APPLICATION OF LIFE CYCLE MANAGEMENT FOR SUSTAINABLE CONSUMPTION AND PRODUCTION OF POLYETHYLENE TEREPHTHALATE (PET) WATER BOTTLE IN THAILAND

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ทักษิณา ชัยอิทธิพรวงศ์ : การประยุกต์ใช้การจัดการวัฏจักรชีวิตสำหรับการผลิตและบริโภคอย่างยั่งยืนของขวดน้ำดื่มเพ็ทในประเทศไทย. (APPLICATION OF LIFE CYCLE MANAGEMENT FOR SUSTAINABLE CONSUMPTION AND PRODUCTION OF POLYETHYLENE TEREPHTHALATE (PET) WATER BOTTLE IN THAILAND) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร.ปมทอง มาลากุล ณ อยุธยา, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ. ดร.ดาวัลย์ วิวรรธนะเดช, 80 หน้า.

บทบาทการมีส่วนร่วมในระดับปฏิบัติของภาคธุรกิจและภาคประชาชน เป็นแนวทางสำคัญต่อผลสัมฤทธิ์การสร้างความยั่งยืนแก่สังคม เศรษฐกิจ และสิ่งแวดล้อม การศึกษาครั้งนี้ มีวัตถุประสงค์ เพื่อนำเสนอการประเมินเชิงประจักษ์ในกระบวนการผลิตและการบริโภคอย่างยั่งยืนของขวดน้ำดื่มเพ็ทในประเทศไทย โดยมุ่งเน้นศึกษากระบวนการผลิตน้ำดื่มบรรจุขวดของผู้ผลิต และการบริโภคขวดน้ำดื่มเพ็ท รวมทั้งการทิ้งขวดที่ใช้แล้วของผู้บริโภค ซึ่งปัจจัยชี้วัดที่ใช้ประเมินการผลิตและการบริโภคอย่างยั่งยืนมี 2 ตัว คือ การใช้ทรัพยากรอย่างคุ้มค่า มีประสิทธิภาพ และการลดผลกระทบต่อสิ่งแวดล้อม กลุ่มประชากรศึกษาในด้านผู้ผลิตได้จาก 2 กลุ่ม คือ ผู้ผลิตดื่มบรรจุขวดเพ็ทที่ถือครองส่วนแบ่งตลาดสูงสุด หรือ ท็อปแบรนด์ และผู้ผลิตรายย่อยทั่วไป หรือ เฮ้าส์แบรนด์ โดยเก็บข้อมูลด้วยวิธีลงพื้นที่สำรวจ-สังเกตการณ์กระบวนการผลิตในโรงงานผลิตน้ำดื่มบรรจุขวด และการสัมภาษณ์พร้อมชุดคำถาม ที่เน้นใน 4 ด้าน คือ ความรับผิดชอบขององค์กรต่อสังคม การออกแบบเพื่อสิ่งแวดล้อม การใช้แนวทาง 3 R และการจัดการวัฏจักรชีวิตของขวดน้ำดื่มเพ็ท ขณะที่ในส่วนข้อมูลด้านการบริโภคได้ใช้ชุดคำถาม ซึ่งแบ่งเป็น 3 ส่วน คือ ข้อมูลด้านประชากร วิธีปฏิบัติและความคิดเห็นต่อการบริโภคน้ำดื่ม และส่วนสุดท้ายเป็นชุดคำถามวัดระดับความเห็นพ้องต่อวิธีการบริโภคน้ำดื่มขวดเพ็ทอย่างยั่งยืน โดยใช้สถิติการวิเคราะห์ความแปรปรวนจำแนกทางเดียวทดสอบความสัมพันธ์ระหว่างตัวแปร ข้อมูลที่ได้จากผู้ผลิตและผู้บริโภคได้นำมาวิเคราะห์ และแปลงผลประเมินตามระดับการวัด 5 ระดับ เพื่อวัดระดับผลสัมฤทธิ์ในการผลิตและบริโภคอย่างยั่งยืนของขวดน้ำดื่มเพ็ท

งานศึกษาได้ข้อค้นพบสำคัญ 3 ประการ คือ บทบาทของผู้ผลิตและผู้บริโภคต่อการผลิตและการบริโภคอย่างยั่งยืนอยู่ในระดับเดียวกัน คือ ระดับปานกลาง ประการต่อไป ทั้งสองฝ่ายคำนึงถึงการใช้ทรัพยากรอย่างคุ้มค่า มีประสิทธิภาพมากกว่าการลดผลกระทบต่อสิ่งแวดล้อม และประการสุดท้ายที่พบคือ การจัดการวัฏจักรชีวิตในวงจรการผลิตและการบริโภคมีความสำคัญอย่างมากต่อผลสัมฤทธิ์ของการพัฒนาการผลิต และการบริโภคขวดน้ำดื่มเพ็ทให้ยั่งยืน การศึกษายังพบด้วยว่า ประเด็นความรับผิดชอบขององค์กรต่อสังคมเพื่อนำไปสู่การผลิตที่ยั่งยืนเป็นสิ่งที่ผู้ผลิตท็อปแบรนด์ให้ความสำคัญมากกว่าแนวทางอื่น นอกจากนี้ผู้ผลิตยังเผชิญกับความท้าทายในเรื่อง การลดการสูญเสียน้ำจำนวนมากจากกระบวนการผลิตน้ำดื่มบรรจุขวดระบบเปิด โดยการเปลี่ยนเป็นระบบปิดที่ลดการสูญเสียทำให้ใช้ทรัพยากรน้ำได้อย่างคุ้มค่า เรื่องการเพิ่มพูนความสามารถเกี่ยวกับเทคโนโลยีการรีไซเคิล และเรื่องวิธีการจัดการผลกระทบโดยการจัดการ วัฏจักรชีวิตให้ครอบคลุมถึงการจัดส่ง การใช้ และการจัดการขยะขวดน้ำดื่มเพ็ท ในส่วนของผู้บริโภคนั้น การศึกษาได้ชี้ให้เห็นว่า ผู้บริโภคให้ความสำคัญกับประเด็นการใช้ทรัพยากรให้คุ้มค่า เกิดประโยชน์สูงสุดด้วยการดื่มน้ำให้หมดขวด และประเด็นการลดผลกระทบด้วยการทิ้งขวดใช้แล้วในที่ทิ้งขยะเท่านั้น ดังนั้น ผู้บริโภคควรหันมาใช้น้ำประปาเพื่อการบริโภค และควรเพิ่มการรีไซเคิลขวดใช้แล้วเพื่อประโยชน์ในด้านอื่น เพื่อรักษาคุณภาพสิ่งแวดล้อม สรุปผลที่ได้รับจากการศึกษาครั้งนี้ คือ (1) ได้รูปแบบเชิงเมตริกซ์ในเรื่องการผลิตและการบริโภคอย่างยั่งยืน (2) เกิดกรณีศึกษาเชิงประจักษ์ของแนวทางพัฒนาเศรษฐกิจ สังคม และสิ่งแวดล้อมอย่างยั่งยืน และ (3) เกิดแนวทางที่ดีในการประยุกต์ใช้การจัดการวัฏจักรชีวิต ในท้ายที่สุด งานวิจัยนี้ให้ข้อคิดว่า สมควรอย่างยิ่งที่จะต่อยอดงานศึกษาเรื่อง การมีส่วนร่วมในระดับปฏิบัติเพื่อพัฒนาแนวคิดการผลิตและการบริโภคอย่างยั่งยืน ให้มีความหลากหลายและมีงานศึกษาเพิ่มมากขึ้น เพื่อช่วยให้บรรลุเป้าหมายการพัฒนาประเทศอย่างยั่งยืนได้ในที่สุด

สาขาวิชา สิ่งแวดล้อม การพัฒนา และความยั่งยืน	ลายมือชื่อนิสิต ....
ปีการศึกษา 2556	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก ....
	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม ....

5287772820 : MAJOR ENVIRONMENT DEVELOPMENT AND SUSTAINABILITY
KEYWORDS: BOTTLED DRINKING WATER / LIFE CYCLE MANAGEMENT / POLYETHYLENE TEREPHTHALATE (PET) BOTTLE / SUSTAINABLE CONSUMPTION AND PRODUCTION / THAILAND

TAKSINA CHAI-ITTIPORNWONG: APPLICATION OF LIFE CYCLE MANAGEMENT FOR SUSTAINABLE CONSUMPTION AND PRODUCTION OF POLYETHYLENE TEREPHTHALATE (PET) WATER BOTTLE IN THAILAND. ADVISOR: ASST. PROF. POMTHONG MALAKUL NA AYUDHAYA, Ph.D., CO-ADVISOR: ASSOC. PROF. Dawan Wiwattanadate, Ph.D., 80 pp.

Bottom-up participation in sustainability is challenging for improving socio-economic and environmental securities. This research was thus aimed to present evidence-based evaluation of implementing sustainable consumption and production (SCP) for polyethylene terephthalate (PET) water bottle in Thailand, with emphasis on performances of the producers and the consumers in production and consumption life cycle management (LCM). Resource efficiency and impact reduction were the key indicators for evaluating producers' performances in sustainable production (SP) and consumers' performances in sustainable consumption (SC). The SP involved bottling system whereas use of the bottle, coupled with disposing of post-used bottle was assigned for the SC. Plant observations and in-depth interviews with survey transcript were conducted for two groups of producer: top brand and house brand, whereas a set of questionnaire was prepared for consumer samples. The top brands' and house brands' performances in four categories: corporate social responsibility (CSR), eco-design, 3 R and LCM, were examined to justify the SP. The analytical statistics of one-way ANOVA was used to interpret the SC variables consisting of demographic data, drinking water consumption and consumer's agreement to the SC practice. The SP and SC results were transformed to a five-point scale for rating the SCP success.

Three most prominent findings are that both producers and consumers moderately account for the SP and the SC, are likely to favor the resource efficiency over the impact reduction, and that the production and consumption LCM are highly potential for the SCP success. The research also reveals that the top brands consider CSR more important for the SP. Producers are challenging for improving water efficiency due to the lost-filled water in the open loop with adapting to the closed loop. Either is recycle technology and cradle-to-grave LCM. The consumers agree to fulfill the consumption efficiency by drinking up a whole bottle of water and reduce the impact by accompanying post-used bottle for solely disposing of them in a trash bin. Therefore, consumers should utilize tap water for drinking and increase recycling post-used bottle for environmental protection. The achieving outcomes are listing as (1) Matrix model bottom-up participation in SCP implementation, (2) Evidence-based case of sustainability in both environment and socio-economic development and (3) Good practice for LCM development. Finally, a bottom-up participation in SCP implementation shall be largely developed to ensure sustainability success in Thai context.

Field of Study: Environment Development and Sustainability

Academic Year: 2013

Student's Signature ....

Advisor's Signature ....

Co-Advisor's Signature ....

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CHAPTER I

INTRODUCTION

Keywords: Bottled drinking water; Life cycle management; Polyethylene terephthalate (PET) bottles; Sustainable consumption and production, Thailand

1.1 Background

The world has been addressing adverse impacts according to materially intensive economies and consumerist lifestyles that are pushing the planet away from sustainability [1]. As a result, many disposable products that can make life possible to fulfill daily needs have become a faster and convenient pace of society [2, 3]. A consumption and production pattern is not only a basic driver of any economy but also plays an important role in shaping the sustainability of economic growth and the future livelihoods [4, 5].

Polyethylene terephthalate (PET)-bottled drinking water has become one of the most common plastic products to be consumed and disposed of on a regular basis, both at and away from home [6-8]. These bottles are eventually translated into consumer wastes. Thailand was ranked near the top in bottled-water consumption in Southeast Asia and is among the top 9 consumers globally [9]. There are more than 6,000 bottling plants throughout Thailand [10] consuming nearly 40,000 tons of PET plastic and producing 2.4 billion liters of bottled water a year [11].

PET plastics actually constitute various pollutions to air, water and soil quality as carbon substance is the key element of resin formulation. The resins that are melted and polymerized consume both material and energy while emitting much of chemical substance, including dust and debris of pollutions and acetaldehyde from the polymer degradation [12]. It was revealed that the production of 1,000 units of single-serve PET bottle can cause about five kilograms equivalent CO_2 (kg CO_2 eq.) emissions [13]. Among the impacts are global warming, eco-toxicity, health consequences, including water conflict with commercializing a public resource. Barlow [14] and the World Bank (including the World Resources Institute) pointed that rapid growth of bottled water business is truly related to depletion of surface-water supplies and groundwater sources. Thus, without greater understanding of how to produce and how to consume PET water bottles in sustainable paradigm, it may even worsen the most disagreeable impacts to the planet.

Coupled with growing concern to environmental issues, it is time to draw a key array of actionable cooperation partnering a top-down state policy to a bottom-up business and individual participation in a more sustainable consumption and production practice [4, 15]. Sustainable consumption and production (SCP), which is an interaction process, enables producer and consumer to apply, individually and within the whole product cycles, to prevent the vulnerable position associated with production and consumption of products or services [4, 5]. It is expected that if enough producers implement SCP they will be able to decouple business growth from environmental degradation [3, 16]. On the other, if more and more consumers are aware that their consumption patterns can cause environmental harms and put themselves at health risks, these consumers can drive change toward the SCP [15, 17]. While life cycle management (LCM) helps in understanding a great deal more about how much harm might come to humans and the environment [18] , SCP is an effective framework for improving resource efficiency and impact reduction [4, 15].

As a consequence, it is challenging to involve businesses and consumers in actionable SCP for greater efficiency in resource consumption and a reduction in environmental, economic and social impacts [4, 16].

1.2 Research Objectives

This research aims to provide evidence-based evaluation of implementing a bottom-up SCP in Thailand, and the role of producers and consumers in the production and consumption of PET water bottles are closely examined.

1.3 Research Questions

- How can integrate the LCM into the SCP implementation?
- What is the vulnerable impact of PET bottle?
- How do the producer and consumer account for the SCP accomplishment of PET water bottle in Thailand?

1.4 Research Design

1.4.1 Terms and scope

1.4.1.1 Conceptual framework. The research has the system boundaries on the interplay between the production and the consumption (use) stages in a life cycle of PET water bottle. Not included in this study are the raw material extraction, the retail (distribution) and the end-of-life management. Neither is water disinfection and purification process. Sustainable production (SP) represents two different bottling systems: open-loop and close-loop processes while the use of PET-bottled drinking water and disposal of post-used bottles designate sustainable consumption (SC).

Two in four thematic concerns in the SCP principle: producer and consumer those standing for the bottom-up participants, are focused while excluding government and other stakeholders. Resource efficiency and impact reduction are keyed to identify producer's and consumer's performances in the SCP. The research framework that was adapted from the SCP concept [4] in respect to the LCM principle [18, 19] can be drawn as in Figure 1.

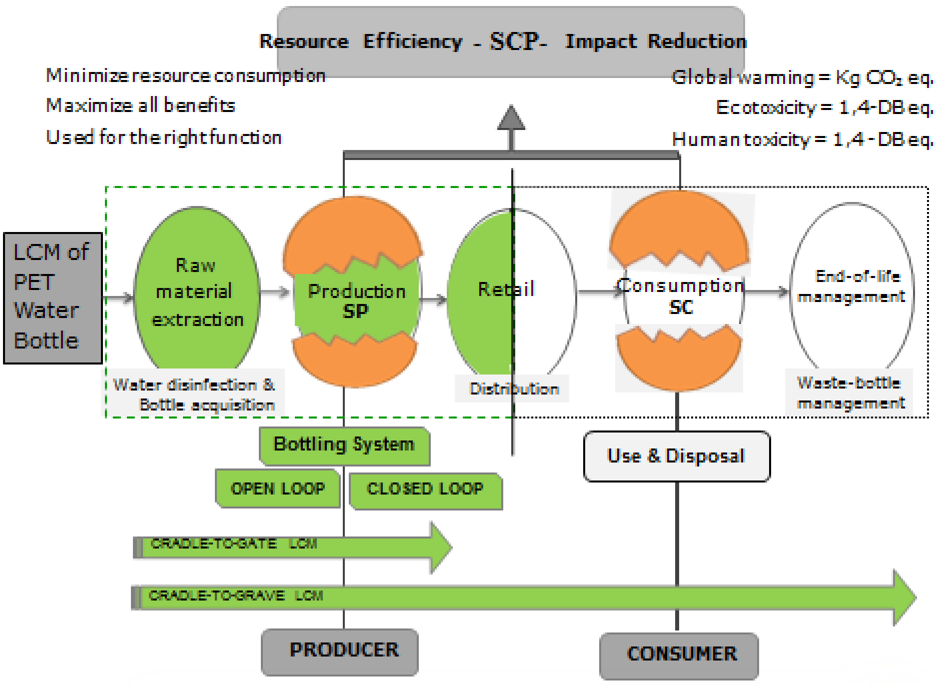

Figure 1. Conceptual framework of SCP implementation for PET water bottle with the LCM perspective.

