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Technologies – Knowledges – Sustainability
Crafting societies in the first millennium CE

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The front page: Amber nuggets and semi-finished amber beads and pendants from pit-house 7/91 in Biskupice, Poland. Photo: Marcin Woźniak.
The back page: Suspension loop for gold bracteate S12625, from Hå on Jæren, Rogaland. Photo: Annette G. Øvrelid.

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Sustainable energy and archaeology

PERNILLE KRUSE

Pernille Kruse 2025. **Sustainable energy and archaeology.** *AmS-Skrifter 29,* 213–220, Stavanger, ISSN 0800-0816, ISBN 978-82-7760-205-9.

The number of linear projects such as transmission lines, pipelines, and roads and cables within solar parks increases rapidly due to changing needs for sustainable energy and energy infrastructure. While the supervision of trenches is undoubtedly valuable, this type of archaeology also holds certain restraints, and the results are not necessarily comparable to systematically excavated sites. According to the current recommendations of the Danish Agency of Culture and Palaces, the solar parks need not be systematically examined, but it is argued here, that they pose an immanent threat to our cultural landscapes. Due to the increasing number of such projects, it is becoming increasingly urgent to address certain methodological problems and to increase the awareness of potential threats to the archaeological remains.

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Key words: Linear projects, trial trenches, solar parks, developer-funded archaeology

Introduction

The theme of the 74th International Sachsensymposion in Stavanger was "Technologies – Knowledges – Sustainability: Crafting Societies in the first millennium CE". The focus of this article is broadly speaking sustainability, however not related to the 1st millennium but to our present-day society. This article aims to address some of the consequences which sustainable energy has for archaeology in terms of methods, results, and research. The political wish to support the development towards sustainable energy has led to a large number of projects involving solar and wind energy, biofuels etc. The energy crisis resulting from the Russian-Ukrainian war has accelerated the process away from fossil fuel sources towards sustainable alternatives. Consequently, the Museum Sønderjylland, Denmark, has carried out an increasing number of projects involving in particular large-scale solar parks and underground power cables. In order to illustrate this process, I have drawn together the information from the projects involving sustainable energy which the Museum Sønderjylland has carried out between 2018 and 2023.

Figure 1. Map showing Denmark (without the island of Bornholm). The area covered by Museum Sønderjylland is marked with a red contour. Map by author.

Study area

The Museum Sønderjylland in southern Denmark is responsible for the protection of the cultural heritage and

