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Utilization Study of Carbonized Coal Briquette as Beef Rendang Cooking Fuel

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Utilization Study of Carbonized Coal Briquette as Beef Rendang Cooking Fuel

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Abstract. Finding the cheaper alternative fuels and shortening the rendang cooking time are the potential efforts to reduce the production cost of rendang. This study aims to use low-rank cheap coal to cook beef rendang and to develop a more efficient rendang cooking method. First, the raw coals were carbonized, then the charcoals obtained were crushed and mixed with the filler and binder. After that, the charcoal mixture was molded into briquettes. Furthermore, the carbonized coal briquettes resulted were characterized and used as fuel to cook beef rendang in a semi-closed moveable-grate stove. To get a more efficient cooking time, a modified cooking method was developed. From the research has been obtained that there was almost no significant odor and smoke emissions during the cooking process except at the initial ignition period, which takes between 10-15 minutes. The modified cooking method took time 3 hours to get the dry beef rendang, 1 hour shorter than that of the normal cooking ones. Briquettes consumption for 1 kg of beef rendang cooking, using the modified cooking method, was about 0.75 kg, equivalent to USD 0.18 if 1 kg of briquette is priced USD 0.24. Finally, it can be summarized that carbonized coal briquette is a solid smokeless fuel that is safe and cheap to cook beef rendang.

1. Introduction

Besides being delicious, beef rendang is also very nutritious food. According to [1], the digested protein content in rendang beef increased by about 44% compared to fresh beef. Apart from containing high digested protein, rendang is also safe to consume. The saturated oil and fat content of beef rendang, which is dominated by long and medium-chain of fatty acids, are not easily degraded [1]. In addition, the presence of spices in the rendang mixture can inhibit the degradation of fatty acids [2]. The friendliness of fatty acids derived from coconut milk for human health has also been previously mentioned in [3].

The cooking process of rendang, at a cooking temperature ranging from 80-93 °C, takes time between 5-6 hours [2]. The rendang cooking process mechanism consists of water evaporating, converting coconut milk into oil, deactivating various enzymes present in the beef and coconut milk, and associating the spices in the rendang mixture. Dry beef rendang has a long shelf life. The lower the water content of beef rendang, the longer its shelf life will be and vice versa.

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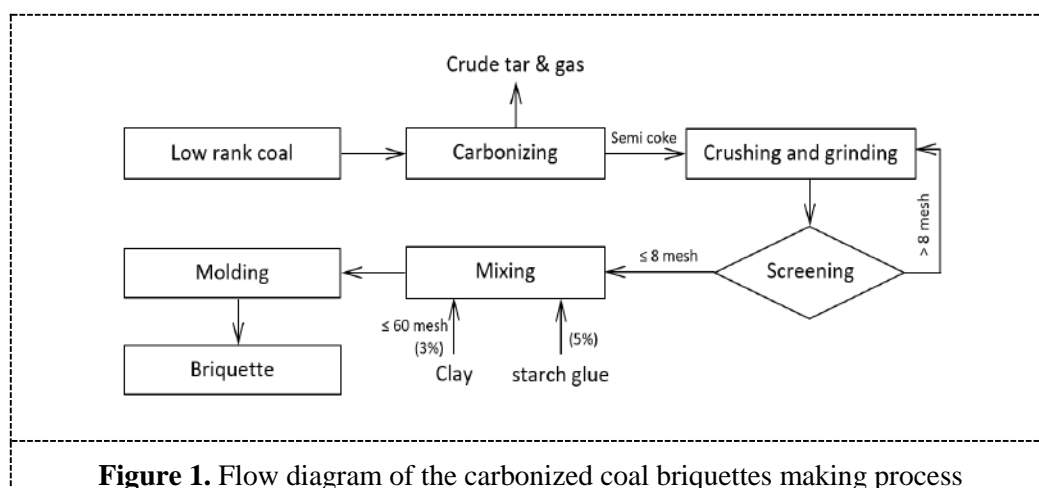
The long cooking process of rendang (5-6 hours) cause fuel consumption to be high and increase the degradation potency of the rendang dough. This is one of the main problems of the rendang food business. This study aims to use low-rank cheap coal to cook beef rendang and to develop a more efficient rendang cooking method. Various problems in using coal as fuel, such as initial ignition difficulty, smoke formation prevention, combustion control difficulty, and user comfort, as stated in [4], have been resolved in this study.

