

**APEC 2019 Expert Consultation on Reducing Food Loss & Waste (FLW)
for Addressing Interlinked Challenges of Food Security and Climate Change
in APEC Member Economies**

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***Assessing the Potential of the Cold Chain to Reduce GHG
Emissions through Food Loss and Waste Reduction***

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Outline

1. Introduction
 - Cold chain definition
 - Temperature abuse and its impacts
2. Cold chain project
3. Discussion-debate?
4. Conclusions



Introduction

Introduction (1/5)

- ❑ **Perishable items (chilled and frozen foods)** are very sensitive to environmental conditions such as temperature, humidity and light, which makes cold chain logistics management a challenging area.
- ❑ **Food loss** refers to any food that is lost in the supply chain between the producer and the market.
- ❑ **Food waste** refers to the discarding or alternative (non-food) use of food that is safe and nutritious for human consumption. (FAO)

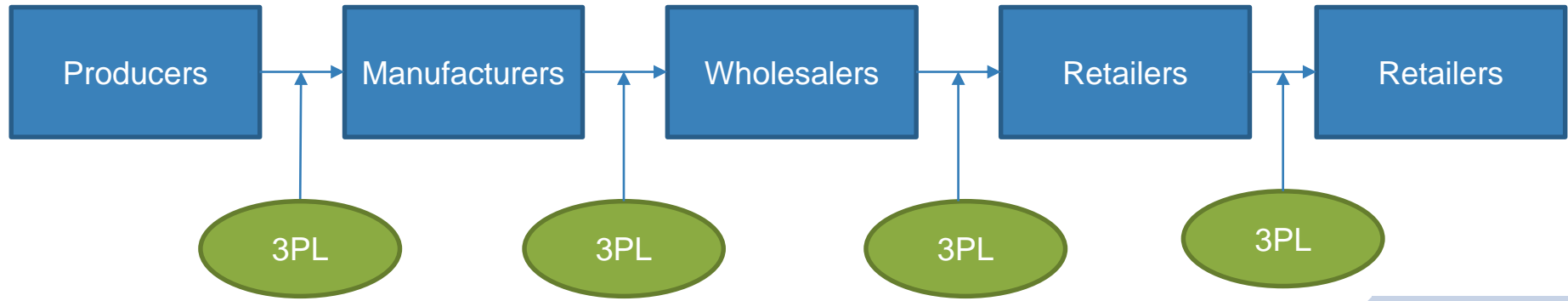
Introduction (2/5)

Food loss and waste causes in different food supply chain stage

stages	Causes	References
Harvesting	<ul style="list-style-type: none">• Inappropriate temperature control• Out-grading due to retail specification (size, colour, mix)• Sorting loss• Spoilage	(Gustavsson <i>et al.</i> , 2011)
Processing	<ul style="list-style-type: none">• Inappropriate temperature control• Sale variability due to weather-related factor• Inaccurate forecasting, overstock• Weight loss during storage	(Kantor <i>et al.</i> , 1997), (Gustavsson <i>et al.</i> , 2011), (Bagherzadeh <i>et al.</i> , 2014), (Bagherzadeh <i>et al.</i> , 2014)
Packaging	<ul style="list-style-type: none">• Improper handling, stacking, improper sizes of packaging	(Ziegler & Floros, 2011), (Segrè & Falasconi, 2011), (Segrè & Falasconi, 2011), (Stuart, 2009), (Stuart, 2009)
Logistics	<ul style="list-style-type: none">• Inappropriate temperature control (shortage of refrigerated carriers)• Delays in shipping• Loss/damage/contamination during loading	(Raak <i>et al.</i> , 2017)

“Cold chain” definition

A cold chain is an uninterrupted-temperature controlled **transport and storage** system of refrigerated goods between upstream suppliers and consumers designed to maintain the quality and safety of food products (Montanari, 2008; Taoukis et al., 2016, pp.285e309).



3PL=third party logistics providers

Introduction (4/5)

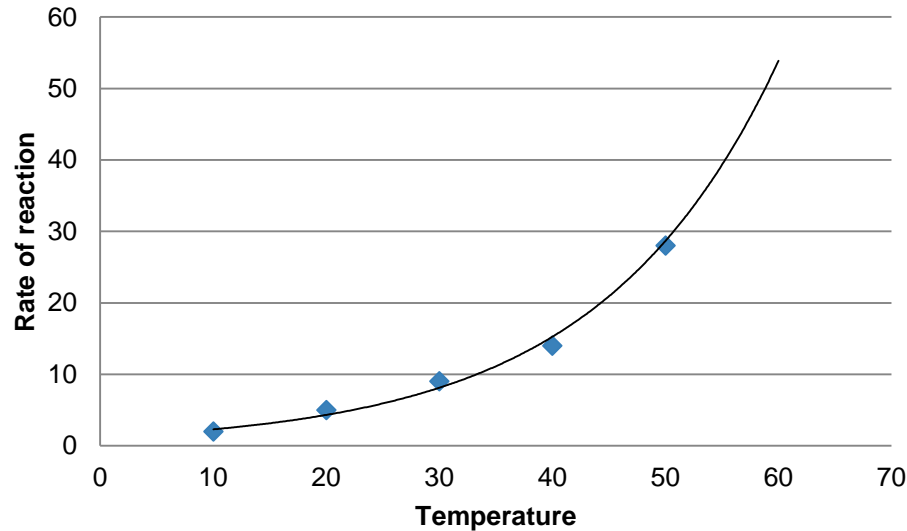
Food product	Optimal temperature range
Ready-to-eat cooled food (i.e. rice ball, sandwich, etc.)	$\approx 18\text{ }^{\circ}\text{C}$
Exotic chilled food (i.e. fruits and vegetables)	$\approx 10\text{ to }15\text{ }^{\circ}\text{C}$
Chilled foods (i.e. fresh vegetables, juice, milk, etc.)	$0\text{ }^{\circ}\text{C to }7\text{ }^{\circ}\text{C}$
Cold-chilled foods (i.e. meat products, poultry products, seafood, etc.)	$0 \pm 2\text{ }^{\circ}\text{C}$
Frozen foods (frozen vegetables, frozen meat, frozen seafood, etc.)	$-18\text{ }^{\circ}\text{C or colder}$
Deeply frozen temperature foods (i.e. fish, etc.)	$-30\text{ }^{\circ}\text{C or colder}$