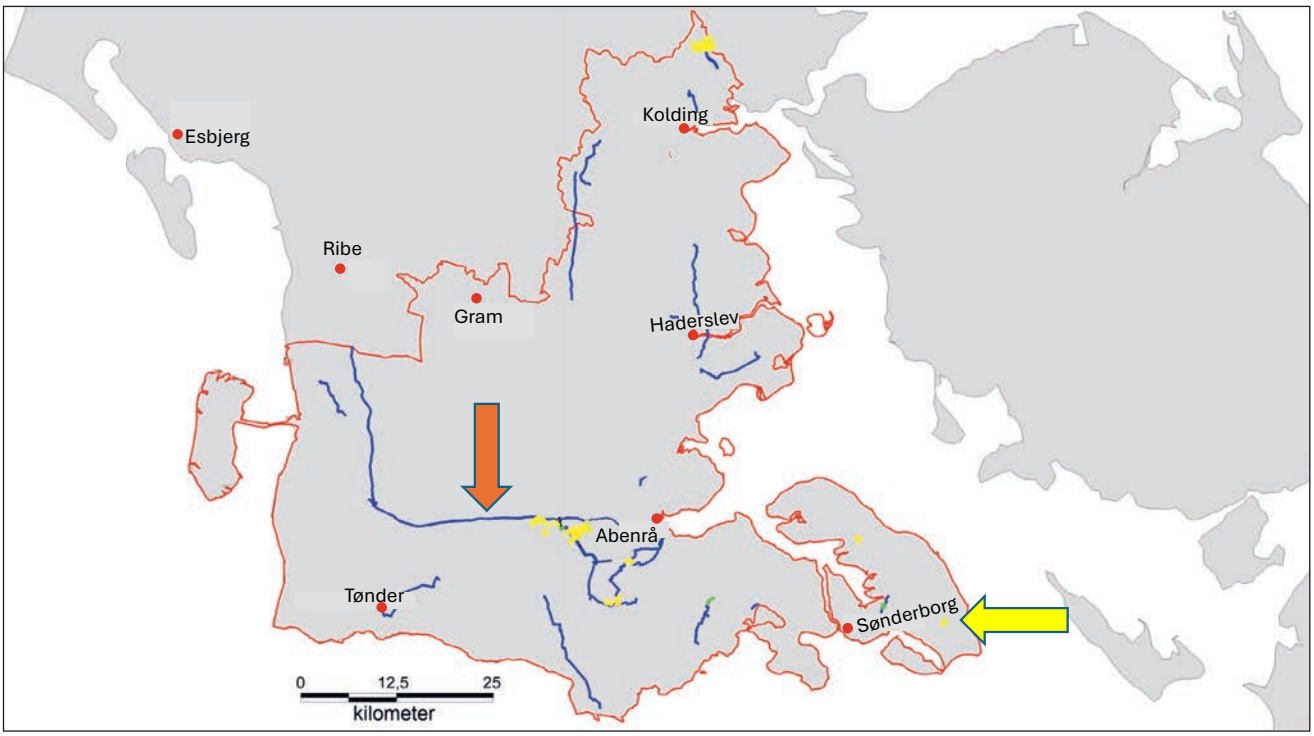

Figure 2. Map of southern Jutland showing the projects related to sustainable energy carried out between 2018 and 2023. Green = bio energy plants; turquoise = hydroenergy plants; yellow = solar parks; blue = transmission lines and pipelines. Sites discussed in more detail are highlighted with arrows: red arrow = Bredebro–Kassø, yellow arrow = Stevning Solcellepark. Map by author.

for carrying out the necessary archaeological excavations within the municipalities of Tønder, Sønderborg, Aabenraa, Haderslev, and Kolding, covering an area of 4041km^2 corresponding to approximately 10% of Denmark (Figure 1). Since 2002, all archaeological surveys and excavations which must be carried out in advance of construction or other development are developer-funded. This financial regulation has meant that more excavations have been carried out compared to the situation before 2002, and in this way the current Museum Legislation ensures that valuable knowledge about our common cultural heritage is professionally excavated and secured before the building or construction activities take place. Close to 100% of the archaeological excavations carried out by the Museum Sønderjylland are developer-funded rescue excavations (Ethelberg and Madsen 2012).

Bio energy and hydrogen plants

Bio energy or hydrogen plants are, archaeologically and methodologically speaking, straight forward to deal with. The areas within which they are constructed are examined systematically with north/south aligned trial trenches every 17.5m. The trenches are 2.5m wide, and extensions east or west of the trench are made when important features are found within the trench. In this way, the trial excavation covers ca. 20% of the project area.

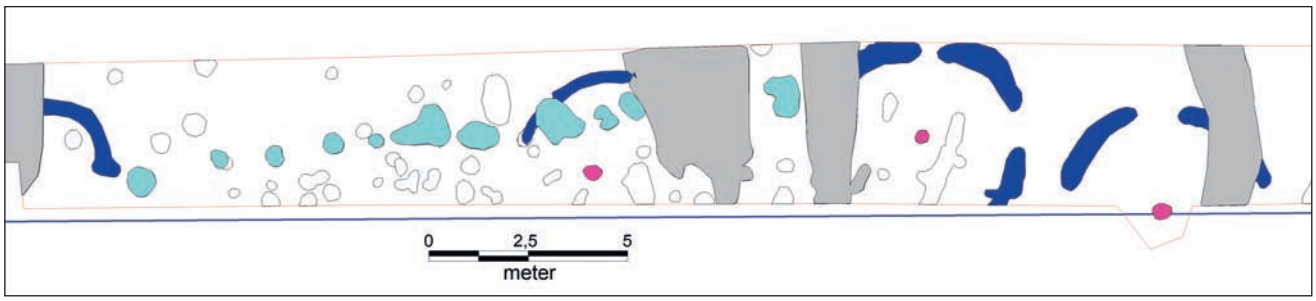

Figure 3. A section of the trial trench (red contour) between Bredebro and Kassø where it cut through a Pre-Roman Iron Age burial site with the urns (pink) placed within ring ditches (blue) and under small barrows, as well as large constructions dating to the Middle Ages, i.e. 13th–14th centuries AD (turquoise). The site was excavated as MSJA 96 Kassø. After Riis forthcoming a.

