The OSeMOSYS Teaching Kit – an example of open educational resources to support sustainable development

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Abstract

This paper explores the role of open online educational resources as a tool for building long-term capacity for Sustainable Development planning. We focus on energy and climate mitigation related to SDG 7 and 13. In particular we explore medium to long term energy systems analysis and modelling - a critical activity for energy infrastructure development. An open teaching kit and online course for the Open Source energy Modelling System (OSeMOSYS) is presented. The OSeMOSYS teaching kit is derived from training and teaching experience on the use of the tool by the OpTIMUS community of practice and its partners.

Several international organisations and consortium have long experience in carrying out capacity building initiatives and programmes in energy systems analysis and modelling across the globe. Yet, knowledge transfer, dissemination and application of newly-learned tools are not as effective as they might be. Enabling conditions for sustained, effective and content-flexible long-term capacity building and teaching in energy systems analysis is necessary. Yet few accessible resources exist. Availability and access to open educational materials can contribute to the development of solid and long-term capacity, particularly in developing country contexts, which often rely on international support for such activities.

The OSeMOSYS open educational resources, including the online course presented in this paper, provide a ready-made example of an energy systems analysis course that can be directly deployed at higher education levels and in-house capacity building initiatives. Its open nature promotes and facilitates the development of a network of practitioners who can contribute back to the community. Users have the option of contributing to, using and reconfiguring materials and course examples of varying levels and specifics. These can then be shared and taken up by the community of practice.

Keywords

Sustainable Development, Energy Systems Analysis, Energy Modelling, OSeMOSYS, Online Learning, Capacity Building, Open Online Resources, Teaching Kit

1. Introduction

Higher education and capacity building programmes hold the potential to support the planning of sustainable energy systems[1]. Enabling access to open educational resources in energy systems analysis and planning provides increased flexibility, accessibility and inclusivity, and can contribute to solid long-term in-country capacity development[2]. The availability of knowledge has the power to fuel the development in the energy sector in a sustainable manner, simultaneously supporting the development and strengthening of a global network of energy systems experts. Access to these types of resources is of particular importance in developing contexts.

Capacity building activities in the field of energy systems analysis is not a new concept. Several international organisations have experience in carrying out such types of activities[3]. However, the efficiency of this capacity building is limited. The targeted audience for such training activities in many cases consist of government officials who do not necessarily continue using the tools in their work after the initial training[4].

The issue lies within effective transfer of knowledge and sustaining the in-country capacity to support national development. By enabling knowledge and expertise in modelling tools and sustainable energy planning, it becomes an area which more people are familiar with and allows incorporation of sustainable planning activities in universities, governments and companies in the country in the future. Further, capacity building activities are constrained, as there are limited teachers or 'trainers' on the subject. By empowering trainers (in the country and out of the country), quality long-term capacity building in a developing country can be supported. And, if done in a dynamic way, the process of change is fuelled. That is because energy sector development can adapt to future requirements and thus, enforce national development[5].

This paper introduces the OSeMOSYS teaching kit. It is developed using material from training and teaching experiences on the use of the tool by KTH Royal Institute of Technology, Simon Fraser University, and the OpTIMUS community and partners. The educational material is developed on an open online educational platform and all of the underlying sub-modules are structured to allow the user to prepare a training course adjusted to the contents of interest and target audience. The course is an extension of

1 "The OPEDUCA Project," accessed March 11, 2019, https://www.opeduca.eu/The_OPEDUCA_Project.html; Al-Mas Sendegeya and Gideon Gope, "Capacity Building for Sustainable Energy Development: The Role of the Academia," 2016.

2 K Harper, K Chen, and D Yen, "Distance Learning, Virtual Classrooms, and Teaching Pedagogy in the Internet Environment," *Technology in Society* 26, no. 4 (November 2004): 585–98, https://doi.org/10.1016/S0160-791X(04)00054-5; Miguel Niño-Zarazúa, "Aid, Education Policy, and Development," *International Journal of Educational Development*, Aid, Education Policy, and Development, 48 (May 1, 2016): 1–8, https://doi.org/10.1016/j.ijedudev.2015.12.002; Cisco Magagula, "Capacity Building Using an Online Training Course," *International Journal of Education and Development Using ICT* 1, no. 3 (November 23, 2005), https://www.learntechlib.org/p/187996/.

3 Emanuela Colombo et al., "THE POWER OF HUMAN CAPITAL MULTI-LEVEL CAPACITY BUILDING FOR ENERGY ACCESS" (International Bank for Reconstruction and Development / THE WORLD BANK, 2017); Peter Virtic and Rebeka Lukman, "The Importance of the Capacity Building for Implementing Energy Efficiency and Renewable Energy Solutions," *Thermal Science* 22 (January 1, 2018): 215–215, https://doi.org/10.2298/TSCI180115215V.

4 Howells and Rogner, "Developing an 'Energy Planning Ecosystem.'"

5 UNEP, DTIE, and ETB, "Ways to Increase the Effectiveness of Capacity Building for Sustainable Development."

regular teaching efforts including the Summer School on Modelling Tools for Sustainable Development[6] and other capacity building activities that use the approach of training trainers. This paper describes a first draft of a teaching kit including learning and teaching material of the Open Source Energy Modelling System (OSeMOSYS) as well as guidelines and recommendations for creating future teaching kits.

In addition, this paper aims to provide insight of the possible benefits an online platform for teaching and learning could have in connection to current capacity building projects. Empowering medium to long term energy decision making processes is critical for sustainable development.

2. Capacity building and learning for sustainable development

Conducting capacity building efforts and teaching in energy systems analysis and planning can contribute towards the achievement of several sustainable development goals (SDG)[7]. From the educational perspective, it specifically contributes to SDG 4, which aims at promoting and providing quality education, aiming at "ensuring inclusive education for all and promote lifelong learning processes"[8]. Equipping individuals and institutions with knowledge that can be applied for strategic planning of energy systems directly contributes to the development and implementation of solutions to tackle SDG 7 (universal access to affordable, reliable and clean energy). Further, as the energy sector is responsible for the bulk of manmade Greenhouse gas (GHG) emissions, its redesign is critical to meet SDG13 (encouraging action against climate change).