1.4.1.2 Potential impacts. The research refers to three impact categories: global warming, eco-toxicity and human toxicity. Due to the International Panel on Climate Change (IPCC), CO_2 emission is normalized as an equivalent weight of carbon dioxide for the relationship between greenhouse gases (GHGs) emission and the 100-year time horizon Global Warming Potentials (GWP)[20]. With this regard, this study uses the equivalent terms of kg CO_2 eq. designates global warming impact [21] while dichlorobenzene (DB) substance, in equivalent terms of kg 1,4-DB eq. represents eco-toxicity and human toxicity consequences [22].

1.4.1.3 Functional unit. A single-serve PET bottle for drinking water varied in 500, 550 and 600 mL water-weighted bottles was a so-called functional unit of PET water bottle referred to in this research. However, in potential impact study of PET bottles, the system of test scenario was solely evaluated on the basis of 1 kg of 500 mL PET bottles.

1.4.1.4 Scope of areas. The study involved with Thai-based implementation. Bangkok and its vicinities (cities like Nonthaburi, Pathum Thani, Samut Prakarn, Samut Sakhon, and Nakhon Pathom) were assigned for completing the SC data. For the SP, the provinces of Ayudhaya, Singburi, Kornkaen, Chiengmai and Had Yai area were included.

1.4.2 Operational Definitions

PET water bottle represents PET-bottled drinking water, which a bottle body is made of polyethylene terephthalate polymer and weighs 500, 550 or 600 mL of drinking water inside.

SP of PET water bottle refers to two bottling systems: the open loop and the closed loop processes of PET water bottle associated with resource efficiency and impact reduction measures in four categories: CSR, Eco-design, 3 R and LCM. Implementation of FDA registration and good manufacturing practice (GMP) certification are not considered to any category, as they are mandatory for bottled-water manufacture in Thailand.

SC of PET water bottle represents the use of PET-bottled drinking water and disposing of post-used bottles in accordance with resource efficiency and impact reduction measures.

Resource efficiency of PET water bottle is defined as performances in SP and SC of PET water bottle in order to maximize all benefits, minimize resource consumption and to reduce impact generation.

Impact reduction of PET water bottle represents the performances in SP and SC of PET water bottle to reduce impacts generation on global warming, ecotoxicity and human toxicity.

Top brand represents four leading brands of PET water bottles produced and commercialized in the Thai market those belonging to Crystal, Namthip, Purelife and Singha. Each brand is written in alphabetical order regardless of market sequence.

House brand is defined for the small and medium bottlers who produce not only unbranded bottled water but also provide bottling service as an original equipment manufacturer (OEM) of PET water bottle.

Producer's performances in SP of PET water bottle refer to the bottler's contributions in terms of policy, plan, project and / or activities, to resource efficiency and impact reduction measures along with the SP of PET water bottle.

Consumer's performances in SC of PET water bottle represent five degree of consumer's agreement, beginning with strongly disagree (1), disagree (2), no idea (3), agree (4) and strongly agree (5), with the ways of resource efficiency and impact reduction for the SC of PET water bottle.

CSR is defined for a framework to justify how bottled-drinking-water business responds to society's expectations, and how that is concurrent to the producer's performances in SP of PET water bottle.

Eco-design refers to the producer's performances in using design for environment, which includes product development, technological process improvement and process planning, in order to take up the SP of PET water bottle.

3 R represents three ways comprising reduce, reuse and recycle performed by the producers to achieve the SP of PET water bottle.

LCM refers to two different dimensions: cradle-to-gate and cradle-to-grave, which are carried out for meeting the SP of PET water bottle. A cradle to gate deals with two in five stages of product life cycle that are material extraction and production, while a cradle to grave extends from the gate to three more lives: retail, use, end-of-life management.

1.4.3 Variables This research places the presumption that achievement in implementing the SCP of PET water bottle is related to producer's and consumer's performances in the SP and the SC, respectively. In the SC subsector, there were three variables: two independent variables of consumer demography, practices and opinion to drinking water consumption, and the SC standing for a dependent variable. Figure 2 is drawn to translate the variable relation that includes the subsector of SC.

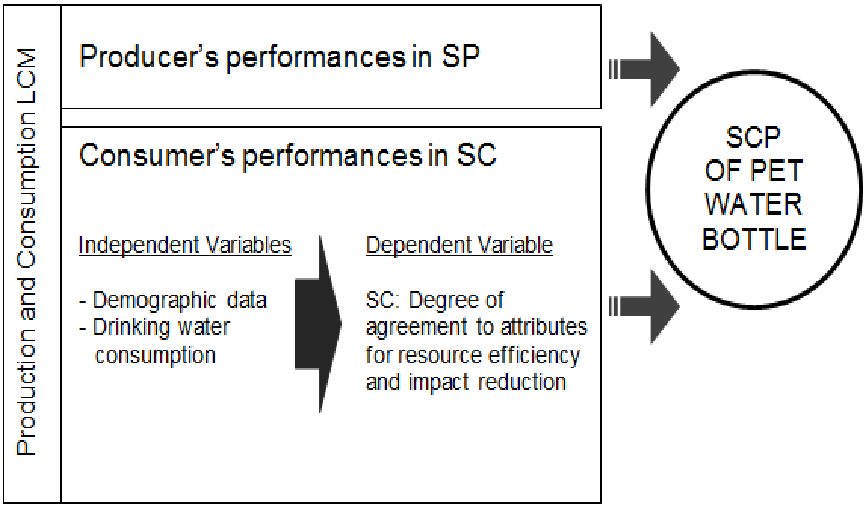

Figure 2. Variables relation between SP, SC, SCP and the subsector of SC

1.5 Research Outcomes

Expected outcome of the research is to enhance a bottom-up participation in establishing the SCP in Thai context. This also fills the gaps by addressing the distinctive linkage among environmental quality, economic growth and sustainable development.

CHAPTER II

LITERATURE REVIEW

This research reviewed certain of literatures involving PET bottles, bottling system, life cycle inventory, life cycle management, sustainable consumption and production, resource efficiency, impact reduction, sustainable production, corporate social responsibility, eco-design, 3 R's principle, sustainable consumption and environmental awareness.

2.1 PET Water Bottles

2.1.1 PET bottles. PET bottles have become the interplay of social, economic and environmental aspects since they were mostly demanded for today-lifestyle [7]. Raskin et al [17] pointed that increasing demand for consumer goods caused a stream of waste and the relevant environment and human health issues. In global context, bottled water has been the top end-used application of PET plastic since its introduction into beverage packaging in the late decade of 1970 [23]. Generally, the half-liter (500 mL) PET-bottled dinging water, was considered for the most produced and consumed pack size available for single-serve market sector [24, 25]. It was however reported that, within characteristics of Thai market, the commercialized single-serve size varied in water volume from 500, 550 to 600 mL bottles at the same market price [24, 26].

Basically, PET resin was a thermoplastic condensed between ethylene glycol with terephthalic acid forming long chains of repeating units of carbon, oxygen and hydrogen. At industrial scale of PET resin production, carbon substance was the key element of PET plastic formulation where actually constituted various pollutions to degradation of ecological system and biodiversity. In bottled water business, plastics and water were main raw materials included in a stage of resource extraction. When producing PET bottles, the resins were melted and polymerized till feasible for a pre-form injection in latter conjunction with a blow molding process. The mentioned stages consumed both material and energy while emitting toxic chemicals. Moreover, much of substance was generated from improving resin performance process, including dust as residue of pollutions and acetaldehyde from the polymer degradation [12].

According to Gironi and Piemonte [13], PET resins caused higher impact on global warming than did the categories of nonrenewable energy, acidification and eutrophication. In view of many researchers [27-29] together with Bach et al [30] , toxic substances, namely antimony and aldehydes were reasoned to health consequences against PET-bottled drinking water consumption. Those included carcinogenic chemicals caused by improper use and multiuse [31]. For example, direct contact between mouth and bottle after leaving it in sunlight exposure and at longer time was also risky to health effect because time was dominant factor to the organic substances leaching out from PET bottle [28, 32, 33]. Moreover, PET refillable bottles could be safely reused, if the bottles derived from the good manufacturing procedures and the appropriate cleaning prior refilling [34]. It was however revealed that most Thai people refilled the used bottles without awareness of health consequences due to improper manner in washing process [35].

Among the proof resulted in the same conclusion that without greater understanding of how to produce and how to consume PET water bottles in sustainable paradigm, it may even worsen the most disagreeable impacts to the planet.

2.1.1.1 Recycling system. In early 1978, PET bottle was first recycled into a fiber product [36]. With the advances in PET recycling technology, the availability of textile fiber and fabric products were then manufactured from 100% recycled PET of bottle grade. Recycled PET was processed by two methods: mechanical recycling and chemical recycling. Both methods had a typical processing sequence of recycling system beginning with the collection, transporting, sorting and separation and reprocessing. For mechanical system, PET plastics were crushed and grinded into small flake for further contaminants separation. Then the flakes were washed and dried before feeding into an extruder where they were heated to melting state and converting into recycled PET manufacturing [37]. Chemical recycling or feedstock recycling was a de-polymerization process, in which a plastic polymer was broken down into its constituents – monomers [38]. There were three main methods in PET chemical recycling: glycol for glycolysis, methanol for methanolysis, and water for hydrolysis, those differed the desired products yield, and environmental impact profile [37]. It was reported that recycled PET produced lower CO_2 emissions than virgin PET, while the majority were fuel-related emissions, not process emissions [20]. However, the environmental profile in comparison for the virgin PET product and the recycled could be changeable. Bartolome et al. [37] noted that the quantities and types of input resources, including material and utility, that varied in recycling method were linked to environmental impact profile for the production of recycled PET. Included were the number of collection, sorting, reprocessing steps and the recycled content [20], those possibly had the recycled PET caused the increasing impacts [39].

2.1.1.2 Recycled PET. Number 1 in the loop of chasing arrows indicated PET resin as the most possibly recyclable plastic, consequently, the scraps could recapture resin properties for a second life in bottles and new applications. PET was recycled in multiple times and was being recycled into a variety of end products. Kuczenski and Geyer [40] mentioned that recycled PET alternated better consequences than the reuse, in terms of cheaper recycled cost, easier recycling process, and 100% recyclable resin possibly used as virgin material for new applications. Similarly, Foolmuan and Ramjeeawon [41], Lehmann et al.[1] and Madival et al. [42] insisted that PET-bottled scraps could be recycled for the efficient use and cost effectiveness, except for environmental environmental concern. Shen et al. [43] noted that the effect of multiple-recycling trips should be taken into account as PET recycling system was related to the two most important products; virgin PET resin for PET bottles and recycled PET from waste-PET bottles for fiber application.

Referring to Wilkins [44], only 14% of post-used bottles were recycled. The balance ended up in landfills, lakes, streams, where they may lead to many impact consequences. Coelho et al. [45] found that 54.80% of post-consumer PET bottles in Brazil were recycled effectively due to lack of standardized procedure for waste management. It was reported that 0.27% of waste PET plastics were incinerated in Thailand in 2005 [46]. As in Song and Hyun [47], environmental impacts has arisen at the highest level when 100% of used PET bottles went to landfill. Shen et al. [43] found, on the one hand, that recycled PET was optimized within three recycling trips. On the other, it was found that CO_2 equivalent released for producing 10,000 units of 12-ounce PET water bottle was not significantly different in comparison between using virgin PET and a mix of recycled resin (682.02 and 641.09 kg CO_2 eq., respectively)[20].

2.1.2 Bottling system. Based on the bottling processes of PET-bottled drinking water, the inputs of plastics and water resources were mainly used together with electricity and fuel energy while delivering the outputs of bottled water and the impacts [48].

Drinking water bottling system was technically classified as the open-loop and the closed-loop processes[49]. The difference was that the close loop began with producing PET stretch-blow-molding bottles from PET pre-forms while the open loop set the production of PET bottles apart. In other words, if manufacturing line of bottle blow-molding was automatically connected to filling stage in the filler room, it indicated the closed-loop process using PET preform appearing in tube-formed object as intermediate material to produce the formed-bottles. In other words, the close loop received empty bottles produced from the connected line of preforms manufacture and fed by electronically-automatic system.

The open loop, which was a semi-manually-conventional system, in which returnable bottles were possibly refilled, initially proceeded with a feeding of the formed-bottles. The empty bottles were usually hand fed onto a conveyor to be filled with drinking water passing through orifice at a continual rate of flow. So, only 60 -70% of drinking water ended up in the bottle, the rest was wasted [50]. Prior to entering filling stage, the open loop used drinking water to clean the inside of the bottles but the close loop used an infrared light scanner and a high speed blower for dust detection and elimination. However, the bottlers those invested in the open-loop process could either exclude PET bottles production from bottled-water business or separate the filling and capping stages (filler room) from the labeling and the bundle packaging. In addition, the open loop enabled the separate operation of cap-sealing unless capper/closure wrapper was specially required. While a label application was an intermediate step following the capping stage in closed-loop process, the open loop allowed the bottles to be labeled either before or after bottle filling step. The linear stages of bottling system can be illustrated as in Figure 3.

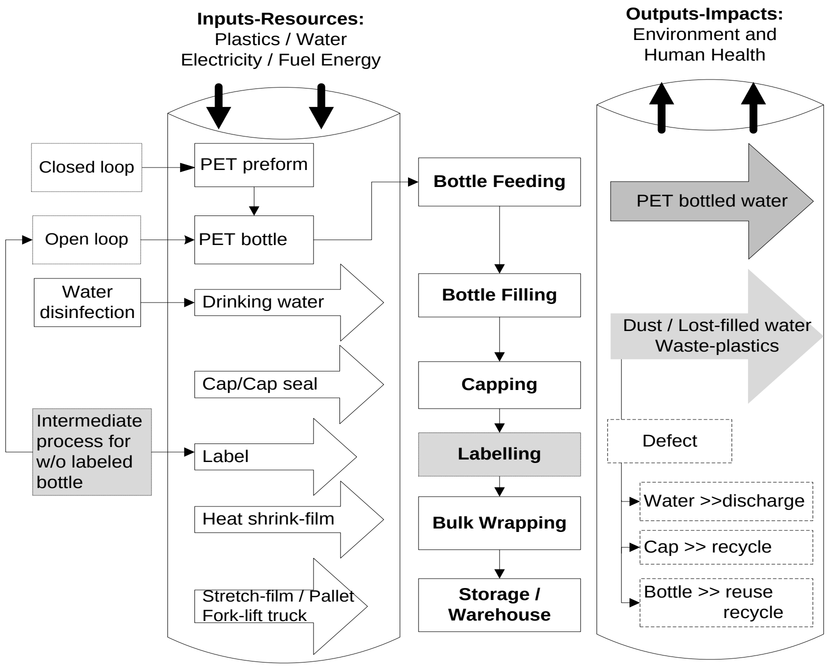

Figure 3. Bottling system of PET-bottled drinking water

2.2 Life Cycle Thinking

2.2.1 Life cycle inventory (LCI). Referring to ISO 14040[1] and 14044[2] principles, a product life cycle assessment included four interactive steps [13]. The first phase was to specify goals and scope of study so that system boundaries could be designated for application and a so-called functional unit of studied object. The second phase represented a product LCI. In this stage, all input-output unit processes were quantified in accordance with a product system[51], to which the third phase was related for impact evaluation towards classification and characterization.

In other words, identifying impact categories was to explore the entire product's LCIs. For examples, impact category of global warming was related to inventory item of CO_2 while Cd (cadmium) and Pb (lead) inventories accounted for impact category of eco-toxicity, including human toxicity when exposed to toxic substances. Due to ISO 14042[3], steps of defining impact category, classification and characterization were mandatory whereas normalization and weighting steps were optional [52]. Finally, interpretation for the whole product's life cycle inventories was carried out so that focused goals and scopes were concluded.

