WPT1.4.1

Estimates of CO_2 emission reduction induced by improved pumping operations

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Table of contents

1 Introduction

The Green WIN project brings together partners from the United Kingdom, France, Belgium, Ireland, and the Netherlands. The overall objective of the project is to improve the efficiency of pumping operations in waterways, in order to reduce operating costs and environmental impact of waterways in Europe. The environmental impact is highly dependent on the electricity generation sources of the country. In this report, the equivalent CO_2 reduction are estimated for a typical pumping station in each partner country.

2 Distribution of energy production

The International Energy Agency provides information about imports/exports in electricity in [6]. With few exceptions, each country is considered self-sufficient in electricity generation, although Ireland and the United Kingdom import more electricity than they export. Figure 1 depicts the distribution of electricity generation among countries. The distribution of electricity generation in Belgium is documented in [4], and [13] provides an overview of electricity generation in France. [14] offers a detailed breakdown of electricity generation in Ireland, and the International Energy Agency presents the distribution of electricity generation in the Netherlands in [6] while information for the United Kingdom distribution is available in [1].

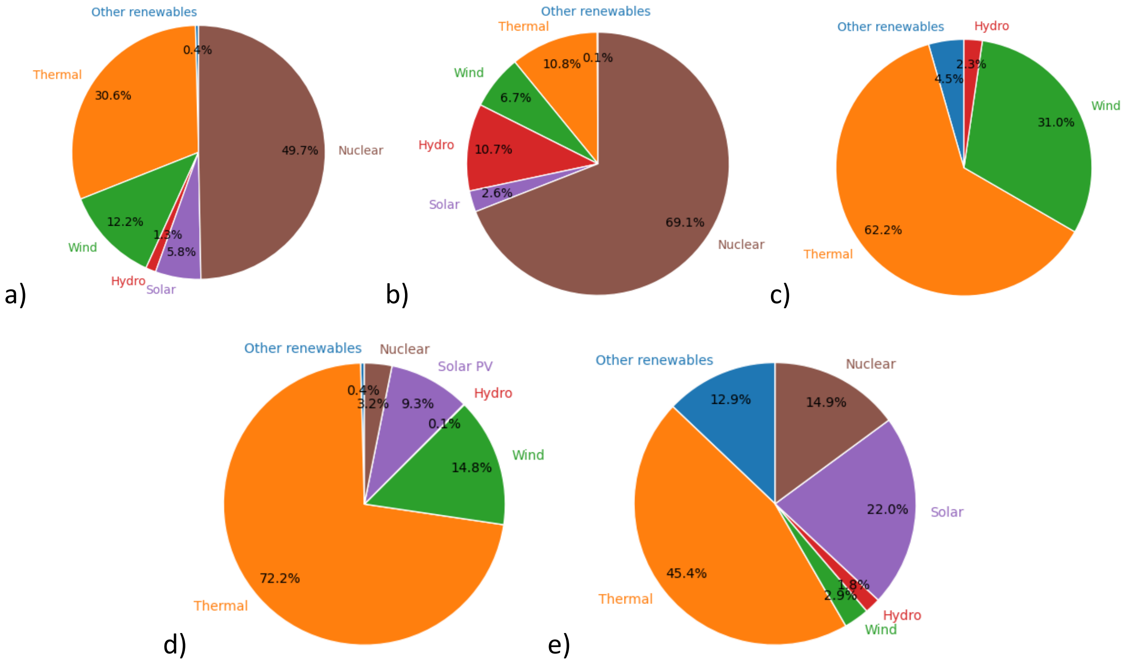

Figure 1: Distribution of electricity generation in 2021 in (a) Belgium, (b) France, (c) Ireland, (d) Netherlands, (e) United Kingdom

Table 1 lists the CO_2 emissions associated with various sources of electricity generation. In [16], thermal power plants are discussed, and their sources include oil, fuel, coal, and biomass (with details provided in [5]). The emissions for oil and fuel, coal, gas, and biomass are 760 gCO_2/kWhe, 1050 gCO_2/kWhe, 358 gCO_2/kWhe, and 250 gCO_2/kWhe, respectively. As a result, the average thermal CO_2 emission is approximately 604.5 gCO_2/kWhe, assuming for the sake of simplicity that the same fraction of each fuel is used. Wind power plants, according to [12], have a CO_2 emission of 15 gCO_2/kWhe.

