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Document Control Sheet

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

1 EXECUTIVE SUMMARY

The specific objectives are to:

1. Identify the potential hazards associated with the gasifier installation.
2. Perform a systematic risk analysis and assessment of the installation.

The identification of significant hazards associated with the BLAZE project is carried out through HAZID and HAZOP workshops, that are structured review techniques for the early identification of significant hazards associated with the biomass gasification, GCU and SOFC plant. They have been performed considering the BLAZE pilot plant configuration.

The workshops have been carried out with the participation of all the BLAZE project team (Enereco, EPFL, HyGear, Solid Power, USGM, UNIVAQ and Walter Tosto).

A table has been prepared to show the human risks (the risks to which the personnel involved in the plant's activities are exposed), the major risks with related consequences and potential recovery measures (Table 2).

A second table is provided to show the major environmental aspects and hazards associated with the operation of the biomass gasification plant (Table 3).

Finally, the details of the existing control measures and documentation meant to minimize any potential risk caused by the health and safety hazards for each unit have been investigated.

2 INTRODUCTION

2.1 Objectives and scope of the document

The main objective of this task is to identify the hazardous conditions for people, asset and environment associated with BLAZE pilot / commercial plant design and operation and propose corrective measures to reduce the risk as low as reasonably practicable.

The HSS considers both processes and final products/end users' issues. It addresses the knowledge and understanding of health and safety issues related to the gasification process and installation and the SOFC technology, which might potentially affect people close to the system and the infrastructure. The main work consists in studying all the working aspects which could cause damage to workers, including specific surveys to industrial installation experts (starting from WT) and partners running real environment tests in BLAZE (HyGear). The HSS covers the following methodology:

- Identify existing hazards for each unit.
- Identify the risk levels and consequences.
- Propose collective and individual correcting measures.

This study includes: involved equipment, chemical products, emissions and other aspects that might occur during the project. Results of the emission monitoring have been compared with the current regulated values which have also been identified, to prevent health problems for the workers and potential risks due to an explosive environment. The outcome from this study is a health and safety evaluation and inputs for the assessment of risks in matter of H&S issues.

For the BLAZE pilot plant design, HAZID and HAZOP workshops have been carried out to outline additional guidelines for a safer design and operation, also applicable to the commercial scale plant.

2.2 Structure of the deliverable

The specific objectives are:

- Identify the potential hazards associated with the gasifier installation;
- Perform a systematic risk analysis and assessment of the installation.

Each part of the gasification plant creates specific occupational, health and safety hazards. The risk reduction measures or decisions help in reduction of severity and frequency of the potential hazardous events and their consequences. These countermeasures have been classified into:

- Risk elimination measures;
- Risk mitigation measures;
- Risk acceptance and transfer.

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3 PROJECT DESCRIPTION

Gasification of biomass is a very promising process to produce energy from agricultural and woody waste materials, but the main pollutants produced during the process, tar and particulate, have to be removed from the product syngas in order to make it exploitable.

The goal of BLAZE plant is to convert biomass waste at high efficiency into electrical and thermal energy. The plant is aimed to mainly work at nominal conditions (maximum power), even though other conditions may be desirable and possible, in the case the BLAZE plant is used as a flexible plant supporting grid balancing.

The nominal conditions of the BLAZE plant are:

- Biomass type: hazelnut shell;
- Gasification temperature: 800 °C;
- Combustor temperature: 930 - 950 °C;
- Steam to biomass ration (S/B) = 0.75;
- Fuel utilisation (FU) = 0.6;
- SOFC power output 25 kW.

The 100 kWth DBFBG produces approximately 31 kg/h of relatively clean syngas (~20 kg/h of biomass + ~15 kg/h of steam) with a high calorific value, at high temperature. About half of the syngas produced by the gasifier will be sent to the SOFC to produce electricity.

The connection among DBFBG and SOFC can be made at high temperatures; however, the syngas stream after the gasifier will have to be cooled down to the gas cleaning units (GCU) temperature, which are important to secure the long-lasting functioning of the fuel cell.

BLAZE plant combines components from already known technologies (gasification, hot gas cleaning / conditioning and SOFC) with more novel concepts, like turbofan that uses the pressurized steam to suck the syngas from gasifier to send to the fuel cell.