Introduction (5/5)

Temperature abuse and its impacts on quality/safety changes

Rate of reaction:

- Quality loss: spoilage, color, texture, odor
- Safety concerns: pathogens growth



Q_{10} temperature coefficient

a measure of the rate of change of a biological or chemical system as a consequence of increasing the temperature by 10 °C.

$$Q_{10} = \left(\frac{R_2}{R_1} \right)^{\left(\frac{10}{T_2 - T_1} \right)}$$

Arrhenius equation

dependence of the rate constant of a chemical reaction on the absolute temperature, a pre-exponential factor and other constants of the reaction

$$k = A e^{-E_a/RT}$$



Cold chain project

Temperature abuse in developing countries and Chinese Taipei

Cold chain project (1/14)

Time-temperature abuse in developed countries

Country	Food chain	Number of samples	Product	Required	Temperature abuse	Reference
Iceland	Air freight and sea transportation	232 boxes	Cod loins and haddock fillet	5 °C	17.0 % and 36.1 % of the total time in two air freight transportations had temperatures higher than 5 °C	(Mai et al., 2012)
Finland	Retailer	84 samples	Fish, meat, ready to eat food	1 °C	50 % of the temperature was higher than 1 °C for 249 to 781 minutes	(Lunden et al., 2014a)
Spain	Retailer	11 supermarkets (101 and 99 food samples)	Fresh meat, meat preparations, and vegetables	4 °C	38.5 % ~ 100 % of the temperature at the top shelves was higher than 4 °C at summer time	(Zubeldia et al., 2016)
France	Retailer	99 samples	Bakeries, pork butcher, dairy	7 °C	70 % of the temperature was higher than 7 °C	(Morelli et al., 2012)

Time-temperature abuse in Chinese Taipei

Cold chain project (2018)

- **Goal:** To improve cold chain performance of Taiwanese food companies

- **Approach:** (one year)

 - Stage 1:** temperature monitoring in cold rooms and refrigerated vehicles in **20** Taiwanese food companies.

 - Stage 2:** propose improvement plan (**pick 3 companies**)

 - Stage 3:** temperature monitoring



Cold chain project –1st stage

20 Taiwanese food companies

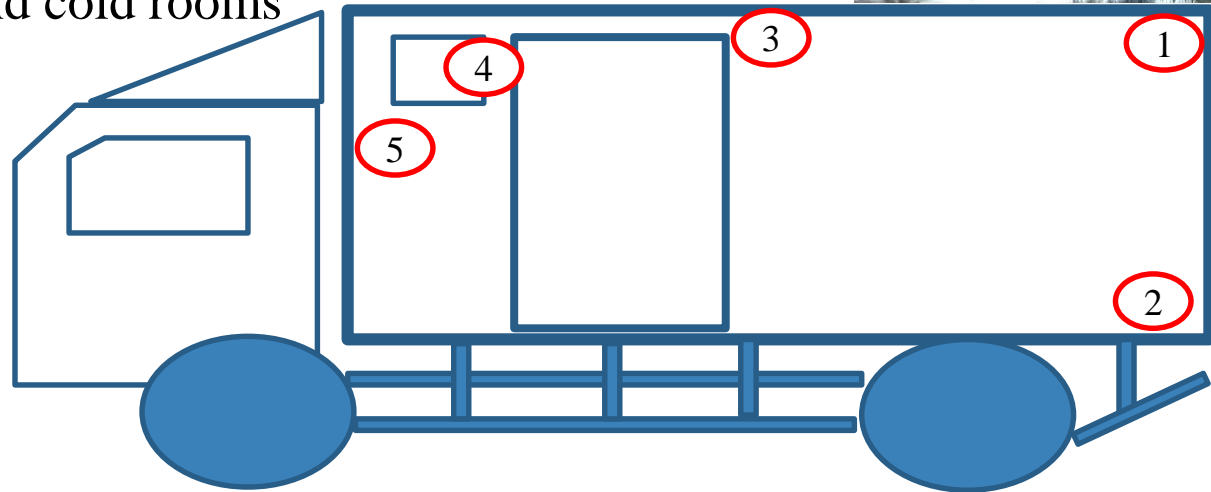
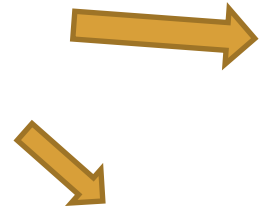
9 food manufacturers,

