KOLOKIUM PENYELIDIKAN 2021
INSTITUT TADBIRAN AWAM NEGARA (INTAN)

EXPERIMENTAL AND STATISTICAL STUDIES ON BIODEGRADABLE AND NON-BIODEGRADABLE MATERIALS IN ELECTROCHEMICAL INDUSTRY

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MOTIVATION

(L-R) John B Goodenough, M Stanley Whittingham, Akira Yoshino

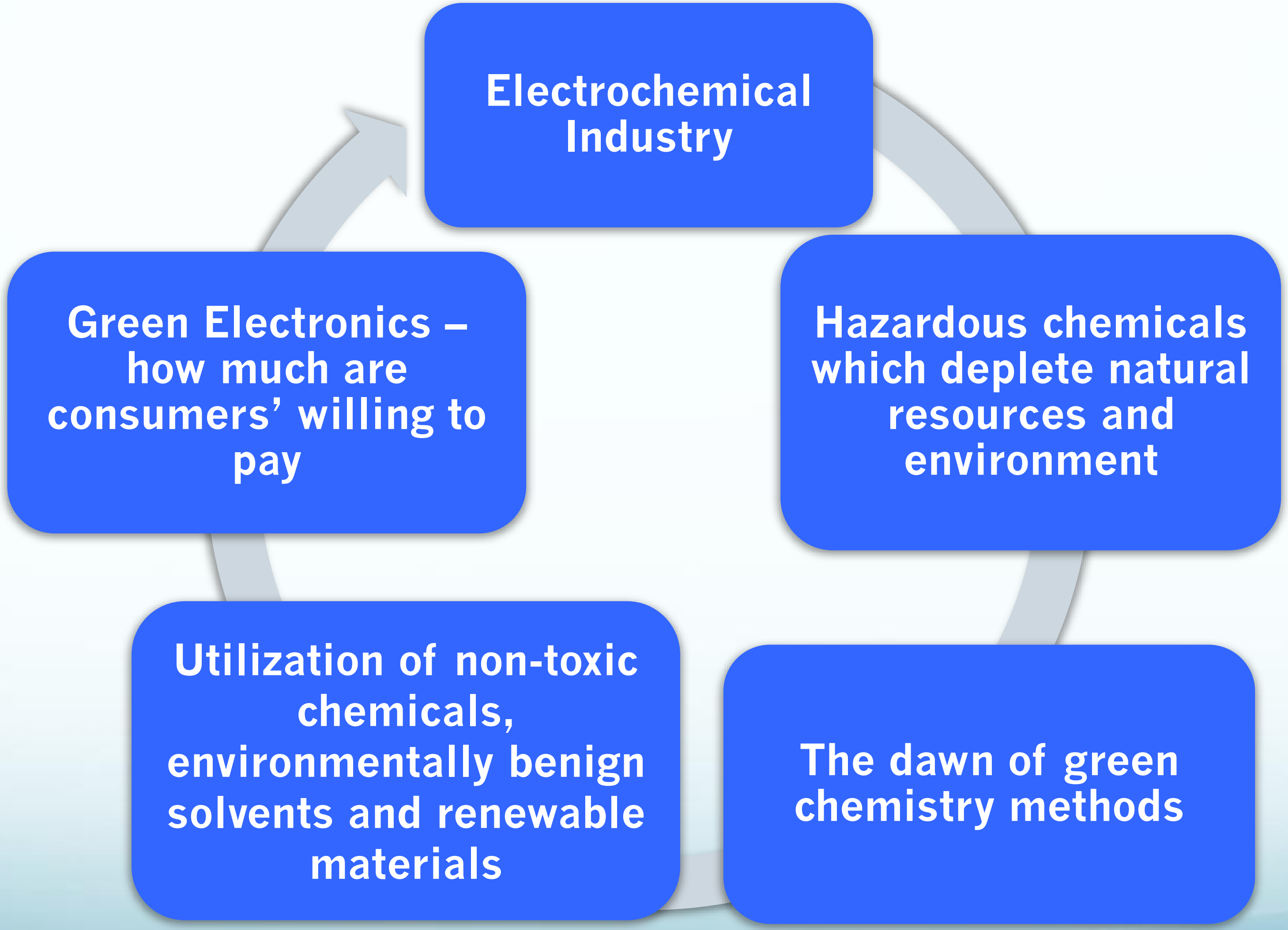
2019 Nobel Prize in Chemistry for the development of lithium-ion batteries.

10 predictions for the next decade:

1. Health care will reach warp speed
2. A cure for cancer may be around the corner
3. Cash will be but a distant memory
4. Semiconductors will be everywhere — and in everything
5. Wearable technology will blur the lines of reality
6. Digital entertainment will take centre stage
7. **Autonomous vehicles will hit the fast lane**
8. **Green machines will rule the road**
9. **Renewable energy will power the world**
10. Innovative companies will make the world better

Source: The World in 2030 by Capital Group®

Overview of Study



Electrochemical Industry

Includes important technological applications i.e batteries - important in storing energy for mobile devices and vehicles, wastewater treatment, and renewable energy conversion technologies.

Medical Industry : Pacemakers - In the 1950s heart patients pushed their pacemakers around on carts. Now surgeons can put pacemakers inside the patient's chest.

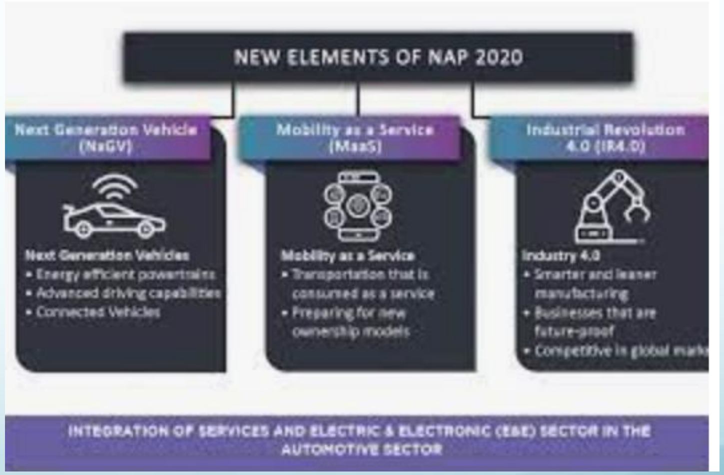
Semiconductor technology - Cochlear implants use computer technology to stimulate the auditory nerve directly, enabling some completely deaf people to hear.

Today, transistors and microchips reduce size of implantable electronic devices, long-lasting batteries power them, and inert materials like titanium and non-crystalline metals resist electrochemical reactions inside the body.

How is it related in the Malaysian context?