Hydro power plants, as detailed in [7], have an average resulting CO_2 emission of 24 $gCO_2/kWhe$. Solar energy is primarily harvested through photovoltaic panels and produces 50 $gCO_2/kWhe$, as reported in [11]. As outlined in [15], nuclear power plants have CO_2 emissions of about 50 gCO2/kWhe.

Source	CO_2 emission ($gCO_2/kWhe$)
Gas	358
Fuel & Oil	760
Coal	1 050
Biomass	250
Mean thermal	604.5
Wind (11.6 %)	15
Hydro	24
Solar (88.4 %)	50
Nuclear	50

Table 1: CO_2 emission of electricity generation sources (also corroborated by [17])

The equivalent CO_2 emission per kWhe can be appreciated for each country by analysing the CO_2 emission levels associated with the various sources of energy and the distribution of sources of electricity generation within the corresponding country. Figure 2 displays the obtained values, compared to reference values found in literature, primarily from [2]. The UK reference value (265 gCO2/kWhe) and Ireland's reference value (348 gCO2/kWhe) are obtained from [9] and [14], respectively. The estimated values are generally consistent with the reference values.

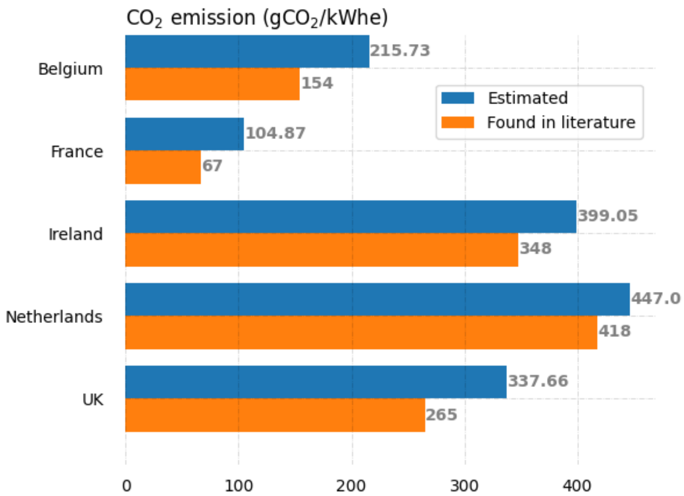

Figure 2: Mean CO2 emission for electric consumption per country

3 CO_2 reduction in an exemplary scenario

We consider here one hypothetical but plausible scenario to exemplify the impact of improving pumping operations on reduction of CO_2 emissions.

The typical volume pumped by a twin-pump station over one year can be of the order of 4 Mm^3. This value corresponds to data recorded in 2019 at Claverton pumping station on the Kennet and Avon canal (UK) operated by Canal and River Trust (CRT).

To illustrate the opportunity for reduction in CO_2 emissions by upgrading pumping practice, a pumping site with a useful head of 3.5 m is assumed, the coefficient describing hydraulic losses in the pipes is taken equal to 20 m/(m^3/s)^2, the pump used at the site is assumed to be an Amarex pump as tested at University of Liège in the framework of this project [Report: WP I1.2.1 "Reports from Laboratory trials"] (Table 2).

Flow rate	170 l/s	Nominal voltage	400 V
Head	6.00 m	Nominal frequency	50 Hz
Operating speed	965 RPM	Nominal electrical power	18 kW
Absorbed power	14.03 kW	Nominal current	35.5 A
Efficiency	71.7 %	Nominal efficiency	87 %
Number of pair of poles	3	Nominal power factor	0.85

Table 2: Operating characteristics of the 'Amarex KRT D 250 - 400/206UG-S' pump

If the pump is operated at full speed, it delivers a flow rate of 187.3 l/s (red star symbol in Figure 3), with an overall efficiency as low as 47 % and a power consumption of 13.71 kW. On a yearly basis, it would consume 40.68 MWh per pump to reach in total 4 Mm^3.

