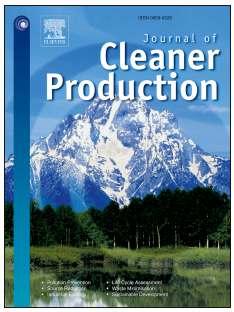
Accepted Manuscript



Developing pricing strategy to optimise total profits in an electric vehicle battery closed loop supply chain

Xiaoyu Gu, Petros Ieromonachou, Li Zhou, Ming-Lang Tseng

PII: S0959-6526(18)32558-7

DOI: 10.1016/j.jclepro.2018.08.209

Reference: JCLP 13993

To appear in: *Journal of Cleaner Production*

Received Date: 23 September 2017

Revised Date: 16 August 2018

Accepted Date: 20 August 2018

Please cite this article as: Gu X, Ieromonachou P, Zhou L, Tseng M-L, Developing pricing strategy to optimise total profits in an electric vehicle battery closed loop supply chain, *Journal of Cleaner Production* (2018), doi: 10.1016/j.jclepro.2018.08.209.

Developing pricing strategy to optimise total profits in an electric vehicle battery closed loop supply chain

Xiaoyu Gu[a,*], Petros Ieromonachou[b], Li Zhou[b], Ming-Lang Tseng[c]

[a]*School of Economics and Management, Nanjing University of Science and Technology, Nanjing*

[b]*Department of Systems Management and Strategy, University of Greenwich, London*

[c]*Lunghwa University of Science and Technology, Taoyuan*

[*]Corresponding author.

Email addresses: x.gu@njust.edu.cn (Xiaoyu Gu), ip07@gre.ac.uk (Petros Ieromonachou), zl14@gre.ac.uk (Li Zhou), tsengminglang@gmail.com (Ming-Lang Tseng)

Abstract

This paper studies a three-period electric vehicle battery recycle and reuse closed-loop supply chain consisting of a battery manufacturer and a remanufacturer. Differing from other products and existing research, used electric vehicle batteries can be instantly reused for other purposes before recycling, such as energy storage. In order to optimize total profits in the whole supply chain in different batteries period of use, this paper develops the optimal pricing strategy between manufacturer and remanufacturer, discusses the relationships between return yield, sorting rate, recycling rate in order to optimize total profit in different period. The result suggests that, comparing with new battery manufacturing, battery recycling and reusing would contribute to reduce raw material consumption hence reduce environmental impact, but may not gain financial benefits. It also notes that although the close-loop supply chain is nonlinearly complicated, some relationships between parameters can be treated as linear or quadratic. The results of this research will help practitioners to better understand the entire closed-loop supply chain in order to enhance its collaboration.

Keywords: Closed-loop supply chain, Electric vehicle battery, Recycle, Reuse, Profit

1. Introduction

Currently, Electric Vehicles (EVs) considered as one of the future development directions for the automotive industry. According to International Energy Agency (2016), from 2005 to 2010 the number of EV sales worldwide, which includes both battery EV and Plug-in Hybrid EV (PHEV), has increased from 1,670 to 12,480. By 2015, EV sales reached 1,256,900 which is almost 752 times than 10 years ago.

One of the most important parts on EV is the battery. Here are two main reasons: Firstly, approximately 50% of the cost of an EV is attributed to the battery (Lih et al., 2012). And secondly, unlike gasoline vehicles (GVs) that have a short refuelling time (5 minutes), the EV charging time is long. A typical EV model (Nissan LEAF 40kWh) takes 8 hours to charge from empty with a 6kW home charging point or 40 minutes super charge from empty to 80% capacity of electricity (Nissan, 2018). Nevertheless, an EV cannot use the original battery until its end of life. Normally, due to performance and safety concerns, the EV battery has to be removed when its capacity falls to 70 ~ 80% (McIntire-Strasburg, 2015). Moreover, with the increasing popularity of EVs, more and more batteries will need to be replaced. Discarding these batteries would constitute bad environmental practice, with more far reaching long term effects. Used batteries must be recycled or reused rather than discarded (Yu et al., 2013).

In many countries, similar to normal batteries, it is not allowed to put used automotive batteries through to landfill or incineration. Instead, various EV battery collection and recycle schemes have been set up. For instance, in North America, Tesla, working with Kinsbursky Brothers, recycles about 60% of its battery packs; in Europe, Tesla started working with Umicore on recycling (Kelty, 2011); Nissan and Volkswagen require their EV customers to return used batteries to licensed points or local authority battery collection schemes (Nissan, 2015; Volkswagen, 2016).

In addition, some organisations have already noticed the reuse of EV batteries when the EV industry just started. In the early 2010, the US National Renewable Energy Laboratory has undertaken a