CHEMICAL ENGINEERING TRANSACTIONS

VOL. 88, 2021

A publication of
AIDIC
The Italian Association
of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Petar S. Varbanov, Yee Van Fan, Jiří J. Klemeš

ISBN 978-88-95608-86-0; **ISSN** 2283-9216

DOI: 10.3303/CET2188068

Cooperative Game-Based Business Model Optimisation for a Multi-Owner Integrated Palm Oil-Based Complex

Yue Dian Tan, Jeng Shiun Lim*, Sharifah Rafidah Wan Alwi

Process Systems Engineering Centre (PROSPECT), School of Chemical and Energy Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia.
jslim@utm.my

To achieve cleaner production in palm oil mills (POM), eliminating palm oil mill effluent (POME) via evaporation provides promising benefits towards palm oil sustainability. The incorporation of POME evaporation creates circular economy opportunities between mill, refinery and cogeneration system via converting mill-refinery effluent to oil recovered-solids and regenerated water, broadening biomass-to-energy potential to support energy-extensive evaporation and water integrations. Such industrial symbiosis scheme named as the integrated palm oil-based complex (POBC) could consider participation from different companies to provide desired processing facilities in achieving the optimal performance of POBC. For the new POBC scheme, the individual interest for each participating facility is hard to define due to the lack of basis for profit distribution. It is crucial to propose an optimal business model for POBC planning to demonstrate the financial allocation among possible partners based on the pooled incremental gains in the POBC coalition. The business model serves as a tool to persuade the companies in collaborating by quantifying their potential economic benefits and contributions for negotiation before forming the POBC. The cooperative game theory model has been useful in distributing cost savings within a coalition of individual plants. On that account, an integrated cooperative game-based optimisation approach is proposed to optimally distribute the profit gain and investment sharing between POM, palm oil refinery and biomass-cogeneration system to develop a feasible business model for a multi-owner POBC. Seven scenarios have been evaluated to generate optimal multi-owner POBC business models achieving 7-13 % improvements in economic potential. The average economic allocations of collaborating POM, refinery and cogeneration system are 91.8 %, 2.4 % and 5.8 % in the multi-owner POBCs.

1. Introduction

At the current practices of palm oil processing industry, enormous amount of waste is being generated including liquid palm oil mill effluent (POME), solid biomass, and greenhouse gas (GHG) emission (Andiappan et al., 2018). Palm oil waste is the largest agricultural waste contributor in Peninsular Malaysia, making up 77 % of the overall waste generation. Circular economy initiatives are essential to close the resource loop within the palm oil industry to boost sustainability, via exploiting the value of waste or by-products in the linear economy chain (Yeo et al., 2020). Yeo et al. (2020) utilised an integrated P-graph optimisation approach to study the circular economy model of palm-based biomass considering recycling of steam, power and fertilizer. Although the results show better economic favorability in the linear make-use-dispose model, the circular business model demonstrated a significant reduction in resource import. Waudby and Zein (2021) proposed to recover POME as biodiesel via microwave heating while investigating its techno-economical and geographical feasibilities at industrial scale. Tan et al. (2020a) attempted a multi-objective optimal design of a new conceptual integrated palm oil-based complex (POBC) which considers POME evaporation and oil recovery in the palm oil mill (POM) to eliminate POME. The effluent-elimination strategy created new integration opportunities between neighbouring POM and palm oil refinery (POR) of single owner to consume refinery effluent and biomass waste for reducing utility import within the closed POBC loop. One of the vital strategies to achieve circular economy is industrial symbiosis (IS), which practices conversion of one’s waste product into another’s process feedstock upon geographical proximity to embrace economic savings (Fraccascia et al., 2020). It is undeniable that the motivation for collaborating companies behind successful IS is the satisfying allocation of economic benefits.

