Princess Sumaya جامعـــة
University الأميـــرة سميّـــة
for Technology للتكنولوجيا

Princess Sumaya University for Technology

Scientific Lecture:

Future Power Generation Scenarios: Grid requirements and Environmental Impact.

By:

Dr. Omar Mohamed (Associate Professor)

Presented in the Scientific Symposium:

Regional Interconnection Prospective

Organized By:

National Electric Power Co. (NEPCO)

About the presenter:
Dr. Omar Mohamed (Associate Professor)
Affiliation:
Princess Sumaya University for Technology
King Abdullah II School of Engineering
Electrical Engineering Department
Research focus: Modeling and Control of Energy Resources
Age: 39 years old.
Martial Status: Married and has three daughters.
h-index: 10
ResearchGate Score: 20.8

Princess Sumaya University for Technology
جامعة الأميرة سميّة للتكنولوجيا

Lecture outline

- Background.
- Common expected schemes for power generation in the future.
- **The first scheme**: The feasibility of 100% renewable framework.
- The arguments of the feasibility of 100% renewable framework.
- **The second scheme**: increased development of carbon capture and storage as a clean fossil technology with considerable share of renewables (mixed power generation scheme).
- Economical and physical justification of the mixed scheme.
- Brief description of carbon capture and storage systems.
- **The third scheme**: towards an increased nuclear generation which is largely CO2 free.
- Conclusion
- References
- Questions and discussion.

Background

- The world is facing the problems of sustainability and global warming. (global issue).
- These two problems have brought a common attention of increasing the renewable energy share into power grids worldwide.
- The emission of greenhouse gases (mainly CO2 and methane) from fossil fuel power plants is an essential cause for the climate change.
- Global warming is a situation of elevating the temperature of the lower atmosphere and the surface of the earth due to those undesired emissions.
- As CO2 and other gases pile in the atmosphere, these gases have caused temperatures to increase.

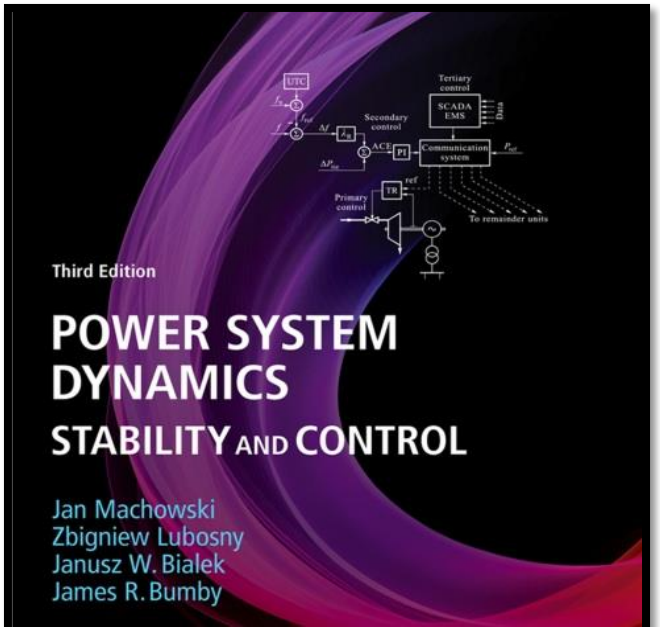
Common expected Solutions for power generation in the future.

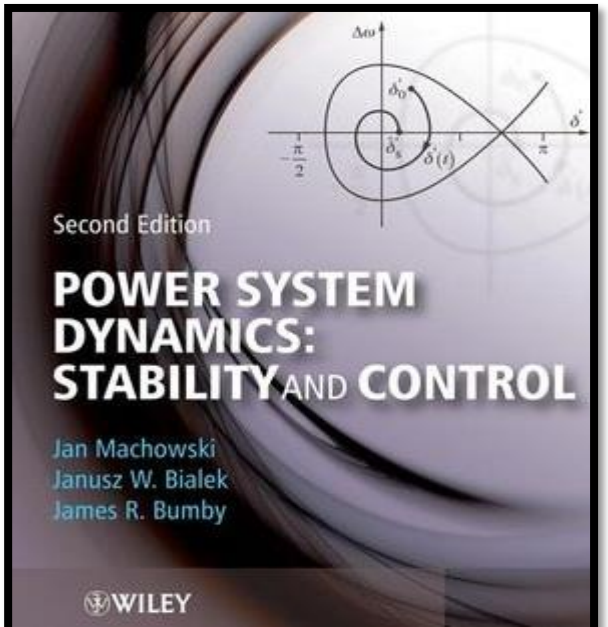
As mentioned in the previous slide, global warming and sustainability have brought considerable interest renewable generation. There are three main ways for future power generation for sustainable generation development and reduction of CO2 emissions [1]:

1. **By replacing the traditional coal/gas/oil-based generation to renewable generation (wind, solar, marine);**
2. **By increasing nuclear power production which is largely CO2-free.**
3. **By using mixed generation with conventional thermal power plants integrated with carbon capture and storage.**

We shall discuss these three scenarios one by one.

[1]

