出國報告（出國類別：進修）

基於食糧安全的永續鄉村發展-進修全球糧食安全與發展碩士課程及研究英國農場可再生能源

Agricultural Elitist Training Project for COA-MSc Global Food Security and Development

服務機關：行政院農業委員會水土保持局臺南分局
姓名職稱：蔡驪曦 正工程司兼課長
派赴國家：英國
出國期間：105.09~106.09
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摘 要

出國人員完成英國諾丁漢特倫特大學全球糧食安全與發展碩士學位課程。經由課程了解目前先進國家對於糧食安全與發展相關議題之觀念與方向，並尋求適當可行方法或模組可運用於我國農村地區，促進農村社區發展，在地經濟活絡，提升農民收益。
本課程所學之糧食安全內容不僅考量糧食自給率，亦包括產量、儲存、貿易、分配、營養及糧食系統等問題。英國鄉村已由農業生產為主的社經角色，擴大對城市區域居民提供旅遊、環境與生態保育及再生能源提供者，英國鄉村以農場可再生能源生產搭配環境農業及傳統農業生產方式，提高農村經濟產值、在地消費及永續鄉村環境維護經驗可以做為我國農村再生工作重要參考。

The author received the Master's degree in Global Food Security and Development at Nottingham Trent University, UK. Through the course, the author understood the concepts of food security and development in developed countries and researched feasible ways or modules, particularly in the field of on-farm renewable energy, that can be applied in Taiwan countryside to promote and revitalize the economic development of local rural communities, and raise farmers' income.
The content of food security in this course not only considers food self-sufficiency but also issues such as production, stock, trade, distribution, nutrition and food system. British rural area is the main area of agricultural production for food, it also provides tourism, environment and ecological conservation and renewable energy for urban residents. Combining traditional agricultural production, environmental agriculture and on-farm renewable energy export, it is effectively kept the food production, improved rural economic value, maintained local consumption and sustainable rural environment in England, this concept can be applied for further rural regeneration in Taiwan.

壹、目的

本出國進修為行政院農業委員會之 105~106 年度農業菁英培訓計畫之一，出國人員前往英國諾丁漢特倫特大學的動物、農村及環境科學學院修讀全球糧食安全與發展碩士課程(MSc Global Food Security and Development, School of Animal, Rural and Environmental Sciences, Nottingham Trent University, UK)，本計畫主要目的為理解基於食糧安全的永續鄉村發展，內容先由研修 4 大課程開始，並由出國人員自行研究完成最後碩士論文。

進修目的緣起於農村再生政策推動，出國人員自農村再生政策開始推動時即擔任南部地區第一線執行單位農村營造業務低階主管，在政策推動過程中，歷經各個鄉村社區誤解-理解-共同尋求最佳解各項過程，也理解鄉村社區再生需要建立在有效發展、經濟分配及維持良好農業生產及環境保護等各項事務，不可僅偏重於鄉村地區硬體建設才是長久發展道理。農村再生政策執行係為促進農村永續發展及農村活化再生，改善基礎生產條件，維護農村生態及文化，提升生活品質，建設富麗新農村。在 21 世紀全球化趨勢、極端氣候、糧食危機威脅下，世界主要先進國家均將永續農村發展，保護農地避免土地劣化，維護農業生產與提高糧食自給率列為重要的施政政策，鑑此，借鏡同屬海島型小農型態之英國農業、糧食安全與發展相關政策，應可做為我國農村再生政策執行之重要參考。

全球各地現今均遭受氣候變遷影響，甚至在傳統溫帶地區亦漸趨暖與熱，熱帶地區乾旱日程及極端暴雨事件強度頻率均顯著增加，全球氣候變遷除了天災頻仍，並導致糧食減產，如我國 2016 年受霸王級寒害影響，使養殖漁業、蔬菜、水果等均受到劇烈損失，其影響期程非短期影響僅有數日而已，其造成市場供需不平衡及糧食價格大幅波動，並導致短期糧食緊急應變壓力大增，進而將影響後續農產品年度間價格與可獲得性，嚴重危害糧食安全。我國因農業轉到工商業的社會型態與經濟結構轉型，以及自由貿易的衝擊，我國糧食安全問題主要在於 2012 年以熱量計算之糧食自給率僅為 32.7%，相較各已開發國家，我國糧食自給率偏低，糧食自給率與糧食安全與發展議

題相關聯性及未來發展值得進一步探討。

參照 APEC 糧食安全政策，在 2010 年新潟宣言提出追求農業部門的永續發展（Sustainable development of the agricultural sector)及投資、貿易和市場的便捷化，並同意對「促進農產品的永續與成長」行動項目，透過增加經濟體的糧食供給能力、提升農業的災害準備能力、發展農村社區，以面對氣候變遷和自然資源管理的挑戰。

2012 年 APEC 糧食安全喀山宣言宣示，就氣候變遷導致糧食安全部份，各國體認國際糧食情勢嚴峻，在增加農業生產與生產力上，創造有利環境促成公私部門對農業投資的重要性、負責任的私人投資扮演關鍵角色、公部門投資對於農民及其他投資者創造有利條件的催化角色，來追求農業永續之基礎建設投資。並特別指出，強化 APEC 各論壇在災害應變、農業生產復原及糧食供應鏈之討論是極為重要的。

2014 年 APEC 糧食安全北京宣言，就氣候變遷相關工作為「透過創新科技及有利之經濟環境，提升農業生產力及食品生產永續發展」，政府應建立有助於農業創新的政策環境，以提升糧食產量並降低環境的影響，且能適應氣候變遷趨勢及頻繁天災的挑戰。

我國立法院已於民國 104 年 12 月 18 日通過國土計畫法，我國國土未來將區分為「國土保育地區」、「海洋資源地區」、「農業發展地區」、「城鄉發展地區」四區，各區依其自然條件發展，其各區劃設均與農委會業務密切相關。特別是「農業發展地區」規劃基本原則於條文明訂為應以確保糧食安全為原則，積極保護重要農業生產環境及基礎設施，並應避免零星發展。目前台灣社會有相當共識，農業是全民的農業，而不單只是農民的農業。農業在糧食安全、生態環境、文化和社會功能，都扮演著重要的角色，沒有農業就沒有台灣的文化。農業面對國際貿易及全球氣候變遷，更須要政府協助農業是有整體競爭力的產業，而不單單僅以農產品價格計算商業產值，而是農業可

以提供多方面供給，提供全國不同需求。OECD 於 1998 年農業部長會議公報確認農業、農村的多功能性為農業的活動達成...景觀形成、國土保全、再生天然資源的永續管理、生物多樣性保全及提供對環境產生利益的效果，使農村地區在社會經濟上的存續能提供其價值。歐美日等先進國家均已導入不帶貿易扭曲效果的綠色政策。OECD 公報亦說明整體糧食安全與發展與鄉村發展、農業生產、環境保存等議題密不可分，這與農村再生相關政策也是不可分割的連結，我國為聯合國認定 4 個最易受到災害影響國家之一，在全球氣候變遷日趨嚴重的 21 世紀，我國糧食安全及鄉村發展相關議題更形重要，本計畫出國人員為理解基於食糧安全的永續鄉村發展，故擬具計畫前往英國進修一年。

貳、過程

一、進修行程

日期	行 程	工作紀要
105.9.20~21	台南-桃園國際機場-荷蘭阿姆斯特丹史基浦國際機場-英國伯明翰國際機場	搭機離台飛往英國伯明翰國際機場
105.9.21	英國伯明翰國際機場-英國英格蘭東密德蘭地區諾丁漢市-諾丁漢特倫特大學市區校區 City Campus	抵達伯明翰後，搭火車至諾丁漢，並到諾丁漢特倫特大學領取學生簽證相關證明，並開始尋找租屋。
105.9.23	諾丁漢特倫特大學 Brackenhurst Campus (Southwell NG25 0QF)	諾丁漢特倫特大學開學周開始，了解大學、學院及系所各項須知及要求。 本課程上課之校區為 Brackenhurst Campus，位於 Southwell 小鎮旁，諾丁漢市中心區東北方約 22KM 處，該校區前身為諾丁漢農業學院，校區被小麥田、油菜籽田及畜牧地圍繞，現為諾丁漢特倫特大學之動物、農村及環境科學學院。
105.10.3	諾丁漢特倫特大學 Brackenhurst Campus	開始第一學期課程，課堂授課共計 10 周，主要為糧食安全與糧食系統及研究方法與資訊分析兩

	(Southwell NG25 0QF)	課程，其餘時間須完成課程各項報告。
106.1.9	諾丁漢特倫特大學 Brackenhurst Campus (Southwell NG25 0QF)	開始第二學期，課堂授課共計 12 周，前段先完成糧食安全與糧食系統及研究方法與資訊分析兩課程，中後段開始糧食安全創新及糧食安全與國際合作組織兩課程，其餘時間須完成課程各項報告。
106.4.19	諾丁漢特倫特大學 Brackenhurst Campus (Southwell NG25 0QF)	開始第三學期課程，課堂授課共計 8 周，完成糧食安全創新及糧食安全與國際合作組織兩課程，其餘時間須完成課程各項報告。
106.6.9	諾丁漢特倫特大學 Brackenhurst Campus 及 Boots library, City Campus	第三學期完全結束，完成所有 4 項課程相關報告，開始畢業論文研究及寫作
106.9.11	諾丁漢特倫特大學 Brackenhurst Campus	完成碩士論文研究海報，並輸出紙本繳交
106.9.18	諾丁漢特倫特大學 Brackenhurst Campus	完成碩士論文紙本，並繳交論文紙本及電子檔
106.9.19~20	諾丁漢-伯明翰國際機場離開英國-巴黎戴高樂機場-香港赤臘角國際機場-桃園國際機場-桃園高鐵站-台南高鐵站-台	繳回租屋，自伯明翰機場搭機離開英國。原定飛往阿姆斯特丹班機嚴重延誤無法銜接返台班機，被迫改經巴黎、香港抵達台灣桃園，於次日凌晨抵達台南。

	南火車站-台南	
106.9.21	水土保持局臺南分局	返回辦公室報到並開始上班。
106.12.8	諾丁漢特倫特大學市區校區 City Campus	諾丁漢特倫特大學畢業典禮，因返台後業務繁忙，且接近年度，各項年度工作均須完成，出國人員無法參加該典禮。畢業證書由學校在畢業典禮後郵寄回臺灣。

諾丁漢特倫特大學 Brackenhurst Campus 空拍全景

選修糧食安全創新課程同學與 Precision Agriculture & GIS 講座合照(UAV 空拍)

二、進修期間年度計畫目標及工作項目

本出國進修計畫分 105、106 兩年度執行，各個年度計畫目標及工作項目分列如下，

(一)、105 年度計畫目標及工作項目

1. 相關手續辦理及行前準備

前往英國進修碩士，首先須通過 IELTS 語言測驗要求，一般英國大學所訂碩士課程語言能力標準為 IELTS 6.5 級分(部分大學則採取更高級標準，如倫敦政經學院等)。IELTS 是赴英國進修，現今採用唯一語言測驗，托福等其他國際英文能力語言測驗已經不能適用於申請英國大學。IELTS 6.5 級分介乎於英語良好的使用者及合格的使用者間，依我國現今公務機關語言能力分級表可列為比照全民英檢(GEPT)高級等級。IELTS 語言等級 6 與 7 之說明如下:

7 良好的使用者	有能力運用英文，大致上可以理解與掌握一些複雜的英文，但在某些情境下會發生不正確、不適切和誤解和缺失
6 合格的使用者	大致上能有效運用英文，雖然會有一些錯誤產生。若是在自己熟悉的情境下，一些較複雜的英文也可被理解及運用

另外申請學校則由網路搜尋，依照鄉村發展與糧食安全相關系所、農業專業、學校排名、學校所在地生活費用等總和考量，故申請諾丁漢特倫特大學就讀全球糧食安全與發展碩士課程。

但出國前面臨最嚴重問題為無法確定租屋處所，因英國現有住宅供給緊張，就讀大學無家庭式宿舍，且因為國際恐怖主義影響，英國政府對於外國人租屋，要求房東需擔負更多安全責任，故無法於台灣逕行託友人尋找租屋，故出發赴英前，尚未租到適當宿舍(到英國兩周後方租到住處，在此感謝台灣長老教會派駐英國曼徹斯特大學鍾淑惠牧師協助)。

2. 完成 Global Food Security and Development 第 1 學期課程

第一學期課堂上課時間計有 10 周，本學期主要研修 2 門課程，分別為整合糧食安全相關專業學門的 1.糧食安全-糧食系統 201617 上半年課程(ARES40140: Food Security-Systems Analysis 201617 Half Year 1)、及一般性的 2.研究方法與資料分析課程(ARES40011: Rsrch Methods &Data Analysis)，英國學制為每年 3 學期，故此兩門課程將持續至下學期。其課程為針對糧食安全，以農業-生態科學、地理、國際發展、社會與政治科學及創新研究的內涵整合性地進行跨域研究，探討與分析全球糧食安全議題。並瞭解影響糧食安全輸出因子，解決糧食安全問題的方法。

全球糧食安全與發展課程師資包含不同研究領域，涉及永續農業與糧食系統、糧食安全、國際農業與鄉村發展、糧食政策與治理、糧食與農業創新與行為改變、鄉村社區組織、水土資源、自然災害、人類遷移及地理空間資訊等領域。

首先在糧食安全-糧食系統 201617 上半年課程方面，該科目為今年主要科目，內容為多領域整合課程。現今國際對於糧食危機有不同領域的關注，目前主要全球糧食安全所面臨的挑戰主要有氣候變遷、水資源危機、土地退化、農業病蟲害及糧食主權問題，在我國除了現在政府持續性投資於農業研究與基礎建設，在未來我國也是會同世界其他國家，特別是熱帶與亞熱帶海島型國家將面對的氣候變遷考驗，修習本課程可以建立糧食安全基本觀念架構，本糧食安全-糧食系統基礎課程可分為自然科學方面與社會科學兩大區塊，非單屬自然科學，也有跨越社會科學領域範疇。

依據聯合國農糧組織定義糧食安全係指糧食安全是所有的人，在任何時候，都能通過實體物質的、社會的和經濟的途徑獲得足夠、安全和營養的食物，滿足人的有活動力及健康生活下的飲食需求及食物喜好。(" Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. ")

糧食安全-糧食系統課程主要議題分別為-糧食安全介紹及其基本概念-主要了解糧食安全四大主軸- 首先國家層級的供應充足 Availability (physical)，到家戶層級的食物可獲得 Access (physical, economic)，個人的營養利用 Utilisation (consumption, nutrition)，加上時間軸的穩定 Stability of the three, Availability, Access and Utilisation (over time))，並有各種不同糧食安全評估工具。課程進行中，教授要求提出不評分的練習報告，由學生研究各類糧食安全評估工具後，提出 3 項較有可能應用於各自國家的評估指標及其理由，經評估，糧食收支表 Food Balance Sheet 及 Household Dietary Diversity Score (HDDS)、Household Hunger Scale (HHS)可能是適合我國這一類已開發國家使用於評估糧食安全。

糧食安全-糧食系統課程在糧食安全理論評估方式-所主要學習理論有 4 種，分別是 A.英國經濟學家馬爾薩斯的人口論與糧食安全 B.1981 年諾貝爾經濟學獎得主 Amartya Kumar Sen 的權利方法 The Entitlement approach C.Friedmann & McMichael 在 1989 提出的糧食政權理論 Food Regime theory D.及因發展中國家遭受 HIV 等新疾病而產生的新型變種飢荒假說 New Variant Famine (NVF)Hypothesis 等四大理論。

在馬爾薩斯理論上，在將來面對糧食安全，對亞太地區糧食安全問題，澳洲學者已提出 5 個相互關聯的挑戰，雖然這 5 個相關糧的挑戰帶有相當的馬爾薩斯學派悲觀的情境設定，但仍然有相當的事實已經呈現在當前台灣與世界的農村，不論是已發展國家、開發中或是落後地區都有面臨相關困難，對未來可能發生情境應當加以積極準備。未來的糧食安全可能面對的 5 項挑戰分別是 1.氣候變遷 2.水資源短缺 3.對流層的臭氧汙染 4.磷肥短缺 5.未來因為人口移動、地區衝突及政府治理不善等造成的交互作用， 都應當要在現在預先做好規劃想定，也就是從社會與

環境、人口成長、農業發展及權利、機會、分配給付等多個面向上做根本的轉變，以達成永續的糧食安全改善 (Butler CD, 2009)。

聯合國預測 2050 年世界人口可能會超過 90 億人，目前世界的可用農耕土地是已經是等同整個非洲大小，若為了養活 90 億的人口，地球可用農耕土地還需要增加一整個巴西國土大小才足夠養活。現今科技發展雖可以以垂直農場、植物工廠或是水耕種植方式提供糧食，但是其投資與種植精緻高價的農作物，目前仍是以蔬菜種植為主，並不能完全有效解決糧食不安全的困難，相對之下，傳統作物生長的農地如何保護，避免其劣化是更為重要工作。但這也與慣行農法與環境友善議題息息相關。另外現今慣行農業方法需要依賴大量石化燃料及化學肥料，在遇到如 2008~2009 年間能源危機及全球肥料飆漲的年代，特別是磷肥的缺乏，將使糧食安全問題更加困難。

人類農業史 9000 年來，人類發展農業的歷史過程中也將原有多樣化的物種馴化與淘汰，在

今日大部分的原始農產品物種大量消失，世界的食物種類與作物品種如同美式早餐一般愈來越趨全球一致。雖然有科學研究單位進行保種，或在挪威北極圈內設置種子庫，但仍難以避免農作物品種日趨單一均質化，對於將來糧食供應的糧食安全議題有極大的威脅。

在 2008 年全球爆發糧食危機，糧食價格飆漲，原有農作物輸出國家實施多項限制出口政策，使糧食價格攀升到歷史高點，但以糧食安全理論及實例證明，糧食安全問題並不只有在於生產不足而造成百姓飢餓，更大的問題在於人民最低程度的生活保障與政府有效分配能力不足下，造成更為嚴重的糧食安全問題，甚至於饑荒，所以正確理解相關經濟分配等社會科學也是理解糧食安全不可忽略的一部分。

近年來不論是在大力推動城鎮化的中國或是嚴格法規限制土地變更的歐洲，都面臨大量農地被轉變用途為建築、工業等不可回復的非農業土地使用，使得已經稀少珍貴的農地被政策剝奪，對於將來的糧食安全威脅更加嚴重。

糧食安全-糧食系統課程在有關全球氣候變遷與糧食安全之關聯-了解全球氣候變遷及極端氣候事件與糧食安全四大主軸相關關聯性及目前先進國家等組織的科學預測。例如依據德國方面之研究，氣候變遷可能會對熱帶及亞熱帶地區所有作物有強烈產量衰減的影響"Stronger yield-depressing effects will occur in tropical and subtropical regions for all crops, which reflect a lower growing temperature threshold capacity in these areas" (Rosegrant et al., 2008)。若是全球氣候變遷下氣候持續如預測趨勢漸趨變熱，長期將對我國的糧食安全將造成威脅，影響國家糧食主權(Food Sovereignty)，農民若無法生產足夠糧食維持生計，將造成農業進一步衰退，農民遷離農村，將對我國鄉村發展有長期影響。

糧食安全-糧食系統課程在農業生態學(Agro-biodiversity)所重視的是長久以來農業行為使得生態系統漸趨弱化，在農業生態學研究領域，主要將農業也視為生態系統的一部分，在現今全球農地普遍面臨土地退化下，日本向聯合國提出的里山倡議也是屬於此類改善方法或農地保存方式的作為。

糧食安全-糧食系統課程在自然災害(Natural Disasters)、全球農業病蟲害(Pest &Diseases)方面，也提出相關案例作為討論與想定減災、避災作為，來避免糧食不安全狀況發生，也討論世界各國面臨各項自然災害及對糧食安全的可能影響，並由學生各自提出 1 個案例分析報告，因為我國主要受到強烈降雨事件影響，如八七水災與八八水災都屬於同類自然災害影響，其對於糧食安全的影響與恢復作為，出國人員也有於課堂提出報告。

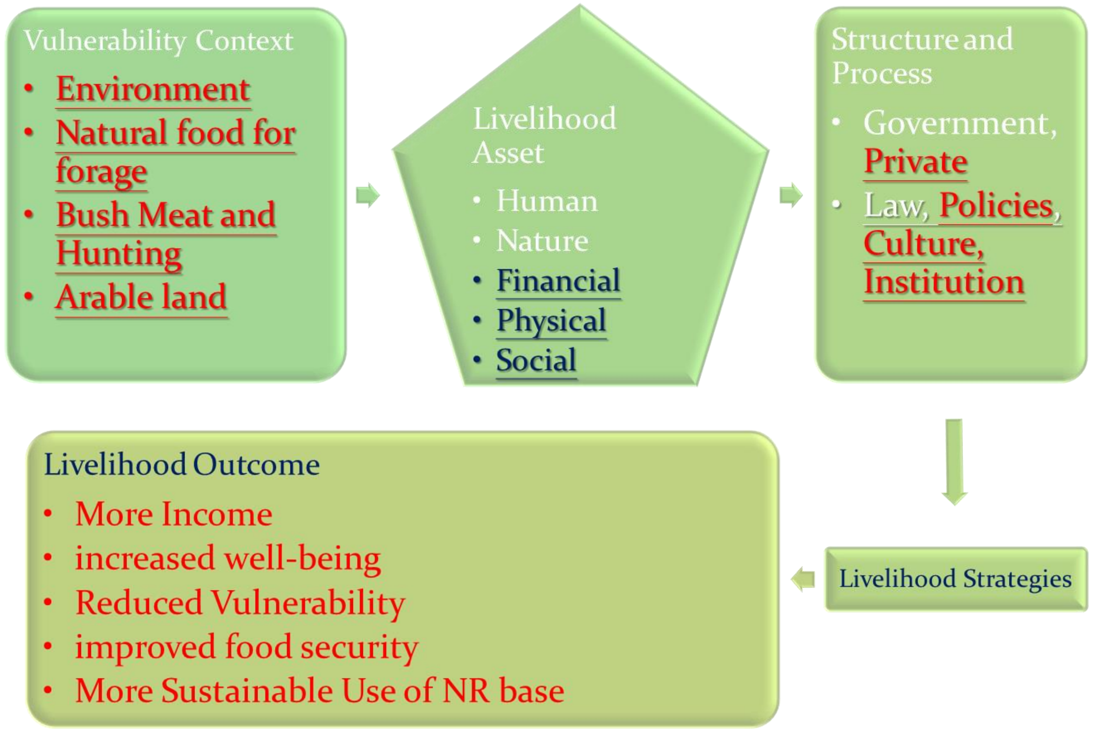
有關糧食安全之自然科學部分議題，雖在台灣公務上也有接觸，在辦公室可能只是將其歸類在氣象學、災害防救，或是與農村產業息息相關但從未接觸的農業病蟲害，但本課程所討論的這些自然科學領域與全球糧食安全議題有相互連結，反而與水土保持業務的傳統農藝方法、植生方法較為接近，也可說是比較接近於水土保持局前身的山地農牧局的業務範疇，彼此有所相關聯。

糧食安全-糧食系統課程在移民工(Migration and labour issues)與糧食安全關聯部分也有所討論， 英國農業區在這部分有跟台灣現況相似之處。在英國主要農村工作主力已經由英國籍農夫轉成從東歐來的年度移工或長期移工，英國籍農夫負責如拖拉機等機械操作，使用到大量熟練人力的蔬果採收和食物處理都是東歐移工為主。歐洲移工系維持英國農業生產到零售市場之間的運作，在英國脫歐公投後，歐洲移民工如何維持英國農業生產是有待觀察，這也是我國農村與農業同樣面臨的議題，長期以來我國的農業一直是面臨缺工問題，是否開放農業外勞之政策也可以參考這樣的作法可待日後研究。

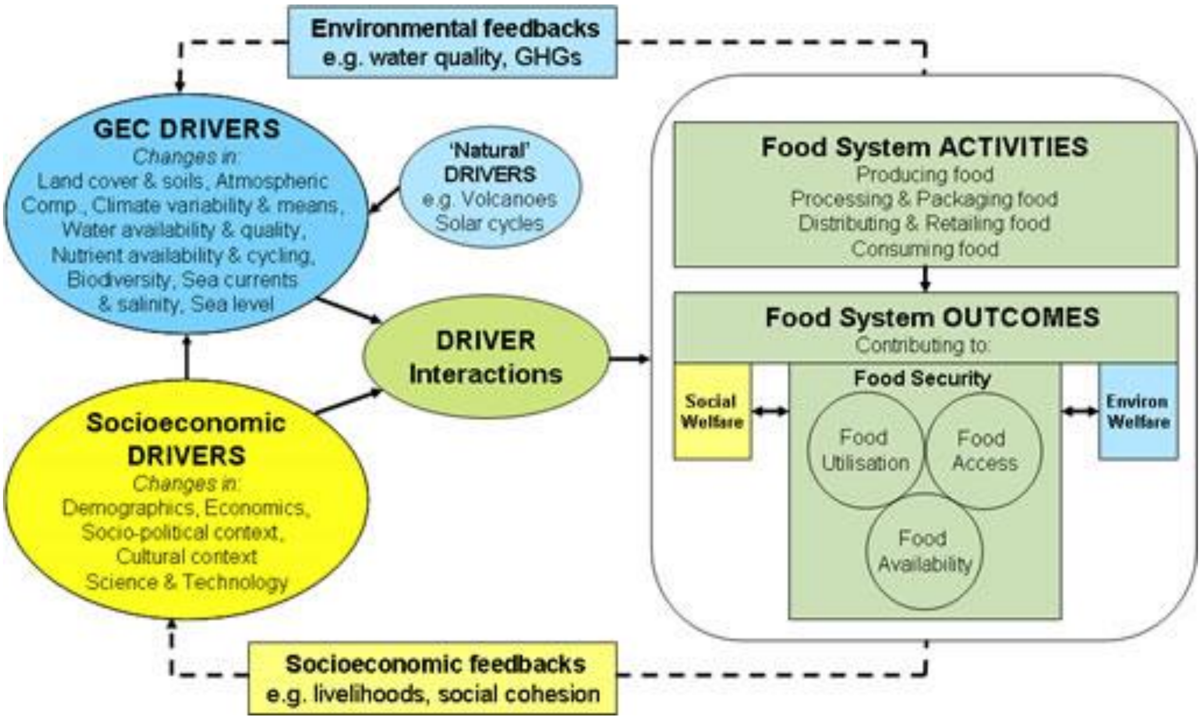
糧食安全-糧食系統課程在全球化、市場(Market)、政策與治理議題(Policy and Governance Issues)方面也有相關連，除課程外，講座並指定全球化浪潮下，食品營養議題與糧食安全之相互作用文獻，也提供聯合國農糧組織在世界發展中國家之糧食市場發展與糧食安全的影響，例如就市場與糧食安全議題而言，選讀尼泊爾在山區道路開通以後，對於市場糧食價格如何降低及改善家戶獲得食物的途徑，並研讀南韓稻米自由化政策相關文獻，提出書面報告，以了解政策、全球化、市場與糧食安全相關交互作用。

糧食安全-糧食系統課程在糧食系統分析，則針對糧食系統進行概念學習，主要分有 4 種架構，分別敘述如後。A.永續家戶生計架構糧食系統 The Sustainable Livelihoods framework-英國國際發展部(DFID)及聯合國農糧組織所發展架構。下圖

為以原住民之永續家戶生計架構糧食系統示意圖(資料來源:出國進修人員自繪)。



B.若是以愛爾蘭大饑荒歷史，則可由 The panarchy framework 說明糧食系統，簡言之，若是生態(或政府)系統失去歧異度但持續增加生物量及連結，可能會在遭遇很小很小的環境問題時卻造成很大很大的衝擊，19 世紀中葉在愛爾蘭因為馬鈴薯病蟲害連續歉收，造成大饑荒及人口大量外移到美國的悲慘歷史。C.社會生態學系統計架構糧食系統-Socio-Ecological Systems framework。D.食物系統架構 Food System frameworks 則主要說明傳統食物與現代商業食物(store food)互動影響架構及對人與環境的相互作用，例如氣候變遷下，依賴傳統食物系統生活的加拿大依努特人受到現代商業食物的飲食文化衝擊，下圖為食物系統架構示意圖(資料來源: http://www.gecafs.org/research/food_system.html)。



講座亦要求學生對國際上糧食系統提出基本看法與學習糧食系統相關理論與學習利用國際通用評估模式並做口頭報告。

另外在研究方法與資料分析課程方面，首先是使用統計工具與在台灣通常使用的不同，在定量研究工作上，主要仍然以統計學為基礎，在統計工具係介紹國際常用開放軟體 R，而不使用 SPSS 軟體或是微軟公司 EXCEL 軟體，是與國內較不相同之處。

而研究方法與資料分析課程在定性研究上，特別是在參考文獻研究上，在諾丁漢特倫特大學是介紹使用 NVivo 軟體，這個軟體可以提供文字資料分類彙整及圖像化分析比重等工作。這也有一部分是因為整合英語系統與 PDF 檔案為基礎所發展出來的軟體，這軟體也是本計畫出國人員最終碩士論文寫作所使用軟體，用於將訪談英國農夫的訪談記錄逐字稿歸納為可分析分類之文字紀錄。

在研究方法與資料分析課程對於口頭報告部分也有說明，特別在於簡報的製作與使用上，應當避免太多文字在同一張簡報，對於閱聽者是很大的負擔，簡報對於任何的口頭發表，都只是工具，重點是協助發表人表達主題意念，應當避免錯用。

研究方法與資料分析課程是諾丁漢特倫特大學全體動物、鄉村及環境學院各科系研究生均需要學習的課程，無論是生物多樣性、頻危物種復育、育馬學、動物健康與福祉或是全球糧食安全課程均是修同一門課，所以在滿足大部分同學不同需求上，課程作業設計有依據不同科目進行修正。在學術倫理議題上，在研究方法課程有特別強調，在有關設計任何動物試驗或執行任何訪談前，都應當進行審議，以避免日後困擾或研究工作努力被抹滅。