LCI was, therefore, related to the compilation and quantification of input- output data regarding the environmental profile of a product [51]. Huber [50] mentioned that the production of one kg of PET resin generated 6 kg CO_2 eq., whereas the finding from Mardival et al. [42] was quite different. Their reported figure was equal to 4.93 kg CO_2 eq., including three liters of petroleum consumption that actually represented the inventories of both energy requirements and environmental emissions [53]. The amount of variation, which was over 5% could not value the representativeness of LCI data[39]. In most cases, the different method used to quantify the environmental profile of a product was considered as the limitations in the coverage of element flows for the product system, including technology coverage and the availability of reference data or system used as the baseline [20, 22, 54].

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[1] ISO 14040 (2006). Environmental management - Life cycle assessment - Principles and framework

[2] ISO 14044 (2006). Environmental management - Life cycle assessment - Requirements and guidelines

[3] ISO 14042 (2000 E). Environmental management - Life cycle assessment - Life cycle impact assessment

2.2.2 Life cycle management (LCM). The United Nations Intergovernmental Panel on Climate Change has addressed that a product life cycle management (LCM) was very close to a reduction of carbon and ecological footprints by minimizing socio-economic burdens and maximizing environmental value and sustainability.

Upon a linear basis, a product was developed, produced, distributed, consumed and disposed. LCM was an efficient tool for handling the impacts occurred from any stage in the entire product life cycle. Gironi and Piemonte [13] noted that assessing the impacts occurred from products or services, directly or indirectly, needed to evaluate the environmental profile that a product interacted with the environment from an initial stage of raw material extraction to material processing, product manufacture, use and reuse, and final destination with the alternatives of landfill, incineration and recycling. As results, LCM refered to a set of activities and processes consuming certain amount of material and energy while causing a series of transformations and releasing emissions of diverse natures [45]. Power [18] added that a product life cycle management helped in turning impact consequences into a product value chain.

The LCM was alternated to three perspectives: a cradle to gate, a cradle to grave, and a cradle to cradle [18, 19]. A cradle-to-gate LCM involved with the stages of material acquisition and manufacture as belonging to inputs and outputs from production operation in factory only. A cradle-to-grave LCM, which was an extension of the cradle-to-gate boundary, included the retail, the use and the end of the useful life of the product. When businesses possessed a partnership with customers and suppliers, they were implementing the LCM from a cradle of product to a grave by thinking about sustainable processes to access sources of raw materials, to deliver and dispose of products as well as to foster environmentally-friendly practices for end-of-life management. As with a cradle-to-grave framework, the logistics and transportation were inclusive factors to reach efficient use of fuel energy and CO_2 emission reduction in distribution management [4, 26]. On a cradle-to-cradle LCM, it required involvement with all stages in a product life cycle so that all wastes were sustainably disposed and recovered for starting a new product life cycle. As a whole, LCM was able to deliver change in the way businesses and consumers had a deal with products and services including the processes used to deliver and dispose of them [8, 18]. The holistic concept of LCM has been illustrated as in Figure 4, which was modified from the original contributions issued by DuPont [19] and Power [18].

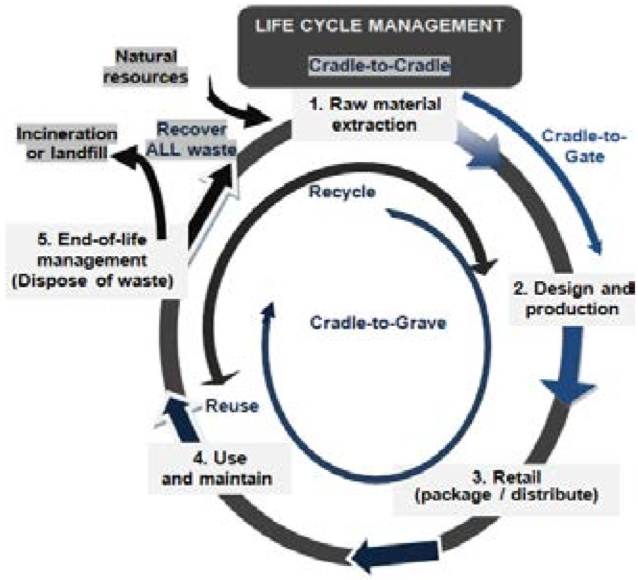

Figure 4. The holistic concept of product life cycle management from a cradle to a gate, to a grave and back to a cradle

2.3 Sustainable Consumption and Production (SCP)

2.3.1 Significances of SCP

As the world has been living beyond nature's carrying capacity, a driver of socio-economic growth on sustainable development must be strengthened by all means [17]. Barlow [14] expressed that sustainable development was needed due to the economic globalization through the unsustainable consumption and production pattern.

In 1987, the vision of sustainability was first referred to in *'Our Common Future'* (Bruntland Report) defining a sustainable development as a pathway to *'meet the needs of the present without compromising the ability of future generations to meet their own needs'* [55]. McKenzie-Mour [56] added that there had to be practical strategies to handle consequences from globalization. Humanities who lived in a finite world were eventually forced to adopt the sustainability issues, which has become a stronger and sensitive linkage between society, environment and economy growth. In 2002, all the nations facing the climate crisis agreed not only to develop a 10-year framework of the SCP programs (the Marrakech Process[4]), but also had the SCP addressed as a prerequisite for sustainable development [44]. With this regard, most definitions of SCP have been internationally discussed in many respects. In strategic view, SCP was a balanced and integrated manner to decouple economic growth from environmental degradation by adopting sustainable lifestyle [15]. SCP aimed to *'meet the rising demand for goods and services that are needed to sustain future livelihoods, while reducing the level of natural resources, GHG emissions, waste, pollutants and energy used or released over the lifecycle'* [4]. Raskin et al.[17] noted that sustainable practices in resource efficiency from less material consumption and less pollution have been universally addressing when environment lost capacity to continuously support the overexploitation placed upon it. In completing the SCP, four parties were involved: producer (business), consumer, government and other stakeholders like retail and distributer [4, 57]. Generally, the government played the role as a regulator either to deliver a top-down policy to the other concerns, to enforce the law and regulation, or to facilitate the treatments [4, 58]. Looking at a bottom-up dimension, the other three elements shared the key roles as belonging to supply side or demand side. A bottom-up SCP success was therefore related to responsible industrial development of supply side as well as a change to sustainable lifestyle, individual and institutional patterns of consumption, in demand side [4, 57].

There existed many empirical studies providing SCP application for such outcomes. To some extent, Liu et al. [5] conducted an interaction analysis (consumption and production life cycle) on sustainable development in China and revealed that consumer's demand for energy-intensive product was the driving force of pollutant emissions. Cellura et al [59] valued for the SCP in identifying impacts from households' consumption. Tukker et al [60] confirmed the essence of SCP as a better solution for impact management and sustainability objectives. Thamrongrat [61] created green production indexes coping with resource efficiency and pollutant emission reduction for sustainability in production and consumption domains. In particular, SCP was a basic driver of any economy and played an important role in shaping sustainability of economic growth. While the SCP was behind the accomplishment of sustainable development [4, 15], the LCM was one of the modalities that specifically challenged for improving impact reduction, environmental protection, and sustainability occurred over the entire life cycle of PET water bottle. As a consequence, Figure 5 was illustrated to show how the SCP could be reconciled with the LCM method for PET water bottle.

[4] The Marrakech Process is a global process leading by UNEP and UN DESA to support the elaboration of a 10-Year Framework of Programs (10YFP) on SCP according to Johannesburg Plan of Action in the World Summit on Sustainable Development (WSSD).

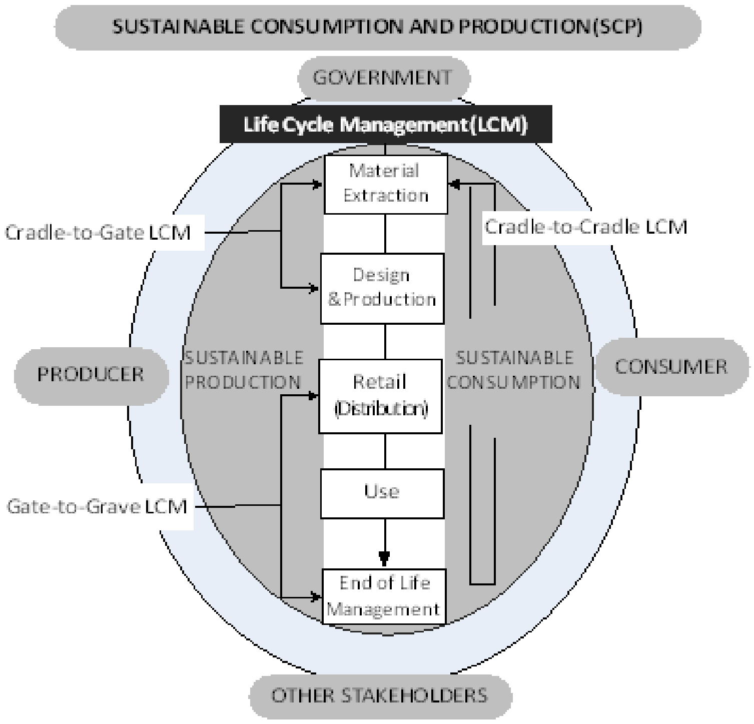

Figure 5. Integration of LCM perspective into the SCP implementation

2.3.1.1 Resource efficiency. All social and economic activity depended on the availability and use of natural resources [4]. Natural resources were extracted and transformed to provide goods and services for supporting the standard of living. To meet the SCP, practices in resource efficiency from less material consumption and less pollution were initially employed on an everyday basis [17]. In other words, the amount of resources that were consumed for a unit of product or service could be used more or less efficiently. It was evident that resource use has increased due to the growth of global population coupled with the advances of new technologies in many respects [2]. These were the primary drivers behind most environmental problems. UNDESA [15] pointed that when people used fewer resources and generate fewer emissions in meeting their demands for food production, transport, construction and housing and energy, they not only minimized natural resource consumption but also maximized its all benefits. Resource efficiency could be expressed as resource intensity, resource productivity, or even material and product flexibility, in relation to the domestic environment and import materials and goods [4]. Consequently, resource efficiency was possibly varied in less resource consumption by applying resource saving technology and utilizing all benefits. It also existed for lower risks in the face of resource scarcity, coupled with lower environmental cost, by minimizing wastes and pollution generation.

In relevance to efficiency implication placing emphasis on reducing resource consumption by increasing reuse, recycling and every recovery, Coelho et al.[41] proposed that the recycling system was more effective to waste-bottle management than did other recoveries. Recycled PET is considered valuable for a reduction of finite resource consumption, volume of landfills, including efficiencies in recapturing and reusing the energy and its raw materials [1, 12, 23]. Using recycled PET is essential for a new application of textile and non-woven product, as well as a million-ton reduction in virgin PET-resin consumption. On the other, a reach of resource efficiency often resulted in lower prices for materials and products. Thereby, efficiency would deliver growth in resource consumption and contradicted efforts to save resources for greater efficiency [4].

2.3.1.2 Impact reduction. Beyond a certain value of resource efficiency, a linkage to a reduction of environmental impacts was in proof [57]. There has been the widely-shared assumption that efficiency in material and product consumption delivered rebound effect to increasing demand for the goods that eventually needed a trade-off between resource efficiency and impact reduction targets. Impact prevention and reduction in the SCP approach was often discussed as a component of resource consumption practices [4, 15]. It involved the use of resources and processes that were able to eliminate pollutants and wastes generation both at the source and within their use [4, 57, 62, 63]. Environmental impacts and human health risk would decrease when business sector became more practical for clean technologies in producing goods and services, whereas societies were aware of the precedent consumerist-lifestyle. People could lessen the environmental and human health impacts caused by several factors, including natural events as well as human activities those involving with procedures in producing and consuming goods and services [15]. In conclusion, the SCP has been directly responsible for preventing natural resource depletion and decreasing potential impacts from GHG emissions, pollutants and wastes generation, including energy used or released over the life cycle of goods and services.

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2.3.2 Sustainable production (SP). SP was an element of SCP and directly related to the business sector. It implied the relevant operations of raw material extraction, production, manufacture and distribution including technological innovation and improvement of production processes [1]. SP helps in reducing unnecessary resource depletion and ensuring sufficient profit as well as creating social value with the LCM essence on production, marketing and distribution aspects [18, 64, 65]. In production operation, either product design or market choice service was valued for increasing business sustainability [18]. When efficiency in material use and waste and pollution control were engaged in product and process development, business could rest assured of achieving an SP [16]. In case businesses go beyond a product value chain to sustainability objectives, they have a viable solution for reducing environmental disruption and compromising economic and social value at the same time [18]. This included using marketing campaign for raising consumer's awareness of sustainable consumption and the removal of unsustainable goods and service from the market [1, 66]. Hence, the SP was possibly improved in various respects. Among the issues of sustainability in production cycle were the LCM, 3 R's principle (reduce, reuse, recycle), eco-design, social responsibility and so on.

2.3.2.1 3 R. According to Ida [67] and Zhang and Kimura [12], 3 R's principle represents three great ways: reduce, reuse, recycle, used for waste elimination and environmental protection. While *'reducing waste saves both materials and energy, and removes the need and expense of disposal'*, re-using can save new material and product consumption. And *'recycling saves valuable raw materials, and cuts down waste collection and disposal costs'* [68]. The 3 R was also referred to in the Marrakech Process as a means to achieve the 10-Year Framework on SCP programs.

2.3.2.2 Eco-design. Besides the LCM and the 3 R, many new practices have been initiated to foster sustainable production achievement. In view of the results of Akenji and Bengtsson [64], use of eco-design for packaging harmonization across brands was able to enhance sustainability in waste reduction and resource efficiency. Ramani et al [63] addressed that design for environment was not only potential for taking up life cycle environmental impacts of a product but also enabled business opportunities. As in Blackburn and Peters [66], Veshagh and Obagun [69], product development, essentially consisting of product and process, was a practice involving new design, manufacturing technology improvement and process planning, with environmental considerations.

2.3.2.3 Corporate social responsibility (CSR). Blaauwbroek [65] added that CSR was substantial to companies that valued sustainability. Consistent with Seri's [70] statement, integration of consumer perceptions with social agenda was at the forefront of CSR implementation resulting in building the corporate image and brand recognition coupled with society's expectations. Thus, CSR had profound implications for business sustainability and became a framework to justify as to how businesses responded to environmental issues [71].

One last thing, the SP practice could be incorporated to business policies, plans, projects and activities that were initiated and presented with concern to both business opportunities and environmental issues.

2.3.3 Sustainable consumption. Sustainable consumption (SC) , a parallel path to complete the SCP, was compared to a set of sustainable lifestyles that refered to the question of how important changes were in individual behavior [72, 73]. In order to attain an SC, Cai et al [72] proposed that economic and humanistic values in a social system had to converge with environmental aspect, so did Flor's statement [62] addressing that environmental protection and management were based on bio-geophysics, social analysis and social action. Raskin et al [17] also noted that daily behavior were mediated by consumption practice that eventually impacted on emissions, energy and water use, and waste produced [40, 41]. Shortly, ESCAP [2] defined the specific term of adopting the SC that it resulted in reduced material and energy intensity per unit of functional utility.

In contemporary society, SC practice needed people participation in adjusting their lifestyle towards low-carbon pattern, coupled with efficient use of products or services with an environmental protectionism and prevention on waste and pollutant emissions [74, 75]. Moreover, Harris [74] noted that this challenge was constructing a new kind of consumers' relationship with the public realm. As with the notification, consumers generally behaved to satisfy the opportunity to consume and the sense of fulfillment and satisfaction upon the experience of social life. McKenzie-Mour [24] summarized that changes in behavior not only directly affected our progress toward sustainability, but they also represented as to how people view themselves. Eventually, consumption pattern was based on the degree to which the market economy has shaped the surroundings and eventually our lives.

Whenever consumers relished their freedom on consumption, they were entering to a state of hyper consumption in which consumption absorbed and integrated more and more spheres of social life for their own pleasure [3, 76]. Wilkins [44] and the Asia-Pacific Economic Cooperation Center [77] also revealed that human activities were demanding nature's resources and producing GHGs at a faster rate than nature regenerated and reabsorbed. Wilasinee [78] concluded that consumption was not simply about the act of purchase but was rather a thoroughly cultural phenomenon that served to legitimate capitalism on an everyday basis.

When asked to rank what was most important to young people aged 5-18 from ten countries worldwide, they ranked watching TV and playing computer games first at 40%. The choice of saving environment was least chosen at only 4 percent [79]. Nevertheless, Flor [62] believed that a sense of responsibility to care, protect and enhance environmental quality has being concerted to people in this decade. Schafer and Herde [80] stressed that unsustainable consumption resulted not only in environmental crisis but also human risk on health security.

