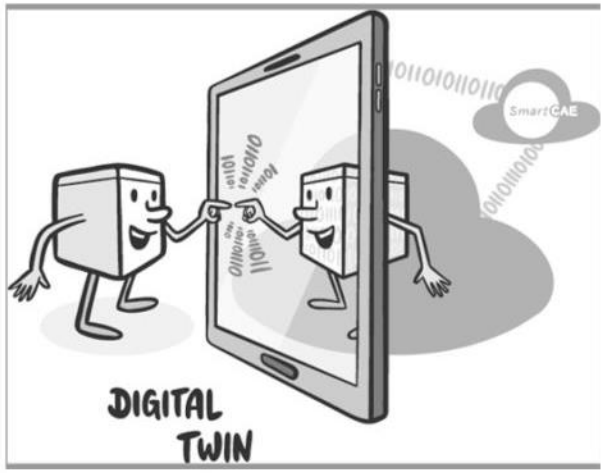
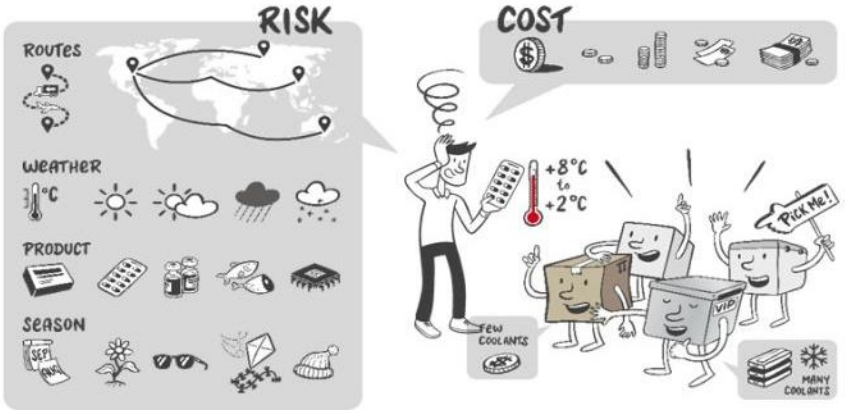
Digital Cold Chain: Learn How This Makes the Cold Chain Transparent, Less Risky, More Cost-Efficient, and Greener

SmartCAE



Reality in the Cold Chain



Who is SmartCAE

Founded in 2002

Thermal engineering company, since 2014 focus on Temperature Controlled Logistics

SmartCAE is the inventor of the **Virtual Cold Chain**

Current customer base around the world >20 countries

- Pharma companies: 10 of the top 20 pharmas work with us
- Packaging companies: most of the global relevant companies

The **Virtual Cold Chain** is an award-winning software platform for the simulation of Temperature Controlled Logistics

Digital Twin

What is the idea of a digital twin

- Definition from Gartner

- A digital twin is a digital representation of a real-world entity or system.
  1. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object or process.
  2. Data from multiple digital twins can be aggregated for a composite view across a number of real-world entities.

- https://www.gartner.com/en/information-technology/glossary/digital-twin

History of Digital Twins

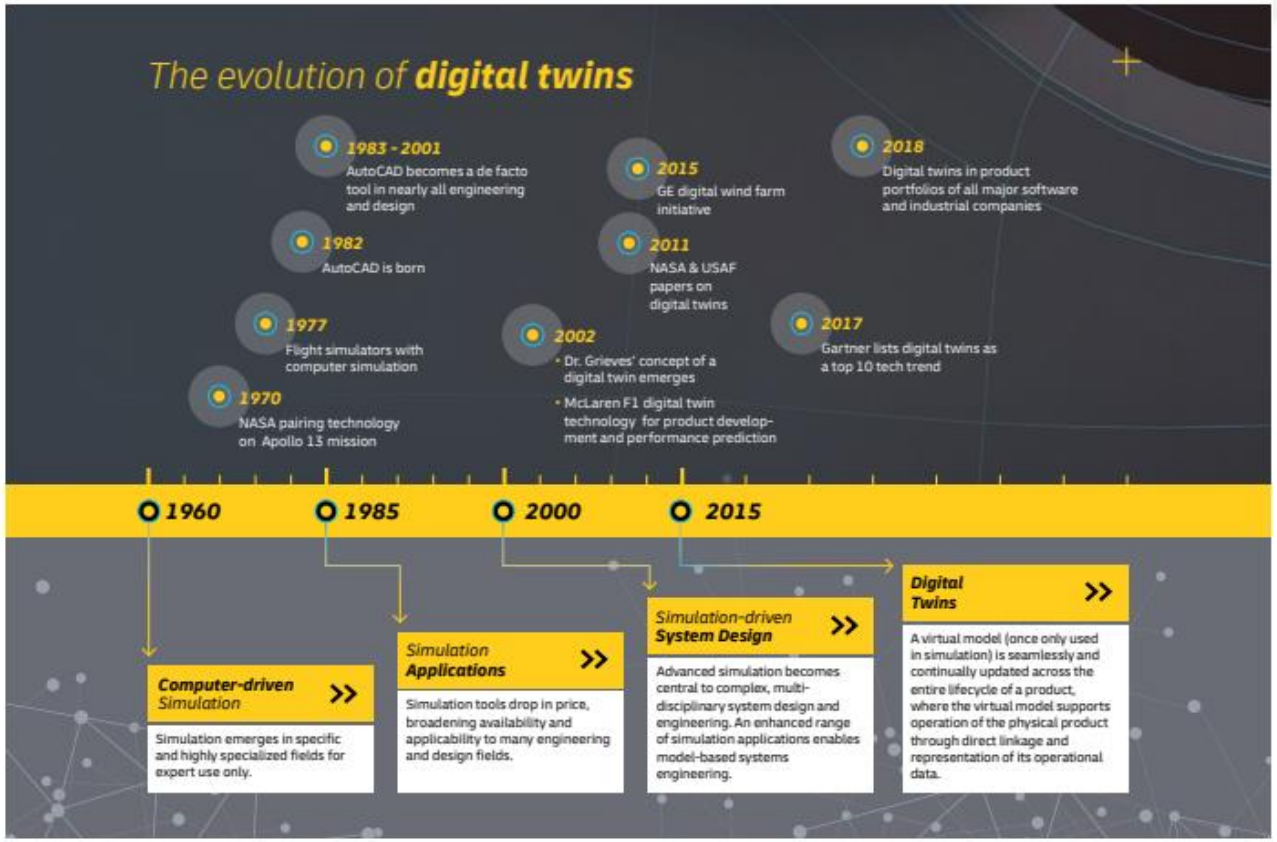


Figure 1

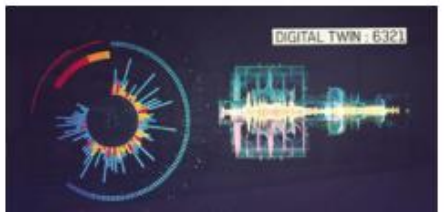
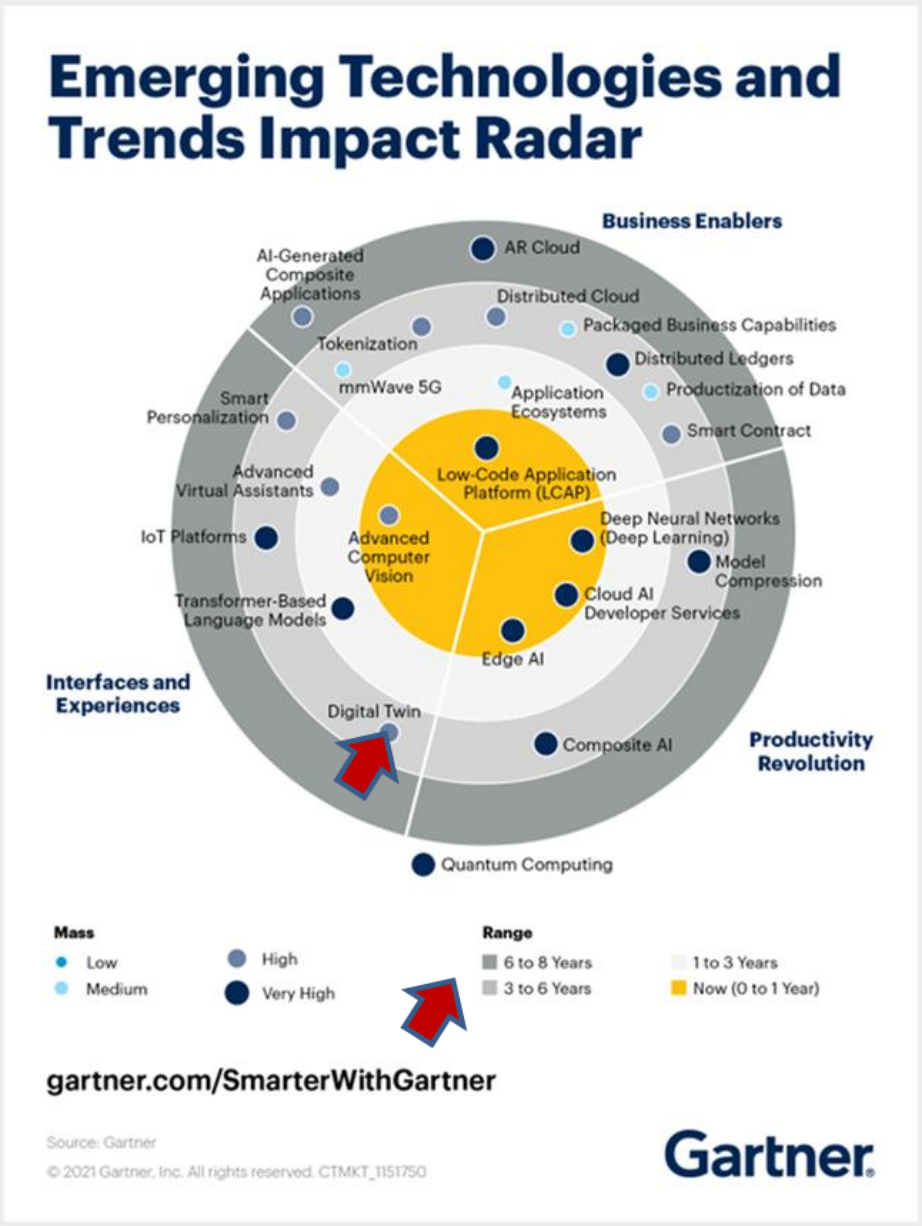


Figure 1: The evolution of digital twins. Source: DHL

Figure 2: GE has created a digital twin of the Boeing 777 engine specifically for engine blade maintenance. Source: GE

- https://www.dhl.com/content/dam/dhl/global/core/documents/pdf/glo-core-digital-twins-in-logistics.pdf

Last study of Gartner before Corona



But the last two years have changed a lot for a digital-first approach

A digital approach was often the only way to determine the risk

And if this works for Covid Treatment it should also work for an Aspirin.

Why there is need for a digital twin in Cold Chain

How many tests in a climate chamber do you make to find the right passive box for a lane

Sie können sehen, wie abgestimmt wurde. Mehr erfahren

<10 tests	38%
<20 tests	38%
<50 tests	10%
50 + tests	14%

Survey Results

ista FORUM 2022 TempPack

Topic	Online Survey	TempPack Poll	Total Votes
Risk Assessment - Selecting and/or implementing temperature-controlled packaging	18		
Lane Qualification	14		

Payload for passive thermal packaging
When do you qualify a passive thermal container, which type of payload do you use?

Sie können sehen, wie abgestimmt wurde. Mehr erfahren

No payload	16%
Empty cardboard boxes	13%
Dummy product	59%
Water bottles	13%

How long does it take to qualify a passive box for a lane?

Sie können sehen, wie abgestimmt wurde. Mehr erfahren

1 week	18%
<1 month	18%
< 3 months	18%
more than 3 months	45%

Which type of data you use for your ambient temperature profile to qualify a passive thermal box for a lane

Sie können sehen, wie abgestimmt wurde. Mehr erfahren

Standardprofile (ISTA, others)	29%
Logger Ambient Temperatur Data	35%
Historical Weather Data	18%
Customized Ambient Profiles	18%

When you run a lane risk assessment for temperature sensitive products, which is for you the most interesting feature

Sie können sehen, wie abgestimmt wurde. Mehr erfahren

Risk of Temperature Excursions	78%
Compute Cost/Risk ratio	17%
A certificate for doing it	4%
How fast+easy it could be done	0%

How do you take tolerances in your qualification process of thermal packaging into account?

Sie können sehen, wie abgestimmt wurde. Mehr erfahren

Multiple climate chamber tests	45%
Extra tests for tolerances	18%
Nothing special	18%
Computer simulations	18%

How long is your security buffer if you qualify a passive thermal box for a lane?

Sie können sehen, wie abgestimmt wurde. Mehr erfahren

0-25%	28%
25-100%	20%
100 + %	0%
Depends on the lane	52%

Most relevant topics for finding the right passive thermal packaging for a lane

Sie können sehen, wie abgestimmt wurde. Mehr erfahren

Total Cost of Ownership	7%
Risk of Temperature Excursions	64%
Ambient Temperature Profile	7%
Type of Payload	21%

Real world shows confusion

How many test shipments you are using for a performance qualification for a passive box?

Sie können sehen, wie abgestimmt wurde. Mehr erfahren

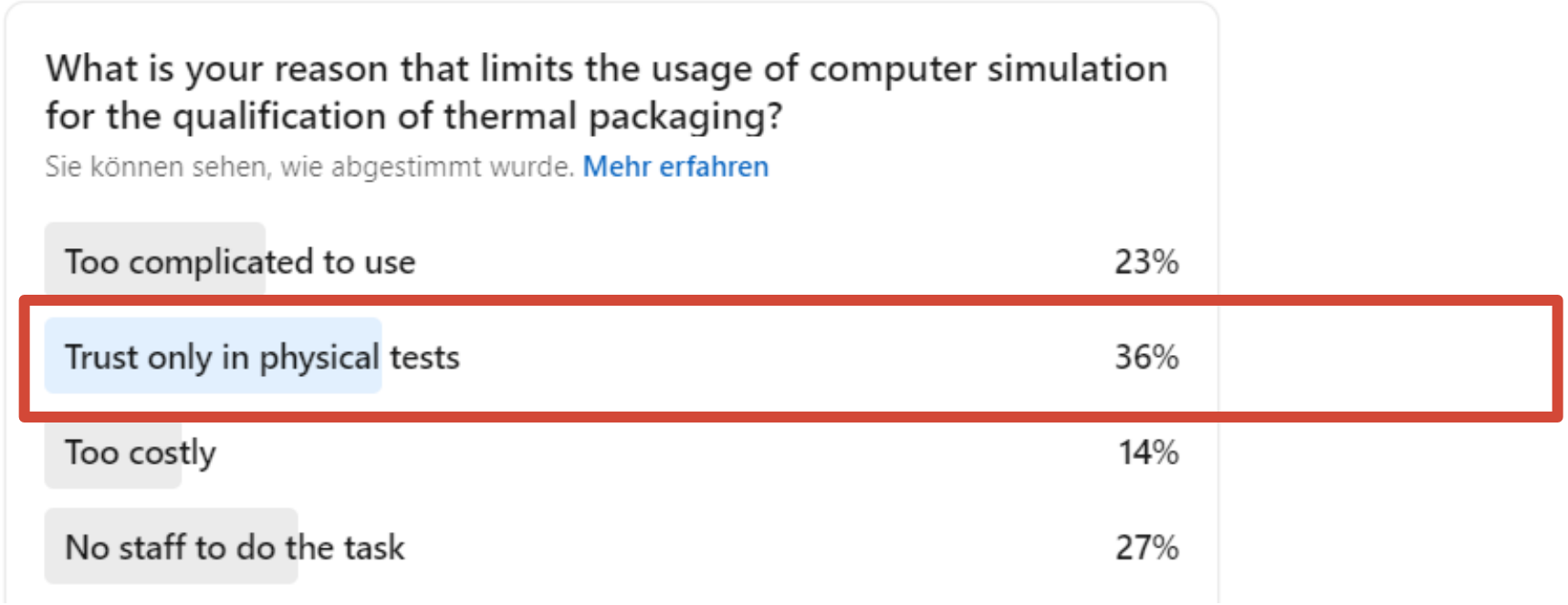
3 shipments	56%
3-10 shipments	28%
10-30 shipments	9%
0 shipment risk based approach	6%

In a performance qualification you make 3 test shipments. If you pass this 3 test shipments what is the result of this

Sie können sehen, wie abgestimmt wurde. Mehr erfahren

No risk on the lane	16%
It's ok for the regulator	16%
You will make more	8%
Risk is still unclear	60%

Why not use computer simulation for qualification

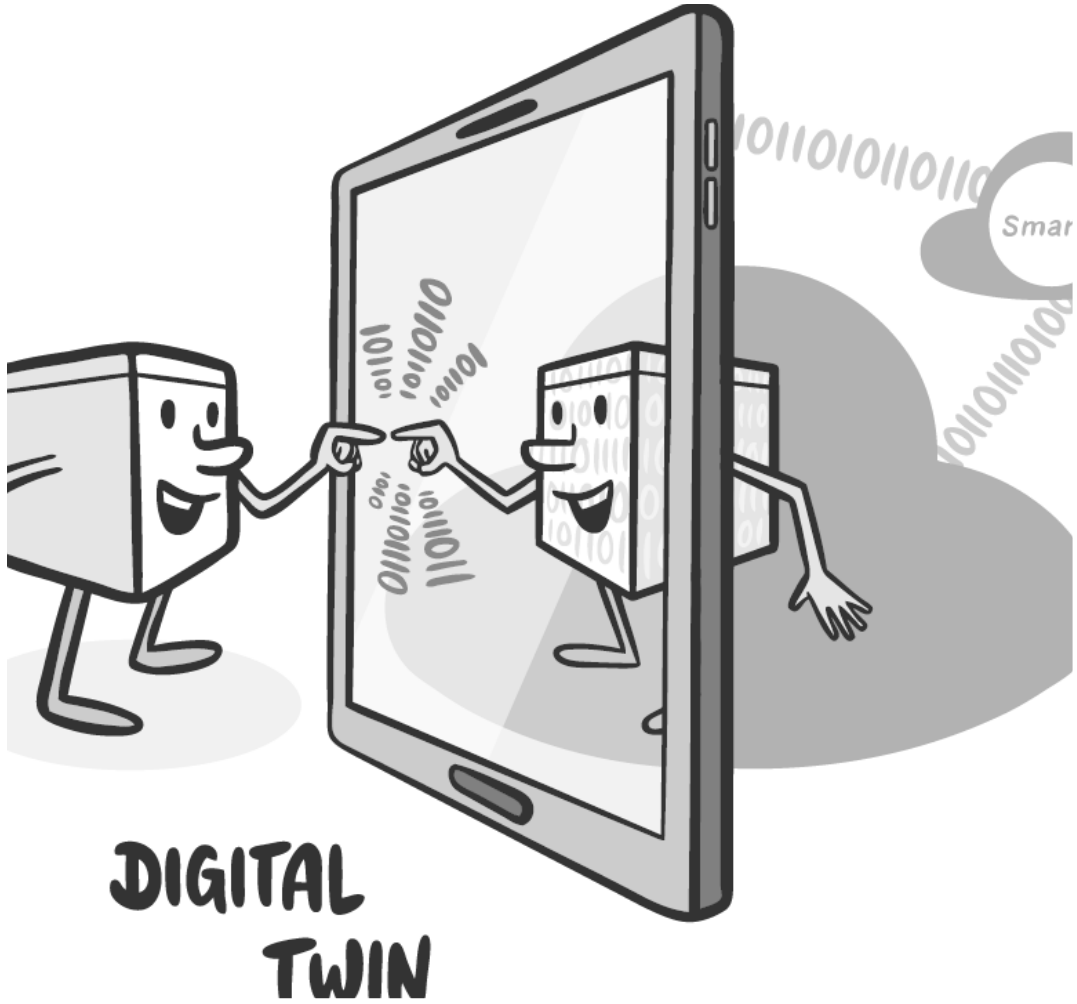


If this reasoning was true in other industries, there would be no driving cars, and no flying airplanes.

Why there is need for a digital twin in Cold Chain

- A lot of parameters are not exactly known (e.g. tarmac times)
- Real world testing is not an option (e.g. no test with real product)
- Plan for the unplanned (e.g. closed Suez channel)
- Testing of passive boxes is time consuming (e.g. a lot of weeks of chamber time)
- Testing is not always realistic (e.g ISTA profile vs. lane from India to Australia)
- Risk versus Cost is important (e.g. VIP box vs. cardboard box)

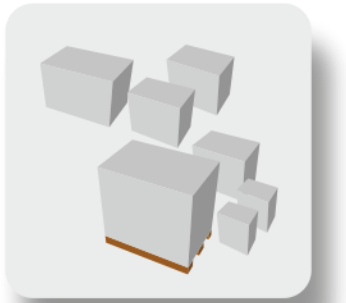
Virtual Cold Chain as a digital twin of your box and your supply chain



SmartCAE

Virtual Cold Chain – connecting all players

Packaging provider

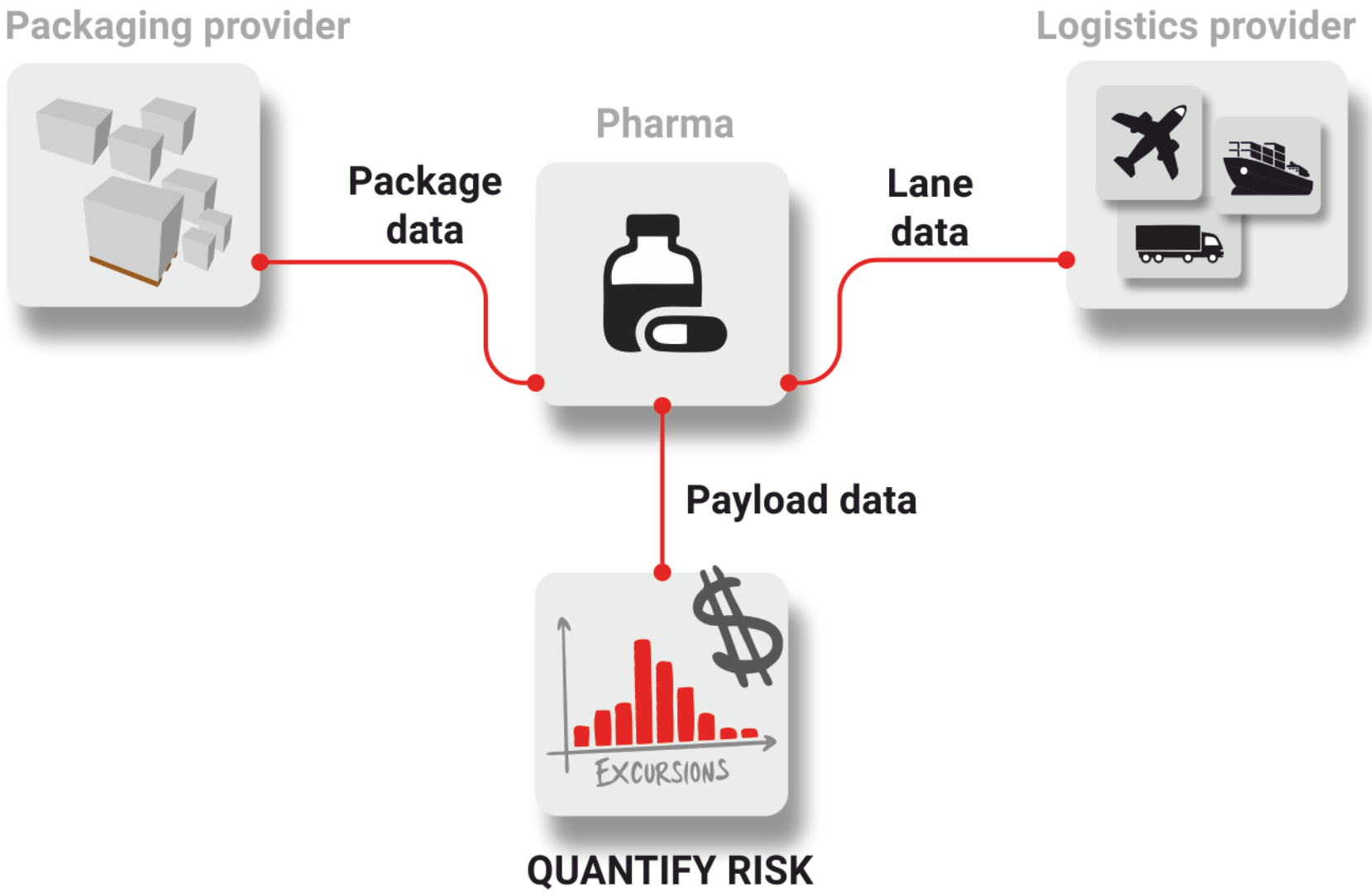


Pharma

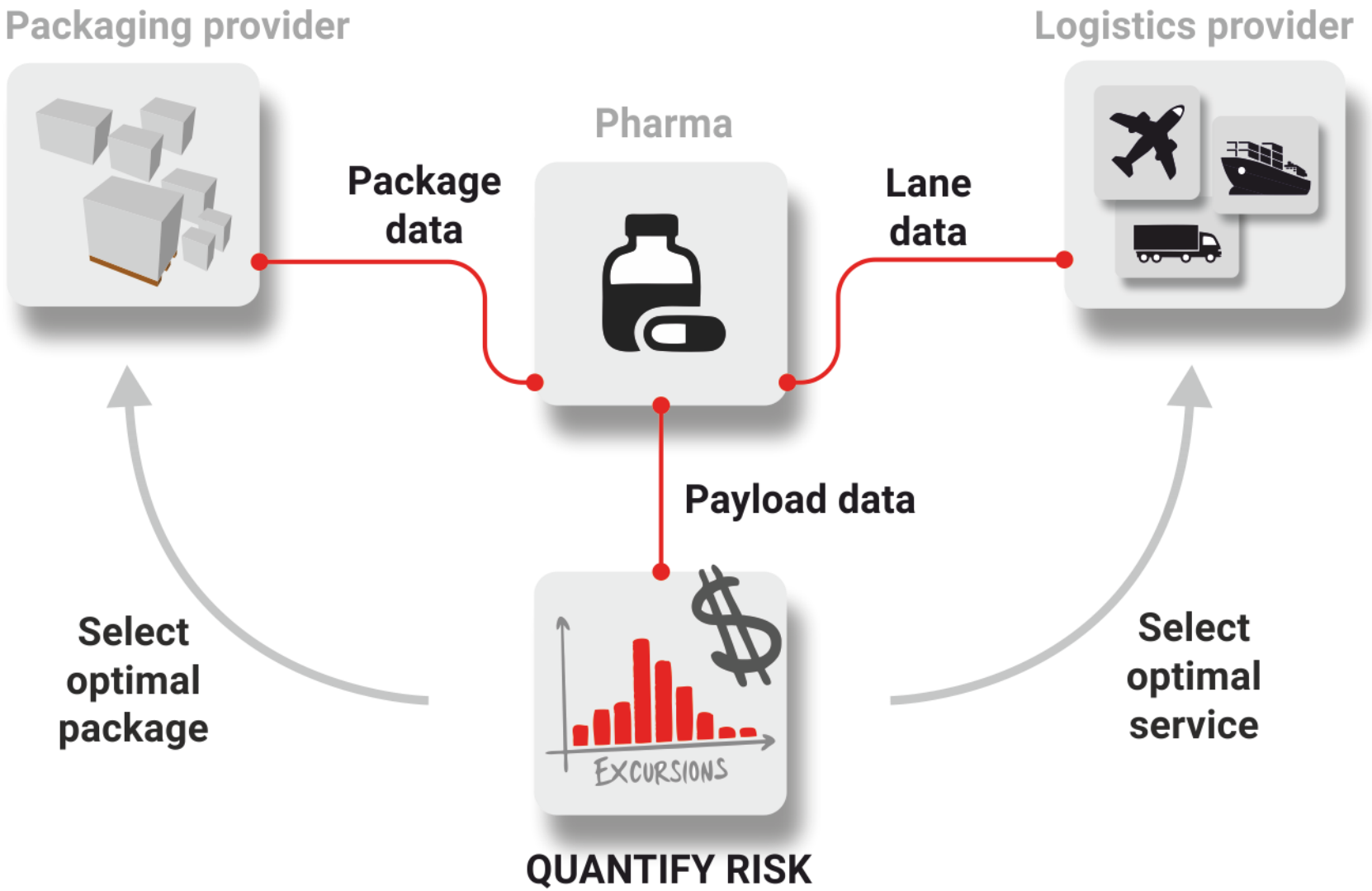
Logistics provider

QUANTIFY RISK

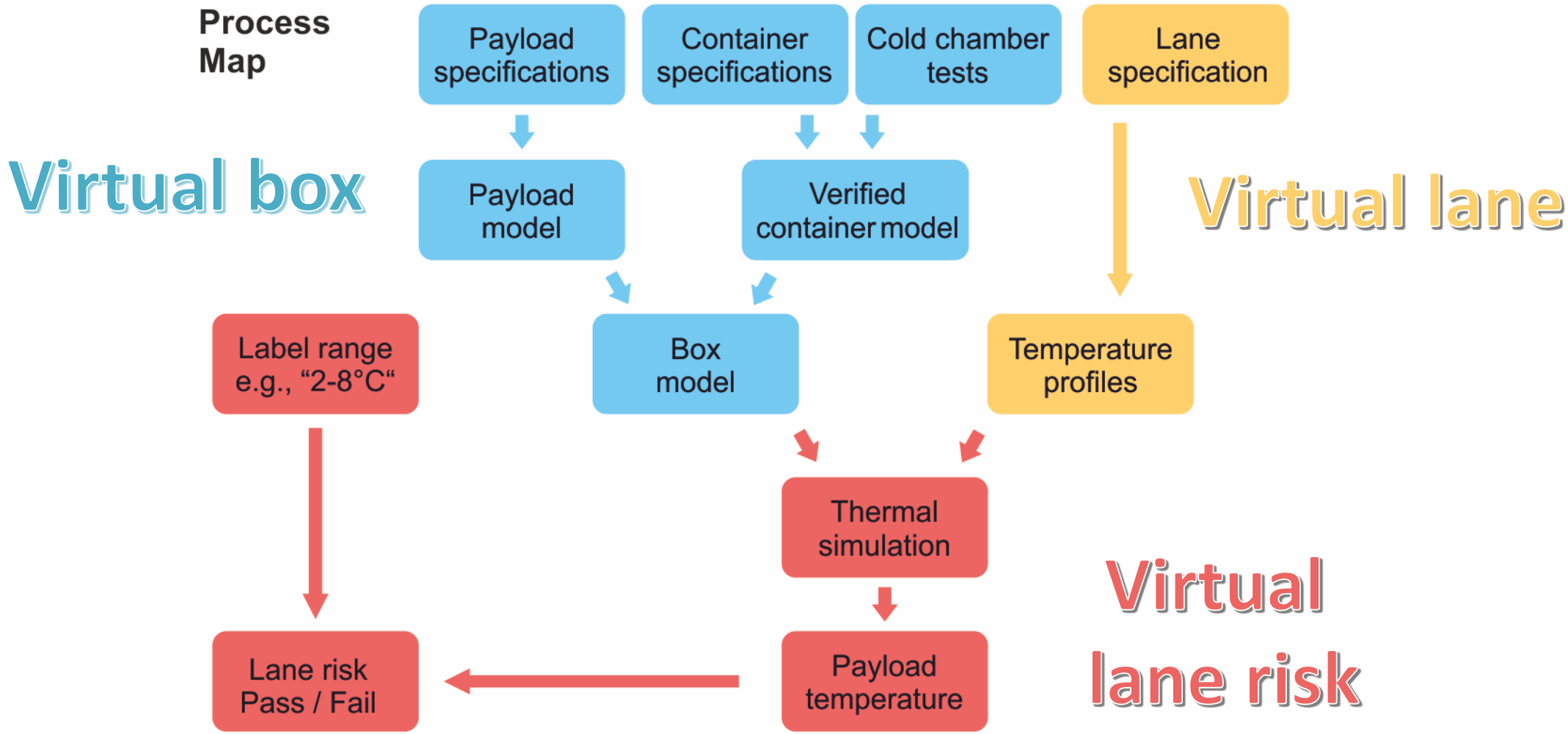
Virtual Cold Chain – connecting all players