Paper Received: 20 May 2021; Revised: 3 September 2021; Accepted: 3 October 2021
Please cite this article as: Tan Y.D., Lim J.S., Wan Alwi S.R., 2021, Cooperative Game-Based Business Model Optimisation for a Multi-Owner Integrated Palm Oil-Based Complex, Chemical Engineering Transactions, 88, 409-414 DOI:10.3303/CET2188068

The work of Tan et al. (2020a) has proven the superiority of POME evaporation in achieving methane elimination in POBC considering economic and environmental trade-offs. Their proposed effluent-evaporated POBC structure could be a new IS scheme if the facilities integrated (POM, POR and conventional heat and power (CHP) facility) are owned by different companies. An optimal multi-owner business model with mutual agreement from each party on the respective benefit and cost sharing in the POBC scheme is thus required as a tool to persuade the companies in collaborating. Ng et al. (2013) suggested the importance of multiple owner consideration in the profit maximisation of palm oil processing complex. The fuzzy optimisation model developed aims to achieve predefined economic interest of multiple companies. Nevertheless, for a new collaborative concept such as POBC, the individual interest for each participating facility will be hard to define due to the unclear distribution of contribution (Tan et al., 2016). The more suitable business model would be the demonstration of economic benefits allocation for each facility to form the multi-owner POBC. Andiappan et al. (2018) suggested a cooperative game theory-based optimisation approach to distribute incremental profits within a palm-based eco-industrial park. In this context, POBC is treated as a “game” whereas the potential collaborating plants (CHP, POM and POR) are the players willing to contribute to achieve IS within the POBC. There is less effort in developing such business model for POM and POR collaboration while considering POME elimination. Previous economic studies for multi-owner palm oil complex lack consideration of distance factor and investment cost distribution. Symbiosis investment cost is defined as the additional capital cost incurred to construct new process unit or facility at the POM site to facilitate IS between companies to form the POBC. It is desired to distribute the symbiosis investment cost rationally among the companies based on their share of economic benefits from the collaboration. To date, no study has analysed the multi-owner business model for effluent-evaporated palm oil complex. There is a need to optimally design a multi-owner POBC for different collaboration modes and rationally distribute the profit and cost. This study presents a new cooperative game-based optimisation approach to optimally distribute the economic potential (EP) between POM, POR and CHP system in the optimum multi-owner POBC business model. The developed mathematical models aim to address the research gaps of distance factor in multi-owner POBC optimisation and symbiosis investment cost distribution. The optimal results should provide insights and guideline for potential palm oil players to participate in the POBC collaboration scheme for palm oil sustainability enhancement.

The problem statement could be addressed as follows:

- Given a set of processes p and resources *i* considered in POM, POR and CHP facilities, essential data for process conversion, cost factors for technology investment, resource transportation, process operation and facility construction, the optimal flowsheet of multi-owner POBC is generated with maximum EP.
- Based on the optimal POBC flowsheet generated, a set of potential collaborating facility c is defined as groups of technology p owned by the same facility. A set of facility collaboration scenario z is also defined by considering potential combinations of facility c within the multi-owner POBC.
- The characteristic function $v(z)$ is defined as the EP contributed by the collaboration of facilities c in scenario z. The values of $v(z)$ are obtained according to the description in Section 2.2.
- The final aim is to optimally distribute the EP among collaborating facilities c in the multi-owner POBC using the cooperative game linear programming (LP) model modified from Maali (2009).

Several assumptions and limitations are considered for this paper. The resource and utility exchanged between collaborating facilities within the multi-owner POBC are assumed with no cost. The profit obtained by each facility is solely based on the allocation of pooled EP achieved by the optimum multi-owner POBC. Steam and electricity delivery from a distanced CHP facility is not considered due to geographical limitations and pressure drop challenges. It is assumed that no cost is incurred for resource exchange between neighbouring facilities.