- NAP 2020 - automotive industry is moving into digital industrial transformation - technology development projects which focus on green energy and recyclability – electrode materials for energy storage in green vehicles

- 10-10 Framework of Science, Technology, Innovation and Economy (MySTIE) and National Science Technology and Innovation Policy both state energy storage as niche areas for socioeconomic drivers



THIS STUDY : GREEN ENERGY STORAGE ELECTROCHEMICAL DEVICE

Problem Statements

Components for electrochemical devices

- Biodegradable or non-biodegradable polymers/ additives (PVA / PEMA)

Biodegradable or non-biodegradable electronics

- Fabrication of electrochemical device
- Analysis of device efficiency

Consumers' willingness to pay for green electronics

- Willing to pay how much?
- What are the determining factors to purchase green electronics

Why do we need to go green…..

- **Most consumer electronics contain harmful toxic devices such as cadmium, copper, lead, nickel and zinc and flame retardants like polychlorinated dioxins and furans which have been proved to be harmful to human health and the environment**

Any regulations against harmful toxins in electronics??

- **EU implemented the waste electrical and electronic equipment (WEEE) directive in August 2005, which advises on reusing and recycling electrical and electronic equipment.**
- **The ROHS (Restriction of Hazardous Substances) directive was enacted, prohibiting electrical and electronics containing toxic substances**

Objectives

- To prepare and characterize biodegradable and non-biodegradable polymer electrolytes

- To fabricate electric double layer capacitor (EDLC) using biodegradable and non-biodegradable polymer electrolytes.

- To examine electrochemical properties and cyclability of the fabricated EDLC for comparison purpose in terms of stability and long-term usage.

- **To investigate consumers' willingness to pay for green electronics.**

- **To examine the determinants for consumers' willingness to pay for green electronics.**

Materials

MATERIALS	ROLE
Poly (vinyl alcohol) (PVA)	Polymer
Poly(ethyl methacrylate) (PEMA)	Polymer
Magnesium triflate $(MgCF_3SO_3)_2$	Salt
1–butyl–3–methylimidazolium bromide (BmImBr)	Ionic liquid
Acetone	Solvent
Distilled water	Solvent

Methodology

EXPERIMENTAL

Preparation of Biodegradable Polymer Electrolyte Films

1. PVA + $(MgCF_3SO_3)_2$
2. . PVA + $(MgCF_3SO_3)_2$ + BmImBr

Preparation of Non-biodegradable Polymer Electrolyte Films

1. PEMA + $(MgCF_3SO_3)_2$
2. PEMA + $(MgCF_3SO_3)_2$ + BmImBr

Characterization – EIS, XRD, DSC, LSV

Electrode Preparation

Fabrication of EDLC - highest conducting Polymer Electrolyte – both biodegradable and non-biodegradable

Characterization of EDLC – Cyclic Voltammetry and Galvanostatic Charge-Discharge

PART 1

SURVEY

- **To investigate consumers' willingness to pay for green electronics.**
- **To examine the determinants for consumers' willingness to pay for green electronics.**

PART 2

Endo Laboratory

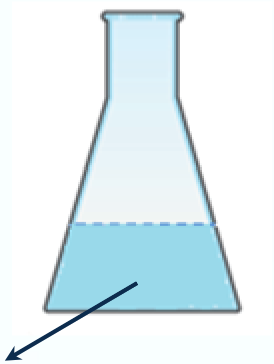
Access to Lab. / Papers / Contact us / Links and Data

Electric double layer capacitor (EDLC)

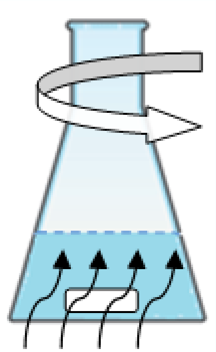
EDLC is an energy storage device, and it is a next-generation device with a possibility of being applied to an auxiliary power supply, and the combined use with photovoltaics equipment and an electromobile.

Memory backup power supplies, Such as a notebook PC and a cellular phone.