本進修計畫內容除了在課堂上聽講座授課外，還有課後的各項指定繳交的書面報告作業及口頭報告(非期末報告)，但全球糧食安全與發展課程負責教授 Dr. Mofa Islam 建議計畫出國人員可以持續提升英語能力，另外在學術論文或作業方面可以尋求特倫特大學圖書館的家教服務，協助課堂不足。故在提升英語能力上，因為學校的語言中心課程不容許學期中途加入(雖然僅開學 2 星期後)，尋求鄰近學校之 ESOL (English for Speakers of Other Languages) 課程協助。在宿舍附近申請在地公益團體 Voluntary Action Broxtowe 所開辦對英文非母語之外國人(含學生)英語課程班，每周 2 小時，持續精進語文。同時諾丁漢特倫特大學圖書館也透過提供網路預約短時間家教協助，雖然每次只有半小時時間，但可以針對學習所遭遇問題諮詢解答，及協助指導修正英文寫作格式錯誤。

在第 1 學期課堂課程結束後，在西方耶誕假期到第 2 學期開學後 2 周期間，糧食安全與糧食系統課程與研究方法與資料分析課程都有指定作業，以向英文專業學術期刊投稿的標準各提出 1 篇有指定格式的課程正式報告，由檢查現有 2 門課程所提供的基本資料開始，收集相關論文，提出討論，設定假說，統計驗證假說或

定性分析整理，完成結論說明的方式寫作，並且在提出書面作業後，再於適當時間提出口頭簡報，方完成課程。這對於非英語系國家學生是一項大考驗。但這也是英國碩士課程只有一年，所以很多學習工作都需要壓縮，長遠而言，節省總體學習歷程反而是到英國進修的優點。

(二)、106 年度計畫目標及工作項目

1. 完成 Global Food Security and Development 第 2、3 學期課程

本項目主要完成本計畫英國諾丁漢特倫特大學的全球糧食安全與發展碩士課程 Msc Global Food Security and Development 第 2 學期、第 3 學期學習。106 年度所接受之學習課程首先接續第 1 學期之糧食安全及糧食系統課程(Food Security-Systems Analysis)及研究方法與資料分析課程(Research Methods &Data Analysis)，完成兩課目之課程期末作業，在第 2 學期以及第 3 學期主要學習兩項課程，分別為糧食安全之創新課程(Innovations for Food Security)、糧食安全之組織合作(Food Security-Dev Cooperation)。講座課程均仍在諾丁漢特倫特大學之蕨菜丘校區(Nottingham Trent University, Brackenhurst Campus) 進行，另外在校外參訪部份，則由授課教授帶領參觀諾丁漢市區之社會企業 Arkwright Meadows Community Gardens 及排名世界最大的作物保護產業及高經濟價值種子第 3 位的先正達公司(Syngenta)在英國南部的研發園區參觀 (Jealott's Hill International Research Centre, Bracknell, Berkshire, RG42 6EY, United Kingdom)，主要參觀作物保護產品如何進行試驗、試驗過程及成果分析，小麥品系育種，新市除草劑相關製品功效評估及該公司全球布局簡報與討論(但涉及保密規定，園區不可拍照記錄)。

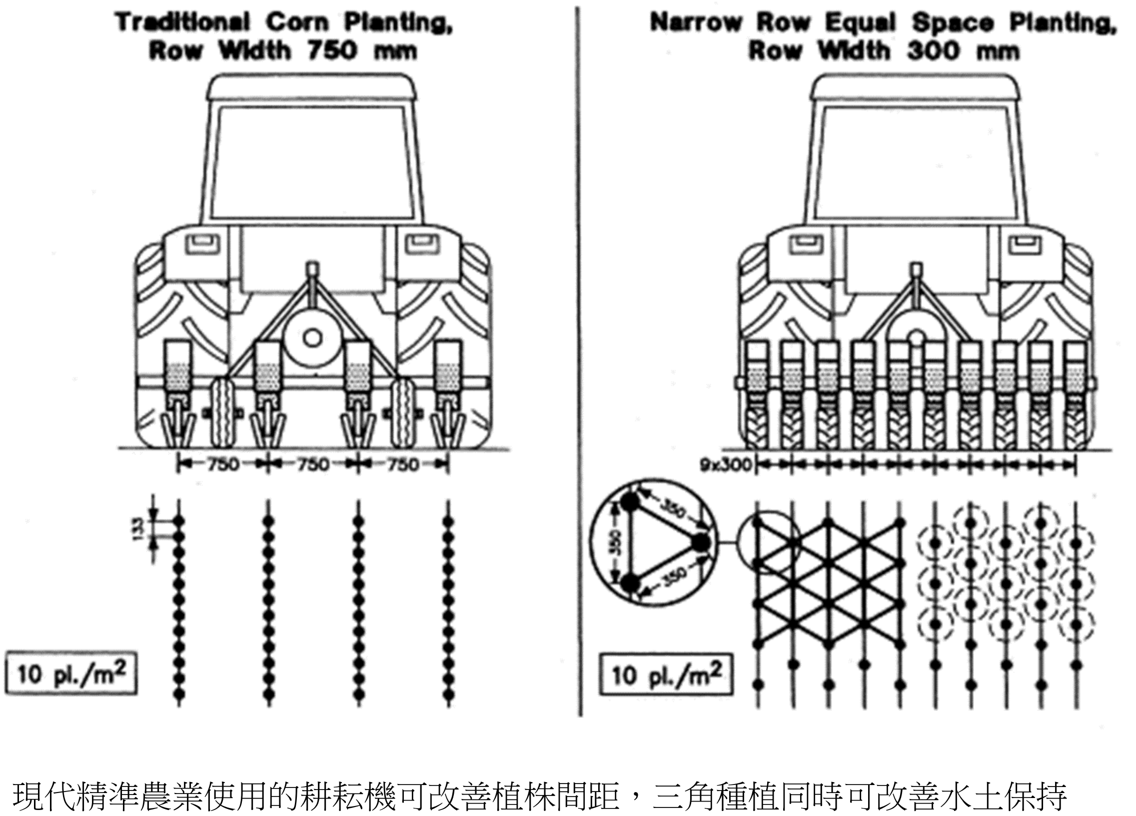
本學期首先接續前一學期之糧食安全及糧食系統分析課程，並以 2008~9 年間全球糧食危機為題材，由學生進行糧食危機發生原因之探討及其連鎖反應，另外完成第一學期開始之研究方法與資訊分析之課程期末報告，主要以衣索比亞之某年度糧食安全問題及糧食援助分配議題進行分析，並以國際通用(如聯合國相關組織)之 R 開放軟體，進行統計分析，並以所獲得資訊進行資訊分析論文寫作實習。本碩

士課程之所有 4 項課程計分方式均是以期末報告為主，課程學習中所進行各項報告及練習均不計分，僅為學生了解課程各項議題所用，故期末報告是學生學習最大考驗。

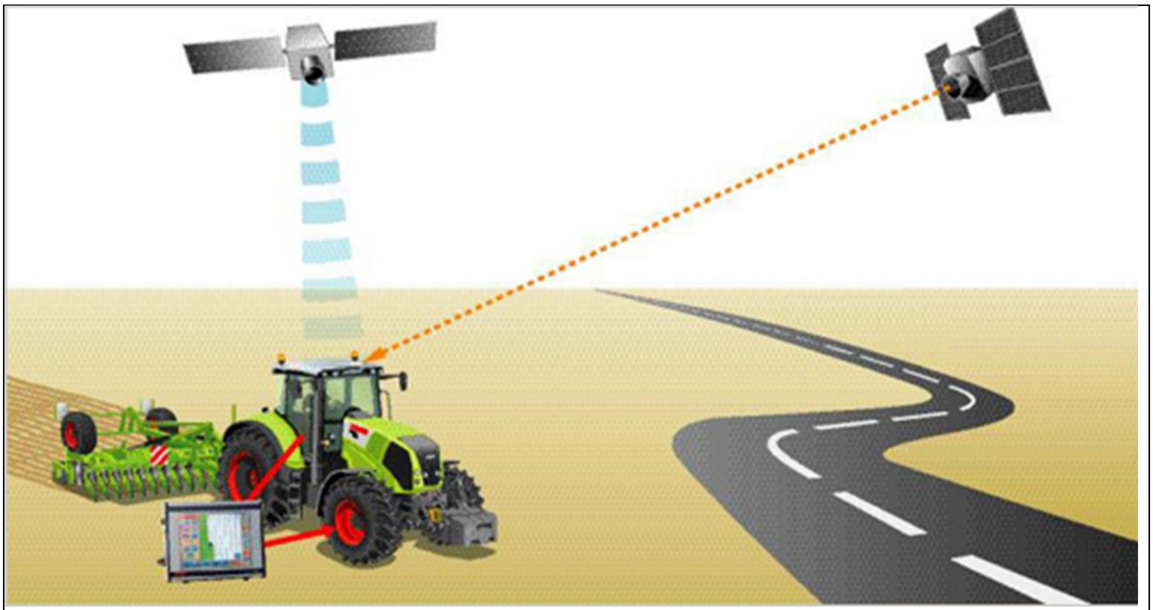
於本學期開始研習糧食安全創新課程，以了解在 21 世紀受到全球氣候變遷影響下，糧食系統及糧食不安全因素可能消除方式，並探討部分農業與科技倫理等相關議題，例如農藥、基改作物、植物工廠等新觀念，並由不同課程講座教授講解例如無人飛行器、衛星影像，科技農業、精準農業與地理資訊系統等新科技對糧食生產之可能效益。另外也開始國際合作組織及糧食安全課程，藉由國際性合作組織之定義、性質及其問題分析方法進行介紹，以利學生了解不同國際組織其共通合作理念及面對不同地域糧食安全與發展課題如何因地制宜制定計畫，在有限資源限制下(如資金、土地)，尋求有系統且可行的實施手段及有效的發展計畫。

糧食安全創新課程首先定義創新，依據世界經濟合作暨發展組織 (OECD)定義創新是指在實際商業行為、工作場域組織或對外關係上一種新的或是有顯著改善的產品或服務、製程、或是新行銷手法、新的組織手法的一種實際執行 "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. (OECD, 2005)"。創新與創造力在定義上有所不同，創新也是與創意發明不同，這是我們先必須明瞭區分的。創新在定義上不僅僅限至於單純軟體或硬體，最重要的是在於實際執行。創新存在於科技面(Technological innovation)、機構面(Institutional innovation)及社會面(Social innovation)3 大面向，現代畜牧業使用 RFID 系統，落後國家小農使用金屬製儲糧筒，在中南美洲武裝衝突地區社區農戶組織合作社與商業銷售連結等方式都是有效的創新。另外在機構(I N S T I T U T I O N) 及組織(ORGANIZATION)的區別，對於創新的影響也有涉及。我國的農村再生政策相關組織做法也均可歸類為創新。

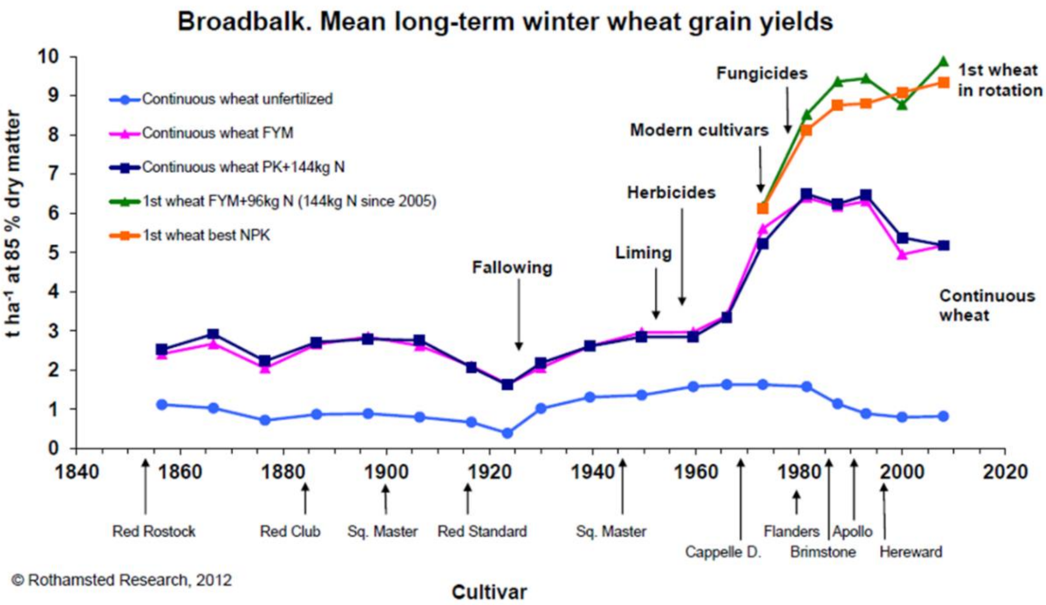
總體而言，糧食安全創新課程則從農業發展歷史開始討論，在人類農業發展上在不同時期都是有不同創新，從英國農業開始使用播種機開始到近代的綠色革命，不同時期的農業就是持續不停的創新，以因應增加的人口、城鎮化及工業革命等不同時期的糧食需求。這項課程從創新的角度重點關注糧食安全問題的解決方案。課程主題將涵蓋初級生產技術創新（例如農作物和動物品種，包括轉基因生物;農業機械，包括地理信息系統和精準農業;植物工廠、垂直農業、土壤和水資源管理關聯性;病蟲害防治技術）以及農產品加工，分銷和零售業產品。這課程也相當著重在農糧部門的非科技面創新，或可以說是糧食安全問題的社會科學部分，包括政策和規則性處置流程以及機構的安排，強調與人的關聯性。 另外，這課程的一個重要方面將是討論促進與糧食和農業有關的創新和行為變化的各種方法，也包含為何有農業創新想法做法，但整體環境與新想法新作法相牴觸時導致的失敗案例。這課程可以訓練以下 4 項目，1. 評估改善糧食安全的創新， 2. 分析糧食安全問題管理工作中的創新擴散效果，知識轉移和行為變化，3. 評估使用概念架構和方法來分析糧食安全計劃和系統的成功，及 4. 選擇並應用適當的方法和工具來分析創新和行為變化過程。



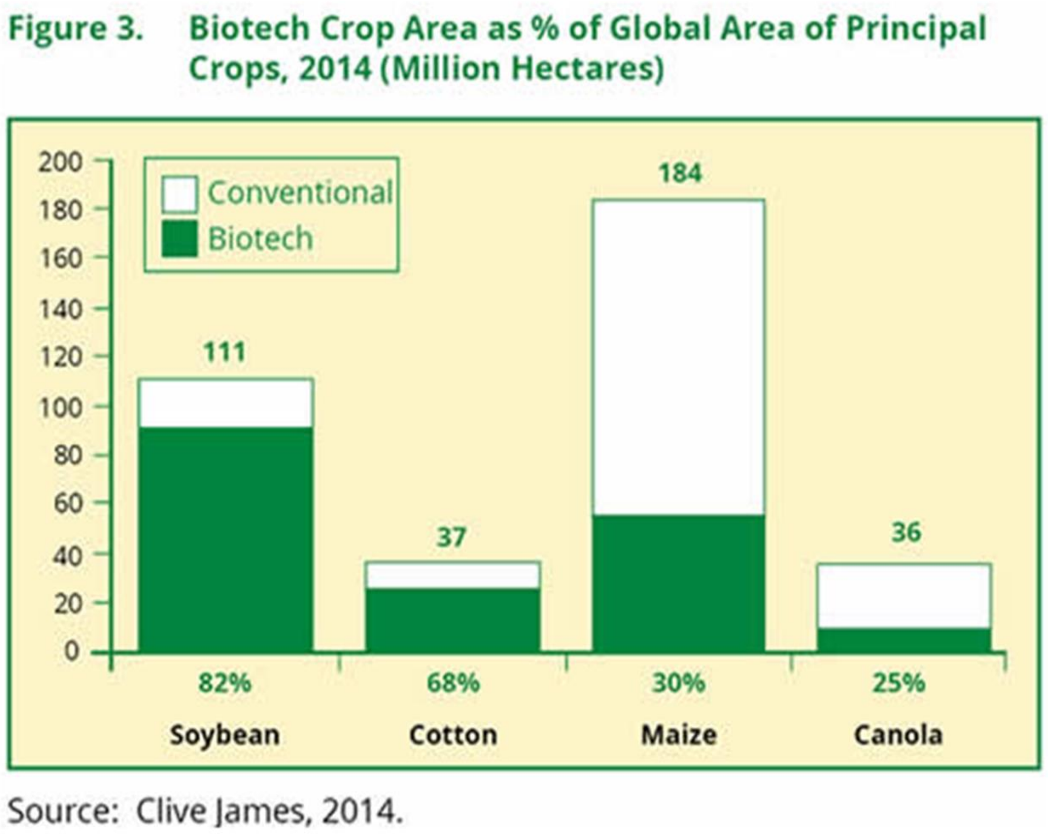
現代精準農業使用的耕耘機可改善植株間距，三角種植同時可改善水土保持



精準農業與地理資訊系統、衛星導航關係密不可分



穀物產量如小麥在綠色革命後(搭配肥料與農藥)大量增加



世界黃豆與棉花產量過半多為基因改造作物

以上圖片資訊來源均為諾丁漢特倫特大學課程講義節錄。

在教室課程以外，特別重要的戶外參觀分別有農業相關的社會企業及參觀先正達(SYNGENTA)公司在英國南部的研究園區。首先對於農業的社會企業部分，學校就近安排參訪諾丁漢市區的社區菜園 Arkwright Meadows Community Gardens，這是NGO 團體與諾丁漢市政府及當地小學共同合作的社會企業，但主要經費贊助還是來自於英國樂透基金(LOTTERY FUNDED)，經營主體仍然是由志工及很少數的專職人員維持，主要發揮功能在於提供周邊社區民眾參與社區共同事務，提供諾丁漢各級學校環境教育校外教學，並協助新住民(例如新搬入社區的英國人、亞洲移民還有最近幾年的中東非洲難民)安頓在新社區，新住民也產生歸屬感，這些非經濟性效益占的比重較大。還有跟一小部分諾丁漢地區餐廳合作提供新鮮低碳足跡蔬菜，但這部分收益比重甚小，這個計畫雖然在英國可以歸類為社會企業，但與

我國農村再生計畫工作有部分類同，但單純考量經濟效益係偏低。

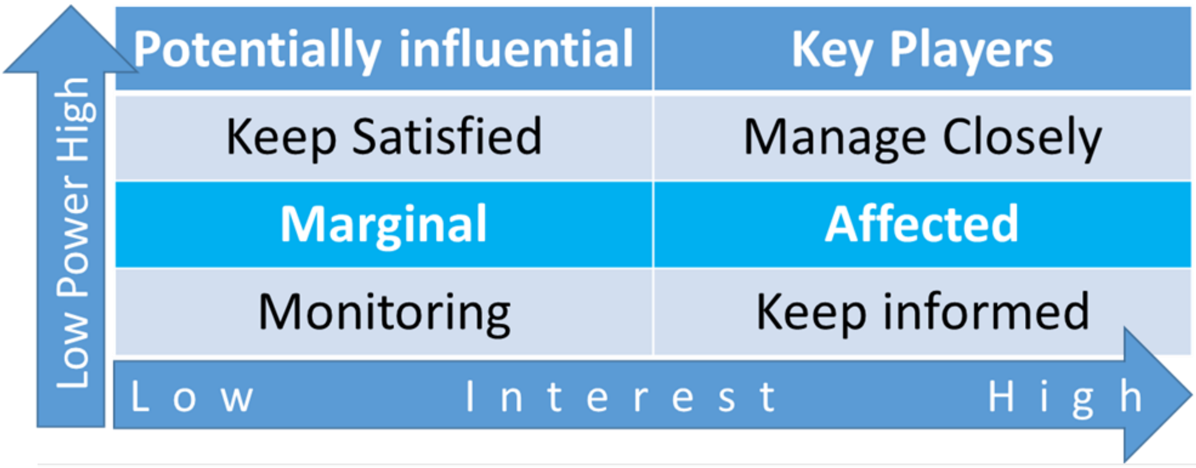
這學期最重要的課程應當是以參觀瑞士先正達公司在英國南部的研究園區對出國進修人員最為震撼衝擊，先正達公司是世界最大的作物保護產品製造商，也是第三大種子供應公司，最近將被中國國營企業中國化工合併，在我國作物保護產品被簡單歸類為農藥、殺蟲劑、除草劑，但參觀先正達公司可以理解在我國常被視為負面的產品，如何在全球銷售而且可以正向推動聯合國永續發展的工作，走向大眾較認同的永續農業，也避免日後耗時花錢的國際訴訟。光是先正達公司一年所投入的 R&D 經費，就達到 11 億美金，也就是每年超過 330 億台幣進行研發工作，平均一樣產品發展時程要長達 10 年方可上市，同時也要符合各國不同法規要求及環境限制，所以如何在銷售目標及環境要求取得平衡，是這樣的大型公司相當重視的，我們認為是農藥廠的國際公司也強調環境友善與永續發展，那也代表後續的收益如何增加與可能的訴訟如何避免，所以在先正達公司的簡報，非常強調部門間團隊合作，跨國的跨領域團隊甚至於法規的團隊合作。例如在我國屏東萬巒，先正達也有農業研究試驗站，在台灣的試驗成果都是對於全世界的農業發展，特別是熱帶地區有重要貢獻的。可惜的是，參觀這研究園區不能自由拍照。

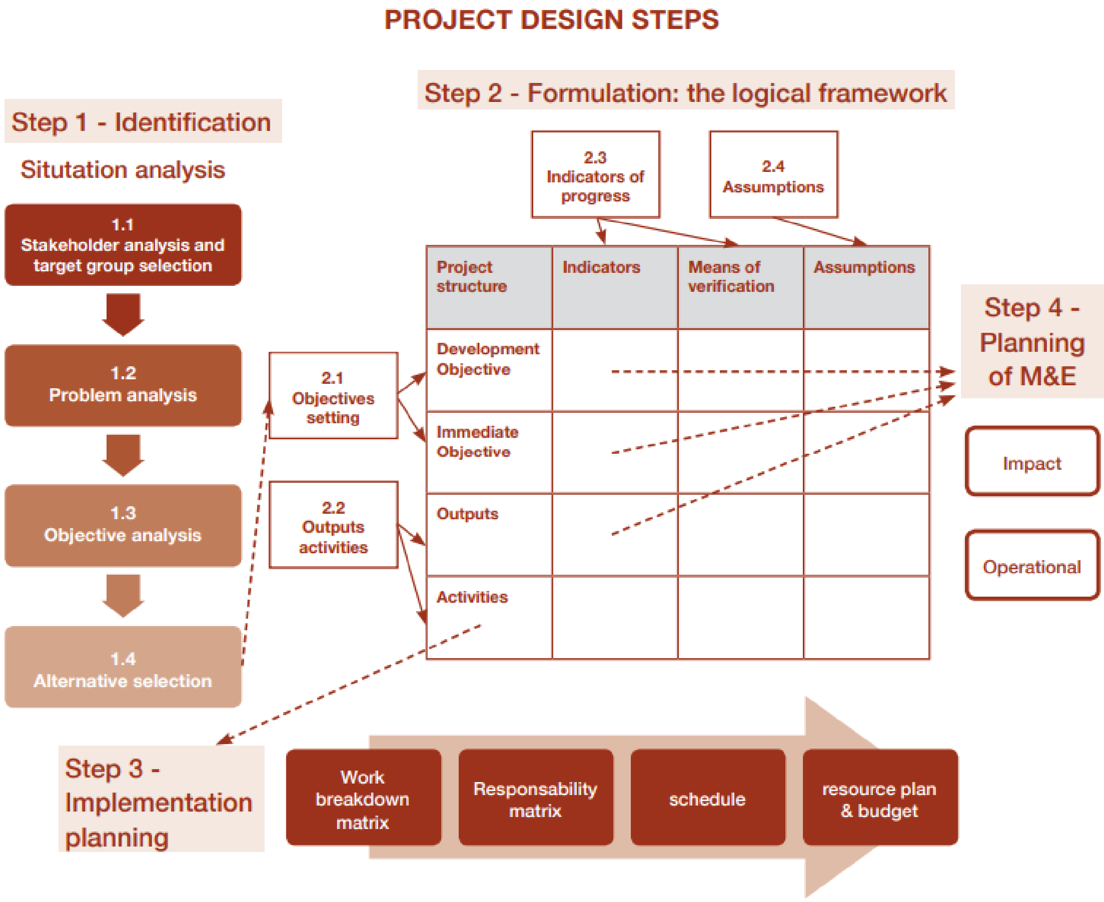
在糧食安全之組織合作(Food Security-Dev Cooperation)課程部分，則是針對國際上雙邊組織或多邊組織，對糧食安全有問題的地區，如何透過發展計畫改善糧食安全問題。本課程原始設計是設定在當本課程學生成為國際發展組織，例如聯合國農糧組織或亞洲開發銀行的專職成員時，如何協助發展中國家進行或設計發展計畫，這工作與當年我國農復會在鄉村地區進行各項發展計畫相當接近。這課程主要介紹發展合作(development cooperation)的概念，探討國際發展合作在減輕發展中國家糧食不安全狀況的作用角色。這課程的主題包括

聯合國世界糧食計劃署(WFP)，聯合國糧食及農業組織(FAO)，英國援助(UKAID)，歐盟援助(EU AID)，美援署(USAID)等機構提供的有關糧食安全的發展援助的各種形式和方式，以及影響其有效性的因素。 課程還討論如何有效規劃和管理農村/農

村發展方案，包括情況分析，規劃，行政，監測和評估等問題。這課程設計使學生可以全面了解與糧食安全計畫和方案有關的國際發展援助的角色和方式，分析影響糧食安全項目和計劃成敗的因素，審慎評估糧食安全發展合作措施，並可以學習應用規劃，監測和評估糧食安全項目和計劃的方法和工具。也能體會團隊合作、文化性的和在地性問題在實施糧食安全和發展項目和計劃方面的重要性。這項課程期許每個學生在完成這樣的課程後，可以獨當一面的完成及評估糧食安全相關發展計畫。

這項國際合作組織課程亦與我國農村再生計劃設計方式高度相關，差別僅在於國際合作或社區自主、政府協力，但我國農村再生計畫較為偏重社區願景，屬於願景規劃，但實際推動會受限於經費、人力及重要性，反使願景實際落實到社區發展工作有所受限，發展方向與社區期待有很大落差。但依據本課程介紹的邏輯架構觀念進行設計發展計畫，偏向發展組織及各國在地公私組織經由系統計畫篩選具體可行發展計畫，因為實際發展計畫受限於時間、資源及各國獨特環境，開放不收斂的單純願景規劃。在執行時將會受到很大限制。同時設計發展計畫首先特別注重於問題(PROBLEM)分析及利益相關者(STAKEHOLDER)分析，藉由問題及利益相關者兩項分析，選擇可行性方案，並進行細部計畫，如此可讓社區在提出計畫之時，就明確了解各項限制，社區各項計畫可以較明確定向，如此應可以相當程度避免發展計畫過度發散，反導致成果受限。下圖為利益相關者分析說明示意(資料來源: 出國人員自行修改繪製)及發展計畫設計步驟圖(ILO2010)。





資料來源: ILO, 2010

在第 3 學期主要接續尚未完成之糧食安全創新課程，主要工作在完成課程期末作業，並開始進行畢業論文先期資訊收集及學術倫理審查相關事務。首先以植物工廠，垂直農業議題進行期中練習報告寫作，了解新一代科技農業或精準農業在有限空間可能的發展與潛力，在期末報告部分則以基因改造作物(GMO)與糧食安全為

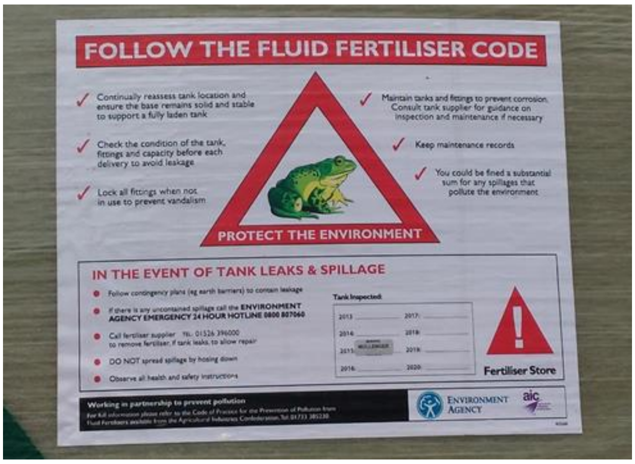
主題，進行全球糧食不安全議題的科技解法的可能性評估報告，也了解新一代農業與全球氣候變遷的相關關聯。另外在國際合作組織與糧食安全課程，則以近年遭逢人道危機的葉門為主題，以國際組織合作課程的相關方法進行預擬，設計可以施行於葉門的糧食安全計畫。

2. 完成英國諾丁漢特倫特大學全球糧食安全與發展碩士學位課程

全球糧食安全與發展課程不偏重在糧食安全或糧食不安全議題，在目前全球糧食生產是足以滿足全球人類所需要，但如何有效分配及廣大鄉村地區如何脫貧與發展才是長期糧食安全的意涵，讓每個人在其飲食、營養需求下，可以適時有效獲得每個人所需要的糧食，才是聯合國認同的糧食安全，故發展係本課程另一主要組成部分，尤其在英國或是我國這一類被歸類為已開發國家，就鄉村發展與農民脫貧議題更為重要。

因以農業相關系所學生加入英國農夫聯合會學生會員，得以報名參觀英國環境農業得獎農場，也發現英國農場通常都是同時維持傳統農業生產及政府補助的環境農業，類似我國推動對地補貼、直接給付政策。也因上課通勤往 Brackenhurst 校區路程中，發現沿路均有於農場設置可再生能源模組，主要以風力、太陽能及小部分農業(畜牧)廢棄物產出生質能之模組，在英國相關農業用地管制嚴格狀況下，仍能設置並運轉，應當是有相關政策及發展策略支持。計畫出國人員懷疑這也與日本現在倡導里山資本主義想法類同，現在如何在日本鄉村地區，經由傳統農業生產、環境維護及再生能源利用，三頭並進，減少鄉村地區現金流淨流出，增加鄉村地區在地經濟活力的作法。經與系所教授討論發現，發現英國農場可再生能源多由農夫或其家庭主導投資設置，變成相當規模的中小型農企業，部分由外來投資者與農戶合資，但在地農夫仍為主要夥伴，非僅提供土地任外來投資者任意胡亂設置農場可再生能源模組。依照傳統農業生產、環境農業及農場可再生能源組合，在相對弱勢農業狀況下(與我國相同)，英國農夫可以增加收入並穩定農業生產，鄉村社區則有較具活力的經濟活動(增加資金收入及減少帳單支出)，與我國目