The project benefits from already existing facilities, the DBFBG of 100 kWth, and from the experience gained during the execution of the EU CH2P project in the conception and construction of a 25 kWe SOFC. The syngas produced excesses the SOFC needs; therefore, the syngas that is not used in the SOFC will be burnt (in the pilot plant).

The following figure summarises the BLAZE plant concept: different biomass waste types feed the gasifier, producing the syngas that is sent to the GCU or to the burner.

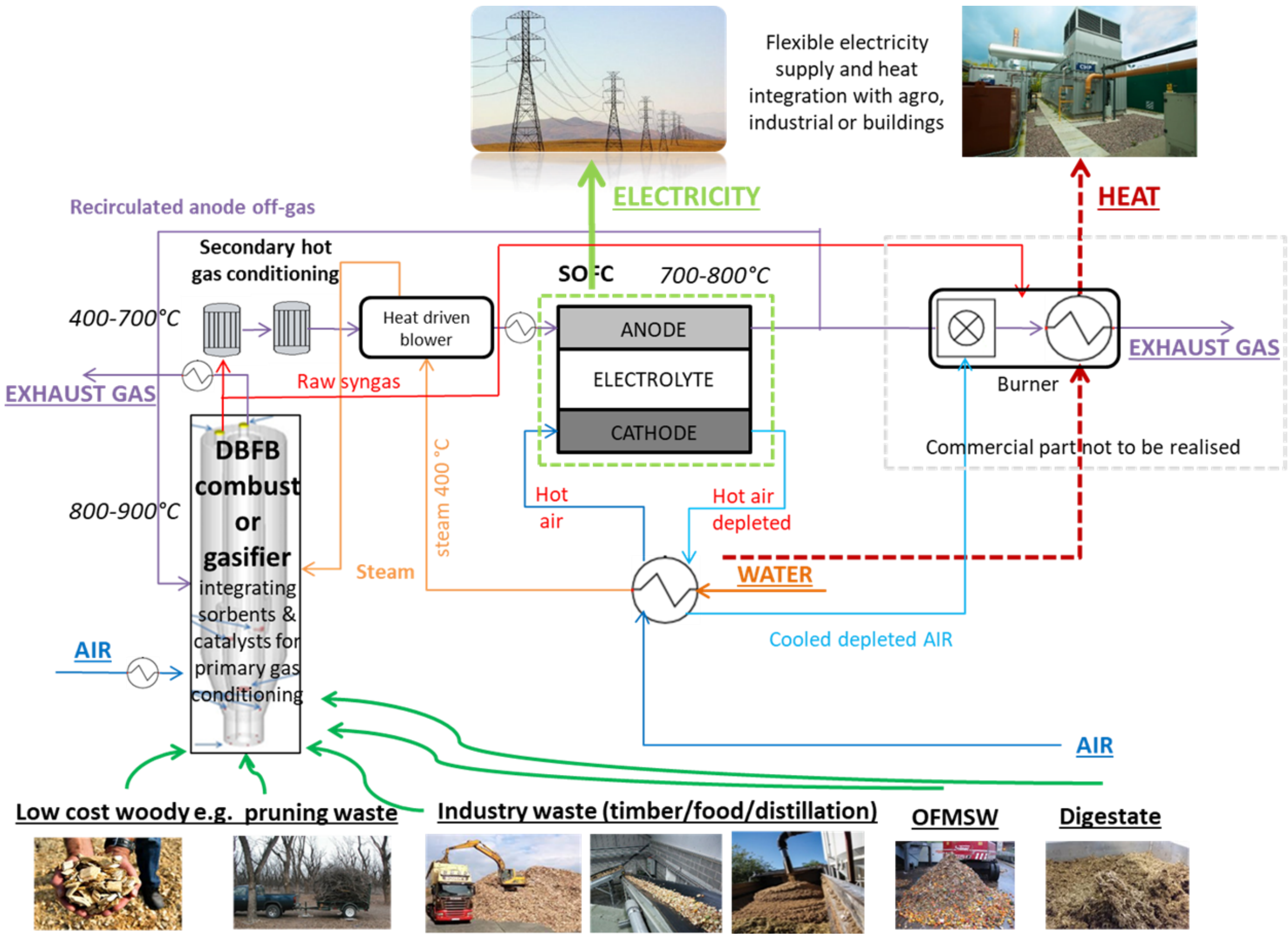

Figure 1 -

The cleaned syngas goes to the SOFC by means of turbofan that increase the pressure of the syngas.