8 logistics service providers,

3 wholesalers/retailers

Cold chain project (3/14)-first stage

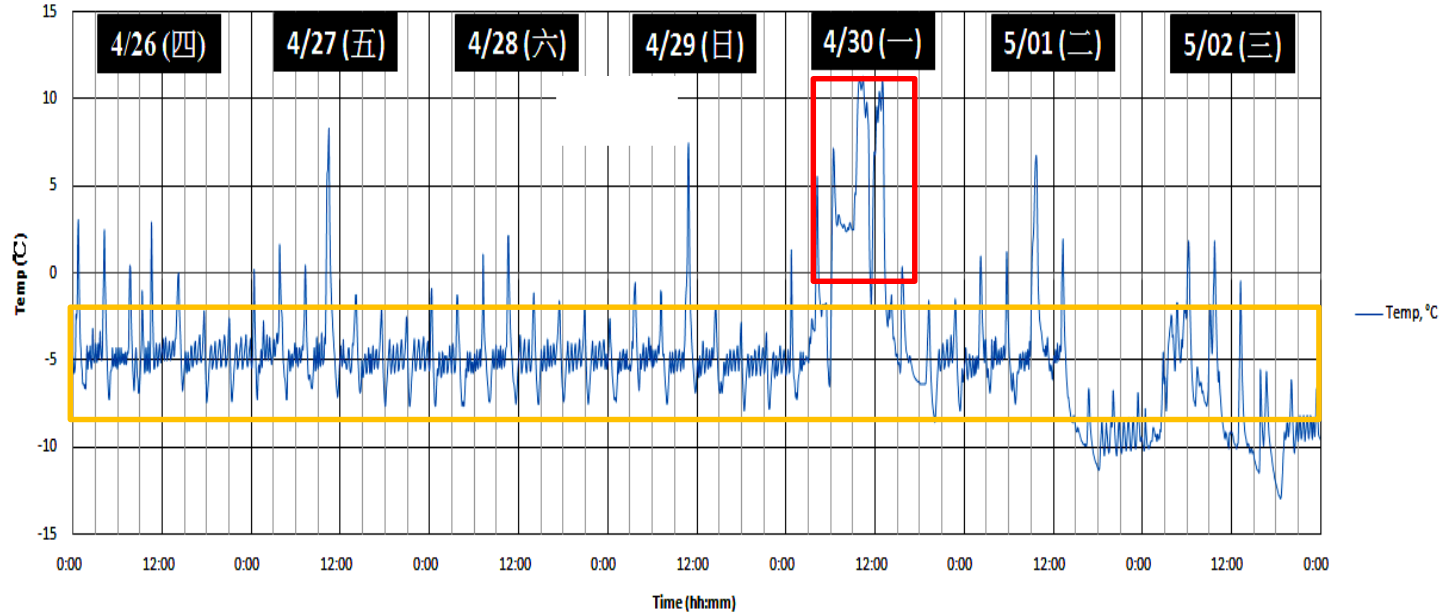
- Temperature monitoring devices: data loggers
- Vehicles and cold rooms



door-top(1), door-bottom (2), middle (3), air conditioner vent(4), return air (5)

Cold chain project (4/14)-first stage

Wholesaler : frozen room



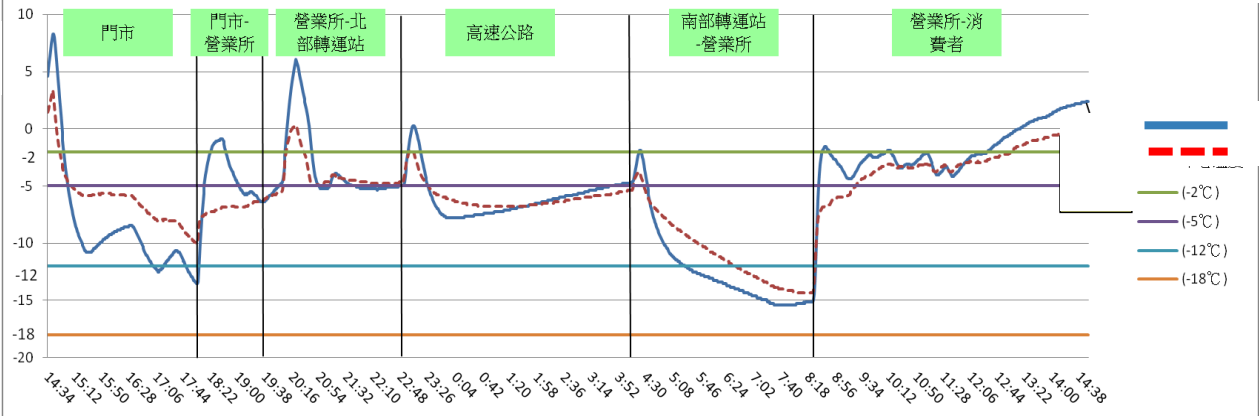
max temp 11.334 °C ; min temp -12.956 °C ; avg temp -4.862 °C