Virtual Cold Chain – connecting all players



Virtual process map



Virtual Box

Virtual Box

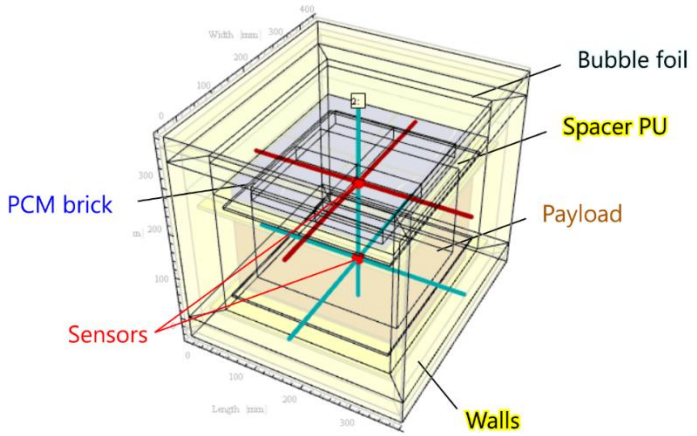
Geometry:

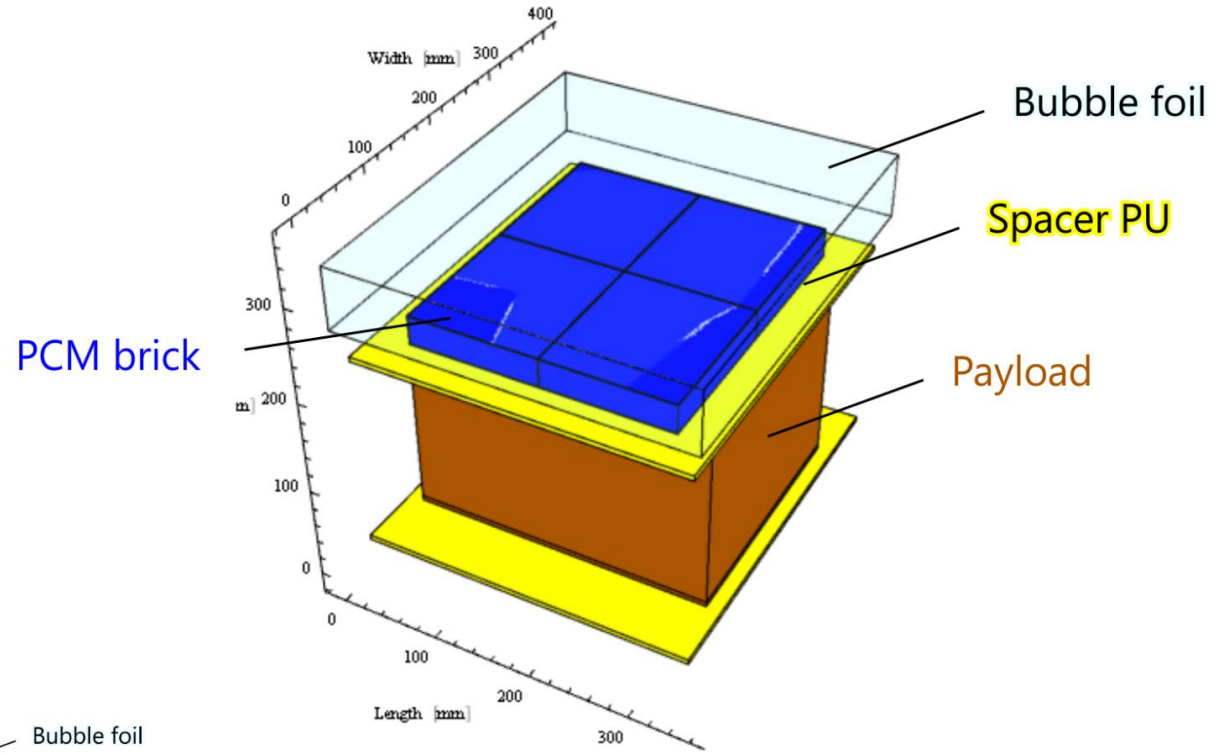
- Length, Width, Height
- Position

Thermal properties:

- Mass density
- Thermal conductivity
- Specific heat capacity
- PCM: Latent heat and melting point

Sensor Positions:

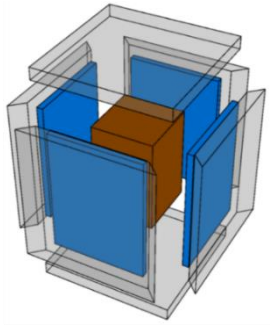


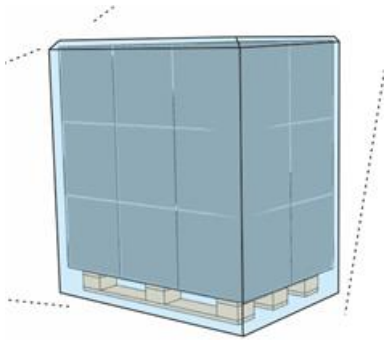


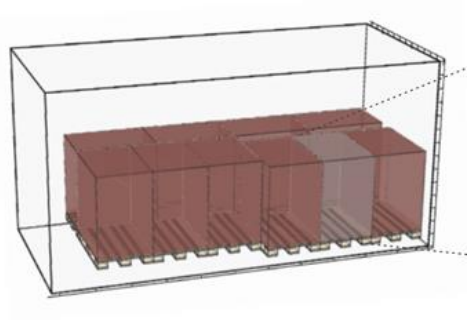
Applicability

What kind of thermal packaging solutions can be simulated?

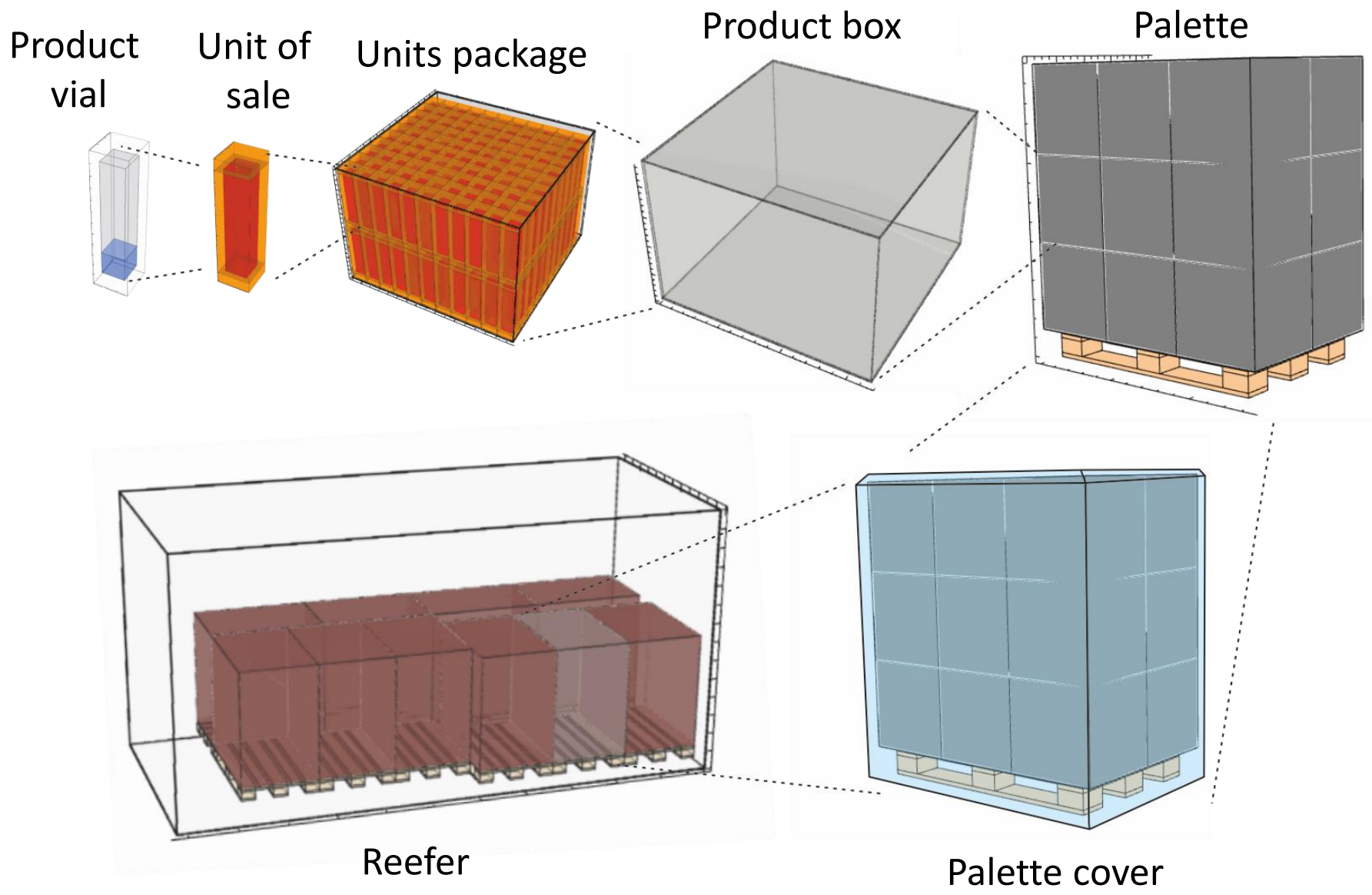
- Any size
- Any transportation (air, ocean, land)
- Any insulation (PU, VIP, thermo covers, …)
- Any type of coolant (ice, dry ice, PCM, …)
- Any temperature range (2-8°C, CRT, deep frozen, …)
- Active and passive systems







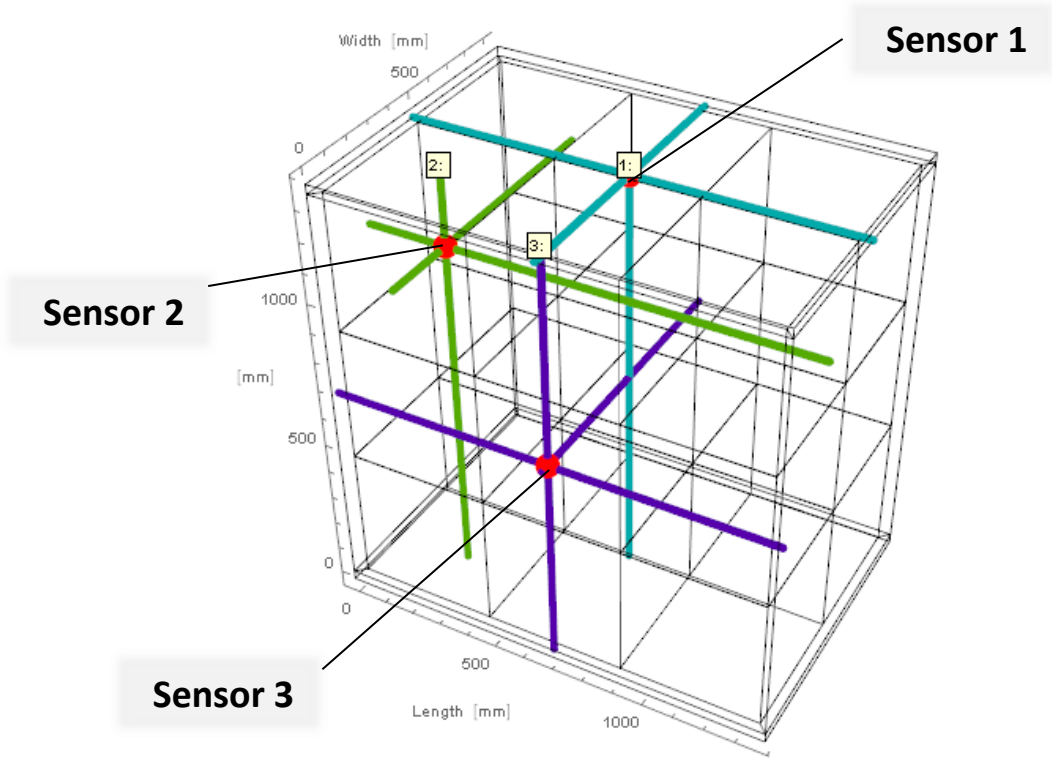
Modeling scales

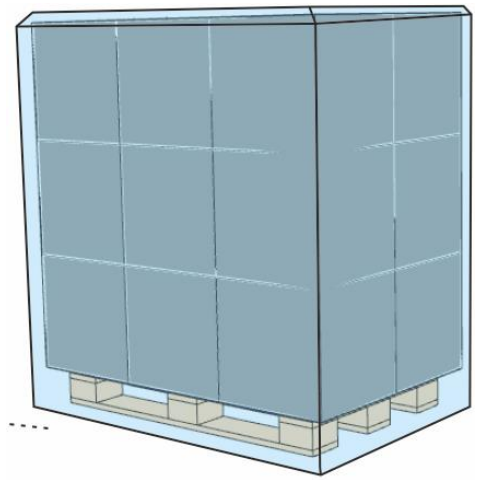


How close is computer simulation to reality

Simulation vs measurement: thermal cover (1/2)

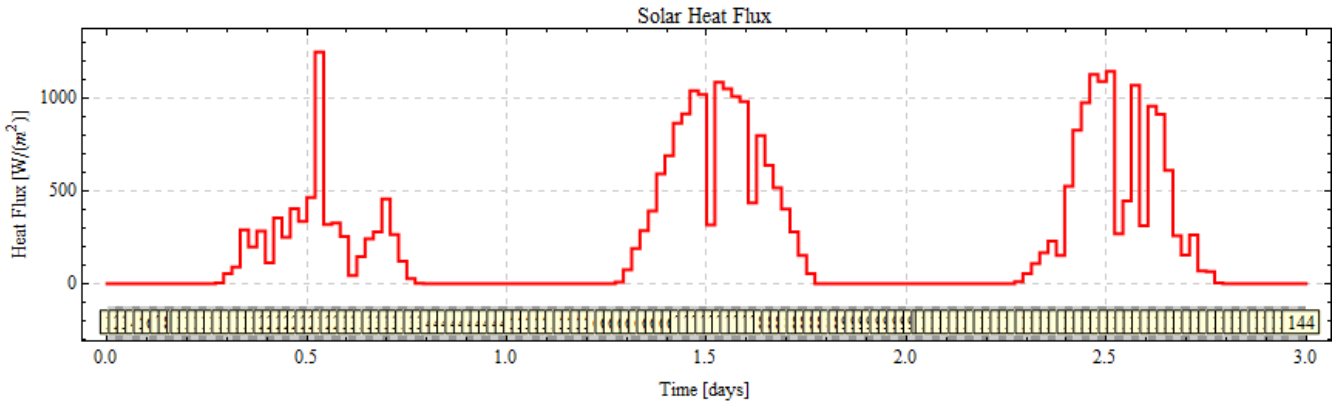
Sensor points in virtual model
pallet shipper with cover.



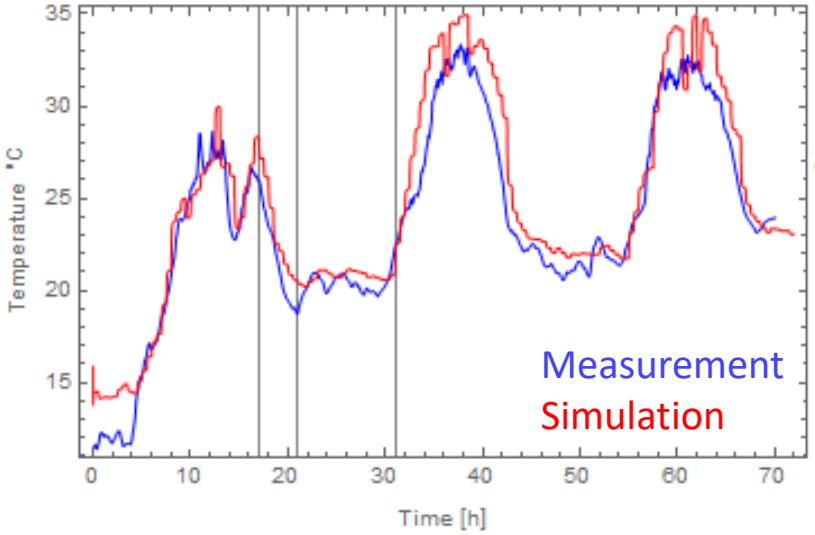


Simulation vs measurement 2: thermal cover (2/2)

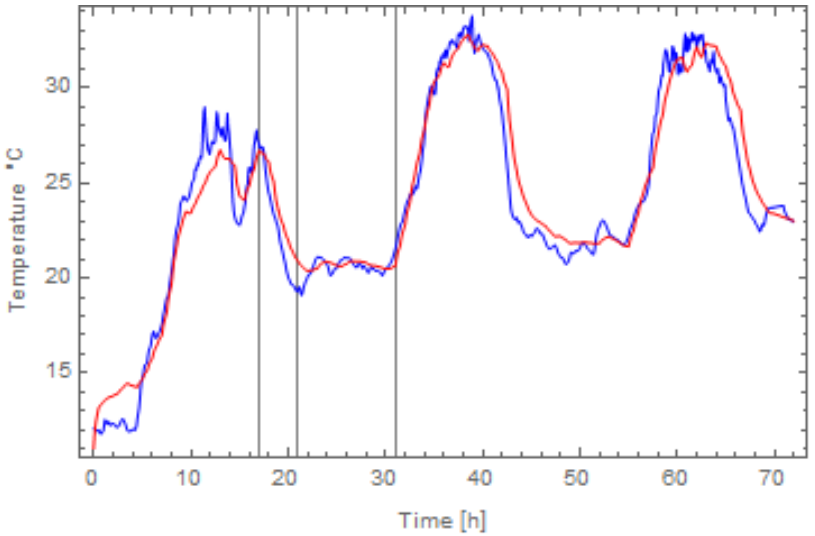
Comparison of simulation and measurement results for pallet shipper with cover using ambient temperature and solar irradiation.



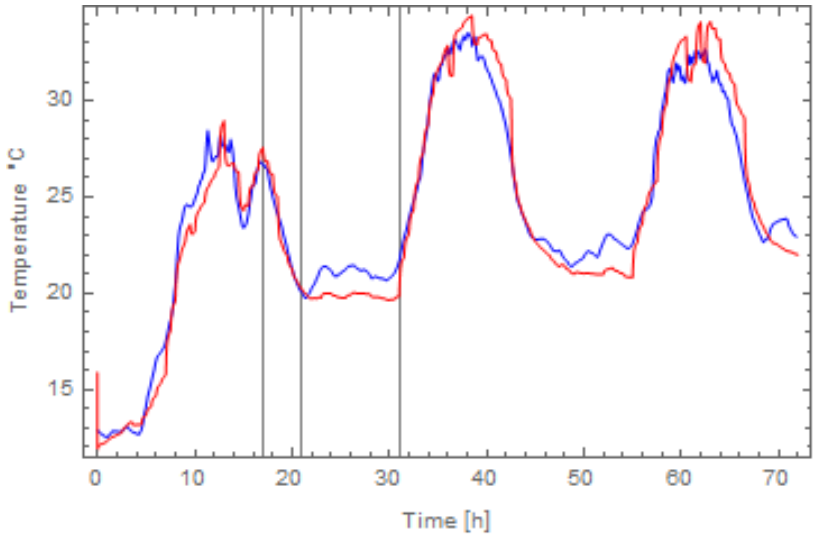
Sensor 1



Sensor 2



Sensor 3



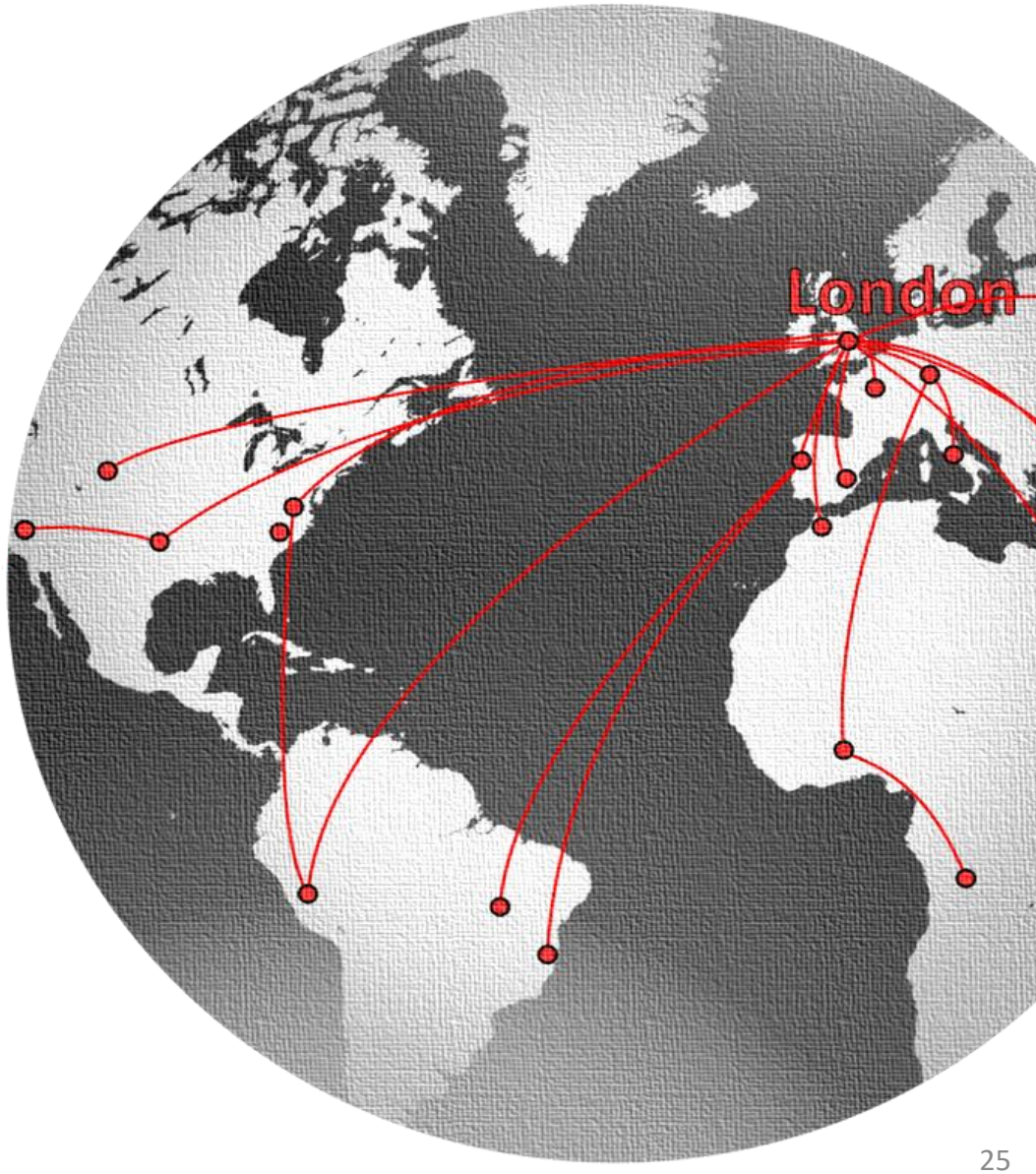
Simulation results from *SmartCAE Thermal Packaging.*

Virtual lane

Lane data

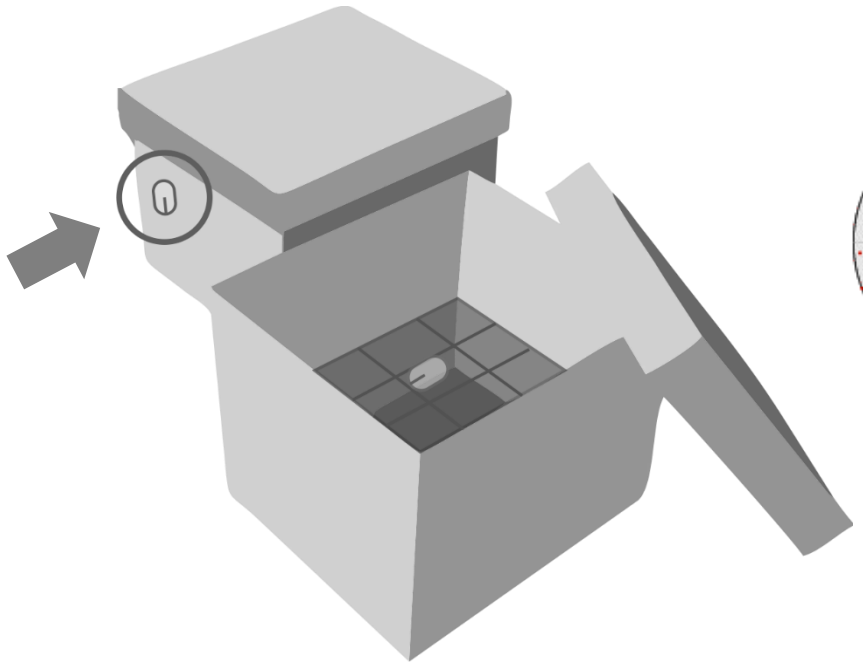
- Cold lab: lane proxies
  - Synthetic reference „lane“, ISTA profile
  - Representative lane
  - Worst case scenario

- The best you can do:
  - Logger data
  - Historical data
  - Forecast data

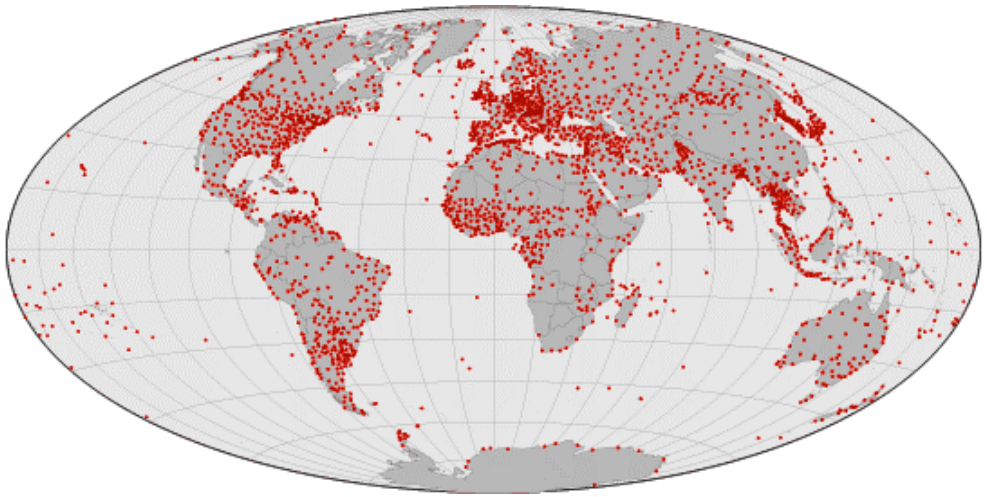


Lane specific data: weather stations

(1) Ambient loggers



(2) Weather stations



https://earthobservatory.nasa.gov/features/GISSTemperature/giss_temperature2.php

Virtual lane by historical data

Input for historical data download:

- Segments (mode/location)
- Start time

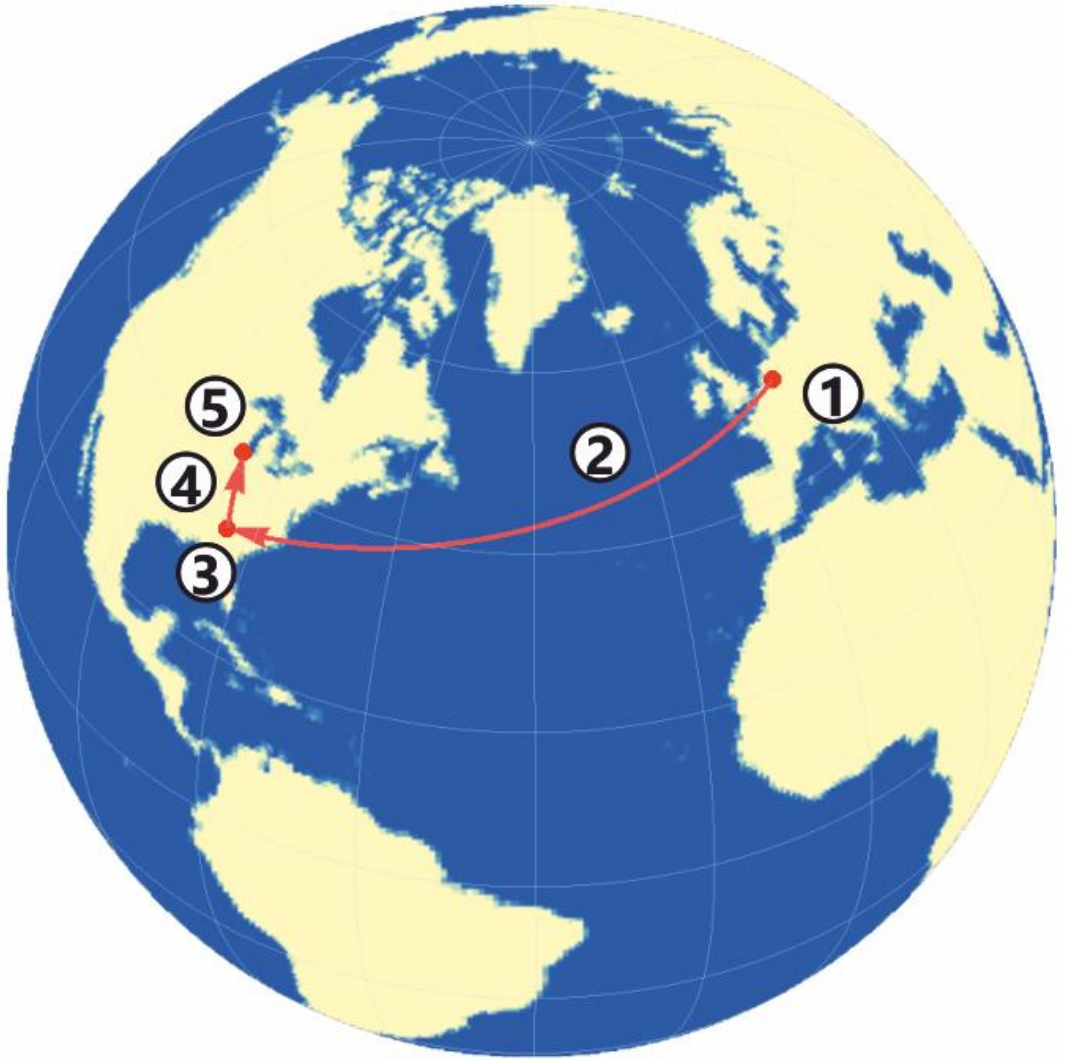
SmartCAE TemperatureProfiles: demo (Lane-Definition) - Wolfram