2. Methodology

The implementation of this research consisted of several stages, namely the briquette manufacturing stage, the briquette characterization stage, and the rendang cooking stage. The brief descriptions of each stage were given below.

2.1. Briquettes Manufacturing Procedure

The manufacturing flow diagram of the carbonized coal briquette used here was shown in figure 1. The low-rank coal from Muaro Jambi area, Jambi Province, Indonesia was carbonized by indirect heating in a multi-retort carbonizer for ± 6 hours. The charcoals obtained were then crushed, ground, and screened to get -8 mesh coal particles. The particles that pass through the 8 mesh sieve were fed to the mixing vessel to make the briquette dough while the rest was returned to the grinding process.



The composition of the briquette mixture consisted of charcoal 92%, filler 3%, and binder 5%. The use of filler is intended to absorb gas emissions and to reduce the fly ash phenomenon during the cooking process. Meanwhile, the use of binder is intended to provide strength to the briquettes so that they are not easily destroyed during transportation, storage, and use [5]. The last step of the briquette making process was the briquettes molding, which was conducted manually.

2.2. The Briquette Characterizations

2.2.1. Physical Characterizations. One of the briquette physical characteristics determined here was density. The briquette density will correlate to the transportation and storage costs; the smaller the briquette density, the greater the transportation and storage volume required, resulting in higher handling costs. In addition, briquettes with small density tend to have low energy content. Conversely, if the briquette density is too high, the combustion performance of the briquette will be low due to the low porosity of the briquette. The quality standard of the briquette density is between 1.0 - 1.5 gr/ml [6].

The briquette density determination referred to ASTM D2395-17 [7]. The procedures were as follows: (a) weighing the mass of a briquette, (b) putting a briquette into a fully filled water vessel, (c) determining the volume of water that is removed from the vessel and record it as the volume of a briquette, (d) calculating the briquette density through equation (1); where ρ is briquette density, m is briquette mass and v is briquette volume. The briquette density was calculated based on an air-dried basis (adb).

$$\rho = \frac{m}{v} \quad (1)$$

Another physical property of the briquettes determined in this study was the shatter index. The shatter index indicated the briquette strength; whether the briquettes could stand or not during transportation, storage, and use can be assessed from the shatter index value. For domestic fuel briquettes, the minimum shatter index required is 0.9 [8].

The determination of the shatter index referred to ASTM D440-86 [9]. The procedures for determining the shatter index were as follows; (a) weighing the initial weight of a briquette, (b) dropping the briquette by gravity from a height of 2 meters onto the metal floor 3 times, (c) weighing the residual weight of the briquette that has been resisted in an 8 mesh sieve, and (d) calculating the shatter index of the briquette through the equation (2). Variable I_s is a shatter index, m_{BI} is an initial mass of briquette, and m_{BR} is a residual mass of briquette [10].

$$I_s = \frac{m_{BR}}{m_{BI}} \quad (2)$$

2.2.2. Proximate Analysis. The parameters determined in the proximate analysis of briquette were water, volatile matter, fixed carbon, and ash contents. Proximate analysis was carried out on an air-dried basis (adb). The determination of the briquettes heating value, using bomb calorimeter, was also conducted in this step.