2. Method

The proposed framework for multi-owner POBC optimisation and optimal distribution of economic potential among collaborating facilities could be divided into several stages. In Stage 1, an optimisation model with resource transportation constraints is developed and solved to generate an optimal flowsheet for different multi-owner POBC scenarios. The essential inputs for the cooperative game model are then calculated in Stage 2 based on the optimal characteristic function obtained in every facility collaboration scenario z. Subsequently in Stage 3, optimal distribution of EP among the collaborating facilities is performed via the cooperative game model. In Stage 4, the multi-owner POBC business models generated for different scenarios are analysed and discussed to determine the economic feasibility of POBC collaboration.

2.1 Multi-owner POBC optimisation model

The mixed-integer non-linear programming (MINLP) optimisation model developed for multi-owner POBC design is extended from the study of Tan et al. (2020a) by integrating resource transportation constraints for different collaboration schemes. The objective of the optimisation model is to maximise the EP of POBC (EP) in

Eq(1). Besides revenue from selling products at optimal amount (PRO_i) and market price (PRICE_i), cost for purchasing resource at required amount ($EXRES_i$) and import price (URCOST_i), electricity export revenue ($ELECREV$) and import cost ($ELECCOST$), operating cost ($OPEX$) and capital cost ($CAPEX$) annualised via capital recovery rate (crf), EP in Eq(2) further includes the transportation cost of exchanged resource ($RCOST_i^{TRANSPORT}$) and external processing cost ($RCOST_i^{EXT}$) of unconsumed product defined by binary indicator ($\mathrm{Rind}_i^{\mathrm{EXPRO}}$) at a cost ($\mathrm{UCOST}_i^{\mathrm{EXT}}$). To calculate $RCOST_i^{TRANSPORT}$ only when a resource is delivered over a distance, constraints Eq(4)-(8) are formulated. The value of binary transported resource variable ($y1_i$) will be 1 if material *i* defined by binary transport indicator ($\mathrm{Rind}_i^{\mathrm{TRANS}}$) is delivered from a distanced collaborating facility within the POBC to be consumed at an amount to a process ($MAT_{i,p}$). On the contrary, the value of binary non-transported resource variable ($y2_i$) will be 1 if the process chose to import resource defined by binary non-transport resource indicator ($\mathrm{Rind}_i^{\mathrm{NONTRANS}}$) at required amount into the POBC loop. The resource transportation cost factor ($\mathrm{COST}_{i,p}^{\mathrm{TRANSPORT}}$) is based on the required distance to deliver resource *i* to process *p* ($\mathrm{DISTANCE}_{i,p}^{\mathrm{TRANSPORT}}$), unit resource transportation cost via truck per km ($\mathrm{UCOST}_i^{\mathrm{TRANSPORT}}$) and unit resource handling cost ($\mathrm{UCOST}_i^{\mathrm{HANDLING}}$).

$$\text{Maximise } EP \tag{1}$$

$$\begin{aligned} EP = \mathrm{AOT} \times \Big(\sum\nolimits_i PRO_i \times \mathrm{PRICE}_i - \sum\nolimits_i EXRES_i \times \mathrm{URCOST}_i - \sum\nolimits_i RCOST_i^{TRANSPORT} \\ - \sum\nolimits_i RCOST_i^{EXT} + ELECREV - ELECCOST\Big) - OPEX \; - CAPEX \times \mathrm{crf} \end{aligned} \tag{2}$$

$$RCOST_i^{EXT} = \mathrm{UCOST}_i^{\mathrm{EXT}} \times \mathrm{Rind}_i^{\mathrm{EXPRO}} \times PRO_i \qquad \forall i \tag{3}$$

$$y1_i + y2_i = 1 \qquad \forall i \tag{4}$$

$$\left[\sum\nolimits_p (MAT_{i,p} \times \mathrm{COST}_{i,p}^{\mathrm{TRANSPORT}}) \times \mathrm{Rind}_i^{\mathrm{TRANS}}\right] - \left(EXRES_i \times \mathrm{Rind}_i^{\mathrm{NONTRANS}}\right) \le 1{,}000 y1_i \;\; \forall i \tag{5}$$