Providing the relevant actors with learning opportunities for the long-term development of the energy sector increases the prospect of sustainable development at local, regional and national levels. In this way, developing countries can take ownership of their own development, in particular in relation to energy systems.

2.1 Challenges of existing capacity building efforts

In certain areas where local capacity is lacking, it is not unusual to outsource specific tasks to external consultants[9]. After the activity, the consultant may leave and the capacity is often gone with the consultant. Without insight of the previous consultant's work, there is a big risk of repeating previous capacity building activities[10].

We would argue that long-term capacity building requires a certain type of implementation of as well as available resources for capacity building activities[11]. To include activities for long-term capacity (i.e training trainers) would not only increase the chances of achieving a sustainable energy system but would also potentially help develop the in-country educational system. And for trainers to be trained, as well as to train, they need access to a teaching kit that can dynamically grow to meet needs (given that the circumstance changes).

6 ICTP, "Joint Summer School on Modelling Tools for Sustainable Development - OpTIMUS | (10-28 June 2019)."

7 "SDGs .:. Sustainable Development Knowledge Platform," accessed July 3, 2019, https://sustainabledevelopment.un.org/sdgs.

8 "SDGs .:. Sustainable Development Knowledge Platform."

9 Howells and Rogner, "Developing an 'Energy Planning Ecosystem.'"

10 UNEP, DTIE, and ETB, "Ways to Increase the Effectiveness of Capacity Building for Sustainable Development."

11 UNEP, DTIE, and ETB.

2.2 Capacity building activities and teaching of energy systems analysis using OSeMOSYS

Open source materials are important to make capacity building work. OSeMOSYS meets this requirement and has been used for capacity development. OSeMOSYS is an energy systems linear optimization model for long-term energy planning. Using OSeMOSYS does not require any financial investment (beyond a computer, which most people already have) since the model and programming tools used are free of charge. The OSeMOSYS code is transparent and straightforward which makes is simple for users to understand and analyse the results[12]. Figure 1 displays the block structure of OSeMOSYS and illustrates how the building blocks in OSeMOSYS can be mapped to the requirements for successful capacity development as discussed above.

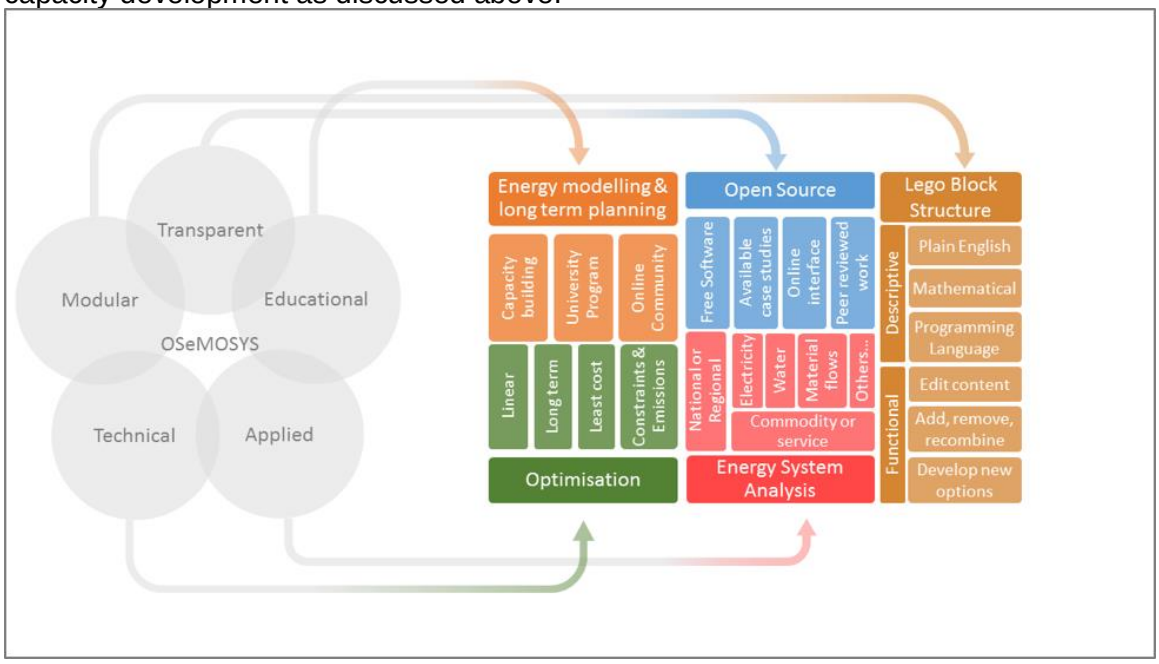

Figure 1. A display of *the OSeMOSYS block structure and how these components can contribute to the capacity development priorities of long term planning, open source code and modularity*[13].

OSeMOSYS has several applications and can be used for assessment of carbon emissions[14] and limits[15], regional electricity planning[16], energy policy planning[17], capacity

12 Howells et al., "OSeMOSYS."

13 KTH Royal Institute of Technology division of Energy Systems Analysis, *Overview of the OSeMOSYS Structure*, 2015, 2015.

14 GIUSEPPE ANDREA ROMEO, "Assessing Future Carbon Emissions through Energy Modelling : The Relevance of Background Input Data," Laurea Magistrale / Specialistica, April 16, 2019, https://www.politesi.polimi.it/handle/10589/146342.

15 José Govea, "An Analysis of the Mexican Electricity Framework under the Adoption of an Emission Trading Scheme," February 4, 2019, https://aaltodoc.aalto.fi:443/handle/123456789/37132.

16 Yong Joo Chung, "Regional Electricity Planning Using Open Source-Based Optimization Model," *The Journal of Information Systems* 28, no. 1 (2019): 133–53, https://doi.org/10.5859/KAIS.2019.28.1.133.

