Potential waste heat not yet fully utilized

The potential for energy-saving in Dutch industry is substantial yet under-publicized and partially unrealized. Residual heat utilization and thermal energy savings in industry can make substantial contributions to CO_2 reduction and are more cost-effective, in terms of euro-per-ton of avoided CO_2, than subsidized sustainable sources such as solar and biomass. Payback timeframes for industrial residual heat projects within their own environs are currently running at around five- to eight years. Industrial energy savings and waste heat utilization, therefore, deserve to receive more attention and priority.

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The savings potential from residual heat use and efficiency improvement in Dutch industry is huge. The approach and realization however, requires specific measures and consequently, does not always receive the necessary allocation of resources for the realization of projects, even though industry still offers substantial, and more cost-effective savings potential in energy and CO_2, compared to the built environment.

Energy transition Eric Wiebes, Minister of Economic Affairs and Climate Policy, recently sent a letter to two hundred of the largest industrial low-calorific gas (G gas) consumers, with the aim of ascertaining how gas consumption from the Groningen field can be terminated by 2022 at the latest.
The energy transition or path to energy efficiency will be very costly, with figures ranging from one- to three per cent of GDP, equivalent to between 7- and 21-billion euros per year. According to the Central Planning Bureau, the domestic energy bill per household is rising by sixty euros per month.
A recent article in Dutch newspaper De Volkskrant, reporting on making households completely sustainable, estimated the investment cost at around thirty thousand euros per household.
TenneT plans to invest 28 billion euros in Germany and the Netherlands in the coming years to increase the capacity of its high-voltage grids, making them suitable for transporting larger surpluses of sustainable wind and solar power.
The enormous savings potential from residual heat use and efficiency improvement in Dutch industry is underpublicized in the discussion in comparison with the focus on sustainable energy generation primarily in the built environment: this while being a major energy consumer with considerable savings potential in energy and CO_2, compared to the built environment. The biggest challenge is the fact that the approach and realization of energy savings and residual heat utilization in industry require custom-built solutions, and, consequently, companies are not always able to make sufficient resources available for the realization of such projects.

Energy consumption In 2015, the whole of the Netherlands consumed 3080 petajoules of energy - equivalent to thirty million cubic meters of gas, or one hundred million kilowatt-hours of electricity. Dutch industry consumes some forty per cent of this total.
Around half of this is converted into end products. A characteristic of various process industries is that high-temperature heat is required, for example, in cracking processes for chemicals, steel, or glass production, which is generated by burning natural gas or oil. These high temperatures are unfortunately not attainable using heat pumps. However, what is interesting is that substantial amounts of residual heat are often a by-product of high-temperature processes.

Energy-reduction scenario Many companies are already struggling to realize the agreed energy savings of two per cent per year of the MJA covenant, or the reduction goal of 1 .5 per cent per year of the MEE covenant.
Nevertheless, some 1,100 companies have joined the covenants, and in 2016 the third round of energy-saving reports was drawn-up and submitted for the period 2017-2020.
Bilfinger Tebodin is convinced that there is still a lot of unrealized potential across industry. To demonstrate the effect of this potential, in line with the ambitious 49 per cent CO_2 reduction target, a simplified energy-reduction scenario has been outlined, with a focus on industry. In this scenario, industry saves six hundred petajoules net-per-year in the period between 2018 and 2030. This scenario requires an annual efficiency improvement of 2 per cent on the final consumption and an additional 2 per cent reduction of the energy consumption through residual heat utilization and electrification: a savings total of 5.7 per cent per year. This also takes autonomous growth in energy use of 0.7 per cent per year into account. This results in a five-fold increase in energy-saving, which means that the potential contribution of industry to climate goals is substantial.
Although ambitious, this ambitious goal is not unattainable, provided that sufficient attention is paid to the potential within the industry.
This potential lies primarily in thermal energy, i.e. process heat and space heating, where savings of three per cent per year can be achieved. The savings potential for electrical energy, which is mainly destined for pumps, compressors, cooling, and drying, is two per cent per year.
Then there is also non-energy-related savings achieved through process efficiency improvement, improved catalysts, and regulation, which delivers an improvement of one per cent per year.
The reuse of residual heat released during non-energy and thermal processes results in energy savings of around two per cent per year.
Finally, electrification and the purchase of sustainable electricity provide an extra efficiency improvement, through electrification, of two per cent per year. The electrical energy generation is made sustainable by a greater focus on (process) efficiency improvement. Examples of this include electrification by using mechanical vapor re-compressors instead of thermal evaporators, the use of low-pressure steam heat pumps instead of steam boilers, or hot water heat pumps instead of steam boilers and steam distribution.