Required temperature -18 °C

Cold chain project (5/14)-first stage

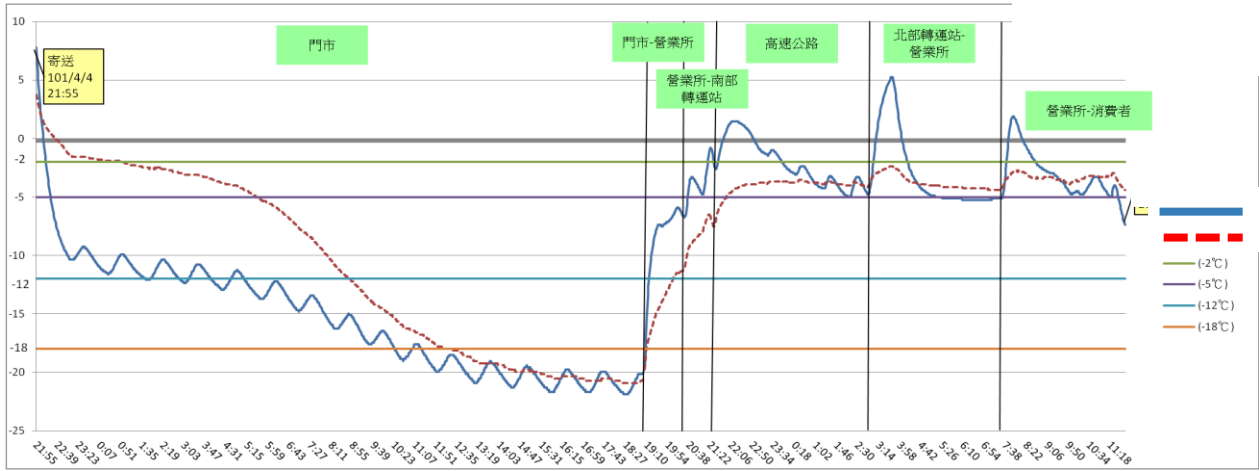
Home delivery service provider : frozen products

Keelung
->
Kaohsiung



Air temp
Product temp

Kaohsiung
->
Keelung

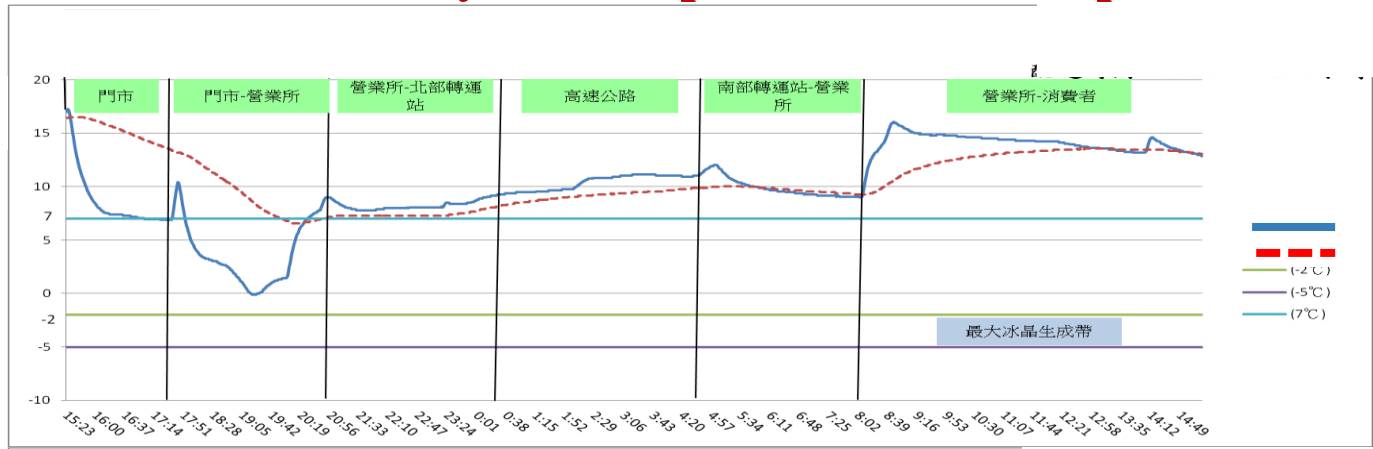


Air temp
Product temp

Cold chain project (6/14)-first stage

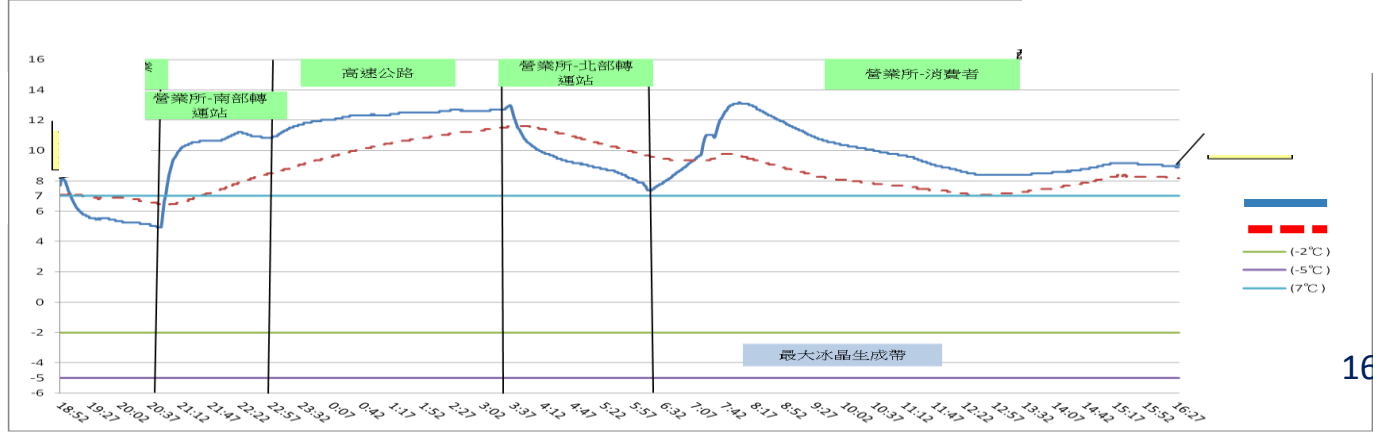
Home delivery service provider : chilled products