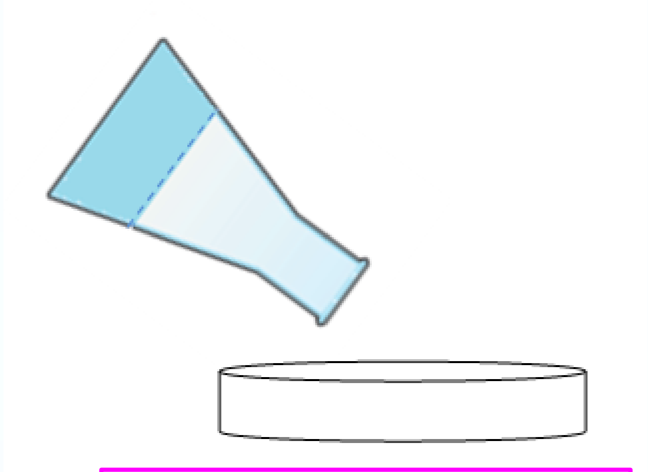
A) Sample Preparation



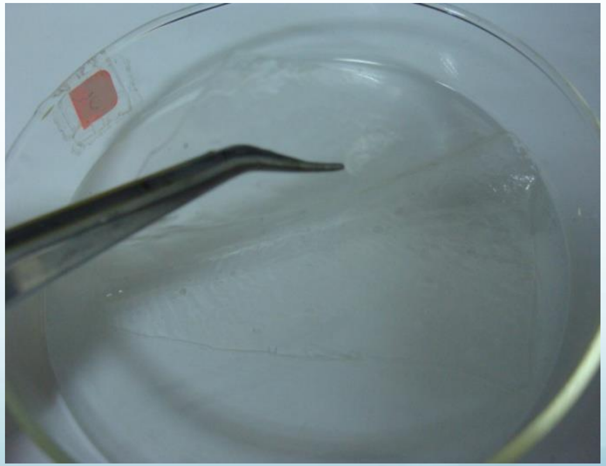
PVA /PEMA+
$MgTf_3$+ BmImBr



Stir and heat at
80 °C



Cast on Petri dish



Formation of free standing polymer electrolyte

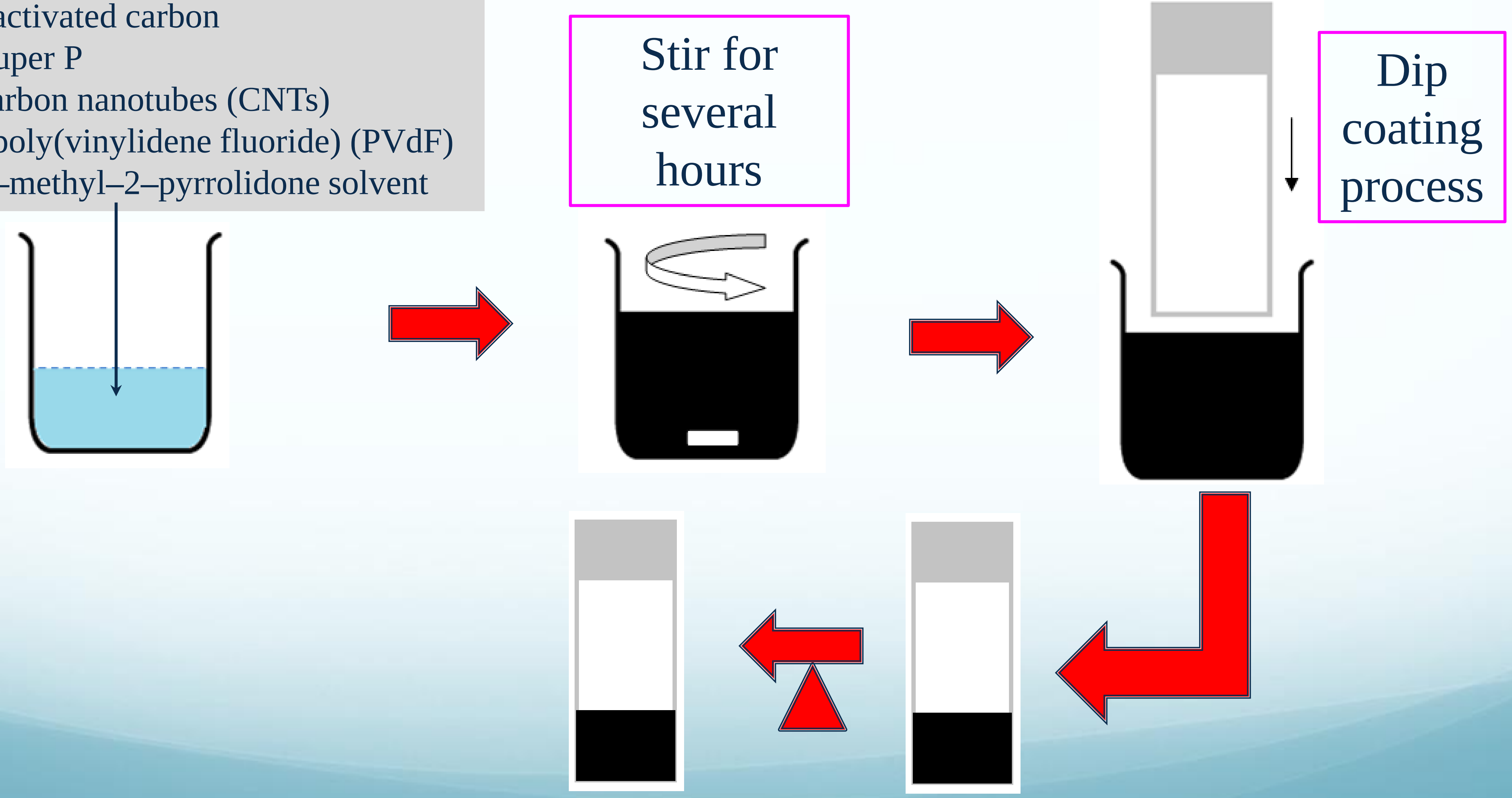
- Electrochemical Impedance Spectroscopy (EIS)
- Differential Scanning Calorimetry (DSC)

Formulation of polymer electrolyte – PVA example

Designation	Materials (wt.%)		
	PVA	$Mg(CF_3SO_3)_2$	BmImBr
PVA 0	70 (0.7g)	30 (0.3g)	0
PVA 1	63 (0.63g)	27 (0.27g)	10 (0.1g)
PVA 2	56 (0.56g)	24 (0.24g)	20 (0.2g)
PVA 3	49 (0.49g)	21 (0.21g)	30 (0.3g)
PVA 4	42 (0.42g)	18 (0.18g)	40 (0.4g)

B) Electrode Preparation

80 wt% of activated carbon
5 wt% of Super P
5 wt% of carbon nanotubes (CNTs)
10 wt% of poly(vinylidene fluoride) (PVdF)
32 mL of 1–methyl–2–pyrrolidone solvent



C) EDLC Fabrication & Characterization

Configuration: electrode/polymer electrolyte/electrode

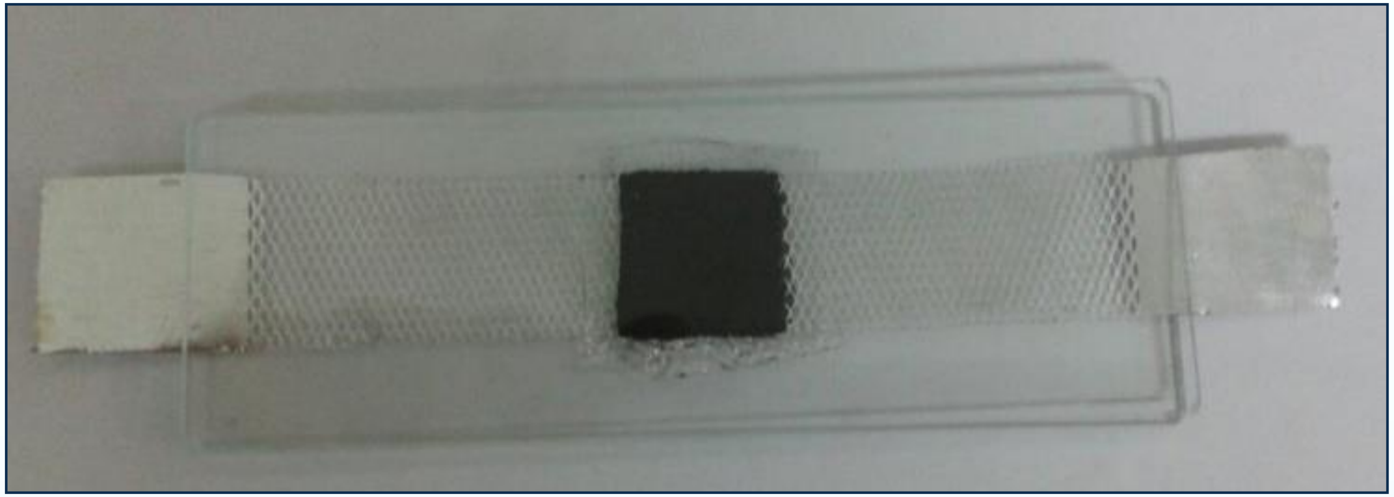


Figure 1: The fabricated EDLC using the highest conducting ionic liquid–based polymer electrolyte from each system.

- ***Cyclic Voltammetry (CV)***
- ***Galvanostatic Charge–Discharge (GCD)***

Survey - Theoretical Framework

Independent Variables

- **Environmental concerns**
- **Health and safety concerns consciousness**
- **Peer pressure / Social value**
- **Price awareness/Availability**
- **Knowledge/Information available**

Dependent Variables

Consumers' Willingness to Pay for Going Green

Demographic Factors

Moderating Variables

Survey Questionnaire

CONSUMERS' WILLINGNESS TO PAY FOR GREEN ELECTRONICS (HANDPHONES)

I am hereby conducting a research on consumers' willingness to pay for green electronics, in particular, handphones. I hope you can spend about 10 minutes of your time to complete the questionnaire.