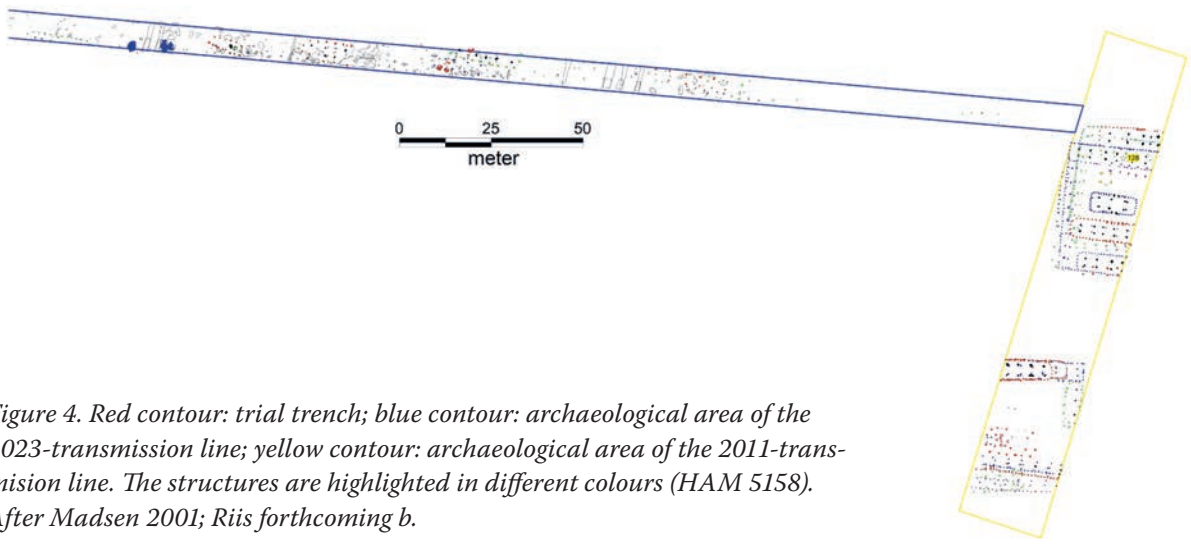

Figure 4. Red contour: trial trench; blue contour: archaeological area of the 2023-transmission line; yellow contour: archaeological area of the 2011-transmision line. The structures are highlighted in different colours (HAM 5158). After Madsen 2001; Riis forthcoming b.

According to the results of the trial excavation, archaeological areas are defined and excavated. Such projects are like any other typical developer-funded project; we can compare the results directly and use the same methods.

Linear projects

In terms of energy transmission lines and pipelines the situation is different (Figure 2, marked blue). Since 2018 and until the end of 2023, the Museum Sønderjylland has carried out trial excavations on thirty such projects, covering more than 145km. The recent transmission lines and pipelines are usually about 7m wide, although they may be considerably narrower or slightly wider.

The 28,6km long transmission line between Bredebro in the west and Kassø in the east has been selected to illustrate various aspects of archaeological excavations of linear projects (project no. 22/6722) (Figure 2, red arrow). The trial excavation and the subsequent excavations of archaeological sites were carried out during spring and summer 2023 (Flensborg 2023). In terms of linear projects, the trial excavation takes the form of a 2.5m wide trench dug lengthwise along the transmission line. When we find structures or other substantial features within the trial trench, we define an archaeological area according to the length within which the features have been identified, but the width is limited to the area which is directly affected by the construction work related to the transmission line.