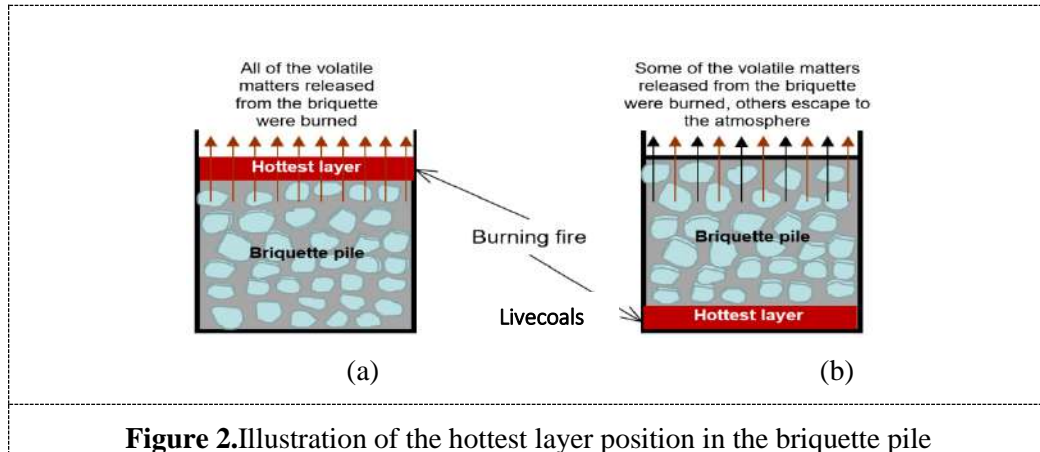
2.2.3. Initial Ignition Time. The initial ignition time of the briquettes is the length of time it takes from the first time the briquettes are ignited until the fixed carbons of the briquettes were burnt stably. The unit of time of the briquettes ignition was expressed in minutes. There were two kinds of ignition materials used in this research, namely kerosene and dry wood branches.

The procedures of using kerosene as an ignition material were as follows: (1) soaking some briquettes into the kerosene liquid for ± 5 minutes, (2) placing the soaked briquettes in the briquette pile, (3) igniting the briquettes with a match, (4) waiting for the fixed carbon of the briquette was burnt stably, (5) recording the time required for initial ignition. If the briquette hasn't been burned yet until the ignition material runs out, inject the kerosene until the briquettes were burnt stably.

Meanwhile, for the dry wood branches ignition material, the procedures were as follows: (1) chopping the dry wood branches up to 5-10 cm in sizes, (2) putting the chopped dry wood branches in a briquette pile, (3) igniting chopped dry wood branches, (4) waiting for the fixed carbon of the briquettes was burnt stably, and (5) recording the time required for initial ignition. If the briquette hasn't been burned yet until the ignition material runs out, add some chopped dry wood branches until the briquettes were burnt stably.

2.2.4. The Hottest Layer Position. There are two placements of the hottest layer in the briquette stove that were tested in this study, namely placement at the top and at the bottom of the briquettes pile. If the stove combustion chamber is first filled with briquettes and ignited later from the top, then the hottest layer position of the briquettes pile is at the top (figure 2.a). Conversely, if the stove combustion chamber is ignited first at the bottom and filled later with briquettes until it is full, then the

position of the hottest layer of the briquettes pile is at the bottom (figure 2.b). The position of the hottest layer at the briquette pile will affect the smoke emission of a briquette stove. An illustration of the hottest layer positions in the briquette stove were shown in figure 2.



2.3. Cooking Test of Beef Rendang Using Briquettes

The type of stove used in the beef rendang cooking test was a semi-closed moveable grate stove, where the grate of the stove can go up and down, as shown in figure 3. According to [11], the recent problem of briquette stove design does not lie in the fuel combustion efficiency but lies in the heat transfer efficiency from the furnace to the cooking vessel. The moveable grate of the stove allows the hottest layer of the briquette pile always close to the cooking vessel so that the thermal efficiency of the stove would be better. The average thermal efficiency of this stove in the water boiling test was reported about $\pm 50\%$ [12].

There were two cooking methods of beef rendang used in this study, namely: (1) a normal method, in which coconut milk and spices were cooked first until the dough releases oil (± 1 hour), then added the beef, and cooked until the dough dries, and (2) a modified method, where at first the beef and spices were sautéed with a little oil for ± 30 minutes, after that thick coconut milk was added and cooked until the dough dries. The time required to cook the beef rendang for both cooking methods was compared.

3. Results and Discussion

3.1. Physical Properties

The briquettes produced in this study was in the form of jengkol briquette with an equivalent diameter of about 41 mm. The appearance of the jengkol briquettes was shown in figure 4. The average density of the briquettes obtained was 1.17 gr/ml. This density value is within the density standard of fuel briquette, namely 1 – 1.5 gr/ml [6]. Meanwhile, the shatter index value of the briquettes obtained was about 96%. This value is above the minimum shatter index, namely 0.9 [8]. From these results, it could be seen that briquettes produced in this study have met the physical standard of the domestic fuel briquette.