前所遭遇困難有所差異，英國目前發展狀況應當可對我國未來農村、農民、農業等發展有所助益，故擬定計畫展開研究如何 HOW 與為何 WHY 英國農夫投入農場可再生能源生產，反思我國可能影響，作為日後我國相關鄉村創新發展與糧食安全均衡考量策略參考。以下照片為出國研究人員於 106 年 6 月間自行報名 NFU Farm Event 參觀 2016 年諾丁漢郡農場環境獎 (The 2016 Nottinghamshire Farm Environmental Award)農場紀錄。

 農場環境獎農場入口	 農場對面的大型太陽能光伏電站
 農場內高 50M 之大型液肥桶	 液肥桶操作須知

 參加活動的英國資深農夫們	 參觀活動的交通工具
 農田的隔離帶吸納可能滲出的汙染物	 農塘作灌溉使用與容納可能滲出化學物質
 綠籬編織由農戶持續進行	 油菜田周邊維持非作物植生

	
農塘水質穩定清澈	邊界倒伏木後方大型太陽能光伏電站

雖然是農場環境獎得獎農場，但簡單來說，這農場其實就是我國實行水土保持農藝方法的實現，就是把我們想像水土保持界所使用的農地水土保持手冊裡面工作項目放在一個農場，但海拔高度是把我們台灣的山坡地農場壓扁到上下 10M 高程的平緩農地，由農夫妥善維護，就是農場環境獎的成果。農場內主要展現重點就是綠籬(Hedge)，農塘和保護帶，再加上油菜田裡會多少長出蘇格蘭薊(Thistle)和罌粟花(Poppy flower)等野花。農夫可以申請政府環境補貼，用來作綠籬、保護帶等工作，但要得這農場環境獎前提是這個農場是要商業化經營的，所以農場主要還是作物生產為主(麥田和油菜田)，作者估計保護措施面積應當不超過 1 成，因農業生產是有成本效益及補助金額相互影響。農場門口有一個 50M 高的液態肥儲槽，我猜應當是鄰近畜牧業的副產品為主，但是農田旁各農塘水質維持良好，肥料控制應有其規定。本次參訪對本計畫執行有相當重要指標意義，作者確實了解英國所謂環境農業之意義，倒是英國農夫們很訝異一個台灣人怎麼會是 NFU 的會員，還來報名參加農場參觀活動。

經全球糧食安全與發展課程訓練及閱讀、觀察英國農業現況，並考量我國現今推動循環經濟、循環農業、耕地沖蝕劣化、氣候變遷及直接給付等相關課題，決定研究英國現已推行多年相較我國成熟的農場可再生能源模組及生產狀況，進行碩士論文寫作題目，並以做為我國鄉村地區日後發展參考。考量研究者在英國為外國人身分及避免侵犯英國傳統農戶、農民的隱私權，選擇以案例分析方法進行定

性分析。經與指導教授 Dr. Md Mofakkarul Islam 討論，以"英國農場可再生能源的成本，收益和限制：對台灣的可能影響"為題目，由研究者實地到英格蘭東密德蘭地區農戶進行農民訪談，現場觀察及參訪，了解英國農民在不同發電容量模組投資相關成本、效益及制約機制進行了解，同時依據歐美相關農場可再生能源及相關農民研究，進行歸納，了解英國農民在維持傳統農業生產及與政府契約的環境農業工作以外，如何(HOW)及為何(WHY)投入農場可再生能源，並了解政府機構與社區對可再生能源的相關制約，並反思我國在目前尋求非核家園同時，農業區可能投入能源生產並可兼顧國家糧食安全重大議題的可能模組與模式。

為完成本碩士課程須完成論文寫作，須以英文完成，字數 10000 字(至多加 10%)為原則。過程中因為外國人身分及大部分農戶拒絕提供相關收益資訊或接受相關詢問，但在大學多位講座協助下，獲得幾位匿名英國農夫協助，於 2017 年 9 月完成可被認可的碩士論文後，未待最後評分結果即返國服務。後續成績則由學校於網路公布，成績已通過獲得碩士學位，評等為 qualify for award commendation。

3. 碩士論文簡要內容- 英國農場可再生能源的成本，收益和限制：對台灣的可能影響

本研究之關鍵詞: 糧食安全、農業多元化、農場可再生能源、太陽能光伏、風力發電機、再生能源電能躉購制度

1. 研究緣起-英國與我國的糧食與能源現況概述

台灣預定在 2025 年將達到“2025 年無核國家”的目標。在 2025 年，可再生能源的佔全國發電比例預定提高到 20%，可再生能源將成為全國電力供應的第三大支柱

（MOEA，2017）。台灣的能源自足比例低於 3%，年均支出約為 2 兆新台幣（約 500 億英鎊）購買燃料（Chinapost, 2016），我國計劃在 2025 年，太陽能發電，陸域風能，生質能將為國家電網產生超過 65%的可再生能源（李世光，2016），若採用此類能源可能需要在農業地區建構相關工程模組。但台灣糧食自給率，2015 年只有 31.4%（依熱量計算）或 66.4%（按價格計算）（COA 農委會，2016）。然受限於台灣土地狀況，大部分可再生能源，太陽能，陸域風能和生質能預估將在相對較大的農村地區而非人口稠密的都市地區生產，近年台灣鄉村地區也常見新興的可再生能源發展，但“農民只能生產食品”或“以經濟原因處理可再生能源生產”的矛盾也是必須討論（Frantál and Prousek, 2016）。對於台灣的糧食生產與可再生能源的競爭或合作，需尋求有效解決。

英國在 2020 年前必須實現其 20%的可再生能源目標（EU, 2009, Boie et. al., 2014）。英國的農業並非高收益的產業，英國的糧食自給率遠比 30 年前低（DEFRA，2014），但以農場價格計算，英國農業仍然產生了超過 60%的原材料提供給農業食品工業(Agri-Food Industry)，這是英國最大的製造業，生產價值超過千億英鎊 (NFU, 2017, Bailey, Davidova & Hotopp, 2017, DEFRA, 2014)，同時，70%以上的英國土地仍得到了農民的良好保護和管理（DEFRA，2013）。與我國現況相似，英國只有 3%的農民在 35 歲以下（Bailey, Davidova & Hotopp, 2017），若以 2015 年農場收入比較，台灣和英國的家禽養殖農場收入最高的，兩地區的穀物種植農戶收入都屬整個農業的中間收入（DEFRA，2016，COA 農委會，2016）。

部分批評者認為農業領域的溫室氣體排放量很高（Garnett，2011），但從 1990 年到 2015 年，英國的農業整體排放量顯著下降了 17%（DEFRA，2017）。目前英國農業部門是風能，太陽能發電和生質能項目的農場可再生能源的重要供應者。估計約為整個英國發電量的 1/10（NFU，2017）。 2013 年，超過三分之一的英國農民擁有或擁有各種可再生能源項目（FARMERS WEEKLY，2013）。英國農民不僅是食品供應商，在 21 世紀扮演著溫室氣體減排的重要角色。儘管一些現有的可再生能源項目是有爭議性，但是在英國已經有對其傳統農業和農場可再生能源相結合的情況進行了檢

驗，同時採用可再生能源發電之前，也同時考慮成本，技術力(technology vitality)，污染，供應效率等相關問題（Bilgili et al., 2015）。本研究目的係了解英國不同種類的農場可再生能源工程項目的成本，效益，限制和驅動因素，以提供台灣的相關應用。本研究將分別就農場可再生能源和糧食安全、英國農場可再生能源項目的成本、收益及制約因素、及可能適用於台灣鄉村地區的農場可再生能源模組進行分析。

2. 相關文獻回顧-糧食安全與能源安全

雖然可再生能源和農場可再生能源在英國很受歡迎，預估台灣將來也可能採用來因應能源需求，但大多數人都對農場可再生能源的意義以及其對農業、溫室氣體間相互關連有所爭議。本研究將先就可再生能源項目的定義，農業和可再生能源之間的關係以及基本的糧食安全議題等相關面向進行討論。

2.1 可再生能源，不可再生能源和農場可再生能源定義

可再生能源被定義為“從自然環境中可不斷或重複出現的能量中獲得的能源”，持續的自然資源如日照、風力、生質、地熱、河川流水、海洋的波浪和潮汐等都被歸類為可再生能源系統（Twidell and Weir, 2014）。除潮汐和地熱外，太陽能，陸上風能，生物質能和部分水電等大部分可再生能源都在鄉村地區廣闊的農田上取得，其主要能源都是太陽輻射的太陽輻射轉換而成（Boyle, Everett and Alexander, 2012）。太陽能光伏(光電)是太陽光直接轉換成電能（Everett，2012），風則是由太陽加熱空氣，在地球表面的不同大氣壓力下移動（Taylor，2012）。由於生物能源產生的關鍵機制是光合作用和碳水化合物（Morris and Scurlock，2012），故生質能也與日照有關。食品和可再生能源之間的太陽輻射轉化的差異在於產品使用者，食物是用於人類飲食和動物飼料的光合作用的產物，但是可再生能源只是為了人類的需求而產生的。

目前大部分溫室氣體是由化石燃料產生的。化石燃料為不可再生能源，對環境不可持續。如果全球糧食消費和飲食趨勢維持為 1995 年數量，農業部門的減排技術選擇則需要減少非二氧化碳的溫室氣體排放（Popp, Lotze-Campen, and Bodirsky, 2010）。表 2-1 顯示了化石燃料和可再生能源的區別如下：

表 2-1 化石燃料和可再生能源的區別 (Source: IEA, 2016 and Everett et al. 2012)

能源種類	2014 年市場比率(%)	使用後可自然可補充?	排氣對人及環境有害?	顯著的社會不公義?
不可再生能源(石油、煤炭及天然氣)	81	否	是 (主要為 CO2, NH4 & SO2)	是
Renewable energy	13.8	是	少(Few)	少(Few)

歐盟委員會(European Commission)將農場可再生能源定義為: 農場可再生能源係在農場生產;農場是基本依靠生物過程生產農產品的經濟型企業，農產品是由自然資源如土地和/或非鹽水產生的食品，飼料，纖維，其他天然材料，燃料等，系統產生的可再生能源由付費或操作的農場或法人進行自用或輸出，主要是電力輸出 (On-farm Renewable Energy is produced on farms; farms are economic enterprises basically relying on biological processes to generate agricultural products – food, feed, fibers, other natural materials, fuels – from natural resources such as land and/or non-saline water", which renewable energy generated by system paid and/or operated by farms or legal entities for domestic use or export, mainly export is electricity)（Pedroli and Langeveld，2011）。可再生能源的生產和使用在農業創新，競爭力，生態系保護，減排等方面發揮著重要作用（Dinu，2013），可再生能源被視為農村發展的一部分（Frantál＆Prousek，2016，Bayer & Urpelainen, 2016），同時農業受到挑戰，需要減少化石燃料使用和生產可再生能源（Pedroli & Langeveld, 2011），有效的農場可再生能源是歐洲農業，農村發展和消除溫室氣體排放的一項關鍵因素。

2.2 溫室氣體，氣候變遷和農業相關關係

氣候變遷與工業革命後使用化石燃料伴隨的溫室氣體排放密切相關（Peake 等，2012）。主要的溫室氣體是二氧化碳（CO2），甲烷（CH4）和一氧化二氮（N2O），這

三種氣體是化性穩定，可在大氣中存在數十年甚至更長的時間，並且導致氣候變化溫室效應（IPCC，2007）。溫室氣體，如水蒸氣、二氧化碳、甲烷像巨大毛毯，讓地球表面平均溫度保持在平均 15 度 C（Boyle, Everett & Alexander, 2012）。然而，1950 年以後由化石燃料所產生的額外溫室氣體排放到大氣中，使多餘的太陽輻射能受困在地球內（Andres et al., 2012）。

二氧化碳是最重要的溫室氣體，如同二十世紀三十年代美國大平原的沙塵暴一般帶來"不可逆轉的旱季降雨量減少"，推估二氧化碳濃度超過 600ppm 時，全球海平面上升將超過 1 米(Solomon, et al., 2009）。據估計，在英國，人們每消耗 1 千瓦電力也會產生 1 公斤二氧化碳（Ramage＆Everett，2012），這種溫室效應改變了天氣系統的長期平衡。英格蘭氣候變遷調適小組委員會(Adaptation Sub-Committee, ASC)指出，2005 年至 2014 年的溫度相較 1961 年至 1990 年的 30 年間上升大約 1 度，然而，20 世紀英格蘭和威爾士的平均生長度-日(Degree-Day)，衡量農業熱積累的指標，也增加 60 度-日（ASC，2016）。在台灣自 1911 年至 2009 年，特別是 2000 年至 2009 年間，暴雨事件（降水量≥200 毫米/天）增加，年降雨日數在過去 30 年卻顯著下降(Hsu, et al, 2011)。同時台灣位於低緯度地區，如果溫度持續上升，由於全球變暖，未來極有可能會對作物生產力產生負面影響（Kang，Khan＆Ma，2009，IPCC，2007）。經由量化全球暖化影響的不確定性研究，熱帶地區由於人為氣候因素，可能會發生持續的炎熱和乾旱事件（Diffenbaugh et al., 2017）。

農業一般被認為是對環境友善的產業，但農業也是溫室氣體的主要來源。 2005 年，全球農業部門排放超過 1.4 億噸溫室氣體，佔全球碳排放量的 10％(Burney, Davis & Lobell, 2010)。農業土壤可以進行碳彙集(carbon sequestration)，全球土地用於農業的比例不到 40％，但估計全球人為產生的超過一半的甲烷（CH4）及超過 4/5 的一氧化二氮（N2O）排放係與農業有關（Smith 等，2008）。主要是有機物質在無氧條件下分解，在沼地和稻田產生甲烷，另外硝酸銨肥料在潮濕狀況下產生一氧化二氮 (Smith, et al., 2008)。此外，溫室氣體以 100 年為時間範圍估計，甲烷和一氧化二氮分別是二氧化碳吸熱的 25 倍和 298 倍效力（IPCC，2007），到 2030 年，全球的甲烷和氧化亞氮排放量預估仍會有明顯的增長（USEPA，2012）。在台灣的研究說明農民若種植粳稻而不是秈稻，甲烷排放量則會明顯下降（Liou，Huang and Lin，2003）。

2.3 糧食安全與能源安全

糧食安全的定義是“糧食安全存在於當所有人在任何時候都能夠身體和經濟地獲得充足，安全和富有營養的食物，以滿足他們的糧食需要和飲食偏好，從而獲得活力健康的生活”(World Food Summit, 1996)，糧食供應，獲取，利用和可持續性(food availability, access, utilization and sustainability)是糧食安全的 4 支柱（FAO，2006）。到 2050 年，預計全球人口將超過 90 億，糧食生產需要較現在增加 70%以上（FAO，2009，聯合國經濟和社會事務部 DESA，2017）。例如在中國，對於下一個農產品倍增產量潛力和研究極為重視（Fan, et al, 2012）。但在台灣，日本，英國等發達國家，糧食安全問題與發展中國家或未開發國家追求產量不甚相同。先進的作物產量提高是減少農業未來溫室氣體排放的首要任務，而不只是尋求廣闊的農田中種植作物（Burney，Davis，＆Lobell，2010）。

能源安全則定義為“以可承受的價格提供不間斷的能源”（IEA，n.d.）。能源安全的可用性，可負擔性，可達性和可接受性 4As（availability, affordability, accessibility and acceptability）概念則由亞太能源研究中心提出(Cherp＆Jewell，2014）。在已開發國家，若糧食和能源使用需求都以能源計算，人均能源需求遠遠高於糧食需求。例如在英格蘭馬斯頓谷地區的人類的食物能量需求量僅為人均日消耗能源，包括熱，運輸和電力的 15%（Burgess 等，2011）。由於人類活動的強烈需求，能源需求和安全問題備受關注。可再生能源可以提高能源安全的可用性，可負擔性和恢復能力(availability, affordability and resilience of energy security)，這是農場可再生能源和國家能源安全的新共生關係（Valentine，2011）。

2.4 農場可再生能源的成本，效益，限制和驅動力

由於近年來農業生產的價格和收益不盡合理（DEFRA，2016，DEFRA，2012），農場可再生能源是農民的多元化經營的一種選擇。除了全球糧食危機的非常時期之外，英國的農業收入趨勢在 1995 年至 2015 年的過去 20 年裡顯著下降。儘管歐元和英鎊間匯率下降，農民所獲得的直接給付增加約 18%，企業化農

民之農業勞動力年度農業收入總額仍下降 7%，2015 年至 2016 年仍低於 19,000 英鎊 （DEFRA，2017），故農民的另一種收入至關重要。Sutherland 研究，農民投資並尋求農場可再生能源，如風力發電機組，以增加有利資本回報的長期經濟可行性，以多元化經營及可受益資本所得來確保他們的農場（Sutherland＆Holstead，2014）。在捷克也進行了類似研究，採用可再生能源技術的農民的主要原因是經濟多元化和穩定農場業務（Frantál＆Prousek，2016）。如果可再生能源技術是為了經濟多元化目的，那麼任何計劃參與這個領域的農民都必須認真考慮成本，效益，限制和驅動因素。

2.4.1 成本

成本是農民在可再生能源項目投資前應該重點關注的第一個項目。在希臘，通過評估加權平均資本成本（WACC）分析，陸上風電 WACC 約為百分之十二，但太陽能光伏發電的成本在 2016 年已經略低於陸上風電成本（Angelopoulos 等，2017）。先前韓國案例研究離網偏遠島的小功率風電機組、太陽能光伏和儲能係統的優化組合，估算運行成本和總淨現值成本，如果系統是純可再生能源組合（無柴油發電機組），必須總是將風力渦輪機組合在一起，高可用性和功率輸出（Ahadi，Kang 和 Lee，2016）。而在英國，可再生能源的申請是一個重要的成本，因為申請並不一定會被地方政府批准。儘管農場可再生能源是合理利用農業資源，賺取非農業收入及降低農業經營成本（特別是畜牧業），但包括交易成本(Transaction Cost)在內的全部成本，如申請期間的正式社區對話，規劃和應用過程中的磋商和參與，甚至最終無利可圖的可再生能源投資都是由所有者或投資者所花費的（Sutherland＆Holstead，2014），儘管通過使用下一代生物燃料和新的生產技術（Koh＆Ghazoul，2008），生物燃料的使用對環境和社會成本這兩項成本可能會減輕或推翻，但關鍵評估也是必要的。

隨著技術創新的發展，可再生能源的成本下降趨勢明顯。 依斯旺森定律：由於半導體產量較高，太陽能電池性能較好，太陽能光伏電池板市場價格在太陽能光伏電源安裝量累積增加一倍時，平均價格平均下降 1/5（Swanson，2006）。據預測，到 2020 年，在美國的電場規模（大於 1MW）的太陽能光伏電站與傳統

天然氣發電廠相較，將具有成本競爭力，商業規模（在 0.1 至 1MW 內）的太陽能光伏電站，即使沒有任何政府補貼，也將在 10 年內具有成本競爭力（Reichelstein＆Yorston，2013）。同時風電成本也持續下降，例如 2007 到 2016 年，中國風機價格下降了近 40%（WEC，2016）。

2.4.2 收益

效益是影響農場可再生能源參與的另一個因素。自 2010 年以來，英國的大部分農場可再生能源項目都受到 ”再生能源電能躉購制度”（Feed in Tariffs, FiTs）的支持，在固定時間內強制性地支付可再生能源項目所產生的電力，並提供保證一定發電量接入國家現有電網（Boyle，2012. Bayer＆Urpelainen，2016，REN21,2016）。 2015 年底，有 110 個國家/地區/國家製定可再生能源聯網電價政策，台灣和英國分別於 2009 年和 2010 年都制定了這項政策（REN21,2016）。由於煤炭燃燒帶來的負面外部效應可以轉化為更好的空氣質量，費用由電力消費者支付，而不是由政府支付，“再生能源電能躉購制度”政策受到民主政府的歡迎。同時政府也可以從不同農村地區獲得投資可再生能源的許多農民獲取政治利益（Bayer＆Urpelainen，2016）。在英國，總裝置容量小於 5MW 的可再生能源發電系統（包括太陽能發電，風力，厭氧消化器 Anaerobic digester 3 類）可以適用再生能源電能躉購制度（Energy saving trust, 2017）(本研究未討論小水頭之水力發電)。農場可再生能源生產也可能正面影響糧食安全和農業生產，如太陽能板與綿羊、雞或蜜蜂的放牧棲息地共存，可以保持農村生態，糧食生產，減少地面植被維護的需要，同時加強水土流失的防治（Hernandez 等，2014）。

2.4.3 制約阻力

農場可再生能源的規範，財務，社區，技術和市場制約因素影響農場可再生能源項目發展。這是因為“農業的多重功能反映在農業和電力部門之間的自然資源獲取的競爭中”（Sutherland，Peter 和 Zagata，2015）。研究“滿足當前英國對陸地可再生能源的能源需求所面臨的主要製約因素以及決策者所面臨的嚴峻選

擇”是嚴肅課題（Burgess et al.，2011）。鄰避效應(NIMBY-ism)是在地社區的主要制約因素，並導致可再生能源專案被擱置或廢棄，民眾對陸上風力發電機組的態度係要求不破壞景觀，故英國開發商學習鄰避效應來建構社區反對民眾意見模式（Jones＆Eiser ，2010，Burningham，Barnett＆Walker，2015）。另一方面，若是可克服最初的可再生能源項目投資限制，英國農民多可以應對延長可再生能源投資回收期（Mbzibain 等，2013）。儘管各項環境影響分析影響都必須通過，但由於景觀、噪音，甚至健康和安全等不同影響問題及在地社區的強烈抵制，約一半的陸上風電機組申請無法通過，（Sturge，While＆Howell，2014）。太陽能光伏安裝的主要挑戰是技術，相關研究和政策，但太陽能光伏對可再生能源領域的環境影響較小（Hernandez 等，2014）。在英國，大型太陽能發電場被視為臨時性結構，其景觀和視覺評估均與風力發電機組相同，但實際視覺影響可以趨近於零（DCLG，2015）。

2.4.4 推動因素

高再生能源電能躉購價格，方便的接入電網和低傳輸費率是促進歐洲和北美可再生能源的主要驅動力（Alagappan, Orans & Woo, 2011）。 在英國，可再生能源技術的創新系統也因為技術成熟度、不同可再生能源項目的創新體系和新政策手段在農場可再生能源工程建設中發揮重要作用（Foxon et al., 2005）。 德國巴伐利亞研究發現，農場可再生能源生產受到國內電網淨轉換能力，農民專業化程度及當地社區影響 (Schaffer & Düvelmeyer, 2016)。農場可再生能源的驅動因素在財務，政策，業務和創新方面相互結合或相互影響。

3. 研究方法與材料

農場可再生能源工程模組與農地，農民相連結，農場可再生能源與傳統農業生產相同，都是一種追求收益的產業。不同農民採用可再生能源工程模組的經驗，可提供判斷可再生能源在不同地區實用性的重要資料。筆者實際訪問英格蘭東密德蘭區已投入農場可再生能源生產的 3 個農場，以案例研究來發現不同的可再生能源工程模組的

效益。

案例研究是“關於現實世界背景下的當代現象的經驗研究 - 尤其是目前現象與內容背景之間的界限不明顯時”（Yin，2012）。案例研究可以用在遭遇描述性或可解釋性的問題時找出“如何”或“為什麼”，例如，農村開發商與當地環境保護者之間的爭議或決策可以通過案例研究來了解（Henn，2009）。研究者不能或很難控制研究課題或事件。目前現象是由受訪者以他們的經驗來表達的。筆者試圖找出真正有助於農民的農場可再生能源工程模組，並進一步了解對台灣農民進行農場可再生能源的可能影響。

本研究採用定性研究。通過定量分析來評估農民為什麼選擇具體的農場可再生能源工程模組。定性研究方法有助於了解當地農民對農村可再生能源項目的評估，因為農民是一個特定的農村景觀中具有不同動機或經驗的特殊“亞文化群體”（Kuehne，2016）。通過定性研究，可以了解農戶採用農戶可再生能源項目的原因和方式。為了解採用農場可再生能源項目的成本，效益，制約因素和驅動因素，假定每個農民採用可再生能源，通過農產品，受多種因素影響的不同類型的成本，收益，約束和驅動因素單一的原因，如農民對可再生能源的個人態度，財務狀況，農民社區和政府影響的製約因素，項目的成本和收益，使用不同項目的機會和資源。通過評估本研究中的不同案例，筆者試圖“出於可預見的原因，預測相似的結果或預測對比結果，”（Yin，2012）。

本研究應用基本需求供給定律設計調查問卷。為了幫助受訪者（農民）了解這個問題，並為進一步推廣不同地區的可再生能源工程模組提出真實意見，本研究採訪問卷設計分為 5 個部分，包括：1，農場和農民的基本資訊， 2 農場可再生能源成本，3 農場可再生能源效益，4 農場可再生能源制約因素，5 農民採用可再生能源之驅動力。本研究於 2017 年 7 月在英格蘭東密德蘭區 3 座 2010 年後投入農場可再生能源生產並實際持續農業生產農場現場實地訪問。英格蘭東米德蘭是英國第 2 大小麥和油菜產區（DEFRA，2017）。東米德蘭地區為英格蘭農業用地比例最高的地區，農業旅遊比例則較低（Beaumont，2009）。選擇東密德蘭區係考慮到台灣南部地區對農業可再生能源可行性，南部係我國主要農業區，同時其農場可再生能源如太陽能和生物質能相對充足，普遍而言，台灣南部的鄉村旅遊也不像其他地區那樣蓬勃發展。訪談問卷

設計如下（見表 3-1）：

表 3-1: 研究調查問卷

Section	Question
General Information 基本資訊	● Location of the farm 農場位置 ● Size of the farm 農場規模 ● Ownership type 所有權類型 ● Type of the farm business 農業生產類型 ● Length of farming 農民實際從農時間 ● Type of renewable energy 可再生能源模組種類 ● Generation capacity 能源生產量 ● Length of the renewable energy enterprise/project 可再生能源模組營運時間 ● Any specific information about the farm 農場特殊資訊 ● Some information about the farmer 農民資訊
Cost of on-farm renewable energy projects 農場可再生能源工程模組之成本	1. How much have you invested so far for this renewable energy technology on your farm? 農民已投資金額 2. How did you raise the money to invest? 如何募資 3. How did you find a designer or professional consultant to help you to build it? How long did it take for you to plan this project? 農民如何尋找專業諮詢及計畫時間 4. How does your renewable energy project affect your

	agricultural production? 可再生能源工程模組對農業生產影響 5. How much time and money did you invest to receive planning permission for your project? What types of activities did you have to do for the permission? 農民獲得可再生能源模組運作許可所投資時間與金額、及須配合作為。 6. How about the annual maintenance cost of this project? What are those costs and how much did you invest for this? 可再生能源模組年度維護費用 7. How much will you pay to retire and remove this project if it is inefficiency after 20 years? 可再生能源模組 20 年後除役所需費用
Benefits of on-farm renewable energy projects 農場可再生能源工程模組之效益	1. What is the financial benefit of this project? How do you feel about this benefit? 可再生能源經濟效益 2. Is all energy produced by your RE project only for sale to power grid, or are some portions used by your farm? How do you make the contract with the power company? 可再生能源只對外輸出或部分自用，農民如何與電力公司簽訂合同 3. How does your energy project benefit your agriculture business? Please explain? 可再生能源模組對農民原有農業生產有無益處 4. What is the non-financial benefit of your energy project, for example, environmental and ecological benefits for your farm or the area, social or

	community benefits? Please explain. 可再生能源模組的非財務收益 5. Do you get other benefits from your energy projects? Please explain if you get any. 可再生能源模組的其他效益
Constraints 制約因素	1. What regulatory constraints have you faced in your RE project? Please explain. 可再生能源模組的法規限制 2. What are the financial constraints that you have faced in your RE project? Please explain. 模組的財務限制 3. What constraints relating to community opposition have you faced in your RE project? Please explain. 社區反對意見 4. What technical constraints have you faced in your RE project? Please explain. 科技面限制 5. What market constraints have you faced in your RE project? Please explain. 市場限制 6. Are there other constraints that you have faced in your RE project? Please explain, if there is any. 其他
Drivers 驅動力	1. What are the business-related or financial drivers that have made you to invest and run on-farm renewable energy project? Please explain. 業務或財務驅動力 2. What are the policy drivers that have made you to invest and run on-farm renewable energy project?

	Please explain. 受政策驅動因素 3. Are there other drivers that have made you to invest and run on-farm renewable energy project? If there is any, please explain. 其他驅動力量 4. So far, based on your experience with on-farm renewable energy projects, will you make the same decision to invest on-farm renewable energy in the future? Why? 未來仍對可再生能源模組投資與否?