17 Oluwatofunmi Oluwatobi Caulcrick, *The Electricity Model for China – Insights and Implications of Energy Policies*, 2018, http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-245874.

expansion in correlation with climate change[18] and many other areas. An example of such is the possibility of including Climate, Land-use, Energy and Water (CLEW) modelling[19]. As done in the Global Least-cost User-friendly CLEWs Open-Source Exploratory (GLUCOSE) toolkit for investigating climate change impacts and mitigation strategies[20].

Activities using OSeMOSYS have spread globally and a number of locations where it is implemented are shown in figure 2. The implementations vary from using OSeMOSYS to inform policy processes (including: the INDC Bolivia, Energy Planning in Cyprus, Energy Planning in Costa Rica, Energy Planning in South Africa, Energy Modelling Research in Europe as well as others) to academia (examples of institutions currently teaching OSeMOSYS are: Universitas Gadjah Mada (IDN), University College London (UK), Politecnico de Milano (ITA), Makerere University (UGA), University of Mauritius (MAU)) and capacity building activities (such as The Summer School on Modelling Tools for Sustainable Development, the Energy Modelling Platform for Africa and in-country projects).

Figure 2. Global overview of a number of locations of OSeMOSYS teaching activities. Colours denote different activity types. Blue – in high level education curricula; yellow – country of origin of participants who have taken part of multi-country training activities and in-country capacity building activities.

2.3 Widening the reach of knowledge transfer through online learning

By using online programs for energy planning without the need of initial investment and providing e-learning on open educational platforms, the only requirements to gain the

[18] MARIA GIULIA PELOSI, "Improved Energy-Water Modelling for Hydropower Capacity Expansion Planning under Climate Change : A Case Study in the Zambezi River Basin," Laurea Magistrale / Specialistica, April 16, 2019, https://www.politesi.polimi.it/handle/10589/146567.

[19] Gardumi et al., "From the Development of an Open-Source Energy Modelling Tool to Its Application and the Creation of Communities of Practice."

[20] UNDESA, "Prototype Global Sustainable Development Report."

knowledge are internet and interest of the user. Distance learning and online education are not new concepts[21]. The expansion of Internet access in recent decades revived the possibilities of distance learning, with universities and higher education institutions increasingly broadening their offer of online courses.

When designing an online course, one important aspect is reaching out, in terms of just pushing out material as well as translations of the material[22]. In addition, it is important to create a community using and administering the online material.

Some of the benefits of online learning consist of inclusivity, due to the group being able to extend and reach participants who are not able to participate in the courses in person[23]. It is important that the e-learning reach the right people. With its open essence, the OSeMOSYS teaching kit has the opportunity to include larger parts of society due to access not requiring any investment.

3. Methodology

The OSeMOSYS teaching kit is the first effort of open educational resources in energy modelling and planning developed by KTH Royal Institute of Technology division of Energy Systems Analysis (KTH-dESA), Simon Fraser University and partners. The open teaching kit functions as a flexible knowledge tool which can be adjusted and updated by the user to fit their objectives in different education and training contexts. The kit allows the user to help build and spread knowledge on modelling tools which can assist the planning of sustainable energy futures.

The potential of the online teaching kit and future aspects of learning and long-term capacity building is connected to access to knowledge and knowledge transfer. The online platform was created upon the base of existing teaching material used for capacity development with OSeMOSYS in past projects by KTH, SFU, UN DESA and others. To optimise the online learning aspect, a literature study was conducted including elements on attention span with regards to online learning and the open essence of the education platform where the kit is developed.

3.1 Teaching and learning material

Prior online educational efforts have been made by developing training materials such as the Atlantis model[24] and Utopia[25]. The material for the online course and teaching are based on the ICTP Joint Summer School on Modelling Tools for Sustainable Development[26] and the Energy Modelling Platform for Africa 2019[27], revised along with comments from trainees and lecturers attending the capacity building activities. Note that this paper presents a first layout of an introductory online course and derivable teaching

21 Jorge Larreamendy-Joerns and Gaea Leinhardt, “Going the Distance With Online Education,” *Review of Educational Research* 76, no. 4 (December 1, 2006): 567–605, https://doi.org/10.3102/00346543076004567.

22 Harper, Chen, and Yen, “Distance Learning, Virtual Classrooms, and Teaching Pedagogy in the Internet Environment.”

23 Harper, Chen, and Yen.

24 “Atlantis.”

25 Howells et al., “OSeMOSYS.”

26 ICTP, “Joint Summer School on Modelling Tools for Sustainable Development - OpTIMUS | (10-28 June 2019).”

27 “EMP-A 2019.”

material of OSeMOSYS. Further development of the online course and teaching platform is considered future work.

3.2 Online platform

Google Open Online Education is an education platform for online learning free of charge[28]. The platform uses the tool Course Builder to easily build a course allowing use of all google-based programmes. Google Open Online Education can be made available for an unlimited number of course participants. The platform gives anyone, experienced teacher or first-time course creator, the opportunity of launching an online course.

Using the platform is aligned with the openness of the project and the purpose of making energy modelling knowledge available for all. By conducting video lectures, written hands-on exercises and multiple-choice questions for different units of the course an overview of the knowledge gained, and difficulties attendees might have with the course are easily gained. The video lectures of the online course were prepared and recorded by PhD candidates from KTH Royal Institute of Technology division of Energy Systems Analysis (KTH-dESA)[29].

4. The OSeMOSYS teaching kit

The following section includes an overview of the OSeMOSYS Teaching Kit. The kit is structured in such a way that the participant starts off with the basics of OSeMOSYS and energy modelling and goes through the simple model SIMPLICITY through hands-on exercises. This is to get familiar with the tools and energy systems analysis. The online material is expected to be used in three ways; i) for stand-alone self-learning, ii) sustaining capacity and lastly, iii) for teaching energy systems analysis in OSeMOSYS. Each unit consists of two to four video lectures, multiple-choice questions and (in most cases) an exercise.

4.1 Teaching kit structure

The course is built up by 15 units which cover different aspects of the energy system and how to model it in OSeMOSYS. An overview of the syllabus can be found in Appendix A.