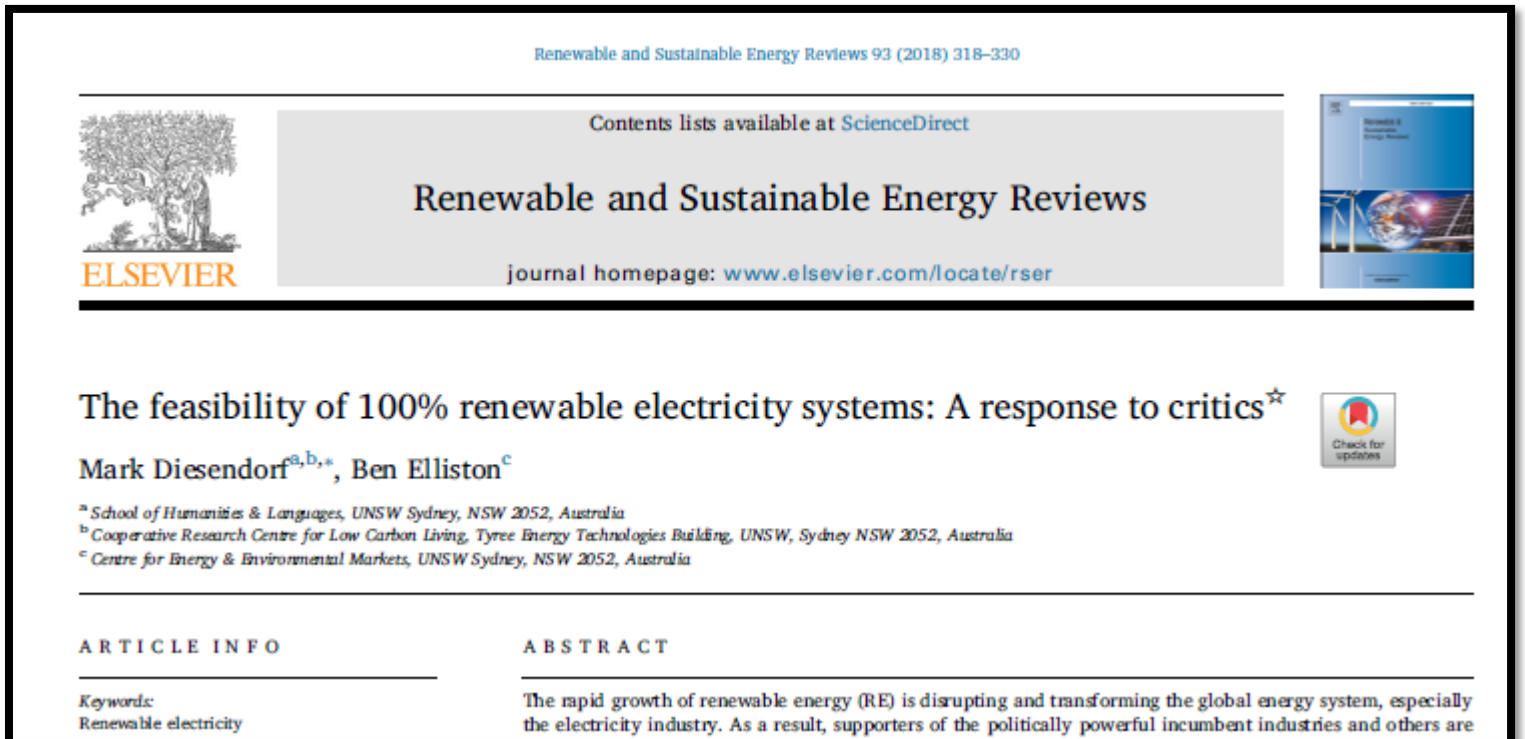




The first scheme: The feasibility of 100% renewable framework.

- There are many published articles, which presents a feasible scenarios for global or large regional 100% scenario.
- A sample paper from recognized journal/publisher could provide a strong and validated argument.
- The paper screen-shot below , reference [2] is discussed as an example

[2]



Renewable and Sustainable Energy Reviews 93 (2018) 318–330

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The feasibility of 100% renewable electricity systems: A response to critics☆

Mark Diesendorf[a,b,*], Ben Elliston[c]

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ARTICLE INFO

Keywords:
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ABSTRACT

The rapid growth of renewable energy (RE) is disrupting and transforming the global energy system, especially the electricity industry. As a result, supporters of the politically powerful incumbent industries and others are

The first scheme: The feasibility of 100% renewable framework.

- **The paper has concluded that the main barriers to 100% renewable energy coverage of load demand are neither technological nor economical, but instead are mainly political, institutional and cultural.**
- **The issue of security and stability of 100 renewable generation has been answered/argued in the paper that the RE systems is able to provide 'synthetic' inertia, because their outputs are integrated with power electronic devices such as inverters to control frequency and voltage before entering the grid.**
- However, it is known that synthetic inertia is very small in comparison to that in thermal units of the heavy rotating mass supplied by huge boilers in thermal power stations, which makes the issue of stability still questionable and not fully answered in that paper.

Information Source: Mark Diesendorf, Ben Elliston. The feasibility of 100% renewable electricity systems: A response to critics. *Renewable and Sustainable Energy Reviews,* Volume 93, 2018, Pages 318-330,

The first scheme: The feasibility of 100% renewable framework.

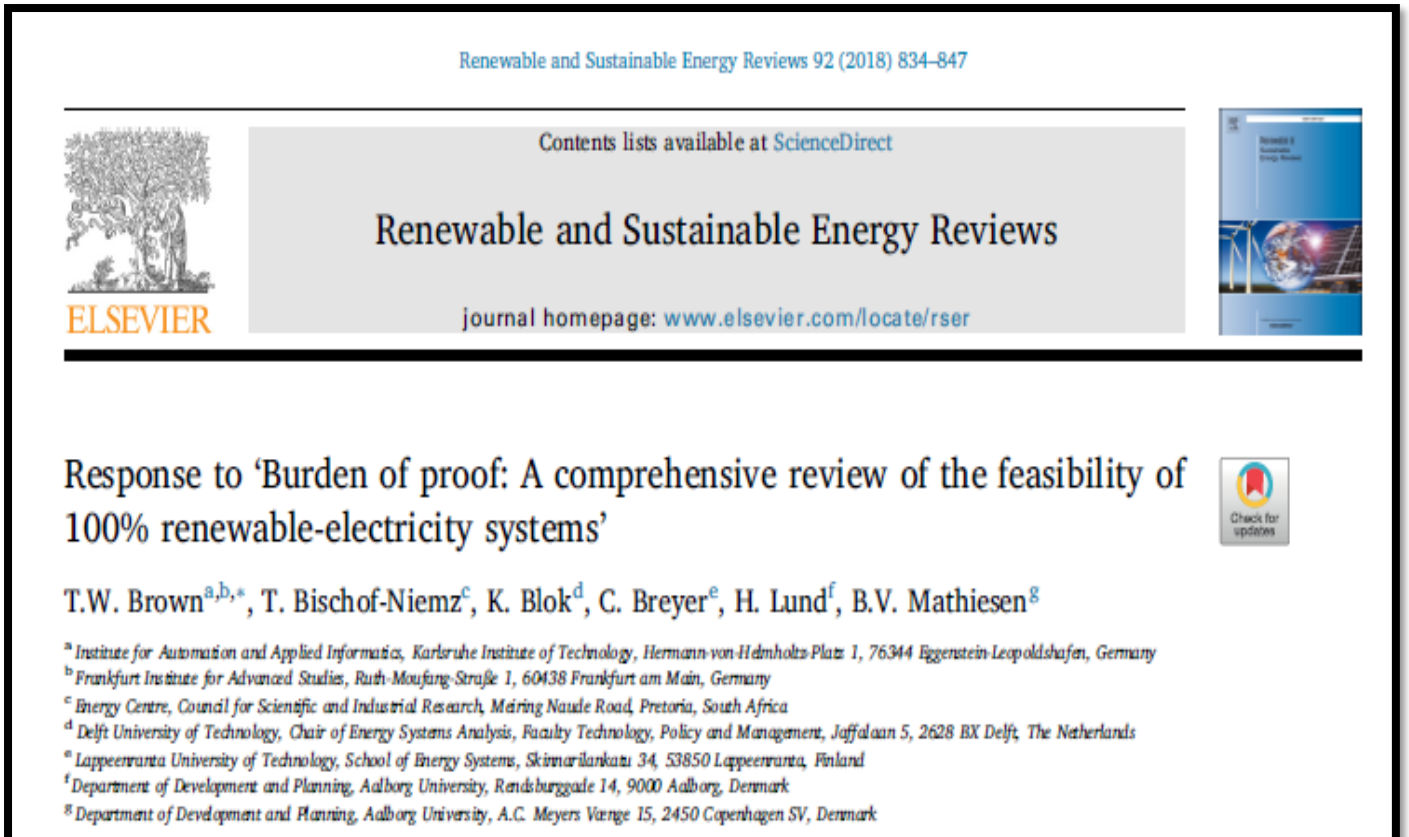
- It can be however better answered with the capability hydro-units, which are generally renewable resource, instead of synthetic inertia solution, which is still not widespread and very small in comparison to the natural inertia of conventional and hydraulic sources .
- As concepts, the security is wider than stability and they are regarded as if they are the same problem in the paper.