The transmission line allowed us to excavate merely a thin slice of e.g. the pre-Roman urn field and a Medieval settlement (Moberg Riis forthcoming a) (Figure 3). This archaeological site is located close to an energy plant, and it is possible that other transmission lines or other companies will in time choose to realise projects in the general area. Such potential development projects would improve the scientific value of the excavations of the transmission line significantly. Due to the developer-funded nature of our excavation projects it is, however, largely due to coincidence whether or not it will be possible to excavate additional parts of the archaeological sites which we locate along the transmission lines.

Transmission lines run in all directions. The transmission line Bredebro–Kassø runs east/west (Figure 4, with a blue contour), and cuts a north/south running pipeline (Figure 4, with a yellow contour) from 2011, and thus not counted among the projects presented here. Figure 4 illustrates the difficulties related to such linear projects. In 2011, we were allowed to open up a 24m wide area because this was the width of the directly affected area of the north/south pipeline. The excavation revealed a large number of houses and fences in several phases. In 2023, however, only 7.5m were affected. A 7.5m wide trench is certainly enough to demonstrate an archaeological site, and it offers valuable overall information about the general settlement structure in the region. However, in cases such as this, where we are dealing with a complex site in several phases whose structures run in different directions, it is difficult to fully understand the character and date of the site, and to assess which structures belong to which phases. We will hardly get any complete constructions within the project area, and without complete constructions the typological date of the structures remains difficult.

The Agency for Culture and Palaces in Denmark publishes strategies and recommendations for excavations related to developer-funded projects. C14-analyses are costly and need to be justifiable. The analyses of the chronological and typological development of buildings

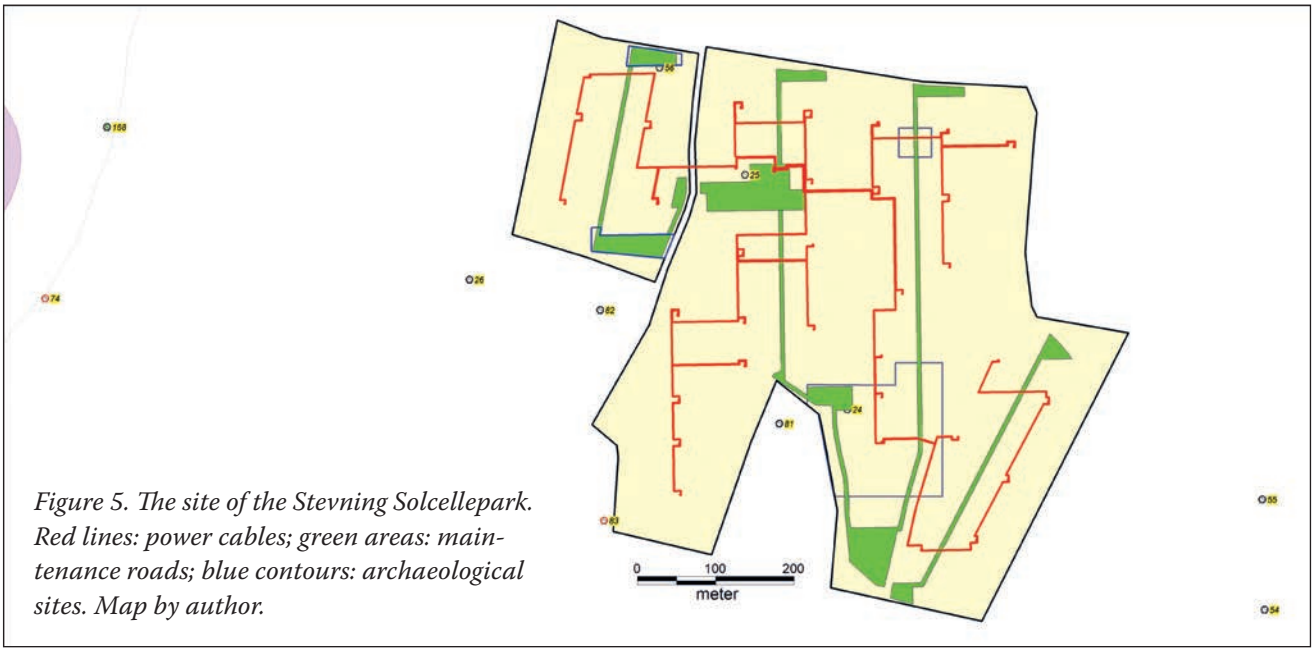

Figure 5. The site of the Stevning Solcellepark. Red lines: power cables; green areas: maintenance roads; blue contours: archaeological sites. Map by author.