There are five main types of educational resources and material used to build the online course:

- Video lectures
- Multiple-choice questions
- Hands-on exercises
- Further reading
- Evaluation and assessment

The objectives of the course were set, and the elements were created following the set objectives. By conducting a course in an area where the modelling tool and parameters (both technical and cost parameters) vary, it is important to keep the online materials modular to increase the effectiveness of updatability.

[28] “Google | Open Online Education.”

[29] Constantinos Taliotis et al., “OSeMOSYS - Thematic Videos - KTH Play,” 2019, https://play.kth.se/channel/OSeMOSYS%2B-%2BThematic%2Bvideos/226882.

4.1.1 Video lectures

Dividing lectures to segments is done both due to online learning aspect and attention span as well as updatability of material[30]. Segments with technology cost parameters and/or other frequently changing parameters should be easily changed without having to redo a full 20-minute lecture.

In the caption of each video the learning objectives are stated for the attendee to get an overlook of the subjects covered by each video. In this way, knowledge is available to all and the user is empowered with the flexibility of taking the course according to their desired pace and ability to learn the material.

4.1.2 Multiple-choice questions

After each segment of video lectures follows a few multiple-choice questions. These are closely related to the topics covered in the unit and the course attendant should be able to answer the questions after watching the videos.

4.1.3 Hands-on exercises

The exercise involves putting together a model for the fictitious country, SIMPLICITY. SIMPLICITY is used in the online course to gain knowledge of the applications of OSeMOSYS and the parameters needed for the energy modelling tool. The exercise is split into short segments which often ends with running the model and analysing results. Analysing results during the course makes sure that the course attendant understands why the specific result is shown. Thus, gets a deeper understanding of the aspects of energy systems modelling.

The segments of the exercise are closely linked to the video lectures and the unit of the course. By going through a hands-on exercise after the lecture videos on the subject the course attendant should be able to follow the steps and understand the applications and reasoning behind the parameters.

4.1.4 Further readings

Further reading material is provided at the end of the online course. It could work as broadening the knowledge of the course participant or be available for students curious of knowing more. Since there is some prior knowledge needed, further readings in the units may include introductory material for such subjects.

4.1.5 Evaluation and assessment

After each unit the course attendant is asked to fill in a small questionnaire relating to the subjects and knowledge gained. The small assessments serve as material for a quick overview of the course and how well the material is working, what is lacking and what to prioritise with regard to updates of current material. Before the teaching kit and after the online course part there should be an evaluation of the full online course. The evaluation will improve the structure of the course and continuous updates to ensure the best possible course and teaching kit.

[30] Harper, Chen, and Yen, “Distance Learning, Virtual Classrooms, and Teaching Pedagogy in the Internet Environment.”

4.2 Teaching material

The OSeMOSYS open educational resources of the online course constitute a ready-made example of an introductory energy systems analysis course that can be directly deployed at higher education levels or in other institutional settings. Its open essence promotes and facilitates the development of a network of practitioners who can participate in the continued development of education materials. In addition, it could encourage the emergence of capacity building programmes and reach audiences outside academia, contributing to bridging the gap between science and policy. On another level, the online course is openly available to all, meaning that any user can access and use the materials.

The teaching kit consists of derivable teaching material such as PowerPoint presentation slides used in the video lectures as well as scripts of the course and all multiple choice questions asked through the online course. In addition, there are suggestions of in-class exercises not conducted through the online portal due to the lack of direct supervision at this stage. The extra segments include group discussions, homework and group analysis of results.

For the teacher to get an overview of the current material available, there is an overview of all modules and units before reaching the derivable material itself. (See appendix B)

A one-time capacity building activity can provide help in the development of the country. However, it does not allow the country to keep developing on their own but rather enforce the dependency of the organizations providing capacity building activities. Developing local teaching activities in form of educational programmes would ensure long-term capacity building opposed to a one-time training activity[31]. Long-term capacity building is directly connected to the importance of academia. The introduction of tools in the curricula that can inform the planning for sustainable development, as part of courses and master's programmes with energy systems analysis options, would lead to new capacity continuously being created in-country.

4.3 The use cases

The resources have been designed to be used in different ways, to achieve different goals and meet different purposes. Implicitly, users and target audiences involved in each use case will also differ. There are three main identified use cases of the online course and teaching kit but we acknowledge that many different use cases will occur. The description of these three use cases is illustrative:

1. The self-learner
2. The sustaining knowledge
3. The teacher

The first case requires prior knowledge of and interest in the energy system and basic understanding of energy modelling. The self-learner would find enough help through the Google Group which is continuously updated and supervised by the OSeMOSYS community[32]. The initial learners would come from a background of energy but not energy modelling and the teaching kit would enable them to expand their knowledge into a new area.

[31] UNEP, DTIE, and ETB, "Ways to Increase the Effectiveness of Capacity Building for Sustainable Development."

[32] "OSeMOSYS - Google Groups," accessed July 29, 2019, https://groups.google.com/forum/?hl=sv#!forum/osemosys.

The second case, for sustaining knowledge, consists of participants who have attended or will attend capacity building activities teaching OSeMOSYS. The capacity building activities are often quite intense and to process new knowledge takes time. It is thereof useful for the participants to use the online course in combination with the activities. Having online learning material can help the attendant prepare *prior* to, better understand *during* and revisit subjects *after* capacity building activities.

The third and last case consisting of teachers and developers of the material are familiar with the tools and existing materials and use the online platform to share their knowledge. The group of teachers either take part in adding teaching material to the platform or use the derivable material to directly apply in the curricula. New material, or resources, can be developed with the base on existing material, following the modularity of the existing teaching kit.

5. Opportunities and challenges of the OSeMOSYS teaching kit

The availability of the teaching kit will have positive impacts for capacity development. The teaching kit enables the continuous and ongoing learning of those involved in energy planning and ensures that basic questions are easy to answer in an accessible online format.

The OSeMOSYS teaching kit will be further developed and linked to the Summer School on Modelling Tools for Sustainable Development[33] to help participants sustain the knowledge gained at the training and further teach the course in their country of residence. Using the material that has been created for the purpose of the summer school ensures the consistency of information as well as in depth reading material and additional material for deeper knowledge of energy modelling.