本研究經由實際農民訪談與現地觀察（Yin，2012），了解英國農民投入可再生能源開始規劃到與國家電網串接後的成本，效益，制約和驅動因素，期待提供我國日後推動農場可再生能源生產之參考。所有訪談都被轉錄到轉錄文件中，並以定性研究軟體 Nvivo 編碼提供進一步研究（Silver & Lewins，2014）。每次訪談都是一個獨立的案例。

農民的名字是匿名的。所有的受訪農民在農業方面都有 40 年以上經驗。他們的農場面積在 100 到 300 公頃，農地由農民擁有或承租。農民種植或種植不同的農產品，如牛肉，小麥，油菜和甜菜，農業生產是他們的核心產業。由政府支付的環境農業費用是農場另一個主要收入。所有的農場可再生能源工程模組都是在 2010 年之後架設(英國開始採行再生能源電能躉購制度政策後)。每一個案農民在開始時都申請太陽能模組，之後又申請風力渦輪機，但是只有經過長期(持續中)的法律爭訟和重新申請之案例 B 風機獲得許可。只有案例 C 採用了生質能模組，但如果沒有外部承包商的配合，生質能模組就不易使用和維護。除了一個公用事業規模的太陽能電站（案例 C，5MW）外，另外兩個農場可再生能源項目由農民自主擁有（案例 A 和 B）。每種情況下的發電量如下（見表 3-2）：

表 3-2。3 案例的可再生能源類型和發電量

Renewable energy type and capacity 可再生能源模組種類及發電量	Case A	Case B	Case C
Solar PV 太陽能光伏	屋頂型，小於*0 千瓦	屋頂型及地面型，小於*00 千瓦	地面型，5MW
Wind turbine 風力	未獲政府許可	超過 300 千瓦	未獲政府許可
Biomass 生質能	-	-	*00kw 主要供熱用
Size 發電量	小型，非家戶型光伏 (Seel, 2014)	中型，風機+商用太陽能光伏	大型，公用事業等級台陽能光伏電站 (Rudolf & Papastergiou, 2013)

案例 B 風機（容量超過 300 千瓦）

案例 C 太陽能光伏電站（容量 5MW）

4. 英國農場可再生能源研究成果

經研究，農場可再生能源項目的成本，效益和製約因素相互連結與影響。 但是，由於可再生能源的申請與產出受到人為因素和自然因素的強烈影響，某些特定因素是最關鍵的決定因素，這些特定因素也導致了所有案例的農民意外的額外成本和時間損失。 以下分 4 部分討論農場可再生能源成本，收益，制約和驅動因素。

4.1 農場可再生能源的成本

從可再生能源項目個案分析，就成本面有 5 個主要成本支出，分別為財務成本、計畫和維護成本、影響農業生產成本、法律規範成本及模組汰除成本。

4.1.1 財務成本

不同的農場資源狀況所遭遇財務成本是影響農民參與可再生能源項目的主要

考量。首先，近年來太陽能光伏板的財務投資較為便宜，幫助農民輕易將小型非住宅太陽能光伏系統安裝在農場。案例 A 與 B 農民訂購第 2 組太陽能光伏系統時，光伏(光電板)單價較首次購買大幅下降。如案例 A 實際成本，第 2 次安裝太陽能光伏（38Kw）容量比第 1 次安裝（10kW）約高 4 倍，但光伏價格僅為 2.37 倍，另電力公司給付農民的金額顯示，第 2 次太陽能系統的年度收益不如第 1 次高，因電力收購價格降低。

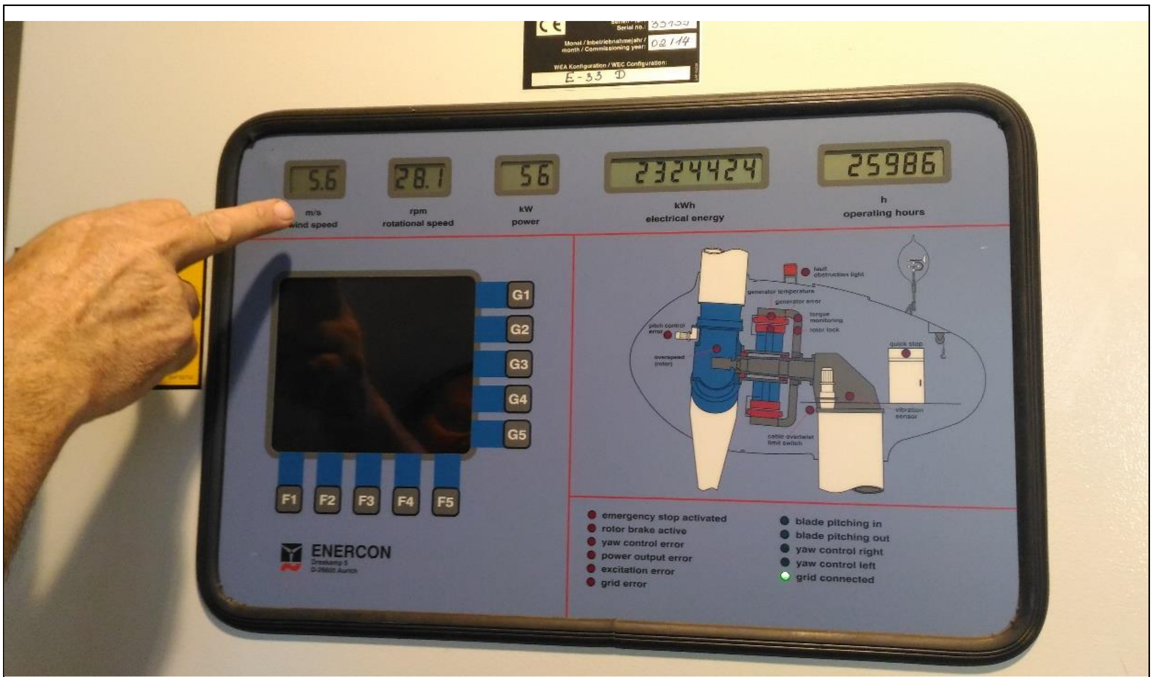
家庭成員是幫助農民投資可再生能源項目的主要支持者或資金來源（如案例 A），銀行也向農民提供貸款服務（案例 B）。如果該項目是公用事業規模(案例 C)，農民可以成為可再生能源項目的合作夥伴，租用他們的土地獲得收益，而不需要支付任何其他的資本成本。如果可再生能源模組是規模較小且可負擔，英國農民傾向以自有資金投資或者向銀行貸款投資（案例 A 和 B），如案例 A 的農民說："我的妻子有錢投資，沒有借款，個人理財"。但如果農戶需要向銀行借貸投資較大型農場可再生能源，其農地須作為抵押品，即使土地價值遠高於所需貸款的情況，案例 B 做為抵押品的土地價值達數百萬英鎊，但風力發電機僅需申貸 50 萬英鎊，這是農民不得不承擔的另一個代價。

4.1.2 計劃和維護成本

英國農民很容易在地區農業展找到可再生能源的設計者，承包商或顧問，但是顧問公司品質不一，且對太陽能光伏系統售後保固並不牢固（如案例 AB）。 事實上，隨著英國近年來可再生能源的發展快速，農民們抱怨諮詢師的素質，普遍認為專業諮詢並不專業，農民也自信能較再生能源專業廠商更快地自行解決問題。但風力電機申請的前期規劃成本甚高，所有調查和評估均必須在申請風機設置許可前完成，風機規劃成本約為風機價格的 1/7（案例 B）。

風機維護費用是必要的，以保持風力發電機日夜正常運作，案例 B 農民需要與製造商簽訂長期維護合約（15 年）。 但是太陽能光伏系統則僅是簡單的電錶，面板和變壓器的組合，農民可輕易自己維護，維護費幾乎為零(所有案例)。不論風力或太陽能，農民沒有需要僱用任何額外的人力來維持可再生能源模組運作，每

座農場都是以原來人力進行農產品生產及環境農業即可。

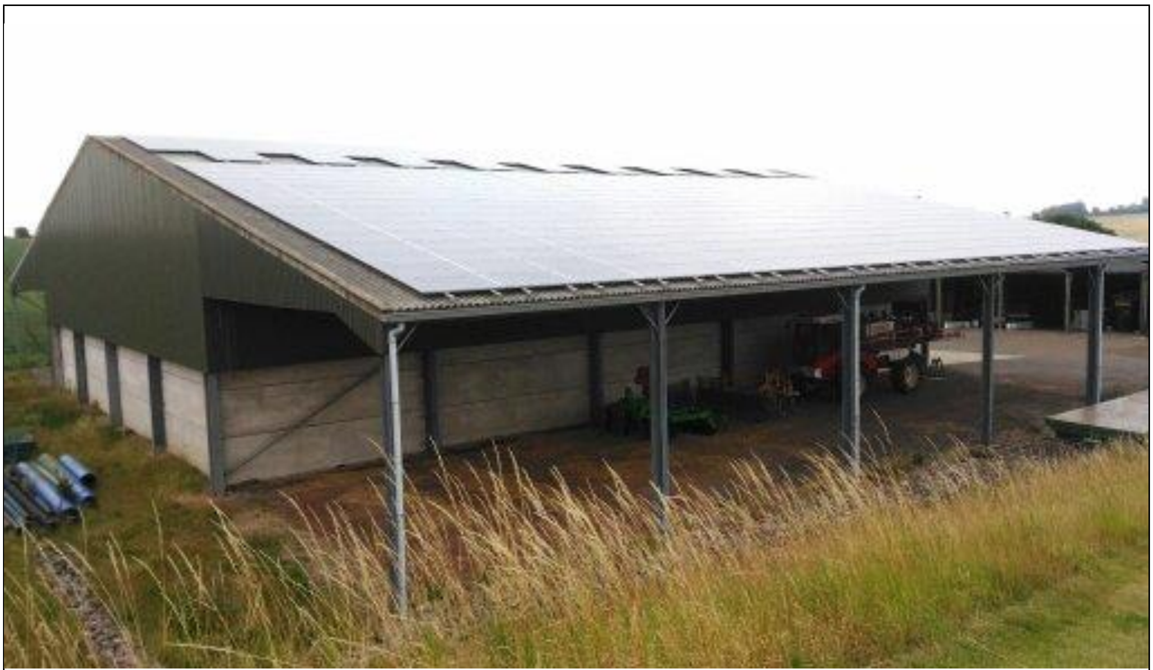


案例 B 風機由農民與製造商簽約遠程監控和維護 15 年

案例 A 太陽能光伏系統僅由簡單的電錶和開關控制

4.1.3 農業受可再生能源模組影響的成本

可再生能源模組是否影響糧食生產或糧食安全常為人爭論，但本研究案例之農民均認為可再生能源項目不影響農業生產，因太陽能光伏模組通常使用邊際農田，或使用地面面積有限，或可使用農業建築屋頂，風力發電機組所需基礎面積也有限。



案例 B 太陽能光伏安裝在建築物屋頂，而不是農田

4.1.4 法律規範成本

在英國，太陽能光伏系統設置許可申請容易且過程較簡單（情況 A 和 B），但很難找到一個真正的風機專業顧問，並排除所有阻礙完成申請設置風機（如案例 B），風力發電機組及其各項規劃都非常昂貴，農民必須完成所有的規劃和調查後，才能申請風力發電機組（所有案例），而政府態度與不斷改變的要求也是重要成本支出。例如案例 A 的農民花費大量時間和金錢來申請風機許可，但因社區反對，預計不會獲准。案例 C 太陽能電站鄰居農戶已經安裝 3 具大型風機，案例 C 農民也與社區溝通完成，但政府仍決定不發許可給案例 C 農民再新設風機，但所有計畫成本均已經由農民(或投資者)支出，位有許可代表無法回收任何成本，政府行政權影響農民投資成本支出。

4.1.5 可再生能源模組汰除成本

除了在案例 C 農民和投資者之間的合同中已詳述 5MW 太陽能電廠屆期拆除，其餘案例農民不確定如何在 2～30 年後汰除不符效益之可再生能源模組。

4.2 農場可再生能源效益

關於效益，這是農民投資農地可再生能源項目的另一個決定性因素。如果發電容量不大於 5MW，英國“再生能源電能躉購制度”政策是吸引農場可再生能源投資的動力。案例 A 小規模太陽能模組，雖效益不如較大型的可再生能源，投資約 13 年就可回收。案例 C 的大型太陽能發電站之財務效益只是地租收入，但收益是同一地塊維持放牧的 8 倍。案例 B 的好處是風能和太陽能項目的結合，發電時間延長，產能提高，為收益最高案例，風力年收益達到 20%，太陽能約為 10%。

本研究之案例均可將農場可再生能源所產生的絕大部分電力出口到國家電網，在英國，農民可以很容易地經由太陽能設備與電力公司簽訂合同(案例 A)，同時也有專業仲介人協助向第三方搓合出售農場可再生能源的電力（案例 B）或外部投資者自行處置（案例 C)。

面臨英國脫歐，雖然農業生產與環境農業是所有農民的主要關注事業，各案例農民預期未來政府的直接支付將減少，農民同意現有可再生能源項目創造新且長期的高“回報收入”，以減少農場能源支出和以可再生能源受益來計劃和投資農場事業。同時所有的農民都表達他們正在為緩解氣候變化，保護環境，野生動物生態和下一代未來作為他們的非經濟利益作出貢獻。

4.3 農場可再生能源的限制

儘管所有的農民都因為較少的監管限制，而對他們的太陽能模組感到滿意，但他們都抱怨風力渦輪機的政府管制。他們抱怨政府不能接受風力發電機組的許

可，他們批評“政府會建議我們走一條路或者走這條路，然後他們會再建議我們走另一條路”，或是政府因為反對者意見而不做許可決定（案例 A），或者先行擱置農民的可再生能源計劃（案例 B，政府並與地方反對風機設置人士訴訟），或者農民認為鄰居有獲得許可，為何自己的申請被拒絕是不公平作為（案例 C）。農民們強烈質疑為什麼風電機組的權限被拒絕，但每一項設置風機前必要的調查評估都已經通過。

財務限制並不是農民參與可再生能源生產主要障礙。所有案例都表明農民家庭態度對可再生能源項目是積極的，甚至家庭成員也是幫助農民投資可再生能源項目的主要支持者或資金來源。

社區少數民眾的反對意見是農民投資風電最大障礙，因為這個申請會被地方政府擱置。反對風力發電機組的少數民眾盡可能多地採取措施封鎖計劃（案例 A 和 B），他們甚至以多年時間來與當地政府（非申請設置許可的農民）進行法律訴訟。筆者實際拜訪農民時，在農場看不到其他鄰居的房子，這些農場的可再生能源項目也是孤立存在的，故筆者質疑所謂鄰避效應範圍是意指 ”無邊際的廣闊後院”。由於法庭訴訟和重複申請的額外交易成本(transaction cost)使農民受到更多損失。另一方面，太陽能光伏模組在農業建築物的屋頂或農民個人擁有的財產（邊際土地）上的視覺影響相當有限，無社區反對狀況下，農民可以擁有自己的太陽能項目，也可以將個人的邊際土地出租給外部太陽能投資者。

技術上的限制不造成農民投入可再生能源障礙，事實上，可再生能源技術使用相當簡單，農民也能理解其原理（案例 B）。 因為綠能政策比率要求，市場對農場再生能源不是障礙，但是國家電網可能會在不同的地區和時間飽和(輸配線網絡問題)，不同農場所生產之能源要連結上電網將會有競爭。

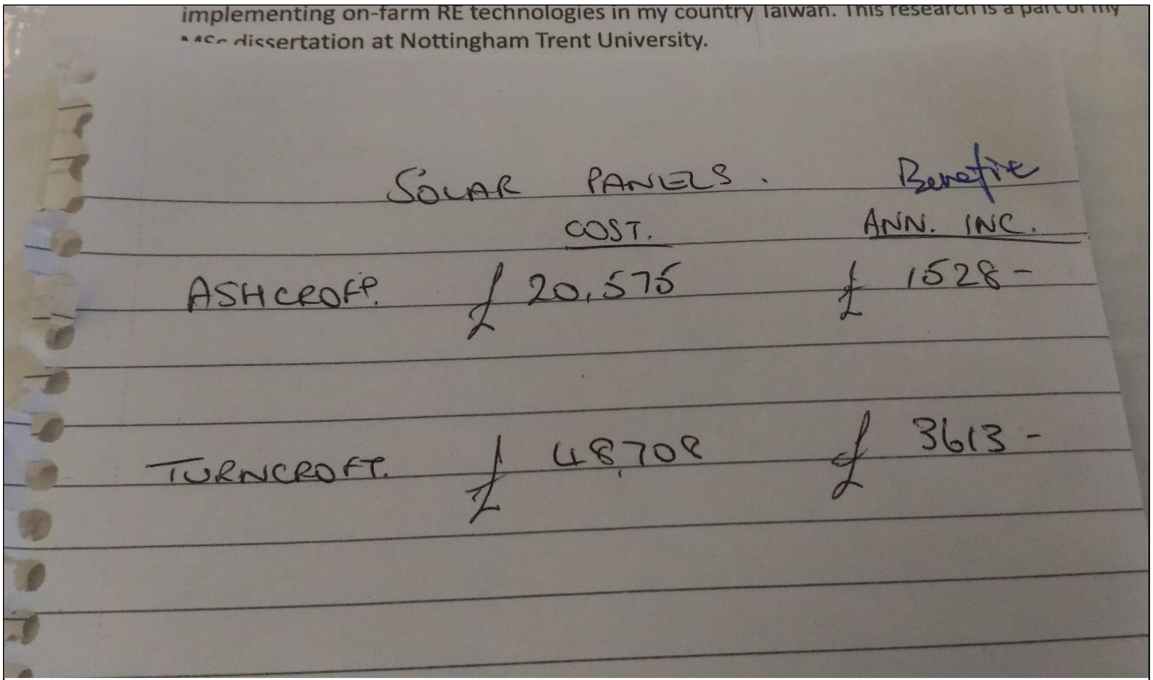
4.4 農場可再生能源的驅動力

由於體認氣候變化加劇，農產品價格下降以及未來政府支付的不確定性等原因，且農業屬於弱勢產業是農民投入可再生能源模組的商業驅動力。農業生產的脆弱性和慷慨的再生能源電能躉購制度是“推與拉”的因素，農民選擇為將來

“投入可以最大的收益的產業（案例 B）”。這項研究中的所有農民都承認可再生能源項目是一個長期的多元化經營，農民們都自信認為自己思考農場未來的眼界都超過政治人物。

最近 10 年，所有案例農民發現英格蘭地區變濕變暖，農田被沖刷成過往未發生的強烈的土壤侵蝕。農民認為燃燒化石燃料是全球氣候變化的主要原因，農民有強烈的意願生產綠色能源，他們提到“絕不馬跑了才關門”(英國諺語)，農民都關心農業的未來，他們相信“未來依賴於我們現在所做的”，“人們不會永遠在這裡”(案例 C 農民所說)。但若政府的支持不夠穩定，社會上的反對意見無法說服，他們會傾向撤出可再生能源項目投資（案例 B）。

實地訪查後，本研究發現的所有農民都有強烈的意願來開發他們的農場可再生能源項目，但也都面臨著與當地社區對風能項目反對意見相同的制約。多元化是農民投入可再生能源初衷，可幫助他們繼續以農業生產為核心業務。在電力收購制度支持下，農民可持續農業可持續發展項目產生了穩定的收入或降低了賬單成本，同時也為公眾創造了環境。農民們相信全球氣候變化的理論，並面臨同樣的低農業效益問題，即使他們認為由於政治不確定性（如英國脫歐）而可能減少政府支付。當農民引導作者實地考察時，農民談到他們把傳統農產品轉移到有機農業上，或者耕地採用輪作制度減少化肥使用，也種植了矮綠籬來減少水土流失，另外在太陽能電站放置蜂箱，以利周邊作物授粉。所有的農民一直努力增加農場獲利，降低農業成本，以可持續的發展觀念保持農場運作。筆者實際觀察小麥田或油菜花田內罌粟花或薊等不同的野花在小麥或油菜植物中生長(非有機田地)，農民雖然與政府簽訂環境農業契約，但也是當使用農藥、畜牧廢棄物液肥及肥料，雉雞、鶴鶉和雲雀在當太陽能光伏電池板下的草地繁殖，野兔傍地走，觀察可見農場可再生能源項目不僅與農業生產共存，也有利於農地自然環境。



案例 A 農民手寫太陽能模組成本與收益紀錄

案例 B 所在村落街景，單一街道小村落，人口高齡化及外流嚴重

案例 B 農場豆類種植現況，遠處為標準英格蘭環境農業狀況

案例 C 旁風力機組明顯，但太陽能光伏電站設備隱身在樹林後邊，視覺影響小

案例 C 太陽能光電模組側面相片，模組間確實留有植生空間，以利生物棲息

資料來源:案例相片均由研究人員在農場現場拍攝

5. 案例討論

以下討論英國所有案例之農場可再生能源模組經驗，並嘗試提出適用於台灣農場可再生能源模組。儘管到 2020 年，歐盟 20%的能源消耗總量規定由可再生能源產生（EU，2009），由於地方政府對可再生能源模組許可核准與否的態度標準變動，所有案例農民都對地方政府提出抱怨。一定時間內，所有案件都有獲得了太陽能光伏項目的許可，例如太陽能項目位於屋頂且內縮於屋頂上，或者所有地面型太陽能光伏所需調查都通過，那麼獲得政府批准就沒有障礙，但在獲得政府風力發電機組許可的同時，卻都面臨問題。

5.1 農場可再生能源的成本

近年太陽能光伏板價格下降，如斯旺森定律（Swanson，2006），農民投資太陽能項目比較容易，案例 A 和 B 都表示，供應商在訂購第二個太陽能項目時提供了更便宜的光伏板單價，但日後太陽能電池板如何回收是有疑慮的，需要適當的政策支持，歐盟也認定回收的責任屬於整個能源行業（Mcdonald＆Pearce，2010）。儘管歐盟要求

所有太陽能光伏板輸出到歐洲市場的生產商，以 2012 年“生產者延伸責任原則”為基礎，為 2012 年太陽能光伏板”終身(end-to-life)”的回收成本提供資金（IRENA，2016，EU，2012），但實際回收情況須待多年後方能證實。

本研究的公用事業級規模的太陽能發電場成本在 2011 年時仍是高的(案例 C)，但沒有補貼狀況的太陽能發電平均能源成本（LCOE）預計仍將繼續下降，在東米德蘭地區的公用事業規模的太陽能發電場的每千瓦時 LCOE 估計為 2015 年下降至 0.09 英鎊，2020 年為 0.07 英鎊，2025 年為 0.06 英鎊，商業型屋頂太陽能項目的 LCOE 和住宅屋頂的太陽能項目的 LCOE 都預估為下降（Reid and Wynn，2015）。雖近年風電機組產生更多的電能，且 LCOE 較低，預計 2010 年的 LCOE 為 80 美元/ MWh（Kumar et al。，2016）但預計太陽能的 LCOE 將在未來十年相等甚至更低。 2015 年太陽能光伏發電在 58 個氣候國家的平均披露資本支出（$ M / MW）為 2.15，略高於 2.02 的海上風電（Climatescope，2016）。但未來狀況將是太陽能光伏項目可能是最具競爭力的可再生能源模組。

5.2 農場可再生能源收益

值得注意的是本研究的英國農民均抱怨風電模組的設置許可，沒有人強調太陽能光伏的好處，但沒有任何案例被否決太陽能模組設置。在這項研究中，風力發電機組是一個最有利可圖的農場可再生能源項目，即使很難發展與獲得許可，反之，太陽能是一個簡單，安靜，可行的“次優”選擇，但大多數農民在訪問時，並不是真正感興趣。研究指出，即使農民“表達了對可持續性的承諾”，採用可再生能源模組上農民仍傾向於最大限度地獲得經濟利益 （Firbank，et al。，2013），實際上因農民的環境意識而種植農場矮籬或轉成有機農業，其經濟效益並不大（van Vliet, et al，2015），反而依據農業環境多元化研究（agri-environmnet diversification , AED）具有環境意識、參與環境農業的農民可能轉向參與可再生能源生產（Sutherland，et al。，2016），本研究所有案例均是如此。

另由案例 B 得知，近幾年在同樣的模組容量，東密德蘭地區風機效益約為太陽能 2 倍。一般來說，由於英國的天氣多雲，英國的風力渦輪機年容量因子約為 25%至 40

%(容量因子（Capacity factor）是發電廠的平均發電量除以額定容量)，而太陽能光伏電池板的風力機年容量係數僅為 10%左右（Boyle，2012）。英國風力渦輪機的平均負載因數可比太陽能光伏電池板高出約 2 倍以上（Staffell＆Green，2014，Reid and Wynn，2015），這也證實風機產生收益確實較高，但設置風險相較太陽能高出太多。

5.3 農場可再生能源的制約限制

“不在我的後院”(NIMBY)是一個抽象的概念，“後院(BACKYARD)”面積有多大是被質疑的（Jones＆Eiser，2010），雖然相當多風機以較“低”的高度（案例 B）申請安裝，但在英國陸上風機只有未達一半申請被核可 (Sturge, While & Howell, 2014, Mason, 2015)。案例的農民們懷疑因為社區的反對意見是阻礙風電從政府獲得許可的主要障礙。其他研究發現，為了風能發展正向效果，風能投資者、當地居民的支持及地方政府的“順暢的行政處理計畫 smooth administrative handling projects”之間存在著密切的連結；地方政府也需要同時滿足”前瞻的許可程序 forward admission process”和“平衡各方利益”（Sperling，Hvelplund＆Mathiesen，2010）。

5.4 農場可再生能源的驅動力

本研究確認弱勢的農業為推動農場可再生能源的主要驅動力。在東米德蘭的農業不是一個有利可圖的生意。 在 2011 年至 2015 年期間，東米德蘭地區的農業總收入下降約 29%，同一期間，全英格蘭下降僅為 24%，但在東密德蘭區生產超過 1/5 的小麥，超過 1/4 的油菜，約 1/3 蔬菜和 1/4 的甜菜產區（DEFRA，2017）。農民需要農業多元化，農場可再生能源成為選項之一。

參、心得及建議

一、學習心得

除碩士學位論文以外，英國全球糧食安全與發展課程 Global Food Security and Development 主要分 4 部分，4 項課程間互有其空間軸與時間軸相關性連結，分別為 1.糧食系統及糧食安全分析(2016 年課程，偏向糧食安全及糧食系統的基本概念、理論)、2.糧食安全創新方法(2017 年課程，較屬於時間軸的未來性面向)、3.糧食安全與國際發展合作(2017 年課程，偏向橫向的國際性組織及區域性組織合作)、4.研究方法與分析(2016 年課程，基礎研究能力建立)等 4 方面。在英國這裡學習有關全球糧食安全相關議題與發展方向及伴隨的相關營養、資源分配與永續性農業，可以瞭解將來全球各個國家政府都將面對的漸趨嚴峻的糧食安全挑戰。

經由課堂講座教授、參訪及課堂討論，體認農業創新為未來全球糧食安全首要工作，而非不斷拓展新的耕地。在現有的土地上，要如何保護土壤、水資源，避免土地沖蝕劣化、水資源流失、維護作物種原多樣性及減少農藥化肥使用，是糧食安全甚至聯合國全球永續發展的基礎。在精準農業、植物工廠等議題上，我國已有相關技術，而在台灣所認知有機和友善環境，仍需要適當的人為科技與觀念配合方可確保糧食安全，單單反對各類人為物質使用於農業是增加糧食安全的不確定性，例如基因改造黃豆、玉米等以上市多年，對於人類是否有無危害，仍無明確證據，甚至基因改造鮭魚也已經在美加上市，對於海洋魚類資源保育反而係正面效益。另依據歷史經驗，農民常常是糧食不安全的受害者，如同當年孟加拉飢荒、綠色革命的例子，如何藉由科技運用與分配手段使農民脫貧、鄉村在地經濟活絡等方式才是糧食安全的最最基本作為，也是任何國家維持糧食安全的最要緊事務。我國屬於已開發國家，單純糧食生產增量並非我國糧食安全最大影響因素，基於糧食安全觀點的鄉村地區永續發展以利農民脫貧、鄉村地區經濟活絡才是維繫長遠糧食安全與保護環境的適當做法，也才真正符合聯合國 17 項永續發展目標要求。在風頭水尾地方，經由過腹還田或陽光空氣交互作

用產生新的農民經濟收入來源，其將來發展可以持續研究。

二、建議

碩士論文研究調查英國農場採用農場可再生能源的成本，收益和制約因素及對台灣影響，企圖尋求對我國鄉村地區永續發展之可行方向。經研究，農場可再生能源道理其實係為水、土、田、糧、風、陽光等自然資源整合應用。雖然英國在歐盟系統下，持續對農民投入農業生產及環境農業工作進行輔導與補貼，但也鼓勵農民進行農場可再生能源生產並視為農業的一部分。本研究以案例分析訪談農民、現場考察和觀察進行。英國政府與農民將農場可再生能源視作農業多元化手段，再生能源電能躉購制度政策影響農場可再生能源投入。簡單來說，本研究發現英國案例農民傾向使用風力再生能源模組，台灣農民則建議以太陽能光電模組為優先。進一步建議可以農業光伏系統和浮動式太陽能讓小農和水產養殖農民維持農業，另可考量將多餘稻田多元化為太陽能農場。

本研究所獲得建議可分以下數點。

1. 我國能從英國的經驗中學到什麼？

在英國，在再生能源電能躉購制度支持下，農民可以通過農場可再生能源和傳統農業相結合的方式繼續農業生產。通過農場可再生能源項目，英國農民實現了盈利多元化，改善了農村發展，並在新的衝突源頭中發揮了食品生產者和清潔能源生產者的作用 (played the roles of food producer and clean energy generator with new sources of conflict) (Holstead，Galắn-Dί az and Sutherland，2017）。雖然目前太陽能項目的經濟效益尚低於風電項目，但由於先進的技術和整個太陽能產業鏈的效率提高，未來將會改變（Swanson，2006，Reid＆Wynn，2015）。在這項研究中，英國農民（案例 B＆C）可以依靠農場可再生能源項目的農業多元化經營來實現長期的農場發展與農業生

產投資規劃。但當台灣農民意圖進行農場可再生能源項目時，哪些可再生能源模組可用，能源生產能否與糧食生產並存？台灣的農場可再生能源項目如何在有限的耕地面積上發電？筆者認為，台灣有創新思路的太陽能模組將有機會發展，陸上風能和生物質能可能較不可行。"農業光伏系統"，"多餘的稻田多元化"和"浮動太陽能光伏模組" (Agrivoltaic system, Diversify surplus rice field and Floating Solar Photovoltaic project)等三種太陽能模組，可能是我國今後農場可再生能源發展的適當解決方案。

2. 台灣農場可再生能源應選擇風電還是太陽能？

台灣西部海岸是全球最好的海上風電場之一（WEC，2016）。但陸上風並不是海上風電，台灣人口稠密，民眾畏懼各種污染，同時也存在著強大的社區鄰避效應主張(NIMBY-ISM)，為解決台灣不同的環境影響案例需要通常賠償和談判(Chiou, Lee and Fung, 2011)。台灣陸上風能有限，只有 7.47%風電資源總量存在台灣陸地上（Chen and Lee，2014）。盡管大型風輪機風力發電機組效率更高，每千瓦小時成本更低，但台灣小農所擁有的平均土地面積很小，渦輪葉片不可能只在單一農民自有土地上旋轉（Ani，Polinder 和 Ferreira，2013 年）。

台灣又未通過類似歐洲推動再生能源相關法律，例如為避免今後發生衝突，丹麥風電項目開發商可以採用能源合作社的規定，向住在一定距離（R≤4.5KM）的社區居民提供 20％以上的股份權（Sperling，Hvelplund＆ Mathiesen，2010）。但另一方面，台灣在全球太陽能電池供應商中名列前茅（Su, 2013），南台灣的緯度是在北迴歸線以南佔有優勢，台灣南部的太陽能電力產出相較英國東米德蘭地區（World Bank, 2017）高出約 45％（見表 1）。太陽能光伏是台灣較成熟的農場可再生能源項目選擇。