Keelung
->
Kaohsiung



Air temp
Product temp

Kaohsiung
->
Keelung

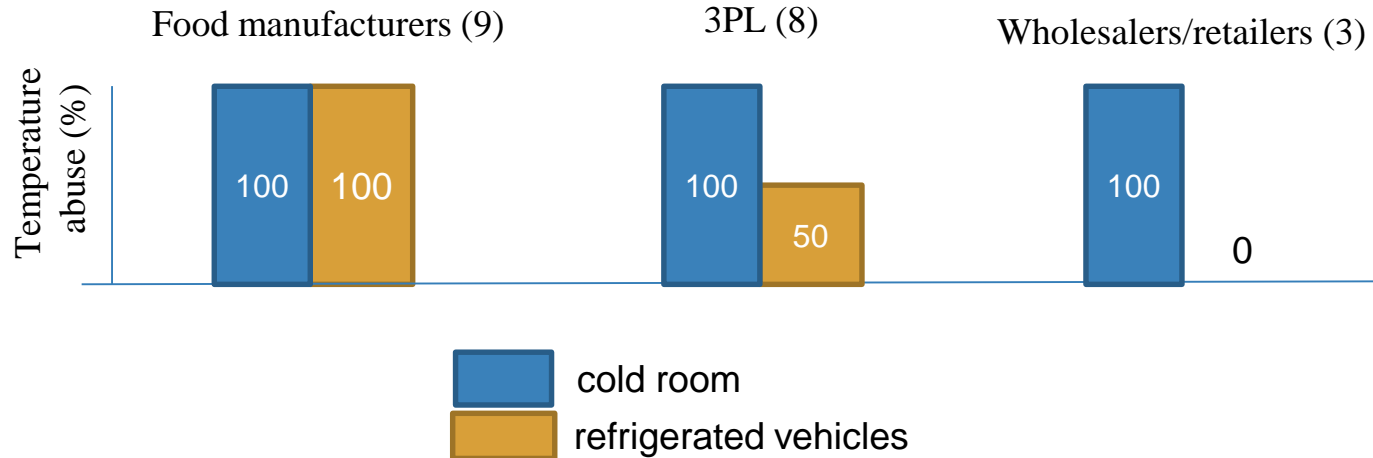


Air temp
Product temp

Cold chain project (7/14)-first stage

Key findings

1. Cold chain performance: food manufacturers > 3PL > wholesalers/retailers
2. Temperature control during transportation is difficult



Key findings

Major reasons behind temperature abuse

1. Wrong temperature setting
2. Frequent door opening during loading/unloading
3. Uncertainty of product receiving temperature
4. Seasonal difference: summer is worse!



Cold chain project –2nd and 3rd stage

A Case example: **a logistics service provider**

- established in 1958
- 1500 employees
- Warehousing, transportation, value-added services etc.

Cold chain project (9/14)-2nd stage



Problem 1: Ceiling condensation
due to huge difference between indoor and outdoor