5.1 Benefits and Requirements

For an online teaching kit and course to operate effectively, there are several requirements that need to be identified as well as benefits of creating an online platform. To get an overview of some identified benefits and requirements please see figure 3 (Further details on the benefits and requirements can be found in Appendix C).

[33] ICTP, “Joint Summer School on Modelling Tools for Sustainable Development - OpTIMUS | (10-28 June 2019).”

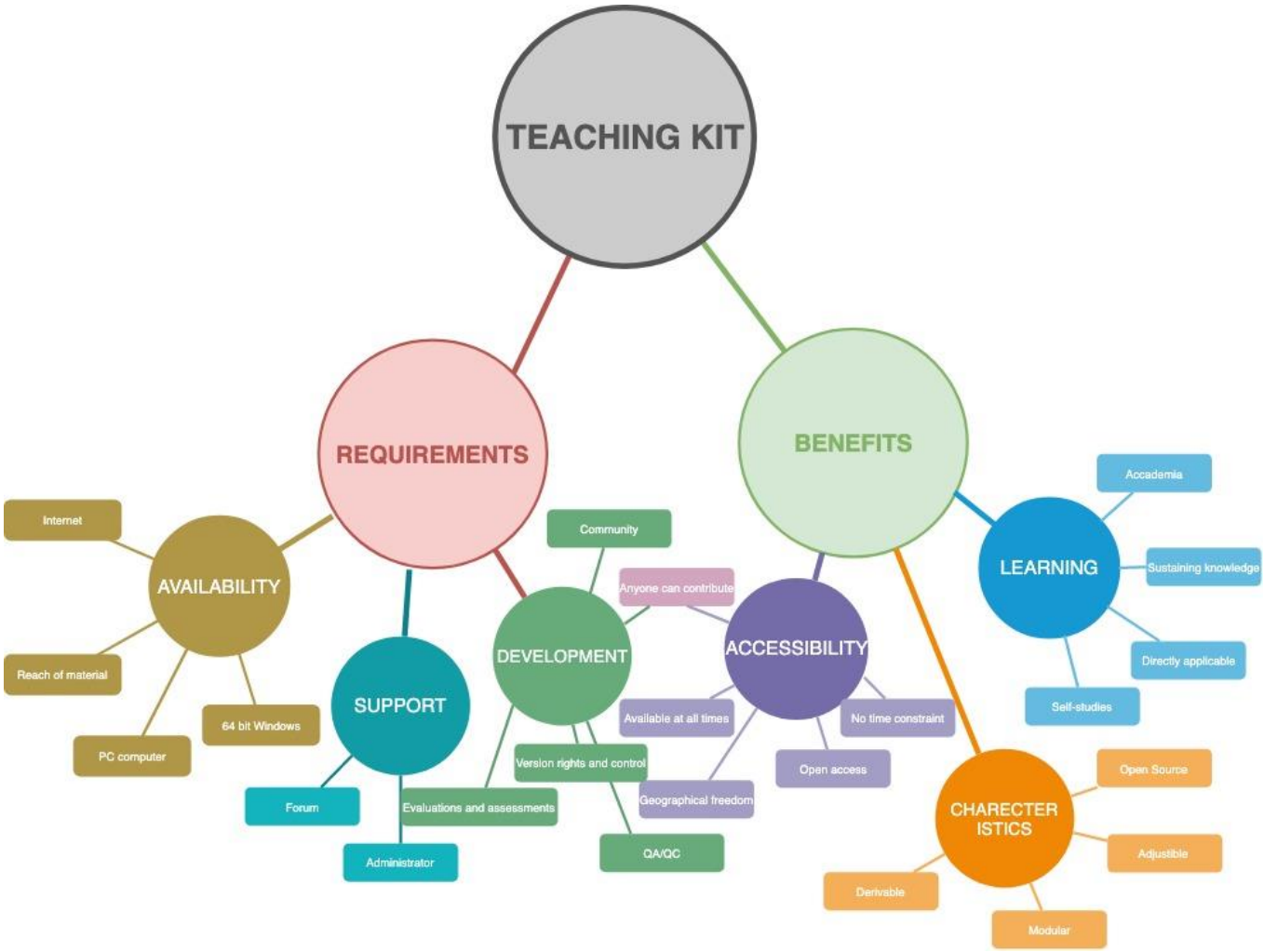

Figure 3. The requirements and benefits of an online course and respective teaching kit.

5.1.1 Benefits

The benefits of online learning related to capacity building include the long-term capacity aspect. Although, country projects that continue for years are common and works well[34], by using online material as complement to these projects provides the attendees of the activities to keep practicing and possibly spread the knowledge with lesser visits form the organisation leading the activity. In addition, it has the potential of making the projects more effective in the sense that the capacity building attendees can refresh and update their knowledge prior to the project activity leading to well-informed questions and issues being dealt with during the activity.

The characteristics of the teaching kit provides a new teacher with ready-made courses and elements to easily implement a new course in the curriculum. By having the material adjustable the teacher has the possibility to adjust the material according to the specific course.

[34] UNEP, DTIE, and ETB, “Ways to Increase the Effectiveness of Capacity Building for Sustainable Development.”

5.1.2 Requirements

As shown in the figure 3, requirements include internet access. While this in some cases can be seen as a benefit (all that is needed is internet access and a PC) it also limits the course. Without internet the material is not accessible. In addition, the material needs to be marketed and targeted at the right group.

For the current online course, additional requirements include basic knowledge of the energy system and units used. Further, support for the course participants in the form of a Google Group[35] could be useful in the learning process. To provide additional support to the online course participants, an administrator of the online course and kit would be able to address specific issues with course material.

For the continuous development of the material, the teachers and developers are required to contribute to the material. The contributors are a key part to the teaching kit and the available material. A proper framework of how to contribute and attributions for contributors should be well-thought out for a functioning online teaching kit community.

5.2 Future aspects and recommendations

For future work on the platform, the main finding was the need of a splitting between learning and teaching material going forward. There is a need for both but given the large community teaching OSeMOSYS and the different ways of teaching, it would be beneficial to split the learning and teaching to two different platforms. Recommendations for the proposed two different platforms are therefore split in different sections below.