表 1、台灣南部和東密德蘭地區及世界其他都市年度光伏發電量比較（Source: Global Solar Atlas, the World Bank）

Place 位置	Photovoltaic electricity output (PVOUT) 光伏電力輸出	Optimum angle of PV modules 光伏組件的最佳角度

Tainan Highspeed Rail Station, Tainan City, Southern Taiwan 台南市台南高鐵站	1428 kWh/kWp per year	21 ° / 180 °
Linbian station, Pingtung, Southern Taiwan 屏東林邊車站	1413 kWh/kWp per year	20 ° / 180 °
Southwell, Nottinghamshire, East Midlands, England 東密德蘭地區 諾丁漢郡 紹斯威爾	951 kWh/kWp per year	38 ° / 180 °
Skegness station, Lincolnshire, East Midlands, England 東密德蘭區 林肯郡 斯凱格內斯車站	1007 kWh/kWp per year	38 ° / 180 °
Madrid, Madrid, Spain 西班牙馬德里	1627 kWh/kWp per year	34 ° / 180 °
Sydney, Australia 澳洲雪梨	1465 kWh/kWp per year	32 ° / 0 °

3. 台灣生物質/生物燃料項目的限制

透過引入生物燃料的生產和消費支持政策，農業部門可以使其農業多元化行為進入長期開放的新市場（IEA，2011）。但實際上，在英國案例 C 的農民並不滿意他的生質能鍋爐的諸多使用限制，生質能需要許多外部承包商進行短期輪換萌生林 short rotation coppice 砍伐和生質能模組維護。同時與單位面積太陽能光伏產生相同電量下，需要更大面積種植生產生質能，如沼氣 Biogas 或生質柴油 Biodisel 分別需要 50 或 150 倍的土地才有相同產量 (Poncet, et al., 2012)。據英國皇家鳥類保護協會（RSPB）研究，生物質能源的溫室氣體排放並不像人們預期的那樣少，如果依英國政府假定生物質能

源是自動無碳的，則可能會使全球暖化更惡化（RSPB，2012）。英國皇家工程院（RAE）建議，只有農業廢棄物和森林工業廢棄物生產的第二代生物燃料具有較高的發展力才能使用為可再生能源，因其溫室氣體排放量較少，土地利用變化風險較小（RAE，2017）。台灣農田面積小，相較於使用農業或畜牧廢棄物來生產生質能，開發由農作物生產的生物質和生物燃料將更困難。

4. 台灣 3 種較可能採行的太陽能光伏模組

本研究發現太陽能光伏項目是未來十年台灣農場可再生能源發展的較好選擇。結合糧食安全和能源生產，本計畫出國人員提出了“農村太陽能系統”、“多餘的稻田多元化”和“浮動式太陽能光伏模組”等 3 個太陽能光伏項目可能較適合在台灣農村發展。

4.1 農業光伏系統

太陽能光伏能效轉換效率比植物光合作用效率高出近 5 倍（Dupraz et al., 2011），最新商用太陽能光伏面板效率甚至超過 20%（Energysage，2017）。 Dupraz 認為，“農業光伏”是一種解決方案，而不是競爭，將農業和農場可再生能源整合到一個綜合系統中，如果將農用電力系統有效地結合起來，全球土地生產力可能會增加 1/3 到 4/3 農業用於耕地有限的國家 (Dupraz et al., 2011)。筆者認為，農業與太陽能光伏項目的結合是一種“互利共生”，儘管太陽能光伏板是人造設備。例如，隨著全球暖化，乾旱季節生長季節最低氣溫每增加 1 攝氏度，大部分水稻生長和產量的影響就會降低 1/10 (Peng, et al., 2004, Krishnan, et al., 2011)。農業光伏系統發電同時，也是提供適當遮蔽，以保護作物免受極端發燒的溫度。

實驗證實，太陽能光伏版遮蔽下可減少生菜和黃瓜的失水量，顯著節水 14～29%，試驗中蔬菜生長用水在農業光伏模組下效率更高（Marrou，Dufour＆Wery，2013）。另一方面，在不同的太陽輻射條件下，由於萵苣通過補償機制適應輻射條件，非全日照狀況生長量與萵苣在全日照條件下生長相當，甚至高於全日照生菜，雖然輻射轉換效率（RCE）變化不明顯，在光伏模組下生菜輻射攔截效率（RIE）有所改善（Marrou et al.，2013）。在美國，單就萵苣生產，如果傳統蔬菜種植轉換為在農業光伏系統種植，估計經濟價值增長超過 30%，創造超過 40GW 可再生能源（Dinesh＆ Pearce，2016）。在中國，由於可再生能源的新就業機會和減少的二氧化碳排放，不僅是對經濟積極作用，這種組合的創新擴散效應也受到關注 (Li, et al., 2017)。

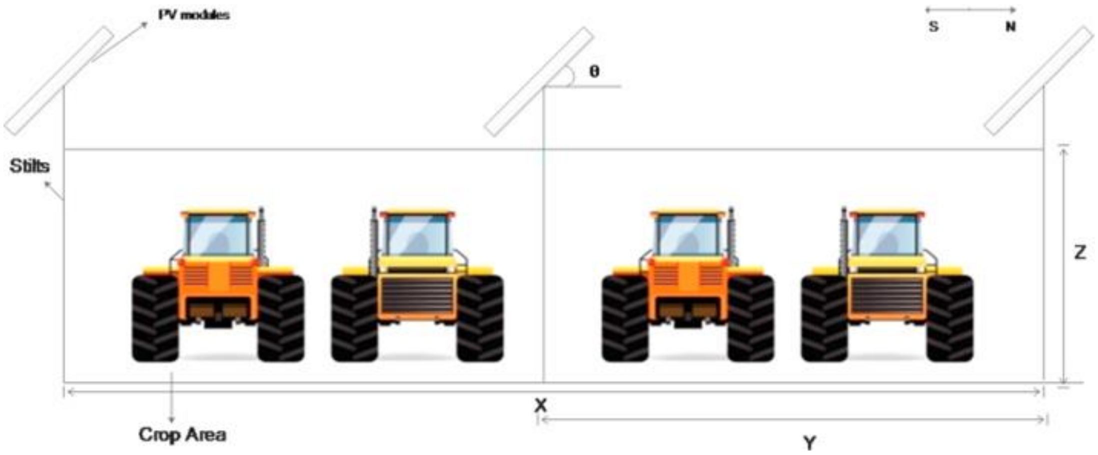


圖 5-1。 光伏組件安裝在支架的農業光伏系統示意圖（來源：Dinesh＆Pearce，2016）。

但由於在不同設備中變化，需要對太陽輻射減少評估，太陽能板覆蓋屋頂面積為 50%的小型溫室（面積為 960 平方米），每年太陽光減少近 2/3（64%），而不僅是一半（Cossu et al.，2014）。棋盤式太陽能板佈置比直線式佈置在陽光入射空間分佈更好（Fatnassi, et al., 2015），這些研究也可以說明，屋頂光伏覆蓋率達到 100%的溫室，其陽光入射不利於蔬菜，瓜類和水稻的生產，沒有陽光入射也沒有農業生產可能，農業光伏系統需要進一步研究不同的設施佈置和植被物種。

4.2 多餘的稻田多元化

聯合國農糧組織預估因為我國的低出生率，2018 年起台灣人口總數將開始下降（FAOstat，2017）。近年來由於價格政策的改善和一定的購買數量，公糧價格仍可在新台幣 21～26 元（約 0.50～0.65 英鎊/千克）間，稻米總生產量依然保持高水位，但美國大米的平均農場價格僅為 10.2～16.3 美元/英擔（約 0.20～0.32 美元/公斤或 6.06～9.72 新台幣/公斤）（Childs，2017）。“保價收購”政策自 1974 年開始實施，也持續達成“農民收入增長”、“國家糧食庫存”和“保價穩定”政策目標。 2007 年研

究指出，台灣稻農的年均收入的 40%由稻米保險收購政策的預算獲得（陳雅惠，2007）。沒有參與“政府以保證價格購稻”政策的台灣農民承擔了利潤損失的風險（Huang，2012）。由於農民注重稻米產量而不考慮品質，一定量的公糧在倉庫中保存數年，導致糧食浪費（Yang，2016）。在 2002 年加入 WTO 之後，台灣仍然是唯一一個推行這一保護稻農保險收購政策的國家，而日本則轉向直接支付（松倉千賀，2013）。

這種多餘的稻米保險收購政策也不利於環境保護，由於施肥、施藥增加了稻米生產的重量，而不是改善稻米質量。濫用肥料是非二氧化碳溫室氣體的主要來源，農場土壤微生物可能排放出一氧化二氮升高，N2O 熱量捕集能力幾乎是二氧化碳的三百倍（IPCC，2007）。這是有害且違反了“消除飢餓，實現糧食安全，改善營養，促進可持續農業”的聯合國可持續發展目標（UN，2016）。儘管這一政策導致了食物浪費，但民主制度中的一項普遍受農民歡迎政策並不容易被廢除。在選定的稻田上進行有效土壤管理的太陽能農場將可緩解環境惡化，農民可以從電力公司獲得收入，而不是單單依靠政府補貼。據研究，在台灣南部的高雄湖內區，太陽能光伏投資回收期只有 12 年（Hsueh，2015）。在英國，只要佔地 2 公頃，即可供 1MW 太陽能電站發電使用（Scurlock，2015），台灣太陽能電力輸出產量較高，也意味需要較少的耕地或同面積可產生更多電力。這種太陽能光電模組反而是對糧食安全和能源安全均有利。

4.3 浮式太陽能光伏模組

除台灣農村的稻田外，還有 4 萬多公頃的魚塘，有不同的平原，特別是在台灣中南部的漁民有 6.8 萬人（漁業署，2017）。由於氣候變化和頻繁的天氣事件造成水產養殖產業脆弱易受害。在台灣南部，從 1950 年到 2010 年，颱風和季風系統引起的強降水事件更多（Chu，Chen＆Lin，2014）。另外，1970 - 2010 年間，降水頻率呈減少趨勢，乾旱天氣增加（Tu and Chou, 2013）。致命的病毒和細菌在較暖和溫暖的環境中，或者在颱風事件之後存在並生長（Ho，et al。，2016） 近年來，位處熱帶的台灣也發生了一些極端的寒害事件。在 2008 年和 2016 年的極端霜凍期間，水產養殖受到嚴重影響，許多水產養殖戶由於意外的寒冷而遭受損失（王安祥等，2016，陳永明等，2008，Chang, et al.，2013）。水產養殖戶依靠更多的電動水車來保持魚類和其他水產

品的生長。由於魚塘蒸發量較高，還需要更多的水。但是，如果可以在大型魚塘上開發農場可再生能源，就可以像農民一樣，幫助水產養殖者減少能源開支，實現水產養殖產業的多元化。

浮式太陽能光伏項目若裝在魚塘上，浮式模組比地面或屋頂類型產生的功率多 10%，因為通過面板和水體之間較冷的空間提高了發電效率（Choi，2014）。在泰國，由於可靠性更高，成本更低，研究推薦裝備蝦池的可再生能源模組（Nookuea，Campana 和 Yan，2016）。浮動太陽能光伏項目在水面上有效覆蓋，亦使蒸發明顯減少（Tsoutsos，Frantzeskaki 和 Gekas，2005）。使用壽命超過 25 年的浮動太陽能光伏項目的成本可能僅需 5 年即可回收，同時達到水溫降低，藻類生長減少，水質穩定的效用 (Sahu, Yadav & Sudhakar, 2016)。在極端寒冷的日子裡，太陽能光伏系統也可以作為水的防風層和蓋子。結合新型工業材料水飽和的 MEPCM 及其放熱，配備太陽能光伏發電項目的魚塘水溫在冬季可以保持溫暖（Ho，Chou 和 Lai，2014）。這些浮式太陽能光伏項目的概念部分與台灣南部屏東"養水種電工程"試範模組類似，該計畫防止地面進一步下沉，振興養殖區經濟，為遭受洪災的當地農民提供新的就業機會和減輕莫拉克颱風侵襲後的土地鹽化（林淑惠，2017，Su, 2014），同樣模組在印度南部水鄉也是普遍採用。

5.本研究總結

5.1 本研究重要結論與對我國的啟發

經由課堂講授及現場參訪，理解糧食安全與創新研發密不可分，現有水土資源保育工作更是糧食安全穩固基礎，面對未來全球氣候變遷等不確定因素影響，持續科技研究及農民脫貧、鄉村發展工作仍是長期糧食安全的基礎工作。

在英國，儘管糧食價格低廉，法規制度可能也阻礙了農場可再生能源的發展，每個案

例的英國農民仍確實整合糧食生產、環境農業及農場可再生能源三項農業工作。本研究中的英國農民願意以“再生能源電能躉購制度”政策為後盾，以保持農業和環境為己任的農業可再生能源業務，實現農業多元化經營，努力降低農場必要的能源支出，提供合理的財務收入，作為農場長期規劃和“永續耕種”的保證。 也由於農民致力於減少溫室氣體排放，並通過其項目為公眾創造更多的農場可再生能源，因此可以預計農業對氣候變遷影響將會減少。在台灣，2015 年台灣總可再生能源消費比例相較英國雖然較低，但年二氧化碳減少排放量大幅度超過 93 萬噸，其效果相當於台灣造林 12 萬公頃（台電，2017）。另外，因地理緯度優越與台灣“相關行業先進技術”，太陽能光伏和風能當被視為新興能源（Chen＆Lee，2014）。

台灣農民在這幾十年面臨著氣候變化的挑戰。農民如何應對天氣，繼續耕種未來幾十年？可再生能源的農業多元化是台灣農民的一個積極選擇，正如英國農民所做的那樣，農村光伏系統和浮法太陽能光伏板項目可能是較好的糧食生產和發電的替代選擇。農民可以保持財務安全，保護他們的固有農業或水產養殖業生產。一些多餘稻田可以轉為太陽能電站，也為傳粉者，蜜源植物和其他野生動物創造更好的自然環境，在未來幾十年，稻農仍然可以獲得合理的經濟效益，保持耕地的肥沃。糧食安全和能源安全也可在台灣共存。

5.2 本研究困難限制說明和對未來研究的建議

本研究試圖訪問更多投入農場可再生能源模組的英國農民，但大多數接觸過的農民拒絕提供他們的經驗。最主要難題就是關於詢問農場可再生能源效益的問題，雖然這項研究中的農民姓名是匿名的，但一個國際學生提出這類獲利效益問題仍是困難的。但作者確定實地訪談和觀察是必要的，方可以較精準方式描繪英國農場可再生能源模組發展的實況。期待後續研究，以利為未來決策提供更準確的信息。

除法規制度約束外，本研究的英國農民希望最大限度地提高農戶的可再生能源營收效益，但也同台灣農民一般面臨從可再生能源模組輸出電力接到電網的電力出口限制。我國未來幾年可能需要德國採用可再生能源的“精細策劃的優先電網接入”和“預期

輸電規劃”以利政府推動農場可再生能源模組（Sutherland＆Holstead，2014，Anaya ＆Pollitt，2015，Alagappan，Orans＆Woo，2011）。

肆、附錄-諾丁漢特倫特大學碩士論文(PDF)

The Nottingham Trent University

The costs, benefits, and constraints of on-farm renewable energy projects in England: Implications for Taiwan

Huan Hsi Tsai

N0653081

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ABSTRACT

In UK, on-farm renewable energy technology and projects are well developed and British farmers continue to drive growth of renewables. In this research, the author tried to understand the costs, benefits, and constraints of on-farm renewable energy projects by three different cases in East Midlands. The research of understand the renewable energy project will help to find out proper projects and groups of farmers to promote the renewable energy development in Taiwan. In this study, basic definitions and identifications of food and energy security were understood. The theory of case study research is utilized to understand the costs, benefits, constraints and drivers of on-farm renewable energy projects by interviews, site visits and observation. This study took the qualitative method to understand different on-farm renewable energy projects which were invested/involved by different farmers in different farm. It was found British farmers are willing to adopt RE as diversification, "Feed in Tariff" policy strongly affected on-farm renewable energy projects adoption, farmers preferred to invest by themselves if the cost is affordable. They all preferred to choose wind turbine projects to maximize their power generation, instead of solar PV projects, but wind turbine permissions were difficult to receive. These mixed factors affected farmers' attitude to invest in renewable energy in the future. In Taiwan, solar PV project adoption is more priority than wind project, agrivoltaic system and floating solar system are options for smallholder farmers and aquaculture farmers. Diversify surplus rice field to solar farm is viable in the future.

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Chapter One: Introduction

1.1 Background

In Taiwan, it is expected to reach the goal of "the 2025 nuclear-free homeland" with the cooperation of government and public in the year of 2025. Following "the energy transition pathway and the short-term and long-term supporting strategies" issued by government, in 2025, it is aimed to increase the power ratio of renewable energy to 20%, the renewable energy will be the third pillar of whole national power supply, with the other two pillars, Coal and Natural gas (MOEA, 2017). It is a significant ambitious goal to achieve due to the extremely low energy self-sufficient ratio in Taiwan is less than 3 percent, and huge annual expenditure, approximate 2 trillion NTD (about 50 billion GBP), spent on fuel (China post, 2016). It is planned the solar PV, onshore wind, biomass will generate over 65% of renewable energy for national power grid in 2025 (Lee, 2016). However, the food self-sufficient ratio in Taiwan is not as high as most developed countries, only 31.4% (calculated by Energy) or 66.4% (calculated by Prices) in 2015 (COA, 2017). In Taiwan, an island as large as half a Scotland, most renewable energy, solar, onshore wind and biomass are expected to be produced in relatively vast rural area, instead of urban zone. Because of the new energy policy, the emerging on-farm renewable energy development is expected in next few years, but the discrepant argument between "farmers should only produce food" or "dealing with renewable energy production for economic reasons" is also needed to be discussed (Frantál and Prousek, 2016). The competition or cooperation between food production and renewable energy generation in Taiwan shall be figured out in next few years.

On the other side of the world, The Renewable Energy Directive sets rules for UK, the EU member state, to achieve its 20% renewables target by 2020 (EU, 2009, Boie et. al., 2014). Agriculture was not a profitable business in UK and the UK food self-sufficient ratio was lower than thirty years ago (DEFRA, 2014), but it still produces over 60% of the raw material (calculated "as the farm-gate value of raw food production divided by the value of raw food for human consumption") for agri-food industry, the largest British manufacturing sector, which is worth over one hundred billion pounds and employs nearly four million people (NFU, 2017, Bailey, Davidova & Hotopp, 2017 and DEFRA, 2014). Meanwhile, more than 70 percent of British land is well protected and managed by farmer (DEFRA, 2013). Young farmers are few, only 3% of farmers were under thirty-five years old (Bailey, Davidova & Hotopp, 2017), it was same that most Taiwan farmers are not young. Surprisingly, the poultry in Taiwan and England both are the highest Farm Business Income by type of farm in the year of 2015, and income of cereal sector in both regions are not the lowest of whole agriculture (DEFRA, 2016 and COA, 2016).

Although some critics argue the greenhouse gas emission from agricultural field is high (Garnett, T., 2011). UK agriculture emission is significantly decreased by 17% lower during the years from 1990 to 2015 (DEFRA, 2017). Specifically, UK agriculture sector is an important power and energy provider of on-farm renewable energy by wind, solar PV and biomass projects. It is estimated about 1/10 of whole UK electricity generation (NFU, 2017). In 2013, over one third of British farmers own or have various renewable energy project (FARMERS WEEKLY, 2013). British farmers are not only food suppliers, they play compelling roles of greenhouse gases emission reduction in the 21st century. There are some implications for Taiwan supposed to be available that had been examined in UK of the combination of conventional agriculture and on-farm renewable energy, despite some existing renewable energy projects are argued by public. It is also necessary to consider some distinct concerns like cost, technology vitality, pollution, supply efficiency before taking renewable energy for power generation (Bilgili et al., 2015).

1.2 Aim and objectives

The aim of this research is to understand the costs, benefits, constraints and drivers of different on-farm renewable energy projects in England in order to draw lessons for Taiwan. The specific objectives are:

- On-farm renewable energy and food security
- What are the costs of on-farm renewable energy projects in England?
- What are the benefits of on-farm renewable energy projects in England?
- What are the constraints of on-farm renewable energy projects in England?
- What are the drivers of on-farm renewable energy projects in England?
- The practical on-farm renewable energy projects and suitable programs implication for Taiwan.

1.3 Dissertation outline

- Introduction: the contemporary development of on-farm renewable energy project in England and Taiwan.
- Literature review: to clear basic ideas of on-farm renewable energy and the costs, benefits, constraints and drivers of on-farm renewable energy project.
- Material and Methods: case study qualitative method was utilized in this study.
- Results: to find out the real condition of on-farm renewable energy projects adopted by English farmers.
- Discussion: verifying collected data and literature to suggest proper projects can be adopted in Taiwan.
- Conclusions: to discuss key study conclusion and lessons for Taiwan.

Chapter Two: Literary Review

2.1 Chapter overview

Although renewable energy and on-farm renewable energy projects were popular in UK and it was expected to adopt in Taiwan for strong energy demand, but most people are confused with the meaning of on-farm renewable energy and the connection between agriculture, greenhouse gases and on-farm renewable energy projects. Many criticisms and misunderstanding are mixed with non-science viewpoints, this chapter will discuss some major points of on-farm renewable energy projects, including definition, relationship between agriculture and renewable energy and basic food security before further study.

2.2 Renewable energy, Non-renewable energy and On-farm renewable energy

Renewable energy is defined as “energy obtained from the continuous or repetitive currents of energy recurring in the natural environment”, continuing natural resources like sunshine, wind, biomass, even geothermal heat, hydropower in river, wave and tide in ocean all are classified in the renewable energy system (Twidell and Weir, 2014). Except to tidal and geothermal energy, all majority renewable energy, such as solar, onshore wind, biomass and certain part of hydropower are received on vast farm land in rural area and their principal energy sources is solar radiation released by the Sun (Boyle, Everett and Alexander, 2012). Solar Photovoltaic energy is the direct conversion of sun light to electricity (Everett, 2012). Wind is generated by the solar heating and moved in different atmospheric pressure on the surface of earth (Taylor, 2012). Biomass is also connected with the sunshine due to “the key mechanism in the use of bioenergy is photosynthesis” and “carbon-hydrate” (Morris and Scurlock, 2012). In other words, the difference of solar radiation transformation between food and renewable energy are the products. Food is the product of the photosynthesis which used for human diet and animal feed, but renewable energy is only generated for human demand.

Most greenhouse gases are generated by fossil fuel. Fossil fuels all are classified as Non-renewable energy and un-sustainable to the environment. If the global food consumption and diet trend remain as the year of 1995, technological mitigation options in the agricultural sector are needed to decrease non-CO2 GHG emissions (Popp, Lotze-Campen, and Bodirsky, 2010). Table 2-1 indicated the difference between the fossil fuel and renewable energy as follow:

Table 2-1. The difference between Non-renewable energy and renewable energy, Source: IEA, 2016 and Everett et al. 2012

Energy Type	Market Share (%) in 2014	Refill by nature at continued use?	Harmful to human and environment due to emission	Significant social injustices?
Non-renewable energy (oil, coal and natural gas)	81	No	Yes (CO2, NH4 & SO2)	Yes
Renewable energy	13.8	Yes	Few	Few

The on-farm renewable energy is defined by the European Commission as "On-farm Renewable Energy is produced on farms; farms are economic enterprises basically relying on biological processes to generate agricultural products – food, feed, fibers, other natural materials, fuels – from natural resources such as land and/or non-saline water", which renewable energy generated by system paid and/or operated by farms or legal entities for domestic use or export, mainly export is electricity (Pedroli and Langeveld, 2011). On-fam renewable energy production and use is a significant role among the agriculture innovation, competitiveness, ecosystem preservation, emissions reduction and so on (Dinu, 2013). It is argued renewable energy is a part of rural development (Frantál & Prousek, 2016. Bayer & Urpelainen, 2016) and agriculture is being challenged to reduce its fossil fuel use and transferred to generate renewable energy (Pedroli & Langeveld, 2011). The on-farm renewable energy is a key role of European agriculture, rural development and elimination of greenhouse gas emission.

2.3 Greenhouse gases, climate change and agriculture

Climate change is main reason why the renewable energy is necessary to the Earth and people live on it. It is believed the climate change is strongly connected with greenhouse gases emission which accompany by the using of fossil fuel after the industrial revolution (Peake et al., 2012). Major greenhouse gases are Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O), these three gases are stable chemical material which can exist in the atmosphere on the earth for decades even longer centuries and conduce to the climate change due to the greenhouse effect (IPCC, 2007). The greenhouse gases, water vapor, CO_2, CH_4, acts as a blanket, it helps to keep the earth's surface average temperature at 15 degrees Celsius which is suitable for life (Boyle, Everett & Alexander, 2012). However, the extra greenhouse gas which is produced by the fossil fuel use after the year of 1950, was emitted to atmosphere and more solar radiation energy is inhibited on the earth (Andres et al., 2012).

Carbon dioxide is the most important greenhouse gas, it will result to "irreversible dry-season rainfall reductions" as the dust bowl on the great plains of the US in the 1930s and rise global sea level over 1 meter when CO_2 concentration exceed to 600ppm (Solomon, et al., 2009). It is approximated that per kilowatt-hour consume by people will also produce one kilogram of CO_2 (Ramage & Everett, 2012). This greenhouse effect changes the long-term balance of weather system. In England, ASC indicated the temperature rise is about 1 degree in the years of 2005 to 2014 than the temperature in the thirty years of 1961 to 1990. However, the longer average growing season was also observed in England and Wales due to about sixty growing degree-days, a measure of heat accumulation in Agriculture, during the 20th century (ASC, 2016). In Taiwan, it was studied by Hsu that heavy rainfall events (Preciption $\geqq$ 200mm/day) increased and annual rainfall days decrease significantly in last thirty years, extremely hot days increase are obvious in the years from 1911 to 2009, especially in the year of 2000 to 2009 (Hsu, et al, 2011). However, due to the low latitudes location of Taiwan, it is highly possible, in the future, crop productivity will be negatively affected due to the global warming if the temperature keeps on rising (Kang, Khan & Ma, 2009, IPCC, 2007). It was recently quantified uncertainty in the global warming influence and the tropic is the area may occur the most sustained hot and dry events due to the severest and most extensive contributions of anthropogenic climate forcing (Diffenbaugh et al., 2017).

Although the agriculture is regarded as an environmental-friendly industry, but agriculture is a main source of GHG. In 2005, over 1.4 gigatons, 10%, of global carbon emissions was produced by the agriculture sector (Burney, Davis & Lobell, 2010). Agricultural soil is a sink of carbon sequestration; however, it is estimated over 1/2 of global anthropogenic methane (CH_4) and over 4/5 of nitrous oxide (N_2O) emission are related with agriculture although the less than 40% of global land is used for agriculture (Smith, et al., 2008). Methane is generated on the graze land and rice field due to organic materials decompose in oxygen-deprived conditions, nitrous oxide (N_2O) is produced by ammonium nitrate fertilizer, especially under wet conditions" (Smith, et al., 2007). Furthermore, in 100-year time horizon, methane and nitrous oxide are 25 times and 298 times harmful than CO_2, respectively (IPCC, 2007), global climate was significantly affected by CO_2 and NH_4. However, global methane and Nitrous Oxide emission are expected to increase obviously in 2030 (USEPA, 2012). In Taiwan, the methane emission in rice paddy was lower if farmers grow Japonica rice instead of long-grain rice (Liou, Huang and Lin, 2003).

2.4 Food security vs. Energy security

Food security is defined as "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" -World Food Summit, 1996, food availability, access, utilization and sustainability are pillars of food security (FAO, 2006). In 2050, it is predicted the global population will be over 9 billion and more 70% increase are needed of food production (FAO, 2009, DESA, 2017). In China, more awareness and further research for the potential of next agricultural doubling in yields are taken more seriously (Fan, et al., 2012). However, in developed countries, like Taiwan, Japan, or UK, food security issue is not same as developing or underdeveloped countries. Advanced crop yield improvement is the first priority effort to reduce future greenhouse emissions in agriculture instead of growing crops on vast farmland (Burney, Davis, & Lobell, 2010).

Energy security is officially defined as “the uninterrupted availability of energy sources at an affordable price” (IEA, n.d.). The 4As (availability, affordability, accessibility and acceptability) concept of energy security, is introduced by Asia Pacific Energy Research Center and be discussed by publications (Cherp & Jewell, 2014). In developed countries, the energy demand per capita is much higher than the food demand if both are calculated at energy. In Marston Vale, England, it is estimated that the energy demand of food, wood and animal feedstock for human diet is only 15% of daily energy demand by per person, including heat, transport and electricity if all items were transferred to Kilowatts/hour (Burgess et al., 2011). The energy demand and its security is concerned due to strong needed by human activities. There is a new symbiosis of on-farm renewable energy and national energy security that renewable energy can enhance availability, affordability and resilience of energy security (Valentine, 2011).

2.5 The cost, benefit, constraints and drivers of on-farm renewable energy

On-farm renewable energy is a diversification to farmers, due to the agricultural production price and benefit is not reasonable in recent years (DEFRA, 2016, DEFRA, 2012). Agriculture industry income trends in UK are descended significantly during the last two decades, since 1995 to 2015, except the dramatical global food crisis period. With the Euro and Sterling exchange rate drop and the direct payment increase about 18%, the “total Income from Farming per annual work unit of entrepreneurial labour (farmers and other unpaid labour)” still fell by 7% and it is less than 19,000 pounds, between 2015 and 2016 (DEFRA, 2017). The diversification in rural area for farmer's another income is critical. It is studied by Sutherland that farmers invested and seek in on-farm renewable energy, like wind turbine, to increase the long-term economic feasibility and to 'future proof' their farms with agricultural diversification and benefitable capital reward (Sutherland & Holstead, 2014). It is also studied in Czech, the main reason of farmers who adopt renewable energy technology is for economic diversification and stabilization of their farm business (Frantál & Prousek, 2016). If the renewable energy technology is for economic diversification, the costs, benefits, constraints and drivers must be considered seriously by any farmers who plan to involve in this field.