Information Source: Mark Diesendorf, Ben Elliston. The feasibility of 100% renewable electricity systems: A response to critics. *Renewable and Sustainable Energy Reviews,* Volume 93, 2018, Pages 318-330,

The first scheme: The feasibility of 100% renewable framework.

- **Other highly accessed and cited article reports a comprehensive review for the feasibility of 100% RE as a response to another article with opposite view.**
- **The article with screenshot below provides a thorough review to prove that Res are not only feasible, but already economically viable and decreasing in cost every year.**

[3]



Renewable and Sustainable Energy Reviews 92 (2018) 834–847

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Response to 'Burden of proof: A comprehensive review of the feasibility of 100% renewable-electricity systems'

T.W. Brown[a,b,*], T. Bischof-Niemz[c], K. Blok[d], C. Breyer[e], H. Lund[f], B.V. Mathiesen[g]

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The first scheme: The feasibility of 100% renewable framework.

- ***Countries already at or close to 100% RE.***
- **Paraguay (99%), Norway (97%), Uruguay (95%), Costa Rica (93%), Brazil (76%) and Canada (62%).**
- **However, the main reason is the abundance of hydraulic generation capacity, either within the grid or through strong interconnection with neighboring countries. Hydraulic is generally flexible and dispatchable, but very limited in the Arabic Country.**

[3]

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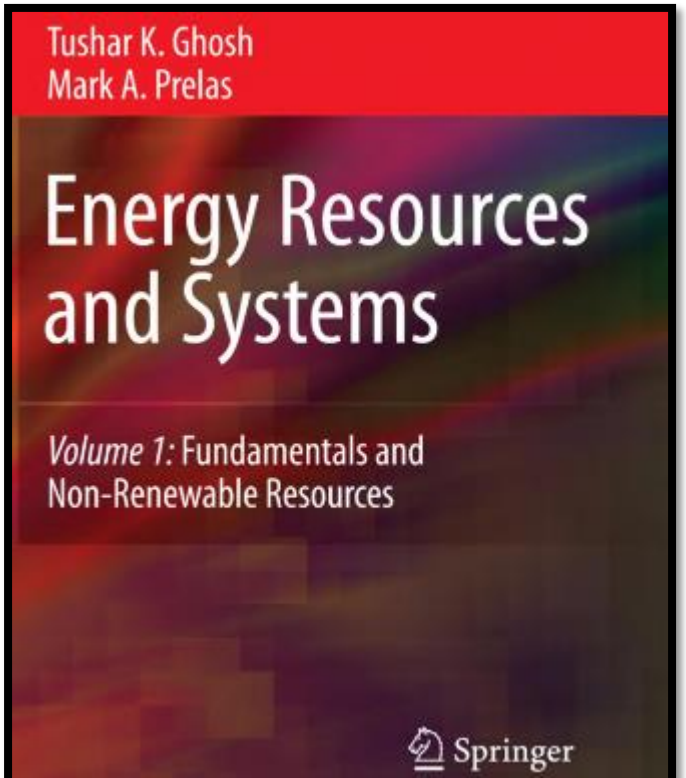
The second scheme: Towards increased development of carbon capture and storage as a clean fossil technology with considerable share of renewables (mixed power generation scheme).

- To guarantee wider range power system stability and security on the long run, fossil-fueled are still unavoidable.
- In this scheme some researchers argue that REs alone are unable to cover the huge energy demand due to their lower energy density.
- This force a major change in power system structure to move renewables from generation to distributed or embedded generation.
- Due to those technical and physical reasons, fossil or thermal power plants are still indispensable globally and also locally in the Arab world.
- However, fossil fuel units must be cleaner.

The second scheme: Towards increased development of carbon capture and storage as a clean fossil technology with considerable share of renewables (mixed power generation scheme).

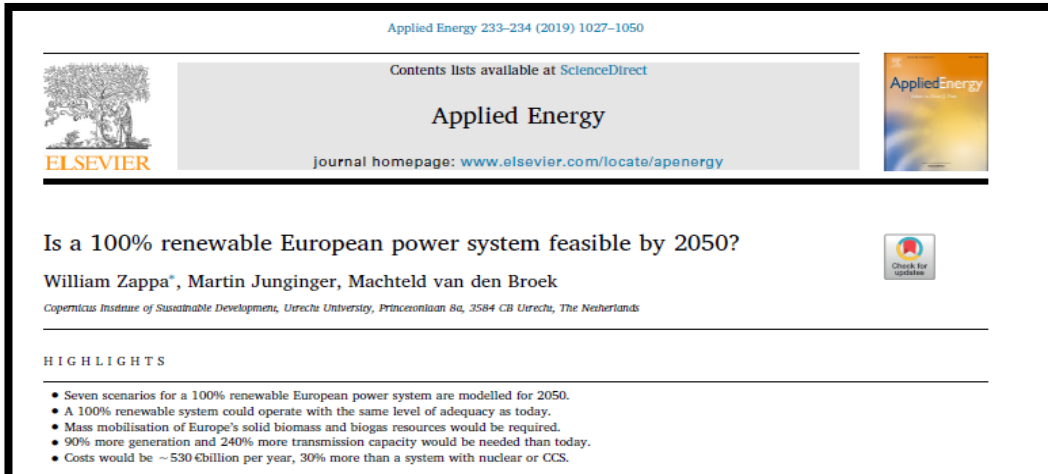
- Clean fossil technologies can be divided into two classifications: Energy efficiency improvement method and emission capture/control method [4].

[4]



The second scheme: Towards increased development of carbon capture and storage as a clean fossil technology with considerable share of renewables (mixed power generation scheme).