5.2.1 Learning material

By developing trainings online, more people will have the opportunity to attend the courses and gain and spread knowledge. However, by reaching more people there is a need for a course administrator that can keep track of the attendees, their possible difficulties with the course and evaluations of materials. To include an administrator for the online course (and future courses) would also ensure that the material is relevant and frequently updated.

Priority should be put on recording the hands-on exercises which are currently only available in text form. Additionally, to add subtitles to recorded lectures and figure explanations to further expand inclusivity would be an additional benefit.

The recommendations for additions to the existing online course would be to add a more detailed lecture on cost optimization and the interfaces used to create a deeper understanding of the tools and how cost optimization works. By providing them with basic understanding in cost optimisation the attendees could gain broader understanding quicker as well as ease the trouble shooting in the future.

To include a derivable kit of the course could potentially still have some benefits. By uploading the material of the online course as a derivable kit at the end gives the teacher an overview of the course content and the option to directly apply the course to the curriculum. Developing more online courses would increase the user benefits and possibilities of online learning and teaching. By following the structure of figure 4, an online

[35] “OSeMOSYS - Google Groups.”

course attendant could potentially gain a broad knowledge of integrated energy modelling and elements of CLEWs.

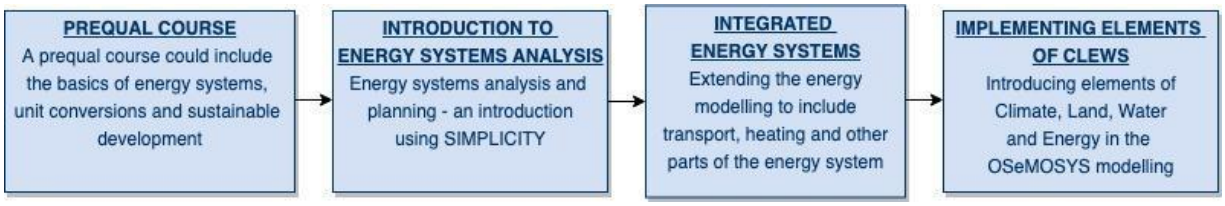

Figure 4 displays suggestions of future online courses in OSeMOSYS

5.2.2 Teaching material

The teaching material should be structured in such a way that the teacher can choose between extracting particular materials and sub-modules or deriving a prepared teaching kit. The derivable kits should be structured and clearly described. The level of difficulty and subjects should be clearly stated. For example: “Introductory course on Energy modelling in OSeMOSYS” or “Modelling elements of CLEWs in OSeMOSYS”. In that way, the teacher can choose between extracting a ready-made course including all elements or collect specific topics suitable for a course layout of their interest and aim. The proposed structure of the future teaching kit is shown in figure 5.

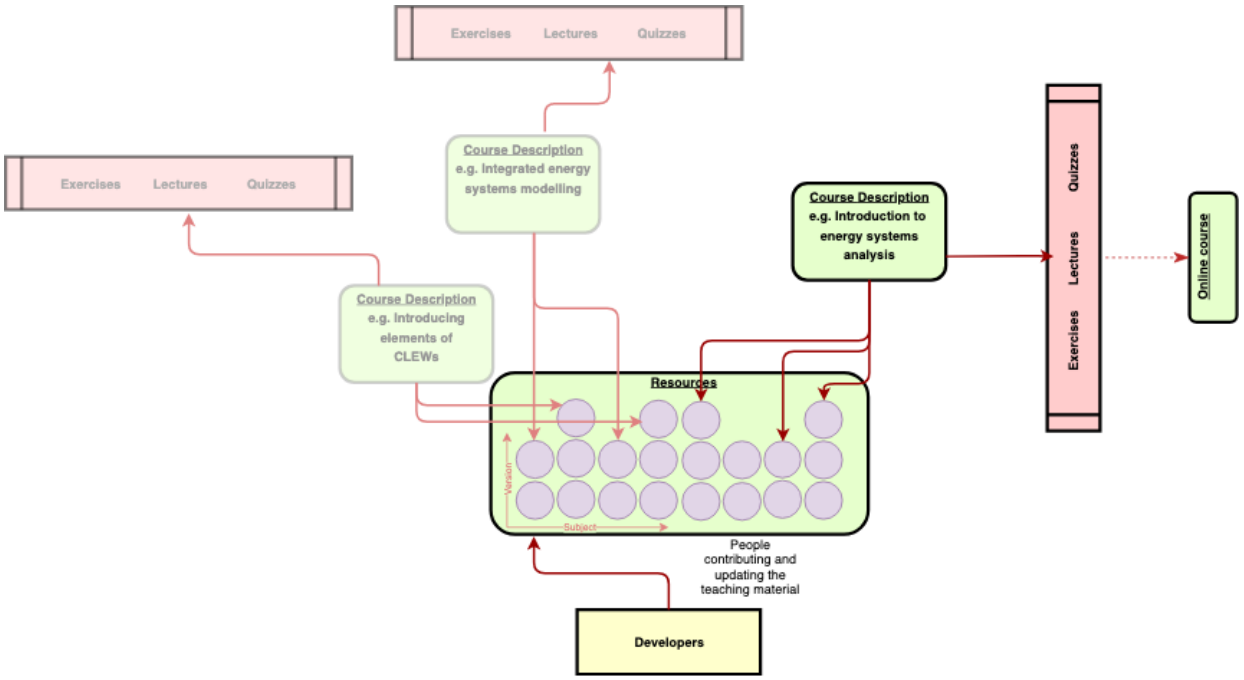

Figure 5. The suggested structure of the future teaching kit and online course. Where the teaching resources and versions are the teaching kit portal and course descriptions are used to provide the user with the correct material in connection to specific keywords, or tags. Examples of a resource description and a course description can be found in Appendices D and E

The resources, or modules, should be collected and structured in such a way that specific keywords, or tags, would lead the teacher to the material in their specific topic and difficulty level. By stating clear information points on each segment, an aspiring teacher could derive the suitable material of interest needed for their specific course. For new teaching material, specific requirements should be set out for contributors. Adding detailed information on the resource should be a requirement before submitting the material. The information should be enough to classify and add the resource with the correct tags to the catalogue with all existing material.