on a regional and national scale depend on fully excavated and well-preserved structures. Such typological analyses are complemented by C14-dates in order to strengthen and refine our understanding of the typological development of buildings. This means, that we in general date only fully or largely fully excavated structures in order to get the scientifically best and most valid results. If only a comparatively small section of a building is uncovered by the trench, how sure can we be of the typology of the particular building? From sites such as these we will not be able to carry out comprehensive macro-fossil analyses or other analyses aiming at the functional use of the building because the complete structures have not been excavated.

Developer-funded archaeology implies that excavations take place in areas which are of relevance to modern day society. The distribution of known archaeological sites reflects past activities, but very much also present activities. Transmission lines and pipelines, however, may run through areas which are otherwise not developed and so largely unknown to us, archaeologically speaking. This is one of the great advantages of linear projects – they allow us a cut through different landscape types and grant us glimpses of otherwise unknown areas/activities. Once again, the transmission line between Bredebro and Kassø may serve as an example (Figure 2). One new site is located on the only slightly elevated and dry area in the middle of what is otherwise characterised by marshes and meadows. Here we have found a small section of a site (MSJA 86 Hvidhøjgård Vest; Flensborg forthcoming a). Parts of two to three structures were identified within the trench.

One of the structures is aligned NNW/SSE and is of considerable size, being ca. 7.5m wide and at least 46m long. Typologically, we dated the structure to the Late Germanic Iron Age, but C14-analyses appear to place this site in the Viking Period (Fensborg forthcoming a). We had no knowledge of this site, no metal detector finds or other indications of activities from this period. In this way the excavation granted us a glimpse of an arguably very interesting site.

Another example of a small-scale excavation with an excellent result is a site located ca. 300m south of the village of Korup (MSJA 88 Korup; Flensborg forthcoming b). Here a one aisled building was excavated, dated typologically to the early Medieval Period, 11th–12th centuries. It is interpreted as the predecessor of the existing village of Korup.

Solar parks

Between 2018 and 2023, seven photovoltaic power sites have been erected within Museum Sønderjylland's area (Figure 2, marked yellow). They range in size between 36ha and 406ha. In total they cover an area of 952ha. The Museum Sønderjylland has only experienced projects involving simple metal frame constructions mounted on the ground (see below), and the following discussion of implications relates to this type only. The more complex moveable systems which track the sun have so far not been erected and are not considered in this article. According to Denmark's Agency of Culture and Palaces, museums are supposed to carry out trial excavations of maintenance roads, areas of power stations etc. where the plough soil is stripped off. Large

areas with photovoltaic panels are erected between the maintenance roads (Figure 7).

The areas where the actual photovoltaic panels are erected are per definition not disturbed by the metal frames onto which the solar panels are fastened. The implication is, that the large solar parks are excavated very extensively. The solar park of Stevning on the island of Als (HAM 6419 Stevning Solceller; Moberg Riis forthcoming c) has been chosen to illustrate this situation (Figure 2, yellow arrow). The solar park covers an area of ca. 36ha (Figure 5). The green areas are 5m wide maintenance roads and areas related to the maintenance and storage of material. We examined the green areas by digging 2.5m wide trenches along the roads, and 2.5m wide trenches every 17.5m across the larger areas. The red lines represent 50cm wide cable lines. This solar park was one of the first parks which we examined, and we have subsequently evaluated the method and are in general not overseeing the construction work related to the narrow cable lines as closely as we did in this case. One recent exception to this general rule is a future project which is expected to be realised during 2025 and 2026 (and thus not included among the sites in the statistics of this article). This 100ha large solar park near Nagbøl, Kolding Kommune, is situated in an area which in 2004 was defined as an area with an exceptional archaeological heritage of international importance (*Kulturarvsareal Dollerup*, sb. 82, Skanderup sogn) by the Agency of Culture and Palaces. Such zoning areas were defined in order to protect the archaeological heritage by creating archaeological reserves – a result of the Malta Convention from 1992. In practice, building activities are still allowed to be carried out within these archaeological reserves. At the most, the archaeological reserves act as a warning to the developer, but there are no additional restrictions or responsibilities related to the development within such areas. In order to honour the status of the Dollerup area, the Museum Sønderjylland would – if the project is realised – want to supervise the construction work related to the relatively narrow cable lines as well as the maintenance roads etc. (see below, discussion). The Agency of Culture and Palaces supports this argument, but it remains unclear whether the developer accepts these terms.

