3
(Holzer and Stern 2019)	MVC	W/(m³/s)	<200
(Holzer and Psomas 2018)	MVC	W/(m³/h)	0.07 - 0.14

Figure 3 : HV system studied

Day-time rate: 350l/s
Night-time rate: 530l/s
Power consumption: 30W

Materials and Methods

Metrics and assumptions

$$Q_{supply} = \dot{m}C_{p,a}(T_i - T_e) \quad \textbf{(1)}$$

$$SPF_{\mathrm{vc,annual}} = \frac{\sum Q_{supply}}{\sum E_{INPUT}} \quad \textbf{(2)}$$

C_{pa} = 1.006kJ/kgK

p_a = 1.2kg/m^3

- Range of E_{INPUT} considered as opposed to calculated
- Only Positive Q_{supply} considered
- Hygienic ventilation rate of 8l/s/p excluded (max occupancy 25)
- T_e of >10°C applied in spring for Automated, $T_e < T_i$ during summer, >15°C for Hybrid.
- Macroflo zonal external flowrate used.

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Results and Discussion

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Part A - Feasibility

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Feasibility – Classroom Cooling Energy Demand

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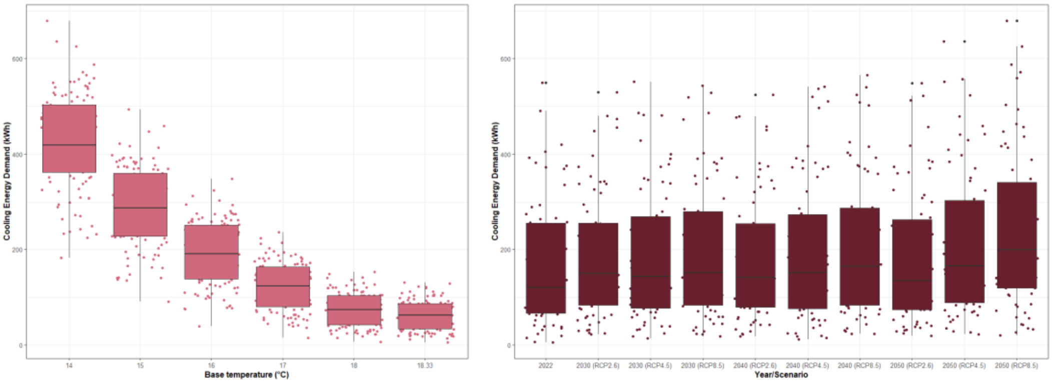

Figure 4: Cooling energy demand for specific classroom with respect to different base temperatures and weather files

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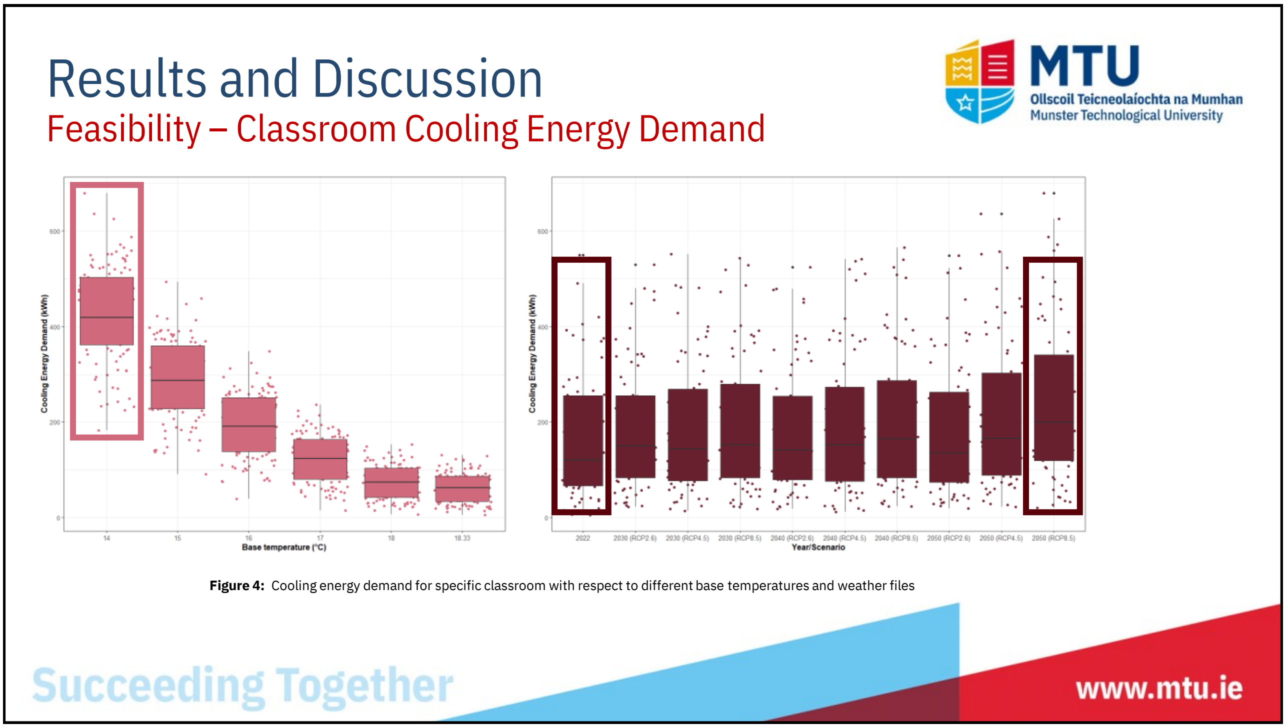