To include information on specific parameters that are objects of change would simplify the updatability of material. Including proper referencing for costs and or other quickly changing parameters that would simplify further updates. In that way, future users of the resources would know where the data comes from and if updated information is available.

An additional useful feature would be a forum and or assessments on where people intend to use the material. Such an assessment would not be a requirement but would map out where the material is being used. For users to fill in their country and/or institution would display the spread of the tool and courses in energy systems analysis and planning around the world.

6. Conclusions

An online teaching kit and course can contribute to sustainable capacity building by giving global access to knowledge in energy modelling tools and encourage self-learning. The components create a base for internal knowledge management where the material can be used for several purposes. To further include online learning aspects in capacity building activities to provide the participants with useful prior knowledge has the potential to increase efficiency of the activities. By providing material for teachers and teaching activities gives the opportunity of easy implementation of energy systems analysis in higher education.

For the current teaching kit there are a number of updates suggested. The inclusion of dynamic quizzes and assessments are needed. In addition, quality assurance of uploaded material would result in a higher standard of the online platform. A number of current lectures need to be re-recorded and other units are missing lectures. All hands-on exercises should be recorded to make the learning process easier.

The teaching resources needs to be developed so that a lecturer can upload material. There should be certain requirements on topics and specifications on the uploaded material such as division into sub-modules or resources. The sub-modules and material should be designed so as to be easily configured to match the need of the course (i.e. topic specific, difficulty level, resource type etc.). By structuring the teaching resources in a dynamic way with subject and level clearly stated, a teacher can easily structure a course in energy systems analysis and planning.

To conduct in-country trainings (as currently done by multiple organisations) are great tools for spreading well-needed knowledge. However, knowledge can be forgotten between trainings, or trainees promoted and thus repeated activities might be planne. In addition, the different entry levels of the participants might affect the outcome of the activity. By creating online material, it is possible to encourage people to preview the material of the training before. This could state on which level the course attendees are

as well as to make the attendees aware of the knowledge requirements of the training. Additionally, the attendees have the possibility of sustaining the knowledge after the capacity building activity by repeating the training online. Further, it provides them (or future external trainers) with tools used to build new capacity in their country.

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8. Appendices

Appendix A

Syllabus of the online course

- 1. Introduction and Objectives — What is energy planning? Why do we need it? What tools are available? These are some of the topics that are discussed in this chapter
- 2. Introduction to Energy Systems — This section covers the basics on energy systems, sustainable development, policy and how to develop your own country model
- 3. Introduction to Energy Modelling — In this section, you will be ntroduced to modelling in OSeMOSYS and the MoManI interface
- 4. Installation of tools — Written and video instructions on how to install the tools on your PC are found in this section
- 5. OSeMOSYS modelling introduction — "How to create a model in OseMOSYS" is a simple introduction to modelling in OSeMOSYS which is found in the following section
- 6. Reference Energy System — This unit explains how to define and design you own Reference Energy System, or RES.
- 7. Time Representation in OSeMOSYS — Why is time representation important? How do we represent time in OSeMOSYS? Thiese and many more time related questions are answered in this section
- 8. Primary Energy Demands — This section explains how we define energy demands in OSeMOSYS
- 9. Primary Energy Supply — Energy supply, how to represent technologies in OSeMOSYS and the conversion capacity to activity are some topics covered in this seciton
- 10. The Electricity Supply System and Thermal power plants in OSeMOSYS — Definition of thermal power plants and electricity supply in OSeMOSYS are explained in this section
- 11. Modelling Hydropower Plants and storage in OSeMOSYS — Hydropower plants with and ithout storage and their technical parameters are covered in this section of the course
- 12. Implementing Renewable Energy technologies in OSeMOSYS — This section goes through wind and solar technologies and how to represent a renewable energy technology in an OSeMOSYS model
- 13. Emission Representation and Renewable Energy Targets — How to implement emissions penalty and set renewable energy targets are explained in this section
- 14. Scenario implementation — To create alternative future scenarios for you model, why it is important and how scenarios can be used, is explained in this section
- 15. Key take-away messages — The main take-away messages and proposed further reading
- 16. The Teaching kit — Under this segment is all available teaching material to this course.

Appendix B

Overview of course modules

Unit	Lecture	*Topic*	*Video time*
1	Lecture 1	Introduction and objective	3min 8s
2	Lecture 2.1	Introduction to energy systems modelling	2min 42s
2	Lecture 2.2	Introduction to energy systems modelling	5min 1s
2	Lecture 2.3	Introduction to energy systems modelling	10min 43s
3	Lecture 3.1	Introduction to linear optimisation and OSeMOSYS	7min 5s
3	Lecture 3.2	Introduction to linear optimisation and OSeMOSYS	3min 52s
4	Lecture 4.1	Installation video	8min 59s
5	Lecture 5.1	Super simple model	35 min 6s
6	Lecture 6.1	Designing a representative RES	6min 22s
6	Lecture 6.2	Designing a representative RES	4min 30s
6	Lecture 6.3	Designing a representative RES	9min 1s
7	Lecture 7.1	Time representation in OSeMOSYS	7min 55s
7	Lecture 7.2	Time representation in OSeMOSYS	2min 47s
8	Lecture 8.1	Defining final energy demands in OSeMOSYS	6min 35s
8	Lecture 8.2	Defining final energy demands in OSeMOSYS	7min 30s
9	Lecture 9.1	Representing primary energy supply in OSeMOSYS	5min 15s
9	Lecture 9.2	Representing primary energy supply in OSeMOSYS	7min 30s
9	Lecture 9.3	Representing primary energy supply in OSeMOSYS	3min 31s
10	Lecture 10.1	Electricity supply system in OSeMOSYS (Thermal power plants and T&D)	8min 16s
10	Lecture 10.2	Electricity supply system in OSeMOSYS (Thermal power plants and T&D)	4min 38s
11	Lecture 11.1	Electricity supply system in OSeMOSYS (Hydropower and storage)	6min 14s
11	Lecture 11.2	Electricity supply system in OSeMOSYS (Hydropower and storage)	3min 52s
11	Lecture 11.3	Electricity supply system in OSeMOSYS (Hydropower and storage)	11min 2s
12	Lecture 12.1	Electricity supply system in OSeMOSYS (wind and solar)	5min 47s
12	Lecture 12.2	Electricity supply system in OSeMOSYS (wind and solar)	7min 50s
13	Lecture 13.1	Emissions representation in OSeMOSYS	5min 11s
13	Lecture 13.2	Implementing renewable energy targets and capacity reserve in OSeMOSYS	-
14	Lecture 14.1	Defining scenarios and implementation in OSeMOSYS	-
15	-	Teaching Kit	-

Appendix C

Table of the benefits and requirements of the online teaching kit and course. The table describes the benefits and requirements shown in figure 3.