$$\left(EXRES_i \times \mathrm{Rind}_i^{\mathrm{NONTRANS}}\right) \le 1{,}000 y2_i \qquad \forall i \tag{6}$$

$$\mathrm{COST}_{i,p}^{\mathrm{TRANSPORT}} = \mathrm{DISTANCE}_{i,p}^{\mathrm{TRANSPORT}} \times \mathrm{UCOST}_i^{\mathrm{HANDLING}} \times \mathrm{UCOST}_i^{\mathrm{TRANSPORT}} \qquad \forall i \; \forall p \tag{7}$$

$$RCOST_i^{TRANSPORT} = \left[\sum\nolimits_p (MAT_{i,p} \times \mathrm{COST}_{i,p}^{\mathrm{TRANSPORT}}) \times \mathrm{Rind}_i^{\mathrm{TRANS}}\right] \times y1_i \qquad \forall i \tag{8}$$

2.2 Cooperative game-based EP distribution model

Subsequently, the optimisation model in Section 2.1 is extended to consider simultaneous optimisation of different facility collaboration scenarios *z* to allocate the respective characteristic function values. Each scenario *z* considers different combination of facility in set c, indicating which facility is collaborating in POBC. To generate scenarios *z*, scenario-specific constraints and parameters formulated by Tan et al. (2020b) are integrated into the optimisation model to differentiate the operating process and resource flow. The characteristic function, $v(z)$, for economic benefit distribution within the multi-owner POBC is defined as the EP achieved by scenario *z* including profit savings, symbiosis investment cost and material cost resulted from the facility collaboration as shown in Eq(9). By solving the integrated MINLP model with the objective function of maximum EP, optimal EP could be obtained for different scenario *z* (EP_z) to calculate values of $v(z)$ using Excel Spreadsheet.

$$v(z) = EP_z \qquad \forall\, z \tag{9}$$

The aim of LP cooperative game model is to optimally distribute the overall EP attained by the optimum multi-owner POBC flowsheet among collaborating facilities *c* to generate the business model. The results obtained by solving the MINLP model are used to formulate Eq(11)-(15) according to Maali (2009). The basis weights of collaborating facilities *c* (W_c) are calculated based on the optimal values of $v(z)$ using Eq(11). Variable $v(z - \{c\})$ represent the value of $v(z)$ achieved by scenario *z* without contribution from facility *c* whereas $v(\aleph)$ describes the $v(z)$ value for full collaboration scenario where the POM, POR and CHP facility of different owners all considered to join the POBC. In Eq(10), the LP optimisation model is solved by maximising variable λ. The distributed EP and percentage EP allocation to each collaborating facility *c* in the POBC are obtained as ALL_c and $PALL_c$. The optimal results are analysed to investigate the feasibility of the business model.