- The economical and physical justifications of this scenario.
- One of the most salient arguments I found in this paper that studies the European Power system feasibility to 100% renewable.
- **Keeping in mind that European power system is much advanced economically and technically than the power systems feeding the Arabian region.**
- **Nevertheless, About 120 billion € increased cost to 100% coverage of the European grid.**
- **Cross-border transmission capacity at least 140GW higher than current levels.**
- **The target of 100% RE can be more difficult in our local network**



Applied Energy 233–234 (2019) 1027–1050

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Is a 100% renewable European power system feasible by 2050?

William Zappa*, Martin Junginger, Machteld van den Broek

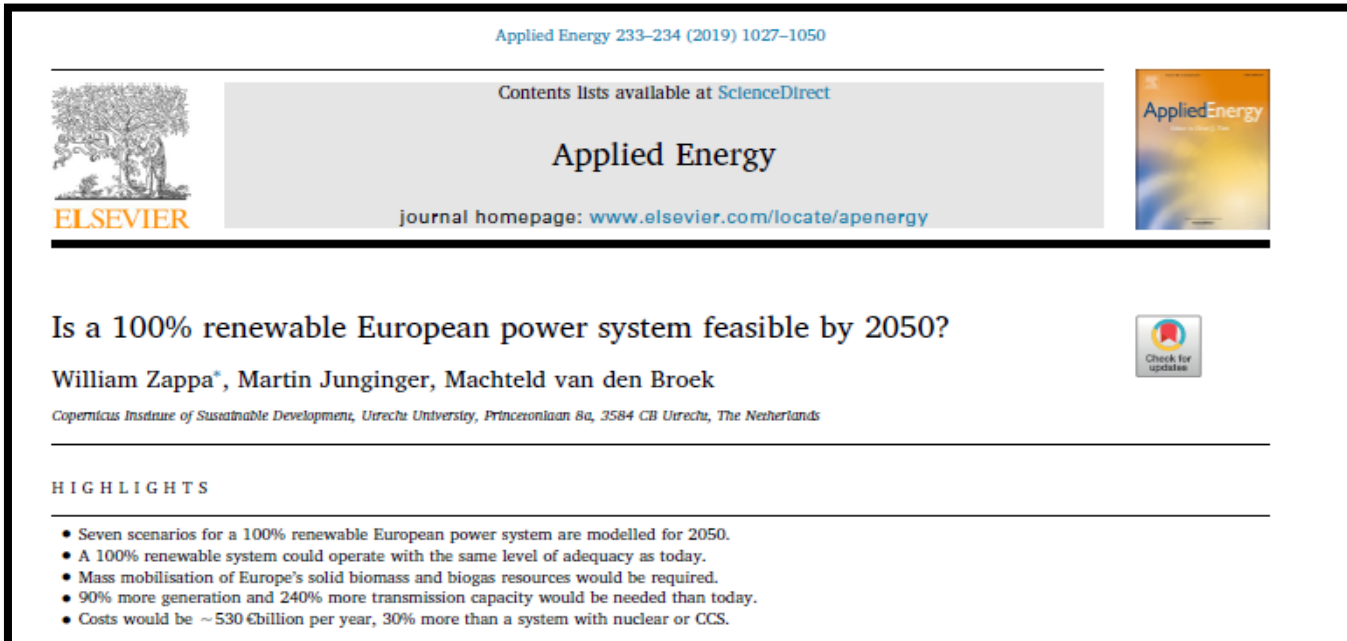
Copernicus Institute of Sustainable Development, Utrecht University, Princetonlaan 8a, 3584 CB Utrecht, The Netherlands

HIGHLIGHTS

- Seven scenarios for a 100% renewable European power system are modelled for 2050.
- A 100% renewable system could operate with the same level of adequacy as today.
- Mass mobilisation of Europe's solid biomass and biogas resources would be required.
- 90% more generation and 240% more transmission capacity would be needed than today.
- Costs would be ~530 €billion per year, 30% more than a system with nuclear or CCS.

The second scheme: Towards increased development of carbon capture and storage as a clean fossil technology with considerable share of renewables (mixed power generation scheme).

- *The paper doesn't study the possibility of 100% for Europe in 2050, but just introduced the economical and physical consequences.*
- **Another argument is that the responses of REs alone for transient stability are not precisely realized.**
- **Most feasibility studies of 100% REs studies focus on system adequacy, NOT security of the network. .**



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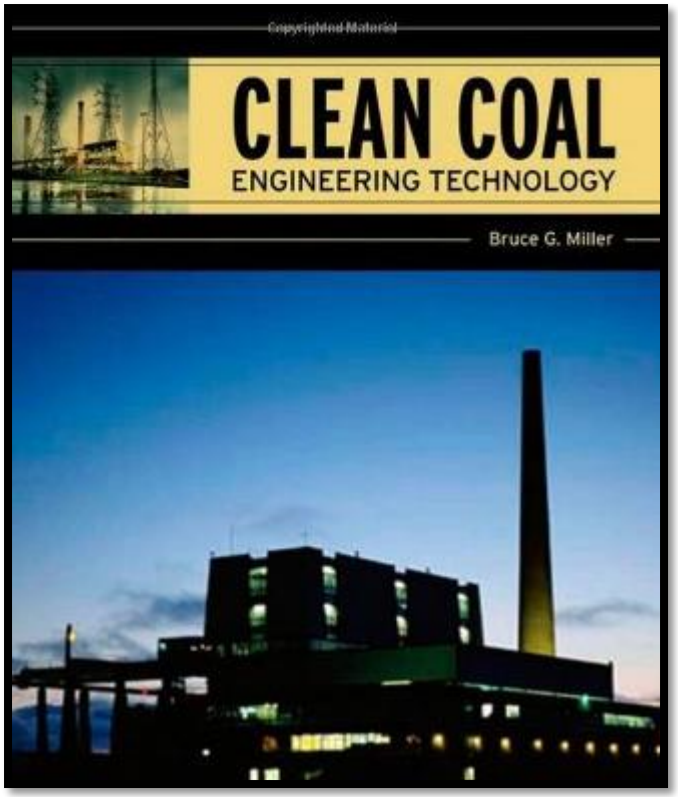
The second scheme: Towards increased development of carbon capture and storage as a clean fossil technology with considerable share of renewables (mixed power generation scheme).

- One method for clean-fossil technologies is CO2 capture and storage.
- A way to reduce CO2 concentration.