3.2. Proximate Analysis

The proximate analysis results of the carbonized coal briquettes and quality standards of the fuel briquette [13], on the air-dried basis (adb), were shown in table 1. From the table, it could be seen that, in terms of moisture and calorific value, the values of proximate analysis of the coal briquettes produced have met the quality standards of fuel briquettes. But in terms of the volatility, the value was

greater than the standard. Besides being caused by the incomplete carbonization process, the addition of tapioca flour was also the cause of the high content of volatile matters from the resulting briquettes. The addition of the tapioca flour used here was 5%, greater than that was recommended by Suganal, namely 3% [5].

Table 1. Proximate analysis of the carbonized coal briquette

No.	Parameter	Experiment	Value SNI*	Suganal's
1.	Moisture, %	6.21	7.5	4.29
2.	Volatile matter, %	19.62	≤ 15	30.81
3.	Fixed carbon, %	57.05	n.d**	29.63
4.	Ash, %	17.12	n.d**	35.27
5.	Calorific value, kkal/kg	5.223	≥ 5000	4.412

* SNI = Standar Nasional Indonesia ** n.d = not be defined

3.3. Initial Ignition Time

The initial ignition time of the briquettes for the kerosene and wood branches was almost the same, ranging from 10-15 minutes. This time on average was slightly longer than the initial ignition time of coal briquettes reported by Suganal in [5], which was ± 10 minutes. This is because the volatile matters of the briquettes used here (19.6%) are lower than the volatile matters used by Suganal, which was 28.7%. The initial ignition time of the briquettes is directly proportional to the reactivity and the volatile matters content of the briquettes. The higher the content of the volatile matter of briquette, the higher its reactivity and the faster its initial ignition time [5].

Both types of ignition substances gave smoke emission at the initial ignition periode, where the smoke emission produced by the kerosene tended to be more than of the dry wood branches. The smoke formation occurred because of the volatile matters that come out from the briquettes were released into the environment without having time to burn in the stove combustion chamber. It was because the stove temperature at the initial use was still low. As time goes by, the temperature of the stove combustion chamber continued to rise, and the fixed carbon of the briquettes started to burn. As a result, the temperature of the stove combustion chamber was higher and the volatile matters of the briquettes would be burned in the combustion chamber before escaping to the environment.

3.4. Hottest Layer Position

From the two positions of the hottest layer that were varied in this study, it was found that the placement of the hottest layer at the top of the briquette pile was better in reducing the smoke emission than the placement of the hottest layer at the bottom. It was because when the hottest layer is at the top, the evolution of the volatile matters from the briquette will pass through and will be burned in the layer so that the smokes emission was not formed. Conversely, when the placement of the hottest layer is at the bottom of the briquette pile, the evolution of the volatile matters will escape to the environment without passing the hottest layer. As a result, a part of the volatile may be burned in the stove combustion chamber but others may be released to the environment as smoke.

Apart from being determined by the placement of the hottest layer position, smoke formation is also influenced by the stove design. The open stove system tends to produce more smoke than the stove with a closed system. This is because, in an open stove system, the evolution of volatile matters can leave the stove from many directions so that it does not always pass through the hottest layer of the stove. In addition, the hottest layer of an open stove system tends to have a lower temperature than a closed stove system, so it is not completely capable of burning the volatile matters that pass through it. The use of a semi-closed stove in this study gave a positive contribution to the absence of smoke. Even though the volatile matter content of the briquette used was slightly above the quality standard, but there is no smoke emission released from this combustion test.

3.5. Cooking Test Results of Beef Rendang Using Briquettes

The appearance of the dry beef rendang resulted from this study was shown in figure 5. From the two cooking rendang methods used here, it was obtained that the cooking time required for 2 kg of beef rendang, using the normal cooking method was ± 4 hours, while the cooking time required using the modified cooking method was about 3 hours. This happens because, in the normal cooking method, some time is sacrificed to produce oil from coconut milk after which the oil is associated with spices and beef [1]. Meanwhile, in the modified cooking method, the association of spices and meat is carried out using an external source of oil, so that this method requires less time. In terms of aroma and taste, the beef rendangs resulted from both of the cooking methods were similar, qualitatively. While, the protein and fatty acid contents of the beef rendangs resulted from both of the cooking methods need further investigation.