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Feasibility – Classroom Cooling Energy Demand

Figure 4: Cooling energy demand for specific classroom with respect to different base temperatures and weather files

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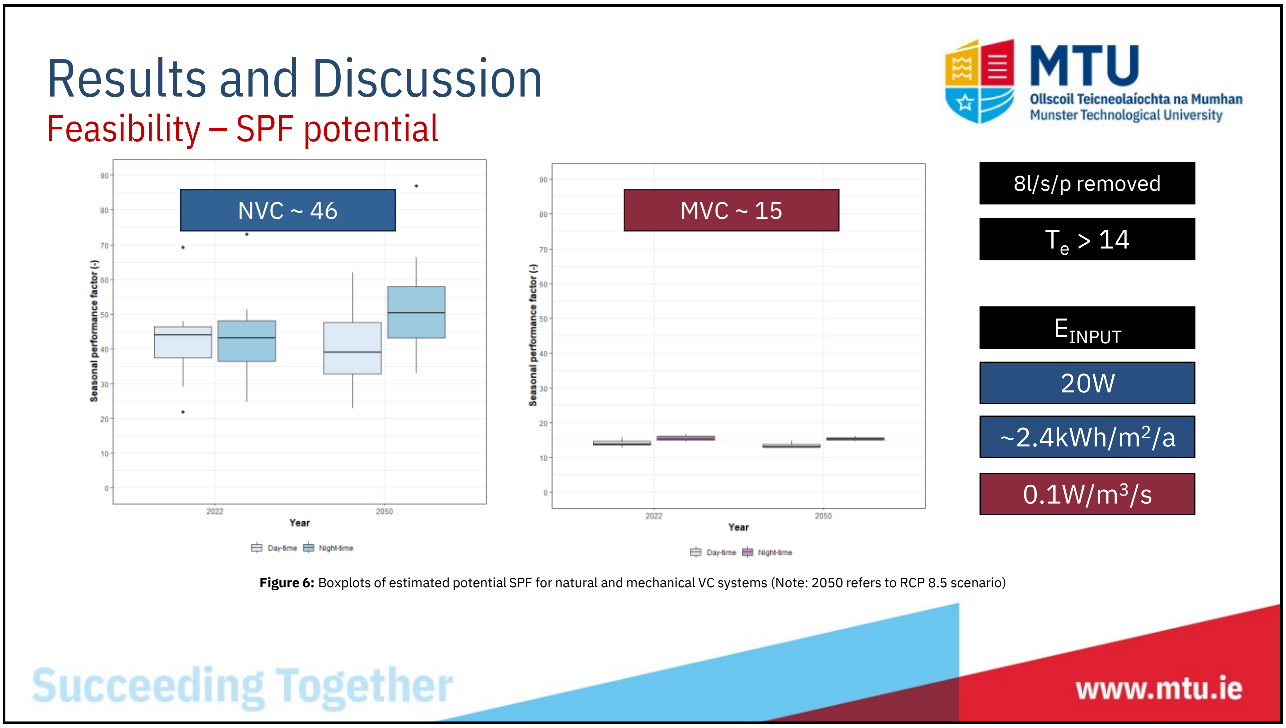