The trial excavation at Stevning solar park resulted in four archaeological areas (Figure 5, blue contours). One example is a Bronze Age settlement in the northwest corner of the site. We excavated two buildings dating to Period V of which one is exceptionally large, measuring approximately 35m x 7.2m, i.e. 252m^2 (Riis forthcoming c). Both buildings contained a wide variety of different kinds of grain, such as emmer wheat, einkorn wheat, and durum wheat, hulled and hulless barley. Hulled barley is particularly unusual as its occurrence in Jutland is not widespread until around the birth of Christ (Gregersen 2023). It is unusual for this period to find this wide a variety within the same site. The most unusual element,

Figure 6. C-shaped metal posts onto which the solar panels will be fastened. Photo: Niclas Horn, Better Energy.

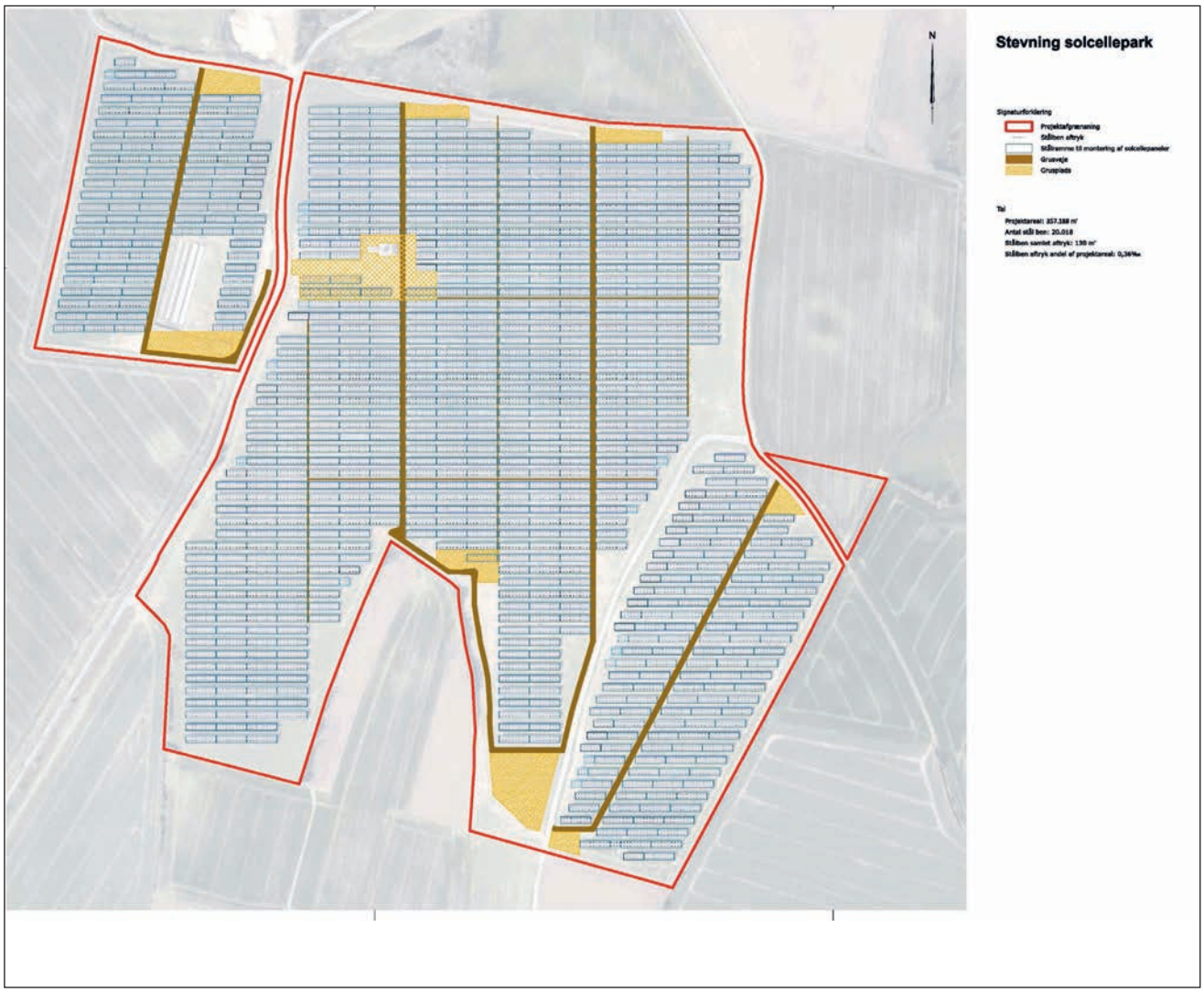

Figure 7. Plan of the Stevning Solcellepark with the erected photovoltaic panels. Graphics: Niclas Horn, Better Energy.

however, is the presence of millet in these samples. Millet is known from a very few Late Bronze Age sites in Denmark, and only very small quantities are known. This find may very well turn out to be the largest concentration of prehistoric millet in Denmark (Gregersen 2023).

The photovoltaic panels are fastened to metal frames with C-shaped posts which are rammed ca. 150cm into the ground in order to be able to withstand the pressure from wind (Figure 6). The inner measurements of the C-shaped posts are 0.0102m^2 and 0.0028m^2 (depending on their position). At the Stevning Solcellepark, the photovoltaic panels required 20.018 iron posts, corresponding to one post per 18m^2 and actively affecting 130m^2 in total of the 36ha large area (Niclas Horn, Better Energy, pers. comm.) (Figure 7). The implication is, that a solar park affects the cultural landscape to a much larger extent than the areas of the maintenance roads, power stations etc. would suggest. The initial erection of solar panels as it was the case in the Stevning example, may arguably not destroy settlement evidence – the