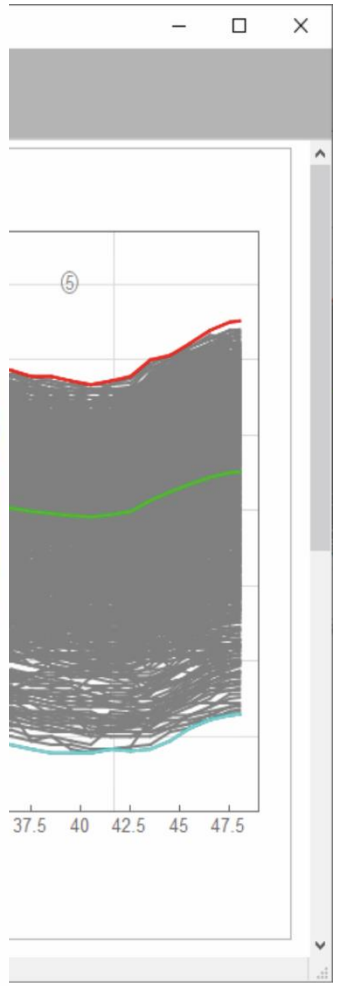
SmartCAE Project Lane Definition: New Load Save

Lane Name: dus–atl–ord

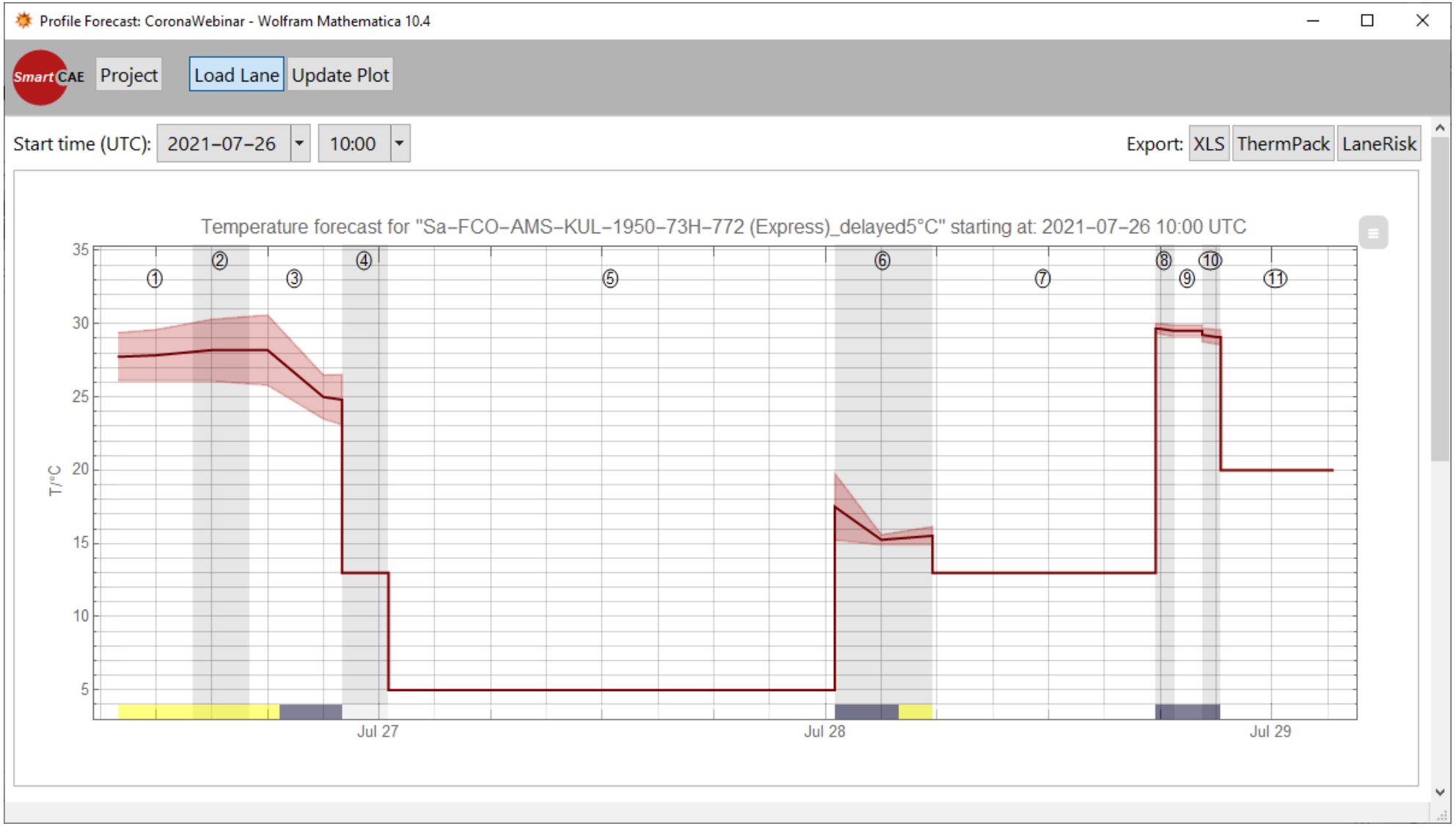
	Name	δt/h	UTC	T/°C	Sun	
1	Dusseldorf	10.00	18:00		✓	×
2	flight	11.00	04:00	15.0		×
3	Atlanta	8.00	15:00		✓	×
4	flight	2.00	23:00	15.0		×
5	Chicago	17.00	01:00			×
	End	48.00	18:00			

+ ?





Forecast


Profile Forecast: CoronaWebinar - Wolfram Mathematica 10.4
Project
Load Lane
Update Plot
Start time (UTC):
2021–07–26
10:00
Export:
XLS
ThermPack
LaneRisk
Temperature forecast for "Sa–FCO–AMS–KUL–1950–73H–772 (Express)_delayed5°C" starting at: 2021–07–26 10:00 UTC
T/°C
35
30
25
20
15
10
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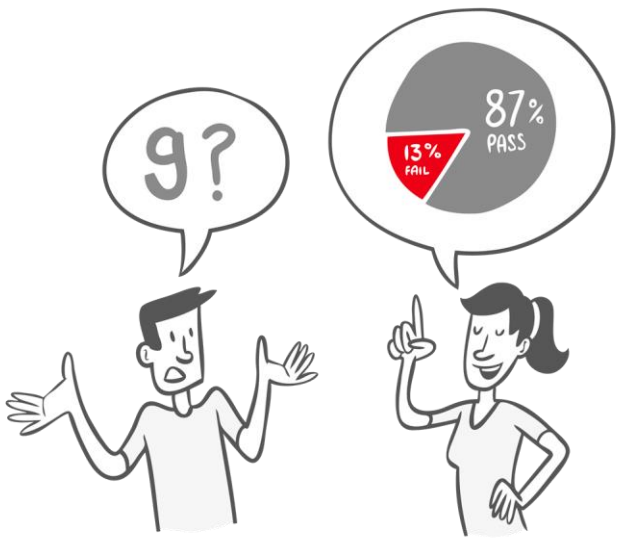
Jul 27
Jul 28
Jul 29

How to quantify the risk of temperature excursions and total costs

Differences between risk numbers and excursion rates



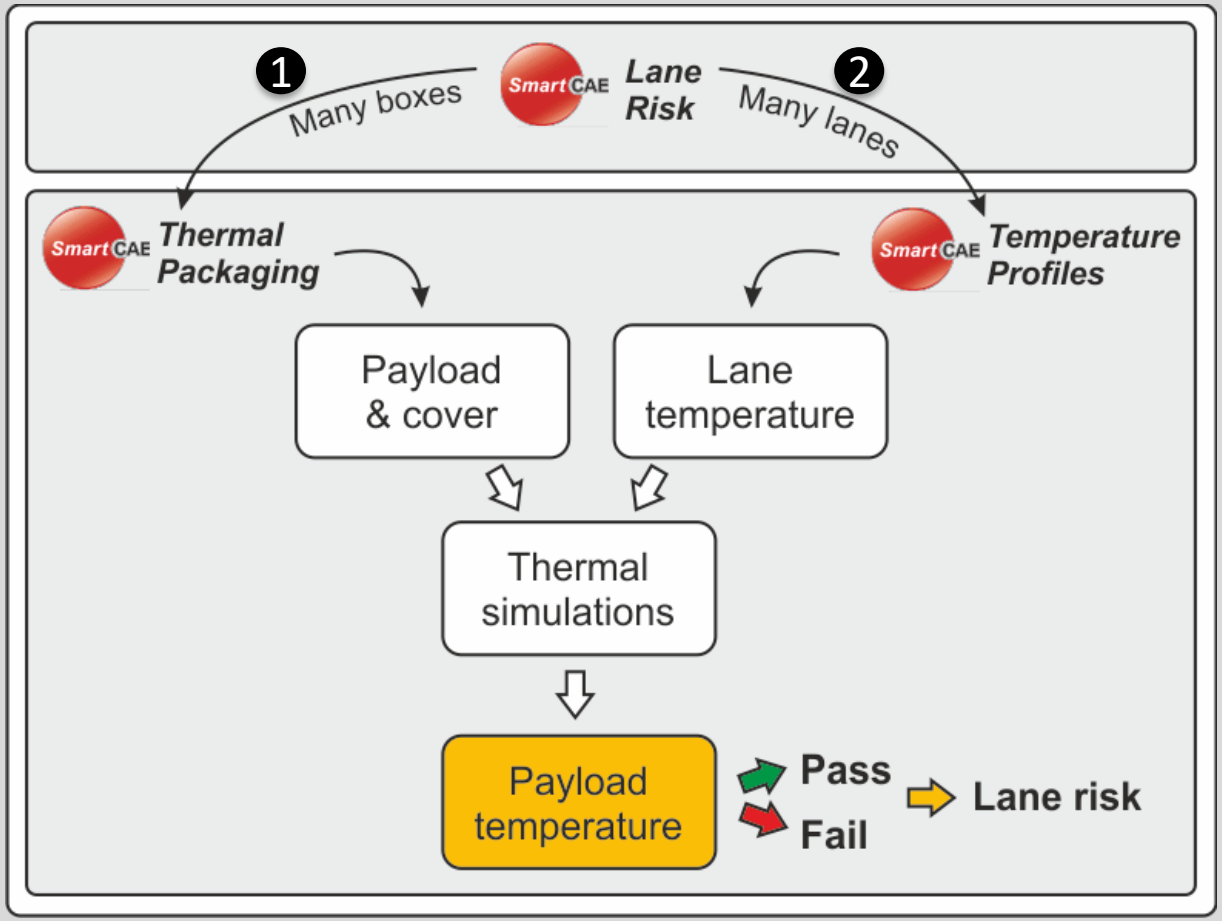
Methodology

Common risk scoring: temperature zones

Season	Months
Winter	Dec – Feb
Spring	Mar – May
Summer	Jun – Aug
Autumn	Sep – Nov

Average Temperature	Category	Risk Level	Risk Score
<0°C	A	High	100
0-10°C	B	Medium	50
10-20°C	C	Low	0
20-30°C	D	Medium	50
>30°C	E	High	100

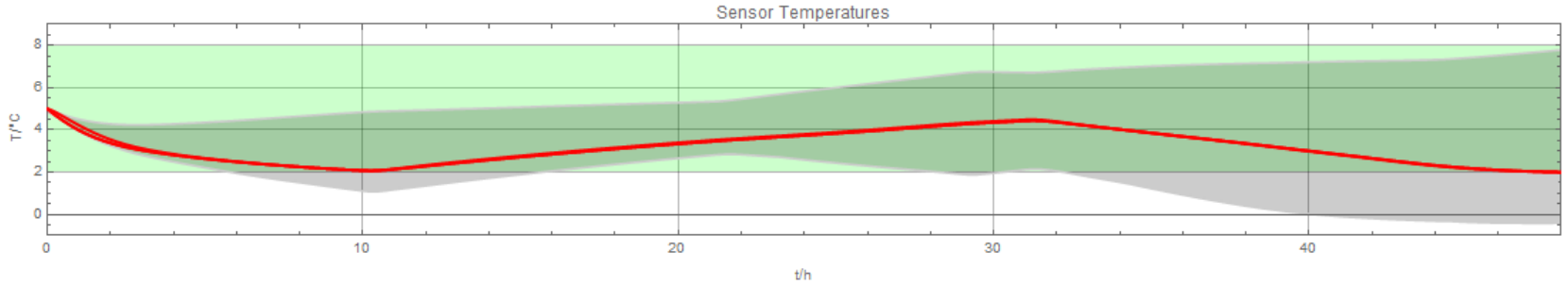
SmartCAE Lane Risk



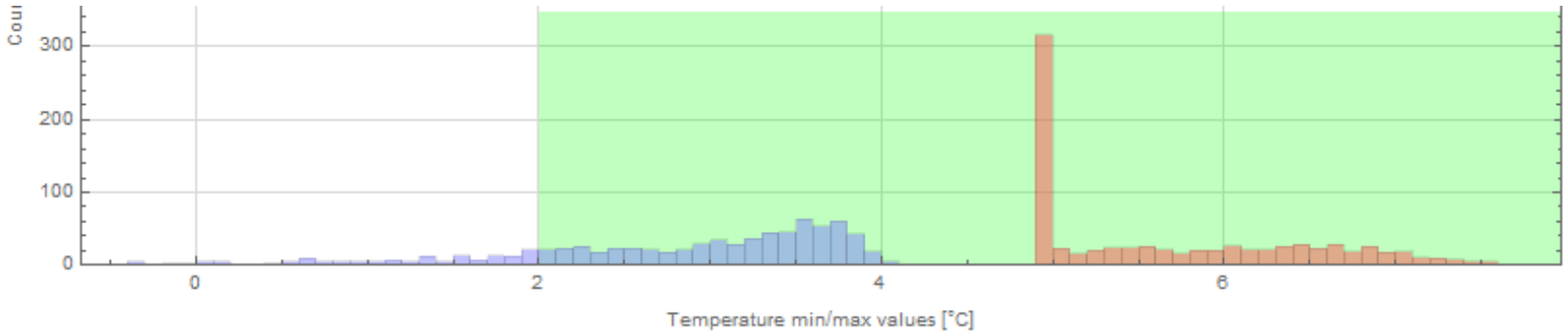
Failure Ratio in VCC

(1) Simulate shipment for many realistic lane scenarios:
For example: **#Shipments = 865**

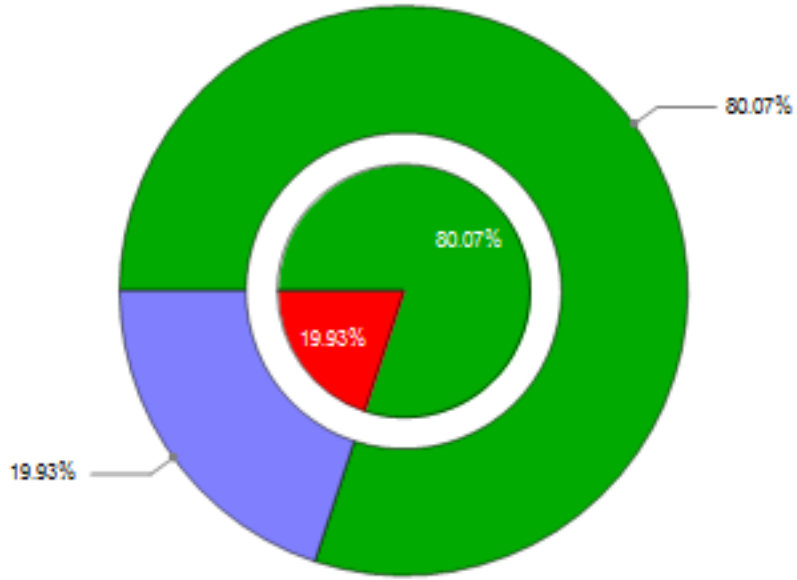
(2) Product temperature for each shipment



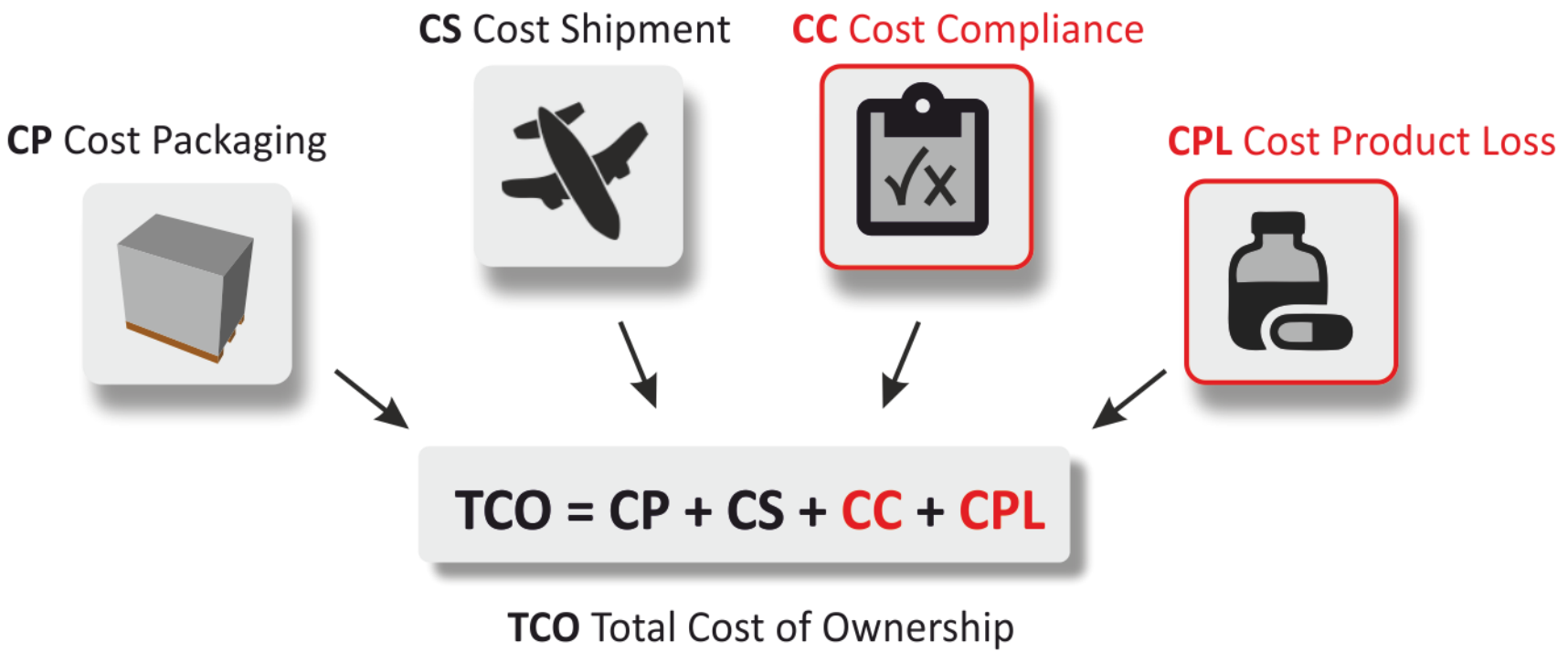
(3) Distribution of Min/Max payload temperatures -> #Excursions



(4) Failure ratio



Simulating Total Cost of Ownership in Temperature Controlled Logistics



Digital Cold Chain, determines the unknown factors using thermal simulation before doing any physical shipment!

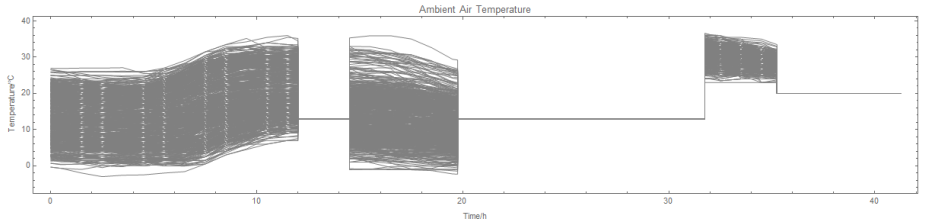
Levels of lane risk computation and possibilities to influence risk

- 1. Historical lane risk
  - ➢ Uses Historical lane temperature for risk calculation

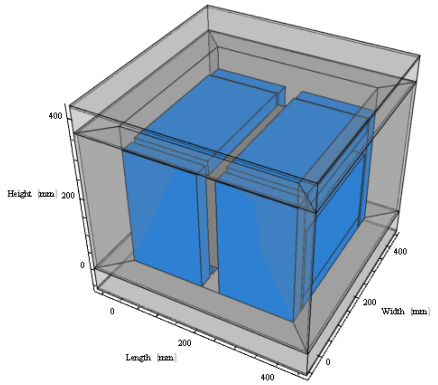
- 2. Predictive lane risk
  - ➢ Uses forecast lane temperature for risk calculation

Historical Lane Risk Assessment:

Historical lane temperature profiles



Virtual box

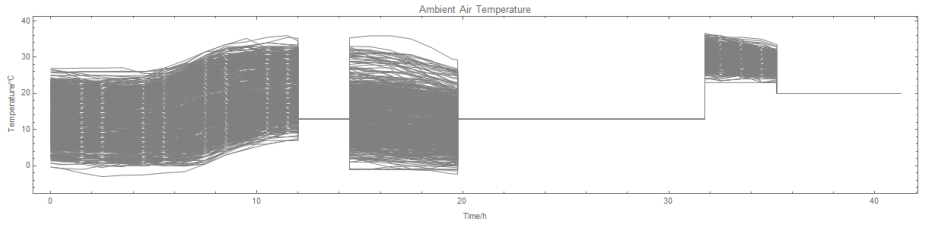


●	PU All-Seasons
●	VIP All-Seasons
●	EPS All-Seasons
●	PU Winter
●	PU Summer

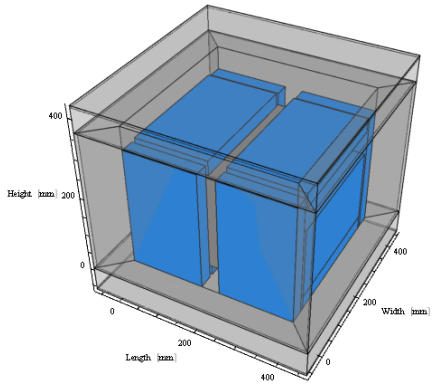
How many days would have led to **excursions**?

Historical Lane Risk Assessment:

Historical lane temperature profiles



Virtual box



●	PU All-Seasons
●	VIP All-Seasons
●	EPS All-Seasons
●	PU Winter
●	PU Summer

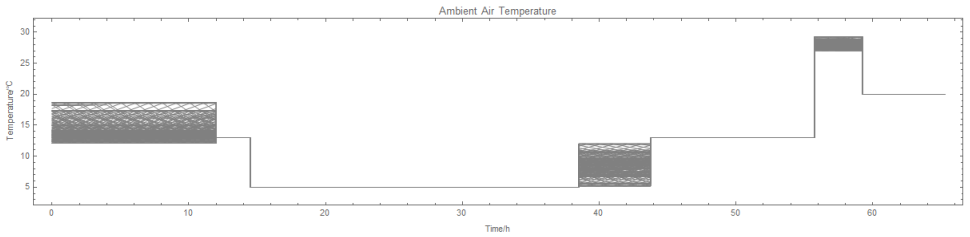
Historical probability of having **no excursions**
(using the given packaging materials)

Risk Mitigation:
Right box or combinations of boxes

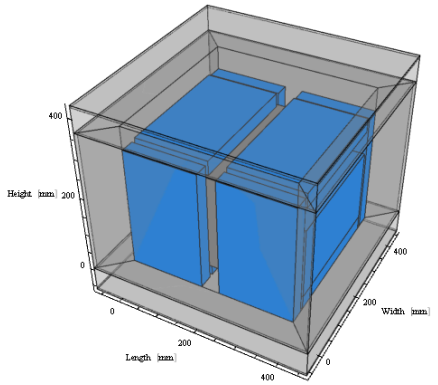
	packaging	#	no excursions	cold excursions	hot excursions	hot&cold excur.
1	Packout–All–Season	462	100.0%	0.0%	0.0%	0.0%
2	Packout–All–SeasonPU	462	100.0%	0.0%	0.0%	0.0%
3	Packout–All–SeasonVIP	462	100.0%	0.0%	0.0%	0.0%
4	Packout–Summer	460	98.7%	1.3%	0.0%	0.0%
5	Packout–Winter	459	4.1%	0.0%	95.9%	0.0%

Predictive Lane Risk Assessment: Next Days

Predicted lane temperature profiles with possible delays



Virtual box

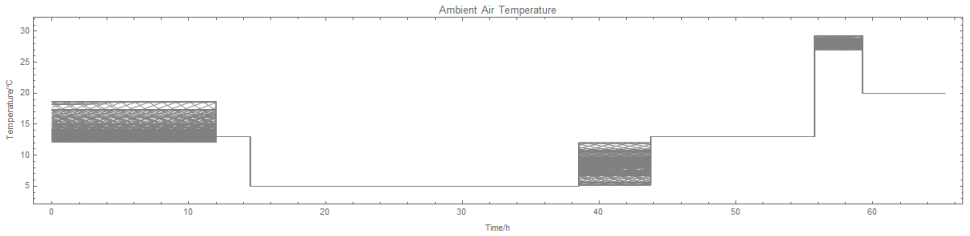


●	PU All-Seasons
●	VIP All-Seasons
●	EPS All-Seasons
●	PU Winter
●	PU Summer

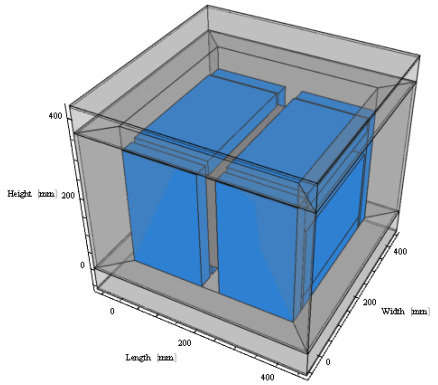
When would you have a risk of **excursion**?