Water drops on ceiling



Water stains on floor

Cold chain project (10/14) -2nd stage

1 **Problem 1: Ceiling condensation**

Suggestion: dock shelter or buffer zone



**After
improvement**

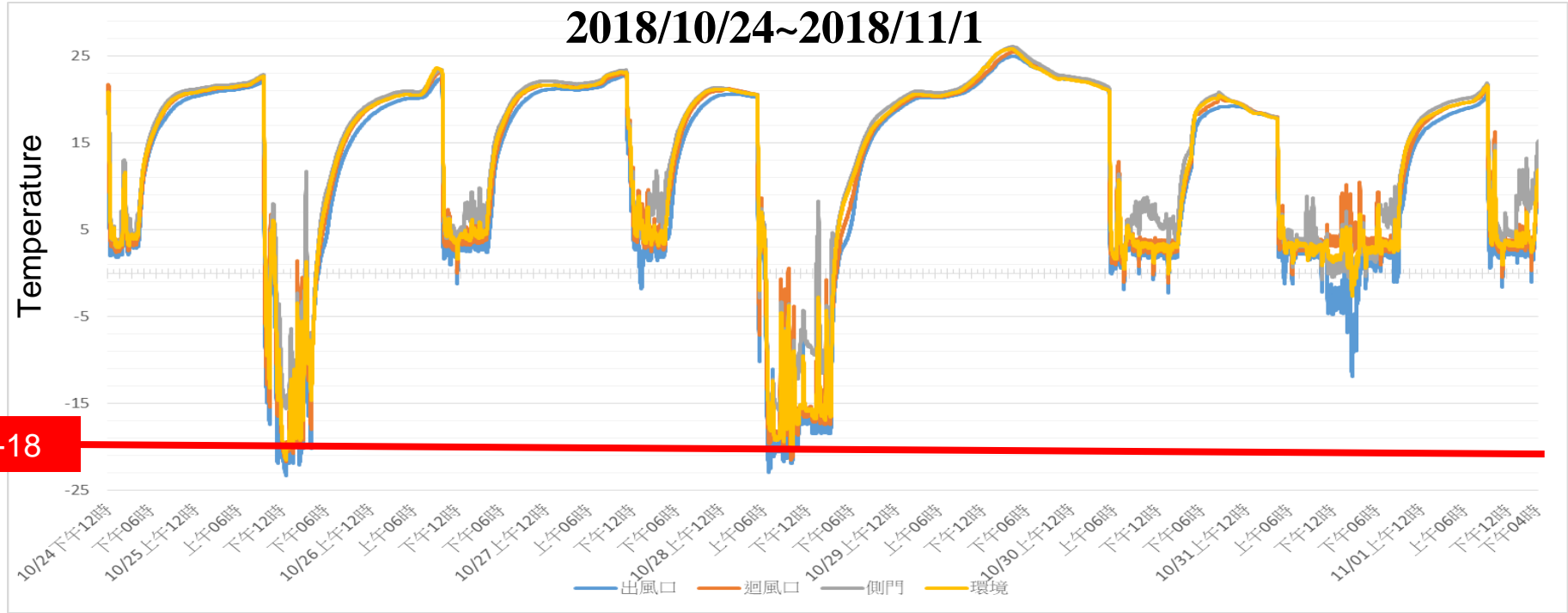


No water drops and Water stains²¹

Cold chain project (11/14)-2nd stage



2 Problem 2: Temperature fluctuation during frozen food transportation



Cold chain project (12/14)-2nd stage



Problem 2: Temperature fluctuation during frozen food transportation



Air temperature loss from vehicles during loading and unloading

Cold chain project (13/14) -2nd stage

Suggestion: improve truck driver's behavior

--add **curtains** and use it **properly**

--**shorten** door opening time







Keep curtains closed "all the time"



Cold chain project (14/14)-3rd stage

Temperature improvement

Temperature	Before → After	improvement
>0°C	22.5% → 2%	
-10~0°C	67% → 22%	
-10~-12°C	9% → 10%	-
-12~-15°C	13% → 16%	-
-15~-18°C	8.5% → 37%	
≤-18°C	20% → 25%	



Discussion-debate

Can cold chain
save greenhouse gas emissions? Or
increase?

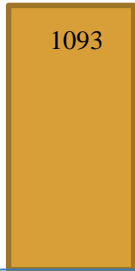
Discussion (1/2)

Literature:

Yes, cold chain reduces food loss and CO₂ emission

Without cold chain

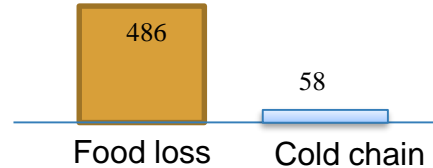
1093 thousand tonnes CO₂ eq



Food loss

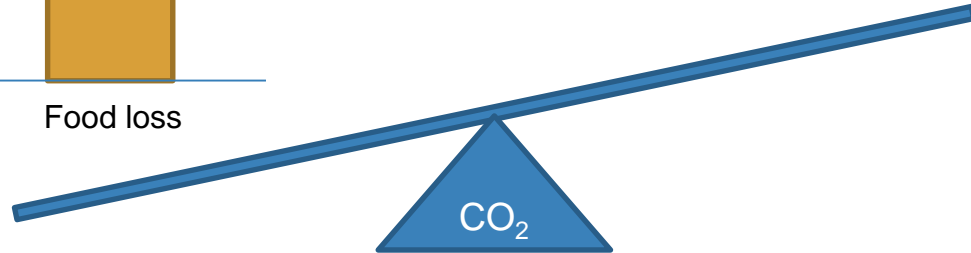
With cold chain

544 thousand tonnes CO₂ eq



Food loss

Cold chain



Source: Global Food Chain Council (2015)

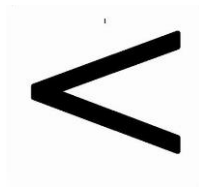
Discussion (2/2)

Literature:

Cold chain increases or reduces CO₂ emission....depends

Without cold chain

With cold chain



+10%
greenhouse gas emissions

-15 %
greenhouse gas emissions

Depending on:
Refrigerated system efficiency, energy efficiency

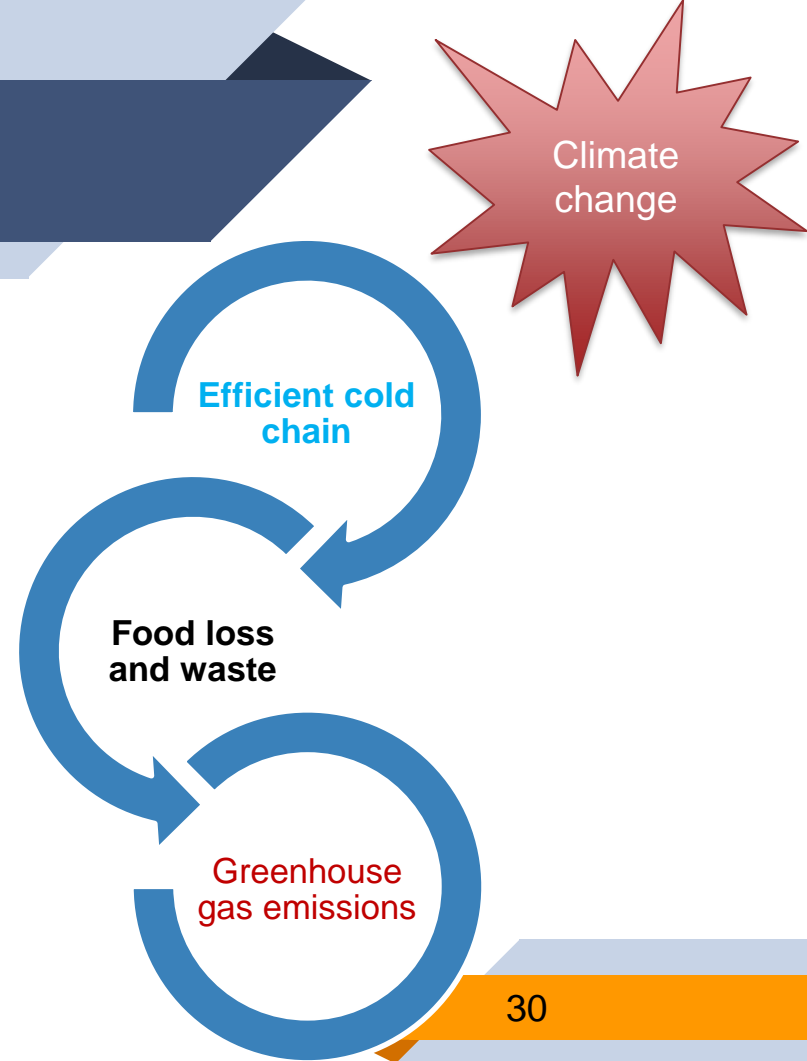


Conclusions

Conclusions (1/2)

Our project findings...