character and interpretation of a settlement is not demolished by a C-shaped post per 18m^2. Archaeological remains such as a cremation burial would, on the other hand, be completely destroyed, and it would be impossible to reconstruct its contents had it been directly affected by the metal frames. In addition, there is the urgent problem of the future development of the solar parks; this question is addressed below.

Discussion

The linear projects, including the solar parks, are in our experience much more time consuming than "normal" developer-funded projects. A very close communication with developers, contractors and sub-contractors is required in order to secure a smooth process where all parties can keep their deadlines and stay within their budgets. When we excavate only a narrow slice of an archaeological site and a very small percentage of the

affected area, we not only have the problem of understanding and dating "half" houses (see above). We are also challenged considering the interpretation of the type of site we are dealing with. Is it a small family burial site, or a small part of something larger? What type of settlement is it? A small settlement site consisting perhaps of only one building? Or a large, well-structured settlement site in several phases indicating the social structures of society? Is it a site with special functions? A trading site? These are questions which we are able to discuss when we excavate large coherent areas, but which are very difficult to address when we deal with the linear projects. The few examples mentioned above clearly illustrate, however, that the linear projects are valuable: we can add points to our distribution map of archaeological sites, and this knowledge is valuable for future projects. In addition, the transmission lines and pipelines allow us to get a glimpse of the past in regions or landscapes which are not otherwise target of large-scale construction work. And occasionally, as it was the case at Stevning solar park on Als, we are lucky to be able to open up a comparatively large area, and not just a trial trench.