Predictive Lane Risk Assessment: Next Days

Predicted lane temperature profiles with possible delays

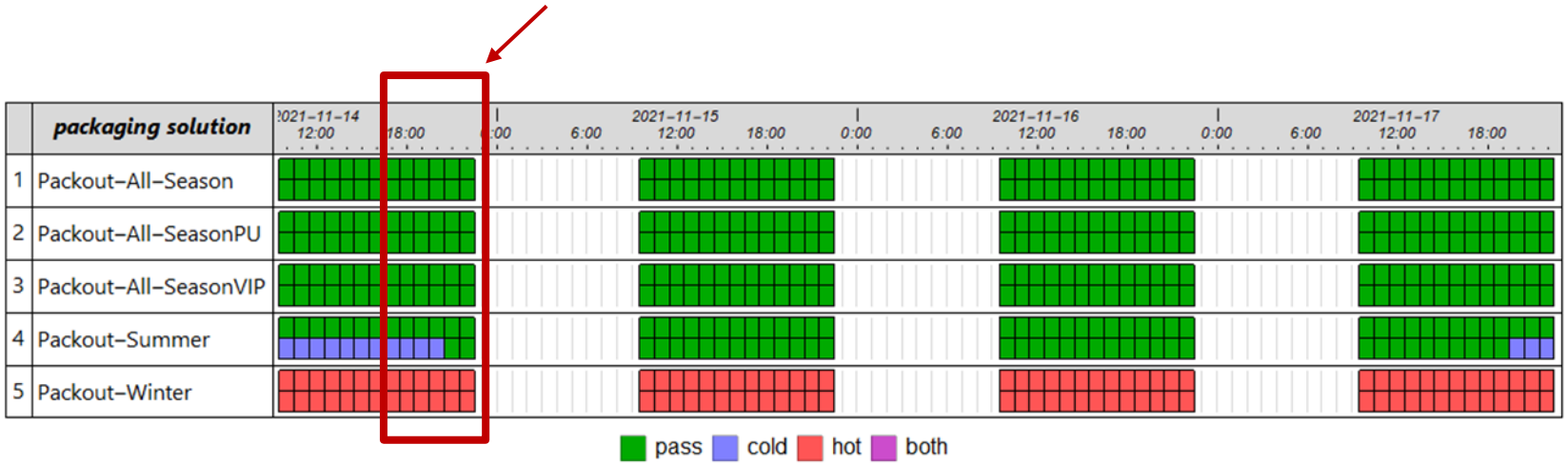


Virtual box



●	PU All-Seasons
●	VIP All-Seasons
●	EPS All-Seasons
●	PU Winter
●	PU Summer

Pass and fail
(for different boxes and dates)

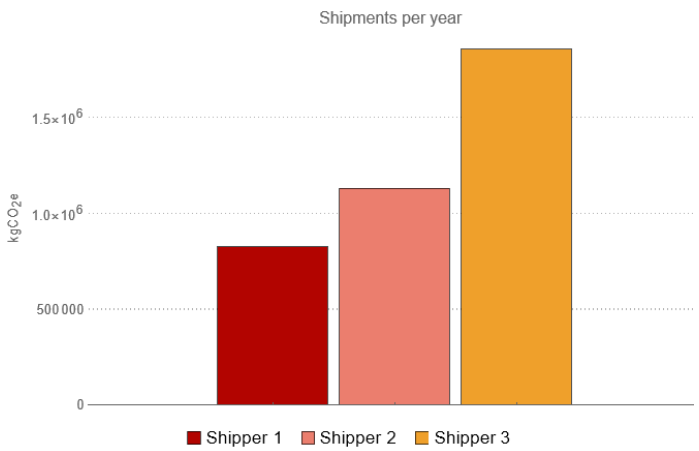


Risk Mitigation:
Right box, starting date and time

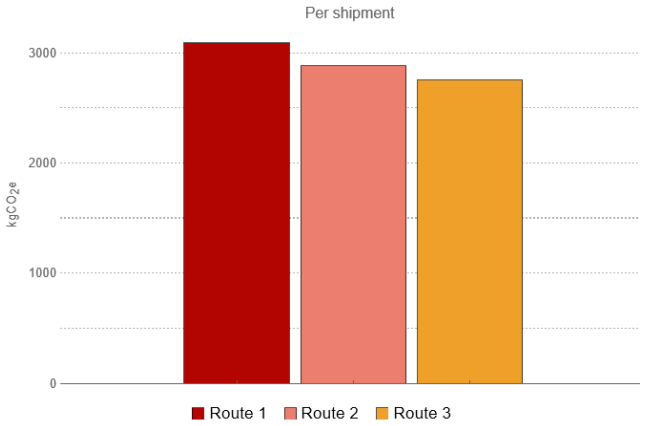
Know your CO2 fingerprint

Carbon footprint calculator

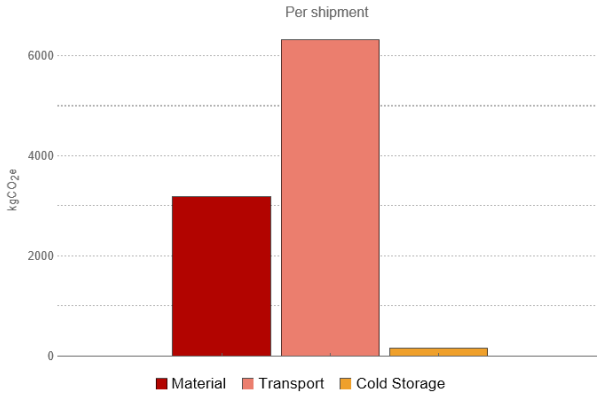
Package comparison



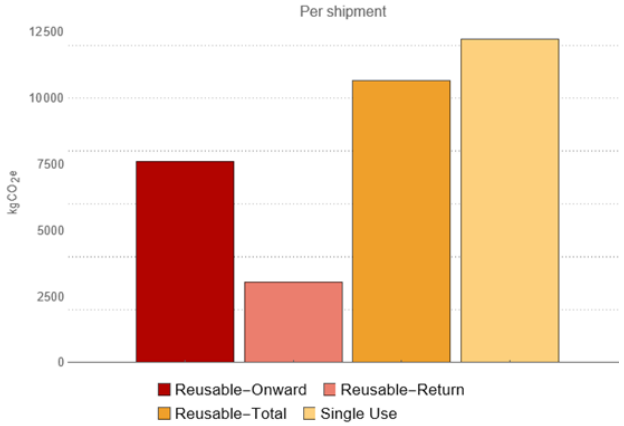
Route and lane comparison



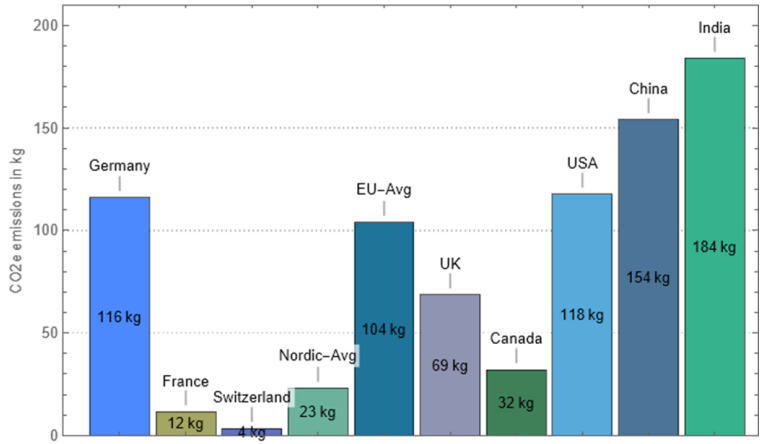
CO_2e contribution breakdown



Single use and reuse shippers with return

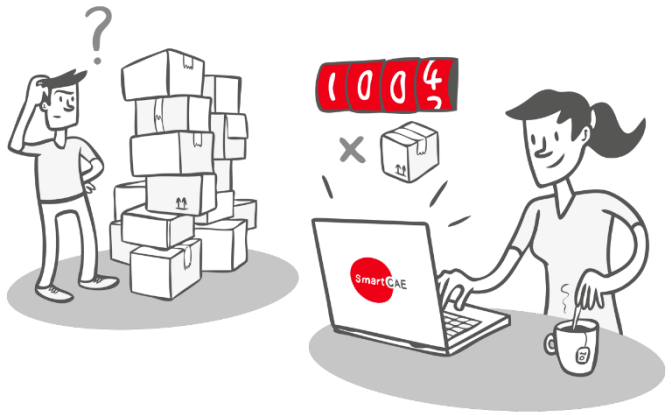


CO2e from Grid - Comparison



Sources: GLEC Framework and others

What if



Typical questions comes up in the Cold Chain

- What if I see in my test shipments no excursions, is there no risk?
- What is the cost of no risk?
- What do box parameter tolerances mean for your product?
- What happens if there are extreme weather conditions?
- What happens if a flight is delayed or missed?
- What happens if my warehouse or truck is or is not temperature controlled?
- What happens if my active container is unplugged?
- What happens on different lanes with different tarmac times?
- What happens with my dry ice box in the supply chain?

…and much more

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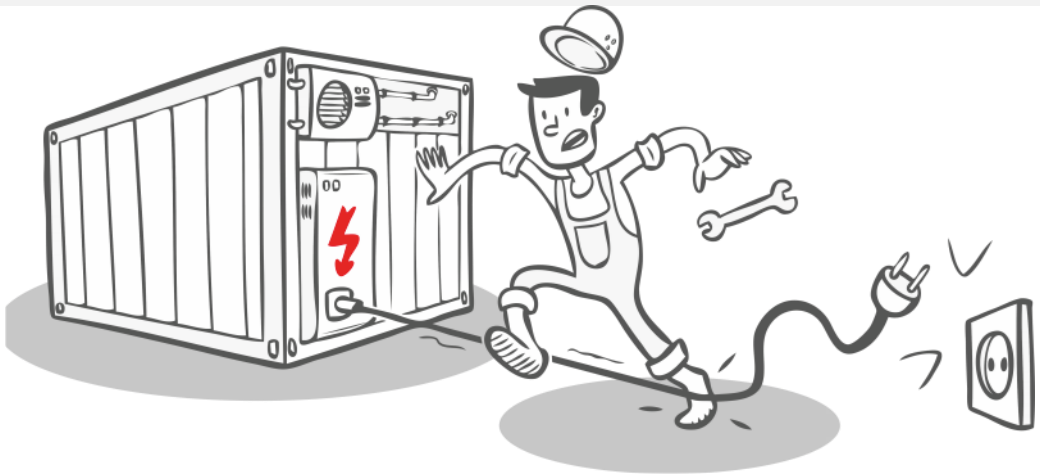
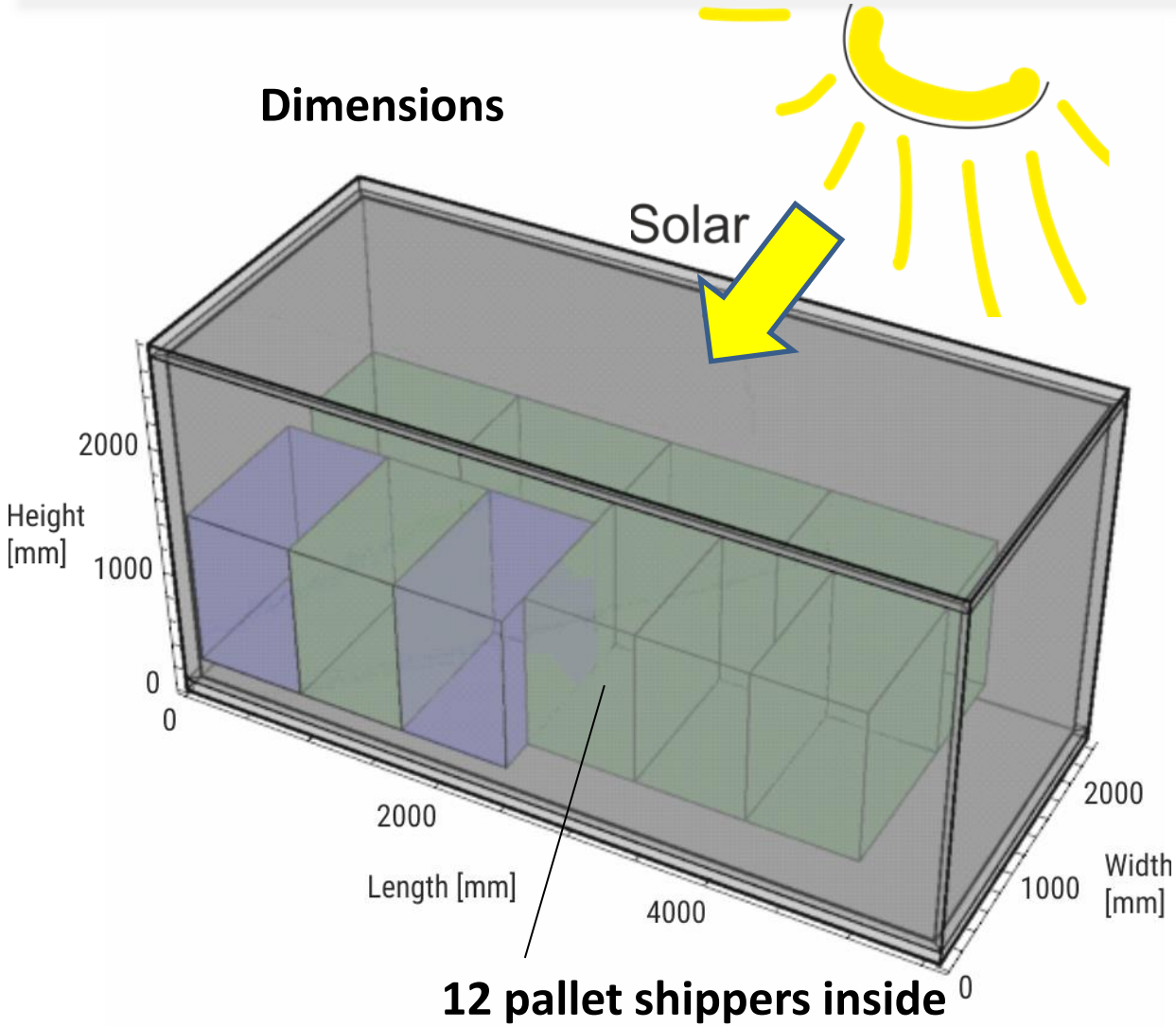
…and much more

What happens if my active container is unplugged



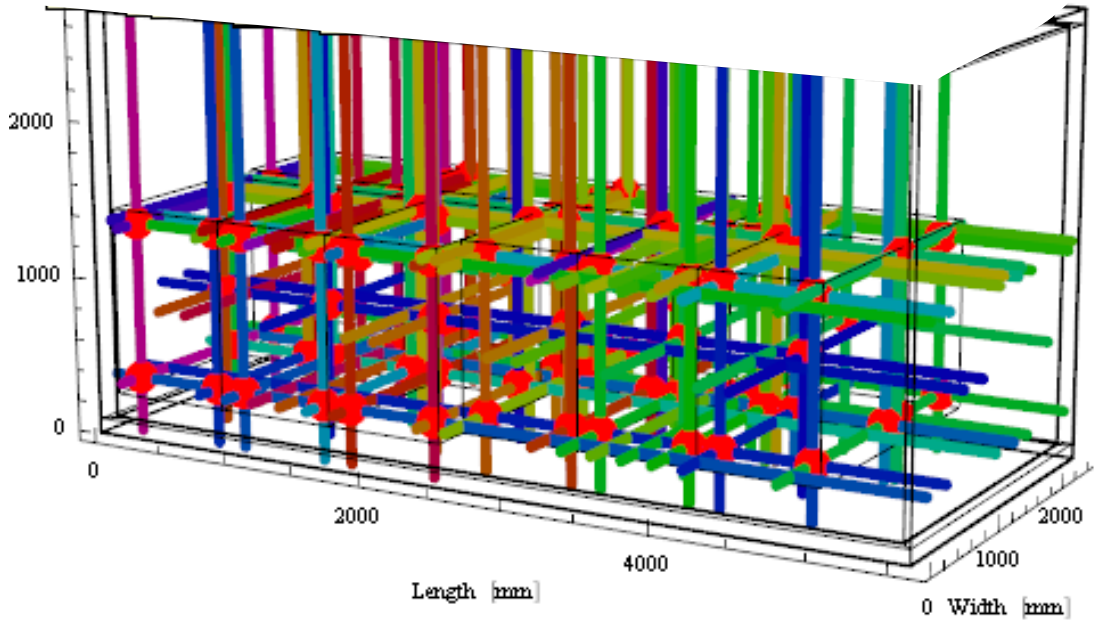
Reefer container

Dimensions



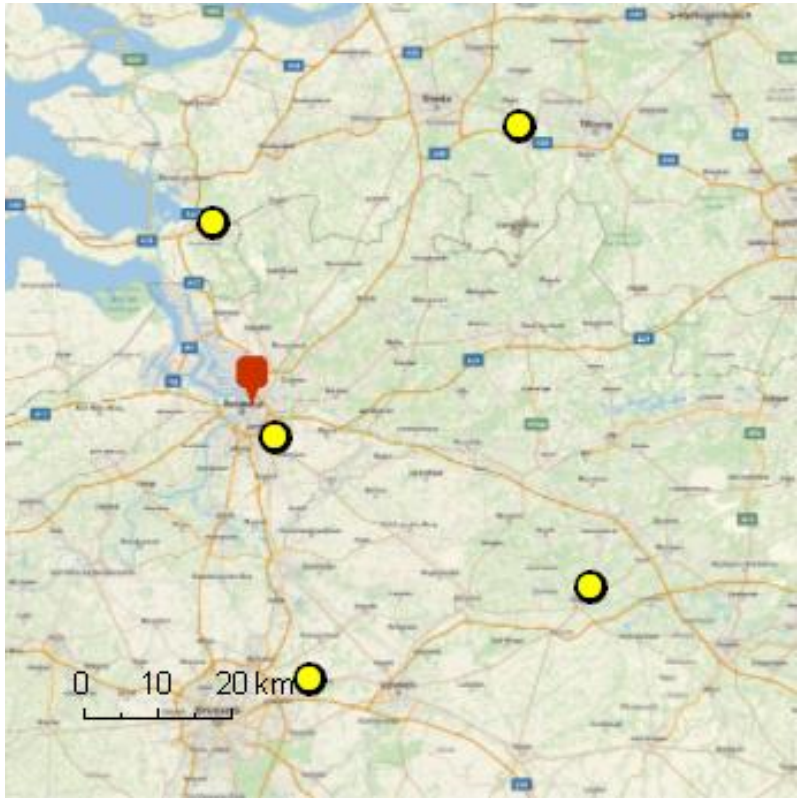
12 pallet shippers inside

Sensor overview



Weather stations

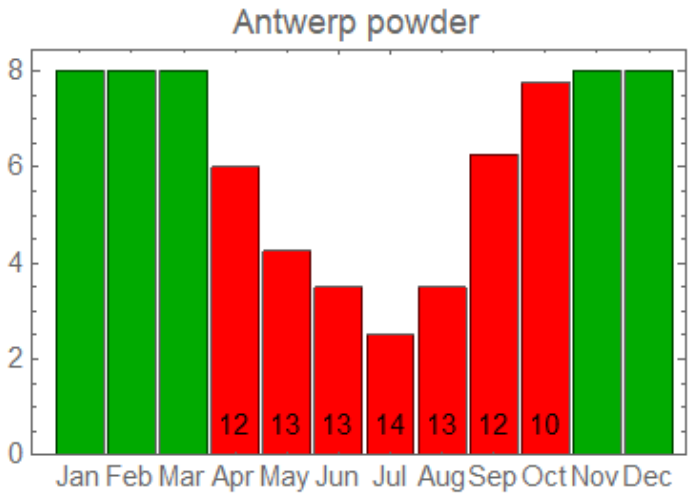
Antwerp, Belgium

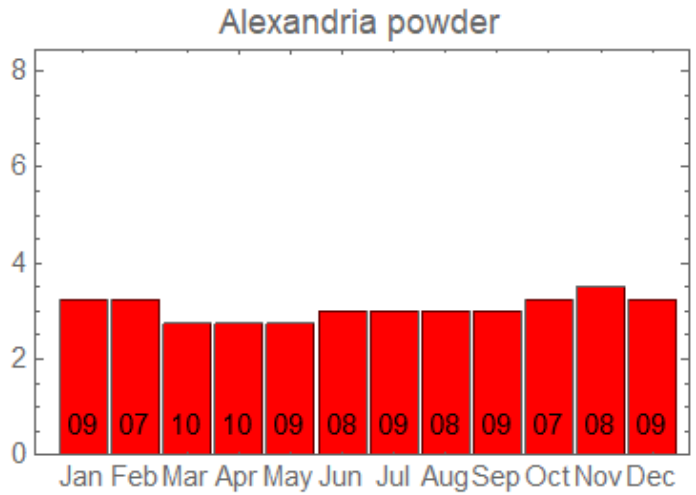


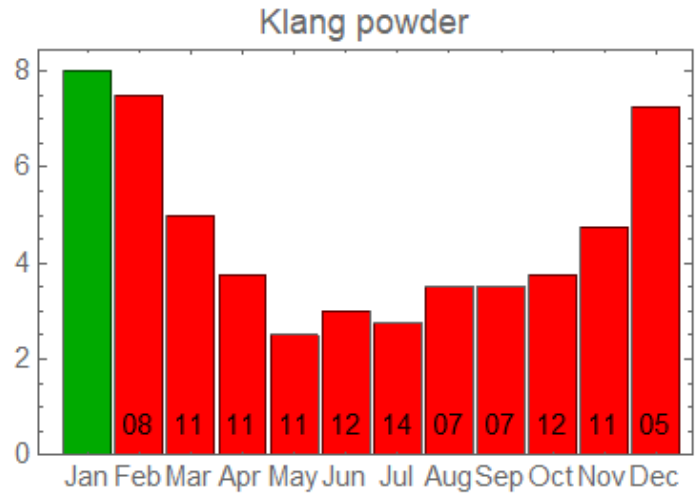
Alexandria, Egypt

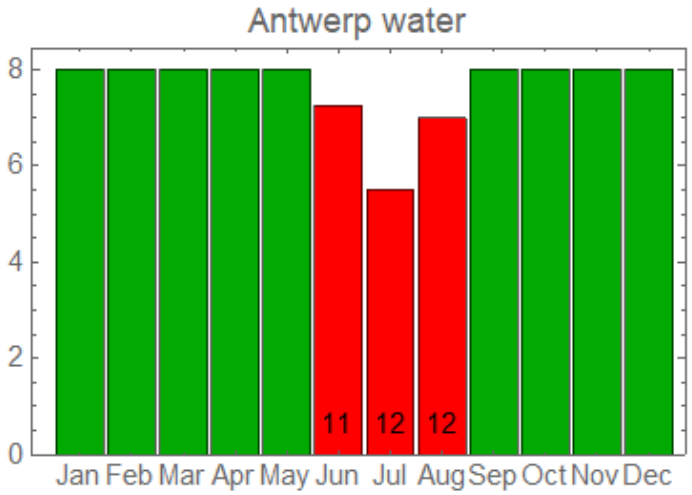
Klang, Malaysia

Worst case time to failure – all results

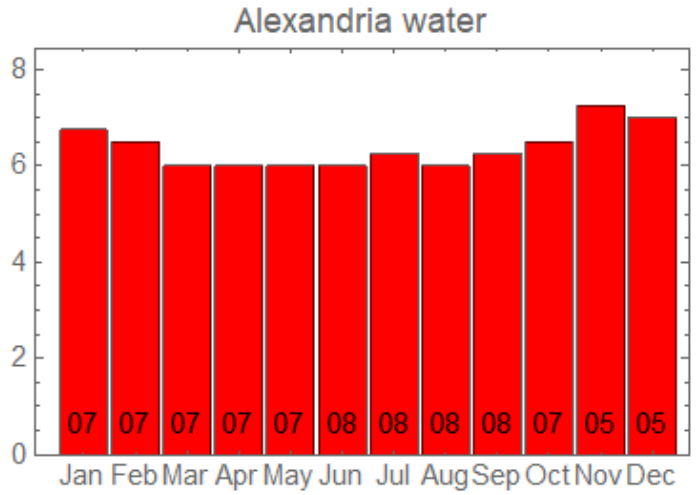




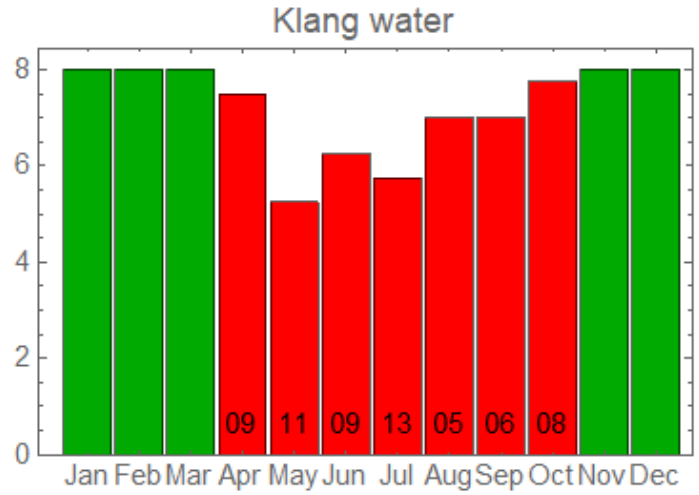




UTC+1

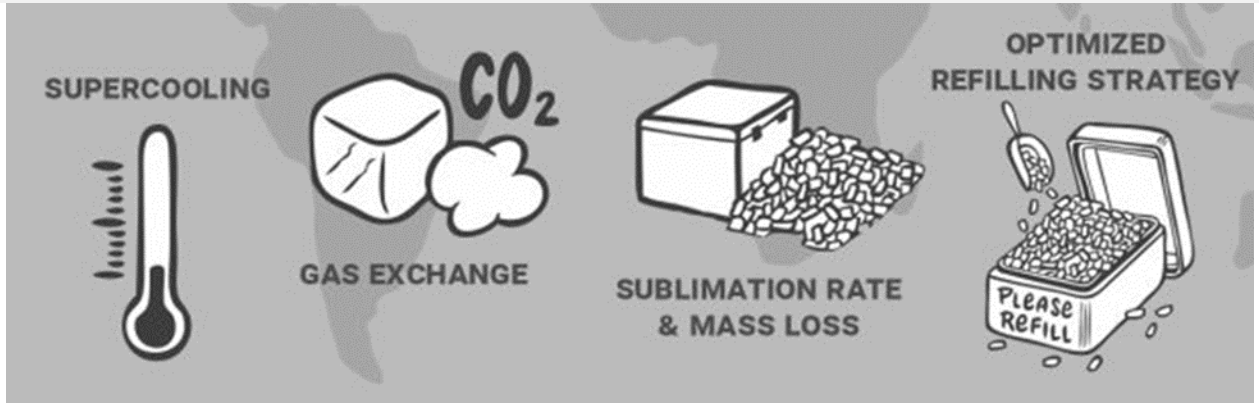


UTC+2



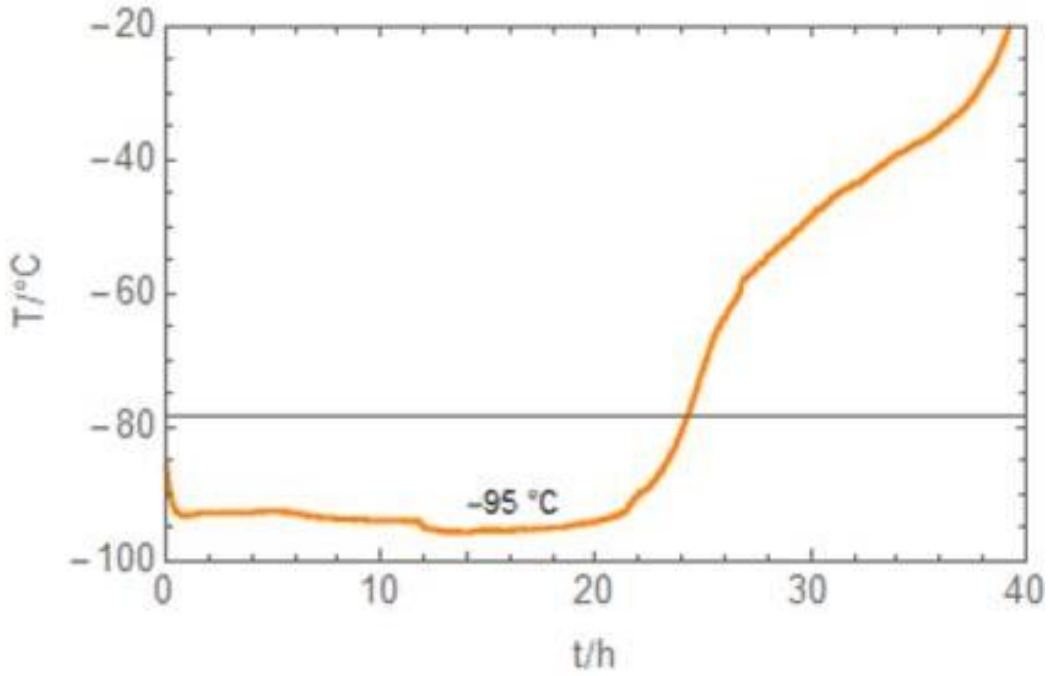
UTC+8

What happens with my dry ice box in the supply chain?



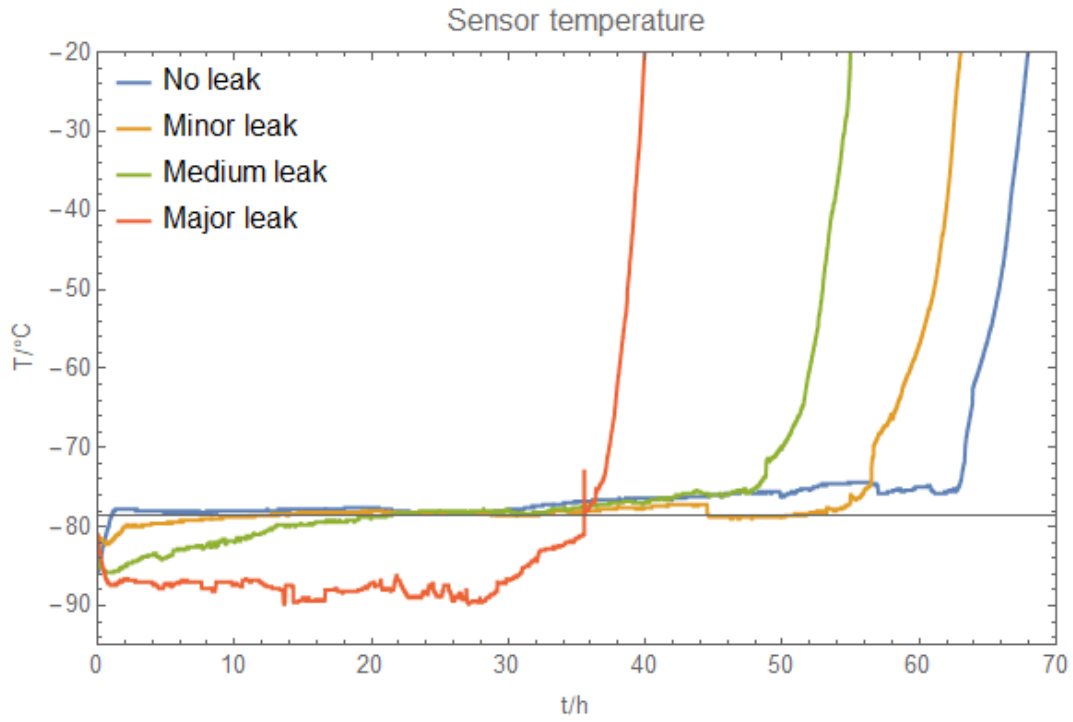
Supercooling

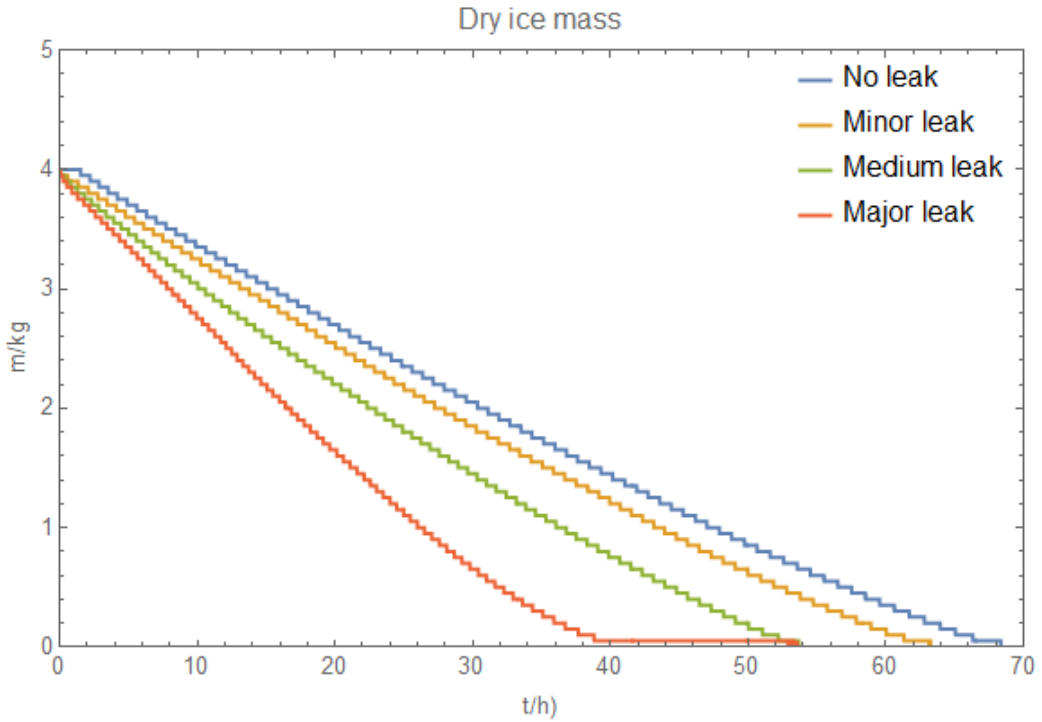
- Strong supercooling due to a major leakage.
- Temperature as low as -95 °C.