The greatest potential is formed by the residual heat utilization categories and thermal energy savings

Cost-effective The energy-reduction scenario illustrates that the greatest potential is formed by the residual heat utilization categories (273 petajoules per year) and thermal energy savings (190 petajoules per year), followed, to a lesser degree, by additional electrification (134 petajoules per year).
In order to achieve the stated efficiency improvements, the current efforts, as defined in the Energy Efficiency Plans, need to be tripled - a considerable extra effort. By intensifying the number of energy-saving studies and using

advanced energy-saving tools such as pinch and pattern-analyses, many more measures with payback periods of less than five years, and additional measures, with payback periods of between five- and eight years, will have to be identified and implemented, such as residual heat projects.
Industrial residual heat utilization is often more cost-effective, in terms of euros per tonne of CO_2 avoided, than expensive renewable energy sources such as solar, biosteam, and geothermal energy.

Barriers The company-EEP (Energy Efficiency Plan) provides an overview of selected energy-saving measures that are to be implemented over the coming four years. The EEP is the product of a selection process of energy-saving ideas, savings opportunities, and detailed savings projects within the company. The energy-saving projects described have been identified on the basis of workshops, energy audits, and best practice studies.
The selection is based on payback period, savings potential and sustainability, complexity, flexibility, and practical applicability. A five-year payback criterion is applied in the Covenants and the Environmental License. Measures with a shorter payback period must, in principle, be implemented.
Bilfinger Tebodin's years of experience in drafting Energy Efficiency Plans and executing energy-saving projects in industry have brought to light a number of bottlenecks that impede further energy savings. One common obstacle is lack of available personnel and time, at sites, to address energy savings in earnest. In many instances, technically-trained staff and engineers are overloaded. Also, there are too few energy specialists or engineers employed, and consequently, personnel never get down to formulating and supervising energy-saving projects.
One way to overcome this is through the creation of Smart Energy Teams. Smart Energy Teams consist of a mix of energy-, utility-, process- and possibly HVAC-, electrical-, or control engineers, who work intensively with the client's team for two-to-three years, while also regularly visiting the site.
The team commences with the drafting of a Roadmap, or future vision, for energy-saving projects. Subsequently, promising savings measures are identified in a workshop. Conceptual engineering is carried out for each measure, resulting in a Capex estimate; the energy-saving potential; the payback period; and the complexity of the measure. In the event of a positive assessment, basic engineering is then carried out per measure, including an in-depth energy-saving analysis, additional measurements, a description (specification) of the measure, and a more accurate Capex estimate.
The project is then put out to tender, executed, and carried-out by a contractor.
One practical idea is to apply the Smart Energy Team concept across several companies with a shortage of manpower. A limited government subsidy, as a catalyst for deploying external engineers during identification, development, and execution, for between two-to-three years, would be very welcome.

Payback period Many industrial companies apply short payback periods for energy-saving projects - often five years - as laid down in the Covenants - and occasionally shorter, internally, due to the fact that decisions can be made outside the Netherlands. Many strategic utility- and process projects have a long technical lifespan of up to 25 to 35 years. Think of modernization of cooling installations, upgrade of steam- or hot water supply, and residual heat projects. It is reasonable to accept a payback period of five- to eight years for energy-saving projects with a long technical lifespan so that large-scale energy-saving projects and modernization of inefficient installations can be realized sooner.
An interesting new instrument that will greatly stimulate energy-saving is the use of so-called internal CO_2 shadow-prices in feasibility calculations for energy-saving measures. This is already being applied by a number of multinationals. The CO_2 shadow-price, a threshold value of fifty-euros-per-ton, for example, is multiplied by the CO_2 emissions of the polluting reference boiler or device. As a result, the variable costs of the polluting reference will increase and the payback period of the proposed savings measures will fall below five years, making it profitable. An increase in the application of incentives already available (e.g. EIA) also contributes to making industrial energy-saving projects more profitable. The instruments mentioned will result in a significant increase in the implementation of the number of measures that will allow for a substantial, additional energy- and CO_2 saving, at relatively low costs per avoided ton of CO_2, as will be explained below.