Results and Discussion

Feasibility – SPF potential

NVC ~ 46

MVC ~ 15

8l/s/p removed

$T_e > 14$

E_{INPUT}

20W

~2.4kWh/m^2/a

0.1W/m^3/s

Figure 6: Boxplots of estimated potential SPF for natural and mechanical VC systems (Note: 2050 refers to RCP 8.5 scenario)

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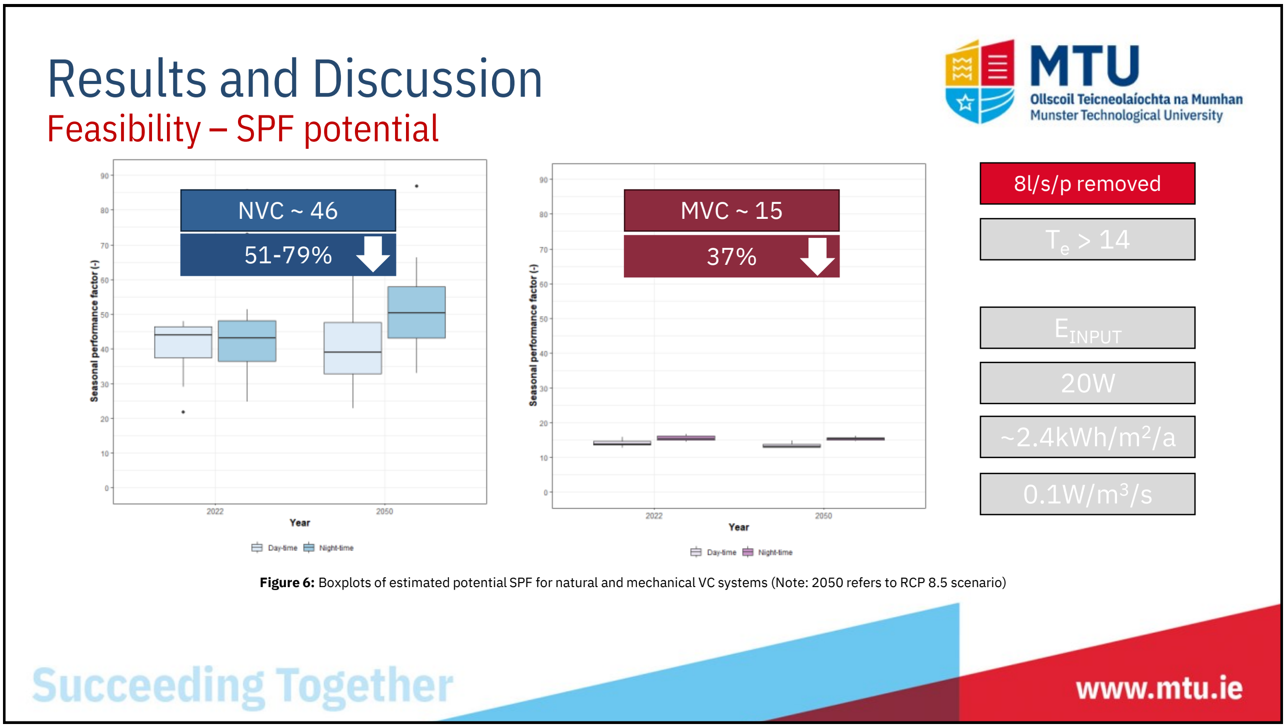