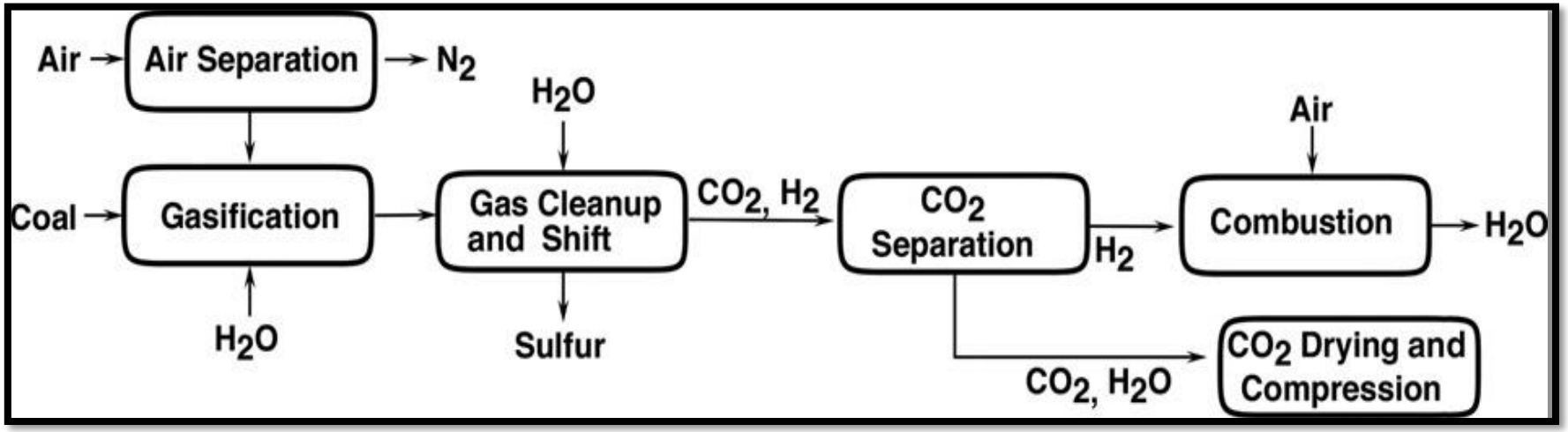
[6]



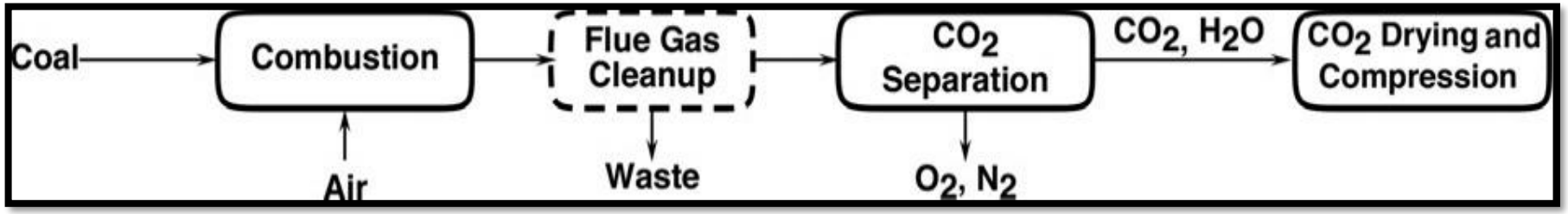
The second scheme: Towards increased development of carbon capture and storage as a clean fossil technology with considerable share of renewables (mixed power generation scheme).

- **CO2 capture methods** [6]

1- Pre-combustion CO2 capture



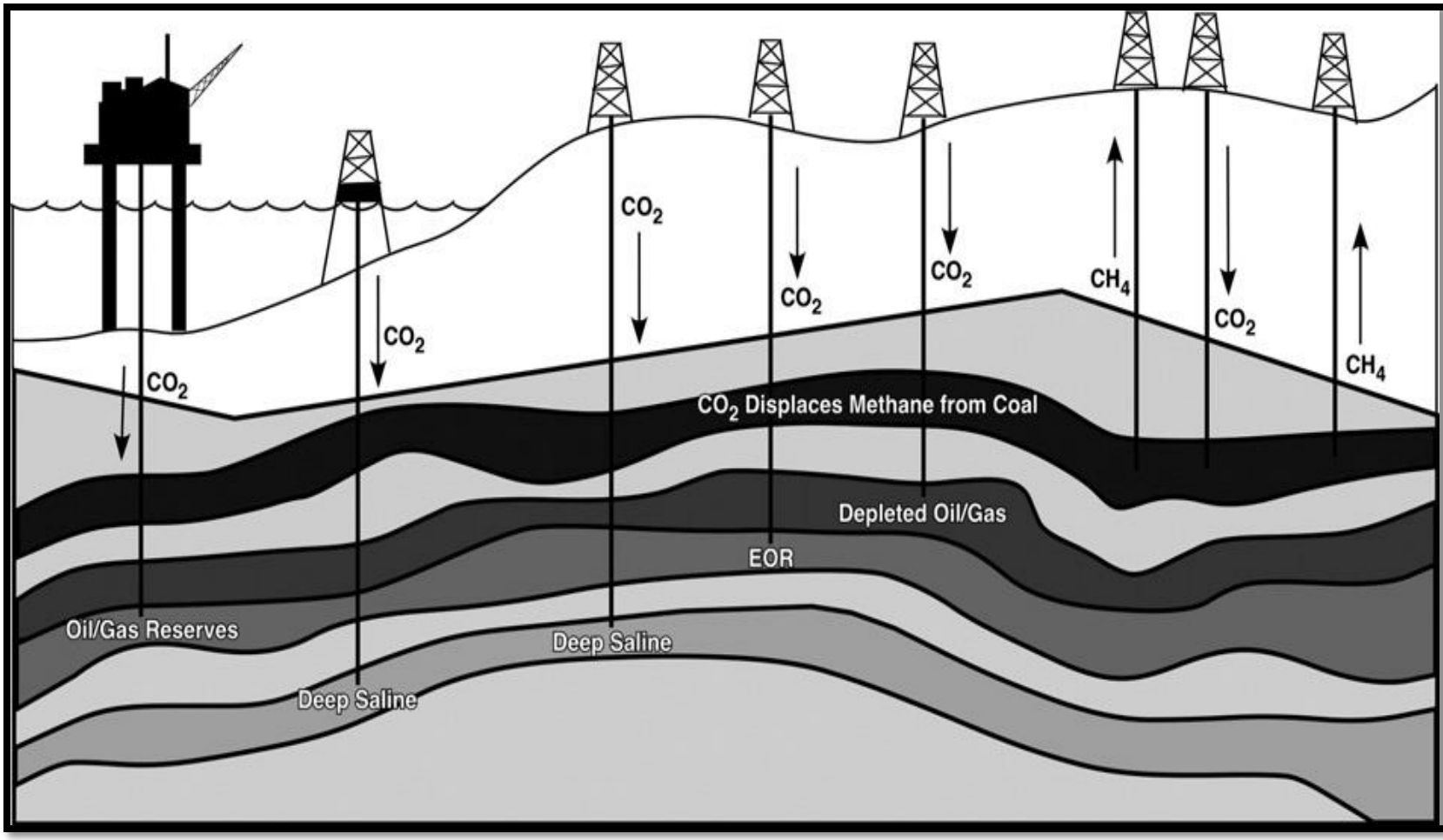
2- Post-combustion CO2 capture



The second scheme: Towards increased development of carbon capture and storage as a clean fossil technology with considerable share of renewables (mixed power generation scheme).