Small and middle sized waste heat projects in industry ->		Case 1; industrial waste heat for HVAC application	Case 2; industrial waste heat (steam) for tankfarm	Case 3; waste heat supply to WBR district heating network	Case 4; heat pump distillation column (COP=4.0)
Capacity waste heat source	MW	**2.7**	**4.0**	**15.0**	**4.8**
Estimated CAPEX (excl. subsidies)	€	1,670,000	1,800,000	5,000,000	4,500,000
Specific project investment	€/kW	619	450	333	938
Annuity factor (15 yr, 4%)	1/year	0.090	0.090	0.090	0.090
Cost of capital	€/year	150,202	161,894	449,706	404,735
Equivalent full load hours	hours/year	4,835	4,000	6,000	8,650
Annual waste heat delivery	GJ/year	46,996	57,600	324,000	149.472
Waste heat price (excl. CO_2 tax ETS companies)	€/GJ	6.0	6.0	2.0	7.0
Annual benefit waste heat delivery	€/year	281,977	345,600	648,000	1,046,304
Additional costs electricity (heat pump)	€/year	minimal	minimal	minimal	415,200
Simple pay back period	**year**	**5.9**	**5.2**	**7.7**	**7.1**
Efficiency reference boilerhouse (incl. deaerator steam)	%	90%	90%	90%	90%
Avoided amount Natural Gas	Nm3/year	1,649,858	2,022,117	11,374,408	5,247,393
Avoided ton CO_2	ton/year	2937	3599	20246	5716
Project duration	year	15	15	15	15
Cost effectiveness Natural Gas	€/Nm3 natural gas equivalents	0.091	0.080	0.040	0.077
Cost effectiveness CO_2 (excl. subsidy)	**€/ton CO_2**	**51.1**	**45.0**	**22.2**	**70.8**

Low electricity prices Wholesale electricity prices (wholesale market) are particularly low. The low electricity prices are partly the result of cheap coal that floods the Dutch market together with electricity from heavily-subsidized renewable energy sources. The low electricity prices impede the payback period of electricity-savings possibilities. On the other hand, the fluctuating price-ratio between gas and electricity provides opportunities for new technologies such as low-pressure steam heat pumps in industry, as a replacement for gas-fired boilers. At present, these heat pumps are still relatively expensive and require significant customization.

Cost-effectiveness The cost and environmental performance of various industrial energy-saving projects can be jointly assessed via the cost-effectiveness and payback indicators. The cost-effectiveness is expressed in euros-per-ton of avoided CO_2.
Six examples illustrate the potential of residual heat. One company connected 2.7 megawatts of residual heat for space-heating of its industrial workspaces and offices. Another company connected 4 megawatts of residual heat to heat its own storage tanks. The industrial residual heat supply of 15 megawatts thermal to the residual heat pipe in Rotterdam is also a good example. The fifth example is the use of speed-limited motors with existing boiler feed-water pumps, which provides a reasonable electrical energy saving.
As the last example, a solar energy project is also being evaluated, in which solar panels are installed on the roofs of industrial workshops.

Residual heat chains The first four saving examples are all residual heat projects. A residual heat system can often be regarded as a residual heat chain. Below is an example of a residual heat chain based on steam distribution and on the basis of hot-water distribution for heating of tank farms.
A number of conclusions can be drawn from the aforementioned examples.
Firstly, the payback periods for these four residual heat projects are in the range of five- to eight years, excluding subsidy. Because the payback periods are slightly too long, or because there is no subsidy, these types of projects are currently under-implemented.
The cost-effectiveness of the industrial residual heat projects is twenty- to fifty euros-per-ton of avoided CO_2, and for the heat-pump example approximately seventy euros-per-ton of avoided CO_2.
The CO_2 cost-effectiveness of the first three residual heat projects is low, compared to electrical saving measures and costs for sustainable energy.
The savings potential of waste heat projects, especially within the factory gates, is large, but often still invisible.
The total residual heat capacity of the four projects cited is 26 megawatts thermal. If we assume, for example, a thousand industrial residual heat projects in the Netherlands, or 6,500 megawatts of thermal residual heat capacity, then the annual savings potential is 140 petajoules per year.
This corresponds to a saving of five billion cubic meters of natural gas and an annual CO_2 emission reduction of eight megatons. This does not seem unreasonable as 1,100 companies from forty sectors already participate in MJA3 and MEE. Many residual heat projects within the own factory gates are expected to have payback periods between five- and eight years, excluding any subsidy.