- “Efficient” cold chain
 1. Reduce air temperature loss from cold rooms, distribution centers, and vehicles. (save energy loss)
 2. Reduce temperature loss from chilled and frozen products. (save product loss)



Conclusions (2/2)

“Efficient cold chain” framework

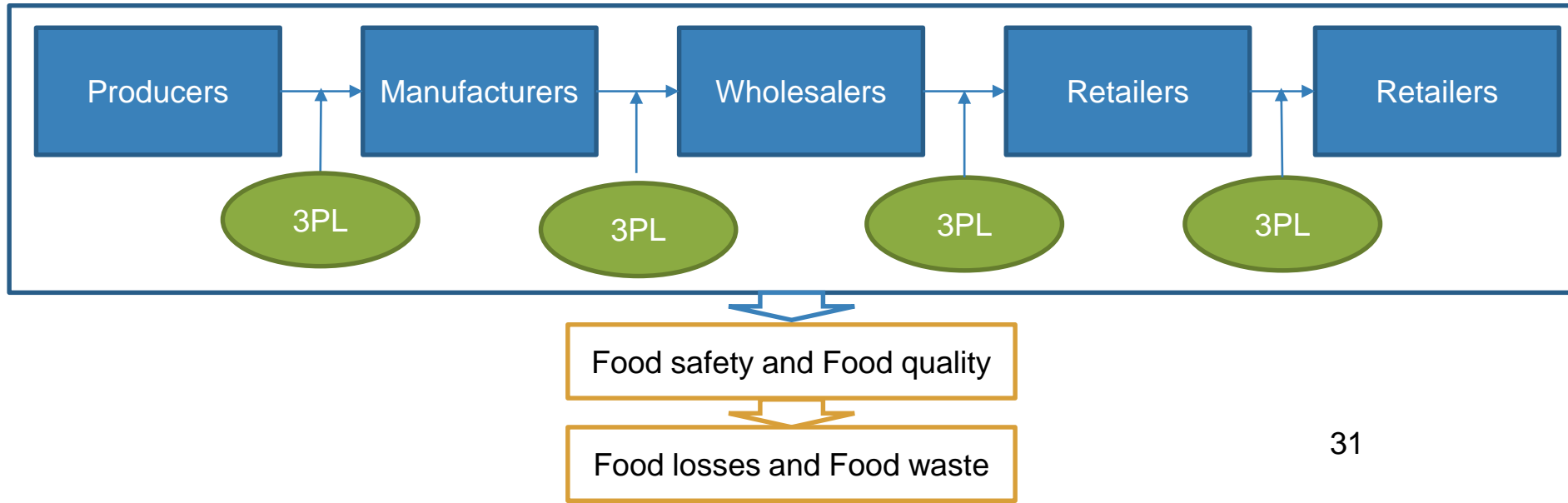
Legal aspects: regulations on temperatures management

Managerial aspects:

- Design of food cold chain
- Training and educations

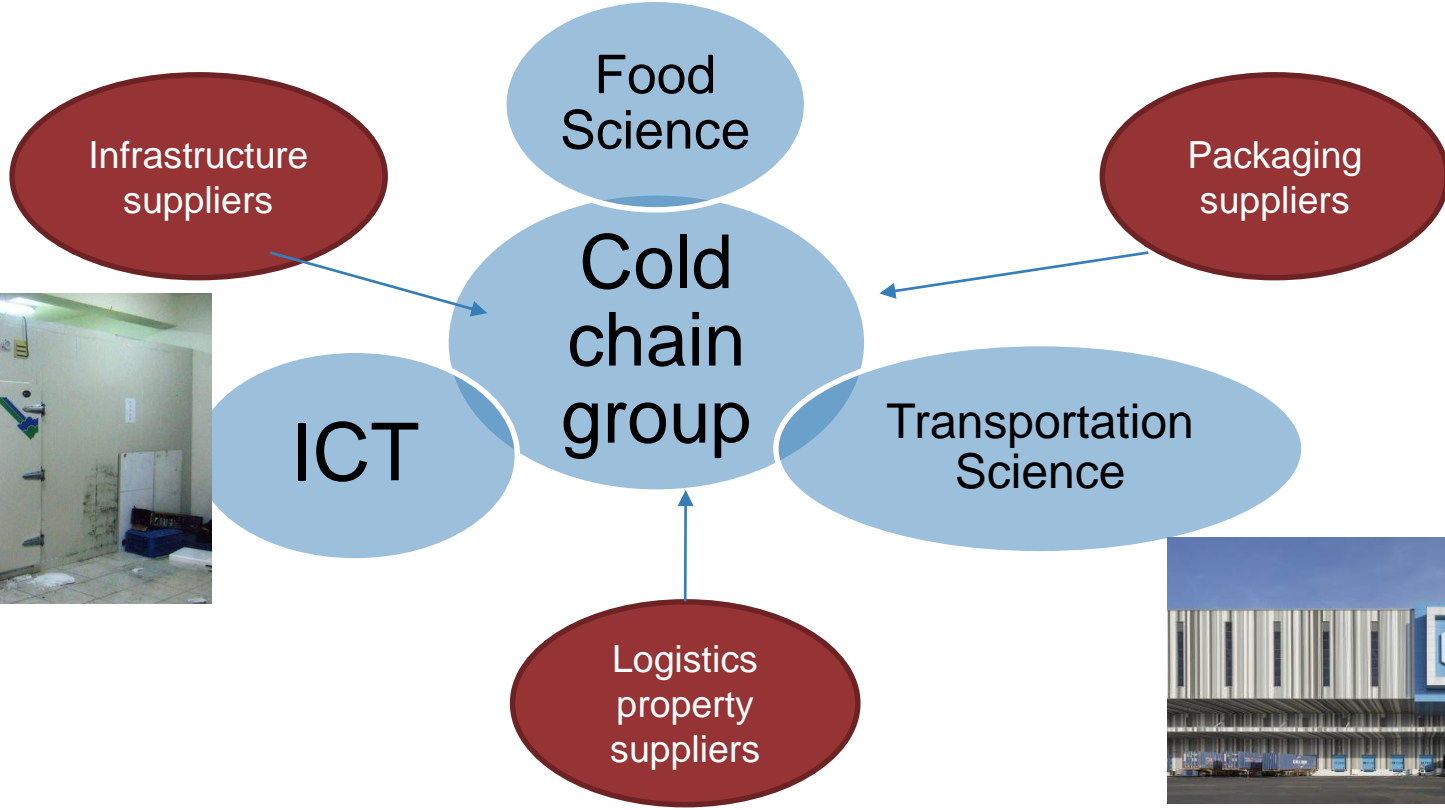
Technological aspects:

Tools for monitoring, storing, analyzing
“temperature information”



Cold Chain Group (NTOU)

multi-discipline participants



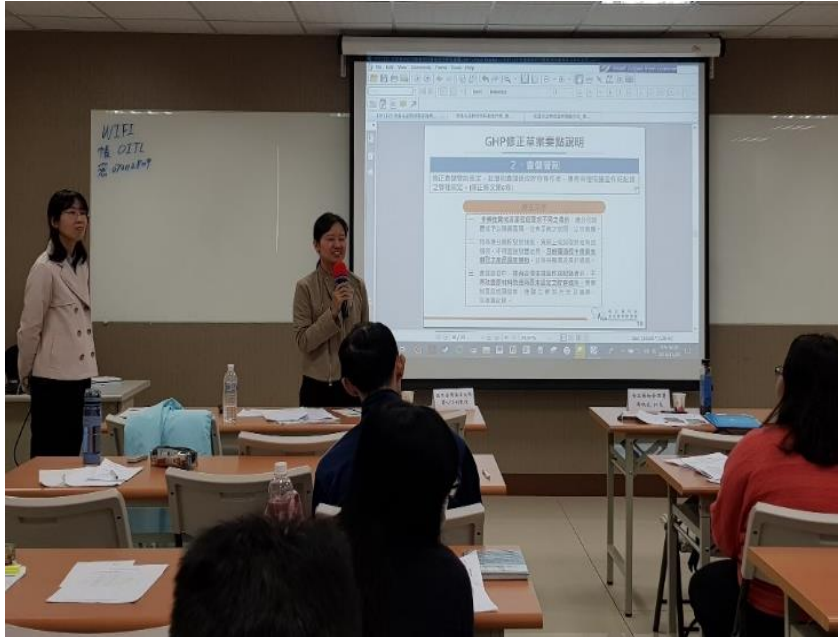
Recent cold chain related publications

Coming soon!



- Nodali Ndraha, Jelena Vlajic, Ching-Cheng Chang, **Hsin-I Hsiao***, “Challenges with food waste management in the food cold chains”, in **Food Industry Wastes**, Elsevier (in press)
- Ndraha, N., **H. I. Hsiao***. (2019). Exposure Assessment and Sensitivity Analysis for Chilled Shrimp during Distribution: A Case Study of the Home-Delivery Services in Taiwan, *Journal of Food Science*, 84(4): 859-870 (SCI, impact factor 2.018).
- Chen, Y. R., C. A. Hwang, L. Huang, V. C.H. Wu, **H. I. Hsiao***. (2019). Kinetic analysis and dynamic prediction of growth of *vibrio parahaemolyticus* in raw white shrimp at refrigerated and abuse temperatures, *Food Control*, 100:204-211 (Impact factor 3.496).
- Ndraha, N., W. C. Sung, **H. I. Hsiao***. (2019). Evaluation of the cold chain management options to preserve the shelf life of frozen shrimps: A case study in the home delivery services in Taiwan, *Journal of Food Engineering*, 242: 21-30 (SCI, Impact factor 3.197,).
- Ndraha, N., **H. I. Hsiao***, J. Vlajic, M. F. Yang, H. T. V. Lin. (2018). Time-temperature abuse in the food cold chain: Review of issues, challenges, and recommendations. *Food Control*, 89: 12-21. (Impact factor 3.496).

Education and training (Good Hygiene Practice for cold chain logistics)



**On-site
diagnosis
(food
processors,
3PL,
exporters)**

Find us ...

Cold chain group (NTOU)

Institute of food safety and risk management

National Taiwan Ocean University

■ <http://www.ifsrm.ntou.edu.tw/files/11-1039-6750.php?Lang=en>



Thank you

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