2.5.1 Cost

The cost is the first item that farmers should focus before their renewable energy project investment. In Greece, by evaluating the weighted average cost of capital (WACC), the onshore wind WACC was approximately twelve percent and the second lowest WACC is the solar PV power plants which is bigger than 1MW, but the debt cost in 2016 the solar PV power is slightly lower than the onshore wind power (Angelopoulos, et al., 2017). In UK, the application of renewable energy is also an important cost, due to the application is not always approved by the local council. Although the RE project making appropriate use of farm resources, earning non-agricultural income and reducing farm business cost (in diary), but total cost which including any transaction cost, formal community dialogue, consultations and involvement during planning and application or even the cost of an unprofitable RE project is spent by the on-farm RE project owner or investor (Sutherland & Holstead, 2014). Critical evaluation of environmental and social cost both are also needed for biofuel use, despite these two costs may will be mitigated or overturn by using next generation biofuel staple and new production tech (Koh & Ghazoul, 2008). It is researched of the optimum combinations of small power wind turbines, PV panels and energy storage system in off-grid remote island by logical approach (Fig. 2-1: Logical approach), it is estimated the operation cost and total net present cost are lower in most island if the system is pure renewable energy combination (without diesel power generator) which wind turbine must be always combined because of its high availability and power output (Ahadi, Kang, and Lee, 2016).

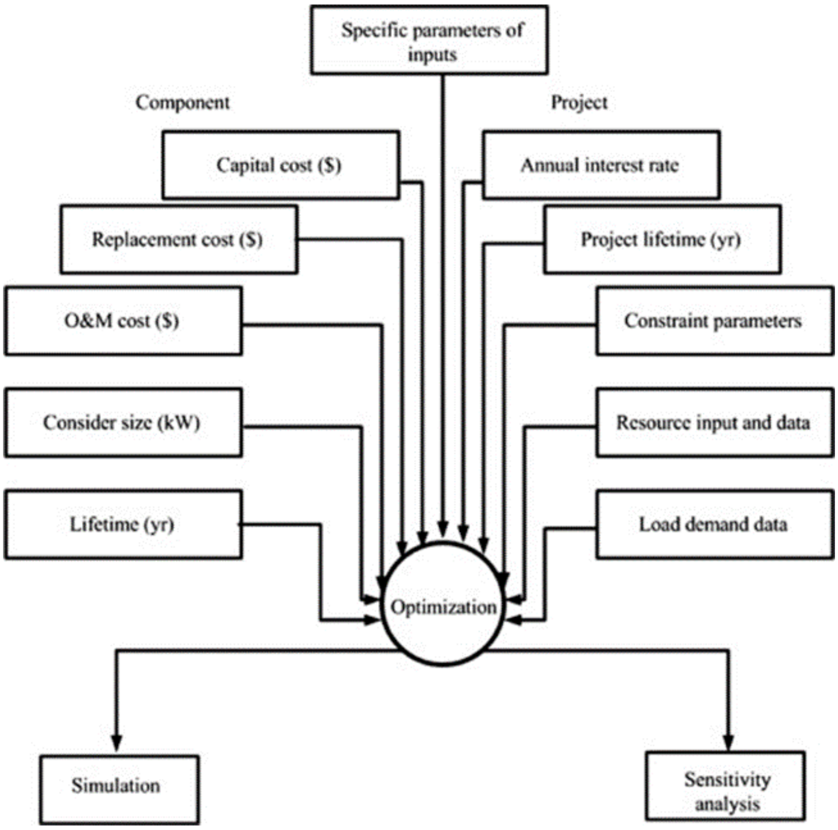


Figure 2-1: Logical approach (Source: Ahadi, Kang, and Lee, 2016)

As the technology innovation developed, the cost of renewable energy drop trend is obvious. It was documented the Swanson's Law: price of solar Photovoltaic panel market price had on average declined about 1/5 when the solar photovoltaic power installation volume cumulation was double due to the higher semiconductor yield, better performance of solar cell (Swanson, 2006). It is predicted, in 2020, utility-scale (larger than 1 MW) solar PV plant in the US will be cost-competitive as the conventional natural gas power plant and commercial-scale (in a range of 0.1 to 1 MW) solar PV will be also cost competitive within 10 years, even without any government subsidies (Reichelstein & Yorston, 2013). The cost of wind power is also decreased in this decade, for instance, Chinese wind turbines price dropped near 40% during the year of 2007 to 2016 (WEC, 2016).

2.5.2 Benefit

Benefit is another factor to affect the involvement of on-farm renewable energy. Most on-farm renewable energy projects in UK is backed by the 'Fit-in Tariffs' (FiTs) since 2010, a mandatory premium payment, during a fixed time, for power which is generated by renewable energy projects and guarantee grid access for them (Boyle, 2012. Bayer & Urpelainen, 2016, REN21, 2016). In the end of 2015, 110 Countries/States/Provinces are enacting Feed-in Tariffs policy, Taiwan and UK enacted this policy in 2009 and 2010 respectively (REN21, 2016). 'Fit-in Tariffs' policy is popular with democratic governments because of the negative externalities caused by coal combustion can be transferred to better air quality, a national public good, and the fee is paid by power consumers, not by government, specifically. It is also a kind of political benefit that government can receive from many farmers who generate income from renewable energy projects in different rural areas with high potential of renewable energy generation (Bayer & Urpelainen, 2016). In UK, three types of 'Fit-in Tariffs' payments, Generation tariff, Export tariff and Energy bill savings, can be received by renewable energy generator, including Solar PV, Wind turbines, Anaerobic digesters, which total installed capacity (TIC) is 5MW or less (Micro combined heat and power (CHP) is 2kW or less) (Energy saving trust, 2017). People argued PV renewable energy production affected food security and agricultural production, the co-existence of grazing habitat for sheep and hens or bee hives may keep ecology, food production, decrease the need of vegetation maintenance and enhance the soil erosion prevention simultaneously in rural area (Hernandez, et al., 2014).

2.5.3 Constraint

The regulatory, financial, community, technical and market constraints of on-farm renewable energy are main factors that affect the development of on-farm renewable energy projects. It is studied because of "the multiple functions of agriculture were reflected in competition between agriculture and electricity sectors over natural resource access" (Sutherland, Peter, and Zagata, 2015). It also was studied that "the major constraints faced in meeting current UK energy demands from land-based renewable energy and the stark choices faced by decision makers" (Burgess et al., 2011). NIMBY-ism is the constraint from local community and make RE projects hanged or abandoned, the general attitude to onshore wind turbine is not to spoil the landscape and NIMBY model is learned by UK developers to construct the opposite publics in local community (Jones & Eiser, 2010, Burningham, Barnett & Walker, 2015). On the other hand, British farmers can handle the extended spread of returns in longer period if the initial RE project investment constraints are overcome (Mbzibain et al., 2013). About 50% of the total application of onshore wind turbine do not pass the planning application due to the intensive resistance from local community on different impact issues, like landscape, noise, even health and safety, although the wind turbine Environmental Impact Analysis combining all the impacts (Sturge, While & Howell, 2014). However, the solar PV projects have lower environmental impacts even among the renewable energy field and the major challenges of solar PV installation are technology, research and policy (Hernandez, et al., 2014). Large solar farm is taken as a temporary structure which landscape and visual assessment is same as wind turbine, but it is available to minimize the impact, even to zero (DCLG, 2015).

2.5.4 Driver

It was studied high Feed in Tariff price, easy transmission access and low transmission charges are main drivers to promote renewable energy in the Europe and North America (Alagappan, Orans & Woo, 2011). In UK, the innovation system of renewable technology also played a significant role of on-farm renewable energy projects buildup because of the technology maturity, innovation system of different renewable energy projects and new policy instrument (Foxon et al., 2005). It was found on-farm renewable energy production in Bavaria, Germany was obviously influenced by domestic grid net transformation ability, farmers' professional degree and local neighborhood effects (Schaffer & Düvelmeyer, 2016). The drivers of on-farm renewable energy are combined or mutual affected in finance, policy, business and innovation.

2.6 Chapter summary

It was studied in this chapter that on-farm renewable energy projects could generate power for human demand and reduce greenhouse gases emission. Meanwhile, farmers can adopt on-farm renewable energy projects as diversification for their farm business. The conflict between food security and energy security could be cleared and each security was a key factor of sustainable development goals of UN. Costs, benefits, constraints and drivers of on-farm renewable energy affected farmers to involve in this field. How these factors affected the on-farm renewable energy projects, the author tried to understand by cases study in England.

Chapter Three: Material and Methods

3.1 Chapter overview

The on-farm renewable energy projects are connected with farmlands and farmers, most farmlands are owned and/or occupied by farmers and kept on agriculture. On-farm renewable energy is a business, it is the same as agriculture. It is important to understand the costs, benefits, and constraints of on-farm renewable energy projects by different farmers who really involved in this business. Their view points, ideas and experience of different renewable energy projects adoption are invaluable data to judge the practicality of renewable energy project in different areas or regions. In this study, the author visited three different farms and farmers where different capacity and types of renewable energy projects were mounted and generated power or energy for demand. The author tried to utilize case study research to find the value of different renewable energy projects.

3.2 Methods

Case study is "an empirical inquiry about a contemporary phenomenon, set within its real-world context - especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2012). Case studies are useful strategy to find out "how" or "why" questions when people met and the question is descriptive or explanatory. For example, the dispute between developer and local environment protectors in a rural village or decision-making could be understood by the case study (Henn, 2009). The researcher is not able or hard to control of the research topic or event that he is interested. The contemporary phenomenon is expressed by users or interviewees with their experience. In this study, the author tried to figure out the proper on-farm renewable energy projects which is really helpful to farmers and further on-farm renewable energy project implications for Taiwan farmers.

In this study, the author took qualitative research. It is popular to take quantitative analysis to evaluate why farmers uptake specific on-farm renewable energy technology or projects. For instance, younger, well-educated, information seeking farmers is studied that they are more likely to involve in ‘agri-environmental diversification’ which including the renewable energy production (Sutherland et al., 2016), or adoption of solar energy is most popular RE technology by farmer and less willing to invest in biomass related RE in UK (Mbzibain et al., 2013). However, without difficult and detail questions, the qualitative research method is useful to understand local farmers’ evaluation to adopt on-farm renewable energy projects due to farmers are a special ‘sub-cultural group’ on a specific rural landscape with different motivations or experience (Kuehne, 2016). By the qualitative research, it is able to understand ‘why and how’ on-farm renewable energy projects are adopted by farmers.

To understand the costs, benefits, constraints and drivers of adopting on-farm renewable energy projects, it is assumed each farmer adopts the renewable energy is judged by farm property, different types of cost, benefit, constraint and drivers which were influenced by multi or single reasons, like drivers of farmer’s personal attitude to renewable energy, financial condition, constraints of the influence from farmer’s community and government, the cost and benefit about their projects, opportunities and resources to use different projects. By assessing different cases in this study, the author tried “to predict similar results or to predict contrasting results but for anticipatable reasons” (Yin, 2012).

The basic economic laws are applied to design the questionnaire of this study. To help respondents (farmers) to understand the question and express their true opinions for further promotion of renewable energy projects in different regions, the questionnaire of interviews of this study is designed in 5 sections, including: 1. General information of farm and farmer, 2. Cost of farmers’ on-farm renewable energy projects, 3. Benefit of farmers’ on-farm renewable energy projects, 4. Constraints of farmers’ on-farm renewable energy projects, and 5. Drivers to make farmers to adopt on-farm renewable energy projects. To develop this study, farmers of three cases who involved in renewable energy business were visited and interviewed in their farms on 3 different days of July in 2017.

The East Midlands is the second largest wheat and oilseed rape production region in England (DEFRA, 2017). East Midlands is also the region has highest proportion of agricultural land of all UK regions and low proportion of running tourism as a diversified activity (Beaumont, 2009). It is expected to study in East Midlands when considering the feasibility of on-farm renewable energy project implications for Taiwan, especially for southern Taiwan where is the main agricultural zone and its renewable energy resources, like solar and biomass, are more adequate. The rural tourism in southern Taiwan is also not as thrive as other regions. The questionnaire of interviews is designed as follow (see Table 3-1.):

Table 3-1. Questionnaire of interviews

Section	Question
General Information	● Location of the farm ● Size of the farm ● Ownership type ● Type of the farm business ● Length of farming ● Type of renewable energy ● Generation capacity ● Length of the renewable energy enterprise/project ● Any specific information about the farm ● Some information about the farmer
Cost of on-farm renewable energy projects	1. How much have you invested so far for this renewable energy technology on your farm? 2. How did you raise the money to invest? 3. How did you find a designer or professional consultant to help you to build it? How long did it take for you to plan this project? 4. How does your renewable energy project affect your agricultural production? 5. How much time and money did you invest to receive planning permission for your project? What types of activities did you have to do for the permission? 6. How about the annual maintenance cost of this project? What are those costs and how much did you invest for this? 7. How much will you pay to retire and remove this project if it is inefficiency after 20 years?

Benefits of on-farm renewable energy projects	1. What is the financial benefit of this project? How do you feel about this benefit? 2. Is all energy produced by your RE project only for sale to power grid, or are some portions used by your farm? How do you make the contract with the power company? 3. How does your energy project benefit your agriculture business? Please explain? 4. What is the non-financial benefit of your energy project, for example, environmental and ecological benefits for your farm or the area, social or community benefits? Please explain. 5. Do you get other benefits from your energy projects? Please explain if you get any.
Constraints	1. What regulatory constraints have you faced in your RE project? Please explain. 2. What are the financial constraints that you have faced in your RE project? Please explain. 3. What constraints relating to community opposition have you faced in your RE project? Please explain. 4. What technical constraints have you faced in your RE project? Please explain. 5. What market constraints have you faced in your RE project? Please explain. 6. Are there other constraints that you have faced in your RE project? Please explain, if there is any.
Drivers	1. What are the business-related or financial drivers that have made you to invest and run on-farm renewable energy project? Please explain. 2. What are the policy drivers that have made you to invest and run on-farm renewable energy project? Please explain. 3. Are there other drivers that have made you to invest and run on-farm renewable energy project? If there is any, please explain. 4. So far, based on your experience with on-farm renewable energy projects, will you make the same decision to invest on-farm renewable energy in the future? Why?

3.3 Material

This research is for understanding the RE adoption farmers' first-hand data of the cost, benefit, constraint and drivers during the time from their initial planning of renewable energy project to follow months/years after connection with national grid, it is studied for the further promotion and decision-making in Taiwan. Three sources of case study evidence were collected, including interviews with farmers, site visit with conversation and direct observation (Yin, 2012). RE adoption farmers' interviews were recorded at each farmers' house (2 of all 3 cases) or by their renewable energy projects. Without considering the unofficial conversation and site visit guided by farmers (without voice recording but longer time than recorded interviews), each case takes about 36 minutes to 1.5 hour, maximum, to finish 3 interviews. All interviews were transferred to transcription files and coded by qualitative software, Nvivo, for further research (Silver and Lewins, 2014). Each interview is an independent case.

Farmers' names in this research were anonymous. All farmers were professional in agriculture for over 40 years. Their farm land area was between by 100 to less than 300 hectares. All farmlands were owned or tenanted by farmers. Farmers grew or raised different agricultural commodities, like beef, wheat, oilseed rape and beetroot, farming was their core business. Environmental agriculture of all cases was another main income paid by government. All on-farm renewable energy projects were applied and mounted on farmlands after 2010, backed by the 'Feed in Tariff' policy in UK. Notably, farmers of all cases applied solar PV project at beginning and applied wind turbines later, but only one wind turbine (Case B) was permitted to run after long-term, unfinished legal battles and twice applications. Only one farmer used a biomass project, however this project was not easy to use and maintain if farmer were not supported by outside contractor. Except one utility-scale solar PV project (5MW), other two cases of on-farm renewable energy projects were owned by farmers (Case A & B). The capacity of power of each case is as follow (see Table 3-2.):

Table 3-2. Renewable energy type and capacity of each case

Renewable energy type and capacity	Case A	Case B	Case C
Solar PV	Less than *0kw on roofs	Less than *00kw on ground and roof	5MW on ground
Wind turbine	-	Over 3*0kw	-
Biomass	-	-	*00kw Boiler
Size	Smallest capacity, non-residential PV system (Seel, 2014)	Medium capacity, wind turbine+ Commercial roof-top PV system	Largest capacity, Utility-scale solar farm (Rudolf & Papastergiou, 2013)

Each renewable energy project of three case are observed during the site visit guided by farmers (see PHOTOGRAPH 3-1~3- 4).

PHOTOGRAPH 3-1. One of on-roof Solar PV projects (10kW) of Case A.

PHOTOGRAPH 3-2. Wind turbine project (over 300 kW capacity) of Case B.

PHOTOGRAPH 3-3. One of Solar PV projects (10kW) of Case B.

PHOTOGRAPH 3-4. 5MW Solar PV project of Case C.

Chapter Four: Results

4.1 Chapter overview

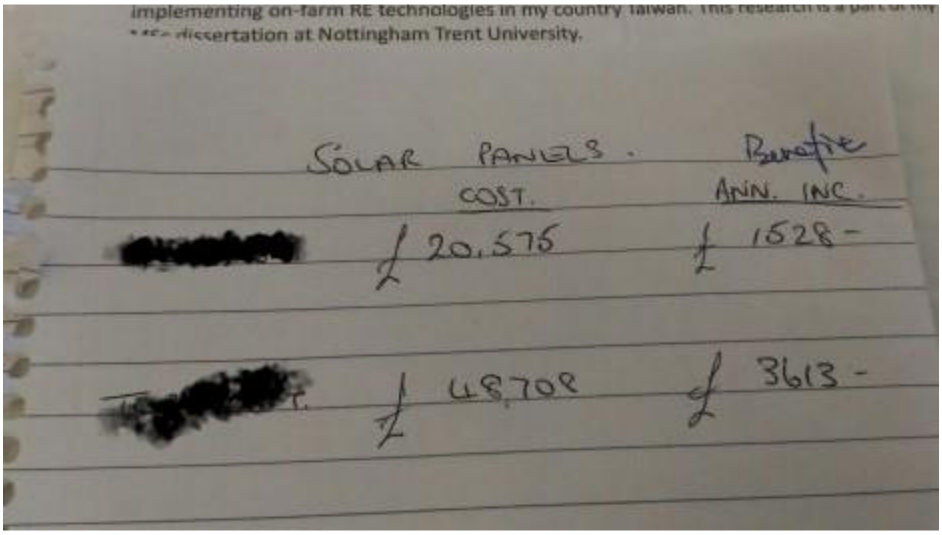
The costs, benefits, and constraints of on-farm renewable energy projects of this study were connected and influenced to each other. However, some specific factors were the most critical determinants due to applications of renewable energy projects was strongly determined by human and nature factors in all 3 cases, these determinants also resulted other unexpected extra cost and time loss or failures to all farmers. The following results were discussed in 4parts as the interviews questionnaire in the cost, benefit, constraint and driver of on-farm renewable energy.

4.2 Costs of on-farm renewable energy

From the three cases of on-farm renewable energy projects investigated 5 main types of costs were identified. These costs were explained as below.

4.2.1 Financial costs

Considering the cost of different on-farm resources is the main part to affect farmer involving in renewable energy projects. All cases focused on this determinant and describe their individual circumstance with comparable results. First, the financial investment in solar PV panels was cheaper in recent years, it helped farmers to mount small non-residential solar PV projects as a package on their farm easily. Unit price of solar PV panel dropped significantly when farmers ordered their second solar projects of Case A and Case B. As PHOTOGRAPH 4-1 showed, the second solar PV project capacity (38Kw) is by 4 times higher than the first project (10kW), but the price was 48 thousand GBP (38Kw) instead of 4 times of 20 thousand pounds (10Kw). However, the annual benefit of second solar PV projects was not as high as the first project due to the contract with power company.

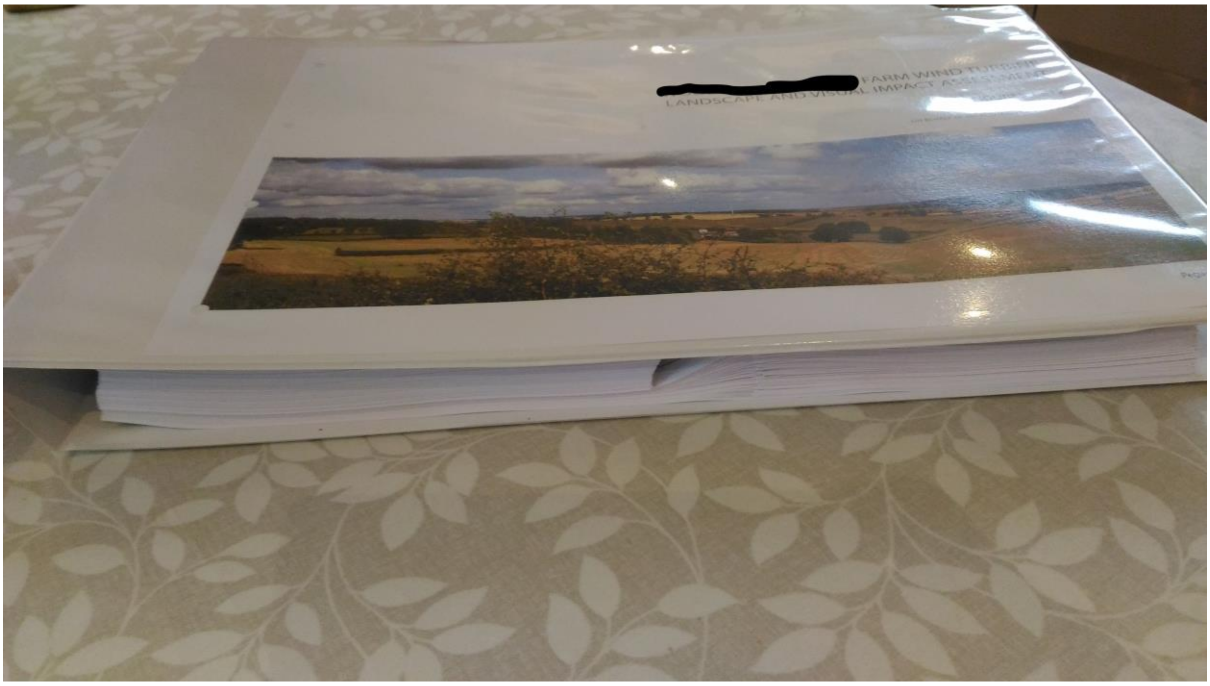


PHOTOGRAPH 4-1. Farmer's hand writing of his cost and annual benefit of two on-roof solar PV projects of Case A.

Family members are main supporter or financial source to help farmers to invest in renewable energy projects (Case A), banks also offered their service to farmers (Case B). If the project is utility-scale, farmer could be a partner of renewable energy project and rented their land to receive benefit without paying any other capital cost as Case C. If RE project is small with affordable price, farmers invested it by their own saving or borrow the loan with collateral from a bank to invest (Case A & B), as farmer of Case A said: "My wife had the money to invest, it wasn't borrowed, personal finance". If farmers needed to borrow a loan from the bank to invest bigger on-farm renewable energy, the farmland is taken as collateral although the land value was much higher than the loan as Case B. The land value of Case B was higher than X millions, but farmers just lend half million pounds for wind turbine. It is another cost that farmer had to afford. However, if farmer just rent land to investor to develop solar farm, farmers didn't need to pay the financial cost like Case C.

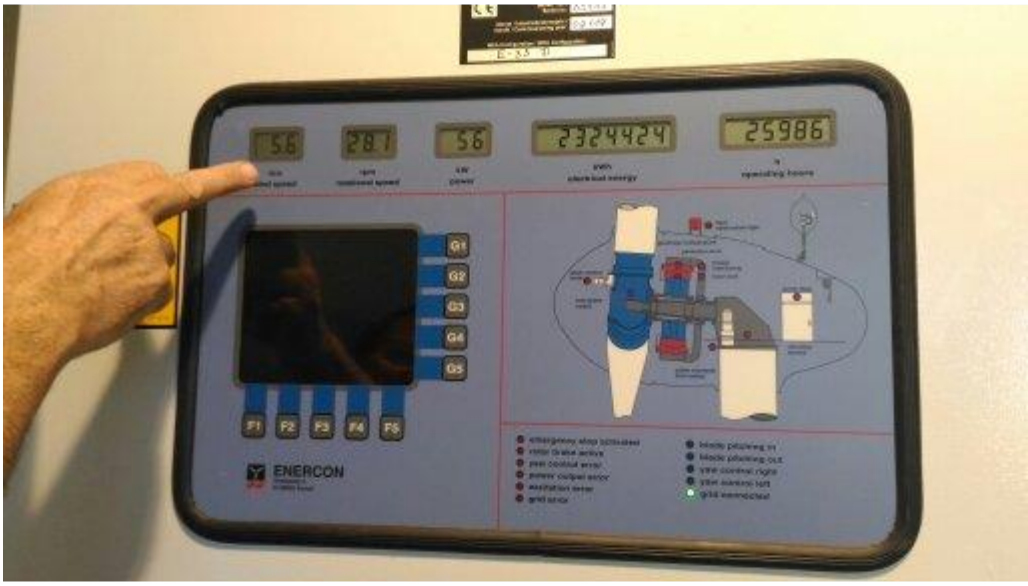
4.2.2 Planning and maintaining costs

Farmers could easily find RE designers, contractors or consultants at agricultural shows, but their guarantee of solar panels were not firm and there was no guarantee if their consultant company was broken (Case B). In fact, as the renewable energy was developed in recent years in England, farmers complained the quality of consultant even they felt consultant was not professional and farmers can solve problem faster than consultant. But the planning cost of wind turbine is high as many survey and assessments must be finished before applying permission (see PHOTOGRAPH 4-2, it is only one of assessments). The planning cost of solar project was combined in total cost (Case A &B), wind turbine planning cost is about 1/7 of wind turbine price (Case B).



PHOTOGRAPH 4-2. Size of thick landscape and visual impact assessment of wind turbine project planning of Case B put on the dining table.

Maintenance fee was necessary and paid to contractor to keep the wind turbine projects on working every day and night (Case B). But, the solar PV projects were easier to maintain by farmers themselves with almost zero maintenance fee as it was the combination of simple power meter, panels and transformer. The maintenance cost of wind project was high and its guarantee was longer because of the manufacture was big, international company, manufactures preferred to offer long-term maintenance contracts with farmer (Case B) (see PHOTOGRAPH 4-3). The maintenance contract period is 15 years long. However, farmers did not hire any extra labour to keep solar and wind projects.



PHOTOGRAPH 4-3. Wind turbine project of Case B is remote monitored and maintained by the manufacture for 15 years.

PHOTOGRAPH 4-4. Solar project of Case A was controlled by simple power meters and switches.

4.2.3 Costs of agriculture affected by projects

Many people concerned renewable energy projects always affects food production, all farmers proofed RE projects didn't affect their agricultural production due to the limited area on marginal farmland, agricultural building roof or small foundation area for wind turbine. The foundation area of wind turbine of Case B is only 0.2 hectare.

PHOTOGRAPH 4-5. Solar PV project of Case B is mounted on building roof, instead of farmland.

4.2.4 Regulatory costs

It was easy to receive solar project permission due to simpler processes in days (Case A & B). However, it was difficult to find a real professional consultant of wind turbine and to apply its permission in all cases (Case B). Every wind turbine and its planning were very expensive and farmers must have finished every planning and survey before apply permission of wind turbine (all 3 cases). Farmers of Case A spent time and money to apply the permission of wind turbine but they didn't receive it yet. Farmer of Case C and investor spent time to communicate with community but the government decided not to offer the permission even 3 huge wind turbines were mounted by the solar farm of Case C.

4.2.5 Retire and remove cost

How to remove retired small RE projects after 2~3 decades were not sure in this study, except the remove of 5MW solar farm (Case C) was detailed in the contract between farmer and investor. Farmers of Case A & B had no idea of how to remove the retired on-farm renewable energy projects.

4.3 Benefits of on-farm renewable energy

About benefit, it is another decisive factor of why on-farm RE projects were invested by farmers. 'Feed in Tariff' policy is the carrot to attract on-farm RE investment if the project capacity is under 5MW in UK. Small scale RE project like Case A, benefit is not as good as larger RE projects, but payback period is estimated to be about 13 years (see PHOTOGRAPH 4-1). The benefit of Case C is the land rent for solar farm, but the benefit of farmer was 8 times higher than agriculture on the same land. The benefit of Case B was high as the combination of wind and solar project. The onshore wind power was more profitable than the solar PV project as longer working hours and higher capacity.

Majority of power generated by on-farm RE projects was exported to national grid in this study. In UK, farmer can easily make a contract with the power company to sell power generated by on-farm renewable energy projects due to third party, brokers or agents will help farmers to match deals with negotiation (Case B) or the outside investor they will solve it by themselves (Case C).

Agricultural income was low and payment from government was expected to be reduced in the future, although agriculture was major concern of all farmers of 3 cases, farmers agreed RE projects create new, long-term and considerable 'high' return income to reduce their bill and "to plan and invest in the farm far more easily" by the benefit of RE projects.

Meanwhile, all farmers felt they were contributing to ease the climate change and protecting environment, wildlife ecology and future of next generation as their non-financial benefit. No other benefits were mentioned in all 3 cases.

4.4 Constraints of on-farm renewable energy

Despite all farmers were satisfied with their solar projects due to fewer regulatory constraints they had faced, they all complained the regulatory constraints of wind turbines. They grumbled council government due to unable to receive permission of wind turbine, they criticized "the government will suggest we go one way or we go that way and then they'll suggest we go another way" (Case A), or they thought government did not make decision because of objections (Case A), farmers were hanged on their plans (Case B), or farmer felt it was not fair that his neighbor received permission but his application was rejected (Case C). Farmers strongly doubted why permissions of wind turbine were rejected although every necessary survey had passed.

However, the financial constraints were not the main barrier to farmers' RE involvement. All cases showed attitude of farmers' families are positive to renewable energy projects even family members were main supporters or financial source to help farmers to invest in RE projects.

The objections from minority of community was the biggest barrier to farmers to invest their wind turbine projects, due to the application would be hanged on by the council government. Minority people who objected wind turbine collected as many signs as they can to block plans (Case A & B), they even had lawsuits with local government (not farmer) for years. It was interesting as the author could not see any other neighbour's house when the author visited farmers, these on-farm renewable energy projects were isolated. The author argued "Is backyard wide as far as the eye can see?". This community constrains also created more lost due to the extra transaction cost of different planning, lawsuits at courts and repeated applications. On the other hand, the solar PV panels generated power on the agricultural buildings' roof or ground of farmers' personal owned property (marginal land) were limited visibility. Farmers could own their solar project or rent personal marginal land to outside solar investor.