Results and Discussion

Feasibility – SPF potential

NVC ~ 46

51-79%

MVC ~ 15

37%

8l/s/p removed

$T_e > 14$

E_{INPUT}

20W

~2.4kWh/m^2/a

0.1W/m^3/s

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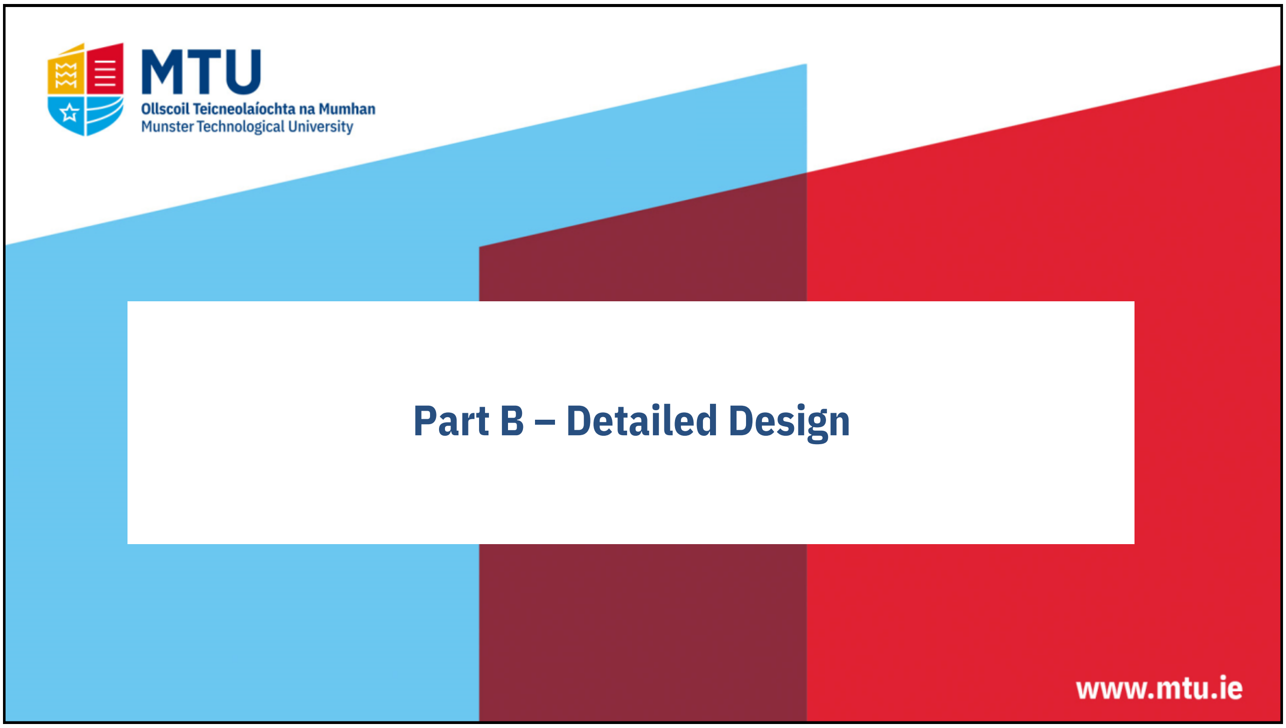

Part B – Detailed Design

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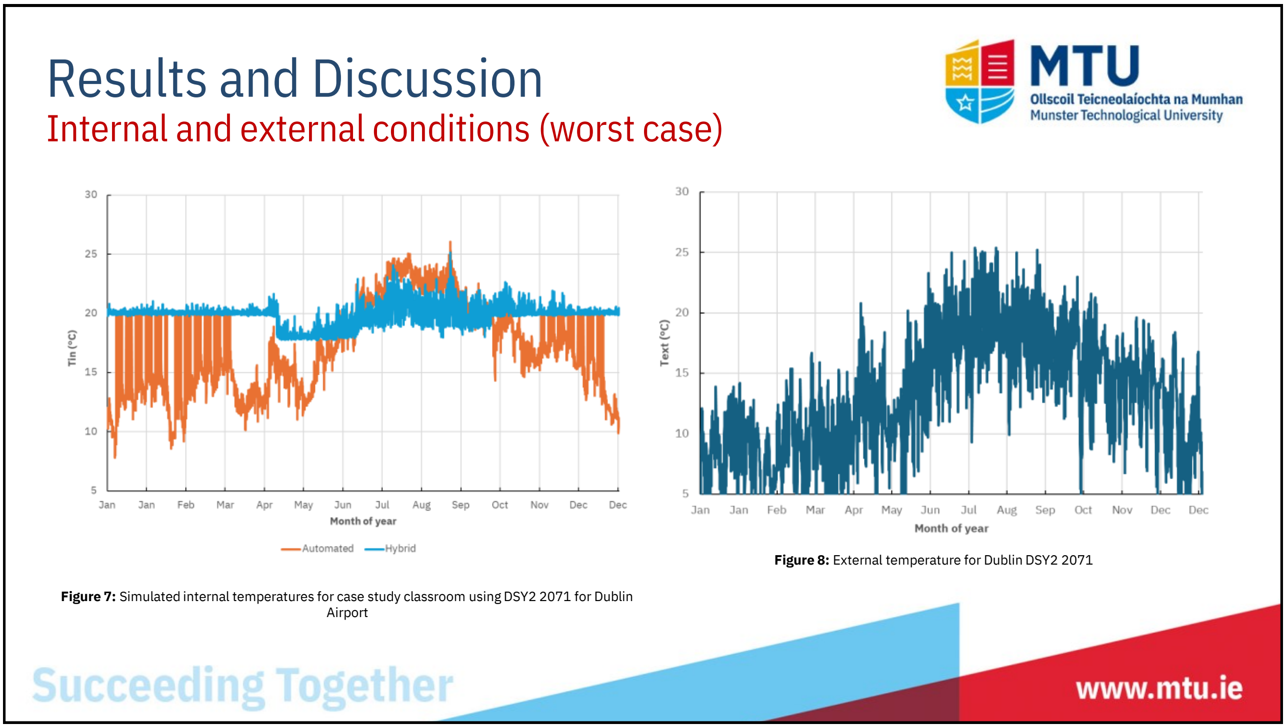