Our objective is to examine whether Malaysian consumers are willing to pay for green electronics which are biodegradable and how much more a consumer would be willing to pay. We are all well aware of the toxic components in handphones and the effect of such toxic elements to our environment. Hence, should you have the opportunity to opt for green, biodegradable handphones to preserve the environment for our future generations, how much would you be willing to pay?

Your true and honest answers are very much appreciated and is extremely important to the success of this research.

Thank you for your time and cooperation. Rest assured that your privacy will be strictly preserved.

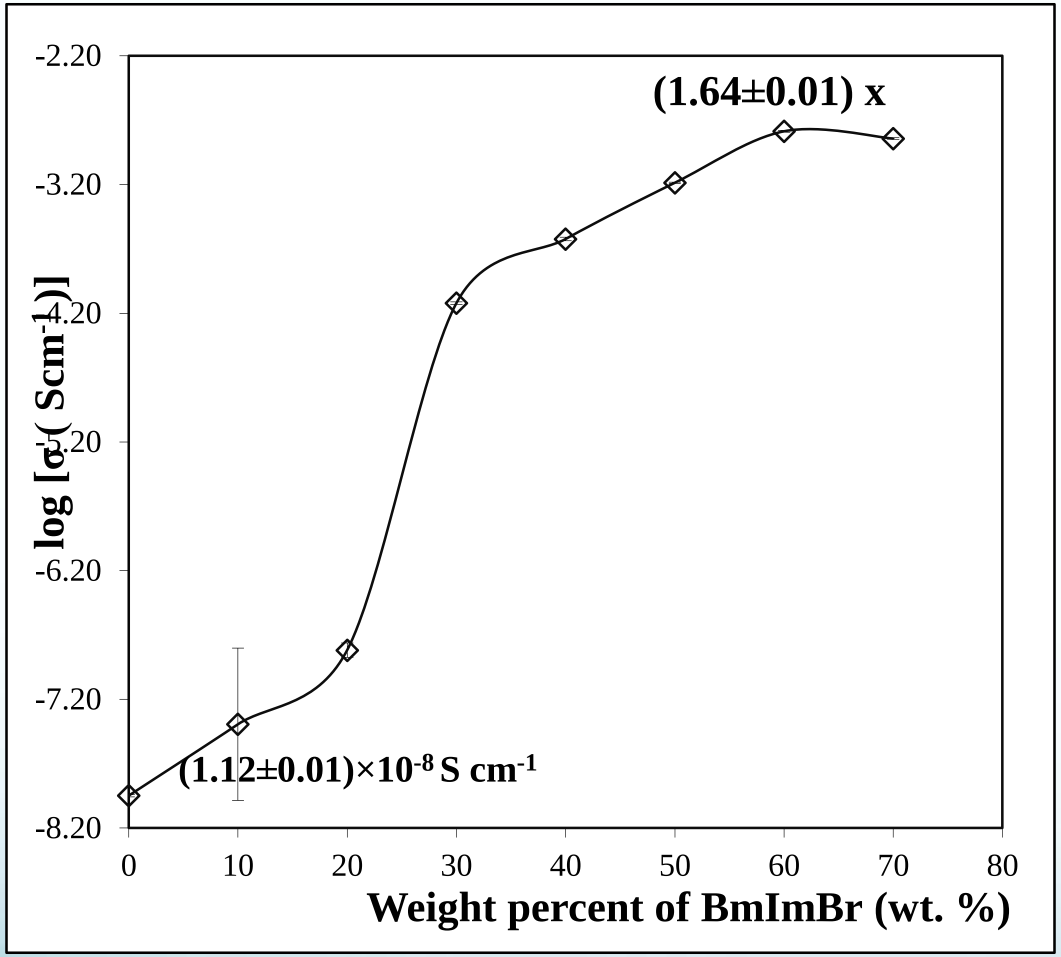
This survey is divided to 3 parts:

Willingness to Pay Survey

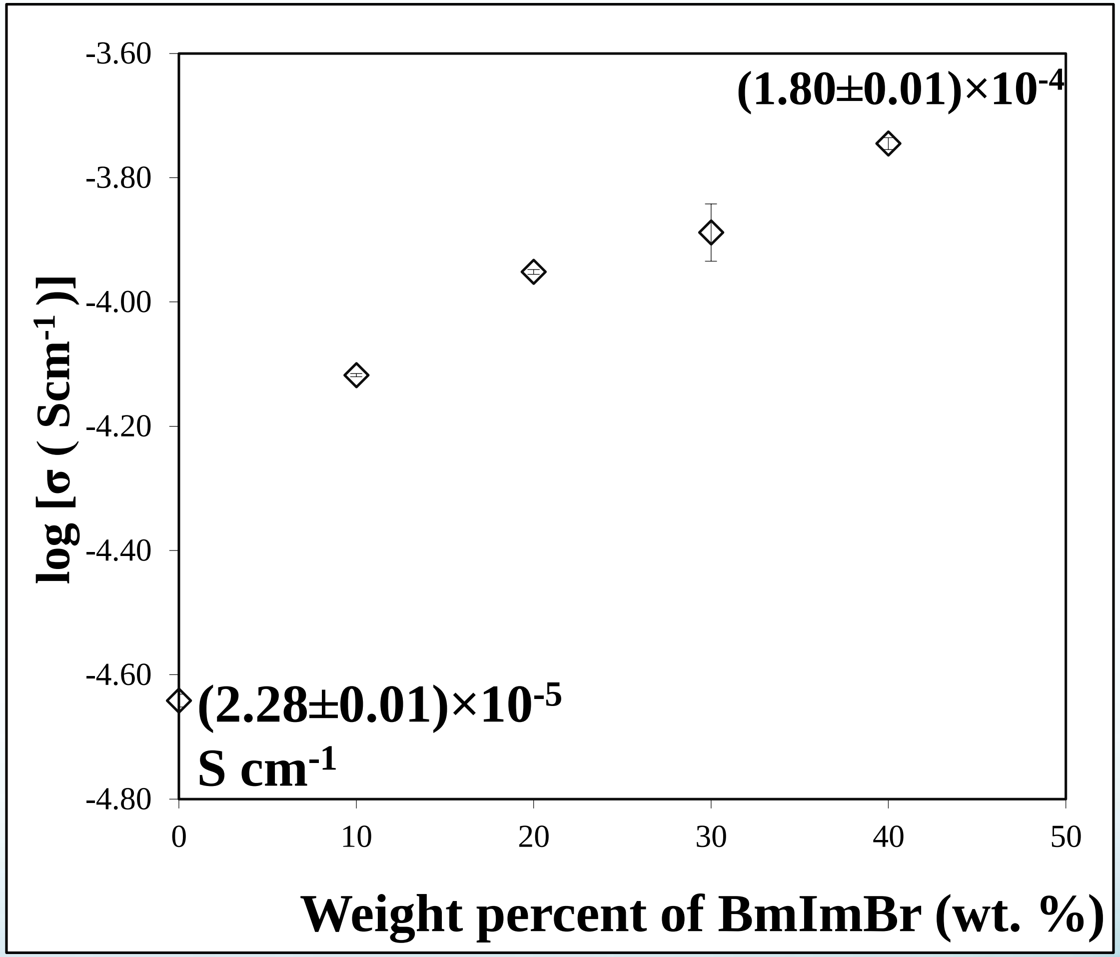
- **Survey questions are distributed online**
- **391 respondents**
- **We need a minimum of 384 respondents to be valid for significant statistical analysis**
- **Analysis Method – Logistic Regression**
- **Method: Contingent Valuation**
  - ***used to determine the monetary value of non-market goods and services as the product has not yet been commercialized.***
  - ***This method creates a hypothetical market and asks respondents how much they would be willing to pay for goods or services by using a survey questionnaire***