Consequently, the role of human factors in bringing about environmental change directly involved with the SC.

2.4 Environmental Awareness

In psychological view, the stages of covert and overt activities and experiences that individuals engaged in their behavioral patterns were conceptualized for an interplayed set of thought and action [81]. Humanities were actually shaped their lives on social action with various factors, including the external influences of norms and values [2, 56] because they wanted to be inside the mainstream behavior [82]. Archom [83] noted that most Thai consumers have not been aware of performing the SCP in their lifestyle. It was however increasingly apparent that consumption pattern in consumerist lifestyle has become one of significant causes of negative environmental, social and economic impacts [56, 62, 84, 85]. According to Raskin et al [17], the experience of social life and the pursuit of pleasure eventually constrained a wider recognition of sustainable lifestyle, which should be reconciled with the ultimate goals on sustainable development.

Shobeiri [86] noted that the desirable actions for environmental protection were dependent to environmental awareness-raising. Similarly, Larijani [75] proposed that level of environmental awareness resulted in actionable resilience against motivational factors. ESCAP [4] addressed that environmental education was a key component to raise public awareness of, and constructive contribution to, sustainability, especially in the SCP practice. UN DESA [15] also considered environmental education most effective to ensure better quality of life when unsustainable consumption and production pattern stood out in public realm. In other words, environmental awareness was becoming a powerful catalyst to transform consumption and production pattern to a more sustainable future [87].

Goldbach [88] proposed that environmental awareness included the understanding and knowledge of causes and solutions regarding environmental issues. Larijani [75] added that the more people had education and information, the more they could account for environmental protection and a change in behavioral perception. When person's actions were expressed with the intention to environmental protection, it represented a linkage of individually-environmental behavior between areas of action and the readiness to act [81, 88]. These were possibly relevant to the institutional attributes to social responsibility in terms of action plan, projects and activities [89]. In addition to psychological discipline, a conceptual form of human behavior was linked between perception and action. The gap between bodily action and mental action resulted in the same conclusion that consumer behavior was the interplay of awareness and action against attitude gap[90].

CHAPTER III

METHODOLOGY

Besides the literature reviews, data sources and instruments used in this research are brief as in Table 1.

Table 1. Sources of Inventory Data for the analysis of SCP Implementation (Single-Serve Size of PET Water Bottle)

Life cycle	Life cycle inventory (LCi)	Type of data	Sources
Production	PET bottle	- Secondary	Literature-based data from SimaPro 7.1 with the method of CML 2 baseline 2000 V2.03 World 1995: - LCI of virgin PET bottle* - LCI of recycled PET bottle**
		- Empirical	Tested scenario of a mix-ratio parameter based on the literature LCI of virgin and recycled PET bottle, with the SimaPro 7.1
	Bottling system	Primary	Plants visits and in-depth interview with survey transcripts
Consumption	- Use of PET-bottled drinking water - Disposal of post-used bottles	Primary	Analytical statistics with a set of questionnaire

Remark: * and ** were the LCI values in SimaPro 7.1 database, those available for the National Metal and Materials Technology Center (MTEC) [51].

[5] SimaPro 7.1 is the software developed by PRé Consultants as the tool for a product life cycle assessment (LCA) through the phase of LCI. It includes several inventory databases, which involve the compilation and quantification of inputs and outputs for a given product systems throughout its life cycle, plus various impact assessment methods, e.g. Eco-indicator, CML (Center of Environmental Science of Leiden University) [91]. More information about the SimaPro system was explained in an appendix A[92].

3.1 Potential Impacts from PET Bottle

In identifying potential impacts from PET bottle, the reference LCI values of virgin PET bottle and recycled PET bottle were used for a tested scenario. The test was created against PET resin quality in three parameters: virgin PET resin, half-by-half between virgin and recycled resin, and 100% recycled PET resin, with functional unit of 1 kg of 500 mL single-serve bottle.

The method of CML 2 baseline 2000 V2.03 for the life cycle assessment was used to interpret LCI of PET bottle in a mix-ratio parameter, with the SimaPro software supported by the National Metal and Materials Technology Center (MTEC). Global warming potential (GWP) was expressed as kg CO_2 eq. inventory while contamination of para-dichlorobenzene (1,4-DB) substance in fresh water aquatic, marine aquatic and terrestrial ecology was translated to inventory data of eco-toxicity and human toxicity. The empirical results for the specified impact categories were presented in a table format as below.

Table 2. Scenario of Potential Impacts for the Life Cycle Inventory of PET Bottle

Parameters (% of quality PET resin)	**Impact sensitivity**					
Functional unit	1 kg of 500 mL-PET bottle					
Impact categories	GWP	Eco-toxicity				Human-toxicity
Inventory item [1]	Kg CO_2 eq.	Kg 1,4-DB eq.				Kg 1,4-DB eq.
		Fresh water aquatic	*Marine aquatic*	*Terrestrial*	Total	
Virgin PET [2]						
Virgin + Recycled 50:50 (%)						
Recycled-PET [3]						

Remarks: [1] Inventory item follows the characterization referred to in the model of CML method baseline 2000 V2.03

[2] and [3] refer to the LCI values in SimaPro 7.1 database, those corresponding to the study approach

3.2 Producer's Performances in Sustainable Production

3.2.1 Population and sampling. Bottling plants located in the scoped areas, were chosen by purposive sampling method. Samples were taken from four top brands that captured approximately 65% of the market in Thailand (Crystal, Namthip, Purelife, Singha) [24, 26], and four house brands that represented the remaining 35% of the market. Due to academic and confidentiality reasons, company title of the house brands was not indicated in this study. The abbreviations T and H designated the top and house brands, respectively. Key informants included policy-makers, engineers, technicians, and those concerning to environmental issues and product development.

3.2.2 Instruments. In-depth interviews and plant visits with survey transcripts, as appearing in an appendix A, were conducted to identify the producer's performances in the SP, with two measures; resource efficiency and impact reduction. The performances were organized to four categories: CSR, eco-design, 3 R and LCM. A default value of one was assigned to each achievement by categories. A number, the percentage and a five-point scale were computed in relation to the equation of the Rule of Three. Determination of five scales started from lowest, low, medium, high and highest [93]. Treatment to the computed data according to the equations was organized as appearing in Table 3, followed by list of definitions.

Table 3. Calculation for Producer Data in the SP by Measures, Categories and Brands

Measures [Amount]	Categories		Achievement					
			Number			% & Scale value (level)		
			T	H	T + H	T	H	T+ H
(A) - RE Resource efficiency	CSR Eco-design 3 R LCM	[XX]* [XX] [XX] [XX]	TCi	HCi	THCi	The Rule of Three		
			RET	REH	RETH			
(B) - IM Impact reduction	CSR Eco-design 3 R LCM	[XX] [XX] [XX] [XX]	TCi'	HCi'	THCi'	The Rule of Three		
			IMT	IMH	IMTH			
(C) - SP Resource efficiency + Impact reduction	CSR Eco-design 3 R LCM	[XX] [XX] [XX] [XX]	TCi"	HCi"	THCi"	The Rule of Three		
			SPT	SPH	SPTH			

Remark: [XX]* represents the amount of approaches per category.

<u>**List of definitions**</u>

RE	= performances in resource efficiency measure	
IM	= performances in impact reduction measure	
SP	= performances in RE and IM	
T	= four T-brands	
H	= four H-brands	
TH	= combined performance of T and H	
C_i	= results of performances in RE	
Ci’	= results of performances in IM	
Ci”	= results of performances in SP	
i	= four categories:	1 = CSR
		2 = Eco-design
		3 = 3 R
		4 = LCM

3.3 Consumer’s Performances in Sustainable Consumption

Inventories data of consumption life cycle of PET water bottle were viewed through consumer’s performances in degree of agreement against the measures.

3.3.1 Population and sampling. Sample size was based on population data in Bangkok Metropolitan Region as in an appendix C, together with Yamane formula of sampling method [94] as in an appendix D. From these appendices, if we choose significance level of ±5%, at population over 100,000 units, the sample size is represented by four hundred respondents. A stratified random sampling was used to classify the samples into two strata. The first stratum referred to two hundred people working in the organizations or studying in the institutes located in certain Bangkok and the vicinities. The other included two hundred visitors to tourist destinations and shopping malls in the scoped areas. These two sample groups were assumed as the likely consumer of PET water bottle.

For the stratum of students and working man samples, the research organized data collection based on the main roads of scoped areas those including Sathorn, Phaya-thai, Phra Nakhon and Vibhavadi for Bangkok, Phahonyothin for Pathumthani, Pakkred-Chaengwattna for Nonthaburi, Petchkasem for Nakhon Pathom, Bangna-Bangplee for Samut Prakarn and Bang Khun Thian for Samut Sakhon. Thirty sets of questionnaire were delivered to the facilitator in the places located on the indicated roads.

The tourist destinations and shopping malls were arranged as following;

a) Bangkok – Grand Palace, Central World

b) Phathumthani – Dream world, Future Park-Rangsit

c) Nonthaburi – Koh Kred

d) Nakhon Pathom – Don Wai Floating market,

e) Samut Prakarn – Bangpoo resort

f) Samut Sakhon – Wat Tha Mai, Mahachai market

Then, simple random sampling was applied for data collection. The response rates of four hundred sets were targeted. Any invalid and wasted responses were replaced, accordingly.

3.3.2 Instruments and data treatment. A set of closed-ended questions, as in an appendix E, was divided to three parts. The first part was devoted to demographic data. The second part coped with the sample's practices and opinion to drinking water consumption. The rest was based on twenty choices of attitude test against degree of agreement so that the research could identify how and how much of which measure, between resource efficiency and impact reduction, influenced the consumer's performances in the SC.

Collective data of the first-two parts were distributed in a number and the percentage. The answers in the third part were computed by the mean and the standard deviation (S.D.) to interpret value of agreeable degree and level determination. The analytical statistics of one-way ANOVA (analysis of variance) was included to identify a correlation of demographic and drinking water consumption to the SC data. Statistics of the t-test and the F-test were applied for hypothesis test of 95% significance.

Similar to the five-point scale used in the SP section, frequency distribution between the intervals was organized with the value of 0.8 based on the formula of range calculation. The five ratings for the degree of agreement can be expressed as shown in Table 4.

Table 4. Range Value of Five-Point Scale for Level Determination and Degree of Agreement

Level	Range value [a]	Level determination [b]	Degree of agreement
5	4.21 - 5.00	Highest	Strongly agree
4	3.41 - 4.20	High	Agree
3	2.61 - 3.40	Medium	No idea
2	1.81 - 2.60	Low	Disagree
1	1.00 - 1.80	Lowest	Strongly disagree

Remarks: [a] and [b] were based on range calculation of a five-point scale method [93, 95].

3.3.3 Consistency of questions

3.3.3.1 Content validity. To ensure consistency of rating questions in the third part, the content validity was justified by reviewing literatures regarding PET water bottle, resource efficiency, impact reduction and environmental awareness. Furthermore, the expert agreement was used to address the adequacy and representativeness, which brought about item editing.

3.3.3.2 Reliability analysis. After finishing content validity, a pre-test was developed with the scale-Alpha reliability [95] to thirty-five samples. The value of reliability analysis was equal to 0.7389 and 0.7031 separated for resource efficiency and impact reduction measures, respectively. The reliability results appear in an appendix F.

3.4 SCP of PET Water Bottle

Finally, the research used the five-point scale, coupled with a matrix format to identify the SCP success. A breakdown of the SP and the SC was arranged in four matrix boxes those covering the different interaction between consumption and production pattern.

The Low-Low box designated the same low values of SP and SC, for which the improvement was required for both aspects. The Low-High and High-Low boxes represented the different attribute between the SP and the SC. The High-High feature was estimated for the ultimate goal of SCP implementation. The outcome of how the production interacts with the consumption in SCP paradigm was illustrated as in Figure 6.

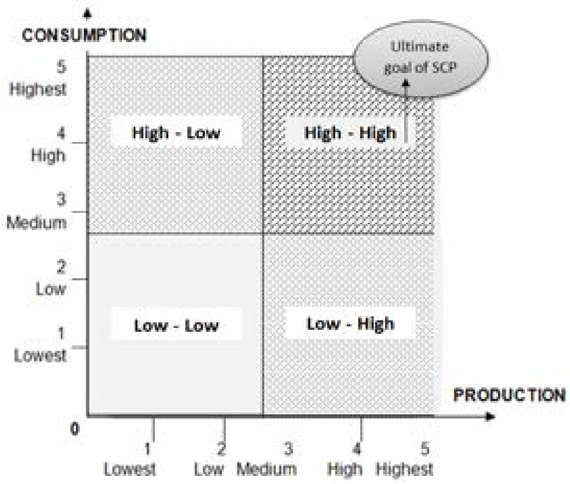

Figure 6. The outcome of SCP implementation in matrix format associated with the interaction of production and consumption pattern

CHAPTER IV

RESULTS & DISCUSSION

This chapter involves analysis and interpretation of collective data in accordance with research questions. The findings cover the potential impacts of PET bottle from tested scenario, the SP accounted by the producers, the SC from the consumers' view and the SCP accomplishment as belonging to the results of SP and SC.

4.1 Impact Sensitivity of PET Bottle

The test reveals that scenario of virgin PET is least responsible for all impact categories: global warming (0.0494 kg CO_2 eq.), eco-toxicity (11.5368 kg 1,4-DB eq.) and human-toxicity (0.0088 kg 1,4-DB eq.). The majority of the eco-toxicity comes from marine aquatic source. The mix ratio of 50%-virgin PET to 50%-recycled PET is most likely to impact both eco-toxicity (675.5046 kg 1,4-DB eq.) and human-toxicity (0.9852 kg 1,4-DB eq.). The recycled PET resin mostly generates global warming impact (2.8108 kg CO_2 eq.). Thus, producing PET bottle with virgin resin delivers better results in impact reduction on every category as drawn in Table 5 and illustrated in Figure 7.

Table 5. Potential Impacts of PET 500 mL Bottle Based on Content Ratio of Resin Quality

Parameters (% of quality PET resin)	**Impact sensitivity**					
Functional unit	1 kg of 500 mL-PET bottle					
Impact categories	GWP	Eco-toxicity				Human-toxicity
Inventory item	Kg CO_2 eq.	Kg 1,4-DB eq.				Kg 1,4-DB eq.
		Fresh water aquatic	*Marine aquatic*	*Terrestrial*	Total	
Virgin PET	0.0494	*0.0014*	*11.5351*	*0.0003*	11.5368	0.0088
Virgin + Recycled 50:50 (%)	2.7364	*0.0962*	*675.3979*	*0.0105*	675.5046	0.9852
Recycled PET	2.8108	*0.0033*	*544.8582*	*0.0022*	544.8637	0.9210

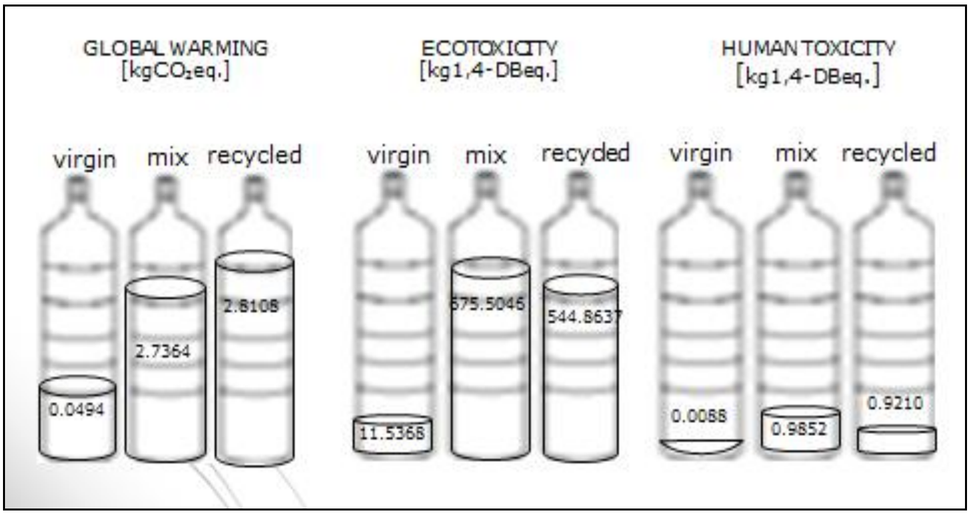

Figure 7. Potential impacts from virgin, mix and recycled PET bottle for global warming, eco-toxicity and human toxicity

Regarding the lower environmental profile from the virgin PET bottle found in the test result, it should be noted that much of the fossil fuel used in the PET bottle is from feedstock energy, which is bound within the product[39]. Included is the factor of source of CO_2 emission from the process energy, transportation and non-process emissions associated with material management options. The multiple-recycling trips (the useful number of lives of the material) for the recycled PET are therefore related to the LCIs of fuel energy, including electrical energy, for processing operation and GHG emissions [20, 41, 43]. Among the factors are the numbers of collection, sorting and reprocessing steps those are not required for the initial use of virgin PET [54, 96]. Either is the coverage on PET recycling method; mechanical or chemical. In chemical process, the impact LCIs can be varied in which the type of de-polymerization is applied for the desired product-yield [37]. Limitations may also exist for the unit process system approach (characterization factor for LCI calculation) and the mix ratio [42, 51, 53]. Based on FAL[20], LCI data which varies within five percent, it is not considered significantly different.