Results and Discussion

Internal and external conditions (worst case)

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Figure 7: Simulated internal temperatures for case study classroom using DSY2 2071 for Dublin Airport

Figure 8: External temperature for Dublin DSY2 2071

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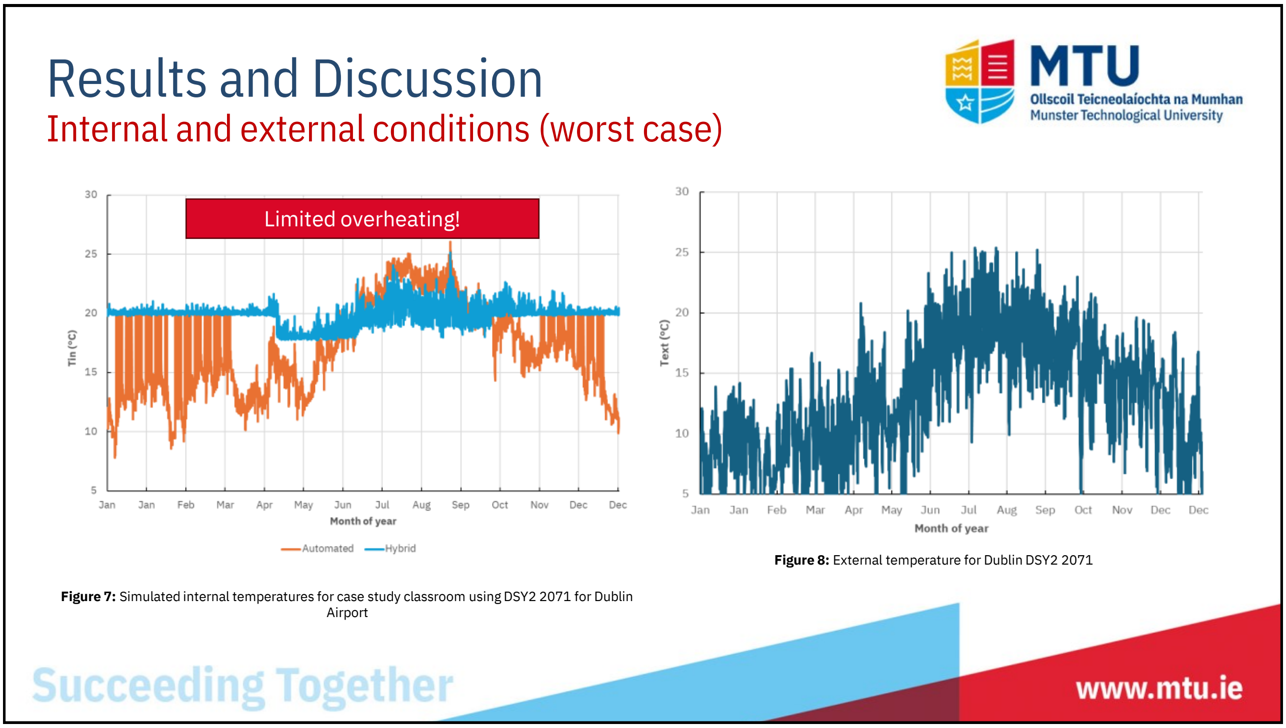

Results and Discussion

Internal and external conditions (worst case)

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Limited overheating!