Findings

Room temperature–ionic conductivity



PVA



PEMA

Temperature dependent ionic conductivity - Vogel–Tamman–Fulcher (VTF) theory

$$\sigma = A_o T^{-\frac{1}{2}} \exp\left(\frac{-B}{T-T_o}\right) = A_o T^{-\frac{1}{2}} \exp\left(\frac{-E_a/k_B}{T-T_o}\right)$$

where

A_o = pre–exponential constant proportional to the number of charge carriers (S cm^{-1} K$^{1/2}$)

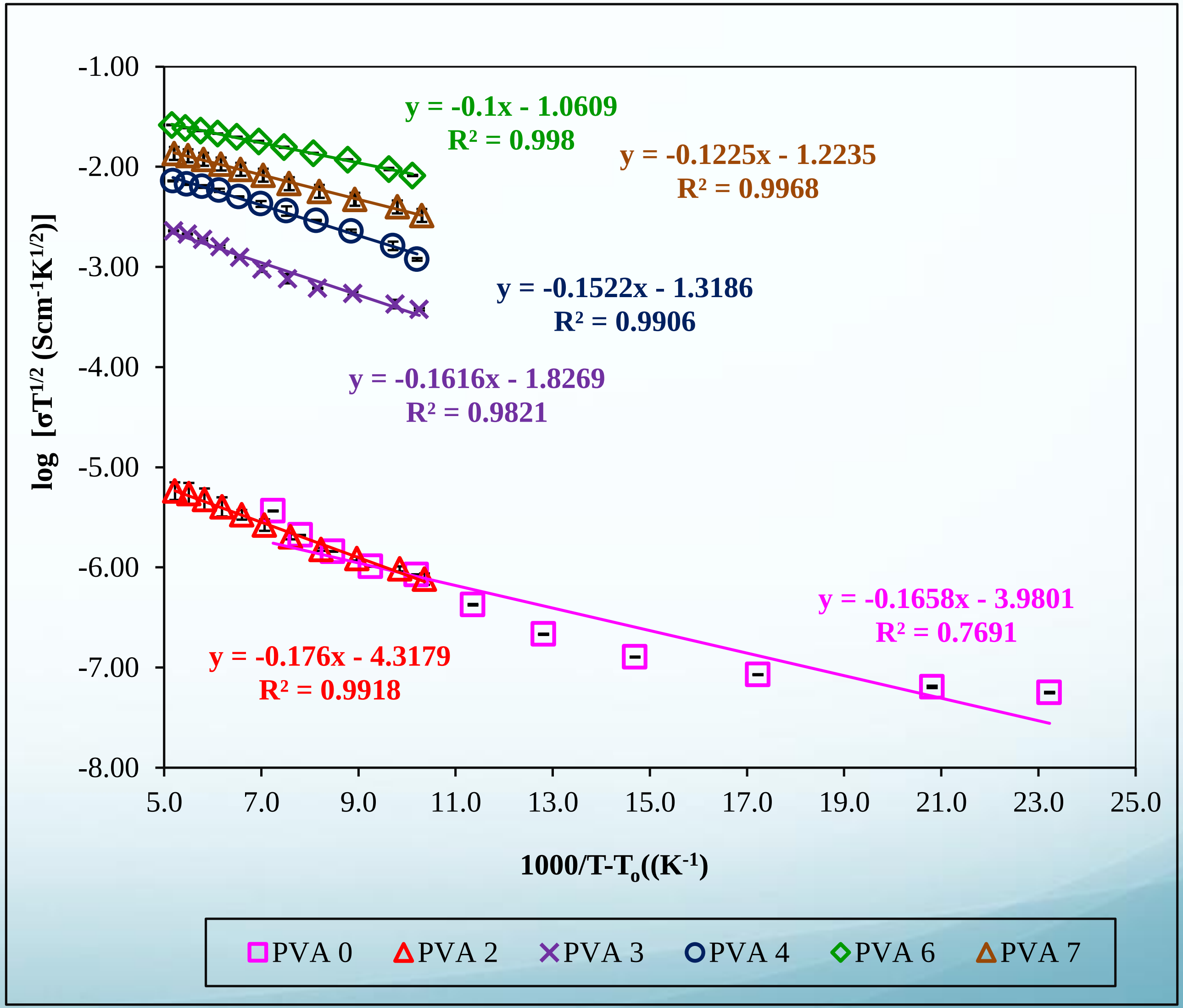
B = a constant which is determined from the gradient of the plot (K^{-1})

E_a =pseudo–activation energy for conduction (eV)

k_b = Boltzmann constant (8.6173×10^{-5} eVK^{-1})

T= the absolute temperature (K)