According to Shen et al. [43] and Zhang and Kimura [12], the PET recycling system is more consistent with the new application than with the bottle application, which is chemically recycled. As such, either virgin PET bottle or recycled PET bottle is actually concurrent to a trade-off between impact reduction and resource efficiency.

4.2 Sustainable Production for PET Water Bottle

4.2.1 Resource efficiency. As in part A of Table 6 and in Table 7, most producers highly account for resource efficiency measure (70.61%, level 4), with 33 evidences from a total of 53 performances. To meet the measure, LCM is the most preferable choice (37.57%), followed by 3 R (30.05%) while CSR is the contrary (5.78%). The T brands better facilitate resource efficiency measure, with 92 achievements (53.18%), than does the H belonging to 81 achievements (46.82%).

Table 6. Producer's Performances in Sustainable Production of PET Water Bottle

Measures	Categories	Achievement					
		Number			% & Scale value (level)		
		T	H	T + H	T	H	T+ H
(A) Resource efficiency	CSR [4]	9	1	10	9.78	1.23	5.78
	Eco-design [7]	23	23	46	25.00	28.40	26.60
	3 R [11]	25	27	52	27.17	33.33	30.05
	LCM [11]	35	30	65	38.05	37.04	37.57
		92	81	173	53.18	46.82	70.61
		Scale value (Level)			*2.66 (3)*	*2.34 (2)*	*3.53(4)*
(B) Impact reduction	CSR [7]	13	4	17	28.89	14.82	23.61
	Eco-design [2]	5	3	8	11.11	11.11	11.11
	3 R [3]	4	2	6	8.89	7.40	8.33
	LCM [8]	23	18	41	51.11	66.67	56.95
		45	27	72	62.50	37.50	29.39
		Scale value (Level)			*3.12 (3)*	*1.88 (2)*	*1.47(1)*
(C) Resource efficiency & Impact reduction	CSR [11]	22	5	27	16.05	4.63	11.02
	Eco-design [9]	28	26	54	20.44	24.08	22.05
	3 R [14]	29	29	58	21.16	26.85	23.67
	LCM [19]	58	48	106	42.35	44.44	43.26
		137	108	245	55.92	44.08	57.78
		Scale value (Level)			*2.80 (3)*	*2.20 (2)*	*2.89 (3)*

Remark: The figure in parentheses [XX] represents the amount of approach per category.

Table 7. Producer's Performances in Resource Efficiency by Categories

Measure: Resource Efficiency	Achievement		
	T	H	T+H
CSR [4]	**9**	**1**	**10**
1. Apply for the Islamic Committee Office of Thailand to facilitate special expectation	2	0	2
2. Campaign for sustainable use of water resource	3	0	3
3. Implementation of measures of social responsibility according to ISO 26000 standard	2	0	2
4. Funding for project of waste-to-energy	2	1	3
Eco-design [7]	**23**	**23**	**46**
1. Narrow cap-width from 32 to 28 mm.	4	4	8
2. Develop thinner-wall bottle	4	3	7
3. Invest in bottle-mold design to reduce cause of bottle defects	4	3	7
4. Design in process planning for production optimization	4	2	6
5. Design in bundle packing for multi-layer stacking for loading efficiency (from 1,728 bottles to 2,016 bottles per pallet and from 13,824 bottles to 16,128 bottles per 6-wheel truck)	3	4	7
6. Increase toughness of bottom part for defect reduction in stacking and storage processes	3	4	7
7. Re-design processes of labeling and cap wrapping for productivity-based production	1	3	4
3 R [11]	**25**	**27**	**52**
1. Re-circulate the lost water to chilling system	4	4	8
2. Select proper material and machine function for defect reduction and machine optimizatior	4	4	8
3. Develop short-neck bottle with 10-12 mm height for bottle and cap	4	4	8
4. Limitation of bottle weight within 17-17.5 gram	3	4	7
5. Invest in closed-loop process for saving 30% of the lost water compared to the open loop	3	1	4
6. Use hi-speed blower, instead of drinking water for cleaning the inside of bottle	3	1	4
7. Use common bottle-shape for reduction of time and pre-processing materials consumption	1	4	5
8. Adjust defective bottles for refilling	1	4	5
9. Develop lighter-weight bottle (12-13 grams) for saving 35% of plastic	1	0	1
10. Implementation of Green dimension with 3 R's principle	1	0	1
11. Recycle in-house plastics scrap for new application	0	1	1
LCM [11]	**35**	**30**	**65**
1. Use common cap for all shapes and sizes of bottle for efficient use (material extraction)	4	4	8
2. Limitation of process-wastes of pre-form and bottle within 0.2% (production)	4	4	8
3. Use multi-layer stacking to decrease trip of distribution for (retail)	4	4	8
4. Limitation of fuel energy cost at Baht 0.25 per bottle (0.01 USD; retail)	4	4	8
5. Minimize distribution cost to Baht 0.50 per bottle (0.02 USD; retail)	4	4	8
6. Limitation of electricity cost at Baht 0.50 per bottle (0.02 USD; production)	3	4	7
7. Develop supply-chain management for PET pre-form and bottle (material extraction)	3	2	6
8. Improve cycle time in filling step down to 0.3-0.4 seconds per bottle (production)	3	1	4
9. Avail of multi-size bottles for efficient use (use)	3	1	4
10. Implementation of multi-plant policy for material allocation and product distribution (material extraction, retail)	3	0	3
11. Value for cross business of plastics molding and bottled water	0	2	2

4.2.1.1 CSR. It is evident that only one performance in CSR domain is accounted by the H brands; *apply for the Islamic Committee Office of Thailand to facilitate special expectation*. Additionally, the T brands have the CSR taken in various manners amounting to 9 achievements. Among these are *campaigning for sustainable use of water resource,* implementing *social responsibility according to ISO 26000* and *funding for project of turning waste-PET bottles to energy*.

4.2.1.2 Eco-design. The T and the H evenly use eco-design for improving efficiency in resource consumption, with 23 achievements for each. They do the same at *narrowing cap width from 32 to 28 mm for reduced use of plastics.* The breakdown of following performances regarding eco-design between the T and the H has no significant difference. These include *development of thinner-wall bottle, investment in bottle-mold design to reduce cause of bottle defects, designed process planning for production optimization, design for multi-layer stacking for loading efficiency (from 1,728 bottles to 2,016 bottles per pallet and from 13,824 bottles to 16,128 bottles per 6-wheel truck)* and *increasing toughness of bottle-bottom part.* One last thing, which is much more common to most of the H brands, than do the T, is consistent with a *process-design of labeling and cap/closure wrapping for productivity-based production.* This is most found for the H brands that operate the open loop and get flexible for mobile production of labeling and cap sealing. On the contrary, it is obvious that the closed loop, which needs an optimized design in space and machine flow is not concurrent to the H those investing in bottled-water business at small and medium scale.

4.2.1.3 3 R. Both the T and the H are likely to employ the similar approaches for 3 R, such as *recirculation of lost-filled water to chilling system, selection of proper material and machine function for defect reduction and machine optimization, development of short-neck bottle with the height of 10-12 mm for reduced use of plastics in bottle and cap* and *limitation of bottle weight within 17-17.5 gram.*

Additionally, nearly all T brands and some house brands those investing in the closed-loop process have benefit on saving 30% of the water in bottle filling compared to the open-loop. The close loop also allows *using hi-speed blower, instead of drinking water for cleaning the inside of bottle*. Corresponding to the H brands' efficiency in 3 R, these exist for *using a common bottle-shape for reduction of time and pre-processing materials consumption, adjusting defective bottles for returnable use* and the endeavor of *recycling in-house plastics scrap for new application*, which is neither developed nor invested by any T brands. On the other, the innovation of squeezed bottle, which leads to a lighter-weight bottle (12-13 grams) for saving 35% of plastic, is neither attractive to the H nor feasible for the other three top-brands. It requires additional investment in nitrogen feeding to fulfill these special bottles. Moreover, a T-brand strengthens the mission to 3 R with the Green dimension that is the umbrella of 3 R.

4.2.1.4 LCM. The T's and the H's performances in using LCM for resource efficiency tend to a cradle-to-gate domain, with the emphasis on factory only. Among these are *common cap for all shapes and sizes, limitation of process-wastes of pre-forms and bottles within 0.2%, limitation of electricity cost at Baht 0.50 per bottle (0.02 USD), and of fuel energy cost at Baht 0.25 per bottle (0.01 USD), improvement of cycle time in filling step down to 0.3-0.4 seconds per bottle* and *making supply-chain management for PET pre-forms and bottles materials.* In most cases, the attempts on a cradle-to-grave boundary are devoted to the retail and the use cycles, for examples, *using multi-layer stacking to decrease trips of distribution* (retail)*, minimizing distribution cost to Baht 0.50 per bottle (0.02 USD*; retail)*, the avail of multi-size bottles for efficient use* (use) and *implementation of multi-plant policy for efficiency in material allocation and product distribution* (retail). It is interesting that a multi-plant policy is possible for only the T to make reach of a cradle-to-grave LCM. Meanwhile, advantage of cross-sector businesses between plastics field and bottled water is truly in evidence of the H.

Plastics. It is noted with regard to the results that the producers account for consumption efficiency in plastics resource over the water though both are two major materials for PET bottled water. Nevertheless, Amano and Ness [6] and Coelho et al.[45] noted that logistics and transportation were related to efficiency in utility consumption, as well as impact generation. The multi-plant policy and truck-loaded management are used throughout Thailand for manufacturers that prioritize cost reduction over impact reduction from reduced consumption of electricity and fuel.

In the bottled-water business, efficiency in plastics consumption mostly begins with a lighter-weight bottle [48, 97]. Usually, a bottle with thinner walls, a shorter neck and a narrow cap reduces PET-plastic consumption. There exist many attempts on a cradle-to-gate LCM for plastics consumption; either by reducing use of plastics or a limitation of reduced defects. Accordingly, the bottlers exclude any reuse and recycling of the process-waste plastic for new application. As PET properties, the scraps can be recycled for a new application (B-T-A) including new bottles (B-T-B). The success in recovering waste-PET bottles to the B-T-A and B-T-B applications, including turning to energy source are in evidence with the advances of recycling technology [16, 98]. It is however apparent that a huge demand for PET-bottle scraps can distort the bottlers' interest in renewable PET technology. PET is thus less frequently recycled among Thai bottlers, with remarking on the relevant laws and regulations prohibiting use of recycled plastics for food packaging. Normal practice among the bottlers in Thailand is to sell them to recycling agents since these flakes are mostly required for export market in China and India [23].

Moreover, the bottling process affects the efficient use of plastics resource. The open loop is generally worthwhile for the brands familiar with plastic injection and blow-molding production. They can utilize their knowledge and skills to establish a cross-sector business regarding plastics injection and blow-molding and bottled-water manufacturing service.

Water. Generally, bottled-water businesses capture the water from artesian wells, with a fee paid to the office of municipal affairs or to the Ministry of Natural Resources and Environment at US$ 0.40-0.50 per cubic meter. Due to the low cost of water resource, the efficiency is not their major concern. The producers using the open-loop bottling system should be aware of the substantial waste of drinkable water, which can reach 30-35%, which can be reduced through the closed-loop process. However, it would be inconceivable for thousands of the house brands to switch to a closed-loop system. As continuity of water supply is the necessity, tap water is an option providing insurance against shortages, as does a reserve of underground water that should supply the companies for approximately 5 years. However, a water conflict in Rayong province between agricultural sector and petrochemical industry [99] during the hot season in 2005 was the most-likely case for bottled-water businesses to shift to a more sustainable use of water resource.

4.2.2 Impact reduction. Referring to part B of Table 6 coupled with Table 8, the research reveals that the bottlers' contribution to the impact reduction is at the lowest level (29.39%; level 1), with 72 achievements separated to 45 and 28 units for the T and the H, respectively. The H account for less of the impact reduction than do the T (37.50%; level 2 v. 62.50%, level 3).

4.2.2.1 CSR. It is obvious that adoption of international and national references is somewhat referred to in CSR application. Almost all T brands, coupled with some of the H, apply for the ISO (International Standards Organization) for *environmental management (ISO 14001)* and *a food safety (ISO 22000).* Most activities are out of the H brands' interest, such as *construction of water basins in historic drought-areas, arranging waste-bottle bank,* and *competition to the Best Factory Award (food product)* and *implementation of ISO 26000 (social responsibility).* However, the data shows that one in four H brands achieves in Green Industry Awards. Neither are the T brands.

Table 8. Producer's Performances in Impact Reduction by Categories

Measure: Impact Reduction	Achievement		
	T	H	T+H
CSR [7]	**13**	**4**	**17**
1. Implementation of environmental management according to ISO 14001	4	2	6
2. Implementation of a food safety according to ISO 22000	3	1	4
3. Implementation of measures of social responsibility according to ISO 26000	2	0	2
4. Provide water basins construction in historic drought-areas	2	0	2
5. Initiate waste-bottles bank to encourage public participation in sustainable waste management	1	0	1
6. Meet Best Factory Award (food product) for sanitation and health treatment of Ministry of Public Health	1	0	1
7. Meet Green Industry Awards for sustainability and environmentally-friendly production of Ministry of Industry	0	0	0
Eco-design [2]	**5**	**3**	**8**
1. Processing waste plastics and discharged water with eco-design in flow of machine operation	4	3	7
2. Develop green-bottle design (squeezed bottle) for ease of waste-bottle management	1	0	1
3 R [3]	**4**	**2**	**6**
1. Use electrometer and infrared light for dust and debris elimination instead of discharging to the air	3	1	4
2. Reduce landfill volume with squeezed bottles for solid waste management	1	0	1
3. Reduce GHGs emissions by using battery energy, instead of fuel oil, for forklift truck	0	1	1
LCM [8]	**23**	**18**	**41**
1. Separate collection of in-house waste plastic (production, end-of-life management)	4	4	8
2. Marking numeric symbol of plastic type to foster recycling (use, end-of-life management)	4	4	8
3. Indications of proper use (keep in cool dry place and away from direct sunlight) and disposal (do not litter post used-bottles) for health risk protection (use)	4	4	8
4. Implementation of quality management system according to ISO 9001 (material extraction, production)	4	3	7
5. Provide cap-seal wrapper to ensure health concern due to primary use (use)	3	3	6
6. Implementation of measures of food safety management according to the HACCP standard (production)	2	0	2
7. Implementation of the Water Quality Index according to the NSF international standard (use)	1	0	1
8. Develop green bottles (squeezed bottles) to foster reduction of landfill volume (end-of-life management)	1	0	1

4.2.2.2 Eco-design. It was found that the interest in using eco-design for reducing the impacts during the bottling operation is quite low (11.11%) as belonging to only two practices: *use eco-design in flow of machine operation for ease of process-waste management* and *green-bottle development (squeezed bottles).*

4.2.2.3 3 R. Both the T and the H are least likely to choose the 3 R for improving impact reduction (8.33%). To reduce pollutant emissions, it is solely possible for the bottlers that employ the close-loop bottling system to alternate *electrometer and infrared light for dust and debris elimination, instead of discharging to the air*. Innovation of squeezed bottle also allows a possibility for *reduction of landfill volume.* One of the H who *replaces use of fuel oil for forklift truck by battery energy can bring about GHG emissions reduction.*

4.2.2.4 LCM. The implication of LCM approached for the two measures is quite different. While a cradle-to-gate is more common to the resource efficiency, a cradle-to-grave LCM is most adopted to the impact reduction from the use and the end-of-life management cycles. Both brands equip for the grave LCM with the following performances. They similarly *separate collection of in-house waste plastics* (end-of-life management)*, mark numeric symbol of plastic type to foster recycling* (end-of-life management)*, indicate proper use (keep in cool dry place and away from direct sunlight) and disposal (do not litter post used-bottles*; use)*, and provide cap-seal wrapper to ensure health concern due to primary use* (use). Using the grave aspect, which are solely employed by each of the T, exist for *implementation of the Water Quality Index according to the NSF international standard* (use) and *green-bottles development (squeezed bottles*; end-of-life management*).* The attribute to green bottle is used for raising consumers' awareness of environmental protection. In case of the gate LCM, there exists for the implementations *of quality management system (ISO 9001)* and *HACCP (the Hazard Analysis and Critical Control Point International Standard)* in food safety management.