The question is not whether it is worth our while to supervise transmission lines etc., but rather how we deal with these projects. On "normal" developer-funded projects, our trial trenches are supposed to cover approximately 20% of the area. The solar parks, however, are examined very extensively and irregularly as we are only allowed access to the specific areas where the plough soil is removed (Figure 5). These "trial trenches" cover only a few percent of the total project area, which is not comparable to the systematically laid out north/south aligned trial trenches covering 20% of an area. Unfortunately, there is evidence from other Danish museums that contractors/subcontractors do not restrict the heavy traffic to the official maintenance roads which have been cleared by the archaeological trial trenches in advance of construction work. Instead, heavily loaded trucks drive across the site outside the maintenance roads during the construction phase, thus breaking through the top soil and affecting, in fact destroying, the underlying subsoil and the potential archaeological remains. In this way, the areas actually affected by the erection of photovoltaic panels are considerably larger than the maintenance roads, cable lines etc. would suggest. It is out of our hands what happens at the site during the construction phase after we have completed the trial trenches and/or excavations. The enormous scale of the solar parks makes it practically impossible for the museums to notice such constructional "short cuts", let alone prevent them from happening. Systematic trial trenches across the entire project area of the solar parks would make sure that our archaeological heritage were registered and excavated professionally before it is destroyed forever.

Another issue regarding the solar parks is that according to the developers they will remain in use for some 30 years. The implication is, that nothing else will take place there for the next few decades. There will be no heavy ploughing of the areas, for example, and in that way the area is preserved and there will be no erosion of the archaeological remains during – supposedly – the next 30 years. In the case of the simple constructions of metal frames pressed into the ground, the archaeological remains are arguably not threatened significantly (as discussed above). In the recently revised recommendations from the Agency of Culture and Palaces from 2024, such constructions are not considered to pose a threat to common types of archaeological remains such as settlements. The revised recommendations do, however, acknowledge that less robust remains may be threatened. In areas where archaeological sites or vulnerable archaeological remains are known or presumed it will – according to the revised recommendations – be possible to suggest systematic trial trenches. This is an improvement compared to the previous regulations, but in the concrete example of Nagbøl, the existence of a defined area of archaeological heritage of international importance (as discussed above) was not considered important or delicate enough to qualify for systematic trial trenches of the project area.

The recommendations take into account only the initial erection of photovoltaic panels. A neighbouring museum has experienced that misplaced panels were dug up during the construction phase, resulting in large craters (Esben Klinker Hansen, Vejlemuseerne, pers. comm.). What happens in e.g. 30 years when the solar parks area abandoned, or the panels need to be replaced? We have as yet no knowledge of this part of the process. Will the posts be pulled out gently, leaving thousands of holes in the ground? Or will they be dug up resulting in large craters? Even if the 1st generation C-shaped posts each only affects a small area, what will the area look like after the 2nd, 3rd or more generations? There is an immanent danger that the solar parks will effectively erode entire cultural landscapes.

Conclusions

The Museum Sønderjylland has been dealing with linear projects for decades, and there is no doubt that linear projects, whether resulting from large-scale transmission lines across the country or from comparatively small-scale renewals of pipelines within medieval town centres are highly valuable and bring about information about

our common past, which would otherwise have been lost. The scope of this article is certainly not to question whether the archaeological supervision of such projects is worthwhile – Museum Sønderjylland successfully carries out such projects on a daily basis, and has been for decades. Instead, the intention of this article is to address certain methodological problems and to increase the awareness of potential threats to the archaeological remains. Needless to say, the Museum Sønderjylland is not the only archaeological museum in Denmark dealing with linear projects and large-scale solar parks. Verbal communication with colleagues from other Danish museums has revealed an increasing frustration when it comes to the solar parks in particular. Our neighbours and colleagues in Schleswig-Holstein, Germany, are following comparable principles and are experiencing similar problems (Stephanie Klooss, Archäologisches Landesamt Schleswig-Holstein, pers. comm.). While we have been dealing with linear projects for decades, there is no doubt that the number of such projects increases rapidly due to changing needs for sustainable energy and energy infrastructure. Consequently, the methodological issues addressed here are becoming increasingly urgent to deal with.

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