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Results and Discussion

SPF calculations

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Table 6: Calculated seasonal performance factors for different systems

System	Year	Q_{supply} max (kWh)	Q_{supply} VC only (kWh)	E_{INPUT} MVC total (kWh)	E_{INPUT} MVC VC only (kWh)	E_{INPUT} NVC min (kWh)	E_{INPUT} NVC max (kWh)	SPF_{min} (-)	SPF_{max} (-)
Automated	2021 DSY	2883	1776	0	0	72	173	10.3	24.7
	2071 DSY	3282	2300	0	0	72	173	13.3	31.9
Hybrid	2021 DSY	3448	807	707	166	72	173	2.4	3.4
	2071 DSY	3144	811	813	177	72	173	2.3	3.3

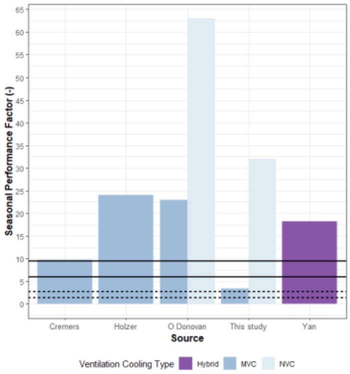

Figure 9: Maximum SPF values achieved in literature updated (Lines show thresholds according to Renewable Energy Directive EU and Ireland)

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Results and Discussion

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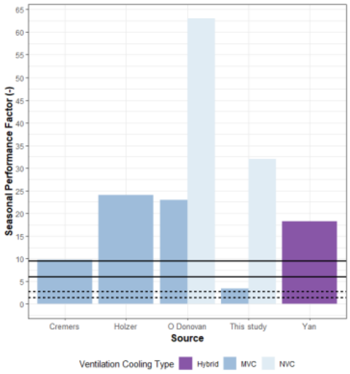

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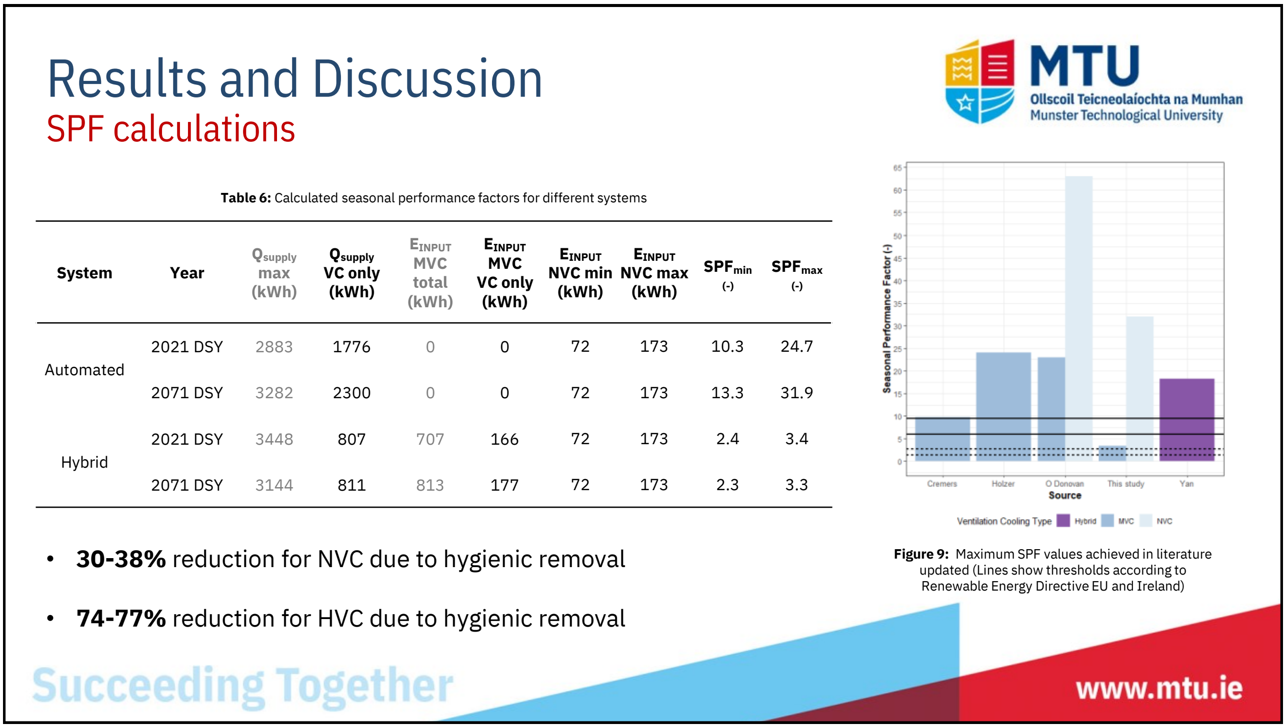