Plastics. Most impacts of PET water bottle derive from the waste bottles, especially on the ecological quality [23, 50]. The amount of PET plastics used in bottled-water businesses is quite interesting. The house brands consume PET resources amounting to 120 tons per month, while the leading brands approximate 400 tons, excluding the peak period in the hot season (when consumption reaches 500 tons per month) [23]. However, all producers assert that the bottling system generates no CO_2 emissions to the air, water and soil. They consider the closed-loop process a cleaner technology as it enables use of electrometers and infrared device for debris and dust elimination. For the open loop, outsourcing of PET-bottle manufacturing is an excuse to this subject. What should be taken into consideration is a priority of waste-to-energy application according to a legal constraint on using recycled material for food packaging, enforced by the Food and Drug Administration (Thailand), coupled with the threat of knowledge about recycling technology. This is concurrent to grow a cradle-to-grave LCM into PET-bottled water business. Moreover, the research would like to remark that if the CSR is largely reconciled with bottled water businesses, a cradle-to-grave LCM can foster sustainability target to a production and consumption pattern of PET water bottle.

Water. According to the World Bank (including the World Resource Institute), surface-water supplies and groundwater sources are highly vulnerable to depletion. Bottled-water manufacturing is the fastest-growing business and is simply established due to the low cost of water resources, which are mostly tap water [14]. The belief that the discharged drinking water is neither hazardous nor wastewater is not considered justified by those aware of the water crisis. Bottled water business is in need of sustainable paradigm as long as most bottling plants are located, in the watershed areas, in the provinces along the Chao Phraya River and its tributaries that can cause the profound impact on ecological system. Thus, the cradle-to-gate LCM for the underground-water extraction should be encompassed in the laws and regulations concerning PET water bottle.

4.2.3 Sustainable production. According to part C in Table 6 and Figure 8, the data shows that producers are engaged in the SP at medium level (57.78%; 2.89), with 245 achievements. Most producers favor the resource efficiency (70.61%) over the impact reduction (29.39%). It means the producers are least likely to deal with the impact reduction (level 1) but highly value for the resource efficiency (level 4). The T brands perform better in the SP (55.92%; level 3) while the H do less well (44.08%; level 2).

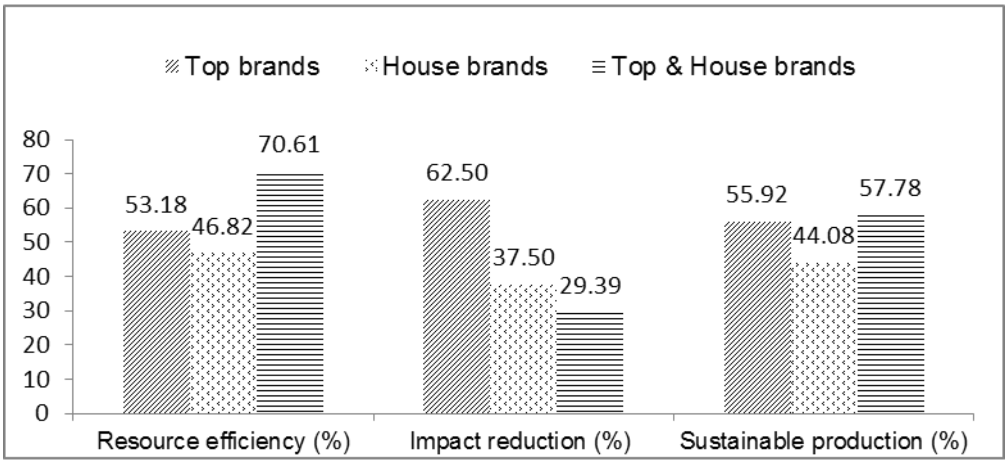

Figure 8. Comparative results between brands for resource efficiency, impact reduction and the SP

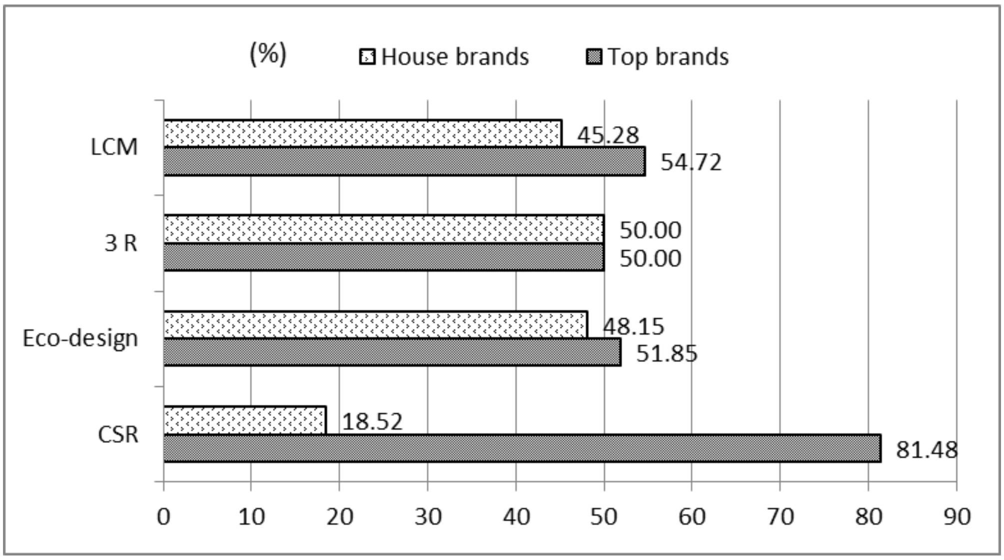

Figure 9. Results in the SP by category and brand comparison

It is apparent with regard to Figure 9 that the T brands' interest in the CSR is dramatically higher than do the H brands (81.48% v. 18.52%). The rest are taken into similar account. Almost every T brand has generated a large number of environmentally sound projects and activities supporting CSR, while they have been ignored by most H brands (22 approaches v. 5 approaches). In category comparison, LCM is most reconciled with the impact reduction measure (56.95%), followed by CSR (23.61%). The least option belongs to 3 R (8.33%).

The outcomes of CSR in bottled water business is better understood to companies that value sustainability. The T brands evidently incorporate the business plan into the social agenda. According to Power [18] and Thongchai [71], CSR can deliver a range of benefits, such as business opportunities, market penetration and, at the industry scale, a higher degree of cross-sector business. As results, the CSR is fruitful for building the corporate image and brand recognition, including consumer perceptions to the product [57, 70]. This is however a discrepancy for the H brands those referring to thousands of Thai bottled-water manufacturers, which generally do not value brand identification and corporate image [10, 26].

4.3 Sustainable Consumption for PET Water Bottle

The reader can take up with the results and discussion of this part by looking through the data shown in Table 9 describing the likely consumer and the attribute to drinking water consumption, and in Table 10 presenting consumer’s degree of agreement to the SC indicators.

Table 9. Majority Data of the Likely Consumer and Drinking Water Consumption

Items		Majority	
		N = 400	100%
I. **Demographic data** : the likely consumer			
1. Gender:	*female*	263	65.75
2. Age (year):	*26-35*	125	31.25
3. Career:	*working*	278	69.50
4. Income (baht / month):	*10,000 – 30,000*	195	48.75
5. Main vehicle used in daily life:	*own car*	154	38.50
II. **Drinking water consumption** : practice and opinion			
6. Amount of daily consumption (glass of water):	*6-8*	151	37.75
7. Daily purchasing amount of 500/550/600 ml bottled water:	*1-2 bottles*	237	59.25
8. Most influencing factor to buy PET bottled water:	*Convenient use and easy to carry*	160	40.00
9. Practice in working days when demanding drinking water:	*Buy PET bottled water*	287	71.75
10. Practice during travelling or shopping when demanding drinking water:	*Buy PET-bottled water along the journey*	319	79.50
11. Most cause the health risk:	*Refill drinking water without proper cleaning*	273	68.25
12. Best explained for popular use of PET-bottled water:	*Purified, clean and safe for drink*	138	34.50
13. Most preferable action for the SC of PET-bottled water:	*Drink up the whole bottle of water*	201	50.25
14. Best solution for waste-bottles management:	*Turn waste bottles to energy*	233	58.25
15. What should be most implemented by bottled water business? :	*Focus on corporate social responsibility*	141	35.25
16. Best practice for achieving the SCP of PET-bottled drinking water:	*Foster turning waste bottles-to-energy development*	163	40.75
17. Who should be first prioritized for developing SCP of PET-bottled drinking water?:	*Producer / Business sector*	197	49.25

4.3.1 Consumer's demographic data. According to demographic data of consumer samples in Table 9, the majority of respondents are female, 26-35 years of age with working status, earn monthly income around baht 10,000-30,000 and mostly use their own car for transportation in daily life.

4.3.2 Practices and opinion to drinking water consumption. Most informants consume 6-8 glasses of drinking water a day (37.75%), followed by 3-5 glasses (36.25%), while 1-2 glasses are least practiced (4.75%). When asking about purchasing volume and reason to choose one-way bottled water, the statement of convenient use and easy to carry is outstanding (40.00%), with a maximum of 1-2 bottles bought in a day. Price and packaging exhibits the second choice (30.75%) while factors of eco-product reference and brand loyalty are least considered to their buying decision (5.50%; 5.75%).

Normal practice in working days or during travelling and shopping when hungry results the same conclusion. Most choose to buy PET-bottled water (71.75%; 79.75%) while drinking tap water is evenly ignorant (0.75%). It is however evident that the second option, which is chosen for working days differs from that of travelling case. In working days, they use the water from coin-machine and freezer services, while the water preparation from home is the alternative when travelling.

On the one hand, most consumers perceive that using post-used bottles for refilling without proper cleaning can cause the health risk (68.25%). On the other, performing a mouth-to-bottle, without a straw or pouring into a glass is least considered that is related to health risk (1.50%). In their opinion, popular use of PET-bottled drinking water comes from its qualification of purified, clean and safe product (34.50%), followed by convenience and well-responsive to satisfaction (29.50%). Most consumers do not think that a sign of today lifestyle can be addressed for its popularity (3.00%).

When asking about what action can best respond for a sustainable consumption of PET-bottled drinking water, they are most likely to choose drinking up a whole bottle of water (50.25%). Collecting post-used bottles for selling to junk shop is the contrary (6.50%). However, they consider turning waste-to-energy the most effective to waste-bottles management (58.25%). The moderate choices are recycling technology improvement and increase of recycle bin. Landfill and burning solution is least considered to be appropriate for handling the wastes (2.25%). Moreover, most respondents believe that solution of turning waste-to-energy is best if targeting on the SCP achievement (40.75%), followed by technology of cleaner production (24.00%). The enactment of the Polluter Pays Principle (PPP) is least favored (5.25%).

In identifying the most concern to SCP development, the research found that producer (business sector) is first prioritized (49.25%), closed by consumer (36.00%). Role of government is least allotted (2.50%). Some informants add that both producer and consumer, including all concerns, should share the equal responsibility (6.50%). Moreover, consumers are most likely to have bottled water business implement the CSR (35.25%), followed *by establishing supply-chain management and technology of cleaner production* (23.75%). Following the 3 R is least requested (8.75%).

Table 10: Consumer's Performances in Sustainable Consumption for PET water bottle

Resource efficiency	Degree of agreement						Impact reduction
	Mean	S.D.	Level	Level	S.D.	Mean	
● Drink up a whole bottle of water	4.14	.757	4	4	.805	3.86	● Accompany post-used bottle if cannot find a litter bin
● Refill drinkable water	4.07	.910	4	4	.667	3.47	● Clean post-used bottle before refilling
● Take the leftover for further use	4.01	.992	4	4	.967	3.42	● Arrange waste-bottle zone in gas stations and shopping malls
● Spend less on unfrozen bottle	3.86	.985	4	3	.904	2.82	● Dispose of waste bottle in recycle bin
● Prepare personal flask when away from home	3.71	.994	4	3	.839	2.81	● Order glass bottles or refillable jug when eating out
● Avoid using bottled water for coffee, tea and cooking	3.64	.862	4	2	.999	2.52	● Avoid performing mouth-to-bottle
● Recycle the bottle for other purposes when not in use	2.36	.979	2	2	.994	2.40	● Avoid using the bottle that has been opened and exposed to direct sunlight
● Sell waste bottles to junk shop	2.24	.902	2	2	.950	2.33	● Forbidden use of bottled water in office
● Choose tap water when hungry	1.67	.853	1	2	.857	2.07	● Increase tap-water drinking
● Tap water is safe enough for drinking	1.59	.954	1	1	.917	1.69	● Recycle post-used bottle
Total value	3.4550	.508	4	3	.378	3.1650	Total value
Total value of the SC: Mean = 3.2675, S.D. = .44321, Level = 3 (medium)							

4.3.3 Consumer's degree of agreement. Regarding the data expressed as the mean hierarchy in Table 10, it reports that consumer's performances in resource efficiency rise to high level (3.4550) while impact reduction covers the medium level (3.1650). This leads to a conclusion that the consumers moderately perform the SC (3.2675). In consumer's view, the general trend to the SC is towards efficiency in bottled-water consumption than impact reduction for the waste bottles.

4.3.3.1 Resource efficiency. In most cases, the strength of strong agreement is not considered to any choice of improving resource efficiency. Neither is degree of no idea. Six in ten items are weighted at agreeable degree. The rest are evenly separated for disagreeable and strongly disagreeable options. It means most consumers agree to *drink up a whole bottle of water*, *refill the water*, *take the leftover for further use*, *spend less on unfrozen bottle*, *prepare personal flask when away from home* and *avoid using bottled water for coffee, tea and cooking*. On the contrary, they disagree to *recycle the bottle for other purposes when not in use* and to *sell waste bottles to junk shop*. Meanwhile, the consumers strongly disagree at either *choosing tap water when hungry* or at the statement that *tap water is safe enough for drinking.*

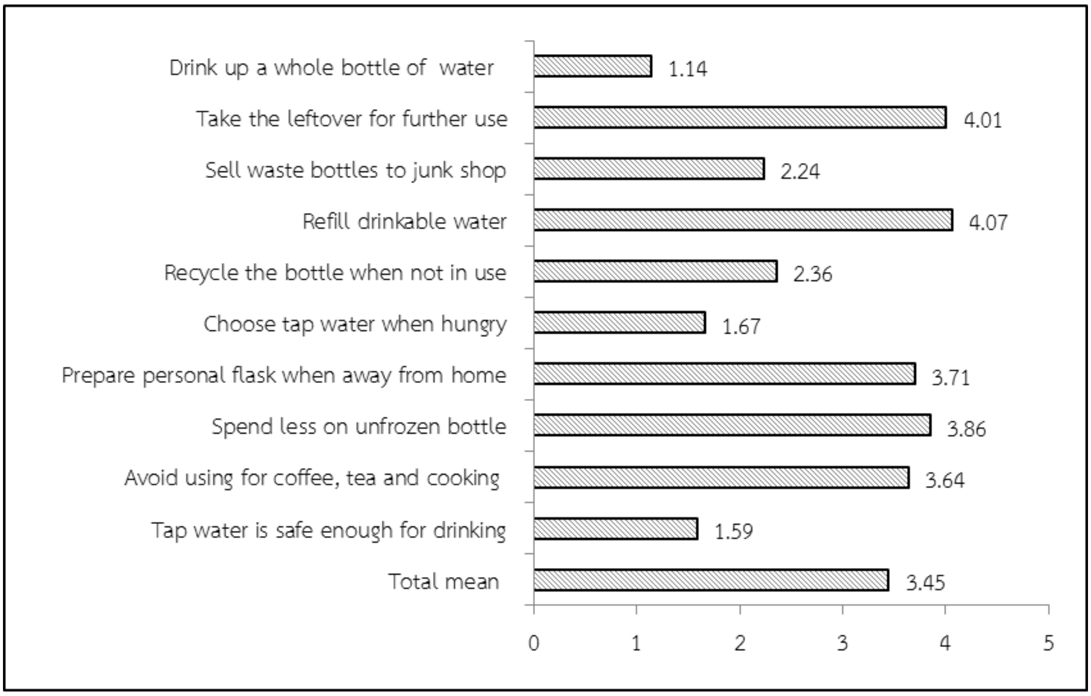

Figure 10. Degree of consumer's agreement to resource efficiency
in the mean comparison

In view of consumption efficiency associated with Figure 10, the results show the consumers' interest to optimize all benefits of product and minimize resources used with the reuse. The pattern can be reconciled with the 3 R's principle (reduce, reuse, recycle) when consumers mostly maximize the water by drinking up a whole bottle, continued use of the leftover and optimize the blank bottles for refilling. It is significant that tap water is not a preferable option to improve efficiency in bottled-water consumption by reduced use due to negative consumer perception of the impurity of tap water [7, 66] although most house brands bottle tap water.

