

Renewable Energy Online  
Tanja Behrendt, Detlev Heinemann

# Renewable Energy Resources and Conversion

Lehrbrief



**PUBLIKATION DER BILDUNGSALLIANZ MINT.ONLINE:  
UNIVERSITÄT OLDENBURG, UNIVERSITÄT KASSEL, UNIVERSITÄT STUTT GART, FERNUNIVERSITÄT IN  
HAGEN, FRAUNHOFER-GESELLSCHAFT, DLR-INSTITUT FÜR VERNETZTE ENERGIESYSTEME (EHEMALS  
NEXT ENERGY)**



GEFÖRDERT VOM



Bundesministerium  
für Bildung  
und Forschung

Das diesem Bericht zugrundeliegende Vorhaben wurde mit Mitteln des Bundesministeriums für Bildung, und Forschung unter dem Förderkennzeichen 16OH12044 gefördert. Die Verantwortung für den Inhalt dieser Veröffentlichung liegt beim Autor/bei der Autorin.

Renewable Energy Online



Energy Resources and Conversion

by

Detlev Heinemann  
Tanja Behrendt

(C) CARL VON OSSIETZKY UNIVERSITY OF OLDENBURG (2017)

This document has been typeset using the L<sup>A</sup>T<sub>E</sub>X2e bundle on T<sub>E</sub>X.

compilation date: September 29, 2017

## Imprint:

---

Authors:	Detlev Heinemann, Tanja Behrendt
Publisher:	Carl von Ossietzky University of Oldenburg
Edition:	First edition (2017)
Editors:	Andreas Günther
Layout:	Robin Knecht
Copyright:	© 2017 Carl von Ossietzky University of Oldenburg. Any unauthorized reprint or use of this material is prohibited. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system without express written permission from the author/publisher.

---

Oldenburg, September 2017

# Contents

<b>I</b>	<b>Solar Energy Meteorology</b> .....	<b>1</b>
<b>1</b>	<b>Radiation Basics</b> .....	<b>3</b>
1.1	Energy transfer through radiation	4
1.2	Concept of blackbody radiation and Radiation Laws	6
1.3	Extraterrestrial radiation, solar constant	9
<b>2</b>	<b>Solar Geometry</b> .....	<b>1</b>
2.1	Extraterrestrial Radiation: Eccentricity	2
2.2	Irradiance on any given plane: Angle of Incidence	4
2.3	Angle of Incidence	11
<b>3</b>	<b>Atmospheric Interaction</b> .....	<b>1</b>
3.1	Constituents of the Atmosphere	2
3.2	Extinction Processes	4

3.3	Direct, Diffuse, and Global Solar Radiation	13
3.4	Spectral Irradiance	13
3.5	Radiation Climatology	15
<b>4</b>	<b>Solar Radiation Modeling</b> .....	<b>1</b>
4.1	Solar Irradiance on a tilted plane	4
4.2	Diffuse (sky) irradiance modeling	6
4.3	Diffuse fraction models	8
4.4	Modeling of clear sky irradiance	10
4.5	Solar radiation data	16
<b>5</b>	<b>Surface Solar Irradiance</b> .....	<b>1</b>
5.1	Basic principle for satellite derived irradiance data	4
5.2	Satellite platforms	6
5.3	The HELIOSAT Methode	9
	<b>II Wind Energy Meteorology</b> .....	<b>1</b>
<b>6</b>	<b>Atmospheric Flow</b> .....	<b>1</b>
6.1	Energy of the Atmosphere	2
6.2	Heat Balance of the Atmosphere	3
6.3	Physical Principles of Atmospheric Motion	5
6.4	Balances of the Horizontal Wind Field	11
6.5	Wind Climatology	15
<b>7</b>	<b>Atmospheric Boundary Layer</b> .....	<b>1</b>
7.1	Atmospheric Stability and Adiabatic Motion	3

7.2	Ekman Layer	8
7.3	Geostrophic Drag Law	10
<b>8</b>	<b>Wind Resource Assessment</b> .....	<b>1</b>
8.1	Statistical Characterization of Meteorological Time Series	3
8.2	Weibull Distribution	4
8.3	European Wind Atlas	8
	<b>III Energy Systems</b> .....	<b>1</b>
<b>9</b>	<b>Basics</b> .....	<b>1</b>
9.1	Energy System	2
9.2	Energy Units	2
9.3	Forms of Energy and Energy Chain	4
9.4	Primary Energy Equivalent	9
9.5	Global Primary Energy Statistics	13
9.6	Literature	15
<b>10</b>	<b>Resources and Reserves</b> .....	<b>1</b>
10.1	Terminology	2
10.2	Statistics	11
10.3	Literature	24
<b>11</b>	<b>Energy and Economy</b> .....	<b>1</b>
11.1	Gross Domestic Product	2
11.2	Purchasing Power Parity	5
11.3	Energy Intensity	10

11.4	Literature	14
<b>12</b>	<b>Energy End-Use Efficiency</b> .....	<b>1</b>
12.1	Energy Losses	2
12.2	Cascade Energy Use	5
12.3	Final Energy	5
12.4	Literature	10
<b>13</b>	<b>Energy Scenarios</b> .....	<b>1</b>
13.1	Principles	2
13.2	Examples	5
13.3	Literature	10
<b>14</b>	<b>Energy Systems Analysis</b> .....	<b>1</b>
14.1	General Energy Analysis	2
14.2	Methods for Energy Analysis	2
14.3	Life Cycle Analysis	10
14.4	Energy Payback Ratio of Energy Options	13
14.5	Literature	15
<b>15</b>	<b>Power Plant Technology Basics</b> .....	<b>1</b>
15.1	Thermodynamic Cycles and Heat Engines	2
15.2	Combined Heat-and-Power (CHP) Plant	25
15.3	Energy Utilization Factor and Heat-to-Power Ratio	28
<b>16</b>	<b>Electric Power Systems</b> .....	<b>1</b>
16.1	Basic Physical Laws	3



<b>16.2 AC Systems</b>	<b>3</b>
<b>16.3 Electric Transmission System</b>	<b>5</b>
<b>16.4 Substations</b>	<b>7</b>
<b>16.5 System Operation</b>	<b>7</b>
<b>16.6 System Load</b>	<b>8</b>
<b>16.7 Load Management</b>	<b>8</b>
<b>16.8 Reactive Power</b>	<b>8</b>
<b>16.9 Energy Losses</b>	<b>9</b>
<b>16.10 Load Forecasting</b>	<b>9</b>