T_o = ideal vitreous transition temperature (K) = T_g –50



The VTF theory–based temperature–dependent plot of polymer electrolytes - PVA

Temperature dependent–ionic conductivity Vogel–Tamman–Fulcher (VTF) theory

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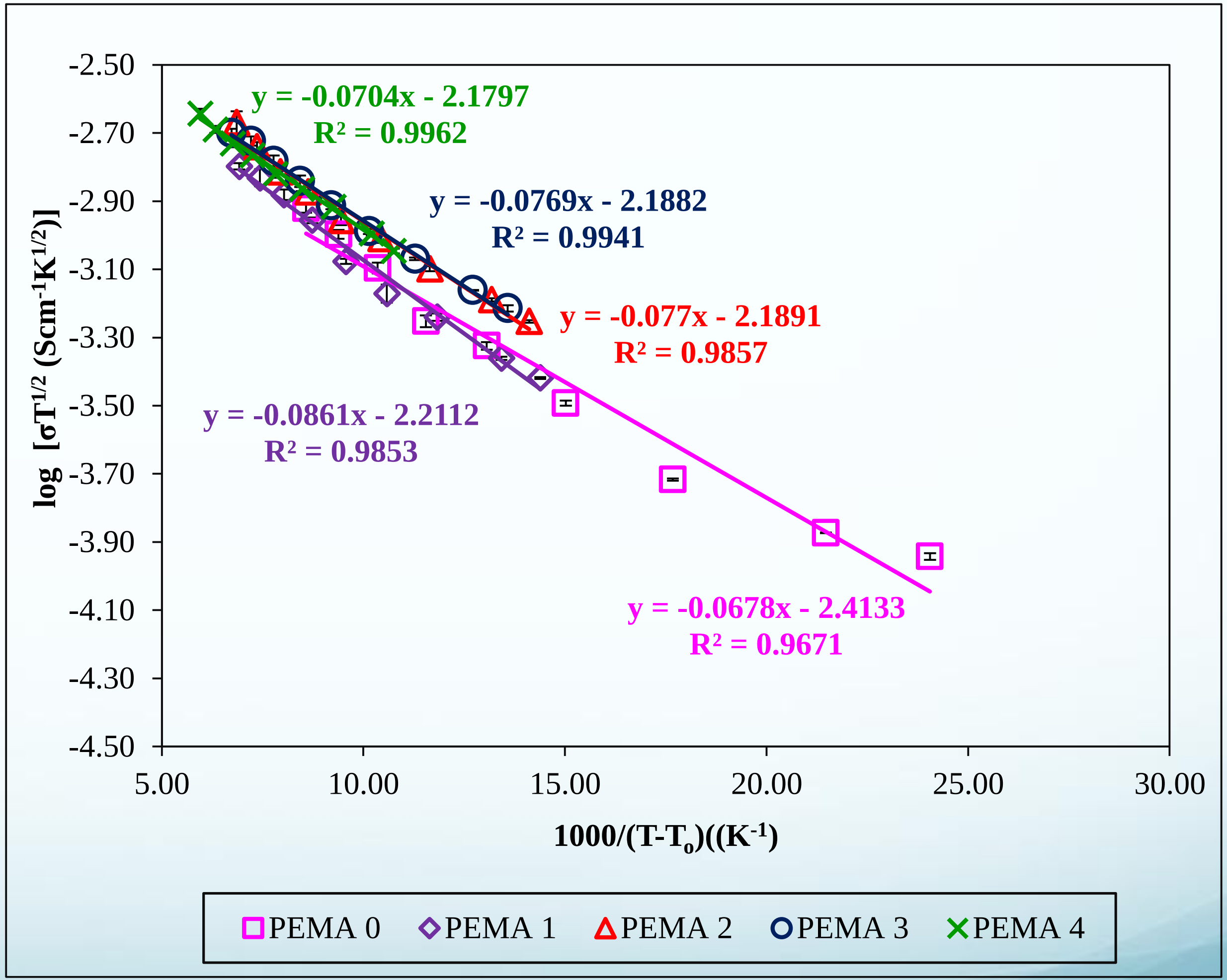
$= T_g - 50$



The VTF theory–based temperature–dependent plot of polymer electrolytes - PEMA

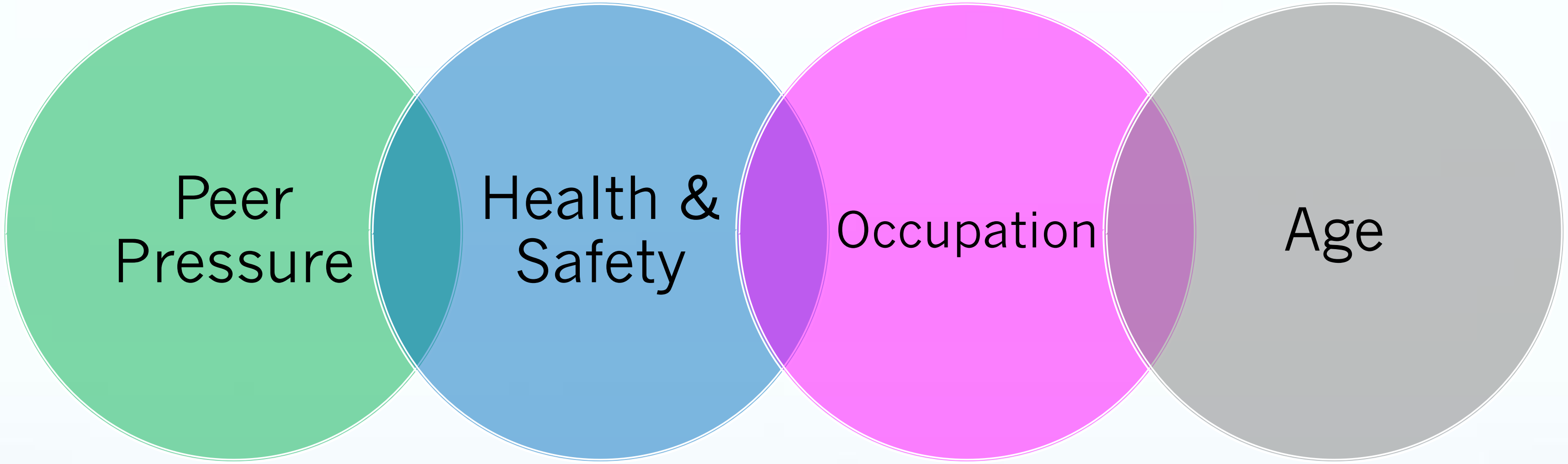
Experimental Conclusions

Parameter	PVA system	PEMA system
Ionic conductivity	$(1.64 \pm 0.01) \times 10^{-3}$ S cm^{-1}	$(1.80 \pm 0.01) \times 10^{-4}$ Scm^{-1}
Specific capacitance	45.95 Fg^{-1}	7.34 Fg^{-1}
Electrochemical potential window	2.6V	1.3V

- Based on experimental results, the ionic conductivity, specific capacitance and electrochemical potential window shows improved values in biodegradable system compared to non-biodegradable system.