In contrast, if the pump is controlled by a variable frequency drive (VFD) with an assumed efficiency of 95%, adjusting the frequency of operation of the pump enables reaching a best efficiency point corresponding to a flow rate of 95.8 l/s as shown in Figure 3. The overall efficiency increases up to 58.9 % (accounting for the VFD losses) and a power consumption of 5.58 kW, which is less than half the consumption of the same pump operating at full speed. The total energy use drops to 32.37 MWh, which leads to saving 8.3 MWh per year per pump. Though, pumping a specified volume of water would take considerably more time with the VFD solution (from 123 days to 241 days). Hence, a trade-off should be found between energy-efficiency and operational constraints (e.g., acceptable time for returning to nominal water level in the navigation channels, acceptable variability in this level …) which depend on the actual use of the waterway.

Assuming 50 pumping stations using twin pumps in a country, it corresponds to an 830 MWh saving a year. This gain is represented in terms of CO_2 per country in Figure 4. The lowest gain appears in France because of the relatively low carbon emissions by nuclear power plants. In terms of order of magnitude, the gain in Ireland would be 288.84 TCO_2/year, which is equivalent to the yearly CO_2 footprint of about 12 households [10]. Although this is a modest contribution compared to the European target of 40% reduction by 2030 [3], it is definitely worth picking up each possible carbon emission reduction. Also, many pumping stations bring up water at considerably higher useful head (example: ten to twenty times more) so that the opportunity for energy savings become correspondingly higher.

The carbon footprint of a VFD is 3.65 $kgCO_2$/kW (in [8]). In our example, a 14 kW VFD results in a 51.1 $kgCO_2$ emission. In the worst case scenario (France: 55.61 TCO_2/year), the return period of this CO_2 investment is really small, approximately one-third of a day.

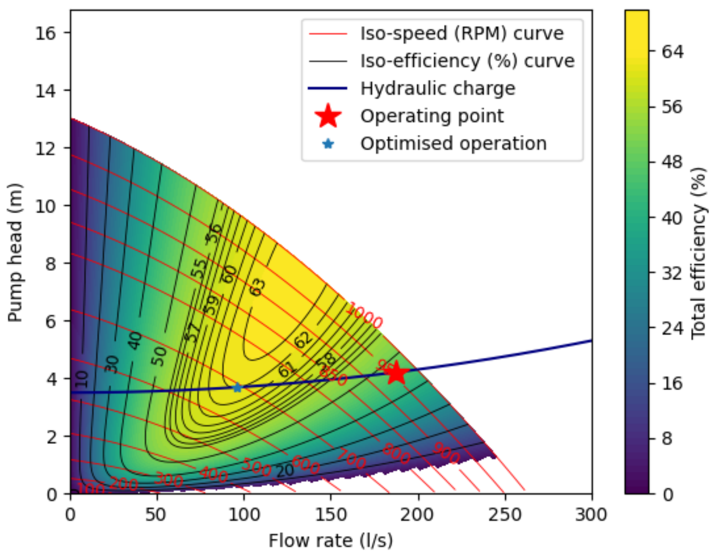

Figure 3: Overall pump efficiency of the Amarex pump with two different operating points: (red star) at full frequency and (blue star) at optimised frequency

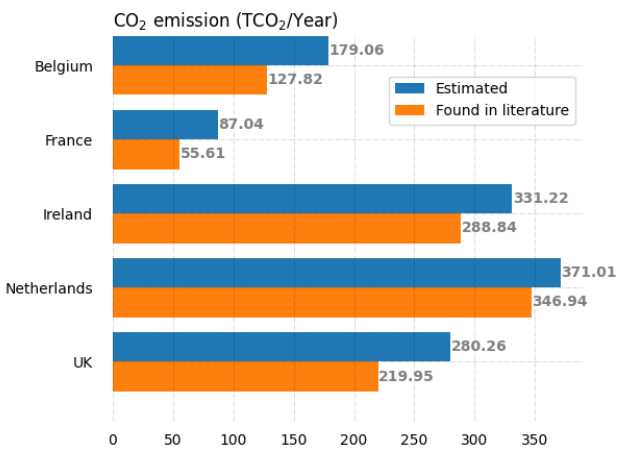

Figure 4: CO_2 reduction per year in each partner's country

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