PHOTOGRAPH 4-6. Bird view point of Case B, there is not any neighbor's house that author could see on the hill.

PHOTOGRAPH 4-7. View of Case A, there is not any neighbor's house that author could see on the farm.

Technical constraints were also not bans to farmers, in fact, RE technology is simple to use and to understand by farmers (Case B). Market constraints were also not major obstacles to farmers in this study, however, in the future, the national grid might be full at different region and time due to tension, competition over RE development to connect to grid.

4.5 Drivers of on-farm renewable energy

Vulnerable agricultural business is a business-related driver to farmers to develop their RE project, due to changeable weather, worsen climate change, cheaper food price and uncertainty of future government payment. Vulnerable agricultural business and generous 'Feed in Tariff' policy were "Push And Pull" factors to farmers to " invest in the one that gives us the biggest return (Case B)" for their future. All farmers in this study acknowledged RE project is a long-term diversification and they thought everything of their farms further than politicians.

Meanwhile, it was wetter and warmer in England; farm land was washed away as strong soil erosion that they have never met before (Case B). Fossil fuel burning was a main reason of global climate change, farmers have strong wish to generate green energy and they mentioned "don't shut the door when the horse is gone" (Case C). Farmers all concerned the future of agriculture and they believed "the future relies on what we do now", "People are not going to be here forever (Case C)". However, they would prefer to withdraw renewable energy project investments if the support from government was not stable, sufficient and the community objections are not persuadable (Case B).

4.6 Chapter summary

All farmers of this study owned strong intention to develop their on-farm RE projects, however they all faced the same constraint from local community objections of their wind projects. Diversification is their main purpose to help them keep on agriculture, their core business. With back of generous 'Feed in Tariff', farmers' on-farm RE projects generated stable income or reduced bill cost, but also benefited the environment for public. Farmers believed the theory of global climate change and face the same problem of low agricultural benefit, even they thought fewer payment from government is possible due to political uncertainty (like Brexit). When they guided the author on site visit, farmers talked about they transferred their conventional agricultural products to organic beef and organic soft fruit, or they adopted rotation system to fertilize arable land with reduced fossil-fertilizer use and they planted more hedges to reduce soil erosion. They even keep beehives on solar farm to enhance pollination for agriculture (see PHOTOGRAPH 4-8, 4-9). All farmers kept on trying to maximize their benefit and minimizing their agricultural cost. With sustainable development ideas, farmers kept their farms well when author visited. Different wild flowers, like poppy or thistle, grew among wheat or oilseed rape plants, pheasants, quails and skylarks flew high suddenly from dense grass under solar PV panels when the author walked by, hares leaped or sat by the agricultural unpaved road when a vehicle passed (see PHOTOGRAPH 4-10). The on-farm renewable energy projects not only coexisted with agriculture production, it also benefited the natural environment.

PHOTOGRAPH 4-8. Bee hives were kept on solar farm of Case C, vegetation beneath solar PV panels was a food source of bees.

PHOTOGRAPH 4-9. Bee hives warning sign hanged on fence of solar farm of Case C

PHOTOGRAPH 4-10. Wild flowers blossomed and bird hide by the solar farm of Case C

Chapter Five: Discussion

In this chapter, the author discussed what had learnt from all cases in England and try to suggest proper on-farm renewable energy projects for Taiwan.

5.1 Overview of Cases in England

It is interesting that council government is grumbled by all farmers due to the attitude and permission release of renewable energy, although the goal of 20% of the EU's gross energy consumption set to be generated by renewable energy sources by 2020 (EU, 2009). All cases received the permission of solar PV projects, but they also faced problems to receive wind turbine permission from council government. If the solar project was on a building's roof which area was smaller than roof or all surveys of earth mounted PV project were passed, there was no obstacle to receive permission from government.

5.1.1 Costs of on-farm renewable energy

Price of solar PV panels dropped in recent years, it is easier to farmers to invest on solar project, Case A & B both indicated that much cheaper unit price of PV panels was offered by suppliers when they ordered their second solar projects. It was a testimony of Swanson's Law (Swanson, 2006). But, it was studied PV panels recycle is negative, troublesome without appropriate policies to support and the responsibility of recycle belongs to the entire energy industry (Mcdonald & Pearce, 2010). Although EU required all producers offering PV panels to European market to finance the recycling costs of 'end-to-life PV panels' from 2012, based on the "extended-producer responsibility principle" (IRENA, 2016, EU, 2012), the real situation will be tested in 20 years later instead of this moment.

The utility-scale solar farm cost in this study was high in 2011, the levelized cost of energy (LCOE) of solar power without subsidy was expected to keep on dropping, LCOE per kWh of utility-scale solar farm in East Midlands was estimated to decrease to 0.09 GBP in 2015, 0.07

pound in 2020 and 0.06 pound in 2025, LCOE of commercial roof solar project and LCOE of solar project on residential roof both were assumed to decline (Reid and Wynn, 2015). Wind turbine produced more power to grid with lower LCOE in recent years, its LCOE is predicted to by 80 USD/MWh in the last year of 2010s (Kumar et al., 2016). The LCOE of solar was expected to be equal, even lower in next decade. In 2015, the "Average disclosed capex (capital expenditure) in 58 Climatescope countries ($m/MW)" of solar PV is 2.15, just a little higher than onshore wind power which figure is 2.02 (Climatescope, 2016). In the future, solar PV project might be most competitive project.

5.1.2 Benefits of on-farm renewable energy

Notably, every farmer complained wind project permissions and no one emphasised their benefit of solar PV projects. In this study, wind turbine was difficult to develop although it was a profitable on-farm renewable energy project, solar project was an easy, quiet, feasible "second best", but most farmers were not really interested in it when they share ideas to the author. Farmers preferred to maximize financial benefits when they uptook renewable energy projects, even farmers "expressed their commitment to sustainability" (Firbank, et al., 2013). Farmers' benefit of agriculture is relatively low and it is proofed that farmers' environmental awareness like changes of planting hedges or organic farming have few or zero economic benefits (van Vliet et al., 2015). The study of agri-environmnet diversification (AED) also indicated that farmer with environmental awareness participated environmental agricultural may lead to renewable energy production as the author found in all 3 cases (Sutherland, et al., 2016).

It was confirmed by farmers of Case B that wind project generated by double benefit more than solar project within the same capacity in last few years. Generally, a wind turbine annual capacity factor in UK is about 25% to 40%, only about 10% for solar PV panels due to the weather in UK is cloudy (Boyle, 2012). The average load factor of wind turbine is about more than 2 times higher than solar PV panels in UK (Staffell & Green, 2014, Reid and Wynn, 2015).

5.1.3 Constraints of on-farm renewable energy

'Not in my back yard' or 'NIMBY' is an abstract idea and how big is 'back yard' is doubted (Jones & Eiser, 2010). Farmers doubted community objections might be major barriers to delay the permissions of wind RE project from government. It is studied the strong connection existed among investor of turbine, support of local citizens and a "smooth administrative handling projects" by local government for positive effects of wind power, local government also need "forward admission process" and "balance all interests involved" simultaneously (Sperling, Hvelplund & Mathiesen, 2010). Only about half or less than half applications of onshore wind turbine projects in UK will be accepted although the wind turbine gearbox was mounted on relatively 'low' attitude (like Case B) for less objections of visibility (Sturge, While & Howell, 2014, Mason, 2015).

5.1.4 Drivers of on-farm renewable energy

Vulnerable agriculture is confirmed as the main driver to push on-farm renewable energy in this study. The agriculture in the East Midlands was not a profitable business. During the period of 2011 to 2015, East Midlands total agricultural income decreased over 400 million pounds, about 29%, the decrease for whole England was only 24%. However, over 1/5 of wheat, more than a quarter of oilseed rape, almost 1/3 of field grown vegetable and by 1/4 of sugar beet of total growing area of England are occupied in the East Midlands (DEFRA, 2017). Diversification were needed by farmers.

5.2 What is Taiwan able to learn from the British experience

In UK, backed by Feed in Tariff policy, farmers could keep on agriculture business by the combination of on-farm renewable energy and conventional farming. By the on-farm renewable energy projects, UK farmers took a profitable diversification, improved rural development and played the roles of food producer and clean energy generator with new sources of conflict (Holstead, Galán-Díaz and Sutherland, 2017). Although the financial benefit by solar project was less than wind project, it may be changed in recent years because of advanced technology and the increased efficiency of whole solar value chain (Swanson, 2006, Reid & Wynn, 2015). It was found farmers relied on the diversification of on-farm renewable energy projects for their long-term agricultural planning in this study (case B & C). When Taiwan farmers imply for on-farm renewable energy project, which projects are available and energy generation can coexist with food production? How on-farm renewable energy projects in Taiwan can generate power on limited arable land area? The author argued there is an opportunity for solar project with innovation ideas to develop in Taiwan, instead of onshore wind and biomass. Three programs of solar project, 'Agrivoltaic system', 'Diversify surplus rice field' and 'Floating Solar Photovoltaic project', may be proper solutions for future on-farm renewable energy development in next years.

5.3 Wind project or solar project in Taiwan?

Western coast of Taiwan is one of the best global locations for offshore wind (WEC, 2016). But onshore wind is not offshore wind, strong community NIMBY-ism also existed in Taiwan due to high population density and fear of pollution, compensation and negotiation were needed to solve different environmental impact cases in Taiwan (Chiou, Lee and Fung, 2011). Onshore wind energy is limited because of only 7.47% of total wind power resource is forecasted above Taiwan land (Chen and Lee, 2014). Average land area owned by smallholder in Taiwan is small, it is impossible that turbine blade only rotated on single farmer's own land but wind turbine with larger rotor was more efficient and lower cost of per kilowatt-hour (Ani, Polinder and Ferreira, 2013). To avoid future conflicts, the regulations of energy co-operatives may be adopted that Denmark wind project developer must offer more than 20% of ownership to community people who lived in certain distance (R≦4.5KM) to buy shares (Sperling, Hvelplund & Mathiesen, 2010). On the other hand, Taiwan was ranked as top two of global solar cell supplier (Su, 2013) and the solar energy in Southern Taiwan is about 45 percent higher (see Table 5-1) than in East Midlands, England (World Bank, 2017) because of the latitude of

Southern Taiwan is in the south of the Tropic of Cancer. The solar PV is a mature on-farm renewable energy project to Taiwan.

Table 5-1. Annual PV electricity output in Southern Taiwan and East Midlands (Source: Global Solar Atlas, the World Bank)

Place	Photovoltaic electricity output (PVOUT)	Optimum angle of PV modules
Tainan Highspeed Rail Station, Tainan City, Southern Taiwan	1428 kWh/kWp per year	21 ° / 180 °
Linbian station, Pingtung, Southern Taiwan	1413 kWh/kWp per year	20 ° / 180 °
Southwell, Nottinghamshire, UK	951 kWh/kWp per year	38 ° / 180 °
Skegness station, Lincolnshire, East Midlands, England	1007 kWh/kWp per year	38 ° / 180 °
Madrid, Madrid, Spain	1627 kWh/kWp per year	34 ° / 180 °
Sydney, Australia	1465 kWh/kWp per year	32 ° / 0 °

5.4 Limit of Biomass/Biofuel project in Taiwan

By introducing support policies for the production and consumption of biofuels, the agricultural sector can diversify its activities and open access to new markets that are economically viable in the long term (IEA, 2011). However, farmer of Case C was not satisfied with his biomass boiler as too much limits that many outside contractors were needed for short rotation coppice and maintenance. Meanwhile, large area is needed to produce biomass. It was 50 or 150 times larger land are needed for biogas or biodiesel yield if same quantity of power was generated by solar PV panels on unit area in Europe (Poncet, et al., 2012). The Royal Society for the Protection of Birds (RSPB) suggested the greenhouse gas emissions from biomass power is not as people expect, it might make global warming worse if the UK government assumed biomass power is automatically carbon free (RSPB, 2012). It is recommended by the Royal Academy of Engineering (RAE) that only the second-generation biofuels which is made from agricultural waste and residues of forest industry have higher capability, with fewer GHG emission and no risk of land-use change, to be used as renewable energy (RAE, 2017). The area of farm land in Taiwan is small, it is more difficult to develop biomass and biofuel derived from crops, instead of agricultural waste.

5.5 Three suggested solar project programs in Taiwan

In this study, it was found solar PV project is a better choice of on-farm renewable energy development in Taiwan for next decade. Combining food security and energy generation, the author suggested 3 programs of solar PV projects is possible to develop in Taiwan rural area, including 'Agrivoltaic system', 'Diversify surplus rice field' and 'Floating Solar Photovoltaic project'.

5.5.1 Agrivoltaic system

Solar PV energy transformation efficiency is about 5 times higher than the photosynthesis effect of plant (Dupraz et al., 2011), the efficiency of latest commercial solar PV panel is even over 20% (Energysage, 2017). Dupraz argued "Agrivoltaic" is a solution, instead of a competition, to combine agriculture and on-farm renewable energy into an integrated system and the global land productivity may increase over 1/3 to nearly 4/3 if the Agrivoltaic system is efficiently combined with agriculture for countries with limited farmland (Dupraz et al., 2011). The author argued the combination of farming and solar photovoltaic project is a type of "Facultative Mutualism", although the solar photovoltaic panel is man-made device. For example, as global warming, elevated temperature affected most rice growth and yield decreased by one tenth for every 1 Celsius degree increase in growing-season minimum temperature in the dry season (Peng, et al., 2004, Krishnan, et al., 2011). Agrivoltaic system is a shade to protect crops from the extreme feverish temperature.

It was examined that the water losses of lettuce and cucumber through evapotranspiration are reduced and significant water saving of evapotranspiration, 14~29%, under the photovoltaic panels shade. Growing water use of selected vegetable species is more efficient in agrivoltaic systems (Marrou, Dufour & Wery, 2013). On the other hand, under different solar radiation type, the relative lettuce yield at harvest was equal or higher than the lettuce grew with full sunshine radiation because of lettuce adapted to radiation conditions by its compensatory mechanism, the lettuce Radiation Interception Efficiency (RIE) in the PV panels shade was improved although its Radiation Conversion Efficiency (RCE) change is not obvious (Marrou et al., 2013). In the US, only in the lettuce production, it was estimated to over 30% of economic value increase of shade-tolerant crop production under solar power generation system and create over 40 GW renewable energy if vegetable cultivation is converted to agrivoltaic system (Dinesh & Pearce, 2016). In China, not only the positive effects of economy, the diffusion effect of this combination is also concerned due to the new jobs of renewable energy and reduced carbon dioxide emission (Li, et al., 2017).

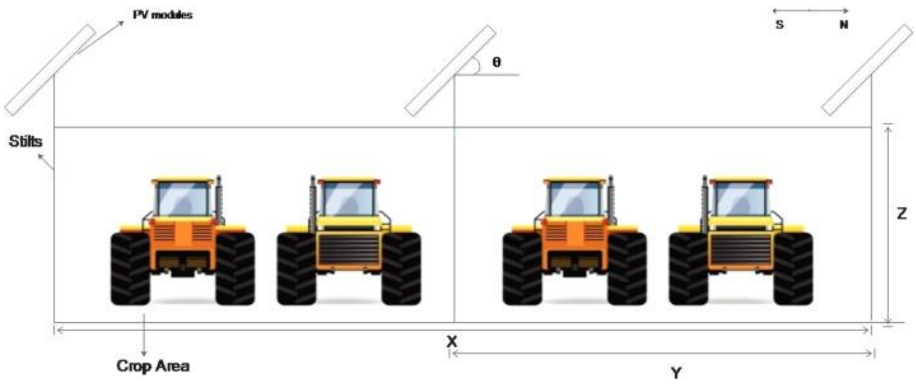


Figure 5-1. Agrivoltaic farm having PV modules mounted on stilts (Source: Dinesh & Pearce, 2016).

However, solar radiation reduction evaluation is required as it changed in different facilities. A small greenhouse (area=960m2) with 50% roof area is covered by solar PV, the annual solar light reduction was almost 2/3 (64%), not only half (Cossu et al., 2014). The checkerboard PV panel arrangement is better in sunlight spatial distribution than straight-line PV arrangement (Fatnassi, et al., 2015). These researches also hint us that greenhouse with

100% photovoltaic cover on roof is not conducive to vegetable, melon and rice production. Further researches of different facilities arrangement and vegetation species are needed.

5.5.2 Diversify surplus rice field

It is expected that Taiwan population will decrease due to the low birth rate in 2018 (FAOstat, 2017). However, the annual rice production in recent years grew significantly because of farmers were encouraged to grow rice by a better 'rice purchasing at guaranteed price' policy, higher price for "public rice", offered by government since the year of 2011 (Yang, 2016). It was expected to reduce about 30,000 ha farmland which were growing rice (Hsu, 2015). However, in recent years total rice production was still high due to the improved price policy and certain purchase quantity with guaranteed price by NT$21~26 (about 0.50 to 0.65 GBP/Kg). The average farm price of rice in the USA was only 10.2~16.3 $/cwt (about 0.20~0.32 $/Kg or 6.06~9.72 NT$/Kg) (USDA, 2017). This 'rice purchasing at guaranteed price' policy is executed since 1974 and its three policy goals of "farmer's income rise" , "national food stock" and "keeping food price stable" have achieved over forty years. Studied by Chen in 2007, over 40% of annual average income of domestic rice farmers is paid by the budget of rice insured acquisition policy (Chen, 2007). Taiwan farmers who do not participate in "rice purchasing by government at guaranteed price" policies undertook the risk of profit losses (Huang, 2012). Due to the policy, it was allowed that farmers just focus on quantity of production without considering rice quality and it resulted to food waste that certain amount of 'public rice' was kept in the warehouses for several years (Yang, 2016). After joining WTO in 2002, Taiwan is the only country still promotes this insured acquisition policy for protecting rice farmers, while Japan shifted to run a direct payment (Matsukura, 2013).

This surplus rice insured acquisition policy is also not positive to environment conservation, due to the overuse of fertility, pesticide to increase weight of rice production instead of rice quality. Overuse of fertilizers is the main source of non-CO2 greenhouse gas, soil microbes on farms may emit unexpectedly elevated levels of nitrous oxide which heat-trapping power is almost three hundred times stronger than carbon dioxide (IPCC, 2007). It is harmful and in violation of UN sustainable development goal, “End hunger, achieve food security and improved nutrition and promote sustainable agriculture” (UN, 2016). However, a popular policy is not easy to be dismissed in a democracy regime although this policy resulted to food waste. Solar farm with soil management on selected rice field will ease the environmental degradation, farmers can receive income from power company instead of government subsidy. It was studied, in Hunei, southern Taiwan, the solar PV investment payback period was only 12 years (Hsueh, 2015). In UK, it takes 2 hectares land for 1MW solar power generation (Scurlock, 2015), the PV output in Taiwan is higher and less farmland is needed. This program is positive for food security and energy security.

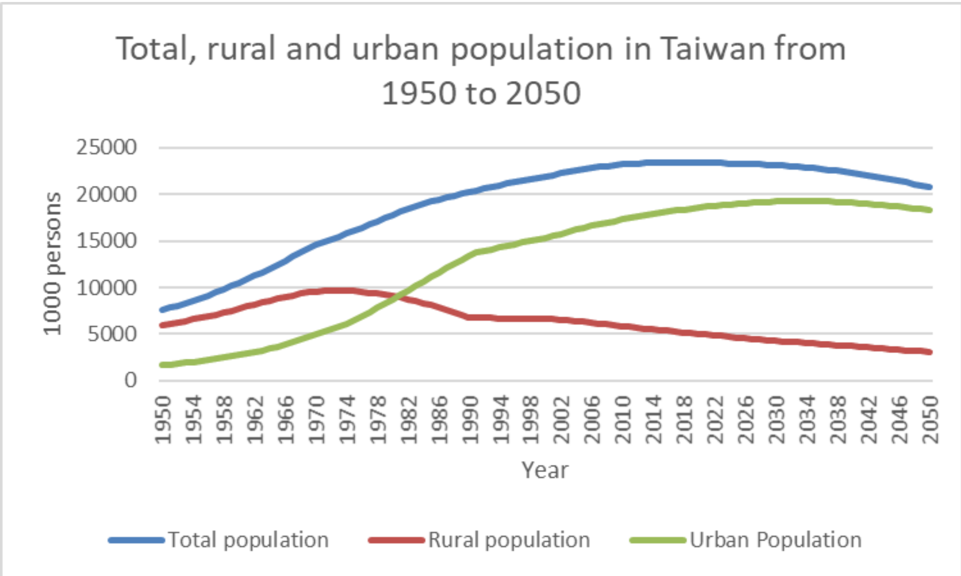


Figure 5-2. Total, rural and urban population in Taiwan from 1950 to 2050 (Source: FAOstat)

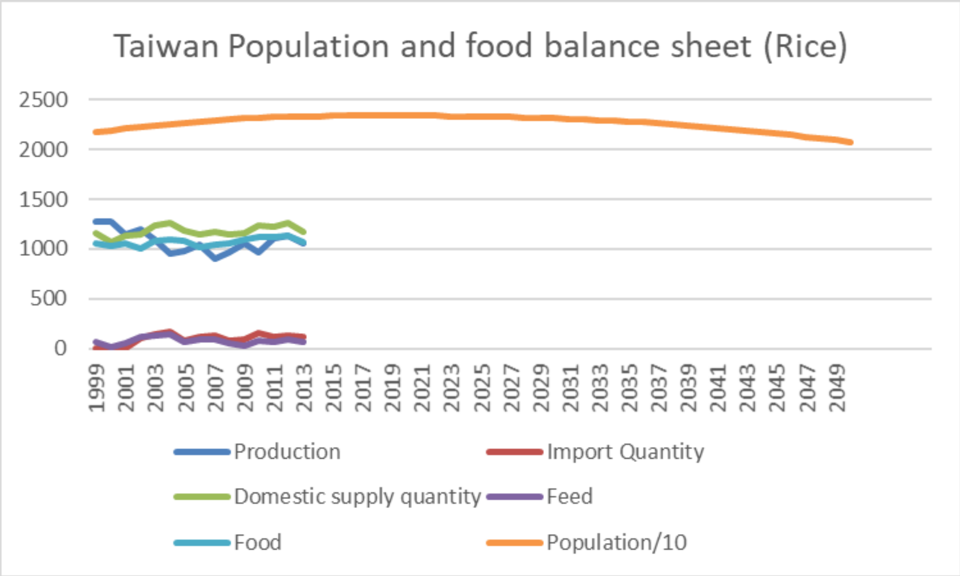


Figure 5-3. Total, rural and urban population and food balance sheet of rice in Taiwan from 2000 to 2050 (Source: FAOstat)

5.5.3 Floating Solar Photovoltaic project

Except rice fields in Taiwan rural area, there are over 40,000 hectares of fish ponds with 68,000 aquaculture farmers located in different plains, especially in the central and southern Taiwan (Fishery Agency, 2017). The aquaculture is vulnerable because of the climate change and frequent weather events. The trend of longer drought duration is obvious, particularly in Southern Taiwan and more strong-rainfall events induced by typhoons and monsoon system are noted from the year of 1950 to 2010 (Chu, Chen & Lin, 2014). Moreover, the frequency of lighter rain shows a decreasing trend, dry days add in the period of 1970 to 2010 (Tu & Chou, 2013). Fatal virus and bacteria exist and grow in the warmer and warmer environment or after the typhoon events (Ho, et al., 2016) There are some extreme frost events also happened in this hot island in recent years. Aquaculture was seriously affected during extreme frost 2008 and 2016, many aquaculture farmers suffered and lost due to unexpected cold (NCDR, 2016, NCDR, 2008, Chang et al., 2013). Aquaculture farmers will rely on more electrical waterwheels to keep the fish and other aquatic products on growing. It also need more water due to higher evaporation in fish ponds. However, if the on-farm renewable energy is available to develop on vast fish ponds, it will help aquaculture farmers reduce their energy bills and diversified their aquaculture business just as crop farmers do.

Floating solar PV project is equipped on the fish ponds, this project even generates over 10% more power than ground or on-roof types because of the higher power generation efficiency enhanced by cooler space between panels and water body (Choi, 2014). In Thailand, it was studied and recommended to equip renewable energy projects for shrimp ponds due to the higher reliability and lower cost (Nookuea, Campana, and Yan, 2016). With effective cover on the water surface by the floating solar Photovoltaic projects, the evaporation was reduced significantly (Tsoutsos, Frantzeskaki and Gekas, 2005). The cost of a floating solar Photovoltaic project with over 25 years life span might be recovered in only 5 years with lower water temperature and algae growth reduction and stable water quality (Sahu, Yadav & Sudhakar, 2016). It also can be used as the windbreaks and covers of the water during the extreme frost days. Combining new industrial material, water-saturated MEPCM and its heat release, water temperature of fish pond equipped with solar PV project could be kept during frost winter (Ho, Chou and Lai, 2014). These concepts of floating solar Photovoltaic project was similar to the experimental project of "Raise Water, Grow Electricity Project" in Pingtung, southern Taiwan, which tried to prevent further land subsidence and revitalized domestic economy with new job opportunities for local farmers who suffered from flood and land salinization after fatal Morakot Typhoon invasion (Lin, 2017, Su, 2014).

Chapter 6: Conclusions

6.1 Key study conclusions

In UK, farmers produced food and on-farm renewable energy for households, although food price is low and regulatory, community constraints obstructed on-farm renewable energy development. British farmers in this study were willing to involve in on-farm renewable energy business with the backing of "Feed in Tariff" policy and their personal belief about keeping agriculture and environment, they diversified their agriculture business, tried to reduce their energy cost and earn reasonable financial income as future proof for their long-term planning of keeping their farms and "farm as though they are going to farm forever". Less, slighter impacts of climate change can be expected as farmers devote to reduce greenhouse gases emission and generate more on-farm renewable energy by their projects for public.

6.2 Lessons for Taiwan

In Taiwan, the renewable energy percentages of Taiwan total power consumption were still low, about 0.6% by wind and 0.5% by solar in 2015, but coal saving and carbon dioxide emission reduction in this year were tremendous, over 930 thousand tonnes and 1.33 million tonnes, respectively, and its effect was equal to 120 thousand hectares of afforestation in Taiwan (Taipower, 2017). Furthermore, solar PV and wind energy were regarded as up-and-coming energy sources due to the superior geographical latitude and "advanced technological acquired in the related industries" in Taiwan (Chen & Lee, 2014).

Taiwan farmers faced challenges of climate change in these decades. How can they cope with the weather and keep on farming for next decades? Diversification of renewable energy is a positive choice to Taiwan farmers as what British farmers did, agrivoltaic system and float solar PV panel projects are alternative options for better food production and power generation. Farmers can keep in financial safety and protect their agricultural or aquaculture productions and poverties. Furthermore, some rice fields can be transferred to solar farm to create better nature environment for pollinators, nectariferous plants and other wildlife, rice farmers can still receive reasonable economic benefit and preserve their arable lands with fertility for the future few decades. Food security and energy security will coexist in Taiwan.

6.3 Study limitations & Recommendation for future studies

It is limited in this study due to only three cases is studied, the author tried to visit more farmers who involved in on-farm renewable energy projects, most farmers refused to offer their experience. One of the difficulties is the question about benefit of on-farm renewable energy although farmers' names in this research were anonymous, it seemed rude to ask this question by an international student. But, the vis-à-vis interview to observe and interview are necessary to plot a picture of on-farm renewable energy project development in England. This study should be kept on researching for years to find more precise information for policy making.

Except regulatory constraint, farmers of this study faced the limit of power export from projects to grid although they wished to maximize their on-farm renewable energy benefit. The "well-planned, priority grid access" for renewable power that adopted in Germany and "anticipatory transmission planning" are needed in next few years (Sutherland & Holstead, 2014, Anaya & Pollitt, 2015, Alagappan, Orans & Woo, 2011) if any government wish to promote on-farm renewable energy projects.

References

Ahadi, A., Kang, S. and Lee, J., 2016. A novel approach for optimal combinations of wind, PV, and energy storage system in diesel- free isolated communities. Applied Energy, 170, 101-115.

Alagappan, L., Orans, R. and Woo, C.K., 2011. What drives renewable energy development? Energy Policy, 39 (9), 5099-5104.

Anaya, K.L., and Pollitt, M.G., 2015. Integrating distributed generation: Regulation and trends in three leading countries. Energy Policy, 85, 475-486.
Andres, R.J., Boden, T.A., F.-M. Bréon, Ciais, P., Davis, S., Erickson, D., Gregg, J.S., Jacobson, A., Marland, G., Miller, J., Oda, T., Olivier, J.G.J., Raupach, M.R., Rayner, P. and Treanton, K., 2012. A synthesis of carbon dioxide emissions from fossil- fuel combustion. Biogeosciences, 9 (5), 1845-1871.

Angelopoulos, D., Doukas, H., Psarras, J. and Stamtsis, G., 2017. Risk-based analysis and policy implications for renewable energy investments in Greece. Energy Policy, 105, 512-523.

Ani, S.O., Polinder, H. and Ferreira, J.A., 2013. Comparison of Energy Yield of Small Wind Turbines in Low Wind Speed Areas. Sustainable Energy, IEEE Transactions on, 4 (1), 42-49.

ASC, 2016. UK Climate Change Risk Assessment 2017 Evidence Report – Summary for England [online]. London: Committee on Climate Change. Available at: https://www.theccc.org.uk/tackling-climate-change/preparing-for-climate-change/uk-climate-change-risk-assessment-2017/national-summaries/england/. [Accessed 30 July 2017].

Bailey, A., Davidova, S., Hotopp, U., 2017. AGRICULTURE IN THE UK [online]. London: National Institute of Economic and Social Research. Available at: http://www.niesr.ac.uk/sites/default/files/publications/NIESR%20GE%20Briefing%20Paper%20No.%204%20-%20Agriculture%20in%20the%20UK_0.pdf, [Accessed 14 July 2017]

Bayer, P., and Urpelainen, J., 2016. It Is All about Political Incentives: Democracy and the Renewable Feed-in Tariff. The Journal of Politics, 78 (2), 603-619.

Beaumont, J., 2009. Portrait of the East Midlands [online]. Cardiff, UK: Office for National Statistics. Available at: https://www.ons.gov.uk/ons/rel/regional-trends/regional-trends/no--41--2009-edition/portrait-of-the-east-midlands.pdf [Accessed 17 August 2017]

Bilgili, M., Ozbek, A., Sahin, B. and Kahraman, A., 2015. An overview of renewable electric power capacity and progress in new technologies in the world. Renewable and Sustainable Energy Reviews, 49, 323-334.