This study also revealed that the fuel consumption for cooking 2 kg of beef rendang by the modified cooking method was 1.5 kg of briquettes. While in the normal cooking method, the briquette consumed was 2.1 kg. If 1 kg of briquettes is priced at USD 0.24, then the fuel cost of 1 kg of beef rendang will be USD 0.18.

4. Conclusion

The cooking test of beef rendang using carbonized coal briquettes on a semi-closed moveable grate stove has been successfully carried out. Several results have been obtained, among them: (1) in general, the quality of the coal briquettes produced can meet the quality standards of fuel briquettes; both physically and chemically, (2) the initial ignition of coal briquettes, for both ignition materials, takes time between 10-15 minutes, (3) placing the hottest zone at the top of the briquette pile is more effective in reducing smoke emissions than placing it at the bottom, (4) using the briquettes as fuel in a semi-closed moveable grate stove did not emit smoke except during initial ignition, (5) cooking rendang using the modified cooking method was more efficient than that of the normal cooking method, (6) the quality of the beef rendangs resulted from both of the cooking methods needs further investigation, especially in terms of protein and fatty acid contents, (7) the length of time needed to cook 2 kg of beef rendang by the modified cooking method was 3 hours with a briquette consumption of ± 1.5 kg, and (8) if the price of the carbonized coal briquettes is USD 0.24 per kg, the fuel cost for cooking 1 kg of beef rendang is about USD 0.18. Finally, it could be concluded that cooking beef rendang using carbonized coal briquettes is safe and cheap.

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In 2007 he left UCL to become the Chief Executive Officer of the Engineering and Physical Sciences Research Council, stepping down in 2014. He was then Chair of the Defence Scientific Advisory Council from 2014 to 2017 and Chair of the Strategic Advisory Board for the UK National Quantum Technologies Programme from 2014 to 2019.

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Before joining IOP Publishing in 2018, Antonia worked for Wiley and before that Blackwell Publishing, in a number of Senior Executive roles managing portfolios in Science, Health, Social Science and Humanities across markets and product types.



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Tom Grinyer joined Institute of Physics in June 2022 as Group Chief Executive Officer. The IOP is the sixth membership organisation he has worked for in the past 25 years and the third as Chief Executive. He joined the IOP from the British Medical Association (BMA), where he was Group Chief Executive; during that time he led the organisation through the Covid-19 pandemic and restructured the BMA with a particular emphasis on membership engagement and experience.

Prior to moving to the BMA, Tom led the Royal College of Anaesthetists, which grew substantially under his leadership, and before this was Executive Director of Strategy, Communications and Policy at the Royal College of Physicians, England's oldest medical royal college, where he was also interim Chief Executive and introduced the organisation's first ever strategy in its 500-year history.



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Miriam is a member of the STM Board, the global industry body for scholarly communications and a Trustee for the New Phytologist Foundation, a not-for-profit organisation dedicated to promoting research in plant biology. In addition, she has served on Research4Life's Executive Council since 2019, advising on strategic and operational issues.



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Andy is a fellow of the CIPD, with 30 years of experience. His career has spanned HR leadership roles across several sectors internationally, including financial services, telecoms, technology and medical services in both private and not-for-profit organisations.



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Adam Sewell joined IOP Publishing in February 2023. He was previously Chief Technology Officer at Metropolis, a group that specialises in business and consumer media and discount programmes. Prior to joining Metropolis, he was Chief Information Officer at the Copyright Licensing Agency from 2012, and Associate Director for Business Systems at Nature Publishing Group from 2001. He began his career in IT at Lane Clark and Peacock, a firm of Consulting Actuaries. Adam has a BEng in Telecommunications from Queen Mary and Westfield, University of London.



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Julian Wilson joined IOP Publishing in October 2020 as Sales and Marketing Director.

He was previously at John Wiley & Sons Ltd where he spent 15 years and held a variety of senior sales positions. He has extensive experience of leading sales teams across a wide range of products and markets, most recently as Wiley's Europe, Middle East and Africa sales director responsible for library sales growth across the region.



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KitPing Au-Yeung has 28 years of global experience with different multinational corporations in the textile and hospitality industries. She has held various senior leadership positions, worked and lived in Hong Kong, China, Australia, the Philippines, Vietnam and the United Kingdom. KitPing has over two decades of board experiences as an executive and non-executive director for commercial and not-for-profit organisations.