4.3.3.2 Impact reduction. As shown in Figure 11, the data indicates that most respondents express their attitude to the impact reduction at almost all degrees, besides a strongly-agreeable caption. They agree to follow three practices: *accompany post-used bottle if cannot find a litter bin*, *clean post-used bottle before refilling* and *arrange waste-bottle zone in gas stations and shopping malls*. Most samples have no idea on the matters of *disposing of waste bottle in recycle bin* and *ordering glass bottle or refillable jug when eating out*. Disagreeable degree is most allotted with four in ten items. It means the consumers disagree to *use a straw or a glass* but prefer *mouth-to-bottle practice.* They *do not avoid using the bottle that has been opened and exposed to direct sunlight contact*. In contrast, neither *a forbidden use of bottled water in office*, nor *increasing tap-water drinking* is selected for impact reduction. A choice of recycling post-used bottles designates a strongly-disagreeable answer.

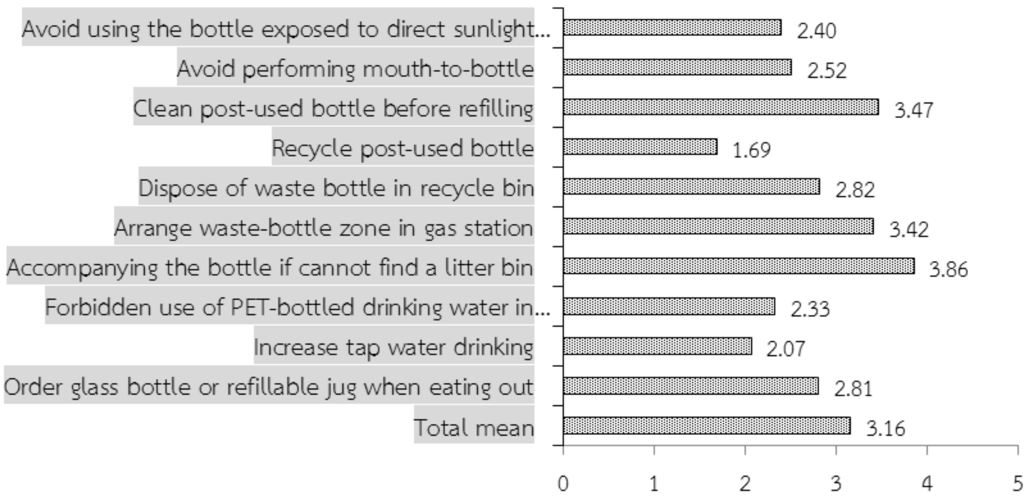

Figure 11. Degree of consumer's agreement to impact reduction in the mean comparison

It is evident with regard to Figure 11 that the level of environmental protection can be measured by the strength of consumers' agreement to avoid the manners, which are known to be damaging to the environment [15]. The consumers are reluctant to consumer tap water and dispose of post-used bottles solely in a litterbin. These can be explained with a lower degree of agreement and the expression of no idea when asked about sustainable actions for reducing the impacts. Particularly, a decline in recycling the bottles and deterring the idea of forbidden use of bottled water in offices are in evidences that what is necessary and what is not [56, 73, 90]. As a whole, consumption pattern of PET-bottled drinking water is somewhat away from impact reduction implication due to the increasingly disposable products, coupled with speeding up of lifestyles.

4.3.4 Significance test. In relevance to the one-way ANOVA test, none of demographic data is related to the SC at the statistical significance, while three independent variables regarding practices and opinion to drinking water consumption are found to be statistically significant at both 0.05 and 0.01 level. Those include the most practice in buying bottled water when hungry during travelling and shopping (99%), the most suggested for waste-bottle management with waste-to-energy solution (95%), and the best solution for achieving the SCP by fostering waste-to-energy development (99%). Table 11 was drawn to present the level of statistics confidence at 0.05% and 0.01% associated with the variables.

Table 11. One-way ANOVA Test for a Correlation of the SC Variables

Independent variables	SC	
	Statistics value	Sig.
1. Practice during travelling and shopping when demanding drinking water	F = 5.230	.001**
2. Best solution for waste-bottles management	F = 2.758	.028*
3. Best solution for achieving the SCP of PET water bottle	F = 10.211	.000**

The results are somewhat consistent with the way recycling technology of waste bottles has been advanced for handling the rebound effect from the growth of disposable products in daily life basis. [6, 8, 40, 45]. It should be also noted with regard to the significant findings that the end of useful bottle is one of major causes for the impacts on global warming, ecological degradation and health risk [14, 20, 45, 59]. Thus, the necessity of recovering all waste bottles to the applications of B-T-A, especially fiber and textile, and B-T-B, including recaptured energy, are in urgent evidence [12, 43, 47].

4.4 SCP of PET Water Bottle

As reported in previous sections, the SP shows the performances at the medium level of five-rating scale (2.89; level 3; Table 6), so does the SC belonging to the means value 3.2675 (level 3; Table 10). In Figure 12, the breakdown of SP and SC levels, which are based on a matrix format, is consistent with the *High-High* feature. It shows that both the production and consumption of PET water bottle is concurrent to the SCP paradigm.

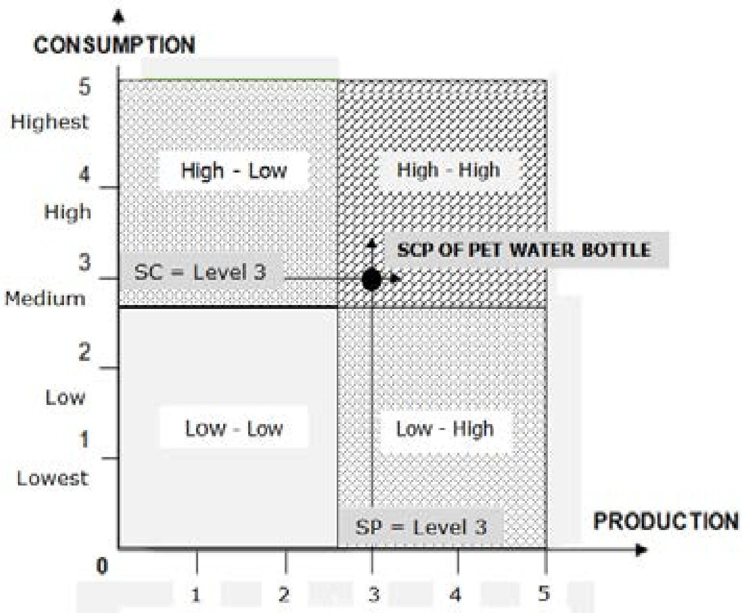

Figure 12. The SCP of PET water bottle towards the interaction of production and consumption LCM

It is apparent with regard to the fact that a consumption and production pattern is the interaction process [4, 16, 98], consequently, a bottom-up matrix model is potential for the SCP implementation. The SCP of PET water bottle, which concerns to the environmental and health security on the every day life shall be the evidence-based case of socio-economic development with environmental care on sustainability path [6, 15, 35]. Included is the good practice for LCM development. In other words, integration of sustainability issue into the business and individual lifestyle is a great deal for both the producer and consumer of PET water bottle. With growing concern to environmental problem, the micro-scale SCP implementation can enrich the value of LCM as well as shall provide a participatory framework for those aware of sustainable solution to climate agenda.

CHAPTER V

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

5.1.1 Potential impacts of PET bottle

Due to the limitations associated with LCI data, the results can draw first consideration about producing and consuming recycled PET for finite resource efficiency. The test leads to a notation that PET water bottle eventually involves a trade-off between resource efficiency and impact reduction.

5.1.2 Sustainable production

The role of producers in the bottle-filling system for the SP offers an important set of organizing principles for defining industrial policy and activities to the SCP of PET water bottle. However, no approach is superior for impact reduction. The producers focus largely on efficiency improvements for reducing plastic resource consumption over the impact reduction. The top brands address the resource efficiency and impact reduction measures at the medium whereas the house brands' performances are quite low, whereas there is no difference between the brands to better perform the resource efficiency than does the impact reduction. Both take nearly the same account for eco-design, 3 R and LCM, while the CSR is dramatically different. The top brands do most but the house brands have the very less concern. Either reduced use of plastics or reduced defects, is a major concern in all producers, in all categories, whereas water is least recognized due to the lost water in open-loop process. The closed-loop bottling system is equipped for all the top brands whereas the house brands, including every branch of top brands, are common to the open loop. However, almost every producer has no intention to improving impact reduction in bottle-filling operation, with the explanation that bottled water is clean product and bottling system generates no CO_2 emissions to the air, water and soil. With the increasing demand for the scrap from waste-PET bottles, the bottlers rarely consider the returnable value of recycled PET for either new applications or new bottles. Thus, the Thai-based bottling system is challenging for improving sustainable use of water resource and plastics recyclability.

5.1.3 Sustainable consumption

When there is no legislation, nor strict enforcement of disposing municipal wastes, consumers must be aware of their duties and responsibilities for their citizenship [6, 59]. A consumption pattern is related to some aspect of a real life, therefore, the rapidly-increasing demand for PET water bottle shows what social gains for better living is what we have lost [56, 83]. There are the correlation of the SC with the manners in consuming drinking water when travelling, handling waste bottles, and in choosing the way for succeeding in SCP implementation. The likely consumer of PET water bottle is consistent with the city people those still working and earning the life with the monthly-30,000 baht income. Consumers moderately perform the SC, with the high level of resource efficiency and the medium level of impact reduction measure. The choice of drinking up a whole bottle of water is most allotted for reaching resource efficiency target. To cope with the impact reduction, most consumers agree to accompany post-used bottle if cannot find a litterbin but strongly disagreeable when asked for recycling post-used bottles. However, they strongly disagree that tap water is safe enough for drinking and they totally decline to choose tap water when hungry. Most consumers have no idea whether they agree or disagree to reduce the impacts by disposing of waste bottles in recycle bin. Either is ordering glass bottles or refillable jug when eating out. The convenient use is most reasoned for buying decision and the popularity of PET water bottle; either in or away from home. Most consumers support the idea of zoning gas station and shopping mall for ease of disposing of waste bottles but object against a forbidden use of bottled water in the offices. In consumer's opinion, turning waste bottles to energy is most appropriate for handling the waste management, by which is expected for the SCP success, which should be established by business sector.

5.1.4 SCP of PET water bottle

As in the literatures, many concepts within sustainability are not new. However, the constructive application at micro-scale, from the bottom-up participation, has not been largely adopted. This study shows how the production and consumption pattern creates a discrepancy of resource efficiency and impact reduction. However, the conclusion comes true that it is potential for the SCP development for PET water bottle, with emphasis on the roles of producer and consumer. Three major conclusions are found. First, both producers and consumer favor the resource efficiency over the impact reduction. Secondly, comparative results between the producer and consumer slightly differ as their successes go to the same medium level. Finally, the breakdown towards the matrix format can fulfill the ultimate goal of SCP implementation that links business growth and individual fulfillment to environmental protection and the planet sustainability. In brief, the results bring to the crucial statement that SCP will remain ever elusive unless the top-down state policy is transformed to the concrete steps with the bottom-up participation.

5.2 Recommendation

The recommendations after critically studying the micro-scale of SCP implementation go to several respects. Due to funding and time constraints, a further study of implementing the SCP for PET water bottle is advisable. An exploration of possible pathways to the SCP can be branched in alternative directions, either by considering externality cost comparison or for different products analysis. This study is by no means exhaustive, but enables a potential for the methods and datasets. Thus the improvement of assessment methodologies from a multi-disciplinary perspective could be set for reframing current public understanding towards mitigation and adaptation behavior. The extension could be observed in the differences of sampling method, focused group selection, changing demographic pattern, areas of study, including new research designs. Due to the growing consumers concerns over potable water, other types of products in bottled water market, such as soft drinks, functional drinks and any popular drinkable water, should be reviewed to identify causes, effects and solutions on sustainability target themselves. In particular, there should be opportunities for future research about SCP that provides greater interdisciplinary expectations.

This study is particularly timely since PET water bottle and water crisis is shifting from one of problem-framing to new agendas that are much more concerned with sustainability objectives. Under the leadership of the government, its role remains an option for getting there, with a wide representation of actors, such as bottlers, retailers, researchers, local and municipal authorities, environmental groups and independent experts in bottled water, life cycle thinking, including recycling system. The government can drive a consumption and production pattern away from or toward sustainability by shaping the business practice to influence consumer behavior, and to formulate solution taken by each stakeholder. This is important in the realm of SCP success in which regulatory policies and environmental consciousness have not been fully developed. We must accept that without environmental awareness education, the SCP will not advance the larger development in industry practice and consumer behavior. For more transformative efforts in the industrial responsible development, it will be valuable if government focuses on promoting the existing tool and approach of CSR for the SP that eventually ensuring the SCP success as well as grounding to the sustainable development.

More rigorous consideration of the role of recycling agents and retailers in responsibility for waste-bottle logistics; collection, transportation, recycling system and recovery of material should be organized in order to prevent the reverse channel from inappropriate approach at landfills and dumping areas. The government should separately set minimum recycling standards and indicate material combinations with recycled PET for the new packaging those covering non food-contact products. Technological knowledge about recovery of waste-plastics and about recycling system should be provided for community-based groups. Any public policy, with marketing-based instruments to support cleaner technologies along a value chain of PET water bottle could be established. Producer and consumer who produce and consume a sustainable product or eco-product could be rewarded an eco-tax or a refund fee. If any below, they could be charged a fee towards funding environmental rehabilitation and finally edited out of the market. The ways of water access and water treatment regarding extraction and acquisition procedures shall be in vision so that sustainable management of land, water and biodiversity can be fulfilled and experienced among the concerns. The mission for completing tap water availability throughout nationwide has to be prioritized as the indicator of sustainable development.

It is clear that a paradigm shift to the holistic view and sustainable action for PET water bottle is totally required so as to bring the implementable solutions to, and from, all the concerns; industry, government entities, and the public. These concerns must be particularly addressed for the Department of Industrial Works, Department of Industrial Promotion, Department of Environmental Quality Promotion, Department of Health and Department of Mineral Resources, especially water resource, including Provincial Waterworks Authority.

Moreover, there has to be a thematic agenda inspiring people for tap water quality appropriate for drinking. Businesses shall employ more environmental themes in advertising and marketing processes. Nonetheless, environmental awareness-raising should be continuously educated so that a large scale positive change in production and consumption pattern can translate to larger sustainability gains.