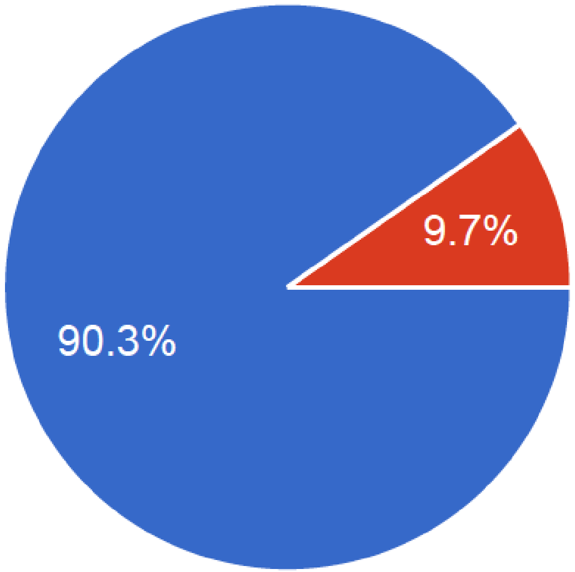
Survey Results

Significant variables



- **Government employees more willing to pay for green hand phone**
- **18-24 years old most willing to pay for green hand phones**

Willingness to Pay



Yes	**353**	90.3%
No	**38**	9.7%

Figure 17: Willingness to Pay to purchase a Green Hand phone

- **90.3% consumers willing to pay for green hand phone and 9.3% not willing to pay**
- **Most consumers' who are NOT willing to pay is due to THE PRICE FACTOR**

Willingness to Pay - Amount

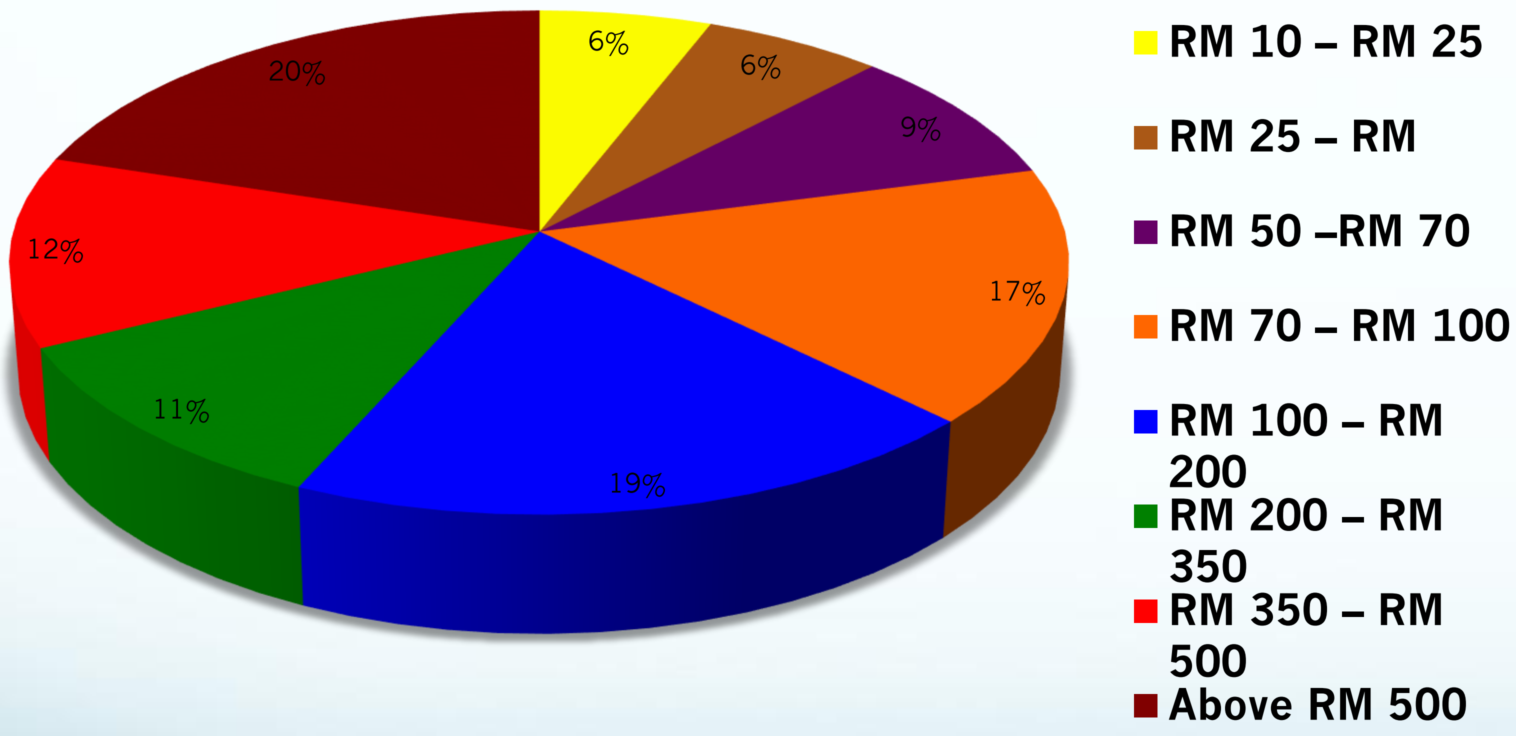


Figure 18: Amount Willing to Pay EXTRA only ONCE for a Green Hand phone

- **Most consumers are willing to pay substantially high amounts to purchase 'green' cell phones**
- **In a study done by Milovantseva (Milovantseva, 2016) on a similar subject on a population from USA, the frequency of people willing to pay for green cell phones decreased as the amount willing to pay was increased**