Leakage and supercooling

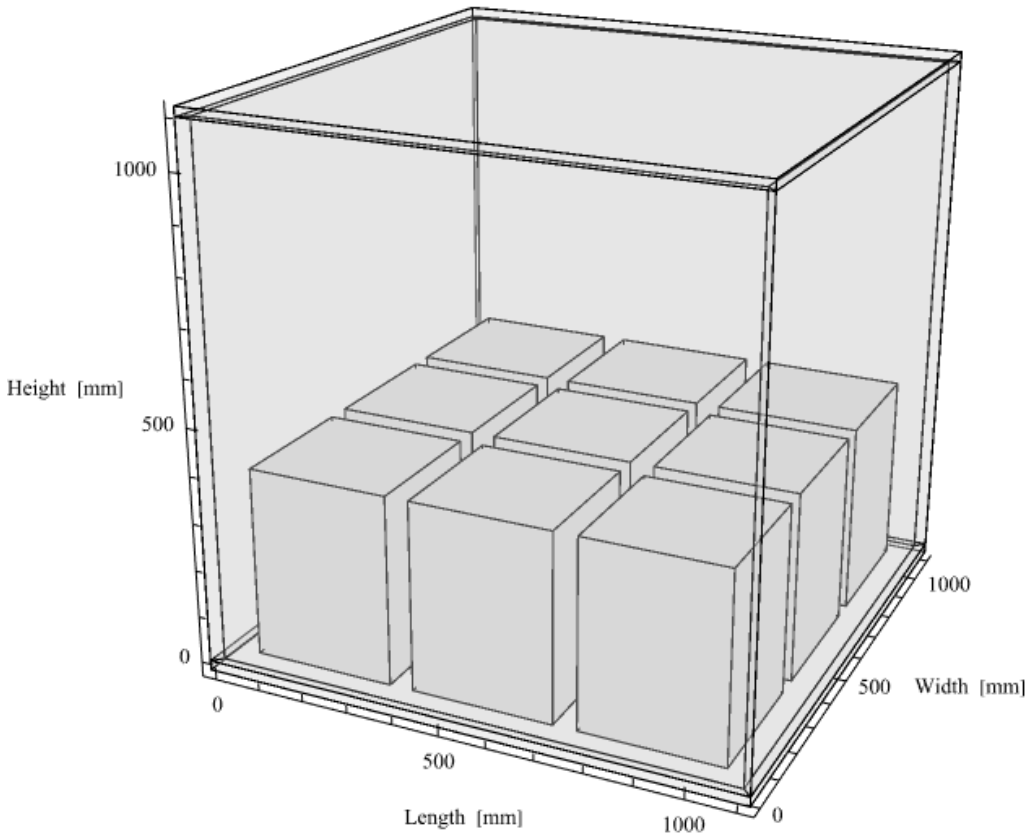
- Identical boxes with same amount of dry ice and different leakage volume.
- Ambient temperature, 15 °C.
- Lifetime lowers with increased leakage.

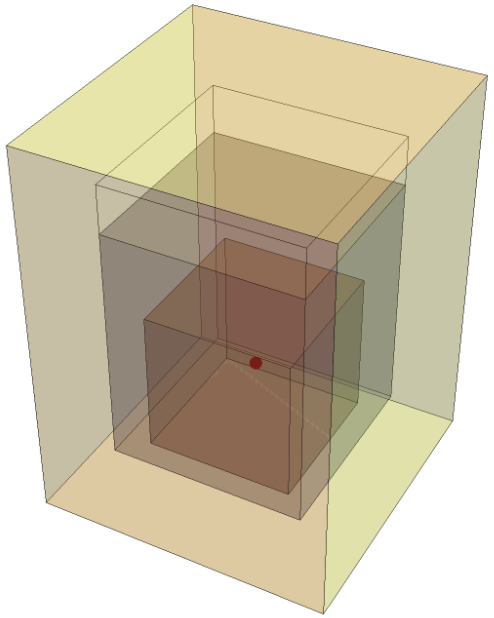


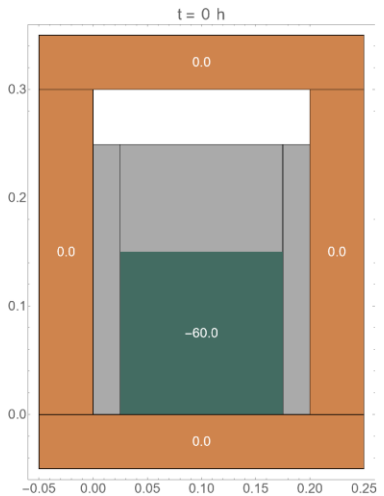


Dry Ice Box with leakage in a climate chamber

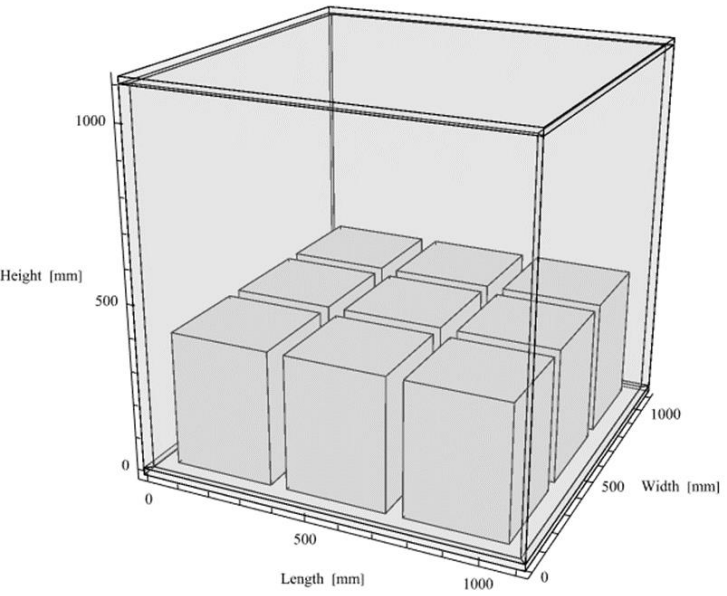
- Test in a chamber

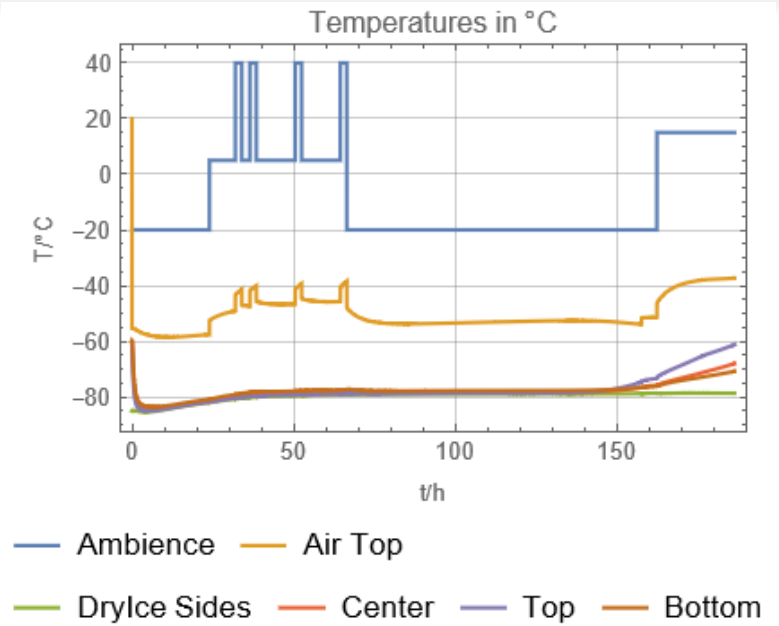


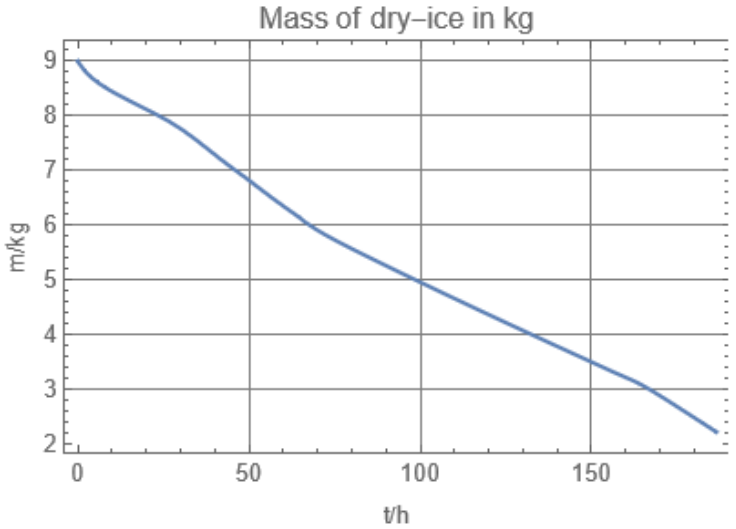




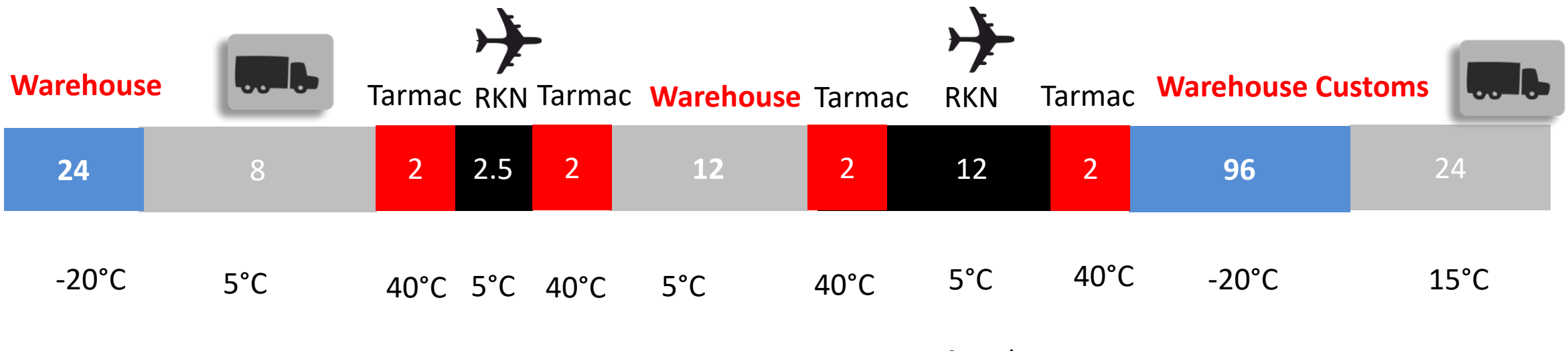
Test of the box in the climate chamber with the temperature profile

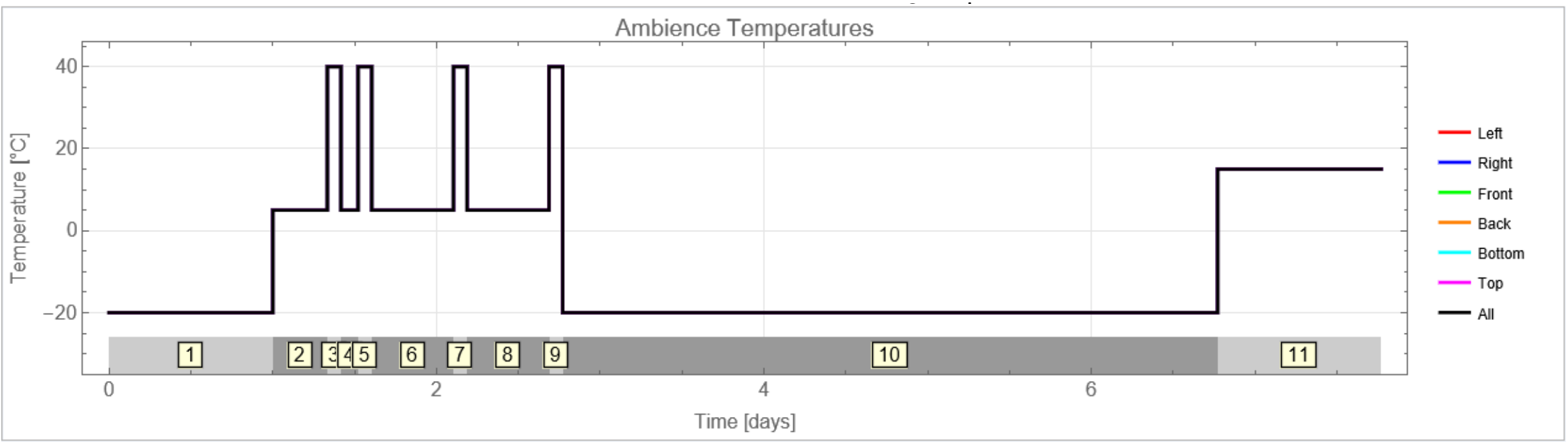






Transport in the supply chain

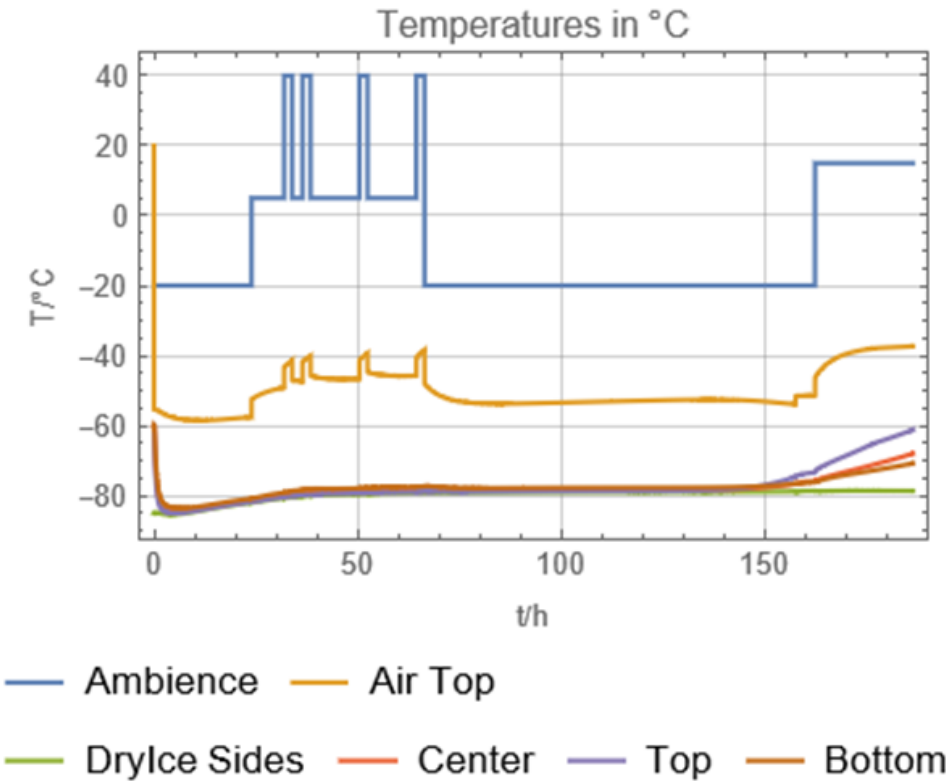




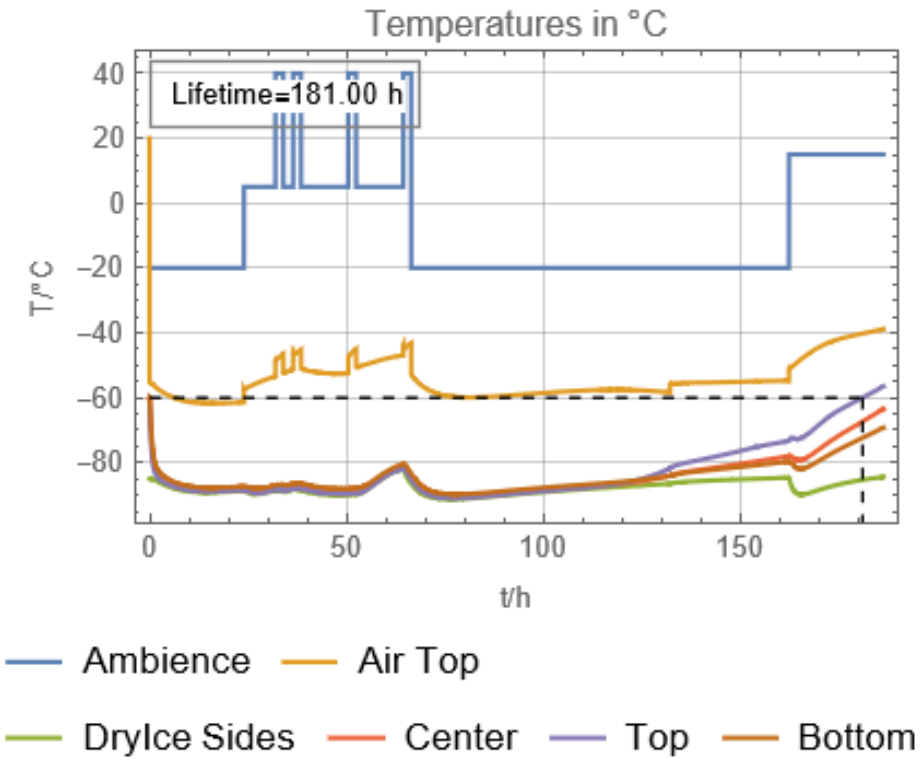
Dry Ice Shippers are different in a climate chamber as in reality

It‘s not only the temperature, it‘s also the C02 concentration around the box in transport

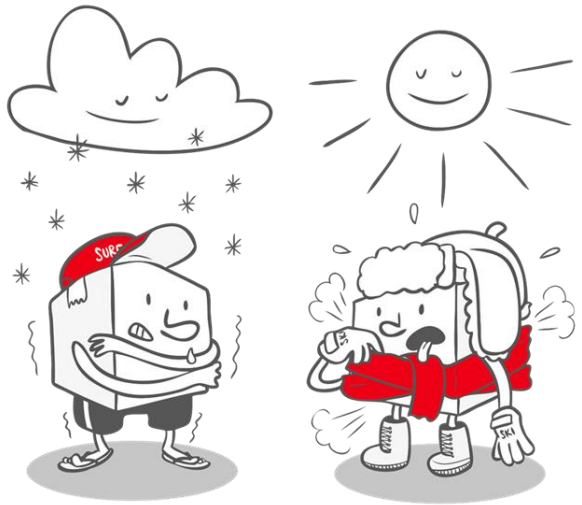
Climate Chamber **Pass**



Real Supply Chain **Fail**



What happens if there are extreme weather conditions ?



Lane: FCO – AMS – DEL

Define Lane: [Corona] FCO-AMS-DEL 50Szenario1

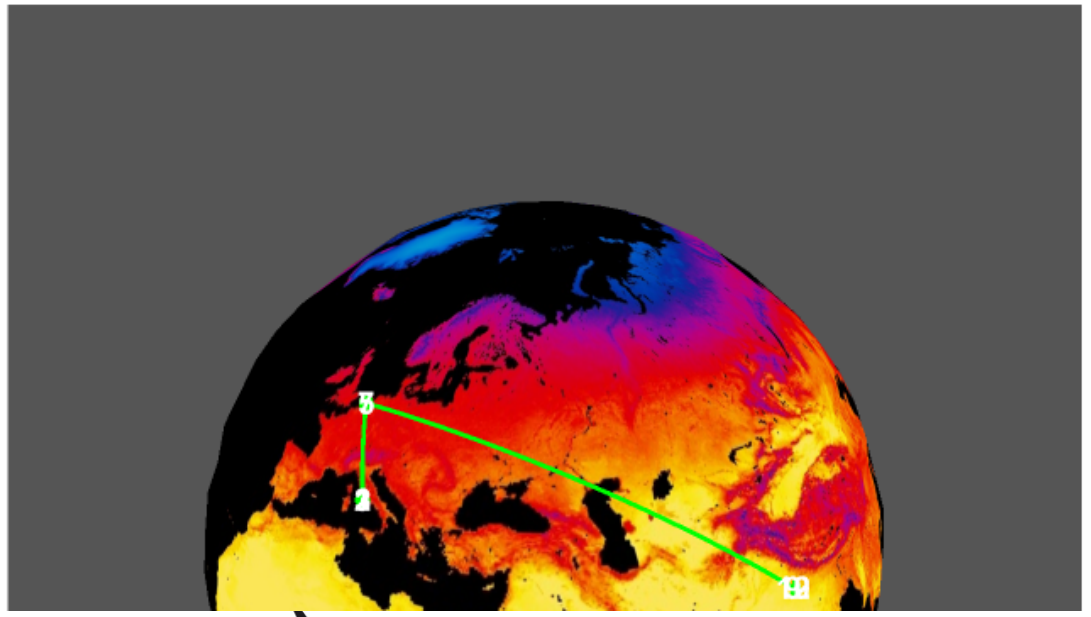
New | Open | Save | Save As | Import | Export | Historical Profiles | Profile Forecast | Solar Irra

Start–Time [UTC]: 00:20

	Name	δt/h	UTC	T/°C	Sun
1	Lead time acceptance area FCO	4.00	00:20		
2	Lead time build up area FCO	3.00	04:20		
3	Rome Tarmac	3.00	07:20		
4	Flight	2.50	10:20	15.0	
5	Amsterdam Airport Schiphol Tarmac	3.00	12:50		
6	Warehouse	19.00	15:50	20.0	
7	Amsterdam Airport Schiphol Tarmac	3.00	10:50		
8	Flight	9.00	13:50	15.0	
9	Lead time next to aircraft NewDelhi	1.00	22:50		
10	Lead time transport aircraft to warehouse NewDelhi	1.50	23:50		
11	Leadtime break down area NewDelhi	1.00	01:20	5.0	
12	Custom	10.00	02:20		
13	Truck	6.00	12:20	5.0	
	End	66.00	18:20		

Edit | Maps | Labels

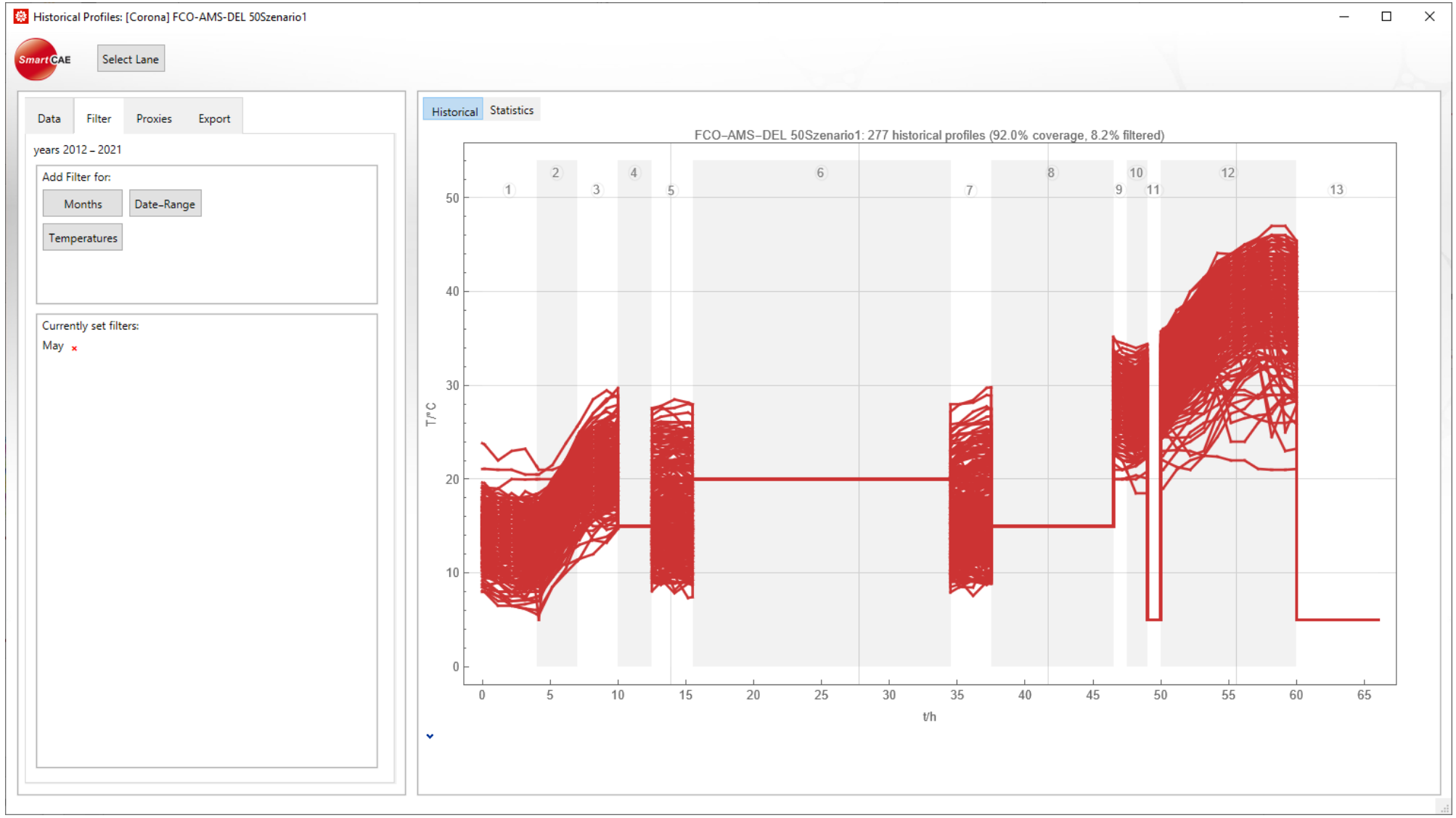
Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec



FCO → **AMS** → **DEL**

Standard	10	2.5	25	9	19.5	**66 h**

Historical weather for May 2012-2021



Temperature range and stability data

Product name:

Acceptable product temperature range:

T/°C: 2 – 8

Stability budgets:

	Tmin/°C	Tmax/°C	Budget/h	
1	1.	2.	0.5	×
2	8.	12.	1	×

+

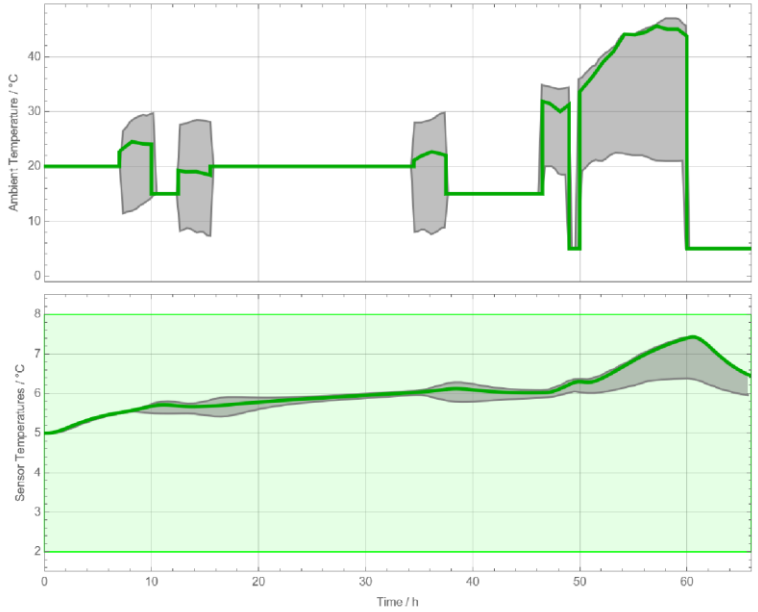
Lane Risk results based on historical May 2012-2021 data

SmartCAE LaneRisk - Wolfram Mathematica 13.0

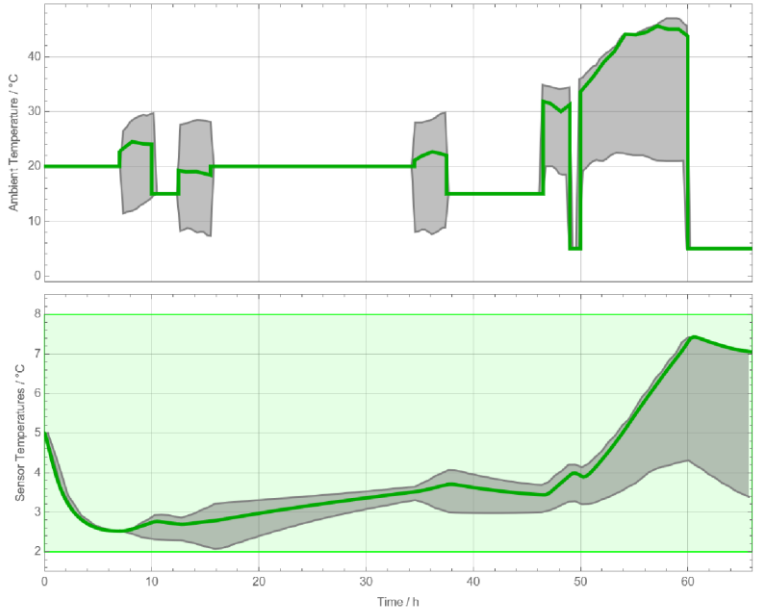
New | Open | Save | SaveAs | Import | Export | FCO–AMS–DEL 50Szenario1_2012–2021 (1) (Daily)

	packaging	#	no excursions	cold excursions	hot excursions	hot&cold excur.
1	Packout-All-Season	278	1.8%	0.0%	98.2%	0.0%
2	Packout-All-SeasonPU	278	82.0%	0.0%	18.0%	0.0%
3	Packout-All-SeasonVIP	278	100.0%	0.0%	0.0%	0.0%
4	Packout-Summerlight	278	100.0%	0.0%	0.0%	0.0%
5	Packout-SummerNew	278	100.0%	0.0%	0.0%	0.0%