BENEFITS	
ACCESSIBILITY	
No time constraint	There is no set time limit for taking the course. The participant has freedom to schedule the online course however they please.
Open access	The online course and teaching material are open source and free of charge which makes the material available for anyone
Geographical freedom	Since all material is hosted online, the geographical location of the participant is not constraint (however, access to Internet can be). Participants from all around the world have the opportunity to access the course contents.
Available at all times	The course is available 24 hours a day given the online essence and self-sustaining design.
Anyone can contribute	This particular characteristic is viewed as both a benefit and a requirement. On the benefits side, it can result in a larger teaching kit base; whereas it as a requirement needs to have teachers contribute for continuous development of the teaching materials.
CHARACTERISTICS	
Modular	The course components are designed to be modular for simplifying the updatability of materials. And to allow people to derive the exact topics of their choosing for teaching.
Open source	The platform, tools and materials are all open source not requiring any payments which further increase inclusivity
Adjustable	The material is adjustable by all making it easy for new teachers to design e course in energy systems analysis
Derivable	All material available on the platform is downloadable and free to use for all.
LEARNING	
Academia	The material on the platform can be used for courses at higher educational levels and easily incorporated in academic purposes.
Self-studies	The learning material is available for anyone with interest supporting self-learning initiatives.
Directly applicable	The ready-made teaching kits are directly applicable to courses making it easy for teachers to set up new courses; also applicable or easily adjustable to capacity building activities.
Sustaining knowledge	For attendees of capacity building activities teaching OSeMOSYS, the online platform can provide support in sustaining knowledge. By going through the online course components after a finished training, the participant can repeat and thus sustain the knowledge better.

REQUIREMENTS	
	AVAILABILITY
Internet	To access the material there is a need of internet access
PC computer	To properly follow the instructions of the online course the participant is required to have a PC computer
Windows 64 bit	The PC computer is required to be equipped with a Windows 64-bit operating system
Reach of material	The material is available everywhere, but there is a need to properly reach out to people that could have use for the knowledge. There for the reaching out is an important requirement for a successful teaching kit
	DEVELOPMENT
Evaluation and Assessment	The development of material would benefit greatly by collecting evaluations from course attendees. This would enlighten the administrator what needs to be developed
Community	There is a need for a community surrounding the teaching kit to keep developing it and interactions
QA / QC	Quality assurance and control of the materials
Version rights and control	Authorship and Method for tracking versions, development and updates
	SUPPORT
Administrator	To have an administrator to keep track of evaluations and difficulties would be very much needed as well as providing support for online users.
Forum	There is a current OSeMOSYS forum that is very active. The Google Group could provide the online course attendant or teacher with great support and insightful discussions.

Appendix D
Example of a resource description

Resource Description

Description

Sub Module title	General representation and key characteristics of a technology		
Topic	Primary Energy Supply	**Version**	X.X.X
Key words	Representing a technology, Characteristics of a technology, Primary energy supply		
Level of difficulty	Introductory level	**Year**	2019
Author(s)	Taliotis, C., Gardumi, F., Shivakumar, A., Sridharan, V., Ramos, E., Beltramo, A., Henke, H., Rogner, H., Howells, M.		

Overview

Learning objectives	• Understanding how to represent a technology in OSeMOSYS • Knowing the key characteristics of a technology in OSeMOSYS		
Available online	6.1 Representing Primary Energy Supply in OSeMOSYS	**Duration**	5 min 14 s
Type of activity	Lecture		
Link to online material	https://youtu.be/FDT-LGWpGrA	**No Slides**	11

Appendix E
Example of Course description

Course Plan

Course ID

Course Title	Introduction to Energy Systems Modelling in OSeMOSYS			**Version**	X.X.X
Key words	Introductory, reference energy system,introduction of energy systems, introduction of energy modelling, time representation in OSeMOSYS, primary energy demands, primary energy supply, thermal power plants, hydropower plants, renewable energy technology, storage, emissions representation, scenario implementation				
Target Group	Beginners of energy modelling	**Duration**	3 weeks	**Group size**	10
Prerequisite skills / prior knowledge	Basic knowledge of energy systems, unit conversions, data mining, basic computer skills				

Course Description

Course Summary	The context, role and process of energy systems analysis for medium to long-term decision making; Elucidate the role of energy modeling for Policy, technology, economic assessments; Have the student design, implement and apply a fully-fledged optimization energy systems model to a given assessment. Why Energy Systems (rather than discrete energy technology) are important and how systems are analyzed and modeled. The process of energy-environment-economic (3E) modeling: knowing why modeling is important, as well as who the stakeholders and decision makers are.
Learning Outcomes	To understand the development of energy service and energy demand projections. Characterization of resources, technologies, economic, policy, and other elements to be considered within the modeling process. The role of scenarios and assumptions (forecasting, backcasting etc…) and the importance of transparency. The relationship between modeling and action (policy/investment formulation/technology development). Learn how to generate a model with OSeMOSYS

Materials & Resources required	**Technology – Hardware:**	**Technology – Software:**	**Printed Materials:**
	Computer	Database / Spreadsheet	-
	Internet connection	Internet web browser	**Supplies:**
	Projection system	Word processing	**-**
	Printer	Model versions (exercises)	**Other:**
	Video conference equipment	Multimedia	-
	…	…	…