$$\text{Maximise } \lambda \tag{10}$$

$$W_c = \frac{\sum_z v(z) - v(z - \{c\})}{v(\aleph)} \quad \forall c \tag{11}$$

$$\frac{1}{W_c} ALL_c \geq \lambda \qquad \forall c \tag{12}$$

$$ALL_c \geq v(\{c\}) \qquad \forall c \tag{13}$$

$$\sum_c ALL_c = v(\aleph) \tag{14}$$

$$PALL_c = \frac{ALL_c}{v(\aleph)} \qquad \forall c \tag{15}$$

3. Case study application

The developed multi-owner POBC optimisation framework and models are used to solve a case study adapted from Tan et al. (2020a) and literature. A palm oil company aims to retrofit its existing POM operating at 60 t/h FFB capacity for 4,350 h/y to apply POME elimination. A POR from different owner originally imports crude palm oil (CPO) at 492 USD/t to generate palm fatty acid distillate, refined, bleached, deodorised palm olein and palm stearin. Another enterprise owns a CHP plant that could convert purchased palm-based biomass into electricity to sell at 90 USD/MWh by investing in high-efficiency boiler. As a circular economy initiative, the POM plans to form a POBC by performing IS with the multi-owner POR and CHP plant. The CHP facility could satisfy the steam and power demand of nearby POM and POR by utilising the available biomass from POM. CPO produced by POM could be directly delivered to POR for refining. Note that in the POBC context, all internal material exchange, i.e., biomass, CPO etc., is considered free between collaborating facilities as opposed to the individual plant scenario without symbiosis. To encourage waste elimination within POBC, POME evaporation and solvent extraction units invested at POM allow effluent and water integration with POR and CHP to reduce the costs for effluent treatment and water purchase. To deliver resource between POBC facilities, the unit transportation cost for CPO, effluent and water by truck is 0.1 USD/t/km whereas 0.2 USD/t/km is incurred for biomass delivery (Lam et al., 2013). The unit handling cost for all resources is 0.05 USD/t. The capital recovery rates of POM, POR, CHP and POBC are assumed at 0.096 for 15 y in both POBC and individual cases. The optimal multi-owner POBC flowsheet is desired at maximum EP considering the additional revenue, cost savings, symbiosis investment cost, logistic cost for resource exchange between POM, POR and CHP facility. Subsequently, rational distribution of pooled EP is performed to propose the optimal multi-owner business model. To evaluate various multi-owner business models for different POBC collaboration modes, seven scenarios are analysed in this paper. The key differences in the seven scenarios are tabulated in Table 1. Scenario 1 considers existing facilities situated side-by-side whereas Scenarios 2 to 4 consider distanced facilities situated at selected locations in the work of Lam et al. (2013) to incur resource delivery cost. Scenarios 5 to 7 evaluates the collaboration of POM with new facilities to be constructed at fixed capital costs to form the POBC coalition in the multi-owner business model. The related data for new technology or facility installation is given in Table 2. The other economic and process data applied are based on the work of Tan et al. (2020a).

Table 1: Case study details for Scenario 1 to 7

Scenarios	Existing facility			Distance (km)			Process/facility to be installed at POM site		
	POM	POR	CHP	POM to CHP	POM to POR	CHP to POR	POME evaporation + solvent extraction + advanced boiler	CHP (Boiler and turbine)	POR (Physical refining + fractionation)
1	√	√	√	-	-	-	√		
2	√	√	√	-	7	7	√		
3	√	√	√	46	-	46	√		
4	√	√	√	39	7	46	√		
5	√	√		-	-	-	√	√	
6	√		√	-	-	-	√		√
7	√			-	-	-	√	√	√

Table 2: Cost data for new process/facility installation (Tan et al., 2020a)

Process/Facility	Unit capital cost (USD/unit)	Unit operating cost	Design capacity
POME evaporation	$1.400x10^6$	12,000 USD/y	22 t POME per unit
Solvent extraction	$0.180x10^6$	540 USD/y	20 t concentrate per unit
Advanced boiler	$0.182x10^6$	15 USD/y	5 MWh electricity per unit
CHP (Ng et al., 2013)	$0.400x10^6$	15 USD/y	5 MWh electricity per unit
POR (Ng et al., 2013)	$9.750x10^6$	870 USD/y	15 t CPO per unit

4. Results and discussion

The MINLP model developed in Section 2.1 is used to solve seven optimisation case studies in the General Algebraic Modelling System (GAMS) software (version 24.7.4) using the CPLEX solver (12.6.3.0). EP-optimal results for the seven multi-owner POBC scenarios are summarised in Table 3. The imported resources are the input materials procured externally into the POBC loop at market prices if resource exchange between collaborating facilities is not economically favourable. Subsequently, the maximum EP for each scenario is rationally distributed via the cooperative game approach described in Section 2.2 among POBC facilities. Optimal EP allocations for the multi-owner POBC business models in Scenarios 1 to 7 are compiled in Table 4. The baseline studies for each facility and the whole POBC are given in Table 4 to calculate the percentage EP improvements attained by each collaborating POM, POR and CHP based on distributed EPs. Note that the baseline EP is the maximum EP obtained in the optimum case of single facility scenarios. The baseline EPs for stand-alone POM, CHP facility, existing and newly constructed POR are given as $36.76x10^6$, 0, $2.46x10^6$ and $1.52x10^6$ USD/y while the baseline EP for the overall POBC is $36.76x10^6$ USD/y considering stand-alone POM.