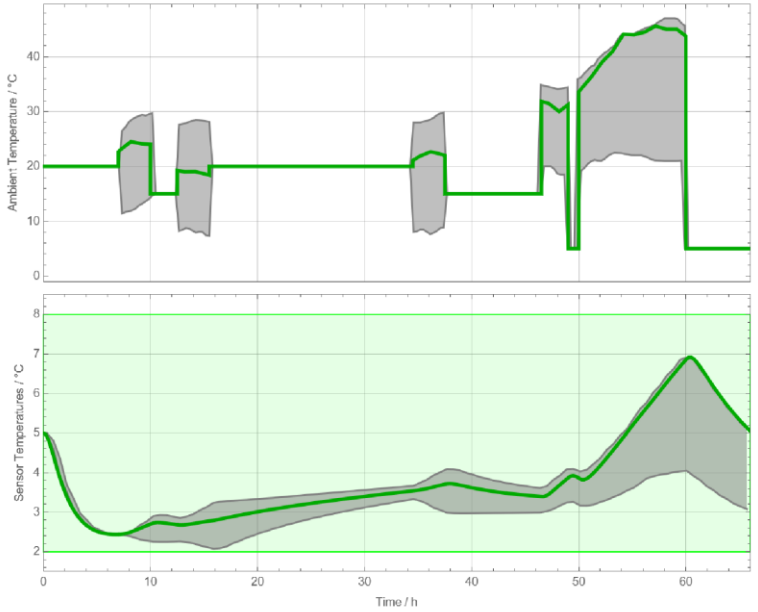
VIP



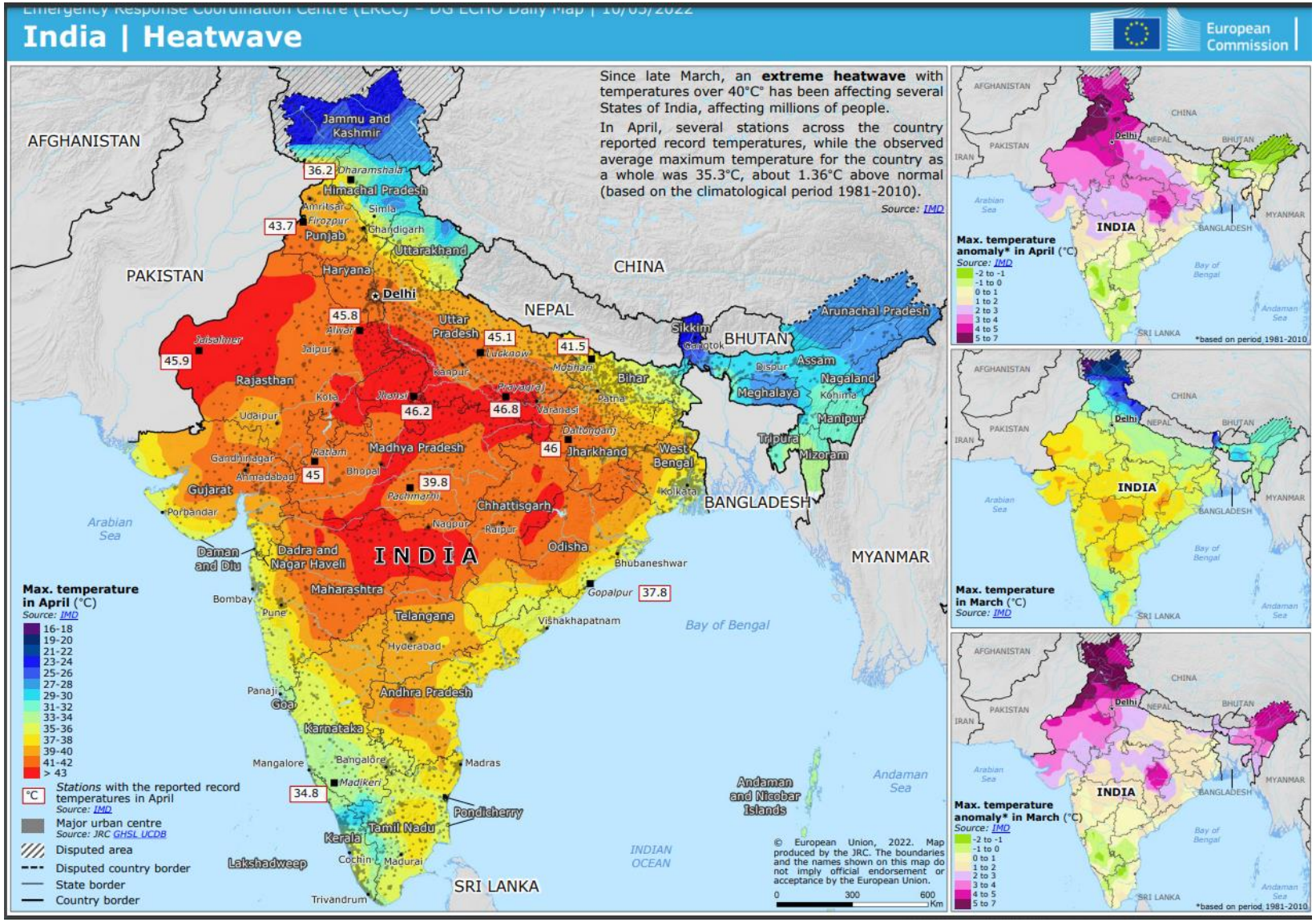
Summerlight



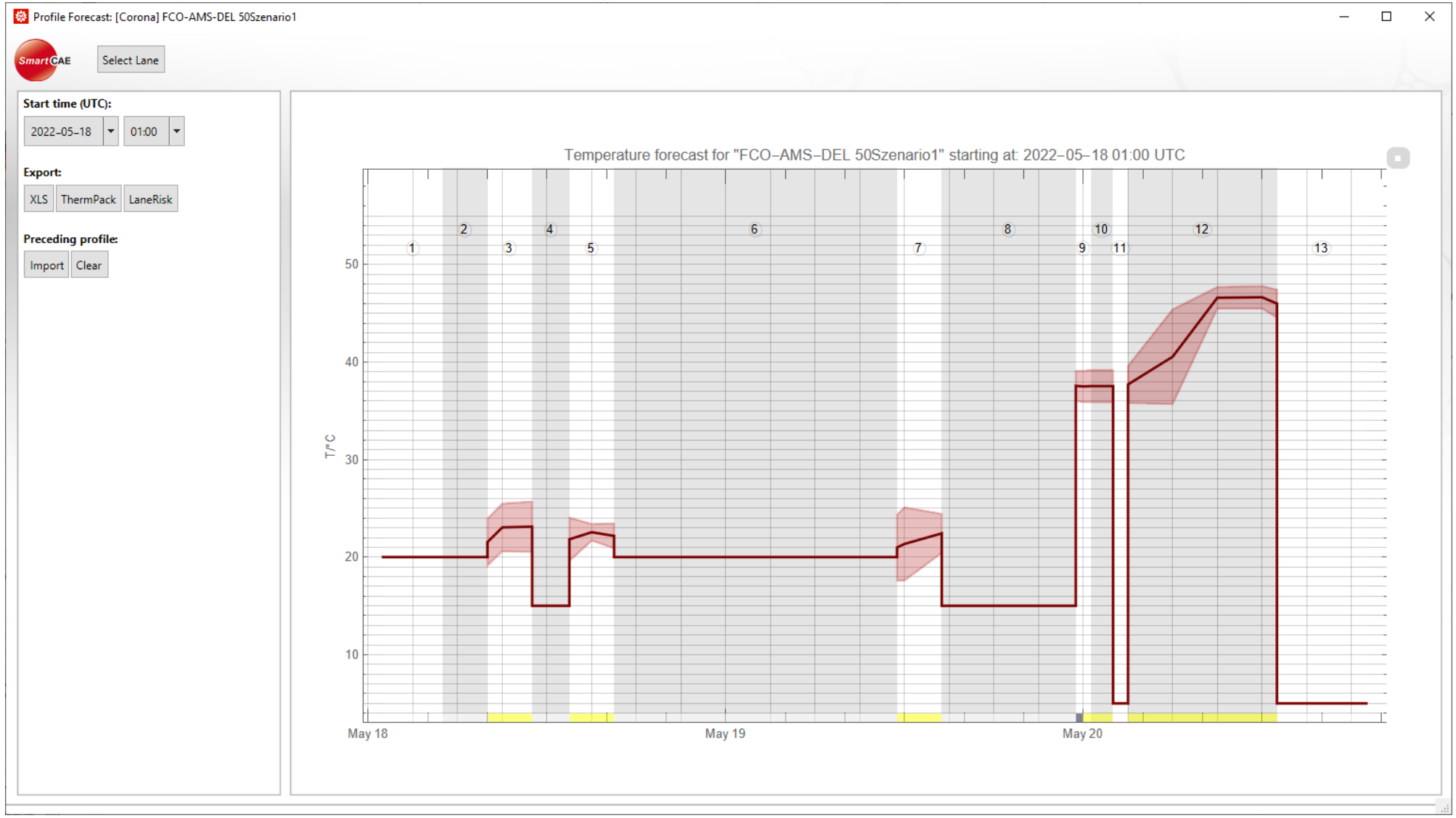
SummerNew



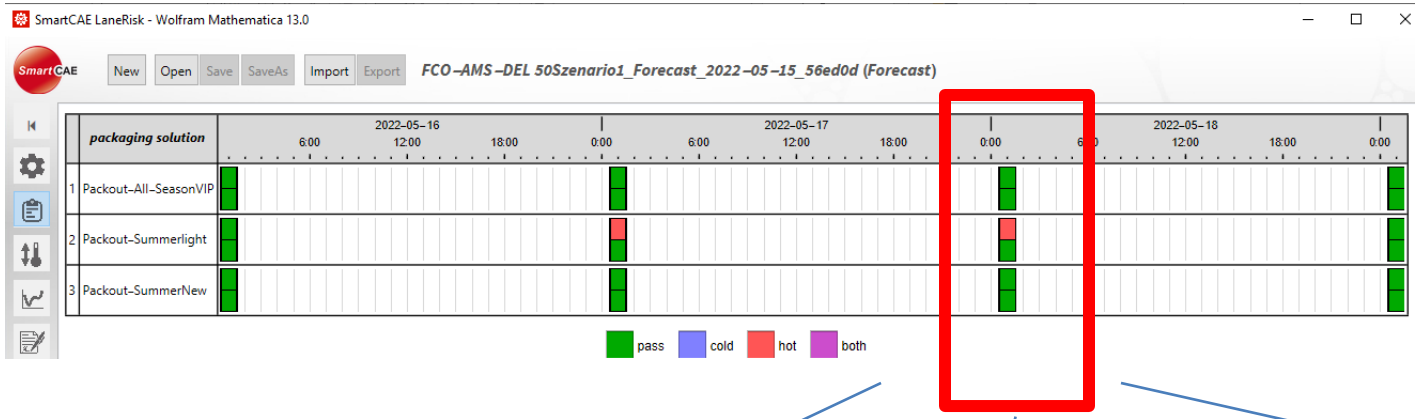
In April/May starts a heat wave in India



Weather forecast for four days in May



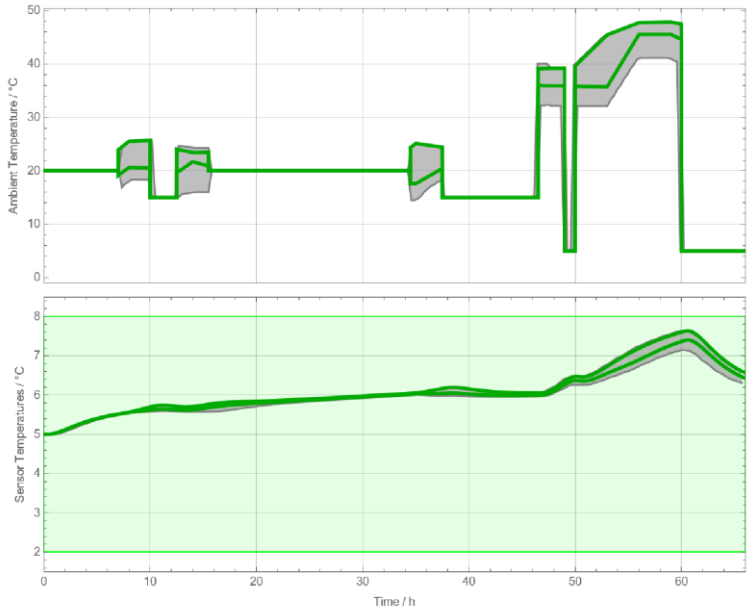
Lane Risk results based on weather forecast for the next days

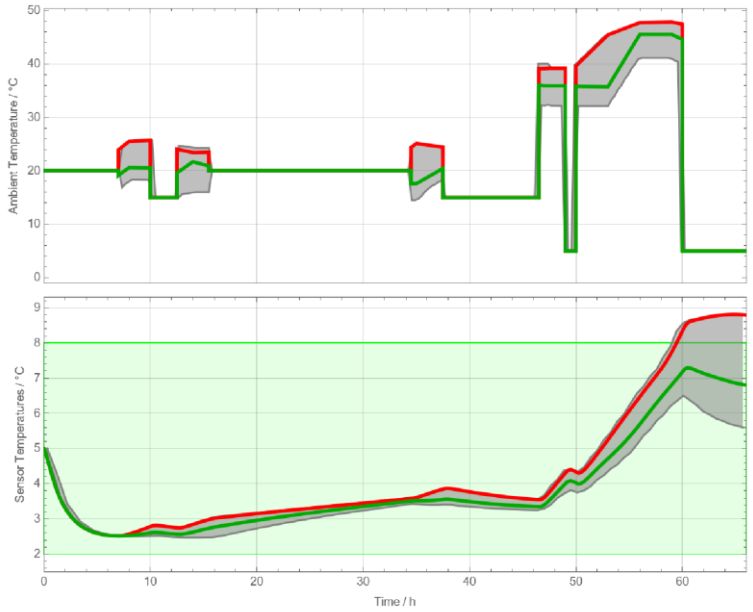


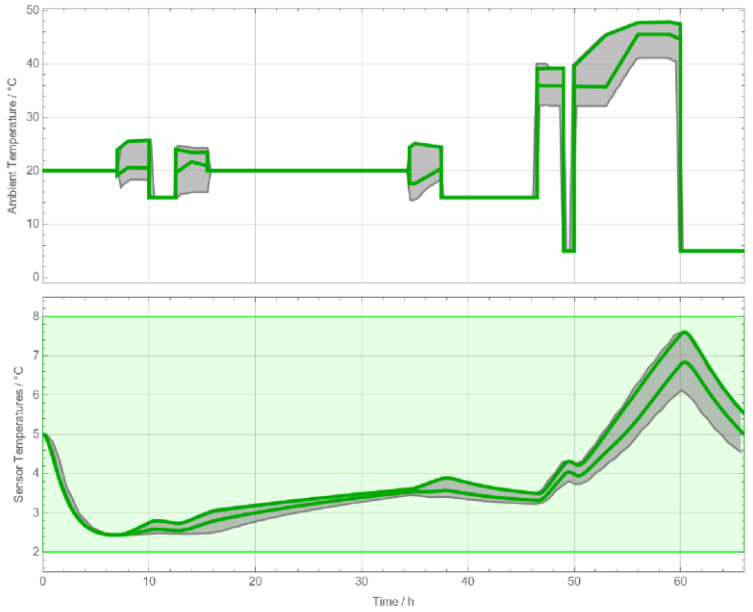
VIP

Summerlight

SummerNew







What happens if a flight is delay or missed

What happens if my warehouse or truck is not temperature controlled

Including delays in the Lane Risk

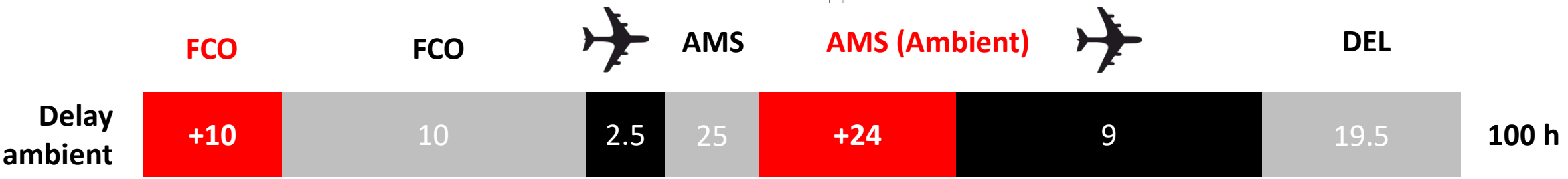
- 10 h delayed flight @ FCO
- 24 h longer stop in AMS @ **ambient storage**

Define Lane: [Corona] FCO-AMS-DEL 50Szenario2 (1)

New | Open | Save | Save As | Import | Export

Start-Time [UTC]: 14:20

	Name	δt / h	UTC	T/℃	Sun
1	Ambient Delay FCO	10.00	14:20		
2	Lead time acceptance area FCO	4.00	00:20	20.0	
3	Lead time build up area FCO	3.00	04:20	20.0	
4	Rome Tarmac	3.00	07:20		
5	Flight	2.50	10:20	15.0	
6	Amsterdam Airport Schiphol Tarmac	3.00	12:50		
7	Warehouse	19.00	15:50	20.0	
8	Warehouse Ambient	24.00	10:50		
9	Amsterdam Airport Schiphol Tarmac	3.00	10:50		
10	Flight	9.00	13:50	15.0	
11	Lead time next to aircraft NewDelhi	1.00	22:50		
12	Lead time transport aircraft to warehouse NewDelhi	1.50	23:50		
13	Leadtime break down area NewDelhi	1.00	01:20	5.0	
14	Custom	10.00	02:20		
15	Truck	6.00	12:20	5.0	
	End	100.00	18:20		



Including delays in the Lane Risk

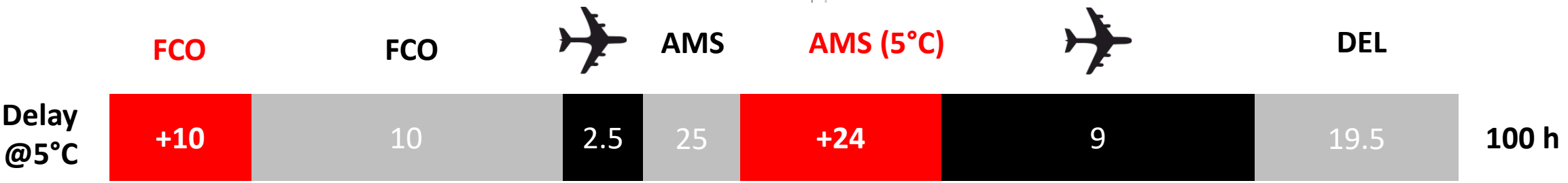
- 10 h delayed flight @ FCO
- 24 h longer stop in AMS @ **5°C**

Define Lane: [Corona] FCO-AMS-DEL 50Szenario3

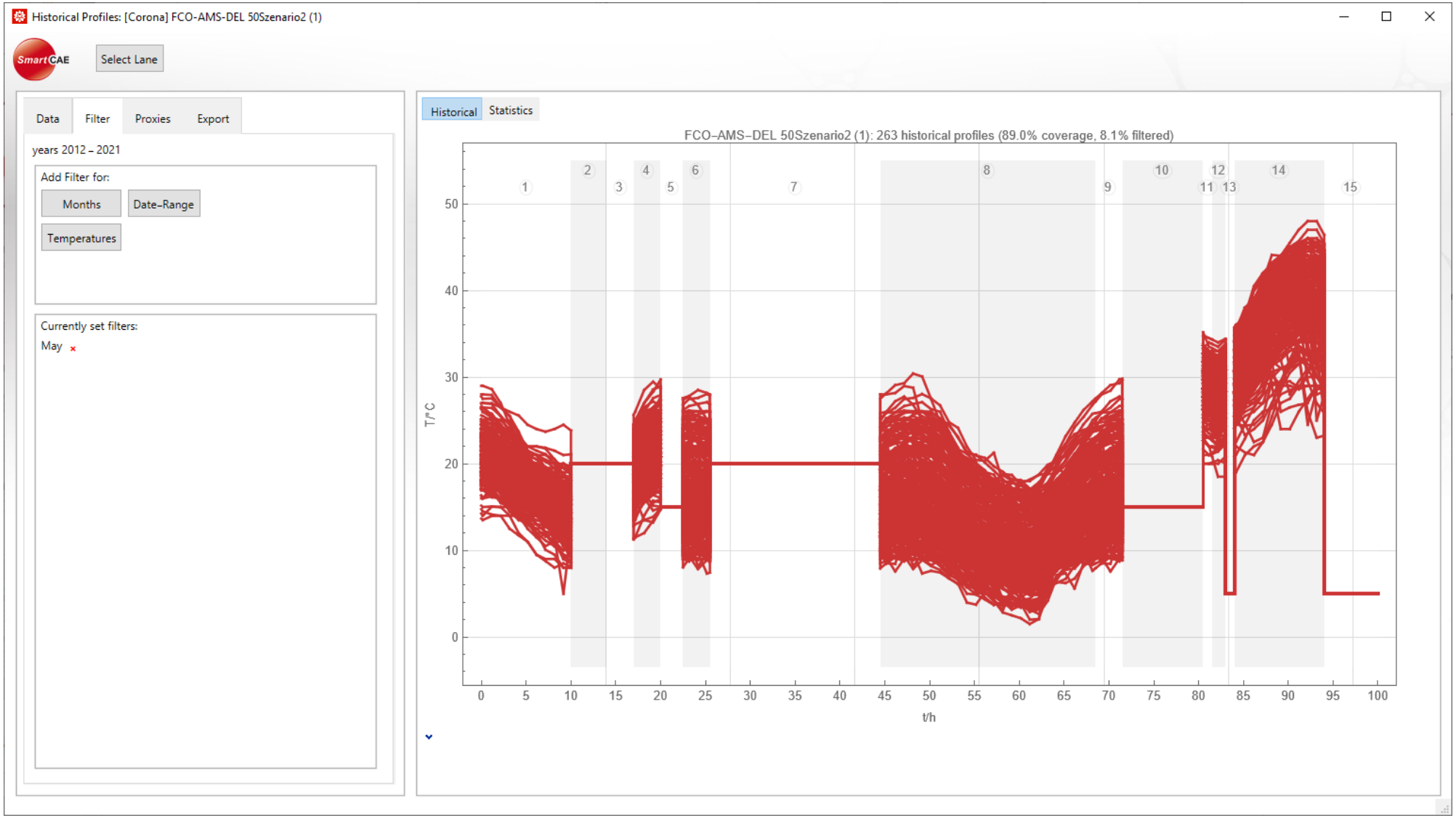
SmartCAE | New | Open | Save | Save As | Import | Export

Start-Time [UTC]: 14:20

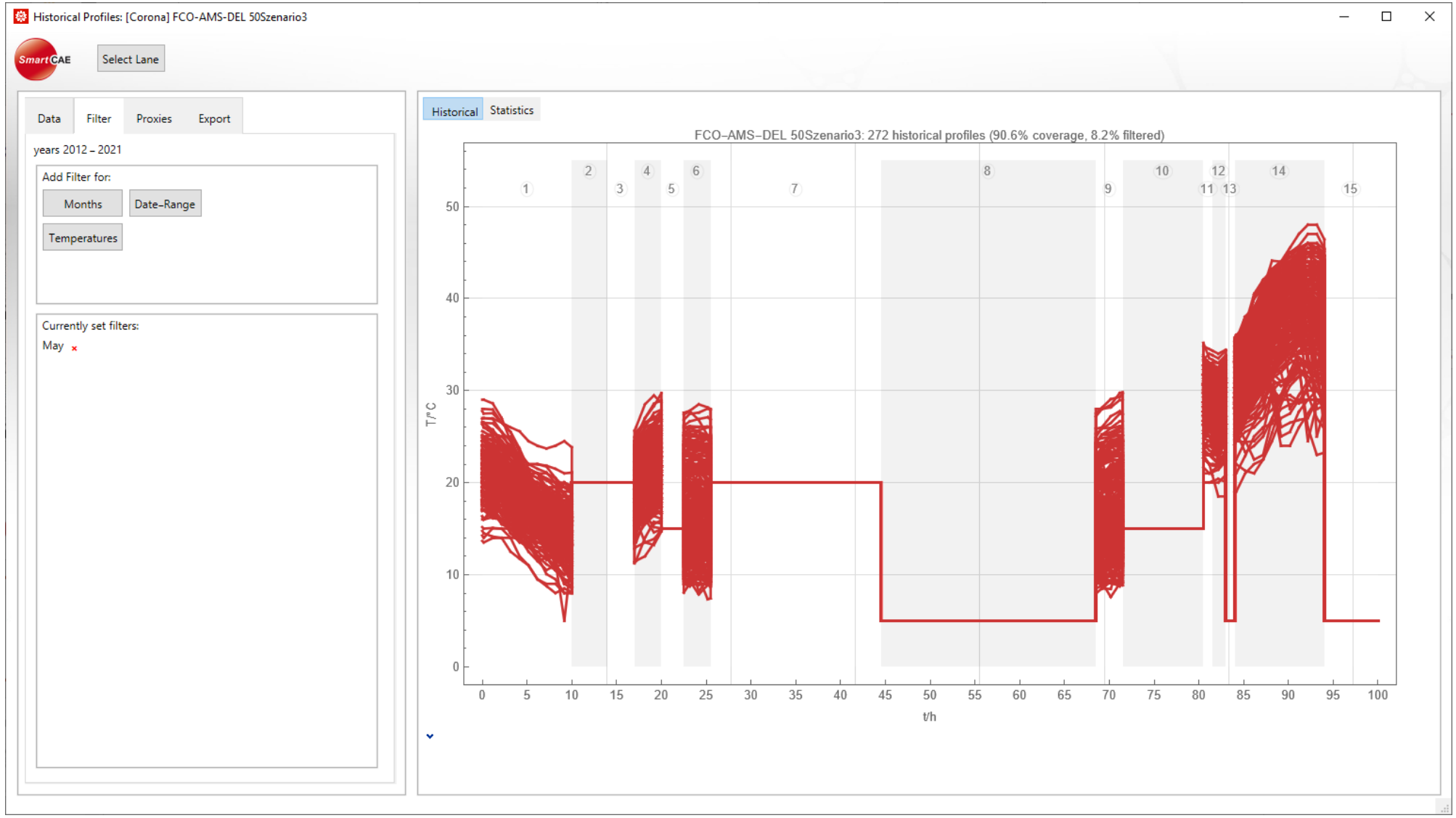
	Name	δt / h	UTC	T/°C	Sun
1	Ambient Delay FCO	10.00	14:20		
2	Lead time acceptance area FCO	4.00	00:20	20.0	
3	Lead time build up area FCO	3.00	04:20	20.0	
4	Rome Tarmac	3.00	07:20		
5	Flight	2.50	10:20	15.0	
6	Amsterdam Airport Schiphol Tarmac	3.00	12:50		
7	Warehouse	19.00	15:50	20.0	
8	Warehouse Ambient	24.00	10:50	5.0	
9	Amsterdam Airport Schiphol Tarmac	3.00	10:50		
10	Flight	9.00	13:50	15.0	
11	Lead time next to aircraft NewDelhi	1.00	22:50		
12	Lead time transport aircraft to warehouse NewDelhi	1.50	23:50		
13	Leadtime break down area NewDelhi	1.00	01:20	5.0	
14	Custom	10.00	02:20		
15	Truck	6.00	12:20	5.0	
	End	100.00	18:20		



Historical weather for May 2012-2021 ambient storage



Historical weather for May 2012-2021 5°C storage



Lane Risk results historical May 2012-2021 data ambient storage

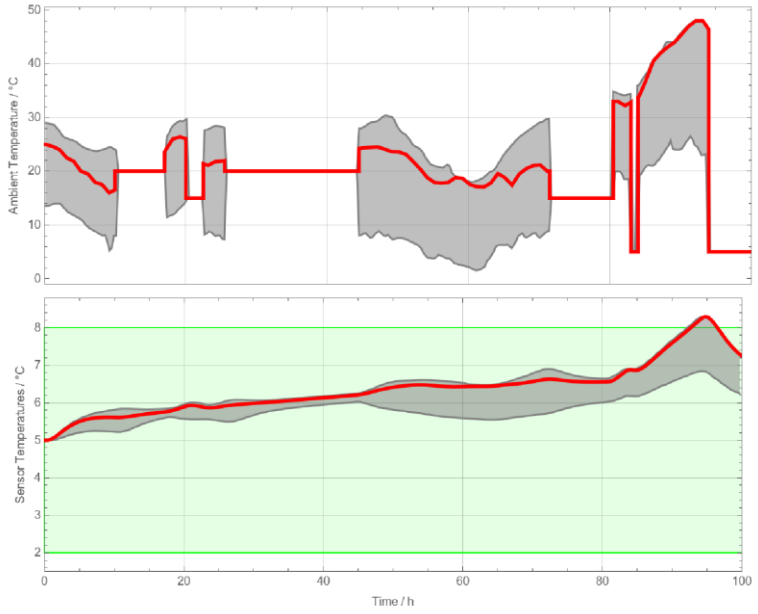
SmartCAE LaneRisk - Wolfram Mathematica 13.0

New | Open | Save | SaveAs | Import | Export

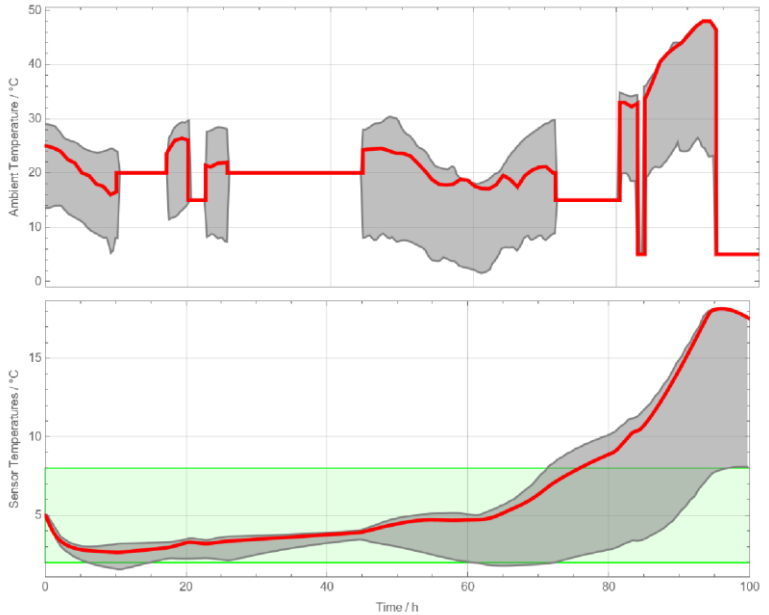
FCO–AMS–DEL 50Szenario2 (1)_2012–2021 (Daily)

	packaging	#	no excursions	cold excursions	hot excursions	hot&cold excur.
1	Packout–All–SeasonVIP	263	95.8%	0.0%	4.2%	0.0%
2	Packout–Summerlight	263	0.0%	0.0%	90.1%	9.9%
3	Packout–SummerNew	263	34.2%	12.2%	51.7%	1.9%