She is an internationally certified Transformative and Results Coach, Neuro Change Practitioner, NLP Coach and Practitioner.

KitPing is now the Founder & CEO of UTransform Life and Business Limited, a purpose-driven organisation to inspire and support transformative changes in businesses and individuals.



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Philip Carpenter is a Board member and Adviser in the areas of Publishing and Higher Education. Besides his role as a Non-Executive Director of IOP Publishing, he is Pro-Chancellor of the University of York and a member of the University Council. In addition he advises the board of Kortext Ltd., the UK's leading digital platform for student learning materials.

Philip's most recent publishing experience was as Executive Vice President, Research at John Wiley, where he was responsible for the company's global journals publishing and for related digital services for the research community. Prior to this, he led Wiley's publishing for the Humanities and Social Sciences. He began his publishing career at Blackwell's, where he was Director, Academic and Science Books, prior to Wiley's acquisition of the company.



Phil Clarke, Independent Non-Executive Director

Phil Clarke is a Board member and Business advisor, working across several sectors. He is a Non-Executive Director at Riverford Organic Limited and an Independent Governor at De Montford University. Alongside these roles, Phil is also Business advisor to a number of smaller high growth businesses.

In his Executive career, Phil was Chief Operating Officer at The White Company responsible for Finance, I.T., Supply Chain and Business Change. He was also CFO at Ann Summers and Group CFO of the Selfridges Group.



Kersty Drinkwater, Independent Non-Executive Director

Kersty Drinkwater is an IOPP Board member and Business Advisor, and also sits on the IOP Audit and Risk Committee. Beyond her role as a Non-Executive for the IOPP and IOP, Kersty is the Group Director of Audit & Risk for Kingfisher plc, a FTSE 100 retail Group.

Her executive career includes roles in both professional services and industry. She has been a partner in PwC LLP and EY LLP advising organisations across a broad range of sectors on how to effectively identify, manage and assure their key risks. Previously she has held risk and audit senior leadership roles in BP and G4S.

Kersty also chairs the Audit, Risk and Remuneration Committee for St Peters College, Oxford. Prior to this she was a member of the Audit, Risk and Scrutiny Committee for Oxford University.



Martin Freer, IOP Vice President of Science and Innovation, Trustee Non-Executive Director

Professor Martin Freer is a nuclear physicist, and Director of the Birmingham Energy Institute (BEI) at the University of Birmingham. He is also Director of the Energy Research Accelerator (ERA), which comprises eight internationally-renowned Midlands universities which are part of the Midlands Innovation partnership, together with the British Geological Survey.

Martin is former Director of the Birmingham Centre for Nuclear Education and Research, which he established in 2010. He has overseen the development of the BEI, helped establish Energy Capital and has co-led the establishment of the joint University of Birmingham–Fraunhofer Germany research platform. He led the development of the Birmingham Energy Innovation Hub and the co-development of Tyseley Energy Park in Birmingham.

In 2015 he co-led the BEI Commission "Doing Cold Smarter" chaired by Lord Teverson, and in 2012 he led the Policy Commission "Future of Nuclear Energy in the UK" chaired by Lord Hunt, he co-led the Policy Commission with Sir David King which saw the creation of Energy Innovation Zone in the West Midlands and in 2020 published a report on The Road to Low-Carbon Heat with the CBI chaired by Lord Billimoria. His main research area is the study of the structure of light nuclei, using nuclear reactions. He received the Friedrich Wilhelm Bessel Prize, Humboldt Foundation, in 2004 and the Rutherford Medal in 2010



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Eefke Smit is Managing Director of the International Publishers Rights Organisation, which represents international STEM publishers in the collection and repartition of copyright fees. For many years she served as the Director of Standards and Technology for STM, the International Association of STM Publishers, to coordinate activities for STM members in the areas of technology developments and standards. Part of this were the annual STM Trends forecast, initiatives on research data, seamless access and authentication, Artificial Intelligence and Digital Preservation.

Eefke has been active in academic and professional publishing for more than 35 years (in physics, mathematics, computer science) and in electronic product development (Scopus, ScienceDirect). She holds a masters' degree in public administration and started her working life as a writer/ journalist on research and technology (in NRC Handelsblad).

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