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APPENDICES

Appendix A

SimaPro LCA Software

A. Description of the tool. SimaPro LCA software is famous for its flexibility in handling different impact assessment methods to model products and systems from a life cycle perspective. SimaPro is used for a variety of applications, like: Carbon footprint calculation, Product design and eco-design, Environmental Product Declarations (EPD), Environmental impact of products or services' Environmental reporting (GRI)' Determining of key performance indicators

B. Instruments functionally supported by the tool. Design for environment (DfE, DfR), Life cycle assessment (LCA), Life cycle costing (LCC), Life cycle impact assessment (LCIA), Life cycle inventory (LCI), Life cycle management (LCM), Life cycle sustainability assessment (LCS), Life cycle engineering (LCE), Product stewardship, supply chain management, social LCA, Substance/material flow analysis (SFA/MFA)

C. Functionality

1. Inventory Modelling. SimaPro, can handle very advanced inventory techniques, but is at the same time very easy to use and understand; novice users can really make things simple. There is even a dedicated LCA wizard that lets you define your data model, by answering a series of questions. SimaPro comes with very large and up to date datasets. SimaPro process records can be used for systems and unit processes, as well as input output data. Each process record, can have multiple outputs; each with an allocation percentage; it is also possible to combine this way of allocation with avoided products (system boundary expansion). Inputs can come from nature or technosphere. These links can both be expressed in physical units and financial terms, allowing to make hybrid data models that combine input output and traditional processes. In this respect it is important to notice that loops may be modeled, as the calculation routines use matrix inversions. In each process record, emissions can be specified into air, water, soil, but it is also possible to specify solid waste, and waste streams (gas, liquid and solids) can be linked to a waste treatment. Emissions can be defined using the sub compartments used by Eco-invent (i.e. emission in high and low population density can be separated). All inputs and outputs can contain uncertainty data, specified as lognormal, normal triangular and even distributions. These uncertainties can be evaluated in a Monte Carlo analysis. All amount fields can also be defined as parameters. Parameters can be defined directly by the user, or the result of an expression; a white range of lineair and non-lineair, or conditional expressions can be defined. In some versions, it is possible to link an amount field directly to an external data source, like excel or an SQL dataset. This makes it possible to store data outside SimaPro but use it without typing over. Many documentation fields are available.

2. Impact Assessment Methodology. Impact assessment methods are defined in SimaPro as a series of tables for impact categories, normalization and weighting. More than ten different impact assessment methods are included. These methods can be copied to your project, so they can easily edited, extended etc. It is also easy to define completely new methods. If an impact assessment method is selected, all impact categories can be displayed as a profile in the same graph.

3. Analysis and Interpretation of Results. Inventory results can be presented as a table, that can be presented in may ways. For instance it is possible to show only the inventory results that contribute to a certain impact category, and it is also possible to show the uncertainties of every inventory result in a table The impact assessment results can be displayed as a graph or table, and it is very easy to shift from characterization to damage assessment, normalization or weighting (if the method allows). The user can double click on the graph to get a specification of substances or processes that contribute to the impact category that was clicked on. A separate contribution analysis is available that also displays pie-charts. With every impact result a completeness check is available that displays substances that were in the inventory, but not in the impact assessment result. SimaPro can compare two or more versions of a product system, each with different parameter settings. Similar graphs are also available to show the result of the Monte Carlo analysis if a single system is analyzed. If a comparison is evaluated, SimaPro will show the DIFFERENCE between two product systems, which gives the user the chance to see if the difference between product systems are indeed relevant, and for which impact category. In this procedure the correlations between identical processes in both LCI's are taken into account. SimaPro can generate a process network, in which each process has a small bar chart showing the contribution of this process to the total environmental load. The bar chart can display a single score, an impact category indicator or an individual inventory parameters. It is also possible to show product or financial flows.

4. Database Management

Data are organized as a set of libraries with data that can be used in all projects. Users can define any number of projects. Data can be copied between libraries and projects. SimaPro is available as a multi user version, that allows multiple users to work in the same database and same projects.

5. Documentation

Inventory data are well documented with many text fields. Also impact assessment methods are documented. Separate database manuals are included, that describe the impact assessment methods and libraries. It is also possible to ad comments to the goal and scope, as well as the interpretation in your project, for future reference.

6. Main database

SimaPro database: Contains all add on databases, and a library with eleven impact assessment methods. All datasets are completely harmonized regarding structure, nomenclature and fit well with all impact assessment methods.

7. System requirements

All Window versions from Win 98 and up; no other software needed; 256MB internal memory recommended; for XP 512 recommended

Remarks:

Name of tool, version N°: SimaPro 7 (Released: 13/03/2006)

Software website: www.pre.nl/simapro or www.simapro.com

Developer: PRé Consultants B.V.

Provider: 2.-0 LCA consultants, 2B, PRé Consultants B.V.

Source: European Commission http://lca.jrc.ec.europa.eu/lcainfohub/tool2.vm?tid=216 [92]

Appendix B

Survey Transcripts for In-Depth Interview

Research Topic:	Application of Life Cycle Management for Sustainable Production and Consumption of Polyethylene Terephthalate [PET] Water Bottles in Thailand
For Dissertation of	Miss Taksina Chai-ittipornwong, Doctoral Program of Environment Development and Sustainability, Graduate School, Chulalongkorn University
Thesis Advisors:	Assistant Professor Pomthong Malakul Na Ayudhaya, Ph.D.
Thesis Co-Advisor:	Associate Professor Dawan Wiwattnadate, Ph.D.
Target Informants:	Two sampling groups - Four top brands (Crystal, Namthip, Purelife, Singha, placed in alphabetical order) - Four house brands

Data Collection Period: 2012

Attachments: 1. Holistic concept of product life cycle management: a cradle-to-gate, a cradle-to-grave, a cradle-to-cradle
2. Bottle-filling system of PET-bottled water

Please provide the following information

Name...

Position...

Company...

Work responsibility...

Questions:

I. Policy, plan, project and activities involving environmental protection and social responsibility (CSR)

1. How does your company contribute to environmental protection due to the production of PET-bottled water?
2. Have any of the environmental issues resulted in concrete policies or initiatives being developed (or in the process of being developed)? If so, please describe the related proposal and its impact.
3. Please identify which of the environmental-protected policy and activities your company put the concerns.
4. Does your company have any activities on environmental impact assessments (EIA, HIA, SEA, etc.)?
5. How do you measure the outcomes?
6. Have your company ever received any reward or certificate regarding environmental issue? If so, how have your business objectives been incorporated into environmental issue?
7. Have your company implemented any environmental issue associated with governmental policy or regulation?
8. Do the activities on environmental issue offer a competitive advantage?

II. Product & process development on design for environment.(Eco-design)

9. Which practice of design in your product did you find useful and effective?
10. How does your company involve with sustainability dialogue to allow the eco- product?
11. What type of eco-design process is your company aware of?
12. What is involved in product and process development that your company acquires?

III. Implementation of the 3 R principle (reduce, reuse, recycle)

13. How does your company incorporate resource efficiency and waste control within production process?
14. How can the 3 R's principle be reconciled with the bottle-filling system?
15. Please explain the area (s) of resource consumption reduction and reduced defect that your company has been working on.
16. What challenge of recycling system does your company face?
17. What do you think is deterring bottled-water businesses from recycling system?

IV. Approach to life cycle management

18. As involving in bottled water business, do your business system and services be on the track of product life cycle thinking?
19. What additional device do you suggest to make the production of bottle filling more sustainable and effective?
20. What future plan or goal associated with product life cycle management does your company have?
21. How do you choose service activities of retail and marketing corresponding to life cycle management for PET-bottled water?
22. What stage in the life cycle of bottled water does your company consider the most important?
23. What is the expectation if following a cradle-to-grave life cycle management?

V. Additional Views

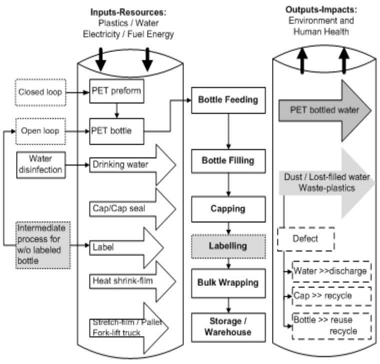
24. What is the current state of bottled-water business in Thailand?
25. What is the current industrial responsibility of bottle-water business related to fulfilling the objectives of sustainable consumption and production for PET-bottled water?

Attachment 1:

Holistic concept of product life cycle management: a cradle-to-gate, gate-to-grave, a cradle-to-cradle

Attachment 2:

Bottle-filling system of PET-bottled water



Appendix C

Population in Bangkok and Its Vicinities

Provinces	Population
Bangkok+ Vicinities	10,455,800
Bangkok	5,673,560
Nakhon Pathom	874,616
Nonthaburi	1,141,673
Pathum Thani	1,033,837
Samut Prakan	1,223,302
Samut Sakhon	508,812

Source: Department of Provincial Administration, Ministry of Interior, as of December 2012.

Appendix D

Sample Size Calculation

Table of sample size for ±3%, ±5%, ±7% and ±10% Precision levels where confidence level is 95%

Size of Population	Sample Size (n) for Precision (e) in relevance to significance level of:			
	±3%	±5%	±7%	±10%
500	a	222	145	83
600	a	240	152	86
700	a	255	158	88
800	a	267	163	89
900	a	277	166	90
1,000	a	286	169	91
2,000	714	333	185	95
3,000	811	353	191	97
4,000	870	364	194	98
5,000	909	370	196	98
6,000	938	375	197	98
7,000	959	378	198	99
8,000	976	381	199	99
9,000	989	383	200	99
10,000	1,000	385	200	99
15,000	1,034	390	201	99
20,000	1,053	392	204	100
25,000	1,064	394	204	100
50,000	1,087	397	204	100
100,000	1,099	398	204	100
>100,000	1,111	400	204	100

a = Assumption of normal population is poor (Yamane, 1967). The entire population should be sampled.

Source: Israel [94]

Appendix E

Questionnaire

Thesis Title:	Application of Life Cycle Management for Sustainable Production and Consumption of Polyethylene Terephthalate [PET] Water Bottles in Thailand
For Dissertation of	Miss Taksina Chai-ittipornwong, Doctoral Program of Environment Development and Sustainability, Graduate School, Chulalongkorn University
Thesis Advisors:	Assistant Professor Pomthong Malakul Na Ayudhaya, Ph.D.
Thesis Co-Advisor:	Associate Professor Dawan Wiwattnadate, Ph.D.
Target Informants:	Two sampling groups: - People working in the organizations or studying in the institutes located in the scoped areas - Visitors to tourist destinations and shopping malls
Scoped areas:	Bangkok, Nonthaburi, Pathum Thani, Samut Prakarn, Samut Sakhon and Nakhon Phathom
Data Collection Period:	2012
Definitions:	
PET bottled water	means a potable 500/550/600 ml-PET bottle for single-serve that contains drinking water inside.
Sustainable consumption	means the manner of consuming products or services with the awareness of environmental protection by improving efficient use and impact reduction
Questions:	3 parts (I = demographic data, II = drinking water consumption, III = degree of agreement)
Total pages:	5 pages

I. General information. Please provide your demographic data

1. Gender
male
female
2. Age (year)
16-25
26-35
36-45
46 up
3. Career
high school / undergraduate
working
stay home / retired
4. Income (baht / month)
less than 10,000
10,000 – 30,000
30,001 – 60,000
more than 60,000

5. Main vehicle used in daily life
own car
bus /taxi / tuk-tuk / van service
BTS / MRT / BRT
motorcycle
others (boat / bicycle / walking)

II. Habitual practice for drinking water consumption.

Please choose only one answer for each question.

6. Amount of daily consumption for drinking water (glass of water)

1-2

3-5

6-8

more than 8

7. Daily purchasing amount of 500/550/600 ml bottled water

less than 1 bottle

1 - 2 bottles

3 - 4 bottles

more than 4 bottles

8. Most influencing factor to buying decision of PET-bottled water

price and packaging

eco-product reference

convenient use and easy to carry

product quality

brand loyalty

9. Practice in working days when demanding drinking water

buy PET-bottled water

prepare personal flask from home

taken from coin machine and freezer services

drink tap water if available

10. Practice during travelling or shopping when demanding drinking water

buy PET-bottled water along the journey

prepare the estimation of use from home

taken from coin machine and freezer services

drink tap water if available

11. What practice do you think can mostly cause the health risk?

Continue using the bottle that has been opened and left in a car

perform a mouth-to-bottle, instead of using a straw or a glass

refill drinking water without proper cleaning

place PET-bottled water in high temperature room and/or exposed to direct sunlight

12. Best explanation for popular use of PET-bottled water
purified, clean and safe for drinking
responsive to convenience and satisfaction
constitute a large number of waste-plastics in rivers and seas
sign of today life style
5) provide better and more nutrients than tap water

13. What is your most preferable action for sustainable consumption of PET-bottled water?
dispose of post-used bottles in recycle bin
drink up a whole bottle of water
reuse and refill the bottle in many times
recycle post-used bottles for multipurpose
collect post-consumer bottles for selling to junk shop

14. What is the best solution for waste-bottles management
increase the avail of recycle bins
turn waste-PET bottles into energy
use landfill and burning methods
improve technology of recycled-PET application
facilitate export option

15. What should be most implemented by PET-bottled drinking water business?
focus on corporate social responsibility (CSR)
use sustainable design (eco-design) in product and process development
follow 3 R's principle in business operation
establish supply-chain management and technology of cleaner production
incorporate environmental protection into business missions

16. What is the best solution for achieving the SCP of PET-bottled drinking water?
promote 3 R practice (Reduce, Reuse, Recycle)
foster waste-to-energy development
educate environmental awareness
employ technology of cleaner production
enact the polluter pays principle (PPP)

17. Who should be first prioritized for implementing a sustainable consumption and production pattern of products or services available in the market?
producer / business sector
consumer
government
retails
if any, please indicate..

III. Questions about degree of agreement towards the choices

Please circle on the degree that corresponds to your idea.

18. What is your idea towards these suggestions for improving efficiency in PET-bottled water consumption?

Items of Resource Efficiency	Degree of agreement				
	Strongly agree	Agree	No idea	Disagree	Strongly disagree
Choose tap water when hungry	⑤	④	③	②	①
Drink up a whole bottle of water	⑤	④	③	②	①
Take the leftover for further use	⑤	④	③	②	①
Prepare personal flask when away from home	⑤	④	③	②	①
Avoid using bottled water for coffee, tea and cooking	⑤	④	③	②	①
Tap water is safe enough for drinking	⑤	④	③	②	①
Refill drinkable water	⑤	④	③	②	①
Recycle the bottles for other purposes when not in use	⑤	④	③	②	①
Spend less on unfrozen bottles	⑤	④	③	②	①
Sell waste bottles to junk shop	⑤	④	③	②	①

19. What is your idea towards these suggestions for reducing impacts from PET-bottled water consumption?

Items of Impact Reduction	Degree of agreement				
	Strongly agree	Agree	No idea	Disagree	Strongly disagree
Dispose of waste bottles in recycle bin	⑤	④	③	②	①
Avoid using the bottles that have been opened and exposed to direct sunlight	⑤	④	③	②	①
Clean post-used bottle before refilling	⑤	④	③	②	①
Order glass bottles or refillable jug when eating out	⑤	④	③	②	①
Increase tap-water drinking	⑤	④	③	②	①
Recycle post-used bottles	⑤	④	③	②	①
Accompany post-used bottle if cannot find a litter bin	⑤	④	③	②	①
Use a straw or a glass, instead of performing mouth-to-bottle	⑤	④	③	②	①
Enforce a forbidden use of bottled water in offices	⑤	④	③	②	①
Arrange waste-bottles zone in gas stations and shopping malls	⑤	④	③	②	①

Appendix F

Reliability Analysis – Scale (Alpha)

A. Item: Resource efficiency

No. of items: 10 (R1 – R10), No. of cases: 35, Alpha = .7389

Items	Scale Mean if Item Deleted	Scale Mean if Item Deleted	Corrected item-Total Correlation	Alpha if Item Deleted
R1	31.7714	25.5933	.4061	.7204
R2	32.3714	21.9462	.5788	.6876
R3	32.2286	21.0050	.7275	.6630
R4	32.6000	23.6000	.3981	.7183
R5	31.9714	22.4992	.5411	.6948
R6	33.8571	26.8319	.0890	.7648
R7	32.0000	21.8824	.6457	.6785
R8	32.8857	24.5160	.2822	.7381
R9	32.6571	25.4084	.3392	.7264
R10	32.6857	27.3395	.0719	.7616

B. Item: Impact reduction

No. of items: 10 (P1 – P10), No. of cases: 35, Alpha = .7031

Items	Scale Mean if Item Deleted	Scale Mean if Item Deleted	Corrected item-Total Correlation	Alpha if Item Deleted
P1	28.7714	20.7697	.5684	.6410
P2	29.0000	24.7059	1497	.7182
P3	30.2571	23.4319	.2906	.6931
P4	29.6857	24.7513	.1993	.7058
P5	28.6571	22.9378	.2921	.6948
P6	28.8286	20.2050	.6256	.6288
P7	29.1429	24.5378	.2616	.6957
P8	29.0571	22.6437	.3922	.6752
P9	29.2857	21.9748	.4739	.6607
P10	29.9429	23.5849	.4024	.6761

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