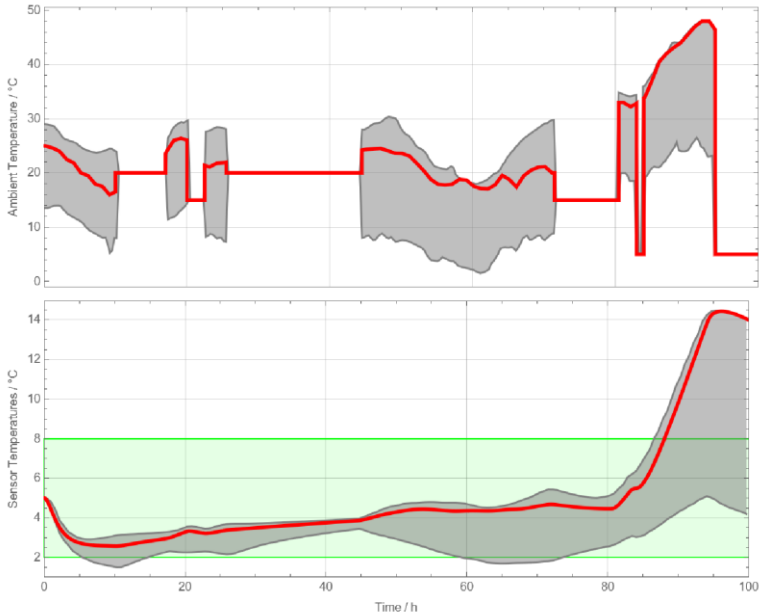
VIP



Summerlight



SummerNew



Lane Risk results historical May 2012-2021 5°C storage

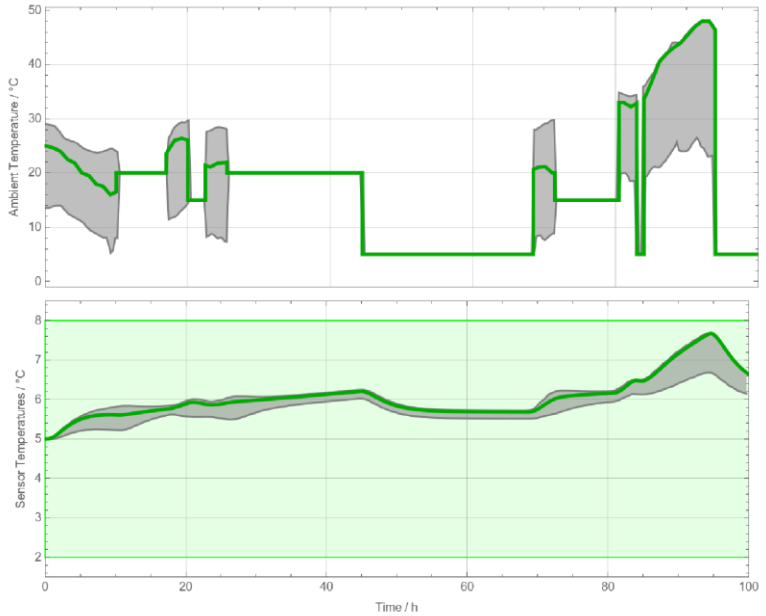
SmartCAE LaneRisk - Wolfram Mathematica 13.0

New | Open | Save | SaveAs | Import | Export

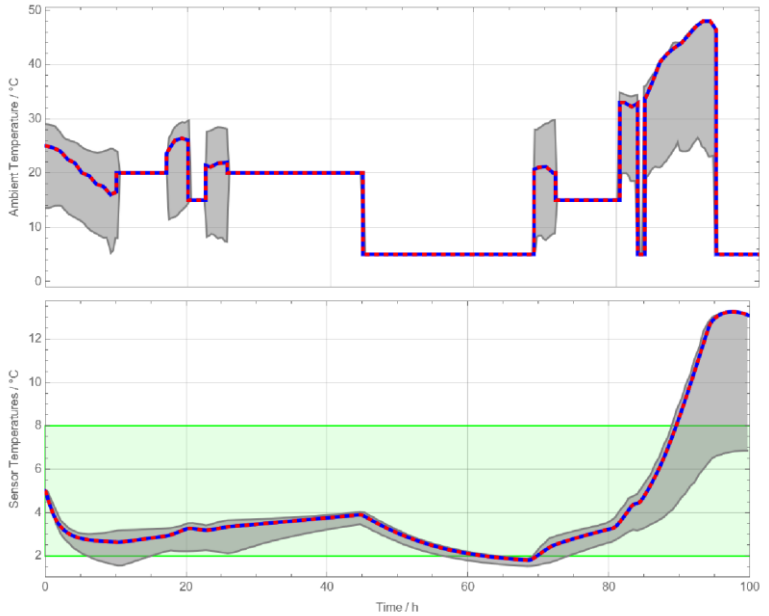
FCO–AMS–DEL 50Szenario3_2012–2021 (Daily)

	packaging	#	no excursions	cold excursions	hot excursions	hot&cold excur.
1	Packout–All–SeasonVIP	272	100.0%	0.0%	0.0%	0.0%
2	Packout–Summerlight	272	0.0%	2.9%	0.0%	97.1%
3	Packout–SummerNew	272	0.0%	100.0%	0.0%	0.0%

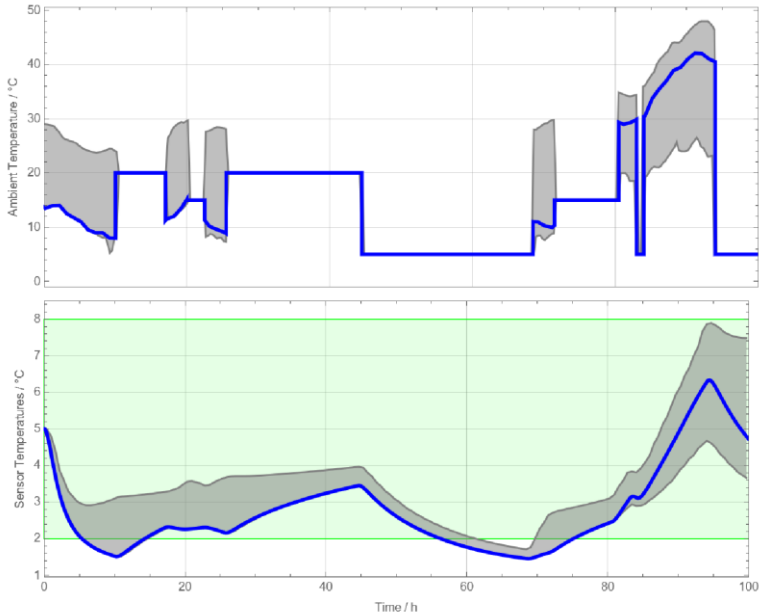
VIP



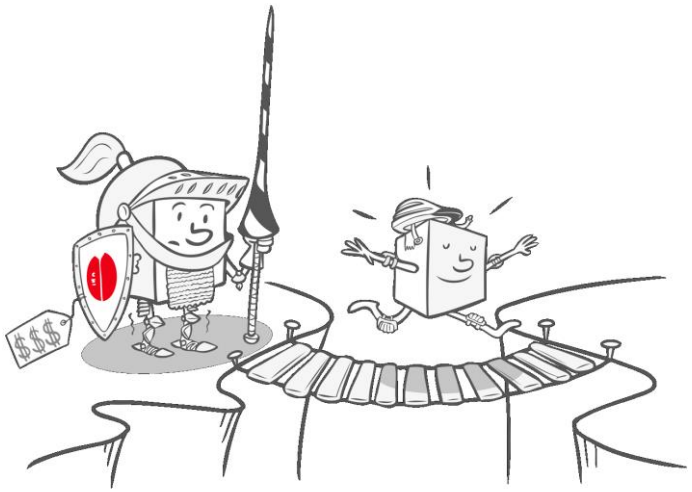
Summerlight



SummerNew



Find the right box to minimize total costs



Case study parameters

Scenario

- *Lane:* Rome–Amsterdam–New Deli, all year
- *Payload:* 2 – 8°C, stability data to decide product loss
- *4 available packouts:* summer, summer light, all-season VIP, all-season VIP reuse

Task

- Which packout?
- When change it, if needed?

Strategy

- Determine failure risk over the year for each container
- Find the optimal solution in terms of cost/risk

Lane: FCO – AMS – DEL

Define Lane: [Corona] FCO-AMS-DEL 50Szenario1

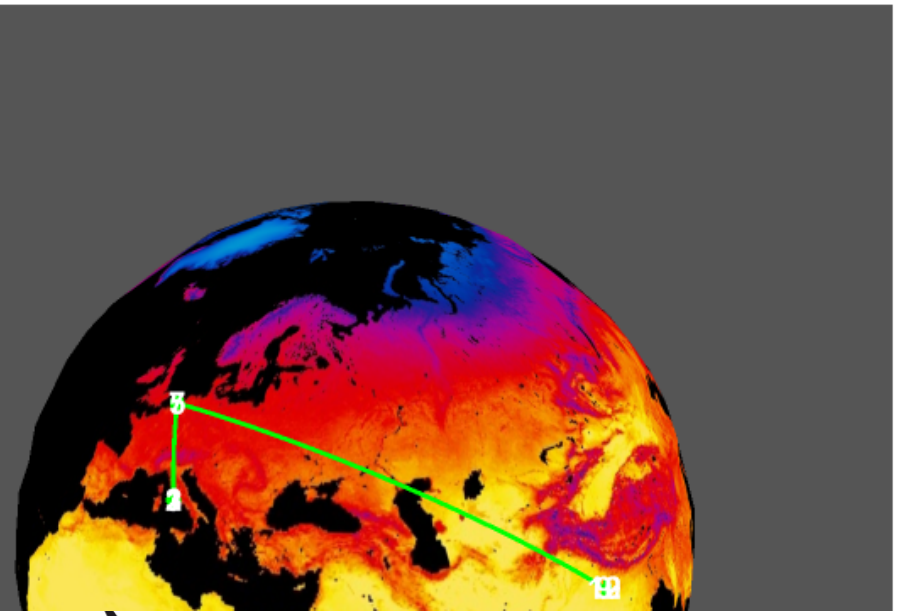
New | Open | Save | Save As | Import | Export | Historical Profiles | Profile Forecast | Solar Irra

Start–Time [UTC]: 00:20

	Name	δt/h	UTC	T/°C	Sun
1	Lead time acceptance area FCO	4.00	00:20		
2	Lead time build up area FCO	3.00	04:20		
3	Rome Tarmac	3.00	07:20		
4	Flight	2.50	10:20	15.0	
5	Amsterdam Airport Schiphol Tarmac	3.00	12:50		
6	Warehouse	19.00	15:50	20.0	
7	Amsterdam Airport Schiphol Tarmac	3.00	10:50		
8	Flight	9.00	13:50	15.0	
9	Lead time next to aircraft NewDelhi	1.00	22:50		
10	Lead time transport aircraft to warehouse NewDelhi	1.50	23:50		
11	Leadtime break down area NewDelhi	1.00	01:20	5.0	
12	Custom	10.00	02:20		
13	Truck	6.00	12:20	5.0	
	End	66.00	18:20		

Edit | Maps | Labels

Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec



FCO → **AMS** → **DEL**

Standard	10	2.5	25	9	19.5	**66 h**

Price of air freight rates

statista

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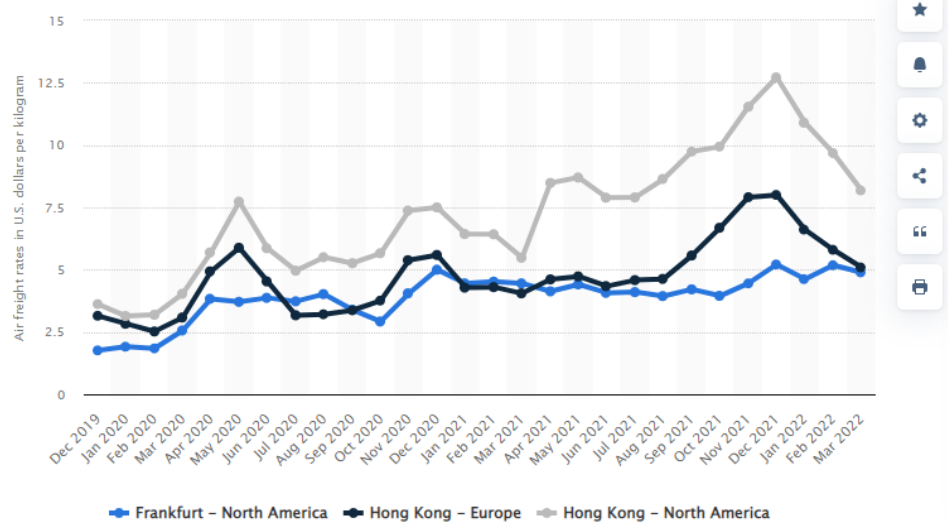
Transportation & Logistics › Aviation

PREMIUM

Impact of coronavirus on major global air freight rates between December 2019 to March 2022

(in U.S. dollars per kilogram)



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- Use Ask Statista Research Service

Release date
March 2022

Region
Worldwide

Survey time period
December 2019 to March 2022

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Additional Information

Show source

Air freight rates change since the beginning of COVID-19 outbreak 2019-2022

Assumptions

Packaging	Costs / $	Weight / kg
Packout–All–SeasonVIP	150.	17.334
Packout–SummerNew	55.	18.814
Packout–Summerlight	38.	13.019
Packout–All–SeasonVIPReuse	62.	34.4
Packout–All–SeasonPU	90.	14.09

→ Reverse Logistics

Costs for: Transport / $/kg	Excursion / $	Product loss / $
5.	6500	10 000.

Checks for excursions: (◉) Excursions ( ) Stability Data

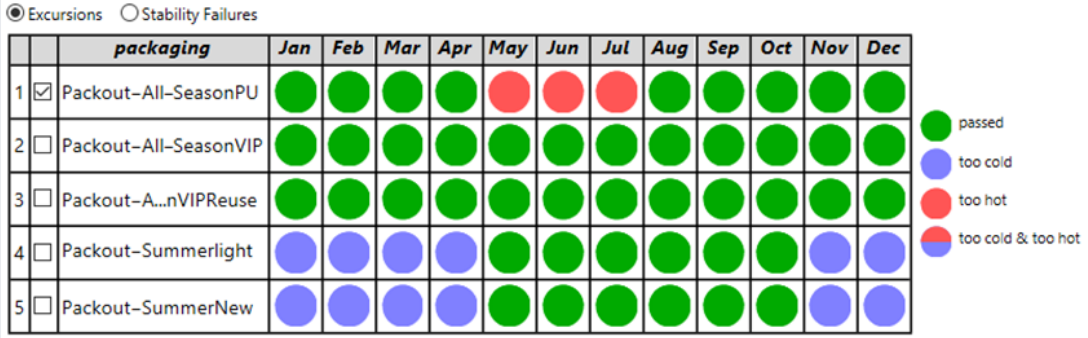
Checks for failures: ( ) Excursions (◉) Stability Data

Shipments per ( ) Year (◉) Month

Jan	1000	Feb	416	Mar	417	Apr	417
May	417	Jun	416	Jul	417	Aug	700
Sep	800	Oct	417	Nov	590	Dec	417

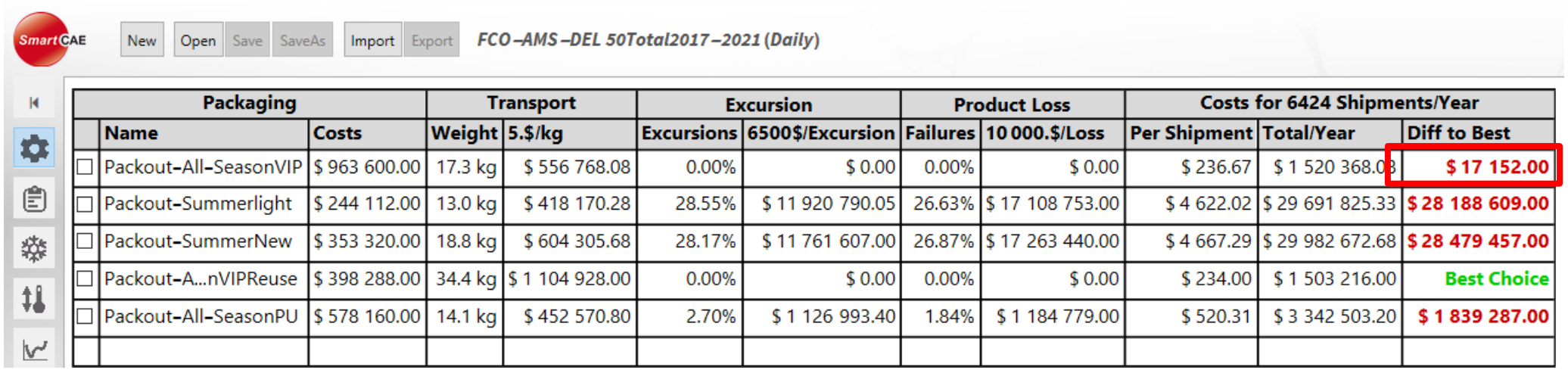
Exursions are important

	packaging	#	no excursions	cold excursions	hot excursions	hot&cold excur.	stability checks
1	Packout-All-SeasonPU	1712	96.6%	0.0%	3.4%	0.0%	97.7%
2	Packout-All-SeasonVIP	1712	100.0%	0.0%	0.0%	0.0%	100.0%
3	Packout-A...nVIPReuse	1712	100.0%	0.0%	0.0%	0.0%	100.0%
4	Packout-Summerlight	1712	75.5%	24.5%	0.0%	0.0%	77.4%
5	Packout-SummerNew	1712	75.8%	24.2%	0.0%	0.0%	77.2%



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	1	1	1	1	1	1	1	1	1	1	1	1
	100.0%	100.0%	100.0%	100.0%	85.2%	74.5%	98.7%	100.0%	100.0%	100.0%	100.0%	100.0%
					14.8%	25.5%						
% pass	100.0	100.0	100.0	100.0	85.2	74.5	98.7	100.0	100.0	100.0	100.0	100.0
% cold	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% hot	0.0	0.0	0.0	0.0	14.8	25.5	1.3	0.0	0.0	0.0	0.0	0.0
% both	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% fail	**0.0**	**0.0**	**0.0**	**0.0**	**14.8**	**25.5**	**1.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
# profiles	140	129	148	141	135	145	153	146	133	150	141	151

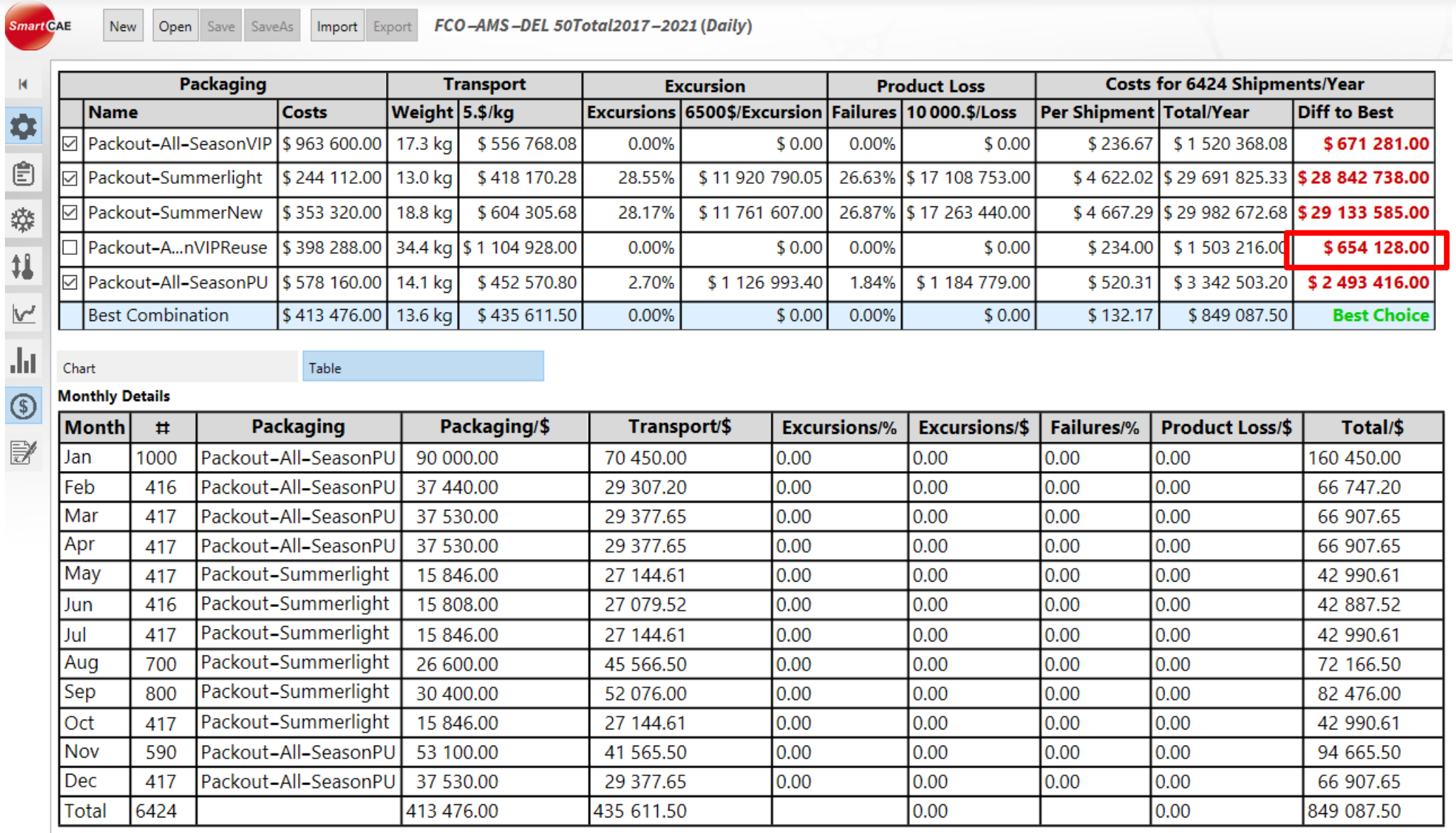
Total costs for single solutions



Packaging		Transport		Excursion		Product Loss		Costs for 6424 Shipments/Year		
Name	Costs	Weight	5.$/kg	Excursions	6500$/Excursion	Failures	10 000.$/Loss	Per Shipment	Total/Year	Diff to Best
Packout-All-SeasonVIP	$ 963 600.00	17.3 kg	$ 556 768.08	0.00%	$ 0.00	0.00%	$ 0.00	$ 236.67	$ 1 520 368.08	$ 17 152.00
Packout-Summerlight	$ 244 112.00	13.0 kg	$ 418 170.28	28.55%	$ 11 920 790.05	26.63%	$ 17 108 753.00	$ 4 622.02	$ 29 691 825.33	$ 28 188 609.00
Packout-SummerNew	$ 353 320.00	18.8 kg	$ 604 305.68	28.17%	$ 11 761 607.00	26.87%	$ 17 263 440.00	$ 4 667.29	$ 29 982 672.68	$ 28 479 457.00
Packout-A...nVIPReuse	$ 398 288.00	34.4 kg	$ 1 104 928.00	0.00%	$ 0.00	0.00%	$ 0.00	$ 234.00	$ 1 503 216.00	Best Choice
Packout-All-SeasonPU	$ 578 160.00	14.1 kg	$ 452 570.80	2.70%	$ 1 126 993.40	1.84%	$ 1 184 779.00	$ 520.31	$ 3 342 503.20	$ 1 839 287.00

Saving
With No Risk

Total costs for best combination single use



Packaging			Transport		Excursion		Product Loss		Costs for 6424 Shipments/Year		
	Name	Costs	Weight	5.$/kg	Excursions	6500$/Excursion	Failures	10 000.$/Loss	Per Shipment	Total/Year	Diff to Best
☑	Packout-All-SeasonVIP	$ 963 600.00	17.3 kg	$ 556 768.08	0.00%	$ 0.00	0.00%	$ 0.00	$ 236.67	$ 1 520 368.08	$ 671 281.00
☑	Packout-Summerlight	$ 244 112.00	13.0 kg	$ 418 170.28	28.55%	$ 11 920 790.05	26.63%	$ 17 108 753.00	$ 4 622.02	$ 29 691 825.33	$ 28 842 738.00
☑	Packout-SummerNew	$ 353 320.00	18.8 kg	$ 604 305.68	28.17%	$ 11 761 607.00	26.87%	$ 17 263 440.00	$ 4 667.29	$ 29 982 672.68	$ 29 133 585.00
☐	Packout-A...nVIPReuse	$ 398 288.00	34.4 kg	$ 1 104 928.00	0.00%	$ 0.00	0.00%	$ 0.00	$ 234.00	$ 1 503 216.00	$ 654 128.00
☑	Packout-All-SeasonPU	$ 578 160.00	14.1 kg	$ 452 570.80	2.70%	$ 1 126 993.40	1.84%	$ 1 184 779.00	$ 520.31	$ 3 342 503.20	$ 2 493 416.00
	Best Combination	$ 413 476.00	13.6 kg	$ 435 611.50	0.00%	$ 0.00	0.00%	$ 0.00	$ 132.17	$ 849 087.50	Best Choice

Saving

With No Risk

Chart | Table

Monthly Details

Month	#	Packaging	Packaging/$	Transport/$	Excursions/%	Excursions/$	Failures/%	Product Loss/$	Total/$
Jan	1000	Packout-All-SeasonPU	90 000.00	70 450.00	0.00	0.00	0.00	0.00	160 450.00
Feb	416	Packout-All-SeasonPU	37 440.00	29 307.20	0.00	0.00	0.00	0.00	66 747.20
Mar	417	Packout-All-SeasonPU	37 530.00	29 377.65	0.00	0.00	0.00	0.00	66 907.65
Apr	417	Packout-All-SeasonPU	37 530.00	29 377.65	0.00	0.00	0.00	0.00	66 907.65
May	417	Packout-Summerlight	15 846.00	27 144.61	0.00	0.00	0.00	0.00	42 990.61
Jun	416	Packout-Summerlight	15 808.00	27 079.52	0.00	0.00	0.00	0.00	42 887.52
Jul	417	Packout-Summerlight	15 846.00	27 144.61	0.00	0.00	0.00	0.00	42 990.61
Aug	700	Packout-Summerlight	26 600.00	45 566.50	0.00	0.00	0.00	0.00	72 166.50
Sep	800	Packout-Summerlight	30 400.00	52 076.00	0.00	0.00	0.00	0.00	82 476.00
Oct	417	Packout-Summerlight	15 846.00	27 144.61	0.00	0.00	0.00	0.00	42 990.61
Nov	590	Packout-All-SeasonPU	53 100.00	41 565.50	0.00	0.00	0.00	0.00	94 665.50
Dec	417	Packout-All-SeasonPU	37 530.00	29 377.65	0.00	0.00	0.00	0.00	66 907.65
Total	6424		413 476.00	435 611.50		0.00		0.00	849 087.50

A closer look on the CO2 footprint and costs again

Lane: FCO – AMS – DEL

Define Lane: [Corona] FCO-AMS-DEL 50Szenario1

New | Open | Save | Save As | Import | Export | Historical Profiles | Profile Forecast | Solar Irra

Start–Time [UTC]: 00:20

	Name	δt/h	UTC	T/°C	Sun
1	Lead time acceptance area FCO	4.00	00:20		
2	Lead time build up area FCO	3.00	04:20		
3	Rome Tarmac	3.00	07:20		
4	Flight	2.50	10:20	15.0	
5	Amsterdam Airport Schiphol Tarmac	3.00	12:50		
6	Warehouse	19.00	15:50	20.0	
7	Amsterdam Airport Schiphol Tarmac	3.00	10:50		
8	Flight	9.00	13:50	15.0	
9	Lead time next to aircraft NewDelhi	1.00	22:50		
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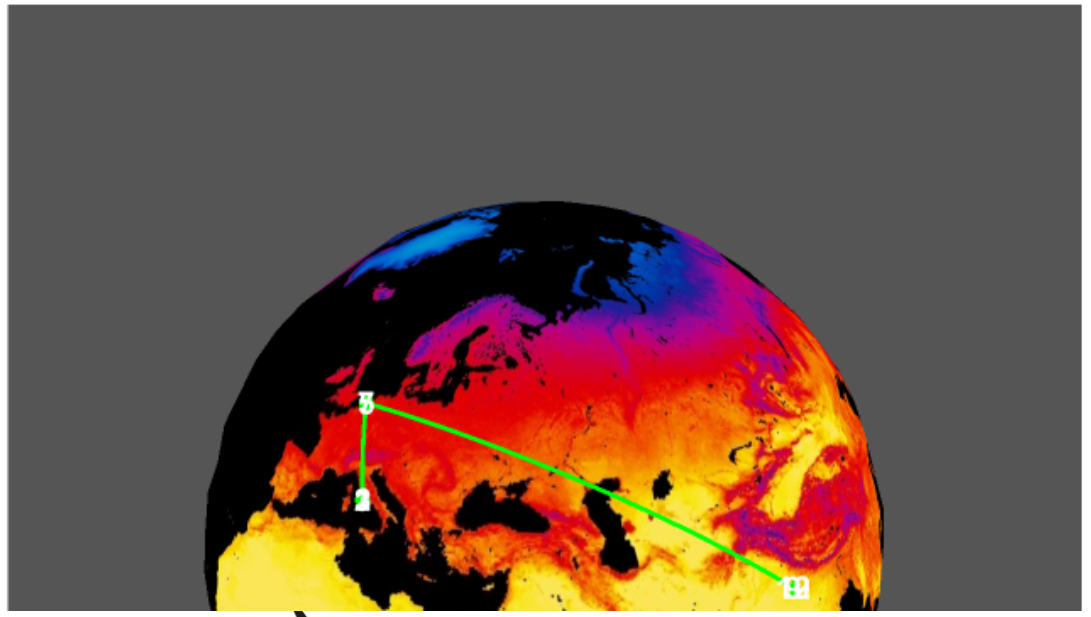
12	Custom	10.00	02:20		
13	Truck	6.00	12:20	5.0	
	End	66.00	18:20		