- CO2 storage (geological storage)

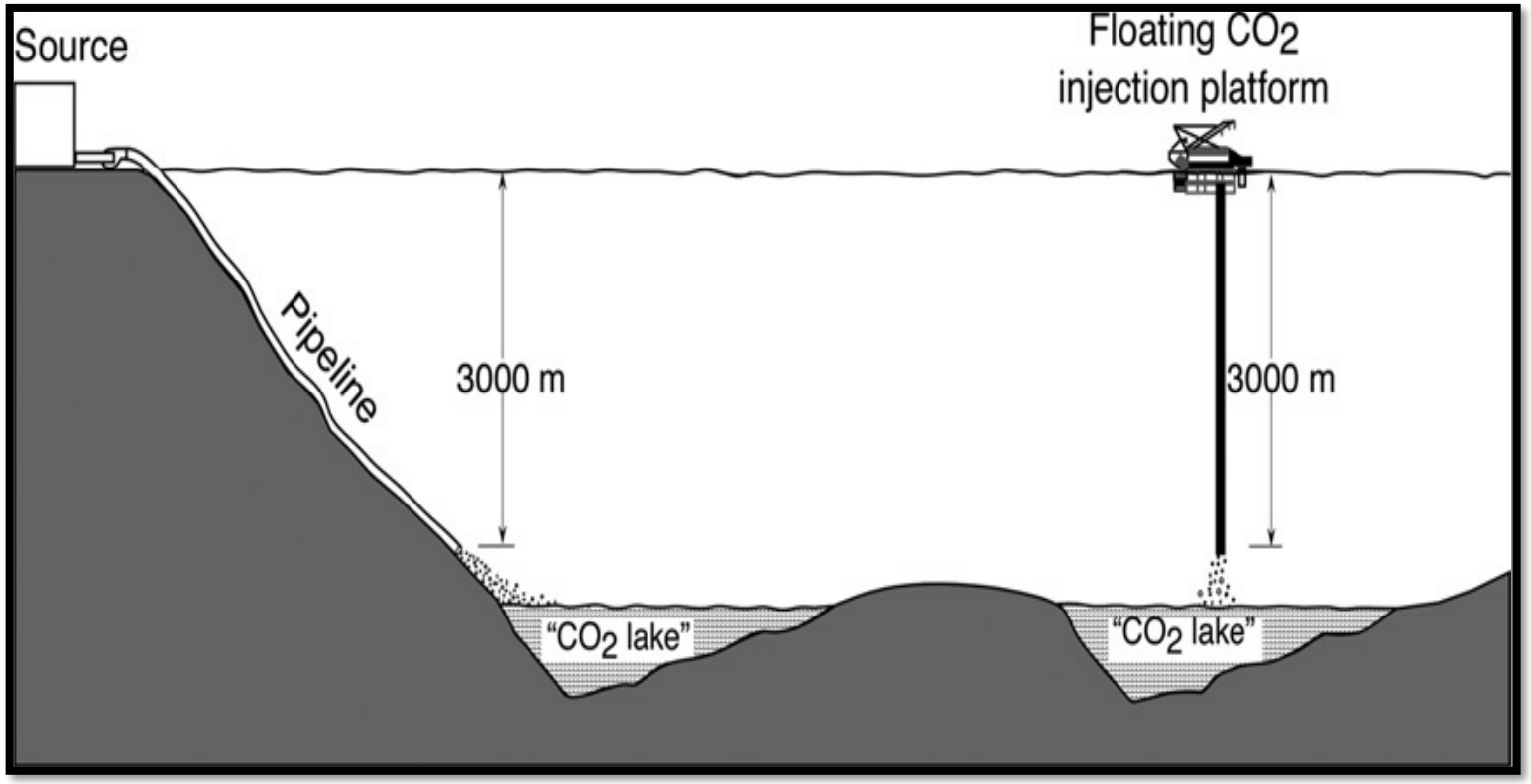
[6]



The second scheme: Towards increased development of carbon capture and storage as a clean fossil technology with considerable share of renewables (mixed power generation scheme).

- CO2 storage (ocean storage)

[6]



- **Ocean storage might be more suitable for the Mediterranean Sea than the red sea due to the depth. (lower than 3000 m in case of the red sea)**

The second scheme: Towards increased development of carbon capture and storage as a clean fossil technology with considerable share of renewables (mixed power generation scheme).

- **The second method is Energy Efficiency Improvements methods**
- This includes:

1- supercritical technology **(the most suitable and some of them already exist in Egypt, Saudi Arabia, and UAE). (adopted for coal, gas, or oil)**

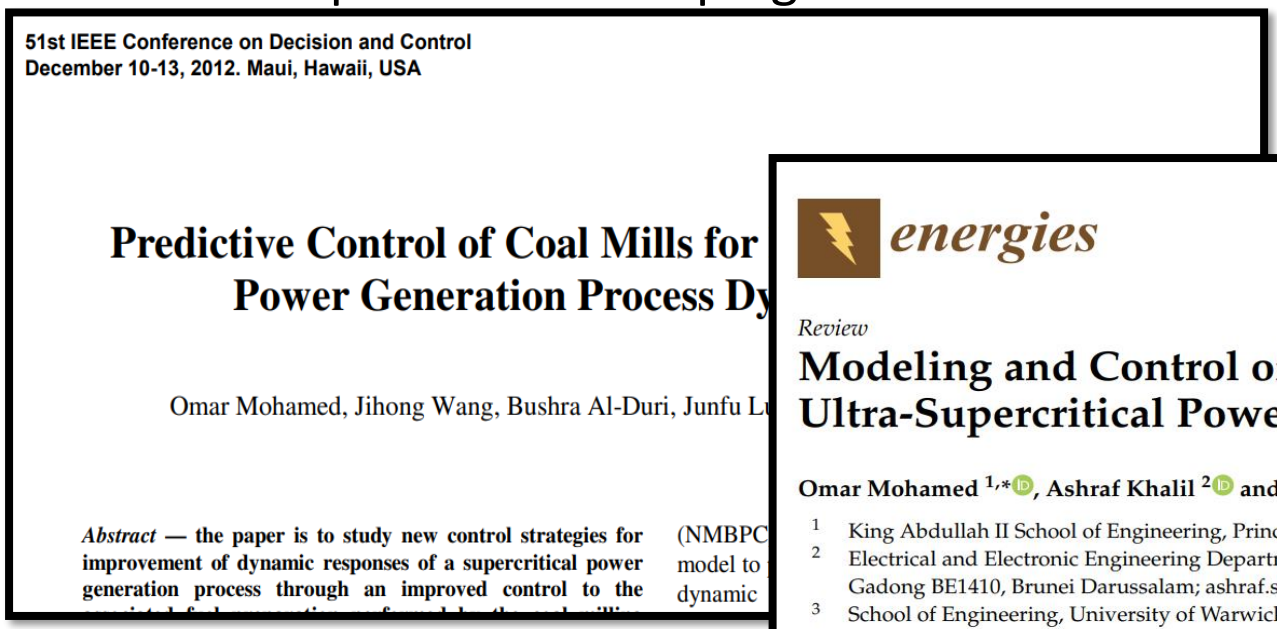
2- coal gasification.