Both, the gasifier and the turbo fan unit need steam. This steam is generated within the plant and, if excess heat is still available, it can be provided to agricultural or industrial partners, or building.

Combustor and AOG exhausted flue gases are the heat sources. Steam (for gasifier and blower) and air for combustor and cathode SOFC are the heat sinks.

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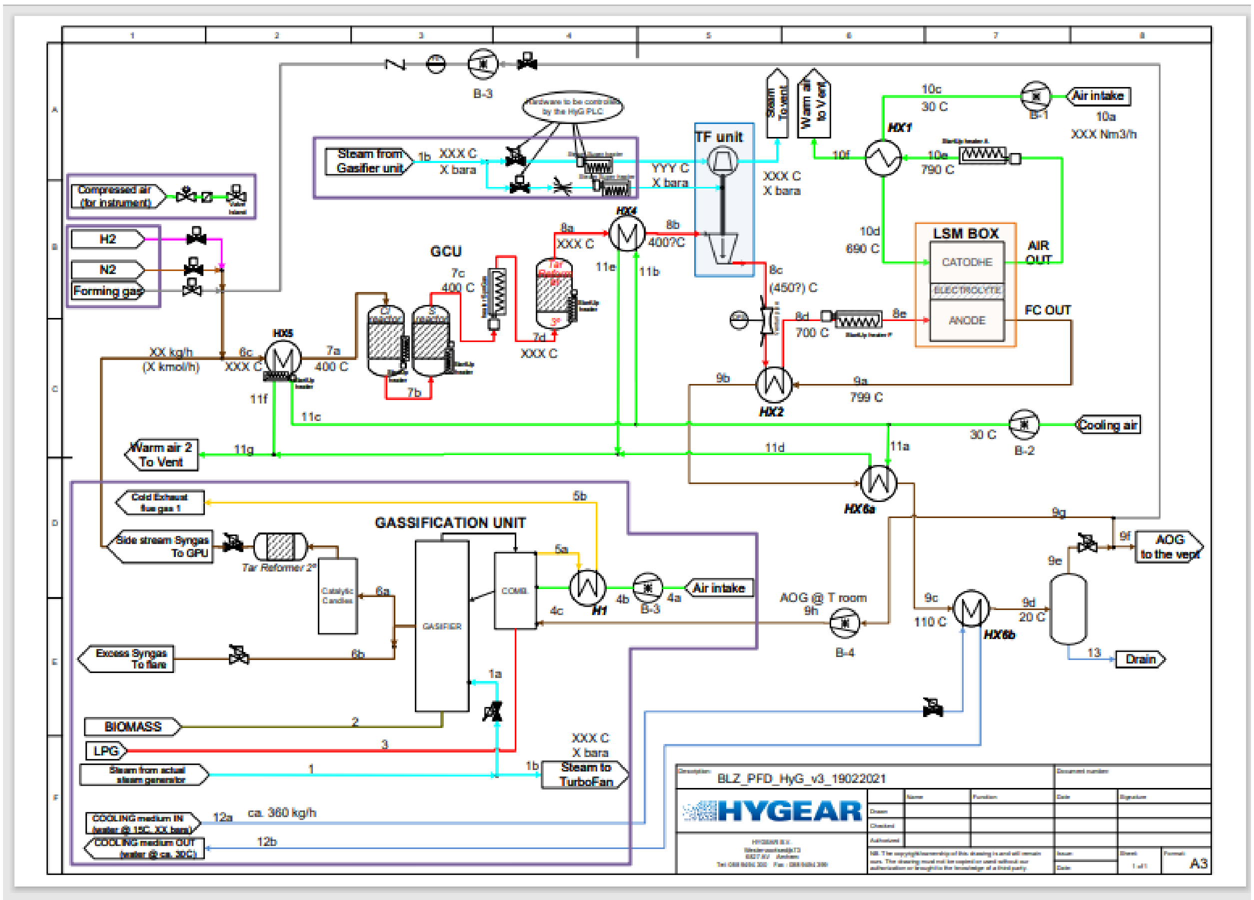