Edit | Maps | Labels

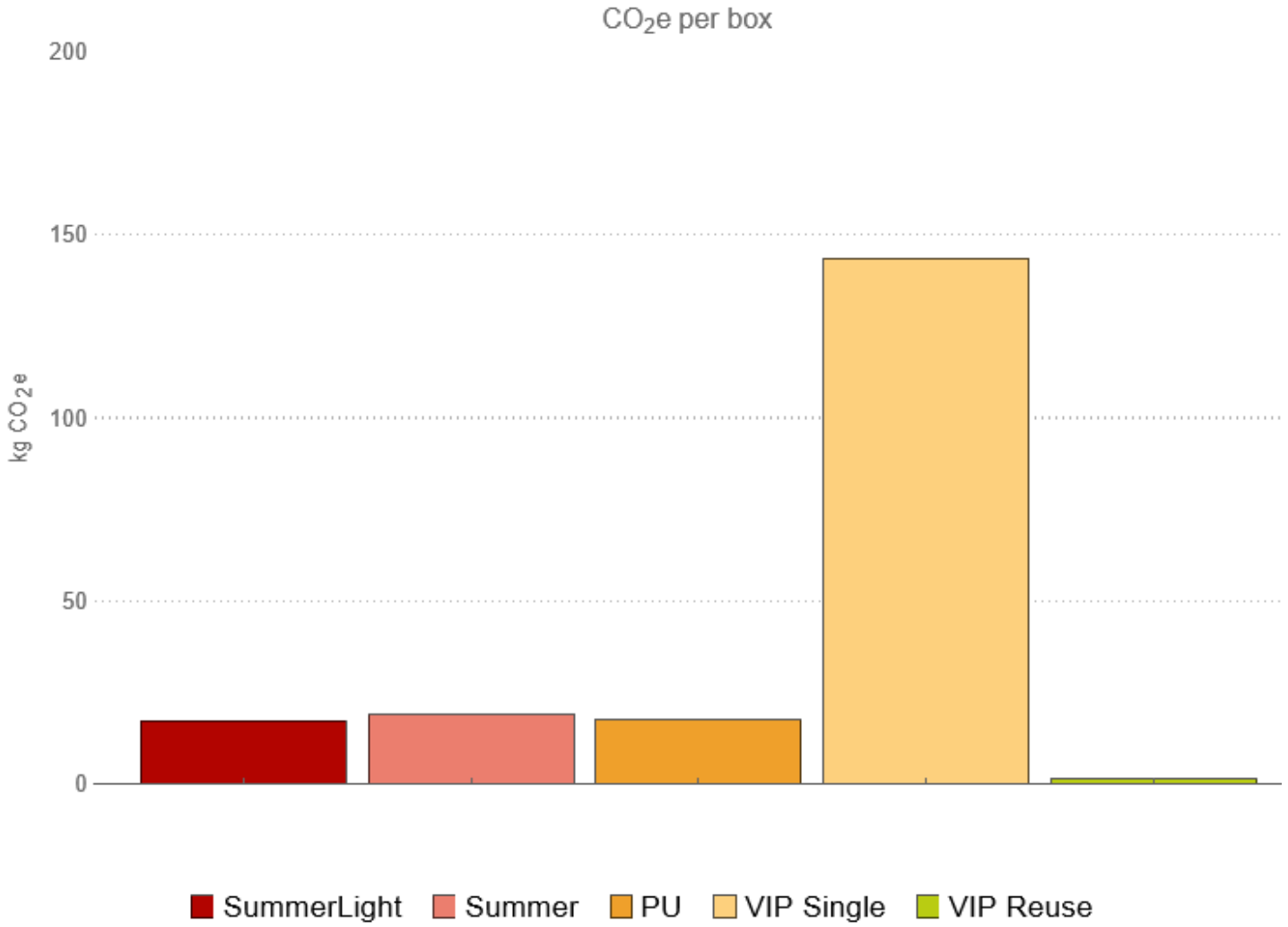
Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec



FCO → **AMS** → **DEL**

Standard	10	2.5	25	9	19.5	**66 h**

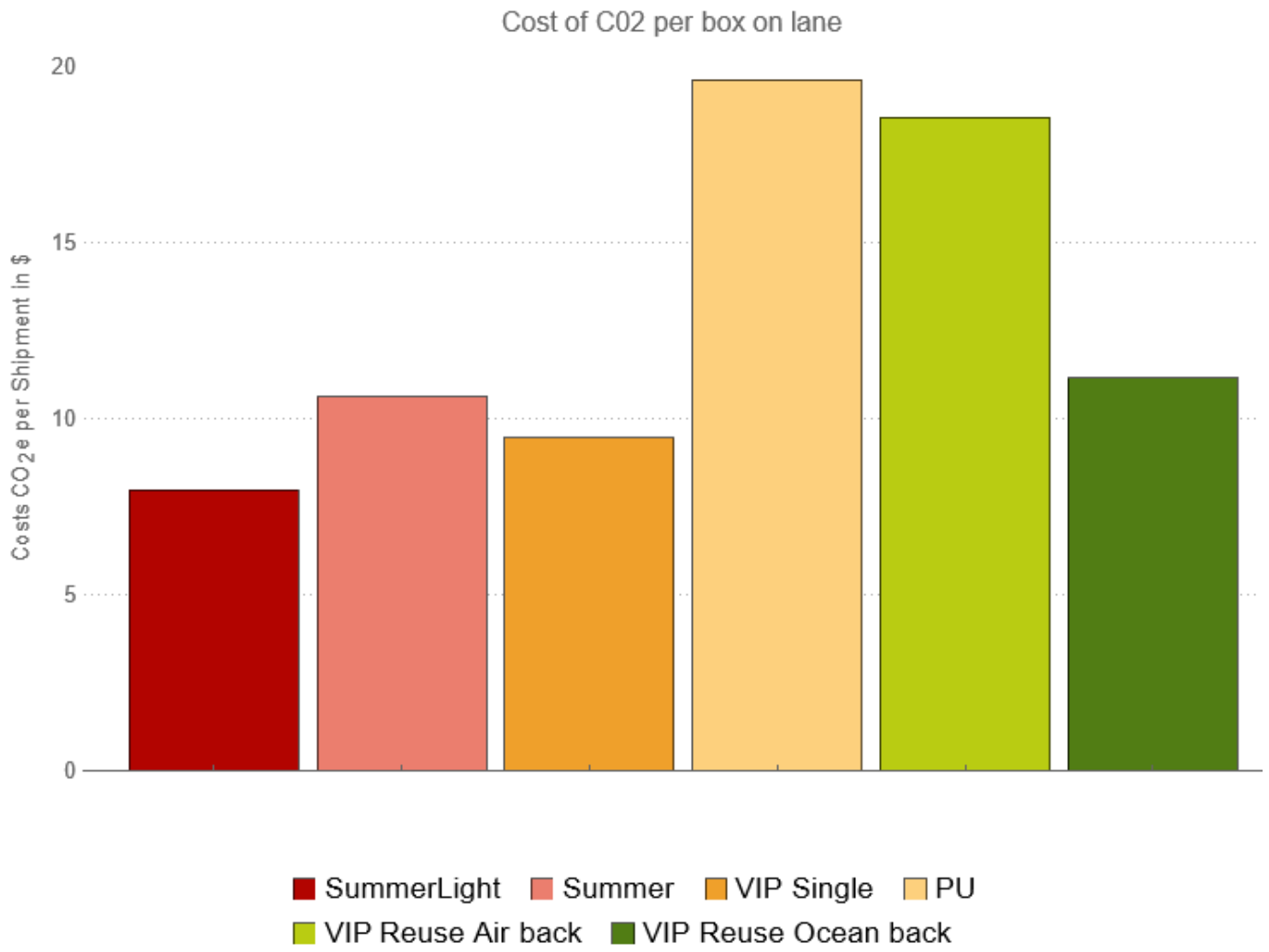
CO2 Fingerprint per used boxes



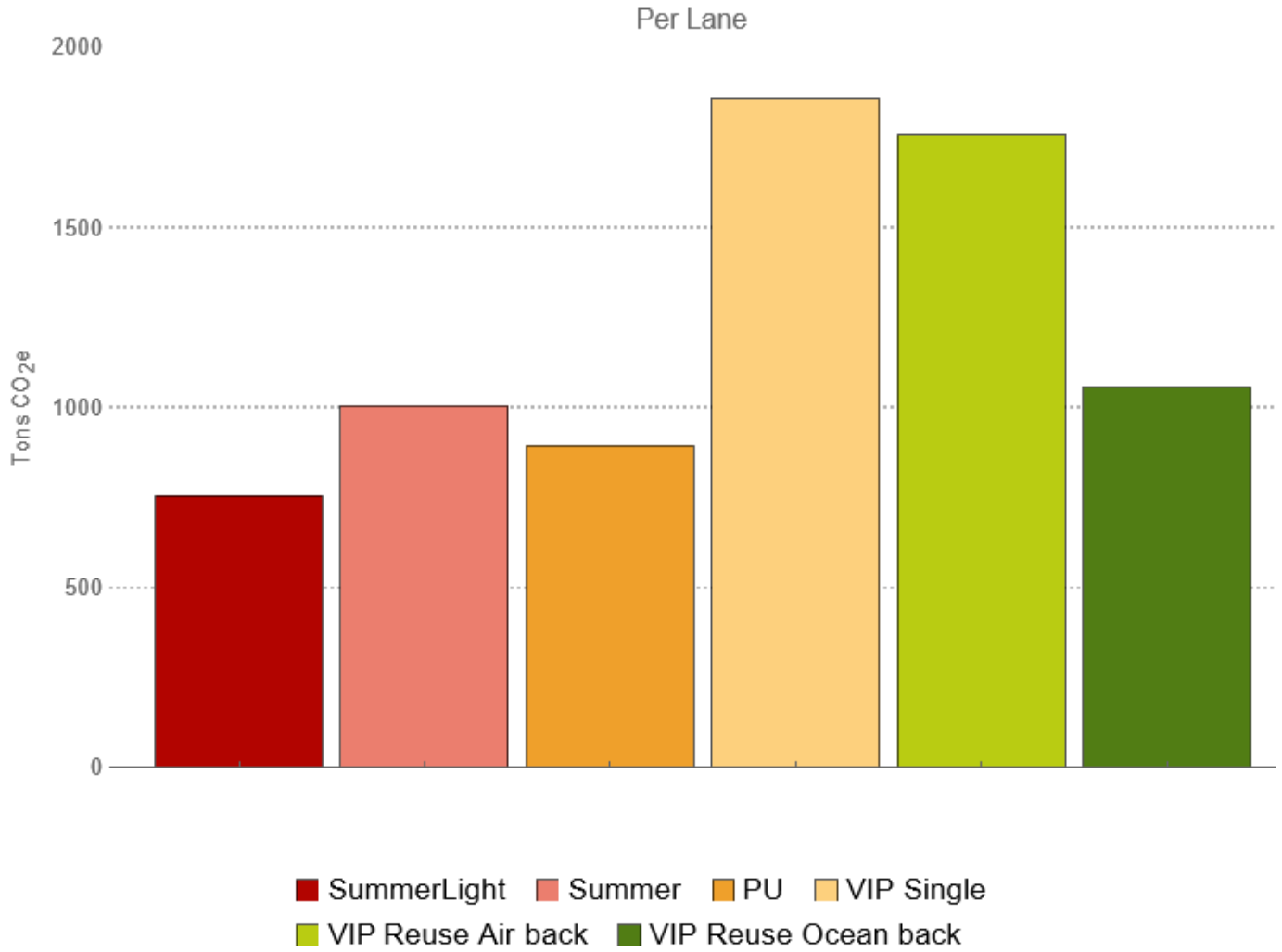
100 times reused

Price of CO2/ton

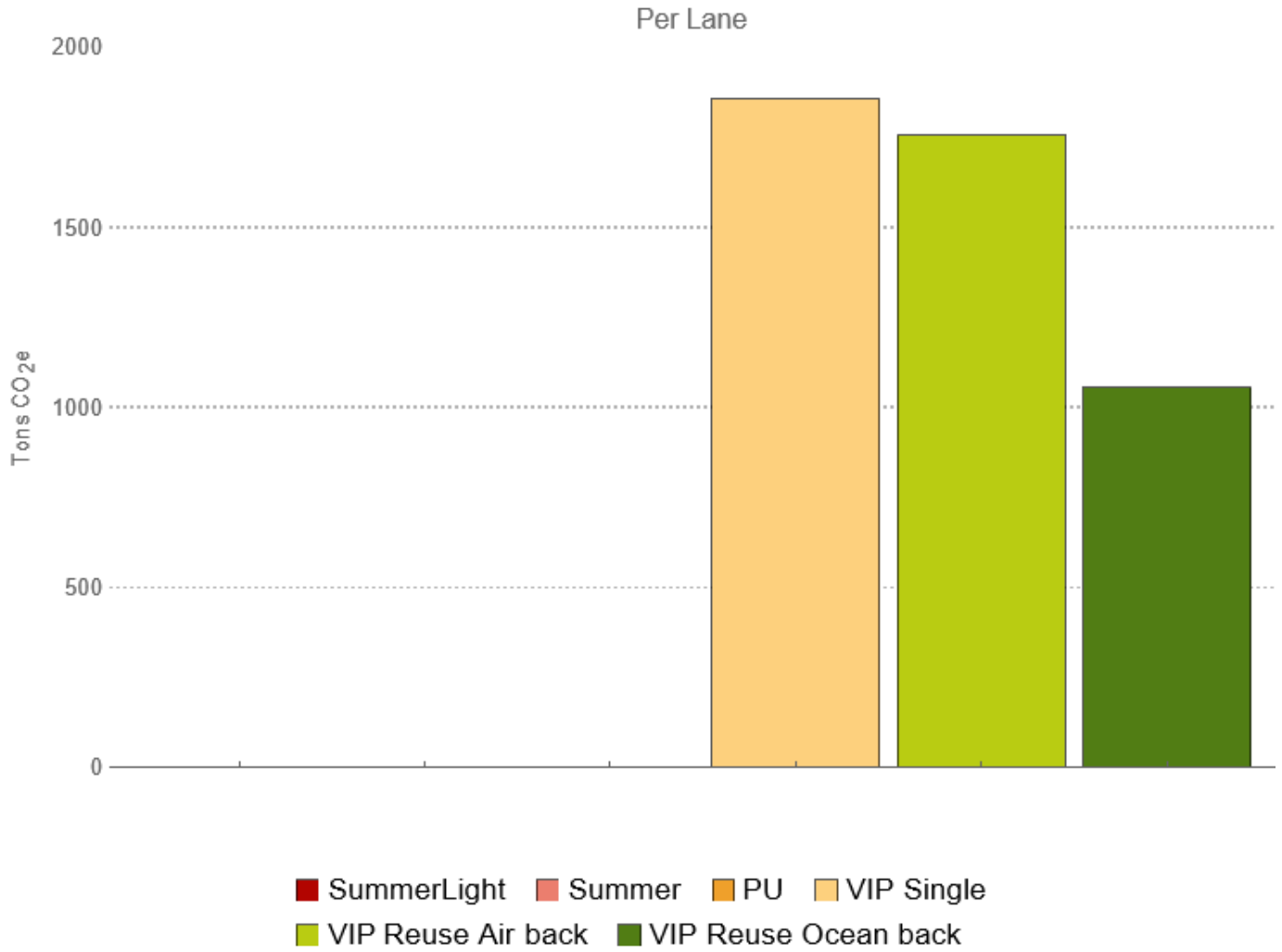
CO2 costs per box on lane 68 $/ton



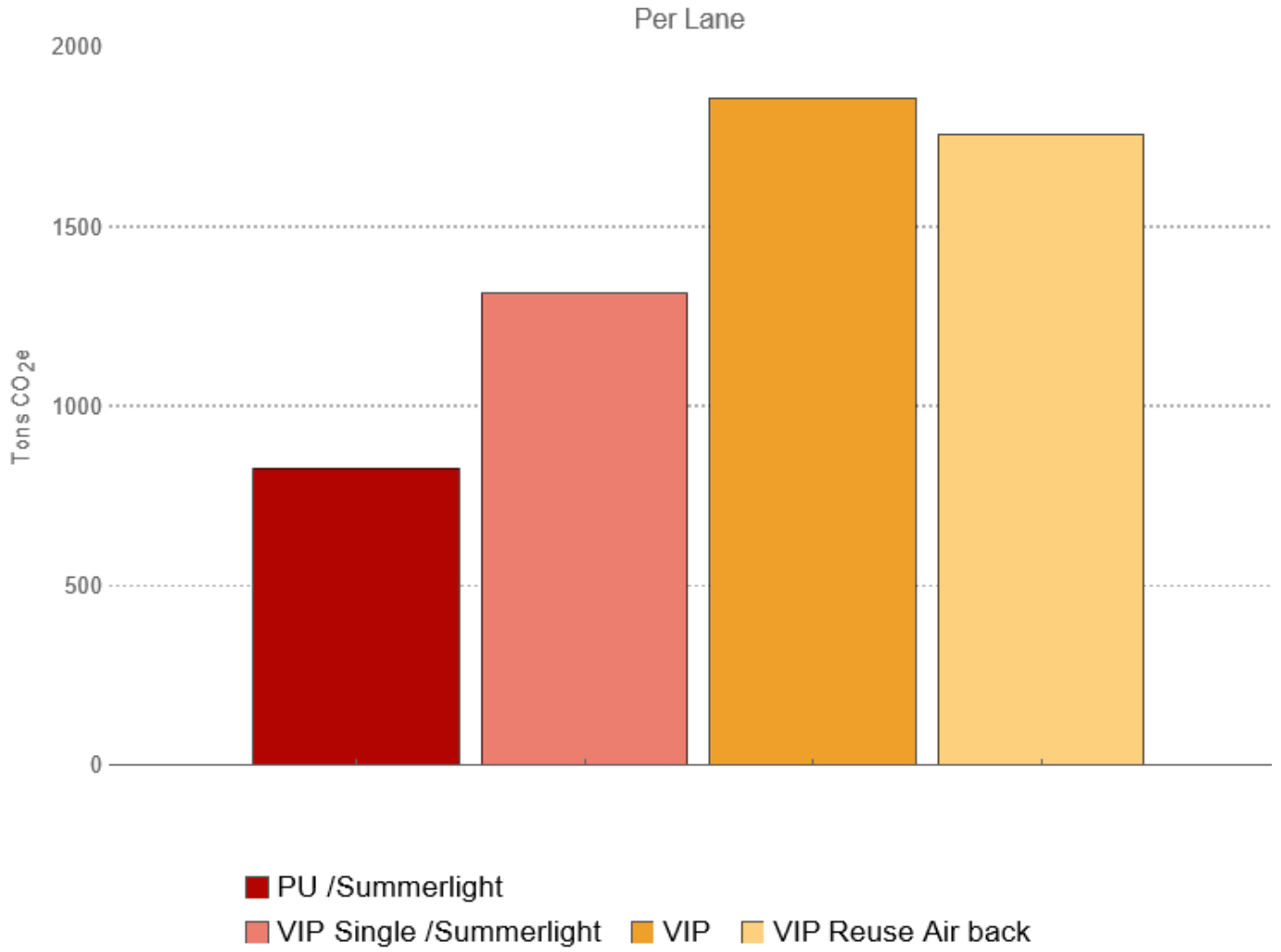
CO2 Fingerprint per lane all boxes



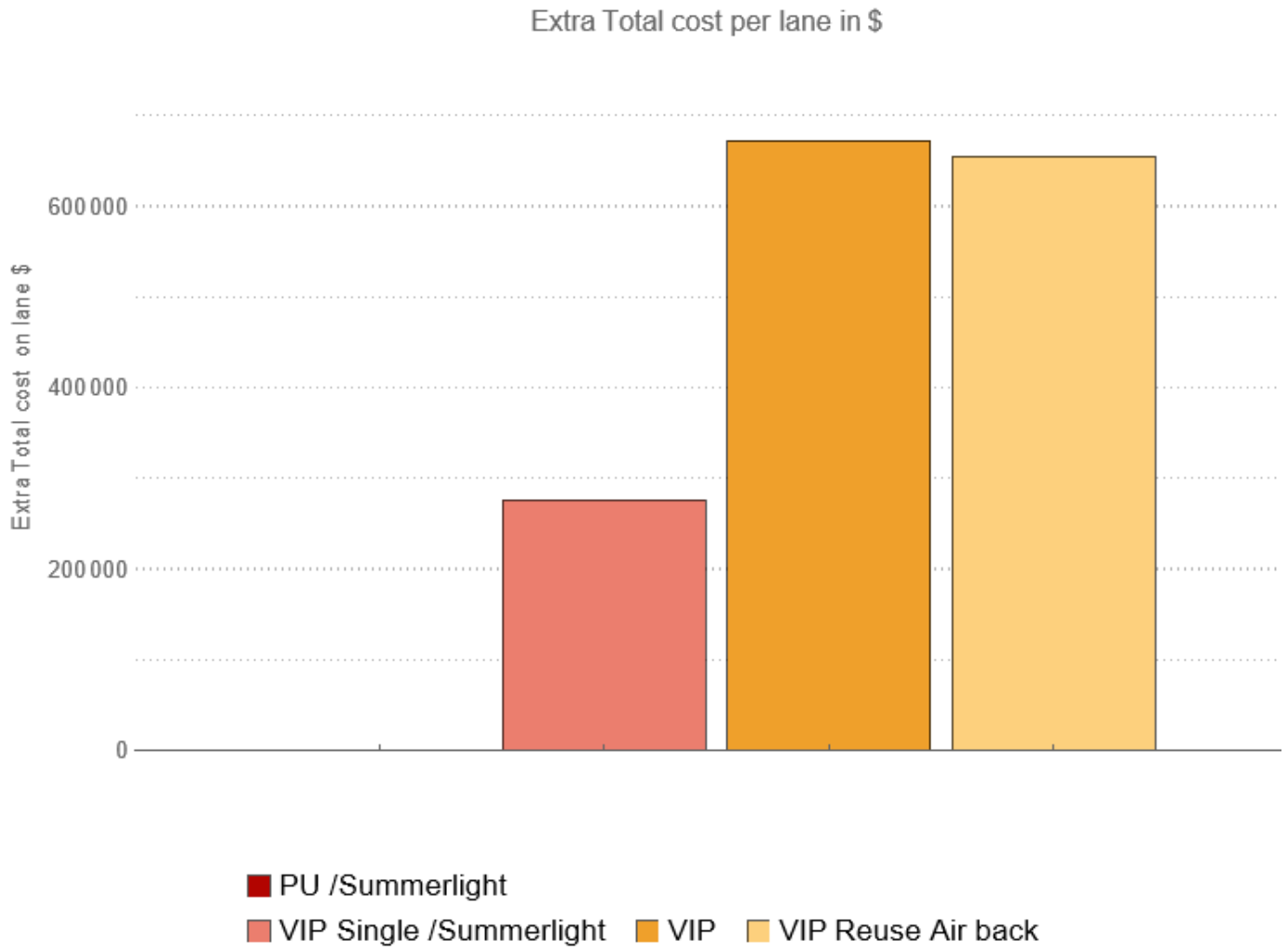
CO2 Fingerprint per lane only compliant boxes



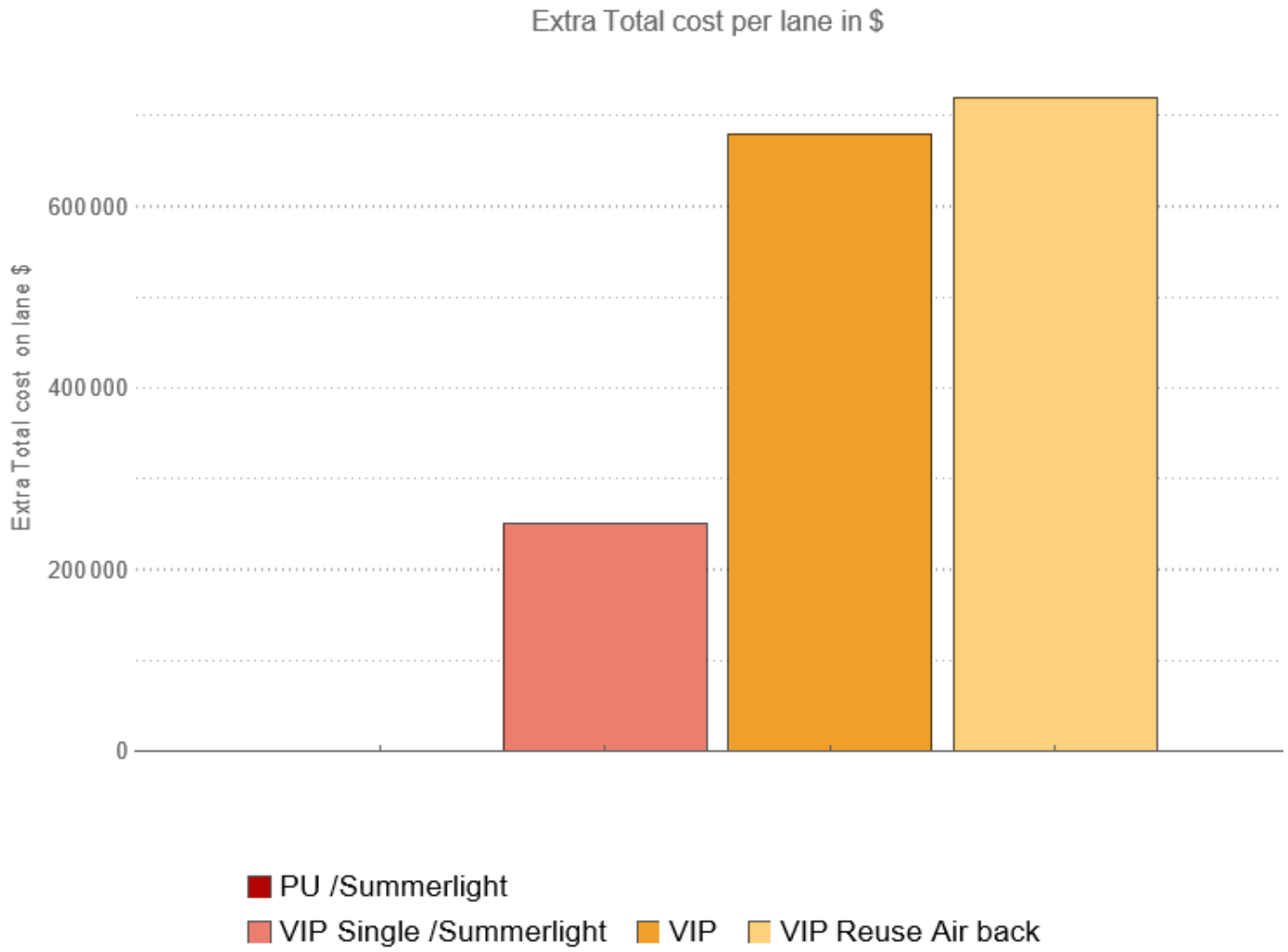
CO2 Fingerprint per lane only compliant and cost effective combinations of boxes



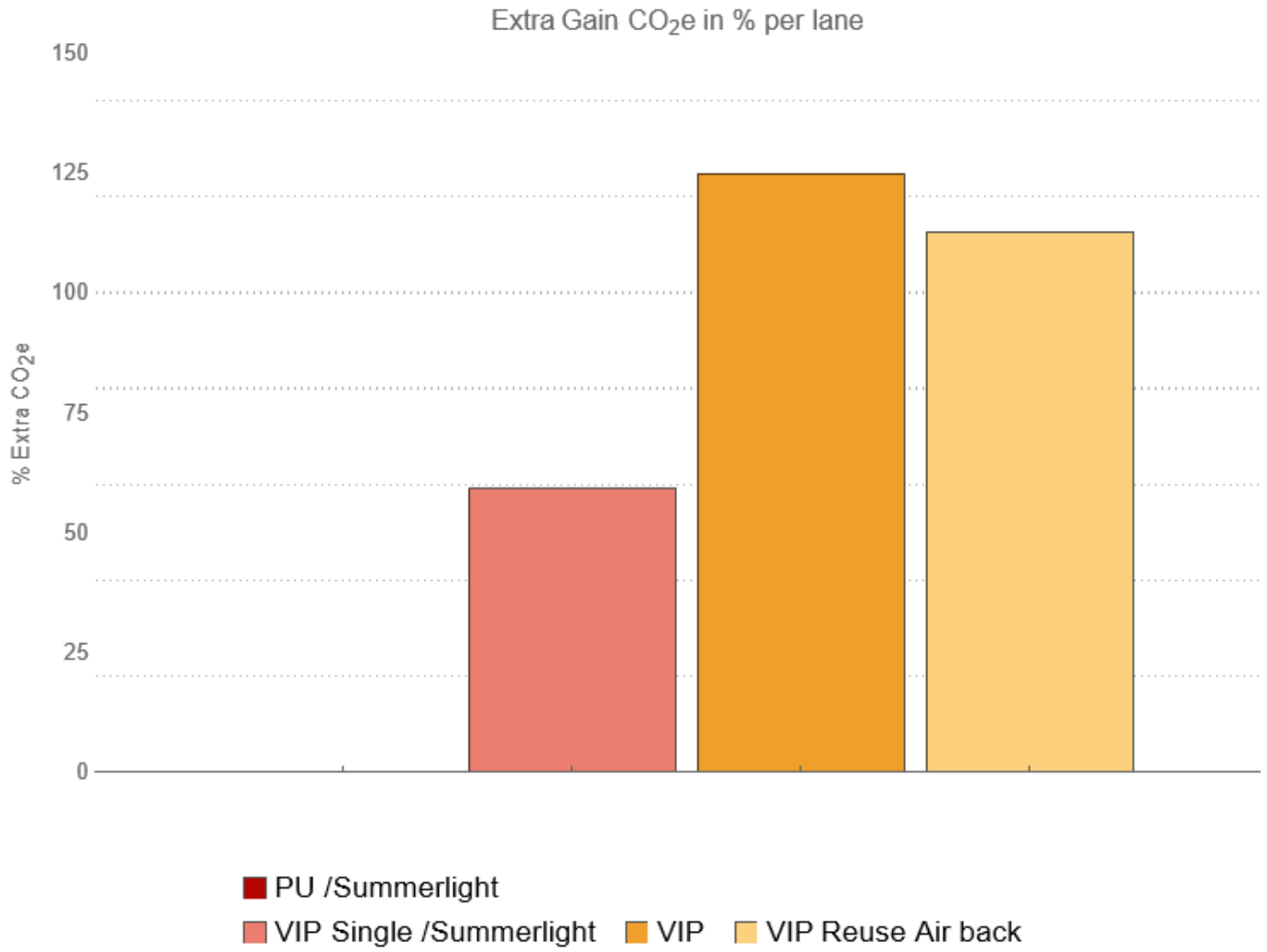
Extra total cost without C02 costs for 6424 shipments



Extra total cost with C02 costs for 6424 shipments



Extra C02 gain



Key takeaways

- Virtual Cold Chain – a digital twin for your temperature controllled logistics
  - Allows to play with the what if‘s
  - Reduces temperature excursions
  - Minimize Total Costs
  - Makes CO2 footprint transparent