3- Fluidized bed combustion.

- We will discuss the first one.
- Supercritical means above critical point of pressure and temperature.
- Higher thermal energy can be harvested from the boiler.
- **10% improvements in efficiency means 25% reduction in CO2 emissions and substantial fuel savings.**
- The system will be more complicated to control because it will introduce another control system objective, which is preserving the supercritical conditions inside the boiler

The second scheme: Towards increased development of carbon capture and storage as a clean fossil technology with considerable share of renewables (mixed power generation scheme).

- Chemical engineering methods are not the only way to improve the efficiency.
- In Power Engineering, Modeling and control methods can be also viable solution.
- These technologies are still dominant technology for many developed and developing countries.


51st IEEE Conference on Decision and Control
December 10-13, 2012. Maui, Hawaii, USA

Predictive Control of Coal Mills for
Power Generation Process Dy

Omar Mohamed, Jihong Wang, Bushra Al-Duri, Junfu Lu

Abstract — **the paper is to study new control strategies for improvement of dynamic responses of a supercritical power generation process through an improved control to the**

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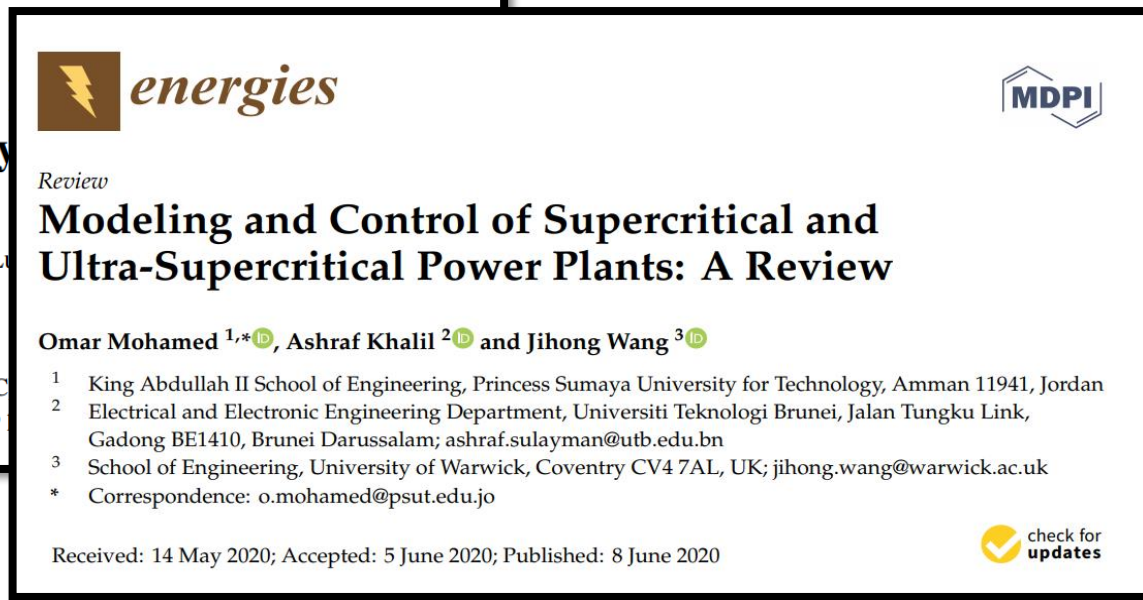
energies

MDPI

Review

Modeling and Control of Supercritical and Ultra-Supercritical Power Plants: A Review

Omar Mohamed [1,*], Ashraf Khalil [2] and Jihong Wang [3]

1 King Abdullah II School of Engineering, Princess Sumaya University for Technology, Amman 11941, Jordan
2 Electrical and Electronic Engineering Department, Universiti Teknologi Brunei, Jalan Tungku Link, Gadong BE1410, Brunei Darussalam; ashraf.sulayman@utb.edu.bn
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The second scheme discussion:

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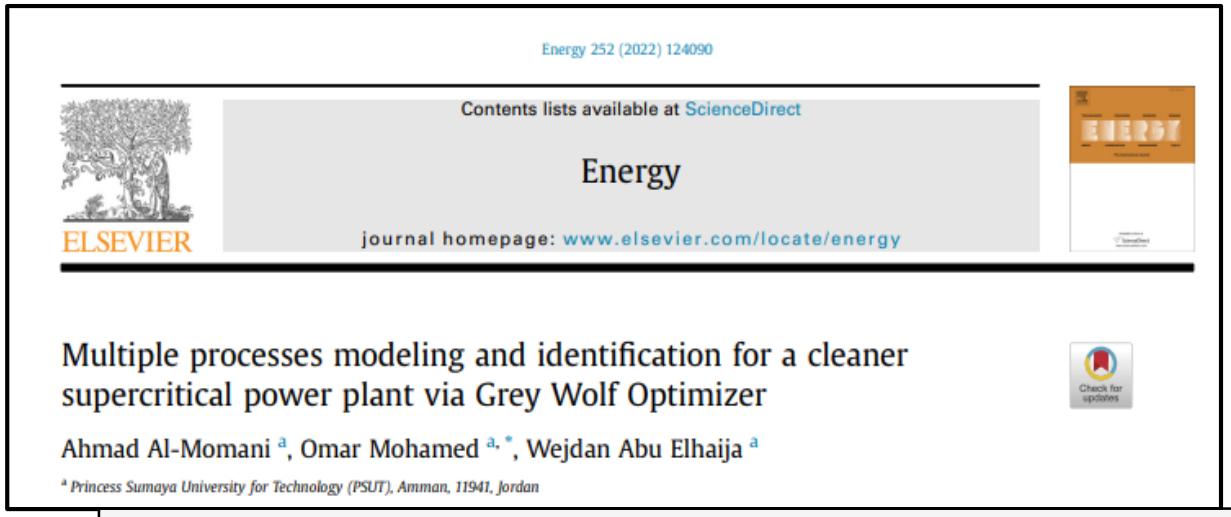