Figure 2 – PFD of pilot plant

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4 RISK IDENTIFICATION

Risk elimination measures aim at setting procedures that completely eliminate a previously identified risk. Risk elimination can be achieved through a series of planned steps over a period of time designed to gradually reduce, or mitigate, the risk or hazard to a point where it is eventually eliminated. Risk mitigation is achieved in the same way as risk elimination; in this case, instead of completely eliminating the hazard, decisions are made to implement applied selected countermeasures that reduce the risk to a safe and acceptable level by either reducing its likelihood, or lowering the consequence of the risk if it were to exist.

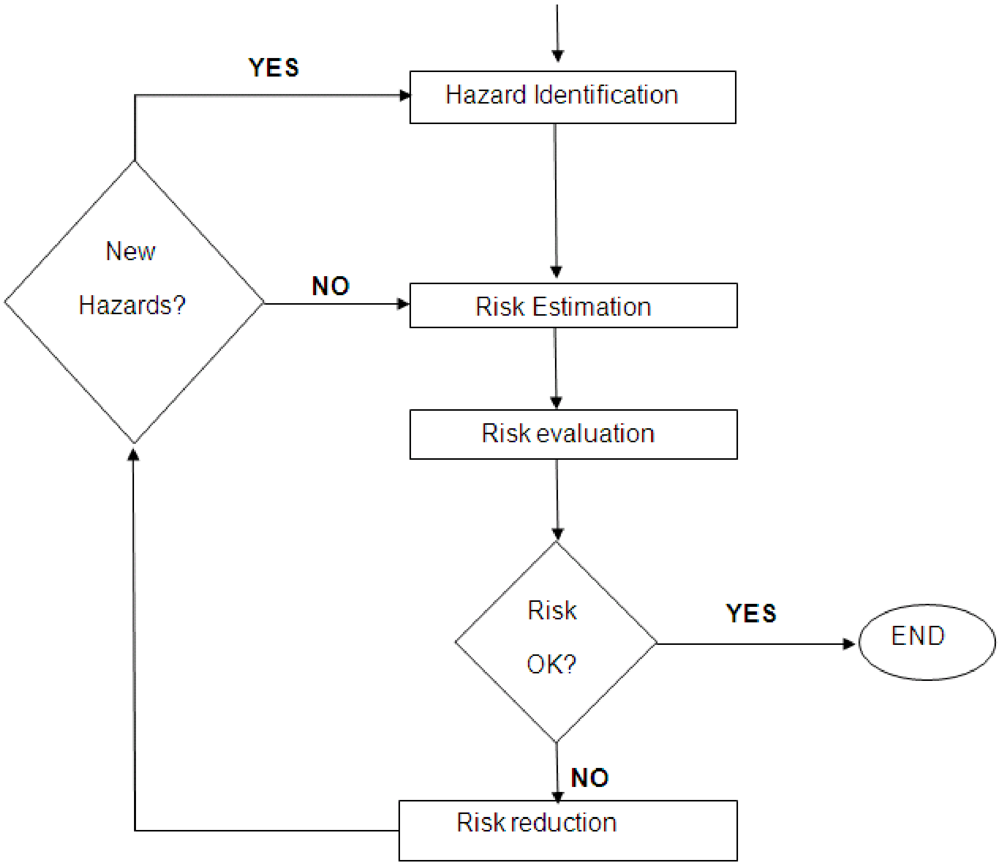

Figure 3 - Procedures for risk assessment.

A gas analysis, performed at P=1.3 bar and T=800°C - considering a flow of 32.5 Nm3/h (30 kg/h), on site show the following composition:

	Vol%	Mass%
H2	27%	3%
CH4	6%	5%

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CO	19%	26%
CO2	15%	33%
H2O	23%	20%
C6H6	0.15%	0.55%
C7H8	0.11%	0.47%
C10H8	0.08%	0.47%
N2	9%	13%
	ppmv	**ppmw**
H2S ppm	100	165
HCl equivalent (HCl, NaCl, KCl)	100	176
NH3	6400	5300
	g/Nm3	**g/Kg**
Solid particles	10	11

The hazardous scenarios in the plant are the possibility of an explosion due to the presence of flammable components (in particular, within enclosed spaces), the toxic atmosphere that CO and H_2S could cause, and the pollution due to the emission of CO_2.