Table 3: EP-optimal results for multi-owner POBC in Scenarios 1 to 7

Scenario *s*	1	2	3	4	5	6	7
Max EP (10^6 USD/y)	41.48	41.16	39.31	39.35	41.40	40.54	40.46
EP improvement (%)	12.82	11.95	6.93	7.02	12.61	10.27	10.07
Imported water (t/h)	22.80	37.85	0	31.22	22.80	22.80	22.80
Imported palm fibre (t/h)	0	6.87	0	10	0	0	0
Imported electricity (MWh)	0	1.5	2.47	2.47	0	0	0
Resource transportation cost (10^6 USD/y)	0	0.06	0	0.06	0	0	0
Capital investment (10^6 USD/y)	2.13	1.94	1.58	1.94	2.93	11.9	12.7

Table 4: EP distribution and comparative results for Scenarios 1 to 7

s	POM			CHP			POR		
	EP allocation (%)	Distributed EP (10^6 USD/y)	EP increment (%)	EP allocation (%)	Distributed EP (10^6 USD/y)	EP increment (%)	EP allocation (%)	Distributed EP (10^6 USD/y)	EP increment (%)
1	89.9	37.28	1.40	3.6	1.49	149.10	6.5	2.71	10.40
2	91.1	37.50	2.01	3.0	1.22	121.85	5.9	2.44	-0.76
3	93.7	36.82	0.16	0	0.00	0.00	6.3	2.49	1.38
4	93.7	36.85	0.24	0	0.00	0.00	6.3	2.49	1.48
5	90.2	37.33	1.54	3.3	1.36	135.74	6.6	2.71	10.56
6	92.0	37.28	1.42	3.6	1.44	144.34	4.5	1.81	19.26
7	92.2	37.30	1.47	3.4	1.37	137.00	4.4	1.79	17.77

In Table 3, Scenario 1 considering neighbouring facilities for POBC collaboration attains the highest EP at $41.48x10^6$ USD/y with 12.82 % improvement from the baseline study due to the incremental profit from material and utility exchange without delivery charges or new facility investment. Investment in effluent elimination strategies is economically favourable with attractive revenue from oil recovery and reduced costs for water purchase and effluent treatment. Note that Scenarios 5 to 7 generate similar POBC product portfolio despite the high capital cost in new facility construction. This implies that the POBC collaboration mode involving construction of new POR or CHP near an existing POM is economically favourable in achieving desired sustainability performance. Multi-owner business models in Table 4 for Scenarios 5 to 7 show an average 3.4 %, 139 % and 15.9 % EP improvement for individual POM, CHP and POR to join the effluent-evaporated POBC IS scheme. In Scenario 2 and 4, only delivery of CPO and effluent is considered between POM and POR within a 7 km distance. This highlights the favourability of mill-refinery effluent integration and evaporation. Additional biomass is imported for electricity generation in Scenario 2 to balance the cost of grid electricity import to the distanced POR. The water utility and biomass demands in distanced CHP and POR are satisfied by external sources in Scenario 4 due to high delivery charges. In Scenario 3 and 4 where CHP is situated 39-46 km away from POM and POR, CHP collaboration is not considered in the multi-owner POBC business model due to high biomass delivery charges, resulted in zero EP allocation in Table 4. It is recommended to study the impacts of transportation distance on the optimum POBC flowsheet via sensitivity analysis in future works. Based on Table 4, POBC collaboration has helped the multi-owner POM, POR and CHP to improve their individual EP in almost all scenarios. The percentage EP allocation and distributed EP in Table 4 could serve as the benchmarks for profit and symbiosis investment cost sharing among collaborating POM, POR and CHP to persuade them in implementing the respective optimal multi-owner POBC business model in Table 3.