Energy 252 (2022) 124090

Contents lists available at ScienceDirect

Energy

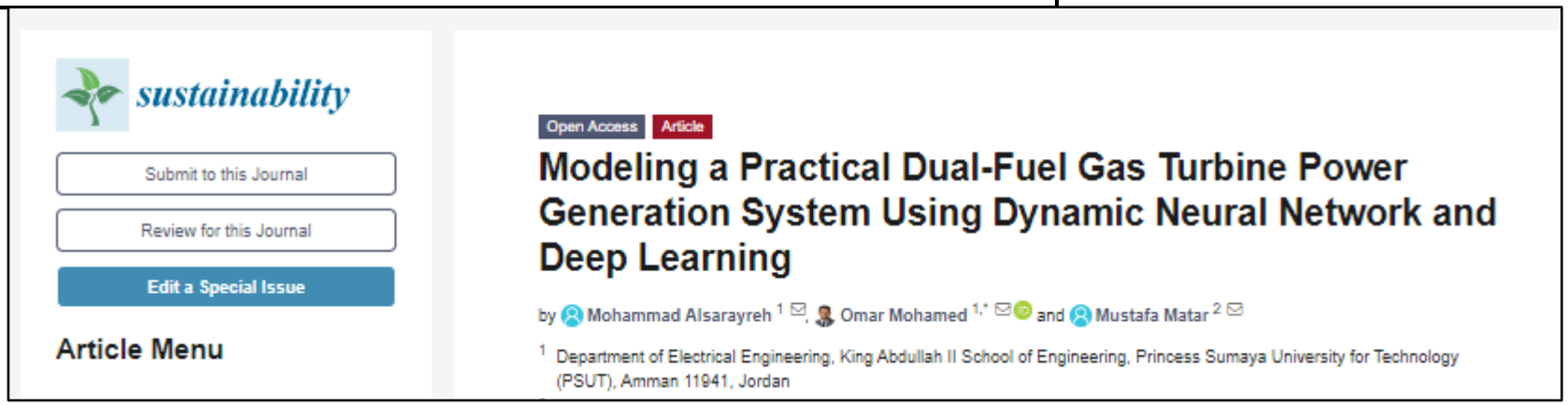
journal homepage: www.elsevier.com/locate/energy

ELSEVIER

Multiple processes modeling and identification for a cleaner supercritical power plant via Grey Wolf Optimizer

Ahmad Al-Momani [a], Omar Mohamed [a, *], Wejdan Abu Elhaija [a]

[a] Princess Sumaya University for Technology (PSUT), Amman, 11941, Jordan



sustainability

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Modeling a Practical Dual-Fuel Gas Turbine Power Generation System Using Dynamic Neural Network and Deep Learning

by Mohammad Alsarayreh [1], Omar Mohamed [1,*] and Mustafa Matar [2]

[1] Department of Electrical Engineering, King Abdullah II School of Engineering, Princess Sumaya University for Technology (PSUT), Amman 11941, Jordan

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Journal of Cleaner Production 326 (2021) 129323

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Parameter identification of a highly promising cleaner coal power station

Amal Haddad [a], Omar Mohamed [a,*], Mustafa Zahlan [a], Jihong Wang [b]

Process Integration and Optimization for Sustainability
https://doi.org/10.1007/s41660-022-00243-5

ORIGINAL RESEARCH PAPER

Speeding-up Startup Process of a Clean Coal Supercritical Power Generation Station via Classical Model Predictive Control

Omar Abu Znad[1] · Omar Mohamed[1] · Wejdan Abu Elhaija[1]

Springer

Received: 21 February 2022 / Revised: 22 March 2022 / Accepted: 28 March 2022

The third scheme: Increasing the share of Nuclear Power Plants

- Nuclear power plants are largely CO2 free.
- There are considerable arguments for their sustainability.
- Retain the conventional structure of the power system.
- However, there are not flexible for power demand variation because the thermal energy is given by nuclear reactor instead of boiler.
- They are more suitable for base load operation.
- Radioactive waste storage. .

The third scheme: Increasing the share of Nuclear Power Plants

- Regarding flexibility, there are some original attempts to make nuclear generation flexible.
- The paper below introduces a new method based on a novel mixed integer linear programming formulation to widen the technical operating constraints of nuclear generation more precisely, Including impacts of transients in the reactor core.
- It has been then integrated with unit commitment and economic dispatch problem of power system.
- The study is limited to simulation.
- No practical satisfaction to the issue of flexibility.

Applied Energy 222 (2018) 872–884

Contents lists available at ScienceDirect

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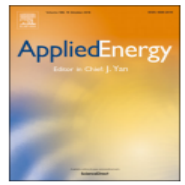
journal homepage: www.elsevier.com/locate/apenergy



The benefits of nuclear flexibility in power system operations with renewable energy

J.D. Jenkins[a], Z. Zhou[b], R. Ponciroli[c], R.B. Vilim[c], F. Ganda[c], F. de Sisternes[d], A. Botterud[b,e,*]

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[e] The Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

Conclusion

- It shouldn't be the question of which year the 100% RE would be possible.
- Instead, the scientific merit of each of the three scenarios are discussed.
- The main purpose is that to provide feasible and healthy alternatives of the generation scenarios in case of not reaching the target of 100%.
- Thereby keeping the development in all generation technologies to do just that.
- The subjective target should be the continuity of electricity service (security & stability) as well as minimum cost of production, which can be achieved by all generation technologies together.
- In the Arabian power network, the concentrated solar power (CSP) power plants should be an essential technology towards the feasibility of 100% in the light of stability of the grid and continuity of service.
- However, the difference in currency between Arabian states and differences in the prices kW·h is also a common barrier.

Conclusion

- **Even by simple mathematical optimization of the Arabian grid, it will be very beneficial economically to have the same price and currency for the resources to be profitable.**
- **Since biogas and natural gas can be fired in the same device (the gas turbine or GT), it can be attractive solution beside solar in order to provide the required adequacy security ancillary services.**
- **Combined cycle power plant with supercritical HRSG can be a clear target to save substantial amounts of fuel**

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Thank you.

Any Questions?