Boie, I., Fernandes, C., Frías, P. and Klobasa, M., 2014. Efficient strategies for the integration of renewable energy into future energy infrastructures in Europe – An analysis based on transnational modeling and case studies for nine European regions. Energy Policy, 67, 170-185.

Boyle, G., 2012. Appendix B, Renewable energy: power for a sustainable future. 3rd ed. ed. Oxford: Oxford: Oxford University Press.

Boyle, G., Everett, B., Alexander, G., 2012. Chapter 1, Renewable energy: power for a sustainable future. 3rd ed. ed. Oxford: Oxford: Oxford University Press.

Boyle, G., 2012. Chapter 3, Renewable energy: power for a sustainable future. 3rd ed. Oxford: Oxford University Press.

Burgess, P.J., Rivas Casado, M., Gavu, J., Mead, A., Cockerill, T., Lord, R., van, D.H. and Howard, D.C., 2011. A framework for reviewing the trade- offs between, renewable energy, food, feed and wood production at a local level. Renewable and Sustainable Energy Reviews, 16 (2012) 129–142.
Bayer, P. & Urpelainen, J., 2016. It Is All about Political Incentives: Democracy and the Renewable Feed-in Tariff. The Journal of Politics, 78(2), pp.603–619.

Burney, J.A., Davis, S.J. & Lobell, D.B., 2010. Greenhouse gas mitigation by agricultural intensification. Proceedings of the National Academy of Sciences of the United States of America, 107(26), pp.12052–7.

Burningham, K., Barnett, J. & Walker, G., 2015. An Array of Deficits: Unpacking NIMBY Discourses in Wind Energy Developers' Conceptualizations of Their Local Opponents. Society & Natural Resources, 28(3), pp.246–260.

Chang, Y., Lee, M., Lee, K. and Shao, K., 2013. Adaptation of fisheries and mariculture management to extreme oceanic environmental changes and climate variability in Taiwan. Marine Policy, 38, 476-482.

Chen, H.H., and Lee, A.H.I., 2014. Comprehensive overview of renewable energy development in Taiwan. Renewable and Sustainable Energy Reviews, 37, 215-228.

Chen, Y., 2007. The Adjustment of Taiwan’s Rice Policy: An Economic Analysis, http://handle.ncl.edu.tw/11296/ndltd/81663852650192276713

Cherp & Jewell, 2014. The concept of energy security: Beyond the four As. Energy Policy, 75, pp.415–421.

Childs, N., 2017. Rice Outlook- U.S. 2017/18 Rice Production Projected at 201.0 Million Cwt [online]. Washington DC: USDA. Available at: https://www.ers.usda.gov/webdocs/publications/83523/rcs-17e.pdf?v=0 [Accessed 1 August 2017].

China Post, 2016. Tsai's policy chief draws big picture at forum for photovoltaic business. China Post [online]. 24 Feruary 2016. http://www.chinapost.com.tw/print/459064.htm, [Accessed 13 July 2017]

Chiou, C., Lee, J. and Fung, T., 2011. Negotiated Compensation for NIMBY Facilities: Siting of Incinerators in Taiwan. Asian Geographer, 28 (2), 105-121.

Choi, Y.-., 2014. A study on power generation analysis of floating PV system considering environmental impact. International Journal of Software Engineering and its Applications, 8 (1), 75-84.

Chu, P., Chen, D. & Lin, P., 2014. Trends in precipitation extremes during the typhoon season in Taiwan over the last 60 years. ATMOSPHERIC SCIENCE LETTERS, 15, pp.37–43.

CLIMATESCOPE, 2016. KEY FINDINGS [online]. Bloomberg New Energy Finance. Available at: http://global-climatescope.org/en/summary/. [Accessed 26 August 2017]

COA, 2016. Council of Agriculture, Related Statistic Information [online]. Taipei, Taiwan: COA. Available at: http://eng.coa.gov.tw/ws.php?id=2505315, [Accessed 13 July 2017]

COA, 2016. Results of the survey of the main farm in 2015, 104 年主力農家所得調查結果, Agriculture policy and review 農政與農情, October 2016, 105 年 10 月(第 292 期). Taipei, Taiwan: COA. http://www.coa.gov.tw/ws.php?id=2505701, [Accessed 14 July 2017]

Cossu, M., Murgia, L., Ledda, L., Deligios, P.A., Sirigu, A., Chessa, F. and Pazzona, A., 2014. Solar radiation distribution inside a greenhouse with south-oriented photovoltaic roofs and effects on crop productivity. Applied Energy, 133, pp.89–100.

DCLG, 2015. Guidance: Renewable and low carbon energy [online]. London: Department for Communities and Local Government. Available at: https://www.gov.uk/guidance/renewable-and-low-carbon-energy#solar-farms. [Accessed 17 August 2017]

DEFRA, 2012. Diversification and Renewable Energy Production on Farms in England 2010 [online]. London: DEFRA. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226310/structure-diversification2010-02aug13.pdf. [Accessed 13 July 2017]

DEFRA, 2013. Sustainable Land and Soils and Sustainable and Competitive Farming Strategy: Joint Evidence Plan [online]. London: DEFRA. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/221058/pb13928-evidenceplan-land-soils-farming-strategy.pdf, [Accessed 14 July 2017]

DEFRA, 2014. UK food production to supply ratio (commonly referred to as the "self-sufficiency" ratio) [online]. London: DEFRA. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/316223/trade-selfsuff-02jun14.xls, [Accessed 14 July 2017]

DEFRA, 2016. Farm Business Income by type of farm in England, 2015/16 [online]. London: DEFRA. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/562946/fbs-businessincome-statsnotice-27oct16.pdf. [Accessed 13 July 2017]

DEFRA, 2016. Farm Business Income by type of farm in England, 2015/16 [online]. London: DEFRA. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/562946/fbs-businessincome-statsnotice-27oct16.pdf, [Accessed 14 July 2017].

DEFRA, 2017. Defra Statistics: Agricultural Facts England Regional [online]. York, UK: Farming Statistics, Department for Environment, Food and Rural Affairs. Available at: Profileshttps://www.gov.uk/government/uploads/system/uploads/attachment_data/file/583682/regionalstatistics_overview_170117.pdf. [Accessed 17 August 2017]

DEFRA, 2017. Farming Statistics – provisional arable crop areas at 1 June 2017 England [online]. London: DEFRA. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/638223/structure-jun2017provcrops-eng-17aug17.pdf. [Accessed 17 August 2017]

DEFRA, 2017. Total Income from Farming in the United Kingdom, First estimate for 2016 [online]. London: Defra. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/615850/agriaccounts-tiffstatsnotice-25may17.pdf. [Accessed 30 July 2017].

DESA, 2017. World Population Prospects: The 2017 Revision, Key Findings and Advance Tables [online]. New York: The Department of Economic and Social Affairs of the United Nations Secretariat. Available at: https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf. [Accessed 17 August 2017]

Diffenbaugh, N., Singh, D., Mankin, J., Horton, D., Swain, D., Touma, D., Charland, A., Liu, Y., Haugen, M., Tsiang, M. and Rajaratnam, B., 2017. Quantifying the influence of global warming on unprecedented extreme climate events. Proceedings of the National Academy of Sciences of the United States of America, 114 (19), 4881.

Dinesh & Pearce, 2016. The potential of agrivoltaic systems. Renewable and Sustainable Energy Reviews, 54, pp.299–308.

Dinu, M., 2013. The main objectives of the EU rural development policy for 2014-2020. Bucharest: Faculty of Agro - Food and Environmental Economics - Bucharest University of Economic Studies.

Dupraz, C., Marrou, H., Talbot, G., Dufour, L., Nogier, A. and Ferard, Y., 2011. Combining solar photovoltaic panels and food crops for optimising land use: Towards new agrivoltaic schemes. Renewable Energy, 36 (10), 2725-2732.

Dupraz, C., Marrou, H., Talbot, G., Dufour, L., Nogier, A. and Ferard, Y., 2011. Combining solar photovoltaic panels and food crops for optimising land use: Towards new agrivoltaic schemes. Renewable Energy, 36(10), pp.2725–2732.

Energy saving trust, 2017. Feed-in Tariffs [online]. London: Energy saving trust. Available at: http://www.energysavingtrust.org.uk/renewable-energy/electricity/solar-panels/feed-tariffs. [Accessed 8 August 2017]

Energysage, 2017. What are the most efficient solar panels on the market? [online]. USA: Energysage. Available at: http://news.energysage.com/what-are-the-most-efficient-solar-panels-on-the-market/, [Accessed 14 July 2017]

EU, 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [online]. Brussels: European Union. Available at: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0028 [Accessed 28 August 2017]

EU, 2012. Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) [online]. Brussels: EU. Available at: http://eur-lex.europa.eu/eli/dir/2012/19/oj. [Accessed 25 August 2017]

Europe Commission, 2010. Europe 2020 strategy [online]. Brussels: EU. Available at: https://ec.europa.eu/info/strategy/european-semester/framework/europe-2020-strategy_en#thestrategysetouttargetsinthe5followingfields. [Accessed 16 July 2017]

Europe Commission, 2013. Overview of CAP Reform 2014-2020 [online]. Brussels: EU. Available at: https://ec.europa.eu/agriculture/sites/agriculture/files/policy-perspectives/policy-briefs/05_en.pdf. [Accessed 16 July 2017].

European Commission, 2017. Factsheet on 2014-2020 Rural Development Programme of England (United Kingdom) [online]. Brussels: EU. Available at: https://ec.europa.eu/agriculture/sites/agriculture/files/rural-development-2014-2020/country-files/uk/factsheet-england_en.pdf, [Accessed 17 July 2017].

Everett, B., 2012. Chapter 2, Renewable energy: power for a sustainable future. 3rd ed. ed. Oxford: Oxford: Oxford University Press.

Fan, M., Shen, J., Yuan, L., Jiang, R., Chen, X., Davies, W.J. and Zhang, F., 2012. Improving crop productivity and resource use efficiency to ensure food security and environmental quality in China. Journal of Experimental Botany, 63 (1), 13-24.

FAO, 2006. Policy Brief- Food Security [online]. Rome: FAO, Available at: http://www.fao.org/forestry/13128-0e6f36f27e0091055bec28ebe830f46b3.pdf. [Accessed 17 July 2017].

FAO, 2009. How to Feed the World in 2050 [online]. Rome: FAO, Available at: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf. [Accessed 17 August 2017]

FAOSTAT, 2017. Annual population [online]. Rome: FAO, Available at: http://www.fao.org/faostat/en/#data/OA [Accessed 22 July 2017]

FAOSTAT, 2017. Food Balance Sheets [online]. Rome: FAO, Available at: http://www.fao.org/faostat/en/#data/FBS [Accessed 22 July 2017]

FARMERS WEEKLY, 2013. Survey shows great potential for on-farm renewables [online]. Surrey: FARMERS WEEKLY. Available at: http://www.fwi.co.uk/business/survey-shows-great-potential-for-on-farm-renewables.htm, [Accessed 14 July 2017]

Fatnassi, H., Poncet, C., Bazzano, M.M., Brun, R. and Bertin, N., 2015. A numerical simulation of the photovoltaic greenhouse microclimate. Solar Energy, 120, p.575.

Firbank, L.G., Elliott, J., Drake, B., Cao, Y. and Gooday, R., 2013. Evidence of sustainable intensification among British farms. Agriculture, Ecosystems and Environment, 173, 58-65.

Fishery Agency, 2017. Fishery Statistics Annual Report 2015 漁業統計年報 2015 [online]. Kaohsiung Taiwan: Fishery Agency. Available at: https://www.fa.gov.tw/cht/PublicationsFishYear/. [Accessed 22 June 2017]

Foxon, T.J., Gross, R., Chase, A., Howes, J., Arnall, A. and Anderson, D., 2005. UK innovation systems for new and renewable energy technologies: drivers, barriers and systems failures. Energy Policy, 33 (16), 2123-2137.

Frantál & Prousek, 2016. It's not right, but we do it. Exploring why and how Czech farmers become renewable energy producers. Biomass and Bioenergy, 87, pp.26–34.

Frantál, B., and Prousek, A., 2016. It's not right, but we do it. Exploring why and how Czech farmers become renewable energy producers. Biomass and Bioenergy, 87, 26-34.

Frantál, B., and Prousek, A., 2016. It's not right, but we do it. Exploring why and how Czech farmers become renewable energy producers. Biomass and Bioenergy, 87, 26-34.

Garnett, T., 2011. Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? Food Policy, 36, S23-S32.

Henn, M., 2009. A critical introduction to social research. 2nd ed. ed. London: London: SAGE.

Hernandez, R.R., Easter, S.B., Murphy-Mariscal, M., Maestre, F.T., Tavassoli, M., Allen, E.B., Barrows, C.W., Belnap, J., Ochoa-Hueso, R., Ravi, S. and Allen, M.F., 2014. Environmental impacts of utility- scale solar energy. Renewable and Sustainable Energy Reviews, 29, 766-779.

Ho, C., Chen, J., Nobuyuki, Y., Lur, H. and Lu, H., 2016. Mitigating uncertainty and enhancing resilience to climate change in the fisheries sector in Taiwan: Policy implications for food security. Ocean and Coastal Management, 130, 355-372.

Ho, C.J., Chou, W. and Lai, C., 2014. Application of a water- saturated MEPCM- PV for reducing winter chilling damage on aqua farms. Solar Energy, 108, 135-145.

Holstead, K.L., Galán-Díaz, C. and Sutherland, L., 2017. Discourses of on-farm wind energy generation in the UK farming press. Journal of Environmental Policy & Planning, 19(4), pp.391–407.

Hsu, 2015. It is planned to reduce 100 thousand tonnes of rice acquisition at guaranteed price 保價收購將減收 10 萬噸公糧. The Chinatimes, 26 May 2015, Available via: http://www.chinatimes.com/newspapers/20150526000411-260114 [Accessed 1st August 2017].

Hsu, Huang-Hsiung, Chia Chou, Yi-chao Wu, Mong-Ming Lu, Cheng-Ta Chen, Yung-Ming Chen, 2011. Climate Change in Taiwan: Scientific Report 2011 (Summary). National Science Council, Taipei, Taiwan, ROC, 67pp.

Hsueh, S., 2015. Assessing the effectiveness of community-promoted environmental protection policy by using a Delphi-fuzzy method: A case study on solar power and plain afforestation in Taiwan. Renewable and Sustainable Energy Reviews, 49, 1286-1295.

Huang, C., 2012. Impact of Public Grain Purchasing Policies on Unit Profit of Rice Crops 公糧收購政策對稻作單位利潤之影響. M. thesis, Chang Gung University.

IEA, 2011. Renewable Energy: Policy Considerations for Deploying Renewables [online]. Paris: IEA. Available at: https://www.iea.org/publications/freepublications/publication/Renew_Policies.pdf, [Accessed 17 July 2017]

IEA, 2016. Key Renewables Trends Excerpt from: Renewables information [online]. Paris: IEA. Available at: http://www.iea.org/publications/freepublications/publication/KeyRenewablesTrends.pdf [Accessed 17 July 2017]

IEA, n.d. What is energy security? [online]. Paris: IEA. Available at: https://www.iea.org/topics/energysecurity/subtopics/whatisenergysecurity/. [Accessed 29 August 2017]

IPCC, 2007. Climate Change 2007: Working Group I: The Physical Science Basis [online]. Geneva: IPCC. https://www.ipcc.ch/publications_and_data/ar4/wg1/en/tssts-2-1.html [Accessed 26 July 2017]

IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22.

IRENA, 2016. END-OF-LIFE MANAGEMENT Solar Photovoltaic Panels [online]. Abu Dhabi: International Renewable Energy Agency. Available at: http://www.irena.org/DocumentDownloads/Publications/IRENA_IEAPVPS_End-of-Life_Solar_PV_Panels_2016.pdf. [Accessed 25 August 2017]

Jacobson, M.Z., Delucchi, M.A., Bazouin, G., Bauer, Z.A.F., Heavey, C.C., Fisher, E., Morris, S.B., Piekutowski, D.J.Y., Vencill, T.A. and Yeskoo, T.W., 2015. 100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for the 50 United States. Energy & Environmental Science, 8 (7), 2093-2117.

Jones, C. & Eiser, J., 2010. Understanding 'local' opposition to wind development in the UK: How big is a backyard? Energy Policy, 38(6), pp.3106–3117.

Kang, Khan & Ma, 2009. Climate change impacts on crop yield, crop water productivity and food security – A review. Progress in Natural Science, 19(12), pp.1665–1674.

Koh, L.P., and Ghazoul, J., 2008. Biofuels, biodiversity, and people: Understanding the conflicts and finding opportunities. Biological Conservation, 141(10), pp.2450–2460.

Krishnan, P., Ramakrishnan, B., Reddy, K.R. and Reddy, V.R., 2011. High- Temperature Effects on Rice Growth, Yield, and Grain Quality. Advances in Agronomy, 111, 87-206.

Kuehne, G., 2016. Eight Issues to Think About Before Interviewing Farmers. Forum: Qualitative Social Research, 17 (2).

Kumar, Y., Ringenberg, J., Depuru, S., Devabhaktuni, V.K., Lee, J., Nikolaidis, E., Andersen, B. and Afjeh, A., 2016. Wind energy: Trends and enabling technologies. Renewable and Sustainable Energy Reviews, 53, 209-224.

Lee, C., 2016. Taiwan’ s new energy policy and prospect 我國新能源政策及展望 [online]. Taipei, Taiwan: MOEA. Available at: https://www.moea.gov.tw/MNS/populace/leader/wHandMinisterSpeak_File.ashx?speak_id=178, [Accessed 13 July 2017]

Li, C., Wang, H., Miao, H. and Ye, B., 2017. The economic and social performance of integrated photovoltaic and agricultural greenhouses systems: Case study in China. Applied Energy, 190, pp.204–212.

Lin, S., 2017. Local Collaborative Adaptation for Climate Change—A Case Study of “Raise Water, Grow Electricity Project” and “Guan— Tsai Wetland Project” in PingTung(2010-2016). 因應氣候變遷的在地協力調適行動—以屏東養水種電及光采濕地的推動經驗為例（2010–2016）. Ph.D. thesis, National Cheng Kung University.

Liou, R., Huang, S. and Lin, C., 2003. Methane emission from fields with differences in nitrogen fertilizers and rice varieties in Taiwan paddy soils. Chemosphere, 50 (2), 237-246.

Marrou, Dufour & Wery, 2013. How does a shelter of solar panels influence water flows in a soil–crop system? European Journal of Agronomy, 50, pp.38–51.

Marrou, H., Wery, J., Dufour, L. and Dupraz, C., 2013. Productivity and radiation use efficiency of lettuces grown in the partial shade of photovoltaic panels. European Journal of Agronomy, 44, pp.54–66.

Mason, R., 2015. Six in 10 UK onshore windfarms rejected, says report. The Guardian, 21 January 2015. Available at https://www.theguardian.com/environment/2015/jan/21/six-in-10-uk-onshore-wind-farms-rejected-report. [Accessed 17 August 2017]

Matsukura, C., 2013. Agriculture Policy-Making Mechanisms in Taiwan and Japan: -An Examination of Rice Subsidy before and after Accession to the WTO 台灣與日本農業政策決策機制－以加入 WTO 前後稻米補貼政策為例. M. thesis, National Taiwan University.

Mbzibain, A., Hocking, T.J., Tate, G. and Ali, S., 2013. Renewable enterprises on UK farms: Assessing levels of uptake, motivations and constraints to widespread adoption. Biomass and Bioenergy, 49, pp.28-37.

Mcdonald & Pearce, 2010. Producer responsibility and recycling solar photovoltaic modules. Energy Policy, 38(11), pp.7041–7047.

MOEA, 2017. Ministry of Economic Affairs Explains Energy Transition Pathway, Forward-Looking Green Energy Infrastructure and Stable Electricity Supply in This Summer [online]. Taipei Taiwan: MOEA. Available at: http://www.moeaboe.gov.tw/ECW/english/news/News.aspx?kind=6&menu_id=958&news_id=8730, [Accessed 13 July 2017]

Morris, D. and Scurlock, J., 2012. Chapter 4, Renewable energy: power for a sustainable future. 3rd ed. ed. Oxford: Oxford: Oxford University Press.

National Science & Technology Center for Disaster Reduction (NCDR), 2016. Aggregation and analysis of the extreme frost event in Taiwan on January 2016 [online]. Taipei City: NCDR. Available at: http://satis.ncdr.nat.gov.tw/ndd/pdf_his/2016/2016012-2016%E5%B9%B41%E6%9C%88%E8%87%BA%E7%81%A3%E5%9C%B0%E5%8D%80%E5%AF%92%E5%AE%B3%E4%BA%8B%E4%BB%B6%E5%BD%99%E6%95%B4%E8%88%87%E5%88%86%E6%9E%90.pdf. [Accessed 10 August 2017].

National Science & Technology Center for Disaster Reduction (NCDR), 2008. Analysis of the extreme frost event in Penghu on February 2008 [online]. Taipei City: NCDR. Available at: http://ncdr.nat.gov.tw/news/newsletter2/035/035.pdf. [Accessed 10 August 2017].

NFU, 2017. Contributions of UK Agriculture [online]. Warwickshire, England: NFU. Available at: https://www.nfuonline.com/assets/93457, [Accessed 13 July 2017]

Nookuea, W., Campana, P.E. and Yan, J., 2016. Evaluation of Solar PV and Wind Alternatives for Self Renewable Energy Supply: Case Study of Shrimp Cultivation. Energy Procedia, 88, 462-469.

Peake, Everett, Boyle and Ramage, 2012. Penalties: assessing the environmental and health impacts of energy use. In: Energy systems and sustainability: power for a sustainable future. 2nd ed. Oxford: Milton Keynes: Oxford: Oxford University Press; Milton Keynes: Open University, pp. 505-569.

Pedroli, B. & Langeveld, H., 2011. IMPACTS OF RENEWABLE ENERGY ON EUROPEAN FARMERS CREATING BENEFITS FOR FARMERS AND SOCIETY [online]. Wageningen Netherlands: Alterra Wageningen UR. Available at: https://ec.europa.eu/agriculture/sites/agriculture/files/external-studies/2012/renewable-energy-impacts/full_text_en.pdf. [Accessed 16 July 2017]

Peng, S., Huang, J., Sheehy, J.E., Laza, R.C., Visperas, R.M., Zhong, X., Centeno, G.S., Khush, G.S. and Cassman, K.G., 2004. Rice Yields Decline with Higher Night Temperature from Global Warming. Proceedings of the National Academy of Sciences of the United States of America, 101 (27), 9971-9975.

Poncet, C., Muller, M.M., Brun, R., & Fatnassi, H., 2012. Photovoltaic greenhouses, non-sense or a real opportunity for the greenhouse systems? Acta Hort. (ISHS), 927 (2012), pp. 75-79

Popp, A., Lotze-Campen, H. and Bodirsky, B., 2010. Food consumption, diet shifts and associated non- CO 2 greenhouse gases from agricultural production. Global Environmental Change, 20 (3), 451-462.

RAE, 2017. Sustainability of liquid biofuels [online]. London: Royal Academy of Engineering. Available at: http://www.raeng.org.uk/publications/reports/biofuels. [Accessed 8 August 2017]

Ramage, J. & Everett, B., 2012. Coal. In: Energy systems and sustainability: power for a sustainable future. 2nd ed. Oxford: Milton Keynes: Oxford: Oxford University Press; Milton Keynes: Open University, pp. 141-177.

Reichelstein, S., and Yorston, M., 2013. The prospects for cost competitive solar PV power. Energy Policy, 55, 117-127.

Reid, G., and Wynn, G., 2015. The Future of Solar Power in the United Kingdom. Energies, 8 (8), 7818-7832.

REN21, 2016. Renewables 2016 Global Status Report [online]. Paris: REN21 Secretariat. Available at: http://www.ren21.net/wp-content/uploads/2016/06/GSR_2016_Full_Report.pdf [Accessed 8 August 2017]

RSPB, 2012. Dirtier than coal? Why Government plans to subsidise burning trees are bad news for the planet [online]. Bedfordshire, England: RSPB. Available at: https://www.rspb.org.uk/Images/biomass_report_tcm9-326672.pdf [Accessed 1 August 2017].

Rudolf, V., and Papastergiou, K.D., 2013. Financial analysis of utility scale photovoltaic plants with battery energy storage. Energy Policy, 63, 139-146.

Sahu, Yadav & Sudhakar, 2016. Floating photovoltaic power plant: A review. Renewable and Sustainable Energy Reviews, 66, pp.815–824.

Schaffer, A., and Düvelmeyer, C., 2016. Regional drivers of on- farm energy production in Bavaria. Energy Policy, 95, 361-369.

Scurlock, J., 2015. Solar photovoltaic electricity in agriculture – on your roofs and in your fields [online]. Warwickshire: NFU, Available at: https://www.nfuonline.com/assets/43906. [Accessed 21 July 2017]

Seel, J. 2014. An Analysis of Residential PV System Price Differences Between the United States and Germany [online]. Lawrence Berkeley National Laboratory: Lawrence Berkeley National Laboratory. Available at: http://escholarship.org/uc/item/0s43p660. [Accessed 8 September 2017]

Silver, C., 2014. Using software in qualitative research: a step-by-step guide. Second edition. ed.

Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, O. Sirotenko, 2007: Agriculture. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O., Howden, M., McAllister, T., Pan, G., Romanenkov, V., Schneider, U., Towprayoon, S., Wattenbach, M. and Smith, J., 2008. Greenhouse Gas Mitigation in Agriculture. Philosophical Transactions: Biological Sciences, 363 (1492), 789-813.

Solomon, S., Plattner, G., Knutti, R. and Friedlingstein, P., 2009. Irreversible climate change due to carbon dioxide emissions. Proceedings of the National Academy of Sciences of the United States of America, 106 (6), 1704.

Sperling, K., Hvelplund, F. and Mathiesen, B.V., 2010. Evaluation of wind power planning in Denmark – Towards an integrated perspective. Energy, 35 (12), 5443-5454.

Sturge, D., While, A. and Howell, R., 2014. Engineering and energy yield: The missing dimension of wind turbine assessment. Energy Policy, 65, 245-250.

Su, S., 2014. The Political Ecology of Land Subsidence: A Case Study of the Solar Energy-Farming Scheme, Pingtung County, Taiwan. In: Meadows, M. & Lin, J., ed., Inaugural Meeting of the Commission on Earth Surface Processes in a Dynamic Environment, Taipei, TAIWAN. September 2014. pp. 103-124.

Su, Y., 2013. Competing in the Global Solar Photovoltaic Industry: The Case of Taiwan. International Journal of Photoenergy, 2013.

Sutherland, L., and Holstead, K.L., 2014. Future- proofing the farm: On- farm wind turbine development in farm business decision- making. Land use Policy, 36, 102-112.
Sutherland, L., Peter, S. and Zagata, L., 2015. Conceptualising multi-regime interactions: The role of the agriculture sector in renewable energy transitions. Research Policy, 44 (8), 1543-1554.

Sutherland, L., Toma, L., Barnes, A.P., Matthews, K.B. and Hopkins, J., 2016. Agri- environmental diversification: Linking environmental, forestry and renewable energy engagement on Scottish farms. Journal of Rural Studies, 47, 10-20.

Sutherland, L., Toma, L., Barnes, A.P., Matthews, K.B. and Hopkins, J., 2016. Agri- environmental diversification: Linking environmental, forestry and renewable energy engagement on Scottish farms. Journal of Rural Studies, 47, 10-20.

Swanson, R.M., 2006. A Vision for Crystalline Silicon Photovoltaics. PROGRESS IN PHOTOVOLTAICS: RESEARCH AND APPLICATIONS. Prog. Photovolt: Res. Appl. 2006; 14:443–453

Taipower, 2017. Development of renewable energy [online]. Taipei: Taiwan Power Company. Available at: http://www.taipower.com.tw/content/new_info/new_info-b31.aspx?LinkID=8 [Accessed 22 June 2017]

Taipower, 2017. Renewable energy power generation benefits [online]. Taipei: Taiwan Power Company. Available at: http://www.taipower.com.tw/content/new_info/new_info-b32.aspx?LinkID=8 [Accessed 22 June 2017]

Taylor, D., 2012. Chapter 7, Renewable energy: power for a sustainable future. 3rd ed. ed. Oxford: Oxford: Oxford University Press.

Tsoutsos, T., Frantzeskaki, N. and Gekas, V., 2005. Environmental impacts from the solar energy technologies. Energy Policy, 33 (3), 289-296.

Tu, J.-Y. & Chou, C., 2013. Changes in precipitation frequency and intensity in the vicinity of Taiwan: typhoon versus non-typhoon events. Environmental Research Letters, 8(1), p.7.

Twidell, J. & Weir, Anthony D. author, 2014. Renewable energy resources [electronic resource] 3rd ed., Available via: NTU Library OneSearch, [Accessed 14 July 2017]

UN, 2016. Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture [online]. New York: UN. Available at: http://www.un.org/sustainabledevelopment/hunger/ [Accessed 1 August 2017].

USEPA, 2012. Summary Report: Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990 – 2030 [online]. Washington DC: Office of Atmospheric Programs Climate Change Division of USEPA. Available at: https://www.epa.gov/sites/production/files/2016-05/documents/summary_global_nonco2_projections_dec2012.pdf [Accessed 30 July 2017].
Valentine, S.V., 2011. Emerging symbiosis: Renewable energy and energy security.

van Vliet, J., de Groot, H.L.F., Rietveld, P. and Verburg, P.H., 2015. Manifestations and underlying drivers of agricultural land use change in Europe. Landscape and Urban Planning, 133, 24-36.

WEC, 2016. World Energy Resources Wind 2016. [online]. London: World Energy Council. Available at: https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Wind_2016.pdf. [Accessed 8 August 2017]

World Bank, 2017. Global Solar Atlas. [online]. Available via: http://globalsolaratlas.info. [Accessed 31 August 2017].

Yang, M., 2016. The review of pilot direct payment policy of rice paddy 試辦「稻作直接給付」之政策評論 [online]. Taichung, Taiwan: The Rural Economics Society of Taiwan. Available at: http://www.rest.org.tw/upload/2016111409464796.pdf [Accessed 1st August 2017]

Yin, R.K., 2012. Applications of case study research. 3rd ed. ed. London: London: SAGE.