5. Conclusion

This paper has proposed an integrated optimisation framework to generate the EP-optimal POBC in multi-owner scenarios and subsequently demonstrate the rational EP sharing between collaborating facilities using the cooperative game model. The optimal results have proven the economic feasibilities of multi-owner POBC business models considering collaboration between retrofitted POM and existing or newly constructed POR and CHP facilities located near to each other with overall EP between 40.5 $x10^6$ to 41.5 $x10^6$ USD/y and promising EP improvements ranging from 10-13 %. Collaboration with distanced CHP facility is not preferred for EP-optimal POBC business models due to the expensive resource transportation costs. POM receives the largest percentage of EP in all scenarios thus should be allocated with the largest portion of profit and investment cost during POBC collaboration. The optimal business models and comparative analysis could provide useful insights to palm oil players in considering industrial symbioses for effluent elimination and EP increment. The multi-owner POBC optimisation framework and mathematical models could be easily revised to perform business model analysis and economic benefit distribution for any IS scheme. Sensitivity analysis on the distance factor and environmental benefits considerations in multi-owner POBC optimisation is highly recommended to provide more comprehensive results in future studies.

Acknowledgements

The authors would like to thank Universiti Teknologi Malaysia (UTM) Research University Grant (grant number R.J130000.7851.5F388 and Q.J130000.3551.05G97) for the financial support.

References

Andiappan V., Ng D.K.S., Tan R.R., 2018, Cooperative Game Theory Analysis For Implementing Green Technologies In Palm Oil Milling Processes, Chapter in: DCY Foo, MK Tun Abdul Aziz (Eds.), Green technologies for the oil palm industry, Springer Singapore, Singapore, 173-190.

Fraccascia L., Yazdanpanah V., van Capelleveen G., Yazan, D.M., 2020, Energy-based industrial symbiosis: a literature review for circular energy transition, Environment, Development and Sustainability, 1-35.

Lam H.L., Ng W.P., Ng R.T., Ng E.H., Aziz M.K.A., Ng D.K., 2013, Green strategy for sustainable waste-to-energy supply chain, Energy, 57, 4-16.

Maali Y., 2009, A multiobjective approach for solving cooperative n-person games, International Journal of Electrical Power & Energy Systems, 31, 608-610.

Ng R.T.L., Ng D.K.S., Tan R.R., 2013, Systematic approach for synthesis of integrated palm oil processing complex. Part 2: Multiple owners, Industrial & Engineering Chemistry Research, 52, 10221-10235.

Tan R.R., Andiappan V., Wan Y.K., Ng R.T.L., Ng D.K.S., 2016, An optimization-based cooperative game approach for systematic allocation of costs and benefits in interplant process integration, Chemical Engineering Research and Design, 106, 43-58.

Tan, Y.D., Lim, J.S., Wan Alwi, S.R., 2020a, Multi-objective optimal design for integrated palm oil mill complex with consideration of effluent elimination, Energy, 202, 117767.

Tan Y.D., Lim J.S., Wan Alwi S.R., Andiappan V., 2020b, Targeting anchor process via cooperative game-based optimisation approach within integrated palm oil-based complex, Chemical Engineering Transactions, 81, 31-36.

Waudby H., Zein S.H., 2021, A circular economy approach for industrial scale biodiesel production from palm oil mill effluent using microwave heating: Design, simulation, techno-economic analysis and location comparison, Process Safety and Environmental Protection, 148, 1006-1018.

Yeo J.Y.J., How B.S., Teng S.Y., Leong W.D., Ng W.P.Q., Lim C.H., Ngan S.L., Sunarso J., Lam H.L., 2020, Synthesis of sustainable circular economy in palm oil industry using graph-theoretic method, Sustainability, 12, 8081.