The personnel involved in the plant's activities are exposed, for first analysis, to the following major risks and related consequences:

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Table 1 - Possible hazard or risk in the plant

Process unit.	Possible hazard or risk	Consequence	Potential recovery measure
Biomass storage	Fire outbreak due to burning of feedstock; whether the stored biomass is a dust, potential dusty atmosphere.	Fire /explosion, injury to operator.	• Control of ignition sources, such as ATEX requirements (note 1) • Operating procedures for biomass handling /loading. • Biomass storage to be placed in a safe location. • Presence of firefighting devices (note 2)
Biomass preparation and feeding	• Particulate matter exposure • Operator errors with wood cutter	• Danger to operator health, pollution • Possibility of harm/injury to operator.	• Personal Protective Equipment (PPE); • Procedures for biomass handling and personnel training.
Gasifier reactor	Handling and disposal of hazardous waste materials (ashes, charcoal, TAR and potential presence of heavy metals)	• Fire outbreak • Potential poisoning of operators. • Environmental pollution	• Procedures for hazardous waste materials handling and personnel training. • Personal Protective Equipment (PPE); • Presence of firefighting devices (note 2) • Gasification unit and relevant waste materials located on paved area; • Presence of drainage collection and water treatment systems .
	Leakages and air penetration during fuel feeding	• Explosions • CO and Particulate matter exposure; • Environmental pollution (note 3)	• Control of ignition sources, such as: ATEX requirements (note 1); • Emergency response plan for the BLAZE plant and relevant training for operators;
	Hot surfaces of the reactor	Harm to operators Fire hazards	• Insulation of pipes and equipment. • Personal Protective Equipment (PPE); • Presence of firefighting devices (note 2).
	Gas coatings on doors of the reactor and lock hopper	Unbalancing of the lock hopper, hence air leakage into system leading to explosion	
	Pressure build-ups	Potential explosions.	

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	Operator errors with the reactor	Accidents and damage to equipment	• Process control systems and alarms • Operating manuals and personnel training; • Control of ignition sources, such as: ATEX requirements (note 1). • Emergency response plan for the BLAZE plant and relevant training for operators;
	Flames through the gasifier reactor nozzles.	Explosion hence harm to operator	
Flare system	• Heat radiation from flare	• Potential injures for operator	• Flare to be provided at safe location (note 4). • Flare ignition system.
	• Potential flare flame out	• Flare gas dispersion and potential explosion.	
Gas conditioning Filter system	• Gas leakages, air leakages into system or syngas leaking out of the system	• Explosions • Exposure to CO and PM Environmental pollution (note 3);	Forced ventilation with protection, CO detection and alarms, leak test, safety relief valves
	Hot surfaces	Harm to operators (scalds and burns).	Insulation, warning signs
Gas- Steam Blower	Gas leakages, air leakages into system or syngas leaking out of the system	• Explosions Flammable mixture, release of toxic gas	Forced ventilation with protection, CO detection and alarms, leak test, safety relief valves
Fuel Cell	Gas leakages, syngas leaking out of the system	• Explosions Flammable mixture, release of toxic gas	dedicated ventilation of LSM box via a suction blower, connected on a UPS, dedicated H2- detection, pressure sensors with alarms, safety relief valves installed in piping Forced ventilation with protection, CO detection and alarms, leak test, safety relief valves

Notes:

1. Hazardous area classification minimum requirements shall be determined through a dedicated study (refer to paragraph 4.1).
2. The minimum requirements of fire protection systems to be provided at BLAZE type plant shall be established at least on the basis of:
   - Local regulations
   - BLAZE commercial plant capacity;
   - Quantity and type of flammable substances (e.g. biomass, fuel for gasification, etc.) handled / stored.