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- **30-38%** reduction for NVC due to hygienic removal
- **74-77%** reduction for HVC due to hygienic removal

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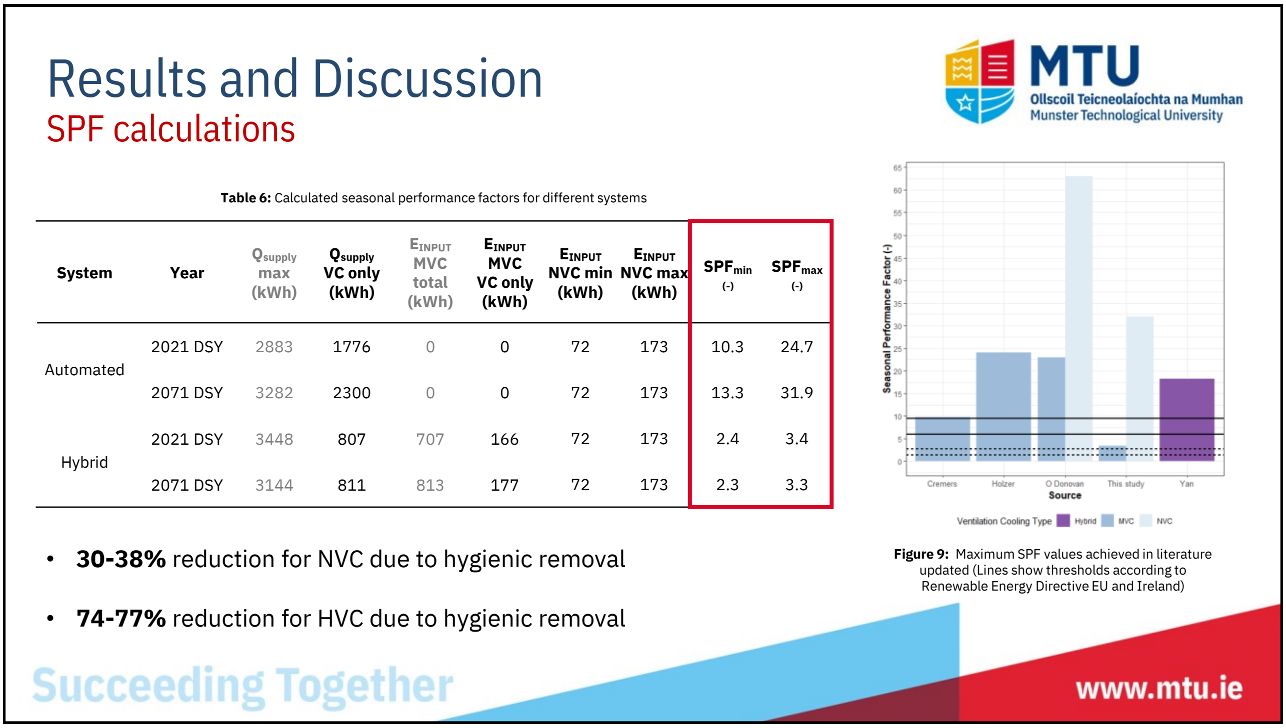

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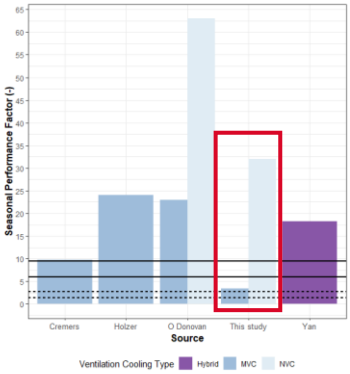

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Implications and future work

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Implications and future work

Renewable ventilative cooling in Ireland

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Potential Implications

- VC is a renewable system, **should grants be offered for it?** How will they be demonstrated?
- They may need to be **part-operated** in some regions, what does this mean for grants?

Future work

- Need for VC industry to provide **more detailed information** on VC systems (E_{INPUT}, Q_{supply}, etc)
- Need to **study real systems**, however, metering the heat of VC systems can be a challenge.
- More work needed in stress testing VC solutions in different external conditions.
- Need to consider **the role of hygienic ventilation** and exclusion

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Thank You, Any Questions?

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