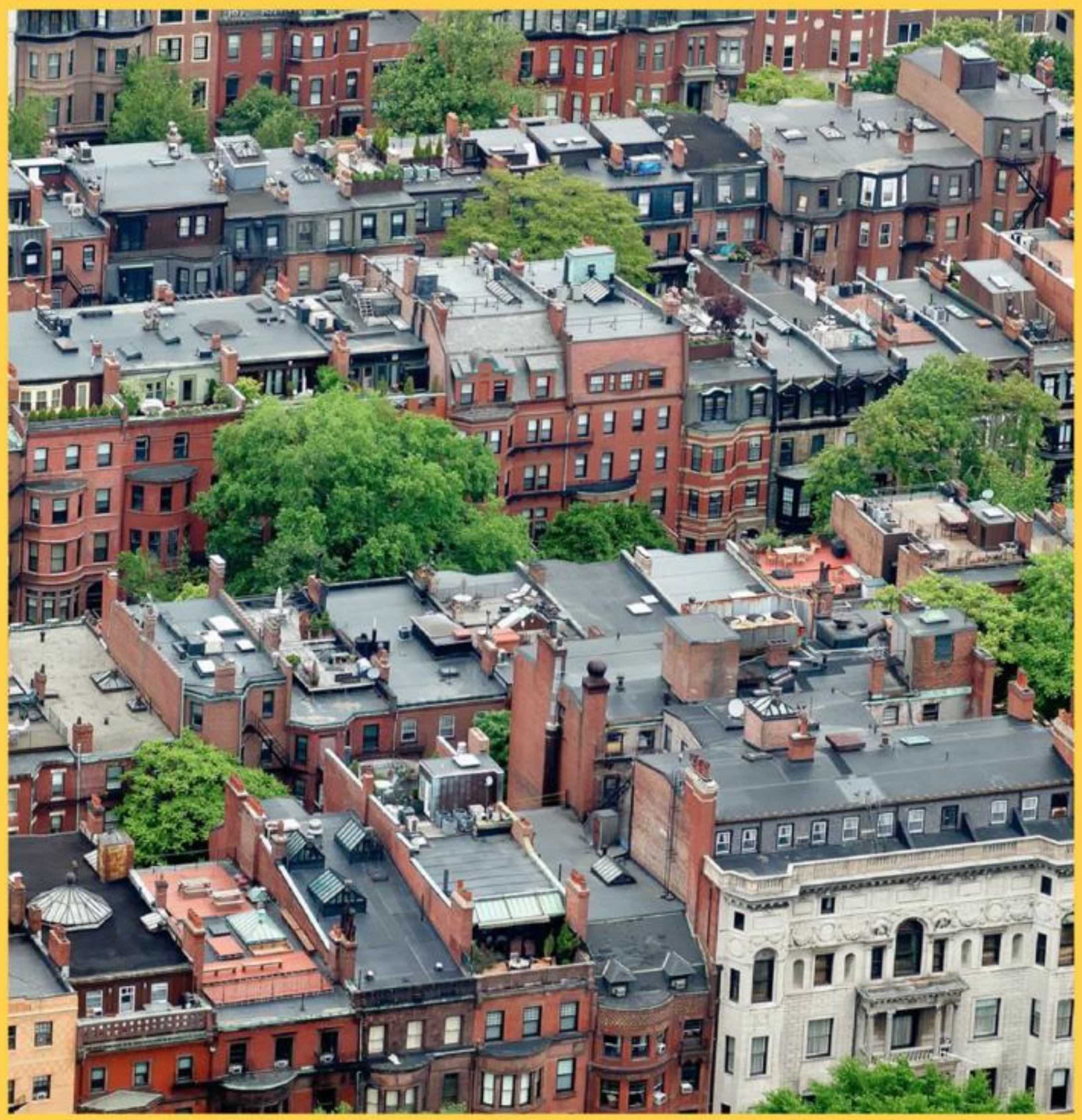
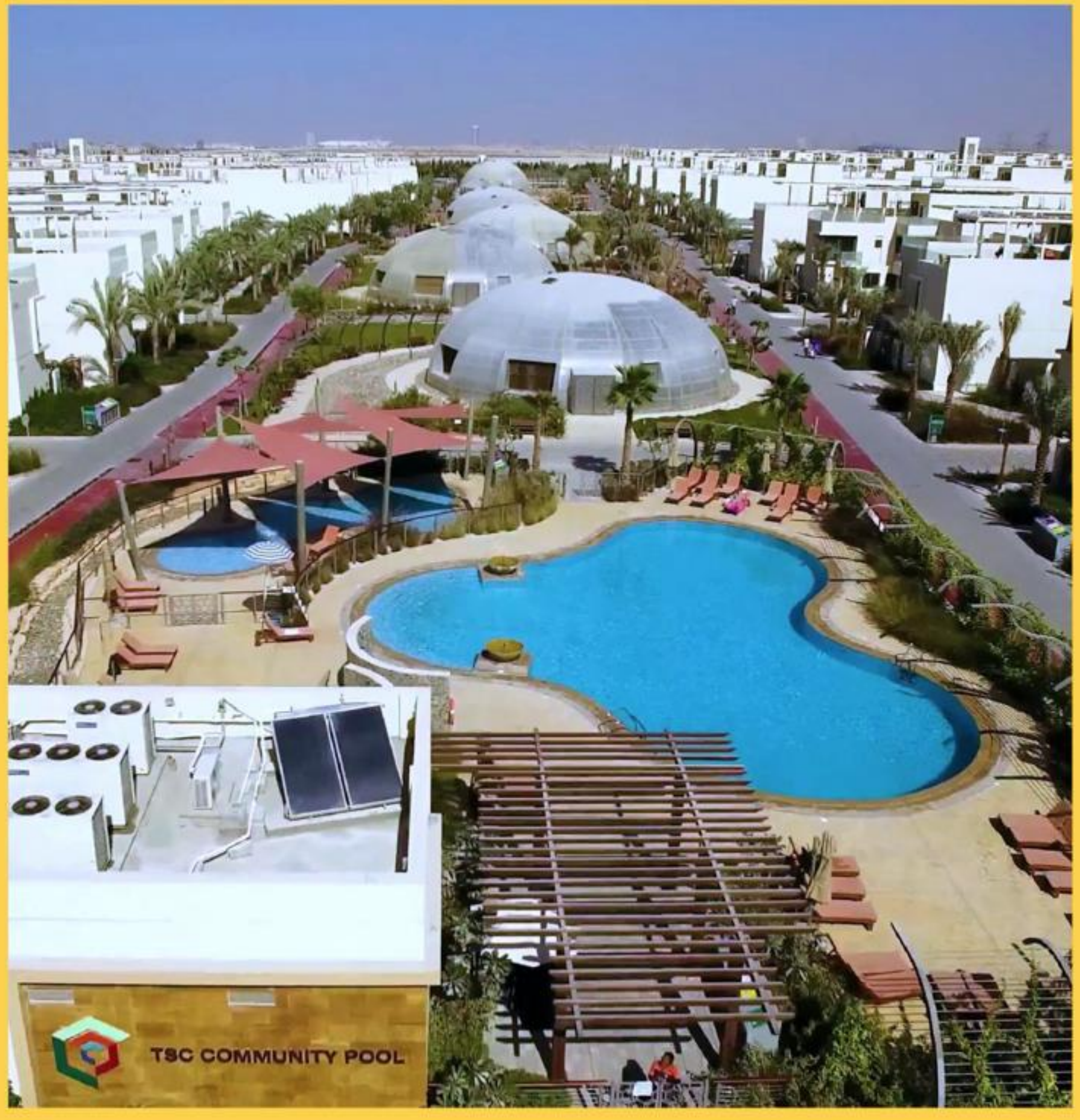
Survey Conclusions

Health and safety

- ***Malaysians value their health and realize the increasing awareness on the relationship between environment and health.***
- ***Malaysians are aware of the health implications due to chemicals in food, air quality, water quality and a clean environment.***
- ***Consumers' who are aware of the negative effects of chemicals and heavy metals in electronics would also be aware of its implications to health and would prefer to purchase green electronics.***

Peer pressure

- ***Modern age trend to want to fit-in***
- ***In addition to the positive effect, peer pressure can also create a negative feeling of guilt if the individual does not do as asked by the group or friend. This feeling can become psychological hence forcing a habit just to be accepted.***
- ***Supports age as a significant determinant***



TSC COMMUNITY POOL

- Supervisors and lab members
- Institute of Postgraduate Studies, UM
- Hadiah Latihan Persekutuan (HLP) JPA
- My Family and Friends

Thank you