   At least, portable fire fighting extinguishers shall be provided at BLAZE type plant.
3. For the BLAZE pilot plant, pollution due to a potential release in atmosphere of anode off gas, steam, flue gas and flare discharge in atmosphere is considered negligible compared to WT facility emissions.
4. Minimum flare height should be verified by a dedicated study. On BLAZE pilot plant, flare is located over the WT roof workshop, where there is no personnel access.

4.1 Risk of explosive atmosphere

Hazardous Area Classification aims to define those industrial plant areas where a potential risk of explosion can occur, due to the presence of dangerous quantities and concentrations of flammable gas or vapour (or combustible dust). In the identified areas, technical and/or organizational protective measures need to be applied to reduce the risk of explosions.

Hazardous area classification shall be developed in accordance with EN 60079-10. The HAC is part of the risk assessment of the "explosive atmosphere" which workers can be exposed, regulated by the European Directive 1999/92/EC and local regulations (e.g., in Italy by the D. Lgs. 81/2008 Title XI - Protection from explosive atmospheres).

The classification of areas where flammable gas or vapour or dust hazards may arise may be used as basis to support the proper selection and installation of equipment to be placed in these hazardous zones, in accordance with ATEX Directive 2014/34/EU.

The flammable substances present in BLAZE plant, which may generate hazardous areas, are:

- Syngas, which is mainly formed by a mixture of hydrogen and carbon monoxide.
- Fuel gas for gasifier burners;
- Biomass (e.g. dusts, etc).

Considering the BLAZE pilot plant, hazardous areas relevant for gasification unit could be considered as follows:

- open areas: gasification unit does not generate hazardous areas;
- enclosed areas: hazardous area classification study should be carried out to determine adequate requirements for electrical equipment and instrumentation, considering actual ambient ventilation.

Whether hazardous classification is required, electrical equipment and instrumentation should be adequate at least for fluid and temperature class IIC T1 due to the presence of hydrogen.

The GCU and SOFC are placed inside a container. The container is equipped with forced ventilation and guarded with flow protection. There are two air inlets on one side of the container for fresh air intake. This would lead to an ATEX 2NE classification. During operation it is not allowed for personnel to enter the container.

5 CONCLUSIONS

The hazard identification process was limited to events that could happen during the regular operation of the gasification, GCU and SOFC plant. This was done by use of a HAZID and HAZOP workshops, that are structured review techniques for the early identification of significant hazards associated with the biomass gasification, GCU and SOFC plant. The workshops have been carried out by a team composed by project discipline engineer(s), operators and other stakeholders representatives. Other hazards were identified through literature review, past incidents occurring within the plant and close monitoring by visual inspection within the plant. Experiments were also done to investigate the possible presence of toxic hazards within the plant through continuous sampling techniques.

The details of the existing control measures and documentation meant to minimize any potential risks caused by the health and safety hazards within each unit have been investigated. These measures were identified based on relevant documentation, visual inspection of the work place, internal work procedures and instructions. The topics covered are physical controls/barriers, Training, working instructions, procedures and policies put in place and Personal Protective Equipment. This information was used in identifying the degree of risk posed by each identified hazard.

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6 REFERENCES

Please ensure that every reference cited in the text is also present in the reference list in alphabetic order (and vice versa).

Citation in text: *(Surname of Autor(s), year)*

EXAMPLES:

Reference to a journal publication:

Van der Geer, J., Hanraads, J. A. J., & Lupton, R. A. (2010). *The art of writing a scientific article*. Journal of Scientific Communications, 163, 51–59. www.....

Reference to a book:

Strunk, W., Jr., & White, E. B. (2000). *The elements of style*. (4th ed.). New York: Longman, (Chapter 4).

Reference to a chapter in an edited book:

Mettam, G. R., & Adams, L. B. (2009). *How to prepare an electronic version of your article*. In B. S. Jones, & R. Z. Smith (Eds.), Introduction to the electronic age (pp. 281–304). New York: E-Publishing Inc.

Reference to a website:

100% Renewable Energy Across Europe Is More Cost-Effective Than The Current Energy System. (2019). https://cleantechnica.com/2019/02/08/proven-100-renewable-energy-across-europe-is-more-cost-effective-than-the-current-energy-system/